225th Meeting of the AAS

Seattle, WA – January, 2015

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Sessions With Abstracts

90 – HAD I: Astronomy and the First World War

AAS Special Session
World War II (1939-45) has been called the physicists' war, for radar, rockets, and nuclear bombs, and World War I the chemists' war, for advances in nitrogen fixation, synthetic rubber, poison gases, and much else). But in fact both wars and the years between caused and witnessed enormous changes in all the sciences, including astronomy. The session (currently consisting of 7 talks of varying length) will glance at chemistry and physics and a bit about WWII (whose centenary we may not all be here to observe), but will focus on the significance of WWI for astronomy, its practitioners, institutions, infrastructure, and available tools and resources. A logical starting point is the Russian imprisonment of a German solar eclipse expedition that had gone to the Crimea to observe the 21 August 1914 event under Erwin Freundlich. Since they had hoped to measure gravitational bending of light by the sun, you might choose the 1919 British expedition that did measure the effect as your end point. An alternative is the founding of the International Astronomical Union in Brusselles in 1919, spearheaded by George Ellery Hale, whose International Solar Union had been dissolved by the war and resulting treaties, just as the members were planning to expand the organization to include all of astronomy.

90.01 – Physics in WWI: Fighting the Acoustic War

World War I was the first high-technology war, and when the United States began to prepare for it in 1915 the federal government turned to the storied inventor Thomas Edison. Edison formed a board that included industrial executives and engineers but only one physicist, its members holding that they wanted people who would do things and not just talk about them. However, in 1916, the nation’s scientists managed to create a place for themselves in the preparedness effort by organizing the National Research Council under the National Academy of Sciences. Once the United States went to war, in April 1917, the NRC brought academic and industrial physicists together in efforts to detect incoming aircraft, submerged submarines, and the location of long-range artillery. The efforts employed devices that relied in the main on the detection and identification of sound waves from these weapons. The devices were passive responders, but they were marked by increasing sophistication and enabled the United States and its allies to prosecute an acoustic war. That branch of the war was militarily effective, overshadowed the work of Edison’s group, and gained physicists high standing among leaders in both the military and industry.

Author(s): Daniel Kevles[1]
Institution(s): *1. Yale University*

90.02 – Two Eclipses, a Theory, and a World War

Both the beginning and ending of World War I were signalled by total solar eclipses at which attempts were made to measure the deflection, predicted by Albert Einstein, of starlight passing close to the Sun. An American team led by W. W. Campbell and a German team led by E. F. Freundlich travelled to Russia to observe the eclipse of 1914 August 21. The Americans were foiled by the weather, and the Germans were interned as enemy aliens, so no successful measurements were made. British astronomers, led by A. S. Eddington, mounted two expeditions to observe the eclipse of 1919 May 29, one to Brazil, the other, with Eddington personally in charge, to an island off the west coast of Africa. The results, presented with much fanfare, appeared to constitute a spectacular confirmation of general relativity, although much debate surrounded the observations and their interpretation in later decades. The stories of Freundlich and Eddington intertwine not only with controversial questions about how best to make and to reduce the observations, but also with attitudes toward the war, notably the extreme anti-German sentiment that pervaded the countries of the western alliance, contrasted with the Quaker pacifism of Eddington himself; and also with differing attitudes to relativity among European and American astronomers. Eddington later played a role in bringing Freundlich to the United Kingdom after the rise of Hitler and the Nazis. Ironically, in later life, Freundlich became increasingly sceptical of general relativity and proposed a theory of proton-proton interaction to account for the cosmological red-shifts.

Author(s): Alan H. Batten[1]
Institution(s): *1. retired*

90.03 – G.W. Ritchey's Optical Work for the Army during WWI.

During the first World War, the Mount Wilson optical shop was remodeled into a production facility, making lenses and prisms for military optics. G.W. Ritchey, H.S. Kinney, and J.S. Dalton managed the project, joined by Ritchey's son Willis and a large team of workers. Tens of thousands of lenses and prisms were produced, notably the exacting roof prisms needed for altimeters.
This sizeable project is documented in correspondence and a 'Report on Technical Details of Optical Work', authored by

G.W. Ritchey and reproduced in typewriter carbon copy with tipped-in photographs. The retrofitting of the MWO optical shop, and the complicated production methods, are detailed in the report.

Author(s): Peter Abrahams[1]
Institution(s): *1. Independent*

90.04 – The War's Positive Impact on the Canadian Astronomical Community

At the beginning of WWI, the Canadian astronomical community was tiny and astrophysical research was just beginning. By the end of the war, the country had established the forerunner of its National Research Council and had the world's largest fully operational telescope, thanks to the late entry of the USA into the conflict. By 1918, Canada was on the verge of making significant contributions to science.

In spite of the immense loss of life in this pointless war, I am aware of only one casualty affecting Canadian professional astronomers, and that was the indirect death of James Chant, son of University of Toronto's only professor of astronomy. Other Canadian astronomers, including Tom Parker, Bert Topham, and Harry Plaskett were on active service; each of their stories is unique.

Among those engaged in scientific work during the war were two Canadians temporarily in England: John McLennan whose helium research for dirigibles led him to establish a cryogenic lab in Toronto where the green line in the spectrum of the aurora was identified in 1925, and Allie Douglas who worked as a statistician in the War Office. Later work with Eddington led her to become his biographer and to her distinction as the first person in Canada to earn a PhD in astronomy (in 1926).

Author(s): Peter Broughton[1]
Institution(s): *1. RASC*

90.05 – Impact of World War I on Chemistry

Mention chemistry and the Great "War to End all Wars" in the same sentence, and nearly everybody who ever had a history class will nod sorrowfully and say,"Yes, poison gases." True enough, and Fritz Haber, who led the development of them for the Central Powers, was the one German scientist whom Rutherford never forgave or spoke to again. Such substances (not all really gaseous, and something like 50 have been tried) were used by both sides from 1915 onward, killed about 90,000 people (about 1% of the total), maimed many more, and arguably loosened constraints on future uses of chemical weapons in other wars, prison camps, and terrorist actions. But the war was not determined by them and could have been fought without them. On the other hand, the sudden blockading of ports and termination of most international trade forced Germany (etc) to expand very quickly processes for fixing nitrogen for explosives and for fertilizers in lieu of Chilean guano (yes there is also a Haber process for that). They needed in addition to find domestic replacements for rubber (for tires, hoses, and gas masks) and liquid fuels for tanks and aircraft. The Allies, for their part, had been heavily dependent on German dyestuffs, optical-quality glass for binoculars, and phosphates (fertilizer again). Production facilities for derivatives of coal tars, cottonseed oil, etc. were of necessity scaled up rapidly. And once people have learned to do these things, there is no way to have them be forgotten. The same is, of course, true of the nuclear weapons of World War II and of whatever biological and/or cybernetic entities prove to be essential in the next war.

Author(s): Virginia L. Trimble[1]
Institution(s): *1. UC, Irvine*

90.06 – The Impacts of Military, Industrial, and Private Support on Modern Astronomy

In contrast to the period following WW I, governmental support for astronomy grew enormously after WWII and during the Cold War. In spite of reservations expressed by leading astronomers like Harlow Shapley at Harvard and Otto Struve at Yerkes, tools provided by the military took astronomy into directions neither Shapley nor Struve could possibly have imagined — radio, X-ray, gamma-ray and infrared astronomy. It was a great ride that lasted half a century. Had it been up to Shapley and Struve, they would have opted for a return to where pre-war optical astronomy had left off — themes over which they could exert personal control.
The problem today, however, as I will show, is that the directions the military supported, while still fruitful, may be keeping us from vigorously pursuing new problems astrophysics needs to consider, the nature of dark energy and dark matter, or the pursuit of intelligent life elsewhere in the universe, none of which appear of interest to the military or industry. Topics of this kind could be supported by the very rich, like Yerkes and Hooker in the past, the Keck Foundation and Paul Allen more recently, or by less affluent but highly skilled volunteers. Support by the wealthy has occasionally been questioned, as in a front page article by William Broad in the International New York Times on March 17, 2014, in which he worried that the ultrarich would likely be idiosyncratic and know too little. Whether this fear is justified can be debated. However, failing this kind of philanthropic support, astronomy might opt for aid through the recently developed "economy of the commons," pioneered by Elinor Ostrom, which tends to succeed by world-wide support on

smaller scales coordinated largely through the internet. This movement is sometimes referred to as crowd sourcing. It tends to attract thoughtful, like-minded individuals from across the globe who wish to contribute their skills and have the required talents.
I will review both the great strengths and developing weaknesses of governmental post WWII support for astronomy, and will end by talking about the potential need but also the difficulties of obtaining support from private sources.

Author(s): Martin Harwit[1]
Institution(s): *1. Cornell University*

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91 – HAD II: Ideas of Evolution Inside and Outside of Astronomy during the Long 19th Century

AAS Special Session

91.01 – William Herschel during the 1780-1810 era: A natural historian studies "maturation" of stars over immeasurable time

(A) William Herschel (1738-1822) considered himself a natural historian, different only from the usual natural historians in that his focus was on stars and nebulae rather than plants, animals, and minerals. In this regard, he developed ideas concerning changes over very long times, inferred from his catalogues of 2500 star clusters and nebulae. By assuming that all the observed types of star clusters and morphologies of nebulae represented different stages in the formation of stars and clusters under the action of gravity, Herschel argued for a sequence of "maturation," or evolution as we would call it. He could put no definite time scale on these dynamic processes, but inspired by contemporary geologists such as James Hutton and John Michell (yes, he was a geologist, too!), he felt that the time scales must be very long. In further support, he photometrically estimated that the very faintest stars that he could see in his giant 40-ft telescope were about two million light-years distant. Herschel's findings on the structure and age of the Milky Way system, his "construction of the heavens," were also influenced by geological notions of the formation and subsequent warping of strata over long times, and the geologists' attempts to uncover the interior and distant past of the Earth.

(B) Herschel was a very successful professional musician for two decades, primarily in the fashionable resort city of Bath, England. And then he discovered Uranus in 1781 at age 43, an event that catapulted him into celebrity and allowed him immediately to transform himself into a full-time astronomer. He composed over twenty symphonies, many concertos, and a large number of organ and choral works. During this session, a chorus of University of Washington students will present a short concert featuring Herschel's most popular composition, a novelty number called "The Eccho Catch," as well as contemporary pieces with astronomical themes by other composers.

Author(s): Woody Sullivan[1]
Institution(s): *1. U. of Washington*

91.02 – John Herschel, Charles Lyell, and the planet Earth

John Herschel and Charles Lyell are not usually seen as scientists who had much in common. One was an astronomer, the other a geologist. They shared, however, an active interest in the age of the Earth and in the history of the physical processes that produced the planet before us. Herschel brought to this discussion a well-polished mastery of celestial mechanics and the chemistry and optics of crystals, and Lyell brought with him a familiarity with fossils, strata, and rock types. This talk focuses on Herschel and Lyell's discussions about the Earth through time and space, and about what qualified (to them) as acceptable geo-theory. Along the way, more attention is paid to Herschel's interests in terrestrial topics, since this is less well known.

Author(s): Gregory Good[1]
Institution(s): *1. AIP*

91.03 – Thermodynamics, Life, the Universe and Everything

The laws of thermodynamics were developed in the first half of the nineteenth century to describe processes governing the working of steam engines. The mechanical equivalent of heat, which quantified the relationship between heat and motion, enabled the quantification and comparison of all energy transformation processes. The energy laws and the mechanical equivalent of heat quickly moved out of the narrower field of physics to form the basis of a cosmic narrative that began with stellar evolution and continued to universal heat death. Newer physiological theories turned to the energy laws to explain life processes, energy and entropy were integrated into theories of biological evolution and degeneration, and economists and cultural theorists turned to thermodynamics to explore both the limits of natural resources and economic expansion and the contradictions of industrial modernity. This paper discusses the career of thermodynamics as an explanatory model and cultural commonplace in the late nineteenth and early twentieth centuries, and the different scientific, religious, and social perspectives that could be expressed through this model. Connected through the entropy law intimately to irreversible processes and time, thermodynamics provided an arena to debate which way the world was going.

Author(s): Elizabeth Neswald[1]
Institution(s): *1. Brock University*

91.04 – The William Ellery Hale Lectures at the National Academy of Sciences, 1914-1918

In 1913 George Ellery Hale, together with his brother William and sister Martha pledged $1000 per year for five years to inaugurate an annual series of lectures in memory of their father. The series would explore "the general subject of Evolution, which is designed to give a clear and comprehensive outline of the broad features of inorganic and organic evolution in the light of recent research." (NAS Annual Report 1914 p. 24). Here we look briefly at how evolution entered into astronomical thinking in the late 19th Century, and specifically into George Ellery Hale's universe as an organizing principle for research and institutional development, as illustrated by this lecture series, which brought the likes of Ernest Rutherford, W. W. Campbell and T. C. Chamberlin to speak before scientific Washington.

Author(s): David H. DeVorkin[1]
Institution(s): *1. Smithsonian Inst.*

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101 – Kavli Foundation Lecture: New Results About the Earth's Van Allen Radiation Belts, Daniel Baker (University of Colorado)

101.01 – New Results About the Earth’s Van Allen Radiation Belts

The first great scientific discovery of the Space Age was that the Earth is enshrouded in toroids, or “belts”, of very high-energy magnetically trapped charged particles. Early observations of the radiation environment clearly indicated that the Van Allen belts could be delineated into an inner zone dominated by high-energy protons and an outer zone dominated by high-energy electrons. Subsequent studies showed that electrons in the energy range 100 keV < E< 1 MeV often populated both the inner and outer zones with a pronounced “slot” region relatively devoid of energetic electrons existing between them. This two-belt structure for the Van Allen moderate-energy electron component was explained as being due to strong interactions of electrons with electromagnetic waves just inside the cold plasma (plasmapause) boundary. The energy distribution, spatial extent and particle species makeup of the Van Allen belts has been subsequently explored by several space missions. However, recent observations by the NASA dual-spacecraft Van Allen Probes mission have revealed wholly unexpected properties of the radiation belts, especially at highly relativistic (E > 2 MeV) and ultra-relativistic (E > 5 MeV) kinetic energies. In this presentation we show using high spatial and temporal resolution data from the Relativistic Electron-Proton Telescope (REPT) experiment on board the Van Allen Probes that multiple belts can exist concurrently and that an exceedingly sharp inner boundary exists for ultra-relativistic electrons. Using additionally available Van Allen Probes data, we demonstrate that these remarkable features of energetic electrons are not due to a physical boundary within Earth’s intrinsic magnetic field. Neither is it likely that human-generated electromagnetic transmitter wave fields might produce such effects. Rather, we conclude from these unique measurements that slow natural inward radial diffusion combined with weak, but persistent, wave-particle pitch angle scattering deep inside the Earth’s magnetosphere can conspire to create an almost impenetrable barrier through which the most energetic Van Allen belt electrons cannot migrate.

Author(s): Daniel Baker[1]
Institution(s): *1. University of Colorado*

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102 – The Milky Way, The Galactic Center I

102.01 – Does the Milky Way lie on the Tully-Fisher Relation?

Using new estimates of the optical properties of the Milky Way, we can for the first time place it accurately on the Tully-Fisher relation (TFR) and other scaling relations for spiral galaxies. We make use of improved measurements of both the stellar mass and luminosity of our Galaxy from our recent work. We find that the properties of the Milky Way are in excellent agreement with the best-fit optical, stellar-mass, and baryonic TFRs followed by other spiral galaxies, contrary to prior claims in the literature. We also investigate our Galaxy’s position in the 3D luminosity-velocity-size (LVS) parameter space, incorporating measurements of the disk scale length for both the Milky Way and external galaxies. Using updated measurements of the stellar *light* distribution of the Galactic disk, we find that the Milky Way is typical compared the best-fit LVS scaling relation derived via Principal Component Analysis. However, when using the best-to-date, dynamically-measured distribution of stellar *mass* in the Galactic disk, we find the Milky Way is off the LVS relation at the ~2σ level. Since scale lengths for external galaxies are measured using starlight, the former should be the more appropriate comparison. Overall, given this level of consistency, our ability to study the Milky Way in more intimate detail than other galaxies may ultimately help us to decipher the origins of the Tully-Fisher relation.

Author(s): Timothy Licquia[1], Jeffrey Newman[1]
Institution(s): *1. University of Pittsburgh*

102.02 – A New Luminosity Function for Stars in the Galactic Bulge

We present a new calculation for the luminosity function of stars in the galactic bulge. We describe our analysis of archival HST data combined with VISTA VIRCAM-VVV survey data and Microlensing Observations in Astrophysics (MOA) data and include in-depth discussions of calibration, charge transfer efficiency, cosmic ray removal, and disk star decontamination. We describe how the luminosity function, and thus the mass function, varies with galactic latitude. This calculation permits a new estimate for the microlensing event rate in portions of the galactic bulge not accessible to current survey methods due to obscuration by dust. Finally, we outline the general characteristics of the observed populations and discuss implications for field selection for NASA's Wide-Field Infrared Survey Telescope mission.

Author(s): Emily Gilbert[1], Sean Terry[1], Ryan Pfeifle[1]
Institution(s): *1. NASA Goddard Space Flight Center*

102.03 – The Best and Brightest Metal-Poor Stars

The chemical abundances of large samples of extremely metal-poor (EMP) stars can be used to investigate metal-free stellar populations, supernovae, and nucleosynthesis as well as the formation and galactic chemical evolution of the Milky Way and its progenitor halos. However, current progress on the study of EMP stars is being limited by their faint apparent magnitudes. We have developed a new, efficient selection that uses only public, all-sky APASS optical, 2MASS near-infrared, and WISE mid-infrared photometry to identify bright metal-poor star candidates through their lack of molecular absorption near 4.6 microns. High-resolution follow up has revealed that 3.8% of our candidates have $[Fe/H] < -3.0$ and 32.5% have $-3.0 < [Fe/H] < -2.0$. We are using the Automated Planet Finder, Gemini, and Magellan to follow up all of our metal-poor candidates with $V < 12$ in both hemispheres with the goal of collecting the most information-rich sample of metal-poor stars ever assembled.

Author(s): Kevin Schlaufman[1]
Institution(s): *1. MIT Kavli Institute for Astrophysics and Space Research*

102.04 – The GALAH Survey: overview and goals

The GALAH (GALactic Archaeology with HERMES) survey is a large Australian-led project that will measure the chemical compositions and radial velocities of 1 million stars in the Milky Way. Using the new HERMES spectrograph at the Anglo-Australian Telescope, GALAH takes high-quality (S/N>100), high-resolution (R~28,000) spectra for up to 400 stars per hour. I will discuss the scientific goals of GALAH: to identify chemically similar groups of stars in the Galactic disk, which are most likely long-disrupted star clusters, and to decipher the history of star formation, chemical enrichment, stellar migration and minor mergers in the Milky Way. More than 100,000 stars will have been observed by the end of 2014. I will also discuss our parallel project, the Kepler K2 Galactic Archaeology survey, which seeks to derive seismic parameters for many GALAH stars.

Author(s): Jonathan Bland-Hawthorn[1]
Institution(s): *1. The University of Sydney*
Contributing team(s): The GALAH Team

102.05 – The GALAH Survey: observational overview

The GALAH (GALactic Archaeology with HERMES) survey is a large Australian-led project that will measure the chemical compositions and radial velocities of 1 million stars in the Milky Way. GALAH is on track to acquire high-quality (S/N>100), high-resolution (R~28,000) spectra for nearly 100,000 stars in the first year of observing operations. I will describe the observing strategies and capabilities that enable this high data rate, discuss the observational progress to date, and show examples of the data acquired thus far.

Author(s): Sarah L. Martell[1]
Institution(s): *1. University of New South Wales*
Contributing team(s): GALAH Survey team

102.06 – The GALAH Survey: Early Science Results

The GALAH (GALactic Archaeology with HERMES) survey is a large Australian-led project that will measure the chemical compositions and radial velocities of 1 million stars in the Milky Way. The primary science goals have to do with "chemical tagging": using groups of stars with matching chemical abundance patterns to study the history of star formation and chemical evolution in the disk. However, there are many other astrophysical questions that can be addressed with GALAH data. I will discuss early results across a broad range of GALAH science goals.

Author(s): Daniel B. Zucker[1]
Institution(s): *1. Macquarie University*
Contributing team(s): GALAH Team

102.07 – Galactic Center Source G1 and other G2-like Sources

We present new measurements of the Galactic Center source G1, an extremely red source was discovered in 2004 to be within 0.20 arcsec of the black hole. This source has moved significantly on the plane of the sky and, when modeled as Keplerian orbital motion, it appears to have a very eccentric orbit (e = 0.99 $^{+0.002-0.02}$) and has recently passed through periapse (T^{o} = 2001.2 ± 0.6). Our observations and orbital fit suggest that G1 and G2 have similar orbital orientations, but similar analyses for other sources show that not all infrared excess sources have the same orientation. Additionally, the survival of G1 through periapse passage implies that these red objects are stellar in nature.

Author(s): Breann Sitarski[4], Andrea M. Ghez[4], Mark Morris[4], Gunther Witzel[4], Jessica R. Lu[3], Tuan Do[2], Anna Boehle[4], Randall Campbell[5], Leo Meyer[4], Sylvana Yelda[4], Keith Matthews[1]
Institution(s): *1. Caltech, 2. Dunlap Institute, University of Toronto, 3. Institute for Astronomy, University of Hawaii, 4. UCLA, 5. W. M. Keck Observatory*

102.08 – G2's closest approach to the Galactic Center black hole

We report new observations of Galactic Center sources G2 and Sgr A* from the W. M. Keck Observatory. Both sources are of great interest and vary temporally; G2 is the putative gas cloud now passing through periapse in its orbit around the black hole at the center of the Milky Way Galaxy and Sgr A* is the emission associated with the central black hole. Our observations were obtained on 2014 March 19 & 20 (UT) with the Keck II laser guide star adaptive optics system (LGSAO) and the facility near-infrared camera (NIRC2) through the K' and L' broadband filters. At this time, G2 was expected to have been at closest approach with a separation from Sgr A* of only ~20 mas and, therefore, to be spatially unresolved from Sgr A*. Nevertheless, the two can be disentangled spectrally. In the L'-band, both Sgr A* and G2 contribute to the total flux; however, Sgr A*'s L' flux is estimated and removed based on (1) the analysis of K'-band maps showing bright and low states of Sgr A* (2) the well measured and constant K'-L' color of Sgr A*. We conclude that G2, which is currently experiencing its closest approach, is still intact and compact, in contrast to predictions for a simple gas cloud hypothesis and therefore most likely hosts a central star.

Author(s): Gunther Witzel[2], Andrea M. Ghez[2], Mark Morris[2], Breann Sitarski[2], Anna Boehle[2], Randall Campbell[1]
Institution(s): *1. Keck observatory, 2. UCLA*

102.09 – An Update on Chandra/VLA Galactic Center Campaigns Targeting Sgr A* and G2

The much-anticipated close approach between the G2 object and Sgr A* has now come and gone. High-energy emission from the collision was expected to rise toward pericenter (Spring 2014) and continue over several years as the material circularized, but no clear changes in Sgr A*'s X-ray or radio emission have been detected. In the mean time, our rich multiwavelength data sets continue to probe the physical processes that underlie rapid flares originating near the black hole's event horizon, and we have detected the brightest-ever X-ray flare in our Chandra and VLA observations. The appearance of a new magnetar (SGR J174540.2-290029, 2.4" from Sgr A*) and an outburst from a very faint X-ray binary (CXO J174540.0-290005) are also yielding new Galactic Center science. We present an update on our Chandra and VLA campaigns and discuss the constraints these data place on theoretical models for the Sgr A*/G2 encounter and Sgr A*'s X-ray flares.

Author(s): Daryl Haggard[1], Frederick K. Baganoff[2], Gabriele Ponti[3], Craig O. Heinke[6], Nanda Rea[7], Joseph Neilsen[2], Michael Nowak[2], Sera Markoff[7], Nathalie Degenaar[8], Farhad Yusef-Zadeh[4], Douglas A. Roberts[4], Christaan Brinkerink[9], Casey J. Law[5], Stefan Gillessen[3], Riley Connors[7]
Institution(s): *1. Amherst College, 2. Massachusetts Institute of Technology, 3. Max-Planck-Institut für extraterrestrische Physik, 4. Northwestern University/CIERA, 5. UC Berkeley, 6. University of Alberta, 7. University of Amsterdam, 8. University of Michigan, 9. University of Nijmegen*

103 – AGN, QSO, Blazars I

103.01 – AGN Space Telescope and Optical Reverberation Mapping Project. I. *Hubble Space Telescope* Spectroscopy of NGC 5548

Beginning in 2014 February, we obtained 170 *HST* COS ultraviolet spectra of the Seyfert 1 galaxy NGC 5548 at an approximately daily cadence as part of a large reverberation-mapping program whose goals are (1) to determine the geometry and kinematics of the broad emission-line region and (2) to measure the central black hole mass. This is the largest UV reverberation program that has ever been undertaken, and it has been supported by optical ground-based imaging and spectroscopy and by space-based observations with *Swift*, *Chandra*, and *Spitzer*. The UV continuum and broad emission lines varied strongly during the course of this campaign, and individual "events" were well-resolved in time, with the variations of the strong emission lines (Lyman alpha and C IV 1549) lagging behind those in the UV continuum with delays of 5 – 6 days. We report here on the initial results of this program.

Author(s): Bradley M. Peterson[1]
Institution(s): *1. Ohio State Univ.*
Contributing team(s): The AGN STORM Team

103.02 – AGN Space Telescope and Optical Reverberation Mapping Project II. Ultraviolet and Optical Continuum Analysis

The AGN STORM collaboration recently completed an extensive reverberation mapping campaign, targeting NGC 5548 with observations spanning the hard X-rays to mid-infrared. This campaign represents a massive collaborative effort, with far UV continuum spectrophotometry obtained through an intensive *HST COS* program, and near-UV/optical broad band photometry obtained from *Swift* and over 25 ground-based telescopes (in BVR and griz). The campaign spanned the entire 2014 observing season with virtually daily cadence, which allows us to compare with unprecedented accuracy the detailed structure of the observed UV and optical continuum emission signals in this archetypal AGN. We find statistically significant time delays between lightcurves from different wavebands, and this result has implications for the temperature, ionization, and geometric configuration of the AGN's sub-parsec scale environment. We will present the UV/optical continuum lightcurves from this campaign, as well as an analysis of the wavelength-dependent structure of the time delays.

Author(s): Michael Fausnaugh[1]
Institution(s): *1. Department of Astronomy, The Ohio State University*
Contributing team(s): The AGN STORM Team

103.03 – AGN Space Telescope and Optical Reverberation Mapping Project. III. Optical Emission Line Analysis of NGC 5548

We report on the results of a ground-based optical spectroscopy monitoring campaign that was designed to measure the H-beta reverberation in NGC 5548 simultaneously with *Hubble Space Telescope* C IV monitoring in the UV. We obtained 144 epochs of spectroscopy from the MDM 1.3 m telescope, 41 epochs from the Lick Observatory 3 m telescope, 24 epochs from the Asiago Observatory 1.2 m telescope, 13 epochs from the Apache Point 3.5 m telescope, 6 epochs from the WIRO 2.3 m telescope, and 4 epochs from the 2.5 m Nordic Optical Telescope, making this one of the most intensive and well-sampled reverberation mapping programs to date. We will present the H-beta and optical continuum light curves and the H-beta reverberation lag measurements, as well as velocity-resolved lags spanning the broad H-beta line profile. We will also compare the H-beta response with the C IV reverberation lag measured simultaneously from the *HST* campaign.

Author(s): Liuyi Pei[1]
Institution(s): *1. Unviersity of Californina Irvine*
Contributing team(s): The AGN STORM Team

103.04 – AGN Space Telescope and Optical Reverberation Mapping Project. IV. Velocity-Delay Mapping of Broad Emission Lines in NGC 5548

Two-dimensional velocity-delay maps of AGN broad emission line regions can be recovered by modelling observations of reverberating emission-line profiles on the assumption that the line profile variations are driven by changes in ionising radiation from a compact source near the black hole. The observable light travel time delay resolves spatial structure on iso-delay paraboloids, while the doppler shift resolves kinematic structure along the observer's line-of-sight. Velocity-delay maps will be presented and briefly discussed for the Lyman alpha, CIV and Hbeta line profiles based on the HST and ground-based spectrophotometric monitoring of NGC 5548 during the 2014 AGN STORM campaign.

Author(s): Keith D. Horne[1]
Institution(s): *1. Univ. of St. Andrews*
Contributing team(s): The AGN STORM Team

103.05 – AGN Space Telescope and Optical Reverberation Mapping Project V. Continuum Time Delays and Disk Inclinations

Reverberation mapping is a proven method for obtaining black hole mass estimates and constraining the size of the BLR. We analyze multi-wavelength continuum light curves from the 7 month AGN STORM monitoring of NGC 5548 and use reverberation mapping to model the accretion disk time delays. The model fits the light curves at UV to IR wavelengths assuming reprocessing on a flat, steady-state blackbody accretion disk. We calculate the inclination-dependent transfer function and investigate to what extent our model can determine the disk inclination, black hole MMdot and power law index of the disc temperature-radius relation.

Author(s): David Starkey[1]
Institution(s): *1. University of St Andrews*
Contributing team(s): The AGN STORM Team

103.06 – Space Telescope and Optical Reverberation Mapping Project VI. Variations of the Intrinsic Absorption Lines in NGC 5548

The AGN STORM collaboration monitored the Seyfert 1 galaxy NGC 5548 over a six-month period, with observations spanning the hard X-ray to mid-infrared wavebands. The core of this campaign was an intensive HST COS program, which obtained 170 far-ultraviolet spectra at approximately daily intervals, with twice-per-day monitoring of the X-ray, near-UV, and optical bands during much of the same period using Swift. The broad UV absorption lines discovered by Kaastra et al. (2014) and associated with the new soft X-ray obscurer are continuously present in the STORM campaign COS spectra. Their strength varies with the degree of soft X-ray obscuration as revealed by the Swift X-ray spectra. The narrow associated absorption lines in the UV spectrum of NGC 5548 remain strong. The lower-ionization transitions that appeared concurrently with the soft X-ray obscuration vary in response to the changing UV flux on a daily basis. Their depths over the longer term, however, also respond to the strength of the soft X-ray obscuration, indicating that the soft X-ray obscurer has a significant influence on the ionizing UV continuum that is not directly tracked by the observable UV continuum itself.

Author(s): Gerard A. Kriss[1]
Institution(s): *1. STScI*
Contributing team(s): AGN STORM Team

103.07 – New insights from deep JVLA data on the candidate recoiling super massive black hole CID-42

We present deep 3 GHz JVLA observations of the candidate recoiling black hole CID-42 detected in the Chandra COSMOS survey. CID-42 shows two optical sources in the HST/ACS image and a large velocity offset of ≈ 1300 km s^{-1} between the broad and narrow Hβ emission line in the optical spectrum. X-rays are emitted by the point source in the optical image, while the second optical source could host a star forming region with a SFR=6 Msun/yr. With a 7σ detection in the JVLA data, we find that the entire observed 3 GHz radio emission can be associated with the optical point source of CID- 42, coincident with the detected X-ray emission. We use our 3 GHz data combined with other radio data from the literature ranging from 320 MHz to 9 GHz, which include the VLA, JVLA, VLBA and GMRT data, to construct a radio synchrotron spectrum of CID-42. The radio spectrum suggests a type I unobscured radio-quiet flat-spectrum AGN in the optical extended component which may be surrounded by a more extended region of old synchrotron electron population or shocks generated by the outflow from the supermassive black hole. Our data are consistent with the recoiling black hole picture but cannot rule out the presence of an obscured and radio quiet or quiescent SMBH in the second optical source.

Author(s): Francesca M. Civano[2], Mladen Novak[1], Vernesa Smolcic[1]
Institution(s): *1. University of Zagreb, 2. Yale University*

103.08D – Modeling Reverberation Mapping Data: Precise Black Hole Masses and Constraints on the Geometry and Dynamics of the Broad Line Region

We present dynamical modeling of the broad line region (BLR) using high-quality reverberation mapping data taken as part of the Lick AGN Monitoring Project 2008 and 2010 MDM campaigns. While traditional reverberation mapping analysis yields estimates of the mean radius of the BLR, c τ, and black hole mass, $M^{vir} = (f\ v^2\ c\ \tau)/G$, the dynamical modeling approach yields further constraints on the geometry and dynamics of the BLR and a measurement of the black hole mass that does not depend upon the normalizing factor f. For this combined sample of 10 AGN, we generally measure the black hole mass to within 0.15-0.3 dex uncertainty, a significant improvement over the ~0.4 dex uncertainty assumed when using an average value of f. We also find that the Hβ-emitting BLR is typically a nearly face-on thick disk with dynamics dominated by near-circular or inflowing orbits. We also test whether the normalizing factor f is correlated with any properties of the BLR or AGN that might lead to more precise reverberation mapping or single-epoch black hole mass measurements without dynamical modeling. Measuring black hole masses precisely in AGN is crucial for understanding the co-evolution of black holes and their host galaxies. Dynamical modeling of reverberation mapping data has provided the first detailed constraints on the geometry and dynamics of the BLR and has the potential to provide a more precise measurement of the average f factor, reducing the uncertainties in all AGN black hole mass measurements.

Author(s): Anna Pancoast[4], Brendon J. Brewer[3], Tommaso Treu[2], Catherine Grier[1]
Institution(s): *1. Penn State, 2. Universitiy of California Los Angeles, 3. University of Auckland, 4. University of California Santa Barbara*
Contributing team(s): LAMP 2008

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104 – Supernovae I

104.01 – Interaction of a Type Ia Supernovae with Circumstellar Mass

We study the radiation signatures of a type Ia supernova interacting with circumstellar mass (CSM) of various configurations. Although it is hypothesized that type Ia supernovae originate from binary systems with one star donating mass to a carbon-oxygen white dwarf, the nature of the mass donor companion remains a mystery. One way to distinguish the companion is from signatures of the supernova colliding with CSM created by the mass transfer mechanism (e.g. nova shells, wind). CSM is rarely observed, which may be a challenge for different models to explain. In a one-dimensional hydrodynamical simulation, we collide a normal type Ia supernova with CSM of various configurations (e.g. composition, position, density) and calculate various radiation signatures for each case, such as synchrotron, X-ray signal, and hydrogen line luminosity. With this we can study degeneracies between different CSM configurations, accurately calculate the radiation signature of a shell, guide observational tests, and interpret existing observations of interacting supernovae.

Author(s): Chelsea Harris[1], Peter E. Nugent[2], Daniel Kasen[1], Nathaniel Roth[1]
Institution(s): *1. California - Berkeley, University of, 2. Lawrence Berkeley National Laboratory*

104.02D – Spectrum formation at late times in type Ia supernovae

Spectra of type Ia supernovae near maximum light are characterized by broad and blended P Cygni profiles from many atomic lines. Disentangling them in order to glean information about the line forming regions in the supernova ejecta is a challenging task. After maximum light the spectra undergo a complicated transition from being P Cygni-dominated to emission-dominated. At these later times the spectra probe deeper regions of the ejecta, providing valuable insight regarding the initial stages of the explosion, which remain largely unknown. I have performed a series of analytic and numerical calculations to explore in detail the underlying physics and radiative transfer mechanisms which lead to the observed properties of late-time spectra. I have constructed a simple model of an optically thick scattering line embedded in a medium emitting optically thin continuum radiation, and have shown that, compared to traditional P Cygni profiles, these spectral features appear qualitatively similar but undergo noticeable wavelength shifts which may be incorrectly interpreted as Doppler shifts of the line-forming region, or else may lead to misidentification of the line altogether. Within the context of supernova spectra, this model may be representative of certain strong lines, e.g., resonance lines of iron-peak elements, which may shift in wavelength due to the surrounding weak emission from the forest of forbidden lines which appear after maximum light. More recently, I have performed detailed radiative transfer calculations of a delayed-detonation explosion model and have shown that, even several months post-maximum light, the near-infrared spectra consist primarily of permitted lines from iron and cobalt. I also identify the observed emission at 1.98 microns as a forbidden line of nickel-58, which is produced during phases of high-density nuclear burning during the supernova explosion. Finally, I have compared synthetic spectra from this same model to even later optical and ultraviolet spectra of the nearby SN 2011fe and have shown that, even 1 year post-maximum light, the optical and especially the ultraviolet consists of a complicated blend of permitted and forbidden lines of iron-peak elements.

Author(s): Brian Friesen[1]
Institution(s): *1. University of Oklahoma*

104.03D – Helium Shells on Sub-Chandrasekhar White Dwarfs: Ignition and Convection

Sub-Chandrasekhar white dwarfs accreting an envelope of helium allow for a range of explosive phenomena that could yield a variety of observable transients. Helium novae, so-called "point" Ia supernovae (.Ia SNe), rapid decline type Ia, and normal type Ia supernovae are all potential outcomes of helium accretion onto sub-Chandrasekhar white dwarfs. In this talk we outline why these systems have received a great deal of scrutiny recently and present our 3D models of convective nuclear burning in the helium envelope. We focus on thin, low-mass envelopes that are the best candidates for yielding normal type Ia supernovae. The envelope is modeled with the low-Mach hydrodynamics code Maestro. Maestro is optimized for modeling sub-sonic convective flow over long timescales while still being able to capture local compressibility effects due to nuclear burning as well as large-scale adjustments of stellar hydrostatic equilibrium. With it we model the convective burning in low-mass helium shells for carbon/oxygen white dwarf cores of 0.8, 1.0, 1.1, and 1.2 solar masses. For a suite of models we characterize the geometry, timing, and thermodynamics of ignition as well as the envelope's convective properties. Finally, we discuss the implications of our results for the viability of these systems as transient progenitors with a focus on normal type Ia supernovae.

Author(s): Adam M. Jacobs[2], Michael Zingale[2], Andrew Nonaka[1], Ann Almgren[1], John Bell[1]
Institution(s): *1. Lawrence Berkeley National Laboratory, 2. Stony Brook University*

104.04 – The Progenitor System of the Type Iax SN 2012Z

Type Iax supernovae (SNe Iax) are stellar explosions that are similar to SNe Ia at maximum light, except with lower ejecta velocities and luminosities. At late times, their spectroscopic properties diverge from other SNe, but their composition (dominated by iron-group and intermediate-mass elements) suggests these objects are thermonuclear in origin. We present the detection of a luminous, blue source coincident with the Type Iax SN 2012Z from deep HST pre-explosion imaging of NGC 1309. This is likely the first time the progenitor system of a white dwarf (WD) supernova has been observed. We explore some of the possible scenarios that are consistent with our observations. Based on its luminosity, colors, and environment, as well as a similarity to the pre-outburst Galactic helium nova system V445 Puppis, our favored model of SN 2012Z is the explosion of a WD accreting from a helium-star companion. Future HST observations scheduled for January 2015, after SN 2012Z has faded, could corroborate this hypothesis, or else show that this supernova was actually the explosive death of a massive star.

Author(s): Curtis McCully[2], Saurabh Jha[3], Ryan J. Foley[1]
Institution(s): *1. University of Illinois at Urbana-Champaign, 2. Las Cumbres Observatory Global Telescope Network, 3. Rutgers, The State University of New Jersey*

104.05D – Superluminous Supernovae: A Pan-STARRS1 Perspective

Wide-field optical time-domain surveys like Pan-STARRS and PTF provide an opportunity to discover and decipher new types of transients. One such discovery in the past decade is a new class of "superluminous" supernovae (SLSNe), which have bolometric luminosities 10-100 times those of normal core-collapse and Type Ia SN and spectra that do not match known supernova classes. These SLSNe represent a challenge to our understanding of the deaths of massive stars, the mechanism for powering optical emission in SNe, and to the standard core-collapse picture. In this talk, I will present results from the Pan-STARRS1 Medium Deep Survey, which has discovered ~20 SLSNe out to redshift 1.6 in its four years of operation. I will address the nature of SLSNe from two angles: 1) by characterizing the explosions themselves and comparing the observed properties to model predictions, and 2) by constraining the progenitor population through a comprehensive study of SLSN host galaxy environments.

Author(s): Ragnhild Lunnan[1], Ryan Chornock[2], Edo Berger[1]
Institution(s): *1. Harvard University, 2. Ohio University*
Contributing team(s): Pan-STARRS1 CfA/JHU Transient Team

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105 – Extrasolar Planets: Kepler's Legacy I

105.01D – Increasing the sensitivity of Kepler to Earth-like exoplanets

Many transiting exoplanets have been discovered using photometry from the Kepler mission but the results are still very incomplete in some of the most interesting parts of parameter space: small planetary radius and long orbital period. We have developed a method for detecting transiting exoplanet signals in stellar light curves that is more sensitive to small planets on long orbits than previously published procedures. It is standard practice to start by "de-trending" the light curves—by filtering—to remove the instrumental systematics and stellar variability from the time series. Instead, we build an flexible model for these effects using a Gaussian Process. We use as inputs to the Gaussian Process not just time but also the light curves of dozens of other stars. This exploits the causal structure of the problem: permitting the noise model to capture spacecraft-induced covariability. Since we know a priori that the other stars are causally unrelated to the star of interest, any information that they share must be due to systematics. A key motivation for our work is that any filtering—no matter how robust—reduces the amplitude of the signals of interest. By marginalizing over the stellar and instrumental variability while simultaneously fitting for the transits, we maintain sensitivity to transit signals and reduce contamination. We apply our method to light curves from the Kepler mission. Using synthetic transits generated by realistic planetary systems injected into raw aperture photometry from the pipeline, we determine the detection efficiency of our method and train a supervised classification algorithm to weed out false signals. Our pipeline returns all of the ingredients needed for studies of exoplanet populations: a catalog of planet candidates, posterior samples for the physical parameters of these planets and their host stars, and an empirical measurement of the detection efficiency as a function of all of these parameters.

Author(s): Daniel Foreman-Mackey[2], David W. Hogg[2], Bernhard Schölkopf[1], Dun Wang[2]
Institution(s): *1. Max Planck Institute for Intelligent Systems, 2. New York University*

105.02 – Implications for the False-positive Rate in *Kepler* Planet Systems from Transit Duration Ratios

Confirming transiting exoplanet candidates through traditional follow-up methods is challenging, especially for faint host stars. Most of *Kepler's* validated planets relied on statistical methods to separate true planets from false-positives. Multiple transiting planet systems (MTPS) have been previously shown to have low false-positive rates and over 851 planets in MTPSs have been statistically validated so far (Lissauer et al. 2014; Rowe et al. 2014). We show that the period-normalized transit duration ratio (ξ) offers additional information that can be used to establish the planetary nature of these systems. We briefly discuss the observed distribution of ξ for the Q1-Q16 *Kepler* Candidate Search. We also utilize ξ to develop a Bayesian statistical framework combined with Monte Carlo methods to determine which pairs of planet candidates in a MTPS are consistent with the planet hypothesis for a sample of 676 MTPSs that include both candidate and confirmed planets. This analysis proves to be efficient and advantageous in that it only requires catalog-level bulk candidate properties and galactic population modeling to compute the probabilities of a myriad of stellar blend scenarios, without needing additional observational follow-up. Our results agree with the previous results of a low false-positive rate in the *Kepler* MTPSs. Out of our sample of 1,358 pairs of candidates, we find that about 100 pairs have a probability greater than 0.99 of being a MTPS associated with the target star, over 800 pairs have a probability greater than 0.99 of being a MTPS associated with the target star or another star blended in the photometric aperture. Further more, we find that well over a 1,000 pairs have a probability greater than 0.99 to be planetary in nature, either orbiting the same star or separately orbiting two different stars in the aperture. This implies, independently of any other estimates, that most of the MTPSs detected by *Kepler* are very likely to be planetary in nature, but that a substantial fraction could be orbiting stars other than the putative target star, and therefore may be subject to significant error in the inferred planet parameters resulting from unknown or mismeasured stellar host attributes.

Author(s): Robert C. Morehead[1], Eric B Ford[1]
Institution(s): *1. The Pennsylvania State University*

105.03 – New Constraints on the False Positive Rate for Short-Period Kepler Planet Candidates

The Kepler space mission has discovered thousands of potential planets orbiting other stars, thereby setting the stage for in-depth studies of different populations of planets. We present new multi-wavelength transit photometry of small (Rp < 6 Earth radii), short-period (P < 6 days) Kepler planet candidates acquired with the Gran Telescopio Canarias. Multi-wavelength transit photometry allows us to search for wavelength-dependent transit depths and subsequently identify eclipsing binary false positives (which are especially prevalent at the shortest orbital periods). We combine these new observations of three candidates with previous results for five other candidates (Colón & Ford 2011 and Colón, Ford, & Morehead 2012) to provide new constraints on the false positive rate for small, close-in candidates. In our full sample, we identify four candidates as viable planets and four as eclipsing binary false positives. We therefore find a higher false positive rate for small, close-in candidates compared to the lower false positive rate of ~10% determined by other studies for the full sample of Kepler planet candidates (e.g. Fressin et al. 2013). We also discuss the dearth of known planets with periods less than ~2.5 days and radii between ~3 and 11 Earth radii (the so-called "sub-Jovian desert"), since the majority of the candidates in our study are located in or around this "desert." The lack of planets with these orbital and physical properties is not expected to be due to observational bias, as short-period planets are generally easier to detect (especially if they are larger or more massive than Earth). We consider the implications of our results for the other ~20 Kepler planet candidates located in this desert. Characterizing these candidates will allow us to better understand the formation processes of this apparently rare class of planets.

Author(s): Knicole D. Colón[1], Robert C. Morehead[2], Eric B. Ford[2]
Institution(s): *1. Lehigh University, 2. The Pennsylvania State University*

105.04 – *Kepler*'s Missing Planets: Using QATS to Search for Planets with TTVs

Thousands of planet candidates have been discovered in the *Kepler* data. Many of the multi-planet systems show dynamical interactions between the planets via transit timing variations (TTVs). Systems displaying TTVs allow for precise mass measurements to be made without any radial velocity followup, and even allow for the detection and characterization of non-transiting companions. While systems with large amplitude TTVs are thus one of the most interesting subsets of *Kepler* candidates, planet discovery pipelines largely search only for strictly periodic transits; their sensitivity to planets with TTVs greater than even half the transit duration are greatly reduced and many such systems may be missed.

We present initial results from our quasi-periodic automated transit search (QATS), which explicitly searches for planets with TTVs up to 3% of its period. Using this method, we have discovered several completely new planet candidates, often with periods near resonance to known KOIs and showing anti-correlated TTVs. We present notable features and preliminary analysis of the most exciting candidates.

Author(s): Ethan Kruse[1], Eric Agol[1]
Institution(s): *1. University of Washington*

105.05 – The distribution of period ratios in Kepler planetary systems

Kepler's multi-planet systems are a valuable tool to understand the architectures and dynamics of the inner parts of planetary systems. I present an analysis of the distribution of orbital period ratios from candidate systems identified in the Quarter 8 catalog (Burke et al. 2014). This distribution is corrected for the effects of geometric transit probabilities and the completeness of the data reduction pipeline. We find that the distribution of period ratios falls as a power law with exponent –1.26 ± 0.05. We also identify a new, statistically significant feature near a period ratio of 2.2. These observations may provide insights into the formation and evolution of these systems.

Author(s): Jason H. Steffen[1], Jason A. Hwang[1]
Institution(s): *1. Northwestern University*

105.06 – Dissecting Kepler's Objects of Interest: Complete Uniform MCMC modeling of the KOI Database

We present an analysis of the Kepler Object of Interest Catalogue based on complete MCMC modeling to provide posterior distributions. We show how planet-candidates, eclipsing binaries, background blends and false-alarms assemble into populations based on fundamental transit parameters such as transit duration and depth. Our work identifies regions of parameter space that allow one to identify planets with low false-positive contamination. We also present a 'HR-diagram' based on exoplanetary transits and measure the underlying eccentricity distribution and the rate of the stellar blends due to binarity.

Author(s): Jason Rowe[4], Thomas Barclay[1], Natalie M. Batalha[2], Christopher J. Burke[4], Joseph Catanzarite[4], Jessie Christiansen[3], Jeffrey Coughlin[4], Michael R Haas[2], Kelsey L. Hoffman[4], Fergal Mullally[4], Elisa V. Quintana[2], Susan E. Thompson[4]
Institution(s): *1. BAERI, 2. NASA-Ames Research Center, 3. NExSCi, 4. SETI Institute*
Contributing team(s): Kepler Team

105.07 – Delivering on the promise of transit timing variations

Transiting timing variations (TTVs) have held the promise of enabling the measurement of planet masses and radii in multi-transiting planet systems found with the Kepler spacecraft. However, when a single TTV frequency is detected, a degeneracy commonly exists between the eccentricities and masses of the planets (Lithwick, Xie & Wu 2012), making the masses and eccentricities indeterminate. In some cases this degeneracy has been broken with n-body integrations, but this enshrouds the answer in complex numerics. It may also be broken statistically, but this still does not provide measurements for individual planets.

We show how this degeneracy may be broken with a measurement of TTV at the synodic frequency, which has an amplitude that depends strongly on the planet-star mass ratios and on the planets' semi-major axis ratio, yet weakly on their eccentricities. This "chopping" signal is generally modest in amplitude, but when it is detected it can provide the primary constraint upon planet masses, such as in Kepler 11d&e and KOI-872c. We show by example how harmonic analysis of TTVs combined with analytic formulae can break the eccentricity-mass degeneracy without the need for dynamical integrations, thus delivering on the promise of TTVs, while at the same time clarifying the origin of the planetary mass constraints resulting from TTV analysis.

Author(s): Eric Agol[2], Katherine Deck[1]
Institution(s): *1. Caltech, 2. Univ. of Washington*

105.08 – Planet Hunters 2 in the K2 Era

Planet Hunters (http://www.planethunters.org) is an online citizen science project enlisting hundreds of thousands of people to search for planet transits in the publicly released *Kepler* data. Volunteers mark the locations of visible transits in a web interface, with multiple independent classifiers reviewing a randomly selected ~30-day light curve segment. In September 2014, Planet Hunters entered a new phase. The project was relaunched with a brand new online classification interface and discussion tool built using the Zooniverse's (http://www.zooniverse.org) latest technology and web platform. The website has been optimized for the rapid discovery and identification of planet candidates in the light curves from K2, the two-wheeled ecliptic plane *Kepler* mission. We will give an overview of the new Planet Hunters classification interface and Round 2 review system in context of the K2 data. We will present the first results from the Planet Hunters 2 search of K2 Campaigns 0 and 1 including a summary of new planet candidates.

Author(s): Megan E. Schwamb[2], Debra Fischer[5], Tabetha S. Boyajian[5], Matthew J. Giguere[5], Sascha Ishikawa [1], Chris Lintott[4], Stuart Lynn[1], Joseph Schmitt[5], Chris Snyder[1], Ji Wang[5], Thomas Barclay[3]
Institution(s): *1. Adler Planetarium, 2. Institute of Astronomy & Astrophysics, Academia Sinica (ASIAA), 3. NASA Ames Research Center, 4. University of Oxford , 5. Yale University*

106 – HEAD I: Centennial of General Relativity: An Astrophysical Perspective

AAS Special Session
To celebrate the centenary of the publication of Einstein's Field Equations, the AAS High Energy Astrophysics Division and NASA's Physics of the Cosmos program are pleased to co-host two special sessions on Theory of General Relativity. The first session provides a historical perspective on the development of the theory of general relativity and astrophysical constraints of General Relativity. The second session looks forward from current astrophysical constraints to next-generation measurements ranging from space-based measurements of gravitational waves and the powerful tests made possible through studies of binary pulsars through to cosmological tests of General Relativity.

106.01 – A History of High Energy Astrophysics, the Subject and the Section

The phrase "high energy astrophysics" appears as the title of the proceedings of a 1965 Varenna summer school; HEAD began in 1968; and the similarly-purposed IAU Commission 48 on High Energy Astrophysics, the APS Division of Cosmic Physics, and the Texas Symposia on Relativistic Astrophysics date from 1970, 1970, and 1963 respectively. Many of the founders are still with us: EN Parker, 1st chair of HEAD; MJ Rees, 1st Vice President of C48; CJ Waddington, 1st Secretary-Treasurer of DCP; and I Robinson & E Schucking, 2 of the 3 co-founders of Texas. DCP has become the Division of Astrophysics, C48 voted itself out of existence, but HEAD and Texas continue to fluorish. Their subject matter has, however, evolved considerably. Varenna editor Livio Gratton wrote: "The words...are thus meant to indicate not merely processes in which large amounts of energy are involved, but mainly those in which the rate of energy release per second and per gram is very high as compared with the more usual processes going on in normal stars and galaxies." Needing physics beyond Newtonian gravitation and Maxwell's equations has also been a common trait. At times the territories have expanded: cosmology at HEAD meetings, interstellar molecules and large telescopes at Texas symposia, but at other times narrowed: C48 to become nearly synonymous with astronomy from space, and HEAD to focus on X- and gamma-ray astronomy, with cosmic rays in and out of the inventory. The talk will address how the structure of HEAD changes in its early years, the evolution of its subject matter, and some of the great discoveries that belong to all four of these organizations. For what it is worth, VT has chaired HEAD and DAP and been on the governing committees of C48 and Texas.

Author(s): Virginia L. Trimble[1]
Institution(s): *1. UC, Irvine*

106.02 – Testing General Relativity in the Strong-Field Dynamical Regime

General relativity has been well tested in the weak-field slow-motion regime of the solar system. In binary pulsar systems, tests of strong-field aspects of the theory have been carried out and will continue to improve. Testing GR in the strong-field, highly dynamical regime is becoming a dominant theme in experimental relativity. We describe a number of tests that can be carried out, including tests using astrophysical phenomena around black holes, tests using gravitational waves, and tests of black hole no-hair theorems using observations of stars orbiting our galactic center black hole.

Author(s): Clifford M. Will[1]
Institution(s): *1. Univ. of Florida*

106.03 – The Black Hole concept circa 1960 with recent comments

I was privileged to be a student of John Archibald Wheeler in the 1950's as he worked to make gravitation a respectable area of physics. In the most important step after Oppenheimer and Snyder toward understanding the nature of black holes (as yet unnamed), David Finkelstein described the "unidirectional membrane" at $r=2M$ in the Schwarzschild metric. Subsequent work advanced the theory of both the ultimate fate of the matter that collapsed to form a black hole and of the nature of the object itself, which was found to have properties independent of its mode of formation. These two areas of interest can now be categorized usefully in terms of Gerald Holton's concept of "themes" which both set goals and suggest speculations in the development of physical understanding. The works studying the classically predicted Schwarzschild singularity are emphasized by those who inclined to the "reductionist" theme that seeks deep scientific understanding by finding the ultimate constituent of matter (the "ur-atom") and its interactions. The works studying the black hole remnant of a collapse, such as its stability and uniqueness, are more highly respected by those impressed by the "emergence" theme where one finds more insight into Nature is provided by the exploration of emergent theories. These are theories whose language and laws study properties that were invisible at the ur-atom level, as is the case for pressure, volume, and temperature which are not native concepts in the Schrödinger picture of atomic physics.

Author(s): Charles W Misner[1]
Institution(s): *1. University of Maryland*

107 – Extrasolar Planets: Atmospheres I

107.01 – An Open-Source Bayesian Atmospheric Radiative Transfer (BART) Code, with Application to WASP-12b

Atmospheric retrievals for solar-system planets typically fit, either with a minimizer or by eye, a synthetic spectrum to high-resolution ($\Delta\lambda/\lambda$ ~ 1000-100,000) data with S/N > 100 per point. In contrast, exoplanet data often have S/N ~ 10 per point, and may have just a few points representing bandpasses larger than 1 um. To derive atmospheric constraints and robust parameter uncertainty estimates from such data requires a Bayesian approach. To date there are few investigators with the relevant codes, none of which are publicly available. We are therefore pleased to announce the open-source Bayesian Atmospheric Radiative Transfer (BART) code. BART uses a Bayesian phase-space explorer to drive a radiative-transfer model through the parameter phase space, producing the most robust estimates available for the thermal profile and chemical abundances in the atmosphere. We present an overview of the code and an initial application to Spitzer eclipse data for WASP-12b. We invite the community to use and improve BART via the open-source development site GitHub.com. This work was supported by NASA Planetary Atmospheres grant NNX12AI69G and NASA Astrophysics Data Analysis Program grant NNX13AF38G. JB holds a NASA Earth and Space Science Fellowship.

Author(s): Joseph Harrington[3], Jasmina Blecic[3], Patricio Cubillos[3], Patricio Rojo[2], Thomas J. Loredo[1], M. Oliver Bowman[3], Andrew S. D. Foster[3], Madison M. Stemm[3], Nate B. Lust[3]
Institution(s): *1. Cornell University, 2. Universidad de Chile, 3. University of Central Florida*

107.02D – Observations and Thermochemical Calculations for Hot-Jupiter Atmospheres

I present Spitzer eclipse observations for WASP-14b and WASP-43b, an open source tool for thermochemical equilibrium calculations, and components of an open source tool for atmospheric parameter retrieval from spectroscopic data. WASP-14b is a planet that receives high irradiation from its host star, yet, although theory does not predict it, the planet hosts a thermal inversion. The WASP-43b eclipses have signal-to-noise ratios of ~25, one of the largest among exoplanets. To assess these planets' atmospheric composition and thermal structure, we developed an open-source Bayesian Atmospheric Radiative Transfer (BART) code. My dissertation tasks included developing a Thermochemical Equilibrium Abundances (TEA) code, implementing the eclipse geometry calculation in BART's radiative transfer module, and generating parameterized pressure and temperature profiles so the radiative-transfer module can be driven by the statistical module.
To initialize the radiative-transfer calculation in BART, TEA calculates the equilibrium abundances of gaseous molecular species at a given temperature and pressure. It uses the Gibbs-free-energy minimization method with an iterative Lagrangian optimization scheme. Given elemental abundances, TEA calculates molecular abundances for a particular temperature and pressure or a list of temperature-pressure pairs. The code is tested against the original method developed by White at al. (1958), the analytic method developed by Burrows and Sharp (1999), and the Newton-Raphson method implemented in the open-source Chemical Equilibrium with Applications (CEA) code. TEA, written in Python, is modular, documented, and available to the community via the open-source development site GitHub.com. Support for this work was provided by NASA Headquarters under the NASA Earth and Space Science Fellowship Program, grant NNX12AL83H, by NASA through an award issued by JPL/Caltech, and through the Science Mission Directorate's Planetary Atmospheres Program, grant NNX12AI69G.

Author(s): Jasmina Blecic[1], Joseph Harrington[1], M. Oliver Bowman[1], Patricio Cubillos[1], Madison Stemm[1]
Institution(s): *1. University of Central Florida*

107.03D – Exoplanet Atmospheres: From Light-Curve Analyses to Radiative-Transfer Modeling

Multi-wavelength transit and secondary-eclipse light-curve observations are some of the most powerful techniques to probe the thermo-chemical properties of exoplanets. Although the small planet-to-star constrast ratios demand a meticulous data analysis, and the limited available spectral bands can further restrain constraints, a Bayesian approach can robustly reveal what constraints can we set, given the data.
We review the main aspects considered during the analysis of Spitzer time-series data by our group with an aplication to WASP-8b and TrES-1. We discuss the applicability and limitations of the most commonly used correlated-noise estimators. We describe our open-source Bayesian Atmospheric Radiative Transfer (BART) code. BART calculates the planetary emission or transmission spectrum by solving a 1D line-by-line radiative-transfer equation. The generated spectra are integrated over determined bandpasses for comparison to the data. Coupled to our Multi-core Markov-chain Monte Carlo (MC3) statistical package, BART constrains the temperature profile and chemical abundances in the planet's atmosphere. We apply the BART retrieval code to the HD 209458b data set to estimate the planet's temperature profile and molecular abundances.
This work was supported by NASA Planetary Atmospheres grant NNX12AI69G and NASA Astrophysics Data Analysis Program grant NNX13AF38G. JB holds a NASA Earth and Space Science Fellowship.

Author(s): Patricio Cubillos[3], Joseph Harrington[3], Jasmina Blecic[3], Patricio Rojo[2], Madison Stemm[3], Nathaniel B. Lust[3], Andrew S. Foster[3], Thomas J. Loredo[1]

Institution(s): *1. Cornell University, 2. Universidad de Chile, 3. University of Central Florida*

107.04 – Features in the broad-band eclipse spectra of exoplanets: signal or noise?

A planet's emission spectrum contains information about atmospheric composition and structure. We compare the Bayesian Information Criterion (BIC) of blackbody fits and idealized spectral retrieval fits for the 48 planets with published eclipse measurements in multiple thermal wavebands, mostly obtained with the Spitzer Space Telescope. The evidence for spectral features depends on eclipse depth uncertainties. Spitzer has proven capable of eclipse precisions better than 10^{-4} when multiple eclipses are analysed simultaneously, but this feat has only been performed four times. It is harder to self-calibrate photometry when a single occultation is reduced and analysed in isolation; we find that such measurements have not passed the test of repeatability. Single-eclipse measurements either have an uncertainty floor of 5×10^{-4}, or their uncertainties have been underestimated by a factor of 3. If one adopts these empirical uncertainties for single-eclipse measurements, then the evidence for molecular features all but disappears: blackbodies have better BIC than spectral retrieval for all planets, save HD 189733b, and the few planets poorly fit by blackbodies are also poorly fit by self-consistent radiative transfer models. This suggests that the features in extant broad-band emission spectra are due to astrophysical and instrumental noise rather than molecular bands. Claims of stratospheric inversions, disequilibrium chemistry, and high C/O ratios based solely on photometry are premature. We recommend that observers be cautious of error estimates from self-calibration of small data sets, and that modellers compare the evidence for spectral models to that of simpler models such as blackbodies.

Author(s): Nicolas B. Cowan[1], Christopher James Hansen[2], Joel Colin Schwartz[2]
Institution(s): *1. Amherst College, 2. Northwestern University*

107.05 – Balancing the Energy Budget of Short-Period Giant Planets

Tidally locked planets receive stellar energy on a single face, and thus reach thermal equilibrium dictated by the combination of dayside absorption and day-night atmospheric heat transport. These processes are controlled by the irradiation temperature, T_o, which describes the amount of stellar radiation impinging on a planet, the planet's Bond albedo, A_B, defining the fraction of this energy that is absorbed, and heat recirculation efficiency, ε, which relates how much of the absorbed energy is transported to the planet's nightside. Dayside effective temperatures can be inferred by combining eclipse depths at various infrared wavelengths. We consider 41 transiting short-period giant planets on circular orbits ($e<0.01$) and with multiple published thermal eclipse depths. We find that dayside effective temperatures are roughly proportional to irradiation temperatures, indicating uniformly low Bond albedo for these planets. When this first-order trend is divided out, there is tentative evidence for a correlation between T_d/T_o and T_o, suggesting day-night heat transport may be inhibited at the highest temperatures. Incorporating thermal phase variation amplitudes permits a joint constraint on A_B and ε, which we conduct for five suitable transiting planets: HD 149026b, HD 189733b, HD 209458b, WASP-12b, and WASP-18b. These thermal observations demonstrate a tendency towards lower day-night heat transport as T_o climbs. All of the above trends are significant even if the precision of single-eclipse measurements has been overstated. Lastly, we attempt to break the A_B--ε degeneracy for 8 planets with both thermal and optical eclipse observations. However, we find numerous challenges in the conversion from A_g to A_B, which undermines using optical measurements to constrain exoplanetary energy budgets.

Author(s): Joel Colin Schwartz[2], Nicolas B. Cowan[1]
Institution(s): *1. Amherst College, 2. Northwestern University*

107.06 – The Elemental Compositions and Cloud Properties of Hot Jupiters: A Comprehensive Atmospheric Retrieval Study of Hot Jupiter Transmission Spectra

Recent transit surveys using the Hubble Space Telescope have provided an unprecedented set of high-SNR hot Jupiter transmission spectra. Here, I present the main conclusions from a comprehensive atmospheric retrieval study of eight hot Jupiters using the new self-consistent atmospheric retrieval framework SCARLET. For each planet, I derive statistically robust constraints on the metallicity and carbon-to-oxygen ratio of the atmospheric gas, as well as the particle size and vertical extend of clouds and hazes, by combining self-consistent modeling of the atmospheric chemistry and physics with robust Bayesian statistics.

Author(s): Björn Benneke[1]
Institution(s): *1. Caltech*

107.07 – Magnetohydrodynamic Simulations of Hot Jupiter Thermospheres

The majority of models of atmospheric escape from hot Jupiters have focused on one-dimensional, spherically-symmetric models. We present the results from 2-dimensional axisymmetric simulations of hot Jupiters including tidal gravity and magnetic fields as well as photo-ionization and photoelectric heating due to multiple atomic species. Escape is suppressed in polar and equatorial regions by tidal gravity and magnetic fields, respectively, reducing mass-loss estimates achieved through 1-dimensional models. For sufficiently large magnetic field strengths, an equatorial magnetic dead zone creates a static reservoir of hot gas extending to multiple planetary radii and exhibiting temperatures hotter than found within the escaping gas. The possibility of observing this reservoir of gas is discussed, as well as the influence of heavy atoms on the result.

Author(s): Duncan Christie[1], Phil Arras[1], Zhi-Yun Li[1]
Institution(s): *1. University of Virginia*

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108 – The Emerging Multiwavelength View of Planetary Nebulae

AAS Special Session
The traditional view of the formation and evolution of planetary nebulae (PNe) as the simple interaction of two epochs of spherical mass loss -- a slow wind from an expiring asymptotic giant branch (AGB) star, followed by a fast wind from the newly-exposed, proto-white dwarf at the AGB star's core -- has been challenged by observations from modern telescopes and satellite observatories. From the radio to X-ray, the emerging view of PNe is reshaping and potentially redefining our understanding of these iconic celestial objects. Multiwavelength observations of PNe hold the potential to test theories invoking, e.g., magnetic fields, jets, and binary interactions in generating asymmetric PN outflows and structures. In this Special Session we showcase the new perspectives of PNe afforded by multiwavelength observations, and the efforts to reconcile theory and observations, with emphasis on the latest results from the Chandra (X-ray) and Herschel (far-IR) Planetary Nebula Surveys (ChanPlaNS and HerPlaNS).

108.01 – ChanPlaNS: The Chandra Planetary Nebula Survey

The physical mechanisms responsible for the morphological diversity among planetary nebulae (PNe) have been the subject of intense interest and hot debate among PN researchers over the past two decades. The PN shaping problem is multifaceted, with connections to (and implications for) a wide variety of astrophysical systems. Two areas of particular importance are (1) binary star astrophysics and (2) wind interactions and their implications for nebular shaping. X-ray observations play a pivotal role in the study of both of these fundamental aspects of PNe, by revealing (1) point-like X-ray sources at PN central stars that may be indicative of binary companions, and (2) diffuse X-ray emission generated by energetic, PN-shaping shocks. To assess the frequency of appearance and characteristics of these respective PN X-ray sources, we have undertaken the Chandra Planetary Nebula Survey (ChanPlaNS), the first comprehensive X-ray survey of planetary nebulae (PNe) in the solar neighborhood. ChanPlaNS began with a combined Cycle 12 Large Program and archival survey of 35 PNe, with emphasis on high-excitation nebulae, and continued via a Cycle 14 Large Program targeting an additional 24 known compact (R_neb <~ 0.4 pc) PNe. For the latter category of relatively young nebulae, we estimate that the ChanPlaNS survey is ~90% complete within ~1.5 kpc from the Sun. For the ~60 nebulae within this distance observed by Chandra, the point source detection rate is ~36%, and the diffuse X-ray source detection rate is ~27%. However, the point-like and diffuse X-ray detection rates, respectively, are significantly higher for PNe known to harbor binary central stars (~60%) and for the compact (young) PN subsample (~50%). These results demonstrate the potential for insight into PN shaping processes provided by ChanPlaNS. In companion presentations at this meeting (Montez et al.; Freeman et al.), we present highlights of the astrophysics gleaned to date from these Chandra detections (and nondetections) of X-ray emission from PNe and their central stars.

Author(s): Joel Kastner[1], Rodolfo Montez[2], Marcus Freeman[1]
Institution(s): *1. Rochester Institute of Technology, 2. Vanderbilt University*
Contributing team(s): ChanPlaNS Team

108.02 – Emerging Trends Gleaned from Central Star and Hot Bubble X-ray Emission of ChanPlaNS Planetary Nebulae

The X-ray imaging-spectrometry of planetary nebulae (PNe) provided by the Chandra X-ray Observatory reveals compact point-like sources and extended diffuse sources. Utilizing the spatial and spectral capabilities of our observations, we have studied 59 PNe that are part of the Chandra Planetary Nebulae Survey (ChanPlaNS). We present their spatial and spectral features and emerging trends in the characteristics, origins, and longevity of X-ray emission from PNe across the evolutionary sequence. Amongst the point-like sources we find a tendency for harder (>0.5 keV) than expected emission from the most luminous central stars, indicating an origin in self-shocking stellar winds. However, we find that known and suspected short-period binary systems tend to feature the hardest (>1 keV) point-like sources of X-ray emission, indicating the role of binary evolution and, perhaps, renewed activity from spun-up late-type companions. Diffuse sources of X-ray emission originate from the collision of stellar winds that fill the PN cavity with shocked gas, called the "hot bubble". Our analysis confirms previous trends that suggest hot bubbles are well-regulated to temperatures of a few MK. Such low temperatures can be explained by several processes: (a) formative winds of a few hundreds of km/s versus extant winds of a few thousands of km/s, (b) heat conduction between the nebular gas and the hot bubble gas, or (c) moderate-velocity PN-sculpting collimated winds and outflows. Altogether, the point-like and diffuse sources of

X-ray emission from PNe provide footholds for theory and corroborative multiwavelength studies that can enhance our ability to constrain models of PN shaping.

Author(s): Rodolfo Montez[2], Joel H. Kastner[1], Marcus Freeman[1]
Institution(s): *1. Center for Imaging Science, Rochester Institute of Technology, 2. Vanderbilt University*
Contributing team(s): ChanPlaNS Team

108.03 – Herschel Planetary Nebula Survey: Spectroscopic Probing of the Nebular Components

The HerPlaNS program was initiated as an imaging and spectroscopic survey of 11 planetary nebulae (PNe) in the far-IR performed with the *Herschel* Space Observatory. Using the entire data set in the Herschel Science Archive, the HerPlaNS survey can now be expanded to include nearly 200 PNe with broadband imaging data and 50 PNe with spectroscopic data. In this contributed talk, I will concentrate on the spectroscopic analysis to yield spatially-resolved distribution maps of the electron density and electron temperature and the elemental abundances for the gas component of the nebulae, which are compared against the dust distribution maps obtained from the broadband imaging analysis so that the dust-to-gas mass ratio maps are empirically derived. Such spatially-resolved nebular characteristics provide new insights into the history of mass loss of the progenitor stars and of the dynamical processes of the nebular shaping.

Author(s): Toshiya Ueta[2], Djazia Ladjal[1], Rebecca Rattray[2]
Institution(s): *1. Gemini Observatory, 2. University of Denver*
Contributing team(s): The HerPlaNS team

108.04 – The HerPlaNS far-IR photometric survey of Planetary Nebulae and its contribution to the Emerging Multi-wavelength View

The Herschel Planetary Nebula Survey (HerPlaNS) is a far-IR photometric and spectroscopic survey of 11 Planetary Nebulae (PNe) using the Herschel Space Observatory. The HerPlaNS data explore a new wavelength range that extends from 52um to 650um. This wavelength range traces the colder dust and gas components of the PNe giving us some insights onto the older mass loss history and evolution of these objects.
I will present the results of the HerPlaNS photometry data at 70um, 160um, 250um, 350um and 500um. These data reveal extended faint haloes in the far-IR that correspond to the extended haloes of ionised gas seen in narrow band optical data. Combining the Herschel data to other literature observations gives us a multi-wavelength view of PNe that spans from the Xray to the far-IR. Imaging PNe across wavelengths is crucial in identifying the different energy regimes that fuel these complex systems and understanding how these different components interact with each other and affect the evolution of PNe.

Author(s): Djazia Ladjal[1]
Institution(s): *1. Gemini Observatory*
Contributing team(s): the HerPlaNS Consortium

108.05 – Herschel Planetary Nebula Survey (HerPlaNS): First Detection of OH^+ in Planetary Nebulae

The Herschel Planetary Nebula Survey (HerPlaNS) is an imaging and spectroscopy survey of 11 planetary nebulae (PNe) in the far-IR using the PACS and SPIRE instruments aboard the Herschel Space Observatory. A line survey in these PNe over the entire spectral range between 51 µm and 672 µm revealed the first detections of OH^+ emission in PNe. The rotational emission lines of OH^+ at 152.99, 290.20, 308.48, and 329.77 µm were detected in the spectra of three PNe: NGC 6445, NGC6720, and NGC 6781. Excitation temperatures and column densities in the range of 27 – 47 K and 2×10^{10} – 4×10^{11} cm^{-2}, respectively, were derived from these lines. In these objects, the OH^+ rotational line emission is mostly likely produced in the photodissociation region (PDR). The emission of OH^+ is observed only in PNe with hot central stars (T^{eff} > 100000 K), with ring-like or torus-like structure. The fact that we do not detect OH^+ in objects with T^{eff} < 100000 K suggests that the hardness of the ionizing central star spectra (i.e. the production of soft X-rays, ≈ 100 – 300 eV) could be an important factor in the production of OH^+ emission in PNe, as seems to be the case in recent OH^+ detections in ultraluminous galaxies and supernovae remnants.

Author(s): Isabel Aleman[5], Toshiya Ueta[12], Djazia Ladjal[12], Katrina Exter[4], Joel Kastner[8], Rodolfo Montez[14], Xander Tielens[5], You-Hua Chu[13], Hideyuki Izumiura[6], Iain McDonald[10], Raghvendra Sahai[3], Natasza Siódmiak[7], Ryszard Szczerba[7], Peter A. M. van Hoof[9], Eva Villaver[11], Wouter Vlemmings[1], Markus Wittkowski[2], Albert Zijlstra[10]
Institution(s): *1. Chalmers University of Technology,, 2. ESO, 3. Jet Propulsion Laboratory, 4. Katholieke Universiteit Leuven,, 5. Leiden University, 6. National Astronomical Observatory of Japan, 7. Nicolaus Copernicus Astronomical Center, 8. Rochester Institute of Technology,, 9. Royal Observatory of Belgium, 10. The University of Manchester, 11. Universidad Autonoma de Madrid, 12. University of Denver, 13. University of Illinois, 14. Vanderbilt University,*

108.06 – The new MQ/AAO/Strasbourg mutli-wavelength and spectroscopic PNe database: MASPN

We are in a new golden age of PN discovery. This is thanks in particular to high sensitivity, wide-field, narrow-band surveys of the Galactic plane undertaken on the UKST in Australia and the Isaac Newton telescope on La Palma. Together these telescopes and their H-alpha surveys have provided very significant Planetary Nebulae (PNe) discoveries that have more than doubled the totals accrued by all telescopes over the previous 250 years. However, these PNe are not simply more of the same found in previous catalogues. Most new PNe are more obscured, evolved and of lower surface brightness than previous compilations while others are faint but compact and more distant. This has required an extensive and time-consuming programme of spectroscopic confirmation on a variety of 2m and 4m telescopes that is now largely complete. The scope of any future large-scale PNe studies, particularly those of a statistical nature or undertaken to understand true PNe diversity and evolution should now reflect this fresh PN population landscape of the combined sample of ~3500 Galactic PNe now available. Such studies should be coloured and nuanced by these recent major discoveries and the massive, high sensitivity, high resolution, multi-wavelength imaging surveys now available across much of the electromagnetic spectrum.

Following this motivation we provide, for the first time, an accessible, reliable, on-line "one-stop" SQL database for essential, up-to date information for all known Galactic PN. We have attempted to: i) Reliably remove the many PN mimics/false ID's that have biased previous compilations and subsequent studies; ii) Provide accurate, updated positions, sizes, morphologies, radial velocities, fluxes, multi-wavelength imagery and spectroscopy; iii) Link to CDS/Vizier and hence provide archival history for each object; iv) Provide an interface to sift, select, browse, collate, investigate, download and visualise the complete currently known Galactic PNe diaspora and v) provide the community with the most complete and reliable data with which to undertake new science.

Author(s): Quentin Andrew Parker[1]
Institution(s): *1. Macquarie University*
Contributing team(s): And the MASPN database Team (key members: Dr Ivan Bojicic, Dr David Frew, Prof Agnes Acker)

108.07 – What Are M31 Disk Planetary Nebulae Trying to Tell Us?

Over the past eight years we have observed optical spectra of planetary nebulae (PNe) in the disk of M31 using DIS on the 3.5-m ARC telescope at Apache Point Observatory and OSIRIS on the 10.4-m GTC on La Palma. We have so far studied more than two dozen objects over a projected galactocentric radius range from 5 – 33 kpc; this corresponds to a deprojected in-disk range of 15 – 106 kpc. Using *ELSA*, a five-level atom package, we have derived nebular diagnostics and ionic and total nebular abundances of He and O, as well as estimates for other elements. The average 12+log(O/H) for 23 disk PNe we have observed is 8.6, or about 80% of the solar value. The inferred oxygen abundance gradient across the disk is surprisingly shallow (~ –0.004 dex/kpc) out to R(deprojected)~60 kpc. CLOUDY models we have computed for many of these objects indicate central star masses whose main-sequence progenitors are estimated to be in the range of 1.7–2.5 solar masses, with lifetimes under ~2 Gyr. The existence of such young, relatively massive, and metal-rich stars past the outer edge of the spiral arms at ~18 kpc and the H I warp at ~30 kpc (beyond which stellar [Fe/H] < –1) is unexpected, and disagrees with standard models of outer galaxy assembly via assimilation of metal-poor dwarf galaxies. Star formation from inner-disk ISM ejected by a putative gravitational encounter between M31 and M33 about 3 GY ago (Bernard et al. 2012, ApJ 420, 2625) supplies a possible explanation.

Author(s): Karen B. Kwitter[4], Bruce Balick[3], Richard B. C. Henry[2], Romano L.M. Corradi[1]
Institution(s): *1. IAC, 2. University of Oklahoma, 3. University of Washington, 4. Williams College*

108.08 – Observing Planetary Nebulae with JWST and Extremely Large Telescopes

Most stars in the Universe that leave the main sequence in a Hubble time will end their lives evolving through the Planetary Nebula (PN) evolutionary phase. The heavy mass loss which occurs during the preceding AGB phase is important across astrophysics, dramatically changing the course of stellar evolution, dominantly contributing to the dust content of the interstellar medium, and influencing its chemical composition. The evolution from the AGB phase to the PN phases remains poorly understood, especially the dramatic transformation that occurs in the morphology of the mass-ejecta as AGB stars and their round circumstellar envelopes evolve into mostly PNe, the majority of which deviate strongly from spherical symmetry. In addition, although the PN [OIII] luminosity function (PNLF) has been used as a standard candle (on par with distance indicators such as Cepheids), we do not understand why it works. It has been argued that the resolution of these issues may be linked to binarity and associated processes such as mass transfer and common envelope evolution.
Thus, understanding the formation and evolution of PNe is of wide astrophysical importance. PNe have long been known to emit across a very large span of wavelengths, from the radio to X-rays. Extensive use of space-based observatories at X-ray (Chandra/ XMM-Newton), optical (HST) and far-infrared (Spitzer, Herschel) wavelengths in recent years has produced significant new advances in our knowledge of these objects. Given the expected advent of the James Webb Space Telescope in the near future, and ground-based Extremely Large Telescope(s) somewhat later, this talk will focus on future high-angular-resolution, high-sensitivity observations at near and mid-IR wavelengths with these facilities that can help in addressing the major unsolved problems in the study of PNe.

Author(s): Raghvendra Sahai[1]
Institution(s): *1. JPL, Caltech*

108.09 – Binary Interactions and the Formation of Planetary Nebula

In this talk we present new results demonstrating how binary interactions involving an AGB star and a companion can create conditions with direct consequences for the Planetary Nebula phase. We begin with a brief review of disk formation and MHD wind launching in PNe environments. Then, using the AMR multi-physics code AstroBEAR 2.0, we carry forward high-resolution simulations of episodic mass loss in binary systems. In particular we show how fall-disk shells and disks can result when companion gravitationally focuses brief pulses of mass loss from the AGB star. We then explore if and when such focused mass loss can account for the disks seen in post-AGB settings.

Author(s): Adam Frank[1]
Institution(s): *1. Univ. of Rochester*

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109 – Molecular Clouds, HII Regions, Interstellar Medium I

109.01 – A 20pc Resolution Dust Map of M31 from the Panchromatic Hubble Andromeda Treasury (PHAT)

We present a new technique for mapping the distribution of dust in external galaxies. We use near-infrared stellar photometry to measure the distribution of reddening with ~20pc resolution in M31, using data from the Panchromatic Hubble Andromeda Treasury (PHAT). Specifically, we model the color-magnitude diagram of red giant branch stars as a combination of a narrow, unreddened foreground population and a background population that samples lines of sight through a log-normal distribution of extinction. We then fit the color-magnitude diagram to derive the median extinction, the dimensionless width of the log-normal, and the fraction of reddened stars, in 20pc bins. The maps show superb morphological agreement with other dust tracers (i.e., emission from dust and gas), but have a factor of >4 times better resolution, while providing a more direct measurement of the dust column. The fits are less robust at very low extinctions, where they become sensitive to the exact structure of the unreddened red giant branch. We diagnose a significant calibration issue with widely-used dust models, which overpredict the observed extinction by a factor of ~2 when modeling the dust emission. Fixing this calibration error would significantly revise the dust budget in local galaxies. In contrast, our results agree well with extinctions predicted from the gas distribution, asssuming a standard Milky Way gas-to-dust ratio.

Author(s): Julianne Dalcanton[6], Morgan Fouesneau[2], David W. Hogg[3], Dustin Lang[1], Adam K. Leroy[5], Karl D. Gordon[4], Karin Sandstrom[7], Daniel R. Weisz[6], Benjamin F. Williams[6]
Institution(s): *1. CMU, 2. MPIA, 3. New York University, 4. STScI, 5. The Ohio State University, 6. Univ. of Washington, 7. University of Arizona*
Contributing team(s): The Panchromatic Hubble Andromeda Treasury Team

109.02D – Probing the Multiphase Interstellar Medium and Star Formation in Nearby Galaxies through Far Infrared Emission

We have studied the complex interplay between physical processes that play a crucial role in galaxy formation and evolution, in particular star formation and the thermal balance in the neutral and molecular interstellar medium. This work was based on far-infrared photometry and spectroscopy of nearby galaxies using Spitzer and Herschel space observatories. In our first project, we study the dust properties of one of the the most metal poor systems known in the local Universe, I Zw 18. We measured a dust-to-gas ratio in the range $3.2\text{-}13\times10^{-6}$, which suggest that low metallicity galaxies, like I Zw 18, do not follow the same linear relationship between metallicity and dust-to-gas ratio as typical local spirals. In our second project, we studied the reliability of the [CII] 158 μm emission as a star formation tracer. The [CII] line is the major coolant for the neutral atomic gas and it can be observed by ALMA in normal, star forming galaxies at z > 2. Based on resolved observations of 46 nearby galaxies from the KINGFISH sample, we conclude that [CII] emission can be used for measurements of star formation rates (SFR) on both, global and kiloparsec scales, in normal star-forming galaxies in the absence of strong active galactic nuclei. The main source of scatter in the correlation is associated with regions that exhibit warm IR colors, and we provide an adjustment based on IR color that reduces the scatter. We show that the color-adjusted $\Sigma^{[CII]}$ - Σ^{SFR} correlation is valid over almost 5 orders of magnitude in Σ^{SFR}, holding for both normal star-forming galaxies and non-AGN luminous infrared galaxies. Using [CII] luminosity instead of surface brightness to estimate SFR suffers from worse systematics, frequently underpredicting SFR in luminous infrared galaxies. We suspect that surface brightness relations are better behaved than the luminosity relations because the former are more closely related to the local far-UV field, most likely the main parameter controlling the heating efficiency. Finally, we studied the properties of the diffuse, warm ionized gas in 22 nearby galaxies by combining the fine-structure transitions [NII] 122 μm and [NII] 205 μm observed by Herschel as part of the Beyond the Peak project.

Author(s): Rodrigo Herrera-Camus[4], Alberto D. Bolatto[4], Mark G. Wolfire[4], John-David T. Smith[6], Robert Kennicutt[3], Daniela Calzetti[5], Kevin V. Croxall[2], David B. Fisher[1]
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Contributing team(s): KINGFISH, Beyond the Peak

109.03 – Comparing polarized submm emission and near-infrared extinction polarization in the Vela C giant molecular cloud

We present one of largest studies to date of combined near-infrared and submillimeter linear polarization data for a giant molecular cloud. The dust polarized emission data (at 250, 350 and 500 µm) were obtained using the Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry (BLASTPol) during its 2012 Antarctic flight. The near-infrared polarization, which is produced by dichroic extinction of background starlight, was measured in the *I* band (0.8 µm) using the Pico dos Dias Observatory in Brazil. The study targets the Vela C cloud, a conspicuous star-forming environment at a distance of approximately 700 pc, hosting HII regions, protostars, and dense filamentary structures. By studying the relationship between polarized emission and polarized absorption, we can investigate how this relates to the physical properties of dust grains. The area of overlap of the two data sets corresponds to a large fraction of the molecular cloud (approximately 1.5° × 2.0°), with hundreds of combined polarization pseudo-vectors distributed mainly along the borders of the cloud. For most sight-lines, the inferred magnetic field orientations match within 20°. Visual extinction values (A^V) for near-infrared pseudo-vectors are estimated from 2MASS photometry. Based on these extinction values, we determine and correct for a small foreground contribution (~0.4%) in the near-infrared sample. We calculate the polarization efficiency ratio, defined as the polarization fraction at 500 µm divided by the polarization efficiency in the near-infrared (defined as P/A^V). Models of aligned dust grains are helpful for producing predicted polarization maps from numerical simulations of turbulent molecular clouds, and the polarization efficiency ratio provides a constraint for such dust alignment models. Preliminary results show that the measured polarization efficiency ratio appears to be roughly consistent with the predictions of the Draine and Fraisse (2009) models.

Author(s): Fabio P. Santos[9], Peter A. R. Ade[3], Peter Ashton[9], Francesco E Angilè[13], Steven J. Benton[14], Mark J. Devlin[13], Bradley J. Dober[13], Laura M. Fissel[9], Yasuo Fukui[6], Nicholas Galitzki[13], Natalie N. Gandilo[14], Jeffrey Klein[13], Andrei L. Korotkov[1], Zhi-Yun Li[15], Lorenzo Moncelsi[2], Tristan G. Matthews[9], Fumitaka Nakamura[8], Calvin B. Netterfield[14], Giles Novak[9], Enzo Pascale[3], Frédérick Poidevin[4], Giorgio Savini[10], Douglas Scott[11], Jamil A. Shariff[14], Juan D. Soler[5], Nicholas E. Thomas[7], Carole E. Tucker[3], Gregory S. Tucker[1], Derek Ward-Thompson[12]
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Contributing team(s): BLASTPol

109.04 – Are PAH molecules the carriers of Unidentified Infrared Emission bands?

Polycyclic aromatic hydrocarbon (PAH) molecules are widely considered as the preferred candidate for the carrier of the unidentified infrared emission bands observed in the interstellar medium and circumstellar envelopes. In this paper we report the result of fitting a variety of non-PAH spectra (silicates, hydrogenated amorphous carbon, coal and even artificial spectra) using the theoretical infrared spectra of PAHs from the NASA Ames PAH IR Spectroscopic Database. We show that these non-PAH spectra can be well fitted by PAH mixtures. This suggest that a general match between astronomical spectra and those of PAH mixtures does not necessarily provide definitive support for the PAH hypothesis.

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109.05 – NGC 1976 in the Radio Range with the Green Bank Telescope

NGC 1976 (Orion A) is the best studied HII region in the Milky Way and therefore it is often used to test models of HII regions. In particular, the radial dependence of the electron temperature is able to distinguish between different models. Optical determinations of electron temperature in the outer regions are affected by scattered light from the center. We have observed the radio recombination line (RRL) and continuum emission near 5 GHz at 4 arc minutes East, West and South of the peak HII region emission in NGC 1976 using the Green Bank Telescope (GBT). The Full Width to Half Power at the observing frequency, 5 GHz, was 2 arc minutes. The result is that the average electron temperature for these offset positions is = 7200 ± 300 K, significantly lower than the electron temperature of the peak position = 8200 ± 300 K, consistent with the HII region model of Wilson et al. (2012).

Author(s): Thomas L. Wilson[3], Thomas M. Bania[1], Dana S. Balser[2]
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109.06 – The role of the magnetic field in the formation of structure in molecular clouds as revealed by Planck

Using the polarized thermal emission from Galactic dust observed by Planck at 353 GHz, we have statistically evaluated the relative orientation of the magnetic field projected on the plane of sky and the column density structures in a sample includes ten nearby (d < 450 pc) Gould Belt molecular clouds.
The relative orientation is evaluated pixel by pixel and analyzed in column density bins using the histogram of relative orientation (HRO), a statistical tool that uses the gradient to characterize the column density structures in each region.
In most of the clouds in the sample, the relative orientation changes progressively from parallel or no preferred orientation in areas of the region with the lowest column density, to perpendicular in the areas with the highest column density. This trend in relative orientation is comparable to the signature of Alfvénic and sub-Alfvénic turbulence found in simulations of magnetohydrodynamic (MHD) turbulence in molecular clouds.
We compare this trend in relative orientation to the magnetic field strength estimates obtained using the Chandrasekhar-Fermi technique and discuss how the Planck polarization observations lead to the integration of the magnetic fields to the general picture of molecular cloud formation and evolution.

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Contributing team(s): the Planck Collaboration

109.07 – Magnetic field in Photodissociation Regions (PDRs) : A case study of PDR in NGC 2024

We present images of C110α and H110α radio recombination line (RRL) emission at 4.8 GHz and images of H166α, C166α and X166α RRL emission at 1.4 GHz, observed toward the starforming region NGC 2024. The 1.4 GHz image with angular resolution $\sim$ 70\arcsec\ is obtained using VLA data. The 4.8 GHz image with angular resolution $\sim$ 17\arcsec\ is obtained by combining VLA and GBT data. These images reveal that the spatial distributions of C110α line emission is confined to the southern rim of the \HII\ region close to the ionization front whereas the C166α line emission is extended in the north-south direction across the \HII\ region. The LSR velocity of the C110α line is 10.3 \kms\ similar to that of lines observed from molecular material located at the far side of the \HII\ region. This similarity suggests that the photo dissociation region (PDR) responsible for C110α line emission is at the far side of the \HII\ region. The LSR velocity of C166α is 8.8 \kms. This velocity is comparable with the velocity of molecular absorption lines observed from the foreground gas, suggesting that the PDR is at the near side of the \HII\ region. Non-LTE models for carbon line forming regions are presented. Typical properties of the foreground PDR are $T_{PDR} \sim 100$ K, $n_e^{PDR} \sim 5$ \cmthree, $n_H \sim 1.7 \times 10^4$ \cmthree, path length $l \sim 0.06$ pc and those of the far side PDR are $T_{PDR} \sim$ 200 K, $n_e^{PDR} \sim$ 50 \cmthree, $n_H \sim 1.7 \times 10^5$ \cmthree, $l \sim$ 0.03 pc. Our modeling indicates that the far side PDR is located within the \HII\ region. Using the method proposed by Roshi (2007), we estimate magnetic field strength in the foreground PDR to be 60 μG and that in the far side PDR to be 220 μG. Our field estimates compare well with the values obtained from OH Zeeman observations toward NGC 2024.

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Institution(s): *1. National Radio Astronomy Observatory, 2. National Radio Astronomy Observatory, 3. Universidad de Guanajuato*

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110 – Star Formation I

110.01 – A survey of ionized carbon in starburst galaxies at high redshift

We present [CII] observations of 20 strongly lensed dusty star forming galaxies at 2.1 < z < 5.7 using APEX. The sources were selected on their 1.4 mm flux (S1.4 mm > 20 mJy) from the South Pole Telescope survey, with far-infrared (FIR) luminosities determined from extensive photometric data. The [CII] line is robustly detected in 17 sources, all but one being spectrally resolved. Eleven out of 20 sources observed in [CII] also have low-J CO detections from ATCA. The [CII], low- J CO, and FIR data allow us to constrain the properties of the interstellar medium. We find [CII] to CO(1–0) luminosity ratios in the SPT sample of 5200 ± 1800, with significantly less scatter than in other samples. We argue that this line ratio can be best described by a medium of [CII] and CO emitting gas with a higher [CII] than CO excitation temperature, and high optical depth (τ > 1) for both the [CII] and CO lines.

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Contributing team(s): SPT SMG

110.02D – Formation of Magnetized Prestellar Cores in Turbulent Cloud

In GMCs, shocks in the turbulent flow create high-density regions, in which filaments grow and then fragment gravitationally into prestellar cores. This process is influenced by the cloud's magnetic field, which is also amplified during the shock. We showed in three-dimensional simulations that in typical GMC environments, the turbulence-compressed regions are strongly-magnetized sheet-like layers. Within these layers, dense filaments and embedded self-gravitating cores form via gathering material along the magnetic field lines. As a result of the preferred-direction mass collection, velocity gradients perpendicular to the filament major axis are a common feature seen in our simulations, which is in good agreement with the most recent results from CARMA Large Area Star Formation Survey (CLASSy). From our simulations, we identified hundreds of self-gravitating cores with masses, sizes, and mass-to-magnetic flux ratios comparable to observations. We found that core masses and sizes do not depend on the coupling strength between neutrals and ions, and ambipolar diffusion is not necessary to form low-mass supercritical cores. This is a result of anisotropic contraction along field lines, which can explain the fact that magnetically supercritical cores are commonly observed even in a strongly magnetized medium. We then confirmed the anisotropic core formation model by extending the parameter space of the three-dimensional, turbulent MHD core formation simulations, and quantified how the scalings of median core properties depend on the pre-shock inflow velocity and upstream magnetic field strength.

Author(s): Che-Yu Chen[2], Eve C. Ostriker[1]
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Contributing team(s): CLASSy Team

110.03 – CARMA observations of magnetic fields in star-forming filaments

Here we present interferometric observations of polarization in both low- and high-mass star-forming filaments. All of the data discussed here were obtained with the CARMA 1.3 millimeter dual-polarization receiver system as part of the TADPOL survey, a key project at CARMA. In the high-mass category we have NGC 7538 IRS 1, where ~2.5'' resolution images show a remarkable spiral pattern in the magnetic field (B-field), the dust emission, and the molecular outflow. And in the low-mass category we have a string of three low-mass cores in Serpens, all of which appear to have formed along the same filament. The B-field toward two of these cores, Ser-emb 8 and 8(N), looks as if it may lie along the filament, and appears to be unrelated to the orientation of the bipolar outflows from the cores. It is now becoming clear that filamentary structures are ubiquitous across many orders of magnitude in spatial scale; studying both B-field morphology and dynamics in these filaments will be crucial for understanding the role B-fields play in the star- and filament- formation processes. And more specifically, understanding the B-fields in filaments will help to explain the results from the CARMA TADPOL survey, which found that (1) overall, magnetic fields and outflows in protostellar cores are randomly aligned at 1000 AU scales; however (2) in cores with lower polarization fractions, B-fields tend to be perpendicular to outflows, which suggests that in these sources the B-fields have been wrapped up by envelope rotation.

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110.04D – Filament and core formation in nearby molecular clouds: results from the CARMA Large Area Star Formation Survey

Stars rarely form in isolation, so it is critical to understand how the parsec-scale molecular cloud environment shapes the formation of individual dense cores at the sub-0.1 pc scale. To address the pathway to core formation in a clustered environment, I co-developed the CARMA Large Area Star Formation Survey, which spectrally imaged dense gas tracer lines across 800 square arcminutes of the Perseus and Serpens Molecular clouds with 7'' angular resolution. There are four key results from initial papers. First, I created a new non-binary dendrogram code that shows correlation between the hierarchical complexity of dense, N2H+ (J=1-0) structures and the amount of star formation activity in a cluster. This may imply that feedback from young protostars changes the structure of dense gas within a cluster and increases the amount of high column density material. Second, we discovered strong radial velocity gradients within filaments that are an order of magnitude larger than detected axial gradients. We see similar radial gradients in filaments formed in numerical simulations of converging, turbulent flows; this suggests that the observed filaments are accreting material from an environment that is flattened at larger scales, and that they are more likely to fragment locally into cores than to support the flow of gas along the filament length. Third, we constructed two size-linewidth relations using the dendrogram-identified gas structures and our high resolution maps of the gas centroid velocity and line-of-sight velocity dispersion. The two relations show distinct behavior, and we developed a theoretical framework based on isotropic turbulence to show that they support the clustered regions being flattened (sheet-like) at parsec scales, with depths on the order 0.1-0.2 pc into the sky. Finally, we found that many filaments seen with Herschel show substructure in our high resolution maps, which implies that measuring the widths of filaments may be more complex than initial Herschel results imply. These new observational results can be used as constraints for numerical simulations of filament and core formation in turbulent molecular clouds.

Author(s): Shaye Storm[4], Lee G. Mundy[4], Manuel Fernández-López[1], Katherine I Lee[4], Eve C. Ostriker[2], Leslie Looney[3], Che-Yu Chen[4]
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Contributing team(s): The CLASSy Collaboration

110.05 – The SMA Legacy Survey of the Central Molecular Zone

We present preliminary results from the Sub-Millimeter Array (SMA) ongoing legacy survey of the Central Molecular Zone (CMZ, central 500 pc) of our Galaxy. Analogous to high-redshift galaxies in global properties (kinematics, baryonic composition, and density), the CMZ provides our nearest laboratory to understand extreme star formation throughout the universe. The CMZ comprises the largest reservoir of dense molecular gas in the Milky Way, yet its star formation rate is about an order of magnitude lower than expected given current star formation theories. To understand this paucity of star formation, we exploit the SMA's unique combination of large primary beam, high angular resolution, and large instantaneous bandwidth to map the dense gas and dust in the CMZ at sub-pc scales for the first time. Over the course of 2-3 years, we plan to map 240 sq. arcminutes of the highest column density structure in the CMZ at 0.1 pc resolution at 230 GHz, tracing both dust (to a point source sensitivity of ~10 solar masses) and a multitude of molecular transitions including CO isotopologues and tracers of dense gas, hot cores, and shocks/outflows. We expect to measure (i) a complete census of the most massive and dense cloud cores, (ii) the location and strength of strong shocks, (iii) core temperatures and turbulent line widths, and (iv) the relationship of star formation, dense gas fraction, and turbulent line width to environmental conditions in regions throughout the CMZ. These measurements allow us to address fundamental questions regarding the nature of star formation in extreme environments. Here we present results from year 1 of the survey, focusing on tracing the locations, star-forming signatures, and properties of dense cores as a function of environment in the CMZ.

Author(s): Cara Battersby[2], Eric R. Keto[2], Qizhou Zhang[2], Jens Kauffmann[5], Thushara Pillai[5], Xing Lu[2], Steve Longmore[4], Daniel Walker[4], Mark Graham[2], Adam Ginsburg[1], John Bally[6], Diederik Kruijssen[5], Nimesh A. Patel[2], Volker Tolls[2], Luis C. Ho[3]
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110.06 – Investigating the Milky Way Using the Cosinusoidal Potential

The Cosinusoidal Potential is a proposed replacement for Newtonian gravity, namely:
$\Phi(r) = -GM/r \cos(2\pi r/\lambda^0)$ with $\lambda^0 = 400$pc. The potential is consistent with the flat rotation curve and obviates the need for dark matter. It provides the possibility for orbits around the z-axis and for extended alternating regions of minima (attractive) and maxima (repulsive) along the polar axis. With such a potential matter outside of radius r, can a significant impact on the matter inside of r. Start formation occurs predominantly on ridges of the potential.

Author(s): John Perry Cumalat[1]
Institution(s): *1. University of Colorado, Boulder*

110.07 – Cosinusoidal Potential with Separate Z's for the formation of Galaxies and Clusters of Galaxies

Evidence for Dark Matter, Dark Energy and the Inflationary period immediately after the Big Bang remains controversial. In lieu of these, we propose a Cosinusoidal gravitational potential $\phi^g=-(GM/r)\mathrm{Cos}[k^o r]$ and a complementary Yukawa electric potential $\phi^e=(Q/r)\mathrm{Exp}[-k^o r]$, where $k^o=2\pi/(400$ pc). The expansion of the universe is generally retarded by the related magnetic field of the Yukawa potential (a(t) scales as $t^{1/2}$), but the universe coasts (a(t) scales as t) in two intervals. During the Dark Age immediately after recombination the universe is almost completely uncharged. In the immediate past where the universe is generally regarded to be accelerating, the Cosinusoidal potential gives a different gravitational lensing than expected. The difference is such as to make intervening galaxies between us and the Sn1a much more of a nuisance for low-altitude observatories than for the Hubble Space Telescope. .
We identify the time of extensive creation of stars Z^G =2. with the peak in the evolution of the luminosity function of Quasars. Z^G is a time when when the temperature of the black body radiation is about 9 K comparable to the temperature in star-forming molecular clouds.
Periodicity in the observed linear distribution of cluster's of galaxies has been observed by Broadhurst et al and others at about 128 h^{-1}- Mpc (Broadhurst 1990). We identify the lookback Z^{CG} with the ratio between the Broadhurst periodicity and 400 pc, $\mathrm{Log}^{10}[Z^{CG}]=5.66$. This Z corresponds to a time between nucleosynthesis and recombination.
Ref: Bartlett & Cumalat web site: http://www-hep.colorado.edu/Cosinusoidal

Author(s): David F. Bartlett[1]

Institution(s): *1. Univ. of Colorado*

111 – Evolution of Early-type Galaxies

111.01 – Shocked Post-starbust Galaxy Survey: Candidate Post-Starbust Galaxies with Narrow Emission Line Ratios Arising from Shocks

As galaxies age they move from the blue cloud (star forming) to the red sequence (`dead' galaxies) in the color-magnitude diagram of galaxies. Galaxies between the blue cloud and red sequence (i.e., the green valley) are caught in the act of transitioning and they show large Balmer jump and high order Balmer absorption lines in their optical spectra. These galaxies answer to many names (i.e., E+A, K+A, Hdelta-strong, post-starburst), all with similar but slightly different selection criteria. Many studies of transitioning galaxies invoke strong constraints on emission lines in order to guarantee a dominant post-starburst (rather that actively star bursting) stellar population, however these constraints bias the sample against narrow-line emission not arising from star formation, namely active galactic nuclei, low-ionization nuclear emission regions and shocks. Using the Oh-Sarzi-Schawinski-Yi (OSSY) emission and absorption line measurements for SDSS DR7 galaxies we study the intersection between transitioning galaxies and those with shock line ratios. We show that a significant fraction of transitioning galaxies have emission-line ratios indicative of shocks. We postulate that these shocks may be in part responsible for the shepherding of blue star forming galaxies to passive early-types.

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Institution(s): *1. Australian National University, 2. Departamento de F ́ısica Teo ́rica y del Cosmos, 3. IPAC, 4. NRAO, 5. Yale University*

111.02 – Using SDSS and WISE to Catch Quenching Galaxies

The onset of large surveys, such as the Sloan Digital Sky Survey, or the WISE All-sky Survey have opened an unprecedented view of the nature of galaxy transitions from the blue cloud to the red sequence, allowing for synergies between these instruments and surveys to emerge. I will present the discovery of the WISE Infrared Transition Zone, a prominent bifurcation in WISE [4.6]-[12] micron colors between early-type and late-type galaxies. This Infrared Transition Zone (IRTZ) is far more prominent than the optical green valley, and seems to represent a different phase in evolution, corresponding to the time when the optical colors have mostly made the transition. I will discuss possible causes for this bifurcation, including the complete exhaustion of the interstellar medium and the presence of active galactic nuclei. This new population of transitioning galaxies, identified by WISE might shed light on later stages in galaxy transition, after the optical colors no longer provide a beacon for these transitioning galaxies, either at late stages of a merger, or through the complete strangulation of the available interstellar medium.

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Contributing team(s): The SPOGS Team

111.03D – On the Formation of Elliptical Galaxies via Mergers in Galaxy Groups

Giant elliptical galaxies have long been thought to form through gas-rich "major" mergers of two roughly equal-mass spiral galaxies. However, elliptical galaxies are often found at the centers of groups, and so are likely to have undergone several significant mergers. We test the hypothesis that ellipticals form through multiple, mainly minor and dry mergers in groups, using a novel sample of hundreds of N-body simulations of mergers in groups of three to twenty-five spiral galaxies.
Realistic mock observations of the simulated central merger remnants show that they have comparable surface brightness profiles to observed ellipticals from SDSS and ATLAS3D - so long as the progenitor spirals begin with concentrated bulges. The remnants follow tight size-luminosity and velocity dispersion-luminosity relations (<0.12 dex scatter), with similar slopes as observed. Stochastic merging can produce tight scaling relations if the merging galaxies follow tight scaling relations themselves. However, the remnants are too large and have too low dispersions at fixed luminosity. Some remnants show substantial ($v/\sigma > 0.1$) rotational support, but most are slow rotators with $v/\sigma << 0.5$. Ellipticals also follow a tight "fundamental plane" scaling relation between size R, mean surface brightness μ and velocity dispersion σ: $R \propto \sigma^a \mu^b$, with small (<0.06 dex) scatter and significantly different coefficients from the expected scaling (a "tilt"). The remnants lie on a similar fundamental plane, with even smaller scatter (0.02 dex), as well as a tilt in the correct sense - albeit weaker than observed. This tilt is mainly driven by variable dark matter fractions within R^{eff}, such that massive merger remnants have larger central dark matter fractions than their lower-mass counterparts.
These results suggest that massive ellipticals can originate from multiple, mainly minor and dry mergers. However, significant gas dissipation may be needed to produce lower-mass, rapidly-rotating ellipticals.

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Institution(s): *1. University of Toronto, Dept. of Astronomy & Astrophysics*

111.04 – Dissecting the Assembly Histories of Spheroidal Post-merger and Unusually Blue Elliptical Galaxies from the SDSS

The modern merger hypothesis predicts the formation of new elliptical galaxies (Es) through the merging of two equal-mass, gas-rich spirals. Under the right conditions, simulations predict that such mergers produce a strong, central burst of star formation (SF) in the remnant. If merger-induced SF is subsequently quenched, this scenario offers an attractive blue-to-red migration channel to explain the buildup of massive quiescent galaxies over cosmic time. To test this prediction, we study 12 high-mass (Mstar>1e10 Msun), nearby (z<0.03) galaxies from the SDSS that are plausible new E candidates with unusually blue optical colors and visually either spheroidal post-merger (SPM) remnants or Es with a range of morphological peculiarities. We use IFU spectroscopy to track the stellar Balmer absorption and 4000A break strength indices as a function of galactic radius out to 1.5-3.0 R50 to distinguish galaxies with a recent central starburst from those with other SF histories. We find that the index values and their radial dependence correlate with specific morphological features. Only one of 4 SPMs has clear evidence for a recent (<1 Gyr) central starburst. The other 3 have strong Balmer absorption at all radii, global SF colors, bluer cores, and low central D4000 values indicative of younger stars, but no clear evidence of a recent burst. These galaxies are consistent with merger simulations that predict progenitor mass ratio, gas fraction and orbital dynamics need to be fine tuned to produce a central burst. The 3 blue Es with indices intermediate between typical star-forming and quiescent galaxies show small D4000 gradients, Balmer absorption that is stronger at R>1 R50, dust-reddened core colors, and inner morphological features (rings, dust). These galaxies are the best candidates for a "frosting" of young stars a top an older population, and their properties are consistent with a recent accretion of a gas-rich satellite. The remaining 5 Es are inconsistent with the merger hypothesis. They have quiescent-like indices, strong radial index gradients suggesting older core stars, and 80% exhibit broad LSB asymmetries at large radii that are consistent with being remnants of recent gas-poor (dry) merging.

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111.05D – Star formation in the most massive galaxies

While the most massive galaxies typically have negligible ongoing star formation, there is a minority of massive galaxies that buck this trend. This includes Perseus A and Centaurus A, which are often used as illustrations of AGN feedback in galaxies.

How often do massive galaxies undergo episodes of star formation? Can recent star formation contribute significantly to the growth of massive galaxies? Why does star formation occur in a minority of massive galaxies? To answer these questions, we have selected samples of low redshift massive galaxies from 245 X-ray selected galaxy clusters and from the 2MASS Redshift Survey field galaxy sample, and measured the star formation rates of these galaxies using WISE mid-infrared photometry. We find that Perseus A is an exceptional galaxy in the z<0.1 Universe, and only 1% of brightest cluster galaxies have comparable star formation rates.

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111.06 – How did Quiescent Galaxies Grow in Size? New Results from Deep Keck Spectroscopy

Quiescent galaxies at high redshift are physically smaller than their local counterparts. Since these galaxies are not forming new stars, any growth in physical size over the last 10 billion years is surprising. One possibility is that their structure changed as a consequence of mergers, particularly with smaller galaxies. An alternative scenario, often called progenitor bias, posits that the observed size evolution is due to a change in the galaxy population: when larger star-forming galaxies are quenched into passive objects, the average size of the quiescent population increases. Using the LRIS and MOSFIRE instruments at Keck, I collected deep spectroscopic data for the largest sample of quiescent galaxies at z > 1, with the goal of investigating the nature of this size growth. Using spectral features like the 4000 Å break and the Balmer series I calculated the mean stellar age of each galaxy, and using public Hubble Space Telescope imaging I measured their sizes. I found that young systems have significantly larger sizes, confirming the progenitor bias hypothesis. However, by comparing the sizes of the oldest objects at z~1.3 with those directly observed at higher redshift, I determined that progenitor bias accounts only for half of the observed growth in the intervening period. The remainder arises from genuine physical growth of individual galaxies. The spectra also provide accurate stellar velocity dispersions. Assuming these dispersions are largely unaffected by minor mergers, as indicated theoretically, it is possible to link high-redshift progenitors with their local descendants. In this way I measured the growth in both size and mass and found their ratio over 0 < z < 1.5 in excellent agreement with the expectations for minor mergers. However, an ongoing survey with MOSFIRE data in the redshift range $2 < z < 2.5$ confirms a much faster growth, and it seems that mergers are incapable of explaining the emerging data. Further spectroscopy is addressing this remaining puzzle in the history of massive quiescent galaxies.

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111.07 – Extreme gas velocity dispersions in progenitors of massive, compact quiescent galaxies at z~2

The mechanisms responsible for the remarkably small sizes of the most massive quiescent galaxies at z~2 are poorly understood. Partly because the nature of their progenitors is still unknown. Barro+13,14 used the deepest HST WFC3/F160W data to identify, for the first time, a population of massive compact star-forming galaxies (cSFGs) at $2 < z < 3$, whose small sizes, stellar structures and number densities strongly suggest that they are the immediate progenitors of such population.
These cSFGs have spheroidal morphologies and centrally-concentrated mass profiles very similar to those of quiescent galaxies. Yet, they still are strongly star-forming and heavily dust obscured, as evidenced by their H-alpha emission and far-IR (Spitzer/Herschel) colors. This strongly suggests that cSFGs are rapidly growing a dense stellar core, as those observed in quenched galaxies. Quite remarkably, this is confirmed by their gas dynamics. Barro+14b revealed that cSFGs at z~2 have high gas velocity dispersions of ~250 km/s, consistent with the stellar kinematics of equally massive quiescent galaxies, and indicative of their large dynamical masses.

Author(s): Guillermo Barro[3], Jonathan Trump[3], David C. Koo[3], Avishai Dekel[2], Susan A. Kassin[1], Dale Kocevski[4], Sandra M. Faber[3]
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Contributing team(s): CANDELS

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112 – Fundamental Properties of Low and Intermediate Mass Stars

112.01 – Absolute Optical Photometry and a Photometric Metallicity Relation for the Nearby Cool Stars from the MEarth Project

There is renewed interest in understanding the low mass stars and brown dwarfs of the solar neighborhood. Since M dwarfs make up the vast majority of stars in the universe, it is essential that we understand their fundamental physical properties. Their ubiquitousness makes them excellent kinematic and chemical probes of the Galaxy, provided we can accurately measure their distances, absolute magnitudes, and metallicities. Additionally, current and future exoplanet surveys that are focused on M dwarfs, such as SPIRou, CARMENES, and the Habitable Zone Planet Finder will uncover a plethora of planetary systems around these stars. Unfortunately, many of the nearby low mass stars are poorly characterized with current data. The MEarth survey has been monitoring approximately 1800 mid-to-late M dwarfs since 2008 and each night also observes a set of Landolt standard stars. We measure a precise optical magnitude in our MEarth bandpass, a red broadband filter similar to the Bessel I filter, for 1500 of these systems. By combining this work with our recent work measuring the trigonometric parallaxes and metallicities of a subset of these M dwarfs, we construct a photometric metallicity relation. We then apply it to the full sample of MEarth-North M dwarfs.

The MEarth project gratefully acknowledges funding from the David and Lucile Packard Fellowship for Science and Engineering, the National Science Foundation under grants AST-0807690, AST-1109468, and AST-1004488, and the John Templeton Foundation.

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112.02D – M Dwarf Multiplicity in the Solar Neighborhood

Stellar multiplicity provides fundamental clues about the nature of star formation, the evolution of stellar systems over time, and the distribution of baryonic mass in the Universe. How stars are parceled into singles, doubles, and higher order multiples also provides clues about the angular momentum distribution in stellar systems and constraints on whether or not planets may be found. Because of their large numbers, arguably the best sample that can be studied to understand stellar multiplicity are the nearby M dwarfs.
Previous companion searches for M dwarfs have had sample sizes on the order of 100 stars, resulting in a weak statistical understanding of the distribution of companions. We have systematically surveyed ~1250 red dwarfs that have trigonometric parallaxes placing them within 25 pc of the Sun for stellar companions at separations of 1" to 10'. Because the systems all have accurate parallaxes, biases inherent to photometrically-selected samples are eliminated.

We obtained I-band images using the CTIO/SMARTS 0.9m in the south and the Lowell 42in in the north, probing the environs of these systems for companions at separations of 1" to 3'. A complementary reconnaissance of wider companions out to 10' was also done via blinking of SuperCOSMOS archival BRI images. In addition, we have have long-term astrometric information on hundreds of the stars that can be used to estimate the number of companions closer than 1", and we have incorporated results from radial velocity work as well.
The results allow statistical analyses of the nearby M dwarf population, refinement of the solar neighborhood membership roster, and improvement of the mass function for these objects at the end of the main sequence. This is the largest, most comprehensive study ever done of the multiplicity of the most common stars in the Galaxy.
This work is supported by NSF grant AST 09-08402, the Sigma Xi Grants-in-Aid-of-Research Program, the SMARTS Consortium, and Georgia State University.

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112.03 – The Age of the Ursa Major Moving Group from Interferometric Measurements of Its A-type Members

A set of six A-type stars in the nearby Ursa Major moving group have been observed and spatially resolved with the CHARA Array, using the Classic and/or CLIMB beam combiners. At least four of these stars are rapidly rotating ($v\sin i \geq 170\ kms^{-1}$) and are expected to be oblate. These interferometric measurements and the stars' observed photometric energy distributions (PEDs) are used to construct oblate star models from which stellar properties ($R(\vartheta)$, $T(\vartheta)$, etc.) are determined. The results are compared with MESA stellar evolution models to determine mass and age. This analysis provides an independently determined mean age estimate for the Ursa Major moving group of 490 Myr with a standard deviation of 98 Myr, consistent with previous age estimates. This validated technique can be used to provide independent age estimates of field A-stars, including those that host directly imaged substellar companions (e.g. HR 8799, κ And).

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112.04 – Calibrating Gyrochronology using Kepler Asteroseismic Targets

Measuring ages for intermediate and low-mass stars on the Main Sequence is challenging but important for a wide range of studies, from Galactic dynamics to stellar and planetary evolution. Among the available methods, gyrochronology is a powerful one because it requires knowledge of only the star's mass (or effective temperature, or colour) and its rotation period. However, it is not well calibrated at late ages and suffers from large uncertainties. Asteroseismic ages are now available for some of the brightest stars observed by Kepler. We use rotation period measurements of stars with asteroseismic ages, plus some cluster and field stars with well defined spectroscopic ages, to calibrate the gyrochronology relation. Our Bayesian methodology enables us not only to account robustly for uncertainties on all our observables, but also to examine posterior probability distributions over the parameters of the gyrochronology relation using different subsets of our targets, and thus to investigate to what extent a single period-colour-age relationship can provide a good match to the cluster, field star and asteroseismic sample.

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112.05 – Properties of 75 Solar-type Kepler Targets from the Asteroseismic Modeling Portal

Recently the number of main-sequence and subgiant stars exhibiting solar-like oscillations that are resolved into individual mode frequencies has increased dramatically. While only a few such data sets were available for detailed modeling just a decade ago, the Kepler mission has produced suitable observations for hundreds of new targets. This rapid expansion in observational capacity has been accompanied by a shift in analysis and modeling strategies to yield uniform sets of derived stellar properties more quickly and easily. We use previously published asteroseismic and spectroscopic data sets to provide a uniform analysis of 75 solar-type Kepler targets from the Asteroseismic Modeling Portal (AMP). We find that fitting the individual frequencies typically doubles the precision of the asteroseismic radius, mass and age compared to grid-based modeling of the global oscillation properties, and improves the precision of the radius and mass by about a factor of three over empirical scaling relations. We demonstrate the utility of the derived properties with several applications.

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Contributing team(s): Kepler Asteroseismic Science Consortium

112.06D – Characterizing M dwarf planet hosts and enabling precise radial velocities in the near-infrared

M dwarfs account for ~70% of the stars in the Solar neighborhood and represent a rich frontier for upcoming surveys for M dwarf planets, including the Habitable Zone Planet Finder (HPF) radial velocity (RV) survey, which will search for planets around nearby M dwarfs in the near-infrared (NIR). Crucial for the construction of target lists for these surveys and the interpretation of survey results is the development of techniques for measuring M dwarf stellar composition, activity, and age. Measurements of these parameters are made difficult by the complexity of M dwarf spectra and their slow evolution once on the main sequence. I will outline our application of empirically-calibrated techniques for measuring [Fe/H], which has enabled our development of new activity and age indicators based on NIR spectra from the low-resolution IRTF-SpeX spectrograph. I will discuss the implications of these new measurements, which hint at the effects of alpha element enrichment and youth, and reveal a strong connection between metallicity and stellar infrared luminosity. These new techniques allow refinements of existing calibrations, and contribute to a catalog of the stellar parameters of ~900 M dwarfs that will be an invaluable resource for the upcoming HPF survey.
I will also outline developments in simulations and design for HPF, which will be among the first of the next generation of NIR precision RV instruments on large telescopes. I will describe an end-to-end instrument simulator that has helped optimize the HPF spectral coverage and instrumental configuration, the extensive study of vacuum phase holographic grating cross-disperser that will optimize the efficiency of HPF, and the precise characterization of the physical properties and behavior of the HPF H2RG near-infrared detector array. This hardware work will enable the 1-3m/s precision required for HPF to find Earth-mass planets in the habitable zones of nearby M dwarfs, and the stellar parameters in the M dwarf catalog will provide the information necessary to optimize the scientific yield of HPF by ensuring a large number of well-characterized planet hosts.

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112.07 – Confronting predictions of stellar evolution theory: the case of single field M dwarf stars

Using a homogenous sample of single field M dwarf stars from the CONCH-SHELL catalog, we confront the reliability of predictions from low mass stellar evolution models. Empirical values for the bolometric flux, effective temperature, and stellar radius are typically determined with better than 1%, 2%, and 5% precision, respectively. Coupled with precise [M/H] values, these observations place strong constraints on the accuracy of stellar models. A Markov Chain Monte Carlo (MCMC) formalism is used to establish the most likely stellar properties, with associated uncertainties, by interpolating within a dense grid of Dartmouth stellar evolution models with mass, age, metallicity, and distance as free parameters. The observed effective temperature and bolometric flux are adopted as independent observables in the MCMC likelihood function with the addition of the observed [M/H] and distance as informative Bayesian priors. Results are presented comparing model mass estimates to those from an empirical mass-luminosity calibration, and showing how well stellar models reproduce the observed radii, effective temperatures, and luminosities. Reliability of stellar models is then investigated as a function of mass, [M/H], equivalent width of H-alpha, and X-ray luminosity. Finally, we briefly discuss various physical mechanisms to explain the observed trends, particularly in the context of the hypothesis that magnetic activity is the source of model-observation discrepancies.

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113 – Catalogs/Surveys/Computation - SDSS and Radio

113.01 – First Results from the Survey of the MAgellanic Stellar History (SMASH)

Clear observational signatures of hierarchical galaxy formation have been found around the Milky Way and other nearby massive galaxies. However, the build-up of smaller dwarf galaxies and the extent to which they harbor relics of past interactions such as stellar halos and substructure is not well-known. In an effort to observationally constrain structure formation on small scales, SMASH (Survey of the MAgellanic Stellar History), an approved NOAO community DECam survey, is imaging ~2400 square degrees (at 20% filling factor) to 24th mag in gri (uz~23) allowing us to map the expected stellar debris and extended stellar populations of the Clouds with unprecedented fidelity. SMASH will (a) search for the stellar components of the Magellanic Stream and Leading Arm, (b) detect and map the extended smooth components and substructure of the Magellanic Clouds, and (c) derive spatially resolved, precise star formation histories out to large radii. Our first year of data reveal (1) Large Magellanic Cloud (LMC) stellar populations extending out to a radius of at least 19 deg (~17 kpc) in several directions, (2) clear signatures of two dominant LMC star formation episodes at intermediate radii as revealed by multiple subgiant branches, and (3) evidence for an expansive stellar substructure in the Milky Way halo at a distance of ~30 kpc.

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Contributing team(s): SMASH

113.02 – The Time Domain Spectroscopic Survey: Taking Spectra of 250,000 Optical Variables

The Time Domain Spectroscopic Survey (TDSS) is an SDSS-IV subproject that will take spectra of 250,000 optical variables including 185,000 quasars and 65,000 variable stars. TDSS began taking data in August, 2014 and will continue for 4-6 years. TDSS uses a unique, variability-only selection algorithm that does not focus on targeting any specific type of variable. TDSS will find unusual quasars that could not be found by conventional color selection and will allow us to see how quasar variability is related to other properties of the AGN. TDSS will also produce the largest sample of spectroscopic stellar variable classifications and will show how the concentrations of different types of stellar variables vary across the sky. Most excitingly, TDSS's unprecedented scale and broad selection algorithm promise to identify new classes of astrophysical variables.

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Contributing team(s): TDSS Team, SDSS Collaboration, PS1 Consortium

113.03 – Science with the VLA Sky Survey (VLASS)

The Very Large Array Sky Survey (VLASS) was initiated to develop and carry out a new generation large radio sky survey using the recently upgraded Karl G. Jansky Very Large Array. The proposed VLASS is a modern, multi-tiered survey with the VLA designed to provide a broad, cohesive science program with forefront scientific impact, capable of generating unexpected scientific discoveries, generating involvement from all astronomical communities, and leaving a lasting legacy value for decades.
VLASS will observe from 2-4 GHz and is structured to combine comprehensive all sky coverage with sequentially deeper coverage in carefully identified parts of the sky, including the Galactic plane, and will be capable of informing time domain studies. This approach enables both focused and wide ranging scientific discovery through the coupling of deeper narrower tiers with increasing sky coverage at shallower depths, addressing key science issues and providing a statistical interpretational framework. Such an approach provides both astronomers and the citizen scientist with information for every accessible point of the radio sky, while simultaneously addressing fundamental questions about the nature and evolution of astrophysical objects.
VLASS will follow the evolution of galaxies and their central black hole engines, measure the strength and topology of cosmic magnetic fields, unveil hidden explosions throughout the Universe, and chart our galaxy for stellar remnants and ionized bubbles. Multi-wavelength communities studying rare objects, the Galaxy, radio transients, or galaxy evolution out to the peak of the cosmic star formation rate density will equally benefit from VLASS.
Early drafts of the VLASS proposal are available at the VLASS website (https://science.nrao.edu/science/surveys/vlass/vlass), and the final proposal will be posted in early January 2015 for community comment before undergoing review in March 2015. Upon approval, VLASS would then be on schedule to start observing in 2016.

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Contributing team(s): Extragalactic Science Working Group, Galactic Science Working Group, Transient Science Working Group

113.04 – Technical Implementation Plan for the VLA Sky Survey (VLASS)

The Karl G. Jansky Very Large Array is a recently completed rejuvenation of the VLA, providing observers with significantly increased continuum sensitivity and spectral survey speeds. Given the potential for new centimeter-wavelength sky surveys with this enhanced facility, the VLA Sky Survey (VLASS) was initiated to exploit the science and technical opportunities for a new large survey. In this presentation we describe the survey design and the Technical Implementation Plan (TIP) for the VLASS.
The proposed VLASS showcases the strengths and unique capabilities of the Jansky VLA, namely high resolution imaging and exquisite point-source sensitivity, which are critical for source identification, and full polarimetry with good performance even in lines of sight with high Faraday depth. This has led to the choice of observing from 2-4 GHz at 2MHz frequency resolution and 0.7"-2.1" angular resolution. The VLASS will be observed in multiple epochs over the span of at least 5 years. The data will be available in the NRAO archive immediately with no proprietary period and science data products will be provided to the community in a timely manner.
To achieve its science goals requires the VLASS to address a number of key challenges in data management, computation, image processing, and analysis, and quality assurance. The VLASS basic data products include: raw visibility data, calibrated data, quick-look continuum images, single-epoch images and spectral image cubes, single-epoch basic object catalogs, cumulative "static sky" images and image cubes and basic object catalogs (generated after each epoch beyond the first). The storage required for these multi-epoch images range from 300TB to >80PB depending upon the desired time and spectral resolution. Devising an affordable strategy for providing these services, for example through use of "process on-demand" rather than image storage, is therefore critical. We will discuss opportunities for community involvement in VLASS technical areas, including the development of Enhanced Data Products and Services.

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113.05D – Exploring the Dynamic Radio Sky

Most of what is currently known about slow radio transients (supernovae, gamma-ray bursts, tidal disruption events, stellar flares, etc.) has come via radio follow-up of objects identified by synoptic telescopes at optical, X-ray or gamma-ray wavelengths. However, with the ability to capture obscured, unbeamed and magnetically-driven phenomena, radio surveys offer unique discovery strong diagnostic for cosmic transients. For the first time, we are systematically exploring the dynamic radio sky on timescales between one day to several years using multi-epoch large surveys with the Karl G. Jansky Array (VLA). We have carried out surveys in the COSMOS deep field as well as wide fields like Stripe 82. I have developed a unique infrastructure for near-real-time calibration, imaging, transient search, transient vetting, rapid multiwavelength follow-up, and contemporaneous optical surveys to better characterize radio transient phenomena. A large part of my thesis includes the commissioning of a new observing mode at the VLA: On-The-Fly Mosaicking. This mode has significantly improved the survey efficiency of the VLA, and it is a driver for VLASS, the future all-sky survey planned with this telescope. Through our radio surveys we have discovered several fascinating transients that are unique to the radio. These surveys have established the VLA as an efficient transient discovery machine. My thesis has enormous implications for how to design efficient transient surveys for the next generation of radio interferometer facilities like ASKAP, MeerKAT, WSRT/Apertif and LOFAR. My work has also provided answers to key problems such as the rates of transients, demographics of variability of radio sources including AGN, and false-positive foreground for future searches for the radio counterparts of gravitational-wave (GW) sources.

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113.06 – The LWA1 Low Frequency Sky Survey

The LWA1 Low Frequency Sky Survey is a survey of the sky visible from the first station of the Long Wavelength Array (LWA1) across the frequency range of 35 to 80 MHz. The primary motivation behind this effort is to improve our understanding of the sky at these frequencies. In particular, an understanding of the low frequency foreground emission is necessary for work on detecting the epoch of reionization and the cosmic dark ages where the foreground signal dwarfs the expected redshifted HI signal by many orders of magnitude (Pritchard & Loeb 2012, Rep. Prog. Phys., 75, 086901). The leading model for the sky in the frequency range of 20 to 200 MHz is the Global Sky Model (GSM) by de Oliveria-Costas et al. (2008, MNRAS, 288, 247). This model is based upon a principle component analysis of 11 sky maps ranging in frequency from 10 MHz to 94 GHz. Of these 11 maps, only four are below 1 GHz; 10 MHz from Caswell (1976, MNRAS, 177, 601), 22 MHz from Roger et al. (1999, A&AS, 137, 7), 45 MHz from Alvarez et al. (1997, A&AS, 124, 315) and

Maeda et al. (1999, A&AS, 140, 145), and 408 MHz from Haslam et al. (1982, A&AS, 47, 1). Thus, within this model, the region of interest to both cosmic dawn and the epoch of reionization is largely unconstrained based on the available survey data, and are also limited in terms of the spatial coverage and calibration. A self-consistent collection of maps is necessary for both our understanding of the sky and the removal of the foregrounds that mask the redshifted 21-cm signal.

We present the current state of the survey and discuss the imaging and calibration challenges faced by dipole arrays that are capable of imaging nearly 2π steradians of sky simultaneously over a large fractional bandwidth.

Construction of the LWA has been supported by the Office of Naval Research under Contract N00014-07-C-0147. Support for operations and continuing development of the LWA1 is provided by the National Science Foundation under grants AST-1139963 and AST-1139974 of the University Radio Observatory program.

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Contributing team(s): LWA Collaboration

113.07 – Advancing Astrometry: Revisiting the VLBA Calibrator Surveys

The original VLBA Calibrator Surveys (VCS) were a series of 6 VLBA campaigns from 1994 to 2007 in which more than 2000 compact extragalactic radio sources were observed at X/S bands. The goals were to obtain precise positions (uncertainties ~1 mas or better) of many hundreds of new sources for use as VLBI phase referencing calibrators, and to make snapshot images of them for morphological studies. These VCS campaigns were highly successful, resulting in accurate positions and scientific-grade images maps for a majority of sources. These observations were later used to approximately triple the number of sources contained in the second realization of the International Celestial Reference Frame by VLBI (ICRF2). However, the VCS sources in ICRF2 represent a class of 'single epoch' sources with average position uncertainties ~5 times greater than the other ~1200 ICRF2 sources which are observed much more frequently in geodetic VLBI sessions. In an attempt to greatly reduce their position uncertainties, we are re-observing ~2400 VCS sources at X/S bands on the VLBA in 8 24-hr sessions. With the recent VLBA sensitivity upgrade, the sensitivity is now nearly 5 and 3 times greater at X and S bands than the original VCS sessions. Five of these sessions have been run so far, re-observing 1500 sources. Preliminary analysis shows an improvement in the average position uncertainties by a factor of ~3.2 times for these re-observed sources. We will present and discuss these improvements and their implication for ICRF3 development (planned for 2018). Images are also being produced and examples will be presented.

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Contributing team(s): VCS Team

113.08 – Murchison Widefield Array (MWA) - 1st Year Science Results

The Murchison Widefield Array (MWA) is the first radio telescope in the Southern Hemisphere designed specifically to explore the astronomical sky between 80 and 300 MHz with arcminute angular resolution and high survey efficiency. The MWA has the goal of detecting 21 cm emission from neutral hydrogen during the reionization epoch. It provides unique opportunities for studies of our Galactic environment, including ISM turbulence, magnetic fields, cosmic rays, and supernova remnants, as well as extragalactic surveys, time-domain astrophysics, and solar imaging and space weather. Early results will be reported highlighting the capabilities of the instrument. Featured science will include initial reionization analysis, preliminary searches for exoplanets and variable sources, spectral properties of radio sources, ionospheric fluctuations, and solar imaging.

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Contributing team(s): Murchison Widefield Array (MWA) Collaboration

115 – The Sun and Solar System in Perspective

115.01 – Is the Alfvén wave propagation in the solar atmosphere affected by cutoff frequencies or not?

The question posed in the title does not have a unique answer. Some researchers argue that the Alfvén wave propagation in the solar atmosphere is cutoff-free, while others claim that it is exactly the opposite! To resolve this longstanding puzzle, we solved numerically the initial-value problem for the Alfvén wave propagation and identified a range of wave frequencies for which the wave's behavior changes from propagating to non-propagating at certain heights in the solar atmosphere. We determined the locations of these heights in the atmosphere and identified them with the so-called transition and turning points, which we use to introduce cutoff frequencies for Alfvén waves. We find that there is not one unique cutoff frequency for Alfvén waves but instead the cutoffs depend on the method used to define them as well as on the choice of the wave variable selected to describe the waves. Our results provide strong theoretical evidence for the existence of the cutoff frequencies for the Alfvén wave propagation in the solar atmosphere. We discuss the relevance of our results to the current observational data.

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115.02 – The Corona at Solar Maximum as Imaged during the Total Solar Eclipses of 2012 November 13-14 and 2013 November 3-4

The total solar eclipses of 2012 November 13-14 and 2013 November 3-4 coincided with peaks of activity in solar cycle 24. Despite challenging observing conditions due to weather patterns in both Australia and central Africa, respectively for these two eclipses, white light images were successfully obtained from groups stationed at different sites along the path of totality on both occasions. We show here how the corona during these two eclipses was remarkable in many ways. In 2012, a prominence eruption reflecting a classic example of a current sheet, with a linear extension of almost 0.25 Rs, ending in a bubble-shaped cavity, was captured in white light. In 2013, two plasmoids were observed at more than a solar radius above the solar limb, both associated with filament eruptions, and one ending in a classic CME bubble. In addition, the intricate complexity of the corona at these two eclipses, revealed by state-of-the art image processing, reflected the ubiquitous presence of large expanding loops, and the fingerprints of plasma instabilities in the form of twisted helical structures and vortex rings.

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115.03 – Comparing Accretion Histories of Earth, Mars, and Theia Analogs

The canonical scenario for the formation of the Moon predicts that a Mars-mass impactor collided with the proto-Earth in a glancing collision that threw material into orbit around the Earth. However, such a scenario results in a Moon largely composed of material from the impactor rather than the proto-Earth. Since meteorites from Mars and the asteroid belt have markedly different oxygen isotope abundance ratios than Earth, this Moon origin scenario appears at odds with the nearly identical oxygen isotope signatures of lunar and terrestrial rocks. Here we test the possibility that the proto-Earth and Theia (the lunar impactor) had similar enough accretion histories before their collision to yield a moon with nearly identical oxygen isotope abundances to the Earth. To do this, we perform many numerical models of the final giant impact phase of terrestrial planet formation. In these models, we impose primordial distributions of oxygen isotopes that are tuned to yield final $\Delta^{17}O$ differences between fully formed Earth and Mars analogs that match the observed differences between the two planets. Regardless of the assumed form for the inital $\Delta^{17}O$ distribution among planetesimals, we find a probability of ~5% or less that a Theia analog will have an identical oxygen isotope composition to an Earth analog in any given simulated system.

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115.04 – Transit Spectra of a Hazy World Revealed by Titan

Hazes dramatically influence exoplanet observations by obscuring deeper atmospheric layers. This effect is especially pronounced in transit spectroscopy, which probes large pathlengths through an exoplanet atmosphere as it crosses the disk of its host star. While hazes are proposed to explain observed featureless transit spectra, it is difficult to make inferences from the observations because of the need to disentangle effects of noise, gas absorption, and haze extinction. Here, we turn to Titan, an extremely well studied world with a hazy atmosphere, to better understand how high altitude hazes can impact exoplanet transit observations. We use solar occultation observations from the Visual and Infrared Mapping Spectrometer (VIMS) aboard NASA's Cassini spacecraft to generate transit spectra. Our approach exploits symmetry between occultations and transits, producing transit radius spectra that inherently include the effects of haze multiple scattering, refraction, and gas absorption. The data, which span 0.88–5 microns at a resolution of 12–18 nm, show strong methane absorption features, and weaker features due to other gases, including acetylene and carbon monoxide. Unlike the usual assumption made when modeling and interpreting transit observations of potentially hazy worlds, the slope set by haze in our spectra is not flat, and creates a variation in transit height whose magnitude is comparable to those from the strongest gaseous absorption features. We use a simple model of haze extinction to explore how Titan's haze affects its transit spectrum, and demonstrate how high altitude hazes can severely limit the atmospheric depths probed by transit spectra, bounding our observations to pressures smaller than 0.1–10 mbar, depending on wavelength. Overall, these new data challenge our understanding of how hazes influence exoplanet transit observations, and provide a means of testing proposed approaches for exoplanet characterization. Additionally, our findings will help with the interpretation of future exoplanet observations, especially since the VIMS instrument overlaps in wavelength with several instruments that will launch with NASA's James Webb Space Telescope.

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115.05D – TNOs as probes of planet building: the Plutino size- & colour-distributions

Planetesimals are the building blocks of giant planet cores; some are preserved as large transneptunian objects (TNOs). Previous work concluded steep power-law size-distributions for TNOs of diameters > 100 km. Recent results claim a dramatic roll-over or divot (sudden drop in number of objects at a transition size) in the size-distribution of Neptunian Trojans and scattering TNOs, with a significant lack of intermediate-size D<100 km planetesimals. One theoretical explanation is that planetesimals were born big, skipping the intermediate sizes, contrary to the expectation of bottom-up planetesimal formation.
Using the Canada-France-Hawaii Telescope, our 32 sq.deg. survey, near RA=2 hr with limiting magnitude m_r=24.6, detected and tracked 77 TNOs and Centaurs for up to 28 months, providing both the high-quality orbits and the quantitative detection efficiency needed for precise modelling. We used the 18 Plutinos (3:2 Neptunian mean motion resonance) from our survey to constrain the size- and orbital-distribution model of this population. We show that the Plutino size-distribution cannot continue as a rising power-law past H_r ~ 8.3 (D~ 100 km); a sharp dramatic change must occur near this point. A single power-law is rejectable at >99% confidence; a double power law cannot be rejected outright, but appears to be a uncomfortable match to the available data. A divot, with the parameters found independently for scattering TNOs by Shankman et al. (2013, ApJ vol 764), provides an excellent match; the best match, found from an extensive parameter search, comes with only slightly different parameters; this size-distribution also satisfies the known Neptunian Trojan data.
We also present g-r photometric colours for our Plutino sample, obtained with the Gemini North telescope in 2013-2014.
Both large TNOs and small nearby Centaurs are known to feature a bimodal colour-distribution; however, recent work (Peixinho et al. 2012, A&A vol 546) has suggested that intermediate-size TNOs may not show bimodality. Our telescopically-expensive endeavour has provided us with unique insight into the colour-distribution of the physically smallest Plutinos.

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115.06 – Near-infrared spatially resolved spectroscopy of 136108 Haumea's multiple system

The trans-Neptunian 136108 Haumea is a very fast rotator (~3.9h). It also displays a highly elongated shape and hosts two small moons, all covered with crystalline water ice, similarly to their central body. Haumea is also known to be the largest member of a TNO family, itself the outcome of a catastrophic collision likely responsible for Haumea's unique characteristics.

We report here on the analysis of a new set of near-infrared Laser Guide Star assisted observations of Haumea obtained with the IFU spectrograph SINFONI at the ESO-Very Large Telescope Observatory. Combined with previous data published by Dumas et al. (2011), and using photometric light curve measurements (Lacerda 2009, Lellouch et al. 2011) to associate each spectrum with Haumea's corresponding rotational phase, we were able to derive an accurate rotationally resolved spectroscopic study of the surface of this trans-neptunian. A particular region of interest was the dark-red spot identified on the surface of Haumea from multi-band light curve analysis (Lacerda et al. 2008). We will present the results of applying Hapke modeling to our data-set, and our conclusions regarding the surface heterogeneity of Haumea. Additionally, thanks to the IFU capabilities to reconstruct images from our spectral cube, we were able to obtain relative astrometric position measurements for the two satellites and constrain dynamical models for their orbital motion.

Author(s): Christophe Dumas[1], Florian Gourgeot[5], Benoit Carry[2], Pedro Lacerda[3], Frederic Merlin[4], Frederic Vachier[2], Maria Antonieta Barucci[4], Jerome Berthier[2]
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115.07 – The Whipple Mission: Exploring the Kuiper Belt and the Oort Cloud

Whipple will characterize the small body populations of the Kuiper Belt and the Oort Cloud with a blind occultation survey, detecting objects when they briefly (~1 second) interrupt the light from background stars, allowing the detection

of much more distant and/or smaller objects than can be seen in reflected sunlight. Whipple will reach much deeper into the unexplored frontier of the outer solar system than any other mission, current or proposed. Whipple will look back to the dawn of the solar system by discovering its most remote bodies where primordial processes left their imprint.
Specifically, Whipple will monitor large numbers of stars at high cadences (~12,000 stars at 20 Hz to examine Kuiper Belt events; as many as ~36,000 stars at 5 Hz to explore deep into the Oort Cloud, where events are less frequent). Analysis of the detected events will allow us to determine the size spectrum of bodies in the Kuiper Belt with radii as small as ~1 km. This will allow the testing of models of the growth and later collisional erosion of planetesimals in the early solar system. Whipple will explore the Oort Cloud, detecting objects as far out as ~10,000 AU. This will be the first direct exploration of the Oort Cloud since the original hypothesis of 1950.
Whipple is a Discovery class mission that will be proposed to NASA in response to the upcoming Announcement of Opportunity. The mission is being developed jointly by the Smithsonian Astrophysical Observatory, Jet Propulsion Laboratory, and Ball Aerospace & Technologies, with telescope optics from L-3 Integrated Optical Systems.

Author(s): Matthew J. Holman[2], Charles Alcock[2], Almus T. Kenter[2], Ralph P. Kraft[2], Paul Nulsen[2], Matthew John Payne[2], Jan M. Vrtilek[2], Stephen S. Murray[3], Ruth Murray-Clay[6], Hilke Schlichting[5], Michael E. Brown[1], John H Livingston[4], Amy R Trangsrud[4], Michael W. Werner[4]
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119 – The Milky Way, The Galactic Center II

119.01 – The CRRP and SMHASH programs: Mapping the Milky Way and its neighbours with RR Lyraes in the mid IR

The CRRP and SMHASH programs are Spitzer Warm mission programs studying RR Lyrae in the Milky Way and its nearest neighbors.
The calibration program (CRRP) studies individual calibrator RR Lyrae stars that will be observed by Gaia, in addition to 45 MW and LMC globular clusters and 36 fields in the MW bulge and halo. These observations provide the calibration of the RR Lyrae mid-IR PL relation, allow us to measure metallicity effects using objects such as ω Cen, and will allow us to study the structure of the MW itself.
Our follow-on program, SMHASH, builds on the CRRP foundation to do a larger scale structural study of the MW. In this program we have targeted the Sagittarius dwarf, Sagittarius and Orphan Streams and several dwarf galaxies neighboring the MW.
I will discuss the two programs, giving preliminary results showing the first measurements of the RR Lyrae mid-IR PL relation from full phase coverage observations. I will show how the measurements from CRRP/SMHASH are critical for both the structural studies of the MW and for an independent measure of the distance to the LMC, providing a complementary test of the Cepheid distance ladder.

Author(s): Victoria Scowcroft[1], Wendy L. Freedman[1], Kathryn V. Johnston[2], Barry Madore[1]
Institution(s): *1. Carnegie Institution for Science, 2. Columbia University*
Contributing team(s): CRRP team, SMHASH team

119.02 – Inferring the Galactic gravitational potential with Gaia and friends

In the coming decade the Gaia satellite will measure the positions and velocities of an unprecedented number of stars in our Galaxy, with unprecedented precision. Among many firsts, this revolutionary new data set will include full six-dimensional phase space information for millions of stars in the Galactic halo, including stars in many tidal streams. These streams, the products of hierarchical accretion, can be used to infer the Galactic gravitational potential thanks to the common origin of the stars in each one. We present a method for doing so by maximizing the information content (i.e. clumpiness) of the action space of the stream stars. This statistical approach eliminates the need to assign stars to particular streams. Using a toy model of the stellar halo in a known potential, and including updated error models for Gaia, we show that ground-based spectroscopic follow-up of faint halo stars is essential to complete the six-dimensional Gaia catalog and properly constrain the scale radius of the potential. By fitting a spherical NFW potential to streams in a cosmologically simulated halo, we show how oversimplification of the potential model affects fit results. This material is based upon work supported by the National Science Foundation under Award No. AST-1400989.

Author(s): Robyn Ellyn Sanderson[2], Johanna Hartke[3], Amina Helmi[3], David W. Hogg[1]
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119.03D – Hypervelocity Stars in the Sloan Digital Sky Survey

There are only 18 confirmed hypervelocity stars (HVSs) and all are young, massive, B-type stars that are thought to be boosted to extreme velocities through interactions with the supermassive black hole at the center of the Milky Way. We identify candidate hypervelocity stars from samples of Sloan Digital Sky Survey (SDSS) F dwarfs and Sloan Extension for Galactic Understanding and Exploration (SEGUE) G and K dwarfs. Previous searches for hypervelocity stars have only focused on large radial velocities; in these studies we also use proper motions to select the candidates. We determine the hypervelocity likelihood of each candidate, considering the significant errors often associated with high proper motion stars via Monte Carlo simulations. Using the observed 6-d positions and velocities, we also calculate the orbits of these candidates in order to determine their place of origin within the Galaxy. We find that, for the G and K dwarf sample, nearly half of the candidates exceed their escape velocities with at least 98% probability and no candidate's orbit is consistent with a Galactic Center origin.

Author(s): Lauren E. P. Campbell[1], Kelly Holley-Bockelmann[1]
Institution(s): *1. Vanderbilt University*

119.04 – Reinterpreting The Sagittarius Dwarf Tidal Debris

Tidal debris from the Sagittarius dwarf galaxy (Sgr) has been used as a primary constraint in several determinations of the Milky Way Galaxy's total mass and dark matter distribution. However, the apparent "bifurcation" of both the leading and trailing tidal tails has never been satisfactorily explained. Using the powerful MilkyWay@home volunteer computing platform, we were surprised that the apparently fainter of the bifurcated tidal tails required an extremely wide stream to fit the observed stellar densities. Here, through additional analysis, we show that both the primary and secondary tidal tails of Sgr, as well as the Virgo overdensity, are all wider than previously thought, and dominate star counts in the Galactic halo. Additionally, we present evidence of a stellar "envelope" about the primary Sgr stream, which may be direct evidence for a subhalo-rich (or "lumpy") dark matter distribution. This research was supported by the NSF through grant AST 10-09670, and crowd funding from the MilkyWay@home volunteers.

Author(s): Matthew T. Newby[1], Heidi Jo Newberg[1], Jeffery M. Thompson[1], Jake Weiss[1]
Institution(s): *1. Rensselaer Polytechnic Institute*

119.05 – Orbit of the Ophiuchus Stream

Ophiuchus Stream is the most recently discovered stellar stream in the Milky Way (Bernard et al. 2014). Due to its location (~5 kpc from the Galactic center) and its puzzling morphology (a thin and short stream, and yet with no visible progenitor), this stream may represent an important piece in our efforts to understand the Galactic potential and the dynamical evolution of accreted structures. In this talk, I will present a followup study of the stream during which we obtained high-quality spectroscopic data on 14 stream member stars using Keck and MMT telescopes. I will show how these newly acquired spectroscopic and existing photometric data enabled us to constrain i) the distance and line-of-sight extent of the stream, ii) the full 3D kinematics of the stream, iii) the chemical properties of the stream and the nature of its progenitor, and iv) the orbit of the stream. I will finish by discussing future prospects in this field in light of the upcoming public release of Pan-STARRS1, Palomar Transient Factory, and GAIA data.

Author(s): Branimir Sesar[5], Edouard J. Bernard[4], Jo Bovy[3], Judith G. Cohen[1], Nelson Caldwell[2], Melissa Ness[5], Christian I. Johnson[2], Annette M. N. Ferguson[4], Nicolas Martin[5], Hans-Walter Rix[5], Eddie Ford Schlafly[5]
Institution(s): *1. Caltech, 2. Harvard-Smithsonian Center for Astrophysics, 3. Institute for Advanced Study, 4. Institute for Astronomy, University of Edinburgh, Royal Observatory, 5. Max Planck Institute for Astronomy*
Contributing team(s): Pan-STARRS1 Collaboration

119.07 – Rings and Radial Waves in the Disk of the Milky Way

We show that in the anticenter region, between Galactic longitudes of $110^{o} < l < 229^{o}$, there is an asymmetry in the main sequence star counts on either side of the Galactic plane using data from the Sloan Digital Sky Survey. This asymmetry oscillates from more stars in the north at distances of about 2 kpc from the Sun to more stars in the south at 4-6 kpc from the Sun to more stars in the north at distances of 8-10 kpc from the Sun. We also see evidence that there are more stars in the south at distances of 12-16 kpc from the Sun. The three more distant asymmetries form roughly concentric rings around the Galactic center, opening in the direction of the Milky Way's spiral arms. The northern ring, 9 kpc from the Sun, is easily identified with the previously discovered Monoceros Ring. Parts of the southern ring at 14 kpc from the Sun (which we call the TriAnd Ring) have previously been identified as related to the Monoceros Ring and others have been called the Triangulum Andromeda Overdensity. The two nearer oscillations are approximated by a toy model in which the disk plane is offset by of the order 100 pc up and then down at different radii. We also show that the disk is not azimuthally symmetric around the Galactic anticenter and that there could be a correspondence between our observed oscillations and the spiral structure of the Galaxy. We suggest that the TriAnd and Monoceros Rings could be accreted satellites that form an outer disk. More complex modeling is necessary to understand the observations. This research is supported by the NSF grant AST 09-37523, and NSF China grant Nos. 11203030 and the National Key Basic Research Program of China 2014CB845703.

Author(s): Heidi Jo Newberg[4], Yan Xu[3], Jeffrey L. Carlin[4], Chao Liu[3], Licai Deng[3], Jing Li[2], Ralph Schoenrich[5], Brian Yanny[1]
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120 – AGN, QSO, Blazars II

120.01 – Bayesian analysis of X-ray jet features of the high redshift quasar jets observed with Chandra

X-ray emission of powerful quasar jets may be a result of the inverse Compton (IC) process in which the Cosmic Microwave Background (CMB) photons gain energy by interactions with the jet's relativistic electrons. However, there is no definite evidence that IC/CMB process is responsible for the observed X-ray emission of large scale jets. A step toward understanding the X-ray emission process is to study the Radio and X-ray morphologies of the jet. Results from Chandra X-ray and multi-frequency VLA imaging observations of a sample of 11 high- redshift ($z > 2$) quasars with kilo-parsec scale radio jets are reported. The sample consists of a set of four $z \geq 3.6$ flat-spectrum radio quasars, and seven intermediate redshift ($z = 2.1 - 2.9$) quasars comprised of four sources with integrated steep radio spectra and three with flat radio spectra.We implement a Bayesian image analysis program, Low-count Image Reconstruction and Analysis (LIRA) , to analyze jet features in the X-ray images of the high redshift quasars. Out of the 36 regions where knots are visible in the radio jets, nine showed detectable X-ray emission. Significant detections are based on the upper bound p-value test based on LIRA simulations. The X-ray and radio properties of this sample combined are examined and compared to lower-redshift samples.

This work is supported in part by the National Science Foundation REU and the Department of Defense ASSURE programs under NSF Grant no.1262851 and by the Smithsonian Institution, and by NASA Contract NAS8-39073 to the Chandra X-ray Center (CXC). This research has made use of data obtained from the Chandra Data Archive and Chandra Source Catalog, and software provided by the CXC in the application packages CIAO, ChIPS, and Sherpa. Work is also supported by the Chandra grant GO4-15099X.

Author(s): Kathryn McKeough[1], Aneta Siemiginowska[2], Vinay Kashyap[2], Nathan Stein[4], Chi C. Cheung[3]
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120.02 – A census of gas outflows in type 2 AGNs out to z ~ 0.2

We investigate the kinematics of ionized gas in the narrow-line region, using a large sample of 32,000 type 2 AGNs out to $z = 0.2$. By measuring the velocity shift of narrow emission lines with respect to the systemic velocity measured from the stellar absorption lines, we detected the [OIII] velocity offset for ~50% AGNs. Considering the projection effect, the fraction of type 2 AGNs with the [O III] velocity offset is comparable to that of type 1 AGNs. We find that the velocity dispersion of [OIII] is larger than that of Ha, ranging from 50 to 500 km/s (i.e., $140 < \mathrm{FWHM/kms} < 1400$), suggesting that outflow is prevalent in type 2 AGNs. A weak correlation of the OIII luminosity with velocity shift and velocity dispersion indicates that outflow velocity is stronger for higher luminosity AGNs. Based on our 3-D biconical outflow models with simple assumptions on the velocity structure, we simulate the projected 2-D velocity and velocity dispersion maps, which are spatially integrated to reproduce the measurements of SDSS AGNs. By comparing the distribution of the measured velocity and velocity dispersion of OIII, with the model grids, we constrain the intrinsic outflow velocities. The outflow velocity ranges from a few hundreds to a thousand km/s, implying a strong feedback to ISM.

Author(s): Jong-Hak Woo[1], Hyun-Jin Bae[1]
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120.03 – Superluminal Motions at 500 Mpc: New Results on Nearby AGN Jets with HST

I will present results from recent HST observations of several nearby AGN Jets. Using over 20 years of archival data in combination with the most recent deep ACS/WFC imaging, we have found evidence for superluminal motions in optical kpc-scale jets, beyond the only previously reported case of M87. Our observations show that relativistic bulk motions extend to the outermost parts of these jets, and our continuous refinement of astrometric techniques suggests that the reach of Hubble observations, and the constraints on jet models implied by these measurements, may extend beyond 500 Mpc. The presentation will include movies of these jets in which the motions of the plasma can be seen by eye.

Author(s): Eileen T. Meyer[2], Markos Georganopoulos[3], William B. Sparks[2], John A. Biretta[2], Roeland P. Van Der Marel[2], Jay Anderson[2], Marco Chiaberge[2], Eric S. Perlman[1], Colin Arthur Norman[2]
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120.04 – 5-day photo-polarimetric WEBT Campaign on Blazar S5 0716+714 – a Study of Microvariabiltiy in Blazar

A whole earth blazar telescope (WEBT) campaign on blazar S5 0716+714 was organized to simultaneously monitor the source in multiple photo-polarimetric filters as a study of the nature of microvariability in blazar. The campaign, starting on March 2nd 2014, lasted for five consecutive days resulting in a rich data set– flux in B,V,R,I and near IR filters, and polarization degree (PD) and position angle (PA) in mainly R filter. Such a rich information provides with an unique opportunity to look deep into the localized emission regions in the jet of the blazar. During the campaign, the source remained active with 0.93 duty cycle and went through an oscillation of 0.3 magnitudes along with 5% change in PD and 50 degrees swing in PA. For 6.19 hrs the activity suddenly stopped in all the filters resulting in a plateau around 14 magnitudes in R filter light curve and then brightens by 0.14 mag in 2.96 hr time. We employed time series analysis in search of possible quasi-periodic oscillations and found some of the significant timescales present in the light curve which could reflect on the physical processes in the turbulent jet environment. In the color-magnitude analysis, we looked for 'bluer-when-brighter' trend widely claimed to be found in some of the blazars including the source. Although we found some of such incidences, they could not claimed to be persistent through out the campaign period. Similarly, no clear trend of correlation between flux and PD, and flux and PA could be established. A modeling of the mini-flares lasting few hours as stochastic synchrotron pulses on top of relative stable back ground emission and that incorporates simultaneous the change of color, PA and PD is underway.

Author(s): Gopal Bhatta[5], Michal Ostrwoski[5], Lukasz Stawarz[13], Staszek Zola[5], Damian Jableka[5], R Bachev [12], Erika Benitez[14], Sarah M. Dhalla[10], Andy Cason[17], Daniele Carosati[9], Goran Damljanovic[6], A. Frasca[15], Shao Ming Hu[18], Svetlana G. Jorstad[11], O Kurtanidze[3], Valeri Larionov[4], Giuseppe Leto[15], Alan P. Marscher[11], Joseph Moody[16], Johhanes Ohlert[7], Nicola Rizzi [19], Alberto C. Sadun[2], Mahito Sasada[1], Sergey Sergeev [8], Anton Strigachev[12], Oliver Vince [6], James Raymond Webb[10]
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Contributing team(s): Whole Earth Blazar Telescope

120.05 – Investigating a Correlation Between AGN Inclination and Mid-IR Color

In our recent studies of the narrow-line region (NLR) kinematics in active galactic nuclei (AGN) with HST, we identified 17 Seyfert 1 and 2 galaxies with biconical outflows and determined the inclinations of their bicone axes (and presumably obscuring tori) with respect to our line of sight. We were able to identify several observed parameters that correlate with inclination to go beyond the simple Seyfert 1/2 dichotomy; these include total hydrogen column density, width of the broad lines, and mid-IR continuum shape from Spitzer IRS observations. Here we present a correlation between AGN inclination and mid-IR color from photometry by the WISE satellite at 3.4, 4.6, 12, and 22 microns. At lower inclinations (i.e., moving from Seyfert 2s to Seyfert 1s), the relative fluxes at the shorter wavelengths increase, as we presumably see more of the hot inner throat of the torus. We examine the scatter in this relationship in an attempt to identify its origin and to assess the feasibility of using mid-IR color as a proxy for AGN inclination.

Author(s): D. Michael Crenshaw[1], Travis C. Fischer[1], Steven B. Kraemer[3], Henrique R. Schmitt[2]
Institution(s): *1. Georgia State Univ., 2. Naval Research Laboratory, 3. The Catholic University of America*

120.06 – Implications of Asymmetric Broad-Line Reverberation for Binary Black Hole Searches

One proposed method for identification of binary supermassive black holes involves searching for temporal variations in the line-of-sight velocity of broad emission lines in quasars. If one member of a binary black hole is active and possesses a broad-line region, then the orbital motion of the binary will cause the observed broad-line velocity centroid to oscillate over an orbital period. However, with only a few observations it is difficult to distinguish orbital motion from other possible causes of velocity changes. We will discuss the impact of reverberation on broad-line velocity shifts. If the reverberation transfer function is asymmetric due to radial motions in the broad-line region, reverberation will cause temporal variations in broad-line velocity centroids that can mimic the appearance of acceleration. We will illustrate this effect with simulations and with data from the Lick AGN Monitoring Project 2011, where we find reverberation-induced velocity shifts of up to ~250 km/s over 1-month timescales. When only two widely-separated epochs of spectroscopic observations are available, such profile shifts will be difficult to distinguish from genuine acceleration, and we suggest that the majority of candidate binaries selected by detection of velocity shifts in two-epoch observations will be spurious.

Author(s): Aaron J. Barth[1]
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Contributing team(s): LAMP2011 Collaboration

120.07 – Exploring AGN Unification through Mid-Infrared Spectroscopic Analysis

The emission of silicate dust and species of low- and high-ionization dominate the mid-infrared (MIR) spectra of active galactic nuclei (AGN). The dust, expected to be in a toroidal distribution about a central, supermassive black hole, may or may not obscure optical broad-line emission emanating from within, providing the type 2 and type 1 AGN classes, respectively. In the context of AGN unification, type 1 and 2 AGN may inherently be similar objects which are distinguished by the viewing angle of the observer. Many avenues have been explored to decipher AGN unification, or the lack thereof. We present the findings of a two method approach analyzing an archival sample of AGN observed by the Infrared Spectrograph aboard the Spitzer Space Telescope. The first approach implements MIR spectral energy distributions to determine the arrangement of dust within the torus and if there are similarities between the AGN classes. The second is a comparative analysis of prominent MIR ionization lines between the two AGN classes. We also discuss implications of the star formation present in the MIR spectroscopic observations and their potential influence on the premise of AGN unification.

Author(s): Grant D. Thompson[2], Murray E. Macnamara[1]
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120.08 – High Resolution Radio Imaging of Powerful, Distant, Heavily Obscured Active Galaxies

High resolution radio imaging provides a powerful probe of the dense, dusty interiors of interacting, merging and active galaxies. Only at radio wavelengths is there a combination of sub-kiloparsec resolution, source transparency and sensitivity that can delineate complex structures and unveil spatial relationships between energetic phenomena such as relativistic jets and shocks. We discuss recent results from JVLA and VLBA observations of a population of highly obscured, extremely luminous, cosmologically distant active galaxies, thought to be in a transitional state between intense nuclear star formation and accretion-powered activity. The radio morphologies of these objects across a range of angular scales will be reviewed, and interpreted in terms of relativistic jets and their likely interactions with a dense, dusty, inhomogeneous medium. We assess the potential of more comprehensive radio and ALMA imaging for testing current models of the birth of AGN radio jets and their role in the disruption and dissipation of a star forming circumnuclear medium.

Author(s): Colin J. Lonsdale[2], Carol J. Lonsdale[3], Rachel Thorp[1], Mark Lacy[3], Mark Whittle[4], Andrew Blain[5], Amy E. Kimball[3], Palavi Patil[4], Adam Tripp[4]
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120.09 – Observational signatures of Intermediate Mass Black Holes in AGN disks

Intermediate mass black holes (IMBH) are expected to grow efficiently in AGN disks. I will present expected signatures of gap-opening IMBH in AGN disks, including changes to the Fe Kalpha line and the SED. I will describe possible search strategies and detection techniques. Some of these techniques should also apply to detecting SMBH-SMBH binaries in AGN disks (expected from galaxy-galaxy mergers). The detection of any gap in an AGN disk also provides significant constraints on the disk parameters H/r and alpha. I will also briefly discuss the implications of this new predicted population of massive binary black holes for gravitational wave observations.

Author(s): K.E. Saavik Ford[2], Barry McKernan[2], Bence Kocsis[3], Wladimir Lyra[4], Lisa M. Winter[1]
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121 – Supernovae II

121.01 – Strongly Lensed Supernovae from the HST Frontier Fields

The Hubble Frontier Fields survey is using 6 strong-lensing galaxy clusters as "cosmic telescopes" to reach deeper into the early universe than can be achieved with HST alone. I will describe results from the first year of the FrontierSN program, a 3-year project that has detected a unique sample of ~20 supernovae and other explosive transients, reaching to z~1.5. This sample is small but special: it includes high-z SN with unique leverage for measuring rates, testing progenitor models and constraining cosmology, as well as lensed sources that can validate cluster mass models with direct measurements of the lensing magnification and time delay.

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Institution(s): *1. Johns Hopkins University*
Contributing team(s): the FrontierSN Team

121.02 – Exploring the unified class of Type II Supernovae with the Las Cumbres Observatory Global Telescope Network

Traditionally Type II supernovae (SNe) have been separated into two distinct classes based on the shape of their light curves after peak: Type II plateau (IIP) and Type II linear (IIL) SNe. Recent works suggest that Type II SNe form a continuum of objects from a single progenitor system. Here we present data for a set of Type II SNe collected with the Las Cumbres Observatory Global Telescope (LCOGT) Network and observed simultaneously with UVOT-Swift. In the growing sample of Type II SNe, we search for clear evidence to distinguish the two classes. SNe IIL show a similar drop at the end of their short steep plateau that resemble the drop visible in SNe IIP. We show that also at early phase SNe IIP and IIL are similar both in the UV and in the optical. Our analysis is consistent with the scenario that SNe IIP and IIL come from similar progenitors but with SN IIL progenitors having been stripped of their hydrogen envelope before explosion. While SNe IIL are on average more luminous than SNe IIP, we show that they both produce a comparable amount of nickel.

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Institution(s): *1. Las Cumbres Observatory Global Telescope Network, 2. Texas Tech University*

121.03 – Explaining the Type II supernova rate-mass relation as a combination of galaxy downsizing and star-formation rates

Using a sample of local supernovae (SNe), the Lick Observatory Supernova Search discovered that more massive galaxies exhibit lower SN rates per unit mass for all types of SNe. This was a surprising result and so far no satisfactory, robust, measurement-driven explanation has been given for the core-collapse SN rates. Here, we show that the rate-mass relation for Type II SNe can be explained by a combination of the known correlations between galaxy stellar mass and both star-formation rate (SFR) and specific SFR (sSFR), and newly-measured correlations between the Type II SN rates per unit mass and either SFR or sSFR. Using a proprietary code that detects and classifies SNe in galaxy spectra, we have detected a sample of 91 Type Ia and 16 non-interacting Type II (II-P and II-L) SNe among ~740,000 galaxies from the 9th Data Release of the Sloan Digital Sky Survey. Of the SNe in our sample, eight Type II and 22 Type Ia SNe are new discoveries. We measure the Type II SN rate per unit mass as a function of stellar mass in a sub-sample of ~200,000 BPT-diagram-selected star-forming galaxies and confirm the Type II SN rate-mass relation at a median redshift of 0.075. We also show that there are "rate-SFR" and "rate-sSFR" relations, which together with the known correlations between galaxy stellar mass and either SFR or sSFR, provide predictions of the rate-mass relation that are consistent with our measurements. As the "rate-SFR" and "rate-sSFR" relations are a result of the short delay time between the formation and explosion of the progenitors of core-collapse SNe, this explanation should hold for stripped-envelope core-collaspe (Ib/c and IIb) SNe as well, although we do not test it here. Finally, we convert our mass-normalized rate into a measurement of the volumetric core-collapse SN rate at a redshift of 0.075.

Author(s): Or Graur[1], Maryam Modjaz[1]
Institution(s): *1. New York University*

121.04 – The fist homogeneous, multi-color photometric and spectroscopic sample of Stripped Envelope Super Novae and what it can tell us about their progenitors

Stripped envelope supernovae (stripped SN) arise from the spectacular death of massive stars which have lost their outer layers of Hydrogen and Helium in the late stages of their lives. They hold clues to study the final stages of the life of massive stars and the chemical enrichment of the Universe, and are intrinsically as common as SN type Ia. However, they have been observed and studied far less than SN Ia. The scarcity of data has thus far impaired the detailed study of their characteristics and a clear picture of the progenitor channels still eludes us.
The CfA produced the first large stripped SN survey that includes multi-color photometry in the optical and NIR (Bianco et al. 2014) as well as spectroscopy (Modjaz et al. 2014) of over 50 stripped SN. This dataset allows us to accurately derive bolometric lightcurves, and measure ejecta velocities in a consistent fashion for the entire sample. We can set constraints on the ejecta masses of SN IIb, Ib, Ic and Ic-BL, and probe the diversity in the explosions and in the progenitor channels. The study of our sample allows a direct comparison of the ejecta characteristics with the outcome of recent stellar evolution studies, confirming that binary evolution plays an important role in the late stages of the life of high mass stars.

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Contributing team(s): the CfA supernova group

121.05 – Neutrino Emission from Core-Collapse Supernovae

Core-collapse supernovae are some of the most energetic events in the modern universe. They are powered by the release of gravitational binding energy that occurs when the iron core of a massive star collapses into a neutron star. By far, the majority of the energy released is radiated in neutrinos. Since these neutrinos travel unimpeded through the mantle of the massive star, they are one of the best ways to observationally probe the inner workings of core-collapse supernovae. In this presentation, I will discuss predictions of neutrino emission from core-collapse supernova simulations and describe what its detection in Earth-based detectors can tell us about massive star evolution and the properties of the central engine of core-collapse supernovae.

Author(s): Evan O'Connor[1]
Institution(s): *1. North Carolina State University*

121.07D – Nucleosynthesis in Axisymmetric Ab Initio Core-Collapse Supernova Simulations of 12-25 $M_{\odot}$ Stars

We investigate core-collapse supernova (CCSN) nucleosynthesis with axisymmetric simulations using the multidimensional radiation hydrodynamics code Chimera. Computational costs have traditionally constrained the evolution of the nuclear composition in CCSN models to, at best, a 14-species α-network. Such a simplified network limits the ability to accurately evolve detailed composition, neutronization and the nuclear energy generation rate. Using passive tracer particles, we are able to extend the nuclear network evolution by incorporating more realistic networks in post-processing nucleosynthesis calculations. We present post-processing results for a series of CCSN 2D models initiated from stellar metallicity, non-rotating progenitors of Woosley & Heger (2007) and evolved for at least 1.4 seconds after core bounce with the smaller α-network. We also provide preliminary results from ongoing simulations evolved with a more realistic 150-species nuclear reaction network, thereby directly addressing the limitations of the smaller network.

Author(s): James Austin Harris[5], William R. Hix[4], Merek A Chertkow[5], Stephen W. Bruenn[1], Eric J. Lentz[5], O. E. Bronson Messer[4], Anthony Mezzacappa[5], John M. Blondin[3], Pedro Marronetti[2], Konstantin Yakunin[5]
Institution(s): *1. Florida Atlantic University, 2. National Science Foundation, 3. North Carolina State University, 4. Oak Ridge National Lab, 5. University of Tennessee-Knoxville*

121.08 – Impact of the third dimension on simulations of core-collapse supernovae

Modeling of core-collapse supernovae (CCSNe) has been an ongoing challenge to produce explosions that resemble observed supernovae, hampered by availability of appropriate computational resources and codes. For example, the most successful and complete CCSN simulations have been limited to axisymmetry (2D), which alters the behaviors of fluid flows and potentially the simulation outcome. Using a sophisticated 3D simulation from a 15 $M_{\odot}$ progenitor computed using the Chimera code with appropriate physical detail, we show a delay in the revival of the stalled accretion shock and the development of the explosion energy relative to a comparison 2D simulation. We consider the physical and numerical origins of the differences between 2D and 3D simulations and their long-term impacts on simulation outcomes; and the prospects for the future.

Author(s): Eric J. Lentz[5], Stephen W. Bruenn[1], William R. Hix[4], O. E. Bronson Messer[4], Anthony Mezzacappa[5], John M. Blondin[2], Eirik Endeve[4], James Austin Harris[5], Pedro Marronetti[3], Konstantin Yakunin[5]
Institution(s): *1. FAU, 2. NCSU, 3. NSF, 4. ORNL, 5. Univ. of Tennessee*

122 – Extrasolar Planets: Kepler's Legacy II

122.01D – The Power of a Planet Population: Kepler's Super-Earth Compositions, Mass-Radius Relation, and Host Star Multiplicity

The Kepler Mission has found thousands of planetary candidates with radii between 1 and 4 times that of Earth. These planets have no analogues in our Solar System, providing an unprecedented opportunity to assess planet formation and evolution processes for an entirely new planetary population. By coupling theoretical work with sophisticated statistical modeling, we place quantitative constraints on the distribution of physically relevant properties, such as planet compositions, while accurately incorporating the large uncertainties and biases in the Kepler data. We first apply this framework to the composition distribution of Kepler's sub-Neptunes: assuming an internal structure consisting of a rocky core with a hydrogen and helium envelope, we find that these envelopes are most likely to be ~ 1% of these planets' total mass with an intrinsic scatter of ± 0.5 dex. Our results do not produce a one-to-one relationship between super-Earth masses and radii. Accordingly, we derive a probability density function that incorporates the intrinsic scatter in planetary masses at a given radius, which provides dynamical studies a more appropriate means to map Kepler radii to masses. Finally, we present first results from our campaign to detect stellar companions to Kepler super-Earth host stars using the laser guide star adaptive optics systems at Lick Observatory, and discuss implications for the orbital evolution of this entirely new class of planets.

Author(s): Angie Wolfgang[1]
Institution(s): *1. University of California, Santa Cruz*

122.02 – Characterizing K2 Planet Discoveries

We present an effort to confirm the first planet discovered by the two-wheeled *Kepler* mission. We analyzed K2 photometry, correcting for nonuniform detector response as a function of the spacecraft's pointing, and detected a transiting planet candidate. We describe our multi-telescope followup observing campaign, consisting of photometric, spectroscopic, and high resolution imaging observations, including over 40 HARPS-N radial velocity measurements. The new planet is a super-Earth orbiting a bright star amenable to followup observations. HARPS-N was funded by the Swiss Space Office, the Harvard Origin of Life Initiative, the Scottish Universities Physics Alliance, the University of Geneva, the Smithsonian Astrophysical Observatory, the Italian National Astrophysical Institute, the University of St. Andrews, Queens University Belfast, and the University of Edinburgh.

Author(s): Andrew Vanderburg[3], Benjamin Montet[1], John Johnson[3], Lars A Buchhave[3], Li Zeng[3], Allyson Bieryla[3], David W. Latham[2], David Charbonneau[3]
Institution(s): *1. California Institute of Technology, 2. Harvard University, 3. Harvard-Smithsonian Center for Astrophysics*
Contributing team(s): The HARPS-N Collaboration, The Robo-AO team

122.03 – The Kepler Q1 - Q16 Planet Candidate Catalog

We present an update of the Kepler planet candidate catalog based on analysis of 16 quarters of data. The addition of one more year of data over that presented by Rowe et al. (2015) yields nearly 1500 new objects of interest, from which we identify over 500 new planet candidates. These new candidates are typically smaller, and have longer orbital periods than the KOI sets from our previous work. The full catalog is available at the NASA Exoplanet Archive. We discuss a few features of the catalog that may trip up an unsuspecting user, and highlight some interesting planet candidates.

Author(s): Fergal Mullally[1]
Institution(s): *1. NASA Ames/SETI*
Contributing team(s): Kepler Team

122.04 – Planet Population Statistics With Kepler Q1-Q16: Stellar Effective Temperature Dependence

We explore extrasolar planet population statistics and the dependence of planet occurrence rates on stellar effective temperature from analysis of the Kepler Q1-Q16 planet candidate sample. The analysis takes advantage of the recent work on the Q1-Q16 Kepler planet candidate sample, extensive Monte-Carlo transit signal injection and recovery tests of the Kepler Pipeline, and updates to the stellar parameters provided by the Kepler Stellar Working Group. Results focus of intermediate orbital periods, 50 〈 Porb 〈300 day, where astrophysical and instrumental contamination of the planet sample is low.

Author(s): Christopher J. Burke[3], Fergal Mullally[3], Jessie Christiansen[2], Daniel Huber[1], Shawn Seader[3], Joseph Catanzarite[3], Steve Bryson[1], Jeffrey Coughlin[3], Jason Rowe[3], Susan E. Thompson[3], Bruce Clarke[3], Peter Tenenbaum[3], Natalie M. Batalha[1], Michael R Haas[1], Jon Michael Jenkins[1]
Institution(s): *1. NASA Ames Research Center, 2. NASA Exoplanet Science Institute/Caltech, 3. SETI Institute*
Contributing team(s): Kepler Project

122.05 – Expected Exoplanet Yields of Direct-Imaging Missions, Based on the Kepler Population

The expected number of exoplanets that could be detected by a future direct-imaging mission will depend on the parameters of the instrumentation as well as the distribution function of the underlying population of exoplanets, in terms of radius and period, and other parameters such as those of the star itself. In this paper I use the instrument parameters of some potential future missions, combined with the estimated and extrapolated exoplanet population distribution function derived from the Kepler mission, to estimate the exoplanet yields of these missions.

Author(s): Wesley A. Traub[1]
Institution(s): *1. Jet Propulsion Laboratory*

122.06 – A Transit Timing Posterior Distribution Catalog for all Kepler Planet Candidates

Thanks to the unprecedented precision of Kepler, the first unambiguous observations of transit timing variations (TTVs) are now in hand. TTVs have afforded us the ability to precisely characterize both transiting and non-transiting exoplanets by observing dynamical interactions in multi-transiting systems. Catalogs attempting to publish transit times of large numbers of Kepler systems exist. However, these catalogs are incomplete: for each event only a point estimate and assumed Gaussian uncertainity of the transit time is included. Moreover, published catalogs only include long-cadence data, do not cover the full Kepler observing baseline, and assume the Kepler noise is perfectly uncorrelated. Here, we present a complete TTV catalog, in which we produce full posterior distributions on the time of each transit for every Kepler planet candidate without any assumptions of Gaussianity in the transit times.

Author(s): Benjamin Montet[1], Juliette Becker[3], John Johnson[2]
Institution(s): *1. California Institute of Technology, 2. Harvard-Smithsonian Center for Astrophysics, 3. University of Michigan*

122.07 – Statistical Eclipses of Kepler Neptune-like Candidates

We present the results of our work to detect secondary eclipses of Neptune-like planets in Kepler's long cadence data and to determine their average albedo. Our method is inherently statistical in nature: we scale and combine photometric data for groups of planets to infer their average eclipse depths, and to greatly increase the signal-to-noise. We have modified our method for averaging short cadence light curves of multiple planet candidates (ApJ, in press), and have applied it to long cadence data. We transform the phase of the individual candidates to match a reference candidate, such that the light curves add constructively, and we account for the broadening of the eclipse due to the 30 minute cadence. In the short cadence data, we found that a group of close-in sub-Saturn candidates (1 to 6 Earth radii) was more reflective than typical hot Jupiters. With the larger number of candidates available in long cadence, we expect to improve the resolution in radius, focusing on Neptune-like planets.

Author(s): Holly A. Sheets[1], Drake Deming[1]
Institution(s): *1. University of Maryland*

122.08 – Preparing for the Kepler K2 Microlensing Survey: A Call to Arms

In 2016 the ninth campaign of K2 (the extended, two-wheel Kepler mission) will be targeted towards the Galactic bulge, where it will perform the first wide-field, space-based microlensing survey. This survey will discover tens of both bound and free-floating planets by itself, but its real value will come from simultaneous ground-based observations that will provide parallax measurements enabling both mass and distance measurements for the majority of these planets and their hosts. These will include the first ever measurements of free-floating planet masses.
K2's immediate public data release policy offers a huge one-time-only opportunity to build up the US's expertise in exoplanetary microlensing surveys in preparation for the WFIRST mission. Unbeknownst to most astronomers at home and abroad, the US also owns the best instrument in the world for conducting ground-based microlensing surveys -- DECam on the Blanco 4m, whose etendue is a factor of 20 larger than OGLE's at equal resolution. A simultaneous survey using ~80 half nights on DECam (as part of a NOAO large survey program) could also make its data immediately public, catapulting US astronomers to the forefront of planetary microlensing surveys, measuring masses of and distances to microlensing exoplanets on a never-before-possible scale. This is an opportunity that should not be missed and I will outline ways in which you can get involved.

Author(s): Matthew Penny[1]
Institution(s): *1. Ohio State University*

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123 – HEAD II: Centennial of General Relativity: Looking Forward

AAS Special Session
To celebrate the centenary of the publication of Einstein’s Field Equations, the AAS High Energy Astrophysics Division and NASA's Physics of the Cosmos program are pleased to co-host two special sessions on Theory of General Relativity. The first session provides a historical perspective on the development of the theory of general relativity and astrophysical constraints of General Relativity. The second session looks forward from current astrophysical constraints to next-generation measurements ranging from space-based measurements of gravitational waves and the powerful tests made possible through studies of binary pulsars through to cosmological tests of General Relativity.

123.01 – Binary Pulsar Constraints on General Relativity

Binary pulsars provide indispensable laboratories for precision tests of gravity. Effects that can be studied in great detail include the emission of gravitational waves, Shapiro delays, orbital precession and more. But also fundamental differences between general relativity and alternative theories of gravity can be probed, such as possible violations of the strong equivalence principle, preferred frame effects or the existence of gravitational dipole radiation or scalar fields. Also the effects of spin precession in strongly self-gravitating bodies can be studied by observing effects of geodetic precession. These and an other tests will be discussed.

Author(s): Michael Kramer[1]

Institution(s): *1. Max-Planck-Institut fuer Radioastronomie*

123.02 – Cosmological tests of GR

In the search to understand cosmic acceleration a variety of alternatives to Einstein's cosmological constant, including modifications to General Relativity, are currently under consideration. We discuss the observational implications of such gravity-based dark energy theories and how upcoming cosmological surveys will provide insights into the nature of gravity on cosmic scales.

Author(s): Rachel Bean[1]
Institution(s): *1. Cornell Univ.*

123.03 – The Centennial of GR: Looking forward to Black Hole Mergers at Cosmic Dawn

Einstein's theory of gravity has fundamentally altered mankind's conception of the Universe and its contents. Once outlandish notions such as the Universe expanding from a mere speck to its current vast size, or stars collapsing to form black holes are now well supported pillars of modern astronomy. Gravity is the dominant force that shapes the Universe, and gravity is behind all extremely energetic astrophysical phenomena. However, we are currently blind to the most powerful events in nature - bursts of pure gravitational wave energy from the collision of two black holes. A Laser Interferometer Space Antenna (LISA) will be able to record these collisions throughout the Universe, and provide unique insights into the co-evolution of galaxies and massive black holes. Motivated by the GR centennial, I'll take a look back at the rich and turbulent history of the LISA mission, and a look forward to the incredible science potential of its current incarnation as the European L3 eLISA mission.

Author(s): Neil J. Cornish[1]
Institution(s): *1. Montana State Univ.*

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124 – Extrasolar Planets: Atmospheres II

124.01D – Super-Earths, Warm Neptunes, and Hot Jupiters: Transmission Spectroscopy for Comparative Planetology

The detections and non-detections of molecular species in transiting planets-- such as water, methane, and carbon monoxide-- lead to greater understanding of planet formation and evolution. Recent significant advances in both theoretical and observational discoveries from planets like HD189733b, HD209458b, GJ436b, as well as our own work with HAT-P-11b and GJ1214b, have shown that the range of measurable atmospheric properties spans from clear, molecular absorption dominated worlds to opaque worlds, with cloudy, hazy, or high mean molecular weight atmospheres. Characterization of significant non-detections allowed us to infer the existence of opaque cloud layers at very high altitudes or mean molecular weights upwards of ~1000x solar. The prevalence of these atmospheres was unexpected from extrapolations of solar system analogs. I will present our published results from GJ1214b and HAT-P-11b, as well as our recent work using both Spitzer and Magellan. Our results, combined with transmission spectra obtained for other similar planets, connect to develop a better understanding about the nature of these distant and alien worlds

Author(s): Jonathan D. Fraine[3], Drake Deming[3], Andres Jordan[2], Heather Knutson[1]
Institution(s): *1. California Institute of Technology Division of Geological & Planetary Sciences, 2. Pontificia Universidad Católica de Chile Instituto de Astrofísica, 3. University of Maryland*

124.02D – Spectral Fingerprints of Earth-like Planets Orbiting Other Stars

A wide range of potentially rocky planets in the habitable zone (HZ) have been detected by Kepler as well as ground-based searches. The type of host star influences our ability to detect atmospheric features with future space- and ground-based telescopes like JWST and E-ELT. We present a complete suit of stellar models as well as model atmospheres for an Earth-analogue planets in their HZ for stellar effective temperature from Teff = 2300K to 7000K, sampling the entire FGKM stellar type range. The UV emission from a planet's host star dominates the photochemistry and thus the resultant observable spectral features of the planet. Using the latest UV spectra obtained by Hubble as well as IUE, we model the effect of activity on Earth-like planets. We focus on the primary detectable atmospheric features that indicate habitability on Earth, namely: H2O, O3, CH4, N2O and CH3Cl. We model the emergent as well as transit spectra of Earth-analogue planets orbiting our grid of FGKM stars in the VIS/NIR (0.4 – 4 microns) and the IR (5 – 20 microns) range as input for future missions like JWST and concepts like Darwin/TPF.

Author(s): Sarah Rugheimer[2], Lisa Kaltenegger[1], Dimitar Sasselov[2]
Institution(s): *1. Cornell University, 2. Harvard University*

124.03 – On the Confidence of Molecular Detections in the Atmospheres of Exoplanets from Secondary Eclipse Spectra

Armed with a sizable and ever-growing list of confirmed exoplanets we are beginning to face the big question of atmospheric characterization: *What are these planets made of*? Transit transmission and emission spectroscopy provide a means to probe the composition of exoplanet atmospheres. However, relatively few high-resolution spectra have been obtained for transiting exoplanets leaving attempts at atmospheric characterization to rely heavily on ground and space-based broadband photometric observations. More recently, early claims of molecular detections in exoplanet atmospheres using broadband photometry are called into question as featureless blackbodies can be shown to reproduce the low signal-to-noise observations. In this study, we determine with what confidence we are able to detect spectrally dominant molecules in the atmospheres of nine exoplanets observed in secondary eclipse. Using the Bayesian atmospheric retrieval suite, CHIMERA, we find that the detection of molecules from broadband ground-based and space-based photometry generally fails to breach 3σ confidence. However, observations that include spectral data lead to strong molecular detections. Furthermore, we simulate *Hubble Space Telescope* Wide Field Camera 3 spectral observations from 1.1 to 1.6 microns for a handful of planets to suggest how future observations may lead to molecular detections.

Author(s): Jacob A Lustig-Yaeger[2], Michael R. Line[1], Jonathan J. Fortney[1]
Institution(s): *1. University of California, Santa Cruz, 2. University of Washington*

124.04 – The Thermal Emission and Albedo of Super-Earths with Flat Transmission Spectra

Vast resources have been dedicated to characterizing the handful of planets with radii between Earth's and Neptune's that are accessible to current telescopes. Observations of their transmission spectra have been inconclusive and do not constrain the atmospheric composition. Here, we present a path forward for understanding this class of small planets: by understanding the thermal emission and reflectivity of small planets, we can break these degeneracies and constrain the atmospheric composition.

Of the ~five small planets studied to date, four have radii in the near-IR consistent with being constant in wavelength. This suggests either that these planets all have higher mean molecular weight atmospheres than expected for hydrogen-dominated bulk compositions, or that the atmospheres of small planets are consistently enshrouded in thick hazes and clouds. For the particularly well-studied planet GJ 1214b, the measurements made using HST/WFC3 can rule out atmospheres with high mean molecular weights, leaving clouds as the sole explanation for the flat transmission spectrum. We showed in Morley et al. 2013 that these clouds and hazes can be made of salts and sulfides, which condense in the upper atmosphere of a cool H-rich atmosphere like GJ 1214b, or made of photochemical hazes such as soots, which result from methane photodissociation and subsequent carbon chemistry. Here, we explore how clouds thick enough to obscure the transmission spectrum change both thermal emission spectra and albedo spectra. These observations are complementary to transmission spectra measurements. Thermal emission probes deeper layers of the atmosphere, potentially below the high haze layer obscuring the transmission spectra; albedo spectra probe reflected starlight largely from the cloud particles themselves. Crucially, these complementary observations of planets with flat transmission spectra may allow us to break the degeneracies between cloud materials, cloud height and longitude, and bulk composition of the atmosphere. We make predictions for the observability of known planets for current and future telescopes.

Author(s): Caroline Morley[2], Jonathan J. Fortney[2], Mark Marley[1]
Institution(s): *1. NASA Ames Research Center, 2. University of CA - Santa Cruz*

124.05 – Characterizing Transiting Exoplanet Atmospheres with Gemini/GMOS: First Results

We present the first results from a 4-year ground-based survey of nine transiting exoplanet atmospheres. The program uses the Multi-Object Spectrograph (GMOS) on both Gemini north and south to repetitively measure transit lightcurves of individual exoplanets at high spectrophotometric precision. I will present the first results from this program. We attain photometric precisions per spectral bin of 200-600 ppm. Such precision enables us to construct transmission spectra of hot Jupiters. These transmission spectra reveal the dominant upper-atmosphere absorbers in the optical bandpass. Our overarching goal is to understand the prevalence and formation of high altitude clouds and hazes, and other important atmospheric constituents.

Author(s): Catherine Huitson[4], Jean-Michel Desert[4], Jacob Bean[3], Jonathan J. Fortney[2], Kevin B. Stevenson[3], Marcel Bergmann[1]
Institution(s): *1. NOAO/Gemini, 2. University of California at Santa Cruz, 3. University of Chicago, 4. University of Colorado at Boulder*

124.06 – Probing exoplanet atmospheres through their Rayleigh scattering signatures

Low-resolution transit spectroscopy of the handful of small exoplanets suitable for such observations has resulted in flat, featureless spectra in the infrared. This makes it difficult to determine the composition and scale height of their atmospheres. GJ 3470b - a warm, Neptune-size planet orbiting a nearby M dwarf star - is no exception. However, recent observations in the visible regime suggest the possible presence of Rayleigh scattering in this planet's atmosphere, but this tentative conclusion was based on data obtained during a single transit and was not confirmed. We present LCOGT and Kuiper telescope multi-color photometry acquired during several transits of GJ 3470b. The resulting transmission spectrum shows a strong Rayleigh scattering slope detected with high confidence. Our analysis indicates that a hazy atmosphere containing highly scattering particles is the best fit to the current combined data set. We discuss how a measurement of the Rayleigh scattering slope can constrain the atmospheric scale height of low-density exoplanets even in the presence of hazes that obscure spectroscopic features at longer wavelengths.

Author(s): Diana Dragomir[3], Ian Crossfield[2], Bjoern Benneke[1], Kyle Pearson[2], Lauren I Biddle[2]
Institution(s): *1. CALTECH, 2. University of Arizona, 3. University of California Santa Barbara*

124.07 – Highly Evolved Exoplanet Atmospheres

It has been found that sub-Neptune-sized planets, although not existing in our Solar System, are ubiquitous in our interstellar neighborhood. This revelation is profound because, due to their special sizes and proximity to their host stars, Neptune- and sub-Neptune-sized exoplanets may have highly-evolved atmospheres. I will discuss helium-dominated atmospheres as one of the outcomes of extensive atmospheric evolution on warm Neptune- and sub-Neptune-sized exoplanets. The spectral characteristics, and the formation conditions of the helium atmosphere, as applied to GJ 436 b, will be discussed. As the observations to obtain the spectra of these planets continue to flourish, we will have the opportunity to study unconventional atmospheric chemical processes and test atmosphere evolution theories.

Author(s): Renyu Hu[1]
Institution(s): *1. Jet Propulsion Laboratory*

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125 – Final Results from BOSS

AAS Special Session
The Baryon Oscillation Spectroscopic Survey (BOSS) of the Sloan Digital Sky Survey III has completed a 6-year effort to map the spatial distribution of luminous galaxies and quasars and probe the inter-galactic medium. The goals of the survey were to constrain the characteristic scale imprinted by baryon acoustic oscillations in the early universe, the growth of structure through redshift space distortions, the matter power spectrum and the evolution of massive galaxies and quasars. This session highlights science results from the completed survey. This special session follows the final data release of the SDSS-III/BOSS data. This includes spectra and redshifts for 1.35 million unique Luminous Red Galaxies spanning redshifts 0.15 < z < 0.7 and 230,000 quasars of which 169,000 are at z > 2.15 and appropriate for Lyman-alpha forest studies. These objects cover of footprint of 10,2000 square degrees of the extragalactic sky at declinations -11 < dec < +69 deg.

125.01 – Overview of the Baryon Acoustic Oscillation Survey (BOSS)

The Baryon Oscillation Spectroscopic Survey has completed its imaging and spectroscopic program covering 10,000 square degrees of the northen extragalactic sky. The resulting redshift-space maps are used for precision measures of the baryon acoustic oscillation (BAO) scale and redshift-space distortions. These in turn constrain cosmological parameters including the effects of dark energy on the expansion history.

The BOSS survey includes high-quality spectra of 1.35 million galaxies and 160,000 high-redshift quasars spanning wavelengths 3600-10,000 Ang. These data were observed with the Sloan Telescope from 2008-2014 to a uniform depth, and achieve a high (>95%) redshift completeness for the galaxy samples. The effective volume for large scale structure studies is 5 (h^-1 Gpc)^3. All of the BOSS spectra and spectral classifications are in the December 2014 Data Release 12.

Author(s): David J. Schlegel[1]
Institution(s): *1. LBNL*
Contributing team(s): SDSS-III collaboration

125.02 – Cosmology from BOSS Galaxy Clustering and Redshift-Space Distortions

We present results obtained from the clustering galaxies observed by The Baryon Oscillation Spectroscopic Survey (BOSS). The BOSS galaxy sample includes 1.35 million luminous galaxies spanning redshifts 0.15 < z < 0.7 and distributed over 10000 deg^2. At large physical scales, this BOSS data set affords unprecedented precision in the measurement of the 3D clustering of galaxies. We present these clustering measurements, in configuration space and in Fourier space, and transverse and parallel to the line-of-sight. From these, we obtain robust and precise measurements of the position of the baryon acoustic oscillation (BAO) feature (better than 1% precision) and the rate of structure growth (better than 2.5% precision). We use these measurements to measure the properties of dark energy and test their consistency with

General Relativity.

Author(s): Ashley J Ross[1]
Institution(s): *1. CCAPP, Ohio State University*
Contributing team(s): SDSS-III collaboration

125.03 – Cosmology from the BOSS Lyman-Alpha Forest

After six years of observations, the Baryon Oscillation Spectroscopic Survey (BOSS) ended last summer, and recently made its data public (SDSS Data Release 12). During these years, it has used the SDSS telescope to obtain spectra of 1.5 million galaxies to get very accurate measurements of the Baryon Acoustic Oscillations (BAO) scale at redshift z ~0.5. At the same time, BOSS observed over 184 000 high redshift quasars (z>2.15) with the goal of detecting the BAO feature in the clustering of the intergalactic medium, using a technique known as the Lyman alpha forest (LyaF).
In this talk I will overview several results from the LyaF working group in BOSS, including the measurement of BAO at z=2.4 both from the auto-correlation of the LyaF (Delubac et al. 2014), and from its cross-correlation with quasars (Font-Ribera et al. 2014). From the combination of these studies we are able to measure the expansion rate of the Universe 11 billion years ago with a 2% uncertainty.

Author(s): Andreu Font-Ribera[1]
Institution(s): *1. Lawrence Berkeley National Laboratory*
Contributing team(s): SDSS-III collaboration

125.04 – What BOSS has taught us about Quasars.

This talk presents science highlights from the SDSS-III BOSS Quasar Survey, which has obtained spectra for over 300,000 quasars, 200,000 of which are at redshift z>2. Using this dataset, new measurements of the luminosity function have been made, with the faint end of the luminosity function now measured to z~5. New clustering results from DR12 are presented, and the weak luminosity dependence of quasar clustering at z~0.5 is also discussed.
New studies of the broad absorption line (BAL) quasar population have also been performed, with a sample of BAL quasars from the original SDSS being re-observed. These new data have shown the disappearance of CIV BAL troughs and indeed the transformation of BAL QSOs to non-BAL QSOs. BAL disappearance, and emergence, events appear to be extremes of general BAL variability, and have shed light on accretion-disk wind models.
We highlight the discovery of new classes of quasars including: a population of broad-line Mg II emitters found in a passive galaxy sample; objects with extremely red optical-to-mid infrared colors; objects with very curious UV line (LyA:NV) ratios and potentially the long-sought after high-redshift Type 2 Quasar population.
Finally, we describe two new dedicated programs, one focusing on reverberation mapping, the other on X-ray selected quasars.
A full list of papers connected to the BOSS Quasar Survey is given at: http://www.sdss3.org/science/publications.php

Author(s): Nicholas Ross[1]
Institution(s): *1. Drexel University*
Contributing team(s): The SDSS-III BOSS Quasar Science Working Group

125.05 – The BOSS Cosmological Model

This talk presents the cosmological implications from our recent analyses of SDSS-III BOSS galaxy clustering and Lyman alpha forest correlations, using data from Data Releases 11 and 12. BOSS allows unprecedented precision in the measurement from baryon acoustic oscillations (BAO) of the distance scale out to redshift 3. BAO measurements now have enough volume and redshift range to by themselves give interesting constraints on dark energy and spatial curvature. When combined with data on microwave background anisotropies and type Ia supernovae, these constraints tighten further, giving some of our best tests of the standard cosmological model. BOSS also investigates the growth predictions of the standard model via redshift-space distortions; the talk will summarize the latest results and their implications for tests of General Relativity and neutrino masses.

Author(s): Daniel Eisenstein[1]
Institution(s): *1. Harvard Univ.*
Contributing team(s): SDSS-III Collaboration

125.06 – The Start of SDSS-IV and eBOSS

The Extended Baryon Oscillation Spectroscopic Survey (eBOSS), the successor to BOSS and one of the key projects of Sloan Digital Sky Survey IV, has begun taking data. This multi-year survey will map cosmic structure over 9,000 deg^2 in the redshift range $0.7 < z < 2.0$, an area that has not been probed by previous surveys. We will achieve this by targeting a combination of luminous red galaxies and emission line galaxies at z<1, and QSOs at z>1. Each target sample will yield a

BAO distance measurement at or better than 2%. Additionally, eBOSS will increase the number of QSO spectra at z>2.15, doubling the amount of information obtainable from the Lyman alpha forest. Each target class will also yield a precision measurement of the growth of structure.

eBOSS will provide a wealth of opportunity for galaxy and QSO science as well. These data will yield constraints on the growth of massive galaxies from z=1. Once this survey is complete, the total sample of QSO spectra from all SDSS projects will number 850,000, more than half of which come from eBOSS alone.

Author(s): Jeremy Tinker[1]
Institution(s): *1. New York University*
Contributing team(s): SDSS-IV Collaboration

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126 – Astronomy Across Africa: A New Dawn - II

AAS Special Session
In January 2013 we requested two special sessions entitled, “Astronomy Across Africa: A New Dawn.” The AAS received a record number of requests for special sessions for that meeting but the Society was able to grant us one session, which was scheduled on Thursday morning. All of our speakers, including four from Africa, were able to attend the meeting and the session. We had an incredible turnout with a standing room only crowd and at least six current directors and a previous director of major facilities and observatories in the audience. The session has since been featured in a number of news articles and various member of the AAS community have expressed an interest in becoming more involved in collaborating with the young and fast growing astronomy community on the African continent. With this proposal we request another special session to continue our goal of increasing awareness, interactions and collaboration between US and African astronomers and educators. We would also like to request that the session be scheduled on the first or second day of the meeting so that there is additional time for the speakers from Africa to communicate and interact with AAS members and vice-versa. As noted in our past proposal an explosion of cutting edge multi-wavelength facilities have begun or are expected to be operating namely SALT, HESS, MITRA, AVN, PAPER, MeerKAT, African VLBI and the SKA. The CTA is also likely to be situated in Namibia, which combined with HESS will engage in premier high energy astrophysics activity. At the same time countries across the continent are developing human capacity in science and technology using astronomy as a gateway science. As astronomy is set to explode across Africa, its astronomy community, facilities and on-going science remain relatively unknown to the US community. With this second special session we seek to highlight the latest developments in astronomy in Africa, specifically the African-VLBI network, CTA and HESS – the high energy astrophysics facilities, and education / development projects across the continent in Ethiopia, Nigeria and Burkina Faso. We will also highlight the efforts by the US State Department in growing scientific interactions and connections with the African continent. Finally we note that the session is co-sponsored by AUI / NRAO, Committee for Status of Minorities in Astronomy (CSMA), South Africa’s Department of Science and Technology (DST), and South Africa’s National Research Foundation (NRF), and by members of the National Society of Black Physicists (specifically Dr. Charles Mcgruder and Dr. Lawrence Norris). All of the sponsors are particularly interested in improving diversity and broadening participation in astronomy and the advancement of African astronomers is well-aligned with the mission of the sponsors. Challenges faced by African astronomers are very similar to those faced by minority groups in the US and lessons can be learned between the two. For NRAO/AUI, an additional reason for the sponsorship is its mission statement to help train the next generation of scientists in radio astronomy.

126.01 – KAT-7 Science Verification Highlights

KAT-7 is a pathfinder of the Square Kilometer Array precursor MeerKAT, which is under construction. Its short baselines and low system temperature make it sensitive to large scale, low surface brightness emission. This makes it an ideal instrument to use in searches for faint extended radio emission and low surface density extraplanar gas. We present an update on the progress of several such ongoing KAT-7 science verification projects. These include a large scale radio continuum and polarization survey of the Galactic Center, deep HI observations (100+ hours) of nearby disk galaxies (e.g. NGC253 and NGC3109), and targeted searches for HI tidal tails in galaxy groups (e.g. IC1459). A brief status update for MeerKAT will also be presented if time permits.

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Contributing team(s): KAT-7 Science Data and Processing Team, KAT-7 Science Commissioning Team

126.02 – The African VLBI network project

The AVN is one of the most significant vehicles through which capacity development in Africa for SKA participation will be realized. It is a forerunner to the long baseline Phase 2 component of the mid-frequency SKA. Besides the 26m HartRAO telescope in South Africa, Ghana is expected to be the first to establish a VLBI-capable telescope through conversion of a redundant 32m telecommunications system near Accra. The most widely used receivers in the EVN are L-band and C-band (5 GHz). L-band is divided into a low band around the hydrogen (HI) line frequency of 1420 MHz, and a high band covering the hydroxyl line frequencies of 1612-1720 MHz. The high band is much more commonly used for VLBI as it provides more bandwidth. For the AVN, the methanol maser line at 6668 MHz is a key target for the initial receiver and the related 12178MHz methanol maser line also seen in star-forming regions a potential future Ku-band receiver. In the potential future band around 22GHz(K-band), water masers in star-forming regions and meg-maser galaxies at 22.235 GHz are targets, as are other radio continuum sources such as AGNs. The AVN system will include 5GHz and 6.668GHz receiver systems with recommendation to partner countries that the first upgrade should be L-band receivers. The original satellite telecommunications feed horns cover 3.8 – 6.4 GHz and should work at 5 GHz and operation at 6.668 GHz for the methanol maser is yet to be verified. The first light science will be conducted in the 6.7 GHz methanol maser band.

Telescopes developed for the AVN will initially join other global networks for VLBI. When at least four VLBI-capable telescopes are operational on the continent, it will be possible to initiate stand-alone AVN VLBI. Each country where an AVN telescope becomes operational will have its own single-dish observing program.

Capacity building to run an observatory includes the establishment of competent core essential observatory staff in partner countries who can train larger teams in science, engineering and technology issues and collaborate with the broader global science community to develop new African radio astronomy science communities.

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126.03 – Astronomy Development in Nigeria: Challenges and Advances

Nigeria evidently has huge potentials to develop a strong astronomy community. Much of the strength lies in the great number of intelligent students with the potential of becoming good astronomers. Sadly, astronomy development in Nigeria has stagnated in the past decades owing to poor funding and/or indifferent attitude of the funding bodies, research-unfriendly environment, and non-existence of facilities. Currently, efforts toward fuelling advancement in astronomy are focused on building 'critical mass', establishing collaborations with universities/astronomy institutes outside Nigeria, converting out-of-use communication antennas into radio telescopes, and acquiring out-of-use telescopes for educational and low-level research purposes.

Author(s): James Okwe Chibueze[1]
Institution(s): *1. National Astronomical Observatory of Japan*

126.04 – The NRAO NINE Program: Faculty & Student Partnerships Across Africa

We present an update on NRAO's International National Exchange (NINE) program, a growing partnership between universities and institutions across Africa and the United States. The NINE program seeks to foster mutually beneficial scientific and technical collaborations with an overall goal of co-mentoring and training the next generation of scientists and engineers. African students visit NRAO or partner US institutions as a cohort during their MSc or PhD studies as part of the NINE program. This model allows students to familiarize themselves with the US research community and culture while preventing a brain drain from Africa. Similarly visits by US-based faculty and students to Africa have been beneficial in understanding the changing landscape of African astronomy and improving our ties to each other. I will describe the progress of the program, lessons learned from student and faculty exchanges, and the challenges that remain. Tme permitting, I will also describe on-going scientific research and results from the NINE students.

Author(s): Kartik Sheth[1]
Institution(s): *1. NRAO*

126.05 – Astronomy Landscape in Africa

The vision for astronomy in Africa is embedded in the African Space Policy of the African Union in early 2014. The vision is about positioning Africa as an emerging hub for astronomy sciences and facilities. Africa recognized the need to take advantage of its natural resource, the geographical advantage of the clear southern skies and pristine sites for astronomy. The **Pan African University** (PAU) initiative also presents an opportunity as a post-graduate training and research network of university nodes in five regions of Africa and supported by the African Union. The Southern African node based in South Africa concentrates on space sciences which also includes astronomy. The PAU aims to provide the opportunity for advanced graduate training and postgraduate research to high-performing African students. Objectives also include promoting mobility of students and teachers and harmonizing programs and degrees.

A number of astronomy initiatives have burgeoned in the Southern African region and these include the Southern Africa Largest Optical Telescope (SALT), HESS (High Energy Stereoscopic System), the SKA (Square Kilometre Array) and the AVN

(African Very Long Baseline Interferometer Network). There is a growing appetite for astronomy sciences in Africa. In East Africa, the astronomy community is well organized and is growing – the East African Astronomical society (EAAS) held its successful fourth annual conference since 2010 on 30 June to 04 July 2014 at the University of Rwanda. Centred around the "Role of Astronomy in Socio-Economic Transformation," this conference aimed at strengthening capacity building in Astronomy, Astrophysics and Space Science in general, while providing a forum for astronomers from the region to train young and upcoming scientists.

Author(s): Takalani Nemaungani[1]
Institution(s): *1. South African Government*

126.06 – Joint Exchange Development Initiative (JEDI) with the SKA Africa

The teaching is a process whereby one mediates between another person and the materials. There exists many teaching models from lectures, discussion, questioning, to independent learning and self-teaching. The Joint Exchange Development Initiative (JEDI) is a way to maximize on the teaching methodologies. The JEDI is a concept to enhance development and education via direct transfer of skills and expertise in any specific field. It is an initiative to provide development via joint exchange among stakeholders. In this paper, we describe the various JEDI workshops carried out in the Square Kilometre Array (SKA Africa) partner countries and demonstrate how these workshops are proving to be successful.

Author(s): Nadeem Oozeer[2], Bruce A Bassett[1]
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126.07 – An Inquiry-based Astronomy Summer School in West Africa

In October 2013 over 75 undergraduate science students and teachers from Nigeria and Ghana attended the week-long West African International Summer School for Young Astronomers. The school was organized by a collaboration of astronomers from the University of Toronto, the University of Nigeria, and the Nigerian National Space Research and Development Agency. We designed and led activities that taught astronomy content, promoted students' self-identity as scientists, and encouraged students to think critically and figure out solutions themselves. I will describe the inquiry-based and active learning techniques used in the school, share results from the qualitative and quantitative evaluations of student performance, and describe future plans for holding the school in 2015, supporting our alumni, and building a sustainable partnership between North American and Nigerian universities.

Author(s): Linda Strubbe[1], Bonaventure Okere[4], James Chibueze[2], Kelly Lepo[5], Heidi White[5], Jielai Zhang[5], Daniel Okoh[4], Mike Reid[5], Lisa Hunter[3]
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126.08 – H.E.S.S. and CTA - Southern Africa's Involvement

The High Energy Stereoscopic System (H.E.S.S.), located in Namibia and operated by a collaboration of about 260 scientists from 11 countries in Europe and southern Africa, is the currently largest and most powerful Cherenkov telescope facility in the world for the study of very-high-energy (photon energies above 100 GeV) gamma-rays. The next-generation Cherenkov telescope facility, the Cherenkov Telescope Array (CTA), is in a state of advanced planning by a world-wide consortium of about 1200 scientists in 28 countries on 6 continents. Four institutions in South Africa and 2 institutions in Namibia are involved in both of these gamma-ray astronomy projects, with North-West University (Potchefstroom, South Africa) constituting the lartest H.E.S.S. and CTA member group in Africa. Namibia (along with Chile) has been proposed as the host country for the southern CTA, with site negotiations currently on-going. This talk will briefly summarize the capabilities of and science conductyed with H.E.S.S. and the South African involvement in both H.E.S.S. and CTA, as well as the scientific prospects for the future CTA.

Author(s): Markus Bottcher[1]
Institution(s): *1. North-West University*

127 – Molecular Clouds, HII Regions, Interstellar Medium II

127.01 – Measuring the Mass-to-Flux Ratio in Molecular Clouds via Zeeman Observations

The details of the star formation process are not yet well understood, despite many theoretical and observational studies. One question that remains is the role played by magnetic fields. If the fields are strong enough, and strict coupling between the gas and the field is maintained, they can delay, or even prevent, the gravitational collapse of a cloud and subsequent star formation. One way to determine the effect of magnetic fields is to determine the mass-to-flux ratio, the ratio between the gravitational and magnetic energies, within the clouds. Although much work has been done to characterize the cores of molecular clouds, very little is currently known about magnetic fields outside the cores where most of the molecular gas resides. We have conducted the first systematic observational survey aimed at determining this ratio in molecular clouds as a whole. We use the Arecibo telescope to determine mass-to-flux ratios via the Zeeman effect in 18 cm OH absorption lines toward extragalactic continuum sources distributed at random through the sky. We present the results of this survey and what implications they may have upon the current theories of star formation. TT acknowledges support from NSF grant AST 0908841.

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127.02 – Observations of Turbulence Dissipating in Low Velocity Shocks in the Perseus B1-E5 Starless Core

Molecular clouds contain significant supersonic turbulence that is expected to decay rapidly. I present observations of the CO J = 6-5 line obtained with the Herschel Space Observatory towards the Perseus B1-E5 starless core. Photodissociation region models fit to lower J CO lines all underpredict the observed 6-5 intensity, thereby indicating the presence of a second warm gas component in the core, consistent with models of turbulence dissipating in low velocity shocks. With the aid of low velocity shock models, parameters such as the turbulent energy dissipation rate, the turbulent dissipation timescale, and the shock heated gas volume filling factor are derived.

Author(s): Andy Pon[1], Doug Johnstone[2], Michael J. Kaufman[3], Paola Caselli[1], Rene Plume[4]
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127.03D – Line Ratio Diagnostics Along the Disc of Two Edge-on Lenticular Galaxies, NGC 4710 and NGC 5866

We present interferometric observations of a multitude of CO lines and dense gas tracers in two nearby edge-on lenticular galaxies, NGC~4710 and NGC~5866. 12CO(1-0), 12CO(2-1), 13CO(1-0), 13CO(2-1), HCN(1-0), HCO+(1-0), HNC(1-0) ad HNCO(4-3) were detected in both galaxies. The detections of HNC(1-0) and HNCO(4-3) are presenting here for the first time in these early-types. Our observations reveal that the CO gas is much more extended compared with the dense gas tracers which are generally centrally concentrated except HCN(1-0) which was also detected in the outskirts of NGC~5866. The unique X-shape (two-component velocity distributions indicating nuclear disc and inner ring) position-velocity diagram (PVD) of these barred edge-on galaxies allows us to study integrated line intensity ratios as a function projected radius along the velocity components. We study the gas physical conditions of two-component molecular ISM, i.e. one traced by CO and one traced by HCN, HCO+, HNC and HNCO, in each velocity component separately seen on the PVD by performing line ratio diagnostics in three complementary ways. In the nuclear disc, the CO gas is gravitationally unstable, optically thinner, hotter and dense gas fraction is higher, while in the inner ring the gas is more settled, optically thick, colder and the dense gas fraction is lower. We also compare the line ratios to that obtained in the nucleus of other lenticular, spiral, seyfert, starburst and peculiar galaxies as well as that obtained in the GMCs of some other spirals/starbursts. We found that the gas in the nuclear discs of NGC~4710 and NGC~5866 has line ratios similar to that in the center of starburst galaxies while the gas in the inner rings show some differences. We finally perform non-LTE radiative transfer code to the two-component ISM using a multitude of tracers. The model results, which are agree with the empirical results, indicate that there is a factor of 2 difference in the density of the gas traced by CO and the one traced by high density tracers in the nuclear disc but average kinetic temperature is similar, while the gas in the inner ring is relatively colder and less dense compared with the gas in the nuclear disc.

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127.04 – The Envelope of the Molecular Cloud L1599B

We have carried out observations of ionized carbon ([CII] 158 micron fine structure line) with GREAT on SOFIA and CO J = 2-1, and CI 1-0 from APEX, and used these together with existing HI and other data on the filamentary dark cloud L1599B. This cloud is unusual in that a deficiency in HI emission was previously found to coincide with the molecular cloud defined by CO. We use the detections of CII to probe the envelope of the molecular cloud and to evaluate the possible role of accretion of atomic gas onto the molecular cloud. We have clear detections of [CII] and find that the [CII] emission is stronger than that found at the boundary of the Taurus molecular cloud suggestive of a higher value of the interstellar radiation field. The availability of ionized and neutral carbon, together with multiple CO transitions allows detailed modeling of the cloud envelope and the CO dark molecular gas.

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Institution(s): *1. JPL*

127.05 – New perspective on the Fan Region: Polarized synchrotron emission tracing Galactic structure beyond the Perseus Arm

The Fan Region is one of the dominant features of the polarized radio continuum sky, long thought to be a local (d < 500 pc) synchrotron emission feature. We present 1.5 GHz polarized radio continuum observations from the Global Magnetoionic Medium Survey (GMIMS) obtained with the John A. Galt Telescope of the Dominion Radio Astrophysical Observatory. By comparing the resulting maps of the Fan Region to spectroscopically-resolved Halpha emission from the Wisconsin H-Alpha Mapper Northern Sky Survey, we find that the 1.5 GHz polarized radio emission is anti-correlated with Halpha emission from the Perseus Arm, 2 kpc away. This strongly suggests that ionized gas in the Perseus Arm depolarizes the Fan Region emission, reducing the observed brightness temperature from ≈0.45 K to ≈0.3 K. This indicates that some of the Fan Region emission originates in or beyond the Perseus Arm. The synchrotron emission must be produced along a large path length, suggesting the presence of a coherent magnetic field in the plane in the outer Galaxy. We argue that the polarized emission from the Fan Region is a consequence of the structure of the Galactic magnetic field and ISM. A depolarization model reproduces many of the observed features, including a much lower observed rotation measure measured from the emission than measured towards background point sources in the same direction.

Author(s): Alex S. Hill[3], T. L. Landecker[2], E Carretti[1], Kevin A. Douglas[5], Xiaohui Sun[7], Bryan M. Gaensler[7], Sui Ann Mao[4], Naomi M. McClure-Griffiths[1], Maik Wolleben[2], Marijke Haverkorn[6], Dominic Schnitzeler[4]
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127.06 – Collision of the Smith Cloud and its dark matter halo with the magnetized Galactic disk

The Smith Cloud is a massive High Velocity Cloud (HVC) that may have passed through the Milky Way disk in the recent past. Previous studies using hydrodynamic simulations suggest that a dark matter halo may have provided the confinement neccessary for the Smith Cloud to survive passage through the Galactic corona and disk. However, the models of the Galaxy that were used in these studies did not include a magnetic field, while magnetic fields are known to have confining properties. Other studies have shown that the Galactic magnetic field can inhibit mass exchange between the corona and the disk due to magnetic field compression. We extend upon these studies via FLASH magnetohydrodynamic simulations to consider the effects of a Galactic magnetic field on an infalling, dark matter confined HVC.

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127.07 – Resolving Molecular Clouds in the Nearby Galaxy NGC 300

We present results from our ongoing Submillimeter Array (SMA) survey in which we resolve Giant Molecular Clouds (GMCs) for the first time in the nearby (D = 1.9 Mpc) spiral galaxy NGC 300. We have conducted CO(2-1) and 1.3 mm dust continuum observations of several massive star-forming regions in NGC 300, following up on the Atacama Pathfinder Experiment (APEX) survey of Faesi et al. (2014). We find that the unresolved CO sources detected with APEX at ~250 pc resolution typically resolve into one dominant GMC in our SMA observations, which have a resolution of ~3.5” (30 pc). The majority of sources are significantly detected in CO, but only one exhibits dust continuum emission. Comparing with archival H-alpha, GALEX far-ultraviolet, and Spitzer 24 micron images, we note physical offsets between the young star clusters, warm dust, and ionized and molecular gas components in these regions. We recover a widely varying fraction -- between 30% and almost 100% -- of the full APEX single dish flux with our interferometric observations. This implies that the fraction of CO-emitting molecular gas that is in a diffuse state (i.e. with characteristic spatial scales > 100 pc) differs greatly amongst star forming regions in NGC 300. We investigate potential trends in the implied diffuse molecular gas fraction with GMC properties and star formation activity. We compute virial masses and analyze the velocity structure of these resolved extragalactic GMCs and compare to results from surveys of the Milky Way and other nearby galaxies.

Author(s): Christopher Faesi[1], Charles J. Lada[2], Jan Forbrich[3]
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128 – Star Formation II

128.01 – The Relationship Between Gas and Star Formation in the Magellanic Clouds

The low-mass, low-metallicity Magellanic Clouds provide ideal laboratories to study the physics of star formation at high resolution. We map the molecular gas distribution in the Large and Small Magellanic Clouds (LMC and SMC, respectively) by using the dust emission from HERITAGE Herschel data, which avoids the known biases of CO. Given the high resolution of the data (r~20"~5 pc for the LMC HERITAGE maps), we show the effect of convolving to resolutions up to r~1 kpc and how the resolution differences compare to other studies of nearby galaxies. We find that the relationship between the molecular gas and star formation rate is consistent with studies of higher mass disk galaxies (i.e., Bigiel et al. 2011, Leroy et al. 2013), although the average molecular gas depletion time in the Magellanic Clouds may be shorter (~0.5 Gyr) than more massive, higher metallicity galaxies (typically ~2 Gyr). In the SMC, we find warm molecular gas fractions of ~10% using S^4MC Spitzer IRS data of the rotational H^2 lines, which is also consistent with higher mass, higher metallicity galaxies. Finally, we compare the total gas (atomic and molecular) and the star formation rate in the Magellanic Clouds to the model predictions from Krumholz (2013) and Ostriker, McKee, & Leroy (2010) and find that both models are consistent with the data.

Author(s): Katherine Jameson[3], Alberto D. Bolatto[3], Adam K. Leroy[1], Margaret Meixner[2], Julia Roman-Duval[2], Karl D. Gordon[2]
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Contributing team(s): HERITAGE Collaboration

128.02D – A Multi-Wavelength Survey of Intermediate-Mass Star-Forming Regions

Current research into Galactic star formation has focused on either massive star-forming regions or nearby low-mass regions. We present results from a survey of Galactic intermediate-mass star-forming regions (IM SFRs). These regions were selected from IRAS colors that specify cool dust and large PAH contribution, suggesting that they produce stars up to but not exceeding about 8 solar masses. Using WISE data we have classified 984 candidate IM SFRs as star-like objects, galaxies, filamentary structures, or blobs/shells based on their mid-infrared morphologies. Focusing on the blobs/shells, we combined follow-up observations of deep near-infrared (NIR) imaging with optical and NIR spectroscopy to study the stellar content, confirming the intermediate-mass nature of these regions. We also gathered CO data from OSO and APEX to study the molecular content and dynamics of these regions. We compare these results to those of high-mass star formation in order to better understand their role in the star-formation paradigm.

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128.03 – Identification of Young Stars and Sub-Clusters in Rich Cluster Environments

A significant fraction of stars in our Galaxy form in large clusters with thousands of members. I will present our program to combine ground-based near-infrared observations with mid-infrared observations from Spitzer and WISE to identify young stelar objects that belong to some of the richest clusters in the Galaxy. We use these populations to examine how the degree and size scale of sub-clusterting of young stellar object populations varies in different star-forming environments.

Author(s): Sarah Willis[1], Joseph L. Hora[1], Gozde Saral[1]
Institution(s): *1. Harvard-Smithsonian CfA*

128.04 – Do filaments cross core "boundaries"?

Thanks to extensive observations of the Perseus star-forming region, and the Barnard 5 (B5) star-forming core within it, we can study filamentary structure at scales from tens of pc down to to hundredths of pc using a wide variety of gas and dust tracers. Recently, in compositing Herschel dust emission maps of Perseus with GBT and JVLA maps of ammonia in B5, we noticed that the large scale (>1 pc) filaments that lead to the B5 core appear to continue across the "coherent core" boundary, right down into the sub 0.1 pc scales traced by ammonia. We find this result very surprising, since it suggests that the "core" is not as distinct from its filamentary surroundings as we--and current conventional wisdom--would have predicted. Numerical simulations on 1-10 pc scales typically create "sink" particles on scales small enough to correspond to our JVLA measurements. The new B5 results presented here should inspire new simulations which offer enough dynamic range to trace the morphology of self-gravitating, non-isothermal turbulence continuously from 10 to 0.01 pc scales, in order to see how, why, and how long filamentary structure is maintained across these scales.

Author(s): Alyssa A. Goodman[2], Hope Chen[2], Jaime E. Pineda[1], Stella Offner[3]
Institution(s): *1. ETH Zurich, 2. Harvard-Smithsonian, CfA, 3. UMass Amherst*

128.05D – The ALFALFA Hα Survey

The ALFALFA Hα survey uses a volume-limited sample of HI-selected galaxies from the ALFALFA survey to study star formation in the local universe. ALFALFA detects galaxies with HI masses smaller than 10^8 $M^{\odot}$ in our survey volume, probing well into the flat portion of the HI mass function. By selecting galaxies via their HI emission, we have included essentially every galaxy capable of making stars in our survey volume. We have obtained senstitive narrow-band Hα images for more than 1500 galaxies. The ALFALFA Hα survey's large, complete sample of galaxies gives us robust statistics and allows us to cover a wide range of galaxian environments. A main goal of this survey is to produce the best possible measurement of the local star-formation rate density. We present an overview of the entire survey and results based on the Fall sample. We also highlight additional applications of this legacy data set for the study of galaxies in the nearby universe.

Author(s): Angela Van Sistine[1]
Institution(s): *1. Indiana University*

128.06 – A Complete Census of Dense Cores in Chamaeleon I: Results from an ALMA Cycle 1 Survey

Stars form from the gravitational collapse of dense molecular cloud cores, yet many details relating to the onset of collapse and fragmentation into multiple systems remain unknown. I will present the results of an ALMA cycle 1 survey of all known dense cores (starless and protostellar) in the Chamaeleon I molecular cloud complex (d~170pc). The goals of this survey are to provide a complete census of protostars, including those too young, too low in luminosity, and/or too deeply embedded to detect in previous infrared and (sub)millimeter surveys, and to characterize when and how dense cores fragment into multiple systems. With these results we will report new detections of protostellar multiplicity and provide updated constraints on the fraction of starless cores that are truly starless, the lifetime of the first hydrostatic core phase, and the relative durations of the starless and protostellar core populations. We will also report a lack of detections among the starless cores and discuss implications of these results.

Author(s): Michael Dunham[2], Scott Schnee[6], Jaime E. Pineda[1], Stella Offner[9], Daniel Price[5], Hector G. Arce[10], James Di Francesco[3], Doug I. Johnstone[3], Tyler L. Bourke[8], John J. Tobin[4], Xuepeng Chen[7]
Institution(s): *1. ETH, 2. Harvard-Smithsonian Center for Astrophysics, 3. HIA, 4. Leiden University, 5. Monash University, 6. NRAO, 7. PMO, 8. SKA, 9. UMass, 10. Yale*

128.07 – Detailed Magnetic Field Morphology of the Vela C Molecular Cloud from the BLASTPol 2012 flight

In order to understand the role of magnetic fields in the process of star formation, we require detailed observations of field morphology on scales ranging from clouds to cores. However, ground based millimetre/submillimetre polarimetry is usually limited to small maps of relatively dense regions. BLASTPol, the Balloon-borne Large Aperture Sub-mm Telescope for Polarimetry, maps linear polarization at 250, 350 and 500 microns with arcminute resolution. Its high sensitivity and resolving power allow BLASTPol to bridge the gap in spatial scales between the polarization capabilities of Planck and ALMA.

I will present early results from the second flight of BLASTPol, focusing on our observations of the Vela C molecular cloud, an early stage intermediate mass star forming region (d~700 pc). With thousands of independent measurements of magnetic field direction, this is the most detailed sub-mm polarization map of a GMC to date. The field we observe in this elongated cloud exhibits a coherent, large-scale ~ 90 degree bend between its high latitude and low latitude edges. I will discuss what we can learn about star formation in Vela C from the combination of BLASTPol polarization maps and velocity information from molecular line observations, and what the variation of polarization strength across the cloud can tell us about dust grain alignment in GMCs.

Author(s): Laura Marion Fissel[9], Peter Ade[3], Francesco E Angilè[13], Peter Ashton[9], Steven J Benton[14], Mark J. Devlin[13], Bradley Dober[13], Yasuo Fukui[6], Nicholas B Galitzki[13], Natalie Gandilo[14], Jeff Klein[13], Andrei Korotkov[1], Zhi-Yun Li[15], Lorenzo Moncelsi[2], Tristan Matthews[9], fumitaka nakamura[8], Calvin Barth Netterfield[14], Giles Novak[9], Enzo Pascale[3], Frédérick Poidevin[5], Giorgio Savini[10], Fábio Pereira Santos[9], Douglas Scott[11], Jamil Shariff[14], Juan Diego Soler[4], Nicholas Thomas[7], carole tucker[3], Gregory S. Tucker[1], Derek Ward-Thompson[12]
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129 – Dwarf and Irregular Galaxies I

129.01 – Interpreting Resolved Stellar Populations in Local Group Dwarfs

Isolated field dwarfs in the Local Group of galaxies are ideal places to test the physics of star formation and the role of stellar/supernova feedback. Recent advances in the modeling of dwarfs have allowed simulators to explain a number of long-standing puzzles related to dwarf galaxy observations (like the existence of bulgeless disks and dark matter cores). We present results from high resolution, fully cosmological simulations of isolated dwarf galaxies that successfully match observational trends, and use them to explain a number of puzzles presented by dwarf galaxy observations. We show that the same processes that act to create dark matter cores also expand the stellar orbits. The redistribution of stars allows us to match the observed dwarf galaxy gradients. In particular, we show that dwarf galaxies form from the inside out, despite appearing to form from the outside in.

Author(s): Alyson Brooks[1], Maureen Teyssier[1]

Institution(s): *1. Rutgers University*

129.02D – Exploring Dwarf Galaxy Evolution through Metallicity Distributions

As the most numerous type of galaxy, dwarf galaxies are ideal for examining galactic evolution on small scales. Additional clues to galactic evolution come from the metallicity distribution function (MDF), which is influenced by the star formation, accretion, outflows and galaxy interactions. We derived stellar MDFs for the Leo I, Leo II, IC 1613, and Phoenix dwarf galaxies using HST images in order to examine how their evolution compares as a function of various galaxy properties. These galaxies span a range of different morphologies, masses, SFHs and distances from the MW. We fit a simple evolution model and an accretion model to the MDFs in order to quantify the effect of gas flows and enrichment within the galaxies. The MDFs of Leo II (dSph), Phoenix (dTrans) and IC 1613 (dIr) have similar shapes, though their peak metallicities differ. Additionally, we find the accretion model, over the simple model, is a better fit chemical evolution model for these three galaxies. However these best fit accretion models do not require a significant amount of additional gas to explain the MDF shapes. In contrast the chemical evolution model that best fits the narrow MDF of Leo I implies twice the additional gas accretion. The similarities in the MDF shapes of Leo II, Phoenix and IC 1613, even though these galaxies all have different morphologies, implies that the current morphology is not the driving factor in shaping the MDF of these galaxies.

Author(s): Teresa Ross[1]
Institution(s): *1. New Mexico State University*

129.03 – Uncovering Blue Diffuse Dwarf Galaxies

Extremely metal-poor galaxies (XMPs) and the star-formation within their chemically pristine environments are fundamental to our understanding of the galaxy formation process at early times. However, traditional emission-line surveys detect only the brightest metal-poor galaxies where star-formation occurs in compact, starbursting environments, and thereby give us only a partial view of the dwarf galaxy population. To avoid such biases, we have developed a new search algorithm based on the morphological, rather then spectral, properties of XMPs and have applied to the Sloan Digital Sky Survey database of images. Using this novel approach, we have discovered ~100 previously undetected, faint blue galaxies, each with isolated HII regions embedded in a diffuse continuum. In this talk I will present the first results from follow-up optical spectroscopy of this sample, which reveals these blue diffuse dwarfs (BDDs) to be young, very metal-poor and actively forming stars despite their intrinsically low luminosities. I will present evidence showing that BDDs appear to bridge the gap between quiescent dwarf irregular (dIrr) galaxies and blue compact galaxies (BCDs) and as such offer an ideal opportunity to assess how star-formation occurs in more `normal' metal-poor systems.

Author(s): Bethan James[1], Sergey Koposov[1], Daniel Stark[2], Vasily Belokurov[1], Max Pettini[1], Edward W. Olszewski[2]
Institution(s): *1. Institute of Astronomy, 2. University of Arizona*

129.04 – Two Local Dwarf Galaxies Discovered in HI

We report the discovery of two dwarf galaxies from a blind 21 cm HI search. The galaxies were identified via optical imaging and spectroscopy of a set of HI clumps identified in the GALFA-HI survey. They have properties consistent with being in the Local Volume (<10Mpc), and one has stars well-resolved enough that it may be on the outer edge of the Local Group (~1 Mpc from M31). While the distance uncertainly makes application and interpretation ambiguous, they are likely some of the faintest starforming galaxies known. They hence may be the "tip of the iceberg", representing a large population of faint dwarfs comparable to the satellites of the Local Group.

Author(s): Erik Jon Tollerud[1]
Institution(s): *1. Yale University*

129.05 – Are dwarf galaxies killed by reionization?

The ΛCDM cosmological model has been very successful at predicting the large-scale structure of the Universe. However, for dwarf galaxies, simulations have failed to reproduce the number and structure of satellite and isolated dwarf galaxies. The inclusion of baryons in simulations has been found to alleviate the small-scale issues within ΛCDM, such as the core-cusp, missing satellites, and too-big-to-fail problems. To address these concerns, we analyzed state-of-the-art, high-resolution hydrodynamical simulations of galaxy formation created using the ART code. These simulations model relevant physical processes of star formation and stellar feedback including stellar winds, supernovae feedback, and radiation pressure. We examined 1,000 galaxies from the VELA suite of simulations and find steep velocity functions for satellite galaxies and a large spread in the stellar halo mass relation for a given virial mass or maximum circular velocity. The star formation histories of these galaxies agree with recent observations in that they have an initial burst and then are roughly constant. Reionization does not completely suppress star formation in the majority of these galaxies and only acts to decrease the star formation rate. 73% of galaxies with virial masses greater than 10^8 $M^{\odot}$ are luminous, which contributes to a larger abundance of these low mass objects than are observed. Analysis of these kinds of simulations can shed light on the role of baryons in the overabundance and structure problems.

Author(s): Kenza S. Arraki[1], Anatoly A. Klypin[1], Sebastian Trujillo-Gomez[4], Daniel Ceverino[2], Joel R. Primack[3]
Institution(s): *1. New Mexico State University, 2. Universidad Autonoma de Madrid, 3. University of California, Santa Cruz, 4. University of Zurich*

129.06D – Satellite Quenching and the Lifecycle of Dwarf Galaxies.

In the past ten years the known population of Local Group dwarf galaxies has expanded substantially, both to greater distances from the Milky Way and to lower dwarf masses. This growing sample allows us to study the dwarf system as a population, and ask if we can see in aggregate the signs of processes that would otherwise be difficult to trace in dwarfs individually. Following this strategy I will discuss how the quenching of dwarf galaxies can be modeled and understood at the population-level, and how we use that to constrain how possible quenching mechanisms must work if they are to reproduce the Local Group system that we see. I show that the distribution of quenched satellites can be reproduced by environmental quenching if and only if a single pericenter passage is sufficient to end star formation in low mass dwarfs. I also show that there is a significant transition in the effectiveness of quenching between low mass dwarfs and dwarfs at Magellanic cloud-like masses, with the higher mass dwarfs much more resilient to quenching. I present both ram pressure and delay time models to try to understand the origin of this transition.

Author(s): Colin Slater[1], Eric F. Bell[1]
Institution(s): *1. University of Michigan*

129.07 – First Spectacular Panoramic UV Images of the Magellanic Clouds from GALEX

We present the first complete, panoramic ultraviolet maps of the Large and Small Magellanic Clouds obtained from by the Galaxy Evolution Explorer (GALEX) near the end of its mission. These are the deepest and highest quality UV images yet obtained for the Clouds. We present first scientific results including measurements of total and local star formation rates across the Clouds and their outskirts, and a detailed view of specific star-forming regions and the interplay of gas, dust and young stars. We also discuss the novel techniques used to build these maps — a challenge for the standard GALEX — pipeline with observations that routinely far exceeded the GALEX bright source limits. These images provide a powerful legacy data set for the GALEX mission. This work was supported by NASA ADAP grant NNX14AF81G.

Author(s): David Schiminovich[2], Mark Seibert[1]
Institution(s): *1. Carnegie Observatories, 2. Columbia University*
Contributing team(s): GALEX Science Team

130 – Low-Mass Stars and Brown Dwarfs

130.01 – Reliable Radii for M Dwarf Stars

Precise and accurate parameters for late-type (late K and M) dwarf stars are critical for characterizing their planets. A deluge of planets discovered by Kepler has driven the need for even more precise stellar radii. We present our efforts to better constrain the luminosity-radius and Teff-radius relations for late-type (K5-M6) stars, taking advantage of improved techniques to calculate bolometric fluxes and [Fe/H] for M dwarfs. We determine effective temperatures for these stars by comparing observed spectra to atmospheric models, and confirm the accuracy of these temperatures using stars with temperatures determined from long-baseline optical interferometry. Using the Stefan-Boltzmann law we can empirically determine radii for these stars to better than 5%. We find the Teff-radius relation depends strongly on [Fe/H], which was missed in earlier studies that used smaller samples or less precise methods. We expect our empirical relations to be increasingly useful with the arrival of Gaia parallaxes in the near future.

Author(s): Andrew Mann[2], Gregory A. Feiden[3], Eric Gaidos[1]
Institution(s): *1. University of Hawaii, 2. University of Texas at Austin, 3. Uppsala University*

130.02 – Surface gravity analysis of the NIRSPEC Brown Dwarf Spectroscopic Survey

We present an analysis of J band spectra for over two hundred M, L, and T dwarfs obtained from the Brown Dwarf Spectroscopic Survey (BDSS) using NIRSPEC on the Keck II Telescope. This R~2000 sample includes spectra presented in McLean et al. (2003), as well as many new, unpublished spectra observed for the BDSS, more than doubling the size of the original survey. We determine surface gravity-sensitive spectral indices from the literature, which probe K I and FeH absorption, and we estimate uncertainties using a Monte Carlo iterative method. With these indices we characterize surface gravities of our targets in order to disentangle temperature and age of brown dwarfs and low mass stars of various masses.

Author(s): Emily Martin[2], Ian S. McLean[2], Gregory N. Mace[3], Sarah E. Logsdon[2], Emily L. Rice[1]
Institution(s): *1. College of Staten Island, CUNY, 2. UCLA, 3. UT Austin*

130.03 – Atmospheric Characterization of T-Dwarfs via Bayesian Retrieval Methods

Infrared spectra of brown dwarfs have the potential to tell us about their temperature structures and molecular abundances. With such information we can explore the atmospheric chemistry and dynamics within the brown dwarf atmospheres. The standard approach to interpreting brown dwarf spectra has been through the use of self-consistent grid models that attempt to fit basic stellar parameters such as the effective temperature and surface gravity and occasionally eddy diffusivity. Line et al. 2014 presented a novel inverse approach based upon earth and solar system atmosphere remote sensing techniques to determine the detailed temperature profile and molecular gas abundances in brown dwarf atmospheres without the need for grid models. Such approaches make few assumptions about the nature of the molecular compositions and temperature structure, thus obtaining an unbiased estimate of the objects atmospheric properties. In this investigation we improve upon and expand the work of Line et al. 2014 by first by implementing a Markov Chain Monte Carlo estimator and second applying our analysis to ~10 cloud-free late T-dwarf SPEX spectra. From the analysis of many objects we aim to understand the dispersion of atmospheric properties such as their effective temperature, gravity, radii, water abundances, methane abundances, temperature structures, C/O ratios and other properties within a given spectral class. Furthermore we can identify how various spectral indices such as the J-K or H-K etc., colors correlate with the various aforementioned atmospheric properties. Such investigations allow us to better understand the physics and chemistry operating in brown dwarf atmospheres in an unbiased way.

Author(s): Michael R. Line[2], Mark Marley[1], Jonathan J. Fortney[2]
Institution(s): *1. NASA-Ames, 2. University of California-Santa Cruz*

130.04D – Constraining the Properties of the Dust Haze in the Atmospheres of Young Brown Dwarfs

Brown dwarfs and exoplanets are thought to share physical properties such as radii similar to Jupiter, cool temperatures, and clouds in their atmospheres. Warm, young brown dwarfs (~ 2000 K, < 100 Myr) look spectroscopically similar to massive exoplanets and their cloud properties are likely to be similar to those of young gas giant planets. A better understanding of the role of clouds in brown dwarfs will inform our understanding of the clouds inferred to exist in directly imaged planets.
One feature young brown dwarfs and massive exoplanets share is very red near infrared spectral energy distributions. We hypothesize that a dust haze of small grains (< 1 micron), in addition to the clouds made of larger grains, is causing this observed reddening in young brown dwarfs. Current atmosphere models include clouds composed of ~ 1 micron sized grains with power law or log-normal particle size distributions and do not reproduce the observed reddening. In order to explain the observed reddening with the proposed dust haze, we used the Mie theory with forsterite as scattering grains with Hansen particle size distributions. We used MCMC methods to constrain the mean effective radius, effective variance, and column density of the dust haze. We found that realistic populations of small particles (~ 0.3 micron) can explain the reddening observed in young brown dwarfs.

Author(s): Kay Hiranaka[2], Kelle L. Cruz[2], Mark S. Marley[3], Stephanie Douglas[1]
Institution(s): *1. Columbia University, 2. Hunter College, 3. NASA Ames Research Center*
Contributing team(s): BDNYC

130.05 – Clouds in the Coldest Brown Dwarfs

The NASA WISE satellite has been extremely effective at discovering and characterizing the coldest brown dwarfs. Among the objects in the "300 K or below club" are our best analogs to Jupiter (~125 K). Since 2011 our team has been using the Magellan FourStar infrared imager to measure parallaxes of a subset of the current collection of Y dwarfs. We have also used the VLT ISAAC infrared imager to record J, H and/or K band magnitudes. In this contribution, we will report new parallax and photometric measurements for a subset of the population and examine atmospheric implications from model comparisons of color magnitude diagrams. While warmer T dwarfs are often regarded as cloudless, we find that clouds return as temperatures cool and sulfide clouds help explain the diversity in absolute magnitudes of Y dwarfs. In the case of the coldest brown dwarf known (W0855; Luhman 2014) there are indications that water and sulfide ice clouds are present in the atmosphere.

Author(s): Jacqueline K. Faherty[2], Christopher G. Tinney[4], J. Davy Kirkpatrick[1], Andrew Skemer[3]
Institution(s): *1. Caltech, 2. Carnegie Institution of Washington, 3. University of Arizona, 4. UNSW*

130.06 – Watching the Weather in Real Time: Spitzer Light Curves of Variable L/T Transition Brown Dwarfs

Recent observations of cool brown dwarfs in the time-domain have revealed large-amplitude variability at near-infrared wavelengths for a subset of objects spanning the transition between cloudy L-dwarf and clear T-dwarf spectral types.

This quasi-periodic variability is indicative of patchy clouds and evolving weather patterns. Follow-up observations of 5 highly variable L/T transition brown dwarfs with Warm Spitzer are reported. Light curves spanning several consecutive rotations were obtained, with our longest observation of the highly variable T1.5 dwarf 2MASS 2139+02, spanning 48 hours. For all but one target, the dominant temporal component of the variability can be associated with rotation. Further changes in light curve shape are observed from rotation to rotation, demonstrating that cloud features evolve on timescales of hours. The amplitude, shape, and evolution timescales of the light curve place constraints on the dynamical regime of the atmosphere, including the nature of the cloud patchiness and whether the atmosphere is dominated by zonal jets or large-scale turbulence. In at least one case, light curves at [3.6] and [4.5] are not strongly correlated, indicating that different cloud and/or thermal structures reside at different atmospheric pressures.

Author(s): Jacqueline Radigan[5], Nicolas B. Cowan[1], Adam P. Showman[2], Daniel Apai[6], Stanimir A. Metchev[9], Mark S. Marley[4], Etienne Artigau[7], Adam J. Burgasser[8], Ray Jayawardhana[10], Bertrand Goldman[3]
Institution(s): *1. Amherst College, 2. LPL, 3. MPIA, 4. NASA Ames, 5. STScI, 6. University of Arizona, 7. University of Montreal, 8. University of San Diego, 9. University of Western Ontario, 10. York University*

130.07 – T Dwarf Variability Amplitudes Are Likely Stronger in the Optical

We have monitored twelve T dwarfs using an f814w filter (0.7-0.95 microns) to place in context the remarkable 10-20% variability exhibited by the nearby T dwarf Luhman 16B in this wavelength regime. The motivation was the poorly known red optical behavior of T dwarfs, which have been monitored almost exclusively at infrared wavelengths, where variability amplitudes greater than 10% have been found to be very rare. We detect highly significant variability in two T dwarfs. The T2.5 dwarf 2MASS 13243559+6358284 shows consistent ~17% variability on two consecutive nights. The T2 dwarf 2MASS J16291840+0335371 exhibits ~10% variability that may evolve from night to night, similarly to Luhman 16B. Both objects were previously known to be variable in the infrared, but with considerably lower amplitudes. We also find evidence for variability in the T6 dwarf J162414.37+002915.6, but since it has lower significance, we conservatively refrain from claiming this object as a variable. We explore and rule out various telluric effects, demonstrating that the variations we detect are astrophysically real. We suggest that high-amplitude photometric variability for T dwarfs is likely more common in the red optical than at longer wavelengths. The two new members of the growing class of high-amplitude variable T dwarfs offer excellent prospects for further study of cloud structures and their evolution.

Author(s): Aren Heinze[1], Stanimir Metchev[2], Kendra Kellogg[2]
Institution(s): *1. State University of NY, Stony Brook, 2. University of Western Ontario*

131 – Infrared Properties of Galaxies

131.01D – Origin and evolution of high-redshift ultraluminous infrared galaxies

Ultraluminous infrared galaxies dominate the total star formation rate density at z>1. However, it remains unclear whether the intense star formation are triggered by galaxy interactions/mergers like their local counterparts or the elevated gas supply in the early universe. We will present our efforts to characterize the optical morphology for >2000 z~1 infrared-luminous galaxies revealed by *Herschel*, and a systematic comparison with their local *IRAS*-selected counterparts. We find that the frequency of galaxy mergers shows a strong increasing trend with the increase of infrared luminosity as well as the deviation from the star-forming galaxy main sequence, suggesting that galaxy interactions remain a critical mechanism to trigger the extreme star formation out to z~1. Nonetheless, the merger fraction of ultraluminous infrared galaxies decreases from more than 90% at z<0.3 to only ~50% at z>1, which implies that other mechanisms such as rapid, smooth gas accretion also play a critical role to trigger high-z intense star formation. However, based on a careful comparison of optical morphologies between local and z~1 ultraluminous galaxies, we find that this difference in the merger fraction can be explained by systematic biases in the datasets at least out to z~1.

Author(s): Chao-Ling Hung[1], David B. Sanders[1], Caitlin Casey[3], Howard Alan Smith[2]
Institution(s): *1. Institute for Astronomy, University of Hawaii, 2. Smithsonian Astrophysical Observatory, 3. University of California at Irvine*

131.02 – Gravitationally Lensed Dusty Star-forming Galaxies Discovered by Herschel: A Unique Tool to Study Galaxy Evolution

Wide-field surveys conducted by the Herschel Space Observatory have discovered an exciting population of dusty star-forming galaxies (DSFGs) at z>2 that are gravitationally lensed by an intervening galaxy or group of galaxies along the line of sight. These systems are extremely useful probes of galaxy evolution because (1) they act as cosmic telescopes that increase the apparent brightness and size of the background source, facilitating follow-up observations; and (2) they provide an independent measurement of the mass of the foreground lens(es).

We present 0.5" continuum imaging at 880um from the Atacama Large Millimeter/submillimeter Array (ALMA) and the Submillimeter Array (SMA) of a sample of 59 candidate lensed DSFGs. With these data, we resolve every Herschel source and are able to pinpoint which objects are strongly lensed, which are weakly lensed, and which are unaffected by lensing. We develop and present a publicly available software tool, uvmcmcfit, that we use to model every object in the ALMA and SMA samples. This modeling process accounts for the effects of gravitational lensing as well as the use of interferometers like the ALMA and SMA to obtain the data. uvmcmcfit can be obtained via github: https://github.com /sbussmann/uvmcmcfit and has extensive documentation at: http://uvmcmcfit.readthedocs.org.
The results of our model fits show a wide range in intrinsic sizes and luminosities of Herschel-selected DSFGs, suggesting that a similarly wide range of physical mechanisms are likely responsible for their prodigious luminosities. We present statistical model predictions for magnification factors as a function of apparent 870um flux density to show that the intrinsic luminosity function of DSFGs must be very steep at the bright end to accomodate the paucity of DSFGs with intrinsic 870um flux densities above 10 mJy.
Finally, we use optical spectroscopy from Gemini-South and the MMT to measure redshifts for the lenses discovered by Herschel, showing that they tend to have lower masses and/or lie at higher redshift than optically-selected lenses. The combination of our spectroscopic data and our lens models allows us to directly constrain the properties of dark matter in galaxies out to z~1.

Author(s): R. Shane Bussmann[2], Dominik A. Riechers[2], Anastasia Fialkov[5], Chris Hayward[1], Francesco De Bernardis[2], Abraham Loeb[3], Ismael Perez-Fournon[4]
Institution(s): *1. Caltech, 2. Cornell University, 3. Harvard University, 4. Instituto Astrophysico de Canarias, 5. International Center for fundamental Physics at Ecole Normale Superieure*
Contributing team(s): HerMES, H-ATLAS

131.03D – Optical and Infrared Morphologies of Local Luminous Infrared Galaxies

Luminous and Ultra-luminous infrared galaxies (LIRGs and ULIRGs) are a mixture of advanced mergers, interacting systems, and single galaxies. In order to better understand the role of galaxy interactions on star formation,luminosity, and other galaxy properties, we have developed a visual morphological classification scheme for galaxies that fully accounts for all possible interactions seen in local LIRGs. We have also refined the methods for automated galaxy classification by carefully selecting the galaxy pixel members using a surface brightness algorithm. Major galaxy interactions are clearly a driving force in the increased infrared luminosity of local galaxies, however, below an infrared luminosity of $10^{11.5}L_\odot$ minor mergers and secular processes dominate. We empirically derive a separation between merging and non-merging galaxies using automatic classification parameters. Furthermore, the M^{20} parameter separates galaxies into different merger stages. Our new deep Spitzer 3.6 and 4.5 µm observations of 202 local LIRGs and ULIRGs reveal large stellar debris fields that extend up to 100 kpc around the galaxies and contain 5 to 15% of the total galaxy flux. We analyzed the mass and structure of extended infrared emission and show that the infrared stellar debris fields around the galaxies build up throughout the merging process.

Author(s): Kirsten L. Larson[1], David B. Sanders[1]
Institution(s): *1. University of Hawaii*
Contributing team(s): GOALS Team

131.04 – The Modes of Star Formation in Luminous and Ultraluminous Infrared Galaxies

In the local universe, Ultraluminous Infrared Galaxies (ULIRGs, $L^{IR}>10^{12}$ L^{sun}) are all interacting and merging systems. To date, studies of ULIRGs at high redshift have found a variety of results due to their varying selection effects and small sample sizes. Some studies have found that mergers still dominate the galaxy morphology while others have found a high fraction of morphologically normal or clumpy star forming disks. Near-infrared imaging is crucial for interpreting galaxy structure at high redshift since it probes the rest frame optical light of a galaxy and thus we can compare directly to studies in the local universe. We explore the evolution of the morphological properties of (U)LIRGs over cosmic time using a large sample of galaxies from Herschel observations of the CANDELS fields (including GOODS, COSMOS, and UDS). In particular, we investigate whether the role of galaxy mergers has changed between z~2 and now using the extensive visual classification catalogs produced by the CANDELS team. The combination of a selection from Herschel, near the peak of IR emission, and rest-frame optical morphologies from CANDELS, provides the ideal comparison to nearby (U)LIRGs. We then study the how role of galaxy mergers and the presence of AGN activity correspond to the galaxy's position in the star formation rate - stellar mass plane. Are galaxies that have specific star for
mation rates elevated above the main sequence more likely to be mergers?

Author(s): Jeyhan S. Kartaltepe[1]
Institution(s): *1. National Optical Astronomy Observatory*
Contributing team(s): CANDELS Team

131.05 – Are Dusty Galaxies Blue? Insights on UV Attenuation from Dust-Selected Galaxies

Galaxies' rest-frame ultraviolet (UV) properties are often used to directly infer the degree to which dust obscuration affects the measurement of star formation rates. While much recent work has focused on calibrating dust attenuation in galaxies selected at rest-frame ultraviolet wavelengths, locally and at high-z, here we investigate attenuation in dusty, star-forming galaxies (DSFGs) selected at far- infrared wavelengths. By combining multiwavelength coverage across 0.15–500 μm in the COSMOS field, in particular making use of Herschel imaging, and a rich dataset on local galaxies, we find a empirical variation in the relationship between rest-frame UV slope (β) and ratio of infrared-to- ultraviolet emission (LIR/LUV≡IRX) as a function of infrared luminosity, or total star formation rate, SFR. Both locally and at high-z, galaxies above SFR ~> 50 M⊙ yr−1 deviate from the nominal IRX–β relation towards bluer colors by a factor proportional to their increasing IR luminosity. We also estimate contamination rates of DSFGs on high-z dropout searches of <<1% at z= 4 − 10, providing independent verification that contamination from very dusty foreground galaxies is low in LBG searches. Overall, our results are consistent with the physical interpretation that DSFGs, e.g. galaxies with > 50 M⊙ yr−1, are dominated at all epochs by short-lived, extreme burst events, producing many young O and B stars that are primarily, yet not entirely, enshrouded in thick dust cocoons. The blue rest-frame UV slopes of DSFGs are inconsistent with the suggestion that most DSFGs at z ~ 2 exhibit steady-state star formation in secular disks.

Author(s): Caitlin Casey[7], Nicholas Scoville[2], David B. Sanders[10], Nicholas Lee[10], Asantha R. Cooray[7], Peter L. Capak[6], Alexander J. Conley[8], Gianfranco De Zotti[5], Duncan Farrah[12], Hai Fu[11], Emeric Le Floc'h[3], Olivier Ilbert[1], Rob Ivison[9], Tsutomu T Takeuchi[4]
Institution(s): *1. Aix Marseille Universite/CNRS, 2. Caltech, 3. CEA-Saclay, 4. Nagoya University, 5. Osservatorio Astronomico di Padova, 6. Spitzer Science Center, 7. UC Irvine, 8. University of Colorado, 9. University of Edinburgh, 10. University of Hawaii, 11. University of Iowa, 12. Virginia Tech*

131.06 – Evolution of Dust Obscured Star Formation

The GOODS- and CANDELS-Herschel projects have taken the deepest FIR imaging in the GOODS-S, -N, COSMOS, and UDS fields. Taking advantage of Herschel measurements of the far-infrared dust emission peak to minimize uncertainties in the bolometric corrections, we are able to explore the evolution of dusty star formation via infrared luminosity functions. In addition, the multiple lines-of-sight of the very deep observations of the CANDELS fields let us average out the cosmic variance. Together with the HST-CANDELS data, we can correlate the far-infrared properties of both typical star-forming and starburst galaxies with other aspects such as unobscured star formation seen in the ultraviolet and optical, dust extinction, galaxy structure, stellar masses, obtained from the CANDELS multi-wavelength data and the high-resolution near-infrared imaging that only HST/WFC3 can provide.

Author(s): Hanae Inami[1], Mark Dickinson[1]
Institution(s): *1. NOAO*
Contributing team(s): Herschel+CANDELS Team

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132 – HAD V: Contributed Talks & Osterbrock Book Prize Talk

AAS Special Session

132.01 – The pre-history of the University of Washington Astronomy Department: 1891-1965

The University of Washington (UW) created its first Professor of Astronomy (within the Mathematics Department) in 1891, only two years after Washington itself became a state. Joseph Taylor bought a Warner & Swasey refractor with a 6-inch John Brashear lens, and installed it in a dome in 1895 when the university moved to a new campus outside of downtown Seattle. The small observatory became only the second building on the present campus, and is listed on the State Register of Historical Buildings. Over succeeding decades, Taylor was followed, amongst others, by Samuel Boothroyd (who after nine years left for Cornell in 1921) and for two years by Herman Zanstra (of "Zanstra method" fame).
In 1928 Theodor Jacobsen joined the faculty after having obtained his Ph.D. at the University of California (Berkeley) and spending two years as a staff member at Lick Observatory. Jacobsen's research over the years focused on the spectra and motions of variable stars, especially of the Cepheid type. In the 1970s Jacobsen published a paper about secular changes in one particular Cepheid variable still using his own data extending as far back as the 1920s. For 42 years until his retirement, Jacobsen taught courses in astronomy (although there never was an astronomy major and only two graduate degrees were ever awarded), navigation, and a variety of mathematical topics.
In the decade following Sputnik and the birth of NASA, UW astronomy ceased to be a one-man effort with the creation of a modern department, founding of a graduate program, and hiring of two new faculty members: George Wallerstein and Paul Hodge came from Berkeley in 1965 and are both still engaged in research 50 years later.

Author(s): Woodruff T. Sullivan[1]
Institution(s): *1. Univ. of Washington*

132.02 – History of the University of Washington Astronomy Department: 1965-1995

The Department of Astronomy of the University of Washington (UW) is celebrating its fiftieth anniversary this year, starting in 1965 when George Wallerstein and Paul Hodge joined Theodor Jacobsen to significantly expand research and initiate a graduate program. Three additional faculty members in astrophysical theory were added before the end of the decade: James Bardeen, Karl-Heinz Böhm and Erika Böhm-Vitense. In addition, plans were started to establish a research telescope in the State of Washington, primarily for training graduate students. The site survey for what eventually became Manastash Ridge Observatory (MRO) started in 1965. The 30-inch telescope at MRO in the eastern Cascades was dedicated in 1972.
Four more faculty with a broad range of expertise were added in the 1970s and the number of graduate students expanded to about 15. Wallerstein was Chair of the department from 1965-1980. Part of his vision for the department was for UW astronomers to have access to a large, well-equipped telescope at a good observing site. He realized that such a goal would have to be accomplished in collaboration with other institutions and he spent years seeking partners. Newly-arrived faculty member Bruce Margon served as Chair from 1981-87 and from 1990-1995. In 1983 the Astrophysical Research Consortium (ARC) was formed with UW as a partner. UW played a major role in the construction of the ARC 3.5-m telescope in New Mexico, which was dedicated in 1994 and continues to function robustly. The department hired several more faculty with a variety of interests, both in multi-wavelength studies and astrophysical theory. An undergraduate astronomy major was added in the mid-1980s.
In the mid-1980s ARC started to think about a sky survey which would encompass both imaging and spectroscopy. This became the original Sloan Digital Sky Survey (SDSS), which took place between 1990 and 1995, again with the UW as a major partner. At this time, UW Astronomy experienced growth in faculty, graduate students, postdoctoral fellows, research scientists and undergraduate majors.

Author(s): Julie H. Lutz[1]
Institution(s): *1. Univ. of Washington*

132.03 – Why Spectroscopy Went South

All but forgotten, the first observatory established for astrophysical research in Chile sits atop Cerro San Cristóbal overlooking downtown Santiago. Now called the Manuel Foster Observatory and cared for by the Pontificia Universidad Católica de Chile, the equipment was originally brought to the country by staff of the Lick Observatory in California at the outset of the 20th century under the auspices of the D. O. Mills Expedition. The present paper explores the initial motivation for the expedition. Partial insight can be gained by situating the establishment of the observatory in the context of the so-called ‘sidereal problem’—mapping the structure of the stellar system. However, the motivation for this expedition can be further elucidated by understanding the possibilities afforded by the instruments of the ‘new astronomy’. Astronomical spectroscopy opened up new observational prospects that turn of the century astronomers simply exploited opportunistically. Understanding the motivation for the observatory will not only be important background for any comprehensive history of the observatory, but also serves to illuminate the exploratory approach characteristic of American astronomers in the early days of astrophysics.

Author(s): Nora Mills Boyd[1]
Institution(s): *1. University of Pittsburgh*

132.04 – Unravelling Starlight: William and Margaret Huggins and the Rise of the New Astronomy

In November 1862, William Huggins (1824-1910), a retired silk merchant and self-taught amateur astronomer, presented a paper on celestial spectroscopy to the Royal Astronomical Society. The event marked a watershed moment in the history of science. Astronomers would never look at-or understand-the denizens of the celestial realm in the same way again. Who was this man? What moved him to adapt the spectroscope, then a staple of chemical and physical laboratories, to new astronomical purposes? More importantly, what prompted others to follow his lead?
This paper goes beyond published accounts of Huggins's work to offer a fresh, three-dimensional picture of his contributions to the development of what came to be called "astrophysics". New evidence gleaned from his unpublished notebooks and correspondence places his pioneering efforts more realistically within the context of the fertile theoretical and methodological flux in late-nineteenth century Britain's astronomical community and sheds new light on the collaborative contributions of his wife, the former Margaret Lindsay Murray.

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133 – Stellar Abundances and Metallicity Effects

133.01 – Ultraviolet Spectroscopy of Metal-Poor Stars: New Detections of Phosphorus, Germanium, Arsenic, Selenium,

Cadmium, Tellurium, Lutetium, Osmium, Iridium, Platinum, Gold, and More!

Ultraviolet spectroscopy with HST/STIS provides a 30% increase in the number of elements that can be detected in metal-poor stars. Although nearly every element from hydrogen through bismuth is probably present in most metal-poor stars, not all elements can be detected. The resonance lines of the dominant species of some elements are only found in the UV in late-type stars. The chemical compositions of these stars reflect the history of stellar nucleosynthesis from the first stars to today. Here, I present a summary of recent work that has expanded the chemical inventory in metal-poor stars using UV spectroscopy conducted using HST/STIS. The highlights include new detections of phosphorus, germanium, arsenic, selenium, cadmium, tellurium, lutetium, osmium, iridium, platinum, and gold in metal-poor stars. These detections reveal new insights into stellar nucleosynthesis in the earliest generations of massive stars, provide new constraints on the r-process, and open new channels for chemically-tagging stars that have assembled to form the Milky Way stellar halo.

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133.02D – Characterizing The Nearest Young Moving Groups Through High Resolution Spectroscopy

We present a detailed method for characterizing the nearest young moving groups via high resolution spectroscopy. This method has three diagnostics which classify a moving group: (1) Chemical Homogeneity, (2) Kinematic Traceback, and (3) Isochrone Fitting. We have applied this technique on 10 F- and G-type stars from the AB Doradus Moving Group (ABD) and found 8 stars share similar metal abundances with an average abundance for ABD of $<[M/H]> = -0.03 \pm 0.06$; of the two outliers, one is metal rich and the other metal poor. Seven stars follow a common traceback and share a common origin around 125 Myr. One of the outlying traceback stars diverges around 90-100 Myr, and is the same star which is metal rich. Eight stars fall along the same isochrone of 100 Myr, which is synonymous with the main sequence. We further evaluated this technique on 5 members of the newly discovered Octans-Near Moving Group (ONMG). Two of these were listed as possible members with the other three being probable members. There is a large spread in the metal abundance with $<[M/H]> = -0.17 \pm 0.1$ and no core group of stars that define the cluster in abundance space. ONMG is also enigmatic because several age indicators (e.g. lithium abundance, surface gravities, activity) indicate a much younger cluster; however, the traceback age shows these stars were closest around 150 Myr (though this age should be taken very lightly) and 4 of the 5 stars fall on the main sequence. We therefore conclude that while these stars do share present day velocities and positions, the group is not well defined in abundance, origin, or age, and should be concidered with caution.

Author(s): Kyle McCarthy[1], Ronald J. Wilhelm[1]
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133.03D – Magnesium isotopes in giants in the Milky Way inner disk and bulge: First results with 3D stellar atmospheres.

The Milky Way bulge is one of the most poorly understood components of our galaxy and its formation history is still a matter of debate (early collapse vs. disk instability). All knowledge of its chemical evolution history has been so far derived by measuring elemental abundances: no isotopic mixtures have been measured so far in the Bulge. While quite challenging, isotopic measurements can be accomplished with present instruments in bulge stars for a few elements, Magnesium being one of them.
Of the three stable Mg isotopes, the most common one, ^{24}Mg, is mainly produced by α capture in SN II, while the other two, ^{25}Mg and ^{26}Mg, can be produced efficiently in massive AGB stars, through the ^{22}Ne(α, n)^{25}Mg(n, γ)^{26}Mg reactions as well as the Mg-Al chain. Moreover, SN II production of ^{25}Mg and ^{26}Mg increases with increasing progenitor metallicity, so in older stellar populations, where only the signature of metal-poor SNe is to be expected, one should not see a significant ^{25}Mg or ^{26}Mg fraction. However, if larger ^{25}Mg/^{24}Mg and ^{26}Mg/^{24}Mg ratios are observed, relative to what is produced in SNe, this is a clear sign of an AGB contribution. *As such, Mg isotopic ratios are a very useful probe of AGB pollution onset and chemical enrichment timescale in a stellar population.*
Here, we present the first ever measurements of Mg isotopes in 7 red giant stars in the Milky Way bulge and inner disk, including two stars in the bulge globular cluster NGC6522. The isotopic abundances have been derived from high resolution, high signal-to-noise VLT-UVES spectra using both standard 1D atmospheric models as well as state-of-the-art 3D hydrodynamical models and spectrosynthesis. The use of 3D atmospheric models impacts the derived ratios and this work represents the first derivation of Mg isotopes using full 3D spectrosynthesis. These results yield new constraints on the proposed formation scenarios of the Milky Way bulge.

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133.04 – Magnetorotational instability in the presence of composition gradients

Recent space asteroseismic results have revealed that red giant cores are rotating far slower than theoretically expected. State-of-the art stellar evolution codes cannot reproduce these results even using extreme values for the parameters of known angular momentum transport mechanisms, suggesting that unknown transport mechanisms are operating. Evolved stars have dynamically significant composition gradients in their cores. Understanding how angular momentum transport proceeds in the presence of such gradients is of crucial importance in understanding the rotational evolution of low-mass, post-main sequence stars with radiative cores. We will report on our investigations into the local, axisymmetric, linear stability of differentially rotating, magnetized, stratified fluids in the presence of composition gradients. This is a generalization of the classical magnetorotational instability, adding not only stratification and composition gradients but also the diffusion of momentum, heat, and magnetic field. Previous work has demonstrated that such instabilities can transport angular momentum in solar-like interiors without composition gradients. We will present a survey of the conditions under which magnetorotational instabilities are present when composition gradients are important, and comment on the applicability of this mechanism to evolved, low-mass stars.

Author(s): Jeffrey S. Oishi[1], Kristen Menou[2]
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133.05 – A Photometric Method for Discovering Extremely Metal Poor Stars

I present a new non-parametric machine-learning method for predicting stellar metallicity ([Fe/H]) based on photometric colors from the Sloan Digital Sky Survey (SDSS). The method is trained using a large sample of ~150k stars with SDSS spectra and atmospheric parameter estimates (Teff, log g, and [Fe/H]) from the SEGUE Stellar Parameters Pipeline (SSPP). For bright stars (g < 18 mag) with 4500 K < Teff < 7000 K and log g > 2, corresponding to the stars for which the SSPP estimates are most reliable, the method is capable of predicting [Fe/H] with a typical scatter of ~0.16 dex. This scatter is smaller than the typical uncertainty associated with [Fe/H] measurements from a low-resolution spectrum. The method is suitable for the discovery of extremely metal poor (EMP) stars ([Fe/H] < -3), as high purity (P > 50%), but low efficiency (E ~ 10%), samples of EMP star candidates can be generated from the sources with the lowest predicted [Fe/H]. To improve the efficiency of EMP star discovery, an alternative machine-learning model is constructed where the number of non-EMP stars is down-sampled in the training set, and a new regression model is fit. This alternate model improves the efficiency of EMP candidate selection by a factor of ~2. To test the efficacy of the model, I have obtained low-resolution spectra of 56 candidate EMP stars. I measure [Fe/H] for these stars using the well calibrated Ca II K line method, and compare our spectroscopic measurements to those from the machine learning model. Once applied to wide-field surveys, such as SDSS, Pan-STARRS, and LSST, the model will identify thousands of previously unknown EMP stars.

Author(s): Adam Miller[1]
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133.06 – The C/M ratio in the disk of M31

The C/M ratio has been used to study AGB stars throughout the Local Group. It has been well established observationally that the C/M ratio increases at low metallicity. Theoretically, this is because metal-poor stars have less oxygen in their atmospheres and thus require fewer dredge-up events before they become carbon-rich. However, when observing a region ~2kpc from the center of M31, Boyer et al. 2013 found many fewer carbon stars than would be expected from extrapolating the observed C/M-metallicity relationships. The reason for this absense of C-stars is not yet clear. We expand on these findings by calculating the C/M ratio across the NE half of M31's disk, using C- and M-stars identified using both moderate-resolution optical spectra, from the SPLASH survey, and six-filter HST photometry, from the PHAT survey.

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Institution(s): *1. NASA Goddard Space Flight Center, 2. University of California Santa Cruz*
Contributing team(s): SPLASH collaboration, PHAT collaboration

133.07 – Is the Globular Cluster Colour-Metallicity Relation Universal?

Visible at much greater distances than resolved stars, globular clusters are important tools for studying galaxy formation and assembly. Studies of extragalactic globular clusters typically use optical colours to derive metallicites. We use Keck DEIMOS spectroscopy and Subaru Suprime-Cam photometry from the SLUGGS Survey to investigate how the globular cluster colour-metallicity relation varies galaxy to galaxy and with globular cluster luminosity. As in previous studies we see variations in the shape of the relationship between (g − i) colour and the strength of the calcium triplet spectral feature. To measure weaker spectral features in the DEIMOS spectra, we stack the spectra by colour and by magnitude. Comparing spectra with the same colours and luminosities but from different galaxies, we see significant differences in the strengths of several spectral features, including the calcium triplet and weak iron lines. We interpret this as strong evidence that the globular cluster colour-metallicity relation varies galaxy-to-galaxy. We suggest differences in globular cluster ages between galaxies and in the abundances of light elements (helium, carbon, nitrogen and oxygen) between galaxies as possible explanations for the observed variations in the colour-metallicity relation.

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Contributing team(s): The SLUGGS Survey Team

134 – Plenary Talk: Back to the Beginning: The Rosetta Mission at Comet 67P/Churyumov-Gerasimenko, Paul R. Weissman (JPL/Caltech)

134.01 – Back to the Beginning: The Rosetta Mission at Comet 67P/Churyumov-Gerasimenko

Cometary nuclei are the most primitive bodies in the solar system and thus retain a cosmo-chemical record of conditions in the solar nebula at the time the planets were forming, 4.5 billion years ago. Previous spacecraft missions to comets have all been fast flybys providing only snapshot views of these icy-conglomerate objects. Rosetta is the first spacecraft to rendezvous with and orbit a cometary nucleus, having arrived on August 6, 2014. Developed by the European Space Agency with participation by NASA, Rosetta carries a suite of 11 instruments to study the nucleus, the cometary coma (the outflowing gas and dust atmosphere) and the solar wind interaction. Rosetta also carries a lander named Philae, developed by the DLR, which will be deployed to the nucleus surface on November 12, 2014 (UT). Philae caries an additional 10 instruments for probing directly into the nucleus surface. Early results from Rosetta have revealed a nucleus that appears to be two multi-kilometer-sized bodies stuck together, and varied topographic features, such as layered circular terrains that may be sublimation pits, and steep ciffs up to 900 meters high. The nucleus also includes numerous boulders on the surface, with some evidence that the nucleus interior may be packed with 1-4 meter diameter boulders and rubble. There is evidence of mass wasting and many areas appear to be covered by a blanket of finer particles, not yet resolved by imaging. The nucleus surface has a low albedo of 4-5% and a spectrum with few absorption features, similar to that of carbonaceous chondrites, the most primitive meteorites. Nucleus temperatures are consistent with the black-body temperatures expected for such a dark object. No evidence of ice has been found on the nucleus surface to date, though the gas coma is predominantly water molecules. Perhaps most interesting is the measured bulk density of the nucleus, 0.43 g/cm^3, which is less than half the density of water ice and implies a nucleus porosity of 75% or more. Additional results from the Rosetta mission will be revealed during this talk. This work was supported by the NASA U.S. Rosetta Project and performed at the Jet Propulsion Laboratory under contract with NASA.

Author(s): Paul R. Weissman[1]
Institution(s): *1. Jet Propulsion Laboratory/Caltech*

135 – Plenary Talk: The Discovery of High Energy Astrophysical Neutrinos: First Light, New Questions, Kara Hoffman (University of Maryland)

135.01 – The Discovery of High Energy Astrophysical Neutrinos: First Light, New Questions

In the summer of 2012, the IceCube Neutrino Observatory announced the observation of two neutrino interactions deep in the south polar icecap, each with energies in excess of 10^{15} eV, making them the highest energy neutrinos ever observed. Further analysis and additional data revealed that these events formed the tail of a spectrum that is inconsistent with the background from neutrinos produced by cosmic ray interactions with the atmosphere. While the measured rates agree with longstanding theoretical predictions of an astrophysical neutrino flux, many questions remain. Where did they come from? Does the spectrum abruptly cut off just above a PeV, or is it steeply falling? I will review this exciting discovery and describe ongoing and future efforts in this quickly evolving field.

Author(s): Kara Hoffman[1]
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137 – The Sun and Solar System in Perspective Posters

137.01 – Predicting Ground Illuminance

Our Sun outputs 3.85 x 10^{26} W of radiation, of which roughly 37% is in the visible band. It is directly responsible for nearly all natural illuminance experienced on Earth's surface, either in the form of direct/refracted sunlight or in reflected light bouncing off the surfaces and/or atmospheres of our Moon and the visible planets. Ground illuminance, defined as the amount of visible light intercepting a unit area of surface (from all incident angles), varies over 7 orders of magnitude from day to night. It is highly dependent on well-modeled factors such as the relative positions of the Sun, Earth, and Moon. It is also dependent on less predictable factors such as local atmospheric conditions and weather.

Several models have been proposed to predict ground illuminance, including Brown (1952) and Shapiro (1982, 1987). The Brown model is a set of empirical data collected from observation points around the world that has been reduced to a smooth fit of illuminance against a single variable, solar altitude. It provides limited applicability to the Moon and for cloudy conditions via multiplicative reduction factors. The Shapiro model is a theoretical model that treats the atmosphere as a three layer system of light reflectance and transmittance. It has different sets of reflectance and transmittance coefficients for various cloud types.

In this paper we compare the models' predictions to ground illuminance data from an observing run at the White Sands missile range (data was obtained from the United Kingdom's Meteorology Office). Continuous illuminance readings were recorded under various cloud conditions, during both daytime and nighttime hours. We find that under clear skies, the Shapiro model tends to better fit the observations during daytime hours with typical discrepancies under 10%. Under cloudy skies, both models tend to poorly predict ground illuminance. However, the Shapiro model, with typical average daytime discrepancies of 25% or less in many cases, performed somewhat better than the Brown model during daytime hours. During nighttime hours under cloudy skies, both models produced erratic results.

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Institution(s): *1. U.S. Naval Observatory*

137.02 – The Pisgah Astronomical Research Institute

The path of the total solar eclipse across the United States on August 21, 2017 crosses the Pisgah Astronomical Research Institute (PARI) located in western North Carolina. The partial eclipse begins at about 17:08 UT, followed by the nearly 2 minute total eclipse which begins at about 18:37 UT. The PARI campus includes radio and optical telescopes, as well as earth science instruments that include a seismometer, geomagnetometer, EarthScope Plate Boundary Observatory, time standards, and several weather stations. The instruments stream data to the PARI website and will be available for the eclipse. In anticipation of the 2017 solar eclipse, we present the instruments and infrastructure of the PARI campus. We invite astronomers to explore the use of the PARI campus as a site for their own instruments and/or the use of instruments already located at PARI.

Author(s): J. Donald Cline[1]
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137.03 – Angular Variation of Solar Feature Contrast in Full-Disk G-Band Images

We investigate the center-to-limb variation (CLV) of the contrasts of four types of solar surface features observed in the G-Band (430.6 nm, FWHM 1.2 nm) by analyzing 12 high quality full-disk images obtained from the Rome Precision Solar Photometric Telescope. The studied features, specifically network, enhanced network, plage, and bright plage, were singled out based on their brightness signatures in mean simultaneous Ca II K images using an intensity threshold technique. We compared our results with those obtained from high-resolution (HR) observations, and with the outputs of the spectral synthesis performed on semi-empirical models and magneto hydrodynamic (MHD) simulations. We find that the measured contrasts are systematically lower than those of HR observational results, as was expected due to the lower resolution of the analyzed observations. We also find that our observations best reflect the CLV derived from the recent one-dimensional atmospheric models described in Fontenla et al 2011 with respect to results obtained from earlier similar models. The measured CLV also agrees with those derived from the syntheses of MHD simulations and HR observations, if spatial resolution effects are properly taken into account. This work was carried out through the National Solar Observatory Summer Research Assistantship (SRA) Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation. This work was also partially supported by the European Union's Seventh Programme for Research, Technological Development and Demonstration under the grant agreements in 312495 (SOLARNET) and 313188 (SOLID).

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137.04 – The relation between umbral magnetic field strength and area density of umbral dots

Interiors of sunspots are modeled either as a monolithic block of magnetic flux or groups of flux bundles. Umbral dots (UDs) – small bright grains inside the dark umbra - are harder to explain in the monolithic model, but they fit into the group of flux bundle model as field-free intrusions that push magnetic field lines aside due to their convective nature. The goal of this project was to determine if there is a relationship between the UD density and the area of the umbra as well as the magnetic field strength of the umbra. Routines were developed in IDL that located the UDs and then would find the respective areas and magnetic field strength of the umbrae. These routines can be applied to both numerical simulations and observational data. Our findings show that there is an indication of correlation between the UD density and the umbral area, but there is no clear indication of a correlation with the UD density and the magnetic field strength. The simulations show a significantly larger UD density than the observations This work is carried out through the National Solar Observatory Summer Research Assistantship (SRA) Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

Author(s): Sierra Ferguson[2], Christian Beck[1]
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137.05 – Comparing High-speed Transition Region Jets in Coronal Holes and Quiet Sun Regions

The complicated energy transfer and plasma motion in the transition region, between the photosphere and the corona, may play a significant role in the formation and acceleration of the solar wind. New observations from the Interface Region Imaging Spectrograph (IRIS) have revealed unprecedented levels of detail in this less-studied region. Coronal holes in particular are a likely source of solar wind material, though the formation and acceleration mechanisms of the fast solar wind are still largely unknown. In our previous work, we have reported the prevalence of small-scale high-speed (~80-250 km/s) jets with transition region temperatures from the network structures of coronal holes. Here we undertake a comparative study of these short-lived episodic network jets in a coronal hole region and a quiet sun region using IRIS sit-and-stare slit-jaw imaging in the 1330 Angstrom (C II) passband. The pointing coordinates, exposure time, observing cadence, and field of view of both observations are all identical. Our preliminary study suggests that the speeds and lengths of the network jets may differ between quiet sun and coronal hole regions. The quiet sun region exhibits many compact bright regions with sizes of 5-10 arcseconds which produce very few jets. The jets that do exist tend to propagate at much slower speeds over smaller distances than their coronal hole counterparts. Comparatively, in the coronal hole, such compact regions are almost absent and all network patches are permeated by the intermittent high-reaching jets. Such a difference suggests that magnetic loops are much smaller in the coronal hole and the network jets are produced at low heights. The recurrence frequency seems to be higher in the coronal hole region, with many of the isolated quiet sun region jets demonstrating curved trajectories.
This work is supported under contract 8100002705 from Lockheed-Martin to SAO and by the NSF-REU solar physics program at SAO, grant number AGS-1263241.

Author(s): Rebecca Tate Arbacher[1], Hui Tian[2], Steven R. Cranmer[2]
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137.06 – Automated Kinematics Analysis of Off-Limb Coronal Bright Fronts Observed with SDO/AIA

Coronal mass ejections (CMEs) are thought to generate shock waves in the low and middle corona, which are seen by the Atmospheric Imaging Assembly (AIA) as associated extreme ultraviolet (EUV) large-scale coronal bright fronts (CBFs). Shocks associated with CMEs are known to accelerate ions to very high energies, creating solar energetic particles (SEPs). However, it is not presently known whether the low-coronal shocks seen as CBFs are efficient in accelerating particles to SEP energies. We investigate a number of CME events over a period from 2010-2014, using an automated algorithm to measure the kinematics of the associated CBFs in AIA data. We focus on off-limb events, since they allow for better determination of the three-dimensional structure of CBFs. Using a new suite of computer programming tools, we are able to automatically compute velocities and accelerations associated with the observed CBFs. The statistical analysis performed in this study will provide a database of promising CBFs for future analysis of shock evolution using data-driven magnetic field and shock acceleration models.

Author(s): Alexander K Kendrick[2], Kamen A. Kozarev[1]
Institution(s): *1. Harvard-Smithsonian Center For Astrophysics, 2. Harvey Mudd College*

137.07 – Modelling Magnetic Reconnection and Nano-flare Heating in the Solar Corona

Current models describing magnetic reconnection in the solar corona assume single reconnection events occurring at random crossings between magnetic flux tubes. However, in the avalanche model of magnetic reconnection, multiple reconnections are expected to occur. The purpose of this research is to first, calculate the point of the greatest stress between magnetic flux tubes and then to allow for dynamic evolution utilising the avalanche model. This represents a significant increase in sophistication over previous models. This undertaking is not purely theoretical since we compare the results of our modelling with HI-C data. Using key inputs from the HIC and AIA observations such as loop length and magnetic field strength, we predict the number of reconnection events likely to take place. As a single reconnection event cannot currently be directly observed, the distribution of flare events are recorded instead. The power law fit yielded as a result of our simulations is within the expected range given the observational evidence of flare distributions and temperature values in the corona. This provides further evidence to support the role of Nano-flares in the heating of the corona.

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Institution(s): *1. Harvard- Smithsonian Center for Astrophysics, 2. The University of Edinburgh*

137.08 – X-ray Flare Associated with a Quiescent Filament Eruption and Coronal Mass Ejection

To date, solar active regions are where most flares are found to occur. We present an analysis of multi-waveband observations of the large eruption of a 'quiescent' (outside of an active region) solar filament contemporaneous with X-ray emission. The eruption covers a 2-day time span, from 2013 September 29 to 2013 September 30. The event was observed using the *Reuven Ramaty High Energy Solar Spectroscopic Imager* (RHESSI), the *Solar Dynamics Observatory* (SDO), and the *Fermi Gamma-ray Space Telescope*. Though not classified as a flare, the GOES class of the event was C1 and the X-ray light curves include a small impulsive-phase peak followed by a gradual-phase rise. The eruption produced a coronal mass ejection (CME) with a velocity of 1179 km/s. SDO Atmospheric Imaging Assembly (AIA) movies during the time span show that the filament lies outside any active region on the sun, and spans a length on the order of 600 arcseconds. Spatially resolved RHESSI emission during the gradual phase is found to come from an area along the post-eruption arcade, close to the westward expanding ribbon but confined to a length of only 150 arcseconds. No RHESSI emission is found along the eastward expanding ribbon. We infer the strength and geometry of the magnetic field during the eruption with the SDO Helioseismic and Magnetic Imager (HMI) and find a small (~ 100 arcseconds long) dipolar element within the filament channel that appears to be spatially correlated with the RHESSI emission. The dipolar element is observed to have magnetic field strengths as high as 1000 Gauss. The evolution of both the X-ray emission and AIA data support the notion that the flare was a consequence of magnetic reconnection between the dipole's magnetic field and the magnetic field supporting the filament. We conclude that solar eruptive events, which consist of both a flare and a CME, can occur outside active regions in association with a quiescent filament eruption if new, sufficiently strong magnetic flux emerges in the immediate area and reconnects with the filament's magnetic field.

Author(s): Adi Foord[1], Gordon D. Holman[1]
Institution(s): *1. NASA GSFC*

137.09 – Analysis of Polar Reversals of Solar Cycle 22 and 23

We study the relationship between polar field reversals and decayed active region magnetic flux. Photospheric active region flux is dispersed by differential rotation and turbulent diffusion, and is transported poleward by meridional flows and diffusion. We investigate in detail the relationship between the transport of decayed active region flux to high latitudes and changes in the polar field strength, including reversals in the magnetic polarity at the poles. By means of stack plots of low- and high-latitude slices of synoptic magnetograms, one to three activity complexes (systems of active regions) were identified in each reversal as the main cause of polar field reversals in each cycle. The poleward transport of large quantities of decayed lagging-polarity flux from these complexes was found to correlate well in time with the polar field changes. In each case significant latitudinal displacements were found between the positive and negative flux centroids of the complexes, consistent with Joy's law bipole tilt with lagging-polarity flux located poleward of leading-polarity flux. This result indicates the importance of the Joy's law tilt and consequent high-latitude polarity bias in polar reversals.
This work is carried out through the National Solar Observatory Summer Research Assistantship (SRA) Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

Author(s): Sophie Ettinger[1]
Institution(s): *1. National Solar Observatory*

137.10 – A Moderate Migration Scenario for Jupiter to form the Terrestrial Planets

The early solar system contained a gas-dominated protoplanetary disk that could cause the migration of the giant planets. This migration can be in the form of a two-stage migration, including an inward and then outward migration. One of the current favored theories, the Grand Tack theory, states that Jupiter migrates in to 1.5 AU, creating a planetesimal disk truncated at 1 AU to then form the terrestrial planets during the subsequent outward migration of Jupiter. There are reasons to believe that such a large movement by Jupiter may be impractical, namely the disk would need to be massive and long-lived. An exploration of migration parameters that involve smaller migration distances and shorter timescales can shed light on whether such extreme displacements are necessary for the formation of the solar system. We examine more moderate migration simulations, where Jupiter starts near the conjectured location of the ice line and migrates a moderate radial distance inward for a variety of distances and times. After the inward migration, Jupiter moves outwards to its final orbital configuration today. We find that the planetesimal disk need not be truncated at 1 AU to form planets with similar characteristics to those in the solar system. We vary the number and mass of planetesimals in the disk to see how this affects the characteristics of the forming terrestrial planets. We find a number of scenarios that provide systems of terrestrial planets similar to those in the solar system. We thus propose an alternative to the Grand Tack theory where Jupiter's migration is less extreme than proposed in the Grand Tack theory.

Author(s): Zoe Todd[1], Steinn Sigurdsson[1]

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137.11 – Direct Wind Measurements in Io’s Atmosphere

Io's atmosphere, which is mainly composed of SO2 along with other minor species, is known to present a highly heterogeneous spatial distribution. Ionian atmospheric dynamic models argue that winds are expected to flow from high-density to low-density regions, which, in the context of a sublimation-sustained atmosphere, would correspond to a wind pattern flowing outward from the sub-solar point. Until now, only one direct wind measurement was available, and was at odds with the model predictions. With the Atacama Large Millimeter Array (ALMA), observations were taken with a spatial resolution of 0.86”, 0.46”, allowing one to resolve Io's disk (~1.15"). ALMA, located in Chili on the Chajnantor plateau, is the world's most sensitive (sub) millimeter interferometer thanks to its large collective area and its high altitude and dry
site. Two observations of a strong SO2 transition were taken one Io day apart. Doppler-shift mapping was performed on the SO2 emission line to measure the line-of-sight projected winds on the leading hemisphere. Our main conclusion is that the global wind pattern, with projected
winds moving from the eastern limb to the western, does not match the models. Once Io’s rotational velocity is accounted for, the derived wind velocities are relatively small compared to the previous direct wind observation.

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137.12 – Update on VLBA Astrometry of Cassini

The NRAO Very Long Baseline Array (VLBA) has been used to measure positions of the Cassini spacecraft 2-3 times per year during the decade since it arrived at Saturn. Combining these measurements with fits for Cassini's orbit about Saturn from Doppler tracking by the NASA Deep Space Network provides accurate positions for the Saturn system barycenter in the inertial International Celestial Reference Frame (ICRF) at each observing epoch. These positions in turn help to improve our knowledge of Saturn's orbit and thus the planetary ephemeris on which future interplanetary spacecraft navigation, pulsar timing, and studies of solar system dynamics depend. This observational program will continue to the end of Cassini's mission in 2017, thereby covering as large a fraction of Saturn's orbital period as possible. A multi-year period of accurate astrometry also increases the range of times over which ephemeris improvements can be extrapolated. Our current residuals with respect to JPL's DE430 ephemeris are approximately 0.2 mas in right ascension and 0.3 mas in declination. The primary error sources are residual troposphere delay calibration errors and uncertainties in the ICRF positions of some of our phase reference sources. The reference source position uncertainties are being reduced by continuing VLBI observations. Similar VLBI techniques will be applied to the Juno spacecraft when it begins orbiting Jupiter in 2016, thereby improving the orbit for this planet as well.
This work has been carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. Support from the NASA Planetary Astronomy Program is gratefully acknowledged. The VLBA is a facility of the National Radio Astronomy Observatory, which is operated by Associated Universities, Inc, under a cooperative agreement with the National Science Foundation.

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137.13 – A Hazy Situation: Using exoplanet retrieval techniques to characterize Titan's atmosphere from a Cassini transit spectrum

One of the main discoveries in exoplanet atmosphere characterization over the past several years is the dramatic role of clouds in shaping the transit spectra of close-in planets. High altitude clouds/hazes obscure molecular absorption features, leading to detrimental effects in studying transiting planet atmospheres. To investigate these effects with a "ground truth" solar system example, we utilize a transit spectrum obtained using NASA's Cassini spacecraft of Saturn's moon Titan. Titan, with its well-studied atmosphere and high-altitude hydrocarbon haze layer gives insight into how hazes affect exoplanetary transit spectra. To test how well current exoplanet atmosphere models can account for and extract information from hazy planets, we use the Bayesian CHIMERA transit spectrum model and a Markov-Chain Monte Carlo affiant-invariable ensemble technique to retrieve well-known atmospheric and planetary parameters for Titan. These include the CH^4, C^2H^2, and CO abundances, haze scattering parameters, temperature, pressure, and gravity. We discuss how our findings compare to in situ and other Cassini remote sensing measurements, and the implications of our results for the accuracy of exoplanet retrievals for hazy bodies.

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137.14 – The Mimas 5:3 Bending Wave at Equinox: Initial Models

In 2009, Cassini captured images of Saturn's rings during equinox, when the Sun's rays strike the ring nearly edge-on. These data provide a rare opportunity to study the vertical nature of structures such as bending waves. In the equinox images, the Mimas 5:3 bending wave (BW) was observed to exhibit quite different brightness profiles for the two imaging geometries at which it was imaged. With the sunlight shining largely along wave-troughs (hereafter geometry G1), the brightness profile shows a deep notch at the top of each wave peak. With the sunlight shining largely across wavetroughs (geometry G2), there are two bright peaks at the beginning of the wave, with the rest of the wave exhibiting the expected profile.

We conducted a qualitative analysis of these differences by creating a model Mimas 5:3 BW with a ring thickness of 50m and wave amplitude of 400m and modeling the resultant brightness curve for G1 and G2 as well as a non-equinox geometry G3. Our model assumes no re-scatter or absorption occurs and that the ring particles are all of the same size and homogeneously distributed. Light is scattered and detected at every path length step with a scattered intensity determined by the ring's optical depth. We compared our model brightness profiles with the observed brightness profiles for both equinox geometries as well as the non-equinox geometry. Our models of G1 and G3 show qualitative agreement with the observed brightness profiles, but our model of G2 does not reproduce the most prominent features of the observed brightness profile.

Qualitatively, the model brightness profiles indicate that attenuation when photons cross the ring multiple times can account for the peculiar notched wave peaks of the Mimas 5:3 BW in G1, but the anomalously bright peaks at the beginning of the wave in G2 may indicate unexplained structure. A more complex analysis is needed in order to improve our understanding of the observed brightness profiles of the Mimas 5:3 BW at equinox. With a more accurate model of how light is scattered and detected in the equinox images, the wave amplitude, ring thickness, and particle properties in the region of the Mimas 5:3 BW could be better characterized or constrained.

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137.15 – Trio of stellar occultations by Pluto One Year Prior to New Horizons' Arrival

Our campaign in July 2014 yielded three successful stellar occultations (~m=15, 17, and 18) of Pluto (~m=14), observed from telescopes in New Zealand, Australia, and Chile. Telescopes involved included Chile: Magellan's Clay (6.5 m), SOAR (4.1 m), Carnegie's DuPont (2.4 m); Australia: AAT (4 m); and Canterbury's Mt. John McLellan (1-m); as well as various smaller telescopes in Australia and Chile. One of the events was also observed, with negative results, from GROND on La Silla (2.2 m) and SMARTS's ANDICAM at CTIO (1.3 m). Though our observations were coordinated across continents, each successfully observed event was seen from only one site because of bad weather at the other sites. Two of the events were uniquely observed from Mt. John (Pasachoff et al., DPS 2014) and one, with only Chile sites in the predicted path, from the Clay (Person et al., DPS 2014). This last event was expected to be of the brightest star with the largest telescope we have ever observed for a Pluto occultation, but clouds arrived at the 6.5-m Clay 90 s before the predicted time; a 1% occultation was nonetheless seen and eventually, confirmed by Keck AO observations, to be of a 15th magnitude star previously hidden in the brightness of the 12th mag star. Our scientific conclusion is that as of these observations, one year before New Horizons' passage of Pluto, the atmosphere of Pluto remained robust and of the same size. Details on our analysis of the three events will be presented.
Acknowledgments: This work was supported in part by NASA Planetary Astronomy grants to Williams College (NNX12AJ29G) and to MIT (NNX10AB27G), as well as grants from USRA (#8500-98-003) and Ames Research (#NAS2-97-01) to Lowell Observatory. A.R.S. was supported by NSF grant AST-1005024 for the Keck Northeast Astronomy Consortium REU, with partial support from U.S. DoD's ASSURE program. P.R. acknowledges support from FONDECYT through grant 1120299. J.M.P. thanks Andrew Ingersoll and Caltech Planetary Astronomy for hospitality.

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137.16 – A Targeted Search for Trojan Asteroids in Kepler Lightcurves

"Trojan" asteroids, or asteroids trapped in stable gravitational positions preceding and trailing a planet in its orbit, accompany almost every planet of our Solar System. They were captured into their current locations in the early stages of our solar system's formation, and their presence hints at the dynamical history of bodies orbiting the Sun. However, we have no reason to assume that our own planets are alone in possessing Trojan asteroids. NASA's Kepler mission, launched in 2009, has been instrumental in the recent search for exoplanets. It has identified thousands of new worlds to date. However, exo-Trojan asteroids have as-yet eluded detection. If asteroids are captured at both Lagrangian points, their folded transit signature is not strictly periodic (since transits occur 1/6th of the planetary period before and after transit), and may be missed by traditional search algorithms. Our targeted search, at the predicted times of transit, is best suited for identifying candidate Trojans. Moreover, we have focused our investigation upon the set of Kepler Objects of Interest (KOIs) that we predict will be most fruitful for Trojan detection. However, if we are unable to detect these Trojan asteroids, we will be able to set limiting constraints on the presence of asteroids in exoplanetary systems. Observations of these Trojan asteroids, or the lack thereof, would give insight to the evolution and migration models of these systems.

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137.17 – Characterizing Asteroids Multiply-Observed at Infrared Wavelengths

We report Markov chain Monte Carlo fits of the thermophysical model of Wright (arXiv:astro-ph/0703085) to the fluxes of 10 asteroids which have been observed by both WISE and NEOWISE. This model is especially useful when one has observations of an asteroid at multiple epochs, as it takes advantage of the views of different local times and latitudes to determine the asteroid's spin axis and thermal inertia parameter, and it includes a physical basis for the beaming effect. Many of the asteroids NEOWISE observes will have already been imaged by WISE, so this proof of concept shows there is a great opportunity to use Wright's model to accurately characterize a large number of asteroids.

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137.18 – Near-Earth Asteroid Characterisation: Gotta catch 'em All!

Near-Earth Asteroids (NEAs) are a subject of interest for several reasons: They pose a hazard to Earth through collisions, are prime targets for human exploration missions, and can contain valuable materials such water or Platinum Group Metals (PGMs). Since the 2005 George E. Brown Congressional mandate to find 90% of NEAs >140 m by 2020, the number of NEAs detected has increased to over 1000/year. However the rate of NEA characterisation has not kept pace and is currently only ~10% of the discovery rate. An earlier study (Galache et al. 2014) has shown that most NEAs are found near their brightest and fade below follow-up magnitudes within ~10 days. Moreover small (H>22) NEAs are typically much fainter on any subsequent apparition within 10 years. Hence there is a strong 'need for speed' in making follow-up measurements. We have studied how many NEAs can be characterised per year based on telescope size, location or type, using available ephemeris data from the Minor Planet Centre. We describe how these constraints define strategies for characterising NEAs in bulk.

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137.19 – Using the One Degree Imager to Study Active Asteroids

Active asteroids are asteroids that eject material, which can be caused by several different mechanisms that act on the asteroid, such as collisions, rotational instability, or radiation pressure. We study these asteroids in order to better understand these ejection mechanisms, and gauge their contribution to the zodiacal dust in the Solar System. For this project at the NOAO/KPNO REU program, we chose to focus on two specific asteroids, P/2010 A2 and 300160. Both asteroids were observed with the partial One Degree Imager on the WIYN 3.5 meter telescope on Kitt Peak. P/2010 A2 has an impressive debris tail made up of ejected dust that stretches for over a million kilometers. The wide field of pODI allowed us to construct a surface brightness profile for almost the entire extent of the tail. From this we can investigate the ejection mechanisms that caused the tail to form, and estimate the dust mass. For 300163 we did follow up observations to search for any current activity. We did not identify any trace of nebulosity in our data which indicate that the previously seen nebulosity was part of a transient event. This gives us clues about the possible ejection mechanisms acting on 300163.

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137.20 – Planetary Embryo Bow Shocks as a Mechanism for Chondrule Formation

We investigate the plausibility of a planetary embryo bow shock as a mechanism for chondrule formation in the early solar system. A Mars-size planetary embryo traveling on a moderately excited orbit through the dusty early environment of the solar system will experience supersonic velocities relative to the circularly orbiting gas and dust. The resulting bow shock can thermally process solids that pass through it, with a wide range of possible conditions depending on impact radius. Volatile outgassing by the embryo along with some gas capture from the surrounding nebula can produce temporary atmospheres. We use radiation hydrodynamics simulations with direct particle integration to model the consequences of solids that encounter a bow shock produced by a 3000 km embryo with relative speeds to the gas of 5, 6, and 7 km/s. The embryos are envisaged to be surrounded by low- and high-mass atmospheres (0.75 and 6.25 Martian-mass atmospheres, respectively), and we explore different opacities for the gas. We find that a high-mass atmosphere and low dust opacity can produce peak temperatures and cooling rates that are most consistent with constraints set by chondrule furnace studies for plausible shock speeds.

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137.21 – Using an integral-field unit spectrograph to study radical species in cometary coma

We have observed several comets using an integral-field unit spectrograph (the George and Cynthia Mitchell Spectrograph) on the 2.7m Harlan J. Smith telescope at McDonald Observatory. Full-coma spectroscopic images were obtained for various radical species (C^2, C^3, CN, NH^2). Various coma enhancements were used to identify and characterize coma morphological features. The azimuthal average profiles and the Haser model were used to determine production rates and possible parent molecules. Here, we present the work completed to date, and we compare our results to other comet taxonomic surveys. This work was funded by the National Science Foundation Graduate K-12 (GK-12) STEM Fellows program (Award No. DGE-0947419), NASA's Planetary Atmospheres program (Award No. NNX14AH18G), and the Fund for Astrophysical Research, Inc.

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137.22 – LCOGT Network observations of spacecraft target comets

Las Cumbres Observatory Global Telescope (LCOGT) network currently has 12 telescopes at 6 locations in the northern and southern hemispheres with expansion plans for more. This network is versatile and can respond rapidly to target of opportunity events and also perform long term monitoring of slowly changing astronomical phenomena.
We have been using the LCOGT Network to perform photometric monitoring of comet 67P/Churyumov-Gerasimenko to support the ESA *Rosetta* comet mission and of C/2013 A1 (Siding Spring) as part of the ground-based observation teams for these important comets. This broadband photometry will allow a vital link between the detailed in-situ measurements made by the spacecraft and the global properties of the coma, at a time when the comet is only visible for short periods from single sites. The science we can extract includes the rotational state of the nucleus, characterization of the nucleus' activity, gas and dust properties in the coma (e.g., outflow velocities), chemical origin of gas species in the coma, and temporal behavior of the coma structure when the comet is close to the sun. Comet Siding Spring is a dynamically new comet on its first approach to the Sun that will pass close to Mars, so we can directly sample the composition of an original unaltered remnant of the protoplanetary disc. We will also be making use of specialized comet filters available at LCOGT's 2-m Faulkes Telescope North (FTN) to obtain a unique data set on comet C/2013 A1 (Siding Spring), as part of a large worldwide campaign. As one of only two robotic telescope equipped with cometary narrowband filters in the Northern hemisphere and having the largest aperture plus a high quality site, FTN can provide critical regular monitoring that cannot be achieved by any other single facility in the campaign.

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137.23 – Far-UV observations of comet C/2012 S1 (ISON) with FORTIS

Far-UV imagery and objective grating spectroscopy of comet C/2012 S1 (ISON) were acquired from NASA sounding rocket 36.296 UG, launched on 20 November 2013 at 04:40 MST (20.48 Nov 2013 UT), 8.32 days pre-perihelion, from the White Sands Missile Range, NM. The comet was 0.1° below ground horizon, 0.44 AU from the Sun, 0.86 AU from the Earth, and at a solar elongation of 26.3°. The payload reached an apogee of 279 km and the total time pointed at the comet was 353 s. At the time of launch ISON was undergoing a factor of 5 increase in water production rate, going from 3.5e29 to 19.6e29 molecules s^{-1} between 19.6 and 21.6 Nov (Combi et al. 2014), marking what is thought to be a final fragmentation event (Sekanina & Kracht 2014). Our instrument, a wide-field multi-object spectro-telescope called FORTIS (Far-UV Off Rowland-circle Telescope for Imaging and Spectroscopy), observed Lyα emissions in an objective grating mode through an open microshutter array, developed at the Goddard Space Flight Center, over a $(1/2°)^2$ field-of-view. After accounting for slit losses and deadtime corrections we find a preliminary lower limit to the Lyα surface brightness of ~ 400 kilorayleighs, yielding a hydrogen production rate of Q^H ~ 5e29 atoms s^{-1}, in reasonable agreement with the Combi result. We also acquired a broadband image of the comet in the 1280 to 1900 Å bandpass. This image shows a drop in count rate proportional to altitude caused by increased absorption of cometary emissions by terrestrial O^2 located in the lower thermosphere. O^2 absorption acts as a selective time dependent filter that attenuates cometary emissions from different atomic and molecular species at different rates during descent. Preliminary analysis suggests that the dominant species in a $(1e5\ km)^2$ nuclear region is neutral carbon. The radial profile in comparison to a Haser model suggests that the C parent molecule had a lifetime (at 1 AU) ~ 10^5 s; much shorter than the expected lifetime of

CO. We conclude there was little CO produced from the interior volume that was exposed during the final fragmentation of this dynamically new comet, in accord with the low CO production rate derived from *HST*/COS spectra obtained on 1 November 2013 (Weaver et al. 2014).

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137.24 – Photonic Local Oscillator Test System for Atacama Large Millimeter/submillimeter Array (ALMA) - Summer Student Project

The Atacama Large Millimeter Array (ALMA) consists of 66 high-precision antennas in Chile and draws great worldwide interest from astronomers and engineers. The objective of my summer research was to construct a subset of the installed Photonic Local Oscillator (LO) test station at the National Radio Astronomy Observatory (NRAO) in Charlottesville, VA. Installation of a full test system expedites the preparation of a fifth Laser Synthesizer (LS) for integration in the ALMA system. By utilizing the capabilities and partnership of fiber optics and electronics, the Charlottesville, Central LO Test System (cvCLOTS) was completed to test the LS, troubleshoot future malfunctioning parts, and creates an opportunity for other future ALMA upgrades.

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138 – Low Mass Stars and Brown Dwarfs Posters

138.01 – Accuracy of Astrometric Positions, Parallaxes, and Proper Motions

We discuss the accuracy of several astrometric results. The limitations to absolute positions usually depend on reference catalogs, and will improve dramatically with data from Gaia. Parallaxes and proper motions depend more on relative astrometry that is more precise - and can be very accurate. Measurements of QSOs made at the Naval Observatory are used to demonstrate that parallax accuracy levels of 0.2 mas and proper motion accuracy of 0.1 mas/yr can be routinely achieved. This level of astrometry accuracy gives confidence that the small parallaxes for distant stars such as distant white dwarfs, central stars of planetary nebulae, and dwarf carbon stars can be trusted.

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138.02 – The RECONS 25 Parsec Database

The REsearch Consortium On Nearby Stars (RECONS, www.recons.org) Team has been mapping the solar neighborhood since 1994. Nearby stars provide the fundamental framework upon which all of stellar astronomy is based, both for individual stars and stellar populations. The nearest stars are also the primary targets for extrasolar planet searches, and will undoubtedly play key roles in understanding the prevalence and structure of solar systems, and ultimately, in our search for life elsewhere.
We have built the RECONS 25 Parsec Database to encourage and enable exploration of the Sun's nearest neighbors. The Database, slated for public release in 2015, contains 3088 stars, brown dwarfs, and exoplanets in 2184 systems as of October 1, 2014. All of these systems have accurate trigonometric parallaxes in the refereed literature placing them closer than 25.0 parsecs, i.e., parallaxes greater than 40 mas with errors less than 10 mas. Carefully vetted astrometric, photometric, and spectroscopic data are incorporated into the Database from reliable sources, including significant original data collected by members of the RECONS Team. Current exploration of the solar neighborhood by RECONS, enabled by the Database, focuses on the ubiquitous red dwarfs, including: assessing the stellar companion population of ~1200 red dwarfs (Winters), investigating the astrophysical causes that spread red dwarfs of similar temperatures by a factor of 16 in luminosity (Pewett), and canvassing ~3000 red dwarfs for excess emission due to unseen companions and dust (Silverstein). In addition, a decade long astrometric survey of ~500 red dwarfs in the southern sky has begun, in an effort to understand the stellar, brown dwarf, and planetary companion populations for the stars that make up at least 75% of all stars in the Universe.
This effort has been supported by the NSF through grants AST-0908402, AST-1109445, and AST-1412026, and via observations made possible by the SMARTS Consortium.

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138.03 – Circumstellar Environments of Southern M Dwarfs in the Solar Neighborhood

We present the first results from SIRENS, the Search for InfraRed Excesses around Nearby Stars. Our goal is to characterize the circumstellar environments of the most common and closest stars in the Universe, the ubiquitous red dwarfs. In this phase of the study, we search 1404 southern M dwarfs within 25 parsecs of the Sun, as reported in Winters et. al 2014, using (Johnson-Kron-Cousins) optical, (2MASS) near-infrared, and (WISE) mid-infrared photometry for circumstellar disks and low-mass companions. Several studies have recently used WISE photometry to detect circumstellar disks and companions --- searches around members of the nearby young moving groups, objects with parallaxes from Hipparcos, and many northern M stars in the SDSS. However, no work has yet been done that focuses on the nearest red dwarfs, which account for at least 75% of all stars. This study, a volume-limited search around M dwarfs in the southern sky, includes statistical conclusions applicable to a majority of the stars in the universe, and opens potential gateways to a better understanding of star and planet formation.

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138.04 – Dynamical Evolution of the Alpha and Proxima Centauri Triple System

Proxima Centauri is approximately 15,000 AU from the Alpha Centauri binary and moving through the galaxy on a similar path, and is thought to be in a loosely bound orbit about the binary. Dynamic simulations show that this configuration can form from a less extreme triple system. As our nearest neighbors, these stars command great interest as potential planet hosts, and the dynamics of the stars govern the formation of any planets within the system. Here we present a scenario for the evolution of Alpha Centauri A and B and Proxima Centauri as a triple system, to establish limits on the evolution of the binary since formation and allow for a better understanding of planet formation therein.

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138.05 – *V* and *K*-band Mass-Luminosity Relations for M dwarf Stars

Applying Hubble Space Telescope Fine Guidance Sensor astrometric techniques developed to establish relative orbits for binary stars (Franz et al. 1998, AJ, 116, 1432), determine masses of binary components (Benedict et al. 2001, AJ, 121, 1607), and measure companion masses of exoplanet host stars (McArthur et al. 2010, ApJ, 715, 1203), we derive masses with an average 2.1% error for 24 components of 12 M dwarf binary star systems. Masses range 0.08 to 0.40 solar masses. With these we update the lower Main Sequence *V*-band Mass-Luminosity Relation first shown in Henry et al. (1999, ApJ, 512, 864). We demonstrate that a Mass-Luminosity Relation in the *K*-band has far less scatter than in the *V*-band. For the eight binary components for which we have component magnitude differences in the *K*-band the RMS residual drops from 0.5 magnitude in the *V*-band to 0.05 magnitude in the *K*-band. These relations can be used to estimate the masses of the ubiquitous red dwarfs that account for 75% of all stars, to an accuracy of 5%, which is much better than ever before.

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138.06 – A SUPERBLINK look at the Hyades and Pleiades clusters

With mean proper motions in excess of 0.04 seconds of arc per year, the Hyades and Pleiades are the only clusters on the sky whose members are within proper motion detection range of the SUPERBLINK proper motion survey. A search of the recently expanded SUPERBLINK catalog for known and possible members of the Hyades shows that the cluster contains at least 401+/-24 main-sequence stars, with probable members up to 11 degrees (9 parsecs) away from the cluster center. A similar search for Pleiades members shows that the cluster contains at least 767+/-30 main-sequence stars, with probable members up to 4.5 degrees (10 parsecs) away from the cluster center. Both estimates include previously confirmed members, and also account for contamination from field stars. At least 63% of the Hyades and 74% of the Pleiades are found to be M dwarfs, having optical-to-infrared colors V-J>2.7. The distribution of these low-mass members shows the signature of mass segregation in both clusters, with most of the least massive candidates found in the outer half of each clusters.

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138.07 – Investigating the Low-Mass Stellar Initial Mass Function in Draco

We investigate the low-mass (~0.5 to 0.8 $M_\odot$) stellar initial mass function (IMF) in three different regions of the Draco dwarf spheroidal galaxy using archival imaging of resolved stars taken with HST/ACS and WFC3. We model the optical color-magnitude diagrams of each field assuming two different IMF models (power-law, log-normal), three different stellar evolution libraries (Padova, BaSTI, Dartmouth), and a binary star model. For the power-law model, we find that the best-fit IMF slope varies per field, and that none are in good agreement with a Salpeter IMF. All fields show more consistent log-normal parameters, which are also in reasonable agreement with values for a standard Chabrier IMF. However, there are large degeneracies between the characteristic mass and dispersion of the log-normal, that can only be reduced with data that extends to lower stellar masses. Finally, we note that application of different stellar models can lead to drastically different IMF results, particularly in the case of the power-law fit. We therefore caution that uncertainties in stellar evolution models may be the dominant sources of uncertainty in studies of the low-mass IMF.

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138.08 – Preliminary M-dwarf Binary Statistics from *Kepler*

Though the original mandate of the NASA *Kepler* space mission was to discover exoplanet systems, its long observing baseline, unprecedented photometric precision, and rich repository of targets are ideal for studying a wider variety of periodic transient phenomena. Among them are eclipsing binaries. Thousands of them. That eclipsing binaries are superb for stellar astrophysics is well-established: they have precisely determined stellar and orbital properties, in particular radius and mass. Furthermore, the overall binary demographics provides clues to the formation and evolution process of stellar populations.

Information on sub-year-period binarity rate is encoded by binaries which eclipse in *Kepler*. Such information can be extracted statistically. We use a framework akin to calculations of planetary occurrence from planetary transits to constrain binary fractions of low-mass stars with *Kepler* M-dwarf eclipsing binary observations. Here we shall present the preliminary results.

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138.09 – The Baryon Oscillation Spectroscopic Survey SLoWPoKES Catalog

We present preliminary results from the Baryon Oscillation Spectroscopic Survey (BOSS) SLoWPoKES Catalog. The Sloan Low-mass Wide Pairs of Kinematically Equivalent Stars (SLoWPoKES) catalog contains 1342 widely separated, low-mass binary pairs that have common proper motions and similar distances. One of the limitations of the original SLoWPoKES catalog is that most of the stars do not have spectroscopic observations. We overcame this limitation by including SLoWPoKES binary candidates as spectroscopic targets in two of the SDSS III BOSS ancillary programs. BOSS completed spectroscopic observations of both members of 370 SLoWPoKES systems. Of these, 237 pairs, and one triple star system, have late-K or M dwarf members with radial velocities matching to 2σ, confirming their status as co-moving systems in three dimensions. Our scientific goals are to investigate how magnetic activity varies with binary separation, and use the BOSS spectra to constrain the latest techniques for calculating the metallicity of low-mass stars. For our catalog, we analyzed many spectral features including Hα emission (a tracer of magnetic activity) and numerous molecular bands (e.g. TiO, CaH,O2, etc.) and atomic lines (e.g. Na, K, etc.). We also extracted photometry from the Sloan Digital Sky Survey and computed 3D space motions and distances for a subset of our sample.

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138.10 – Using APOGEE Data to Examine Late-K and Early-M Dwarfs

The Apache Point Galactic Evolution Experiment (APOGEE) has obtained high resolution (R~22,500) near-infrared spectra of over 100,000 stars, including a subset of ~4000 low-mass dwarfs with estimated effective temperatures of 3500 K < Teff < 4200 K. We use data from standard stars to confirm the accuracy of APOGEE parameters for these stars, which sit at the low temperature, high gravity end of the APOGEE model grid. We then cross-match these late-K and early-M dwarfs with photometry from SDSS, 2MASS, and WISE to examine the relationships between effective temperature, metallicity, and color for these low mass stars. In this effective temperature regime, u-g, g-r, and W1-W2 colors are metallicity sensitive, while r-z is a better tracer of Teff. We compare Teff, metallicity, and colors with parameters derived from the Padova, Dartmouth, and BT-Settl model grids, finding that while no set of models fits exactly, each set reproduces similar general trends.

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138.11 – Accurate Alpha Abundance and C/O of Low-mass Stars

We investigate methods for measuring elemental abundances in M dwarf stars from high resolution (R>25,000), near-infrared spectra. With synthetic spectra from the BT-Settl model atmosphere library, we identify NIR features sensitive to enhancement of alpha elements (C, O, Mg, Si, S, Ca, and Ti) in M dwarfs. We also describe a method for measuring the amount of oxygen not bound in CO from molecular and atomic features in the NIR Y-band that, when combined with recently published methods of measuring carbon abundance in M dwarfs from K-band spectra, provides the ratio of carbon to oxygen (C/O). The ratio of carbon to oxygen is an important parameter for determining interior structures of exoplanets and processes that drive planet formation as evidenced by recent studies of the super Earth 55 Cnc e. We outline a potential observing program to empirically calibrate these methods via a sample of M dwarfs with widely-separated (5’’-1500’’), but associated, F, G or K-type binary companions. Once calibrated, we will apply these methods to a survey of nearby M dwarfs, including many stars that will be observed by NASA's Transiting Exoplanet Survey Satellite (TESS).

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138.12 – Measuring Fundamental Stellar Properties with Theremin

The emergent spectrum from a star is a complicated function of atmospheric structure, metallicity, geometry, and magnetic field strength. Consequently, stellar spectra are powerful diagnostic tools of physical conditions in photospheres. We present Theremin, a python-based code to measure physical stellar parameters (effective temperature, surface gravity, and magnetic fields). The code works by comparing observed stellar spectra to a grid of model spectra generated by the polarized radiative transfer code MOOGStokes (and can be adapted to grids of model spectra calculated with other codes). Theremin uses available python tools for Gaussian processes to account for correlated noise in the flattening of the observed spectra, as well as a popular MCMC tool to sample the probability distributions in each dimension spanned by the model grid. We present the results of applying Theremin to observations of TW Hydrae using spectra from different instruments (IGRINS, XSHOOTER, and SpeX), measuring effective temperature, surface gravity, and mean magnetic field strength.

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138.13 – SME@XSEDE: An automated spectral synthesis tool for stellar characterization

Over the last decade, large scale discovery surveys like Kepler have produced vast catalogs of newly discovered extrasolar planetary systems. Most of these systems require stellar characterization of the host stars in order to derive the host star masses and completely solve for the planetary properties. Currently, there is no widely accepted and standardized method to determine fundamental parameters from stellar spectra. Here, we present a new approach to automating stellar characterization of large datasets of high resolution spectra. Our software, called SME@XSEDE, is based on one of the most widely used spectral synthesis algorithms, Spectroscopy Made Easy (SME), originally described in Valenti and Piskanov (1996). Like SME, SME@XSEDE compares an observed spectrum to synthetic model spectra derived through radiative transfer calculations for a range of stellar parameters in order to find the global stellar properties (temperature, gravity, metallicity, vsini, and individual abundances) that result in a synthetic spectrum that best matches an observed spectrum. We use the XSEDE super computer cluster to run many sets of initial guesses of stellar parameters to determine robust SME-based solutions without extensive, hands-on work. In this paper, we describe our software in detail and compare results derived from the application of SME@XSEDE to several well-studied datasets of stellar parameters including Valenti and Fischer 2005, Torres et al. 2012, and Huber et al 2013.

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138.14 – Resolving the Discrepancy of Low-Mass Stars with IGRINS

Observed properties of low-mass stars (M < 0.8 solar msses) have been found to be in disagreement with stellar models, the observed radii being inflated and the observed temperatures being too low. To study this discrepancy, we are observing a sample of low-mass eclipsing binaries using the 2.7-m Harlan J. Smith telescope at McDonald Observatory as well as the LCOGT network to increase the number of well-characterized systems. We are also using IGRINS, a new high resolution (R=40,000) IR (H+K) spectrograph on the 2.7-m HJST, to measure the fundamental stellar parameters (Teff, R, M, abundances, activity) of a sample of eclipsing binaries consisting of two low-mass components. Finally, to calibrate these eclipsing binaries, we are observing a temperature calibration sample of single M dwarfs with precise temperature measurements from interferometry and a metallicity calibration sample of M dwarfs in wide binaries with solar-type stars. Relationships between these parameters will help us better understand the discrepancy between models and observed properties of low-mass stars.

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138.15 – Stratified Convection in Stellar Interiors

Stars on the lower main sequence have substantial, stratified convection zones that span many density scale heights. There, low Mach number convection dominates the transport of heat, angular momentum and the dynamo generation of magnetic fields. Many aspects of low Mach number stratified convection remain unclear. Here we use the open-source Dedalus pseudospectral framework to study for the first time low Mach number fully nonlinear, fully compressible convection in stratified stellar interiors. We study what processes determine the scales of convective motions and the nature of turbulent transport in highly stratified atmospheres.

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138.16 – Testing Stellar Evolution Models: Absolute Dimensions of the Low-Mass Eclipsing Binary Star V651 Cassiopeiae

We report accurate values of several key quantities for the low-mass, 0.9968096 day period, double-lined eclipsing binary V651 Cas. We determine accurate values for the masses, radii and temperatures of the primary and secondary as follows: M = 0.8553(81) solar masses, R = 0.957(17) solar radii, and effective temperature = 5733(100) K for the primary component, and M = 0.7564(48) solar masses, R = 0.771(15) solar radii, and effective temperature = 5113(105) for the secondary component, with formal uncertainties shown in parentheses. A comparison with the stellar evolution models from the Dartmouth Stellar Evolution Program suggests an age of 11(1) Gyr for a best-fit metallicity of [Fe/H] = -0.2. While the isochrone mentioned correctly reproduces the measured radii and temperatures of the stars within the current uncertainties, we note that the secondary radius appears marginally larger and the temperature marginally cooler than models would predict. This is consistent with similar discrepancies found for other low-mass stars, generally accredited to surface activity. With further improvement in the measurement errors, and a spectroscopic measure of the metallicity, V651 Cas should be a valuable system for understanding the effects of magnetic activity on the global structure of low-mass stars and for providing guidance to improve stellar evolution models.
This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

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138.17 – Rotation periods for nearby, mid-to-late M dwarfs estimated from the MEarth Project

Knowledge of M dwarfs’ rotation is essential to understanding the generation of their magnetic fields and the mechanism by which they lose angular momentum. It is also important for characterizing the environment of planets that might orbit them. The most direct way to infer rotation periods is from variations in stars' brightnesses as dark spots rotate in and out of view. Most rotation periods estimated prior to this decade are the result of dedicated photometric studies. If care is taken to preserve astrophysical variability and limit systematics, transiting planet surveys generate the high-cadence monitoring required to estimate stellar rotation periods. While targeted surveys of clusters have provided data at young ages, observations of field M dwarfs are required to constrain their late-term evolution. Rotation periods of the smallest stars are also needed: the Kepler mission produced exquisite light curves of several thousand cool dwarfs, but field stars below 0.3 solar masses are not well-represented in the sample. The MEarth Project is a transiting planet survey targeting mid-to-late M dwarfs within 33 parsecs; it provides a unique data set for exploring rotation in a large sample of fully convective stars. We present a catalog of rotation periods for these stars. Our measurements are particularly useful because many of the MEarth targets have parallaxes, multi-wavelength photometry, and optical and near-infrared spectra. We present our methods for estimating rotation periods and quantifying our uncertainties, and discuss our results in the context of other surveys.

The MEarth project gratefully acknowledges funding from the David and Lucile Packard Fellowship for Science and Engineering, the National Science Foundation under grants AST-0807690, AST-1109468, and AST-1004488, and the John Templeton Foundation

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138.18 – Anchoring the age-rotation relation with the ZAMS cluster α Per

Calibrating the age-rotation-activity relation in low-mass stars requires systematically mapping out stellar properties, such as rotation and coronal or chromospheric activity, in coeval populations. The Palomar Transient Factory (PTF) Open

Cluster Survey (POCS) is an effort to measure rotation periods and tracers of magnetic activity for stars in clusters ranging from 80 Myr and 3 Gyr. The survey will produce a complete description of the age-rotation relation and the age-activity relation for low-mass stars from their arrival on the zero-age main sequence (ZAMS) until they are about three-fifths the Sun's age. We present preliminary results for Alpha Persei (α Per), the youngest cluster in the POCS sample. Late-type stars in this cluster are arriving on the ZAMS, and provide an essential anchor point for modeling the age-rotation relation. We revisit the cluster membership, and construct a revised catalog that considers a star's distance from the cluster center in addition to photometric and proper-motion data from a number of surveys. We also present preliminary period measurements extracted from nearly eight months of PTF optical monitoring of α Per. Prior to our POCS survey, periods had been measured for fewer than 40 members of α Per, limiting the cluster's utility as a benchmark for the early-stage age-rotation relation. With updated membership catalogs and newly measured rotation periods enabled by PTF, α Per will provide critical data for defining the ZAMS-era age-rotation relation.

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138.19 – Rotation and Activity in Praesepe and the Hyades

Open clusters are single-age stellar populations that can be used to investigate the connection between angular-momentum evolution and magnetic activity for stars of different masses over their lifetimes. The Palomar Transient Factory (PTF) Open Cluster Survey (POCS) is an effort to measure rotation periods (Prot) and tracers of magnetic activity for stars in clusters ranging from 80 Myr and 3 Gyr. We present the results of a comparative study of the rotation-activity relationship in two benchmark 600 Myr-old open clusters: Praesepe and the Hyades. As they have similar ages and approximately solar metallicity, these clusters serve as an ideal laboratory for testing the agreement between theoretical and empirical rotation-activity relations at this age. We have compiled a sample of spectra -- more than half of which are new observations -- for 516 high-confidence members of Praesepe, along with new observations of 130 high-confidence Hyads. We have also collected Prot for 135 Praesepe members (including 40 Prot from POCS) and 87 Hyads. Unlike previous authors, we find no difference between the two clusters in their H-alpha equivalent width distributions, and therefore take the merged H-alpha and Prot data to be representative of 600-Myr-old stars. Our analysis shows that H-alpha activity in these stars is saturated for Rossby numbers Ro<0.11. Above that value activity declines as a power-law with a slope of -0.73, which is much shallower than has been observed for activity-rotation relations in the literature. These data provide a useful anchor for calibrating the age-activity-rotation relation beyond 600 Myr.

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138.20 – Chromospheric and coronal variation across stellar activity cycles

We investigate cyclic chromospheric and coronal activity in main-sequence stars, using Ca II H and K core emission and X-ray luminosities, respectively. From a sample of 244 nearby stars with high-cadence Keck optical spectroscopy spanning up to 17 years (obtained for the California Planet Search program), we use automated sinusoid modeling and goodness-of-fit criteria to identify 33 stars with highly significant cyclic R'HK variability. The cycle periods are refined using mmag APT optical photometry. We also construct a comparison sample of 23 stars that show virtually no R'HK variability. The cyclic and flat stars have similar B-V and absolute magnitude distributions but the cyclic stars tend to be more active, with greater median R'HK values. We present new Swift/XRT observations of 10 cyclic stars and 1 flat star, totaling 32.6 ks; 5/11 are detected in this snapshot pilot survey. A comparison of their current-epoch X-ray luminosities to archival ROSAT values shows variation by a factor of 2-3 is common on decade-long timescales. Several stars also show suggestive evidence for X-ray variability on much shorter timescales, perhaps related to stellar rotation and coronal inhomogeneity or to small flares. We use the chromospheric activity cycles to calculate the phase of each X-ray observation. Additional Swift observations are ongoing and with this larger dataset we will measure the typical amplitude of cyclic X-ray variation. We discuss our initial results in the context of magnetic dynamo activity and consider the implications for exoplanet atmosphere heating and evaporation.

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138.21 – Finding X-ray Coronal Cycles in Low Mass Stars

We seek to increase the number of stars known to have an X-ray coronal cycle. Four stars (including the Sun) are known

to experience periodic long-term coronal flux variability but the statistics are not superb. In this analysis, we analyze four stellar sources that have been observed frequently by Chandra and XMM-Newton over the last ~11 years. These four sources were the brightest among numerous stellar point sources within the Chandra Deep Field South. Solar flares can dramatically increase the flux measured for our stars on short time intervals and, in observations with insufficient time coverage, can be confused for the maximum of the stars' magnetic cycles (if they have one). We have discarded times where solar proton flares are detected in the data. We utilize an APEC model, which represents the coronal plasma, to fit our stellar spectra. As our sources are very faint, we do not subtract the background, but instead we fit the background and source spectra simultaneously. We use the chi-squared statistic to evaluate the confidence of our fits. We present four light curves which suggest that a long-term X-ray flux variability similar to our Sun (the solar X-ray flux can vary by a factor of 10 over ~11 years) is not present in these stellar sources. None of our stars experienced a flux variability exceeding a factor of 3 over an 11 year time scale but one of the four stars in our sample exhibits short term variability over a one year period. However, our stellar sources are too faint to conclusively state that the flux remains constant throughout all epochs.
This work is supported by the National Science Foundation REU and Department of Defense AS-SURE programs under NSF Grant no. 1262851 and by the Smithsonian Institution.
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138.22 – Connecting Flares and Transient Mass Loss Events in Active Stars

We explore the ramification of associating the energetics of extreme stellar magnetic reconnection events with transient stellar mass loss in a stellar analogy with solar eruptive events. We establish energy partitions relative to the total bolometric radiated flare energy for different observed components of stellar flares, and show that there is rough agreement for these values between solar and stellar flares. We apply an equipartition between the bolometric radiated flare energy and kinetic energy in an accompanying mass ejection, seen in solar eruptive events and expected from reconnection, so that an observed distribution of flare frequency with energy in a particular waveband can be used to estimate the amount of transient mass loss. This approach is supported by a good correspondence between observational flare signatures on high flaring rate stars and the Sun, which suggests a common physical origin. If the frequent and extreme flares that young solar-like stars and low-mass stars experience are accompanied by transient mass loss in the form of coronal mass ejections, then their cumulative effect may be large. We find that for young solar-like stars and active M dwarfs the total mass lost due to transient ejections of mass as part of magnetic eruptive events can have significant implications for the stars themselves and potentially for planet formation, disk evolution, exoplanet habitability, and dispersal into the ISM.
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138.23 – Flares and Antiflares on Young Solar Analog EK Draconis

EK Draconis (HD129333: G1.5 V) is a well-known young (50 Myr) solar analog. In 2012, *Hubble Space Telescope* returned to EK Dra to follow up a far-UV SNAPshot visit by *HST's* Cosmic Origins Spectrograph two years earlier. The brief SNAP pointing had found surprisingly redshifted subcoronal Si IV (T~ 8×10^4 K), which also displayed impulsive variability, curiously uncorrelated with species at lower temperatures (C II: 2×10^4 K) or higher (Fe XXI: 1×10^7 K). Serendipitously, the follow-on program witnessed one of the largest FUV flares ever recorded on a sun-like star, which nevertheless displayed even stronger redshifts (downflows) than had been seen earlier, contrary to the violent *blueshifts* expected from such explosive events. At the same time, a velocity cross-calibration by Space Telescope Imaging Spectrograph (STIS) uncovered systematic deviations in the wavelength scales of COS, that were partly, but not entirely, responsible for the previously reported SNAP redshifts. However, the (now smaller, but still about 10 km s^{-1}) Si IV redshifts did not vary with rotational phase, so are not likely caused by "Doppler imaging" effects. Instead, the downflows might be signatures of catastrophic coronal cooling events (`"antiflares"). All in all, the new COS/STIS program documents a complex, energetic, dynamic outer atmosphere of the young solar analog.
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138.24 – Exploring a Threat to Foreign Worlds: Detecting Coronal Mass Ejections on Nearby Stars

Coronal mass ejections (CMEs) likely play a significant role in the mass loss and angular momentum evolution of active stars, and may significantly affect exoplanetary magnetospheres and atmospheres. It is difficult to quantitatively predict the magnitude of these effects because there have been no definitive detections of CMEs outside our own solar system. Dynamic radio spectroscopy of stellar flares offers the potential to make such detections. Broadband dynamic spectroscopy has long been used to study coherent radio emission associated with solar CMEs (known as Type II bursts), but such emission has not yet been detected from other stars. Type II bursts sweep downwards in frequency on

timescales of tens of minutes, tracing the motion of a CME outwards through the stellar atmosphere into progressively lower plasma densities. I will present JVLA active M dwarf observations showing coherent stellar radio bursts that are extremely bright, comparable in luminosity to the brightest solar Type II bursts ever recorded. These stellar radio bursts are morphologically similar to solar Type II bursts except that the stellar bursts sweep upwards in frequency over time. We interpret these bursts as either bulk plasma motion downwards into the stellar atmosphere or polar auroral radiation modulated by rotation. I will also present progress on the Starburst program, a 3-year nightly observing program using two 27-meter telescopes at the Owens Valley Radio Observatory (the equivalent of a JVLA baseline). The Starburst program will survey stellar coherent radio bursts in order to characterize the rate and energetics of CMEs on nearby stars, combined with complementary observations to image and characterize the detected CMEs.

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138.25 – The Heating of Helium Across Interplanetary Shocks in front of Coronal Mass Ejections

Several times per day during solar maximum, Coronal Mass Ejections (CMEs) send billions of tons of material from the Sun streaming through interplanetary space. Shocks form in the solar wind plasma ahead of the CMEs and can accelerate solar wind plasma to high kinetic energies. Understanding the shock propagation and the transport of plasma through the heliosphere is important due in particular to the role played by shocks in space weather. Ions heavier than protons in the solar wind, which create a seed population for energetic particle acceleration, have been used as tracers for heating mechanisms. Helium, the most abundant heavy ion, is studied in a series of shocks associated with CMEs. The heating seen in helium after the shock passage is compared to the proton heating in the same shock using data from the *Wind* spacecraft. Developing an understanding of these contributions to energy budget in interplanetary shocks is crucial for improving space-weather forecasting and energetic particle acceleration theory.

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138.26 – HAZMAT II: Modeling the Evolution of Extreme-UV Radiation from M Stars

M dwarf stars make up nearly 75% of the Milky Way's stellar population. Due to their low luminosities, the habitable zones around these stars are very close in (~0.1-0.4 AU), increasing the probability of finding terrestrial planets located in these regions. While there is evidence that stars emit their highest levels of far and near ultraviolet (FUV; NUV) radiation in the earliest stages of their evolution while planets are simultaneously forming and accumulating their atmospheres, we are currently unable to directly measure the extreme UV radiation (EUV). High levels of EUV radiation can alter the abundance of important molecules such as H^2O, changing the chemistry in extrasolar planet atmospheres. Most previous stellar atmosphere models under-predict FUV and EUV emission from M dwarfs; here we present new models for M stars that include prescriptions for the hot, lowest density, atmospheric layers (chromosphere, transition region and corona), from which this radiation is emitted. By comparing our model spectra to GALEX near and far ultraviolet fluxes, we are able to predict the evolution of EUV radiation for M dwarfs from 10 Myr - 1 Gyr. This research is the next major step in the HAZMAT (HAbitable Zones and M dwarf Activity across Time) project to analyze how the habitable zone evolves with the evolving properties of stellar and planetary atmospheres.

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138.27 – A comprehensive statistical assessment of star-planet interaction

We investigate whether magnetic interaction between close-in giant planets and their host stars produce observable statistical enhancements in stellar coronal or chromospheric activity. New Chandra observations of 12 nearby (d<60 pc) planet-hosting solar analogs are combined with archival Chandra, XMM-Newton, and ROSAT coverage of 11 similar stars to construct a sample inoculated against inherent stellar class and planet-detection biases. Survival analysis and Bayesian regression methods (incorporating both measurements errors and X-ray upper limits; 13/23 stars have secure detections) are used to test whether "hot Jupiter" hosts are systematically more X-ray luminous than comparable stars with more distant or smaller planets. No significant correlations are present between common proxies for interaction strength (Mp/a^2 or 1/a) versus coronal activity (Lx or Lx/Lbol). In contrast, a sample of 198 vetted FGK main-sequence stars does show a significant (~99% confidence) increase in X-ray luminosity with Mp/a^2. While selection biases are incontrovertibly present within the main-sequence sample, we demonstrate that the effect is primarily driven by a handful of extreme hot-Jupiter systems with Mp/a^2>450 Mjup/AU^2, which here are all X-ray luminous but to a degree commensurate with their Ca II H and K activity, in contrast to presented magnetic star-planet interaction scenarios that predict enhancements relatively larger in Lx. We discuss these results in the context of cumulative tidal spin-up of stars hosting close-in gas giants (potentially followed by planetary infall and destruction). We also test our main-sequence sample for correlations between planetary properties and UV luminosity or Ca II H and K emission, and find no significant dependence.

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138.28 – Constraining Kepler Eclipsing Binary Properties with Time-Series and Multi-band Photometry

We perform simultaneous fits to time-series (Kepler) and multi-band (SDSS griz + 2MASS JHKs) photometry to constrain stellar and orbital parameters of eclipsing binaries (EBs) from the Kepler Eclipsing Binary Catalogue. We infer the stellar parameters by comparing Padova stellar evolution models to the extinction-corrected multi-band photometric data, and use the results as inputs to a Keplerian orbit model for the lightcurves. This method yields a self-consistent analysis and jointly constrains properties of both stars (orbital elements e, ω, i, t^{pe}, p + stellar parameters r^A, r^B, m^A, m^B, f^B/f^A, [Fe/H], age, and quadratic limb darkening coefficients u^{A1}, u^{A2}, u^{B1}, u^{B2}). We apply our coupled time-series photometry and SED model to a sub-sample of detached EBs with p = 10 - 40 d, to minimize the influence of tidal or Doppler effects. The results of this analysis will feed into our circumbinary planet search, wherein we apply barycentric corrections to the Kepler EB lightcurves to look for signals due to planetary companions.

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138.29 – Eclipsing the Need for Spectroscopy: Constraining Eclipsing Binary Parameters Using Only Kepler Photometry

Eclipsing binary (EB) stars provide accurate measurements of stellar mass and radius and therefore play a critical role in constraining stellar evolution models. Despite their utility in understanding the distribution of stellar properties, previous studies have been limited by the observational challenges inherent to identifying and characterizing EBs, namely, the need for both high-cadence, continuous photometric monitoring and follow-up spectroscopy for radial velocity (RV) measurements. Fortunately, the time-resolved data from the Kepler mission offer a new opportunity to assemble large samples of EBs, as well as place preliminary constraints on their masses and radii without the need for additional observations. While current EB models (e.g., JKTEBOP) and Kepler photometric data alone can be used to produce estimates of stellar parameters, we investigate the accuracy of this method by solving for orbital solutions with and without additional ground-based data (multi-color photometry and RVs). Here we present three Kepler EBs that have ground-based data from a new monitoring program recently initiated at Apache Point Observatory and Manastash Ridge Observatory (see corresponding poster by T. Wilkinson et al.), and use these systems to investigate any discrepancies between the two approaches. Considering the observational costs to targeting all Kepler EBs (> 2500) for ground-based follow-up, using select EBs such as these as test cases may allow for the development of a reliable method to determine stellar radii and temperatures exclusively from photometric data and thereby provide a useful tool for streamlining future EB analyses.

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138.30 – Ground-based Data on Kepler Eclipsing Binaries

Kepler has provided precise photometry for more than 2500 eclipsing binaries, which may be used to obtain fundamental stellar parameters such as mass and radius. We report on the initial results of a new ground-based program at Apache Point Observatory and Manastash Ridge Observatory to obtain spectra and photometry of Kepler eclipsing binaries. We present multi-color light curves, radial velocites, and additional characterization of the stellar spectra. The new ground-based data will be used to inform modeling efforts for these objects (see companion poster by K. Weisenburger et al.).

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138.31 – Star-spot crossing transits in long-cadence Kepler data: a search for correlations between spot and stellar properties

As visible manifestations of strong magnetic fields, starspots provide an opportunity for us to explore small-scale properties of magnetic fields. With the launch of NASA's Kepler satellite, we now have access to near-continuous high-precision photometry of thousands of transiting planet host stars that we can use to study starspots. We have written a program that uses long cadence photometry of all transiting planet host stars to measure starspot variability caused as the planet transverses in front of starspots. Through our program, we identified host stars whose light curves are strongly affected by in-transit starspots. We are using this sample to investigate correlations between the presence of starspots and global stellar parameters such as effective temperature and rotation period. In addition, we are using the known position and impact parameter of the planet to explore the latitude of the starspots on the transiting planet

host stars.

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138.32 – A Catalog of Nearby Ultracool Dwarfs

This work consists of a compilation and analysis of nearby (d < 25 pc) ultracool dwarfs (< M6V) with a focus on brown dwarfs. We have incorporated newly discovered (post 1991) cool companions to Gliese-Jahreiß stars that had been previously been undetectable; with the advent of wide-field CCD cameras and all-sky surveys, numerous ultracool dwarfs have since been discovered with such missions as 2MASS, the Deep Near-Infrared Southern Sky Survey, the Wide-field Infrared Survey, and the Sloan Digital Sky Survey. We then expanded our efforts to include isolated ultracool dwarfs and other nearby multiple systems with at least one ultracool dwarf component. In this poster we will summarize the components of the catalog and describe physical trends we are able to extract from this large compilation of brown dwarf properties.

Author(s): Angelle M. Tanner[3], Christopher Ramos[3], Jonathan Gagne[4], Adric R. Riedel[1], Todd J. Henry[2]
Institution(s): *1. American Museum of Natural History, 2. Georgia State University, 3. Mississippi State University, 4. Université de Montréal, Physics*
Contributing team(s): RECONS

138.33 – HLIMIT 2.0: Towards a Deeper Understanding of the Low Mass End of the Main Sequence

We describe the observing strategies and scientific goals of a project aimed at providing a deeper understanding of the low mass end of the stellar main sequence. The work outlined here will expand upon the results presented in Dieterich et al. 2014, where radius trends in the local M and L dwarf population were used to gain insight about the stellar/substellar boundary, with evidence for the end of the stellar main sequence at spectral type L2. We now discuss our plans to make the sample volume-complete so that population properties can be studied in a non-biased manner. We also plan to analyze the effects of variations in metallicity using spectroscopy, and link observational properties to known dynamical masses.

This work is made possible by the NSF Astronomy and Astrophysics Postdoctoral Fellowship Program through grant AST-1400680. Additional support comes from NSF grants AST-0908402, AST-1109445, AST-1412026, and from the Carnegie Institution for Science. Observations are made possible in part by the SMARTS Consortium.

Author(s): Sergio B. Dieterich[1], Alan P. Boss[1], Alycia J. Weinberger[1], Todd J. Henry[3], Jennifer G. Winters[2], Wei-Chun Jao[2]
Institution(s): *1. Carnegie Inst. of Washington, 2. Georgia State University, 3. RECONS*
Contributing team(s): RECONS

138.34 – Fundamental Parameters for an Age Calibrated Sequence of the Lowest Mass Stars to the Highest Mass Planets

We combine optical, near-infrared and mid-infrared spectra with all-sky survey photometry to construct nearly complete spectral energy distributions (SEDs) for 135 field age (>1 Gyr) and 38 young (10-150 Myr) ultracool (M6-T8) dwarfs. This range of spectral types includes very low mass stars, brown dwarfs, and planetary mass objects, providing bulk properties of an age-calibrated sample across both the hydrogen and deuterium burning minimum masses. We use parallaxes to determine precise bolometric luminosities (L^{bol}) that account for over 97 percent of the emergent flux for most objects. Where parallaxes are not available for low gravity objects, we determine kinematic distances based on membership in nearby young moving groups. Radius estimates from evolutionary models then give semi-empirical effective temperatures (T^{eff}) for the full range of young and field age late-M, L and T dwarfs. We attempt to disentangle the effects of highly degenerate physical parameters such as T^{eff}, surface gravity and clouds on spectral morphology with age sensitive color-magnitude and temperature-spectral type relationships. We also characterize the redistribution of flux from the NIR to the MIR in young L dwarfs and identify a systematic T^{eff} difference of ~300K from field age objects of the same spectral type. Determination of fundamental parameters independent of model atmospheres for this large and diverse age-calibrated sample places important constraints on the atmospheres and evolution of substellar objects.

Author(s): Joe Filippazzo[4], Emily L. Rice[3], Jacqueline K. Faherty[2], Michael Cushing[6], Kelle L. Cruz[5], Adric R. Riedel[1], Mollie Van Gordon[1]
Institution(s): *1. American Museum of Natural History, 2. Carnegie Department of Terrestrial Magnetism, 3. College of Staten Island, 4. CUNY Graduate Center, 5. Hunter College, 6. University of Toledo*
Contributing team(s): BDNYC

138.35 – Identification of Young Ultracool Dwarf Candidates from the BOSS Ultracool Dwarf (BUD) Sample

We present an analysis of youth indicators on the BOSS Ultracool Dwarf (BUD) of 12,000 M7-L8 dwarfs. These ultracool dwarfs were selected based on Sloan Digital Sky Survey (SDSS) spectroscopic and photometric data that were cross-matched to near-infrared photometry from the Two Micron All Sky Survey (2MASS) and the Wide-Field Infrared Survey Explorer (WISE). The focus of this study was to identify young (less than 700-million-year-old) ultracool dwarfs to better understand the distribution of young brown dwarfs in the field population. Red J-K^S colors as well as gravity sensitive spectral features, particularly weak Na I and K I doublets, FeH, Tio, VO, Rb, and Cs as well as enhanced H-alpha were used as youth diagnostics. We present our initial results , including 12 possible young ultracool dwarfs near the Orion star forming region which exhibit particularly weak Na I and K I doublets as well as enhanced H-alpha in their SDSS spectra.

Author(s): Amber Medina[1], Sarah J. Schmidt[1], Jennifer Johnson[1]
Institution(s): *1. The Ohio State University*

138.36 – Searching for Proper-Motion Brown Dwarfs in the Mid-IR

We have carried out a sensitive search for infrared proper-motion sources in the 10 square degree Spitzer/IRAC Bootes field with imaging that covers a ten-year timespan. With the latest epoch, from the Decadal IRAC Survey of Bootes (DIBS), a Cycle 10 Spitzer program, we have identified more than 2000 4.5 micron sources with proper motions in excess of 3-sigma significance, between 0.05 and 0.7 arcsec/yr. Based on the extensive multiband photometry available for our sources, we estimate rough types and distances. A fraction of these dim, nearby sources are brown dwarfs--objects which are typically very difficult to detect at visible wavelengths because they are optically dim. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Author(s): Zequn Li[1], Matthew Ashby[1], Joseph L. Hora[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics*

138.37 – Untangling Physical Parameters of Warm Brown Dwarfs

Warm brown dwarfs offer insights into exoplanetary atmospheres because they have temperatures similar to those of hot gas giant exoplanets. However, fitting synthetic spectra to low-resolution data often produces unreasonable physical parameters (effective temperature, surface gravity, cloud parameters, etc) for brown dwarfs. Given that low- and moderate-resolution NIR data are widely available for M and L dwarfs, and that JSWT will provide moderate-resolution spectra of hot jupiters, it is important to know how well low- and medium-resolution data can constrain physical parameters given current models. We compare low- and moderate-resolution SpeX spectra (R=120-2000) for M and L dwarfs to synthetic spectra from several atmospheric models, including the Gaia-Dusty, BT-Settl, and Marley models. We employ Markov-Chain Monte Carlo (MCMC) methods to robustly fit the models to data. MCMC provides the full posterior probability distribution, illustrating any multi-modality or correlations between parameters. We present results showing how this method provides more realistic uncertainties on effective temperature, surface gravity, and cloud parameters of M and L dwarfs at low- and moderate- resolution. We also show the extent of model-to-model differences in these paramter estimates. Finally, we present an open-source code for fitting grids of synthetic spectra to data - we invite others to use it for their own studies, and we welcome conversations about and involvement in future development.

Author(s): Kelle L. Cruz[2], Stephanie Douglas[1]
Institution(s): *1. Columbia U., 2. Hunter College, CUNY*
Contributing team(s): BDNYC

138.38 – The Young and the Red: A study of the ages and evolution of brown dwarfs.

We present a study of nearby red L dwarfs with spectroscopy, photometry, and parallaxes taken from our upcoming paper. With the results of this study, we deliver new insights into the age-, luminosity- and temperature-related trends in L dwarf evolution. We can also provide new developments in the study of the tangential velocity distribution of nearby stars, and their relation to youth. Overall, we have greatly increased the diversity of brown dwarf members of nearby young moving groups.

Author(s): Adric R. Riedel[2], Jacqueline K. Faherty[1], Kelle L. Cruz[3], Emily L. Rice[2]
Institution(s): *1. Carnegie Institute of Washington, 2. CUNY/College of Staten Island, 3. CUNY/Hunter College*
Contributing team(s): BDNYC

138.39 – Medium-resolution Analysis of Unusually Red and Blue L Dwarfs

We present an analysis of medium-resolution NIRSPEC (R~25,000) and SpeX cross-dispersed (R~2,000) J band spectra for a sample of unusually red and blue L dwarfs. Some red L dwarfs are low surface gravity, young objects whose spectra present weak Na I doublets and FeH absorption bands, but strong VO features (Cruz et al. 2009). Some blue L dwarfs are subdwarfs with low metallicity spectral features such as greater H^2 absorptions, stronger metal hydride bands, and enhanced TiO absorption (Burgasser et al. 2008c). Our sample of interest is composed of L dwarfs that present J-K^S color deviations that are greater than 0.4 mag and that lack the spectral features usually accompanying these extreme colors. To analyze the cause of the unusual color and compare them, we have been performing multi-resolution analysis across our sample. We measured equivalent widths and full width at half maximum of KI lines at 1.1773 µm, 1.1776 µm, 1.2436 µm, and 1.2525 µm for objects with high-resolution NIRSPEC data. These spectral line measurements in high resolution have been implemented with medium resolution data fitting. The coefficients from these polynomial fits to the pseudo-continuum have been employed in investigating the differences between standard L dwarf subtypes and unusually red and blue L dwarfs. We expect a trend in the values of the coefficients for the 3rd and 4th order polynomial fits when plotted for each L subtype versus the average J-K^S colors. The result of this analysis will allow us to further probe into the underlying physical properties of L dwarfs that cause the extreme J-K^S colors that we have been exploring.

Author(s): Sara Camnasio[3], Munazza Khalida Alam[3], Emily L. Rice[2], Kelle L. Cruz[3], Jacqueline K. Faherty[1], Gregory N. Mace[4], Emily Martin[1], Sarah E. Logsdon[4], Ian S. McLean[4]
Institution(s): *1. Carnegie Institution of Washington, 2. CUNY College of Staten Island, 3. CUNY Hunter College, 4. UCLA*
Contributing team(s): BDNYC

138.40 – High-Resolution Spectral Analysis of KI Lines in Unusually Red & Blue L Dwarfs

L dwarfs have a range of near-infrared colors at a given optically-defined spectral subtype. L dwarfs of the same spectral subtype are thought to have similar surface temperatures, and the presence of extreme near-IR colors in some L dwarfs suggests that parameters other than temperature influence their spectra. For some of these objects, diagnostic spectral features indicate the cause of extreme near-IR color. Blue L dwarfs that have low metallicity spectral features, called subdwarfs, are known to have old ages. Red L dwarfs that have low surface gravity spectral features are known to be young. The spectra of some blue and red L dwarfs do not show evidence for low metallicity or low gravity. This project investigates the cause of extreme color in these photometric outliers by comparing spectral line measurements for a sample of red, blue, and standard L dwarfs to elucidate their underlying atmospheric and physical properties. We use KI lines to make these comparisons because they are pressure-broadened and therefore sensitive to temperature, gravity, and metallicity. We use high-resolution NIRSPEC J band spectra to measure equivalent widths, line depths, and full width at half maximum (FWHM) of KI lines at 1.1773 um, 1.1776 um, 1.2436 um, and 1.2525 um. Consistent with trends in the literature, our preliminary results suggest that unusually blue L dwarfs are field age or older.

Author(s): Munazza Khalida Alam[3], Sara Camnasio[3], Emily L. Rice[2], Kelle L. Cruz[3], Jacqueline K. Faherty[1], Gregory N. Mace[4], Emily Martin[4], Sarah E. Logsdon[4], Ian S. McLean[4]
Institution(s): *1. Carnegie Institution of Washington , 2. CUNY College of Staten Island, 3. CUNY Hunter College, 4. UCLA*
Contributing team(s): Brown Dwarfs in New York City (BDNYC)

138.41 – Simulating Unresolved Binary Brown Dwarfs for Cameras on the Hubble Space Telescope

Identification of binary brown dwarf (BD) systems with small separations can be difficult because of the inability to resolve each component according to the Rayleigh criterion and the possibility of the secondary BD being much fainter than the primary BD. Using models of the point spread function (PSF) created for several filters and cameras on the Hubble Space Telescope (HST), we have developed a technique to determine the probability that an apparently single BD observed with HST may actually be an unresolved binary. To test the detection limits of this method, we have developed code to produce simulated binary systems for several HST cameras and their filters. The simulated data cover the full range of parameter space (delta_magnitude, separation, position angle, background noise, etc.) that we might expect to encounter when searching for binary brown dwarfs in real HST data. With the simulated data, we find that we can positively identify binary brown dwarf systems in the HST archives with separations that are much smaller than the Rayleigh criterion. Our simulations also place upper limits on the separation and flux of undetected secondary companions for apparently single BD in the HST archives.

Author(s): Douglas B. Gardner[1], Thomas E. Stephens[1], Denise C. Stephens[1], Elora N. Salway[1]
Institution(s): *1. Brigham Young University*

138.42 – Extended Baseline Photometry of Rapidly Changing Weather Patterns on the Brown Dwarf Binary, Luhman-16

Luhman-16 (WISE~J1049-0053) was recently discovered to be a nearby (~2pc) brown dwarf binary which exhibits an high degree of photometric variability (delta m~0.1 mag). This is thought to be due to the evolution of ``cloud'' features on the photosphere, but Luhman-16 was found to show unusually rapid changes, possibly resulting from fast-evolving ``weather''. This target is of particular interest because it consists of a co evolutionary pair of brown dwarfs spanning the transition between L and T types (L7.5 and T0.5), which are expected to be associated with changes in cloud surface coverage. Being comparatively bright (I~15.5mag), the target is well suited for observation with the new LCOGT network of 1m telescopes. We present long-time baseline photometric observations from two of LCOGT's southern hemisphere sites, which were used in tandem to monitor Luhman-16 for up to 13.25hrs at a time (more than twice the rotation period), for a total of 42 days in SDSS-i' and Pan-STARRS-Z filters. We use this dataset to characterize the changing rotational modulation, which may be explained by the evolution of cloud features at varying latitudes on the surfaces of the two brown dwarfs.

Author(s): Rachel Street[1]
Institution(s): *1. Las Cumbres Global Telescope Network, Inc.*

138.43 – Brown dwarf science at Project 1640: the case of HD 19467 B

Project 1640 is an extreme-AO, coronagraphic, hyperspectral direct-imaging instrument designed to characterize substellar companions in the giant planet to brown dwarf mass regime. It also plays an important role in the TRENDS survey, which targets solar-type stars with Doppler accelerations known to be caused by brown dwarf-sized companions. A recent highlight from TRENDS is HD 19467 B -- this is currently the only directly-imaged benchmark T dwarf known to induce a measurable Doppler acceleration around its host. J- and H-band spectra taken by the Project 1640 integral field spectrograph were fitted against SpeX/IRTF T dwarf standards and synthetic spectra from BT-Settl atmospheric models. These classified HD 19467 B as a T7.5±1 brown dwarf with an effective temperature of T^{eff} = 800±50 K. However, there is significant disagreement in the mass and age predicted from model-derived surface gravities and temperatures, with the mass and age limits derived from radial velocity data and stellar isochrones. We expect that new data from the ongoing TRENDS survey will help shed light on these discrepancies and improve our understanding of brown dwarf atmospheres in high mass ratio systems.

Author(s): Jonathan Aguilar[5], Justin R. Crepp[8], Emily L. Rice[3], Laurent Pueyo[7], Aaron Veicht[2], Ricky Nilsson[2], Rebecca Oppenheimer[2], Sasha Hinkley[1], Douglas Brenner[2], Gautam Vasisht[4], Eric Cady[4], Charles A. Beichman[6], Lynne Hillenbrand[1], Thomas Lockhart[4], Christopher T. Matthews[8], Lewis C. Roberts[4], Anand Sivaramakrishnan[7], Remi Soummer[7], Chengxing Zhai[4], Paige Giorla[3]
Institution(s): *1. California Institute of Technology, 2. American Museum of Natural History, 3. College of Staten Island, 4. Jet Propulsion Laboratory, 5. Johns Hopkins University, 6. NASA Exoplanet Science Institute, 7. Space Telescope Science Institute, 8. University of Notre Dame*

138.44 – T Dwarfs Model Fits for Spectral Standards at Low Spectral Resolution

We present model fits to the T dwarf spectral standards which cover spectral types from T0 to T8. For a complete spectral range analysis, we have included a T9 object which is not considered a spectral standard. We have low-resolution (R~120) SpeX Prism spectra and a variety of higher resolution (R~1,000-25,000) spectra for all nine of these objects. The synthetic spectra are from the BT-SETTL 2013 models. We compare the best fit parameters from low resolution spectra to results from the higher resolution fits of prominent spectral type dependent features, where possible. Using the T dwarf standards to calibrate the effective temperature and gravity parameters for each spectral type, we will expand our analysis to a larger, more varied sample, which includes over one hundred field T dwarfs, for which we have a variety of low, medium, and high resolution spectra from the SpeX Prism Library and the NIRSPEC Brown Dwarf Spectroscopic Survey. This sample includes a handful of peculiar and red T dwarfs, for which we explore the causes of their non-normalcy.

Author(s): Paige Giorla[1], Emily L. Rice[1], Stephanie T. Douglas[2], Gregory N. Mace[3], Ian S. McLean[3], Emily C. Martin[3], Sarah E. Logsdon[3]
Institution(s): *1. College of Staten Island, 2. Columbia University, 3. UCLA*

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139 – The Emerging Multiwavelength View of Planetary Nebulae Posters

139.01 – ChanPlaNS: Investigating the Diffuse X-ray Emission within Compact Planetary Nebulae

We present highlights of results from the Chandra Planetary Nebula Survey (ChanPlaNS), the first comprehensive X-ray survey of planetary nebulae (PNe) in the solar neighborhood (i.e., within ~ 1.5 kpc of the Sun). We are finding that diffuse X-ray emission is restricted to compact (R^{neb} <~0.15 pc) nebulae; this characteristic size scale corresponds to a PN-shaping wind collision timescale of <~ 5 x 10^3 yr. Furthermore, we find that all ChanPlaNS PNe that display diffuse X-ray emission have closed structures and characteristic nebular densities n^e >~ 1000 cm^{-3}, while older, lower-n_e nebulae remain difficult to detect. This relationship between nebular density and energetic wind interactions suggests that optical spectroscopy of density-sensitive lines (e.g., [O II], [S II]) can be used to establish whether a PN might be in an active wind-collision phase. Of the diffuse X-ray detections, 100% (5/5) of PNe with [WR]-type central stars (CSPNe) within ~ 1.5 kpc have detected. We present preliminary results from 3D structural reconstructions of PNe that are designed to investigate the apparent systematic differences between the diffuse X-ray emission morphologies of [WR] and non-[WR] CSPNe, as well as the possibility of enhanced X-ray absorption due to photoionized and neutral nebular gas.

Author(s): Marcus Freeman[1], Rodolfo Montez[2], Joel H. Kastner[1]

Institution(s): *1. Rochester Institute of Technology, 2. Vanderbilt University*
Contributing team(s): ChanPlaNS Team

139.02 – Cospatial Longslit UV-Optical Spectra of Ten Galactic Planetary Nebulae with HST STIS: Description of observations, global emission-line measurements, and empirical CNO abundances

This poster describes details of HST Cycle 19 (program GO 12600), which was awarded 32 orbits of observing time with STIS to obtain the first *cospatial* UV-optical spectra of 10 Galactic planetary nebulae (PNe). The observational goal was to measure the UV emission lines of carbon and nitrogen with unprecedented S/N and wavelength and spatial resolution along the disk of each object over a wavelength range 1150-10270 Ang . The PNe were chosen such that each possessed a near-solar metallicity but the group together spanned a broad range in N/O. This poster concentrates on describing the observations, emission-line measurements integrated along the entire slit lengths, ionic abundances, and estimated total elemental abundances using empirical ionization correction factors and the ELSA code. Related posters by co-authors in this session concentrate on analyzing CNO abundances, progenitor masses and nebular properties of the best-observed targets using photoionization modeling of the global emission-line measurements [Henry et al.] or detailed analyses of spatial variations in electron temperatures, densities, and abundances along the sub arcsecond resolution slits [Miller et al. & Shaw et al.]. We gratefully acknowledge AURA/STScI for the GO 12600 program support, both observational and financial.

Author(s): R. J. Dufour[3], K. B. Kwitter[6], R. A. Shaw[2], B. Balick[5], R. B. C. Henry[4], T. R. Miller[4], R. L. M. Corradi[1]
Institution(s): *1. IAC, 2. NOAO, 3. Rice University, 4. Univ. of Oklahoma, 5. Univ. of Washington, 6. Williams College*

139.03 – New CNO Elemental Abundances in Planetary Nebulae from Spatially Resolved UV/Optical Emission Lines

We obtained *HST*/STIS long-slit spectra spanning 0.11 to 1.1 μm of co-spatial regions in 10 Galactic planetary nebulae (Dufour, et al., this conference), of which six present substantial changes in ionization with position. Under the assumption that elemental abundances are constant within these nebulae (but exterior to the wind of the central star), these spectra present a unique opportunity to examine the applicability of common ionization correction factors (ICFs) for deriving abundances. ICFs are the most common direct method in abundance analysis for accounting for unobserved or undetected ionization stages in nebulae, yet most ICF recipes have not been rigorously examined through modeling nor empirically tested through observation. In this preliminary study, we focussed on the astrophysically important abundances of C and N where strong ionic transitions are scarce in optical band, but plentiful in the satellite UV. We derived physical diagnostics (extinction, T^{e}, N^{e}) and ionic abundances for the species of interest at various positions along the slit for each PN. We compared the elemental abundances derived from direct summation of the ionic abundances in the UV and optical to those derived using only optical emission, but corrected using standard ICFs. We found that the abundances were usually in good agreement, but there were significant exceptions. We also found that setting upper limits on emission from undetected ions was sometimes helpful in constraining the correction factors. Work is underway to construct photoionization models of these nebulae (see Miller, et al., this conference) to address the question of why ICFs are sometimes inaccurate, and to explore other ICF recipes for those cases.

Support for Program number GO-12600 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555.

Author(s): Richard A. Shaw[2], Karen B. Kwitter[6], Richard B. C. Henry[4], Reginald J. Dufour[3], Bruce Balick[5], Romano Corradi[1]
Institution(s): *1. IAC, 2. NOAO, 3. Rice University, 4. University of Oklahoma, 5. University of Washington, 6. Williams College*

139.04 – Geometry of the Dusty Mass Loss from Low- to Intermediate Mass Stars

Low- to intermediate-mass stars lose a significant fraction of their mass while they are on the asymptotic giant branch (AGB). The material ejected from the stellar photosphere forms a circumstellar envelope in its surroundings and this mass loss is considered to determine the final stages of their evolution. By studying the layers of the circumstellar envelope we are actually studying the footprint of the mass-loss history.
AKARI is the first Japanese satellite dedicated to infrared astronomy, was launched in 2006, and in 2011, ended science operations. The main objective was to perform an all-sky survey with better spatial resolution and wider wavelength coverage than IRAS (Neugebauer et al. 1984), mapping the entire sky in six infrared bands from two focal plane instruments. Inserted within the continuous survey operation is the slow scan pointed observation mode. The MLHES (excavating Mass Loss History in Extended dust shells of Evolved Stars) data set was observed within this mode and used the FIS (Far Infrared Surveyor) focal plane instrument. The FIS detector has four photometric bands between 50 – 180 μm. Far-IR radiation is optically thin and thus the surface brightness distribution of the target circumstellar shells allows us to see the whole nebula volume along the line of sight.

MLHES is the largest data set to date for the analysis of circumstellar dust around evolved low- to intermediate- mass stars and was designed to systematically investigate some of the open questions surrounding circumstellar dust while utilizing the benefits of far-IR radiation. What is the time evolution of the mass-loss rate? What is the geometry of the mass-loss process? How do the characteristics of the progenitor star effect the mass-loss?
The work presented here focuses on the characterization of the geometric properties of the PSF subtracted images of the circumstellar material. By subtracting the PSF, we are able to obtain an undisturbed picture of the shape of the mass loss and thus more accurately quantify the circumstellar distribution of the dust. We share our findings pertaining to the overall trends determined from this geometric analysis.

Author(s): Rachael Tomasino[3], Toshiya Ueta[3], Issei Yamamura[1], Satoshi Takita[1], Hideyuki Izumiura[2]
Institution(s): *1. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2. Okayama Astrophysical Observatory, National Astronomical Observatory of Japan, 3. University of Denver*

139.05 – Spatially Resolved Far-Infrared Spectroscopic Analysis of Planetary Nebulae

Planetary Nebulae (PNs) are late-life intermediate-mass (1-8 solar mass) stars that have shed their outer layers. A wide variety of morphologies and physical conditions is seen in PNs, but a complete understanding of what causes these various conditions is still needed. Spatially resolved far-infrared spectroscopic analysis has been performed on 11 targets using both PACS and SPIRE instruments on the Herschel Space Observatory as part of the Herschel Planetary Nebula Survey (HerPlaNS). Far-IR lines probe the ionized parts of the nebulae and suffer less extinction than optical lines, so observations in the far-IR are critical to our complete understanding of PNs. Because PNs are extended objects, the spectral mapping capabilities of both PACS and SPIRE allow us to better understand the spatial variations of the objects by tracking line strengths as a function of location within the nebula. The far-IR lines detected in this study can be used as tracers of electron density and electron temperature which are critical parameters in radiative transfer modeling of PNs. Information on atomic, ionic, and molecular lines identified in these 11 targets will be presented.

Author(s): Rebecca Rattray[1], Toshiya Ueta[1]
Institution(s): *1. University of Denver*

139.06 – *HST* Search for Planetary Nebulae in Local Group Globular Clusters

If every star of about solar mass produces a planetary nebula (PN) near the end of its life, there should be several dozen PNe in the globular clusters (GCs) of the Local Group. However, ground-based surveys of Milky Way GCs have revealed only 4 PNe. A converse argument is that it is likely that the remnants of stars now evolving in ancient GCs leave the AGB so slowly that any ejected PN dissipates long before the star becomes hot enough to ionize it. Thus there should not be *any* PNe in Milky Way GCs--but there are four! It has been suggested that these PNe are the result of binary mergers of binary stars within GCs, i.e., that they are descendants of blue stragglers. To explore these issues and extend them beyond the Milky Way, I carried out a Snapshot imaging survey of GCs throughout the Local Group with the *Hubble Space Telescope*. Observations were made with the WFPC2 camera in 2007-2008, and with WFC3 in 2009-2011. Frames were obtained in a narrow-band [O III] 5007 filter and in a broad V filter (F555W). In this filter combination, a PN will have a comparable signal in both bandpasses, but stars will be much brighter in the V filter. I surveyed 41 GCs in M31, 4 in M33, 8 in the Magellanic Clouds, 2 in Fornax, and 1 each in NGC 6822, WLM, and NGC 147. Only one candidate PN was found, in the M31 GC B086. My results appear to be consistent with a ground-based spectroscopic survey for PNe in the M31 GCs by Jacoby et al. (2013), which found only 3 PN candidates in 274 clusters. PNe are very rare in GCs, but a few do exist, and they may require binary interactions for their formation.

Author(s): Howard E. Bond[1]
Institution(s): *1. Pennsylvania State University*

139.07 – Exploring the Late Evolutionary Stages of Sun-like Stars with LSST

We examine how the Large Synoptic Survey Telescope (LSST) can be used to test and advance our understanding of the late stages of stellar evolution for low- to intermediate-mass stars. From the tip of the asymptotic giant branch (AGB) to the planetary nebulae (PNe) phase, we establish the limiting volume through which LSST will be able to detect stars in these brief but luminous phases of stellar evolution. We consider ugrizy color-magnitude and color-color diagrams that can be used to distinguish these types of evolved stars. We demonstrate the potential for LSST to advance studies that explore the period-luminosity relation of AGB stars, the influence of binary companions on the shaping of mass loss, and pulsational instabilities that potentially probe the composition of hot pre-white dwarf cores. We argue that LSST will directly confront the binary hypothesis on the origin of planetary nebulae by providing photometric and temporal constraints on binary companions to the central stars and by vastly expanding the number of known planetary nebulae.

Author(s): Margaret Morris[1], Rodolfo Montez[2]
Institution(s): *1. Brandeis, 2. Vanderbilt University*

139.08 – Multiwavelength Spatial and Spectral Study of Shock Conditions in the Young Planetary Nebula NGC 7027

We present analysis of Chandra X-ray Observatory (CXO) observations of the young planetary nebula NGC 7027 obtained ~14 years apart (in Cycles 1 and 15). There is compelling evidence that the X-ray emission from NGC 7027, originally detected in Cycle 1 (Kastner et al. 2001), arises from highly collimated outflows that are actively disrupting and reshaping the nebula. Our spatial-spectral analysis of the CXO observations yields evidence for two distinct temperature regimes in the X-ray emitting plasmas within NGC 7027, possibly resolving the ambiguity emerging from previous, discrepant modeling results. Analysis of archival multiwavelength narrowband imaging performed by the Hubble Space Telescope yields corroborating evidence for such a multiple-shock model. The presence of these shocks may help explain the complex chemistry within NGC 7027, including the formation of water in the nebula. Finally, with a 14 year baseline between the two CXO observations, we attempted to measure the expansion of the X-ray emitting region, and we compare this result to previous expansion measurements of NGC 7027.

Author(s): Rodolfo Montez[2], Joel H. Kastner[1]
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140 – Supernova, SNe Remnants and Planetary Nebulae Posters

140.01 – Multi-epoch, Ultraviolet Spectroscopy of Type Ia Supernovae

Type Ia supernovae (SNe Ia), having large and standard luminosities, are our primary dark energy probe. Although we believe that SNe Ia are produced by white dwarfs (WDs) in binary systems, the type of companion star is still unclear. Using a SN as a backlight, we can probe the gas along the line-of-sight to a SN Ia, including possible circumstellar gas from the companion star. For a handful of SNe Ia, repeated measurements of the narrow Na D doublet have shown variable absorption that we interpret as the recombination of circumstellar Na atoms after being ionized by the initial UV SN flash. This is perhaps the best evidence that at least some SNe Ia have a main-sequence or red-giant companion. Using Hubble Space Telescope ultraviolet spectroscopy, we probe several additional species with varying ionization potentials for 8 SNe Ia. Since these features have different ionization potentials from species seen in the optical, they probe new physical regions of the circumstellar system. Although these features can potentially reveal previously hidden circumstellar gas, we do not detect any variable features in our best examples, indicating that these systems had no circumstellar gas or that the gas was particularly distant.

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140.02 – A 3D Kinematic Study of the Northern Ejecta "Jet'' of the Crab Nebula

We present [O III] 4959,5007 emission line spectra (FWHM = 40 km/s) of the Crab Nebula's northern ejecta 'jet'. These data, along with a recent [O III] image of the Crab, are used to build 3-dimensional models of the jet and adjacent remnant nebulosity to better understand the jet's properties and possible formation. We find that the jet's radial velocities range from -190 to +480 km/s with transverse velocities from 1600 to 2650 km/s from base to tip. The jet appears virtually hollow in [O III] emission with the exception of some material at the jet's base where the it connects with the remnant. Our 3D reconstructions indicate that the jet is elliptical in shape and slightly funnel-like rather than a straight cylindrical tube as previously thought. At the base of the jet we find evidence for a significant opening or "channel" in the Crab's main nebula shell. Our analysis of the jet's expansion properties and location supports the theory that the jet may simply represent the highest velocity component of the Crab's N-S bipolar expansion.

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140.03 – SweetSpot Data Release 1: 70 Type Ia Supernovae in the Near Infrared in the Nearby Hubble Flow

SweetSpot is an NOAO Survey program from 2012B-2015A that is observing 150 Type Ia supernovae (SNeIa) in the Hubble flow to obtain reliable NIR luminosities free from peculiar-velocity confusion and the uncertainties of dust.

Our full SweetSpot program will (1) extend the NIR Hubble diagram past currently available samples; (2) quantitatively demonstrate the degree to which SNeIa are robust standard candles in the NIR; (3) provide key insights about the color evolution and intrinsic properties of SNeIa and their host galaxies; and (4) establish a well-calibrated low-redshift anchor for future NIR supernova surveys from JWST, Euclid, and WFIRST/NEW. By the end of the survey we will have measured the relative distance to a redshift of z~0.05 to 1%. Nearby Type Ia supernova (SN Ia) observations such as these will test the standard nature of SNeIa in the restframe NIR, allow insight into the nature of dust, and provide a critical anchor for future cosmological SN Ia surveys at higher redshift.

We here present our Data Release 1 which includes 70 supernovae observed from 2011B-2013B. Along with an updated NIR Hubble diagram combining these SNeIa with those from the literature, we explore the relationships between SNIa

NIR luminosity and properties of the host galaxy.

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140.04 – Systematic X-ray Mapping of Metal-Rich Ejecta in Bright Supernova Remnants.

We apply our adaptive mesh technique coupled with simple automated NEI spectral modelings for archival Chandra data of several bright supernova remnants (SNRs) DEML71, N132D, E0102-72.3, G292.0+1.8, G299.2-2.9, Kepler, and Tycho. Based on the chi-square distributions of these model fits, we identify regions in which metal elements are enhanced compared to the circumstellar/interstellar abundances, and thus map over-abundant ejecta regions throughout these SNRs. With these maps we also reveal spatial structures of the individual ejecta elements O, Ne, Mg, Si, and Fe. We find that this simple chi-square mapping is effective to study spatial distributions of ejecta elements without performing extensive spectral model fits for individual sub-regions in SNRs. These ejecta maps may also be useful to reveal global structures such as the contact discontinuity. We present our preliminary results demonstrating the utility of this method.

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140.05 – Observing Supernovae and Supernova Remnants with JWST

The James Webb Space Telescope (JWST) will enable near- and mid-infrared studies of supernovae (SN) and supernova remnants (SNR) in the Milky Way and galaxies throughout the local universe and to high redshift. JWST's instrumentation provides imaging, coronography, and spectroscopy (R<3000) over the wavelength range 1-29 microns. The unprecedented sensitivity and angular resolution will enable spectroscopic study of new and recent supernovae, including molecule and dust formation, in galaxies at least out to 30 Mpc, and imaging to much greater distances. The Target of Opportunity response time can be as short as 48 hours, enabling quick follow-up observations of important SN events. JWST will be ideal for the study of Galactic and Magellanic Clouds supernova remnants, particularly young remnants with hot dust. Its high angular resolution (0.07" at 2 microns, 0.7" at 20 microns) will allow direct comparison between the IR, optical, and X-ray morphologies, identifying sites of dust emission in both the ejecta and the shocked ISM unresolved by previous IR telescopes. There is a rich spectrum of atomic lines (H, He I, [Si I], [Fe II], [Ni I-III], [Co II-III], [S III-IV], [Ar II-III], [Ne II, III, V], [O IV]) and molecules (CO, SiO, H2) of importance for SN and SNR studies. JWST is a large aperture (6.5m), cryogenic, infrared-optimized space observatory under construction by NASA, ESA, and CSA for launch in 2018. The JWST observatory will be placed in an Earth-Sun L2 orbit by an Ariane 5 launch vehicle provided by ESA. The observatory is designed for a 5-year prime science mission, with consumables for 10 years of science operations. The first call for proposals for JWST observations will be released in 2017.

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140.06 – Supernova Host Galaxy Identification in the Dark Energy Survey

Using catalog data from the Dark Energy Survey (DES), including information about galaxy position, shape, and photometric redshifts, we develop and test methods for matching supernovae to their host galaxies. Host-galaxy matching is a crucial step for modern supernova (SN) surveys, which, in the absence of SN spectroscopy to determine SN types, rely mainly on host galaxy spectra to obtain redshifts. In addition, SN luminosities are known to correlate with host galaxy properties. Therefore, reliable identification of host galaxies is essential for cosmology and SN science.

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Contributing team(s): Dark Energy Survey

140.07 – The LCOGT Supernova Key Project

I present first results from the Las Cumbres Observatory Global Telescope Network (LCOGT) Supernova Key Project. LCOGT is a network of 11 robotic one and two meter telescopes spaced around the globe with imaging and spectroscopic capabilities. The supernova key project is a 3 year program to obtain lightcurves and spectra of at least 450 supernovae. About half are expected to be core-collapse supernovae, and half thermonuclear. We will start light curves and spectroscopy within hours of discovery, and focus on those SNe caught soon after explosion. The goals are fivefold: (1) observe supernovae soon after explosion to search for signs of their progenitors, (2) obtain a large homogeneous sample of supernovae for next generation cosmological studies, (3) obtain a large sample of supernovae for statistical studies comparing groups that are split into different populations, (4) obtain some of the first large samples of the recently discovered classes of rare and exotic explosions, (5) obtain the optical light curves and spectroscopy in support of studies at other wavelengths and using other facilities including UV observations, IR imaging and spectroscopy, host galaxy studies, high resolution spectroscopy, and late-time spectroscopy with large telescopes.

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Institution(s): *1. Las Cumbres Global Telescope Network, Inc.*
Contributing team(s): The LCOGT Supernova Key Project

140.08 – Diversity in Type Ibn supernovae

Type Ibn supernovae (SNe Ibn) are rare explosions of massive stars whose spectra exhibit narrow helium emission lines but no hydrogen lines. The narrow lines are thought to indicate interaction between the SN ejecta and circumstellar material from previous episodes of mass loss. Only a handful of SNe Ibn have been observed, and even fewer have been caught near the time of explosion. However, in the single case where a SN Ibn had multiple observations during the rising phase (iPTF13beo), its light curve exhibited a double peak. Here we present well-sampled multi-band photometry and spectroscopy of another SN Ibn, iPTF14aki, combining data from the intermediate Palomar Transient Factory (iPTF), the Las Cumbres Observatory Global Telescope Network (LCOGT), and the Public ESO Spectroscopic Survey of Transient Objects (PESSTO). We compare this object to other published and previously unpublised SNe Ibn and find that not all such events have a double-peaked light curve. We also discuss constraints on prior episodes of mass loss and the properties of the group as a whole.

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Contributing team(s): iPTF, PESSTO

140.09 – The Los Alamos Supernova Light Curve Project: Current Projects and Future Directions

The Los Alamos Supernova Light Curve Project models supernovae in the ancient and modern universe to determine the luminosities of observability of certain supernovae events and to explore the physics of supernovae in the local universe. The project utilizes RAGE, Los Alamos' radiation hydrodynamics code to evolve the explosions of progenitors prepared in well-established stellar evolution codes. RAGE allows us to capture events such as shock breakout and collisions of ejecta with shells of material which cannot be modeled well in other codes. RAGE's dumps are then ported to LANL's SPECTRUM code which uses LANL's OPLIB opacities database to calculate light curves and spectra. In this paper, we summarize our recent work in modeling supernovae.

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Contributing team(s): Los Alamos Supernovae Research Group

140.10 – A Census of Galactic and Extragalactic Double Supernovae

The observed properties of recently discovered Type IIn supernovae have challenged several long-held notions of stellar evolution. The largely unanticipated ability of massive, H-rich stars to eject sizable shells of material only a few years before a terminal explosion suggests that the poorly understood late phases of nuclear burning are likely to be unstable and may promote large-scale internal mixing of chemical layers.

The extent to which similar eruptive processes or other more exotic ones may occur in H-poor systems is not well constrained. Theory predicts scenarios wherein massive stars may produce more than one supernova-like outburst exhibiting emissions resembling those of Type I supernovae. Observationally, however, cases of H-poor eruptions and interactions with those eruptions are rare and/or debatable. A crucial confirmation of this scenario would be to observe multiple outbursts from the same system.

Motivated by the fact that the timescales between observable eruptions of H-poor massive stars may be much longer than those of Type IIn supernovae, we have completed an extensive search of historical records to look for "double supernovae" - i.e., supernovae of different names with coincident coordinates. The search successfully uncovered a handful of potential H-poor extragalactic double supernova systems, and we investigate the likelihood that these sets of events are physically linked. We also discuss scant-yet-tantalizing records of historical Galactic supernovae with suggestive evidence for rebrightening decades before and/or after the accepted explosion date.

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140.11 – Extragalactic Transients Discovered by the All-Sky Automated Survey for SuperNovae

Even in the modern era, only human eyes scan the entire optical sky for the violent, variable, and transient events that shape our universe. The "All Sky Automated Survey for SuperNovae" (ASAS-SN or "Assassin") is changing this by monitoring the extra-galactic sky down to V~17 mag every 2-3 days using multiple telescopes in the northern and southern hemispheres, hosted by Las Cumbres Observatory Global Telescope Network. The primary goal of ASAS-SN is a complete survey of bright, nearby supernovae (SNe), and since April 2013 ASAS-SN has discovered over 40 new Type-Ia SNe and over 15 new core collapse SNe, including roughly half of all the SNe currently visible with V<17 mag. ASAS-SN also discovers many other interesting extragalactic transients, the most exciting of which was the recent tidal disruption event (TDE) ASASSN-14ae at ~200 Mpc, the closest TDE ever discovered at optical wavelengths. The brightness of these nearby events allows detailed follow-up at many wavelengths. Here we present some of these data on recent ASAS-SN extragalactic transients.

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Contributing team(s): ASAS-SN Team

140.12 – Photometric Classification of Supernovae

Photometric classification of supernova cosmology samples currently depends on a limited number of core-collapse templates for both the classification and production of simulated test samples. We present the results of systematic template variations for both classification and simulation, using the sncosmo package to classify core-collapse supernovae simulated with the SNANA package. Our goal is to understand better the template uncertainties in future photometrically-classified supernova cosmology samples.

Author(s): Daniel Zimmerman[2], John Cunningham[2], Steve Kuhlmann[1], Ravi Gupta[1], Eve Kovacs[1], Harold Spinka[1]
Institution(s): *1. Argonne National Laboratories, 2. Loyola University Chicago*

140.13 – Building a Type Ia Supernova Model with SNfactory Spectrophotometric Time Series

We present a spectral time series model built using Nearby Supernova Factory (SNfactory) data. The spectrophotometric time series of over one hundred Type Ia supernovae in the data set offer much more information than photometric light curves for use in improving the standardization of Type Ia supernova magnitudes: spectrophotometric observations are interpolated onto a spectral time series surface using Gaussian processes, then Principal Component Analysis (PCA) is used to calculate spectral time series templates. The model is verified using K-fold cross-validation. We discuss the potential for using the PCA coefficients to lower the dispersion in standardized magnitudes on the Hubble diagram.

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Contributing team(s): The Nearby Supernova Factory

140.14 – Locating Type Ia Supernovae in HST Archival Data via an Artifical Neural Network

The rate of type Ia supernovae (SNe Ia) in the early universe puts important constraints on the nature of SN Ia progenitors, and had implications on dark energy. The precise limits on these rates are challenged by etendue and resolution factors which make real time investigations largely impractical, and the limited "per event" information which make archival studies seemingly inconceivable. There is, however, a wealth of information on high-redshift (z > 1) events from the GOODS, CANDELS, and other HST SN surveys, largely based on brightness constraints in relation to their host galaxy characteristics, that put high-z SNe Ia in a somewhat unique (and identifiable) parameter space. We describe our program to map these observed characteristics of SNe Ia and their host galaxies at z > 1 with artificial neural networks, and in turn use these trained networks to probabilistically locate undiscovered SNe Ia in MAST using the developing Hubble Source Catalog. We expect that the orders of magnitude increase in survey area will lead to a more statistically definitive sample, determining the exact trend in the cosmic SN Ia rate history in this crucial epoch.

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140.16 – The Search for Light Echoes of Historic SNe in the Southern Hemisphere with DECam

In recent years, light echoes of ancient SNe have been discovered with the Mosaic II cameras at the CTIO Blanco and KPNO Mayall telescopes. We have found light echoes in the LMC (Rest et al. 2005, 2008a) and near the historical Galactic events Cas A, Tycho, and Eta Car (Rest et al. 2008b, 2011a, 2012). However, searches for light echoes near the Kepler SN and SN 1006 have not yet been successful. We have started a search for light echoes in the southern hemisphere using DECam at the CTIO Blanco telescope. DECam is an excellent light echo detection system with its larger field of view and much faster read time compared to Mosaic II. This increases the efficiency of the search by more than a factor of 10, allowing us to cover significantly larger areas of the sky. We report on strategy, progress, current coverage, and first results of our project.

Author(s): Armin Rest[7], Federica Bianco[4], Ryan Chornock[5], Alejandro Clocchiatti[6], Ryan J. Foley[10], David James[1], Thomas Matheson[3], Gautham Narayan[3], Knut A. Olsen[3], Sean Points[1], Jose Luis Prieto[11], R. Chris Smith[1], Nathan Smith[9], Nicholas B. Suntzeff[8], Douglas L. Welch[2], Alfredo Zenteno[1]
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140.17 – Expansion of the Optical Remnant from Tycho's Supernova

Tycho's supernova remnant (SNR) is the expanding remnant from SN 1572, the penultimate Galactic supernova to have been recorded by contemporary observers. Its optical light is almost exclusively faint hydrogen Balmer emission around the periphery of the SNR, produced where fast nonradiative shocks encounter partly neutral preshock interstellar material. A variety of filaments, presumably thin sheets oriented tangentially, surround about one-third of the radio/X-ray shell. We have used CCD images, taken from KPNO over seven epochs from 1986 to 2009, to give the first optical expansion measurement of Tycho's SNR of the CCD era. Thirty filaments were identified and measured; the majority of them are at or near the remnant's outer rim and have proper motions from 0.19'' ± 0.01'' yr^{-1} to 0.26'' ± 0.02'' yr^{-1}. The associated expansion indices, defined as the ratio of the current expansion rate to the historical mean, range from 0.35 ± 0.03 to 0.52 ± 0.05. Our measurements are consistent with those from the classic study by Kamper & van den Bergh (1978, ApJ, 224, 851) for the same filaments, but the CCD measurements have higher precision, and we have measured several additional fainter filaments. For direct comparison with X-ray and radio measurements, we selected the subset of optical filaments lying exactly at the outer rim, as identified in Chandra and VLA images. Considering only these filaments, virtually all have expansion indices greater than 0.40, the Sedov value. In addition to the rim filaments, there are several seen in the interior (in projection) that have smaller proper motions; these may have been decelerated, and/or they could be directed non-tangentially. Our final epoch of images, taken from the 3.5m WIYN telescope in 2009, reveals previously undetected extremely faint optical emission surrounding well over half of the remnant shell. This newly detected faint emission agrees well with the limb as defined in X-ray and radio images.

This work has been supported in part by NSF grant AST-098566.

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140.18 – Constraining Cosmic Ray Origins Through Spectral Radio Breaks In Supernova Remnants

Supernova remnants (SNRs) have long been hypothesized to accelerate Galactic cosmic rays. The energy of accelerated protons can be measured if gamma-ray emission arises primarily from inelastic collisions with the surrounding gas through neutral pion decay. Here, we constrain the accelerated particle spectrum of both electrons and protons through modeling the non-thermal emission from radio to gamma rays. We analyze the synchrotron radiation spectrum of four bright radio sources detected by the Fermi Gamma-Ray Space Telescope: IC443, HB21, Cygnus Loop, and Puppis A. WMAP and Planck data were used to extend the radio spectrum to millimeter wavelengths to constrain the spectrum of relativistic electrons. We detect spectral breaks for SNRs: HB 21, IC443 and Puppis A. This complements the possible spectral breaks previously reported for WMAP data, and is consistent with spectral breaks found in the Planck collaboration microwave survey of SNRs. The presence of a break in the radio synchrotron spectrum for Puppis A is inconsistent with leptonic models of gamma-ray emission. In Cygnus Loop, the lack of a break is only consistent with hadronic models.

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140.19 – Treasure Hunting for Type Ia Supernova Ex-Companion Stars in the Large Magellanic Cloud

Observations of the central region of Type Ia supernova remnants (SNRs) can be used to place constraints on, and in some cases identify, the progenitor systems of nearby supernovae. This procedure has been employed in both the Milky Way and the Large Magellanic Cloud (LMC), with varying levels of success. We present an overview of all of our results for the four confirmed Type Ia supernova remnants in the LMC, including our new results on the stars in the central regions of LMC SNR 0505-67.9 (DEM L71) and LMC SNR 0509-68.7 (N103B), both of which have potential leftover ex-companion stars from single degenerate progenitor systems. Additionally, we present our recent spectrum of the nebulous region at the center of LMC SNR 0509-67.5 showing it to be a background galaxy unrelated to the supernova remnant, which was caused by a Type Ia supernova with a double degenerate progenitor 400 ± 50 years ago. In summary, we can identify the progenitor for one of the four LMC SNRs (LMC SNR 0509-67.5), we can place constraints on one additional progenitor system (LMC SNR 0519-69.0), and we find that all single and double degenerate progenitor systems are still viable options for the final two (LMC SNR 0505-67.9 and LMC SNR 0509-68.7).

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140.20 – Second Epoch Hubble Space Telescope Imaging of Kepler's Supernova Remnant

We have obtained new HST/WFC3 images of Kepler's supernova remnant in H-alpha (F656N) and [N II] (F658N) emission line filters. The bright radiative shocks in dense clumps are detected in both filters, while non-radiative shocks are seen as faint filaments only in the H-alpha image. Most of these Balmer filaments lie around the periphery of the remnant where the blast wave encounters partially neutral interstellar gas. We compare the new images with HST/ACS images taken nearly 10 years previously, and find that these filaments tracing the forward shock have moved 0.6"-0.9" between the two epochs. Assuming a distance of 4 kpc to the remnant, these proper motions correspond to shock velocities of 1160-1740 km/s, which are consistent with the published values, 1550-2000 km/s (e.g. Blair et al. 1991, ApJ 366, 484). We also find a few Balmer filaments with highly non-radial proper motions. In one particularly interesting case in the projected interior of the remnant, SE of the center, the shock appears to have wrapped around a sharp density enhancement and moved about 0.3" in the period between the observations.

The images allow us to study the evolution of the shock around an ejecta knot, which is punching through the remnant boundary in the northwest. The forward shock, visible as an arcuate Balmer filament, has moved about 1". At the trailing edges, the system of radiative knots formed by Rayleigh-Taylor instabilities have undergone significant changes - some knots have disappeared, new ones have appeared, and many have changed in brightness. Elsewhere in the remnant we find changes in the relative intensities of many small, bright knots over the 10 year baseline, indicating the short radiative lifetimes of these features.

This work has been supported in part by grant HST-GO-12885 to the Universities Space Research Association.

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140.21 – Old Supernova Dust Factory Revealed at the Galactic Center by SOFIA/FORCAST

Using FORCAST aboard the Stratospheric Observatory for Infrared Astronomy to image dust emission at 7.7, 19.7, 25.2, 31.5, and 37.1 µm, we reveal the presence of ~0.01 $M^{\odot}$ of warm (T^{d} ~ 100 K) dust near the center of the ~10^{4} yr-old Sgr A East supernova remnant (SNR) located at the Galactic center. We argue that the dust is associated with the SNR ejecta based on analysis of its thermal structure and possible heating sources such as collisions with energetic (T^{e} ~ 10^{7} K) electrons in the ejecta and/or radiative heating by the luminous central cluster (L^{cent} ~ 4 × 10^{7} $L^{\odot}$). Utilizing the DustEM code, we fit dust emission models to spectral energy distributions (SEDs) at six different locations throughout the dusty concentration that require both a very small (VSG; a ~ 0.001 µm) and a larger (LG; a ~ 0.04 µm) distribution of grains. The SED models reveal an enhanced VSG-to-LG mass ratio (~ 14 - 71%) relative to the Milky Way interstellar medium (~13%). In order to explain the location, size distribution, and morphology of the dust within the SNR, we propose a dust evolution scenario in which the SNR expands into an asymmetric, dense surrounding medium that leads to the preferential destruction of ejecta dust southwest of the center of the remnant. Since sputtering timescales in diffuse (n^{e} ~ 10 cm^{-3}) regions of the shocked ejecta are much shorter than the age of the remnant, we require the dust to have formed in dense (n^{e} ~ 150 cm^{-3}) ejecta knots. The speed of the reverse shock in the knots is slowed to a regime where sputtering timescales become longer than the remnant age and shattering via grain-grain collisions is efficient at redistributing mass from large to small grains, which explains the existence of the grains as well as the enhanced VSG-to-LG mass ratio. These results suggest that dust formation in ejecta knots, followed by grain-grain shattering may be a viable mechanism for explaining how dust survives the destructive processes of a supernova to be injected into the interstellar medium.

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140.22 – NuSTAR Observations of Hard X-ray Continuum from SN 1987A

We present hard X-ray observations with the NuSTAR satellite of the remnant of Supernova 1987A in the Large Magellanic Cloud. We detect continuum emission up to at least 25 keV. The continuum spectrum between 3 and 25 keV can be described by a power-law (Gamma = 3.43 +/- 0.02) or by the tail of a synchrotron spectrum from electrons with a power-law distribution with exponential cutoff at some Emax, or, somewhat more poorly, by a purely thermal shock model with a temperature of 3.27 +/- 0.03 keV. For the cutoff model, the peak photon energy emitted by electrons with Emax is 0.19 +/- 0.01 keV. We also detect a weak Fe K alpha line with centroid 6.6 +/- 0.05 keV, indicating that at least some of the emission above 6 keV is thermal. The purely thermal shock model requires an iron abundance at least a

factor of two lower than general LMC abundances. Unless much of the expected iron is in the form of dust grains, a substantial nonthermal contribution to the continuum is required. The spectrum we observe argues strongly against an attribution to a pulsar-wind nebula (PWN), requiring that any nonthermal component be produced by electrons accelerated in the remnant blast wave. In this case, however, the shock accelerating the electrons must be modified by cosmic-ray pressure, both to produce a concave-up spectrum from radio to X-rays, and to increase the magnetic field to at least 60 microG to allow shock acceleration to X-ray-emitting energies in only 27 years. Magnetic-field strengths of order 100 microG mean that Emax is between 10 and 100 TeV. Fluxes in both the 3 -- 8 keV and 8 -- 25 keV ranges are increasing, with a rate reasonably well described by an exponential with e-folding time about 5000 days, slower than earlier rates reported for either 3 -- 8 keV X-rays or for radio emission. The flux increase provides additional evidence against a PWN interpretation.

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Contributing team(s): NuSTAR Team

140.23 – A *Suzaku* Observation of the Galactic Supernova Remnant 3C 396 (G39.2-0.3)

We present an analysis of a *Suzaku* observation made of the Galactic supernova remnant (SNR) 3C 396 (G39.2-0.3). This SNR was detected by prior *Spitzer* IRAC and MIPS surveys of Galactic SNRs and the measured infrared colors for 3C 396 are consistent with emission from shocked ionized gas. A *Chandra* observation suggests that the X-ray emitting gas may have a significant ejecta component: in addition, the X-ray morphology is complex, with flux detected from an outer shell, portions of the interior and a central neutron star. To investigate the X-ray properties of 3C 396 more thoroughly, we have conudcted an 80 kilosecond observation of 3C 396 with *Suzaku*. The main goals of this observation are to determine if the X-ray emission from 3C 396 is indeed ejecta-dominated and if the X-ray emitting plasma of the SNR is overionized. Initial results will be presented and discussed.

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140.24 – Near-infrared HST [S III] Imaging of High-Velocity Ejecta in the Cassiopeia A Supernova Remnant

We present HST WFC3/IR images of the Cassiopeia A supernova remnant taken using the F098M filter sensitive to [S III] 9069,9531 line emissions. These images reveal a far more extensive debris field in both the remnant's NE and SW `jets' or streams of high-velocity ejecta than previously realized. We find ejecta knots in the NE extend out to at least 310 arcsec from the remnant's center of expansion indicating ejecta knot transverse velocities of 15,000 km/s (D/3.4 kpc; age = 330 yrs). Follow-up 4m KPNO and 6.5m MMT spectra show that ejecta near the farthest tip in the NE exhibit surprisingly low radial velocities (< 1000 km/s) and Ca- and S-rich but O-poor spectra. Although their nature is uncertain, these streams of unusually high speed ejecta originating from the S-Si-Ca-Ar layer may be evidence for an internally aspherical explosion of the Cas A progenitor.

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140.25 – Supernova Progenitors and a Light Echo in LEGUS Galaxies

The Legacy ExtraGalactic UV Survey (LEGUS) is a Hubble Space Telescope (HST) Cycle 21 Treasury program, aimed at the investigation of star formation and its relation with galactic environment over a range of scales in 50 galaxies within 12 Mpc. It consists of five-band imaging, from the near-ultraviolet to the I-band, primarily with the Wide Field Camera 3. During the course of the Survey, two supernovae (SNe) happened to occur in galaxies in our sample, SN 2014bc in M106 and ASASSN-14ha in NGC 1566. The sites of these SNe were precisely established in these host galaxies via observations of the SNe as part of a separate Cycle 21 HST target-of-opportunity program. From the galaxy imaging data we have been able to place constraints on the nature of the progenitor stars for these two events. In addition, we report on the characterization, based on all five of the imaging bands, of a scattered light echo around the core-collapse SN 2012aw in the LEGUS galaxy M95. Support for GO-13364 and GO-13341 was provided by NASA through grants from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555.

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Contributing team(s): LEGUS Team

140.26 – Improved distance measurements using twin supernovae from SNfactory

The Nearby Supernova Factory (Aldering, et al. 2002) has collected spectrophotometric timeseries of many Hubble-flow type Ia supernovae. Using this dataset, we discuss a novel method of standardizing supernovae by finding "twin" supernovae with matching spectral data. The analysis uses Gaussian processes to interpolate data from supernovae, and matches them up, allowing only relative dust extinction. We find that the best spectral twins have a much lower dispersion in relative brightness than the overall sample. We demonstrate both the usage of this method and the data requirements to implement it.

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140.27 – Synchrotron X-Ray Rims in Tycho's Supernova Remnant are Energy Dependent

Several young supernova remnants exhibit thin X-ray bright rims of synchrotron radiation at their forward shocks. Thin rims have been taken to indicate that shock-accelerated electrons rapidly cool downstream of the shock, requiring strong magnetic field amplification. But, magnetic field damping immediately behind the shock could produce similarly thin rims. Synchrotron loss-limited rim widths should decrease with energy whereas damping limited rims should be relatively energy-independent. To discriminate between models, we measured rim widths around Tycho's supernova remnant in 5 energy bands using an archival 750 ks Chandra observation. Rims narrow with increasing energy, favoring loss-limited radiation over magnetic damping and corroborating similar observations in the remnant of SN 1006. Observed widths are best fit by electron transport models requiring amplified magnetic fields of ~200–1000 μG and particle diffusion coefficients ~1–100x Bohm values, consistent with prior work on Tycho's SNR. Non-negligible diffusion results in some degeneracy between magnetic field strength and diffusion coefficient in setting observed rim widths, but strong magnetic fields are required for all measurements. A different approach may be needed to better constrain diffusion at supernova remnant shocks.

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140.28 – An Archival Chandra Study of the Young Core-Collapse Supernova Remnant 1E 0102.2-7219 in the Small Magellanic Cloud

Based on the deep 273 ks archival *Chandra* data we performed detailed spectral and imaging analysis of the young O-rich supernova remnant (SNR) 1E 0102.2-7219 in the Small Magellanic Cloud. Our aim in this study is to reveal spatial and chemical structures of this remnant in unprecedented details. We examined radial and azimuthal structures in the electron temperature, ionization timescale, density, and elemental abundances. We present our preliminary results from this study.

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140.29 – Supernova Emulators: Connecting Massively Parallel SN Ia Radiative Transfer Simulations to Data with Gaussian Processes

Collaboration between the type Ia supernova (SN Ia) modeling and observation communities hinges on our ability to directly connect simulations to data. Here we introduce supernova emulation, a method for facilitating such a connection. Emulation allows us to instantaneously predict the observables (light curves, spectra, spectral time series) generated by arbitrary SN Ia radiative transfer simulations, with estimates of prediction error. Emulators learn the mapping between physically meaningful simulation inputs and the resulting synthetic observables from a training set of simulation input-output pairs. In our emulation framework, we model PCA-decomposed representations of simulated observables as an ensemble of Gaussian Processes. As a proof of concept, we train a bolometric light curve (BLC) emulator on a grid of 400 simulation inputs and BLCs synthesized with the publicly available, gray, time-dependent Monte Carlo expanding atmospheres code, SMOKE. We emulate SMOKE simulations evaluated at a set of 100 out-of-sample input parameters, and achieve excellent agreement between the emulator predictions and the simulated BLCs. In addition to predicting simulation outputs, emulators allow us to infer the regions of simulation input parameter space

that correspond to observed SN Ia light curves and spectra. We present a Bayesian framework for solving this inverse problem using Markov Chain Monte Carlo sampling. We fit published bolometric light curves with our emulator and obtain reconstructed masses (nickel mass, total ejecta mass) in agreement with reconstructions from semi-analytic models. We discuss applications of emulation to supernova cosmology and physics, including how emulators can be used to identify and quantify astrophysical sources of systematic error affecting SNe Ia as distance indicators for cosmology.

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140.30 – A case study of nucleosynthesis in multi-dimensional supernova simulations

We present a case study of several multi-dimensional smoothed particle hydrodynamics simulations with large nuclear network post-processing in which the effects of asymmetries on nucleosynthesis in supernovae are assessed. The abundances and spatial distribution of the short-lived radionuclides 26Al, 41Ca, and 60Fe are evaluated along with the coproduced oxygen isotopes and the S/Si ratio, used as an observational tracer. We also examine 44Ti and 56Ni and the bulk abundances of key common elements. Particular attention is paid to the composition of the Rayleigh-Taylor Instability driven "bullets" of material observed in young supernova remnants.

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140.31 – Four extended gamma-ray supernova remnants newly identified by Fermi-LAT Pass 8 data

Identifying gamma-ray emission from supernova remnants is crucial to determine the origin of Galactic cosmic rays. Despite the excellent sensitivity and spatial resolution of the Fermi Gamma-ray Space Telescope, it has proven difficult to clearly identify these sources as they are buried in the bright diffuse Galactic background and may be confused with other gamma-ray sources, such as pulsars. Here we report the detection of extended emission from four supernova remnants - CTB 109, PKS 1209-51/52, CTB 37A, RCW 86 - using 5 years of observations with Fermi and the new Pass 8 event reconstruction developed by the LAT collaboration. The improvements with Pass 8 promise to rapidly grow the population of gamma-ray supernova remnants identified through their spatial extension.

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Contributing team(s): the Fermi-LAT collaboration

140.32 – Constraining the Post-Shock Magnetic Field Strength of SN1006 from the Rotation Measure of Radio Galaxy ESO 328-13

In a radio polarization study of the supernova remnant (SNR) of SN1006, we found evidence for variable Faraday rotation toward the FR-I radio galaxy ESO 328-13. The background source lies on the eastern edge of the SNR, and its jets are aligned east to west. The core and western lobe lie within the remnant's interior, and the eastern lobe extends from the interior to the exterior of the SNR's shell. The rotation measure (RM) of the eastern lobe experiences a shift of 20 rad/m^2 as it traverses the shell, then exhibits a gradient whose magnitude decreases toward the interior so that the RM is the same for the edges of the radio galaxy's eastern and western lobes. After rotating the field vectors to zero wavelength, we found that the magnetic field orientation of the SNR is radial with respect to the shell, while the magnetic vectors of the radio jets are perpendicular to their axes, a typical trait of FR-I sources. These results suggest the variation in RM is not intrinsic to the radio galaxy; rather, the variation is a direct effect of SN1006's post-shock environment.

This discovery presents us with a unique opportunity to constrain the post-shock magnetic field and electron density distribution of SN1006. The SNR behaves as a magnetized plasma screen partially covering the background radio galaxy. The Faraday depth of the screen is a maximum at the edge of the shell and decreases toward the interior. Assuming an electron density of 0.20 cm^{-3} (estimated from IR and X-ray observations) and a path length of 6 pc through the SNR, we derive a line-of-sight magnetic field of 20 μG at the edge of the shell. For a range of aspect angles with respect to the line of sight, from zero to 80 degrees, the magnitude of the field could range from 20 to > 100 μG. This result compares well with theoretical estimates of 14 to 130 μG, extracted from SN1006's synchrotron emissivity at multiple wavelengths. While the complexity of the post-shock magnetic field and electron density could have a significant impact on estimates of the field strength, we are encouraged by this simple result.

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140.33 – Revisiting the SNR Content of NGC 6946 with Deep WIYN Images

Studying supernova remnants (SNRs) in external galaxies allows us to understand patterns of star formation and constrain supernova rates. We present the results of an optical search for SNRs in the spiral galaxy NGC 6946, which is well-known for its high supernova rate, with close to 10 being observed in the past century.
Using deep Ha and [SII] WIYN 3.5m telescope images of about a third of the galaxy, we redetect all 15 SNRs within our field of view that were found by previous authors. Since our [SII] and Ha images are deeper, and have better seeing, than past surveys, we can detect smaller and fainter SNRs than previously possible despite using the same selection criteria. By completing the census of candidate SNRs in NGC 6946, and particularly by finding smaller, fainter remnants, we will refine the estimate of the supernova rate in this galaxy.

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140.34 – A Newly Recognized Very Young Supernova Remnant in M83

As part of a spectroscopic survey of supernova remnant candidates in M83 using the Gemini-South telescope and GMOS, we have discovered one object whose spectrum shows very broad lines at Halpha, [O I] 6300, and [O III] 5007, similar to those from other objects classified as `late time supernovae.' Although six historical supernovae have been observed in M83 since 1923, none were seen at the location of this object. Hubble Space Telescope Wide Field Camera 3 images show a nearly unresolved emission source, while Chandra and ATCA data reveal a bright X-ray source and nonthermal radio source at the position. Objects in other galaxies showing similar spectra are only decades post-supernova, which raises the possibility that the supernova that created this object occurred during the last century but was not observed. Using photometry of nearby stars from the HST data, we suggest the precursor was at least 17 M(sun), and the presence of broad Halpha in the spectrum makes a type II supernova likely. The supernova must predate the 1983 VLA radio detection of the object. We suggest examination of archival images of M83 to search for evidence of the supernova event that gave rise to this object, and thus provide a precise time since the explosion.

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140.35 – The Extraordinary Supernova Remnant in NGC 4449 Revisited

NGC 4449, a Magellanic-type irregular galaxy at a distance of about 4 Mpc, contains the most luminous known supernova remnant (SNR) in both X-ray and optical bands. Its optical spectrum is characterized by broad lines from O, Ne, S, Ar, and Ca, and its size and expansion velocity (6000 km/s) suggest that the unobserved SN exploded about 65 years ago. The remnant¹s extraordinary brightness can be attributed to the interaction of supernova ejecta with unusually dense and extensive circumstellar material. We will present new Chandra imaging, together with UV/Optical spectra of the SNR from HST/STIS and the MMT. The X-ray luminosity of the SNR is less than when it was detected with Einstein in 1980, but the luminosity and X-ray spectral shape have remained relatively constant over the last 10 years. In the FUV, the HST spectra show for the first time broad line emission from C IV 1550 Å, as well as Si IV + O IV at 1400 Å and O III] at 1660 Å. The new NUV and optical spectra are fairly similar to earlier HST/FOS spectra and to ground-based spectra we have obtained over the last decade. Here we describe these new observations, and our attempts to understand the nature of the progenitor of the SNR.

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140.36 – The evolution of hydrocarbons past the asymptotic giant branch: the case of MSX SMC 029

We present an optimally extracted high-resolution spectrum of MSX SMC 029 obtained by the Infrared Spectrograph on the Spitzer Space Telescope. MSX SMC 029 is a carbon-rich object in the Small Magellanic Cloud that has evolved past the asymptotic giant branch (AGB). The spectrum reveals a cool carbon-rich dust continuum with emission from polycyclic aromatic hydrocarbons (PAHs) and absorption from simpler hydrocarbons, both aliphatic and aromatic, including acetylene and benzene. The spectrum shows many similarities to the carbon-rich post-AGB objects SMP LMC 011 in the Large Magellanic Cloud and AFGL 618 in the Galaxy. Both of these objects also show infrared absorption features from simple hydrocarbons. All three spectra lack strong atomic emission lines in the infrared, indicating that we are observing the evolution of carbon-rich dust and free hydrocarbons in objects between the AGB and planetary nebulae. These three objects give us a unique view of the elusive phase when hydrocarbons exist both as relatively simple molecules and the much more complex and ubiquitous PAHs. We may be witnessing the assembly of amorphous carbon into PAHs.

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140.38 – High-Velocity Features in the Spectra of Type-Ia Supernovae

Spectra of Type-Ia supernovae (SNe Ia) obtained before maximum brightness sometimes show high-velocity features (HVFs). They are most often seen in Si II and Ca II and in the most obvious cases appear as a second, separate absorption feature at ~7000-10000 km/s higher expansion velocity than the more normal photospheric-velocity features (PVFs). We have investigated how often HVFs occur, at what epochs, and how they evolve with time using a large sample of low-resolution, optical and NIR spectra of nearby SNe Ia. Our ongoing study indicates that HVFs are quite common in SNe Ia spectra obtained prior to 5 days before maximum brightness. Correlations between photometric observables and the relative line strengths and expansion velocities of both HVFs and PVFs are currently being sought and some intriguing results have already been found and will be discussed. Various explanations for the existence and behavior of the HVFs are being considered, with possibilities including density enhancements in the outer portion of the SN ejecta and low levels of interaction with circumstellar material.

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140.39 – Evidence of Circumstellar Material for Type Ia supernova 2014J in High Resolution Spectra from the Automated Planet Finder Telescope

We present a time series of very high resolution spectra for nearby Type Ia supernova 2014J in M82. These spectra were obtained in 11 epochs over 33 days around peak brightness with the Levy Spectrograph, which as an R~110000 at 5500 Angstroms, on the Automated Planet Finder telescope at Lick Observatory. We identify multiple absorption components for Na I D and K I, as well as absorption by Ca I and several of the more common diffuse interstellar bands (DIBs). We see no evolution in any component of Na I D, nor in the DIBs, but do discern the weakening/disappearance of two of the most blueshifted components in K I. We find that these observations can be plausibly explained by shielded photon-ionization of circumstellar material closest to the progenitor, which provides tentative evidence of the single degenerate scenario for SN2014J.

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140.40 – The Metrology of Type IA Supernova Lightcurves

The use of Type IA supernovae as standard candles depends crucially on precise measurements of the properties of their light curves. The currently most widely used indicator is $\Delta m^{15}(B)$, the luminosity drop, measured in magnitudes, in the first 15 days after maximum luminosity. It was selected instead of an estimate of the luminosity decline rate in order to avoid the well known numerical instability in estimating derivatives for measured data. Unfortunately it does not really succeed in this goal, but it is still possible to correlate the widely scattered Δm^{15} estimates with the absolute magnitude at peak luminosity. The estimation procedure is improved by fitting an accelerated radioactive decay (ARD) model to the measured light curve and making the estimate from that fit. Such fits typically have R^2 values greater than 0.99 and produce the expected normally distributed residuals, but still the instability in estimating Δm^{15} persists. The model has 7 adjustable parameters, one of which, α^4, is the acceleration rate for the Ni→Co→Fe nuclear decays. This rate is estimated from the fit to the whole light curve rather than to just a section of it, and α^4 is much more tightly correlated with the absolute magnitude at maximum than is Δm^{15}. This paper will compare the two indicators and also suggest two others they may prove useful in the future.

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140.41 – Type Ia Supernova Host Galaxies and Luminosity Calibration

Type Ia supernova (SN Ia), the highly luminous explosions of white dwarf stars, make possible distance measurements across the last ~8 Gyr of the cosmic expansion history, and are among the most important tools of modern cosmology. Recent work has shown, however, that their luminosities vary, after correction for light curve shape and color, with properties of their host galaxies. I will describe a new analysis of their host galaxies that may offer insight into their progenitor populations.

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140.42 – PTF11iqb: Bridging the gap between Type IIN and normal Type II

The recent supernova (SN) PTF11iqb was classified as a Type IIn event caught very early after explosion. It showed narrow Wolf-Rayet (WR) spectral features on day 2, but the narrow emission weakened quickly and the spectrum morphed through several stages resembling normal Types II-P and II-L. At late times, Hα emission ex- hibited a complex, multi-peaked profile reminiscent of SN 1998S. Overall, we find that PTF11iqb was a near twin of the classic object SN 1998S, except with a factor of 2- 4 weaker interaction with circumstellar material (CSM) at early times, and stronger CSM interaction at late times. We match the main light curve with a simple model for weak CSM interaction (with a mass loss rate of roughly 10−4 M⊙ yr−1) added to the light curve of a normal SN II-P (the relatively weak CSM interaction allowed this plateau to be seen more clearly than in other SNe IIn). This plateau in the underlying light curve requires that the progenitor had an extended hydrogen envelope like a cool (red or yellow) supergiant at the moment that it exploded. The likely cool supergiant progenitor is significant because PTF11iqb showed WR features in its early spectrum. Overall, PTF11iqb seems to bridge SNe IIn with weaker pre-SN mass loss seen in SNe II-L and II-P, thereby implying that episodic pre-SN mass loss on a wide range of time and mass scales could be more frequent than implied by standard SNe IIn.

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140.43 – X-ray measurements of a Ca-rich gap transient

We present Chandra measurements of a calcium-rich gap transient. These objects have properties that would be well-explained by tidal detonation of He white dwarfs, something which can be done by intermediate-mass black holes, but not by supermassive black holes. Previous groups' theoretical calculations have suggested that tidal detonations lead to substantial amounts of returning material, which is then accreted by the black hole. Our X-ray upper limits on the flux from SN 2012hn show that it is unlikely to be a tidal detonation by an intermediate mass black hole unless the black hole is at the low end of the IMBH mass distribution. We discuss the possibility that the detonation was instead due to a three-body interaction involving a stellar mass black hole.

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140.44 – The Rediscovery of the Antlia Supernova Remnant

While undertaking a survey of velocity-resolved diffuse optical emission from the [S II] 6716 A line with the Wisconsin H-alpha Mapper, we have rediscovered the Antlia Supernova remnant, a 26 degree diameter remmant near the Gum Nebula that was originally detected in SHASSA (Southern H-alpha Sky Survey Atlas) by P. McCullough in 2002. The original discovery showed this remnant was associated with ¼ keV X-ray emission in the ROSAT All-Sky Survey, and argued that Antlia was potentially the closest remnant to the Sun. We will present an analysis of the H-alpha and [S II] lines in this direction: the ratio of these lines indicate the shell is consistent with being a supernova remnant and the velocities allow us to constrain its age. We discuss this remnant in the context of the evolution of the entire Gum Nebula region, noting that its proximity and age make it possible to search for geochemical evidence of this remnant on Earth. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

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140.45 – The Fall and Rise of X-ray Supernova 2005kd

Supernova (SN) 2005kd belongs to the class of Type IIn SNe, which show narrow lines in their early spectra. It is one of the most luminous X-ray SNe known - in excess of $L^x = 10^{41}$ ergs/s at peak. The evolution of its X-ray luminosity with time is rather atypical, with a general dimming, as expected, followed by an unexpected re-brightening. We report on a recent 30 ks Chandra observation of SN 2005kd, which extends the X-ray lightcurve of this SN from 2005 to 2013. We use the time evolution of the X-ray flux to explore the expansion of the forward and reverse shock of the SN within the surrounding medium, as well as to study the structure of the surrounding medium.

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140.46 – The Possible Progenitor System or Stellar Remant of a Type Iax Supernova

Type Iax supernovae (SNe Iax) are thermonuclear explosions that are related to SNe Ia, but are physically distinct. The most important differences are that SNe Iax have significantly lower luminosity (1%–50% that of typical SNe Ia), lower ejecta mass (~0.1–0.5 M⊙), and may leave a bound remnant. The most extreme SN Iax is SN 2008ha, which peaked at $M^V = -14.2$ mag, about 5 mag below that of typical SNe Ia. Here, we present Hubble Space Telescope (HST) images of UGC 12682, the host galaxy of SN 2008ha, taken 4.1 years after the peak brightness of SN 2008ha. In these deep, high-resolution images, we detect a source coincident (0.86 HST pixels; 0.043''; 1.1 σ) with the position of SN 2008ha with $M^{F814W} = -5.4$ mag. We determine that this source is unlikely to be a chance coincidence, but that scenario cannot be completely ruled out. If this source is directly related to SN 2008ha, it is either the luminous bound remnant of the progenitor white dwarf or its companion star. The source is consistent with being an evolved ~3 M⊙ initial mass star, and is significantly redder than the SN Iax 2012Z progenitor system, the first detected progenitor system for a thermonuclear SN. If this source is the companion star for SN 2008ha, there is a diversity in SN Iax progenitor systems, perhaps related to the diversity in SN Iax explosions. If the source is the bound remnant of the white dwarf, it must have expanded significantly.

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140.47 – Central Star Properties and C-N-O Abundances in Eight Galactic Planetary Nebulae from New HST/STIS Observations

We present detailed photoionization models of eight Galactic planetary nebulae (IC2165, IC3568, NGC2440, NGC3242, NGC5315, NGC5882, NGC7662, & PB6) based on recently obtained HST STIS spectra. Our interim goal is to infer T^{eff}, luminosity, and current and progenitor masses for each central star, while the ultimate goal is to constrain published stellar evolution models which predict nebular CNO abundances. The models were produced by using the code CLOUDY to match closely the measured line strengths derived from high-quality HST STIS spectra (see poster by Dufour et al., this session) extending in wavelength from 1150-10270 Angstroms. The models assumed a blackbody SED. Variable input parameters included T^{eff}, a radially constant nebular density, a filling factor, and elemental abundances. For the eight PNs we found a birth mass range of 1.5-2.9 M^{sun}, a range in $\log(L/L^{sun})$ of 3.10-3.88, and a T^{eff} range of 51-150k K. Finally, we compare CNO abundances of the eight successful models with PN abundances of these same elements that are predicted by published stellar evolution models. We gratefully acknowledge generous support from NASA through grants related to the Cycle 19 program GO12600.

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140.48 – Analysis of Co-spatial UV-Optical STIS Spectra of Planetary Nebulae From HST Cycle 19 GO 12600

We present an analysis of five spatially resolved planetary nebulae (PNe), NGC 5315, NGC 5882, NGC 7662, IC 2165, and IC 3568, from observations in the Cycle 19 program GO 12600 using HST STIS. Details of the observations and data are presented in the poster by Dufour et al. in this session. These five observations cover the wavelength range 1150-10,270 Å with 0.2 and 0.5 arcsec wide slits, and are co-spatial to 0.1 arcsec along a 25 arcsec length across each nebula. This unprecedented resolution in both wavelength and spatial coverage enabled detailed studies of physical conditions and abundances from UV line ion emissions (compared to optical lines). We first analyzed the low- and moderate-resolution UV emission lines of carbon using the resolved lines of C III] 1906.68 and 1908.73, which yielded a direct measurement of the density within the volume occupied by doubly-ionized carbon and other similar co-spatial ions. Next, each PN spectrum was divided into spatial sub-regions in order to assess inferred density variations among the sub-regions along the entire slit. Variations in electron temperature and chemical abundances were also probed. Lastly, these nebulae were modeled in detail with the photoionization code CLOUDY. This modeling tested different density profiles in order to reproduce the observed density variations and temperature fluctuations, and constrain central star parameters. We gratefully acknowledge generous support from NASA through grants related to the Cycle 19 program GO 12600, as well as from the University of Oklahoma.

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140.49 – The Detection of Neutron-Capture Elements in Magellanic Cloud Planetary Nebulae

We present deep, high-resolution 0.8--2.5 µm spectra of ten Magellanic Cloud planetary nebulae (PNe). These data were obtained with the FIRE spectrometer (Simcoe et al. 2013, PASP, 125, 270) on the 6.5-m Baade Telescope at Las Campanas Observatory. The primary goal of these observations is to detect fine-structure emission lines of the neutron(*n*)-capture elements Se and Kr. These elements can be produced by *s*-process nucleosynthesis in thermally-pulsing asymptotic giant branch (AGB) stars, the progenitors of PNe, and are enriched along with carbon in AGB envelopes by convective dredge-up. Extragalactic PNe are particularly valuable for studying *s*-process enrichments, since their distances are well-determined (unlike most Galactic PNe). Before our study, *n*-capture element detections had been reported in only one extragalactic PN, Hen 2-436 in the Sagittarius Dwarf (Wood et al. 2006, BAAS, 38, 1113; Otsuka et al. 2011, ApJ, 729, 39). Remarkably, we detect [Kr III] 2.199 and/or [Se IV] 2.287 µm in seven of the ten PNe (six of seven in the LMC and one of three in the SMC). At our resolution of *R*=4800, these lines are resolved from nearby H^2 lines and therefore are unaffected by blending. A preliminary abundance analysis indicates that several of these PNe exhibit *s*-process enrichments, as expected given their high C/O ratios. The well-known distances to the LMC and SMC allow *s*-process enrichment factors to be studied as a function of PN luminosity and potentially initial progenitor mass. Moreover, this sample will provide new insights into *n*-capture nucleosynthesis at low metallicities. Beyond the Se and Kr lines, the spectra are incredibly rich, with typically 100-200 emission lines detected in LMC PNe and up to 100 in SMC objects, including lines of H^2, [P II], [S II], [S III], [Cl II], [Fe II], and a number of as yet unidentified features. Our results demonstrate the utility of nebular spectroscopy for studying *n*-capture nucleosynthesis in extragalactic environments.

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140.50 – A New Analysis of *s*-process Enrichments in Planetary Nebulae

We present a new analysis of selenium and krypton enrichments in planetary nebulae (PNe), using recently determined atomic data for these elements. Se and Kr are the two most widely-detected neutron-capture elements in PNe, and can be enriched by *s*-process nucleosynthesis in PN progenitor stars. With the photoionization code Cloudy (Ferland et al. 2013, RMxA&A, 49, 1), we computed grids of models that span the range of physical conditions in most PNe to investigate the ionization balance of Se and Kr. The new atomic data were tested by modeling 15 PNe that exhibit emission from multiple Kr ions. We found systematic discrepancies between the modeled and observed Kr lines, which could not be satisfactorily explained by observational uncertainties or approximations in the models. The observed ionization balance is reproduced more accurately by empirically adjusting the photoionization cross sections of Kr^{+}—Kr^{3+} within their cited uncertainties, and the dielectronic recombination rate coefficients by slightly larger amounts. We present new analytical ionization correction factors for Se and Kr, based on correlations between the ionic fractions of detected Se and Kr ions and those of routinely observed O, Ar, and S ions. The correction factors are applied to the K band survey of Sterling & Dinerstein (2008, ApJS, 174, 158) to derive improved Se and Kr abundances in 120 PNe. The revised abundances are 0.1—0.3 dex lower than the previous values in most PNe, reducing the estimated fraction of enriched objects from 52% to 37%. However, this figure depends on the assumed initial abundances of Se and Kr in the progenitor stars, which may be subsolar in some cases and may differ for objects belonging to different stellar populations. We find that the primary conclusions of Sterling & Dinerstein still hold: Kr is more strongly enriched than Se in PNe, in accordance with nucleosynthetic predictions; PNe with more massive progenitors show little if any *s*-process enrichment; and Se and Kr enrichments correlate positively with nebular C/O ratios. NCS acknowledges support for this work from NSF Astronomy and Astrophysics Postdoctoral Fellowship AST-901432, and HLD received support from NSF grant AST-0708245.

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140.51 – A Mid-IR Search for Planetary Nebulae

Motivated by the dearth of relatively faint, compact planetary nebulae (PNe) in uncrowded fields that could serve as potential spectral calibration sources for the Euclid Mission, we have conducted a search for PNe at high Galactic latitudes based on WISE data. Previous studies have largely focused on the Galactic Plane or searched for mid-IR counterparts to optically selected PNe. We instead identify the WISE mid-IR color locus of PNe and investigate the cataloged sources fulfilling these color criteria. We will present preliminary results from this study, including new PNe candidates.

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140.52 – 3D Versus 1D Radiative Transfer Modeling of Planetary Nebulae

Planetary nebulae are the products of the fast stellar wind from the end of the AGB star phase. To date, there are many one-dimensional radiative transfer codes, and a few fully 3D codes that can model the ionization of the planetary nebulae. Some limitations on 1D codes are that they can only make spherical or parallel plane models, while 3D codes take much computing power and memory to run. A pseudo-3D code such as pyCloudy can model a planetary nebula in 3D by making multiple runs of a 1D code such as Cloudy in different angles from the center of the nebula. We compared the 1D models with pseudo-3D models to determine if the 1D models give good approximations for the observed parameters of the planetary nebulae. We find that one-dimensional codes can actually give good estimates for electron temperature and density in a bipolar planetary nebula.

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140.53 – The Close Binary Central Star of the Planetary Nebula PHR J1602-4127

We are undertaking a search for binary central stars in planetary nebulae by detecting variations in brightness indicative of a binary companion. By modeling discovered binary star systems, the resulting parameters will give insight into how the binary central star interacts with its surrounding nebula. Here we announce the discovery of a close binary central star in the Planetary Nebula PHR J1602-4127. The central binary is an irradiated system with a cool companion and an orbital period of 0.29592 days. We have B, V, and R light curves from the SARA-South Telescope and orbit-resolved spectra obtained with the Gemini-South telescope. Using a binary star modeling program we have found possible parameter sets for physical values of this binary central star.

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140.54 – The Current Sample of Known Close Binary Central Stars of Planetary Nebulae

I present recently discovered photometrically variable central stars of planetary nebulae and discuss them in the context of the known sample of close binary central stars. The newly discovered variables were found through a photometric survey of central stars from a distance-limited sample of planetary nebulae. One goal of the survey is to determine the fraction of close binary stars in planetary nebulae. I describe the current status of that value and review the physical parameters of known binary central stars.

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140.55 – Electron Temperatures and Densities of Compact Planetary Nebulae

We present preliminary results from an optical spectroscopic survey of compact planetary nebulae (PNe) in the Galactic disk. This is an ongoing optical+infrared spectral survey of 150 compact PNe to build a complete database of Galactic PN chemical abundances. We obtained optical spectra of 27 PNe with the Southern Astrophysical Research (SOAR) Telescope in 2012 and 2013. Here we present physical diagnostics such as electron temperature and density for each PN derived from the reddening-corrected line intensities, and compare these to dust thermal temperature and dust type derived from *Spitzer* spectra. We will use these diagnostics to derive the elemental abundance of He, N, O Ne, S and Ar from combined optical and IR spectra in subsequent analyses.

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140.56 – Analyzing the largest spectroscopy data set of Stripped SNe to improve SN identification and to constrain their progenitors

Dozens of Stripped-Envelope Core-Collapse Supernovae (SESNe; SNe of Types IIb, Ib-norm, Ic-norm, and broad-lined Ic) are discovered every year but only a few of them have good spectra and photometry. Given the difficulty of collecting data of many SESNe, people usually focus on a specific SN. The latest paper that statistically compared spectra of different SESNe subtypes was conducted in 2001 by Matheson et al., using spectra of 28 SESNe among which many didn't have a good light curve to determine phases of spectra. Recently, Modjaz et al. (2014) published optical spectra of 73 SESNe collected at the Harvard-Smithsonian Center for Astrophysics (CfA), doubling world-supply of well observed SESNe. Forty-four of these 73 SESNe have a date of maximum light. Besides the above data, we have collected the spectra of most of the literature SESNe, thus we can analyze optical spectra of our very large sample of 71 SESNe with a well-defined maximum and type. It's time to understand different subtypes of SESNe in a statistical way. This presentation will focus on spectroscopic comparison between Type Ib-norm SNe (SNe Ib), Type IIb SNe (SNe IIb), and Type Ic-norm SNe (SNe Ic). By comparing the strength of He I λ5876 with respect to that of Hα in SNe Ib and SNe IIb, we found that there is a continuum of hydrogen envelope in their progenitors. The strength and velocity of He I lines are different in SNe Ib and SNe IIb especially when the spectra were taken around three weeks after the date of maximum light, enabling us to differentiate SNe Ib from SNe IIb even without spectra taken around maximum date. We quantified the diversity within each SESNe subtype by constructing average spectra for SNe of the same subtype and analyzing line strength evolution of individual SN. We also found that O I λ7774 line is stronger in SNe Ic than in SNe Ib. This is consistent with the measurements done by Matheson et al. (2001), but contradicts the predictions made by Dessart et al. (2012) using a model where SNe Ib and SNe Ic have the same progenitors but different level of ^{56}Ni mixing.

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141 – Molecular Clouds, HII Regions, Interstellar Medium Posters

141.01 – [CII] emission across M31 seen by Herschel and ISO

The [CII] 158 micron line is typically the brightest far-IR emission line from star-forming (SF) galaxies. As such, this line is a potentially useful tracer of star formation. To calibrate such applications, we must understand the relative contributions of different ISM phases to the [CII] emission. Using high physical resolution observations of the [CII] 158 micron line from Herschel PACS in five 3'x3' field in M31 and optical IFU spectra from PPaK and ancillary IR data, we are able to spatially separate out the ISM phases. Additionally, to study the full radial profile of heating and cooling of the ISM in Andromeda, we include [CII] observations from ISO in the bulge. We find that SF regions in M31 do not exhibit a "[CII] line deficit" on 50 pc scales, even in regions where the dust is very warm. Using the optical line emission, we determine the fraction of [CII] emission spatially associated with SF regions. Our method implies a high fraction ~20-90% of [CII] emission is coming from diffuse regions. These diffuse regions appear to dominated by the UV interstellar radiation field which arises from B stars and possible photon leakage from the SF regions. Due to the presence of this large diffuse fraction, we find on ~50pc scales that the relation between [CII] and SFR is sub-linear in most of the fields. However, when averaged over ~700pc scales it becomes steeper and is in agreement with other extragalactic studies on similar scales. Interestingly, even with this correlation of SFR & [CII], we find that [CII]/TIR decreases with radius by a factor of ~3 from 16 to 7 kpc, with a slight increase in the bulge. We discuss metallicity, stellar radiation fields and emission from diffuse ionized phase as possible explanations for these trends.

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Contributing team(s): Survey of Lines in M31 (SLIM)

141.02 – Propagation of cosmic rays in dense molecular clouds

Collisional processes involving cosmic ray protons contribute to the galactic diffuse gamma ray flux as the particles propagate through the dense galactic medium. In order to better understand the nature of the sources of cosmic rays via gamma ray observations, an understanding of the propagation of cosmic ray protons through this medium is required. Specifically, the presence of dense regions in the medium (e.g. molecular clouds) has an effect on the geometry of the galactic magnetic field. Gravitational collapse of these clouds “pinches” local magnetic field lines, inducing magnetic focusing and mirroring effects. In this work, we numerically simulate the propagation of cosmic ray protons through this altered field geometry. Taking into account magnetic focusing and mirroring, we also stochastically simulate pitch angle scattering of protons due to turbulence in the field. We then present parameters of the density of the medium sampled by the protons as they pass through the cloud, as functions of cosmic ray momentum and amplitude of turbulent magnetic field perturbations, as reported by our simulations.

This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

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141.03 – Interstellar Extinction Toward Young Stars

We present work on a molecular hydrogen (H2) fluorescence model to characterize the ultraviolet (UV) extinction curve along the line of sight towards young stars with circumstellar disks. Stellar UV radiation plays a strong role in heating the disk gas and driving chemical reactions, so it is important to measure the UV extinction curve in order to reconstruct the intrinsic stellar UV flux impacting the disk. To measure the extinction, we compare modeled H2 fluorescence spectra to observed H2 lines. Lyman-alpha radiation from the stars pumps electronic transitions of H2 in the disk, and we model the flux that is re-emitted through the subsequent fluorescent cascade. We then extract the extinction along the line-of-sight over the 1100-1700 Angstrom wavelength region from the difference between the modeled H2 fluorescence and the *HST*-COS data. The shape of the extinction curve allows us to characterize the dust grain distribution in the intervening material as well as to recover the intrinsic spectral energy distribution of the stars over a wide wavelength range.

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141.04 – What Happens to a High Velocity Cloud When it Hits the Milky Way's Disk: Is Dark Matter Necessary for Survival?

Dark matter halos enshroud some of the most massive high velocity clouds. Their gravitational pull confines the clouds as they pass through the intergalactic medium. Given the ability of dark matter halos to stabilize their embedded baryonic clouds against hydrodynamic interactions that would otherwise disrupt them, it has further been suggested that dark matter halos could enable high velocity clouds to survive impacts with the Milky Way's disk. The survival of high velocity clouds, such as the Smith Cloud, during a passage through the disk has been cited as evidence for the presence of dark matter. However, a second actor, the magnetic field, may also be at play. In order to characterize, measure, and disentangle their effects, we have performed magnetohydrodynamic simulations of massive high velocity clouds as they impact a galactic disk. Here, we present the rate at which material dissipates in a variety of situations that include or exclude dark matter and magnetic fields.

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141.05 – Mid-Infrared Observations of H^2O towards AFGL 2591

Using the Echelon-Cross-Echelle Spectrograph, EXES, we observed the massive protostar AFGL 2591 during the second commissioning flight of EXES on SOFIA, the Stratospheric Observatory for Infrared Astronomy. We used the high spectral resolution mode to observe from 6.086 to 6.135 microns. We resolve numerous absorption lines from the v^2 band of H^2O including absorption from the ground state of para-H^2O, two absorption features from vibrationally excited states, and one feature from $H^{218}O$. All features have similar profiles and the velocity suggests this is outflowing gas. We analyze the data and compare it to previous measurements. We also present general information regarding EXES on SOFIA.

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141.06 – The Translucent Clouds toward HD 204827

Translucent clouds represent a middle ground between the diffuse and dense interstellar medium. In these clouds the total dust extinction lies in the range of A^V = 1.5 to 10 magnitudes, hydrogen is predominantly in molecular form, and carbon becomes neutral and then molecular (in the form of CO). Our goal is to characterize such clouds toward HD 204827, which has spectral type O9 V, V = 7.94, E(B-V) = 1.11, a total extinction A^V ~ 3.5, and very steep far-UV extinction. HD 204827 is also a spectroscopic binary -- enabling a clear distinction between stellar and interstellar absorption lines. Diffuse interstellar bands (DIBs) have been cataloged; this sight line is the exemplar for the so-called C^2 DIBs. The observed molecular abundances (e.g., for CN, C^2, C^3, CO) are higher than those found for diffuse clouds, also suggesting the presence of translucent material.
We will discuss our multi-wavelength observations of HD 204827 -- including mm-wave spectra, IR spectra and photometry, optical spectra, and UV (*HST*) spectra, along with laboratory data on interstellar analogs -- which enable a uniquely comprehensive study of the abundances, depletions, chemistry, and physical conditions characterizing the translucent material in this sight line.

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141.07 – Local Group Galaxy Emission-line Survey

We present the results of the Local Group Galaxy Emission-line Survey of Hα emission regions in M31, M33 and seven dwarf galaxies in (NGC6822, IC10, WLM, Sextans A and B, Phoenix and Pegasus). Using data from the Local Group Galaxy Survey (LGGS – see Massey et al, 2006), we used continuum-subtracted Ha emission line images to define emission regions with a faint flux limit of 10^{-17} ergs-sec^{-1}-cm^{-2} above the background. We have obtained photometric measurements for roughly 7450 Hα emission regions in M31, M33 and five of the seven dwarf galaxies (no regions for Phoenix or Pegasus). Using these regions, with boundaries defined by Hα-emission flux limits, we also measured fluxes for the continuum-subtracted [OIII] and [SII] images and constructed a catalog of Hα fluxes, region sizes and [OIII]/ Hα and [SII]/ Hα line ratios. The HII region luminosity functions and size distributions for the spiral galaxies M31 and M33 are compared with those of the dwarf galaxies NGC 6822 and IC10. For M31 and M33, the average [SII]/ Hα and [OIII]/ Hα line ratios, plotted as a function of galactocentric radius, display a linear trend with shallow slopes consistent with other studies of metallicity gradients in these galaxies. The galaxy-wide averages of [SII]/ Hα line ratios correlate with the masses of the dwarf galaxies following the previously established dwarf galaxy mass-metallicity relationship. The slope of the luminosity functions for the dwarf galaxies varies with galaxy mass. The Carleton Catalog of this Local Group Emission-line Survey will be made available on-line.

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141.08 – Red Clump Giants in the Region of Open Cluster M29

The interstellar extinction is investigated in a 1.5 square degree area in the region of the open cluster M29 (NGC 6913) in Cygnus, centered at RA = 20 h 24 m, DEC = +38 deg 30 min. The study is based on the investigation of 1147 red clump giants (RCGs), identified by using some combined two-color diagrams of the 2MASS and Spitzer surveys in the region of highly variable extinction. In the whole area a steep rise of the extinction A^V is observed at a distance of ~800 pc; it should be related with dust clouds in the Great Cygnus Rift obscuring the stars behind it by A^V ~ 3.0 ± 0.5 mag. Another rise of the extinction by additional ~5 mag seems to be present at 1.3 kpc, the frontside of the CygX complex of dust and molecular clouds.

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141.09 – 21-SPONGE Detects Unexpectedly "Warm" Neutral Medium

We present results from "21 cm Spectral Line Observations of Neutral Gas with the (E)VLA" (21-SPONGE), a large survey for Galactic HI absorption with the Karl G. Jansky Very Large Array (VLA). With RMS noise in optical depth of $<10^{-3}$ per 0.42 km/s channel over 58 lines of sight (40 fully analyzed), 21-SPONGE is the largest HI absorption survey with such high sensitivity ever undertaken. This sensitivity allows us to detect weak absorption by diffuse, warm HI (``warm neutral medium", WNM) directly, and to measure its previously-unconstrained physical properties. We obtain corresponding HI emission spectra from the Arecibo Observatory and calculate column densities and spin temperatures of Gaussian-fitted clouds along each line of sight. To maximize our sensitivity, we stacked the spectral residuals from the first 19 sources, and detected a statistical WNM absorption signature with Ts= 7200(+1800,-1200) K (68% confidence). This high temperature requires a significantly larger density of Lya photons in the ISM than is predicted by recent theoretical and numerical studies. We extend this analysis to measure the effect of Galactic environment on statistical WNM properties.

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Contributing team(s): 21-SPONGE Team

141.10 – Search for 54-MHz Maser Emission from Interstellar Hydroxyl Using the Long Wavelength Array

We present the results of an observational campaign using the Long Wavelength Array (LWA). The level splitting of the rotational ground state of the hydroxyl (OH) molecule gives rise to the four familiar 1.7-GHz (18-cm) transitions by which OH is known in the interstellar medium. There are also two magnetic-dipole transitions among these states at frequencies of 53.2 MHz and 55.1 MHz. These 54-MHz transitions have never been detected astronomically. Because of the relative weakness of the magnetic-dipole radiative process, it is expected that only maser emission will generate a detectable 54-MHz signal. Many of the prevailing pumping models for 18-cm masers are also suggestive of population inversions of the 54-MHz transitions. We have targeted our search toward Galactic locations that are known to exhibit strong 1720-MHz maser emission from OH with the expectation that either of the 54-MHz transitions will also be overpopulated.

Using the LWA station LWA1, we have searched the sources NGC 7538, G33.64-0.21, W75N, and Sgr A. For each target we employed 20 hours of integration time in beam-formed mode. We employed 1024 spectral channels in a 250-kHz observing band for each of the two transitions, resulting in a velocity resolution of approximately 1.4 km/s. We did not detect masers in either transition toward any of the sources. Previously reported observations of W75N using LOFAR also resulted in a non-detection; none of the other sources have been searched previously for either 53.2- or 55.1-MHz emission. We discuss the results in the context of previous and ongoing searches for 54-MHz emission.

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141.11 – The Cosmic Ray Anisotropy Mystery: Turbulent Anisotropic Interstellar Medium Magnetic Field Effects

The distribution of cosmic rays observed at Earth by a host of experiments, including IceCube, has been found to be anisotropic for a wide range of energies, spanning from ~TeV to ~PeV. The anisotropic distribution consists of both large angular scale and small angular scale components. The cause of the anisotropic distribution of cosmic rays, especially in the case of the small scale anisotropies, is a hotly debated topic in contemporary plasma physics and astrophysics. We perform simulations of cosmic rays propagating through the anisotropic, turbulent magnetic field of the interstellar medium to test hypotheses attempting to explain the observed anisotropy. We find that the mean free path of the cosmic rays is ~half the injection scale of the turbulence, indicating that the diffusion approximation for propagating cosmic rays may not be applicable. We also find that the angular power spectra derived from our simulations matches well the angular power spectra derived from observations. In this work, we discuss the implications of our findings.
This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

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141.12 – Chemical Complexity in the Shocked Outflow L1157 Revealed by CARMA

Amino acids, the complex organic molecules which are the building blocks of life, have been found in meteoritic samples and, most recently, in samples from Comet Wild-2. Yet, no amino acids have been detected in the gas-phase in the interstellar medium, which seeds and enriches these meteorites and comets. Glycine, the simplest amino acid, has been shown to form in the laboratory through the reaction of hydroxylamine (NH^2OH) with acetic acid (CH^3COOH), a known interstellar molecule. This has prompted a move to search for NH^2OH as a proxy of identifying regions where subsequent searches for glycine may prove the most fruitful.
A search for NH^2OH was conducted in seven diverse, molecule-rich sources and resulted in non-detections for all seven (Pulliam, et al. 2012). Theoretical work suggested the temperature of the sources was perhaps too low for NH^2OH to thermally-desorb into the gas phase. Searches in shocked molecular regions, however, may overcome this barrier, as complex molecules are non-thermally liberated into the gas-phase by these shocks.
Here, we present results from a targeted search toward the prototypical shocked outflow L1157. L1157-B0, -B1, and -B2 are shocked regions within the outflow from the infrared source L1157-mm. Using observations from the Combined Array for Research in Millimeter-wave Astronomy (CARMA), we have mapped a variety of molecular tracers in the region and conducted an interferometric search for NH^2OH with typical spatial resolutions of ~3”. We find that the prototypical complex molecule methanol (CH^3OH) peaks in B2, the newer shock. We compare this with the distributions of HCN and HCO^+ and discuss the implications for chemical evolution within the region. HCN, used as a density tracer, also peaks in B2 while HCO^+ is shown as diffuse throughout B0. We also present the first maps of isocyanic acid (HNCO) in L1157. HNCO is found to peak in B2, cospatial with CH^3OH and HCN. Finally, we report a non-detection of three NH^2OH transitions following a spatially-targeted search.
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141.13 – Instability of Magnetized Ionization Fronts Surrounding H II Regions

An ionization front (IF) surrounding an H II region is a sharp interface through which a cold neutral gas makes transition to a warm ionized phase by absorbing UV photons from central massive stars. We investigate the structure and stability of a plane-parallel D-type IF threaded by parallel magnetic fields. We find that weak D-type IFs always have the post-IF magnetosonic Mach number $\mathcal{M}_{\rm M2} \leq 1$. For such fronts, magnetic fields increase the maximum propagation speed of the IFs, while reducing the expansion factor by a factor of $1+1/(2\beta_1)$ compared to the unmagnetized case, with β_1 denoting the plasma beta in the pre-IF region. IFs become unstable to distortional perturbations due to gas expansion across the fronts, exactly analogous to the Darrieus-Landau instability of ablation fronts in terrestrial flames. The growth rate of the IF instability is proportional linearly to the perturbation wavenumber as well as the upstream flow speed. The IF instability is stabilized by gas compressibility and becomes completely quenched when the front is D-critical. The instability is also stabilized by magnetic pressure when the perturbations propagate in the direction perpendicular to the fields. When the perturbations propagate in the direction parallel to the fields, on the other hand, it is magnetic tension that reduces the growth rate, completely suppressing the instability when $\mathcal{M}_{\rm M2}^2 < 2/(\beta_1 - 1)$. When the front experiences an acceleration, the IF instability cooperates with the Rayleigh-Taylor instability to make the front more unstable.

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141.14 – A Faraday Rotation Investigation to Probe the Shells of HII Regions with Associated Stellar Bubbles

We performed polarimetric observations with the Very Large Array of 11 extra-galactic radio sources with lines of sight through the shell of the Rosette Nebula (VLA project AS1110). This investigation supplements the study of the shell of the Rosette Nebula by Savage et al. (2013). We utilize two methods for calculating the rotation measure (RM) for the new lines of sight. The first is using the traditional method of least-squares fit to $\chi(\lambda^2)$, and the second is using RM Synthesis (Brentjens & Bruyn 2005). We present a comparison of the two methods of obtaining RM values, and we find excellent agreement between the two methods. In addition, we discuss a plasma shell model, which is intended to reproduce the sign and magnitude of the observed RM due to the shell, with a new method of determining the model parameters, such as the inner and outer radii and the electron density, for specific lines of sight. This treatment of the model parameters allows us to extend our investigation to HII regions that do not have spherical symmetry, like the Heart Nebula/W4. We describe a new method of fitting a local shell model to specific lines of sight and then calculating the associated RM. By modeling the magnitude of the RM for specific lines of sight, we can better distinguish between a scenario where an observed excess in RM is due to an amplification of the magnetic field or one where it is exclusively due to an increase in the density of the shell. This research was supported at the University of Iowa by grant AST09-07911 and ATM09-56901 from the National Science Foundation.
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141.15 – The Warm Dust Component in the S106 Region

We present SOFIA/FORCAST images of S106 at the wavelengths 19, 25, 31, and 37 microns. We use these images to produce color temperature and optical depth maps in order to analyze the warm (~ 60 - 150 K) dust component. We resolve the disk shadow region into several relatively cool (~ 60 - 78 K) lanes with a radially dependent temperature gradient and warmer (~ 75 - 85 K) pockets of dust with a more uniform temperature distribution. The warmer pockets are spatially correlated with pockets of polycyclic aromatic hydrocarbon and HI emission as seen in the images presented by Smith et al. (2001). These results indicate that the disk is clumpy or contains holes with relatively higher UV throughput than the most obscuring parts. We also combine the SOFIA data with data from Spitzer/IRAC (3.6 - 8.0 microns), Herschel/PACS (70 and 160 microns), and the literature to produce the infrared spectral energy distributions of dust at locations in the disk shadow, bipolar lobes, compact sources, and the southwestern edge of the photodissociation region. From the SEDs and radiative transfer modeling, we constrain the mass abundances and size distributions of PAHs and dust grains such as silicates, carbonaceous grains, and very small, transiently heated grains, in these dramatically different regions.

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Contributing team(s): Spitzer Cygnus-X Legacy Team, Herschel Cygnus-X Team

141.16 – Enhanced Turbulence in M82 and M51 from Observations of Interstellar CH^+

Recent observations of diffuse molecular gas in M82 toward SN 2014J and in M51 toward its companion galaxy NGC 5195 have led to the discovery of high CH^+ abundances in these extragalactic lines of sight. The column densities of CH^+ are much higher in these directions (relative to the CH column densities) than would be expected based on other properties of the material. The equivalent widths of the λ5780.5 and λ5797.1 diffuse interstellar bands, for example, are suggestive of weak ambient radiation fields and/or significantly shielded environments, where the CH^+ abundance would normally be expected to be rather low. We interpret these findings within the framework of recent models of turbulent dissipation regions, which find that the CH^+ abundance is directly proportional to the average turbulent dissipation rate and inversely proportional to the square of the gas density. The high CH^+ abundances toward SN 2014J and NGC 5195 then suggest that the average turbulent dissipation rates could be significantly enhanced in M82 and M51 (relative to typical values characterizing the local Galactic interstellar medium). As both M82 and M51 are interacting with neighboring galaxies, such enhanced interstellar turbulence could be due to those interactions, either directly (i.e., as a result of the gravitational encounter) or indirectly (e.g., through increased star formation and supernova rates).

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141.17 – Warm Molecular Gas in Galaxies Characterized with CO from Archival Herschel Data

We have completed an initial pilot study of 17 galaxies (21 pointings) of molecular gas in nearby galaxies using CO rotational lines from J=1-0 to J=13-12; we are beginning to apply our methods to up to 150 galaxies observed with the Herschel SPIRE FTS. Observations to such high frequency in CO were unavailable until the launch of Herschel. This sample has a range of galaxy types (starburst galaxies, AGN, and elliptical galaxies) and far-infrared luminosities. The physical properties (temperature, density and mass) of the molecular gas are derived using non-LTE excitation modeling of CO. Dust properties (temperature and mass) are derived from SPIRE and IRAS/ISO/Spitzer archival photometry. The gas and dust properties will be compared as a function of galaxy type and far-infrared luminosity and will be used to ascertain the dominant excitation mechanism of the warm molecular gas and assess the effects of feedback from star formation and AGN in galaxies.

Our results find that CO is emitted from a low-pressure/high-mass component traced by the low-J lines and a high-pressure/low-mass component (kinetic temperatures of 100s of K) which dominates the luminosity. The CO J=6-5 line primarily arises in the warm component and its line luminosity is well correlated with the total CO luminosity. That transition, and other mid- to high-J, can be used as a reliable tracer of warm molecular emission. We find gas-to-dust-mass ratios < 120. We will discuss systematic effects of single-component and multi-component CO modeling. Through comparison to Galactic molecular emission, we show the molecular interstellar medium of starburst galaxies is not simply an ensemble of Galactic-type GMCs. The warm gas emission is likely dominated by regions resembling the warm extended cloud of Sgr B2.

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141.18 – Filamentary Dense Gas Clump Structures in the Galactic Center

The Galactic Center is a violent place where large amounts of gas and dust follow trajectories that lead to frequent cloud-cloud collisions. The gas is funneled from the disk along self-intersecting x1 orbits toward the inner, orthogonal x2 orbits. We present interferometric ATCA data which is sensitive to the cold, clumpy structure of the dense gas. The data are insensitive to the large-scale, extended, warmer gas envelopes that otherwise dominate Galactic Center gas maps. We use NH3 as a gas tracer and we show that a large fraction of gas clump locations seem to be aligned. Some of the gas likely follows the 100pc dust ring, but other structures may be due to re-alignment due to the mechanical impact of massive star clusters. We also show the relation of large scale magnetic field structures to the dense gas clumps. In particular we find an anti-correlation of the thin thermal and non-thermal radio continuum filaments with the dense gas clumps which indicates that large scale magnetic fields only have limited influence on the formation and alignment of dense gas filaments.

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141.19 – A simple analytic model for explaining the '[CII] deficit'.

The 158 µm far-infrared (FIR) fine-structure emission line of ionized carbon is quickly becoming the workhorse for studying high-z galaxies in the millimeter and submillimeter wavelength regimes. Given the capabilities of Atacama Large Millimeter Array it is sure to be used even more widely future for understanding early galaxies. This scientific popularity is owed much to its brightness, as easily 1% of a galaxies total FIR luminosity can appear just in the [CII] line itself. That being said, there are still many complexities involved in fully understanding the nature of [CII] emission in the plethora of different galaxies found in the universe. Of critical concern is understanding the "[CII] deficit" seen in low-z systems that showed a decline in the [CII]/FIR luminosity ratio for increasing FIR luminosity. While numerous studies of low-z systems have duplicated this result, observations of high-z systems break the trend. Here I present a simple analytic model that explains the trends in the [CII]/FIR ratio versus both total FIR luminosity and IR luminosity surface density, while consistently explaining the differences seen between low and high-z systems. This model assumes that star-forming ionized regions can be described by a simple Stromgren sphere. All trends in the [CII]/FIR ratio are then accounted for by either variations in the average luminosity of the ionizing source producing this average HII region or by changing the total number of said HII regions. Comparisons of the model with existing studies will be discussed as well as additional observation that can direct test the viability of the model.

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141.20 – The Structure of Dark Molecular Gas in the Galaxy - I First Results from a GBT Pilot Survey for 18-cm OH emission towards L~105, B~1

We report the first results from a ``blind'' survey for 1665, 1667, and 1720 MHz OH emission over a small region of the

Outer Galaxy centered at L = 105.0, B = +1.0. This sparse, high-sensitivity survey (Delta Ta= 3 mK rms in 0.55 km/s channels), was carried out as a pilot project with the Green Bank Telescope (FWHM 7.6') on a 3 X 9 grid at 0.5 deg spacing. The pointings were chosen to correspond with those of the CO(1-0) CfA survey of the Galaxy carried out earlier with substantially the same angular resolution (8.4'). Using 2-hr integrations, 1667 MHz OH emission was detected with the GBT at more than 21 of the 27 survey positions, confirming the ubiquity of molecular gas in the ISM as traced by this spectral line. With very few exceptions the 1665/1667 line ratios are in the LTE ratio of 5:9, and the few exceptions are familiar examples of anomalous OH emission. No OH absorption features are recorded in the area of the present survey, in agreement with the low levels of continuum background emission in this direction. With very few exceptions, peaks in the OH profiles coincide with peaks in the HI spectra (obtained concurrently with the GBT, FWHM 8.9'), although not every HI peak has associated OH emission. At each pointing the OH appears in several components extending over a wide range of radial velocity and coinciding with well-known features of Galactic structure such as the Local Arm and the Perseus Arm. In contrast, little CO emission is seen in the survey area; less than half of the 53 identified OH spectral features show detectable CO counterparts at the CfA sensitivity levels, and these are generally relatively faint. While higher-sensitivity CO data would undoubtedly turn many of the CO upper limits into measurements, such data is not likely to recover the missing CO profile line strengths. The 18-cm main lines of OH therefore appear to be a new tracer for the ``CO-Dark'' molecular gas in the Galactic ISM. Quantitative estimates for this dark molecular gas will be presented.

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141.21 – OH as a Tracer for Molecular Gas in the Galaxy: Line Ratios and Signatures of non-LTE Findings in the ISM

While carrying out a blind survey of OH emission in a quiescent region towards the outer galaxy near l = 105 degrees, b = 1 degree using the Green Bank Telescope, we analyzed the ratios of the line strengths and identified several non-LTE emission sources in addition to the majority that were in LTE. The fact that the majority of OH features were in LTE ratios suggests that in general, OH can be a useful tracer for components of the molecular ISM that may not be traced by CO. However, the several non-LTE OH features observed demonstrate that such a blind survey can also be put to other uses. One of the non-LTE features was identified as a known OH-IR star, which we found could be easily identified with 1665 and 1667 MHz spectra alone, even though OH-IR stars are most prominent in 1612 MHz. We also identified several 1720 MHz masers features in the local ISM, which were found at adjacent positions in the sky along an arc shape. These masers are likely to be tracing a C-shock propagating through the local ISM, covering several survey positions.

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141.22 – Multiple Methanol Transitions Detected in W51-E2 from the Arecibo Galactic Chemistry Survey

Two major components of the star-forming region W51 have been observed with the Arecibo 305-m telescope as a part of the Arecibo Galactic Chemistry Survey. Located at a distance of ~6 kpc towards the Sagittarius Arm, W51 is one of the most luminous and massive (upper 5-10% by mass and upper 1% by size of all Giant Molecular Clouds in our Galaxy; Carpenter & Sanders, 1998). The infrared source, IRS1, was observed over 1.1 – 10 GHz from 2010 through 2012, and the angularly nearby compact component, E2, over 4.3 – 4.9 GHz and 8.0 – 10.2 GHz in 2014. Methanol (CH^3OH) transitions at 8.34-GHz (4(1,3)-4(1,4)–+), 9.94-GHz (9(-1,9)-8(-2,7)), 9.98-GHz (4(3,2)-5(2,3)++), and 10.06-GHz (4(3,1)-5(2,4)—) were detected towards W51-E2 for the first time, some showing a mixture of emission and absorption. The peak emission ratios for the 9.94- to 9.98-GHz, and the 9.94- to 10.06-GHz transitions are consistent with the predictions of Slysh, Kalenskii & Val'tts (1993). All three 6-cm wavelength hydroxyl (OH) transitions were also detected, with the 4.66-GHz satellite line masing strongly. In IRS1, the intense methanol maser at 6.67 GHz (Araya et al. 2013) was observed to have a flux density of > 200 Jy, with the 4.66-GHz OH maser having an intensity of ~1 Jy. In IRS1, we also detected the methanol 9.94-GHz transition featuring emission with multiple components. Additionally, a total of over 60 H, 30 He, and 8 C radio recombination lines (RRLs) were identified in E2 over the two frequency ranges observed. This includes the highest frequency spectral line yet detected at Arecibo, namely the He(86)α RRL at 10.17 GHz. Over 120 H, 70 He, and 40 C recombination lines were identified in IRS1 over the frequency range of 4 – 10 GHz.

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141.23 – A Survey of AU-Scale Na I Structure in the Diffuse ISM

We present multi-epoch, high-resolution (R~230,000), high S/N observations of the interstellar Na I absorption toward a sample of 20 stars taken over the past 10 years with the KPNO Coude Feed telescope. These spectra reveal line profile variations (since 2004) in 12 of the 20 stars indicative of Na I structure on scales of ~10 to ~50 AU in the intervening diffuse ISM. Half of these 12 sightlines are located in Orion with the rest in Auriga, Eridanus, Leo, Monoceros, and Ophiuchus. The most dramatic Na I variations have been found in high-velocity gas associated with the Monoceros Loop (a ~100,000 year-old supernova remnant) toward the star HD 47240. Over the past 8 years, a single, narrow, high-velocity Na I component toward this star has oscillated significantly in strength and steadily widened into two narrow components. Given the 1.3 milli-arcsec/yr proper motion of HD 47240 and the ~50 km/s expansion velocity of the ~1.6 kpc distant Monoceros Loop, these absorption variations are sampling the structure of Na I gas in the Loop over a transverse distance scale of ~10 AU/yr. Almost all of the 12 sightlines exhibiting AU-scale Na I structure are associated with known H I shells, supernova remnants, or stellar bow shocks. Since Na I is not a dominant ion in diffuse clouds, temporal variations in its absorption along a particular sightline can be due to AU-scale fluctuations in either the gas column (*N(H I)*) or environmental conditions such as the cloud density (*n(H)*). Previous multi-epoch studies of UV interstellar lines have found that temporal dominant-ion absorption variations are exceedingly rare (Lauroesch 2007). Thus, it is most likely that the Na I variations reported here are due to AU-scale density fluctuations stimulated by turbulence or converging gas flows. Our new results suggest that such fluctuations may be common in some diffuse ISM regions (especially Orion).

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141.24 – Multi-Dimensional Hydrodynamic Simulations with Non-Equilibrium Radiative Cooling Calculations

In the optically thin gas within the temperature range of 10^4 to a few times 10^6 K, radiative cooling due to line emission from abundant metal ions such as carbon, nitrogen, oxygen, neon, silicon, and iron ions can affect the gas dynamics and it becomes important to calculate the cooling rates accurately while running the hydrodynamic simulations. The accurate calculation should trace together the detailed processes of ionization and recombination for all the relevant ions of each metal at each hydrodynamic time step, i.e., in a non-equilibrium fashion. So far, due to the computational cost, it has been delayed to implement this non-equilibrium cooling calculation in the multi-dimensional hydrodynamic simulations, but it is now possible to do this thanks to the rapidly growing computing powers. By using the platform of the FLASH code, we have implemented the non-equilibrium radiative cooling calculation in the multi-dimensional hydrodynamic simulations. Here we present the code development process and the results of some test problems.

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141.25 – CO Line Ratios in Nearby Galaxies

We present a systematic analysis of low-J CO line excitation across the disks of 40 nearby, star forming galaxies. We combine the HERACLES survey of ^{12}CO(2-1) emission conducted with the IRAM 30-m with the JCMT Nearby Galaxies Legacy Survey of ^{12}CO(3-2) emission. These data are supplemented with archival ^{12}CO(1-0) data from several facilities. We use a Bayesian formulation to robustly estimate the line ratios R^{21} = CO(2-1)/CO(1-0) and R^{32} = CO(3-2)/CO(2-1) in the presence of intrinsic scatter, non-detections, and a small fraction of unreliable data. We find that the canonical value of $R^{21} = 0.7$ only typifies galactic centers and that a value of $R^{21} = 0.5$ better typifies most galactic disks. We find $R^{32} = 0.5$ over a wide range of physical parameters with little change though R^{21} can vary more significantly. CO excitation is compared to local galactic properties. Of note, we find that star formation rate tracers are most clearly associated with higher values of R^{21} and R^{32}.

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Contributing team(s): HERACLES Team, NGLS Team

141.26 – A Three-Dimensional Look at the High Galactic Latitude Interstellar Medium

The structure of and relationship between ISM structures seen at high Galactic latitude is explored with the aid of distances determined from optical reddening profiles obtained from analysis of the Sloan Digital Sky Survey DR9 photometric catalog. This three-dimensional map contains high latitude molecular clouds, dust associated with intermediate velocity (-100 km/s < vlsr < -30 km/s) HI gas, and the ubiquitous Galactic cirrus. The distances and errors in the distances for the extinction layers due to the presence of interstellar dust are computed via a Monte Carlo algorithm. The reliability of the distance determination method is characterized as a function of the far-IR based extinction values predicted by Schlegel, Finkbeiner, and Davis (1998). The limiting performance of this technique is found in the results for the "blank field" regions defined by A_r < 0.05, whose reddening profiles are dominated by measurement noise and astrophysical scatter.

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141.27 – Tracing the Dense Molecular Gas in the Large Magellanic Cloud

We report findings from the Magellanic Mopra Assessment (MAGMA) Dense Gas Survey of the Large Magellanic Cloud (LMC), which comprises spectra of HCO^+(1-0), HCN(1-0), and HNC(1-0) toward 48 giant molecular clouds (GMCs) distributed across the LMC. ^{12}CO(1-0) and ^{13}CO(1-0) data from the MAGMA survey were also included. These molecules trace dense gas and hence are the ingredients of future star formation. We investigate possible correlations between the dense gas tracers and various physical and dynamical properties across the LMC. No correlation between the dense gas fraction (CO/HCN) and the position of the parent GMC is observed in the LMC. We compare our ^{12}CO data in these clouds to the 70 micron flux at those locations and find that our results are not consistent with the Kennicutt-Schmidt Law. However we do find that star formation rate is linearly correlated with the dense gas as traced by HCN. This further validates the usefulness of HCN to trace the dense gas in the molecular clouds. The analogous correlation using HCO^+ is found to be more complex. It appears that HCO^+ may saturate below a certain amount of star formation, hinting at an additional diffuse component in HCO^+. We find that the HCO^+/HCN line ratio is greater than 2 in the clouds studied here, whereas previous studies of this ratio in other galaxies typically report HCO^+/HCN roughly 1. This provides additional evidence for enhanced HCO^+.

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141.28 – Simulations of the Dynamics of Precursor Organic and Prebiotic Carbon-rich Moleculess

Not only has mid-IR imaging revealed an extraordinary variety of carbon-rich molecules present in the galaxy, but also that they can be seen in a host of different astronomical bodies; from HII regions to planetary nebula, and from young stellar objects to old post-AGB sources. The range of organic species discovered so far include PAHs, fullerenes, long chain hydrocarbons and carbonaceous clusters, some of which are biologically important. There's strong evidence that much of the terrestrial water was delivered to Earth during the Late Heavy Bombardment (LHB) approximately 3.8 - 4.1 Gyr ago [1]. Comparisons of the deuterium-hydrogen ratio of the Vienna Mean Standard Ocean Water and comets like Harley 2, have revealed a striking similarity [2]. It's not without reason to assume that prebiotic molecules may have been delivered to Earth, too. In this work, reactive molecular dynamics simulations [3] are performed to probe the formation of carbon-rich molecules and clusters on graphitic surfaces. The simulations are run over a range of temperatures, densities and carbonaceous surfaces and a comparison is made of the distribution of chain and cluster formation in the gas and condensed phases. Results from these simulations will be presented.

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141.29 – Exploring the ISM Supershell Structure Toward the Jewel Box

Analysis of archival HST high-resolution (R ~ 110,000) interstellar C I absorption spectra has revealed evidence of high-pressure gas toward two stars in the open cluster NGC 4755, also known as the Jewel Box. This cluster is a subset of the larger Centaurus OB1 association, which is surrounded by the H I supershell GSH305+01-24. Previous studies of H I emission from GSH305+01-24 yielded a velocity of v(LSR)= -24 km/s, with a shell expansion velocity of ~ 7 km/s (McClure-Griffiths 2001). Due to the paucity of sightlines with sensitive high-resolution UV spectra toward the Jewel Box, it is unclear if the high-pressure gas observed toward the cluster stars HD 111934 at v(LSR)=-41 km/s and CPD-59 4552 at v(LSR)=-33 km/s is associated with the cluster, the expanding supershell, or some other intervening cloud. Analysis of high S/N optical Na I absorption toward a number of stars in the Jewel Box shows a velocity component (v(LSR) ~ -40 km/s) for stars near the center of the cluster, but not for stars on its outer edges. Additionally, Na I observations of stars within 1 degree of the Jewel Box reveal a similar velocity component that appears to surround the cluster. One possible explanation for the observed velocity components is gas being driven outward from the cluster. The formation of H I shells is generally attributed to a combination of stellar winds and supernovae, and previous research has suggested that overpressures within clusters can drive material outward and provide the energy necessary to form supershells. Our work investigates the relationship between the Jewel Box and GSH305+01-24, and aims to determine if the cluster has been a key contributor to the evolution of the supershell.

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141.30 – Characterizing Interstellar Ammonia Masers in the Galactic Star Forming Region DR21(OH)

Using the Green Bank Telescope, we observed the (J,K)=(10,6), (11,6), (12,6), and (8,3) transitions of ammonia in DR21(OH). We detected neither emission nor absorption, with an upper limit of 3σ=0.11 Jy. From observations in 1984, DR21(OH) is known to have a (9,6) maser. There are three suggested possibilities for maser emission at higher rotational levels of ammonia: (1) there could be a maser in the adjacent (10,6) level, (2) there could be a maser in alternating levels, including (11,6), or (3) there could be no pumping above (9,6). NGC 7538 is known to have both a (9,6) and (10,6) maser, with a flux density ratio of 4.83:1, and no maser in either (11,6) or (12,6). If the excitation conditions in DR21(OH) are the same as in NGC 7538, a (10,6) maser with a flux density of 0.15 Jy would be expected in DR21(OH) but is not observed. Other possibilities are also discussed in detail.

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141.31 – From Gas to Stars in Energetic Environments: Chemistry of Clumps in Giant Molecular Clouds Within the Large Magellanic Cloud

We present parsec scale interferometric maps of HCN and HCO^{+} emission from dense gas in the star-forming region 30 Doradus, obtained using the Australia Telescope Compact Array (ATCA). This extreme star-forming region, located in the Large Magellanic Cloud (LMC), is characterized by a very intense ultraviolet ionizing radiation field and sub-solar metallicity, both of which are expected to impact molecular cloud structure. We detect 13 bright, dense clumps within the 30 Doradus-10 giant molecular cloud. Some of the clumps are aligned along a filamentary structure with a characteristic spacing that is consistent with formation via the varicose fluid instability. Our analysis shows that the filament is gravitationally unstable and collapsing to form stars. There is a good correlation between HCO^{+} emission in the filament and signatures of recent star formation activity including H$_{2}$O masers and young stellar objects (YSOs). We present detailed comparisons of clump properties (masses, linewidths, sizes) in 30Dor-10 to those in other star forming regions of the LMC (N159, N113, N105, N44). Our analysis shows that the 30 Doradus-10 clumps have similar mass but wider linewidths and similar HCN/HCO^{+} (1-0) line ratios as clumps detected in other LMC star-forming regions. Our results suggest that the dense molecular gas clumps in the interior of 30Dor-10 are well-shielded against the intense ionizing field that is present in the 30 Doradus region. We also present preliminary results from follow up observations with the ATCA of a several molecular lines detected from the brightest clumps in 30 Doradus-10, N113 and N159W. The maps cover the following dense gas, photo-dominated regions (PDRs), and shock tracers: HCN, HCO^{+}, C$_{2}$H, SiO, HNCO, SiS, N$_{2}$H^{+}, CS, CH$_{3}$H, CH$_{3}$CN, ${13}^CS, OCS, H$_{2}$, ${34}^$CS. These giant molecular clouds have varying radiation fields and energetics. We compare the chemistry within these giant molecular clouds to one another to obtain a detailed understanding on how the changing energetics and radiation fields affect star formation within the LMC.

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141.32 – Combining MeV-GeV γ-ray and X-ray Observations: A Broadband View of Supernova Remnant Kes 41

We report the detection of γ-ray emission coincident with the supernova remnant (SNR) Kes 41, using data from the Large Area Telescope on board the *Fermi Gamma-ray Space Telescope*. Kes 41 is believed to be interacting with molecular clouds, as evidenced by observations of hydroxyl (OH) maser emission at 1720 MHz in its direction and other observational information. SNR shocks are expected to be sites of cosmic ray acceleration, and clouds of dense material can provide effective targets for production of γ-rays from π^0-decay. We model its broadband nonthermal emission (from radio to γ-ray) using a simple one-zone model, and after considering scenarios where the MeV-GeV source originate in either π^0-decay or leptonic emission, we conclude that the γ-rays must be produced through the hadronic channel and derive a lower limit to the density with which the SNR is interacting. Additionally, we analyze the *XMM-Newton* X-ray observation of this remnant and derive an approximate density of the emmitting material. The discrepancy between the densities derived from the X-ray and γ-ray is discussed.

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141.33 – Radio Recombination Line Observations of Flickering Ultracompact HII Regions

High resolution, radiation-hydrodynamic and MHD simulations show that the accretion flows that form massive stars are gravitationally unstable, with the resulting dense clumps and filaments stochastically trapping and exposing stellar ionizing radiation. In these models, the developing HII region surrounding the star flickers between hypercompact and ultracompact states throughout the main accretion phase, rather than monotonically expanding. We have observed the well-studied, Galactic massive star forming region Sgr B2 with the EVLA at 7 mm and 1.3 cm in the continuum, and have detected evidence of ultracompact (UC) sources that change significantly in flux density over an $~$20 year baseline. These flickering sources also have been observed in the H52, H53, H66 and H68α radio recombination lines with the EVLA. Several of the flickering sources show broad recombination lines (ΔV > 50 km/s) and have rising spectral indices from 1.3 cm to 7 mm . We present results from the 1.3 cm (H66α and H68α) radio recombination line observations, and compare these lines to the 7 mm recombination line results. Line parameters from multiple radio recombination lines have been used to determine the relative importance of different line broadening mechanisms in individual sources.

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142 – The Milky Way, The Galactic Center Posters

142.01 – The Discovery of New Ammonia Masers in the Galactic Center

The ammonia molecule has long been recognized as a reliable gauge of cloud temperatures. Certain ammonia transitions are known to have a potential for masing, but to date only a handful of these masers have been identified. In this work we have examined several Galactic Center clouds using K-band data from the Very Large Array in DnC configuration (resolution ~3" / 0.1 pc) to identify new ammonia masers in the (3,3) metastable line. At present we have found four compact (< 3'') regions -- two in G0.253+0.016 (The Brick) and two near Sagittarius A -- that we can report with high confidence as newly-discovered ammonia (3,3) masers. A total of 16 additional regions are identified as likely maser candidates requiring additional analysis. Our findings suggest that the maser mechanism will preferentially amplify the main ammonia emission line over its hyperfine satellite lines, resulting in artificially low opacities measured from the ratio of these lines. This property can have the effect of partially hiding the signature of the (3,3) maser in opacity-corrected Boltzmann plots. In the highest confidence regions we measure main-to-hyperfine ratios significantly in excess of the maximum theoretical ratio for an optically-thin line, yielding negative opacities, consistent with our hypothesis of main line maser amplification. These results will be of value not only in future ammonia maser searches but also for the reliability of the ammonia molecule as a temperature tracer, and for the determination of ammonia ortho-to-para ratios.

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142.02 – Location of Deuterated Ammonia in Sagittarius B2

Multiple transitions of singly-deuterated ammonia was detected in Sagittarius B2 using the Karl G. Jansky Very Large Array (VLA) with a resolution of 3” and the Australia Telescope Compact Array (ATCA) with a resolution of 10”. Deuterated ammonia was detected in two sources in the Northern core of Sgr B2. The most commonly known source, the Large Molecule Heimat, had a velocity of ~61 km/s. The other source we designate as h had a velocity of ~73 km/s. Multiple transitions of ammonia and the isotopologue 15-ammonia were detected as well. NH^3 is a useful tracer of temperature, but in Sgr B2 the transitions were too optically thick to measure accurately. Instead$^{15}NH^3$ was utilized to find a rotation temperature and thus kinetic temperature. The temperature of h was higher than that of LMH, which is unexpected, because LMH is more chemically complex and contains an embedded ultra-compact HII region, suggesting it is the more evolved source, and should have a warmer temperature. The column densities of $^{15}NH^3$ and NH^2D were used to find the deuterated fractions in each source, with the ratio of ^{14}N to ^{15}N previously measured in Sgr B2 was used to infer the total ammonia column density. The deuteration fraction was found to be ~40x higher in h than LMH, which is surprising given h is the hotter source and fractionation reactions that lead to higher deuteration of molecules are favored in cooler temperatures. We will discuss possible explanations for these discrepancies.

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142.03 – Targeted VLA Observations of 22 GHz Water Masers Towards the Galactic Center

The Central Molecular Zone (CMZ) has a unique environment with a large amount (5 x10^7 $M^{\odot}$) of dense (10^4 cm^{-3}) warm (75-200 K) molecular gas. To probe sites of ongoing star formation in this region, we carried out follow-up VLA observations targeting 22 GHz water masers detected by a recent Mopra survey of the inner 3° x 1° of the Galactic Center (Chambers et al. 2014, A&A 563, A68). We present preliminary results of these measurements with higher angular resolution (2" x 0.9"), spectral resolution (0.2 km s^{-1}), and sensitivity (40 mJy $beam^{-1}$) and a velocity coverage of -200 to 250 km s^{-1}. A total of 32 maser positions are detected. Several sources display complex spectra with a number of new velocity components. From the 32 maser positions, over 200 spectral features have been identified, indicating clusters of masers. The complex spectra are indicative of young (< 10^5 years) star forming regions, with some of the components likely being produced from outflows. The brightest component is over 500 Jy $beam^{-1}$ towards the HII region G359.14+0.03 with a v^{LSR} of -9 km s^{-1}. The most prominent location of water masers is the star forming region Sgr B2, where over 80 spectral components are identified from 9 different positions with peak flux densities ranging from 0.8 to 142 Jy $beam^{-1}$. Three of these positions contain enhanced 4.5 µm green extended sources, indicating these masers are likely associated with outflows. Sgr C contains 3 separate maser positions with a total of 4 spectral components ranging from -70 to -66 km s^{-1} and peak flux densities of 4 to 15 Jy $beam^{-1}$. One of these positions is also associated with a green source. We will compare the water maser positions with positions of radiatively pumped 6.7 GHz methanol masers and other green (3-8 µm) sources. This comparison will be used to verify that star formation is the underlying source of these masers and to identify masers associated with outlfows.

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142.04 – New Temperature Constraints for the Circumnuclear Disk

The clumpy collection of clouds and dust around our Galaxy's central supermassive black hole is known as the Circumnuclear Disk (CND). With a radius of 1.5 pc, it is the closest reservoir of molecular gas to the black hole. Using combined observations of the ammonia molecule from the Karl G. Jansky Very Large Array and the Robert C. Byrd Green Bank Telescope (resolution: 3'' / 0.1 pc), we study the temperature of the CND, in order to better understand its future evolution: whether it will form stars or feed the black hole. Our results indicate the presence of hot (T= 200-300K) gas components in both CND clumps and other clumps with large negative velocities to the west and east of the CND. The temperatures we measure allow us to revise previous estimates of the average densities of CND clumps to be all less than 2.5*10^6 molecules / cm^3. This is less than the Roche limit for gas to be tidally stable at this distance from the supermassive black hole, indicating there is likely not yet star formation in these clumps.

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142.05 – Densities of Galcatic Center Clouds

The central 300 parsecs of the Galaxy is full of giant molecular clouds containing 10^7 solar masses worth of gas. However, our Galactic center is not forming as many stars as we think it can, based on the amount of molecular gas in this region. By studying the densities of the Galactic center clouds we hope to better understand why there is not much star formation occurring. Using data from the Green Bank and MOPRA telescopes we have observed multiple rotation transitions of HC^3N and its 13C isotopologues. By measuring the integrated intensity of the HC^3N we are able to calculate the densities of these giant molecular clouds. The measured intensities are used with a radiative transfer code called RADEX, to determine volume densities. Our initial results suggest that there may be either less dense or cooler gas in these clouds that previously thought. If there is a significant quantity of gas less dense than 10^4 molecules/cm^3, this could explain the lack of ongoing star formation in these clouds, and might also suggest a shorter timescale for dynamical disruption of theses clouds. In the future, we plan to improve these results by observing additional HC^3N transitions, allowing us better to constrain the relative contributions of multiple temperature and density components in Galactic center clouds.

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142.06 – New Background Infrared Sources for Studying the Galactic Center's Interstellar Gas

We describe an ongoing survey of several hundred highly reddened pointlike objects in the Central Molecular Zone (CMZ) of the Galaxy. The goal is to find bright objects with smoooth spectra that are suitable for high resolution infrared absorption spectroscopy of the Galactic center's interstellar gas, on slightlines spread across the CMZ. Until recently very few such objects have been known outside of the Arches, Quintuplet, and Central clusters. We have used 2MASS and Spitzer (GLIMPSE) photometry to identify objects with a significant likelihood of being stars embedded in circumstellar dust, and have been acquiring low resolution K-band spectra of them to determine their natures. Although by far the majority of objects turn out to be highly reddened red giants, approximately ten percent of them have smooth spectra rising steeply to longer wavelengths and are luminous, dust embedded stars. Based on follow- up spectroscopy of CO and H^{3+} a very few are foreground objects, but most are in the GC.

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142.07 – Star-Disk Collisions in the Galactic Center

Recent observations of the Milky Way's Galactic Center (GC) have revealed a relative paucity of red giant stars surrounding the GC's supermassive black hole (SMBH). It has recently been suggested that these 'missing' red giants can be explained by the interaction of red giant stars with the accretion disk that is likely to have existed around the SMBH (Amaro-Seoane & Chen, 2014). The key idea is that red giant stars can be rendered unobservable if they lose a significant fraction of their tenuous stellar envelopes or are entirely disrupted in such collisions. We set out to test this theoretical prediction with hydrodynamical simulations of star-disk collisions.

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142.08 – Star Formation in the Galactic Center: Radial Cloud Orbits via Feedback and Radiative Losses

Simulations of misaligned gas streamers in the vicinity of supermassive black holes indicate that highly radial molecular flows are marked precursors of star formation in the Galactic Center (GC), yet the manner by which cold gas can adopt such orbits remains unclear. Through hydrodynamic models of the circumnuclear disk (CND), we investigate the development of such trajectories due to catastrophic angular momentum redistribution driven by stellar feedback (supernovae). For an improved equation of state, a prescription for optically thin cooling is included and heating arising from black hole X-ray radiation, interstellar radiation fields, and cosmic ray ionization is used in agreement with dust and gas measurements of the GC. Compared to adiabatic simulations, models with full thermal physics show density enhancements of a few orders of magnitude. Furthermore, the filaments forming in these simulations are characterized by lower angular momentum orbits. Combined, these effects suggest that fragmentation of the CND can provide an avenue for the development of highly radial molecular gas in-fall and the subsequent formation of stars.

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142.09 – The Stellar Cusp in the Galactic Center: Three-Dimensional Orbits of Stars

We present new findings from our long term study of the nuclear star cluster around the Galaxy's central supermassive blackhole (SMBH). Measurements where made using speckle and laser guided adaptive optics imaging and integral field spectroscopy on the Keck telescopes. We report 13 new measurable accelerating sources around the SMBH, down to ~17 mag in K band, only 4 of which are known to be young stars, the rest are either known to be old stars or have yet to be spectral typed. Thus we more than double the number of measured accelerations for the known old stars and unknown spectral type population (increasing the number from 6 to 15). Previous observations suggest a flat density profile of late-type stars, contrary to the theorized Bahcall-Wolf cusp (Bahcall & Wolf 1976, 1977; Buchholz et al. 2009; Do et al. 2009; Bartko et al. 2010). With three-dimensional orbits of significantly accelerating sources, we will be able to better characterize the stellar cusp in the Galactic center, including the slope of the stellar density profile.

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142.10 – Understanding the Morphology and Kinematics of the Local Interstellar Medium

In our 2008 paper (Redfield and Linsky ApJ 673, 283), we proposed a model of the local interstellar medium (LISM) containing 15 warm partially ionized clouds, each with its own velocity vector, located within 15 pc of the Sun. Since then we have obtained many new high-resolution spectra from HST and optical spectra of nearby stars containing a large number of interstellar absorption lines (see Malamut et al. ApJ 787, 75 (2014)). With this large increase in interstellar data, we have developed a new three-dimensional model of the LISM consisting of a larger number of partially ionized clouds, revised cloud shapes, and including constraints of Stromgren spheres surrounding hot white dwarfs and the location of stars with detected astrospheres inside of clouds with neutral gas. We discuss which clouds are likely to be filamentary and where cloud-cloud interactions likely occur. We present a new model for the shape of the Local

Interstellar Cloud and show that its irregular shape may be determined by the directions of bright sources of extreme-UV radiation. We consider whether the LISM is best described by a complex of distinct partially ionized clouds each a different velocity vector or a continuous medium with a complex velocity structure.
This work is supported by grants and HST observing time from the Space Telescope Science Institute

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142.11 – The Milky Way Skeleton

Recently, Goodman et al. (2014) argued that a very long, very thin infrared dark cloud "Nessie" lies directly in the Galactic mid-plane and runs along the Scutum-Centaurus arm in position-position-velocity space as traced by low density CO and high density NH^3 gas. Nessie was presented as the first "bone" of the Milky Way, an extraordinarily long, thin, high contrast filament that can be used to map our galaxy's "skeleton." We present the first evidence of additional "bones" in the Milky Way Galaxy, arguing that Nessie is not a curiosity but one of many filaments that could potentially trace galactic structure. Our ten bone candidates are all long, filamentary, mid-infrared extinction features which lie parallel to, and no more than twenty parsecs from, the physical Galactic mid-plane. We use CO, N^2H+, and NH^3 radial velocity data to establish the location of the candidates in position-velocity space. Of the ten filaments, three candidates have a projected aspect ratio of >50:1 and run along, or extremely close to, the Scutum-Centaurus arm in position-velocity space. Evidence suggests that these three candidates are Nessie-like features which mark the location of the spiral arms in both physical space and position-velocity space. Other candidates could be spurs, feathers, or interarm clouds associated with the Milky Way's galactic structure. As molecular spectral-line and extinction maps cover more of the sky at increasing resolution and sensitivity, we hope to find more bones in future studies, to ultimately create a global-fit to the Galaxy's spiral arms by piecing together individual skeletal features. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

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142.12 – The GBT HII Region Discovery Survey: Galactic Structure

The HII region discovery survey (HRDS) has significantly expanded the census of HII regions in the Galaxy using the Green Bank Telescope (GBT). HII regions are the formation sites of massive OB stars and reveal the locations of current Galactic star formation. They are the archetypical tracers of spiral arms since, unlike other tracers, the identification of an HII region unambiguously locates massive star formation. Their chemical abundances indicate the present state of the ISM and reveal the elemental enrichment caused by the nuclear processing of many stellar generations. We determine kinematic distances in a self consistent way and explore Galactic structure across the Milky Way disk. In thermal equilibrium metal abundances are expected to set the nebular electron temperature with high abundances producing low temperatures. We derive the electron temperature using the radio recombination line-to-continuum ratio and use these values to explore metallicity structure.

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142.13 – Modelling the Accretion History of the Galactic Disk (and the Gravitational Lensing of a High-z Galaxy)

Over its long history, the Milky Way is expected to have accreted many dwarf galaxies. The debris from the destruction of most of these dwarf galaxies will by now be fully phase-mixed throughout the Galaxy and hence undetectable as local over-densities in position-space. However, the debris from these systems could have distinct kinematic signatures that may help distinguish these stars from, for example, the Galactic disk. We aim to construct a reliable method of determining the contributions to the Milky Way disk from accreted structures that could be applied to current kinematic data sets, such as SDSS's APOGEE survey. In an effort to mimic the kinematic traits of an accreted satellite, we construct single-orbit models to compare to a cosmologically motivated simulation of satellite accretion. We find that these orbit models adhere to the kinematic signatures of certain types of accreted galaxies better than others, giving us insight on which parameters to trust when searching for accreted populations.

As a bonus, we describe a separate project in which we attempt to deduce the intrinsic properties of the 8 o'clock arc, a gravitationally lensed Lyman break galaxy at redshift 2.73. Using the *lensmodel* code and its pixel-based source reconstruction extension *pixsrc*, we derive a de-lensed image of the galaxy in the source plane.

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142.14 – Kinematics of the AEGIS Spectroscopic Sample of Milky Way Halo- and Disk-System Stars from SkyMapper

We report a first-pass analysis of the kinematics of the AEGIS (AAOmega Evolution of Galactic Structure) sample of some 70,000 stars selected from the Australian SkyMapper Southern Survey (SMSS), based on medium-resolution (R ~ 2000) spectra obtained with the AAOmega spectrograph on the 3.9m Australian Astronomical Telescope. This sample was chosen in order to cover the range of metallicities included in the SMSS, as part of its calibration, and includes substantial numbers of stars in both the halo and disk systems of the Galaxy. The nature of these populations is explored, and compared with previous studies.

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Contributing team(s): The SkyMapper Team, The AEGIS Collaboration

142.15 – The Relative Ages of the α-rich and α-poor Stellar Populations in the Galactic Halo

The inner Galactic halo is thought to contain two populations; an α-rich component of stars formed in situ and an α-poor component of stars accreted from dwarf galaxies. The fraction and ages of these in situ and accreted stars can be used to disentangle the importance of accretion events in the assembly of the Galactic halo. We present here recent results on the relative ages of the α-rich and α-poor populations in the (inner) Galactic halo using the Sloan Digital Sky Survey (SDSS). To separate low-resoultion SDSS spectra based on [α/Fe], we have developed a new semi-empirical spectral-index based method. The method can be used to estimate the [α/Fe] directly providing a new and widely applicable way to estimate chemical abundances from low-resolution spectra. Results indicate that halo stars appear to be older than 8 Gyr confirming the idea that the Galactic halo was formed very early on. Interesingly, a bifurcation appears in the age-metallicity relation such that in the low -metallicity regime the α-rich and α-poor populations are coeval while in the high-metallicity regime the α-rich population is older than the α-poor population. Our results also indicate that the α-rich halo population, which has shallow age–metallicity relation, was formed in a rapid event with high star formation, while the α-poor stars were formed in an environment with a slower chemical evolution time-scale.

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142.16 – Dissecting the Milky Way disk with LAMOST

The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) survey has obtained over 3 million stellar spectra through its first two years of operations. This vast ensemble of bright star spectra is an unprecedented resource for detailed kinematical studies of the nearby Galactic disk. We detail recent results from LAMOST that uncover asymmetries in the vertical and radial (Galactocentric) velocity components of Milky Way disk stars. Using effective temperature as a proxy for stellar age, we have found that cooler stars in the extended Solar neighborhood appear to be in equilibrium, and that the velocity substructure is mostly present among warmer -- and thus younger -- stars. We detail our continued efforts to improve estimates of stellar distances and proper motions, which are vital to the process of disentangling complicated disk kinematics. With the huge number of spectra observed by LAMOST covering large contiguous sky areas, it is becoming possible to dissect the kinematical structure of the local disk in minute detail, while also reconstructing the larger-scale dynamics of the disk. This research was supported by NSF grants AST 09-37523 and AST 14-09421.

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142.17 – Probing Kinematic Substructures in the Virgo Overdensity using RR Lyrae from Recent Surveys

The Virgo Overdensity is one of the most intriguing features of the galactic halo, as it covers a large portion of the sky and seems to contain several kinematic substructures. It has been suggested that the remnants of several merger events coexist in this region. RR Lyrae stars are an excellent tracer for disentangling the different components of this overdensity, since they are excellent standard candles; by using both positions and pulsation-corrected radial velocities, we can identify distinct groups in phase space. In the last year, several surveys for RR Lyraes covering the Virgo region have become publicly available. We present analysis of ~300 spectra for ~200 stars in the Virgo overdensity region. This is a significant increase in the known sample of these stars in the region, spanning a significantly larger area of the sky than previous studies. Photometry for these data are taken primarily from the La Silla and Venezuela QUEST variability surveys with spectra provided by SDSS Data Release 10. Radial velocities for type ab RR Lyrae stars are corrected using the new set of template radial velocity curves for Balmer and metallic lines given by Sesar (2012). We combine data from QUEST, the Catalina Sky Survey, LINEAR, and spectroscopic observations from Duffau (2014) to give our full sample. A preliminary analysis reveals confirmation for several known stellar streams.

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142.18 – Testing the Dark Matter Caustic Theory Against Observations in the Milky Way

We test a particular theory of dark matter, in which dark matter axions form ring “caustics” in the plane of the Milky Way. According to this theory, cold collisionless dark matter particles with angular momentum flow in and out of the Milky Way as it forms. These flows form caustic rings (at the positions of the rings, the density of the flow is infinite) at the locations of closest approach to the Galactic center. We show that the caustic ring dark matter theory reproduces a roughly logarithmic halo, with large perturbations near the rings. We show that the theory can reasonably match the known Galaxy rotation curve. We explore the effects of the caustic rings on dwarf galaxy tidal disruption using N-body simulations. Simulations of the Sagittarius dwarf galaxy in a caustic halo potential match observations as far as 90 kpc from the Galactic center. The source code for calculating the caustic halo acceleration has been made publicly available in the NEMO Stellar Dynamics Toolbox and the Milkyway@home client repository. This research was funded by NSF grant AST 10-09670, the NASA-NY Space Grant, and the American Fellowship from AAUW.

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142.19 – Globular Cluster Streams as Galactic High-Precision Scales - The Poster Child Palomar 5

We model the tidal stream of the Milky Way globular cluster Palomar 5 (Pal 5), and show that the unique geometry of the problem yields powerful constraints on the model parameters characterizing the Local Standard of Rest (LSR), the Milky Way and Pal 5 itself. Using only SDSS data and a few radial velocities from the literature, we find that the distance of the Sun from the Galactic Center is 8.30+/-0.25 kpc, and the LSR transverse velocity is 242+/-16 km/s. Assuming that the dark halo of the Galaxy follows a NFW density profile, we fit it with a virial mass of (1.6+/-0.4) 10^{12} M^{sun}, a virial radius of 195+/-19 kpc, and hence a rather low concentration of 5+/-2. Moreover, we find it with a flattening of q^z = 0.95(+0.16)(-0.12) to be essentially spherical - at least within the inner 25 kpc, which are effectively probed by Pal 5. We also determine Pal 5's mass, distance and proper motions independently from other methods, which enables us to perform vital cross-checks for these methods. We conclude that finding more globular cluster streams is essential for mapping out the structure of the halo of our Galaxy to high precision. Finally, we point out that all our best-fit models yield similar substructure patterns as the ones observed in the Pal 5 stream within about 5 kpc of the cluster. The origin of these substructures is epicylic motion of stars along the stream. Such epicylic substructures have to be taken into account when searching tidal streams for signs of past encounters with dark-matter subhalos

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142.20 – The Three-Dimensional Density Distribution of Candidate AGB Stars in the Milky Way

We study the structure of the Milky Way disk candidate asymptotic giant branch (AGB) stars selected from the infrared ALLWISE catalog. The advantages of our approach, compared to most recent similar works such as those based on SDSS data, are large distance limits due to the high luminosity of AGB stars, small interstellar dust obscuration due to longer wavelengths, and the all-sky coverage of the WISE survey. The candidate AGB stars are color-selected with high completeness and low contamination, as quantified using samples of known AGB stars and other objects with known classifications from the SIMBAD and SDSS databases. Distances to candidate AGB stars are estimated simultaneously with interstellar dust extinction along the line of sight using a 3-dimensional dust distribution model developed to support LSST simulations and a color vs. absolute magnitude relation calibrated using the LMC and the Galactic bulge. We find that the Galactic disk extends radially out to about 15 kpc, and that it is flaring towards its edge. We present measurements of the vertical scale height and scale length for double-exponential disk models. We find that the density distribution of AGB candidates within 9 kpc from the Galactic center is consistent with that of a double-exponential profile, while at larger radii the distribution is indistinguishable from a single-exponential profile.

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142.21 – Defining Spatial Extent of Sagittarius Dwarf Tidal Stream and the Virgo Overdensity with MilkyWay@home

We refine and present tests of the statistical photometric parallax methods used to measure substructure of the halo stars with MilkyWay@home. This newer algorithm is showing promise for separating three substructure components, including the two parts of the bifurcated Sagittarius tidal stream and the Virgo Overdensity, while also fitting a smooth background component simultaneously. We show that the Sagittarius tidal streams and the Virgo Overdensity are much wider than previously imagined. We present the new results in the context of previous measurements of the properties of these halo substructures. This research was funded by NSF grant AST 10-09670, the Rensselaer Center for Open Source Software (RCOS), and crowd funding from the MilkyWay@home volunteers.

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142.22 – Probing Galactic Structure with the Spatial Correlation Function of SEGUE G-dwarf Stars

We apply a commonly-used tool in large scale structure surveys, the 3-dimensional two-point correlation function, to G dwarfs in the Milky Way in an effort to constrain Galactic structure and to search for statistically significant stellar clustering. Our G-dwarf sample is constructed from SDSS SEGUE data by Schlesinger et al. (2012). We find that the correlation function shape along individual SEGUE lines of sight depends sensitively on both the stellar density gradients and the survey geometry. By fitting mock measurements of smooth disk galaxy models to SEGUE data measurements, we obtain strong constraints on the thin and thick disk components of the Milky Way. We also find that the two smooth disks model cannot fully explain the SEGUE data, which indicates substructure on very small scales.

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142.23 – Halo Substructure in the Hercules-Aquila Cloud

We present the velocity substructure in the direction of the northern portion of the Hercules-Aquila Cloud using observations taken at Apache Point Observatory (APO), in conjunction with Data Release 10 of the Sloan Digital Sky Survey (SDSS). The Hercules Aquila Cloud is an overdensity of halo stars found at low Galactic latitudes in the direction of the Galactic center. Using Blue Horizontal Branch stars (BHBs), we identify several structures as overdensities in distance and velocity. The most prominent of these structures covers ~ 250 deg^2 of the sky centered around (l,b)~(55°,45°) and ranges in distance from 16~27 kpc. This structure is found to be metal poor, [Fe/H] ~ -2.0, with a tight velocity distribution of -60 km/s < v^{gsr} < -20 km/s. Although this halo substructure has about the same location and distance as the Hercules Aquila Cloud, the line-of-sight velocity differs by 220 km/s from the published velocity for this cloud. The other low metallicity substructures that appear to clump in distance and velocity have similarly large spatial distributions on the sky, which may point to additional ancient accretion events. This research is supported by the NSF through grants AST 09-37523 and AST 10-09670, as well as the NASA-NY Space Grant.

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142.24 – A Spectroscopic Study of Hydra I: The Possible Progenitor of the Eastern Banded Structure

We present initial results of an MMT/Hectochelle spectroscopic study of the Hydra I spatial overdensity located along the Eastern Banded Structure (EBS) stellar stream. The extended double-lobed structure and strength of the overdensity suggest that Hydra I may be the stream's progenitor and undergoing active disruption. With its distance of only ~10 kpc, Hydra I presents a unique opportunity to study the disruption of a star cluster or dwarf galaxy. In past work, SDSS/SEGUE velocities revealed Hydra I to be a kinematically cold structure. However, the small number of candidate members and the significant SEGUE velocity uncertainties (~10 - 15 km/s) precludes testing the nature of Hydra I. To better understand its chemo-dynamic properties, we have begun a spectroscopic survey of the Hydra I/EBS region in order to (i) obtain a robust, velocity-based selection of candidate member stars, (ii) use precise velocities to measure the velocity dispersion, (iii) study the spatial distribution of spectroscopic members, and (iv) measure its proper motion. At present, we have surveyed a ~3 deg x ~3 deg region, which encompasses the entire ~4 sq. deg spatial extent of Hydra I. We have obtained a total of 1354 spectra in this region, with RV uncertainties smaller than ~5 km/s at magnitudes brighter than g~21.6. This work presents our confirmation of Hydra I as a cold halo structure, as well as a more detailed analysis of the membership and spatial/velocity structure of Hydra I.

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142.25 – The Milky Way Dwarf Galaxy Population in the DES and LSST Era

We predict the spatial distribution and number of Milky Way dwarf galaxies to be discovered in the DES and LSST surveys, by completeness correcting the observed SDSS dwarf population. We take steps to overcome the limitations of past predictions by using (i) multiple models for how dwarf galaxies populate dark matter halos, (ii) multiple LCDM simulations of Milky Way/M31 pairs, and (iii) updated SDSS detection limits. We find that the observed spatial distribution of Milky Way dwarfs in the LSST-era will discriminate between the earliest infall and other simplified models for which dark matter subhalos host dwarf galaxies. Inclusive of all toy models and simulations, at 90% confidence we predict a total of 37 - 114 L > 10^3 $L^{\odot}$ dwarfs and 131 - 782 L < 10^3 $L^{\odot}$ dwarfs within 300 kpc. These numbers of L > 10^3 $L^{\odot}$ dwarfs are dramatically lower than previous predictions, owing primarily to our use of updated detection limits and the decreasing number of SDSS dwarfs discovered per sky area. For an effective limiting magnitude of r ~ 25.8 mag, we predict: 3 - 13 L > 10^3 $L^{\odot}$ and 9 - 99 L < 10^3 $L^{\odot}$ dwarfs for DES, and 18 - 53 L > 10^3 $L^{\odot}$ and 53 - 307 L < 10^3 $L^{\odot}$ dwarfs for LSST. These enormous predicted ranges ensure a coming decade of near-field excitement with these next generation surveys. This work was supported by NSF AST-1151462.

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143 – Evolution of Galaxies Posters

143.01 – Coupling Semi-Analytic Models and N-Body Simulations: A New Way of Making Galaxies and Stellar Halos

Stellar halos give insight to the initial conditions that existed when a host galaxy first formed and provide details on disrupted satellites by looking at the different stellar populations. An algorithm that is computationally inexpensive compared to hydrodynamic simulations is necessary in order to theoretically study the structure and formation of galactic stellar halos in sufficient detail to probe substructure. Currently being developed is CoSANG (Coupled Semi-Analytic/N-body Galaxies), a new computational method that will couple pure dark matter N-body simulations with a semi-analytic model. At each timestep, results from the N-body simulation will feed into the semi-analytic code, whose results will feed back into the N-body code making the evolution of the dark matter and baryonic matter dependent on one another. CoSANG will require much less computing power than hydrodynamical simulations, and will enable a variety of galaxy formation science, including analysis of stellar populations, halo merging, satellite accretion, supermassive black holes, and indirect and direct dark matter detection.

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143.02 – Comparison of Merging Dark Matter Halo Histories

The histories of colliding galaxies are analyzed using cosmological simulations. We compare results from different halo finders, programs that trace dark matter halos (in which galaxies are embedded) through time using different algorithms. We construct merger trees using different halo finders. Tools such as merger trees are important in creating a foundation for galaxy formation and in better understanding the evolution of the cosmic structure of the universe. This project focused on analyzing the history of one current-day dark matter halo in detail. By using one simulation of a Milky Way-mass galaxy, two halo finders output data sets for the single current-day dark matter halo. The use of a database assists in analyzing merger trees to compare the reliability of different halo finders, and to conduct resolution convergence tests. Discrepancies were found between two different halo finders in the structure of their respective merger trees. We are investigating the origin of these discrepancies in detail. This project has been supported by funding from National Science Foundation grant PHY-1263280.

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143.03 – Physical Properties and Evolution of Gravitationally Bound Halo Structures in Cosmological Dark Matter Simulations

Dark matter halos existing around visible galaxies are important for studies of galaxy formation and evolution. Since dark matter does not interact with light and cannot be observed directly, studies of dark matter halos are advanced by computer simulations. Normally, halos are defined by their virialized regions; however, regions that are non-virialized can still be gravitationally bound, like the collision-bound Milky Way and Andromeda galaxies. Our project is the first comprehensive characterization of gravitationally bound halo structures, their properties, and their evolution. This study found the bound regions surrounding every dark matter halo from a 100 Mpc cube of the Bolshoi Simulation at redshifts 0, 1, and 2. We optimized computation by removing subhalos, implementing a search radius, and parallelizing code across 160 supercomputer cores. Then, we created a mass function, circular velocity function, and correlation function to describe these regions. The evolution of these properties was consistent with predictions from a ΛCDM universe model. We characterized the sizes and shapes of these bound regions across different mass intervals and redshifts. Most bound regions are elongated, although they become more spheroidal with time. The results enable astronomers to predict how dark matter halos behave in non-virialized regions of space and deepen our understanding of galaxy formation.

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143.04 – Magnetic Field Seeding through Supernova Feedback

Stellar feedback occurring at small-scales can significantly impact the evolution of galaxies at much larger scales. For example, an appropriate feedback mechanism, including thermal and radiative components, can help regulate star formation, particularly in low-mass galaxies. While feedback models are generally prevalent in numerical simulations, the magnetic component is often neglected. However, measurements of galaxies indicate the presence of fields with a strength on the order of μG. Previous studies have demonstrated the formation of these fields through the amplification of a primordial magnetic field. Here, we describe a self-consistent prescription where magnetic fields are injected in supernova injections, calibrated by observations of magnetic fields in supernova remnants. These fields will then become seeds that evolve by way of mixing and turbulence to result in galactic-scale magnetic fields. As a proof of concept, we apply this method to model the supernova of a single Population III star and trace the evolution of the injected magnetic field. Future studies will apply this prescription to study not only the effects of magnetic fields on galaxy formation and evolution, but also the growth of the magnetized bubbles that form in the IGM.

Author(s): Daegene Koh[1], John Wise[1]
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143.05 – Stirring the Galactic Recipe: Studying the Effects of Galaxy Mergers and Cosmic Flows on Accreting Black Holes in Milky Way-Size Galaxies

Through the use of cosmological hydrodynamic simulations, we explore the nature of the gas that fuels supermassive black holes in Milky Way-sized galaxies. By following the gas from its origins to its accretion onto the supermassive black hole, we can focus in particular on the relative importance of cold flow gas and gas accreted through galaxy mergers. We choose present-day Milky Way analogs with very different evolutionary pathways, one with a quiescent history and one which undergoes several major mergers, to better probe the effect merger history has on black hole growth. This study is an extension of Bellovary et. al. 2013, which examined early black hole assembly within high mass galaxies and found that the initial angular momentum of the gas was more crucial than the source and state of the gas itself. We present preliminary results on fuel that preferentially grows supermassive black holes in Milky Way analogs from seeds to the present epoch.

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143.06 – Modeling the Accretion and Feedback Processes of Galaxies Similar to the Milky Way

Composed of sheets, walls, and filaments, the cosmic web connects clusters of galaxies together and is responsible for regulating galaxy evolution by the accreting mass into galaxies via filaments. In an effort to further understand the evolution of galaxies, we first study filaments and devise an interactive analytical model for disk galaxies with accurate inflow and outflow rates of matter. Using accretion rates and feedback rates from different regions in the Galaxy, it is now possible to model and predict galactic behavior for a galaxy with similar mass and morphology as the Milky Way. Other models simulate feedback or accretion processes numerically and in greater detail. Here we consolidate the rates to make one single model for the galaxy as a whole. In this model, we take the rates from other papers and use them to calculate the total mass flowed, energy used, distance travelled, and current location of the gas from the following parameters: change in time, redshift value, morphology of the galaxy, and type of active galactic nuclei (AGN) the galaxy has at its center. Although, we have just begun to make this detailed model, it will serve as the foundation for future work to be done to further understand galaxy evolution.

Author(s): Steven Hyatt[1], Lara Arielle Phillips[2]
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143.07 – Generation of composite galaxies in dynamic equilibrium

We present a program to construct disk galaxies in dynamic equilibrium using the moment-based approach. The method is highly modular, allowing components such as bulges, halos, point-particle black holes, and interstellar clouds to be easily added or removed. The gravitational potential and its derivatives for a given galactic configuration are stored on a high-resolution linear/exponential grid in the *R-z* plane and can be scaled based on component mass. This allows one grid to be used for different sets of initial conditions, drastically reducing computing time. The method is used to initialize and simulate two coaxial, counterrotating disk galaxies undergoing a vertical merger, among other simulations.

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143.08 – The Impact of Galaxy Flybys on Disk Galaxies

Fast, one-off interactions, or flybys, between galaxies are surprisingly common and can even out number mergers at low redshift for massive halos. While these interactions are transient and occur well outside a galaxy's disk, they can still significantly impact the galaxy. We present results from collisionless simulations of three co-planar flybys between pure-disk galaxies demonstrating that flybys can both trigger bar formation and spin-up dark matter halos.

Author(s): Meagan Lang[1], Kelly Holley-Bockelmann[1], Manodeep Sinha[1]
Institution(s): *1. Vanderbilt University*

143.09 – Shrinking Galaxy Disks with Fountain-Driven Accretion from the Halo

Star formation in most galaxies requires cosmic gas accretion because the gas consumption time is short compared to the Hubble time. This accretion presumably comes from a combination of infalling satellite debris, cold flows, and condensation of hot halo gas at the cool disk interface, perhaps aided by a galactic fountain. In general, the accretion will have a different specific angular momentum than the part of the disk that receives it, even if the gas comes from the nearby halo. Then the gas disk expands or shrinks over time. Here we show that condensation of halo gas at a rate proportional to the star formation rate in the fountain model will preserve an initial shape, such as an exponential, with a shrinking scale length, leaving behind a stellar disk with a slightly steeper profile of younger stars near the center. This process is slow for most galaxies, producing imperceptible radial speeds, and it may be dominated by other torques, but it could be important for Blue Compact Dwarfs, which tend to have large, irregular gas reservoirs and steep blue profiles in their inner stellar disks.

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143.10 – Stellar metallicity evolution in a simulated disc galaxy

We explore the chemical evolution of two galaxies simulated using the same initial conditions but different feedback schemes (MUGS and MaGICC). We examine the age-metallicity relation (AMR), time—[O/Fe] and metallicity-[O/Fe] distributions of the stars in different galactic components, e.g. the bulge, disc and halo. The MUGS galaxy is replete with substructure, which is lacking in MaGICC, because MUGS feedback allows for more satellites. The AMR saturates at a certain point for each galaxy, while the metallicity of some objects can even decrease with time. This implies that the common assumption that metallicity is an increasing function of time, used in reconstructions of star formation histories of galaxies, is far from justified.

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Institution(s): *1. University of Alabama, 2. University of Central Lancashire, 3. University of Michigan*

143.11 – Modeling the Chemical Evolution of Elliptical Galaxies

Stellar abundance patterns uniquely trace the chemical enrichment of their galaxies. These abundance patterns can be related to galactic star formation and assembly histories using chemical evolution codes. The Milky Way has been extensively modeled over the past 40 years, however, little work has been done to analyze the abundance properties of early-type galaxies. In the past year, Conroy et al published the first abundance measurements of elements such as Ni and Co in elliptical galaxies. I introduce the semi-analytical chemical evolution model for early-type galaxies that I have developed to understand the trends found in this newly available data. I demonstrate the validity and explore the limitations of my code using fits to Milky Way data. I also present models for elliptical galaxies and discuss the implications for their assembly, particularly the need for galactic outflows.

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143.12 – The Effects of Compositeness on Stellar Populations

This is a time when chemodynamical galaxy formation models are starting to predict abundance distribution functions (ADFs) along with star formation histories, bringing a new level of promise to understanding the web of galaxy formation. The present work aims to raise the ADF to a measurable quantity, at least in passively evolving galaxies.

The effects of metallicity-compositeness on the integrated light of a stellar population are explored theoretically. The main parameter controlling the observables is the width of the ADF, though the asymmetry matters as well. Because metal poor populations are brighter per unit mass, two effects are seen as overall heavy element content (metallicity) is increased. “Red lean” is the tendency for narrower ADFs to “look” metal-rich compared to wider ones. “Red spread” is the observation that red lean effects are amplified as the population becomes more metal rich.

Now that the chemical mixtures in early type galaxies are known, measuring metallicity compositeness apears possible using photometry that spans from UV to IR, with the caveat that both in-situ dust extinction and the UV-bright helium burning stellar populations must be modeled with confidence. Spectral feature proxies are also available.

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143.13 – Magellanic Clues to Spatially-resolved Extinction Corrections for Distant Galaxies in the HST/JWST Era

Extinction by dust hampers our understanding of galaxies at all redshifts, and is not constant within or across the face of a galaxy, nor from galaxy to galaxy. We presented an empirical method to correct galaxy images for extinction due to interstellar dust on a pixel by pixel basis, using only rest-frame 3.6 and 0.55μm images. While this "β^V" method is approximate in nature, in its first applications we revealed hidden coherent galaxy structures like a stellar bar and ridges of dust, while anomalous inferred central extinctions proved powerful tracers of hidden AGN. This method is particularly promising for deep mid-IR imaging surveys with JWST in fields covered by HST in visible light, since their resolutions will be well-matched. Here we report on our follow-up investigation to explore the applicability, robustness, and fidelity of the β^V method on linear size scales from pc to kpc and in regions of varying star formation histories, metallicities, and dust content/distribution. We do so by combining WISE 3.4(Spitzer/IRAC 3.6)μm images of the LMC and SMC---the nearest astrophysical laboratories with a range of sub-solar metallicities--- with 2MASS near-IR and OGLE-III multi-year V and I reference images and catalogs. We assess at ~1" (~0.25--0.35pc) resolution the properties of the stellar populations that contribute to the flux in each WISE(IRAC) resolution element using the 2MASS and OGLE-III data. That allows us to measure the observed V-to-3.4(3.6)μm flux ratio per WISE(IRAC) resolution element. Subsequent resampling and PSF-matching at geometrically increasing scales from pc to kpc resolution elements allows us to assess the accuracy and fidelity of the method as a multi-variate function of the resolution, underlying stellar population mixture, physical environments, and projected distribution of dust. A companion poster (D. Kim et al.) discusses the modeling of the inherent flux ratios of composite stellar populations as functions of metallicity and star formation histories. Resulting predicted $\beta^{V,0}$ will serve as calibrations for the spatially-resolved extinction correction of galaxies at all redshifts where the method is proved reliable. This work is funded by NASA/ADAP grant NNX12AE47G.

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143.14 – Analysis of the Intrinsic $\beta^{\lambda,0}$ Ratio using Spectral Synthesis Models of Composite Stellar Populations

Light from galaxies is extincted by dust via scattering and absorbtion. Studying galaxies without correcting for this extinction could lead to incorrect results. Therefore, a careful study of dust correction in the nearby universe should be done first. Tamura et al. (2009) developed an approximate method, dubbed the "β^V" method, which corrects for dust extinction on a pixel by pixel basis by comparing the observed and the intrinsic flux ratios of optical and MIR (L;~3.5μm) broadband data. A NASA/ADAP funded program "*Magellanic Clues to Spatially-resolved Extinction Corrections for Distant Galaxies in the HST/JWST Era*" (P.I. : Rolf Jansen), aims to validate and test the limits of the "β^V" method by using imagery of the LMC and SMC in various filters and extensive modeling to test assumptions for the intrinsic flux ratios. For the latter, we build spectral energy distribution (SED) models of simple stellar population (SSP), by adopting Starburst99 and BC03 models for young (<9Myr) and old (>100Myr) stellar populations, respectively, and linear combinations of these for intermediate ages. We then construct composite stellar population (CSP) SEDs by combining SSP SEDs as functions of various star formation histories (SFHs). Filter response/throughput curves (*V,I,WISE* W1(3.4μm), *Spitzer* IRAC-1 (3.6μm) and *L*-band) were convolved with the model SEDs to obtain the intrinsic flux ratios ($\beta^{\lambda,0}$). We present the values of $\beta^{\lambda,0}$ as a function of the age and metallicity of stellar populations, and discuss the effect of various SFHs. We also present ranges of $\beta^{\lambda,0}$ values for different types of galaxies.

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143.15 – Investigating the Depth and Data of A Wide Field Survey of the Small Magellanic Cloud

We investigated the photometric depth of a wide field survey of the Small Magellanic Cloud (SMC) stellar halo. The aim of the survey is to search for evidence of galaxy mergers at the smallest scales. To achieve this it is crucial to understand how the data quality across the survey effects the apparent stellar density profile along different lines of sight. We explored the impact of a variety of factors on the photometric depth of the data including foreground dust extinction and employed two independent methods for determining the photometric completeness. These results will be used to help determine a global stellar density profile of the SMC, as well as show variations with azimuth and to highlight the presence of any deviations.

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143.16 – Washington and Stromgren Study of the Isolated Dwarf Galaxy WLM

WLM galaxy is unique in that it is the closest dwarf irregular (dIrr) in the Local Group to have not undergone a merger event. Dwarf Irregular galaxies offer an excellent testing ground for our current understanding of galaxy formation as they are relatively isolated, and are not affected by the dark matter halo of nearby massive galaxies. However, these galaxies are difficult to study due to their low luminosity. This makes it especially difficult to spectroscopically resolve the older population. Using data taken at Apache Point Observatory (APO) and Cerro Tololo Inter-American Observatory (CTIO) we present photometric metallicities from both Washington and Stromgren filter sets that will allow us to reach the less luminous older population. With this data, we will observationally test two different theoretical predictions for the kinematics of dwarf galaxies.

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143.17 – Detection of a Remnant Stellar Halo Around G1/Mayall II

One of the most luminous and massive globular clusters in the local universe is G1 (Mayall II), a satellite of M31. Because it is quite massive, harbors a central black hole, and exhibits a wide metallicity spread, it has been speculated that G1 is not a globular cluster but the surviving nucleus of a dwarf elliptical galaxy which has been stripped via tidal interactions with M31. As such, G1 may prove key to understanding the origin of ultra-compact dwarf galaxies (UCD) which could be formed by similar 'threshing' processes; indeed, G1 may be the nearest representative of the UCD class. Revealing the true nature of G1 -- giant globular star cluster or tiny remnant of a more luminous galaxy -- has ramifications for the formation of luminous spirals such as M31 which may be built at least in part by destruction and accretion of dwarf galaxy satellites over a Hubble time. Using precision velocities of red giants measured with the DEIMOS spectrograph at Keck Observatory, we have recently made the first detection of tidally stripped stars around G1. These stars are distributed over a much wider area than expected for originating directly from the present compact G1, indicating that they once belonged to a much larger envelope, now nearly completely stripped away. This is strong evidence that G1 was once the nucleus of a dwarf elliptical, and that luminous spiral galaxy disks grow by destruction and accretion of dwarf satellite debris from an early epoch.

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143.18 – A *Herschel* and *CARMA* synergistic study of turbulent gas in Hickson Compact Groups

We have performed deep PACS and SPIRE imaging, [CII] and [OI] spectroscopy and CARMA CO J= 1-0 imaging of a dozen Hickson Compact Groups (HCGs). The observations attempt to explore the physical conditions of the gas in a subset of galaxies containing large quantities of warm molecular hydrogen based on previous *Spitzer* IRS observations. The H2 is too powerful to be heated in PDR regions, and is most likely powered by turbulence and shocks. Such galaxies are found to fall in a region of the IR color-color space believed to show galaxies rapidly transitioning from the blue cloud to the red sequence, and so shocks may play a role in quenching star formation. We explore far-IR line luminosities and surface densities for extended diffuse [CII] emission and compare this to similar quanties in the CO emitting gas, and the far-IR continuum. Preliminary results suggest that high [CII]/FIR and [CII]/CO ratios are common in these systems, and in some cases correlate with peculiar velocities in the CO emitting gas. Star formation suppression *may* be seen in some of the systems with the highest warm H2/PAH ratios found by *Spitzer*, implying that turbulence may suppress star formation.

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Contributing team(s): Hickson Compact Group Team

143.19 – HDI in Action: Comparison Imaging of the Interacting Starburst Galaxy NGC 3310

NGC 3310 is an interacting starburst galaxy located approximately 18 Mpc away. Previous studies reveal a circumnuclear starburst, substantial star formation in its spiral arms, and an extensive system of tidal debris likely induced from the collision with and subsequent merger of a now-destroyed companion galaxy. A study by Wehner et al. in 2006 revealed the presence of a previously undetected tidal loop in the Northeast quadrant of the system. We have obtained follow up observations of this system using the newly-built Half Degree Imager (HDI) recently mounted on the WIYN 0.9m telescope in Kitt Peak, Arizaon. We present a comparison of deep imaging of NGC 3310 from HDI and from S2KB, the former primary CCD camera on the 0.9m. We present our results for comparison of image depth and image quality in order to assess the new HDI camera for future low surface brightness observations.

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143.20 – Tidal Debris Around Merger Remnants.

We present images of the interacting pair NGC 3310. These images were taken using the HDI camera on the 0.9m at Kitt Peak in Arizona. NGC 3310 is a starburst galaxy which recently underwent a collision with a much smaller mass galaxy. It has been postulated that this galaxy was then scattered in the orbit of NGC 3310 creating multiple tidal loops around the galaxy. In order to observe and study these loops, the data must be clear of noise within 1% error. We present our method of correcting to this precision level and an analysis of the tidal loop system. We will also discuss the implications of this stellar debris on the evolutionary history of this galaxy.

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143.21 – Exploring Stellar Populations in the Tidal Tails of NGC3256

Galaxy interactions can inject material into the intergalactic medium via violent gravitational dynamics, often visualized in tidal tails. The composition of these tails has remained a mystery, as previous studies have focused on detecting tidal features, rather than the composite material itself. With this in mind, we have developed an observing program using deep, multiband imaging to probe the chaotic regions of tidal tails in search for an underlying stellar population. NGC3256's Western and Eastern tidal tails serve as a case study for this new technique. Our results show median color values of $u - g = 1.12$ and $r - i = 0.09$ for the Western tail, and $u - g = 1.29$ and $r - i = 0.21$ for the Eastern tail, corresponding to ages of approximately 450 Myr and 900 Myr for the tails, respectively. A $u - g$ color gradient is seen in the Western tail as well, running from 1.32 to 1.08 (~2000 Myr to 400 Myr), suggesting ages inside tidal tails can have significant variations.

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143.22 – Behavior of Neutral Hydrogen in the NGC 877/6 Galaxy Group

We observed a 5 square degree area centered on -02:17:31, 14:32:00 at 21-cm as part of the Arecibo Galaxy Environment Survey (AGES) with the NGC 877/6 galaxy group at a velocity of 4000 km/s as the primary target. Our observations covered the redshift range -5,000 < cz < 20,000 km/s allowing for a large volume in front and behind the complex to be analyzed. The NGC 877/6 group contains 8 galaxies inside a common HI envelope with a total neutral hydrogen mass of LogMHI = 10.73. HI is detected outside of the optically-identified galaxies and there are a number of tidal features within the complex. These include AGC 749170, a possible tidal remnant identified by ALFALFA and whose detection we confirm here. Another, smaller group associated with UGC 1742 (Log^{MHI} = 9.95; cz = 6900 km/s) was identified as showing signs of galaxy interaction as well as the possibility of a tidal formation not catalogued in NED as a galaxy. Of the 44 HI sources identified in the data cube, 12 (27%) were not previously recorded in the NED database as galaxies. We will continue our analysis with data from the Mock spectrometers which will extend the redshift range to 45000 km/s.

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143.23 – A General Purpose Stacking Technique to Analyze Low Brightness Signal

We present an implementation of a general purpose stacking technique in which the detections of bright emission lines are used as priors to analyze low-brightness signal. We demonstrate the use of the technique on ALMA observations of the nuclear region of the nearby galaxy NGC 253 but emphasize its general applicability to a wide class of problems. The conceptual basis for the technique is to use closely associated brighter lines as priors to establish the local velocity (and potentially velocity profile) of a faint line. With this prior, the faint line can be coherently averaged by assuming that it shares a mean velocity with the bright prior. The coherent spectral averaging allows one to more clearly distinguish real astronomical signals from systematic effects, unstable baselines, or imaging artifacts. In our example application, we apply the technique to measure the intensity of faint isotopologues of dense gas tracers in NGC 253, lines that are otherwise hard to distinguish from the noise. The implementation of the code is intended for release as a general purpose cube analysis tool compatible with other astronomical python packages.

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143.24 – Zooming in on Extreme Environments: Using JVLA Observations and Kinematic Models of Arp 220 to Study Physical Conditions in ULIRGs

Using new Jansky VLA capabilities we observe Arp 220, the nearest ULIRG. With a high star formation rate similar to high-z galaxies, but at a close distance from the Milky Way, Arp 220 allows us to explore these extreme conditions at high resolution. With the availability of high-frequency (K, Ka, and Q band) receivers and wide bandwidths, we detect multiple line species, in particular multiple metastable ammonia inversions which are excellent tracers of kinetic temperature and density. Conditions and composition vary greatly throughout Arp 220, especially when offset from the two bright nuclei. By characterizing the temperature and density throughout the system, we can better understand the conditions associated with high star formation rates, which can then be applied to ULIRGs at high-z. Additionally, the strength and isolation of some lines allows for detailed kinematic modeling in both absorption and emission, allowing us to isolate anomalous material and characterize the dynamics of the system.

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143.25 – Identifying OH Imposters in the ALFALFA HI Survey

OH megamasers (OHMs) are rare, luminous molecular masers that are typically observed in (ultra) luminous infrared galaxies and serve as markers of major galaxy mergers. In blind emission line surveys such as the ALFALFA (Arecibo Legacy Fast Arecibo L-Band Feed Array) survey for neutral hydrogen (HI) in the local universe, OHMs at z~0.2 can mimic z~0.05 HI lines. We present the results of optical spectroscopy of ambiguous HI detections in the ALFALFA 40% data release [1] detected by WISE but with uncertain optical counterparts. The optical redshifts, obtained from observations at the Apache Point Observatory 3.5m telescope, identified 127 HI optical counterparts and discovered five new OHMs. Fifty-six candidates remain ambiguous. The new OHMs are the first detected in a blind spectral line survey.
The number of OHMs in ALFALFA matches predictions based on the OH luminosity function [2]. Additionally, the OHMs found in a blind survey do not seem to differ from those found in previous targeted surveys. This provides validation of the methods used in previous IR-selected OHM surveys and indicates there is no previously unknown OHM-producing population at z~0.2. We also provide a method for future surveys to separate OH and HI lines without expensive spectral observations. This method utilizes infrared colors and magnitudes, such as WISE mid-IR data. Since the fraction of OHMs found in flux-limited HI surveys is expected to increase with the redshift of the survey [3], this analysis can be applied to future flux-limited high-redshift hydrogen surveys.
We thank the ALFALFA team for observing and producing the survey dataset. The ALFALFA team at Cornell is supported by NSF AST-1107390 and the Brinson Foundation.
[1] Haynes, M. P., R. Giovanelli, A. M. Martin, K. M. Hess, A. Saintonge, et al. 2011, Astron J, 142, 142
[2] Darling, J. & R. Giovanelli 2002, Astrophys J, 572, 810
[3] Briggs, F. H. 1998, A&A, 336, 815

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143.26 – Comparing Stellar Populations Across the Hubble Sequence

Previous work (Jansen et al., 2000, Taylor et al., 2005) has revealed trends in the optical wavelength radial profiles of galaxies across the Hubble Sequence. Radial profiles offer insight into stellar populations, metallicity, and dust concentrations, aspects which are deeply tied to the individual evolution of a galaxy. The Nearby Field Galaxy Survey (NFGS) provides a sampling of nearby galaxies that spans the range of morphological types, luminosities, and masses. Currently available NFGS data includes optical radial surface profiles and spectra of 196 nearby galaxies. We aim to look for trends in the infrared portion of the spectrum for these galaxies, but find that existing 2MASS data is not sufficiently deep. Herein, we expand the available data for the NGFS galaxy IC1639 deeper into the infrared using new data taken with the Infrared Sideport Imager (ISPI) on the 4-m Blanco Telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. Images taken in J, H, and Ks were reduced using standard IRAF and IDL procedures. Photometric calibrations were completed by using the highest quality (AAA) 2MASS stars in the field. Aperture photometry was then performed on the galaxy and radial profiles of surface brightness, J-H color, and H-Ks color were produced. For IC1639, the new ISPI data reveals flat color gradients and surface brightness gradients that decrease with radius. These trends reveal an archetypal elliptical galaxy, with a relatively homogeneous stellar population, stellar density decreasing with radius, and little-to-no obscuration by dust. We have obtained ISPI images for an additional 8 galaxies, and further reduction and analysis of these data will allow for investigation of radial trends in the infrared for galaxies across the Hubble Sequence.

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143.27 – The Optical and Near-Infrared Low Surface Brightness Properties of Five Nearby Galaxies

We present results from new deep BVR observations of five nearby galaxies from the KPNO 4m telescope. These observations are bolstered by the addition of deep 3.6 um data from the Extended Disk Galaxy Exploration Science (EDGES) Survey. These observations detect the extremely low surface brightness features of these galaxies, including the inner stellar halo and tidal streams. We examine the physical properties of these low surface brightness features as well as the implications these detections have for LambdaCDM galactic simulations.

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Contributing team(s): EDGES

143.28 – MaNGA: Target selection and Optimization

The 6-year SDSS-IV MaNGA survey will measure spatially resolved spectroscopy for 10,000 nearby galaxies using the Sloan 2.5m telescope and the BOSS spectrographs with a new fiber arrangement consisting of 17 individually deployable IFUs. We present the simultaneous design of the target selection and IFU size distribution to optimally meet our targeting requirements. The requirements for the main samples were to use simple cuts in redshift and magnitude to produce an approximately flat number density of targets as a function of stellar mass, ranging from $1x10^9$ to $1x10^{11}$ $M^{\odot}$, and radial coverage to either 1.5 (Primary sample) or 2.5 (Secondary sample) effective radii, while maximizing S/N and spatial resolution. In addition we constructed a “Color-Enhanced” sample where we required 25% of the targets to have an approximately flat number density in the color and mass plane. We show how these requirements are met using simple absolute magnitude (and color) dependent redshift cuts applied to an extended version of the NASA Sloan Atlas (NSA), how this determines the distribution of IFU sizes and the resulting properties of the MaNGA sample.

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143.29 – MaNGA: Mapping Nearby Galaxies at Apache Point Observatory

I present the design and execution of a new survey to obtain resolved spectroscopy for 10,000 nearby galaxies called MaNGA (Mapping Nearby Galaxies at Apache Point Observatory). One of three core programs in the 6-year SDSS-IV project that began on July 1st, 2014, MaNGA will deploy 17 fiber-bundle IFUs across the Sloan 2.5m Telescope's 3 degree field-of-view, targeting a mass-selected sample with a median redshift of 0.03, typical spatial resolution of 1-2 kpc, and a per-fiber signal-to-noise ratio of 4-8 in the outskirts of target galaxies. For each galaxy in the sample, MaNGA will provide maps and measured gradients of the composition and dynamics of both stars and gas. Early results highlight MaNGA's potential to shed light on the ionization and chemical enrichment of gas in galaxies, spatial patterns in their star formation histories, and the internal makeup of stellar populations. MaNGA's unprecedented data set will not only provide powerful new insight on galaxy formation and evolution but will serve as a valuable benchmark for future high-z observations from large telescopes as well as space-based facilities.

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143.30 – Reassessing the Relation Between Stellar Mass, Metallicity, and Star Formation Rate in the Local Universe

There is considerable evidence that the well-established mass-metallicity relation in galaxies depends on a third parameter: star formation rate (SFR). The observed strength of this dependence varies substantially depending on the choice of metallicity calibration, but has significant implications for theories of galaxy evolution, as it constrains the interplay between infall of pristine gas, metal production due to star formation, and ejection of enriched gas from galaxies. We present a new analysis of the relation between stellar mass, gas phase metallicity and SFR for ~140,000 star-forming galaxies in the Sloan Digital Sky Survey. Using a new set of theoretically calibrated abundance diagnostics from Dopita et al. (2013), we find a weaker dependence of metallicity on SFR at fixed stellar mass than was found by previous studies using different calibration techniques for gas phase metallicity. We analyze possible biases in the derivation of mass, metallicity, and SFR that could cause the observed strength of the metallicity dependence on SFR to differ from reality, as the calculation of each of these quantities is subject to systematic errors. Chemical evolution models must carefully consider these sources of potential bias when accounting for metallicity dependence on SFR.

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143.31 – The Role of Neighbors on Galaxy Evolution

The galaxy-galaxy interaction is one of the key factors in galaxy evolution. Yet, how exactly a galaxy is affected by its neighbors remains an open question. We examine the role of neighbors on galaxy evolution in terms of recent star formation rate (SFR). We identify the most influential neighbor of each galaxy in the Sloan Digital Sky Survey and classify them into three groups based on their neighbors' morphology and distance: (*a*) ones with an early-type galaxy as an most influential neighbor, (*b*) ones with a late-type neighbor, and (*c*) isolated ones with no neighbor. We construct well-controlled samples of the three groups to ensure each group has same characteristics (i.e., mass, local environment, and redshift) except their neighbor's properties, and compare their SFR derived from *Hα* emission, *NUV-r*, and *u-r*. We show that galaxy evolution is affected by their interacting neighbor's properties. For instance, the late-type sample with "late-type" neighbors tends to show enhanced SFR compared to the isolated group. By contrast, the late-type sample with "early-type" neighbors shows even lower SFR than the isolated group. We also show that the early-type group is noticeably less affected by the presence of neighbors than the late-type group.

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143.32 – Colliding Galaxies in the Big Data of the Huge Universe (BIDHU) project

Colliding galaxies are excellent laboratories to study star formation under extreme environments. Recently, we have started a project aiming at identifying bright colliding galaxies, in pairs and in groups, using the Sloan Digital Sky Survey (SDSS III). Here we present the method we have used to select our sample as part of the project Big Data of the Huge Universe (BIDHU). We started with a small equatorial slice of the SDSS data and adopted a maximum angular separation of 1 arcmin to select a sample of 70 pairs in close contact. The search has now been expanded to the entire Sloan Survey and a machine learning code has been built to identify close pairs out of approximately 45,000 pair-candidates. The BIDHU colliding-galaxy sample will be made available to the community and will have excellent targets for follow up observations with large telescopes. Our major goal is to use ALMA and large ground-based telescopes to understand how stars are formed in tidal interaction.

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143.33 – Searching for Massive Major Mergers in Dense Environments at Late Cosmic Time

Major gas-poor (dry) merging between two comparably massive spheroidal galaxies are postulated to be the central mechanism responsible for the assembly of the most massive (Mstar>1e11 Msun) elliptical galaxies. Numerical simulations predict that these mergers may occur at late cosmic times and typically in dense environments. Previous work based on a complete sample of high-mass (>5e10 Msun) galaxies with z<0.12 selected from the Yang et al. (2007) SDSS Galaxy Group Catalog and analyzed for residual asymmetric features in SDSS r-band images provided a lower limit to the frequency of massive pairs with interaction signatures residing in groups and clusters with halo masses >2.5e13 Msun. The tidal signatures of such interactions may often be too faint to be clearly detected at the sensitivity of SDSS imaging data. To improve constraints and test the identification of dry merging, we obtained V-band images 1.5 mag deeper than SDSS for a random selection of one-quarter of the pairs with no SDSS tidal signatures, plus a subset of six previously identified interactions. This sample contains 27 pairs, each shares the same group halo, and has small projected separations and spectroscopic redshift differences. Using GALFIT image residuals, we visually identify interactions signatures with surface brightnesses down to ~26.5 mag/arcsec^2 at S/N ≥ 5. We confirm 80% of previous interaction identifications based on shallower SDSS imaging, and identify four new systems with mutual tidal signatures that were previously classified non-interacting. Applying these new deeper detection statistics based on very small numbers indicates that the frequency and, thus, the rate of massive major mergers in dense environments is 50% to 3 times larger than previously estimated with the SDSS. As such, 2-5% of high-mass galaxies in large groups are involved in the major merger assembly of massive galaxies.

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143.34 – Galaxy Zoo : Evidence for a Diversity of Routes through the Green Valley

Understanding the ways in which galaxies change as they move from blue to red is critical to understanding the build up of the present-day galaxy population, and can best be addressed by looking at systems in the process of transitioning. We present the results of a new analysis of the population of galaxies which passes through the 'green valley' evident in optical colour-mass diagrams. Using data from SDSS and Galex, and a Bayesian analysis of their most probable star formation histories, we show that multiple routes through the green valley exist. By using Galaxy Zoo morphologies, we are able to draw on probabilistic estimates of morphology and find - in contrast to previous work - that there is evidence for slow, intermediate and rapid transitions from blue to red. Constraining these populations provides evidence for rapid morphological change in some populations, presumably through major mergers, and underpins our understanding of the build up of the red sequence.

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Contributing team(s): Galaxy Zoo

143.35 – The Undead: Fossil Galaxy Alive Again

This project investigates the formation and evolution of fossil galaxies, specifically the history of active galactic nucleus (AGN) activity as it relates to galaxy mergers. We used low-frequency radio data from the J-VLA radio telescope's new P-band receivers [300-350MHz] to observe fossil galaxy J171811.93+563956.1 (referenced as FG30) at a red-shift of z=0.114. This galaxy was selected for its strong X-ray emission from the surrounding IGM, because it is indicative of an AGN. After cleaning and calibrating the data using CASA, images were generated to map the intensity of radio emission, revealing that FG30 is nearly a point source and lacks any prominent AGN jets. Analysis of the SDSS optical spectrum of FG30 revealed strong evidence of shocks. We believe that past AGN activity heated the intergalactic medium (IGM) to produce the strong X-ray emission, though the jets have been dormant for long enough that the IGM filled in the regions previously cleared by jets. The density of new material is now causing strong shocks when hit by newly restarted jets. This implies the start of a new epoch of AGN activity for FG30, which was most likely caused by a recent galaxy merger. This observation demonstrates that not all fossil groups have been quiescent, as the dominant theories suggested.
*This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

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143.36 – A Comparison of Radio-loud and Radio-quiet E+A Galaxies

E+A galaxies are systems undergoing an important evolutionary transition. Their optical spectra show significant numbers of A-type stars in an elliptical galaxy that has little to no star formation (SF). These galaxies have likely experienced a recent starburst (< 1 Gyr) followed by an even more recent quench in their SF. What caused their recent SF quench remains one of the most prominent questions surrounding E+A galaxies. Within the Goto (2007, MNRAS 381,187) catalogue of 564 E+A galaxies, there is a small fraction (~3%) that have detectable radio continuum emission from FIRST or NVSS. One possible cause for the observed radio continuum is active galactic nuclei (AGN). AGN feedback is believed to be important in galaxy evolution, including SF quenching (Dubois et al. 2013, MNRAS 433, 3297). In an effort to understand better the differences between radio-loud and radio-quiet E+As, we obtained and compared their spectral energy distributions (SEDs) using the publicly available data from SDSS, 2MASS, and WISE. We also compared them to the SEDs of other known galaxy types. We find that the radio-loud and radio-quiet samples exhibit statistically insignificant differences in the optical, near-infrared, and mid-infrared bands. We also compare the two samples on a (J-H) vs. (H-K) color-color diagram. This work was supported by the National Science Foundation via grant AST-1004583 to the CUNY College of Staten Island, and grant AST-1004591 to the American Museum of Natural History.

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143.37 – Just-After THE FALL: Post-Starburst Galaxies and the E+B Phase

A key question in galaxy evolution is how star formation is quenched. Post-starburst galaxies, which can be identified by their distinctive optical spectra, are excellent laboratories for studying various quenching processes. However, canonical post-starbursts, called E+A's or K+A's, are several 100 Myr past the epoch of active quenching, making it challenging to measure quenching timescales and make inferences about the processes at work. To address this problem, we have identified a sample of 23 young, B-star dominated post-starbursts (E+B's) at z = 0.45 – 0.82 in SDSS-III's Baryon Oscillation Spectroscopic Survey (BOSS). In this new class of objects, we determine how abruptly star formation is truncated and probe the role of various possible feedback mechanisms.
This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

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143.38 – Probing the Magnetic Fields in the Environment of Mg II Absorbers

We present a rotation measure survey of radio luminous QSOs with known Mg II absorption line systems, the purpose of which is to measure the characteristics of magnetics fields in and around galaxies at intermediate redshift. A sample of 38 high Galactic latitude QSOs have been selected as our primary targets. Each QSO has a single absorption line system between a redshift of 0.38<0.65 and we have excellent photometry on the galaxies associated with each absorber. In addition we identify a statistically significant sample of QSOs without intervening Mg II absorbers as a control sample. We use the control sample to correct for both the Galactic foreground and the Faraday rotation internal to the background QSOs. With these data we plan to derive the mean strength of the coherent field in the intermediate redshift galaxies and correlate variations in the observed RM with galaxy color, Mg II equivalent width, and impact parameter. At this time, we present preliminary total intensity images and RMs of the target objects in our sample. Additionally, observed radio jets in a portion of the sample provide an interesting comparison between the RMs of the disks of the galaxies versus those measured in the jets. The ultimate goal for this study is to provide robust constraints on models of the origin and evolution of the global magnetic fields in galaxies like the Milky Way. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881.

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143.39 – The Detection of Extended Galactic Wind Emission in Distant Galaxies

Galactic winds are observed to be ubiquitous at intermediate redshift, but their physical extent is yet unknown. In this work we used a sample of 2000 galaxies from the DEEP3 redshift survey to study the average physical size of the winds at this epoch using the near UV Mg II emission line. By constructing a high signal-to-noise co-added spectra, we were able to detect novel excess Mg II emission from wind out to 10 kiloparsecs in radius that cannot be accounted for by stellar emission in the galaxy. We also find that low mass galaxies and edge-on galaxies show more enhanced wind signatures.

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143.40 – Spectral Indices of Faint Radio Sources

The significant improvement in bandwidth and the resultant sensitivity offered by the Karl G. Jansky Very Large Array (VLA) allows us to explore the faint radio source population. Through the study of the radio continuum we can explore the spectral indices of these radio sources. Robust radio spectral indices are needed for accurate k-corrections, for example in the study of the radio - far-infrared (FIR) correlation. We present an analysis of measuring spectral indices using two different approaches. In the first, we use the standard wideband imaging algorithm in the data reduction package CASA. In the second, we use a traditional approach of imaging narrower bandwidths to derive the spectral indices. For these, we simulated data to match the observing parameter space of the CHILES Con Pol survey (Hales et al. 2014). We investigate the accuracy and precision of spectral index measurements as a function of signal-to noise, and explore the requirements to reliably probe possible evolution of the radio-FIR correlation in CHILES Con Pol.

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143.41 – Pitch Angle Survey of GOODS Spiral Galaxies

This research looks at how the pitch angles of galaxies change over scales of cosmic time. We measure the pitch angle, or tightness of spiral winding, using a new code, Spirality. We then compare the results to those obtained from established software, 2DFFT (2 Dimensional Fast Fourier Transform). We investigate any correlation between pitch angle and redshift, or distance from Earth. Previous research indicates that the pitch angle of a galaxy correlates with its central bulge mass and the mass of its central black hole. Thus any evolution in the distribution of pitch angles could ultimately prove to be indicative of evolution in the supermassive black hole mass function. Galaxies from the Hubble GOODS (Great Observatories Origins Deep Survey) North and South were measured. We found that there was strong agreement between Spirality and 2DFFT measurements. Spirality measured the pitch angle of the GOODS galaxies with a lower error than 2DFFT on average. With both software a correlation between pitch angle and redshift was found. Spirality observed a 6.15^0 increase in pitch per unit redshift. The increase in pitch angle with redshift suggests that in the past galaxies had higher pitch angles, which could be indicative of lower central black hole masses (or, more directly, central bulge masses).

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Contributing team(s): Arkansas Galaxy Evolution Survey, Arkansas Center for Space and Planetary Sciences

143.42 – Diverse Galaxies: Clumpy Regions In The UVUDF at 0.5 ≤ z ≤ 1.5

We present an investigation of clumpy galaxies using the deepest ultraviolet data in the Hubble Ultra Deep Field (HUDF) taken with Wide Field Camera 3 UVIS detector. We use 3 new post-flashed UV images taken with the F225W, F275W, and F336W filters. Here we present an analysis of all galaxies in the 0.5 to 1.5 redshift range. These galaxies show a variety of properties, with objects having just a single clump to galaxies littered with clumps. We perform an optical morphological study of ultraviolet-detected galaxies using a visual classification scheme similar to that employed by the Hubble CANDELS survey team. We find that the majority of the objects that are clumpy in the ultraviolet have optical morphologies that are disks, followed by irregulars. We measure galaxy luminosities in the rest-frame UV, clump sizes, and luminosities for each clump in 7 passbands from the UV to the optical. We find that the majority of these UV bright clumpy galaxies are classified as Scd and starburst spectral types and have clump sizes between 0.7 to 1.9 kpc. We quantify the contribution of the clumps to the global star formation rate of the galaxy.

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Contributing team(s): UVUDF Team

143.43 – Clumpy Galaxies at High Redshifts: Insights from the FIRE Simulations

It has been observationally established that star-forming galaxies at high redshifts have more irregular morphologies compared to the ones in the local Universe. The morphologies of these galaxies are often dominated by large clumps which are believed to form via gravitational instabilities in gas-rich disks. Typically, these clumps have masses on the order of 10^7-10^9 solar masses, and extend over kiloparsec scales. It has been proposed in a number of studies that giant clumps, provided that they live long enough, could have an important impact on the morphology and evolution of their host galaxy. For example, as clumps migrate inwards through dynamical friction, they can sink to the center of the galaxy and form a bulge. However, this picture holds only if clumps can survive sufficiently long to reach the center without being destroyed by feedback from intense star formation that takes place within them. Therefore, determining typical lifetime of a giant clump, while taking into account different modes of feedback from star formation, is crucial for understanding the role they play in the evolution of their host galaxy. In this study we use the results of the FIRE (Feedback in Realistic Environments) simulations of galaxy evolution - a suite of high-resolution cosmological simulations with explicit physical models of stellar feedback and the multi-phase interstellar medium (Hopkins et al. 2014) – to investigate how feedback affects the formation and evolution of giant clumps in massive, gas-rich galaxies around z~2.

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143.44 – Galaxy Evolution Spectroscopic Explorer (GESE)

One of the key goals of NASA's astrophysics program is to answer the question: How did galaxies evolve into the spiral, elliptical, and irregular galaxies that we see today? We know that the star-formation rate density reached a peak at redshift, z~1.9, and then declined to the modest level of today, but we don't know what the physical processes were that drove galaxy evolution in the critical z=1-2 era. To fully *understand* galaxy evolution requires spectra in the rest-frame far-UV, a spectral region that is rich in diagnostics of young, massive stars, ionized nebulae, and the interstellar medium. Such spectra are beyond the reach of ground-based telescopes. We are therefore developing a space-telescope concept called Galaxy Evolution Spectroscopic Explorer (GESE), which will fill the z~1-2 gap by surveying the rest-frame far-UV spectra of 10^5 star-forming galaxies. When combined with optical-NIR spectra of the same galaxies from the Subaru Prime Focus Spectrograph and other telescopes, GESE spectra will enable us to track the properties of star-forming galaxies at all redshifts using the *same* spectral diagnostics. GESE spectra will thus enable us to identify the main drivers of galaxy evolution in the critical z=0.8-2 era (age of universe 3.3-6.8 Gyr).

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143.45 – Starbursting Dwarf Galaxies at z > 1

Recently we uncovered with Hubble Space Telescope (HST) WFC3 imaging and spectroscopy an abundant population of extreme emission line galaxies (EELGs) at 1.3 < z < 2.3. While rare in the local universe, such EELGs are ubiquitous at higher redshift and plausibly represent the star-forming progenitors of today's dwarf galaxies. I will present ground-based follow-up spectroscopy using the VLT and the LBT, as well as SED modeling of broad-band photometry and emission line fluxes, which confirms high star formation rates, young ages, low stellar masses, and low metallicities. I will also present a comprehensive search for EELGs in data from the 3D-HST grism-spectroscopic survey, providing a first measurement of their cosmic number density evolution. I will use this to constrain the duty cycle of this bursty mode of star formation, and argue that most stars in today's dwarf galaxies formed in a small number of these bursts at z > 1.

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Institution(s): *1. Max Planck Institute for Astronomy*
Contributing team(s): 3D-HST

143.46 – Host galaxies of submicro-Jansky radio sources

We combine a deep 1.4 GHz deep radio survey in the Lockman Hole with infrared and optical data in the same field, including the SERVS and UKIDSS and SERVS near-infrared surveys, to make the largest study to date of the redshift distribution, the K −z relation and the stellar masses of the hosts of sources with typical radio flux densities ~ 100μJy. We use mid-infrared diagnostics to show that this μJy radio source population contains a roughly equal mix of starforming galaxies, “spin-driven” (hot-mode accretion) radio AGN and cold-mode accreting AGN. We see the breakdown in the K −z relation at faint radio flux densities as being due to populations becoming dominated by sources with radio luminosities ~ 1023WHz−1 with typical host galaxies about a factor of two fainter than radio sources with luminosities > 1024WHz−1. This dependency is similar for both hot and cold-mode accreting AGN, suggesting the mechanism producing radio jets has little dependence on accretion mode. We show that out to at least z ~ 2, galaxies with stellar masses > 1011.5M⊙ have a radio-loud fraction up to ~ 30%, consistent with there being sufficient numbers of radio sources to play a significant role in galaxy evolution through feedback on the interstellar media of their hosts.

Author(s): Kristen Luchsinger[1]
Institution(s): *1. St. John's College*
Contributing team(s): NSF REU Program, NRAO REU Program

143.47 – The AGN Contribution to Galaxy Merger Infrared Luminosities

We investigate the contribution of AGN activity to the infrared luminosity of interacting galaxies by analyzing dust radiative transfer calculations of a hydrodynamically simulated merger, created with the code GADGET-2. We focus on emission in the mid-IR to far-IR wavelength ranges, and trace the luminosity density of an interacting gas-rich galaxy pair throughout its evolution. We find that the AGN contribution to IR luminosity is greatest during and immediately after coalescence of the galaxies’ central black holes. This period lasts roughly 80 Myr, during which time the increased influx of gas to the center of the merger increases the total luminosity by a factor of a thousand or more due to both increased star formation rate (SFR) and black hole accretion. We compare different interstellar medium models used to describe sub-resolution gas and dust clouds in the radiative transfer calculations by studying the color evolution of our merger in the Herschel Space Observatory photometric filter bands, and compare the results to Herschel observations. We conclude that using infrared luminosity as a simple surrogate for SFR can overestimate the true rate, due to the contribution of AGN or other dust heating mechanisms. This conclusion has an especially significant impact in assessing the star formation activity in high-redshift galaxies for which luminosity (the best measured property) may not accurately measure the SFR, and in cases where the molecular gas content can differ from that of local systems. Further work will extend this analysis to simulations of mergers between late-type galaxies. This work was supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851, by the Smithsonian Institution and by NASA grant NNX14AJ6IG.

Author(s): Lee Rosenthal[3], Christopher C. Hayward[1], Howard Smith[2], Matthew Ashby[2], Chao-Ling Hung[2], Rafael Martinez-Galarza[2], Aaron Weiner[2], Andreas Zezas[2], Lauranne Lanz[4]
Institution(s): *1. California Institute of Technology, 2. Harvard-Smithsonian Center for Astrophysics, 3. Haverford College, 4. IPAC*

143.48 – Characterizing HII regions in High-z ULIRGs with far infrared fine structure lines

The nature of star-forming ULIRGs in the early Universe remains mysterious. Is their star formation fueled predominantly through cold flow accretion, or through major mergers? What fraction of the sources have AGN, and what is the stellar mass function powering the HII regions? Of particular importance to these questions is the characterization of the ionized gas properties, and the coupling with the cooler photodissociation region (PDR) gas. To address these issues we have undertaken a mini-survey of several z~1-2 luminous galaxies observed in multiple ionized oxygen far infrared fine structure lines. These fine structure lines allow us to constrain the density and radiation field of the ionized gas and test for the presence of harder AGN powered radiation. Coupled with previous data including the [CII] and [OI] fine structure lines emanating from PDR gas, we will also test the ability to simultaneously model both PDR and HII gas components. This survey, modest in extent, offers an illustrative snapshot of the diversity of systems in the early Universe.

Author(s): Drew Brisbin[4], Carl Ferkinhoff[3], Gordon J. Stacey[2], Stephen Parshley[2], Steve Hailey-Dunsheath[1], Cody Lamarche[2]

Institution(s): *1. Caltech, 2. Cornell University, 3. MPIA, 4. NRAO*

143.49 – HST rest-frame optical characteristics of WISE-selected galaxies at z>1.7

We present resolved H-band images of 12 Wide-field Infrared Survey Explorer color-selected galaxies with confirmed redshifts 1.8 to 2.7, probing the rest-frame optical at ~1 kpc scales. Our sample was originally selected for HST imaging due to their AGN-like, red WISE colors (Eisenhardt et al. 2012), and includes six with extended Ly-α emission. The latter are thought to be a part of a very rare population of galaxies caught in a short-lived "blowout phase" which is thought to cause the extended Ly-α emission in blobs (LABs; Bridge, et al. 2013). The environments in the H-band represent a diverse sample, and do not reveal any strong relation with a blowout process without more resolved wavelength coverage. The morphologies appear as multiple interacting nuclei, or a single undisturbed object. We analyze, in detail, two objects, including a discussion on individual components in possible major merger and/or the blowout phase. Also, we analyze the global properties of the sources using the unresolved photometry from WISE and Herschel PACS along with the H-band. Comparisons with dust obscured galaxies (DOGs from Bussman et al. 2009) at the same redshift, reveal color signatures stemming from a different phase of dusty starburst+AGN. Our sample show H-[12] colors 4.8-7.8 with a mean of 6.2. The DOGs are bluer with H-[12] colors 3.9-7.5 and mean of 5.2. The H-[12] v. [12]-[22] colorspace reveals a distinct population: only two DOGs reside on the same region. In addition, the reddest [12]-[22] colors are the bluest in H-[12] for the respective samples. Herschel/PACS "red" (130-210 μm) filter images give a range in flux densities from 0.04-0.1 Jy. These preliminary results indicate a distinct formation stage for dusty starburst+AGN, which play a key role in the continuum of ULIRG properties at high-z.

Author(s): Sara M. Petty[9], Andrew Blain[7], Carrie Bridge[1], Jennie Paine[9], Duncan Farrah[9], Tom Jarrett[6], Dominic J. Benford[2], Peter R. Eisenhardt[3], Sean E. Lake[5], Mariana Lazarova[8], Leonidas A. Moustakas[3], S. Adam Stanford[4], Chao-Wei Tsai[3], Edward L. Wright[5]
Institution(s): *1. Caltech, 2. NASA/Goddard, 3. NASA/JPL, 4. UC Davis, 5. UCLA, 6. University of Cape Town, 7. University of Leicester, 8. University of Nebraska, 9. Virginia Tech*
Contributing team(s): WISE

143.50 – The HETDEX Pilot Survey & 3DHST: What Makes a Lyman-alpha Emitter?

We compare the 3D-HST H-beta emitters at z~2 to Lyman-alpha emitters found in the same redshift range by the HETDEX Pilot Survey to investigate any differences in the physical and morphological parameters that could elucidate how or why Lyman-alpha is escaping. We use one-dimensional and multi-dimensional statistics, as well as machine learning techniques to try to find differences between these datasets. However, we are unable to find statistically significant differences between these populations. This demonstrates that Lyman-alpha emitters are pulled randomly from the distribution of star-forming galaxies, and there are seemly no strong physical or morphological requirements to be a Lyman-alpha emitter. We also use this information to inform a toy model of Lyman-alpha emission that poses all star-forming galaxies are LAEs if view along certain lines of sight.

Author(s): Alex Hagen[1], Gregory Zeimann[1], Caryl Gronwall[1], Robin Ciardullo[1], Joanna Bridge[1]
Institution(s): *1. Pennsylvania State University*
Contributing team(s): HETDEX

143.51 – Classification of Low/High Redshift Galaxies Using Machine Learning

We can learn about how the universe has evolved through cosmic time by observing galaxies at different redshifts. Using the Hobby-Eberly Telescope Dark Energy eXperiment (HETDEX) survey as our proving grounds, we look to separate high-redshift Lyman Alpha Emitting (LAE) galaxies from low-redshift [OII] emitting galaxies, in order to use LAEs for investigating the behavior of Dark Energy at high redshift. Other successfully employed techniques rely on one's knowledge of the LAE and [OII] equivalent width distributions and luminosity functions. We take an alternative approach and we seek to classify galaxies using machine learning (ML). We train a support vector machine algorithm in identifying LAEs within our simulated dataset, and show that it performs very well in reducing incompleteness and minimizing contamination. Our work in progress includes a more realistic simulation of emission line ratios in galaxies, as well as a systematic comparison of different ML classification algorithms.

Author(s): Mario R Martin[1], Viviana Acquaviva[1]
Institution(s): *1. CUNY New York City College of Technology*

143.52 – The Lyman Continuum Escape Fraction of The Cosmic Horseshoe

In this study, we investigate the escaping Lyman continuum of the Cosmic Horseshoe, a gravitationally lensed star forming galaxy at z = 2.38. Its large magnification (~25x) as well as a possibly patchy interstellar medium make it an ideal case for detection of its Lyman continuum. We obtained a deep (10 orbit) Hubble near-UV image using the WFC3/UVIS F275W filter that is just below the Lyman limit at the redshift of Horseshoe, in an attemp to detect escaping ionizing photons. We present the constraints on the escape fraction, after fully accounting for the uncertainties in the galaxy's star formation rate history and the opacity of the intergalactic medium as well as the charge transfer inefficiency of the WFC3 CCDs. Our results indicate a significant mismatch between the measured escape fraction and the expected escape fraction based on the estimated covering fraction of the interstellar medium of the Horseshoe. We investigate the causes for the mismatch and also will discuss the implications for future surveys aiming to directly detect escaping Lyman continuum.

Author(s): Kaveh Vasei[2], Brian D. Siana[2], Alice E. Shapley[1], Anahita Alavi[2]
Institution(s): *1. UCLA, 2. UCR*

143.53 – Massive Spheroidal Galaxies: Nature and Evolution During 0.6

Spheroidal galaxies are linked to the observed buildup of massive non-star-forming (quiescent) galaxies over cosmic time. Yet, it remains unclear whether the primary growth channel involves the formation of new bulge-dominated galaxies followed by the quenching of star formation (SF), or the cessation of star production preceded by the transformation from disk-dominated to spheroidal galaxies. Using a new comprehensive catalog of visual classifications based on the HST/WFC3 imaging from the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS), we study the nature and evolution of high-mass (Mstar>1e10 Msun) 'spheroids' (elliptical and bulge-dominated galaxies) over a wide redshift range (0.6<z<2.5) in the Ultra Deep Survey (UDS) and the Great Observatories Origins Deep Survey South (GOODS-S) fields. These spheroids are rounder, smaller and more centrally-concentrated than visually disk-dominated galaxies. Using either rest-frame UVJ colors or total SF rates (IR + UV) when available, which we've verified yield similar selections in these fields, we find a clear increase in the fraction of high-mass galaxies that are quiescent spheroids with decreasing redshift, accompanied by a relatively constant low fraction (10-25%) of star-forming spheroids at z>1, and a possible drop to lower fractions at z<1. We find quantitatively similar results using spheroid samples defined solely or jointly by automatic (Sérsic n>2) selection. We find that as the high-mass galaxy population becomes more quenched, it also becomes more dominated by spheroids with very few quiescent disks (<10%) at any redshift. Taken together, these results are consistent with a scenario in which new spheroids were continuously added and subsequently quenched, and inconsistent with an evolutionary process that primarily added newly quenched disks. The actual picture likely includes contributions from multiple channels and requires detailed modeling to better constrain the relative amounts from each.

Author(s): Zachary Rizer[9], Daniel H. McIntosh[9], Joshua Cook[9], Jeyhan S. Kartaltepe[3], Stijn Wuyts[2], Arjen van der Wel[1], Guillermo Barro[5], Anton M. Koekemoer[4], Christopher Conselice[10], Eric F. Bell[8], Dale Kocevski[6], David C. Koo[5], Mauro Giavalisco[7]
Institution(s): ***1. Max Planck Institute for Astronomy, 2. Max Planck Institute for Extraterrestrial Physics , 3. National Optical Astronomy Observatory, 4. Space Telescope Science Institute , 5. University of California - Santa Cruz, 6. University of Kentucky , 7. University of Massachusetts, 8. University of Michigan, 9. University of Missouri - Kansas City, 10. University of Nottingham***

143.54 – Morphologically Disturbed Massive Galaxies: Nature and Evolution During 0.6 < z < 2.5 in the CANDELS UDS and GOODS-S Fields

Merging is predicted to be an important process in the early and turbulent assembly of massive galaxies. These violent encounters heavily impact galaxy morphology and structure. As such, the evolution of morphologically disturbed systems may help constrain the relative importance of merging, the answer to which is largely debated especially at higher redshifts. Disagreements between studies however, may be attributed to the various methods used to identify merging galaxies such as visual or quantitative classifications based on different rest-frame wavelengths. Using a new comprehensive catalog of visual rest-frame optical classifications based on HST/WFC3+ACS imaging from the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS), we compare the nature and evolution of merging and highly disturbed galaxy subsamples within the UDS and GOODS-S fields. We limit our sample for completeness to high-mass objects (Mstar > 1e10 Msun) with redshifts between 0.6 < z < 2.5. Most disturbed galaxies are star-forming and two-thirds have masses under 3e10 Msun. We note that one-third appear to be neither interacting nor merging, rather they are isolated and visually disk-like. Under the assumption that many disturbed or unusual morphologies are related to merging, we compare visually-selected subsamples to merger selections based on two popular quantitative methods (Gini-M20 and CAS). We find that all selections produce similar fractions across our redshift range, but the individual galaxies making up the respective fractions are often different. This may indicate that different classification methods are preferentially selecting objects undergoing either different processes such as major merging, minor merging and violent disk instabilities, or different stages of the same process.

Author(s): Joshua S. Cook[7], Daniel H. McIntosh[7], Zachary Rizer[7], Jeyhan S. Kartaltepe[3], Anton M. Koekemoer[4], Jennifer Lotz[4], Christopher Conselice[8], Philip F. Hopkins[5], Stijn Wuyts[2], Michael Peth[1], Guillermo Barro[6]

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Contributing team(s): CANDELS Collaboration

143.55 – What Determines the Strength of Lyman Alpha Emission in Star-Forming Galaxies?

We have conducted a study of 225 star-forming galaxies at 2.0 ≤ z ≤ 3.4 in the Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (CANDELS) GOODS-S field to investigate the relationship between Lyman-α emission and the physical properties of these galaxies. Using spectra from the GOODS/VIMOS catalog, rest-frame Lyα equivalent widths were measured and galaxies were classified as Lyα emitters, absorbers, combination, or noise. We performed Spectral Energy Distribution (SED) fitting on photometry from the CANDELS multi-wavelength catalog and constrained mass, age, and E(B-V). Strong Lyα emitters were found to be relatively dust-free and lower in mass. In contrast with a recent study by Kornei et al. (2010), we find younger median ages and no significant correlation between Lyα equivalent width and the age of a galaxy since star formation began. We also place these galaxies on the SFR-M* diagram and compare their locations with the main star-forming locus.
We gratefully acknowledge support from NSF through grant AST-1055919.

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Contributing team(s): CANDELS Team

143.56 – Spectroscopic Study of Massive and Evolved Systems at z>3

We present the results of our deep Keck/DEIMOS spectroscopic observation of massive and evolved galaxies at z>3 selected from deep HST/WFC3 observations by CANDELS and identified based on the strength of the Balmer break (Balmer Break Galaxies or BBGs). We spectroscopically confirm the existence of such systems at high redshifts. The very presence of these galaxies provides a significant challenge for scenarios of galaxy formation (e.g. CDM). We stack the spectra of the BBGs and compare it to the stacked spectrum of star forming Lyman Break Galaxies and Lyman Alpha Emitters at similar redshifts. The stacked spectrum of BBGs shows much stronger metal absorption features with equivalent widths that are several times larger than the LBG selected star forming systems. This seems to indicate that the passive systems are less dominated by outflows that are characteristics of star forming systems at high redshifts. Studying the photometrically derived properties of these systems we see that the spectroscopic trends agree well with the SED inferred age and SSFRs for this population.

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Institution(s): *1. UC Irvine, 2. UC Riverside*
Contributing team(s): CANDELS

143.57 – Serendipitous sources in deep ALMA archival pointings

We have searched the ALMA Cycle 0 archive for deep pointings that are now public, finding a number of serendipitous candidate continuum and line emitters. Our continuum source counts are consistent with studies of lensed sources using single dish observations, and with other ALMA archival studies. We also have a handful of candidate emission lines, if real these are most likely [CII] emitters at z=5-7. The star formation rate density we estimate from these is above the estimates from optical studies at these redshifts by a factor ~2. In this poster we present our most promising candidates and discuss the possibilities for finding further objects now that Cycle 1 data is becoming available in the archive.

Author(s): Mark Lacy[1]
Institution(s): *1. NRAO*

143.58 – First Light: Exploring the Spectra of Galaxies in the Early Universe

We present synthetic observations for galactic halos in the early Universe (z>6). Due to the strong impact of nebular emission lines and the relatively compact scale and dynamics of emissive HII regions, high resolution cosmological simulations and a robust suite of analysis tools are required to properly simulate spectra. Using cosmological radiation hydrodynamic Enzo simulations of the first galaxies, we created a software pipeline consisting of FSPS, Hyperion, Cloudy and our own tools to generate synthetic IR observations from a fully three-dimensional arrangement of gas, dust, and stars. Our prescription allows us to include emission lines for a complete chemical network and tackle the effect of dust extinction and scattering in the line of sight of the observer. We provide the spectra and associated photometry for several dark matter halos in the rare peak zoom-in region of the Renaissance Simulation (Xu et al. 2013), a study of resolution on our method, and time series progressions of spectra for individual galaxies during their assembly for both

HST and JWST IR bands. Our resulting synthetic spectra show high variability between galactic halos with a strong dependence on star formation history.

Author(s): Kirk Stuart Simeon Barrow[1], John Wise[1]
Institution(s): *1. Georgia Institute of Technology*

143.59 – Contribution of Low Mass Galaxies to Reionization

Here we quantify the abundance of faint galaxies at high redshifts and their ionizing photon budget using a complete sample of ~ 10,000 simulated galaxies from the Vulcan simulation, a new state of the art cosmological simulation of a 25Mpc per side volume, with unprecedented spatial resolution. Their predicted population is consistent with the most recent observations of the UV luminosity function up to z ~ 8. In addition, we measure the fraction of photons that can escape their host halo and ionize neutral hydrogen in the IGM. With the uniform resolution of our simulation we have ~ 100 systems with reliable morphologies, and therefore realistic distributions of young stars (sources) relative to the neutral hydrogen (absorbers). With this model, we predict the contribution of low mass galaxies to reionization, in line with the theory that star forming galaxies are a major source of ionizing photons, especially if there is an underlying faint population undetectable by current surveys.

Author(s): Lauren M. Anderson[3], Thomas R. Quinn[3], Fabio Governato[3], Alyson Brooks[1], Andrew Pontzen[2]
Institution(s): *1. Rutgers University, 2. University College London, 3. University of Washington*

143.60 – Spectro-polarimetry of a Lyman-alpha Nebula at z=3.09

We present a follow-up study to the imaging polarimetry performed by Hayes, Scarlata & Siana (2011) on one of the largest Lyman-alpha (Lya) nebula currently known, dubbed LAB1. We obtain deep, spatially resolved spectro-polarimetric measurements of LAB1, whose extended Lya emission is likely due to Lya photons produced from a powerful star-forming galaxy and scattered at large radii by the surrounding neutral gas. However, questions still remain on the precise nature of the kinematics in the system. We find spectrally integrated polarization consistent with our prior imaging results. We find wavelength dependent polarization consistent with zero at line center and rising to approximately 12% in the wing of the line profile which supports the idea of a large scale outflow. We discuss how the detected wavelength dependence of the Lya polarization can help in constraining the geometry of the scattering nebula.

Author(s): Melanie Beck[2], Claudia Scarlata[2], Matthew Hayes[1]
Institution(s): *1. Stockholm Observatory, 2. University of Minnesota*

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144 – AGN, QSO, Blazars Posters

144.01 – Distance Measurements to Host Galaxies of Reverberation-Mapped AGN

We present new distance measurements for the host galaxies of several nearby active galactic nuclei (AGN) with reverberation-based black hole masses. Neutral hydrogen (HI) line widths and flux measurements are determined using our radio spectra from the Green Bank Telescope. With our optical images from the MDM observatory, a surface brightness fitting program is applied to subtract the AGN contribution from the brightness profile and constrain the total galaxy magnitude. We then apply the luminosity-line width (Tully-Fisher) relation to determine the galaxy distance. Comparisons of these distances can be made with those inferred from the baryonic Tully-Fisher relation, which considers the mass of interstellar gas in addition to the mass from stars.

The distance measurements will improve black hole mass scaling relationships, which currently rely upon distances estimated by redshift. These scaling relationships include the relation between the black hole mass and the bulge luminosity, and the relation between the radius of the broad emission line region and the luminosity of the AGN. Since peculiar velocities can significantly affect the observed redshifts for nearby galaxies, distance measurements that are independent of redshift are especially pertinent for reducing the scatter in the scaling relationships.

Author(s): Benjamin Ou-Yang[2], Misty Bentz[2], Megan C. Johnson[1]
Institution(s): *1. CSIRO, 2. Georgia State University*

144.02 – The AGN Black Hole Mass Database

The AGN Black Hole Mass Database is a compilation of all published spectroscopic reverberation-mapping studies of active galaxies. We have created a public web interface, where users may get the most up-to-date black hole masses from reverberation mapping for any particular AGN, as well as obtain the individual measurements upon which the masses are based and the appropriate references. The database currently includes more than 50 AGNs and reverberation-mapping measurements obtained from more than 80 articles in peer-refereed journals. The AGNs span the range of observed Type I activity, including Seyfert 1.8-1.9, narrow-line Seyfert 1s, double-peaked AGNs, and flat-spectrum radio quasars in addition to the "classic" Seyfert 1s. The host galaxies also show a broad diversity, ranging from bulgeless disk galaxies to typical massive spirals (both barred and unbarred) to ellipticals. Many of the AGN hosts show signs of recent or ongoing merger activity but many others do not. While the database currently focuses on the measurements necessary for black hole mass determinations, we also plan to expand it in the future to include additional useful information, such as host-galaxy characteristics including luminosity, mass, and bulge stellar velocity dispersion.

Author(s): Misty C. Bentz[1]
Institution(s): *1. Georgia State University*

144.03 – The Effect of Host Galaxy Morphology on the M^{BH}-L^{bulge} Relation for Reverberation-Mapped AGN in the Near-IR

We present updated and nearly finalized results of our study on the effects of host galaxy morphology on the M^{BH}-L^{bulge} relation for reverberation mapped AGN in the near-IR. Previous studies have suggested that the M^{BH}-σ^* relation may have an offset depending on whether the host galaxy has a bulge or pseudobulge. This would make using the M^{BH}-σ^* relation for black hole mass determinations problematic because it would require knowledge of each galaxy's structure, which would be observationally intensive and thus defeat the purpose of such a scaling relation. We have undertaken to determine whether there exists the same morphological offset in the M^{BH}-L^{bulge} relation. Historically, the optical M^{BH}-L^{bulge} relation has been known to exhibit a larger scatter than the M^{BH}-σ^* relation likely due to star formation regions and dust obscuration. Therefore, we have conducted our study in the H-band in order to mitigate such effects. Our updated results include preliminary measurements for most of the sample, and we also included the NICMOS measurements of Veilleux et al. 2009. If we find that the M^{BH}-L^{bulge} relation has less intrinsic scatter and is less affected by galaxy morphology than M^{BH}-σ^* , then perhaps M^{BH}-L^{bulge} is the more fundamental scaling relation and is a better predictor of black hole mass when direct mass measurements are not feasible.

Author(s): Emily Manne-Nicholas[1], Misty C. Bentz[1]
Institution(s): *1. Georgia State University*

144.04 – The Nature of Variability of the Ultraviolet & Optical Spectral Energy Distribution of Active Galactic Nuclei

Chonołiewski (1981) showed that, after subtracting off a constant host galaxy light contribution, the UBVRI colors of AGNs stay remarkably constant as the AGN varies. This can be used to estimate the amount of host galaxy light and to determine the reddening of an AGN but the underlying cause of the constant optical spectral energy distribution (SED) is unknown. We investigate whether variable external illumination can be responsible for the constant optical SED. The external illumination model predicts that the SED varies more in the ultraviolet as the flux level changes. We compare these predictions with observations of ultraviolet and optical variability.

Author(s): Manfred Virgil Tanael Ambat[1], C. Gaskell[2]
Institution(s): *1. Bellarmine College Preparatory, 2. University of California, Santa Cruz*

144.05 – Measuring the Luminosity and Virial Black Hole Mass Dependence of Quasar-Galaxy clustering at z ~ 0.8

We study the dependence of quasar clustering on quasar luminosity and black hole mass by measuring the angular overdensity of photometrically selected galaxies imaged by WISE about z ~ 0.8 quasars from SDSS. By measuring the quasar-galaxy cross-correlation function and using photometrically selected galaxies, we achieve a higher density of tracer objects and a more sensitive detection of clustering than measurements of the quasar autocorrelation function. We test models of quasar formation and evolution by measuring the luminosity dependence of clustering amplitude. We find a significant overdensity of WISE galaxies about z ~ 0.8 quasars at 0.2--6.4 h^{-1} Mpc in projected comoving separation. We find no appreciable increase in clustering amplitude with quasar luminosity across a decade in luminosity, and a power-law fit between luminosity and clustering amplitude gives an exponent of -0.01±0.06 (1 sigma errorbar). We also fail to find a significant relationship between clustering amplitude and black hole mass, although our dynamic range in true mass is suppressed due to the large uncertainties in virial black hole mass estimates. Our results indicate that a small range in host dark matter halo mass maps to a large range in quasar luminosity.

Author(s): Alexander Krolewski[1], Daniel Eisenstein[1]
Institution(s): *1. Harvard University*

144.06 – Reddenings estimated from optical continuum variability for reverberation-mapped active galactic nuclei

We have used the Choloniewski flux variability gradient method to estimated reddenings for reverberation-mapped AGNs for which the host galaxy starlight contamination has been determined from Hubble Space Telescope surface photometry. We find that the median reddening due to dust associated with the AGN is about ten times greater than the reddening due to dust in the solar neighborhood. This corresponds to about a factor of two underestimate of the optical luminosity and a factor of ten underestimate of the far-UV luminosity. Some AGNs can have internal reddening substantially greater than this. Internal reddening is an important factor that needs to be taken into account when estimating black hole masses.

Author(s): Austin Zong Tuan[3], Christine Suhyun Cho[2], Manfred Virgil Tanael Ambat[1]
Institution(s): *1. Bellarmine College Preparatory, 2. Castilleja, 3. Phillips Academy*

144.07 – Estimating Reddening for Reverberation-Mapped Active Galactic Nuclei

The most widely used method for estimating black hole masses is the Dibai single-epoch-spectrum, which assumes the size of the broad line region of an AGN using the optical luminosity. To determine black hole masses, it is necessary to correct for the host galaxy light contamination and extinction. The Choloniewski flux variability gradient method was applied to 28 AGNs using blue flux to visible flux ratios to estimate the internal reddenings so that the effect of dust changing the shape of the spectrum can be allowed for more accurately. Previous papers, including Bentz et al. (2013) that calculate the luminosities of supermassive black holes believed the reddening of the AGN was negligible; thus, only the Milky Way Galaxy reddening was accounted for. However, our findings demonstrate that the internal reddening is much greater than the Milky Way Galaxy reddening, and the internal reddening is in fact not negligible, but rather significant. The internals reddenings of the AGNs ranged from 0.02-0.81 mag and the median reddening ≈ 0.23 mag. Since the AGNs are much brighter in the optical and ten times as bright in the ultraviolet, our findings demonstrate that the estimated luminosities of black holes are 100 times greater than previously thought.

Author(s): Christine Suhyun Cho[1]
Institution(s): *1. Castilleja*
Contributing team(s): Martin Gaskell, Manfred Virgil Ambat, Austin Tuan

144.08 – Photometric Reverberation Mapping using a Meter-class Telescope

For the past several decades, mass estimates for supermassive black holes hosted by active galactic nuclei (AGNs) have been made using the reverberation mapping (RM) technique. This methodology has produced consistent results and has been used to establish several relations that link the characteristics of the host galaxy to the mass of the central black hole. Despite this success, there are less than 50 AGNs with black hole masses derived from RM. This low number is generally attributed to the difficulties in coordinating large blocks of telescope time for making the simultaneous photometric and spectroscopic observations. In addition, the spectroscopic observations generally require several months of nightly observations with moderate to large size telescopes.
We have made photometric observations of several AGNs in selected filters in order to evaluate a photometric methodology for determining the lag time between the variations observed in the continuum and the response signal that is seen coming from the broad-line region (BLR) gas. This time delay represents the mean light travel time to the BLR, and is therefore a measurement of the mean BLR radius. In traditional RM campaigns, this time lag is combined with a measure of the width of the broad line to determine the velocity of the gas and then make a virial estimate of the black hole mass. We investigate results obtained using photometric time lags and a single epoch spectroscopic measurement of the line width in order to estimate the mass of the central black hole.
We present results from our photometric observations of several target AGNs made with the West Mountain Observatory 0.9 m reflector during the spring and summer of 2014.
This research was supported by the College of Physical and Mathematical Sciences at Brigham Young University as well as through a fellowship from the NASA Rocky Mountain Space Grant Consortium.

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144.09 – The Most Massive Active Black Holes at z~1.5-3.5 have High Spins and Radiative Efficiencies

I will present new constraints on the radiative efficiencies (η) of a large sample of 72 luminous unobscured active galactic nuclei at z~1.5-3.5, powered by some of the most massive black holes (BHs). The analysis is based on accretion disk (AD) models, which link the continuum luminosity at rest-frame optical wavelengths and the BH mass (M^{BH}) to the accretion rate through the AD, dM^{AD}/dt. The data are gathered from several literature samples with detailed measurements of the Hβ emission line complex, observed at near-infrared bands. When coupled with standard estimates of bolometric luminosities (L^{bol}), the analysis suggests high radiative efficiencies, with most of the sources showing $\eta > 0.2$, that is, higher than the commonly assumed value of 0.1, and the expected value for non-spinning BHs ($\eta = 0.057$). Even under more conservative assumptions regarding L^{bol} (i.e., $L^{bol} = 3\times L^{5100}$), most of the extremely massive BHs in the sample (i.e., $M^{BH} \geq 3\times10^9\ M^{\odot}$) show radiative efficiencies which correspond to very high BH spins (a^*), with typical values well above $a^* \approx 0.7$. These results stand in contrast to the predictions of a "spin-down" scenario, in which a series of randomly oriented accretion episodes leads to $a^* \sim 0$. Instead, the analysis presented here strongly supports a "spin-up" scenario, which is driven by either prolonged accretion or a series of anisotropically oriented accretion episodes. Considering the fact that these extreme BHs require long-duration or continuous accretion to account for their high masses, it is argued that the most probable scenario for the super-massive black holes under study is that of an almost continuous sequence of randomly yet not isotropically oriented accretion episodes.

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144.10 – Surface Photometry of Reverberation-Mapped Active Galactic Nuclei

I present a statistical analysis of the surface photometry obtained for a sample of Hubble Space Telescope (HST) archival images of the host galaxies containing active galactic nuclei (AGN), whose time-delay between continuum and broad emission line variations have been analyzed (i.e., reverberation mapping). For quiescent galaxies, strong correlations exist between central black hole mass and host galaxy structure. If there are similar correlations for AGN between central black hole masses derived from reverberation mapping and the host galaxy structure that I have derived from archival HST images, this would imply some validation of the assumptions underlying reverberation mapping concerning the structure, kinematics, and orientation of the broad line regions in AGN.
The correlations for quiescent galaxies bewteen central black hole mass and host galaxy structure imply that there might be a strong causal connection between the formation and evolution of the black hole and the galaxy bulge. A current hypothesis is that bulges, black holes, and quasars formed, grew, or turned on as parts of the same process, in part because the collapse or merger of bulges might provide a rich fuel supply to a central black hole.
One way of testing this hypothesis would be to plot AGN as a function of redshift on these correlations. However, two severe obstacles limit the ability to measure black hole masses in AGN using HST to analyze the central stellar and/or gas dynamics: (1) since spatial resolution becomes more limited at larger distances, only two reverberation-mapped AGN are close enough to Earth to render the analysis feasible, and (2) it is
difficult to obtain useful spectra of the stars and/or gas in the presence of the bright nonstellar nucleus. The most useful alternative is to exploit reverberation mapping, which uses the time delay in a given AGN between variations in the continuum emission and broad emission lines.

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144.11 – Photometric Reverberation Mapping with a Small Aperture Telescope

We present photometric observations of a sample of bright, broad-line AGN in order to monitor variability and verify their black hole masses using the photometric reverberation mapping technique. Observations were taken, primarily remotely, using the 20-inch telescope at the Murillo Family Observatory, a campus-based observatory located on the outskirts of the Southern California metro area, in both monitored and automated mode nightly in BVRI over a period of 2-5 months. We will show the viability of such a technique for small-aperture telescopes in bright-sky locations and discuss the possibilities of extending this program in the future. We also note that undergraduate students (both from 4-year and community colleges) have been and will continue to be instrumental in the success of similar research programs at CSUSB.

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144.12 – Deconstructing Dynamics: Improving Stellar Velocity Dispersion Measurements for Reverberation Mapped AGNs

Nearly all galaxies host a central supermassive black hole, and scaling relations between black hole mass (M^{BH}) and various host-galaxy properties are essential tools for investigating the evolution of structure across cosmic time. Since evolutionary studies are limited to active galaxies, well constrained and accurately calibrated scaling relations for AGNs are of particular interest. The tightest of these is the $M^{BH} - \sigma_\star$ relation, which relates M^{BH} and bulge stellar velocity dispersion ($\sigma_\star$), and as such it is one of the most frequently used for such studies. However, its utility is currently limited by the accuracy of the calibration. The majority of active galaxies for which M^{BH} has been determined are late-type spirals, which contain significant kinematic substructure including bars, disks, and rings, in addition to the central bulge. The presence of this substructure is known to contaminate and bias $\sigma_\star$ determinations from long-slit spectroscopy, and thus the quality of currently available $\sigma_\star$ measurements is perhaps the most significant hindrance to accurate calibration. We have undertaken a long-term project to significantly improve bulge stellar velocity dispersion measurements for the reverberation mapped sample of active galaxies that is currently used to calibrate the $M^{BH} - \sigma_\star$ relation for AGNs. Using integral field spectroscopy we will generate spatially resolved two dimensional velocity dispersion maps for these galaxies, with which we can investigate the kinematic signatures of galaxy subcomponents. We present preliminary results and show how these data can be used to identify kinematic substructure, thus allowing for better constrained $\sigma_\star$ measurements, free from contamination by dynamically distinct subcomponents.

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144.13 – Quasar Rain

Velocity resolved reverberation mapping (VRRM) has shown clear evidence for inflows in the broad emission line (BEL) region of active galactic nuclei: redshifted BELs at zero lag (AGNs, e.g. Arp 151, Bentz et al. 2010; Grier et al. 2013). While radiative transfer in rotating disks can give shorter red side lags than blue, a zero lag has to be along our line of sight, so it is hard to escape infall. The BEL region is normally considered to be rotating or in outflow so this result is a surprise. Infalling BEL gas cannot fall far without the need to lose angular momentum for accreting gas producing an accretion disk.
I suggest that quasar continuum irradiation induced cooling instabilities (Chakravorty et al 2009; Krolik, McKee & Tarter 1981) lead to dense BEL clouds condensing out of the semi-ubiquitous warm absorber (WA) outflows found in AGNs and that these clouds may produce a VRRM inflow signature.
Unlike WA gas, dense high column density BEL clouds are hard to accelerate with radiation pressure (Risaliti & Elvis 2010; Mushotzky, Solomon & Strittmatter 1972). BEL clouds will thus stall in the outflow and begin to fall back toward the central black hole after a dynamical time, "raining out" of the WA medium. If these BEL clouds condense out before these outflows reach escape velocity [v(esc)] then this inflow can potentially produce the observed VRRM signature. As the clouds fall back in they will be moving on elliptical orbits supersonically through the WA gas with Mach number ~(2000 km/s)/(100km/s) ~20. This will produce comet-like structures with narrow opening angles, as seen in asymmetric X-ray absorbing "eclipses" (Maiolino et al. 2010). They will survive only a few months, as required to avoid forming a disk. For this picture to work the condensation time must be less than the acceleration time to v(esc) and the destruction time must be longer than the dynamical time.

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144.14 – The Search for Active Black Holes in Local Dwarf Galaxies Using Optical and Mid-IR Data

The study of AGN in the low-mass regime is important in order to understand BH formation and evolution, as well as their connection with the host galaxies. Starting from a sample of ~ 48000 nearby low-mass galaxies ($M^\star \leq 10^{9.5}$ $M_\odot$, z < 0.1) in SDSS, we searched for AGN using two different techniques: BPT selection, and a mid-IR color criterion. We compiled a sample of 239 AGN candidates. Out of them, 43 are selected with the BPT diagram (~ 0.1% of the parent sample) and 199 with the mid-IR color criterion (~ 0.4%). Only 3 objects are selected by both criteria. The observed occupation fraction at low-mass regime seems to be at least one order of magnitude below what found for more massive objects. The AGN candidates selected by the two selection criteria show different physical properties. BPT selected AGN show red optical colors and high stellar masses, while mid-IR selected AGN are both bluer and with lower stellar masses. In addition, part of the AGN candidates sample shows an unexpected deficit of mid-IR emission, which could be due to a dust deficit and the absence of an obscuring torus. We are currently obtaining follow-up X-ray observations of some of these sources.

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144.15 – Quasar Clustering from SDSS DR7: Dependencies on FIRST Radio Magnitudes

Clustering is a measure of the dark matter environments in which galaxies are embedded. Quasars are a tracer of the state of active black holes throughout the Universe. The clustering of quasars as a function of their physical properties is thus a key measure in determining how black hole activity correlates with dark matter environment throughout cosmic history. Currently, the most abundant sample of quasars suitable for clustering measurements over most of cosmic history (and certainly over redshifts of about $0.8 < z < 2.2$) is the uniform sample of quasars assembled as part of the seventh incarnation of the Sloan Digital Sky Survey (SDSS DR7). We study the clustering of quasars as a function of their physical properties using the $\sim4000 \rm{deg}^2$ Sloan Digital Sky Survey Data Release Seven and a homogenous sample of 37,574 quasars. This work confirms the findings of Shen (2009) using DR5 and expands upon it using the larger DR7 catalog. We find that at lower redshifts quasar clustering depends weakly on luminosity. Cross-correlation of FIRST detected (radio-loud) quasars and autocorrelation of non-FIRST detected (radio-quiet) quasars indicates that radio-loud quasars cluster more strongly than do radio-quiet quasars. We agree with the conclusion that radio-loud quasars reside in more massive and denser environments, implying the possibility that it is the density of environment which determines a quasar's radio loudness, rather than a duty cycle.

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144.16 – Evidence from the Very Long Baseline Array that J1502SE/SW are Double Hotspots, not a Supermassive Binary

Black Hole

SDSS J150243.09+111557.3 is a merging system at z = 0.39 that hosts two confirmed active galactic nuclei (AGNs), one unobscured and one dust-obscured, offset by several kiloparsecs. Deane et al. recently reported evidence from the European VLBI Network (EVN) that the dust-obscured AGN exhibits two flat-spectrum radio sources, J1502SE/SW, offset by 26 mas (140 pc), with each source being energized by its own supermassive black hole (BH). This intriguing interpretation of a close binary BH was reached after ruling out a double-hotspot scenario, wherein both hotspots are energized by a single, central BH, a configuration occurring in the well-studied compact symmetric objects. When observed with sufficient sensitivity and resolution, an object with double hotspots should have an edge-brightened structure. We report evidence from the Very Long Baseline Array (VLBA) for just such a structure in an image of the obscured AGN with higher sensitivity and resolution than the EVN images. We thus conclude that a double-hotspot scenario should be reconsidered as a viable interpretation for J1502SE/SW, and suggest further VLBA tests of that scenario. A double-hotspot scenario could have broad implications for feedback in obscured AGNs. We also report a VLBA detection of high-brightness-temperature emission from the unobscured AGN that is offset several kiloparsecs from J1502SE/SW. The NRAO is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

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144.17 – Searching for the Nearest Extragalactic Binary Black Hole: A Spectroscopic Study of NGC4736

In 1995 and 1996, Maoz et al. concluded that the nearby galaxy NGC4736 is in the late stages of a merger event. After further investigation, in 2005, Maoz et al. observed UV variability in the nuclear region of NGC4736, implying a second unknown source in the nucleus. With late stage mergers being an ideal location to search for binary black holes (BBHs), this led us to hypothesize that the second source of this galaxy is a black hole, making this a BBH system. While the existence of BBHs are necessary for many theoretical predictions and play an important role in astrophysics, evidence for their existence remains sparse. To date, only NGC6420 (Komossa et al., 2003) and Arp 299 (Ballo et al., 2004) have been discovered as merging galaxies with two active galactic nuclei (AGN). In January of 2008, NGC4736 was observed with the GMOS-N instrument on Gemini North. Optical longslit spectra of the nuclear region were obtained with spatial resolution of ~0.5". With this resolution, the two nuclear sources at a projected separation of 2.5", are therefore spatially resolved (Maoz et al., 2005). As a result, we can classify the nature of the second source by looking at the optical line ratios following Ho et al. (1997). At a distance of 4.9 Mpc, NGC4736 would be the nearest BBH system. This enables high-spectral and spatial resolution observations which will be a significant step forward in validating models of galaxy mergers.

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144.18 – The environment of PDS456

I present optical spectroscopic and narrow-band imaging data on the luminous, low redshift (z=0.184) quasar, PDS456, and its environment. This quasar has been the subject of multiple X-ray observations over the past ~15 years, which show strong variability and a high velocity outflow (e.g. Reeves et al. 2014 and references therein). Radio continuum, CO(1-0) and sub-millimeter data reveal both ULIRG- and quasar-like properties and suggest that the object is in a transient phase of evolution from a ULIRG to a bona fide quasar (Yun et al 2004). On a K-band image, there are three compact sources to the southwest of the quasar and within 2-3" from it (~10 kpc if at the quasar redshift) which Yun et al. propose may be remnants of a merger or interaction.

A 3200-10000 angstrom spectroscopic observation with the Multi-Object Double Spectrograph (MODS1) at the Large Binocular Telescope (LBT), with the slit position angle set to capture both the quasar and the fainter K-band source, reveals, at an angular separation of ~6" from the quasar and in the same direction as the K-band source, a compact narrow emission line region, with lines of H-alpha, [NII], [SiII], [OII], H-beta, and [OIII], at the quasar redshift. To determine a more precise location for this narrow line emitting region and to look for others, narrow-band imaging, through redshifted H-alpha (7780/84) and continuum filters, was obtained using the 90Prime camera at the Bok 2.3-m telescope. The contribution of these data to our understanding of this intriguing quasar will be discussed.

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144.19 – Diagnostic Power of Broad Emission Line Profiles in Searches for Binary Supermassive Black Holes.

Motivated by advances in observational searches for sub-parsec supermassive black hole binaries (SBHBs) made in the past few years we develop a semi-analytic model to describe the spectral emission line signatures of these systems. The goal of this work is to test one of the leading models of binary accretion flows in the literature: SBHB in a circumbinary disk. In this context, we model SBHB accretion flows as a set of three accretion disks: two mini-disks that are gravitationally bound to the individual black holes and a circumbinary disk that forms a common envelope about a gravitationally bound binary. We find that emission line profiles tend to have different statistical properties depending on the semi-major axis, mass ratio, eccentricity of the binary, and the alignment of the triple-disk system, and can in principle be used to infer the statistical distribution of these parameters.

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144.20 – Accretion Disk and Dust Emission in Low-Luminosity AGN

Observations obtained in the near-infrared (near-IR; 0.8 - 2.5 μm) can assist our understanding of the physical and evolutionary processes of galaxies. Using a set of near-IR spectra of nearby galaxies obtained with the cross-dispersed mode of GNIRS on the Gemini North telescope, we investigate how the accretion disk and hot dust emission depend on the luminosity of the active nucleus. We recover faint AGN emission from the starlight-dominated nuclear regions of the galaxies, and measure properties such as the spectral shape and luminosity of the accretion disk and dust. The aim of this work is to establish whether the standard thin accretion disk may be truncated in low-accretion-rate AGN, as well as evaluate whether the torus of the AGN unified model still exists at low luminosities.

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144.21 – A WISE Selection of MIR AGN in Different Environments

This study was undertaken to understand the role of large scale environment in the evolution of MIR-selected AGN. In this study we examine AGN candidates in two types of environments: 7 clusters and 6 blank fields. Two types of clusters were studied in this project: 3 virialized and 4 non-virialized. The redshift of the clusters ranged $0.22 \leq z \leq 0.28$. We used the mid-infrared WISE All-Sky database to identify AGN, applying various methods to refine our AGN candidate selection. To ascertain if there is an excess or deficit of MIR AGN in galaxy clusters vs. blank fields, we compared the AGN candidate distributions in virialized vs. non-virialized clusters to the blank fields. After close examination and comparison of the results to X-ray selected AGN from the Gilmour et al. (2009) study, we concluded that we do not detect an excess or deficit of MIR AGN in our clusters whether the cluster was virialized or non-virialized. This contrasted the conclusion of the Gilmour et al. (2009) study where there was an excess of X-Ray selected AGN in clusters.We also note an interesting feature in our WISE color-color plots that might be used for further investigation.

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144.22 – Probing the Inner Accretion Disk of AGNs Via Optical Power Spectra

We present an expanded analysis of the spectral luminosity from accretion disks in AGNs, computing the fraction of the flux in an optical band that originates in an inner radial region of the disk. This will help to assess the extent to which optical monitoring of AGNs can provide information about these inner regions, where the mysterious quasi-periodic oscillations (QPOs) are produced. As an example, the period of the most robust (g-) mode, which is gravitationally trapped near the temperature maximum of the disk, is 11 - 40 (M/10^8 solar masses) (1+Z) hours (for maximum – zero spin). One goal is to optimize the target selection strategy, as a function of black hole mass [for fixed L/L(Edd)], spin and redshift. Various inclinations of the accretion disk will also be considered. Large redshifts are required, since the maximum temperature of the disk is ~ 10^5 K for 10^8 solar masses; targets could be u-band dropouts (Z=3.4). The ultimate goal is deep power spectra from high cadence, long duration monitoring, such as within the deep drilling fields of LSST. We plan to employ existing monitoring data to implement planning of the observing strategy.

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144.23 – Optical Microlensing and Accretion Disk Structure in the Lensed Quasar SDSS 1520+530

We analyze uncorrelated variability in seven seasons of SDSS r-band monitoring data from the doubly-imaged gravitationally lensed quasar SBS 1520+530 to yield a measurement of the size of the near-UV continuum emission region in this quasar. Photometry in the SBS 1520+530 system is complicated significantly by the proximity of a very bright star whose diffraction spike blends with the the lens, so we employed a mirror-flip subtraction technique to correct for this contamination.
We conclude by testing our accretion disk measurement against the Quasar Accretion Disk Size - Black Hole Mass Relation.

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144.24 – Coronal-Line Forest AGN: the best view of the inner edge of the AGN torus?

We introduce Coronal-Line Forest Active Galactic Nuclei (CLiF AGN), AGN which have a rich spectrum of forbidden high-ionization lines (FHILs, e.g. [FeVII], [FeX] and [NeV]), as well as unusually strong narrow (~300 km s^{-1}) Hα emission. We find that the kinematics of the CLiF emitting region are similar to those of the forbidden low-ionization emission-line (FLIL) region. We compare emission line strengths of both FHILs and FLILs to CLOUDY photoionization results and find that the CLiF emitting region has both higher densities ($10^{5.5} < n^{H} < 10^{7.0}$ cm^{-3}) and ionization parameters ($-1.5 < \log^{10} U < 0$) when compared to the FLIL emitting region ($10^{3.0} < n^{H} < 10^{4.5}$ cm^{-3}; $-2.5 < \log^{10} U < -1.0$). In addition, we find that the CLiF region requires an ionizing power-law slope of ~-0.8, whereas the FLIL emitting region requires a flatter power-law of ~-1.2. We use the photoionization results to calculate the CLiF regions radial distances and find that they are comparable to the dust grain sublimation distance ($0.05 < R^{CLiF} < 1.25$ pc). We suggest that the inner torus wall is the most likely location of the CLiF region, and the unusual strength of the FHILs is due to a specific viewing angle of the far wall of the torus.

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144.25 – Galaxy Zoo: AGN may be fueled by stellar bars in the local Universe

Bars are a mechanism that have been proposed to explain how gas in the outer regions of a galaxy can be channeled inward and fuel AGN. Multiple observational studies have reported a significantly higher bar fraction in AGN than non-AGN. To accurately probe whether an excess of bars in AGN host galaxies exists *because* the galaxies host a bar, it is necessary to compare bar and AGN fractions at fixed mass and color, because the presence of bars strongly correlates with both. Thus, a sufficiently large sample is necessary to maintain adequate numbers in subsets of fixed mass and color. We have created a large, volume-limited sample of 19,765 disc galaxies using data from the Sloan Digital Sky Survey. By using morphological classifications from the Galaxy Zoo 2 project, we identify stellar bars in 51.8% of AGN hosts and 37.1% of star-forming disk galaxies. Once mass and color are fixed, there remains a statistically significant increase in the fraction of barred AGN over their unbarred counterparts. Using the $L^{[O\ III]}/M^{BH}$ ratio as a measure of accretion efficiency, we also show that barred AGN do not exhibit stronger accretion than unbarred AGN at fixed mass or color. The data are consistent with a model in which bar-driven fueling does contribute to the probability of an actively growing black hole, but in which other dynamical mechanisms must contribute to AGN fueling via smaller, non-axisymmetric perturbations.

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Contributing team(s): Galaxy Zoo Science Team

144.26 – Clustering and Photometric Redshifts of Galaxies in Low Redshift Quasar Fields

We present the final results of our clustering analysis in ~1 square degree fields around 12 quasars with $0.06 < z < 0.37$ using deep *ugri* photometry obtained with the 90Prime instrument on the Bok 2.3 meter telescope. We find correlation amplitudes in all bands to be consistent with galaxy-galaxy clustering, with some indication of enhanced clustering in the i band within the uncertainties. The relative bias of galaxies and AGN in the u band is larger compared to that calculated in the other bands, but it does not correlate with AGN luminosity, black hole mass, or AGN activity via the luminosity of the [O III] emission line. We conclude that the large scale environments around these quasars out to 0.5 h^{-1} Mpc contain no significant signatures of accretion activity in the AGN and that this sample of mostly (10/12) radio quiet Seyfert galaxies may thus exhibit a non-merger mode of AGN activity. We also present photometric redshifts for the galaxies in our catalog. We combine these results with absorption line data on the sample quasars and empirical results of studies of the circumgalactic medium to devise a statistical approach to determining galaxy-absorber pairs within the catalog sample.

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144.27 – Near Infrared Spectroscopy of Active Galactic Nuclei Using FSpec

Using data from the 2.3 meter Bok telescope on Kitt Peak and the FRANKENSpec spectrograph, we aim to investigate the circumnuclear region of over twenty active galaxies in the J, H, and K passbands in order to obtain high signal to noise spectra with reasonable investment of observing time. The sample is selected to cover a wide range of AGN types of activity in luminous nearby galaxies. The primary goal of this project was to sort and process the 9,000+ spectra, including dark subtraction, flat fielding, and creation of and application of bad pixel masks. The 2-D spectra were processed to a 1-D spectra and wavelength calibrated to reveal the exact wavelength of each peak in the spectra. Using standard stars is of utmost importance so the atmospheric lines can be corrected for and the data can be used for precise analysis. With the reduced and calibrated spectra, we measure the Paschen α, β, and γ Hydrogen lines, the Brackett γ Hydrogen line and the FeII line in the near infrared emitted from the circumnuclear regions of the galaxies. These data unveil details of what the environment is like in the area surrounding the supermassive black holes that are found in the heart of each of these galaxies.

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144.28 – Tidal Disruption Events From Nearby Dwarf Galaxies

When a star passes near a massive black hole, the tidal forces may disrupt the star, and the fallback of stellar debris onto the black hole may give rise to a luminous, long-duration flare. These tidal disruption flares are rare, but provide an important probe into quiescent nuclear black holes, and particularly intermediate-mass black holes (IMBHs). We discuss tidal disruption flares which we have identified in archival X-ray data. Two such flares have likely been produced by IMBHs. One, identified in archival observations of Abell 1795 and confirmed via deep Gemini spectroscopy, is in one of the smallest galaxies confirmed to host a massive black hole. Another is found in ROSAT data, supports higher a disruption rate than has previously been determined from the ROSAT All-Sky Survey.

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144.29 – Self-Consistent Synchrotron Spectra from Trans-Relativistic Electron Acceleration

Most existing analytical models describing the second-order Fermi acceleration of relativistic electrons due to collisions with MHD waves assume that the injected seed particles are already highly relativistic, despite the fact that the most prevalent source of particles is usually the non-relativistic thermal background gas. This presents a problem because the momentum dependence of the momentum diffusion coefficient describing the interaction between the electrons and the MHD waves is qualitatively different in the non-relativistic and highly relativistic limits. The lack of an analytical model has forced workers to rely on numerical simulations to obtain particle spectra describing the trans-relativistic case. In this work, we present the first analytical solution to the global, trans-relativistic problem of electron acceleration, obtained by using a hybrid form for the momentum diffusion coefficient, given by the sum of the two asymptotic forms. We refer to this process as "quasi hard-sphere scattering." The model also incorporates the appropriate momentum dependence for the particle escape timescale, and the effect of synchrotron and inverse-Compton losses, which are critical for establishing the location of the high-energy cutoff in the particle spectrum. Since synchrotron and inverse-Compton losses are included in the transport equation, the resulting radiation spectra are computed self-consistently. The results can be used to model the acceleration of radiating electrons in AGN and solar environments, applications of both types are discussed.

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144.30 – Modeling the optical/UV emission from tidal disruption events

We perform radiative transfer calculations to compute the spectral energy distribution and emission line strengths from the tidal disruption of a main sequence star by a massive black hole at the time of peak emission. Informed by hydrodynamic simulations of tidal disruption events, our model consists of a luminous accretion-powered source surrounded by an extended envelope of stellar debris in a spherical geometry. We account for non-LTE atomic level populations for hydrogen and helium, bound-free and free-free radiation processes, and electron scattering. We show how effective these processes are in converting the ultraviolet radiation from the disk into an optical continuum as a function of the mass of the envelope, the luminosity of the accretion disk, and the radial distribution of mass in the envelope. We also quantify the extent to which optical line emission can be thermalized and blended into the optical continuum. We use our results to analyze observations of tidal disruption candidates.

Author(s): Nathaniel Roth[2], Daniel Kasen[2], James Guillochon[1], Enrico Ramirez-Ruiz[3]
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144.31 – Community Detection Algorithms as a Diagnostic Tool for SDSS Dataset Networks

We explore methods for identifying similar groups of objects in large astronomical datasets, where those similarities are not trivial to determine using standard methods to identify groups or trends. We focus on the use of graph theory to identify network communities of objects, drawing on its wide usage in the biological and social sciences, specifically the k-clique and cluster modularity diagnostics. As a test case, we apply these diagnostics to the SDSS BOSS QSO catalogue, which we categorize based on their MgII and CIV equivalent widths. We find approximately 12 communities, which are moderately robust against choice of algorithm and do not appear to be consistent with a random distribution. We briefly discuss some implications of these results.

Author(s): John Taylor Burleson[1]
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144.32 – The Birth of Quasars

Active galactic nuclei (AGNs) play an important role in the evolution of structure in the universe. Through the accretion process, they convert gravitational potential energy into radiative and mechanical energy and inject it into surrounding media, influencing star formation and gravitational condensation processes. The sequence of black hole formation, fueling, AGN birth, and associated suppression of star formation in galaxies is poorly understood, and difficult to observe due to the relative brevity of this phase, compounded by the high dust opacities at optical and infrared wavelengths. By selecting a sample of rare, luminous transition objects from the all-sky WISE survey and studying members of the sample with high resolution radio imaging, it is possible to gain insight into the role of AGN jets in this evolutionary sequence. We present VLBA data for 90 distant, highly obscured AGNs, hypothesized to be very young, and image their radio structures on scales of 10- 100pc. We provide image analysis results, including flux densities, fitted sizes, energy densities and pressures of the structures. The structures we observe can be interpreted in terms of interactions between a powerful jet and a dense, clumpy interstellar medium. Plans for future observations with greater sensitivity and covering a wider range of size scales are described.

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144.33 – Exploring the Variability Characteristics of the Fermi AGN Sample

The Fermi Gamma-Ray Space Telescope (*Fermi*) has cataloged nearly 2000 gamma-ray *(>100 MeV*) point sources of which more than 1100 are likely AGN (these numbers will likely increase by ~50% in the near future with the forthcoming 3FGL catalog). The AGN are predominantly representative of the radio-loud “blazar” subclass. The emission from these objects is known to be dominated by relativistic beaming and is almost always variable, often exhibiting high-amplitude flaring. To date there have been numerous studies of individual objects including multi-wavelength campaigns with some including parsec-scale radio jet morphological studies. Collectively, these studies have led to new insight in to our understanding of the blazar phenomena and jet propagation. However, there remains a dearth of statistical information on the variability characteristics of the population in aggregate. What, for example, are the distributions of flare amplitudes, durations, temporal profiles and recurrence histories among the gamma-ray blazar subclasses? In two related contributions we present present some results of our study of a large (~10^3) set of gamma-ray light curves. In this presentation we consider the brightest subset of our identified AGN flares, comprising initially a few tens of events, and then explore in greater detail their properties such as morphologies and their rise and decay timescales. We include where plausible the associated energy dependencies of these rise and decay profiles. We discuss our results in terms and the possible implications on the scale and location of jet structures associated with the emission sites and the cooling timescales of the electron population producing the gamma rays.

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144.34 – Evaluating the Detection of Diskoseismic Modes in AGNs

The existence of diskoseismic modes would presumably reveal itself as a modulation in the luminosity signal from accretion disks in AGNs. A theoretical determination of what fraction of the flux would be collected by an optical band for specific sources constitutes thus an important tool for the detection of these modes (which lie in the inner part of the accretion disk) and for the measurement of the elusive black hole angular momentum parameter. We report on the development of a web platform which will enable researchers to assess in a user-friendly way, and for different AGN sources, the Optical Power Spectra. The main goal of the presentation is to generate observational strategies in parameters such as cadence, monitoring and band range for present and future AGN survey projects in the spirit of diskoseismic mode detection.

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144.35 – An Investigation of Quasar Variability as a Damped Random Walk in the PanSTARRS-1 Medium Deep Fields

We model the lightcurves of 755 optically varying quasars from the Pan-STARRS Medium Deep Field 7 *r* band using a Damped Random Walk (DRW) model. The DRW describes quasar variability by its characteristic timescale, τ, and its variability at infinite time, V^{∞}. We use Monte Carlo techniques to fit our data as a DRW. The model parameters are compared to physical properties of the quasars such as black hole mass, Eddington ratio, and bolometric luminosity. We find that bolometric luminosity, Eddington ratio, and black hole mass are positively correlated with V^{∞} and negatively correlated with τ. Quasars of greater luminosity, black hole mass, or Eddington ratio generally display smaller variations, and on longer timescales as estimated in the DRW model framework. This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

Author(s): Virginia Cunningham[3], Paul J. Green[2], Eric Morganson[2], Yue Shen[1]
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144.36 – Testing Mergers as a Trigger for Active Galaxies

What makes a galaxy become active? It is often thought that galaxy mergers trigger the most luminous active galaxies (AGN)--quasars--but lower-luminosity AGN are started by milder processes. In our recent work, we analyzed a range of lower-luminosity AGN at redshifts of 0.5 < z < 0.7 and found no trend of rising merger incidence with luminosity.
To reach the high luminosities thought to require mergers, we have now imaged 20 quasars to expand the range of the sample. We have removed the nuclear point sources to reveal the host galaxies beneath, allowing a comparison of galaxy properties.

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144.37 – Disentangling Quasar Nomenclature

The terms Type 1, Type 2, Obscured, Unobscured, Compton-thin and Compton-thick are cemented naming conventions for describing AGN and QSOs. However, all too often, they are used interchangeably to describe seemingly similar/different entities, leading to confusion towards the physical mechanisms that give rise to them. Furthermore, as is often the case in scientific discovery, initial designations and acronyms become obsolete. In this poster, using data and new results from the SDSS, SDSS-III BOSS, Bootes, DEEP2 and WISE surveys, we present a comprehensive QSO Glossary giving clear definitions of numerous AGN terms and the physical interpretation behind them. We further elucidate to the physical nature of hot dust obscured galaxy population (``hot DOGs'') and the long-sought after high-z Type 2 QSO population.

Author(s): Nicholas Ross[2], Andrew D. Goulding[1]
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144.38 – Quasar Selection in the Optical + MIR

We identify 885,503 type 1 quasar candidates to i<22 using the combination of optical and mid-IR photometry. Optical photometry is taken from SDSS-III, while mid-IR photometry comes from a combination of data from ALLWISE and several large-area Spitzer-IRAC fields. Selection was based on a training sample of 157,701 spectroscopically-confirmed type 1 quasars with both optical and mid-IR data. Of these candidates, 306,686 lack spectroscopic confirmation, including 8665 quasar candidates with 3.5<z<5. Our algorithm is more complete to z>3.5 than the traditional mid-IR selection ``wedges'' and to 2.2<z<3.5 quasars than the SDSS-III/BOSS project. This catalog paves the way for luminosity-dependent clustering investigations of large numbers of faint, high-redshift quasars. This work was supported in part by NASA-ADAP grant NNX12AI49G.

Author(s): Gordon T. Richards[1], Adam D. Myers[2], Christina M. Peters[1]
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144.39 – Tranverse correlation of quasar pairs

For the last five billion years the universe has been expanding in size at an increasing rate. With modern technology we are able to observe objects at very high redshift, which were created in the early universe. Being able to analyze and observe these objects allows us to put specific constraints on the universe (age, size, dark matter fraction…etc). Looking at the spectra of highly redshifted objects, such as quasars, we can see a series of absorption lines called the Lyman alpha forest.
The angular correlation in the Lyman alpha spectra of quasar pairs allows us to measure the size of the absorbing objects. This works best at very small-scale (below one arcmin). The most recent use of this method consisted of 32 quasar pairs and only two of those had a sky separation below 1 arcmin (Coppolani et al., 2006). The sample size that is used in this work is from the SDSS-III DR12. This catalog has over 1500 quasars pairs below two arcmin separation, giving us much lower error bars, and therefore putting much better constraints on the cosmological parameters that can be inferred from the correlation function

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Contributing team(s): Dr.Isabelle Paris, BOSS/SDSS

144.40 – Variability of Carbon-IV Emission and Multi-Epoch Virial Mass Estimation in High-Redshift Quasars

The CIV emission line in quasar spectra is well-known to show systematic blue-shifts often attributed to accretion disk winds. We investigate the variability of the CIV line properties in a large sample of multi-epoch quasar observations from the SDSS DR11 BOSS survey, focusing on potential correlations of the blueshift variability with line and continuum properties. Preliminary findings show very weak to no variability in the blue-shifting of the region of interest and weak correlation between line blue-shift and change in continuum flux between epochs, indicating near constant outflow speeds. We will also continue to investigate the use of multiple epoch luminosities of the CIV line as a probe of virial mass of the host SMBH. By recalibrating estimates built on the use of single epoch data and correcting for any changes in outflow speed, it is hoped to more finely tune BH mass estimates.

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144.41 – The Fermi Large Area Telescope Flare Advocate Program: Rapid Sharing of Results with the Community

The Fermi Flare Advocate (also known as Gamma-ray Sky Watcher) program provides a quick look and review of the gamma-ray sky observed daily by the Fermi Large Area Telescope (LAT) through on-duty LAT Flare Advocates and high-level software pipelines like the LAT Automatic Science Processing and the Fermi All-sky Variability Analysis. The FA-GSW service provides rapid alerts and communicates to the external scientific community potentially new gamma-ray sources, interesting transients and flares. News items are regularly posted through the Fermi multiwavelength mailing list, Astronomer's Telegrams and Gamma-ray Coordinates Network notices. A weekly digest containing the highlights about the variable LAT gamma-ray sky at E>100 MeV is published on the web ("Fermi Sky Blog"). From July 2008 to September 2014 more than 290 ATels and 90 GCNs have been published by the Fermi LAT Collaboration. Target of opportunity observing programs with other satellites and telescopes have been triggered by Flare Advocates based on gamma-ray flares from blazars and other kinds of sources.

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Contributing team(s): Fermi Large Area Telescope Collaboration

144.42 – First Results from the NuSTAR Survey of Swift/BAT AGN

Launch of the first focusing hard X-ray telescope, the Nuclear Spectroscopic Telescope Array (NuSTAR), enabled studies of the local active galactic nuclei (AGN) to extend into the spectral window above 10 keV with unprecedented spatial resolution and two orders of magnitude higher sensitivity than any other instrument operating in that bandpass. As a part of its long-term Extragalactic Surveys program, NuSTAR will survey the nearby population of AGN detected at hard X-ray energies in the Swift/BAT all-sky survey. We present a survey of ~100 Swift/BAT AGN observed in the first two years of NuSTAR operation. A short 15-25 ks NuSTAR exposure of a source detected with the Swift/BAT instrument provides a sufficiently detailed hard X-ray spectrum to provide well-constrained model parameters for each one individually. This sample forms an atlas of the best hard X-ray spectra available to date for a substantial number of AGN. Assuming a range of spectral models, both phenomenological and physically motivated, we determine the distributions of spectral parameters, such as the spectral index, absorption column, reflection strength and iron line equivalent width. We discuss the implications for the local Seyfert 2 population and the limitations of the current results. We also highlight more detailed studies of particular AGN, and preliminary results on multiplicity and variability in the hard X-ray band.

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Contributing team(s): NuSTAR Extragalactic Surveys Team

144.43 – Quasar Selection using Optical Photometry and Variability

We used the Non-parametric Bayesian Classification Kernel Density Estimation (NBC KDE) quasar selection algorithm to identify 30,755 type 1 quasar candidates on the Sloan Digital Sky Survey (SDSS) Stripe 82 using the combination of optical photometry and variability. Optical photometry is taken from the SDSS-I/II, while the variability parameters are calculated by fitting the structure function of the object with a power law. Selection was based on a training sample of 13,784 spectroscopically-confirmed type 1 quasars from the SDSS-I/II and the Baryon Oscillation Spectroscopic Survey (BOSS). Using variability alone, colors alone, and combining variability and colors we achieve 85%, 90%, and 95% quasar completeness respectively, with particular improvement in the selection of quasars at $2.7<z<3.5$ where quasars and stars have similar optical colors. Of these candidates, 17,491 lack spectroscopic confirmation including 181 with a coadded i magnitude brighter than 19.1 (a 10% increase over the training sample), 103 with $2.7<z<3.5$; and 871 with a coadded i magnitude brighter than 20.2 (a 12% increase), 172 with $2.7<z<3.5$. This work was supported by NSF grant 1411773.

Author(s): Christina M. Peters[1], Gordon T. Richards[1], Adam D. Myers[2], Nicholas Ross[1]
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144.44 – The Distribution of Optically Variable AGN in Red Sequence Galaxy Clusters

Active galactic nuclei (AGN) are fueled by gas infall onto the black holes in the centers of galaxies, making them optically variable on the timescale of hours to decades. We use the Multi-Epoch Nearby Cluster Survey from the Canada France Hawaii Telescope to identify optically variable AGN in red sequence members of massive low-redshift galaxy clusters. Red sequence galaxies are thought to be mostly gas-free, yet we find probable AGN candidates via photometric variability. We detect candidate AGN by searching for point sources in difference images, and apply selection criteria based on their position relative to the cores of red sequence galaxies, color, and signal-to-noise ratio. We find that most AGN varied only during one epoch of the survey and that most clusters have a only small fraction of galaxies with AGN. We also find a dearth of optically variable AGN in the central 200kpc of clusters, which indicates that red sequence galaxies containing AGN have a different radial distribution from the general population. To test the purity and completeness of our variability detection technique, we cross-check our AGN candidates with a sub-sample of our red sequence galaxies for which we obtained spectra with Hectospec at the MMT Observatory.

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144.45 – A Kepler Galaxy Survey: Establishing the Temporal Baseline for Extragalactic Systems

The Kepler Mission's combination of high photometric precision and near-continuous observing cadence provides new insight on galaxies by opening up the time domain in previously unavailable detail. Kepler's permits us to: (a) assess the baseline photometric stability of galactic systems over a range of amplitudes and timescales, (b) quantify the existence and amplitude of AGN signals in galaxy cores, (c) provide a direct measure of supernovae rates across galaxy types, complementary to ground-based supernova searches, and (d) measure the early brightening of any detected supernova, and (e) detect low-level transients from embedded active nuclei, highly luminous stars, and other compact objects.
Here we provide an initial analysis of a subset of the complete galaxy dataset observed during the Kepler prime mission, ~1200 light curves of ~150 galaxies observed during Q3-10 & ~1400 light curves of galaxies observed serendipitously from Q2-16. The vast majority of light curves appear generally featureless after instrumental systematics are removed. A number of systems exhibit continuous variations at the sub-millimag level, with the caveat that that robust identification of low-level variations remains challenging in the context of systematic structure in the light curves. Several systems show variable behavior in 1-2 quarters but are otherwise quiescent in other quarters. Approximately 5% show some variability. We also will provide a preliminary look at galaxy time series collected during K2 - C0 including techniques used to create light curves.
As a step towards analysis of the entire Kepler galaxy database, we are constructing the Kepler Galaxy Legacy Archive. This archive federates morphological and photometric parameters for each galaxy along with observing logs and photometric statistics derived from the light curves. We are also developing an associated software toolkit, coded in IDL. Examples of the procedures in this toolkit are: (a) ability to overlay the aperture pixel mask on any image of the larger FOV and, (b) filtering and display of the entire source pixel set to identify transients occurring outside of the optimal aperture.

This project is supported by NASA ADAP Grant NNX13AF17G.

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144.46 – Optical Variability and Classification of High Redshift (3.5 < z < 5.5) Quasars on SDSS Stripe 82

Recent studies have shown promise in combining optical colors with variability to efficiently select and estimate the redshifts of low- to mid-redshift quasars in upcoming ground-based time-domain surveys. We extend these studies to fainter and less abundant high-redshift quasars using light curves from 235 sq. deg. and 10 years of Stripe 82 imaging reprocessed with the prototype LSST data management stack. Sources are detected on the i-band co-adds (5σ: i ~ 24) but measured on the single-epoch (ugriz) images, generating complete and unbiased lightcurves for sources fainter than the single-epoch detection threshold. Using these forced photometry lightcurves, we explore optical variability characteristics of high redshift quasars and validate classification methods with particular attention to the low signal limit. In this low SNR limit, we quantify the degradation of the uncertainties and biases on variability parameters using simulated light curves. Completeness/efficiency and redshift accuracy are verified with new spectroscopic observations on the MMT and APO 3.5m. These preliminary results are part of a survey to measure the z~4 luminosity function for quasars (i < 23) on Stripe 82 and to validate purely photometric classification techniques for high redshift quasars in LSST.

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144.47 – A Survey of Low-Frequency Radio AGN in the MWA Epoch of Reionization Field

The extragalactic radio continuum is dominated by emission from galaxies hosting active galactic nuclei (AGN) powered by accretion onto supermassive black holes. These sources are the dominant obstacle to a detection of the faint neutral Hydrogen signal from the Epoch of Reionization (EoR) and must be accurately modeled and subtracted. Sensitive observations from the Murchison Widefield Array (MWA) occur at a 2-minute cadence on the EoR field. This allows for reliable and independent foreground source characterization. Source extraction, association, and classification are accomplished using novel clustering and machine learning methods. The resulting 180MHz catalog significantly reduces the residual power due to foreground AGN in the EoR power spectrum figure of merit. These measurements are complemented by surveys at higher frequency, and the potential for time domain information holds promise for the study of AGN variability.

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Contributing team(s): Murchison Widefiled Array EoR Collaboration, UW Radio Cosmology Group

144.48 – Jansky VLA Imaging of Heavily Obscured, Luminous Quasars at Redshifts ~ 2

High resolution radio imaging provides a powerful probe of the dense, dusty interiors of interacting, merging and active galaxies. Only at radio wavelengths is there a combination of sub-kiloparsec resolution, source transparency and sensitivity that can delineate complex structures and unveil spatial relationships between energetic phenomena such as relativistic jets and shocks. We present JVLA imaging in X-band for 150 of the most luminous, heavily obscured and radio-intermediate / radio-loud quasars found in the WISE survey. Observations in both A-array and B-array have been acquired, demonstrating that the majority of the quasars are compact at these frequencies, and lack extended lobes. They are therefore interpreted as young systems with similarities to GPS and CSS sources.

Author(s): Carol J. Lonsdale[2], Palavi Patil[3], Adam Trapp[3], Mark Whittle[3], Mark Lacy[2], Colin J. Lonsdale[1]
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144.49 – Slow-blue PanSTARRS transients

Photometric and spectroscopic monitoring of 50 blue, nuclear "transients" in PanSTARRS-1 has revealed different types of extremely variable AGN. The majority show a gradual brightening by ~2 mag from the SDSS observation a decade ago and may represent a new class of AGN microlensed by foreground galaxies. Spectra from the William Herschel Telescope identify these as z~1 AGN with atypical spectroscopic properties. We present an analysis of their photometric and spectroscopic variability in an effort to constrain the detailed structure of the source AGN.

Author(s): Chelsea L MacLeod[4], Alastair Bruce[4], Andy Lawrence[4], Martin Ward[3], James Collinson[3], Martin Elvis[1], Suvi Gezari[5], Steven Smartt[2], Ken Smith[2], Darryl Wright[2], Morgan Fraser[2]
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144.50 – How Complete is Mid-Infrared Selection of Active Galactic Nuclei?

Essentially every galaxy hosts a supermassive black hole, and roughly 10% of those black holes are currently growing as active galactic nuclei (AGNs). Given the compelling evidence that galaxies and black holes co-evolve, there is strong motivation to study how black holes assemble their mass through cosmic time. However, this is challenging because a large fraction of black hole growth is enshrouded by gas and dust. Deep and wide surveys at X-ray and infrared wavelengths offer a powerful way to study the obscured AGN population, but an important caveat is that X-ray surveys are not complete for the most highly absorbed sources and infrared surveys are not able to distinguish low-luminosity AGNs from normal galaxies. To help address these outstanding issues and to analyze the completeness of mid-infrared AGN selection, we use Spitzer and WISE photometry to study the mid-infrared colors of a complete sample of local AGNs. The sample is drawn from the revised Shapley-Ames galaxy catalog and includes every galaxy in the sky brighter than B=13 that is known to host Seyfert activity. This sample is unique in its sensitivity to low-luminosity and highly obscured sources. Our main result is that most of these known AGNs would be classified as normal galaxies on the basis of their mid-infrared colors, implying that analogs to local Seyfert galaxies would not be identified as AGNs in existing surveys. We find that this a strong function of AGN luminosity, and we also present trends as a function of AGN obscuration, galaxy luminosity, and stellar mass. These results provide important insights into the AGN population that is missing from our census of black hole growth in the distant universe. This work was supported by the National Science Foundation's REU program through NSF Award AST-1004881. We also acknowledge support from The Grainger Foundation and from gifts made to the Department of Astronomy at UW-Madison.

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144.51 – Using WISE to Find Obscured AGN Activity in SDSS Mergers and Interactions

In simulations, major encounters between gas-rich galaxies are predicted to drive gas to the centers of interacting and merging systems triggering new star formation (SF) and fueling an active galactic nucleus (AGN). Depending on the rate of SF, large amounts of obscuring dust can make detection of merger-induced activity difficult and may be at the heart of the ongoing merger-AGN connection debate. To provide better constraints on the importance of obscured AGNs, we use data from the Wide-field Infrared Survey Explorer (WISE) for a comprehensive sample of over 1000 major galaxy interactions and ongoing mergers visually selected from the SDSS with Mstar>1e10 Msun and 0.01 < z < 0.08. We examine the [3.4]-[4.6] versus [4.6]-[12] micron color-color plane and find that most interactions and mergers have the same colors as normal (non-interacting and non-merging) galaxies, which define a narrow [3.4]-[4.6] micron locus and span a wide range in [4.6]-[12] micron colors from spectroscopically quiescent (blue, no dust) to galaxies with SF emission (dust-reddened). We find that 2-6% of mergers (and 2-3% of interactions) have unusually red [3.4]-[4.6] micron colors, which are associated with dust-obscured (Type-2) AGNs. We note that mergers (interactions) are 4-15 (3-8) times more likely to host a buried AGN than normal galaxies. We also find that optical emission-line AGNs (Seyferts) identified as mergers are 3-7 times more likely to be obscured than non-merging Seyferts. We investigate whether the obscured AGN subset of our sample have unique properties and find that their stellar masses, mass ratios, pair separations, and environments are not statistically different from those of the bulk of mergers and interactions with normal WISE colors. We note that among mergers and interactions with an AGN, the WISE-selected AGN favor higher [OIII] luminosities associated with higher AGN power than their unobscured counterparts. Our findings support an AGN-merger connection.

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144.52 – The Rate of Occurrence of PV Absorption in a Low Redshift Sample of BALQSOs

We present the rate of occurrence of PV broad absorption lines in a relatively heterogenous sample from the Hubble Space Telescope archive. Absorption from P^{+4} can be used as an effective tool to determine upper limits on column densities, as it is rarer than typical ions found in Broad Absorption Line Quasar (BALQSO) outflows (e.g absorption lines in the rest UV from C^{+3}, Si^{+3}, and O^{+5}), and thus less likely to be saturated. Here we present FOS, COS, and STIS observations for BALQSOs with redshifts between z~0.1 and z~1.3. We searched for absorption doublet profiles in SiIV, CIV, and then OVI. We modeled the continuum by using a powerlaw with emission components. In some cases where blending was severe, it was necessary to use a quasar composite spectrum. In determining the upper limits on column density, we applied absorption doublet profiles to the P^{+4} region, selected the appropriate tau value and derived the upper constraints of the log column density of P^{+4}. We measured the PV absorption profiles when present, and obtained upper limits of all targets. We found that the frequency of PV in low redshift BALQSOs is lower than that of higher redshifts: 6% compared to approximately 30% for the higher redshift sample from the Sloan Digital Sky Survey (Hamann et al. 2013). We speculated on what these results indicate for the kinetic energy equation. Our sample is characterized by a lower luminosity than the SDSS sample. Therefore, the lower incidence of PV in our sample is simply explained if lower luminosity objects are less likely or unable to drive high column density outflows.

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144.53 – Broadband Observations of the FSRQ PKS 2326−502 during Active and Quiescent Gamma-Ray States

A multi-wavelength campaign observed the Flat Spectrum Radio Quasar PKS 2326-502 in two flaring states and one quiescent state. Quasi-simultaneous observations were made using instruments in the gamma-ray, x-ray, UV, optical and radio for flaring states from 2010 July 31 to 2010 September 29 and from 2012 June 25 to 2012 July 05. A quiescent state was observed between 2011 December 18 and 2012 January 29. These multi-wavelength data were used to constrain model Spectral Energy Distributions (SEDs) and the model parameters were used to investigate the causes of these flares. The 2010 flare required only changing the electron spectrum while the 2012 flare required a change in the electron spectrum as well as the size of the emitting region. This supports previous results (e.g. Dutka et al. 2013) finding two distinct types of flares one in which only the electron spectrum changes and one in which a change in the emitting region and/or magnetic field is required.

Author(s): Bryce D. Carpenter[2], Michael Dutka[2], Roopesh Ojha[2], Justin Finke[3], Phillip Edwards[1], Matthias Kadler[5], Jörn Wilms[4], Felicia Krauss[5], Cornelia Mueller[5], Neil Gehrels[2]
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Contributing team(s): Fermi-LAT Collaboration

144.54 – The variable comparison stars in the field of the TeV blazar 1ES 1959+650

We present the result of a study of two variable comparison stars in the field of the TeV blazar 1ES1959+650: star 5 (also known as the eclipsing binary MM Dra) and star 3 (currently of unknown type) from the comparison sequence of Villata et al. (1998). Thirteen years of data obtained with the three telescopes in WKU's telescope network (the 1.3m Robotically Controlled Telescope , the 0.6m Bell Observatory and the 1.3m AZT 11 at the Crimean Astrophysical Observatory) are analyzed and presented. Light curves created via differential photometry and phase diagrams are presented and discussed. We hope to resolve a discrepancy in the reported period of MM Dra and confirm/classify the variable nature of star 3.

Author(s): Stacy Hancock[2], Michael T. Carini[2], Kirill Antoniuk[1], S Belan[1], K Grankin[1], N Pit[1], D Shakhovsky[1]
Institution(s): *1. CRAO, 2. Western Kentucky University*

144.55 – The K2 view of blazars

The K2 mission, through its superb photometric precision and its ability to continuously sample light curves on timescales of minutes to months will provide unrivaled information on blazar variability. In its previous incarnation as the Kepler mission, only a few blazars were present in its field of view. Nevertheless, Kepler's observations of blazars uncovered rich and complicated variability down to the most rapid timescales it could sample and indicated a need for more roboust time-series analysis techniques. K2 will observe hundreds of blazars during its lifetime, providing a unique set of blazars with light curves sampled on timescales not possible with ground based observatories. We present the first blazar results from the K2 mission and discuss the analysis challenges they pose.

Author(s): Michael T. Carini[1], Joshua Williams[2]
Institution(s): *1. Western Kentucky Univ., 2. Western Kentucky University*

144.56 – The Power Spectral Density of ZW 229.015 from Kepler Observations.

ZW 229.015 is the brightest AGN in the Kepler field of view. It has been extensively monitored with the Kepler spacecraft throughout the entire Kepler mission. The light curve from Kepler is unmatched by any optical light curve ever obtained for an AGN. In this poster, we present the results of an analysis of the power spectral density (PSD) of this light curve using the PSRESP methodology. In addition to presenting the PSD of the full, unbinned Kepler light curve, we analyze the effects that the length of the time series analyzed has on the PSD.

Author(s): Joshua Williams[1], Michael T. Carini[1]
Institution(s): *1. Western Kentucky University*

144.57 – Defining and Exploring Flare-States in the Fermi LAT Blazar Population

In two related contributions we present some results of our study of a large (~10^3) set of gamma-ray light curves. To investigate blazar outbursts, we study the flux variability of the approximately 2000 point sources cataloged by the Fermi Gamma-Ray Space Telescope concentrating on the 1100 sources that are likely AGN. A comparison of intrinsic flux variability, flare durations, recurrence times, and temporal profiles across blazar sub-classes is important for furthering our understanding of the responsible physical environments. Insights into the scale and location of jet structures responsible for the high-energy emission may emerge from such studies. Our approach is to characterize the intrinsic flux variability of all sources at the single day and weekly timescales. This provides a typical range of expected flux measurements, and by locating epochs for which the flux is signifcantly above this range one can define a flare state. These flare states are then candidates for a more detailed analysis. Here we describe the details, limitations, and results of this flare state analysis.

Author(s): Daryl J. Macomb[1], Chris R. Shrader[2]
Institution(s): *1. Boise State Univ., 2. NASA/GSFC*

144.58 – The Power Source(s) of Nearby Low-Ionization Nuclear Emission Regions

The majority of low-ionization nuclear emission regions (LINERs) harbor supermassive black holes (SMBHs) with very low accretion rates. Since SMBHs spend most of their lifetimes in these low-accretion rate states, understanding LINERs is important for understanding active galactic nuclei (AGN) in the context of galaxy evolution. On scales of ~100 pc, the energy budget of LINERs appears to be deficient when the only source of power considered is the AGN. Thus, other energy sources are likely to contribute to the excitation of the emission-line gas. To probe these sources, we observed three nearby, bright LINERs, NGC 1052, NGC 4278 and NGC 4579, with the Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope (HST). We specifically looked at the 0.1-1 arcsecond (corresponding to 5-50 pc) scale to find what and how far from the nucleus these other energy sources are. After subtracting both the unresolved nuclear light and the spatially-extended starlight, we measured a number of diagnostic emission line ratios. We find that line ratios, such as [O III]/[O II] and [O III]/H-beta change as a function of distance from the nucleus. Within 5 pc, the line ratios suggest AGN photoionization. At larger distances the line ratios seem to be inconsistent with AGN photoionization, but they appear to be consistent with excitation by hot stars or shocks.

Author(s): Mallory Molina[3], Michael Eracleous[3], Dan Maoz [4], Aaron J. Barth[5], Jonelle Walsh[6], Luis C. Ho[2], Joseph C. Shields[1]
Institution(s): *1. Ohio University, 2. Peking University, 3. Pennsylvania State University, 4. Tel Aviv University, 5. University of California, Irvine, 6. University of Texas*

144.60 – Color-Magnitude Relationships Among Quasars and Type I Seyfert Galaxies

Data from the Sloan Digital Sky Survey (SDSS) and the Galaxy Evolution Explorer (GALEX) satellite were used to construct color-magnitude diagrams of quasars combined with Type I Seyfert galaxies with redshift values of $0.1 < z < 0.8$. This study improved upon previous studies by having a much larger sample size and by increasing the covered wavelengths from 0.15 microns to 0.9 microns. Color was plotted against absolute magnitude in several bandwidths revealing correlations at multiple wavelengths at certain z-values.

Author(s): Thomas Rutherford[5], Varoujan Gorjian[2], Theresa Paulsen[1], Nicole Granucci[3], John Blackwell[4], Kayla Jenkins[5], Erica McCormick[4], Brendan Rosseau[4], Rebecca Shpak[3], Taryn Wisniewski[3]
Institution(s): *1. Ashland High School, 2. JPL/California Institute of Technology, 3. Oxford High School, 4. Phillips Exeter Academy, 5. Sullivan South High School*

144.61 – X-ray Power Spectral Densities of Mkn 79 and NGC 4593 using Markov Chain Monte Carlo

Strong and highly variable X-ray emission is one of the defining characteristics of active galaxies. The power spectrum of the light curve typically takes the form of a broken power law, with the break frequency closely related to the black hole mass and accretion rate. Previous efforts to measure the break frequency involved Monte Carlo simulations which are often computationally intensive, and do not provide a clear estimate of errors for parameters. Here we apply Markov Chain Monte Carlo methods to estimate the power spectra of 2 objects, Mkn 79 and NGC 4593. Break frequencies are clearly detected in each object. For NGC 4593 the detected break frequency is close to the expected value. However for Mkn 79, the measured break timescale is significantly shorter than expectations. This may be due to variability arising in a truncated accretion disk. We also discuss in detail the method used to calculate each power spectrum, along with interpretation of the results and their uncertainties.

Author(s): Kevin Marshall[1]
Institution(s): *1. Widener Univ.*

144.62 – Determining the Narrow-Line Region Geometry of Mrk 3 with Gemini/NIFS

We present a study of the narrow-line region (NLR) and inner disk of the Seyfert 2 Mrk 3, based on observations from the Gemini Near-Infrared Integral Field Spectrometer (NIFS). Mrk 3 exhibits emission-line knots within the NLR that are in the shape of a backward S, which is likely due to dust/gas spirals in the galaxy's disk that have been illuminated by the AGN's ionizing bicone. With our NIFS observations, we determine the kinematics of Mrk 3 using an automated Bayesian model selection algorithm. Comparing the NLR kinematics measured with NIFS to those previously measured with the Hubble Space Telescope (HST) Space Telescope Imaging Spectrograph (STIS), we are able to test the accuracy of our previous kinematic outflow model.

Author(s): Crystal L. Pope[1], Travis C. Fischer[1], D. Michael Crenshaw[1]
Institution(s): *1. Georgia State University*

144.63 – An Extended Look at the Narrow-Line Region Kinematics of Markarian 573

In our previous studies of the narrow-line region (NLR) of the Seyfert 2 galaxy Markarian 573, we successfully constructed a geometric model that accurately fit its inner-region kinematics, but failed to fit the outflow at extended distances larger than ~700 pc. We now present a study based on observations from the ARC 3.5m telescope's dual imaging spectrograph (DIS) that shows the kinematics of the outflowing ionized gas at distances up to ~4500 pc in an attempt to explain the lack of deceleration, as predicted by our models, at these large distances. We find that the kinematics at medium distances (~700 pc - ~1000 pc) can be explained by both in-situ acceleration of the gas off dust lanes and emission from a rotating disk, while the kinematics at larger distances (>~1000 pc) can be accredited solely to emission from a rotating disk.

Author(s): Camilo Machuca[1], Travis C. Fischer[1], D. Michael Crenshaw[1]
Institution(s): *1. Georgia State University*

144.64 – New Constraints on Quasar Variability based on 8,000 SDSS Stripe 82 Quasars with both SDSS and CRTS Lightcurve Data

We present improved constraints for the Damped Random Walk (DRW) quasar variability model based on synergistic analysis of optical lightcurves obtained by SDSS and CRTS (Catalina Real-Time Transient Survey) for a sample of 8,000 SDSS quasars from the MacLeod et al. (2010) Stripe 82 catalog. We fit observed lightcurves with a number of varying stochastic Gaussian Processes, specified by different covariance matrices. Apart from using the DRW (Ornstein-Uhlenbeck process) exponential covariance matrix, we use modified covariance functions developed by Zu et al. (2012), as well as their fitting software (Javelin). We also compare the sampling properties of the unified SDSS+CRTS dataset to anticipated cadence properties of the main LSST survey.

Author(s): Krzysztof Suberlak[3], Zeljko Ivezic[3], Branimir Sesar[2], Chelsea Louise MacLeod[1]
Institution(s): *1. Institute for Astronomy, 2. Max Planck Institute for Astronomy, 3. University of Washington*

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145 – HAD III: Posters

145.01 – Urania in the Marketplace: Observatories as Holiday Destinations

During the twentieth century astronomical imagery was frequently incorporated, by manufacturers of industrial and consumer goods, into advertisements which appeared in popular magazines in America. The domes and telescopes of major observatories were often featured. In some cases, particularly within the Golden State of California, major astronomical facilities (notably the Lick and Mt. Wilson Observatories) were touted as tourist attractions and were publicized as such by tourist bureaus, railroads, and hotels.
A particularly interesting example is provided by the Hotel Vendome in San Jose. With completion of the Lick Observatory (and the 36-inch Great Refractor) in 1887, the local business community felt that the city needed a first-class resort hotel. The architectural firm of Jacob Lenzen & Son was hired to design a grand hotel, comparable to those found in locales such as Monterey and Pasadena. The resulting four-story, 150-room structure cost $250,000, a phenomenal sum in those days. Yet, within just fourteen years, tourist demand led to the construction of a 36-room annex. Of course, a great resort hotel would not be complete without the opportunity for excursion, and the Mt. Hamilton Stage Company offered daily trips to the famous Lick Observatory.
Farther south, the Mt. Wilson Observatory began construction of its own hotel in 1905.
The original structure was destroyed by fire in 1913, and replaced by a second which was used by visitors until 1966.
Early examples of advertisements for these observatories, recalling the heyday of astronomical tourism, are presented.
A few more recent ones for Arecibo and Palomar are included for comparison.

Author(s): Kenneth S. Rumstay[1]
Institution(s): *1. Valdosta State Univ.*

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200 – Plenary Talk: Gaia - ESA's Galactic Census Mission, Gerry Gilmore (Institute of Astronomy)

200.01 – Gaia - ESA's Galactic Census mission.

Gaia - Science with one billion objects in 3 dimensions
Gaia is an ESA mission to provide precise astrometry, spectrophotometry, and stellar parameters for one billion stars, the complete sample brighter than magnitude 20. Spectra for radial velocities and abundances will be obtained for the 60 million brightest stars.
The Gaia science case anticipates major advances in stellar and Galactic evolution, solar system asteroids, fundamental physics, cosmology, and the transient universe. Gaia was launched in December 2013, completed commissioning and began regular science operation in July 2014. I will provide an overview of the Gaia mission, the present status of the spacecraft, the anticipated precision of the data products, and when and what will be available.

Author(s): Gerard Gilmore[1]
Institution(s): *1. Institute of Astronomy*

201 – AAS Prize Presentations: Weber, Van Biesbroeck, Education

202 – Extrasolar Planets: Ground and Space Based Surveys I

202.01 – The Transiting Exoplanet Survey Satellite: Mission Status

The Transiting Exoplanet Survey Satellite (TESS) will discover thousands of exoplanets in orbit around the brightest stars in the sky. In a two-year survey of the solar neighborhood, TESS will monitor more than 200,000 bright stars for temporary drops in brightness caused by planetary transits. This first-ever spaceborne all-sky transit survey will identify planets ranging from Earth-sized to gas giants, around a wide range of stellar types and orbital distances.
TESS stars will typically be 30-100 times brighter than those surveyed by the Kepler satellite; thus, TESS planets will be far easier to characterize with follow-up observations. For the first time it will be possible to study the masses, sizes, densities, orbits, and atmospheres of a large cohort of small planets, including a sample of rocky worlds in the habitable zones of their host stars. Full frame images with a cadence of 30 minutes or less will provide precise photometric information for more than 20 million stars during observation sessions of several weeks. The brighter TESS stars will potentially yield valuable asteroseismic information as a result of monitoring at a rapid cadence of 2 minute or less. An extended survey by TESS of regions surrounding the North and South Ecliptic Poles will provide prime exoplanet targets for characterization with the James Webb Space Telescope (JWST), as well as other large ground-based and space-based telescopes of the future.
TESS will issue data releases every 4 months, inviting immediate community-wide efforts to study the new planets. The TESS legacy will be a catalog of the nearest and brightest main-sequence stars hosting transiting exoplanets, which will endure as the most favorable targets for detailed future investigations.
TESS has a planned launch date in 2017 as a NASA Astrophysics Explorer mission.

Author(s): George R. Ricker[1]
Institution(s): *1. MIT*
Contributing team(s): TESS Team

202.02 – Target Selection for the TESS Mission

The goal of the TESS mission is to discover small, rocky planets transiting bright stars. To reach that goal, we have constructed a compiled catalog of stars from which to select TESS targets. The catalog contains all dwarf stars in the sky with spectral types F5 and later, and $I < 12$, along with selected sets of fainter M stars. Provisions are being made to augment the target list with stars that fall outside the nominal spectral type and magnitude limits, and to permit dynamic updating of the catalog to accommodate new survey data being released (e.g. GAIA). We will describe the overall target selection strategy, and the current catalogs that have been constructed, and how we intend to further expand and refine our target lists.

Author(s): Joshua Pepper[2], Keivan Stassun[5], Nathan M. De Lee[4], Martin Paegert[5], David W. Latham[1], Joshua N. Winn[3]
Institution(s): *1. Center for Astrophysics, 2. Lehigh University, 3. MIT, 4. Northern Kentucky University, 5. Vanderbilt University*
Contributing team(s): TESS collaboration

202.03D – KMTNet: A Cold Exoplanet Census Through a Global Microlensing Survey

The unique sensitivity of gravitational microlensing to low-mass planets near and beyond the snow line makes it an indispensable tool for understanding the distribution and formation mechanisms of exoplanets. The Korean Microlensing Telescope Network (KMTNet) consists of three 1.6m telescopes each with a 4 deg^2 field of view and will be dedicated to monitoring the Galactic Bulge in order to detect exoplanets via gravitational microlensing. With its relatively large aperture, large field of view, high (~10-minute) cadence, and near-complete longitudinal coverage of the Galactic Bulge for 8 months a year, KMTNet is expected to increase the the annual detection rate of exoplanets via microlensing by a factor of ~5 over current surveys, pushing down to the mass of Earth for bound and unbound planets. I will summarize the predicted yields of KMTNet's survey based on detailed simulations, highlighting its sensitivity to low-mass planets and its expected haul of free-floating planets. I will also describe the prospects for characterization of the exoplanetary systems KMTNet will detect, focusing on the variety of techniques current and future high-resolution facilities such as VLT, GMT, and *JWST* can use to measure the flux from the host stars and ultimately derive planet masses.

Author(s): Calen B. Henderson[3], B. Scott Gaudi[3], Cheongho Han[2], David Nataf[1], Jan Skowron[4], Matthew Penny[3], Andrew Gould[3]
Institution(s): *1. Australian National University, 2. Chunbguk National Unviersity, 3. The Ohio State University, 4. Warsaw University Observatory*

202.04 – The KELT-North Transit Survey: Hot Planets around Hot, Bright Stars

The KELT-North is a small-aperture, wide-angle automated telescope located in southern Arizona that has been surveying roughly 40% of the northern sky for transiting planets since 2006. By virtue of its small aperture and large field-of-view, KELT is most sensitive to hot Jupiters transiting relatively bright (V~8-10), and thus relatively hot stars. Roughly half of the over 200,000 dwarf stars targeted by KELT are hotter than 6250K; such stars pose novel challenges, but also provide unique opportunities. I will present the first transiting substellar companions discovered by KELT, focusing in detail on a few particularly interesting systems. I will discuss our plans for determining the frequency and demographics of short-period companions to hot stars from KELT; comparison with similar results for cooler stars may provide important constraints on theories of the emplacement and tidal evolution of low-mass stellar companions. Finally, I will speculate on how the lessons learned from KELT may inform the target selection and survey strategies for the TESS mission.
This work was supported by NSF CAREER grant AST-1056524.

Author(s): B. Scott Gaudi[3], Thomas G. Beatty[4], Jason D Eastman[1], Michael Lund[5], Matthew Penny[3], Joshua Pepper[2], Joseph E. Rodriguez[5], Robert Siverd[1], Keivan Stassun[5], Daniel J. Stevens[3]
Institution(s): *1. LCOGT, 2. Lehigh University, 3. Ohio State Univ., 4. Penn State University, 5. Vanderbilt University*
Contributing team(s): The KELT-North Collaboration

202.05 – Humans Need Not Apply: Robotization of Kepler Planet Candidate Vetting

Until now, the vast majority of Kepler planet candidate vetting has been performed by a dedicated team of humans. While human expertise has been invaluable in understanding the nuances of Kepler data, human vetting is very time-consuming and can be inconsistent. Over 20,000 threshold crossing events have been produced by the latest pipeline run on all 17 quarters of Kepler mission data, and many more artificial planet transits have been injected to estimate completeness. Given these large numbers, human vetting is no longer feasible on a reasonable time-scale, and would be difficult to characterize. We have created automated vetting programs known as "robovetters" that are specifically designed to mimic the decision-making process employed by the humans. They analyze both the light curve and pixel-level data in order to produce specific reasons for identifying false positives. We present benchmark tests on the Q1-Q16 Kepler planet catalog, which was vetted by humans, and present preliminary robovetter results based on a recent transit-search of the newly reprocessed Q1-Q17 data set.

Author(s): Jeffrey Coughlin[1], Fergal Mullally[1], Susan E. Thompson[1]
Institution(s): *1. SETI Institute*
Contributing team(s): The Kepler Team

202.06 – High-Precision Stellar Photometry with the K2 Mission

The K2 mission is a repurposed use of the Kepler spacecraft to perform high-precision photometry of selected fields in the ecliptic. We have developed an aperture photometry pipeline for K2 data which performs dynamic automated aperture mask selection, background estimation and subtraction, and positional decorrelation to minimize the effects of spacecraft pointing jitter. Here we describe that pipeline and the photometric precision we are capable of achieving with K2, illustrated by application to Campaign 0 data, and suggest future improvements in our algorithm.

Author(s): Lindsey Carboneau[1], Derek L. Buzasi[1], Carly Hessler[1], Andy Lezcano[1], Heather L. Preston[1]
Institution(s): *1. Florida Gulf Coast University*

202.07 – The Evryscope: the first full-sky gigapixel-scale telescope

Current time-domain wide-field sky surveys generally operate with few-degree-sized fields and take many individual images to cover large sky areas each night. We present the design and project status of the Evryscope ("wide-seer"), which takes a different approach: using an array of small telescopes to form a single wide-field-of-view pointed at every part of the accessible sky simultaneously and continuously. The Evryscope is a gigapixel-scale imager with a 10,000 sq. deg. field of view and has 10% of the etendue of LSST. Each 2-minute exposure will reach V=16.4; 3-mmag-level scinitillation-limited photometry will be obtained on bright stars every 15 minutes. Each year the Evryscope will generate 70,000+ photometric datapoints on tens of millions of stars. The system will search for transiting exoplanets around bright stars, M-dwarfs and white dwarfs, as well as detecting microlensing events, nearby supernovae, and gamma-ray burst afterglows. All data will be recorded long-term, allowing post-facto follow-up of interesting events. The Evryscope is currently under construction and is planned for deployment in 2015. We present the current project status, including an update on the Evryscope prototype telescopes we have been operating for the last three years in the Canadian High Arctic.

Author(s): Nicholas M. Law[1], Octavi Fors[1], Jeffrey Ratzloff[1], Philip J. Wulfken[1]
Institution(s): *1. University of North Carolina*

202.08 – K2 M Dwarf Program: Program Overview and Update

Planets around low-mass M dwarfs are easier to find and their atmospheres are easier to study than planets around Sunlike stars. NASA's Kepler mission targeted only a few thousand M dwarfs and so relatively few planets were found in these systems. Kepler's new "K2" program uses 80-day campaigns, which makes it ideally suited to find large numbers of small and habitable planets around low-mass stars.
Our "K2 M Dwarf Program" is using K2 to dramatically expand the number of planets known around low-mass stars. We expect to find hundreds of planets, tens of which will have K < 10 mag, be good spectroscopy targets for JWST, and/or lie in their stars' habitable zones; with this new sample we aim to measure planet occurrence frequencies, and refine theories of planet formation, evolution, interiors, and atmospheres for low-mass planetary systems. This talk will lay out our program methodology and present the first results from our photometry, transit search, and follow-up validation efforts.

Author(s): Ian Crossfield[8], Joshua E. Schlieder[6], Erik Petigura[9], Andrew Howard[3], Kimberly Mei Aller[3], Niall Deacon[5], Thomas Henning[5], Sebastien Lepine[2], Thomas P. Greene[6], Michael C. Liu[3], Lisa Kaltenegger[1], David R. Ciardi[4], Justin R. Crepp[7], Bradley M. Hansen[10], Travis Barman[8], Christian Obermeier[5]
Institution(s): *1. Cornell U, 2. Georgia State University, 3. IfA/Hawaii, 4. IPAC, 5. MPIA, 6. NASA/Ames, 7. Notre Dame U, 8. U. Arizona/LPL, 9. UC Berkeley, 10. UCLA*

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203 – The Milky Way, The Galactic Center III

203.01 – The Serendipitous Discovery of High-Velocity Shocks in the Galactic Center

Previous studies with Spitzer have shown that the Galactic Center (GC) contains widespread (although of low abundance) lines from high-excitation gas, such as [O IV] (ionization potential IP = 55 eV), even though most of its diffuse ionized interstellar medium is low excitation, dominated by singly ionized species like Ne^{+} or doubly ionized species whose singly ionized IP is below the 13.6 eV needed to ionize hydrogen, like S^{++}. Because of the O^{3+}, the GC cannot be considered a normal H II region, which is ionized by massive O and B stars whose extreme ultraviolet spectra essentially cut off at 54 eV, owing to the high opacity of the helium and metals in their atmospheres. The consequence is that highly ionized species, like He^{++}, O^{3+}, etc, with IP > 54 are not seen in Milky Way H II regions, whereas such gas is commonly found in AGN with their hard radiation fields. In order to investigate the energy inputs to the Galactic Center, we have reduced all the Infrared Spectrograph data in the Spitzer archive with positions in the GC. We find that the highest excitation gas isn't uniformly distributed over the GC but is concentrated in compact clumps, unlike the low-excitation gas. Ten of these highly-excited regions have [Ne V] (IP = 97 eV) lines. Such high-energy gas cannot be excited by the OB stars that ionize H II regions, but is found only in high-velocity shocks and high-excitation planetary nebulae (PNe). The shocks could be due to outflows from massive young stellar objects or red supergiants. Analysis of the emission lines reveals that the energies of the clumped gas range from 10^{36} to 10^{37} erg/s for assumed GC distances of 8 kpc if the high-excitation regions are shocks with velocities of order several hundred km/s and similar energies if the regions are excited by the hot stars required for PNe. We will show examples of the high-excitation regions, which range from the bubble surrounding the Sgr B1-C ultra-compact H II region to several high-excitation regions located (on the sky) near OH/IR stars. In addition, we will show that shock- or possibly X-ray-excited Fe^{+}, seen in the [Fe II] 5.34 and 17.94 micron lines, is prevalent in the region closest to Sgr A and is particularly strong in Sgr A East.

Author(s): Janet P. Simpson[1]
Institution(s): *1. SETI Institute*

203.02 – Probing the Milky Way's Nuclear Wind with QSO Absorption Lines

Like other spiral galaxies, the Milky Way drives a biconical nuclear wind. Outflowing gas is visible in enhanced emission in many parts of the electromagnetic spectrum, including Fermi gamma-ray bubbles and radio lobes extending above and below the Galactic Center. We present early results from a 49-orbit Hubble Space Telescope program to study the kinematics and extent of the nuclear outflow, using UV spectroscopy of AGN and halo stars lying close on the sky to the Galactic Center. The variation in absorption properties with Galactic latitude allows us to constrain the physical conditions in the outflowing gas. The observed kinematics of absorption components will be discussed and compared to predictions from biconical outflow models.

Author(s): Andrew Fox[3], Edward B. Jenkins[2], Svea Hernandez[3], Blair D. Savage[5], Rongmon Bordoloi[3], Bart P. Wakker[5], Jonathan Bland-Hawthorn[4], Felix J. Lockman[1], Jason Tumlinson[3], David V. Bowen[2], Robert A. Benjamin[6]
Institution(s): *1. NRAO, 2. Princeton, 3. STScI, 4. University of Sydney, 5. UW-Madison, 6. UW-Whitewater*

203.03 – Modeling Diffuse X-ray Emission around the Galactic Center from Colliding Stellar Winds

The Galactic center is a hotbed of astrophysical phenomena. The ~30 evolved massive stars orbiting the SMBH on scales <10" inject a large fraction of the matter that accretes onto the SMBH, and potentially creates large swaths of hot, X-ray emitting material around Sgr A* from their wind-wind collisions. Using the Gadget-2 SPH simulations of these evolved stars ejecting their winds over the last 1100 years from Cuadra et al. 2008, we solve the formal solution to the equation of radiative transfer for a grid of rays through the 6"x6" simulation volume to calculate the thermal X-ray emission from the diffuse hot gas. We then fold each of these energy-dependent pixel maps through the Chandra ACIS-S response function to directly compare with the recent 3Ms X-ray Visionary Program observations of the Galactic center (Wang et al. 2013). The model X-ray flux, in absolute units, agrees well with the observations just outside the SMBH (whose emission is not included in this modeling), indicating that the shocked wind material from the evolved massive stars is indeed the source of diffuse X-ray emission at the Galactic center. The emission of the IRS13 cluster, though, is overestimated by two orders of magnitude, indicating a potential revision in the cluster stellar parameters. We will conclude by discussing future work, such as implementing the “pressure-entropy” formulation of SPH for this calculation and including O stars and closely orbiting binaries.

Author(s): Christopher Michael Post Russell[1], Jorge Cuadra[2], Q. Daniel Wang[4], Stanley P. Owocki[3]
Institution(s): *1. NASA/GSFC, 2. Pontificia Universidad Católica de Chile , 3. University of Delaware, 4. University of Massachusetts Amherst*

203.04 – VERITAS Observations of The Galactic Center Ridge

The Galactic Center Ridge is perhaps the most local, busy environment for high energy particle acceleration; home to many relativistic particle accelerators such as pulsar wind nebulae, supernova remnants, and the central supermassive black hole SgrA*. Observations with VHE (>100 GeV) gamma-ray telescopes of the region have revealed multiple point sources associated with well known objects, as well as regions of extended emission not directly associated with targets at other wavelengths. More importantly, the detection of a large, diffuse component of >300 GeV gamma-ray emission by the HESS collaboration is strongly believed to be the result of accelerated cosmic rays interacting with molecular cloud regions, thus providing a window into high energy cosmic ray acceleration. Here we present the VERITAS observations of the Galactic Center Ridge taken from 2008-2014 in the >2 TeV regime. We will focus on the VERITAS results on the known HESS sources in the region, as well as the diffuse component of TeV emission along the plane. Due to the much higher energy threshold of the VERITAS observations, our data provide a new window into some of the highest energy particle acceleration occurring in the center of our galaxy.

Author(s): Andrew Smith[1]
Institution(s): *1. University of Maryland College Park*
Contributing team(s): VERITAS

203.05 – NuSTAR Observation of Sgr B2: Reflection of Past Sgr A* X-ray Outburst, Cosmic Ray Illumination or Both?

The Galactic Center (GC) supermassive black hole Sgr A* radiates at a level about 9 orders of magnitude lower than its Eddington luminosity. But indication of its glorious past has come from X-ray observations of surrounding giant molecular clouds. Their varying neutral iron lines and continuum emission could be due to reflection of Sgr A* X-ray outbursts hundreds of years ago. However, such observational facts can also be explained by low energy cosmic ray electron (LECRe) illumination. It has remained a long-standing question which scenario gives rise to the molecular cloud emission: X-ray reflection, LECRe or both.
In this talk, I present the NuSTAR observation of Sgr B2, the densest and most massive GC molecular clouds. Its substructure at energies greater than 10 keV is revealed for the first time. The direct comparison with iron line emission morphology is consistent with X-ray reflection from a source in the direction of Sgr A*. We also applied physical models of X-ray reflection and LECRe to the broadband X-ray spectra. Results show that the X-ray reflection model is preferred over the LECRe model. We derived that both the iron fluorescence line emission and the Compton scattered continuum

emission point to a faraway primary source with photon index of 2 and a luminosity of ~10^39 erg/s, probably due to a past Sgr A* outburst. Though probably not a dominant process, the LECRe contribution can be constrained by the data. Besides Sgr B2, I will also briefly talk about the NuSTAR observation of other GC molecular clouds and the nature of their X-ray emission.

Author(s): Shuo Zhang[1]
Institution(s): *1. Columbia University*
Contributing team(s): NuSTAR Galactic Plane Survey Team

203.06 – Galactic Ridge X-ray Emission study with NuSTAR

The paradigm of the Galactic Ridge X-ray Emission (GRXE) or hard X-ray background of the Milky Way has been dramatically changed over the past years. The stellar origin of the GRXE has been strongly supported by morphological and spectral studies with RXTE, INTEGRAL and Chandra observatories. The GRXE does not arise from the interaction of cosmic rays with the interstellar medium, as was believed before, but is associated with the (predominantly old) stellar population of the Galaxy, namely with hard X-ray emission from accreting white dwarfs and coronaly active stars. I will present results of the GRXE spectral study with NuSTAR hard X-ray mission launched into the orbit in 2012. The GRXE measurements have been done in a part of the Galactic Center survey program 2012-2014. New data allow us to reconstruct both GRXE spatial distribution and broadband (3-80 keV) spectrum, providing another test for its interpretation.

Author(s): Roman Krivonos[1]
Institution(s): *1. UC Berkeley*
Contributing team(s): NuSTAR

203.07 – The X-Ray Variability of Sagittarius A*

Over the last decade, X-ray observations of Sgr A* have revealed a black hole in a deep sleep, punctuated roughly once per day by brief ares. The extreme X-ray faintness of this supermassive black hole has been a long-standing puzzle in black hole accretion. To study the accretion processes in the Galactic Center, *Chandra* (in concert with numerous ground- and space-based observatories) undertook a 3 Ms campaign on Sgr A* in 2012. With its excellent observing cadence, sensitivity, and spectral resolution, this *Chandra* X-ray Visionary Project (XVP) provides an unprecedented opportunity to study the behavior of our closest supermassive black hole. We present a progress report from our ongoing study of X-ray flares, including one of the brightest flares ever seen from Sgr A*. Focusing on the statistics of the flares, the quiescent emission, and the relationship between the X-ray and the infrared, we discuss the physical implications of X-ray variability in the Galactic Center.

Author(s): Joseph Neilsen[3], Michael Nowak[3], Charles F. Gammie[7], Jason Dexter[6], Sera Markoff[5], Daryl Haggard[1], Sergei Nayakshin[8], Q. Daniel Wang[9], Nicolas Grosso[4], Delphine Porquet[4], John Tomsick[6], Nathalie Degenaar[10], P. Christopher Fragile[2], Rudy Wijnands[5], Jon M. Miller[10], Frederick K. Baganoff[3]
Institution(s): *1. Amherst College, 2. College of Charleston, 3. MIT Kavli Institute, 4. Observatoire Astronomique de Strasbourg, CNRS, 5. University of Amsterdam, 6. University of California Berkeley, 7. University of Illinois Urbana-Champaign, 8. University of Leicester, 9. University of Massachusetts Amherst, 10. University of Michigan*

203.08 – The Galactic magnetic field and some of its unexpected implications

Our understanding of the Galactic magnetic field (GMF) has improved considerably in recent years, although it remains far from adequate. The Jansson-Farrar (2012) (JF12) GMF model is the most realistic and comprehensive model available, having been constrained by fitting all-sky Faraday Rotation Measures of extragalactic sources simultaneously with WMAP polarized (Q,U) and total synchrotron emission maps – a total of more than 10,000 datapoints, each with measured variances. In addition to disk and toroidal halo components, a coherent poloidal field can be shown to be necessary. Moreover a “striated” random component is needed in addition to a fully random component, in both disk and halo.
The out-of-plane (poloidal) field provides a heretofore-overlooked escape route for CRs by anisotropic diffusion along its field lines, drastically modifying CR transport. The spatial distribution and energy spectrum of Galactic cosmic rays enters into constraining the GMF with synchrotron data, predicting astrophysical backgrounds to dark matter annihilation signals, and understanding the WMAP-Fermi-Planck "bubble" emanating from the Galactic center. Having a good model of the Galactic magnetic field is crucial for determining the sources of UHECRs and for modeling synchrotron emission (especially the spatial variation of the spectral index) to accurately subtract foreground to CMB signals essential to see the effects of primordial gravity waves. Given a 3D dust map, the structure of the polarized dust emission can potentially be estimated.
In this talk, I will focus on 3 recent developments: establishing the robust features of the global structure of the coherent field, determining how the GMF lenses UHECRs with charges as high as Z=26, and constraining models for composition

and origin of CRs above 100 PeV (the Galactic-extragalactic CR transition by) by anisotropy constraints. Preliminary results of efforts to simultaneously constrain the GMF and the Galactic cosmic ray electron distribution (pertinent to Dark Matter background studies) will also be reported.

Author(s): Glennys R. Farrar[1]
Institution(s): *1. New York University*

204 – AGN, QSO, Blazars III

204.01 – Discovery of the First Changing-Look Quasar

SDSS J015957.64+003310.5, an X-ray selected AGN from the Stripe 82X survey, transitioned from a Type 1 quasar to a Type 1.9 AGN between 2000 and 2010. This is the most distant and luminous changing-look AGN to date. Between 2000 and 2010, the AGN continuum faded by a factor of ~8.5 while the broad H-alpha line broadened and dimmed. X-ray observations from both the bright and faint optical states show a similar decrease in X-ray flux though absorption signatures are absent. Time-varying absorption does not explain the observed spectroscopic or photometric properties of the AGN. Instead, we interpret the changing-state to be caused by a decrease in the AGN continuum which reduces the supply of available photons to ionize the gas near the black hole. J0159+0033 thus provides information about the intermittency of black hole growth in quasars as well as an unparalleled opportunity to study quasar physics and host galaxy properties in the same source.

Author(s): Stephanie M. LaMassa[7], Sabrina Cales[7], Edward C. Moran[6], Adam D. Myers[5], Gordon T. Richards[1], Michael Eracleous[2], Timothy M. Heckman[4], Luigi C. Gallo[3], C. Megan Urry[7]
Institution(s): *1. Drexel University, 2. Penn State, 3. St. Mary's University, 4. The Johns Hopkins University, 5. University of Wyoming, 6. Wesleyan University, 7. Yale University*

204.02D – The NIR to UV Spectral Energy Distributions of Gamma-Ray Bright Blazars

In the small fraction of quasars classified as blazars, relatively unprocessed radiation from the accretion disk, known as the big blue bump (BBB) in the spectral energy distribution (SED), mixes with synchrotron radiation from the jet at optical-UV wavelengths. Decoupling of the contribution to the SED from these two components can be accomplished through the use of spectropolarimetric observations. The spectral index, α^{s}, of the synchrotron emission is revealed from observations at Steward Observatory of the polarized flux spectrum at λ= 4000-7000 Å in the observer's frame. The BBB emission is then obtained by fitting a two-component model of the form $F^{\nu} = A\ \nu^{\alpha^{s}} + B\ \nu^{\alpha^{BBB}}$ to the full spectrum and fixing α^{BBB}, the spectral index of the BBB, to 1/3. Another prominent emission feature of AGN is from an IR-emitting dusty molecular torus located ~1-10 pc from the central engine. The spectral signature of the dusty torus is also intertwined with synchrotron emission. Using near-IR (NIR) and optical observations with a time baseline of several years, we separate the NIR and optical SED of a number of gamma-ray bright blazars into a rapidly variable and a relatively constant component. Subtracting the former component, from synchrotron radiation, allows the hidden dust component to be revealed. We can also attempt to use the dataset to determine the variability (if any) of the the BBB and dust emission. If successful, this would allow us to determine the radiation environment encountered by electrons in the jet, important for inverse Compton models designed to explain gamma-ray production in blazars. This research has been supported in part by NASA Fermi Guest Investigator grants NNX11AQ03G and NNX11AO40G.

Author(s): Michael P. Malmrose[1], Alan P. Marscher[1], Svetlana G. Jorstad[1]
Institution(s): *1. Boston Univ.*

204.03 – The Effects of S/N on Measuring CIV Broad Emission Line Widths in Quasars - An Early Science Result from the Sloan Digital Sky Survey Reverberation Mapping Project

The Sloan Digital Sky Survey Reverberation Mapping (SDSS-RM) Project spectroscopically monitored ~850 quasars over a seven square degree field for approximately six months with the BOSS spectrograph. While the time series analysis of the quasar continuum and emission-line variability, and thereby the potential to measure reverberation time delays from this sample, is still underway, we have used the subset (roughly half) of this sample containing the CIV 1549A broad emission line to investigate the effects of S/N on measuring this broad emission line width. Line width measurements are necessary for inferring the broad line region gas velocities used to determine the quasar black hole mass. However, literature studies have suggested line width measurements, and therefore black hole mass estimates, may be biased by the use of relatively low S/N, typical survey-quality, data, compared to the high S/N data that calibrate single-epoch black hole mass scaling relations. The SDSS-RM data set provides a unique opportunity to search for any systematic uncertainties in CIV line width measurements through a comparison of line widths measured from the single-epoch spectra, which are roughly equivalent to other SDSS/BOSS quasar spectra (though still twice the exposure time) to those measured from the high-S/N, campaign co-added spectra, which contain more than 30 epochs of each

source. Here we present results from this investigation, which have implications for estimating CIV single-epoch black hole masses from the SDSS/BOSS and other surveys.

Author(s): Kelly Denney[1]
Institution(s): *1. The Ohio State University*
Contributing team(s): The SDSS-RM Team

204.04 – Correcting Velocity Dispersion Measurements for Inclination and Implications for the M-Sigma Relation

The relation between central black hole mass and stellar spheroid velocity dispersion (the M-Sigma relation) is one of the best-known correlations linking black holes and their host galaxies. However, there is a large amount of scatter at the low-mass end, indicating that the processes that relate black holes to lower-mass hosts are not straightforward. Some of this scatter can be explained by inclination effects; contamination from disk stars along the line of sight can artificially boost velocity dispersion measurements by 30%. Using state of the art simulations, we have developed a correction factor for inclination effects based on purely observational quantities. We present the results of applying these factors to observed samples of galaxies and discuss the effects on the M-Sigma relation.

Author(s): Jillian M. Bellovary[4], Kelly Holley-Bockelmann[4], Kayhan Gultekin[2], Charlotte Christensen[1], Fabio Governato[3]
Institution(s): *1. Grinnell College, 2. University of Michigan, 3. University of Washington, 4. Vanderbilt University*

204.05 – Spectral energy distributions and photometric redshifts for WISE-selected obscured quasars

Dust-obscured quasars represent a significant fraction of the powerful accreting black holes in the Universe. However, the nature of these "hidden" quasars has remained poorly understood, largely due to the challenge of detecting these objects in large surveys. With the advent of the Wide-Field Infrared Survey Explorer (WISE), we can now identify hundreds of thousands of obscured quasars via mid-IR and optical photometric selection. However, to fully exploit this sample for statistical studies requires robust estimates of redshift and other physical properties. We present analyses of the optical (SDSS) through mid-IR (WISE) spectral energy distributions and estimates of photometric redshift for a sample of WISE selected quasars, calibrated using existing spectroscopy and multiwavelength data. When applied to the full WISE quasar data set, these results can be utilized for studies of obscured AGN luminosity functions, clustering, and host galaxy properties, to better understand the nature of these powerful "hidden" accreting black holes. This material is based upon work supported by the National Science Foundation under Grant Nos. 1211096 and 1211112, and by the NASA ADAP under Grant No. NNX12AE38G.

Author(s): Ryan C. Hickox[1], Christopher M Carroll[1], Kevin Nicholas Hainline[1], Chien-Ting J. Chen[1], Adam D. Myers[2], Michael A. DiPompeo[2]
Institution(s): *1. Dartmouth College, 2. University of Wyoming*

204.06 – What can we learn from the Fourier analysis of blazar light curves?

Blazars display strong variability on multiple timescales and in multiple radiation bands. Their variability can be characterized by power spectral densities (PSDs) and time lags as a function of Fourier frequency. We develop a new theoretical model based on analysis of the electron continuity equation carried out in the Fourier domain. This model predicts features in the synchrotron, synchrotron self-Compton (SSC), and external Compton (EC) PSDs and time lags associated with electron cooling, escape, and light travel time effects across the electromagnetic spectrum, from sub-mm to gamma-rays. We also find that FSRQs should have steeper PSD power-law indices than BL Lac objects at low Fourier frequencies if FSRQs produce gamma-rays by EC and BL Lac objects by SSC emission, in qualitative agreement with reported observations by the Fermi Large Area Telescope.

Author(s): Justin Finke[1]
Institution(s): *1. US Naval Research Laboratory*

204.07 – The Origin of the Extragalactic Gamma-ray Background

The Fermi Large Area Telescope (LAT) has provided a new measurement of the Extragalactic Gamma-ray Background (EGB) up to ~820 GeV. This talk will review our current understanding of the generation of the EGB focusing in particular on the blazar class. Using an improved modeling of the blazar spectra and of their evolution we estimate the broad band integrated emission of blazars. Thanks to their hard spectra and large space density BL Lacertae objects provide a substantial contribution to the EGB at > 100 GeV. This energy range is particularly interesting because both the extragalactic background light and the intergalactic magnetic field might play an important role. We will also show that blazars, together with radio and star forming galaxies can account for most of the measured EGB intensity. This places competitive constraints on the cross-section for Dark Matter annihilation.

Author(s): Marco Ajello[2], Dario Gasparrini[1]

Institution(s): *1. ASI Data Center , 2. Clemson*
Contributing team(s): on behalf of the Fermi-LAT Collaboration

204.08 – How are Seyfert Active Galactic Nuclei Fueled?

With a matched sample of Seyfert and quiescent galaxies probed on scales of 1 kpc down to 5 pc we find that fueling of a Seyfert nucleus is associated with the formation of a dynamically cold structure within the central few hundred parsecs. This structure is composed of a significant gas reservoir and a comparatively young stellar population. We also identify two distinct modes by which gas is carried inward to fuel the Seyfert nucleus that are correlated with the environment in which the host galaxy resides. The molecular gas kinematics in the active galaxies are complex with both inflow and outflow superimposed on the disk rotation while their stellar kinematics show no significant deviations from circular rotation. Molecular gas is not detected in the majority of the inactive galaxies, and in those in which it is measurable the circumnuclear gas is counter-rotating with respect to the main gas component. We find a link between the circumnuclear gas kinematics and dust structures and the density of the local environment of the host galaxies that suggests that both external accretion and secular processes (in particular large-scale bar driven inflow) are mechanisms by which material is driven into the circumnuclear regions and Seyfert nuclei are ultimately fueled.

Author(s): Erin K. Hicks[5], Richard Davies[3], Witold Maciejewski[1], Matthew Arnold Malkan[4], Francisco Mueller Sanchez[2]
Institution(s): *1. Astrophysics Research Institute, 2. Center for Astrophysics and Space Astronomy, 3. Max Plank Institute, 4. UCLA, 5. University of Alaska Anchorage*

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205 – Supernovae III

205.01 – Uncovering the Putative B-Star Binary Companion of the SN 1993J Progenitor

Type IIb supernova (SN IIb) models typically invoke H envelope stripping by mass transfer in a binary system. Located in M81, at a distance of only 3.6 Mpc, SN 1993J offers one of the best opportunities to test such models. Already, 93J is one of only four SNe IIb with the progenitor primary star directly identified in pre-explosion images. Resulting models suggest that the 93J progenitor companion grew to 22 M_solar and became a source of ultraviolet (UV) excess, but the direct detection of continuum emission from the predicted companion has proven difficult. In 2002, an excess flux in the near-UV and B bands suggested the possible presence of the hot companion. In 2004, Keck optical spectra showed evidence for absorption lines consistent with a hot (B2 Ia) star, but the field was crowded and dominated by flux from the SN. In 2012, the SN flux finally faded below the expected continuum level of the companion star. Here I present recently published Hubble Space Telescope (HST) Cosmic Origins Spectrograph (COS) far- and near-UV spectra, along with Wide-Field Camera 3 (WFC3) photometry of SN 1993J observed in 2012. These observations provide the best opportunity yet for uncovering the UV continuum properties from the putative companion.

Author(s): Ori Dosovitz Fox[2], Azalee Bostroem[3], Schuyler D. Van Dyk[1], Alex Filippenko[2]
Institution(s): *1. Caltech, 2. UC, Berkeley, 3. UC, Davis*

205.02 – Explaining the progenitors of peculiar type Ia supernovae

Type Ia supernovae (SneIa) are believed to be triggered in white dwarfs having mass close to the Chandrasekhar limit of 1.44 $M^{\odot}$. However, observations of several peculiar, highly under- and over-luminous SNeIa argue for exploding masses widely different from this limit. The over-luminous SNeIa, e.g. SN 2003fg, SN 2006gz, SN 2007if, SN 2009dc, seem to invoke super-Chandrasekhar white dwarf progenitors, having mass 2.1-2.8 $M^{\odot}$. While, the under-luminous SNeIa, e.g. SN 1991bg, SN 1997cn, SN 1998de, SN 1999by, seem to favor sub-Chandrasekhar explosion scenarios. In order to explain the existence of super-Chandrasekhar white dwarfs, we have exploited the enormous potential of magnetic fields, which can affect the structure and properties of the underlying white dwarf in a variety of ways. We have progressed from a simplistic to more rigorous and self-consistent models in the following sequence - spherically symmetric Newtonian model with a constant central magnetic field; spherically symmetric general relativistic model with varying magnetic field and finally, a model including self-consistent departure from spherical symmetry obtained from general relativistic magnetohydrodynamic (GRMHD) simulations. Here we particularly present the results of the GRMHD simulations, whereby we have constructed equilibrium models of strongly magnetized, static, white dwarfs. Interestingly, we find that significantly super-Chandrasekhar white dwarfs are obtained for many possible field configurations, namely, poloidal, toroidal and mixed. Further, due to the inclusion of deformation in the white dwarf structure caused by a strong magnetic field, super-Chandrasekhar white dwarfs are obtained for relatively lower magnetic field strengths compared to that in the simplistic model. Finally, driven by the aim to establish a unification theory of under- and over-luminous SNeIa, we have shown that a modification of Einstein's theory of gravity leads to both significantly sub- and super-Chandrasekhar limiting masses, determined by a single model parameter. Explosions of these sub- and super-Chandrasekhar limiting mass white dwarfs can explain both the peculiar, under- and over-luminous SNeIa respectively.

Author(s): Upasana Das[1], Banibrata Mukhopadhyay[1]
Institution(s): *1. Indian Institute of Science*

205.04 – Chronicling an Era: 15 Years of SN 1987A with Chandra

Due to its close proximity, the remnant of SN 1987A is the only supernova remnant in which we can study the early developmental stages in detail, providing insight into stellar evolution, the mechanisms of the supernova explosion, and the transition from supernova to supernova remnant as the debris begins to interact with the surrounding CSM. We present here 15 years of X-ray observations with Chandra, including 4 new observations. The X-ray emission traces the progress of the blast wave and functions as a probe of the CSM. About 5000 days after the explosion, the blast wave began impacting the fringes of a dense equatorial ring. With Chandra, we are able to resolve this ring in X-ray images and monitor how it changes over time. We measure the apparent expansion rate of the ring, finding a sudden decrease in the velocity, from ~9000 km/s to ~2000 km/s, as the blast wave impacted the main body of the ring near day 5700. The soft X-ray flux has steadily increased, indicating the blast wave has continued to move through dense material. However, the latest observations suggest the flux has leveled off, a sign that the blast wave may be exiting the ring and on the verge of illuminating the previously unseen material beyond.

Author(s): Kari A. Frank[1], David N. Burrows[1]
Institution(s): *1. Pennsylvania State University*

205.06D – An Optical Study of the Two Youngest Balmer-dominated Supernova Remnants in the Large Magellanic Cloud

Supernova remnants in the Large Magellanic Cloud (LMC) are particularly useful in understanding the properties of high-speed shocks in the interstellar medium. Thanks to their well-known distances (unlike for their Galactic brethren) I can convert angular proper motion measurements of their shock waves, as traced by Hα emission, into accurate shock speeds in physical units. Furthermore in some high-speed shocks the Hα emission displays a two-component nature consisting of broad and narrow components. The broad line arises from charge exchange of electron from neutral hydrogen that passes through the shock with a post-shock ion. The narrow component comes from collisional excitations of the electrons bound to neutral hydrogen as it passes through the shock. The shock velocity, in conjunction with the Hα broad-line width and the broad-to-narrow flux ratio, can be used to test Balmer shock models (Vanadelsberg et al. (2008); see Heng (2010) for a thorough review), assess the level of temperature between post-shock electrons and ions, and search for evidence of efficient cosmic ray acceleration.
In this thesis I study two young supernova remnants (SNRs) in the LMC, 0509-67.5 and 0519-69.0, where I measure the shock velocity directly from proper motion measurements using narrow-band Hα imaging from the Hubble Space Telescope. I then use optical longslit spectroscopic data obtained from the FORS2 spectrograph (Very Large Telescope) and the Robert Stobie Spectrograph (Southern African Large Telescope). Example results for SNR 0509-67.5 include: a global shock speed of 6,500 km sec^{-1}, an age of 230-390 years, a neutral hydrogen density of 0.84($\varepsilon^{H\alpha}$/0.2)$^{-1}$ cm^{-3}, and a degree of equilibration ($T^{e,sh}/T^{ion,sh}$) of less than ~0.03 in the NE of the remnant without the need to invoke CR precursors or efficient cosmic ray acceleration.

Author(s): Luke Hovey[2], John Patrick Hughes[2], Kristoffer Eriksen[1], Curtis McCully[2]
Institution(s): *1. LANL, 2. Rutgers University*

205.07 – Death by Dynamics: Can a planet trigger a Type Ia supernova?

As a white dwarf (WD) travels through a galaxy it interacts with a variety of masses: comets, asteroids, planets, and stars. Using a set of simple assumptions we have computed the rates of WD interactions. We find that the calculated rates of the disruption of asteroids by WDs are compatible with the rates inferred from observations, implying that not all of the disrupted asteroids need to have formed in the WD's stellar system. In addition, for every 100 tidal disruptions, a collision is expected. We are exploring the amount of energy potentially released by WD collisions with comets, asteroids, and planets and find that these energetic events should be detected by future wide-field surveys. The most energetic event generated by a WD is a Type Ia supernova. Should our mechanism produce Type Ia explosions, it could contribute significantly to the total rate and become a solution to the Type Ia supernova puzzle. Regardless of whether direct collisions with planetoids provoke supernovae, the full set of interactions we consider includes wider interactions (0.1 AU to 100 AU) between a WD (and possible companions) and other stellar systems. Although only a small fraction of these interactions produce significant effects, the overall impact may have consequences for the evolution of binary-star and triple-star Type Ia progenitor models, as well as for a variety of other WD binaries.

Author(s): Rosanne Di Stefano[1], Robert Fisher[2], James Guillochon[1], James Steiner[1]
Institution(s): *1. Harvard-Smithsonian CfA, 2. University of Massachusetts*

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206 – Science with the 3D-HST Survey

AAS Special Session

3D-HST is a 248-orbit spectroscopic survey with the Hubble Space Telescope designed to study galaxy evolution at z>1. 3D-HST provides redshifts and rest-frame optical emission line diagnostics via slitless optical and near-IR grism spectra for a large unbiased sample of galaxies in the distant Universe. The 3D-HST observations, in combination with the tremendous amount of ancillary space- and ground-based data already available, open new possibilities for science and discovery in the deep extragalactic fields also targeted by the CANDELS survey: AEGIS, COSMOS, GOODS-N, GOODS-S and UKIDSS-UDS. With HST observations and our photometric data release (Skelton et al., 2014) completed, we are planning our next key data release for late 2014. As a result, a AAS session dedicated to results from the survey will be very timely. 3D-HST has already produced over 30 peer-reviewed publications, not only from the survey team but also from the wider community. With this session we would like to bring together researches trying to address a variety of questions regarding galaxy evolution using this unique data set, to showcase the broad range of topics that 3D-HST opens for explorations and to discuss the relevance of this survey for future missions such as WFIRST and JWST. We aim to have eight oral presentations. Currently confirmed speakers will cover the evolution of the mass function, the properties of massive galaxies at high-redshift, the search for the progenitors of z~2 compact quiescent galaxies, the growth of black holes as a function of redshift, and results on the search for the first galaxies. We hope the remaining slots will be filled with contributed talks from outside the team. Additional results can be presented in the accompanying poster session.

206.01 – 3D-HST results and prospects

The 3D-HST survey is providing a comprehensive census of the distant Universe, combining HST WFC3 imaging and grism spectroscopy with a myriad of other ground- and space-based datasets. This talk constitutes an overview of science results from the survey, with a focus on ongoing work and ways to exploit the rich public release of the 3D-HST data.

Author(s): Pieter G. Van Dokkum[1]
Institution(s): *1. Yale University*

206.02 – HST/WFC3 grism spectroscopy of star forming galaxies at z~1: the growth of disks

With the unique capabilities of the WFC3 grism on HST we can now, for the first time, measure the spatial distribution of star formation directly in large samples of galaxies at high redshift. Using Halpha maps for ~1000 galaxies at z~1 from the 3D-HST survey, we show how the star formation distribution varies with a galaxy's position in the star formation - mass plane. In galaxies on the main sequence, star formation is located in normal, exponential disks, similar to spiral galaxies today. Galaxies above the main sequence show a large variety of Halpha morphologies. However, averaging the distributions, we find that star formation is enhanced at all radii, not just in the central regions. Although the dominant physical processes may depend on the location of a galaxy with respect to the main sequence, our results are consistent with the idea that star formation typically occurs in disks during the peak of the star formation epoch.

Author(s): Erica Nelson[1]
Institution(s): *1. Yale University*

206.03 – The Lyman Continuum Escape Fraction of Dwarf, Star-Forming Galaxies at z~1

The dominant astrophysical source(s) of Lyman Continuum (LyC, λ<912Å) photons which reionized neutral Hydrogen in the IGM at high (z > 6) redshift remains uncertain. Unfortunately, the direct detection of LyC photons escaping from the analogs of such sources --- i.e., star-forming galaxies --- in the low redshift (z<~1) universe has proven to be remarkably difficult with space-based observatories. Motivated by the few (~2) direct detections of LyC in the local Universe and the results of recent cosmological simulations of galaxy evolution which demonstrate that *low-mass* ($M<\sim10^9M^{\odot}$) star-forming galaxies may be uniquely suited to contribute to the ionizing, UV background, we present results of recent work to study the LyC escape fraction in z~1 dwarf, star-forming galaxies. We present an independent re-reduction of the WFC3 IR grism data obtained as part of the 3DHST and AGHAST surveys, and identify and select star-forming galaxies at z=0.9-1.4 by their Hα emission. At this redshift range, GALEX FUV and NUV images can be used to cleanly measure the ratio of LyC to UV non-ionizing continuum (i.e., $LyC^{esc,rel}$) photons. We join our line and redshift identifications with public photometric-redshift catalogs made available by the 3DHST team in order to select an ideal sample of star-forming galaxies which excludes likely contaminants (e.g., AGN, low-redshift interlopers, etc.). Stacking archival GALEX images of ~500 UV non-detected star-forming ($SFR<\sim5M^{\odot}yr^{-1}$) galaxies, we measure an upper limit to $f^{LyCesc,rel}$ equal to ~5%. With these data we are also able to directly constrain $f^{LyCesc,rel}$ for a population of isolated, high equivalent width (EW>200Å), dwarf ($M<10^9M^{\odot}$) star-forming galaxies, measuring an upper limit of $f^{LyCesc,rel}<$ ~20% from an analysis of stacked data. We will discuss the implications for reionization of these escape fractions measured from the stacking analysis, as well as possible UV detections from *individual* dwarf galaxies.

Author(s): Michael J. Rutkowski[4], Claudia Scarlata[4], Harry I. Teplitz[1], Matthew Hayes[3], Mara Salvato[2], Melanie Beck[4], Vihang Mehta[4], Anthony Pahl[4]
Institution(s): *1. IPAC-CalTech, 2. MPE, 3. Stockholm University, 4. University of Minnesota*

206.04 – *HST* Emission-Line Galaxies at z ~ 2: The Mystery of Neon

We used two near-IR grism surveys (AGHAST and 3DHST) from the *Hubble Space Telescope* to examine the strength of [Ne III] 3869 relative to H-beta, [O II] 3727 and [O III] 5007 in 236 low mass (7.5 < log(Mstar/Msolar) < 10.5) star-forming galaxies in the redshift range 1.90 < z < 2.35. By stacking the data by stellar mass, we showed that the [Ne~III]/[O~III] ratios of the z ~ 2 universe are enhanced by ~0.2 dex more than those seen in a comparable set of local SDSS galaxies. We considered possible explanations for this 4-sigma result, including higher oxygen depletion out of the gas-phase, denser H II regions, and the existence of a larger population of X-ray obscured AGN at z ~ 2 compared to z ~ 0. None of these simple scenarios, alone, are favored to explain the observed line ratios.

Author(s): Gregory Zeimann[1], Robin Ciardullo[1], Caryl Gronwall[1], Henry Gebhardt[1], Alex Hagen[1], Joanna Bridge[1], Jonathan Trump[1], Donald P. Schneider[1]
Institution(s): *1. Penn State University*

206.05 – The Molecular Gas Contents of z=1.62 cluster galaxies and their Last Gasp of Star Formation

I will present JVLA CO imaging in the 1-0 transition of a z=1.62 galaxy cluster located in the UKIDSS/UDS and covered by the 3D-HST data. These are the deepest existing data in CO(1-0), corresponding to nearly 100 hours of JVLA observations, and are giving us the powerful ability to study the molecular gas contents of massive cluster galaxies when they were in the last throes of their star formation. The 3D-HST data are crucial to this endeavor as they 1) give us accurate redshifts with which to confirm membership, 2) give us the ability to reject cluster interlopers, and 3) serve as a strong redshift prior to search for weak CO lines. We securely detect two cluster members in CO(1-0) at the expected frequency given the grism redshifts. This nearly doubles the number of published CO(1-0) detections of normal star-forming galaxies at high redshift. These two galaxies are massive, with log(Mstar~11) and extremely gas rich (Mgas/Mbaryon~0.6-0.7). One hosts a non-energetically important x-ray AGN and the other is an edge-on star-forming disk. Despite their very large gas reservoirs they are forming stars at a sedate pace for their stellar mass and lie on or below the main star formation sequence. Coupling with rest-frame optical size measurements from CANDELS we are able to measure the star formation rate and molecular gas surface densities and find that these two galaxies are at the very low end of star formation efficiency for high redshift star forming galaxies. Our molecular gas masses are unusually robust as we use the CO(1-0) line, which has minimal excitation corrections compared to higher CO transitions. I will comment on the implications of this interesting finding for understanding the truncation of gas accretion onto distant cluster galaxies, the end of star formation in the massive cluster galaxy population, and the biases in existing CO surveys that target galaxies based primarily on their star formation rates.

Author(s): Gregory Rudnick[6], Fabian Walter[1], Jacqueline Hodge[2], Casey J. Papovich[3], Kim-Vy Tran[3], Ivelina G. Momcheva[7], Christopher Willmar[5], Amelie Saintonge[4]
Institution(s): *1. Max-Planck-Institute for Astronomy, 2. NRAO, 3. Texas A and M University, 4. University College London, 5. University of Arizona, 6. University of Kansas, 7. Yale University*

206.06 – Strangers in Our Midst: Massive, Evolved, Highly-obscured Galaxies at z > 1

Among the most massive galaxies at z > 1, we have uncovered a significant population of galaxies with unique SEDs that are best fit with highly-obscured evolved stellar populations (log M > 11, Av > 2, age > 1 Gyr). These are not galaxies at the detection limit or galaxies with the most extreme optical-IR colors: they have always been lurking in IR-selected photometric surveys but with their redshifts significantly overestimated and subsequently-biased derived stellar population properties. Characterizing this population has previously been impossible even with medium-band near-IR photometry due to strong degeneracies between photometric redshifts and SED shapes, which we can now critically break with robust emission-line redshifts obtained from the 3D-HST grism survey (H-alpha and [OIII] at 1 < z < 2). Understanding this population is imperative for interpreting the evolution of the high-mass end of the galaxy stellar mass function. Intriguingly, these galaxies could represent an evolutionary bridge between dusty starbursts and relatively unobscured quiescent galaxies, both of which are found among massive galaxies at z > 1 but with the latter dominating at lower redshifts.

Author(s): Gabriel Brammer[1]
Institution(s): *1. STScI*
Contributing team(s): 3D-HST Survey Team

206.07 – 3D-HST/WFC3 grism spectroscopy of distant quiescent galaxies

Galaxies with evolved stellar populations that are no longer actively forming new stars, or quiescent galaxies, have been identified in large numbers based on rest-frame colors at z~2. However, only a small number of these galaxies have been spectroscopically confirmed to show that their rest-frame optical spectra show either strong Balmer or metal absorption lines. We can now unambiguously identify metal absorption lines in the median rest-frame optical stacked spectra of mass-complete samples of photometrically quiescent galaxies at z~2 with the 3D-HST survey. This finding demonstrates that galaxies with relatively old stellar populations already existed when the universe was only 3 Gyr old, and that rest-frame color selection techniques can efficiently select them. Although the spectrum is dominated by an evolved stellar population, we also find [OIII] and Hβ emission. Interestingly, the spatial resolution of the grism allows us to determine that this emission is more centrally concentrated than the continuum, indicating residual central star formation or nuclear activity. The high spatial resolution of the HST/WFC3 NIR grism spectroscopy will serve as a powerful tool to resolve the stellar populations of these enigmatic galaxies.

Author(s): Katherine E. Whitaker[1]
Institution(s): *1. NASA/GSFC*
Contributing team(s): 3D-HST collaboration

207 – Extrasolar Planets: Dynamics and Stability of Planetary Systems

207.01D – The orbital dynamics and long-term stability of planetary systems

A large population of low-mass exoplanets with short orbital periods has been discovered using the transit method. At least 40% of these planets are actually part of compact systems with more than one planet. The closeness of the planetary orbits in these multi-planet systems leads to strong dynamical interactions that imprint themselves on the transit light curve as transit timing variations (TTVs). By modeling the orbital evolution of these planetary systems, one can fit the observed variations and strongly constrain the masses and orbits of the interacting planets, parameters which, given the faintness of the host stars, often cannot be determined using other techniques. This type of analysis is performed for KOI-984, a system with a single transiting planet perturbed by at least one non-transiting companion. By modeling the gravitational interaction between the planets using our code TTVFast, we are able to show that in the context of a two-planet model, the planetary orbits must be distinctly non-coplanar. However, solutions with two non-transiting companions with nearly coplanar orbits cannot be ruled out, given the data, and so we cannot yet determine the true three dimensional architecture of the system.

The dynamical interactions that lead to observable TTVs can also lead to orbital instability and chaos. The Kepler 36 system has the closest confirmed pair of planets to date, with unique TTVs that tightly constrain the orbits, in turn allowing for detailed analysis of the long-term dynamics of the system. We find the system to be strongly chaotic, characterized by the very human timescale of ~10 years. We are able to understand the source of this rapid chaos, and to show that despite its presence, the system can be long-lived. But how compact can two planetary orbits be before being unstable? We consider more generally the long-term stability of two-planet systems within the framework of first-order resonance overlap. We determine a stability criterion for close pairs of planets which we then compare to other analytic criteria and to numerical integrations. This work provides a step towards understanding the long-term evolution of more complex planetary systems.

Author(s): Katherine Deck[1]
Institution(s): *1. Caltech*
Contributing team(s): Matthew Holman, Joshua N. Winn, Eric Agol, Joshua Carter, Matthew Payne, David Nesvorny, Roberto Sanchis-Ojeda, Howard Isaacson, Guillermo Torres, Jack J. Lissauer

207.02D – Orbital Architectures of Dynamically Complex Exoplanet Systems

The most powerful constraints on planet formation will come from characterizing the dynamical state of complex multi-planet systems. Unfortunately, with that complexity comes a number of factors that make analyzing these systems a computationally challenging endeavor: the sheer number of model parameters, a wonky shaped posterior distribution, and hundreds to thousands of time series measurements. We develop a differential evolution Markov chain Monte Carlo (RUN DMC) to tackle these difficult aspects of data analysis. We apply RUN DMC to two classic multi-planet systems from radial velocity surveys, 55 Cancri and GJ 876. For 55 Cancri, we find the inner-most planet "e" must be coplanar to within 40 degrees of the outer planets, otherwise Kozai-like perturbations will cause the planet's orbit to cross the stellar surface. We find the orbits of planets "b" and "c" are apsidally aligned and librating with low to median amplitude ($50\pm^{610}$ degrees), but they are not orbiting in a mean-motion resonance. For GJ 876, we can meaningfully constrain the three-dimensional orbital architecture of all the planets based on the radial velocity data alone. By demanding orbital stability, we find the resonant planets have low mutual inclinations (Φ) so they must be roughly coplanar ($\Phi^{cb} = 1.41\pm^{0.620.57}$ degrees and $\Phi^{be} = 3.87\pm^{1.991.86}$ degrees). The three-dimensional Laplace argument librates with an amplitude of $50.5\pm^{7.910.0}$ degrees, indicating significant past disk migration and ensuring long-term stability. These empirically derived models will provide new challenges for planet formation models and motivate the need for more sophisticated algorithms to analyze exoplanet data.

Author(s): Benjamin E. Nelson[1]
Institution(s): *1. Pennsylvania State University*

207.03 – Crushed Exoplanet systems: Did it happen here?

Kepler revealed the common existence of tightly-packed super-Earth systems around solar-type stars, existing entirely inside the orbit of our Venus. Those systems must be stable for the ages of their host stars (~10^9 years); their formation mechanism must provide inter-planet spacings that permit long-term stability. If one postulates that most planetary systems form with tightly-packed inner planets, their current absence in some systems could be explained by the collisional destruction of the inner system after a period of meta-stability. The signatures of intense collisional environments have been observed around stars in the form of rapidly varying debris disks; in these disks the collisional products of the ensuing cascade are disposed of via drag down onto the star or grinding to the nearly instantaneous dust blow-out limit.

We posit that our Solar System also originally had a system of multiple planets interior to the orbit of Venus. This would resolve a known issue that the energy/angular momentum of our inner-planet system is best explained by accreting the current terrestrial planets from a disk limited to 0.7-1.1 AU; in our picture the disk material closer to the Sun also formed planets, but they have since been destroyed. By studying the orbital stability of systems like the known Kepler systems, we demonstrate that orbital excitation and collisional destruction could be confined to just the inner parts of the system. In this scenario, Mercury is the final remnant of the inner system's destruction via a violent multi-collision (and/or hit-and-run disruption) process.

This would provide a natural explanation for Mercury's unusually high eccentricity and orbital inclination; it also fits into the general picture of long-timescale secular orbital instability, with Mercury's current orbit being unstable on 5 Gyr time scales. The common decade spacing of instability time scales raises the intriguing possibility that this destruction occurred roughly 0.6 Gyr after the formation of our Solar System and that the lunar cataclysm is a preserved record of this apocalyptic event that began when slow secular chaos generated orbital instability in our former super-Earth system.

Author(s): Kathryn Volk[1], Brett Gladman[1]
Institution(s): *1. University of British Columbia*

207.04 – Long-lived Chaotic Orbital Evolution of Exoplanets in Mean Motion Resonances with Mutual Inclinations

Mean motion resonances, in which two orbital frequencies are close to an integer multiple of each other, are common throughout the Solar System and exoplanetary systems. We present N-body simulations of resonant planets with inclined orbits and show that orbital eccentricities and inclinations can evolve chaotically for at least 10 Gyr. A wide range of behavior is possible, ranging from fast, low amplitude variations to a complete sampling of all parameter space, i.e. eccentricities reach 0.999 and inclinations 179.9 degrees. While the orbital elements evolve chaotically, at least one resonant argument librates, the traditional metric for identifying resonant behavior. This chaotic evolution is possible in the 2:1, 3:1 and 3:2 resonances, and for a range of planetary masses from lunar- to Jupiter-mass. In some cases, orbital disruption occurs after several Gyr, implying the mechanism is not rigorously stable, just long-lived relative to the main sequence lifetimes of solar type stars. We also re-examine simulations of planet-planet scattering and find that they produce planets in inclined resonances that evolve chaotically in about 0.5% of cases. Our results suggest that 1) approximate methods for identifying unstable orbital architectures may have limited applicability, 2) some short-period exoplanets may be formed during tidal circularization when the eccentricity is large, 3) those exoplanets' orbital planes may be misaligned with the host star spin axis, 4) on average, systems with resonances may be systematically younger than those without, 5) the distribution of period ratios of adjacent planets detected via transit may be skewed, and 6) potentially habitable planets may have dramatically different climatic evolution than the Earth. We show that the known systems HD 73526, HD 45364 and HD 60532 system may be in chaotically-evolving resonances. The GAIA spacecraft is capable of discovering giant planets in these types of planetary systems.

Author(s): Rory Barnes[3], Russell Deitrick[3], Richard Greenberg[2], Thomas R. Quinn[3], Sean N. Raymond[1]
Institution(s): *1. Laboratoire de Bordeaux, 2. University of Arizona, 3. University of Washington*

207.05 – The Outer Architecture of M Dwarf Planetary Systems

High-contrast imaging probes the outer architecture of planetary systems and enables direct studies of extrasolar giant planet atmospheres. M dwarfs have largely been neglected from previous surveys despite having more favorable planet-star contrasts and representing about 75% of all stars. As a result, little is known about the population of gas-giant planets at moderate separations (10-100 AU) in this stellar mass regime. I will describe results from the Planets Around Low-Mass Stars (PALMS) high-contrast adaptive optics imaging program targeting nearby (<35 pc) young (<300 Myr) M dwarfs with Keck/NIRC2 and Subaru/HiCIAO. With a sample size of over 120 stars, PALMS is the largest direct imaging planet search in this stellar mass regime. I will present the survey discoveries, statistical results, and implications for the formation of gas-giant planets around the most common stars in our galaxy.

Author(s): Brendan P. Bowler[1], Michael C. Liu[4], Evgenya Shkolnik[2], Motohide Tamura[3]

Institution(s): *1. Caltech, 2. Lowell Observatory, 3. NAOJ, 4. University of Hawaii*

207.06 – New Insights into Exoplanet System Architectures from Obliquity Measurements of Kepler Planet-Host Stars

The angle between the a planet's orbital angular momentum vector and its host star's spin axis is one of the most important clues about the system's formation and evolution. Also known as the stellar obliquity, this quantity has been measured for more than 80 exoplanetary systems. Most of these measurements have used the Rossiter-McLaughlin effect, the observation of which requires intensive monitoring, a bright host star, and a large planet. However, most exoplanets discovered by the Kepler mission---a substantial majority of all known planets---are not amenable to such observations. Alternatively, the obliquity of a transiting planetary system can be estimated by combining single-epoch high-resolution spectroscopy with measurement of the stellar rotation period. By applying this technique to a large number of Kepler planet hosts, we show that stars with only a single transiting planet tend to have larger obliquities than stars hosting multiple transiting planets. This result suggests that a significant fraction of Kepler's single-transiting systems may represent dynamically hotter, less orderly systems than the "pancake-flat" multiple-transiting systems.

Author(s): Timothy Morton[3], Joshua N. Winn[2], Erik Petigura[4], John Johnson[1], Geoffrey W. Marcy[4], Andrew Howard[5]
Institution(s): *1. Harvard, 2. MIT, 3. Princeton University, 4. UC, Berkeley, 5. University of Hawaii*

207.07 – The dynamical effects of an outer planet on the evolution and observability of Kepler-11-like systems

Among the short-period multiplanet systems is Kepler 11, which contains six known planets with masses in the range of super-Earths and mini-Neptunes, all transiting their solar-type host with periods between about 10 and 120 days. The formation of such a system is poorly understood, and it is unknown whether additional planets are harbored at larger orbital distances. We explore the dynamical interactions of Kepler-11-like systems with an envisaged outer planet. We find that the presence of an outer planet can change the observability of such systems by, for example, making the inner system dynamically rigid, affecting the mutual inclinations of the planets. An outer planet can also affect the dynamical outcome should the inner system become unstable, with potential implications for systems that have lower planet multiplicity.

Author(s): Agueda Paula Granados Contreras[1], Aaron C. Boley[1]
Institution(s): *1. University of British Columbia*

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208 – Gamma Ray Bursts

208.01D – Reverse Shocks in Gamma-Ray Bursts: Clues to the Nature of the Relativistic Ejecta

Reverse shocks in GRBs afford a rare means of studying the relativistic ejecta directly. While long-predicted theoretically, their observational confirmation has been scattered and uncertain. Using extensive multiwavelength observations of the unusually bright GRB 130427A at z=0.340, we find clear evidence for the presence of a reverse shock in the afterglow light. Tracking the emission from both forward and reverse shocks over three orders of magnitude in time and nine orders of magnitude in frequency, we constrain the ejecta magnetization, explosion energy, and the mass loss rate of the progenitor prior to explosion.

Author(s): Tanmoy Laskar[1], Edo Berger[1], Bevin Zauderer[1], Raffaella Margutti[1]
Institution(s): *1. Harvard University*

208.02 – The Swift GRB Host Galaxy Legacy Survey

I introduce the Swift Host Galaxy Legacy Survey (SHOALS), a comprehensive multiwavelength program to characterize the demographics of the GRB host population across its entire redshift range. Using unbiased selection criteria we have designated a subset of 130 Swift gamma-ray bursts which are now being targeted with intensive observational follow-up. Deep Spitzer imaging of every field has already been obtained and analyzed, with major programs ongoing at Keck, GTC, and Gemini to obtain complementary optical/NIR photometry to enable full SED modeling and derivation of fundamental physical parameters such as mass, extinction, and star-formation rate. Using these data I will present an unbiased measurement of the GRB host-galaxy luminosity and mass functions and their evolution with redshift between z=0 and z=5, compare GRB hosts to other star-forming galaxy populations, and discuss implications for the nature of the GRB progenitor and the ability of GRBs to probe cosmic star-formation.

Author(s): Daniel A. Perley[1]
Institution(s): *1. Caltech*

208.04 – Effects of the Metal Aversion of LGRBs

Recently we compared the metallicity of the hosts of LGRBs, broad-lined Type Ic (Ic-bl) supernovae (SNe), and Type II

SNe to each other and to the metallicity distribution of star-forming galaxies using the Sloan Digital Sky Survey (SDSS) to represent galaxies in the local universe and the Team Keck Redshift Survey (TKRS) for galaxies at intermediate redshifts. The differing metallicity distributions of LGRB hosts and the star formation in local galaxies forces us to conclude that the low-metallicity preference of LGRBs is an intrinsic difference in the LGRB formation rate as a function of the metallicity in their environment. The presence of the strong metallicity difference between LGRBs and Type Ic-bl SNe largely eliminates the possibility that the observed LGRB metallicity bias is a byproduct of a difference in the initial mass functions of the galaxy populations. Rather, metallicity below half-solar must be a fundamental component of the evolutionary process that separates LGRBs from the vast majority of Type Ic-bl SNe and from the bulk of local star formation. While most work to date has been on using GRB hosts to better understand GRBs, the converse is now emerging: it is possible to use GRBs as tracers of primordial star-formation and the spectrally clean emissions of GRB afterglows provide an ideal opportunity to study the properties of their hosts via absorption. Both dust and molecular gas emission had been detected in GRB host galaxies. GRBs provide a unique opportunity to study interstellar dust, atomic & molecular gas, and metals in both emission and absorption studies. However it in necessary to take the low metallicity environmental preference of LGRBs in to account in these efforts, especially as there is a population of LGRBs that occur in high metallicity host galaxies.

Author(s): John Graham[1]
Institution(s): *1. Max Planck Institute for extraterrestrial Physics*

208.05D – Searches for Gravitational Waves Associated with Gamma-Ray Bursts

The central engines of gamma-ray bursts (GRBs) are expected to be bright sources of gravitational waves. Over the past decade, coherent analysis techniques have been applied to search for gravitational-wave signals associated with GRBs, using data from the first generation of the LIGO and Virgo detectors. In these searches, no detection candidates were found, but upper limits were placed on the emission of gravitational waves from the GRB progenitors. The advanced LIGO and Virgo instruments are expected to begin operation in the next few years, and an extrapolation of upper limits from the first generation indicates that joint observations between gamma-ray satellites and gravitational-wave detectors is possible for certain progenitor models and event rates.

Author(s): Daniel Hoak[1]
Institution(s): *1. University of Massachusetts, Amherst*
Contributing team(s): LIGO Scientific Collaboration, Virgo Collaboration

208.06 – RMHD simulations of collision-induced magnetic dissipations in Poynting flux dominated jets

We perform a 3D relativistic ideal MHD simulation to study the collision between high-σ magnetic blobs which contain both poloidal and toroidal magnetic field components, which can mimic the interactions inside a highly variable Poynting flux dominated jet. We discover a significant Poynting flux energy dissipation component in addition to the dissipation due to the evolution of the blob without collision. We identify this additional Poynting flux energy dissipation as being mainly facilitated by the collision driven magnetic reconnections, through both observing the reconnection events in the simulations and quantitative calculations of the energy dissipation rate. Additional resolution and parameter studies show a robust result that our results are nearly independent of the numerical resolution or most physical parameters in the relevant parameter range. Our results give a good support to some theories in astrophysical systems, such as the internal collision-induced magnetic reconnection and turbulence (ICMART) model for GRBs, and some reconnection triggered mini-jet model for AGNs.

Author(s): Wei Deng[2], Hui Li[1], Bing Zhang[2], Shengtai Li[1]
Institution(s): *1. Los Alamos National Lab, 2. University of Nevada, Las Vegas*

208.07 – The effect of black hole spin on winds from neutron star merger remnant accretion disks

Neutron star mergers result in the formation of a remnant accretion disk around a black hole or a hypermassive neutron star. The secular evolution of these disks leads to outflows that can eject a varying fraction of the disk, in amounts comparable to or larger than material ejected promptly due to tidal forces. Here we present results from two-dimensional, time-dependent hydrodynamic simulations of the long-term (viscous) evolution of these disks, which include the relevant physics needed to characterize the dynamics and composition of the disk. In particular, we show that a spinning black hole at the center leads to a significant enhancement in the mass ejection relative to the non-spinning case, with the composition becoming slightly less neutron-rich. Disk winds generally contribute to a ~week long transient peaking in the near-infrared (kilonova), although an optical precursor can manifest as a signature of delayed black hole formation or high black hole spin. Results have implications for the detection of electromagnetic counterparts of LIGO sources and for the Galactic r-process element generation.

Author(s): Rodrigo Fernandez[2], Daniel Kasen[2], Brian D Metzger[1], Eliot Quataert[2]
Institution(s): *1. Columbia University, 2. UC Berkeley*

209 – What Have We Learned from the NSF ADVANCE Program and What's Next?

AAS Special Session
As exemplified by the recent CSWA Demographics Survey, while the number of women obtaining PhDs in STEM has been increasing for decades, their numbers have yet to reach parity in the upper echelons of the most prestigious jobs, and overall they are still underrepresented in almost all academic fields. The NSF ADVANCE program, which began in 2001 and invested over $135 million in projects, endeavored to increase the representation and advancement of women in academic STEM careers by addressing specific aspects of academic/institutional culture that affected women differently. Such aspects include, but are not limited to, stereotype threat, explicit and implicit bias, sexual harassment, lack of family leave support/policies that ztreat women equally, and lack of women in leadership and decision-making positions. From the NSF ADVANCE summary, “The cumulative effect of such diverse factors has been to create infrastructural barriers that impact the number of women entering, persisting and advancing in STEM careers.” The goal of ADVANCE, which ceased awarding grants in 2012, was to “seminally contribute to and inform the general knowledge base on gender equity in the academic STEM disciplines.” This Special Session will highlight the most influential (measurable) outcomes of NSF ADVANCE towards meeting its goals, focusing on broadly-applicable best practices and knowledge gained, not (just) specific products/statistics. E.g., if an institution increased participation of undergraduate women in STEM from 20% to 30%, how did they do it, what were the challenges, how do they plan to continue, how is their strategy transferable to other institutions? In this session we will hear from speakers with a diverse background in promoting the equity of women in STEM to learn from their experiences, with the aim of bringing together more universal policies and recommendations to help equalize women (and all minority) participation and advancement in Astronomy. This session will also be open for posters that discuss evidence-based, proactive research and programming related to women and minority equity in Astronomy. NSF ADVANCE was a momentous effort from the national government and many individuals, and with this session we want to pause and assess where we are after ADVANCE, and the best directions to move in the near future.

209.01 – Has ADVANCE Affected Senior Compared to Junior Women Scientists Differently?

Substantial evidence exists to demonstrate that the NSF ADVANCE Inititiative has made a positive impact upon institutions. Since it began in 2001, ADVANCE has changed the conversation, policies, and practices in ways to remove obstacles and systemic barriers preventing success for academic women scientists and engineers. Results from ADVANCE projects on campuses have facilitated consensus nationally about policies and practices that institutions may implement to help to alleviate issues, particularly for junior women scientists.

Although getting women into senior and leadership positions in STEM constituted an initial impetus for ADVANCE, less emphasis was placed upon the needs of senior women scientists. Surveys of academic women scientists indicate that the issues faced by junior and senior women scientists differ significantly. The focus of ADVANCE on junior women in many ways seemed appropriate--the senior cohort of women scinetists is fed by the junior cohort of scientists; senior women serve as mentors, role models, and leaders for the junior colleagues, while continuing to struggle to achieve full status in the profession. This presentation will center on the differences in issues faced by senior compared to junior women scientists to explore whether a next step for ADVANCE should be to address needs of senior academic women scientists.

Author(s): Sue Rosser[1]
Institution(s): *1. San Francisco State University*

209.02 – Successful ADVANCE Initiatives for Junior Women Faculty in STEM

The NSF ADVANCE program was designed to transform university policies, procedures, and practices so that women faculty could advance in STEM faculty careers, obtain tenure, and ultimately become academic leaders. The results have been impressive. The most recent data from the American Society of Engineering Education (Fall 2013) show that the average percentage of women faculty in U.S. Colleges of Engineering is now 14.5%; it was just 9% when ADVANCE started in 2001.

This talk will describe programs to support and promote junior women faculty that have been successful in recruiting and retaining women in STEM. These programs include mentoring, professional development, and work/life balance initiatives. Suggestions will be made for ways to disseminate low-cost successful ADVANCE programs to other institutions so that they can successfully support their own women faculty in STEM. One effort is the University of Washington’s LEAD-it-Yourself! online toolkit that will enable other universities to run their own leadership workshops for department chairs and deans.

Author(s): Eve Riskin[1]

Institution(s): *1. University of Washington*

209.03 – Individuals and Institutions : How to Advance Women in Science

The inception of the NSF ADVANCE program marked a change in NSF's efforts to improve the advancement of women in the sciences. Previous efforts had focused on providing women with funding to pursue their research. ADVANCE focuses on changing the institutions in which women do their research. Evidence of ADVANCE's successes can be seen both in the careers of individual women and in hiring and retention figures at the institutions that received funding.
In Part 1, I will review interventions that help women to succeed, with a focus on the Sponsorship Program and the Workshop Series for Junior Faculty that the Gender Equity Project at Hunter College developed. In Part 2, I will review successes in changing hiring practices, with a focus on ADVANCE programs from the University of Michigan and the University of Wisconsin. In Part 3, I will analyze the costs and benefits of the two types of intervention, including the long time course of institutional change, the helpful or hurtful role that leaders can play, the need for intervention at the departmental level, and the potential for individuals to change institutions.

Author(s): Virginia Valian[1]
Institution(s): *1. Hunter Coll & CUNY Grad Ctr*

209.04 – Advancing Women in STEM at Florida International University

Florida International University (FIU) was awarded an NSF ADVANCE grant in 2011 to fund a partnership with the University of Michigan (UM) in order to improve the advancement of women faculty in STEM fields at FIU. FIU is a Carnegie "High Research Activity" doctoral granting institution, and is the fifth largest university in the country with over 54,000 students and 1,100 full-time faculty. The project at FIU was designed to adapt and implement some of the tools and practices shown to have increased the participation and advancement of women in the sciences at UM. The FIU ADVANCE program was funded from 2011-2014, and resulted in increased awareness of the issues facing women faculty in STEM fields, increased hiring of women into STEM faculty positions at FIU, and improved satisfaction for women in terms of some gender equity issues, pay, and recognition at FIU. I will give an overview of the program structure and components, provide examples and evidence of change, and discuss no-cost changes that can be implemented at other institutions.

Author(s): Caroline E. Simpson[1]
Institution(s): *1. Florida International Univ.*

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210 – Molecular Clouds, HII Regions, Interstellar Medium III

210.01 – The relative orientation between the magnetic field and structures traced by interstellar dust

The role of the magnetic field in the formation of the filamentary structures observed in the interstellar medium (ISM) is a debated topic. The Planck all-sky maps of linearly polarized emission from dust at 353GHz provide the required combination of imaging and statistics to study the correlation between the structures of the Galactic magnetic field and of interstellar matter, both in the diffuse ISM and in molecular clouds. The data reveal structures, or ridges, in the intensity map with counterparts in the Stokes Q and/or U maps. We focus on structures at intermediate and high Galactic latitudes with column density from 10^20 to 10^22 cm^−2. We measure the magnetic field orientation on the plane of the sky from the polarization data, and present an algorithm to estimate the orientation of the ridges from the dust intensity map. We use analytical models to account for projection effects. Comparing polarization angles on and off the structures, we estimate the mean ratio between the strengths of the turbulent and mean components of the magnetic field to be between 0.6 and 1.0, with a preferred value of 0.8. We find that the ridges are preferentially aligned with the magnetic field measured on the structures. This trend becomes more striking for increasing polarization fraction and decreasing column density. We interpret the increase of alignment with polarization fraction as a consequence of projections effects. The decrease of alignment for high column density is not due to a loss of correlation between the structures and the geometry of the magnetic field. In molecular complexes, we observe structures perpendicular to the magnetic field, which cannot be accounted for by projection effects. We discuss our results in the context of models and MHD simulations, which describe the formation of structures in the magnetized ISM.

Author(s): Andrea Bracco[1]
Institution(s): *1. Institut d'Astrophysique Spatiale*
Contributing team(s): On behalf of the Planck Collaboration

210.02D – Investigating the Life Cycle of Molecular Clouds in the Andromeda Galaxy

There is currently a great divide between high resolution studies of stellar clusters and molecular clouds in the Milky

Way, and those done in extragalactic systems, where individual stars and clouds cannot usually be resolved. For my thesis work, I combined several astronomical data sets to investigate the life cycle of molecular clouds in the Andromeda Galaxy. The primary data sets I used are the Panchromatic Hubble Andromeda Treasury (PHAT), which catalogued over 200 million stars, and a molecular cloud catalogue that is constructed from new high spatial/spectral resolution (20 pc, 1 km/s) CARMA observations. Several ancillary data sets, including H-alpha and Spitzer IR emission maps were also used, taking advantage of broad wavelength coverage to search for indicators of star formation with different timescales. Comparisons were also made with the PHAT cluster sample, and the youngest (<10 Myr) stellar clusters were used as an additional star formation indicator. The ages and masses of these clusters were determined by fitting the color-magnitude diagrams (CMDs) of their resolved stars to theoretical isochrones. The distribution of the youngest clusters shows a strong correlation with the molecular cloud distribution, while no correlation is evident for clusters greater than 30 Myr. Each molecular cloud in the sample was then classified as a star-forming cloud or a non-star forming cloud, based on the presence of any one of several star formation indicators. About 60% of the clouds in the sample were found to be associated with massive star formation. Based on the comparison between these observations and the results from a Monte Carlo simulation, I will also demonstrate how we can constrain the timescales for the relative phases in a cloud's life.

Author(s): Lori Beerman[4], Julianne Dalcanton[4], Andreas Schruba[2], Adam K. Leroy[3], Lent C. Johnson[4], Daniel R. Weisz[4], Morgan Fouesneau[1]
Institution(s): *1. Max Planck Institute for Astronomy, 2. Max Planck Institute for Extraterrestrial Physics, 3. National Radio Astronomy Observatory, 4. University of Washington*
Contributing team(s): PHAT Collaboration

210.03 – What you (think) you see is what you get: A case study concerning interstellar HI structure

High-velocity "cloud" MI is not a cloud at all but is a part of a twisted filamentary feature that shows a complex morphology. Seen projected on the sky, the filament exhibits prominent loops and when segments of similar or smaller loops are twisted into the line-of-sight the illusion of cloudiness is created. HI data obtained with several angular resolutions will be shown in order to illustrate that the interpretation of the data is seriously biased by the method of display. This has far-reaching consequences as regards untangling interstellar HI structure, which is surely far more complex than we care to imagine, or perhaps even can imagine.

Author(s): Gerrit L. Verschuur[2], Mahboubeh Asgari-Targhi[1]
Institution(s): *1. Center for Astrophysics, 2. University of Memphis*

210.04 – Dense Molecular Gas in the First Galactic Quadrant: A New Distance Estimation Technique and the Molecular Cloud Clump Mass Function, Physical Properties, and Galactic Distribution from the Bolocam Galactic Plane Survey

Large submillimeter and millimeter Galactic dust continuum surveys of the Milky Way, such as the Bolocam Galactic Plane Survey (BGPS), Hi-GAL, ATLAS-GAL, and JCMT-JPS cumulatively have discovered 10^5 cores, clumps, and other structures in Galactic molecular clouds. Robust distance measurements to these structures are needed to enable the large range of quantitative astrophysics that these surveys promise, such as physical properties of clumps, the clump mass function, and the three-dimensional distribution of dense gas and star formation in the Milky Way. We have developed a technique for deriving distances to continuum-identified molecular cloud clumps employing kinematic distances and a suite of distance estimators for breaking kinematic distance ambiguities. Application to the BGPS has yielded 3,700 distance probability density functions (DPDFs) and 1,800 well-constrained distances (typical $\sigma^{dist} \approx 0.5$ kpc). These have been used to determine sizes and masses of molecular cloud clumps, derive the clump mass function, and map the three-dimensional distribution of dense gas in the first Galactic quadrant. Among the interesting results are a mass function intermediate between molecular clouds and the stellar initial mass function and inter-arm star formation. Next, we plan to apply the technique to Hi-GAL, which covers the entire Galactic plane and whose submilllimeter maps provide for temperature and bolometric luminosity measurements of cloud structures.

Author(s): Jason Glenn[1], Timothy Ellsworth-Bowers[1]
Institution(s): *1. Univ. of Colorado*
Contributing team(s): Bolocam Galactic Plane Survey

210.05 – Behavior of C/O vs. O/H through MCMC Chemical Abundance Determination

We investigated the behavior of C/O vs. O/H in order to constrain the production mechanism of carbon. We obtained the chemical abundances of a small but statistically meaningful sample of starburst galaxies through the traditional nebular analysis and through a Marcov Chain Monte Carlo (MCMC) method. This method has not been exploited for nebular chemical abundance determinations before. We measured emission-line intensities in a spectral range from 1600 to 10,000 A on STIS long-slit spectra of 18 starburst galaxies carefully selected to measure the strength of the C III] 1909 and other diagnostic lines. We chose 11 strong emission lines over the wide spectral range and compared the measured intensities with those modeled by Cloudy with a Starburst99 spectrum as ionizing source. The input parameters for the chosen Cloudy models varied according to the MCMC algorithm. We obtained the final abundance set through a Chi^2 minimization.

Author(s): Maria Angeles Peña-Guerrero[1], Claus Leitherer[1]
Institution(s): *1. Space Telescope Science Institute*

210.06D – Time-Dependent Diffusive Shock Acceleration in Slow Supernova Remnant Shocks

Recent gamma ray observations show that middle aged supernova remnants interacting with molecular clouds can be sources of both GeV and TeV emission. Models involving re-acceleration of pre-existing cosmic rays in the ambient medium and direct interaction between supernova remnant and molecular clouds have been proposed to explain the observed gamma ray emission. For the re-acceleration process, standard DSA theory in the test particle limit produces a steady state particle spectrum that is too flat compared to observations, which suggests that the high energy part of the observed spectrum has not yet reached a steady state. We derive a time dependent DSA solution in the test particle limit for situations involving re-acceleration of pre-existing cosmic rays in the preshock medium. Simple estimates with our time dependent DSA solution plus a molecular cloud interaction model can reproduce the overall shape of the spectra of IC 443 and W44 from GeV to TeV energies through pure π^0-decay emission.
We allow for a power law momentum dependence of the diffusion coefficient, finding that a power law index of 0.5 is favored.<!--EndFragment-->

Author(s): Tang Xiaping[1], Roger Chevalier[1]
Institution(s): *1. University of Virginia*

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211 – Star Formation III

211.01 – The Real Protostars and Star Formation Relations in the Solar Neighborhood

We present the results of the the MIsidentified YSOs from SED Fits (MISFITS) HCO+ Survey of Class I and Flat SED sources in the Spitzer Gould Belt nearby (d < 500 pc) cloud surveys. Our goal is to provide a uniform indicator of whether or not these sources are likely to be Stage I protostars. Using this new sample of Stage I protostars, we discuss the interrelationship between their spatial distribution, cloud structure properties, star formation and gas density in the Solar Neighborhood.

Author(s): Amanda L. Heiderman[1]
Institution(s): *1. University of Virginia*
Contributing team(s): Spitzer c2d and Gould Belt survey Teams

211.02D – New benchmarks on studying the growth of galaxies at z < 3 from deep infrared surveys

Recent large scale surveys in the infrared have paved the way for studying galaxy evolution in the high-redshift universe. We make use of the wealth of data from three legacy fields (GOODS-S, COSMOS and UDS) targeted by the FourStar Galaxy Evolution Survey (ZFOURGE). We compile a mass-complete sample of >15000 galaxies across a broad redshift range down to $M \approx 10^{9.5}$ $M^{\odot}$ at z = 3 and use these data to estimate stellar masses and SFRs. We present the most precise measurement to date of the evolving galaxy stellar mass function (SMF) and show that its behavior at z ≤ 2 is distinctly non-Schechter, but tends to steepen towards stellar masses below 10^{10} $M^{\odot}$. Furthermore, this steepening is not strictly due to a buildup of quenched low-mass galaxies as the same behavior is found for the SMF of star-forming galaxies. We also make use of far-infrared imaging in these fields from the *Spitzer* and *Herschel* space telescopes to estimate star-formation rates. These measured SFRs are in marginal agreement with the inferred mass growth from the SMF which will allow us to place constraints on the contribution of mergers to galaxy growth.

Author(s): Adam R. Tomczak[2], Kim-Vy Tran[2], Ryan Quadri[2], Casey J. Papovich[2], Ivo Labbe[1], Caroline Straatman[1]
Institution(s): *1. Sterrewacht Leiden, 2. Texas A&M University*
Contributing team(s): ZFOURGE

211.03 – Triggered star-formation in the bright rimmed globule IC1396A

IC1396 is a well known HII region and molecular cloud complex surrounding the Trumpler 37 cluster of OB stars in the Cepheus OB2 association. The dense, elephant trunk shaped globules in this region typically show bright rims facing the central exciting O6 star HD~206267. This region, at a distance of 870 pc, is an excellent astrophysical laboratory for studying the feedback effects of massive stars on neighboring molecular clouds. Triggered star formation occurs when dense cores (which would otherwise remain stable) are compressed and made unstable by the sustained energy input from the OB association. Observationally it remains challenging to prove whether the onset of star-formation in such

globules is triggered or spontaneous.
Using the Submillimeter Array (SMA), we observed IC1396 globule A (Pottasch 1958 nomenclature), targeting four newly discovered protostars from recent Herschel PACS observations. Here we present 230 GHz molecular line (CO, 13CO, C18O, N2D+ and H2CO) and continuum results for the source IC1396A-PACS-1 (Sicilia-Aguilar et al. 2014). This is a Class 0 source very close to the edge of the ionization front and Herschel observations show this to be a most promising case of triggered star-formation. The SMA 230 GHz continuum source has a flux density of 280 mJy. We estimate a dust mass of about 0.1 Msun in this source which appears very compact in our 5" beam. CO, 13CO and C18O emission is largely resolved out by the interferometer and will require combined imaging with single-dish observations. (We have a parallel ongoing study being carried out with the IRAM 30m telescope). SMA N2D+ emission peaks on the continuum source
and is partially resolved. H2CO emission appears to avoid the peak of continuum and N2D+, suggesting depletion. Both the morphology and kinematics in H2CO emission are indicative of internal disturbance, away from the PDR region into the globule.

Author(s): Nimesh A. Patel[1], Aurora Sicilia-Aguilar[3], Paul Goldsmith[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Jet Propulsion Laboratory, 3. University of St Andrews*

211.04 – Spatially Resolved Magnetic Field Structure in the Disk of a T Tauri Star

The formation of disks around protostars is thought to be regulated through magnetic fields, and theoretical models suggest that the fractional polarization should be approximately 2-3%. However, resolved observations of disks in T Tauri stars have remained undetected and are constrained to have fractional polarization of less than 1%. With CARMA observations of HL Tau, we recently found the first detection of a resolved magnetic field about a T Tauri Star. While poloidal field components appear to be completely absent for HL Tau at the 80 AU scale, a purely toroidal field does not fit the observations well either, suggesting the system is more complicated than theoretically expected. Incoming ALMA observations of both HL Tau and Class 0 protostellar disks will help disentangle the true magnetic field morphology in the disks of protostars.

Author(s): Ian Stephens[2], Leslie Looney[4], Woojin Kwon[3], Manuel Fernandez Lopez[4], A. Meredith Hughes[7], Lee G. Mundy[5], Richard Crutcher[4], Zhi-Yun Li[6], Ramprasad Rao[1], Dominique Segura-Cox[4]
Institution(s): *1. Academia Sinica, 2. Boston University, 3. SRON Netherlands Institute for Space Research, 4. Universitiy of Illinois at Urbana-Champaign, 5. University of Maryland, 6. University of Virginia, 7. Wesleyan University*

211.05 – Dust and Gas Emission from MIR Bubble N56

Mid-infrared (MIR) bubbles, identified in galactic surveys, have been extensively studied with the aim of understanding both their structure and influence on the surrounding interstellar medium. Studies of MIR bubbles aim to explore the relationship between bubble expansion and subsequent star formation. We present observations toward bubble N56 using the Herschel Space Telescope and Green Bank Telescope (GBT). The Herschel continuum observations indicate that N56 may be forming within a high mass-scale environment. The GBT $NH^3(1,1)$ and $NH^3(2,2)$ spectral line observations indicate evidence of line broadening and velocity changes coincident with the MIR-identified bubble rim. The temperature, density, and kinematics of the gas along the bubble rim are presented. We also discuss the relationship between the kinematics, physical properties, and star formation in N56.

Author(s): Kathryn E. Devine[1], Christer Watson[2], Tierra Candelaria[1], Paula Rodriguez[2], Cassiemarie Low[1], Joseph Pickett[1]
Institution(s): *1. College of Idaho, 2. Manchester University*

211.06D – The state of the art in smoothed particle magnetohydrodynamics simulations

Magnetic fields. They play a role in nearly every astrophysical problem. For star formation, they reduce the efficiency of gas conversion into stars by expelling material through jets and outflows, and by slowing gravitational collapse through the addition of magnetic pressure. Simulations face a number of computational difficulties when including the physics of magnetic fields, and my thesis work has focused on reducing these difficulties in SPH simulations. I have developed new methods to uphold the divergence-free constraint on the magnetic field and to reduce numerical dissipation in shock capturing schemes. These methods have been used to produce the first SPH simulations of stable, long-lived, magnetically propelled jets from forming stars. They have been tested in a major comparison project with grid-based methods on the small-scale dynamo amplification of magnetic fields in supersonic turbulence (using conditions representative of molecular clouds). I found excellent agreement on the amplification rate of magnetic energy, power spectra of magnetic energy, and range of magnetic field strengths during both the amplification phase and once the magnetic field has reached saturation. These results demonstrate that SPH is capable of simulating magnetic fields for a wide range of astrophysical systems.

Author(s): Terrence Tricco[1]

Institution(s): *1. University of Exeter*

211.07 – Connecting the small scale to the large scale: young massive stars and their environments from the Red MSX Source Survey.

We have conducted a detailed multi-wavelength investigation of a variety of massive star forming regions in order to characterise the impact of the interactions between the substructure of the dense protostellar clumps and their local environment, including feedback from the embedded proto-cluster.

A selection of 70 MYSOs and HII regions identified by the RMS survey have been followed up with observations of the ammonia (1,1) and (2,2) inversion transitions made with the KFPA on the GBT. These maps have been combined with archival CO data to investigate the thermal and kinematic structure of the extended envelopes down to the dense clumps. We complement this larger-scale picture with high resolution near- and mid-infrared images to probe the properties of the embedded objects themselves.

We present an overview of several sources from this sample that illustrate some of the the interactions that we observe. We find that high molecular column densities and kinetic temperatures are coincident with embedded sources and with shocks and outflows as exhibited in gas kinematics.

Author(s): Charles C. Figura[3], James S Urquhart[1], Lawrence Morgan[2]
Institution(s): *1. Max Planck Institute for Radio Astronomy, 2. Met Office, 3. Wartburg College*

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212 – Dwarf and Irregular Galaxies II

212.01 – Ultra-Compact Dwarfs Forming in Stellar Streams

Ultra-Compact Dwarfs (UCDs), objects with half-light radii between 10-100 pc and luminosities greater than ~10^6 $L_\odot$, represent a middle ground in size and luminosity between globular clusters and typical compact elliptical galaxies. Since their discovery a decade and a half ago, their origin has been the subject of considerable discussion in the literature. In short, the issue can be distilled down to a simple question: are UCDs the largest star clusters, or are they the smallest compact galaxies? UCDs in formation have not been identified to this point, so previous studies have relied on indirect inferences using observable UCD properties to address this issue. We identify several objects with the size and luminosity of UCDs embedded in stellar streams around various nearby galaxies, and we argue that these objects are in the process of being stripped during accretion onto more massive galaxies. Using the luminosity of the stellar stream as a lower limit on the stellar mass of the accreted galaxy, we able to both identify UCDs in formation as the stripped nuclei of accreted systems and directly link the properties of the UCD to the properties of the parent galaxy.

Author(s): Zachary G Jennings[2], Jean P. Brodie[2], Aaron J. Romanowsky[1]
Institution(s): *1. San Jose State University, 2. UC Santa Cruz*
Contributing team(s): SAGES Collaboration

212.02 – The Role of Dwarf-Dwarf Interactions in the Evolution of Low Mass Galaxies

We present the initial results from TiNy Titans, the first systematic study of a sample of isolated interacting dwarf galaxies and the mechanisms governing their star formation. Mergers of massive galaxies provide a significant mode of galaxy evolution; they are observed to trigger intense starbursts and significantly rearrage the gas, dust, and stars. Large volume simulations of structure formation, based in LambdaCDM cosmology, predict that mergers between low mass galaxies should occur more frequently than those between massive galaxies at all redshifts. However, the merger sequence for low mass galaxies is relatively unexplored. A few intriguing examples of dwarf-dwarf interactions exist in the literature, but the efficiency of gas removal and the enhancement of star formation in dwarfs via pre-processing (i.e. dwarf-dwarf interactions occuring before the accretion by a massive host) have never been studied for a sample of dwarfs covering a range of interaction stages. Our multiwavelength approach gathers high resolution optical, UV, and radio imaging to probe the effects of interactions on the star formation and ISM in a sample of dwarfs selected from the Sloan Digital Sky Survey. We find that: 1) star formation is enhanced in paired dwarfs over their unpaired analogs, 2) the enhancement in star formation is more pronounced as a function of pair separation than that observed in massive galaxy pairs, 3) the dwarf-dwarf interactions contribute significantly to the population of starbursting dwarfs, and 4) the paired dwarfs still have large gas reservoirs and exhibit no signs of quenching.

Author(s): Sabrina Stierwalt[5], Gurtina Besla[2], David R. Patton[3], Kelsey E. Johnson[5], Nitya Kallivayalil[5], Mary E. Putman[1], George C. Privon[4], Glen Ross[3]
Institution(s): *1. Columbia University, 2. Steward Observatory, 3. Trent University, 4. Universidad de Concepcion, 5. University of Virginia*

212.03D – Dwarf Galaxies in Voids: Galaxy Luminosity and HI Mass Functions Using SDSS and ALFALFA

We examine the first statistically-significant sample of dwarf galaxies in voids with matched optical (Sloan Digital Sky Survey) and radio (Arecibo Legacy Fast ALFA Survey) observations, which allow us to probe the impact of voids on the luminosity function, the HI mass function, and star formation history of galaxies. Large-scale voids provide a unique environment for studying galaxy formation and evolution. Previous theoretical work predicts that galaxies residing in large-scale voids evolve as if they were in a universe with lower matter density, higher dark energy density, and larger Hubble constant. Environmental processes such as ram pressure stripping and galaxy-galaxy interactions should be less important for void galaxies than for galaxies in denser regions (wall galaxies). We measure the effects of environment on two fundamental tests of galaxy formation: the galaxy luminosity function (LF) and the HI mass function (HIMF). In both cases, we find a significant shift towards lower-mass, fainter galaxies in voids. However, we do not detect a dependence on environment of the low-mass/faint end slope of the HIMF and LF. We further investigate how surface brightness selection effects impact the r-band LF. We also examine how HI selection of galaxies affects the optical LF. Utilizing both optical and HI information on nearby galaxies, we determine how star formation efficiency and star formation rates depend on environment.

Author(s): Crystal M Moorman[1], Michael S Vogeley[1]
Institution(s): *1. Drexel University*
Contributing team(s): ALFALFA Collaboration

212.04 – Stellar Kinematics and Structural Properties of Virgo Cluster Dwarf Early-Type Galaxies from the SMAKCED Project

We analyze the stellar kinematics of 39 dwarf early-type galaxies (dEs) in the Virgo cluster. This is the largest survey conducted so far on spatially resolved kinematics of dEs. This sample is representative of the early-type population in the absolute magnitude range -19.0 < M_r < -16.0. For each dE, we measure the rotation curve and velocity dispersion profile and fit an analytic function to the rotation curve. We study the significance of the departure of the rotation curve from the best fit analytic function (poorly fit) and of the difference between the approaching and receding sides of the rotation curve (asymmetry). We find that 62+/-8% (23 out of the 39) of the dEs have a significant anomaly in their rotation curve. Analysis of the images reveals photometric anomalies for most galaxies. However, there is no clear correlation between the significance of the photometric and kinematic anomalies.
Based on the specific stellar angular momentum and the ellipticity, we find 11 slow rotators and 28 fast rotators. The fast rotators in the outer parts of the Virgo cluster rotate significantly faster than fast rotators in the inner parts of the cluster. Moreover, 10 out of the 11 slow rotators are located in the inner Mpc of the cluster. The fast rotators contain subtle disky structures that are visible in high-pass filtered optical images, while the slow rotators do not exhibit these structures. In addition, two of the dEs have kinematically decoupled cores and four more have emission partially filling in the Balmer absorption lines.
These properties suggest that Virgo cluster dEs may have originated from late-type star-forming galaxies that were transformed by the environment after their infall into the cluster. The correlation between the specific angular momentum and the clustercentric distance can be explained by a scenario where low luminosity star-forming galaxies fall into the cluster, their gas is rapidly removed by ram pressure stripping, although some of it can be retained in their core, their star-formation is quenched but their stellar kinematics are preserved. After a long time in the cluster and several passes through its center, the galaxies are heated up and transformed into slow rotating dEs.

Author(s): Elisa Toloba[7], Puragra Guhathakurta[7], Reynier Peletier[3], Alessandro Boselli[4], Thorsten Lisker[6], Eric Emsellem[2], Joshua D. Simon[1], Glenn van de Ven[5]
Institution(s): *1. Carnegie Observatories, 2. ESO, 3. Kapteyn Astronomical Institute, 4. Laboratoire d'Astrophysique de Marseille-LAM, 5. MPIA, 6. University of Heidelberg, 7. Universty of California Santa Cruz*
Contributing team(s): SMAKCED collaboration

212.05 – Next Generation Virgo Survey Photometry and Keck/DEIMOS Spectroscopy of Globular Cluster Satellites of Dwarf Elliptical Galaxies in the Virgo Cluster

We present results from an ongoing study of globular cluster (GC) satellites of low-luminosity dwarf elliptical (dE) galaxies in the Virgo cluster. Our 21 dE targets and candidate GC satellites around them in the apparent magnitude range g ~ 20–24 were selected from the Next Generation Virgo Survey (NGVS) and followed up with medium-resolution Keck/DEIMOS spectroscopy (resolving power: R ~ 2000; wavelength coverage: 4800–9500 Angstrom). In addition, the remaining space available on the nine DEIMOS multi-slit masks were populated with "filler" targets in the form of distant Milky Way halo star candidates in a comparable apparent magnitude range. A combination of radial velocity information (measured from the Keck/DEIMOS spectra), color-color information (from four-band NGVS photometry), and sky position information was used to sort the sample into the following categories: (1) GC satellites of dEs, (2) other non-satellite GCs in the Virgo cluster (we dub them "orphan" GCs), (3) foreground Milky Way stars that are members of the Sagittarius stream, the Virgo overdensity, or the field halo population, and (4) distant background galaxies. We stack the GC satellite population across all 21 host dEs and carry out dynamical modeling of the stacked sample in order to constrain the *average* mass of dark matter halos that these dEs are embedded in. We study rotation in the system of GC satellites of dEs in the handful of more populated systems in our sample – i.e., those that contain 10 or more GC satellites per dE. A companion AAS poster presented at this meeting (Chu, J. et al. 2015) presents chemical composition and age constraints for these GC satellites relative to the nuclei of the host dEs based on absorption line strengths in co-added spectra. The orphan GCs are likely to be intergalactic GCs within the Virgo cluster (or, equivalently, GCs in the remote outer envelope of the cluster's central galaxy, the giant elliptical M87).

This project is funded in part by the National Science Foundation. Some of this research was conducted by high-school students working under the auspices of the Science Internship Program at the University of California Santa Cruz.

Author(s): Puragra Guhathakurta[7], Elisa Toloba[7], Eric W Peng[4], Biao Li[5], Stephen Gwyn[3], Laura Ferrarese[3], Patrick Cote[3], Jason Chu[2], Lea Sparkman[1], Stephanie Chen[6], Samyukta Yagati[2], Meredith Muller[7]
Institution(s): *1. Castilleja School, 2. Harker School, 3. HIA, 4. KIAA, 5. Peking University, 6. Stanford University, 7. UC, Santa Cruz*
Contributing team(s): Next Generation Virgo Survey collaboration

212.06 – Ultra-deep H-alpha Imaging of Nearby Dwarf Galaxies

I will present new results on diffuse H-alpha emission in nearby dwarf galaxies. Observations have been obtained with the Magellan Maryland Tunable Filter, and are 8-10 times deeper in surface brightness than previous standard narrowband imaging of local galaxies. The new observations were initially motivated by the finding that the H-alpha flux from dwarf and low surface brightness galaxies systematically under-predicts the star formation rate relative to expectations based on the far ultraviolet flux. While detailed follow-up studies of many of the potential causes of the-lower-than-expected H-alpha fluxes have been performed, the possibility that previous imaging has missed a non-negligible fraction of the diffuse flux has not been addressed. I will show what the new observations reveal, and discuss implications for the measurement of the star formation rate, the propagation of ionizing photons into the halos of dwarf galaxies, and the properties of low-luminosity HII regions.

Author(s): Janice C. Lee[1]
Institution(s): *1. Space Telescope Science Institute*

212.07 – Escape fraction of ionizing photons from a dwarf galaxy NGC 4214

Recent studies suggest that starburst dwarf galaxies played an important role in the early universe. Because these galaxies dominate by number, their leaked ionizing photons are likely main contributors to the reionization of the intergalactic medium (IGM). However, the complex structure of the interstellar medium (ISM) even at the pc scale makes it hard to predict the escape fraction of ionizing photons from high-redshift galaxies accurately. Analogues to their high-redshift counterparts, nearby starburst dwarf galaxies provide excellent laboratories to study the impact of star formation on the surrounding ISM and IGM in detail. Thanks to its proximity, the dwarf galaxy, NGC 4214, has been imaged with the high-resolution of WFC3 on HST from the near-UV to the near-IR (F225W, F336W, F438W, F814W, F110W, and F160W). These observations yielded measurements of the broad spectral energy distributions (SEDs) for ~36,000 resolved stars within this galaxy. We developed a probabilistic tool (Bayesian Extinction and Stellar Tool, a.k.a. BEAST) to simultaneously infer from their SEDs the stellar properties of individual stars and the intervening dust properties along the line of sight to each star. With the aid of BEAST, we are able to infer the intrinsic ionizing flux produced by individual stars. By comparing this intrinsic ionizing flux with the flux that is used to ionize the ISM in the galaxy, derived based on the extinction-corrected Hα emission, we can estimate the escape fraction and its local variation within the galaxy. Our preliminary results show that the global UV leakage of NGC 4214 is ~10%.

Author(s): Yumi Choi[5], Morgan Fouesneau[1], Karl D. Gordon[3], Benjamin F. Williams[5], Julianne Dalcanton[5], Daniel R. Weisz[5], Heddy Arab[3], Karin Sandstrom[4], Andrew E. Dolphin[2]
Institution(s): *1. MPIA, 2. Raytheon Company, 3. STScI, 4. University of Arizona, 5. University of Washington*

212.08 – *Herschel*'s View of LITTLE THINGS Metal-Poor Dwarf Galaxies

Dwarf galaxies present interesting challenges for the studies of various galaxy properties, due in part to their faintness and their typically low metal content. Low metallicity can lead to quite different physical conditions in the ISM of these systems, which can affect star formation and other processes. To determine the structure of star-forming molecular clouds at low metallicity and moderate star formation rates, far infrared (FIR) fine-structure lines were mapped with *Herschel* in selected regions of five dwarf irregular galaxies with metal abundances ranging from 13% down to 5% of solar. Abundances of [C II] 158, [O I] 63, [N II] 122, and [O III] 88 microns - the major FIR cooling lines - help to probe the conditions in the gas, and allow us to put these dwarfs in context with spirals and other galaxy types. We report our integrated fluxes and line ratios, and discuss the results: [C II] is the dominant FIR coolant in these systems, and it mostly originates in PDRs instead of the more diffuse phase. Funding for this project was provided by NASA JPL RSA grant

1433776.

Author(s): Phil Cigan[4], Lisa Young[4], Diane Cormier[2], Vianney Lebouteiller[1], Deidre Ann Hunter[3], Suzanne Madden[1]
Institution(s): *1. CEA Saclay, 2. Heidelberg University, 3. Lowell Observatory, 4. New Mexico Tech*
Contributing team(s): LITTLE THINGS

213 – Star Associations, Star Clusters - Galactic & Extra-galactic I

213.01D – Old Star Clusters in Spiral Galaxies: M101 as a Case Study

Most stars form in groups and clusters, at least a small fraction of which can be extremely long-lived. However, many details of how star clusters form and how they disrupt are still unclear. We present and examine a catalog of old star clusters in the nearby spiral galaxy M101, and compare with the known properties of old star clusters in other spiral galaxies. Data include multi-band *Hubble Space Telescope* images and *Gemini*-GMOS spectra. Among the properties examined are luminosity distributions, colors, sizes, spatial distributions, and velocities. We highlight the somewhat surprising result of a population of old, disk clusters in M101, which are unlike populations found in the Milky Way and M31.

Author(s): Lesley Ann Simanton[1]
Institution(s): *1. University of Toledo*

213.02 – The High Mass Stellar IMF in M31

I will present a progress report on our analysis of the high mass stellar initial mass (IMF) in M31 from the Panchromatic Hubble Andromeda Treasury program (PHAT), an 828-orbit HST survey of 1/3 of M31’s star-forming disk. To date, we have measured the present day mass function (MF) above 2 $M^{\odot}$ for nearly 1000 young star clusters (< 300 Myr) by modeling their resolved star color-magnitude diagrams. The MF slopes of individual clusters show a tremendous degree of scatter, with some clusters differing substantially from Salpeter. There appears to be little correlation between physical properties of the clusters (e.g., mass, age) and their MF slopes. From analysis of the ensemble of clusters, we recover a global MF that is both steeper than Salpeter and one that exhibits a high degree of variance, which, if taken at face value, does not appear comapabilte with a universal IMF model. We are using an extensive suite of artificial clusters, designed to mimic observations, to investigate whether effects such as finite sampling statistics, dynamical evolution (e.g., mass segregation), stellar multiplicity, cluster membership, crowding, and/or completeness can be responsible for the observed MF properties, or if the M31 cluster population has an intrinsically non-universal IMF.

Author(s): Daniel R. Weisz[1]
Institution(s): *1. Univ. of Washington*
Contributing team(s): PHAT

213.03D – PHAT Star Clusters in M31: Insight on Environmental Dependence of Star & Cluster Formation

Theoretical studies of star cluster formation suggest that the star formation efficiency (SFE) of a cluster's progenitor cloud dictates whether or not a gravitationally bound grouping will emerge from an embedded region after gas expulsion. I measure the fraction of stars formed in long-lived clusters relative to unbound field stars on a spatial resolved basis in the Andromeda galaxy. These observations test theoretical predictions that star clusters are formed within a hierarchical interstellar medium at peaks in the gas density where local SFEs are enhanced and regions become stellar dominated. Using data from the Panchromatic Hubble Andromeda Treasury (PHAT) survey and ancillary observations of M31’s gas phase, I investigate how cluster formation correlates with galactic environment and galaxy-scale properties of the star formation.
We construct a sample of >2700 star clusters through a crowd-sourced visual search of the high spatial resolution HST imaging data. Our catalog uses ~2 million image classifications collected by the Andromeda Project citizen science website to provide an unparalleled census of clusters that spans ~4 orders of magnitude in mass (50% completeness at ~500 $M^{\odot}$ at <100 Myr) and increases the number of known clusters within the PHAT survey footprint by a factor of ~6. Cluster ages and masses are obtained by fitting to color-magnitude diagrams (CMDs) of individually resolved stars within each cluster. Furthermore, we insure our ability to accurately interpret cluster age and mass distributions through careful catalog completeness characterization, made possible by thousands of synthetic cluster tests included during catalog construction work.
We combine our high quality cluster sample with spatially resolved star formation histories, derived from CMD fitting of PHAT’s photometry of ~117 million resolved field stars. We derived the fraction of stars formed in long-lived clusters and show that only a few percent of coeval stars are found in clusters within the 10-100 Myr age range. These results are consistent with theoretical predictions of declining bound fractions with decreasing star formation rate density.

Author(s): Lent C. Johnson[3], Julianne Dalcanton[3], Anil Seth[2], Lori Beerman[3], Alexia Lewis[3], Morgan Fouesneau[1], Daniel R. Weisz[3]
Institution(s): *1. Max Planck Institute for Astronomy, 2. University of Utah, 3. University of Washington*
Contributing team(s): Andromeda Project Team, PHAT Team

213.04 – Lifetimes of isolated hierarchical triple stars

Hierarchical triple systems under Newton's force law are unstable if allowed to evolve over an unlimited period of time. However, for a given time span, like for the case of triple stars in a star clusters, there is a practical stability boundary which can be expressed using 6 parameters of the system. The limit is a simple separable function of the variables, with a time dependent coefficient. Here we derive the time dependence of this coefficient for the first time.

Author(s): Mauri J. Valtonen[2], Aleksandr Mylläri[1]
Institution(s): *1. St.George's Univ., 2. Univ. Turku*

213.05 – Galaxy Evolution and the Survival of Globular Clusters

We present the results of direct N-body simulations with which we study the effects of galaxy evolution on the survival of globular clusters. N-body simulations of globular clusters in a realistic Milky-Way-like potential allowed us to determine the impact of the host galaxy disk mass and geometry on the survival of star clusters. Different geometries in a disk of identical mass can determine either the survival or dissolution of an orbiting star cluster.
The evaporation rate of globular clusters evolving in a strong tidal field is also derived through through the analysis of these large, multi-mass N-body simulations. We estimate how the evaporation rate increases for a globular cluster that decays through dynamical friction into the center of the galaxy. We discuss the findings of this work in relation to the formation of nuclear star clusters and super-massive black holes by inspiraling globular clusters.

Author(s): Juan P. Madrid[2], Jarrod Hurley[4], Marie Martig[3], Nathan Leigh[1]
Institution(s): *1. American Museum of Natural History, 2. Gemini Observatory, 3. Max-Planck-Institut für Astronomie, 4. Swinburne Univ.*

213.06D – Spitzer Local Volume Legacy (LVL) Star-Forming Regions: Luminosity Functions

The conversion of gas into stars is one of the most fundamental processes in the universe, yet the effects of environmental conditions are poorly constrained. Observations of star-forming regions (young star clusters and HII regions) have shown evidence of a fractal pattern in their mass and luminosity distributions. The Mass Function (MF), and similarly the Luminosity Function (LF), of star-forming regions can be approximated as a power-law and is characterized by the power-law slope. A consistent slope of -2 has been observed across numerous galaxies, however, systematic deviations from this canonical slope have been measured across different environments. We present the LF slopes for 258 nearby galaxies in the Local Volume Legacy (LVL) sample utilizing tens of thousands of Hα- and FUV-selected sources. We test any relationships between LF slope and global galaxy properties to quantify the effect of environment on the star formation process. In addition, we combine the entire star-forming region sample in an attempt to characterize a previously proposed break in the HII region LF power-law at L~38.6 erg/s.

Author(s): David O. Cook[2], Daniel A. Dale[2], Janice C. Lee[1]
Institution(s): *1. Space Telescope Science Institute, 2. University of Wyoming*
Contributing team(s): LVL Team

214 – Pulsars in the High Energy Regime

214.01 – When a Standard Candle Flickers: Hard X-ray Variations in the Crab Nebula

In the first two years of science operations of the Fermi Gamma-ray Burst Monitor (GBM), August 2008 to August 2010, a ~7% (70 mcrab) decline was discovered in the overall Crab nebula flux in the 15 - 50 keV band, measured with the Earth occultation technique. This decline was independently confirmed with four other instruments: the RXTE/PCA, Swift/BAT, INTEGRAL/IBIS, and INTEGRAL/SPI. The pulsed flux measured with RXTE/PCA from 1999-2010 was consistent with the pulsar spin-down, indicating that the observed changes were nebular. From 2001 to 2010, the Crab nebula flux measured with RXTE/PCA was particularly variable, changing by up to ~3.5% per year in the 15-50 keV band. These variations were confirmed with INTEGRAL/SPI starting in 2003, Swift/BAT starting in 2005, and Fermi GBM starting in 2008. Before 2001 and since 2010, the Crab nebula flux has appeared more stable, varying by less than 2% per year. At higher energies, above 50 keV, the Crab flux appears to be slowly recovering to its 2008 levels. I will present updated light curves in multiple energy bands for the Crab nebula, including recent data from Fermi GBM, Swift/BAT, INTEGRAL, MAXI, and NuSTAR and a 16-year long light curve from RXTE/PCA. We will compare these variations to higher energies as well, e.g. Fermi LAT.

Author(s): Colleen Wilson-Hodge[12], Michael L. Cherry[9], Gary L. Case[7], Wayne H. Baumgartner[2], Elif Beklen[13], Narayana P. Bhat[14], Michael Stephen Briggs[14], Rolf Buehler[3], Ascension Camero-Arranz[4], Valerie Connaughton[14], Roland Diehl[10], Mark H. Finger[16], Neil Gehrels[11], Jochen Greiner[10], Fiona Harrison[1], Elizabeth A. Hays[11], Keith Jahoda[11], Peter Jenke[14], R. Marc Kippen[8], Chryssa Kouveliotou[12], Hans A. Krimm[2], Erik Kuulkers[6], Kristin Madsen[1], Craig Markwardt[11], Charles A. Meegan[14], Lorenzo Natalucci[5], William Simon Paciesas[16], Robert D. Preece[14], James Rodi[9], Nikolai Shaposhnikov[2], Gerald K. Skinner[15], Douglas A. Swartz[16], Andreas von Kienlin[10], Xiao-Ling Zhang[10]
Institution(s): *1. CalTech, 2. CRESST & NASA/GSFC, 3. DESY, 4. IEECC-CSIC, 5. INAF-IASF, 6. ISOC/ESA/ESAC, 7. La Sierra Univ., 8. LANL, 9. LSU, 10. MPE, 11. NASA's GSFC, 12. NASA's MSFC, 13. SDU/NRAO, 14. UAH, 15. Univ. of Birmingham, 16. USRA/MSFC*

214.02 – Spectra and Polarization from Comptonized Emission in Magnetar Flares

Magnetar flares exhibit extremely large luminosities, usually far in excess of the non-magnetic Eddington limit for neutron stars. The energetics of these outbursts implies large Thomson optical depths. Their spectra in the 2-200 keV band drive the expectation that Comptonized emission is present. The spectra observed from the storm of bursts in SGR J1550-5418 in January 2009 are compatible with a sum of two blackbodies (or more), which can be physically interpreted as hot regions in disparate locations in the neutron star magnetosphere. In strong magnetic fields, there are different Compton scattering cross sections for the two linear polarization modes, and furthermore these become resonant at the cyclotron frequency. These generate different opacities and different locales for the photospheres associated with the two modes. Considering the polarization of emission provides a natural way to explain the dual blackbody spectral fits. In order to address these observations, we are developing a spectral model of polarized radiation transfer due to Compton scattering in superstrong magnetic fields. We use a Monte Carlo simulation to examine the spectrum, polarization and anisotropy of photons emerging from a region of prescribed magnetic field and electron density. The initial results indicate that the emergent spectrum is often dominated by the extraordinary polarization mode near and below the cyclotron frequency for different values of the magnetic field strength and optical depth in the Thomson regime.

Author(s): Joseph Barchas[1], Matthew G. Baring[1]
Institution(s): *1. Rice University*

214.03 – X-ray jets from B2224+65: A Middle-aged Pulsar's New Trick

Pulsars, though typically not aged ones, are believed to be an important source of energetic cosmic rays. Therefore, it may not be too surprising to detect an X-ray jet associated with the middle-aged radio/X-ray pulsar B2224+65, which is well known for its very high proper motion and its trailing ``Guitar Nebula''. Most unexpected, however, is that this jet is offset from its proper motion direction by 118 degree. Furthermore, an X-ray counter jet and a faint X-ray trail associated with the ``Guitar Nebula'' are now identified in the combined data set of three epoch Chandra observations with a total exposure of 200 ks. We are carrying out a detailed measurements of the X-ray spectral variation with time and across the jets and are critically testing scenarios proposed to explain this enigmatic phenomenon. The study should have strong implications for understanding the origin of cosmic rays, as well as similar linear nonthermal X-ray-emitting features that are associated with more distant pulsars, especially pulsar wind nebula candidates in the central 100 pc region of the Galaxy.

Author(s): Q. Daniel Wang[1], Seth Johnson[1]
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214.04 – X-ray analysis of the proper motion and PWN for PSR J1741-2054

We report on the X-ray analysis of PSR J1741-2054 carried out as a part of the Chandra XVP program (6 ACIS-S observations, totalling ~300 ks over 5 months). By registering this new epoch of observations using X-ray point sources in the field of view to an archival observation taken 3.2 years earlier, we are able to measure the proper motion of the pulsar with $>3\sigma$ significance. We also investigate the spatial and spectral properties of the pulsar, its compact nebula and extended tail. We find that the compact nebula can be well described with an absorbed power-law with photon index of $\Gamma=1.6+/-0.2$, while the tail shows no evidence of variation in the spectral index with the distance from the pulsar. We have also investigated the X-ray spectrum of the neutron star. We find non thermal emission accompanied by a significant thermal component and will provide constraints on the overall nature of the emission.

Author(s): Katie Auchettl[2], Patrick O. Slane[2], Roger W. Romani[4], Oleg Kargaltsev[1], George G. Pavlov[3]
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214.05 – New view of the Vela pulsar from Fermi LAT

The Vela pulsar (PSR J0835-4510) is the brightest persistent source in the GeV sky, and the Large Area Telescope (LAT)

onboard Fermi has so far characterized this pulsar with unparalleled precision. These results are now further improved thanks to Pass 8, the new event reconstruction and selection strategy developed by the Fermi LAT Collaboration. We will report on the most recent results on the Vela pulsar, obtained using a larger dataset and the new Pass 8 performance. We will show an highly-detailed characterization of the light curve at different energies, as well as a spectrum that extends to lower and higher energy than before. These are the most detailed results obtained so far on a gamma-ray pulsar and are crucial to better constrain theoretical models and provide a more detailed insight into the physics of pulsar magnetospheres.

Author(s): Giovanna Pivato[3], Philippe Bruel[1], Alice Kust Harding[2], Massimiliano Razzano[3]
Institution(s): *1. LLR - Ecole Polytechnique, 2. NASA Goddard Space Flight Center, 3. University of Pisa*
Contributing team(s): Fermi LAT Collaboration

214.06 – Two-Photon Pair Creation Opacities in Gamma-Ray Pulsars

A major portion of the Fermi mission's legacy is centered on its enormous increase in the gamma-ray pulsar database. This has included the identification of exponential maximum energy turnovers in the 1-10 GeV window in the majority of Fermi pulsars. This regulation is remarkable given the wide disparities in light cylinder radii and field strengths there, and also spin-down luminosities among the pulsar population. It is distinctly possible that magnetospheric attenuation of GeV gamma-rays via two-photon pair creation with surface X-rays can cause or contribute to the formation of these turnovers. This paper computes two-photon pair opacities for a comprehensive range of altitudes, colatitudes and surface X-ray temperatures and latitudinal distributions. In a handful of middle-aged pulsars with observed thermal X-ray spectra, their pulse profiles, coupled with gamma-ray diagnostics on rotator obliquity and observer viewing angles, are used to constrain the surface X-ray distribution. It is found that for the major portion of the magnetosphere, excepting near the stellar surface and in the equatorial light cylinder zones, the pair opacity is insufficient to generate the observed turnovers for typical surface temperatures, indicating that the accelerating gap potentials do not vary substantially from pulsar to pulsar.

Author(s): Matthew G. Baring[1], Sarah Story[1]
Institution(s): *1. Rice University*

214.07 – Magnetoluminescence - Rapid Release of Electromagnetic Energy in Relativistic Sources

Pulsar Wind Nebulae, relativistic jets and Gamma Ray Bursts all seem to be capable of the rapid release of electromagnetic energy applied in the form of toroidal magnetic field through the acceleration of TeV-PeV electrons and the emission of gamma rays, a process we style as “magnetoluminescence”. It is suggested that the magnetic field in these sources organizes itself into discrete, current-carrying “ropes” which become increasingly knotted, linked and tangled following topology-changing reconnection. It is tempting to associate this reconnection with quasi-steady acceleration of intermediate energy electrons. However, there may also be dramatic untanglings of the ropes without serious change in topology and these can create large, space-filling, inductive electric field which may be responsible for the largest flares. These events may be followed by implosion which can augment the energy release.
Some new approaches to describing magnetoluminescent flaring in cosmic sources will be presented.

Author(s): Roger D. Blandford[1], Yajie Yuan[1], Jonathan Zrake[1]
Institution(s): *1. KIPAC, Stanford University*

214.08 – The Neutron Star Interior Composition Explorer (NICER) mission: post-CDR status update

NASA's Neutron Star Interior Composition Explorer (NICER), in development for deployment to the International Space Station as an external attached payload, will address decades-old questions about the structure, dynamics, and energetics of neutron stars through high-precision timing of the soft X-ray emissions of rotation- and accretion-powered pulsars. NICER's performance in timing, spectroscopy, and high-throughput sensitivity to 0.2–12 keV X-rays represents a substantial enhancement over existing capabilities, enabling a rich diversity of investigations in both neutron star science as well as broader X-ray astrophysics, the latter through a proposed Guest Observer program. Having successfully passed its Critical Design Review in September 2014, the NICER development team is proceeding with implementation of flight systems. This talk briefly summarizes the NICER design and the status of hardware fabrication and testing, currently on pace to deliver the NICER payload for its planned launch in late 2016.

Author(s): Zaven Arzoumanian[1], Keith Gendreau[1]
Institution(s): *1. NASA/GSFC*
Contributing team(s): NICER Team

214.09 – Determining neutron star masses and radii via analysis of NICER energy-resolved waveform data

The masses and radii of neutron stars, if precisely and accurately known, would provide invaluable information about the properties of cold matter at several times nuclear saturation density. One promising way to obtain this information involves the analysis of the energy-resolved waveforms produced by hot spots on rotating neutron stars. Indeed, this is the prime method that will be used by the upcoming NASA mission NICER (Neutron star Interior Composition Explorer). We have developed sophisticated new Bayesian analysis methods that enable us to estimate quickly the masses and radii of rapidly rotating, oblate neutron stars using the energy-resolved waveforms of their X-ray burst oscillations and to determine the uncertainties in these mass and radius estimates. We find that fits to synthetic data that have realistic modulation amplitudes and total counts comparable to the number that could be obtained with NICER determine the gravitational mass M and the equatorial circumferential radius R_eq to within 3%-7% for rotation rates >300 Hz and spot and observer inclinations >60 degrees. We also find that fitting a model that assumes a uniform-temperature spot to waveforms generated using a spot in which the temperature varies with latitude by 25% does not significantly bias M and R_eq estimates. Thus, although more work needs to be done, this method appears to be relatively robust against systematic deviations from our model assumptions as well as being able to yield precise masses and radii for favorably oriented systems.

Author(s): M. Coleman Miller[1], Frederick K. Lamb[2]
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215 – HAD VI: History of Astronomy

215.01 – Hawaii and the Real-Time Evolution of Cultural Astronomy

While the field of historical astronomy is often interested in the ways that astronomical conceptions change over time, the majority of that work involves discussions of cultural evolution in the distant past. Hawaii provides an interesting case study, in that it involves near-time and real-time examples of the de-evolution of a culture's astronomy knowledge (via colonization), and a renaissance of that knowledge through research, sociocultural exchange, practical application, and a willingness to embrace cultural fusion and a modern era. This paper presents a brief summary of the forces that have shaped, and are currently shaping, an ancient and very modern model of the known sky, from primary documents, field notes and observations.

Author(s): Stephanie Slater[2], Ahia Dye[2], Celeste Ha'o[1], Timothy F. Slater[2], Kalepa Chad Baybayan[1], Rubellite Johnson[2], John Mahelona[2], Clive Ruggles[2]
Institution(s): *1. 'Imiloa Astronomy Center, 2. CAPER Ctr Phys and Astro Educ Res*

215.02 – Kilohoku - Hoʻokele Waʻa: Hawaiian Navigational Astronomy

Over thousands of years of Pacific Basin settlement, Polynesians developed a complex, scientific understanding of the cosmos, including a generative view of the celestial sphere. Memorizing the location and spatial relationships of hundreds of stars, across changing latitudes, this astronomy was one of the four scientific knowledge bases Polynesians used to navigate thousands of miles, across open water, without instrumentation. After Western colonization, this large body of knowledge was nearly lost to Hawaiians. Since the Hawaiian Renaissance, much of this knowledge has been reconstructed, and is again in use in open oceanic navigation. While some of this knowledge has been shared with the broader public, much of what we know has been unavailable to those beyond the family of navigators. This paper represents an attempt to begin sharing this catalog of knowledge with the outside world, with the hopes that the larger community will appreciate the complexity of astronomical knowledge possessed by navigators, and that the international body of astronomy historians will help insure that this knowledge will not be lost again. This paper will present, Na ʻOhanahōkū, the Hawaiian star families that divide the celestial sphere into four wedges, running from the circumpolar north, beyond the horizon to the south. Na Hoku Huihui, or Hawaiian constellations will be discussed, in addition to a brief introduction to the setting and rising pairs that are used to determine direction and latitude.

Author(s): Ahia Dye[1], Celeste Ha'o[1], Timothy F. Slater[3], Stephanie Slater[2]
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215.03 – Tracking the Origins of an Ancient Star Scene on a Nova Scotian Chancel Ceiling

The recent reconstruction of St. John’s Church in Lunenburg, Nova Scotia, a World Heritage Site, following a disastrous 2001 fire, led to the 2004 discovery that the chancel ceiling star pattern emplaced in 1870-72 was designed to replicate the sky seen locally at the traditional beginning of the first Christmas. The resulting media blitz following the discovery generated several unanswered questions: who designed the original pattern?, who was the artist responsible for the work?, and why was such a scene used at St. John’s? Further research into such questions has made little progress, mainly because there is no direct archival evidence related to the events of 1870-72. Indirect archival clues are more revealing, however, and lead to a likely scenario that explains all available evidence, including why Lunenburg residents referred to the original star pattern as “the Mariner’s Sky.” The original work appears to have been completed under the guise of a Canadian Confederation project, and provides graphic evidence for more extensive astronomical expertise in

Nova Scotia in that era than previously believed.

Author(s): David G. Turner[1]
Institution(s): *1. Saint Mary's Univ.*

215.04 – Universe boundary in Einstein 1931 same as Lemaître 1927

Einstein and Lemaître derived the same boundary for our universe, independently. Both may have been on the right track. Einstein's unpublished 1931 dynamic equilibrium theory - only recently reported - is a hybrid theory of general relativity incorporating both dynamic and static theories. In its basics, it is identical to Lemaître's 1927 dynamic equilibrium theory, also reported on only recently. Both dynamic equilibrium theories are based on the same relationship between Einstein's gravitational constant, κ, rest matter density, ρ, and radius, r, and the same equation, namely: $1 = \kappa\rho r^2$. Because the dynamic equilibrium theory has finite limits, it gives us testable and realistic estimates of the universe's age, virial radius and mass, and Hubble constant of expansion. Those estimates are 14.2 Gyr, 14.2 Gly, 9.12×10^{22} solar mass, and $H = 68.7$ km/s/Mpc, respectively. Abundant observational evidence supporting those estimates means cosmology might be on the verge of a revolution. Because of the relatively recent discovery of vacuum energy, cosmology could come full circle back to an old idea abandoned by two of the greatest cosmologists: dynamic equilibrium. Quintessentially, a vacuum energy filled universe in balance, changing but always steady, eternal but ever-reborn, is exactly what we observe.

Author(s): Ian Steer[1]
Institution(s): *1. NED*

215.05 – 400th Anniversary of Marius's Book with the First Image of an Astronomical Telescope and of Orbits of Jovian Moons

Simon Mayr's (Marius's) *Mundus Iovialis Anno M·DC·IX Detectus Ope Perspicilli Belgici* (*The World of Jupiter...*) was published in Nuremberg in 1614; Marius was the Ansbach court mathematician. The frontispiece includes not only a portrait of Marius (1573-1624) himself but also, in the foreground, a long tube labelled "perspicillum," the first known image of a telescopic device used for astronomy; the name "telescope" came later. A schematic diagram of Jupiter with four moons orbiting appears at upper left; Marius, following a suggestion from Kepler, gave these Galilean satellites the names now still in use: Io, Europa. Ganymede, and Callisto. The title continues *Hoc est, Quatuor Joviali cum Planetarum, cum Theoria, tum Tabulae, Propriis Observationibus Maxime Fundate....* A pair of conferences was held in Germany in 2014 to commemorate the 400th anniversary of Marius's book and to discuss Marius's work and its relation to Galileo's work (http://www.simon-marius.net; http://www.simon-marius.net/index.php?lang=en&menu=1; 28 languages are available). Marius (Mayr) had independently discovered the four satellites of Jupiter, apparently one day after Galileo, on December 29 O.S., 1609; by the time he published his work four years later (a local-circulation publication had appeared in Nuremberg in 1611 in *Prognosticon Astrologicum auf das Jahr 1612*), Galileo had gained fame and priority, and Galileo accused Marius of plagiarism in *Il Saggiatore* (1623). With his Belgian telescope, Marius also noted the tilt of the orbital plane of Jupiter's moons, sunspots (1611), and the Andromeda Nebula (1612). He claimed to have worked out a system of cosmology similar to the Tychonic system in 1596, contemporaneously to Kepler's *Mysterium Cosmographicum.* A crater, the Marius Hills, and the Rima Marius on the Moon are named for him by the I.A.U., as well as, to celebrate the quadricentennial, a main-belt asteroid, now (7984) Marius. *Acknowledgment:* JMP thanks Seth Fagen, PRPH Books in New York, for introducing him to Marius's book 18 years ago.

Author(s): Jay M. Pasachoff[2], Pierre Leich[1]
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215.06 – A Modern Update and Usage of Historical Variable Star Catalogs

One of the earliest modern variable star catalogs was constructed by Henrietta Swan Leavitt during her tenure at the Harvard College Observatory (HCO) in the early 1900s. Originally published in 1908, Leavitt's catalog listed 1777 variables in the Magellanic Clouds (MCs). The construction and analysis of this catalog allowed her to subsequently discover the Cepheid period-luminosity relationship, now known as the Leavitt Law. The MC variable star catalogs were updated and expanded by Cecilia Payne-Gaposchkin in 1966 and 1971. Although newer studies of the MC variables have been performed since then, the new information has not always been correlated with the old due to a lack of modern descriptors of the stars listed in the Harvard MC catalogs. We will discuss the history of MC variable star catalogs, especially those compiled using the HCO plates, as well as our modernized version of the Leavitt and Payne-Gaposchkin catalogs. Our modern catalog can be used in conjunction with the archival plates (primarily via the Digital Access to a Sky Century @ Harvard scanning project) to study the secular behavior of the MC variable stars over the past century.

Author(s): Ashley Pagnotta[1], Or Graur[2], Zachary Murray[1], Julia Kruk[1], Lucien Christie-Dervaux[1], Dong Yi Chen[1]
Institution(s): *1. American Museum of Natural History, 2. New York University*

215.07 – What Can a Historian Do with AstroGen?

"Astrogen", the Astronomy Genealogy Project, is in the development stage. Patterned after the Mathematics Genealogy Project at http://genealogy.math.ndsu.nodak.edu, it will eventually include most of the world's astronomers, past and present, and provide information about their years of life, highest degrees, universities, and thesis titles. There will also be links to online theses, home pages, and obituaries when these are available. Although a few details remain to be worked out before it becomes public, it is possible to make some use of what has already been compiled. I will give an example, comparing graduates of Harvard University, the University of California at Berkeley, and the University of Chicago from different decades, with information about their professional careers and publication records. The author welcomes queries about AstroGen and is seeking more participants.

Author(s): Joseph S. Tenn[1]
Institution(s): *1. Sonoma State Univ.*

216 – Dust

216.01 – The Origin of Dust in the Magellanic Clouds

The nature and origin of interstellar dust are still not well understood. Models of dust evolution in galaxies have shown that the dust destruction rate by SN shocks in the interstellar medium (ISM) exceeds the dust injection rates by stellar sources and supernovae (SNe), and that these source cannot account for the dust masses observed in neither low nor high redshift galaxies. This discrepancy may be explained by either a significant overestimate of the amount of dust destruction, or an additional source of dust that we are not accounting for. I will present detailed estimates of the dust destruction rates in the Magellanic Clouds (MCs), derived using a complete sample of resolved supernova remnants and observations of their local environments. Our study concludes that the dust destruction rate in the MCs is significantly higher than the maximum injection rate by massive stars and SNe, and suggests that grain growth in dense molecular clouds may be an important source of dust in the ISM. I will also discuss the implications of our study for models of dust evolution in other galaxies.

Author(s): Tea Temim[1]
Institution(s): *1. NASA GSFC*

216.02D – A Unified Model of Polarized Extinction and Emission from Interstellar Dust

Through full-sky observations of the polarized intensity of Galactic dust emission, the Planck satellite has furnished important new constraints on the composition, size, and shape of interstellar grains. We present new models of interstellar dust consisting of silicate and carbonaceous components of spheroidal shape that are consistent with available data on interstellar abundances, polarized and total extinction, and polarized and total emission in the diffuse interstellar medium. Possible contributions from ferromagnetic iron are also considered, including the polarization signatures of this component. We discuss updates to the Draine and Li 2007 optical properties of these components on the basis of new data, and present models that successfully reproduce the observed relatively flat NIR extinction curve. Finally, we discuss the prospects of extending our models to probe physical variations in the grain population in various Galactic environments, such as regions of high extinction, and in extragalactic sources, such as the Magellanic Clouds.

Author(s): Brandon Hensley[1], Bruce T. Draine[1]
Institution(s): *1. Princeton University*

216.03 – *Spitzer*-IRS Spectroscopic Studies of Oxygen-Rich Asymptotic Giant Branch Star and Red Supergiant Star Dust Properties

We analyze the dust emission features seen in *Spitzer Space Telescope* Infrared Spectrograph (IRS) spectra of Oxygen-rich (O-rich) asymptotic giant branch (AGB) and red supergiant (RSG) stars. The spectra come from the Spitzer Legacy program SAGE-Spectroscopy (PI: F. Kemper) and other archival Spitzer-IRS programs. The broad 10 and 20 micron emission features attributed to amorphous dust of silicate composition seen in the spectra show evidence for systematic differences in the centroid of both emission features between O-rich AGB and RSG populations. Radiative transfer modeling using the GRAMS grid of models of AGB and RSG stars suggests that the centroid differences are due to differences in dust properties. We present an update of our investigation of differences in dust composition, size, shape, etc that might be responsible for these spectral differences. We explore how these differences may arise from the different circumstellar environments around RSG and O-rich AGB stars. BAS acknowledges funding from NASA ADAP grant NNX13AD54G.

Author(s): Benjamin A. Sargent[4], Sundar Srinivasan[1], Angela Speck[8], Kevin Volk[6], Ciska Kemper[1], William T. Reach[5], Eric Lagadec[2], Jean-Philippe Bernard[3], Iain McDonald[7], Margaret Meixner[6]

Institution(s): *1. Academia Sinica, Institute of Astronomy and Astrophysics, 2. Cornell University, 3. IRAP/CNRS, 4. Rochester Institute of Technology, 5. SOFIA/USRA, 6. Space Telescope Science Institute, 7. The University of Manchester, 8. University of Missouri*

216.04 – Dust and metallicity in carbon stars

The Infrared Spectrograph on the Spitzer Space Telescope observed over 200 carbon stars in nearby metal-poor dwarf galaxies. These spectra probe how the quantity and composition of dust produced by carbon stars depend on initial metallicity, initial mass, and pulsational properties. For stars to produce significant quantities of dust, they must be pulsating in the fundamental mode with strong amplitudes. The spectra confirm that carbon stars with longer pulsation periods produce more dust and that the amount of dust shows no strong dependence on metallicity. This sample includes more carbon stars with low mass and reveals that for a given pulsation period, higher-mass stars produce less dust. Evidence is building for the layering of dust grains, with SiC cores in grains produced by metal-rich carbon stars, and mantles of MgS around grains in all embedded stars.

Author(s): Gregory C. Sloan[2], Martin Groenewegen[7], Sundar Srinivasan[1], Eric Lagadec[6], Kathleen E. Kraemer[3], Iain McDonald[4], Martha L. Boyer[5], Albert Zijlstra[4], Ciska Kemper[1]
Institution(s): *1. Academia Sinica Institute for Astronomy and Astrophyics, 2. CRSR, Cornell University, 3. Inst. for Scientific Research, Boston College, 4. Jodrell Bank Centre for Astrophysics, 5. NASA Goddard Space Flight Center, 6. Observatoire de la Cote d'Azur, 7. Royal Observatory of Belgium*

216.05 – A Test of Dust Grain Alignment via Far-Infrared Polarization

Interstellar dust grains are aligned with their physical and spin axes parallel to the ambient magnetic field. This fact is supported by polarization observations from ultraviolet to millimeter wavelengths. The radiative torque (RT) mechanism, by which the grains become aligned, has recently survived a number of specific observational tests. One such observation is the relation between the alignment efficiency and the angle between the magnetic field and the radiation responsible for the RTs. The interaction of light with irregularly shaped grains results in a net torque and spin-up of the grain, while magnetization arising within a spinning grain results in precession of the spin axis about the magnetic field. The combination of these two effects leads to alignment of the grain with the field and predicts a correlation between alignment efficiency and the angle between the radiation- and magnetic- field directions. Andersson et al. (2011, A&A, 534, A19) showed that the alignment efficiency, centered on the star HD 97300, varied with angle about the star with a 180-degree period, consistent with theory. While the geometry towards HD 97300 provides a strong test of the RT-vs.-angle prediction, finding such simple geometries for further tests is difficult. Here we identify a similar geometry towards the Becklin-Neugebauer/Kleinmann-Low (BNKL) object in the Orion molecular cloud. Using polarized emission at 100, 350, and 850 micron we find a clear periodic signal in polarization vs. azimuth centered on BNKL, again, in agreement with RT theory predictions. Additionally, the signal is stronger at shorter wavelengths, as would be expected if the same photons providing the RTs are also heating the dust grains.

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217 – Cannon Award: New Frontiers in Stellar Astrophysics: Massive Stars as Cosmological Tools, Emily Levesque (University of Colorado Boulder)

217.01 – New Frontiers in Stellar Astrophysics: Massive Stars as Cosmological Tools

Massive stars are crucial building blocks in the study of star-forming galaxies, stellar evolution, and transient events, and their applications as fundamental astrophysical tools span a broad range of subfields. Unfortunately, many key traits of massive stars - from their physical properties and ionizing radiation to their evolution and core-collapse deaths - remain poorly understood. I will discuss several current research programs focused on developing a comprehensive picture of massive stars across the cosmos. These include observational surveys and population synthesis models of star-forming galaxies; progenitor and host environment studies of transient phenomena such as supernovae and gamma-ray bursts; and the remarkable reach of extragalactic stellar observations, which recently led to the discovery of the first Thorne-Zytkow object candidate. With cutting-edge theoretical models and the capabilities of current ground-based and orbital observatories, we are ideally poised to make substantial progress in our understanding of massive stars over the coming decade. This in turn will equip us with the tools we need to take full advantage of the frontiers opened up by new observational facilities such as JWST, the ELTs, and LSST, allowing us to immediately begin probing the new corners of the universe that they reveal.

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Institution(s): *1. University Of Colorado Boulder*

219 – Extrasolar Planets: Ground and Space Based Surveys II

219.01D – Aiming for the next bright super earth — Synergies of Ground and Space based Transiting Planets Survey

With the great success of the Kepler space mission, our knowledge of Exoplanets has been dramatically extended. Nevertheless, ground based transit surveys pioneered the searching of transiting planets and developed many state-of-art techniques widely adopted by the transit community. The HATNet project is one of the most fruitful ground based transit surveys. Been operated for ~10 years, the survey yields ~50 HAT planets, constitute one fourth of the known population with accurate (<=10%) mass determinations.
During the operation of Kepler Mission, HATNet team used our state-of-art pipeline and our long terms of observations in Kepler field to assist the analysis of Kepler data and the discovery of new candidates. The large sky coverage of HAT observations will provide continuous supports for the ongoing and future space based transit missions, such as K2 and TESS.
On the other hand, we are able to learn about our noise characteristics and candidate selection limitations with the high precision photometric data from Kepler and our simultaneous observations.
By exploiting synergies between ground based transit surveys and space transit missions, we'll be able to progress towards discover of bright super earths that are suitable for follow up spectroscopic observations to investigate their atmosphere properties and chemical compositions.
In this talk, I will first briefly review the contributions from the HATNet team in the Kepler mission. I will then present our latest effort in improving the yields and statistics of ground based transit surveys by simultaneous observations of Kepler's field and employing machine learning techniques in our candidate selection processes. To finish up, I'll demonstrate the roles ground based transit surveys would play in the context of K2 and TESS.

Author(s): Xu Huang[1], Gaspar Bakos[1], Joel Hartman[1]
Institution(s): *1. Princeton University*
Contributing team(s): HATNet Team

219.02D – Transits and Occultations of Hot Jupiters

Astronomy has rapidly progressed from the first discovery of an extrasolar planet less than two decades ago to today's age of abundant exoplanet characterization observations. However, interpretation of these observations remains challenging. Resolved spectra of exoplanets, particularly in the infrared, where strong features due to H^2O, CO, CO^2, and CH^4 are expected, could break model degeneracies and answer many questions about C/O ratios and pressure-temperature atmospheric structures. While not the first, Wide Field Camera 3 (WFC3) on the Hubble Space Telescope is the only current space-based opportunity to study spectrally resolved exoplanet atmospheres in the infrared. We focus on hot Jupiter type exoplanets, and use WFC3 (as well as ancillary data from Spitzer and ground based facilities) to try to break degeneracies between models, resolve past observing conflicts, and determine these planets' atmospheric composition and structure. I report spectroscopic analysis of the transit of WASP-17 b, the occultation of WASP-4 b and WASP-33 b, and both the transit and occultation of WASP-12 b and WASP-19 b. I analyze the data for each planet using a strategy similar, in certain aspects, to the techniques used by Berta et al. (2012), but extend their methodology to allow for correction of channel- or wavelength-dependent instrumental effects by utilizing the band-integrated time series and measurements of the drift of the spectrum on the detector over time. For WASP-33 we find evidence for an oxygen rich atmosphere. The final transit spectra for all three objects in the study are consistent with the presence of a broad absorption feature at 1.4 µm most likely due to water. However, the amplitude of the absorption is less than that expected based on previous observations with Spitzer, possibly due to hazes absorbing in the NIR or non-solar compositions. The degeneracy of models with different compositions and temperature structures combined with the low amplitude of any features in the data preclude our ability to place unambiguous constraints on the atmospheric composition without additional observations with WFC3 to improve the signal-to-noise ratio and/or a comprehensive multi-wavelength analysis.

Author(s): Korey Haynes[1]
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219.04 – ExoEarth Yield Estimates for a Future Large Aperture Direct Imaging Mission

ExoEarth yield is a critical science metric that will constrain the required aperture of a future exoplanet-imaging mission. I will present a numerically efficient method for maximizing the yield of exoEarth candidates by simultaneously optimizing the exposure time of every star, number of visits per star, and delay time between visits, while maximally adapting the target list to the mission's capabilities. This method can potentially double the exoEarth candidate yield compared to previous methods. I will show how the yield scales with mission parameters, including aperture size and high level coronagraph parameters, and address the impact of astrophysical uncertainties on exoEarth yield.

Author(s): Christopher C. Stark[2], Aki Roberge[2], Avi Mandell[2], Shawn Domagal-Goldman[2], Karl R. Stapelfeldt[2], Tyler Robinson[1]
Institution(s): *1. NASA Ames Research Center, 2. NASA Goddard Space Flight Center*

219.05 – Defining A Risk Analysis Strategy for Exo-Earth Yields from a Future Large Aperture UVOIR Space Telescope

The discovery and characterization of Earth-like planets around Sun-like stars using high-contrast imaging is a critical science metric for constraining the requirements on the next-generation large UVOIR space telescope. The dominant driver for the observatory architecture, cost and schedule is the telescope aperture size. Therefore it is important to provide as much constraint as possible on the required aperture size early in the design and planning process.
An estimate of the detection yield for Earth-like planets can be calculated using a Monte Carlo simulation of a design reference mission (DRM), allowing the exploration of a variety of mission design and astrophysical parameters. We have developed such a code (Stark et al. 2014); it optimizes the target list and exposure times to maximize mission yield for a specific set of mission parameters. However, many of the important astrophysical quantities and future technical capabilities that feed into these parameters are not well constrained. This leads to a large uncertainty in the final mission architecture needed to achieve a specific exo-Earth yield.
In this presentation we discuss the various physical and technological parameters that go into the DRM simulations, and the associated uncertainties based on the current state of research. We then present a strategy for a three-tiered risk assessment using these uncertainties, and conclude with a discussion of the current range in telescope aperture size associated with each risk level.

Author(s): Avi Mandell[2], Christopher C. Stark[2], Aki Roberge[2], Shawn Domagal-Goldman[2], Karl R. Stapelfeldt[2], Tyler Robinson[1]
Institution(s): *1. NASA ARC, 2. NASA GSFC*

219.06 – Visible Wavelength Exoplanet Phase Curves from Global Albedo Maps

To investigate the effect of three-dimensional global albedo maps we use an albedo model that: calculates albedo spectra for each points across grid in longitude and latitude on the planetary disk, uses the appropriate angles for the source-observer geometry for each location, and then weights and sums these spectra using the Tschebychev-Gauss integration method. This structure permits detailed 3D modeling of an illuminated planetary disk and computes disk-integrated phase curves. Different pressure-temperature profiles are used for each location based on geometry and dynamics. We directly couple high-density pressure maps from global dynamic radiative-transfer models to compute global cloud maps. Cloud formation is determined from the correlation of the species condensation curves with the temperature-pressure profiles. We use the detailed cloud patterns, of spatial-varying composition and temperature, to determine the observable albedo spectra and phase curves for exoplanets Kepler-7b and HD189733b. These albedo spectra are used to compute planet-star flux ratios using PHOENIX stellar models, exoplanet orbital parameters, and telescope transmission functions. Insight from the Earthshine spectrum and solid surface albedo functions (e.g. water, ice, snow, rocks) are used with our planetary grid to determine the phase curve and flux ratios of non-uniform Earth and Super Earth-like exoplanets with various rotation rates and stellar types. Predictions can be tailored to the visible and Near-InfraRed (NIR) spectral windows for the *Kepler* space telescope, *Hubble* space telescope, and future observatories (e.g. WFIRST, JWST, Exo-C, Exo-S). Additionally, we constrain the effect of exoplanet urban-light on the shape of the night-side phase curve for Earths and Super-Earths.

Author(s): Matthew Webber[1], Kerri Lynn Cahoy[1]
Institution(s): *1. Massachusetts Institute of Technology*

219.07 – Studying Atmosphere-Dominated Kepler Phase Curves

We identify three Kepler transiting planet systems, Kepler-7b, Kepler-12b, and Kepler-41b, whose orbital phase-folded light curves are completely dominated by atmospheric processes including thermal emission and reflected light, while the impact of other processes, beaming (Doppler boosting) and tidal ellipsoidal distortion, is negligible. Therefore, these systems allow a direct view of their atmospheres, in visible light, without being hampered by the approximations used in the inclusion of both atmospheric and non-atmospheric processes while modeling the phase curve shape. We model Kepler-12b and Kepler-41b atmosphere based on their Kepler phase curve, while the modeling of Kepler-7b was already presented elsewhere. We confirm Kepler-12b and Kepler-41b show a westward phase shift between the brightest region on the planetary surface and the substellar point, similar to Kepler-7b. We find that reflective clouds located on the west side of the substellar point can best explain the phase shift. The identification of a bright-spot shift in all three systems we studied suggests it occurs also in other phase curves, where both atmospheric and non-atmospheric effects are present and where accounting for it can present a degeneracy in the model. Finally, the relatively large albedo measured for these three transiting planets suggests that the photometric modulations induced by reflected light in non-transiting but otherwise similar planets can be used to detect them, although their mass is too small to show a signal from non-atmospheric processes.

Author(s): Avi Shporer[1], Renyu Hu[1]
Institution(s): *1. JPL*

220 – Cosmic Microwave Background

220.01D – Measuring the cosmic microwave background polarization with POLARBEAR

POLARBEAR is a cosmic microwave background (CMB) polarization experiment located in the Atacama desert in Chile. POLARBEAR-1 started observations in 2012, and in 2014, the POLARBEAR team published results from its first season of observations on a small fraction of the sky. These results include the first measurement of a non-zero B-mode polarization angular power spectrum, measured at sub-degree scales where the dominant signal is gravitational lensing of the CMB. We also published a measurement of the large-scale gravitational structure deflection power spectrum derived from CMB polarization alone, which demonstrates a powerful technique that can be used to measure nearly all of the gravitational structure in the universe. Improving these measurements requires precision characterization of the CMB polarization signal over large fractions of the sky, at multiple frequencies. To achieve these goals, POLARBEAR has begun expanding to include an additional two 3.5 meter telescopes with multi-chroic receivers, known as the Simons Array. Phased upgrades to receiver technology will improve sensitivity and capabilities, while continuing a deep survey of 80% of the sky. POLARBEAR-2 is the next receiver that will be installed in 2015 on a new telescope, with a larger area focal plane with dichroic pixels, with bands at 95 GHz and 150 GHz, and a total of 7,588 polarization sensitive antenna-coupled transition edge sensor bolometers. The focal plane is cooled to 250 milliKelvin, and the bolometers will be read-out by SQUID amplifiers with 40x frequency domain multiplexing. The array is designed to have a noise equivalent temperature of 5.7 µK√s.

Author(s): Darcy Barron[1]
Institution(s): *1. University of California, San Diego*
Contributing team(s): The POLARBEAR Collaboration

220.02 – SPT-3G: The third generation camera and survey for the South Pole Telescope

We discuss the design and status of the third generation camera, SPT-3G, for the South Pole Telescope (SPT), and the scientific goals of the resultant SPT-3G survey. The SPT is a 10-m telescope located at the NSF Amundsen-Scott South Pole station optimized for low-noise and high-resolution imaging of the cosmic microwave background (CMB). The camera will consist of 16,200 polarization-sensitive transition-edge sensors (TES), contained within 2,700 multichroic pixels with observing bands centered at 95, 150, and 220 GHz. The SPT-3G survey will observe for four years starting in 2016. It will map 2500 square degrees to a depth of approximately 2 µK·arcmin in temperature: an order of magnitude lower noise than current state-of-the-art arcminute-scale surveys over comparable areas. This unprecedented map depth will enable high signal-to-noise imaging of B-modes due to gravitational lensing of the CMB. These measurements will place constraints on the sum of the neutrino masses and the shape and amplitude of an inflationary B-mode signal at larger angular scales. The SPT-3G survey will also detect several thousand clusters, in particular significantly expanding the number of known high-redshift massive clusters, enabling new constraints on gravity and cosmology.

Author(s): Jason Henning[1]
Institution(s): *1. University of Chicago*
Contributing team(s): SPT-3G Collaboration

220.03D – Design, deployment, and early results from ACTPol, a millimeter wavelength, polarization sensitive receiver for the Atacama Cosmology Telescope

We highlight considerations for the design and operation of ACTPol, a new receiver for the Atacama Cosmology Telescope (ACT), capable of making polarization-sensitive, millimeter-wavelength observations of the Cosmic Microwave Background (CMB) at arcminute angular scales. ACT is a six-meter telescope located in northern Chile, dedicated to enhancing our understanding of the structure and evolution of the early Universe by direct measurement of the CMB. We describe the design of the ACTPol focal plane at full-deployment, consisting of dual 150 GHz array package modules and a multichroic array package with simultaneous 90 GHz and 150 GHz sensitivity. Each of these detector array packages reside behind a set of custom-designed, high-purity silicon reimaging optics with a novel anti-reflective coating geometry, the characteristics of which will be detailed. Each array package module consists of ~1000 transition-edge sensor (TES) bolometers used to measure the response of ~500 feedhorn-coupled polarimeters, enabling characterization of the linear orthogonal polarization of incident CMB radiation. The polarimeters are arranged in three hexagonal and three semi-hexagonal silicon wafer stacks, mechanically coupled to an octakaidecagonal, monolithic corrugated silicon feedhorn array (~140 mm diameter). Readout of the TES polarimeters is achieved using time-division SQUID multiplexing. Each array package is cooled using a custom-designed dilution refrigerator providing a sub-100 mK bath temperature to the detectors, which have a target Tc of 150 mK. Given the unique cryomechanical constraints associated with this large-scale monolithic superconducting focal plane, we address the design considerations necessary for integration with the optical and cryogenic elements of the ACTPol receiver. With first light achieved in July 2013 with the first of three polarimeter arrays, and operation now underway with dual 150GHz polarimeter arrays deployed, details of the ACTPol receiver deployment and early results will be highlighted, as well as the outlook for full-deployment operations, projected to begin in early-2015.

Author(s): Benjamin Schmitt[1]
Institution(s): *1. University of Pennsylvania*
Contributing team(s): for the ACTPol Collaboration

220.04D – Gravitational lensing of the CMB with SPTpol

Measurements of gravitational lensing of the cosmic microwave background (CMB) directly probe the projected mass in the universe out to high redshifts. Gravitational lensing encodes a wealth of information in the CMB about the growth and geometry of large-scale structure, which is sensitive to cosmic acceleration (dark energy), the expansion history of the universe and the properties of neutrinos. Additionally, gravitational lensing can be used to improve inflationary gravitational wave searches in the CMB, and constrain the relationship between dark and luminous matter at high redshifts. I will present recent lensing results from the first two years of data from the South Pole Telescope polarimeter (SPTpol) and discuss future opportunities for this powerful technique.

Author(s): Kyle Tyler Story[1]
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Contributing team(s): SPTpol collaboration

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221 – AGN, QSO, Blazars IV

221.01D – AGN accretion, obscuration and star formation in luminous galaxies

We explore the origin of the correlation between the star formation rate (SFR) and the supermassive black hole (SMBH) accretion rate in galaxies. Through the investigation of a large sample of star-forming (SF) galaxies in Boötes, we show that far-IR luminosity is a good proxy for SFR even for galaxies hosting active galactic nuclei (AGN). We divide the SF galaxies into bins of SFR and measure the average SMBH accretion rate with an X-ray stacking analysis. We find a strong correlation between SFR and the average SMBH accretion rate. This highlights that even though the growth rates of the SMBHs and the host galaxies in individual galaxies hosting AGN are not directly correlated due to the short variability timescale of AGN relative to SF, averaging over the full AGN population still yields a strong linear correlation between AGN and and star formation. We also present evidence for a link between nuclear obscuration and host galaxy star formation in the most luminous AGN: quasars. We developed template-based SED fitting codes spanning near-UV to far-IR wavelengths to decompose galaxy and AGN contributions. In combination with stacking analysis in both far-IR and X-ray wavelengths, we confirm that SFR can still be measured with the inclusion of far-IR photometry even in luminous quasars in which AGN radiation outshine the host galaxy at most wavelengths. We find that obscured quasars have ~2 times larger far-IR detection fraction, far-IR flux and SFR than unobscured quasars. The quasar obscred fraction also rises from 0.3 to 0.7 between infrared SF luminosity of $4 - 40 \times 10^{11} L^{sun}$. This suggests that in addition to the orientation-based, pc-scale torus model, the large-scale gas and dust in powerful star-forming galaxies may also be obscuring the AGN radiation in quasars selected based on the presence of hot dust. These results support a scenario in which galaxy and SMBH grow from the same gas reservoir that can also obscures the central SMBH during the luminous quasar phase.

Author(s): Chien-Ting J. Chen[1], Ryan C. Hickox[1], Stacey Alberts[2], Alexandra Pope[2]
Institution(s): *1. Dartmouth College, 2. University of Massachusetts*
Contributing team(s): The Boötes Collaboration

221.02D – Accretion Timescales from Kepler AGN

We constrain AGN accretion disk variability mechanisms using the optical light curves of AGN observed by Kepler. AGN optical fluxes are known to exhibit stochastic variations on timescales of hours, days, months and years. The excellent sampling properties of the original Kepler mission - high S/N ratio (10^5), short sampling interval (30 minutes), and long sampling duration (~ 3.5 years) - allow for a detailed examination of the differences between the variability processes present in various sub-types of AGN such as Type I and II Seyferts, QSOs, and Blazars. We model the flux data using the Auto-Regressive Moving Average (ARMA) representation from the field of time series analysis. We use the Kalman filter to determine optimal mode parameters and use the Akaike Information Criteria (AIC) to select the optimal model. We find that optical light curves from Kepler AGN cannot be fit by low order statistical models such as the popular AR(1) process or damped random walk. Kepler light curves exhibit complicated power spectra and are better modeled by higher order ARMA processes. We find that Kepler AGN typically exhibit power spectra that change from a bending power law (PSD ~ $1/f^a$) to a flat power spectrum on timescales in the range of ~ 5 - 100 days consistent with the orbital and thermal timescales of a typical 10^7 solar mass black hole.

Author(s): Vishal P. Kasliwal[1], Michael S. Vogeley[1], Gordon T. Richards[1]
Institution(s): *1. Drexel University*

221.03 – The Emission Line AGN Census: Biases of Line Ratio Selection, and Uniform Black Hole Accretion Regardless of Galaxy Mass

Optical emission line ratios offer a powerful tool to reveal accretion onto supermassive black holes, with the ability to find both unobscured and obscured active galactic nuclei (AGNs) in extraordinarily large galaxy samples (like the SDSS). I will demonstrate, however, that classic line ratio selection techniques significantly underestimate the AGN fraction by a factor of >10 in low-mass and star-forming galaxies. Previous conclusions that AGNs require massive green-valley hosts are purely a result of this "star formation dilution" bias. Careful treatment of the biases reveals that AGN accretion is uniform across star-forming galaxies of any stellar mass, similar to the results of bias-corrected X-ray AGN studies. This has dramatic implications for AGN feedback in dwarf galaxies and constraints on the black hole seed population.

Author(s): Jonathan R. Trump[2], Gregory Zeimann[2], Stephanie Juneau[1], Mouyuan Sun[2], Cuyler Luck[3]
Institution(s): *1. CEA-Saclay, 2. Penn State, 3. State College High School*

221.04D – Radio-Quiet Quasars in the VIDEO Survey: Evidence for AGN-powered radio emission below 1 mJy

Several lines of evidence suggest that the interaction between active galactic nucleus (AGN) activity and star formation is responsible for the co-evolution of black hole mass with galaxy bulge mass. Therefore studying this interplay is crucial to our understanding of galaxy formation and evolution. The new generation of radio surveys are able to play a key role in this area, as both processes produce radio emission.

We use a combination of optical and near-infrared photometry to select a sample of 72 quasars from the VISTA Deep Extragalactic Observations (VIDEO) Survey, over 1 deg^2. The depth of VIDEO allows us to study very low accretion rates and/or lower-mass black holes. 26% of the candidate quasar sample has been spectroscopically confirmed using the Southern African Large Telescope and the VIMOS VLT Deep Survey. We then use a radio-stacking technique to sample below the nominal flux-density threshold of existing Very Large Array data at 1.4 GHz. In agreement with other work, we show that a power-law fit to the radio number counts is inadequate, with an upturn in the counts being observed at these faint luminosities. Previous authors attribute this to an emergent star-forming population. However, by comparing radio emission from our quasars with that from a control sample of galaxies, we suggest that this emission is predominantly caused by accretion activity. Further support for an AGN origin is provided by a comparison of two independent estimates of star formation rate. These findings have important implications for modelling radio populations below 1 mJy, which is necessary for the development of the Square Kilometre Array.

Author(s): Sarah White[2], Matt Jarvis[2], Boris Haeussler[2], Natasha Maddox[1]
Institution(s): *1. ASTRON, 2. University of Oxford*

221.05 – Stellar Tidal Disruption Event Rates as Probes of the Supermassive Black Hole Mass Function

Rates of stellar tidal disruption events (TDEs) by supermassive black holes (SMBHs) due to two-body relaxation are calculated using a large galaxy sample (N~200) in order to explore the sensitivity of TDE rates to observational uncertainties, such as the parameterization of galaxy surface brightness profiles, and the stellar mass function. The largest uncertainty arises due to the poorly constrained occupation fraction of SMBHs in low-mass galaxies, which otherwise dominate the total TDE rate. The detection rate of TDE flares by optical surveys is calculated as a function of SMBH mass and other observables for several physically-motivated models of TDE emission. If the majority of the detected events are characterized by super-Eddington luminosities (such as disk winds, or synchrotron radiation from an off-axis relativistic jet), then the measured SMBH mass distribution will severely constrain the low-end SMBH occupation fraction. If Eddington-limited emission channels dominate, however, then the occupation fraction sensitivity is much less pronounced in a flux-limited survey (although still present in a volume-complete event sample). We discuss the implications of the SMBH mass distribution in the current sample of TDEs for the shape of the SMBH occupation fraction.

Author(s): Nicholas Stone[1], Brian D Metzger[1]

Institution(s): *1. Columbia University*

221.06 – The Dark Matter Halos of Moderate Luminosity AGN

Understanding the relationship between galaxies hosting active galactic nuclei (AGN) and the dark matter halos in which they reside is key to constraining how black-hole fueling is triggered and regulated. Previous efforts have relied on simple halo mass estimates inferred from clustering, weak gravitational lensing, or halo occupation distribution modeling. In practice, these approaches remain uncertain because AGN, no matter how they are identified, potentially live a wide range of halo masses with an occupation function whose general shape and normalization are poorly known. Instead, in this work, we use host mass as a prior to derive halo masses for moderate luminosity AGN. Using 382 moderate luminosity X-ray AGN at z<1 from the COSMOS field, we report the first measurements of weak gravitational lensing from an X-ray selected sample. Comparing this signal to predictions from the global stellar-to-halo mass relation, we find that, contrary to previous results, most X-ray AGN do not live in group-scale dark matter halos---nearly half reside in halos with Mhalo ~ 10^12.5 Msun. By highlighting the relatively ``normal'' way in which moderate luminosity X-ray AGN hosts occupy halos, our results suggest that the environmental signature of distinct fueling modes for luminous QSOs compared to moderate luminosity X-ray AGN is less obvious than previously claimed.

Author(s): Alexie Leauthaud[5], Andrew Benson[1], Francesca M. Civano[9], Alison L. Coil[8], Kevin Bundy[5], Richard Massey[2], Malte Schramm[5], Andreas Schulze[5], Peter L. Capak[7], Martin Elvis[3], Andrea Kulier[6], Jason Rhodes[4]
Institution(s): *1. Carnegie, 2. Durham University, 3. Harvard Smithsonian Center, 4. JPL, 5. Kavli Institute for the Physics and Mathematics of the Universe, 6. Princeton, 7. Spitzer Science Center, 8. University of California at San Diego, 9. Yale*

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222 – The NuSTAR Extended Mission

AAS Special Session
The Nuclear Spectroscopic Telescope Array (NuSTAR), launched in June 2012, is the first focussing hard X-ray mission in orbit and has opened the high-energy (>10 keV) sky to sensitive study. NuSTAR has been approved for extended mission, starting in late 2014, will will be comprised of a mixture of Guest Observer (GO) programs (50%), large legacy Galactic and extragalactic surveys (25%), as well as Target of Opportunity (ToO) and Director's Discretionary (DD) time (25%). The legacy surveys will be planned and executed by the NuSTAR science team based on community input. All survey data will be released publicly after validation. We request a Town Hall at the Winter 2015 AAS meeting to describe the NuSTAR extended mission plans, describe various large survey possibilities, and solicit community input.

222.01 – NuSTAR Galactic Center Survey

During its 2-year baseline mission, the Nuclear Spectroscopic Array (NuSTAR) has carried out a survey of the Galactic Center region with total area coverage of ~0.7 deg^2 and total exposure of ~2 Msec. The NuSTAR survey with ~40 ksec depth has detected over 30 point sources above 10 keV, including three known X-ray transients during their outbursts. Some of the NuSTAR point sources have remarkably hard X-ray spectra beyond 40 keV, indicating that they are either Intermediate Polars or X-ray binaries with neutron star or black hole. We will present our spectral and timing analysis to identify the hard X-ray sources. Deep Sgr A* observations with total exposure of ~400 ksec detected Sgr A* flares above 10 keV, and most remarkably NuSTAR's sub-arcminute images above 20 keV revealed previously undetected diffuse hard X-ray emission around Sgr A*. Hard X-ray emission above 40 keV is dominated by a point-like source that is spatially and spectroscopically consistent with the PWN candidate G359.95-0.04, a potential counterpart of the TeV source HESS J1745-290. In Sgr A and B2 region, NuSTAR has spatially resolved the molecular clouds for the first time above 10 keV, and broad-band X-ray spectroscopy was used to explore an origin of their X-ray emission, either due to low energy cosmic-ray heating and/or X-ray reflection of giant flares from Sgr A* in the past. We will also discuss NuSTAR detection of non-thermal X-ray filaments and implications for their emission mechanisms.

Author(s): Kaya Mori[1]
Institution(s): *1. Columbia University*
Contributing team(s): NuSTAR

222.02 – NuSTAR Norma Arm Survey

One part of the Galaxy that was surveyed during the Nuclear Spectroscopic Array (NuSTAR) primary mission is a region of the Norma Arm that was observed with Chandra in 2011. The Norma Arm is a region of recent star formation containing a large number of OB associations and was targeted to search for and study X-ray sources associated with massive stars, such as high-mass X-ray binaries (HMXBs) and colliding wind binaries (CWBs). The Norma Chandra survey covered a 2 deg x 0.8 deg field and NuSTAR has observed about half of this field to date with ~50 ks depth. We detect at least 29 NuSTAR sources in this region and present their spectral and timing properties. Four of these sources are relatively well-studied and have been observed with a number of other instruments; NuSTAR is providing new insights into these sources, which include two pulsar wind nebulae, a black hole binary, and an obscured HMXB. Four sources are NuSTAR discoveries, at least two of which are transients. We have obtained infrared spectra of the IR counterparts of seven of the remaining 21 NuSTAR sources to facilitate their identification. Two sources have high-mass stellar counterparts and are likely HMXBs or CWBs. Five have low-mass counterparts and are likely intermediate polars or low-mass X-ray binaries; one of these sources has spectral and timing properties that are consistent with a black hole binary. The 14 sources without detected IR counterparts are likely a mixture of distant intermediate polars, active galactic nuclei, and magnetars.

Author(s): Francesca Fornasini[1]
Institution(s): *1. University of California-Berkeley*
Contributing team(s): NuSTAR

222.03 – The NuSTAR Galactic Plane Survey: The Legacy Program

The NuSTAR Galactic Plane Survey was part of the level one science for the two-year baseline mission. Key aspects of the program were surveying a ~0.7 deg^2 region of the Galactic Center to understand the nature of the large source population uncovered by Chandra, and speculated to be magnetic cataclysmic variables; revealing the origin of diffuse emission in molecular clouds and non-thermal filaments by studying their hard X-ray morphology and spectroscopy; revealing the history of past and present activity in Sgr A* through studies of flares and molecular clouds; reveal the overall hard X-ray morphology of the Galactic Center which included detection of numerous PWN, Sgr A-East and the previously unknown central hard X-ray emission.

The NuSTAR legacy program is meant to provide significant time (~1.5 Msec) to conduct follow-up observations to maximize the science return from select projects described above, especially those where there would be broad community interest in such follow up, and to conduct new observations whose scale or level of risk might make it difficult for individuals to successfully obtain data through guest observer proposals. The legacy program will be designed with community input, and the data will be immediately public. Examples might include continued monitoring of the Galactic Center for Sgr A* flares and other time-variable sources; large scale follow up of unidentified HESS and INTEGRAL sources; deeper observations of select regions near the Galactic Center to better understand the hard X-ray logN-logS of the Chandra point sources. The talk will serve as a forum for providing input to the design of the legacy program, and to provide information on how to further engage in the process of legacy program design.

Author(s): Charles James Hailey[1]
Institution(s): *1. Columbia Univ.*
Contributing team(s): NuSTAR

222.04 – The NuSTAR Survey of Swift/BAT Sources

Launch of the first focusing hard X-ray telescope, the Nuclear Spectroscopic Telescope Array (NuSTAR), enabled studies of the local active galactic nuclei (AGN) to extend in the spectral window above 10 keV with unprecedented spatial resolution and two orders of magnitude higher sensitivity than any other instrument operating in that bandpass. As a part of its long-term Extragalactic Surveys program, NuSTAR will survey the nearby population of AGN detected at hard X-ray energies in the Swift/BAT all-sky survey. In the first two years of operation we surveyed ~100 Swift/BAT AGN, which we present here. A short 15-25 ks NuSTAR exposure of a source detected with the Swift/BAT instrument provides a sufficiently detailed hard X-ray spectrum to provide well-constrained model parameters for each one individually. This sample forms an atlas of the best hard X-ray spectra available to date for a substantial number of AGN. Assuming a range of spectral models, both phenomenological and physically motivated, we determine the distributions of spectral parameters, such as the spectral index, absorption column, reflection strength and iron line equivalent width. Here we discuss the implications for the local Seyfert 2 population and the limitations of the current results. We also highlight more detailed studies of particular AGN, and preliminary results on multiplicity and variability in the hard X-ray band.

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Institution(s): *1. California Institute of Technology*
Contributing team(s): NuSTAR

222.05 – The NuSTAR Serendipitous Survey

A great breakthrough in studying the cosmic X-ray background (CXB) population is the Nuclear Spectroscopic Telescope Array (NuSTAR), the first focusing X-ray observatory with high sensitivity at > 10 keV. Here we present results from the NuSTAR serendipitous survey, the largest area (~7 deg^2) component of the NuSTAR extragalactic survey programme. The source statistics are relatively good for a high energy X-ray survey, with ~150 detections and ~100 spectroscopically identified sources to-date. Studying the X-ray emission at > 10 keV, where X-rays from the central black hole are relatively unabsorbed, allows intrinsic properties such as column densities and luminosities to be well constrained. The X-ray analysis is supplemented by broad-band UV to mid-IR spectral energy distribution (SED) analyses. The dominant source population sampled by the NuSTAR serendipitous survey is quasars with L(10-40)keV > 10^{44} erg/s. This population is broadly similar to the population of nearby high-energy selected AGNs sampled by Swift/BAT, but scaled up in luminosity and mass.

Author(s): George B Lansbury[1]
Institution(s): *1. Durham University*
Contributing team(s): NuSTAR

222.06 – The NuSTAR Survey of the COSMOS Field

NuSTAR executed a medium-area survey of the 2deg^2 COSMOS field, region with plenty of multiwavelength data available. This survey is matched in depth to the Chandra coverage in the field. In the ~120 observations performed by NuSTAR on COSMOS, 91 sources were detected over the redshift range 0.1 < z < 2.5 down to a flux limit of 5.9 x10^{-14} erg/s/cm^2 in the 3-24 keV band. With this survey, we detected highly obscured AGN with column densities exceeding 10^{23} cm^{-2}, including sources with Compton-thick (>1.5 x 10^{24} cm^{-2}) obscuration.

Author(s): Francesca M. Civano[1]
Institution(s): *1. Dartmouth College*
Contributing team(s): NuSTAR

222.07 – The NuSTAR Survey of the Extended Chandra Deep Field South (ECDFS)

I will present the first results from the NuSTAR survey of the full 30'x30' area of the Extended Chandra Deep Field South. At its deepest, the survey reaches a depth of 360ks, corresponding to sensitivity limits of 1.3, 3.4 and 3.0 x 10^{-14} ergs/s/cm2 in the 3-8keV, 8-24keV and 3-24keV bands, respectively. In total, we detect 49 unique sources, spanning the redshift range z=0.22-2.7, and probe below the "knee" of the 10-40keV luminosity function at z~1 for the first time.

Author(s): James Mullaney[1]
Institution(s): *1. Durham University*
Contributing team(s): NuSTAR

222.08 – The NuSTAR Extragalactic Surveys: Number Counts and Directly Resolved Fraction of the Cosmic X-ray Background

NuSTAR has carried out a multi-tiered extragalactic survey program, consisting of deep (~400 ks) observations of the ~0.3 deg2 Extended Chandra Deep Field South (ECDFS) and ~0.25 deg2 Extended Groth Strip (EGS), medium depth (~100 ks) observations of the 2 deg2 COSMOS field, and a serendipitous program covering >7 deg2 to a range of depths. I present measurements of the intrinsic number counts as a function of flux (logN-logS) from the combination of the three survey elements, including direct measurements of the number counts at 8-24 keV energies that reach two orders of magnitudes fainter in flux than previous studies. I will also show how NuSTAR has directly resolved >30% of the Cosmic X-ray background at 8-24 keV energies -- a factor ~30 times more than previous >10 keV observatories.

Author(s): James Aird[1]
Institution(s): *1. Durham University*
Contributing team(s): NuSTAR

222.09 – Extended Mission NuSTAR Extragalactic Survey Plans

During the extended mission, NuSTAR is reserving substantial time for additional extragalactic surveys. Examples of such surveys include targeting additional fields (e.g., the Chandra Deep Field-North), increasing our integration time in previously surveyed fields, or target well-defined samples of targets. The NuSTAR Science Team solicits community input in defining this aspect of the extended mission. The talk will serve as a forum for providing input to the design of the legacy program, and to provide information on how to further engage in the process of legacy program design.

Author(s): Daniel Stern[1]
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Contributing team(s): NuSTAR

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223 – Luminous Stars in Nearby Galaxies and the Local Group

223.01 – Caught in the Act: Imaging the Disk and Outflows in V Hya, a carbon-rich AGB star in transition to a Bipolar Pre-Planetary Nebula

The carbon star V Hya is experiencing heavy mass loss as it undergoes the transition from AGB star to a bipolar pre-planetary nebula (PPN). V Hya is possibly the earliest object known in this brief phase, which is so short that few nearby stars are likely to be caught in the act. Using STIS/HST we discovered a high velocity (>200 km/s) blob that was ejected very recently from near (<0.3 arcsec) the star and measured its proper motion. We found time-variable high-velocity absorption features in the CO 4.6 micron vibration-rotation lines from a multi-epoch study - modelling shows that these are produced in compact clumps of outflowing gas with significant temperature gradients. Millimeter wave interferometry with 3.5 arcsec resolution shows that the high-velocity outflow is collimated and bipolar. The STIS data and recent mid-infrared interferometry also suggest the presence of a small (<0.55 arcsec size) circumstellar disk. We report new observations to investigate V Hya's high-velocity outflow and disk with STIS (HST) and GPI (Gemini South). Our STIS data show that the high-velocity outflow emission has weakened significantly over a 12-year period. Our Y-band coronagraphic polarimetric imaging with GPI reveals the presence of an inclined disk in scattered light, aligned roughly north-south, i.e., orthogonal to the high-velocity outflow. We discuss the implications of these results for the disk/outflow system in V Hya in particular, and in nascent PPNe, in general.

Author(s): Raghvendra Sahai[1], Jayadev Rajagopal[2], Mark Morris[3], Kenneth H. Hinkle[2], Richard R. Joyce[2]
Institution(s): *1. JPL, 2. NOAO, 3. UCLA*

223.02 – A Direct Measurement of Lifetimes and Stellar Luminosities on the AGB

The asymptotic giant branch (AGB) represents the phase of stellar evolution where stars become their brightest and reddest. As such, understanding stellar lifetimes and luminosities during this evolutionary phase is crucial to accurately interpret red and infrared light from galaxies using population synthesis models. Recently, there has been much controversy over the inferred ages and masses of infrared galaxies due to our lack of understanding of this phase. In this presentation, I'll present a direct measurement of the stellar core mass growth on the AGB by comparing the initial core masses to the post AGB core masses measured from spectroscopy of white dwarfs. The resulting data allows us to calculate the stellar lifetime and luminosity on the AGB, and to compare to popular models that are used to interpret light from distant galaxies.

Author(s): Jason S. Kalirai[1], Paola Marigo[2], Pier-Emmanuel Tremblay[1]
Institution(s): *1. Space Telescope Science Institute, 2. Universita' di Padova*

223.03D – Observational Constraints on Models of Rapidly Evolving Luminous Stars

Resolved stellar populations in galaxies are excellent laboratories for testing our understanding of galaxy formation, integrated colors and luminosities, supernova progenitor masses, and energy input from stellar feedback. However, the usefulness of resolved stellar populations rests on the ability to accurately model the evolution of the underlying stars. Part of my thesis work is focused on two uncertain phases of stellar evolution; the luminous core helium burning (HeB) phase and the thermally pulsating AGB (TP-AGB) phase. Dwarf galaxies, imaged as part of the ACS Nearby Galaxy Survey Treasury and its HST/NIR follow-up campaign, provide ideal testing grounds for new models because the galaxies span ~2 dex in metallicity, many have significant HeB populations (i.e, the HeB sequence is populated with stars with masses from ~2-15 Msun), and many contain large numbers of TP-AGB stars. I will present how I used ANGST to constrain low metallicity stellar evolution models with the Padova-Trieste Stellar Evolution Code (PARSEC; the recently updated Padova Stellar Evolution Library) and COLIBRI (a new tool for modeling TP-AGB stars). Specifically, I will show how increasing the strength of core overshooting with increasing mass in HeB stars improves data and model agreement. I will also present constraints to the mass loss prescriptions of low mass, low metallicity TP-AGB stars.

Author(s): Philip Rosenfield[3], Julianne Dalcanton[3], Alessandro Bressan[2], Leo Girardi[1], Paola Marigo[4]
Institution(s): *1. INAF, 2. SISSA, 3. University of Washington, 4. Univesitá Degli Studi Di Padua*
Contributing team(s): ANGST Team

223.05 – An Emerging Class of Extragalactic Self-Obscured Stars

The evolution of the most massive stars such as η\,Carinae is controlled by the effects of mass-loss. Understanding these stars is challenging because no true analogs of η\,Car have been clearly identified in the Milky Way or other galaxies. Copious mass-loss leads to circumstellar dust formation, obscuring the star in the optical. But as the light is re-emitted by the dust, these objects become very luminous in the mid-IR. We have carried out a systematic search for η\,Car analogs in 7 galaxies, utilizing data from Spitzer, Herschel, HST and other sources. Our search detected no true analogs of η\,Car, however, we do identify a significant population of 18 lower luminosity $\left(\log(L/L_\odot)\simeq5.5-6.0\right)$ dusty stars. Stars enter this phase at a rate that is a fraction $0.09 \lesssim F \lesssim 0.55$ of the ccSN rate, and this is consistent with all $25~<~M_{ZAMS}~<~60M_\odot$ stars undergoing an obscured phase at most lasting a few thousand years once or twice. These phases constitute a negligible fraction of post-main sequence lifetimes of massive stars, which implies that these events are likely to be associated with special periods in the evolution of the stars. The mass of the obscuring material is of order $\sim M_\odot$, and we simply do not find enough heavily obscured stars for these phases to represent more than a modest fraction ($\sim 10\%$ not $\sim 50\%$) of the total mass lost by these stars. While this search has been feasible using archival Spitzer data, JWST will be a far more powerful probe of these stars. The HST-like resolution of JWST will either greatly reduce the problem of confusion or greatly expand the possible survey volume. Far more important will be the ability to carry out the survey at 24μm, which will increase the time over which dusty shells can be identified from hundreds of years to thousands of years, greatly improving the statistics and our ability to survey the long term evolution of these systems and the relationship between stellar eruptions and supernovae.

Author(s): Rubab M. Khan[1]
Institution(s): *1. NASA GSFC*

223.06D – Observed rotational properties of the O-type stars in 30 Doradus: single stars and binaries

The initial distribution of the spin rates of massive stars is a fingerprint of their formation process. The stellar spin rate is also one of the main properties that control the evolution and ultimate fate of these objects.
Using ground-based multi-object optical spectroscopy obtained in the framework of the VLT/FLAMES Tarantula Survey we established the projected rotational velocities, vsini, of a sample of ~330 O-type objects located in the 30 Doradus (30 Dor) region in the Large Magellanic Cloud. The sample is composed by ~200 spectroscopic single stars and ~110 stars in binary systems (~110 primaries and ~30 secondaries). The vsini values are derived from the most commonly used methods, i.e. full-width at half-maximum, Fourier transform, and line profile fitting, applied to a set of spectral lines. The most distinctive feature of the vsini distributions of the presumed-single stars, primaries, and secondaries in 30 Dor is a low-velocity peak at around 100 km/s. Stellar winds are not expected to have spun-down the bulk of the stars significantly since their arrival on the main sequence and therefore the peak of presumed-single stars is likely to represent the outcome of the formation process. Whereas the spin distribution of presumed-single stars shows a well developed tail of stars rotating more rapidly than 300 km/s, primaries and secondaries do not feature such a high-velocity tail. The tail of the presumed-single star distribution is attributed for the most part -- and could potentially be completely due -- to spun-up binary products that appear as single stars or that have merged. This would be consistent with the lack of such post-interaction products in the binary sample, that is expected to be dominated by pre-interaction systems. The peak in this distribution is broader and is shifted toward somewhat higher spin rates compared to the distribution of spectroscopic-single stars. Systems displaying large radial velocity variations, typical for short period systems, appear mostly responsible for these differences. Tidal interaction are expected to spin up the components and may also explain the absence of rapidly rotating primary and secondary stars in binary systems.

Author(s): Oscar Hernan Ramirez Agudelo[1], Hugues Sana[2], Alex de Koter[1], Frank Tramper[1], Selma de Mink[1]
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Contributing team(s): VLT-FLAMES Tarantula Survey

223.07 – First OB-stars in the iron-poor Local Group galaxy sextans A

The study of the early Universe relies on our ability to check our models by analyzing the behaviour of astrophysical objects at conditions close to those of the first epochs. Low-metallicity nearby galaxies with young massive stars may be used as laboratories to study these objects that have been proposed as active agents of the reionization of the Universe and dominate the energy budget of galaxies.
We present observations and analyses of individual OB stars in the sub-SMC metallicity galaxy Sextans A (which the lowest confirmed Fe abundance in the Local Group, kaufer et al. 2004 & Hosek et al. 2014), obtained with OSIRIS@GTC. This work extends the limits of this kind of studies to unprecedented low metallicities.

Author(s): Ines Camacho[1]
Institution(s): *1. Instituto de Astrofisica de Canarias*

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224 – Extrasolar Planets: Formation and Evolution

224.01D – Debris from giant impacts - signatures of forming and dynamic planetary systems

Collisions between planetary embryos are an important stage in the formation of planets. In addition to building large planetary bodies these giant impacts also release copious quantities of smaller dust and debris which then goes into orbit around the star, forming a circumstellar dust disk. These disks of dust and debris have distinctive features; they are bright and readily detectable, and they show strong asymmetries. The characteristics of the disks are strongly tied to the properties of the parent bodies, and can thus provide us with key insights into evolving planetary systems. Such dust disks may indeed be our only way of accessing Earth-like planets during the epoch of formation, since directly detecting the influence of the planet is stymied by high stellar activity and the circumstellar dust. While giant impacts are expected to be most common during the chaotic epoch of formation, they may occur at any time, particularly in association with late dynamical instabilities. For example, the disruption of the Kuiper belt proposed by the Nice model is likely to have led to such events, perhaps including the impact that formed the Pluto-Charon system.

There are a growing number of debris disks that exhibit asymmetries, variability, or compositions that are difficult to explain with traditional disk models, or that are simply too bright to be consistent with a primordial disk that has been quiescently grinding down over the lifetime of the star. Debris released in giant impacts provides a possible explanation for these features. Furthermore since planetary systems that are actively forming terrestrial planets should be expected to possess detectable dust from the ongoing giant impacts, we can use observations of dust in young systems to place constraints on the fraction of stars that form terrestrial planets.

Author(s): Alan Patrick Jackson[1]
Institution(s): *1. Arizona State University*

224.02 – Hazy Archean Earth as an Analog for Hazy Earthlike Exoplanets

Hazy exoplanets may be common (Bean et al. 2010, Sing et al. 2011, Kreidberg et al 2014), and in our solar system, Venus and Titan have photochemically-produced hazes. There is evidence that Earth itself had a hydrocarbon haze in the Archean (Zerkle et al. 2012, Domagal-Goldman et al. 2008) with important climatic effects (Pavlov et al. 2001, Trainer et al. 2006, Haqq-Misra et al. 2008, Wolf and Toon 2012). We use a 1D coupled photochemical-climate model and a line-by-line radiative transfer model to investigate the climactic and spectral impacts of a fractal hydrocarbon haze on Archean Earth. The haze absorbs significantly at shorter wavelengths and can strongly suppress the Rayleigh scattering tail, a broadband effect that would be remotely detectable at low spectral resolution at wavelengths less than 0.5 µm. Hazes may have a more significant impact on transit transmission spectra. Using the transit transmission radiative transfer model developed by Misra et al. (2014) to generate hazy Archean spectra, we find that even a thin hydrocarbon haze masks the lower atmosphere from the visible into the near infrared where the haze optical depth exceeds unity. The transit transmission spectra we generate for hazy Archean Earth are steeply sloped like the Titan solar occultation spectrum observed by Robinson et al. (2014). Thick hazes can also cool the planet significantly: for example, the thick fractal haze generated around Archean Earth with 0.3% CH4, 1% CO^2 and 1 ppm C^2H^6 cools the planet from roughly 290 K without the haze to below freezing with the haze. Finally, we investigate the impact of host star spectral type on haze formation, comparing the hazes generated around a solar-type star to those generated at an Earth analog planet around the M dwarf AD Leo. Our results indicate hazes around M dwarfs for the same initial atmospheric composition may be thinner due to decreased UV photolysis of methane and other hydrocarbons needed for haze formation. Earthlike planets around M dwarfs may therefore be more likely to remain haze-free than those around G dwarfs; therefore, they may be easier to examine spectrally.

Author(s): Giada Arney[3], Victoria Meadows[3], Shawn Domagal-Goldman[1], Mark Claire[2], Edward Schwieterman[3]
Institution(s): *1. Goddard Space Flight Center, 2. University of St. Andrews, 3. University of Washington*

224.03 – Atmospheric Escape from Super-Earths and Mini-Neptunes: Determining the Limits of Hydrogen Atmospheres

Planets form within gas-rich disks. While embedded in these disks, they host hydrogen atmospheres. When disk gas dissipates, terrestrial planets quickly lose primordial hydrogen, while Jupiters remain bound even on short-period orbits. The ability of super-Earths and mini-Neptunes to maintain primordial hydrogen atmospheres is strongly dependent on their stellocentric separations. I will present a framework for determining the physical regime of hydrogen loss as a function of planetary and stellar parameters and discuss implications for the bulk compositions of intermediate-mass planets.

Author(s): Ruth Murray-Clay[1]
Institution(s): *1. University of California, Santa Barbara*

224.04 – Structures, Cooling, and Mass Loss for Super-Earths and Sub-Neptunes

Many exoplanets have been discovered with radii of 1–4 Earth radii, between that of Earth and Neptune. A number of these planets have densities consistent with a low-mass hydrogen-helium envelope and are subject to high stellar fluxes, raising the possibility that they have been significantly affected by mass loss. In order to understand how the measured masses and radii of such planets can inform their structures and composition, we construct structural models for both solid layered planets and for planets with solid cores and gaseous envelopes, exploring a range of core and envelope masses. For planets in the super-Earth/sub-Neptune regime with both masses and radii observed, we estimate how each is partitioned into a solid core and gaseous envelope. We also model the evolution with mass loss of exoplanets in this mass regime, with a view towards understanding their history and the current observed partitioning between envelope and core.

Author(s): Alex Howe[1], Adam Seth Burrows[1]
Institution(s): *1. Princeton University*

224.06 – Planets migrating into stars: Rates and Signature

New measurements of the occurrence distribution of planets (POD) make it possible to make the first determination of the rate of planet migration into stars as a function of the strength of stellar tidal dissipation. We show how the period at which there is falloff in the POD due to planets migrating into the star can be used to calculate this rate. We show that it does not take extremely weak tidal dissipation for this rate to be low enough to be supplied by a reasonable number of planets being scattered into the lowest period region. The presence of the shortest period giant planets can be better explained by the ongoing migration of giant planets into stars. The presence of giant planets in period on the order of a day and less had prompted some to conclude that tidal dissipation in stars must necessarily be much weaker for planet mass than for binary star mass companions. However, a flow of less than one planet per thousand stars per gigayear could explain their presence without requiring as much of a difference in tidal dissipation strength in stars for planetary than for stellar mass companions. We show several new analytical expressions describing the rate of evolution of the falloff in the POD, as well as the rate of planet. The question of how strong is the tidal dissipation (the quality factor "*Q*") for planet-mass companions may be answered within a few years by a measurable time shift in the transit period. We show that the distribution of remaining planet lifetimes indicates a mass-dependence of the stellar tidal dissipation. The possibility of regular merger of planets with stars has led us to find several correlations of iron abundance in stars with planet parameters, starting with the iron-eccentricity correlation (Taylor 2012, Dawson & Murray-Clay 2013). These correlations change in the presence of a stellar companion. We show that the distribution of planets of iron-rich planets is significantly different from the distribution of iron poor stars in several ways which indicate that both formation and whole planet pollution play roles in producing several recently discovered planet-star correlations.

Author(s): Stuart F. Taylor[1]
Institution(s): *1. Participation Worldscope*

224.07 – Chemical Constraints on Hot Jupiter Migration

The origin of close-in giant exoplanets is a long-standing puzzle. Planet formation theories suggest that such planets are unlikely to have formed in-situ but instead may have formed at large orbital separations beyond the snow line and migrated inward to their present orbits. Two competing hypotheses suggest that the planets migrated either through interaction with the protoplanetary disk during their formation, or by disk-free mechanisms such as gravitational interactions with a third body. Observations of eccentricities and spin-orbit misalignments of hot Jupiter systems have been unable to differentiate between the two hypotheses. In the present work, we show that chemical abundances of exoplanetary atmospheres may be used to constrain their formation and/or migration mechanisms. We use spectroscopic observations, obtained using HST, Spitzer, and ground-based facilities, of several giant exoplanets to derive stringent constraints on their atmospheric C and O abundances. We then use the chemical abundances along with planet formation models to place the first rigorous constraints on the formation and migration pathways of the exoplanets in our sample. Our results suggest in particular that chemical depletions in hot Jupiter atmospheres have the potential to constrain their migration mechanisms which have thus far remained elusive based on dynamical measurements. We find that sub-solar carbon and oxygen abundances in Jovian-mass hot Jupiters around Sun-like stars are hard to explain by disk migration. Instead, such abundances are more readily explained by giant planets forming at large orbital separations, either by core accretion or gravitational instability, and migrating to close-in orbits via disk-free mechanisms involving dynamical encounters. Our results open a new means for understanding the origins of exoplanets which have thus far been investigated based largely on dynamical properties of their orbits. We will discuss several open questions in this new frontier.

Author(s): Nikku Madhusudhan[1], Mustafa A. Amin[1], Grant M. Kennedy[1]
Institution(s): *1. Institute of Astronomy, University of Cambridge*

225 – Stellar and Intermediate-Mass Black Holes

225.01 – A Bayesian Model for the Detection of X-ray Binary Black Holes

In X-ray binary systems consisting of a compact object that accretes material from an orbiting secondary star, there is no simple means to determine if the compact object is a black hole or a neutron star. To assist this process we develop a Bayesian statistical model, which makes use of the fact that X-ray binary systems appear to cluster based on their compact object type when viewed from a particular 3- dimensional coordinate system derived from spectral data. In particular we utilize a latent variable model in which the latent variables follow a Gaussian process prior, and hence we are able to induce the spatial correlation we believe exists between systems of the same type. The key parameters of this model are the probabilities that an observation comes from a black hole, a pulsar, or non-pulsing neutron star. A benefit of this approach is of a computational nature – the assumption of a prior which follows a multivariate normal distribution allows for the implementation of elliptical slice sampling for performing inference, a fast and stable alternative to standard Metropolis-Hastings or Gibbs sampling (Murray 2010). Our model is fit from 13 years worth of spectral data from 30 X-ray binary systems. Its predictive power is evidenced by the accurate prediction of system types using inferred probabilities from the aforementioned model.

Author(s): Giri Gopalan[2], Luke Bornn[2], Saku Vrtilek[1]
Institution(s): *1. Harvard CFA, 2. Harvard University*

225.02D – Inner Accretion Disk Regions of Black Hole X-ray Binaries

The innermost regions of accretion disks in black hole X-ray binaries dominate the observed X-ray emission, which is the main diagnostic that one uses to gain insights into the physics of black holes and accretion. The standard spectrum predicted from a geometrically thin, optically thick disk experiences non-trivial modification due to conspiring physical effects operating within the vertical disk structure such as Comptonization, free-free emission/absorption, bound-free opacities, and energy dissipation by magnetic processes. The complicated interplay of these effects cause the seed accretion disk spectrum to become hardened and it is this hardened emergent spectrum that we observe. To zeroth order, this hardening can be described by a phenomenological parameter called the spectral hardening factor.

In practice, the adopted degree of spectral hardening is confined to lie within a rather restrictive range. I will discuss the following consequences of relaxing this criterion, while still requiring the spectral hardening factor to take on physically plausible values. Examining multiple state transitions of the black hole X-ray binary GX 339-4 with archival data from the *Rossi X-ray Timing Explorer*, I will show that appealing to a spectral hardening factor that varies during state transitions provides a viable alternative to a truncated disk model for the evolution of the inner accretion disk. Having demonstrated that moderate degrees of accretion disk spectral hardening cannot be ruled out by observations, I will explore this possibility from a theoretical standpoint. Extending previous work on radiative transfer modeling coupled to the vertical disk structure, I present the impacts on the emergent accretion disk spectrum caused by disk inclination and by allowing accretion power to be dissipated in the corona. Using magnetohydrodynamic simulations of a localized patch of the accretion disk (i.e., shearing box) performed with the *Athena* code, I will present the evolution of magnetic structures in the corona. Lastly, I will demonstrate that adopting physically plausible values for the spectral hardening factor can alleviate discrepancies between different black hole spin measurement techniques.

Author(s): Greg Salvesen[1]
Institution(s): *1. University of Colorado at Boulder*

225.03D – Listening to the beat of a 400 solar-mass, middle-weight black hole

Accreting X-ray point sources with luminosities exceeding the Eddington limit of a 20 solar mass black hole are referred to as ultraluminous X-ray sources. The brightest of these have long been suspected to host intermediate-mass black holes (mass range of a few 100-1000 solar masses). On such object is M82 X-1, thought to be an intermediate-mass black hole because of its extremely high X-ray luminosity and variability characteristics, although some models suggested that its mass may be only of the order of 20 solar masses. The previous mass estimates were based on scaling relations which used low-frequency characteristic timescales which have large intrinsic uncertainties. In stellar-mass black holes we know that the high frequency quasi-periodic oscillations that occur in a 3:2 frequency ratio (100-450 Hz) are stable and scale inversely with black hole mass with a reasonably small dispersion. The discovery of such stable oscillations thus potentially offers an alternative and less ambiguous mass determination for intermediate-mass black holes, but has hitherto not been realized. I will discuss the discovery of stable, twin-peak (3:2 frequency ratio) X-ray quasi-periodic oscillations from M82 X-1 at the frequencies of 3.32 Hz and 5.07 Hz and how this helps overcome the systematic uncertainties present in previous studies. Assuming we can extend the stellar-mass relationship, I estimate its black hole mass to be 428+-105 solar masses. This work was recently published in Nature (DOI:10.1038/nature13710). I will also discuss future prospects of detecting more of such oscillations to weigh other intermediate-mass black hole candidates.

Author(s): Dheeraj R Pasham[2], Tod E. Strohmayer[1], Richard Mushotzky[2]
Institution(s): *1. NASA/GSFC, 2. University of Maryland College Park*

225.04 – Do Magnetic Fields Destroy Black Hole g-Modes?

Diskoseismology, the theoretical study of normal mode oscillations in geometrically thin, optically thick accretion disks, is a strong candidate to explain the QPOs in the power spectra of many black hole X-ray binary systems. The existence of g-modes, presumably the most robust and visible of the modes, depends on general relativistic gravitational trapping in the hottest part of the disk. As the existence of the required cavity in the presence of magnetic fields has been put into doubt by theoretical calculations, we will explore in greater generality what the inclusion of magnetic fields has to say on the existence of g-modes. We use an analytical perturbative approach on the equations of MHD to assess the impact of such effects. Our main conclusion is that there appears to be no compelling reason to discard g-modes. In particular, the inclusion of a non-zero radial component of the magnetic field enables a broader scenario for cavity non- destruction, especially taking into account recent simulations' saturation values for the magnetic field.

Author(s): Manuel Ortega-Rodriguez[2], Hugo Solis-Sanchez[2], Agustin Arguedas-Leiva[2], Robert V. Wagoner[1], Adam Levine[1]
Institution(s): *1. Stanford University, 2. Universidad de Costa Rica*

225.05 – The effect of spectral state transitions in accretion onto black holes regulated by radiative feedback

It is known that black hole spectrum in high-energy X-ray shows distinct features switching between hard and soft states depending on the accretion luminosity. Thus, it is important to study how the spectral state transition is linked with the accretion luminosity not only for understanding the physics of the accretion flow but also for estimating the accretion rate. We explore the effect of spectral state transitions of an accreting black hole to the radiation-regulated accretion using radiation-hydrodynamic simulations. First, we explore the relative effects of Compton heating and photo-heating as a function of the spectral slope of a power-law spectrum which is fixed during a simulation. We find that the relative importance of the Compton heating over photo-heating decreases and the oscillatory behavior becomes stronger as the spectrum softens. Our simulations show consistent results with the radiatively inefficient advection-dominated accretion flow where the accretion rate is low and the spectrum is hard. Secondly, we implement the effect of spectral state transitions by changing the hardness of the spectrum constantly during a simulation as a function of the accretion luminosity.

Author(s): KwangHo Park[2], Massimo Ricotti[3], Tiziana DiMatteo[1], Christopher S. Reynolds[3], Tamara Bogdanovic[2]
Institution(s): *1. Carnegie Mellon University, 2. Georgia Institute of Technology, 3. University of Maryland at College Park*

225.06 – Thin Disks Gone MAD: Magnetically Arrested Accretion in the Thin Regime

The collection and concentration of surrounding large scale magnetic fields by black hole accretion disks may be required for production of powerful, spin driven jets. So far, accretion disks have not been shown to grow sufficient poloidal flux via the turbulent dynamo alone to produce such persistent jets. Also, there have been conflicting answers as to how, or even if, an accretion disk can collect enough magnetic flux from the ambient environment. Extending prior numerical studies of magnetically arrested disks (MAD) in the thick (angular height, H/R~1) and intermediate (H/R~.2-.6) accretion regimes, we present our latest results from fully general relativistic MHD simulations of the thinnest BH (H/R~.1) accretion disks to date exhibiting the MAD mode of accretion. We explore the significant deviations of this accretion mode from the standard picture of thin, MRI-driven accretion, and demonstrate the accumulation of large-scale magnetic flux.

Author(s): Mark J. Avara[1], Jonathan C. McKinney[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland*

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227 – Spiral Galaxies

227.01 – Effect of Galactic Flyby Encounters on Disk Galaxy Evolution: Stellar and Gaseous Warp Formation

Galactic flyby encounters are known to be very common in dense environments. We present a study on the evolution of stellar and gaseous disks that underwent impulsive flybys with the other galaxies. We focus particularly on the morphological and kinematical structures of the galactic warp. Three major parameters of flyby interactions are tested by using Gadget2; (1) the impact parameter, i.e., the minimum distance between galaxies, (2) the mass ratio of the two galaxies of interest, and (3) the incident angle of the flyby intruder. The warp amplitude is tied up with all three parameters, in that the closer, more massive perturbers when their incident angles are more close to 45^{o} or 135^{o} (diagonally approaching), the more evident are the warps. The warp lifetime, on the other hand, is mainly determined by the incident angle. The ways in which the stellar and gaseous disks react against impulsive flybys are nearly identical, yet the gaseous disk, being more radially extended than the stellar one, has a larger warp amplitude and a longer lifetime. Interestingly, non-symmetric S-shaped warps are often developed in both stellar and gaseous disks. We speculate that successive, multiple flybys with opposite incident direction may account for the creation of U- and L-shaped warps. We discuss pros and cons about our simulations in comparison with existing observations.

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227.02 – Tidal Stream Models From Simple to Complex

Many tidal streams have been found recently in the Milky Way halo and in more distant galaxies. These have spurred the development of several algorithms for fitting them and extracting the maximum information about their host potential. Here I discuss a code package intended to allow progression from the simplest, cheapest method (orbit fitting) to the most accurate and expensive (N-body simulations) in a relatively seamless way. A particle-spray technique fills the gap between these methods. To get the right spread of the stream particles and reproduce the significant substructure visible in the youngest streams, care must be taken to choose the right initial conditions for the particles and to account for the evolving mass of the satellite. I present results for some example applications to streams in the Milky Way. I also present an example of a satellite on a chaotic orbit, which has a dramatic effect on the resulting tidal stream.

Author(s): Mark A. Fardal[1]
Institution(s): *1. University of Massachusetts*

227.03 – Simulated DIsk Galaxies over Cosmic Time

We analyze the evolution of vertical disk structure and the stellar age-velocity relations in a series of high-resolution, cosmological SPH simulations. We compare current MW observations with detailed mock observations of the simulated galaxies at z=0, accounting for the latest constraints on the solar position and the selection functions of modern surveys. We show that the particular implementation of these mock observations becomes an increasingly crucial component of any quantitative comparison between theory and data; a point that will only be emphasized in the GAIA era. At z=0, our fiducial simulation reproduces the stellar age-velocity relationship measured in the solar neighborhood. Present-day simulated mono-age populations also have velocity dispersions nearly independent of height, matching the puzzling isothermal nature of mono-abundance populations in the MW. We identify two main ingredients governing the evolution of these quantities: ``upside-down'' formation and scattering processes. The galaxy forms upside-down in the sense that
progressively younger stellar populations are born with increasingly smaller vertical velocity dispersion, tracing the kinematics of the collapsing gas disk from which they form. After birth, the evolution in stellar structure and kinematics is largely governed by scattering processes. We demonstrate that ``upside-down'' disk growth is necessary to simultaneously match: (1) the observed evolution of gas and stellar kinematics in disk galaxies from z~2 to now, (2) the cosmic star formation rate, and (3) the dynamical properties of intermediate age stars in the MW observed today.

Author(s): Jonathan C. Bird[1]
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227.04 – Galaxy Zoo: spiral galaxy morphologies and their relation to the star-forming main sequence

We examine the relationship between stellar mass and star formation rate in disk galaxies at z<0.085, measuring different populations of spirals as classified by their kiloparsec-scale structure. The morphologies of disk galaxies are obtained from the Galaxy Zoo 2 project, which includes the number of spiral arms, the arm pitch angle, and the presence of strong galactic bars. We show that both the slope and dispersion of the star-forming main sequence (SFMS) is constant no matter what the morphology of the spiral disk. We also show that mergers (both major and minor), which represent the strongest conditions for increases in star formation at a constant mass, only boost the SFR above the main relation by 0.3 dex; this is a significant reduction over the increase seen in merging systems at higher redshifts (z > 1). Of the galaxies that do lie significantly above the SFMS in the local Universe, more than 50% are mergers, with a large contribution from the compact green pea galaxies. We interpret our results as evidence that the number and pitch angle of spiral arms, which are imperfect reflections of the galaxy's current gravitational potential, are either fully independent of the various quenching mechanisms for star formation or are completely overwhelmed by the combination of outflows and feedback.

Author(s): Kyle Willett[7], Kevin Schawinski[1], Karen Masters[2], Tom Melvin[2], Ramin A. Skibba[4], Robert Nichol[2], Edmond Cheung[5], Chris Lintott[8], Brooke D Simmons[8], Sugata Kaviraj[6], William C. Keel[3], Lucy Fortson[7]
Institution(s): *1. ETH Zurich, 2. ICG, University of Portsmouth, 3. University of Alabama, 4. University of California San Diego, 5. University of California Santa Cruz, 6. University of Hertfordshire, 7. University of Minnesota, 8. University of Oxford*
Contributing team(s): Galaxy Zoo volunteers

227.05 – ALMA and HST Observations of the Molecular Environment, Star formation Activity and Cluster Dissolution In NGC 1097

Barred spiral galaxies, such as NGC 1097, are an ideal laboratory for studying the interplay between the molecular gas environment and recent star formation activity because there are several dynamically distinct environs (the circumnuclear ring, the bar dust lanes and spurs, the bar end, the inner ring and spiral arms) where the SF activity varies by over three orders of magnitude. We present new ALMA Cycle 1 data showing the CO(1-0), HCN, HCO+, CS, 13CO, C18O emission across the entire disk of NGC 1097 at a resolution of 75 pc (1"). We map the distribution and kinematics of the molecular ISM and quantify the free fall time and shear to constrain what initiates (or inhibits) the star formation activity. By combining the 12m primary array, ACA-7m and total power data we show the most complete maps of NGC 1097. We use the high resolution data to measure the gas inflow rate and accretion onto the circumnuclear ring and constrain the feeding of the central AGN. The 13CO / 12CO ratio across the different environments is used to measure and quantify the diffuse versus dense phases of the molecular ISM across the disk of the galaxy. Finally we compare the ALMA data to new HST UV & optical data to measure the ages and locations of young star clusters. By comparing the cluster age and morphology to the ALMA data we constrain the cluster dissolution time scales as a function of the molecular ISM. Finally we show new JVLA C, X and Ka band continuum data to distinguish between old and young star formation activity.

Author(s): Kartik Sheth[3], Michael W. Regan[4], Buntu Ngcebetsha[5], Kotaro Kohno[2], Peter J. Teuben[6], Stuart N. Vogel[6], Eric Villard[1], Tommy Wiklind[1], Andreas Lundgren[1]
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227.06 – Counter-Rotating and Lagging Extra-planar HI in NGC 4559

We use new deep 21 cm HI observations of NGC 4559 in the Westerbork Hydrogen Accretion in LOcal GAlaxies (HALOGAS) survey to investigate the properties of extra-planar gas associated with this moderately inclined galaxy building upon a previous study by Barbieri et al. (2005). We use the Tilted Ring Fitting Code (TiRiFiC) to construct high-resolution simulated data cubes to match the HI observations. We find that the data cannot be adequately reproduced without a thick disk component of scale height ~2 kpc, characterized by a negative vertical gradient in its rotation velocity (lag), suggesting the presence of a non-trivial amount of extra-planar gas. The values of lag in the approaching and receding halves of the galaxy were fit independently and are -13±5 and -7± 3 km s^{-1} kpc^{-1}, respectively. We quantify the amount of extra-planar gas using the HI line profile in the data cube, then extract that gas from each HI line profile. We find that of the ~4.5×10^9 $M^{\odot}$ total HI mass, ~4.0×10^8 $M^{\odot}$ of that HI is not a part of the traditionally rotating disk, and is likely extra-planar. The spatial extent of the extra-planar gas is coincident upon the star-forming disk of the galaxy and is likely of galactic fountain mechanism origin. We use ancillary Hα imaging to estimate the star formation properties in quadrants of the galaxy, finding remarkably uniform star formation rates. An emission feature located in the kinematically 'forbidden' region of the position-velocity diagram along the major axis is found to contain ~1.4×10^6 $M^{\odot}$ of HI. We explore the possible origins of this counter-rotating feature and its potential connection to a large nearby HI hole, which would require ~10^7 $M^{\odot}$ to fill.

Author(s): Carlos J. Vargas[2], George Heald[1], Rene A.M. Walterbos[2], Filippo Fraternali[3], Maria T. Patterson[4]
Institution(s): *1. ASTRON, 2. New Mexico State University, 3. University of Bologna, 4. University of Chicago*
Contributing team(s): HALOGAS

227.07 – Nuclear Rings in Barred Galaxies

Nuclear rings are common structures in the inner region of barred galaxies. We use high-resolution hydrodynamical simulations to study nuclear rings in barred galaxies. The location and thickness of nuclear rings are tightly correlated with galactic properties. We discuss the detailed formation mechanism of nuclear rings. We propose a new simple method to predict the bar pattern speed for barred galaxies possessing a nuclear ring, without actually doing simulations. We apply this method to some real galaxies and find that our predicted bar pattern speed compare reasonably well with other estimates. Our study may have important implications for using nuclear rings to measure the parameters of real barred galaxies with detailed gas kinematics.

Author(s): Juntai Shen[1]
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227.08 – M51 and the Effect of the Arm Resonance and Interaction on Diffuse X-ray Emission

Interacting galaxies lead to enhanced star formation that should be represented by enhanced emission of hot gas. Resonances in the arms of "grand design" spirals should also lead to enhanced hot gas. We describe fits to spectra of diffuse emission extracted from merged Chandra observations of the interacting galaxy M51. The spectra are taken from multiple locations on the two spiral arms of M51. The spectra differ significantly in flux yet exhibit similar fitted temperatures. This implies that the number densities differ significantly as well. We discuss whether resonances in the arms can match the observed fluxes. We also discuss whether stellar winds can solely account for the hot gas, or whether supernovae are also required.

Author(s): Laura D. Vega[1], Eric M. Schlegel[2], Marilyn Moore[2]
Institution(s): *1. Fisk University, 2. Univ of Texas at San Antonio*

227.09 – Extragalactic Ultraviolet Reflection Nebulae

Dust in the gaseous halos of star-forming galaxies scatters light that leaks out of the disk. The scattering is efficient in the UV and the sky is dark, making it the best waveband to detect extragalactic reflection nebulae, which have a luminosity of at most a few percent of the galaxy. Using archival Swift and GALEX data, we have detected UV nebulae around a large number of nearby, edge-on galaxies, in many cases up to about 10 kpc above the disk. The spectral energy distribution of each nebula allows us to constrain the amount of dust and its composition, which are related to the metal content of the halo gas. We can also map the SED as a function of position around the galaxy. Thus, extragalactic reflection nebulae are a potentially powerful new probe of the disk-halo connection, with applications to the metallicity of halo gas, the diffuse ionized gas, starburst winds, and halo structure models.

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228 – The International Year of Light 2015 (IYL2015): Education and Outreach Opportunities

228.01 – Galileoscope: From IYA 2009 to IYL 2015

The Galileoscope program (http://galileoscope.org) was originally launched as a Cornerstone Project for the 2009 International Year of Astronomy. By design, the Galileoscope is not only a telescope kit but also an optics kit, promoted for and useful in classrooms and by individuals to learn optics principles. As such, it is well placed to be a major component of the 2015 International Year of Light, as part of the "Cosmic Light" Cornerstone Project managed under the auspices of the International Astronomical Union. The successful donation and teacher-education programs conducted during IYA 2009 have motivated us to launch a similar campaign for IYL 2015, with the goal to place at least 100,000 Galileoscopes into classrooms for science education in optics and astronomy. The ready availability of teaching materials and classroom activities tied to national science standards, combined with the existing worldwide network of Galileoscope users and the large number of workshops and education programs already utilizing Galileoscopes, makes this a particularly valuable program for teachers and other science educators for IYL 2015.

Author(s): Douglas N. Arion[1], Richard Tresch Fienberg[1]
Institution(s): *1. Galileoscope LLC*

228.02 – Dark Skies Preservation through Responsible Lighting: the IYL2015 Quality Lighting Kit

Poor quality lighting not only impedes astronomy research, but creates safety issues, affects human circadian sensitivities, disrupts ecosystems, and wastes more than a few billion dollars/year of energy in the USA alone. The United Nations-sanctioned the International Year of Light in 2015 (IYL2015) is providing an opportunity to increase public awareness of dark skies preservation, quality lighting and energy conservation. The Education and Public Outreach (EPO) group at the National Optical Astronomy Observatory (NOAO) has received a small grant through the International Astronomical Union (IAU) to produce official "Quality Lighting Teaching Kits" for the IYL2015 cornerstone theme, "Cosmic Light". These kits will emphasize the use of proper optical design in achieving quality lighting that promotes both energy efficiency and energy conservation of an endangered natural resource, our dark skies. The concepts and practice of "quality lighting" will be explored through demonstrations, hands-on/minds-on activities, formative assessment probes, and engineering design projects that explore basic principles of optics and the physics of light. The impact of the kits will be amplified by providing professional development using tutorial videos created at NOAO and conducting question and answer sessions via Google+ Hangouts for the outreach volunteers. The quality lighting education program will leverage NOAO EPO's work in the last ten years on lighting and optics education (e.g., the IAU "Dark Skies Africa", APS "Dark Skies Yuma" and "Hands-On Optics" programs). NOAO's partners are CIE (International Commission on Illumination), IDA (International Dark-Sky Association) and SPIE (International Society for Optics and Photonics), as well as the IAU Office of Astronomy for Development, Galileo Teacher Training Program, Universe Awareness, and Global Hands-on Universe. Their networks will disseminate the program and kits to formal and informal audiences worldwide. The impact sought is a change in knowledge, attitude, and behavior in each community by learning how to light responsibly, improving the quality of life in "illuminating" ways.

Author(s): Constance E. Walker[1]
Institution(s): *1. NOAO*

228.03 – "Light: Beyond the Bulb": A Project for the International Year of Light 2015

"Light: Beyond the Bulb" (LBTB) is a free grass-roots international exhibition program for the International Year of Light 2015 that showcases the different types and behaviors of light across the electromagnetic spectrum as well as a multitude of ways that light is being used in research and technology (including astronomy) today. LBTB contains striking images and informative captions that have been crowd-sourced and then expert-curated for science content, high-quality printability, beauty, and ability to engage the greater public. Spearheaded by the team that created "From Earth to the Universe" for the International Year of Astronomy 2009 and "From Earth to the Solar System" for NASA's Year of the Solar System 2010-2011, LBTB will bring this "public science" model to IYL and place light-based content into traditional and non-traditional science outreach locations. This talk will outline the LBTB project, describe opportunities for how the astronomical community can get involved, and discuss the potential benefits that LBTB may provide for the disciplines related to the AAS and its members.

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Institution(s): *1. Chandra X-ray Center*

228.04 – Losing the Dark: Public Outreach about Light Pollution and Its Mitigation

Losing the Dark is a PSA video available for public outreach through fulldome theaters as well as conventional venues (classroom, lecture hall, YouTube, Vimeo). It was created by Loch Ness Productions for the International Dark Sky

Association. It explains problems caused by light pollution, which targets astronomy, health, and the environment. *Losing the Dark* also suggests ways people can implement "wise lighting" practices to help mitigate light pollution. The video is available free of charge for outreach professionals in planetarium facilities (both fulldome and classical), science centers, classroom, and other outreach venues, and has been translated into 13 languages. It is available via download, USB key (at cost), and through online venues. This paper summarizes the program's outreach to more than a thousand fulldome theaters, nearly 100,000 views via four sites on Youtube and Vimeo,a number of presentations at other museum and classroom facilities, and shares some preliminary metrics and commentary from users.

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Institution(s): *1. International Dark Sky Association, 2. Loch Ness Productions, 3. National Optical Astronomy Observatory*
Contributing team(s): International Dark Sky Association Education Committee

228.05 – NASA SOFIA International Year of Light (IYL) Event: Infrared Light: Hanging out in the Stratosphere

As an International Year of Light committee endorsed event, *Infrared Light: Hanging out in the Stratosphere* will engage learners around the world, linking participants with scientists at work on board NASA SOFIA, the world's largest flying observatory. This major event will showcase science-in-action, interviews, live data, and observations performed both aboard the aircraft and at partner centers on land.

SOFIA (Stratospheric Observatory For Infrared Astronomy) is an 80% - 20% partnership of NASA and the German Aerospace Center (DLR) consisting of an extensively modified Boeing 747SP aircraft carrying a reflecting telescope with an effective diameter of 2.5 meters. SOFIA is a program in NASA's Science Mission Directorate, Astrophysics Division. Science investigators leverage SOFIA's unique capabilities to study the universe at infrared wavelengths by making observations that are impossible for even the largest and highest ground-based telescopes. SOFIA received Full Operating Capacity status in May, 2014, and astrophysicists will continue to utilize the observatory and upgraded instruments to study astronomical objects and phenomena, including star birth and death; planetary system formation; identification of complex molecules in space; planets, comets, and asteroids in our solar system; and nebulae and dust in galaxies.

This landmark event will reflect and build on the ProjectLink. In October 1995, SOFIA's predecessor, the Kuiper Airborne Observatory (KAO), performed the first satellite links from an airplane to the ground. The KAO downlinked to the Exploratorium museum (SF, CA), where over 200 students watched the webcast, conversed, and participated in simultaneous observations at the world-renowned science museum. SOFIA will now take this concept into the 21st century, utilizing internet technologies to engage and inspire 100,000+ learners of all ages through simultaneous presentations and appearances by over 70 SOFIA Educators at schools and informal learning institutions across the U.S. and around the world, and build bridges for future authentic opportunities with high impact in STEM education.

Author(s): Coral Clark[3], Dana E. Backman[1], Pamela Harman[2], Nicholas Veronico[1]
Institution(s): *1. NASA SOFIA, 2. SETI Institute, 3. USRA*

228.06 – Joliet Junior College and the 2015 International Year of Light's Cosmic Light Theme

We teach "Descriptive Astronomy" and "Life in the Universe" courses for non-science majors at Joliet Junior College, Joliet IL. We also occasionally present planetarium shows at the college's planetarium. In 2015, we plan to highlight the "Cosmic Light" theme of the 2015 International Year of Light through some of our teaching and outreach activities. For several years, together with our students, we have participated in the Globe at Night light pollution program. In 2015, we plan to continue our participation in this program and we will continue to encourage our students to participate on their own from other locations. We will present a live planetarium show on Light Pollution in Spring 2015 as part of the college's Brown Bag Lecture Series. We plan to develop and present one or two live planetarium presentations that focus on studying astronomical objects across the electromagnetic spectrum during 2015. Also in Spring 2015, we plan to include projects that highlight the International Year of Light in our Descriptive Astronomy course offerings. Our poster will provide details of these "Cosmic Light" activities.

Author(s): Noella L. D'Cruz[1]
Institution(s): *1. Joliet Junior College*

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229 – Activity and Variability in Low-Mass Stars

229.01 – Predicting Lyman-alpha and Mg II Fluxes from Low-Mass Stars

A star's UV emission can greatly affect the atmospheric chemistry and physical properties of closely orbiting planets with the potential for severe mass loss. In particular, the Lyman-alpha emission line at 1216 A, which dominates the far-ultraviolet (FUV) spectrum, is a major source of photodissociation of important atmospheric molecules such as water and methane. The intrinsic flux of Lyman-alpha, however, cannot be directly measured due to the absorption of neutral hydrogen in the interstellar medium and contamination by geocoronal emission. To date, reconstruction of the intrinsic Lyman-alpha line based on Hubble Space Telescope spectra has been accomplished for a few dozen nearby stars, 28 of which have also been observed by the Galaxy Evolution Explorer (GALEX). Our investigation provides a correlation between published intrinsic Lyman-alpha and GALEX FUV and near-ultraviolet (NUV) chromospheric fluxes for K and M stars. The negative correlations between the ratio of the Lyman-alpha to the GALEX fluxes reveal how the relative strength of Lyman-alpha compared to the broadband fluxes weakens as the FUV and NUV excess flux increase. We also correlate GALEX fluxes with the strong near-ultraviolet Mg II h+k spectral emission lines formed at lower chromospheric temperatures than Lyman-alpha. The reported correlations provide estimates of intrinsic Lyman-alpha and Mg II fluxes for the thousands of K and M stars in the GALEX all-sky surveys. These will constrain new stellar upper-atmosphere models for cool stars and provide realistic inputs to models describing exoplanetary photochemistry and atmospheric evolution in the absence of ultraviolet spectroscopy.

Author(s): Evgenya Shkolnik[2], Kristina Rolph[1], Sarah Peacock[3], Travis Barman[3]
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229.02 – Examining Flare Rates in Close M dwarf + White Dwarf binary pairs

We present a preliminary study to examine the statistical flare rates for M dwarfs with close white dwarf companions (WD+dM; typical separations < 1 AU). Previous studies have shown a strong correlation between M dwarfs that are active (showing Hα in emission) and their stellar flare rates. Our analysis of M dwarfs with close WD companions demonstrated that the M dwarfs are more active than their field counterparts. One implication of having a close binary companion is presumed to be increased stellar rotation through disk-disruption, tidal effects, and/or angular momentum exchange; increased stellar activity has long been attributed to an increase in stellar rotation. We examine the difference between the flare rates observed in close WD+dM binary systems and field M dwarfs. Our sample consists of a subset of 202 (70 of which are magnetically active) close WD+dM pairs from Morgan et al. that were observed in the Sloan Digital Sky Survey Stripe 82, a transient observing mode where multi-epoch observations in the Sloan *ugriz* bands were obtained. We present results that will assist in identifying and categorizing transient phenomena and limiting expensive follow-up observations for future time-domain studies, such as LSST.

Author(s): Dylan P. Morgan[1], Andrew A. West[1], Andrew C. Becker[2]
Institution(s): *1. Boston Univ., 2. University of Washington*

229.03 – Living with an Old Red Dwarf: X-ray-UV Emissions of Kapteyn's Star - Effects of X-UV radiation on Habitable Zone Planets hosted by old Red Dwarf Stars

Red dwarfs (dM) stars make up over 75% of the local stellar population and a significant fraction (~40-50%) are older than the Sun. Because of the high frequency of red dwarfs and their longevity (> 50 Gyr), there is a greater possibility of more advanced life in red dwarf-exoplanet systems. *MEarths, UVES, SDSS-III*, and the upcoming *TESS* mission are some surveys that are targeting red dwarfs in the search for hosted potentially habitalble planets. As part of Villanova's "Living with a Red Dwarf" program, we have obtained *HST-COS* Ultraviolet spectra (1150-3000A) and Chandra X-ray observations of Kapteyn's star (GJ 191; M1 V, V = 8.85 mag , d = 12.76 +/- 0.05 ly). Kapyteyn's Star is important for the study of old red dwarfs because it is the nearest (Pop II) halo star with a radial velocity of +245.2 km/s and an estimated age of 11.2 +/-0.9 Gyrs. Recently Kapteyn's Star was found to host two super-Earth mass planets – one of these is orbiting inside the star's Habitable Zone (Anglada-Escude' 2014: MNRAS 443, L89). In our program, Kapteyn's star is the oldest red dwarf and as such serves as an anchor for our age, rotation, and activity relations. The spectra obtained from HST/COS provide one of the cleanest measurements of the important HI Lyman-alpha 1215.6 A emission flux for red dwarfs. This is due to the large Doppler shift from the high radial velocity, separating the stellar Ly-alpha emission from by the Ly-alpha ISM and local geo-coronal sources. These observations further provide calibrations at the old age/low rotation/low activity extremes for our relations. As the nearest and brightest old red dwarf star, Kapteyn's Star also provides insights into its magnetic properties to investigae coronal x-ray and UV emission for the large population of old, slowly rotating red dwarf stars. Kapteyn's star also serves as a proxy for the numerous metal-poor old disk - Pop II M dwarfs by providing information about X-UV emissions. This information is crucial for determining X-ray-UV irradiances for habitable zone planets hosted by these old numerous, cool low luminosity stars.

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Author(s): Edward F. Guinan[1], Allyn J. Durbin[1], Scott G. Engle[1]
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229.04 – Rotation, Activity, and Planets in a Large Uniform Sample of Solar Analogs

We have conducted an in-depth analysis of light curves from four years of data for more than 2300 narrowly-selected solar analogs in the Kepler field. The sample includes both probable exoplanet host stars (KOIs) and stars without detected planetary systems. We are able to reliably detect and characterize variability at levels below that seen in the Sun, and thus to retrieve rotation periods for essentially all of the targets. In this work, we show the distribution of rotation periods and the period-activity relation for the sample, and discuss implications for gyrochronology. In addition, we examine systematic differences between the photometric behavior of KOIs and non-KOIs and illustrate how these differences can be used to identify the best candidates for future planet searches. Finally, we discuss the frequency of white-light flares in our sample.

Author(s): Derek L. Buzasi[1], Andy Lezcano[1], Lindsey Carboneau[1], Carly Hessler[1], Heather L. Preston[1]
Institution(s): *1. Florida Gulf Coast University*

229.05 – Predicting the Detectability of Granulation Flicker in the K2 Era

The high-precision light curves obtained by NASA's *Kepler* mission reveal the signatures of granulation in Sun-like stars through photometric "flicker," which we showed could yield the stellar surface gravity with a precision of ~0.1-0.2 dex. With its degraded photometric precision, however, it is unclear whether the re-purposed, Two-Wheeled *Kepler* Mission (K2) will produce light curves of sufficient photometric quality to permit the measurement of surface gravities via flicker, particularly for dwarf stars. In order to predict how well we may expect to detect granulation flicker from K2 data, we artificially degrade existing light curves of *Kepler* asteroseismic standards to observed K2 precision. We inject noise into these *Kepler* light curves to simulate additional instrumental noise found in the recently released K2 light curves, and we process the data to remove the K2-like instrumental noise using a technique similar to what will be used with real K2 data. We then measure flicker from these simulated K2 light curves and compare them with the asteroseismically measured surface gravities. We present our initial results, which suggest that flicker-based gravities, including those of dwarf stars, can be measured from K2 light curves, though perhaps with somewhat lower precision than from *Kepler* light curves.

Author(s): Fabienne A. Bastien[3], Andrew Vanderburg[1], John A. Johnson[1], Joshua Pepper[2]
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229.06 – The Stellar Activity of an M Dwarf Binary from Deconvolved Kepler Light Curves

The M5+M5 pair GJ 1245AB was monitored almost continuously by Kepler for four years, providing a unique opportunity to study the stellar activity of two coeval, nearly-equal mass M dwarfs that are fully convective. The stars are 7" apart on the sky, and separate light curves for each star cannot be generated via aperture photometry due to Kepler's large 4"/pixel plate scale. Instead, we generated separate light curves from the target pixel files using the PyKE pixel response function modeling procedures. Intriguingly, the angular separation of the two stars decreases over the four years of Kepler observations in a manner consistent with an astrometric perturbation from the much fainter, unseen M8 (GJ 1245C) companion to GJ 1245A. Analyzing the separated light curves, we observe long lived starspot features on both stars that evolve on multi-year timescales. Both stars flare at nearly the same rate, despite having rotation rates that differ by almost a factor of three. Consistent with recent studies of active M dwarf binaries, these results provide further insight into the roles of age and rotation rate in stellar activity.

Author(s): John C. Lurie[1], James R. A. Davenport[1], Suzanne L. Hawley[1], Tessa D. Wilkinson[1]
Institution(s): *1. University of Washington*

229.07D – Using Transiting Planets to Model Starspot Evolution with Kepler

Photometry from Kepler has revealed the presence of cool starspots on the surfaces of thousands of stars, presenting a wide range of spot morphologies and lifetimes. Understanding the lifetime and evolution of starspots across the main sequence reveals critical information about the strength and nature of stellar dynamos. We probe the dynamo by modeling starspot features observed in Kepler light curves, using an MCMC-based light curve modeling code. We study planetary systems like Kepler 17, where spot-occulting transits probe smaller-scale starspot regions on the stellar surface along a fixed latitude region. Our approach is novel in modeling both the in- and out-of transit features in the light curve, allowing us to break fundamental degeneracies between spot size, latitude, and contrast. With continuous monitoring from Kepler we are able to observe small changes in the positions and sizes of spots from many transits, spanning 4 years of data. Additionally, for stars without transiting planets like GJ 1243, we are able to recover subtle, long term changes in spot sizes and longitudes, leading to the slowest differential rotation rate yet measured for a low mass star. These studies constrain properties that are key to understanding the stellar dynamo, including rotation period, differential rotation, and spot diffusion timescales.

Author(s): James R. A. Davenport[2], Leslie Hebb[1], Suzanne L. Hawley[2]
Institution(s): *1. Hobart and William Smith Colleges, 2. University of Washington*

229.08 – Large Scale Dynamos in Stars

We show that a differentially rotating conducting fluid automatically creates a magnetic helicity flux with components along the rotation axis and in the direction of the local vorticity. This drives a rapid growth in the local density of current helicity, which in turn drives a large scale dynamo. The dynamo growth rate derived from this process is not constant, but depends inversely on the large scale magnetic field strength. This dynamo saturates when buoyant losses of magnetic flux compete with the large scale dynamo, providing a simple prediction for magnetic field strength as a function of Rossby number in stars. Increasing anisotropy in the turbulence produces a decreasing magnetic helicity flux, which explains the flattening of the B/Rossby number relation at low Rossby numbers. We also show that the kinetic helicity is always a subdominant effect. There is no kinematic dynamo in real stars.

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Institution(s): *1. University of Saskatchewan*

230 – Star Associations, Star Clusters - Galactic & Extra-galactic II

230.01D – Photometric and Kinematic Studies of Extragalactic Globular Cluster Systems

Globular clusters (GCs) are compact, luminous collections of stars created during the early stages of galaxy formation. As a result, the properties of GC systems provide important clues about the formation, merger history, and structure of their host galaxies. In particular, kinematic studies of GCs can be used to investigate the dark matter distribution in galaxy halos and provide observational evidence that can be used to constrain models of galaxy formation. I will present our study of the GC systems of two spiral galaxies, NGC 891 and NGC 1055, and show how we used wide-field BVR imaging from the WIYN 3.5-m telescope to detect the GC population and measure the global properties of the system. We quantified the radial distribution of the GC system and total number of GCs in these galaxies and compared the results to those of other galaxies.

I will also present the results of spectroscopic follow-up for two giant galaxies: the S0 galaxy NGC 4594 (M104), and the elliptical galaxy NGC 3379 (M105). Using spectra taken with AAT/AAOmega, WIYN/HYDRA, and MMT/Hectospec, I measured the radial velocities of GCs, and combined them with published results to determine the mass distribution and V-band mass-to-light (M/L^V) ratio profile for each galaxy out to large effective radius (7-9 R^e). I compared our results to mass estimates from other kinematic tracers and also considered them in the context of galaxy formation models. For both galaxies, I found that the M/L^V profiles increase with radius and do not flatten, which suggests that the dark matter halos in these galaxies extend to the edge of our data. I also looked for evidence of rotation within the GC systems, and found that neither system exhibits significant rotation around the host galaxy. Finally, I examined the velocity dispersion of each GC system as a function of radius and found kinematic differences between the red, metal-rich and blue, metal-poor GC subpopulations.

Author(s): Jessica L. Windschitl-Dowell[1]
Institution(s): *1. Indiana University*

230.02 – Uncovering Multiple Populations in Globular Clusters with Washington Photometry

Globular Clusters (GCs), long considered as ideal Simple Stellar Populations, are now known to harbor a wide variety of chemical inhomogeneities. Multiple populations (MP) are being found in a growing number of Galactic globular clusters (GCs) via both photometric and spectroscopic techniques. Indeed, it has been suggested that a GC is an object that possesses MP. A definitive investigation of MP in GCs will undoubtedly provide a profound improvement in our understanding of their formation and evolution.
However, most studies employ either high resolution VLT spectroscopy, HST photometry or inefficient filters from the ground. A ground-based photometric system which is both efficient and effective would be especially excellent for uncovering MP. We demonstrate that the Washington system meets these goals. The Washington C filter, in addition to being specifically designed for the purpose of detecting MPs, is both much broader and redder than competing UV filters, making it far more efficient at detecting MPs and much less sensitive to reddening and extinction.
Our analysis of the well-studied GC NGC 1851 shows indeed that the C filter is both very efficient and effective at detecting its previously discovered MPs in the RGB and SGB, using relatively little telescope time on only a 1-meter telescope. Remarkably, we have also detected an intrinsically broad MS best characterized by two distinct but heavily overlapping populations that cannot be explained by binaries, field stars, or photometric errors. Detailed analysis shows that the MS distribution is in very good agreement with that seen on the RGB. This is the first time MPs in a MS have been discovered from the ground, and just as strikingly, using only a 1-meter telescope. The Washington system thus proves to be a very powerful tool for investigating MPs, and holds particular promise for extragalactic objects where photons are limited.

Author(s): Douglas Geisler[3], Jeff Cummings[2], Sandro Villanova[3], Giovanni Carraro[1]
Institution(s): *1. European Southern Observatory, 2. Johns Hopkins University, 3. Universidad de Concepcion*

230.03 – Optical and Near-Infrared Photometry of Globular Clusters in the Coma cD NGC 4874

We present space-based optical and near-infrared (NIR) photometry of the globular cluster (GC) system in the halo of the cD galaxy NGC 4874 at the core of the Coma cluster of galaxies (Abell 1656). The NGC 4874 field was observed with the *HST* Advanced Camera for Surveys (ACS) in the F475W and F814W bands, g^{475} and I^{814}, respectively, as well as the Wide Field Camera 3 IR Channel (WFC3/IR) in F160W. The imaging data reductions, photometric measurements, and GC candidate selection criteria are described. We adopt an empirical approach to understanding nonlinear behavior in the color-metallicity relations through the observed color-color diagrams. The GCs around NGC 4874 exhibit a bimodal optical color distribution with more than half of the GCs falling on the red side at g^{475}–I^{814} ~ 1.1; this bimodality is weakened in the optical-NIR color. The quantitative Gaussian Mixture Modeling analysis on both color distributions shows the bimodalities are different, and thus the colors cannot both linearly reflect an underlying metallicity bimodality. Our results thus reinforce the importance of taking into account nonlinearities in the projection of metallicity to color. We also find a very significant color-magnitude trend, the so-called blue tilt, for the NGC 4874 GC system. Finally, we are conducting an optical-NIR color study of GCs in 16 early-type galaxies in the Fornax and Virgo clusters by cross-matching our WFC3/F160W data with the F475W and F850LP catalogues from the ACS Fornax and Virgo Cluster Surveys; the status of this larger *HST* WFC3/IR project will be presented.

Author(s): Hyejeon Cho[4], John P. Blakeslee[1], Young-Wook Lee[4], Eric W. Peng[2], Joseph B. Jensen[3]
Institution(s): *1. NRC-HIA, 2. Peking University, 3. Utah Valley University, 4. Yonsei University*

230.04D – Ruprecht 147: The oldest nearby benchmark star cluster

Ruprecht 147 is the oldest nearby star cluster, with an age of 3 Gyr at 300 pc, which allows R147 to serve as a sorely needed intermediate-aged benchmark. Stellar ages are difficult to infer for main sequence stars, but age can reveal itself through the spin down of stars via magnetic braking, which also causes magnetic activity to wane with time. I will present the membership and cluster properties, and chromospheric activity measurements relative to stars in younger and older clusters. Our chromospheric and coronal activity data shed light on the high-energy environments of exoplanetary systems at an age when multicellular life began evolving on Earth. I will demonstrate how the stars of Ruprecht 147 can serve as touchstones for characterizing isolated field stars, particularly non-Solar exoplanet hosts. Finally, I will discuss the research potential of the forthcoming K2 survey of Ruprecht 147 scheduled for Campaign 7 in late 2015.

Author(s): Jason L. Curtis[1], Jason Wright[1]
Institution(s): *1. Penn State University*

230.05 – Identifying new massive stars in Carina

We have conducted an optical and infrared spectroscopic survey of 94 candidate OB stars in the Great Carina Nebula. Candidates were selected on the basis of their infrared spectral energy distributions, which was used to estimate bolometric luminosity and effective temperature. Additionally, the presence of X-ray emission -- a sign of young, dynamic atmospheres -- was used to increase the likelihood of selecting newly formed massive stars associated with the Carina star formation region. Here, we present the preliminary results of this study including spectral types and the OB star confirmation rate. We also discuss the spatial distribution of the new OB stars with respect to the various clusters and sub-clusters and speculate on the implications of additional massive stars on the global mass function of the Carina star forming complex.

Author(s): Michael J Alexander[2], M. Virginia McSwain[2], Matthew S. Povich[1], Richard J Hanes[2]
Institution(s): *1. California State University, 2. Lehigh Univeristy*

230.06 – A VLBI Resolution of the Pleiades Distance Controversy

The Pleiades is the best studied open cluster in the sky. It is one of the primary open clusters used to define the "Zero Age Main Sequence" and hence it serves as a cornerstone for programs which use main-sequence fitting to derive distances to other clusters in the Milky Way Galaxy. This role is called into question by the "Pleiades distance controversy" - the distance to the Pleiades from the Hipparcos space astrometry mission of about 120 pc is significantly different from the distance of 133 pc derived from other techniques. In order to resolve this issue, the Very Long Baseline Array combined with the Green Bank, Effelsberg, and Arecibo telescopes are being used to derive a new, independent trigonometric parallax distance to the Pleiades. From four Pleiades systems we find a distance of 136.2+/-1.2 pc, the most accurate and precise distance to the cluster yet measured. In this contribution we present preliminary parallaxes for the remaining four Pleiades systems not published in Melis et al. (2014, Science 345, 1029). Additionally, binary orbit model fits and preliminary stellar masses are presented for two multiple systems in our sample with significant orbital motion observed during our VLBI monitoring.

Funding for this research came from the NSF through awards No. AST-1003318 and No. AST-1313428.

Author(s): Carl Melis[5], Mark J. Reid[2], Amy J. Mioduszewski[4], John R. Stauffer[3], Geoffrey C. Bower[1]
Institution(s): *1. ASIAA, 2. Harvard/CfA, 3. IPAC/Caltech, 4. NRAO, 5. UC San Diego*

230.07 – Integrated Light Chemical Abundance Analyses of 7 M31 Outer Halo Globular Clusters from the Pan-Andromeda Archaeological Survey

Detailed chemical abundances of globular clusters provide insight into the formation and evolution of galaxies and their globular cluster systems. This talk presents detailed chemical abundances for seven M31 outer halo globular clusters (with projected radii greater than 30 kpc), as derived from high resolution integrated light spectra. Five of these clusters were recently discovered in the Pan-Andromeda Archaeological Survey (PAndAS). The integrated abundances show that 4 of these clusters are metal-poor ([Fe/H] < -1.5) while the other 3 are more metal-rich. The most metal-poor globular clusters are α-enhanced, though 3 of the 4 are possibly less α-enhanced than MW stars (at the 1σ level). Other chemical abundance ratios ([Ba/Eu], [Eu/Ca], and [Ni/Fe]) are consistent with origins in low mass dwarf galaxies (similar to Fornax). The most metal-rich cluster ([Fe/H] ~ -1) stands out as being chemically distinct from Milky Way field stars of the same metallicity---its chemical abundance ratios agree best with the stars and clusters in the Large Magellanic Cloud (LMC) and the Sagittarius dwarf spheroidal (Sgr) than with the Milky Way field stars. The other metal-rich clusters, H10 and H23, look similar to the LMC and Milky Way field stars in all abundance ratios. These results indicate that M31's outer halo is being at least partially built up by the accretion of dwarf satellites, in agreement with previous observations.

Author(s): Charli Sakari[4], Kim Venn[3], Dougal Mackey[1], Matthew D. Shetrone[2], Aaron L. Dotter[1], George Wallerstein[4]
Institution(s): *1. Australian National University, 2. McDonald Observatory, University of Texas at Austin, 3. University of Victoria, 4. University of Washington*

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231 – Galaxy Simulations and Techniques

231.01 – Dynamical Scaling Relations and the Angular Momentum Problem in the FIRE Simulations

Simulations are an extremely important tool with which to study galaxy formation and evolution. However, even state-of-the-art simulations still fail to accurately predict important galaxy properties such as star formation rates and dynamical scaling relations. One possible explanation is the inadequacy of sub-grid models to capture the range of stellar feedback mechanisms which operate below the resolution limit of simulations. FIRE (Feedback in Realistic Environments) is a set of high-resolution cosmological galaxy simulations run using the code GIZMO. It includes more realistic models for various types of feedback including radiation pressure, supernovae, stellar winds, and photoionization and photoelectric heating. Recent FIRE results have demonstrated good agreement with the observed stellar mass-halo mass relation as well as more realistic star formation histories than previous simulations. We investigate the effects of FIRE's improved feedback prescriptions on the simulation "angular momentum problem," i.e., whether FIRE can reproduce observed scaling relations between galaxy stellar mass and rotational/dispersion velocities.

Author(s): Denise Schmitz[1], Philip F. Hopkins[1], Eliot Quataert[3], Dusan Keres[4], Claude-Andre Faucher-Giguere[2]
Institution(s): *1. California Institute of Technology, 2. Northwestern University, 3. University of California, Berkeley, 4. University of California, San Diego*

231.02 – Supernova Feedback and Multiphase Interstellar Medium

Without feedback, galaxies in cosmological simulations fail to generate outflows and tend to be too massive and too centrally concentrated, in contrast to the prominent disks observed ubiquitously in our universe. The nature of supernova (SN) feedback remains, however, highly uncertain, and most galaxy simulations so far adopt ad hoc models. Here we perform parsec-resolution simulations of a patch of the interstellar medium (ISM), and show that the unresolved multiphase gas in cosmological simulations can greatly affect the SN feedback by allowing blastwaves to travel in-between the clouds. We also show how ISM clumping varies with the mean gas density and SN rate encountered in real galactic environments. We emphasize that the inhomogeneity of the ISM must be considered in coarse-resolution simulations. We discuss how the gas pressure maintained by SN explosions can help to launch the galactic winds, and compare our results with the sub-grid models adopted in current cosmological simulations.

Author(s): Miao Li[1], Jeremiah P. Ostriker[3], Renyue Cen[3], Greg Bryan[1], Thorsten Naab[2]
Institution(s): *1. Columbia University, 2. Max Planck Institute for Astrophysics, 3. Princeton University*

231.03 –
Modeling the Dynamics of Interacting Galaxy Pairs - Testing Identikit Using GADGET SPH Simulations

We develop and test an automated technique to model the dynamics of interacting galaxy pairs. We use Identikit (Barnes & Hibbard 2009; Barnes 2011) as a tool for modeling and matching the morphology and kinematics of the interacting pairs of similar-size galaxies. In order to reduce the effect of subjective human interference, we automate the selection of phase-space regions used to match simulations to data, and we explore how selection of these regions affects the random uncertainties of parameters in the best-fit model. In this work, we used an independent set of GADGET SPH simulations as input data, so we determined the systematic bias in the measured encounter parameters based on the known initial conditions of these simulations. We tested both cold gas and young stellar components in the GADGET simulations to explore the effect of choosing HI vs. Hα as the line of sight velocity tracer. We found that we can group the results into tests with good, fair, and poor convergence based on the distribution of parameters of models close enough to the best-fit model. For tests with good and fair convergence, we ruled out large fractions of parameter space and recovered merger stage, eccentricity, viewing angle, and pericentric distance within 2σ of the correct value. All of tests on gaseous component of prograde systems had either good or fair convergence. Retrograde systems and most of tests on young stars had poor convergence and may require constraints from regions other than the tidal tails. In this work we also present WIYN SparsePak IFU data for a few interacting galaxies, and we show the result of applying our method on this data set.

Author(s): S Alireza Mortazavi[2], Jennifer Lotz[3], Joshua E. Barnes[1]
Institution(s): *1. Institute for Astronomy, University of Hawaii, 2. Johns Hopkins University, 3. Space Telescope Science Institute*

231.04D – The Faint Extragalactic Radio Sky at Small and Large Angular Scales

Understanding the faint extragalactic radio sky from both point sources and extended emission has important implications for studying galaxy evolution, the star formation history, cluster emission, and even dark matter particles, in addition to being important for designing future deep radio surveys. Using the deepest 3GHz data from the Karl G Jansky Very Large Array, noise rms of ~1μJy/beam with an 8arcsec beam, we use the P(D) confusion technique along with Monte Carlo Markov Chain analysis to obtain new estimates and constraints on the discrete radio source count down to the sub-μJy level along with its contribution to the cosmic radio background temperature. We find good agreement with our model and published source counts, though in the 10 to several hundred μJy range our model yields higher counts than several evolutionary models. With data from the Australia Telescope Compact Array we perform a similar analysis at 1.75 GHz on extended radio emission on arcmin scales with a noise rms of approximately 52 μJy/beam with a beam size of 150×60 arcsec. We fit several simple phenomenological models as well as looking at a model of cluster halo emission and two models of WIMP dark matter particle annihilation. The data yield constraints on predicted models from these emission mechanisms. We find a confusion rms of 1.2 μJy/beam at 3GHz and 155 μJy/beam at 1.75GHz, with an excess after discrete source subtraction of 76±23 μJy/beam. From this we obtain a background temperature at 1.4 GHz from discrete sources of 115 ± 5 mK with an upper limit on the temperature from extended emission of 18 ± 12 mK. Additionally, we are also using this data to measure the clustering of the radio sky by looking at the angular power spectrum.

Author(s): Tessa Vernstrom[3], Jasper Wall[3], Douglas Scott[3], James J. Condon[2], Kenneth I. Kellermann[2], William D. Cotton[2], Richard A. Perley[2], Edward B. Fomalont[2], Ray Norris[1], Neal A. Miller[4]
Institution(s): *1. CSIRO, 2. NRAO, 3. University of British Columbia, 4. University of Maryland*

231.05 – Improving Photometric Redshift Accuracy and Computational Efficiency

Deriving high-quality photometric redshifts is necessary for extracting physical information from large-scale extragalactic surveys, but is computationally difficult. Although current grid-based template-fitting provide a sufficient level of accuracy for most purposes, they spend the majority of time for any given object (>99%) sampling regions of extremely low probability, are inefficient at exploring the relevant high-dimensional parameter space at fine resolution, and encourage a fundamental “discretizing” of the space. We present preliminary results from a new MCMC-based algorithm that is able to use information on the entirety of parameter space and is designed to perform well even in extremely “bumpy” spaces, yet at the same time is ~50 times more efficient than traditional grid-based approaches and easily parallelizable. We also explore machine learning-driven improvements to both the decision-making process as well as improvements in the input models that might allow substantial improvements in our determination of star formation histories and extinction curves for high-redshift galaxies.

Author(s): Josh S Speagle[2], Peter L. Capak[1], Daniel Masters[1], Charles L. Steinhardt[1]
Institution(s): *1. Caltech, 2. Harvard University*

231.06 – Simultaneous Estimation of Photometric Redshifts and SED Parameters: Improved Techniques and a Realistic Error Budget

We present the results of recent work seeking to improve the accuracy of joint galaxy photometric redshift estimation and spectral energy distribution (SED) fitting. By simulating different sources of uncorrected systematic errors, we show that if the uncertainties on the photometric redshifts are estimated correctly, so are those on the other SED fitting parameters, such as stellar mass, stellar age, and dust reddening. Furthermore, we find that if the redshift uncertainties are over(under)-estimated, the uncertainties in SED parameters will be over(under)-estimated by similar amounts. These results hold even in the presence of severe systematics and provide, for the first time, a mechanism to validate the uncertainties on these parameters via comparison with spectroscopic redshifts. We show that template incompleteness, a major cause of inaccuracy in this process, is ``flagged" by a large fraction of outliers in redshift and that it can be corrected by using more flexible stellar population models. We propose a new technique (annealing) to re-calibrate the joint uncertainties in the photo-z and SED fitting parameters without compromising the performance of the SED fitting + photo-z estimation. This procedure provides a consistent estimation of the multidimensional probability distribution function in SED fitting + z parameter space, including all correlations.

Author(s): Viviana Acquaviva[2], Anand Raichoor[1], Eric J. Gawiser[3]
Institution(s): *1. CEA, 2. CUNY NYC College of Technology, 3. Rutgers, the State University of New Jersey*

231.07 – Redefined Galaxy Stellar Masses with Multi-Band Imaging

Multi-band, high-resolution imaging for nearby galaxies enables, in principle, the study of their internal stellar mass distributions and structures. However, the number of resolution elements involved in mapping the stellar masses of individual galaxies can exceed 10^{5-6}! This makes pixel-by-pixel SED fitting (for all but the most basic parameter spaces and simplest statistical methods) to convert light into mass for large samples of galaxies computationally prohibitive. Relations between stellar mass-to-light ratio [M^*/L] and colour [MLCRs] offer a solution by reducing M^*/L computations to the evaluation of an analytic function at some given locations. A glaring shortcoming of the MLCR method though is that its uncertainties (both random and systematic) are poorly known. To address this situation, we have conducted a series of tests spanning the optical and near-infrared [NIR] domain using MLCRs of our own design and from the literature, as well as mock and real galaxies. We also devise a novel implementation of MLCRs with multi-band colours aimed at achieving accurate determinations of M^*/L, as opposed to just using a single colour. Our tests reveal that MLCRs introduce no significant bias in stellar mass measurements relative to those from SED fitting. The uncertainties in the masses derived from these two methods are also quite comparable. Furthermore, comparing stellar masses obtained via integrated and spatially-resolved data (e.g. mass maps) suggests that the integrated masses suffer typical inaccuracies of ~0.05-0.10 dex, depending on the bands being modelled, though errors can be as high as 0.25 dex. Increasing the number of bands from the optical-NIR range lowers the random errors in MLCR-based measurements. Our work validates the use of MLCRs, especially for large data sets with multi-wavelength, resolved galaxy images.

Author(s): Joel C. Roediger[1], Stephane Courteau[2]
Institution(s): *1. NRC Herzberg Astronomy & Astrophysics, 2. Queen's University*

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232 – Licensing Astrophysics Codes: What You Need to Know

AAS Special Session
Research in astronomy is increasingly dependent on software methods and astronomers are increasingly required to share their codes; those who write software need to choose a license that delineates whether, when and how others may use and extend this software. Building on comments and questions about licensing in the January 2014 AAS special session “Astrophysics Code Sharing II: The Sequel”, this session, organized by the Astrophysics Source Code Library (ASCL) and AAS's Working Group on Astronomical Software (WGAS), and the Moore-Sloan Data Science Environment, explores why providing an explicit license for software is important, explains different common licenses, examines intellectual property concerns common to universities, and provides information on restrictions that arise from ITAR. A panel of speakers will discuss code licensing, share considerations that arise when choosing a license, and benefits of the licenses they chose. Institutional and governmental concerns about intellectual property, its licensing, use, and release, will also be covered. The floor will then be open for discussion and questions.

232.01 – Copy-left and Copy-right

Any discussion of open licensing almost invariably devolves into a debate between copy-left licenses and permissive licenses, both sides defending their views with a nearly religious fervor. Copy-left licenses, typified by the GPL family of licenses, require all derived products to maintain the open, GPL license. Permissive licenses, typified by the BSD family of licenses, do not impose such requirements. I’ll briefly explore the common arguments put forth in favor of either approach, and discuss some concrete examples of where these approaches have helped or hindered the software packages that used them.

Author(s): Jacob VanderPlas[1]
Institution(s): *1. University of Washington*

232.02 – University tech transfer perspective on software licensing

Software is released every day from universities around the world. The way it's shared can support and accelerate a lab's research goals – or have unintended effects. This talk will help you gain insight into issues that arise when university employees want to release software.

Author(s): Laura Dorsey[1]
Institution(s): *1. University of Washington*

232.03 – Relicensing the Montage Image Mosaic Engine.

In June 2014, the Montage Image Mosaic software (http://montage.ipac.caltech.edu) was relicensed from a proprietary clickwrap license, which forbade redistribution of the software, to a BSD 3-clause license. This decision was made primarily in response to requests from end-users wishing to redistribute and modify the software. The reasoning behind the choice of license and the benefits and consequences of this choice will be described.

Author(s): G. Bruce Berriman[1]
Institution(s): *1. Caltech*

232.04 – Export Controls on Astrophysical Simulation Codes

Amidst concerns about nuclear proliferation, the US government has established guidelines on what types of astrophysical simulation codes can be run and disseminated on open systems. I will review the basic export controls that have been enacted by the federal government to slow the pace of software acquisition by potential adversaries who seek to develop weapons of mass destruction. The good news is that it is relatively simple to avoid ITAR issues with the Department of Energy if one remembers a few simple rules. I will discuss in particular what types of algorithm development can get researchers into trouble if they are not aware of the regulations and how to avoid these pitfalls while doing world class science.

Author(s): Daniel Whalen[1]
Institution(s): *1. Heidelberg ITA*

232.05 – Why licensing is just the first step

Choosing a license for your software is an important part of sharing your work with others but just because your project is open source doesn't mean that you're guaranteed to receive contributions from others. In this talk I'll highlight some strategies employed by popular open source projects and offer some guidance on how to bootstrap your project to maximise your chance of creating a successful open source collaboration.

Author(s): Arfon M Smith[1]
Institution(s): *1. GitHub Inc.*

232.06 – Licenses in the wild

Beyond the important legal and social implications of licensing, it's interesting to look into how licenses are used at a community level. Which licenses are the most popular? Does this vary with project popularity, language, or any other factors? To explore these questions, I've collected READMEs, licenses, and social metadata for millions of repositories hosted on GitHub. One of the most interesting results is that we can use this dataset to build a topic model to classify projects into domains or fields and look at how licensing practices vary across discipline.

Author(s): Daniel Foreman-Mackey[1]
Institution(s): *1. NYU*

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233 – Celebrating 10 Years of Diversity in Astronomy With Pre-MAP

AAS Special Session
The 225th AAS meeting in Seattle coincides with the 10th year of the Pre-Major in Astronomy Program (Pre-MAP) at the University of Washington. Pre-MAP focuses on increasing the representation of women and minorities in astronomy and STEM fields through engaging college freshman and transfer students in research, mentoring, and community building as soon as they begin at UW. In this session and its associated poster session we have three goals: 1) to share the techniques that have sustained Pre-MAP and strategies that have proved successful for mentoring under-represented students; 2) to celebrate the numerous programs at different institutions that promote diversity in physics and astronomy; and 3) to highlight the hard work done by undergraduate students that have gone through -- or are currently enrolled -- in Pre-MAP and similar programs.

233.01 – Overview of the University of Washington's Pre-Major in Astronomy Program

The fraction of science PhDs awarded to women, African American, Latino, and other minority students is currently far smaller than the fraction of the general population that these groups constitute (NSF 06-320, NSF 04-317). The future of Physics and Astronomy in the United States depends on recruiting and retaining these students in STEM majors and careers (Norman et al., 2009). The greatest obstacles for persistence in science reported by students are loss of interest, intimidation, poor advising, and lack of acceptance (Seymour & Hewitt, 1997). In 2005, a group of University of Washington graduate students created the Pre-Major in Astronomy Program (Pre-MAP) to connect incoming undergraduate students to authentic research experiences as a means of recruiting and retaining them in STEM. Pre-MAP was one of only 13 initiatives supported by the President's Diversity Appraisal Implementation Fund and has proved to be one of its greatest success stories. At its core is a 10-week seminar in which undergraduates learn astronomical research techniques (e.g., computing, data analysis, documentation, statistics, and literature review) and apply them to projects conducted in small groups, under the supervision of faculty and postdocs. Now in its tenth year, Pre-MAP has engaged more than 100 undergraduates — its ongoing success has made it a model for similar programs at UW and other universities.

I will outline the beginnings, funding streams, and structure of this long-running diversity program. The Pre-MAP sessions that follow will highlight our best practices and lessons learned, and feature first-hand accounts from several of our fantastic Pre-MAP alumni.

Author(s): Daryl Haggard[1]
Institution(s): *1. Amherst College*
Contributing team(s): Pre-Major in Astronomy Program

233.02 – Recruiting Diverse Students and Enabling Them to Succeed in STEM

Improving the diversity within the rapidly growing fields of science, technology, engineering, and mathematics (STEM) has become a forefront issue facing collegiate departments today. It is well known that there are large gaps in the participation and performance of minorities, women, and low-income students within these fields and that special attention must be paid in order to close this gap. Since 2005, the Pre-Major in Astronomy Program (Pre-MAP) at the University of Washington (UW) Department of Astronomy has made a concentrated effort to recruit and retain underrepresented undergraduates in STEM, at which it has been very successful. Of course, recruiting these students can be a challenge, as is creating a curriculum and atmosphere that enables undergraduates to successfully participate in real astronomy research during their first or second year at a four-year college. Pre-MAP recruits a significant population of minorities and women into the program. The structure of the seminar is intended to not only provide necessary skills and experience, but also create a collaborative and supportive atmosphere among each cohort. I will discuss the recruitment practices of Pre-MAP as well as the structure of the seminar and how it addresses the goal of early participation and success in STEM research and course work.The intent of this talk is to share our methods so that more programs like Pre-MAP can be adopted successfully in other institutions.

Author(s): Michael J. Tremmel[1]
Institution(s): *1. University of Washington*
Contributing team(s): Pre-Major in Astronomy Program

233.03 – Evaluation of UW's Pre-MAP Program

The University of Washington Pre-Major in Astronomy Program (Pre-MAP) has been recruiting and training underrepresented undergraduates in science, technology, engineering and mathematics (STEM) since 2005. We discuss results from our formal evaluation of Pre-MAP. Pre-MAP students come from a large variety of math backgrounds, and we have found that Pre-MAP students that initially place into lower math courses as freshmen are more successful at completing a STEM degree than the general population of UW undergraduates. Pre-MAP students also perform well academically compared both with the overall UW population and with STEM students regardless of their initial math placement. We will also briefly discuss recommendations for other programs analogous to Pre-MAP based on our evaluation. This evaluation was supported by NSF AST-1009314.

Author(s): John P. Wisniewski[2], Sarah M Garner[3], Michael J. Tremmel[3], Sarah J. Schmidt[1], Eric Agol[3]
Institution(s): *1. Ohio State University, 2. University of Oklahoma, 3. University of Washington*

233.04 – Boston University Pre-Majors Program (BU Pre-Map): Promoting Diversity through First-Year Undergraduate Research

One of largest points of attrition for underrepresented minorities in STEM fields is the transition from high school to college. A report from Building Engineering and Science Talent (BEST) demonstrates that underrepresented minorities begin college interested in STEM fields at rates equal to (if nor slightly above) their representation in both college and the population (25%). However, by the time they graduate, underrepresented minorities make up only 15% of STEM majors and only 9% of the STEM advanced degrees. Most of the attrition occurs during the first year of college, when large classes, a lack of mentors and challenging courses lead many students (from all backgrounds) to consider other majors.

In 2012 I started the Boston University Pre-Majors Program (or BU Pre-MaP), which is modeled after the University of Washington Pre-Majors in Astronomy Program (UW Pre-MAP), a program for recruiting, mentoring and training underrepresented, first-year introductory astronomy students (and of which I was an architect). As a significant part of the Pre-MAP (or Pre-MaP) model, first-year students are engaged in a research project with a faculty or grad-student mentor and learn many of the skills needed to be successful in science.
The BU Pre-MaP uses weekly seminars to introduce students to BU and the college environment, discuss ways to be successful in and out of the classroom, highlights the importance of peer mentoring and cohort building and serves as a mechanism to introduce first-year students to research skills. In teams of two, the Pre-MaP students select (with assistance) a research mentor and work with him/her on a original research project.
In addition, Pre-MaP students attend several field trips including (but not limited to) viewing original science documents at the Boston Public Library (including a first edition Copernicus) and an observing run at Lowell Observatory in Arizona.

Author(s): Andrew A. West[1]
Institution(s): *1. Boston Univ.*

233.05 – AstroCom NYC: A Partnership to Support Underrepresented Minorities in Astronomy and Astrophysics Research and Education

AstroCom NYC is an NSF-funded partnership between astronomers at The City University of New York (CUNY), The American Museum of Natural History (AMNH) and Columbia University, designed to increase recruitment and retention of underrepresented minorities in astronomy and astrophysics. I will discuss the major program elements, including: recruitment, student selection, a 'Methods of Scientific Research' (MSR) course, summer research experience and ongoing structured mentoring. I will also discuss how the programs are integrated into each institution and present progress updates from our first two years.

Author(s): K.E. Saavik Ford[2], Timothy Paglione[5], Dennis Robbins[4], Mordecai-Mark Mac Low[1], Marcel A. Agueros[3]
Institution(s): *1. American Museum Natural History, 2. Borough of Manhattan Community College - CUNY, 3. Columbia University, 4. Hunter College, 5. York College*

233.06 – The First Year of GRAD-MAP

Graduate Resources Advancing Diversity with Maryland Astronomy and Physics (GRAD-MAP) strives to build strong ties with mid-Atlantic minority-serving institutions (MSIs) through seminars, forums, workshops, science discussions, and research. Our goal is to give underrepresented students the skills and experience to successfully pursue graduate degrees in physics and astronomy. In doing so, we will significantly improve the diversity of Physics and Astronomy graduate students. We will describe our collaboration with the larger National Astronomy Consortium (NAC) and the GRAD-MAP program three-pronged approach with the Fall Collaborative Seminar Series, Winter Workshop for undergraduates, and Spring Symposium. Our first year was highly successful with Collaborative Seminars with 5 institutions, 10-day Winter Workshop with 7 underrepresented minority undergraduate students, and our Spring Symposium with 34 attendees from 10 different institutions.

Author(s): Katherine Jameson[1], Ashlee N. Wilkins[1], Sylvia Zhu[1], Alexander McCormick[1], David Green[1], Myra Stone[1], Corbin James Taylor[1], Sonali J. Shukla[1], Stuart N. Vogel[1]
Institution(s): *1. University of Maryland*

233.07 – Columbia's Bridge to the Ph.D. Program: A research-focused initiative facilitating the transition to graduate school

Columbia University's Bridge to the Ph.D. in the Natural Sciences Program aims to enhance the participation of students from underrepresented groups in Ph.D. programs. To achieve this, the Bridge Program provides an intensive research, coursework, and mentoring experience to post-baccalaureates seeking to strengthen their graduate school applications and to prepare for the transition into graduate school. To date, 20 Bridge Program alumni --- including four in astronomy --- have gone on to Ph.D. programs at Columbia, the University of Michigan, Johns Hopkins, the University of Washington, Albert Einstein, Yale, and SUNY-Albany, among others. In this talk, I will touch on some of the connections between Pre-MAP and the Bridge Program, and particularly how my involvement in the former prepared me to lead the latter.

Author(s): Marcel A. Agüeros[1]
Institution(s): *1. Columbia Univ.*

233.08 – The Fisk-Vanderbilt Masters-to-PhD Bridge Program

We describe the Fisk-Vanderbilt Masters-to-PhD Bridge program as a successful model for effective partnerships with minority-serving institutions toward addressing the problem of the underrepresentation of minorities in the physical sciences. Since 2004 the program has admitted 79 students, 68 of them underrepresented minorities (48% female), with a retention rate to STEM Ph.D. programs of 82% (compared to the national average of 50%). We summarize the main features of the program including two of its core strategies: (1) partnering a minority-serving institution and a major research university through collaborative research, and (2) using the master's degree as a deliberate stepping stone to the PhD. We specifically discuss our mentoring and student tracking strategies, and note that a large number of our materials available online as part of the Bridge Program Architects Toolkit: http://www.vanderbilt.edu/gradschool /bridge/tools.htm.

Author(s): Jillian M. Bellovary[2], Keivan Stassun[2], Kelly Holley-Bockelmann[2], Rodolfo Montez[2], Dina Myers Stroud[2], Arnold Burger[1]
Institution(s): *1. Fisk University, 2. Vanderbilt University*

233.09 – CAMPARE and Cal-Bridge: Two Institutional Networks Increasing Diversity in Astronomy

We describe two programs, CAMPARE and Cal-Bridge, with the common mission of increasing participation of groups traditionally underrepresented in astronomy, particularly underrepresented minorities and women, through summer research opportunities, in the case of CAMPARE, scholarships in the case of Cal-Bridge, and significant mentoring in both programs, leading to an increase in their numbers successfully pursuing a PhD in the field.
CAMPARE is an innovative REU-like summer research program, currently in its sixth year, comprising a network of comprehensive universities and community colleges in Southern California and Arizona (most of which are minority serving institutions), and ten major research institutions (University of Arizona Steward Observatory, the SETI Institute, JPL, Caltech, and the five Southern California UC campuses, UCLA, UCI, UCSD, UCR, and UCSB).
In its first five summers, CAMPARE sent a total of 49 students from 10 different CSU and community college campuses to 5 research sites of the program. Of these 49 participants, 25 are women and 24 are men; 22 are Hispanic, 4 are African American, and 1 is Native American, including 6 female Hispanic and 2 female African-American participants.
Twenty-one (21) CAMPARE participants have graduated from college, and more than half (11) have attended or are attending a graduate program, including 8 enrolled in PhD or Master's-to-PhD programs. Over twenty CAMPARE students have presented at the AAS and other national meetings.
The Cal-Bridge program is a diverse network of higher education institutions in Southern California, including 5 UC campuses, 8 CSU campuses, and 7 community colleges dedicated to the goal of increasing the number of underrepresented minority and female students attending graduate school in astronomy or related fields. We have recently selected our inaugural group of five 2014 Cal-Bridge Scholars, including four women (two Hispanic and one part Native American), and one Hispanic man.
Once selected, the Cal-Bridge Scholars benefit from three years of financial support, intensive, joint mentoring by CSU and UC faculty, professional development workshops, and exposure to research opportunities at the participating UC campuses.

Author(s): Alexander L. Rudolph[1], Chris David Impey[5], Cynthia B. Phillips[3], Matthew S. Povich[1], Edward E. Prather[2], Tammy A. Smecker-Hane[4]
Institution(s): *1. Cal Poly Pomona, 2. Center for Astronomy Education (CAE) Univ. of Arizona, 3. SETI Institute, 4. UC Irvine, 5. University of Arizona Steward Observatory*

233.10 – On the Importance of Proudness Projects During Transitions: Design Principles and Examples

When are we most likely to feel proud of the work that we do? In this talk I will suggest that students engaging in work that they are proud of is particularly important during transitional years such as their freshman year in college. I will define "ideal proudness projects," and lay out a set of design principles that support educators in the development of such projects. Many diversity programs, including The Compass Project at the University of California, Berkeley, are already engaging their students in a variety of activities that would qualify as proudness projects. I will discuss a number of such examples, but focus primarily on The Compass Project.

Author(s): Angie Little[1]
Institution(s): *1. Graduate School of Education, UC Berkeley*

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234 – Heineman Prize: The Dark and Light Side of Galaxy Formation, Piero Madau (University of California, Santa Cruz)

234.01 – The Dark and Light Side of Galaxy Formation

In recent years, precision measurements across cosmic time have led to a widely accepted cosmological paradigm for galaxy assembly and evolution, the cold dark matter (ΛCDM) model. Within this theory, galaxies form “bottom-up,” with low-mass objects (“halos”) collapsing earlier and merging to form larger and larger systems over time. Ordinary matter follows the dynamics dictated by the dominant dark matter until radiative, hydrodynamic, and star-formation processes take over. Although ΛCDM has had great success in explaining the observed large-scale distribution of mass in the universe, the nature of the dark matter particle is best tested on small scales, where its physical characteristics manifest themselves by modifying the structure of galaxy halos and their lumpiness. It is on these scale that detailed comparisons between observations and theory have revealed several discrepancies and challenged our understanding of the mapping between dark matter halos and their baryonic components. In this talk I will review the triumphs and tribulations of the theory. While the latter may indicate the need for more complex physics in the dark sector itself, emerging evidence suggests that a poor understanding of the baryonic processes involved in galaxy formation may be at the origin of these controversies.

Author(s): Piero Madau[1]
Institution(s): *1. University of California, Santa Cruz*

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235 – HEAD Rossi Prize Talk: The Fermi Bubbles; Douglas Finkbeiner, Tracy Slatyer, Meng Su

The scientists awarded the 2014 Rossi Prize were Professor Douglas Finkbeiner of the Harvard-Smithsonian Center for Astrophysics (CfA), Professor Tracy Slatyer of the Massachusetts Institute of Technology (MIT) and Meng Su, a joint Einstein/Pappalardo fellow of physics at MIT and the Kavli Institute for Astrophysics and Space Research for their discovery, in gamma rays, of the large unanticipated Galactic structure now called the "Fermi Bubbles." From end to end, Fermi bubbles extend 50,000 light years, or roughly half of the Milky Way's diameter. These structures may be the remnant of an eruption from a supersized black hole at the center of our Galaxy.

235.01 – The Fermi Bubbles

The Fermi Bubbles are a pair of giant lobes at the heart of the Milky Way, extending roughly 50 degrees north and south of the Galactic Center, and emitting photons with energies up to 100 GeV. This previously unknown structure could be evidence for past activity of the central supermassive black hole, or enhanced star formation towards the inner Galaxy. We will describe the path to discovery of the Bubbles in multiwavelength data, from the first hints in microwave radiation measured by WMAP and X-rays from ROSAT, to the unveiling of their shape and spectrum using public gamma-ray data from the Fermi Gamma-ray Space Telescope, to more recent measurements by Planck and XMM-Newton. We will outline the current state of knowledge of the Bubbles’ spectrum, morphology and internal structure, and discuss theoretical proposals and numerical simulations for their nature and origin.

Author(s): Douglas P. Finkbeiner[1]
Institution(s): *1. Harvard Univ.*

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239 – Celebrating 10 Years of Diversity in Astronomy with Pre-MAP Posters

239.01 – Dust Attenuation at High Redshift

In this work we study the dust distribution of the 100 most massive systems in the Vulcan simulation, a new state of the art cosmological simulation of a 25 Mpc per side volume, with unprecedented spatial resolution. The galaxies in our sample have typical stellar masses of 10**8.5-10.5 solar masses and star formation rates in the range 1-100 solar masses per year, typical of galaxies observed in the CANDELS survey. Interstellar dust remarkably affects how we observe galaxies – it comprises only ~ 0.1% of the total mass in a galaxy yet absorbs nearly 50% of it’s starlight and reradiates it as far infrared continuum emission. Here we use a complete set of resolved systems to study how this attenuation varies with halo mass and metallicity, as well as star formation history, and orientation at high redshift. To measure the effects of dust we use Sunrise, a 3D radiative transfer code, which processes stellar light through dust in arbitrary geometries, and calculates the SED of every resolution element, from the far-UV to far-infrared. Using Sunrise, we can realistically calculate the attenuation of each resolved galaxy to quantify its variation with physical quantities. In addition, with these ‘simulated observations’, we compare our sample to the high redshift IRX-beta relationship observed in Lyman break galaxies, and investigate the cause of its intrinsic scatter.

Author(s): Danielle Skinner[1], Lauren M. Anderson[1], Thomas R. Quinn[1], Fabio Governato[1], Michael J. Tremmel[1]
Institution(s): *1. University of Washington*

239.02 – Flare Rate and Statistics for the M Dwarf GJ 1243 With Kepler

Light curve data taken from the Kepler space telescope have been used to detect stellar flares. These data are a valuable resource for the study of flare rates and morphology, but currently flare samples must be validated by hand. FBEye (Flares By Eye) is an interactive program created to detect and manually validate these flares, with the goal of removing the need for human input. As a first year undergraduate student, I participated in this project by analyzing Kepler light curves and vetting stellar flares. Using 11 months of one-minute cadence data from GJ 1243, an M dwarf star, we classified each flare by energy and morphology. This work has been used to refine the FBEye program, which will eventually be applied to the entire catalogue of Kepler data. It is also part of a research paper on GJ 1243, which is currently in the publication process.

Author(s): Emily Johnson[1], James R. A. Davenport[1], Suzanne L. Hawley[1]
Institution(s): *1. University of Washington*

239.03 – The Effects of Clouds and Hazes on the Spectra of Terrestrial and Sub-Neptune Planets

Recent evidence suggests that aerosols may be a common component of exoplanet atmospheres (Bean et al. 2010, Sing et al. 2011, Kreidberg et al 2014). We investigate the effects of varied types of clouds and hazes on the spectra of Earth-analog and sub-Neptune worlds around solar-type and M dwarf stars to observe how the composition of the aerosols affects the spectrum. We simulate direct beam and transit transmission planetary spectra for worlds with a combination of water, ZnS, KCl, hydrocarbon and sulfuric acid aerosols in their atmospheres using the Spectral Mapping Atmospheric Radiative Transfer Model (SMART). In addition to varied compositions, we vary the aerosol atmospheric altitudes and cloud thicknesses. For the hydrocarbon aerosols, we also test the spectral impact of changing the shape of the particles (fractal vs. spherical hazes). By compiling a catalog of terrestrial and sub Neptune hazy and cloud spectra, this work will help future missions such as TPF or ATLAST identify the atmospheric aerosols of other exoplanets.

Author(s): Guadalupe Tovar[1], Giada Arney[1], Victoria Meadows[1]
Institution(s): *1. University of Washington*

239.04 – Measuring Direction and Miximiation of a Pulsed Plasma Thruster

Cube satellites (informally called ‘CubeSats’) have gained increasing popularity in the last decade amongst universities because they are inexpensive to build, require little power, and bypass expensive launch prices by hitching rides on other missions launched by the government administrations and potentiallyor private industriesy. Traditionally, Cubeats have used Teflon as a source of propulsion; our CubeSat wants to explore the possibility of using sulfur as a propellant. Sulfur would greatly increase our orbit time in space thus increasing our scientific capabilities. However, because sulfur has never been used as a propellant, assessment of its behavior in the (near) vacuum of space needs to be made. We present the first results measuring thrust direction and maximization of our new sulfur propulsion system within a camber vacuum capable of maintaining a base pressure of 2μTorr.

Author(s): Brittney Dodosn[1], Robert Winglee[1], Ian Johnson[1]
Institution(s): *1. University of Washington*

239.05 – The Grinnell Science Project: Results of Over Two Decades of Reform Aimed at Inclusion in Science and Mathematics

The Grinnell Science Project (GSP) is a program that was developed starting in the early 1990's at Grinnell College -- a selective liberal arts college in Grinnell, Iowa. The GSP program is committed to developing the talents of all students interested in science and mathematics, especially those from groups underrepresented in the sciences -- students of color, first-generation college students, and women in physics, mathematics and computer science. The program developed over several years, drawing on national studies and efforts, and aimed at addressing barriers to success in the sciences. It has involved curricular and mentoring changes, activities and structures that foster acclimation to college life and a community of scientists, and improvement of student achievement. Prior to the full implementation of the Grinnell Science Project, from 1992–1994, an average of 42 science majors graduated annually who were women and eight who were students of color. By 2008, those numbers had jumped to 90 women (a 114% increase) and 21 students of color (a 162.5% increase). In 2009, the GSP was honored with the Presidential Award for Excellence in Science, Engineering, Mathematics, and Engineering Mentoring, administered by the National Science Foundation. Components of the GSP are now mainstream throughout the science curriculum at Grinnell, and almost all science and math faculty have played some role in the program.

Author(s): Minna Mahlab[1]
Institution(s): *1. Grinnell College*
Contributing team(s): Grinnell Science Project Team -- Grinnell College

239.06 – CAMPARE and Cal-Bridge: Two Institutional Networks Increasing Diversity in Astronomy

We describe two programs, CAMPARE and Cal-Bridge, with the common mission of increasing participation of groups traditionally underrepresented in astronomy, particularly underrepresented minorities and women, through summer

research opportunities, in the case of CAMPARE, scholarships in the case of Cal-Bridge, and significant mentoring in both programs, leading to an increase in their numbers successfully pursuing a PhD in the field.
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In its first five summers, CAMPARE sent a total of 49 students from 10 different CSU and community college campuses to 5 research sites of the program. Of these 49 participants, 25 are women and 24 are men; 22 are Hispanic, 4 are African American, and 1 is Native American, including 6 female Hispanic and 2 female African-American participants.
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Once selected, Cal-Bridge Scholars benefit from financial support, intensive, joint mentoring by CSU and UC faculty, professional development workshops, and exposure to research opportunities at the participating UC campuses.

Author(s): Alexander L. Rudolph[1], Chris David Impey[5], Cynthia B. Phillips[3], Matthew S. Povich[1], Edward E. Prather[2], Tammy A. Smecker-Hane[4]
Institution(s): *1. Cal Poly Pomona, 2. Center for Astronomy Education (CAE) Univ. of Arizona, 3. SETI Institute, 4. UC Irvine, 5. University of Arizona Steward Observatory*

239.07 – CU-STARs: Promoting STEM Diversity by Addressing First-year Attrition of Underrepresented Minorities

Upon first entering university, the fraction of students interested in pursuing a STEM major are distributed according to societal demographics (with 25% being underrepresented minorities), but by graduation, the fraction of students receiving STEM degrees is unbalanced, with underrepresented minorities receiving only 15% of STEM bachelor's degrees. The CU-STARs (CU Science, Technology, and Astronomy Recruits) program at the University of Colorado, Boulder is targeted to address the main triggers of early career attrition for underrepresented minorities in STEM disciplines. A select group of students are given financial support through work-study at the Fiske planetarium on campus, while resources to address other triggers of attrition are available to the entire cohort of interested students (typically ~5-10 per year). These resources are designed to promote social engagement and mentorship, while also providing a support network and resources to combat inadequate high school preparation for STEM courses. We achieve these goals through activities that include social events, mentor meetings, free tutoring, and special events to meet and talk with scientists. The culmination of the program for the recruits are a series of high school outreach events in underserved areas (inner city and rural alike), in which they become the expert. The STARs are paid for their time and take the lead in planning, teaching, and facilitating programs for the high school students, including classroom presentations, interactive lab activities, solar observing, and star parties. The high school outreach events provide role models and STEM exposure for the underserved high school community while simultaneously cementing the personal achievements and successes for the STARs. CU-STARs is now in its 4th year and is still growing. We are beginning the process of formal assessments of the program's success. We present details of the program implementation, a discussion of potential obstacles and future plans, and initial results of the program assessment, which speak highly of the program's contribution to individual student success.

Author(s): Cara Battersby[1], Devin W. Silvia[2], Erica Ellingson[3], Andrew P. Sturner[3], Courtney Peck[3]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Michigan State University, 3. University of Colorado at Boulder*

239.08 – A community of scientists: cultivating scientific identity among undergraduates within the Berkeley Compass Project

The Berkeley Compass Project is a self-formed group of graduate and undergraduate students in the physical sciences at UC Berkeley. Our goals are to improve undergraduate physics education, provide opportunities for professional development, and increase retention of students from populations typically underrepresented in the physical sciences. For students who enter as freshmen, the core Compass experience consists of a summer program and several seminar courses. These programs are designed to foster a diverse, collaborative student community in which students engage in authentic research practices and regular self-reflection. Compass encourages undergraduates to develop an identity as a scientist from the beginning of their university experience.

Author(s): Ana V. Aceves[1]

Institution(s): *1. University of California, Berkeley*
Contributing team(s): The Berkeley Compass Project

239.09 – A community of educators: professional development for graduate students within the Berkeley Compass Project

The Berkeley Compass Project is a self-formed group of graduate and undergraduate students in the physical sciences at UC Berkeley. Our goals are to improve undergraduate physics education, provide opportunities for professional development, and increase retention of students from populations typically underrepresented in the physical sciences. Graduate students, together with upper-level undergraduates, design and run all Compass programs. We strive to create a community of educators that incorporates best practices from the science education literature. Along the way, we develop experience in curriculum development, fundraising, grant writing, interfacing with university administration, and other aspects of running an effective organization. Our experience in Compass leaves us better poised to be successful researchers, teachers, and mentors.

Author(s): Josiah Schwab[1], Nathaniel Roth[1]
Institution(s): *1. University of California, Berkeley*
Contributing team(s): The Berkeley Compass Project

240 – Undergraduate Majors and Graduate Students: Diversity, Retention, Mentorship, and Research Posters

240.01 – Past and Future: NSF PAARE at SC State

We review our progress to date and the path forward under the NSF program “Partnerships in Astronomy and Astrophysics Research and Education (PAARE)”. Our project “A Partnership in Observational and Computational Astronomy (POCA)” was a part of the 2008 PAARE cohort and in August 2014 we received a second award (POCA II) to continue for another three years. Our partnership includes South Carolina State University (a Historically Black College/University), Clemson University (a Ph.D. granting institution) and the National Optical Astronomy Observatory as well as individual investigators at NASA Ames and Carnegie Mellon University. We present our recent publications which include educational courseware in cosmology, a study of long-period variables using Kepler and spectroscopic variability of peculiar stars. Our graduate student successes include support for two females who have completed their Ph.Ds. in astronomy plus two additional students from underrepresented groups who have received their M.S. degrees in astronomy but are continuing their doctoral work in related fields. At SC State we have graduated 3 physics majors with the astronomy option with five more in the pipeline and review the challenges and obstacles faced along the way. We discuss our strategic plan for POCA II, which is based on lessons learned under POCA and moves us forward to the follow-on period when our efforts will be sustained by other resources.

Our support includes NSF awards AST-0750814 and AST-1358913 to South Carolina State University as well as resources and support provided by Clemson University and the National Optical Astronomy Observatory. Support for the Kepler observations is provided by NASA to South Carolina State University under awards NNX11AB82G and NNX13AC24G.
Additional details can be found at: http://physics.scsu.edu/paare/

Author(s): Donald K. Walter[5], Sean D. Brittain[2], Jennifer Cash[5], Dieter Hartmann[2], Kenneth H. Hinkle[4], Shirley Ho[1], Steve B. Howell[3], Jeremy R. King[2], Mark D. Leising[2], Kenneth J. Mighell[4], Daniel M. Smith[5]
Institution(s): *1. Carnegie Mellon University, 2. Clemson University, 3. NASA Ames Research Center, 4. National Optical Astronomy Observatory, 5. South Carolina State Univ.*

240.02 – The Council On Undergraduate Research Division of Physics and Astronomy Distributed REU Program: Outcomes from the First Year of the Pilot Program

Virtual collaborations are a feature of modern research groups. As such, the Council on Undergraduate Research Division of Physics and Astronomy developed a distributed REU pilot program. Projects in physics and astronomy spanned theoretical, experimental, and computational areas. Funding for the REU brought students from across the country to work with research groups at partner institutions. Students were selected from institutions with fewer opportunities for research, with a focus on students from smaller universities or community colleges. Faculty and students at the host institutions collaborated virtually during the summer, attending seminars and discussions via web conferencing. Interactions among the students in the six-campus REU cohort took place on-line with the experience culminating in an in-person meeting at Central Washington University that included presentations on the students' work. We present the outcome of the first year of this NSF-funded work, seeking to leverage the collective experience of faculty mentors across a spectrum of physics and astronomy projects. We will review some of the assessment data from the first year of the project, and present the benefits and challenges to such virtual collaborations.

Author(s): John C. Armstrong[3], Michael Jackson[1], John Mateja[2]
Institution(s): *1. Central Washington University, 2. Murray State, 3. Weber State Univ.*

240.03 – The National Astronomy Consortium (NAC) - the University of Wisconsin-Madison Cohort

The UW-Madison Research Experiences for Undergraduates (REU) program in astrophysics (http://www.astro.wisc.edu /undergrads/uw-madison-reu-program/) is partnering with the National Radio Astronomy Observatory, the National Society of Black Physicists, and other universities in an entity called the National Astronomy Consortium (NAC; see https://sites.google.com/site/nraonac/). The mission of the NAC is to increase the numbers of students who might otherwise be overlooked by the traditional academic pipeline into STEM, or related, careers. This begins with a cohort of students who are part of the regular REU program. In addition to working on original research projects under the mentorship of university astronomers and astrophysics, the cohort students participate in professional development seminars and join other NAC cohort sites in a diversity speaker series. The mentor-student and student-student connections continue beyond the summer, including a fall meeting of the national NAC cohorts. The UW-Madison REU program is supported by the National Science Foundation through Award AST-1004881.

Author(s): Eric Hooper[2], Kartik Sheth[1], Elisabeth A.C. Mills[1]
Institution(s): *1. NRAO, 2. Univ. of Wisconsin-Madison*
Contributing team(s): National Astronomy Consortium

240.04 – Preparing new Earth Science teachers via a collaborative program between Research Scientists and Educators

The Master of Arts in Teaching (MAT) Program at the American Museum of Natural History is a innovative program designed to prepare participants to be world-class Earth Science teachers. New York State is experiencing a lack of qualified Earth Science teachers, leading in the short term to a reduction in students who successfully complete the Earth Science Regents examination, and in the long term potential reductions in the number of students who go on to pursue college degrees in Earth Science related disciplines. The MAT program addresses this problem via a collaboration between practicing research scientists and education faculty. The faculty consists of curators and postdoctoral researchers from the Departments of Astrophysics, Earth and Planetary Sciences, and the Division of Paleontology, as well as doctoral-level education experts. During the 15-month, full-time program, students participate in a residency program at local urban classrooms as well as taking courses and completing field work in astrophysics, geology, earth science, and paleontology. The program targets high-needs schools with diverse populations. We seek to encourage, stimulate interest, and inform the students impacted by our program, most of whom are from traditionally underrepresented backgrounds, about the rich possibilities for careers in Earth Science related disciplines and the intrinsic value of the subject. We report on the experience of the first and second cohorts, all of whom are now employed in full time teaching positions, and the majority in high needs schools in New York State.

Author(s): Jana Grcevich[1], Ashley Pagnotta[1], Mordecai-Mark Mac Low[1], Michael Shara[1], Kennet Flores[1], Patricia A Nadeau[1], Jocelyn Sessa[1], Gokce Ustunisik[1], Nasser Zirakparvar[1], Denton Ebel[1], George Harlow[1], James D Webster[1], Rosamond Kinzler[1], Maritza B MacDonald[1], Julie Contino[1], Natasha Cooke-Nieves[1], Elaine Howes[1], Marion Zachowski[1]
Institution(s): *1. American Museum of Natural History*

240.05 – Using Data-Collection Sensors to Improve Reasoning About Experiment Design and Hypothesis Testing: An Undergraduate Course for Underrepresented Minorities Pursuing Careers Astrophysics Research

Strategies to improve the retention of underrepresented students in STEM fields include directly targeted programs and specialized courses. The NSF-supported “AstroCom NYC” program, a collaboration of the City University of New York, American Museum of Natural History (AMNH), and Columbia University is one example of such a program with the explicit goal of increasing the participation of underrepresented minorities in astronomy and astrophysics through pedagogical mentoring and research experiences for undergraduate students. In addition, “AstroCom NYC” provides students with a semester-long specialized course emphasizing scientific reasoning and mathematical modeling. The course curriculum uses computers and interfaced digital probeware (sensors) in a laboratory environment that encourages collaborative and active learning.

We share course materials on preparing students to reason about control of variable experiment design and hypothesis testing and provide course data on student understanding of scientific reasoning, mathematical modeling and views about science.

Author(s): Dennis M. Robbins[2], K.E. Saavik Ford[1]
Institution(s): *1. Borough of Manhattan Community College, 2. Hunter College*

240.06 – AstroCom NYC: Expanding the Partnership

AstroCom NYC is an undergraduate mentoring program designed to improve urban minority student access to opportunities in astrophysical research by greatly enhancing partnerships between research astronomers in New York City (City University of New York – an MSI, American Museum of Natural History, and Columbia). AstroCom NYC provides centralized, personalized mentoring as well as financial and academic support, to CUNY undergraduates throughout their studies, plus the resources and opportunities to further CUNY faculty research with students. The goal is that students' residency at AMNH helps them build a sense of belonging in the field, and readies and inspires them for graduate study. AstroCom NYC provides a rigorous Methods of Scientific Research course developed specifically to this purpose, a laptop, research and career mentors, outreach activities, scholarships and stipends, Metrocards, and regular assessment for maximum effectiveness. Stipends in part alleviate the burdens at home typical for CUNY students so they may concentrate on their academic success. AMNH serves as the central hub for our faculty and students, who are otherwise dispersed among all five boroughs of the City. For our second cohort, we dramatically improved the application and screening process, implemented a number of tools to evaluate their potential for grad school, and began growing a network of potential hosts for summer internships around NY State and the US. We review these implementations and outcomes, as well as plans for Year 3, when we expect many of our current students to compete for external summer REUs, and after greatly expanding the program reach through a NASA community college initiative.

Author(s): Timothy Paglione[5], Saavik Ford[2], Marcel A. Agueros[3], Mordecai-Mark Mac Low[1], Dennis Robbins[4]
Institution(s): *1. AMNH, 2. BMCC, CUNY/AMNH, 3. Columbia U., 4. Hunter Coll., CUNY, 5. York College, CUNY/AMNH*

240.07 – The Undergraduate ALFALFA Team: A Model for Involving Undergraduates in Major Legacy Astronomy Research

The NSF-sponsored Undergraduate ALFALFA (Arecibo Legacy Fast ALFA) Team (UAT) is a consortium of 19 institutions founded to promote undergraduate research and faculty development within the extragalactic ALFALFA HI blind survey project and follow-up programs. The collaborative nature of the UAT allows faculty and students from a wide range of public and private colleges and especially those with small astronomy programs to develop scholarly collaborations. Components of the program include an annual undergraduate workshop at Arecibo Observatory, observing runs at Arecibo, computer infrastructure, summer and academic year research projects, and dissemination at national meetings (e.g., Alfvin et al., Martens et al., Sanders et al., this meeting). Through this model, faculty and students are learning how science is accomplished in a large collaboration while contributing to the scientific goals of a major legacy survey.

In the 7 years of the program, 23 faculty and more than 220 undergraduate students have participated at a significant level. 40% of them have been women and members of underrepresented groups. Faculty, many of whom were new to the collaboration and had expertise in other fields, contribute their diverse sets of skills to ALFALFA related projects via observing, data reduction, collaborative research, and research with students. 142 undergraduate students have attended the annual workshops at Arecibo Observatory, interacting with faculty, graduate students, their peers, and Arecibo staff in lectures, group activities, tours, and observing runs. Team faculty have supervised 131 summer research projects and 94 academic year (e.g., senior thesis) projects. 62 students have traveled to Arecibo Observatory for observing runs and 46 have presented their results at national meetings. 93% of alumni are attending graduate school and/or pursuing a career in STEM. Half of those pursuing graduate degrees in Physics or Astronomy are women.

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Institution(s): *1. Chicago State University, 2. Colgate University, 3. Cornell University, 4. George Mason University, 5. Georgia Southern University, 6. Hartwick College, 7. Ithaca College, 8. Lafayette College, 9. Macalester College, 10. Saint Lawrence University, 11. Saint Mary's College of California, 12. Siena College, 13. Skidmore College, 14. Union College, 15. University of Puerto Rico, 16. University of San Francisco, 17. University of Wisconsin, 18. University of Wisconsin-Stevens Point, 19. West Texas A&M Univesity*
Contributing team(s): ALFALFA Team

240.08 – Professional Development Through The University of Arizona Astronomy Club

The University of Arizona Astronomy Club creates a unique environment for undergraduates to accomplish goals early in their academic career. The club provides research opportunities with advisors, graduate students, and projects organized by fellow undergraduates. Undergraduates that work side-by-side develop strong working relationships which keeps students interested in astronomy and enables them to thrive in their studies and research. Club members are encouraged to attend and present their research at professional conferences where they are exposed early to the scientific research community, learn about internship and REU opportunities, and get information about graduate programs. In addition to preparing undergraduates to thrive in their academic career, the club also offers outreach opportunities for members to actively educate the southern Arizona community. Members of the club design and create many of their outreach materials including 3D models of our local stellar neighborhood and astronomical objects. Astronomy Club has had a positive impact on its members, the Department of Astronomy, and the southern Arizona community for the past seven years. The club continues to strive to improve undergraduate retention and prepare students for their future careers.

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240.09 – Learning the Constellations: From Junior High to Undergraduate Descriptive Astronomy Class

As part of two separate studies we have examined the ability of students to learn and remember a group of constellations, bright stars, and deep sky objects. For a group of junior high students we tested their knowledge of only the constellations by giving them a ‘constellation quiz’ without any instruction. We then provided the students with a lab session, and retested. We also tested a large number of undergraduate students in our descriptive astronomy classes, but in this case there were the same 30 constellations, 17 bright stars, and 3 deep sky objects. The undergraduate students were tested in a number of ways: 1) pre-testing without instruction, 2) self-reporting of knowledge, 3) normal constellation quizzes as part of the class, and 4) retesting students from previous semesters. This provided us with a set of baseline measurements, allowed us to track the learning curve, and test retention of the material. We will present our early analysis of the data.

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240.10 – The Lowell Observatory Predoctoral Scholar Program

Lowell Observatory is pleased to solicit applications for our Predoctoral Scholar Fellowship Program. Now beginning its seventh year, this program is designed to provide unique research opportunities to graduate students in good standing, currently enrolled at Ph.D. granting institutions. Lowell staff research spans a wide range of topics, from astronomical instrumentation, to icy bodies in our solar system, exoplanet science, stellar populations, star formation, and dwarf galaxies. The Observatory's new 4.2 meter Discovery Channel Telescope has successfully begun science operations and we anticipate the commissioning of several new instruments in 2015, making this a particularly exciting time in our history. Student research is expected to lead to a thesis dissertation appropriate for graduation at the doctoral level at the student's home institution. The Observatory provides competitive compensation and full benefits to student scholars. For more information, see http://www2.lowell.edu/rsch/predoc.php and links therein. Applications for Fall 2015 are due by May 1, 2015.

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240.11 – Astrobites: Four Years of Astro-blogging

Astrobites (astrobites.com) is now entering its fifth year publishing readable and accessible blog posts summarizing recent research in astrophysics and serving as an online hub for science communication. We continue to focus on our primary goal of making active research accessible to undergraduates by helping to break down technical descriptions and define jargon. However, our readership includes not only undergraduates, but also graduate students and professionals within astronomy, astronomy enthusiasts, and educators. With an average of more than 1000 page views per day, Astrobites reaches a large and diverse audience. We provide not only paper summaries, but also career guidance, practical “how-to” articles, reports on attending conferences (such as this one), and astronomy news. Astrobites continues to be authored, operated, and led exclusively by a graduate students in astronomy, with our author list spanning the United States and beyond. We reflect on the first four years of Astrobites, including our emphasis on providing both graduate students and undergraduates with opportunities to write about their research for broad audiences, and present results from our latest readership survey. We also look forward at our continued involvement in broader science communication efforts, including ComSciCon (comscicon.com), the series of science communication workshops for graduate students.

Author(s): Christopher Faesi[2], Elisabeth R. Newton[2], Maria Drout[2], Meredith L. Rawls[3], Benjamin Montet[1], Nathan Sanders[2]
Institution(s): *1. California Institute of Technology, 2. Harvard Univ., 3. New Mexico State University*
Contributing team(s): Astrobites collaboration

241 – Education Practice: Undergraduate Non-Science Majors Posters

241.01 – Shedding Light on Astronomy Textbooks for Astro 101

Astronomy textbooks present new vocabulary and concepts to students in different and unique ways. Understanding the differences between textbooks is useful for confirming that the textbook you use in your class is the best possible match for how you teach astronomy. We compare the treatment of terms and equations dealing with the Sun and properties of light in over ten different introductory textbooks. For example, nearly every textbook uses a different equation for angular resolution. (Come by the poster to vote for your favorite!) There are also various forms of the equation for Wien's Law and different uses of the terms "hydrostatic equilibrium" and "blackbody radiation." We discuss possible reasons for the approximations and simplifications made by textbook authors.

Author(s): Andrea Urban[1], Julia D. Silge[1]
Institution(s): *1. Sapling Learning*

241.02 – From Picas to Pixels: An Astro 101 e-book

What to do when a publisher discontinues publishing a textbook? That was the dilemma we were presented with. Given that we know we have a high quality product that can contribute to student understanding of science in general and astronomy in particular, and that significant efforts had already been expended on the project, we decided to self-publish, even knowing that the challenges, and the gamble in terms of time and personal expense, were great.

Self publication provides an opportunity to produce an updated edition at great cost savings to students---something faculty often say is an important consideration in their choice of a book.

We present the end result: a completed publication in various e-book formats and with links to the *Discovering Astronomy Concept Videos* made for the book. The *Discovering Astronomy Activities Manual* will again be available. Details of the book, a sample chapter, and other information are available at discoveringastronomy@weebly.com.

Author(s): Stephen J. Shawl[4], Gene G. Byrd[3], Susana E. Deustua[2], Michael C. LoPresto[1]
Institution(s): *1. Henry Ford College, 2. Space Telescope Science Institute, 3. University of Alabama, 4. University of Kansas*

241.03 – Automated Estimation of the Orbital Parameters of Jupiter's Moons

Every semester in Introductory Astronomy at the University of St. Thomas, students complete a Jupiter lab. This involves measuring the distances from Jupiter to its moons in approximately twenty images and tracing the orbital curves of the moons by hand. When students make errors, instructors can sometimes have difficultly troubleshooting the error in real time. It would be much easier to spot and fix errors if the instructor had the solution ahead of time, but creating the solution by hand is very time consuming and takes over an hour. To help the instructors, we have automated the process. Given a list of images, we automatically extract the positions of Jupiter and its moons and generate a plot of the positions along with fitted orbital curves.

Author(s): Emma Western[1], Gerald T. Ruch[1]
Institution(s): *1. University of St. Thomas*

241.04 – Integrating Robotic Observatories into Astronomy Labs

The University of St. Thomas (UST) and a consortium of five local schools is using the UST Robotic Observatory, housing a 17" telescope, to develop labs and image processing tools that allow easy integration of observational labs into existing introductory astronomy curriculum. Our lab design removes the burden of equipment ownership by sharing access to a common resource and removes the burden of data processing by automating processing tasks that are not relevant to the learning objectives.

Each laboratory exercise takes place over two lab periods. During period one, students design and submit observation requests via the lab website. Between periods, the telescope automatically acquires the data and our image processing pipeline produces data ready for student analysis. During period two, the students retrieve their data from the website and perform the analysis. The first lab, "Weighing Jupiter," was successfully implemented at UST and several of our partner schools. We are currently developing a second lab to measure the age of and distance to a globular cluster.

Author(s): Gerald T. Ruch[1]
Institution(s): *1. University of St. Thomas*

241.05 – Community College Non-Science Undergraduates Observe Exoplanet Transits with 8-inch Observatory in

Glendale, Arizona

Using the 8-inch Celestron telescopes at the Glendale Community College North Observatory in Glendale, Arizona, a group of undergraduate students, most of whom are non-science majors, observed exoplanet transits during the Fall 2014 semester. These students, members of the Glendale Community College's Astronomy Students for Telescope Research and Outreach (A.S.T.R.O.) Club, selected targets observable with telescopes of this size and the conditions of the sky. With these observations and using concepts and skills learned in introductory astronomy courses for non-science majors, the co-authors recorded detections of exoplanet transits consistent with published professional results. These results demonstrate that post-secondary institutions can teach hands-on, practical astronomy experience given equipment that is readily available and affordable, regardless of the size of the student body majoring in the physical sciences.

Author(s): Brian Gleim[1], Henry Esteban[1], Connor Lincoln[1], Jason Price[1], Elizabeth Giroux[1], Noreen Lentowski[1], Leslie Valencia[1], Bryce Morris[1], Blake Smith[1], Chris Leffler[1], Matt Bonilla[1], Sara D. Watt[1]
Institution(s): *1. Glendale Community College*

241.06 – Authentic Learning and Alien Worlds

Glendale Community College has developed a laboratory course and observing program which provides non-science majors with opportunities to perform authentic science in a community college setting. The program is designed around experiential learning which allows students to meaningfully construct concepts within contexts that involve real-world problems that are relevant to the learner. Students learn observational astronomy and data analysis techniques by observing exoplanet transits using 8-inch Celestron telescopes. The exoplanet data gathered and analyzed by the students is contributed to the exoplanet database. This poster presents an overview of the program and highlights early educational results.

Author(s): Sara D. Watt[1], Keith Watt[1], Brian Gleim[1]
Institution(s): *1. Glendale Community College*

241.07 – At what distance can the human eye detect a candle flame?

Various claims in television commercials and on the web suggest that the human eye can detect a candle flame 3.5 to 30 miles away. These claims are wrong, in large part because the background light of the sky is not taken into account. Even at a dark sky site, the *V*-band sky brightness on a moonless night varies from 21.0 to 22.0 mag/sec^2 (136 to 54 nL) over the course of the 11 year solar cycle. One calculation on the web sets the background to 0.1 nL, as if one had a photographic dark room miles in extent. The most direct way to estimate the maximum distance at which a candle can be seen is to first determine how far one has to be situated from a candle such that it is comparable in brightness to a star of magnitude V = 0, such as Vega or Rigel. We find that this distance is 160 to 200 m. This can be double checked with a CCD imager. A candle flame equivalent to a star of magnitude V = 6 would be 15.85 times more distant, or roughly 2.85 km. We present the results of our own experiments and discuss formulations that take into account the background light.

Author(s): Kevin Krisciunas[1], Don W. Carona[1]
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241.08 – Writing an Electronic Astronomy Book with Interactive Curricular Material

With the rise of tablets, the past few years have seen an increase in the demand for quality electronic textbooks. Unfortunately, most of the current offerings do not exploit the accessibility and interactivity that electronic books can deliver. In this poster, we discuss how we are merging our curriculum development projects (Physlets, Easy Java/JavaScript Simulations, and Open Source Physics) with the EPUB electronic book format to develop an interactive textbook for use in a one-semester introductory astronomy course. The book, *Astronomy: An Interactive Introduction*, combines the narrative, equations, and images of a traditional astronomy text with new JavaScript simulations.

Author(s): Kristen L. Thompson[1], Mario Belloni[1], Wolfgang Christian[1]
Institution(s): *1. Davidson College*

241.09 – A Planetary System Exploration Project for Introductory Astronomy and Astrobiology Courses

I have created three-part projects for the introductory astronomy and astrobiology courses at Westfield State University which simulate the exploration of a fictional planetary system. The introductory astronomy project is an initial reconnaissance of the system by a robotic spacecraft, culminating in close flybys of two or three planets. The astrobiology project is a follow-up mission concluding with the landing of a roving lander on a planet or moon. Student responses in earlier parts of each project can be used to determine which planets are targeted for closer study in later parts. Highly realistic views of the planets from space and from their surfaces can be created using programs such as

Celestia and Terragen; images and video returned by the spacecraft are thus a highlight of the project. Although designed around the particular needs and mechanics of the introductory astronomy and astrobiology courses for non-majors at WSU, these projects could be adapted for use in courses at many different levels.

Author(s): Richard F. Rees[1]
Institution(s): *1. Westfield State University*

241.10 – Activities Joining Learning Objectives to Assessments in Introductory Astronomy

In recent years, accreditation boards and other governing bodies have been pushing hard for explicit learning goals and quantitative measures of assessment for general education courses such as Astronomy 101. This added assessment burden can be problematic, especially for harried adjuncts teaching multiple courses at multiple institutions. It would be helpful to have a field-tested set of combined hands-on activities and assessment tools that help instructors meet these assessment requirements. The authors have produced just such a set. We have been using hands-on activities in our classrooms for more than 15 years. These activities require no special equipment or preparation and can be completed within an hour by most students working in groups of two or three. The sections of each activity are arranged in steps, guiding the students from initial knowledge-level questions or practice to a final evaluation or synthesis of what they have just accomplished. Students thus get practice thinking at higher cognitive levels. A recent addition to these activities is the inclusion of formalized learning objectives and accompanying pre- and post-activity questions. The pre-activity questions address common misconceptions, relate familiar analogous terrestrial examples to the activity, and act as a brief refresher meta-concepts like scale factors, measurements, and basic mathematics review. The post-activity questions review the most important concepts introduced in the activity. We present a number of examples as well as a summary as to how we have initiated their use in a large lecture setting of 300 students, in smaller classrooms of 15 students, and in a community college online course.

Author(s): Stacy E. Palen[2], Ana M. Larson[1]
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241.11 – "ASTRO 101" Course Materials 2.0: Next Generation Lecture Tutorials and Beyond

Early efforts to create course materials were often local in scale and were based on "gut instinct," and classroom experience and observation. While subsequent efforts were often based on those same instincts and observations of classrooms, they also incorporated the results of many years of education research. These "second generation" course materials, such as lecture tutorials, relied heavily on research indicating that instructors need to actively engage students in the learning process. While imperfect, these curricular innovations, have provided evidence that research-based materials can be constructed, can easily be disseminated to a broad audience, and can provide measureable improvement in student learning across many settings. In order to improve upon this prior work, next generation materials must build upon the strengths of these innovations while engineering in findings from education research, cognitive science, and instructor feedback. A next wave of materials, including a set of next generation lecture tutorials, have been constructed with attention to the body of research on student motivation, and cognitive load; and they are responsive to our body of knowledge on learning difficulties related to specific content in the domain. From instructor feedback, these materials have been constructed to have broader coverage of the materials typically taught in an ASTRO 101 course, to take less class time, and to be more affordable for students. This next generation of lecture tutorials may serve as a template of the ways in which course materials can be reengineered to respond to current instructor and student needs.

Author(s): Stephanie Slater[1], Kevin Grazier[1]
Institution(s): *1. CAPER Ctr Phys and Astro Educ Res*

241.12 – Strange Horizons: Teaching Usual and Unusual Atmospheric Effects using APOD

Unusual Sun and moonsets are not only photogenic -- they are educational. Images appearing on the Astronomy Picture of the Day (APOD) that demonstrate dramatic examples of the green flash, the Moon illusion, Fata Morgana, and the Etruscan vase effect are discussed in terms of how they demonstrate atmospheric refraction, chromatic aberration, and temperature inversions. A lesson plan is given for undergraduate classrooms as well as estimates of how each effect might alter the perceived time of a common sunset.

Author(s): Teresa Wilson[1]
Institution(s): *1. Michigan Technological University*

242 – Extending the Reach of Astronomical Professionals Posters

242.01 – Modern Publishing Approach of Journal of Astronomy & Earth Sciences Education

Filling a needed scholarly publishing avenue for astronomy education researchers and earth science education researchers, the *Journal of Astronomy & Earth Sciences Education* – JAESE published its first volume and issue in 2014. The *Journal of Astronomy & Earth Sciences Education* – JAESE is a scholarly, peer-reviewed scientific journal publishing original discipline-based education research and evaluation, with an emphasis of significant scientific results derived from ethical observations and systematic experimentation in science education and evaluation. International in scope, JAESE aims to publish the highest quality and timely articles from discipline-based education research that advance understanding of astronomy and earth sciences education and are likely to have a significant impact on the discipline or on policy. Articles are solicited describing both (i) systematic science education research and (ii) evaluated teaching innovations across the broadly defined Earth & space sciences education, including the disciplines of astronomy, climate education, energy resource science, environmental science, geology, geography, agriculture, meteorology, planetary sciences, and oceanography education. The publishing model adopted for this new journal is open-access and articles appear online in *GoogleScholar*, *ERIC*, and are searchable in catalogs of 440,000 libraries that index online journals of its type. Rather than paid for by library subscriptions or by society membership dues, the annual budget is covered by page-charges paid by individual authors, their institutions, grants or donors: This approach is common in scientific journals, but is relatively uncommon in education journals. Authors retain their own copyright. The journal is owned by the Clute Institute of Denver, which owns and operates 17 scholarly journals and currently edited by former American Astronomical Society Education Officer Tim Slater, who is an endowed professor at the University of Wyoming and a Senior Scientist at the CAPER Center for Astronomy & Physics Education Research. More information about the journal and its policies are available online at http://www.JAESE.org

Author(s): Timothy F. Slater[1]
Institution(s): *1. University of Wyoming*

242.02 – Google Hangouts: Leveraging Social Media to Reach the Education Community

Research shows that educator professional development is most effective when it is sustained and/or when a follow-on component is included to support the learning process. In order to create more comprehensive learning experiences for our workshop participants, the education team at the Space Telescope Science Institute is working collaboratively with scientific staff and other experts to create a follow-on component for our professional development program. The new component utilizes video conferencing platforms, such as Google's Hangouts On Air, to provide educators with content updates and extended learning opportunities in between in-person professional development experiences. The goal is to enhance our professional development program in a cost-effective way while reaching a greater cross-section of educators. Video broadcasts go live on Google+, YouTube, and our website – thus providing access to any user with a web browser. Additionally, the broadcasts are automatically recorded and archived for future viewing on our YouTube channel. This provides educators with anywhere, anytime training that best suits their needs and schedules. This poster will highlight our new Hangouts for educators as well as our cross-departmental efforts to expand the reach of our Hubble Hangouts for the public through a targeted recruitment strategy.

Author(s): Bonnie Eisenhamer[1], Frank Summers[1], Dan McCallister[1], Holly Ryer[1]
Institution(s): *1. STScI*

242.03 – Introducing Astronomy Allies: We are here to help!

Imagine you are a grad student, at your first conference, and a prominent senior scientist shows interest in your work, and he makes things get way too personal? What would you do? Would you report it? Or would you decide, after a few other instances of harassment, that maybe you shouldn't pursue astronomy? Harassment is under-reported, the policies can be difficult to understand or hard to find, and it can be very intimidating as a young scientist to report it to the proper individuals. The Astronomy Allies Program is designed to help you with these sorts of problems. We are a group of volunteers that will help by doing the following: provide safe walks home during the conference, someone to talk to confidentially, as an intervener, as a resource to report harassment. The Allies are a diverse group of scientists committed to acting as mentors, advocates, and liaisons. The Winter 2015 AAS meeting will be the first meeting that has Astronomy Allies, and Astronomy Allies will provide a website for information, as well as a twitter, email, and phone number for anyone who needs our help or would like more information. We posted about the Astronomy Allies on the Women In Astronomy blog, and this program resonates with many people: either they want to help, or they have experienced harassment in the past and don't want to see it in the future. Harassment may not happen to most conference participants, but it's wrong, it's against the AAS anti-harassment policy (http://aas.org/policies/anti-harassment-policy), it can be very damaging, and if it happens to even one person, that is unacceptable. We intend to improve the culture at conferences to make it so that harassers feel they can't get away with their unprofessional behavior.

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242.04 – An Update on the NASA Planetary Science Division Research and Analysis Program

Introduction: NASA's Planetary Science Division (PSD) solicits its Research and Analysis (R&A) programs each year in Research Opportunities in Space and Earth Sciences (ROSES). Beginning with the 2014 ROSES solicitation, PSD will be changing the structure of the program elements under which the majority of planetary science R&A is done. Major changes include the creation of five core research program elements aligned with PSD's strategic science questions, the introduction of several new R&A opportunities, new submission requirements, and a new timeline for proposal submission
ROSES and NSPIRES: ROSES contains the research announcements for all of SMD. Submission of ROSES proposals is done electronically via NSPIRES: http://nspires.nasaprs.com. We will present further details on the proposal submission process to help guide younger scientists. Statistical trends, including the average award size within the PSD programs, selections rates, and lessons learned, will be presented. Information on new programs will also be presented, if available.
Review Process and Volunteering: The SARA website (http://sara.nasa.gov) contains information on all ROSES solicitations. There is an email address (SARA@nasa.gov) for inquiries and an area for volunteer reviewers to sign up. The peer review process is based on Scientific/Technical Merit, Relevance, and Level of Effort, and will be detailed within this presentation.
ROSES 2014 submission changes: All PSD programs will use a two-step proposal submission process. A Step-1 proposal is required and must be submitted electronically by the Step-1 due date. The Step-1 proposal should include a description of the science goals and objectives to be addressed by the proposal, a brief description of the methodology to be used to address the science goals and objectives, and the relevance of the proposed research to the call submitted to.
Additional Information: Additional details will be provided on the Cassini Data Analysis Program, the Exoplanets Research program and Discovery Data Analysis Program, for which Dr. Richey is the Lead Program Officer.

Author(s): Christina Richey[1], Max Bernstein[1], Jonathan Rall[1]
Institution(s): *1. NASA HQ*

243 – Education and Public Outreach Posters

243.01 – Light Pollution Awareness through Globe at Night & IYL2015

The International Astronomical Union (IAU) will be coordinating extensive activities to raise awareness of light pollution through running the Cosmic Light theme of the International Year of Light (IYL2015) and by partnering in particular with the popular Globe at Night program.
Globe at Night (www.globeatnight.org) is an international campaign to raise public awareness of the impact of light pollution by having people measure night-sky brightness and submit observations in real-time with smart phone or later with a computer. In 2015, Globe at Night will run for 10-nights each month, an hour after sunset til before the Moon rises. Students can use the data to monitor levels of light pollution around the world, as well as understand light pollution's effects on energy consumption, plants, wildlife, human health and our ability to enjoy a starry night sky.
Since its inception in 2006, more than 115,000 measurements from 115 countries have been reported. The last 9 years of data can be explored with Globe at Night's interactive world map or with the "map app" to view a particular area. A spreadsheet of the data is downloadable from any year. One can compare Globe at Night data with a variety of other databases to see, for example, how light pollution affects the foraging habits of bats.
To encourage public participation in Globe at Night during IYL2015, each month will target an area of the world that habitually contributes during that time. Special concerns for how light pollution affects that area and solutions will be featured on the Globe at Night website (www.globeatnight.org), through its Facebook page, in its newsletter or in the 365DaysofAstronomy.org podcasts.
Twice during IYL there will be a global Flash Mob event, one on Super Pi Day (March 14, 2015) and a second in mid-September, where the public will be invited to take night-sky brightness measurements *en masse.* In April, the International Dark-Sky Week hosted by the International Dark-Sky Association will be featured (www.darksky.org/int-l-dark-sky-week-main) and The World at Night will co-host the sixth annual International Earth and Sky Photo Contest (www.TWANight.org/contest).
The poster will provide further updates.

Author(s): Constance E. Walker[1]
Institution(s): *1. NOAO*

243.02 – STARtorialist: Astronomy Outreach via Fashion, Sci-Fi, & Pop Culture

Astronomical images in the public domain have increasingly been used as inspiration and patterns for clothing, accessories, and home decor. These "AstroFashion" items are as diverse as DIY projects, handmade and boutique products, mass-produced commercial items, and haute couture. STARtorialist is a Tumblr-based blog that curates the proliferation of these products with the goal of celebrating the beauty of the universe and highlighting the science behind the images. The blog also includes sci-fi, space, and science-related aspects of popular culture. Each post features images and descriptions of the products, and often where/how we found them and/or the people wearing them, with links to the original astronomical images or other relevant science content. The popularity of each post is evident in the number of “notes”, including “faves” (personal bookmarks) and “reblogs” (shares with other users). Since launching the blog in December 2013, with an average of one post per day, we’ve attracted hundreds of followers on Tumblr and Twitter and thousands of notes on Tumblr. We will present our most popular posts and recommend how education, outreach, and press offices can add Tumblr to their social media repertoire.

Author(s): Emily L. Rice[1], Summer Ash[2]
Institution(s): *1. College of Staten Island, 2. Columbia University*

243.03 – Columbia University Public Outreach: Looking Beyond the Bright Lights in the Big City

Columbia University astronomers have been inviting the public to come and share in our love of the skies for several decades now, but only within the last ten years has this program become a sustained tool for public outreach and professional development. Columbia's Public Outreach engages with multiple audiences, from the general public to teachers to students of all ages, year-round. In the last three years alone, we have interacted with approximately 7500 people via school visits, teacher-training events, and our public lecture and stargazing series. Our outreach efforts are unique in that they are staffed entirely by graduate students and undergraduate majors who volunteer their time, and coordinated by a dedicated science-trained staff member in the department. Our program is particularly suited to be a vehicle for graduate-student training in science communication and public speaking. We describe the various components of our program and provide an analysis of the populations reached.

Author(s): Summer Ash[1], Marcel A. Agueros[1]
Institution(s): *1. Columbia University*

243.04 – Reaching for the Stars in your Golden Years: The Importance of Outreach for Senior Citizens

Astronomy outreach is often conducted in science classrooms, museums, observatories, and even at the local park. The intended audiences are usually families with young children, who we are training to be the next generation of scientists, inventors and world-changers. Science outreach is rarely geared towards senior citizens, and yet this group can be the most receptive audience, willing to share past experiences and engage in learning. Educating our seniors about astronomy, especially current discoveries, upcoming technology, and funding challenges, is of the utmost importance. Here, I share my experience conducting astronomy outreach at senior living communities in Rochester, NY as part of their Lifelong Learning initiative, and discuss why this type of outreach is important.

Author(s): Valerie Rapson[1]
Institution(s): *1. Rochester Institute of Technology*

243.05 – Scientific Discovery through Citizen Science via Popular Amateur Astrophotography

Can popular astrophotography stimulate real astronomical discovery? Perhaps surprisingly, in some cases, the answer is yes. Several examples are given using the Astronomy Picture of the Day (APOD) site as an example venue. One reason is angular -- popular wide and deep images sometimes complement professional images which typically span a more narrow field. Another reason is temporal -- an amateur is at the right place and time to take a unique and illuminating image. Additionally, popular venues can be informational -- alerting professionals to cutting-edge amateur astrophotography about which they might not have known previously. Methods of further encouraging this unusual brand of citizen science are considered.

Author(s): Robert J. Nemiroff[2], Jerry T. Bonnell[3], Alice Allen[1]
Institution(s): *1. Astrophysics Source Code Library, 2. Michigan Technological Univ., 3. University of Maryland*

243.06 – The Arizona Galileoscope Project: A 5th Grade Rural Education Program

The Galileoscope is a low cost, high quality telescope kit developed for the International Year of Astronomy (IYA). Over 200,000 Galileoscopes have been sold and used by the public and education programs around the world.

The National Optical Astronomy Observatory has been a leader in Galileoscope education programs. In 2009 we started the Arizona Galileoscope Star Party Program. We have partnered with rural school districts around the state including Flagstaff, Safford, Yuma, Globe and Payson to bring Galilesocope educational program to the students and teachers. The program begins with a professional development workshop where teachers learn about the optics of telescopes and how to assemble the Galileoscope and use it on a tripod. The teachers receive a Teaching With Telescopes (TWT) kit that contains a variety of lenses, lasers and lights to do all the activities in the workshop and a classroom supply of Galileoscopes and tripods to take back to their classroom. Their students learn about telescope optics and how to use a Galileoscope. Several weeks after the professional development workshop, a district wide star party is held for the parents, teachers and students.

In the coming years, we are expanding the program in cooperation with Science Foundation Arizona. We are currently in the process of recruiting new cities to join the program in addition to supporting our previous communities. We will describe our past efforts, the evaluation of the program and our future expansion.

Author(s): Robert T. Sparks[1], Stephen M. Pompea[1], Constance E. Walker[1]
Institution(s): *1. NOAO*

243.07 – Dark Skies, Bright Kids Year 6

Now entering our sixth year of operation, Dark Skies, Bright Kids (DSBK) is an entirely volunteer-run outreach organization based out of the Department of Astronomy at the University of Virginia. Our core mission is to enhance elementary science education and literacy in central Virginia through fun, hands-on activities that introduce basic Astronomy concepts beyond Virginia's Standards of Learning. Our primary focus is hosting an 8-10 week after-school astronomy club at underserved elementary and middle schools. Each week, DSBK volunteers take the role of coaches to introduce astronomy-related concepts ranging from the Solar System to galaxies to astrobiology, and to lead students in interactive learning activities. Another hallmark of DSBK is hosting our Annual Central Virginia Star Party, a free event open to the community featuring star-gazing and planetarium shows.

DSBK has amassed over 15,000 contact hours since 2009 and we continue to broaden our impact. One important step we have taken in the past year is to establish a graduate student led assessment program to identify and implement directed learning goals for DSBK outreach. The collection of student workbooks, observations, and volunteer surveys indicates broad scale success for the program both in terms of student learning and their perception of science. The data also reveal opportunities to improve our organizational and educational practices to maximize student achievement and overall volunteer satisfaction for DSBK's future clubs and outreach endeavors.

Author(s): Sandra Liss[1], Nicholas William Troup[1], Kelsey E. Johnson[1], Loreto D Barcos-Munoz[1], Rachael Beaton[1], Lauren Bittle[1], Henry J Borish[1], Andrew Burkhardt[1], Joanna Corby[1], Janice Dean[1], Danielle Hancock[1], Jennie King[1], Brian Prager[1], Charles Romero[1], Kimberly R. Sokal[1], Sabrina Stierwalt[1], Trey Wenger[1], Catherine Zucker[1]
Institution(s): *1. University of Virginia*

243.08 – RU SciTech: Weaving Astronomy and Physics into a University-sponsored Summer Camp for Middle School Students

We present a successful model for organizing a small University-sponsored summer camp that integrates astronomy and physics content with other science disciplines and computer programming content. The aim of our science and technology camp is to engage middle school students in a wide array of critical thinking tasks and hands-on activities centered on science and technology. Additionally, our program seeks to increase and maintain STEM interest among children, particularly in under-represented populations (e.g., Hispanic, African-American, women, and lower socioeconomic individuals) with hopes of decreasing disparities in diversity across many STEM fields.

During this four-day camp, organized and facilitated by faculty volunteers, activities rotated through many STEM modules, including optics, telescopes, circuit building, computer hardware, and programming. Specifically, we scaffold camp activities to build upon similar ideas and content if possible. Using knowledge and skills gained through the AAS Astronomy Ambassadors program, we were able to integrate several astronomy activities into the camp, leading students through engaging activities, and conduct educational research. We present best practices on piloting a similar program in a university environment, our efforts to connect the learning outcomes common across all the modules, specifically in astronomy and physics, outline future camp activities, and the survey results on the impact of camp activities on attitudes toward science, technology, and science careers.

Author(s): Quyen N. Hart[1]
Institution(s): *1. Regis University, Regis College*

243.09 – Using USNO's API to Obtain Data

The U.S. Naval Observatory (USNO) is in the process of modernizing its publicly available web services into APIs (Application Programming Interfaces). Services configured as APIs offer greater flexibility to the user and allow greater usage. Depending on the particular service, users who implement our APIs will receive either a PNG (Portable Network Graphics) image or data in JSON (JavaScript Object Notation) format. This raw data can then be embedded in third-party web sites or in apps.
Part of the USNO's mission is to provide astronomical and timing data to government agencies and the general public. To this end, the USNO provides accurate computations of astronomical phenomena such as dates of lunar phases, rise and set times of the Moon and Sun, and lunar and solar eclipse times. Users who navigate to our web site and select one of

our 18 services are prompted to complete a web form, specifying parameters such as date, time, location, and object. Many of our services work for years between 1700 and 2100, meaning that past, present, and future events can be computed. Upon form submission, our web server processes the request, computes the data, and outputs it to the user. Over recent years, the use of the web by the general public has vastly changed. In response to this, the USNO is modernizing its web-based data services. This includes making our computed data easier to embed within third-party web sites as well as more easily querying from apps running on tablets and smart phones. To facilitate this, the USNO has begun converting its services into APIs. In addition to the existing web forms for the various services, users are able to make direct URL requests that return either an image or numerical data.
To date, four of our web services have been configured to run with APIs. Two are image-producing services: "Apparent Disk of a Solar System Object" and "Day and Night Across the Earth." Two API data services are "Complete Sun and Moon Data for One Day" and "Dates of Primary Phases of the Moon." Instructions for how to use our API services as well as examples of their use can be found on one of our explanatory web pages and will be discussed here.

Author(s): Michael V. Lesniak[2], Daniel Pozniak[2], Tarun Punnoose[1]
Institution(s): *1. Science & Engineering Apprenticeship Program (SEAP), 2. U.S. Naval Observatory*

243.10 – The *Aloha Telescope* for K-12 STEM Education

How does one bring night-time astronomical observations into the classroom? How does a teacher – during the school day – show students the craters on the Moon, the rings of Saturn, or the four Galilean moons of Jupiter? One of the greatest drawbacks to teaching Astronomy is the lack of real-time telescopic observations during the school day, and yet this is a very exciting time for astronomical discoveries.

The solution is to access a telescope in a substantially different time zone where it is still night. This facility – the *Aloha Telescope* – on Maui has already been established by a partnership between Georgia Tech and the Air Force Research Lab. This robotic telescope's sole purpose is for K-12 education, as it is equipped with a video-camera and is operated remotely via high-speed internet connections. This facility and its outreach program allow east-coast teachers and, in turn, students to have local daytime access to – and direct control of – the telescope. When observing the Moon, teachers and students will move the telescope wherever they wish across the highly-magnified lunar surface (~ 5 arcminute FOV). This telescope will enable night-time astronomical observations to come alive as day-time activities and will be an important tool for STEM education and activities. The use of the *Aloha Telescope* requires minimal training and is free after registering for a date and time.

Dr. Sowell has written specific telescopic exercises and surface feature tours appropriate for K-12 and college-level users. These exercises, and other aspects of the *Aloha Telescope* and program, are posted on the website at **http://aloha.gatech.edu**.

Author(s): James R. Sowell[1]
Institution(s): *1. Georgia Inst. of Tech.*

243.11 – Developing the OORCC: A Multifaceted Astronomical Research and Outreach Facility at the University of Oregon

The University of Oregon (UO) owns and operates Pine Mountain Observatory (PMO), located in central Oregon on the summit of Pine Mountain at an elevation of 1980 meters. PMO consists of four telescopes ranging in size from 0.35 - 0.8 meters. The Oregon Observatory Remote Control Center (OORCC) is a remote-observing center within the Department of Physics on the UO campus (~140 miles from the observatory) that has a direct connection to PMO through a dedicated fiber-optic cable. With this facility, we will enable UO undergraduate student researchers, UO faculty, and the non-scientific community to fully control and operate a newly installed robotic telescope on the summit of Pine Mountain from Eugene, or any other authorized site in Oregon. In addition to providing undergraduates with instrumentation and engineering experience, we will implement research by photometrically monitoring bright and variable astronomical sources including main belt comets, Herbig Ae/Be stars, and active galactic nuclei in extragalactic systems. The primary objective with the OORCC is to manage a multifaceted astronomy and astrophysics research facility, extending as a state-wide resource for K-12 STEM activities and public outreach programs. With the OORCC, we intend to bring unique and enriching astronomy exposure to many different groups of people throughout the state of Oregon.

Author(s): Teiler J Kwan[1], Jeremy Bullis[1], Annika Gustafsson[1], Robert Scott Fisher[1]
Institution(s): *1. University of Oregon*

243.12 – Physically Based Rendering in the Nightshade NG Visualization Platform

This poster describes our work on creating a physically based rendering model in Nightshade NG planetarium simulation

and visualization software (project website: NightshadeSoftware.org). We discuss techniques used for rendering realistic scenes in the universe and dealing with astronomical distances in real time on consumer hardware. We also discuss some of the challenges of rewriting the software from scratch, a project which began in 2011.
Nightshade NG can be a powerful tool for sharing data and visualizations. The desktop version of the software is free for anyone to download, use, and modify; it runs on Windows and Linux (and eventually Mac). If you are looking to disseminate your data or models, please stop by to discuss how we can work together.
Nightshade software is used in literally hundreds of digital planetarium systems worldwide. Countless teachers and astronomy education groups run the software on flat screens. This wide use makes Nightshade an effective tool for dissemination to educators and the public.
Nightshade NG is an especially powerful visualization tool when projected on a dome. We invite everyone to enter our inflatable dome in the exhibit hall to see this software in a 3D environment.

Author(s): Karrie Berglund[1], Trystan Larey-Williams[1], Rob Spearman[1], Arthur Bogard[1]
Institution(s): *1. Digitalis Education Solutions, Inc*

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244 – NASA/IPAC Teacher Archive Research Program (NITARP) Posters

244.01 – NITARP Summative Evaluation Report: 2013 Class

NITARP, the NASA/IPAC Teacher Archive Research Program, provides educators with an authentic astronomical research experience. We partner small groups of educators with a mentor astronomer for a year-long original research project, during which the teams echo the entire research process: writing a proposal, conducting research, writing up and presenting the results at an AAS meeting. This program differs from other programs that we know of that get real astronomy data into the classroom: (a) Each team works on an original project. There are no canned labs! (b) Each team presents their results in AAS posters, in science sessions (not just outreach sessions). The posters are distributed throughout the meeting, in amongst other researchers' work and not isolated; the participants are not "given a free pass" because they are teachers. (c) The 'product' of each project is the scientific result, not a curriculum packet. (d) While teachers directly include some students in their research, they also seek to bring aspects of their projects into the broader classroom learning environment to the benefit of all of their students. In 2012, we embarked on a summative evaluation of the 2013 NITARP class, whose intensive work ran from Jan 2013-Jan 2014. Our goals were to determine both the cognitive and affective impacts of NITARP on teacher participants, and also to ascertain the extent to which NITARP changes teaching styles, or desires to teach science differently. The results of this evaluation will be discussed in this poster as part of quantifying NASA Astrophysics E/PO Impact. The findings include the following. NITARP is an invaluable authentic research experience that clarifies for educators the true nature of scientific research. Examples of personal and professional growth were enthusiastically offered at every stage, starting as early as April, demonstrating the value of NITARP as a significant professional development experience. NITARP reinvigorated educators' love of learning and teaching. NITARP reminded educators of what it is like to be a learner struggling with difficult content, subsequently engendering empathy for students and improving teaching practice.

Author(s): Luisa M. Rebull[1], Kim Burtnyk[3], Varoujan Gorjian [2], Gordon K. Squires[1]
Institution(s): *1. Caltech, 2. JPL, 3. Science for Society: Science Communication Consulting and Evaluation*
Contributing team(s): NITARP team

244.02 – Crowd Sourcing as a Means of Collecting Astronomical Data

The discovery of previously unknown, extreme sources of infrared excess was a highly engaging activity for five teachers, a veteran astronomer, and more than 30 students in the NITARP program (NASA/IPAC Teacher Archive Research Program). Beginning with over one million sources culled from Spitzer Enhanced Imaging Products (SEIP) archive, the group used color-color plots to identify just over one hundred sources that appeared to exhibit extreme infrared excess. The team then developed a computer selection system that allowed group members to rate the reliability of each source based on cutout images from the SEIP server. The crowd sourcing proved to be an integral part of the process. Decisions on which objects qualified for further review were based on the results of this crowdsourcing exercise. This research was made possible through the NASA/IPAC Teacher Archive Research Program (NITARP) and was funded by NASA Astrophysics Data Program.

Author(s): Linda Childs[3], Todd Burke[2], Varoujan Gorjian [4], Caroline Odden[6], Sarp Orgul[6], David Strasburger[5], Kevin Tambara[1]
Institution(s): *1. Bert Lynn Middle School, 2. Estes Park High School, 3. Florida Virtual School, 4. JPL , 5. Noble & Greenough School, 6. Phillips Academy*

244.03 – Next Generation Scientists - Creating opportunities for high school students through astronomical research

Through various opportunities and experiences with extracurricular scientific research, primarily astronomical research with programs like NASA/IPAC Teacher Archive Research Project (NITARP), and the Mars Exploration Student Data Teams (MESDT), we have noticed a change in our learning style, career path, and general outlook on the scientific community that we strongly believe could also be added to the lives of many other high school students given similar opportunities. The purpose of our poster is to emphasize the importance of granting high school students opportunities to explore different styles and methods of learning. We believe that although crucial, a basic high school education is not enough to expose young adults to the scientific community and create enough interest for a career path. As a result, we wish to show that more of these programs and opportunities should be offered to a greater number of students of all ages, allowing them to explore their passions, develop their understanding of different fields, and determine the paths best suited to their interests. Within our poster, we will emphasize how these programs have specifically impacted our lives, what we hope to see in the future, and how we hope to attain the growth of such opportunities. We include such proposals as; increasing outreach programs, expanding the exposure of young students to the sciences, both in the classroom and out, allowing high school students to participate in active scientific research, and involving students in hands-on activities/experiments within school clubs, the classroom, at home, or at local events. Spreading these opportunities to directly interact with the sciences in similar manners as that of professional scientists will allow students to discover their interests, realize what being a scientist truly entails, and allow them to take the first steps into following their career paths.

Author(s): Madeline Kelly[2], Hannah Cebulla[1], Lynn Powers[2]
Institution(s): *1. Bozeman High School, 2. NITARP*

244.04 – NITARP: Measuring The Effectiveness of an Authentic Research Experience in Secondary Astronomy Education Through Concept Mapping

For secondary students to make use of astronomical data in a school setting, they previously needed access to large telescopes, expensive equipment and difficult-to-use software. This has improved as online data archives have become available; however, difficulties remain, including searching and downloading the data and translating it into formats that high school students can readily analyze. To address these issues, the NASA/IPAC Teacher Archive Research Program (NITARP) selects teams consisting of teachers and students from several schools. Each year, new teams of educators attend an introductory workshop at the winter AAS conference where they select a research project that will use the archived data. Throughout the spring, educators engage in weekly teleconferences, write proposals, and begin working with their students. The teams meet at Caltech in the summer to learn how to access and analyze the IPAC data and continue to work throughout the fall. Through this experience, participants learn how to search, download, translate, and analyze authentic astronomical data. They learn the nature of scientific communication through developing and presenting their findings alongside practicing astronomers at the following winter AAS. In order to measure how successful the 2014 NITARP summer visit was in teaching participating high school students the terminology and processes necessary to analyze IPAC data, students were asked to create concept maps showing the main and subsidiary ideas and concepts related to their research. They then synthesized their group webs into a master web. When additional terms and concepts were presented, the students were able to integrate them into the master web, showing that they understood the relationship of ideas, concepts, and processes needed for their research. Our companion poster, Gibbs et al., presents the scientific aspects of this project. This research was made possible through the NASA/IPAC Teacher Archive Research Program (NITARP) and was funded by the NASA Astrophysics Data Program.

Author(s): Elin Deeb[1], Luisa M. Rebull[2], David V Black[5], John Gibbs[3], Estefania Larsen[4]
Institution(s): *1. Bear Creek High School, 2. Caltech, 3. Glencoe High School, 4. Millard South High School, 5. Walden School of Liberal Arts*

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245 – Astronomy Education Research Posters

245.01 – Fostering a positive attitude towards science through college courses

For non-science majors, a general education course in college is often the last science course they will ever take. General education courses are often regarded by students as a right of passage in which they have no interest. Thus strict coursework might aggravate students against the matter taught, and decrease their general interest in the subject.
To test whether general education courses killed the students' interest in science, we administered a science attitude inventory at the beginning and at the end of an introductory astronomy course. We compared the gain/loss in science attitude with that experienced by students of a writing course as a baseline. Finally, we evaluated the gain/loss in science attitude for students enrolled in a general education course on science and society, where no formal science knowledge was taught, but where the students discussed the different aspects of the relation between science and society.
This study (once tested on a larger scale) could serve as a guideline for educational policies aiming to foster a positive attitude in the population of college graduates.

Author(s): Helene Flohic[1]
Institution(s): *1. University of the Pacific*

245.02 – Astronomy for Astronomical Numbers: a Worldwide Massive Open Online Class

Astronomy: State of the Art is a massive, open, online class (MOOC) offered through Udemy by an instructional team at the University of Arizona. With over 18,000 enrolled, it is the largest astronomy MOOC available. The astronomical numbers enrolled do not translate into a similar level of engagement. The content consists of 14 hours of video lecture, nearly 1000 PowerPoint slides, 250 pages of background readings, and 20 podcast interviews with leading researchers. Perhaps in part because of the large amount of course content, the overall completion rate is low, about 3%. However, this number was four times higher for an early cohort of learners who were selected to have a prior interest in astronomy and who took the class in synchronous mode, with new content being added every week. Completion correlates with engagement as measured by posts to the online discussion board. For a subset of learners, social media like Facebook and Twitter provide an additional, important mode of engagement. For the asynchronous learners who have continuously enrolled for the past 15 months, those who complete the course do so quickly, with few persisting longer than two months. The availability of a completion certificate had no impact of completion rates. This experiment informs a future offering of this MOOC via Coursera, along with a co-convened “flipped” introductory astronomy class at the University of Arizona, where the video lectures will be online and class time will be used exclusively for small group labs and hands-on activities. Despite their typically low completion rates, MOOCs have the potential to add significantly to public engagement with science.

Author(s): Carmen Austin[1], Chris David Impey[1], Matthew Wenger[1]
Institution(s): *1. University of Arizona*

245.03 – Applying Neurological Learning Research to an Intro Astronomy Online Lab Course

The neurological research used the “Tower of London”, a well-tested puzzle requiring multi-step planning toward a solution. Four and five year-olds are starting multistep reasoning and provide good puzzle subjects. Preschoolers who talked to themselves about future moves had greatly improved performance over those who did not. Adults given preplanning time prior to solving the same puzzle showed more neural activation during preplanning, especially in brain areas which serve higher level thinking. Applying these results to teaching astronomy, we modified an online introductory lab course in which students take a multiple choice final exam. We composed questions related to the learning objectives of the course modules (LOQs). Students could “talk to themselves” by discursively answering these for extra credit prior to the final. Results were compared to an otherwise identical previous unmodified class. Modified classes showed statistically much better final exam average scores (78% vs. 66%). This modification helped those students who most need help. Students in the lower third of the class preferentially answered the LOQs to improve their scores and the class average on the exam. These results also show the effectiveness of relevant extra credit work. For more details plus an application to a lecture course, see Byrd and Byrd http://www.ncolr.org/issues/jiol/v12/n2/3 (Journal of Interactive Online Learning). The online lab course emphasized real photographic and quantitative astronomical observations. We also discuss and show equipment found to be most useful for the online lab course, including a “pin-hole protractor”, telescope kit and "AL-henge" telescope mount..

Author(s): Gene G. Byrd[2], Dana Byrd[1]
Institution(s): *1. Texas A & M University-Kingsville, 2. University of Alabama - Tuscaloosa*

245.04 – Preliminary Evaluation of a New Cosmology Curriculum

Informed by our research on student understanding of cosmology, *The Big Ideas in Cosmology* is an immersive set of web-based learning modules that integrates text, figures, and visualizations with short and long interactive tasks and real cosmological data. This enables the transformation of general education astronomy and cosmology classes from primarily lecture and book-based courses to a more engaging format that builds important STEM skills.
During the spring 2014 semester, we field-tested a subset of chapters with the general education astronomy and cosmology classes at Sonoma State University in a flipped-classroom format. We administered pre and post content and attitude assessments in the two flipped classes as well as two lecture classes. The majority of cosmology students had taken astronomy before whereas the astronomy students had not.
When switching to an active mode of learning (e.g., flipped classroom instead of lecture), many instructors report pushback from students. We saw this effect from students in course evaluations, who reported dissatisfaction with "having to do more work." However, the students in the flipped section in astronomy made greater gains on the multiple choice content assessment than the students in either of the two lecture sections. On the attitude assessment (the CLASS), the cosmology students made a small shift toward more expert-like opinions. Preliminary results from open-ended content surveys indicate that, prior to instruction, students had difficulty answering “why” or “how do we know” questions; that post-instruction, students are less likely to respond "I don't know" or to leave an answer blank; and that students using the modules made gains in their content knowledge.

Module development was supported by NASA ROSES E/PO Grant #NNXl0AC89G, the Illinois Space Grant Consortium, the Fermi E/PO program, Sonoma State University's Space Science Education and Public Outreach Group, and Great River Technology/Kendall-Hunt Publishing.

Author(s): Kimberly A. Coble[1], Dominique Martin[1], Patrycia Hayes[1], Tom Targett[2], Janelle M. Bailey[3], Lynn R. Cominsky[2]
Institution(s): *1. Chicago State Univ., 2. Sonoma State Univ., 3. Temple Univ.*

245.05 – Learning to Work with Databases in Astronomy: Quantitative Analysis of Science Educators' and Students' Pre-/Post-Tests

Astronomy is increasingly moving towards working with large databases, from the state-of-the-art Sloan Digital Sky Survey Data Release 10, to the historical Digital Access to a Sky Century at Harvard. Non-astronomy fields as well tend to work with large datasets, be it in the form of warehouse inventory, health trends, or the stock market. However very few fields explicitly teach students the necessary skills to analyze such data. The authors studied a matched set of 37 participants working with 200-entry databases in astronomy using Google Spreadsheets, with limited information about a random set of quasars drawn from SDSS DR5. Here the authors present the quantitative results from an eight question pre-/post-test, with questions designed to span Bloom's taxonomy, on both the topics of the skills of using spreadsheets, and the content of quasars. Participants included both Astro 101 summer students and professionals including in-service K-12 teachers and science communicators. All groups showed statistically significant gains (as per Hake, 1998), with the greatest difference between women's gains of 0.196 and men's of 0.480.

Author(s): Andria C. Schwortz[1], Andrea C Burrows [1], Adam D. Myers[1]
Institution(s): *1. University of Wyoming*

245.06 – Enhancing Undergraduate Education through Mentored Research and Practical Writing Experiences

Twenty years ago I attended my very first AAS meeting as a 21-year old undergraduate physics major. At that meeting I presented the light curve of a variable star I had studied as part of a mentored research program at BYU. That opportunity to do mentored research, and to attend a professional meeting of astronomers, helped to set the foundation for my success today as an associate professor of physics and astronomy. Twenty years ago I was the student, now I am the mentor! I have eight undergraduate students whom I currently supervise in active research, four of which are presenting their senior projects at the 225th meeting of the AAS.

My experience has shown me that the full impact of mentored research cannot be measured by yearly numbers or statistics. When we mentor a student, we influence their career path and choices for years to come. Where feasible, every undergraduate should have the opportunity to do research if they so choose. It is a sacrifice of our time and our effort that cannot be easily measured through numbers or results, and is only visible many years down the road as these students become the future leaders in astronomy and policy. In this poster, I will discuss the benefits of mentored research, the growth we have seen at BYU over the past twenty years with the introduction of a mentored research program, and ideas for implementing mentored research and writing into course curricula to enhance the undergraduate educational experience.

Author(s): Denise C. Stephens[1], Eric G. Hintz[1], Michael D. Joner[1], J. Ward Moody[1]
Institution(s): *1. Brigham Young Univ.*

245.07 – Using Multiple Methods to teach ASTR 101 students the Path of the Sun and Shadows

It seems surprising that non-science major introductory astronomy students find the daily path of the Sun and shadows created by the Sun challenging to learn even though both can be easily observed (provided students do not look directly at the Sun). In order for our students to master the relevant concepts, we have usually used lecture, a lecture tutorial (from Prather, et al.) followed by think-pair-share questions, a planetarium presentation and an animation from the Nebraska Astronomy Applet Project to teach these topics. We cover these topics in a lecture-only, one semester introductory astronomy course at Joliet Junior College. Feedback from our Spring 2014 students indicated that the planetarium presentation was the most helpful in learning the path of the Sun while none of the four teaching methods was helpful when learning about shadows cast by the Sun. Our students did not find the lecture tutorial to be much help even though such tutorials have been proven to promote deep conceptual change. In Fall 2014, we continued to use these four methods, but we modified how we teach both topics so our students could gain more from the tutorial. We hoped our modifications would cause students to have a better overall grasp of the concepts. After our regular lecture, we gave a shorter than usual planetarium presentation on the path of the Sun and we asked students to work through a shadow activity from Project Astro materials. Then students completed the lecture tutorial and some think-pair-share questions. After this, we asked students to predict the Sun's path on certain days of the year and we used the planetarium projector to show them how well their predictions matched up. We ended our coverage of these topics by asking students a few more think-pair-share questions. In our poster, we will present our approach to teaching these topics in Fall 2014, how our Fall 2014 students feel about our teaching strategies and how they fared on related test

questions.

Author(s): Noella L. D'Cruz[1]
Institution(s): *1. Joliet Junior College*

245.09 – Do Gains in Secondary Teachers' Content Knowledge Provide an ASSET to Student Learning?

During the Summer of 2013, a group of East Texas middle and high school science teachers attended the first year of the Astronomy Summer School of East Texas (ASSET), a two-week NASA funded workshop. This workshop focused on providing area teachers with a rigorous two-week experience loaded with interactive content lessons combined with hands-on activities, all relating to the universal laws of astronomy as well as solar system concepts.
The effectiveness of this workshop was gauged in part through a series of content surveys given to each participating educator at the beginning and end of the workshop. Similar content surveys were also administered to each teacher's students as pre/post-content surveys in an effort to determine the extent to which teacher gains were transferred into student gains, as well as to judge the effectiveness of the teachers' lessons in conveying these concepts to the students. Overall, students performed best on concepts where teachers exhibited the highest gains in their learning and focused most of their emphasis. A question-by-question analysis, though, suggests that a broad analysis paints an incomplete picture of student learning. We will present an item analysis of student gains by topic along with a comparison of content coverage and teacher gains. Looking beyond these numbers will present results that demonstrate that giving secondary teachers professional development opportunities to increase content knowledge, and tools to present such knowledge to their students, can improve student learning and performance, but is dependent on teacher confidence and level of coverage.
This project is supported by the NASA Science Mission Directorate Education and Public Outreach for Earth and Space Science (EPOESS), which is part of the Research Opportunities in Space and Earth Sciences (ROSES), Grant Number NNX12AH11G.

Author(s): Travis Hites[1]
Institution(s): *1. Sam Houston State University*

245.10 – Perspectives on Science Teacher Professional Development: A study of the ASSET Experience

The Astronomy Summer School of East Texas (ASSET) is a two-year NASA-funded teacher professional development program created to help improve middle and high school science teachers' knowledge of and attitudes toward astronomy. During an intensive summer astronomy course experience, science teachers are taught astronomy concepts and principles through engaging pedagogical techniques. The workshop models hands-on/minds-on teaching strategies that strengthened teachers' own pedagogical content knowledge and ways of teaching astronomy to students.
As part of our second year of ASSET, participants were observed and interviewed before, during and after the workshop experience to ascertain their perspectives on their own professional development and understanding of astronomy. Interview data, participant observations, surveys, and artifact data (journaling, one-minute papers, etc...) were analyzed and three broad themes emerged regarding the significance of the ASSET experience on teacher enhancement of content knowledge, pedagogical content knowledge (PCK), and the significance of teacher professional development communities in teaching and learning science. We will discuss the major implications of our observations and outline what tools and techniques can be best implemented as part of professional development workshops such as ASSET.
This project is supported by the NASA Science Mission Directorate Education and Public Outreach for Earth and Space Science (EPOESS), which is part of the Research Opportunities in Space and Earth Sciences (ROSES), Grant Number NNX12AH11G.

Author(s): Katrina Reeves[1], Scott Miller[1], Andrea Foster[1]
Institution(s): *1. Sam Houston State University*

245.11 – The Siren Song of the Absurd Answer

Conventional wisdom states that students rarely choose absurd multiple choice distractors, which therefore simply add noise. In contrast, it is observed that introductory astronomy students are sometimes inexorably drawn to multiple choice answers that are clearly absurd to an expert. I demonstrate this phenomenon using data from the University of Alabama's introductory astronomy for non-majors course and investigate possible explanations, with an eye towards improving multiple choice as an assessment method. I finish with a plea for other instructors to include the same questions in their exams in order to dramatically increase the sample size and uncover correlations with other student behavior that can help understand what leads them to make such obvious mistakes.

Author(s): Jeremy Bailin[1]
Institution(s): *1. University of Alabama*

245.12 – Have Astronomers Been to Neptune? Results of a Study of High School Students' Ideas about How Astronomers Study the Solar System

The Earth and Space Science Partnership (ESSP) continues to collaborate with Pennsylvania teachers to research how grades 4-9 students learn selected topics in Earth and Space Science. We have previously conducted semi-structured interviews with students across a wider range of grade levels (4 - 16) to facilitate the development of an empirical "learning progression." This learning progression will reveal the pathways students follow as they progress from novice to expert understanding of the astronomical phenomena presented in an instructional sequence that includes study of the Solar System. During the initial round of interviews, we also included questions to determine student ideas about what experimental techniques astronomers use in their work as they study these phenomena. We found that because students rarely engaged directly in observational astronomy, they often relied on cultural experiences or classroom experiences from other scientific disciplines to construct an answer. For example, many believed that the only way for astronomers to study a planet is to directly sample it and return that material to Earth.

Because the questions in our original interview protocol did not allow us to fully sample student ideas in this particular area, we have designed a new study to answer the question "What are students' ideas about the scientific practices used by astronomers in their study of the properties of objects that make up the Solar System?" In this poster, we will present preliminary findings of our analysis of a new round of interviews that uses a newly designed, open-ended interview protocol to query students from two different 9th grade Earth and Space Science classes from a large Pennsylvania high school. We will also present our ideas for how instruction can support student understanding of these ideas in astronomy, and how other, similar studies in other scientific domains may allow us to more generally study how students reason about scientific practices across disciplines.

We gratefully acknowledge support from the NSF MSP program award DUE#0962792.

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Institution(s): *1. Penn State Univ.*
Contributing team(s): The Earth and Space Science Partnership

245.13 – Recognition of American Sign Language (ASL) Classifiers in a Planetarium Using a Head-Mounted Display

A traditional accommodation for the deaf or hard-of-hearing in a planetarium show is some type of captioning system or a signer on the floor. Both of these have significant drawbacks given the nature of a planetarium show. Young audience members who are deaf likely don't have the reading skills needed to make a captioning system effective. A signer on the floor requires light which can then splash onto the dome. We have examined the potential of using a Head-Mounted Display (HMD) to provide an American Sign Language (ASL) translation. Our preliminary test used a canned planetarium show with a pre-recorded sound track. Since many astronomical objects don't have official ASL signs, the signer had to use classifiers to describe the different objects. Since these are not official signs, these classifiers provided a way to test to see if students were picking up the information using the HMD.

We will present results that demonstrate that the use of HMDs is at least as effective as projecting a signer on the dome. This also showed that the HMD could provide the necessary accommodation for students for whom captioning was ineffective. We will also discuss the current effort to provide a live signer without the light splash effect and our early results on teaching effectiveness with HMDs.

This work is partially supported by funding from the National Science Foundation grant IIS-1124548 and the Sorenson Foundation.

Author(s): Eric G. Hintz[1], Michael Jones[1], Jeannette Lawler[1], Nathan Bench[1]
Institution(s): *1. Brigham Young Univ.*

245.14 – Design of the i*STAR* International STudy on Astronomy Reasoning

Beginning in 2013, a small international collaborative of discipline-based astronomy education researchers began to build the foundation to start the *International STudy on Astronomy Reasoning* Project, known simply as i*STAR*. The project was a direct result of the inability of existing large international investigations into the learning of science, such as the TIMSS and PISA studies, to provide actionable intelligence on either strengths or weaknesses of astronomy teaching across the world. This is not because those studies were flawed; rather, they focused on the general characteristics of teaching and learning across all sciences. Prior to the i*STAR* effort, there has been no systematic effort to measure individual's conceptual astronomy understanding across the globe. The goal of studying a widely dispersed international sample is to identify cultural subpopulations that do not conform to our existing knowledge of student misconceptions, highlighting unexpected cultural or educational practices that hint at alternative, and perhaps more effective, means of instruction. As a first step, we are carefully translating the *Test Of Astronomy STandards* – TOAST multiple-choice assessment instrument and carefully attending to nuances that occur during the translation process as cultural clues to differences in the teaching and learning of astronomy. We are actively welcoming and seeking international partners in this work through the CAPERteam.com website and at https://www.surveymonkey.com/s/iSTAR-Registration . This project is sponsored and managed by the CAPER Center for Astronomy & Physics Education Research in collaboration with members of the International Astronomical Union-Commission 46.

Author(s): Coty B. Tatge[2], Stephanie J. Slater[1]
Institution(s): *1. CAPER Center for Astronomy & Physics Education Research, 2. University of Wyoming*

245.15 – What types of astronomy images are most popular?

Stunning imagery helps make astronomy one of the most popular sciences -- but what types of astronomy images are most popular? To help answer this question, public response to images posted to various public venues of the Astronomy Picture of the Day (APOD) are investigated. APOD portals queried included the main NASA website and the social media mirrors on Facebook, Google Plus, and Twitter. Popularity measures include polls, downloads, page views, likes, shares, and retweets; these measures are used to assess how image popularity varies in relation to various image attributes including topic and topicality.

Author(s): Alice Allen[1], Jerry T. Bonnell[4], Paul Connelly[3], Ralf Haring[2], Stuart R. Lowe[5], Robert J. Nemiroff[6]
Institution(s): *1. , 2. , 3. , 4. CRESST / Goddard Space Flight Center, 5. Jami Institution Test, 6. Michigan Technological University*

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246 – Astronomy Research for K-12 Students and Teachers Posters

246.01 – Astronomy across State Lines: A Collaborative Model for Astronomical Research

Scientists do not work in isolation, nor should student scientists. In a collaborative effort, students from three high schools examined plates from the Sloan Digital Sky Survey (SDSS) to estimate the number of galaxies that contain evidence of a black hole. Working under the direction of Don York, former SDSS director, the three teachers used Google hangouts to discuss weekly progress. At their home institutions, students examined optical spectra from SDSS Data Release 10 to determine if a quasar could be discerned. Both Type I and Type II quasars can be seen in the SDSS data. Seven teams of students from different schools compared their findings and collaborated online to discuss potential discoveries.

This project can serve as a model for high school teachers who want to facilitate their students participating in an authentic research project. The keys to a successful project are working with a mentor who can guide the group through difficult concepts and communicating frequently throughout the project.

Author(s): Chelen H. Johnson[1], Jacqueline Barge[4], Marcella Linahan[2], Donald G. York[3], David Cante[4], Mary Cook[4], Maeve Daw[2], Katherine E Donahoe[2], Sydney Ford[4], Lille W Haecker[1], Cecily A Hibbs[1], Eleanor B Hogan[1], Demetra N Karos[1], Kendall G Kozikowski[1], Taylor A Martin[1], Fernando Miranda[4], Emily Ng[4], Imany Noel[4], Sophie E O'Bryan[1], Vikrant Sharma[4], David Zegeye[4]
Institution(s): *1. Breck School, 2. Carmel Catholic High School, 3. University of Chicago, 4. Walter Payton College Prep High School*

246.02 – Teaching Advanced Data Analysis Tools to High School Astronomy Students

A major barrier to becoming an astronomer is learning how to analyze astronomical data, such as using photometry to compare the brightness of stars. Most fledgling astronomers learn observation, data reduction, and analysis skills through an upper division college class. If the same skills could be taught in an introductory high school astronomy class, then more students would have an opportunity to do authentic science earlier, with implications for how many choose to become astronomers. Several software tools have been developed that can analyze astronomical data ranging from fairly straightforward (AstroImageJ and DS9) to very complex (IRAF and DAOphot). During the summer of 2014, a study was undertaken at Brigham Young University through a Research Experience for Teachers (RET) program to evaluate the effectiveness and ease-of-use of these four software packages. Standard tasks tested included creating a false-color IR image using WISE data in DS9, Adobe Photoshop, and The Gimp; a multi-aperture analyses of variable stars over time using AstroImageJ; creating Spectral Energy Distributions (SEDs) of stars using photometry at multiple wavelengths in AstroImageJ and DS9; and color-magnitude and hydrogen alpha index diagrams for open star clusters using IRAF and DAOphot. Tutorials were then written and combined with screen captures to teach high school astronomy students at Walden School of Liberal Arts in Provo, UT how to perform these same tasks. They analyzed image data using the four software packages, imported it into Microsoft Excel, and created charts using images from BYU's 36-inch telescope at their West Mountain Observatory. The students' attempts to complete these tasks were observed, mentoring was provided, and the students then reported on their experience through a self-reflection essay and concept test. Results indicate that high school astronomy students can successfully complete professional-level astronomy data analyses when given detailed instruction tailored to their experience level along with proper support and mentoring.

This project was funded by a grant from the National Science Foundation, Grant # PHY1157078.
Author(s): David V Black[2], Julie Herring[2], Eric G. Hintz[1]
Institution(s): *1. Brigham Young Univ., 2. Walden School of Liberal Arts*

246.03 – A Survey of Light Pollution in the Rogue Valley, Southwest Oregon, By St. Mary's School, Medford, Oregon

Rural areas in Oregon, including the Rogue Valley, are renowned for beautiful dark skies. Electric light came to Medford, Oregon, the largest town in the Rogue Valley, in 1894. During the past 100 years the Rogue Valley grew from 2,500 individuals in 1895 to a population of 76,462 and a metropolitan area population of 208,545, in 2012. The increased population density resulted in increased light pollution. A light pollution chart using DMSP, Defense Meteorological Satellite Program, data was published in 2006, but did not show the spatial variation in detail. In the spring of 2014, the 9th grade physics students, astronomy students, and members of the Astronomy Club from St. Mary's School conducted the first detailed night sky survey. The purpose of the survey is to create a baseline of the variations in light pollution in the Rogue Valley.

The project started with a talk by Steve Bosbach, former Texas IDA coordinator, on the topic of light pollution and how it affects our lives and the environment. Groups of students were given the tasks of measuring the night sky brightness in the Rogue Valley, doing a light audit in an area of their choice, and researching what light pollution is and its effects on the environment. From this they created a presentation for a final physics grade. The basis for this project, along with procedures can be found on the Globe at Night (www.globeatnight.org) website. The light audit and research portion were developed from the Dark Sky Rangers section (www.globeatnight.org/dsr/) of the website. In the fall of 2014, astronomy students and club members extended this study to the town of Ashland and the Sothern Oregon University campus, areas of the valley not surveyed in the Spring.

This survey will increase awareness of light pollution in the Rogue Valley, as well as educate developers and city planners on the impact that light pollution has on the environment in Southern Oregon. It will help determine areas of concern and areas of dark sky compliant lighting, which could spur appropriate regulation regarding outdoor lighting.

Author(s): Holly Bensel[1]
Institution(s): *1. St. Mary's School*
Contributing team(s): Arianna Ashby, Colin Cai, Thomas Cox, Genna Dorrell, Gabe FitzPatrick, Meaghan FitzPatrick, Jason Mars Liu, Mitchell Moczygemba, Kieran Rooney, Emry Timmons, and Ray You, students, (St. Mary's School)

246.04 – Exoplanet Research at a Southwestern Urban High School: Lessons Learned from the Tucson High Astronomy Club Research Program

We present the results of introducing talented youth to research astronomy projects related to the study of exoplanets. We present the results of students' development of their identities as scientist, their interest in the STEM field as a career, and their knowledge retention through individual surveys. The design of the student interaction was to have weekly after-school club meetings where basic material would be taught to aid the students addressing the research problems themselves by planning observations, observing, and ultimately reducing the data of observations of their selected exoplanets. The after-school club was composed of 12 students of varying backgrounds attending the urban Tucson
Magnet High School. The program is ongoing and began September 2013.

Author(s): Zachary T. Watson[1], Stephen M. Pompea[1]
Institution(s): *1. National Optical Astronomy Observatory*
Contributing team(s): Tucson High Astronomy Research Club

246.05 – Collaboration Between Astronomers at UT Austin and K-12 Teachers: Connecting the Experience of Observing and Research with the Classroom

McDonald Observatory has a long history of providing teacher professional development (PD), and recently we have developed a new workshop model for more advanced participants. By choosing a select group of middle and high school teachers from those previously involved in our past PD programs, we have created a joint workshop / observing run program for them. After traveling to the observatory, the teachers participate in an actual observing run with a research astronomer. The teachers are trained first-hand how to take observations, operate the telescope, set up the instrument, and monitor observing conditions. The teachers are fully put in the role of observer. They are also given background information before and during the workshop related to the science and data they are helping to collect. The teachers work in teams to both perform the nightly observations with an astronomer, but to also perform new interactive classroom activities with education staff, and use other telescopes on the mountain. This is a unique experience for teachers since it allows them to take the resources and experiences directly back to their classrooms and students. They can directly relate to their students what skills for specific careers in STEM fields are needed. Evaluation from these workshops shows that there is: increased content knowledge among participants, greater impact that will be passed on to their students, and an authentic research experience that can't be replicated in other PD settings. In addition, not only is this program beneficial to the teachers, but this group is benefit to the education program of McDonald Observatory. Building on an existing PD program (with a 16 year history) we have the opportunity to test out new products and new education endeavors with this devoted group of well-trained teachers before bringing them to wider teacher and student audiences. This program is currently supported by the NSF grant AST-1211585 (PI Sneden).

Author(s): Keely D. Finkelstein[1], Christopher Sneden[1], Mary Kay Hemenway[1], Sandra Preston[1]
Institution(s): *1. University of Texas at Austin*
Contributing team(s): EXES Teachers Associate Program

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247 – Star Associations, Star Clusters - Galactic & Extra-galactic Posters

247.01 – The Globular Cluster System of the Elliptical Galaxy NGC 2937 as a Marker of its Evolutionary History

Using imaging data from the Hubble Space Telescope archive, we examine the rich globular cluster population of the giant elliptical galaxy NGC 2937, located at a distance of 70 Mpc. We present a color-magnitude diagram and two-color diagram of the galaxy's globular cluster system and discuss their possible implications for the evolutionary history of the galaxy.

Author(s): Emily Longley[1]
Institution(s): *1. Carleton College*
Contributing team(s): Dr. Michael West Maria Mitchell Observatory, Dr. William Harris McMaster University

247.02 – Analysis of the changing brightness of stars in nearby young stellar clusters

We present initial results of a photometric variability study of 19 stars in the TW Hydrae Association (TWA). TWA is a stellar moving group made up of young (10 Myr) dispersed stars moving across the sky. By studying individual brightness variations we hope to learn more about intermediate periods of stellar formation. We have identified 19 stars in the TWA in our data set of irregularly spaced, photometric observations of the southern sky obtained over the past 4 years with KELT-South, the Kilodegree Extremely Little Telescope located in Sutherland, South Africa. We will present light curves of these stars and assess their photometric variability.

Author(s): Emily Rolen[1], Joseph E. Rodriguez[1], David A. Weintraub[1], Joshua Pepper[1], Keivan Stassun[1]
Institution(s): *1. Vanderbilt University*
Contributing team(s): KELT-South Science Team

247.03 – A Wide-Field Photometric Survey of Globular Clusters in the Merger Remnant M85

M85 is an intriguing merger remnant in the northernmost region of the Virgo Cluster. It shows notable features indicating that it experienced the recent merging. In order to trace the merging history of M85, we obtained deep and wide field images of M85 covering one square degree using CFHT/MegaCam and ugi filters. We detect about 1000 globular cluster candidates in these images. The color distribution of globular clusters in the outer region shows a bimodality with stronger blue component, which is in contrast to the previous results based on HST/ACS images of a small central field in the ACSVCS. We find that the spatial distribution of the globular cluster candidates is elongated along the faint stellar light in the outer region of M85, and that this feature is prominent with the blue objects. We discuss these results in relation with the formation history of M85.

Author(s): Youkyung Ko[3], Myung Gyoon Lee[3], Jubee Sohn[3], Sungsoon Lim[2], Hong Soo Park[1], Narae Hwang[1], Byeong-Gon Park[1]
Institution(s): *1. Korea Astronomy and Space Science Institute, 2. Peking University, 3. Seoul National University*

247.04 – Tidal streams in triaxial systems

Tidal streams form from the steady disruption of stellar systems orbiting within the gravitational field of some parent galaxy. Many streams and debris structures have been discovered in the halo of the Milky Way and have been used to model the potential of the Galaxy. However, few of these models have yet explored the properties of tidal debris in triaxial potentials. The existence of a variety of orbits, resonances, and chaotic regions in such potentials suggest that the morphologies and dispersal timescales of debris could differ significantly from the simpler spherical and oblate cases. In this work we use a series of N-body simulations of stellar systems over a range of masses of disruption in triaxial potentials to understand the influence of the nature and types of orbits on debris morphologies. Our results suggest that the mere existence of the multitude of thin streams already known to orbit the Milky Way provides significant constraints on the classes of triaxial potentials that provide a good representation for its dark matter halo.

Author(s): Adrian M. Price-Whelan[1], Kathryn V. Johnston[1], Sarah Pearson[1], Andreas Hans Wilhelm Kupper[1]
Institution(s): *1. Columbia University*

247.06 – Radial Stellar Population Gradients in the Galactic Globular Cluster 47 Tucanae

We present a deep near-infrared color-magnitude diagram of the Galactic globular cluster 47 Tucanae, obtained with the Visible and Infrared Survey Telescope for Astronomy (VISTA) as part of the VISTA near-infrared *Y, J,* K^s survey of the Magellanic System (VMC). The cluster stars comprising both the subgiant and red-giant branches exhibit apparent, continuous variations in color-magnitude space as a function of radius. Subgiant-branch stars at larger radii are systematically brighter than their counterparts closer to the cluster core; similarly, red-giant-branch stars in the cluster's periphery are bluer than their more centrally located cousins. The observations can very well be described by adopting an age spread of ~0.5 Gyr as well as radial gradients in both the cluster's helium abundance (Y) and metallicity (*Z*), which change gradually from Y = 0.28, *Z* = 0.005 in the cluster core to Y = 0.25, *Z* = 0.003 in its periphery. We conclude that the cluster's inner regions host a significant fraction of second-generation stars, which decreases with increasing radius; the stellar population in the 47 Tuc periphery is well approximated by a simple stellar population.

Author(s): Richard de Grijs[1], Chengyuan Li[1]
Institution(s): *1. Kavli Institute for Astronomy and Astrophysics, Peking University*

247.07 – Sizes and Shapes of Young, Massive Star Clusters in M83

Using HST imaging, the surface brightness profiles of individual star clusters in nearby galaxies can be resolved, in that clusters are clearly more extended than the stellar PSF. Previous studies of the sizes and shapes of star clusters find little variation with cluster age, mass, or galaxy environment. We use observations from seven pointings on M83 from HST/WFC3 programs GO/DD-11360 (PI O'Connell) and GO-12513 (PI Blair) to obtain a large sample of young, massive star clusters. We measure the half-light radii and power-law indices of the EFF light profile (Elson, Fall, & Freeman 1987) of these clusters using the galfit software package (Peng et al. 2002). We present our results on the relationships between cluster size, shape, age, mass, and environment in the disk of M83.

Author(s): Jenna E. Ryon[4], Nate Bastian[1], Angela Adamo[2], Esteban Silva-Villa[3], John S. Gallagher[4]
Institution(s): *1. Liverpool John Moores University, 2. Stockholm University, 3. Universite Laval, 4. University of Wisconsin - Madison*

247.08 – The extinction law inside the 30 Doradus nebula

We have studied the interstellar extinction in a field of ~ 3' x 3' at the core of the 30 Dor nebula, including the central R 136 cluster, in the Large Magellanic Cloud. Observations at optical and near-infrared wavelengths, obtained with the WFC3 camera on board the Hubble Space Telescope, show that the stars belonging to the red giant clump are spread across the colour–magnitude diagrams because of the considerable and uneven levels of extinction in this region. Since these stars share very similar physical properties and are all at the same distance, they allow us to derive the absolute extinction in a straightforward and reliable way. Thus we have measured the extinction towards about 180 objects and the extinction law in the range 0.3 – 1.6 µm. At optical wavelengths, the extinction curve is almost parallel to that of the diffuse Galactic interstellar medium, but the value of $R^V = 4.5 \pm 0.2$ that we measure indicates that there is an extra grey component due to a larger fraction of large grains. At wavelengths longer than ~ 1 µm, the contribution of the grey component tapers off as $\lambda^{-1.5}$, like in the Milky Way, suggesting that the nature of the grains is otherwise similar to those in our Galaxy, but with a ~ 2.2 times higher fraction of large grains. These results are consistent with the addition of "fresh" large grains by supernova explosions, as recently revealed by Herschel and ALMA observations of SN1987A.

Author(s): Guido De Marchi[1], Nino Panagia[2]
Institution(s): *1. European Space Agency, 2. STScI*

247.09 – Kinematics of Intracluster Globular Clusters in the Core of the Virgo Cluster

The Virgo Cluster is known as a dynamically young galaxy cluster. Recent studies found that it hosts numerous globular clusters in galaxies as well as intracluster globular clusters. Kinematics of globular clusters in giant galaxies in Virgo has been studied in numerous studies. However, little is known about the kinematics of intracluster globular clusters. We obtained spectra of globular cluster candidates in the core region of the Virgo Cluster, including famous gEs M86, M84 and a part of M87, using MMT/Hectospec. The observing coverage is four square degrees, covering 50 kpc to 500 kpc from the M87 center. We select intracluster globular clusters using their spatial location. Then we investigate their kinematics in comparison with the kinematics of globular clusters in galaxies. We find that they show kinematic difference from galaxy globular clusters in the mean value of radial velocity and velocity dispersion. Implications of the results will be discussed with regard to the origin of the intracluster globular clusters.

Author(s): Myung Gyoon Lee[4], Youkyung Ko[4], Ho Seong Hwang[2], Jubee Sohn[4], Sungsoon Lim[3], Hong Soo Park[1], Narae Hwang[1], Byeong-Gon Park[1], In Sung Jang[4]
Institution(s): *1. Korea Astronomy and Space Science Institute, 2. Korea Institute for Advanced Study, 3. Peking University, 4. Seoul National University*

247.10 – The Search for Mass Correlations between Globular Cluster Systems and their Host Galaxies

Globular star clusters are found in all large galaxies, but their origins are not well understood. The goal of this project is to attempt to bridge the gap between our understanding of globular cluster systems (GCSs) and their host galaxies. We conglomerate available data on GCSs with significant numbers of individual globular cluster velocity measurements, 12 galaxies in all. From the velocity data, dynamical masses are calculated for the host galaxies through application of the virial theorem to the globular cluster velocities. After averaging and plotting the dynamical mass data in several ways, we notice distinct trends in nearly all of the observed galaxies. The calculated dynamical mass curve for each galaxy appears to increase until a point between 5 and 7 effective radii, after which it plateaus. Additionally, the red (metal-rich) and blue (metal-poor) clusters seem to split in their dynamical mass estimates just prior to this plateau, with blue clusters giving higher masses. Our results show statistically significant correlations between our dynamical masses and the galaxies' bulge masses, GCS masses, and halo masses. A slightly weaker correlation is found with stellar mass. In all cases the correlation is stronger for the red clusters than the blue clusters. This result may provide key information for the role of different types of globular clusters in galaxy formation models.

Author(s): Jonathan Jackson[1], Gretchen L. H. Harris[1], Michael West[1]
Institution(s): *1. Maria Mitchell Observatory*

247.11 – Does the linear conversion between calcium infrared triplet and metallicity of globular clusters in early-type galaxies hold in the whole range of metallicity?

The calcium infrared triplet (CaT) is one of the prominent absorption features in the infrared wavelength regime. Recently, these absorption features have been getting attention in the prediction of metallicity of globular clusters (GCs) in early-type galaxies (ETGs) because of its strong sensitivity to the metallicity and calcium abundance of a star. However, based on our population synthesis model for CaT, we find that measuring metallicity directly from CaT is inaccurate because the formation mechanism of Ca II ionised line is very inefficient in the cool stars which are abundant in metal-rich stellar populations. This characteristics of Ca II ionised line make the CaT-metallicity relation to converge around 8 angstrom in the metal-rich regime. This is why the metallicity of simple stellar populations, such as GCs, greater than [Fe/H]~-0.5 is unreliable when the linear conversion between CaT and metallicity is applied to derive metallicity. In addition, we have successfully simulated the metal-rich CaT peaks found in GCs in ETGs by using the nonlinear CaT–metallicity relation in the metal-rich regime. This can also explain the difference between color and CaT distributions of GCs in various ETGs. Based on these results, we suggest that CaT is not a good metallicity indicator for the metal-rich stellar populations.

Author(s): Chul Chung[1], Suk-Jin Yoon[2], Young-Wook Lee[2], Sang-Yoon Lee[2]
Institution(s): *1. Center for Galaxy Evolution Research, 2. Yonsei University*

247.12 – Is Latham 1 a True Cluster?: A High-Resolution Chemical and Dynamical Analysis.

We explore the kinematics and chemistry of the reported moving group Latham 1 to determine if the stars in it have a common origin. Latham et al 1991, identified a potential cluster moving group in SA 57 at the North Galactic pole, that had an observed velocity dispersion of ~0.27 km s^{-1}, and lies within a circle of radius 0.5 ° on the sky. Spatially, the W11450 group (Latham 1) has distances consistent with all stars being within 2 pc of each other. We have followed up a select set of these stars with the Otto Struve 2.1m telescope and Sandiford Cass Echelle Spectrometer (SES) at McDonald Observatory. Radial velocities measured from the high resolution (R~60,000) and high S/N data show a similar small velocity dispersion as found in Latham et al 1991. We present the measurements of the chemical homogeneity of the star association from high resolution stellar spectroscopy, and show whether this group shares a common star formation history. Funding for this work was provided by an NSF REU Site grant
(PHY-1358770).

Author(s): Kylee Marie Martens[3], Julia O'Connell[1], Peter M. Frinchaboy[1], Matthew D. Shetrone[2]
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247.13 – Color-magnitude Diagrams for the Stellar Open Cluster M 67 in the Vilnius Photometric System

Stellar photometry in the Vilnius Photometric System requires one percent quality for deriving luminosity class and spectral type subclass. We use such existing photometry of the open cluster M 67 to calibrate new CCD observations at

the Vatican Advanced Technology Telescope (VATT) for correcting the flat-fielding zero-point and deriving the color-transformation in this intermediate-band, seven filter system (Boyle et al., BAAS 37 #4, 2005).
Recently we have developed a "tie-in" observational practice to apply the zero-point and color transformation of the M 67 observations to neighboring starfields of interest that have no existing photometry. Sky transparency must remain constant to better than one percent during a round of short exposures in a filter between the field having calibrated photometry and the new field having no photometry as if the new field was exposed simultaneously with the master field.
Proof of success for this "tie-in" method is shown with the master field being M 67 and the "tie-in" field being the nearby extended "corona" area. The distinctive color-magnitude diagrams of the old open cluster
M 67 reveal the sensitivity to having constant sky transparency during the round of short exposures on M 67 and its extended area. For the extended area has the same form in its color-magnitude diagram as M 67. So variation in sky transparency shows displacement on the color-magnitude diagrams at the one percent quality.
We will attempt new analysis concerning evolution of this very old open cluster (2.56 Gyr, WEBDA, http://www.univie.ac.at/webda/) and the surrounding "coronal" extent with reference to previous work by Chupina and Vereshchagin (Astron. Astrophys, 334, 552, 1998).

Author(s): Richard P. Boyle[1], Robert Janusz[1]
Institution(s): *1. Vatican Observatory*

247.14 – UBV Photometry of the young open cluster Berkely 87

We obtained UBV imaging of a field in the young open cluster Berkeley 87. From these images, we measured the brightness of ~180 stars in the cluster. Our photometry was calibrated using published photometry (Turner & Forbes 1982 PASP 94, 789) of a subset of stars in our field. The cluster is in a region of the sky with strongly varying extinction. Therefore we made a (U-B)-(B-V) color-color diagram of the field and used this to de-redden the stars on a case by case basis. We de-reddened the stars using the unreddened supergiant and main sequence colors from Astrophysical Quantities (Cox 2000).The color-magnitude diagrams of the de-reddened stars are compared to the Padova isochrones(Marigo et al 2008 A&A 482 883). The isochrones are generated for a range of ages, with solar metalicity and no α enhancement. The best fit for the isochrones was the main sequence de-reddened stars from which the age of the cluster is estimated to be 20 million years. This is older than previous age estimates (1-5 million years) from earlier studies of the cluster. This may indicate age variation in the cluster.
We acknowledge the support of the Physics and Astronomy department, and the College of Science and Engineering, Minnesota State University, Mankato.

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Institution(s): *1. Minnestota State University*

247.15 – A WIYN Study of the Globular Cluster Population of the Virgo Elliptical Galaxy NGC 4473

We present results from an analysis of the globular cluster system of NGC 4473, a moderate-luminosity elliptical galaxy in the Virgo Cluster. The properties of globular clusters – in particular, their ages, luminosities, and spatial distributions – make them especially useful probes of the star formation and assembly histories of their host galaxies. We used the 10’ x 10’ Minimosaic camera on the WIYN 3.5-meter telescope to image the globular cluster system of NGC 4473 over its full radial extent. Globular cluster candidates were identified as point sources and selected by their magnitudes and colors in three filters (B, V, R) in order to minimize contamination from foreground and background sources. Our deep images, which have 0.5” - 0.7” seeing and 50% completeness levels for point-source detection at B = 25.7, V = 25.5, and R = 25.2, allow us to cover 75 percent of the intrinsic globular cluster luminosity function (GCLF) for NGC 4473. The surface density of globular clusters in our final corrected radial profile drops to zero within the errors at ~7’, or ~33 kpc from the galaxy center. These results will be presented along with our findings regarding the total number (N^{GC} = 480 ± 50), specific frequency (S^N = 2.2 ± 0.4), and color (metallicity) distribution of the globular clusters in this galaxy.

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247.16 – Globular Cluster Populations of 11 Giant Elliptical Galaxies in Clusters Associated with the Shapley Supercluster

Recent evidence shows that number of globular clusters (GC), N^{tot}, scales with dark matter halo mass of the host galaxy, M^{halo}. We are probing the high mass end of this relation by investigating the globular cluster systems of 11 giant elliptical galaxies in clusters associated with the Shapley Supercluster, the largest mass concentration in the local universe and possibly a major source of the Local Group's 630 km/s motion with respect to the cosmic microwave background. The sample galaxies were imaged with the Advanced Camera for Surveys Wide Field Channel in the F814W bandpass and are in the redshift range z=0.035-0.048. We find a nonlinear relationship between the host galaxy luminosity L^V and number of globular clusters N^{tot} , with N^{tot} scaling as L^V to the power of 1.6; thus, the GC specific frequency, S^N, increases with L^V for these high-mass galaxies. Our data show good consistency with the U-shape relationship between S^N and host galaxy magnitude M^V found in other recent GC studies. Galaxies at intermediate luminosities near the low point of the U-shape have both the lowest S^N values and highest stellar mass ratios, indicating that N^{tot} scales more closely with the dark halo mass than with stellar mass. For one galaxy in our sample, ES0325-G004, we obtained additional multi-band imaging and find a bimodal GC color distribution with characteristics typical of most giant ellipticals. The correlation between N^{tot} and M^{halo} gives us a window into GC formation efficiency.

Author(s): Regina Barber DeGraaff[2], John Blakeslee[1]
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247.17 – Neutron Capture Elements in the Open Cluster Chemical Abundance & Mapping (OCCAM) Survey

The Open Cluster Chemical Abundance & Mapping (OCCAM) survey is a systematic survey of Galactic open clusters using data primarily from the SDSS-III/APOGEE-1 survey. The high-resolution (R=22,500), near-infrared (H-band) APOGEE-1 survey allows for cluster membership probability determination and analysis of light and iron-peak elements. Neutron capture elements, however, prove to be elusive in the IR region covered by APOGEE. In an effort to fully study detailed Galactic chemical evolution, we conducted a high resolution (R~60,000) spectroscopic abundance analysis of neutron capture elements for OCCAM clusters in the optical regime to complement the APOGEE results. We present results based on prominent resonance lines for Eu, La, Ba, and Ce in the ~5400-6750 AA range using data obtained at McDonald Observatory with the 2.1m Otto Struve telescope and Sandiford Echelle Spectrograph.

Author(s): Julia O'Connell[3], Peter M. Frinchaboy[3], Matthew D. Shetrone[4], Fred R. Hearty[2], Steven R. Majewski[5], Gail Zasowski[1]
Institution(s): *1. Johns Hopkins University, 2. Pennsylvania State University, 3. Texas Christian University, 4. University of Texas, 5. University of Virginia*
Contributing team(s): SDSS III/APOGEE-1

247.18 – Optical and Infrared Stellar abundances in the globular clusters NGC 5466 and NGC 5024

Stellar chemical abundances in globular clusters (GCs) can reveal clues about the formation history of stellar populations within the Milky Way (MW). In particular, abundance ratios such as [α/Fe] and [Fe/H] can be used to distill accreted GCs from those that are believed to form in situ. Two GCs which have uncertain origins (i.e. show a tidal tail or have been associated with a stellar stream) are NGC 5466 and 5024; these clusters also have had little to no chemical abundance analyses performed in the past. In this work we present a detailed chemical abundance analysis on 5 stars in these two clusters. The abundances are derived from high-resolution spectroscopic observations at both optical (with the HRS on the Hobby-Eberly Telescope) and infrared (from the APOGEE survey) wavelengths. We have two major aims in the abundance analysis: i) to find clues as to the origins of both clusters and ii) to compare the results of independently observed spectra between two different wavelength regions. For NGC 5466 and 5024 we find an average [Fe/H] = -2.06, -2.16, respectively. We find the typical abundances ratios of both clusters follow chemical trends of both stars and GCs within the MW, indicating from this sample that both clusters do not show evidence of being accreted; although we note the abundance patterns of dwarf and massive galaxies are similar at such low metallicities. We also find that the infrared analysis is in generally good agreement with the optical observations and that the two wavelength analyses complement each other in a powerful way. Developing infrared observing and analysis strategies is greatly beneficial to the emerging field, especially when considering observations in regions where infrared wavelengths are an advantage (i.e. the Galactic Bulge).

Author(s): Masen Lamb[1]
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247.19 – Mass Functions for the Three Main Sequences in NGC 2808

We present new F390W, F555W, and F814W photometry, based on images taken with the WFC3 camera on the Hubble Space Telescope, of the Galactic globular cluster NGC 2808. NGC 2808 has three visible main sequences assumed to be due to differing helium abundances. We successfully create independent mass and luminosity functions for the each of the main sequences and reveal mass function slopes that are significantly different for the three main sequences. As we show, this is the expected behavior if the blue, helium enriched, stars were enriched by accretion late in their formation.

Author(s): Nathaniel Paust[3], Henny J. G. L. M. Lamers[1], Nate Bastian[2]
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247.20 – Chemical Abundances in NGC 5053: A Very Metal Poor and Dynamically Complex Globular Cluster

NGC 5053 provides a rich environment to test our understanding of the complex evolution of globular clusters (GCs).

Recent studies have found that this cluster has interesting morphological features beyond the spherical distribution expected from GCs. These features include a ~6° tidal stream (Lauchner et al. 2006), and a possible, but still debated, bridge-like structure between it and its nearby neighbor NGC 5024 (Chun et al. 2010). These features suggest that the evolution of these clusters has not only been greatly affected by their gravitational interaction with the Galaxy, but possibly each other. Additionally, simulations have shown that NGC 5053 could be a likely candidate to belong to the Sgr dSph stream (Law & Majewski 2010). Using the WIYN-Hydra multi-object spectrograph, we have collected high quality (S/N ~75-90), medium-resolution spectra for red giant branch (RGB) stars in NGC 5053. Using these spectra we have measured the Fe, Ca, Ti, Ni, Ba, Na, and O abundances in the cluster. We measure an average cluster [Fe/H] abundance of -2.46 with a standard deviation of 0.05 dex, making NGC 5053 one of the most metal poor GCs in the Milky Way. The [Ca/Fe], [Ti/Fe], and [Ba/Fe] we measure are consistent with the abundances of Milky Way halo stars at a similar metallicity, with high alpha values and slightly depleted [Ba/Fe]. The Na and O abundances show the Na-O anti-correlation found in most GCs. From our abundance analysis it appears that NGC 5053 is at least chemically similar to other GCs found in the Milky Way. This does not, however, rule out NGC 5053 being a member of the Sgr dSph stream.

Author(s): Owen Boberg[1], Eileen D. Friel[1], Enrico Vesperini[1]
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247.21 – Sample Selection and [Fe/H]-variations in NGC 3201

We have examined Strömgren data on the rare retrograde globular cluster, NGC 3201. Since 1998, several groups have disagreed on whether this cluster shows a >0.1 dex variation in [Fe/H] content; we show that the spread is real, as long as the samples of stars used are unbiased and preferably, statistically significant. Some spectral samples infer a spread in [Fe/H] of up to ~0.4 dex (around an average of [Fe/H] = -1.5 dex), and others state claim it is less than 0.12 dex. However, even the studies that do not find a distinguishable spread in [Fe/H] show other chemical signatures of multiple episodes of star formation. Photometric studies are complicated by a steep extinction gradient towards the cluster; we studied several different methods of removing the uneven interstellar extinction, to minimize the effects on Strömgren photometry of the stellar population, but we found that the best solution is the reddening free index, [m], as the extinction law does not appear anomalous. We investigate the relationship of [m] to [Fe/H] and other elements, and we find that there is strong evidence of a spread in [Fe/H] of at least 0.4 dex, amongst the unmixed stars on the giant branch, below the level of the horizontal branch.

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247.22 – The Structure of the Nearest Nuclear Star Clusters

The occupation fraction of massive black holes in low-mass galaxies is a poorly constrained quantity. Understanding the rate at which tidal disruption events occur is critical to constraining the occupation fraction of black holes. It is known that most, if not all, galaxies with sub-Milky Way mass have a nuclear star cluster present. We have proposed to survey an extensive archive of HST observations of 80 galactic nuclei within 10 Mpc from Earth. At these distances, HST supplies us with adequate spatial resolution to create accurate surface brightness profiles that can then be used to create models of the nuclei's mass distribution and morphology. Our collaborators will use these data to generate models, based on black hole mass and cluster mass distribution, that predict occurrence rates of tidal disruption events. These models will then be compared to observations of tidal disruption events.
We have begun the survey by generating models of the surface brightness profiles for two galaxies in our selection: M51 and NGC 404. I will discuss how these models were generated and what challenges were faced throughout the process. Finally, I present these models along with color maps and radial residual plots of each galaxy.

Author(s): Christopher DiLullo[1]
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247.23 – A Science Portal and Archive for Extragalactic Globular Cluster Systems Data

For several years we have been carrying out a wide-field imaging survey of the globular cluster populations of a sample of giant spiral, S0, and elliptical galaxies with distances of ~10-30 Mpc. We use mosaic CCD cameras on the WIYN 3.5-m and Kitt Peak 4-m telescopes to acquire deep BVR imaging of each galaxy and then analyze the data to derive global properties of the globular cluster system. In addition to measuring the total numbers, specific frequencies, spatial distributions, and color distributions for the globular cluster populations, we have produced deep, high-quality images and lists of tens to thousands of globular cluster candidates for the ~40 galaxies included in the survey.

With the survey nearing completion, we have been exploring how to efficiently disseminate not only the overall results, but also all of the relevant data products, to the astronomical community. Here we present our solution: a scientific portal and archive for extragalactic globular cluster systems data. With a modern and intuitive web interface built on the same framework as the WIYN One Degree Imager Portal, Pipeline, and Archive (ODI-PPA), our system will provide public access to the survey results and the final stacked mosaic images of the target galaxies. In addition, the astrometric and photometric data for thousands of identified globular cluster candidates, as well as for all point sources detected in each field, will be indexed and searchable. Where available, spectroscopic follow-up data will be paired with the candidates. Advanced imaging tools will enable users to overlay the cluster candidates and other sources on the mosaic images within the web interface, while metadata charting tools will allow users to rapidly and seamlessly plot the survey results for each galaxy and the data for hundreds of thousands of individual sources. Finally, we will appeal to other researchers with similar data products and work toward making our portal a central repository for data related to well-studied giant galaxy globular cluster systems. This work is supported by NSF Faculty Early Career Development (CAREER) award AST-0847109.

Author(s): Michael Young[1], Katherine L. Rhode[1], Arvind Gopu[1]
Institution(s): *1. Indiana University*

247.24 – Exploring Evidence for Cosmic Ray Acceleration in Westerlund 1

Westerlund 1 (Wd 1) is a massive stellar cluster located within the Galaxy at a distance of ~5 kpc from the Earth. The cluster is thought to be a site of significant Galactic cosmic ray acceleration. Further insight into this possibility can be gained through the study of gamma-ray emission from the cluster. The High Energy Stereoscopic System (HESS) has detected an extended TeV source coincident with Wd 1 and now the Fermi Large Area Telescope (LAT) has detected extended GeV gamma-ray emission from the region. Examining this data allows for a more precise understanding of the emission originating from Wd 1 itself. We modeled the source as a 2-dimensional gaussian and, considering the region within 15º of the nominal position of Wd 1, determined the maximum likelihood spectrum, position, and extension. It is clear that a significant, extended GeV source is present and may be associated with the stellar cluster. We will additionally explore any energy dependence in the source's morphology to understand implications, particularly for the source association. Continued examination of the emission originating from the Wd 1 region will reveal details about the acceleration and composition of particles, both leptons and hadrons, originating in the region.

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Contributing team(s): The Fermi LAT Collaboration

247.25 – Comparing AGB and RGB Sodium Abundances in the Globular Cluster 47 Tucanae (NGC 104)

We present [Fe/H] and [Na/Fe] abundances for 35 asymptotic giant branch (AGB) stars in the Galactic globular cluster 47 Tucanae, using high resolution spectra obtained with the Michigan/Magellan Fiber System (M2FS) spectrograph on the Magellan-Clay 6.5m telescope. The abundances and model atmosphere parameters were derived using standard equivalent width and spectrum synthesis techniques. We find an average [Fe/H]=-0.68, in agreement with previous literature estimates. For sodium, we compare the [Na/Fe] distributions between the AGB stars measured here and a similar RGB sample published previously. Although the average [Na/Fe] abundance is lower in the AGB sample, we do not find this difference to be significant. Additionally, the dispersion and inter quartile range of [Na/Fe] are similar between the AGB and RGB samples, and we argue that the distribution of Na-poor and Na-rich stars is equivalent between the two data sets. The data presented here offer a counter example to the case of NGC 6752, which has recently been found to exhibit a drastically different [Na/Fe] distribution between its AGB and RGB populations. The 47 Tuc data suggest that the RGB [Na/Fe] abundance alone is insufficient for predicting if a star will ascend the AGB, and additional information, such as horizontal branch morphology or metallicity, must also be taken into account.

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247.26 – Characterizing the Stellar Content of the Young Open Cluster Blanco 1

In this work we seek to derive the age of the nearby and young open cluster Blanco 1. This solar metallicity cluster, is located far from the Galactic plane making it quite unusual and astrophysically interesting. The methods that we used to determinate the age of Blanco 1 employed color magnitude diagrams and various flavors of stellar evolution models. Initially, the data that we used are a suite of F- and G-star spectra, which were acquired using the low-resolution cassegrain spectrograph installed on the 1.9m Radcliffe telescope located at the South African Astronomical Observatory. Comparing optical photometry with spectral types, we hoped to derive reddening vectors to help us with the isochrone fitting of Blanco 1. However, magnetic activity on our target stars prevented us from completing this analysis. We instead used hot, higher-mass, early-spectral type stars in the cluster to derive its reddening vectors.

To fit the distance we tried with the HIPPARCOS (209 pc) distance, that have no a good fit in the main sequence. On the other hand we found that the best fit is 240 pc by isochrones D'Antona & Mazzitelli (1997).
Finally, isochrones generated from theoretical stellar models were compared to the cluster's color magnitude diagrams, allowing us to estimate the distance-dependent age of Blanco 1. We find that its photometric age is ~150 Myr, comparable to its lithium and gyrochronology age.

Author(s): Piera Andrea Soto King[2], David James[1]
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247.27 – WIYN Open Cluster Study: Lithium in the Open Cluster NGC 6811

We present Li abundances of photometric candidate main-sequence stars of the open cluster NGC 6811 derived from WIYN Hydra spectra. We discuss the Li-T^{eff} morphology and report on an interesting G star with a significantly higher Li abundance than the trend.

Author(s): Aaron J. Steinhauer[2], Daniel M Krolikowski[2], Luke Thomas Taverne[2], Constantine P. Deliyannis[1], Barbara J. Anthony-Twarog[3], Bruce A. Twarog[3]
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247.28 – WIYN Open Cluster Study: UBVRI Photometry of NGC 2158

We present WIYN 0.9m HDI UBVRI photometry of NGC 2158, a very rich, intermediate-aged, open cluster located near the galactic anti-center. We report derived values for the cluster age, distance, reddening.

Author(s): Luke T Taverne[2], Aaron J. Steinhauer[2], Constantine P. Deliyannis[1]
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247.29 – Photometrically Derived Metallicities of Open Clusters Czernik 17 and Kronberger 60

We analyze data from the 1.8 meter telescope at the Dominion Astrophysical Observatory taken through v, b, and y Strömgren filters to determine the metallicity of two open clusters: Czernik 17 and Kronberger 60. These objects represent two of 60 clusters studied by Tadross (2009) and are part of an ongoing study to calculate the metallicity and membership of these little-studied clusters based on observability from mid-northern latitudes. We make use of various IRAF packages to reduce the data and perform photometry through iterative PSF-fitting, take advantage of isochrones fit by TRILEGAL for these clusters, and use statistical analysis procedures from clean3201 to distinguish between field stars and cluster members. To obtain a metallicity index m1 for the stars in each cluster, we use a simple arithmetic relation among the vby Strömgren filters, which can then be converted to the metallicity [Fe/H] as calibrated by Calamida et al. (2007). For Czernik 17 we report an average [Fe/H] of 4.35±0.06, and -1.26±0.08 for Kronberger 60.

Author(s): Juan David Trujillo[1], Ramon Sharma[1], Tiffany C Jansen[1], Ana M. Larson[1], Meagan Albright[1]
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248 – Dwarf and Irregular Galaxies Posters

248.01 – The Initial Mass Function and Star Formation Law in The Outer Disk of NGC2915

We constrain the Initial Mass Function (IMF) and Star Formation Law (SFL) in the outer disk of NGC2915 using photometry of resolved stellar populations from HST combined with ground based Halpha observations. We find evidence that the IMF is at least modestly deficient in high-mass stars compared to a standard Kroupa IMF. The slope of the SFL is near the standard Kennicutt-Schmidt slope although the normalisation is much lower. Our results imply that the outer disk contributes 11% to 28% of the total star formation in NGC2915.

Author(s): Gerhardt Meurer[6], Sarah Bruzzese[6], Claudia Lagos[1], Edward C Elson[5], Jessica Werk[4], John Blakeslee[2], Holland Ford[3]
Institution(s): *1. European Southern Observatory, 2. National Research Council, 3. The Johns Hopkins University, 4. University of California Santa Cruz, 5. University of Cape Town, 6. University of Western Australia*

248.02 – Investigating the Diffuse Ionized Gas throughout the Magellanic Cloud System with WHAM

We present early stages of an H-α survey of the Magellanic System using the Wisconsin H-α Mapper (WHAM). Our maps of the Small Magellanic Cloud, Large Magellanic Cloud, and Magellanic Bridge are the most sensitive kinematic maps of ionized gas throughout the System. With a velocity resolution of 12 km/s, WHAM observations can cleanly separate diffuse emission at Magellanic velocities from that of the Milky Way and terrestrial sources. These new maps of the SMC and LMC compliment observations of the Magellanic Bridge by Barger et al. (2013), who found H-alpha emission extending throughout and beyond the observed H I emission. Using WHAM's unprecedented sensitivity to the limit of atmospheric line confusion (~ 10s of mR), we find that ionized gas emission extends at least 5 degrees beyond the traditional boundary of the SMC when compared to recent deep-imaging surveys (e.g., MCELS; Smith et al. 2005). The diffuse ionized emission extent is similar to the neutral gas extent as traced by 21 cm. We present spectra comparing H I and H-alpha kinematic signatures throughout the emission region, which are dominated by galactic rotation. Multi-wavelength observations are also underway in [S II] and [N II] for the SMC and LMC. WHAM research and operations are supported through NSF Award AST-1108911.

Author(s): Brianna Smart[4], L. Matthew Haffner[4], Kathleen Barger[3], Gregory J Madsen[2], Alex S. Hill[1]
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248.03 – Kinematic Anomalies in Dwarf Elliptical Galaxies: New Constraints on Current Evolutionary Models

We analyze the shapes of the rotation curves of the 60 Virgo cluster dwarf early-type galaxies (dEs) available in the literature. For each dE, we fit an analytical Polyex function to the rotation curve and identify and quantify three different types of anomalies: how poorly the Polyex function fits the data, how asymmetric the rotation curve looks like, and how different is the shape of the approaching and receding sides of the rotation curve. We find that a high percentage of our dEs (77%, 46 out of 60) has a significant anomaly in their rotation curve. We also find that anomalous dEs tend to rotate faster than the dEs with symmetric and smooth rotation curves. On average, galaxies with anomalous rotation curves have rotation speeds of 24 km/s compared to symmetric galaxies that have rotation speeds of 7 km/s. Our results support the results of a previous study done by Toloba et al. (2014). The presence of such a large fraction of anomalous rotation curves suggests that dEs are commonly found in non-equilibrium. Any evolutionary theory needs to explain these results regarding dE kinematics.
This project is funded in part by the National Science Foundation. We thank the Science Internship Program (SIP) for its guidance.

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248.04 – Two-Component Models of Dwarf Galaxy Tidal Disruption

Using MilkyWay@Home, a distributed computing platform running BOINC (Berkley Open Infrastructure for Network Computing), we employ 0.5 PFLOPs of computational power to recover the parameters that define a two-component dSph (dark matter and baryons) that has been tidally disrupted in the Milky Way galaxy. Our model consists of nested spherical profiles, each contributing independent scale parameters to the optimization problem, and exploits the properties of the linear Boltzmann equation and statistical equilibrium properties of dSph distributions. The n-body code is based on NEMO Stellar Toolbox and is shown to agree with this software package in the one-component limit. In addition, we employ a new 2D Earth Mover Distance (EMD) algorithm to calculate the similarity between the results of the simulations and the actual distribution of stars in tidal streams. The model has been distributed over approximately 30,000 computers each using a different parameter set; asynchronous optimization algorithms are used to find an optimal set of parameters to generate the Orphan Stream. Our method is calibrated and tested on mock data, and the stability of our model is explored. This work is funded by NSF grant AST 10-09670 and crowd funding from the MilkyWay@home volunteers.

Author(s): Jacob Bauer[2], Heidi Jo Newberg[2], Roland Judd[2], Larry Widrow[1], Siddartha Shelton[2], Jeffery Thompson[2], Jake Weiss[2]
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248.05 – Centaurus A halo through the eye of the PISCeS: a plethora of new satellites and streams

We present the first results from our wide-field resolved Panoramic Imaging Survey of Centaurus and Sculptor (PISCeS), aimed at investigating the halo of two nearby galaxies (D~3.5 Mpc) out to a galactocentric radius of 150 kpc with Magellan/Megacam. Our goal is to search for faint satellites in two environments substantially different from the Local Group, i.e. the loose Sculptor group of galaxies and the Centaurus A
(CenA) group dominated by an elliptical. In particular, our resolved survey of CenA's halo has led to the discovery of 15 satellites and additional streams/substructures which we could place at the distance of CenA,
and for which follow-up with HST imaging has been approved for 2015. The PISCeS survey provides the first complete census of dwarf satellites around an elliptical galaxy down to an unprecedented M_V<-8. Our results represent a crucial step in refining theoretical modeling of the different physical processes acting on star formation at the low-mass end of the galaxy luminosity function, to ultimately achieve a more complete picture of the galaxy formation process.

Author(s): Denija Crnojevic[4], David J. Sand[4], Nelson Caldwell[2], Puragra Guhathakurta[5], Brian A. McLeod[2], Anil Seth[6], Joshua D. Simon[1], Jay Strader[3], Elisa Toloba[5]
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University, 5. UC Santa Cruz, 6. University of Utah

248.06 – New, Faint Satellite Galaxies of NGC253

As part of the Panoramic Imaging Survey of Centaurus and Sculptor (PISCeS), we present our initial search for faint dwarf galaxies around the nearby spiral galaxy NGC253 (D~3.5 Mpc). While simulations of structure formation match observational constraints on the largest scales, they struggle to reproduce observations below that of individual galaxies. For a point of comparison, and to extend the search for faint dwarf galaxies beyond the Local Group, we have begun a search for faint dwarfs around two of our nearest galaxy neighbors: Centaurus A and NGC253. Here we present five new dwarf galaxy candidates to NGC253, all in resolved stellar light. We summarize their basic properties including their structure, star formation history and distances. When complete, the PISCeS survey will provide a complete census of dwarf satellites around NGC253 down to M_V~-8, allowing for direct comparisons with simulations and recent work around both the Milky Way and M31.

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Institution(s): *1. Carnegie Observatories, 2. Michigan State University, 3. Smithsonian Center for Astrophysics, 4. Texas Tech University, 5. UC Santa Cruz, 6. University of Utah*

248.07 – Exploring the Faint End of the Luminosity-Metallicity Relation with Hα Dots

The well-known correlation between a galaxy's luminosity and its gas-phase oxygen abundance (the luminosity-metallicity (*L-Z*) relation) offers clues toward our understanding of chemical enrichment histories and evolution. Bright galaxies are comparatively better studied than faint ones, leaving a relative dearth of observational data points to constrain the *L-Z* relation in the low-luminosity regime. We present high S/N nebular spectroscopy of low-luminosity star-forming galaxies observed with the KPNO 4m using the new KOSMOS spectrograph to derive direct-method metallicities. Our targets are strong point-like emission-line sources discovered serendipitously in continuum-subtracted narrowband images from the ALFALFA Hα survey. Follow-up spectroscopy of these "Hα dots" shows that these objects represent some of the lowest luminosity star-forming systems in the local Universe. Our KOSMOS spectra cover the full optical region and include detection of [O III] λ4363 in roughly a dozen objects. This paper presents some of the first scientific results obtained using this new spectrograph, and demonstrates its capabilities and effectiveness in deriving direct-method metallicities of faint objects.

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248.08 – Deep Optical Imaging of TiNy Titans Dwarf Galaxy Interactions

Galaxy interactions are of fundamental importance to the evolution of massive galaxies -- they have been observed to impact morphology, star formation rates, and galaxy composition. Such interactions also occur frequently between low mass dwarf galaxies, but this process is poorly understood and largely overlooked in comparison. Although the majority of mergers at all redshifts are expected to take place between low mass galaxies, until now there have not been comparable systematic studies of dwarf galaxy interactions, leaving open the question of whether interactions between low mass galaxies can strongly affect their own evolution. TiNy Titans, designed to address this gap in knowledge, is a complete sample of isolated dwarf galaxy pairs selected from the Sloan Digital Sky Survey. Here we present follow-up deep broadband g and r imaging of a subset of the TiNy Titans galaxies obtained with MMTCam on the 6.5m MMT. Based on these deep images, we classify the stellar populations in the dwarf galaxies at various stages of interaction. For two of the pairs, we also obtained narrowband Hα imaging which reveals asymmetric star forming structures.

Author(s): Sandra Liss[3], Catherine Zucker[3], Kelsey E. Johnson[3], Sabrina Stierwalt[3], Gurtina Besla[2], Nitya Kallivayalil[3], David R. Patton[1]
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248.09 – Confirming Tiny Dwarf Galaxy Candidates on the Edge of the Local Group

I will present ongoing work in which we address the mass assembly of galaxies at late times by exploiting observations of their occasionally faintly star-forming neutral hydrogen content. Detections of dwarf galaxies probe not only one of the more easily recognizable methods of ongoing accretion of gas and stars onto galaxies, but they also represent some of the lowest rates (and in many cases the most metal poor examples of) recent star formation. Studying the smallest dwarfs in the vicinity of the Milky Way provides the added advantage of relatively high resolution, which is especially useful in the context of their being potential nearby analogs to high redshift, low mass star forming galaxies. We have identified potential tiny dwarf galaxies in the vicinity of the Local Group from two recent surveys of the Galactic plane using their HI signatures. In this poster, we present the current highlights from our follow-up campaigns and confirmations of new, nearby, very low mass dwarf galaxies.

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248.10 – Galactic Needle in a Haystack: The Search for Ultra Compact Dwarf Galaxies

We used photometric data from the Sloan Digital Sky Survey to search for ultra-compact dwarf galaxies (UCDs) and intergalactic globular clusters (IGCs). Our selection criteria, which were derived from Principal Component Analysis of known UCDs in SDSS color space, returned ~100 objects of interest, including several confirmed new UCDs based on their velocities, magnitudes, and visual compact appearance. This study confirms the potential for using SDSS to identify UCDs and IGCs and may significantly increasing the number of discovered UCDs.

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248.11 – The unique structural parameters of the underlying host galaxies in Blue Compact Dwarfs

The nature of possible evolutionary pathways between various types of dwarf galaxies is still not fully understood. Blue compact dwarf galaxies (BCDs) provide a unique window into dwarf galaxy formation and evolution and are often thought of as an evolutionary stage between different classes of dwarf galaxies. In this study we use deep optical and near-infrared observations of the underlying hosts of BCDs in order to study the structural differences between different types of dwarf galaxies. When compared with dwarf irregular galaxies of similar luminosities, we find that the underlying hosts of BCDs have significantly more concentrated light distributions, with smaller scale lengths and brighter central surface brightnesses. We demonstrate here that the underlying hosts of BCDs are distinct from the broad continuum of typical dwarf irregular galaxies, and that it is unlikely that most dwarf irregular galaxies can transform into a BCD or vice versa. Furthermore, we find that the starburst in a BCD only brightens it on average by ~0.8 mag (factor of two), in agreement with other studies. It appears that a BCD is a long-lived and distinct type of dwarf galaxy that exhibits an exceptionally concentrated matter distribution. We suggest that it is this compact mass distribution that enables the strong star formation events that characterize this class of dwarf galaxy, that the compactness of the underlying host can be used as a distinguishing parameter between BCDs and other dwarf galaxies, and that it can also be used to identify BCDs which are not currently experiencing an intense starburst event.

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248.12 – A systematic search for dwarf counterparts to ultra compact high velocity clouds

Observations of the Universe on scales smaller than typical, massive galaxies challenge the standard Lambda Cold Dark Matter paradigm for structure formation. It is thus imperative to discover and characterize the faintest dwarf galaxy systems, not just within the Local Group, but in relatively isolated environments as well in order to properly connect them with models of structure formation. Here we report on a systematic search of public ultraviolet and optical archives for dwarf galaxy counterparts to so-called Ultra Compact High Velocity Clouds (UCHVCs), which are compact, isolated HI sources recently found in the Galactic Arecibo L-band Feed Array-HI (GALFA-HI) and Arecibo Legacy Fast ALFA (ALFALFA-HI) surveys. Our search has uncovered at least three strong dwarf galaxy candidates, and we present their inferred star formation rate and structural properties here.

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248.13 – Searching for Stellar Counterparts to ALFALFA Ultra-Compact High Velocity Clouds with WIYN / pODI

A current issue in cosmology is the disagreement between models and observations regarding the number of low-mass galaxies in the Local Volume. While simulations of structure formation in a Lambda-CDM universe predict large numbers of low-mass dark matter halos, observational campaigns have not yet found sufficient numbers of faint, low-mass galaxies to match the models. The ALFALFA neutral hydrogen (HI) survey has detected a sample of isolated ultra-compact high-velocity HI clouds (UCHVCs) with kinematic properties that make them likely members of the Local Volume. This UCHVC sample as a group possesses properties similar to other known ultra-faint dwarf galaxies like Leo T (at 1 Mpc, HI masses of ~10^5-10^6 $M_\odot$, HI diameters of ~2-3 kpc, and dynamical masses of ~10^7-10^8 $M_\odot$). We have initiated a campaign to obtain deep optical imaging of the UCHVCs using the 24' x 24' pODI camera on the WIYN 3.5-m telescope. Here we present a technique to search for faint but resolved stellar counterparts to the UCHVCs in our optical images.

We begin by processing and stacking the pipeline-reduced pODI g'- and i'-band images in order to maximize the number of sources we can detect while preserving the photometric integrity of the data. We then remove extended sources and

measure calibrated g' and i' magnitudes for all the resulting point sources in the images. We apply a color-magnitude filter, constructed using theoretical isochrones for old stellar populations, to select stars in a single population and at a given distance. The spatial distribution of the point sources selected by the filter is then smoothed on a number of spatial scales. Strong overdensities in the resulting smoothed spatial distributions indicate the possible presence of a dwarf galaxy counterpart to the UCHVC. We have also developed statistical tests that quantify the likelihood of detecting true stellar overdensities in our images. We show recent examples of our results.

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248.14 – WSRT HI imaging of ultra-compact high velocity clouds: gas-bearing dark matter minihalos?

A long standing problem in cosmology is the mismatch between the number of low mass dark matter halos predicted by simulations and the number of low mass galaxies observed in the Local Volume. We recently presented a set of isolated ultra-compact high velocity clouds (UCHVCs) identified within the dataset of the Arecibo Legacy Fast ALFA (ALFALFA) HI line survey that are consistent with representing low-mass gas-bearing dark matter halos within the Local Volume (Adams+ 2013). At distances of ~1 Mpc, the UCHVCs have HI masses of ~10^5 Msun and indicative dynamical masses of 10^7-10^8 Msun. The HI diameters of the UCHVCs range from 4' to 20', or 1 to 6 kpc at a distance of 1 Mpc.

We have selected the most compact and isolated UCHVCs with the highest average column densities as representing the best galaxy candidates. These systems have been observed with the Westerbork Synthesis Radio Telescope (WSRT) to enable higher spatial resolution (~60") studies of the HI distribution. The HI morphology revealed by the WSRT data offers clues to the environment and origin of the UCHVCs, the kinematics of the HI allow the underlying mass distribution to be constrained, and the combination of spatial and spectral resolution allow the detection of a cold neutral medium component to the HI. The WSRT HI observations discriminate among the selected galaxy candidates for those objects that are most likely gas-bearing dark matter halos.

One UCHVC, AGC198606, is of particular interest as it is located 16 km/s and 1.2 degrees from Leo T and has similar HI properties within the ALFALFA dataset. The WSRT HI observations reveal a smooth HI morphology and a velocity gradient along the HI major axis of the system consistent with rotation. These properties are consistent with the hypothesis that this object is a gas-bearing low-mass dark matter halo.

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248.15 – Metallicities of Low Mass Inefficient Star Forming Dwarfs in S^4G: Testing the Closed Box Paradigm

Low mass dwarf galaxies are the most numerous extragalactic population in the Local Universe. Many gas-rich dwarfs appear to be forming stars less efficiently than normal, massive disk galaxies and are therefore important laboratories for the study of star formation. Here we present new observations using the Palomar Double Spectrograph for 19 dwarf galaxies from the S^4G Survey with the lowest stellar to HI mass ratios. Preliminary analysis of the data indicate a wide range of metallicities which vary by as much as 0.5 dex in a single galaxy in different star forming regions. Such a dispersion in metallicities favors an open box model and the results suggest a varied star formation history, possibly induced via minor mergers and accretion.

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248.16 – A Radio Continuum Study of Dwarf Galaxies: 6 cm imaging of LITTLE THINGS

To bypass uncertainties introduced by extinction caused by dust at optical wavelengths, we examine to what extent the radio continuum can probe star formation (SF) in dwarf galaxies. We provide VLA 6-cm C-array (4 to 8 GHz) radio continuum images with integrated flux densities for 40 dwarf galaxies taken from LITTLE THINGS. We find 27 harbor significant emission coincident with SF tracers; 17 are new detections. We infer the average thermal fraction to be 39 +- 25%. The LITTLE THINGS galaxies follow the Condon radio continuum - star formation rate (SFR) relation down to an SFR of 0.1 Msol/yr. At lower rates they follow a power-law characterized by a slope of 1.2 +- 0.1 with a scatter of 0.2 dex . We interpret this as an underproduction of the non-thermal radio continuum component. When considering the non-thermal radio continuum to star formation rate slope on its own, we find the slope to be 1.2. The magnetic field strength we find is typically 9.4 +- 3.8 muG in and around star forming regions which is similar to that in spiral galaxies. In a few dwarfs, the magnetic field strength can reach as high as 30 muG in localized 100 pc star forming regions. The underproduction of non-thermal radio continuum is likely due to the escape of Cosmic Ray electrons from the galaxy. The LITTLE THINGS galaxies are consistent with the radio continuum - far infrared luminosity relation. We observe a power-law slope of 1.06 +- 0.08 with a scatter of 0.24 dex which suggests that the 'conspiracy' of the radio continuum - far infrared relation continues to hold even for dwarf galaxies.

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Contributing team(s): LITTLE THINGS collaboration

248.17 – CO at Low-metallicity: Molecular Clouds in the dwarf galaxy WLM

Metallicity is not a passive result of galaxy evolution, but a crucial driver. Dwarf galaxies are low in heavy elements, which has important consequences for the ability to form cold, dense clouds that form stars. Molecular cores shrink and atomic envelopes grow in star-forming clouds as the metallicity drops. We are testing this picture of changing structure with metallicity with Herschel [CII]158 micron images of the photo-dissociation regions and ALMA maps of CO in star-forming regions in 4 dwarf irregular galaxies. These galaxies cover a range in metallicity from 13% solar to 5% solar. Here we report on the structure of the molecular clouds in WLM, a dwarf galaxy at 13% solar abundance where we for the first time detected CO emission at such a low heavy element abundance.

The Herschel part of this work was supported by grant RSA #1433776 from JPL.

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248.18 – CO Observations of DDO 68: An Extreme Outlier on the Mass-Metallicity Relation

We present sensitive observations in the CO J = 1→0 emission line of the dwarf galaxy DDO 68, obtained with the CARMA interferometer. This system is one of the very most metal-poor galaxies known in the local universe, with a nebular oxygen abundance of 3% (equal to the famous dwarf galaxies Leo P and I Zw 18). The galaxy is overly massive for its metal content and thus represents an extreme outlier on the mass-metallicity relationship. The origin of the abnormal mass to metallicity ratio in DDO 68 remains a mystery and presents a major problem for models of the chemical evolution of galaxies. While CO was not detected in the galaxy, the system's relative proximity allows a stringent CO emission limit of 1.07×10^5 K km s^{-1} pc^2 to be determined. We also leverage supporting datasets at multiple wavelengths to derive limits to the L^{CO}/L^B and L^{CO}/SFR ratios. Due to the unique properties of this system and the dearth of CO emission data at such extreme metallicities, these limits provide important constraints on the CO to H^2 conversion factor and the chemical composition of metal-poor gas clouds.

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248.19 – Discovery Of A Gas-Rich Companion To The Exteremely Metal-Poor Galaxy DDO 68

We present H I spectral-line imaging of the extremely metal-poor galaxy DDO 68. This system has a nebular oxygen abundance of only ~3% Solar, making it one of the most metal-deficient galaxies known in the local volume. Surprisingly, DDO 68 is a relatively massive and luminous galaxy for its metal content, making it a significant outlier in the mass-metallicity and luminosity-metallicity relationships. The origin of such a low oxygen abundance in DDO 68 presents a challenge for models of the chemical evolution of galaxies. One possible solution to this problem is the infall of pristine neutral gas, potentially initiated during a gravitational interaction. Using archival H I spectral-line imaging obtained with the Karl G. Jansky Very Large Array, we have discovered a previously unknown companion of DDO 68. This low-mass ($M^{HI} = 2.8 \times 10^7\ M^{\odot}$), recently star-forming ($SFR^{FUV} = 1.4 \times 10^{-3}\ M^{\odot}\ yr^{-1}$, $SFR^{H\alpha} < 7 \times 10^{-5}\ M^{\odot}\ yr^{-1}$) companion has the same systemic velocity as DDO 68 (V^{sys} = 506 km s^{-1}; D = 12.74 ± 0.27 Mpc) and is located at a projected distance of ~42 kpc. New H I maps obtained with the 100 m Robert C. Byrd Green Bank Telescope provide evidence that DDO 68 and this companion are gravitationally interacting at the present time. Low surface brightness H I gas forms a bridge between these objects.

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248.20 – The SHIELD Multi-Wavelength Archive

We present WCS-registered data products from the "Survey of HI in Extremely Low-Mass Dwarfs" (SHIELD). This ALFALFA follow-up program targets sources that inhabit the faint end of the HI luminosity function. The final SHIELD data suite includes UV, optical, infrared, and HI imaging, providing a unique opportunity to study the panchromatic properties of low-mass, gas-rich galaxies. Ongoing analysis of the rotational dynamics and patterns of star formation in these systems will be disseminated in forthcoming manuscripts. The final SHIELD data products will be made available to the public on an archival website.

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248.21 – Do Tidal Interactions Trigger Starbursts in Dwarf Galaxies?

Starburst dwarf galaxies are extensively studied systems, though the mechanism that triggers starbursts is poorly understood. Tidal interactions and gas accretion are thought to be potential starburst trigger mechanisms, although internal, secular drivers have not been ruled out. If starbursts are a result of external perturbations, then one would expect to see signatures of interaction in the gaseous disk of the galaxy. To examine this hypothesis, we analyze both archival and newly-obtained deep, wide-field HI maps from the Green Bank Telescope (GBT) of a sample of nineteen well-studied nearby starburst dwarf galaxies to search for such signs of interactions. Our sample is unique in that we have previously derived the star formation histories from Hubble Space Telescope imaging of the resolved stellar populations for all galaxies. In this work we focus on NGC 784 and NGC 672, which both may lie on a filament of dark matter isolated in space. We evaluate methods to determine the presence and properties of low surface-brightness neutral gas in the outer disk regions. This work serves as a prototype for forthcoming analysis of the full sample. With our results we hope to not only establish an effective data analysis procedure, but to also confirm or rule-out tidal interactions as a triggering mechanism of starbursts in this sample of dwarf galaxies.

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248.22 – Comparing Chemical Compositions of Dwarf Elliptical Galaxies and Globular Clusters

Because of their abundance in cluster environments and fragility due to their low mass, dwarf elliptical galaxies (dEs) are excellent specimens for studying the physical processes that occur inside galaxy clusters. These studies can be used to expand our understanding of the process of galaxy (specifically dE) formation and the role of dark matter in the Universe. To move closer to better understanding these topics, we present a study of the relationship between dEs and globular clusters (GCs) by using the largest sample of dEs and GC satellites to date. We focus on comparing the ages and chemical compositions of dE nuclei with those of satellite GCs by analyzing absorption lines in their spectra. To better view the spectral features of these relatively dim objects, we employ a spectral co-addition process, where we add the fluxes of several objects to produce a single spectrum with high signal-to-noise ratio. Our finding that dE nuclei are younger and more metal rich than globular clusters establishes important benchmarks that future dE formation theories will consider. We also establish a means to identify GCs whose parent galaxies are uncertain, which allows us to make comparisons between this GC group and the satellite GCs.

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249 – Elliptical Galaxies Posters

249.01 – Discovery of Compact Quiescent Galaxies at Intermediate Redshifts in DEEP2

Compact quiescent galaxies in the redshift range $0.6 < z < 1.1$ are the missing link needed to complete the evolutionary histories of these objects from the high redshift $z \geq 2$ Universe to the local $z \sim 0$ Universe. We identify the first intermediate redshift compact quiescent galaxies by searching a sample of 1,089 objects in the DEEP2 Redshift Survey that have multi-band photometry, spectral fitting, and readily available structural parameters. We find 27 compact quiescent candidates between $z = 0.6$ and $z = 1.1$ where each candidate galaxy has archival Hubble Space Telescope

(HST) imaging and is visually confirmed to be early-type. The candidates have half-light radii ranging from 0.83 < $R^{e,c}$ < 7.14 kpc (median $R^{e,c}$ = 1.77 kpc) and virial masses ranging from 2.2E10 < M^{dyn} < 5.6E11 M^{sun} (median M^{dyn} = 7.7E10 M^{sun}). Of our 27 compact quiescent candidates, 13 are truly compact with sizes at most half of the size of their *z* ~ 0 counterparts of the same mass. In addition to their structural properties bridging the gap between their high and low redshift counterparts, our sample of intermediate redshift quiescent galaxies span a large range of ages but is drawn from two distinct epochs of galaxy formation: formation at *z* > 2 which suggests these objects may be the relics of the observed high redshift compact galaxies and formation at *z* ≤ 2 which suggests there is an additional population of more recently formed massive compact galaxies. This work is supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

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249.02 – Star formation and nuclear activity in the blue early-type galaxy NGC 5373

We present new optical and X-ray observations of NGC 5373, an isolated star-forming elliptical that has a stellar mass of 7e10 solar and lies at a distance of 175 Mpc. Our B and R band Magellan IMACS imaging substantially improves on SDSS resolution and sensitivity, enabling accurate modeling of the galaxy surface brightness profile. As expected from its mass, NGC 5373 is a core galaxy with a best-fit Sersic profile of n~3.8; no prominent tidal tails or shells are found, although there are slight residual asymmetries. The H-alpha emission in the SDSS spectrum is narrow, and the line ratios confirm a star-forming classification in the BPT diagram, near the transition/composite line. The star formation rate is about 6 solar masses per year, making NGC 5373 an extreme outlier relative to typical local early-type galaxies of similar mass. Our 50 ks Chandra ACIS-S exposure provides a clear detection of a central X-ray source, with a hardness ratio consistent with a power-law photon index of 2.0+/-0.5. The unabsorbed luminosity is Lx = 2e40 erg/s over 0.3–8 keV. Comparison with a MARX simulated point spread function suggests the central source may be extended, for example due to contributions from one or more unresolved high-mass X-ray binaries, as might be present given the high star formation rate. For a black hole of 1.6e8 solar masses as predicted from scaling relations, Lx/Ledd is then around 1e-6 (or potentially lower).

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249.03 – Recovering the Dynamical Structure and Formation History of Early-Type Galaxies

Many early-type galaxies show clear signatures of non-axisymmetry in their photometry, as well as in their kinematics. A general technique to model those triaxial systems is provided by Schwarzschild's (1979) numerical orbit superposition method, which is implemented in triaxial geometry (van den Bosch et al. 2008, 2009, van de Ven et al. 2008). We have constructed Triaxial Schwarzschild models for simulated elliptical-like merger remnant galaxies. The total mass distribution and orbital structure derived from these models are confronted with the real distribution of the simulated galaxies. The results of this comparison can help towards understanding how well one can recover the real orbital and mass distribution of early-type galaxies, as well as to constrain their formation history, using orbit-based dynamical modeling.

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249.04 – Morphology, star formation, and nuclear activity in void galaxies

We report on new Chandra observations of six early-type galaxies located within cosmic voids, from a program examining the influence of Mpc-scale environment upon star formation and low-level supermassive black hole activity. Simple feedback prescriptions are predicted to operate independently of the surrounding density once outside the dark matter halo, and further link star formation quenching to black hole activity. Alternatively, mediation of the cold gas supply by the large-scale environment, for example through increased cold-stream accretion and reduced harassment or stripping within more isolated regions, could mutually enhance star formation and (perhaps indirectly) low-level supermassive black hole activity. The six targeted early-type galaxies have comparable stellar masses of 6-9e10 solar, chosen to be near the predicted "critical value" for efficient feedback, but span a wide range of star-formation rates. Specifically, they have SFRs of 6.5, 1.4, 0.45, 0.10, 0.04, and 0.03 solar masses per year. All galaxies are detected in the Chandra ACIS-S observations with 0.3-8 keV X-ray luminosities ranging from 2e39 to 1e41 erg/s. Specifically, they have log Lx values of 40.4, 41.1, 41.1, 39.3, 39.2, and 39.2, again ordered by decreasing SFR. The three galaxies with moderate-to-high star formation rates have nuclear X-ray luminosities that are significantly greater than those of the three galaxies with low star formation rates. This result is more consistent with a symbiotic relationship between current low-level star formation and supermassive black hole activity than with simple feedback quenching models. We additionally situate these galaxies in the context of void and cluster galaxies in the local universe, model their optical surface brightness profiles and color gradients, discuss caveats including the possibility of X-ray binary contamination, and consider other supermassive black hole activity indicators.

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250 – Spiral Galaxies Posters

250.01 – EDGES: Deep Multi-Wavelength Photometry and Radial SED Analysis for NGC4707 and NGC5229

New deep ugr imaging was obtained on the Wyoming Infrared Observatory 2.3 meter telescope for NGC4707 and NGC5229, two galaxies in the Extended Disk Galaxy Exploration Science survey. These data are coupled with deep GALEX ultraviolet and Spitzer infrared imaging to study the radial variations in the spectral energy distributions. Results from the CIGALE SED modeling software will be presented, including trends in the galaxy star formation histories. This work is supported by the National Science Foundation under REU grant AST 1063146.

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250.02 – EDGES: Deep Multi-Wavelength Photometry and Radial SED Analysis for Six Nearby Galaxies

New deep ugr imaging was obtained on the Wyoming Infrared Observatory 2.3 meter telescope for NGC4220, NGC4618, NGC5055, NGC5523 and NGC5608, five galaxies in the Extended Disk Galaxy Exploration Science Survey (EDGES). Additional imaging was obtained for NGC4625, a non-EDGES target of opportunity. These data are coupled with deep GALEX ultraviolet and Spitzer/WISE infrared imaging to study the radial variations in the spectral energy distributions. Results from the CIGALE SED modeling software will be presented, including trends in the galaxy star formation histories. This work is supported by the National Science Foundation under REU grant AST 1063146.

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250.03 – EDGES: Deep Multi-Wavelength Photometry and Radial SED Analysis for NGC4242 and UGC7301

New deep ugr imaging was obtained on the Wyoming Infrared Observatory 2.3 meter telescope for NGC4242 and UGC7301, two galaxies in the Extended Disk Galaxy Exploration Science survey. These data are coupled with deep GALEX ultraviolet and Spitzer/WISE infrared imaging to study the radial variations in the spectral energy distributions. Results from the CIGALE SED modeling software will be presented, including trends in the galaxy star formation histories. This work is supported by the National Science Foundation under REU grant AST 1063146.

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250.04 – EDGES: Deep Multi-Wavelength Photometry and Radial SED Analysis for NGC4485, NGC4490 and NGC5273

New deep ugr imaging was obtained on the Wyoming Infrared Observatory 2.3 meter telescope for NGC4485, NGC4490 and NGC5273, three galaxies in the Extended Disk Galaxy Exploration Science survey. These data are coupled with deep GALEX ultraviolet and Spitzer/Herschel infrared imaging to study the radial variations in the spectral energy distributions. Results from the CIGALE SED modeling software will be presented, including trends in the galaxy star formation histories. This work is supported by the National Science Foundation under REU grant AST 1063146.

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250.05 – EDGES: Deep Multi-Wavelength Photometry and Radial SED Analysis for UGC8303 and UGC8320

New deep ugr imaging was obtained on the Wyoming Infrared Observatory 2.3 meter telescope for UGC8303 and UGC8320, two galaxies in the Extended Disk Galaxy Exploration Science survey. These data are coupled with deep GALEX ultraviolet and Spitzer infrared imaging to study the radial variations in the spectral energy distributions. Results from the CIGALE SED modeling software will be presented, including trends in the galaxy star formation histories. This work is supported by the National Science Foundation under REU grant AST 1063146.

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250.08 – Exploration of a SMBH Mass-Pitch Angle Relation at Intermediate Redshifts

Previous studies have established a correlation between central black hole mass M and spiral arm pitch angle P in disk galaxies. The mathematical form of this relation was developed for local objects ($z < 0.04$; Berrier, J. C. et al, 2013, *ApJ*, 769, 2), but the form at higher redshifts is currently unknown. Here we aim to develop an extended M-P relation in a sample of spiral galaxies with type 1 AGN, using spectroscopic techniques to estimate black hole masses and image analysis to measure pitch angle of the host galaxy. The sample was chosen from a list of 545 X-ray selected objects previously identified as type 1 AGN (Lusso, E. et al., 2010, *A&A*, 512, A34) and limited to those that had available spectral data (327 of 545) and visible spiral structure (14 of 327). The final sample consisted of thirteen objects with $0.196 < z < 1.34$.

Black hole masses were measured using optical or UV spectroscopic information from a number of emission lines, including [OIII] l5007, the broad-line component of Hβ, MgII, and CIV. Each spectrum was extinction corrected and fitted with an FeII template, an underlying power law curve, and Gaussian curves for the emission line(s) under consideration. Relationships developed by Vestergaard & Peterson (Vestergaard, M. & Peterson, B., 2006, *ApJ*, 641, 2) and Salviander & Shields (Salviander, S. & Shields, G. A., 2013, *ApJ*, 764, 82) use information from these fits to estimate $\log(M^{BH})$.

Measurement of pitch angles was accomplished using a two-dimensional fast Fourier transform technique, 2DFFT (Davis, B. et al. 2012, *ApJS*, 199, 2). HST images were formatted for and processed by the 2DFFT program; output was analyzed for ranges of stable P for an appropriate number of spiral arms. Average pitch angle over these ranges were calculated using an extension of 2DFFT.

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250.09 – Spirality: A Noval Way to Measure Spiral Arm Pitch Angle

We present the MATLAB code Spirality, a novel method for measuring spiral arm pitch angles by fitting galaxy images to spiral templates of known pitch. For a given pitch angle template, the mean pixel value is found along each of typically 1000 spiral axes. The fitting function, which shows a local maximum at the best-fit pitch angle, is the variance of these means. Error bars are found by varying the inner radius of the measurement annulus and finding the standard deviation of the best-fit pitches. Computation time is typically on the order of 2 minutes per galaxy, assuming at least 8 GB of working memory. We tested the code using 128 synthetic spiral images of known pitch. These spirals varied in the number of spiral arms, pitch angle, degree of logarithmicity, radius, SNR, inclination angle, bar length, and bulge radius. A correct result is defined as a result that matches the true pitch within the error bars, with error bars no greater than ±7°. For the non-logarithmic spiral sample, the correct answer is similarly defined, with the mean pitch as function of radius in place of the true pitch. For all synthetic spirals, correct results were obtained so long as SNR > 0.25, the bar length was no more than 60% of the spiral's diameter (when the bar was included in the measurement), the input center of the spiral was no more than 6% of the spiral radius away from the true center, and the inclination angle was no more than 30°. The synthetic spirals were not deprojected prior to measurement. The code produced the correct result for all barred spirals when the measurement annulus was placed outside the bar. Additionally, we compared the code's results against 2DFFT results for 203 visually selected spiral galaxies in GOODS North and South. Among the entire sample, Spirality's error bars overlapped 2DFFT's error bars 64% of the time. For those galaxies in which Source code is available by email request from the primary author.

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250.10 – SAMI Galaxy Survey: Disk and Bar Kinematics, Mass Decompositions with Dark Matter

The SAMI Galaxy Survey (SGS, P.I. Scott Croom, U. of Sydney) uses a custom multiple-integral-field feed to the Australian Astronomical Telescope (AAT) AAOmega dual-spectrograph to map the inner 15 arcsec diameter of 3400 galaxies a dozen at a time. The SGS spans environmental densities up to clusters, out to z = 0.1. (See http://sami-survey.org/edr for ~100 galaxies in the public Early Release Data.) We discuss circular speed curves (CSCs) of gas and stars derived from non-parametric fits to a flat disk in ~130 late-type barred and unbarred galaxies across the full mass range of the SGS, and at radii up to 4 r_e. Gas and stellar rotational fields agree well, but can differ substantially in line of nodes. At least 2/3 of the fitted CSCs are compatible with the ``universal rotation curve''. Velocity model residuals are compared to residuals from single-Sersic profile fits to SDSS photometry that highlight light asymmetries. For galaxies where photometry minus model residuals delineate stellar bars, the VIKING Z-band image is fit with a dual-Sersic form, one component addressing the bulge/bar, then gas kinematics are refit to include a bisymmetric (m=2) velocity distortion in the disk. This distortion often aligns with photometric residuals, and has amplitude at most 80 km/s but usually <20 km/s in the disk plane. Thus we debias the CSC from, and map the effects of, gas streaming due to a bar/oval. Because of generally low in-plane velocity distortions, only 2 of 18 barred galaxies have shock-indicating, emission-line flux ratios that correlate with m=2 spatio-kinematical variations and concentrate near the bar ends. Each dual- or single-Sersic fit is mapped into mass using one M/L constant with radius and the non-axisymmetric or axisymmetric CSC to decompose the mass distribution into luminous bulge and disk, and dark halo components. Some fits require a maximal luminous disk, others require a non-negligible or even dominant dark halo within the SAMI aperture. We discuss interesting individual systems and statistics of our sample from the first 600 galaxies surveyed. GC was a visiting professor supported by U. of Sydney. The SAMI and GAMA surveys are supported by grants from the Australian Research Council.

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Contributing team(s): SAMI Galaxy Survey Team, GAMA Survey Team

250.11 – Halo Mass Concentration and the Morphology of Simulated Spiral Galaxies

Using a model based on the Milky Way, we vary the central concentration of the dark matter halo component of simulated spiral galaxies. We evolve 11 galaxies in isolation under the effects of gravity for a time of 3 Gyr and look for differences in the disk structure. We primarily quantify morphological differences with measurements of the spiral arms' pitch angle by using a two-dimensional fast Fourier transform code (2DFFT).

Preliminary results indicate that while overall spiral arm structure is dynamic throughout the duration of the time range given, pitch angle values tend to restabilize during periods of reemerging spiral structure. This suggests that pitch angle may be fairly stable on timescales of a few Gyr, even if it tends to change at timescales of Myr. While concentration does seem to determine both the relative age at which simulated galaxies develop clearly visible spiral structure and the specific expression of spiral arms, a clear relationship between concentration vs pitch angle cannot be confirmed at this time.

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Contributing team(s): Arkansas Galaxy Evolution Survey

250.12 – The Effect of Large-Scale Structure on the Formation of Disk Galaxies : Specific Angular Momentum Point of View

We investigate the correlation between the environment parameters and central surface brightness of disk galaxies in order to study the effect of the large-scale structure on the formation of disk galaxies. In the standard galaxy formation picture, galaxy discs form out of primordial gas due to density fluctuation while conserving its specific angular momentum. The specific angular momentum of the pre-collapse gas is generally assumed to be equal to that of the dark matter, which is acquired by the tidal interactions with the surrounding matter distribution at its proto-halo stage. The difference of specific angular momentum of host dark matter halos is the favored origin for the difference between low surface brightness galaxies (LSBGs) and high surface brightness galaxies (HSBGs) which results in the different evolutionary paths. We utilize broadband photometry data from Simard et al. (2011) to extract the environment parameters and properties of individual galaxies. We calculate central surface brightness (μ^0) for 1,123,718 galaxies based on absolute magnitude of model disk and exponential disk scale lengths in g'- and r'- bands. We convert g'- and r'-band central surface brightnesses into B-band central surface brightness ($\mu^{0,B}$) using conversion from Smith et al. (2002). We classify disk galaxies with $\mu^{0,B} \geq 22.5$ mag arcsec^{-2} as LSBGs while ones with $\mu^{0,B} < 22.7$ mag arcsec^{-2} as

HSBGs.Then we compute a surface galaxy number density estimated from the fifth nearest neighbour galaxies (Σ^5). We are presenting a preliminary result based on our sample selection process and discussing the future prospect for the studies of disk galaxy formation with current and future facilities.

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250.13 – A Census of Galactic Disk Warps with an Automated Process

We present a statistical study on the optical warp of disks in a sample of ~1,500 nearby (z < 0.1) edge-on galaxies from SDSS DR7. This marks an attempt to achieve the most massive census of the galactic warp. A new automatic scheme suitable to edge-on disks (b/a < 0.3) is developed, which is highly efficient at measuring geometric warp parameters. We demonstrate that more than a half of all disk galaxies in our sample are warped and the majority show wobbly disk planes. About 43% of galaxies show "L"-shaped warps, 27% are "S"-shaped, and only 16% are "U"-shaped. Most disks tend to show asymmetric warps in their outer part. We find a correlation between the warp frequency and the local environment in the sense that the warped and lopsided disk galaxies highly prefer dense regions.

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250.15 – The Role of Cold Gas in Low-level Supermassive Black Hole Activity

The connection between low-level supermassive black hole activity and galactic cold gas, if any, remains debated. It has been hypothesized that mechanical feedback can heat and potentially expel gas and quench star formation; alternatively, central black holes may feed at higher rates in gas-rich galaxies, either directly or as a secondary consequence of greater stellar-wind mass loss. We test this relationship in local spiral galaxies using new HI fluxes from the ongoing ALFALFA 21cm blind survey, in combination with radio data from the literature, and archival X-ray measurements from the Chandra X-ray observatory. We consider late-type galaxies with distances d < 50 Mpc and optical absolute magnitudes MB < -18 as selected from the HyperLeda database. After matching to radio and X-ray coverage and eliminating edge-on galaxies to reduce the complicating effects of internal extinction, our sample consists of 135 spirals. Of these, 75 host a nuclear X-ray source within 2'' of the optical galaxy center, a 56% detection fraction. We estimate the possibility of contamination from high-mass X-ray binaries for each galaxy as a function of the nuclear X-ray luminosity, the star formation rate, and the enclosing projected size of the Chandra point spread function. We perform linear regression (on logarithmic quantities) to fit nuclear X-ray luminosity as a function of galaxy optical luminosity and as a function of HI mass, taking into account measurement uncertainties in both variables and X-ray upper limits. There is a highly significant correlation between Lx and MB, and a tentative correlation (significant at the 2.5 sigma level) between Lx and HI mass. Specifically, we find that log Lx scales with log HI mass with a slope of 0.79+/-0.32, albeit with a large intrinsic scatter of 1.37+/-0.13 dex. These findings suggest that supermassive black holes may indeed accrete at a faster rate in an environment with more cold gas. This work has been supported by NSF grant AST-1211005.

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250.17 – Resolving Andromeda's Structure with PHAT

We present density maps of red giant branch (RGB) stars from the Panchromatic Andromeda Hubble Treasury Survey. Using an infrared photometric selection technique we select all metal-rich RGB stars with A_V < 10, creating a smooth map of the stellar density of the old (>1 Gyr) stars that dominate the mass of Andromeda. Residuals from model fits to the map show significant non-exponentiality in Andromeda's disk, including a 40% overdensity roughly coincident with the 10 kpc ring. This structure must therefore be long-lived or dynamically generated, and is not merely a star-forming ring.

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Contributing team(s): PHAT Team

250.18 – Color Index Imaging of the Stellar Stream Around NGC 5907

We have obtained deep g, r, and i-band Subaru and ultra-deep 3.6 micron Spitzer/IRAC images of parts of the stellar stream around the nearby edge-on disk galaxy NGC 5907. We report on the color index distribution of the resolved emission along the stream, and indicators of recent star formation associated with the stream. We present scenarios regarding the nature of the disrupted satellite galaxy, based on our data. This work is based in part on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of

Technology under a contract with NASA. This work is based in part on data collected with the Subaru Telescope, which is operated by the National Astronomical Observatory of Japan. Support for this work was provided by NASA through an award issued by JPL/Caltech.

Author(s): Seppo Laine[3], Carl J. Grillmair[3], David Martinez-Delgado[1], Aaron J. Romanowsky[6], Peter Capak[3], Richard G. Arendt[5], Matthew Ashby[4], James E Davies[4], Steven R. Majewski[7], R. Jay GaBany[2]
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250.19 – Population Gradients in Stellar Halos from GHOSTS

We report on recent results from the Galaxy Halos, Outer disks, Substructure, Thick disks, and Star clusters (GHOSTS) survey, an HST ACS+WFC3 imaging survey to study stellar populations in and around 16 nearby spiral galaxies. By using HST resolution to resolve the stellar halos into individual red giant branch (RGB) stars, we are able to detect distinct stellar populations at several points throughout the halo of the half dozen massive highly-inclined galaxies in the sample. In approximately half of these galaxies, we detect a gradient in the color of the RGB; which we interpret as a metallicity gradient. Stellar halo formation models predict a wide variety of metallicity gradients: those in which the halos are dominated by stars formed in situ predict stronger gradients than we observe, while accretion-dominated halo models predict weaker or nonexistent gradients. Our measurements therefore provide a useful discriminator between stellar halo models, and at first look appear most consistent with the accretion-based model of Cooper et al. (2010).

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Contributing team(s): GHOSTS Survey

250.20 – Flux Calibration and Spectral Typing of the SPLASH Sample

We present the spectroscopic identification of M-stars in the disk of the Andromeda Galaxy (M31) and revised spectral types for the M-stars in the X-Shooter Library (XSL). Our dataset consists of optical spectra taken with the DEIMOS spectrograph on the Keck II 10-m telescope as part of the Spectroscopic Landscape of Andromeda's Stellar Halo (SPLASH) survey. We use stars from the MILES and X-Shooter Libraries to perform a first order flux calibration of these spectra, then use TiO-based indices from Fluks et al. 1994 to determine the probable M spectral subtype. While testing this procedure on the M-stars of the XSL, we find that the spectral subtypes derived from the spectra themselves are different from the spectral subtypes obtained from the literature and that XSL includes several spectra with subtypes seemingly later than M10. We suggest that this is due to stellar variability. We also identify ~2000 M-stars in the SPLASH sample. We present the distribution of subtypes here.

This research was funded by grants from the National Science Foundation and the Space Telescope Science Institute. Some of the research presented here was conducted by high-school students under the auspices of the University of California Santa Cruz's Science Internship Program.

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250.21 – The nuclear near-infrared spectral properties of nearby galaxies

We present spectra of the nuclear regions of 50 nearby (D = 1 – 92 Mpc, median = 20 Mpc) galaxies of morphological types E to Sm. The spectra, obtained with the Gemini Near-IR Spectrograph on the Gemini North telescope, cover a wavelength range of approximately 0.85–2.5 µm at R~1300–1800. There is evidence that most of the galaxies host an active galactic nucleus (AGN), but the range of AGN luminosities (log (L2−10 keV [erg s−1]) = 37.0-43.2) in the sample means that the spectra display a wide variety of features. Some nuclei, especially the Seyferts, exhibit a rich emission-line spectrum. Other objects, in particular the type 2 Low Ionisation Nuclear Emission Region galaxies, show just a few, weak emission lines, allowing a detailed view of the underlying stellar population. These spectra display numerous absorption features sensitive to the stellar initial mass function, as well as molecular bands arising in cool stars, and many other atomic absorption lines. We compare the spectra of subsets of galaxies known to be characterised by intermediate-age and old stellar populations, and find clear differences in their absorption lines and continuum shapes. We also examine the effect of atmospheric water vapor on the signal-to-noise ratio achieved in regions between the conventional NIR atmospheric windows, of potential interest to those planning observations of redshifted emission lines or other features affected by telluric H2O. Further exploitation of this data set is in progress, and the reduced spectra and data reduction tools are made available to the community.

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250.22 – Mapping the Star Formation in NGC 1097 Using the JVLA

We present new C- and L-band VLA continuum observations of the prototypical, nearby barred spiral galaxy, NGC 1097. The circumnuclear ring is well-imaged and C-band continuum is also detected along the bar dust lanes and the bar end. The VLA data is combined with GALEX and Hα data to inventory the obscured and unobscured star formation activity within the ring, at the ends of the bar, and along the bar. We estimate the synchrotron and thermal contributions from the VLA data and compare the thermal star formation estimate to those measured from the Hα data. The observations are used to understand how star formation progresses in the circumnuclear ring, the bar and at the bar ends.

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250.23 – Magnetic Fields In NGC 6946 Using Wide-Band Radio Polarimetry

Magnetic fields are important ingredients in the interstellar medium of galaxies. They accelerate cosmic rays, affect star formation, and regulate the redistribution of matter and energy. Despite their ubiquitous presence, the growth and coevolution of magnetic fields with galactic processes are not well understood. We examine the interplay of these galactic components in the spiral galaxy NGC 6946 using wide-band polarization observations. We map the turbulent and coherent line-of-sight magnetic fields across the disk of the galaxy by fitting models of the magnetic fields structure to 3-21cm polarization observations taken with the Westerbork Synthesis Radio Telescope. We spatially correlate the results of these fits with star formation tracers and HI line profiles to determine how magnetic field structure is related to different galactic processes. This work is just one example of how the advanced capabilities of modern radio telescopes have opened a new frontier for the study of cosmic magnetism.

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250.24 – Taking the Radio Blinders Off of M83: A Wide Spectrum Analysis of the Historical Point Source Population

We present low frequency observations of the grand design spiral galaxy, M83, using the C and L bands of the Karl G. Jansky Very Large Array (VLA). With recent optical (HST) and X-ray (Chandra) observations and utilizing the newly expanded bandwidth of the VLA, we are exploring the radio spectral properties of the historical radio point sources in M83. These observations allow us to probe the evolution of supernova remnants (SNRs) and to find previously undiscovered SNRs. These observations represent the fourth epoch of deep VLA observations of M83. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities.

Author(s): Christopher Stockdale[5], Clayton Keefe[5], Michael Nichols[5], Colton Rujevcan[5], William P. Blair[4], John J. Cowan[10], Leith Godfrey[1], James Miller-Jones[2], K. D. Kuntz[4], Knox S. Long[8], Larry A. Maddox[7], Paul P. Plucinsky[3], Tyler A. Pritchard[9], Roberto Soria[2], Bradley C. Whitmore[8], P. Frank Winkler[6]
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250.25 – An Unusual DRAGN: The Spiral Galaxy, 0313-192

Radio galaxies are typically hosted by elliptical galaxies with rare exceptions including the edge-on spiral galaxy 0313-192. This galaxy is at z=0.067 and hosts double radio lobes spanning 360 kpc with some sign of radio jets extending to 17 kpc. Previously, researchers used data collected from the Australian LBA illustrating this galaxy's lack of core structure. In this presentation, the authors examine the core of the galaxy and provide evidence that the central source has structure in the form of jets near the active nucleus. The authors present VLBA data in X-band that shows the core of 0313-192 with a total flux of 80.5 mJy and jets protruding to the south-west. The direction of the jets align with previous work done on a scale three orders of magnitude larger. Comparing the LBA results to our VLBA results, the authors find a spectral index of +0.3, indicating an inverted and more flat spectral index than what is expected for average synchrotron emission. This result provides further evidence for a SMBH and suggests the core is partially

optically thick.

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250.26 – A Shock in M51 Between NGC 5194 and NGC 5195?

We describe the X-ray emission and spectra of two diffused regions in M51 that lie between NGC 5194 and NGC 5195. The emission regions are arc-like in shape. Both lie on a line connecting the two nuclei, but the inner arc is offset slightly to the west while the outer arc is offset slightly to the east. We describe the model fits to the emission as well as describe radial profiles.

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250.27 – Detection of an Extended Outflow in NGC 4102

We report the detection of an extended galactic outflow in narrowband H alpha imaging of NGC 4102, a nearby spiral galaxy that hosts a low ionization nuclear emission region (LINER) and a circumnuclear H II region. NGC 4102 is a moderate luminosity galaxy, M_B = −19.3, in the Ursa Major Cluster. The outflow protrudes out to 60” (5 kpc at an adopted distance of 17.4 Mpc) to the northwest of the galactic center and may extend as much as 75” (6.3 kpc.) Follow-up integral field spectroscopic observations reveal split line profiles over the outflow region, indicative of both blue and red shifted emission-line components. Based on [N II] / H alpha and [S II] flux ratios of this region, the line emission appears to be nonthermal. We discuss possible origins of the outflow, including both nuclear and/or starburst activity.

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Institution(s): *1. Indiana University, 2. University of Minnesota*
Contributing team(s): EDGES

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251 – Starburst Galaxies Posters

251.01 – A new view on the radiocontinuum emission in NGC 3079 from CHANG-ES

First results from a new radiocontinuum study of the edge-on galaxy NGC 3079 will be presented. This study is based on data from CHANG-ES (Continuum Halos in Nearby Galaxies – an EVLA Survey, PI Judith Irwin) which has observed 34 edge-on spiral galaxies with the JVLA in two frequency bands (L- and C-band) and in three array configurations (D, C, B). For the study presented here we have analyzed L- and C-band observations in the D and C-configurations, respectively. The detection of extended polarized signal was possible with the help of the rotation measure (RM) synthesis technique. This method in its simplest form takes advantage of the multi-channel capability of the JVLA by avoiding bandwidth depolarization and hence recovering the polarized signal along the line-of-sight of the galaxy. The analysis reveals large scale magnetic fields perpendicular to the disc on the northern side of the target, resembling the X-shaped field patterns found in other edge-on spiral galaxies. In the very center both sides of the well known nuclear outflow bubble show up in our maps which reach an unprecedented quality.

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Contributing team(s): CHANG-ES

251.02 – Survey of Water and Ammonia in Nearby galaxies (SWAN): Physical Conditions in NGC 253

Nearby galaxies provide the vital link between local Galactic findings and integrated, galaxy-wide properties of star formation. We have observed four nearby star forming galaxies with the VLA in K and Ka bands, yielding a resolution on order of a few tens of parsecs. The sample spans a range of star formation rates and galactic environments. We present the first results from the nearby, prototypical starburst galaxy NGC 253. The K band observations cover ammonia inversion transitions from (1,1) to (5,5) in addition to the 22.3GHz water maser line with a resolution of ≈63pc. Ammonia is a known temperature probe and traces gas densities greater than 10^2 cm^{-3}. We observe relatively warm and uniform temperature distribution in the inner 0.5 kpc. The (3,3) line appears to be masing in the innermost 200 pc. Furthermore, we see indications of extended H20 maser components in the direction of the galactic outflow.

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251.03 – Resolved Molecular Gas Properties in Local Luminous Infrared Galaxies

Luminous infrared galaxies (LIRGs) in the local universe are mergers of gas-rich galaxies. The merger event funnels the molecular gas towards the central kiloparsec, compressing the gas, and triggering an extreme starburst, making LIRGs the perfect laboratory for studying extreme modes of star formation. We use the Submillimeter Array sample and observations of Wilson et al. (2008), supplemented with new CARMA and ALMA observations, to constrain the physical conditions such as temperature, density and column density of the molecular gas in the sample of 7 LIRGs. We use the radiative transfer code RADEX (van der Tak et al. 2007) and a Bayesian likelihood code to fit the most probable physical conditions. Comparison of the molecular gas physical conditions shows that earlier merger stage LIRGs such as Arp 299 and NGC 1614 have denser (> 10^3 cm^{-1}) molecular gas than a later stage merger such as VV 114. We measure the CO luminosity to H2 mass conversion factor, $\alpha^{CO,}$ using the radiative transfer analysis results and find that the values are a factor of 4-10 times lower than the Galactic value of 4.3 $M^{\odot}$ (K km s^{-1} $pc^2)^{-1}$. We also find unusually large ^{12}CO-to-^{13}CO abundance ratios (> 130), more than 2 times the local Galactic value.

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251.04 – The Uses of Fine Structure Lines in Constraining the Physical Properties of a Starburst

Located roughly 80 Mpc away, at a redshift of z≈0.02, IRAS08339+6517 is a galaxy undergoing rapid star formation. Its relatively close proximity, unique combination of atomic far infrared fine structure lines, and well studied optical properties make it a good candidate for a potential template for studying higher-redshift galaxies from the epoch of peak star and galaxy formation. By comparing our Herschel PACS data to models of the different regions of the ISM, we determine the physical characteristics—density, temperature, ionizing field strength, etc.—of those regions. With this information, we'll be able to compare this galaxy to other well-studied starbursts, and make inferences about the uses of fine structure lines as effective diagnostic tools for less-studied galaxies. We will present the properties constrained from our models.

Author(s): Moiya McTier[1], Drew Brisbin[2]
Institution(s): *1. Harvard University, 2. NRAO*

251.05 – Accurate Galactic Wind Simulations Require Gas Cooling to 10 K

Starbursts and AGN winds in galaxy cores can produce large-scale outflows or galactic winds (GW). Whether a starburst can form a GW depends on several variables including mechanical power into the ISM and the rate at which mass is loaded into the flow. Previous simulations (e.g. Hill+12, Cooper+08, Sutherland and Bicknell 2007) have included radiative cooling but only down to 10,000 K. We have modified the public Athena hydro code (Stone+08) to include a combined cooling curve from Sutherland and Dopita (1993) and Koyama and Inutsuka (2002) down to 10 K. We analyze grids of high-resolution 3D simulations of starbursts with an initial stellar mass ranging from 5e6 $M^{\odot}$ to 1e8 $M^{\odot}$. We find a 10-fold decrease of Hα emission in the halo resulting from the GW when we cool the gas down to 10 K vs the 10,000 K of previous simulations. We find that cooling to 10,000 K deposits 80% of the total GW gas mass in the warm phase (emitting Hα) whereas cooling to 10 K deposits only 7% in the warm phase but leaves 25% of the total GW gas mass in cold gas (< 100 K). Even with the shift in the gas mass in the GW to cold temperatures, cold gas swept up into the halo by the GW is 4-5 orders of magnitude fainter than cold gas that remains in the disk. Thus detection of a cold GW component will be very difficult. Our results demonstrate that there are substantial differences in simulations with cooling down to 10 K vs cooling down to 10,000 K. Our work is funded by NASA/Herschel and NC Space Grant.

Author(s): Ryan Tanner[1], Fabian Heitsch[1], Gerald N. Cecil[1]
Institution(s): *1. University of North Carolina*

251.06 – An Atlas of Starburst Galaxy Emission Lines

Recent observations of high ionization lines (e.g. [Ne V] and He II λ4686) from star-forming regions have prompted a need to study the production mechanisms of these high ionization lines. Our study addresses the following questions: 1. What are specific cloud parameters that influence the strength of emission lines in starburst galaxies? 2. How can these parameters be tuned in simulations to match observations? We adopt the locally optimally emitting cloud model, a model previously used to study AGN, for our study of star-forming regions. We present the results of hundreds of photoionization simulations spanning 15 orders of magnitude in hydrogen ionizing photon flux and 10 orders of magnitude in hydrogen density. We vary both properties of the starbursts (SEDs, evolutionary histories, ages), as well as cloud properties (such as the abundances and metallicity), tracking nearly 100 emission lines ranging from the UV to the near IR. Finally, we compare these results to the results of other studies on star-forming regions. The results of our photoionization calculations should prove useful for the analysis of starburst galaxy emission-line data.

Author(s): Helen Meskhidze[1], Chris T. Richardson[1], Gary J. Ferland[2]

Institution(s): *1. Elon University, 2. University of Kentucky*

251.07 – Analyzing Hydrogen Recombination Lines in the Infrared and Optical to Determine Extinction and SFRs of Local LIRGs

We report on measurements for dust extinction and star formation rates (SFRs) for luminous infrared galaxies (LIRGs). We utilized the hydrogen recombination lines Brα, Hα, and Hβ observed in the infrared and optical wavelengths with AKARI and the Lick Observatory's Kast Double spectrograph to produce spectra. By calculating Brα/Hα ratios for the target galaxies, extinction is estimated. A possible correlation between higher L^{IR}, IR/UV, specific SFRs and higher Brα/Hα has been found. Through comparisons with Hα/Hβ, it may be possible to determine if Hα is, in fact, underestimating extinction, since Hα is more strongly affected by extinction compared to longer wavelengths such as Brα. The accuracy of using Hα in extinction corrections is important for SFR studies, and, thus, one goal is to find a more accurate reddening correction factor. Payne was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program (AST-1262829).

Author(s): Anna Payne[2], Hanae Inami[1]
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251.08 – The CO-H^2 conversion factor and the CO excitation ladder

Indirect measurements of molecular hydrogen mass are can be made using the CO line intensity. Previous work has shown that the star formation rate surface density can be used to parameterize the conversion factor (X^{CO}). There is further evidence to suggest that the physical conditions which determine the CO spectral line energy distribution (SLED) also determine the conversion factor from CO line intensity to molecular gas mass conversion factor (X^{CO}). Here, we present a series of SPH simulations of idealized galaxies in evolution, focusing on their Giant Molecular Cloud properties. We simulate a range of both disk galaxies and galaxy mergers with a wide range of star formation rates, velocity dispersions, gas metallicities and temperatures. From these varying simulations we perform full radiative transfer calculations with conditions derived from the simulated GMCs. These calculations will determine theoretical values of the conversion factor (X^{CO}) as well as CO SLEDs. We aim to find a relationship between X^{CO} and the CO SLED that will help inform observers in the era of ALMA.

Author(s): Joel Robert Christian[1], Desika Narayanan[1]
Institution(s): *1. Haverford College*

251.09 – Indirect Evidence for Escaping Lyman Continuum Photons in Local Lyman Break Galaxy Analogs

A population of early star-forming galaxies is the leading candidate for the re-ionization of the universe. It is still unclear, however, what conditions and physical processes would enable a significant fraction of the ionizing photons to escape from these gas-rich galaxies. In addition, studies of high redshift galaxies have yet to uncover a large sample of galaxies with the required high escape fraction of ionizing photons.

We have uncovered a sample of local analogs to high-redshift, star-forming Lyman Break Galaxies (LBGs) called Lyman Break Analogs (LBAs) by matching the Sloan Digital Sky Survey (SDSS) and Galaxy Evolution Explorer (GALEX) catalogs. These galaxies are remarkably similar to LBGs in their properties-- morphology, size, UV luminosity, SFR, mass, velocity dispersion, metallicity and dust content. We obtained HST COS far-UV spectroscopy plus ancillary multi-waveband data of a sample of 22 LBAs to look for indirect evidence of escaping ionizing radiation (leakiness).

We measure three parameters: (1) the residual intensity in the cores of saturated interstellar low-ionization absorption-lines, which indicates incomplete covering by that gas in the galaxy. (2) The relative amount of blue-shifted Lyman alpha line emission, which can indicate the existence of holes in the neutral hydrogen on the front-side of the galaxy outflow, and (3) the relative weakness of the [SII] optical emission lines that trace matter-bounded HII regions. We find all three diagnostics agree well with one another. Finally, we find the strongest correlation between these leakiness indicators and both the compactness of the galactic star-forming region (size and star formation rate/area) and the speed of the galactic outflow. This suggests that extreme feedback- a high intensity of ionizing radiation and strong pressure from both radiation and a hot galactic wind- combines to create significant holes in the neutral gas. These results not only shed new light on the physical mechanisms that can allow ionizing radiation to escape from intensely star-forming galaxies, they also provide indirect observational indicators that can be used at high-redshift where direct measurements of escaping ionizing radiation is impossible.

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251.10 – Massive Compact Galaxies with High-velocity Outflows: Morphological Analysis and Constraints on AGN Activity

We investigate the process of rapid star formation quenching in a sample of 12 massive galaxies at intermediate redshift ($z \sim 0.6$) that host high-velocity ionized gas outflows ($v > 1000$ km s^{-1}). We conclude that these fast outflows are most likely driven by feedback from star formation rather than active galactic nuclei (AGNs). We use multiwavelength survey and targeted observations of the galaxies to assess their star formation, AGN activity, and morphology. Common attributes include diffuse tidal features indicative of recent mergers accompanied by bright, unresolved cores with effective radii less than a few hundred parsecs. The galaxies are extraordinarily compact for their stellar mass, even when compared with galaxies at $z \sim 2$–3. For 9/12 galaxies, we rule out an AGN contribution to the nuclear light and hypothesize that the unresolved core comes from a compact central starburst triggered by the dissipative collapse of very gas-rich progenitor merging discs. We find evidence of AGN activity in half the sample but we argue that it accounts for only a small fraction (≤10 per cent) of the total bolometric luminosity. We find no correlation between AGN activity and outflow velocity and we conclude that the fast outflows in our galaxies are not powered by ongoing AGN activity, but rather by recent, extremely compact starbursts.

Author(s): Paul Sell[7], Christina A. Tremonti[7], Ryan C. Hickox[1], Aleksandar M. Diamond-Stanic[7], John Moustakas[3], Alison L. Coil[4], Anna Williams[7], Gregory Rudnick[5], Aday Robaina[6], James Geach[2], Sebastian Heinz[7], Eric M. Wilcots[7]
Institution(s): *1. Dartmouth College, 2. McGill University, 3. Siena College, 4. University of California San Diego, 5. University of Kansas, 6. University of Michigan, 7. University of Wisconsin-Madison*

251.11 – High-resolution dust emission and the resolved star formation law in the z~4 submillimeter galaxy GN20

We present high-resolution observations of the 880μm (rest-frame far-infrared) continuum emission in the z=4.05 submillimeter galaxy GN20. These data, taken with the IRAM Plateau de Bure Interferometer (PdBI), allow us to resolve the obscured star formation on scales of 0.3”×0.2” (~2.1×1.3 kpc). The observations reveal a bright (16±1 mJy) dusty starburst centered on the cold molecular gas reservoir as traced by previous high-fidelity CO(2-1) imaging and showing a bar-like extension along the galaxy's major axis. The striking anti-correlation with the HST/WFC3 imaging suggests that the copious dust surrounding the starburst heavily obscures the rest-frame UV/optical light in all but one small region several kpc from the nucleus. A comparison with 1.2 mm PdBI data reveals no evidence for variations in the dust continuum slope across the source. A detailed star formation rate surface density map reveals values that peak at 119±8 $M_\odot$ yr^{-1} kpc^{-2} in the galaxy's center, showing that the star formation in GN20 remains sub-Eddington on scales down to 3 kpc^2. Lastly, we examine the resolved star formation law on the same scales, deriving a power law slope of $\Sigma^{SFR} \sim \Sigma^{H\_22.1\pm1.0}$ and a mean depletion time of 130 Myr. Despite its disk-like morphology and the use of custom-derived CO-to-H^2 conversion factors, GN20 lies roughly in-line with the other existing resolved starbursts and above the sequence of star forming disks, implying that the offset is not due solely to choice of conversion factor.

Author(s): Jacqueline Hodge[4], Dominik A. Riechers[2], Roberto Decarli[3], Fabian Walter[3], Chris Luke Carilli[5], Emanuele Daddi[1], Helmut Dannerbauer[6]
Institution(s): *1. CEA, 2. Cornell, 3. MPIA, 4. NRAO, 5. NRAO, 6. University of Vienna*

251.12 – Large Millimeter Telescope Observations of Extremely Luminous High Redshift Infrared Galaxies Detected by the Planck Survey

We present 8″ resolution, 1.1mm, continuum imaging and CO spectroscopic redshift measurements of extremely bright sub-millimeter galaxies identified from the *Planck* and *Herschel* surveys, taken with the *Large Millimeter Telescope*’s AzTEC and Redshift Search Receiver instruments. Due to their exceedingly high flux density in the *Herschel*/SPIRE 250, 350, and 500 micron bands (S_250 ~ S_350 ~ S_500 > 100 mJy), these sources are likely to be strongly lensed dusty galaxies at high redshift. We compiled this target list of lens candidates after cross-correlating the *Planck Surveyor* mission’s highest frequency channel (857 GHz/350 μm, FWHM = 4.5′) data with archival data taken with the *Herschel* Spectral and Photometric Imaging Receiver (SPIRE). Every *Planck-Herschel* counterpart found within a 150″ radius is further examined using the higher angular resolution *Herschel* and *WISE* images to identify only dusty, high-z starburst galaxies.

Author(s): Kevin Corneilus Harrington[1], Min Su Yun[1], John R Cybulski[1], Grant Wilson[1]
Institution(s): *1. University of Massachusetts-Amherst*
Contributing team(s): Large Millimeter Telescope (LMT) Team

251.13 – Analyzing Star Formation Properties in Dusty Early Universe Galaxies Using Gravitational Lensing

Strong gravitational lensing has recently become one of the most important tools for studying star formation properties in extremely high redshift galaxies. Dust-obscured star-forming galaxies found at far-infrared/sub-millimeter wavelengths are important in the assembly of stellar mass and the evolution of massive galaxies. We present Submillimeter Array (SMA) imaging of Lockman 102, a strongly lensed submillimeter galaxy at z=5.29, discovered by the Herschel Space Observatory. The system was observed at 250, 350, 500 and 1000 microns, corresponding to rest frame wavelengths of 40, 56, 80, and 159 microns respectively. The observations were targeted at the thermal dust emission and the [CII] interstellar medium cooling line. We report an estimated photometric redshift of ~1.9 for the lensing galaxy, making it possibly the most distant lens currently known. We use uvmcmcfit, a publicly available Markov Chain Monte Carlo software tool we have developed for interferometric data, to fit lens models to Lockman 102. The results obtained from uvmcmcfit suggest the lensed system is composed of a single lensing galaxy and two extended sources. We have strong constraints on an intrinsic flux density of Lockman 102 of 4.55 $\pm$ 0.45 mJy magnified by a factor of 12.5 $\pm$ 1.2. From a modified blackbody fit we compute an intrinsic far infrared luminosity of 5.5e12 $L^{\odot}$.This implies a star formation rate of ~950 $M^{\odot}$ yr^{-1}, making Lockman 102 an extremely active dusty galaxy. We also compare Lockman 102 to other dusty luminous starburst galaxies at similar redshift, HLS0918 (Rawle et al. 2014) and AzTEC-3 (Riechers et al. 2014a) and determine it is among the most luminous and active galaxies ~1 Gyr after the Big Bang. It is only with strong lensing that the SMA is able to undertake such a detailed study of a galaxy at this distance; the continued improvements from new facilities such as ALMA offer a promising future in observing even more distant lensed systems.

Author(s): Jaclyn C Bradli[1], R. Shane Bussmann[1], Dominik A. Riechers[1], David Clements[2], Ismael Perez-Fournon[3]
Institution(s): *1. Cornell University, 2. Imperial College London, 3. Instituto de Astrofisica de Canarias*

251.14 – Multiplicity of High-z Submillimeter Galaxies from Cosmological Simulations

Sub-millimeter galaxies (or SMG's) are some of the most luminous galaxies in the universe, yet are nearly invisible in the optical. Theorists have long struggled to simulate SMG's and accurately match their spectral properties and abundance to observations. Recent high-resolution observations, however, suggest that what were previously thought to be single sub-millimeter sources on the sky, may break up into multiple components when viewed with sufficient resolving power. Here, we present a combination of high-resolution cosmological hydrodynamic zoom simulations of massive galaxies in formation with a new dust radiative transfer package in order to understand this multiplicity in simulated SMGs. We find that multiplicity is a natural element of SMG formation as numerous subhalos bombard the central during its peak growth phase

Author(s): David Ball[4], Desika Narayanan[2], Philip F. Hopkins[1], Matthew Turk[3]
Institution(s): *1. California Institute of Technology, 2. Haverford College, 3. NCSA, 4. Whitman College*

251.15 – The Formation of High-Redshift Submillimeter Galaxies

The dominant paradigm for submillimeter galaxy formation is major galaxy mergers. In this presentation, I'll show both why this is an infeasible mechanism for driving the bulk of the population, but present a new model for the origin of these luminous starbursts.

Author(s): Desika Narayanan[1]
Institution(s): *1. Haverford College*

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252 – Galaxy Cluster Posters

252.01 – Can Thermal Instability Explain the Cold Gas in Galaxy Cluster Centers?

Massive galaxies in the cores of some galaxy clusters take part in a feedback cycle in which cooling gas powers their active galactic nuclei (AGN), while jets from the AGN heat the gas and reduce the rates of cooling and star formation. Thermal instabilities are believed to play a crucial role in feeding these AGN. The Field length is the distance scale above which thermal conduction is unable to smooth out inhomogeneities; if the radius of a cloud of gas is greater than the Field length, the cloud may become thermally unstable. Additionally, angular momentum can promote thermal instability by preventing a dense cloud from falling to its equilibrium position, where heating balances cooling. This requires a low viscosity, which can be tested by a similar criterion to the Field condition for thermal instability. For this reason, the Field parameter, given by the Field length squared over the radius squared, is calculated in order to determine whether a gas cloud at a given radius can become thermally unstable. In this study, we calculate the Field parameter as a function of the radius for a sample of five galaxy clusters known to produce Halpha emission, a marker of cold gas and star formation, and one cluster known not to contain cool gas. We find that all of the clusters with Halpha emission appear to be thermally unstable by the Field criterion, while the cluster without cool gas is not. This work was supported in part by the NSF REU and DOD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution. This research has made use of data obtained from the Chandra Data Archive and the Chandra Source Catalog, and software provided by the Chandra X-ray Center (CXC) in the application packages CIAO and ChIPS.

Author(s): Christopher Cappiello[1], Paul Nulsen[2]
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252.02 – A search for counterparts to unconfirmed *Planck* cluster candidates in ROSAT, *Chandra*, *XMM-Newton*, and *Swift* archival data

In this project we aim to identify counterparts to unconfirmed galaxy cluster candidates detected by the *Planck* satellite. One of the objectives of the *Planck* mission was to generate a catalogue of galaxy clusters by observing spectral distortions in the cosmic microwave background that arise due to interactions between CMB photons and the intracluster medium (ICM), a phenomenon known as the Sunyaev-Zel'dovich (SZ) effect. *Planck* detected a total of 1227 candidates; as of June 2014, 366 had yet to be confirmed as clusters. We searched available source catalogues from the ROSAT, *Chandra*, and *XMM-Newton* missions for counterparts to these unconfirmed candidates. All searches were conducted using a matching radius of 5 arcmin to the *Planck* location. Twenty-nine *Planck* candidates returned matches in one or more of the above catalogues, including 11 that we determined to be high-likelihood candidates. The likelihood of each candidate was assessed by considering the offset of the source from the *Planck* location, the significance and spatial extent of the X-ray signal, and the abundance of potential cluster member galaxies in optical and infrared images. We also generated a list of 50 candidates that were potentially within the field-of-view of pointed observations from ROSAT, *Chandra*, *XMM-Newton*, and the *Swift* narrow field instruments. Here we present the new confirmed *Planck* clusters and upper limits on the X-ray fluxes of those we do not confirm. Many *Planck* candidates were not observed by any of the above telescopes, so other methods, e.g., optical or infrared imaging, will be necessary to confirm them as clusters.

Author(s): August Jon Miller[1], John Patrick Hughes[4], Felipe Menanteau[2], Felipe Barrientos[3], Leopoldo Infante[3]
Institution(s): *1. Bowdoin College, 2. NCSA, 3. Pontifica Univ Catolica de Chile, 4. Rutgers University*

252.03 – The Chandra Observation of the Planck SZ Selected Cluster RXC J0528.9-3927

With the benefit of high resolution of Chandra observations, we now have access to more detailed information on the evolution of
galaxy clusters than ever before. Here we perform a spectroscopy and imaging analysis for the Chandra observation of a merging cluster RXC J0528.9-3927 (RXJ0528 hereafter). We carefully examine the morphology of the cluster, and find a cold front and three boxy ``sloshing edges'' near the BCG center, which are signatures of the gas sloshing. We detect a hot region to the northeast of the main cluster, which may be a subcluster. The gaseous atmosphere of the subcluster is hotter than expected for its mass, which suggests the subcluster gas has been shock heated through an interaction with the main cluster. Similar structures have been found in another cluster RXCJ 1347.5-1145 (Johnson et al. 2012), where a subcluster to the southeast of the main cluster is interacting with the main cluster. However the subcluster gas in RXJ0528 is more diffuse. Here we suggest that a subcluster, whose gas mass is at least ~ 10^{12} solar mass, triggered the core gas sloshing in RXJ0528 a few Gyrs ago, and has been disrupted through the merging process. Excluding the subcluster region, we also measure the global temperature, luminosity, overall temperature profile and density profile for the main cluster, and estimate its gas mass and total mass. This work is supported in part by the School of Astronomy and Space Science in Nanjing University and by the Smithsonian Institution.

Author(s): Zhoujian Zhang[3], Christine Jones[2], Marie E. Machacek[2], Ralph P. Kraft[2], Scott W. Randall[2], Felipe Andrade-Santos[2], Elke Roediger[1]
Institution(s): *1. Hamburg University Observatory, 2. Harvard-Smithsonian, CfA, 3. Nanjing University*

252.04 – Jet-driven redistribution of metal in galaxy clusters

We present numerical simulations of mixing driven by AGN jets in galaxy clusters. The ICM in galaxy clusters is metal enriched, typically to about 30% of solar metallicity, out to large radii. However, metals should form mostly in galaxies and remained bound to their progenitor systems. To enrich the ICM, effective mixing of gas needs to occur across large scales. Our simulations show jets lifting gas out of the center of the cluster, redistributing metals and adding energy to the ICM. We compare our results to X-ray observations of metallicity in clusters.

Author(s): Brian J. Morsony[3], Sebastian Heinz[1], Christopher S. Reynolds[3], Mateusz Ruszkowski[4], Marcus Brüggen[2]
Institution(s): *1. Univ. Of Wisconsin Madison, 2. University of Hamburg, 3. University of Maryland, 4. University of Michigan*

252.05 – Time Evolution of Clustering Statistics During Simulated Galaxy Cluster Mergers

Galaxy cluster mergers occur at the intersection of filamentary structures which comprise the largest scale structure in the universe, the cosmic web. Galaxy clusters are thought to form hierarchically, with the most massive clusters having experienced many such mergers in their histories. Astronomers are hindered in our study of these mergers since they occur over much longer timescales than our observations allow. How then can we hope to understand the conditions under which these mergers took place? In this study, we use simulated galaxy cluster merger data and bring to bear several clustering statistics to examine the efficacy of such statistics during mergers. By projecting this 3-dimensional data onto a 2-dimensional plane, we are able to simulate these clusters as we might actually view them on the sky. We find that significant events (such as pericentric crossings) are identifiable across the 2-dimensional position and 1-dimensional velocity space, as well as over a range of merger initial conditions and from many different lines of sight.

Author(s): Ryan Johnson[1], Tessa J Thorsen[1], Andre J Hinds[1], John A. ZuHone[2]
Institution(s): *1. Gettysburg College, 2. NASA GSFC*

252.06 – High precision measurements of galaxy cluster escape velocities through phase-space stacking.

Under Newtonian dynamics, the escape velocity is related to the gravitational potential via the Poisson equation. Galaxies within clusters that cannot escape the gravitational potential define a characteristic shape in radius/velocity phase space. The extrema of the velocities in this phase space define a surface, the escape velocity profile, which can be observed in projected sky coordinates. The main systematic uncertainty in the observed surface results from the non-spherical shape of galaxy clusters. We use simulations to show that stacked phase-spaces greatly reduce the systematic errors on escape velocity inferred cluster masses.

Author(s): Christopher J. Miller[1], Daniel Gifford[1], Nicholas S. Kern[1]
Institution(s): *1. University of Michigan*

252.07 – The Gemini Frontier Field: Multi-conjugate Adaptive Optics Ks-band imaging of selected HST Frontier Field galaxy clusters

We use the Gemini Multi-Conjugate Adaptive Optics System (GeMS) and the Gemini South Adaptive Optics Imager (GSAOI) at the Gemini South telescope to image three of the six Hubble Space Telescope (HST) Frontier Field targets. These observations cover the gap between the HST observations beyond 1.7 microns and the 3.6 micron provided by Spitzer. GeMS is the first multi-conjugate adaptive optics system in use at an 8
meter telescope. It delivers and uniform, close to diffraction-limited near-infrared images over a 2′ field of view. In this presentation we describe the release of 100′′ x 100′′ high resolution wide-field images obtained for the galaxy clusters MACS J0416.1-2403 and Abell 2744 in Ks-band. The angular resolution achieved is between 70 to 110 mas, twice as high as HST/WFC3, using a single natural guide star only. This is a demonstration that even for fields at high galactic latitude, where natural guide stars are scarce, current multi-conjugated adaptive optics technology at 8m-telescopes has opened a new window on the distant Universe.

Author(s): Gaetano Sivo[1]
Institution(s): *1. Gemini South Observatory*
Contributing team(s): Rodrigo Carrasco, Mischa Schirmer, Peter Pessev, Claudia Winge, Vincent Garrel, Benoit Neichel, Fabrice Vidal

252.08 – Determining the Dynamical Mass of Subclusters within HST Frontier Fields Cluster MACSJ0171.5+3745

Using galaxy position and redshift data, we sought to identify through multiple clustering algorithms four or possibly five previously found subclusters within the HST Frontier Fields cluster MACSJ0717.5+3745 at a redshift of 0.55. Dynamical mass estimates for each subcluster will be compared with other independent mass estimates from X-rays and gravitational lensing with the goal of understanding the dynamics of this very massive merging cluster and to compare our subclustering results to the distribution of X-ray gas and lensing maps produced from HST observations.

Author(s): Aquiel Warner[3], Christine Jones[1], Michael West[2], Reinout J. Van Weeren[1], Felipe A Santos[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Maria Mitchell Organization, 3. Yale University*

252.09 – Digging Deep in Pandora's Cluster

Abell 2744, the first and nearest (z=0.31) of the Hubble Frontier Fields, is extraordinarily rich in the number and variety of galaxies it contains. Nicknamed "Pandora's Cluster," it exhibits multiple peaks in the dark matter, X-ray, and galaxy density distributions, suggesting an ongoing collision of several massive clusters. The exceptional depth of the Hubble Frontier Field imaging now makes it possible to throw open Pandora's cluster and peer deep inside. To do this, we first model and remove the stellar light of the cluster galaxies; underneath we find not only distant background galaxies, but (like the Hope that lay at the bottom of Pandora's box) a large population of globular star clusters and compact cluster members within Abell 2744 itself. Our earlier work on the massive lensing cluster Abell 1689 (Alamo-Martinez et al. 2013) revealed the largest known population of globular clusters, with a spatial profile intermediate between the galaxy light and the dark matter. Abell 2744 is similarly massive, but far less regular in its density distribution; we examine what implications this has for the copious globular clusters coursing through its multiple cores.

Author(s): John P. Blakeslee[2], Karla Alamo-Martinez[3], Elisa Toloba[1], Guillermo Barro[1], Eric W Peng[3]
Institution(s): *1. Lick Observatory, 2. NRC Herzberg Institute of Astrophysics, 3. Peking University*

252.10 – Analysis of Spectral Lines from SparsePak Observations of Brightest Cluster Galaxies Abell 1668, Abell 2199, MKW3s, and Zw8338

Spectral data of four local Brightest Cluster Galaxies (BCGs) was collected using the SparsePak instrument on the 3.5m

WIYN telescope. We observed the galaxies in clusters MKW3s, Abell 1668, Abell 2199 and Zw8338, which were originally drawn from the NOAO Fundamental Plane survey. We chose galaxies with redshifts between 0.045 and 0.063 to capture diagnostic features. Our targets were observed with three different pointings in order to fully spatially integrate the field. Data was then reduced and sky subtracted. Here we present maps of the distribution of the absorption and emission line strenghts for each BCG, and maps of stellar population parameters where available.

Author(s): Saisneha Koppaka[1], Louise O. V. Edwards[1], Hannah Alpert[1], Tara Abraham[1]
Institution(s): *1. Yale University*

252.11 – Spectral Line Maps of a Sample of Local Brightest Cluster Galaxies

We characterize multiple stellar populations in a sample of fifteen z < 0.1 Brightest Cluster Galaxies (BCGs) by measuring stellar absorption and nebular emission lines. We compare the stellar populations in the inner and outer regions of each galaxy and its nearby neighbors, and present maps of key absorption and emission lines for each system. We calculate age, metallicity, and star formation rate, and count the number of close pairs in each system in order to gauge the importance of interactions in their formation and evolution. Some of the BCGs appear to have prominent Hα emission; at times it is concentrated at the core, indicating AGN, while in other instances it is extended beyond the center, indicating star formation.

Author(s): Hannah Alpert[1], Louise O. V. Edwards[1], Tara Abraham[1], Vasilije Dobrosavljevic[1]
Institution(s): *1. Yale University*

252.12 – The Alignment of Red-Sequence Dwarf Galaxies

The alignment of cluster galaxies has been used to determine the impact of the high-density environment on the evolution of galaxies. We have undertaken a study to measure the alignment of cluster dwarf galaxies based on a sample of 57 low-redshift Abell clusters imaged at KPNO using the 0.9-meter telescope. To supplement our KPNO sample, we have included an additional 64 low-redshift clusters from the WINGS dataset. From the combined cluster sample (121 clusters), we have selected cluster dwarf galaxies based on their position relative to the cluster red-sequence. We present our preliminary results based on the alignment of the dwarf galaxies with: 1) the major axis of the brightest cluster galaxy, 2) the major axis of the cluster defined by position of the cluster members, and 3) a radius vector pointing from the cluster center to the dwarf galaxy.

Author(s): Haylee Archer[2], Wayne Barkhouse[2], Jaford Burgad[2], Gregory Foote[2], Cody Rude[2], Omar Lopez-Cruz[1]
Institution(s): *1. Instituto Nacional de Astrofisica, 2. University of North Dakota*

252.13 – Star Formation in Dwarf Galaxies as a Function of Cluster-Centric Radii

Galaxy clusters form the largest structures in the universe. The cluster galaxy population differs both by morphology and star formation histories relative to the field population. Several physical mechanisms have been proposed to account for these differences, including ram pressure stripping due to the intracluster medium, and harassment from close encounters with other galaxies. Dwarf galaxies could prove to be particularly important as their low mass makes them more susceptible to external influences. This study looks for evidence of enhanced/quenching of star formation in dwarf galaxies using photometric *u*- and *r*-band data of several Abell clusters taken with the CFHT. From the combined sample, scaled by r^{200}, composite luminosity functions (LFs) and histograms of galaxy color at various cluster-centric radii are constructed. An increase in the faint-end slope of the *u*-band LF relative to the *r*-band is a possible indicator of enhanced star formation. Comparisons of the inner and outer regions of the cluster sample may yield insights into the physical mechanisms that affect star formation of infalling cluster dwarf galaxies.

Author(s): Cody Rude[1], Wayne Barkhouse[1]
Institution(s): *1. University of North Dakota*

252.14 – Evolution of Star Formation Rates in Clusters Using Spitzer MIPS Imaging

Galaxy clusters provide a laboratory for studying the evolution of galaxies in dense environments. Star formation in cluster galaxies seems to be suppressed relative to field galaxies. Recent studies suggest that star formation continues in some cluster galaxies, but in a mode where a larger fraction of the light from young stars is obscured by dust. To detect this dust-obscured star formation, we use Spitzer MIPS imaging, which is sensitive to the thermal emission from dust heated by young stars. We focus on a sample of 36 X-ray-selected clusters, all of which have high-quality masses from Chandra data. For 12 of the clusters, we use extensive MMT/Hectospec optical spectroscopy to identify cluster members. For galaxies without spectroscopy, we estimate photometric redshifts using SDSS and IRAC imaging and stellar population synthesis models. We use statistical background subtraction to estimate cluster-wide star formation rates for the entire cluster sample. The optical spectra test the accuracy of these estimates for the clusters with available data. Our final results will inform models of star formation within galaxy clusters.

Author(s): Ethan Batson[3], Kenneth J. Rines[3], Rose Finn[1], Alexey Vikhlinin[2]
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252.15 – Dynamical Properties of Luminous Galaxies in 132 Clusters

While numerical simulations provide insight into the history of formation and evolution of dark matter halos, observations allow only for the study of galaxies. Many models of galaxy formation and evolution assume that galaxies form at the center of dark matter halos, an assumption that is difficult to test. Because both cluster galaxies and intracluster gas probe the distribution of dark matter halos, Brightest Cluster Galaxies (BCGs) offer a unique test of the relation between galaxies and dark matter halos. To test these assumptions, we study BCGs in a sample of 132 X-ray flux selected clusters. First, we examine the velocity offset of the BCG with respect to the center of the cluster. Second, we compare the projected spatial position of the BCG to the position of the X-ray emitting center of the cluster. In addition to applying these methods to the BCG, we extend the tests to the second-brightest (G2) through the fifth-brightest (G5) cluster galaxies. Initially, our results have shown that while many BCGs are centrally located, some of the BCGs are found to have large velocity and spatial offsets from the center of the cluster. In addition, non-central BCGs have luminosities which are similar to G2s while centrally located BCGs represent a typically brighter population. We have also found that lower-ranked galaxies (G2-G5) are found progressively further from the cluster center. We quantify this effect using randomly selected member galaxies. Our measurements of the properties of BCGs and other top-ranked galaxies will provide a useful benchmark for models of galaxy formation and evolution.

Author(s): Zachary Schutte[4], Kenneth J. Rines[4], Margaret J. Geller[2], Antonaldo Diaferio[3], Ho Seong Hwang[1]
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252.17 – HeCS-SZ: The Hectospec Cluster Survey of SZ-Selected Clusters

Masses of galaxy clusters can be inferred by several independent techniques. Comparing mass estimates from different methods can reveal potential systematic uncertainties in the relation between cluster mass and commonly used observable mass proxies. The recent availability of an all-sky catalog of clusters selected from Planck observations of the Sunyaev-Zeldovich (SZ) effect motivated us to obtain spectroscopic observations of a complete, SZ-selected sample of clusters. We present the first results from HeCS-SZ, a spectroscopic survey with MMT/Hectospec of galaxy clusters selected by their SZ signal. The project builds on earlier samples (CIRS and HeCS) selected by X-ray flux. We measure dynamical masses for 21 additional clusters (using over 8000
new redshifts) to yield a sample of 116 clusters, and a SZ-complete sample of 81 clusters, by far the largest compilation to date. We show that the velocity dispersions scale with the integrated Compton Y parameter according to the scaling expected from X-ray-SZ calibrations. We discuss the impact of X-ray flux selection on the measured scaling relation. Our results provide a test of SZ measurements as cluster mass proxies.

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252.18 – The C4 Cluster Abundance Function Using Caustic Mass Estimates

The strength of the abundance function of galaxy clusters is exponentially sensitive to the amplitude of matter fluctuations. While the theory behind cluster abundance studies for cosmology tell us how to compute the number of clusters as a function of mass, cluster masses are not directly observable and difficult to measure. Due to this challenge, many independent techniques exist to estimate cluster masses from cluster observables across the EM spectrum. We use mass measurements for ~1000 galaxy clusters in the SDSS C4 catalog to estimate the abundance function. The cluster masses are measured using the caustic technique, a dynamical method that infers the mass from the cluster escape velocity profile, and are self-calibrated by stacking on observable quantities. Stacking allows us to overcome the systematic biases associated with measuring accurate and precise masses including shape and velocity biases. These measurements, combined with the well studied selection function of the C4 cluster survey allow us to place constraints on cosmological parameters.

Author(s): Daniel Gifford[2], Christopher J. Miller[2], Nicholas S. Kern[2], Alyssa Keimach[2], Ryan C. Hickox[1], Kevin Nicholas Hainline[1]
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252.19 – Merger Activity and Radio Emission Within A2061

Abell 2061 is a galaxy cluster located in the Corona Borealis Supercluster that boasts radio and X-ray structures indicative of a merger. A2061 is located at a redshift z = .0784, contains two brightest cluster galaxies, and has another cluster (A2067) about 2.5 Mpc to the NE, falling towards it. Within A2061, there exists an elongated structure of soft X-ray

emission extending to the NE of cluster's center (referred to as the "Plume") along with a hard X-ray shock region (the "Shock") located just NE of the cluster's center. Previous observations in the radio have indicated the presence of a extended, central radio halo/relic accompanying the cluster's main X-ray emission but with slight NE displacement and further NE extension. Also emitting in the radio, to the SW of A2061, is a radio relic. The X-ray structures of A2061 were previously examined in 2009 by a *Chandra* observation. Here we present the results of an August 2013 *XMM-Newton* observation of the cluster. This *XMM-Newton* observation, imaged by three detectors, covers a greater field of view with a longer exposure (48.6 ks) than the previous Chandra observation. We will present images and spectra of various regions of the cluster. In addition, we will discuss the dynamics of the cluster, the nature of the Plume, Shock and other features, and origin of the central diffuse radio halo/relic and SW radio relic. These X-ray observations will also be compared to a numerical simulation from the Simulation Library of Astrophysics cluster Mergers (SLAM).

Author(s): Avery Bailey[8], Craig L. Sarazin[8], Tracy E. Clarke[4], Marios Chatzikos[6], Taylor Hogge[1], Daniel R. Wik[3], Lawrence Rudnick[7], Damon Farnsworth[7], Reinout J. Van Weeren[2], Shea Brown[5]
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252.20 – Probing the intragroup medium with bent-double lobed radio sources

We present results from a new multi-faceted study of bent-double lobed radio sources in galaxy groups. Bent-double sources, sometimes referred to as wide- or narrow-angle tails, are most likely the result of ram pressure from either the motion of the source through a dense medium or the "cluster weather." These unusual sources have long been associated with high density, high velocity dispersion, and turbulent environments of massive clusters, however a surprising number have been found in lower mass systems. We focus our attention on a sample of such sources in galaxy groups where the velocity dispersion is significantly lower. With new multi-frequency radio continuum observations using the GMRT and VLBA we measure the jet properties and curvature. Combining these data with new optical spectroscopy to measure the velocity dispersion of the groups hosting bent-double sources, we derive and estimate of the density of the intergalactic medium in these groups. The implication of our study is that groups may contain a significant amount of baryons that remain largely undetected in X-ray surveys of groups.

Author(s): Danielle M. Nielsen[1], Eric M. Wilcots[1]
Institution(s): *1. University of Wisconsin - Madison*

252.21 – Optical Follow-Up Observations for the High-z COBRA (Clusters Occupied by Bent Radio AGN) Survey

Galaxy clusters are unique laboratories for exploring galaxy formation and evolution. Relatively few galaxy clusters have been spectroscopically confirmed beyond a redshift of 1. Different methods of searching for galaxy clusters are adding to these numbers, including detecting regions with a high-density of galaxies in the optical and IR regimes, detecting the hot intracluster medium in the X-ray, and measuring the Sunyaev-Zel'dovich effect. Another promising method for discovering high-redshift galaxy clusters uses radio observations of AGN. In particular, we use bent-double lobed radio sources, known often to reside in nearby clusters, as markers for distant galaxy clusters. We present initial results from the high-redshift COBRA (Clusters Occupied by Bent Radio AGN) survey. We have *Spitzer* IRAC observations of 653 bent-double radio sources with hosts too faint to be detected in the SDSS. Since the host galaxies for these radio sources are usually giant ellipticals, lack of detection in the SDSS means they are likely at $z > 0.7$. We have begun deep follow-up optical observations using the 4.3 m Discovery Channel Telescope and have determined from these initial optical observations that ~50% of the observed fields are overdense and thus good cluster candidates. Additionally, we have created optical-IR color magnitude diagrams to estimate the redshifts of our cluster candidates by identifying the red sequence. The distribution of galaxies on the red sequence can be used to limit galaxy formation models.

Author(s): Emmet Golden-Marx[1], Elizabeth L. Blanton[1], Rachel Paterno-Mahler[1], Joshua Wing[2], Matthew Ashby[3], Mark Brodwin[4]
Institution(s): *1. Boston University, 2. CfA, 3. SAO, 4. University of Missouri-Kansas City*

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253 – Large Scale Structure, Cosmic Distance Scale and Intergalactic Medium, QSO Absorption Line Systems Posters

253.01 – An Evolving Neighborhood: Tracking the Local Environment and its Influence on the Evolution of Galaxies

We present new cosmological simulations, generated using GADGET-2 modified with radiative cooling, star formation and supernova feedback physics, and a new structure finding algorithm adapted from computer vision methods. By probing the cosmological structure at multiple scales and assigning each region a most probable structure type and size, the algorithm allows us to self-consistently define and track clusters, filaments, and voids in the simulations. Using these simulations and algorithm, we can determine the environment of a galaxy at each stage of its evolution, enhancing our understanding of the role of environment on the properties of galaxies. We can also trace the enrichment, temperature and density evolution of the baryonic gas.

Author(s): L. A. Phillips[1], Ali Snedden[1]
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253.02 – A Computational Analysis of the Expanding Photosphere Method and the Distances to Type II-P Supernovae

We present the results of research into the Expanding Photosphere Method (EPM) and its use in determining the distance to a supernova and the epoch in which the explosion occurred. This research was part of a six-week summer program pairing faculty with undergraduate students, computationally determining the distance and explosion epoch through the EPM's assumption of blackbody luminosity with empirically-derived correction factors. This method was applied to a sampling of supernovae with data sets covering different post-explosion time periods. We compare our distance and explosion epoch calculations to those determined by other means, demonstrate which types of data sets can be more reliably applied to the EPM, and describe the uncertainties involved. Although it is inconclusive for now as to how effective the EPM is as an indicator of the explosion epoch, this research provides further evidence of its effectiveness as an indicator of distance, provided the data set is large enough and covers earlier post-explosion phases of the supernova.

Author(s): Robert C. Mitchell[1], Brian Didier[1]
Institution(s): *1. St. Ambrose University*

253.03 – Assembly Bias of Dark Matter Halos in LasDamas

Assembly bias of dark matter halos refers to the phenomenon in which the clustering of dark matter halos of a fixed mass depends significantly on a second property, in particular: age, concentration or spin. This discovery suggests a challenge for halo occupation distribution and other models that connect galaxy properties solely to halo mass. To investigate assembly bias we use the Large Suite of Dark Matter Simulations (LasDamas) to calculate the large-scale clustering of distinct halos as a function of a variety of properties including mass. We first investigate whether some property other than mass is better able to single-handedly predict clustering, i.e., eliminate the need for a second parameter, but we find no such property. Noting that for many halos the current mass is significantly lower than the peak mass it attained over its history, we revisit assembly bias using only halos that have maintained a significant fraction of their peak mass. We find that the dependence of clustering on a second halo parameter is significantly reduced without the inclusion of these high mass-loss halos. This strongly suggests that part of the theoretical explanation for assembly bias may be that a large fraction of halos do not continually grow in mass, as assumed in spherical collapse models, but instead lose significant amounts of their mass at later times due to interactions with other halos.

Author(s): Andres Nicolas Salcedo[1], Andreas A. Berlind[3], Ariyeh Maller[2], Manodeep Sinha[3]
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253.04 – The Theoretical Basis of Surface Brightness Fluctuations for Precision Cosmology and Stellar Population Studies

For more than two decades, the technique of measuring spatial surface brightness fluctuations (SBF) of galaxies has been used successfully to determine precise and accurate extragalactic distances. While the empirical success of the method is well documented, we present a more formal theoretical approach to the technique and measurement methods and examine the assumptions underlying SBF measurements. The goals of this presentation are to make the assumptions as quantitatively clear as possible and to facilitate future adaptations of the technique. The current theoretical presentation is intended as a theoretical tie of an underlying stellar population to actual measurements of the surface brightness fluctuations of the observed stellar population.

Depending on a galaxy's distance, typical SBF measurements require moderately long integration times and subarcsecond seeing. Consequently, while much SBF work has been done successfully from the ground, the *Hubble Space Telescope* has in recent years been the primary facility for high quality SBF distance measurements out to the Coma cluster and beyond. Future SBF measurements are likely to be conducted on specialized instruments from the ground such as the Gemini Multi-Conjugate Adaptive Optics System (GeMs), currently available in the Southern Hemisphere, and at future observatories like JWST, TMT, GMT, and E-ELT. This work is intended to solidify the future use of the SBF technique in determining individual galaxy distances, in measuring H^0 to high precision, and in probing stellar populations.

Author(s): Edward A. Ajhar[2], John Blakeslee[1], Joseph B. Jensen[3]
Institution(s): *1. NRC Herzberg Institute of Astrophysics, 2. St. Thomas University, 3. Utah Valley University*

253.05 – The Surface Brightness Fluctuation Distance to the Coma Cluster

The Coma cluster, as one of the closest very rich clusters of galaxies, is commonly used as a reference point in the cosmic distance ladder. We measured the surface brightness fluctuation (SBF) distance to NGC 4874, the cD galaxy in the Coma cluster, using the F160W (H-band) filter in the WFC3/IR camera on the Hubble Space Telescope. To compute the distance to NGC 4874, we relied on a calibration of the F160W SBF distance scale derived from WFC3/IR measurements of 12 galaxies in the Virgo and Fornax clusters. We present this new IR SBF calibration, which is based on optical SBF distances calibrated using Cepheid variable stars. The Cepheid/SBF calibration gives a distance of 96 +/- 5 Mpc to the Coma cluster. We also measured SBF in the disk of NGC 4258. The discovery of water masers in NGC 4258 provided a precise and accurate geometrical distance measurement, making it a popular first rung on the extragalactic distance ladder. While the SBF measurement for this galaxy is not very reliable due to the presence of young stars and dust lanes, it is useful to better understand stellar population variations and their effects on SBF measurements.

Author(s): Joseph B. Jensen[3], John Blakeslee[1], Hyejeon Cho[4], Hyun-chul Lee[2], Crystal-Lynn Bartier[3], Zachary Gibson[3]
Institution(s): *1. NRC - Herzberg, 2. University of Texas Pan-American, 3. Utah Valley University, 4. Yonsei University*

253.06 – Interstellar Silicate Dust Grain Properties in Distant Galaxies Probed by Quasar Absorption Systems

Dust grains are a fundamental component of the interstellar medium, and significantly impact many of the physical processes driving galaxy evolution, including star formation, and the heating, cooling and ionization of interstellar material. Using the absorption features produced by dust in the spectra of luminous background quasars, it is possible to study the properties of extragalactic interstellar dust grains. We will present results from an ongoing program utilizing existing Spitzer Space Telescope infrared quasar spectra to probe silicate dust grain properties in $z<1.4$ quasar absorption systems. In combination with complementary ground-based data on associated gas-phase metal absorption lines, we explore connections between the interstellar dust and gas in the quasar absorption systems. Our project yields clear detections of the 10 micron silicate dust absorption feature in the studied systems, as well as detections of the 18 micron silicate dust absorption feature in sources with adequate spectral coverage. Based on measured variations in the breath, peak wavelength, and substructure of the 10 micron absorption features, there appear to be differences in the silicate dust grain properties from system-to-system. We also show indications of trends between the gas-phase metal properties, such as metallicity and gas velocity spread, with the silicate dust grain absorption properties. Support for this work is provided by NASA through an award issued by JPL/Caltech and through NASA grant NNX14AG74G, and from National Science Foundation grants AST-0908890 and AST-1108830 to the University of South Carolina.

Author(s): Monique C. Aller[1], Varsha P. Kulkarni[4], Donald G. York[3], Daniel E. Welty[3], Giovanni Vladilo[2], Debopam Som[4]
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253.07 – Characterizing the non-equilibrium ionization state of the intergalactic medium

One of the most common ions used to track metals in the intergalactic medium (IGM) is OVI. Ion species in the IGM are typically assumed to be in ionization equilibrium, but owing to the low density of the plasma they may be significantly out of equilibrium. Divergences from equilibrium would make estimates of the amount and evolution of metals in the IGM incorrect. Using a new software package for building and solving complex chemical networks coupled to cosmological hydrodynamic + N-body simulations, we investigate the non-equilibrium properties of the IGM. In particular, we explore how significantly the ionization structure of the IGM diverges from the equilibrium state as a function of time and physical environment. Motivated by the abundant observational data that probes the intergalactic medium via OVI absorption lines in quasar spectra, we track all ionization states of atomic oxygen alongside those of hydrogen and helium. We use the results of these non-equilibrium simulations to characterize the mass content and ionization properties of the IGM and help interpret current observations made by the Cosmic Origins Spectrograph.

Author(s): Devin W. Silvia[1], Brian W. O'Shea[1], Britton D. Smith[5], J. Michael Shull[4], Matthew Turk[2], Daniel Reynolds[3]
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253.08 – Realistic Multi-ion Absorption Spectra from Simulations of the Intergalactic Medium

Observational efforts to form a complete baryon census below a redshift of z ~ 3 have proven to be a difficult undertaking. Simulations suggest that much of this baryonic matter may exist between galaxies at low to moderate densities and temperatures of 10^5 to 10^7 K, which is best detected by absorption features in the spectra of distant quasars. Due to the challenges of detecting the warm-hot intergalactic medium (WHIM), single ion studies are insufficient in tracing the properties of the WHIM and multi-ion studies are becoming increasingly important. Using cosmological simulations of the IGM, we investigate the ionization structure using multiple ions, including commonly observed species such as OVI, CIV, and NeVIII. To examine the simulation in a manner similar to observations of the IGM, we created a pipeline for producing synthetic absorption spectra from simulated light rays that mimic spectra acquired by observations. Specifically, we add observational noise and convolve the synthetic spectrum with the line spread function of the Cosmic Origins Spectrograph. We then fit the realistic spectra using an automatic process, to determine the properties of the IGM that the light ray intersects. Using the fitted spectra and the inferred physical properties, we help interpret on-going observational studies of the intergalactic medium and aid in forming a complete baryon census.

Author(s): Jacob Kneibel[1], Devin Silvia[1], Brian W. O'Shea[1]
Institution(s): *1. Michigan State University*

253.09 – The Effect of Galaxy Environment on Lyα Absorption

We present results from a large study of Lyα absorbers as a function of galaxy environment in the nearby universe (cz <= 10,000 km/s) using archival QSO spectra from the Cosmic Origins Spectrograph (COS) on HST. Of the over 250 usable QSO sightlines, we select 40 high-priority sightlines based on their proximity to large galaxies. We show how the ~150 Lyα systems found along these 40 sightlines depend on nearby galaxy inclination, azimuthal angle, diameter, impact parameter and type. Finally, we present and discuss a newly discovered dichotomy between red and blue-shifted Lyα absorbers in equivalent width-inclination space.

Author(s): David M French[1], Bart P. Wakker[1]
Institution(s): *1. University of Wisconsin - Madison*

253.10 – More Constraints on the Physical Conditions of the Kinematically Complex, Multiphase Absorption Line System at z=0.93 toward PG1206+459

We present the results of photo- and collisional ionization modeling of the strong MgII absorption system at redshift z~0.93 towards the quasar PG1206+459. This system has been extensively studied over the last two decades (Churchill & Charlton 1999; Ding et al. 2003; Tripp et al. 2011) using a combination of spectra from Keck/HIRES, HST/FOS, HST/STIS, and HST/COS. Here we present new
constraints using the most complete spectral coverage including more recent observations of OVI and the Lyman series from HST/COS. Numerous absorption components are seen over a large velocity spread (~1500km/s), and multiple ionization phases are required to account for the detected transitions, which include MgI, MgII, FeII, SiII, SiIII, SiIV, CII, CIII, CIV, SIII, SIV, SV, SVI, NIII, NIV, NV, OIII, OIV, OV, OVI, and NeVIII. Considering the new constraints, we revisit the question of the physical nature of the structures that produce this absorber.

Author(s): Ben Rosenwasser[1], Sowgat Muzahid[1], Jackson Norris[1], Jane C. Charlton[1]
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253.11 – Resolving the Distribution of IGM Metals with Quasar Pair Spectroscopy

Though the minimum intergalactic medium (IGM) metallicity is only approximately 3x10^-3 Z_solar, the presence and abundance of these metals have important cosmological implications. Metals in the IGM are thought to affect radiative cooling rates and thus the formation of massive galaxies as well as the chemical evolution of our Milky Way galaxy via enriched inflows. The progenitors of this metal enrichment probably impacted the velocity structure of the IGM and could have stripped the baryons from galaxies with M <= 10^10 M_sun.
Despite their importance, the abundances, distribution, and progenitors of the IGM metals are still not well understood today. The two principal mechanisms proposed for the enrichment of the IGM are galactic outflows and population III stars. However distinguishing between these two possible scenarios has proven tricky due to the difficulty in directly observing either phenomenon. Fortunately, the observed large-scale clustering of metal absorbers should depend on the masses of these progenitors while their energetics could be constrained by the small-scale clustering of metal absorbers.
In this work, we present analysis of the clustering of commonly detected ions in a large sample of high resolution quasar absorption spectra pairs. We determine the clustering amplitude as a function of metal line strength in both the line-of-sight and transverse direction, allowing us to disentangle the clustering signal due to relative motions within a galaxy and that of clustering between galaxies.

Author(s): Jason X. Prochaska[1], Camille N Leibler[1]
Institution(s): *1. UC, Santa Cruz*

253.12 – Detection of Extend Wind Emission out to 10 kpc from starforming galaxies at z~1

Galactic winds are observed to be ubiquitous at intermediate redshifts, but their physical extent is yet unknown. In this work, we used a large sample galaxies (~1500) from the DEEP3 redshift survey to study the average physical size of the winds at z~0.7-1.5 using the near UV Mg II emission line. By constructing a high signal-to-noise co-added spatial line profile, we were able to detect excess Mg II emission from winds out to 10 kpc in radius. We explore the dependence of wind emission with host galaxy properties such as mass and inclination.

Author(s): Hassen Yesuf[1], Sandra M. Faber[1], David C. Koo[1], Aaron Huang[1], Pranav Sekhar[1]
Institution(s): *1. University of California Santa Cruz*
Contributing team(s): DEEP3 Redshift Survey

253.13 – The Ionization Source and Distance to the Magellanic Stream

We present multiline observations of the ionized gas along the Magellanic Stream towards 39 sight lines. Using the Wisconsin Hα Mapper telescope, we detect Hα emission brighter than 30–50 mR in 29/39 sight lines. This Hα emission extends more than 2° off the HI emission. We further find that the ionization fraction of the Stream increases as the HI column density deceases. Based on comparisons of the [O I] and Hα emission, regions with HI column densities between $10^{19.5}$ and $10^{20.0}$ cm^{-2} are 15 − 65%. These ionization fractions closely agree with those found in absorption-line studies, implying that there is very little ionization change on the < 1° scale. The sight lines positioned off or on the edge of HI gas of the Stream tend to have higher Hα intensities than those that align with the high HI column density gas. The spectral profiles of these offset sight lines are typically kinematically displaced from the HI emission by as much as 30 km s^{-1}. We conclude that these low H I column density sight lines are less shielded from the surrounding coronal gas and ionizing radiation field and are likely evaporating into the Galactic halo. The Hα detections, from this and previous studies, towards high H I column density sight lines follow the strength of the incident photoionizing radiation field from the Magellanic Clouds (MCs), the Milky Way (MW), and the extragalactic background (EGB). This compatibility places the distance to the Magellanic Stream at 100° from the Magellanic Clouds between 50 – 75 kpc away from the Sun. This agreement suggests that the combined ionized and neutral gas mass of the Stream is ~2 × 10^9 $M^{\odot}$, based on the work of Fox et al. 2014 for this distance. Additionally, this agreement implies that an ionizing photon escape fraction of ~5% for the Galactic disk, ~4% for the Large Magellanic Cloud, and ~6% for the Small Magellanic Clouds. However, if the trailing gas lies further away, then other sources must also contribute to the ionization. The ionizing contribution from these sources will decreases if the Stream is located further away with a ~50% at 100 kpc and ~15% at very large distances (> 200 kpc).

Author(s): Kathleen Barger[3], Gregory J. Madsen[4], Andrew Fox[2], Bart P. Wakker[8], Jonathan Bland-Hawthorn[7], David L. Nidever[5], L. Matthew Haffner[8], Nicolas Lehner[6], Alex S. Hill[1]
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254 – Gamma Ray Burst Posters

254.00 – The GRB All-sky Spectrometer Experiment II: Data Collection and Analysis

The GRB All-sky Spectrometer Experiment (GASE) is a widefield interferometer radio telescope designed to look for Gamma Ray Bursts in the 30 to 50 MHz range. It is based and operated as a wholly undergraduate experiment at the University of Washington. This poster will focus on data analysis and the relation of data analysis to the commissioning process of our 8 element GASE array.

Author(s): Elana Voigt[1], Zachary Martinot[1], Zachary Banks[1], Jonathan Pober[1], Miguel F. Morales[1]
Institution(s): *1. University of Washington*

254.01 – The GRB All-sky Spectrometer Experiment I: Instrument Overview and Science Drivers

The GRB All-sky Spectrometer Experiment (GASE) is an experiment designed to detect low frequency highly dispersed radio emission in the afterglow of a GRB. The detection of such a signal could provide a probe of IGM density as well as the conditions near the source of a GRB. The instrument used is an eight-element array of dipole antennas located on the University of Washington campus. This poster will further elaborate the design of the instrument and its scientific goals.

Author(s): Zachary Martinot[1], Elana Voigt[1], Zachary Banks[1], Jonathan Pober[1], Miguel F. Morales[1]
Institution(s): *1. University of Washington*

254.02 – The GRB All-sky Spectrometer Experiment III: Upgrades and Commissioning

The GRB All-sky Spectrometer Experiment (GASE) is designed to detect low frequency radio emission following a gamma ray burst. GASE currently uses 8 dipole antennas to detect these emissions. This poster will discuss the commissioning and associated troubleshooting of setting up these antennas. This will include the challenges presented by having the instrument located here in Seattle such as water damage, corrosion, and RFI.

Author(s): Zachary Banks[1], Zachary Martinot[1], Elana Voigt[1], Jonathan Pober[1], Miguel F. Morales[1]
Institution(s): *1. University of Washington*

254.03 – A New Astrometric Technique Applied to the Likely Tidal Disruption Event, Swift J166+57

We have developed a new technique to align Hubble Space Telescope (HST) data using background galaxies as astrometric markers. This technique involves the cross correlation of cutouts of regions about individual galaxies from different epochs, enabling the determination of an astrometric solution. The method avoids errors introduced by proper motion when the locations of stars are used to transform the images. We have used this approach to investigate the nature of the unusual gamma-ray source Sw J1644+57, which was initially classified as a long gamma ray burst (LGRB). However, due to the object's atypical behavior in the X-ray and optical, along with its location within the host (150 ± 150 pc, see Levan et al. 2011) it has been suggested that the transient may be caused by a tidal disruption event (TDE). Additional theories have also been suggested for its origin which remain based on the collapsar model for a long burst, such as the collapse of a red giant, rather than a stripped star as is typical in LGRBs, or the creation of a magnetar.

Precise astrometry of the transient with respect to the galaxy can potentially distinguish between these scenarios. Here we show that our method of alignment dramatically reduces the astrometric error of the position of the transient with respect to the nucleus of the host. We therefore discuss the implication of our result on the astrophysical nature of the object.

Author(s): Rebekah Alianora Hounsell[1], Andrew S. Fruchter[1], Andrew J Levan[2]
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254.04 – Searching for Progenitor Clues in the Local Environments of Long GRB Hosts

This study explores the sub-galactic environments in the host galaxies of Long Gamma-Ray Bursts (GRBs) to shed light on their progenitor population. Pre-*Swift* studies indicate GRB positions to be correlated with star formation, consistent with the standard picture of long GRBs originating from massive star explosions. We set out to test this using data accumulated over the last decade for *Swift* bursts. Using late-time *HST* imaging of a sample of 100 long GRB events and relative astrometry from ground-based afterglow detections we measure the projected offsets of long GRBs from their host centers. As the host centers are often not well-defined for the typically disturbed and irregular morphologies of long GRB hosts, we also employ a morphology-independent technique of assessing the relative brightness of the GRB site compared to the total host light distribution. As this study is currently in progress, preliminary results will be presented. This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. DGE1144152.

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254.05 – A Comprehensive Analysis of GRB Afterglows with Deep Chandra Follow-up: Implications for Off-Axis Jets

We present a sample of 27 GRBs with detailed Swift light curves supplemented by late time Chandra observations. By fitting to empirical mathematical functions, we find a higher fraction of jet-break candidates (56%) than previous studies using Swift-only samples and different analysis techniques (12%). To answer the missing jet-break problem in general, we further develop a numerical simulation-based model which can be directly fit to the data using Monte Carlo methods. Our numerical model takes into account all the factors that can shape a jet break: (i) lateral expansion (ii) edge effects and (iii) off-axis effects. Comparing to the empirical function fit, our results provide improved fits to the light curves and better constraints on physical parameters. More importantly, our results suggest that off-axis effects are important and must be included in interpretations of GRB jet breaks.

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Contributing team(s): et al.

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255 – Cosmology, CMB, and Dark Matter Posters

255.01 – The Effects of Massive Neutrino Self-Interactions on the Cosmic Microwave Background and Large Scale Structure

Exploring potential effects of the neutrino's mass can reveal new and exciting knowledge about the universe. The standard interpretation is that neutrinos decoupled from the primordial plasma at T~1.5 MeV and then began free-streaming. However, it has been shown that by incorporating massless neutrino self-interactions into cosmological models, the decoupling temperature can be driven as low as 25 eV. In this scenario, neutrinos decouple from the baryon plasma while still self-interacting and they later decouple from themselves. Delaying the onset of free-streaming has significant effects on the CMB and matter power spectra. For this reason, we further the investigation of new neutrino physics by studying the effects of massive neutrino self-interactions on the CMB and LSS. We present the results of incorporating the mass corrected collision term into the Boltzmann hierarchies programmed in CAMB. We find that neutrino self-interactions and the neutrino mass have an additive damping effect at small scales (< 1 Mpc/h) in the matter power spectrum, and we pursue the degeneracy among these parameters. We use an updated version of the Markov Chain Monte Carlo code CosmoMC that incorporates nested sampling to determine the likelihood of our cosmological parameters.

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255.02 – Extinction and the rate of superstring microlensing detection for WFIRST survey of the Bulge

A network of superstrings produced during the epoch of inflation gives birth to long-lived string loops if, as current observational constraints imply, the string tension $G\mu/c^2 < 10^{-9}$. String loops track dark matter when galaxy formation occurs. As part of an ongoing Cornell project we investigate the detection rate of string loop microlensing of stars within the Galaxy and make detailed estimates for the WFIRST survey of the Bulge. In particular, here we compare the rate estimates for different models of J-band extinction. Most of the stars microlensed by strings reside near the Galactic center and the range of variation in extinction models induces a factor of 5 in the overall rate. While this rate-sensitivity is non-trivial we conclude that the overall microlensing rate is sufficiently large that detecting strings over a tension range 10^{-14} to 10^{-10} is feasible. For a well-defined model of the string loop population, stellar blending and our effective magnitude cutoff in the WFIRST survey currently dominate our rate uncertainties. For example, detection rates at $S/N=10^2$ (cutoff of 23) are about an order of magnitude less than rates at marginal S/N (cutoff of 27). Future work will explore the effective cutoff and the resultant rates.

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255.03 – Instrumental Simulations of the 21cm Epoch of Reionization Signal

The Epoch of Reionization (EoR) represents an unexplored phase in early cosmic history when the light from the first galaxies and stars ionized the majority of the hydrogen in the universe. A powerful way of probing EoR fluctuations is by mapping the red-shifted 21cm hyperfine transition of neutral hydrogen, and current telescope arrays such as the Donald C. Backer Precision Array for Probing the Epoch of Reionization (PAPER), Murchison Widefield Array (MWA), and their recently funded successor, the Hydrogen Epoch of Reionization Arrays (HERA) aim to do this. Because the detection of EoR requires the difficult isolation of a signal $\sim 10^5$ times fainter than galactic foregrounds, as well as unprecedented levels of sensitivity, it is important to develop realistic end-to-end simulations that accurately capture instrumental effects. Here we present simulation efforts within the HERA collaboration, demonstrating capabilities that will be necessary for a confirmed detection of the cosmological 21cm signal.

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Contributing team(s): HERA Collaboration

255.04 – Simulations of Galaxy-Galaxy Lensing by SDSS Galaxies

Weak gravitational lensing is a powerful probe of the amount and distribution of dark matter in the universe. Here we present results of simulations of galaxy-galaxy lensing using large, contiguous regions of the Sloan Digital Sky Survey (SDSS). We compute the expected galaxy-galaxy lensing signal due to the SDSS galaxies ($z^{med} \sim 0.1$) on a plane of source galaxies with fixed redshift ($z^{source} = 0.4$), and we explicitly compute the net weak lensing shear for each source due to all foreground galaxies. This is important because previous work has shown that in typical galaxy-galaxy lensing data sets, background sources have been lensed at a comparable level by two or more foreground galaxies and, for a given source, the lens with the smallest impact parameter is frequently not the dominate lens. We model the dark matter halos of the lens galaxies by Navarro, Frenk & White profiles, where the virial masses and concentration parameters are obtained from known scaling relations of the galaxy luminosity and rest frame color. The coordinates and redshifts (spectroscopic where available, photometric otherwise) of the lens galaxies are assigned using the SDSS values. We compute the mean tangential shear, $\gamma^T(\theta)$, using the final, lensed shapes of the source galaxies and we explore the degree to which $\Delta\Sigma(\theta) = \Sigma^c \gamma^T(\theta)$, where $\Delta\Sigma(\theta)$ is the mean excess surface mass density and Σ^c is the mean critical surface mass density. We find that when Σ^c is simply computed as a mean over all lenses, the excess surface mass density inferred from the mean tangential shear tends to underestimate the actual excess surface mass density.

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255.05 – Creating an Analysis Pipeline to Discover the Epoch of Reionization

Radio interferometry data from the Murchison Widefield Array will generate over two petabytes in the coming months, requiring an elegant and robust processing pipeline in order to discover the Epoch of Reionization. University of Washington leads the development and analysis of the constant inflow of data, employing techniques which are unique to the radio community. Reducing foregrounds 4-5 orders of magnitude brighter than the signal, calibrating without luminous sources in the field, and separating the smooth galactic signal from the hydrogen data are all key features of the analysis. Thus far, preliminary results using power spectra demonstrate a proof of concept. With ever-deeper observations, we can continue to improve our understanding of both our instrument and astrophysical foregrounds, enabling a detection of the signal from the Epoch of Reionization.

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255.06 – Comparison of Intrinsic Alignment of Galaxies in MassiveBlack-II Hydroynamic and N-body Simulations

The intrinsic alignment of galaxies with the large-scale density field is an important astrophysical systematic in upcoming weak lensing surveys whilst offering insights into galaxy formation and evolution. We compare the intrinsic alignments of galaxies in the cosmological hydrodynamic MassiveBlack-II (MBII) simulation that includes stellar matter and AGN feedback, in a volume of $(100h^{-1}\mathrm{Mpc})^3$ with that of a dark matter only *N*-body simulation (DMO) performed with the same volume, resolution, cosmological parameters, and initial conditions. For subhalos matched in the two simulations, we find that the axis ratios of the dark matter subhalos of MBII, obtained using the reduced inertia tensor are larger, meaning that subhalos in MB-II are rounder than in the DMO simulation. The shapes of stellar matter in subhalos of MBII are more misaligned with the shapes of dark matter in the corresponding subhalos of the DMO simulation when compared to the misalignment with dark matter shapes of MBII. The fractional change in the mean misalignment angle is larger in galaxies of low mass and it varies from ~ 37% - 13% as we go from low to high mass galaxies. Similarly, the projected intrinsic alignment density-shape correlation function, $w^{\delta+}$ for the shapes of galaxies in the MBII simulation is smaller in comparison to the $w^{\delta+}$ obtained using shapes of dark matter subhalos in DMO with larger decrease at low mass thresholds. These results are necessary if we wish to map the intrinsic alignments from hydrodynamic simulations onto large mock catalogs based on *N*-body simulations that will be used by upcoming surveys to interpret weak lensing measurements.

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255.07 – Testing MONDian Dark Matter with Galactic Rotation Curves

MONDian dark matter (MDM) is a new form of dark matter quantum that naturally accounts for Milgrom's scaling, usually associated with modified Newtonian dynamics (MOND), and theoretically behaves like cold dark matter (CDM) at cluster and cosmic scales. In this paper, we provide the first observational test of MDM by fitting rotation curves to a sample of 30 local spiral galaxies (z=0.003). For comparison, we also fit the galactic rotation curves using MOND and CDM. We find that all three models fit the data well. The rotation curves predicted by MDM and MOND are virtually indistinguishable over the range of observed radii (1 to 30 kpc). The best-fit MDM and CDM density profiles are compared. We also compare with MDM the dark matter density profiles arising from MOND if Milgrom's formula is interpreted as Newtonian gravity with an extra source term instead of as a modification of inertia. We find that discrepancies between MDM and MOND will occur near the center of a typical spiral galaxy. In these regions, instead of continuing to rise sharply, the MDM mass density turns over and drops as we approach the center of the galaxy. Our results show that MDM, which restricts the nature of the dark matter quantum by accounting for Milgrom's scaling, accurately reproduces observed rotation curves.

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255.08 – Prospects for Detecting a Cosmic Bulk Flow

The ΛCDM model is based upon a homogeneous, isotropic space-time leading to uniform expansion with random peculiar velocities caused by local gravitation perturbations. The Cosmic Microwave Background (CMB) radiation evidences a significant dipole moment in the frame of the Local Group. This motion is usually explained with the Local Group's motion relative to the background Hubble expansion. An alternative explanation, however, is that the dipole moment is the result of horizon-scale curvature remaining from the birth of space-time, possibly a result of quantum entanglement with another universe. This would appear as a single velocity (a bulk flow) added to all points in space.

These two explanations differ observationally on cosmic distance scales (z > 0.1). There have been many differing attempts to detect a bulk flow, many with no detectable bulk flow but some with a bulk flow velocity as large as 1000 km/s. Here we report on a technique based upon minimizing the scatter around the expected cosine distribution of the Hubble redshift residuals with respect to angular distance on the sky. That is, the algorithm searches for a directional dependence of Hubble residuals. We find results consistent with most other bulk flow detections at z < 0.05, i.e. a bulk flow velocity of ~300 km/s pointed at (l, b) = (280, 29) in galactic coordinates. Simulations were run to analyze whether a bulk flow can be detected at higher redshifts, z < 0.3. For detecting a bulk flow velocity of <1,000 km/s at such distances one would need distance modulus errors from Type Ia Supernovae to be ~0.01, whereas the current error (~0.2.) is more than an order of magnitude too large for the detection of bulk flow beyond z~0.05.

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255.09 – Propelling Reionization with the Faintest Galaxies

Starlight from galaxies plays a pivotal role throughout the process of cosmic reionization. We present the statistics of dwarf galaxy properties at z > 7 in halos with masses up to 10^9 solar masses, using a cosmological radiation hydrodynamics simulation that follows their buildup starting with their Population III progenitors. We find that metal-enriched star formation is not restricted to atomic cooling (T^{vir} > 10^4 K) halos, but can occur in halos down to masses ~10^6 solar masses, especially in neutral regions. Even though these smallest galaxies only host up to 10^4 solar masses of stars, they provide nearly 30 percent of the ionizing photon budget. We find that the galaxy luminosity function flattens above M^{UV} ~ -12 with a number density that is unchanged at z < 10. The fraction of ionizing radiation escaping into the intergalactic medium is inversely dependent on halo mass, decreasing from 50 to 5 percent in the mass range $10^{7.5}$ to $10^{8.5}$ solar masses. Using our galaxy statistics in a semi-analytic reionization model, we find a Thomson scattering optical depth consistent with the latest Planck results, while still being consistent with the UV emissivity constraints provided by Lyman-alpha forest observations at z = 4-6.

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255.10 – The Hubble Expansion is Isotropic in the Epoch of Dark Energy

The isotropy of the universal Hubble expansion is a fundamental tenet of physical cosmology, but it has not been precisely tested during the current epoch, when dark energy is dominant. Anisotropic expansion will produce a shearing velocity field, causing objects to stream toward directions of faster expansion and away from directions of slower expansion. This work tests the basic cosmological assumption of isotropic expansion and thus the isotropy of dark energy. The simplest anisotropy will manifest as a quadrupolar curl-free proper motion vector field. We derive this theoretical signature using a tri-axial expanding metric with a flat geometry (Bianchi I model), generalizing and correcting previous work. We then employ the best current data, the Titov & Lambert [1] proper motion catalog of 429 objects, to measure the isotropy of universal expansion. We demonstrate that the Hubble expansion is isotropic to 7% (1 sigma), corresponding to streaming motions of 1 microarcsecond per year, in the best-constrained directions (-19% and +17% in the least-constrained directions) and does not significantly deviate from isotropy in any direction. The Gaia mission, which is expected to obtain proper motions for 500,000 quasars, will likely constrain the anisotropy below 1%, but this is still orders of magnitude larger than the history-integrated anisotropy constraint provided by the cosmic microwave background.

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[1] Titov, O. & Lambert, S. 2013, A&A, 559, A95

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255.11 – Cosmology with the Nearby Supernova Factory

Nearby Type Ia supernovae serve as the critical reference for measurement of the accelerating expansion of the universe and its absolute expansion rate locally. Using the unique spectrophotometric spectral time series of Type Ia supernovae in the nearby smooth Hubble flow assembled by the Nearby Supernova Factory, whose flux calibration is carefully tied to both standard stars and the tertiary stars of high-redshift supernova surveys, and employing corrections for biases affecting current cosmological measurements, we are able to produce new determinations of the dark energy equation of state and the local expansion rate.

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Contributing team(s): Nearby Supernova Factory

255.12 – The Union3 Supernova Ia Compilation

High-redshift supernovae observed with the Hubble Space Telescope (HST) are crucial for constraining any time variation in dark energy. In a forthcoming paper (Rubin+, in prep), we will present a cosmological analysis incorporating existing supernovae with improved calibrations, and new HST-observed supernovae. We combine these data with most of the world's current literature data, and fit using SALT2-4 to create the Union3 Supernova compilation. We present a new analysis framework that allows non-linear light-curve width and color corrections, direct modeling of color dispersion, and a redshift-dependent host-mass correction.

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Contributing team(s): Supernova Cosmology Project

255.13 – Testing Quantum Mechanics and Bell's Inequality with Astronomical Observations

We propose an experiment which would leverage cosmology to test quantum mechanics using astronomical observations. Our experiment would send entangled photons to detectors over 100 kilometers apart, whose settings would be rapidly chosen using real-time telescopic observations of distant, causally disconnected, cosmic sources - such as pairs of quasars or patches of the Cosmic Microwave Background - all while the entangled pair is still in flight. This would, for the first time, close close the so-called "setting independence" or "free will" loophole in experimental tests of Bell's inequality, whereby an alternative theory could mimic the quantum predictions if the experimental settings choices shared even a small correlation with some local "hidden variables" due to unknown causal influences a mere few milliseconds prior to the experiment. Our "Cosmic Bell" experiment would push any such hidden variable conspiracy all the way back to the hot big bang, since the end of any period of inflation, 13.8 Gyr ago, an improvement of 20 orders of magnitude. We demonstrate the real world feasibility of our experimental setup. While causally disjoint patches of the cosmic microwave background radiation at redshift $z \sim 1090$ could be used to set the detectors, $z > 3.65$ quasars observed at optical wavelengths are arguably the optimal candidate source pairs using present technology. Our proposal is supported by some of the world's leading quantum experimentalists, who have begun to collaborate with us to conduct the experiment in the next 2-3 years using some of the instrumentation they have already built and used at two astronomical observatories in the Canary Islands. Such an experiment has implications for our understanding of nature at the deepest level. By testing quantum mechanics in a regime never before explored, we would at the very least extend our confidence in quantum theory, while at the same time severely constraining large classes of alternative theories. If the experiment were to uncover discrepancies from the quantum predictions, there could be crucial implications for early-universe cosmology, the security of quantum encryption, and even new theoretical physics, including quantum gravity.

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255.14 – Variability Search in GALFACTS

The Galactic ALFA Continuum Transit Survey (GALFACTS) is an all-Arecibo-sky survey using the seven-beam Arecibo L-band Feed Array (ALFA). The Survey is centered at 1.375 GHz with 300-MHz bandwidth, and measures all four Stokes parameters. We are looking for compact sources that vary in intensity or polarization on timescales of about a month via intra-survey comparisons and long term variations through comparisons with the NRAO VLA Sky Survey. Data processing includes locating and rejecting radio frequency interference, recognizing sources, two-dimensional Gaussian fitting to multiple cuts through the same source, and gain corrections. Our Python code is being used on the calibrations sources observed in conjunction with the survey measurements to determine the calibration parameters that will then

be applied to data for the main field.

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255.15 – The HST Frontier Fields: Current Status and Complete Science Data Products Release for the First Two Clusters

We present the current status and data release from the Hubble Space Telescope Frontier Fields program, a large Director's Discretionary program to carry out ultra-deep observations of up to six lensing galaxy clusters and parallel deep blank fields, aimed at probing the most distant galaxies currently observable. Observations of the first two clusters in this program, Abell 2744 and MACS J0416.1-2403, are now complete, each having been observed to 140 orbits on the main cluster and its parallel field, using ACS (F435W, F606W, F814W) and WFC3/IR (F105W, F125W, F140W, F160W). Current progress of observations on the third and fourth clusters are also described. We present the design of the science data pipeline for the processing and calibration, including a new approach to ACS self-calibration, as well as improvements to WFC3/IR processing to mitigate time-variable background sky and persistence. We describe the high-level science products that we are distributing through the Mikulski Archive for Space Telescopes (MAST) at STScI, including full-depth distortion-corrected mosaics in all the filters, as well as associated products. We deliver these high-level science products to the community on a rapid timescale to enable the widest, most timely scientific use of these data, as well as ensuring a public legacy dataset of the highest possible quality that is of lasting value to the entire community.

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255.16 – Hubble Space Telescope Wide Field Camera 3 Observations of Escaping Lyman Continuum Radiation from Galaxies and AGN at Redshifts z~2.3–6.

We present an assessment of how much of Lyman Continuum (LyC) radiation may be escaping from galaxies with measured spectroscopic redshifts at z~2.29–5.98. For this, we analyzed the Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3) and Advanced Camera for Surveys (ACS) mosaics of the Early Release Science (ERS) field in four filters where LyC can be observed.

With our best current assessment of the WFC3 systematics, we find that the LyC emission of faint galaxies at $<z>\sim2.37$, 2.65, 3.45, and 5.23 is detected at the $1.7\geq\sigma\geq4.2$ level in typical image stacks of 6–18 objects in the WFC3/UVIS filters F225W, F275W, F336W, and ACS/WFC F435W filter respectively. The LyC flux of weak AGN are detected at similar levels at z~2.29–3.47, but with fewer objects in F225W and F275W.

The measured signal corresponds to total LyC fluxes of $m^{AB}\sim27.4$–30.2 mag. With SED-fitting of the UV-continuum longwards of Lyα, the observed flux corresponds to an average LyC escape fraction of order $f^{esc}\sim6$–16% in these redshift bins, respectively. Our results suggest that faint galaxies collectively, and to some extent weak AGN, may have measurably contributed to maintaining cosmic reionization at redshifts z~2.29–5.98, although their average LyC escape fractions are relatively low in this epoch. Complete reionization at $z\leq6$–7 may additionally require the steep faint-end of the luminosity function of galaxies at higher redshifts, integration to very faint luminosities ($M^{AB}\sim$-14 to -10 mag), and possibly f^{esc} increasing at those fainter luminosities and lower metallicities at higher redshifts than sampled here.

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255.17 – See-Change: an HST program to probe Dark Energy time variation

Using the Hubble Space Telescope, the Supernova Cosmology Project is performing a type Ia supernova search in the highest-redshift, most massive clusters known to date. This program was awarded 174 orbits spanning HST cycles 22-23. It will improve the constraint by a factor of 3 on the Dark Energy equation of state above z ~ 1, allowing an unprecedented probe of Dark Energy time variation. When combined with the improved cluster mass calibration provided by the deep WFC3-IR observations of the clusters, the SNe + clusters observed also will triple the Dark Energy Task Force Figure of Merit. We present the supernova survey strategy and cluster selection criteria, and discuss the first few months of the program.

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255.18 – Optimizing the LSST Dither Pattern for Survey Uniformity

The Large Synoptic Survey Telescope (LSST) will gather detailed data of the southern sky, enabling unprecedented study of Baryonic Acoustic Oscillations, which are an important probe of dark energy. These studies require a survey with highly uniform depth, and we aim to find an observation strategy that optimizes this uniformity. We have shown that in the absence of dithering (large telescope-pointing offsets), the LSST survey will vary significantly in depth. Hence, we implemented various dithering strategies, including random and repulsive random pointing offsets and spiral patterns with the spiral reaching completion in either a few months or the entire ten-year run. We employed three different implementations of dithering strategies: a single offset assigned to all fields observed on each night, offsets assigned to each field independently whenever the field is observed, and offsets assigned to each field only when the field is observed on a new night. Our analysis reveals that large dithers are crucial to guarantee survey uniformity and that assigning dithers to each field independently whenever the field is observed significantly increases this uniformity. These results suggest paths towards an optimal observation strategy that will enable LSST to achieve its science goals. We gratefully acknowledge support from the National Science Foundation REU program at Rutgers, PHY-1263280, and the Department of Energy, DE-SC0011636.

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Contributing team(s): LSST Dark Energy Science Collaboration

255.19 – GeV excess electrons upscattering the CMB: a possible resolution to the "Photon Underproduction Crisis"

Recently a gamma-ray excess has been identified in the inner Milky Way, which may be associated with the final state photon shower following DM annihilation to standard model final states. In this scenario ~ GeV electrons are also produced and, given their long energy loss timescale (~ Gyr), they can diffuse and escape the galaxy before losing too much energy. If such an electron population exists in the IGM, one observable consequence would be inverse Compton scattering on the CMB, which would produce UV photons that can efficiently ionize the IGM. This may be a possible resolution to the "Photon Underproduction Crisis", recently pointed out by Kollmeier et al. (2014). Regardless of the relevance to this crisis, the existence of a ~ GeV electron population in the IGM can put constraints on DM annihilation parameters considering the known X-ray backgrounds.

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255.20 – The Spatial Distribution of Spectroscopically Selected Satellite Galaxies

We use a mock redshift survey of the first Millennium Run simulation to investigate the spatial locations of spectroscopically selected satellite galaxies. The host-satellite systems were selected using typical redshift space proximity criteria and, therefore, the satellite sample includes a large number of "interlopers" (i.e., false satellites). Fifty percent of the satellites are located outside the virial radii of their host galaxies and 34% are located more than 500 kpc from their host galaxy. The host galaxies reside in relatively isolated regions of space and have stellar masses that span the range $10.3 < \log^{10}[M^*/M^S] < 11.5$. The 3D locations of the satellites are well-fitted by a combination of a Navarro, Frenk & White (NFW) density profile and a power law. At fixed stellar mass, the NFW scale parameter, r^s, for the satellites of red hosts exceeds that for the satellites of blue hosts, and in both cases the dependence of r^s on host stellar mass is well-fitted by a power law. For the satellites of red hosts, $r^s \sim (M^*/M^S)^{0.71}$, while for satellites of blue hosts $r^s \sim (M^*/M^S)^{0.48}$. For hosts with large stellar masses ($\log10[M^*/M^S] > 10.8$), the satellites of the red hosts are significantly (4σ) less concentrated than is the halo dark matter, while the satellites of blue hosts are marginally (2σ) more concentrated than is the halo dark matter. We perform model fits to the projected locations of the satellites and find that, with the exception of the satellites of the most massive red hosts, the 2D analysis accurately recovers the values of r^s that were found using the 3D analysis. Therefore, even in the limit of a large population of "interlopers" in the satellite sample, the 3D distribution of the satellites can be recovered using 2D information alone. However, since the concentration of the satellite distribution differs from that of the dark matter in the case of high mass host galaxies, this calls into question whether spectroscopically selected satellites can be used to directly infer the concentration of the dark matter surrounding the host galaxies.

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255.21 – Warped Universe: Analysis of Strong Lens Candidates from Early Dark Energy Survey Data

Over five observing seasons, which started in August 2013, the Dark Energy Survey (DES) will carry out a wide field survey of 5000 square degrees of the Southern Galactic Cap. As much of the wide-field area has not yet been systematically surveyed, we expect to discover many new strongly lensed galaxies and quasars.
DES has identified 24 strong lens candidate objects (galaxy- and galaxy clusters-scale) in data from the Science Verification season and has performed spectroscopic follow-up on a subset of these candidates as part of a Gemini Large and Long program. We present the current state of progress on the photometric and spectroscopic analysis of the lens candidate systems.
One of the main objectives of the strong lensing science program in DES is to derive constraints on dark energy. The two major components of this part of the program will be exploiting (1) lenses with background sources at multiple redshifts and (2) lensed quasars. In addition to cosmology, we will use the cluster-scale lens sample to study dark matter mass profile, along with the large sample of sources at varying redshifts to study of galaxy evolution and substructure.
To obtain precise lens and source positions and to verify the candidate system as a lensing system, we must obtain spectroscopic redshifts. In order to model the lens potential to the required level of precision, we also require high-resolution imaging, both available at the Gemini South facility.
To select lenses with arc-like features we use a combination of automated arc-finders, catalog searches and visual scans. We carry out these searches on the annual DES data release. The first target list of 24 candidates comes from the Science Verification season, which was undertaken during the 2012/2013 observing season and is about 300 square degrees. Using the upgraded GMOS spectrographs at Gemini South, we have begun spectroscopic observations through the Gemini Large and Long program, awarded to PI Liz Buckley-Geer to follow-up DES strong lens candidate systems.

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Institution(s): *1. Fermi National Accelerator Laboratory*

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256 – Dust Posters

256.01 – Star Formation and HI Content of Galaxies Within Groups

We compare the star formation rates with the respective HI properties of 4854 galaxies in 743 different groups. Using data from the SDSS and the GALEX all sky survey (AIS) we measure the star formation rates and NUV-r colors as a function of the total group mass, position within the group, and HI content as derived from the Arecibo Legacy Fast ALFA (ALFALFA) survey. The NUV-r colors are consistent with star forming field galaxies. We show how the quenching of the star formation is correlated with galaxy HI content and how both are affected by a group environment. The Undergraduate ALFALFA team supported this work with NSF grant AST-1211005.

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Contributing team(s): Undergraduate Aerocibo Legacy Fast ALFA Team

256.02 – Kinematics of Filaments in Perseus and Serpens: Testing Filament Formation

The CARMA Large Area Star formation Survey (CLASSy) used the N^2H^+ molecule to trace the kinematics cool, dense filaments in Perseus and Serpens. A number of these filaments showed velocity gradients perpendicular to the long axis of filaments which were interpreted as gravity induced inflow of material from a dense post-shock layer in a turbulent cloud based on simulations (Chen and Ostriker 2014; Mundy et al 2014). These gradients were not as visible in HCN and HCO^+, which were also mapped by CLASSy, due to the higher optical depth in these J=1-0 transitions. In this poster, we present the initial observations of the $H^{13}CO^+$ and HNC transitions toward a number of target filaments from the CLASSy. The goals of the observations are to confirm the kinematics seen in N^2H^+, hence confirming that the observed gradients are not due to a chemical effect in N^2H^+, and to see if these molecular lines can provide additional information about the kinematics of the filaments.

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Contributing team(s): the CLASSy Team

256.03 – Extreme Star Formation in the Center of Our Galaxy

The central region of our Galaxy, referred to as the central molecular zone (CMZ; the inner 500 pc), provides an excellent laboratory for testing star formation theories due to its extreme environment at close proximity. Current observations suggest that the star formation rate in the CMZ is of an order of magnitude lower than predicted by current models. To improve our knowledge of star forming activity in this region, we have used the Sub-Millimeter Array (SMA) to conduct the first ever large scale, high-resolution survey of the CMZ taking advantage of the SMA's unique wide-area mapping capabilities. The resulting data set provides the best ever glimpse into this intriguing region of the Galaxy. A combination of the large scale and sub-pc resolution of the SMA survey have allowed us to use a variety of techniques designed to determine and characterize the rate of star formation in different locations around the CMZ. We have studied the population of gas clouds by mapping the temperature distribution of a number of clouds using the line ratios of formaldehyde emission at ~218 GHz. We have also measured the dense gas fraction and turbulent line width in order to understand how the star formation rate is affected by different environmental conditions. It is expected that the results from this survey will shed light on the nature of star formation in extreme environments and will be used to further constrain star formation laws. Analysis is ongoing and preliminary results are presented

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256.04 – An Investigation of Three Methods for Determining Young Star Spectral Types

We present an investigation of several spectral typing techniques applied to 6 young, low-mass binary systems in the Taurus star-forming region (2 Myr). Spectra of resolution ~2000 were taken in the K band at Keck II using NIRC2 in grism spectroscopy mode where adaptive optics allowed us to resolve subarcsecond separations. We tested three different methods to determine spectral type to compare and contrast the strengths and weaknesses of each method. First, we used fits to standard star spectra to determine spectral types, extinctions, and K-band excesses. This method resulted in anomalously high extinctions not supported in the literature. It was also often difficult to distinguish between best fits. Second, we used the equivalent width ratios of IRTF SpeX standards to determine linear relationships onto which we plotted the equivalent width ratios of our sample stars. This method was complicated by low signal to noise in weak lines and the presence of significant circumstellar material around some of our sample of young stars, which may have inconsistently veiled and skewed our results. Third, we used K-band spectral indices and solar metallicity models to infer effective temperatures for our sample. This promising approach, applicable for the M-type stars in our sample, yields effective temperatures of several hundred degrees Kelvin lower than the other methods. Our main goal in this work is to highlight the uncertainties inherent in the typical procedures used for determining young star spectral types and encourage a concerted effort to define a more accurate and precise approach to the measurement of pre-main sequence effective temperature. Temperature is a fundamental stellar property without which our calibration of young star evolution, and by inference planet formation, is highly uncertain, even in the face of precisely measured stellar masses.

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256.05 – Mass Assembly of Stellar Systems and their Evolution with the SMA (MASSES)

We present the first results from a legacy project of the SMA: Mass Assembly of Stellar Systems and their Evolution with the SMA (MASSES). The MASSES project surveys a complete sample of all 73 known protostars in the Perseus molecular cloud complex, with both dust continuum and molecular line observations in a variety of dense gas and outflow tracers. The goal of the project is to understand how stars gain their mass through core and disk fragmentation, the formation and evolution of protostellar disks, and outflow-regulated mass accretion. The survey is complementary to a VLA protostar survey with dust continuum (Tobin et al, in prep), which shows a high fraction of multiple protostars. With this larger, unbiased sample and better sensitivity, MASSES will build on results from previous protostar surveys to discern evolutionary trends and to provide a better understanding of the stellar mass assembly process.

Author(s): Katherine I Lee[1], Michael Dunham[1], Philip C. Myers[1], Lars Kristensen[1], Alyssa A. Goodman[1], Tyler L. Bourke[4], John J. Tobin[3], Jaime E. Pineda[2], Jes Jorgensen[5], Hector G. Arce[8], Stella Offner[6], Eduard Vorobyov[7]
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256.06 – 6.7 GHz Methanol Masers Associated with Jets in Very Early High Mass Protostars

6.7 GHz (or class II) methanol masers have been detected exclusively toward high mass star forming regions and may be a tracer of an accretion disk around a highly embedded high mass protostar. Several studies have shown a lack of radio continuum associated with methanol maser emission, which could indicate that these masers are related to the earliest stages of high mass star formation. We recently performed a large, high sensitive (~3-10 uJy) Karl G. Jansky Very Large Array (VLA) survey to search for radio continuum emission from a sample of hot molecular cores and infrared dark cloud cores, previously undetected in the radio continuum at 1 mJy sensitivity. The morphology and spectrum of most of our radio detections are consistent with being ionized jets. As models of star formation predict that jets are collimated by accretion disks, we have selected 6 prominent examples of ionized jet candidates to study the behavior of the masers with respect to the jet and to understand the role that both disks and jets play in the process of high mass star formation. Using the VLA, we performed simultaneous observations of the radio continuum and the 6.7 GHz methanol maser, obtaining accurate relative positions between them. From the accuracy of our observations, we found that all the methanol masers detected are associated with the radio continuum from the jet. Furthermore, for some sources the maser spots show a linear distribution with a velocity gradient nearly perpendicular to the ionized jet, a further indication of emission from an accretion disk.

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256.07 – Ammonia and HC^7N Emission in Starless Dense Cores

Dense cores represent the transition between the turbulent, diffuse ISM and protostars. Thus, understanding dense cores' chemical and physical properties provides valuable information about the early stages of low mass star formation. We present an analysis of 13 starless dense cores in the Taurus Molecular Cloud using new data taken with the Green Bank Telescope. Our observations consist of ammonia (NH^3) (1,1) and (2,2) and HC^7N (J=21-20) emission. We present new detections of HC^7N (a carbon chain bearing species) in four cores and confirm detection in two cores. We also present temperature and velocity gradient maps. These results are the foundation of a more complete survey and illustrate an important relationship between ammonia and the carbon chain bearing species HC^7N.

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Contributing team(s): Scott Schnee, Kathryn Devine, John Carpenter, Paola Caselli, Mario Tafalla, Youngmin Seo, Yancy Shirley, James Di Francesco, John Tobin, Shadi Chitsazzadeh, Sarah Sadavoy, Alyssa Goodman, Luca Ricci, and Shigehisa Takakuwa

256.08 – The Star Formation in Radio Survey: Mapping Star Formation in Nearby Galaxies with 33GHz Emission

We present initial results from the 33GHz phase of the Star Formation in Radio Survey (SFRS), including a gallery of 2" resolution Jansky Very Large Array (VLA) images and spatially resolved thermal / synchrotron emission models in a subset of sources. The SFRS is targeting 118 galaxy nuclei and extranuclear star-forming regions in 56 nearby (d < 30Mpc) galaxies included in the Spitzer/SINGS and Herschel/KINGFISH legacy programs. VLA observations of the entire sample have recently been completed at 3GHz (S band), 15GHz (Ku band) and 33GHz (Ka band). For an initial subset of 9 targets, we have also obtained 90GHz ALMA continuum and line imaging during cycle 1 observations.
The frequency spacing of our complete radio data set will allow us to accurately measure the radio spectral index of these targets, in order to model the physical processes that produce the radio emission. In particular, 33GHz observations of HII regions probe free-free emission, providing a sensitive, dust-unbiased measure of the current star formation activity in each complex. We can use the differences between 33GHz derived star formation rates and those derived with other tracers such as synchrotron radiation, extinction corrected UV and Hα emission, and infrared luminosity to examine the dependence of each tracer on separately measured variables such as extinction, metallicity and ionizing radiation field strength. Consequently, these data will help calibrate other empirically-derived star formation rate diagnostics that are more easily measured for high redshift studies, and help interpret rest-frame 33GHz observations from a new generation of deep high frequency (>10GHz) radio surveys.
As an example of the science that can be done with SFRS data, we have used our images along with an archival 1.4GHz and a new 5GHz VLA image to map the spectral index, spectral curvature, and the separated thermal and synchrotron components of NGC1266, a low level AGN with a mass outflow rate of > 50 $M^{\odot}$ / yr. These maps are currently being used to model the age and diffusion history of synchrotron electrons that were presumably accelerated by the AGN.

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256.09 – NGC 1097:Constraining mechanisms for star formation with the VLA

The project goal is to trace the precise location of star forming regions in the barred spiral NGC 1097. Specifically we want to better understand how the star formation progresses in the bar and at the bar ends. Our hydrodynamic gas flow model indicates gas flow should never cross dust lanes yet previous azimuthal cross-correlation analysis have indicated that the Hα emission is offset on the leading side of the bar dust lanes. It is critical to verify the precise locations of the stars forming regions. Is the star formation initiated in the dust lanes, or perhaps in dust spurs on the trailing side of the galaxy? We will measure synchrotron and thermal radiation contributions to quantify recent activity and compare to existing Hα, GALEX, archival VLA, and new ALMA Cycle 0 and Cycle 1 observations. This project will help catalog current and past star formation activity in the bar of NGC 1097 and thus help constrain the mechanisms for star formation.

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256.10 – Velocity Gradients in Star-forming Dense Cores

Initial conditions of a star-forming core, such as its mass, rotation rates and angular momentum, are vital to the study of star formation. The current study sought to reevaluate relationships between the velocity gradients of dense cores and their size. 7 regions: L1448, IC348, B5, L1445 in the Perseus Molecular Cloud and OphB, OphC, OphF in the Ophiuchus Molecular Cloud were studied using ammonia maps obtained by the Green Bank Telescope (GBT). Using a dendrogram technique on the velocity cubes paired with maps of ammonia integrated intensity, we subdivided regions into substructures. By fitting a solid-body-rotation model to each of the sub-regions, we derived sub-regions' velocity gradients. With higher resolution data, the current study showed the existence of previously overlooked substructures and filaments. While looking at velocity gradients of substructures, we found that substructures inside previously well defined dense cores exhibit rotations different from that of the overall core, and that the substructures themselves might be the true dense cores. By comparing the rotation rates of substructures to their size, we also found that velocity gradients of substructures dramatically increase at the size of <0.2 parsecs. The newly discovered radius of 0.2 parsecs matches up with the previously identified radius of coherence and provides new insight to defining the boundaries of star-forming dense cores.

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256.11 – Low-Mass Visual Companions to Young Spectroscopic Binaries

Astronomers' knowledge of higher order multiplicity in young spectroscopic binaries is mostly anecdotal. However, surveys have found that most short-period, main sequence spectroscopic binaries are associated with companions. We present incremental results from our diffraction-limited adaptive optics imaging program to survey all pre-main sequence, spectroscopic binaries for tertiary companions down to delta(mag)=5 at separations >1" and delta(mag)=2 at >0.04”. We will explore the timescale for angular momentum evolution by comparing our results to the results from surveys of main sequence binaries in the literature.

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256.12 – SOFIA multi-wavelength observations of nearby star-forming clusters

We conduct a SOFIA FORCAST survey of bright, nearby star-forming cluster cores. The survey is focussed on cores that saturate Spitzer (24 microns) and WISE (22 microns). The structure of these regions is explored thanks to SOFIA's high angular resolution at 11.1, 19.7, 31.5 and 37.1 microns. We identify protostar candidates that could not be resolved previously with Spitzer or WISE, and estimate their spectral energy distributions. This helps complete the mass function of young stellar objects in these very dense regions of star formation.

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256.13 – An Investigation into PAH Destruction in Nearby Supernova Remnants, North Polar Spur and Cygnus Loop

Our goal in conducting this research was to look at the polycyclic aromatic hydrocarbon (PAH)/large dust grain emission intensity ratio in nearby supernova remnants to find evidence for selective PAH destruction by hot gas and high velocity shock waves within these regions, as predicted by the models of Arendt et al. (2010) and Micelotta et al. (2010a,b). Two supernova remnants were studied- the North Polar Spur (NPS) and the Cygnus Loop. The data for PAHs were obtained from the WISE W3 12 micron all-sky map processed by Meisner & Finkbeiner (2014), and the data for the larger grains come from the IRAS 100 micron all-sky map processed by Schlegel, Finkbeiner & Davis (1998). After obtaining a control PAH/large grain intensity ratio of ~2.8 (DN/px)/(MJy/sr) from two high latitude clouds, MBM 30 and MBM 32, we found that the intensity ratios across the NPS and Cygnus Loop were not far off- ~2.7 (DN/px)/(MJy/sr) and ~3.1 (DN/px)/(MJy/sr), respectively- showing no evidence of selective large-scale PAH destruction in supernova remnants. The individual intensities for both PAHs and large grains do decrease inside the Cygnus Loop, however, suggesting a decrease in abundances of both grain types, which could mean total dust grain destruction with the normal ratios coming from foreground and background dust located in the line of sight of the remnant. In addition, temperature and E(B-V) measurements taken from calibrated IRAS images show that while the dust column density increases in the Eastern Veil of the Cygnus Loop, the dust temperature reaches a local maximum, indicating the heating of large grains by interaction with the hot gas in the remnant. The PAH/large grain ratio in the Eastern Veil does decrease and could be indicative of currently ongoing active grain destruction there, with the PAHs being destroyed on a more rapid timescale than the large grains.

We are grateful for financial support from the NSF REU Program grant to the Department of Physics & Astronomy at the University of Toledo.

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256.14 – A 100-3000 GHz model of thermal dust emission observed by Planck, DIRBE and IRAS

We apply the Finkbeiner et al. (1999) two-component thermal dust emission model to the Planck HFI maps. This parametrization of the far-infrared dust spectrum as the sum of two modified blackbodies serves as an important alternative to the commonly adopted single modified blackbody (MBB) dust emission model. Analyzing the joint Planck/DIRBE dust spectrum, we show that two-component models provide a better fit to the 100-3000 GHz emission than do single-MBB models, though by a lesser margin than found by Finkbeiner et al. (1999) based on FIRAS and DIRBE. We also derive full-sky 6.1' resolution maps of dust optical depth and temperature by fitting the two-component model to Planck 217-857 GHz along with DIRBE/IRAS 100μm data. Because our two-component model matches the dust spectrum near its peak, accounts for the spectrum's flattening at millimeter wavelengths, and specifies dust temperature at 6.1' FWHM, our model provides reliable, high-resolution thermal dust emission foreground predictions from 100 to 3000 GHz. We find that, in diffuse sky regions, our two-component 100-217 GHz predictions are on average accurate to within 2.2%, while extrapolating the Planck Collaboration (2013) single-MBB model systematically underpredicts emission by 18.8% at 100 GHz, 12.6% at 143 GHz and 7.9% at 217 GHz. We calibrate our two-component optical depth to reddening, and compare with reddening estimates based on stellar spectra. We find the dominant systematic problems in our temperature/reddening maps to be zodiacal light on large angular scales and the cosmic infrared background anistropy on small angular scales. We have recently released maps and associated software utilities for obtaining thermal dust emission and reddening predictions using our Planck-based two-component model.

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256.15 – Modeling the Carbon Dust Around Evolved Carbon Stars

We used a 3D Monte Carlo radiative transfer code to model the dust emission around the evolved carbon star, IRAS 07134+1005. We assume the axially symmetric superwind dust shell model as defined by Meixner et al. 1997 (ApJ, 482, 897). IRAS 07134+1005 is a ‘21 mm’ object and is, thus, a carbon-rich, low metallicity star with a large infrared excess. In order to determine the characteristics of the circumstellar carbonaceous dust, we use a set of optical constants for carbonaceous materials computed over a range of H/C and band-gaps. This is the first study to use a set of known hydrocarbon types that covered a range of hydrogen atom fractions and thus a span of aromatic rich (low hydrogen atom fraction) to aliphatic rich (high hydrogen atom fraction) hydrocarbon materials. Our observational data (photometry and spectroscopy from the literature) cover the wavelength range from 0.352-100 mm. We compare our model spectrum and simulated mid-IR images to the observed spectral energy distribution and images to draw conclusions about the nature of the hydrocarbon dust around IRAS 07134+1005.
Support for this work came from National Science Foundation under Award No. AST-1322432, a PAARE Grant for the California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE) and AST-1359346, an REU Site Grant at the SETI Institute, and by the John Templeton Foundation through its New Frontiers in Astronomy and Cosmology, administered by Don York of the University of Chicago.

Author(s): John Derby[1], Jean E. Chiar[5], Matthew S. Povich[1], Michael P. Egan[4], Anthony P. Jones[2], Xander Tielens[3]
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256.16 – A Generalized Method for Measuring R^V in the Milky Way

We present a simple but effective technique for measuring angular variation in R^V across the sky. We divide stars from the Pan-STARRS1 catalog into Healpix pixels and determine the posterior distribution of reddening and R^V for each pixel using a Metropolis-Hastings Monte Carlo. We find some agreement with previous high-precision photometric studies. Since current studies of R^V are limited to isolated clouds, we hope to develop a systematic method for comparing R^V values for the majority of observable dust.

Author(s): Albert Lee[1], Gregory Green[1], Edward Ford Schlafly[2], Aaron M. Meisner[1], Douglas P. Finkbeiner[1]
Institution(s): *1. Harvard University, 2. Max Planck Institute for Astronomy*

256.17 – Uncertainty in the Extinction-to-Reddening Ratio in the Near Infrared Due to Uncertainty in the Assumed Spectral Type of Main-Sequence Background Stars

Extinction due to interstellar dust may be inferred from observed reddening by using a value for the extinction-to-reddening ratio, *R*. Calculating *R* from a reddening ratio requires an assumption about the spectral type of a background star. Previous studies have investigated the uncertainty in *R* due to uncertainty in observed colors. Uncertainty in spectral type, however, introduces a more complicated source of uncertainty in *R*. In this work, we build sets of models where assumed spectral type is incorrect and then calculate resulting values of *R* to assess the uncertainty in *R* using intrinsic colors in the near infrared.
We show that the range of calculated *R* values is non-uniform and asymmetric across spectral type; it depends on reddening and the shape of the intrinsic color curve. We compare this range of *R* values to the real range of *R* caused by actual variations in the optical properties of foreground dust. Setting limits on the uncertainty in *R* allows us to identify the circumstances for which unusual observed values of *R* are likely to be real. Because the value of *R* is so important for inferring extinction from reddening, understanding the sources of uncertainty in *R* will improve the accuracy of photometric studies in astronomy.

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256.18 – 3D Dust Mapping Reveals that Orion Forms Part of a Large Ring of Dust

The Orion Molecular Complex is the nearest site of ongoing high-mass star formation, making it one of the most extensively studied molecular complexes in the Galaxy. We have developed a new technique for mapping the 3D distribution of dust in the Galaxy using Pan-STARRS1 photometry. We isolate the dust at the distance to Orion using this technique, revealing a large (100 pc, 14° diameter), previously unrecognized ring of dust, which we term the "Orion dust ring." The ring includes Orion A and B, and is not coincident with current Hα features. The circular morphology suggests formation as an ancient bubble in the interstellar medium, though we have not been able to conclusively identify the source of the bubble. This hint at the history of Orion may have important consequences for models of high-mass star formation and triggered star formation.

Author(s): Edward Ford Schlafly[2], Gregory Green[1], Douglas P. Finkbeiner[1], Hans-Walter Rix[2]
Institution(s): *1. Harvard, 2. MPIA*

256.19 – Milky Way Dust and Stars in 3D

We present a three-dimensional map of dust reddening, along with a catalog of stellar distances and properties, determined from Pan-STARRS 1 and 2MASS photometry. Our method uses stars as tracers of the dust column; by inferring distances and reddenings to a billion stars, we determine reddening as a function of distance across three quarters of the sky. Our map has a typical angular resolution of ~7', a distance resolution of ~25%, and saturates at about 1.5 mag in E(B-V). Inferred distances to a large number of clouds agree well with literature distances, and the projected two-dimensional reddening agrees well with maps based on far-infrared dust emission (e.g., SFD '98) away from the Galactic plane. We envision many uses for a 3D map of dust and stars, among them: investigating the structure of the Milky Way and its stellar streams, correctly de-reddening photometry for objects embedded in the plane of the Galaxy, distance determinations to objects of known reddening, and studying the structure of star-forming regions.

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257 – Extrasolar Planets: Characterization Posters

257.01 – Constraining the Atmospheric Composition of WASP-18b

WASP-18b is one of the hottest and fastest orbiting hot Jupiter exoplanets discovered so far. The goal of this work is to constrain the composition of its atmosphere by comparing the data to theoretical models; and to advance our knowledge of atmospheric processes such as cloud formation. The data consist of optical transmission spectra via multi-object spectroscopy with wide slits, taken using IMACS on the Magellan telescopes at the Las Campanas Observatory, Chile. We are also searching for titanium oxide in the atmosphere of WASP-18b to study hazes & thermal inversions and what causes them. Our result will contribute to comparative studies of exoplanets over a wide range of radii, masses and temperatures and allow us to refine theories about exoplanet atmospheric chemical, radiative and dynamical processes through modelling. This work will take a step towards probing planets around nearby stars in the next few years and studies of potentially habitable planets. Data reduction was done in a pipeline written by the ACCESS collaboration. ACCESS (Arizona-CfA-Católica Exoplanet Spectroscopy Survey) is a project to create a comprehensive database of optical exoplanet spectra, using ground based facilities. I present the work done so far on WASP-18b.

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257.02 – Fundamental Parameters of the Two Hall-of-Famers HD 189733 and HD 209458

HD 189733 and HD 209458 are two of the most thoroughly studied exoplanet systems. They also represent the only transiting systems for which spectroscopy studies have produced radial velocity signatures of both the planets and the parent stars, yielding direct mass measurements. We present the results of our interferometric radius measurements and spectrophotometric observations of these two hall-of-fame exoplanet hosts. Our results, combined with trigonometric parallaxes and literature broad-band photometry, yield empirical values for stellar and planetary radii and stellar effective temperatures and luminosities. Using the directly determined component masses from previous studies, we calculate surface gravities and bulk densities for the parent stars and their exoplanets, creating a nearly model-independent set of fundamental astrophysical parameters for two of exoplanet science's most important stepping stones.

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257.03 – Empirically determined properties of the K-dwarf HD 189733 and implications for evolutionary models of low-mass stars

We present direct measurements of the stellar radii and effective temperatures for HD189733 and HD209458 (see poster by von Braun et al.). We use the stellar radius and temperature along with the mass from the Keplerian orbital solution to explore deviations with model predictions. The stellar properties for HD209458, a F9 dwarf, are consistent with indirect estimates derived from spectroscopic and evolutionary modeling. However, we find that models are unable to reproduce the observational results for the K2 dwarf, HD 189733. We show that, for stellar evolutionary models to match the observed stellar properties of HD 189733, adjustments lowering the solar-calibrated mixing length parameter need to be employed.

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257.04 – A Pair of Massive Planets Orbiting an Oscillating *Kepler* Red Giant in a Binary System

We present the radial-velocity confirmation of a massive planet transiting an evolved *Kepler* star, as well as the discovery of an outer non-transiting planet and a faint visual stellar companion that may be physically bound. The host star exhibits high S/N asteroseismic oscillations, which enable a measurement of the stellar mass, radius, age, and spin axis inclination. In conjunction with the radial velocities, an N-body simulation and stability analysis help constrain the parameters of the outer planetary orbit. With precisely derived stellar and planetary properties, the system provides a rare opportunity to study giant planet evolution around evolved stars and at long periods. The planets reside inside the ice line (P^b≈52.5 days, P^c≈407 days), which indicates that migration has occurred, and their high eccentricities (e^b≈0.51, e^c≈0.48) hint that they may have been scattered inward. However, the inclination of the stellar spin axis is nearly edge-on, implying a likely alignment between the stellar spin and the orbit of the inner (transiting) planet. We suggest that despite the long period, the star and planet may have experienced tidal interaction leading to realignment of the stellar spin axis.

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Contributing team(s): Kepler Science Team, Kepler Asteroseismic Science Consortium

257.05 – The Properties of Exomoons Around the Habitable Zone Planet, Kepler 22b

As part of a larger study to understand the formation, evolution, and stability of satellites around exoplanets, we have examined the Kepler 22 system. A single planet of mass 2×10^{26} kg, Kepler 22b orbits within the habitable zone (Kopparapu et al. 2013) at 0.85 AU. While Kepler 22b may be habitable, there also exists the possibility that any satellites of the planet may also be life sustaining.

A series of N-body simulations were performed to examine the most probable configuration of moons orbiting Kepler 22b. Initially, a moonlet disk of 100 bodies ($m^{disk} = 4.29 \times 10^{22}$ kg) was randomly placed around Kepler 22b. The moonlet disk spanned 10 – 80% of Kepler 22b's Hill sphere (Kasting et al. 1993). Simulations were run for 500 kyrs, with the star, planet, and moonlets allowed to gravitationally evolve.

The Kepler 22b system was able to retain three to four moons in 96% of the simulations. . The remaining simulations produced systems of two moons on highly eccentric orbits. It is unlikely that the two-moon configuration would remain stable for a significant amount of time. We present the properties of the stable satellites. We have run an additional set of simulations examining the rotational effects satellites will have on Kepler 22b, given the high likelihood that the planet possesses a system of moons. We were specifically investigating if the presence of moons reduces the precession of Kepler 22b, increasing the planet's habitability.

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257.06 – Analysis of Secondary Eclipse Observations of Exoplanet WASP-34b

WASP-34b is a short-period exoplanet with a mass of 0.59 +/- 0.01 Jupiter masses orbiting a sun-like star with a period of 4.3177 days and an eccentricity of 0.038 +/- 0.012 (Smalley, 2010). We observed WASP-34b using the 3.6 and 4.5 micron channels of the Infrared
Array Camera aboard the Spitzer Space Telescope in 2010 (Program 60003). We present eclipse-depth measurements, estimates of infrared brightness temperatures, and refine the orbit using our secondary eclipse measurements.

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257.07 – A Gemini Planet Imager investigation of the atmosphere of the HD 95086b planet

We present Gemini Planet Imager (GPI) near-infrared observations of the ~5 M^{jup} companion to the young, dusty A-type star HD 95086, observed during the course of the verification and commissioning of the instrument. By combining binned low-resolution *H* and *K*-band IFS spectra from GPI, with literature near and mid-IR photometry, we have undertaken the most comprehensive analysis of the spectral energy distribution of HD 95086 b to-date. Comparing these observational results with atmospheric models, we constrain key parameters such as the effective temperature and surface gravity, and place the results in the context of analyses of other directly imaged planetary-mass companions (e.g. HR 8799 bcde, β Pic b), and other substellar companions at a similar age (e.g. HD 106906 b, GQ Lup b). We also comment on the sensitivity of companions interior and exterior to HD 95086 b. Lastly, we present the color-corrections derived during the course of this study that are required to transform photometry obtained with GPI in the *K1* and *K2* filters into both the MKO and 2MASS photometric systems, essential for the propoer interpretation of *K*-band photometry measurements obtained with GPI.

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Contributing team(s): Gemini Planet Imager team

257.08 – Metallicity Analysis of Kepler-65, Kepler-93, Kepler-99, Kepler-102, Kepler-406, and Kepler-409

This study aims to examine the influence stellar metallicity may have on planet formation in various exoplanet systems discovered by NASA's Kepler spacecraft. We have analyzed Keck/HIRES spectra of the planetary hosts Kepler-65, Kepler-93, Kepler-99, Kepler-102, Kepler-406, and Kepler-409 systems and derived the abundances of 17 elements for these stars. Results from previous studies have suggested that stellar abundance patterns or "signatures" may indicate the presence of planets, possibly terrestrial planets in particular, and thus such patterns may be used to identify stars with planets, including potentially Earth-like terrestrial planets. Here we present the results of our abundance analysis of 6 stars with a variety of exoplanet systems discovered by Kepler. Support for this work has been generously provided by grant NNX13AH78G
to S.C.S. from the National Aeronautics and Space Administration.

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257.09 – High-Resolution Abundance Analysis of Stars with Small Planets Discovered by Kepler

We have derived the parameters and abundances of 17 elements of four planetary host stars discovered by Kepler through an analysis of high-resolution Keck/HIRES spectra. All of the stars have planets with masses of 10 $M_\oplus$ or less, and densities have been determined for planets in at least two of the systems. The abundances have been analyzed for possible signatures of planetary formation, including potential abundance trends with condensation temperature of the elements. Here we present the results of our abundance analysis of the four stars with small planets and discuss the possible connection between Tc-dependent abundance patterns and the presence of planets.

Support for this work has been generously provided by grant NNX13AH78G
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257.10 – Exoplanet Transmission Spectroscopy in the Near Infrared with Keck/MOSFIRE

We present transit transmission spectroscopy of hot sub-Jupiter WASP-6 b with MOSFIRE, a near infrared multi-object spectrograph at W. M. Keck Observatory. These K-band spectra offer a window into exoplanet atmospheres at wavelengths sensitive to absorption by methane and carbon monoxide but not water, providing a potentially valuable perspective on exoplanet atmospheric chemistry for planets that produce featureless spectra in the optical due to water clouds. We use MOSFIRE's Configurable Slit Unit in a wide and long configuration with a 15 arcsecond slit to simultaneously collect spectra from a comparison star and the exoplanet host star during a transit. We perform differential spectrophotometry to obtain a spectrum of the atmosphere of WASP-6 b, providing constraints on its chemical composition. In combination with pending observations, we will use transit transmission spectra from MOSFIRE to better inform our understanding of planet formation.

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257.11 – Dayside emission spectrum of Kepler-13Ab from HST and ground-based observations

Secondary eclipse observations of transiting planets are a unique tool to probe the thermal emission of planetary atmospheres. High precision and multi-wavelength measurements are critical for obtaining meaningful constraints on the physical and chemical properties of those atmospheres. Here we present our HST WFC3 observations of the highly inflated hot Jupiter Kepler-13Ab. The planet is among the hottest of all hot Jupiters. Its A-type host star has the highest temperature among all known hot Jupiter hosts, producing extreme irradiation and making the environment of the planet different from other close-in planets. The planet host has a stellar companion of similar brightness and spectral type only 1.2 arcsec away, thereby providing a unique opportunity for cross calibration of the HST data. We combine HST observations in the water bands between 1.1-1.7 microns and existing ground-based and Spitzer observations to better characterize the planet's atmosphere and its physical properties.

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257.12 – KELT-7b: A Hot Jupiter Transiting a Bright V=8.57 F-Star

We report the discovery of KELT-7b, a transiting hot Jupiter with a mass of 1.28 Mj, radius of 1.53 R^{j}, and an orbital period of 2.73 days. The bright host star, V=8.57, is an F star (HD33643) with Teff=6789, [Fe/H]=0.139, and log g=4.149. It has a mass of 1.535 $M^{\odot}$ and a radius of 1.732 $R^{\odot}$. This is the brightest star around which the KELT-North survey has discovered a transiting planet and the ninth brightest star to host a transiting planet. This is also the fifth most massive transiting planet host known and also the fifth hottest host star. This is a great target for detailed characterization, given its relatively low surface gravity, high equilibrium temperature, and bright host star. Due to the rapid rotation of the host star, 73 km/s, we were able to observe the Rossiter-McLaughlin effect to determine that the orbit of the planet is likely aligned with the spin of its host star (λ = 9.7 ± 5.2).

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257.13 – Secondary Eclipse Observations of the Hot-Jupiter WASP-26b

WASP-26b is a hot-Jupiter planet that orbits an early G star every 2.7566 days at a distance of 0.03985 AU. Using the Spitzer Space Telescope in 2010 as a part of the Spitzer Exoplanet Target of Opportunity program (program 60003) we observed two secondary eclipses of the planet, one in the 3.6-micron channel on 7 September and one in the 4.5-micron channel on 3 August. We present eclipse-depth measurements and estimates of infrared brightness temperatures. We also refine its orbit using our own secondary eclipse measurements in combination with external radial-velocity and transit observations from both professional and amateur observers. Spitzer is operated by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA. This work was supported by NASA Planetary Atmospheres grant NNX12AI69G and NASA Astrophysics Data Analysis Program grant NNX13AF38G.

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257.14 – Constructing Mass-radius Relationships of Low Mass Gaseous Exoplanets with MESA

To date, over 3500 exoplanets and planetary candidates have been discovered. This astonishing feat allows us to answer a cornerstone question in astronomy and planetary science: what are these “other worlds” in the solar neighborhood like? Apart from characterization efforts based on observations, a good avenue to explore is to use computer simulations to model the planets' atmospheres and interiors under the influence of stellar irradiation. We present a prescription to extend the stellar evolution code MESA (Modules for Experimental Stellar Astrophysics) to model the thermal evolution of low mass exoplanets having hydrogen-helium envelopes. With the addition of routines treating the planet core luminosity, heavy element enrichment, and mass loss due to hydrodynamic winds, the evolutionary pathways of planets with diverse properties are accurately constrained. Using these dynamic models, we construct mass-radius relationships of planets from 1 to 300 M^{Earth} with varying ages, energy flux received, envelope metallicity and opacity. These relations are benchmarked against previous theoretical studies and the current census of observed planets. In doing so, we demonstrate MESA's ability to incorporate these planetary phenomena in its 1D numerical computations. We anticipate that this versatile, user-friendly code will see widespread applications in complementing future exoplanetary surveys such as *K-2, TESS, and PLATO.*

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257.15 – Clouds in Super-Earth Atmospheres: Chemical Equilibrium Calculations

Recent studies have unequivocally proven the existence of clouds in super-Earth atmospheres (Kreidberg et al., 2014). However, the composition of these clouds remains unknown and is poorly constrained by theory. We provide a theoretical context for the formation of clouds in super-Earth atmospheres by determining which condensates are likely to form, under the assumption of chemical equilibrium. The composition of rocky planets is determined by the accretion of chondritic material. We model super-Earth atmospheres assuming that they are formed by degassing of volatile elements from a solid chondritic core. The atomic abundances of the atmospheres are then specified by the composition of volatiles released during the degassing process. Given the atomic make-up of the atmosphere, we minimize the Gibbs free energy of over 300 gases, condensed liquids, and solids, to obtain the molecular composition of the atmosphere. Clouds should form along the temperature-pressure boundaries where the condensed species appear in our calculation. Our results determine the plausible composition of clouds that could form in degassed super-Earth atmospheres.

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257.16 – The Effects of Modeling Clouds and Hazes in Transit Transmission Spectra of Extra Solar Planets

In the past decade, several planets that transit across their parent star have been discovered. Models of atmospheric radiative transfer in combination with statistical methods, known as atmospheric retrieval, have been used to interpret the observed spectra of these transiting exoplanets. These analyses seek to give information about the chemical composition and temperature structure of these planets. The model assumptions in these analyses, however, can have profound effects on the information about the physical properties of the planet given by the atmospheric retrieval. In this study, we compare this retrieved information using two transmission spectra models describing atmospheric radiative transfer; one of which accounts for clouds and hazes in the atmosphere and the other does not. In the model that accounts for these sources of attenuation, clouds and hazes are treated with three parameters. One of these parameters is the elevation of the cloud top, below which light of all wavelengths passing through the atmosphere from the parent star is blocked. Above this elevation, we assume clouds and hazes cause scattering that we can describe with two parameters relating to the strength of the scattering and the scattering power-law. To compare these two models, we generate synthetic spectra that are representative of currently observed transit spectra in terms of the noise and number of data points. We then use each model in combination with a Bayesian statistical analysis to retrieve the water abundance and temperature of these generated atmospheres. We find that for planets with clouds high in the atmosphere, the retrieved abundance of water and temperature are noticeably different from the values used to generate the synthetic spectra. This result in combination with the fact that we generally do not know the constraints on cloud properties beforehand when analyzing real planetary spectra leads us to the conclusion that clouds and hazes cannot be neglected when analyzing transit transmission spectra.

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257.17 – Exo-Transmit: A Publicly Available Exoplanet Transmission Spectrum Code and Accompanying Spectral Library

We present a publicly available library of exoplanet transmission spectra, focusing on planets in the super-Earth size and mass range. The spectra cover a broad range of parameter space that is appropriate for super-Earth atmospheres in terms of atmospheric composition and temperature. Other parameters, such as surface gravity and planetary radius are straightforward to scale, so that the library as a whole can be used to predict the transmission spectra of a wide variety of exoplanet atmospheres of interest. We furthermore have released the code responsible for generating the spectral library. The code, called Exo-Transmit, is publicly available on GitHub. It comes with instructions for use and can be used to model exoplanets beyond the scope of the published library. For example, Exo-Transmit has functionality to calculate transmission spectra for cloudy exoplanets, whereas the spectral library only includes cloud-free models. The published code, along with the accompanying spectral library can be useful for observers and instrument builders, as they plan for future observations or instrumentation. The models are also useful for interpreting observations of exoplanet transmission spectra and could be used as the underpinnings for spectral retrieval techniques.

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257.18 – Examining the Relative Compositions of Giant Planets and their Parent Stars

Observational knowledge of the connection between giant planet compositions and their parent stars' metal abundances is limited. These planets appear consistently enriched, but the sample size is small -- only our solar system and a handful of transiting extrasolar planets. Understanding this relationship in uninflated planets could help in constraining the inflationary mechanism in hotter planets. Thus, we consider a population of nearly 40 transiting massive planets which have sufficiently low insolation that they are not inflated. Using thermal evolution models, we determine their bulk metallicity Z_planet from their mass, radius, and age. Comparing this against parent star metal enrichment Z_star, which we derive from the iron abundance [Fe/H], we note a number of patterns. We see a previously suggested minimum metal content at ~10 earth masses, as well as a strong negative negative correlation in enrichment (Z_planet / Z_star) against planet mass. This can be used to give constraints on planet formation and population synthesis models. This metal relative enrichment is even seen up to ~10 Jupiter masses, around the brown dwarf transition mass, which represents an observational difference between very massive planets and low-mass brown dwarfs.

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257.19 – Effects of Photoevaporation on Planet Migration

The final locations of planets may be influenced by turning points in their migration tracks called "planet traps" (Hasegawa & Pudritz 2013, 2014). We explore a new planet trap caused by photoevaporation of a protoplanetary disk. Near the end of the lifetime of the gas disk, photoevaporation rates on the inner disk begin to exceed viscous accretion rates, initially resulting in a gap being formed at ~1 AU. Disk material inside the gap is quickly drained and then the gap widens until the gas disk is entirely blown away. Using a combination of analytical calculations and numerical simulations, we show that the variations of disk density resulting from this process affect the migration tracks of planets. In particular, the initial photoevaporative gap at ~1 AU stops planets from migrating inward from the gap for tens of thousands of years, until photoevaporation disperses the remaining disk and the planets lose their primary source of migration. This process may explain the apparent pileup of exoplanets at ~1 AU.

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257.20 – Formation of Giant Planets by Gravitational Instability in Layered Accretion Disk: A Study on Dust Settling

Formation of super-massive planets at a distance ranging from around 5 to 20 AU cannot be adequately explained by core accretion, even in the most optimistic scenario. The only promising alternative is the fragmentation mechanism in which giant planets are formed directly from the contraction of a clump of gas produced by gravitational instability. In our current work we investigate whether grain settling can trigger gravitational instability at these distances. We study the physics of grain growth and how grains of different sizes are subject to sedimentation, and more importantly, whether grain growth and dust settling can effectively decrease the opacity for the gas to become unstable. We take a prototype disk which is hot on the surface and has a quiscent midplane, which, because of being less turbulent allows the grains to grow more efficiently. In this context, we examine the gravitational stability of a layered accretion disk experiencing dust-settling and review the possibilities of super-massive planet formation at the range of distances concerned.

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257.21 – The Impact of Stellar Multiplicity on Planet Occurrence

The majority of searches for extrasolar planets have concentrated exclusively on single stars, actively avoiding close binary systems where the companion might complicate the observations and data analysis. However, the major ity of solar-type stars are found in binary systems. These binary companions should exert a strong dynamical influence on any planetary system, and hence this systematic bias leaves out knowledge of planet formation fundamentally incomplete. We will present the ongoing results of a high-resolution imaging survey to identify binary companions among a volume-limited sample of 600 Kepler planet hosts within 500 parsecs. This survey exploits nonredundant aperture-mask interferometry (NRM) to super-resolve binary companions down to 1/4 of the diffraction limit (15 mas; <5 AU at 300 pc), identifying the dynamically significant binary companions that are missed by standard imaging surveys. Our results show that binarity does indeed have a profound influence on planet occurrence, suppressing the planet frequency by a factor of 4 in 5-50 AU binaries. However, unexpected trends for planet survival also are starting to emerge.

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257.22 – The In Situ Formation of Systems with Tightly-packed Inner Planets

The Kepler space mission has revealed numerous planetary types and systems, shaping our understanding of planet formation. Among the quickly-growing data is a subclass of multi-planet configurations referred to as Systems with Tightly-packed Inner Planets (STIPs). Their large abundance (>10% of stars) suggests that they are one of the principal outcomes of planet formation. The prototype STIP is Kepler-11, which hosts six known transiting planets, five of which have measured masses in the super-Earth and mini-Neptune regimes. The known planetary orbits in this system are spaced between a=0.09 and 0.47 AU, with small eccentricities and mutual inclinations. The lack of low-order mean motion resonances among planets in STIPs suggests that migration may have not played a dominant role in placing all of these planets on short orbital periods. While the formation of massive planetary systems on the hot side of the water ice line may be difficult to reconcile under the current paradigm of planet formation, we must explore whether many STIP planets formed by and large in situ. We discuss an overlooked mechanism that may allow the in situ formation of planetary systems on very short orbital periods. As solids spiral inward due to aerodynamic drag, they will enter disk regions that are characterized by high temperatures, densities, and pressures. High partial pressures of rock vapor can reduce net evaporation of incoming material, which could promote collisions between partially molten solids, allowing rapid growth and overcoming the classic meter barrier.

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257.23 – The Orbital Architectures of Planet-Hosting Binary Systems

Until recently, observational biases in exoplanet discovery have left the frequency, properties, and provenance of planets in most binary systems largely unconstrained. Results from our ongoing survey of a volume-limited sample of 600 Kepler planet hosts within 500 parsecs indicate that binary companions at solar-system scales of 4–40 AU suppress the occurrence of planetary systems by a factor of at least 4. However, some planetary systems do survive, and it is unclear why. We present Keck AO astrometric monitoring of these planet-hosting binary systems from which we measure orbital arcs. Monte Carlo analysis of the observed motion provides joint constraints on the eccentricity and inclination of each binary system, as well as a statistical study of the underlying distributions of these orbital parameters across the entire sample of binaries. We can thereby test for co-planarity between the edge-on transiting planet and the binary companion orbits and determine whether the survival of planetary systems depends on eccentricity, e.g., if circular orbits are preferred in our sample. Our detailed investigation into the orbital architectures of binary systems that host planets provides important clues toward the physical processes governing the survival of planetary systems in general.

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257.24 – A secular model for efficient exploration of mutually-inclined planetary systems

Dynamical studies of exoplanets largely assume coplanarity because of the lack of inclination information in many cases. However, the multiplanet system Upsilon Andromedae has orbital planes inclined by 30 degrees, models of planet-planet scattering predict large mutual inclinations, and astrometry missions such as Gaia have the power to reveal the 3 dimensional architecture of planetary systems. As the dynamics of systems with non-planar orbits will be key to understanding origins, and ultimately habitability where applicable, we present a computationally efficient model for the orbital evolution of planetary systems with modest inclinations and eccentricities which are not in a mean motion resonance. Specifically, our model is based on the disturbing function and extends to 4th order in eccentricity and inclination. We present comparisons to N-body models for known systems, such as the Solar System and Upsilon Andromedae, and hypothetical systems with a range of orbital configurations. We describe the eccentricity and inclination conditions under which the model is valid. We further calculate the rotational evolution of planets based on the orbital evolution and the stellar torque and find a wide range of obliquity evolution is possible. As obliquity is a key driver of planetary climate, Earth-like planets in non-planar systems may have climates dominated by their orbital evolution.

Author(s): Russell Deitrick[1], Rory Barnes[1]
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257.25 – Direct imaging of exoplanets around multiple star systems

Direct imaging of extra-solar planets is now a reality, especially with the deployment and commissioning of the first generation of specialized ground-based instruments such as the Gemini Planet Imager and SPHERE. These systems will allow detection of Jupiter-like planets 10^7 times fainter than their host star. Obtaining this contrast level and beyond requires the combination of a coronagraph to suppress light coming from the host star and a wavefront control system including a deformable mirror (DM) to remove residual starlight (speckles) created by the imperfections of telescope. However, all these current and future systems focus on detecting faint planets around a single host star or unresolved binaries/multiples, while several targets or planet candidates are located around nearby binary stars such as our neighboring star Alpha Centauri.
Here, we present a method to simultaneously correct aberrations and diffraction of light coming from the target star as well as its companion star in order to reveal planets orbiting the target star. This method works even if the companion star is outside the control region of the DM (beyond its half-Nyquist frequency), by taking advantage of aliasing effects.

Author(s): Sandrine Thomas[1]
Institution(s): *1. NASA/UARC*

257.26 – High-precision ground-based observations of transiting exoplanets to detect their magnetic fields and undiscovered companions

Here we present U and B band photometric light curves of several bright transiting exoplanets observed with the University of Arizona's 61''/Mont4k in order to better determine their physical parameters and search for their magnetic fields and undiscovered planetary companions. Recent studies suggest that it is possible to determine the presence and constrain the strength of a magnetic field by observing an exoplanet's bow shock. The shock would be detected via asymmetries in the UV and optical light curves, specifically if the ingress in the near-UV occurs earlier than in the optical. The size of this offset indicates the planet's magnetic field strength. In addition, our photometry, which spans multiple nights, is used to more precisely measure the radius of these exoplanets and determine any transit timing variations that could potentially indicate a nearby companion. The data are reduced via an in-house, publicly available pipeline, ExoDRPL. Our research group, AzGOE, is made primarily of undergraduate students from the University of Arizona in cooperation with the University of Arizona Astronomy Club, and gives these students the ability to take, reduce, and publish their own ground based observations.

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Contributing team(s): AzGOE

257.27 – Connecting historical disk interactions with current planetary system architectures

Recent analyses of Kepler's multiplanet systems show several statistically significant peaks in the distribution of period ratios (Steffen & Hwang arXiv:1409.3320). One prominent peak is near a period ratio of 2.2. Usually planets that migrate in a gas disk become trapped at period ratios of 2:1, 3:2, etc. Thus, standard disk migration would not predict a large number of planets near 2.2. A paper by Baruteau, C. & Papaloizou, J. (2013, ApJ, 778, 7-21) may have identified an explanation to the unexpected peak. Planets in a gas disk that open a common gap often bypassed the 2:1 resonance and stopped their migration at smaller period ratios. However, planets that did not open a common gap often stopped their migration wide of the 2:1 resonance due to interactions with the wakes left by the planets. Using FARGO3D to model planet/disk interactions I hope to identify the system parameters that are needed to produce the observed period ratios. This information will give important insights into the dynamical evolution of planetary systems. We present the results of our simulations.

Author(s): Emily Ellinger[1], Jason H. Steffen[1]
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257.28 –
Inclination Excitation in Extrasolar Planetary Systems

The Kepler Mission has detected dozens of planetary systems with more than four transiting planets. This sample provides a collection of planetary systems with little or no excited inclination between the inferred orbits. This present study examines the magnitude and efficacy of three potential mechanisms for exciting orbital inclination in these systems: self-excitation of orbital inclination in initially coplanar planetary systems, perturbations by larger bodies within the planetary systems, and perturbations by massive bodies external to the systems. For each of these mechanisms, we determine the regime(s) of parameter space for which orbital inclination excitation is effective. This work provides constraints on the properties (masses and orbital elements) of possible additional bodies in observed planetery systems, and on their dynamical history. One interesting application is to consider the relative size of the external perturbations both in and out of clusters.

Author(s): Juliette Becker[1], Fred C. Adams[1]
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257.29 – Shedding Light on the Eccentricity Valley: Gap Heating and Eccentricity Excitation of Giant Planets in Protoplanetary Disks

We show that the first order (non-co-orbital) corotation torques are significantly modified by entropy gradients in a non-barotropic protoplanetary disk. Such non-barotropic torques can dramatically alter the balance that, for barotropic cases, results in the net eccentricity damping for giant gap-clearing planets embedded in the disk. We demonstrate that stellar illumination can heat the gap enough for the planet's orbital eccentricity to instead be excited. We also discuss the "Eccentricity Valley" noted in the known exoplanet population, where low-metallicity stars have a deficit of eccentric planets between ~0.1 and ~1 AU compared to metal-rich systems. We show that this feature in the planet distribution may be due to the self-shadowing of the disk by a rim located at the dust sublimation radius ~0.1 AU, which is known to exist for several T Tauri systems. In the shadowed region between ~0.1 and ~1 AU, lack of gap insolation allows disk interactions to damp eccentricity. Outside such shadowed regions stellar illumination can heat the planetary gaps and drive eccentricity growth for giant planets. We suggest that the self-shadowing does not arise at higher metallicity due to the increased optical depth of the gas interior to the dust sublimation radius.

Author(s): David Tsang[1], Neal J. Turner[2], Andrew Cumming[1]
Institution(s): *1. McGill University, 2. NASA JPL*

257.30 – Analyzing Mass Loss and Tidal Circularization as a Source for Sustained Eccentric Orbits in Hot Jupiters

As the number of extrasolar planets and planet candidates increases, so does the number of systems that look strikingly different from our own. Hot Jupiters are such a system and are characterized by a Jupiter mass planet with a close-in orbit. Because of the proximity of the planet to its parent star, we would expect these systems to be tidally circularized. However, we observe many with significant eccentricities, suggesting that a mechanism must exist to account for sustained eccentric orbits. Previous analyses found that, in a population of eccentric hot Jupiters generated by planet-planet scattering, a significant fraction will overfill their Roche lobe at periastron. Other work has noted that mass loss in systems similar to hot Jupiters can act to increase the eccentricity of the orbit of a binary system. Here, we consider the effects of tidal circularization and mass loss on the orbital evolution of the hot Jupiters. By analyzing the balance between the tidal circularization and mass loss, we can determine an equilibrium eccentricity as a function of planet mass and the tidal quality factor, Q. If such an equilibrium value exists, then it is possible for this mechanism to be responsible for the sustained eccentric orbits of hot Jupiters that we observe. We present the orbital parameters for these equilibrium orbits over a broad parameter space and compare those results to the current population of observed extrasolar planets.

Author(s): Rachel L. Salmon[1], Jeremy F. Sepinsky[1]
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257.31 – Characterizing the Hot Kepler Objects of Interest

Thousands of exoplanets have been discovered to date; most orbit stars that are similar to our Sun (FGK dwarfs) or cooler (M dwarfs). Detecting planets orbiting hotter stars (A dwarfs) is a challenge because hot stars have rotationally-broadened spectral features and large radii. Accumulating a statistical sample of well-characterized planets orbiting A stars is important to constrain trends in planet occurrence and orbital properties as a function of stellar mass. Throughout its four years of operation, the Kepler mission monitored a few thousand hot stars (T_eff > 7000K) with sufficient photometric precision to detect the transits of Jupiter-size planets. We characterize the main sequence A stars with transiting planet candidates detected by Kepler. We identify likely A stars in the Kepler Input Catalog (KIC) by their stellar effective temperatures, derived from KIC grizJHK photometry using the empirical relations from Boyajian et al. (2013). To verify the classification of a subset of these stars, we measure their spectra using Palomar DBSP and collect high-resolution images with Keck NIRC2. We determine the physical parameters of the transiting planets' orbits by fitting the Kepler transit light curves with Markov Chain Monte Carlo methods. By constraining the semi-major axis and eccentricity distributions of planets orbiting A stars, we gain insights into the formation and tidal evolution of planets in a relatively uncharted region of the H-R diagram.

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257.32 – MINERVA-Red: A Census of Planets Orbiting the Nearest Low-mass Stars to the Sun

Recent results from Kepler and ground-based exoplanet surveys suggest that low-mass stars host numerous small planets. Since low-mass stars are intrinsically faint at optical wavelengths, obtaining the Doppler precision necessary to detect these companions remains a challenge for existing instruments. We describe MINERVA-Red, a project to use a dedicated, robotic, near-infrared optimized 0.7 meter telescope and a specialized Doppler spectrometer to carry out an intensive, multi-year campaign designed to reveal the planetary systems orbiting some of the closest stars to the Sun. The MINERVA-Red cross-dispersed echelle spectrograph is optimized for the “deep red”, between 800 nm and 900 nm, where these stars are relatively bright. The instrument is very compact and designed for the ultimate in Doppler precision by using single-mode fiber input. We describe the spectrometer and the status of the MINERVA-Red project, which is expected to begin routine operations at Whipple Observatory on Mt Hopkins, Arizona, in 2015.

Author(s): Cullen Blake[5], John Johnson[1], Peter Plavchan[2], David Sliski[5], Robert A. Wittenmyer[4], Jason D Eastman[1], Stuart Barnes[3]
Institution(s): *1. Harvard University, 2. Missouri State University, 3. Stuart Barnes Optical Design, 4. University of New South Wales, 5. University of Pennslyvania*

257.33 – Inferring Planet Occurrence Rates With a Q1-Q16 Kepler Planet Candidate Catalog Produced by a Machine Learning Classifier

NASA’s Kepler Space Telescope monitored the photometric variations of over 170,000 stars within a ~100 square degree field in the constellation Cygnus, at half-hour cadence, over its four year prime mission. The Kepler SOC (Science Operations Center) pipeline calibrates the pixels of the target apertures for each star, corrects light curves for systematic error, and detects TCEs (threshold-crossing events) that may be due to transiting planets. Finally the pipeline estimates planet parameters for all TCEs and computes quantitative diagnostics that are used by the TCERT (Threshold Crossing

Event Review Team) to produce a catalog containing KOIs (Kepler Objects of Interest). KOIs are TCEs that are determined to be either likely transiting planets or astrophysical false positives such as background eclipsing binary stars. Using examples from the Q1-Q16 TCERT KOI catalog as a training set, we created a machine-learning classifier that dispositions the TCEs into categories of PC (planet candidate), AFP (astrophysical false positive) and NTP (non-transiting phenomenon). The classifier uniformly and consistently applies heuristics developed by TCERT as well as other diagnostics to the Q1-Q16 TCEs to produce a more robust and reliable catalog of planet candidates than is possible with only human classification. In this work, we estimate planet occurrence rates, based on the machine-learning-produced catalog of Kepler planet candidates. *Kepler* was selected as the 10th mission of the Discovery Program. Funding for this mission is provided by NASA, Science Mission Directorate.

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Contributing team(s): Kepler Science Operations Center

257.34 – Estimates of Planetary System Properties using TTV data and Least-Excited Orbital Configurations

Kepler's precise measurements of planetary transit times have enabled the study of transit timing variations (TTVs) caused by gravitational interactions between planets in multi-planet systems. Using analytic models, Hadden and Lithwick (ApJ, 787, 80, 2014) analyzed the TTVs for 139 *Kepler* planets and obtained nominal masses. However, due to a degeneracy between mass and eccentricity in the analytical formulae, systems with high eccentricity planets have nominal masses larger than their true masses—sometimes significantly larger. We investigate the constraints that can be placed on the eccentricities of the planets in these systems by minimizing the system's angular momentum deficit. This analysis gives an effectives lower bound on the orbital eccentricities and gives insight into their dynamical histories.

Author(s): Daeyoung Lee[1], Jason H. Steffen[1]
Institution(s): *1. Northwestern University*

257.35 – Identifying transiting planets candidates in Kepler data using PyKE

A study of M-dwarf stars has shown that there exists an abundance of planets around this star class (Muirhead, 2013). Kepler stellar data contains a vast collection of M-dwarfs that are too faint to be analyzed with regular photometry, due to the background light from neighboring stars and the undersampling of the stars' image. We used PyKE (Still & Barclay 2012), a software package for the reduction and analysis of Kepler data. This open source software project is developed and distributed by the NASA Kepler Guest Observer Office. A special PyKE package fits a PSF model to a specific image within a target pixel file in order to separate the target's light from other stars. Using this package, we were able to obtain cleaner light curves for 113 Kepler targets. This increases the probability of identifying a transiting planet and/or binary star from their light curve. I will present results for a few potential planets and describe the methodology.

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257.36 – The Kepler False Positive Table

The Kepler Space Telescope has detected thousands of candidate exoplanets by observing transit signals in a sample of more than 190,000 stars. Many of these transit signals are false positives, defined as a transit-like signal that is not due to a planet orbiting the target star (or a bound companion if the target is a multiple-star system). Astrophysical causes of false positives include background eclipsing binaries, planetary transits not associated with the target star, and non-planetary eclipses of the target star by stellar companions. The fraction of Kepler planet candidates that are false positives ranges from about 10% at high Galactic latitudes to 40% at low Galactic latitudes. Creating a high-reliability planet candidate catalog for statistical studies such as occurrence rate calculations requires removing clearly identified false positives.

The Kepler Object of Interest (KOI) catalog at the NExScI NASA Exoplanet Archive flags false positives, and will soon provide a high-level classification of false positives, but lacks detailed description of why a KOI was determined to be a false positive. The Kepler False Positive Working Group (FPWG) examines each false positive in detail to certify that it is correctly identified as a false positive, and determines the primary reason(s) a KOI is classified as a false positive. The work of the FPWG will be published as the Kepler False Positive Table, hosted at the NExScI NASA Exoplanet Archive.

The Kepler False Positive Table provides detailed information on the evidence for background binaries, transits caused by stellar companions, and false alarms. In addition to providing insight into the Kepler false positive population, the false positive table gives information about the background binary population and other areas of astrophysical interest. Because a planet around a star not associated with the target star is considered a false positive, the false positive table likely contains further planet candidates. This poster describes the creation of the false positive table, how false positives are certified, and the logical relationship between the various types of evidence and the final false positive determination.

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Contributing team(s): The Kepler False Positive Working Group

257.37 – Orbital Phase Curves of Kepler Exoplanetary Systems

For the past twenty years, two detection and characterization methods have dominated exoplanet research: transit and radial velocity studies. With the advent of highly sensitive, space-based, optical telescopes such as Kepler, we can now observe the optical phase curve of an exoplanet as it orbits its host star. By modeling and fitting four photometric effects —reflected light, thermal emission, ellipsoidal variations, and Doppler boosting—to these phase curves, it is possible to more fully characterize exoplanets. Not only can we break the mass-inclination degeneracy, but a phase curve analysis can derive the exoplanet's day- and night-side temperatures, as well as calculate rudimentary atmospheric characteristics. This analysis is possible even for non-transiting exoplanets. We will present phase curve analyses of Kepler exoplanet candidates, and initial results from a search of the Kepler database for phase curves of non-transiting exoplanets. We will also assess the potential for phase curve studies of data from the K2 phase of the mission. We gratefully acknowledge the generous support of the Connecticut Space Grant Consortium.

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257.38 – Modelling Phase Curves and Occultations in KOI Light Curve

Clues about the atmospheric and surface conditions of a planet are buried within the Kepler light curve of the host star. We select several Kepler Objects of Interest (KOI) which show phase variations and occultations to estimate the temperature and albedo of the exoplanet. We apply a Fourier decomposition filtering technique to remove variations in the KOI light curves that are likely of stellar origin. Finally, we use an MCMC algorithm to fit the different amplitudes of phase variations and compute the planet’s mass, nightside temperature, and geometric albedo.

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257.39 – Characterizing Retired A Stars

A complete understanding of the formation and evolution of planetary systems depends on the precise characterization of the planets and their host stars. The stellar mass is particularly important because it might influence the planet occurrence and it is used to constrain the planetary masses, thus providing information about the systems' architectures. Single FGK stars on the main sequence usually have precise masses estimated from evolutionary tracks, but the results of this method for subgiants and giants have recently been called into question. In this work, we describe the ongoing efforts to precisely constrain the the masses of evolved stars using a sample of more than 250 retired A stars as well as some benchmark subgiants and giants. Different input atmospheric parameters (from excitation and ionization equilibria, spectral synthesis, interferometry and photometry) and methods (evolutionary tracks, lithium abundances and asteroseismology) are used to critically evaluate the stellar masses and its uncertainties. Preliminary results are discussed and suggest that current mass determinations for evolved stars do not present any systematic errors.

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257.40 – Young Nearby Suns and Stellar Jitter Dependence on Age

Finding the nearest young planets offers the most direct way to improve our understanding of how planets form, how they migrate, and how they evolve. However, most radial velocity (RV) surveys have avoided young stars because of their problematic characteristics, including high levels of stellar activity. Recent advancements in infrared (IR) detectors as well as wavelength calibration methods have provided new ways of pursuing high-precision RV measurements of young stars. While this work has been successfully applied to many young late-K and M dwarfs, much less RV work has been done on young Sun-like stars, with the very recent exception of adolescent stars (~600 Myr) in open clusters. In order to better understand the dynamical and structural forces that shaped our own Solar system, we must begin to explore the more massive realm of Sun-like stars.

We present precision optical radial velocity data of 5 young, nearby, Sun-like stars in AB Dor and assess our ability to detect young planets with current spectroscopic methods. The data were obtained with the TRES spectrograph on the 1.5-m Tillinghast Reflector at the Fred L. Whipple Observatory and with SOPHIE on the 1.95 m Telescope at the Observatoire de Haute Provence. We obtained a RV precision of ~8 m/s with TRES and ~7 m/s precision with SOPHIE;

average observed dispersions are 38 m/s and 33 m/s, respectively. We combine our results with spectroscopic data of Sun-like stars spanning a broad range of youthful ages (< 1 Gyr) from the literature to investigate the relationship between stellar jitter and stellar age. The results suggest that the jitter of Sun-like stars decreases below 100 m/s for stars older than ~30 Myr, which would enable the discovery of hot Jupiters orbiting these adolescent age stars.

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Institution(s): *1. Georgia State University, 2. Harvard-Smithsonian, CfA, 3. Université Joseph Fourier*

257.41 – KIC 12557548 and Similar Stars as SETI Targets

This project aims to construct a robust information theoretic metric to quantify anomalous transit light curves and compare regular and irregular transits in a reproducible way. Using this metric we can distinguish natural transits from predicted extraterrestrial intelligence (ETI) communication that utilizes transiting mega-structures to alter the transit shape and depth in a measurable way. KIC-12557548b (KIC-1255b) is such an anomalous planet, with highly variable consecutive transit depths and shapes that have been explained by Rappaport et al. (2012) and Croll et al. (2014) as due to a disintegrating sub-Mercury sized planet with a debris tail encompassing the planetary orbit. However, Arnold (2005) and later Forgan (2013) presented models showing that planet-sized, non-circular artificial structures transiting their host star could be identified as non-natural by light curves anomalous in their duration and asymmetry, as in the case of KIC-1255b. If such mega-engineering structures were able to alter their aspects on orbital timescales, the resulting transit depths could be used to transmit information at low bandwidth. We use KIC-1255b as a benchmark case for separating anomalous transit signals that resemble ETI predictions but are naturally occurring. To do this, we use the Kullback-Leibler (KL) divergence of the KIC-1255b transit depth time series to quantify the entropy of the transit depth series. We calibrate our relative entropy metric by calculating the KL divergence of the Kepler-5b transits, which are markedly constant compared to KIC-1255b. Artificially generated transit depth time series data using Arnold's beacons allow us to calculate the KL divergence of predicted ETI communications and show that while KIC-1255b might match ETI predictions of shape and depth variations, the entropy content of the datasets are distinct by our metric. Thus we can use the entropy metric to test other cases of anomalous transits to separate out those transiting planets that can be explained through natural models and those for which an ETI hypothesis might be entertained.

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258 – Extrasolar Planets: Detection Posters

258.01 – The MEarth project: an all-sky survey for transiting Earth-like exoplanets orbiting nearby M-dwarfs

The MEarth project is an operational all-sky survey searching for transiting Earth-like exoplanets around 3,000 of the closest mid-to-late M-dwarfs. These will be among the best planets in their size class for atmospheric characterization using present day and near-future instruments such as HST, JWST and ground-based Extremely Large Telescopes (ELTs), by virtue of the large observational signal sizes afforded by their small and bright host stars. We present an update on the status and recent scientific results of the survey from our two observing stations: MEarth-North at Fred Lawrence Whipple Observatory, Mount Hopkins, Arizona, and MEarth-South at Cerro Tololo Inter-American Observatory, Chile. MEarth-North discovered the transiting mini-Neptune exoplanet GJ 1214b, which currently has the best-studied atmosphere of any exoplanet in its size class. In addition to searching for planets, we actively pursue stellar astrophysics topics and characterization of the target star sample using MEarth data and supplementary spectroscopic follow-up. This has included measuring astrometric parallaxes for more than 1500 nearby stars, the discovery of 6 new low-mass eclipsing binaries amenable to direct measurement of the masses and radii of their components, and rotation periods, spectral classifications, metallicities and activity indices for hundreds of stars. The MEarth light curves themselves also provide a detailed record of the photometric behavior of the target stars, which include the most favorable and interesting targets to search for small and potentially habitable planets. This will be a valuable resource for all future surveys searching for planets around these stars. All light curves gathered during the survey are made publicly available after one year.

The MEarth project gratefully acknowledges funding from the David and Lucile Packard Fellowship for Science and Engineering, the National Science Foundation under grants AST-0807690, AST-1109468, and AST-1004488, and the John Templeton Foundation.

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258.02 – Exoplanets with LSST: Period Recoverability of Transiting Hot Jupiters

The Large Synoptic Survey Telescope (LSST) will generate light curves for an unprecedented one billion stars across the night sky. While the LSST was not conceived or designed to find exoplanets, the data can nevertheless be exploited for that purpose. Although the LSST will have a much lower observing cadence compared to dedicated exoplanet surveys, the sheer number of stars that LSST will survey could result in a very large number of transiting exoplanet detections. In particular, LSST will probe stellar populations currently undersampled in most transit surveys, including out to extragalactic distances. Since period detection is one of the necessary criteria for transit detection, here we report on a test of the efficiency of a standard boxed-least-squares (BLS) algorithm at accurately recovering the periods of exoplanets using simulated LSST data. Specifically, we test the case of a 1 solar mass star at 7000 pc from Earth, transited by an 8-, 10-, and 12- Earth radius planet at input periods ranging from 0.5 to 20 days. At short periods, BLS was highly accurate at recovering the input period, with accuracy trailing off quickly for LSST regular cadence observation but much more gradually for "deep drilling" cadence observation. For example, in the 10-Earth radius case, we find that the transits are correctly recovered at least 50% of the time for planet periods up to 2.5 days in the regular cadence mode, and 15 days in the deep-drilling mode.

Author(s): Savannah Jacklin[3], Michael Lund[2], Joshua Pepper[1], Keivan Stassun[2]
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258.03 – A Novel Technique for Narrow-Band Tunable Filter Photometry to Enable Ground-Based Detection of Earth-Sized Exoplanets

We present a novel technique for the removal of sky rings from narrow-band photometry, which arise due to atmospheric OH emission. Our goal is to achieve very high-precision ground-based photometry to enable detection of small transit or occultation signals from exoplanets. We demonstrate our technique on narrow-band photometry of the super-Earth-size transiting planet CoRoT-7b acquired with the OSIRIS tunable filter imager on the 10.4-meter Gran Telescopio Canarias. Without removing sky rings, we do not detect a transit of CoRoT-7b at any significance, but after removing sky rings with our technique, we detect a transit at a significance of 3.2-sigma. Our detection of the transit suggests that this technique can enable ground-based detection of exoplanets with transit or occultation depths on the order of 0.1 mmag. At the time of writing, we believe this to be the first ground-based detection of a transit of a super-Earth orbiting a Sun-like star. This implies that the characterization of Earth-sized planets discovered by space-based missions like Kepler and the future TESS mission may be possible from the ground.

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258.04 – Testing the refurbished 30-inch Leuschner telescope and its exoplanet detection capabilities

The 30-inch Ritchey-Chretien telescope at Leuschner Observatory has recently been refurbished through a collaboration between San Francisco State University (SFSU) and UC Berkeley. The telescope is equipped with an SBIG STL-11000M CCD and is now being operated remotely from both campuses. We have carried out observations from SFSU to test the telescope's performance and to characterize the site in Lafayette, CA. We present the results of photometric calibrations in B, V and R filters carried out using Landolt standards, and of tests of the pointing and tracking accuracy of the refitted mount. We have also monitored the seeing at the site and measured the sky brightness in B, V and R filters. Finally, using observations of the open star cluster M34, we test the accuracy with which we can measure relative magnitudes, with the goal of using this telescope to detect exoplanet transits.

Author(s): Eileen Gonzales[1], Adam Fries[1], Adrienne Cool[1]
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258.05 – Determining the Photometric Precision of the 0.9-m CTIO SMARTS Telescope

Exoplanet detections are becoming more and more frequent as our ability to detect transits and Doppler shifted stellar spectra improves. Here, we report on eight observing nights at the SMARTS 0.9m telescope in Chile at the Cerro Tololo Inter-American Observatory (CTIO), covering 13 nearby stars in the range of 11th to 14th visual magnitude. We used the defocus method to spread the point spread function (PSF) of the star across a larger portion of the CCD to achieve longer exposure times yielding a higher signal to noise ratio and a higher amount of data every night as less time was spent on CCD read-out and data storage per image. Spreading the PSF and increasing exposure time has drawbacks, as it inevitably increases the sky background in each image and makes it difficult to extricate the target star's PSF from a crowded background of neighboring stars. We explore the short term, high time-resolution ability of the 0.9m CTIO telescope to produce stable photometry of M-dwarfs. The results show that the 0.9m telescope can to produce stable photometry to ~1 milli-mag if user error does not introduce artificial noise. We can use this telescope to compare the noise of stars to the predictions of starspot models. There is also value searching for a correlation between photometric and radial velocity noise in stars that could mask or produce false positive exoplanet detections.

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Contributing team(s): RECONS, SMARTS

258.06 – Mechanical design for the Evryscope: a minute cadence, 10,000-square-degree FoV, gigapixel-scale telescope

We designed, tested, prototyped and built a compact 27-camera robotic telescope that images 10,000 square degrees in 2-minute exposures. We exploit mass produced interline CCD Cameras with Rokinon consumer lenses to economically build a telescope that covers this large part of the sky simultaneously with a good enough pixel sampling to avoid the confusion limit over most of the sky. We developed the initial concept into a 3-d mechanical design with the aid of computer modeling programs. Significant design components include the camera assembly-mounting modules, the hemispherical support structure, and the instrument base structure. We simulated flexure and material stress in each of the three main components, which helped us optimize the rigidity and materials selection, while reducing weight. The camera mounts are CNC aluminum and the support shell is reinforced fiberglass. Other significant project components include optimizing camera locations, camera alignment, thermal analysis, environmental sealing, wind protection, and ease of access to internal components. The Evryscope will be assembled at UNC Chapel Hill and deployed to the CTIO in 2015.

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258.07 – Image Quality of the Evryscope: Method for On-Site Optical Alignment

Previous wide field surveys have been conducted by taking many images each night to cover thousands of square degrees. The Evryscope is a new type of system designed to search for transiting exoplanets around nearby bright stars, M-dwarfs, white dwarfs, and other transients. The Evryscope is an array of 70 mm telescopes that will continuously image 10200 square degrees of the night sky at once. One of the image quality requirements is for the PSFs to be well-sampled at two pixels across and it was found that tilt caused by slight misalignment between the optics and the CCD increased the size of the FWHM towards the edges and corners of the image. Here we describe the image quality of the Evryscope cameras and the alignment procedure to achieve the required 2 pixel FWHM.

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258.08 – Calibrating the pixel-level Kepler imaging data with a causal data-driven model

In general, astronomical observations are affected by several kinds of noise, each with it's own causal source; there is photon noise, stochastic source variability, and residuals coming from imperfect calibration of the detector or telescope. In particular, the precision of NASA Kepler photometry for exoplanet science—the most precise photometric measurements of stars ever made—appears to be limited by unknown or untracked variations in spacecraft pointing and temperature, and unmodeled stellar variability. Here we present the Causal Pixel Model (CPM) for Kepler data, a data-driven model intended to capture variability but preserve transit signals. The CPM works at the pixel level (not the photometric measurement level); it can capture more fine-grained information about the variation of the spacecraft than is available in the pixel-summed aperture photometry. The basic idea is that CPM predicts each target pixel value from a large number of pixels of other stars sharing the instrument variabilities while not containing any information on possible transits at the target star. In addition, we use the target star’s future and past (auto-regression). By appropriately separating the data into training and test sets, we ensure that information about any transit will be perfectly isolated from the fitting of the model. The method has four hyper-parameters (the number of predictor stars, the auto-regressive window size, and two L2-regularization amplitudes for model components), which we set by cross-validation. We determine a generic set of hyper-parameters that works well on most of the stars with $11 \le V \le 12$ mag and apply the method to a corresponding set of target stars with known planet transits. We find that we can consistently outperform (for the purposes of exoplanet detection) the Kepler Pre-search Data Conditioning (PDC) method for exoplanet discovery, often improving the SNR by a factor of two. While we have not yet exhaustively tested the method at other magnitudes, we expect that it should be generally applicable, with positive consequences for subsequent exoplanet detection or stellar variability (in which case we must exclude the autoregressive part to preserve intrinsic variability).

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258.09 – High-contrast imager for Complex Aperture Telescopes (HiCAT): APLC/shaped-pupil hybrid coronagraph designs

HiCAT is a high-contrast imaging testbed designed to provide complete solutions in wavefront sensing, control and starlight suppression with complex aperture telescopes. Primary mirror segmentation, central obstruction and spiders in the pupil of an on-axis telescope introduces additional diffraction features in the point spread function, which make high-contrast imaging very challenging. The testbed alignment was completed in the summer of 2014, exceeding specifications with a total wavefront error of 12nm rms with a 18mm pupil. Two deformable mirrors are to be installed for wavefront control in the fall of 2014. In this communication, we report on the first testbed results using a classical Lyot coronagraph. We have developed novel coronagraph designs combining an Apodized Pupil Lyot Coronagraph (APLC) with shaped-pupil type optimizations. We present the results of these new APLC-type solutions with two-dimensional shaped-pupil apodizers for the HiCAT geometry. These solutions render the system quasi-insensitive to jitter and low-order aberrations, while improving the performance in terms of inner working angle, bandpass and contrast over a classical APLC.

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258.10 – Design of an occulter testbed at flight Fresnel numbers

An external occulter is a spacecraft flown along the line-of-sight of a space telescope to suppress starlight and enable high-contrast direct imaging of exoplanets. Laboratory verification of occulter designs is necessary to validate the optical models used to design and predict occulter performance. At Princeton, we are designing and building a testbed that allows verification of scaled occulter designs whose suppressed shadow is mathematically identical to that of space occulters. Here, we present a sample design operating at a flight Fresnel number and is thus representative of a realistic space mission. We present calculations of experimental limits arising from the finite size and propagation distance available in the testbed, limitations due to manufacturing feature size, and non-ideal input beam. We demonstrate how the testbed is designed to be feature-size limited, and provide an estimation of the expected performance.

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258.11 – Performance characterization of a PIAA complex focal plane mask

The Phase Induced Amplitude Apodization Complex Mask Coronagraph (PIAACMC) is an architecture for directly observing extrasolar planets, and can achieve performance near the theoretical limits for any direct-detection instrument. PIAACMC can be designed for centrally-obscured and segmented apertures, which is particularly useful for next-generation telescopes. The PIAACMC architecture includes aspheric PIAA optics, and a complex phase-shifting focal plane mask that provides a pi phase shift to a portion of the on-axis starlight. The phase-shifted starlight is forced to interfere destructively with the un-shifted starlight, causing the starlight to be eliminated, and allowing a region for high-contrast imaging near the star.

The main challenge in designing the complex focal plane mask is to achieve deep contrast over a wide spectral band. Another challenge for the mask design is to avoid sharp features, which can be difficult to manufacture. We present a solution to the design challenge by dividing the mask into sections and optimizing the phase shift produced by each section. We also demonstrate a method to design the mask with a smooth profile. One remaining challenge is to measure the performance of the mask. We present a method to compute the phase profile of the mask based on measurements of the diffraction pattern. The computed phase profile is used to simulate the expected coronagraph performance.

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258.12 – Advances in Focal Plane Wavefront Estimation for Directly Imaging Exoplanets

To image cold exoplanets directly in visible light, an instrument on a telescope needs to suppress starlight by about 9 orders of magnitude at small separations from the star. A coronagraph changes the point spread function to create regions of high contrast where exoplanets or disks can be seen. Aberrations on the optics degrade the contrast by several orders of magnitude, so all high-contrast imaging systems incorporate one or more deformable mirrors (DMs) to recover regions of high contrast. With a coronagraphic instrument planned for the WFIRST-AFTA space telescope, there is a pressing need for faster, more robust estimation and control schemes for the DMs. Non-common path aberrations limit conventional phase conjugation schemes to medium star-to-planet contrast ratios of about 1e-6. High-contrast imaging requires estimation and control of both phase and amplitude in the same beam path as the science camera. Field estimation is a challenge since only intensity is measured; the most common approach, including that planned for WFIRST-AFTA, is to use DMs to create diversity, via pairs of small probe shapes, thereby allowing disambiguation of the electric field. Most implementations of DM Diversity require at least five images per electric field estimate and require narrowband measurements. This paper describes our new estimation algorithms that improve the speed (by using fewer images) and bandwidth of focal plane wavefront estimation. For narrowband estimation, we are testing nonlinear, recursive algorithms such as an iterative extended Kalman filter (IEKF) to use three images each iteration and build better, more robust estimates. We are also exploring the use of broadband estimation without the need for narrowband sub-filters and measurements. Here we present simulations of these algorithms with realistic noise and small signals to show how they might perform for WFIRST-AFTA. Once validated in simulations, we will test these algorithms experimentally in Princeton's HCIL and in the Jet Propulsion Laboratory's (JPL's) High Contrast Imaging Testbed (HCIT). Developing these faster, more robust wavefront estimators is a crucial for increasing the science yield of the WFIRST-AFTA coronagraphic instrument.

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258.13 – KLIP-ing for Analogs - Detection Statistics for HR8799-like systems

In late 2008, the announcement of the discovery of the directly imaged quadruple planetary system HR8799 was made. This system is unique not only due to the number of planets it contains but also because it poses a serious threat to our current understanding of planetary core accretion. Namely, the observed radial separations between the planets and their A/F-type host star are not consistent with the amount of gas we would expect the planets to have accreted, as well as the fact the system as a whole contains more than 70 times the mass of our own solar system.

In order to examine whether or not planetary systems similar to HR8799 are anomalous, this project has conducted the largest survey to date of directly imaged A/F-type stars. Using the NACO-VLT imaging system, we implement a modern image reduction algorithm known as KLIP on over 60 targets to detect analogs. KLIP is a PCA based algorithm and operates by creating a library of PSF eigenimages for a given set of input images. This library contains all of the time-independent PSF sources that rotate with the field of view for the input images. Once the PSF library is created, KLIP then recreates any target from the input images as a superposition of known PSF eigenimages from the library and subtracts this from the original, leaving behind possible planetary candidates.

The results of this project provide a quantitative comparison of KLIP and other image reduction algorithms for this data set. We will also use a Monte Carlo based simulation to determine the frequency of HR8799 analogs around AF type stars based on our detection statistics.

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258.14 – Direct Imaging of Radial Velocity Exoplanets with the WFIRST-AFTA Coronagraph

The study of exoplanetary systems is an accelerating field as we continue to discover new planets due to advances in detection techniques and instrumentation. However, the majority of planets are detected via indirect methods, such as radial velocity (RV) and transit photometry. These methods rely on observing the effects of exoplanets on the stars they are orbiting, and can therefore limit the planets we can detect and the information we can gather. To further expand the types of planets we can investigate, various direct imaging methods and tools are being developed. One such instrument is a proposed coronagraph for the Wide-Field Infrared Survey Telescope Astrophysics Focused Telescope Assets (WFIRST-AFTA). One science case for this instrument is the direct imaging and spectral characterization of previously discovered exoplanets.
In this work, we present a method to find the best times to directly image the subset of RV exoplanets detectable by WFIRST-AFTA. We model the orbits of RV exoplanets using their fit orbital parameters (and error ranges) along with unbiased priors for all unknown parameters. We then map the times (with respect to maximum elongation) when the exoplanet will be geometrically unobscured to the coronagraph to the corresponding radial velocity profiles in order to determine the best times for direct imaging. We find that only 22 out of 534 radial velocity exoplanets are detectable by coronagraph with an inner working angle (IWA) of 200 mas, and 68 using an IWA of 100 mas. These results are folded into a larger instrument model with other factors, such as the coronagraph contrast and throughput, also taken into consideration, to produce a more detailed prediction for the RV exoplanet imaging capabilities of the WFIRST-AFTA coronagraph.

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258.15 – Development of Integral Field Spectroscopy for the AFTA Coronagraph using an Electron Multiplication CCD

The AFTA coronagraph, under development at JPL, is a candidate guest observer instrument for the AFTA WFIRST mission. The primary science objective of the coronagraph is detection and spectral characterization of exoplanets. In support of the coronagraph development, the technical maturity of key components is being advanced. Though integral field spectrographs (IFS) are well established in instruments on ground-based observatories, a lenslet based integral field spectrograph (IFS) has no space flight heritage. Other differences between the AFTA coronagraph IFS and similar spectrographs that have ground based heritage are i) the use of a pinhole mask on the output surface of the lenslet array and ii) the need to demonstrate high instra-scene contrast. A test-bed IFS is being built by GSFC to demonstrate these features on the NASA HCIT coronagraph(s). The design and analysis of a test-bed version IFS is presented. The AFTA IFS will utilize an electron multiplication CCD (ECCD) to carry out low noise photon detection. The plan to raise the maturity of the EMCCD from TRL-4 to -6 is presented. As part of this plan we will test and evaluate both standard thickness silicon and deep depletion (DD) silicon versions of the e2v CCD201-20 EMCCD with particular emphasis on dark current and responsivity. In addition, various operational methods will be tested to minimize the clock induced charge and the radiation induced degradation of charge transfer efficiency.

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258.16 – Finding the Needle in the Haystack: High-Fidelity Models of Planetary Systems for Simulating Exoplanet Observations

Future missions to characterize exoplanets will require instruments tailored to the problem of finding a habitable exoplanet: suppressing the bright star while still directly observing planets at small angular separations. This problem is compounded by interplanetary dust, which will likely be a significant source of astrophysical background noise. Instrument parameters must be constrained with detailed performance simulations, which must then be analyzed to determine if the instruments are capable of discerning the desired exoplanet characteristics. One valuable characteristic is the mass of the planet. A constraint on a planet's mass can quickly show if it is likely to be a rocky terrestrial planet, which may have the potential to form life as we know it. Unfortunately, it is difficult to measure the masses of small planets with traditional indirect techniques (e.g. radial velocity).

A planet's gravitational effects on nearby interplanetary dust (or "exozodi") can be more easily observed than the planet itself. A single observation of a planetary disk could constrain the mass of an exoplanet if the dust distribution varies sufficiently to be distinguished by future instruments. The NASA Haystacks team (PI: A. Roberge) has completed preliminary high-fidelity spectral image cubes of our entire Solar System at visible and near-infrared wavelengths, including star & planet spectra and scattered light from dust. In addition to these models, we present new planetary system architectures designed to test whether we can distinguish between mini-Neptune-mass planets and Earth-mass planets by their effects on the dust structure. These spectral image cubes will be processed through instrument simulators, allowing comparison of known disk structure with simulated observations of the disk. The results will help inform future exoplanet telescope missions in development (e.g. WFIRST/AFTA and ATLAST).

Spectral image cubes will be available for download from a NASA website once finalized.

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Contributing team(s): the Haystacks Team

258.17 – A re-analysis of planet candidates common to the HARPS and Anglo-Australian Planet Search

We present a re-analysis of HARPS spectra using a new extraction technique that includes a 2-dimensional description of the PSF. Additionally, to compute our Doppler velocities we use a spectrum matching technique that builds a reference spectrum from the observations of the target star. This method allows the breaking up of the spectrum into small chunks that can be treated independently and provide a more reliable estimate of the velocity error. The independently-derived HARPS velocities are combined with data from the 16-year Anglo-Australian Planet Search to confirm the claims of planets for selected targets common to both surveys. Our new Keplerian solutions refine the orbits of some planetary systems and cast doubt on the veracity of other planet candidates.

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258.18 – RV Search for Young Hot Jupiters in the Infrared

We present initial findings from our infrared RV survey of young stars in search of young hot Jupiters utilizing high dispersion IR (2.3micron) spectra from the Phoenix spectrograph formerly on Gemini South and from the CRIRES instrument on VLT. This survey of young (8-12Myr) associations using multi-epoch RV data has yielded 2 candidate RV variables, and 2 spectroscopic binaries, including a known double star in the Tuc-Hor association making it a triple system. Our technique uses telluric features as an absolute wavelength reference, allowing us to achieve a precision of

~40m/s for slowly rotating field stars. Although RV jitter is lower at IR wavelengths, it is still ~100m/s, thus limiting our sensitivity to hot Jupiters.

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258.19 – Giant Planet Candidates, Brown Dwarfs, and Binaries from the SDSS-III MARVELS Planet Survey.

We report the discoveries of giant planet candidates, brown dwarfs, and binaries from the SDSS-III MARVELS survey. The finalized 1D pipeline has provided 18 giant planet candidates, 16 brown dwarfs, and over 500 binaries. An additional 96 targets having RV variability indicative of a giant planet companion are also reported for future investigation. These candidates are found using the advanced MARVELS 1D data pipeline developed at UF from scratch over the past three years. This pipeline carefully corrects most of the instrument effects (such as trace, slant, distortion, drifts and dispersion) and observation condition effects (such as illumination profile, fiber degradation, and tracking variations). The result is long-term RV precisions that approach the photon limits in many cases for the ~89,000 individual stellar observations. A 2D version of the pipeline that uses interferometric information is nearing completion and is demonstrating a reduction of errors to half the current levels. The 2D processing will be used to increase the robustness of the detections presented here and to find new candidates in RV regions not confidently detectable with the 1D pipeline. The MARVELS survey has produced the largest homogeneous RV measurements of 3300 V=7.6-12 FGK stars with a well defined cadence of 27 RV measurements over 2 years. The MARVELS RV data and other follow-up data (photometry, high contrast imaging, high resolution spectroscopy and RV measurements) will explore the diversity of giant planet companion formation and evolution around stars with a broad range in metallicity (Fe/H -1.5-0.5), mass (0.6-2.5M(sun)), and environment (thin disk and thick disk), and will help to address the key scientific questions identified for the MARVELS survey including, but not limited to: Do metal poor stars obey the same trends for planet occurrence as metal rich stars? What is the distribution of giant planets around intermediate-mass stars and binaries? Is the “planet desert” within 0.6 AU in the planet orbital distribution of intermediate-mass stars real?

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Contributing team(s): SDSS-III MARVELS Team

258.20 – Illumination Profile & Dispersion Variation Effects on Radial Velocity Measurements

The Multi-object APO Radial-Velocity Exoplanet Large-Area Survey (MARVELS) measures radial velocities using a fiber-fed dispersed fixed-delay interferometer (DFDI) with a moderate dispersion spectrograph. This setup allows a unique insight into the 2D illumination profile from the fiber on to the dispersion grating. Illumination profile investigations show large changes in the profile over time and fiber location. These profile changes are correlated with dispersion changes and long-term radial velocity offsets, a major problem within the MARVELS radial velocity data. Characterizing illumination profiles creates a method to both detect and correct radial velocity offsets, allowing for better planet detection. Here we report our early results from this study including improvement of radial velocity data points from detected giant planet candidates. We also report an illumination profile experiment conducted at the Kitt Peak National Observatory using the EXPERT instrument, which has a DFDI mode similar to MARVELS. Using profile controlling octagonal-shaped fibers, long term offsets over a 3 month time period were reduced from ~50 m/s to within the photon limit of ~4 m/s.

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Contributing team(s): SDSS-III

258.21 – Precise Near-Infrared Radial Velocities

We present precise radial velocity time-series from a 2.3 micron near-infrared survey to detect exoplanets around ~30 red, low mass, and young stars. We use the CSHELL spectrograph (R~46,000) at the NASA InfraRed Telescope Facility, combined with an isotopic methane absorption gas cell for common optical path relative wavelength calibration. We have developed a sophisticated RV forward modeling code that accounts for fringing and other instrumental artifacts present in the spectra (see poster by Gao et al. at this meeting). We are able to reach long-term radial velocity dispersions of ~15-30 m/s on our survey targets. With a spectral grasp of only 5 nm, this performance is near the expected photon and detector noise limit. We highlight future applications of our instrumentation and RV forward modeling code to iSHELL at IRTF (R~75,000), and an upgraded NIRSPEC on the Keck II telescope (R~50,000). With the increased spectral grasp of both spectrometers, we should be able to obtain a precision of less than 5 m/s in the near-infrared.

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258.22 – Retrieval of Precise Radial Velocities from High Resolution Near-Infrared Spectra of M Dwarfs

We present a data analysis pipeline focused on obtaining precision radial velocities (RV) of M Dwarfs from spectra taken between 2.309 and 2.316 microns by the CSHELL spectrograph (R~46,000) at NASA's Infrared Telescope Facility with the aid of a methane isotopologue gas cell (see poster by Plavchan et al. at this meeting). The pipeline compares the observed spectra with a forward model defined by parameters that are optimized using a simplex amoeba algorithm. The stellar template is optimized simultaneously with the fit parameters in an iterative process. The pipeline accounts for temporal variations in the spectral wavelength solution, line spread function, and interference fringes due to instrumental effects. We apply our pipeline to the M Dwarfs GJ 15 A and GJ 876 and the M Giant SV Peg. For GJ 15 A, we are able to obtain 30 m/s RV precision. For the planet host GJ 876, the two most massive planets are easily retrievable from our RV curve. For SV Peg, the single night RV precision can be as low as 15 m/s, with < 5 m/s obtainable through data stacking.

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258.23 – The Habitable-zone Planet Finder (HPF): Achieving high precision radial velocities and mitigating stellar activity noise

HPF is a stabilized, fiber-fed, near infrared (NIR) spectrograph currently being built at Penn State for the 10m Hobby-Eberly Telescope (HET). HPF will be capable of discovering low mass planets in the Habitable Zones of mid-late M dwarfs via radial velocity (RV). We discuss the development of critical sub-systems like our high-stability temperature control system, vacuum cryostat, and implementation of new wavelength calibration techniques. The design of the HET enables queue-scheduled operation, but its variable pupil requires attention to both near- and far-field fiber scrambling, which we accomplish with double scramblers and octagonal fibers.
HPF will provide partial bandwith coverage of the information-rich z, Y and J NIR bands at a spectral resolving power of R$\sim$50,000. While stellar activity induced RV noise is lower in the NIR than at visible wavelengths, we have carefully included NIR activity indicators in our spectral bandpass to help discriminate stellar activity from real planet signals, as has been recently demonstrated for Gliese 581 and Gliese 667C systems.

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258.24 – Spotting Spots: Simulating Stellar Noise for Spot Detection

Stellar noise masks planetary signals and prevents the detection of low-mass exoplanets. In order to identify and eventually subtract noise originating from starspots, we constructed a simulator that models spot-based periodic variations. Given smoothed radial velocity (RV) data, our simulator calculates basic stellar parameters and the fractional surface area covered by starspots for the target star. We applied the simulator to Tau Ceti RV measurements taken with the CHIRON spectrometer in the hopes of determining whether coherent signals exhibited in the data are planetary or spot-based in nature. The results were then compared with the starspot activity of Tau Ceti-like stars in the Kepler database to assess the reliability of the simulator. This work aims to produce an effective tool for future identification and removal of starspot noise, and facilitate further discoveries of low-mass exoplanets.

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258.25 – MINERVA: A Dedicated Observatory for Detection of Nearby Low-Mass Exoplanets

Detection of low-mass planets around GKM stars requires sub-meter-per-second radial velocity precision. Stellar noise sources (starspots, oscillations, and granulation) necessitate high cadence observations. MINERVA is a dedicated observatory for velocimetric detection of low mass exoplanets orbiting nearby stars. Our array of four robotic 0.7-meter PlaneWave telescopes feeds a purpose-built, temperature-stabilized, iodine cell spectrometer from Callaghan Innovation. We will monitor bright, sun-like stars within 100 pc every clear night from Whipple Observatory on Mt Hopkins, Arizona. Each telescope is also equipped with an Andor CCD for followup photometry and education use. Commissioning is underway on the site and science observations will begin in early 2015.

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258.26 – Optimization of the MINERVA Exoplanet Search Strategy via Simulations

Detection of low-mass exoplanets requires high spectroscopic precision and high observational cadence. MINERVA is a dedicated observatory capable of sub meter-per-second radial velocity precision. As a dedicated observatory, MINERVA can observe with every-clear-night cadence that is essential for low-mass exoplanet detection. However, this cadence complicates the determination of an optimal observing strategy. We simulate MINERVA observations to optimize our observing strategy and maximize exoplanet detections. A dispatch scheduling algorithm provides observations of MINERVA targets every day over a three-year observing campaign. An exoplanet population with a distribution informed by *Kepler* statistics is assigned to the targets, and radial velocity curves induced by the planets are constructed. We apply a correlated noise model that realistically simulates stellar astrophysical noise sources. The simulated radial velocity data is fed to the MINERVA planet detection code and the expected exoplanet yield is calculated. The full simulation provides a tool to test different strategies for scheduling observations of our targets and optimizing the MINERVA exoplanet search strategy.

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Contributing team(s): MINERVA

258.27 – Autonomous Observing and Planet Discovery with the Automated Planet Finder (APF)

The Automated Planet Finder (APF) is a dedicated, ground-based precision radial velocity facility located at Lick Observatory, operated by University of California Observatories (UCO). The 2.4-m telescope and accompanying high-resolution echelle spectrograph were specifically designed for the purpose of detecting planets in the habitable zone of low-mass stars. The telescope is operated every night (weather permitting) to achieve meaningful signal-to-noise gains from high cadence observing and to avoid the aliasing problems inherent to planets whose periods are close to the lunar month.
The APF has been taking science quality data for over a year and has contributed to two planet discovery papers with data at a 1 m/s level of precision. The detection of these planets, especially the Uranus mass planet around GL687, indicates that the APF telescope is well suited to the discovery of low-mass planets orbiting low-mass stars in the as-yet relatively un-surveyed region of the sky near the north celestial pole.
To take full advantage of the consistent influx of data it is necessary to analyze each night's results before deciding the next evening's targets. We are in the process of developing a fully automated reduction pipeline that will take data from raw FITS files to final radial velocity values and integrate those values into a master database. The database is then run through the publicly available Systemic console, a publically available software package for the analysis and combined multiparameter fitting of Doppler radial velocity observations. Systemic will re-calculate the possibility of planetary signals in the data and use this value, along with other considerations such as the star's brightness and chromospheric activity level, to assign it a priority rating for future observations.
When the telescope is again on sky it uses a suite of stellar and atmospheric calibrations derived from the part year's observations to calculate the expected exposure time for each potential target given its desired radial velocity precision. Our in-house dynamic scheduler, Heimdallr, then combines this information with each star's observing priority to select the optimal target for that particular time and date.

Author(s): Jennifer Burt[2], Russell Hanson[2], Bradford Holden[2], R. Paul Butler[1], Steven S. Vogt[2], Greg Laughlin[2]
Institution(s): *1. Carnegie Institute of Washington, 2. University of California - Santa Cruz*

258.28 – Stellar Radial Velocities with Subaru/IRCS and an Ammonia Absorption Cell

The search for exoplanets orbiting low-mass stars is an exciting frontier in astronomy. The Doppler technique is a powerful tool for detecting exoplanets and has worked extremely well for Sun-like stars. Doppler measurements are made with a 'spectral ruler,' such as an Iodine absorption cell, which allows for the precise measurement of shifts in the stellar spectrum. Observing low-mass stars at infrared wavelengths presents a number of challenges. One challenge is the need for an alternative to the Iodine cell, since the Iodine spectrum is relatively featureless at infrared wavelengths. In this poster, we present a technique that uses an Ammonia absorption cell as a simultaneous wavelength reference. Using data from the Subaru Telescope's Infrared Camera and Spectrograph (IRCS) and forward-modeling the Ammonia spectrum, we show it is possible to make precise radial velocity measurements in the infrared.

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Institution(s): *1. National Astronomical Observatory of Japan, 2. University of Pennsylvania*

258.29 – The Spectroastrometric Detection of Exomoons

Although nearly two thousand exoplanets have been discovered and confirmed to date, no exomoons have yet to be detected orbiting these planets. The presence of a moon could give insight into planetary formation, and may also provide interesting possibilities concerning extrasolar habitability. This project proposes a new method for exomoon detection that would require only one observational exposure using a space telescope equipped with a spectrograph and a starlight-blocking coronagraph. Current telescopes are not capable of spatially resolving a planet and its moon – their light combines, thus appearing like one object. However, a moon may shine brighter than its planetary host at wavelengths where the planet is dim, perhaps due to atmospheric absorption. Because the center of light is weighted toward the more luminous object, we expect to see the centroid wobble between the moon and its planet when observing in different spectral bands - the spectroastrometric signal. For this project, we used model spectra of a warm Jupiter with the Earth as its moon, orbiting a sun-like star at 1 AU. Using this method, we simulated the spectroastrometric detection, and obtained the highest signal to noise ratio (SNR) when observing between the 0.92 µm methane absorption band and the spectroscopic M-band at low spectral resolutions. Similarly, for an Earth-Moon system like our own, the highest SNR was obtained between the 6.6 µm water vapor absorption band and 0.44 µm. Our simulation determined the need for an 18-meter telescope to obtain the minimum SNR required for the detection of both systems for distances within about 10 light years. These results show that the spectroastrometric detection of exomoons is possible for systems such as those presented here. Further work will apply this method to known exoplanetary systems in order to simulate the probability of an exomoon detection.

Author(s): Tiffany C. Jansen[1], Brianna Lacy[1], Tyler D. Robinson[1], Eric Agol[1]
Institution(s): *1. University of Washington*
Contributing team(s): The Virtual Planetary Laboratory

258.30 – Differential Astrometry to detect giant planets around A-stars

The exoplanet field has remained vibrant and exciting due to the continuous development of new observing techniques and the refinement of older ones, both from the ground and from space. Here we propose to push the exoplanet frontier through the development of a new interferometric experiment that takes advantage of the Michigan Infrared Combiner (MIRC) on the CHARA Array, a visible and near-infrared interferometer boasting the longest baselines and finest angular resolution in the world. The ARMADA (ARrangement for Micro-Arcsecond Differential Astrometry) Project will search for astrometric wobble in a sample of hot stars (spectral type A,B) to search for giants planets in P$<$3 year orbits. Recent radial velocity (RV) work studying evolved sub-giants --``retired A stars" -- suggest up to a five-fold increase in the presence of massive gas giant planets in about 1 AU orbits compared to solar-type stars. Confirmation of this disputed result on A stars themselves would have profound effect on theories of planet formation but is difficult or impossible due to the broad, weak lines of hot stars. Using a novel etalon module already designed and fabricated to maintain precision wavelength calibration (Dl/l ~$1x10^{-5}$), we aim to measure separations with <10 *micro*-arcsecond-level precision for binaries up to 0.25” separation.

Author(s): John D. Monnier[4], Keith Johnson[4], Samuel Swihart[4], Michael Ireland[1], Ming Zhao[3], Theo Ten Brummelaar[2]
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258.31 – Short duration microlensing events: Searching for rogue planets

Einstein described gravitational microlensing in 1936, at the same time suggesting it to be an unobservable phenomenon. He did not foresee technological advancements that would lead to microlensing becoming a productive tool for astronomy. Of particular interest may be the role it has begun to play in the discovery of rogue planets - exoplanets that are not bound to a star or stars. Rogue planets may be formed independently, or they may be formed in the confines of a stellar system and then ejected by gravitational interactions. Currently fewer than a dozen rogue planets are known but estimates of their abundance conservatively start at double the number of stars in our galaxy. The Optical Gravitational Lensing Experiment (OGLE) and Microlensing Observations in Astrophysics (MOA) teams have collectively detected approximately 2500 events this year alone. A significant portion of these events are of short duration, with an Einstein crossing time of less than 10 days. Microlensing events generally occur on a timescale of weeks to months, so short duration events are an interesting class for study, particularly with regard to searches for rogue planets. We have undertaken a systematic study and categorization of the short duration microlensing events from recent OGLE and MOA alerts, with a special eye to identifying exoplanet candidates.

Author(s): Kathryn E. St. Laurent[2], Rosanne Di Stefano[1], Francis A. Primini[1], Wei Peng Lew[1], Lai Su Gau[1], Sophie Benson[1]
Institution(s): *1. Harvard-Smithsonian CfA, 2. UMass Dartmouth*
Contributing team(s): The Optical Gravitational Lensing Experiment, Microlensing Observations in Astrophysics

258.32 – The Subaru SEEDS Direct Imaging Survey for Planets of Early-Type Stars

We present results from the Subaru SEEDS sub-program to search for extrasolar planets around early-type (mostly A-type) stars. SEEDS, the Strategic Exploration of Exoplanets and Disks with Subaru, is a multi-year, direct-imaging survey to explore the link between planets and disks, and the evolution of protoplanetary systems and debris disks. With first observations carried out in 2009, the early-type star sub-program uses the Subaru 8-meter Telescope, the AO188 adaptive optics system, the HiCIAO near infrared science camera, and an Angular Differential Imaging observing procedure to distinguish faint orbiting companions from the overwhelming light of the parent star. We summarize progress to date, including the nature of our data processing techniques, improved software sensitivities, and our prior discovery of the 'Super-Jupiter' Kappa Andromedae b.

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Contributing team(s): SEEDS Survey Team

259 – Probe-Scale Exoplanet Mission Concepts Posters

259.01 – Probe-Scale Mission Concepts for Direct Imaging and Spectroscopy of Nearby Exoplanet Systems

Two mission concepts are now under study for detecting visible light from exoplanets orbiting nearby stars through high-contrast imaging and for characterizing them through spectroscopy. Exo-S uses a starshade (external occulter) that flies in front of a telescope to block out the central starlight; Exo-C uses a coronagraph with an internal occulter to accomplish the suppression of starlight. Both concepts have the objective of taking optical spectra of nearby exoplanets in reflected light, searching for previously undetected planets, and imaging structure in circumstellar debris disks.
The concepts are being developed by two NASA-selected community-led Science and Technology Definition Teams (STDTs), supported by study design teams from NASA's Exoplanet Exploration Program. In addition to developing concepts with an estimated cost ~$1B, the Teams are identifying key enabling technologies needed for their designs. These concepts complement existing NASA missions that do exoplanet science (such as transit spectroscopy and debris disk imaging with HST and Spitzer) or are under development or active study (TESS, JWST, WFIRST-AFTA).
Final Reports from the two studies will be published in early 2015. This poster serves as an introduction to a series of posters featuring the two studies. At the conclusion of the studies in early 2015, NASA will evaluate them for further technology development and possible development as flight missions. This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. © 2015 California Institute of Technology. Government sponsorship acknowledged.

Author(s): Stephen C. Unwin[2], Sara Seager[3], Karl R. Stapelfeldt[1], Keith Warfield[2], Frank G Dekens[2], Gary Blackwood[2]
Institution(s): *1. GSFC, 2. JPL, 3. MIT*
Contributing team(s): Exo-S Science and Technology Definition Team, Exo-C Science and Technology Definition Team, JPL Probe Study Design Teams

259.02 –
Exoplanet Science with a Starshade: Exo-S Study Results

"Exo-S" is NASA's first community-directed study of a starshade (or "external occulter") plus telescope system for a space-based direct imaging mission to discover and spectrally characterize exoplanets. The Exo-S final report will be submitted in early 2015, and it includes two options: (1) a standalone mission using a modest aperture (1.1-m) space telescope launched together with a 30-m starshade, and (2) a 34-m starshade launched independently to rendezvous with an existing larger space telescope (in this case we specifically consider WFIRST/AFTA). In this poster we present the estimated science yields. Both options can image nearby exo-Earths, sub-Neptunes, and previously known and newly discovered Jupiters. Both missions can characterize the atmospheres of giant planets with low-resolution spectroscopy, while the larger mission can also characterize exo-Earths and mini-Neptunes. Once the study has concluded, NASA will evaluate the Exo-S concept for potential future development.

Author(s): Margaret C. Turnbull[1], Sara Seager[3], Aki Roberge[4], Shawn Domagal-Goldman[4], Stuart Shaklan[2]

Institution(s): *1. Global Science Institute, 2. JPL, 3. MIT, 4. NASA GSFC*
Contributing team(s): Exo-S Science and Technology Definition Team

259.03 – Imaging Exoplanets with the Exo-S Starshade Mission: Key Enabling Technologies

There is increasing interest in the use of a starshade, a spacecraft employing a large screen flying in formation with a space telescope, for providing the starlight suppression needed to detect and characterize exoplanets. In particular, Exo-S is a NASA study directed at designing a probe-scale exoplanet mission employing a starshade. In this poster we present the enabling technologies needed to make a starshade mission a reality: flight-like petals, a deployable truss to support the petals, optical edges, optical diffraction studies, and formation sensing and control. We show the status of each technology gap and summarize our progress over the past 5 years with plans for the next 3 years in demonstrating feasibility in all these areas. In particular, since no optical end-to-end test is possible, it is necessary to both show that a starshade can be built and deployed to the required accuracy and, via laboratory experiments at smaller scale, that the optical modeling upon which the accuracy requirements are based is validated. We show our progress verifying key enabling technologies, including demonstrating that a starshade petal made from flight-like materials can be manufactured to the needed accuracy and that a central truss with attached petals can be deployed with the needed precision. We also summarize our sub-scale lab experiments that demonstrate we can achieve the contrast predicted by our optical models.

Author(s): N. Jeremy Kasdin[2], Doug Lisman[1], Stuart Shaklan[1], Mark Thomson[1], David Webb[1], Eric Cady[1]
Institution(s): *1. Jet Propulsion Laboratory, 2. Princeton University*
Contributing team(s): Exo-S Science and Technology Definition Team, Exoplanet Program Probe Study Design Team

259.04 – Imaging Exoplanets with the Exo-S Starshade Mission: Baseline Design

Starshades suppress on-axis starlight to enable the direct imaging of exoplanets with non-specialized space telescopes of variable size. Even relatively small, commercially available telescopes are capable of imaging Earth-like planets in the habitable zone, and larger telescopes provide the capability to characterize planet atmospheres with increasing spectral resolution. We detail two options developed by the STDT for probe-class starshade missions (Exo-S): a co-launch of a starshade with a dedicated 1.1m telescope, and a standalone starshade to augment an existing large telescope such as WFIRST-AFTA. For these concepts, we describe the optical and mechanical design, the formation flying system, and the augmentations required to make a telescope “starshade-ready”. We also lay out typical design reference missions for each and their scientific yield, and show both concepts have the capability to image terrestrial exoplanets orbiting nearby stars.

Author(s): Eric Cady[1], Doug Lisman[1], Stefan Martin[1], Daniel Scharf[1], Stuart Shaklan[1], Rachel Trabert[1], David Webb[1]
Institution(s): *1. Jet Propulsion Laboratory*
Contributing team(s): Exo-S Science and Technology Definition Team, Exoplanet Program Probe Study Design Team

259.05 – High Contrast Science Program for the Exo-C Space Telescope Mission

Exo-C is a detailed study of the science capability, engineering design, technology requirements, and costing for a modest-aperture space telescope with an internal coronagraph that could directly image exoplanetary systems. During its three year mission, Exo-C will carry out imaging and spectroscopy over the wavelength range 0.45-1.0 um towards the following goals: 1) Characterize the atmospheres of at least a dozen known, nearby radial velocity planets. Exo-C spectra will diagnose their atmospheric composition and the presence of clouds, performing the first such measurements of cool giant exoplanets like those in our own solar system. 2) Conduct an imaging survey of at least 100 additional nearby stars down to ~3e-10 contrast, enabling the discovery of new exoplanets down to super-Earth sizes. Sub-Neptune and super-Earth planets are relatively common in the exoplanet population, but have no counterparts in our Solar System. Exo-C spectra will provide the first atmospheric characterization for these intriguing objects. 3) Image several hundred circumstellar disks, revealing structures induced by planetary perturbations and the time evolution of disk properties. If exozodi is low and a very stable telescope can be achieved, habitable zone planets down to Earth size might be detected in a small sample of nearby stars including the alpha Cen system. Science targets, observing protocols, and future work will be discussed.

Author(s): Karl R. Stapelfeldt[3], Mark S. Marley[2], Geoffrey Bryden[1], Victoria Meadows[4], Ruslan Belikov[2], Michael W. McElwain[3]
Institution(s): *1. Jet Propulsion Laboratory / Caltech, 2. NASA Ames Research Center, 3. NASA Goddard Space Flight Center, 4. University of Washington*
Contributing team(s): Exo-C Science and Technology Definition Team

259.06 – Exo-C: Mission and Science Payload Design

We present NASA's Exoplanet Coronagraph (Exo-C) mission design and science payload completed as part of a probe-class concept study under consideration for launch following JWST. The payload consists of an unobscured Cassegrain telescope with a 1.4-m clear aperture, a barrel assembly, and an internal coronagraph instrument. The mission has a 3 year lifetime and is in a highly stable Earth-trailing orbit. The coronagraph instrument is mounted laterally on the anti-Sun side of the telescope, obviating the need for high incidence reflections and better isolating it from spacecraft disturbances. The instrument has both an Imaging Camera and an Integral Field Spectrograph (IFS). The former obtains filter imaging with 1e−9 raw contrast from 2 − 20 λ/D in radius, while the IFS delivers the same contrast with spectral resolution of R = 70 from 450 to 1000 nm, but with a reduced outer working angle.

The Exo-C science performance requirements are achieved with a specialized observatory design enabled by several new technologies. The telescope is designed for precision pointing and high stability to maintain a slowly evolving speckle pattern. Vibration isolation is achieved with two stages between the reaction wheels and the science payload. The solar arrays and high gain antenna are body-fixed, and a stiff barrel assembly is used as the telescope metering structure. Telescope pointing is updated at a high rate by monitoring the bright science target star with a low order wavefront sensor and driving a fine steering mirror for compensation. Active thermal control is used to minimize thermal drifts of the telescope, instrument, and barrel assemblies. Stability analyses via modeling of the structural, thermal, and optical performance of this configuration show that the proposed mission configuration would enable unprecedented exoplanet and circumstellar disk science with direct imaging.

Author(s): Frank G Dekens[2], Karl R. Stapelfeldt[1], Keith Warfield[2], Stephen C. Unwin[2]
Institution(s): *1. GSFC, 2. JPL*
Contributing team(s): Exo-C Science and Technology Definition Team, Exo-C JPL Study Design Team

259.07 – Enabling Technologies for Characterizing Exoplanet Systems with Exo-C

The Exoplanet Science and Technology Definition Team's Internal Coronagraph mission design, called "Exo-C", utilizes several technologies that have advanced over the past decade with support from the Exoplanet Exploration Program. Following the flow of photons through the telescope, the science measurement is enabled by (i) a precision pointing system to keep the target exoplanet system precisely positioned on the detector during the integration time, (ii) high-performance coronagraphs to block the parent star's light so that the planet's reflected light can be detected, (iii) a wavefront control system to compensate for any wavefront errors such as those due to thermal or mechanical deformations in the optical path, especially errors with high spatial frequencies that could cause contrast-reducing speckles, and (iv) an integral field spectrograph (IFS) that provides moderate resolution spectra of the target exoplanets, permitting their characterization and comparison with models and other data sets. Technologies such as the wavefront control system and coronagraphs will also benefit from other funded efforts in progress, such as the Wide Field Infrared Survey Telescope Astrophysics Focused Telescope Assets (WFIRST-AFTA) program. Similarly, the Exo-C IFS will benefit from the Prototype Imaging Spectrograph for Coronagraphic Exoplanet Studies (PISCES) demonstration. We present specific examples for each of these technologies showing that the state of the art has advanced to levels that will meet the overall scientific, cost, and schedule requirements of the Exo-C mission. These capabilities have matured with testbed and/or ground-telescope demonstrations and have reached a technological readiness level (TRL) that supports their inclusion in the baseline design for potential flight at the end of this decade. While additional work remains to build and test flight-like components (that concurrently meet science as well as size, weight, power, and environmental requirements) and to integrate these subsystems together for a hardware-in-the-loop end-to-end demonstration, the overall readiness of the suite of enabling technologies makes a compelling case for Exo-C among the exoplanet direct imaging mission candidates.

Author(s): Kerri Lynn Cahoy[1], Ruslan Belikov[2], Karl R. Stapelfeldt[3], Supriya Chakrabarti[5], John T. Trauger[4], Eugene Serabyn[4], Michael W. McElwain[3], Christopher M. Pong[4], Paul Brugarolas[4]
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260 – Astrobiology Posters

260.01 – On the thermal, magnetic, and orbital evolution of tidally heated Earth-mass exoplanets

The thermal and magnetic evolution of terrestrial planets influences surface tectonics, outgassing rates, atmospheric composition, and magnetic shielding, all of which are important habitability factors. We focus here on the habitable zone around M-stars where tidal heating is likely important and tidal locking is expected. Our model couples the thermal, magnetic, and orbital evolution to explore how tidal dissipation in the interior influences these habitability factors. Internal heat generated by radioactive decay and tidal dissipation is balanced by convective and advective (melt) heat loss. This balance controls the cooling rate of the interior and the geological time over which a planet may be habitable. Efficient heat transport can cool the core fast enough to drive thermal convection by a superadiabatic heat flow, compositional convection associated with the crystallization of the inner core, or both. Tidal dissipation drives orbital migration, which in turn influences the tidal heating rate and surface insolation. We identify habitability regimes where mantle cooling is efficient enough to maintain an Earth-like core dynamo and moderate volatile degassing rates, and regimes where the planet is not habitable due to either (i) a long lived magma ocean, (ii) a runaway greenhouse associated with excessive insolation or rapid outgassing, or (iii) no magnetic field due to the suppression of convection in the core. The composition and surface tectonics of terrestrial exoplanets is unknown, but future observations of atmospheric composition and magnetic field cyclotron emissions can test these predictions.

Author(s): Peter E. Driscoll[1], Rory Barnes[1]
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260.02 – Enumerating the Progress of SETI Observations

In a long-term project like SETI, accurate archiving of observations is imperative. This requires a database that is both easy to search – in order to know what data has or hasn't been acquired – and easy to update, no matter what form the results of an observation might be reported in. If the data can all be standardized, then the parameters of the nine-dimensional search space (including space, time, frequency (and bandwidth), sensitivity, polarization and modulation scheme) of completed observations for engineered signals can be calculated and compared to the total possible search volume. Calculating a total search volume that includes more than just spatial dimensions needs an algorithm that can adapt to many different variables, (e.g. each receiving instrument's capabilities). The method of calculation must also remain consistent when applied to each new SETI observation if an accurate fraction of the total search volume is to be found. Any planned observations can be evaluated against what has already been done in order to assess the efficacy of a new search. Progress against a desired goal can be evaluated, and the significance of null results can be properly understood.
This paper describes a new, user-friendly archive and standardized computational tool that are being built at the SETI Institute in order to greatly ease the addition of new entries and the calculation of the search volume explored to date. The intent is to encourage new observers to better report the parameters and results of their observations, and to improve public understanding of ongoing progress and the importance of continuing the search for ETI signals into the future.

Author(s): Lindsay Lesh[1], Jill C. Tarter[2]
Institution(s): *1. Bowling Green State University, 2. The SETI Institute*

260.03 – Detecting Traces of Life in the Plume of Enceladus

Saturn's moon Enceladus presents one of the most promising bodies in the solar system on which to detect (at least traces of) extraterrestrial life. We present a study of biomarkers in the plume. A variety of potential biomarkers were considered and their applicability to the plume was assessed. Our study focused primarily on the relative abundances of hydrocarbons to methane, and amino acids. Concentrations of these biomarkers were estimated by combining data from studies of methanogenic and hydrothermal communities with a plume density model. We studied mass spectrometry as a possible means to detect these indicators of life. We performed a parameterized study by considering mass spectrometers with a sensitivity of 10, 100, and 1000 times that of Cassini's mass spectrometer. Promisingly, the concentration of biogenic hydrocarbons is around an order of magnitude higher than the detection threshold of the most sensitive mass spectrometer we considered. Therefore, analysis of such hydrocarbons on a future mission is a promising approach to detecting biochemical processes within Enceladus.

Author(s): Daniel M. Krolikowski[2], Jonathan I. Lunine[1]
Institution(s): *1. Cornell University, 2. State University of New York, College at Geneseo*

260.04 – Habitability of Planets Orbiting Binaries Consisting of Solar Mass Twins

An important problem in astrobiology is the study of the potential habitability of planets orbiting binary stars. Theoretical and observational studies of circumbinary planets indicate that it is not uncommon for circumbinary planets to be located in the habitable zones surrounding main sequence binaries. However, it is also clear that the time evolution of stellar activity of the individual stars in close binaries is of primary concern for the habitability of planets. For example, planets orbiting active stars may lose the entirety of their water budget due to atmospheric mass loss; despite being in the standard radiative habitable zone. Alternatively, stars in some binaries may undergo a reduction in stellar activity due to tidal effects that cause the rotation of the stars to slow faster than single stars. Thereby, magneto-coronal activity is reduced to less aggressive levels, allowing circumbinary planets to maintain surface water. We summarize these effects, which we call the Binary Habitability Mechanism (BHM). We performed orbital integrations of circumbinary, Earth-like, planets and find that resonances play a particularly important role in the stability of habitable zone planets orbiting solar twin binaries in the 20-60 day period range, allowing for the possibility of several habitable planets orbiting some binaries. We present numerical simulations of the effects of colliding winds in binaries containing solar mass twins. We used stellar wind parameters based on solar like conditions for our 3D hydrodynamic simulations. We find devastating effects for close in planets, yet relatively mild stellar wind conditions exist within the circumbinary habitable zone.

Author(s): **Paul A. Mason**[3], Jorge I Zuluaga[1], Andrey G Zhilkin[2], Dmitry V Bisikalo[2]
Institution(s): *1. Harvard, Visiting Fulbright Scholar, 2. Russian Academy of Sciences, Institute for Astronomy, 3. Univ. Of Texas at El Paso*

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300 – Plenary Talk: The Interactions of Exoplanets with their Parent Stars, Katja Poppenhaeger (Harvard-Smithsonian Center for Astrophysics)

300.01 – The Interactions of Exoplanets with their Parent Stars

Many exoplanets orbit their parent stars at close distances, with semimajor axes of only a few stellar radii. It is therefore a long-standing question if such close-in planets can influence the physical properties of their host stars, especially their magnetic activity level. While cool stars usually spin down with age and become inactive, an input of angular momentum through tidal interaction, as seen for example in close binaries, can preserve high activity levels over time. This may also be the case for cool stars hosting massive, close-in planets. A variety of magnetic interaction scenarios has also been explored in models. However, selection effects from planet detection methods may skew the activity levels seen in samples of exoplanet host stars, so caution is warranted. Several observational and theoretical advances have been made in studying the interactions between exoplanets and their host stars, and I will review these developments and outline the observational opportunities arising with current and upcoming telescopes.

Author(s): Katja Poppenhaeger[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics*

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301 – Cosmology I

301.01 – Gravitational wave signature in B-modes and the power in ΛCDM models on large and small scales

The cosmic microwave background (CMB) angular power spectrum has a drop in power at low multipoles (large scales), which is in tension with the standard ΛCDM + power-law spectrum model. This deficit is exacerbated if there is a significant tensor contribution to the CMB power spectrum, as recently suggested by the BICEP2 results. We show that this deficit appears naturally in the axion monodromy inflation model, where the inflaton potential contains a gentle oscillation, thus generating an oscillating power spectrum with a suppression of power at large scales while still achieving enough e-foldings to solve the horizon problem. Using a combined data set of Planck, ACT, and SPT temperature data along with WMAP polarization data, we find a best-fit tensor-to-scalar ratio r=0.07^{+0.06}_{-0.03} in this model. The BICEP2 result r ~ 0.2 is disfavored by the data at the 99% confidence level. We show further that this oscillating power spectrum will also suppress power on small-scales, alleviating the too-big-to-fail in dwarf galaxies. Conversely, if a large-field inflation model such as axion monodromy is responsible for the deficit of power at large and small scales, then the imprint of gravitational waves on the CMB should be observable by B-mode polarization experiments in the future.

Author(s): Quinn Eliot Minor[1], Manoj Kaplinghat[2]
Institution(s): *1. Borough of Manhattan Community College, 2. University of California, Irvine*

301.02 – New 21 cm Power Spectrum Upper Limits From PAPER I : Results from PAPER 64

We present power spectrum results from a new season of observations with the Donald C. Backer Precision Array for Probing the Epoch of Reionization (PAPER)-64. PAPER is a low frequency radio interferometer that aims to directly observe the Epoch of Reionization through the highly redshifted 21 cm transition. With more antennas, longer integration times, and an improved analysis pipeline, this represents further improvements upon existing published upper limits on the 21 cm power spectrum during reionization. This new upper limit enables stringent constraints on X-ray heating of the IGM during EoR.

Author(s): Zaki Shiraz Ali[1], Aaron Parsons[1], Jonathan Pober[2]
Institution(s): *1. University of California Berkeley, 2. University of Washington*
Contributing team(s): Team PAPER

301.03 – New 21 cm Power Spectrum Upper Limits From PAPER II: Constraints on IGM Properties at z = 7.7

Using a simulation-based framework, we interpret the power spectrum measurements from PAPER of Ali et al. in the context of IGM physics at z = 7.7. A cold IGM will result in strong 21 cm absorption relative to the CMB and leads to a 21 cm fluctuation power spectrum that can exceed 3000 mK^2. The new PAPER measurements allow us to rule out extreme cold IGM models, placing a lower limit on the physical temperature of the IGM. We also compare this limit with a calculation for the predicted heating from the currently observed galaxy population at z = 8.

Author(s): Jonathan Pober[2], Zaki Ali[1], Aaron Parsons[1]
Institution(s): *1. UC Berkeley, 2. University of Washington*
Contributing team(s): PAPER Team

301.04D – Epoch of Reionization observations from the first semester of data from the Murchison Widefield Array

The Murchison Widefield Array has collected over a thousand hours of data in an effort to characterize the stars and galaxies that drove the Epoch of Reionization. Teams from the US, Australia, and India are hard at work reducing the large volume of data to remove systematics, mitigate foregrounds, and reach a measurement of large scale hydrogen at redshifts 7 to 10. I will overview the US reference pipeline and present the first semester results.

Author(s): Adam Beardsley[1]
Institution(s): *1. University of Washington*
Contributing team(s): MWA Collaboration

301.05 – Reference MWA EoR Power Spectrum analysis

Observations of the Epoch of Reionization using redshifted 21cm HI emission promise to provide sensitive new cosmological constraints in the next few years. The current generation of HI EoR telescopes are targeting a statistical detection of the EoR in the power spectrum of the 21cm emission. The principal challenge lies in extracting the faint cosmological signal in the face of bright foregrounds and instrumental systematics that threaten to overwhelm it.
We present the UW EoR power spectrum code, the reference code for the MWA and the first power spectrum analysis to analytically propagate the error bars through the full data analysis pipeline. We demonstrate the sensitivity of the power spectrum as a diagnostic tool for identifying subtle systematics and show power spectra of the first season of MWA observations.

Author(s): Bryna Hazelton[1], Jonathan Pober[1], Adam Beardsley[1], Miguel F. Morales[1], Ian S. Sullivan[1]
Institution(s): *1. University of Washington*
Contributing team(s): MWA Collaboration

301.06 – The same with less: The cosmic web of warm versus cold dark matter dwarf galaxies

We explore fundamental properties of the distribution of low mass dark matter halos within the cosmic web using warm dark matter (WDM) and cold dark matter (CDM) cosmological simulations. Using self abundance-matched mock galaxy catalogs, we show that the distribution of dwarf galaxies in a WDM universe wherein low mass halo formation is heavily suppressed, is nearly indistinguishable to that of a CDM universe whose low mass halos are not seen because galaxy formation is suppressed below some threshold halo mass. However, if the scatter between dwarf galaxy luminosity and halo properties is large enough, low mass CDM halos would sometimes host relatively bright galaxies thereby populating CDM voids with the occasional isolated galaxy
and reducing the numbers of completely empty voids. Otherwise, without high mass to light scatter, all mock galaxy clustering statistics that we consider–the auto-correlation function, the numbers and radial profiles of satellites, the numbers of isolated galaxies, and the PDF of small voids–are nearly identical in CDM and WDM. WDM voids are neither larger nor emptier than CDM voids, when constructed from abundance- matched halo catalogs. It is thus a challenge to determine whether the CDM problem of the over-abundance of small halos with respect to the number density of observed dwarf galaxies has a cosmological solution or an astrophysical solution. However, some clues about the dark matter particle and the scatter between the properties of dwarf
galaxies and their dark matter halo hosts might be found in the cosmic web of galaxies in future surveys of the local volume.

Author(s): Darren Reed[1], Aurel Schneider[3], Robert E Smith[2], Joachim Stadel[3], Ben Moore[3]
Institution(s): *1. Barcelona (ICE - CSIC, IEEC), 2. Sussex, 3. University of Zurich*

301.07 – Comparison of Observed and Simulated Reionization Foregrounds from the Murchison Widefield Array

Foreground emission severely limits the detection of 21 cm emission from the epoch of reionization (EoR) at redshifts z > 6. Radio interferometer observations, through the instrumental transfer function, imprint chromatic signatures of foreground emission onto the measured power spectrum. We analyze these foreground signatures using the delay spectrum technique on an all-sky foreground model. The largest contamination in the EoR HI power spectrum is found to arise from foreground power received far away from the primary field of view. Comparing data from recent Murchison Widefield Array (MWA) observations with simulations separated into diffuse and compact components, we find diffuse emission near the horizon is a significant contributing factor, even on wide antenna spacings. Compact objects dominate the foreground contamination in the primary field of view. The resultant of these two mechanisms is a characteristic “pitchfork” signature in Fourier space. Based on these results, we propose a foreground mitigation technique of selectively down–weighting baselines based on length, direction, and time, which will remove a large fraction of foreground contamination in reionization HI power spectrum analysis.

Author(s): Nithyanandan Thyagarajan[1], Danny Jacobs[1], Judd D. Bowman[1]
Institution(s): *1. Arizona State University*
Contributing team(s): MWA EoR Collaboration

301.08 – Calibration and Imaging for next generation 21cm EoR arrays

Next generation radio interferometer arrays such as the SKA precursor MWA and PAPER are collecting thousands of hours and Petabytes of data probing the Epoch of Reionization. The exceptionally wide fields of view and deep integrations demand new precision calibration and imaging techniques to incorporate full direction- and antenna-dependent effects while remaining computationally efficient. We demonstrate results from the MWA, showing the flexible but powerful abilities of Fast Holographic Deconvolution (FHD) and describe an imaging pipeline for HERA.

Author(s): Ian S. Sullivan[1], Miguel F. Morales[1], Bryna Hazelton[1], Adam Beardsley[1]
Institution(s): *1. University of Washington*
Contributing team(s): MWA Collaboration

302 – Results from the SDSS-III/APOGEE Survey I

AAS Special Session
Our understanding of the structure, formation, and evolution of the Milky Way Galaxy is being revolutionized by a new generation of spectroscopic surveys and the recently launched astrometric Gaia satellite. At the forefront of these efforts is the SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE). APOGEE is a recently completed high-resolution, near-infrared (NIR) spectroscopic survey of more than 100,000 stars in the Milky Way disk, bulge, and halo. The bulk of these stars are luminous red giants that in the NIR can be traced out to distances of 10 kpc and beyond, providing us for the first time with a comprehensive view of the Galactic disk and bulge populations. The high-resolution spectra allow precise radial velocities and elemental abundances of 15 elements to be measured. This special session will present the exciting and varied scientific explorations allowed by the high-quality APOGEE data, including the chemodynamical structure of the Milky Way disk, the structure of the bulge, new methods to trace the interstellar medium with diffuse interstellar bands, constraints on stellar physics and Galactic structure from the combination of the APOGEE data with asteroseismology from Kepler and CoRoT, the structure of young nebulous clusters, and others. A presentation of the second stage of APOGEE in SDSS-IV (2014-2020), which will expand the sky coverage to the Southern hemisphere, will also be given. This Special Session will include a survey overview and a combination of invited and contributed talks and posters, highlighting important APOGEE science results from the full three-year survey.

302.01 – Apache Point Observatory Galactic Evolution Experiment (APOGEE): Status and Overview of Results

The Apache Point Observatory Galactic Evolution Experiment (APOGEE), one of four surveys in the Sloan Digital Sky Survey III (SDSS-III) has over the past three years collected more than 600,000 high-resolution (R~22,500), high quality (S/N > 100) spectra in the near-infrared H-band (1.51-1.68 µm) for about 155,000 stars covering all stellar populations of the Milky Way. The full data set will be released as part of SDSS-III’s Data Release 12 (DR12) in January 2015. I will present an overview of the APOGEE project and summarize some of the exciting science results generated by this large, detailed, spectroscopic survey of Milky Way stars.

Author(s): Jo Bovy[1], Steven R. Majewski[2]
Institution(s): *1. Institute for Advanced Study, 2. University of Virginia*
Contributing team(s): SDSS-III/APOGEE Collaboration

302.02 – Stellar Populations with APOGEE and Kepler

The history of the Milky Way is recorded in its stars, but dissecting stellar populations is not a straighforward process. Key information is gained by analyzing the absorption lines from high-resolution spectroscopy of stellar atmospheres by the APOGEE survey and analyzing the frequencies in power spectra of photometric lightcurves by Kepler Asteroseismic Science Consortium, in particular the large frequency separation and the frequency of maximum power. From spectroscopy, we measure effective temperature, rotation, metallicity and abundance ratios, while seismology provides gravities, rotation,
and evolutionary state. Combined, these two techniques yield other fundamental parameters such as mass and radius. I will discuss revolutionary insights into Galactic evolution gained by this extensive dataset.

Author(s): Jennifer Johnson[13], Marc H. Pinsonneault[13], Yvonne P Elsworth[15], Courtney R. Epstein[13], Saskia Hekker[10], Szabolcs Meszaros[6], William J Chaplin[15], Rafael Garcia[3], Jon A. Holtzman[11], Savita Mathur[14], Ana García Pérez[18], Sarbani Basu[19], Leo Girardi[5], Víctor Silva Aguirre[1], Matthew D. Shetrone[17], Dennis Stello[16], Thaise Rodrigues[5], Carlos Allende-Prieto[8], Deokkeun An[4], Paul Beck[3], Dmitry Bizyaev[2], Jo Bovy[7], Katia M. L. Cunha[12], Joris De Ridder[9], D Garcia-Hernandez[8]
Institution(s): *1. Aarhus University, 2. Apache Point Observatory, 3. CEA/DSM-CNRS, 4. Ewha Women's University, 5. INAF, Osservatorio Astronomico di Padova, 6. Indiana University, 7. Institute for Advanced Study, 8. Instituto de Astrofiscia de Canarias, 9. KU Leuven, 10. Max-Planck-Institut fur Sonnensystemforschung, 11. New Mexico State University, 12. Observatorio Nacional, 13. Ohio State Univ., 14. Space Science Institute, 15. University of Birmingham, 16. University of Sydney, 17. University of Texas at Austin, 18. University of Virginia, 19. Yale University*

302.03 – The INfrared Survey of Young Nebulous Clusters (IN-SYNC): Surveying the Dynamics and Star Formation Histories of Young Clusters with APOGEE

Young clusters are the most prolific sites of star formation in the Milky Way, but demographic studies indicate that relatively few of the Milky Way's stellar clusters persist as bound structures for 100 Myrs or longer. Uniform & precise measurements of the stellar populations and internal dynamics of these regions are difficult to obtain, however, particularly for extremely young clusters whose optical visibility is greatly hampered by their parental molecular cloud. The INfrared Survey of Young Nebulous Clusters (IN-SYNC), an SDSS-III ancillary science program, leverages the stability and multiplex capability of the APOGEE spectrograph to obtain high resolution spectra at near-infrared wavelengths, where photospheric emission is better able to penetrate the dusty shrouds that surround sites of active star formation. We summarize our recent measurements of the kinematics and stellar populations of IC 348 and NGC 1333, two young clusters in the Perseus Molecular Cloud, and of the members of the Orion Nebula Cluster (ONC) and L1641 filament in the Orion molecular complex. These measurements highlight the dynamically 'warm' environment within these young clusters, and suggest a range of stellar radii within these quasi-single-age populations. We close with a preview of plans for continuing this work as part of the APOGEE-2 science portfolio: self-consistent measurements of the kinematics and star formation histories for clusters spanning a range of initial conditions and ages will provide a opportunity to disentangle the mechanisms that drive the formation and dissolution of sites of active star formation.

Author(s): Kevin R. Covey[12], Michiel Cottaar[1], Jonathan B. Foster[13], Nicola Da Rio[7], Jonathan Tan[7], Michael Meyer[1], David L. Nidever[8], Kevin M. Flaherty[11], Hector G. Arce[13], Luisa M. Rebull[5], S. Drew Chojnowski[3], Peter M. Frinchaboy[6], Fred R. Hearty[4], Steven R. Majewski[9], Michael F. Skrutskie[9], Keivan Stassun[10], John C. Wilson[9], Gail Zasowski[2]
Institution(s): *1. ETH - Zurich, 2. Johns Hopkins Univ., 3. New Mexico State University, 4. Penn State Univ., 5. Spitzer Science Center, 6. Texas Christian Univ., 7. Univ. of Florida, 8. Univ. of Michigan, 9. Univ. of Virginia, 10. Vanderbilt Univ., 11. Wesleyan Univ., 12. Western Washington University, 13. Yale University*

302.04 – Results from the APOGEE IN-SYNC Orion: parameters and radial velocities for thousands of young stars in the Orion Complex.

I will present the results of our characterization of the dynamical status of the young stellar population in the Orion A star forming region. This is based on radial velocity measurements obtained within the SDSS-III Apogee IN-SYNC Orion Survey, which obtained high-resolution spectroscopy of ~3000 objects in the region, from the dense Orion Nebula Cluster - the prototypical nearby region of active massive star formation - to the low-density environments of the L1641 region. We find evidence for kinematic subclustering along the star forming filament, where the stellar component remains kinematically associated to the gas; in the ONC we find that the stellar population is supervirial and currently expanding. We rule out the existence of a controversial candidate foreground cluster to the south of the ONC. These results, complemented with an analysis of the spatial structure of the population, enables critical tests of theories that describe the formation and early evolution of Orion and young clusters in general.

Author(s): Nicola Da Rio[1]
Institution(s): *1. University of Florida*
Contributing team(s): SDSS Apogee IN-SYNC ancillary program team

302.05 – The APOGEE Low-Mass Star Ancillary Project

As a high-resolution, near-infrared, fiber-fed instrument, APOGEE presents a unique opportunity to obtain multi-epoch radial velocity measurements of a large number of low-mass stars. These observations will reveal unseen companions, improving our understanding of stellar multiplicity at the bottom of the Main Sequence, and may even identify candidate sub-stellar companions. These same data contains an unprecedented wealth of information about the kinematics, rotation, and metallicities of these stars. I will describe the status of our Ancillary Science program, and ongoing efforts to get the best possible radial velocity precision from the APOGEE data.

Author(s): Cullen Blake[6], Suvrath Mahadevan[3], Rohit Deshpande[3], Chad F. Bender[3], Ryan Terrien[3], Justin R. Crepp[5], Joleen K. Carlberg[2], David L. Nidever[4], Keivan Stassun[8], Suzanne L. Hawley[7], Fred Hearty[3], Carlos Allende-Prieto[1]

Institution(s): *1. Instituto de Astrofisica de Canarias, 2. NASA/Goddard Space Flight Center, 3. Pennsylvania State University , 4. University of Michigan, 5. University of Notre Dame, 6. University of Pennslyvania, 7. University of Washington, 8. Vanderbilt University*

302.06 – Chemical Abundance Comparisons Between ASPCAP and Manual Analyses in Open Cluster Red Giants

The APOGEE Stellar Parameter and Chemical Abundance Pipeline (ASPCAP) has now produced individual chemical abundances for 15 different elements: C, N, O, Na, Mg, Al, Si, S, K, Ca, Ti, V, Mn, Fe, and Ni. We will present comparisons of the ASPCAP abundances for stars in clusters with those derived from manual stellar parameter and abundance analyses of the same stars using the APOGEE spectra. These comparisons can be used to assess whether any of the elemental results from the automated pipeline contain larger than expected scatter, systematic offsets, or trends with stellar parameters, such as effective temperature, surface gravity, or metallicity. Using the subset of trustworthy abundances, we present early results of peculiar chemical substructures found in the APOGEE dataset.

Author(s): Verne V. Smith[7], Katia M. L. Cunha[8], Diogo Souto[8], Matthew D. Shetrone[10], Szabolcs Meszaros[1], Carlos Allende-Prieto[2], Dmitry Bizyaev[6], Joleen K. Carlberg[4], Ana García Pérez[2], Sten Hasselquist[5], Jon A. Holtzman[5], Jennifer Johnson[9], Steven R. Majewski[11], Ricardo P. Schiavon[3], Jennifer Sobeck[11], Nicholas William Troup[11]
Institution(s): *1. ELTE Gothard Astrophysical Observatory, 2. Instituto de Astrofisica de Canarias, 3. Liverpool John Moores Unversity, 4. NASA Goddard Spaceflight Center, 5. New Mexico State University, 6. NMSU/APO, 7. NOAO, 8. Observatorio Nacional, 9. Ohio State University, 10. University of Texas at Austin, 11. University of Virginia*

302.07 – The Cannon

We present a method to estimate stellar parameters and abundances (or "labels") for APOGEE spectra that does not require direct comparison to synthetic model spectra. Our method, called The Cannon, transfers labels (e.g. Teff, logg, [Fe/H]) from a training set of data whose parameters are well determined (i.e. members of open and globular clusters) to the entire set of stars in the survey. We show we can reproduce the stellar parameters for the APOGEE survey for DR10 and achieve this at a fraction (25%) of the signal to noise required by minimisation techniques. We obtain this performance via characterising the relationship between the labels of the stars in our training set and their flux, at each pixel. Our method is expandable to additional labels and relevant for chemical tagging. This approach argues for an established set of standard stars with well-determined labels. Given such standard calibrators, it is possible, via this technique of label transfer, to place every stellar survey of the Milky Way on the same stellar parameter scale and homogeneously map the stellar population of the Milky Way from Northern and Southern hemispheres and using different wavelength regions.

Author(s): Melissa Ness[2], David W. Hogg[3], Hans-Walter Rix[2], Gail Zasowski[1]
Institution(s): *1. John Hopkins University, 2. MPIA, 3. New York University*

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303 – AGN, QSO, Blazars V

303.01 – New Insights on Weak Emission Line Quasars from X-shooter Spectroscopy

Over the past 15 years, examples of exotic radio-quiet quasars with intrinsically weak or absent broad emission line regions (BELRs) have emerged from large-scale spectroscopic sky surveys. These weak-lined quasars (WLQs) challenge both the standard orientation-based quasar unification paradigm, and also quasar models that explicitly include factors beyond orientation (e.g., “disk+wind” BELR models). WLQs thus represent a new extreme of quasar parameter space. A key to understanding the unusual BELR properties of WLQs is to simultaneously compare the properties of high- vs. low-ionization emission lines. In this presentation, we show X-shooter spectroscopy of six WLQ candidates at z=1.4-1.7. These observations provide unprecedented spectral coverage from the ultraviolet through optical rest-frame (covering CIV through Halpha). From these data, we test if WLQ BELRs are (1) unusually gas deficient or (2) in an unusual ionization state. Understanding the physical mechanisms that prevent strong emission lines from forming in this extreme population will provide new insight into the formation of BELRs in all quasars.

Author(s): Richard Plotkin[7], Ohad Shemmer[8], Benny Trakhtenbrot[3], Scott F. Anderson[9], W. Niel Brandt[4], Xiaohui Fan[6], Elena Gallo[7], Paulina Lira[5], Bin Luo[4], Gordon T. Richards[1], Jianfeng Wu[2]
Institution(s): *1. Drexel University, 2. Harvard-Smithsonian Center for Astrophysics, 3. Institute for Astronomy, ETH, 4. Pennsylvania State University, 5. Universidad de Chile, 6. University of Arizona, 7. University of Michigan, 8. University of North Texas, 9. University of Washington*

303.02 – High Energy Emission from Quasar Jets: HST polarimetry, X-ray and Gamma-ray Emission and the IC/CMB hypothesis

One of the unique legacies of the Chandra X-ray Observatory is the discovery of X-ray emission from a large number of extragalactic jets (over 100 are now known). In less powerful, FR I radio jets this emission is generally understood to be synchrotron emission from the highest energy electrons, requiring in situ particle acceleration, but the nature of the high-energy emission from the more powerful quasar jets is less well constrained. In quasar jets, the emission extends for tens to hundreds of kiloparsecs, and the observed X-rays are harder and at a higher flux than expected from an extrapolation of the radio to optical spectrum. Over the last 15 years, a persistent debate has arisen as to the nature of this emission, with the leading model being inverse-Comptonization of the Cosmic Microwave Background radiation. This explanation requires the jet to be relativistic out to hundreds of kiloparsecs from the nucleus, and requires an electron spectrum that extends to very low Lorentz factors. The combination of these two results in a very high kinetic power, very close to or over the Eddington limit if the electron spectrum continues to gamma ~ 1. We discuss recent work with HST polarimetry and the X-ray to gamma-ray spectrum that we believe makes it necessary to re-examine the IC/CMB hypothesis. In many quasar jets, the optical and X-ray emission is joined by a single spectral component, and HST polarimetry in that high-energy component is detecting high polarizations, making it difficult to explain the high-energy emission via the IC/CMB hypothesis. So far, this has been found in 2 jets (PKS 1136-135, Cara et al. 2013, and 1150+497), with observations of a third (3C 273) scheduled for January. In addition, IC/CMB of the highest energy synchrotron photons predicts that we should be detecting GeV gamma-ray emission from the extended jets (Georganopoulos et al. 2006, Meyer & Georganopoulos 2014). These lines of evidence have made the IC/CMB hypothesis very unlikely for three objects (PKS 1136-135, 1150+497 and 3C 273). We discuss these findings, alternate explanations and theoretical implications.

Author(s): Eric S. Perlman[1], Markos Georganopoulos[3], Eileen T. Meyer[2], Mihai Cara[2]
Institution(s): *1. Florida Institute of Technology, 2. Space Telescope Science Institute, 3. University of Maryland, Baltimore County*

303.03 – The Ultraviolet Spectra of Active Galaxies WIth Double-Peaked Balmer Emission Lines

We present the UV spectra of eight nearby AGNs with broad, double-peaked Balmer emission lines in their optical spectra. We find that the Mg II UV lines have similar widths and profiles as the optical Balmer lines but the higher-ionization UV lines as well as Lyα have single peaked and relatively "cuspy" profiles. We find that the Lyα/Hα ratio in double-peaked emitters increases with Eddington ratio; it ranges from less than unity for the objects with the lowest Eddington ratios to a few for objects with Eddington ratios of order a few tenths. We quantify the profile shapes by means of the ratio of widths at half maximum and quarter maximum, which is a proxy for the kurtosis. We find that the kurtosis of the UV lines of double-peaked emitters is substantially lower than that of the same lines of ordinary quasars (i.e., the UV lines of double-peaked emitters are less "cuspy"). We interpret these observational results in the context of a picture where the broad-line region is an accretion disk and its associated wind. We suggest that the relative strengths and profiles shapes of double-peaked emitters correspond to a wind with a small optical depth and small emission measure, which is a consequence of a low Eddington ratio.

Author(s): Michael Eracleous[3], Karen T. Lewis[5], Jules P. Halpern[1], Alexei V. Filippenko[6], Thaisa Storchi-Bergmann[2], Mario Livio[4], Andrew S. Wilson[7]
Institution(s): *1. Columbia University, 2. IF-UFRGS, 3. Pennsylvania State Univ., 4. STScI, 5. The College of Wooster, 6. University of California, 7. University of Maryland*

303.04 – Quasar Line Emission at the Bluest Extreme UV Wavelengths

Quasars exhibit remarkably consistent emission lines and line strengths across a large range of luminosity and mass. These lines are fairly well modeled as arising in photoionized regions using a locally optimally emitting cloud (LOC) model. However, the bluest observable extreme-UV wavelengths (~300–500 Å) are puzzling, showing strong line variability between objects and almost universally lacking the only strong line predicted by standard photoionization, He II Lyα. We discuss the array of possible lines seen in very low resolution spectra, and present the most detailed medium-resolution observations yet of a quasar exhibiting likely line emission in this region. We compare with photoionization models, and offer a tentative line identification.

Author(s): David Syphers[1], Joshua Moloney[2]
Institution(s): *1. Eastern Washington University, 2. University of Colorado*

303.05 – Far-Infrared Properties of Boss Quasars.

Using data from the Herschel HeLMS program, we stacked the FIR fluxes of SDSS DR9 BOSS quasars in the redshift range $2 < z < 3$. We studied the relationships between the stacked fluxes and the FIR luminosity function as function of redshift. We found the FIR luminosity function peaks at z~2.3, which correlates with the peak of AGN activity. We also investigate the correlation between the FIR luminosity with the IMag, and EW of CIII, CIV and MgII. We will discuss the consequences of all these relations.

Author(s): Kathryn Amy Harris[4], Duncan Farrah[4], Bernhard Schulz[1], Marco Viero[1], Nicholas Ross[2], Rachel E. Elliott[4], Sara M. Petty[4], Mariana S. Lazarova[3]
Institution(s): *1. CalTech, 2. Lawrence Berkeley National Laboratory , 3. University of Nebraska, 4. Virginia Tech*

303.06D – Searching for Dual AGNs in Galaxy Mergers: Understanding Double-Peaked [O III] and Ultra Hard X-rays as Selection Method

When galaxies merge, gas accretes onto both central supermassive black holes. Thus, one expects to see close pairs of active galactic nuclei (AGNs), or dual AGNs, in a fraction of galaxy mergers. However, finding them remains a challenge. The presence of double-peaked [O III] or of ultra hard X-rays have been proposed as techniques to select dual AGNs efficiently. We studied a sample of double-peaked narrow [O III] emitting AGNs from SDSS DR7. By obtaining new and archival high spatial resolution images taken with the Keck 2 Laser Guide Star Adaptive Optics system and the near-infrared (IR) camera NIRC2, we showed that 30% of double-peaked [O III] emission line SDSS AGNs have two spatial components within a 3” radius. However, spatially resolved spectroscopy or X-ray observations are needed to confirm these galaxy pairs as systems containing two AGNs. We followed up these spatially-double candidate dual AGNs with integral field spectroscopy from Keck OSIRIS and Gemini GMOS and with long-slit spectroscopy from Keck NIRSPEC and Shane Kast Double Spectrograph. We find double-peaked emitters are caused sometimes by dual AGN and sometimes by outflows or narrow line kinematics. We also performed Chandra X-ray ACIS-S observations on 12 double-peaked candidate dual AGNs. Using our observations and 8 archival observations, we compare the distribution of X-ray photons to our spatially double near-IR images, measure X-ray luminosities and hardness ratios, and estimate column densities. By assessing what fraction of double-peaked emission line SDSS AGNs are true dual AGNs, we can better determine whether double-peaked [O III] is an efficient dual AGN indicator and constrain the statistics of dual AGNs. A second technique to find dual AGN is the detection of ultra hard X-rays by the Swift Burst Alert Telescope. We use CARMA observations to measure and map the CO(1-0) present in nearby ultra-hard X-ray Active Galactic Nuclei (AGNs) merging with either a quiescent companion galaxy or a companion galaxy hosting a second AGN, in order to understand the role molecular gas plays in feeding this unusual population of ultra-hard X-ray AGNs and to understand ultra-hard X-rays as a dual AGN selection method.

Author(s): Rosalie C. McGurk[2], Claire E. Max[2], Anne Medling[1], Gregory A. Shields[3]
Institution(s): *1. Australia National University, 2. University of California Santa Cruz, 3. University of Texas*

303.07 – A Comparison of [OIII] and Mid-Infrared Luminosity Indicators In Optically-Selected Type I and Type II Quasars

Quasars, the most luminous active galactic nuclei, are excellent probes for relating the growth of supermassive black holes to galaxy evolution. Quasars are often separated into Type I, or unobscured quasars and Type II, or obscured quasars, and the difference is often attributed to dust obscuration along our line of sight. To compare samples of quasars in an unbiased way, it is vital to estimate accurate quasar luminosities. Here, we compare the luminosities for two samples of optically-selected Type I and Type II quasars derived using two common indicators: [OIII]5007 emission-line flux and mid-IR continuum emission. While we observe a trend between the two indicators across two orders of magnitude, we find that at a given [OIII] luminosity, Type I quasars have a larger mid-IR luminosity than Type II quasars by a factor of 2-3. We explore this difference using SED template fitting to estimate the effects of dust obscuration on the mid-IR continuum, and find that our dust-corrected mid IR luminosities are similar for Type I and Type II quasars. These results indicate the importance in accounting for obscuration of mid-IR flux by cool dust in Type II quasars to properly estimate mid-IR luminosities.

Author(s): Kevin N. Hainline[1], Ryan C. Hickox[1], Christopher M. Carroll[1]
Institution(s): *1. Dartmouth College*

303.08 – Rapid CIV BAL Variability in an SDSS-RM Quasar

The Sloan Digital Sky Survey Reverberation Mapping Project (SDSS-RM) recently completed its first round of spectroscopic observations of a sample of ~850 quasars with the SDSS-III BOSS spectrograph. From 2014 January-July, more than 30 epochs of spectroscopy were obtained for this quasar sample, and supporting observations were carried out at the Canada-France-Hawaii Telescope and the Steward Observatory Bok telescope. A number of quasars observed as a part of this project have broad absorption line (BAL) features in their spectra; we here report on observations of one such target that displays very rapid BAL variability --- the CIV trough is variable on rest frame timescales shorter than a few days. We will discuss the observed short-timescale variability of this BAL and the implications for the physical environment and physics regulating BALs in active galactic nuclei.

Author(s): Catherine Grier[2], Patrick B. Hall[4], W. Niel Brandt[2], Jonathan Trump[2], Yue Shen[1], M. Vivek[3]
Institution(s): *1. Carnegie Observatories, 2. Pennsylvania State University, 3. University of Utah, 4. York University*

303.09 – Detection of Quasar Feedback from the Thermal Sunyaev-Zel'dovich Effect in Planck

Poorly understood feedback processes associated with highly-luminous black hole accretion in quasars may dramatically affect the properties of their host galaxies. We search for the effect of quasar feedback on surrounding gas in Planck maps of the thermal Sunyaev-Zel'dovich effect (tSZ). By stacking tSZ Compton-y maps centered on the locations of 26,686 spectroscopic quasars from the Sloan Digital Sky Survey, we detect a strong but unresolved tSZ Compton-y excess at >5 sigma significance that likely originates from a combination of virialized halo atmosphere gas and quasar feedback effects. Through estimates of the expected tSZ signal from virtualized gas in quasar host halos, we show that feedback effects are likely dominate our observed quasar tSZ signal. We also show that this quasar tSZ signal scales with black hole mass and bolometric luminosity, further supporting a dominant feedback interpretation. We estimate the mean angularly-integrated Compton-y of quasars at z ~ 1.5 to be 3.9 x 10^-6 Mpc^2, and discuss the implications for quasar feedback energetics and efficiencies. If confirmed, this detection would have important implications for the effects of quasar feedback on the host galaxy and the surrounding intergalactic medium.

Author(s): John J. Ruan[1], Matthew McQuinn[1], Scott F Anderson[1]
Institution(s): *1. University of Washington*

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304 – Galaxy Clusters I

304.01 – The Merging Cluster Collaboration (MC^2) Analysis of Merging Galaxy Cluster CIZA J2242+5301

Merging galaxy clusters are ideal probes of plasma physics, environmental effects on galaxy evolution, and dark matter physics. CIZA J2242+5301 is a textbook major cluster post-merger system where the intra-cluster medium has become dissociated from the galaxies and dark matter. We have conducted the first comprehensive optical and spectroscopic survey of the system. We will present our redshift, galaxy evolution, dynamics, and weak lensing analysis. We find that CIZA J2242+5301 is a very massive system (>$2\times10^{15}M^{sun}$) two cluster meger, with the merger occuring very nearly in the plane of the sky. Our dynamics analysis coupled with galaxy evolution traces is enabling us to infer the impact of the merger on the evolution of its constituent galaxies. We also measure ~arcminute offsetes between the galaxies and dark matter, perhaps indicative of self-interacting-dark matter.

Author(s): William Dawson[4], Myungkook J. Jee[6], Andra Stroe[5], David Sobral[3], David M. Wittman[6], Marcus Brüggen[2], Henk Hoekstra[5], Huub Röttgering[5], Reinout J. Van Weeren[1]
Institution(s): *1. CfA, 2. Hamburger Sternwarte, 3. Instituto de Astrofisica e Ciencias do Espaco, 4. Lawrence Livermore Nat. Lab, 5. Leiden Observatory, 6. UC Davis*
Contributing team(s): Merging Cluster Collaboration

304.02D – Cooking a `Sausage': the impact of merger shocks in cluster gas and galaxy evolution

Galaxy clusters mainly grow through mergers with other clusters and groups. Major mergers give rise to important astrophysical phenomena such as the segregation of dark and luminous matter and the formation of cluster-wide traveling shocks and also drive galaxy evolution. The observable effects of shock waves can be seen at radio wavelengths as relics: elongated, diffuse synchrotron emitting areas located at the periphery of merging clusters. Despite the great interest in relics, candidates with simple geometry, undisturbed morphology and high surface brightness are scarce. The `Sausage' cluster hosts an extraordinary Mpc-wide relic, which enables us to study to study particle acceleration and the effects of shocks on cluster galaxies. We use a unique combination of facilities (INT, WHT, Keck, Subaru, CFHT, GMRT, WSRT, AMI) to obtain the first cluster-wide, multi-wavelength, multi-method analysis aimed at giving a complete picture of a merging cluster with relics. Using the radio data, we derive shock properties and the magnetic field structure for the relic. Using spectral modeling, we test acceleration and electron energy-loss mechanisms and resolve the discrepancy between the Mach number calculated from the radio and X-rays. Our results indicate that particles are shock-accelerated, but turbulent re-acceleration or unusually efficient transport of particles in the downstream area and line-of-sight mixing are important effects. We demonstrate the feasibility of high-frequency observations of radio relics, by presenting a 16 GHz detection of the `Sausage' relic. The radio analysis is complemented by Hα mapping of the cluster volume, aimed at providing the first direct test as to whether the shock drives or prohibits star formation. We find numerous Hα emitting galaxies in close proximity to the radio relic which are extremely massive, metal-rich, mostly star-forming with evidence for gas mass loss though outflows. We speculate that the complex interaction between the merger, the shock wave and gas is a fundamental driver in the evolution of cluster galaxies from gas rich spirals to gas-poor ellipticals.

Author(s): Andra Stroe[4], David Sobral[4], Jeremy Harwood[2], Reinout J. Van Weeren[6], Clare Rumsey[1], Huib Intema[5], Huub Röttgering[4], Marcus Brüggen[3], Richard Saunders[1], Martin Hardcastle[2], Matthias Hoeft[7]
Institution(s): *1. Astrophysics Group, Cavendish Laboratory, 2. CAR Hertfordshire, 3. Hamburg Observatory, 4. Leiden Observatory, 5. National Radio Astronomy Observatory, 6. Smithsonian Astrophysical Observatory, 7. Thüringer Landessternwarte*

304.03D – Effects of Mergers and Dynamical State on Galaxy Clusters in Cosmological Simulations

Cosmological constraints from X-ray and microwave observations of galaxy clusters are subjected to systematic uncertainties. Non-thermal pressure support due to internal gas motions in galaxy clusters is one of the major sources of astrophysical uncertainties, which result in large bias and scatter in the hydrostatic mass estimate. In this work, we analyze a sample of massive galaxy clusters from the Omega500 high-resolution hydrodynamic cosmological simulation to examine the effects of dynamical state on non-thermal pressure. We use the Adaptive Refinement Tree (ART) code, an Eulerian grid-based adaptive refinement mesh code, which is well suited for modeling shock heating of gas and generation of bulk and turbulent motions from cosmic accretion. We examine the effects of cluster mergers on the hydrostatic mass bias and the evolution of non-thermal pressure. We find that during a major merger about a third of the total pressure support in the system is in non-thermal pressure from random gas motions, which leads to a ~30% bias in the hydrostatic mass estimate. Even after the clusters relax, we find a residual 10% bias due to the residual non-thermal pressure sustained by continuous gas accretion and minor mergers in cluster outskirts. However, when the non-thermal pressure support is accounted for in the mass estimates of relaxed clusters, we are able to recover the true mass to within a few percent. Moreover, by accounting for the additional pressure contribution from gas accelerations, we find that the bias in the HSE can be reduced by about half for our whole cluster sample. We also characterize the non-thermal pressure fraction profile and study its dependence on redshift, mass, and mass accretion rate. We find a universal, redshift-independent fitting formula for describing the fractional pressure support due to bulk motions. Within the relation, we find that the mass accretion rate has a systematic effect on the amount of non-thermal pressure in clusters, with more rapidly accreting systems containing a larger fraction of pressure due to gas motions. We will discuss implications of our results for the recent tension in the Planck CMB and galaxy cluster cosmological constraints.

Author(s): Katherine L. Nelson[1], Daisuke Nagai[1]
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304.04 – The spectacular merger event in A3411: Shock fronts and radio relics

The study of galaxy cluster merger events is of major astrophysical interest as they have a profound and long-lasting impact on the thermodynamic evolution of the ICM. Observed as part of our large Chandra XVP program on the Planck ESZ sample, we discovered that the cluster A3411 is undergoing a spectacular merger event. Radio observations also reveal the presence of large-scale diffuse emission, suggesting the presence of shocks and turbulence in the ICM. Most interestingly, in the Chandra observations we indeed find evidence of a brightness discontinuity, roughly at the location of the radio emission. This suggests that a shock could be responsible for the acceleration of particles to relativistic energies and makes A3411 an ideal laboratory
to study this poorly understood process.

Author(s): Felipe Andrade-Santos[1], Christine Jones[1], William R. Forman[1], Reinout J. Van Weeren[1], Georgiana A Ogrean[1], Stephen S. Murray[2]
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Contributing team(s): Chandra-Planck Collaboration

304.05D – A Multi-component Radio Halo in the Merging Galaxy Cluster A2319: Implications for Cluster Dynamics and Cosmic Rays

Diffuse radio emission in the form of radio halos in galaxy clusters indicates the existence of cosmic rays and magnetic fields that permeate the thermal, X-ray emitting intracluster medium (ICM). However, the origins of these nonthermal components and the effects they have on the thermal ICM are not well understood. We present the results from observations of A2319 at 20 cm with the Jansky Very Large Array and a re-analysis of the X-ray observations from XMM-Newton, to investigate the interactions between the thermal and nonthermal components in merging clusters. We report on the discovery of a distinct core to the radio halo, approximately 800 kpc in extent, that is strikingly similar in morphology to the X-ray emission. We detect additional radio emission trailing off from the core, which blends smoothly into the 2 Mpc halo previously detected with the Green Bank Telescope. We also confirm previous reports of an X-ray cold front. We speculate on the possible mechanisms for such a two-component radio halo, with sloshing playing a dominant role in the core. By directly comparing the X-ray and radio emission, we find that a hadronic origin for the cosmic ray electrons responsible for the radio halo would require a magnetic field and/or cosmic ray proton distribution that increases with radial distance from the cluster center, and is therefore disfavored.

Author(s): Emma Storm[1], Tesla E. Jeltema[1], Lawrence Rudnick[2], Stefano Profumo[1]
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304.06 – *NuSTAR* Observations of Galaxy Clusters

Efforts to characterize the hard (>10 keV) X-ray emission from galaxy clusters have historically been hampered by a lack of observatories with imaging capabilities. As the first orbiting observatory with mirrors able to focus >10 keV X-rays, *NuSTAR* makes possible the most sensitive searches yet for inverse Compton emission associated with radio halos and relics and for tight constraints on the temperatures of shocked regions. I will present highlights from the galaxy clusters so far observed by *NuSTAR* including the Bullet Cluster, the Coma Cluster, the Cygnus A Cluster, and Abell 2256. In particular, I will spotlight a Bullet Cluster temperature map derived from joint spectral fits to ~414 ks of *Chandra* and 266 ks of *NuSTAR* data, the latter of which constrains the temperatures of the hottest (~20 keV) shocked gas in the cluster, and discuss its implications on the thermalization and dynamical state of the intracluster medium.

Author(s): Daniel R. Wik[1]
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Contributing team(s): NuSTAR team

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305 – Supermassive Black Holes

305.01 – The evolving corona and evidence for jet launching from the supermassive black hole in Markarian 335

Through detailed analysis of the X-rays that are reflected from the accretion disc, it is possible to probe structures right down to the innermost stable circular orbit and event horizon around the supermassive black holes in AGN. By measuring the illumination pattern of the accretion disc, along with reverberation time lags between variability in the X-ray continuum and reflection, unprecedented detail of the geometry and spatial extent of the corona that produces the X-ray continuum has emerged when the observed data are combined with insight gained from general relativistic ray tracing simulations.
We conducted detailed analysis of both the X-ray continuum and its reflection from the accretion disc in the narrow line Seyfert 1 galaxy Markarian 335, over observations spanning nearly a decade to measure the underlying changes in the structure of the X-ray emitting corona that gave rise to more than an order of magnitude variation in luminosity. Underlying this long timescale variability lies much more complex patterns of behaviour on short timescales. We are, for the first time, able to observe and measure the changes in the structure of the corona that give rise to transient phenomena including a flare in the X-ray emission seen during a low flux state by Suzaku in July 2013. This flaring event was found to mark a reconfiguration of the corona while there is evidence that the flare itself was cased by an aborted jet-launching event. More recently, detailed analysis of a NuSTAR target of opportunity observation is letting us understand the sudden increase in X-ray flux by a factor of 15 in Markarian 335 seen in September 2014.
These observations allow us to trace, from observations, the evolution of the X-ray emitting corona that gives rise to not only the extreme variability seen in the X-ray emission from AGN, but also the processes by which jets and other outflow are launched from the extreme environments around black holes. This gives us important insight into the physical processes by which energy is liberated from black hole accretion flows and allows observational constraints to be placed upon theoretical models of how these extreme objects are powered.

Author(s): Daniel Wilkins[1], Luigi C. Gallo[1]
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305.02 – Tidal Disruption Events Exhibit a Continuum of H- to He-Rich Spectra and Prefer E+A Galaxies

A star passing close to a super-massive black hole will undergo a tidal disruption event (TDE), possibly accompanied by an optical/UV flare. Such events can be used to study otherwise quiescent black holes out to large distances. I will present three TDE candidates discovered by the Palomar Transient Factory. Analyzing their observed properties, together with those of TDE candidates from the literature, we find, for the first time, a continuum of spectral features from He-dominated events to H-dominated ones. Almost all the TDE candidates in our sample occur in rare E+A hosts (usually interpreted as post-merger galaxies). The unification of this class of transients on a continuous scale of spectral characteristics supports their interpretation as TDEs, and their preference for E+A galaxies could be an important clue regarding their formation.<!--EndFragment-->

Author(s): Iair Arcavi[1]
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305.03 – The ongoing hunt for supermassive black hole binaries

Supermassive black hole binaries (SBHBs) are thought to be a natural, if not inevitable, phase in scenarios in which most massive galaxies host central black holes and undergo frequent mergers as they evolve. While there are convincing examples of kiloparsec-separation pairs, there is currently no robust evidence for the close, sub-parsec binaries that are expected to exist. The detection of this population would contribute important evidence in favor of the prevailing galaxy evolution scenarios, and is also of interest in other fields including gravitational wave astronomy. We have undertaken a systematic search for close SBHBs based on the hypothesis that the secondary black hole in the binary accretes at a much higher rate than the primary, and its emission lines are doppler shifted due to its orbital motion (analogous to a single-line spectroscopic binary). Our sample of 88 candidates is therefore selected from z<0.7 SDSS quasars via substantial (>1000 km s^{-1}) shifts of their broad Hβ lines relative to their systemic redshifts. I will present an update on our efforts to evaluate the credentials of the candidates, including new radial velocity measurements from the spectroscopic monitoring program and a comparison of the spectral variability of the binary candidates to the broader quasar population.

Author(s): Jessie C. Runnoe[5], Gavin Mathes[4], Michael Eracleous[5], Todd A. Boroson[3], Jules P. Halpern[1], Steinn Sigurdsson[5], Tamara Bogdanovic[2]
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305.04 – One Step Beyond: What Can Be Learned From a Sample of Supermassive Black Hole Binaries?

A search for a well defined sample of sub-parsec supermassive black hole binaries (SBHBs) remains one of the principal goals in the field of black holes and galaxy evolution. However, an equally important and timely consideration is: what can be learned once such sample is available? Motivated by advances in observational searches for SBHBs made in the past few years we develop a model to describe the spectral emission line signatures of these systems. The ultimate goal of this work is to enhance the scientific return of spectroscopic searches for binaries and use them to test one of the leading models of binary accretion flows in the literature: SBHB in a circumbinary disk. I will describe results from our first-generation model and their implications for our ability to learn about the properties of sub-parsec SBHBs.

Author(s): Tamara Bogdanovic[1], Khai Nguyen[1], Michael Eracleous[2], Jessie C. Runnoe[2], Steinn Sigurdsson[2]
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305.05 – Modeling the Observability of Recoiling Black Holes as Offset Quasars

The merger of two supermassive black holes (SMBHs) imparts a gravitational-wave (GW) recoil kick to the remnant SMBH. In extreme cases these kicks may be thousands of km/s -- enough to easily eject them from their host galaxies. Moderate recoil kicks may also cause substantial displacements of the SMBH, however. An actively-accreting, recoiling SMBH may be observable as an offset quasar. Prior to the advent of a space-based GW observatory, detections of these offset quasars may offer the best chance for identifying recent SMBH mergers. Indeed, observational searches for recoiling quasars have already identified several promising candidates. However, systematic searches for recoils are currently hampered by large uncertainties regarding how often offset quasars should be observable, where they are most likely to be found, and whether BH spin alignment prior to merger is efficient at suppressing large recoils. Motivated by this, we have developed a model for the observable population of recoiling quasars in a cosmological framework, utilizing detailed information about the progenitor galaxies from state-of-the-art cosmological hydrodynamic simulations (the Illustris Project). The model for offset quasar lifetimes includes a physically-motivated, time-dependent model for accretion onto kicked SMBHs, and results are analyzed for a range of possible BH spin alignment models. We find that the observability of offset quasars depends strongly on the efficiency of pre-merger spin alignment, with promising indications that observations of recoils could distinguish between at least the extreme limits of spin alignment models. Our results also suggest that observable offset quasars should inhabit preferred types of host galaxies, where again these populations depend on the degree of pre-merger spin alignment. These findings will be valuable for planned and future dedicated searches for recoiling quasars, and they indicate that such objects might be used to place indirect constraints on SMBH spins.

Author(s): Laura Blecha[7], Paul Adam Torrey[5], Mark Vogelsberger[5], Shy Genel[2], Volker Springel[3], Debora Sijacki[1], Greg Snyder[6], Simeon Bird[4], Dylan R. Nelson[2], Dandan Xu[3], Lars E. Hernquist[2]
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305.06 – Songlines from Direct Collapse Seed Black Holes

In the last decade, the growth of supermassive black holes (SMBHs) has been intricately linked to galaxy formation and evolution, and is a key ingredient in the assembly of galaxies. Observations of SMBHs with masses of 10^9 solar at high redshifts (z~7) poses challenges to the theory of seed black hole formation and their growth in young galaxies. Fundamental to understanding their existence within the first billion years after the Big Bang, is the identification of their formation processes, growth rate and evolution through cosmic time. We perform cosmological hydrodynamic simulations following the growth of direct collapse seed black holes (DCBH) including X-ray irradiation from the central black hole, stellar feedback both from metal-free and metal-rich stars and H^2 self-shielding. These simulations demonstrate that X-ray irradiation from the central black hole regulates its growth and influence the formation of stellar population in the host halo. In particular, X-ray radiation enhances H^2 formation in metal-free gas and initially induces the star formation in the halo. However, in the long term, X-ray irradiation from the accreting seed DCBH stifles the initial growth relative to the Eddington rate argument. This further complicates the explanation for the existence of SMBHs in the early universe.

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Institution(s): *1. Georgia Institute of Technology , 2. Kapteyn Astronomical Institute, 3. Leiden Observatory, Leiden University*

305.07 – Off The Beaten Path: Modeling the Dynamics of Supermassive Black Holes in Cosmological Simulations

Cosmological simulations are an essential tool to understand the co-evolution of supermassive black holes (SMBHs) and their host galaxies. However, the limited resolution of these simulations presents unique challenges to successfully modeling black hole dynamics. We present a novel, physically motivated method for improving the dynamics of black holes in cosmological simulations, by accounting for the unresolved dynamical friction that SMBHs feel from stars and dark matter. We show how this approach, which naturally scales with resolution, is a major step forward compared to more commonly used “advection” models that often assume SMBHs sink very rapidly toward the center of their host galaxies. Here, we demonstrate that our method is able to prevent numerical heating of SMBHs while allowing for realistic dynamics.
Our implementation will allow us to more realistically model SMBH dynamics, accretion, and mergers in cosmological simulations, giving us the ability to better understand how SMBHs grow with their host galaxies. This also provides an opportunity for more detailed studies of SMBHs in dwarf galaxies, which can give crucial insight into constraining black hole seed formation models.

Author(s): Michael J. Tremmel[2], Fabio Governato[2], Marta Volonteri[1], Thomas R. Quinn[2]
Institution(s): *1. University of Michigan, 2. University of Washington*

305.08 – General Relativistic Ray Tracing for X-ray Reverberation and Polarimetry Studies of Black Holes

We present the results of General Relativistic (GR) ray tracing calculations of the X-ray emission from mass accreting stellar mass and supermassive black holes. Our study aims at exploring the X-ray reverberation and X-ray polarimetry signatures of different accretion flow geometries and different spacetime backgrounds (GR and non-GR backgrounds). We present first results derived for the well-known lamp-post model, where a point source of continuum emission illuminates an accretion disk with high energy photons which are tracked by parallel transporting the photon wave and polarization vectors. The simulation code models the reprocessing and reflection by of photons impinging on the accretion disk. We study the degeneracy of astrophysical parameters (parametrizing the geometry of the accretion disk and the location and properties of the lamppost photon source) and the parameters describing the underlying metrics. We emphasize furthermore the difference of the observational signatures for stellar mass and supermassive black holes.

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306 – Extrasolar Planets: Host Stars and Interactions

306.01D – Detecting Exoplanetary Magnetic Fields

Asymmetries in exoplanet transits are proving to be a useful tool for furthering our understanding of magnetic activity on both stars and planets outside our Solar System.
Near-UV observations of the WASP-12 system have revealed asymmetries in the timing of the transit when compared with the optical light curve. A number of possible explanations have been suggested for this variation, including the presence of a magnetospheric bow shock arising from the interaction of the planet’s magnetic field with the stellar wind from it's host star. Such observations provide the first method for directly detecting the presence of a magnetic field on exoplanets.
The shape and size of such asymmetries is highly dependent on the structure of the host stars magnetic field at the time of observation. This implies we may observe highly varying near-UV transit light curves for the same system. These variations can then be used to learn about the geometry of the host star's magnetic field.
In this presentation I will show modelling a bow shock around an exoplanet can help us to not only detect, but also also place constraints on the magnetic field strength of hot Jupiters. For some systems, such as HD 189733, we have maps of the surface magnetic field of the star at various epochs. I will also show how incorporating these maps into a stellar wind model, I can model the formation of a bow shock around the planet and hence demonstrate the variability of the near-UV transits.

Author(s): Joe Llama[1]
Institution(s): *1. Lowell Observatory*

306.02D – The Effect of Star-Planet Interactions on Planetary Climate

In this work I explored the effect on planetary climate and habitability of interactions between a host star, an orbiting planet and additional planets in a stellar system. I developed and tested models that include both radiative and gravitational effects, and simulated planets covered by ocean, land and water ice, with incident stellar radiation from stars of different spectral types. These simulations showed that ice-covered conditions occurred on an F-dwarf planet with a much smaller decrease in stellar flux than planets orbiting stars with less near-UV radiation, due to ice reflecting strongly in the visible and near-UV. The surface ice-albedo feedback effect is less important at the outer edge of the habitable zone, where ~3-10 bars of CO^2 could entirely mask the climatic effect of ice and snow, leaving the traditional outer limit of the habitable zone unaffected by the spectral dependence of water ice and snow albedo. The exit out of global ice cover was also sensitive to host star spectral energy distribution. A planet orbiting an M-dwarf star exhibited a smaller resistance to melting out of a frozen state, requiring a smaller stellar flux to initiate deglaciation than planets orbiting hotter, brighter stars. Given their greater climate stability, planets orbiting cooler, lower-mass stars may be the best candidates for long-term habitability and life beyond the Solar System. A specific case was explored—that of Kepler-62f, a potentially habitable planet in a five-planet system orbiting a K-dwarf star. Simulations using a 3-D Global Climate Model indicated that Kepler-62f would have areas of the planet with surface temperatures above the freezing point of water with 1 bar or more of CO^2 in its atmosphere. In a low-CO^2 case, increases in planetary obliquity and orbital eccentricity coupled with an orbital configuration that places the summer solstice at or near pericenter generated regions of the planet with above-freezing surface temperatures, which may cause surface melting of an ice sheet formed during an annual cycle. The methods presented here can be used to assess the possible climates of newly discovered potentially habitable planets in systems with a wide range of orbital architectures.

Author(s): Aomawa Shields[2], Victoria Meadows[5], Cecilia Bitz[5], Raymond Pierrehumbert[3], Manoj Joshi[4], Tyler Robinson[1], Eric Agol[5], Rory Barnes[5], Benjamin Charnay[5]
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Contributing team(s): Virtual Planetary Laboratory

306.04 – Validation of a Warm Jupiter Transiting a Rapidly Rotating Star

Transiting giant planet candidates are typically confirmed using follow-up radial velocity observations to measure the reflex motion of the host star. This is not feasible for rapidly rotating stars, however, as these stars' rotationally broadened spectral lines prevent the measurement of the stellar radial velocity to sufficient precision to detect the reflex motion. An alternative approach is to use Doppler tomography, where we spectroscopically resolve the distortion in the stellar line profile during the transit due to the Rossiter-McLaughlin effect. Detection of this effect validates the planet candidate by excluding the possibility that a blended background eclipsing binary is the cause of the observed transits. Doppler tomography also allows the measurement of the spin-orbit misalignment. We present our validation of a *Kepler* warm Jupiter orbiting a rapidly-rotating mid-F star using Doppler tomography. This is the longest-period planet yet observed with Doppler tomography, and is one of only a handful of warm Jupiters with a measured spin-orbit misalignment.

Author(s): Marshall C. Johnson[1], William D. Cochran[1], Michael Endl[1]
Institution(s): *1. University of Texas at Austin*

306.05 – Deriving stellar inclination of slow rotators using stellar activity signal

Stellar inclination is an important parameter for many astrophysical studies. In the context of exoplanets, this allows us to derive the true obliquity of a system if the projected stellar spin-planetary orbit angle can measured via the Rossiter-Mclaughlin effect. Although different techniques allow us to estimate stellar inclination for fast rotators, it becomes much more difficult when stars are rotating slower than 2-2.5 $km.s^{-1}$. By using the new activity simulation SOAP 2.0 that can reproduce the photometric and spectroscopic variations induced by stellar activity, we are able to fit the activity variation of solar-type stars and derive their inclination. The case of the equator-on star HD189733 will be presented, as well as the case of Alpha Centauri B, which present an inclination of 45^{+9-19} degrees, implying that the earth-mass orbiting planet is not transiting if aligned with its host star. Other exemples will also demonstrate the power of the technique, that can infer a stellar inclination, even for slow rotators like Alpha Centauri B, that present a projected rotational velocity smaller than 1.15 $km.s^{-1}$. In addition, the SOAP 2.0 simulation can be used to correct for the effect of activity when one major active region is dominating the RV signal. This could enhance the detection of small mass exoplanets orbiting slightly active stars.

This project is funded by *ETAEARTH* (European Union Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n. 313014)***,*** a transnational collaboration between European countries and the US (the Swiss Space Office, the Harvard Origin of Life Initiative, the Scottish Universities Physics Alliance, the University of Geneva, the Smithsonian Astrophysical Observatory, the Italian National Astrophysical Institute, the University of St. Andrews, Queens University Belfast, and the University of Edinburgh) setup to optimize the synergy between space-and ground-based data whose scientific potential for the characterization of extrasolar planets can only be fully exploited when analyzed together.

Author(s): Xavier Dumusque[1]
Institution(s): *1. Harvard-smithsonian Center for Astrophysics*

306.06 – Deciphering thermal phase curves of tidally locked terrestrial planets

Next-generation space telescopes will allow us to characterize terrestrial exoplanets. To do so effectively it will be crucial to make use of all available data. We therefore investigate which atmospheric properties can, and cannot, be inferred from a tidally locked planet's broadband thermal phase curve. First, we use dimensional analysis to show that phase curves are controlled by six nondimensional parameters. Second, we use an idealized general circulation model (GCM) to explore the relative sensitivity of phase curves to these parameters. We find that the feature of phase curves most sensitive to its atmospheric parameters is the peak-to-trough amplitude. Moreover, except for hot and rapidly rotating planets, the phase amplitude is primarily sensitive to only two nondimensional parameters: 1) the ratio of dynamical to radiative timescales, and 2) the longwave optical thickness at the surface. As an application of this technique, we show how phase curve measurements could be combined with transit or emission spectroscopy to constrain the surface pressure and atmospheric mass of terrestrial planets. Such constraints will be important for studying the atmospheric evolution of terrestrial exoplanets, and for characterizing the surface conditions on habitable planets.

Author(s): Daniel D.B. Koll[1], Dorian S Abbot[1]
Institution(s): *1. University of Chicago*

306.07 – Accurate Stellar Parameters for Exoplanet Host Stars

A large impedement to our understanding of planet formation is obtaining a clear picture of planet radii and densities. Although determining precise ratios between planet and stellar host are relatively easy, determining accurate stellar parameters is still a difficult and costly undertaking. High resolution spectral analysis has traditionally yielded precise values for some stellar parameters but stars in common between catalogs from different authors or analyzed using different techniques often show offsets far in excess of their uncertainties. Most analyses now use some external constraint, when available, to break observed degeneracies between surface gravity, effective temperature, and metallicity which can otherwise lead to correlated errors in results. However, these external constraints are impossible to obtain for all stars and can require more costly observations than the initial high resolution spectra. We demonstrate that these discrepencies can be mitigated by use of a larger line list that has carefully tuned atomic line data. We use an iterative modeling technique that does not require external constraints. We compare the surface gravity obtained with our spectral synthesis modeling to asteroseismically determined values for 42 Kepler stars. Our analysis agrees well with only a 0.048 dex offset and an rms scatter of 0.05 dex. Such accurate stellar gravities can reduce the primary source of uncertainty in radii by almost an order of magnitude over unconstrained spectral analysis.

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307 – Neutron Stars in Binary Systems and Millisecond Pulsars

307.01 – Radio Timing and Analysis of Black Widow Pulsar J2256-1024

Pulsar J2256-1024, discovered in a 350MHz GBT drift-scan survey and subsequently detected by Fermi-LAT, is a black widow millisecond pulsar in an eclipsing binary system. Black widow pulsars have a rather interesting history. They started life in a binary system, were then spun up by their companions into millisecond pulsars but at some point started ablating those companions, slowly destroying them - thus the moniker "black widow". They are characterized by relatively short orbital periods, in this case 5.1 hours, a low companion mass and, if the inclination angle is right, eclipses. For J2256-1024 we see very clear radio eclipses. Black widow systems used to be few and far between but are now more common with at least 18 currently known. Black widows are interesting for a variety of reasons. They provide potential insight into the formation of isolated millisecond pulsars which must have formed in a binary but are now seen alone, and in eclipsing systems pulses travel through the magnetosphere of the companion providing a probe of that region. Here we present timing and polarization results for J2256-1024 based on radio observations with the GBT.

Author(s): Kathryn Crowter[5], Ingrid H. Stairs[5], Christie A. McPhee[5], Anne M. Archibald[1], Jason Boyles[9], Jason Hessels[1], Victoria M. Kaspi[3], Vlad I. Kondratiev[1], Duncan Lorimer[8], Ryan S. Lynch[3], Maura McLaughlin[8], Timothy Pennucci[7], Scott M. Ransom[4], Mallory Roberts[2], Kevin Stovall[6], Joeri van Leeuwen[1]
Institution(s): *1. ASTRON, 2. Eureka Scientic, 3. McGill University, 4. National Radio Astronomy Observatory, 5. University of British Columbia, 6. University of New Mexico, 7. University of Virginia, 8. West Virginia University, 9. Western Kentucky University*

307.02D – Wideband Timing of Millisecond Pulsars

The use of backend instrumentation capable of real-time coherent dedispersion of relatively large fractional bandwidths has become commonplace in pulsar astronomy. However, along with the desired increase in sensitivity to pulsars' broadband signals, a larger instantaneous bandwidth brings a number of potentially aggravating effects that can lead to degraded timing precision. In the case of high-precision timing experiments, such as the one being carried out by the North American Nanohertz Observatory for Gravitational Waves (NANOGrav), subtle effects such as unmodeled intrinsic profile evolution with frequency, interstellar scattering, and dispersion measure variation are potentially capable of reducing the experiment's sensitivity to a gravitational wave signal. In order to account for some of these complications associated with wideband observations, we augmented the traditional algorithm by which the fundamental timing quantities are measured. Our new measurement algorithm accommodates an arbitrary two-dimensional model ``portrait'' of a pulsar's total intensity as a function of observing frequency and rotational phase, and simultaneously determines the time-of-arrival (TOA), the dispersion measure (DM), and per-frequency-channel amplitudes that account for interstellar scintillation. Our publicly available python code incorporates a Gaussian-component modeling routine that allows for independent component evolution with frequency, a ``fiducial component'', and the inclusion of scattering. Here, we will present results from the application of our wideband measurement scheme to the suite of NANOGrav millisecond pulsars, which aimed to determine the level at which the experiment is being harmed by unmodeled profile evolution. We have found thus far, and expect to continue to find, that our new measurements are at least as good as those from traditional techniques. At a minimum, by largely reducing the volume of TOAs we will decrease the computational demand associated with probing posterior distributions in the search for gravitational waves. The development of this algorithm is well-motivated by the promise of even larger fractional bandwidth receiver systems in the future of pulsar astronomy.

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Institution(s): *1. National Radio Astronomy Observatory, 2. University of Virginia*
Contributing team(s): The North American Nanohertz Observatory for Gravitational Waves (NANOGrav)

307.03 – Heating Before Eating: X-Ray Observations of Redback Millisecond Pulsar Systems in the Ablation State

Redbacks are eclipsing millisecond radio pulsars in close orbits around companions which are non-degenerate and nearly Roche-lobe filling. Several have been observed to transition between a state where the radio pulsar is visible and there is X-ray emission from a shock between the pulsar wind and the ablated material off of the companion, and a state where there appears to be an accretion disk and the radio pulsations are not visible. Here we present X-Ray studies of two recently discovered systems. A Chandra observation of PSR J1628-3205 over its entire 5 hour orbit with Chandra shows little evidence for X-Ray variability. An XMM-Newton observation of PSR J2129$-$0429 over its 15.2 hour orbit shows strong orbital variability with an intriguing two peaked light curve. We compare these systems' X-Ray properties to other redbacks and comment on the differences between their properities and those of black widows.

Author(s): Mallory Roberts[2], Maura McLaughlin[5], Paul S. Ray[3], Scott M. Ransom[4], Jason Hessels[1]
Institution(s): *1. ASTRON, 2. Eureka Scientific, 3. Naval Research Lab, 4. NRAO, 5. West Virginia University*

307.04 – Spectral Modeling of the Comptonized Continua of Accreting X-Ray Pulsars

We are undertaking a program to analyze the X-ray spectra of the accretion flows onto strongly magnetic neutron stars in high mass binary systems such as Cen X-3, and XTE J1946+274. These accreting pulsars typically have X-ray spectra consisting of broad Comptonized cutoff power-laws. Current theory suggests these X-ray spectra result from radiation-dominated shocks that develop in the high-velocity magnetically channeled plasma accretion flows onto the surfaces of the neutron stars. These X-ray pulsars often, but not always, show cyclotron resonant scattering features implying neutron star surface magnetic field strengths above 10^{12} G. Proper fitting of cyclotron line centroids (for example, to investigate how the line centroid varies with X-ray luminosity) requires a robust model for the Comptonized X-ray continuum upon which the cyclotron lines are superposed, and this can be provided by a continuum model based on the physics of the accretion column.
We discuss in this presentation our ongoing program for the analysis of the X-ray spectra formed in these systems. Our program consists of two parts. First, we are modeling the X-ray spectra from the Suzaku X-ray satellite of accreting X-ray pulsars Cen X-3 and XTE J1946+274 utilizing the best currently existing empirical models. The second part of our program is building a new analysis tool based on the analytical model of Becker and Wolff (2007). In the high temperature optically thick plasma flows, the processes of bremsstrahlung emission from the hot plasma, black body emission from a thermal mound near the neutron star surface, and cyclotron emission from electrons in the first Landau excited state, all contribute to the total observed X-ray spectrum. We show recent results from our new implementation and its comparison with the Suzaku data for these X-ray pulsars.
This research is supported by the NASA Astrophysics Data Analysis Program.

Author(s): Michael Thomas Wolff[2], Katja Pottschmidt[4], Peter A. Becker[1], Diana Marcu[4], Jörn Wilms[3], Kent S. Wood[2]
Institution(s): *1. George Mason University, 2. NRL, 3. Universitaet Erlangen-Nuernberg, 4. University of Maryland - Baltimore County*

307.05 – On Gravitational Wave Limit Determination in the 10 micro-Hertz to 20 milli-Hertz Band Using Millisecond Pulsar Timing

Continuous pulsar timing observations over a 24-hr period provide a method for probing intermediate gravitational wave (GW) frequencies of 10 micro-Hertz to 20 milli-Hertz. Despite the fact that we expect no particularly strong GW sources at these GW frequencies typically associated with eLISA, there are nonetheless no current constraints from pulsar timing arrays (PTAs) in the 10 micro-Hertz regime. The North American Nanohertz Observatory for Gravitational Waves (NANOGrav), the Parkes Pulsar Timing Array, the European Pulsar Timing Array, and the entire International Pulsar Timing Array all use millisecond pulsar observations to constrain GWs at nano-Hz frequencies. PTAs have also been shown to be well-suited for probing GWs at frequencies from approximately 1 nano-Hertz to 10 micro-Hertz. We show a calculation that takes into account the changes in time-of-arrival precision vs. time due to interstellar scintillation modulations and to different telescope sensitivities. In the case of the J1713 24-Hour Global Campaign (Dolch & Lam et al. 2014), a continuous set of broadband timing residuals from PSR J1713+0747, the negligible change in dispersion measure allows for a white noise model to be used with the timing residuals in order to constrain any contributions from GWs. Finally, we show that improved GW strain limits at GW frequencies ~10 micro-Hertz can be obtained with simultaneous, dense timing campaigns using large collecting area telescopes, with one telescope per pulsar. The PTA limits are higher than those obtained using Cassini Doppler tracking but can be improved by simultaneous, continuous observations of multiple pulsars.

Author(s): Timothy Dolch[1], Shami Chatterjee[1], James M. Cordes[1], Michael T. Lam[1], Dustin Ray Madison[1]
Institution(s): *1. Cornell University*
Contributing team(s): NANOGrav Collaboration

307.06 – PSR J1930-1852: a Pulsar in the Widest Known Orbit Around Another Neutron Star

<!--StartFragment-->In the summer of 2012, during a Pulsar Search Collaboratory workshop, two high-school students discovered J1930-1852, a pulsar in a double neutron star (DNS) system. Most DNS systems are characterized by short orbital periods, rapid spin periods and eccentric orbits. However, J1930-1852 has the longest spin period (Pspin~185 ms) and orbital period (Porb~45 days) yet measured among known, recycled pulsars in DNS systems, implying a shorter than average and/or inefficient recycling period before its companion went supernova. We measure a relativistic advance of periastron for J1930-1852 of 0.00077(3) deg/yr, which implies a total mass (Mtot=2.54(3) Msun) consistent with other DNS systems. The constraints that advance of periastron places on the pulsar and companion masses (Mp<1.25 Msun and Mc>1.30 Msun respectively) however, imply a unique evolutionary history; given the mass constraints placed on Mp and Mc, J1930-1852 may be the first observed example of a DNS where the primary formed via electron capture supernova and the secondary, via iron core-collapse.<!--EndFragment-->

Author(s): Joe K Swiggum[4], Rachel Rosen[3], Maura McLaughlin[4], Duncan Lorimer[4], Sue Ann Heatherly[3], Ryan S. Lynch[2], Sarah A. Scoles[3], Brad Barlow[1]
Institution(s): *1. High Point University, 2. McGill University, 3. NRAO, 4. West Virginia University*
Contributing team(s): Pulsar Search Collaboratory

307.07 – Coalescence of Magnetized Binary Neutron Star Systems

We present simulations of the merger of binary neutron star systems calculated with full general relativity and incorporating the global magnetic field structure for the stars evolved with resistive magnetohydrodynamics. Our simulation tools have recently been improved to incorporate the effects of neutrino cooling and have been generalized to allow for tabular equations of state to describe the degenerate matter. Of particular interest are possible electromagnetic counterparts to the gravitational radiation that emerges from these systems. We focus on magnetospheric interactions that ultimately tap into the gravitational potential energy of the binary to power a Poynting flux and deposition of energy through Joule heating and magnetic reconnection. We gratefully acknowledge the support of NASA through the Astrophysics Theory Program grant NNX13AH01G.

Author(s): Patrick M. Motl[4], Matthew Anderson[3], Luis Lehner[6], Steven L Liebling[5], David Neilsen[1], Carlos Palenzuela[2], Marcelo Ponce[7]
Institution(s): *1. Brigham Young University, 2. Canadian Institute for Theoretical Astrophysics, 3. Indiana University, 4. Indiana University Kokomo, 5. Long Island University, 6. Perimeter Institute for Theoretical Physics, 7. University of Guelph*

308 – Reports from NASA's Program Analysis Groups (CoPAG, PhysPAG and ExoPAG)

AAS Special Session
This special session will report on the current activities of NASA's Program Analysis Groups (PAGs.) These groups serve

as forums for soliciting and coordinating input and analysis from the scientific community in support of the Astrophysics Division's program objectives. This session will begin with an introduction to the PAGs by representatives from NASA Headquarters and then include reports on current activities from the Chairs of the Exoplanet Exploration PAG (ExoPAG), the Cosmic Origins PAG (COPAG), and Physics of the Cosmos PAG (PhysPAG). Topics to be discussed include synergy between HST and WFIRST as well as future possibilities for space-based studies of both exoplanets and the imprint of primordial gravitational waves on the Cosmic Microwave Background.

308.01 – Overview of NASA Astrophysics Program Analysis Groups

NASA Astrophysics Program Analysis Groups (PAGs) are responsible for facilitating and coordinating community input into the development and execution of NASAs three astrophysics science themes: Cosmic Origins (COPAG), Exoplanet Exploration (ExoPAG), and Physics of the Cosmos (PhysPAG). The PAGs provide a community-based, interdisciplinary forum for analyses that support and inform planning and prioritization of activities within the Astrophysics Division programs. Operations and structure of the PAGs are described in their Terms of Reference (TOR), which can be found on the three science theme Program Office web pages. The Astrophysics PAGs report their input and findings to NASA through the Astrophysics Subcommittee of the NASA Advisory Council, of which all the PAG Chairs are members. In this presentation, we will provide an overview of the ongoing activities of NASAs Astrophysics PAGs in the context of the opportunities and challenges currently facing the Astrophysics Division. NASA Headquarters representatives for the COPAG, ExoPAG, and PhysPAG will all be present and available to answer questions about the programmatic role of the Astrophysics PAGs.

Author(s): Wilton T. Sanders[1], Rita M. Sambruna[1], Mario R. Perez[1], Douglas M. Hudgins[1]
Institution(s): *1. NASA Headquarters*

308.02 – Report from the COsmic Origins Program Analysis Group (COPAG)

The Cosmic Origins Program Analysis Group (COPAG) is tasked by the NASA Advisory Council's Astrophysics Subcommittee to support community coordination and analysis of scientific and technological issues impacting NASA's Cosmic Origins Program. NASA's Cosmic Origins theme encompasses a diversity of astrophysical phenomena ranging from the formation of stars to the development and evolution of the largest assemblages of matter in the universe. The principal tasks of the COPAG are to assess and provide input on technological needs for future space missions, and to study science-driven issues related to NASA space missions that perform (or will perform) observations that advance Cosmic Origins science objectives. The COPAG is currently studying the science cases for overlapping operations of the Hubble Space Telesacope (HST) and James Webb Space Telescope (JWST), Cosmic Origins science to be performed with the WFIRST-AFTA coronagraph and WFIRST-AFTA archives, and synergies between the Spitzer Space Telescope and JWST. This talk will summarize the status of recent COPAG efforts, describe upcoming activities, and outline synergies between the COPAG and other astrophysics PAGs.

Author(s): Kenneth Sembach[1]
Institution(s): *1. STScI*

308.03 – Report from the Exoplanet Exploration Program Analysis Group (ExoPAG)

The Exoplanet Exploration Program Analysis Group (ExoPAG) is responsible for soliciting and coordinating community input into the development and execution of NASA's Exoplanet Exploration Program (ExEP). The ExoPAG serves as a community-based, interdisciplinary forum for analysis in support of activity prioritization and for future exploration. It provides findings of analyses to NASA through the Astrophysics Subcommittee (APS) of the NASA Advisory Council (NAC). The ExoPAG is making an effort to engage a broad cross-section of the exoplanet community, in order to solicit input on ways in which NASA might advance exoplanet research over the next decade. A summary of ExoPAG activities to this end, as well as the recent ExoPAG 10 and 11 meetings, will be presented.

Author(s): B. Scott Gaudi[1]
Institution(s): *1. Ohio State Univ.*
Contributing team(s): The Exoplanet Exploration Program Analysis Group

308.04 – Physics of the Cosmos Program Analysis Group (PhysPAG) Report

The Physics of the Cosmos Program Analysis Group (PhysPAG) serves as a forum for soliciting and coordinating input and analysis from the scientific community in support of the PCOS program objectives. I will outline the activities of the PhysPAG over the past year, since the last meeting during the AAS meeting in National Harbor, and mention the activities of the PhysPAG related Scientific Interest Groups.

Author(s): John A. Nousek[1]
Institution(s): *1. Penn State Univ.*

309 – Elliptical Galaxies

309.01D – Not Dead Yet: Low-Level Star Formation and Active Nuclei in the Continued Evolution of Nearby Early-Type Galaxies

We present the results of sensitive Jansky Very Large Array continuum observations of nearby early-type galaxies (ETGs) at 1.4 and 5 GHz. Our sample comprises a subset of the volume- and magnitude-limited ATLAS-3D survey of ETGs, which has a rich database of ancillary data including CO observations. The 1.4 GHz observations were designed to explore the properties of star formation (SF) in ETGs at ~5” (~300 pc) spatial resolution. Here, we find that some CO-rich ETGs have radio luminosities consistent with extrapolations from H2 mass-derived SF rates (SFRs) and standard radio-SFR calibrations. However, at low H2 masses, many have weaker radio emission than expected. The infrared-radio relation shows similar behavior at low luminosities, with a systematic tendency for ETGs to lie below the standard infrared-radio relation developed for spirals, even when substantial reservoirs of H2 are available. Thus, many nearby ETGs are radio deficient compared to both their H2 and infrared emission. Several mechanisms likely conspire to cause this, but evidence is most compelling for a combination of decreased SF efficiency, a bottom-heavy IMF, weak magnetic fields, and higher incidence of environmental effects compared to spirals.

We also study the prevalence and properties of 5~GHz radio cores at subarcsecond (~30 pc) resolution for two distinct kinematic classes: slow rotators (SRs) and fast rotators (FRs). SRs preferentially host nuclear radio emission compared to FRs, and they also host the most powerful radio sources in our sample, consistent with previous findings for ellipticals. In contrast to FRs, SRs also show signs of relationships between radio luminosity and stellar mass. In both FRs and SRs, the presence of dust and ionized gas are strong predictors of the detection of a radio core. All of this suggests that the nuclear activity in ETGs is related to their formation histories. In this picture, FRs are built-up by minor mergers and interactions that leave behind ample cold gas but lower-mass central black holes. SRs are the products of major mergers and, although their accretion rates are very low, their more massive central black holes can result in powerful levels of radio emission.

Author(s): Kristina Nyland[2], Lisa Young[2], Joan Wrobel[3], Raffaella Morganti[1]
Institution(s): *1. ASTRON, 2. New Mexico Tech, 3. NRAO*
Contributing team(s): ATLAS-3D

309.02D – The evolution of early-type galaxies: a strong lensing perspective

Early-type galaxies are believed to grow as a result of mergers, but the details of this process are still largely unknown. Do the mergers involve galaxies of comparable mass (major) or are they dominated by small systems (minor)? Is there dissipation (wet) or not (dry)? Different processes leave different signatures on the mass structure of early-type galaxies. Gravitational lensing provides a unique way to detect these signatures. The SL2S project measured the evolution of the mass profile of massive early-type galaxies during the last 7 billion years, including constraints on the mean density slope, dark matter fraction, inner dark matter slope and stellar IMF. Based on collected data, we find that theoretical models for the evolution of early-type galaxies through dry mergers alone are unable to reproduce the observed trends. Additional physical processes, likely related to baryonic physics, are necessary to match the entire set of observables.

Author(s): Alessandro Sonnenfeld[6], Tommaso Treu[5], Philip J Marshall[4], Raphael Gavazzi[2], Sherry Suyu[1], Carlo Nipoti[7], Matthew Auger[3]
Institution(s): *1. Academia Sinica Institute of Astronomy and Astrophysics, 2. Institut d'Astrophysique de Paris, 3. Institute of Astronomy, University of Cambridge, 4. Kavli Institute for Particle Astrophysics and Cosmology, 5. UC Los Angeles, 6. UC Santa Barbara, 7. University of Bologna*
Contributing team(s): Team 1

309.03 – The Black Hole Safari: Big Game Hunting in 30+ Massive Galaxies

The current census of the most massive black holes in the local universe turns up an odd variety of galaxy hosts: central galaxies in rich clusters, second- or lower-ranked cluster members, and compact relics from the early universe. More extensive campaigns are required to explore the number density and environmental distribution of these monsters. Over the past three years we have collected a large set of stellar kinematic data with sufficient resolution to detect the gravitational signatures of supermassive black holes with $M^{BH} > 10^9$ M^{Sun}. This Black Hole Safari targets enormous galaxies at the centers of nearby galaxy clusters, as well as their similarly luminous counterparts in weaker galaxy groups. To date we have observed more than 30 early-type galaxies with integral-field spectrographs on the Keck, Gemini North, and Gemini South telescopes. Here I present preliminary stellar kinematics from 10 objects.

Author(s): Nicholas J. McConnell[3], Chung-Pei Ma[2], Ryan Janish[2], Karl Gebhardt[4], Tod R. Lauer[1], James R Graham[2]
Institution(s): *1. NOAO, 2. UC Berkeley, 3. University of Hawaii, 4. UT Austin*

309.04D – The story of Brightest Cluster Galaxies told through merger signatures in their stellar populations

Brightest cluster galaxies (BCGs) are among the most massive galaxies in the Universe and have been predicted to have gone through more mergers than less massive galaxies. We use integral field spectroscopy to study the spatially-resolved stellar populations of BCGs and their close massive companions with the aim of tracking back their accretion histories. Our sample is composed of slow rotating and fast rotating BCGs. Therefore, we explore the possibility of a connection between stellar kinematics and stellar populations. We find that BCGs have high central metallicities, intermediate central ages, and shallow stellar population gradients. Our analysis suggests that all BCGs have an active accretion history that triggers star formation at high redshifts and disrupt the stellar population gradients at low redshifts. The evolutionary histories of BCGs are different from those of early-type galaxies of similar mass which appear to be passively evolving.

Author(s): Paola Oliva-Altamirano[2], Sarah Brough[1], Kim-Vy Tran[3], Warrick Couch[1]
Institution(s): *1. Australian Astronomical Observatory, 2. Swinburne University of Technology, 3. Texas A&M*

309.05D – Investigating [X/Fe], IMF, and compositeness in integrated-light models

Modelling elliptical galaxy integrated-light characteristics with old, metal-rich stellar populations is a common and promising way to study these distant objects. However, different model parameters may change the characteristics in a similar way, causing degeneracy, e.g., the age-metallicity degeneracy. Here, we investigate several under-appreciated effects with the evolving Worthey models, and discuss their detectabilities.
We model composite stellar populations with realistic abundance distribution functions (ADFs), tracking the trends of individual elements as a function of overall heavy element abundance as observed in MW bulge stars in addition to solar neighborhood stars. Comparing bulge versus elliptical galaxies, Fe, Ti, and Mg trend about the same for both but C, Na, and Ca seem irreconcilably different.
Exploring the behavior of abundance compositeness leads to the concepts of ``red lean'' where a narrower ADF appears more metal rich than a wide one, and ``red spread'' where the spectral difference between wide and narrow ADFs increases as the ADF peak is moved to more metal-rich values. The prospects of measuring the width of the ADF of an old stellar population were investigated and seem bright using UV to IR photometry.
Next, we try to disentangle the effects of 1) low-mass cut-off; 2) IMF slope; and 3) AGB strength in several IMF-sensitive indices and NIR colors. In most of the NIR-optical colors, varying low-mass cut-off and AGB strength leads to about 0.03 mag drift, which is comparable to the observable limits. Using a mix of photometric and spectral absorption indices (e.g. [MgFe], Wing-Ford, V-K, and B-V) degeneracy can be lifted, although at an observationally challenging amplitude. We go on to include ADF width and abundance ratio effects, and discuss the accuracy of disentangling multiple effects from integrated-light measurements.

Author(s): Baitian Tang[1], Guy Worthey[1]
Institution(s): *1. Washington State University*

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310 – White Dwarfs and Variable Stars

310.01 – Numerical Simulations of Giant Eruptions from Massive Stars and their Recoveries

We use a 3D hydro code to model the response of a massive star to a high mass loss episode. Starting with a modified version of the 1D stellar evolution code MESA, we obtain a model of an evolved massive star, with properties similar to those of Eta Carinae, known for its giant eruption in the 19th century.
We simulate a giant eruption using two approaches:
1.Removing a layer from the star using energy from inner layers.
2.Extracting energy from the core to outer layers that spontaneously causes mass loss.
We then follow the evolution of the star using the FLASH code. Our hydrodynamical simulation includes radiation transfer with realistic opacities and convection.
We find that the star develops a strong wind, powered by pulsation in the inner parts of the star. The strong eruptive mass loss phase lasts for a few years, followed by centuries of continually weakening mass loss.

Author(s): Amit Kashi[1], Kris Davidson[1], Roberta M. Humphreys[1]
Institution(s): *1. University of Minnesota*

310.02 – Optimal Model Discovery of Periodic Variable Stars

Precision modeling of periodic variable stars is important for various pursuits such as establishing the extragalactic distance scale and measuring the Hubble constant. Many difficulties exist, however, when attempting to model the light curves of these objects, as photometric observations of variable stars tend to be noisy and sparsely sampled. As a consequence, existing methods commonly fail to produce models that accurately describe their light curves. In this talk, I introduce a new machine learning approach for modeling light curves of periodic variables that is robust to the presence of these effects. I demonstrate this method on fifty thousand Cepehid and RR Lyrae variable stars in the galaxy as well as the Magellanic Clouds and show that it significantly outperforms existing methods.

Author(s): Earl Patrick Bellinger[1], Shashi Kanbur[2], Daniel Wysocki[2]
Institution(s): *1. Indiana University, 2. SUNY Oswego*

310.03D – Classical Cepheids: High-precision Velocimetry, Cluster Membership, and the Effect of Rotation

Classical Cepheids are crucial calibrators of the extragalactic distance scale and excellent laboratories for stellar astrophysics. This thesis addresses both research domains via three primary topics: (1) the behavior of Cepheid pulsations via highly precise multi-epoch Doppler measurements (velocimetry); (2) open cluster membership via a newly-developed 8-dimensional astro-statistical method; (3) the effect of rotation on populations of classical Cepheids based on predictions by Geneva stellar evolution models.
Using highly-precise velocimetry (1), I revealed additional complexity (modulation) present in Cepheid radial velocity curves that can bias distance estimates based on the Baade-Wesselink (BW) method by up to 15%. Two types of modulation were found: a) steady long-term amplitude variations over the timescale of the observing program (3 years) for short-period Cepheids; b) stochastic cycle-to-cycle variations for long-period Cepheids. It is thus crucial to obtain contemporaneous measurements of angular and linear radius variations to ensure accuracy of BW distances.
The eight-dimensional census of Cepheids belonging to Galactic open clusters (2) established a bona-fide sample of cluster Cepheids useful for calibrating the Cepheid period-luminosity relation. Several new cluster Cepheid candidates were identified, one of which has been recently confirmed by independent investigators. The method's quantitative nature and fast computation renders it particularly interesting for large data sets such as those expected from ESA's Gaia space mission.
Finally, this thesis presents the first detailed investigation of the effect of rotation on populations of Cepheids (3). Using Geneva stellar evolution models, we show that a) rotation provides a suitable explanation for the long-standing Cepheid mass discrepancy and that b) rotation can lead to an intrinsic dispersion in the period-luminosity relation. Rotation should no longer be neglected in Cepheid-related studies, since the rotational history of Cepheid progenitors significantly affects their present-day luminosity.
Further research is in progress to exploit these findings with the goal of improving the accuracy of Cepheid-based distances.

Author(s): Richard Irving Anderson[1]
Institution(s): *1. Geneva Observatory, University of Geneva*

310.04 – Observations of Interesting Cataclysmic Variables

Cataclysmic Variables (CVs) comprise one category of active mass transfer binaries containing a white dwarf accreting from an orbiting late main-sequence companion. Undoubtedly, non-magnetic CVs, intermediate polars and polars constitute a powerful probe of the structure of accretion onto white dwarfs and the theories of angular momentum loss, which elucidate the long-term evolution leading to the formation of these short period compact binaries. Combining photometric and spectroscopic data from space and ground telescopes can lead to novel discoveries. The SDSS survey provided a large dataset of spectra of different types of CVs. Followup photometry and spectroscopy is still underway to determine the unique properties of the objects identified as CVs. The Kepler program provided the first look at the variability of CVs over a continuous timescale of months. The extension of the program to the K2 fields allows further sets of CVs to be explored. We present some interesting results for several new CVs found in the SDSS and Kepler surveys which include their behavior during quiescence and outburst. These observations further demonstrate the complexities of CVs. This research was partially funded by CAS visiting scholar grant, NSF grant AST-1008734 and NASA grant HST-GO12870.

Author(s): Zhibin Dai[3], Paula Szkody[2], Peter M. Garnavich[1], Mark Kennedy[1]
Institution(s): *1. Univ. of Notre Dame, 2. University of Washington, 3. Yunnan Observatories*

310.05 – HST spectrophotometry of accreting white dwarf pulsators

The discovery of non-radial pulsations in cataclysmic variables has opened a new venue of opportunity to probe the stellar parameters of accreting variable white dwarfs using asteroseismic techniques. A unique model fit to the observed periods of the variable white dwarf can reveal information about the stellar mass, core composition, age, rotation rate, magnetic field strength, and distance. Mode identification is an essential step in determining an unambiguous model fit, that could be achieved by determining optical and ultra-violet pulsation amplitudes. We will be presenting our results on ultra-violet HST observations acquired with contemporaneous ground based optical data for several cataclysmic variables. The HST spectrophotometry also yields the effective temperatures of the accreting white dwarfs, allowing us to improve our present determination of the instability strip for accreting pulsators. We thank NASA for the grant HST-GO12870 that has supported this research.

Author(s): Anjum S. Mukadam[1], Paula Szkody[1], Boris T Gaensicke[2]
Institution(s): *1. Univ. of Washington, 2. University of Warwick*

310.06 – Asteroseismology of Stars in NGC 6791 Using Kepler ``Superstamps''

The Kepler space telescope has been a gold mine for asteroseismology thanks to its unprecedented photometric precision and uninterrupted span of observations. One major drawback of Kepler though was that it only read out a few pixels around pre-selected target stars and thus, no information was gathered for most of the stars in the Kepler field of view. Fortunately, for the open clusters NGC 6791 and NGC 6819, Kepler also read out larger ``superstamps'' which contained complete images of the central region of each cluster. These cluster images can be used to study additional stars in the open clusters that were not originally on Kepler's target list. We adapted conventional crowded-field photometric routines to carry out photometry on these superstamps. We present select results from this study in order to show the power and usefulness of using the superstamps. The techniques created for this project will be even more useful in the new K2 mission which will include additional open clusters and, for the first time, globular clusters in its fields of view.

Author(s): Charles A. Kuehn[2], Jason Drury[2], Beau Bellamy[2], Dennis Stello[2], Timothy R Bedding[2], Mike Reed[1], Breanna Quick[1]
Institution(s): *1. Missouri State University, 2. University of Sydney*

310.07 – Recent seismic discoveries for pulsating subdwarf B stars using Kepler data

During Kepler's main mission, 18 pulsating subdwarf B (sdB: extreme horizontal branch stars) were discovered. Many of these stars were observed continuously in short cadence for three years making them the best studied pulsating sdB stars to date. Discoveries from these data include nearly-evenly-spaced asymptotic period overtones and rotationally-induced frequency multiplets which have made it possible to identify pulsation modes and determine rotation rates. In this talk I will highlight some of our recent discoveries including multiplets which indicate radially differential rotation, overtone sequences which indicate trapped modes in one star and no mode trapping in another, and oscillations that display stochastic properties.

Author(s): Mike Reed[2], Heather Foster[2], John H Telting[3], Andrzej S Baran[4], Roy H Ostensen[1]
Institution(s): *1. KU Leuven, 2. Missouri State Univ., 3. Nordic Optical Telescope, 4. Pedagogical University*

310.08 – Recent developments on SU UMa stars - theory vs. observation

Kepler light curves of short period dwarf novae have resparked interest in the nature of superoutbursts and led to the question: Is the thermal-tidal instability needed, or can the plain vanilla version of the accretion disk limit cycle do the job all by itself? A detailed time-resolved study of an eclipsing SU UMa system during superoutburst onset should settle the question − if there is a dramatic contraction of the disk at superoutburst onset, Osaki's thermal-tidal model would be preferred; if not, the plain disk instability model would be sufficient. I will present recent results that support the contention by Osaki & Kato that the time varying negative superhump frequencies can be taken as a surrogate for the outer disk radius variations. Finally, it may be necessary to look beyond the short period dwarf novae to gain perspective on the nature of embedded precursors in long outbursts.

Author(s): John K. Cannizzo[1]
Institution(s): *1. NASA/GSFC/CRESST/UMBC*

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311 – Instrumentation: Space Missions - Ground Based or Airborne I

311.01 – How to Directly Image a Habitable Planet Around Alpha Centauri with a ~30cm Space Telescope

Several mission concepts are being studied to directly image planets around nearby stars. Direct imaging enables spectroscopic detection of biomarkers such as atmospheric oxygen and methane, which would be highly suggestive of extraterrestrial life. It is commonly thought that directly imaging a potentially habitable exoplanet requires telescopes with apertures of at least 1m, costing at least $1B, and launching no earlier than the 2020s.
A notable exception to this is Alpha Centauri (A and B), which is an extreme outlier among FGKM stars in terms of apparent habitable zone size. Specifically, Alpha Centauri habitable zones span about 0.5-1” in stellocentric angle, ~3x wider than around any other FGKM star. This enables a ~30cm visible light space telescope equipped with a modern high performance coronagraph or starshade to resolve the habitable zone at high contrast and directly image any potentially habitable planet that may exist in the system. Due to the extreme apparent brightness of the stars, exposure times can be as short as minutes with ideal components, or days with realistic ones. This makes it possible to do color photometry on potentially habitable planets sufficient to differentiate Venus-like, Earth-like, and Mars-like planets from

each other and establish the presence of Earth-pressure atmosphere through Rayleigh scattering.
The raw contrast requirements for such an instrument can be relaxed to 1e-8 if the mission spends 2 years collecting tens of thousands of images on the same target, enabling a factor of 500-1000 speckle suppression in post processing.
The light leak from both stars is controllable with a special wavefront control algorithm known as Multi-Star Wavefront Control (MSWC), which independently suppresses diffraction and aberrations from both stars using independent modes on the deformable mirror (see Thomas et al. at this conference).
The presentation will describe the general studies and calculations in more detail and briefly present examples of small coronagraphic mission concepts currently being developed to take advantage of this opportunity. (For more detail about one such concept, see Bendek et al. at this conference).

Author(s): Ruslan Belikov[1]
Institution(s): *1. NASA Ames Research Center*
Contributing team(s): ACEND team, ACESat team

311.02 – Space mission and instrument design to image the Habitable Zone of Alpha Centauri

The Alpha Centauri System is particularly well suited for high-contrast imaging. The angular separation of the A and B stars Habitable Zone ranges from 0.7” to 1.63” and 0.4” to 0.95” respectively, with contrast ratios for an earth-like planet in the order of 10^{-10}. A 35cm telescope using an aggressive coronagraph is capable of imaging and constrain the contents of earth-like, or larger planets, from the inner HZ out to the equivalent orbit of a Jupiter class planet. Here we present a mission concept design, which considers an off-axis telescope with elliptical aperture primary mirror, an embedded Phase Induced Amplitude Apodization lossless Coronagraph (PIAA), and a Kilo DM deformable mirror for wavefront control and speckle nulling. Our goal is to obtain $2x10^{11}$ contrast at 0.7” and $6x10^{11}$ contrast at 0.4” after post processing. To solve the binary diffraction contamination we will use the Multiple Star Wavefront Control approach than can correct for the light of both stars. We baseline a 3 year mission on a heliocentric orbit, that provides a thermally stable environment and continuous access to the target.

Author(s): Eduardo Bendek[1], Ruslan Belikov[1], Sandrine Thomas[1], Julien Lozi[1]
Institution(s): *1. NASA Ames*

311.03 – Absolute Calibration of the Radio Astronomy Flux Density Scale from 22 to 43 GHz using Planck

The Planck mission detected hundreds of extragalactic radio sources at frequencies from 28 to 857 GHz. Since Planck's calibration is absolute, based on the satellite's annual motion around the Sun, and since its beams are well-characterized at the sub-percent levels, Planck's flux density measurements are absolute to percent-level accuracy. We have made coordinated Planck, VLA and ATCA observations of ~60 strong, unresolved sources in order to compare Planck's absolute calibration to that used by these two interferometers at 22, 28 and 43 GHz. The flux densities of the sources used to calibrate the VLA observations are taken from Perley and Butler (2013), which is fundamentally based on models of the planet Mars calibrated via WMAP observations. The flux densities of the sources used to calibrate the ATCA observations are based on models of the planet Uranus. Despite the scatter introduced by the variability of many of the sources, the three flux density scales are determined to agree to 1-2% accuracy.

Author(s): Bryan J. Butler[5], R. Bruce Partridge[3], Richard A. Perley[5], Jamie B. Stevens[2], Marcos Lopez-Caniego[6], Graca Rocha[4], Ben Z. Walter[3], Andrea Zacchei[1]
Institution(s): *1. Astronomical Observatory, 2. CSIRO, 3. Haverford College, 4. JPL, 5. NRAO, 6. University of Cantabria*

311.04 – Low Frequencies on the NRAO VLA and the new VLA Ionospheric and Transient Experiment (VLITE)

The Karl G. Jansky Very Large Array (VLA), operated by the National Radio Astronomy Observatory (NRAO), has recently undergone an upgrade to a fully digital broadband system covering the frequency range of 1-50 GHz. The Naval Research Laboratory (NRL) has collaborated with NRAO to return low frequencies to the VLA in a new broadband receiver system. This system covers two bands from 56-86 MHz (4-band) and 240-470 MHz (P-band). Currently, the higher frequency (P-band) system is in regular use as part of the General Observing (GO) program on the VLA, while the lower frequency band is undergoing testing with a new feed design. We present an overview of the capabilities of the P-band system with some initial science results.
NRL has expanded the collaboration with NRAO to broaden the VLA low frequency capabilities through the development of the VLA Low Band Ionospheric and Transient Experiment (VLITE) which has dedicated samplers and fibers that tap the signal from 10 VLA P-band receivers and correlate those through a dedicated VLITE DiFX correlator. This commensal observing system greatly expands the science output of those antennas by adding the low frequency system with no additional resources needed from the VLA system. VLITE system is expected to obtain more than 3000 hours per year on-the-sky at P band. The primary science drivers for VLITE are ionospheric science and astrophysical transients. We present an overview of the VLITE project and current status.
Basic research in Radio Astronomy at the Naval Research Laboratory is funded by 6.1 Base funding.

Author(s): Tracy E. Clarke[1], Namir E. Kassim[1], Joseph F. Helmboldt[1], Paul S. Ray[1], Wendy M. Peters[1], Brian Hicks[1], Walter Brisken[2], Richard A. Perley[2], Frazer N. Owen[2], Huib Intema[2]
Institution(s): *1. Naval Research Lab., 2. NRAO*

311.05 – The Low Band Observatory (LOBO): Expanding the VLA Low Frequency Commensal System for Continuous, Broad-band, sub-GHz Observations

The Naval Research Laboratory (NRL) and the National Radio Astronomy Observatory (NRAO) are currently commissioning the VLA Low Frequency Ionosphere and Transient Experiment (VLITE) on a subset of JVLA antennas at modest bandwidth. Its bounded scientific goals are to leverage thousands of JVLA on-sky hours per year for ionospheric and transient studies, and to demonstrate the practicality of a prime-focus commensal system on the JVLA. Here we explore the natural expansion of VLITE to a full-antenna, full-bandwidth Low Band Observatory (LOBO) that would follow naturally from a successful VLITE experience.

The new Low Band JVLA receivers, coupled with the existing primary focus feeds, can access two frequency bands: 4 band (54 – 86 MHz) and P band (236-492 MHz). The 4 band feeds are newly designed and now undergoing testing. If they prove successful then they can be permanently mounted at the primary focus, unlike their narrow band predecessors. The combination of Low Band receivers and fixed, primary-focus feeds could provide continuous, broad-band data over two complimentary low-frequency bands. The system would also leverage the relatively large fields-of-view of ~10 degrees at 4 band, and ~2.5 degrees at P band, coupling an excellent survey capability with a natural advantage for serendipitous discoveries.

We discuss the compelling science case that flows from LOBO's robust imaging and time domain capabilities coupled with thousands of hours of wide-field, JVLA observing time each year. We also touch on the possibility to incorporate Long Wavelength Array (LWA) stations as additional "dishes" through the LOBO backend, to improve calibration and sensitivity in LOBO's 4 band.

Author(s): Namir E. Kassim[2], Tracy E. Clarke[2], Joseph F. Helmboldt[2], Wendy M. Peters[2], Walter Brisken[1], Scott D. Hyman[3], Emil Polisensky[2], Brian Hicks[2]
Institution(s): *1. NRAO, 2. NRL, 3. Sweetbriar College*

311.06 – An Accurate Flux Density Scale from 50 MHz to 50 GHz

The flux density scale proposed by Perley and Butler (2013) determined the flux densities for four compact radio sources from 1 to 50 GHz with an accuracy of 1 to ~5%, with the greater errors at the lowest and highest frequency ends. The scale is based on emission models of the planet Mars (Rudy et al. 1987), which are in turn calibrated against the absolute microwave background via WMAP observations (Weiland et al. 2011). Because Mars is an extremely weak emitter at low frequencies, the Perley and Butler scale did not extend below 1 GHz, and has degraded accuracy between 1 and 4 GHz. The NRAO has recently completed installation of new highly linear, wide-band low frequency receivers on the VLA. We have utilized this new system over a frequency range of 230 to 460 MHz to accurately determine the flux density ratios between 16 well known sources, including several primary sources proposed for new low-frequency arrays, and Cygnus A. The ratios are converted to flux densities using the absolutely calibrated flux density of Cygnus A provided by Baars et al. (1977). These new data, plus 74 MHz observations made with the legacy VLA system, are used to extended the Perley and Butler scale to cover 50 MHz through 50 GHz. As a part of this program, these same 16 sources were observed using the VLA's L, S, C and X-band receivers (covering 1 through 12 GHz). We use these observations to fix the flux density scale of Cygnus A and the other sources to that of the Perley and Butler scale from 1 to 12 GHz.

Author(s): Richard A. Perley[1], Bryan J. Butler[1]
Institution(s): *1. NRAO*

311.07 – An Evolvable Space Telescope for NASA's Next UVOIR Flagship Mission

NASA has sponsored several studies to develop conceptual designs for the next UVOIR Flagship mission, including an Advanced Technology Large Space Telescope (ATLAST). These studies concluded that a space observatory launched in ~2030 will require a telescope aperture of 8 to 16 meters to address the most compelling astrophysical questions raised by missions such as HST, Kepler, TESS, JWST and WFIRST as well as the large ground based telescopes that will coming on-line in the next decade. This telescope will be designed to search for the bio-signatures of life in the universe as well as to study the physics of star formation and to unravel the complex interactions between dark matter, galaxies and the intergalactic medium.
Unfortunately, telescopes with this aperture will have a long development time with peak funding requirements that will absorb most NASA's Astrophysics budget for many years. To minimize this impact on NASA's budget and to drastically shorten the time between program start and "first light" for this UVOIR space observatory we have been developing

conceptual designs for an Evolvable Space Telescope (EST) that would be assembled on-orbit in three stages, beginning with the launch of a 2 mirror 4 x 12 meter telescope with 2 instruments 5 to 7 years after program start, and then adding mirror segments and instruments ay ~ 5 year intervals to obtain a 12-m filled aperture, and then a 20-m filled aperture telescope. We describe our approach in this presentation.

Author(s): Charles F. Lillie[2], James B. Breckinridge[1], Howard A. MacEwen[4], Ronald S. Polidan[3], Martin Flannery[3], Dean Dailey[3]
Institution(s): *1. Breckinridge Associates, LLC, 2. Lillie Consulting, LLC, 3. Northrop Grumman Aerospace Systems, 4. Reviresco LLC*

311.08 – The Advanced Energetic Pair Telescope (AdEPT), a Medium-Energy Gamma-Ray Polarimeter

Since the launch of AGILE and FERMI, the scientific progress in high-energy (E^g > 200 MeV) gamma-ray science has been, and will continue to be dramatic. Both of these telescopes cover a broad energy range from ~20 MeV to >10 GeV. However, neither instrument is optimized for observations below ~200 MeV where many astrophysical objects exhibit unique, transitory behavior, such as spectral breaks, bursts, and flares. Hence, while significant progress from current observations is expected, a significant sensitivity gap will remain in the medium-energy regime (0.75 – 200 MeV) that has been explored only by COMPTEL and EGRET on CGRO. Exploring this regime with angular resolution near the kinematic limit and high polarization sensitivity requires a gamma-ray telescope design with a low density electron track imaging detector.
The medium-energy (~5 to ~200 MeV) **Advanced Energetic Pair Telescope (AdEPT)**, will achieve angular resolution of ~0.6° at 70 MeV, similar to the angular resolution of Fermi/LAT at ~1 GeV that brought tremendous success in identifying new sources. AdEPT will also provide unprecedented polarization sensitivity of ~1% for a 1 Crab source. The enabling technology for AdEPT is the **Three-Dimensional Track Imager (3-DTI)** a low-density, large volume, gas time-projection chamber with a 2-dimensional readout. The 3-DTI provides high-resolution three-dimensional electron tracking with minimal Coulomb scattering that is essential to achieve high angular resolution and polarization sensitivity.
We describe our ROSES/APRA funded program to build a 50´50´100 cm3 AdEPT prototype, measure the angular resolution and polarization sensitivity of this prototype at an accelerator, and highlight some of the key science questions that AdEPT will address.

Author(s): Stanley D. Hunter[1]
Institution(s): *1. NASA's GSFC*

311.09 – Optimizing the Choice of Filter Sets for Space Based Imaging Instruments

We investigate the challenge of selecting a limited number of filters for space based imaging instruments such that they are able to address multiple heterogeneous science goals. The number of available filter slots for a mission is bounded by factors such as instrument size and cost. We explore methods used to extract the optimal group of filters such that they complement each other most effectively. We focus on three approaches; maximizing the separation of objects in two-dimensional color planes, SED fitting to select those filter sets that give the finest resolution in fitted physical parameters, and maximizing the orthogonality of physical parameter vectors in N-dimensional color-color space. These techniques are applied to a test-case, a UV/optical imager with space for five filters, with the goal of measuring the properties of local stars through to distant galaxies.

Author(s): Rachel E. Elliott[1], Duncan Farrah[1], Sara M. Petty[1], Kathryn Amy Harris[1]
Institution(s): *1. Virginia Polytech Institute*

312 – Relativistic Astrophysics, Gravitational Lenses & Waves

312.01D – A novel approach toward gravitational wave analyses with pulsar timing arrays

My doctoral studies provide a novel approach toward gravitational wave (GW) analyses, including the generalization of nanoHertz stochastic GW background searches, strict limits on when assumptions made in GW background analyses break down, and how to extract information about the masses and spins of supermassive black hole binaries using pulsar timing arrays. A pulsar timing array is galactic-scale nanoHertz GW detector that looks for small deviations in the ultra-stable arrival time of radio pulses from millisecond pulsars to infer the presence of GWs. I show that the standard analysis for isotropic stochastic GW backgrounds can be generalized in a conceptually straightforward way to the case of generic anisotropic background radiation. If evidence for a signal is found in the data, testing the assumption of isotropy could be one of the methods to confirm its cosmological origin. However, if one expects some deviations from isotropy, which may be the case for a background created by a finite population of supermassive black hole binaries, my method can be used to extract constraints on the underlying physical population. Moreover, I assess the assumptions made when computing the correlation functions used in the stochastic GW background searches, and found that when pulsars are separated by less than 3o, correlated phase changes can occur between the pulsars which are important to model. Lastly I show that the detection of GWs from individual supermassive black hole binary systems can yield direct information about the masses and spins of the black holes, provided that the GW-induced timing fluctuations both at the pulsar and at Earth are detected. This in turn provides a map of the nonlinear dynamics of the gravitational field and a new avenue to tackle open problems in astrophysics connected to the formation and evolution of supermassive black holes.

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Institution(s): *1. California Institute of Technology*
Contributing team(s): University of Birmingham Gravitational Wave Group (A. Vecchio, K. Grover, R. Smith, T. Sidery, I. Mandel)

312.02D – Exploring the cosmos with gravitational-waves

Gravitational-wave (GW) astronomy will open up a new frontier in astrophysical studies of neutron stars (NSs) and black-holes (BHs). Near-future detections will shed light on the coalescence rate of compact-object binaries, present an independent means of constraining cosmological parameters, and offer a host of other exciting opportunities. My doctoral research has followed two threads, linked by the common goal of mining rich information from near-future GW observations. In the first thread of my dissertation, I developed a technique to probe cosmological parameters with GWs in the absence of any electromagnetic counterparts. This exploits the potential for a network of GW interferometers to extract the distance of each system from the measured gravitational waveform. I use the observed intrinsic narrowness of the NS-NS mass-distribution, along with GW-measured redshifted-masses, to deduce candidate redshift distributions for each system, thereby allowing a probe of the distance-redshift relation. I find that an advanced LIGO-Virgo network can place independent, complementary constraints on the Hubble constant, whilst a third-generation network will be capable of probing the dark energy equation-of-state and the star-formation rate of the NS-NS progenitor population. In the second thread, I studied the potential for high-precision timing of millisecond pulsars to infer the perturbing influence of passing GWs. I developed a robust data-analysis pipeline to constrain the levels of anisotropy in a stochastic nanoHertz GW background using an ensemble of these pulsars. This technique cross-correlates pulse time-of-arrival deviations from many pulsars, leveraging the common influence of a stochastic background against noise sources, and mines the cross-correlation signature for information on the angular distribution of GW-power. Additionally, I developed several rapid inference techniques applicable to pulsar-timing searches for individual supermassive BH binary sources of GW radiation, which imprint a signature of their orbital evolution as the emitted GWs propagate past each pulsar. Coherently including these signatures within an accelerated pipeline can boost detection prospects in single-source searches.

Author(s): Stephen R Taylor[3], Jonathan R Gair[2], Ilya Mandel[4], Lindley Lentati[1], Justin Ellis[3]
Institution(s): *1. Battcock Centre for Experimental Astrophysics, University of Cambridge, 2. Institute of Astronomy, University of Cambridge, 3. Jet Propulsion Laboratory, 4. University of Birmingham*

312.03D – Searching for Gravitational Waves using Pulsar Timing Arrays

Gravitational Waves (GWs) are tiny ripples in the fabric of space-time predicted by Einstein's theory of General Relativity. Pulsar timing arrays (PTAs) offer a unique opportunity to detect low frequency GWs in the near future. Such a detection would be complementary to both LISA and LIGO GW efforts. In this frequency band, the expected source of GWs are Supermassive Black Hole Binaries (SMBHBs) and they will most likely form in an ensemble creating a stochastic GW background with the possibility of a few nearby/massive sources that will be individually resolvable. A direct detection of GWs will open a new window into the fields of astronomy and astrophysics by allowing us to constrain the coalescence rate of SMBHBs, providing further tests on the theory of General Relativity, and giving us access to properties of black holes not accessible by current astronomical techniques.

This dissertation work focuses primarily on the development of several robust data analysis pipelines for the detection and characterization of continuous GWs and a stochastic GW background. The data analysis problem for PTAs is quite difficult as one must fully take into account the timing model that must be fit in order to obtain the residuals, uneven sampling (including large gaps), and potential red noise processes. The data analysis techniques presented here handle all of these effects completely while allowing additional freedom in parameterizing the noise present in the data. The accumulation of work from this dissertation has resulted in a fully functional, robust, and efficient data analysis pipeline that has been successfully applied to the 5 and 9-year NANOGrav data releases. Here we will discuss the highlights of this work and comment on future directions.

Author(s): Justin Ellis[1]
Institution(s): *1. JPL/Caltech*
Contributing team(s): NANOGrav

312.04 – The Effect of Large-Scale Structure on the Magnification of High-Redshift Sources by Cluster-Lenses

Cluster gravitational lensing surveys like the HST Frontier Fields survey will detect distant galaxies 10-50 times fainter than any yet discovered. Using these surveys to measure the luminosity function of such faint, distant galaxies, however, requires that magnification maps built from the constraints of strongly-lensed images be accurate. For models that assume the cluster and nearby (correlated) structures are the only significant sources of lensing, a potential source of error in these maps comes from the fact that light rays also suffer weak deflections by uncorrelated large-scale structure (LSS) along the line-of-sight. Using a semi-analytical model based on the power spectrum of nonlinear matter density fluctuations, I will discuss the effects of this LSS on the magnification maps of cluster-lenses, and the implications of these effects for current and future cluster-lensing surveys.

Author(s): Anson D'Aloisio[1], Priyamvada Natarajan[2], Paul R. Shapiro[1]
Institution(s): *1. University of Texas at Austin, 2. Yale University*

312.05 – Stars as resonant absorbers of gravitational waves

Oscillation modes in stars that are quadrupolar can resonate with incident gravitational waves (GW) & grow non-linear at the expense of GW intensity. Populations of low mass stars near strong sources of GW (such as merging black hole binaries in galactic nuclei) may brighten on short timescales, signposting mergers before they occur. More massive stars that brighten on longer timescales, signpost mergers after they have occurred, potentially allowing us to carry out merger 'archaeology'. Since GW absorption is a fractional effect, stars far from the source (including our Sun) can eclipse sources of GW at resonant frequencies.
This is an overlooked prediction of General Relativity.

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312.06 – Fermi-LAT stares and double gamma-ray flares in the gravitationally lensed blazar B0218+357

Results from Fermi Large Area Telescope (LAT) gamma-ray observations of the double-image gravitationally lensed blazar B0218+357 will be presented. These include the successful measurement at >100 MeV energies of a delay between the two lensed images of 11.46 ± 0.16 days during a period of enhanced activity in 2012, as well as results from recent flaring activity in July 2014. At both times, Fermi-LAT target-of-opportunity observations were obtained when the delayed flaring emission was expected and revealed dissimilar behavior in the second image due either to a change in the lensing geometry or to microlensing. The gamma-ray delay from 2012 in particular is about 1 day longer than previously measured at radio wavelengths and could be the imprint of differing locations of the emission sites along the blazar jet.

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Contributing team(s): on behalf of the Fermi-LAT collaboration

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313 – Protoplanetary Disks and Stellar Accretion

313.01 – The end of an era: A search for flickering accretion in T Tauri stars

Classical T Tauri stars are associated with circumstellar disks and accrete gas at substantial rate as revealed by their copious emission line spectra. When the disk is fully dissipated, stars move to the Weak Line T Tauri phase of their evolution, with accretion absent and only mild line emission related to chromospheric activity. Considering the high accretion variability of Classical T Tauri stars and a necessarily finite timescale associated with the end of the accretion phase, objects most likely undergo an intermediate phase where their accretion flickers from significant to non-detectable. To quantify the frequency (and thus associated timescale) of this phenomenon, we have undertaken a spectroscopic monitoring campaign of 31 IR-selected disk-bearing T Tauri stars in the Taurus star-forming region. Using medium resolution optical spectrographs (R ~ 2000-5000) at several observatories, we have obtained an average of 9 spectra per target, providing a dense time sampling on timescales ranging from 1 day to 14 month. Our primary goal was to measure the equivalent width and 10% width of the Halpha line to determine whether some of the disk-bearing sources are actually not accreting, which would indicate the presence of a so-called passive disk. Here we present the main results of this campaign, which has identified several intriguing objects although the only passive disks that we have identified are associated with transition disks, i.e., disks with a substantial inner hole. This demonstrates that the situation in which a circumstellar disk is present in the immediate vicinity of the central star but where accretion is absent are actually very rare, indicating that the timescale associated with the break-up of the star-disk connection is extremely fast.

Author(s): Gaspard Duchene[1]
Institution(s): *1. University of California Berkeley*

313.02 – The Surprising Outburst Behavior of Z Canis Majoris, and Resolving the Alpha Oph Companion Near the Diffraction limit

We present recent high resolution Palomar and Keck observations on two intriguing binary star systems: Z Canis Majoris and Alpha Ophiuchus. We have obtained near-infrared Keck and Palomar photometry and spectra for each component of the Z Canis Majoris system, a very young binary composed of an FU Ori object and a Herbig Ae/Be object. Our high angular resolution photometry of this very young (~1 Myr) binary conclusively determines that the outburst was due solely to the embedded Herbig Ae/Be member, supporting results from earlier works. Further, our high-resolution K-band spectra during a quiescent phase definitively demonstrate that the 2.294 micron CO absorption feature seen in composite spectra of the system is due solely to the FU Ori component, while a prominent CO emission feature at the same wavelength, long suspected to be associated with the innermost regions of a circumstellar accretion disk, can be assigned to the Herbig Ae/Be member. These findings greatly clarify previous analyses of the origin of the CO emission in this complex system. In a different study, we detected the faint companion to the star Alpha Ophiuchus using the Palomar 5m Hale Telescope Adaptive Optics system combined with kernel phase interferometry, a recently-developed post-processing technique for high contrast imaging. The technique of kernel phase interferometry has never before been used to detect faint companions to nearby stars using ground-based observations. Our Palomar observations detect the Alpha Oph companion passing near its periastron point with separation of only ~130 miliarcseconds, close to the Palomar infrared diffraction limit. Alpha Oph is a particularly important binary system with the primary star rotating close to its breakup velocity. Thus, establishing the host star mass with high precision through dynamical orbital analysis is extremely valuable. This technique holds great promise for detecting high contrast objects at, or just inside, the formal diffraction limit of ground-based telescopes equipped with extreme adaptive optics.

Author(s): Sasha Hinkley[6], Benjamin Pope[8], Frantz Martinache[7], Lynne Hillenbrand[3], Adam L. Kraus[4], Michael Ireland[2], Ben R. Oppenheimer[1], Emily L. Rice[5], John D. Monnier[9], Peter Tuthill[10], Alexey Latyshev[10]
Institution(s): *1. American Museum of Natural History, 2. ANU, 3. California Institute of Technology, 4. CfA, 5. College of Staten Island, 6. Exeter University, 7. Observatoire de la Cote d'Azure, 8. Oxford University, 9. University of Michigan, 10. University of Sydney*

313.03 – Extreme Carbon Overabundance in the 49 Ceti Circumstellar Gas

We present analysis of C and O absorption in high-resolution HST-STIS FUV spectra of the nearby A1V star 49 Ceti. This disk system is one of the few showing the dust properties of a debris disk, but harboring relatively abundant molecular gas more characteristic of a low-mass protoplanetary disk. Since the disk is nearly edge-on, the line-of-sight to the central star passes through the disk, permitting sensitive probes of the circumstellar gas with absorption spectroscopy.

Our FUV spectra show many narrow circumstellar gas lines arising from several atomic species, including neutral carbon (a gas not seen in the local ISM) and neutral oxygen. We present an estimate of the total carbon column density in the line-of-sight gas and limits on the oxygen column density. Comparing the carbon abundance to a previous measurement of the line-of-sight iron abundance, we see that the carbon is extremely overabundant relative to the solar abundance. A similar overabundance is seen in the Beta Pic disk gas, where the carbon brakes other gases from being rapidly blown out by radiation pressure. The carbon in the 49 Cet gas may play a similar role.

Author(s): Aki Roberge[4], Barry Welsh[2], Inga Kamp[3], Alycia J. Weinberger[1], Carol A Grady[2]
Institution(s): *1. Carnegie Institution for Science, 2. Eureka Scientific, 3. Kapteyn Institute , 4. NASA GSFC*

313.04 – Ground and space-based observations of water vapor in protoplanetary disks

The characteristics of planets depend sensitively on the chemical environment of their birth. There has been significant progress towards studying the chemistry in protoplanetary disks in the last decade, thanks to the discovery of several simple molecules (including water vapor) in planet-forming regions with the Spitzer Space Telescope. I will present more recent follow-up observations of water vapor in protoplanetary disks with both ground- and space-based spectrographs, and discuss how these observations are being used to understand the origins of planetary diversity.

Author(s): Colette Salyk[4], Joan R. Najita[4], Simon Bruderer[2], John S Carr[3], Klaus Pontoppidan[5], Geoffrey A. Blake[1], Matthew Richter[6], Neal J. Evans[7]
Institution(s): *1. California Institute of Technology, 2. Max Planck Institute for Extraterrestrial Physics, 3. Naval Research Laboratory, 4. NOAO, 5. Space Telescope Science Institute, 6. University of California, Davis, 7. University of Texas at Austin*

313.05 – Radio Monitoring of Protoplanetary Discs

We present new results from a radio monitoring survey conducted with ATCA where we measured the flux variability for 11 protoplanetary disks in the Chameoleon and Lupus star forming regions at 7 and 15 mm and 3+6 cm. We determined the source of the excess flux and discuss its effect on grain growth to cm-size pebbles. We found that for most targets the 7 mm flux variability is consistent with the presence of thermal free-free emission and that the targets with excess emission above thermal dust emission also have signatures of grain growth to cm-size pebbles. Our results indicate that the presence of other emission mechanisms does not seem to negatively affect the grain growth process.

Author(s): Catarina Ubach[4], Sarah Tahli Maddison[4], Chris M. Wright[5], David J. Wilner[2], Dave J.P. Lommen[3], Baerbel Koribalski[1]
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313.06 – A Ring of C2H in the Protoplanetary Disk Orbiting TW Hya

The circumstellar disk orbiting the nearby (D = 54 pc), ~8 Myr-old, ~0.8 M^{sun} classical T Tauri star TW Hya represents a rich source of information concerning the chemical composition of a protoplanetary disk in its late evolutionary stages, just at or after the epoch of giant planet formation. Following up on the detection of strong mm-wave C^2H (4-3) emission from this disk via an unbiased single-dish line survey (Kastner et al. 2014, ApJ, 793, 55), we have used the SMA to image C^2H (3-2) at ~1.5" resolution. We find the C^2H emission emanates from a relatively narrow ring of inner radius ~1" (~50 AU). We consider various interpretations of this striking, ring-like C^2H emission morphology, including whether C^2H might serve as a disk "snow line" marker (as is the case for N^2H^+; Qi et al. 2013, Science, 341, 630) and the possibility that C^2H traces particularly efficient photodissociation of hydrocarbons and/or the photoevaporation of small, C-rich grains in this region of the disk.

Author(s): Joel H. Kastner[3], Chunhua Qi[1], Uma Gorti[4], Pierre Hily-Blant[2], Thierry Forveille[2], Karin I. Oberg[1]
Institution(s): *1. Center for Astrophysics, 2. IPAG, 3. RIT Center for Imaging Science, 4. SETI Institute*

313.07D – Ionization Driven Chemistry in Protoplanetary Disks and Observational Signatures of Ionization Suppression

Circumstellar disks around young stars set the stage for the formation of planetary systems. The ionization fraction of the disk fundamentally regulates turbulence, which drives accretion onto the star and plays a role in the formation of planetesimals. Ionization is also central to the chemistry of the coldest disk gas, where comets and other icy bodies are assembled. During my PhD I studied the expected levels --- including possible severe suppression --- of the primary ionizing agents in disks, including cosmic rays, X-rays and the decay of short-lived radionuclides. Within this framework, I examined how each of these sources impacts turbulence-free "dead zones," and I identified submillimeter molecular emission tracers that can be used to spatially map-out ionization in disks with ALMA. I applied these theoretical results to SMA and ALMA observations of the extensively studied TW Hya protoplanetary disk, and I measured a disk-averaged upper limit to the cosmic ray ionization rate ~100 times below the canonical rate of 10^{-17} s^{-1} per H^2. These results point to extensive CR deflection by either natal winds or twisted magnetic fields from the background environment or within the disk itself. One of the important implications of this work is that cold disk chemistry is inefficient without sufficient ionization, and as a direct result, deuterated water (HDO) is not significantly produced in disks. Given the elevated levels of HDO/H^2O present throughout Solar System bodies, these results point to a substantial interstellar inheritance of deuterium-enriched ices during the formation of our own planetary system.

Author(s): Lauren Ilsedore Cleeves[1], Edwin A. Bergin[1]
Institution(s): *1. University of Michigan*

313.08 – Observational Signatures of MRI-driven Turbulence in Protoplanetary Disks: Connecting Numerical Simulations with ALMA

Protoplanetary disks play a key role in star and planet formation processes. Turbulence in these disks, which arises from the magnetorotational instability (MRI), not only causes accretion of mass onto the central star, but also sets the conditions for processes such as dust settling, planetesimal formation, and planet migration. However, the exact nature of this turbulence is still not very well constrained in these systems.

In this talk, I will describe new work, utilizing both state-of-the-art numerical simulations and high resolution radio observations, to directly link numerical predictions for the turbulent velocity structure of protoplanetary disks to observations by the Atacama Large Millimeter Array (ALMA). ALMA's unprecedented resolution will allow us to generate a three-dimensional view of disk turbulence by measuring the turbulent broadening component of molecular lines at different disk heights and radii. A direct comparison between the observed turbulence values and those obtained from simulations will strongly constrain our theoretical understanding of these disks and the conditions under which planetary systems develop.

Author(s): Jacob B. Simon[3], A. Meredith Hughes[4], Kevin M. Flaherty[4], Xue-Ning Bai[1], Philip J. Armitage[2]
Institution(s): *1. Harvard University, 2. JILA/University of Colorado, 3. Southwest Research Institute, 4. Wesleyan University*

314 – Intergalactic Medium, QSO Absorption Line Systems I

314.01 – TeV blazar heating in a inhomogeneous universe

The intergalactic medium (IGM) contains 90 % of the baryons of the Universe and is the reservoir for structure formation. Acting as a calorimeter, its thermal evolution traces the conditions for structure formation and evolution. It was recently shown that TeV blazars heat up the IGM as the gamma-rays they produce turn into pairs which lose their kinetic energy to the surrounding medium through plasma instabilities. Assuming uniform heating, the heating increases the temperature of the IGM and produces an inverted temperature-density relation in underdense regions. We recently extended this work to take into account heating fluctuations due to clustering and find that the resulting temperature-density relation presents a wide scatter. We model the resulting Lyman alpha forest and compare with recent observations.

Author(s): Astrid Lamberts[1], Philip Chang[1]
Institution(s): *1. University of Wisconsin-Milwaukee*

314.02D – The Simulated Lyα Forest: Converged Statistics and Reconstructed Maps

The Lyα Forest traces density fluctuations at high redshift and at moderate overdensities, making it an excellent tool for mapping large-scale structure and constraining cosmological parameters. Although the computational machinery for simulating the Lyα Forest has existed for over a decade, we are just now approaching the scale of computing required to simultaneously capture large cosmological scales and the smallest absorption systems. We will discuss the pitfalls of low-resolution simulations and present results from a suite of large hydrodynamic simulations demonstrating converged flux statistics. We have also compared flux statistics derived from simulations using different discretizations and hydrodynamic schemes (Eulerian finite volume vs. SPH) and will discuss differences in their convergence behavior and their overall agreement. Finally, we will show how we can use the Lyα Forest to construct high-redshift tomographic maps with Megaparsec resolution. We have developed a fast Wiener Filtering code to make this problem tractable, using new techniques to reduce the computational and memory complexity. We have found that large-scale flux decrements trace protocluster environments, which we will search for in the ongoing CLAMATO survey.

Author(s): Casey W. Stark[1]
Institution(s): *1. UC Berkeley*

314.03 – Halo Mass Dependence of HI Absorption: Evidence for Differential Kinematics

We present an analysis of the kinematics of HI and OVI absorption surrounding 14 $z < 1$ galaxies within a projected distance of D=300 kpc of background quasars. With high resolution HST/COS spectroscopy and HST/WFPC2 imaging, we are able to accurately derive absorbing cloud velocities and galaxy virial masses. Relating the cloud velocities to the galaxy escape velocity at the projected distance, we have determined that lower mass galaxies, with virial masses less than $\log(M) < 11.5$ solar masses, have a larger fraction of clouds with velocities exceeding the galaxy escape velocity (65% of clouds around lower mass galaxies are observed moving faster than the escape velocity, compared to only 5% around higher mass galaxies). In fact, we show that any clouds with velocities greater than the galaxy escape velocity must trace outflowing gas. Our findings support a theoretical scenario of differential wind recycling, as proposed by Oppenheimer+ 2010, where outflows preferentially leave the CGM and pollute the IGM around lower mass galaxies, but remain bound within the CGM and can recycle in higher mass galaxies. We test theoretical wind models and find the data inconsistent with wind speeds that scale with galaxy mass; however, we do show a range of wind scenarios which can reproduce the observed differential kinematics. These observations help to explain both the observed mass metallicity relationship in the ISM of nearby galaxies and the shape of the stellar to halo mass function.

Author(s): Nigel Mathes[1], Christopher W. Churchill[1], Glenn Kacprzak[2], Nikole M. Nielsen[1], Sebastian Trujillo-Gomez[1], Jane C. Charlton[3], Sowgat Muzahid[3]
Institution(s): *1. New Mexico State University, 2. Swinburne University of Technology, 3. The Pennsylvania State University*

314.04 – Discovery of a Massive Halo Around the Andromeda Galaxy

Using archival HST COS ultraviolet spectroscopy observations of 19 QSOs piercing the halo of Messier 31, we demonstrate the presence of an extended and massive halo around M31 that extends at least to 50 kpc, and possibly up to its virial radius. Within the virial radius, the covering factor is consistent with 100% while it drops rapidly beyond R^{vir} to less than 20%. We find that the halo of M31 is multiphase, mostly ionized, and becomes more highly ionized gas at larger distances from M31. We estimate using Si II, Si III, and Si IV a CGM metal mass of 3×10^6 $M^{\odot}$ and gas mass of 4×10^9 $(Z^{\odot}/Z)$ $M^{\odot}$ within 50 kpc, implying nearly as much metal and gas mass within $1/6R^{vir}$ of the halo of M31 as in its disk. Compared with L* galaxies surveyed by COS-Halos, the CGM of M31 appears to be quite typical for a L* galaxy.

Author(s): Nicolas Lehner[1], J. Christopher Howk[1], Bart P. Wakker[2]

Institution(s): *1. Univ. Of Notre Dame, 2. University of Wisconsin-Madison*

314.05D – MApping the Most Massive Overdensity Through Hydrogen (MAMMOTH)

We have searched for the most massive and overdense galaxy structures at z=2-3, traced by the highest optical depth of intergalactic Ly-alpha absorption over large scale of 10-30 Mpcs. These overdense regions represent the most massive proto-clusters in the early universe at the peak of the galaxy formation epoch. They bridge the most luminous quasars observed at z~6-7 and the most massive clusters in the local universe. The cosmic abundance and physical properties of these highly biased regions provide powerful tests to cosmology and galaxy formation. Our cosmological simulations show a strong correlation between the optical depth of 1-D intergalactic Ly-alpha absorption and 3-D mass overdensities. By examining spectra of ~ 150,000 sight lines provided by SDSS-III quasar survey, we have identified overdensities of intergalactic medium (IGM) over a volume of ~1.5 (h^-1 Gpc)^3. This volume is more than one orders of magnitude larger than any existing Lyman break galaxy (LBG) survey. By examining the absorption spectra of ~100,000 quasar sight-lines at over a volume of 0.5 Gpc^3 in the SDSS-III, we have identified an overdensity traced by group of Ly-alpha absorption systems at z=2.32+/-0.03. Our KPNO-4m/MOSAIC wide field narrowband imaging have suggested a significant overdensity of bright Ly-alpha emitting galaxies (LAEs) with L>2\times L^* over the scale of 40 Mpc. Our follow-up LBT/LBC further suggest an overdensity of BX galaxies coincides with the LAE density peak. Our inital LBT/MODS observations have spectroscopically confirmed this massive large-scale structure by obtaining ~15 Ly-alpha emission lines for BX and LAEs associated with this large-scale structure in an area of 50 arcmin^2.

Author(s): Zheng Cai[5], Xiaohui Fan[5], Fuyan Bian[5], Brenda L. Frye[5], Ian D. McGreer[5], Sebastien Peirani[3], Martin White[4], Shirley Ho[2], Yujin Yang[1], Ann I. Zabludoff[5]
Institution(s): *1. Argelander-Institut fur Astronomie, 2. Carneigie Mellon University, 3. Institut D'Astrophysique De Paris, 4. Lawrence Berkeley National Laboratory, 5. Steward Observatory, University of Arizona*

314.06 – Generating Synthetic Spectra for Observing the Simulated CGM and IGM

Hydrodynamical simulations can provide great insight into the behavior of many astrophysical problems. However, it can be difficult to extract the relevant quantities from these simulations for comparison against observational datasets. I will demonstrate methods for generating synthetic observations from hydrodynamical simulations using the open-source yt analysis code. Specifically, I will focus on creating realistic simulated spectra, which mimic quasar absorption line studies of the circumgalactic medium and the intergalactic medium as observed by the Cosmic Origins Spectrograph aboard HST. By producing simulated observations like those obtained with real telescopes, we can best compare theoretical models against their observational counterparts.

Author(s): Cameron B. Hummels[3], Hilary Egan[4], Molly S. Peeples[2], Devin W. Silvia[1], Britton D. Smith[5], Matthew Turk[6]
Institution(s): *1. Michigan State University, 2. Space Telescope Science Institute, 3. University of Arizona, 4. University of Colorado at Boulder, 5. University of Edinburgh, 6. University of Illinois, Urbana-Champaign*

314.07 – Revealing the Properties of Mg II Absorbing Galaxies at z > 1 with HST WFC3/IR

Intervening absorption from Mg II in the spectra of distant quasars is understood to trace the tidal stripping, accretion and outflows of cold, enriched gas in the circumgalactic medium of galaxies, independent of luminosity, to high redshift. Tens of thousands of Mg II absorbers in the range 0.3 < z < 2.2 have been extracted to date from the SDSS spectroscopic quasar sample, but their utility in aiding our understanding of the gaseous processes driving galaxy evolution has been hindered by the observational difficulties of detecting their host galaxies at intermediate and high redshifts and at small angular separations from brighter background quasars. We present first results from an 18-orbit HST Cycle 21 WFC3/IR program, which has obtained direct imaging and grism observations of galaxies in the fields surrounding the 9 quasar sight lines in the SDSS with the highest frequency of uncorrelated foreground Mg II absorption in the range 0.7< z < 2.2. These highly efficient observations include 56 Mg II absorbers, most all of which are matched unambiguously to galaxies in the grism data, thereby doubling the number of spectroscopically confirmed Mg II absorbing galaxies at z > 1. The data further enable precise measurements of the impact parameters, morphologies, inclination angles, star formation rates, and star formation rate surface densities of typical Mg II-selected galaxies, as a function of Mg II absorption strength, which are complete for a large range in projected separations (7-450 kpc) and to low star formation rates (~1.3 Msun/yr).

Author(s): Britt Lundgren[5], Dr. Gabriel Brammer[2], Donald G. York[3], John P. Chisholm[5], Dawn Erb[6], Varsha P. Kulkarni[4], Lorrie Straka[1], Christina A. Tremonti[5], Pieter G. Van Dokkum[7], David Wake[5]
Institution(s): *1. Leiden Observatory, 2. Space Telescope Science Institute, 3. University of Chicago, 4. University of South Carolina, 5. University of Wisconsin - Madison, 6. University of Wisconsin - Milwaukee, 7. Yale University*

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315 – Astroinformatics and Astrostatistics in Astronomical Research: Steps Towards Better

Curricula

AAS Special Session
The AAS Working Group on Astroinformatics and Astrostatistics hereby proposes a Special Session for the 225th AAS meeting in Seattle which will highlight the importance of data analytics training in astronomy, both for the sake of astronomical research and in order to make astronomy graduates more employable. Although astronomy and astrophysics are witnessing dramatic increases in data volume as detectors, telescopes, and computers become ever more powerful, the traditional training of astronomy and physics students is not providing skills to handle such voluminous and complex data sets. Equally worrisome, research funds and hiring options in astronomy are diminishing; in particular, a number of candidates for permanent (or steady) jobs significantly exceeds the job availability. As a result many of astronomy graduates have transitioned out of astronomy to work in areas where their analytic skills become highly valuable. Invited talks by a recent astronomy Ph.D. graduate who transitioned to industry, and an industry representative, will critically compare academic and industrial environments. The main goals of the proposed session are to discuss ways to improve Big Data training and research in astronomy, as well as to explore the connections between data science in astronomy and in the other research or technology areas where astronomy postdocs or recent graduates could excel and compete. We will use moderated panel method to facilitate discussion of graduate curriculum at Astronomy Departments, and invited talks to highlight connections to industry.

315.01 – Working on interesting problems

BSc Chemistry, The University of Sheffield 2001... PhD Astrochemistry, The University of Nottingham 2006... Scientist at GitHub Inc. 2013.

From the outside, the path an individual has taken from academia to industry is not an obvious one. In this session I'll (try and) explain how an interest in software, engineering and chasing interesting problems makes internet startup in San Francisco a great home.

Author(s): Arfon M Smith[1]
Institution(s): *1. GitHub Inc.*

315.02 – Astronomer to Data Scientist

Jessica Kirkpatrick received her PhD in Astrophysics from Berkeley in 2012. After an exhaustive job search within academia and beyond, she accepted a job as a data scientist / analyst for the social network Yammer (acquired by Microsoft) and is now the Director of Data Science for Education Company InstaEDU. Now instead of spending her days finding patterns in the large scale structure of galaxies, she finds patterns in the behaviors of people. She'll talk about her transition from astrophysics to tech, compare and contrast the two fields, and give tips about how to land a tech job, and discuss useful tools which helped her with her transition.

Author(s): Jessica Kirkpatrick[1]
Institution(s): *1. InstaEDU*

316 – Plenary Talk: Inflation and Parallel Universes: Science or Fiction?, Max Tegmark (MIT)

316.01 – Inflation and Parallel Universes: Science or Fiction?

We humans have repeatedly underestimated not only the size of our cosmos, but also the power of our humans minds to understand it using mathematical equations. I focus on the status of cosmological inflation and its predictions in light of the latest results from the BICEP2 and Planck. I also highlight mysteries such as the nature of dark matter, dark energy and the cosmic dark ages, and how creating the largest-ever 3D maps of our universe can shed new light on them.

Author(s): Max Tegmark[1]
Institution(s): *1. MIT*

318 – Cosmology II

318.01 – Improving Cosmic Microwave Background Constraints with 21cm Cosmology

As measurements of the Cosmic Microwave Background (CMB) become increasingly precise, it becomes necessary to search for qualitatively new ways to reduce uncertainties and degeneracies in cosmological constraints. One such source of uncertainty and degeneracy is reionization, which produces free electrons in the intergalactic medium that dampen

CMB anisotropies through scattering. Currently, this is accounted for by the optical depth parameter, which must be fit for in the CMB data as a nuisance parameter, resulting in increases in the final uncertainties of other cosmological parameters. In this talk, we show how direct observations of reionization using the redshifted 21cm line allow the CMB optical depth to be predicted and removed as a nuisance parameter from CMB studies. We discuss how this is relatively robust to the astrophysical uncertainties of reionization, and forecast the ability of arrays such as the recently funded Hydrogen Epoch of Reionization Array (HERA) to improve CMB constraints.

Author(s): Adrian Liu[2], Jonathan R. Pritchard[1], Michael Mortonson[2], Aaron Parsons[2]
Institution(s): *1. Imperial College London, 2. University of California Berkeley*
Contributing team(s): HERA collaboration

318.02D – Hydrogen and the First Stars: First Results from the SCI-HI 21-cm all-sky spectrum experiment

The “Sonda Cosmologica de las Islas para la Deteccion de Hidrogeno Neutro” (SCI-HI) experiment is an all-sky 21-cm brightness temperature spectrum experiment studying the cosmic dawn (z~15-35). The experiment is a collaboration between Carnegie Mellon University (CMU) and Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE) in Mexico. Initial deployment of the SCI-HI experiment occurred in June 2013 on Guadalupe; a small island about 250 km off of the Pacific coast of Baja California in Mexico. Preliminary measurements from this deployment have placed the first observational constraints on the 21-cm all-sky spectrum around 70 MHz (z~20), see Voytek et al (2014).
Neutral Hydrogen (HI) is found throughout the universe in the cold gas that makes up the intergalactic medium (IGM). HI can be observed through the spectral line at 21 cm (1.4 GHz) due to hyperfine structure. Expansion of the universe causes the wavelength of this spectral line to stretch at a rate defined by the redshift z, leading to a signal which can be followed through time.
Now the strength of the 21-cm signal in the IGM is dependent only on a small number of variables; the temperature and density of the IGM, the amount of HI in the IGM, the UV energy density in the IGM, and the redshift. This means that 21-cm measurements teach us about the history and structure of the IGM. The SCI-HI experiment focuses on the spatially averaged 21-cm spectrum, looking at the temporal evolution of the IGM during the cosmic dawn before reionization.
Although the SCI-HI experiment placed first constraints with preliminary data, this data was limited to a narrow frequency regime around 60-85 MHz. This limitation was caused by instrumental difficulties and the presence of residual radio frequency interference (RFI) in the FM radio band (~88-108 MHz). The SCI-HI experiment is currently undergoing improvements and we plan to have another deployment soon. This deployment would be to Socorro and Clarion, two islands further from mainland Mexico than Guadalupe. With the new data, we anticipate being able to place tighter constraints over a wider range of redshifts than our current results.

Author(s): Tabitha Voytek[1], Jeffrey Peterson[1], Omar Lopez-Cruz[2], Jose-Miguel Jauregui-Garcia[2]
Institution(s): *1. Carnegie Mellon University, 2. INAOE*
Contributing team(s): SCI-HI Experiment Team

318.04 – The STRong-lensing Insights into Dark Energy Survey (STRIDES)

Recent work has demonstrated that strongly lensed quasars can be used to measure cosmological parameters with high accuracy and precision. The constraints obtained from time delays are comparable in precision to those obtained by baryonic acoustic oscillation experiments and provide a powerful complement to other probes of dark energy like the cosmic microwave background (Suyu et al. 2014). At the moment, a main limitation of this technique is that lensed quasars are rare in the sky and not enough suitable lenses are known. To overcome this challenge we have formed a DES broad external collaboration (STRIDES), aimed at discovering and following-up 100 previously unknown gravitationally lensed quasars. I will present novel search algorithms based on data mining techniques as well as the first results from the search.

Author(s): Tommaso Treu[1], Adriano Agnello[1]
Institution(s): *1. University of California*
Contributing team(s): STRIDES Team

318.05 – Removing Line Foregrounds from CO Intensity Mapping Surveys

Intensity mapping surveys provide a powerful tool for mapping large scale structure at high redshifts, however as with many cosmological observables it can be difficult to isolate the target signal from various foreground sources. The problem of removing foregrounds with continuum spectra has been well studied, but since intensity mapping surveys involve mapping fluctuations of a single spectral line, other lines from different redshifts can contaminate the survey. For example, the CO(1-0) line can be confused with a lower redshift HCN(1-0) line. These foreground lines can be removed by cross-correlating an intensity map with another tracer of large scale structure, however doing so sacrifices some information about the target auto power spectrum. We present an alternative method for removing foregrounds by progressively masking the brightest pixels in a map. Since lower redshift sources tend to have steeper luminosity functions, the brightest pixels are more likely to be dominated by foreground emission. We demonstrate that by examining how the power spectrum changes as pixels are masked it is possible to determine the CO auto power spectrum from a map contaminated by HCN. This technique could possibly be applied to intensity mapping surveys using other spectral lines such as Lyman alpha and CII.

Author(s): Patrick Breysse[1], Ely Kovetz[1], Marc Kamionkowski[1]
Institution(s): *1. Johns Hopkins University*

318.06D – Formation of the first galaxies under Population III stellar feedback

The first galaxies, which formed a few hundred million years after the big bang, are related to important cosmological questions. Given that
they are thought to be the basic building blocks of large galaxies seen today, understanding their formation and properties is essential
to studying galaxy formation as a whole. In this dissertation talk, I will present the results of our highly-resolved cosmological ab-initio simulations to understand the assembly process of first galaxies under the feedback from the preceding generations of first stars, the so-called Population~III (Pop~III). The first stars formed at $z\lesssim30$ in dark matter (DM) minihalos with $M_{\rm vir}=10^5-10^6\msun$, predominately via molecular hydrogen ($\rm H_2$) cooling. Radiation from Pop~III stars dramatically altered the gas within their host minihalos, through photoionization, photoheating, and photoevaporation. Once a Pop~III star explodes as a supernova (SN), heavy elements are dispersed, enriching the interstellar (ISM) and intergalactic medium (IGM), thus initiating the process of chemical evolution. I will begin by presenting how the SN explosion of the first stars influences early cosmic history, specifically assessing the time delay in further star formation and tracing the evolution of metal-enriched gas until the second episode star formation happens. These results will show the role of Pop~III supernovae on the star formation transition from Pop~III to Population~II. Additionally, the more distant, diffuse IGM was heated by X-rays emitted by accreting black holes (BHs), or high-mass X-ray binaries (HMXBs), both remnants of Pop~III stars. I will present results of a series of simulations where we study the impact of X-ray feedback from BHs and HMXBs on the star formation history in the early universe, and discuss the resulting implications on reionization. I will also present the role of X-rays on the early BH growth, providing constraints on models for supermassive black hole formation. Finally, I will discuss key physical quantities of the first galaxies derived from our simulations, such as their stellar population mix, star formation rates, metallicities, and resulting broad-band color and recombination spectra.

Author(s): Myoungwon Jeon[1]
Institution(s): *1. The University of Texas at Austin*

318.07 – From Darkness to Light: Observing the First Stars and Galaxies with the Redshifted 21-cm Line using the Dark Ages Radio Explorer

The Dark Ages Radio Explorer (DARE) will reveal when the first stars, black holes, and galaxies formed in the early Universe and will define their characteristics, from the Dark Ages (z=35) to the Cosmic Dawn (z=11). This epoch of the Universe has never been directly observed. The DARE science instrument is composed of electrically-short bi-conical dipole antennas, a correlation receiver, and a digital spectrometer that measures the sky-averaged, low frequency (40-120 MHz) spectral features from the highly redshifted 21-cm HI line that surrounds the first objects. These observations are possible because DARE will orbit the Moon at an altitude of 125 km and takes data when it is above the radio-quiet, ionosphere-free, solar-shielded lunar farside. DARE executes the small-scale mission described in the NASA Astrophysics Roadmap (p. 83): “mapping the Universe’s hydrogen clouds using 21-cm radio wavelengths via lunar orbiter from the farside of the Moon”. This mission will address four key science questions: (1) When did the first stars form and what were their characteristics? (2) When did the first accreting black holes form and what was their characteristic mass? (3) When did reionization begin? (4) What surprises emerged from the Dark Ages (e.g., Dark Matter decay). DARE uniquely complements other major telescopes including Planck, JWST, and ALMA by bridging the gap between the smooth Universe seen via the CMB and rich web of galaxy structures seen with optical/IR/mm telescopes. Support for the development of this mission concept was provided by the Office of the Director, NASA Ames Research Center and by JPL/Caltech.

Author(s): Jack O. Burns[6], Joseph Lazio[3], Judd D. Bowman[1], Richard F. Bradley[4], Abhirup Datta[6], Steven Furlanetto[5], Dayton L. Jones[3], Justin Kasper[8], Abraham Loeb[2], Geraint Harker[7]
Institution(s): *1. Arizona State University, 2. Harvard University, 3. JPL/Caltech, 4. NRAO, 5. UCLA, 6. Univ. of Colorado at Boulder, 7. University College London, 8. University of Michigan*

319 – Results from the SDSS-III/APOGEE Survey II

AAS Special Session
Our understanding of the structure, formation, and evolution of the Milky Way Galaxy is being revolutionized by a new generation of spectroscopic surveys and the recently launched astrometric Gaia satellite. At the forefront of these efforts is the SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE). APOGEE is a recently completed high-resolution, near-infrared (NIR) spectroscopic survey of more than 100,000 stars in the Milky Way disk, bulge, and halo. The bulk of these stars are luminous red giants that in the NIR can be traced out to distances of 10 kpc and beyond, providing us for the first time with a comprehensive view of the Galactic disk and bulge populations. The high-resolution spectra allow precise radial velocities and elemental abundances of 15 elements to be measured. This special session will present the exciting and varied scientific explorations allowed by the high-quality APOGEE data, including the chemodynamical structure of the Milky Way disk, the structure of the bulge, new methods to trace the interstellar medium with diffuse interstellar bands, constraints on stellar physics and Galactic structure from the combination of the APOGEE data with asteroseismology from Kepler and CoRoT, the structure of young nebulous clusters, and others. A presentation of the second stage of APOGEE in SDSS-IV (2014-2020), which will expand the sky coverage to the Southern hemisphere, will also be given. This Special Session will include a survey overview and a combination of invited and contributed talks and posters, highlighting important APOGEE science results from the full three-year survey.

319.01 – Tracing chemical evolution over the extent of the Milky Way's Disk with APOGEE Red Clump Stars

I employ the APOGEE data to investigate the abundance distribution of ~10,000 red-clump stars over a large part of the MW disk. The [alpha/Fe] vs. [Fe/H] distribution exhibits a bimodality in [alpha/Fe] at intermediate metallicities, but at higher metallicities the two sequences smoothly merge. This abundance pattern is found throughout the Galaxy and is affected little by the selection function. The [alpha/Fe] trend of the high-alpha sequence is surprisingly constant throughout the Galaxy, with little spatial variation. Using simple galactic chemical evolution models a high star formation efficiency is derived for the high-alpha sequence that agrees with the nearly-constant value found in molecular-gas-dominated regions of nearby spirals. This result suggests that the early evolution of the MW disk was characterized by stars that shared a similar star formation history and were formed in a well-mixed, turbulent, and molecular-dominated ISM with a gas consumption timescale ~2 Gyr.

Author(s): David L. Nidever[5], Jo Bovy[1], Jonathan C. Bird[7], Brett Andrews[4], Michael R. Hayden[3], Jon A. Holtzman[3], Steven R. Majewski[6], Verne V. Smith[2]
Institution(s): *1. Institute for Advanced Study, 2. National Optical Astronomy Observatory, 3. New Mexico State University, 4. Ohio State University, 5. University of Michigan, 6. University of Virginia, 7. Vanderbilt University*
Contributing team(s): APOGEE

319.02 – Chemical Cartography with SDSS-III APOGEE: DR12 Results

The SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE) spectrograph provides an unprecedented view of the Milky Way disk, due in part to its ability to observe in the infrared, where the effects of extinction are significantly reduced compared to optical surveys. We present updated results on mean metallicity and chemical abundance gradients using the full three years of APOGEE1 observations and new results of the metallicity distribution function (MDF) and the [α/Fe] vs. [Fe/H] plane at different locations in the Milky Way disk. Our sample comprises nearly high signal-to-noise observations of nearly 100,000 red giant stars taken from SDSS DR12. These observations span the entire Milky Way visible from the northern hemisphere, ranging from the bulge to the edge of the disk (0

Author(s): Michael R. Hayden[6], Jon A. Holtzman[6], Jo Bovy[2], Steven R. Majewski[12], David L. Nidever[10], Gail Zasowski[4], Ricardo P. Schiavon[5], Peter M. Frinchaboy[9], Fred Hearty[8], Carlos Allende-Prieto[3], Ana García Pérez[3], Annie Robin[1], Katia M. L. Cunha[7], Timothy C. Beers[11]
Institution(s): *1. Institut UTINAM/OSU THETA, 2. Institute for Advanced Study, 3. Instituto de Astrofisica de Canarias, 4. Johns Hopkins University, 5. Liverpool John Moores University, 6. New Mexico State University, 7. Observatorio Nacional, 8. Pennsylvania State University, 9. Texas Christian University, 10. University of Michigan, 11. University of Notre Dame, 12. University of Virginia*
Contributing team(s): The APOGEE Team

319.03 – Probing Milky Way Structure with Near-Infrared Diffuse Interstellar Bands

Astronomers have studied the set of interstellar absorption features known as the diffuse interstellar bands (DIBs) for nearly a century, characterizing them into families and using them as probes of local interstellar medium (ISM) conditions even while trying to understand their origin. Though most DIB studies have focused on the optical features, recent DIB identifications at infrared (IR) wavelengths -- where extinction by interstellar dust is significantly decreased -- provide us with tracers of ISM along heavily extincted, previously inaccessible sightlines. This talk will briefly summarize results from a project using the strongest of these IR DIBs (detected in more than 60,000 sightlines towards cool, distant giant stars observed as part of the SDSS-III/APOGEE survey) to characterize the large-scale distribution and properties of the Galactic ISM, including in the heavily reddened bulge and inner disk. The DIB absorption's tight correlation with foreground reddening makes it a powerful, independent probe of line-of-sight dust extinction. For the first time, we map the velocity field of a DIB on large scales and find that it displays the signature of the rotating Galactic disk. Three-dimensional modeling of the carrier distribution reveals not only large-scale gradients consistent with other ISM components, but also substructures that coincide with particular Galactic bulge and disk features. Finally, we find that features that are outliers in the distribution of DIB profile shapes may have an origin in circumstellar, rather than interstellar, environments along these particular sightlines, and the properties of these atypical features may contain clues towards identifying the currently-unknown carrier molecule of this DIB.

Author(s): Gail Zasowski[4], Brice Ménard[4], Dmitry Bizyaev[1], D Garcia-Hernandez[3], Ana García Pérez[10], Michael R. Hayden[6], Fred Hearty[8], Jon A. Holtzman[6], Jennifer Johnson[7], Karen Kinemuchi[1], Steven R. Majewski[10], David L. Nidever[9], Kristen Sellgren[7], Matthew D. Shetrone[5], David G. Whelan[2], John C. Wilson[10]
Institution(s): *1. APO/NMSU, 2. Austin College, 3. IAC, 4. Johns Hopkins University, 5. McDonald Observatory, 6. NMSU, 7. OSU, 8. PSU, 9. U. of Michigan, 10. UVa*

319.04 – Unravelling The Chemical History Of The Solar Neighborhood With Giants

In the age of high-resolution spectroscopic surveys, elemental abundance measurements for large samples of stars allow us to identify individual populations within the Milky Way disk, however; absolute age measurements are needed to put the evolution of the stellar disk populations in a Galactic context. We present a sample of 700 local (d <400 pc) red giant stars observed using the New Mexico State University 1m telescope with the SDSS-III Apache Point Observatory Galactic Evolution Experiment (APOGEE) spectrograph, for which we estimate ages from the high-resolution spectroscopic stellar parameters and accurate distance measurements from Hipparcos. The high-resolution (R $\sim$ 23,000), near infrared (H-band, 1.5-1.7 \textmu m) APOGEE spectra provide measurements of the stellar atmospheric parameters (temperature, surface gravity, and overall metallicity), as well as abundances of 15 individual elements. Due to the smaller uncertainties in surface gravity possible with high-resolution spectra and accurate Hipparcos distance measurements, we are able to calculate the masses of our stars to within 40\%. We target giants because the relatively rapid evolution of stars up the red giant branch allows an age to be estimated based on the mass using a mass-age relation of evolved stars from model isochrones. Using these age estimates and the APOGEE abundances, we examine the abundance trends of individual elements with age in the solar neighborhood. As with other recent surveys of disk stars, we find older stars to be enhanced in α-elements, while younger stars have solar α-abundances. We find a flat age-metallicity relation with a large spread in metallicity at a given age, however; we note that our sample lacks metal-poor stars. This method of estimating ages of red giants is developed with the intent of estimating ages for the much larger sample of $>10,000$ APOGEE survey giants that will have parallax measurements from Gaia.

Author(s): Diane Feuillet[1], Jon A. Holtzman[1], Leo Girardi[2]
Institution(s): *1. New Mexico State University, 2. Osservatorio Astronomico di Padova*
Contributing team(s): The APOGEE team

319.05 – Detection of Neodymium in APOGEE H-band Spectra and its Application to Chemical Tagging

We report the successful detection of the rare earth element Neodymium (Nd) in the high-resolution, H-band spectra from the SDSS III Apache Point Observatory Galactic Evolution Experiment (APOGEE). Using the Nd II transition at 16058.014 angstroms, we have detected significant Nd enhancements in all stars observed by APOGEE belonging to the Sagittarius (Sgr) Dwarf Spheroidal (dSph) galaxy. Because Sgr is known to be enhanced in heavy s-process elements such as Nd, we can use this feature to identify and chemically tag Sgr stream members that have been observed in the Galactic halo by APOGEE. We also use this feature to characterize rare earth element abundance variations in clusters observed by APOGEE.

Author(s): Sten Hasselquist[4], Matthew D. Shetrone[9], Verne V. Smith[5], Jon A. Holtzman[4], James E. Lawler[12], Inese I. Ivans[10], Steven R. Majewski[11], Ricardo P. Schiavon[3], Gail Zasowski[2], David L. Nidever[7], Fred Hearty[6], Carlos Allende-Prieto[1], Timothy C. Beers[8], Ana García Pérez[1], Jennifer Sobeck[11]
Institution(s): *1. Instituto de Astrofisica de Canarias, 2. Johns Hopkins University, 3. Liverpool John Moores Unversity, 4. New Mexico State University, 5. NOAO, 6. Pennsylvania State University, 7. University of Michigan, 8. University of Notre Dame, 9. University of Texas, 10. University of Utah, 11. University of Virginia, 12. University of Wisconsin*
Contributing team(s): APOGEE team

319.06 – A Detailed Characterization of the Milky Way Bulge with APOGEE

An important part of the history of the Milky Way is encoded in the dynamics and chemistry of the inner Galaxy, which contains about 30% of its mass. It is only in the last few years that a composite picture of the bulge has begun to emerge: recent evidence points towards a population made of multiple components. The origin of the bulge appears to be in the disk and the disk-instabilities, although a component associated with mergers (a classical bulge) may also exist. The high-resolution (R=22,500), near-infrared (*H*-band) SDSS-III/APOGEE-1 survey provides a more complete characterization of the entire bulge as it penetrates the dust and probes down to the Galactic plane. APOGEE-1 collected spectra for approximately 15,000 inner Galaxy stars and derived the associated chemical composition data via an automated spectral analysis based on accurate stellar spectra models. Our statistical analysis of the highly accurate (~0.1 dex) bulge metallicities confirms the presence of multiple bulge components, which change in proportion to each other as a function of height from the plane. There are two metal-rich components that seem to dissipate in our high latitude fields ($b \geq 12^o$), and the metal-poor components become very weak at low latitude ($|b| < 4^o$). We are analyzing and comparing the individual element abundances for this sample (which includes α and C, among other elements) to that of other Galactic components. This enhances the characterization of the bulge and permits a thorough exploration of the origin and formation of its component populations (e.g., a classical bulge or a thick disk component).

Author(s): Ana E García Pérez[1], Jennifer Johnson[7], Carlos Allende-Prieto[1], Katia M. L. Cunha[5], Fred Hearty[6], Jon A. Holtzman[4], Steven R. Majewski[9], David L. Nidever[8], Ricardo P. Schiavon[3], Jennifer Sobeck[9], Gail Zasowski[2]
Institution(s): *1. Instituto de Astrofisica de Canarias, 2. John Hopkins University, 3. Liverpool John Moores University, 4. New Mexico State University, 5. NOAO, 6. Pennsylvania State University, 7. The Ohio State University, 8. University of Michigan, 9. University of Virginia*

319.07 – Double Vision: The Dual Hemisphere Viewpoint of the SDSS-IV/APOGEE-2 Survey

The second stage of the Apache Point Observatory Galactic Evolution Experiment, APOGEE-2, is one of three cornerstone projects of the Sloan Digital Sky Survey IV. The APOGEE-2 Survey performs a composite and systematic investigation of the entire Milky Way Galaxy with near-infrared, high-resolution, and multiplexed instrumentation. Observations are being carried out at both Northern and Southern Hemisphere locations: the 2.5m Sloan Foundation Telescope of the Apache Point Observatory (APOGEE-2N; Q3 2014 operations start) and the 2.5m du Pont Telescope of the Las Campanas Observatory (APOGEE-2S; Q4 2016 approximate operations start). The dual hemisphere view of APOGEE-2 extends the APOGEE-1 chemodynamical examination of the Milky Way to include: all disk quadrants, the inner and outer halo, the full expanse of the bulge, tidal streams, and local satellite galaxies. APOGEE-2 also continues the spectroscopic follow-up of Kepler and CoRoT targets. By the end of the six-year survey period, highly-reliable abundances and radial velocities will have been derived for a few hundred thousand stars from all components of the Galaxy. I will discuss in detail the scientific objectives of the APOGEE-2 Survey. Additionally, I will present data from the first few months of APOGEE-2 observations and provide a status report.

Author(s): Jennifer Sobeck[1]
Institution(s): *1. University of Virginia*
Contributing team(s): SDSS-IV/APOGEE-2 Collaboration

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320 – AGN, QSO, Blazars VI

320.01 – A Chandra survey of X-ray emission from radio jets: Correlations of the jet X-ray flux

We have completed a Chandra survey for X-ray emission from 54 radio jets that are extended on arcsecond scales. These are in flat spectrum radio loud quasars and have redshifts in the range z=0.3 to z=2.1. We detect X-ray emission from 60% of the jets. The study reported here considers the straight part of the jet nearest to the quasar. The X-ray counting rate from this correlates very well to that from the quasar. Correlation with redshift, the jet radio flux, the radio core flux, or visual apparent magnitude is poor or non-existent.
This research was supported by NASA contract NAS8-03060, SAO Grant GO9-0121B, and HST Grant HST-GO-11838.04-A

Author(s): Daniel A. Schwartz[5], Herman L. Marshall[7], Diana M Worrall[8], Mark Birkinshaw[8], Eric S. Perlman[4], Jim Lovell[10], David L. Jauncey[3], David William Murphy[6], Jonathan Gelbord[9], Leith Godfrey[1], Geoffrey V. Bicknell[2]
Institution(s): *1. ASTRON, 2. Australian National University, 3. CISRO, 4. Florida Institute of Technology, 5. Harvard-Smithsonian, CfA, 6. Jet Propulsion Lab, 7. MIT, 8. Physics Department, University of Bristol, 9. The Pennsylvania State University, 10. University of Tasmania*

320.02 – Radio Loud and Radio Quiet Quasars

It has been half a century since the population of radio quiet quasars has been recognized. Although all quasars are thought to contain a supper massive black hole which powers their extraordinary optical luminosity, it is still not clear why only a small fraction of optically selected quasars are strong radio sources. Using 5 GHz VLA observations, we compare the radio and optical properties of 179 quasars selected from the SDSS with absolute magnitude brighter than -23 and contained within a volume limited sample defined by redshifts between 0.2 and 0.3.

Author(s): Kenneth I. Kellermann[2], Amy E. Kimball[1], James J. Condon[2], Richard A. Perley[2], Zeljko Ivezic[3]

Institution(s): *1. CSIRO, 2. NRAO, 3. Univ. of Washington*

320.03 – A ~100y study of extreme AGN flares with DASCH

Flaring and extreme variability are characteristic of QSOs, Blazars and AGN generally and are probes of their accretion disks and jet structure. WIth increasing sky coverage (now ~20%) from scanning the Harvard plates with our DASCH project, we present preliminary results on flare size distributions and statistics of the maximum amplitudes reached. A sample of bright PG QSOs, Blazars (including OJ287) and lower luminosity AGN are presented. Both power spectral and autocorrelation as well as periodogram analysis is described that constrain AGN variability and power on timescales from days to decades.

Author(s): Jonathan E. Grindlay[1], George Franklin Miller[1]
Institution(s): *1. Harvard-Smithsonian, CfA*

320.04D – The highest redshift quasars with Pan-STARRS1

High-redshift quasars provide unique information about the evolution of supermassive black holes (SMBHs) and the intergalactic medium (IGM) at early cosmic time. Numerous studies have established a sample of ~60 quasars at $5.5 \le z \le 7.1$. These studies demonstrated the existence of SMBHs less than a Gyr after the Big Bang, and indicated that the end of reionization occured at z~6. These findings suggest that fundamental changes are happening in the IGM at $6 \le z \le 7$. The discovery and characterization of a statistically significant sample of quasars in this redshift range is crucial to further study this important era in the history of the Universe. I will present how in less than 2 years we almost doubled the number of known $5.7 \le z \le 6.0$ quasars using the Pan-STARRS1 survey. The sample shows a variety of properties, including a number of weak-line quasars and radio-loud quasars. I will show the preliminary results of our search for z~6.5 quasars that will allow us to put constraints on the number density of SMBHs 850 Myr after the Big Bang. I will also discuss the implications of our search for high-redshift radio-loud quasars for the evolution of the radio-loud fraction of quasars across cosmic time.

Author(s): Eduardo Banados[1], Fabian Walter[1], Bram Venemans[1]
Institution(s): *1. Max Planck Institute for Astronomy*
Contributing team(s): Pan-STARRS1

320.05 – Dust-reddened Quasars in SDSS-III: Trends with Evolution or Orientation?

We are involved in a multi-faceted study to estimate the dust reddening and measure trends with reddening in the emission and broad absorption line (BAL) properties of 60,532 quasars at redshifts 2.1 to 3.4 in the SDSS-III/BOSS survey. We are particularly interested in indicators of the orientation or evolutionary status of the quasar/host galaxy environments. We parameterize the reddening by E(B-V) based on SDSS – WISE W1 colors (F. Hamann, in prep.). Our main results were presented previously: 1) Redder quasars tend to have stronger and narrower broad emission lines consistent with lower black hole masses or higher accretion rates (L/Ledd) that might support evolution schemes where redder QSOs are younger. 2) BALs are more common with stronger/deeper profiles in redder quasars, consistent with previous studies. And 3) the Baldwin Effect (a trend for smaller emission line REWs with increasing luminosity) has characteristics similar to the reddening trends in our data, but it is weaker than the reddening trends and might be overestimated if reddening (UV extinction) is not taken into account. Here we focus on the following new results: 1) We now use estimates of the monochromatic luminosity at 1450 angstroms and 1 micron (rather than the corresponding magnitudes) to study the trends with luminosity. We perform a more thorough analysis of the Baldwin effect, which mimics the reddening trends to first order with stronger/peakier lines in fainter sources. However the dependence on reddening is much stronger than the dependence on (reddening corrected) luminosity, so the usual Baldwin effect is partly a reddening trend. 2) We incorporate line fits that provide measurements of the dispersion of the C IV emission line. The dispersion results in better black hole mass estimates compared to using the FWHM. 3) We present more detailed comparisons to other samples including narrow line Seyfert 1 galaxies and a sample of 100 bright quasars at redshift z~3.5 with VLT X-SHOOTER spectra.

Author(s): Hanna Herbst[4], Fred Hamann[4], Carolin Villforth[5], Isabelle Paris[1], Nicholas Ross[2], Kelly Denney[3]
Institution(s): *1. Institut d'Astrophysique de Paris, 2. Lawrence Berkeley National Lab, 3. Ohio State University, 4. University of Florida, 5. University of St Andrews*
Contributing team(s): BOSS QSO Team

320.06 – Clustering-based redshifts of WISE galaxies and quasars.

We present the clustering-based redshift estimation of millions of extragalactic sources detected by the Wide-field Infrared Survey Explorer (WISE) using the data-driven method proposed by Menard et al. (2013). This technique derives redshift distributions from measurements of spatial correlations without any assumption on spectral energy distributions. Applying it to the entire WISE dataset as a function of brightness and colors we present the redshift distributions of WISE sources, including passive & star-bust galaxies as well as obscure and unobscured quasars.

Author(s): Alexander Mendez[1], Brice Ménard[1], Mubdi Rahman[1]
Institution(s): *1. Johns Hopkins University*

320.07 – Revealing Massive Black Holes in Dwarf Galaxies with X-ray and Radio Observations

Searching for and studying massive black holes in present-day dwarf galaxies is currently our best observational probe of the primordial BH seed population. Reines et al. (2013) recently completed the first systematic search for AGN in dwarf galaxies using optical spectroscopy, increasing the number of known dwarfs with massive BHs by more than an order of magnitude. However, this optical search is biased towards BHs radiating at high fractions of their Eddington limit in galaxies with little on-going star formation. Alternative search techniques and diagnostics at other wavelengths are necessary to make further progress. I will discuss our efforts to find and study massive BHs in dwarf galaxies using observations from Chandra and the VLA. These X-ray and radio observations are more sensitive to weakly accreting massive BHs and are already beginning to reveal massive BHs hidden at optical wavelengths in star-forming dwarf galaxies (Reines et al. 2011; Reines et al. 2014).

Author(s): Amy E. Reines[1]
Institution(s): *1. University of Michigan*

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321 – Galaxy Clusters II

321.01 – X-ray Observations of the Outskirts of the Nearest Non-Cool Core Cluster: the Antlia Cluster

Suzaku X-ray observations have revealed hot gas properties of a number of clusters of galaxies out to their virial radii (R200), allowing us to explore regions that was not possible in the past. We present results of our Suzaku mosaic observations of the nearest non-cool core cluster, the Antlia Cluster (distance D = 39 Mpc), out to its degree-scale virial radius (R200 = 1 Mpc = 88 arcmin) in the East direction. Together with Chandra and XMM-Newton observations, we are able to reduce the systematic uncertainty caused by background point sources. We compare our results to: 1) a similarly nearby system but with a cool core, the Virgo Cluster (D = 16 Mpc), which has a similar virial temperature and radius as the Antlia Cluster, 2) the universal pressure profile, and 3) the entropy profile predicted with self-similar model. Our results suggest that the outskirts of this non-cool core are similar to those of the cool cores. More observations with (regular) non-cool cores are needed to test if this
is general.

Author(s): Ka-Wah Wong[1], Jimmy Irwin[3], Daniel R. Wik[2]
Institution(s): *1. Eureka Scientific, 2. GSFC, 3. University of Alabama - Tuscaloosa*

321.02D – An X-ray View of Galaxies in Compact Groups and the Coma Cluster Infall Region

As the majority of galaxies in the nearby universe exist in groups and clusters, it is imperative for our understanding of galaxy evolution to examine the effects these environments have on their member galaxies. In particular, compact groups of galaxies (CGs) occupy an interesting part of the parameter space having low velocity dispersions and high number densities. These characteristics increase the likelihood of multi-galaxy interactions over long timescales. Infrared observations of galaxies in CGs have suggested that CG members experience accelerated evolution from star-forming to passive. Using X-ray imaging spectroscopy from the Chandra X-ray Observatory, I characterize the luminosity and morphology of the hot intragroup gas in 19 CGs and compare the results with known galaxy cluster scaling relations and other group properties. Only the most massive CGs have hot intragroup gas similar to galaxy clusters. At low group masses, the hot gas becomes associated with individual galaxies and is linked to star formation. The low derived hot gas densities and low galaxy velocities imply that ram-pressure stripping, a common quenching process in galaxy clusters, is probably not the cause of the accelerated evolution in CGs. Using deep XMM observations, I also examine the X-ray emission from individual galaxies in the Coma cluster infall region, inside which the galaxies have infrared properties suggestive of accelerated evolution similar to CG members. While the Coma galaxies have X-ray emission consistent with known scaling relations between X-ray luminosity, star formation rate, and stellar mass, a CG galaxy comparison sample shows enhanced X-ray emission sometimes an order of magnitude more luminous than the expected value. Thus, while the mid-infrared properties of CG and Coma infall galaxies are similar, the X-ray data reveal that there are marked differences between these environments. While it has been hypothesized that low gas-phase metallicity may cause enhanced X-ray emission in galaxies, the unique star formation histories of CG and Coma infall galaxies must also play a role.

Author(s): Tyler D. Desjardins[1]
Institution(s): *1. The University of Western Ontario*

321.03D – Cosmological Simulations of Galaxy Cluster Outskirts

The observational study of galaxy cluster outskirts is a new territory to probe the thermodynamic and chemical structure of the X-ray emitting intracluster medium (ICM) and the intergalactic medium (IGM). Cluster outskirts are particularly important for modeling the Sunyaev-Zel'dovich effect, which is sensitive to hot electrons at all radii and has been used to detect hundreds of galaxy clusters to high-redshift (z<1) with recent microwave cluster surveys such as ACT, Planck, and SPT. In cluster-based cosmology, measurements of cluster outskirts are an important avenue for estimating the cluster mass, as the outskirts are less sensitive to astrophysical uncertainties associated with gas cooling, star formation, and energy injection from supermassive black holes. However, recent observations of cluster outskirts deviate from theoretical expectations, indicating that cluster outskirts are more complicated than previously thought. For instance, recent observations from Suzaku X-ray satellite showed clusters with flat entropy profiles and gas fractions exceeding the cosmic baryon fraction at large radii. Computational modeling of cluster outskirts is necessary to interpret these observations. In my dissertation talk, I will present hydrodynamical cosmological simulations of galaxy cluster formation that follow the thermodynamic and chemical structures in the virialization regions of the ICM and transition to the IGM. Specifically, I show how observational signatures of galaxy clusters are affected by (a) gas density and temperature inhomogeneities in the ICM due to infalling gas clumps and large-scale filaments, and (b) non-equilibrium electrons generated by accretion shocks at the outer boundary of clusters. As an example of how this work is directly relevant for observations, I will discuss implications for recent ultra-deep Chandra XVP observations of Abell 133.

Author(s): Camille Avestruz[1]
Institution(s): *1. Yale University*

321.04 – The Morphology and Characteristics of the Planck ESZ Detected Clusters of Galaxies Compared to X-ray and Optically Selected Cluster Samples

We examine samples of galaxy clusters selected through their SZ decrements, through the presence of a hot intracluster medium or by their galaxy overdensities to determine the impact of biases in cluster selection. In particular, for each cluster sample, we use X-ray observations to determine cluster morphologies and we use X-ray luminosities as a mass proxy. For each cluster sample, we determine the fractions of merging and regular clusters, as well as the number of cool core clusters and the number of clusters with cavities in their X-ray gas, likely produced by AGN outbursts. For the SZ cluster sample, we use Chandra observations of 169 Planck detected ESZ clusters with redshifts < 0.35. We compare the fractions of merging, regular and cool core clusters found in the Planck ESZ sample with the populations of these clusters in the X-ray selected HIFLUGCS and B55 cluster catalogs and in the optically selected Abell clusters. We do not find significant differences in the percentages of merging and regular clusters based on the different selection methods. However we do find a higher fraction of cool core clusters, and thus a higher fraction of clusters with X-ray cavities, in the X-ray selected cluster samples compared to the Planck SZ selected cluster sample. Since the X-ray emission in cool core clusters is centrally peaked, a higher fraction of these clusters is to be expected in X-ray-selected samples. This work was supported in part by a Chandra Observatory grant and by the Smithsonian Astrophysical Observatory.

Author(s): Christine Jones[1], William R. Forman[1], Felipe Andrade-Santos[1], Stephen S. Murray[2], Eugene Churazov[3]
Institution(s): *1. Harvard-Smithsonian, CfA, 2. Johns Hopkins University, 3. MPA-Garching*
Contributing team(s): Chandra-Planck XVP Cluster Consortium

321.05D – The Dynamical Evolution of Galaxies and Their Gas in Group and Cluster Environments

Galaxies in group and cluster environments tend to be gas-poor and lack active star formation in comparison with field galaxies. Some of these differences arise from environmental influences such as ram pressure and tidal stripping. We investigate these influences using N-body simulations of galaxies within idealized group, cluster, and group-cluster merger environments. Using these simulations, we study the velocity distributions and phase-space structure of infalling group galaxies as they virialize within their host cluster and relate them to the observed dynamics of Virgo dwarf elliptical galaxies. We additionally use N-body plus hydrodynamic simulations to study the stripping of hot gaseous coronae from galaxies in groups and clusters. We use these simulations to characterize ram pressure wakes and their dependence on galaxy mass and environmental properties. We also generate mock X-ray observations of the simulated galaxies and use a stacking analysis to evaluate the detectability of the remaining gas.

Author(s): Rukmani Vijayaraghavan[1], Paul M. Ricker[1]
Institution(s): *1. University of Illinois at Urbana-Champaign*

321.06 – Strong Lensing and Giant Arc Statistics In the South Pole Telescope Cluster Survey

Galaxy cluster-scale strong lenses are powerful probes of cosmology, large scale structure, and astrophysical processes in the most massive bound structures in the universe. I will discuss new results of an ongoing effort to systematically identify strong lensing clusters among the South Pole Telescope SZ cluster catalog. The SPT-SZ survey finds all clusters above a well-defined mass threshold, such that a systematic search for giant arcs in SPT clusters will produce a large sample of mass-selected cluster lenses spanning all redshifts; this giant arc sample is the gold standard for comparing the statistics of giant arcs observed against predictions from simulations. I will present the SPT-SZ strong lensing cluster sample - including its selection properties -- and compare the properties of the sample against predictions from simulations. I will also show how we can use strong lensing samples like the one defined for the SPT-SZ galaxy cluster catalog to look identify correlations between different galaxy cluster mass observables. These correlations would allow us to use strong lensing searches to reduce the effective scatter in mass-observable relations, and to look for the signatures of different astrophysical processes on mass observables such as velocity dispersions, gravitational lensing, X-rays and the SZ effect.

Author(s): Matthew Bayliss[2], Lindsey Bleem[1]
Institution(s): *1. Argonne National Laboratory, 2. Harvard-Smithsonian Center for Astrophysics*
Contributing team(s): the South Pole Telescope Collaboration

322 – The Quest for Gravitational Waves, 100 years After Einstein

AAS Special Session
This session will present the past, present and future of the search for gravitational waves, which is reaching a very exciting phase at the 100th anniversary of Einstein's publication of the General Theory of Relativity that predicts . After decades of theoretical doubts on whether gravitational waves were "real", the predictions on measurable effects on detectors and on astrophysical observations started the exciting search for gravitational waves. The observation by Hulse and Taylor of orbital decay of the PSR B1913+16 binary pulsar provided another clear proof of Einstein's theory and showed beautifully the reality of gravitational waves carrying energy. Since then, we have seen many groups devise ways to detect the effects of astrophysical sources producing gravitational waves of many different wavelengths in the spectrum: early universe with cosmological scales imprinted in the CMB polarization, background of orbiting binary supermassive black holes with galactic size wavelengths in correlations in radio signals arrival times on Earth from pulsars, colliding galaxies and galactic binary white dwarfs producing AU wavelengths detectable by space instruments, colliding black holes and neutron stars generating 105 m waves detectable on ground based interferometers. We will present the history and status of the search for gravitational waves with a diverse spectrum of sources and detectors.

322.01 – "The Quest for Gravitational Waves, 100 years After Einstein"

I will present a brief introduction to the topic and the speakers of this exciting and timely session.

Author(s): Gabriela Gonzalez[1]
Institution(s): *1. Louisiana State University*

322.02 – A brief history of gravitational waves - theoretical insight to measurement

Advances in technology and new discoveries in astrophysics have made it possible gravitational radiation from astrophysical sources will be directly measured in the next few years. What appeared as an interesting, though impossible to measure, phenomena in the development of General Relativity in 1916 could well lead, in our epoch, to a revolution in astrophysics. The various steps in this evolution will be presented.

Author(s): Rainer Weiss[1]
Institution(s): *1. MIT*
Contributing team(s): on behalf of the LIGO Scientific Collaboration

322.03 – Detecting Gravitational Waves with the LIGO and Virgo Detectors

The upcoming start of Advanced LIGO and Advanced Virgo will mark the beginning of a new era in gravitational wave astronomy. In this talk I will outline the path towards first direct detection with the second generation of gravitational wave interferometers, with focus on gravitational wave transients: coalescences of neutron star and/or black hole binary systems, core-collapse supernovae, isolated neutron star instabilities. I will describe the status of detector readiness, the analysis plan, prospects for detection rates and astrophysical inference and the potential for multi-messenger astronomy.

Author(s): Laura Cadonati[1]
Institution(s): *1. Georgia Institute of Technology*
Contributing team(s): LIGO Scientific Collaboration, Virgo Collaboration

322.04 – Astrophysical sources of gravitational waves and electromagnetic counterparts

With the advent of advanced gravitational wave observatories, the next few years should see the birth of gravitational wave astrophysics. The most likely sources for LIGO and Virgo are the inspirals and mergers of stellar mass binary systems, such as pairs of neutron stars and/or black holes. In addition to being extraordinarily loud in gravitational waves, these systems may be associated with short gamma-ray bursts and other electromagnetic phenomena, and thus may be visible in the electromagnetic spectrum. This offers the promise of multi-messenger astronomy: the combination of gravitational wave and electromagnetic observations to elucidate the physics and astrophysics of the sources. We discuss issues related to multi-messenger astronomy, including the process of identifying sources and potential scientific results.

Author(s): Daniel Holz[1]
Institution(s): *1. University of Chicago*

322.05 – Detecting Gravitational Waves of Galactic and AU scales

What you need to detect long wavelengths is long detector arms! The pulsar timing array experiments have arms that are hundreds of parsecs long, and are able to detect gravitational waves from massive black hole binaries, both from single sources and from a background ensemble of many such sources. In most ways pulsar timing is a completely analogous experiment to ground-based interferometric techniques, and as such, it has the potential to recover waveforms and directions of sources. The background may be dominated by a few bright sources, and therefore non-isotropic. Recent analysis techniques account for this in clever ways. Finally, I'll discuss the most recent estimates of when pulsar timing will make a detection.

Author(s): Andrea N. Lommen[1]
Institution(s): *1. Franklin and Marshall College*
Contributing team(s): NANOGrav

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323 – Extrasolar Planets: Individual Systems

323.01D – Constraining the Thermal Structure, Abundances, and Dynamics of the Exoplanet HD 209458b

HD 209458b has been extensively studied from the UV to IR as it is one of the brightest of the transiting exoplanets and has a large planet-to-star contrast. However its thermal profile and abundances remain constrained to at best 3 orders of magnitude (Line et al. 2014), largely due to a lack of spectral coverage. We expand HD 209458b's wavelength coverage with ground and space observations. Our ground H, K, and L-band secondary eclipse spectroscopy, which explores HD 209458b's emission mechanisms, is motivated by multiple detections of bright 3.3 μm emission on HD 189733b, resembling the CH_4 v3 band and potentially non-LTE fluorescence (Swain et al. 2010; Waldmann et al. 2012). CH_4 fluorescence has previously been observed on Titan (Kim et al. 2000), Saturn, and Jupiter (Drossart et al. 1999; Brown et al. 2003), thereby likening exoplanets to their Solar System counterparts. We find that the hotter HD 209458b lacks to ~3σ a bright 3.3 μm feature as seen on HD 189733b, which is consistent with thermochemical equilibrium predictions (Moses et al. 2011). We measure HD 209458b's longitudinally-varying thermal structure with Spitzer/IRAC full-orbit phase curve observations, and revise a previous 4.5 μm emission measurement downward by ~35%. This change is significant because the high 4.5 and 5.8 μm brightness temperatures were interpreted as a thermal inversion (e.g., Line et al. 2014). While our 4.5 μm photometric emission point does not require an inversion, the shape of the phase curve, particularly the location and brightness temperature of the hot spot, suggests that HD 209458b has a dayside inversion. However the nightside is much cooler than predicted by a GCM. This discrepancy is potentially due to the GCM lacking quenching where vertical mixing outpaces reaction rates, causing increased CO and CH_4 abundances at higher altitudes. We explore evidence for CH_4 quenching with IRAC 3.6 micron data, which overlap the wings of the CH_4 v3 band, allowing us to longitudinally-measure the CH_4 content across HD 209458b's disk. The shape of the phase curve indicates the radiative time constant and thus the presence of a thermal inversion. This presentation also covers the reduction and analysis methods of the datasets.

Author(s): Robert Zellem[3], Caitlin Ann Griffith[3], Nikole Lewis[4], Mark R. Swain[2], Heather Knutson[1]
Institution(s): *1. California Institute of Technology, 2. Jet Propulsion Laboratory, California Institute of Technology, 3. Lunar and Planetary Laboratory - University of Arizona, 4. Massachusetts Institute of Technology*

323.02D – The Unusual Disintegrating Planet Candidate KIC 125557548b and Hot Jupiter CoRoT-1b in Transmission

Transiting exoplanets are amenable to characterization because they absorb and scatter light from their host star when interrupting our line of sight. The wavelength dependence of the transit constrains the composition of the atmosphere. This in turn can be used to understand a planet's temperature profile and the possible launching mechanisms for evaporating atmospheres. To enable high precision transmission spectrum measurements, we acquire a target star and simultaneous reference star in the low-resolution mode of the SpeX spectrograph on the ground-based Infrared Telescope Facility (IRTF). This observational setup has achieved transit depth precision of 900 ppm and below for faint (K

> 12) systems, allowing for characterization of interesting exoplanets discovered by the CoRoT and Kepler spacecraft. We test the TiO/VO hypothesis on a hot Jupiter CoRoT-1b (that TiO and VO create a temperature inversion) and characterize the debris escaping from the disintegrating rocky planet candidate KIC 12557548b.

Author(s): Everett Schlawin[1], Ming Zhao[3], Johanna K. Teske[2], Terry L. Herter[1]
Institution(s): *1. Cornell University, 2. Department of Terrestrial Magnetism Carnegie Institution of Washington, 3. Penn State*

323.04 – 3D modeling of clouds in GJ1214b' s atmosphere

GJ1214 b is a warm super-Earth/mini-Neptune and one of the few whose atmosphere is characterizable by current telescopes. Recent observations indicated a flat spectrum in near infrared which has been interpreted as the presence of high and thick condensate clouds or photochemical haze. However, the presence of such high and thick cloud/haze is not well understood and probably requires a strong vertical mixing linked to the atmospheric circulation. We studied the atmospheric dynamics and cloud formation on GJ1214 b with the Generic LMDZ, a very flexible 3D GCM developed to simulate any kind of atmosphere. In this talk, I will present results obtained with the Generic LMDZ about the dynamics of GJ1214 b' s atmosphere for different atmospheric composition (i.e. solar, solar enriched in heavy elements and pure water) and with condensate clouds (i.e. KCl and ZnS). I will discuss the conditions for the formation of high condensate clouds, and I will show their impacts on the thermal structure, transit spectra and thermal phase curves.

Author(s): Benjamin Charnay[2], Victoria Meadows[2], Jeremy Leconte[1], Amit Misra[2]
Institution(s): *1. University of Toronto, 2. Virtual Planetary Laboratory, University of Washington*

323.05 – Compositional Constraints on the Best Characterized Rocky Exoplanet, Kepler-36 b

Kepler-36 is an extreme planetary system, consisting of two transiting sub-Neptune-size planets that revolve around a sub-giant star with orbital periods of 13.84 and 16.24 days. Mutual gravitational interactions between the two planets perturb the planets' transit times, allowing the planets' masses to be measured. Despite the similarity of their masses and orbital radii, the planets show a stark contrast in their mean densities; the inner planet (Kepler-36 b) is more than eight times as dense as its outer companion planet (Kepler-36 c). We perform a photo-dynamical analysis of the Kepler-36 system based on more than three years of Kepler photometry. With N-body integrations of initial conditions sampled from the photo-dynamical fits, we further refine the properties of the system by ruling out solutions that show large-scale instability within 5 Giga-days. Ultimately, we measure the planets' masses within 4.2% precision, and the planets' radii with 1.8% precision. Kepler-36 b is currently the rocky exoplanet with the most precisely measured mass and radius. Kepler-36 b’s mass and radius are consistent with an Earth-like composition, and an iron-enhanced Mercury-like composition is ruled out.

Author(s): Leslie Rogers[1], Katherine Deck[3], Jack J. Lissauer[4], Joshua A. Carter[2]
Institution(s): *1. California Institute of Technology, 2. Harvard-Smithsonian Center for Astrophysics, 3. Massachusetts Institute of Technology, 4. NASA Ames Research Center*

323.06 – Characterization of the KOI-273 Planetary System with HARPS-N

The NASA Kepler mission detected thousands of planets with radii between 1 and 3 Earth radii, a population with no analog in our own solar system. The composition of these objects is not yet well understood; some of these may be planets that are predominantly rocky and others may be planets with a large fractional composition of volatiles or a substantial hydrogen envelope. There are only seven planets smaller than 2.5 R^e with published mass estimates with a precision better than 20%, the minimum required to distinguish between different compositional models.
HARPS-N is an ultra-stable, fiber-fed, high-resolution spectrograph optimized for the measurement of very precise radial velocities. A primary goal of the HARPS-N collaboration is to measure precisely the masses of small transiting planets and so constrain their individual compositions.
KOI-273 is a solar-like star (T^{eff} = 5783, log(g) = 4.43, V = 11.68) with a 1.8 Earth-radius planet candidate in a 10.5-d orbit. During the 2014 Kepler observing season, we obtained 50 observations of this star, with a median photon-limited radial velocity precision of 1.9 m/s. Our data indicated the presence of an outer, massive companion. We present the orbital solution of this system and measure the bulk density and inferred composition of the inner planet.
HARPS-N was funded by the Swiss Space Office, the Harvard Origin of Life Initiative, the Scottish Universities Physics Alliance, the University of Geneva, the Smithsonian Astrophysical Observatory, and the Italian National Astrophysical Institute, University of St. Andrews, Queens University Belfast, and University of Edinburgh. This work was made possible through a grant from the John Templeton Foundation.

Author(s): Sara Gettel[1], David Charbonneau[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics*
Contributing team(s): HARPS-N Collaboration

323.07 – Detection and characterization of the atmospheres of the HR 8799 b and c planets with high contrast HST/WFC3 imaging

We present results from our Hubble Space Telescope program to characterize the atmospheres of two planets, b and c, in the HR8799 system, the only directly imaged multi-planet system currently known. Images were taken in three near-infrared medium-band filters -- F098M, F127M and F137M -- using the Wide Field Camera 3. One of the three filters is sensitive to water absorption bands inaccessible from ground-based observations, providing a unique probe of the thermal emission from the atmospheres of these young, warm giant planets. To enable the detections, we utilized the exquisite pointing accuracy of HST in combination with an innovative pipeline designed to combine the dithered, angular differential imaging data which improved the image resolution while accurately capturing the photometric information. The program spanned 15 orbits and the full data set was analyzed with the Karhunen-Loeve Image Projection (KLIP) routine, an advanced image processing algorithm designed specifically to work with HST data. The results include the first images of the outer-most planet HR 8799 b in the water-band filter, and both the two outer planets in the J-band peak. By probing in regions of the planet spectral energy distribution previously unobservable, we place unique constraints on their atmospheric properties.

Author(s): Abhijith Rajan[1], Travis Barman[5], Remi Soummer[3], Laurent Pueyo[3], Jenny Patience[1], J. Brendan Hagan[3], Bruce Macintosh[4], Christian Marois[2], Quinn M. Konopacky[6]
Institution(s): *1. Arizona State University / SESE, 2. NRC Canada, 3. Space Telescope Science Institute, 4. Stanford University, 5. University of Arizona/ LPL, 6. University of Toronto*

323.08 – New, Near-to-Mid Infrared High-Contrast Imaging of the Young Extrasolar Planets, HR 8799 bcde

We present new thermal IR imaging for the young, planet-hosting star HR 8799 obtained with Keck/NIRC2, VLT/NaCo and Subaru/IRCS. We easily detect all four HR 8799 planets but fail to identify a fifth planet, "HR 8799 f", at r < 15 *AU* at a 5-sigma confidence level. We rule out an HR 8799 f with mass of 5 *MJ* (7 *MJ*), 7 *MJ* (10 *MJ*), and 12 *MJ* (13 *MJ*) at *rproj* ~ 12 *AU*, 9 *AU*, and 5 *AU*, respectively. All four HR 8799 planets have red early T dwarf-like *L'* - [4.05] colors. Atmosphere models assuming thick, patchy clouds appear to better match HR 8799 bcde's photometry than models assuming a uniform cloud layer. While non-equilibrium carbon chemistry is required to explain HR 8799 bc's photometry/spectra, evidence for it from HR 8799 de's photometry is weaker. Pending execution of upcoming observations, we will also present unpublished imaging of HR 8799 with the Gemini Planet Imager (GPI) and Subaru Coronagraphic Extreme Adaptive Optics project (SCExAO): two of a new generation of dedicated extreme-AO facilities.

Author(s): Thayne M. Currie[4], Adam Seth Burrows[7], Julien Girard[3], Ryan Cloutier[11], Misato Fukagawa[6], Satoko Sorahana[10], Marc J. Kuchner[5], Scott Kenyon[2], Nikku Madhusudhan[1], Yoichi Itoh[9], Ray Jayawardhana[11], Soko Matsumura[8], Tae-Soo Pyo[4]
Institution(s): *1. Cambridge, 2. CfA, 3. ESO, 4. NAOJ, 5. NASA-Goddard, 6. Osaka University, 7. Princeton, 8. University of Dundee, 9. University of Hyago, 10. University of Tokyo, 11. University of Toronto*

324 – Galaxies, Mergers and Black Holes

324.01D – Evolution of local luminous compact blue galaxies

Luminous compact blue galaxies (LCBGs) are a type of very blue, very compact star-forming galaxy that was common at z~1 but is rare in the local universe. While it is clear from this discrepancy that LCBGs must be a rapidly-evolving class of galaxy, it is not clear what type(s) of galaxy they become. Fortunately, since they are bright and nearby, the rare examples of z~0 LCBGs are easily studied across a large range of wavelengths. We have conducted a study of z~0 analogs to the z~1 LCBGs to investigate their galaxy-wide internal properties in order to determine what is triggering their current episode of star formation, for how long the star formation can continue, and what the galaxies may become once their star formation rates decrease from current levels. We have taken resolved H I observations of nine LCBGs and unresolved radio continuum observations of 35 LCBGs and combined this data with archival broad-band data to probe their global properties. We conclude that LCBGs are rotationally-supported, star-forming disk galaxies that, while they may be forming small central bulges or bars, are highly unlikely to evolve into dwarf elliptical, dwarf spheroidal, or elliptical galaxies on their own due to their masses and rotation velocities. LCBGs will likely fade to be spiral galaxies with lower surface brightnesses once their current episodes of star formation conclude. In addition, we have modeled the SEDs of the LCBGs in our sample to determine whether LCBGs' star formation is ramping up or winding down, and for how much longer their current active phase of star formation will last. We have begun to put together a picture of the current evolutionary stage of this class of galaxies, and have better constrained their future evolutionary paths.

Author(s): Katherine Rabidoux[1], Daniel J. Pisano[1]
Institution(s): *1. West Virginia University*

324.02 – The Galactic Tango: The Elegant Dance of Galaxies and their Supermassive Black Holes

For well over a decade, it has been known that a supermassive black hole resides in the center of almost every galaxy, and that these black holes strongly correlate with the stellar velocity dispersion (the M^{BH}-σ correlation) and stellar mass (the M^{BH}-M^{host} correlation) of their hosts. The origins of these correlations, however, have yet to be determined. To explore the interplay between black holes and galaxies, we have utilized a sample of nearby spiral and elliptical galaxies as well as a sample of AGN in the redshift range z = 0-3. By examining galaxy properties such as mass, kinematics, and growth history, we have determined that these two correlations have distinct origins: the M^{BH}-σ relation may be the result of virial equilibrium, whereas the M^{BH}-M^{host} relation may be the result of self-regulated black hole growth and star formation in galaxies. These results confirm the predictions of our previous theoretical model.

Author(s): Sydney Sherman[1], Yuexing Li[1], Qirong Zhu[1]
Institution(s): *1. Penn State University*

324.04D – Kinematic and Metallicity Comparisons between Dwarf Galaxies and Brightest Cluster Galaxies

Using the VIMOS Integral Field Unit (IFU) spectrograph on the Very Large Telescope (VLT), we spatially map the kinematic properties of 10 nearby Brightest Cluster Galaxies (BCGs) and 4 nearby companion galaxies at z<=0.1. We measure λ^{Re} as a proxy for angular momentum, in order to determine whether these galaxies are fast or slow rotators. We find that 30% (3/10) of the BCGs and 100% of the BCG companion galaxies (4/4) are fast rotators. We also find that when comparing BCGs to similarly massive early-type galaxies, the ratio of fast rotating galaxies in the two populations is the same, suggesting that mass plays a more important role than environment when determining whether a galaxy is fast or slow rotating. We have also obtained metallicity measurements of these BCGs and find that most exhibit very shallow metallicity gradients in contrast to the steep metallicity gradients observed in intermediate mass galaxies. We extend this analysis to low stellar masses with a sample of nearby dwarf galaxies, for which we also have VIMOS IFU observations. Current results suggest that although the dwarf galaxies exhibit far lower metallicities, the metallicity gradients are similarly flat in the low mass and high mass regimes.

Author(s): Jimmy[3], Kim-Vy Tran[3], Sarah Brough[1], Amelie Saintonge[4], Paola Oliva-Altamirano[1], Anja Von Der Linden[2]
Institution(s): *1. Australian Astronomical Observatory, 2. Stanford, 3. Texas A&M University, 4. University College London*

324.05 – Star formation, quenching, black hole feedback and the fate of gas reservoirs

Massive galaxies are broadly split into those forming stars on the main sequence, and those which are quiescent. The physical processes by which galaxies quench their star formation remain poorly understood. I analyze the properties of galaxies and track their evolutionary trajectories as they migrate from the blue cloud of star forming galaxies to the red sequence of quiescent galaxies via the `green valley'. I show that there must be two fundamentally star formation quenching pathways associated with early- and late-type galaxies which are intricately linked to how hydrogen gas reservoirs are destroyed or shut off. In the quenching of late-type galaxies, environment (or halo mass) is a key parameter, while for early-types, an internal mechanism such as black hole feedback is more likely. I will present recent HI observations supporting this picture.

Author(s): Kevin Schawinski[1], Ivy Wong[4], C. Megan Urry[5], Kyle Willett[3], Brooke D Simmons[2]
Institution(s): *1. ETH Zurich, 2. Oxford University, 3. University of Minnesota, 4. University of Western Australia, 5. Yale University*
Contributing team(s): Galaxy Zoo team

324.06 – Supermassive Black Holes at Work: ``Fossil Records'' of Outbursts from Supermassive Black Holes and the Effects of Outbursts on the Evolution of Gas Rich Galaxies, Groups, and Galaxy Clusters

Supermassive black holes (SMBHs) play key roles in galaxy and cluster evolution. This is most clearly seen in the ``fossil record'' that is imprinted in the gas rich atmospheres of early type galaxies, groups, and clusters by powerful SMBH outbursts. From detailed X-ray studies of clusters and groups, we present the properties of typical SMBH outbursts, their evolution, and the energy partition between shocks and the enthalpy of the gas cavities inflated by the SMBHs focussing on M87. The interplay between gas cooling and SMBH outbursts can be traced over cosmological time. We discuss several galaxies where SMBH outbursts at very early epochs have truncated star formation and altered the ``normal'' evolution of the stellar component of galaxy bulges. We conclude by describing a future mission that would allow us to understand the evolution of SMBHs and their host galaxies from high redshifts to the present.

Author(s): William R. Forman[2], Eugene Churazov[1], Christine Jones[2], Sebastian Heinz[3], Akos Bogdan[2]
Institution(s): *1. MPE, 2. SAO-CfA, 3. University of Wisconsin*

324.07 – An ALMA detection of circumnuclear molecular gas in M87

We present the detection of circumnuclear molecular gas in M87 using the Atacama Large Millimeter/submillimeter Array (ALMA).
M87 (3C 274) is an archetypal giant elliptical galaxy at the centre of the Virgo cluster and is a unique object in which to study the origin and properties of the interstellar medium (ISM) in a radio galaxy located in a dense environment. While a very well-known object across most of the electromagnetic spectrum, M87 has long lacked a detailed study in the (sub)millimeter range, requiring the advance in both sensitivity and angular resolution only now made possible by ALMA.
Molecular gas in the inner part of M87 has previously been detected in single-dish observations, suggesting that the molecular gas likely resides in a circumnuclear disk-like structure. However, the unique ALMA capabilities now allow us to make the first detailed, interferometric, investigation of the properties of the ISM around the galaxy's supermassive black hole.
Here, we present results of ALMA band 3 and 7 data which we have used to map the CO J=1-0 and CO J=3-2 lines, respectively. With this data we are able to trace the bulk of the molecular gas, the warmer denser gas, and the continuum emission, at an angular resolution of 1 arcsecond (~80 pc), providing the deepest and highest spatial resolution image yet of the molecular gas content of this giant elliptical galaxy.

Author(s): Catherine E Vlahakis[2], Stephane Leon[2], Sergio Martin[1]
Institution(s): *1. IRAM, 2. Joint ALMA Observatory*

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326 – Low Redshift (z<3) Galaxies

326.01 – Minor mergers: fundamental but unexplored drivers of galaxy stellar mass growth

We use the SDSS Stripe 82 to quantify the stellar-mass growth triggered by minor mergers in the nearby (z<0.1) Universe. We first estimate the minor-merger-driven mass growth in local spirals and then combine that with the corresponding value in early-type galaxies to calculate the fraction of cosmic star formation that can be directly attributed to this process.

Since major mergers destroy discs and create spheroids, morphologically disturbed spirals are remnants of minor mergers. Disturbed spirals exhibit enhanced specific star formation rates (SSFRs), the enhancement increasing in galaxies of 'later' morphological type (which have more gas and smaller bulges). By combining the SSFR enhancements with the fraction of time spirals spend in this 'enhanced' mode, we estimate that ~40% of the star formation in local spirals is directly triggered by minor mergers. Combining our results with the star formation in early-type galaxies - which is minor-merger-driven and accounts for ~14 per cent of the star formation budget - suggests that *around half of the star formation activity in the nearby Universe is triggered by the minor-merger process.*

(Based on Kaviraj 2014, MNRAS, 440 2944 and Kaviraj 2014, MNRAS, 437, L41)

Author(s): Sugata Kaviraj[1]
Institution(s): *1. University of Hertfordshire*

326.02 – GLASS: detailed structure of high redshift galaxies from HST grism spectroscopy

The Grism Lens-Amplified Survey from Space (GLASS) is obtaining slitless near-IR spectroscopy of 10 galaxy clusters selected for their strong lensing properties, including all six Hubble Frontier Fields. The GLASS survey will have gathered more than ten thousand spectra upon completion in early 2015. Slitless grism spectra are ideal for mapping emission lines such as [O II], [O III], and Hα at z=1-3 as well as Lyα at z>6. The combination of strong gravitational lensing and HST's diffraction limit provides excellent sensitivity (~1e-18 erg/s/cm2 RMS) with spatial resolution as fine as 100 pc for highly magnified sources, and ~500 pc for less magnified sources near the edge of the field of view. This enables precise measurements of metallicity gradients, the distribution of star formation, and other details of the physical structure of high redshift galaxies with masses as low as ~10^7 $M^{\odot}$ at z=2. I will discuss measurements of these physical properties and implications for galaxy evolution based on the largest sample available to date with such high resolution at z>1.

Author(s): Tucker Jones[3], Tommaso Treu[2], Kasper B. Schmidt[3], XIN WANG[3], Gabriel Brammer[1]
Institution(s): *1. Space Telescope Science Institute, 2. University of California, Los Angeles, 3. University of California, Santa Barbara*
Contributing team(s): GLASS

326.03 – Metal-poor, Strongly Star-forming Galaxies in the DEEP2 Survey: The Relationship between Stellar Mass, Temperature-based Metallicity, and Star Formation Rate

The chemical enrichment of galaxies, driven by star formation and regulated by gas flows from supernova and cosmic accretion, is a key process in galaxy formation that remains to be understood. The most reliable metallicity determination is made possible by detecting [OIII]4363. The technique is often called the "direct" method for its ability to determine the electron temperature of the ionized gas, and hence the gas-phase metallicity. However, this nebular emission line is intrinsically weak, and thus have not been detected for large samples of galaxies, especially at higher redshift. In this work, I present new results from the detection of [OIII]4363 in a sample of ~30 metal-poor, strongly star-forming galaxies at z~0.8. The sample is selected from the DEEP2 Galaxy Redshift Survey. Using the existing Keck spectra with ancillary imaging data, I explore the relationship between stellar mass, dust-corrected star formation rate (SFR), and temperature-based gas metallicity. I find that these galaxies are undergoing rapid evolution with stellar mass doubling times of about 100 Myr, a factor of 10 faster than typical z~1 star-forming galaxies on the star-formation "main sequence." I also find that these galaxies deviate toward lower metallicity on the mass-metallicity relation. Finally, I will show that these galaxies are inconsistent with the local mass-metallicity-SFR relation (i.e., the "fundamental metallicity relation"), and discuss the implications of these results.

Author(s): Chun Ly[1], Jane R. Rigby[1], Michael Cooper[2], Renbin Yan[3]
Institution(s): *1. NASA GSFC, 2. University of California, Irvine, 3. University of Kentucky*

326.04D – Starbursting Dwarf Galaxies at z > 1

Recently we uncovered with Hubble Space Telescope (HST) WFC3 imaging and spectroscopy an abundant population of extreme emission line galaxies (EELGs) at 1.3 < z < 2.3. While rare in the local universe, such EELGs are ubiquitous at higher redshift and plausibly represent the star-forming progenitors of today's dwarf galaxies. I will present ground-based follow-up spectroscopy using the VLT and the LBT, as well as SED modeling of broad-band photometry and emission line fluxes, which confirms high star formation rates, young ages, low stellar masses, and low metallicities. I will also present a comprehensive search for EELGs in data from the 3D-HST grism-spectroscopic survey, providing a first measurement of their cosmic number density evolution. I will use this to constrain the duty cycle of this bursty mode of star formation, and argue that most stars in today's dwarf galaxies formed in a small number of these bursts at z > 1.

Author(s): Michael Maseda[1], Arjen van der Wel[1], Hans-Walter Rix[1]
Institution(s): *1. Max Planck Institute for Astronomy*
Contributing team(s): 3D-HST

326.05 – UV Spectral Slope and Dust Attenuation of Faint Star-Forming Galaxies at 1 < z < 3 Behind the Lensing Cluster A1689

Based on our recent study on the galaxy cluster Abell 1689, the faint star-forming galaxies ($M^{UV} \geq -18$) account for the majority of ultraviolet luminosity density at the peak epoch of star formation activity. In this study, we provide a comprehensive measurement of the rest-frame UV spectral slopes of the faint star-forming galaxies at the corresponding epoch. We combine very deep HST/WFC3 UVIS photometry in F225W, F275W and F336W bands with HST/ACS optical and HST/WFC3 IR images. The high magnification from the lensing cluster Abell 1689, enables us to extend our study down to a very faint UV absolute magnitude M^{UV}=-12 (~$0.001L^{*z=1}$). We find more than 150 faint galaxies in the range $1 \leq z \leq 3$ based on a photometric redshift selection technique. We study the trends of UV continuum slope with luminosity and redshift. These faint galaxies follow the same trends as seen in the other studies, where galaxies get bluer as their UV luminosities decrease. Using the results of a hydro-dynamical simulation of dwarf galaxies with bursty star formation history, we investigate the intrinsic scatter in the UV continuum color measurements. We determine the level of dust attenuation with luminosity and redshift, but also consider other factors that may affect the dust extinction such as metallicity and star formation history.

Author(s): Anahita Alavi[3], Brian D. Siana[3], Alberto Dominguez[3], Johan Richard[4], Marc Rafelski[1], Daniel Stark[2]
Institution(s): *1. IPAC, 2. University of Arizona, 3. University of California Riverside, 4. University of Lyon*

326.06D – KPC-Scale Properties of Emission-line Galaxies

We perform a detailed -combined spectroscopic and photometric- study of resolved properties of galaxies at kpc scale and investigate how small-scale and global properties of galaxies are related. The sample consists of 119 galaxies to z~1.3 with the unique feature of having very high-resolution spectroscopic data from long exposure observations with the KECK/DEIMOS. Using HST/ACS and WFC3 data taken as part of the CANDELS project, we produce resolved rest-frame (U-V) color, stellar mass and star formation surface densities, stellar age and extinction maps and profiles along the galaxies rotation axes. We model the optical nebular emission lines using the high-resolution DEIMOS spectra and construct the optical line ratio profiles diagnostic of metallicity (R23) and nebular extinction (Ha/Hb). We find that the nebular dust extinction profile, inferred from Balmer decrement, is in agreement with the average extinction derived from the resolved SED modeling. Using the R23 metallicity profiles we examine, for the first time, the mass metallicity relation across galaxies and explore how this relation changes as a function of spatial position. We identify red and blue "regions" of statistical significance within individual galaxies, using their rest-frame color maps. As expected, for any given galaxy, the red regions are found to have higher stellar mass surface densities and older ages compared to the blue regions. Furthermore, we quantify the spatial distribution of red and blue regions with respect to both redshift and stellar mass, finding that the stronger concentration of red regions toward the centers of galaxies is not a significant function of either redshift or stellar mass. We find that the “main sequence” of star forming galaxies exists among both red and blue regions inside galaxies, with the median of blue regions forming a tighter relation with a slope of 1.1±0.1 and a scatter of ~ 0.2 dex compared to red regions with a slope of 1.3 ± 0.1 and a scatter of ~ 0.6 dex. The blue regions show higher specific Star Formation Rates (sSFR) than their red counterparts with the sSFR decreasing since z ~ 1, driver primarily by the stellar mass surface densities rather than the SFRs at a giver resolution element.

Author(s): Shoubaneh Hemmati[1], Bahram Mobasher[1]
Institution(s): *1. UC Riverside*
Contributing team(s): CANDELS

326.07 – The MOSDEF Survey: Outflows from Star-forming Galaxies at z~2.3

The MOSFIRE Deep Evolution Field (MOSDEF) survey is using the MOSFIRE instrument on the Keck I telescope to obtain more than 1500 rest-frame optical spectra of galaxies from redshift 1.5 to 3.6 over four years. We are using the first ~500 spectra to investigate the prevalence of outflows measured in emission in broad components of the nebular emission lines. We have produced stacks of galaxies based on properties such as star formation rate, stellar mass, specific star formation rate, and star formation rate surface density (controlling for the presence of AGNs) in order to study how outflow strength depends on these factors. Furthermore, we have created stacked spectra by redshift to understand how outflows change over time. We decompose the Hα line into broad and narrow Gaussian components and use the fraction of line flux in the broad component as the relative outflow strength in these galaxies. We will show how this broad component changes with various galaxy properties and redshift.

Author(s): William R. Freeman[1], Brian D. Siana[1], Alice E. Shapley[3], Mariska T Kriek[2], Naveen Reddy[1], Bahram Mobasher[1], Alison L. Coil[4], Sedona Price[2], Ryan Sanders[3], Irene Shivaei[1], Laura DeGroot[1]
Institution(s): *1. Univ of CA Riverside, 2. Univ. of CA, Berkeley, 3. Univ. of CA, Los Angeles, 4. Univ. of CA, San Diego*

327 – Astronomy Education Research

327.01 – Investigating Student Ideas About the Fate of the Universe

Data from recent surveys have enabled astronomers to precisely quantify the composition of the Universe, though the nature of its primary component, dark energy, remains a mystery. The evolution of dark energy and how it might impact the Universe in the future is an area of intense study. As astronomers further develop an understanding of the fate of the Universe, it is essential to study student ideas on this fate so that instructors can communicate the field’s current status and its underpinnings more effectively to their students. In this study, we examine undergraduate students’ pre-instruction ideas of the fate of the Universe in twelve semester-long courses at four institutions. We also examine ideas about the fate of the Universe as undergraduate students progress through an introductory or advanced astronomy course at two institutions. The data include pre-course surveys given during the first week of instruction [N=291], midterm and final exam questions [N=58], post-course surveys [N=26], and student interviews [N=7]. We find that, though the term was not necessarily used, students that respond tend to describe a “big freeze” scenario in the pre-course surveys. Students mention the Universe’s expansion when describing how we know the fate of the Universe but do not discuss how we know the Universe is expanding or the relationship between expansion and the fate of the Universe. We also find that students discuss the fate of the solar system or the galaxy in the pre-course surveys instead of the fate of the Universe, suggesting conflation of the Universe with the solar system or the galaxy. At the end of the course, we find that students continue to describe a “big freeze” scenario and fail to explain how we determine the fate of the Universe. We also find that student tendency to discuss the fate of the solar system or galaxy instead of the fate of the Universe is diminished by the end of the course.

Author(s): Mallory Conlon[4], Kimberly A. Coble[1], Janelle M. Bailey[3], Lynn R. Cominsky[2]
Institution(s): *1. Chicago State University, 2. Sonoma State University, 3. Temple University, 4. University of Illinois at Urbana-Champaign*

327.02 – Comparison of Student Performance in Video Game Format vs. Traditional Approach in Introductory Astronomy Classes

In Spring of 2014, Penn State debuted an online Introductory Astronomy (AST 001) section that was designed as a video game. Previous studies have shown that well-designed games help learners to build accurate understanding of embedded concepts and processes and aid learner motivation, which strongly contributes to a student's willingness to learn. We start by presenting the learning gains as measured with the Test of Astronomy Standards (TOAST) from this new course design. We further compare the learning gains from the video game section with learning gains measured from more traditional online formats and in-person lecture sections of AST 001 taught at Penn State over the last five years to evaluate the extent to which this new medium for online Astronomy education supports student learning.

Author(s): Daniel Barringer[1], Julia M. Kregenow[1], Christopher Palma[1], Julia Plummer[1]
Institution(s): *1. Pennsylvania State University*

327.03 – Beyond the Wobbles: Teaching Students About Detecting Planets with the Transit and Gravitational Microlensing Methods

Members of the Center for Astronomy Education (CAE) at the University of Arizona's Steward Observatory in collaboration with JPL scientists, visualization experts, and education and public outreach professionals with the Exoplanet Exploration Program (ExEP) have recently completed classroom field-testing of a new suite of educational materials to help learners better understand how extrasolar planets are detected using the transit and gravitational microlensing techniques. This collaboration has created a set of evidence-based Think-Pair-Share questions, Lecture-Tutorials, animations, presentation slides, and instrucotrs guide that can be used together or separately to actively engage learners in reasoning about the data and scientific representations associated with these exciting new extrasolar planet detection methods. In this talk we present several of the conceptually challenging collaborative learning tasks that students encounter with this new suite of educational materials and some of the assessment questions we are using to assess the efficacy of their use in general education, college-level astronomy courses.

Author(s): Edward E. Prather[1], Colin Scott Wallace[3], Timothy G. Chambers[1], Gina Brissenden[1], Wesley A. Traub[2], W. M Greene[2], Anya A Biferno[2], Joshua Rodriguez[2]
Institution(s): *1. Center for Astronomy Education (CAE) Univ. of Arizona, 2. NASA Jet Propulsion Laboratory, 3. Univ. of North Carolina at Chapel Hill*

327.04 – How should we teach faculty about research-based teaching?

Faculty professional development (PD) workshops are the primary mechanism used to increase the adoption and adaptation of research-based instructional strategies (RBIS). PD workshops draw in large numbers of physics and astronomy instructors and can serve a critical role in changing instructional practices within our community. Our research focuses on two of the largest and longest-running PD workshops accessible to faculty: the New Physics and Astronomy Faculty Workshop and the Center for Astronomy Education Tier I Teaching Excellence Workshop. We seek to reveal opportunities to improve these workshops through increased awareness of instructors' experiences and prior knowledge, and increased awareness of how these workshops are designed and implemented.
Other studies often assume that instructors have coherent theories of teaching and learning, and conclude that many have wrong ideas that need to be confronted or "fixed". Our approach is to first investigate the ideas that instructors have about teaching and learning, and identify what we call their "potentially productive resources". This approach is better suited to inform respectful PD efforts that build on instructors' intuitions, and we have analyzed interviews with several young astronomy/physics faculty members who were about to attend these PD workshops to demonstrate how this approach can be applied. The primary findings of our first study are: 1) instructors are trying out practices that show some alignment with common RBIS; 2) instructors' values show alignment with common discipline-based education research goals; and 3) instructors often experience dissatisfaction with specific aspects of their instruction. Taken together our findings are poised to inform changes to existing PD efforts.
Our ongoing research focuses on the development of a real-time observation tool to document what happens during workshops and what learning opportunities these PD practices create for participants. We will show the preliminary results of this work.

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327.05 – Test Of Astronomy STandards TOAST Survey of K-12 Teachers

Discipline-based education research in astronomy is focused on understanding the underlying mental mechanisms used by students when learning astronomy and teachers when teaching astronomy. Systematic surveys of K-12 teacher' knowledge in the domain of astronomy are conducted periodically in order to better focus and improve professional development. These surveys are most often done when doing contemporary needs assessments or when new assessment instruments are readily available. Designed by Stephanie J. Slater of the CAPER Center for Astronomy & Physics Education Research, the 29-item multiple-choice format *Test Of Astronomy STandards* – TOAST is a carefully constructed, criterion-referenced instrument constructed upon a solid list of clearly articulated and widely agreed upon learning objectives. The targeted learning concepts tightly align with the consensus learning goals stated by the American Astronomical Society – *Chair's Conference on ASTRO 101*, the American Association of the Advancement of Science's *Project 2061 Benchmarks*, and the National Research Council's 1996 *National Science Education Standards*. Without modification, the TOAST is also aligned with the significantly less ambitious 2013 *Next Generation Science*

Standards created by Achieve, Inc., under the auspices of the National Research Council. This latest survey reveals that K-12 teachers still hold many of the same fundamental misconceptions uncovered by earlier surveys. This includes misconceptions about the size, scale, and structure of the cosmos as well as misconceptions about the nature of physical processes at work in astronomy. This suggests that professional development in astronomy is still needed and that modern curriculum materials are best served if they provide substantial support for implementation.

Author(s): Timothy F. Slater[2], Stephanie Slater[1], Debra J Stork[2]
Institution(s): *1. CAPER Center for Astronomy & Physics Education Research, 2. University of Wyoming*

327.06 – First Results from the i*STAR* International STudy on Astronomy Reasoning

Our best efforts in the United States to dramatically improve teaching and learning in astronomy courses has been less than satisfactory despite Herculean efforts. A possible solution is to expand our view beyond our own culture's borders and presumptions in order to bring our shortcomings in discipline-based astronomy education research to light. Before we can begin the process of international comparisons of student conceptual understanding, we need to better understand how different citizens of different countries position astronomy culturally. Under the banner of the *International STudy on Astronomy Reasoning* Project, i*STAR*, we are now carefully observing how foreign experts in teaching astronomy and the science of astronomy translate the *Test Of Astronomy STandards* – TOAST multiple-choice assessment instrument to look for subtle clues revealed during the translation process. The TOAST is the widely used standard to evaluate students' gains in the United States' Astronomy classrooms. We hope that the process of translation itself will help us comprehend how other cultures think differently about astronomical concepts and eventually we are looking to obtain useful data of how other cultures develop their society's understanding of particular astronomy aspects where we may fall short. Several of the i*STAR* Project's bilingual speakers are documenting their thoughts and insights as they translate the TOAST. The end-goal is to collect a comprehensible, well-defined, and logical translation in various languages that are culturally sensitive and linguistically accurate. This project is sponsored and managed by the CAPER Center for Astronomy & Physics Education Research at CAPERTeam.com in collaboration with members of the International Astronomical Union-Commission 46.

Author(s): Coty B. Tatge[2], Stephanie J Slater[1], Timothy F. Slater[2]
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327.07 – Impacts of Chandra X-ray Observatory Public Communications and Engagement

The Chandra X-ray Observatory Center runs a multifaceted Public Communications & Engagement program encompassing press relations, public engagement, and education. Our goals include reaching a large and diverse audience of national and international scope, establishing direct connections and working relationships with the scientists whose research forms the basis for all products, creating peer-reviewed materials and activities that evolve from an integrated pipeline design and encourage users toward deeper engagement, and developing materials that target underserved audiences such as women, Spanish speakers, and the sight and hearing impaired. This talk will highlight some of the key features of our program, from the high quality curated digital presence to the cycle of research and evaluation that informs our practice at all points of the program creation. We will also discuss the main impacts of the program, from the tens of millions of participants reached through the establishment and sustainability of a network of science 'volunpeers.'

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327.08 – Visualizing Moon Phases in Virtual and Physical Astronomy Environments

We report on the development and testing of a "Visualization Lab," which includes both physical and virtual models, designed to teach middle school students about the cause of the Moon's phases and eclipses, phenomena that require students to visualize complex 3D relationships amongst the Sun, Earth, and Moon. The physical models included styrofoam balls, a lamp, and hula hoops, and we used two different kinds of virtual models: a simple 2D simulator, vs. a complex 3D model in WorldWide Telescope (WWT), an immersive, free astronomy data visualization environment
In Phase I, all students used the physical model first, then one of the two virtual models. Students who used WWT as the virtual model had stronger learning gains than students who used the 2D simulator, and they had more interest in continuing to explore the computer model independently after the formal instruction was complete.
In Phase 2, all students used WWT, but half used the physical model first, while the other half used WWT first. The Phase 2 pilot (N=68) showed that level of prior knowledge may influence which model order would be more beneficial to student learning. Students with low prior knowledge benefited from using the physical model first, and students with high prior knowledge benefited from using WWT first. Three additional cohorts in 2013-14 (N=226) showed that performance on the multiple choice assessment is comparable regardless of model order, with a regression analysis showing a slight benefit to using WWT first for all levels of prior knowledge.
For two cohorts where we have coded open responses, students who used WWT first expressed fewer misconceptions

about the cause of Moon phases on the posttest. Despite the stronger learning outcomes from using WWT first, only 19% of students preferred having WWT first or wish they had WWT first.

Author(s): Patricia S. Udomprasert[2], Alyssa A. Goodman[2], Susan Sunbury[2], Zhihui Zhang[1], Philip M. Sadler[2], Mary E. Dussault[2], Qin Wang[3], Erin Johnson[2], Erin Lotridge[2], Jonathan Jackson[2], Ana-Maria Constantin[2]
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328 – Instrumentation: Space Missions -Ground Based or Airborne II

328.01 – Monitoring All the Sky All the Time with the Owens Valley Long Wavelength Array

The Owens Valley LWA is a new array of 256 dual polarization antennas at Caltech's Owens Valley Radio Observatory that instantaneously images the entire viewable sky every second. It hosts the LEDA correlator, which enables 60 MHz instantaneous bandwidth, allowing us to correlate the 25-85 MHz band instantaneously. An upgrade to the array is currently underway, involving 32 additional antennas powered by solar panels and serviced by optical fiber, that will improve the resolution by a factor of 10, giving instantaneous all-sky images with ~10 arcminute resolution. The primary science goals are i) searching for low frequency radio transients, particularly the low frequency auroral radio emission from extrasolar planets, ii) probing the Cosmic Dawn era by constraining the sky-averaged HI signature at z~20 and iii) dynamic imaging spectroscopy of the Sun. I will present the first images and movies produced by this new array and discuss the science motivation for its construction, with particular focus on our efforts to continuously monitor the low frequency radio transient sky to search for radio emission from exoplanets. Finally, I will discuss plans to build a much larger array at or near the Owens Valley Radio Observatory, involving all-sky imaging with 2,000 antennas.

Author(s): Gregg Hallinan[1], Stephen Bourke[1], Marin Anderson[1], Michael Eastwood[1], Ryan Monroe[1], Lincoln J. Greenhill[2], Gregory B. Taylor[4], Joseph Lazio[3], Sander Weinreb[1]
Institution(s): *1. California Institute of Technology, 2. Harvard CfA, 3. Jet Propulsion Laboratory, 4. University of New Mexico*

328.02 – Instrumentation to Detect the Dark Ages

The Large-aperture Experiment to detect the Dark Ages (LEDA) is a new experiment that seeks to detect emission from neutral Hydrogen in the intergalactic medium before the first stars formed. Detection will deliver observational constraints on the formation of the first stars and black holes in the Universe. In this talk, I will introduce the LEDA instrument at the Owen's Valley Radio Observatory, and how it will be used to measure neutral Hydrogen radio emission at redshifts of 15-30, about 100 million years after the Big Bang. I will introduce the instrumentation that enables our ground-based observations, and the observation strategy we are using to address calibration challenges. In particular, I report on the flexible correlator architecture that allows us to correlate up to 576 inputs over a 50 MHz band, and the three-state switched radiometer system we are using for calibration of our total-power data.

Author(s): Danny C Price[1]
Institution(s): *1. Harvard*

328.03 – Hydrogen Epoch of Reionization Array (HERA)

The Hydrogen Epoch of Reionization Arrays (HERA - reionization.org) roadmap uses the unique properties of the neutral hydrogen (HI) 21cm line to probe our cosmic dawn: from the birth of the first stars and black holes, through the full reionization of the primordial intergalactic medium (IGM). HERA is a collaboration between the Precision Array Probing the Epoch of Reionization (PAPER - eor.berkeley.edu), the US-based Murchison Widefield Array (MWA - mwatelescope.org), and MIT Epoch of Reionization (MITEOR) teams along with the South African SKA-SA, University of KwaZulu Natal and the University of Cambridge Cavendish Laborabory. HERA has recently been awarded a National Science Foundation Mid-Scale Innovation Program grant to begin the next phase.
HERA leverages the operation of the PAPER and MWA telescopes to explore techniques and designs required to detect the primordial HI signal in the presence of systematics and radio continuum foreground emission some four orders of magnitude brighter. With this understanding, we are now able to remove foregrounds to the limits of our sensitivity, culminating in the first physically meaningful upper limits. A redundant calibration algorithm from MITEOR improves the sensitivity of the approach.
Building on this, the next stage of HERA incorporates a 14m diameter antenna element that is optimized both for sensitivity and for minimizing foreground systematics. Arranging these elements in a compact hexagonal grid yields an array that facilitates calibration, leverages proven foreground removal techniques, and is scalable to large collecting areas. HERA will be located in the radio quiet environment of the SKA site in the Karoo region of South Africa (where

PAPER is currently located). It will have a sensitivity close to two orders of magnitude better than PAPER and the MWA to ensure a robust detection. With its sensitivity and broader frequency coverage, HERA can paint an uninterrupted picture through reionization, back to the end of the Dark Ages.
This paper will present a summary of the current understanding of the signal characteristics and measurements and describe the funded and planned HERA telescope to be built to detect and characterize the EoR power spectrum.

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Contributing team(s): HERA

328.04 – The Zwicky Transient Facility

The Zwicky Transient Facility (ZTF) is a next-generation optical synoptic survey. Building on the experience and infrastructure of the Palomar Transient Factory (PTF), ZTF will use a new 47-square degree survey camera on the 48-inch Palomar Oschin Schmidt Telescope. ZTF will survey more than an order of magnitude faster than PTF, enabling an unprecedented wide area, high-cadence survey. Its major science goals include discovering young supernovae, searching for electromagnetic counterparts to gravitational wave sources, identifying stellar variables, and detecting Near-Earth Asteroids. Public surveys and data releases will enable broad utilization of the ZTF data.

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Contributing team(s): ZTF Collaboration

328.05 – Optical Spectroscopy with Starbugs, from TAIPAN to the Giant Magellan Telescope

The majority of astronomical fibre-fed spectroscopic instruments rely on sequential positioning of fibres that require significant time (up to an hour in some cases) to reconfigure a field for observation, thus reducing the amount of on-sky time available for any instrument. Starbugs, a novel fibre-positioning technology developed by the Australian Astronomical Observatory, allow for simultaneous positioning of hundreds of fibres. Enabled by this new technology, future instruments are being designed to take advantage of a much faster observing cadence -- with possibly as little as two minutes between observations. I will describe the operating principles of Starbugs, as well as recent refinements made to the technology that recently culminated in successful on-sky tests using the UK Schmidt Telescope at Siding Spring Observatory. I will also describe the TAIPAN instrument, which is being constructed with 150 Starbugs at its heart and will soon engage in a southern hemisphere survey of hundreds of thousands of galaxies and stars. I will conclude with a look forward to MANIFEST, the Many-Instrument Fibre Positioner System that will deploy Starbugs on the Giant Magellan Telescope to greatly enhance the scientific capabilities of that extremely large telescope.

Author(s): Kyler Kuehn[1], David Brown[1], Scott Case[1], Matthew Colless[2], Robert Content[1], Luke Gers[1], James Gilbert[3], Michael Goodwin[1], Andrew Hopkins[1], Michael Ireland[2], Nuria Lorente[1], Rolf Muller[1], Vijay Nichani[1], Azizi Rakman[1], Samuel Richards[1], Will Saunders[1], Nick Staszak[1], Julia Tims[1], Lewis Waller[1]
Institution(s): *1. Australian Astronomical Observatory, 2. Australian National University, 3. University of Oxford*

328.06 – The SDC: high contrast imaging with a multistage vortex coronagraph

The Stellar Double Coronagraph is a flexible coronagraphic platform operated behind the P3K extreme-AO system. We present the design and first light results, including results from single-, dual- , and ring apodized vortex observing modes, demonstrating improved contrast and the ability to remove the negative effects of the secondary mirror obscuration from the focal plane. We discuss future improvements and directions for the SDC, including focal plane wavefront sensing, self-referencing, and new science detectors.

Author(s): Michael Bottom[1], Chris Shelton[2], J. Kent Wallace[2], Jonas Kuhn[2], Bertrand Mennesson[2], Randall D. Bartos[1], Rick Burruss[2], Dimitri Mawet[1], Gene Serabyn[2]
Institution(s): *1. California Institute of Technology, 2. Jet Propulsion Lab*

328.07 – ALTAIR: Precision Photometric Calibration via Low-Cost Artificial Light Sources Above the Atmosphere

Understanding the properties of dark energy via SNIa surveys (and to a large extent via other methods as well) requires unprecedented photometric precision. Laboratory and solar photometry and radiometry regularly achieve precisions on the order of parts in ten thousand, but photometric calibration for non-solar astronomy presently remains stuck at the percent or greater level. We present our project, ALTAIR, sponsored by federal agencies in the U.S. and Canada, to erase this discrepancy, and current steps toward achieving laboratory-level photometric precision for major sky surveys late this decade. In particular, we show far- and near-field imaging of the balloon-borne light source we presently launch to altitudes of approximately 20 km, and our initial calibration results (in addition to prior work with a present calibrated source in low-Earth orbit). Our technique is additionally applicable to microwave astronomy. Observation of gravitational waves in the polarized CMB will similarly require unprecedented polarimetric and radiometric precision, and we briefly present our plans for a calibrated microwave source above the atmosphere as well.

Author(s): Justin Albert[5], Karun Thanjavur[5], Yorke Brown[1], Christopher Stubbs[2], J. Paul Kovacs[5], Divya Bhatnagar[5], James Hartwick[5], Keith Vanderlinde[6], Matt Dobbs[3], Arnold Gaertner[4]
Institution(s): *1. Dartmouth College, 2. Harvard University, 3. McGill University, 4. National Research Council of Canada, 5. Univ. of Victoria, 6. University of Toronto*
Contributing team(s): ALTAIR

328.08 – The Gemini Instrument Feasibilities Studies project

The Gemini Instrument Feasibilities Studies (GIFS) project is part of a program that will provide a number of community-created science-driven instrumentation design study reports and presentations to the observatory, conforming to a number of desired principles.
By the time of the AAS, Gemini will have received a number of proposals and will be evaluating them shortly afterwards with the expectation of placing 3 or more feasibility study contracts based on a facility instrument costing between USD 8,000,000 and USD 12,000,000. These instrument studies will provide synergies with new capabilities coming online (e.g. LSST, JWST, ALMA, etc)
Following the project, Gemini together with the Gemini Science and Technical Advisory Committee (STAC) and input from the wider community will decide on the top-level instrument requirements for the next facility instrument (Gen4#3) and launch a targeted Request for Proposals to design, build, test and deliver a suitable instrument. Gemini expects to release an RfP for Gen4#3 in Q4 2015.
Each feasibility study will include fully developed science case(s), optical, mechanical, electronic and software design elements at the conceptual level as needed to demonstrate the technical viability. In particular, each design study will thoroughly identify and mitigate key risks.
Each study team will present a status summary presentation at the *2015 Meeting on the Science and Future of Gemini* held in Toronto in June 2015. The final GIFS reports and presentations are expected in Sept 2015.
We will discuss the status of GIFS and the currently plans for Gen4#3.

Author(s): Pascale Hibon[1], Stephen J. Goodsell[1], Kayla Hardie[1]
Institution(s): *1. Gemini Observatory*

328.09 – Submillimeter Dust Polarimetry with the BLAST-TNG Telescope

Polarized thermal emission from dust grains can be used to trace magnetic fields in molecular clouds and the ISM. The Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry (BLASTPol) flew from Antarctica in 2010 and 2012 and has produced degree scale polarization maps of multiple nearby molecular clouds with arcminute resolution. The success of BLASTPol has motivated a next-generation instrument, BLAST-TNG, with additional resolution and sensitivity to fully understand the role magnetic fields play in the early stages of the star formation process. BLAST-TNG will use an array of ~1500 linear polarization sensitive pixels populated with Microwave Kinetic Inductance Detectors (MKIDs) combined with a 2.5 m diameter carbon fiber primary mirror to make diffraction limited observations at 250, 350, and 500 microns. With 16 times the mapping speed of BLASTPol, sub-arcminute resolution, and a longer flight time, BLAST-TNG will be able to examine nearby molecular clouds and the diffuse galactic dust polarization spectrum in unprecedented detail. Additionally, the instrument will be in a unique position to link the all-sky, five arcminute resolution, dust polarization maps of Planck with the high resolution, but small area, polarization maps from ALMA allowing us to trace magnetic fields from protostellar cores out to the surrounding molecular clouds and ISM.
BLAST-TNG is scheduled to fly from Antarctica in 2016 for 28 days and will be the first balloon-borne telescope to offer a quarter of the flight for "shared risk" observing by the community.

Author(s): Nicholas Galitzki[13], Peter Ade[3], Francesco E Angilè[13], Peter Ashton[7], James Howard Beall[6], Dan Becker[6], Kristi J. Bradford[1], George Che[1], Hsiao-Mei Cho[8], Mark J. Devlin[13], Bradley Dober[13], Laura M. Fissel[7], Yasuo Fukui[4], Jiansong Gao[6], Christopher E. Groppi[1], Seth N. Hillbrand[2], Gene Hilton[6], Kent Irwin[9], Jeffrey Klein[13], Jeffrey Van Lanen[6], Dale Li[6], Zhi-Yun Li[15], Nathan Lourie[13], Hamdi Mani[1], Peter G. Martin[14], Philip Mauskopf[1], Fumitaka Nakamura[5], Giles Novak[7], David P. Pappas[6], Enzo Pascale[3], Giampaolo Pisano[3], Fabio P. Santos[7], Giorgio Savini[10], Douglas Scott[11], Sara Stanchfield[13], Carole Tucker[3], Joel Ullom[6], Matthew Underhill[1], Michael Vissers[6], Derek Ward-Thompson[12], Hannes Hubmayr[6], Simon Doyle[3]
Institution(s): *1. Arizona State University, 2. California State University, 3. Cardiff University, 4. Nagoya University, 5. National Astronomical Observatory, 6. National Institute of Standards and Technoilogy, 7. Northwestern University, 8. SLAC National Accelerator Laboratory, 9. Stanford University, 10. University College London, 11. University of British Columbia, 12. University of Central Lancashire, 13. University of Pennsylvania, 14. University of toronto, 15. University of Virginia*

329 – Galaxy Star Formation Rate and Stellar Mass

329.01 – The Star Forming Main Sequence and its Scatter as Conequences of the Central Limit Theorem

Star formation rates of disk galaxies strongly correlate with stellar mass, with a small dispersion in specific star formation rate at fixed mass. With such small scattter this main sequence of star formation has been interpreted as deterministic and fundamental. Here it is demonstrated that it is a simple consequence off he central limit theorem. Treating the star formation histories of galaxies as integrable, non-differentiable functions, where stochastic changes in star formation rate in a galaxy's history are not fully independent of each other, we derive the median specific star formation rate for the flat part of the main sequence from $0<z<10$, as well as the observed scatter. The derived time evolution matches published data with sufficient accuracy to derive cosmological parameters, with almost no free parameters. A number er of consequences will be discussed.

Author(s): Daniel Kelson[1]
Institution(s): *1. Carnegie Inst. of Washington*

329.02 – The Star Formation Rate-Stellar Mass Correlation: Does the Scatter Matter?

Observation of a correlation between the star formation rate (SFR) and stellar mass (M*) of distant star-forming galaxies has generated a major effort to measure and model the distribution of galaxies on the SFR-M* diagram as a function of redshift. The correlation is often referred to, confusingly, as the "Galaxy Main Sequence". While the correlation at a given epoch could be interpreted as a sequence of galaxies at different stages of a uniform star formation history (SFH), the evolution of the normalization and slope of this correlation with redshift implies a different average SFH. I will argue that the scatter around this correlation is of greater interest, with galaxies lying above the main locus exhibiting temporarily-higher SFR due to starbursts and galaxies lying below the main locus exhibiting possibly-temporary quenching of their star formation. The amplitude of the scatter reveals the relative importance of stochasticity in galaxy formation versus the quiescent star formation traced by the average SFH. I will place results from Spectral Energy Distribution fitting for low-mass, high-redshift galaxies from MUSYC, CANDELS, and UVUDF on this diagram to probe the limits of the correlation.

We gratefully acknowledge support from the NSF through grant AST-1055919.

Author(s): Eric J. Gawiser[1]
Institution(s): *1. Rutgers University*

329.03D – A Turn-over in the Galaxy Main Sequence of Star Formation at $M^* \sim 10^{10}$ M^{sun}

The relationship between galaxy star formation rates (SFR) and stellar masses (M^*) is re-examined using a mass-selected sample of ~62,000 star-forming galaxies at $z < 1.3$ in the COSMOS 2 deg^2 field. We measure infrared luminosities and SFRs using photometry from Herschel-PACS and SPIRE, Spitzer 24 µm, and the NRK method based on galaxies' locations in the restframe color-color diagram (NUV-r) vs. (r-K). Using these new SFRs, we find that the relationship between median SFR and M^* follows a power-law at low stellar masses, but flattens to nearly constant SFR at high stellar masses. We describe a new parameterization that provides the best fit to the main sequence and charaterizes the low mass power-law slope, turnover mass, and overall scaling of the relationship. The turnover in the main sequence occurs at a characteristic mass of about $M^0 \sim 10^{10}$ M^{sun} at all redshifts. The low mass power-law slope ranges from 0.9-1.3 and the overall scaling of the main sequence rises as a function of $(1+z)^{4.2\pm0.10}$. A broken power-law fit below and above the turnover mass gives relationships of $SFR \propto M^{*0.88\pm0.06}$ below the turnover mass and $SFR \propto M^{*0.27\pm0.04}$ above the turnover mass. On average, galaxies more massive than $M^* > 10^{10}$ M^{sun} have a much lower specfic star formation rate ($SSFR = SFR/M^*$) than would be expected by simply extrapolating the traditional linear fit to the main sequence found for less massive galaxies.

Author(s): Nicholas Lee[1]
Institution(s): *1. University of Hawaii*
Contributing team(s): COSMOS team

329.04 – Constraining the Low-Mass Slope of the Star Formation Sequence at $0.5 \le z \le 2.5$

A wealth of data from deep extragalactic surveys have revealed a picture where star-forming galaxies follow a tight relation between star formation rate and stellar mass. This observed star formation sequence encapsulates information about feedback, gas density and gas accretion rates over cosmic time. I will present a self-consistent empirical study measuring the slope of this relation for a complete sample of galaxies selected from the 3D-HST photometric catalogs at $0.5 \le z \le 2.5$, using deep photometry in the CANDELS fields. Probing a factor of ten lower in stellar mass than previous high-redshift studies, we show that the slope of the star formation rate - stellar mass relation is mass-dependent; we measure a steep slope of order unity out to z=2.5 for low mass galaxies, and a slope that becomes increasingly flatter with time at the highest masses. These observations of the star formation sequence help reconcile existing tensions with theoretical galaxy formation models.

Author(s): Katherine E. Whitaker[2], Marijn Franx[1], Joel Leja[5], Pieter G. Van Dokkum[5], Alaina L. Henry[2], Rosalind Skelton[3], Mattia Fumagalli[1], Ivelina G. Momcheva[5], Gabriel Brammer[4], Ivo Labbe[1], Erica Nelson[5], Jane R. Rigby[2]
Institution(s): *1. Leiden Observatory, 2. NASA/GSFC, 3. SAAO, 4. STScI, 5. Yale University*
Contributing team(s): 3D-HST collaboration

329.05D – Inferring Galaxy Star Formation Histories from Statistical Metrics: What Ensemble Data Has and Hasn't Taught Us about Galaxy Growth

The growth of galaxies is a central theme of the cosmological narrative, but we do not yet understand how these objects build their stellar populations over time. Largely, this is because star formation histories must be inferred from statistical metrics (at $z > 0$), e.g., the cosmic star formation rate density, the stellar mass function, and the SFR/stellar mass relation. The relationship between these observations and the behavior of individual systems is unclear, but it deeply affects views on galaxy evolution. Here, I discuss key issues complicating this relationship, and explore attempts to deal with them from both “population-down” and “galaxy-up” perspectives. I suggest that these interpretations ultimately differ in their emphasis on astrophysical processes that “quench” versus those that diversify galaxies, and the extent to which individual star formation histories encode these processes. I close by highlighting observations which might soon reveal the accuracy of either vision.

Author(s): Louis Evan Abramson[1]
Institution(s): *1. University of Chicago*
Contributing team(s): IMACS Cluster Building Survey

329.06 – Impact of star formation history on the measurement of star formation rates

Measuring star formation across the Universe is key to constraining models of galaxy formation and evolution. Yet, determining the SFR (star formation rate) of galaxies remains a challenge. In this talk we will present a recent investigation of the impact of a variable star formation history on the measurement of the SFR. To do so, we have combined 23 state-of-the-art hydrodynamical simulations of z=1-2 galaxies on the main sequence with the cigale spectral energy distribution modelling code. This allows us to generate synthetic spectra every 1 Myr for each simulation, taking the stellar populations and the nebular emission into account. Using these spectra, we estimate the SFR from classical estimators, which we compare with the true SFR we know from the simulations. We find that except for the Lyman continuum, classical SFR estimators calibrated over 100 Myr overestimate the SFR from ~25% in the FUV band to ~65% in the U band. Such biases are due 1) to the contribution of stars living longer than 100 Myr, and 2) to variations of the SFR on timescales longer than a few tens of Myr. Rapid variations of the SFR increase the uncertainty on the determination of the instantaneous SFR but have no long term effect. The discrepancies between the true and estimated SFR may explain at least part of the tension between the integral of the star formation rate density and the stellar mass density at a given redshift. To reduce possible biases, we suggest to use SFR estimators calibrated over 1 Gyr rather than the usually adopted 100 Myr timescales.

Author(s): Mederic Boquien[2], Veronique Buat[1], Valentin Perret[3]
Institution(s): *1. Laboratoire d'Astrophysique de Marseille, 2. University of Cambridge, 3. University of Zurich*

329.07 – Sizing Up Dwarf Galaxies at z > 1: UV Colors, Stellar Masses and Star Formation Rates

Deep HST imaging allows the detection and study of dwarf galaxies at z > 1. Our recent multiwavelength analyses of continuum and Ly-alpha selected galaxies in the Hubble UltraDeep Field (HUDF) and CANDELS fields reveals a diversity of physical properties. We show that these galaxies are on the whole bluer than comparable luminosity galaxies in the local universe, although they are as diverse in their UV colors as local dwarf galaxies. On the SFR-M* diagram, Ly-alpha selected galaxies fall above the main sequence, implying bursty star formation. In this presentation, we illustrate that low luminosity continuum selected galaxies appear to lie on the main sequence, suggesting a more quiescent evolution. The systematic study of low luminosity galaxies spanning the epoch of peak cosmic star formation will elucidate the mechanisms of formation and evolution for the bulk of the present day galaxy population.

Author(s): Peter Kurczynski[3], Eric J. Gawiser[3], Marc Rafelski[2], Harry I. Teplitz[1], Duilia F. De Mello[5], Steven L. Finkelstein[6], Jonathan P. Gardner[2], Anton M. Koekemoer[4], Emmaris Soto[5]
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Contributing team(s): UVUDF Team

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330 – Circumstellar and Debris Disks

330.01 – DiskDetective.org: The First 1,000,000 Classifications

Have you discovered a planetary system today? If not, don't worry. At DiskDetective.org, you can help scour the data archive from NASA's WISE mission to find new planetary systems, homes of planetary systems and candidate advanced extraterrestrial civilizations. Volunteers at this new citizen science website have now performed roughly 1,000,000 classifications of WISE sources, searching a catalog 8x the size of any previously published survey. We will describe some of the first results from these classifications, a growing catalog of candidate debris disks, protoplanetary disks, and other interesting objects with 22 micron excess all around the sky.

Author(s): Marc J. Kuchner[2], Steven Silverberg[3], Alissa Bans[1]
Institution(s): *1. Adler Planetarium, 2. NASA's GSFC, 3. University of Oklahoma*
Contributing team(s): The Disk Detective Team

330.02D – Planetary Collisions outside the Solar System: Time Domain Characterization of Extreme Debris Disks

Luminous debris disks of warm dust in the terrestrial planet zones around solar-like stars are recently found to vary, indicative of ongoing collisions of rocky objects. We use Spitzer 3.6 and 4.5 micron time-series observations in 2012 and 2013 to monitor 5 more extreme debris disks, including P1121 in the open cluster M47 (80 Myr), HD 15407A in the AB Dor moving group (80 Myr), HD 23514 in the Pleiades (120 Myr), HD 145263 in the Upper Sco Association (10 Myr), and the field star BD+20 207 (>1 Gyr). Together with the published results for ID8 in NGC 2547 (35 Myr), this makes the first systematic time-domain investigation of planetary impacts outside the solar system. Significant variations with timescales shorter than a year are detected in five out of the six extreme debris disks we have monitored. However, different systems show diverse sets of characteristics in the time domain, including long-term trends, disk temperature variations, and possible periodicity.

Author(s): Huan Meng[1], Kate Y.L. Su[1], George Rieke[1]
Institution(s): *1. University of Arizona*

330.04 – Evidence of Sculpting by Stellar and Sub-stellar Companions in Debris Disks in the ScoCen

We study the location and composition of the dust in debris disk systems in the Scorpius-Centaurus OB Association by modeling their Spitzer IRS infrared spectra features. Nearly all of our sources can be modeled as one or two belts of dust consisting of amorphous silicates. In those systems with stellar companions, there is evidence of disk truncation at the outer radius caused by the binary. No circumbinary debris disks are identified. We explore the possibility that the two-belt systems result from gaps carved out by unseen planets and constrain the location and masses of those planets based on how closely spaced those belts are.

Author(s): Hannah Jang-Condell[7], Christine Chen[3], Erika Nesvold[2], Marc J. Kuchner[2], Tushar Mittal[5], Manoj Puravankara[4], Dan M. Watson[6], Casey M. Lisse[1]
Institution(s): *1. JHU-APL, 2. NASA-GSFC, 3. STScI, 4. Tata Institute of Fundamental Research , 5. UC Berkeley, 6. University of Rochester, 7. University of Wyoming*

330.05 – Gemini Planet Imager Polarimetry of the Circumstellar Ring around HR 4796A

Using the Gemini Planet Imager we have obtained imaging polarimetry of the circumstellar ring around HR 4796A, revealing surprisingly complex morphology that challenges models and has forced us to drastically revise our understanding of the physical properties of this disk.
GPI's differential polarimetry mode not only provides an increase in contrast for better detection of dust-scattered light, but also provides new insights into the properties of the scattering dust through measurement of the polarized scattering phase function. In polarized light, the disk is seen all the way in to its semi-minor axis for the first time, and exhibits surprisingly strong asymmetry in polarized intensity. Based on a synthesis of the total and polarized intensities, our revised model now envisions an optically thick ring composed of relatively large silicate dust particles, with the west side closer to us, contrary to most prior interpretations. These findings suggest that the ring is geometrically narrow and dynamically cold, perhaps shepherded by larger bodies in the same manner as Saturn's F ring. Deep multiwavelength observations from J to K bands are allowing further tests of this model.

Author(s): Marshall D. Perrin[2], Gaspard Duchene[3], Michael P. Fitzgerald[4], Max Millar-Blanchaer[6], James R. Graham[3], Sloane Wiktorowicz[5], Paul Kalas[3], Bruce Macintosh[1]
Institution(s): *1. Stanford University, 2. STScI, 3. UC Berkeley, 4. UCLA, 5. UCSC, 6. University of Toronto*
Contributing team(s): the Gemini Planet Imager Team

330.06D – Modeling Collisions in Circumstellar Debris Disks with SMACK

Observations of resolved debris disks show a spectacular variety of features and asymmetries, including inner cavities and gaps, inclined secondary disks or warps, and eccentric, sharp-edged rings. Embedded exoplanets could create many of these features via gravitational perturbations, which sculpt the disk directly and by generating planetesimal collisions.

The Superparticle-Method Algorithm for Collisions in Kuiper belts and debris disks (SMACK) is the first code to simultaneously model the dynamical and collisional evolution of planetesimals in three dimensions. We use SMACK to investigate the effects of collisions on the morphology of a disk of planetesimals perturbed by a planet and apply our model to a number of resolved debris disks including Fomalhaut, beta Pictoris, and HR 4796. We find that collisions can significantly alter the morphology of disks. Including collisions can yield estimates for planet masses 5x smaller than collisionless models, and collisions can expand the pericenter glow model of eccentric rings to explain observed apocentric excesses at long wavelengths.

Author(s): Erika Nesvold[2], Marc J. Kuchner[1]
Institution(s): *1. NASA/Goddard Space Flight Center, 2. University of Maryland, Baltimore County*

330.07 – Kozai-Lidov Oscillations of Circumstellar Disks

It has been known for over 50 years that the orbit of an object in a binary system can undergo strong tilt and eccentricity oscillations. This effect, known as the Kozai-Lidov effect, may explain several observed astronomical phenomena, including the high eccentricities observed for some extra-solar planets. Martin et al. 2014 recently reported simulation results showing that fluid disks can undergo Kozai-Lidov oscillations. Such oscillations can have important consequences on disk and planet evolution. We have continued investigating the conditions for which such oscillations are possible.

Author(s): Stephen H. Lubow[2], Wen Fu[1], Rebecca G. Martin[3]
Institution(s): *1. Rice University, 2. STScI, 3. University of Colorado*

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331 – Intergalactic Medium, QSO Absorption Line Systems II

331.01 – Thermal Evolution of the Intergalactic Medium

The thermal evolution of the intergalactic medium (IGM) can provide clues regarding the reionization history of the IGM. Recent temperature measurements of the IGM from Lyman alpha forest data have given insight into the timeline of these reionization events, specifically the reionization of HeII at z~3. We model the thermal history of the IGM from HI reionization through HeII reionization based on well established heating and cooling processes. We present a comparison of such modeling of the thermal evolution with the recent observational constraints and discuss additional heating mechanisms.

Author(s): Phoebe Upton Sanderbeck[1], Matthew McQuinn[1]
Institution(s): *1. University of Washington*

331.02 – Probing Quasar Winds Using Intrinsic Narrow Absorption Lines

We use the spectra of 73 quasars (1.5 < z < 5) from the VLT UVES archive to catalog and study narrow absorption lines (NALs) that are physically associated with (intrinsic to) the quasars. Our aim is to better understand the characteristics of the NALs and their relations to the quasar hosting them. We identify 412 NAL systems containing C IV, N V, and/or Si IV doublets. Based on the assumption that only systems intrinsic to the quasar can exhibit partial coverage of the background source(s), we identify 39 reliably intrinsic NAL systems, as well as 12 systems that are potentially intrinsic. The minimum fraction of quasars with at least one intrinsic NAL system is shown to be 41%. We identify intrinsic NALs with a wide range of properties, including ejection velocity, coverage fraction, ionization level, and preferred host quasar type. We also compare our sample of intrinsic NALs with those from low redshift quasars to determine evolutionary effects. We find that there is a continuum of properties within the intrinsic NAL sample, rather than discrete families, ranging from partially covered CIV systems with black Lya and with a separate low ionization gas phase to partially covered NV systems with partially covered Lya and without detected low ionization gas. Additionally, we construct a toy model describing the spatial distributions, geometries, and varied ionization structures of intrinsic NALs.

Author(s): Christopher S. Culliton[1], Amber Roberts[1], Jane C. Charlton[1], Michael Eracleous[1], Rajib Ganguly[3], Toru Misawa[2]
Institution(s): *1. Pennsylvania State University, 2. Shinshu University, 3. University of Michigan, Flint*

331.03D – Optical depth ratios and metal-line absorption around *z*≈2.3 star-forming galaxies: insights from observations and simulations

We study metal-line absorption around 854 *z*≈2.3 star-forming galaxies taken from the Keck Baryonic Structure Survey. The galaxies in this survey lie in the fields of 15 hyper-luminous background QSOs, with galaxy impact parameters ranging from 35 proper kpc (pkpc) to 2 proper Mpc (pMpc). Using the pixel optical depth technique, we present the first galaxy-centered 2-D maps of the median absorption by OVI, NV, CIV, CIII, and SiIV, as well as updated results for HI. At small galactocentric radii we detect a strong enhancement of the absorption relative to randomly located regions that extend out to at least 180 pkpc in the transverse direction, and ±240 km s^{-1} along the line-of-sight (LOS, ~1 pMpc in the case of pure Hubble flow) for all ions except NV. Limiting the sample to the 340 galaxies with redshifts measured from nebular emission lines does not decrease the extent of the enhancement along the LOS compared to that in the transverse direction, which rules out redshift errors as the source of the observed redshift-space anisotropy and implies that we have detected the signature of gas peculiar velocities from infall, outflows, or virial motions. Looking next at optical depth ratios, we isolate pixel pairs at small galactocentric distances (within 180 pkpc in the transverse direction and 170 km s^{-1} along the LOS) and find that the optical depth of OVI at fixed HI is enhanced with respect to the full sample. Comparison with CLOUDY models, and assuming photoionisation, results in nearly solar metallicities at intergalactic overdensities, which we consider to be unphysical. Invoking collisional ionisation, we are able to place a lower limit on [O/H] of ~1/100th solar, and conclude that we are likely probing collisionally ionised gas near galaxies. Finally, we turn to the EAGLE cosmological hydrodynamical simulations to interpret our results, and furthermore to study the evolution of the column density profiles as a function of impact parameter for different metal ions and galaxy halo masses.

Author(s): Monica Turner[3], Joop Schaye[3], Charles C. Steidel[1], Gwen C. Rudie[2], Allison Strom[1]
Institution(s): *1. California Institute of Technololgy, 2. Carnegie Observatories, 3. Leiden Observatory*

331.04 – Simultaneous detections of a Milky Way type 2175 Å bump and CI, CO in a metal-rich and highly dust depleted absorption system at z=2.12 towards QSO J1211+0833

We report the detection of a Milky Way-type strong 2175 Å extinction bump at z=2.12 in the quasar spectrum towards QSO J1211+0833 from the SDSS-III BOSS DR10. We conduct follow up observations with the Echelle Spectrograph and Imager (ESI) onboard the Keck-II telescope and the Ultraviolet and Visual Echelle Spectrograph (UVES) on the VLT. This 2175 Å absorber is remarkable in that it shows rich metal lines and we simultaneously detect neutral carbon (CI) and carbon monoxide (CO). The Lyman alpha absorption line enables the measurement of absolute metal abundances. It is also qualified as a damped Lyman alpha absorber (DLA) with a measured hydrogen column density of log N(HI) = 21.0 cm^{-2}. J1211+0833 is found to be metal-rich and has a dust depletion pattern resembling that of the Milky Way disk clouds. The Voigt profile fitting on the UVES spectrum reveals a complicated velocity structure with nine velocity components. The physical conditions in the absorber can be derived from the CI fine structure lines. Given the simultaneous presence of CI, CO, and the 2175 Å bump combined with the high metallicty, high dust depletion level and overall low ionization state of the gas, J1211+0833 supports the scenario that the presence of the bump requires an evolved stellar population. The host of the J1211+0833 2175 Å bump is likely to be a massive and evolved galaxy, possibly a rotating disk galaxy.

Author(s): Jingzhe Ma[2], Paul Caucal[3], Pasquier Noterdaeme[3], Jian Ge[2], Shaohua Zhang[4], Tuo Ji[4], J. Xavier Prochaska[1]
Institution(s): *1. Department of Astronomy and Astrophysics, UCO/Lick Observatory, 2. Department of Astronomy, University of Florida, 3. Institut d' Astrophysique de Paris, 4. Polar Research Institute of China*

331.05 – Searching for HI at N^{HI}~10^{17} cm^{-2} around nearby galaxies.

One of the outstanding questions in astronomy today is how galaxies obtain the gas that they need to continue forming stars for more than a few billion years. Simulations suggest that for low mass galaxies in low density environments, gas should remain cool while it is accreted along filaments from the intergalactic medium. Unfortunately, to date, observations have identified only about 10% of the needed accretion to sustain star formation. Most of these searches have been limited to searching for neutral hydrogen (HI) at column densities above 10^{19} cm^{-2}. We have used the Green Bank Telescope (GBT) to search for cold accretion being traced by HI in emission down to N^{HI}~10^{17} cm^{-2} around three local galaxies. I will report on the results of our search and the implications for the accretion rate in the local universe.

Author(s): Daniel J. Pisano[2], Felix J. Lockman[1], Spencer A. Wolfe[2]
Institution(s): *1. National Radio Astronomy Observatory, 2. West Virginia University*

331.06D – Kinematics of Baryons Cycling Through Galaxy Halos

In a modern view of galaxy evolution, the baryon cycle is key to understanding the observed global properties of galaxies. Red galaxies passively evolve due to quenching of their star formation, whereas blue galaxies actively evolve, presumably due to a replenishing gas supply. Signatures of the baryon cycle such as IGM accretion, minor mergers, and stellar-driven outflows and fountains are best probed in gaseous halos, i.e., the circumgalactic medium (CGM). We study the spatial and kinematic distribution of the low-ionization metal-enriched CGM with QSO absorption lines for a population of 182 galaxies in the MgII Absorber-Galaxy Catalog (MAGIICAT). We present our findings detailing how the extent and patchiness of the CGM depends on MgII absorption strength, and galaxy luminosity and color. For the first time, we placed the kinematics of 39 MgII absorbers with high-resolution spectra in the context of their host galaxy color, redshift, and orientation. By examining the velocity dispersions of absorbers, we find possible effects of quenching on red galaxies where the velocity dispersions decrease over 2 Gyrs time and are smaller at larger radii. The velocity dispersions for blue galaxies remain constant over time and radius and possibly indicate a sustained flow of baryons feeding star formation. Blue, face-on galaxies probed along the minor axis show the largest velocity dispersions to very high significance. This result provides the strongest direct evidence to date for galactic-scale outflows which, for this orientation, are pointing nearly towards the observer. We discuss how our results place observational constraints on simulations which are just now beginning to accurately model the baryon cycle and its role in galaxy evolution.

Author(s): Nikole M. Nielsen[1]
Institution(s): *1. New Mexico State University*

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332 – Catalogs/Surveys/Computation - UVOIR

332.01 – Results from the Pan-STARRS1 Sky Surveys

Results from the Pan-STARRS1 Sky Surveys spanning the field of astronomy from Near Earth Objects to Cosmology will be presented.

Scientific highlights from the PS1 Sky Surveys include: the photometric and astrometric reference catalog with unprecedented size, accuracy, and dynamic range discovery of 1200 NEO's, 120 PHAs, 60 comets; discovery of rotational break up as the origin of catastrophic disruption of solar system bodies; first free floating planet PSO 318-22 and other ultra-cool objects; first 3-dimensional map of dust in the Milky Way; new distances to molecular clouds; new stellar streams in the Milky Way and new globular clusters; new satellite galaxies of M31; eclipsing binaries in M31 - an important step for the distance ladder; micro-lensing events and other variables in M31: super-luminous and under-luminous stellar explosions; first clear tidal disruption of star by supermassive black hole; many new high redshift quasars; and a new determination of the dark energy equation of state from SnIa photometry.

The nearly 4 year Pan-STARRS1 Science Mission has now completed. The reprocessing of the entire data set is underway. The Public Release of the entire image, catalog and metadata set of the PS1 Sky Surveys is scheduled for April 1, 2015 from the STScI MAST archive. It is expected that a great many more scientific results will come with community access to the data set.

The Pan-STARRS1 Surveys have been made possible through contributions of the Institute for Astronomy of the University of Hawaii; the Max-Planck Society and its participating institutes: the Max Planck Institute for Astronomy, Heidelberg and the Max Planck Institute for Extraterrestrial Physics, Garching; The Johns Hopkins University; Durham University; the University of Edinburgh; Queen's University Belfast; the Harvard-Smithsonian Center for Astrophysics, the Las Cumbres Observatory Global Telescope Network Incorporated; the National Central University of Taiwan; the Space Telescope Science Institute; NASA Grant No. NNX08AR22G; the National Science Foundation under Grant No. AST-1238877; the University of Maryland; the Eotvos Lorand University; and the Los Alamos National Laboratory.

Author(s): Kenneth C. Chambers[1]
Institution(s): *1. University of Hawaii*
Contributing team(s): PS1 Science Consortium

332.03 – Establishing a Network of Next Generation SED Standards with DA White Dwarfs

Photometric calibration uncertainties are the dominant source of error in current type Ia supernova dark energy studies, and other forefront cosmology efforts, e.g., photo-redshifts for weak lensing mass tomography. Modern 'all-sky' surveys require a network of calibration stars with 1) known SEDs (to properly and unambiguously account for filter differences), and 2) that are on a common photometric zero-point scale. We use the HST to establish this essential network of faint (16-20th mag) spectrophotometric standards, by eliminating the time-variable Earth's atmosphere, and by exploiting the well-understood energy distributions of DA white dwarfs. We present UVOIR data from cycle 20, early data from cycle 22, and high S/N ground-based spectroscopy from a variety of large aperture facilities. Our data allows us to simultaneously determine temperature, log(g) and any applicable reddening. This allows our sample to be used as flux standards at wavelengths well beyond the range of HST, and in any arbitrary passband. This sample will constitute the gold-standard with which to directly calibrate, and cross-validate the survey data products. We demonstrate sub-percent precision between the different objects. Our program is critical to extending the precision photometric heritage from HST to the benefit of essentially all existing and upcoming surveys, standardizes (spectro)photometry across observatories and facilities, and directly addresses one of the current barriers to understanding the nature of dark energy.

Author(s): Gautham Narayan[2], Abhijit Saha[2], Thomas Matheson[2], Jay B. Holberg[4], Edward W. Olszewski[4], Christopher Stubbs[1], Susana E. Deustua[3], Ralph Bohlin[3], Ronald L. Gilliland[3], Armin Rest[3], Elena Sabbi[3], John W. MacKenty[3], Tim S. Axelrod[4]
Institution(s): *1. Harvard Univ., 2. National Optical Astronomy Observatory, 3. Space Telescope Science Institute, 4.*

University of Arizona

332.04 – The Panchromatic Hubble Andromeda Treasury Survey: UV-IR Photometry of 117 Million Stars

We have measured resolved stellar photometry using HST/WFC3 and HST/ACS imaging in near ultraviolet (F275W, F336W), optical (F475W, F814W), and near infrared (F110W, F160W) with simultaneous point spread function fitting across all bands at all source positions. All images were aligned to 5-10 milliarcsecond relative accuracy and to 50 milliarcsec global accuracy. In the outer disk, the photometry reaches a completeness-limited depth of F475W~28, while in the crowded, high surface brightness bulge, the photometry reaches F475W~25. We find that simultaneous photometry and optimized measurement parameters significantly increase the detection limit of the lowest resolution filters (WFC3/IR) providing color-magnitude diagrams that are up to 2.5 magnitudes deeper when compared with color-magnitude diagrams from WFC3/IR photometry alone. This stellar catalog is the largest ever produced for equidistant sources, and is publicly available for download by the community. The quality of the photometry catalog, as well as examples of some initial results from model fitting will be discussed. PHAT is supported by HST GO-12055 administered by NASA.

Author(s): Benjamin F. Williams[4], Dustin Lang[1], Julianne Dalcanton[4], Andrew E. Dolphin[3], Daniel R. Weisz[4], Lent C. Johnson[4], Nell Byler[4], Dylan Gregersen[5], Anil Seth[5], Leo Girardi[2]
Institution(s): *1. Carnegie Mellon University, 2. Padova, 3. Raytheon, 4. Univ. of Washington, 5. University of Utah*
Contributing team(s): PHAT Survey Team

332.05 – Version 1 of the Hubble Source Catalog

The Hubble Source Catalog (HSC) is an initiative to combine the tens of thousands of visit-based Hubble Legacy Archive (HLA - available at http://hla.stsci.edu) source lists into a single master catalog. The HSC currently includes ACS/WFC, WFPC2, and WFC3 source lists generated using the Source Extractor software (Bertin & Arnouts 1996), cross-matched using the technique described in Budavari & Lubow (2012). The astrometric residuals for the HSC individual objects are typically within 10 mas and the magnitude residuals between repeats are generally within 0.10 mag. Version 1 of the HSC is scheduled to be released in winter 2015. Some of the primary improvements over the current Beta 0.3 version of the HSC include: 1) improved WFC3 source lists, 2) two more years of WFC3 data, 3) improved matching algorithms, 4) a draft paper to be submitted to PASP, 5) inclusion in the MAST Discovery Portal (http://mast.stsci.edu), and 6) a CasJobs capability for advanced searches. Demonstrations will be provided at the Space Telescope Science Institute booth during the conference and people will have the opportunity to use the system interactively. The URL for the HSC is http://archive.stsci.edu/hst/hsc/ .

Author(s): Bradley C. Whitmore[2], Sahar S. Allam[2], Tamas Budavari[1], Tom Donaldson[2], Stephen H. Lubow[2], Lee Quick[2], Louis-Gregory Strolger[2], Geoff Wallace[2], Richard L. White[2]
Institution(s): *1. JHU, 2. STScI*

332.06 – GLASS: Spectroscopic samples of Lyα emitters at z > 6

The ongoing Grism Lens-Amplified Survey from Space (GLASS) is providing slitless HST grism spectroscopy of 10 massive galaxy clusters, including the 6 Hubble Frontier Fields. By the completion in February 2015 GLASS will have collected more than 10000 spectra of objects brighter than 25 in H-band. Due to the lensing magnification of the clusters, spectroscopic samples of objects behind the clusters go deeper than otherwise possible. In particular, the spectra of intrinsically faint Lyman break galaxies and Lyα emitters (LAEs) at the epoch of reionization (z>6) reach flux sensitivities of ~1e-18 erg/s/cm2. These, otherwise unreachable spectroscopic limits, enable confirmation of large samples of galaxies at the epoch of reionization. I will present the first results from a rigorous search for LAEs at z > 6 behind the GLASS clusters, revealing tens of high confidence candidates and numerous firm detections. These large spectroscopic samples of LAEs from GLASS will, for the first time, enable a large-scale search for CIII] in samples of confirmed galaxies at z > 6.

Author(s): Kasper B. Schmidt[2], Tommaso Treu[1]
Institution(s): *1. University of California Los Angeles (UCLA), 2. University of California Santa Barbara (UCSB)*
Contributing team(s): The GLASS Collaboration

332.07 – Wide Integral Field Infrared Spectroscopic Survey of Nearby Galaxies

We are constructing a novel infrared integral field spectrograph with a large field of view (~50”x20”) that will be available on the Kitt Peak 90” Bok telescope this spring. This wide integral field infrared spectrograph (WIFIS) operates over two wavelength ranges, zJ-band (0.9-1.35 microns) and H-band (1.5-1.8 microns), and has moderate spectral resolving power, 3,000 in zJ-band and 2,200 in H-band, respectively. WIFIS’ field-of-view is comparable to current optical integral field spectrographs that are carrying out large galaxy surveys, e.g. SAMI, CALIFA, and MaNGA. We are designing

a large nearby galaxy survey to complement the data already been taken by these optical integral field spectroscopic surveys. The near-infrared window provides a sensitive probe of the initial mass functions of stellar populations, the OB stellar fractions in massive star forming regions, and the kinematics of and obscured star formation within merging systems. This will be the first large scale infrared integral field spectroscopic survey of nearby galaxies.

Author(s): Suresh Sivanandam[2], Dae-Sik Moon[4], Dennis F. Zaritsky[3], Richard Chou[1], Elliot Meyer[4], Ke Ma[4], Miranda Jarvis[4], Joshua A. Eisner[3]
Institution(s): *1. ASIAA, 2. Dunlap Institute, 3. University of Arizona, 4. University of Toronto*

332.09 – Targeted-mode pipeline for the Evryscope: a minute cadence, 10,000-square-degree FoV, gigapixel-scale telescope

The Everyscope consists of 27 mass-produced telescopes placed into a dome which mimics the sky's hemisphere. It has a field of view of 10,200 square degrees, a pixel sampling of 13.3 arcsec, 778MPix per exposure, a two-minute imaging cadence, and a limiting magnitude V=16.4 (3-σ) for that exposure time. Among other observational programs, transits surveys around nearby bright, M-dwarfs, and bright white dwarfs hosts stars will be conducted with unprecedented level of efficiency thanks to the unique Evryscope specifications. All data will be stored to be to made available to interested astronomers.

Evryscope brings a unique opportunity to tackle challenges in the areas of computation and data analysis, given its sustained 0.76Gb/min data-flow. We have implemented an initial targeted-mode version of the Evryscope pipeline (Evrypipe-I), which delivers to end user science products from a limited list of targets of interest. The pipeline first performs CCD calibration, astrometric reduction, and source extraction, and generates uncalibrated photometry catalogs for all acquired images. Next, image cutouts around the compiled targets are considered. These much smaller images allow us to feasibly compute multi-epoch light curves on the reduced data-sets, including proper systematics analysis which the millimagnitude precision goals require. This last step includes source association, differential photometry, polynomial differential airmass correction, detrending, and phase folding.
From end user point of view, Evrypipe-I delivers fully calibrated WCS FITS image cutouts and multi-epoch light curves around the compiled/requested targets. The development of a more complex all-sky every-star analysis pipeline, covering the 10s of millions of targets measured in each Evryscope exposure, is planned to start in the near future.

Author(s): Octavi Fors Aldrich[1], Nicholas M. Law[1], Philip J. Wulfken[1], Jeffrey Ratzloff[1]
Institution(s): *1. University of North Carolina at Chapel Hill*

333 – Plenary Talk: Bringing the High Energy Universe into Focus: Science Highlights from the NuSTAR Mission, Fiona Harrison (Caltech)

333.01 – Bringing the High Energy Universe into Focus: Science Highlights from the NuSTAR Mission

The Nuclear Spectroscopic Telescope Array, the first focusing high-energy X-ray (3 – 79 keV) telescope in orbit, extends sensitive X-ray observations above the band pass where Chandra and XMM-Newton operate. With an unprecedented combination of sensitivity, spectral and imaging resolution above 10 keV, NuSTAR is advancing our understanding of black holes, neutron stars, and supernova remnants. I will describe the mission, and present science highlights to-date from the two-year baseline mission.

Author(s): Fiona Harrison[1]
Institution(s): *1. Caltech*

334 – Plenary Talk: Cosmological Results from Planck 2014, Martin White (University of California, Berkeley)

334.01 – Cosmological results from Planck 2014

The European Space Agency's Planck satellite was launched on 14 May 2009, and surveyed the sky 9 times over its lifetime. In late 2014, ESA and the Planck Collaboration released to the public a complete set of data products from the full mission, including maps of CMB polarization. I will review some of the highlights of this release and the implications for cosmology and early Universe physics.

Author(s): Martin White[1]
Institution(s): *1. UC, Berkeley*

336 – Catalogs, Surveys, and Computation Posters

336.00 – Sharper Fermi LAT Images

The Large Area Telescope on the Fermi Gamma-ray Space Telescope has a point spread function with large tails, consisting of events affected by tracker ineffiencies, inactive volumes, and hard scattering; these tails can make source confusion a limiting factor. The parameter CTBCORE, available in the publicly available Extended Fermi LAT data, estimates the quality of each event's direction reconstruction; by implementing a cut in this parameter, the tails of the point spread function can be suppressed at the cost of losing effective area. We implement cuts on CTBCORE and present updated instrument response functions derived from the Fermi LAT data itself, along with all-sky maps generated with these cuts. Having shown the effectiveness of these cuts, especially at low energies, we encourage their use in analyses where angular resolution is more important than Poisson noise.

Author(s): Stephen Portillo[1], Douglas P. Finkbeiner[1]
Institution(s): *1. Harvard University*

336.01 – The X-ray Source Population of M33 as seen by *XMM-Newton*

We present results from the deepest survey of M33 with *XMM-Newton* to date. The survey consists of 8 overlapping EPIC fields covering an area beyond the D25 isophote down to a limiting sensitivity of L(0.2-4.5 keV) > 4e+34 erg/s. This larger field of view coupled with the higher soft sensitivity of *XMM-Newton* provides an excellent complement to the *Chandra* ACIS Survey of M33 (ChASeM33). Comparison of our source catalog with the *Chandra* survey allows us to identify variable sources as well as previously undetected soft sources. Our coverage of the full M33 disk reveals many new sources including SNRs previously undetected in X-rays. The radial coverage extends far enough to provide high-quality background statistics, including a radial density distribution of bright sources which suggests that roughly 15% of sources with L > 3.6e+35 erg/s are likely to be associated with M33. The accurate background statistics allow us to perform a simultaneous fit of our background and observed luminosity functions, which yields a slope consistent with the presence of a significant population of HMXBs. The combined *XMM-Newton* and *Chandra* data will allow the most detailed study of the X-ray population of a late-type spiral possible with currently-available facilities. We will show preliminary work in studying new HMXB candidates using *HST*.

Author(s): Kristen Garofali[7], Benjamin F. Williams[7], Brian Wold[7], Frank Haberl [3], William P. Blair[2], Terrance J. Gaetz[1], K. D. Kuntz[2], Knox S. Long[6], Thomas Pannuti[5], Wolfgang Pietsch [3], Paul P. Plucinsky[1], P. Frank Winkler[4]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Johns Hopkins University, 3. Max-Planck-Institut fur extraterrestrische, 4. Middlebury College , 5. Morehead State University , 6. Space Telescope Science Institute , 7. University of Washington*

336.02 – Fermi's Other Source Class: The Unassociated Sources of the Fermi-LAT 3FGL Catalog

The Fermi Gamma-ray Space Telescope Large Area Telescope (LAT) has been gathering science data since August 2008, surveying the full sky every three hours. The Fermi-LAT Collaboration has now prepared a third source catalog (3FGL) of 3033 sources, a third of which are not associated with any known gamma-ray producing source. At high Galactic latitudes, these unassociated sources are likely dominated by faint active galactic nuclei (AGN) along with a small number of gamma-ray millisecond pulsars. Along the Galactic plane, three different populations of pulsars, supernova remnants and AGN are combined, and appear to account for the majority of the sources. We investigate these disparate populations and discuss their relative contributions to the unassociated source "class." Further, we discuss how gamma-ray spectral information can be used to inform the estimated contribution for each major contributing class.

Author(s): Elizabeth C. Ferrara[1], Nestor R. Mirabal[1]
Institution(s): *1. NASA/GSFC*
Contributing team(s): Fermi-LAT Collaboration

336.03 – Science with the Cherenkov Telescope Array

The Cherenkov Telescope Array (CTA) is the next-generation ground-based observatory with an unprecedented sensitivity to gamma rays with energies from a few tens of GeV to more than 100 TeV. CTA will address a wide range of scientific questions, which can be grouped into three broad themes: cosmic particle acceleration and propagation, probing extreme environments, and physics frontiers. The first and second themes include improving our understanding of the sites of particle acceleration in our galaxy, in the jets and lobes of active galaxies, and in many other extreme regions. The physics frontier theme includes the search for the nature and distribution of Dark Matter, and using high-energy photons to investigate whether the speed of light deviates from a constant. CTA observations will address these science themes with deep surveys and monitoring observations to build source populations and study transient phenomena.

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336.04 – Planning the installation of the Dark Energy Spectroscopic Instrument on the NOAO Mayall telescope

The NOAO Nicholas U. Mayall 4-meter telescope located at Kitt Peak National Observatory in Arizona is to be the host facility for the Dark Energy Spectroscopic Instrument (DESI). DESI will record broadband spectra simultaneously for 5000 objects distributed over a 3-degree diameter field of view; it will record the spectra of approximately 20 million galaxies and quasi-stellar objects during a five-year survey. This survey will improve the combined precision of measurement on the dark energy equation of state today (w^0) and its evolution with redshift (w^a) by approximately a factor of ten. Installation of DESI on the telescope is a complex procedure, involving a complete replacement of the telescope top end, routing of massive fiber cables, and installation of banks of spectrographs in an environmentally-controlled lab area within the dome. Furthermore, assembly of the instrument and major subsystems must be carried out on-site given their size and complexity. A detailed installation plan is being developed early in the project in order to ensure that DESI and its sub-systems are designed so they can be safely and efficiently installed, and to ensure that all telescope and facility modifications to enable installation are identified and completed in time.

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336.05 – The Dark Energy Spectroscopic Instrument (DESI): Science from the DESI Survey

The Dark Energy Spectroscopic Instrument (DESI) will enable an ambitious redshift survey to probe dark energy by the baryon acoustic oscillation and redshift-space distortion methods. The same data set will serve numerous other goals in cosmology and astrophysics. Using a new 5000-fiber instrument and 8 square degree field of view at the Mayall telescope, the DESI survey plans to cover 14,000 square degrees and about 25 million high-redshift objects. The targets include 4M luminous red galaxies (redshift 0.4-1.0), 18M emission line galaxies (redshift 0.6-1.6), and 2.4M quasars, including 0.7M Lyman-alpha forest sight lines. With this, DESI can map the expansion history of the Universe to redshift 3, achieving unprecedented performance from the baryon acoustic oscillation method. We will describe the present state of the survey design and the cosmological forecasts for dark energy, inflation, and neutrino physics. We also give an update on the DESI Science Collaboration.

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336.06 – The Dark Energy Spectroscopic Instrument (DESI): Bright-Time Science Program

The Dark Energy Spectroscopic Instrument (DESI) is a new 5000-fiber spectrograph with an 8 square degree field of view, to be installed at the Mayall telescope. Here we describe a Bright-Time Survey, to be executed by the DESI collaboration when the sky is too bright for the dark-time survey of higher redshift galaxies. Using ~ 450 hours of bright time per year over 5 years, we plan a survey of tens of millions of bright galaxies and stars. The Bright Galaxy Survey will get redshifts for ~10 million galaxies with $r < 19.5$, a high completeness survey over at least 14,000 square degrees. This survey will increase the Dark Energy Figure of Merit of the dark-time survey by ~30% using BAO alone, and will enable multi-tracer Redshift Space Distortion (RSD) measurements, cross-correlation with imaging surveys, redshift calibration of photometric surveys, measurements of galaxies in groups and clusters, redshifts for more than 10,000 SN hosts, and significant tests of Modified Gravity models. Concurrently, DESI will perform a Milky Way Survey, measuring radial velocities and metalicities for more than 10 million stars, mapping out the structure of the Milky Way and significantly enhancing GAIA science.

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336.07 – The Dark Energy Spectroscopic Instrument (DESI): The NOAO DECam Legacy Imaging Survey and DESI Target Selection

The DECam Legacy Survey will conduct a 3-band imaging survey of the Sloan Digital Sky Survey (SDSS) extragalactic footprint. The Dark Energy Camera (DECam) will be used to image the 6700 square degree footprint overlapping SDSS in the region $-20 < \mathrm{Dec} < +30$ deg, to depths of $g=24.7$, $r=23.9$, $z=23.0$. The survey will be conducted from Fall 2014 through Spring 2017, with periodic data releases beginning in March 2015. These releases will include catalogs constructed with

the Tractor-based multi-wavelength forced photometry applied to the DECam and WISE satellite data.
The Dark Energy Spectroscopic Instrument (DESI) will observe 24 million galaxies and quasars in a 14,000 square degree extragalactic footprint. The targeting in that footprint will be provided by a combination of these DECam data, the MOSAIC camera on the Mayall 4-meter, and the 90Prime camera on the Bok Telescope.

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Contributing team(s): DECam Legacy Survey Collaboration

336.08 – The Dark Energy Spectroscopic Instrument (DESI): The Spectrographs

The Dark Energy Spectroscopic Instrument (DESI) will conduct a large-area galaxy and quasi-stellar object redshift survey from the Mayall Telescope. It includes of ten spectrographs each recording 500 simultaneous object spectra collected by 5,000 positioned optical fibers in the focal plane of an 8-square degree telescope corrector. The spectrographs use dichroic filters to divide light into three optical channels that together cover the 360 - 980 nm pass band with a spectral resolution of 2,000 to 5,100. Each channel includes a volume phase holographic grating (VPHG) and a 5-element camera that images spectra onto a cryostatic detector. We describe the spectrograph design and predicted performance and the production of the first spectrograph’s optical elements.

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336.09 – The Dark Energy Spectroscopic Instrument (DESI): Data Systems

We present the design, status, and plans for the data systems of the Dark Energy Spectroscopic Instrument (DESI), a spectroscopic redshift survey of 25 million galaxies, quasars, and stars to be operated at the Kitt Peak National Observatory 4-m Mayall telescope from 2018–2023. DESI will obtain 5000 spectra (3600–9800 Å) per exposure using robotically positioned fibers. DESI data systems include the target selection pipeline, survey planning and operations, the spectroscopic data reduction pipeline, instrument simulations, and data transfer, archive, and distribution. While building on the heritage of previous galaxy redshift surveys, DESI is upgrading all aspects of the algorithms and pipelines to maximize the science reach of the new instrument and survey.

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Contributing team(s): DESI Collaboration

336.10 – The Dark Energy Spectroscopic Instrument (DESI): Tiling and Fiber Assignment

DESI will measure the redshifts of 25 million galaxies drawn from a list of targets identified photometrically. The spectra will be obtained using 5000 automated positioners populating the instrument's 7.5 square degree focal plane. With about 10,000 pointings, each spot in the 14,000 square degree footprint will be covered more than five times, on average. The galaxies will be of three primary kinds, luminous red galaxies (LRGs), emission line galaxies (ELGs), and quasars (QSO).
The pattern of telescope pointings generates a tiling of the sky, which we consider to be made of five separate passes, each providing nearly full coverage of the 14,000 square degrees. The first pass forms a particularly symmetric pattern. The subsequent passes are made by rotations of the first pass.
For each pointing of the telescope, each fiber positioner must be directed to a galaxy within its reach. The choice of galaxy is dictated by priorities established to maximize the value of the full suite of observations. In addition to the galaxy targets, some fibers must be reserved for calibration with standard stars and others for measuring sky alone. We demonstrate the effectiveness of the fiber assignment algorithm when applied to mock catalogs observed with planned tiling patterns.

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336.11 – A Comparison of Kinematic and Photometric Inclinations in the RESOLVE Survey

Using standard prescriptions relating axial ratios to inclinations, the inferred distribution of inclinations for galaxies in the REsolved Spectroscopy Of a Local VolumE (RESOLVE) survey departs from theoretical expectations for a complete volume-limited sample. We compare kinematic inclinations from velocity fields of ~200 disk galaxies in RESOLVE with their respective photometric inclinations to examine the origin of this discrepancy. We further investigate which galaxy properties may correlate with differences between inclination estimates, considering morphology, mass, optical size, and rotation curve asymmetry. Our test sample spans galaxy masses between 10^9 and 10^{11} $M_\odot$, axial ratios between 0.2 and 0.9, rotation curve asymmetries between 0% and 30%, and the full range of morphological types, which are representative of the distribution for the parent survey, RESOLVE. However, the test sample does not represent the optically largest or smallest galaxies in RESOLVE, denoted by 90% r-band light radii greater than 70" or less than 6". The kinematic data for our sample galaxies were acquired with our custom image slicer on the SOAR telescope/Goodman spectrograph, and inclinations were measured using DiskFit. This analysis will contribute to the RESOLVE kinematic database in preparation. This research was supported by the National Science Foundation under an REU supplement to CAREER award AST-0955368.

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336.12 – Galaxy and Group Baryonic Mass Functions for the RESOLVE Survey

We present a comparison of the galaxy and group baryonic mass functions for a subvolume of the RESOLVE (Resolved Spectroscopy Of a Local VolumE) survey. RESOLVE occupies A and B semester volumes totaling ~52,000 cubic Mpc, complete in baryonic mass to ~10^9.3 Msun and 10^9.0 Msun respectively, with galaxies and groups ranging in halo mass from 10^11-10^14 Msun. The A semester volume is surrounded by the larger ECO catalog, which lacks complete HI data but occupies ~561,000 cubic Mpc. We define the observed baryonic mass of a galaxy or group to be the sum of its stellar and cold atomic hydrogen components, with the latter inferred indirectly for much of ECO. For groups, we infer the total baryonic mass by summing the observed components of each constituent galaxy and add the likely hot halo gas based on prescriptions from observations and semi-analytic models. We perform subhalo/halo abundance matching between observed galaxies/groups and dark matter simulations, and we compare derived halo properties based on matching on luminosity vs. on observed baryonic mass (or on inferred total baryonic mass for groups). We also present a status update on the galaxy and group velocity functions for these surveys, which will allow for more direct comparison with dark matter simulations. This project was supported by NSF funding for the RESOLVE survey (AST-0955368).

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336.13 – Measuring the Properties of Void Galaxies in Environmental COntext (ECO) using RESOLVE

We measure the environmental dependence of multiple galaxy properties inside the Environmental COntext survey focusing primarily on void galaxies for this project. We define void galaxies to be ~5% of galaxies having the lowest local density, where density is determined using the Nth nearest neighbor method. We examine the stellar mass, color, fractional stellar mass growth rate (FSMGR), fractional gas mass determined from a photometric gas fraction relation calibrated with the RESOLVE survey, and morphology distributions of the void galaxy population and compare them to those of galaxies in other large-scale structures (such as filaments or clusters). First, we show that our void galaxies typically have lower stellar masses than galaxies in denser environments, and they display the properties expected of a lower stellar mass population: they have late-types, are bluer, have higher FSMGR, and are more gas rich. Since color, star-formation, gas content, and morphology all correlate with stellar mass, we therefore move on to control for stellar mass and investigate the extent to which void galaxies are different at fixed mass. We show that void galaxies are indeed bluer and slightly more star forming at fixed stellar mass than galaxies in other environments. We also show that the ratio of blue early types to red early types is higher inside voids than in any other environment.

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336.14 – Characterizing Compact Core Galaxies in the RESOLVE Survey

We identify a population of 67 "compact core galaxies" (CCGs) in the highly complete RESOLVE survey, which includes both compact ellipticals (cEs) and galaxies with dense cores surrounded by an envelope of gas and stars, possibly representing earlier or later evolutionary stages of cEs. CCGs are identified as objects having core effective radius <800pc, based on deconvolutions of UKIDSS NIR imaging using Galapagos and GALFIT. We select all CCGs with log Mstars >8.8Msun to ensure a complete, volume-limited sample. These CCGs have radii from ~200-800pc, which includes objects nearly as compact as the prototype M32 and comparable to the isolated cE found by Huxor et al. (2013). We find that our CCGs reside in a variety of environments, including 4 CCGs that are >1Mpc away from any other galaxy, as well as 6 in a massive group halo with log Mhalo~13.8Msun. Making use of cross-matched GALEX data, we compute fractional stellar mass growth rates, and find that many CCGs have recently formed stars. The CCG baryonic mass distribution appears to strongly tail off above the gas-richness threshold scale (log Mbary < ~9.9 Msun) and disappears above the bimodality scale (log Mbary < ~10.6 Msun) as galaxies quench, which could point to a formation scenario involving intensely dissipative conditions (gas-rich mergers or cold flows). Using velocity dispersions derived from Gemini IFU data, we look for CCGs offset to higher or lower dispersion from the Faber-Jackson relation, which may indicate tidal stripping or dissipative formation, respectively. Initial results show several CCGs following the dissipative formation track. To put our results in context with the literature, we compare the kinematics and star formation histories of our sample CCGs with those of the lower-mass UCDs/cEs/dE,Ns in the AIMSS (Archive of Intermediate Mass Stellar Systems) catalog. This work is supported by the National Science Foundation under AST-0955368 and by the grant HST-AR-12147.01-A.

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336.15 – Open Exploration of the Time Domain with the Catalina Real-Time Transient Survey (CRTS)

Catalina Real-Time Transient Survey (CRTS; http://crts.caltech.edu) is systematically exploring and characterizing the faint, variable sky. It uses data streams generated by the Catalina Sky Survey, which searches for near-Earth asteroids, to search for variable objects and transient events. The CRTS survey has been in operation since 2008, with the archival data going back to 2005. A continuation of the survey has been funded by the NSF, and we are forming an international consortium for an expanded and extended coverage and a broader scientific exploitation. We have a completely open data policy: all discovered transient events are published in real time with no proprietary delay period, and all data are made public, in order to better serve the entire community, and maximize the scientific returns. The survey covers the total area of ~33,000 deg2, down to ~19-21 mag per exposure, with time baselines from 10 min to ~9 years, and growing; there are now typically ~ 300-400 exposures per pointing, and coadded images reach deeper than ~ 23 mag. The area coverage rate will increase substantially as new cameras are being deployed, and possible new data streams opened. The survey has so far detected nearly 10,000 unique, high-amplitude transients, including ~2,500 supernovae (for the last 5 years we published more supernovae than any other survey), >1,200 CVs (the great majority of them previously uncatalogued), >3,000 of blazars and other AGN, and a broad variety of other types of objects. We have ~500 million light curves, which are have been made public and which are being updated continuously. This is an unprecedented data set for the exploration of the time domain, in terms of the area, depth, and temporal coverage. Numerous scientific projects have been enabled by this data stream, including: discoveries of ultraluminous and otherwise peculiar SNe; unusual CVs and dwarf novae; mapping of the structure in the Galactic halo using RR Lyrae; variability-based discovery of AGN and probes of their physics; etc. We also have a major effort on the automated classification of transient and variable sources. CRTS is both a scientific and methodological precursor to LSST, and its data are open to the entire community.

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336.16 – APASS - The Latest Data Release

The AAVSO Photometric All-Sky Survey has just finished a new data release. This survey calibrates the entire sky, from 10.5mag to 16.5mag at V, and with 2.5arcsec resolution. Johnson B,V and Sloan g',r',i' filters are included. Each field is observed a minimum of 4 times on separate nights, with nightly calibrations using Landolt and SDSS standard stars. The current accuracy is 0.02mag photometry and 200mas astrometry. We have nearly completed the data acquisition for the main survey, and are starting a bright extension, measuring stars as bright as 7th magnitude and with additional u',z' and Y bandpasses. Copies of the current release can be obtained from our website or at the poster.

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336.17 – Pan-STARRS-1 Medium Deep Survey

The Panoramic Survey Telescope And Rapid Response System-1 (Pan-STARRS-1, PS1) has been in full operation since Spring 2010 and concluded the PS1 Science Consortium (PS1SC) observational program in early 2014. The Medium Deep Survey (MDS) component of the program, allocated 25% of the time, regularly visited 10 fields (~7 sq. deg. each) with significant multi-wavelength overlap from previous and concurrent surveys (e.g. SDSS, DEEP2, CDFS, COSMOS, GALEX). The cadence generally includes the g,r,i,z filters for a MDS field every 3 days with a nightly stack depth of r,i~23.5 mag and the y filter primarily during bright time over the 6-8 month season the field is visible. While regularly producing data for the transient event discovery and science consortium programs, development work continued to improve the single exposures though production of deep stacks for reprocessing into the final and public release. The data products, to be publicly available after the post-observing proprietary period, will be summarized.

For details on PS1 and the Science Collaboration, visit http://ps1sc.org/

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336.18 – SpIES:The *Spitzer* IRAC Equatorial Survey

The Spitzer-IRAC Equatorial Survey, SpIES, is an Exploration Science program using Warm Spitzer to map over 100deg^2 of the SDSS Stripe 82 field, and is the largest extragalactic area surveyed by Spitzer. The primary science drivers are: the measurement of z>3 quasar clustering and the luminosity function in order to test different "AGN feedback'' models; to identify obscured AGN (and take advantage of the wide range of multi-wavelength, multi-epoch ancillary data on the Stripe 82 field); to identify z>6 quasars, and to support other wide-field ancillary science. With our observations very recently completed, we present the first preliminary science results from SpIES. This work is based [in part] on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided by NASA through an award issued by JPL/Caltech.

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Contributing team(s): SpIES Team

336.19 – Understanding Galaxy Cluster MKW10

As part of the Undergraduate ALFALFA Team (UAT), we are studying the galaxy cluster MKW 10 (RA = 175.454, Dec = 10.306, z ~ 0.02), a poor cluster with a compact core in which tidal interactions have occurred. This cluster has been observed in HI and Hα. We used SDSS and NED to search for optical counterparts. By comparing data at multiple wavelengths, we hope to understand the structure, environment, and star formation history of this cluster. Following the techniques of others involved in the groups project and using the program TOPCAT to manipulate the data, we explored both the spatial and velocity distributions to determine cluster membership. We have determined that this cluster consists of 11 galaxies, mostly spiral in shape. Chicago State University is new the UAT and we began our work after taking part in the winter workshop at Arecibo.
This work was supported by: Undergraduate ALFALFA Team NSF Grant AST-1211005 and the Illinois Space Grant Consortium.

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336.20 – Low Mass Stellar Companions to Nearby A and B Stars

Recent discoveries of planets orbiting retired A-stars on close orbits and young A-stars on very wide orbits have renewed interest in the properties of nearby intermediate-mass stars. Especially interesting are the young stars, because directly-imaged planets orbiting them may be bright enough for characterization (e.g. HR 8799, Beta Pictoris, etc). However, intermediate-mass stars and especially young intermediate mass stars are part of multiple systems more often than not. Close stellar companions may affect the formation and orbital evolution of any planets, and the properties of the companions can help constrain the binary formation mechanism. The mass ratio distribution of a population of stars, especially if it is significantly different from the distribution for wide companions, is helpful to distinguish companions that were born in or affected by the circumprimary disk from those which formed through fragmentation of the molecular core. We have conducted a spectroscopic survey of 400 nearby A- and B-type stars, aimed at detecting stellar companions as late as M4 for all orbital separations <100 AU. We have searched for companions to the stars by cross-correlating the spectra against model templates for F-M type stars; a significant peak in the cross-correlation function indicates a detection. Our cross-correlation technique can detect low-mass companions with orbits that are too wide to detect with radial velocity monitoring and too small to detect with imaging techniques, making it complementary to work already done. We present initial results from our survey and present the distribution of mass ratios for inner companions.

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336.21 – Galaxy Evolution Explorer (GALEX): Galactic Plane Survey

The Galaxy Evolution Explorer (GALEX) completed its survey of the Galactic plane in the near-ultraviolet during 2012. Although preliminary data were released shortly after the completion of the survey, the full dataset was reanalyzed during 2014 using refined attitude correction techniques that yield angular resolution-limited images. The GALEX Galactic plane survey includes more than 75% of the sky between 10 > b > -10 degrees. The initial photon dataset contains about 400 individual scans, each of which is a vertical slice of the Galactic plane. Each slice spans 1500-1700 seconds, during which the 1.24 degree diameter field of view performed a double-pass sweep across the Galactic plane. The Galactic Plane survey was the only time this non-standard, high scan rate acquisition mode was exercised during the mission, and required specialized processing and astrometric refinement to produce high quality sky maps. We present the first high-resolution map of the Galactic plane in the near-ultraviolet as well as a catalogue of thousands of sources for follow-up with HST. This work was partially supported by the Keck Institute for Space Studies.

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336.22 – PHAT Youths: Metallicity Gradient of M31 using Young Stars in the PHAT Survey

Many recent studies have revealed metallicity gradients across galaxies, which are used as important constraints for models of chemical evolution. Existing observations of young stellar metallicities in M31 consist of spectroscopic studies (Zurita & Bresolin 2012; Sanders et al. 2012), which were limited to tens to hundreds of measurements of HII regions. We present photometric metallicity measurements of tens of thousands of young main sequence stars in M31 using multi-band photometry from the Panchromactic Hubble Andromeda Treasury (PHAT). We use UV and optical photometry of young massive main sequence stars to determine the extinction and metallicities of each individual star using isochrone fitting. We then use these measurements to examine metallicity gradients within Andromeda.

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336.23 – Grism Data Products from the 3D-HST Survey

The grism spectroscopic capabilities of HST/WFC3 are one of the unique features of Hubble: they allow for spatially resolved spectra of high-redshift galaxies over the full 0.8 to 1.6um range. At redshifts between 1 and 3, this range captures the rest frame optical spectra and allows for studies of galaxy evolution impossible from the ground. However, the lack of slits and the low resolution of the spectra have presented us with new challenges in reducing and analyzing the data. In an effort to improve upon the existing WFC3 grism reductions, the 3D-HST team has developed a new pipeline and created new calibration images. We review our approaches to background and sky subtraction, co-adding dithered exposures, modeling and redshift-fitting of the grism spectra, and discuss the effect of these on the final data products. We present the public release data products of the survey including a grism redshift catalog for all objects down to F140W=24.0. Even though these techniques have been developed for 3D-HST, they have proved applicable to many other WFC3 grism programs and have also been generalized to the ACS grism spectra.

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336.24 – Searching for Distant Galaxies with HST and Spitzer

The recently completed Spitzer-Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (S-CANDELS) provides an extremely deep NIR view of five extragalactic fields: COSMOS, EGS, UDS, HDF-N, and ECDFS. The addition of this deep near-infrared photometry to the existing CANDELS HST imaging is expected to improve redshift and stellar population parameter estimation, and enable selection of galaxies to higher redshift by capturing the 4000 Angstrom break out to 3.6 microns. Here we present an isolated galaxy sample based upon IRAC detection that is free from the effects of source confusion. The sample includes both objects for which CANDELS HST photometry is available, and a small number of objects detected by S-CANDELS but not by WFC3/F160W. We derive photometric redshifts for the matched objects, and demonstrate the efficacy of an IRAC color cut in selecting high-redshift sources. In addition, we apply aperture photometry to the HST images of apparent F160W dropouts. We explore the properties of the high-significance dropouts at other wavelengths, and attempt to distinguish between heavily-shrouded AGN and sources at redshift greater than 7.

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336.25 – The Hubble Legacy Archive: Data Processing in the Era of AstroDrizzle

The Hubble Legacy Archive (HLA) expands the utility of Hubble Space Telescope wide-field imaging data by providing high-level composite images and source lists, perusable and immediately available online. The latest HLA data release (DR8.0) marks a fundamental change in how these image combinations are produced, using DrizzlePac tools and Astrodrizzle to reduce geometric distortion and provide improved source catalogs for all publicly available data. We detail the HLA data processing and source list schemas, what products are newly updated and available for WFC3 and ACS, and how these data products are further utilized in the production of the Hubble Source Catalog. We also discuss plans for future development, including updates to WFPC2 products and field mosaics.

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Contributing team(s): The Hubble Legacy Archive Team, The Hubble Source Catalog Team

336.26 – Identification and Classification of Infrared Excess Sources in the Spitzer Enhanced Imaging Products (SEIP) Catalog

The Spitzer Space Telescope's original cryogenic mission imaged roughly 42 million sources, most of which were incidental and never specifically targeted for research. These have now been compiled in the publicly accessible Spitzer Enhanced Imaging Products (SEIP) catalog. The SEIP stores millions of never before examined sources that happened to be in the same field of view as objects specifically selected for study. This project examined the catalog to isolate previously unknown infrared excess (IRXS) candidates. The culling process utilized four steps. First, we considered only those objects with signal to noise ratios of at least 10 to 1 in the following five wavelengths: 3.6, 4.5, 5.8, 8 and 24 microns, which narrowed the source list to about one million. Second, objects were removed from highly studied regions, such as the galactic plane and previously conducted infrared surveys. This further reduced the population of sources to 283,758. Third, the remaining sources were plotted using a [3.6]–[4.5] vs. [8]-[24] color-color diagram to isolate IRXS candidates. Fourth, multiple images of sixty-three *outlier* points from the extrema of the color-color diagram were examined to verify that the sources had been cross matched correctly and to exclude any candidate sources that may have been compromised due to image artifacts or field crowding. The team will ultimately provide statistics for the prevalence of IRXS sources in the SEIP catalog and provide analysis of those extreme outliers from the main locus of points. This research was made possible through the NASA/IPAC Teacher Archive Research Program (NITARP) and was funded by NASA Astrophysics Data Program.

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336.27 – The G-HAT Search for Advanced Extraterrestrial Civilizations: The Reddest Extended *WISE* Sources

Freeman Dyson (1960) theorized how to identify possible signatures of advanced extra-terrestrial civilizations by their waste heat, an inevitable byproduct of a civilization using a significant fraction of the luminosity from their host star. If a civilizations could tap the starlight throughout their host *galaxy* their waste heat would be easily detectable by recent infrared surveys. The Glimpsing Heat from Alien Technologies (G-HAT) pilot project aims to place limits on the existence of extraterrestrial civilizations at pan-galactic scales. We present results from the G-HAT cleaned catalog of 563 extremely red, extended high Galactic latitude ($|b| \geq 10$) sources from the *WISE* All-Sky Catalog. Our catalog includes sources new to the scientific literature along with well-studied objects (e.g. starburst galaxies, AGN, and planetary nebulae) that exemplify extreme WISE colors. Objects of particular interest include a supergiant Be star (48 Librae) surrounded by a resolved, mid-infrared nebula, possibly indicating dust in the stellar wind ejecta, and a curious cluster of seven extremely red *WISE* sources (associated with IRAS 04287+6444) that have no optical counterparts.

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336.28 – An Analysis of Offset, Gain, and Phase Corrections in Analog to Digital Converters

Many high-speed analog to digital converters (ADCs) use interwoven ADCs to greatly boost their sample rate. This interwoven architecture can introduce problems if the low speed ADCs do not have identical outputs. These errors are manifested as phantom frequencies that appear in the digitized signal although they never existed in the analog domain. Through the application of offset, gain, and phase (OGP) corrections to the ADC, this problem can be reduced. Here we report on an implementation of such a correction in a high speed ADC chip used for radio astronomy. While the corrections could not be implemented in the ADCs themselves, a partial solution was devised and implemented digitally inside of a signal processing field programmable gate array (FPGA). Positive results to contrived situations are shown, and null results are presented for implementation in an ADC083000 card with minimal error. Lastly, we discuss the implications of this method as well as its mathematical basis.

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336.29 – Searching for Fast Radio Bursts (FRBs) in GALFACTS Data

The GALFA Continuum Transit Survey (GALFACTS) is a full-polarization, continuum survey of the whole Arecibo sky. It is made with the 7-beam Arecibo feed array, ALFA, between 1225 and 1525 MHz. One GALFACTS data stream, known as the High-Time Low-Spectral resolution (HTLS) stream, preserves the raw-data time resolution of 1 msec, but decimates the frequency resolution to 256 channels across the 300-MHz bandwidth. Using this data stream, Rotating RAdio Transients (RRATs) and Fast Radio Bursts (FRBs) may be discovered. The search for FRBs is relatively new, only some half dozen FRBs having been detected to date. Certainly, the full-Stokes GALFACTS HTLS database can contribute significantly to this emerging field through detection of new objects, and the study of their dispersion measures, pulse shapes and polarization characteristics. All these properties should provide insight into the FRB phenomena, which is most likely extragalactic in origin. Over the summer of 2014, we have set up a pipeline to search the HTLS data for very short duration radio transients, with the full search to be imminently initiated.

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336.30 – A Blind Search for Neutral Hydrogen

Measurements of neutral hydrogen (HI) are important in our understanding of the universe. Hydrogen within galaxies passes through a neutral phase as it cools and collapses into stars. The reservoir and distribution of HI associated with galaxies is therefore closely tied to how galaxies grow and evolve. Unfortunately, most of our observational information on HI is limited to the local universe, impeding our ability to see how the HI properties of galaxies change over time. Using the newly upgraded Very Large Array (VLA) radio telescope, located in Socorro, New Mexico, we are working on a far-reaching survey of HI gas around galaxies: The COSMOS HI Large Extragalactic Survey (CHILES). For the first time, we can search for HI over one-third of the age of the universe in a single observation. This survey will provide HI mass, morphology, and kinematics over a substantial, continuous distance range, and in a wide range of cosmic environments. Detection of HI sources is typically done by eye and sometimes with the help of optical catalogs of galaxies with known locations. Given that this is a blind search over a very large volume and that these HI sources can be very faint, this standard approach is unlikely to allow us to fully exploit these rich data. In light of this, we are looking into the use of algorithms to aid in the detection of HI sources. We present a source-finding application and discuss its strengths and limitations for these kinds of data. This is a step in advancing data-analysis tools to keep up with the technological advancements of radio telescopes. Once fully tested and applied, our application will help provide the most reliable, complete data set for us to gain insight into the evolution of galaxies as traced by HI and as function of location in the underlying large-scale structure of the universe.

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336.31 – Direction Dependent Effects In Widefield Wideband Full Stokes Radio Imaging

Synthesis imaging in radio astronomy is affected by instrumental and atmospheric effects which introduce direction dependent gains.The antenna power pattern varies both as a function of time and frequency. The broad band time varying nature of the antenna power pattern when not corrected leads to gross errors in full stokes imaging and flux estimation. In this poster we explore the errors that arise in image deconvolution while not accounting for the time and frequency dependence of the antenna power pattern. Simulations were conducted with the wideband full stokes power pattern of the Very Large Array(VLA) antennas to demonstrate the level of errors arising from direction-dependent gains. Our estimate is that these errors will be significant in wide-band full-pol mosaic imaging as well and algorithms to correct these errors will be crucial for many up-coming large area surveys (e.g. VLASS)

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336.32 – Galactic Science with the Very Large Array Sky Survey

The Very Large Array Sky Survey (VLASS) is a proposed survey of the northern sky with the VLA at a wavelength of 10 cm (3 GHz). The VLASS is structured to combine comprehensive all-sky coverage with deeper coverage in carefully identified parts of the sky, including the Galactic plane, with a multi-epoch approach that enables time-domain science. We describe key Galactic science topics which motivate the design of the survey: informing the physics of stars, investigating the interplay of stars with their surroundings, and constraining fundamental physics with exotic pulsars. The VLASS exploits the VLA's capability to achieve arc second resolution, with a notional angular resolution of better than 2". This angular resolution will allow the both the multi-wavelength identification and followup of sources as well as the detection of any transients that might be Galactic in nature.

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336.33 – Monitoring the Low Frequency Sky with the LWA1 and the Prototype All-Sky Imager

We present findings from the Prototype All-Sky Imager (PASI), a backend correlator of the first station of the Long Wavelength Array (LWA1). PASI cross-correlates a live stream of all 260 dual-polarization dipole antennas of the LWA1, creates all-sky images, and uploads them to the LWA-TV website in near real-time. PASI has recorded over 14,000 hours of all-sky images at frequencies between 10 and 88 MHz. These data have resulted in the discovery of radio emission from large meteors (Fireballs), and has been used to set improved limits on slow transients at 38, 52, and 74 MHz. PASI is also being used to characterize how the ionosphere affects low frequency transient astronomy. Construction of the LWA has been supported by the Office of Naval Research under Contract N00014-07-C-0147. Support for operations and continuing development of the LWA1 is provided by the National Science Foundation under grants AST-1139963 and AST-1139974 of the University Radio Observatory program.

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336.34 – A Pipeline for High Resolution Radio Images

The VLBA Calibrator Survey (VCS) is a database of ~2200 extragalactic radio sources evenly distributed on the sky between declinations of -40 and +90 degrees. In addition to providing a list of potential phase and bandpass calibrators for science observations, the very high astrometric accuracy of the VCS has also proven enormously useful in establishing and refining the International Celestial Reference Frame (ICRF). Using the VLBA at 2.3 and 8.4 GHz, we have recently begun a new epoch of snapshot observations of ~2400 compact VCS sources. Here, we present the preliminary results of a project, conducted with the Common Astronomy Software Applications package (CASA), to design and implement an imaging pipeline for these observations . This pipeline provides images of the sources that are useful for determining their quality as VLBA calibrators and for potentially revealing details that might make them scientifically interesting in their own right. As the observations of this survey are still in progress, we present preliminary images of a few of the sources that have been observed thus far. When completed, these observations will allow significant improvements in the next generation ICRF.

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Contributing team(s): The VCS Team

336.35 – ADMIT: ALMA Data Mining Toolkit

ADMIT (ALMA Data Mining Toolkit) is a toolkit for the creation and analysis of new science products from ALMA data. ADMIT is an ALMA Development Project written purely in Python. While specifically targeted for ALMA science and production use after the ALMA pipeline, it is designed to be generally applicable to radio-astronomical data. ADMIT quickly provides users with a detailed overview of their science products: line identifications, line 'cutout' cubes, moment maps, emission type analysis (e.g., feature detection), etc. Users can download the small ADMIT pipeline product (< 20MB), analyze the results, then fine-tune and re-run the ADMIT pipeline (or any part thereof) on their own machines and interactively inspect the results. ADMIT will have both a GUI and command line interface available for this purpose. By analyzing multiple data cubes simultaneously, data mining between many astronomical sources and line transitions will be possible. Users will also be able to enhance the capabilities of ADMIT by creating customized ADMIT tasks satisfying any special processing needs. Future implementations of ADMIT may include EVLA and other instruments.

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336.36 – Overview of the SOFIA Data Processing System: A generalized system for manual and automatic data processing at the SOFIA Science Center

The Stratospheric Observatory for Infrared Astronomy (SOFIA) is an airborne astronomical observatory comprised of a 2.5-meter telescope mounted in the aft section of a Boeing 747SP aircraft. SOFIA is designed to execute observations at altitudes between 37,000 and 45,00 feet, above 99% of atmospheric water vapor. During routine operations, several instruments will be available to the astronomical community including cameras and spectrographs in the near- to far-IR. Raw data obtained in-flight require a significant amount of processing to correct for background emission (from both the telescope and atmosphere), remove instrumental artifacts, correct for atmospheric absorption, and apply both wavelength and flux calibration. In general, this processing is highly specific to the instrument and telescope. Once this post-processing is complete, the data can be used in scientific analysis and publications. In order to maximize the scientific output of the observatory, the SOFIA Science Center must provide these post-processed data sets to Guest Investigators in a timely manner. To meet this requirement, we have designed and built the SOFIA Data Processing System (DPS): an in-house set of tools and services that can be used in both automatic ("pipeline") and manual modes to process data from a variety of instruments. In this poster paper, we present an overview of the DPS concepts and architecture, as well as operational results from the first two SOFIA observing cycles (2013--2014).

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336.37 – A Prototype External Event Broker for LSST

LSST plans to have an alerts system that will automatically identify various types of "events" appearing in the LSST data stream. These events will include things such as supernovae, moving objects, and many other types, and it is expected that there will be millions of events nightly. It is expected that there may be tens of millions of events each night. To help the LSST community parse and make full advantage of the LSST alerts stream, we are working to design an external "events alert broker" that will generate real-time notification of LSST events to users and/or robotic telescope facilities based on user-specified criteria. For example, users will be able to specify that they wish to be notified immediately via text message of urgent events, such as GRB counterparts, or notified only occasionally in digest form of less time-sensitive events, such as eclipsing binaries. This poster will summarize results from a survey of scientists for the most important features that such an alerts notification service needs to provide, and will present a preliminary design for our external event broker.

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336.38 – LSST Site: Sky Brightness Data

The Large Synoptic Survey Telescope (LSST) is an upcoming robotic survey telescope. At the telescope site on Cerro Pachon in Chile there are currently three photodiodes and a Canon camera with a fisheye lens, and both the photodiodes and Canon monitor the night sky continuously. The NIST-calibrated photodiodes directly measure the flux from the sky, and the sky brightness can also be obtained from the Canon images via digital aperture photometry.

Organizing and combining the two data sets gives nightly information of the development of sky brightness across a swath of the electromagnetic spectrum, from blue to near infrared light, and this is useful for accurately predicting the performance of the LSST. It also provides data for models of moonlight and twilight sky brightness. Code to accomplish this organization and combination was successfully written in Python, but due to the backlog of data not all of the nights were processed by the end of the summer.

Burke was supported by the NOAO/KPNO Research Experiences for Undergraduates (REU) Program which is funded by the National Science Foundation Research Experiences for Undergraduates Program (AST-1262829).

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336.39 – Simulating Optical Surveys with the LSST Software Stack

In preparation for construction, the LSST Image Simulation group has developed a series of software packages that are capable of taking a catalog of objects (literally a list of RA, Dec, spectral energy densities, and profile shapes), simulating realistic images accounting for atmospheric and telescope effects, and finally performing object detection on those simulated images. We present here a basic illustration of this process along with instructions for generalizing this process to simulate any optical survey.

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Contributing team(s): LSST Image Simulation Team

336.40 – The LSST Metrics Analysis Framework (MAF)

Studying potential observing strategies or cadences for the Large Synoptic Survey Telescope (LSST) is a complicated but important problem. To address this, LSST has created an Operations Simulator (OpSim) to create simulated surveys, including realistic weather and sky conditions. Analyzing the results of these simulated surveys for the wide variety of science cases to be considered for LSST is, however, difficult. We have created a Metric Analysis Framework (MAF), an open-source python framework, to be a user-friendly, customizable and easily extensible tool to help analyze the outputs of the OpSim.
MAF reads the pointing history of the LSST generated by the OpSim, then enables the subdivision of these pointings based on position on the sky (RA/Dec, etc.) or the characteristics of the observations (e.g. airmass or sky brightness) and a calculation of how well these observations meet a specified science objective (or metric). An example simple metric could be the mean single visit limiting magnitude for each position in the sky; a more complex metric might be the expected astrometric precision. The output of these metrics can be generated for a full survey, for specified time intervals, or for regions of the sky, and can be easily visualized using a web interface.
An important goal for MAF is to facilitate analysis of the OpSim outputs for a wide variety of science cases. A user can often write a new metric to evaluate OpSim for new science goals in less than a day once they are familiar with the framework. Some of these new metrics are illustrated in the accompanying poster, "Analyzing Simulated LSST Survey Performance With MAF".
While MAF has been developed primarily for application to OpSim outputs, it can be applied to any dataset. The most obvious examples are examining pointing histories of other survey projects or telescopes, such as CFHT.

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336.41 – Analyzing Simulated LSST Surveys With MAF

The LSST will make around 2.5 million observations in 6 filters over a 10-year survey. Optimizing the scheduling of these observations involves a variety of scientific trade-offs. We illustrate the wide variety of survey metrics that can be designed and implemented with the Metrics Analysis Framework using simulated LSST surveys. In particular, we illustrate how MAF can (1) be used to compare dithering strategies, (2) quantify how well the observing cadence allows for the characterization of periodic sources, and (3) quantify how efficiently the survey discovers solar system objects. There is nothing LSST-specific about MAF, and we show how it can be easily extended to analyze other surveys such as Stripe 82 in SDSS.

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336.42 – Building POCS: An open source observatory control system for amateur telescopes used by the PANOPTES project for the detection of extrasolar planets

The Panoptic Astronomical Networked OPtical observatory for Transiting Exoplanets Survey (PANOPTES, www.projectpanoptes.org) project is a citizen science project consisting of a wide network of low-cost imaging units built using commerically available products and working toward the identification of transiting exoplanets. The PANOPTES Observatory Control System (POCS) is a an open source software system designed to act as the control mechanism for the operation of the unit. POCS defines an Observatory class that is responsible for automated control of a commercially available equatorial mount, including image analysis and corresponding mount adjustment to obtain a percent-level photometric precision. Also responsible for controlling the two digital cameras and the archiving of 5 GB of nightly data, the Observatory class works via a state machine and in conjuction with a configurable target object scheduler, local environmental monitoring, and an inter-task messaging system for total hardware and software control. POCS is written in modern python and attempts to adhere to best practices within the astropy and scipy communities. An overview of the system is presented, along with key technical challenges and design considerations due to the open source and citizen science oriented aspect of PANOPTES.

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Contributing team(s): PANOPTES Team

336.43 – Adaptive Optics Images of the Galactic Center: Using Empirical Noise-maps to Optimize Image Analysis

Adaptive Optics images are one of the most important tools in studying our Galactic Center. In-depth knowledge of the noise characteristics is crucial to optimally analyze this data. Empirical noise estimates - often represented by a constant value for the entire image - can be greatly improved by computing the local detector properties and photon noise contributions pixel by pixel. To comprehensively determine the noise, we create a noise model for each image using the three main contributors—photon noise of stellar sources, sky noise, and dark noise. We propagate the uncertainties through all reduction steps and analyze the resulting map using Starfinder. The estimation of local noise properties helps to eliminate fake detections while improving the detection limit of fainter sources. We predict that a rigorous understanding of noise allows a more robust investigation of the stellar dynamics in the center of our Galaxy.

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336.44 – Recovering Astrophysical Signals Lost in Noise: Light Curves of Background Objects in Kepler Data

The NASA Kepler mission was designed to discover transiting extrasolar planets, but its observations of ~160,000 stars can be used for a wide variety of science investigations. Kepler's high photometric precision and long-baseline observing strategy provide opportunities for studying many types of astrophysical phenomena, ranging from red giants to intrinsic variables and multiple stellar systems. We examine observed targets in the Kepler data set, performing pixel-level data analysis and custom aperture photometry to identify contaminating astrophysical sources. We seek to determine whether variability identified in the released Kepler light curves is a result of true variation in the target stars (i.e. eclipsing binaries, pulsating variables, etc.) or if the photometric signals have been contaminated by the presence of background astrophysical sources. To do this, we are developing a customized suite of Python routines to perform photometry, differential image analysis, visualization, and data reduction. As a proof-of-concept for our software, we demonstrate that we can distinguish between target stars and background contaminants for many types of objects, such as RR Lyr, gamma Dor, EBs, delta Sct, and W UMa types and starspots.

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336.45 – An Exploration Tool for Very Large Spectrum Data Sets

We present an exploration tool for very large spectrum data sets such as the SDSS, LAMOST, and 4MOST data sets. The tool works in two stages: the first uses batch processing and the second runs interactively. The latter employs the NASA hyperwall, a configuration of 128 workstation displays (8x16 array) controlled by a parallelized software suite running on NASA's Pleiades supercomputer. The stellar subset of the Sloan Digital Sky Survey DR10 was chosen to show how the tool may be used. In stage one, SDSS files for 569,738 stars are processed through our data pipeline. The pipeline fits each spectrum using an iterative continuum algorithm, distinguishing emission from absorption and handling molecular absorption bands correctly. It then measures 1659 discrete atomic and molecular spectral features that were carefully preselected based on their likelihood of being visible at some spectral type. The depths relative to the local continuum at each feature wavelength are determined for each spectrum: these depths, the local S/N level, and DR10-supplied variables such as magnitudes, colors, positions, and radial velocities are the basic measured quantities used on the hyperwall. In stage two, each hyperwall panel is used to display a 2-D scatter plot showing the depth of feature A *vs* the depth of feature B for all of the stars. A and B change from panel to panel. The relationships between the various (A,B) strengths and any distinctive clustering are immediately apparent when examining and inter-comparing the different panels on the hyperwall. The interactive software allows the user to select the stars in any interesting region of any 2-D plot on the hyperwall, immediately rendering the same stars on all the other 2-D plots in a unique color. The process may be repeated multiple times, each selection displaying a distinctive color on all the plots. At any time, the spectra of the selected stars may be examined in detail on a connected workstation display. We illustrate how our approach allows us to quickly isolate and examine such interesting stellar subsets as EMP stars, CV stars and C-rich stars.

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336.46 – Understanding and Using the Fermi Science Tools

The Fermi Science Support Center (FSSC) provides information, documentation, and tools for the analysis of Fermi science data, including both the Large-Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). Source and binary versions of the Fermi Science Tools can be downloaded from the FSSC website, and are supported on multiple platforms. An overview document, the *Cicerone*, provides details of the Fermi mission, the science instruments and their response functions, the science data preparation and analysis process, and interpretation of the results. *Analysis Threads* provide the user with step-by-step instructions for many different types of data analysis: point source analysis - generating maps, spectra, and light curves, pulsar timing analysis, source identification, and the use of python for scripting customized analysis chains. The *reference manual* gives details of the options available for each tool. We present an overview of the structure of the Fermi science tools and documentation, and how to acquire them. We also provide information on recent updates incorporated in the Science Tools as well as upcoming changes that will be included in the upcoming release of the Science Tools in early 2015.

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Contributing team(s): Fermi Science Support Center

336.47 – Fact Checking LIGO's Radiometer Code with Simulated LIGO Data.

Gravitational waves are predicted by various models, ranging from cosmological sources to astrophysical objects. One example of an astrophysical source is a neutron star in a binary system. The strongest example of this is from Scorpios X-1. A key set of instruments that are used to search for gravitational waves are the LIGO detectors. As the signal strength is expected to be small relative to the background noise from a single LIGO detector, data from two detectors are cross-correlated to increase sensitivity to any potential gravitational waves. In order to test the effectiveness of the cross-correlation 'radiometer' code in detecting point sources similar to Scorpius X-1, the code was modified to have the capability to add multiple simulated pulsar signals. To validate the changes to the radiometer code, two trials were run. The first trial compared results from simulated data read in through previously existing means with simulated data read in through the modified code. The second trial read in realistic LIGO data through the traditional means and explored the effects of adding simulated data via the modified code. Once the modified code has completed its vetting, it will be used to ascertain how well injected signals can be recovered when they fall on the border between frequency bins. After running multiple trials with different frequency shifts, the amount of attenuation found for each bin shift agrees with theory, and it was found that the bin shifting does have the ability to completely attenuate signals at higher frequencies.

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336.48 – AstroML: "better, faster, cheaper" towards state-of-the-art data mining and machine learning

We present AstroML, a Python module for machine learning and data mining built on numpy, scipy, scikit-learn, matplotlib, and astropy, and distributed under an open license. AstroML contains a growing library of statistical and machine learning routines for analyzing astronomical data in Python, loaders for several open astronomical datasets (such as SDSS and other recent major surveys), and a large suite of examples of analyzing and visualizing astronomical datasets. AstroML is especially suitable for introducing undergraduate students to numerical research projects and for graduate students to rapidly undertake cutting-edge research. The long-term goal of astroML is to provide a community repository for fast Python implementations of common tools and routines used for statistical data analysis in astronomy and astrophysics (see http://www.astroml.org).

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336.49 – Bayesian Identification of Emission–Line Galaxies with Photometric Equivalent Widths

We present a Bayesian approach to the classification of emission-line galaxies as an alternative to the traditional limit of requiring Lyman-alpha emitting (LAE) galaxies to have rest-frame equivalent width (EW) > 20 Angstroms. The Bayesian method relies on known distributions of line luminosities and equivalent widths as prior probabilities and returns the probability that an object is an LAE given the observed characteristics. This will be directly relevant for the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX), which seeks to classify more than a million emission-line galaxies into LAEs and low-redshift [O II] emitters. For a simulated HETDEX catalog with realistic measurement noise, the Bayesian method recovers a majority of the LAEs missed by the EW > 20 Angstroms cutoff over $2 < z < 3$. The method is robust, performing at least as well as the EW > 20 Angstroms cut in contamination (false positives) and incompleteness (false negatives). Trade-off between contamination and incompleteness can be achieved by adjusting the stringency of the probability requirement for classifying an observed object as an LAE. A basic implementation of the Bayesian reduces errors in cosmological parameters by ~22%, which is equivalent to obtaining ~40% more data. The inclusion of the color of the galaxies, contingent on the availability of this information, increases the discriminating power of Bayesian separation and results in further reductions in errors. The Bayesian method is also being used to determine which single broadband filter produces the best performance. This method would enable large-scale structure analyses to be performed directly on emission-line objects labeled with probabilities of being LAEs rather than splitting the sample into LAEs and [O II] emitters.
We gratefully acknowledge support from NSF through grant AST-1055919.
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Contributing team(s): HETDEX Collaboration

336.50 – Statistical Computing for Galaxy Modeling and Residual Detection

We have developed a strong gravitational lens detection technique by first using Markov Chain Monte Carlo (MCMC) techniques to model the light profile of the lensing galaxy with a mixture of gaussians (MOG), and second to inspect the model deviations for potential lens candidates. Strong gravitational lenses are interesting cosmological laboratories, but too few are known to enable precise cosmological constraints. In fact, many of the known lenses have been found serendipitously. Improved, systematic lens detection techniques will lead to more opportunities for investigations of general relativity, dark matter, and dark energy. If the lensing galaxy is of a moderate mass, the background source will be blended with the lensing galaxy light, making detection difficult. By modeling the light profile of the lensing galaxy and subtracting the model light, gravitational lenses can be identified by examining residuals. Several modeling approaches, such as Sersic functions, have been developed to quantify galaxy light profiles; most of these, however, are computationally inefficient. A MOG provides an accurate, rapid approximation to these more formal models. Meanwhile, MCMC algorithms efficiently calculate the likelihood over the entire model parameter space, which allows for more informed model selection compared to standard techniques. Following these improvements, we have developed a modeling pipeline that calculates the most probable MOG model by using MCMC. We have tested this new pipeline against approximately one thousand simulated strong lens images. The procedure is successful at modeling the galaxy light and identifying lenses among the residuals. With acceleration, this technique shows promise as a means to systematically search for strong lenses en masse, and could also be adopted into a formal survey pipeline.
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336.51 – Separating Stars and Galaxies Probabilistically Based on Color

Using photometric data from the Deep Lens Survey (DLS) we develop a star-galaxy separation algorithm based on objects' colors in six bands (B,V,R,z,J,K). Using a training set selected from a catalog of stars classified via their DLS shapes, we fit a third order polynomial to the filtered color-color data to approximate the stellar locus. Our algorithm produces a weighted probability of an object being a star. Based on each object's distance from the stellar locus in color-color space, we fit the resulting histogram as the sum of two Gaussians. We find that near-infrared information (J and K) provide the best separation, but explore using optical information alone to determine the classification as well. Our results demonstrate that the use of color information in a probabilistic algorithm has the potential to dramatically improve star-galaxy classification when used in conjunction with existing shape-based algorithms.
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336.52 – Visualizing SPH Cataclysmic Variable Accretion Disk Simulations with Blender

We present innovative ways to use Blender, a 3D graphics package, to visualize smoothed particle hydrodynamics particle data of cataclysmic variable accretion disks. We focus on the methods of shape key data constructs to increase data i/o and manipulation speed. The implementation of the methods outlined allow for compositing of the various visualization layers into a final animation. The viewing of the disk in 3D from different angles can allow for a visual

analysis
of the physical system and orbits. The techniques have a wide ranging set of applications in astronomical visualization, including both observation and theoretical data.

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336.53 – Computer analysis of digital sky surveys using citizen science and manual classification

As current and future digital sky surveys such as SDSS, LSST, DES, Pan-STARRS and Gaia create increasingly massive databases containing millions of galaxies, there is a growing need to be able to efficiently analyze these data. An effective way to do this is through manual analysis, however, this may be insufficient considering the extremely vast pipelines of astronomical images generated by the present and future surveys. Some efforts have been made to use citizen science to classify galaxies by their morphology on a larger scale than individual or small groups of scientists can. While these citizen science efforts such as Zooniverse have helped obtain reasonably accurate morphological information about large numbers of galaxies, they cannot scale to provide complete analysis of billions of galaxy images that will be collected by future ventures such as LSST. Since current forms of manual classification cannot scale to the masses of data collected by digital sky surveys, it is clear that in order to keep up with the growing databases some form of automation of the data analysis will be required, and will work either independently or in combination with human analysis such as citizen science. Here we describe a computer vision method that can automatically analyze galaxy images and deduce galaxy morphology. Experiments using Galaxy Zoo 2 data show that the performance of the method increases as the degree of agreement between the citizen scientists gets higher, providing a cleaner dataset. For several morphological features, such as the spirality of the galaxy, the algorithm agreed with the citizen scientists on around 95% of the samples. However, the method failed to analyze some of the morphological features such as the number of spiral arms, and provided accuracy of just ~36%.

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336.54 – Report of the Committee on the Participation of Women in the Sloan Digital Sky Survey

The Committee on the Participation of Women in the SDSS (CPWS) was formed by the SDSS to evaluate the gender climate within the collaboration. The CPWS seeks to foster gender balance in our collaboration by fielding concerns from our members and by recommending best practices for establishing the SDSS leadership team. An important aspect of the mission of the CPWS is to regularly assess gender diversity and inclusiveness within the SDSS. Against the backdrop of the transition from SDSS-III to SDSS-IV, the CPWS has been collecting data relevant to gender issues through interviews and surveys. In April, 2014, the CPWS surveyed 251 SDSS-IV members (~50% of active membership) regarding gender and leadership. Broad findings from this survey include that the male-to-female ratio in SDSS-IV is about 3:1 and that the male-to-female ratio among those that identify themselves as being in an SDSS-IV leadership role is also close to 3:1. About 35% of those surveyed self-identify as an SDSS-IV "leader," though we recognize the possibility that active stakeholders might be more likely to respond to a demographics survey. About 80% of those that self-identify as leaders consider their leadership role within SDSS-IV to be officially acknowledged, regardless of gender. The fraction of women in SDSS leadership roles appears to be a weak function of current job position in that 6 of 32 (19%) senior faculty that are SDSS leaders are women, compared to 4 of 13 (31%) postdocs. Similarly, the fraction of SDSS leaders who are women is highest (32%) amongst those leaders who received their PhDs 6-10 years ago, while the fraction of female leaders amongst other age demographics is somewhat lower (20%). Although these are small sample sizes, this hints at a trend where women are most likely to fill SDSS leadership roles at certain stages of their lives and careers. The CPWS intends to use this initial survey data to establish a baseline for tracking SDSS-IV demographics, and thus hopes to identify and maximize leadership opportunities for all SDSS-IV researchers.

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Contributing team(s): The SDSS-III Collaboration, The SDSS-IV Collaboration

336.55 – Improved Functionality and Curation Support in the ADS

In this poster we describe the developments of the new ADS platform over the past year, focusing on the functionality which improves its discovery and curation capabilities.
The ADS Application Programming Interface (API) is being updated to support authenticated access to the entire suite of ADS services, in addition to the search functionality itself. This allows programmatic access to resources which are specific to a user or class of users.
A new interface, built directly on top of the API, now provides a more intuitive search experience and takes into account the best practices in web usability and responsive design. The interface now incorporates in-line views of graphics from

the AAS Astroexplorer and the ADS All-Sky Survey image collections.
The ADS Private Libraries, first introduced over 10 years ago, are now being enhanced to allow the bookmarking, tagging and annotation of records of interest. In addition, libraries can be shared with one or more ADS users, providing an easy way to collaborate in the curation of lists of papers. A library can also be explicitly made public and shared at large via the publishing of its URL.
In collaboration with the AAS, the ADS plans to support the adoption of ORCID identifiers by implementing a plugin which will simplify the import of papers in ORCID via a query to the ADS API. Deeper integration between the two systems will depend on available resources and feedback from the community.

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336.56 – Online Activity Around Scholarly Astronomy Literature - A Discussion of Altmetrics

So, your research is mentioned or gets discussed in social media, in blogs and other online channels. Do you care? Should you care? Will this exposure result in better science? Researchers probably should care, and most likely policy makers already care, because it matters how research, funded by them, is being portrayed in society. We have pretty solid ideas about how to quantify the impact of research on itself. This has been studied for decades in the fields of informetrics, bibliometrics and scientometrics. But how do you quantify the societal impact of research? You will need to assume that this impact can be measured in principle, and that is possible to come up with a recipe that quantifies this impact. Assuming that there is a societal impact seems quite reasonable for most disciplines in science. It is definitely true for parts of astronomy and physics. Just think of the attention given to the LHC or to the hunt for exoplanets. Enter the concept of "alternative metrics", or "altmetrics". As a result of the growing interest in altmetrics, various services (like the websites impactstory.org and altmetric.com) claim to have found a way to quantify the societal impact of research, either in a person-centric or publication-centric way. On this poster we explore, using data provided by altmetric.com, how astronomy fits in this altmetrics picture. How do popular science articles compare to those in the core astronomy journals? Is there any correlation between the altmetric measure and indicators like downloads, reads or citations? We briefly discuss the benefits that altmetrics might offer and the pitfalls involved in quantifying such measures.

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336.57 – Astrophysics Source Code Library -- Now even better!

The Astrophysics Source Code Library (ASCL, ascl.net) is a free online registry of codes used in astronomy research. Indexed by ADS, it now contains nearly 1,000 codes and with recent major changes, is better than ever! The resource has a new infrastructure that offers greater flexibility and functionality for users, including an easier submission process, better browsing, one-click author search, and an RSS feeder for news. The new database structure is easier to maintain and offers new possibilities for collaboration. Come see what we've done!

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336.59 – Beyond The Prime Directive: The MAST Discovery Portal and High Level Science Products

The Mikulski Archive for Space Telescopes (MAST) is a NASA-funded archive for a wide range of astronomical missions, primarily supporting space-based UV and optical telescopes. What is less well-known is that MAST provides much more than just a final resting place for primary data products and documentation from these missions. The MAST Discovery Portal is our new search interface that integrates all the missions that MAST supports into a single interface, allowing users to discover (and retrieve) data from other missions that overlap with your targets of interest. In addition to searching MAST, the Portal allows users to search the Virtual Observatory, granting access to data from thousands of collections registered with the VO, including large missions spanning the electromagnetic spectrum (e.g., Chandra, SDSS, Spitzer, 2MASS, WISE). The Portal features table import/export, coordinate-based cross-matching, dynamic chart plotting, and the AstroView sky viewer with footprint overlays. We highlight some of these capabilities with science-driven examples. MAST also accepts High Level Science Products (HLSPs) from the community. These HLSPs are user-generated data products that can be related to a MAST-supported mission. MAST provides a permanent archive for these data with linked references, and integrates it within MAST infrastructure and services. We highlight some of the most recent HLSPs MAST has released, including the HST Frontier Fields, GALEX All-Sky Diffuse Radiation Mapping, a survey of the intergalactic medium with HST-COS, and one of the most complete line lists ever derived for a white dwarf using FUSE AND HST-STIS. These HLSPs generate substantial interest from the community, and are an excellent way to increase visibility and ensure the longevity of your data.

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336.60 – IRSA's New Look: Design Considerations

The NASA/IPAC Infrared Science Archive undertook a major upgrade to its website and user experience this year. The work was motivated by the need to facilitate access to a growing number of astronomical data sets and exploration tools. The guiding principle of the redesign was to focus on the most important items, while providing easy access to the full set of IRSA's holdings and services. We discuss the redesign process and the key features of the new website.

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336.61 – The Science Content and Usage of the the Keck Observatory Archive

The Keck Observatory Archive (KOA) (https://koa.ipac.caltech.edu) now curates raw ("level 0") data from all eight active instruments and two decommissioned instruments. These data comprise all observations acquired since the commissioning of each instrument, going back to 1994 in some cases. The archive contains over 35 TB of data, including 2.5 million raw science and calibration files. KOA serves reduced ("level 1") browse products for four instruments, generated by adapting and automating existing data reduction packages and algorithms. A major effort for KOA will be to develop similar, automated pipelines for all instruments. Under the terms of a data access policy that guarantees PIs exclusive access to their data for at least 18 months, nearly 70% of the data are now public. The archive has received 1.3 million queries since opening to the public in 2006, with 15 TB of data downloads. To date, a total of 69 papers have cited KOA, including studies of the atmospheres of exoplanets and the composition of the extragalactic medium. The latest version of the "makee" pipeline reduction package, underwritten by KOA to support an upgrade to the HIRES spectrograph, has received over 100 citations in the literature.

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Contributing team(s): KOA Team

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337 – Instrumentation: Ground Based or Airborne Posters

337.01 – Spectroscopic Capability of a New 17--27 GHz Dual-Horn Receiver on the NASA 70 m Canberra Antenna

A new dual beam, dual polarization, low noise receiver has been installed on the NASA 70-m antenna near Canberra, Australia. It operates in either of two 2-GHz wide bands centered at 22 and 24 GHz. A similar receiver covering five 2-GHz bands from 17 to 27 GHz *simultaneously* has been built and tested at Caltech and will be installed in March 2015. Currently, four ROACH signal processors each provide 32K channel spectra across four 1000 MHz bands, for 0.4 km/s velocity resolution at 22 GHz. In the 23-25 GHz band, the following 16 spectral lines were observed simultaneously in Orion KL: **NH3** 1^1, 2^2, 3^3, 4^4, 5^5; **CH^{3}OH** $2^{2,0}$-$2^{1,1}$ E, $3^{2,1}$-$3^{1,2}$ E, $4^{2,2}$-$4^{1,3}$ E, $5^{2,3}$-$5^{1,4}$ E, $10^{1,9}$-$9^{2,8}$ A, $9^{2,7}$-$10^{1,10}$ A;and **recombination lines** H64α, H65α, H81$^{\beta}$, H83$^{\beta}$ and H93γ.
The receiver temperature measured at the feed is 21-22K at 22 GHz and under good conditions, the system temperature at zenith is as low as 42K in the 21-22 GHz band. The native polarization is linear but can be converted to circular. The downconverters have complex mixers, followed by quadrature hybrids which can convert the quadrature phase channels into an upper and lower sideband, each 1000 MHz wide. In double Dicke mode test the receiver achieved a noise level of 7 mK r.m.s. in 30 minutes of integration and 31 kHz resolution.
The NASA 70-m antennas have a 45” beamwidth at 22 GHz and an aperture efficiency of 50% giving a sensitivity of 0.7 K/Jy. This new system on the NASA 70 m antenna is a powerful complement to ALMA for sources in the southern hemisphere. The telescope is available to guest observers through proposals submitted to ATNF or JPL.

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Institution(s): *1. Caltech, 2. Caltech-JPL, 3. CSIRO-CDSCC, 4. Harvard-Smithsonian CfA, 5. NYU Abu Dhabi*

337.02 – Flux density calibration of compact low frequency aperture arrays

New large-N dipole aperture arrays like the first station of the Long Wavelength Array (LWA1) with 256 cross-dipole elements pose particular challenges especially for calibration and imaging. In the context of astronomical flux density calibration we have developed new tools to facilitate the day-to-day operation, calibration, and imaging of cross-correlated data from this array. Here we present results from our ongoing astronomical flux density monitoring campaigns below 100 MHz that have been running for over a year now. These observations are used to determine the Cygnus A/Cassiopeia A flux density ratio and decay rate, as well as provide a baseline and reference points for the calibration of regular science observations performed with LWA1. We showcase a newly developed GPU-based simulation code that allows the calculation of sensitivities for beam-formed data of LWA1. With an updated global sky model below 100 MHz we are now able to provide absolute flux density calibration for the total power measured by the beam-former despite significant levels of primary beam confusion, galactic diffuse emission, and other instrumental effects.

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Contributing team(s): LWA1 Collaboration

337.03 – Characterization and monitoring of Flamingos-II, a near-IR imager and spectrograph at Gemini South

We present results of the characterization and continual monitoring of the Flamingos-II instrument. Currently installed at Gemini South Observatory, Flamingos-II is a near-IR imager and longslit/multi-object spectrograph. In addition to the characterization of the detector, methodologies and results of the Science Verification pipeline, Telluric corrections, and Multi-Object Spectrograph (MOS) mask design software are presented.

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337.04 – Preliminary Design of the iLocater Acquisition Camera for the LBT

Radial velocity instruments for planet detection are limited by systematic errors that result from their seeing-limited design. iLocater, an ultra-precise spectrometer that operates at the diffraction limit, has been officially approved for installation at the Large Binocular Telescope (LBT) and will search for Earth-like planets orbiting the nearest stars. Commissioning of iLocater will coincide with the launch of the Transiting Exoplanet Surveying Satellite (TESS).

In this poster we present a preliminary design for iLocater’s acquisition camera to couple starlight from the telescope into small (single-mode) optical fibers. Our design uses the combined (incoherent) beam from both LBT dishes to reduce photon-noise limited errors to below 20 cm/s for bright stars.

We have designed and constructed a demonstration system for use with the Krizmanich 0.8-meter telescope located at the University of Notre Dame. In conjunction with laboratory testing, the system has been used to measure on-sky coupling efficiency for fibers of varying diameter and numerical aperture. This process has been used to verify the suitability of our design for the LBT.

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337.05 – Commissioning new Hamamatsu CCDs for GMOS-S

The Gemini South Multi-Object Spectrograph (GMOS-S) has been collecting science data since early 2003 with the original blue sensitive EEV CCDs. In June 2014 those detectors were replaced with red sensitive deep depletion devices manufactured by Hamamatsu Photonics. While sacrificing some sensitivity blueward of 500nm, these detectors deliver significantly improved sensitivity for wavelengths longer than 700nm, extending the useful wavelength range for GMOS-S beyond 1.03 microns. These detectors also exhibit far reduced fringing, somewhat faster readout times and slightly lower readout noise compared to the old GMOS-S CCDs. We also present the current status of plans to install the same devices in the GMOS-N instrument on Gemini North.

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337.06 – Scheduling Algorithm for the Large Synoptic Survey Telescope

The Large Synoptic Survey Telescope (LSST) is a wide-field telescope currently under construction and scheduled to be deployed in Chile by 2022 and operate for a ten-year survey. As a ground-based telescope with the largest etendue ever constructed, and the ability to take images approximately once every eighteen seconds, the LSST will be able to capture the entirety of the observable sky every few nights in six different band passes. With these remarkable features, LSST is primed to provide the scientific community with invaluable data in numerous areas of astronomy, including the observation of near-Earth asteroids, the detection of transient optical events such as supernovae, and the study of dark matter and energy through weak gravitational lensing.
In order to maximize the utility that LSST will provide toward achieving these scientific objectives, it proves necessary to develop a flexible scheduling algorithm for the telescope which both optimizes its observational efficiency and allows for adjustment based on the evolving needs of the astronomical community.
This work defines a merit function that incorporates the urgency of observing a particular field in the sky as a function of time elapsed since last observed, dynamic viewing conditions (in particular transparency and sky brightness), and a measure of scientific interest in the field. The problem of maximizing this merit function, summed across the entire observable sky, is then reduced to a classic variant of the dynamic traveling salesman problem. We introduce a new approximation technique that appears particularly well suited for this situation. We analyze its effectiveness in resolving this problem, obtaining some promising initial results.

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337.08 – The 20-20-20 Airships NASA Centennial Challenge

A NASA Centennial Challenge; (www.nasa.gov/challenges) is in development to spur innovation in stratospheric airships as a science platform. We anticipate a multi-million dollar class prize for the first organization to fly a powered airship that remains stationary at 20km (65,000 ft) altitude for over 20 hours with a 20kg payload. The design must be scalable to longer flights with more massive payloads.
In NASA's constrained budget environment, there are few opportunities for space missions in astronomy and Earth science, and these have very long lead times. We believe that *airships* (powered, maneuverable, lighter-than-air vehicles) could offer significant gains in observing time, sky and ground coverage, data downlink capability, and continuity of observations over existing suborbital options at competitive prices. This technology would also have broad commercial applications including communications and asset tracking. We seek to spur private industry (or non-profit institutions, including Universities) to demonstrate the capability for sustained airship flights as astronomy and Earth science platforms. This poster will introduce the challenge in development and provide details of who to contact for more information.

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337.09 – Photometric commissioning results from MINERVA

MINERVA is a robotic observatory with four 0.7 meter telescopes at Mt. Hopkins, Arizona, dedicated to precise photometry and radial velocity observations of bright, nearby stars for the discovery and characterization of small exoplanets. Here we present the first photometric results from MINERVA during commissioning at our test facility in Pasadena, California, demonstrating sub-millimag precision on 3-5 minute timescales over several hours. These results show that MINERVA is well-equipped to address its secondary science goal of searching for transits of known and newly discovered super-Earth exoplanets detected by radial velocity, including potential detections from the MINERVA spectrograph.

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337.10 – Manhattan Solar Cannon

We describe a 2.4 m hexagonal solar collector atop a Manhattan office building used for a solar / arts project. The collector uses an afocal design to concentrate the sunlight into a 0.6 m diameter beam which is directed by mirrors into a 80 m long fiber optic sculpture which descends an interior stairwell. The collector is fully steerable and follows the sun each day robotically. The control system and the optical design of the collector as well as the fiber optic sculpture will be discussed.

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Institution(s): *1. Loisos + Ubbelohde, 2. Optical Mechanics Inc., 3. Starman Systems, LLC*

337.11 – BCK Network of Optical Telescopes

The BCK network consists of three research grade telescopes: 0.6m (B) at the Bell Observatory near Western Kentucky University (WKU), 1.3m (C) at the Crimean Astrophysical Observatory and a 1.3m (K) at Kitt Peak National Observatory. The Bell Telescope is operated remotely from WKU while the Robotically Controlled Telescope (RCT) at Kitt Peak possesses an autonomous scheduler. The BCK telescopes are distributed longitudinally over 145º and can be used to observe continuously up to 21.2 hours/day. The network will be chiefly employed to observe variable stars, blazars and unpredictable celestial events.
Because celestial objects with ground-based telescopes cannot be observed optically during the daytime, continuous ground-based astronomical observations are only possible via a network of longitudinally distributed telescopes. When the sun rises in Crimea after it sets at Bell, continuous observations are possible. This occurs for about six and ½ months per year – mid September to early April. A network is highly desirable for events that are not predictable for instance the appearance of supernovae, gamma-ray bursts, or undiscovered exoplanets
Variable stars are really only known in significant numbers to about 14 mag. But, as the magnitude increases the number of stars in any field increases very sharply, so there are many variable stars to discover at faint magnitude (m > 14). Discovering new variables makes great undergraduate student projects, a major component of astronomical research at WKU. In addition, pinning down the periods of variable stars is greatly facilitated with a network of telescopes.
The BCK telescope network will also be used for monitoring the optical variability of blazars. The network provides increased coverage on daily variability timescales by minimizing interruptions due to weather and or mechanical problems at any one observatory and is used for obtaining continuous (12+ hours) of observations of rapid variability in blazars which would not be possible with any individual observatory.

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337.12 – CHARIS Construction Status, Design, and Future Science

Princeton University is funded by the National Astronomical Observatory of Japan to build an integral field spectrograph (IFS) dubbed the Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS). CHARIS is part of the ongoing exoplanet science effort at the Subaru Telescope, and will serve as the science imager for the Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) and AO188 systems. The principal science goals are disk imaging and high contrast spectra of brown dwarfs and hot Jovian planets across J, H, and K bands. SCExAO is a coronagraphic and wavefront control system that will be capable of extreme adaptive optics and quasi-static speckle suppression. Speckle suppression is meant to reduce the residual speckle to a level that makes it possible to detect planets at very low inner working angles (~80 mas). Even so, CHARIS must mitigate spectral contamination from the residual speckle halo due to crosstalk between the closely packed spectra of the image. CHARIS mitigates crosstalk via an array of field stops behind the lenslet array and carefully toleranced relay optics. This reduces uncertainty in the measured spectrum of the exoplanets by increasing robustness of the spectrograph to nearby bright speckles. Mitigating crosstalk in hardware both improves science and reduces computational overhead. Combined with a detailed wavefront budget this improves the utility of CHARIS in the speckle control loop. Another defining feature of CHARIS is its disperser design. In addition to imaging in individual J, H, and K bands, CHARIS has a fourth mode that images across all three simultaneously. This required an improvement in the linearity of dispersion from 1.15 to 2.38 microns. To do so the CHARIS project has chosen a new high-index dispersing material and characterized its properties at cryogenic temperatures. We present the build status of the spectrograph, including status and viability of operating an H2RG detector directly using a SAM card via gigabit Ethernet over Linux. In addition to the stated and as-built specifications of the instrument hardware, we discuss the future of science impacts of CHARIS at the Subaru telescope.

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337.13 – Progress on the Low Frequency All Sky Monitor

The Low Frequency All Sky Monitor (LoFASM) is a system of geographically separated radio arrays dedicated to the study of radio transients. LoFASM consists of four stations, each comprised of 12 cross-dipole antennas designed to operate between 10-88MHz. The antennas and front end electronics for LoFASM were designed by the Naval Research Laboratory for the Long Wavelength Array (LWA) project (cf. Hicks et al. PASP 124, 1090 (2012)). All four stations are currently operational and in the commissioning stage . Over the last 3 years, undergraduate and graduate students from the University of Texas at Brownsville's Center for Advanced Radio Astronomy have been establishing these stations around the continental US, consisting of sites located in Port Mansfield, Texas, the LWA North Arm site of the LWA1 Radio Observatory in New Mexico, adjacent to the North Arm of the Very Large Array, the Green Bank Radio Observatory, West Virginia, and the Goldstone Deep Space Communications Complex, California. In combination with the establishment of these sites was the development of the analog hardware, which consists of custom RF splitter/combiners and a custom amplifier and filter chain designed at Center for Advanced Radio Astronomy (CARA). This poster will expound on progress in site installation and the development of the analog signal chain, specifically the redesigned analog receiving system.

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Contributing team(s): Center for Advanced Radio Astronomy, University of Texas at Brownsville, University of New Mexico, Naval Research Laboratory, Jet Propulsion Laborator

337.14 – Low Frequency All Sky Monitor Data, A First Look

The Low Frequency All Sky Monitor (LoFASM) is a distributed array of dipole antennas that are sensitive to radio frequencies from 10 to 88 MHz. LoFASM consists of antennas and front end electronics that were originally developed for the Long Wavelength Array by the U.S. Naval Research Lab, the University of New Mexico, Virginia Tech, and the Jet Propulsion Laboratory. LoFASM, funded by the U.S. Department of Defense, consists of 4 individual stations, each consisting of 12 dual-polarization dipole antennas. The primary science goals of LoFASM are the detection and study of low-frequency radio transients, a high priority science goal as deemed by the National Research Council's decadal survey.

LoFASM's data acquisition system currently consists of a real time correlating spectrometer implemented with field programmable gate array chip that is hosted on a Reconfigurable Open Architecture Computing Hardware (ROACH) board developed by the Collaboration for Astronomy Signal Processing and Electronics Research (CASPER). This poster presents a first look at data taken by LoFASM, UT-Brownsville's first radio telescope, during its early commissioning runs.

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337.15 – Systematic and Performance Tests of the Hard X-ray Polarimeter X-Calibur

X-ray polarimetry has great potential to reveal new astrophysical information about the emission processes of high energy sources such as black hole environments, X-ray binary systems, and active galactic nuclei. Here we present the results and conclusions of systematic and performance measurements of the hard X-ray polarimeter, X-Calibur. Designed to be flown on a balloon-borne X-ray telescope, X-Calibur will achieve unprecedented sensitivity and makes use of the fact that polarized X-rays preferentially Compton-scatter perpendicular to their E-field vector. Extensive laboratory measurements taken at Washington University and the Cornell High-Energy Synchrotron Source (CHESS) indicate that X-Calibur combines a detection efficiency on the order of unity with a high modulation factor of $\mu \approx 0.5$ averaged over the whole detector assembly, and with values up to $\mu \approx 0.7$ for select subsections of the polarimeter. Additionally, we are able to suppress background flux by more than two orders of magnitude by utilizing an active shield and scintillator coincidence. Comparing laboratory data with Monte Carlo simulations of both polarized and unpolarized hard X-ray beams illustrate that we have an exceptional understanding of the detector response.

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337.16 – Early Results from the HexPak and GradPak Variable-Scale Dual-Head IFUs on the WIYN 3.5-meter Telescope

The WIYN Observatory recently installed two new integral field units (IFUs) on its 3.5-meter telescope on Kitt Peak, Arizona. Each IFU is unique in that it contains different sized fibers in the same head to optimize the tradeoff between spatial resolution and surface brightness sensitivity for observations of galaxies. These instruments were designed and constructed (M. Bershady, PI) at the University of Wisconsin's Washburn Astronomical Laboratory. HexPak, with a central core of 1 arcsec fibers surrounded by a halo of 3 arcsec fibers, was designed for early type, face-on disk, and quasar host galaxies. GradPak, with a series of rows of fibers of increasing diameter from 2 arcsec to 6 arcsec (5 different diameters total), was designed for edge-on galaxies, where the small fibers lie along the midplane and larger fibers sample the progressively lower surface brightnesses above the plane. The instruments were installed alongside the existing SparsePak IFU in late 2013 and have been used in several observing runs since. The different fiber sizes present additional data reduction challenges, particularly regarding flux calibration and sky subtraction. Early results on studies of the stellar populations of galaxies are quite promising and demonstrate the advantages of fiber sizes tailored to the objects under study. HexPak and GradPak were built with funds from NSF award ATI-0804576.

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337.17 – The Goddard Integral Field Spectrograph at Apache Point Observatory: Current Status and Progress Towards Photon Counting

We present the current status and progress towards photon counting with the Goddard Integral Field Spectrograph (GIFS), a new instrument at the Apache Point Observatory’s ARC 3.5m telescope. GIFS is a visible light imager and integral field spectrograph operating from 400-1000 nm over a 2.8’ x 2.8’ and 14” x 14” field of view, respectively. As an IFS, GIFS obtains over 1000 spectra simultaneously and its data reduction pipeline reconstructs them into an image cube that has 32 x 32 spatial elements and more than 200 spectral channels. The IFS mode can be applied to a wide variety of science programs including exoplanet transit spectroscopy, protostellar jets, the galactic interstellar medium probed by background quasars, Lyman-alpha emission line objects, and spectral imaging of galactic winds. An electron-multiplying CCD (EMCCD) detector enables photon counting in the high spectral resolution mode to be demonstrated at the ARC 3.5m in early 2015. The EMCCD work builds upon successful operational and characterization tests that have been conducted in the IFS laboratory at NASA Goddard. GIFS sets out to demonstrate an IFS photon-counting capability on-sky in preparation for future exoplanet direct imaging missions such as the AFTA-Coronagraph, Exo-C, and ATLAST mission concepts. This work is supported by the NASA APRA program under RTOP 10-APRA10-0103.

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337.18 – Towards Using Smartphones to Refine Sunrise and Sunset Time Models

Current atmospheric models used to predict the times of sunrise and sunset have a minimum error of about one minute. Particularly at higher latitudes, slight changes in refraction may result in significant discrepancies, such as causing the Sun to appear to set several minutes prematurely or remain continuously above the horizon for an unexpectedly long time. Atmospheric models could be better constrained by a substantial collection of observed sunset times with associated meteorological data such temperature, pressure and height of observer. We report on the development of a project recording the necessary data with a few smartphones that will then be the groundwork of a citizen science project.

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338 – Instrumentation: Space Mission Posters

338.01 – First Year of WFIRST/AFTA Coronagraph Technology Development: Testbed Progress Update

NASA’s WFIRST/AFTA mission study includes the first high-contrast stellar coronagraph in space. This coronagraph will be capable of imaging and spectrally characterizing giant exoplanets similar to Neptune and Jupiter and possibly super-Earths, as well as circumstellar disks. After a transparent and rigorous downselect process, NASA chose in December of 2013 a primary design called an Occulting Mask Coronagraph (OMC) that combines two technical approaches, Shaped Pupil and Hybrid Lyot, in one instrument. The Phase-Induced Amplitude Apodization Complex Mask Coronagraph was selected as the backup design.
The OMC coronagraph technologies were assessed to have the highest likelihood of passing the WFIRST/AFTA flight

readiness gates and the ability to produce compelling science by working with the existing 2.4-meter telescope "as is," including its central obscuration, expected thermal drift, and the observatory pointing jitter. NASA set us the objective of maturing the WFIRST/AFTA coronagraph to Technology Readiness Level (TRL) 5 by October 1, 2016. A set of technical milestones was agreed upon to track the progress toward achieving TRL 5.
Substantial advances in WFIRST/AFTA coronagraph technology have been made during 2014, and the OMC progress is currently running ahead of the schedule laid out by the milestones. Our poster will present some of these key recent results to the community, including:
(1) Fabrication and characterization of WFIRST/AFTA coronagraph pupil plane and focal plane masks designed to work with the existing 2.4 telescope.
(2) Experimental results demonstrating high contrast achieved on a coronagraph testbed in narrowband and broadband light – first such results obtained with an obscured pupil.
(3) Progress in the development of the low-order wavefront sensing and control subsystem that will use rejected starlight to sense and correct both high frequency pointing jitter and slow varying low order aberrations. This subsystem will be integrated with the OMC coronagraph in mid-2015 for the next phase of starlight suppression experiments with dynamic input wavefront.

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338.02 – Moving Target Photometry Using WISE and NEOWISE

WISE band 1 observations have a significant noise contribution from confusion. The image subtraction done on W0855-0714 by Wright et al. (2014) shows that this noise source can be eliminated for sources that move by much more than the beamsize. This paper describes an analysis that includes a pattern of celestially fixed flux plus a source moving with a known trajectory. This technique allows the confusion noise to be modeled with nuisance parameters and removed even for sources that have not moved by many beamwidths. However, the detector noise is magnified if the motion is too small. Examples of the method applied to fast moving Y dwarfs and slow moving planets will be shown.

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338.03 – Recent Refinements to HST/ACS Image Reduction Tools: WFC Bias De-striping Using Region Masking, and CTE Correction for WFC 2K Subarrays

All post Servicing Mission 4 images taken with ACS contain row-correlated noise attributed to the CCD Electronics Box Replacement, as well as increasing levels of degraded charge transfer efficiency (CTE). Fixing both these issues simultaneously with the default Advanced Camera for Survey's (ACS) calibration pipeline (CALACS) is not always possible, particularly if you are using ACS subarrays. To address these issues the ACS team has created a stand alone Python calibration script to CTE correct 2K subarray frames, and to more accurately destripe crowded field/bright object science images. This script contains the logic to run each step of CALACS independently, and adjust for each individual image case. It also accepts mask files that are used with the improved stand alone destripe code, which provides a more accurate stripe correction when run on crowded fields by ignoring astronomical source pixels.

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Contributing team(s): ACS Team

338.04 – New ACS/WFC Geometric Distortion Model and New 47Tuc Astrometric Catalog

We present a new time-dependent distortion model for the Wide Field Channel (WFC) of the Hubble Space Telescope's (HST) Advanced Camera for Surveys (ACS). The newly derived geometric distortion is based on an improved astrometric reference catalog created from all observations within 3' of the center of the calibration field in the globular cluster 47Tuc through F606W filter over the lifetime of ACS/WFC. The improved astrometric reference catalog includes calculations for proper motion of the stars within the cluster and provides accurate positions of stars for the epoch 2012, which allowed us to re-examine the ACS/WFC geometric distortion. A complete correction of the ACS/WFC geometric distortions contain: 1) correction for the pixel-grid irregularities due to the manufacturing process of the WFC detectors: 2) 5th order polynomial solution; 3) correction for time dependency of the linear terms in both X and Y solutions; 4) correction for non-polynomial filter-dependent component of distortion due to the optical properties of ACS/WFC filters itself. The new distortion model is meant for use with the newer versions of the STSDAS/DrizzlePac software (version 2.0 or higher), which has been updated to accept the new model and remove higher order distortion from images.

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338.05 – WFC3/UVIS Photometry of HST standards: Encircled Energy and Spatial Stability with Wavelength

We present encircled energy measurements for the UVIS channel derived from observations of HST photometric standards over several years. These white dwarf and solar analog standard stars were observed in all 42 filters at multiple positions across the detector and allow us to characterize wavelength-dependent structure of the point-spread function (PSF). From these measurements we compute the average sensitivity ratio per chip for all UVIS filters, which are important for deriving the new chip-dependent zeropoints. They are also ideal for quantifying the accuracy of the flat fields by comparing the observed photometry at various locations across the detector.

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338.06 – WFC3: Instrument Status and Advice for Proposers and Observers

The Wide Field Camera 3 continues as the most used HST instrument after over five productive years in space. We sumarize its basic performance characteristics including our analysis of its stable and time variable calibrations. Key recent improvements in our calibrations and instrument characterizations will be discussed including the development of improved libraries of Point Spread Functions, better models of persistence in the infrared detector, and advances in our understanding of sources of variable infrared backgrounds. Basic calibration improvements include the adoption of a CCD specfic QE curve for the UVIS channel together with improved flat fields, an ongoing effort to include more filter elements with high precision astrometric calibration, and a time dependent calibration of the UVIS photometric zero points. Recent lesssons learned regarding the use of the spatial scan technique to enable extremely high precision photometric and astrometric measurements will be presented. The calibration program for Cycle 22 will also be summarized.

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Contributing team(s): WFC3 Team

338.07 – WFC3 UVIS Detector Performance

The Wide Field Camera 3 (WFC3) is a fourth-generation imaging instrument installed on the Hubble Space Telescope (HST) during Servicing Mission 4 (SM4) in May 2000. WFC3 has two observational channels, UV/visible (UVIS) and infrared (IR); both have been performing well on-orbit. Since installation, the WFC3 team has been diligent in monitoring the performance of both detectors. The UVIS channel consists of two e2v, backside illuminated, 2Kx4K CCDs arranged in a 2x1 mosaic. We present results from some of the monitoring programs used to check various aspects of the UVIS detector. We discuss the growth trend of hot pixels and the efficacy of regular anneals in controlling the hot pixel population. We detail a pixel population with lowered-sensitivity that evolves during the time between anneals, and is largely reset by each anneal procedure. We discuss the stability of the post-flash LED lamp, used and recommended for CTE mitigation in observations with less than 12 e-/pixel backgrounds. Finally, we summarize long-term photometric trends of the UVIS detector, as well as the absolute gain measurement, used as a proxy for the on-orbit evolution of the UVIS channel.

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Contributing team(s): WFC3 Team

338.08 – WFC3/UVIS Dark Current Calibration and Detector Characteristics

The Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3) is a fourth-generation imaging instrument that was installed during Servicing Mission 4 in May 2009. The WFC3/UVIS detector, comprised of two e2v CCDs, exhibits an inherent dark current (in the absence of any illumination) presently measured at ~6 e-/hr. In addition, detector degradation due to on-orbit radiation damage generates a continuously increasing though small population of hot pixels (dark current exceeding 54 e-/hr, ~4% of each chip) as well as 'sink' pixels (pixels which contain a large number of charge traps). We present the procedures and results of the WFC3/UVIS dark calibration, which provides calibration files used as a correction for these detector characteristics. We discuss the impacts that Charge Transfer Efficiency (CTE) losses and detector post-flashing have on the hot pixel population and overall calibration, as well as the plans for flagging the 'sink' pixels in the calibration pipeline. Finally, we discuss various improvements to the calibration procedure that will increase

the accuracy of dark current and hot pixel measurements.

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Contributing team(s): The WFC3 Team

338.09 – Updated Calibration and Backgrounds for the WFC3 IR Grisms

We present new and improved calibration of the WFC IR (G102 and G141) grism mode. These new calibrations were generated by combining data obtained over six observing cycles and include a better sampling of the field of view. The result is a calibration of the spectral trace that has been improved to better than 0.1 detector pixel. A new fiducial wavelength reference spectrum is now used to calibrate the wavelength dispersion of the grisms and we show that the rms of the solution has been reduced to approximately 7 and 14 Angstrom for the G102 and G141 grisms, over the entire field of view. Overall, both the trace and wavelength calibration have been improved by about a factor of two and the G102 and G141 solutions are in better agreement at wavelengths where the two grisms overlap. We demonstrate that the grism calibration can be extrapolated for objects that are outside of the field of view but still result in dispersed spectra on the WFC3 detector.
We also present new master sky images that can be used to improve the sky background subtraction from grism exposures. The individual components of the new background model include the zodiacal continuum and a strong He I emission line at 1.083 microns from the upper atmosphere. We find that fitting science exposures with a linear combination of these two background components enables modeling of the WFC3/IR grism background with an accuracy that is better than ~0.01 electrons/s/pix across the detector.

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338.10 – The Far Ultraviolet Channel of the Cosmic Origins Spectrograph on HST: Current Status and the Upcoming Lifetime Move

Five and a half years after installation on the Hubble Space Telescope, the Cosmic Origins Spectrograph (COS) is performing well, and work continues in order to optimize its performance as it ages. A significant change will occur in early 2015 when the spectra for most of the FUV modes will be moved to Lifetime Position 3 (LP3) in order to address the effects of gain sag and ensure that the scientific quality of the data obtained by the instrument remain as high as possible in the coming years. With this change, the spectral Lifetime Position and detector high voltage values will be changing regularly – often multiple times within an orbit, depending on the grating setting used for each exposure. A substantial amount of preparatory work has been completed in anticipation of this move; we will discuss some of the data already collected in the optimization, enabling, and calibration phases, and discuss the post-move calibration plan. The data from these programs will be used to update the pipeline reference files in order to maximize the quality of the calibrated data at the new lifetime position.

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338.11 – Status of the JWST Integrated Science Instrument Module

The James Webb Space Telescope (JWST) Integrated Science Instrument Module (ISIM) is the science instrument payload of the JWST. It is one of three system elements that comprise the JWST space vehicle. It consists of four science sensors, a fine guidance sensor, and nine other subsystems that support them. At 1.4 metric tons, it comprises approximately 20% of the JWST mass. The ISIM is currently at 100% integration and has completed 2 of 3 planned element-level space simulation tests. The ISIM is on schedule to be delivered for integration with the Optical Telescope Element during 2015. In this poster, we present an overview of the ISIM and its status.

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338.12 – Small-Grid Dithering Strategy for Improved Coronagraphic Performance with JWST

Contrast performances for most coronagraph designs typically depend rather strongly on the accuracy of target acquisition. For JWST, target acquisition away from the center of the coronagraphs will allow for centroid measurement, which will in turn be used to command a small-angle maneuver (SAM) to accurately place the star behind the coronagraphic mask. With this approach, the SAM accuracy inherently limits the contrast performance of the coronagraphs, especially given that a reference star (or self-reference after telescope roll) might also be required. For such differential measurements, the reproducibility of the TA is therefore a very important factor. Here, we propose a novel coronagraphic observation concept whereby the reference PSF is first acquired using a standard TA, followed by coronagraphic observations on a small grid of dithered positions. Sub-pixel dithers (5-10mas each) provide a small reference PSF library that sample the possible variations in the PSF shape due to imperfect TAs. This small library can then be used for example with principal component analysis for PSF subtraction (e.g; LOCI or KLIP algorithms). Such very small dithers can be achieved with the JWST attitude control system without overhead and with higher accuracy than a SAM since they take advantage of the fine steering mirror under closed-loop fine guidance. We discuss and evaluate the performance gains from this observation scenario compared to the standard TA for MIRI Four-Quadrant Phase Mask coronagraphs and provide numerical simulations for a some astrophysical targets of interest.

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338.13 – The JWST Calibration Pipeline

The James Webb Space Telescope will launch in 2018 and carry four science instruments that will observe the sky at 0.7 - 29 micron: the Near Infrared Camera (NIRCam), the Near Infrared Imager and Slitless Spectrograph (NIRISS), the Near Infrared Spectrograph (NIRSpec), and the Mid Infrared Instrument (MIRI). The Space Telescope Science Institute (STScI) is currently building a data reduction pipeline that will provide not only basic calibrated data but also higher level science products. All of the JWST detectors will be operated in non-destructive readout mode. Therefore, the first step in the pipeline will be to calculate the slopes of indivudal non-destructive readout ramps or integrations. The next step will be to generate calibrated slope images that are represent the basic calibrated data. The final step will be to combine data taken across multiple integrations and exposure. For the direct imaging and integral field spectroscopy modes, the pipeline will produce calibrated mosaicks. For the coronagraphic modes, the pipeline will produce contrast curves and PSF subtracted images.

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338.15 – Cryo-Vacuum Testing of the JWST Integrated Science Instrument Module

In October of 2014, a major milestone in the JWST program was reached: completion of the first (of two planned) cryo-vacuum tests of the fully-assembled Integrated Science Instrument Module. This test, executed in the largest thermal-vacuum chamber of NASA's Goddard Space Flight Center, was a massive undertaking, with round-the-clock testing covering a period of 117 days from door-close to door-open. Over this period, the full complement of ISIM flight instruments, structure, harness radiator, and electronics were put through a comprehensive program of thermal, optical, electrical, and operational tests. In this paper, we briefly summarize the goals, setup, execution, and preliminary results of this important and very successful test.

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338.16 – Observations of Resolved Stellar Populations with the JWST Near Infrared Spectrograph

The James Webb Space Telescope's (JWST) Near Infrared Spectrograph (NIRSpec) will provide a multi-object spectroscopy mode through the four Micro-Shutter Arrays (MSAs). Each MSA is a grid of contiguous shutters that can be configured to form slits on more than 100 astronomical targets simultaneously. The combination of JWST's sensitivity and superb resolution in the infrared and NIRSpec's full wavelength coverage over 1 to 5 micrometers will open new parameter space for studies of galaxies and resolved stellar populations alike. We present a NIRSpec MSA observing scenario for obtaining spectroscopy of individual stars in external galaxies. We examine the multiplexing capability of the MSA as a function of the possible MSA configuration design choices, and investigate the primary sources of error in velocity measurements and the prospects for minimizing them. We discuss how this and other use cases are being used to guide development of the NIRSpec user interfaces, including proposal planning and pipeline calibrations.

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338.18 – Beyond JWST: A Technology Path to the Next Great UVOIR Space Telescope

We report on the AURA "Beyond JWST" committee's considerations and conclusions regarding technology paths for the development of a large UVOIR observatory, to be launched following JWST and WFIRST-AFTA. The ambitious science goals for this mission include the discovery and spectral characterization of exo-earth candidates; the study of galaxies and stellar populations at spatial resolutions of 100 parsec ***at any redshift*** in the UV and visible universe; and multi-object spectroscopy up to R of 50,000, especially in the UV, to probe the chemical evolution and gas kinematics in and around galaxies both near and far. Requirements for aperture size, starlight suppression efficiency, and sensitivity at Far-UV wavelengths, all present significant technology challenges – but challenges that are within reach, building incrementally on current NASA investments and progress within the community. WFIRST-AFTA is pioneering new methods for coronagraphs that work with obscured apertures – work that can be extended to include larger segmented apertures. Exoplanet Program investments in starshade technologies for smaller telescopes inform choices for larger apertures. Cosmic Origins Program and non-NASA investments in mirrors, coatings and detectors already enable a range of telescope and scientific instrument architectures. We will present the consensus recommendations of the AURA committee on both the current readiness levels of these key technologies and on the additional steps needed to support a viable flight concept for a future large UVOIR space telescope.

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338.19 – Beyond JWST: Science Drivers for the Next Great UVOIR Space Telescope

We report on the AURA "Beyond JWST" committee's considerations and conclusions regarding the science case for the development of a large UVOIR observatory, to be launched following JWST and WFIRST-AFTA. We find that a space-based UVOIR telescope of 10 meters or more in aperture will uniquely enable a wide range of transformational science investigations by itself and in tandem with ground-based OIR and radio facilities in its era. The chief goal of this facility is to assess the possibility of life beyond our Solar System by discovering Earth-like planets in the habitable zones of their host stars, via direct imaging, and by searching spectroscopically for biosignature gases in the atmospheres of the best exo-Earth candidates. The large aperture and mission architecture required to characterize the atmospheres of a significant number of potentially life-bearing planets will also transform studies of the galaxies and stars that led up to them. At 10 meters or larger, the telescope will spatially resolve scales of 100 AU everywhere in the Milky Way, 0.1 parsec everywhere in the Local Group, and 100 parsec everywhere in the observable Universe. This unprecedented spatial resolution over large fields, with stable optics and low backgrounds, will allow astronomers to follow, in high definition, the formation and evolution of the star forming regions inside galaxies over the past 10 Gyr, to robustly determine the complete star formation histories in every galaxy within the local volume (to 10 Mpc), and to track the motions of virtually any star in the Milky Way. High spectral resolution and multi-object spectroscopy in the UV will enable revolutionary new studies of gas flows in galaxies, bodies in the outer solar system, and the evolution of the most massive stars. We present these compelling science drivers and their associated observational requirements here; we summarize the technology requirements for high angular resolution, sensitivity, wavefront stability, dynamic range, and access to ultraviolet wavelengths to support these capabilities in a companion poster.

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338.20 – A Future Large-Aperture UVOIR Space Observatory: Study Overview

The scientific drivers for very high angular resolution coupled with very high sensitivity and wavefront stability in the UV and optical wavelength regime have been well established. These include characterization of exoplanets in the habitable zones of solar type stars, probing the physical properties of the circumgalactic medium around $z < 2$ galaxies, and resolving stellar populations across a broad range of galactic environments. The 2010 NRC Decadal Survey and the 2013 NASA Science Mission Directorate 30-Year Roadmap identified a large-aperture UVOIR observatory as a priority future space mission. Our joint NASA GSFC/JPL/MSFC/STScI team has extended several earlier studies of the technology and engineering requirements needed to design and build a single filled aperture 10-meter class space-based telescope that can enable these ambitious scientific observations. We present here an overview of our new technical work including a brief summary of the reference science drivers as well as in-depth investigations of the viable telescope architectures, the requirements on thermal control and active wavefront control systems, and the range of possible launch configurations.

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338.21 – Potential of a Future Large Aperture UVOIR Space Observatory for Breakthrough Observations of Star and Planet Formation

A future large aperture space observatory operating from the UV to the near-infrared with a diameter between 10 and 15 meters will provide a unique opportunity for observations of star and planet formation, from nearby moving groups and associations to star formation in galaxies in the local universe. Our newly formed working group will examine the unique opportunities that such a telescope will give observers in a post-JWST/WFIRST-AFTA era that includes extremely large ground-based observatories such as the TMT, E-ELT, ALMA, and the VLTI. Given a potential suite of instruments for this observatory we will discuss some of the key areas of star and planet formation science where breakthroughs might occur.

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338.22 – A Future Large-Aperture UVOIR Space Observatory: Key Technologies and Capabilities

We present the key technologies and capabilities that will enable a future, large-aperture ultraviolet/optical/infrared (UVOIR) space observatory. These include starlight suppression systems, vibration isolation and control systems, lightweight mirror segments, detector systems, and mirror coatings. These capabilities will provide major advances over current and near-future observatories for sensitivity, angular resolution, and starlight suppression. The goals adopted in our study for the starlight suppression system are 10^{-10} contrast with an inner working angle of 40 milliarcsec and broad bandpass. We estimate that a vibration and isolation control system that achieves a total system vibration isolation of 140 dB for a vibration-isolated mass of ~5000 kg is required to achieve the high wavefront error stability needed for exoplanet coronagraphy. Technology challenges for lightweight mirror segments include diffraction-limited optical quality and high wavefront error stability as well as low cost, low mass, and rapid fabrication. Key challenges for the detector systems include visible-blind, high quantum efficiency UV arrays, photon counting visible and NIR arrays for coronagraphic spectroscopy and starlight wavefront sensing and control, and detectors with deep full wells with low persistence and radiation tolerance to enable transit imaging and spectroscopy at all wavelengths. Finally, mirror coatings with high reflectivity (> 90%), high uniformity (< 1%) and low polarization (< 1%) that are scalable to large diameter mirror substrates will be essential for ensuring that both high throughput UV observations and high contrast observations can be performed by the same observatory.

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338.23 – A Future Large-Aperture UVOIR Space Observatory: Reference Designs

Our joint NASA GSFC/JPL/MSFC/STScI study team has used community-provided science goals to derive mission needs, requirements, and candidate mission architectures for a future large-aperture UVOIR space observatory. Reference designs have been developed for non-cryogenic telescopes that span UVOIR wavelengths. We describe the assessment we are conducting on the requirements and feasibility of system thermal and dynamic stability for supporting coronagraphy. The observatory is in a Sun-Earth L2 orbit providing a stable thermal environment and excellent field of regard. ATLAST has developed a reference design for a 36-segment 9.2 m aperture telescope that stows within a five meter diameter launch vehicle fairing. Compatibility with three different launch vehicles mitigates programmatic risk. A deployed, three-layer, flat stray light shield oriented perpendicular to the sun provides stray light protection and benefits thermal stability. The telescope and instruments are dynamically isolated from spacecraft disturbance sources and the secondary mirror is actively controlled. The team has also assessed an 11.2 m aperture that required a different method of deploying the secondary mirror support structure and has evaluated some on-orbit assembly options. The performance needs developed under the study are traceable to a variety of reference designs, including monolithic apertures. The observatory reference concepts are designed to be serviceable for potential life extension and upgrades, but not requiring servicing for mission success. The details of these reference designs will be presented.

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338.24 – Measurements of High-Contrast Starshade Performance

The external starshade is a prospective method for the direct detection and spectral characterization of terrestrial planets around other stars, a key goal identified in ASTRO2010. As part of an ongoing campaign to validate the starlight-suppression performance of the starshade, we have repeatably measured contrast better than $1X10^{-8}$ using 60 cm starshades. These measurements were made over a 50% spectral bandpass, using incoherent light sources (a white LED), and in challenging outdoor test environments. These measurements confirm not only the overall starlight-suppression capability of the starshade concept but the robustness to optical disturbances enabled by the wide shadow covering the telescope. The spectral coverage is limited only by the optics and detectors in our test setup, not by the starshade itself. Our experimental setup is designed to provide starshade to telescope separation and telescope aperture size that are scaled as closely as possible to the flight system. In this paper, we describe our latest results as well as detailed comparisons of the measured results to model predictions. Plans and status of the next phase of ground testing will also be discussed.

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338.25 – Life Finder Detectors: An Overview of Detector Technologies for Detecting Life on Other Worlds

Future large space telescopes will seek evidence for life on other worlds by searching for spectroscopic biosignatures. Atmospheric biosignature gases include oxygen, ozone, water vapor, and methane. Non-biological gases, including carbon monoxide and carbon dioxide, are important for discriminating false positives. All of these gases imprint spectroscopic features in the UV through mid-IR that are potentially detectable using future space based coronagraphs or star shades for starlight suppression.

Direct spectroscopic biosignature detection requires sensors capable of robustly measuring photon arrival rates on the order of 10 per resolution element per hour. Photon counting is required for some wavefront sensing and control approaches to achieve the requisite high contrast ratios. We review life finder detector technologies that either exist today, or are under development, that have the potential to meet these challenging requirements. We specifically highlight areas where more work or development is needed.

Life finder detectors will be invaluable for a wide variety of other major science programs. Because of its cross cutting nature; UV, optical, and infrared (UVOIR) detector development features prominently in the 2010 National Research Council Decadal Survey, “New Worlds, New Horizons in Astronomy and Astrophysics”, and the NASA Cosmic Origins Program Technology Roadmap.

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338.26 – High contrast imaging with an arbitrary aperture: active correction of aperture discontinuities: fundamental limits and practical trades offs

In a recent paper we discussed a new method to achieve high-contrast images using segmented and/or on-axis telescopes. Our approach, named Active Compensation of Aperture Discontinuities (ACAD) relies on two sequential Deformable Mirrors to compensate for the large amplitude excursions in the telescope aperture due to secondary support structures and/or segment gaps. In this configuration the parameter landscape of Deformable Mirror Surfaces that yield high contrast Point Spread Functions is not linear, and non-linear methods are needed to find the true minimum. In particular we showed that broadband high contrast solutions can be achieved using realistic surface deformations that are accessible using existing technologies for a variety of telescope pupil geometries. In this paper we first focus on the fundamental limits and practical trade-offs associated with ACAD. In a first part we will study the fundamental limits and practical tradeoffs associated with ACAD, regardless of the downstream coronagraphic architecture. The mathematical techniques to finding ACAD DM shapes require to solve a complex differential equation. We will first discuss the scaling laws underlying this non-linear solution and their impact of DM placement and geometry wishing the optical design of an instrument. We will then consider the sensitivity to low order aberrations: in principle an ACAD solution that comprises large strokes will be more sensitive to these aberrations than one with smaller strokes. As a consequence, we will quantify this sensitive both using analytical models and numerical simulations. We will present diffractive end to end simulations and quantify the ultimate contrast and bandwidth achievable with ACAD, which can be reached by superposing using a classical linear wavefront control algorithms on top of the Monge Ampere solution. Finally, recent work has shown that coronagraph designs can also accommodate for secondary support structures and/or segments gaps, at a cost in IWA, throughput and static components complexity. We will devote the last part of our paper to show how can some of the fundamental limits of ACAD can be circumvented by combining ACAD with modern coronagraph designs.

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338.27 – Low Order Wavefront Sensing and Control for WFIRST-AFTA Coronagraph

NASA's WFIRST-AFTA Coronagraph will be capable of directly imaging and spectrally characterizing giant exoplanets similar to Neptune and Jupiter, and possibly even super-Earths, around nearby stars. To maintain the required coronagraph performance in a realistic space environment, a Low Order Wavefront Sensing and Control (LOWFS/C) subsystem is necessary. The LOWFS/C will use the rejected stellar light to sense and suppress the telescope pointing drift and jitter as well as low order wavefront errors due to the changes in thermal loading of the telescope and the rest of the observatory. The measured wavefront information will also be used for the coronagraph data post-processing (PSF subtraction) needed to further remove the speckle field and enhance the contrast. The LOWFS/C uses a Zernike phase contrast wavefront sensor with the phase shifting disk combined with the stellar light rejecting occulting mask, a key concept to minimize the non-common path error. Developed as a part of the Dynamic High Contrast Imaging Testbed (DHCIT), the LOWFS/C subsystem also consists of an Optical Telescope Assembly (OTA) simulator to generate the realistic wavefront error from WFIRST-AFTA telescope's jitter and thermal drift. The entire LOWFS/C subsystem will be integrated, calibrated, and tested in a dedicated LOWFS/C testbed before being integrated into DHCIT. In this paper we will describe the LOWFS/C subsystem design and its integration and test plan. We will also report the LOWFS/C testbed integration progress as well as some preliminary test results.

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338.28 – A Shaped Pupil Lyot Coronagraph for WFIRST-AFTA

The baseline WFIRST-AFTA mission concept includes a shaped pupil coronagraph for imaging and spectroscopy of gas giants in nearby planetary systems. Our newest designs optimize over a three-stage Fourier propagation (shaped pupil apodizer, hard-edged focal plane mask, and Lyot stop) to generate small inner working angle (2.5 lambda/D), broadband (20%), high-contrast (< 10^-8) solutions. Here we describe our methods and performance predictions, in anticipation of testbed verification within the coming year.

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338.29 – Integrated Modeling of the WFIRST AFTA Coronagraph Instrument

The WFIRST AFTA Coronagraph will be the first instrument of its kind capable of reaching contrasts around 1e-9. Reaching these low levels of contrast is not only time expensive because of the low photon rates in the final iterations of deepening the dark hole, but also the sensitivity of the speckle pattern to thermal or dynamic changes in the instrument becomes high. For these reasons integrated modeling that includes the thermal, structural, optical and detector effects not only is necessary but must be validated to by of high fidelity. In this presentation we describe the WFIRST AFTA integrated modeling approach and the latest results on the key tolerances required for successful imaging of planets with contrast below 5e-9.

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338.30 – Post-processing methods for high-contrast imaging in the context of the WFIRST-AFTA telescope

Direct detection and characterization of Earth-like exoplanets with contrasts of 10^9 require space-based instruments optimized for high-contrast imaging. In this context, the Wide-Field Infrared Survey Telescope - Astrophysics Focused Telescope Assets (WFIRST-AFTA) project will reach contrasts of about 10^8, using state-of-the-art starlight suppression and wavefront control techniques. A ten-fold contrast improvement to reach the required contrast of 10^9 is expected to come from post-processing. But the methods of point spread function (PSF) subtraction techniques currently used on both ground-based and space-based instruments have not yet been demonstrated at such high contrast level. In this communication, we explore new ways of implementing post-processing methods on AFTA-like simulated images, taking into account the presence of deformable mirrors, coronagraph and an IFS.

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338.31 – New Stellar Science with Astro-H

The upcoming X-ray mission ASTRO-H has the unprecedented high energy resolution and highly accurate energy determination (i.e., stable gain) of Soft X-ray Spectrometer (SXS). Combined with the broad-band capability of Soft and Hard X-ray Imagers (SXI and HXI), we will be able to explore a new horizon to extend our understanding of stars and related phenomena. We here highlight the stellar science topics that the ASTRO-H team considers of high priority. (1) Formation of a central star in protostars will be shed light on, for the first time, with the detection of the Doppler shifts of Fe K lines, (2) Dynamical movement of materials during flares will be captured as the Doppler shifts of Fe K lines, (3) Evidence for accreting plasma will be examined in T Tauri star with a diagnostic of the density-sensitive lines, (4) The fluorescent Fe emission line will be commonly observed in massive stellar binary, and then the geometry of the hot gas, which illuminates the stellar surface, would be diagnosed, (5) Hot plasma have been found to fill cavities in star forming regions with unidentified lines. The diagnostics of the lines will determine whether they originate from Non-Equilibrium Ionization conditions or charge exchange.

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Contributing team(s): The ASTRO-H team

338.32 – The ASTRO-H Mission: Unprecedented Spectral Coverage in the X-ray and Soft Gamma-Ray Bands

Following in the footsteps of the ASCA and Suzaku satellites, the joint Japan-US-European ``ASTRO-H" space mission is considerably more ambitious and represents a major step forward in our ability to study the high-energy universe. Construction of the satellite is well underway, with an anticipated launch date in late 2015. The unprecedented suite of instruments on Astro-H enables *simultaneous* observations covering 0.1 to 600 keV, including: calorimeter (~5 eV) energy resolution in the 6-7 keV iron line band, good angular resolution and sensitivity, comparable to NuSTAR, at higher energies due to hard X-ray focusing optics, and significant polarization sensitivity above ~50 keV provided by Compton camera electronics. Here we present examples of the spectra expected in a typical 100 kilosecond observation for several classes of sources, focusing on how the combination of Astro-H's instruments enables us to finally break several of the degeneracies that currently hamper modeling efforts for these sources.

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338.33 – Studying Young and Old Supernova Remnants with the Upcoming ASTRO-H X-ray Mission

The upcoming X-ray mission ASTRO-H will open a new discovery window to the high-energy Universe thanks to the unprecedented high-resolution spectroscopy (~7eV) to be achieved with the Soft X-ray Spectrometer (SXS) combined with its broadband coverage (0.5-600 keV) with the Soft X-ray Imager (SXI), Hard X-ray Imager (HXI) and the Soft Gamma-ray Detector (SGD). Supernova remnants (SNRs) are a prime science focus for ASTRO-H, particularly with the SXS providing accurate plasma diagnostics of line-rich spectra expected from the youngest, ejecta-dominated, SNRs to the oldest SNRs impacted by their interaction with the Interstellar Medium (ISM). We here highlight the SNR science topics and program that the ASTRO-H team considers of highest priority and impact. For the younger SNRs, the primary science goals are (1) using abundance measurements to unveil SNR progenitors, (2) using spatial and velocity distribution of the ejecta to understand supernova explosion mechanisms, and (3) revealing the link between the thermal plasma state of SNRs and the efficiency of their particle acceleration. For the older SNRs where thermal emission is dominated or heavily impacted by the ISM, the primary goals are (1) constraining metal abundances and physical processes in the mature limb-brightened SNRs, and (2) understanding the puzzling nature of the `mixed-morphology’ SNRs and the physics of recombining plasma. For the pulsar-powered nebulae, also known as Pulsar Wind Nebulae (PWNe) or plerions with many still lacking thermal X-ray emission from their supernova shells, ASTRO-H will shed light on their progenitors and environment. The hard X-ray coverage on board ASTRO-H will further allow a study of their broadband spectra (for the brightest objects), beyond NuSTAR’s range, filling the gap between the soft X-ray regime (with current X-ray missions) and the gamma-ray regime (with Fermi in the GeV and H.E.S.S. in the TeV), allowing the search for spectral breaks in the hard X-ray band.

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338.34 – New Frontiers in Galaxy Clusters with ASTRO-H

The next generation X-ray observatory ASTRO-H will open up a new dimension in the study of galaxy clusters. For the first time, the focal plane calorimeter aboard ASTRO-H will achieve the spectral resolution required to measure velocities of the intracluster plasma. At the same time, the Hard X-ray Imager (HXI) will extend the simultaneous spectral coverage to energies well above 10 keV, critical for studying both thermal and non-thermal gas in clusters. We present an overview of the capabilities of ASTRO-H for exploring gas motions in galaxy clusters, including their cosmological implications, the physics of AGN feedback, the dynamics of cluster mergers and associated high-energy processes, the chemical enrichment of the intracluster medium, and the nature of missing baryons and unidentified dark matter. By demonstrating these capabilities explicitly on representative galaxy clusters, we hope to aid and encourage the broader astrophysical community in developing ASTRO-H science.

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Contributing team(s): ASTRO-H Team

338.35 – Future ASTRO-H observations of chemical evolution in high-z universe

In this contribution, we demonstrate ASTRO-H's capability to measure the chemical evolution in the high-z (z < 3) universe by observing X-ray afterglows of gamma-ray bursts (GRBs) and distant Blazars. Utilizing these sources as background light sources, the excellent energy resolution of Astro-H/SXS allows us to detect emission and absorption features from heavy elements in the circumstellar material in the host galaxies, from the intergalactic medium (IGM) and in the ejecta of GRB explosions. In particular, we can constrain the existence of the warm-hot intergalactic medium (WHIM), thought to contain most of the baryons at redshift of z < 3, with a typical exposure of one day for a follow-up observation of a GRB afterglow or 300 ks exposure for several distant Blazars. In addition to the chemical evolution study, the combination of the SGD, HXI, SXI and SXS will measure, for the first time, the temporal behavior of the spectral continuum of GRB afterglows and Blazars over a broad energy range and short time scales allowing detailed modeling of jets. The ability to obtain these data from GRB afterglows will depend critically on the availability of GRB triggers and the capability of ASTRO-H to respond rapidly to targets of opportunity. At the present time it seems as if Swift will still be functioning normally during the first two years of ASTRO-H operations providing the needed triggering capability.

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Contributing team(s): ASTRO-H team

338.36 – Astro-H: New Spectral Features Seen in High-Resolution X-rays

The Soft X-ray Spectrometer (SXS) microcalorimeter on Astro-H will provide the first high-resolution X-ray spectra of diffuse astrophysical sources. One key new type of science will be charge exchange spectroscopy, wherein highly-ionized metals interact with neutral hydrogen, helium, or other material. This has been detected with modest resolution in comets and planets, and is thought to be the origin of at least some of the 1/4 keV soft X-ray background. We will report on the predicted emission that the Astro-H SXS may detector from all of these sources using the recently released AtomdB Charge Exchange spectral model acx, and comment on possible other sources such as starburst galaxies. The SXS will also observe complex high-resolution spectra from other diffuse sources such as overionized supernova remnants and galaxy clusters. We will discuss these in the context of advanced spectral models using the recently released AtomDB v3.0 data and non-equilibrium models.

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338.37 – Optimizing Focusing X-Ray Optics for Planetary Science Applications

X-Ray observations are a valuable tool for studying the composition, formation and evolution of the numerous X-Ray emitting objects in our Solar System. Although there are plenty of useful applications for in situ X-Ray focusing instrumentation, X-Ray focusing optics have never been feasible for use onboard planetary missions due to their mass and cost. Recent advancements in small-scale X-Ray instrumentation have made focusing X-Ray technology more practical and affordable for use onboard in situ spacecraft. Specifically, the technology of a metal-ceramic hybrid material combined with Electroformed Nickel Replication (ENR) holds great promise for realizing lightweight X-ray optics. We are working to optimize these lightweight focusing X-Ray optics for use in planetary science applications. We have explored multiple configurations and geometries that maximize the telescope's effective area and field of view while meeting practical mass and volume requirements. Each configuration was modeled via analytic calculations and Monte Carlo ray tracing simulations and compared to alternative Micro-pore Optics designs. The improved performance of our approach using hybrid materials has many exciting implications for the future of planetary science, X-Ray instrumentation, and the exploration of X-Ray sources in our Solar System.

This work was supported in part by the NSF REU and DoD ASSURE programs under NSF grant no. 1262851 and by the Smithsonian Institution.

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338.38 – High-efficiency blazed transmission gratings for high-resolution soft x-ray spectroscopy

High-resolution spectroscopy of astrophysical sources is the key to gaining a quantitative understanding of the history, dynamics, and current conditions of the cosmos. A large-area (> 1,000 cm^2), high resolving power ($R = \lambda/\Delta\lambda > 3{,}000$) soft x-ray spectrometer that covers the lines of C, N, O, Ne and Fe ions is the ideal tool to address a number of high-priority sciences questions from the 2010 Decadal Survey, such as the connection between super-massive black holes and large-scale structure via cosmic feedback, the evolution of large-scale structure, the behavior of matter at high densities, and the conditions close to black holes. Numerous mission concepts that meet these requirements have been studied and proposed over the last few years, including grating instruments for the International X-ray Observatory. Nevertheless, no grating missions are currently approved. To improve the chances for future soft x-ray grating spectroscopy missions, grating technology has to progress and be advanced to higher TRLs. We have developed Critical-Angle Transmission (CAT) gratings that combine the advantages of blazed reflection gratings (high efficiency, use of higher diffraction orders) with those of conventional transmission gratings (low mass, relaxed alignment tolerances and temperature requirements, transparent at higher energies). A CAT grating-based spectrometer can provide performance 1-2 orders of magnitude better than current grating instruments on Chandra and Newton-XMM with minimal resource requirements. We have fabricated large-area free-standing CAT gratings with minimal integrated support structures from silicon-on-insulator wafers using advanced lithography and a combination of deep reactive-ion and wet etching, and will present our latest x-ray test results showing record high diffraction efficiencies in blazed orders.

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338.39 – Testing of a Narrow Gap Detector designed for a sensitive X-ray polarimeter

Time projection polarimeters are gas detectors where incident X-rays interact with a gas atom to produce a photoelectron whose direction is correlated with the polarization of the incident X-ray. By imaging the path of many photoelectrons the polarization of the incident X-ray can be determined.
The next generation of time projection polarimeter incorporates a narrow gap detector to minimize the diffusion in the transfer gap between the gas electron multiplier and the readout strips. We report on the testing performed to bring the narrow-gap design to Technology Readiness Level (TRL)-6.
TRL-6 testing included random and sine burst vibration tests and thermal cycling tests. In addition thermal shock tests and creep tests were performed to further demonstrate that the design would meet requirements, particularly flatness, throughout the life of a 2 year mission.
The post-test inspection following the vibration testing showed no degradation or loss of flatness. Thermal Shock testing showed no indication that the extreme temperature had any effect on the detector. Creep testing showed no positive or negative trends in flatness. Thermal cycle testing also showed no change in detector behavior. All the requirements have been met and the narrow gap polarimeter is at TRL-6.

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338.40 – Polarization from Relativistic Astrophysical X-raY Sourses: The PRAXYS Small Explorer Observatory

Polarization is a sensitive probe of geometry near compact objects, but remains largely unexplored in the X-ray band. Yet polarization should be present where substantial X-ray emission is observed, yielding insight into the geometry of black hole emission, and the origin and nature of X-ray emission in neutron stars and magnetars. Recent progress with detectors capable of imaging the track of a photoelectron generated by a detection of a cosmic X-ray have made sensitive X-ray polarization observatories possible within the constraints of a NASA Small Explorer mission. We report on the observational capabilities and the scientific goals explored with the "Polarization from Relativistic Astrophysical X-raY Sources" (PRAXYS) Observatory, to be proposed to the NASA Small Explorer program.

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338.41 – System Architecture of Explorer Class Spaceborne Telescopes: A look at Optimization of Cost, Testability, Risk and Operational Duty Cycle from the Perspective of Primary Mirror Material Selection

Management of cost and risk have become the key enabling elements for compelling science to be done within Explorer or M-Class Missions. We trace how optimal primary mirror selection may be co-optimized with orbit selection. And then trace the cost and risk implications of selecting a low diffusivity low thermal expansion material for low and medium earth orbits, vs. high diffusivity high thermal expansion materials for the same orbits. We will discuss that ZERODUR®, a material that has been in space for over 30 years, is now available as highly lightweighted open-back mirrors, and the attributes of these mirrors in spaceborne optical telescope assemblies. Lightweight ZERODUR® solutions are practical from mirrors < 0.3m in diameter to >4m in diameter. An example of a 1.2m lightweight ZERODUR® mirror will be discussed.

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338.42 – An Evolvable Space Telescope for Future Astronomical Missions

Astronomical flagship missions after the James Webb Space Telescope (JWST) will require lower cost space telescopes and science instruments. Innovative spacecraft-electro-opto-mechanical system architectures matched to the science requirements are needed for observations for exoplanet characterization, cosmology, dark energy, galactic evolution formation of stars and planets, and many other research areas. The needs and requirements to perform this science will continue to drive us toward larger and larger apertures.
Recent technology developments in precision station keeping of spacecraft, interplanetary transfer orbits, wavefront/sensing and control, laser engineering, macroscopic application of nano-technology, lossless optical designs, deployed structures, thermal management, interferometry, detectors and signal processing enable innovative telescope/system architectures with break-through performance.
Unfortunately, NASA's budget for Astrophysics is unlikely to be able to support the funding required for the 8-m to 16-m telescopes that have been studied for the follow-on to JWST using similar development/assembly approaches without accounting for too large of a portion of the Astrophysics Division's budget. Consequently, we have been examining the feasibility of developing an "Evolvable Space Telescope" that would be 3 to 4-m when placed on orbit and then periodically augmented with additional mirror segments, structures, and newer instruments to evolve the telescope and achieve the performance of a 16-m space telescope.
This paper reviews the technologies required for such a mission, identifies candidate architectures, and discusses different science measurement objectives for these architectures.

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338.43 – Advanced Mirror Technology Development (AMTD) Project: 3.0 Year Status

Advanced Mirror Technology Development (AMTD) is a funded NASA Strategic Astrophysics Technology project. Begun in 2011, we are in Phase 2 of a multi-year effort. Our objective is to mature towards TRL6 critical technologies needed to produce 4-m or larger flight-qualified UVOIR mirrors by 2018 so that a viable astronomy mission can be considered by the 2020 Decadal Review. The developed technology must enable missions capable of both general astrophysics and ultra-high contrast observations of exoplanets. Just as JWST's architecture was driven by launch vehicle, a future UVOIR mission's architecture (monolithic, segmented or interferometric) will depend on capacities of future launch vehicles (and budget). Since we cannot predict the future, we must prepare for all potential futures. Therefore, we are pursuing multiple technology paths. AMTD uses a science-driven systems engineering approach. We mature technologies required to enable the highest priority science AND result in a high-performance low-cost low-risk system. One of our key accomplishments is that we have derived engineering specifications for advanced normal-incidence monolithic and segmented mirror systems needed to enable both general astrophysics and ultra-high contrast observations of exoplanets missions as a function of potential launch vehicle and its inherent mass and volume constraints. Another key accomplishment is that we have matured our technology by building and testing hardware. To demonstrate stacked core technology, we built a 400 mm thick mirror. Currently, to demonstrate lateral scalability, we are manufacturing a 1.5

meter mirror. To assist in architecture trade studies, the Engineering team develops Structural, Thermal and Optical Performance (STOP) models of candidate mirror assembly systems including substrates, structures, and mechanisms. These models are validated by test of full- and subscale components in relevant thermo-vacuum environments. Specific analyses include: maximum mirror substrate size, first fundamental mode frequency (i.e., stiffness) and mass required to fabricate without quilting, survive launch, and achieve stable pointing and maximum thermal time constant.

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338.44 – Future Gravitational-Wave Missions

In November 2013, the European Space Agency (ESA) selected the science theme, the “Gravitational Universe,” for its third large mission opportunity, known as L3, under its Cosmic Vision Programme. The planned launch date is 2034. ESA is considering a 20% participation by an international partner, and NASA's Astrophysics Division has indicated an interest in participating. We have studied the design consequences of a NASA contribution, evaluated the science benefits and identified the technology requirements for hardware that could be delivered by NASA.

The European community proposed a strawman mission concept, called eLISA, having two measurement arms, derived from the well studied LISA (Laser Interferometer Space Antenna) concept. The US community is promoting a mission concept known as SGO Mid (Space-based Gravitational-wave Observatory Mid-sized), a three arm LISA-like concept. If NASA were to partner with ESA, the eLISA concept could be transformed to SGO Mid by the addition of a third arm, augmenting science, reducing risk and reducing non-recurring engineering costs. The characteristics of the mission concepts and the relative science performance of eLISA, SGO Mid and LISA are described. Note that all results are based on models, methods and assumptions used in NASA studies.

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338.45 – A Giant Leap Towards a Space-based Gravitational-Wave Observatory: LISA Pathfinder, the LISA Test Package, and ST7-DRS

The science case for a space-based gravitational wave instrument observing in the milliHertz band covers a wide area of topics in astrophysics and fundamental physics including galaxy formation and evolution, black hole growth, compact object demographics, gravitational physics, and cosmology. This strong science case is largely responsible for the high rankings received by the Laser Interferometer Space Antenna (LISA) mission in major reviews in both the US and Europe. A key element of the development of LISA is the LISA Pathfinder (LPF) technology demonstrator mission, which will launch in the coming year. Led by ESA and a consortium of European national agencies and with a minority contribution from NASA, LPF will demonstrate several key technologies for the LISA concept. LPF includes two scientific payloads: the European LISA Technology Package (LTP) and the NASA-provided ST7-DRS. The mission will place two test masses in drag-free flight and measure the relative acceleration between them. This measurement will validate a number of technologies that are critical to LISA-like gravitational wave instruments including sensing and control of the test masses, drag-free control laws, micro-Newton thrusters, and picometer-level laser metrology. We will present an overview of the LISA Pathfinder mission, the LTP and ST7-DRS payloads, and their expected impact on the larger effort to realize a space-based gravitational wave observatory.

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338.46 – Commissioning COSMOS: Detection of Lithium in Young Stars in Lupus 3 through Multi-Object Spectroscopy

COSMOS, a multi-object spectrograph and imager, is a new instrument on the Blanco 4-meter telescope at the Cerro Tololo Inter-American Observatory. In order to demonstrate the instrument's operations during commissioning, we used COSMOS, its red grism and three custom slit masks to conduct a spectroscopic survey of the star-forming core of the Lupus 3 dark cloud in an effort to detect the presence of Lithium in the T Tauri stars that have been previously identified in that region. We detected the Li I 6708 Angstrom resonance transition in several (but not all) stars that were observed, consistent with prior studies that have observed Lithium in other young stars at the center of the Lupus 3 dark cloud and in other star-forming regions. These results also demonstrate the ability of COSMOS to significantly reduce the time required to complete spectroscopic surveys, relative to single-object instruments.

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338.47 – SubLymE: The Sub-Lyman α Explorer

The Sub-Lyman α Explorer (SubLymE) is a proposed Small Explorer mission. It will provide multi-color imaging in the 102 – 120 nm spectral window with 2 arc second resolution and a field of view of 7 arc minutes. Arc second class astronomical imaging has never been done in this bandpass previously. SubLymE will enable a host of previously impossible astronomical observations but its optical design and operational planning have been optimized around these key projects. 1) Directly measure the Lyman continuum flux from low-redshift galaxies to quantify the mean f^{esc} and determine the stellar contribution to the ionization of the intergalactic medium during the epoch of re-ionization and the modern universe. 2) Conduct a deep survey of local galaxies to identify and quantify the role of O stars in their energy-mass and chemical cycles and their interaction with the circumgalactic medium. 3) Map star forming regions in the Milky Way and Magellanic clouds to understand the physics in their proto-planetary disks at the distances (< 10 AU) which will become their future habitable zones. 4) Observe all local K and M dwarfs known to host exo-planets to quantify the ultraviolet environment in which their planetary atmospheres must exist. 5) Map the energetics of supernova remnants in the primary cooling line of hot gas (O VI 103.2 nm) to quantify their contributions to the mass-energy-chemical cycles in galaxies . Following the completion of the planned surveys, we propose an ongoing guest observer program for SubLymE.

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338.48 – Changes to the Spectral Extraction Algorithm at the Third COS FUV Lifetime Position

Due to the effects of gain sag on flux on the COS FUV microchannel plate detector, the COS FUV spectra will be moved in February 2015 to a pristine location on the detector, from Lifetime Position 2 (LP2) to LP3. The spectra will be shifted in the cross-dispersion (XD) direction by -2.5", about -31 pixels, from the original LP1. In contrast, LP2 was shifted by +3.5", about 41 pixels, from LP1. By reducing the LP3-LP1 separation compared to the LP2-LP1 separation, we achieve maximal spectral resolution at LP3 while preserving more detector area for future lifetime positions. In the current version of the COS boxcar extraction algorithm, flux is summed within a box of fixed height that is larger than the PSF. Bad pixels located anywhere within the extraction box cause the entire column to be discarded. At the new LP3 position the current extraction box will overlap with LP1 regions of low gain (pixels which have lost >5% of their sensitivity). As a result, large portions of spectra will be discarded, even though these flagged pixels will be located in the wings of the profiles and contain a negligible fraction of the total source flux. To avoid unnecessarily discarding columns affected by such pixels, an algorithm is needed that can judge whether the effects of gain-sagged pixels on the extracted flux are significant. The "two-zone" solution adopted for pipeline use was tailored specifically for the COS FUV data characteristics: First, using a library of 1-D spectral centroid ("trace") locations, residual geometric distortions in the XD direction are removed. Next, 2-D template profiles are aligned with the observed spectral image. Encircled energy contours are calculated and an inner zone that contains 80% of the flux is defined, as well as an outer zone that contains 99% of the flux. With this approach, only pixels flagged as bad in the inner 80% zone will cause columns to be discarded while flagged pixels in the outer zones do not affect extraction. Finally, all good columns are summed in the XD direction to obtain a 1-D extracted spectrum. We present examples of the trace and profile libraries that are used in the two-zone extraction and compare the performance of the two-zone and boxcar algorithms.

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338.49 – Planning Efficient NIRSpec MSA Observations

It is projected that JWST's NIRSpec Microshutter Array (MSA), which will provide simultaneous multi-object spectroscopy capability for 100+ sources, will be the most heavily used mode of the NIRSpec instrument. Efficient observational plans for the NIRSpec MSA mode are difficult to make manually for several reasons - target positions must be computed with a high degree of accuracy (including optical distortions of the telescope and instrument fore-optics, and correction for observatory motion relative to the target) to avoid the fixed grid of MSA bars and place targets into shutters. Dithering is also highly recommended to mitigate the effects of detector artifacts and areas of poorer detector response. Given these considerations, designing and managing observations of a large number of targets through a set of dithers is made easier and more efficient for the general observer through the use of the MSA Planning Tool (MPT) in APT. We will discuss the recent developments in MPT and introduce a custom MSA observation planner which we call the "interactive planner". The effect of specific parameter choices on multiplexing efficiency in certain science cases is demonstrated. Finally, we describe how members of the community may provide input to the development process.

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338.50 – Potential Impacts of *ASTRO-H* on the Studies of Accreting White Dwarf Binaries

Interacting binaries in which a white dwarf accretes material from a companion - cataclysmic variables (CVs) in which the mass loss is via Roche-lobe overflow, and symbiotic stars in which the white dwarf captures the wind of a late type giant - are important populations of X-ray sources. Accretion onto the white dwarf surface often creates shocks with temperatures in the 10-50 keV range. If the post-shock region stays optically thin, it produces multi-temperature plasma emission over the medium to hard X-ray band (~0.5-50 keV). This makes them well-matched to the capabilities of the upcoming *ASTRO-H* mission, which will allow high-resolution spectroscopy in the 0.3-10 keV range with the microcalorimeter instrument, Soft X-ray Spectrometer (SXS), and simultaneous imaging spectroscopy in the 5-80 keV range with the Hard X-ray Imager (HXI). We will highlight several areas in which *ASTRO-H* can make unique contributions to the studies of these binaries. For example, X-ray emitting plasma in many of these systems are expected to have such high densities that only the SXS can provide density diagnostics. The prominent Fe K lines will allow dynamical studies of the X-ray emitting plasma for which velocities of order 1,000 km s^{-2} are expected. Finally, we discuss the potential of *ASTRO-H* to study the reflection off the white dwarf surface, both via the continuum bump observable with the HXI and the 6.4 keV fluorescent iron line with the SXS. For near Chandrasekhar-mass white dwarfs, the gravitational redshift of the latter is within reach of the instrumental capability and may provide the best direct measurement of their masses.

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339 – Laboratory Astrophysics Posters

339.01 – Transition Probabilities of the Rare Earth Neutral Lanthanum

In continuation of a long-standing project to measure transition probabilities for rare earth elements, La i is currently being studied. Transition probabilities of the rare earths and other elements are determined in order to assist astronomers in making stellar spectroscopy more quantitative. Atomic spectroscopy is a key tool for astronomers as it provides nearly all the details about the physics and chemistry of the universe outside of our solar system. Rare earth elements tend to have complex electronic structure due to their open 4f, 5d, 6s, and 6p shells. This leads to a rich spectrum throughout the ultraviolet, visible and near-infrared, making them very accessible elements for study in stellar photospheric spectra. A transition probability is the probability per unit time for a transition to occur between an upper level and a lower level. The process for measuring transition probabilities is by using the well-established technique of time-resolved laser-induced fluorescence to measure the radiative lifetimes for each upper level. This is then combined with branching fractions measured using a 1m high-resolution Fourier Transform Spectrometer. Radiative lifetimes for ~70 upper levels of neutral La along with their associated branching fractions will be reported, resulting in the determination of several hundred new transition probabilities. These transition probabilities will assist astronomers in analyzing the chemical compositions of older, cooler stars which give insight into the origins of the chemical elements. This work supported by by NSF grant AST-1211055 (JEL & EDH) and by the NSF REU program (AJP).

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339.02 – Improved log(gf) Values for Lines of V I and V II, New Vanadium Abundances in the Sun and the Metal-Poor Star HD 84937

New emission branching fraction measurements for 836 lines of the first spectrum of vanadium (V I) and 203 lines of V II are determined from hollow cathode lamp spectra recorded with the National Solar Observatory 1m Fourier transform spectrometer (FTS) and a high resolution echelle spectrometer. The branching fractions are combined with new radiative lifetimes from laser induced fluorescence measurements to determine accurate absolute atomic transition probabilities for 1039 lines of V I and V II. The FTS data are also used to extract new hyperfine structure *A* coefficients for both spectra. These new laboratory data are applied to determine the V abundance in the Sun and metal-poor star HD 84937, yielding log ε(V) = 3.96 (σ = 0.04) based on 93 V I lines and log ε(V) = 1.89 (σ = 0.07) based on nine V I lines respectively, and yielding log ε(V) = 3.95 (σ = 0.05) based on 15 V II lines and log ε(V) = 1.87 (σ = 0.07) based on 68 V II lines respectively[1-3].
1. Wood et al., ApJS 214:18 (2014), 2. Den Hartog et al. ApJS in press (2014), 3. Lawler et al. ApJS submitted (2014). This work is supported by NASA grant NNX10AN93G (JEL), NSF AST-1211055 (EDH & JEL), and NSF AST-1211585 (CS).

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339.03 – Analysis of Fe V and Ni V Wavelength Standards in the Vacuum Ultraviolet

The recent publication[1] by J.C. Berengut et al. tests for a potential variation in the fine-structure constant in the presence of high gravitational potentials through spectral analysis of white-dwarf stars.
The spectrum of the white-dwarf star studied in the paper, G191-B2B, has prominent Fe V and Ni V lines, which were used to determine any variation in the fine-structure constant via observed shifts in the wavelengths of Fe V and Ni V in the vacuum ultraviolet region. The results of the paper indicate no such variation, but suggest that refined laboratory values for the observed wavelengths could greatly reduce the uncertainty associated with the paper's findings.
An investigation of Fe V and Ni V spectra in the vacuum ultraviolet region has been conducted to reduce wavelength uncertainties currently limiting modern astrophysical studies of this nature. The analyzed spectra were produced by a sliding spark light source with electrodes made of invar, an iron nickel alloy, at peak currents of 750-2000 A. The use of invar ensures that systematic errors in the calibration are common to both species. The spectra were recorded with the NIST Normal Incidence Vacuum Spectrograph on phosphor image plate and photographic plate detectors. Calibration was done with a Pt II spectrum produced by a Platinum Neon Hollow Cathode lamp.
[1] J. C. Berengut, V. V. Flambaum, A. Ong, et al Phys. Rev. Lett. 111, 010801 (2013)

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339.04 – Improved and Expanded Near-IR Oscillator Strengths for Fe-group Elements

The use of modern experimental techniques, including LIF lifetime and FTS branching fraction measurements, has significantly increased the scope and reliability of laboratory atomic transition probabilities in the UV and visible. However, the combination of these techniques is problematic in the IR, a region of increasing importance due to improved detector, spectrometer, and telescope technologies. The result is a significant gap between the capabilities to record new IR astronomical spectra and the data needed to sufficiently understand and analyze them. To aid in closing this gap, we are developing new laboratory techniques to measure improved and expanded sets of oscillator strengths in the near-IR ($\lambda \approx 1$-$5\ \mu m$), with a primary focus on the Fe-group elements. A description of the methods proposed and their applicability will be presented. Input from the astronomical community is essential in order to focus the research on those lines and atomic species representing the greatest near-IR atomic data needs.

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340 – Results from the SDSS-III/APOGEE Survey Posters

340.01 – A Puzzling Li-rich Red Giant in the APOGEE Field

We report on a spectroscopic study of the unusual Li-rich red giant (RG) recently discovered in NGC 6819. This star was observed by the Apache Point Observatory Galactic Evolution Experiment (APOGEE) survey as part of the survey's calibration cluster sample. We use the high-resolution, near-infrared APOGEE spectrum to address its questionable cluster membership and test the hypothesis that Li was regenerated by nuclear processes and mixed to the surface. Previously reported [Fe/H] and radial velocity (RV) of the Li-rich star are consistent with cluster membership, and the star's optical and infrared colors place it on the cluster's red giant branch (RGB), below the luminosity bump. Most models of internal Li regeneration on the RGB can only explain Li-rich stars at the luminosity bump, but the currently favored model for the Li-rich star is a relatively new variation on Li regeneration that can explain the star's lower RGB position. This model predicts that the ratio of 12C/13C at the stellar surface should be reduced compared to normal Li-poor RGs, a signature we sought to measure. However, the Li-rich star's recently reported asterosesmic properties are inconsistent with cluster membership. Specifically, the log g inferred from asteroseismology is significantly lower than that of similar RGs in the cluster. We find the membership question to be unresolved with our analysis — our spectroscopic measurement of surface gravity confirms the asteroseismic result, but the detailed abundances and RVs that we measure are still consistent with cluster membership. Our Li-enrichment test is more conclusive. We find a C/N ratio that demonstrates that Li dilution should have occurred, but the 12C/13C is consistent with normal dredge-up and inconsistent with Li-enrichment mechanisms that require unusually deep mixing.

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340.02 – A Pipeline for the Analysis of APOGEE Spectra Based on Equivalent Widths

The Apache Point Galactic Evolution Experiment (APOGEE) forms part of the third Sloan Digital Sky Survey and has obtained high resolution, high signal-to-noise infrared spectra for ~1.3 x 10^5 stars across the galactic bulge, disc and halo. From these, stellar parameters are derived together with abundances for various elements using the APOGEE Stellar Parameters and Chemical Abundance Pipeline (ASPCAP). In this poster we report preliminary results from application of an alternative stellar parameters and abundances pipeline, based on measurements of equivalent widths of absorption lines in APOGEE spectra. The method is based on a sequential grid inversion algorithm, originally designed for the derivation of ages and elemental abundances of stellar populations from line indices in their integrated spectra. It allows for the rapid processing of large spectroscopic data sets from both current and future surveys, such as APOGEE and APOGEE 2, and it is easily adaptable for application to other very large data sets that are being/will be generated by other massive surveys of the stellar populations of the Galaxy. It will also allow the cross checking of ASPCAP results using an independent method. In this poster we present preliminary results showing estimates of effective temperature and iron abundance [Fe/H] for a subset of the APOGEE sample, comparing with DR12 numbers produced by the ASPCAP pipeline.

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Institution(s): *1. Apache Point Observatory and New Mexico State University, 2. Dunlap Institute for Astronomy and Astrophysics, University of Toronto, 3. Indiana University, 4. Instituto de Astrofsica de Canarias, 5. Johns Hopkins University, 6. Liverpool John Moores University, 7. National Optical Astronomy Observatory, 8. New Mexico State University, 9. Observatorio Nacional, 10. Ohio State University, 11. Penn State University, 12. Texas Christian University, 13. University of Michigan, 14. University of Texas at Austin, McDonald Observatory, 15. University of Virginia*

340.03 – The Open Cluster Chemical Abundances and Mapping (OCCAM) Survey: Detailed Age and Abundance Gradients using DR12

We present detailed abundance results for Galactic open clusters as part of the Open Cluster Chemical Abundances and Mapping (OCCAM) Survey, which is based primarily on data from the Sloan Digital Sky Survey/ Apache Point Observatory Galactic Evolution Experiment. Using 100 open clusters from the uniformly observed complete SDSS-III/APOGEE-1 DR12 dataset, we present age and multi-element abundance gradients for the disk of the Milky Way. This work is supported by an NSF AAG grant AST-1311835.

Author(s): Peter M. Frinchaboy[8], Benjamin A. Thompson[8], Julia O'Connell[8], Brianne Meyer[8], John Donor[8], Steven R. Majewski[10], Jon A. Holtzman[4], Gail Zasowski[3], Timothy C. Beers[1], Rachael Beaton[10], Katia M. L. Cunha[6], Fred Hearty[7], David L. Nidever[9], Ricardo P. Schiavon[2], Verne V. Smith[5], Michael R. Hayden[4]
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340.04 – The APOGEE-1 Catalog of Keplerian Orbit Fits to RV Variable Sources

In its three years of operation, the Sloan Digital Sky Survey (SDSS-III) Apache Point Observatory Galactic Evolution Experiment (APOGEE-1) observed over 9000 stars which have a enough (≥7) unique, quality radial velocity measurements over a sufficient baseline to fit Keplerian orbits. In this catalog we present the best fit orbital parameters of these systems from our automated Keplerian orbit fitting pipeline. While many multiplicity and exoplanet surveys have focused on FGK dwarf stars and the solar neighborhood, our sample contains >3000 evolved stars (log g <3.5), as well as stars across the disk and into the halo. With a radial velocity precision of ~100 m/s, APOGEE can probe systems with close-in companions down to a few Jupiter-masses (10^{-3} $M_\odot$). In particular, our sample is well suited to comb the elusive brown-dwarf desert. Additionally, stellar parameters and chemical abundances will be available for many of the primary stars in our sample, allowing us to further probe the connection between a host star's abundance and the presence of companions. Finally, we present some of our most interesting systems with detected companions, as well as initial follow-up observations for a subset of these systems.

Author(s): Nicholas W. Troup[9], David L. Nidever[5], Scott W. Fleming[3], Rohit Deshpande[4], Suvrath Mahadevan[4], John P. Wisniewski[6], Matthew D. Shetrone[7], Arpita Roy[4], Nathan M. De Lee[2], Keivan Stassun[10], Joshua Pepper[1], Duy Cuong Nguyen[8], Fred Hearty[4], Jennifer Sobeck[9], Steven R. Majewski[9]
Institution(s): *1. Lehigh University, 2. Northern Kentucky University, 3. Space Telescope Science Institute, 4. The Pennsylvania State University, 5. University of Michigan, 6. University of Oklahoma, 7. University of Texas, 8. University of Toronto, 9. University of Virginia, 10. Vanderbilt University*

340.05 – Two for the Price of One: SB2s in the SDSS-III/APOGEE Survey

We present a catalog of double-lined spectroscopic binaries (SB2s) identified in H-band spectra from the SDSS-III Apache Point Galactic Evolution Experiment (APOGEE). The APOGEE survey utilizes high-resolution, high-signal-to-noise, multi-epoch, H-band spectra of primarily red giant branch stars to study the chemical and dynamical history of the Milky Way Galaxy. In order to identify the SB2 sample, we searched the data for double and triple peaks in the radial velocity cross-correlation functions (RVCCF) obtained through comparison of the observed spectra to synthetic template spectra covering a wide range of stellar parameters. We also consider the singular value decomposition (SVD) method to derive line broadening profiles and search for SB2s. The SB2 identification algorithm will be applied to all data from the APOGEE-2 survey so that SB2 systems are automatically flagged. APOGEE's multi-epoch spectroscopy of SB2s yields dynamically measured mass ratios and, in the case of eclipsing systems, facilitates determination of the true masses and radii. Results for some of the more remarkable SB2 systems will be presented, as will statistics with respect to the SB2 fraction in a large spectroscopic survey like APOGEE.

Author(s): S. Drew Chojnowski[3], Duy Cuong Nguyen[10], David L. Nidever[8], Gail Zasowski[1], Chad F. Bender[5], Nicholas William Troup[11], Timothy C. Beers[9], Nathan M. De Lee[4], Scott W. Fleming[6], Peter M. Frinchaboy[7], Ana García Pérez[11], Fred R. Hearty[5], Jon A. Holtzman[3], Steven R. Majewski[11], Ricardo P. Schiavon[2]
Institution(s): *1. Johns Hopkins University, 2. Liverpool John Moores University, 3. New Mexico State University, 4. Northern Kentucky University, 5. Pennsylvania State University, 6. Space Telescope Science Institute, 7. Texas Christian University, 8. University of Michigan, 9. University of Notre Dame, 10. University of Toronto, 11. University of Virginia*
Contributing team(s): APOGEE Team

340.06 – A Study of Statistical Binaries with SDSS/APOGEE

We present findings from a multiplicity study of stars found in the Sloan Digital Sky Survey/Apache Point Galactic Evolution Experiment (SDSS/APOGEE) program. The SDSS/APOGEE program uses high-resolution near-infrared spectroscopy to probe the evolution of the Milky Way galaxy. From these data, we searched for close binary candidates statistically by analyzing the radial velocity scatter of each target. We compare the results from this statistical method against suspected binaries in the sample which have robust orbital fits to measure detection sensitivity of our technique.

Author(s): Duy Cuong Nguyen[5], Joleen K. Carlberg[1], Nicholas William Troup[6], David L. Nidever[4], Nathan M. De Lee[2], Scott Suriano[6], Apurva Oza[6], Fred R. Hearty[3], Steven R. Majewski[6]
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341 – Relativistic Astrophysics, Gravitational Lenses & Waves Posters

341.01 – A Detailed Study of Contamination in Deep Rapid Searches for Gravitational Wave Optical Counterparts

The first direct detection of gravitational waves (GW) by the Advanced LIGO/VIRGO (aLIGO/VIRGO) collaboration is expected to occur within the next few years. In order to maximize the science gains from such a detection it is essential that we identify an electromagnetic counterpart. One of the most promising counterparts is the so-called “kilonovae,” a fast-evolving (t ~ days) and faint (z ~ 24 AB mag) optical transient powered by the radioactive decay of r-process elements generated in the merger. However, the poor initial localization of aLIGO/VIRGO (~ 100 sq. deg.) demand the use of wide-field telescopes. Furthermore, the cadences and depths used by current and future wide-field optical surveys (e.g. PTF/ZTF, PANStarrs, LSST) are sub-optimal for kilonovae detection. We present our attempts to tackle these issues by investigating the theoretical and practical issues associated with optical follow-up of an aLIGO/VIRGO GW event. This includes a systematic study of the potential contaminant population and their impact on kilonovae detectability in simulated observations. We show that kilonovae can remain separated from contaminants by the virtue of their red colors (i - z > 0.5) and short timescales. This theoretical analysis will be tested against observations obtained by the DECam wide-field imager on the CTIO Blanco 4m telescope. These data attempt to simulate the wide area coverage (~ 70 sq. deg.) and rapid cadence (two visits per night in i,z) necessary for targeted GW follow-up and will provide an excellent test bed for understanding the practical issues associated with this endeavor. This work is supported in part by the NSF GRFP grant DGE1144152.

Author(s): Philip Cowperthwaite[1], Edo Berger[1], Ryan Chornock[3], Wen-fai Fong[2]
Institution(s): *1. Harvard University, 2. University of Arizona, 3. University of Ohio*

341.02 – Testing new technologies for the LISA Gravitational Reference Senso

LISA will directly observe low-frequency gravitational waves emitted by sources ranging from super-massive black hole mergers to compact galactic binaries. A laser interferometer will measure picometer changes in the distances between free falling test masses separated by millions of kilometers. A test mass and its associated sensing, actuation, charge control and caging subsystems are referred to as a gravitational reference sensor (GRS). The demanding acceleration noise requirement of < 3×10^{-15} m/sec^{2}Hz$^{1/2}$ for the LISA GRS has motivated a rigorous testing campaign in Europe and a dedicated technology mission, LISA Pathfinder, scheduled for launch in the summer of 2015. At the University of Florida we are developing a nearly thermally noise limited torsion pendulum for testing GRS technology enhancements and for understanding the dozens of acceleration noise sources that affect the performance of the GRS. This experimental facility is based on the design of a similar facility at the University of Trento, and consists of a vacuum enclosed torsion pendulum that suspends mock-ups of the LISA test masses, surrounded by electrode housings. Some of the technologies that will be demonstrated by this facility include a novel TM charge control scheme based on ultraviolet LEDs, an all-optical TM position and attitude sensor, and drift mode operation. This presentation will describe the design of the torsion pendulum facility, its current acceleration noise performance, and the status of the GRS technologies under development.

Author(s): John Conklin[1], Andrew Chilton[1], Taiwo Olatunde[1], Stephen Apple[1], Giacomo Ciani[1], Guido Mueller[1]
Institution(s): *1. University of Florida*

341.03 – Superluminal Sweeping Spot Pair Events in Astronomical Settings

Sweeping beams of light can cast spots that move superluminally across scattering surfaces. Such faster-than-light speeds are well-known phenomena that do not violate special relativity. It is shown that under certain circumstances, superluminal spot pair creation and annihilation events can occur that provide unique information to observers. These spot pair events are not particle pair events -- they are the sudden creation or annihilation of a pair of relatively illuminated spots on a scattering surface. Astronomical settings where superluminal spot pairs might be found include Earth's Moon, passing asteroids, pulsars, and variable nebula. Potentially recoverable information includes three dimensional imaging, relative geometric size factors, and distances.

Author(s): Robert J. Nemiroff[1]
Institution(s): *1. Michigan Technological Univ.*

341.04 – Using the null stream approach to find sky position of PTA sources

A null stream is constructed from the timing residuals of three pulsars by noting that the same source polarization amplitudes appear in the data stream from each pulsar. This is exploited by taking linear combinations of pulsar data streams and factoring them in terms of the polarization amplitudes (in turn based on the “beam pattern functions”).

Null stream mapping of gravitational wave sources has been described for LIGO and LISA. It relies on the fact that there are correlated gravitational wave signals between detectors. The underlying premise of the null stream construction is that for a collection of pulsars observing the same source, the gravitational wave signal is common to all pulsars in the array, but modified by geometric factors related to the relative position of the source on the sky. Linear combinations of a set of individual pulsar data streams can be shown to be a two-parameter family (the two sky position angles of the source) that can be minimized to determine the location of the source on the sky. In noise free data, it will be a true nulling, by definition; in the presence of noise the null stream will simply change the character of the spectrum by suppressing features that are related to the gravitational wave signal. The details of these calculations will be presented in terms of known pulsar timing residuals. We show how multiple sub-arrays of pulsars affect the pointing accuracy and suggest optimal methods for combining pulsars based on their angular separation.

Author(s): Jeffrey S. Hazboun[2], Shane L Larson[1]
Institution(s): *1. Center for Interdisciplinary Exploration and Research in Astrophysics, Northwestern University, 2. Utah State University*

341.05 – BayesWave: Bayesian Inference for Gravitational Wave Bursts and Instrument Glitches

A central challenge in gravitational wave astronomy is identifying weak signals in the presence of non-stationary and non-Gaussian noise. The separation of gravitational wave signals from noise requires good models for both. Searches for "un-modeled" transient signals are strongly impacted by the methods used to characterize the noise. The BayesWave algorithm uses a multi-component, variable dimension, parameterized noise model that explicitly accounts for non-stationarity and non-Gaussianity in data from interferometric gravitational wave detectors. Instrumental transients (glitches) and burst sources of gravitational waves are modeled using a Morlet-Gabor continuous wavelet basis. This method can be applied to several challenges in gravitational wave astronomy. It can be used to distinguish astrophysical signals from instrumental artifacts; reconstruct the spectrum, waveform, and source location of observed signals; and quickly characterize noise contamination in the data. Currently, the algorithm is being applied to detector characterization studies as well as a wide range of gravitational wave source studies, including generic gravitational wave bursts, supernovae, and compact object mergers.

Author(s): Joey Shapiro Key[4], Neil Cornish[2], Tyson Littenberg[3], Jonah Kanner[1]
Institution(s): *1. California Institute of Technology, 2. Montana State University, 3. Northwestern University, 4. University of Texas at Brownsville*

341.06 – Radiation-dominated, relativistic jets and their boundary layers

The energetics of certain astrophysical jets, such as those launched from the progenitors of long gamma-ray bursts and super-Eddington tidal disruption events, are likely dominated by radiation. In the limit that the outflow is optically thick, the shear boundary layer that develops between the jet and the ambient medium is mediated by radiation viscosity. We use the relativistic equations of radiation hydrodynamics in the viscous limit, accurate to first order in the mean-free path of a photon, to describe the dynamics of the boundary layer. A set of boundary layer equations is derived and we solve them in a self-similar manner, demonstrating in the process how the compressibility of the fluid, the variation of the viscosity coefficient, and the relativistic nature of the velocity affect the structure and dynamics of the boundary layer. We apply the model to the case of *Swift* J1644+57, the recently-observed, jetted, super-Eddington tidal distruption event, in an attempt to place tighter constraints on the physical characteristics of the jet.

Author(s): Eric Robert Coughlin[1], Mitchell C. Begelman[1]
Institution(s): *1. JILA, University of Colorado at Boulder and National Institute of Standards and Technology*

341.07 – Rapid Monte Carlo Simulation of Gravitational Wave Galaxies

With the detection of gravitational waves on the horizon, astrophysical catalogs produced by gravitational wave observatories can be used to characterize the populations of sources and validate different galactic population models. Efforts to simulate gravitational wave catalogs and source populations generally focus on population synthesis models that require extensive time and computational power to produce a single simulated galaxy. Monte Carlo simulations of gravitational wave source populations can also be used to generate observation catalogs from the gravitational wave source population. Monte Carlo simulations have the advantes of flexibility and speed, enabling rapid galactic realizations as a function of galactic binary parameters with less time and compuational resources required. We present a Monte Carlo method for rapid galactic simulations of gravitational wave binary populations.

Author(s): Katelyn Breivik[1], Shane L Larson[1]
Institution(s): *1. Center for Interdisciplinary Exploration and Research in Astrophysics & Department of Physics and Astronomy, Northwestern University*

341.08 – Techniques for Analysis and Visualization of Black Hole Spacetimes in Numerical Relativity

The spin of a black hole is a quantity of astrophysical interest. For example, since radiative recoil "superkicks" depend on both the magnitudes and directions of the spins of the merging black holes, spin dynamics are important for determining the probability that merged remnant black holes will be ejected from their host galaxies. There is at present no generally accepted definition of quasi-local black hole spin in non-stationary spacetimes. Here we propose a measure of black hole spin based on an invariant curvature quantity known as the Coulomb scalar and our newly defined "spin scalar". We discuss the relationship of our procedure to other existing methods of computing the spin, including the isolated horizon approach.
Meanwhile, the technique of tendexes and vortexes has recently gained attention as a vehicle for visualization and analysis of strongly curved spacetimes [Owen et al., PRL 106:151101, (2011)]. By splitting the gravitational field into "electric" and "magnetic" components, this approach allows for a presentation of spacetime curvature in terms of field lines that is similar to the one familiar from electromagnetism. We will examine the connection between the tendex-vortex and spin scalar formalisms and present tendex-vortex illustrations of accretion onto a merging black hole binary system.

Author(s): Tehani K. Finch[1], John G. Baker[1], Bernard J. Kelly[1]
Institution(s): *1. NASA / GSFC*

341.09 – NANOGrav Millisecond Pulsar Observing Program

Gravitational waves from sources such as supermassive black hole binary systems are expected to perturb times-of-flight of signals traveling from pulsars to the Earth. The NANOGrav consortium aims to measure these perturbations

in high precision millisecond pulsar timing measurements and thus to directly detect gravitational waves and characterize gravitational wave sources. By observing pulsars over time spans of many years, we are most sensitive to gravitational waves at nanohertz frequencies.
In this presentation we describe the NANOGrav observing program. We presently observe an array of 45 millisecond pulsars, evenly divided between the Arecibo Observatory (for pulsars with declinations between -1 and 39 degrees) and the Green Bank Telescope (for other pulsars, with two pulsars overlapping with Arecibo). Observation of a large number of pulsars allows for searches of correlated perturbations between multiple pulsar signals, which will be crucial for achieving high-significance detection of gravitational waves in the face of uncorrelated noise (from gravitational waves and rotation noise) in the individual pulsars. As new high-quality pulsars are discovered, they are added to the program. Observations of each pulsar are made with cadence of 20 to 30 days, with observations of each pulsar in two separate radio bands. Arrival times for nearly all pulsars are measured with precision better than 1 microsecond (averaged over a typical observation of 20 minutes), and in the best cases the precision is better than 100 nanoseconds.
We describe the NANOGrav nine-year data release, which contains time-of-arrival measurements and high quality timing solutions from 37 pulsars observed over spans ranging between 0.7 to 9.3 years.

Author(s): David J. Nice[1]
Institution(s): *1. Lafayette College*
Contributing team(s): NANOGrav

341.10 – Forecasting the Observability and Demographics of Supermassive Black Holes in the Pulsar Timing Array Band

Pulsar Timing Array (PTA) experiments are currently setting limits on the gravitational wave emission in the nanohertz frequency band. The source of GW emission in this band is expected to be a population of binary supermassive black holes (SMBHs) that form following galactic mergers. However, there is still speculation on how the source population will be spread across the PTA frequency band. Using a new simulation, which incorporates the latest observational estimates of galaxy parameters, we investigate open questions around the stochastic nature of the GW signal, the resolvability of discrete binaries, and the presence of detectable electromagnetic counterparts to binaries that are currently or will soon be emitting GWs in the PTA band.

Author(s): Joseph Simon[2], Sarah Burke-Spolaor[1], Xavier Siemens[2]
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342 – Stellar Evolution and Stellar Population Posters

342.01 – Measuring Boron Abundances in Rapidly Rotating Early-B Stars

We discuss the modeling techniques we have developed to measure boron abundances using crowded, badly blended, and modest resolution UV spectra of rapidly rotating early-B stars. Hi-resolution echelle spectra of narrow-lined stars are first used as templates for improving the atomic data and spectral synthesis. This allows the same fitting techniques to then be used for the more blended spectra. We also present our results for boron abundances for a large sample of early-B stars and discuss implications for models of mixing in the envelopes of rapidly rotating stars.

Author(s): Charles R. Proffitt[1]
Institution(s): *1. Computer Sciences Corporation*

342.02 – The Sample Properties of Metallic-line, A-stars in SDSS, Data Release 8

It has been known for many years that some stars in the spectral range of mid-A to early-F show chemically peculiar spectral lines characterized by very weak absorption in the calcium and scandium lines and overly strong absorption in metallic lines (such as iron) compared to the spectral strength of hydrogen lines in the star. This Am effect is caused by photospheric differentiation and is manifest through a combination of gravitational settling and radiative levitation of the various elements in the quiescent atmosphere of non-convective, slowly rotating A-stars. We identify this effect in a large sample of field blue straggler stars from SDSS DR8, by comparing the strength of the CaII K line to that of metallic regions. We will present results for spatial and kinematic distribution of the Am sample and compare these distributions and specific frequency to the chemically normal sample of blue stragglers. These results will be used to help constrain the nature of stellar features such as the Monoceros stream of stars.

Author(s): Chloe Keeling[1], Ronald J. Wilhelm[1]
Institution(s): *1. University of Kentucky*

342.03 – Ultraviolet Synthetic Spectra for Three Lambda Bootis Stars

Lambda Boo-type stars are a group of late B to early F-type Population I dwarfs that show mild to extreme deficiencies of iron-peak elements (up to 2 dex), but their C, N, O, and S abundances are near solar. We show that the International

Ultraviolet Explorer (IUE) spectra (1280–3200 A) of Lambda Bootis, 29 Cygni (a "confirmed" Lambda Boo star), and Vega (a "mild" Lambda Boo star) can be fit remarkably well by single-temperature synthetic spectra. We computed the full resolution synthetic ultraviolet (UV) spectrum covering the IUE wavelength range using Gray's Stellar Spectral Synthesis Program SPECTRUM. To improve the synthetic spectra, we generated a grid of LTE atmosphere models with the appropriate stellar parameters using ATLAS9 and the existing Castelli and Kurucz 2004 models. One of the improvements of their opacity distribution functions (ODFs) is the addition to the line blanketing near 1400 A and 1600 A by the quasi-molecular absorptions of atomic hydrogen undergoing collisions with protons and other neutral hydrogen atoms. New-ODF fluxes reproduce the ultraviolet observations of Lambda Boo stars in a more realistic way than previous computations. We also constructed our own UV line list for the relevant set of absorption features. Modeling the UV line spectra of Lambda Boo stars allows us to confirm their published surface abundances, including CNO and the iron group elements. It also provides further insight into their photospheric conditions (e.g., T^{eff}, log g, [M/H], micro turbulent velocity, etc.). About 40 percent of the published Lambda Boo candidates have existing IUE spectra. We plan to follow this pilot study and perform UV spectral synthesis for all of them.

Author(s): Kwang-Ping Cheng[2], James E. Neff[3], Richard O. Gray[1], Christopher J. Corbally[4], Dustin Johnson[2], Erik Tarbell[2]
Institution(s): *1. Appalachian State University, 2. California State University, Fullerton, 3. College of Charleston, 4. Vatican Observatory*

342.04 – The Kinematics of Dwarf Carbon Stars

The presence of molecular carbon absorption bands in the spectra of main sequence dwarfs is remarkable, as these stars have not yet evolved through the helium-burning and dredge-up phases that deposit carbon in a stellar photosphere. Dwarf carbon stars are thus generally considered members of post-mass transfer binaries, with the main sequence star polluted by an evolved, often now invisible, companion. For decades only a handful were known. Now it is recognized that carbon dwarfs likely outnumber the better-understood giant carbon stars. Green (2013) has identified more than 700 carbon dwarfs from the Sloan Digital Sky Survey (SDSS). This large sample- distributed nearly evenly throughout the SDSS footprint- makes a study of stellar kinematics possible for dwarf carbon stars as a class.

We examine the proper motions and radial velocities of ~700 carbon dwarfs and compare to a sample of 2×10^4 non-carbon main sequence stars from the SDSS archive. The spectra of carbon dwarfs and giants can appear indistinguishable, and so the relatively faint carbon dwarfs are recognized only if they have a sufficiently large proper motion to exclude the possibility of their being distant giants. We build our non-carbon control sample by the same proper motion criteria and additionally require that the control stars match the carbon dwarf selection with respect to properties such as photometric colors. In order to examine the kinematics of a sample spread across a large portion of sky, we compare each carbon dwarf with a group of control stars separated from it by less than three degrees. Preliminary results suggest that carbon dwarfs' kinematics are similar to the distributions of their neighboring control stars. We will present the results of detailed tests, including an investigation of several carbon dwarfs with atypical radial velocities.

Author(s): Kathryn A. Plant[1], Bruce H. Margon[1], Puragra Guhathakurta[1], Constance M. Rockosi[1]
Institution(s): *1. University of California, Santa Cruz*

342.05 – The PTI Giant Star Angular Size Survey: Effective Temperatures & Linear Radii

We report new interferometric angular diameter observations of over 200 giant stars observed with the Palomar Testbed Interferometer (PTI). These angular diameters are combined with bolometric fluxes derived from detailed spectral energy distribution (SED) fits, to produce robust estimates of effective temperature (T_EFF). These SED fits include reddening estimates and are based upon fits of empirical spectral templates to literature photometry, and narrow-band photometry obtained at the Lowell 31" telescope. Over the range from G5III to M8III, T_EFF estimates are precise to 50K per spectral type. Radius estimates are limited by the improved Hipparcos estimates of van Leeuwen (2007) and are typically ~10% per star.

Author(s): Gerard van Belle[3], David R. Ciardi[2], Kaspar von Braun[3], Genady Pilyavsky[1]
Institution(s): *1. Arizona State University, 2. Caltech, 3. Lowell Observatory*

342.06 – Mid-Infrared Spectroscopy of M Giants from the Spitzer Space Telescope

Spitzer spectra of 20 naked M giants show complex structure with aborption from the SiO fundamental at 8 um, OH bands in the 14-18 um range, and water vapor in the 6-7 um range. The OH bands are strong enough (2.5% continuum to peak) to be seen in individual spectra. Both the SiO and OH band strengths depend only weakly on spectral class, and the scatter within each spectral class is substantial. The water vapor absorption is stronger in stars with spectral classes of M2 or later. It is also stronger in semi-regular variables and weaker in irregulars and stars with undetermined variability. These correlations suggest that water vapor absorption may be associated with stars on the asymptotic giant branch as opposed to first-ascent giants.

Author(s): Christopher Goes[1], Gregory C. Sloan[1], Ramses Ramirez[2], Kathleen E. Kraemer[3], Charles W. Engelke[3]
Institution(s): *1. CRSR, Cornell University, 2. Institute for Pale Blue Dots, Cornell University, 3. Institute for Scientific Research, Boston College*

342.07 – Lithium Abundance in M3 Red Giant

We present the abundance of lithium in the red giant star vZ 1050 (SK 291) in the globular cluster M3. A previous survey of giants in the cluster showed that like IV-101, vZ 1050 displays a prominent Li I 6707 \AA feature. vZ 1050 lies on the blue side of the red giant branch about 1.3 magnitudes above the level of the horizontal branch, and may be an asymptotic giant branch star. A high resolution spectrum of M3 vZ1050 was obtained with the ARC 3.5m telescope and the ARC Echelle Spectrograph (ARCES). Atmospheric parameters were determined using Fe I and Fe II lines from the spectrum using the MOOG spectral analysis program, and the lithium abundance was determined using spectrum synthesis.

Author(s): Rashad Givens[1], Catherine A. Pilachowski[1]
Institution(s): *1. Indiana University of Bloomington*

342.08 – Effects of Age and Metallicity on the RGB and AGB Luminosity

We look into the RGB and AGB luminosity as a function of age and metallicity of stellar populations. We also investigate the similarities and differences of RGB and AGB luminosity from several different isochrones and stellar evolutionary tracks. The outcome is of paramount importance in order to get the precise distance of galaxies using either the RGB tip luminosity or the Surface Brightness Fluctuation. We will present the uncertainties of distance measurements to the galaxies because of the significant disparities of RGB and AGB luminosity from several different isochrones and stellar evolutionary tracks.

Author(s): Hyun-chul Lee[1], Charles Cartwright [1]
Institution(s): *1. The University of Texas - Pan American*

342.09 – Using JVLA Observations of SiO Masers to Probe the Extended Atmosphere of an AGB Star: W Hydrae

The Asymptotic Giant Branch star W Hydrae (W Hya) is known to be a strong source of silicon monoxide (SiO) masers in its extended atmosphere. Jansky Very Large Array imaging observations obtained in February 2014 were used to target eleven SiO J=1-0 rotational transitions near 43 GHz. The vibrational ground state (v=0) lines for the 28SiO, 29SiO, and 30SiO isotopologues were successfully detected, as were the v=1,2,3 lines for 28SiO. Non-detections included the v=1,2 transitions for 29SiO and 30SiO, and the v=4 line for 28SiO. We will summarize the relative shape, size, and intensity of the emission regions of the detected transitions. We have discovered spatially extended ground-state 28SiO emission in a region located approximately 300 to 600 milliarcseconds (projected distance of 34 to 69 AU) from the star. We will discuss a saddle-like distribution and a small gradient in the velocity field for the 28SiO v=1 line, which may help to confirm the existence of a bipolar outflow in W Hya. Additionally, our results indicate that the observed transitions have differing spatial distributions. Peak 28SiO v=1,2,3 emission primarily occupies a region 12 – 42 mas (projected distance of 1.4 – 4.8 AU) west of the star, while the 29SiO and 30SiO isotopologues are located in disparate regions around 45 – 70 mas (5.2 – 8.1 AU) to the northwest of the star.
This work was sponsored by a grant from the National Science Foundation Research Experience for Undergraduate program to MIT Haystack Observatory.

Author(s): Patrick S. Kamieneski[1], Lynn D. Matthews[2]
Institution(s): *1. Bowdoin College, 2. MIT Haystack Observatory*

342.10 – Spectroscopy and Multi-Band Photometry of Yellow and Red Supergiants in M31 and M33

Recent supernova and transient surveys have revealed an increasing number of non-terminal stellar eruptions. Though the progenitor class of these eruptions includes the most luminous stars, little is known of the pre-supernova mechanics of massive stars in their most evolved state, thus motivating a census of possible progenitors. From surveys of evolved and unstable luminous star populations in nearby galaxies, we select a sample of supergiant candidates in M31 and M33 for review of spectral characteristics and spectral energy distributions. Since the position of intermediate and late-type supergiants on the color-magnitude diagram can be heavily contaminated by foreground dwarfs, we employ spectral classification and multi-band photometry from optical and near-infrared surveys to confirm membership. In this study, we present spectral types and discussion of spectral energy distributions of intermediate-type red and yellow supergiants in M31 and M33.

Author(s): Michael Gordon[1], Roberta M. Humphreys[1]
Institution(s): *1. Minnesota Institute for Astrophysics*

342.11 – An Infrared High Resolution Spectroscopic Abundance Study of the Metal-Poor Giant HD 122563

A high resolution, high signal-to-noise spectrum of the very metal-poor giant star HD 122563 has been obtained with the newly commissioned IGRINS H- and K-band high resolution (R = 40,000) spectrograph on the McDonald Observatory 2.7m Smith telescope. With complete spectral coverage in the range 1.5-1.8 and 1.9-2.4 microns and high signal-to-noise (S/N > 200) in the reduced spectrum, we have so far detected about 50
neutral-species transitions of elements Na, Mg, Al, Si, Ca, and Fe, as well as many transitions of OH and CO.
Assuming atmosphere parameters from the literature of this well-studied bright giant (Teff~4600K, log(g)~1.3) we have derived a metallicity of [Fe/H] = -2.8, in agreement with past results. The alpha-elements are enhanced: [(Mg,Si,Ca)/Fe] = +0.3 to +0.4. The OH lines yield an O abundance in good accord with past claims from analyses of the [O I] lines in the visible part of the spectrum. Study of other features in the IGRINS
spectrum is ongoing.
Support for this research from the US National Science Foundation (AST-1211585) and the The Scientific and Technological Research Council of Turkey (TÜBITAK, project No. 112T929) are acknowledged with thanks.

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342.12 – Empirical constraints of stellar evolution models using properties of the red clump and early-AGB bump in M31

The Red Clump (RC) and lesser-known early-AGB bump (AGBb) are recognizable features on the stellar color-magnitude diagram (CMD). The timescale of evolution along the red giant branch (RGB) and horizontal branch (HB) dictates the relative number of stars in each feature and the brightness at which they occur. Thus, they are sensitive to the various theoretical perscriptions employed by stellar evolution models for initial helium abundance, RGB mass loss, and convective overshooting. Previous work exploiting the utility of these features was done with Milky Way globular clusters; this work extends the investigation to an extragalactic environment using deep six-filter photometry from the PHAT survey in M31. We compare observed properties of the AGBb and RC with model predictions to empirically constrain input physics from the Padova stellar evolution models.
PHAT is supported by HST GO-12055 administered by NASA.

Author(s): Nell Byler[3], Philip Rosenfield[2], Morgan Fouesneau[1], Julianne Dalcanton[3]
Institution(s): *1. Max Planck Institute for Astronomy, 2. University of Padova, 3. University of Washington*
Contributing team(s): PHAT Collaboration

342.13 – Stellar Parameter Determination Using Bayesian Techniques.

Spectral energy distributions of stars covering the wavelength range from far UV to far IR can be used to derive stellar atmospheric parameters (effective temperature, surface gravity and iron abundance) with a high reliability. For this purpose we are using a method based on Bayesian statistics, which make use of all available photometric data for a given star to construct stellar parameter probability distribution function (PDF) in order to determine the expectation values and their uncertainties in stellar parameters. The marginalized probabilities allow us to characterize the constraint for each parameter and estimate the influence of the quantity and quality of the photometric data on the resulting parameter values. We have obtained low resolution spectroscopy of blue horizontal branch, blue straggler and normal main sequence A, B, G and F stellar parameter standard stars using the McDonald observatory, 2.1m telescope to constrain both synthetic and empirical stellar libraries like Atlas9, MARCS, MILES and Pickles across a wide range in parameter space. This calibration process helps to evaluate the correlations between different stellar libraries and observed data especially in the UV part of the spectrum. When the calibration is complete the Bayesian analysis can be applied to large samples of data from GALEX, SDSS, 2MASS,WISE etc. We expect significant improvements to luminosity classification, distances and interstellar extinction using this technique.

Author(s): Gemunu B Ekanayake[1], Ronald J. Wilhelm[1]
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342.14 – Studying Semi-Convection by Pseudo-Incompressible Spectral Element with Variable Diffusivity

The treatment and conditions of convection remain two of the weakest aspects of stellar evolution models despite substantial experimental, observational, and numerical effort. One particularly troubling aspect is the mixing that occurs when a fluid is marginally unstable to convection but stabilized by a composition gradient; this scenario is known as semi-convection. Much numerical and theoretical work has been done recently, and we've begun to understand this process phenomenologically but not yet quantitatively. Recent numerical work suggests that semi-convection takes the large-scale form of convective layers, which merge until they fill the simulated domain; however, this could be a failing of the the approximations made in these codes, in particular the approximations of incompressibility and non-variable diffusivity. We are writing a new code tailored to this problem which will eventually loosen both of these restrictions. We present some preliminary results, illustrating how the code compares with other similar codes and highlight some interesting features.

Author(s): Justin Brown[1], Pascale Garaud[1]
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342.15 – The Mass-Transfer Formation Frequency of Blue Straggler Stars in the Old Open Cluster NGC 188

The formation of blue straggler stars (BSSs), commonly categorized as stars bluer and brighter than the main sequence turnoff, has puzzled astronomers since their first detection over sixty years ago. The well-studied BSS population of the old (7 Gyr) open cluster NGC 188 has the potential to settle outstanding issues surrounding the frequency of different BSS formation mechanisms. NGC 188 contains 21 BSSs: 15 long-period single-lined binaries, two short-period double-lined binaries, and four non-velocity variables. We present results of the *Hubble Space Telescope* far-ultraviolet (FUV) ACS/SBC survey of the NGC 188 BSS population. This survey aims to detect white dwarf (WD) companions of BSSs that are indicative of a mass-transfer formation history. We directly detect FUV excesses consistent with four hot WD companions ($T^{\mathrm{eff}} \geq$ 12,000 K). We infer the presence of three additional WD companions with temperatures between 11,000–12,000 K. Since WDs cool as they age, these results indicate that seven BSSs formed through mass transfer within the past 400 Myr. These WD detections set a lower limit mass-transfer formation frequency of 33%. After taking into account other potential formation mechanisms we conclude that 14 long-period binary BSSs likely formed through mass transfer, setting a total NGC 188 BSS mass-transfer formation frequency of 67%. Comparing these results to a sophisticated *N*-body model of NGC 188 implies that binary population synthesis models underproduce mass transfer products, and the parameterization of stable mass transfer may need to be revisited. Finally, when comparing the optical CMD position of young BSSs to the zero-age main sequence (ZAMS), we find that distance from the ZAMS is not necessarily equivalent to BSS age. One must use caution before using standard single-star isochrones to age luminous BSSs.

Support for Program number 12492 was provided by NASA through a grant from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Incorporated, under NASA contract NAS5-26555. This work was funded by the National Science Foundation grant AST-0908082 to the University of Wisconsin-Madison.

Author(s): Natalie M. Gosnell[5], Robert D. Mathieu[6], Alison Sills[2], Aaron M. Geller[3], Nathan Leigh[1], Christian Knigge[4]
Institution(s): *1. American Museum of Natural History, 2. McMaster University, 3. Northwestern University, 4. University of Southampton, 5. University of Texas at Austin, 6. University of Wisconsin-Madison*

342.16 – Barium Enhancement in NGC 6819 Blue Stragglers

Possible formation pathways for blue straggler stars include mergers in hierarchical triple systems, stellar collisions during dynamical encounters, and mass transfer from a giant companion. Extensive work on the blue stragglers in the old open cluster NGC 188 (7 Gyr) has led to exciting discoveries including a binary secondary mass distribution peaked at 0.5 M^{Solar} and the detection of three young white dwarf binary companions. These indicate that mass transfer from an asymptotic giant branch star is the dominant mechanism for blue straggler formation in open clusters. Such mass transfer events should pollute the surface abundance of the blue straggler with nucleosynthesis products from the evolved donor. The other formation pathways, mergers and collisions, are predicted to produce no such enhancements. In an effort to move beyond NGC 188 and into other open clusters we present the first results of a surface abundance study of the blue stragglers in the intermediate-aged open cluster NGC 6819 (2.5 Gyr) using the Hydra multi-object spectrograph on the WIYN 3.5 m telescope. This part of our study centers on the s-process element barium as a tracer of formation via mass transfer. We compare the blue straggler surface abundance of barium to that of a sample of main-sequence stars in NGC 6819 and find multiple blue stragglers with anomalous abundances. Surprising, most of the blue stragglers with barium anomalies show no radial-velocity evidence for a companion. We gratefully acknowledge funding from the National Science Foundation under grant AST- 0908082 and the Wisconsin Space Grant Consortium.

Author(s): Katelyn Milliman[2], Robert D. Mathieu[2], Simon C. Schuler[1]
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342.17 – A Spectroscopic Study of Anomalous Stellar Populations in M67

A population of so-called "yellow straggler" stars occupy precarious color magnitude diagram positions in the old open cluster M67 that cannot be explained by standard single star evolution theory. These stars may have been formed by Roche lobe overflow mass transfer in close binary systems. We present new radial velocities and spectroscopic abundances of M67 yellow stragglers to test this hypothesis, and find that these objects possess a high binary frequency, but no enhancements of s-process elements that might be a smoking gun signature of mass transfer. Observations were conducted using the WIYN 3.5 m telescope in conjunction with the HYDRA spectrograph at Kitt Peak National Observatory. Support for this project was provided by NSF grants AST 09-08342, AST 0607567, and AST 1211699.

Author(s): Courtney McGahee[1], Jeremy R King[2], Constantine P. Deliyannis[3]

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342.18 – A spectroscopic and photometric study of post main sequence stars in M68

We present the results of the spectral analysis for 24 post main sequence stars in the metal poor globular cluster M68 ([Fe/H] = -2.23). Our sample includes lower red giant stars, red giant tip stars, red horizontal branch stars and blue horizontal branch stars, therefore spanning 4000 K in T^{eff}, and 3.0 log(*g*) space. This is the first high-resolution spectroscopic study sampling essentially all post-subgiant evolutionary stages of a very metal poor globular cluster. In the current effort, abundances and atmospheric parameters for all stars in our sample were derived using an internally consistent approach. Special consideration is given to blue horizontal branch stars, as they present a specific set of analytical challenges. Like earlier studies, we also find a small trend of metallicity and evolutionary state, but much less pronounced than before. Abundances of light elements are consistent among the evolutionary stages, while the *n*-capture elements exhibit traces of *r*-process enrichment in this cluster. The combination of these results is considered in the discussion of the evolutionary history of M68 and also the difficulties of deriving self-consistent atmospheric parameters over multiple evolutionary stages. Support for this research from the National Science Foundation (grat AST-1211585) is acknowledged with thanks.

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342.19 – Hunting the Most Distant Stars in the Milky Way

M giant stars offer our best opportunity to explore the outer reaches of the Galactic halo with today's modern wide-field surveys. While challenging to distinguish from the overwhelming number of nearby dwarf stars, when identified, M giants are powerful tracers of the structural and kinematic properties of the Milky Way's halo. Using optical and near-infrared photometry from the SDSS and UKIDSS surveys, we have collected a sample of 500 candidate M giants with estimated distances ranging from 30 to well over 200 kpc, spread over 4,000 sq. degrees. Our group has obtained spectroscopic observations on a fraction of these candidates, confirming the presence of M giants and measuring their radial velocities. We present our findings to date, which include the two most distant stars ever seen in the Milky Way, and discuss the implications of distant Milky Way stars on Λ-CDM formation models and mass estimates of the Milky Way. We gratefully acknowledge the support of NSF grants AST-1151462, AST-1109273 and AST-1255568.

Author(s): John J. Bochanski[6], Beth Willman[4], Nelson Caldwell[2], Robyn Ellyn Sanderson[3], Andrew A. West[1], Jay Strader[5], Warren R. Brown[2], Tobias Fritz[7], Nitya Kallivayalil[7]
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342.20 – The Radial Distribution of Asymptotic Giant Branch Stars in Nearby Dwarf Galaxies

Asymptotic giant branch (AGB) stars are evolved stars that can experience repeated episodes of mass loss and dust production. As such, they are drivers of galactic chemical enrichment and evolution. While AGB populations have been imaged in many nearby galaxies at optical wavelengths, optical imaging can miss up to 50% of this population due to extinction. Not only is a significant population of AGB stars unidentified in optical surveys, it also is unclear whether younger (and more massive) AGB stars are preferentially obscured. Thus, the distribution, radial profile, and, potentially, age gradient of this important class of stars is not well-constrained in galaxies. The DUST in Nearby Galaxies with Spitzer (DUSTiNGS) survey is a 3.6 and 4.5 µm IRAC imaging survey from the post-cryogen Spitzer mission designed to catalog the evolved stars in 50 nearby dwarf galaxies and identify the most luminous, variable AGB stars. The resulting catalog of the resolved stellar populations at infrared wavelengths provides the means to trace the spatial distribution of evolved stars in the host galaxies. In this study, we use the DUSTiNGS dataset to create radial stellar profiles in nine of the DUSTiNGS sample. We compare the radial distribution of the total evolved stellar populations to the distribution of both the intermediate aged AGB stars and the optically identified, older red giant branch (RGB) stars from Hubble Space Telescope archival images. Additionally, we derive elliptical parameters for seven of the systems from the infrared data and compare these to parameters previously derived from optical data.

Author(s): Mallory B. Mitchell[5], Kristen B. McQuinn[5], Martha L Boyer[4], Evan D. Skillman[5], Robert D. Gehrz[5], Greg Sloan[1], Iain McDonald[2], Martin Groenewegen[3]
Institution(s): *1. Cornell University, 2. Keele University, 3. Royal Observatory of Belgium, 4. Space Telescope Science Institution, 5. University of Minnesota*

342.21 – Chemical Abundances in the Small Magellanic Cloud

We analyze the distribution of both sulfur and oxygen in the neutral and ionized gas phases of the Magellanic Clouds. For the neutral gas, we use archival HST/STIS absorption line data toward O-star sightlines. To assess the metal content of the ionized gas, we analyze previously published HII region emission-line spectra of nebulae along the same or nearby lines of sight. In the neutral gas, we find that sulphur is strongly depleted compared to oxygen along a subset of sightlines. Additionally, for a small fraction of our dataset, we find that the oxygen content of the ionized gas may be slightly under-abundant compared to that of the neutral gas. Our findings support the idea that self-enrichment of HII regions by O stars does not have a significant impact on observed emission-line abundances of ionized gas. However, the implications of higher gas-phase metal abundances for the neutral ISM compared to HII regions may have important implications for our understanding of massive star winds and the distribution of metals in galaxies.

Author(s): Evan Lohn[1], Kiana Borjian[1], Jessica Werk[2]
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342.22 – On the Nature of Bright Infrared Sources in the Small Magellanic Cloud: Interpreting MSX through the Lens of Spitzer

We compare infrared observations of the Small Magellanic Cloud (SMC) by the Midcourse Space Experiment (MSX) and the Spitzer Space Telescope to better understand what components of a metal-poor galaxy dominate radiative processes in the infrared. The SMC, at a distance of ~60 kpc and with a metallicity of ~0.1-0.2 solar, can serve as a nearby proxy for metal-poor galaxies at high redshift. The MSX Point Source Catalog contains 243 objects in the SMC that were detected at 8.3 microns, the most sensitive MSX band. Multi-epoch, multi-band mapping with Spitzer, supplemented with observations from the Two-Micron All-Sky Survey (2MASS) and the Wide-field Infrared Survey Explorer (WISE), provides variability information, and, together with spectra from Spitzer for ~15% of the sample, enables us to determine what these luminous sources are. How many remain simple point sources? What fraction break up into multiple stars? Which are star forming regions, with both bright diffuse emission and point sources? How do evolved stars and stellar remnants contribute at these wavelengths? What role do young stellar objects and HII regions play? Answering these questions sets the stage for understanding what we will see with the James Webb Space Telescope (JWST).

Author(s): Kathleen E. Kraemer[1], G. C. Sloan[2]
Institution(s): *1. Boston College, 2. Cornell University*

342.23 – Identification of Red Supergiants in the Magellanic Clouds.

The number and characteristics of red supergiants (RSGs) in the low metallicity environment of the Large and Small Magellanic Clouds (LMC, SMC) provide tests of stellar evolutionary tracks for massive stars. One complication is identifying Magellanic members due to the contamination of foreground stars in the Milky Way. We used the colors and magnitudes from the 2MASS survey to identify RSG candidates in the LMC and SMC, and used the Anglo Australian Telescope coupled with the AAOmega spectrograph to take spectra of 325 LMC and 423 SMC RSG candidates. Using the Ca II triplet, we measured the radial velocity of each candidate by cross correlation and assigned membership. Methods along with physical properties of each star will be presented. We gratefully acknowledge support by the National Science Foundation through the REU program at Lowell Observatory and Northern Arizona University (AST-1004107) and through PM's grant AST-1008020.

Author(s): Brian Allan Barandi[2], Philip Massey[1], Emily M. Levesque[3]
Institution(s): *1. Lowell Observatory, 2. Northern Arizona University, 3. University of Boulder Colorado*

342.24 – DUSTiNGS Reveals Dust Production in Very Metal Poor Galaxies

The survey of DUST in Nearby Galaxies with Spitzer (DUSTiNGS) produced 3.6 and 4.5 µm images of 50 dwarf galaxies with a wide range in metallicity (-2.7 < [Fe/H] < -1 dex) to search for dust-producing stars. Dual-epoch imaging enabled us to identify >500 variable, dust-producing Asymptotic Giant Branch (AGB) stars, including 12 at [Fe/H] < -2 dex. We present the pulsation properties and estimate the dust production rates of these AGB candidates and find that these AGB stars are able to produce large amounts of dust at any metallicity. Our findings suggest that AGB stars contribute significantly to the total dust budgets of metal-poor, high-redshift galaxies.

Author(s): Martha L. Boyer[7], Kristen B. W. McQuinn[4], Pauline Barmby[12], Alceste Z Bonanos[8], Robert D. Gehrz[4], Karl D. Gordon[10], M. A. T. Groenewegen[9], Eric Lagadec[11], Daniel J Lennon[3], Massimo Marengo[5], Iain McDonald[6], Margaret Meixner[10], Evan D. Skillman[4], G. C. Sloan[2], George Sonneborn[7], Jacco Th. van Loon[1], Albert Zijlstra[6]
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343 – Variable Stars and White Dwarfs Posters

343.01 – Multi-mode Observations of Be Stars from the APOGEE and KELT Surveys

Combining astronomical surveys provides an opportunity to evaluate certain classes of phenomena by identifying objects serendipitously observed in multiple surveys. The APOGEE survey has obtained multiple infrared spectra for 226 Be stars. 68 of those stars were also observed by the KELT photometric survey. The broad R-band photometric KELT light curves have baselines of 6-8 years, and about 8,000 observations with a typical cadence of 20 minutes. Some of the objects observed by both surveys have simultaneous spectra and light curves, providing a unique look into the correlation between spectroscopic features and photometric variability. We use these data to examine the processes involved in Be star disk dissipation and renewal, to identify eclipsing systems, and to search for the signatures of nonradial pulsations.

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Institution(s): *1. Austin College, 2. Lehigh University, 3. New Mexico State University, 4. University of Oklahoma*

343.02 – VX Her: Eclipsing Binary System or Single Variable Star

VX Her is a pulsating variable star with a period of .4556504 days. It is believed to be part of an eclipsing binary system (Fitch et al. 1966). This hypothesis originated from Fitch seeing VX Her's minimum point on its light curve reaching a 0.7 magnitude fainter than normal and remaining that way for nearly two hours. If VX Her were indeed a binary system, I would expect to see similar results with a fainter minimum and a broader, more horizontal dip. Having reduced and analyzed images from the Southeastern Association for Research in Astronomy Observatory in Chile and Kitt Peak, as well as images from a 0.15m reflector at East Tennessee State University, I found that VX Her has the standard light curve of the prototype variable star, RR Lyrae. Using photometry, I found no differing features in its light curve to suggest that it is indeed a binary system. However, more observations are needed in case VX Her is a wide binary.

Author(s): Kathleen Perry[2], Michael Castelaz[2], Gary Henson[1], Andrew Boghozian[1]
Institution(s): *1. East Tennessee State University, 2. Pisgah Astronomical Research Institute*

343.03 – Lightcurve Analysis of Six Beta-Lyrae Type Variables

We present light curve analysis of six variable stars: NSVS 5344676, V1071 Her, NSVS 5508151, NSVS 9064159, NSVS 9091101, and NSVS 3714875. These objects are selected from beta-Lyrae candidates published in a paper by Hoffman et al (2008). Light curves are generated using data collected at the Truman State Observatory in four filters: Johnson R, V, B, and IR/UV. We compare our classification to the ones presented by Hoffman et al. We conclude that the first object, previously classified only as a variable star, should be reclassified as an Algol-type variable. The second object may either be a beta-Lyrae variable or a W UMa variable. We confirm Hoffman et al's classification of the third object as a beta-Lyrae variable. Data collection and analysis on the remaining three objects is ongoing. In this poster, we present the light curves on these six objects and comment on their classification as beta-Lyrae, Algol, or W UMa –type variables.

Author(s): Tyler Gardner[1], Orion Guan[1], Vayujeet Gokhale[1]
Institution(s): *1. Truman State University*

343.04 – Radial Velocity Time Corrections and their Effect on Variable Star Periods

We will be applying a radial velocity time correction to variable stars and observing the changes in their periods. We will also investigate the appropriate number of cycles that must be observed before reliable periods can be determined. Using this time corrected data and the changes in the apparent period we hope to be able to find the actual space velocity of the star that, when corrected for, produces data with the most accurate period.

Author(s): Rachael Hunter[1], Eric G. Hintz[1]
Institution(s): *1. Brigham Young University*

343.05 – Mass Loss in Classical and Type II Cepheids

Mass loss in Cepheid variable stars is potentially important to our understanding of both setllar evolution and the effects of pulsation on mass loss. Previously, this has been investigated using infrared excesses determined from surveys such as IRAS, by searching for spectral lines with velocities suggestive of outflow and by imaging the circumstellar clouds. The availability of infrared photometry from the WISE survey offers an opportunity to revisit this question and to take advantage of its sensitivity and spatial resolution to extend the sample. We have used our previous photometry of about 40 classical Cepheids and 100 type II Cepheids in combination with 2MASS and WISE photometry to assess the prevalence of significant mass loss. We find that about 80% of both classical and type II Cepheids lack significant infrared flux in the WISE bands in excess of the photospheric flux.

Author(s): Edward G. Schmidt[1]
Institution(s): *1. Univ. of Nebraska*

343.06 – Establishing a Reliable Reddening Scale for Galactic Cepheids

A variety of sources of reddenings exist for Galactic Cepheids, and reference is often made to a 1990 compilation by Fernie. But subtle errors were evident in that tabulation when it appeared, and alternate practical techniques and methodologies for deriving Cepheid color excesses have since been produced that make it possible to generate a new scale consistent with the best existing schemes, namely field reddenings, spectroscopic methods, and use of reddening-free indices. Small corrections to existing color excesses may seem to be of only minor consequence, yet use of such a scale provides an improved picture of the Cepheid instability strip, as well as period-luminosity and Leavitt laws of smaller internal scatter than was the case previously.

Author(s): David G. Turner[1]
Institution(s): *1. Saint Mary's Univ.*

343.07 – Modernizing the Harvard Observatory Catalog of Variable Stars in the Magellanic Clouds

We have modernized the Harvard College Observatory's catalog of variable stars in the Magellanic Clouds, compiled by Henrietta Swan Leavitt in 1908 and expanded by Cecilia Payne-Gaposchkin in 1966 and 1971. This catalog was originally used by Leavitt in 1912 to formulate the period-luminosity relation for Cepheid variable stars, one of the most important rungs on the extragalactic distance ladder. Many of the stars were identified in current catalogs by only their Harvard Variable number, without coordinates or magnitudes. We have digitized the variable-star catalog and converted the coordinates of the 2,184 variable stars from the Harvard College Observatory's now-defunct planar-grid system to the spherical Equatorial coordinate system. Our modernized version of the catalog will allow for more efficient use of the Harvard archival plates currently being scanned by the Digital Access to a Sky Century @ Harvard (DASCH) project. The combination of DASCH and our catalog allows users to readily access more than a century's worth of data on the variable stars in the Magellanic Clouds, leading to such projects as studying the long-term evolution of variable stars.

Author(s): Zachary Murray[1], Julia Kruk[1], Lucien Christie-Dervaux[1], Dong Yi Chen[1], Or Graur[2], Ashley Pagnotta[1]
Institution(s): *1. American Museum of Natural History, 2. New York University*

343.08 – Field 1: A First Look at the KELT RR Lyrae Project

In this poster we will discuss our ongoing program to use extant light curves from the Kilodegree Extremely Little Telescope (KELT) survey to find and characterize RR Lyrae (RRL) stars in the disk and inner halo of the Milky Way. We will focus on initial results from our testbed region, Field 1. RRL stars are of particular interest because they are standard candles and can be used to map out structure in the galaxy. The periods and shape of RRL light curves also contain information about their Oosterhoff type, which can probe galactic formation history, and metallicity respectively. Although there have been several large photometric surveys for RR Lyrae in the nearby galaxy (OGLE, NSVS, ASAS, and MACHO to name a few), they have each been limited in either sky coverage or number of epochs. The KELT survey represents a new generation of surveys that has many epochs over a large portion of the sky. KELT samples 60% of the sky in both northern and southern hemispheres, and has a long-time-baseline of 4-8 years with a very high cadence rate of less than 20 minutes. This translates into 4,000 to 9,000 epochs per light curve with completeness out to 3 kpc from the Sun.

Recent results from both Kepler and ground based surveys results suggest that as many as 50% of RR Lyrae stars show long-term modulation of their light curve shapes (Blazhko effect). These stars combined with RRL stars that pulsate in more than one mode give a sample of objects that the KELT survey is uniquely suited to explore. This poster uses the RR Lyrae stars in Field 1 of the KELT survey to compare detection methods to previous variable star surveys of the same region. We also discuss the individual RR Lyrae found in Field 1. In particular, we focus on initial characterization of RRL light curves including those with amplitude-modulated or period-modulated light curves. We uses these initial results to discuss future plans for this survey.

Author(s): Nathan M. De Lee[3], Karen Kinemuchi[1], Joshua Pepper[2], Joseph E. Rodriguez[4], Martin Paegert[4]
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343.09 – Periodic Variable Stars Across the Southern Sky

We continue our search for periodic variables within the ~30,000 square degrees of the sky covered by the Catalina Surveys. Here we analyze six years of optical photometry taken by the Siding Spring Survey (SSS), which is sensitive to sources in the range 11 < V < 19. In all, this new analysis covers ten thousand square degrees on the sky at declinations between -20 and -75 degrees. Due to the very large number of periodic variable candidates found, we perform automated classification of the stars using multivariate kernel density estimation based on features selected from previously classified northern data. We test the accuracy of the results by visually validating a large sample of the objects. We also compare the classifications with those from other automated methods. The final SSS catalog contains tens of thousands of new periodic variable stars including eclipsing binaries, RR Lyrae, LPVs, delta Scuti's and Cepheids. By combining the newly discovered LPVs and RR Lyrae with our previous discoveries, we trace the path of the Sagittarius tidal streams system across the entire sky.

Author(s): Andrew J. Drake[2], Matthew Graham[2], Stanislav G. Djorgovski[2], Marcio Catelan[5], Gabriel Torrealba[3], Ashish A. Mahabal[2], Ciro Donalek[2], Eric J. Christensen[4], Stephen M. Larson[4], Robert McNaught[1], Gordon Garradd[1]
Institution(s): *1. ANU, 2. Caltech, 3. Cambridge University, 4. LPL, 5. Pontifica Universidad Catolica*

343.10 – New BVR Photometry of BL Camelopardalis

New BVR photometry of the SX Phe star BL Camelopardalis has been secured with the 0.9 m reflector at the BYU West Mountain Observatory. The new data have been used to determine times of maximum light, standardize light curves in each of the three filters, and examine the frequencies that are currently detectable in the light curves from a single location.

We acknowledge the Brigham Young University College of Physical and Mathematical Sciences as well as the Department of Physics and Astronomy for continued support of this and other research efforts currently being done at the West Mountain Observatory.

Author(s): Michael D. Joner[1]
Institution(s): *1. Brigham Young Univ.*

343.11 – The Evolution of ONeMg Cores with MESA

We present calculations of the evolution of degenerate cores composed primarily of oxygen, neon, and magnesium which are undergoing compression. We make use of the state-of-the-art MESA stellar evolution code, with updated weak reaction rates from Martinez-Pinedo et al. (2014). We perform a detailed parameter study of the effects a number of quantities, including the accretion rate, magnesium mass fraction, and initial core temperature. We discuss the final fate of these ONeMg cores, focusing on cores formed as a result of the merger of two carbon-oxygen white dwarfs.

Author(s): Josiah Schwab[1], Eliot Quataert[1], Lars Bildsten[1]
Institution(s): *1. University of California, Berkeley*

343.12 – Results from recent time-series photometric studies of pulsating extremely low-mass white dwarfs.

Extremely low-mass (ELM; < 0.25 $M_{\odot}$) white dwarfs form from post-main sequence common envelope mass transfer, leaving them with helium cores and hydrogen atmospheres. As they cool, they pulsate in an extension of the DAV (hydrogen-atmosphere variable) instability strip as ELM white dwarf pulsators. We present a synopsis of all pulsating ELM white dwarfs known to date and highlight recent findings from our time-series analyses.

Author(s): Keaton Bell[4], Warren R. Brown[1], Alex Gianninas[3], JJ Hermes[5], S. O. Kepler[2], Mukremin Kilic[3], Michael H. Montgomery[4], Donald E. Winget[4]
Institution(s): *1. Smithsonian Astrophysical Observatory, 2. UFRGS, 3. University of Oklahoma, 4. University of Texas-Austin, 5. University of Warwick*

343.13 – The Local Population of White Dwarfs within 25 pc

We have extended the detailed survey of the local white dwarf population from 20 pc to 25 pc, effectively doubling the sample volume to now include 231 stars. The present 25 pc has an estimated completeness of 70% (the corresponding 20 pc sample is now 85% complete). The space density of white dwarfs remains at $4.8 \pm 0.5 \times 10^{-3}$ pc^{-3}. There exists a curious excess of single stars in the sample 70% vs 30% in systems with one or more companions. A pronounced apparent deficiency remains between the eleven known Sirius-like systems present in the 20 pc sample and only a single such system presently known in the extended 25 pc sample. Also demonstrated, using explicit individual white dwarf cooling ages, is the feasibility of estimating the white dwarf birth rates over the last ~ 5 Gyr.

This work is supported by NSF grant AST-1413537

Author(s): Jay B. Holberg[3], Terry D. Oswalt[2], Edward M. Sion[1]
Institution(s): *1. 3 Department of Astrophysics and Planetary Astronomy, 2. Embry-Riddle Aeronautical University, 3. Lunar and Planetary Laboratory*

343.14 – Origin of Variability of a White Dwarf in the Kepler Field

KIC 9535405 (= BOKS 53856) is a hot (34,000 K), DA (hydrogen-atmosphere) white dwarf in the Kepler field. It was initially identified in the Burrell Optical Kepler Survey (BOKS) as a blue variable object with an approximately 6-hr modulation. Subsequent multi-band photometry and spectroscopy revealed it to be a blue star with the characteristic broad Balmer lines of a hot DA white dwarf (Feldmeier et al. 2011). It is too faint to have been detected in the Two Micron All Sky Survey (2MASS) and the Wide-field Infrared Survey Explorer (WISE) All Sky Survey, and is located in an area of the sky not covered by the Galaxy Evolution Explorer (GALEX). Further, no known X-ray sources are co-incident with KIC 9535405. Kepler observations for 89 days at short cadence in 2009 refined the variability to a non-sinusoidal and asymmetric, but repeating, profile with a period of 6.138 hr and a maximum semi-amplitude of 2.5% (Holberg & Howell 2011). We present a preliminary analysis of new photometric and spectroscopic observations of KIC 9535405 obtained from the ground (during 2012-2014), the Spitzer Space Telescope (Jan 2013), and the Hubble Space Telescope (Sep 2014), as well as a serendipitous UV observation by Swift (Jul 2010). A likely explanation for the observed variability involves confinement of metals in the photosphere of the white dwarf around its magnetic pole(s), which produces a relatively cool "dark spot" viewed as the white dwarf rotates.

Author(s): Donald W. Hoard[1], Steve B. Howell[2]
Institution(s): *1. Max Planck Institute for Astronomy, 2. NASA-Ames Research Center*

343.17 – Luminous Blue Variables are Antisocial: Their Isolation Implies they are Kicked Mass Gainers in Binary Evolution

Based on their relatively isolated environments, we argue that luminous blue variables (LBVs) must be primarily the product of binary evolution, challenging the traditional single-star view wherein LBVs mark a brief transition between massive O-type stars and Wolf-Rayet (WR) stars. If the latter were true, then LBVs should be concentrated in young massive clusters like early O-type stars. This is decidedly not the case. Examining locations of LBVs in our Galaxy and the Magellanic Clouds reveals that, with few exceptions, LBVs systematically avoid clusters of O-type stars. In the Large Magellanic Cloud, LBVs are statistically much more isolated than O-type stars, and (perhaps most surprisingly) even more isolated than WR stars. This makes it impossible for LBVs to be single “massive stars in transition” to WR stars. Instead, we propose that massive stars and supernova (SN) subtypes are dominated by bifurcated evolutionary paths in interacting binaries, wherein most WR stars and SNe Ibc correspond to the mass donors, while LBVs (and their lower-mass analogs like B[e] supergiants, which are even more isolated) are the mass gainers. In this view, LBVs are evolved massive blue stragglers. Through binary mass transfer, rejuvinated mass gainers get enriched, spun up, and sometimes kicked far from their clustered birthsites by their companion’s SN. This scenario agrees better with LBVs exploding as Type IIn SNe in isolation, and it predicts that many massive runaway stars may be rapid rotators. Mergers or Thorne-Zykow objects might also give rise to LBVs, but these scenarios may have a harder time explaining why LBVs avoid clusters.

Author(s): Ryan Tombleson[1], Nathan Smith[1]
Institution(s): *1. Steward Observatory*

343.18 – Low-Cost Automated Variable Star Detection System

We propose a method of variable star detection that utilizes automated data collection with affordable equipment and analysis using open source software. Our DSLR-based camera is currently opperating at Whitman College in Walla Walla, WA. At present, it collects a wide-field image roughly every 10 minutes throughout the day and night. The system observes stars near DEC=+44 and has a magnitude limit better than 8. This system has the possibility of characterizing bright long-period variables, important since the variability of many bright stars is unknown. We present this as a proof of concept and offer guidance for the large scale cataloguing of stars, enabling undergraduate students, amateur astronomers, etc. to make a meaninful contribution to the study of variable stars.

Author(s): Marin Nicole Meades[1], Nathaniel Paust[1]
Institution(s): *1. Whitman College*

343.19 – The Pan-STARRS 1 Medium Deep Field Variable Star Catalog

We present the first Pan-STARRS 1 Medium Deep Field Variable Star Catalog (PS1-MDF-VSC). The Pan-STARRS 1 (PS1) telescope is a 1.8 meter survey telescope with a 1.4 Gigapixel camera, located in Haleakala, Hawaii. The Medium Deep survey, which consists of 10 fields located uniformly across the sky, totalling 70 square degrees, is observed each night, in 2-3 filters per field, with 8 exposures per filter, resulting in 3000-4000 data points per star over a time span of 3.5 years. To find the variables, we select the stars with > 200 detections, between 16th and 21st magnitude. There are approximately 500k stars that fit this criteria, they then go through a lomb-scargle fitting routine to determine periodicity. After a periodicity cut, the ~400 candidates are classified by eye into different types of variable stars. We have identified several hundred variable stars, with periods ranging between a few minutes to a few days, and about half are not previously identified in the literature. We compare our results to the stripe 82 variable catalog, which overlaps part of the sky with the PS1 catalog.

Author(s): Heather Flewelling[1]
Institution(s): *1. University of Hawaii*

343.20 – Starspots on LO Pegasi, 2006-2014

BVRI light curves of LO Pegasi obtained at Perkins Observatory (Ohio Wesleyan University) from 2006-2014 were used to study the evolution of starspots on its surface over that interval. We present surface maps obtained via a constrained non-linear inversion algorithm that uses variations in limb darkening as seen through different filters to improve the latitude resolution of the reconstructions. In addition, a detailed period analysis of the entire data set using the ANOVA method was performed to search for variations associated with differential rotation. No evidence of period change was found, as the periods for each year were equal to within their uncertainties. For the data set as a whole, the period of rotation was determined to be 10.1538 ± 0.0009 hr, in agreement with previously published results.

Author(s): Robert O. Harmon[3], Dominique Berry[2], Mark Chalmers[3], Josh Denison[3], Don Stevens[3], Kaylee Yuhas[1]
Institution(s): *1. Baldwin Wallace University, 2. Florida A&M University, 3. Ohio Wesleyan University*

343.21 – Using RS CVn Binaries as a Novel Approach to Measuring Gravity Darkening

Faint companions of bright giant stars (e.g. RS CVn binaries) are often undetected by direct observations due to small angular distances and large flux ratios. Taking advantage of recent upgrades to the Michigan Infrared Combiner (MIRC) at the CHARA Array allowing for milliarcsecond resolution and large flux ratio detections (>250:1), we make the first detections of the faint main-sequence companions to the giant primary stars of RS CVn systems. These observations give orbital parameter determinations, which lead to model-independent component mass measurements and more accurate evolutionary state estimates. Using the new orbital parameters and 25 years of archival photometry, we have identified weak ellipsoidal variations allowing for a new look at gravity darkening.

Author(s): Rachael M. Roettenbacher[3], John D. Monnier[3], Heidi Korhonen[4], Robert O. Harmon[1], Gregory W. Henry[2]
Institution(s): *1. Ohio Wesleyan University, 2. Tennessee State University, 3. University of Michigan, 4. University of Turku*
Contributing team(s): CHARA Collaboration

343.22 – EE Cep Winks in Full Color

We observe the long period (5.6 years) Eclipsing Binary Variable Star EE Cep during it's 2014 eclipse. It was observed on every clear night from the Maria Mitchell Observatory as well as remote sites for a total of 25 nights. Each night consisted of a detailed time series in BVRI looking for short term variations for a total of >9000 observations. The data was transformed to the Standard System. In addition, a time series was captured during the night of the eclipse. This data provides an alternate method to determine Time of Minimum than traditionally performed. The TOM varied with color. Several strong correlations are seen between colors substantiating the detection of variations on a time scale of hours. The long term light curve shows 5 interesting and different Phases with different characteristics.

Author(s): Gary E. Walker[1]
Institution(s): *1. Maria Mitchell Association Observatory*

343.23 – H-alpha Tracking in the Clusters NGC 659, NGC 663, and Cygnus OB-2

Using the 1.2-m telescope of the Dominion Astrophysical Observatory we developed a calibrated H-alpha index for monitoring both absorption and emission features. Photometric data was then obtained using the BYU West Mountain Observatory 0.9-m telescope and a specially designed set of filters to match the spectrophotometric system. This data covered from July 2013 to October 2014 on three star clusters; NGC 659, NGC 663, and Cygnus OB-2. In total there are over 40 nights of data. We will present our preliminary results from this data set.

Author(s): Eric G. Hintz[1], Michael D. Joner[1]
Institution(s): *1. Brigham Young Univ.*

343.24 – A Search for Variable Stars in Open Cluster NGC 7654

We will present results from an examination of the open cluster NGC 7654, with data obtained from both the Tenagra 0.8-m telescope and the BYU David Derrick 0.4-m Telescope. Our observations were taken on both a short(each on September 26 and 28th, 2006) and long cadence(September 2006 to January 2007) to allow a search for both short and long period variable stars. However, in an effort to refine our techniques we have focused on the data from the night of Sept 26. We have a total of 60 frames taken over a period of an hour and 45 minutes. We are using DAOPhot photometry and a Robust Median Statistic (Rose & Hintz 2007), on this single night to look for low amplitude, short period variable stars in the field.

Author(s): Adam Pierce[1], Eric G. Hintz[1]
Institution(s): *1. Brigham Young University*

343.25 – Discovering Variable Stars in the Open Clusters of Cygnus and Ophiuchus

Over the summer of 2014, we surveyed several open clusters using the 17-inch telescope at Maria Mitchell Observatory on Nantucket Island in Massachusetts. 40 nights of data were taken in the V and R bands, with 800 images total taken for four main clusters (ASCC 105, ASCC 109, NGC 6940, IC 4665) and less then 800 taken for a few others. Approximately half of the nights were of photometric quality, and typical seeing was 2-3 arcseconds. We combined our data with similarly collected data in the B and V bands from the summer of 2013, and used the DAOPHOT suite of photometric software to perform CCD photometry on the images. Several candidate variable stars were found in the field of each cluster, most of which are likely eclipsing binaries. We show color-magnitude diagrams, preliminary light curves, and finding charts.

Author(s): Emma Dahl[3], Peter B. Stetson[1], Chantanelle Nava[2]
Institution(s): *1. Herzberg Insitute for Astrophysics, 2. Montana State University, 3. Whitman College*

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344 – Cataclysmic Variables, Stellar Winds and Ejecta, and Eta Carina Posters

344.01 – New Nova Candidates from the RSBE M31 Nova Survey

Since 1995 the Kitt Peak National Observatory WIYN 0.9-m telescope has been used to monitor M31 for novae as part of the Research-Based Science Education Project (RBSE). The resulting images, which typically cover approximately the inner 20 arc min of M31, are taken through a broad-band H-alpha filter to isolate the strong H-alpha emission lines characteristic of novae shortly after eruption.

We are in the process of reanalyzing the entire RBSE data set covering the period between September 1995 and August 2014 in order to produce an up-to-date list of novae from this survey. Here, we present coordinates and H-alpha magnitudes for 4 new nova discoveries not previous reported. Among the new nova discoveries, one system appears spatially coincident with M31N 1988-09a, and is thus a recurrent nova candidate.

Author(s): Stephanie Lauber[1], Travis A. Rector[2], Allen W. Shafter[1]
Institution(s): *1. San Diego State University, 2. University of Alaska Anchorage*

344.02 – The All-Sky Automated Survey for Supernovae CV Patrol

Even in the modern era, only human eyes scan the entire optical sky for the violent, variable, and transient events that shape our universe. The "All Sky Automated Survey for Supernovae" (ASAS-SN or "Assassin") is changing this by monitoring the extra-galactic sky down to V~17 mag every 2-3 days using multiple telescopes, hosted by Las Cumbres Observatory Global Telescope Network, in the northern and southern hemispheres. By far the most common events observed by ASAS-SN are the Galactic transients. Since April 2013 ASAS-SN has identified over 180 new cataclysmic variable stars and announced over 260 new outbursts of known CVs. To make our data available to the CV community in “real time”, we have launched an automated “CV Patrol” to monitor known CVs for outbursts as a useful tool for both professional and amateurs astronomers. It is a long term goal of ASAS-SN to make all our data public in real-time, and this patrol will serve as a framework for future ASAS-SN data releases.

Author(s): Alexandra Bianca Davis[3], Benjamin John Shappee[1], Bartlett Archer Shappee[2]
Institution(s): *1. Hubble Carnegie-Princeton Fellow, 2. Simplified Complexity Llc, 3. The Ohio State University*
Contributing team(s): ASAS-SN

344.03 – CSS120422: Diving Below the Period Minimum with HST and LBT Spectra

The evolutionary paths of ultracompact interacting binaries often lead to helium transfer in AM CVn systems. But an "evolved main-sequence" channel has long been hypothesized to create ultracompact binaries with detectable hydrogen. CSS120422 is a Cataclysmic Variable with an orbital period of only 55 minutes, well below the hydrogen period minimum. The optical spectrum of CSS120422 is clearly depleted in hydrogen relative to helium, but still has two orders of magnitude more hydrogen than AM CVn stars. Here we present spectroscopy of CSS120422 using the COS FUV instrument on the Hubble Space Telescope and using the MODS spectrograph on the Large Binocular Telescope. The UV spectrum shows SiIV, NV and HeII, but no detectable CIV. The anomalous carbon/nitrogen ratio is seen in a small number of other CVs and suggests a unique binary evolution (Gansicke et al. 2003). We use the time tag data to search for an eclipse suggested by Carter et al. We also use the combined photometry/spectroscopy to hunt for the spiral structure in the disk proposed by Littlefield et al.

Author(s): Mark Kennedy[2], Peter M. Garnavich[2], Paula Szkody[3], Paul Callanan[1]
Institution(s): *1. University College Cork, 2. University of Notre Dame, 3. University of Washington*

344.04 – Characterizing Cataclysmic Variable Stars in NGC 6791 Using Kepler

B7 (V523 Lyr) and B8 (V516 Lyr) are two cataclysmic variable stars believed to be members of the old, metal-rich open cluster NGC 6791. The cluster fell within the Kepler field and B7 and B8 were continuously monitored primarily using a 30-minute cadence. B7 is a nova-like system and the Kepler light curve shows variations with an amplitude of 0.5 mag and a characteristic time-scale of 10 days. Power-spectral analysis shows a very weak, but coherent, periodic signal at 3.80 hours which we interpret as the orbital period of the binary. B8 is a known dwarf-nova system and the Kepler light curve confirms 1.5 mag amplitude outbursts with an interval ranging between 10 and 20 days. Kepler also observed super-outbursts with an amplitude of 3 magnitudes that last 15 days. Super-humps with an average period of 2.097+/-0.003 hours are clearly seen indicating that B8 has an orbital period below the period gap. This makes B8 a member of the SU UMa class of cataclysmic variable.

Author(s): Peter M. Garnavich[2], Katrina Magno[2], Martin D. Still[1], Thomas Barclay[1]
Institution(s): *1. NASA/Ames, 2. Univ. of Notre Dame*

344.05 – 3D Hydrodynamic Simulation of Classical Novae Explosions

This project investigates the formation and lifecycle of classical novae and determines how parameters such as: white dwarf mass, star mass and separation affect the evolution of the rotating binary system. These parameters affect the accretion rate, frequency of the nova explosions and light curves. Each particle in the simulation represents a volume of hydrogen gas and are initialized randomly in the outer shell of the companion star. The forces on each particle include: gravity, centrifugal, coriolis, friction, and Langevin. The friction and Langevin forces are used to model the viscosity and internal pressure of the gas. A velocity Verlet method with a one second time step is used to compute velocities and positions of the particles. A new particle recycling method was developed which was critical for computing an accurate and stable accretion rate and keeping the particle count reasonable. I used C++ and OpenCL to create my simulations and ran them on two Nvidia GTX580s. My simulations used up to 1 million particles and required up to 10 hours to complete. My simulation results for novae U Scorpii and DD Circinus are consistent with professional hydrodynamic simulations and observed experimental data (light curves and outburst frequencies). When the white dwarf mass is increased, the time between explosions decreases dramatically. My model was used to make the first prediction for the next outburst of nova DD Circinus. My simulations also show that the companion star blocks the expanding gas shell leading to an asymmetrical expanding shell.

Author(s): Coleman J. Kendrick[1]
Institution(s): *1. Los Alamos High School*

344.06 – What is the Origin of the Shell Around R Coronae Borealis?

R CrB is the prototype for its eponymous class of stars, which are very rare, and have many unusual characteristics, including extreme hydrogen deficiency, and large, sudden declines in brightness of 8 magnitudes or more. These declines are caused by clouds of carbon dust forming near the atmospheres of the stars, which are later dissipated by radiation pressure. Only about 100 RCB stars are known in the Galaxy. This indicates that these stars are the result of a rare form of stellar evolution or are in an evolutionary phase that lasts only a short time. One clue to the evolution of the RCB stars is the presence of large dust shells around several of the stars, seen by IRAS, Spitzer, and Herschel. In particular, R CrB, itself, has a huge dust shell with a radius of ~10′. There are three possible mechanisms that may have produced the R CrB shell, 1) It is a fossil Planetary Nebula shell, 2) It is mass loss from the white dwarf merger event that formed the star, 3) It is mass loss from the present RCB phase. We will discuss the evidence supporting these three scenarios, and attempt to discern which mechanism was responsible for the R CrB Dust shell.

Author(s): Geoffrey C. Clayton[1], Edward Montiel[1], Dominic Marcello[1], Felix J. Lockman[2]
Institution(s): *1. Louisiana State Univ., 2. NRAO*

344.07 – Searching for IR Excesses around Li-Rich and Rapidly Rotating K Giants Using WISE

As stars evolve from the main-sequence (MS) to the red giant branch (RGB) they exhibit several characteristic changes. Specifically, as the outer layers expand and cool, the star’s rotation rate slows, the convection zone deepens and a series of shell-burning and core-burning phases begin to take place. A number of RGB K-type stars, however, exhibit uncharacteristically rapid rotation rates that also seem to be correlated with high lithium abundances (A(Li)) (Carlberg et al. 2012). These higher rotation rates and A(Li) are inconsistent with those predicted by standard stellar evolutionary models. It has also been suggested that many of these high Li RGB stars have IRAS excesses suggestive of a circumstellar shell or disk (de la Reza et al. 1997, Drake et al. 2002). Various hypotheses have been proposed to explain the Li, rapid

rotation rates and IR excesses, including the accretion of nearby giant planets equivalent to a few Jupiter masses or a newly triggered nuclear fusion stage that could eject a dusty shell. Using higher spatial resolution data from the Wide-field Infrared Survey Explorer (WISE), we have reevaluated these IRAS-selected targets and added a much larger sample of RGB K-type giants from Carlberg et al. (2012) that were selected without regard to IR brightness. Our findings indicate that many of the IRAS sources that exhibited an IR excess were non-stellar objects, clusters of stars or galaxies, or otherwise not RGB stars, casting doubt on the correlations found previously. Very few of the Carlberg et al. sample have IR excesses making it difficult to assess if there is a correlation in this sample. Our companion poster, Deeb et al. presents the educational aspects of this project. This research was made possible through the NASA/IPAC Teacher Archive Research Program (NITARP) and was funded by NASA Astrophysics Data Program.

Author(s): John Gibbs[3], Luisa M. Rebull[2], David V Black[5], Elin Deeb[1], Estefania Larsen[4], Sarah Cashen[3], Ashwin Datta[3], Emily Hodgson[3], Megan Lince[3], Rosie Buhrley[5], Julie Herring[5], Kendall Jacoby[5], Elena Mitchell[5], Shailyn Altepeter[4], Ethan Bucksbee[4], Matthew Clarke[4]
Institution(s): *1. Bear Creek High School, 2. Caltech, 3. Glencoe High School, 4. Millard South High School, 5. Walden School of Liberal Arts*

344.08 – Mining the HST "Advanced Spectral Library (ASTRAL)": Winds of the Evolved M Stars Alpha Ori (M2 Iab) and Gamma Cru (M3.4 III)

The "Advanced Spectral Library (ASTRAL) Project: Cool Stars" (PI = T. Ayres) is an HST Cycle 18 Treasury Program that collected a definitive set of representative, high-resolution (R=30,000-100,000) and high signal/noise (S/N>100) UV spectra of eight F-M evolved cool stars. These extremely high-quality STIS UV echelle spectra are available from the HST archive and through the ASTRAL website at the University of Colorado at http://casa.colorado.edu/~ayres/ASTRAL/ and will enable investigations of a broad range of problems -- stellar, interstellar, and beyond -- for many years. In this paper, we examine the wealth of wind diagnostics contained in the very rich spectra of the two evolved M stars in the sample, the M3.4 III giant Gamma Crucis (GaCrux) and the M2 Iab supergiant Alpha Orionis (Betelgeuse) and characterize the winds at the time of these STIS observations in 2011 and compare the results with those obtained from more limited data taken at earlier epochs with HST/GHRS and IUE. In particular we study the variation of the numerous Fe II profiles with intrinsic strength in the two stars. The shifting wavelengths of the wind absorptions relative to the emission peaks and the changes in relative strengths of the emission peaks reflect the acceleration of the wind from the base of the chromosphere. Although the characteristics of the Gamma Cru wind are relatively stable with time, the Alpha Ori wind outflow appears significantly smaller than seen by Carpenter et al. (1997, ApJ, 479, 970) in GHRS observations taken in 1992 (and in earlier IUE observations). There might in fact be evidence in these STIS spectra that the outflow has turned into an inflow, as reported at epochs prior to IUE by Boesgaard and Magnan (1975 ApJ 198, 369) and Boesgaard (1979 ApJ 232, 485) based on a limited number of lines in the extreme blue end of ground-based spectra.

Author(s): Kenneth G. Carpenter[2], Krister E. Nielsen[1], Gladys V. Kober[1], Thomas R. Ayres[3]
Institution(s): *1. Catholic University of America, 2. NASA's GSFC, 3. University of Colorado*

344.09 – Mass Loss from Hypergiant Stars: Searching for Cool Dust in the Near-to-Mid IR

The final fate of the most massive stars depends on their mass loss histories during their lifetimes. Hypergiant stars residing near the empircal upper limit of luminosity on the HR Diagram shed mass during brief, intense periods of enhanced mass loss, with amounts as high as 10^{-3} $M_{\odot}$ in a single event. Their circumstellar environments show extensive and complex ejecta at visual wavelengths. To further probe their mass-loss histories for evidence of earlier mass loss we have extended the search of hypergiants' circumstellar enviroments into the mid-to-far infrared for four famous objects: the yellow hypergiants IRC +10420 and rho Cas and the red hypergiants VY CMa and mu Ceph. We present high-resolution adaptive optics imaging from LBT/LMIRCam (2 - 5 μm) and MMT/MIRAC (8 - 12 μm), combined with recently obtained far-IR imaging from 11 - 37 μm obtained with SOFIA/FORCAST (Cycle 2). We also discuss their long wavelength SEDs.

Author(s): Dinesh Shenoy[2], Roberta M. Humphreys[2], Terry Jay Jones[2], Massimo Marengo[1], Robert D. Gehrz[2], L. Andrew Helton[3]
Institution(s): *1. Iowa State University, 2. University of Minnesota, 3. USRA/SOFIA*

344.10 – A Tale of Two Impostors

We present recent spectra and photometry for two supernova impostors in the nearby spiral NGC 2403: SN1954j (V12) and SN2002kg (V37). Both of these objects received supernova dsignations, but are examples of non-terminal high mass loss episodes. SN2002kg's eruption was sub-luminous and it was quickly realized that it was not a supernova but a normal LBV/S Dor variable in outburst. SN1954j is famous and was one of Zwicky's Type V supernovae. The nature of SN1954j has been more controversial. Its Halpha emission line shows a classic stellar wind profile with broad wings confirming that SN1954j experienced a giant eruption. It is a survivor.

Author(s): Roberta M. Humphreys[1], Kris Davidson[1], Skyler Grammer[1]
Institution(s): *1. Univ. of Minnesota*

344.11 – Investigating Binary Wolf-Rayet Binary Stars as Potential Gamma-Ray Source

Wolf-Rayets are massive, hot, and luminous evolved stars with strong stellar winds. When paired with another massive star emitting strong stellar winds, the region where their winds collide produces a bow shock that may emit gamma-rays. This work seeks to find such a colliding wind binary by correlating the orbital period of a binary Wolf-Rayet with periodic changes in flux in nearby gamma-ray sources observed by *Fermi Gamma-ray Space Telescope* Large Area Telescope (LAT). We selected three binary Wolf-Rayet stars for analysis. WR 39 and WR 48 are in close proximity to unassociated sources from the LAT 2-Year Point Source Catalog (2FGL). WR 140 was selected on the basis of being a double-lined spectroscopic binary; the close passage of the two stars may contribute to colliding winds that could produce gamma-rays. We first used the *Fermi* Science Tools to calculate average flux values. The orbital period of WR 39 has not been established; so rather than creating a folded light curve, photon data for its proposed 2FGL counterpart were next analyzed using seven-day time bins in an attempt to use periodic behavior in the 2FGL source to find the orbital period of WR 39. However, no periodic behavior was evident in the plotted data. Since WR 48 lies just outside error ellipse of its proposed 2FGL counterpart, we performed the six-year likelihood analysis twice. First, WR 48 was manually inserted as a point source; this resulted in a non-converging fit. Instead, we used the proposed 2FGL counterpart as the object of interest. After calculating the average flux, we separated the photon data into phase bins based on the 18.34 day period of WR 48. The resulting folded light curve does not show any periodic behavior. WR 140 was also manually inserted as a point source; the analysis of the six-year data set failed to establish the existence of a gamma-ray source at the location of WR 140 and no further analysis was performed on this source.
This research took place at Lehigh University and was made possible by generous funding from the National Science Foundation (grants PHY-0849416, PHY-1359195 and AST-1109247).

Author(s): Jacqueline Meadows[1], Michael J Alexander[1], M. Virginia McSwain[1]
Institution(s): *1. Lehigh University*

344.12 – A Chandra Observation of the Eclipsing Wolf-Rayet Binary CQ Cep

The short-period (1.64 day) near-contact eclipsing WN6+O9 binary system CQ Cep provides an ideal laboratory for testing the predictions of X-ray colliding wind shock theory at close separation where the winds may not have reached terminal speeds before colliding. We present results of a Chandra X-ray observation of CQ Cep spanning one day during which a simultaneous Chandra optical light curve was acquired. Our primary objective was to compare the observed X-ray properties with colliding wind shock theory, which predicts that the hottest shock plasma (T > 20 MK) will form on or near the line-of-centers between the stars. The X-ray spectrum is strikingly similar to apparently single WN6 stars such as WR 134 and spectral lines reveal plasma over a broad range of temperatures T ~ 4 - 40 MK. A deep optical eclipse was seen as the O star passed in front of the Wolf-Rayet star but, surprisingly, no significant X-ray variability was detected. Because of the high inclination orbit, this implies that the hottest X-ray plasma is not confined to the region between the stars, at odds with the colliding wind shock picture. We will summarize the Chandra results in the context of predictions from colliding wind theory.

Author(s): Steve L. Skinner[3], Svetozar Zhekov[2], Manuel Guedel[4], Werner Schmutz[1]
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344.13 – Constraining the Dust Mass and Morphology of the Quintuplet Proper Members from SOFIA/FORCAST

We present SOFIA/FORCAST observations of the Quintuplet Proper Members (QPMs) at 19.7, 31.5, and 37.1 µm, and revisit our dust models of their spectral energy distribution (SEDs) using the radiative transfer code DUSTY. We fit the SED models with parameters reflecting the dust distribution arising from colliding wind binaries, which produce the 'pinwheels' previously observed in the near-infrared. Our models use amorphous carbon grains which are consistent with the dusty WC star hypothesis. The positive radial density profile that we fit is consistent with the majority of the dust mass being located away from the site of grain formation. However, the observed spiral/disk geometry is at odds with the large observed IR luminosity, ~10^5 L^{sun}, which is comparable to the luminosity of typical WC stars, implying that the source must be completely enshrouded by dust. This is consistent with the obscuration of J-band features noted in other works. The small observed dust mass, ~10^{-4}-10^{-5} M^{sun}, is consistent with inefficient grain formation or low survivability. Our images provide important spectral information as they are sensitive to cool dust components that are independent of the previously observed hot inner disk. Ultimately these objects remain somewhat of an enigma due to their low observed dust mass and the conflict between the spiral dust morphology and the reradiated luminosity.

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344.14 – The Increased He II Emission and the Continuing Evolution of the Wind During Eta Carinae's 2014.6

Spectroscopic Event

We report our results from HST/STIS observations of the 2014.6 spectroscopic event. In contrast with ground-based observations the HST/STIS resolves the star from the nearby bright inner ejecta. We find significant changes relative to past spectroscopic events specifically the increased strength of the He II 4687 Å emission. He I emission has gradually increased through the last three spectroscopic events. At the same time, Fe II shows a significant decrease in emission and N II shows dramatic shift from absorption to emission. Together these imply a decrease in density and increase in UV flux in wind as part of the ongoing evolution of the primary star.

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344.15 – The X-ray Lightcurve of Eta Carinae, 1996-2014

Eta Carinae is the nearest example of a supermassive, superluminous, unstable star. Mass loss from the system is important in shaping its circumstellar medium and in determining the ultimate fate of the star. Eta Car loses mass via a dense, slow stellar wind and possesses one of the largest mass loss rates known. It is prone to episodes of extreme mass ejection via eruptions from some as-yet unspecified cause; the best examples of this are the large-scale eruptions which occurred in the mid-19th century, and then again about 50 years later. Eta Car is a colliding wind binary in which strong variations in X-ray emission and in other wavebands are driven by the violent collision of the wind of Eta Car and the fast, less dense wind of an otherwise hidden companion star. X-ray variations are the simplest diagnostic we have to study the wind-wind collision and allow us to measure the state of the stellar mass loss from both stars. We present the X-ray lightcurve over the last 20 years from monitoring observations with the Rossi X-ray Timing Explorer and the X-ray Telescope on the Swift satellite, and compare and contrast the behavior of the X-ray emission from the system over that timespan, including surprising variations during the 2014 X-ray minimum.

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344.16 – The interacting winds of Eta Carinae: Observed forbidden line changes and the Forbidden Blue(-Shifted) Crab

The massive binary, Eta Carinae (EC), produces such massive winds that strong forbidden line emission of singly- and doubly-ionized iron traces wind-wind interactions from the current cycle plus fossil interactions from one, two and three 5.54-year cycles ago.
With an eccentricity of >0.9, the >90 solar mass primary (EC-A) and >30 solar mass secondary (EC-B) approach to within 1.5 AU during periastron and recede to nearly 30 AU across apastron. The wind-wind structures move outward driven by the 420 km/s primary wind interacting with the ~3000 km/s secondary wind yielding partially-accelerated compressed primary wind shells that are excited by mid-UV from EC-A and in limited lines of sight, FUV from EC-B. These structures are spectroscopically and spatially resolved by HST's Space Telescope Imaging Spectrograph. At critical binary phases, we have mapped the central 2"x2" region in the light of [Fe III] and [Fe II] with spatial resolution of 0.12" and velocity resolution of 40 km/s.
1) The bulk of forbidden emission originates from the large cavity northwest of EC and is due to ionization of massive ejecta from the 1840s and 1890s eruptions. The brightest clumps are the Weigelt Blobs C and D, but there are additionally multiple, fainter emission clumps. Weigelt B appears to have faded.
2) Three concentric, red-shifted [FeII] arcs expand at ~470 km/s excited by mid-UV of EC-A.
3) The structure of primarily blue-shifted [Fe III] emission resembles a Maryland Blue Crab. The claws appear at the early stages of the high-excitation recovery from the periastron passage, expand at radial velocities exceeding the primary wind terminal velocity, 420 km/s and fade as the binary system approaches periastron with the primary wind enveloping the FUV radiation from EC-B.
4) All [Fe III] emission faded by late June 2014 and disappeared by August 2, 2014, the beginning of periastron passage. Comparisons to HST/STIS observations between 1998 to 2004.3 indicate long-term fading of [Fe II]. Likewise, Na D emission has faded. 3D hydro/radiative models suggest a small decrease (< factor of 2) in primary mass loss rate to be the cause.

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344.17 – Extremely Hard X-ray Emission from Eta Carinae observed with XMM-Newton and NuSTAR around Periastron in 2014.5

The super massive colliding wind binary system, Eta Carinae, experienced another periastron passage in the summer of 2014. We monitored this event using the multiple X-ray observatories, Chandra, XMM-Newton, NuSTAR, Suzaku and Swift. With a high eccentricity of its 5.5 year orbit, X-ray emission from the wind-wind collision (WWC) increases strongly toward periastron but then drops sharply by more than two orders of magnitude in two weeks around periastron due probably to an eclipse and an intrinsic activity decline of the WWC plasma. In this observing campaign, XMM-Newton and NuSTAR coordinated two simultaneous observations around the X-ray flux maximum
on June 6 and just before the flux minimum on July 28. These two observations captured Eta Carinae with X-ray focusing telescopes in the extreme hard X-ray band above 10 keV for the first time.

During the first observation, XMM and NuSTAR detected stable X-ray emission from the central binary system between 1 - 40 keV. A fit of a 1-temperature bremsstrahlung model to the high energy slope in the NuSTAR spectrum derives an electron temperature of ~6 keV, which is significantly higher than an ionization temperature at ~4.5 keV, measured from the Fe K emission lines resolved in the XMM spectrum.
This result suggests the presence of very hot plasma and/or X-ray reflection at surrounding cold material. During the second observation, the X-ray flux between 5 - 10 keV declined steadily by a factor of ~2 in a day, while the other energy bands were rather stable. This variation may be explained by an increase of the line of sight absorption to emission from the plasma component that dominates above 5 keV. NuSTAR did not detect, in either observation, the very hard non-thermal component that dominated emission above 25 keV seen in earlier INTEGRAL and Suzaku observations. We discuss the plasma condition and the wind structure of Eta Carinae around periastron, and the nature of the non-thermal component.

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344.18 – Swift Observations of the Recent X-ray Activity of Eta Carinae

The extremely massive Luminous Blue Variable binary star, Eta Carinae, lies 7,500 light years away, deep within the Homunculus nebula where vigorous Wind-Wind collisions between the primary star and the companion star generate high-energy gases that produce X-rays. Complex X-ray variations occur near periastron, the point of least stellar separation between the two stars. Understanding the variability in Eta Carinae's high-energy spectrum during this period gives us a better understanding of the system's physical and stellar properties. We present the processing techniques and background estimation methods used to process and analyze weekly observations done with Swift's X-ray Telescope during Eta Carinae's most recent periastron passage in 2014. We present analysis of Eta Carinae's current column density and compare it to that of previous cycles. The exact nature of Eta Carinae's X-ray minimum activity, which occurs every 5.54 years, is still unclear. A detailed understanding of the mechanisms of the X-ray deep minimum stage and the associated differences in column density in each cycle will contribute to a clearer understanding of the wind-driven mass-loss from this unique system.

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344.19 – Ultraviolet analysis of Eta Carinae using observations from the International Ultraviolet Explorer

Presented here is an examination of data on the Eta Carinae binary star system obtained by the International Ultraviolet Explorer (IUE) satellite that was in operation from 1978 to 1996. The data were searched for (1) evidence of an ultraviolet flux increase over the time period of IUE's operation and (2) additional evidence for the 5.54-year cycle observed by A. Daminelli et al. This investigation focused on the emission lines of [N III] at 1750Å, Fe II at 1786Å, Si III at 1893Å, Fe III at 1914Å, and Fe II at 2507/2509Å. Through the examination of emission line profiles from IUE ultraviolet spectra, quantitative values for integrated and continuum flux were measured in roughly eighty observations. The fluxes for individual emission line profiles were compared over time and at different phases of the superimposed 5.54 year cycle. In addition, values for emission flux were plotted against time so as to visualize the system's behavior over a multi-cycle time interval. Observations recorded during the brief low-state, periastron event, while few in number, were consistent with the 5.54 period. Fluxes of the [N III], Si III, and Fe III emission features noted previously had increased across the 18-year interval. However, the Fe II emission lines did not show significant long-term flux increases. Examination of the Grotian diagram for Fe^+ demonstrated that hydrogen Lyman alpha can excite the outer electron from the ground state to upper levels, leading to population inversion and over-intensity of the Fe II emissions (Johansson & Letokhov, 2003). Likely, the different 'long-term' behaviors of the [N III], Si III, and Fe III emission lines and the Fe II emission lines arose from the very different physical phenomena that lead to each particular emission lines' existence. The consistency of the Fe II emission fluxes indicated that Eta Carinae's secondary stellar Lyman continuum flux was constant, leading to the conclusion that there was little change, if any, in the secondary star's temperature. The increase in the [N III], Si III, and Fe III emissions supports growing evidence that the primary wind mass-loss rate may have decreased across the time interval observed by IUE.

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344.20 – 3D Model of the Eta Carinae Little Homunculus Nebula

We extend our morpho-kinematic 3D modeling of the Homunculus nebula (Steffen et al., 2014) to the interior nested Little Homunculus. The model is based on spectroscopic observations from HST/STIS. We find that the structure of the interior Little Homunculus is rather flat in the polar regions and interacts with the main Homunculus nebula only on one side, towards the periastron direction of the binary orbit. Furthermore, the two lobes of the LH are misaligned, also towards the periastron direction. As an explanation for the misalignment we propose that, in both cases, shortly after the eruptions that created the bipolar nebulae from the primary star, the off-center wind of the secondary has pushed the ejecta towards the periastron directions, since the secondary is most of the time near the apastron. Future hydrodynamic simulations are warranted to confirm this scenario.

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344.21 – On the changes in the physical properties of the ionized region around the Weigelt structures in η Carinae over the 5.54-yr spectroscopic cycle

We present *HST/STIS* observations and analysis of two prominent nebular structures around the central source of η Carinae, the so-called Weigelt blobs C and D. The former is brighter than the latter for emission lines from intermediate or high ionization potential ions. The brightness of lines from intermediate and high ionization potential ions significantly decreases at phases around periastron. We do not see conspicuous changes in the brightness of lines from low ionization potential ions over the orbital period. Line ratios suggest that the total extinction towards the Weigelt structures is A^V=2.0. Weigelt C and D are characterized by an electron density of $10^{6.9}$ cm^{-3} that does not significantly change throughout the orbital cycle. The electron temperature varies from 5500 K (around periastron) to 7200 K (around apastron). The relative changes in the brightness of He^0 lines are well reproduced by the variations in the electron temperature alone. We found that, at phases around periastron, the electron temperature seems to be higher for Weigelt C than that of D. The Weigelt structures are located close to the Homunculus equatorial plane, at a distance of about 1240 AU from the central source. From the analysis of proper motion and age, the Weigelt complex can be associated with the equatorial structure called `Butterfly Nebula' surrounding the central binary system.

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344.22 – 3D Printing Meets Computational Astrophysics: Deciphering the Structure of Eta Carinae's Colliding Winds Using 3D Prints of Smoothed Particle Hydrodynamics Simulations

We present the first 3D prints of output from a supercomputer simulation of a complex astrophysical system, the colliding stellar winds in the massive (>120 M^{Sun}), highly eccentric (e ~ 0.9) binary Eta Carinae. Using a consumer-grade 3D printer (Makerbot Replicator 2X), we successfully printed 3D smoothed particle hydrodynamics simulations of Eta Carinae's inner (r ~110 AU) wind-wind collision interface at multiple orbital phases. These 3D prints reveal important, previously unknown 'finger-like' structures at orbital phases shortly after periastron (ϕ ~1.045) that protrude radially outward from the spiral wind-wind collision region. We speculate that these fingers are related to instabilities (e.g. Rayleigh-Taylor) that arise at the interface between the radiatively-cooled layer of dense post-shock primary-star wind and the hot, adiabatic post-shock companion-star wind. The success of our work and easy identification of previously unknown physical features highlight the important role 3D printing can play in the visualization and understanding of complex 3D time-dependent numerical simulations of astrophysical phenomena.

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345 – Binary Stellar Systems & X-Ray Binaries Posters

345.01 – FIRST, a fibered aperture masking instrument: Results of the Lick observing campaign

FIRST is a prototype instrument aimed at achieving high dynamic range and angular resolution in ground-based images at visible wavelengths near the diffraction limit. FIRST utilizes an aperture masking-like technique that makes use of single-mode fibers and pupil remapping to maximize the area of the telescope mirror in use. While located at Lick observatory in 2011 and 2012, FIRST observed 25 binary systems with the Shane 3m telescope, with separations ranging from 20 to 200 mas, comparable to the 50 mas diffraction limit for our central wavelength. Huby et al. (2013) has reported results for the Capella system that established the utility of FIRST for characterizing stellar binaries using the directly measured spectral flux ratio. Using an improved data analysis pipeline, we obtained closure phase measurements for a majority of the targets observed at Lick, and derived angular separations and spectral flux ratios. From the spectral flux ratios we obtained spectra for the companions over at least 600-850 nm with R~300. Finally, by obtaining results for many binary systems we have better constrained the current performance of FIRST, which has an exciting future ahead at its current location behind SCExAO at the Subaru 8.2 m telescope, where it will eventually become available for general use by the astronomical community.

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345.02 – New data on separation and position angle of selected binaries

We report on a sample of the data aquired on may 2012 at the 31 inch NURO telescope at Anderson Mesa near Flagstaff, Arizona pertaining the separation and position angle of selected binary stars. A CCD camera coupled to the NURO telescope allows for a simple and straightforward procedure for obtaining the images of the binaries. Analysis of the images is straigthforward and both direct and software methodology yield the separation and position angle of the binary stars. The data obtained is suitable for insertion in the Washington Double Star Catalog of the US Naval Observatory.

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345.03 – Multiplicity of the Galactic Senior Citizens: A high-resolution search for cool subdwarf companions

Cool subdwarfs, with spectral types late K and M, are the oldest members of the low-mass stellar population. Mostly present in the galactic halo, subdwarfs are characterized by their low metallicity and high proper-motions. Understanding their binary fraction could give key insights into the star formation process early in the Milky Way's history. However, because of their low luminosity and relative rarity in the solar neighborhood, binary surveys of cool subdwarfs have suffered from small sample sizes and large incompleteness gaps. It appears, however, that the binary fraction of red subdwarfs is much lower than for their main-sequence cousins. Using the highly efficient Robo-AO system, we present the largest high-resolution survey of subdwarfs yet. We find from 349 target cool subdwarfs, 39 are in multiple systems, 13 newly discovered, for a binary fraction of 11 ± 1.8%.

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345.04 – Follow-up Observations and Analysis of V530 Andromedae: A Totally Eclipsing Shallow Contact Solar Type Binary

We follow up on early, single coverage, $UBVR^cI^c$ light curves (2013) and analyses. These early curves were taken in September 27 and 29 2011. Our present, BVR^cI^c, but full coverage light curves were taken on 6 nights: October 1,2,9, November 4,5, 2013 and January 4, 2014 by RGS, DBC, JDC, TS with the Dark Sky Observatory 0.81-m reflector of Appalachian State University and a (-40ºC) 2KX2K Apogee Alta CCD. Our present curves reveal V530 Andromedae as a totally eclipsing, shallow contact solar type binary rather than semidetached, near contact one. The newly determined times of minima include:
HJD MinI = 2456566.84275 ±0.00007
HJD MinII = 2456598.881995±0.0004, 24556600.6111±0.0002, 2456601.76665±0.00046.
Using a new method of obtaining minima from earlier patrol light curves, in this case, NSVS, nine low weight timings of minimum light were added to the period study. Including these additional timings, we uncovered a period change. In our now, extended, period study over 9000 epochs, a 14.25 year interval, we find that the period is decreasing. This fits

the scenario of magnetic breaking for solar type binaries. The temperatures of the primary and secondary components are estimated at 7000 and 6300 K, respectively, a large temperature difference for a contact binary. The fill-out, however, is a mere 4%. (Our earlier scant light curves modeled very nearly in contact.) The mass ratio, M^2/M^1, was found to be 0.385, almost identical with our first curves solution. The two star spots, probably magnetic in origin, were determined. A hot spot was modeled by the iterative process on the polar region of the smaller star. A cool spot is on the larger star facing the smaller star. The spot parameters have changed appreciably over the course of the two intervening years. We believe the binary has recently come into contact and thermal contact has not yet been achieved.

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345.05 – BVRI Photometric Analysis of the W UMa Binary, V428, in the field of NGC188

V428 is a faint 15th magnitude binary observed in a study of the open cluster NGC188. However, its distance from the core of the cluster might exclude its membership. Its light curve was classified as a short period EB type eclipsing binary with a period of 0.3079 d and amplitude of ~0.7 mags in all curves. V428 was observed as a part of our student/professional collaborative studies of interacting binaries from data taken from Dark Sky Observatory of Appalachian State University, North Carolina. The difference in component temperatures is some DT =180 K and its fill-out is 35%. This undoubtedly has a semi-extreme mass ratio (q) otherwise its fill-out might dictate a smaller $\triangle$T. A brief, 2.5 year period study gives, as expected, a constant period, P=0.3076789 d. Five times of minimum light were calculated, 3 primary and 2 secondary eclipses from our present observations:
HJD I = 2456598.6746±0.0007, 2456599.5990±0.0014, 2456600.8292±0.0013
HJD II = 2456598.8299±0.0026, 2456599.7548±0.0025.
The improved linear ephemeris is:
JD Hel MinI = 2456599.5990(±0.0010) + 0.30767885(±0.00000043)d X E (1)
More monitoring is needed to determine its true orbital evolution. The inclination, 80º is not quite enough to produce total eclipses, so a q-search was performed. Our best solution gives a q=0.4. A cool spot was modeled on the primary component to take care of the light curve asymmetries. It is a K-type W UMa contact binary.

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345.06 – Period Change in the Near-Contact Binary UU Lyncis

The near-contact binary UU Lyncis has a known decreasing period as the stars move closer together. We report 10 new times of primary minimum for this system from photometric data gathered from the BYU David Derrick 0.4-m telescope and BYU West Mountain Observatory 0.9-m telescope. Using this data we refine the period change for the system and examine a small oscillatory variation in the O-C diagram. The modified period change and interpretations of the small variations will be reported.

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345.07 – Title: BVRI Photometric Study and Spectra of Algol type Pre-contact W UMa Binary, V500 Pegasi

V500 Pegasi is a NSVS and TYCHO variable, fortuitously observed by ASAS-3, 2003-2009. It is an eclipsing binary with a period of 0.57983 d. The light curves have the appearance of a detached binary. Our spectroscopy reveals that it is of F5V-type. A continuous14-year period study reveals a period increase in the orbital period at about the 1 sigma level. This is probably due to weak matter transfer to the primary component. The light curve has a large difference in primary and secondary amplitudes which is typical of detached binaries. The final solution shows a total secondary eclipse. The solution is that of a classical Algol system, but of solar type. As expected in binaries of this type, it has a large cool spot region. The secondary component has a temperature of ~4700 K (K3), which means it is somewhat over-luminous for its mass.

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345.08 – Another Component in the V523 Cassiopeiae Eclipsing Binary System

V523 Cassiopeiae is a W Usra Majoris type eclipsing binary with a period of 0.23 days, one of the shortest period binaries in its class. Samec et al. (2004) collected all available times of minimum, a total of 567 eclipse timings. They find a 101 year sinusoidal variation suggesting the presence of a third component to the system. They predicted that the O-C diagram would depart from a typical parabolic curve in 2013 if a third star is part of the system. We observed about 30 eclipses of V523 Cas in October and November 2012 and October and November 2013 using the Pisgah Astronomical Research Institute 0.4-m telescope in V, R, and I. The O-C diagram derived from this new data clearly shows the influence of a third component to this system. The third component appears to have a mass of 0.49 M with an orbital period of 101 years.

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345.09 – Heartbeat Stars: Spectroscopic Orbital Solutions for Six Highly Eccentric Binary Systems

We present multi-epoch spectroscopy of "Hearteat Stars," eccentric binaries with dynamic tidal distortions and tidally induced pulsations originally discovered with the Kepler satellite. Optical spectra of six known Heartbeat Stars using the Wyoming Infrared Observatory 2.3 m telescope allow measurement of stellar effective temperatures and radial velocities from which we determine orbital parameters including the periods, eccentricities, and approximate mass ratios. These spectroscopic solutions confirm that the stars are members of eccentric binary systems with eccentricities e>0.33 and periods P=7-20 days, strengthening conclusions from prior works which utilized purely photometric methods. Heartbeat stars in this sample have A- or F-type primary components. Loose constraints on orbital inclinations indicate that five of the six systems have mass ratios q=0.25-0.75, implying that most secondaries are probable G-K dwarfs; one system is an eclipsing, double-lined spectroscopic binary with roughly equal-mass mid-A components. This work constitutes the first measurements of the masses of secondaries in a statistical sample of Heartbeat Stars. The good agreement between our spectroscopic orbital elements and those derived using a photometric model support the idea that photometric data are sufficient to derive reliable orbital parameters for Heartbeat Stars.

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345.10 – Stellar Masses in the Mysterious Young Triple Star System AS 205

The lack of accurate absolute mass measurements for young, low-mass pre-main sequence stars is problematic for the calibration of stellar evolutionary track models. An on-going program to increase the sample of young star masses begins with mass ratio measurements in spectroscopic binaries. By the end of its 5-year duration, the GAIA all-sky mission will provide new astrometric measurements for young spectroscopic binaries down to separations of tens of microarcseconds, yielding absolute masses for double-lined systems. We obtain mass ratios by taking high-resolution spectra of young double-lined spectroscopic binaries over a few epochs to construct a radial velocity versus phase diagram. For the young spectroscopic binary AS 205B, using eight of our own spectra supplied by the CSHELL instrument on the IRTF at Mauna Kea, plus one from the literature, we estimate a period of approximately 140 days, an eccentricity of 0.7, and a mass-ratio of 0.5. This spectroscopic system comprises the secondary in a 1.4’’ visual binary in which both the A and B components are surrounded by optically thick, actively accreting disks, making AS 205B a member of that rare class of young spectroscopic binaries with a primordial circumbinary disk.

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345.12 – Modeling Gyrosynchrotron Coronae of Radio-Loud Stars

Fast gyrosynchrotron codes are used to model the emission in close, active binary star systems. Multiple magnetic field topologies, plasma densities, and scale heights for the emitting plasma are tested for in an attempt to duplicate the emission characteristics detected using high-resolution VLBI imaging of the close active binaries UX Arietis and Algol. Also included are effects of occlusion by the companion star. It is found that a co-orbiting coronal loop oriented toward the companion star with its feet anchored on the poles of the active star is consistent with the observed emission from these two radio-loud stars.

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Institution(s): *1. Augustana College*

345.13 – Simulations of lightcurves of common envelope binary interactions

Close binary stars can go through a common envelope interaction, which reduces the orbital separation leading to close, evolved binaries, such as the progenitors of type Ia supernovae, or mergers. New and upcoming time-domain surveys will increasingly observe transient events that may be due to such interactions. We present a module to post-process the light of common envelope interaction simulations. This is the first step to predict such lightcurves, thereby fine-tuning observational strategies of upcoming observations. These synthetic light curves will also be used to interpret the lightcurve of current observations in order to explain transient phenomena and, in turn, constrain the simulations.

Author(s): Orsola De Marco[2], Pablo Galaviz[2], Jan E. Staff[2], Jean-Claude Passy[1], Roberto Iaconi[2]
Institution(s): *1. Argelander Instutute, University of Bonn, 2. Macquarie University*

345.14 – Hydrodynamic Simulations of the Interaction between Giant Stars and Planets

We show the results of 3 dimensional hydrodynamic simulations of the interaction between AGB or RGB stars with massive planets. We aim at understanding the degree of disruption of the star during and after the interaction. The planet is initially at a separation such that the giant fills its Roche lobe, causing mass transfer and soon thereafter, inspiral. Very little gas is unbound in the process, as expected. However, the planet can stir up the outer layers of the star increasing the photospheric radius, before the final plunge at which point the planet can be disrupted. Finally, we show the calculated light curves for these events and comment on the likelihood of observing them.

Author(s): Jan E. Staff[1], Orsola De Marco[1], Jean-Claude Passy[2], Pablo Galaviz[1]
Institution(s): *1. Macquarie University, 2. University of Bonn*

345.15 – Optical and Infrared Photometry of Low-Mass Stars in Eclipsing Binaries

We report eclipse timings and optical/infrared photometry of a sample of binary stars that include low-mass nondegenerate stars, some of which are post-common envelope (PCE) secondary companions to hot subdwarf B (sdB) stars. We model the reflection effect in the latter systems to characterize the temperature of the heated hemisphere of the secondaries, first from blackbody fits and then by comparison to libraries of the spectral energy distribution of dwarf M stars. We explore how consistent our phenomenological results are with the properties inferred from analysis of light curve shapes, and discuss the prospects for turning these reflection effect systems into double-lined spectroscopic binaries for characterization of the mass-radius relationship of low-mass PCE secondaries.

Author(s): Zachary Hartman[1], Donald M. Terndrup[1]
Institution(s): *1. Ohio State University*

345.16 – The Double Red Giant Binary With Odd Oscillations

Red giants in eclipsing binaries are excellent tools for studying the interplay among stellar evolution, binarity, and solar-like oscillations. We present a detailed look at one unique system composed of two red giants, KIC 9246715. One of the stars exhibits solar-like oscillations that are weaker than expected, and the other shows none at all. To address this oddity, we combine four years of *Kepler* light curves, radial velocity curves for both stars, and stellar atmosphere models for each star's extracted spectrum. Our final, well-constrained photodynamic model yields new physical insights for both stars in the binary, puts asteroseismology to the test, and paves the way for detailed studies of other red giant eclipsing binaries with main-sequence companions. This work summarizes the main results of a new paper by Rawls et al.

Author(s): Meredith L. Rawls[2], Patrick Gaulme[2], Jean McKeever[2], Jerome A. Orosz[3], David W. Latham[1], Jason Jackiewicz[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. New Mexico State University, 3. San Diego State University*

345.17 – Monitoring Symbiotic Stars for Photometric Variability

Seven new symbiotic star systems, discovered by spectroscopic follow-up of candidates from the IPHAS survey, have been photometrically observed for evidence of variability on the order of weeks to months. The IPHAS survey identified a number of symbiotic stars through analysis of their red colors and H-alpha emission, however, none of their other properties or behaviors were studied. The seven targets were monitored during the summers of 2013 and 2014 at the University of Washington's Manastash Ridge Observatory, each along with a unique set of five comparison stars using the H-alpha and Sloan r’ and i’ filters. The data from 2013 demonstrated variation of several targets by a few tenths of a magnitude in the H-alpha filter and large variations of almost one magnitude in the Sloan r' and i' filters. The 2014 observing season is ongoing, and the results will be presented in the accompanying poster.

Author(s): Caitlin Doughty[1], Julie H. Lutz[1]
Institution(s): *1. University of Washington*

345.18 – Kepler and the Eclipsing Symbiotic System CH Cyg

Kepler data have been used to explore the details of the CH Cyg light curve. CH Cyg is a symbiotic binary in a 15 year orbit. It is also an AGB Long Period Variable (LPV) with a 100 day semi-regular period and a 750 day long secondary period (LSP). The cause of LSP variations in LPVs remains unexplained. In order to explore the various time scales in the Kepler data the instrumental long term trends and quarterly changes had to be removed from the light curve. We review this data reduction process. Revised orbital data based on a continuing series of near-IR radial velocity observations are presented. The CH Cyg AGB star eclipsed its hot companion during the period observed. We report on the eclipse and implications for the LSP.

Author(s): Kenneth H. Hinkle[2], Francis C. Fekel[3], Richard R. Joyce[2], Thomas Lebzelter[4], Erich Hartig[4], Jennifer L. Sokoloski[1]
Institution(s): *1. Columbia University, 2. NOAO, 3. Tennessee State University, 4. University of Vienna*

345.19 – Compact Binaries Discovered and Characterized by the Palomar Transient Factory

The Palomar Transient Factory (PTF) is a 7.25 sq. deg imager on the Oschin Smidt Telescope at Palomar. PTF has been observing since 2009 and has accumulated 10's to 1000's of observations per field on fields including most of the northern sky, primarily in R- and g-bands. These include recent synoptic observations of the Galactic Plane for detection of variable and transient sources.

We describe recent PTF studies of compact binaries. These include: AM CVn systems, eclipsing white dwarf binaries, compact sdB binaries, and redback millisecond pulsar systems. These studies are an indication of the wealth of binary science expected to come from the upcoming public release of PTF data as well as the future public surveys of the Zwicky Transient Facility (ZTF).

Author(s): Thomas Allen Prince[1]
Institution(s): *1. Caltech*
Contributing team(s): PTF Collaboration, iPTF Collaboration

345.20 – A Bayesian Estimation for Spica's Apsidal Period from 111 years of Spectroscopic Observations

Toward the goal of constraining the short period (P = 4.01 d) massive binary star Spica's apsidal constant, which in turn constrains the internal structure of the primary star (B1.5 IV), we have modified the Bayesian Markov Chain Monte Carlo code EXOFAST (Eastman et al. 2013) to fit six radial velocity (RV) data sets obtained between 1889 to 2000. The code was modified to take radial velocity input from two stars rather than a single exoplanet host star. In addition the apsidal period (U) and the RV amplitude of the secondary star (K2) have been added as fit parameters, and the longitude of periastron is now a function of time. Measurements from Vogel (1889), Baker (1910), Struve & Ebigghausen (1934), Struve et al. (1958), Shobbrook et al. (1972) and Riddle (2000) provide 338 and 239 RV measurements for the primary and secondary stars respectively.
Preliminary results yield: (1) a median apsidal period (U) of 118.9±1.3 years with 68% confidence consistent with the value of Herbison-Evans et al. (1971), 124±11 years. The ratio of the orbital period to the apsidal period (P/U), one of three parameters needed for observationally determined apsidal-motion constant k2obs (Claret & Willems 2002), is now tentatively constrained to 1%, $P/U = 9.24\pm0.01\times10^{-5}$. (2) The eccentricity is constrained in our solution with an uncertainty of 9%, down from an uncertainly of 20% found by Riddle (2000). (3) The uncertainty in $k2^{obs}$ is dominated by the uncertainty of the ratio of the primary star radius, R1,to the semi-major axis, a, since $k2^{obs}$ is proportional to $(R^1/a)^5$. The semi-major axis can be found from a●sin*i* which is constrained with an uncertainty of 3%, similar to previous work. The influence of the prior values on the posterior distributions will be described. The next step is to constrain the inclination from the light curve and long-baseline near-IR interferometry.

Author(s): Jason P. Aufdenberg[1], Timothy M Robinette[1]
Institution(s): *1. Embry-Riddle Aeronautical Univ.*

345.21 – A Search for Microlensing Signals in the Kepler Field

We are searching through the 4 year public Kepler data set (Q1-17), for inverse transit signals. In a gravitationally bound binary system consisting of a compact object and normal star the compact object can act as a lens as it orbits the host star. Time-series photometry of such a system would show an increase in brightness, appearing as an inverse transit, as the compact object passes between the host star and the observer. This type of microlensing signal has been identified in the system KOI-3278 by Kruse and Agol (2014). Here we present the progress of our search with Kepler photometry.

Author(s): Kelsey L. Hoffman[1], Jason Rowe[1]
Institution(s): *1. NASA-Ames Research Centre*

345.22 – Prospect with ASTRO-H on New Sciences of Accreting Pulsars, Magnetars, & Related Sources

As the endpoints of massive star evolution, neutron stars are enigmatic celestial objects characterized by extremely dense and exotic nuclear matter, magnetospheres with positrons (antimatter), rapid rotation and ultra-strong magnetic fields. Such an extreme environment has provided an accessible astrophysical laboratory to study physics under conditions unattainable on Earth and to tackle a range of fundamental questions related to: the aftermath of stellar evolution and the powerful explosions of massive stars, the equation of state and physics of some of the most exotic and magnetic stars in the Universe, the workings of the most powerful particle accelerators in our Galaxy and beyond,

and the sources of gravitational waves that are yet to be detected. Recent observations revealed a great diversity of neutron stars, including ultra-strongly magnetized pulsars, referred to as “magnetars”, and unusual types of accreting X-ray pulsars. In this paper, we high-light the prospects of the upcoming X-ray mission, ASTRO-H, in studying these highly magnetized neutron stars.

Author(s): Shunji Kitamoto[4], Teruaki Enoto[3], Samar Safi-Harb[6], Masha Chernyakova[1], Carlo Ferrigno[5], Katja Pottschmidt[2]
Institution(s): *1. Dublin Institute for Advanced Studies, 2. NASA/GSFC, 3. Riken, 4. Rikkyo University, 5. University de Geneve, 6. University of Manitoba*
Contributing team(s): ASTRO-H collaboration, High-mass binaries and magnetars

345.23 – X-ray Sources Discovered in the Cores of Galactic Globular Clusters NGC6717 and NGC6287

We present the results of Swift and Chandra Observations of the Galactic globular clusters NGC 6717 and NGC 6287. A shallow survey with the Swift-XRT has detected previously unknown X-ray sources within the cores of these GCs which have been followed-up with Chandra ACIS imaging (20 ks and 40 ks respectively) to reveal in greater detail the nature of the sources in these cluster cores. We present spectral and timing analyses of the detected sources, discuss their probable nature, and consider these GCs in the context of similar work carried out on other galactic GCs.

Author(s): David C Morris[1], Ruel Mitchel[1]
Institution(s): *1. University of the Virgin Islands*

345.24 – A Survey of the Discrete X-ray Source Population of M51

The nearby galaxy M51 is perhaps the best example of a major interacting galaxy in the nearby universe. We present a discussion of the discrete X-ray source population of M51 using data from a Chandra Very Large Project (PI Kuntz). Using new and archival observations, we obtain a total exposure of 865 ksec. This thus represents the deepest exposure in high-resolution X-ray imaging of the full disk of any spiral galaxy. In this poster we discuss our pipeline for X-ray data reduction, the products produced, and the advantages and disadvantages as compared with other publicly available reduction pipelines. We also demonstrate interactive data-driven methods for displaying the survey products, and discuss how this technique can aid in data analysis.

Author(s): Catherine Ann Martlin[3], Roy E. Kilgard[4], Trevor Dorn-Wallenstein [4], K. D. Kuntz[2], Greg Schulman[1]
Institution(s): *1. Clark University, 2. John Hopkins, 3. Swarthmore College, 4. Wesleyan University*
Contributing team(s): The M51 Chandra VLP Collaboration

345.25 – Properties of the Discrete X-ray Source Population of M51

The nearby galaxy M51 is perhaps the best example of a major interacting galaxy in the nearby universe. We present a discussion of the discrete X-ray source population of M51 using data from a Chandra Very Large Project (PI Kuntz). In this poster we present an analysis of the survey data, including X-ray colors, variability, spectra, and discrete source luminosity functions. We examine X-ray and multiwavelength properties of the sources to determine X-ray source classifications. We also discuss the ultraluminous X-ray source population with an emphasis on those sources that are likely black holes with high stellar mass counterparts.

Author(s): Trevor Z Dorn-Wallenstein[4], Roy E. Kilgard[4], Catherine Martlin[3], K. D. Kuntz[2], Greg Schulman[1]
Institution(s): *1. Clark University, 2. Johns Hopkins University, 3. Swarthmore College, 4. Wesleyan University*
Contributing team(s): The M51 Chandra VLP Collaboration

345.26 – Hydrodynamic Simulations of Contact Binaries

The motivation for our project is the peculiar case of the “red nova" V1309 Sco which erupted in September 2008. The progenitor was, in fact, a contact binary system. We are developing a simulation of contact binaries, so that their formation, structural, and merger properties could be studied using hydrodynamics codes. The observed transient event was the disruption of the secondary star by the primary, and their subsequent merger into one star; hence to replicate this behavior, we need a core-envelope structure for both the stars. We achieve this using a combination of Self Consistant Field (SCF) technique and composite polytropes, also known as bipolytropes. So far we have been able to generate close binaries with various mass ratios. Another consequence of using bipolytropes is that according to theoretical calculations, the radius of a star should expand when the core mass fraction exceeds a critical value, resulting in interesting consequences in a binary system. We present some initial results of these simulations.

Author(s): Kundan Kadam[2], Geoffrey C. Clayton[2], Juhan Frank[2], Dominic Marcello[2], Patrick M. Motl[1], Jan E. Staff[3]
Institution(s): *1. Indiana University Kokomo, 2. Louisiana State University, 3. Macquarie University*

345.27 – A Radio Emission Analysis of Nova Puppis 1991 (V351 Pup)

Classical Nova Puppis 1991 (V351 Pup) went into outburst at the end of 1990, powered by a thermonuclear runaway on the surface of a white dwarf in a close binary system. Multi-frequency radio detections from one epoch were published for V351 Pup in the early 1990's, yet the remaining data collected by the Very Large Array telescope (VLA) has remained unpublished since. We analyzed the remaining radio continuum observations for V351 Pup and fit the resulting light curve as expanding thermal ejecta. A well-fit model provides great insight into the total ejected mass, density profile, and the kinetic energy of a nova eruption. Radio light curves are one of the best ways to derive fundamental parameters, and the archival V351 Pup data are a wonderful opportunity to expand the sample of well-studied novae.

Author(s): Carolyn Wendeln[1], Laura Chomiuk[1]
Institution(s): *1. Michigan State University*

345.28 – Combining Fits of The Optical Photometry and X-ray Spectra of the Low Mass X-ray Binary V1408 Aquilae.

V1408 Aquilae is a binary system with a black hole primary accreting matter from a low mass secondary. We observed the system at the McDonald Observatory and collected 126 hours of high speed optical photometry on the source. We modeled the optical light curve using the XRbinary light curve synthesis software. The best fits to the optical light curve seem to suggest that the primary is a low mass black hole, however we cannot exclude some high mass solutions. Our models slightly favor a 3 solar mass primary at an inclination of about 13 degrees. In order to further constrain these parameters, and verify their validity we compared the fits of the optical light curve to fits to the X-ray spectra of the source. Using data from the Chandra Transmission Grating Catalog and Archive and the ISIS software analysis package we modeled the spectra of the source with a multi-temperature blackbody for a relativistic accretion disk around a spinning black hole and an additional photon power law component. The fits to the optical lightcurve and X-ray spectra are in agreement, from this we conclude that the case for V1408 Aql to be at a low inclination and harbor a low mass black hole is plausible.

Author(s): Sebastian Gomez[2], Paul A. Mason[2], Edward L. Robinson[1]
Institution(s): *1. University of Texas at Austin, 2. University of Texas-El Paso*

345.29 – Two tracks in Three Dimensions: Correlations between optical, soft X-ray and hard X-ray brightness variations of the Neutron Star X-ray Binary Aquila X-1

We present long-term multi-wavelength correlation among the fluxes in optical, soft x-ray, and hard x-ray wavelengths in the neutron star x-ray binary system Aquila X-1. We present over fourteen years of optical data obtained with the SMARTS 1.3m telescope, paired with quasi-simultaneous observations in the 2-10 keV soft X-ray range (from RXTE/ASM and MAXI), and in the 15-50 keV hard X-ray range (from Swift/BAT). We find no single correlation between the long-term optical, soft X-ray and hard X-ray fluxes, extending similar findings by Maitra & Bailyn (2008) using only the optical and soft X-ray data till 2007. In this work we show that there are in fact two distinct correlations among these 3 wavelength bands, viz., when quasi-simultaneous optical, soft X-ray, and hard X-ray fluxes are shown on a 3D plot they fall in two distinct branches. This is strongly indicative of two distinct physical mechanisms that may be operating during outbursts of Aql X-1. We speculate on plausible scenarios such as recently discovered transitions between radio-pulsar phase and an X-ray bright phase for some neutron star binaries.

Author(s): John Scarpaci[1], Dipankar Maitra[1]
Institution(s): *1. Wheaton College*

345.30 – Does the HMXB IGR J18214-1318 contain a black hole or neutron star?

Measuring the fraction of high-mass X-ray binaries (HMXBs) that harbors a black hole (BH) rather than a neutron star (NS) can improve our understanding of the role of stellar winds and mass transfer in the evolution of massive stars and help constrain estimates of the numbers of NS/BH and BH/BH binaries in the Galaxy, potential sources of gravitational waves that could be detected by Advanced-LIGO. Some population synthesis studies have shown that BHs are likely to be rare among the Be HMXB population (Belczynki & Ziolkowski, 2009, ApJ, 707, 870) and the one BH Be HMXB that has been discovered has very low X-ray luminosity (Casares et al., 2014, Nature, 505, 378), indicating that BH Be HMXBs may exist but remain undetected by current surveys. However, since luminous supergiant BH HMXBs are known to exist (i.e. Cyg X-1), it is possible that some of the supergiant HMXBs discovered by INTEGRAL may host BHs. Therefore, we are trying to identify the nature of the compact objects in the IGR HMXBs by using NuSTAR and XMM-Newton to search for NS signatures in these systems: pulsations, cyclotron absorption lines, and exponential cutoffs with e-folding energies below ~20 keV. The absence of such features would make an HMXB an excellent black hole candidate. We present the spectral and timing properties of our first target, IGR J18214-1318.

Author(s): Francesca Fornasini[7], John Tomsick[6], Matteo Bachetti[5], Felix Fuerst[1], Lorenzo Natalucci[3], Katja Pottschmidt[4], David M. Smith[8], Joern Wilms[2]
Institution(s): *1. Caltech, 2. Dr. Karl Remeis Observatory, 3. INAF-IAPS, 4. NASA/GSFC, 5. Osservatorio Astronomico di Cagliari, 6. Space Sciences Laboratory, UC Berkeley, 7. UC Berkeley, 8. UC Santa Cruz*

345.31 – Study of the Correlations and the MAXI Hardness Ratio between the Anomalous and Normal Low States of LMC X-3

The bright, unusual black-hole X-ray binary LMC X-3 has been monitored virtually continuously by the Japanese MAXI X-ray All-Sky Monitor aboard the International Space Station (Matsuoka, et al., PASJ, 2009) from August 2009 to the present. Comparison with RXTE PCA and ASM light curves during the ~2.33-year period of overlap demonstrate that despite slight differences in energy-band boundaries both the ASM and MAXI faithfully reproduce characteristics of the high-amplitude, nonperiodic long-term variability, on the order of 100-300 days, clearly seen in the more sensitive PCA monitoring. The mechanism for this variability at a timescale many times longer than the 1.7-day orbital period is still unknown. Models to explain the long-term variability invoke mechanisms such as changes in mass transfer rate, and/or a precessing warped accretion disk. Observations of LMC X-3 have not definitely determined whether wind accretion or Roche-love overflow is the driver of the long-term variability. Recent MAXI monitoring of LMC X-3 includes excellent coverage of a rare anomalous low state (ALS) where the X-ray source cannot be distinguished from the background, as well as several normal low states, in which the source count rate passes smoothly through a low, yet detectable value. Pointed Swift XRT and UVOT observations also sample this ALS and one normal low state well. We combine these data sets to study the correlations between the wavelength regimes observed during the ALS versus the normal low. We also examine the behavior of the X-ray hardness ratios using XRT and MAXI monitoring data during the ALS versus the normal low state.

Author(s): Trevor Torpin[1], Patricia T. Boyd[2], Alan P. Smale[2]
Institution(s): *1. Catholic University of America, 2. NASA's GSFC*

345.32 – Global Simulations of the Interaction of Microquasar Jets with a Stellar wind in High-Mass X-ray Binaries

Jets powered by high-mass X-ray binaries must traverse the powerful wind of the companion star. We present the first global 3-D simulations of jet-wind interaction in high-mass X-ray binaries. We show that the jet can be re-collimated where the internal jet pressure is equal to the wind ram pressure, and beyond the re-collimation, the jet thickness, h, follows from pressure equilibrium between the jet and bow-shock. Based on this analytic jet model, we analyze the effects of jet-wind interaction, bending the jet to an asymptotic angle ψ^{∞}. Through both numerical study and analytic approach, we formularize the ψ^{∞} as a function of jet power and wind thrust, which can be used to constrain the jet power with known wind parameters. For example, we apply the formula to the case of Cygnus X-1, and show that given wind parameters for the O9.7 Iab companion, the jet power should be larger than 1.47×10^{36} ergs s^{-1} to keep the jet straight against the wind momentum flux as it is observed by VLBA. We further discuss the case where the initial jet is inclined relative to the binary orbital axis, which shows asymmetric behavior between approaching jet and receding jet from the companion star. We also analyze the case of Cygnus X-3 and show that jet bending is likely negligible unless the jet is significantly less powerful or much wider than currently thought.

Author(s): Doosoo Yoon[1], Sebastian Heinz[1]
Institution(s): *1. University of Wisconsin,Madison*

345.33 – The 0.3–30 keV spectra of Powerful Starburst Galaxies: NuSTAR and Chandra observations of NGC 3256 and NGC 3310

We present nearly simultaneous Chandra and NuSTAR observations of two actively star-forming galaxies: NGC 3256 and NGC 3310. The NuSTAR galaxy-wide spectra of both galaxies follow steep power law distributions, similar to the spectra of bright individual ultra-luminous X-ray sources (ULXs) that have been studied by NuSTAR. The X-ray emission from both galaxies is spatially resolved by Chandra, which indicates that hot gas dominates the E < 1 – 3 keV emission, while ULXs make up a majority of the emission at E > 1-3 keV. Using new and archival Chandra data we found that both galaxies have candidate AGNs coincident with nuclear regions. However, the steep NuSTAR spectra of both galaxies restricts these candidates to be low luminosity AGN, and a non-AGN nature cannot be ruled out. We find the average 0.3 –30 keV SFR-normalized spectra of NGC 3256 and NGC 3310, combined with equivalent measurements for M83 and NGC 253, show sharpening power-law slopes at energies above 3 – 6 keV due to ULX populations. Our observations therefore constrain the average spectral shape of an unbiased population of ULXs to be similar to the super-Eddington accreting ULXs that have been studied by NuSTAR. We also find that for NGC 3310, there is a factor of 5 times excess X-ray emission, due to an overabundance of ULXs in the galaxy compared to typical galaxies. We argue that the excess is due to the relatively low metallicity of the young stellar population in the galaxy.

Author(s): Joshua Tyler[3], Bret Lehmer[2], Ann E. Hornschemeier[3], Mihoko Yukita[2], Daniel R. Wik[2], Andrew Ptak[3], Daniel Stern[4], Fiona Harrison[1], Tom Maccarone[6], Andreas Zezas[5], Vallia Antoniou[5]
Institution(s): *1. Caltech, 2. JHU, 3. NASA GSFC, 4. NASA JPL, 5. SAO, 6. Texas Tech*
Contributing team(s): NuSTAR Starburst Team

346 – Pulsars and Neutron Stars Posters

346.01 – A flexible real-time pulsar processing system for the VLA

With its large collecting area, sensitive octave-bandwidth receivers and wide-band digital correlator, the Karl G. Jansky Very Large Array (VLA) has potential to become a useful instrument for radio pulsar science. Most observations of this type are currently performed by large single-dish telescopes (e.g., GBT, Arecibo). In certain cases, an array instrument like the VLA can provide a unique complement to "traditional" single-dish pulsar data. It is also an excellent development platform for planned future large-area, array-based pulsar telescopes.
We have developed a new flexible real-time software signal processing system for "phased array" pulsar observing. In this mode, signals from each antenna in the array are coherently summed to form a sensitive single beam on the sky. This is ideal for timing observations in which pulsars with accurately known positions are monitored for years or decades in order to study their binary properties, explore the nature of dense neutron star matter, test general relativity, and possibly directly detect gravitational radiation. Phased array observing can also be used for pulsar searches; the small field-of-view makes it primarily suited for targeted observations of specific areas of interest.
Here we describe the system design and current technical capabilities of this system. Phased, summed data from the correlator are sent over ethernet to a computer cluster that performs filterbank, coherent dedispersion, and/or pulse period folding in software. The system utilizes existing VLA computing resources, and no additional hardware costs were required to enable the new capabilites. The software architecture uses code developed for the GUPPI pulsar instrument together with the community-developed DSPSR pulsar signal processing library, both publicly-available open-source software packages. To date, we have demonstrated processing of up to 4 GHz total bandwidth.
We also summarize initial observations and results obtained using this system. These include constraints on unpulsed emission from the eclipsing binary pulsar Terzan 5A; and a new sensitive 8-12 GHz search for pulsars at the galactic center.

Author(s): Paul Demorest[5], Bryan J. Butler[5], James M. Cordes[2], Shami Chatterjee[2], Adam Deller[1], Vivek Dhawan[5], Joseph Lazio[3], Walid A. Majid[3], Scott M. Ransom[4], Robert Wharton[2]
Institution(s): *1. ASTRON, 2. Cornell University, 3. Jet Propulsion Laboratory, 4. National Radio Astronomy Observatory, 5. National Radio Astronomy Observatory*

346.02 – The Arecibo Remote Command Center at Franklin and Marshall College

We present an overview of the recently established Arecibo Remote Command Center (ARCC) program at Franklin and Marshall College. ARCC allows undergraduates to remotely use the Arecibo 305-m radio telescope for pulsar survey observations and to search the data collected for new radio pulsars using a custom pulsar candidate viewer. Students at Franklin and Marshall also have the opportunity to interact with and make research presentations via teleconference to other ARCC groups located at the University of Texas at Brownsville and the University of Wisconsin Milwaukee. This program serves as an effective introduction to radio pulsar research, and students develop skills that can be usefully employed in other pulsar research projects. A total of 22 Franklin and Marshall students have participated in ARCC since 2013. To date, one new pulsar has been found by the Franklin and Marshall ARCC group.

Author(s): Fronefield Crawford[1], Fredrick Jenet[2], Xavier Siemens[3], Andrea N. Lommen[1], Emma Handzo[2], Nicolas Mahany[1], Kristina Rolph[1], Sierra Blazer[1], Richard Camuccio[1], Abel Gebeyehu[1], Christopher Haylon[1], Mark Lederer[1], Kathleen Lefebvre[1], Yaoyue Liang[1], Daniel Mix[1], John McMahon[1], Christopher Morrow[1], Jonathan Munro[1], Ryan Nesselrodt[1], Caitlin Rose[1], Chase TenBrook[1], Matthew Tibbetts[1], Lam Tran[1], Rachel Umberger[1], Emily Wilson[1], Kristen Wymer[1]
Institution(s): *1. Franklin and Marshall College, 2. University of Texas at Brownsville, 3. University of Wisconsin Milwaukee*

346.03 – Pulsar Search Results from the Arecibo Remote Command Center

This poster presents the pulsar discoveries made by students in the Arecibo Remote Command Center (ARCC) program. The ARCC program was started at the University of Texas - Brownsville (UTB) within the Center for Advanced Radio Astronomy (CARA) as a group of scientists, faculty, graduate, undergraduate, and high school students interested in astrophysics. It has since expanded to form other ARCC programs at the University of Wisconsin-Milwaukee (UWM) and Franklin and Marshall College (F&M). The students in the ARCC group control the world's largest radio telescopes to search and discover pulsars. Pulsars are exotic neutron stars that emit beams of electromagnetic radiation. ARCC students use a web application to view and rate the images of radio pulsar candidates based on their signal characteristics. To date, ARCC students have searched through thousands of candidates and have discovered 61 pulsars to date.

Author(s): Miguel Rodriguez[4], Kevin Stovall[3], Shawn A Banaszak[5], Alison Becker[5], Christopher M Biwer[5], Keith Boehler[4], Keeisi Caballero[4], Brian Christy[1], Stephanie Cohen[4], Fronefield Crawford[1], Andres Cuellar[4], Andrew Danford[4], Louis Percy Dartez[4], David Day[5], Joseph D Flanigan[5], Aldo Fonrouge[4], Adolfo Gonzalez[4], Kathy Gustavson[2], Emma Handzo[4], Jesus Hinojosa[4], Fredrick A Jenet[4], David L.A. Kaplan[5], Andrea N. Lommen[1], Chasity Longoria [4], Janine Lopez[4], Grady Lunsford[4], Nicolas Mahany[1], Jose Martinez[4], Alberto Mata[4], Andy Miller[4], James Murray[4], Chris Pankow[5], Ivan Ramirez[4], Jackie Reser[4], Pablo Rojas[4], Matthew Rohr[5], Kristina Rolph[1], Caitlin Rose[1], Philip Rudnik[4], Xavier Siemens[5], Andrea Tellez[4], Nicholas Tillman[5], Arielle Walker[5], Bradley L Wells[5], Jonathan Zaldivar[4], Adrienne Zermeno[4]
Institution(s): *1. Franklin and Marshall College, 2. Nicolet High School, 3. University of New Mexico, 4. University of Texas at Brownsville, 5. University of Wisconsin-Milwaukee*
Contributing team(s): GBNCC Consortium, PALFA Consortium, GBTDRIFT Consortium, AO327 Consortium

346.04 – Hybrid Imaging-Periodicity Search for Radio Pulsars: A Pilot VLA Survey

Almost all of the ~2300 known pulsars have been discovered using the standard period-dispersion measure (P-DM) search. In a P-DM search, time series intensity data are collected, de-dispersed for a set of trial DMs, and searched for periodic signals usually with frequency-domain algorithms but with fast-folding algorithms for long-period objects. Here we describe a hybrid imaging-periodicity search, an alternate method that uses an imaging survey to select radio point sources as pulsar candidates, followed by a deep P-DM search of these candidates using new or archival data. Since the hybrid search is largely conducted in the imaging domain of time-averaged intensities, it does not suffer reduced sensitivity (as the P-DM method does) when a pulsar signal is heavily modulated by orbital motion, pulse-broadened by scattering, or intermittently emitting (due to large-scale magnetospheric changes, eclipses, etc). As such, the hybrid method is sensitive to systems that are highly selected against in P-DM searches such as compact neutron star binaries, highly scattered millisecond pulsars, and pulsars with spin periods less than a millisecond (should they exist). Interferometric imaging also requires a lower significance threshold for detection than a periodicity search and is more robust against radio-frequency interference. We present preliminary results of a wide-field high dynamic range imaging survey conducted with the Jansky VLA at 1-2 GHz in a pilot program to test the efficacy of a hybrid imaging-periodicity search for radio pulsars in the Galactic plane. The survey region covers four square degrees (Galactic longitudes 32.5-36.5 degrees) using 38 pointings and overlaps with the Arecibo PALFA pulsar survey, which will be used as the periodicity component of our hybrid search. We analyze the observed properties of the 23 known radio pulsars in the survey region and discuss the implications for the selection process needed to narrow the thousands of detected compact sources down to high probability pulsar candidates for a full hybrid survey.

Author(s): Molly Finn[7], Robert Wharton[2], Shami Chatterjee[2], James M. Cordes[2], David L.A. Kaplan[8], Sarah Burke-Spolaor[1], Fronefield Crawford[3], Adam Deller[6], Joseph Lazio[4], Scott M. Ransom[5]
Institution(s): *1. California Institute of Technology, 2. Cornell University , 3. Franklin and Marshall College, 4. Jet Propulsion Laboratory, 5. National Radio Astronomy Observatory, 6. The Netherlands Institute for Radio Astronomy, 7. University of Rochester, 8. University of Wisconsin, Milwaukee*

346.05 – Phased-Array Search for Pulsars within 0.3 pc of Sgr A* using the Jansky VLA

We present the results of a search for radio pulsars around Sgr A* using the Jansky VLA in phased-array mode. This is one of the most sensitive Galactic center pulsar searches to date and the first using the new phased-array search capabilities of the VLA. The VLA is an excellent instrument for pulsar searches around Sgr A* because it has a large effective collecting area (approx same as 100m single dish), large bandwidths (4 GHz between 7.2 and 12.1 GHz), and a small synthesized beam (~7 arcsec at 10 GHz in D-config) to reduce the noise contribution of large scale structures in the Galactic center. Our observations were conducted in September 2014 during the transition from D->DnC configuration over the course of two days. On each day, we observed Sgr A* for 5.5 hours using 4.1 GHz of bandwidth spanning 7.2-9.3 GHz and 10.1-12.1 GHz. Throughout the observation, we clearly detect the radio-emitting magnetar J1745-2900. We will report on the analysis of the data using an acceleration search (capable of detecting a binary pulsar with orbital period above about 50 hours), a sideband search (for orbital periods shorter than about 4 hours), and a single pulse search. Finally, we discuss the implications of this search on the population of radio pulsars in the immediate vicinity of Sgr A*.

Author(s): Robert Wharton[2], Paul Demorest[5], Adam Deller[1], Joseph Lazio[3], Scott M. Ransom[4], Shami Chatterjee[2], James M. Cordes[2], Walid A. Majid[3]
Institution(s): *1. ASTRON, 2. Cornell University, 3. JPL/Caltech, 4. NRAO, 5. NRAO*

346.07 – Discovery of a 1.69 ms radio pulsar associated with the X-ray binary XSS J12270-4859

XSS J12270-4859 is an X-ray binary associated with the Fermi LAT gamma-ray source 1FGL J1227.9-4852 (Hill et al. 2011). In 2012 December, the source underwent a transition where the X-ray and optical luminosity dropped suddenly and spectral signatures of an accretion disk disappeared (Bassa et al. 2014). We report the discovery of a 1.69 millisecond pulsar using the Giant Metrewave Radio Telescope at 607 MHz associated with this source, confirming that system is now an active radio millisecond pulsar. We report on radio timing observations of the source with the GMRT and Parkes Telescope that allow precise determination of the orbital parameters of the system. In addition, using simultaneous radio imaging and timing observations with the GMRT, we are able to study the eclipse behavior.

Author(s): Paul S. Ray[4], Jayanta Roy[5], Bhaswati Bhattacharyya[5], Benjamin Stappers[5], Jayaram N. Chengalur[3], Julia S. Deneva[2], Fernando M. Camilo[1]
Institution(s): *1. Columbia University, 2. National Research Council, 3. NCRA, 4. NRL, 5. University of Manchester*

346.08 – A Low Frequency Survey of Giant Pulses from the Crab Pulsar

We present a low frequency survey of giant pulses from the Crab Pulsar as observed with the first station of the Long Wavelength Array (LWA1). Over 2000 pulses have been detected between 20 - 84 MHz over a period of seven months. This is currently the largest sample of giant pulses below 100 MHz. We examine pulse characteristics, including width distributions, pulse shapes, and power law indices for amplitude distributions. These properties are compared to those derived at higher frequencies in an attempt to constrain emission mechanisms. Since low frequency pulses are particularly susceptible to pulse broadening, an analysis of the scattering tail probes the electron density of the interstellar medium, including line-of-sight crossings by ionized clouds and filaments within the nebula itself. We also discuss potential correlations with the gamma-ray emission during what appears to be a substantial increase in the occurrence of pulses over the seven month period. Construction of the LWA has been supported by the Office of Naval Research under Contract N00014-07-C-0147. Support for operations and continuing development of the LWA1 is provided by the National Science Foundation under grants AST-1139963 and AST-1139974 of the University Radio Observatory program.

Author(s): Tarraneh Eftekhari[1], Gregory B. Taylor[1], Kevin Stovall[1]
Institution(s): *1. University of New Mexico*

346.09 – LOFAR discovery of a quiet emission mode in PSR B0823+26

PSR B0823+26, a 0.53-s radio pulsar, displays a host of emission phenomena over a range of timescales, from seconds to (at least) hours, including nulling, subpulse drifting, and mode-changing. Studying pulsars like PSR B0823+26 provides further insight into the relationship between these various emission phenomena and what they might teach us about pulsar magnetospheres. I will report on the LOFAR discovery that PSR B0823+26 has a weak and sporadically emitting `quiet' (Q) emission mode that is over 100 times weaker (on average) and has a nulling fraction forty-times greater than that of the more regularly-emitting `bright' (B) mode. Previously, the pulsar has been undetected in the Q-mode, and was assumed to be nulling. I will also present simultaneous observations taken with the LOFAR, Westerbork, Lovell, and Effelsberg telescopes between 105 and 2700 MHz, which demonstrate that the transition between emission modes occurs within one single rotation of the neutron star, and that it is concurrent across the range of frequencies observed. I will also show further results from single-pulse variability studies for each emission mode.

Author(s): Charlotte Sobey[1]
Institution(s): *1. ASTRON*
Contributing team(s): LOFAR collaboration

346.10 – An improved algorithm for inferring neutron star masses and radii using NICER waveform data

We have developed a new, faster Bayesian analysis algorithm that enables us to use energy-resolved waveforms of X-ray burst oscillations, like those that will be obtained using NICER, to estimate quickly the masses and radii of rapidly rotating, oblate neutron stars and determine the uncertainties in these estimates. We use the oblate-Schwarzschild (OS) approximation, which Cadeau et al. (2007) showed provides a very accurate description of the waveforms produced by hot spots on rapidly rotating, oblate neutron stars. We show that the angular radius of the hot spot and a phase-independent but otherwise arbitrary background must be included as part of the fit; to do otherwise is observationally incorrect and leads to misleadingly tight constraints on the mass and radius. A simple, single-hot-spot waveform model with 30 energy channels has 38 parameters. If the waveform data is informative, i.e., if they tightly constrain the mass M and the equatorial radius R of the star, the high-probability regions of the full parameter space are small. A grid search of this space would therefore require a prohibitive number of waveform computations. Here we describe a different procedure that is much more efficient. This new procedure (1) generates waveforms by interpolating in a table of pre-computed waveforms and (2) computes bounding ellipsoids that encompass points in the waveform parameter space that have interestingly high likelihoods. Using these bounding ellipsoids typically reduces the volume of the Monte Carlo integration by a factor ~ 30. The net result of these improvements is that whereas the analysis procedure used in Lo et al. (2013) took 50-150 clock hours on a 150-core cluster and did not search the (M,R) volume of interest, the new analysis procedure takes 50-150 clock hours on a 5-core desktop computer to perform a completely blind search of the full volume, despite the additional complexity of the OS waveform model used in the new algorithm.

Author(s): Frederick K. Lamb[1], M. Coleman Miller[2]

Institution(s): *1. Univ. of Illinois, 2. Univ. of Maryland*

346.11 – An Exploration of X-ray Based Distance Estimates to Pulsars

X-ray observations are often used to estimate distances to pulsars based on correlation between the spin-down power and the X-ray luminosity, the fit value of the absorption, or the thermal emission from an assumed surface area. None of these methods are entirely reliable, and none of them have been tested systematically. There is a need for an accurate method of distance measurement, especially for X-ray and gamma-ray pulsars that have no radio counterparts. We will present results of systematic analysis of MSPs with accurate parallax distances using archival and new X-ray data. We use the results to derive a new luminosity-spin-down power relationship for mid and low energy pulsars.

Author(s): Kristof Bognar[2], Mallory Roberts[2], Shami Chatterjee[1]
Institution(s): *1. Cornell University, 2. New York University Abu Dhabi*

346.12 – On the Sensitivity of Black Widow Pulsars to the Stochastic Gravitational Wave Background

In the past five years, one third of the 65 pulsars discovered by observing Fermi unassociated sources are black widow pulsars. Black widow pulsars are eclipsing binary millisecond pulsars with masses ranging from 0.01-0.1 solar masses. The companions in black widow systems exert small torques on the system causing the orbit to change on small but measurable time scales. Because adding parameters to a timing model reduces sensitivity to a gravitational wave signal, the need to fit many orbital frequency derivatives to the timing data is potentially problematic for using black widow pulsars to detect gravitational waves with pulsar timing arrays. Using simulated data with up to four binary frequency derivatives, we show that fitting for orbital period derivatives absorbs less than 5% of the low frequency spectrum expected from a stochastic gravitational wave background signal. Furthermore, this result does not change with orbital frequency. Therefore, we suggest that if timing noise can be accounted for by modeling orbital frequency derivatives and is not caused by spin frequency noise, pulsar timing array collaborations should include black widow pulsars in their array.

Author(s): Christopher Bochenek[1], Scott M. Ransom[1], Paul Demorest[1]
Institution(s): *1. National Radio Astronomy Observatory*

346.13 – A Search for Gamma-ray Emission from Wind-Wind Interactions in Black Widow and Redback Millisecond Pulsars

Recent radio surveys, particularly those targeting unassociated *Fermi* Large Area Telescope (LAT) sources with pulsar-like characteristics, have greatly increased the number of known millisecond pulsars (MSPs) in binary systems with short orbital periods (less than a day) and low-mass companions (of order 0.2 Solar masses for redbacks and less than 0.08 Solar masses for black widows). These systems are likely laboratories for studying wind-wind interactions, and we here describe a search for unpulsed gamma-ray emission, possibly arising from these interactions, in the off-peak intervals. We will also search the off-peak and phase-averaged data for evidence of modulation at the orbital periods, correcting for exposure variations, and stack the off-peak intervals in the event that the emission is below threshold in any given source. Studying this emission will allow us to better understand the pulsar wind and how these systems evolve. Portions of this research performed at the US Naval Research Laboratory are sponsored by NASA DPR S-15633-Y and *Fermi* GO proposal 061103.

Author(s): Tyrel J. Johnson[3], Paul S. Ray[4], Fernando M. Camilo[1], Mallory S. E. Roberts[2]
Institution(s): *1. Columbia University, 2. Eureka Scientific, Inc., 3. George Mason University, 4. US Naval Research Laboratory*
Contributing team(s): Fermi Large Area Telescope Collaboration

346.14 – PINT, a New Pulsar Timing Software

We are presenting a new pulsar timing software PINT. The current pulsar timing group are heavily depending on Tempo/Tempo2, a package for analysis pulsar data. However, for a high accuracy pulsar timing related project, such as pulsar timing for gravitational waves, an alternative software is needed for the purpose of examing the results. We are developing a Tempo independent software with a different structure. Different modules is designed to be more isolated and easier to be expanded. Instead of C, we are using Python as our programming language for the advantage of flexibility and powerful docstring. Here, we are presenting the detailed design and the first result of the software.

Author(s): Jing Luo[4], Fredrick A Jenet[4], Scott M. Ransom[3], Paul Demorest[3], Rutger Van Haasteren[2], Anne Archibald[1]
Institution(s): *1. ASTRON, 2. JPL, 3. NRAO, 4. The University of Texas at Brownsville*

346.15 – Long-term Timing of the Pulsar Triple System in M4

Radio pulsars often serve as unique and exquisite probes of gravitational interactions and system-formation mechanisms within different types of orbital systems. In this poster, we summarize ongoing observations and analyses of PSR B1620-26, a pulsar in a hierarchical triple system that is composed of a 191-day "inner" orbit with a white dwarf and a ~60 year "outer" orbit with a Jupiter-mass planet; this triple system is embedded within the M4 globular cluster. Our expanding data set spans 26 years since the pulsar's discovery and has used the following facilities for data collection: the 100-m Robert C. Byrd Green Bank Telescope; the 100-m Effelsberg Radio Telescope; the 76-m Lovell Telescope at Jodrell Bank Observatory; the Karl G. Jansky Very Large Array; and the 140-m and 43-m NRAO radio telescopes at Green Bank, West Virginia.

The lack of outer-orbital coverage has so far prevented a full, time-explicit model of the system, but we argue that a robust pulsar-timing solution of both orbits and third-body perturbations will be available in the next few years when the orbit reaches its point of inflection. This new and unique information will help derive inertial and geometric properties of the system, and help shed further light on the nature and evolution of the planetary companion.

Author(s): Emmanuel Fonseca[5], Ingrid H. Stairs[5], Zaven Arzoumanian[2], Steinn Sigurdsson[4], Stephen E. Thorsett[7], Michael Kramer[1], Nicolas Caballero[1], Benjamin Stappers[6], Andrew Lyne[6], Anne Archibald[3]
Institution(s): *1. Max Planck Institute for Radio Astronomy, 2. NASA Goddard Space Flight Center, 3. The Netherlands Institute for Radio Astronomy, 4. The Pennsylvania State University, 5. The University of British Columbia, 6. The University of Manchester, 7. Willamette University*

346.16 – The Double Pulsar: Timing and Strong-Field Gravity

The double pulsar is a highly relativistic system in which both neutron stars are known to be radio pulsars. As expected from binary evolutionary theory, one pulsar is recycled and the other young. This binary provides the most stringent tests of strong-field relativistic gravity to date and offers the prospect of entirely new tests. We present updated timing results from this unique system, derived in large part from sensitive observations with the 100-m Green Bank Telescope.

Author(s): Ingrid H. Stairs[5], Michael Kramer[4], Marta Burgay[1], Robert D. Ferdman[3], Paulo Freire[4], Duncan Lorimer[7], Andrew Lyne[6], Richard N. Manchester[2], Maura McLaughlin[7], Andrea Possenti[1], John Sarkissian[2], Norbert Wex[4]
Institution(s): *1. Osservatorio Astronomico di Cagliari, 2. CSIRO Astronomy and Space Science, 3. McGill University, 4. MPIfR, 5. Univ. of BC, 6. University of Manchester, 7. West Virginia University*

346.17 – Flux Density Variations in the Parkes Pulsar Timing Array Millisecond Pulsars

Precise timing of an ensemble of pulsars spread across the sky (a pulsar timing array, PTA) can be used to search for gravitational waves. The Parkes Pulsar Timing Array project (PPTA) currently observes 23 pulsars with the Parkes Radio Telescope, largely in the southern sky, with the primary goal of searching for gravitational waves. The pulsars in the sample show large variations in flux density due to refractive scintillation in the interstellar medium (ISM). These flux variations cause timing uncertainty to vary by more than an order of magnitude. A better understanding of flux-density variations associated with the interstellar medium (ISM) is crucial for optimizing observing strategy and increase the sensitivity of the PPTA to gravitational waves. Flux-density variations can also potentially be caused by magnetospheric state changes. We use flux density time series and structure functions to examine both the properties of the ISM and search for intrinsic flux variation in these pulsars. We present intriguing features of the datasets and general implications of the results.

Author(s): Renée Spiewak[2], Ryan Shannon[1], George Hobbs[1], Matthew Kerr[1]
Institution(s): *1. CSIRO Astronomy and Space Science, 2. University of WI - Milwaukee*

346.18 – Precision Pulsar Timing at the DSN

Millisecond pulsars are a class of radio pulsars with extremely stable rotations. The excellent timing stability of millisecond pulsars can be used to study a wide variety of astrophysical phenomena. In particular, observations of a large sample of these pulsars can be used to detect the presence of low-frequency gravitational waves. We have developed a precision pulsar timing backend for the Deep Space Network (DSN), which will allow the use of short gaps in tracking schedules to observe and time pulses from an ensemble of millisecond pulsars. The NASA Deep Space Network (DSN) operates clusters of large dish antennas (up to 70-m in diameter), located roughly equi-distant around the Earth, for communication and tracking of deep-space spacecraft. The backend system will be capable of removing entirely the dispersive effects of propagation of radio waves through the interstellar medium in real-time. We will describe our development work, initial results, and prospects for future observations scheduled later this year.
This research was performed at the Jet Propulsion Laboratory,
California Institute of Technology, under the Research and Technology
Development Program, under a contract with the National Aeronautics and
Space Administration.

Author(s): Walid A. Majid[1]

Institution(s): *1. JPL/Caltech*

346.19 – The Effect of Thermalization on Light Curves from Kilonova

Our best chance to detect electromagnetic emission from compact object mergers may be through the observation of "kilonovae": radioactively powered transients that peak days to weeks post-merger. Detailed models of kilonova can enhance our understanding of gravitational wave sources and the nucleosynthesis of the heavy elements. A key uncertainty in modeling the light curves of kilonova is the efficiency with which radioactive decay products (e.g., non-thermal electrons, alpha particles, fission fragments, and gamma rays) are absorbed within the ejecta. The effectiveness of this thermalization sets the kilonova's overall luminosity budget. Modeling the thermalization is challenging due to the exotic nature of the *r*-process material ejected by the merger and the ejecta's uncertain physical properties. Each decay product thermalizes via a unique set of processes which depend on the various physical characteristics of the ejecta. We calculate the time-dependent thermalization efficiencies of the decay products, exploring the impact of the ejecta's mass, velocity, composition, and magnetic field configuration. We also investigate the sensitivity of our results to the decay products' energy spectra. We examine the effects of thermalization on kilonova light curves, and we assess the extent to which these effects may be used to probe of the composition and magnetic field geometry in the post-merger outflow.

Author(s): Jennifer Barnes[1], Daniel Kasen[1]
Institution(s): *1. University of California - Berkeley*

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347 – Black Hole Posters

347.01 – The Black Hole Formation Probability

A longstanding question in stellar evolution is which massive stars produce black holes (BHs) rather than neutron stars (NSs) upon death. It has been common practice to assume that a given zero-age main sequence (ZAMS) mass star (and perhaps a given metallicity) simply produces either an NS or a BH, but this fails to account for a myriad of other variables that may effect this outcome, such as spin, binarity, or even stochastic differences in the stellar structure near core collapse. We argue that instead a probabilistic description of NS versus BH formation may be better suited to account for the current uncertainties in understanding how massive stars die. Using the observed BH mass distribution from Galactic X-ray binaries, we investigate the probability that a star will make a BH as a function of its ZAMS mass. Although the shape of the black hole formation probability function is poorly constrained by current measurements, we believe that this framework is an important new step toward better understanding BH formation. We also consider some of the implications of this probability distribution, from its impact on the chemical enrichment from massive stars, to its connection with the structure of the core at the time of collapse, to the birth kicks that black holes receive. A probabilistic description of BH formation will be a useful input for future population synthesis studies that are interested in the formation of X-ray binaries, the nature and event rate of gravitational wave sources, and answering questions about chemical enrichment.

Author(s): Drew R. Clausen[1], Anthony Piro[2], Christian D. Ott[1]
Institution(s): *1. Caltech, 2. Carnegie Observatories*

347.02 – A Second Look at the Accretion Disk Wind in GRS 1915+015 as Observed with *Chandra* and *RXTE*

We present a re-analysis of simultaneous *Chandra* and *RXTE* observations of the microquasar GRS 1915+015 observed in a soft state first presented by Ueda et al. (2009). In our extended analysis, we incorporate a number of previously unpublished highly ionized absorption lines above 7.5 keV, as well as self-consistent relativistic reflection models, updated ISM cross-sections, and detailed XSTAR photoionization models for a self-consistent treatment of the continuum and the accretion disk wind. Through a time-resolved spectral analysis, we confirm and tightly constrain the ionization parameter and column density variability of the wind during the observations. We discuss properties of the wind, including its evolution and mass loss rate, and the relationship between accretion, ejection, and ionization processes revealed by our updated modeling.

Author(s): Mason Keck[1], Joseph Neilsen[1]
Institution(s): *1. Boston University*

347.03 – Temporal Variability in a Long, Global Accretion Disk Simulation

Photometric variability is a ubiquitous feature of accreting astrophysical objects; however, the physical processes driving and affecting the variability are poorly understood. Global oscillation modes ("diskoseismic" modes) and magnetic dynamos have been invoked to explain patterns in the variability, like frequency dependent correlations and quasi-periodic oscillations (QPOs). Reproducing these features with a numerical model has been difficult due to the

computational requirements needed to fully resolve the small-scale MHD and hydrodynamic features while running the simulation long enough to allow the processes to fully evolve. Using a long, global magnetohydrodynamic (MHD) simulation of a geometrically thin accretion disk around a black hole, we investigate the diskoseismic modes and report the presence of a dynamo in the azimuthal magnetic field. Additionally, we present spectral breaks in the power spectra of synthetic light curves generated from the simulation's cooling function.

Author(s): J. Drew Hogg[1], Christopher S. Reynolds[1]
Institution(s): *1. University of Maryland*

347.04 – The impact of non-thermal electrons on resolved black hole accretion disk images

Recent developments in radio astronomy (in particular, the Event Horizon Telescope) allow us for the first time to resolve length scales around the Milky Way's Sgr A* comparable to the event horizon radius. These observations are opening up new opportunities to study strong gravity and accretion physics in the vicinity of a supermassive black hole. However, the processes governing black hole accretion are not well understood. In particular, the electron thermodynamics in black hole accretion disks remain mysterious, and current models vary significantly from each other. The impact of these differences between current electron thermodynamics models on results obtained from EHT images is not well understood. Thus, in this work, we explore the effects of non-thermal electrons on black hole images and radio spectra in the context of both semi-analytic and numerical models of accretion flows. Using general relativistic ray-tracing and radiative transfer code, we simulate images of the accretion disk around Sgr A* and compare our simulations to observed radio data. We estimate the range of electron energy distribution functions permissible by the data. In so doing, we also explore the range and variety of black hole images obtained by varying the distribution function.

Author(s): Shengkai Mao[2], Jason Dexter[1], Eliot Quataert[2]
Institution(s): *1. Max Planck Institute for Extraterrestrial Physics, 2. UC Berkeley*

347.05 – Stellar Tidal Disruption by a Supermassive Black Hole Binary

Stellar tidal disruption events occur when stars approach the immediate vicinity of a massive black hole and are torn apart by the tidal field. These produce luminous transient sources, probing accretion physics, stellar dynamics and strong gravity near black holes. While the fate of the bound material around a single black hole has been well-studied, not much attention has been given to either the bound or unbound material of stellar debris in the presence of a black hole binary. With both analytic calculations and numerical simulations, we explore the effects of a secondary black hole on tidal disruption events, in which we discover that accretion might not happen and the behavior of the unbound material becomes important.

Author(s): Angelo Ricarte[2], Priyamvada Natarajan[2], Lixin J. Dai[1]
Institution(s): *1. University of Maryland, 2. Yale University*

347.06 – Recoiling Supermassive Black Holes: a search in the Nearby Universe

The coalescence of a binary black hole can be accompanied by a large gravitational recoil due to anisotropic emission of gravitational waves. A recoiling supermassive black hole (SBH) can subsequently undergo long-lived oscillations in the potential well of its host galaxy, suggesting that offset SBHs may be common in the cores of massive ellipticals. We have analyzed HST archival images of 14 nearby core ellipticals, finding evidence for small (<=10 pc) displacements between the AGN (locating the SBH) and the center of the galaxy (the mean photocenter) in 10 of them. Excluding objects that may be affected by large-scale isophotal asymmetries, we consider six galaxies to have detected displacements, including M87, where a displacement was previously reported by Batcheldor et al. 2010. In individual objects, these displacements can be attributed to residual gravitational recoil oscillations following a major or minor merger within the last few Gyr. For plausible merger rates, however, there is a high probability of larger displacements than those observed, if SBH coalescence took place in these galaxies. Remarkably, the AGN-photocenter displacements are approximately aligned with the radio source axis in four of the six galaxies with displacements, including three of the four having relatively powerful kpc-scale jets. This suggests intrinsic asymmetries in radio jet power as a possible displacement mechanism, although approximate alignments are also expected for gravitational recoil. Orbital motion in SBH binaries and interactions with massive perturbers can produce the observed displacement amplitudes but do not offer a ready explanation for the alignments.

Author(s): Davide Lena[4], Andrew Robinson[4], Alessandro Marconi[1], David Axon[5], Alessandro Capetti[3], David Merritt[4], Daniel Batcheldor[2]
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347.07 – Constraining the Orbits of the Supermassive Binary Blackhole Pair 0402+379

Galaxy mergers are a relatively common occurrence in the Universe. Given that most large galaxies harbor supermassive black holes in their centers, it should follow that two supermassive black holes could be found in the centers of galaxies that have recently undergone a merger event. Supermassive black hole binaries (SMBHB) with small separation (referred to as "tight binaries"), however, are quite rare, implying that the mergers happen less often than we think, or that the binary black hole merger happens much more quickly than expected from simulations. We present observations of one of the best candidates for a tight SMBHB, 0402+379, made in 2003, 2005, and 2009 using the VLBA at 3 frequencies, and report on their apparent relative component motions over this time frame. Additionally, these results are compared to earlier observations of 0402+379 which can help establish a long time baseline. This information, although still preliminary, can be used to provide constraints on the orbits of this binary system which in turn may yield insight as to why these binary systems are not significantly more commonly detected in, for example, ULIRGs in the late stages of merger.

Author(s): Ben Holland[1], Alison B. Peck[2], Gregory B. Taylor[5], Robert T. Zavala[4], Roger W. Romani[3]
Institution(s): *1. Colorado School of Mines, 2. NRAO, 3. Stanford University, 4. U.S. Naval Observatory Flagstaff Station, 5. University of New Mexico*

347.08 – Supermassive Black Hole Binary Mergers within Axisymmetric Galaxies: An Orbital Perspective.

Within a galactic center, two supermassive black holes (SMBH)s will become bound as a SMBH binary whose orbit will shrink as it scatters away stars within its loss cone. In a perfectly spherical galaxy model, there are not enough stars within the loss cone to allow the SMBHs to coalesce, and the binary separation stalls at about a parsec. If the galaxy is mildly flattened, however, the SMBHs coalesce within a few billion years, bypassing the stalling seen in spherical systems. Here, we explore the orbital content within an N-body model of a mildly-flattened, non-rotating, SMBH-embedded elliptical galaxy to understand why axisymmetry can drive the SMBHs to merge. Using both a frequency-mapping and an angular momemtum criteria, we identify a wealth of centrophilic orbits in the axisymmetric model, including saucers, that are absent from an otherwise identical spherical system. To address the final parsec problem furthermore, we analyze the time-dependent structure of the axisymmetric model during the SMBH binary merger, paying particular attention to the origin of those stars that are three-body scattered by the SMBH binary. We discuss implications for galaxy structure, hypervelocity stars, and gravitational wave sources.

Author(s): Baile Li[2], Kelly Holley-Bockelmann[2], Fazeel Khan[1]
Institution(s): *1. Institute of Space Technology, 2. Vanderbilt University*

347.09 – Data formats for a library of Kerr metric transfer functions

As part of a project to model time-resolved X-ray obscuration in AGN, we have reimplemented and improved the Reynolds et al (1999, ApJ 514, 164) approach to calculating the transfer functions which give the redshift and projected orientation of an accretion disk element in the observer frame. We define a multi-extension FITS image array format which contains the computed transfer function for a given value of observation angle and black hole spin parameter. Each extension contains an image, in observer plane coordinates, of a different physical quantity: redshift, direction cosine, geodesic coordinates, etc. This allows us to build up a library of transfer function files for different observation angles, each with moderate (less than 200 Mbyte) storage requirements. Use of the FITS format allows us to record the associated model parameters and coordinate systems in a standard way and to visualize the results using standard analysis tools such as ds9. We illustrate preliminary spectral modelling results obtained using this approach.

Author(s): Jonathan C. McDowell[2], Laura Brenneman[2], Christopher S. Reynolds[3], Mason Keck[2], Guido Risaliti[1]
Institution(s): *1. Arcetri (INAF), 2. Harvard-Smithsonian CfA, 3. University of Maryland*

347.10 – A systematic search for z ≥ 5 active galactic nuclei in the *Chandra* Deep Field South

We investigate early black hole growth through the methodical search for z ≥ 5 AGN in the *Chandra* Deep Field South. We base our search on the *Chandra* 4-Ms data that should allow us to detect Compton-thin AGN with $M^{BH} > 10^7 M^{\odot}$ accreting at Eddington ratios > 0.1.
The *Chandra* Deep Field South contains over 600 z ≥ 5 Lyman Break Galaxies. These high-redshift galaxies are the progenitors of massive, local galaxies and based on lower redshift relations we would expect ~ 20 of them to host AGN. We combine the *Chandra* data with GOODS/ACS, CANDELS/WFC3 and *Spitzer*/IRAC data. After excluding clear low-redshift sources our sample consists of 58 high-redshift candidates. We use a range of redshift estimators including a photo-z code, stacking, colour criteria and the Lyman Break Technique. We also use the X-ray Hardness Ratio as additional information.
The final z ≥ 5 candidates that remain after we combine our redshift tests, are likely to be low-redshift interlopers. We thus conclude that, contrary to our expectation of finding at least a few high-redshift AGN, the field does not contain any convincing z ≥ 5 AGN candidates.
Our results place interesting constraints on early black hole growth and we discuss a range of possible explanations.

Author(s): Anna K. Weigel[1], Kevin Schawinski[1], Ezequiel Treister[2], Michael Koss[1], C. Megan Urry[3], Benny Trakhtenbrot[1]
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347.11 – The impact of Lyman-alpha trapping on the massive black hole seed formation

Supermassive black holes with masses up to a few billion solar masses have been observed when the universe was only one billion years old. One viable seeding mechanism for these black holes is the direct gaseous collapse into a massive black hole on the order of 10^4 - 10^6 solar masses. This process can only occur when atomic hydrogen line cooling is efficient and fragmentation is suppressed during the collapse, thus requiring metal-line and molecular hydrogen cooling to be insignificant. As the cloud collapses to high densities, neutral hydrogen becomes optically thick to Lyman-alpha radiation, limiting the effectiveness of radiative cooling. We improve on previous methods of treating the optically thick regime, such as an effective equation of state, by formulating an approximate method to calculate the local trapping of Lyman-alpha radiation, which considers both non-coherence scattering and line cooling from the Lyman series. Here we explore its effect on massive black hole formation in cosmological simulations with the adaptive mesh refinement code Enzo. We show that Lyman-alpha trapping can further suppress fragmentation and affect the local thermodynamical state of the central collapsing gas cloud. By including this process at high densities, we expect that our results will provide more accurate conditions and accretion rates, leading to the formation of a supermassive star or quasistar.

Author(s): Qi Ge[1]
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347.12 – The Dynamics of Seed Black Holes in the First Galaxies

The discovery of bright quasars at redshift z≥6 in the Sloan Digital Sky Survey (SDSS) implies that black holes (BHs) as massive as 10^9 solar masses were already assembled within 1 Gyr. Generically, these SMBHs are thought to have assembled by mergers with other BHs and by gas accretion onto less massive seed BHs. One candidate of such seed BHs are Population III (Pop III) stellar remnants. In order to map out plausible scenarios such massive objects form from Pop III remnants, we run a cosmological adaptive refinement mesh simulation of an overdense region of about 300 Mpc^3, which forms a few 10^9 solar mass dark matter halos and over 13000 Pop III stars by redshift 15. Then we focus on one of these massive halos, containing 20 Pop III stellar remnants, to study the dynamical behavior of these BH seed candidates. Here we report on the evolution of the orbital properties of stellar-mass seed BHs in one of the first galaxies. They are distributed throughout the halo, creating a swarm of BHs, gradually falling toward the halo center through dynamical friction. From these characteristics, we estimate the BH merger rate in this particular galaxy, which is an important quantity to assess during the early buildup of massive BHs.

Author(s): Chao Shi[1], John Wise[1], Hao Xu[3], Michael L. Norman[3], Brian W. O'Shea[2]
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348 – Young Stellar Objects, Very Young Stars, T-Tauri Stars, H-H Objects Posters

348.01 – Dissecting a Molecular Shock: Spatially Resolved H^2 Line Ratios Across the HH7 Bow Shock

We report on a detailed study of the physics of molecular shocks using Gemini NIFS (Near-Infrared Field Spectrometer) *K*-band spectra of a 3.”2 x 2.”9 region near the tip of the HH7 bow shock. The IFU data have an angular resolution of 0.3", much higher resolution then in any previous study of a molecular shock, and a velocity resolution of 60 km/s. We have detected 20 H^2 emission lines with upper state energies as high as 28,000 K, and 6 additional unidentified lines which share the same bow shock morphology as the H^2. We use excitation temperatures derived from line pairs measured in 0.15” x 0.15” bins to attempt to constrain the shock type and distinguish between low velocity jump shocks, continuous shocks, and dissociative shocks in which the H^2 line emission arises from newly reformed H^2.

Author(s): Rosemary E. Pike[5], Thomas R. Geballe[1], Michael G. Burton[4], Antonio Chrysostomou[3], Peter Brand[2]
Institution(s): *1. Gemini Observatory, 2. Royal University Edinburgh, 3. University of Hertfordshire, 4. University of New South Wales, 5. University of Victoria*

348.02 – Spectro-astrometric Study of HI emission lines from Herbig Ae/Be Stars

We present a spectro-astrometric study of the Pa β and Br γ lines from six Herbig Ae/Be stars using NIFS on Gemini North. The goal of this study is to determine the origin of the HI emission lines. By combining the high angular resolution (0.1") and intermediate spectral resolution (R~5000) of GEMINI/NIFS we measured the spectro-astrometric signal of the Pa β and Br γ emission lines at the 0.1 mas level. The HAe stars showed no significant spectro-astrometric signal, while the HBe stars did show significant detections. We compare our results to models and discuss the implications for understanding the origin of the HI lines in Herbig Ae/Be stars and their utility for measuring the accretion rate. We also discuss various artifacts in the data and prospects for more sensitive measurements in the future.

Author(s): Steven Cade Adams[2], Sean D. Brittain[2], Catherine Dougados[3], Myriam Benisty[5], Linda Podio[1], Emma Whelan[4]
Institution(s): *1. Arcetri Astrophysical Observatory, 2. Clemson University, 3. Universidad de Chile, 4. Universität Tübingen, 5. Université de Grenoble*

348.03 – Revisiting Forbidden Lines in T Tauri stars

Low excitation forbidden lines of [O I], [S II], and [N II] in the spectra of accreting young stars have long been recognized as mass outflow tracers due to their primarily blueshifted emission. The profiles often possess two kinematic components, a high velocity component (centroids from -50 to -200 km/s) arising in an extended collimated jet and a low velocity component (centroids from -5 to -10 km/s) possibly arising in some form of disk wind. Moreover, a recent paper by Rigliaco et al. (2013) explores the possibility that the low velocity component may itself be comprised of distinct broad and narrow kinematic contributions.

Using high-resolution spectra acquired with the Keck I HIRES spectrograph, at a velocity resolution of 5 km/s, we aim to separate the various kinematic components in T Tauri forbidden lines. Observed profiles from lines of [O I] 6300, [0 I] 5577, and [S II] 6731 are decomposed via Gaussian fits into components that share kinematic features across multiple lines.

For the high velocity components, we modernize the relation between mass ejection in the jets and mass accretion rates onto the star, originally found by Hartigan, Edwards, and Ghandor (1995). For the low velocity components, we confirm that a combination of broad and narrow components is commonly observed, and line ratios of each component are compared to those expected from models of slow photo-evaporative flows from the disk.

Author(s): Wanda Feng[2], Suzan Edwards[2], Ilaria Pascucci[3], Elisabetta Rigliaco[1]
Institution(s): *1. ETH Zurich, 2. Smith College, 3. University of Arizona*

348.04 – Multi-Wavelength Spectroscopy of Two Classical T Tauri Stars

X-ray, optical, and near-infrared spectra of two accreting T Tauri stars: TW Hya and BP Tau are analysed for a comparison of accretion properties and effects. The two stars form a valuable pair for study. While similar in spectral type (K7) and mass (0.8 M_sun), they differ in other properties. TW Hya is a 10 Myr star, viewed pole-on thus placing the accretion process in full view. BP Tau, in comparison, is younger (1 Myr), accreting material at a much higher rate and is viewed at 45 degrees. Deep CHANDRA spectra (HETG and LETG) of both stars characterize the corona and accretion parameters. Additional optical and near-IR spectra at high resolution
(Magellan/MIKE, FLWO/TRES, KPNO/PHOENIX, KECK/NIRSPEC) were taken both simultaneously and contemporaneously to detail the post-shock material and the stellar wind.

Author(s): Andrea K. Dupree[1], Nancy S. Brickhouse[1], Steven R. Cranmer[1]
Institution(s): *1. SAO*

348.05 – Measurement of ^{12}CO, ^{13}CO, and C^{18}O Ratios in HL~Tau and GV~Tau

We present measurements of three CO isotopologues taken from the high resolution 4.7 um fundamental and 2.3 um overtone ro-vibrational CO absorption spectraobtained using the NIRSPEC infrared spectrometer on the Keck II telescope. These CO absorption lines arise from the circumstellar material surrounding the Classical T Tauri Stars GV Tau and HL Tau. For HL Tau, we find that the ^{12}CO/^{13}CO and ^{12}CO/C^{18}O abundances are consistent with their abundance in the local ISM and previously published values. For GV Tau we find that ^{13}CO and C^{18}O are heavily depleted relative to their abundance in the ISM. The depletion in GV Tau is consistent with that of selective photodissociation in the disk. In our poster, we will discuss why the depletion of ^{13}CO and C^{18}O is higher in GV Tau than in HL Tau and the implications this may have for the abundance of ^{18}O in meteorites.

Author(s): Scott Davis[1], Thomas Teasley[1], Sean D. Brittain[1], Greg Doppmann[3], Joan R. Najita[2]
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348.06 – No evidence of disk destruction by OB stars

It has been suggested that the hostile environments observed in massive star forming regions are inhospitable to protoplanetary disks and therefore to the formation of planets. The Orion Proplyds show disk evaporation by extreme ultraviolet (EUV) photons from Theta1 Orionis C (spectral type O6). In this work, we examine the spatial distributions of disk-bearing and non-disk bearing young stellar objects (YSOs) relative to OB stars in 17 massive star forming regions in the MYStIX (Massive Young Star-Forming Complex Study in Infrared and X-ray) survey. Any tendency of disky YSOs, identified by their infrared excess, to avoid OB stars would reveal complete disk destruction.

We consider a sample of MYStIX that includes 78 O3-O9 stars, 256 B stars, 5,606 disky YSOs, and 5,794 non-disky YSOs. For each OB star, we compare the cumulative distribution functions of distances to disky and non-disky YSOs. We find no significant avoidance of OB stars by disky YSOs. This result indicates that OB stars are not sufficiently EUV-luminous and long-lived to completely destroy a disk within its ordinary lifetime. We therefore conclude that massive star forming regions are not clearly hostile to the formation of planets.

Author(s): Alexander J.W. Richert[1], Eric Feigelson[1]
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348.07 – Mid-Infrared Variability Among YSOs in Rho Oph, IRAS 20050+2720 and GGD 12-15 Star Formation Regions

We present partial results of the *Spitzer* YSOVAR mid-IR monitoring survey of 3 star forming regions which have also been subjected to X-ray surveys. Monitored young stellar objects (YSOs) include: 179 members of IRAS 20050+2720, 57 members of the Rho Oph dark Cloud (Lynds 1688) and over 90 Class II and 25 Class 0/I sources within 5' of the GGD12-15 star forming regions. The monitoring took place during the *Spitzer* Space Telescope in its warm mission phase and exceeded 40 days for all clusters. Over 80% of the Class 0-II objects are found to be variable at mid-IR wavelngths. Periodic variability was identified for about 25% of the sources. Among the IR variables is a highly embedded *Herschal* source which may among the least evolved sources with a measured X-ray extinction. The amplitude of the variability is larger in more embedded YSOs. Many of the Class II and Class I YSOs exhibit redder colors in a fainter state, compatible with time-variable absorption. But a few become becomes bluer when fainter, which can be explained with significant changes in the structure of the inner disk. We analyze the slopes of the tracks of the variable sources in the color-magnitude diagram and find that sources with longer time scales tend to show trends indicative of more disk activity. A search for reflexive changes in the IR due to X-ray events was carried out, no direct trends are found. However, we do find that signal coherence time is longer in the X-ray detected Class II sources than a similar set of non-X-ray emitting Class IIs.

Author(s): Scott J. Wolk[2], Katja Poppenhaeger[2], Hans Moritz Günther[2], Luisa M. Rebull[1]
Institution(s): *1. Caltech, 2. SAO*
Contributing team(s): YSOVAR Team

348.08 – Nature or Nurture: the peculiar HH 900 jet and outflow system in the Carina nebula

We present new optical and IR spectroscopy and Hubble Space Telescope imaging of HH 900, a peculiar protostellar outflow in the Carina nebula. Previous Hα imaging from HST revealed an unusually broad, bipolar outflow emerging from a small, tadpole-shaped globule that is illuminated by the many O-type stars in nearby Trumpler 16. Near-IR narrowband [Fe II] images reveal a symmetric, collimated jet that bisects the broad outflow traced by Hα. In a giant H II region like Carina, [Fe II] emission traces dense gas that is self-shielded from Lyman continuum photons from nearby O-type stars, but is excited by non-ionizing FUV photons that penetrate the ionization front within the jet. New Gemini AO images of near-IR H^2 emission show that molecules survive in the outflow, and follow the Hα morphology. Position-velocity diagrams of the three lines also reveal very different kinematics. [Fe II] traces steady, jet-like velocities that are faster than those observed in H^2 emission. Most strikingly, Hα velocities resemble the Hubble wedges seen in the position-velocity diagrams of some molecular outflows, but few other protostellar jets. We propose that [Fe II] emission traces the protostellar jet itself while H^2 emission reveals the molecules that (briefly) survive in the outflow, and Hα traces the ionized skin of the outflow sheath entrained by the jet. The high estimated mass-loss rate of the jet requires a high accretion rate, implying that the unseen driving source is an intermediate-mass (~2-8 Msun) protostar. We propose that HH 900 provides a bridge between molecular outflows driven by deeply embedded sources, and jets from unobscured low-mass protostars because external irradiation from nearby O-type stars illuminates both the collimated atomic jet core and the material it sweeps up.

Author(s): Megan Reiter[1], Nathan Smith[1], Megan M. Kiminki[1], John Bally[2]
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348.09 – Vertically Global, Horizontally Local Models for Astrophysical Disks

Barotropic fluids, for which the pressure is only a function of the density, rotate on cylinders in the presence of a gravitational potential, so that the angular frequency of such a disk is independent of height. Therefore the shearing box framework, representing a small disk volume with height-independent angular frequency, can consistently model barotropic disks. If the fluid in the disk is baroclinic, the angular frequency does in general depend on height and it is thus necessary to go beyond the standard shearing box approach. We demonstrate that given a global disk model, it is possible to develop consistent models that are local in horizontal planes and global in height with shearing-periodic boundary conditions. These models can be non-axisymmetric for globally barotropic disks but should be axisymmetric for globally baroclinic disks. We illustrate the potential for this framework by studying a vertical shear instability, and examining the modes associated with the magnetorotational instability. The framework provided by the vertically global shearing box will benefit the study of a wide variety of astrophysical phenomena in baroclinic disks; including instabilities, convection, turbulent transport, as well as the structure and dynamics of disk coronae and winds, and the interstellar medium in galactic disks.

Author(s): Colin P. McNally[1], Martin Pessah[1]
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348.10 – EVLA Observation of Centimeter Continuum Emission from Protostars in Serpens South

Serpens South is a protocluster with an unusually high abundance of Class 0 and I protostars, suggesting it is in a very early phase of star formation and may eventually form a star cluster. Following its discovery in 2008 with the Spitzer space telescope, infrared and millimeter observations and analysis quickly followed, however, Serpens South has yet to be fully explored in the radio. Radio observations at centimeter wavelengths have long been used as a tool to probe the dynamical processes of young protostars that are still heavily shrouded in their protostellar envelopes and thus cannot be seen at longer wavelengths. Radio observations then become an important tool in understanding Serpens South due to its young age. To this end, we have conducted EVLA C band continuum observations of the central region of the Serpens South protostellar cluster in order to map the centimeter continuum emission in a region of high Class 0 / I protostellar surface density. We report the detection of centimeter emission corresponding to protostars identified by Spitzer, and to protostars identified but blended by Herschel. We characterize their centimeter emission, and put them in context with previous Spitzer and Herschel infrared and far-infrared observations, as well as IRAM millimeter observations. Additionally, we make an assessment of the protostars' bolometric luminosity, and compare them to the known protostellar 3.6 cm to 6.0 cm luminosity vs. bolometric luminosity relation. With the EVLA, we present a mid-resolution map of centimeter emission from the central region of Serpens South with the highest sensitivity to date, with a beam size of ~5 arcseconds and rms on the order of 15 microJansky.

Author(s): Nicholas S. Kern[3], John J. Tobin[1], Jared A. Keown[4], Robert A. Gutermuth[2]
Institution(s): *1. University of Leiden, 2. University of Massachusetts, 3. University of Michigan, 4. University of Victoria*

348.11 – Time-series Photometry of the Pre-Main Sequence Binary V4046 Sgr: Testing the Accretion Stream Theory

Most stars are born in binaries, and the evolution of protostellar disks in pre-main sequence (PMS) binary stars is a current frontier of star formation research. PMS binary stars can have up to three accretion disks: two circumstellar disks and a circumbinary disk separated by a dynamically cleared gap. Theory suggests that mass may periodically flow in an accretion stream from a circumbinary disk across the gap onto circumstellar disks or stellar surfaces. Thus, accretion in PMS binaries is controlled by not only radiation, disk viscosity, and magnetic fields, but also by orbital dynamics.

As part of a larger, ongoing effort to characterize mass accretion in young binary systems, we test the predictions of the binary accretion stream theory through continuous, multi-orbit, multi-color optical and near-infrared (NIR) time-series photometry. Observations such as these are capable of detecting and characterizing these modulated accretion streams, if they are generally present. Broad-band blue and ultraviolet photometry trace the accretion luminosity and photospheric temperature while NIR photometry provide a measurement of warm circumstellar material, all as a function of orbital phase. The predicted phase and magnitude of enhanced accretion are highly dependent on the binary orbital parameters and as such, our campaign focuses on 10 PMS binaries of varying periods and eccentricities. Here we present multi-color optical (U, B,V, R), narrowband (Hα), and multi-color NIR (J, H) lightcurves of the PMS binary V4046 Sgr (P=2.42 days) obtained with the SMARTS 1.3m telescope and LCOGT 1m telescope network. These results act to showcase the quality and breadth of data we have, or are currently obtaining, for each of the PMS binaries in our sample. With the full characterization of our sample, these observations will guide an extension of the accretion paradigm from single young stars to multiple systems.

Author(s): Benjamin M. Tofflemire[3], Robert D. Mathieu[3], David R. Ardila[1], David R. Ciardi[2]
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348.12 – Stellar Radius Measurements of the Young Debris Disk Host AU Mic

We present results from our on-going program to directly measure the sizes of nearby young stars using the CHARA Array interferometer. Here we highlight several recent successes, including a precise size measurement of AU Mic (GJ 803), a M1 spectral type star that harbors a debris disk and is a member of the Beta Pictoris Moving Group. The star is spatially resolved with an angular diameter of 0.78 milli-arcseconds, corresponding to a physical radius of 0.83 solar radii; the measurement is accurate to better than 3 percent, which is especially remarkable given the low elevation of this star when observed from the northern hemisphere (DEC = -31 degrees). This size is roughly 70% larger than the average size of similar temperature main sequence stars, also determined from interferometric measurements. It is a bona-fide pre-main sequence star, and the first such low mass star ever spatially resolved. The results provide an independent age estimate of the Moving Group, a temporal stamp on the evolutionary state of the debris disk, and offer a benchmark for theories of how low mass stars gravitationally settle toward the main sequence.

Author(s): Russel J. White[1], Gail Schaefer[1], Theo Ten Brummelaar[1], Christopher D. Farrington[1], Harold A. McAlister[1], Stephen T. Ridgway[1], judit sturmann[1], Laszlo Sturmann[1], Nils H. Turner[1]
Institution(s): *1. Georgia State University*

348.13 – SLICC: Spectral LInear Combination for Coronagraphy

The STIS corongraph is the only remaining working coronagraph on HST, but one, due to use of the unfiltered CCD, which has a bandpass spanning from 2000-10,000 A. This resulted in extreme sensitivity to the color of a source (Grady et al. 2005), and prompted use of ad
hoc linear combinations of point spread function template observations to reveal the circumstellar disks associated with T Tauri stars. A limited set of T Tauri stars have low resolution spectrophotometry spanning 1150-10,000 A, with sufficiently many epochs to permit us to fit both the imagery and the broadband optical spectral energy distribution. We present the results of this quantitative test of spectral deconvolution of STIS coronagraphy.

Author(s): Andrew W Cox[2], Carol A Grady[1]
Institution(s): *1. Eureka Scientific, 2. University of Maryland, Baltimore County*

348.14 – Near-IR Variability of Young Stars in Orion OB1

We present preliminary results of a multi-epoch near-IR study of a sample of 137 T Tauri stars (TTS) in the Orion OB1 association, belonging to the ~10 Myr old 25 Ori cluster and the 4 Myr old OB1b subassociation. We used the NEWFIRM near-IR wide field imager on the Kitt Peak 4m telescope to obtain data in the JHK^S bands for up to 10 epochs spanning 22 days during Oct.-Nov. 2012. We find that on average, that TTS in the 25 Ori cluster vary with amplitudes of ~0.1mag in J and H, and ~0.06 mag in K^S. Among the interesting cases is a Classical T Tauri star in this region with a large variation in all three bands, with J=0.63mag, H=0.39mag and Ks=0.35mag, which we speculate could originate in the innermost region of the disk surrounding this young star.

Author(s): Alexander Contreras[2], Cesar Briceno[1]
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348.15 – Infrared Photometry and Spectroscopy of V582 Mon (KH15D)

We present an analysis of near-IR spectra of V582 Mon, also known as KH15D, that were obtained with the GNIRS instrument at Gemini Observatory. The object is a 3 Myr T Tauri binary system with an orbital period of 48.37 days. The components, star A (K6/K7) and star B (K1), are surrounded by a warped, precessing ring of material. The projection of the ring on the sky acts as a screen that moves across different portions of the binary orbit as the ring precesses. Currently, the system is configured so that the orbital motion of star B carries ~50% of its photosphere above the edge of the screen. Star A is completely occulted at all phases. Previous work in bands *V* through *K* has shown that no starlight is able to pass through the ring when both stars are behind the screen, i.e. that the screen is completely opaque at those wavelengths. However, recent light curves obtained with the Spitzer Space Telescope show that the ring is partially transparent at 3.6 and 4.5 µm near its edge. GNIRS spectra were obtained at several phases and will further constrain the properties of the ring, the stellar components and a putative third light component with a temperature of ~2500 K.

Author(s): Nicole Annemarie Arulanantham[2], William Herbst[2], Sandy K. Leggett[1]
Institution(s): *1. Gemini Observatory, 2. Wesleyan University*

348.16 – A survey of molecular hydrogen emission in the Rosette Molecular Cloud

We survey the embedded stellar clusters of the Rosette Molecular Cloud using near-infrared H^2 imaging to trace the outflow activity in the cloud. Using *Spitzer* IRAC data we distinguish between shock excited and UV excited emission. We identify many of the driving sources of the outflows traced by H^2 emission and find they are predominantly young Class I/0 protostars. Our study shows that younger clusters appear to have more outflow activity and suggests outflows play a significant role in gas removal within the clusters. J.Y. acknowledges partial support from PAPPIT-IN101813.

Author(s): Jason E. Ybarra[1], Carlos Román-Zuñíga[1], Elizabeth A. Lada[4], Scott W. Fleming[3], Randy L. Phelps[2]
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348.17 – Proper motion measurements of HH 224

We measured the proper motion of the components of Herbig-Haro object HH 224 embedded in the rho Ophiuchi cloud core using two epochs of [S II] imaging with a 17-year baseline. Our analysis finds the direction of HH 224N to be consistent with the other components of HH 224S suggesting HH 224S and HH 224N are part of the same flow. We discuss possible driving sources. We acknowledge partial support from PAPPIT-IN101813.

Author(s): Erika F. Perez Rivera[1], Jason E. Ybarra[3], Mary Barsony[4], Randy L. Phelps[2], Carlos Román-Zuñíga[3], Mauricio Tapia[3], Juan José Downes[3]
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348.18 – YSOVAR: Light Curve Classification Scheme

Recently, there have been several efforts aimed at monitoring young stars in the infrared. The light curves have turned out to be incredibly complex, and the behavior in the mid-infrared doesn't always track the behavior at other bands (see, e.g., Cody et al. 2014). Recognizing patterns among the light curves is often the first step towards understanding the underlying physical processes. The YSOVAR (Young Stellar Object VARiability) Spitzer Space Telescope observing program obtained the first extensive mid-infrared (3.6 and 4.5 um) time-series photometry of the Orion Nebula Cluster plus smaller footprints in eleven other star-forming cores. YSOVAR has ~29,000 unique objects with ~39,000 light curves in either or both IRAC bands. All 12 YSOVAR clusters have data taken at a relatively fast cadence over ~40 days in one or both IRAC bands; some clusters have additional data over longer timescales and/or at any of a number of bands (including optical or near-IR data). We are developing a light curve classification scheme that can be applied to these fast cadence IRAC data over all 12 clusters, enabling recognition of patterns across the clusters. We believe that the scheme can be extended to other wavelengths and/or applied to other young star light curves as well. This poster will describe the current state of our classification system.

Author(s): Luisa M. Rebull[1]
Institution(s): *1. Caltech*
Contributing team(s): YSOVAR team

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349 – Circumstellar Disk Posters

349.01 – The shell spectrum of HD 94509

HD 94509 is a 9th magnitude Be star with an unusually rich metallic-lined shell. The absorption spectrum is rich, comparable to that of an A or F supergiant, but Mg II (4481A), and the Si II (4128 and 4130A), are weak, indicating a dilute radiation field, as described by Otto Struve. The H-alpha emission is double with components of equal intensity and an absorption core that dips well below the stellar continuum. H-beta is weaker, but with a similar structure. H-gamma through H-epsilon have virtually black cores, indicating that the shell covers the stellar disk. The stronger metallic absorption lines are wide near the continuum, but taper to very narrow cores. This line shape is unexplained. However, the total absorption can be modeled to reveal an overall particle densities of $10^{10}-10^{12}$ cm^{-3}. An electron density $\log(n_e) = 11.2$ is obtained from the Paschen-line convergence and the Inglis-Tellar relation. Column densities are obtained with the help of curves of growth by assuming uniform conditions in the cloud. These indicate a nearly solar composition. The CLOUDY code (Ferland, et al. Rev. Mex. Astron. Astroph. 49, 137, 213) is used to produce a model that predicts matching column densities of the dominant ions, the $n = 3$ level of hydrogen, the H-alpha strength, and the electron density ($\pm 0.5 dex$).

Author(s): Charles R. Cowley[3], Norbert Przybilla[1], Swetlana Hubrig[2]
Institution(s): *1. Institut fuer Astro- und Teilchen Physik, 2. Leibnitz-Institut fuer Astrophysik, 3. Univ. of Michigan*

349.02 – Transferring Mass between Circumstellar Disks during Stellar Flybys

Early in its life, a star that still lives in its birth cluster has the chance to encounter – or “fly by” – other stars depending on the density of the cluster. These stellar interactions can significantly alter a star’s disk if the flyby is close enough. While previous studies have analyzed what happens to the part of the disk that is able to survive an encounter, we focus on studying the lost disk particles that transfer from one star to the other by simulating the flybys using a hybrid N-body method derived from integrators in the AMUSE package. (1) We conduct a parameter study to simulate a variety of flyby conditions – including [i] the mass ratio of the two stars, [ii] the distance of closest approach of the flyby, and [iii] the eccentricity of the flyby orbit. (2) Quantitatively, we find the furthest flyby distance across the parameter study that can induce disk particles to transfer and find a fit for the percentage of transferred disk particles. We also investigate what types of orbits those transferred particles develop. (3) Lastly, we consider implications for potential stellar flybys in the history of our solar system.

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349.03 – *Spitzer* observations of epsilon Aurigae's disk temperature

We present observations from *Spitzer*'s two IRAC bands at 3.5 µm and 4.5 µm spanning six years (2009-2014), almost 1/4 of this eclipsing binary's orbit. We remove the contribution of the optically bright, primary F0Ia star from the observations in order to analyze the epoch-to-epoch changes of the opaque disk enshrouding the hidden secondary. Previous work suggested the existence of a two-temperature disk: a cooler side at 550 ± 50 K (as observed near eclipse) and a hotter side at 1150 ± 50 K (as observed near the secondary eclipse). The continual monitoring of this unresolved system in the infrared from mid-eclipse to the present demonstrates physical properties of the dusty disk, i.e. thermal inertia effects. How the disk temperature changes adds constraints to the system, particularly the structure and composition of the disk. Monte Carlo radiative transfer codes investigate the parameter space and the impact of the IRAC observations---see Pearson and Stencel, 1 Nov 2014 ApJ.

Author(s): Richard L. Pearson[3], Robert E. Stencel[3], Donald W. Hoard[1], Steve B. Howell[2]
Institution(s): *1. Eureka Scientific, Inc., 2. NASA Ames Research Center, 3. University of Denver*

349.04 – Disk Variability and Pulsation in the Be Star π Aquarii

π Aqr is a bright Be star that lost its circumstellar disk in the late-1990s after showing strong disk emission lines for about five decades. We have analyzed spectra in the Hα/He I 6678 region that were obtained during the hiatus in its mass loss and the epoch of early disk buildup afterwards to investigate the star's pulsation and its possible connection with mass loss activity. The spectra were obtained with the Coudé Feed Telescope at KPNO during three observing runs on 1999 November 20-29, 2000 October 29 - November 3, and 2001 January 4-8. A total of 55 images with a S/N~350 and spectral resolution of 0.103 Å/pixel were obtained. The time resolution was 15 m and the observation sets spanned 1.5-3.0 hr. Rapid nonradial pulsations (NRP) with $l=|m|=5$ were observed with a period of 1.88 ± 0.02 hours. The motion was prograde for a rotation period of 1.8 days. Pulsation amplitudes were largest during the middle observing run. The power in the high frequency signal declined in the final run accompanied by an increase in the low frequency power (as in HD 49330, Huat et al. 2009) suggesting that *p* waves may have been replaced with *g* waves. The photospheric lines are broader during a mass loss episode (increased Hα emission). The NRP variations in Hα during 2000 Nov. 1 suggest a formation in a low pressure gas perhaps at the equator. The NRP bumps are slightly broader in Hα than in He I and C II, which implies a photospheric origin. Since the structure is quite visible in Hα, the apparent NRP is probably occurring in the upper atmosphere, as Stark line broadening would render the features more diffuse if they prevailed at deep layers. Narrow stationary violet and red-shifted features that varied in strength on the time scale of the pulsations were observed in Hα, and suggest that disk changes may be driven by pulsation. Additional spectra from KPNO and the BeSS archive reveal that Hα disk emission peaked in 2011 July (comparable to that observed in 1993 January) and is now steadily declining. Perhaps another diskless phase is coming that will allow further study of the effect of pulsation on mass loss in Be stars. GJP appreciates partial support from USC's Women in Science and Engineering (WiSE) program.

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349.05 – PDS 66 Resolved in Polarimetry with the Gemini Planet Imager

We present H band polarimetry data for the PDS 66 circumstellar disk obtained as part of commissioning tests for the Gemini Planet Imager. GPI's high contrast AO system and coronagraph combined with differential polarimetry provide a clear view of the disk. The disk has an apparent outer radius of ~ 70 AU which is in agreement with previous HST scattered light imaging. We achieve an inner working angle of ~ 0.3'' which surpasses the ~ 0.4'' result accomplished with HST STIS. PDS 66 is a classical T Tauri star and a member of Lower Centaurus Crux with an age of 13 Myrs. The PDS 66 disk appears un-evolved for it's age with a higher than average accretion rate indicative of a near transition disk morphology. Evidence for grain growth within the disk has been seen in both the FIR and millimeter. Early radiative transfer modeling results will also be presented. By comparing the observed polarization fraction to radiative transfer models we can probe the geometry (degree of flaring) and grain distributions (size, density) of the disk.

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Contributing team(s): GPIES Team

349.06 – Characterizing a Young Protoplanetary Disk in the Orion Nebula Cluster

Spatially resolved submillimeter observations of dust and gas in protoplanetary disks provide insight into the location and amount of material available for planet formation. By necessity, most such studies have focused on resolving disks in nearby, low-mass star forming regions, due to the limited sensitivity and angular resolution of sub millimeter interferometers. However most stars, likely including our Sun, form in denser environments near O-type stars, such as the Orion Nebula. Here we present observations of the disk around a young star in the Orion Nebula from the Atacama Large Millimeter/Submillimeter Array (ALMA), at wavelengths of 840 and 867 µm, spatial resolution of 0.5 arcsec, and velocity resolution of 0.4 km/s. The target, 216- 0939, is a Solar-type star surrounded by the largest, most distant disk imaged in the Orion Nebula. We perform a Markov Chain Monte Carlo analysis of the CO(3-2) and HCO+(4-3) molecular line emission. We demonstrate that the velocity field is not well reproduced by a standard circular Keplerian velocity profile, and instead perform a fit to the line emission using an elliptical disk model. We compare our results to observations of similar stars in low-mass star forming environments to investigate the influence of the environment in Orion on planet formation potential around this analog of the young Sun.

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349.07 – Ionization Chemistry and Role of Grains on Non-ideal MHD Effects in Protoplanetary Disks

Ionization in protoplanetary disks (PPDs) is one of the key elements for understanding disk chemistry. It also determines the coupling between gas and magnetic fields hence strongly affect PPD gas dynamics. We study the ionization chemistry in the presence of grains in the midplane region of PPDs and its impact on gas conductivity reflected in non-ideal MHD effects including Ohmic resistivity, Hall effect and ambipolar diffusion. We first develop a reduced chemical reaction network from the UMIST database. The reduced network contains much smaller number of species and reactions while yields reliable estimates of the disk ionization level compared with the full network. We further show that grains are likely the dominant charge carrier in the midplane regions of the inner disk, which significantly affects the gas conductivity. In particular, ambipolar diffusion is strongly reduced and the Hall coefficient changes sign in the presence of strong magnetic field. The latter provides a natural mechanism to the saturation of the Hall-shear instability.

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349.08 – Effects of dust feedback on vortices in protoplanetary disks

We carried out two-dimensional high-resolution simulations to study the effect of dust feedback on the evolution of vortices induced by massive planets in protoplanetary disks. Various initial dust to gas disk surface density ratios (0.001 -- 0.01) and dust particle sizes
(Stokes number 4×10^{-4} -- 0.16) are considered. We found that while dust particles migrate inwards, vortices are very effective in collecting them. When dust density becomes comparable to gas density within the vortex, a dynamical instability is excited and it alters the coherent vorticity pattern and destroys the vortex. This dust feedback effect is stronger with higher initial dust/gas density ratio and larger dust grain. Consequently, we found that the disk vortex lifetime can be reduced up to a factor of 10. We discuss the implications of our findings on the survivability of vortices in protoplanetary disks and planet formation. <!--EndFragment-->

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349.09 – Modeling Far-UV Fluorescent Emission Features of Warm Molecular Hydrogen in the Inner Regions of Protoplanetary Disks

Probing the surviving molecular gas within the inner regions of protoplanetary disks (PPDs) around T Tauri stars (1 – 10 Myr) provides insight into the conditions in which planet formation and migration occurs while the gas disk is still present. We model observed far ultraviolet (FUV) molecular hydrogen (H_2) fluorescent emission lines that originate within the inner regions (< 10 AU) of 9 well-studied Classic T Tauri stars, using the *Hubble Space Telescope* Cosmic Origins Spectrograph (COS), to explore the physical structure of the molecular disk at different PPD dust evolutionary stages. We created a 2D radiative transfer model that estimates the density and temperature distributions of warm, inner radial H_2 (T > 1500 K) with a set of 6 free parameters and produces a data cube of expected emission line profiles that describe the physical structure of the inner molecular disk atmosphere. By comparing the modeled emission lines with COS H_2 fluorescence emission features, we estimate the physical structure of the molecular disk atmosphere for each target with the set of free parameters that best replicate the observed lines. First results suggest that, for all dust evolutionary stages of disks considered, ground-state H_2 populations are described by a roughly constant temperature $T(H_2)$ = 2500 +/- 1000 K. Possible evolution of the density structure of the H_2 atmosphere between intact and depleting dust disks may be distinguishable, but large errors in the inferred best-fit parameter sets prevent us from making this conclusion. Further improvements to the modeling framework and statistical comparison in determining the best-fit model-to-data parameter sets are ongoing, beginning with improvements to the radiative transfer model and use of up-to-date HI Lyman α absorption optical depths (see McJunkin in posters) to better estimate disk structural parameters. Once improvements are implemented, we will investigate the possible presence of a molecular wind component in the observed H_2 fluorescence features by determining blue-shifted flux residuals in the data after best-fit model-to-data comparisons are complete.

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349.10 – Near-infrared Scattered Light Imaging of the Protoplanetary Disk Around V4046 Sgr with the Gemini Planet

Imager

V4046 Sgr is a nearby (d ~73 pc), young (~23 Myr-old) spectroscopic binary that is still surrounded by, and is actively accreting from, a gaseous and dusty protoplanetary disk. Previous submm studies have revealed the presence of an inner "hole" devoid of mm-sized dust grains, suggesting that gas giant planets may be forming in the inner disk. Here, we present near-infrared scattered light imaging of the disk around V4046 Sgr obtained with the Gemini Planet Imager. These images allow us to probe the planet forming region of the disk, down to r = 7 au from the central binary, and search for direct evidence of past or ongoing planet formation.

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349.11 – Understanding Planetary Compositions Using Elemental Ratios in Protoplanetary Disks

The study of the chemical structure of protoplanetary disks is important for understanding the formation of exoplanets and their resulting compositions. Previous work, assuming a static chemistry, demonstrated that the existence of multiple snow lines in protoplanetary disks could explain elevated (superstellar) C/O in planetary atmospheres if the atmosphere is accreted directly from nebular gas. During the lifetime of the disk ($\geq 10^6$ yr) the chemical composition may evolve considerably, however, resulting in different main carriers of C and O in disks and therefore the locations of major snowlines. To address this, we use a time-dependent, (1+1)-dimensional chemical model to trace the chemical evolution of the disk. This allows us to extract the gas- and solid-phase C/O and N/O ratios at different times and locations, which can be used as input to planet formation models.

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349.12 – Modeling Planet-Building Stellar Disks with Radiative Transfer Code

Understanding the nature of the many planetary systems found outside of our own solar system cannot be completed without knowledge of the beginnings these systems. By detecting planets in very young systems and modeling the disks of material around stars from which they form, we can gain a better understanding of planetary origin and evolution. The efforts presented here have been in modeling two pre-transitional disk systems using a radiative transfer code. With the first of these systems, V1247 Ori, a model that fits the spectral energy distribution (SED) well and whose parameters are consistent with existing interferometry data (Kraus et al 2013) has been achieved. The second of these two systems, SAO 206462, has presented a different set of challenges but encouraging SED agreement between the model and known data gives hope that the model can produce images that can be used in future interferometry work. This work was supported by NASA ADAP grant NNX09AC73G, and the IR&D program at The Aerospace Corporation.

Author(s): Jeremy R Swearingen[9], Michael L. Sitko[9], Barbara Whitney[12], Carol A Grady[3], Kevin Robert Wagner[9], Elizabeth H Champney[9], Alexa N Johnson[9], Chelsea C. Warren[9], Ray W. Russell[7], Heidi B. Hammel[6], Casey M. Lisse[1], Michel Cure[8], Stefan Kraus[10], Misato Fukagawa[5], Nuria Calvet[11], Catherine Espaillat[4], John D. Monnier[11], Rafael Millan-Gabet[2], David J. Wilner[4]
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349.13 – Exploring Structures and Variability in the Pre-transitional Disk in HD 169142

We present a theoretical modelling analysis of of the structures in the pre-transisitonal disk in HD 169142 using 3D Monte-Carlo radiative transfer simulation. The multi-epoch broadband spectral energy distribution (SED) exhibits clear evidence of changes to the inner (sub-AU) regions of the disk over a maximum timescale of 10 years with the additional constraint that the shadowing of the outer (>25 AU) disk is non-time-dependent. We find that changes to the inner dust rim (0.2 AU) cannot account for this behavior. Instead, we find that if the inner disk posses an optically thin body of small grains then changes to the outer edge of these structures may successfully reproduce the two states in the SED (analogous to what may be occurring due to accretion onto the central star or dynamical clearing by planets). Furthermore, we explore the density distributions of the outer disk structures as they are constrained by the SED and imaged surface brightness profiles, with the conclusion that a mid-plane density power law profile of r^{-2} and r^{-1} for the 35-70 AU and 70-250 AU regions, respectively, may reproduce the observations to the limit of our available complexity of structures within our modelling software. Finally, we find that a 0.3x density scaling of the 35-70 AU region reproduces the second gap imaged in the near-infrared and at 7 mm, strengthening the link to this structure being cleared by one or more planetary mass bodies.

This work was supported by NASA ADAP grant NNX09AC73G, Hubble Space Telescope grant HST-GO-13032, the IR\&D program at The Aerospace Corporation, and the University of Cincinnati Honors Program.

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349.14 – A Spectro-Astrometric Study of Gas in Transition Disks around HAeBe stars: Evidence of a Forming Companions?

Models of planet-disk interactions predict several signposts of ongoing planet formation such as induced eccentricities in the disk and thermal emission from circumplanetary disks. In this poster we present high resolution NIR spectroscopy and spectro-astrometry of warm gas in disks around Herbig Ae/Be stars and present examples of spectroscopic signatures indicative of these signposts. We also highlight some of the artifacts that can complicate the interpretation of spectro-astrometric measurements and discuss best practices for mitigating these effects. We conclude with a brief discussion of the value of long term monitoring of these systems.

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349.15 – Dust Depletion and Large Scale Asymmetries in Transitional Disks

Different processes shape the structure of circumstellar disks during the epoch of planet formation. Dust and gas depleted cavities, gaps, and/or asymmetries, are generally expected from interactions between the disk and young forming planets. I will present ALMA observations at 0.45 mm that resolve the structure of five transitional disks, and reveal large-scale asymmetries in the outer disks of two young stars in our sample: SAO 206462 and SR 21. These low contrast asymmetries encompass a significant fraction of the disk emission (corresponding to ~2 MJup of material), and are well described by a steady-state vortex prescription. If these are non-transient phenomena, our observations constrain these vortices as radially narrow and azimuthally wide, implying strong turbulence within the vortex (at a level of 1/5 of the sound speed). Additionally, residuals from our modeling trace spiral-like structure, and in the case of SAO 206462, these are roughly coincident with spiral arms traced by scattered light. For the other disks in our sample (LkCa 15, RX J1615-3255, and SR 24S), the structure of the dust continuum emission is axisymmetric. I will discuss our constraints on dust-depletion in their inner disk cavities and present preliminary ALMA Cycle 1 observations for two of these objects.

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349.16 – AU Mic's Debris Disk Chemistry Revealed Using Spatially Resolved Spectroscopy

We present the first coronagraphic spectroscopy of the AU Mic debris disk system obtained with HST/STIS as part of GO-12512. Spectra of the system were taken by placing a long slit in the disk direction while blocking out the central star with an occulting bar. A naked star of similar spectral type was likewise observed for a PSF subtraction. This procedure results in a two dimensional spectrum as a function of disk position between 5200 and 10,200 angstroms for the system. We use the spectra to determine the cold dust grain composition by characterizing the system's color as a function of radial distance along the disk's midplane. This reveals the dynamical perturbations and chemical processing occurring within the disk and traces the potential composition and architecture of any planetary bodies in the system because the planetesimals that form planets produce the observed dust through collisional break up and evaporation.

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349.17 – Probing the AU Microscopii Debris Disk at Close Separations with the Gemini Planet Imager

We present Gemini Planet Imager (GPI) observations of AU Microscopii, a 10-20 Myr old star with a previously imaged debris disk. The data was taken during the commissioning of GPI using both integral field spectroscopy and broadband

imaging polarimetry. Using our integral field spectroscopy data, we present constraints on the mass of possible planets around AU Microscopii. In our broadband imaging polarimetry observations, we detect the disk only in total intensity at separations between ~0.2" to ~2" (~2-20 AU) from the star. We find that the southeast side of the disk is more diffuse and has a larger scale height than the northwest side of the disk at these separations and discuss possible explainations for this. Lastly, we present our upper limits on the polarization fraction of the disk and compare with models.

Author(s): Jason Wang[4], James R. Graham[4], Laurent Pueyo[2], Eric L. Nielsen[3], Gaspard Duchene[4], Max Millar-Blanchaer[5], Paul Kalas[4], Christine Chen[2], Brenda C. Matthews[1]
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Contributing team(s): Gemini Planet Imager team

349.18 – Resolving the Dusty Debris Disk of 49 Ceti

Understanding the dispersal of primordial gas and dust from circumstellar disks is necessary for determining the timeline for giant planet formation. While the current assumption is that the gas and dust evolve simultaneously, there are a few systems that defy this paradigm. The nearby A star 49 Ceti, at a distance of 61 pc, hosts one of only a few known circumstellar disks that exhibits the dust qualities of an older debris disk but still displays a substantial mass of molecular gas, a characteristic normally associated with youth. We present Atacama Large Millimeter/Submillimeter Array (ALMA) observations at 850μm and a spatial resolution of 0.47x0.39 arcsec that resolve emission from the dust disk for the first time. To investigate the properties of the dust grains and the morphology of the disk, we simultaneously model the high-resolution ALMA data and the unresolved spectral energy distribution (SED). The detected emission reveals a disk that extends from 1.16±0.12AU to 286±7AU with an increase in surface density at 113±2AU that is viewed at an inclination of 79.6±.4°. The increase in surface density corresponds to the inner radius of the gas disk, hinting that similar mechanisms may be responsible for sculpting the gas and dust disks at this late stage of disk evolution.

Author(s): Jesse Lieman-Sifry[1], A. Meredith Hughes[1]
Institution(s): *1. Wesleyan University*

349.19 – Exocomets and variable circumstellar gas absorption in the debris disks of nearby A-type stars

Over the past five years, more than a dozen new star systems have been discovered that are similar to the famous and well-described Beta Pictoris system. Like Beta Pictoris, these systems include a young A-type star, a circumstellar gas-poor debris disk, and infalling exocomets. The presence of comets has been inferred from night-to-night changes in the absorption-line characteristics of the circumstellar disk CaII K-line at 3933Å towards these stars. As described by the Falling Evaporated Bodies model of Beust et al (1990, 1998), comet-like planetesimals residing in the outer regions of the dust disk are perturbed into eccentric star-grazing orbits by the action of either mutual collisions or by the gravitational influence of an accompanying massive exoplanet. The plume of gas is liberated at the comet's close approach to the star.
We present new high resolution absorption spectra of the CaII K line recorded over several nights towards the nearby and young (< 50 Myr) A-type stars HD 80007 and HD 109573. Both stars exhibit circumstellar absorption variability that is similar to that frequently observed in other `exocomet-systems', such as Beta Pictoris and 49 Ceti. We also present a list of the physical characteristics of ~40 A-type stars with associated debris disks that possess circumstellar absorption spectra of the CaII K-line observed by us over several nights. Using all of these data we comment on which stellar parameter(s) seem to be the most important in determining whether or not exocomets will be detected in a given system.

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349.20 – ALICE: Analysis of New Debris Disk Images

We have recently resolved 6 debris disks for the first time in scattered light, by reanalyzing the HST-NICMOS coronagraphic archive with advanced post-processing algorithms as part of our ALICE project (Archival Legacy Investigation of Circumstellar Environments). These disks are all young (<40Myr) and nearby (<40pc). Five of them are hosted by F, G stars, one of them being a close analog to the Sun at the epoch of planet formations, and the sixth one is hosted by an M dwarf, making it the second disk ever imaged in scattered light around an M star, with AU Mic. We present here the analysis of each of them.

Author(s): Elodie Choquet[5], Marshall D. Perrin[5], Christine Chen[5], David A. Golimowski[5], John H. Debes[5], Glenn Schneider[6], Laurent Pueyo[5], Dean C. Hines[5], Schuyler Wolff[4], Tushar Mittal[2], Amaya Moro-Martin[5], Dimitri Mawet[3], Julien Milli[3], J. Brendan Hagan[5], Abhijith Rajan[1], Margaret Moerchen[5], Mamadou N'Diaye[5], Jonathan Aguilar[4], Remi Soummer[5]
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Institute, 6. University of Arizona

349.21 – ALICE: Project Overview and High Level Science Products

We report on the status of the ALICE project (Archival Legacy Investigation of Circumstellar Environments), which consists in a consistent reanalysis of the entire HST-NICMOS coronagraphic archive. Over the last two years, we have developed a sophisticated pipeline able to handle the data of the 400 stars of the archive. This pipeline builds on the Karhunen-Loeve Image Projection (KLIP) algorithm, and was completed in the fall of 2014. We discuss the first processing and analysis results of the overall reduction campaign. As we will deliver high-level science products to the STScI MAST archive, we are defining a new standard format for high-contrast science products, which will be compatible with every new high-contrast imaging instrument (GPI, SPHERE, P1640, CHARIS, etc.) and used by the JWST coronagraphs. We present here the specifications of this standard.

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349.22 – New Data Reduction Techniques for Circumstellar Disk Imaging with the Hubble DICE Survey

We present a status report on our efforts to develop an image processing pipeline that combines multiple tools in order to improve the effective sensitivity of Hubble Space Telescope (HST) STIS imaging observations of circumstellar disks around young, nearby stars. The pipeline incorporates a combination of MRRR, LOCI, RSS, RAM, Shizzle, and smoothing algorithms to strip away the overwhelming light from the parent star, remove outlying pixel values, and output high-resolution, sub-pixelated, final images. The developed pipeline has been applied to data collected as part of the Hubble DICE Survey (GO 12228) in an effort to reveal disk substructures which may be signposts of planet formation.

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Contributing team(s): HST/GO 12228 Team

349.23 – Herschel Observations of Dusty Debris Disks

We present results from several Herschel surveys of debris disks around nearby, young stars. The first survey was an OT-1 project based on Herschel PACS far-infrared photometry of six stars to search for the cold component of previously discovered warm debris disks. A second survey was an OT-2 PACS program to further characterize the SEDs of more than a dozen known debris disks. Of the 23 stars observed (across both surveys), 13 showed evidence of a cold disk component similar to the Sun's Kuiper Belt. We also find that 3 out of 4 stars with inner planetary system material having Tdust>300 K also show evidence for cooler dust in their SED fits.
In addition to these two surveys, we present PACS photometry of the debris disk at the star V488 Per that extends its SED into the far-infrared. V488 Per has the largest fractional infrared luminosity (percentage of its bolometric luminosity) known for any main sequence star. Eight of the disks observed with Herschel appear to be resolved at 70 and/or 100 microns. One appears to be resolved at 160 microns. We are able to measure the physical extent of the disks from the images directly and compare the disk radii to the radii inferred from a blackbody fit to the dust emission. This comparison helps us to identify important grain properties. This research was supported by a NASA/JPL grant to UCLA.

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349.24 – Stellar Multiplicity in the DEBRIS disk sample

Circumstellar disks around young stars serve as the sites of planet formation. A common outcome of the star formation process is that of stellar binary systems. How does the presence of multiple stars affect the properties of disks, and thus of planet formation? To examine the frequency of disks around stellar binaries we carried out a multiplicity survey on stars in the DEBRIS sample. This sample consists of 451 stars of spectral types A-M observed with the Herschel Space Telescope. We have examined the stellar multiplicity of this sample by gathering information from the literature and performing an adaptive optics imaging survey at Lick Observatory. We identify 189 (42%) binary or multiple star systems.

In our sample, we find that debris disks are less common around binaries than single stars, though the disk detection frequency is comparable among A stars regardless of multiplicity. Nevertheless, the period distribution of disk-bearing binaries is consistent with that of non-disk binaries and with comparison field samples. Although the frequency of disk-bearing binaries may be lower than in single star systems, the processes behind disk formation are comparable among both single and multiple-star populations.

This work is supported in part by a Chile Fondecy grant #3130520.
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350 – RAS Gold Medal Winner Talk: Looking for the Identity of Dark Matter in and Around the Milky Way, Carlos Frenk (University of Durham)

350.01 – Looking for the identity of the dark matter in and around the Milky Way

One of the most impressive advances in Physics and Astronomy over the past three decades is the development of the ``standard model of cosmology,'' ΛCDM (where Λ stands for Einstein's cosmological constant and CDM for cold dark matter). ΛCDM accounts for an impressive array of data on the structure of the Universe on large-scale scales, from a few gigaparsecs down to a few megaparsecs, where the microwave background radiation and the clustering of galaxies provide clean and well-understood diagnostics. On the scales of galaxies and clusters, however, the model cannot be tested with the same degree of rigour. Yet, it is precisely on these small scales that the nature of the dark matter manifests itself most clearly. I will discuss predictions on small scales from cosmological simulations for different types of dark matter and discuss them in the light of three famous puzzles: the ``core-cusp'', ``missing satellites'' and ``too-big-to-fail'' problems. Possible solutions range from the relatively mundane - that the mass of our galaxy's dark matter halo is smaller than is often thought - through exotic baryonic processes to the more radical assumption that the dark matter is not what the standard model assumes.

Author(s): Carlos S Frenk[1]
Institution(s): *1. Institute for Computational Cosmology, University of Durham*

400 – Plenary Talk: Planetary Nebulae: Reviews and Previews of a Rapidly Evolving World, Bruce Balick (University of Washington)

400.01 – Planetary Nebulae: Reviews and Previews of a Rapidly Evolving Field

Observational results from the ground and space in the past decade and covering the entire spectrum have jolted and energized research into the nature, the formation, and the evolution of planetary nebulae (PNs). The 101-level bubble structure of PNs turned out to be a pleasant but misleading fantasy as observations by HST and ALMA revealed basic details of their infancy. Some combination of close geriatric binary stars (the precusrors of SN Ia's) and magnetic fields dredged into the dusty winds appear to play vital roles in the ejection and collimation of AGB atmospheres. As a result, PNe and their antecedents, AGB stars and prePNs, are providing an array of new opportunities to study asymmetric wind formation, complex gas dynamics, CNO production rates in various galactic environments, and galaxy structure and evolution. I shall review the highlights of recent results, summarize their interpretations, and show some of the observational opportunities to monitor in the next decade, many of which couple strongly to research to related fields. This talk is dedicated to the career of Olivier Chesneau (1972-2014) who pioneered new high-resolution imaging methods that peered into the deep inner cores of nascent planetary nebulae. We remember Olivier as everyone's enthusiastic friend and colleague whose career ended in full stride.

Author(s): Bruce Balick[1]
Institution(s): *1. Univ. of Washington*

401 – Galaxy Clusters III

401.01 – On the Trail of the Most Massive Galaxy Clusters in the Universe

In March 2013, the Planck Collaboration released the first large sample of galaxy clusters, selected through the Sunyaev Zel'dovich (SZ) effect, from a survey covering essentially the entire sky. The Planck SZ (PSZ) catalog contains 861 confirmed clusters, as well as another 366 unconfirmed candidates. The confirmed sample includes the most massive known clusters and extends up to redshifts as high as z~0.9. The Planck confirmation process favored candidates with some signal in ancillary data sets, which resulted in the preferential confirmation of low-redshift systems. The unconfirmed sample, therefore, is likely biased toward massive clusters at redshifts z>0.5. Over the past year we have been actively pursuing the identification of unconfirmed Planck cluster candidates using optical and near-infrared imaging observations on 4-m class telescopes (the Mayall telescope on Kitt Peak and the SOAR telescope on Cerro

Pachon). In this talk we give the first report on our study aimed at unveiling all the most massive galaxy clusters in the Universe.

This work is supported by NASA ADAP grant NNX14AF73G.

Author(s): John Patrick Hughes[3], Felipe Menanteau[1], Felipe Barrientos[2], Leopoldo Infante[2]
Institution(s): *1. NCSA, 2. Pontificia Univ Catolica de Chile, 3. Rutgers Univ.*

401.02D – How well can we measure galaxy cluster masses using galaxies as tracers?

Deriving strong cosmological constraints from galaxy cluster surveys is a complex problem compounded by the difficulty of estimating accurate galaxy cluster masses. In this talk I will present new results on the outcome of an extensive blind study testing the performance of 25 popular galaxy-based cluster mass estimation techniques. I will describe the impact of various initial member galaxy selection procedures on the final mass estimate, focusing on the friends-of-friends, phase space and red sequence -based approaches. I will then explore the accuracy of a diverse set of galaxy-based mass estimation techniques: velocity dispersion, caustic, richness, abundance matching and radial -based methods. I will also discuss the level of scatter and bias delivered by these methods using an ensemble of massive clusters from various mock galaxy catalogues based on both halo occupation distribution and semi-analytic models. Finally, I will address the implications of the magnitude of scatter in the recovered masses for future cosmological surveys relying on cluster masses.

Author(s): Lyndsay Old[13], Ramin A. Skibba[10], Frazer Pearce[13], Darren Croton[6], Stuart Muldrew[11], Juan Carlos Munoz-Cuartas[8], Daniel Gifford[12], Meghan Gray[13], Anja Von Der Linden[5], Gary Mamon[1], Michael Merrifield[13], Volker Mueller[2], Richard Pearson[9], Trevor Ponman[9], Alex Saro[4], Tiit Sepp[7], Cristobal Sifon[3], Elmo Tempel[7], Elena Tundo[13], Yang Wang[13], Radek Wojtak[5]
Institution(s): *1. Institut d'Astrophysique de Paris, 2. Leibniz-Institut fur Astrophysik Potsdam, 3. Leiden Observatory, 4. Ludwig-Maximilians-Universitat, 5. Niels Bohr Institute, 6. Swinburne University of Technology, 7. Tartu Observatory, 8. Universidad de Antiquia, 9. University of Birmingham, 10. University of California, 11. University of Leicester, 12. University of Michigan, 13. University of Nottingham*

401.03 – Calibrating the Cluster Richness-Mass Relation for the Dark Energy Survey

The equation of state for dark energy can be strongly constrained by looking at the formation of galaxy clusters throughout the universe's history. This can be accomplished cheaply and efficiently by examining galaxy cluster richnesses in the optical regime and using these richnesses as proxies for galaxy cluster masses. In order to calibrate the richness-mass relation, I have examined 39 galaxy clusters found in both Dark Energy Survey science-verification data and in archival Chandra data. Using the this data, I have measured a number of X-ray mass proxies for each galaxy cluster and have compared these proxies with the richnesses measured by redMaPPer, a red-sequence cluster-finding algorithm. With more data, this comparison is expected to determine the scatter in the richness-mass relation and improve the Dark Energy Survey figure-of-merit by a factor of two. Funding for this project was provided by NASA through the Chandra X-ray Observatory program.

Author(s): Devon Lawrence Hollowood[2], Tesla E. Jeltema[2], Eli S. Rykoff[1], Eduardo Rozo[1]
Institution(s): *1. SLAC National Accelerator Laboratory, 2. University of California, Santa Cruz*
Contributing team(s): Dark Energy Survey Collaboration

401.04D – Do Cluster Mass Reconstruction Techniques Really Paint The Same Picture?

We present a study of the intrinsic shape and alignment of isodensity surfaces of galaxy cluster halos extracted from the MultiDark Run 1 (MDR1) cosmological simulation. We find that the simulated halos are extremely prolate on small scales, and increasingly spherical on larger ones. Due to this trend, projection along the line-of-sight produces an overestimate of the concentration index as a decreasing function of radius. Using a toy model (prolate spheroidal halos viewed preferentially along the line-of-sight), we find a difference in reconstructed concentrations corresponding to weak and strong lensing to be ~18% (~9%) for low (medium) mass cluster halos with low intrinsic concentrations (c_200 = 1-3). We also discuss ongoing research in which we aggregate all observed concentration and mass measurements spanning multiple reconstruction techniques, representing the most comprehensive view of the observed cluster concentration-mass relation to date. We report a quantitative comparison of the concentration-mass relation as measured by various reconstruction techniques, as well as a comparison to simulations, and also discuss additional insights we have gained regarding the physical meaning of the concentration parameter. Lastly, we also hope to determine the physical causes of biases in measurements, generating a consistent view of cluster properties across all mass-reconstruction techniques.

Author(s): Austen Max Groener[1]
Institution(s): *1. Drexel University*

401.05D – Galaxy Cluster Studies with Weak Lensing Magnification and Shear

The magnification component of weak lensing provides complementary information to the more commonly measured shear distortion. While low redshift halos are better constrained by shear, at increasingly high redshifts the magnification signal becomes quite competitive. We present recent measurements of halo masses from the stacked magnification signal of >18,000 galaxy clusters in the 154 deg^2 Canada-France-Hawaii-Telescope Lensing Survey (CFHTLenS). We perform the first direct cluster mass comparison between magnification and shear, finding global agreement between the independent methods, but with systematic effects influencing particular cluster redshift ranges. We measure the mass-richness scaling relation of the CFHTLenS 3D-MF cluster sample, and search for evidence of its evolution with redshift.

Author(s): Jes Ford[1]
Institution(s): *1. University of British Columbia*

401.06 – The Atacama Cosmology Telescope: Followup Imaging of SZE-Selected Clusters with ATCA, LABOCA, and Herschel

We present 2.1 GHz (ATCA) and 345 GHz (APEX/LABOCA) imaging of ten Sunyaev-Zel'dovich effect (SZE)-selected galaxy clusters from the Atacama Cosmology Telescope (ACT) southern survey. Using a new iterative algorithm to extract signal from the LABOCA maps on multiple scales, and exploiting supplementary Herschel/SPIRE imaging of five clusters, we use these data to disentangle SZE increment signal from the contributions of radio sources and submillimeter galaxies. Five of the ten clusters yield 345 GHz increment detections at high (S/N > 3.5) significance, which we combine with the ACT data to place constraints on the sample's average peculiar velocity relative to the cosmic microwave background.

Author(s): Andrew J. Baker[9], Robert R. Lindner[15], Paula Aguirre[7], John Richard Bond[1], Matt Hilton[14], Adam D. Hincks[12], Kevin Huffenberger[3], John Patrick Hughes[9], Leopoldo Infante[7], Marcos Lima[11], Tobias A. Marriage[4], Felipe Menanteau[13], Michael D. Niemack[2], Lyman Alexander Page[8], Neelima Sehgal[10], Axel Weiss[5], Edward Wollack[6]
Institution(s): *1. Canadian Institute for Theoretical Astrophysics, 2. Cornell University, 3. Florida State University, 4. Johns Hopkins University, 5. MPIfR, 6. NASA' GSFC, 7. Pontificia Universidad Católica de Chile, 8. Princeton University, 9. Rutgers, the State University of NJ, 10. Stony Brook University, 11. Universidade de São Paulo , 12. University of British Columbia, 13. University of Illinois, 14. University of KwaZulu-Natal, 15. University of Wisconsin*
Contributing team(s): Atacama Cosmology Telescope team

402 – Dark Matter & Dark Energy

402.01 – The history of galaxy formation as a cosmological probe

As galaxy formation and evolution over long cosmic time-scales depends to a large degree on the structure of the universe thus the assembly history of galaxies is potentially a powerful approach for learning about the universe itself. As the first step we will present the predicted merger history of dark matter haloes based on the Extended Press-Schechter formalism as a function of cosmological parameters, redshift and halo mass. We calculate how major halo mergers are influenced by changes in the cosmological values of Ω^m, Ω^Λ, σ^8, the dark matter particle temperature (warm versus cold dark matter), and the value of a constant and evolving equation of state parameter w(z). We find that the merger fraction at a given halo mass varies by up to a factor of 3 for haloes forming under the assumption of cold dark matter, within different underling cosmological parameters. Using galaxy mass to halo mass relations we find that the current measurements of the merger history, as measured through observed galaxy pairs as well as through structure, are in agreement with the concordance cosmology. We discuss this implications for this, and the future observations which which will put better limits on using galaxy formation as a probe of cosmology.

Author(s): Christopher Conselice[5], Asa Bluck[4], Alice Mortlock[3], David Peter Palamara[2], Andrew Benson[1]
Institution(s): *1. Carnegie Institute of Washington, 2. Monash University, 3. Royal Observatory Edinburgh, 4. U. Victoria, 5. Univ. of Nottingham*

402.02 – Mapping the Small-Scale Structure of Dark Matter Halos with Strong Gravitational Lensing

The abundance of substructure within dark matter halos surrounding galaxies has been an area of intensive study for over a decade. The number of observed low-mass satellites of the Milky Way is about three orders of magnitude lower than what cold dark matter (CDM) simulations predict, an issue that is referred to as the "Missing Satellite Problem". Disagreement between the abundance of dark matter subhalos and the CDM predictions may lead to exciting insights into the micro-physics of dark matter particles. However, measuring the abundance of subhalos, which may be entirely composed of dark matter, requires a purely gravitational probe. I have simulated observations of gravitationally lensed sub-millimeter galaxies, showing that they can be used to detect dark matter subhalos in the lensing galaxies, using the gravitationally-induced distortions that they cause in the images of background sources. I have shown that by measuring the observed surface brightness correlations of lensed images we can detect the power spectrum of low-mass dark matter subhalos with high significance. In this talk, I will give an overview of an observational campaign that I'm leading to use ALMA and a newly discovered population of strongly lensed sub-millimeter galaxies to measure the mass function of dark matter subhalos with unprecedented accuracy.

Author(s): Yashar D. Hezaveh[1]
Institution(s): *1. Sanford University*

402.03 – Do Dark Matter Axions Form A Bose-Einstein Condensate?

What constitutes the dark matter? As the hunt for direct detection continues, theories abound. An intriguing proposal is due to Sikivie & Yang, who suggest that the dark matter is made up of a hypothetical particle called the axion, and in their picture the axionic dark matter forms an exotic gas known as a Bose-Einstein condensate due to gravitational thermalization. In this talk, I will discuss efforts to understand the Sikivie-Yang proposal, one of which spurred the development of a new framework for studying the Hamiltonian dynamics of gauge theories in curved spaces. I will also discuss the construction of a statistical mechanics for axion-like particles, which have very little interaction with photons.

Author(s): Chanda Prescod-Weinstein[1], Mark Hertzberg[1]
Institution(s): *1. MIT*

402.04 – The Kinematics of Milky Way Satellites as a Test of Dark Matter Models

We apply the Jeans equation to identify subhalos in high-resolution numerical simulations that are potentially consistent with observed properties of Milky Way dwarf spheroidal (dSph) galaxies. We investigate the effects found by several recent studies that show changes to the dynamical properties of galactic substructure: the properties of dark matter (DM), and galaxy formation physics. For those subhalos that we found to provide reasonable fits to the high-quality photometric and kinematic data, they exhibit different properties at present time (e.g. maximum-circular velocity, mass, stellar distribution) and different formation history among the different scenarios that we consider here. Thus those different scenarios provide unique signatures that can be further tested by future surveys. We also examine the possibility of matching the observed dSph luminosity with predicted kinematic properties simultaneously by abundance matching methods and hydrodynamical simulations. These results show that each MW dSphs has had a different star formation history, and these must be understood in concert with DM properties and galaxy formation to better understand the puzzles on sub-galactic scales.

Author(s): Mei-Yu Wang[1], Louis Strigari[1], Till Sawala[3], Mark Lovell[2], Carlos S Frenk[3]
Institution(s): *1. Texas A&M University, 2. University of Amsterdam, 3. University of Durham*

402.05D – Self Interacting Dark Matter and Baryons

Self Interacting Dark Matter (SIDM) is a cosmologically consistent alternative theory to Cold Dark Matter (CDM). SIDM is motivated as a solution to solve problems of the CDM model on small scales including the core/cusp problem, the missing satellites, and halo triaxiality. Each of these problems has secular astrophysical solutions, however taken together and along with suggestions from dark matter (DM) particle physics it is interesting to place constraints on how strong a self interaction would have to be for us to observe it and conversely the null hypothesis of whether we can rule out SIDM. We use high resolution cosmological simulations to compare evolution of stellar populations and (DM) components of dwarf galaxies. Our advanced smooth particle hydrodynamics N-body simulations combine SIDM with baryon physics including star formation, feedback recipes, metal line cooling, UV background, and thermal diffusion that eliminates artificial surface gas tension. We find for a constant SIDM cross section of 2 $cm^2\ g^{-1}$ that DM interactions alone are not significant enough to create cores in dwarf galaxies and for low mass (V^{peak}= 25 km s^{-1}) galaxies the introduction of SIDM fails to decrease the DM central density. Our simulations with star formation feedback are in good agreement with observational estimates of Local Group dwarfs. The lower mass (below $10^8\ M^{\odot}$) halos have inefficient SF, late formation time, and less DM interactions thus small field halos in CDM and SIDM remain cuspy. We conclude that constant cross section SIDM of 2 $cm^2\ g^{-1}$ would be close to unobservable in dwarf galaxies and yet at the same time this cross section is already larger than some observational constraints found in larger (higher velocity) systems. We conclude that to differentiate between SIDM and CDM in an observationally detectable and astrophysically consistent manner a velocity dependent cross section that peaks for halos with small peak velocities will be necessary.

Author(s): Alexander B. Fry[2], Fabio Governato[2], Andrew Pontzen[1], Thomas R. Quinn[2]
Institution(s): *1. University College London, 2. University of Washington*

402.06 – Dark matter or point sources? Utilizing the 1-pt PDF to understand the origin of the GeV excess seen by the Fermi LAT detector

An excess of gamma rays from the Inner Galaxy in the Fermi LAT data has been identified. This emission has been interpreted as a possible signature of the annihilation of dark matter particles, or as originating from a collection of unresolved point sources, such as gamma-ray millisecond pulsars. We explore the clustering properties of the diffuse emission arising from a population of gamma-ray point sources and from the annihilation of dark matter particles in the halo of the Galaxy using the 1-pt probability distribution function of counts in pixels (1pt-PDF, the number of pixels with a specified number of counts as a function of counts); this approach is also known as fluctuation analysis or P(D) analysis. We analyze the 1-pt PDF of the GeV excess within a +/- 5 degree box around the Galactic Center. For both dark matter and point sources we adopt the spatial distribution and spectrum to fit the GeV excess. We determine the contributions to the 1-pt PDF from the Galactic diffuse and isotropic diffuse emission, dark matter, and point sources, and discuss the implications of this analysis for the origin of the GeV excess.

Author(s): Natalie Harrison[2], Jennifer M. Siegal-Gaskins[1]
Institution(s): *1. Caltech, 2. University of Chicago*

402.07 – Self-Scattering for Dark Matter with an Excited State

Self-interacting dark matter scenarios have recently attracted much attention as a possible means to alleviate the tension between N-body simulations and observations of the dark matter distribution on galactic and sub-galactic scales. The presence of internal structure for the dark matter --- for example, a nearly-degenerate state in the spectrum that could decay, or be collisionally excited or de-excited --- has also been proposed as a possible means to address these discrepancies. Such internal structure can be a source of interesting signatures in direct and indirect dark matter searches, for example providing a novel explanation for the 3.5 keV line recently observed in galaxies and galaxy clusters. We analyze a simple model of dark matter self-scattering including a nearly-degenerate excited state, and develop an accurate analytic approximation for the elastic and inelastic s-wave cross sections, which is valid outside the perturbative regime provided the particle velocity is sufficiently low (this condition is also required for the s-wave to dominate over higher partial waves). We anticipate our results will be useful in incorporating inelastic self-scattering into N-body simulations, in order to study the quantitative impact of nearly-degenerate states in the dark matter spectrum on galactic structure and dynamics, and in computing the indirect signatures of multi-state dark matter.

Author(s): Katelin Schutz[2], Tracy Slatyer[1]
Institution(s): *1. MIT, 2. UC Berkeley*

402.08 – Testing a MOND Prediction in NGC3923

We report on a test of MOND using the shell system of the elliptical galaxy NGC3923. NGC3923 has 27 known stellar shells due to the disruption of a galaxy that merged with it. Bilek et al. (2014) used MOND to reproduce locations of the existing shells and predicted an additional, lower-surface-brightness shell at a larger projected radius. This is a clean and important test of MOND. We have imaged a field at the predicted edge of the shell as well as a control field at the location of the known Shell 1N/a using the GMOS-S imaging spectrograph at Gemini South. The known Shell 1N/a is clearly detected. No obvious structures are detected at the location of the predicted shell down to a surface brightness of r ~ 28 mag/sq. arc sec. Ongoing work will quantify the detection limits and look for structures at lower surface brightnesses. Implications will be discussed.

Author(s): Bryan W. Miller[2], Stacy S. McGaugh[1], Chris Mihos[1]
Institution(s): *1. Case Western Reserve University, 2. Gemini Observatory*

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403 – Cosmology III

403.01 – Multi-redshift limits on the Epoch of Reionization 21cm power spectrum from PAPER

The epoch of reionization hydrogen power spectrum is expected to vary strongly with redshift with cosmic history as star formation progressively ionizes the pervasive intergalactic hydrogen. We present an analysis of observations from the Donald C. Backer Precision Array for Probing the Epoch of Reionization (PAPER) telescope which place new limits on the HI power spectrum over the redshift range of 7.5<z<10.5, extending previously published single redshift results to cover the full range accessible to the instrument. The primary challenge to measuring the HI power spectrum is bright foreground emission, which varies slowly with redshift. To suppress these foregrounds, we use filtering techniques adopted from digital signal processing to isolate foreground in power spectrum k-space. This 500 hour integration demonstrates a spectral rejection dynamic range of 10^4. The measured power spectrum uncertainty compares well with the expected thermal noise. Relative to this thermal noise, most spectra exhibit an excess of power at a few sigma. The possible sources of this modest excess include residual foreground leakage, particularly at the highest redshift, and unflagged RFI.

Author(s): Danny Jacobs[1], Jonathan Pober[3], Aaron Parsons[2]
Institution(s): *1. Arizona State University, 2. UC Berkeley, 3. University of Washington*

Contributing team(s): PAPER Team

403.02D – Weak Lensing Tomography Using > 50 High Redshift, z > 0.4, Galaxy Clusters

Weak gravitational lensing is a powerful and unique tool for studying galaxy clusters and cosmology. I will be presenting weak gravitational lensing shear results from a sample set of 57 high redshift galaxy clusters, z > 0.4, from the *Hubble Space Telescope* Advanced Camera for Surveys in several different optical bandpasses. I will discuss point spread function (psf) measurement adaptations in the principal component analysis made to improve the data. I will address the implications that increased sample size, psf changes, background galaxy cuts, mass profile choice and redshift have on the tomography signal and cosmological constraints.

Author(s): Rebecca Santana[1]
Institution(s): *1. Ohio University*

403.03 – Wide-field imaging of the polarized sky with PAPER

We present maps of the polarised southern sky as seen by the Donald C. Backer Precision Array for Probing the Epoch of Reionization (PAPER). Polarized emission is a potential systematic contaminant of the redshifted 21cm signature of neutral hydrogen during reionization, the detection of which is PAPER's primary goal. We use commissioning data from 32 dual-polarization antennas in a minimum-redundancy configuration to create wide-field images in Stokes I, Q, U and V. Here we compare the results of imaging using W-projection and faceting versus m-mode mapping (Shaw et al. 2014a,b), a technique specifically adapted to transit arrays which allows an exact treatment of the spherical sky. We explore differences in the images and potential methods for using the m-mode formalism to extract polarization calibration parameters.

Author(s): Saul Aryeh Kohn[2], James E. Aguirre[2], David Moore[2], Jason Ling[2], Gianni Bernardi[1]
Institution(s): *1. SKA SA, 2. University of Pennsylvania*
Contributing team(s): PAPER

403.04 – Limits on the Polarized Power Spectrum at 126 and 164 MHz from PAPER South Africa 32-Element Data

Faraday-rotated, polarized emission represents a potential contaminating foreground for measurements of the highly redshifted 21 cm power spectrum. There are few existing measurements of polarized foreground emission at meter wavelengths (e.g. Bernardi et al 2013, Jelic et al 2014) and its actual effect on the measured Stokes I spectrum from reionization is unclear. We present new limits on the power spectrum of Stokes Q, U, and V emission at 126 and 164 MHz using PAPER South Africa 32-element data, to supplement existing results for Stokes I (Parsons et al 2014, Jacobs et al 2014). We use upper limits on the Q power spectra to place upper limits on the average polarization fraction of point sources.

Author(s): James E. Aguirre[1], David Moore[1]
Institution(s): *1. University of Pennsylvania*
Contributing team(s): PAPER Collaboration

403.05D – From Enormous 3D Maps of the Universe to Astrophysical and Cosmological Constraints: Statistical Tools for Realizing the Promise of 21 cm Cosmology

21 cm cosmology promises to provide an exquisite probe of astrophysics and cosmology during the cosmic dark ages and the epoch of reionization. An enormous volume of the universe, previously inaccessible, can be directly mapped by looking for the faint signal from hyperfine transition of neutral hydrogen. One day, 21 cm tomography could even eclipse the CMB as the most precise test of our cosmological models. Realizing that promise, however, has proven extremely challenging. We're looking for a small signal buried under foregrounds orders of magnitude stronger. We know that we're going to need very sensitive, and thus very large, low frequency interferometers. Those large interferometers produce vast quantities data, which must be carefully analyzed. In talk, I will present my Ph.D. work at MIT on the development and application of rigorous, fast, and robust statistical tools for extracting that cosmological signal while maintaining a thorough understanding of the error properties of those measurements. These tools reduce vast quanities of interferometric data into the statistics like the power spectrum that can be directly compared with theory and simulation, all while minimizing the amount of cosmological information lost. I will also present results from applying those techniques to data from the the Murchison Widefield Array and will discuss the exciting science they will enable with the upcoming Hydrogen Epoch of Reionization Array.

Author(s): Joshua S. Dillon[1], Max Tegmark[1]
Institution(s): *1. Massachusetts Institute of Technology*

403.06 – Combined Cosmological Constraints using the WiggleZ Multipole Power Spectrum

We present a combined analysis of cosmological parameters using measurements of the matter distribution and redshift-space distortions using the multipole power spectrum from the WiggleZ Dark Energy Survey. The WiggleZ multipole power spectrum data we use consists of measurements of the monopole, quadrupole, and hexadecapole in six regions of the sky at redshifts z=0.4 and 0.8, up to a maximum wavenumber of 0.2 h/Mpc. We combine this data with CMB data from the Planck satellite and weak-lensing data from the CFHTLens survey. We will discuss the existence of tensions in the parameter likelihoods between these datasets, and how those tensions may contribute to interesting values of certain cosmological parameters, particularly the mass of the neutrino.

Author(s): Jason Dossett[1], Chris Blake[2], David Parkinson[3], Signe Riemer-Sørensen[4], Jun Koda[2], Tamara Davis[3]
Institution(s): *1. INAF - Osservatorio Astronomico di Brera, 2. Swinburne University of Technology, 3. The University of Queensland, 4. University of Oslo*

403.07 – Constraining the Thermal State of the IGM at z~20

One of the great challenges of observational cosmology is to trace the thermal history of the Universe during the Dark Age, before the first stars, and immediately following. Theory suggests that the 21 cm transition of Hydrogen can serve as a unique thermometer for the intergalactic medium during this era, and thermal evolution is believed to have depended on a relatively small set of fundamental processes. Detection of the 21cm transition at redshift ~20 should enable strong tests of cosmological models. The ground-based Large Aperture Experiment to Detect the Dark Age (LEDA) is working to establish direct constraint on the thermal history through detection of sky-averaged spectral-line absorption of the Cosmic Microwave Background by the 21cm transition. I will present the latest results from LEDA obtained using stations of the Long Wavelength Array facility and outline technical milestones such as construction of one of the largest radio astronomical correlators in the world and instantaneous confusion-limited images of the full sky (2pi steradian) below 80 MHz.

Author(s): Lincoln J. Greenhill[1]
Institution(s): *1. Harvard-Smithsonian, CfA*
Contributing team(s): LEDA Collaboration

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404 – Planck 2014 Results

AAS Special Session
The Planck 2014 data release includes the full mission data in both temperature and polarization. Scientific results cover a huge range of topics from cosmology to the zodiacal light. A plenary talk on Planck Wednesday afternoon will give an overview of the the principle cosmological results. This Special Session covers: 1. The 2014 Planck mission products, and a general description of the microwave and submillimeter sky, including CMB statistics, global isotropy, and anomalies. 2. Planck measurements of polarization and their implications for both galactic astronomy and cosmology, including large-angular-scale polarization and its implications. 3. Separation and characterization of astrophysical components in the multi-frequency full sky observations by Planck, with all-sky maps of synchrotron, free-free, spinning dust, thermal dust, CO, and SZ emission. 4. Cluster cosmology analysis based on the full Planck data set, including a new cluster catalog and analysis techniques, recent results on cluster masses, and a new look at the tension between clusters and the primary CMB constraints.

404.01 – Planck Cluster Cosmology 2014

As a cosmological probe, galaxy clusters are a powerful complement to the primary cosmic microwave background (CMB) anisotropies. They provide a direct measurement of the density perturbation amplitude at the present epoch that, when combined with primary CMB constraints, tests the validity of the cosmological model. The 2013 Planck analysis uncovered an intriguing tension between the cluster abundance and the primary CMB constraints, a tension that could indicate the need for new physics, such as non-minimal neutrino mass, or an important revision of the cluster mass scale. Unraveling this mystery has been a central focus of cluster cosmology research over the past year. We present our 2014 cluster cosmology analysis based on the full Planck data set. This analysis includes a new cluster catalog and analysis techniques, and incorporates recent results on cluster masses, where significant progress has been made in the past year.

Author(s): James G. Bartlett[1]
Institution(s): *1. Jet Propulsion Laboratory and APC Univ. Paris 7*
Contributing team(s): Planck Collaboration

404.02 – The microwave sky as seen by Planck

Planck has mapped the full sky in nine frequency bands between 30 and 857 GHz, seven of which include polarization observations. In this talk I will present a detailed and comprehensive astrophysical model that faithfully reproduces these observations, both analyzed independently and together with WMAP and 408 MHz observations, consisting of full-sky maps of CMB, synchrotron, free-free, spinning dust, CO, HCN and thermal dust. I will comment on the importance of instrumental effects for these type of measurements, in particular calibration and bandpass uncertainties, and show how to mitigate these effects self-consistently within a global Bayesian analysis framework. Finally, I will show how this new model suggests a path towards improving the overall data quality in the future, by cleanly separating astrophysical contamination from instrumental systematics effects.

Author(s): Ingunn Kathrine Wehus[1]
Institution(s): *1. Caltech/JPL*
Contributing team(s): Planck Collaboration

404.03 – Planck 2014 Cosmological Parameter Constraints

The Planck 2014 cosmology likelihood will for the first time include polarization measurements at small angular scales. I will present parameter constraints on LCDM and extensions from these data, as well as discussing what features of the power spectra lead to these constraints and via which physical phenomenon.

Author(s): Marius Millea[1]
Institution(s): *1. UC Davis*
Contributing team(s): Planck Collaboration

405 – Large Scale Structure, Cosmic Distance Scale I

405.01 – Theoretical Predictions of Large Scale Clustering in the Lyman-alpha Forest

With the recent progress of Lyman-alpha forest power spectrum measurements, understanding of the bias between the measured flux and the underlying matter power spectrum is becoming crucial to the percent level cosmological interpretation of these measurements. Whereas previous theoretical studies of this bias have used N-body and hydro-PM simulations, we have run hydrodynamic simulations to study the response of the Lyman-alpha forest clustering to large wavelength modes of the underlying matter large-scale structure. Our results demonstrate that this can be simulated by evolving smaller, curved universe cosmologies, representing the same universe with different overdense patches. We use these to study the assumptions of the analytical bias formula derived by Seljak (2012), and compare these results with previous numerical methods of determining bias. With several forthcoming large data sets, such theoretical predictions are important to fully understand the clustering of the Lyman-alpha forest.

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405.02D – Position-dependent power spectrum of the large-scale structure: a novel method to measure the squeezed-limit bispectrum

The influence of large-scale density fluctuations on structure formation on small scales is described by the three-point correlation function (bispectrum) in the so-called ''squeezed configurations.'' This bispectrum is generated by non-linear gravitational evolution and possibly also by inflationary physics. We use this fact to show that the bispectrum in the squeezed configurations can be measured without employing three-point function estimators. Specifically, we use the ''position-dependent power spectrum,'' i.e., the power spectrum measured in smaller subvolumes of the survey (or simulation box), and correlate it with the mean overdensity of the corresponding subvolume. This correlation directly measures an integral of the bispectrum dominated by the squeezed configurations. Measuring this correlation is only slightly more complex than measuring the power spectrum itself, and sidesteps the considerable complexity of the full bispectrum estimation. We use cosmological N-body simulations of collisionless particles with Gaussian initial conditions to show that the measured correlation between the position-dependent power spectrum and the long-wavelength overdensity agrees with the theoretical expectation predicted by the ''separate universe approach,'' in which we consider an overdense subvolume as a positively curved universe evolving differently with respect to the background. The position-dependent power spectrum thus provides a new, efficient, and promising way to measure the squeezed- limit bispectrum from large-scale structure observations such as galaxy redshift surveys.

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405.03 – ΛCDM Halo Models of Galaxy Clustering and Evolution in the PRIMUS Survey at $0<z<1$

We utilize ΛCDM halo occupation models of galaxy clustering to investigate the evolving stellar mass and star formation dependent clustering of galaxies in the PRIsm MUlti-object Survey (PRIMUS) from redshifts of z=0.2 to z=1. These clustering measurements provide new constraints on the spatial distribution of galaxies in the 'cosmic web' and on the connections between dark matter halo properties and galaxy properties in the context of the evolving large-scale structure of the universe. Using an analytic model and mock galaxy catalogs, we find a strong correlation between galaxy stellar mass and dark matter halo mass over a wide range of masses, consistent with previous results. However, the stellar-to-halo mass relation (SHMR) and the mass scale where star formation efficiency reaches a maximum appear to evolve more strongly than other models in the literature. Our halo mass constraints obtained from modeling clustering and the stellar mass function are self-consistent only when the COSMOS field, which has relatively strong clustering, is excluded, thus highlighting the importance of 'cosmic variance' effects. We find that the fraction of satellite galaxies in haloes of a given mass increases at higher redshift such that the M^1/M^{min} ratio decreases from ≈20 to ≈12 at z~1. Considering the evolution of the subhalo mass function, this trend has implications for relations between satellite galaxies and halo substructures and for the growth of intracluster mass. Finally, based on the clustering of star-forming and quiescent galaxies, we argue that the efficiency of star formation quenching of central galaxies evolves significantly over the last eight billion years of cosmic time.

Author(s): Ramin A. Skibba[3], Alison L. Coil[3], Alexander Mendez[3], Michael R. Blanton[2], Daniel Eisenstein[1]
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Contributing team(s): PRIMUS

405.04 – Understanding Cosmological Perturbation Theory

Many recent studies have highlighted certain failures of the standard Eulerian-space cosmological perturbation theory (SPT).
Its problems include (1) not capturing large-scale bulk flows [leading to O(1) error in the 1 loop SPT prediction for the baryon acoustic oscillation peak in the correlation function], (2) assuming that the Universe behaves as a pressureless, inviscid fluid,
and (3) treating fluctuations on scales that are non-perturbative as if they were. Recent studies have highlighted the successes of perturbation theory in Lagrangian space or theories that solve equations for the effective dynamics of smoothed fields. Both approaches claim to mitigate some or all of the aforementioned issues with SPT. We discuss these physical developments by specializing to a simplified case and comment on the successes and failures of different perturbation theories (and even whether it is realistic to have an accurate perturbative description of mildly nonlinear scales).

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405.05D – The Cosmic Web Unravelled: A study of filamentary structure in the Galaxy and Mass Assembly survey

I have investigated the properties of the large scale structure of the nearby Universe using data from the Galaxy and Mass Assembly survey (GAMA).
I used a volume limited sample of GAMA groups and galaxies to generate the large scale structure catalogue. This was done with an adapted minimal spanning tree algorithm, which identifies and classifies structures, detecting 643 filaments that measure up to 200 h−1 Mpc, each containing 8 groups on average. A secondary population of smaller coherent structures, dubbed 'tendrils,' that link filaments together or penetrate into voids are also detected. On average, tendrils measure around 10 h−1 Mpc and contain 6 galaxies. The so-called line correlation function is used to prove that tendrils are real structures rather than accidental alignments. A population of isolated void galaxies are also identified. The properties of filaments and tendrils in observed and mock GAMA galaxy catalogues agree well. I go on to show that voids from other surveys that overlap with GAMA regions contain a large number of galaxies, primarily belonging to tendrils. This implies that void sizes are strongly dependent on the number density and sensitivity limits of the galaxies observed by a survey.
Finally, I examine the properties of a mass controlled sample galaxies in different environments. While mass normalised galaxies in voids show subtly higher UV and IR emission, they are no more likely to be blue, faint, or disc-like than their counterparts in filaments. Extending my analysuis to groups and pairs, I fail to see a strong dependence of halo mass on Sersic index and galaxy luminosity, but do find that it correlates very strongly with colour. Repeating this analysis without mass control introduces and amplifies trends in the properties of galaxies in pairs, groups, and large scale structure, indicating that stellar mass is the most important predictor of galaxy properties followed by morphological type, halo mass, pair rank, local density and finally large scale structure.

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Contributing team(s): Galaxy And Mass Assembly (GAMA) survey team

405.06 – CHP-II: The Carnegie Hubble Program to Measure Ho to 3% Using Population II

There has been great progress in the measurement of cosmological parameters in recent years, but controversy has arisen over the Planck/WMAP versus the direct measurement of the Hubble constant. The goal of our Carnegie Hubble Program (CHP) is to obtain a direct measure of Ho to 3%. In CHP I, we used Cepheid variables to calibrate the extragalactic distance scale. In the second phase, CHP II, we are establishing a completely independent route to Ho using RR Lyrae variables, the tip of the red giant branch (TRGB) and Type Ia supernovae (SNe Ia). Not only is the RR Lyrae route independent of the Cepheids, but its PL relation has a scatter that is a factor of 2 smaller. Unlike the Cepheids, the RR Lyrae / TRGB distance scale can be applied to both elliptical and spiral galaxies. This is a great systematic advantage, given the small number of galaxies (9 in total) close enough to have measured Cepheid calibrators within the SNIa hosts. By providing a new calibration using a Pop II distance scale, we will immediately double the number of SN Ia distances based on geometry, linking to over 200 SNe in the pure Hubble flow out to z = 0.7. Four calibrators containing both Cepheids and TRGB stars provide an important cross-check on systematics. Initially, the accuracy of our value of Ho will be set by four galactic RR Lyrae calibrators with HST/FGS parallaxes. With Gaia, both the RR Lyrae zero point and TRGB method will be independently calibrated with at least an order of magnitude more calibrators, each having precisions of 1% or better. This will allow the highest accuracy measurement of Ho to date using the "Distance Ladder" method.

Author(s): Jeffrey Rich[1], Wendy L. Freedman[5], Barry F. Madore[1], Andy Monson[1], Victoria Scowcroft[1], Rachael Beaton[1], Juna A. Kollmeier[1], Mark Seibert[1], Giuseppe Bono[4], Gisella Clementini[2], Soung-Chul Yang[1], Myung Gyoon Lee[3], In Sung Jang[3]
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405.07 – SDSS-IV: Exploring Large-Scale Structure at High Redshift using eBOSS LRGs

SDSS-IV/eBOSS is producing an exciting data set for cosmology which will add to our understanding of the large-scale structure of the Universe.The Luminous Red Galaxy (LRG) component of this survey will cover a redshift regime barely explored by SDSS-III/BOSS and will allow a ~1% measurement of the Baryon Acoustic Oscillation (BAO) scale and a 4.0% Redshift Space Distortion (RSD) measurement using a relatively uniform set of luminous, early-type galaxies in the redshift range 0.6 < z < 1.
Here we briefly review the results of new techniques to select LRGs at redshifts 0.6 < z < 1, utilizing SDSS and WISE photometry in combination. Old stellar populations exhibit a global maximum in their spectral energy distributions (SEDs) at a wavelength of 1.6 µm, commonly referred to as the '1.6 µm bump'. Since LRGs possess very few young stars, this feature generally dominates their overall SEDs. The lowest-wavelength channel in WISE is centered at 3.4 µm, causing LRGs that are at z~1 to be extremely bright in this band compared to the optical. As a result, the r-W1 vs. r-i color-color diagram (where W1 is the 3.4 µm WISE AB magnitude) provides an efficient tool for selecting high-redshift LRGs while avoiding stars.LRGs selected with this method are one of the primary classes of targets for the SDSS-IV/eBOSS survey, as well as for the planned DESI project which aims to obtain high-precision measurements of the BAO distance scale.In this talk, we present the initial results from the eBOSS LRG sample.

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Contributing team(s): The SDSS-IV/eBOSS Collaboration

406 – Extrasolar Planets: Habitable and/or Earthlike

406.01D – The Frequency of Habitable Planets Around Small Stars and the Characterization of Planets Orbiting Bright Kepler Targets

My thesis focuses on the frequency, detectability, and composition of small planets. I revised the parameters of the smallest Kepler main-sequence dwarf stars using Dartmouth Stellar Models and wrote a pipeline to search for planets in the full four-year Kepler data set. I characterized the completeness of my pipeline by injecting transiting planets and recording the fraction recovered. I refined the planet candidate sample by inspecting follow-up observations of planet host stars and correcting for transit depth dilution due to nearby stars. Accounting for possible false positive contamination, I estimated an occurrence rate of 0.2-0.8 potentially habitable planets per M dwarf; the variation in this estimated is dominated by the choice of habitable zone boundaries. For orbital periods <50 days, I measured an occurrence rate of 0.5 Earth-size (1-1.5 REarth) planets per small star.
Using these results, I predicted the population of small planets accessible to current and future planet surveys. I supplemented our small star planet occurrence rate with estimates of the rate for FGK stars from the literature. I found that the nearest transiting, potentially habitable Earth-size planet is likely 10 +/- 4 pc away.
I also conducted an adaptive optics imaging survey of 87 bright Kepler target stars with ARIES at the MMT to search for nearby stars that might be diluting the depths of the planetary transits. I identified visual companions within 1” for 5 targets, between 1” and 2” for 7 targets, and between 2” and 4” for 15 stars. For all stars observed, we placed limits on

the presence of undetected nearby stars.
Finally, I collaborated with the HARPS-N consortium to conduct an intensive observing campaign with the HARPS-N spectrograph at the Telescopio Nazionale Galileo in La Palma, Spain. We studied the Kepler-93 system, which contains a 1.4-Earth-radius planet in a 4.7-day orbit. Kepler-93b is a valuable addition to the exoplanet mass-radius diagram, as the physical parameters of the star have been accurately determined from asteroseismology. As a result, the size of the 1.4-Earth-radius transiting planet has been measured to an unprecedented precision of 120km (1.3%).

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406.02D – Uncovering the Chemistry of Earth-like Planets

We propose to use evidence from our solar system to understand exoplanets, and in particular, to predict their surface chemistry and thereby the possibility of life. An Earth-like planet, born from the same nebula as its host star, is composed primarily of silicate rocks and an iron-nickel metal core, and depleted in volatile content in a systematic manner. The more volatile (easier to vaporize or dissociate into gas form) an element is in an Earth-like planet, the more depleted the element is compared to its host star. After depletion, an Earth-like planet would go through the process of core formation due to heat from radioactive decay and collisions. Core formation depletes a planet’s rocky mantle of siderophile (iron-loving) elements, in addition to the volatile depletion. After that, Earth-like planets likely accrete some volatile-rich materials, called “late veneer”. The late veneer could be essential to the origins of life on Earth and Earth-like planets, as it also delivers the volatiles such as nitrogen, sulfur, carbon and water to the planet’s surface, which are crucial for life to occur. We plan to build an integrative model of Earth-like planets from the bottom up. We would like to infer their chemical compositions from their mass-radius relations and their host stars’ elemental abundances, and understand the origins of volatile contents (especially water) on their surfaces, and thereby shed light on the origins of life on them.

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406.03D – The Prevalence of Earth-size Planets Orbiting Sun-like Stars

In less than two decades since the discovery of the first planet orbiting another Sun-like star, the study of extrasolar planets has matured beyond individual discoveries to detailed characterization of the planet population as a whole. No mission has played more of a role in this paradigm shift than NASA’s Kepler mission. Kepler photometry has shown that planets like Earth are common throughout the Milky Way Galaxy. Our group performed an independent search of Kepler photometry using our custom transit-finding pipeline, TERRA, and produced our own catalog of planet candidates. We conducted spectroscopic follow-up of their host stars in order to rule out false positive scenarios and to better constrain host star properties. We measured TERRA's sensitivity to planets of different sizes and orbital periods by injecting synthetic planets into raw Kepler photometry and measuring the recovery rate. Correcting for orbital tilt and survey completeness, we found that ~80% of GK stars harbor one or more planets within 1 AU and that ~22% of Sun-like stars harbor an Earth-size planet that receives similar levels of stellar radiation as Earth. I will present the latest results from our efforts to characterize the demographics of small planets revealed by Kepler.

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406.04 – Persistence of oceans on Earth-like planets

The habitable zone is an orbital region around a star in which an Earth-like planet can maintain liquid water on its surface given a variety of atmospheric compositions. However, the abundance of water on the Earth’s surface is not controlled by the atmosphere, but rather by the deep water/silicate cycle. On the Earth, volcanic outgassing of water from the mantle is balanced by loss of water to the mantle through subduction of water-rich oceanic seafloor. Much of this water is released immediately back to the surface through shallow, water-induced volcanism. However, a small but significant fraction of the water can be transported to deeper levels of the mantle. Mantle convection has therefore played an important role in controlling the size of Earth’s surface oceans over the planet’s lifetime.

The deep water cycle of Earth has been studied with parameterized convection models incorporating a water-dependent viscosity. The abundance of water in the mantle, which lowers the convective viscosity, evolves along with the mantle temperature. Here we present results from a parameterized convection model extended to high pressures to study the deep water cycles of super-Earths. Assuming compositions similar to the Earth, our models indicate that ocean formation will be delayed on 5 M^{Earth} planets by ~1 Gyr after planet formation. Although ocean mass on these planets increases with time, the oceans remain much shallower than for smaller planets, consistent with previous studies. Intermediate mass planets (2-4 M^{Earth}) have immediate, but gradual outgassing and persistent oceans. Small terrestrial planets (≤ 1 M^{Earth}) have rapid initial outgassing, but will gradually lose a significant fraction of their surface oceans due to mantle sequestration over their lifetimes.

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406.05 – Earth as an Exoplanet: Lessons in Recognizing Planetary Habitability

Earth will always be our best-studied example of a habitable world. While extrasolar planets are unlikely to look exactly like Earth, they may share key characteristics, such as oceans, clouds and surface inhomogeneity. Earth's globally-averaged characteristics can therefore help us to recognize planetary habitability in data-limited exoplanet observations. One of the most straightforward ways to detect habitability will be via detection of "glint", specular reflectance from an ocean (Robinson et al., 2010). Other methods include undertaking a census of atmospheric greenhouse gases, or attempting to measure planetary surface temperature and pressure, to determine if liquid water would be feasible on the planetary surface. Here we present recent research on detecting planetary habitability, led by the NASA Astrobiology Institute's Virtual Planetary Laboratory Team. This work includes a collaboration with the NASA Lunar Science Institute on the detection of ocean glint and ozone absorption using Lunar Crater Observation and Sensing Satellite (LCROSS) Earth observations (Robinson et al., 2014). This data/model comparison provides the first observational test of a technique that could be used to determine exoplanet habitability from disk-integrated observations at visible and near-infrared wavelengths. We find that the VPL spectral Earth model is in excellent agreement with the LCROSS Earth data, and can be used to reliably predict Earth's appearance at a range of phases relevant to exoplanet observations. Determining atmospheric surface pressure and temperature directly for a potentially habitable planet will be challenging due to the lack of spatial-resolution, presence of clouds, and difficulty in spectrally detecting many bulk constituents of terrestrial atmospheres. Additionally, Rayleigh scattering can be masked by absorbing gases and absorption from the underlying surface. However, new techniques using molecular dimers of oxygen (Misra et al., 2014) and nitrogen (Schwieterman et al., 2014) may provide an alternative means to determine terrestrial atmospheric pressure for both transit transmission and direct imaging observations.

Author(s): Victoria Meadows[6], Tyler Robinson[3], Amit Misra[6], Kimberly Ennico[3], William B. Sparks[4], Mark Claire[5], David Crisp[2], Edward Schwieterman[6], D. Ben J. Bussey[1], Jonathan Breiner[6]
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406.06 – The Venus Zone: Seeking the Twin of Earth's Twin

The field of exoplanetary science has seen a dramatic improvement in sensitivity to terrestrial planets over recent years. Such discoveries have been a key feature of results from the Kepler mission which utilizes the transit method to determine the size of the planet. These discoveries have resulted in a corresponding interest in the topic of the Habitable Zone (HZ) and the search for potential Earth analogs. Within the Solar System, there is a clear dichotomy between Venus and Earth in terms of atmospheric evolution, likely the result of the large difference in incident flux from the Sun. Since Venus is 95% of the Earth's radius in size, it is impossible to distinguish between these two planets based only on size. In this talk I will discuss planetary insolation in the context of atmospheric erosion and runaway greenhouse limits for planets similar to Venus. Using the ``Venus Zone'' (VZ), I will present identified potential Venus analogs from Kepler data and subsequent occurance rates of such planets.

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407 – Laboratory Astrophysics and Astrobiology

407.01 – High-*J* Rotational Quenching of CO from Collisions with H

A variety of astrophysical environments feature carbon monoxide, the second most abundant molecule in the universe after molecular hydrogen. The rovibrational transitions of CO are typically observed as absorption in the UV and near-IR and emission in the FIR/submm, and since its lowest rotational transition has an excitation temperature of just ~5.5 K, CO can be collisionally excited to high rotational levels in photon dominated regions, shocks, and other moderately energetic environments. However, in regions such as these, it is often not appropriate to assume local thermodynamic equilibrium (LTE). Collisional excitation rate coefficients with collision partners such as H, H^2, He, and electrons are therefore necessary to produce accurate models. In this work, we report quantum scattering calculations for high-*j* pure rotational deexcitation transitions of CO induced by H. A new ultra-cold scaling technique for predicting rate coefficients along with explicit calculations of collisional rate coefficients for temperatures below 3000 K are presented for CO(v=0,j) deexcitation from j=1-70 to all lower j' levels, where j is the rotational quantum number. This work partially supported by NASA grant NNX12AF42G.

Author(s): Kyle M. Walker[3], Lei Song[2], Benhui H. Yang[3], Gerrit C. Groenenboom[2], Ad van der Avoird[2], Balakrishnan Naduvalath[4], Robert C. Forrey[1], Phillip C. Stancil[3]
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407.02 – Charge Exchange Induced X-Ray Emission of Fe XXVI and Fe XXV

Charge exchange is a vital process to consider in the modeling of X-ray spectra obtained by the Chandra, XMM Newton and Suzaku X-ray Space Observatories. The process is largely relevant in many astrophysical environments including comets (whose emission is primarily a product of charge exchange alone), the heliosphere, astropheres of stars, supernova remnants, the Galactic Center and the Galactic Ridge. The understanding of the X-ray spectra produced by these environments is crippled by the current lack of atomic and molecular data– especially for charge exchange. Here, we apply the Landau-Zener method to calculate total, n-resolved, nℓ-resolved and S-resolved cross sections for Fe^{26+} and Fe^{25+} collisions with H, He, H^2, N^2, H^2O and CO. Using this data in a cascade model for X-ray emission, theoretical spectra for each system are predicted. The resulting spectra are then compared to experimental data for Fe^{26+} and Fe^{25+} collisions with N^2. Fe XXVI and Fe XXV have been selected for study as iron emission lines have been detected in the galactic plane. Further, these systems illustrate computational difficulties for high projectile charges. In the Landau-Zener calculations, several ℓ-distribution models have been tested for the electron capture by the bare ion, Fe^{26+}. Quantum defect methods are also employed to estimate excitation energies and transition probabilities for high-lying Rydberg levels of the He-like Fe^{24+}.

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Contributing team(s): B. J. Wargelin

407.03D – Time-Domain TeraHertz Spectroscopy and Observational Probes of Prebiotic Interstellar Gas and Ice Chemistry

Despite the detection of amino acids in meteoritic and cometary samples, our understanding of the formation of such molecules remains incomplete, because we do not yet fully understand the interplay between chemical reactions occurring within interstellar ices, and the gas-phase chemistry which seeds and enriches them. My dissertation work takes a holistic view of the system, approaching the topic by studying both fundamental spectroscopic and physical properties of astrochemical ices, as well as chemical evolutionary processes in the gas-phase ISM. I'll discuss my work to confirm the detection of *l*-C^3H^+, a potentially key intermediate in interstellar carbon chemistry, as well as the first detection of HNCNH, a potential DNA nucleobase precursor, which must be formed in ices. I'll also present the design and construction of, and initial spectroscopic work with, a time-domain spectrometer built to study astrochemical ices in the largely unexplored TerHertz (far-Infrared) region of the spectrum, and its application to astronomical observations.

Author(s): Brett A. McGuire[1]
Institution(s): *1. National Radio Astronomy Observatory*

407.04 – Extreme Water Loss and Abiotic O^2 Buildup On Planets Throughout the Habitable Zones of M Dwarfs

We show that terrestrial planets in the habitable zones of M dwarfs older than ~1 Gyr could have been in runaway greenhouses for several hundred Myr following their formation due to the star's extended pre-main sequence phase. Such prolonged runaway greenhouses can lead to planetary evolution divergent from that of Earth. During this early runaway phase, photolysis of water vapor and hydrogen/oxygen escape to space can lead to the loss of several Earth oceans of water from planets throughout the habitable zone. We find that the amount of water lost roughly scales with the planet mass: super-Earths, which lose water primarily via the escape of hydrogen, lose more water than Earth-mass planets, which lose water more slowly via the escape of both hydrogen and oxygen. If the surface is able to absorb most of the photolytically produced oxygen, planets around low mass M dwarfs can be completely desiccated for initial inventories of up to several tens of Earth oceans. On the other hand, planets with inefficient oxygen sinks at the surface may build up hundreds to thousands of bars of abiotically produced O^2, resulting in potential false positives for life. The amount of O^2 that builds up also scales with the planet mass; we find that O^2 builds up at a constant rate of ~5 bars/Myr on Earth-mass planets and up to ~25 bars/Myr on super- Earths. The fate of a given planet strongly depends on the extreme ultraviolet flux, the duration of the runaway regime, the initial water content, and the rate at which oxygen is absorbed by the surface. In general, we find that the initial phase of high luminosity may compromise the habitability of many terrestrial planets orbiting low mass stars.

Author(s): Rodrigo Luger[1], Rory Barnes[1]
Institution(s): *1. University of Washington*

407.05 – Examining a link between SPEs and ground level radiation

Researchers have previously found a correlation between solar proton events (SPEs) and congenital malformations (CMs). A similar correlation has also been found between long term solar variability and CMs. We examine the ionizing radiation dose from these events as well as the largest events on record to determine whether these events are capable of producing these effects. We show that the total ionizing radiation dose (consisting of neutrons and muons) at ground level is insufficient for production of the observed increases in CM rate under the current paradigm regarding ionizing radiation from muons and neutrons. Current research on the subject shows that our assumptions regarding muonic ionizing radiation may be underestimating their biologic effect. We recommend further experimentation regarding the radiation dose due to muons, as this may prove to be a more substantial contribution to our radiation environment than previously assumed.

Author(s): Andrew Overholt[1]
Institution(s): *1. MidAmerica Nazarene University*

407.06 – Terrestrial effects of a Solar proton event at AD 774-775

A major increase in ^{14}C at AD 774-775 has been detected in data from tree ring studies. Such an increase implies an increase in high energy radiation produced by astrophysical events such as nearby supernovae or gamma-ray bursts, or extreme Solar energetic particle events. Determining which type of event may have caused this measured increase would help to characterize the rates of such events. Work by several groups to date has indicated that a Solar event is the most likely culprit. I will review this work and then discuss results of modeling the effects of such an event on Earth's atmosphere and biosphere. The intensity of modeled effects is found to vary depending on assumed event parameters, especially properties of the proton spectrum.

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Institution(s): *1. Washburn Univ.*

407.07 – Mechanisms for Generating False Positives for Extrasolar Life

Future mission concepts designed to look for life generally plan to search for oxygen (O^2), ozone (O^3), and/or methane (CH^4). However, mechanisms exist for generating each of these species abiotically. In this presentation, we will review these processes, and discuss the atmospheres that result from them. In general, false positives can form in atmospheres with severe redox imbalance. This redox imbalance can also be thought of as extreme elemental composition, skewed towards very high or very low O/H ratios. Specific examples of this include: 1) loss of H through the top of a planetary atmosphere that leads to high O/H and an atmosphere rich in O^2 and O^3; 2) atmospheres whose volcanism is O-rich and H-poor (i.e., highly oxidized), which leads to an atmosphere that with high O/H that can accumulate O^3 and potentially O^2; 3) atmospheres in which H escape is slow, leading to low O/H and accumulation of CH^4; and 4) atmospheres in which volcanic outgassing is H-rich (highly reduced), leading to low O/H and potential accumulation of CH^4. Each of these cases would constitute a “false positive” for life if O^2, O^3, or CH^4 were detected without obtaining the chemical atmospheric context that could indicate a severe redox imbalance exists.
Methods exist for discriminating between these “false positives” where the gases arise from abiotic sources, and “true positives” where the gases arise by biological sources. The best means of doing this is to obtain measurements of both O-rich (O^2/O^3) and H-rich (CH^4) species, allowing identification of non-extreme O/H ratios in the atmosphere, and eliminating this abiotic source of O^2, O^3, and CH^4. Because this is the most likely cause of abiotic production of these species, the elimination of this explanation would indicate that these gases were instead likely produced by biology. More specific methods to identify each of these false positives mechanisms also exist, but will not be discussed in detail in this presentation.

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Contributing team(s): Virtual Planetary Laboratory

407.08 – Distinguishing True and False Positive Oxygen Signatures with Models and Observations

The spectral detection of oxygen (O^2) or its photochemical bi-product ozone (O^3) in a planetary atmosphere has been considered a robust signature of life because O^2 is highly reactive and significant continuous abiotic sources were thought to be implausible. However, recent work has revealed the possibility that O^2 or O^3 may build up to spectrally detectable levels due to enhanced photolysis of O-bearing molecules by UV-active host stars (Domagal-Goldman et al. 2014, Tian et al. 2014) or photolysis of water and subsequent escape of hydrogen in thin (< 0.2 bar) atmospheres where the water is not cold trapped in the troposphere (Wordsworth et al. 2014). Additionally, there is the possibility that significant amounts of abiotic O^2 could remain in post-runaway greenhouse atmospheres in the habitable zone of late type stars (Luger & Barnes 2014). Using photochemical and spectral models, we examine possible observing strategies that could discriminate between abiotic and biogenic oxygen scenarios. For example, false positives may be confirmed by the spectral detection of sibling molecules generated when large amounts of oxygen are photochemically produced (such as CO). False positives that result from H escape could be detected by measuring the mixing ratio of O^2, which should be high (~1) when H escape causes O^2 buildup. In contrast, true biosignatures could be confirmed by the simultaneous presence of a detectable reduced gas such as methane (CH^4); which should not persist when O^2 build up is caused by past H escape or by photochemical production of O^2 in H-poor atmospheres. We use photochemical and spectral models to predict which combinations of planetary and stellar parameters will be most likely to produce conditions that would allow observational discrimination between true and false positives. We examine the spectral range, resolving power, and minimum integration times necessary to detect true and false positive indicators for a cross-section of model scenarios. This type of study can inform both target selection and telescope requirements for characterizing terrestrial planets in the habitable zone.

Author(s): Edward Schwieterman[3], Shawn Domagal-Goldman[1], Victoria Meadows[3], Rodrigo Luger[3], Rory Barnes[3], Robin Wordsworth[2]
Institution(s): *1. Goddard Space Flight Center, 2. University of Chicago, 3. University of Washington*
Contributing team(s): Virtual Planetary Laboratory

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408 – From Hot Jupiters to Scorched Earths: Understanding the Shortest-Period Exoplanets

AAS Special Session
From wispy gas giants on the verge of disruption to tiny rocky bodies already falling apart, short-period exoplanets pose a severe challenge to theories of planet formation and evolution, but they dominate observational constraints on planetary composition, internal structure, meteorology, and more. This special AAS session will gather together experts in detection, characterization, theory of short period planets, and star-planet interactions. The session will link the lessons learned from hot Jupiters to the characterization of the emergent population of small, short-period planets.
https://sites.google.com/site/spexoplaas225th/

408.01 – Characterizing the shortest-period planets found by Kepler

It is no coincidence that the first exoplanets known to have rocky compositions, CoRoT-7b and Kepler-10b, both have orbital periods shorter than one day. Such ultra-short periods facilitate planet discovery and characterization, by enabling a large number of transits to be observed, enhancing the amplitude of the radial-velocity signal, and allowing a cleaner separation of the radial-velocity signal from the slower spurious variations due to stellar activity. We have constructed a list of 106 planet candidates with periods shorter than one day, based on an independent search of the Kepler database as well as a critical review of previously published candidates. Our survey has revealed that ultra-short-period planets are approximately as common as hot Jupiters, but are almost always smaller than 2 $R^{E.}$ In addition, the ultra-short-period planets tend to be found as part of compact multi-planet systems, in contrast to the “loneliness” of hot Jupiters. I will describe our ongoing efforts to characterize this new family of planets, with a combination of stellar spectroscopy and radial-velocity monitoring using the Keck telescopes.

Author(s): Roberto Sanchis Ojeda[1], Joshua N. Winn[1], Saul A. Rappaport[1]
Institution(s): *1. MIT*

408.02 – Short-period terrestrial planets and radial velocity stellar jitter.

Stellar jitter is the main limitation to ultra-precise radial velocity (RV) measurements. It currently precludes our ability to detect a planet like the Earth. Short-period terrestrial planets present first the advantage of inducing a stronger RV signal. In addition, the signal produced by these planets have a period completely different than stellar activity. This allows us, when the observational strategy is adequate, to decorrelate the planetary signal from the jitter induced by the star using filtering techniques. I will show the examples of Kepler-78b and Corot-7b, where the amplitude of the planetary signal can be detected, despite the stellar activity jitter that is 5 and 3 times larger, respectively. The cases of Alpha Cen Bb will also be reviewed, with a new reduction of the published data that increases the significance of the planetary signal.

This project is funded by ***ETAEARTH,*** a transnational collaboration between European countries and the US (the Swiss Space Office, the Harvard Origin of Life Initiative, the Scottish Universities Physics Alliance, the University of Geneva, the Smithsonian Astrophysical Observatory, the Italian National Astrophysical Institute, the University of St. Andrews, Queens University Belfast, and the University of Edinburgh) setup to optimize the synergy between space-and ground-based data whose scientific potential for the characterization of extrasolar planets can only be fully exploited when analyzed together.

Author(s): Xavier Dumusque[1]

Institution(s): *1. Harvard-smithsonian Center for Astrophysics*

408.03 – Thermal Emission from KELT-1b: Probing Brown Dwarf Atmospheres in Extreme Irradiation

There are currently seven brown dwarfs known to transit single main-sequence stars. These systems give us one of the few ways by which we may directly measure the mass, radius, and approximate age of a brown dwarf, a combination that provides strong constraints on theoretical models of brown dwarf and massive planet interiors and atmospheres. Furthermore, these systems are an opportunity to study the atmospheres of brown dwarfs under strong stellar irradiation, which fundamentally changes their atmospheres. We describe measurements of the dayside thermal emission from the 27MJ transiting brown dwarf KELT-1b, which is on a short (30 hour) orbit about a middle F-dwarf. The short orbit results in KELT-1b receiving the irradiation of a hot Jupiter, but with the mass of an early T-dwarf. As a "missing link" between hot Jupiters and isolated brown dwarfs, KELT-1b allows us to begin making observationally-driven conclusions about how a heavily irradiated brown dwarf differs from isolated brown dwarfs or hot Jupiters, and how these objects can inform our understanding of the atmospheres of both.

Author(s): Thomas G. Beatty[5], B. Scott Gaudi[4], Richard W. Pogge[4], Karen A Collins[9], Jonathan J. Fortney[7], Heather Knutson[1], Jacob M. Bruns[8], Adam P. Showman[6], Jason D Eastman[2], Joshua Pepper[3], Robert Siverd[10], Keivan Stassun[10], John F. Kielkopf[9]
Institution(s): *1. California Institute of Technology, 2. Harvard-Smithsonian Center for Astrophysics, 3. Lehigh University, 4. Ohio State University, 5. Pennsylvania State University, 6. University of Arizona, 7. University of California, Santa Cruz, 8. University of Colorado, Boulder, 9. University of Louisville, 10. Vanderbilt University*

408.04 – Precise Water Abundance Estimates for Hot Jupiters from HST/WFC3

Hot Jupiters provide a unique opportunity to study the chemistry of planetary atmospheres. These planets have such high temperatures that water, thought to be a key building block for planet formation, is present in their atmospheres in gaseous form. By contrast, water on the solar system gas giants has condensed into icy clouds that are out of reach of remote observations. Therefore, high precision spectra of transiting exoplanets can potentially yield more reliable water abundance measurements than currently exist for Jupiter. I will present two recent water abundance estimates for the hot Jupiters WASP-43b and WASP-12b, based on an intensive Hubble Space Telescope observing campaign. These precise, robust measurements enable comparative planetology with the solar system and offer a window into the planets' formation histories.

Author(s): Laura Kreidberg[1]
Institution(s): *1. University of Chicago*

408.05 – The atmospheric circulation of ultra-short period exoplanets

Even though ultra-short period exoplanets comprise only a small fraction of the total exoplanet population, they present a useful probe into the role of fast rotation rates and small orbital distances on atmospheric dynamics. In this regime, advective timescales are longer than radiative timescales such that the temperature contrasts from dayside to nightside are large (>500 K at photospheric pressures); this strong day-night forcing, coupled with the planet's fast rotation rate (and hence small Rossby deformation radius) yields multiple, narrow (~40 degrees) jets in the atmosphere. Here we will present two cases illustrative of the dynamical regime for ultra-short period exoplanets, and how we can use general circulation models to constrain observations of their atmospheres. First, we will present models of WASP-43b, a Jupiter-mass planet in a 19.5-hour orbit around a K7 star. Because WASP-43b has an equilibrium temperature similar to that of HD 209458b, we can explore the role of rotation rate on the dynamics at a fixed stellar flux. We then compare our models to spectrophotometric observations obtained with HST/WFC3 and show how our 5× solar model provides the best match to the data. Next, we explore the dynamical regime of 55 Cnc e, a 7 Earth-mass, 2 Earth-radius planet in a 0.7 day orbit around a K star. Because smaller planets have a large diversity in possible compositions, we compare hydrogen-, water- and carbon dioxide-dominated models and show how differences in opacity structure lead to differences in temperature structure and circulation. We also demonstrate how future observations can distinguish between these possible compositions of 55 Cnc e, particularly in emission.

Author(s): Tiffany Kataria[5], Adam P. Showman[2], Jonathan J. Fortney[3], Kevin B. Stevenson[4], Nikole K. Lewis[1]
Institution(s): *1. Massachusetts Institute of Technology, 2. University of Arizona, 3. University of California, Santa Cruz, 4. University of Chicago, 5. University of Exeter*

408.06 – Warm Jupiters as failed hot Jupiters

The orbits of hot Jupiters often have surprisingly small semi-major axes, large eccentricities, or severe misalignments between their normals and their host stars' spin axes. In some formation scenarios invoking Kozai-Lidov oscillations, an external planetary companion drives a planet onto an orbit having these properties. The mutual inclinations for Kozai-Lidov oscillations can be large and have not been confirmed observationally. Here I present evidence for a population of eccentric warm Jupiters with eccentric giant companions with mutual inclinations just above 40 degrees. These planets may be undergoing a stalled version of tidal migration that produces warm Jupiters over hot Jupiters. I conclude by assessing the contribution of this mechanism to the overall population of short-period hot Jupiters, super-Earths, and mini-Neptunes.

Author(s): Rebekah Ilene Dawson[1], Eugene Chiang[1]
Institution(s): *1. UC Berkeley*

408.07 – Tidal Decay and Disruption of Gaseous Exoplanets

Many gaseous exoplanets in short-period orbits are on the verge or are actually in the process of tidal disruption. Moreover, orbital stability analysis shows tides can drive most known hot Jupiters to spiral inexorably into their host stars. Thus, the coupled processes of orbital decay and tidal disruption likely shape the observed distribution of close-in exoplanets and may even be responsible for producing the shortest-period rocky planets. However, the exact outcome for a disrupting planet depends on its internal response to mass loss and variable stellar insolation, and the accompanying orbital evolution can act to enhance or inhibit the disruption process, depending on the geometry of the atmospheric outflow. In some cases, strong stellar insolation can produce a deep radiative zone in a planet's atmosphere, which can also influence the disruption and therefore the orbital evolution. Understanding these coupled processes and making accurate predictions requires a model that includes both the internal and the orbital evolution of the planet. In this presentation, we will discuss our preliminary work on tidal decay and disruption of close-in gas giants using the fully-featured and robust Modules for Experiments in Stellar Astrophysics (MESA) suite, the capabilities of which were recently upgraded to model gaseous planets with inert, rocky cores.

Author(s): Brian K. Jackson[1], Phil Arras[4], Sarah Peacock[3], Kaloyan Penev[2]
Institution(s): *1. Boise State University, Dept. of Physics, 2. Princeton University, Dept. of Astrophysical Sciences, 3. University of Arizona, Lunar and Planetary Laboratory, 4. University of Virginia, Dept. of Astronomy*

408.08 – Many Ultra-Short-Period Rocky Planets are Evaporated Sub-Neptunes

Recent surveys uncovered an exciting new population ultra-short-period *Kepler* candidates with orbits <1 day. These planets typically have radii < 1.5 Earth Radii, indicating that they likely have rocky compositions. This stands in contrast to the overall distribution of *Kepler* candidates out to ~100 days, which is dominated by low-density sub-Neptunes > 2 Earth radii that must have gaseous envelopes to explain their size. However, on ultra-short-period orbits, planets are bombarded by large amounts of photo-ionizing radiation. On such orbits, gaseous sub-Neptunes are extremely vulnerable to losing their envelopes to XUV-driven photo-evaporation. Using models of planet evolution with XUV-driven photo-evaporation, we show that the USP planets can be explained as a natural continuation of the longer period population found by *Kepler* and that many of the ultra-short-period rocky planets are likely the stripped cores of former sub-Neptunes.

Author(s): Eric David Lopez[1]
Institution(s): *1. Institute for Astronomy, University of Edinburgh*

408.09 – The Transition Between Rocky and Gaseous Planets

The *Kepler* Mission, combined with ground based radial velocity follow-up and dynamical analyses of transit timing variations, has revolutionized the observational constraints on sub-Neptune-size planet compositions. In this talk, I focus on the intriguing transition between rocky exoplanets (comprised of iron and silicates) and planets with voluminous layers of volatiles (H/He and astrophysical ices). Applying a hierarchical Bayesian statistical approach to the sample of *Kepler* transiting sub-Neptune planets with Keck radial velocity follow-up, I constrain the fraction of close-in planets (with orbital periods less than 50 days) that are sufficiently dense to be rocky, as a function of planet radius, and find that the majority of close-in 1.6 Earth-radius planets are not rocky. I conclude by discussing future prospects for constraining the rocky-gaseous transition at longer orbital periods and for resolving compositional sub-populations in the accumulating census of observed exoplanets.

Author(s): Leslie Rogers[1]
Institution(s): *1. California Institute of Technology*

408.10 – Disintegrating Mercuries

Short-period exoplanets can have dayside surface temperatures surpassing 2000 K, hot enough to vaporize rock. Small enough planets can evaporate completely. We discuss the observations and theory underlying disintegrating planets such as KIC 12557548b --- which may have been stripped down to its iron core. Thermal evaporation models assert that the catastrophic disintegration phase lasts only a small fraction of a planet's life, and therefore predict that for every object like KIC 12557548b, there should be many near-quiescent progenitors with sub-day periods whose hard-surface transits may be detectable. Unresolved issues with the theory of mass loss will be highlighted, including the related inverse problem of in-situ formation of rocky bodies.

Author(s): Eugene Chiang[1]
Institution(s): *1. UC Berkeley*

409 – Extrasolar Planets: Radial Velocities

409.01 – Early Science Results from Dharma Planet Survey (DPS), a Robotic, High Cadence and High Doppler Precision Survey of Close-in Super-Earths

The Dharma Planet Survey (DPS) is ready to monitor ~150 nearby very bright FGKM dwarfs during 2014-2017 using the TOU optical high resolution spectrograph (R~100,000) at the AST 2m telescope (2014-2015) and the 50-inch Robotic Telescope (2015-2017). With ~1m/s RV precision and high cadence (~100 observations per target randomly spread over 300 days), a total of about 90 close-in sub-Neptune planets including about 50 super-Earths and Earth-size planets are expected to be detected, which will provide a unique RV low mass planet sample for studying the occurrence rate and properties of this recently identified dominant planet population. The survey also provides the largest single homogenous high precision RV sample of nearby stars for constraining various planet formation models. Early telescope commissioning results show that TOU achieves ~0.5 m/s RV precision over a month with simultaneous ThAr calibration and has reached about 1.3 m/s RV precision with a RV stable star, Tau Ceti, and ~2 m/s for two other RV stable stars (HD 109358 & HD 185144) over one month and confirmed the 70 Vir giant planet with RV precision of 3 m/s (RMS). Early results including low mass planet candidates from the DPS pilot survey of 20 GK dwarfs will be presented.

Author(s): Bo Ma[2], Jian Ge[2], Matthew W. Muterspaugh[1], Sirinrat Sithajan[2], Neil B Thomas[2], Nolan Senan Seieroe Grieves[2], Rui Li[2], Michael Singer[2], Scott Powell[2], Frank Varosi[2], Bo Zhao[2], Jian Liu[2], Sidney Schofield[2], Hali Jakeman[2], William Yoder[2], Michael W Williamson[2], Ted Maxwell[1], Louis Avner[2], Jakob Gittelmacher[2]
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409.02 – Results from the HARPS-N 2014 Campaign to Estimate Accurately the Densities of Planets Smaller than 2.5 Earth Radii

Although the NASA Kepler Mission has determined the physical sizes of hundreds of small planets, and we have in many cases characterized the star in detail, we know virtually nothing about the planetary masses: There are only 7 planets smaller than 2.5 Earth radii for which there exist published mass estimates with a precision better than 20 percent, the bare minimum value required to begin to distinguish between different models of composition.
HARPS-N is an ultra-stable fiber-fed high-resolution spectrograph optimized for the measurement of very precise radial velocities. We have 80 nights of guaranteed time per year, of which half are dedicated to the study of small Kepler planets.
In preparation for the 2014 season, we compared all available Kepler Objects of Interest to identify the ones for which our 40 nights could be used most profitably. We analyzed the Kepler light curves to constrain the stellar rotation periods, the lifetimes of active regions on the stellar surface, and the noise that would result in our radial velocities. We assumed various mass-radius relations to estimate the observing time required to achieve a mass measurement with a precision of 15%, giving preference to stars that had been well characterized through asteroseismology. We began by monitoring our long list of targets. Based on preliminary results we then selected our final short list, gathering typically 70 observations per target during summer 2014.
These resulting mass measurements will have a signifcant impact on our understanding of these so-called super-Earths and small Neptunes. They would form a core dataset with which the international astronomical community can meaningfully seek to understand these objects and their formation in a quantitative fashion.
HARPS-N was funded by the Swiss Space Office, the Harvard Origin of Life Initiative, the Scottish Universities Physics Alliance, the University of Geneva, the Smithsonian Astrophysical Observatory, the Italian National Astrophysical Institute, the University of St. Andrews, Queens University Belfast, and the University of Edinburgh. This work was made possible through a grant from the John Templeton Foundation.

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Institution(s): *1. Harvard Univ.*
Contributing team(s): The HARPS-N Collaboration

409.03 – The SDSS-III DR12 MARVELS radial velocity data release: the first data release from the multiple object Doppler exoplanet survey

We present the first data release from the SDSS-III Multi-object APO Radial Velocity Exoplanet Large-area Survey

(MARVELS) through the SDSS-III DR12. The data include 181,198 radial velocity (RV) measurements for a total of 5520 different FGK stars with V~7.6-12, of which more than 80% are dwarfs and subdwarfs while remainders are GK giants, among a total of 92 fields nearly randomly spread out over the entire northern sky taken with a 60-object MARVELS dispersed fixed-delay interferometer instrument over four years (2008-2012). There were 55 fields with a total of 3300 FGK stars which had 14 or more observations over about 2-year survey window. The median number of observations for these plates is 27 RV measurements. This represents the largest homogeneous sample of precision RV measurements of relatively bright stars. In this first released data, a total of 18 giant planet candidates, 16 brown dwarfs, and over 500 binaries with additional 96 targets having RV variability indicative of a giant planet companion are reported. The released data were produced by the MARVELS finalized 1D pipeline. We will also report preliminary statistical results from the MARVELS 2D data pipeline which has produced a median RV precision of ~30 m/s for stable stars.

Author(s): Jian Ge[5], Neil B Thomas[5], Rui Li[5], Nolan Senan Seieroe Grieves[5], Bo Ma[5], Nathan M. De Lee[3], Brian C. Lee[4], Jian Liu[5], Adam S Bolton[6], Aniruddha R. Thakar[1], Benjamin Weaver[2]
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Contributing team(s): The SDSS-III MARVELS team

409.04 – NRES: The Network of Robotic Echelle Spectrographs

Las Cumbres Observatory Global Network (LCOGT) is building the Network of Robotic Echelle Spectrographs (NRES), which will consist of six identical, optical (390 - 860 nm) high-precision spectrographs, each fiber-fed simultaneously by two 1 meter telescopes and a thorium argon calibration source, one at each of our observatory sites in the Northern and Southern hemispheres. Thus, NRES will be a single, globally-distributed, autonomous observing facility using twelve 1-m telescopes. Simulations suggest we will achieve long-term radial velocity precision of better than 3 m/s in less than an hour for stars brighter than V = 12. We have been funded with NSF MRI and ATI grants, and expect our first spectrograph to be deployed in mid 2015, with the full network operation of all 6 units beginning in 2016. We will discuss the NRES design, goals, robotic operation, and status, as well as the early results from our prototype spectrograph.

Author(s): Robert Siverd[2], Jason D Eastman[1], Timothy M. Brown[2], John Hygelund[2], Todd Henderson[2], Joseph Tufts[2], Julian C. Van Eyken[2], Stuart Barnes[3]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Las Cumbres Global Telescope Network, Inc., 3. Stuart Barnes Optical Design*

409.05 – Constraining the Masses of the Kepler-11 Planets through Radial Velocity Measurements

The six transiting planets of Kepler-11 have all been found to have ultra-low densities through N-body dynamical analysis of the transit timing variations (TTVs) of the six planets. Numerically reproducing TTVs has become a new method for solving the masses of planets, but this method is susceptible to certain dynamic degeneracies: the planet eccentricity is degenerate with the planet mass, and perturbations caused by non-transiting planets could be misattributed to the transiting planets. Furthermore, the masses of planets characterized by TTV analysis are systematically 2x lower than the masses (including non-detections) reported by radial velocity (RV) analysis for planets of the same radius. We address the discrepancy between the TTV- and RV-determined planet masses by measuring the RVs of Kepler-11 at opportunistic times, as determined by the ephemerides of the transiting planets. We place an upper limit on the masses of the Kepler-11 planets using RVs and preliminarily show that the RVs are consistent with the ultra-low mass scenario determined by the TTVs. The lack of disagreement between the TTVs and RVs in the Kepler-11 system bodes well for N-body simulations of TTVs for other Kepler systems that are too faint for RV follow-up.

Author(s): Lauren M. Weiss[1], Geoffrey W. Marcy[1], Howard T. Isaacson[1]
Institution(s): *1. UC Berkeley*

410 – Formal and Informal Education I

410.01 – Communicating the Science from NASA's Astrophysics Missions

Communicating science from NASA's Astrophysics missions has multiple objectives, which leads to a multi-faceted approach. While a timely dissemination of knowledge to the scientific community follows the time-honored process of publication in peer reviewed journals, NASA delivers newsworthy research result to the public through news releases, its websites and social media. Knowledge in greater depth is infused into the educational system by the creation of educational material and teacher workshops that engage students and educators in cutting-edge NASA Astrophysics discoveries. Yet another avenue for the general public to learn about the science and technology through NASA missions is through exhibits at museums, science centers, libraries and other public venues. Examples of the variety of ways NASA conveys the excitement of its scientific discoveries to students, educators and the general public will be discussed in this talk. A brief overview of NASA's participation in the International Year of Light will also be given, as well as of the celebration of the twenty-fifth year of the launch of the Hubble Space Telescope.

Author(s): Hashima Hasan[1], Denise A. Smith[2]
Institution(s): *1. NASA Headquarters, 2. Space Telescope Science Institute*

410.02 – Engaging Scientists in Meaningful E/PO: How the NASA SMD E/PO Community Addresses the Needs of the Higher Ed Community

The NASA Astrophysics Science Education and Public Outreach Forum (SEPOF) coordinates the work of NASA Science Mission Directorate (SMD) Astrophysics EPO projects and their teams to bring cutting-edge discoveries of NASA missions to the introductory astronomy college classroom. The Astrophysics Forum assists scientist and educator involvement in SMD E/PO (uniquely poised to foster collaboration between scientists with content expertise and educators with pedagogy expertise) and makes SMD E/PO resources and expertise accessible to the science and education communities**.** We present three new opportunities for college instructors to bring the latest NASA discoveries in Astrophysics into their classrooms.
To address the expressed needs of the higher education community, the Astrophysics Forum collaborated with the Astrophysics E/PO community, researchers, and Astronomy 101 instructors to place individual science discoveries and learning resources into context for higher education audiences. Among these resources are two Resource Guides on the topics of cosmology and exoplanets, each including a variety of accessible sources.
The Astrophysics Forum also coordinates the development of the Astro 101 slide set series--5 to 7-slide presentations on new discoveries from NASA Astrophysics missions relevant to topics in introductory astronomy courses. These sets enable Astronomy 101 instructors to include new discoveries not yet in their textbooks into the broader context of the course: http://www.astrosociety.org/education/astronomy-resource-guides/.
The Astrophysics Forum also coordinated the development of 12 monthly Universe Discovery Guides, each featuring a theme and a representative object well-placed for viewing, with an accompanying interpretive story, strategies for conveying the topics, and supporting NASA-approved education activities and background information from a spectrum of NASA missions and programs: http://nightsky.jpl.nasa.gov/news-display.cfm?News_ID=611.
These resources help enhance the Science, Technology, Engineering, and Mathematics (STEM) experiences of undergraduates.

Author(s): James Manning[2], Bonnie K. Meinke[3], Gregory R. Schultz[1], Denise A. Smith[3], Brandon L. Lawton[3], Suzanne Gurton[1]
Institution(s): *1. Astronomical Society of the Pacific, 2. NASA Astrophysics SEPOF, 3. Space Telescope Science Institute*
Contributing team(s): NASA Astrophysics E/PO Community

410.03 – NASA Science Mission Directorate Education and Public Outreach: Engaging with Scientists and Educators through the Higher Education Working Group

The NASA Science Mission Directorate (SMD) Education and Public Outreach (EPO) Forums have established a Higher Education Working Group (HEWG), which has explored and surveyed the higher education landscape with regard to different subjects, such as community colleges and diversity. The HEWG is composed of representatives from each of the SMD EPO Forums, along with "external" members who have rotated in and out, and the co-authors here constitute the present membership, chaired by Nicholas Gross. Most recently, the HEWG has worked to identify the key characteristics of higher education STEM programs that reach diverse populations. While increasing the involvement of students from diverse backgrounds in SMD EPO is a core goal for our community, engaging these students meaningfully requires a dedicated strategy using proven techniques. In reality, while most educational programs have this goal, undertaking it meaningfully is more challenging. For higher education, diversity is a long-standing issue, and the working group could have taken many different paths to explore this important topic. The HEWG has undertaken a review of programs that involve engaging undergraduates from diverse backgrounds in SMD-related research internships or hands-on STEM experiments. This information will be synthesized and documented so that future education efforts can incorporate the most valuable components. Meanwhile, the working group is exploring ways that NASA SMD can be more helpful to higher education faculty and students, and community input is solicited as part of this presentation.

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410.04 – Engaging Scientists in Meaningful E/PO: How the NASA SMD E/PO Community Addresses the needs of Underrepresented Audiences through NASA Science4Girls and Their Families

The NASA Astrophysics Science Education and Public Outreach Forum (SEPOF) coordinates the work of individual NASA Science Mission Directorate (SMD) Astrophysics EPO projects and their teams to bring the NASA science education resources and expertise to libraries nationwide. The Astrophysics Forum assists scientists and educators with becoming involved in SMD E/PO (which is uniquely poised to foster collaboration between scientists with content expertise and educators with pedagogy expertise) and makes SMD E/PO resources and expertise accessible to the science and education communities**.** The *NASA Science4Girls and Their Families* initiative partners NASA science education programs with public libraries to provide NASA-themed hands-on education activities for girls and their families. As such, the initiative engages girls in all four NASA science discipline areas (Astrophysics, Earth Science, Planetary Science, and Heliophysics), which enables audiences to experience the full range of NASA science topics and the different career skills each requires. The events focus on engaging this particular underserved and underrepresented audience in Science, Technology, Engineering, and Mathematics (STEM) via use of research-based best practices, collaborations with libraries, partnerships with local and national organizations, and remote engagement of audiences.

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Contributing team(s): NASA SMD E/PO Community

410.05 – Engaging Scientists in Meaningful E/PO: How the NASA SMD E/PO Community Addresses Informal Educators' Preferences for PD and Materials

The NASA Astrophysics Science Education and Public Outreach Forum (SEPOF) coordinates the work of NASA Science Mission Directorate (SMD) Astrophysics EPO projects. These teams work together to capitalize on the cutting-edge discoveries of NASA Astrophysics missions to support educators in Science, Technology, Engineering, and Math (STEM) and to enable youth to engage in doing STEM inside and outside of school. The Astrophysics Forum assists scientists and educators with becoming involved in SMD E/PO, which is uniquely poised to foster collaboration between scientists with content expertise and educators with pedagogy expertise, and makes SMD E/PO resources and expertise accessible to the science and education communities**.**
Informal educators participated in a recent nationally-distributed survey from the NASA SMD SEPOF Informal Education Working Group. The results show the preferences of staff from museums, parks, public libraries, community/afterschool centers, and others with regard to professional development and material resources. The results of the survey will be presented during this session.
In addition, we present opportunities for the astronomy community to participate in collaborations supporting the NASA SMD efforts in K–12 Formal Education, Informal Science Education, and Outreach. These efforts focus on enhancing instruction, as well as youth and public engagement, in STEM via use of research-based best practices, collaborations with libraries, partnerships with local and national organizations, and remote engagement of audiences. The Forums' efforts for the Formal, Informal Science Education and Outreach communities include a literature review, appraisal of informal educators' needs, coordination of audience-based NASA resources and opportunities, professional development, plus support with the Next Generation Science Standards. Learn how to join in our collaborative efforts to support the K–12 Formal Education community and to reach the informal science education and outreach communities based upon mutual needs and interests.

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Institution(s): *1. NASA SMD Astrophysics Forum, 2. Space Telescope Science Institute*
Contributing team(s): NASA SMD Astrophysics E/PO Community

410.06 – NASA Astrophysics E/PO: The Impact of the Space Telescope Science Institute Office of Public Outreach

As the science operations center for Hubble and Webb, the Space Telescope Science Institute (STScI) is uniquely positioned to captivate the imagination and inspire learners of all ages in humanity's quest to understand fundamental questions about our universe and our place in it. With the 25^{th} anniversary of Hubble's launch and deployment approaching in April 2015, this presentation will provide an overview of the impact of the STScI's Office of Public Outreach's programs to engage students, educators, and the public in exploring the universe through audience-based news, education, and outreach programs. At the heart of our programs lies a tight coupling of scientific, education, and communications expertise. By partnering scientists and educators, we assure current, accurate science content and education products and programs that are classroom-ready and held to the highest pedagogical standards. Likewise, news and outreach programs accurately convey cutting-edge science and technology in a way that is attuned to audience needs. The combination of Hubble's scientific capabilities and majestic imagery, together with a deep commitment to creating effective programs to share Hubble science with the education community and the public, has enabled the STScI Office of Public Outreach programs to engage 6 million students and ½ million educators per year, and 24 million online viewers per year. Hubble press releases generate approximately 5,000 online news articles per year with an average circulation of 125 million potential readers per press release news story. We will also share how best practices and lessons learned from this long-lived program are already being applied to engage a new generation of explorers in the science and technology of the James Webb Space Telescope.

Author(s): Denise A. Smith[1], Hussein Jirdeh[1], Bonnie Eisenhamer[1], Ray Villard[1]
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410.07 – NASA Astrophysics E/PO Impact: The Astrophysics Educator Ambassador Program

The NASA Astrophysics Educator Ambassador (EA) Program began in 2001 as part of the GLAST (now Fermi) E/PO effort at Sonoma State University. The program currently supports 15 EAs, sponsored by either Fermi, Swift, XMM-Newton or NuSTAR. This group of master educators work with mission scientists and E/PO personnel to develop curricula and train teachers; they also do workshops for students and outreach events with the general public. We have held six bi-annual weeklong trainings at SSU: each has had a different focus. Special topics of study have included the Dark Universe, Particle Physics and Gravitation. Additionally, time is given for the EAs to share ideas from their own workshops. In the 14 years of the program, the total number of teachers attending EA-run workshops is over 65,000. Over 1500 workshops have been evaluated by participants, and these evaluation scores and comments have been further analyzed by external experts at WestEd. The WestEd report summarizes the results: "Almost universally high ratings are obtained even though a wide range of participants by grade level, teaching experience or interest typically attends EA conference sessions, and they can bring quite different needs or perspectives." In this talk, I will report details of the impacts of the Astrophysics EA program.

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Contributing team(s): SSU E/PO team

410.08 – NASA Astrophysics E/PO Impact: NASA SOFIA AAA Program Evaluation Results

SOFIA is an airborne observatory, studying the universe at infrared wavelengths, capable of making observations that are impossible for even the largest and highest ground-based telescopes. SOFIA also inspires the development of new scientific instrumentation and fosters the education of young scientists and engineers.
SOFIA is an 80% - 20% partnership of NASA and the German Aerospace Center (DLR), consisting of an extensively modified Boeing 747SP aircraft carrying a reflecting telescope with an effective diameter of 2.5 meters (100 inches). The SOFIA aircraft is based at NASA Armstrong Flight Research Center, Building 703, in Palmdale, California. The Science Program and Outreach Offices are located at NASA Ames Research center. SOFIA is a program in NASA's Science Mission Directorate, Astrophysics Division.
Data will be collected to study many different kinds of astronomical objects and phenomena, including star cycles, solar system formation, identification of complex molecules in space, our solar system, galactic dust, nebulae and ecosystems.
Airborne Astronomy Ambassador (AAA) Program:
The SOFIA Education and Communications program exploits the unique attributes of airborne astronomy to contribute to national goals for the reform of science, technology, engineering, and math (STEM) education, and to elevate public scientific and technical literacy.
The AAA effort is a professional development program aspiring to improve teaching, inspire students, and inform the community. To date, 55 educators from 21 states; Cycles 0, 1 and 2; have completed their astronomy professional development and their SOFIA science flight experience. Evaluation has confirmed the program's positive impact on the teacher participants, on their students, and in their communities. The inspirational experience has positively impacted their practice and career trajectory. AAAs have incorporated content knowledge and specific components of their experience into their curricula, and have given hundreds of presentations and implemented teacher professional development workshops. Their efforts have impacted thousands of students and teachers.

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Institution(s): *1. SETI Institute, 2. USRA*
Contributing team(s): Inverness Research SOFIA AAA Evaluation Team, WestEd SOFIA AAA Evaluation Team

410.09 – Frontier Fields: Engaging Educators, the Youth, and the Public in Exploring the Cosmic Frontier

The Frontier Fields is a multi-cycle program of six deep-field observations of strong-lensing galaxy clusters that will be taken in parallel with six deep "blank fields." The three-year long collaborative program is led by observations from NASA's Great Observatories. The observations allow astronomers to look deeper into the universe than ever before, and potentially uncover galaxies that are as much as 100 times fainter than what the telescopes can typically observe. The Frontier Fields science program is ideal for informing audiences about scientific advances and topics in STEM. The study of galaxy properties, statistics, optics, and Einstein's theory of general relativity naturally leverages off of the science returns of the Frontier Fields program. As a result, the Space Telescope Science Institute's Office of Public Outreach (OPO) has initiated an education and public outreach (EPO) project to follow the progress of the Frontier Fields.

For over two decades, the Hubble EPO program has sought to bring the wonders of the universe to the education community, the youth, and the public, and engage audiences in the adventure of scientific discovery. Program

components include standards-based curriculum-support materials, exhibits and exhibit components, professional development workshops, and direct interactions with scientists. We are also leveraging our new social media strategy to bring the science program to the public in the form of an ongoing blog. The main underpinnings of the program's infrastructure are scientist-educator development teams, partnerships, and an embedded program evaluation component. OPO is leveraging this existing infrastructure to bring the Frontier Fields science program to the education community and the public in a cost-effective way.

The Frontier Fields program has just completed its first year. This talk will feature the goals and current status of the Frontier Fields EPO program. We will highlight OPO's strategies and infrastructure that allows for the quick delivery of groundbreaking science to the education community and public.

Author(s): Brandon L. Lawton[1], Bonnie Eisenhamer[1], Denise A. Smith[1], Frank Summers[1], John A. Darnell[1], Holly Ryer[1]
Institution(s): *1. STScI*

411 – Starburst Galaxies I

411.01 – GOALS: HI Mapping of Local (U)LIRGs

Neutral hydrogen (HI) is one of the major constituents of the interstellar medium in local luminous and ultraluminous infrared galaxy ((U)LIRGs; L_IR > 10^11 L_sun) interactions and mergers. Observations of HI can be used to obtain information on the kinematic state of the interaction, search for evidence of interaction in seeminly unperturbed systems, and constrain the amount of fuel available for future star formation. We present preliminary results from an interferometric HI survey of local (U)LIRGs from the Great Observatories All-sky LIRG Survey (GOALS). Here we focus on observations of a subset of systems with undisturbed stellar morphologies – interpreted as suggesting these galaxies have not been significantly perturbed by tidal interactions. Despite this, they show elevated star formation rates. HI observations of these systems show extended features with mophologies and kinematics consistent with ongoing tidal interaction, suggesting these systems are already experiencing tidal perturbation – likely the cause of the enhanced star formation.

Author(s): George C. Privon[7], Aaron S. Evans[8], John E. Hibbard[3], Joshua E. Barnes[2], Raffaella Morganti[5], Tom Oosterloo[5], Sabrina Stierwalt[8], David T. Frayer[4], Joseph M. Mazzarella[1], Lee Armus[6], Ezequiel Treister[7]
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Contributing team(s): GOALS

411.02D – Why is the Radio Continuum Spectral Index of a Star-Forming Galaxy Approximately -0.7?

For local star-forming galaxies, the observed radio continuum spectral index typically falls within +/- 0.1 of -0.7. This narrow distribution is often attributed to a high degree of uniformity in both the ratio of the constituent synchrotron and free-free emission components, as well as to the constancy of their spectral shapes. However, astrophysical models do not generally predict simple power law shapes for the constituent components, nor do they predict a ubiquitous ratio between their contributions to the total integrated spectrum. In this talk, I summarize the results of an investigation into the detailed spectral shapes of these constituent components, as well as their relative contributions to the total spectrum, using observations with high spatial and spectral resolution.

I have analyzed over 30 high-resolution images of two starburst galaxies, M82 and NGC 2146, using observations with the Karl G. Jansky Very Large Array (VLA) at frequencies from 1 to 46 GHz. Substantial variations were detected in the radio spectrum across the face of each galaxy, which demonstrates that the integrated spectrum is a composite of diverse spectral shapes. I have separated the resolved radio emission into thermal and nonthermal components and will present a multi-zone description, with elements including a star-forming disk and galactic wind. I will present evidence for spectral curvature in the synchrotron emission from these objects, and compare these findings to models of energy-dependent cosmic ray cooling, as well as to the predictions from calorimeter models of the radio/far-IR relation. Additionally, I have analyzed faint filamentary emission detected in my very high resolution VLA image of the galaxy M82, and I will discuss this emission in the context of wind outflow channels and magnetic structures.

Author(s): Joshua Marvil[1], Jean Eilek[2], Frazer N. Owen[3]
Institution(s): *1. CSIRO Astronomy & Space Science, 2. New Mexico Tech, 3. NRAO*

411.03 – ALMA (Band 7 & 9) Imaging of Arp 220 in HCN and Dust continuum

We report imaging of Arp 220 at 350 and 700GHz at 0.5 to 0.25 arcsec resolution. Counter-rotating disks are seen in HCN and CS on both nuclei. The dust continuum fluxes are used to estimate ISM masses of 1.9 and 4.2 billion masses for the East and West nuclei respectively. The dynamics are modeled using a kinematic deconvolution technique to match the observed line profiles. The derived dynamical maases are consistent with the dust-emission masses, opneing up a new technique for probing the CO-to-H2 conversion ratio.

Author(s): Nicholas Scoville[1]
Institution(s): *1. Caltech*

411.04D – Molecular Gas in Starburts ARP 220 & NGC 6240: Understanding Mergers using High Density Gas Tracers

NGC 6240 and Arp 220 can be considered the founding members of a very active class of objects called Ultraluminous Infrared Galaxies or ULIRGs. They are in different stages of mergers and hence are excellent case studies to enhance our knowledge about the merging process. We have imaged the dense star-forming regions of these galaxies at sub-arcsec resolution with ALMA and CARMA. Multi-band imaging allows multilevel excitation analysis of HCN, HCO+ and CS transitions which will constrain the properties of the gas as a function of position and velocity (across line profiles). We are doing an extensive multilevel excitation analysis of the merger as a function of radius which enables in depth understanding of the gas dynamics and gas properties such as temperature and density. This in turn probes the homogeneity of the gas in the merging system and hence the regions that facilitate high star formation rates. This tandem use of CARMA with ALMA to map these systems at different merger stages will assemble a more integrated picture of the merger process. We are probing the distribution and dynamics of star forming gas and star formation activity in the dense disk structures to enable new theoretical understanding of the physics, dynamics, star formation activity and associated feedback in the most active and rapidly evolving galactic nuclei. Here we present our observations of Arp 220 and NGC 6240 from ALMA and CARMA.

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411.06 – Extreme Starbursts at z >4

We have developed a method of selecting high-z, extreme (~1000 M_sun/yr), dusty starbursts using their red colors in Herschel/SPIRE maps. Follow-up spectroscopy of the first ten candidate sources has revealed that essentially all of them lie at z > 4, and range up to at least z=6.3. This shows that the population of dusty, star forming galaxies (DSFGs or SMGs) extends to much earlier cosmic epochs than expected from models, which generically predict a very sharp cutoff in the population above z ~ 3 compared with their observed sky density of > 3 per square degree. I will present results from our extensive multi-wavelength follow-up campaigns, including ALMA cycle 2 spectroscopy of additional candidate systems.

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Contributing team(s): HerMES collaboration

411.07 – Cosmic Ray Interactions, Gamma-Rays, and Neutrinos in Starbursting Galaxies

High quality gamma-ray and radio observations of nearby galaxies offer an unprecedented opportunity to study the properties of cosmic rays and their role in the host galaxy in detail. Accounting for various interactions and energy losses, we developed a multi-component, single-zone model of the cosmic ray populations in starburst galaxies. Using observational knowledge of the interstellar medium and star formation, we successfully predict the radio and gamma-ray spectra for nearby starbursts. The models also provide constraints on magnetic field strengths, radiation field energy densities, and galactic wind (advection) speeds and thus on the strengths of several feedback processes. In particular, I will discuss our predictions for the gamma-ray and neutrino spectra of Arp 220, a nearby ULIRG comparable to objects at high redshift.

Author(s): Tova M Yoast-Hull[1], John S. Gallagher[1], Ellen Gould Zweibel[1]
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412 – High Redshift (z>3) Galaxies

412.01 – On the intergalactic attenuation for high-z galaxies

Even after the cosmic reionization, neutral hydrogen still remains in the intergalactic space. These intervening hydrogen atoms absorb the radiation from high-z objects and make a numerous absorption lines, the so-called Lyman alpha forest, in the spectra of the objects. To know the absorption amount as a function of redshift is essentially important for studies of the high-z objects, for example, to predict how much reddening occurs in the spectra of the high-z galaxies, which is used as the so-called Lyman break technique. The current standard model for the intergalactic attenuation is

Madau (1995). However, the intergalactic absorbers' statistics, which is the ingredient of the model, is largely updated during two decades after Madau (1995). Here, I present an update of this kind model. I also show a preliminary result of the absorption excess in a proto-cluster environment found in a composite spectrum of galaxies behind the proto-cluster.

Author(s): Akio K Inoue[1]
Institution(s): *1. Osaka Sangyo University*

412.02 – Investigating the Physical Cause Behind a Constant Characteristic Magnitude at High Redshift

The combination of deep and wide Hubble Space Telescope surveys have allowed the first robust cosmic census of galaxies in the distant universe. We use a combination of datasets from the CANDELS, Hubble Ultra Deep Field, and Hubble Frontier Field surveys to construct a rest-frame ultraviolet luminosity function at z = 4, 5, 6, 7 and 8, over a large dynamic range in UV luminosity. In contrast to studies from the past few years, we find little evolution in the characteristic magnitude M* with redshift, while the characteristic number density decreases significantly towards earlier times. We examine bright galaxies in our sample, and find that contamination by lower redshift galaxies appears minimal. We use abundance matching to derive the typical halo masses for bright galaxies at z > 4, and finding that M_UV=-21 galaxies live in halos with log (Mhalo/Msol) = 11.3 (11.9) at z=7 (z=4). Combining the halo masses with the measured stellar masses of these galaxies, we find that the stellar-to-halo mass fraction increases significantly (3-sigma) from z=4 to 8, in contrast to expectations from a decreasing halo mass. This could be a signature that decreased feedback is resulting in an increased star-formation efficiency. Finally, we examine the evolution of the cosmic star-formation rate density from our integrated luminosity functions, and find that at z > 4 it is proportional to (1+z)^-4.7, and that this trend is consistent with current results at z=9 and 10 without a need to invoke a steep dropoff.

Author(s): Steven L. Finkelstein[5], Russell E. Ryan[3], Casey J. Papovich[4], Mark Dickinson[1], Mimi Song[5], Peter Behroozi[3], Rachel S. Somerville[2], Henry Closson Ferguson[3]
Institution(s): *1. NOAO, 2. Rutgers University, 3. Space Telescope Science Institute, 4. Texas A&M University, 5. University of Texas at Austin*
Contributing team(s): CANDELS Team, S-CANDELS Team

412.03D – Probing stellar mass build-up in galaxies at z=4-7 with CANDELS and S-CANDELS

Over the last few years the advent of the Hubble Space Telescope (HST) Wide Field Camera 3 has enabled us to build statistically significant samples of galaxies out to z=8. We have subsequently witnessed remarkable progress in our understanding of galaxy evolution in the early universe. However, our understanding of the galaxy stellar mass growth in this era has been limited due to the lack of rest-frame optical data at a comparable depth as the HST data. Here we present results on the galaxy stellar mass function at z=4-7 from a sample of ~7500 galaxies over an area of ~280 square arcmin in the CANDELS GOODS-South and North fields, as well as the Hubble Ultra Deep Field. Utilizing deep IRAC data from the S-CANDELS and IUDF10 programs to robustly constrain the stellar masses of galaxies in our sample, we measure the stellar-mass to rest-frame ultraviolet (UV) luminosity trends in each of our redshift bins. We convolve these trends with recent measurements of the rest-frame ultraviolet luminosity function to derive the stellar mass functions. Contrary to initial studies at these redshifts, we find steeper low-mass-end slopes (-1.6 at z=4, and -2.0 at z=7), similar to recent simulations. Our results provide the most accurate estimates to date of the cosmic stellar mass density over the first two billion years after the Big Bang.

Author(s): Mimi Song[3], Steven L. Finkelstein[3], Matthew Ashby[1], Emiliano Merlin[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics , 2. INAF, 3. University of Texas at Austin*

412.04 – Origin of Lyman Alpha Photons in High-Redshift Galaxies

We explore the relationship between the spectral shape of the Lyα emission and the morphology and orientation of the host galaxy, using a sample of 323 Lyα-emitting BVI-dropouts at 3 < z < 7 in the GOODS and COSMOS fields. Using our extensive reservoir of high-quality Keck DEIMOS spectra combined with HST WFC3 data, we measure the Lyα line asymmetry for individual galaxies and compare it to axial ratio in observed J- and H-band (restframe UV) images. We find that the skewness of the line exhibits a large scatter at small elongation (A/B < 2) at all redshifts, and this scatter decreases as a function of elongation as the galaxy appears more edge-on. We examine the relationship for Lyman break galaxies selected with different color-color criteria to investigate the effect of redshift and extinction. Our results have implications for the impact of the observed morphology on the Lyα escape fraction in high-redshift galaxies and its evolution with look-back time.

Author(s): Vivian U[1], Shoubaneh Hemmati[1], Bahram Mobasher[1], Behnam Darvish[1], Hooshang Nayyeri[1]
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412.06 – Do Massive Galaxies at z~6 Present a Challenge for Hierarchical Merging?

The Spitzer Large Area Survey with Hyper-Suprime-Cam (SPLASH) recently released an initial view of the massive star-forming galaxy population at 4 < z < 6 over 1.8 square degrees. SPLASH found approximately 100 galaxy candidates with best-fit stellar masses over 10^11 solar. If even 10% of these are truly this massive and at such a high redshift, the corresponding number density would be inconsistent with the halo mass functions produced at these redshifts by numerical simulations. We will discuss these candidates, prospects for followup observations, and the potential implications for our understanding of the initial formation and early evolution of galaxies in the high-redshift universe.

Author(s): Charles L. Steinhardt[1], Peter L. Capak[1], Daniel Masters[1], Josh S Speagle[2]
Institution(s): *1. Caltech, 2. Harvard*
Contributing team(s): SPLASH

413 – Instrumentation: Space Missions -Ground Based or Airborne III

413.01 – Observing the Sun with ALMA: A New Window into Solar Physics

The Atacama Large Millimeter/Submillimeter Array (ALMA) is a joint North American, European, and East Asian interferometric array that opens the mm-submm wavelength part of the electromagnetic spectrum for general astrophysical exploration, providing high resolution imaging in frequency bands. Despite being a general purpose instrument, provisions have been made to enable solar observations with ALMA, thereby offering a new window into solar physics. Radiation emitted at ALMA wavelengths originates mostly from the chromosphere, which plays an important role in the transport of energy and matter and the heating of the outer layers of the solar atmosphere. Despite decades of intensive research, an understanding of the chromosphere is still elusive, and challenging to observe owing to the complicated formation mechanisms of currently available diagnostics. ALMA will change the scene substantially as it serves as a nearly linear thermometer at high spatial, temporal, and spectral resolution, enabling us to study the complex interaction of magnetic fields and shock waves and yet-to-be-discovered dynamical processes.Moreover, ALMA will play an important role in the study of energetic emissions associated with solar flares at sub-THz frequencies.

This presentations introduces ALMA to the solar physcis community and motivates the science that can be addressed by ALMA using a number of examples based on 3D MHD simulations. In addition, the means by which ALMA is used to acquire and calibrate solar observations will be discussed. Finally, we encourage potential users to join us in further defining and articulating the exciting science to be explored with this fundamentally new instrument.

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Institution(s): *1. NAOJ, 2. NRAO, 3. University of Oslo*
Contributing team(s): the ALMA North American Solar Development Team

413.02 – Observation strategies with the Fermi Gamma-ray Space Telescope

During the first few years of the Fermi mission, the default observation mode has been an all-sky survey, optimized to provide relatively uniform coverage of the entire sky every three hours. Over 95% of the mission has been performed in this observation mode. However, Fermi is capable of flexible survey mode patterns, and inertially pointed observations both of which allow increased coverage of selected parts of the sky. In this presentation, we will describe the types of observations that Fermi can make, the relative advantages and disadvantages of various observations, and provide guidelines to help Fermi users plan and evaluate non-standard observations.

Author(s): Julie E. McEnery[1]
Institution(s): *1. NASA's GSFC*
Contributing team(s): Fermi mission teams

413.03 – The IMACS Occultation Survey for KBOs

We report the results of our campaign to search for occultations of background stars by small (sub-km) Kuiper belt objects (KBOs).
Our study is ground-based, using the Inamori Magellan Areal Camera and Spectrograph (IMACS) instrument on the 6.5m Magellan Baade telescope, at Las Campanas Observatory in Chile.
We implemented a novel shutterless continuous readout mode on the IMACS instrument, with custom-made aperture masks, permitting simultaneous high-speed (40 Hz) photometry for numerous stars, while minimizing the effects of stellar crowding and sky background.
Observing in the southern hemisphere allows us to target the intersection of the ecliptic and galactic planes, where many hundreds of stars can be monitored within a single field of view.

We have observed at Magellan for ~50 hrs, allowing us to obtain ~35,000 star-hours of light curves with per-point SNR > 10.
This represents an order of magnitude increase in star-hours compared to the previous best ground-based survey by Bianco et al. (2009).
We expect that these observation will result in the first ground-based detections of occultations by sub-km objects in the Kuiper-Belt, allowing us to verify and improve upon the sky plane density of sub-km diameter KBOs implied by the HST FGS detections reported by Schlichting et al. (2009, 2012).

Author(s): Matthew John Payne[1], Matthew J. Holman[1], Charles Alcock[1], Hilke Schlichting[1], David J. Osip[1], Federica Bianco[1], Ruth Murray-Clay[1], Pavlos Protopapas[1], Paul Nulsen[1], Ian Thompson[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics*

413.04 – The Dark Energy Spectroscopic Instrument (DESI): Instrument Design

The Dark Energy Spectroscopic Instrument (DESI) will perform a wide-area galaxy and quasar spectroscopic redshift survey covering 14,000 square degrees of sky out to redshift 3.5 using the redshifts of luminous red galaxies (LRGs), emission line galaxies (ELGs) and quasars. The DESI instrument consists of a new wide-field (8 square degree field of view) corrector plus a multi-object spectrometer with 5000 robotically positioned optical fibers and will be installed at prime focus on the Mayall 4m telescope at Kitt Peak, Arizona. The fibers feed 10 three-arm spectrographs producing spectra that cover a wavelength range from 360-980 nm and have resolution of 2000-5100 increasing with the wavelength. Specific details regarding the design of the DESI instrument will be presented. A special focus will be placed on the design choices that will allow the survey to reach the requirements of a Stage IV ground-based dark energy experiment.

Author(s): Claire Poppett[1]
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Contributing team(s): the DESI collaboration

413.05 – SuperHERO: The Next Generation Hard X-Ray Focusing Telescope

SuperHERO is a balloon-borne hard x-ray (20-75 keV) telescope that couples high-angular resolution (~20 arcsecs) electroformed-nickel grazing incidence optics to state-of-the-art fine pixel-pitch (250 µm) Cadmium-Telluride detectors with a 6 m focal length. This telescope, currently in the proposal phase, will have the highest angular resolution of any hard x-ray telescope to date, and comparable energy resolution to that of the Nuclear Spectroscopic Telescope Array. The high angular resolution afforded by focusing optics is essential for mitigating source confusion in crowded fields, for direct imaging of extended sources on fine spatial scales, and for efficient observing through greatly-increased sensitivity. As such, the primary astronomical targets are the Galactic Center, pulsar-powered synchrotron nebulae and diffusive shock accelerated sites in supernova remnants. To facilitate solar observations, the SuperHERO detectors have a high processing rate of ~10 kHz over the entire 80x80 pixel array, or over 5M photons per second over the detector area. The current SuperHERO configuration has a total on-axis effective area of 145 cm^2 at 30 keV and a field of view of ~7 arcmin FWHM at 30 keV (simulated). The optics, developed at NASA Marshall Space Flight Center, have significant flight heritage as similar mirrors have flown on balloon payloads, sounding rockets and a satellite mission. The detectors, developed at Rutherford Appleton Laboratory (RAL), utilize the novel HEXITEC Application Specific Integrated Circuit. RAL has been working on these and similar detectors for over a decade for applications ranging from medical to defense. NASA Goddard Space Flight Center, working with RAL and MSFC has been adapting these detectors for flight, with good progress. The telescope will reside on a carbon-composite frame that will integrate the Wallops Arc Second Pointer. This design will allow for Long Duration Balloon flights from Antarctica that can last up to 4 weeks. The current balloon-based design, along with a design for a space-based version of SuperHERO will be discussed.

Author(s): Jessica Gaskin[3], Colleen Wilson-Hodge[3], Brian Ramsey[3], Ronald Elsner[3], Allyn F. Tennant[3], Kiranmayee Kilaru[6], Douglas A. Swartz[6], Steven Christe[2], Albert Y. Shih[2], Frederick K. Baganoff[1], Paul Seller[5], Matthew Wilson[5], David Stuchlik[4]
Institution(s): *1. MIT Kavli Institute for Astrophysics, 2. NASA Goddard Space Flight Center, 3. NASA Marshall Space Flight Center, 4. NASA Wallops Flight Facility, 5. Rutherford Appleton Laboratory, 6. Universities Space Research Association*

413.06D – The Adaptive Optics Lucky Imager: Diffraction limited imaging at visible wavelengths with large ground-based telescopes

One of the continuing challenges facing astronomers today is the need to obtain ever higher resolution images of the sky. Whether studying nearby crowded fields or distant objects, with increased resolution comes the ability to probe systems in more detail and advance our understanding of the Universe. Obtaining these high-resolution images at visible wavelengths however has previously been limited to the Hubble Space Telescope (HST) due to atmospheric effects limiting the spatial resolution of ground-based telescopes to a fraction of their potential. With HST now having a finite lifespan, it is prudent to investigate other techniques capable of providing these kind of observations from the

ground. Maintaining this capability is one of the goals of the Adaptive Optics Lucky Imager (AOLI).
Achieving the highest resolutions requires the largest telescope apertures, however, this comes at the cost of increased atmospheric distortion. To overcome these atmospheric effects, there are two main techniques employed today: adaptive optics (AO) and lucky imaging. These techniques individually are unable to provide diffraction limited imaging in the visible on large ground-based telescopes; AO currently only works at infrared wavelengths while lucky imaging reduces in effectiveness on telescopes greater than 2.5 metres in diameter. The limitations of both techniques can be overcome by combing them together to provide diffraction limited imaging at visible wavelengths on the ground.
The Adaptive Optics Lucky Imager is being developed as a European collaboration and combines AO and lucky imaging in a dedicated instrument for the first time. Initially for use on the 4.2 metre William Herschel Telescope, AOLI uses a low-order adaptive optics system to reduce the effects of atmospheric turbulence before imaging with a lucky imaging based science detector. The AO system employs a novel type of wavefront sensor, the non-linear Curvature Wavefront Sensor (nlCWFS) which provides significant sky-coverage using natural guide-stars alone.
Here we present an overview of the instrument design, results from the first on-sky and laboratory testing and on-going development work of the instrument and its adaptive optics system.

Author(s): Jonathan Crass[5], Craig Mackay[2], David King[2], Rafael Rebolo-López[3], Lucas Labadie[1], Marta Puga[3], Alejandro Oscoz[3], Victor González Escalera[3], Antonio Pérez Garrido[4], Roberto López[3], Jorge Pérez-Prieto[3], Luis Rodríguez-Ramos[3], Sergio Velasco[3], Isidro Villó[4]
Institution(s): *1. I. Physikalsiches Institut, Universität zu Köln, 2. Institute of Astronomy, University of Cambridge, 3. Instituto de Astrofísica de Canarias, 4. Universidad Politecnica de Cartagena, 5. University of Notre Dame*

413.07D – On-sky validation of an optimal LQG control with vibration mitigation: from the CANARY Multi-Object Adaptive Optics demonstrator to the Gemini Multi-Conjugated Adaptive Optics facility.

Adaptive optics provides real time correction of wavefront perturbations on ground-based telescopes and allow to reach the diffraction limit performances. Optimizing control and performance is a key issue for ever more demanding instruments on ever larger telescopes affected not only by atmospheric turbulence, but also by vibrations, windshake and tracking errors. Linear Quadratic Gaussian control achieves optimal correction when provided with a temporal model of the disturbance. We present in this paper the first on-sky results of a Kalman filter based LQG control with vibration mitigation on the CANARY instrument at the Nasmyth platform of the 4.2-m William Herschel Telescope (La Palma, Spain). The results demonstrate a clear improvement of performance for full LQG compared with standard integrator control, and assess the additional improvement brought by vibration filtering with a tip-tilt model identified from on-sky data (by 10 points of Strehl ratio), thus validating the strategy retained on the instrument SPHERE (eXtreme-AO system for extra-solar planets detection and characterization) at the VLT. The MOAO on-sky pathfinder CANARY features two AO configurations that have both been tested: single- conjugated AO and multi-object AO with NGS and NGS+ Rayleigh LGS, together with vibration mitigation on tip and tilt modes. We finally present the ongoing development done to commission such a control law on a regular Sodium laser Multi-Conjuagated Adaptive Optics (MCAO) system GeMS at the 8-m Gemini South Telescope. This implementation does not require new hardware and is already available in the real-time computer.

Author(s): Gaetano Sivo[1]
Institution(s): *1. Gemini South Observatory*
Contributing team(s): caroline kulcsár, Jean-Marc Conan, Henri-François Raynaud, Éric Gendron, Alastair Basden, Damien Gratadour, Tim Morris, Cyril Petit, Serge Meimon, Gérard Rousset, Vincent Garrel, Benoit Neichel, Marcos van Dam, Eduardo Marin, Rodrigo Carrasco, Mischa Schirmer, William Rambold, Cristian Moreno, Vanessa Montes, Kayla Hardie, Chad Trujillo

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414 – Young Stellar Objects, Very Young Stars, T-Tauri Stars, H-H Objects

414.01 – The Serpens South Protocluster Core as Viewed by SOFIA/FORCAST

With a high ratio of protostars to young stellar objects, the Serpens South Protocluster is among the youngest known clusters. At the time of its discovery, 91 protostars and YSOs were identified based on excess infrared emission; half of these members are found within the densest part, or core, of the cluster. Subsequent studies, including millimeter continuum observations, have increased the number of likely members. Using SOFIA (Stratospheric Observatory for Infrared Astronomy), we observed the core of the cluster at 19.7, 25.4, and 37.1 µm with FORCAST (Faint Object InfraRed CAmera for the SOFIA Telescope), detecting more than two dozen members. Our FORCAST observations reveal a faint protostar about 7” (2900 AU at 415 pc) from a previously known protostar, demonstrating a strength of SOFIA/FORCAST in discovering faint sources previously unresolved from brighter neighboring sources. Including observations from the Spitzer Space Telescope and the Herschel Space Observatory, we construct infrared spectral energy distributions of members, estimate their internal luminosities, and discuss the content of the cluster's core.

Author(s): Tracy L. Huard[1], Marc W. Pound[1], Lee G. Mundy[1]
Institution(s): *1. Univ. of Maryland*

414.02D – Using He I λ10830 to Diagnose Mass Flows Around Herbig Ae/Be Stars

The pre-main sequence Herbig Ae/Be stars (HAEBES) are the intermediate mass cousins of the low mass T Tauri stars (TTSs). However, it is not clear that the same accretion and mass outflow mechanisms operate identically in both mass regimes. Classical TTSs (CTTSs) accrete material from their disks along stellar magnetic field lines in a scenario called magnetospheric accretion. Magnetospheric accretion requires a strong stellar dipole field in order to truncate the inner gas disk. These fields are either absent or very weak on a large majority of HAEBES, challenging the view that magnetospheric accretion is the dominant accretion mechanism. If magnetospheric accretion does not operate similarly around HAEBES as it does around CTTSs, then strong magnetocentrifugal outflows, which are directly linked to accretion and are ubiquitous around CTTSs, may be driven less efficiently from HAEBE systems. Here we present high resolution spectroscopic observations of the He I λ10830 line in a sample of 48 HAEBES. He I λ10830 is an excellent tracer of both mass infall and outflow which is directly manifested as red and blue-shifted absorption in the profile morphologies. These features, among others, are common in our sample. The occurrence of both red and blue-shifted absorption profiles is less frequent, however, than is found in CTTSs. Statistical contingency tests confirm this difference at a significant level. In addition, we find strong evidence for smaller disk truncation radii in the objects displaying red-shifted absorption profiles. This is expected for HAEBES experiencing magnetospheric accretion based on their large rotation rates and weak magnetic field strengths. Finally, the low incidence of blue-shifted absorption in our sample compared to CTTSs and the complete lack of simultaneous red and blue-shifted absorption features suggests that magnetospheric accretion in HAEBES is less efficient at driving strong outflows. The stellar wind-like outflows that are observed are likely driven, at least in part, by boundary layer accretion. The smaller (or absent) disk truncation radii in HAEBES may have consequences for the frequency of planets in close orbits around main sequence B and A stars.

Author(s): Paul W. Cauley[2], Christopher M. Johns-Krull[1]
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414.03 – Recollimation boundary layers as X-ray sources in young stellar jets

Young stars accrete mass from circumstellar disks and in many cases, the accretion coincides with a phase of massive outflows, which can be highly collimated. Those jets emit predominantly in the optical and IR wavelength range. However, in several cases X-ray and UV observations reveal a weak but highly energetic component in those jets (e.g. DG Tau, HH 2, HH 154, RY Tau). X-rays are observed both from stationary regions close to the star and from knots in the jet several hundred AU from the star.
Several models have been suggested in the literature to explain the emission. One of the most prominent ones is the idea of a pulsed jet outflow, where faster material catches up with previous, slower ejecta and a shock forms where they interact. However, in this contribution we want to present an alternative model, that is quasi-stationary and thus naturally explains the stationarity of the observed X-ray emission. We show semi-analytically that a fast stellar wind which is recollimated by the pressure from a slower, more massive disk wind can have the right properties to power stationary X-ray emission. The shocked regions are only a few AU wide and would not be visible in existing optical or IR imaging. Our calculations support a wind-wind interaction scenario for the high energy emission near the base of YSO jets. Since only a very small fraction of the total mass loss comes from the star, the optical and IR properties are dominated by the slower and more massive disk wind, which has been shown to explain many of the observed phaenomena.
For the specific case of DG Tau, a stellar wind with a mass loss rate of $5*10^{-10}M^{sun}$/yr and a wind speed of 800 km/s reproduces the observed X-ray spectrum. We conclude that a stellar wind recollimation shock is a viable (but not unique) scenario to power stationary X-ray emission close to the jet launching point.
The shock model itself is available as a table model in XSPEC format and can be read by all major X-ray spectral fitting packages and we provide the code used to model the shock front in python (for use with the Sherpa fitting package).

Author(s): Hans Moritz Guenther[2], Zhi-Yun Li[3], Peter C Schneider[1]
Institution(s): *1. Hamburger Sternwarte, 2. MIT, 3. University of Virginia*

414.04D – A Study of Galactic Ring-Shaped HII Regions: Searching For Possible Sites of Triggered Star Formation

We report the results of a study of star-formation activity associated with the outer Galaxy ring-shaped HII regions KR7, KR81, KR120 and KR140, using archival Spitzer and WISE data along with deep JHK observations from CFHT. We used CO data cubes from the Five College Radio Astronomy Observatory to define extent of the molecular cloud associated each HII region. Using the infrared data sets, we identified and classified YSO populations within each molecular cloud using measures such as the class I/II ratio and YSO spatial density. Combining our observations of the YSO population distribution with time scales associated with YSO evolution and HII region expansion, we investigated the possible significance of triggered star formation in the molecular cloud surrounding each region.

Author(s): Sung-Ju Kang[1], Charles R. Kerton[1]
Institution(s): *1. Iowa State University*

414.05D – New Exozodi and Asteroid Belt Analogs using WISE

The presence of circumstellar dust in the terrestrial planet zone and asteroid belt regions of stars can be ascertained from the excess flux from main sequence stars in the mid-infrared wavelengths. Finding dust in these regions is significant as it traces material related to terrestrial planet formation. The WISE All-Sky survey presents an opportunity to extend the population of faint disks to flux levels 100x fainter than disks detected by IRAS.
We use the WISE All-Sky Survey data to detect circumstellar debris disks at the 12 and 22 μm bandpasses (W3 and W4, respectively). We present the detection of a sample of over 214 exozodi and asteroid belt analog candidates, 45% of which are brand new detections at confidence levels >99.5%. This was done by cross-matching Hipparcos main-sequence stars with the WISE All-Sky Data Release for stars within 75 pc and outside the galactic plane (|b|>5 deg) and then seeking color excesses at W3 and W4. In addition to applying the standard WISE photometric flags and filters to remove contaminants from our sample, we also improved our selection techniques by correcting for previously unknown systematic behavior in the WISE photometry, thereby including bright saturated stars into our sample. Our debris disk candidates are reliable detections as well as unprecedentedly faint, due in large part to these improved selection techniques. These new nearby excess hosts are optimal targets for direct imaging campaigns to characterize the disk morphology and to provide a larger sample of well characterized disks with which to understand the overall exoplanetary system architecture.

Author(s): Rahul Patel[1], Stanimir Metchev[2], Aren Heinze[1]
Institution(s): *1. SUNY Stony Brook, 2. University of Western Ontario*

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415 – Binaries - Stellar

415.01 – A Joint Approach to the Study of S-Type and P-Type Habitable Zones in Binary Systems: New Results in the View of 3-D Planetary Climate Models

In two previous papers, given by Cuntz (2014a,b) [ApJ 780, A14 (19 pages); arXiv:1409.3796], a comprehensive approach has been provided for the study of S-type and P-type habitable zones in stellar binary systems, P-type orbits occur when the planet orbits both binary components, whereas in case of S-type orbits, the planet orbits only one of the binary components with the second component considered a perturbator. The selected approach considers a variety of aspects, including (1) the consideration of a joint constraint including orbital stability and a habitable region for a possible system planet through the stellar radiative energy fluxes; (2) the treatment of conservative (CHZ), general (GHZ) and extended zones of habitability (EHZ) [see Paper I for definitions] for the systems as previously defined for the Solar System; (3) the provision of a combined formalism for the assessment of both S-type and P-type habitability; in particular, mathematical criteria are devised for which kind of system S-type and P-type habitability is realized; and (4) the applications of the theoretical approach to systems with the stars in different kinds of orbits, including elliptical orbits (the most expected case). Particularly, an algebraic formalism for the assessment of both S-type and P-type habitability is given based on a higher-order polynomial expression. Thus, an a prior specification for the presence or absence of S-type or P-type radiative habitable zones is - from a mathematical point of view - neither necessary nor possible, as those are determined by the adopted formalism. Previously, numerous applications of the method have been given encompassing theoretical star-panet systems and and observations. Most recently, this method has been upgraded to include recent studies of 3-D planetary climate models. Originally, this type of work affects the extent and position of habitable zones around single stars; however, it has also profound consequence for the habitable regions in binary systems (both S-type and P-type), the topic of the intended presentation.

Author(s): Manfred Cuntz[1]
Institution(s): *1. Univ. of Texas at Arlington*

415.03D – The Binary INformation from Open Clusters using SEDs (BINOCS) Project: Radial Migration of Binary Systems in Open Clusters

A majority of stars are formed in open clusters, and then ejected into the Galactic field population through gravitational interactions. Therefore, understanding the internal dynamics of open clusters, through N-Body simulations, will inform the growth of the Galactic stellar population. A major input into these N-Body simulations is the frequency and mass distribution of binary star systems. Current binary detection techniques, such as radial velocity studies, are limited in depth, and therefore provide information only over a very limited mass range. As presented in the literature, different mass ranges may produce different interpretations of the observed binary population. A clearer picture of the binary population, covering a wide mass range, is needed to improve cluster simulations. We introduce a new binary detection method, Binary INformation from Open Clusters Using SEDs (BINOCS). Using newly-observed multi-wavelength photometric catalogs (0.3 - 8 micron) of the key open clusters M35, M36, M37, M67 and NGC 2420, the BINOCS method is able to determine accurate component masses for unresolved cluster binaries. We present results on the dynamical evolution of binaries from 0.4 - 2.5 M_sun within these key clusters, and explore how these results change with mass.

Author(s): Benjamin A. Thompson[1], Peter M. Frinchaboy[1]
Institution(s): *1. Texas Christian University*

415.04 – Observations and Analysis of a Newly Discovered Binary Star in the Hercules Constellation

I will present the results of analysis work that my undergraduate students and I performed on a binary star we discovered in the field of one of the RR Lyrae stars we recently studied. The measured lightcurves were analyzed to find the period of the system which was used to phase shift the B and V lightcurves. The shifted curves were used to determine the mass ratio and other parameters for this newly discovered contact binary system in the constellation Hercules using Binary Maker 3 and the Wilson-Devinney code.

Author(s): W. Lee Powell[1]
Institution(s): *1. University of Nebraska Kearney*

415.05 – A prediction of a luminous red nova eruption

Luminous red novae have been distinguished as a class of stellar eruption in just the past decade. They are hypothesized to be the result of the merger of two main sequence stars. Tylenda et al. (2011) found remarkable confirmation of this hypothesis by showing that OGLE data preceding the 2008 outburst of V1309 Sco exhibited the light curve of a contact binary system with an orbital period spiraling exponentially down to zero.
We will present analysis of light curves of KIC 9832227 (= NSVS 5597755) spanning 15 years that show it is a contact binary system with a negative period derivative and second derivative. The data are taken from the NSVS, WASP, and Kepler surveys, and extended by Calvin Observatory measurements in 2013 and 2014.
Fitting the orbital phase timing to the exponential model of Tylenda et al. (2011) provides a satisfactory fit of the entire data set. While we cannot yet conclude the system will follow the model fit, the prediction it makes will soon be easily falsifiable. The model predicts the period derivative will very soon exceed measured values for all other contact binary stars and that the stars should merge sometime between summer 2019 and summer 2022. If the model holds up, this star presents the unprecedented opportunity to perform a set of targeted observations of a luminous red nova progenitor and to follow carefully the course of the merger.
Tylenda, R., et al. (2011), AA, 528, A114.

Author(s): Lawrence A. Molnar[2], Daniel M. Van Noord[2], Steven D. Steenwyk[2], Chris J. Spedden[2], Karen Kinemuchi[1]
Institution(s): *1. Apache Point Observatory, 2. Calvin College*

415.06 – A triple eclipsing system as a test case for close binary formation through Kozai cycles

Kozai cycles and tidal friction of a binary with a tertiary companion is one of the leading theories for the formation of close binary systems by tightening the orbit of the inner binary (Kozai 1962; Mazeh & Shaham 1979; Kiseleva et al. 1998). According to simulations, such systems should evolve into tight inner binaries with eccentric tertiary companions on wide orbits, and importantly predict the tertiary to have an orbital inclination misaligned relative to the plane of the inner binary, with an angle of misalignment that peaks strongly around 40 degrees (Fabrycky & Tremaine 2007). KIC 2835289 is a triple system comprising a ~0.9-day ellipsoidal variable inner binary and a tertiary on a ~750 day orbit. The tertiary was identified through our eclipse timing variations and our finding of a tertiary eclipse event in the Kepler data (Conroy et al. 2014). We present a comprehensive model of this triple system using Kepler photometric data and eclipse timings in addition to radial velocity measurements. We have determined that the tertiary in this system is on an eccentric orbit inclined with respect to the inner binary, in agreement with theoretical prediction.

Author(s): Kyle E. Conroy[1], Andrej Prsa[2], Keivan Stassun[1]
Institution(s): *1. Vanderbilt University, 2. Villanova University*

415.07 – Fundamental Parameters of *Kepler* Eclipsing Binary KIC 5738698

Eclipsing binaries play an important role in stellar astrophysics, as the determination of their physical parameters informs our understanding of stellar structure and evolution. High precision photometry from space-based missions, such as *Kepler*, provides exquisite light curves of eclipsing binaries with unprecedented detail. Accurately modeling such systems is particularly challenging because of the detection of low amplitude-signals that are related to second order effects in the flux variability, but they can also be used to decipher physical details of the binary that were previously inaccessible. Here we present an analysis of KIC 5738698, a 4.8 day period detached eclipsing binary in the Kepler field. We perform eclipse timing measurements and model the light curve using the Eclipsing Light Curve code (ELC), taking into consideration finite integration times, aperture contamination, light travel time effects, inclination and radii degeneracy, and a slight eccentricity. We also use moderate resolution spectra to determine radial velocities via two-dimensional cross-correlation and tomographic reconstruction to model the individual component spectra. By combining the photometric and spectroscopic results we obtain a binary model for KIC 5738698 consisting of two nearly identical F-type stars, enabling us to derive masses and radii for both components.

Author(s): Rachel A. Matson[1], Douglas R. Gies[1], Zhao Guo[1]
Institution(s): *1. GSU*

415.08 – Ages of Red Giants from Asteroseismology

Red giant stars are a fascinating laboratory to test stellar evolution, and with tools from asteroseismology we can gain a unique perspective into their deep interiors. Given the fast variation of oscillation-mode frequencies as function of evolutionary state along the red giant phase, we are able to determine an age. Stars in eclipsing binary systems also present us with the ability to precisely determine stellar properties, such as mass and radius. We present an initial analysis of the oscillations for several binary systems, all of which include a red giant and an F-type companion. We compare the modes that we observe in the red giant star to those expected from a stellar model. The models are created using the MESA stellar evolution code. Parameters for the stellar model come from binary light curve modeling and analysis of high resolution spectra of the systems.

Author(s): Jean McKeever[1], Patrick Gaulme[1], Meredith L. Rawls[1], Jason Jackiewicz[1]
Institution(s): *1. New Mexico State University*

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416 – Plenary Talk: Alma Presents a Transformational View of the Universe, Al Wootten (NRAO)

416.01 – ALMA Presents a Transformational View of the Universe

ALMA Early Science results began transforming astronomy in 2011. Construction has recently ended as scheduled and on budget.
* Seven receiver bands achieve wavelength coverage sweeping from 3mm to 0.3mm across a decade of nearly complete frequency access, broken only by the atmospheric limitations of its spectacular site. With access to nearly any line redshifted within that range, ALMA's sensitivity allows it to address the questions of how the first stars and galaxies in the Universe were born, to measure the abundances of the first metals and to chronicle the development of isotopic diversity among the elements.
* As this is written, the longest baselines are being commissioned for ALMA, enabling resolutions down to 0.01". Very long baseline capability, also currently under initial testing, can tie other antennas' collecting area in with ALMA's to create a global telescope capable of delineating detail as fine as ten microarcseconds, allowing imaging of the black hole at the center of our galaxy.
Already ALMA has changed paradigms for objects both distant and near. Oxygen and carbon, the most abundant metals produced by the first stars, and CO all have lines detectable by ALMA in its wavelength range. The 157 micron [C II] line has already been detected out to z~7 in ALMA Early Science observations. ALMA's sensitivity and resolution have revolutionized the study of circumstellar planet-forming disks. Molecular imaging has revealed CO 'snow lines' in those disks, delineating where in a disk mid plane where ice grains may form as the temperature drops. ALMA has also imaged highly asymmetric distribution of gas and particularly of dust in evolved disks, revealing 'dust traps' where new planets may form from agglomerated material.
ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada) and NSC and ASIAA (Taiwan), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

Author(s): Al Wootten[1]
Institution(s): *1. NRAO*

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418 – Galaxy Clusters IV

418.01 – 3C320: Second Cousin of Cygnus A

We report on new Chandra observations of the cluster of galaxies hosting 3C320 (z=0.34). With a cumulative exposure of 120ks, we analyze the interactions of the powerful radio galaxy 3C320 (which bears a striking resemblance to Cygnus A) with the intracluster medium. We examine the evidence for the presence of cavities in the hot gas and shocks from the bright lobes. With an estimate of the energy deposited in the ICM from this powerful source, we note that the growing sample of FRII radio galaxies in clusters must be included in global feedback calculations. The work at SAO was supported by NASA grant GO4-15120X.

Author(s): D. E. Harris[2], Martin Hardcastle[1], C. C. Cheung[4], J. Croston[5], F. Massaro[6], Paul Nulsen[2], L. Stawarz[3]
Institution(s): *1. University of Hertfordshire , 2. HEA- Center for Astrophysics, 3. Institute of Space and Astronautical Science JAXA, 4. Naval Research Laboratory, 5. University of Southampton, 6. Yale University*

418.02D – Radio Galaxies in Galaxy Clusters: Feedback, Merger Signatures, and Signposts

Extended, double-lobed radio sources are often located in rich galaxy clusters. I will present results of an optical and X-ray analysis of two nearby clusters with such radio sources – one of the clusters is relaxed (A2029) and one of the clusters is undergoing a merger (A98). Because of their association with clusters, extended radio sources can be used to locate clusters at a wide range of distances. The number of spectroscopically confirmed galaxy clusters with is very low compared to the number of well-studied low-redshift clusters. In the Clusters Occupied by Bent Radio AGN (COBRA) survey, we use bent, double-lobed radio sources as signposts to efficiently locate high-redshift clusters. Using a *Spitzer* Snapshot Survey of our sample of 653 bent, double-lobed radio sources (selected from the FIRST survey and with galaxy hosts too faint to be detected in the SDSS), we have the potential to identify approximately 400 new clusters and groups with redshifts. I will present results from the *Spitzer* observations regarding the efficiency of the method for finding new clusters. These newly identified clusters will be used to study galaxy formation and evolution, as well as the effect that feedback from active galactic nuclei (AGN) has on galaxies and their environments.

Author(s): Rachel Paterno-Mahler[1], Elizabeth L. Blanton[1], Scott W. Randall[3], Felipe Andrade-Santos[3], Matthew Ashby[3], Mark Brodwin[6], Esra Bulbul[3], Tracy E. Clarke[5], Emmet Golden-Marx[1], Ryan Johnson[2], Christine Jones[3], Stephen S. Murray[4], Joshua Wing[3]
Institution(s): *1. Boston Univ., 2. Gettysburg College, 3. Harvard-Smithsonian Center for Astrophysics, 4. Johns Hopkins University, 5. Naval Research Laboratory, 6. University of Missouri-Kansas City*

418.03 – The Abundance of Large Arcs From CLASH

We have developed an automated arc-finding algorithm to perform a rigorous comparison of the observed and simulated abundance of large lensed background galaxies (a.k.a arcs). We use images from the CLASH program to derive our observed arc abundance. Simulated CLASH images are created by performing ray tracing through mock clusters generated by the N-body simulation calibrated tool -- MOKA, and N-body/hydrodynamic simulations -- MUSIC, over the same mass and redshift range as the CLASH X-ray selected sample. We derive a lensing efficiency of 15 ± 3 arcs per cluster for the X-ray selected CLASH sample and 4 ± 2 arcs per cluster for the simulated sample. The marginally significant difference (3.0 σ) between the results for the observations and the simulations can be explained by the systematically smaller area with magnification larger than 3 (by a factor of ~4) in both MOKA and MUSIC mass models relative to those derived from the CLASH data. Accounting for this difference brings the observed and simulated arc statistics into full agreement. We find that the source redshift distribution does not have big impact on the arc abundance but the arc abundance is very sensitive to the concentration of the dark matter halos. Our results suggest that the solution to the "arc statistics problem" lies primarily in matching the cluster dark matter distribution.

Author(s): Bingxiao Xu[2], Marc Postman[3], Massimo Meneghetti[1], Dan A. Coe[3]
Institution(s): *1. Jet Propulsion Laboratory, California Institute of Technology, 2. Johns Hopkins University, 3. Space Telescope Science Institute*
Contributing team(s): CLASH team

418.04D – High Resolution Cluster Pressure Profile Measurements with MUSTANG and Bolocam

Accurate high-resolution intracluster medium (ICM) pressure profiles will help further constrain cosmological parameters as well as baryonic physics in the cores of clusters of galaxies. MUSTANG, a 90 GHz bolometer array on the Green Bank Telescope (GBT) is among the highest resolution (9" FWHM) instruments at 90 GHz, and is among the best instruments to observe the ICM given its sensitivity. We present results from a sub-sample of the Cluster Lensing And Supernova with Hubble (CLASH) clusters of galaxies observed with both MUSTANG and Bolocam. Bolocam, a 150 GHz bolometer array on the CSO with 58" FWHM, and MUSTANG data probe different, and highly complementary, angular (size) scales. We jointly fit spherical electron pressure profiles to the two datasets and find that the addition of the high resolution MUSTANG data can considerably improve constraints on the pressure profiles. A major asset of our fitting algorithm is the ability to uniquely fit for contaminants such as point sources, and thus allowing us to determine the signal from the underlying ICM. We compare our best fit profiles to X-ray determined pressure profiles (provided by ACCEPT), where we find good agreement. Finally we investigate the implications of our results and describe ongoing work to extend this analysis to the full set of CLASH clusters viewable by the GBT, and to obtain even better results with the MUSTANG-1.5 camera

Author(s): Charles Romero[5], Brian S. Mason[2], Jack Sayers[1], Alexander Young[4], Simon Dicker[4], Tony Mroczkowski[3], Erik D. Reese[4], Craig L. Sarazin[5], Nicole G. Czakon[1], Mark J. Devlin[4], Phillip Korngut[1]

Institution(s): *1. California Institute of Technology, 2. National Radio Astronomy Observatory, 3. Naval Research Laboratory, 4. University of Pennsylvania, 5. University of Virginia*

418.05 – Star Formation Histories in CLASH Brightest Cluster Galaxies

The CLASH sample of 25 lensing galaxy clusters contains 11 Brightest Cluster Galaxies (BCG) that exhibit significant unobscured (>5 M^{sol} yr^{-1}) star formation activity. The star formation is inferred from UV emission and from evidence for H-alpha filaments as detected in the ACS and WFC3 observations. We use photometry from the 16-band CLASH imaging along with spectra from the SOAR and SDSS telescopes to examine the star formation histories of these galaxies. Using SED fits to synthetic stellar population and nebular emission models, we constrain the burst histories of the two most UV and H-alpha luminous BCGs in our sample, RXJ1532.9+3021 and MACS1931.8-2635. The BCG in both of these clusters have reddening-corrected UV estimates of star formation rates in excess of 100 solar masses per year. We model the timescales and sizes of the starbursts that can account for the photometric and spectroscopic properties in these BCGs and create maps of their stellar properties on scales of ~350 pc. These maps reveal recent bursts occurring in elongated filaments on relatively long (~0.5-1.0 Gyr) timescales. In addition, we constrain the star formation properties of all of the remaining BCGs in the CLASH sample. These results and their implications for BCG formation and evolution will be presented.

Author(s): Kevin Fogarty[1], Marc Postman[4], Megan Donahue[2], John Moustakas[3], Thomas Connor[2]
Institution(s): *1. Johns Hopkins University, 2. Michigan State University, 3. Siena College, 4. Space Telescope Science Institute*
Contributing team(s): CLASH Science Team

418.06D – Environment and Star Formation Activity in Galaxies out to z~3

It has been known for years that the environment of galaxies has a fundamental effect in shaping their properties. We study the effects of environment on the evolution of galaxies out to z~3 for a flux limited sample of galaxies in the COSMOS field, with an emphasis on two different approaches towards the definition of environment: (1) Environment defined based on the
local surface density of galaxies (2) Environment defined based on the major components of the cosmic web; i.e., filaments, clusters and the field. In the first approach, surface density field is estimated using a variety of estimators (the weighted versions of the kNN, adaptive kernel, Voronoi and Delaunay tessellation). Each estimation method is tested with intensive simulations. Using the estimated surface densities assigned to galaxies, we observe a strong environmental dependence in the main properties of galaxies (e.g. rest-frame color, SFR and the fraction of quiescent galaxies), especially at z<1. We later explore the fractional role of stellar mass and environment in quenching the star formation activity in galaxies. In the second approach, we use the Multi-scale Morphology Filter (MMF) algorithm to disentangle the density field into its major components: filaments, clusters and the field. As an example, We apply this method to a sample of narrow-band selected Hα emitters, as well as color-color selected underlying star-forming galaxies for a large scale structure (LSS) at z=0.84 in the HiZELS-COSMOS field. We show that the observed median SFR, stellar mass, sSFR, the mean SFR-Mass relation and its scatter for both Hα emitters and underlying star-forming galaxies do not strongly depend on the cosmic web. However, the fraction of Hα emitters varies with environment and is enhanced in filamentary structures at z~1. We propose mild galaxy-galaxy interactions as the possible physical agent for the elevation of the fraction of Hα star-forming galaxies in filaments. Our results show that filaments are the likely physical environments which are often classed as the "intermediate" densities, and that the cosmic web likely plays a major role in galaxy formation and evolution which has so far been poorly investigated.

Author(s): Behnam Darvish[1], Bahram Mobasher[1]
Institution(s): *1. University of California, Riverside*
Contributing team(s): the COSMOS science team, the HiZELS science team

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419 – Large Scale Structure, Cosmic Distance Scale II

419.01D – The Very Small Scale Clustering of SDSS-II and SDSS-III Galaxies

We measure the angular clustering of galaxies from the Sloan Digital Sky Survey Data Release 7 in order to probe the spatial distribution of satellite galaxies within their dark matter halos. Specifically, we measure the angular correlation function on very small scales (7 − 320′′) in a range of luminosity threshold samples (absolute r-band magnitudes of -18 up to -21) that are constructed from the subset of SDSS that has been spectroscopically observed more than once (the so-called plate overlap region). We choose to measure angular clustering in this reduced survey footprint in order to minimize the effects of fiber collision incompleteness, which are otherwise substantial on these small scales. We model our clustering measurements using a fully numerical halo model that populates dark matter halos in N-body simulations to create realistic mock galaxy catalogs. The model has free parameters that specify both the number and spatial distribution of galaxies within their host halos. We adopt a flexible density profile for the spatial distribution of satellite galaxies that is similar to the dark matter Navarro-Frenk-White (NFW) profile, except that the inner slope is allowed to vary. We find that the angular clustering of our most luminous samples (Mr < -20 and -21) suggests that luminous satellite galaxies have substantially steeper inner density profiles than NFW. Lower luminosity samples are less constraining, however, and are consistent with satellite galaxies having shallow density profiles. Our results confirm the findings of Watson et al. (2012) while using different clustering measurements and modeling methodology. With the new SDSS-III Baryon Oscillation Spectroscopic Survey (BOSS; Dawson et al., 2013), we can measure how the same class of galaxy evolves over time. The BOSS CMASS sample is of roughly constant stellar mass and number density out to z ~ 0.6. The clustering of these samples appears to evolve very little with redshift, and each of the samples exhibit flattening of wp at roughly the same comoving distance of 100kpc.

Author(s): Jennifer Piscionere[1]
Institution(s): *1. Vanderbilt University*

419.02 – A Geometric Distance to the Megamaser Galaxy NGC 5765b by the Megamaser Cosmology Project

The Megamaser Cosmology Project (MCP) aims to determine the Hubble constant by measuring geometric distances to galaxies in the Hubble flow. Our measurements are based on observations of 22 GHz water vapor megamasers in the circumnuclear accretion disks of active galaxies.

As a continuous effort for the MCP, here we present the distance measurement to the megamaser galaxy NGC 5765b. Recent VLBI observations have confirmed that the water masers trace a thin, sub-parsec Keplerian disk in the nucleus, implying a central binding mass of ~ $4.5x10^7M^{\Theta}$. With single dish monitoring of the maser spectra over the past two years, we measured the secular drift of masers near the systemic velocity of the galaxy. The drift rates fall in the range of 0.5 to 1.2 km s^{-1} yr^{-1}. Fitting a warped, thin disk model to these measurements through Bayesian technique, we determine an angular-diameter distance to NGC 5765b of 121.65 Mpc and the H^0 of 68.5 km s^{-1} Mpc^{-1}, with ~ 7% uncertainty. This is by far the best distance measurement case beyond 100Mpc by using the maser technique. It also demonstrate the potential of reaching higher accuracy for measuring H^0 with the same technique, if more similar systems could be found in the future.

Author(s): Feng Gao[5], James A. Braatz[4], Mark J. Reid[2], Fred K.Y. Lo[4], James J. Condon[4], Christian Henkel[3], Cheng-Yu Kuo[1], Caterina Impellizzeri[4], Dom Pesce[6], Wei Zhao[5]
Institution(s): *1. Academia Sinica Institute of Astronomy and Astrophysics, 2. Harvard-Smithsonian Center for Astrophysics, 3. Max-Planck Institut fur Radioastronomie, 4. NRAO, 5. Shanghai Astronomical Observatory, 6. University of Virnigia*

419.03D – Modeling Large Scale Structure from Photometric Galaxy Surveys

We present our measurements and analysis for the systematic tests, the galaxy two-point angular correlation function, and the best halo-occupation distribution (HOD) model fit for galaxies and compact galaxy groups selected from the seventh data release of the Sloan Digital Sky Survey. We update the flag criteria to select a clean galaxy catalog and detail specific tests that we perform to characterize systematic effects, including the effects of seeing, Galactic extinction, stellar contamination, and the overall survey uniformity. We then measure the correlation function for the full sample as well as for the four magnitude bins. We find that the systematic signals are well below the galaxy angular correlation function for angles less than approximately \$5^\circ\$, which limits the modeling of galaxy angular correlations on larger scales. We then analyze the clustering of photometrically selected galaxy pairs by using the HOD model. We measure the two-point auto-correlation functions, \$\omega(\theta)\$, for galaxies and galaxy pairs and develop an HOD to model their clustering in dark matter halos. Our results are successfully fit by these HOD models, and we see the separation of "1-halo" and "2-halo" clustering terms for both single galaxies and galaxy pairs. With the information that we obtain from the best fit of HOD model, we can further put constrains on the current cosmology model and improve our understanding of galaxy clustering and formation.

Author(s): Yiran Wang[1], Robert Brunner[1]
Institution(s): *1. University of Illinois at Urbana-Champaign*

419.04 – Comparing the 2MTF and 6dFGS Peculiar Velocity Surveys to models from redshift surveys

The 6dF Galaxy Survey (6dFGS) and 2MASS Tully-Fisher Survey (2MTF) are large galaxy peculiar velocity surveys of the local universe, providing distances and peculiar velocities for thousands of galaxies, derived via the Fundamental Plane and Tully-Fisher relations respectively. We compare these observed velocity fields to reconstructed peculiar velocity field models derived from redshift surveys such as the 2MASS Redshift Survey (2MRS) and the IRAS Point Source Redshift Survey (PSCz), addressing the question of whether the galaxy distribution traces the matter distribution, and whether the observed velocity fields include a "residual bulk flow" not predicted by the models. This research was conducted by the Australian Research Council Centre of Excellence for All-sky Astrophysics (CAASTRO), through project number CE110001020.

Author(s): Christopher M. Springob[3], Tao Hong[5], Christina Magoulas[11], Matthew Colless[8], Lister Staveley-Smith[3], Pirin Erdogdu[1], D. Heath Jones[4], John R. Lucey[10], Karen Masters[12], Jeremy R. Mould[6], Tom Jarrett[9], Baerbel Koribalski[2], Lucas M. Macri[7], Morag Scrimgeour[13]
Institution(s): *1. Australian College of Kuwait, 2. CASS / ATNF, 3. ICRAR / University of Western Australia, 4. Monash University, 5. NAOC, 6. Swinburne University, 7. Texas A&M University, 8. The Australian National University, 9. University of Cape Town, 10. University of Durham, 11. University of Melbourne, 12. University of Portsmouth, 13. University of Waterloo*

419.05D – The Evolution of Baryons in Cosmic Large Scale Structure

The environments of galaxies play a critical role in their formation and evolution. We study these environments using cosmological simulations with star formation and supernova feedback included. From these simulations, we parse the large scale structure into clusters, filaments and voids using a segmentation algorithm adapted from medical imaging. We trace the star formation history, gas phase and metal evolution of the baryons in the intergalactic medium as function of structure. We find that our algorithm reproduces the baryon fraction in the intracluster medium and that the majority of star formation occurs in cold, dense filaments. We present the consequences this large scale environment has for galactic halos and galaxy evolution.

Author(s): Ali Snedden[1], Lara Arielle Phillips[1], Grant James Mathews[1], Jared Coughlin[1], In-Saeng Suh[1], Aparna Bhattacharya[1]
Institution(s): *1. University of Notre Dame*

419.06 – Accurate Modeling of Galaxy Clustering on Small Scales: Testing the Standard ΛCDM + Halo Model

The large-scale distribution of galaxies can be explained fairly simply by assuming (i) a cosmological model, which determines the dark matter halo distribution, and (ii) a simple connection between galaxies and the halos they inhabit. This conceptually simple framework, called the halo model, has been remarkably successful at reproducing the clustering of galaxies on all scales, as observed in various galaxy redshift surveys. However, none of these previous studies have carefully modeled the systematics and thus truly tested the halo model in a statistically rigorous sense. We present a new accurate and fully numerical halo model framework and test it against clustering measurements from two luminosity samples of galaxies drawn from the SDSS DR7. We show that the simple ΛCDM cosmology + halo model is not able to simultaneously reproduce the galaxy projected correlation function and the group multiplicity function. In particular, the more luminous sample shows significant tension with theory. We discuss the implications of our findings and how this work paves the way for constraining galaxy formation by accurate simultaneous modeling of multiple galaxy clustering statistics.

Author(s): Manodeep Sinha[3], Andreas A. Berlind[3], Cameron McBride[1], Roman Scoccimarro[2]
Institution(s): *1. CfA, 2. NYU, 3. Vanderbilt University*

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420 – Extrasolar Planets: Binarity, Multiplicity and Moons

420.01D – Detailed Chemical Abundances of Planet-Hosting Wide Binary Systems

We present a detailed chemical abundance analysis of planet-hosting wide binary systems. Each of these binary systems consists of two stars with similar spectral types (ranging from G2V - K2V), and in each system, at least one star hosts a giant planet with an orbital pericenter ~< 0.5 AU. We investigate if giant planets on such orbits could have scattered inner rocky planets into the atmospheres of their host stars, and thereby imprint a detectable chemical signature in the stellar photospheric abundances. Using high-resolution, high signal-to-noise echelle spectra, we derive the chemical abundances ([X/H]) of 15 elements covering a range of condensation temperatures (Tc). For stars in our sample with approximately solar metallicity, the refractory elements (Tc > 900 K) show a positive correlation between [X/H] and Tc. However, for stars with super-solar metallicities, the refractory elements show a negative correlation between [X/H] and Tc. We interpret these results in the context of numerical simulations of giant planet migration that predict the accretion of hydrogen-depleted rocky material by the host star. We demonstrate that a simple model for a solar-metallicity star accreting material with Earth-like composition predicts a positive correlation between [X/H] and Tc, while for a supersolar-metallicity star the model predicts a negative correlation. The stark contrast between the predicted correlations for solar-metallicity and supersolar-metallicity stars may indicate that extracting any chemical signature of rocky planetary accretion is particularly challenging for very metal-rich stars.

Author(s): Claude E. Mack[3], Simon C. Schuler[2], Keivan Stassun[3], Joshua Pepper[1]
Institution(s): *1. Lehigh University, 2. University of Tampa, 3. Vanderbilt University*

420.02 – The Occurrence of Compact Multiple Exoplanetary Systems Orbiting Mid-M Dwarf Stars

We present recent results from an investigation into the occurrence of compact multiple exoplanetary systems orbiting mid-M dwarf stars. We used data and transiting-planet detections from the primary Kepler Mission, combining the Kepler-42 system with two newly confirmed systems as a detected sample. We isolated all mid-M dwarf stars observed for at least one full quarter by the Kepler primary mission that do not have detected transiting planets, and simulated compact multiple systems orbiting those stars. To recover the three confirmed systems, we calculated that between one-fifth and one-quarter of mid-M dwarf stars must host compact multiple exoplanetary systems, regardless of the host star's metallicity. The results suggest that rocky planet formation is efficient in mid-M dwarf protoplanetary disks and that NASA's current K2-mission and future TESS Mission may discover many similar systems in the coming years.

Author(s): Philip Steven Muirhead[2], Andrew W Mann[6], Andrew Vanderburg[4], Timothy D Morton[5], Adam L. Kraus[6], Michael J Ireland[1], Jonathan J Swift[3], Gregory A. Feiden[8], Eric Gaidos[7], J. Zachary Gazak[7]
Institution(s): *1. Australian National University, 2. Boston University, 3. California Institute of Technology, 4. Harvard University, 5. Princeton University, 6. The University of Texas at Austin, 7. University of Hawai'i at Manoa, 8. Uppsala University*

420.03 – Multiplicity of Planets Among the Kepler M Dwarfs

The Kepler data set has furnished more than 130 exoplanetary candidates orbiting M dwarf hosts, nearly half of which reside in multiply transiting systems. I investigate the proposition of self-similarity in this sample: whether a single stellar system architecture explains the multi-planet yield of Kepler. In fact, the data much prefer a model with two distinct modes of planet formation around M dwarfs, which occur in roughly equal measure. One mode is one very similar to the Solar System in terms of multiplicity and coplanarity, and the other is very dissimilar. I investigate astrophysical explanations for this feature of Kepler's multiple planet population orbiting small stars, and discuss the relative unlikelihood of selection bias or unusually high false positive rates as an explanation. I discuss whether stellar properties are predictive of one architecture over the other. By folding in recent analyses about planet multiplicity versus eccentricity, I conclude with a description of how this two-mode model informs both our understanding of planet formation and our search for habitable worlds.

Author(s): Sarah Ballard[2], John Johnson[1]
Institution(s): *1. Harvard University, 2. University of Washington*

420.05 – Friends of hot Jupiters II: No correspondence between hot Jupiter spin-orbit misalignment and the incidence of directly imaged stellar companions

A large fraction of nearby solar-like stars are found in multi-star systems. We currently know very little about the effects that a stellar companion might have on planet formation and evolution in these systems. It has been suggested that such companions might hinder planet formation by dynamically exciting or truncating the protoplanetary disk, or by causing the planets to migrate from their formation locations. We present results from a survey focused on a class of short-period gas giant planets known as hot Jupiters, which must have formed beyond their stars' ice lines and then migrated inwards to their present locations. Many of these planets have orbits that are misaligned with respect to their star's spin axis, and it has been suggested that the most likely explanation for this misalignment is dynamical evolution due to an as-yet undetected outer companion. We surveyed a sample of 50 transiting hot Jupiters with NIRC2 AO K-band imaging and found a total of 20 stellar companions around 18 stars. We obtained a second epoch of data for all candidate companions and found that they were all bound companions to the FGK stars hosting the transiting hot Jupiters. This AO survey is part of a larger Keck-based campaign including both long term radial velocity monitoring with HIRES and high resolution infrared spectroscopy with NIRSPEC, which allows us to detect companions over a broad range of mass ratios and orbital semi-major axes. Our AO survey is sensitive to companions with approximate separations between 10 and 1000 AU. In this regime, we find that companion stars are more common around close-in transiting gas giant planetary hosts than field stars. However, we find no connection between misaligned planet hosts and stellar multiplicity.

Author(s): Henry Ngo[2], Heather A. Knutson[2], Sasha Hinkley[5], Justin R. Crepp[7], Eric B. Bechter[7], Konstantin Batygin[2], Andrew W. Howard[6], John A. Johnson[3], Timothy D. Morton[4], Philip Steven Muirhead[1]
Institution(s): *1. Boston University, 2. California Institute of Technology, 3. Harvard University, 4. Princeton University, 5. University of Exeter, 6. University of Hawaii, 7. University of Notre Dame*

420.06 – Constraints on planet formation from Kepler's multiple planet systems

The recent haul of hundreds of multiple planet systems discovered by Kepler provides a treasure trove of new clues for planet formation theories. The substantial amount of protoplanetary disk mass needed to form the most commonly observed multi-planet systems – small (Earth-sized to mini-Neptune-sized) planets close to their stars – argues against pure in situ formation and suggests that the planets in these systems must have undergone some form of migration. I will present results from numerical simulations of terrestrial planet formation that aim to reproduce the sizes and architecture of Kepler's multi-planet systems, and will discuss the observed resonances and giant planets (or the lack thereof) associated with these systems.

Author(s): Elisa V. Quintana[1]
Institution(s): *1. NASA Ames Research Center*

420.08 – The Hunt for Exomoons with Kepler (HEK) Project: A Survey of 40 New Planetary Candidates for Moons

The Hunt for Exomoons with Kepler (HEK) project has been searching through archival Kepler data for the past two years for evidence of exomoons orbiting transiting planets. Using a Bayesian multimodal nested sampling search algorithm coupled to a photodynamical light curve model, we conduct an exhaustive search of each planetary candidate for both the photometric and dynamical signals of exomoons, and provide exclusion limits in cases of null detections. The primary objective of our survey is to determine the occurrence rate of exomoons around viable planet hosts, eta-sub-moon. To date, we have published null-results for 17 planetary candidates and we achieve a sensitivity to Pluto-Charon mass ratio systems (~10%) for 1 in 3 cases and that of the Earth-Moon (~1%) for 1 in 6.

In this talk, we will present the first results from our latest survey of 40 new planetary candidates. With a sensitivity down to nearly a Ganymede mass in best cases, the results constitute the most sensitive survey for exomoons ever conducted. We discuss the most interesting signals identified in our survey and a preliminary estimate of eta-sub-moon.

Author(s): David M. Kipping[2], Chelsea Huang[3], Guillermo Torres[2], Lars A Buchhave[2], David Nesvorny[4], Gaspar Bakos[3], Joel Hartman[3], Allan Schmitt[1]
Institution(s): *1. Citizen Scientist, 2. Harvard-Smithsonian Center for Astrophysics, 3. Princeton University, 4. Southwest Research Institute*

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421 – Optical and Radio Pulsars

421.01 – Discovery of Optical Circular Polarization of the Crab Pulsar

Nearly 50 years ago at the Lick 3-m Shane telescope, Wampler et al. (1969) discovered optical linear depolarization of the Crab pulsar's main pulse and interpulse regions, which led to the interpretation of synchrotron radiation as the source of pulsed emission. We present phase-resolved, simultaneous linear and circular polarization of the Crab pulsar using the POLISH2 aperture-integrated, optical polarimeter at the Lick 3-m telescope. The two photoelastic modulators in this instrument, used instead of waveplates, AC couple incident Stokes Q, U, and V to unique, independent frequencies between 10 and 200 kHz. Stokes I is measured from the time-averaged intensity of the beam. Thus, this instrument is capable of simultaneous measurement of Q/I, U/I, and V/I in 20 microsecond temporal bins with part-per-million nightly sensitivity on naked eye stars. From just one hour of observations, we confirm linear depolarization of the main pulse and interpulse regions, and we also discover significant optical circular polarization at all pulsar phases. Furthermore, we observe circular depolarization of the main pulse and interpulse regions with respect to the off-pulse region. Observations of strongly polarized calibration stars, as well as lamp observations with a linear polarizer inserted upstream of the modulators, demonstrate that circular polarization results obtained on the Crab pulsar are not due to spurious, instrumental conversion of linear to circular polarization. Therefore, using novel instrumentation, our observations shed new light on this enigmatic object, and we demonstrate that the Lick 3-m Shane telescope still remains at the cutting edge for optical polarimetry.

Author(s): Sloane Wiktorowicz[3], Enrico Ramirez-Ruiz[3], Rainer M. E. Illing[1], Larissa Nofi[2]
Institution(s): *1. Ball Aerospace and Tech. Corp., 2. Institute for Astronomy, University of Hawaii, 3. University of California, Santa Cruz*

421.02D – One Does Not Simply Model Radio Polarization of Pulsars (and Connect It to Data)

Pulsar emission which we observe is fundamentally tied to the strong magnetic fields encasing the neutron star. Charged particles follow these field lines before emitting curvature radiation. the projected polarization position angles of such radiation are a glimpse directly at the structure of these magnetic field lines. The rotating vector model is the typical formulation for relating polarization position angle sweep (versus pulsar phase) data to the geometry of the pulsar. This model assumed a simple dipole for the magnetic field lines and can be described analytically. The rotating vector model works well for a large number of pulsars but fails mostly for high-energy pulsars. In this talk, I explore data-driven, physically-motivated modifications to the rotating vector model. We begin by numerically calculating polarization with models that include relativistic effects, sweep-back effects, and finite altitude emission and compare model to model. Further by including the effects of orthogonal mode jumps, multiple emission altitudes, open zone growth via y-point lowering, interstellar scattering, and inward-directed emission we show a wide range of departures from the rotating vector model (as seen in the polarization data) can be understood while retaining a geometrical picture. Overall, we take the view of letting the data drive our models and our understanding of the emission mechanism in pulsar

magnetospheres.

Author(s): Helen Craig[1]
Institution(s): *1. Stanford University*

421.03 – Pulsar Observations Using the First Station of the Long Wavelength Array

Radio pulsars have largely been unexplored at frequencies below 100 MHz. However, observations at such frequencies can provide extensive information about pulsars as well as the interstellar medium that their signals propagate through. We have begun to use the first station of the Long Wavelength Array (LWA1) to observe radio pulsars and have detected over 40 pulsars within the 30-88 MHz frequency range. This talk will present initial results from these observations, including preliminary results from a program in which we have monitored 3 millisecond pulsars once every 3 weeks for roughly one year. Construction of the LWA has been supported by the Office of Naval Research under Contract N00014-07-C-0147. Support for operations and continuing development of the LWA1 is provided by the National Science Foundation under grants AST-1139963 and AST-1139974 of the University Radio Observatory program.

Author(s): Kevin Stovall[3], Paul Demorest[1], Paul S. Ray[2], Jayce Dowell[3], Frank Schinzel[3], Gregory B. Taylor[3]
Institution(s): *1. NRAO, 2. NRL, 3. University of New Mexico*

421.04D – Emission and rotational variability in pulsars.

The radio emission process in pulsars is poorly understood. However, pulsar timing is successfully used in extracting exciting science from radio pulsars and their environments. We are now approaching the point where the limits in our understanding of pulsar emission affect the precision of pulsar timing experiments. State-switching and intermittent pulsars both show correlated changes between the shape of the average pulse profile and the spin-down rate (first derivative of the rotational period). The spin-down rate changes have been shown to be related to changes in the torque imparted on the neutron star by magnetospheric currents. A comprehensive understanding of this variability will lead to improved timing models and, therefore, reduced timing residuals. Such advances are vital to the direct detection of gravitational waves and tests of fundamental physics. We have applied new variability detection techniques to various slow and millisecond pulsars, and the results will be presented here.

Author(s): Paul Brook[1]
Institution(s): *1. University of Oxford*

421.05 – Low Frequency Study of Rotating Radio Transients

Rotating Radio Transients are a type of radio emitting pulsar, first discovered in 2006, that, while possessing similar pulse widths and pulse intensities to those of regular pulsars, differ from the pulsars observed thus far due to their exhibiting a variability in the emission of their individual pulses – the pulses of RRATs are only emitted intermittently, and individual pulses are found to be emitted on timescales ranging from a few seconds up to a few hours apart. The origin of this transient nature has yet to be determined and some suggest that pulsars may not simply shut off when they near the point that they can no longer emit, but might pulse erratically and exhibit transient behavior, making them RRATs. Alternate theories posit that the RRAT transient behavior is a geometric effect and RRATs may be fundamentally similar to nulling pulsars. Additionally, interactions with a debris field may temporarily reactivate a pulsar causing it to become a RRAT.

There are nearly 100 known RRATs, and it has been predicted that the number of RRATs detected in surveys may only be a small percentage of the actual number that are present in the regions studied in those surveys. If the nature of RRATs is fundamentally similar to those of regular or nulling pulsars, the total number of radio emitting pulsars may be higher than previously predicted, and RRATs may play an important role in in our understanding of the emission mechanism of pulsars and the supernova rate of our galaxy.

We present preliminary results from a survey of RRATs at 30 – 80 MHz undertaken with the first station of the Long Wavelength Array (LWA1). To date very little is known about the properties of RRATs at these low frequencies. Our study aims to determine a variety of the as yet unknown properties of RRATs, such as their pulse shapes, spectral flux densities, and spectral indices. Additional benefits will be finding more accurate values for the dispersion measures and finding timing solutions for newly discovered RRATs. Such information may help place constraints on the theories for the emission mechanisms for the RRAT transient behavior, thereby illuminating their origin and their relation to both regular and nulling pulsars.

Author(s): Michael McCrackan[1], Rossina B. Miller[2], Kevin Stovall[1], Maura McLaughlin[2], Gregory B. Taylor[1]
Institution(s): *1. University of New Mexico, 2. West Virginia University*

421.06 – Observing Rats, Giants, and Ghosts below 100 MHz with the LWA

We will present results from a survey of Rotating Radio Transients (RRATs) being carried out with the first station of the Long Wavelength Array (LWA1). While they have similar pulse widths, periods and intensities as regular pulsars, RRATs pulse only intermittently on time-scales from seconds to hours. Little is known about their low frequency behavior which could be important in understanding them as low frequencies may be sensitive to both emission mechanisms and propagation effects.
We will also present results from a survey of Giant Pulses from the Crab pulsar. We have detected over 2000 giant pulses between 20-84 MHz over the course of a year and will present an analysis of the properties of these pulses and how they change with time. Preliminary results suggest a significant rise in the rate of pulses over the course of our study.
Lastly we will discuss searches for transients with the LWA1, including some dispersed pulses of unknown origin ("ghosts") that we have detected. We will also highlight prospects for further discovery using additional LWA stations now coming on-line, or under construction.
Construction of the LWA has been supported by the Office of Naval Research under Contract N00014-07-C-0147 and by the Air Force Office of Scientific Research DURIP program. Support for operations and continuing development of the LWA1 is provided by the National Science Foundation under grants AST-1139963 and AST-1139974 of the University Radio Observatory program.

Author(s): Gregory B. Taylor[1], Michael J. McCracken[1], Tarraneh Eftekhari[1], Kenneth Obenberger[1], Jayce Dowell[1], Kevin Stovall[1]
Institution(s): *1. Univ. of New Mexico*

422 – Catalogs/Surveys/Computation - High Energy, Large Data, and Classification

422.01 – New constraints on the 2-10 keV X-ray luminosity function from the Chandra COSMOS Legacy Survey

In this talk, we present new results on number counts and luminosity function in the 0.5-2 and 2-10 keV bands, obtained in the Chandra COSMOS Legacy Survey. The COSMOS field is the largest (2 deg^2) field with a complete coverage at any wavelength, and the Chandra COSMOS-Legacy survey uniformly covers the 1.7 deg^2 COSMOS/HST field to ~160 ksec depth, with a total of 2.8 Ms exposure time. This triples the area of the earlier deep C-COSMOS survey (limiting flux ~3e-16 ergs/cm^2/s in the 0.5-2 keV band), and together these two projects cover a total area of 2.2 deg^2, yielding a sample of ~4100 X-ray sources, ~2300 of which have been detected in the new observations. We describe how the survey improves our knowledge in the galaxy-super massive black hole co-evolution.

Author(s): Stefano Marchesi[3], Francesca M. Civano[3], Martin Elvis[2], C. Megan Urry[3], Andrea Comastri[1]
Institution(s): *1. INAF-OABO, 2. SAO - Smithsonian Astrophysical Observatory, 3. Yale University*
Contributing team(s): the Chandra COSMOS Legacy Team

422.02 – The Fermi Large Area Telescope Thrid Gamma-ray Source Catalog

We present an overview of the third Fermi Large Area Telescope source catalog (3FGL) of sources in the 100 MeV - 300 GeV range. Based on the first four years of science data from the Fermi Gamma-ray Space Telescope mission, it is the deepest yet in this energy range. Relative to the 2FGL catalog (Nolan et al. 2012, ApJS 199, 31), the 3FGL catalog incorporates twice as much data as well as a number of analysis improvements, including improved calibrations at the event reconstruction level, an updated model for Galactic diffuse gamma-ray emission, a refined procedure for source detection, and improved methods for associating LAT sources with potential counterparts at other wavelengths. The 3FGL catalog includes 3033 sources, with source location regions, spectral properties, and monthly light curves for each. For approximately one-third of the sources we have not found counterparts at other wavelengths. More than 1100 of the identified or associated sources are active galaxies of the blazar class; several other classes of non-blazar active galaxies are also represented in the 3FGL. Pulsars represent the largest Galactic source class. From source counts of Galactic sources we estimate the contribution of unresolved sources to the Galactic diffuse emission.

Author(s): Thomas E. Stephens[2], Jean Ballet[3], Toby Burnett[5], Elisabetta Cavazzuti[1], Seth William Digel[4]
Institution(s): *1. Agenzia Spaziale Italiana Science Data Center, 2. Brigham Young University, 3. Laboratoire AIM, Saclay, 4. SLAC National Accelerator Laboratory, 5. University of Washington*
Contributing team(s): Fermi LAT Collaboration

422.03 – A Catalog of Fermi-LAT Sources Detected above 50 GeV

The Fermi Large Area Telescope (LAT) has been routinely gathering science data since August 2008, surveying the full sky every three hours. The first Fermi-LAT catalog of sources detected above 10 GeV (1FHL) relied on three years of data to characterize the >10 GeV sky. The improved acceptance and point-spread function of the new Pass 8 event reconstruction and classification together with six years of observations now available allow the detection and characterization of sources directly above 50 GeV. This closes the gap between ground-based Cherenkov telescopes, which have excellent sensitivity but small fields of view and duty cycles, and all-sky observations at GeV energies from orbit. In this contribution we will present the resulting catalog and discuss the properties of the Galactic and extragalactic source populations.

Author(s): Alberto Dominguez[2], Marco Ajello[2], Dario Gasparrini[1], Sara Cutini[1]
Institution(s): *1. ASI Science Data Center, 2. Clemson University*
Contributing team(s): on behalf of the Fermi-LAT collaboration

422.04D – Managing Astronomy Research Data: Case Studies of Big and Small Research Projects

Astronomy data management refers to all actions taken upon data over the course of the entire research process. It includes activities involving the collection, organization, analysis, release, storage, archiving, preservation, and curation of research data. Astronomers have cultivated data management tools, infrastructures, and local practices to ensure the use and future reuse of their data. However, new sky surveys will soon amass petabytes of data requiring new data management strategies.
The goal of this dissertation, to be completed in 2015, is to identify and understand data management practices and the infrastructure and expertise required to support best practices. This will benefit the astronomy community in efforts toward an integrated scholarly communication framework.
This dissertation employs qualitative, social science research methods (including interviews, observations, and document analysis) to conduct case studies of data management practices, covering the entire data lifecycle, amongst three populations: Sloan Digital Sky Survey (SDSS) collaboration team members; Individual and small-group users of SDSS data; and Large Synoptic Survey Telescope (LSST) collaboration team members. I have been observing the collection, release, and archiving of data by the SDSS collaboration, the data practices of individuals and small groups using SDSS data in journal articles, and the LSST collaboration’s planning and building of infrastructure to produce data.
Preliminary results demonstrate that current data management practices in astronomy are complex, situational, and heterogeneous. Astronomers often have different management repertoires for working on sky surveys and for their own data collections, varying their data practices as they move between projects. The multitude of practices complicates coordinated efforts to maintain data.
While astronomy expertise proves critical to managing astronomy data in the short, medium, and long term, the larger astronomy data workforce encompasses a greater breadth of educational backgrounds. Results show that teams of individuals with distinct expertise are key to ensuring the long-term preservation and usability of astronomy datasets.

Author(s): Ashley E. Sands[1]
Institution(s): *1. UCLA*

422.05 – Effects of the Earth’s atmosphere and human neural processing of light on the apparent colors of stars

The aim of this study is to develop a mathematical algorithm for quantifying the perceived colors of stars as viewed from the surface of the Earth across a wide range of possible atmospheric conditions. These results are then used to generate color-corrected stellar images. As a first step, optics corrections are calculated to adjust for the CCD bias and the transmission curves of any filters used during image collection. Next, corrections for atmospheric scattering and absorption are determined for the atmospheric conditions during imaging by utilizing the Simple Model of the Atmospheric Radiative Transfer of Sunshine (SMARTS). These two sets of corrections are then applied to a series of reference spectra, which are then weighted against the CIE 1931 XYZ color matching functions before being mapped onto the sRGB color space, in order to determine a series of reference colors against which the original image will be compared. Each pixel of the image is then re-colored based upon its closest corresponding reference spectrum so that the final image output closely matches, in color, what would be seen by the human eye above the Earth's atmosphere. By comparing against the reference spectrum, the stellar classification for each star in the image can also be determined. An observational experiment is underway to test the accuracy of these calculations.

Author(s): Michael Savino[1], Neil Francis Comins[1]
Institution(s): *1. University of Maine*

422.06 – Fast and accurate probability density estimation in large high dimensional astronomical datasets

Astronomical surveys will generate measurements of hundreds of attributes (e.g. color, size, shape) on hundreds of millions of sources. Analyzing these large, high dimensional data sets will require efficient algorithms for data analysis. An example of this is probability density estimation that is at the heart of many classification problems such as the separation of stars and quasars based on their colors. Popular density estimation techniques use binning or kernel density estimation. Kernel density estimation has a small memory footprint but often requires large computational resources. Binning has small computational requirements but usually binning is implemented with multi-dimensional arrays which leads to memory requirements which scale exponentially with the number of dimensions. Hence both techniques do not scale well to large data sets in high dimensions. We present an alternative approach of binning implemented with hash tables (BASH tables). This approach uses the sparseness of data in the high dimensional space to ensure that the memory requirements are small. However hashing requires some extra computation so a priori it is not clear if the reduction in memory requirements will lead to increased computational requirements. Through an implementation of BASH tables in C++ we show that the additional computational requirements of hashing are negligible. Hence this approach has small memory and computational requirements. We apply our density estimation technique to photometric selection of quasars using non-parametric Bayesian classification and show that the accuracy of the classification is same as the accuracy of earlier approaches. Since the BASH table approach is one to three orders of magnitude faster than the earlier approaches it may be useful in various other applications of density estimation in astrostatistics.

Author(s): Pramod Gupta[1], Andrew J. Connolly[1], Jeffrey P. Gardner[1]
Institution(s): *1. Department of Astronomy, University of Washington*

422.07 – FERRE: A Code for Spectroscopic Analysis

FERRE is a data analysis code written in FORTRAN90. It matches models to data, taking a set of observations and identifying the model parameters that best reproduce the data, in a chi-squared sense. Model predictions are to be given as an array whose values are a function of the model parameters, i.e. numerically. FERRE holds this array in memory, or in a direct-access binary file, and interpolates in it to evaluate model predictions. The code returns, in addition to the optimal set of parameters, their uncertainties, covariances, and the corresponding model prediction. The code is used at the core of the APOGEE Stellar Parameters and Chemical Abundances Pipeline, and it is now publicly available.

Author(s): Carlos Allende-Prieto[1]
Institution(s): *1. Instituto de Astrofisica de Canarias*
Contributing team(s): APOGEE Team

422.08 – Bayesian Model Selection in 'Big Data' Spectral Analysis

As IFU observations and large spectral surveys continue to become more prevalent, the handling of thousands of spectra has become common place. Astronomers look at objects with increasingly complex emission-line structures, so establishing a method that will easily allow for multiple-component analysis of these features in an automated fashion would be of great use to the community. Already used in exoplanet detection and interferometric image reconstruction, we present a new application of Bayesian model selection in `big data' spectral analysis. With this technique, the fitting of multiple emission-line components in an automated fashion while simultaneously determining the correct number of components in each spectrum streamlines the line measurements for a large number of spectra into a single process.

Author(s): Travis C. Fischer[1], D. Michael Crenshaw[1], Fabien Baron[1], Brian K. Kloppenborg[1], Crystal L Pope[1]
Institution(s): *1. Georgia State University*

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423 – Extrasolar Planets: Imaging and Detection Strategies

423.01D – Searching For Planets in "Holey Debris Disks"

Directly imaging planets provides a unique opportunity to study young planets in the context of their formation and evolution. It examines the underlying semi-major axis exoplanet distribution and enables the characterization of the planet itself with spectroscopic examination of its emergent flux. However, only a handful of planets have been directly imaged, and thus the stars best suited for planet imaging are still a subject of debate. The "Holey Debris Disk" project was created in order to help determine if debris disks with gaps are signposts for planets. These gaps may be dynamically caused by planets accreting the debris material as they form. We present the results from our survey with VLT/NACO and the apodized phase plate coronagraph. We demonstrate that these disks with holes are good targets for directly detecting planets with the discovery of a planet around two of our targets, HD 95086 and HD 106906, at L'-band. Our non-detection of HD 95086 b in H-band demonstrates the importance of thermal infrared observations. The detected planets shepherd the outer cool debris belt. The relatively dust-free gap in these disks implies the presence of one or more closer-in planets. We discuss our new constraints on planets around other targets in our survey as well as disk properties of these targets and describe how future instruments will find the inner planets.

Author(s): Tiffany Meshkat[1], Vanessa P. Bailey[2], Kate Y.L. Su[2], Matthew A. Kenworthy[1], Eric E. Mamajek[3], Philip Hinz[2], Paul S. Smith[2]
Institution(s): *1. Leiden University, 2. University of Arizona, 3. University of Rochester*

423.02D – Exploring Planetary System Evolution Through High-Contrast Imaging

Direct imaging of circumstellar disks provides unique information about planetary system construction and evolution. Several hundred nearby main-sequence stars are known to host debris disks, which are produced by mutual collisions of orbiting planetesimals during a phase thought to coincide with terrestrial planet formation. Therefore, detection of the dust in such systems through scattered near-infrared starlight offers a view of the circumstellar environment during the epoch of planet assembly. We have used ground-based coronagraphic angular differential imaging (ADI) with Keck NIRC2 and Gemini Planet Imager (GPI) to investigate disk structures that may act as signposts of planets. ADI and its associated image processing algorithms (e.g., LOCI) are powerful tools for suppressing the stellar PSF and quasistatic speckles that can contaminate disk signal. However, ADI PSF-subtraction also attenuates disk surface brightness in a spatially- and parameter-dependent manner, thereby biasing photometry and compromising inferences regarding the physical processes responsible for the dust distribution. To account for this disk "self-subtraction," we developed a novel technique to forward model the disk structure and compute a self-subtraction map for a given ADI-processed image. Applying this method to NIRC2 near-IR imaging of the HD 32297 debris disk, we combined the high signal-to-noise ratio (S/N) of ADI data with unbiased photometry to measure midplane curvature in the edge-on disk and a break in the disk's radial brightness profile. Such a break may indicate the location of a planetesimal ring that is a source of the light-scattering micron-sized grains. For the HD 61005 debris disk, we examined similar data together with GPI 1.6-micron polarization data and detected the dust ring's swept-back morphology, brightness asymmetry, stellocentric offset, and inner clearing. To study the physical mechanism behind these features, we explored how eccentricity and mutual inclination affect disk morphology by constructing self-subtracted scattered-light models (using our forward-modeling technique) and comparing them with complementary NIRC2 (several-arcsecond scales) and GPI (high S/N close to the star) observations.

Author(s): Thomas Esposito[3], Michael P. Fitzgerald[3], Paul Kalas[2], James R. Graham[2], Max Millar-Blanchaer[1]
Institution(s): *1. U. Toronto, 2. UC, Berkeley, 3. UCLA*
Contributing team(s): GPIES team

423.03 – The Gemini Planet Imager

The Gemini Planet Imager (GPI) is a dedicated facility for directly imaging and spectroscopically characterizing extrasolar planets. It combines a very high-order adaptive optics system, a diffraction-suppressing coronagraph, and an integral field spectrograph with low spectral resolution but high spatial resolution. Every aspect of GPI has been tuned for maximum sensitivity to faint planets near bright stars. GPI has undergone a year of commissioning, verification, and calibration work. We have achieved an estimated *H*-band contrast (5-sigma) of 10^6 at 0.75 arcseconds and 10^5 at 0.35 arcseconds in spectral mode, and suppression of unpolarized starlight by a factor of 800 in imaging polarimetry mode. Early science observations include study of the spectra of β Pic b and HR 8799, orbital investigations of β Pic b and PZ Tel, and observations of the debris disk systems associated with β Pic, AU Mic, and HR 4796A. An 890-hour exoplanet survey with GPI is scheduled to begin in late 2014. A status report for the campaign will be presented.

Author(s): James R. Graham[14], Bruce Macintosh[11], Marshall D. Perrin[12], Patrick Ingraham[11], Quinn M. Konopacky[19], Christian Marois[8], Lisa Poyneer[5], Brian Bauman[5], Travis Barman[17], Adam Seth Burrows[9], Andrew Cardwell[4], Jeffrey K. Chilcote[19], Robert John J De Rosa[14], Daren Dillon[16], Rene Doyon[13], Jennifer Dunn[8], Darren Erikson[8], Michael P. Fitzgerald[15], Donald Gavel[16], Stephen J. Goodsell[4], Markus Hartung[4], Pascale Hibon[4], Paul Kalas[14], James E. Larkin[15], Jerome Maire[19], Franck Marchis[10], Mark S. Marley[6], James McBride[14], Max Millar-Blanchaer[19], Kathleen M. Morzinski[17], Eric L. Nielsen[11], Andew Norton[16], Rebecca Oppenheimer[1], David Palmer[5], Jenny Patience[2], Laurent Pueyo[12], Fredrik Rantakyro[4], Naru Sadakuni[4], Leslie Saddlemeyer[8], Dmitry Savransky[3], Andrew W. Serio[4], Remi Soummer[12], Anand Sivaramakrishnan[12], Inseok Song[18], Sandrine Thomas[6], J. Kent Wallace[7], Jason Wang[14], Sloane Wiktorowicz[16], Schulyer Wolff[12]
Institution(s): *1. AMNH, 2. Arizona State, 3. Cornell, 4. Gemini Observatory, 5. LLNL, 6. NASA/Ames, 7. NASA/JPL, 8. NRC, 9. Princeton, 10. SETI Institute, 11. Stanford, 12. STScI, 13. U. Montreal, 14. UC, Berkeley, 15. UCLA, 16. UCSC, 17. University of Arizona, 18. University of Georgia, 19. University of Toronto*
Contributing team(s): GPI/GPIES team

423.04 – Managing the wavefront for exoplanet imaging with a space coronagraph

We update the designs, demonstrations, and science prospects for the direct imaging and spectroscopic characterization of exoplanetary systems with the hybrid Lyot coronagraph. We compare model predictions for exoplanet science performance with the flagship AFTA/WFIRST mission and dedicated smaller-class space observatories. Together with a pair of deformable mirrors for optical wavefront control, the hybrid Lyot coronagraph creates high contrast dark fields of view extending to within angular separations of 2.5 lambda/D from the central star at visible wavelengths. Performance metrics and design trades are presented, including image contrast, spectral bandwidth, overall efficiency and throughput, and model-validating laboratory demonstrations.

Author(s): John T. Trauger[1], Dwight Moody[1], John Krist[1], Brian Gordon[1]

Institution(s): *1. JPL*

423.05 – Data reduction and astrometric calibration of a starshade test using real starlight

Calibration of data obtained during 2011-2013 for a ground-based optically scaled starshade alignment sensing test is discussed. The equipment included a 3.7-cm starshade-occulter in front of a coelostat at separations of up to 90-metres from a small telescope. Various stellar and planetary sources were observed. Astrometric reduction of images was challenged by variable horizontal refraction and wavefront distortion during occultations and between images which introduced uncertainty in localizing the occulter. Guider software issues were an additional complication in the reduction process and are discussed. The changing conditions during each observing session necessitate careful tagging of different datasets for appropriate treatment in the reduction pipeline. The techniques for handling the data are described along with astrometric results.

Author(s): Ian J.E. Jordan[2], Paul Henze[4], Webster C. Cash[3], Remi Soummer[1], Michael W. Regan[1]
Institution(s): *1. Association of Universities for Research in Astronomy, 2. Computer Sciences Corporation, 3. University of Colorado, 4. Westminster Astronomical Society*
Contributing team(s): Westminster Astronomical Society, New Worlds

423.06 – Science Yield Modeling for the WFIRST-AFTA Coronagraph

We present detailed mission modeling results for the proposed coronagraph for the Wide-Field Infrared Survey Telescope (WFIRST) design based on the Astrophysics Focused Telescope Assets (AFTA). These incorporate detailed optical models of the latest coronagraph instrument designs, realistic mission constraints based on the planned WFIRST-AFTA orbit and exoplanet science duty cycle, and updated distributions of exoplanetary parameters based on the latest results from Kepler and other ground- and space-based exoplanet surveys. We investigate the potential for discovery and spectral characterization of various planet types in a blind search, as well as when targeting systems with known planets from previous surveys. We also explore the effects of target selection, scheduling, and survey execution rules on the final science yield.

Author(s): Dmitry Savransky[1], Aastha Acharya[1], Bruce Macintosh[3], Neil Gehrels[2]
Institution(s): *1. Cornell University, 2. NASA GSFC, 3. Stanford University*

423.07 – Transiting Planets with LSST: Assessing the Potential for LSST Exoplanet Detection

Over its decade-long run, the Large Scale Synoptic Survey (LSST) will gather several hundred multi-band photometric observations of approximately ten billion stars. We demonstrate that while LSST will have a much lower cadence than most transiting planet surveys, a significant number of transiting planets will yet have sufficient photometric signal for detection. We also show that due to LSST's multiple filters and sensitivity to faint stars, LSST opens the door to detecting planets in stellar populations that have not been thoroughly searched by past surveys, including planets around red dwarfs, in star clusters, and even in the Large Magellanic Cloud. While these regimes will have very limited follow-up possibilities, LSST can provide a statistical picture of exoplanet frequencies in interesting stellar environments.

Author(s): Michael Lund[2], Joshua Pepper[1], Keivan Stassun[2], Savannah Jacklin[3]
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424 – Formal and Informal Education II

424.01 – Partial Restoration of Public Education and Outreach at the Dominion Astrophysical Observatory

Since first light on 6 May 1918, DAO's historic 1.8-m Plaskett Telescope has been open on varying schedules to the public for interactions with astronomers and stargazing. In June 2001 the National Research Council of Canada (NRC) opened the adjacent, purpose-built, *Centre of the Universe* (CU) building. It was staffed by professional informal educators offering year-round outreach that helped visitors, including thousands of students annually, appreciate exciting current research, as well as Canada's high standing in contemporary astronomy, development of complex instrumentation and the associated societal benefits. On 24 August 2013 the CU-based EPO program ceased operation. Upon announcement by NRC in June 2013 of the pending closure, swift public reaction—locally, nationally and internationally—led to widespread publicity, predominantly negative, as well as two petitions signed by several thousand people. A November meeting convened by BC Legislator Lana Popham, in whose electoral district the Observatory is located, brought community leaders together with NRC senior managers to discuss ways of making available the physical assets to restore EPO activities through community organizations, rather than Federal employees, a scenario senior NRC management endorsed. Subsequently a smaller community group chaired by Don Moffatt, a DAO interpreter in the 1990s, provided a forum for discussing paths to having some outreach activities in summer 2014. The resulting two successful activities were: a) Saturday night observing sessions run by the amateur astronomers of the Royal

Astronomical Society of Canada, Victoria Centre; and b) week-long space and astronomy camps for children of grades 3-8 run by the University of Victoria's Science Venture program. As will be described, both organizations delivered well-received programs, and are in conversation with NRC about possible continuation and evolution.

Author(s): James E. Hesser[1]
Institution(s): *1. NRC Herzberg Astronomy and Astrophysics*

424.02 – The Air Force Academy's Falcon Telescope Network: An Educational and Research Network for K-12 and Higher Education

The Falcon Telescope Network (FTN) is a global network of small aperture telescopes developed by the Center for Space Situational Awareness Research in the Department of Physics at the United States Air Force Academy (USAFA). Consisting of commercially available equipment, the FTN is a collaborative effort between USAFA and other educational institutions ranging from two- and four-year colleges to major research universities. USAFA provides the equipment (e.g. telescope, mount, camera, filter wheel, dome, weather station, computers and storage devices) while the educational partners provide the building and infrastructure to support an observatory. The user base includes USAFA along with K-12 and higher education faculty and students. The diversity of the users implies a wide variety of observing interests, and thus the FTN collects images on diverse objects, including satellites, galactic and extragalactic objects, and objects popular for education and public outreach. The raw imagery, all in the public domain, will be accessible to FTN partners and will be archived at USAFA. USAFA cadets use the FTN to continue a tradition of satellite characterization and astronomical research; this tradition is the model used for designing the network to serve undergraduate research needs. Additionally, cadets have led the development of the FTN by investigating observation priority schemes and conducting a "day-in-the-life" study of the FTN in regards to satellite observations. With respect to K-12 outreach, cadets have provided feedback to K-12 students and teachers through evaluation of first-light proposals. In this paper, we present the current status of the network and results from student participation in the project.

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424.03 – World's Most Advanced Planetarium Opens; University Partners Sought

The 40 year old-Fiske Planetarium at the Univ. of Colorado has remodeled as the most advanced planetarium ever built. The 20m diameter dome features a stunning video image 8,000 x 8,000 pixels, up to 60 frames per second, produced by 6 JVC projectors. It also features the first US installation of the Megastar IIa Opto-mechanical planetarium that projects 20 million individual stars and 170 deep sky objects. You can use binoculars indoor and see individual Milky Way stars.

The video projectors have high dynamic range, but not as great as the eye. In order to preserve the remarkable Megastar sky while still using video, each projector shines through a computer controlled variable density filter than extends the dynamic range by about 4 magnitudes. It therefore is possible to show a Mauna Kea quality star field and also beautiful bright videos.

Unlike most planetariums, the #1 audience of Fiske is college students – the more than 2,000 who take Introductory Astronomy at Colorado each year. WE ARE SEEKING OTHER UNIVERSITIES WITH FULL-DOME VIDEO PLANETARIUMS to join us in the production of college-level material. We already have a beautiful production studio funded by Hewlett Packard and an experienced full-time Video Producer for Educational Programs. Please seek out Fiske Director Dr. Doug Duncan if interested in possible collaboration.

Author(s): Douglas K. Duncan[1]
Institution(s): *1. Univ. of Colorado*

424.04 – Einstein's Symphony: A Gravitational Wave Voyage Through Space and Time

Einstein's Symphony: A Gravitational Wave Voyage Through Space and Time is a gravitational wave astronomy planetarium show in production by a collaboration of scientists, filmmakers, and artisits from the Center for Gravitational Wave Astonomy (CGWA) at the University of Texas at Brownsville (UTB) and Montana State University (MSU). The project builds on the success of the interdisciplinary *Celebrating Einstein* collaboration. The artists and scientists who created the *A Shout Across Time* original film and the *Black (W)hole* immersive art installation for *Celebrating Einstein* are teaming with the Museum of the Rockies Taylor Planetarium staff and students to create a new full dome Digistar planetarium show that will be freely and widely distributed to planetaria in the US and abroad. The show uses images and animations filmed and collected for *A Shout Across Time* and for *Black (W)hole* as well as new images and animations and a new soundtrack composed and produced by the MSU School of Music to use the full capability of planetarium sound systems. The planetarium show will be narrated with ideas drawn from the *Celebrating Einstein* danced lecture on gravitational waves that the collaboration produced. The combination of products, resources, and team members assembled for this project allows us to create an original planetarium show for a fraction of the cost of a typical show. In addition, STEM education materials for G6-12 students and teachers will be provided to complement and support the show. This project is supported by the Texas Space Grant Consortium (TSGC), Montana Space Grant Consortium (MSGC), and the American Physical Society (APS).

Author(s): Joey Shapiro Key[2], Nico Yunes[1], Irene Grimberg[1]
Institution(s): *1. Montana State University, 2. University of Texas at Brownsville*

424.05 – The National Astronomy Consortium (NAC) - Overview

The National Astronomy Consortium (NAC; see https://sites.google.com/site/nraonac/) is a growing national partnership between majority and minority universities and institutions with the goal of increasing the numbers of under-represented minorities and students who might otherwise be overlooked by the traditional academic pipeline into STEM, or related, careers. The NAC model is based on the successful "Posse Foundation" model for undergraduate success and incorporates all its major components: pre-training of cohorts to prepare them for the research experience, joint weekly cohort activities throughout the research summer, peer- and multiple mentoring, weekly discussion of various aspects of professional and career development, continued engagement of students in science after return to home institution and lifelong mentoring. The mentors also form a cohort, exchanging information and learning from each other. With its partner institutions, the NAC aims to build a complete pipeline from undergraduate through career for the next generation of scientists and engineers. Our annual goal is to create two to three cohorts of four to five students at each site (currently NRAO-Charlottesville, NRAO-Socorro and U. Wisconsin – Madison). Recruitment occurs in the fall semester with seminars and colloquia in partnership with faculty at the minority serving institutions and the GRAD-MAP program at the University of Maryland. In this talk we describe in detail all the components of the NAC and report on our progress. We are keen to interact and partner with new universities and institutions and encourage them to contact the NAC at nac4stem@googlegroups.com.

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Contributing team(s): The National Astronomy Consortium

424.06 – Mentoring Undergraduate Students through the Space Shuttle *Hitchhiker* GoldHELOX Project

In the late 1980s a team of four BYU undergraduate students designed a space-based telescope to image the sun in soft x-rays from 171-181 Angstroms to gain information on microflares and their relation to the corona-chromosphere transition region. The telescope used a near-normal incidence multi-layered mirror imaging onto film through a micro-channel plate. The system was capable of 1.0 sec time resolution and 2.5 arcsec spatial resolution. Aided by a NASA grant in 1991, a system was built and successfully tested in 1998 at Marshall Space Flight Center. Originally designed to be deployed from a Get-Away-Special (GAS) canister in the bay of a space shuttle, the good results of this test elevated GoldHelox to greater-priority *Hitchhiker* status. Even so technical and procedural difficulties delayed a launch until after 2003. Unfortunately after the Columbia re-entry break-up in February 2003, the *Hitchhiker* program was cancelled and the GoldHelox project ended.

Well over 200 undergraduate students worked on GoldHelox. Many of these have since earned advanced degrees in a variety of technical fields. Several have gone on to work in the space industry, becoming NASA scientists and engineers with one becoming a PI on the *Swift* satellite. The broad range of talent on the team has included students majoring in physics, astronomy, mechanical engineering, electrical engineering, manufacturing engineering, design engineering, business and even English majors who have written technical and public relations documents. We report on lessons learned and the pitfalls and successes of this unique mentoring experience.

Author(s): J. Ward Moody[1], Jonathan Barnes[2], Peter Roming[3], Dallin Durfee[1], Branton Campbell[1], Steve Turley[1], Paul Eastman[1]
Institution(s): *1. Brigham Young Univ., 2. Salt Lake Community College, 3. SwRI*

424.07 – Mentoring Student Scientists

The Hawai'i Student Teacher Astronomical Research (HI STAR) program and the Hawai'i Center for Advancing $ystemic Heliophysics Education (HI CA$HED) programs enable middle school and high school students to undertake genuine scientific research. We have found that even students this young can contribute to the scientific community. We will present an overview of the program, metrics of our success, examples of student research, example student projects, and elements that we believe have contributed to our students' outstanding success.

Author(s): James Armstrong[1], Mary Ann Kadooka[1], Michael A. Nassir[1]
Institution(s): *1. University of Hawaii*

424.08 – Teaching Astronomy with Technology

Students today are expected to have access to computers and the Internet. Students young and old, in school and out of school, are interested in learning about astronomy, and have computers to use for this. Teach Astronomy is a website with a comprehensive digital astronomy textbook freely available to students and educators. In addition to the textbook, there are astronomy Wikipedia articles, image archives from Astronomy Picture of the Day and AstroPix, and video lectures covering all topics of astronomy. Teach Astronomy has a unique search tool called the wikimap that can be used to search through all of the resources on the site. Astronomy: State of the Art (ASOTA) is a massive, open, online course (MOOC). Over 18,000 students have enrolled over the past year and half. This MOOC has been presented in various forms. First, only to students on the web, with content released weekly on host site Udemy. Then to university students who met formally in the classroom for educational activities, but were also expected to watch lectures online on their own time. Presently, it is available online for students to go at their own pace. In the future it will be available in an extended format on a new host site, Coursera. ASOTA instructors use social media to interact with students. Students ask questions via the course host site, Udemy. Live question and answer sessions are conducted using Google Hangouts on Air, and interesting and relevant astronomy news, or supplementary educational content is shared via the ASOTA Facebook page. Teaching on the Internet may seem impersonal and impractical, but by learning to use all of these tools, instructors have the ability to interact with students, and keep them engaged.

Author(s): Carmen Austin[1], Chris David Impey[1], Matthew Wenger[1]
Institution(s): *1. University of Arizona*

424.09 – A New Comprehensive Final Exam

Instructors aspire for students to master all the material covered. The final exam should assess the breadth and depth of their learning and be a significant basis for the final grade. I insist on a comprehensive final because I want students to review early material in light of later topics. I believe that this helps students create connections, integrate understanding, and retain knowledge for the long term. For non-science majors, reviewing and retaining the large amount of astronomy material is daunting. I experimented with a final exam format that calmed their fears and encouraged thorough review. It is only practical for a class of about twenty students or less. I provided a number of challenging conceptual and problem solving questions (at least as many as there were students), crafted to interconnect and span the entire range of topics. The order of the questions reflected the sequence in which the topics had been discussed. Students received these questions in ample time to prepare prior to the final. A student could bring up to 5 standard sheets of notes to the final. At the final, each student picked a number out of a hat. This was the question they had to answer in a 5-minute presentation. They were allowed 15 minutes for a final preparation during which they could use their 5 pages of notes. The presentations were given in order, 1- 20. Written comments on at least 10 other talks, explaining what was missed or correcting a mistake were required. They were graded both on their talk and on their comments. This format required students to be prepared for any question and encouraged interaction and communication while studying. Knowing the questions beforehand provided a guide to their studying as well as allayed their fears about what could be asked. The students also received guidance to what constituted a good answer, namely accuracy (correct scientific argument, appropriate facts, no irrelevant material), thoroughness (answered the complete questions, covered relevant material) and the quality of the presentation (polished, professional, use of demonstrations, graphs, pictures etc. and time appropriately to present a clear answer). I will describe this first attempt.

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425 – Starburst Galaxies II

425.01 – A New Interpretation for the Variation in Starburst Galaxy Emission Line Spectra

Starburst galaxies have been easily distinguished from AGN using diagnostic emission line ratio diagrams constraining their excitation mechanism. Previous modeling of the star forming (SF) galaxy sequence outlined on the BPT diagram has led to the interpretation that high metallicity SF galaxies and low ionization SF galaxies are synonymous. Here, we present a new interpretation. Using a large sample of low-z SDSS galaxies, we co-added similar spectra of pure star forming galaxies allowing many weaker emission lines to act as consistency checks on strong line diagnostics. For the first time, we applied a locally optimally-emitting cloud (LOC) model to understand the physical reason for the variation in starburst galaxy emission line spectra. We fit over twenty diagnostic diagrams constraining the excitation mechanism, SED, temperature, density, metallicity, and grain content, making this work far more constrained than previous studies. Our results indicate that low luminosity SF galaxies could simply have less concentrated regions of ionized gas compared to their high luminosity counterparts, but have similar metallicities, thus requiring reevaluation about underlying nature of star forming galaxies.

Author(s): Chris T. Richardson[2], James T Allen[5], Jack A. Baldwin[3], Paul C Hewett[1], Gary J. Ferland[4], Helen Meskhidze[2]

Institution(s): *1. Cambridge University, 2. Elon University, 3. Michigan State University, 4. University of Kentucky, 5. University of Sydney*

425.02D – Hot galactic winds constrained by the X-ray luminosities of galaxies and cool cloud acceleration and destruction in hot winds

Galactic superwinds may be driven by very hot outflows generated by overlapping supernovae within the host galaxy. We use the Chevalier & Clegg (CC85) wind model and the observed correlation between X-ray luminosities of galaxies and their SFRs to constrain the mass loss rates across a wide range of star formation rates (SFRs), from dwarf starbursts to ultra-luminous infrared galaxies. We show that for fixed thermalization efficiency and mass loading rate, the X-ray luminosity of the hot wind scales as Lx ~ SFR^2, significantly steeper than is observed for star-forming galaxies: Lx ~ SFR. Using this difference we constrain the mass-loading and thermalization efficiency of hot galactic winds. For reasonable values of the thermalization efficiency (<~ 1) and for SFR >~ 10 M_sun/yr, we find that the ratio (\beta) of mass loss rate to SFR is \beta <~1, significantly lower than required by integrated constraints on the efficiency of stellar feedback in galaxies, and potentially too low to explain observations of winds from rapidly star-forming galaxies.

On the other hand, the cool gas clouds with temperatures (Vc) from 100 to 10^4 K seen in emission and absorption may be accelerated by the ram pressure of hot flows. We derive general constraints on this mechanism as a function of both hot wind and cool cloud properties. We find that for clouds with T_c ~ 10^3 K, as might be appropriate for absorption studies of the Na D lines, the timescale for destruction via Kelvin-Helmholz instability is shorter than the acceleration timescale, thus the cloud velocity never reaches that of the hot wind, Vc is limited to ~ 200-300 km/s. Similarly, clouds of molecular gas cannot be accelerated by hot flows to velocities > ~ 100 km/s. Only warm clouds with Tc ~ 10^4 K can be accelerated to high velocities. Therefore we conclude that CC85-like hot winds are unlikely the mechanism in accelerating cool neutral and molecular outflows in most star-forming galaxies, expect for some local dwarf starbursts.

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425.03 – Broadband Spectral Modeling of NGC 253 from Hard X-rays to TeV Gamma Rays

An exciting result from *Fermi* is the detection of star-forming galaxies at GeV energies, but the relative contributions of various radiative processes to the gamma-ray signal remain uncertain. NuSTAR observations of NGC 253 in the hard X-ray band (10–30 keV) enable the most sensitive search to date for diffuse inverse Compton emission in that bandpass, which in turn will constrain the role of hadronic and leptonic interactions in producing the GeV emission. We present the latest results from detailed broadband spectral modeling of the nearby starburst galaxy NGC 253 from keV to TeV energies in light of new observations from NuSTAR.

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425.05 – X-raying metal-poor starburst galaxies: Evidence of an overabundance of luminous X-ray binaries

We have studied the high mass X-ray binary (HMXB) populations within two low-metallicity, starburst galaxies, Haro 11 and VV 114. These galaxies are particularly interesting because they are good analogs of high-redshift ($z > 2$) Lyman break galaxies, and are part of a larger sample of Lyman break analogs (LBAs). Previous studies of the X-ray emission in LBAs have found that the X-ray luminosity per star formation rate (SFR) in these galaxies is elevated, potentially because of their low metallicities. Theoretically, XRBs formed in lower metallicity environments lose less mass from stellar winds over their lifetimes, resulting in more numerous and luminous HMXBs per SFR. In this talk, I will present how metallicity influences the X-ray luminosity distribution of HMXBs in these galaxies. This study has greater implications on understanding the evolution of X-ray emission from galaxies over the history of the Universe.

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425.06 – Extragalactic X-ray binaries from 0.5-30 keV with Chandra and NuSTAR

An important ingredient in starburst galaxies is the population of black holes and neutron stars contained in accreting binary populations. We report on X-ray binary (XRB) populations in six nearby starburst galaxies using focused images over 0.5-30 keV with Chandra and NuSTAR. We use a set of hard X-ray color-color and color-count rate diagnostics developed using archival RXTE data, allowing identification of the much fainter extragalactic XRBs. We consistently find that the hard X-ray emission from these galaxies is dominated by XRBs (black holes and neutron stars) except in the well-known Compton-thick AGN candidate Arp 299. The detected XRBs appear dominated by intermediate-state black holes and the overall L_X is dominated by a handful of ULXs whose spectrum is overall well-described by a soft turnover. We discuss the cosmic implications of these results, including for the 7 Ms Chandra Deep Field survey, which will have just finished being observed at the time of the January 2015 AAS, and should include a significant population of X-ray emitting starburst galaxies like the ones discussed here.

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Contributing team(s): NuSTAR team

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426 – Galaxy Morphology

426.01 – Galaxy Zoo: Are Bars Responsible for the Feeding of Active Galactic Nuclei at 0.2 < z < 1.0?

We present a new study investigating whether active galactic nuclei (AGN) beyond the local universe are preferentially fed via large-scale bars. Our investigation combines data from Chandra and Galaxy Zoo: Hubble (GZH) in the AEGIS, COSMOS, and GOODS-S surveys to create samples of face-on, disk galaxies at 0.2 < z < 1.0. We use a novel method to robustly compare a sample of 120 AGN host galaxies, defined to have 10^{42} erg s^{-1} < L^X < 10^{44} erg s^{-1}, with inactive control galaxies matched in stellar mass, rest-frame color, size, Sérsic index, and redshift. Using the GZH bar classifications of each sample, we demonstrate that AGN hosts show no statistically significant enhancement in bar fraction or average bar likelihood compared to closely-matched inactive galaxies. In detail, we find that the AGN bar fraction cannot be enhanced above the bar fraction in the control sample by more than a factor of two, at 99.7% confidence. We similarly find no significant difference in the AGN fraction among barred and non-barred galaxies. Thus we find no compelling evidence that large-scale bars directly fuel AGN at 0.2 < z < 1.0. This result, coupled with previous results at z = 0, implies that moderate-luminosity AGN have not been preferentially fed by large-scale bars since z = 1. Furthermore, given the low bar fractions at z > 1, our findings suggest that large-scale bars have likely never directly been a dominant fueling mechanism for supermassive black hole growth.

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Contributing team(s): Galaxy Zoo, AEGIS, COSMOS, GOODS

426.02 – First Results from Galaxy Zoo CANDELS: The Settling of Galactic Disks from 0.5 < z < 2

Large-scale bar features in disk galaxies are tracers of the dynamical maturity of the population. Previous studies have found that the incidence of bars in disks decreases from the local Universe to z ~ 1, and by z > 1 simulations predict that bar features in dynamically mature disks should be extremely rare. We report the discovery of strong barred structures in massive disk galaxies at z ~ 1.5 in deep rest-frame optical images from CANDELS, implying the host disks are dynamically settled enough to be unstable to bar formation. The fraction of disk galaxies hosting barred structures does not significantly evolve across the redshift range 0.5 < z < 2 (f^{bar} = $10.7^{+6.3-3.5}$% after correcting for incompleteness). We discuss the implications of this discovery in the context of existing simulations and our current understanding of the way disk galaxies have evolved over the last 11 billion years.

Author(s): Brooke Simmons[5], Tom Melvin[6], Chris Lintott[5], Karen Masters[6], Kyle Willett[4], William C. Keel[3], Rebecca Smethurst[5], Edmond Cheung[2], Robert Nichol[6], Kevin Schawinski[1]
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Contributing team(s): Galaxy Zoo, CANDELS

426.03D – Secular evolution in action: unravelling the nature of bars and bulges

Studies of galactic bulges in relation with bars have provided powerful constraints on their formation and evolution.

While spectroscopic measurements in 2D have mainly focused on the interstellar component, two dimensional studies of the stellar counterpart have only become possible with the advent of integral-field spectroscopic surveys. Here we present new results from the BaLROG project (Bars in Low Redshift Optical galaxies), using the integral field spectrograph SAURON. Our 2D maps, combining several SAURON pointings per galaxy, extend beyond corotation and allow us to probe radial dependencies within and past the bar. We develop a new method to measure bar strength based on radial and tangential velocities derived from our kinematic maps and find a good agreement with the torque found via the photometry of Spitzer images. A comparison with N-body simulations using the two distinct torque measurements shows that early-type bars might originate from distinct dark matter (DM) halos. This results in higher DM fractions within the bar region for later types (>50% DM). We also compute line-strength indices to derive SSP-equivalent ages and metallicities and find enhanced iron features likely associated to bar-driven resonances.
To complement this stellar population study we observed three bulges using the high resolution gratings (R=7000) of the WiFeS IFU. The large wavelength coverage along with the high spectral resolution allow the use of full spectral fitting methods to extract the bulges' star formation histories. We find that at least 50% of the stellar mass already existed 12 Gyrs ago, more than currently predicted by simulations. A younger component (age between ~1 to ~8 Gyrs) is also prominent and its present day distribution seems to be affected much more strongly by morphological structures, especially bars, than the older one.
In this talk, we link the observed bulge properties to diverse formation scenarios taking into account results from cosmological simulations. We conclude that our in-depths analyses support the notion of increasing complexity in bulge evolution, which cannot be achieved by mergers alone and require a non-negligible contribution of secular evolution, especially driven by bars.

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426.04 – The rest-frame optical morphology of starburst galaxies at 1 < z < 3.5

Using CANDELS combined with GOODS-Herschel in the GOODS-North and South field, we investigate the rest-frame optical morphologies of starburst galaxies at 1 We compare morphologies of MS and SB galaxies using non-parametric (Sersic Index) and parametric measures as well as the visual identification. FIR luminous starburst galaxies are usually interpreted as major wet mergers. We find that the average morphologies of SB galaxies are disky and generally have much more diffuse optical light profile than massive compact early-type galaxies (ETGs), challenging gas-rich merging as the primary dissipative mechanism to assemble very compact, massive galaxies. We find that the sizes of the SB galaxies are clearly larger than those of the MS galaxies on average. NIR to MIR colors of starburst galaxies show no evidence of highly dust-obscured compact component, which could eventually emerge as the massive compact core. Very compact SB galaxies are rather rare, and hence even from a statistical standpoint, our morphological analysis of starburst galaxies does not support the popular mechanism that powerful starburst in a highly dissipative wet merger of gas-rich disks, and subsequent quenching, is the key driver behind the formation of the massive, compact early-type galaxies observed at z~2. The light distribution of the bulk of stars in starburst galaxies is simply not compact enough to eventually evolve into the massive ultra compact ETGs at high redshift universe.

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Contributing team(s): CANDELS, GOODS-Hershcel

426.06 – The formation and evolution of clumpy galaxies from z=3 to z=0.5

A common feature of star-forming galaxies at z>1 is the existence of giant star-forming clumps, which are fundamental to our understanding of the accretion history of galaxies, formation of bulges, and evolution of gas-rich disks. The origin and evolution of clumps are, however, still unclear. Using the deep and high-resolution optical (HST/ACS) and near--IR (HST/WFC3 IR) imaging data of CANDELS, we study the physical propeties of clumps in star-forming galaxies from z=3 to z=0.5. The CANDELS data enable us to resolve the sub-structures of galaxies to kiloparsec scale in the rest-frame UV and optical bands. In this talk, I will present our work on three aspects of the clumps: (1) the evolution of the fraction of star-forming galaxies with giant clumps from z=3 to z=0.5; (2) the physical properties (stellar mass, star formation rate, age, dust extinction, etc.) of clumps from z=3 to z=0.5; and (3) the connection between the clumpy appearance and the kinematics of settled (rotation dominated) and unsettled (velocity dispersion dominated) disks. The three aspects provide important clues of tracing the physical mechanisms that are responsible for transferring distant clumpy galaxies into disks and/or bulges seen in the local universe.

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Contributing team(s): CANDELS

426.07 – Decoding the Astrophysical Properties of Galaxies: the SAMI Galaxy Survey at 1000 Galaxies

With a sample of 1000 galaxies and counting, the SAMI Galaxy Survey is the most extensive IFU survey of nearby galaxies undertaken to date. Working toward a final sample of ≈3,400 integral-field spectral cubes (spatially resolved spectroscopy), we announced our Early Data Release in July 2014, comprising 107 galaxies that span a large, multi-faceted parameter-space in terms of stellar mass, morphology, angular momentum, and redshift. On behalf of the 100-strong collaboration I will discuss the state of the survey, recent milestones, and early science that includes studies of angular momentum; kinematic morphologies (kinemetry); scaling relations between kinematics and mass; star formation in HII complexes; and more.

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Contributing team(s): The SAMI Galaxy Survey Team

427 – Gas Properties In & Around Galaxies

427.01 – Connection Between the Circumgalactic Medium and the Atomic Hydrogen in Galaxies

We present the first statistical study probing the connection between the circumgalactic medium (CGM) and the atomic hydrogen content within galaxies. The survey utilizes Hubble Space Telescope ultraviolet spectroscopy to probe the hidden baryonic content in the CGM for 47 galaxies from the GALEX Arecibo SDSS Survey (GASS). Information on the atomic gas masses for the galaxies come from the data from Arecibo observatory and the star-formation rates and stellar masses were derived using a combination of GALEX and SDSS data. Our sightlines sample the outer halo (~0.5 to 1 times the virial radius).

While the neutral gas covering fraction (traced by Ly Alpha absorption) in the CGM is almost unity for HI-rich galaxies, the covering fraction drops significantly with decreasing atomic hydrogen content inside the galaxy. We also find a similar trend when comparing star forming/blue galaxies to passive/red galaxies. We also find differences between blue/HI-rich and red/HI-poor galaxies in terms of the Si III content in their CGM. The ratio of SiIII to stellar mass is about twice as large in blue star forming galaxies compared to red passive galaxies. These results imply a connection between the properties of the cool/warm gas in the CGM and the condensed baryons in the disk.

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427.02D – Interpreting Sky-Averaged 21-cm Measurements

Within the first ~billion years after the Big Bang, the intergalactic medium (IGM) underwent a remarkable transformation, from a uniform sea of cold neutral hydrogen gas to a fully ionized, metal-enriched plasma. Three milestones during this epoch of reionization -- the emergence of the first stars, black holes (BHs), and full-fledged galaxies -- are expected to manifest themselves as extrema in sky-averaged ("global") measurements of the redshifted 21-cm background. However, interpreting these measurements will be complicated by the presence of strong foregrounds and non-trivialities in the radiative transfer (RT) modeling required to make robust predictions.
I have developed numerical models that efficiently solve the frequency-dependent radiative transfer equation, which has led to two advances in studies of the global 21-cm signal. First, frequency-dependent solutions facilitate studies of how the global 21-cm signal may be used to constrain the detailed spectral properties of the first stars, BHs, and galaxies, rather than just the timing of their formation. And second, the speed of these calculations allows one to search vast expanses of a currently unconstrained parameter space, while simultaneously characterizing the degeneracies between parameters of interest. I find principally that (1) physical properties of the IGM, such as its temperature and ionization state, can be constrained robustly from observations of the global 21-cm signal without invoking models for the astrophysical sources themselves, (2) translating IGM properties to galaxy properties is challenging, in large part due to frequency-dependent effects. For instance, evolution in the characteristic spectrum of accreting BHs can modify the 21-cm absorption signal at levels accessible to first generation instruments, but could easily be confused with evolution in the X-ray luminosity star-formation rate relation. Finally, (3) the independent constraints most likely to aide in the interpretation of global 21-cm signal measurements are detections of Lyman Alpha Emitters at high redshifts and constraints on the midpoint of reionization, both of which are among the primary science objectives of ongoing or near-future experiments.

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427.03D – The COSMOS HI Large Extragalactic Survey (CHILES): Probing HI Across Cosmic Time

Hydrogen (HI) is the most abundant element in the Universe, and surprisingly, we know very little about the neutral hydrogen beyond z~0.08. The recently upgraded VLA makes it now possible to image the HI in galaxies beyond the local Universe. We are using the broad bandwidth of the VLA to instantaneously probe HI from z=0 to z=0.5 in one pointing of the COSMOS field. Once CHILES is complete, we will have HI images of 300 galaxies across cosmic time in different environments. These images will have a spatial resolution of 0.5 kpc for nearby galaxies and 30 kpc at z~0.5, and a velocity resolution of 7 km/s. In preparation for CHILES, we carried out a pilot study that observed the same pointing out to z~0.2, and detected HI in 33 galaxies in our volume. I will describe the science goals of CHILES, what we learned from the pilot study, and present preliminary results for the first 200 hours of observations of the full survey. After 1002 hours of integration time, we will have high-resolution HI images that will help us understand galaxy evolution across cosmic time and test predictions made by cosmological simulations.

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Contributing team(s): CHILES Team

427.04D – The Influence of Local and Large-Scale Environment on Galaxy Gas Reservoirs in the RESOLVE Survey

There is growing evidence to suggest galaxy gas reservoirs have been replenished over time, but a clear picture of how this process depends on local and large-scale environment is still an active area of research. I will present an analysis of galaxy gas content with respect to environment using the ~90% complete 21cm census for the volume-limited RESOLVE survey, which yields an unbiased inventory of HI masses (or strong upper limits < 5-10% of the stellar mass) for ~1550 galaxies with baryonic mass greater than 10^9 $M^{\odot}$ in >50,000 cubic Mpc of the z=0 universe. We quantify large-scale environment via identification of cosmic web filaments and walls using a modified friends-of-friends technique, while also using photometric redshifts to identify additional potential companions around each galaxy. Combining this powerful data set with estimates of HI profile asymmetries and star formation histories, we examine whether there are local or large-scale environments where cold gas accretion is more effective. Specifically, we investigate whether galaxy interactions can induce enhanced HI content. We also explore whether galaxies residing in large-scale filaments or walls, where simulations show large-scale gas flows, display signatures of enhanced gas accretion relative to other large-scale environments. This project is supported by NSF funding for the RESOLVE survey (AST-0955368), the GBT Student Observing Support program, and a UNC Royster Society of Fellows Dissertation Completion Fellowship.

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Contributing team(s): The RESOLVE Team

427.05 – COPSS: The Carbon Monoxide Power Spectrum Survey

We present current results from work focused on measuring the abundance of carbon monoxide and molecular gas in the early Universe. Molecular gas is a vital component of galactic evolution and star formation. But its distribution among average galaxies at high redshift understood is so poorly that models of the mean abundance of CO for z~3 span orders of magnitude. Direct detection of molecular gas in galaxies at these redshifts has only achieved the most luminous of galaxies ($M^{gas} \geq 10^{11}$ $M^{\odot}$; SFR ≥ 100 $M^{\odot}$ yr^{-1}), whereas the bulk of the molecular gas is expected to be in the unseen masses of smaller galaxies ($M^{gas} \approx 10^9$ $M^{\odot}$ SFR ≈ 1 $M^{\odot}$ yr^{-1}). Theory predicts these smaller galaxies are detectable as an integrated ensemble with the technique of “intensity mapping”, where measurements of different 3D Fourier modes to construct a power spectrum. The Sunyaev-Zel'dovich Array (SZA) offers an opportunity to explore molecular gas at high redshift through this technique. The SZA, an 8-element closely packed array, is capable of observing CO (J=1⇒0) at z = 2.3-3.3.
We present a power spectrum from of our current search for CO at z~3, utilizing a “wide and shallow” legacy dataset with 880 hours of integration time spread across 44 different fields. To 2σ confidence, we find no evidence for CO down to a sensitivity of Δ^{2N}(k=1 h Mpc^{-1}) ≈ 10^3 μK^2 (with sensitivity over size-scales of k= 0.5→2 h Mpc^{-1}). This limit resides a factor of a few below model predictions for CO based on the observed UV star formation rate at these redshifts, as described by Pullen et al., 2013. We also present results from a recent 400 hour “deep and narrow” observation of GOODS-North, a target rich in observational data and ripe with opportunities for cross-correlation, with sensitivity a factor of three better than what was capable with the SZA Legacy survey.

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428 – Binaries - White Dwarf, X-Ray, and Gamma-Ray

428.01D – Constraining the Initial-Final Mass Relation with Wide Double White Dwarfs

Population synthesis models predict the existence of large numbers of wide binaries for which the end state is a wide double white dwarf (DWD) system. I discuss the methods I used to find these systems in the Sloan Digital Sky Survey, which ultimately increased the known number of candidate binaries from ~45 to 112. I then describe an observational campaign to obtain spectra of the bright (g < 18 mag) DWD candidates; fitting these to synthetic models provided masses and cooling ages for the white dwarfs in these pairs. Because these binaries are coeval but evolve as independent stars, they are unique stellar laboratories. In particular, I present a method I applied to this wide DWD sample to place new constraints on the initial-final mass relation, which relates a given main-sequence star to the mass of the white dwarf it will produce. Our analysis avoids some of the difficult-to-model systematics introduced by other methods, generating independent and complementary constraints.

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428.02D – Accretion and Outflows in X-ray Binaries: What's Really Going on During X-ray Quiescence

X-ray binaries, consisting of a star and a stellar-mass black hole, are wonderful laboratories for studying accretion and outflows. They evolve on timescales quite accessible to us, unlike their supermassive cousins, and allow the possibility of gaining a deeper understanding of these two common astrophysical processes. Different wavelength regimes reveal different aspects of the systems: radio emission is largely generated by outflows and jets, X-ray emission by inner accretion flows, and optical/infrared (OIR) emission by the outer disk and companion star. The search for relationships between these different wavelengths is thus an area of active research, aiming to reveal deeper connections between accretion and outflows.
Initial evidence for a strong, tight correlation between radio and X-ray emission has weakened as further observations and newly-discovered sources have been obtained. This has led to discussions of multiple tracks or clusters, or the possibility that no overall relation exists for the currently-known population of X-ray binaries. Our ability to distinguish among these options is hampered by a relative lack of observations at lower luminosities, and especially of truly X-ray quiescent (non-outbursting) systems. Although X-ray binaries spend the bulk of their existence in quiescence, few quiescent sources have been observed and multiple observations of individual sources are largely nonexistent. Here we discuss new observations of the lowest-luminosity quiescent X-ray binary, A0620-00, and the place this object occupies in investigations of the radio/X-ray plane. For the first time, we also incorporate simultaneous OIR data with the radio and X-ray data.
In December 2013 we took simultaneous observations of A0620-00 in the X-ray (Chandra), the radio (EVLA), and the OIR (SMARTS 1.3m). These X-ray and radio data allowed us to investigate similarities among quiescent X-ray binaries, and changes over time for this individual object, in the radio/X-ray plane. In addition, our OIR observations allowed us to examine the radio and X-ray information in relation to the different OIR states of behavior (passive and active) known to exist during X-ray quiescence.

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428.04 – The Longterm Variability of 4u 1705-44---A Chaotic System?

The bright low-mass X-ray binary 4U 1705-44, a bursting Atoll source, exhibits longterm aperiodic variability with a timescale of several hundred days. The All-Sky Monitor (ASM) aboard the Rossi X-ray Timing Explorer (RXTE) observed 4U 1705-44 continuously from December 1995 through January 2012. MAXI, the Japanese X-ray All-Sky Monitor aboard the International Space Station observed the source from August 2009 through the present. Combining the ASM and MAXI data sets yeilds a continuous, uninterrupted, evenly spaced time series containing over fifty cycles at the timescale of interest. We use traditional and novel time series analysis techniques to analyze the longterm variability. A phase space embedding of the flux versus its first derivative shows a strong resemblence to the canonical double-welled nonlinear Duffing osciallator. We find a range of parameters and initial conditions for which the Duffing oscillator closely follows the time evolution of 4U 1705-44. We find evidence for unstable periodic orbits embedded in the aperiodc variabiity of 4U 1705-44, and argue that the period-1 orbit has a period of ~120 days. Clear signatures of period-1, period-2 and period-3 orbits are found in the light curve. We extract these orbits from both the 4U 1705-44 and Duffing oscillator time series and compare their topological information in phase space. It appears that the X-ray long term time variability of 4U 1705-44 can be described by a Duffing oscillator. We discuss the implications of this discovery on the allowable models to describe the longterm variability of 4U 1705-44 and, by extention, to the allowable models describing the class of X-ray binaries which show high amplitude, longterm variabilty at timescales many times the orbital periods of the systems.

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428.05 – Gemini Spectroscopy of Galactic Bulge Sources: A Population of Hidden Accreting Binaries Revealed?

We present Gemini spectroscopy for 21 X-ray sources detected in the Galactic Bulge Survey (GBS), which aims to investigate X-ray binaries in the Galactic Bulge region. For the majority of the sources, we have obtained spectra of the objects that are likely the real optical counterparts to the X-ray sources. Line measurements, spectral classification, and radial velocity analysis were performed on the Gemini spectra. We discover a population of hidden accreting binaries whose Gemini spectra apparently show neither strong Hα emission nor Hα absorption. However, the residual spectra of some sources after subtracting the best-fit stellar spectroscopic templates contain a broad Hα emission line which likely originates in an accretion disk. These hidden accreting sources may constitute a substantial portion of the full accreting binary population. We also identify three likely candidates of eclipsing or high-inclination quiescent low-mass X-ray binaries based on their broad Hα emission line profile and/or their optical light curves. Significant Hα emission line variability was also observed for two GBS sources.

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428.06 – Gamma-Ray Activity from the Binary System PSR B1259-63/LS 2883 Near its 2014 Periastron Passage

PSR B1259-63 is a gamma-ray binary containing a radio pulsar in a long (1236.7 days) and elliptical (e~0.87) orbit around a Be star, LS 2883. We present results of monitoring this system at times near the periastron passage of 2014 May 4, using the Large Area Telescope (LAT) on the Fermi Gamma-ray Space Telescope. In the 2014 cycle the Fermi spacecraft was operated in pointed mode for part of the time after periastron to enhance exposure in the LAT. We confirm that the GeV flare is recurrent. The onset of detectable gamma-ray emission occurred around 2014 June 6, which was 33 days after periastron. We compare GeV behavior near the 2014 periastron with the same portion of the previous 2010-11 cycle, for which a discussion of the radio-to-TeV behavior is available in Chernyakova et al. (2014, MNRAS 439,432). We also present our search for gamma-ray pulsations outside both periastron passages. Fermi LAT analysis is supported by NASA.

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Institution(s): *1. DCU, 2. IEEC-CSIC, 3. NASA-Ames, 4. NRL, 5. SLAC*
Contributing team(s): Fermi LAT Collaboration

429 – The Andromeda Galaxy

429.01D – Uncovering the Detailed Structure and Dynamics of Andromeda's Complex Stellar Disk

Lambda cold dark matter (LCDM) cosmology predicts that the disks of Milky Way-mass galaxies should have undergone at least one merger with a large (mass ratio 1:10) satellite in the last several Gyr. However, the stellar disk in the solar neighborhood of the Milky Way is too thin and dynamically cold to have experienced such an impact. The dynamics of the nearby Andromeda galaxy can serve as a second data point, and help us understand whether the Milky Way may simply have had an unusually quiescent merger history, or whether LCDM theory needs to be revisited. Over the last few years, we have carried out a detailed study of the resolved stellar populations in the disk of the Andromeda galaxy using data from two surveys: six-filter Hubble Space Telescope photometry from the recently-completed Panchromatic Hubble Andromeda Treasury (PHAT) survey, and radial velocities derived from Keck/DEIMOS optical spectra obtained as part of the Spectroscopic and Photometric Landscape of Andromeda's Stellar Halo (SPLASH) program. These detailed, multidimensional data sets allow us to decouple the structural subcomponents and characterize them individually. We find that an old, dynamically hot (velocity dispersion ~150 km/s) RGB population extends out to 20 kpc (the edge of the visible disk) but has a disk-like surface brightness profile and luminosity function. This population may have originated in the disk but been kicked out subsequently in impacts with satellite galaxies. We also study the kinematics of the disk as a function of the age of stellar tracers, and find a direct correlation between age and velocity dispersion, indicating that Andromeda has undergone a continuous heating or disk settling process throughout its lifetime. Overall, both the velocity dispersion of Andromeda's disk and the slope of the velocity dispersion vs. stellar age curve are several times those of the Milky Way's, suggesting a more active merger history more in line with LCDM cosmological predictions.

This research was funded by grants from the NSF and NASA/STScI.

Author(s): Claire Dorman[2], Puragra Guhathakurta[2], Anil Seth[3], Julianne Dalcanton[4], Larry Widrow[1]
Institution(s): *1. Queens University, 2. UC Santa Cruz, 3. University of Utah, 4. University of Washington*
Contributing team(s): SPLASH team, PHAT team

429.02 – The spatially-resolved recent star formation history of M31

We present the spatially-resolved star formation history (SFH) of the Andromeda Galaxy (M31) based on imaging of resolved stellar populations as part of the Panchromatic Hubble Andromeda Treasury (PHAT). We have gridded the survey into ~9000 regions that are ~100 pc x 100 pc in projected size. Treating each region independently, we model the optical color-magnitude diagrams and measure the SFHs over the past 400-600 Myr. We combine the individual SFHs to create maps of star formation (SF) across a contiguous 1/3 of M31's star forming disk, providing an unprecedented perspective on patterns of star formation in an Lstar galaxy. Our maps clearly recover M31's famous ringed structures and reveal that the 5 and 15 kpc rings formed within the last ~250 Myr and are transient in nature. In contrast, the 10 kpc ring appears to be long-lived (>500 Myr), with some evidence for broadening of the ring and dispersion of stars into the stellar disk over the accessible lookback time. It also dominates the global recent SF; the majority of the total stellar mass budget within the last ~500 Myr comes from the 10 kpc ring. Our global SFH of M31 is roughly constant over the last ~500 Myr, with a notable peak 50 Myr ago and a shallow decline toward the present. Extrapolating our SFH to the entire disk, we find that the SFR of M31 over the most recent 100 Myr is ~0.8 Msun/yr.

Author(s): Alexia Lewis[1], Julianne Dalcanton[1]
Institution(s): *1. University of Washington*
Contributing team(s): PHAT Collaboration

429.03D – Andromeda Optical & Infrared Disk Survey: Stellar Populations and Mass Decomposition

M31 is ideal for understanding the structure and stellar populations of spiral galaxies thanks to its proximity and our external vantage point. The Andromeda Optical & Infrared Disk Survey (ANDROIDS) has used MegaCam and WIRCam on the Canada-France Hawaii Telescope to map the M31 bulge and disk out to R=40 kpc in $ugriJK^S$ bands. Through careful sky monitoring and modelling, ANDROIDS is uniquely able to observe both the resolved stars and integrated spectral energy distributions (SEDs) over M31's entire disk (complimenting HST's PHAT program). By simultaneously fitting stellar populations with isochrones and SED models for M31, we can assess the systematic uncertainties of SED fits to more distant unresolved systems, and constrain the stellar populations that contribute to each bandpass. We pay close attention to the near-IR light of asymptotic giant branch (AGB) stars in stellar population models. ANDROIDS has also surveyed M31 in narrowband TiO and CN bands, enabling a clean classification of Carbon AGB stars, and a mapping the ratio of Carbon and M-type AGB stars (C/M) across the entire disk. The correlation between C/M and stellar metallicity is useful for constraining the NIR colors of more distant galaxies. We also present a hierarchical Bayesian model of pixel-by-pixel stellar populations, yielding the most detailed map of M31's stellar mass and star formation history to date. We find that a full six-band optical-NIR fit provides the best constraints to stellar mass, a triumph for modern NIR stellar population synthesis models, though the results are consistent with an optical-only fits. Fits based on the popular *g-i* color combination find M/L^* ratios biased by 0.1 dex, while color-mass-to-light prescriptions in the literature may differ by 0.3 dex. This result affirms that panchromatic SED modelling is crucial even for stellar mass estimation, let alone age and metallicity. Overall, we estimate the stellar mass of M31, within R=30 kpc, to be 10.3 (+2.3, -1.7) x 10^{10} $M^{\odot}$.

Author(s): Jonathan Sick[5], Stephane Courteau[5], Jean-Charles Cuillandre[1], Julianne Dalcanton[6], Roelof S de Jong[3], Michael McDonald[4], R. Brent Tully[2]
Institution(s): *1. Canada-France-Hawaii Telescope, 2. IfA, 3. Leibniz Institute for Astrophysics Potsdam, 4. MIT, 5. Queen's University, 6. University of Washington*

429.04 – Constraints on the early history of formation of the Andromeda galaxy from chemical compositions of its globular clusters

We have determined the abundance patterns of a large sample of old globular clusters from the Andromeda galaxy. We present new results from the analysis of the spatial distribution of a sample of 128 clusters as a function of their chemical composition, discussing the implications for the early history of formation of our giant neighbour.

Author(s): Ricardo P. Schiavon[2], Nelson Caldwell[1]
Institution(s): *1. Harvard Center for Astrophysics, 2. Liverpool John Moores Unversity*

429.05 – The M31 nucleus in the mid-infrared

The central region of the Andromeda Galaxy (M31) is a complicated place, containing a massive but quiescent black hole, a multi-component nucleus, young stars, cold gas, and ionized gas among other ingredients. While this region has been extensively studied at radio, visible, and X-ray wavelengths, it has received relatively little attention in the mid-infrared. Mid-infrared observations constrain the dust properties of the nucleus and surrounding region. As part of a larger project to study the properties of PAH emission in M31, we obtained *Spitzer* low-resolution (R~100) spectroscopy of a 30x50 arcsec (114 x 190 pc) region containing the nucleus. We detected 10 micron silicate emission from a marginally resolved source at the center of the galaxy, consistent with emission from an unobscured but weak active nucleus. We also detected the 11.3 micron polycyclic aromatic hydrocarbon (PAH) emission feature, but not other PAH features, from a region about 15 arcsec north of the nucleus. We discuss these spectral features in comparison with those of other nearby low-luminosity AGN and the properties of the M31 supermassive black hole.

Author(s): Pauline Barmby[3], Dimuthu Hemachandra[3], Els Peeters[3], Steven P. Willner[1], Matthew Ashby[1], Howard Alan Smith[1], Karl D. Gordon[2], Denise A. Smith[2], Giovanni G. Fazio[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Space Telescope Science Institute, 3. Univ. of Western Ontario*

429.06 – Three-Dimensional Self-Gravitating Schwarzschild Models of the Nucleus of M31

We present three-dimensional, self-gravitating eccentric disk models of the nuclear region of M31. We use a Schwarzschild-type orbit superposition method, modelling the potential as a black hole embedded in an eccentric stellar disk that is stationary in a frame rotating at constant pattern speed. The disk potential is derived from the non-parametric Keplerian models of Brown & Magorrian (2013). We fit simultaneously to Wide Field Planetary Camera 2 photometry and kinematics from the Space Telescope Spectroscopy Imaging Spectrograph and the OASIS integral field spectrograph. We explore possible values for the black hole mass, stellar disk mass, disk pattern speed and nuclear orientation. Our models find a nuclear disk unaligned with the main disk of M31 is strongly favoured at an orientation consistent with previous results. We consistently find that a low pattern speed (< 10 km/s/pc) is preferred across a number of disk potentials. We also find that retrograde orbits can improve the quality of fits near the black hole.

Author(s): Calum Brown[1], John Magorrian[1]
Institution(s): *1. University of Oxford*

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431 – Lancelot M. Berkeley Prize: Cosmological Highlights from the Sloan Digital Sky Survey, David Weinberg (Ohio State University)

431.01 – Cosmological Highlights from the Sloan Digital Sky Survey

In its first 15 years of operation, the Sloan Digital Sky Survey (SDSS) has created some of the largest and most detailed maps of the distant universe and the Milky Way galaxy, with deep digital imaging over one third of the sky and spectroscopy of more than 2 million galaxies, 200,000 quasars, and half a million stars. In the fields of cosmology and galaxy formation, highlights from the SDSS include: probing the epoch of reionization with the most distant known quasars; comprehensively characterizing the properties of galaxies and the relations between galaxies and their parent dark matter halos; discovering ubiquitous substructure in the outer Milky Way and more than a dozen new companion satellite galaxies; mapping cosmic expansion over the last four billion years with more than 500 Type Ia supernovae; and, through its precision measurements of structure on very large scales, providing a central pillar of the standard cosmological model based on inflation, cold dark matter, and dark energy. I will review these highlights, with particular attention to results from the recently completed APOGEE and BOSS surveys of SDSS-III. APOGEE uses high-resolution infrared spectroscopy to probe the dynamics and multi-element abundance distributions of the Milky Way, yielding new insights on its mass profile, stellar populations, and chemical evolution. BOSS uses baryon acoustic oscillations to enable the first percent-level measurements of absolute distances beyond the Milky Way, yielding strong constraints on the properties of dark energy and the curvature of space. Other measurements with BOSS galaxy clustering and quasar spectra probe the physics of inflation, the masses of neutrinos, the metal enrichment of the Lyman-alpha forest, and the dark matter halos of luminous galaxies, quasars, and quasar absorption systems. All data from SDSS-III are publicly available in SDSS DR12, which coincides with this AAS meeting. I will conclude with plans and prospects for SDSS-IV, which began observations in July 2014.

Author(s): David H. Weinberg[1]
Institution(s): *1. Ohio State Univ.*
Contributing team(s): SDSS Collaboration

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432 – AGN and Friends Posters

432.01 – Disk+Jet Quasars: Separating the Components with Optical/Infrared Variability

Flat Spectrum Radio Quasar (FSRQ) is a subclass of active galactic nuclei with aligned relativistic jets. The mechanism relating the FSRQ's accretion disk activity to its rapidly varying, non-thermal jet radiation is not well understood, motivating a monitoring campaign for 15 gamma-ray loud FSRQs with big blue bumps at z≈1. Selected quasars were observed in the optical, infrared, and gamma-ray energy bands using Lick Observatory's 40-inch Nickel Telescope, Kitt Peak National Observatory's 2.1 meter Telescope, Smithsonian Astrophysical Observatory's Peters Automated Infrared Imaging Telescope, and NASA's Fermi Gamma-ray Space Telescope for roughly 20 nights over a 12 month period. Differential photometry on a half dozen bright stars in each field yielded measurements with 1-2% level precision. Jets generally dominate the redder emission spectrum due to non-thermal synchrotron radiation and Compton scattering of gamma-rays off high energy electrons, while accretion disks dominate the bluer emission spectrum with rest frame ~2000 Angstroms. Most of the targeted FSRQs varied significantly over the 12 month monitoring period, with increased levels of fluctuation at longer wavelengths. Some correlations between gamma-ray and optical wavelengths were observed.

Author(s): Jennifer Kadowaki[1], Matthew Arnold Malkan[1]
Institution(s): *1. University of California, Los Angeles (UCLA)*

432.02 – Can 3000 IR spectra unveil the connection between AGN and the interstellar medium of their host galaxies?

A central issue in the study of the formation and evolution of galaxies is the connection between the central supermassive black hole (SMBH) and the surrounding bulge stars. There are multiple theories which explore this connection in the context of mechanisms that control galaxy evolution. A key test of such theories is to find evidence that Active Galactic Nuclei (AGN) have an impact on the growth of their host galaxies. Here we present an unexampled atlas of X-ray to radio photometry of 3000 AGN with full MIR and partial optical spectroscopic observations, including over 20,000 emission lines and ~100,000 photometric points observations from which to search for such evidence. Analysis of this data will provide a unique way to study changes in the interstellar medium (ISM) properties in the context of super massive black hole (SMBH) galaxy co-evolution. The IR photometry and spectroscopy will be used to determine of the general dust properties. Rotational H^2 transitions and archival cold gas observations in the millimeter will be used to estimate the reservoirs of molecular gas. The full SED will be use to attempt a decomposition of the AGN/host galaxy contributions to the bolometric luminosities.
We present our methods of assembling this AGN atlas and discuss a preliminary investigation of warm molecular gas and dust as a function of AGN properties. The uniform methodology applied to a large sample to derive dust and gas properties is very useful as it can be reliably compared with other/future studies from ALMA and JWST.

Author(s): Erini Lambrides[1], Andreea Petric[2], Thomas R. Geballe[2], Rachel Mason[2]
Institution(s): *1. American Museum of Natural History, 2. Gemini Observatory*

432.03 – Variability in the Intrinsic UV Absorption in Mrk 279 based on HST/COS Spectra

We present an analysis of the variability of the mass outflow systems in the Seyfert 1 galaxy Mrk 279 based on spectra obtained with the *Cosmic Origin Spectrograph* (COS) aboard the *Hubble Space Telescope* in 2011, compared with observations in 2002 and 2003 obtained with the *Space Telescope Imaging Spectrograph* (STIS). The continuum flux dropped by a factor of fifteen in 2011 compared to 2003, similar to the low flux level observed in 2002. We measure covering factors and ionic column densities for the outflow systems, treating three distinct emission components - continuum, broad line region (BLR) and intermediate line region (ILR). We find that the column densities of C IV and N V have increased in both the low and high velocity kinematic components (radial velocities -265 km/s and -460 km/s), and Si IV has appeared in the former. Based on photoionization models using CLOUDY, we find the column density variations in both components are consistent with a response of the outflow to the drop in ionizing flux. We also find that the covering factor of the ILR in the low velocity component has increased in the 2011 spectrum, while the covering factors in the high velocity component are stable across the three epochs. We use these results to constrain the geometry and physical conditions of the outflows in Mrk 279.

Author(s): Benjamin R Schmachtenberger[2], Jack Gabel[2], D. Michael Crenshaw[3], Steven B. Kraemer[1]
Institution(s): *1. Catholic University of America, 2. Creighton University , 3. Georgia State University*

432.04 – A spectral energy distribution analysis of AGN host galaxies in the Chandra-COSMOS Legacy Survey

We present the host galaxy properties of a large sample of ~ 4000 X-ray selected Active Galactic Nuclei (AGN) in the Chandra COSMOS Legacy Survey to investigate the connection between BH accretion and host galaxy. The COSMOS Legacy survey reaching X-ray fluxes of $2x10^{-16}$ (cgs) in the 0.5-2 keV band, bridges the gap between large area shallow surveys and pencil beamed one. Making use of the existing multi-wavelength photometric data available for 96.6% of the sources, COSMOS Legacy survey provides a uniquely large sample to derive host galaxy properties for both obscured and unobscured sources. We perform a multi-component modeling from far-infrared (500 μm) when available to UV (1500 Å) using a 3-component fitting (nuclear hot dust, galaxy and starburst components) for obscured AGN and a 4-component fitting (nuclear hot dust, AGN big blue bump, galaxy, and starburst components) for unobscured AGN. Galaxy templates are from the stellar population synthesis models of Bruzual & Charlot (2003), nuclear hot dust templates are taken from Silva et al. (2004), and AGN big blue bump templates are from Richards et al. (2006). We use the column density information measured in the X-ray to constrain the AGN in the infrared band when available. Through detailed analysis of the broad-band spectral energy distribution, we derive the stellar masses and the star formation rates of the host galaxy as well as the nuclear and galaxy contribution at each frequency. We study the dependence of host galaxy properties on redshifts, luminosities, and black hole masses to infer the growth history of galaxies and black holes and we compare with a sample of inactive galaxies.

Author(s): Hyewon Suh[2], Francesca M. Civano[3], Guenther Hasinger[2], Martin Elvis[1], Stefano Marchesi[3]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Institute for Astronomy, University of Hawaii, 3. Yale University*

432.05 – The Remarkable Case of NGC 5252 Viewed by Chandra

Ionization cones in Seyfert galaxies are among the best evidence for both AGN unification models and AGN-host galaxy interactions. We have obtained 180 ks Chandra/ACIS-S imaging spectroscopic observation of NGC 5252, an S0 Seyfert 2 galaxy that exhibits spectacular optical ionization cones characterized by a series of prominent ridges. We characterized the detailed X-ray morphology and the photoionization structure along the cones, thereby reconstructing the activity history of the nucleus on a 6×10^4 years timescale.

Author(s): Junfeng Wang[1]
Institution(s): *1. Xiamen University*

432.06 – Optically Elusive AGN in the 3XMM Catalog and the Chandra-COSMOS field

"Optically elusive AGN" are powerful X-ray sources ($L^{HX} > 10^{42}$ erg/s), but are not detected as AGN in the optical. Pons and Watson (2014) showed that in XMM these AGNs are a mix of Narrow Line Seyfert 1s, True Seyfert 2's and weak Seyfert 2s. The nature of these objects, coming from the cross-match of 3XMM with the SDSS-DR9 spectroscopic catalog, has been investigated through a detailed analysis of their IR/optical and X-ray properties.

The fainter Chandra-COSMOS field should be rich in optically elusive AGNs as ¾ of the AGNs there are narrow-lined. There are ~850 Chandra-COSMOS galaxy spectra, mainly from five different telescopes (SDSS, Magellan, MMT, VLT and Keck). To find optically elusive objects, we investigate the optical classification using emission line diagnostic diagrams. For low redshift galaxies (z~<0.7) the standard BPT diagram ([OIII]

Author(s): Estelle Pons[1], Mike Watson[2], Martin Elvis[1], Francesca M. Civano[3]
Institution(s): *1. Harvard Smithsonian Center for Astrophysics, 2. University of Leicester, 3. Yale University*

432.07 – The Effects of Orientation on Proxies for the M-σ^* Relation in Quasars

The correlation between central black hole mass (M) and stellar velocity dispersion (σ^*) in both active and quisecent galaxies suggests an evolutionary relationship between nuclei and their hosts. Direct measurement of both black hole masses and stellar velocity dispersions in the same object is often challenging. In quasars, indirect methods can be employed. Single-epoch scaling relationships permit the estimation of black hole mass based on broad-line velocity width and continuum luminosity, while the velocity width of narrow emission lines permit the estimation of stellar velocity dispersion. We use Sloan Digital Sky Survey Data Release 7 quasar spectra with $z < 0.75$ to estimate M and σ^* in a sample of about 400 radio-loud quasars to investigate how these quantities depend on orientation. We use FIRST Survey maps at 20 cm to measure radio core dominance, an orientation indicator. Conventional scaling relationships that use broad Hβ to estimate black hole mass have a strong orientation bias, likely the result of a flattened broad-line region, and this in turn accounts for a large amount of scatter in the M-σ^* relation when measured with these techniques. Turning this around, we suggest that this ratio of M/σ^* proxies is itself an orientation indicator that can be used for both radio-loud and radio-quiet quasars.

Author(s): Vikram Singh[2], Michael S. Brotherton[2], Jessie C. Runnoe[1]
Institution(s): *1. Penn State, 2. Univerisity of Wyoming*

432.08 – A New Method for Selecting Compton Thick AGN Above 10 keV with NuSTAR and Swift BAT

We present NuSTAR observations of a new sample of heavily obscured AGN identified based on their Swift BAT spectra above 10 keV. We use the 70 month Swift Bat all-sky maps with a scheme optimized to detect nearby, heavily obscured, Compton-thick AGN using the Compton curvature which have excesses between 24-50 keV and decrements in the 14-20 keV band. We demonstrate that these targets are among the brightest examples of reflection-dominated AGN available across the sky, providing a detailed study of nearby Compton-thick AGN.

Author(s): Michael Koss[1]
Institution(s): *1. ETH Zurich*
Contributing team(s): NuSTAR

432.09 – Probing the Non-local M^{BH}-σ Relation: Spectroscopy of Narrow-Line Seyfert 1s

The M^{BH}-σ relation has been a target of intense study, because it implies coevolution between supermassive black holes and their host galaxies. In order to understand the origin of the relation, we must measure it beyond the local universe. Part of the challenge in studying the relation at higher redshifts has been finding galaxies for which we can simultaneously measure the central black hole mass and the host stellar velocity dispersion. In our previous research, we studied galaxies for which this was possible. While the sample sizes have been relatively small, the higher-*z* galaxies studied so far have shown an offset relative to the local relation. However, all of these galaxies have black holes larger than $\sim 10^8$ $M^{\odot}$, thus raising the question of possible sample biasses. In an effort to address this, and to confirm or refute the previously observed offset, we have selected a sample of Narrow-line Seyfert 1 galaxies between $0.2 < z < 0.4$ that are expected to have smaller black hole masses based on the widths of their broad emission lines (<2000 km/s). We will exhibit spectroscopy of the Narrow-line Seyfert 1 sample recently obtained with the Magellan Baade 6.5 m telescope and outline the methods and goals of our investigation.

Author(s): Kyle D Hiner[2], Sabrina Cales[4], Paula Calderon[2], Ezequiel Treister[2], Gabriela Canalizo[3], C. Megan Urry[4], Jong-Hak Woo[1]
Institution(s): *1. Seoul National University, 2. Universidad de Concepción, 3. University of California, Riverside, 4. Yale University*

432.10 – NuSTAR Detection of Multiple Reflections in NGC 1068

We report hard X-ray observations of the archetypal Compton-thick AGN NGC 1068 with NuSTAR and other X-ray facilities. We find no strong continuum or line variability, and thus model several key datasets together. We find that a multi-component reflector with three distinct column densities provides the most reasonable fit to the spectral lines and Compton hump, with near-solar Fe abundances. In this model, the higher*N_H* components provide the bulk of the flux to the Compton hump while the lower *N*Hcomponent produces much of the Fe line emission, effectively decoupling the two key features of Compton reflection. Intriguingly, ~30% of the neutral Fe Ka line flux arises from >2′′ (>140 pc), well outside of a fiducial (few pc) "torus". We discuss some key ramifications.

Author(s): Franz E. Bauer[11], Patricia Arevalo[15], Poshak Gandhi[12], Daniel Stern[8], D. M Alexander[5], Mislav Balokovic[1], Steven E. Boggs[13], W. Niel Brandt[10], Murray Brightman[1], Finn Christensen[4], Andrea Comastri[7], William W. Craig[9], Agnese Del Moro[5], Charles James Hailey[2], Fiona Harrison[1], Ryan C. Hickox[3], Bin Luo[10], Craig Markwardt[6], Andrea Marinucci[16], Giorgio Matt[16], Jane R. Rigby[6], Elizabeth Rivers[1], Cristian Saez[17], Ezequiel Treister[14], C. Megan Urry[18], William Zhang[6]
Institution(s): *1. Caltech, 2. Columbia University, 3. Dartmouth, 4. DTU, 5. Durham, 6. GSFC, 7. INAF-Bologna, 8. Jet Propulsion Laboratories, 9. LLNL, 10. Penn State, 11. Pontificia Universidad Catolica de Chile, 12. Southampton, 13. SSL, 14. Universidad de Concepción, 15. Universidad de Valparaiso, 16. Universitá Roma Tre, 17. University of Maryland, 18. Yale*

432.11 – Characterizing the Jet Precession of Quasar 3C273 at 1.3mm with the Event Horizon Telescope

The Event Horizon Telescope (EHT) is an array of millimeter-wavelength telescopes that observe the nearest supermassive black holes using the technique of very long baseline interferometry (VLBI). The EHT is uniquely capable of resolving structures on angular scales of tens of microarcseconds, corresponding to a few Schwarzschild radii around nearby black holes such as the one in our galactic center, Sgr A*. One of the goals of the EHT is to better understand relativistic outflow processes around black holes, which can be achieved due to its extremely high spatial resolution. To that end, here we present the first high-resolution VLBI observations of 3C273 at 1.3mm. We successfully detected non-zero closure phases, which indicate asymmetric structure that we then fit using simple geometric models. The orientation between model components varied over the range of years that 3C273 was observed, in agreement with multi-epoch data at lower frequencies. Our results suggest that precession can be observed even at sub-parsec scales in 3C273. Furthermore, we demonstrate that polarimetric ratios can be used for relative astrometry between flaring components and discuss the implications of that for future research.

Author(s): Michael Calzadilla[3], Vincent L. Fish[1], Rusen Lu[1], Kazunori Akiyama[2], Sheperd Doeleman[1]
Institution(s): *1. MIT Haystack Observatory, 2. National Astronomical Observatory of Japan, 3. University of South Florida*

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433 – Catalogs and Surveys Posters

433.01 – The U.S. Naval Observatory Robotic Astrometric Telescope 1st Catalog (URAT1)

The 1st USNO Robotic Astrometric Telescope Catalog (URAT1) is about to be released. It contains accurate positions (typically 10 to 30 mas std. error) of 220 million stars, mainly on the northern hemisphere. Proper motions were obtained for 85% of these stars utilizing the 2MASS as 1st epoch. URAT1 is supplemented by 2MASS and APASS photometry. The URAT1 catalog was derived from 2 years of operations (April 2012 to April 2014) of the USNO "redlens" astrograph with its 474 Mpx 4-shooter camera at the Naval Observatory Flagstaff Station (NOFS) in a joint effort between USNO's Astrometry Department and NOFS. Due to a combination of long exposures and short exposures with objective grating, URAT1 observations cover the large 3 to 18.5 magnitude range in a single 680-750 nm bandpass. The catalog properties are presented together with a brief summary of observations and reductions methods. URAT1 has on average about 4-times the number of stars per square degree and is 4-times more accurate than UCAC4. URAT1 will serve as the currently most accurate astrometric and deep photometric optical reference star catalog until the delivery of the Gaia catalog.

Author(s): Norbert Zacharias[1], Charlie T. Finch[1], John P Subasavage[1], Trudy Tilleman[1], Mike DiVittorio[1], Hugh C. Harris[1], Ted Rafferty[1], Gary Wieder[1]
Institution(s): *1. U.S. Naval Observatory*
Contributing team(s): Eric Ferguson, Chris Kilian, Albert Rhodes, Mike Schultheis

433.02 – The Time Domain Spectroscopic Survey: Spectroscopic Variability Investigations Within SDSS-IV/eBOSS

The Time Domain Spectroscopic Survey (TDSS) is an SDSS-IV subproject that began summer 2014 and will continue for 4-6 years. Besides its main program to obtain initial characterization spectra of about 220,000 optical variables selected from PanSTARRS-1, the TDSS includes 9 separate smaller programs to study spectroscopic variability. We describe each of these Few-Epoch Spectroscopy (FES) programs, which target objects with existing SDSS spectroscopy amongst classes of quasars and stars of particular astrophysical interest. These include, in approximate order of decreasing sample size: Broad Absorption Line Quasars (BALQSOs), the most photometrically variable ("HyperVariable") quasars, high S/N normal broad line quasars, quasars with double-peaked or very asymmetric broad emission line profiles, Hypervariable stars, active ultracool (late-M and L-type) dwarf stars with Halpha emission, dwarf carbon stars, white dwarf/M dwarf spectroscopic binaries with Halpha emission, and binary supermassive black hole candidates from MgII broad line velocity shift analysis. We summarize herein the unique and diverse astrophysical investigations facilitated by these TDSS FES programs.

Author(s): Paul J. Green[2], Scott F. Anderson[8], Eric Morganson[2], Michael Eracleous[5], Yue Shen[3], W. Niel Brandt[5], John J. Ruan[8], Sarah J. Schmidt[4], Carles Badenes[7], Andrew A. West[1], Wenhua Ju[6], Jenny E. Greene[6]
Institution(s): *1. Boston University, 2. Harvard-Smithsonian CfA, 3. OCIW, 4. Ohio State University, 5. Pennsylvania State University, 6. Princeton University, 7. University of Pittsburgh, 8. University of Washington*
Contributing team(s): TDSS, PanSTARRS-1, SDSS-IV

433.03 – Searching the All-WISE Data Release for Galactic Substructures

We examine the distribution of point sources in the All-WISE data release to search for evidence of undiscovered Galactic stellar debris streams. The All-WISE data release is significantly deeper than the previous WISE All-Sky release and in principle allows us to explore a considerably larger volume. We discuss some of the limitations of the data for studies of Galactic substructure.

Author(s): Carl J. Grillmair[1]
Institution(s): *1. Caltech*

434 – Computation, Data Handling and Other Matters Posters

434.01 – Spherical harmonic transit analysis with PAPER

We discuss the implementation of an all-sky spherical harmonic transit analysis in the context of observed data from the Donald C. Backer Precision Array for Probing the Epoch of Reionization (PAPER). The technique (Shaw et al. 2014a,b), dubbed the m-mode formalism, circumvents the flat-sky approximation of traditional interferometric analysis and is presented as an option for more effective analysis for instruments investigating 21 cm cosmology. Using this framework, we apply PAPER data obtained from 32 dual-polarization antennas and show preliminary results for imaging. We explore these results and discuss further implications of this m-mode formalism towards data analysis of PAPER including other antenna array configurations and polarization sources.

Author(s): Jason Ling[1], Saul Aryeh Kohn[1], James E. Aguirre[1]
Institution(s): *1. University of Pennsylvania*
Contributing team(s): The PAPER Collaboration

434.02 – Time-domain Surveys and Data Shift: Case Study at the intermediate Palomar Transient Factory

Next generation time-domain surveys are susceptible to the problem of data shift that is caused by upgrades to data processing pipelines and instruments. Data shift degrades the performance of automated machine learning classifiers that vet detections and classify source types because fundamental assumptions are violated when classifiers are built in one data regime but are deployed on data from another. This issue is not currently discussed within the astronomical community, but will be increasingly pressing over the next decade with the advent of new time domain surveys.

We look at the problem of data shift that was caused by a data pipeline upgrade when the intermediate Palomar Transient Factory (iPTF) succeeded the Palomar Transient Factory (PTF) in January 2013. iPTF relies upon machine-learned Real-Bogus classifiers to vet sources extracted from subtracted images on a scale of zero to one where zero indicates a bogus (image artifact) and one indicates a real astronomical transient, with the overwhelming majority of candidates are scored as bogus. An effective Real-Bogus system filters all but the most promising candidates, which are presented to human scanners who make decisions about triggering follow up assets.

The Real-Bogus systems currently in operation at iPTF (RB4 and RB5) solve the data shift problem. The statistical models of RB4 and RB5 were built from the ground up using examples from iPTF alone, whereas an older system, RB2, was built using PTF data, but was deployed after iPTF launched. We discuss the machine learning assumptions that are violated when a system is trained on one domain (PTF) but deployed on another (iPTF) that experiences data shift. We provide illustrative examples of data parameters and statistics that experienced shift. Finally, we show results comparing the three systems in operation, demonstrating that systems that solve domain shift (RB4 and RB5) are superior to those that don't (RB2).

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434.03 – A new ultra-fast Moving Object Discovery Engine for iPTF, ZTF, and beyond

We have developed an efficient and generic Moving Object Discovery Engine (MODE) designed to operate on transient-source catalogs extracted from difference-imaging, or on catalogs where stationary sources have been filtered-out as best as possible. The intent is to support current and upcoming large time-domain surveys that will detect tens of thousands of astrophysical transients per night. The moving-object tracklet-forming algorithm uses a high level of parallelism optimized for the latest in multicore/vector processor technologies. With minimal vetting of transients detected by the intermediate Palomar Transient Factory's (iPTF) real-time difference-imaging pipeline, MODE can detect moving-objects at completeness and reliability levels of >~ 90% and >~ 99% respectively to R_PTF ~ 19.5 mag. MODE's performance on iPTF data demonstrates its adaptability to future surveys, in particular the Zwicky Transient Facility (ZTF) currently under development. ZTF will survey the sky ~10 times faster than iPTF using a 47 square-degree field of view, enabling moving-object discoveries over larger volumes and velocity ranges. It is therefore crucial that the discovery process be efficient, reliable, and fast enough for the follow-up of objects in near real-time.

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434.04 – Comparing the Mass Functions of Simulated Galaxies

We examine and compare two cosmological hydrodynamical simulations run with different codes, but with the same initial conditions. The two codes, *ENZO* and *RAMSES*, use adaptive mesh refinement methods. The codes produce similar mass Milky Way like galaxies at redshift zero, though we found the *ENZO* galaxy to be more massive. Using the simulation's visualization and analysis program *yt* and the halo finding software *Rockstar*, we identify dark matter halos in the two simulations and compare their stellar and gas contents. Surprisingly, we find that while the most massive halo in the *ENZO* run has a more massive galaxy than the RAMSES run, in lower mass halos the situation is reversed. *ENZO* consistently produces less massive galaxies than *RAMSES*. These results give us insight into how differences in feedback implementation affect independent mass scales separately

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434.05 – A New Laboratory for MM-/Sub-MM-Wave Characterization of Cosmic Dust Analogs

Most studies conducted with observatories such as ALMA, SOFIA, PLANCK, and Herschel will benefit from knowledge of (1) the predominant cosmic dust species in various environments, in terms of composition and structure and (2) mm/sub-mm optical properties of cosmic dusts, including the temperature dependent-emissivity and spectral index. A new laboratory has been established for producing and characterizing (in the mm/sub-mm) various silicate/carbonaceous dust candidates. In particular, the optical measurement setup was custom designed, specifically for laboratory studies of dusts, using techniques borrowed from observational cosmology. It features novel designs for a compact Fourier Transform Spectrometer (FTS) and a cold sample holder/exchanger. Construction of this apparatus is now complete; we are currently testing the system. Here, we present the mm/sub-mm measurement scheme and highlight its innovative and aspects.

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434.06 – IPAC Firefly package goes open source

IPAC Firefly package has been developed in IRSA (NASA/IPAC Infrared Science Archive) in last six years. It is a software package utilizing state-of-the art AJAX technology to provide an interactive web user interface for astronomers. It has been used to build Spitzer Heritage Archive, WISE Image Service, Planck Visualization, PTF Image Service, and the new IRSA finder chart. It provides three major components: table display, FITS images visualization, and 2D plot. All three highly interactive components can work together using the same data model or separately to provide any combinations of interactivities among them. Firefly toolkits provide an easy way to put interactivities in an otherwise static web page. With a few lines of simple JavaScript embebded in a web page, Firefly toolkits can add manipulative functions to a static table, display a FITS image, or draw an XY 2D plot interactively.

FIrefly will be in the GItHub soon.

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Contributing team(s): IRSA IPAC

435 – Dwarf and Irregular Galaxies Posters

435.01 – Turbulence and Star Formation in Dwarf Galaxies

We are interested in understanding the nature and role of turbulence in the interstellar medium of dwarf irregular galaxies. Turbulence, resulting from a variety of processes, is a potential source for cloud formation, and thus star formation. We have undertaken an indirect analysis of turbulence via the third (skewness) and fourth (kurtosis) moments of the distribution of atomic hydrogen gas densities using the LITTLE THINGS data for a 40-count sample of nearby (<10.3 Mpc) dwarf galaxies. We followed the formulism used by Burkhart et al. (2010) in a study of the SMC. We found that there is evidence of turbulence in dwarf galaxies at a level comparable to that found in the SMC, but we have found no correlation between integrated star formation rates and integrated kurtosis values nor a clear correlation between kurtosis as a function of radius with gas surface density and star formation profiles. We are grateful for a summer internship provided by the Research Experiences for Undergraduates program at Northern Arizona University, run by Dr. Kathy Eastwood and Dr. David Trilling and funded by the National Science Foundation through grant AST-1004107.

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Contributing team(s): LITTLE THINGS team

435.02 – The Fraction of Binaries in the Distant Dwarf Spheroidal Leo II

The dwarf spheroidal galaxy, Leo II, is one of the most remote galaxies around the MW of its type, with a heliocentric distance of ~230 kpc. We conducted a large spectroscopic survey of 337 red giants in the direction of Leo II, and conclude 169 of them are members based on their radial velocities, surface gravities, and metallicities. Our calculated values for total mass, velocity dispersion, and mass-to-light ratio are consistent with those in the literature. Though we identify one star beyond the tidal radius of Leo II, there is no other evidence that the dwarf has been affected by tides. Most of the stars in our sample were observed multiple times over the course of eight years; combining our radial velocities with those in the literature, we have a baseline of 19 years, which allows us to explore a large range of orbital parameters for binary systems and ultimately quantify the fraction of binaries within Leo II.

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436 – Education and Public Outreach Thursday Posters

436.01 – Hubble’s 25th Anniversary: A Quarter-Century of Discovery and Inspiration

April 24, 2015 marks the 25th anniversary of the launch of the Hubble Space Telescope. In its quarter-century in orbit, the Hubble Space Telescope has transformed the way we understand the Universe, helped us find our place among the stars, and paved the way to incredible advancements in science and technology. NASA and ESA, including STScI and partners, will use the 25th anniversary of Hubble’s launch as a unique opportunity to communicate to the widest possible audience the significance of the past quarter-century of discovery with the Hubble Space Telescope and to highlight that Hubble will continue to produce groundbreaking science results. We will enhance public understanding of Hubble’s many contributions to the scientific world, and will capitalize on Hubble’s cultural popularity by emphasizing its’ successor, the James Webb Space Telescope. This poster highlights many of the upcoming opportunities to join in the anniversary activities, both in-person and online. Find out more at hubble25th.org and follow #Hubble25 on social media.

Author(s): Amber Straughn[1], Hussein Jirdeh[2]
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436.02 – New *Hubble Space Telescope* Multi-Wavelength Imaging of the Eagle Nebula

One of the most iconic images from the *Hubble Space Telescope* has been the 1995 WFPC2 image of the Eagle Nebula (M16, sometimes known as the "Pillars of Creation"). Nineteen years after those original observations, new images have been obtained with *HST*'s current instrumentation: a small mosaic in visible-light, narrow-band filters with WFC3/UVIS, infrared, broad-band filters with WFC3/IR, and parallel Hα imaging with ACS/WFC. The wider field of view, higher resolution, and broader wavelength coverage of the new images highlight the improved capabilities of *HST* over its long-lasting operation, made possible by the upgraded instrumentation installed during Space Shuttle servicing missions. Csite images from these datasets are presented to commemorate the 25th anniversary of *HST*'s launch. Carefully combined, aligned and calibrated datasets from the primary WFC3 fields are available as High-Level Science Products in MAST (http://archive.stsci.edu/prepds/heritage/). Color composite images from these datasets are presented to commemorate the 25th anniversary of *HST*'s launch.

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Contributing team(s): Hubble Heritage

436.03 – Development of an Interdisciplinary STEM Classroom Activity for Radio Receiver Technology

<u>Introduction</u> The development of a mini STEM-based classroom activity designed to integrate these two fields into one project for middle school aged students is presented here. This lesson involves small groups of students constructing a small AM radio receivers. The lesson surrounding the activity focuses on both the physical nature of electromagnetic and AC waves, circuit design, practical applications to AM radio broadcasting, and research applications of radio telescopes. These tools have shown a significant increase in the lesson's primary concept understanding among 6th grade students, as well as net positive STEM awareness and enthusiasm.
<u>Content</u> The primary teaching point for the students to consider and learn during this lesson is “How does scientific application influence engineering design, and vice versa?” The lesson surrounds the hands-on activity of having students construct their own AM radio receiver. Wave theory and the use of radio instruments for astronomy research are also taught in a traditional lecture format. The activity is designed to complement middle school curriculum, although it has been tested and found suitable for high school and older students as well as the general public.
<u>Evaluation and Impact</u>
The evaluation tool that used for the student groups in this project was a Fryer chart, which is a four panel chart with the main topic listed in the center and a single question in each of the four panels. The students are asked to answer the

questions in the chart before and after they participate in the lesson activity, each time in a different colored pencil so that the scores can be given to each student before and after they participated in the activity. Student scores improved from 4.5 to 17.9 out of a total of 20 possible points. This is an overall increase of 67% of the total possible points. The questions asked on the quiz cover the range of wave theory, circuit design, and scientific explanation. This factor of improvement shows that the lesson designed for this fellowship project is effective at teaching students about each of those concepts with a single teaching activity.

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436.04 – Launching Astronomy: Standards and STEM Integration (LASSI)

While astronomy is prevalent in the Next Generation Science Standards, it is often relegated to the "4th nine-weeks" in middle and high school curricula. I.e., it is taught at the end of the year, if time permits. However, astronomy ties in many core ideas from chemistry, earth science, physics, and even biology (with astrobiology being an up-and-coming specialization) and mathematics. Recent missions to Mars have captured students' attention and have added excitement to the fields of engineering and technology. Using astronomy as a vehicle to teach science, technology, engineering, and mathematics (STEM) connects these disciplines in an engaging way. The workshop entitled, "Launching Astronomy: Standards and STEM Integration," (LASSI) is a year-long professional development (PD) opportunity for teachers in grades K-12 to use astronomy as a vehicle to teach STEM and implement science standards through astronomy. Eight teachers participated in a two-week summer workshop and six follow-up sessions are scheduled during the 2014-2015 school year. Additional teachers plan to participate in the upcoming follow-up sessions. We evaluate the effectiveness of the LASSI PD to identify and confront teachers' misconceptions in astronomy, and discuss whether teachers identified topics for which astronomy can be used as a vehicle for standards-based STEM curricula. Teachers from around Wyoming were invited to participate. Participating teachers were surveyed on the quality of the workshop, their astronomy content knowledge before and after listening to talks given by experts in the field, conducting standards-based inquiry activities, developing their own lessons, and their level of engagement throughout the workshop. Two-thirds of teachers planned to incorporate LASSI activities into their classrooms in this school year. Teachers' misconceptions and requests for astronomy-based curriculum were identified in the summer session. These will be addressed during the follow-up session. Ninety percent of teachers reported being highly engaged at least 75% of the time. The majority of teachers also anticipated using activities from LASSI in their classrooms.

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436.07 – Authentic Mars Research in the High School

As a 11th and 12th grade Astrobiology class we were charged with developing a scientific research question about the potential for life on Mars. We narrowed our big picture question to, "Where should the next Mars rover land in order to study the volcanic and water features to find evidence of past or present extremophiles on Mars?"
After a lot of searching through images on JMARS (although not extensive due to high school time constraints) we narrowed our interest to three areas of Mars we thought could be good candidates to land a rover there to do further research. We know from extremophiles on Earth that microscopic life need water and energy. It seems reasonable that Mars would be no different. We developed a research question, "Does Kasei Valles, Dzigai Vallis and Hecate Tholus have volcanic features (lava flow, fractures, volcanoes, cryovolcanoes) and water features (layers of ice, hematite, carbonate, chaos)?"
This question is important and interesting because by having a deeper understanding of whether these places have evidence of volcanic and water features, we will be able to decide where the best place to land a future rover would be. Evidence of volcanic and water features are important to help determine where to land our rover because in those areas, temperatures could have been warm and the land could be wet. In these conditions, the probability of life is higher.
We individually did research through JMARS (CTX, THEMIS) in order to establish if those three areas could contain certain land features (volcanic and water features) that could possibly lead to the discovery of extremophiles. We evaluated the images to determine if the three areas have evidence of those volcanic and water features.
Although we are not experts at identifying features we believe we have evidence to say that all three areas are interesting, astrobiologically, but Dzigai Vallis shows the most number of types of volcanic and water features. More importantly, through this process we as a class began to understand true authentic science and how it is performed.
Thank you to Arizona State University for the curriculum and guidance.

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437 – Evolution of Galaxies Posters

437.01 –
Morphological Transformation and Star Formation Across Cosmic Time

We derive the median morphological and star formation activity for five samples of galaxies across a look-back time of 12 Gyr. The galaxy samples are selected using the Mean Abundance Matching technique as a way of matching progenitors and descendant galaxies. The five samples represent z=0 stellar masses of log(M*/Msun)=10.0 - 11.2, corresponding to z=0 dark matter halos of log(Mh/Msun)=11.5 - 13.5. Using the CANDELS GOODS-S and UDS samples we are complete up to z=2.2, 2.6, 3.6 for the three lowest mass bins and up to z=4 for the two highest mass bins. The morphology of each galaxy is quantified through the single-component Sersic index. With the exception of the galaxies in least massive bin, the average Sersic index at high redshift indicates a disk-like morphology, while at lower redshift the average Sersic index indicates a spheroidal light distribution. The morphology for galaxies in the lowest mass bin remains disk-like from z~2.2 to the limit of completeness at z~0.5. The star formation rate is derived for each galaxy using the dust corrected restframe 1500A luminosity. The galaxies undergo a decrease in star formation activity by ~2-3 orders of magnitude with the most massive systems starting their transformation of star formation activity at earlier times than less massive systems. The transformation of morphology and star formation is decoupled in the sense that galaxies transforms from actively star forming disk-like systems to quiescent disks and only subsequently transform into spheroidal or bulge dominated systems.

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Contributing team(s): CANDELS Team

437.02 – Evolution of ULIRGs Among a Mass-Complete Sample to z=1.1 with MAGES

The MIPS AGN and Galaxy Evolution Survey (MAGES) imaged 9 deg^2 of the Boötes field in all 3 MIPS bandpasses. Using the MAGES 24µm source catalog, which reaches a depth of 0.12 mJy, in combination with both photometric and spectroscopic ancillary data available in the field, we model the spectral energy distributions of a flux-complete sample of 4.5µm-selected galaxies. We use these models to generate likelihood functions for total-infrared (TIR) luminosities and stellar masses for each object, and we use the resulting likelihood functions to determine redshift-dependent TIR luminosity functions and stellar mass functions. We use these functions to determine the evolution in the ULIRG population relative to a comparison sample of galaxies with $M>10^{10}M^{sun}$. We present the results of this analysis and compare the evolution in the measured ULIRG population to evolution in the predicted merger rates using N-body simulations.

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Contributing team(s): The MAGES Team

437.03 – Characterizing a Large-Scale Structure with a Forming Cluster at z=2.44

Wide field surveys of emission line galaxies has enormous potential for studying galaxy cluster formation during the epoch at z≥2 before virialization erased the signatures of the rapid mass assembly and galaxy growth. Here we demonstrate a characterization of a large-scale structure at z=2.44 in COSMOS field using Lyα-selected galaxies (LAEs) discovered in the blind integral field spectroscopy of the HETDEX Pilot Survey (HPS), supplemented with broadband selected galaxies with photometric redshift (photo-z). The structure shows a high concentration of LAEs and a significant volume overdensity in stellar mass of photo-z galaxies. Detailed modeling using cosmological simulations of galaxy formation suggests that part of the structure will collapse to form a galaxy cluster of $\sim10^{14.5}$ $M^{\odot}$ by z=0. A clear excess of extended Lyα halos are found in the structure, some of which are identified as AGN in the X-ray. This indicates that large scale overdense environment might be effective in shaping the co-evolution of galaxies and their supermassive black holes.

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Contributing team(s): HETDEX collaboration

437.04 – UV to FIR SED-fitting with CIGALE on Local Luminous and Ultraluminous Infrared Galaxies from the *IRAS* 2 Jy Redshift Survey

Understanding the connection between nuclear starbursts and AGN in luminous infrared galaxies (LIRGs; 10^{11} < L^{IR} <

10^{12} $L^{\odot}$) and ultraluminous infrared galaxies (ULIRGs; $10^{12} < L^{IR} < 10^{13}$ $L^{\odot}$) is crucial for understanding how these galaxies and galaxies in general evolve, and how the evolution of a galaxy relates to that of its central supermassive black hole (SMBH). To this effort, we perform UV to FIR SED-fitting with CIGALE (Code Investigating GALaxy Emission) for 34 U/LIRGs ($10^{11} < L^{IR} < 10^{13}$ $L^{\odot}$) from the *IRAS* 2 Jy Redshift Survey with $0.01 < z < 0.16$. CIGALE allows for the estimation of numerous physical properties by means of a Bayesian-like analysis, but for this work we focus on derived outputs for the star formation rate (SFR), AGN contribution, D4000, stellar mass (M^{star}), young stellar population age (i.e. the age of the most recent starburst activity), and starburst mass fraction.
First, we find evidence that nuclear starbursts form first in U/LIRGs, and also find that U/LIRGs with relatively similar SFRs have increased AGN activity if they are older. Then, we quantify the timescales at which the starburst activity in our U/LIRGs evolves with the use of the Tukey-Kramer method of statistical analysis, and by fitting an exponential curve to the data to describe the expected amount of decrease in SFR seen for a U/LIRG in our sample over a given change in starburst age. Finally, we find evidence that the stellar mass and burst fractions influence whether a U/LIRG in our sample will have a strong AGN and high SFR, respectively. We compare the SFR-M^{star} relationship seen in our sample with those predicted by models and found from previous observations. We find that the U/LIRGs with older starbursts (>125 Myr) agree with previously found results, while those with younger starbursts show a large dispersion in M^{star}. We conclude that this is supporting evidence that the star formation histories and timescales at which the IR power sources in U/LIRGs evolve are responsible for the scatter found for the SFR-M^{star} relationship.

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437.05 – The dwarf galaxy population of nearby galaxy clusters

The Fornax, Virgo, Ursa Major and Perseus galaxy clusters all have very different characteristics, in terms of their density, mass, and large-scale environment. We can regard these clusters as laboratories for studying environmental influence on galaxy evolution, using the sensitive low-mass galaxies as probes for external mechanisms. Here we report on recent and ongoing observational studies of the said clusters with imaging and spectroscopy, as well as on the interpretation of present-day cluster galaxy populations with the aid of cosmological simulations.
Multicolor imaging data allow us to identify residual star formation in otherwise red early-type dwarf galaxies, which hold clues to the strength of gas stripping processes. Major-axis spectra and 2D kinematical maps provide insight regarding the amount of rotational support and how much dynamical heating a dwarf galaxy may have experienced. To this end, dedicated N-body simulations that follow the evolution of galaxies since early epochs reveal their path through parameter space, and can be compared to observations in order to understand the time-integrated effect of environmental influence.

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Contributing team(s): SMAKCED collaboration, FOCUS collaboration

437.06 – Sussing Merger Trees: The Impact of Halo Merger Trees on Galaxy Properties in a Semi-Analytic Model

Halo merger trees are essential backbones of a semi-analytic model for galaxy formation and evolution. Recent studies have pointed out that extracting merger trees from numerical simulations of structure formation using different tree building algorithms can give differing merger histories. To understand the uncertainties developed from these differences in galaxy formation models, we investigate the impact of different halo merger trees on galaxy properties in a semi-analytic model. We find that the galaxy properties in our model differ between trees when using a common parameter set. The star formation history and the number density of galaxies show marked differences between trees with different construction algorithms. The semi-analytic model can be calibrated for each tree to reduce the discrepancies between the z=0 global galaxy properties, at the cost of increasing the differences in the evolutionary histories of galaxies. The calibration is carries out by adjusting key quantities such as the supernova feedback efficiency differing by factor of 2. Such a change affects the regimes where star formation is primarily suppressed by supernovae. Therefore, halo merger trees extracted from a common halo catalogue using different, but reliable, algorithms can result in a difference in the semi-analytic model. Given the uncertainties in galaxy formation physics, however, these differences may not be viewed as significant.

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437.07 –
NGC 5523: An Isolated Product of a Soft Galaxy Merger

Isolated galaxies are sometimes considered to be systems that have evolved with minimal influence from galaxy-galaxy interactions. The late-type isolated spiral galaxy NGC 5523 offers a counter example to this assumption. Our analysis of multi-band imaging of this system shows a number of unusual features consistent with NGC 5523 (D=20 Mpc) having experienced a significant merger: (1) Near infrared imaging from WHIRC on the WIYN 3.5-m telescope and the Spitzer Space Telescope reveal a nucleated bulge-like structure that is offset from the center of the outer disk by approximately 1 kpc. (2) A feature with characteristics of a tidal stream extends from the bulge structure along the disk. (3) The outermost disk is somewhat asymmetric and appears to have a low density of older stars. We interpret these properties as the results of a past non-disruptive merger between NGC 5523 and a former companion galaxy, which raises the possibility that some galaxies are isolated because they have merged with former companions.

Author(s): Leah Fulmer[1], John S. Gallagher[1], Zishan Xia[1]
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437.08 – The impact of feedback on merger-driven bulge growth

Galaxy mergers have long been assumed to produce classical bulges in disk galaxies. Under this bulge-formation model, though, the high rates of mergers in Cold Dark Matter galaxy formation theory predict many more classical bulges than are observed. Furthermore, simulations of galaxy formation continue to generally produce too massive of bulges. Feedback offers a promising avenue for reducing merger-driven bulge growth by maintaining high gas fractions in galaxies and ejecting gas driven to the centers of galaxies. Here, we use cosmological simulations to explore the ability of feedback to reduce or even prevent bulge growth during mergers. In dwarf galaxies, mergers actually reduce the central concentration of galaxies as the induced burst of star formation drives out low angular momentum material. This result demonstrates the potential for feedback to reduce central mass growth. However, we also show that stellar feedback alone cannot reproduce the small bulges observed in more massive disk galaxies like the Milky Way and argue for an additional source of feedback, such as AGN, to generate the outflows necessary to reproduce observed bulge properties and frequencies.

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437.09 – Pixel-by-Pixel SED Fitting of Intermediate Redshift Galaxies

We select intermediate redshift galaxies from the Hubble Space Telescope CANDELS and GOODS surveys to study their stellar populations on sub-kilo-parsec scales by fitting SED models on a pixel-by-pixel basis. Galaxies are chosen to have measured spectroscopic redshifts (z<1.5), to be bright (H_AB<21 mag), to be relatively face-on (b/a > 0.6), and have a minimum of ten individual resolution elements across the face of the galaxy, as defined by the broadest PSF (F160W-band) in the data. The sample contains ~200 galaxies with BViz(Y)JH band HST photometry. The main goal of the study is to better understand the effects of population blending when using a pixel-by-pixel SED fitting (pSED) approach. We outline our pSED fitting method which gives maps of stellar mass, age, star-formation rate, etc. Several examples of individual pSED-fit maps are presented in detail, as well as some preliminary results on the full sample. The pSED method is necessarily biased by the brightest population in a given pixel outshining the rest of the stars, and, therefore, we intend to study this apparent population blending in a set of artificially redshifted images of nearby galaxies, for which we have star-by-star measurements of their stellar populations. This local sample will be used to better interpret the measurements for the higher redshift galaxies.

Based on observations made with the NASA/ESA Hubble Space Telescope, obtained from the Data Archive at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. This archival research is associated with program #13241.

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438 – Extrasolar Planets Posters

438.01 – Determining the architecture of the Kepler-297 system using transit timing variations

It is essential to explore the architectures of exoplanetary systems as we attempt to understand planet formation histories and determine the rate of occurrence of habitable-zone rocky planets. We focus on the Kepler-297 system which hosts three transiting planets, Kepler-297b, Kepler-297c, and KOI-1426.03. We re-analyze extant *Kepler* data of the system, as well as new *Spitzer* data of Kepler-297c, to constrain the transit time variations (TTVs) of the three transiting planets in the system. We feed these results into a dynamical analysis in which the TTVs of the transiting planets constrain their orbital parameters, as well as those of potential non-transiting planets. The gravitational interactions between the Kepler-297 planets allow us to derive their mass ratios. We find that the orbital parameters of the three transiting planets are well-fit by a model that includes a non-transiting fourth planet outside of the three transitors. We are also able to constrain the orbital parameters of the outer-most transitor, thereby confirming it as the planet Kepler-297d.

Author(s): Hannah Diamond-Lowe[3], Kevin B. Stevenson[3], Daniel Fabrycky[3], Sarah Ballard[4], Eric Agol[4], Jacob Bean[3], Matthew J. Holman[2], Darin Ragozzine[1]
Institution(s): *1. Florida Institute for Technology, 2. Harvard-Smithsonian Center for Astrophysics, 3. University of Chicago, 4. University of Washington*

438.02 – Validation of Twelve Small Kepler Transiting Planets in the Habitable Zone

We report on the work to validate twelve candidate-transiting planets from Kepler with orbital periods ranging from 34 to 207 days initially identified in the pipeline search of three years of Kepler data from quarters 1 to 12. The candidates were selected based on pipeline Data Validation models indicating that they are small and potentially in the habitable zone (HZ) of their parent stars. As their expected Doppler signals are too small for a direct measure of their masses, we verify their planetary nature by validating them statistically using the BLENDER technique. BLENDER simulates large numbers of false-positive scenarios and compares the resulting light curves with the Kepler photometry, taking into account additional information from the analysis of Kepler flux centroids and new follow-up observations, including high-resolution optical and NIR spectroscopy, adaptive optics imaging, and speckle imaging. For eleven of the candidates we show that the likelihood they are true planets is far greater than that of a false positive, to a 99.73% confidence level. For the twelfth candidate, the planet confidence level is about 99.2%. Using improved stellar parameters for the host stars, we derive planetary radii ranging from 1.12 to 2.73 $R^{\oplus}$. All twelve objects are confirmed to be in the HZ, and nine are small enough to be rocky. Excluding three of the candidates that have been previously validated by others, our study doubles the number of known potentially rocky planets in the HZ.

Author(s): Douglas A. Caldwell[10], Guillermo Torres[4], David M. Kipping[4], Sarah Ballard[13], Natalie Batalha[6], William J. Borucki[6], Steve Bryson[6], David R. Ciardi[7], Justin R. Crepp[12], Mark Everett[8], Francois Fressin[4], Christopher Henze[6], Elliott Horch[11], Andrew Howard[5], Steve B. Howell[6], Howard T. Isaacson[1], Jon Michael Jenkins[6], Rea Kolbl[1], Geoffrey W. Marcy[1], Sean D McCauliff[9], Philip Steven Muirhead[3], Elizabeth Newton[4], Erik Petigura[1], Joseph D. Twicken[10], Elisa V. Quintana[6], Thomas Barclay[2]
Institution(s): *1. Astronomy Department, UC Berkeley, 2. Bay Area Environmental Research Corp., 3. Department of Astronomy, Boston University, 4. Harvard-Smithsonian Center for Astrophysics, 5. Institute for Astronomy, UH Manoa, 6. NASA Ames Research Center, 7. NASA Exoplanet Science Institute, 8. National Optical Astronomy Observatory, 9. Orbital Sciences Corp, NASA ARC, 10. SETI Institute, 11. Southern Connecticut State University, 12. University of Notre Dame, 13. University of Washington*

438.03 – Multifractal structures in radial velocity measurements for exoplanets

The radial velocity method is a powerful way to search for exoplanetary systems and it led to many discoveries of exoplanets in the last 20 years.
Nevertheless, in order observe Earth-like planets, such method needs to be refined, i.e. one needs to improve the signal-to-noise ratio.
On one hand this can be achieved by building spectrographs with better performances, but on the other hand it is also central to understand the noise present in the data.
Radial-velocity data are time-series which contains the effect of planets as well as of stellar disturbances. Therefore, they are the result of different physical processes which operate on different time-scales, acting in a not always periodic fashion
I present here a possible approach to such problem, which consists in looking for multifractal structures in the time-series coming from radial velocity measurements, identifying the underlying long-range correlations and fractal scaling properties, and connecting them to the underlying physical processes, like stellar oscillation, granulation, rotation, and magnetic activity.
This method has been previously applied to satellite data related to Arctic sea albedo, relevant for identify trends and noise in the Arctic sea ice (Agarwal, Moon and Wettlaufer, Proc. R. Soc., 2012).
Here we use such analysis for exoplanetary data related to possible Earth-like planets.
Moreover, we apply the same procedure to synthetic data from numerical simulation of stellar dynamos, which give insight on the mechanism responsible for the noise. In such way we can therefore raise the signal-to-noise ratio in the data using the synthetic data as predicted noise to be subtracted from the observations.

Author(s): Fabio Del Sordo[1]
Institution(s): *1. Yale University*
Contributing team(s): Sahil Agarwal, Debra A. Fischer, John S. Wettlaufer

438.04 – Finding Circumbinary Planets via Microlensing

Each of the circumbinary planets discovered so far using Kepler have separations of about 1 AU or less from their host binary. Microlensing can detect circumbinary planets at larger separations, which would be valuable for learning more about the formation of these planets. However, it is first important to know if circumbinary planets would be detected as such via microlensing. This largely depends on the shapes of the caustics of the system, which determine the lightcurves that would be observed. Here we examine the caustic structures of circumbinary systems. We also present animations showing how these caustics are affected by the parameters of the stellar binary. By examining the caustic structures, we can see which circumbinary systems are more likely to be detected.
It is also possible to estimate the fraction of circumbinary planets that would be detected. When the trajectory of the lensed star crosses a caustic, the lightcurve exhibits a noticeable spike. By comparing the number of caustic crossings in the circumbinary systems to the number of caustic crossings in similar systems that do not contain a circumbinary planet, we can estimate the percentage of detectable circumbinary planets. We find that when the binary separation is large enough, detection of both the planet and the binary would be possible up to 50 percent of the time.

Author(s): Jacob K. Luhn[1], Matthew Penny[1], B. Scott Gaudi[1]
Institution(s): *1. Ohio State University*

438.05 – Multiplexed Fiber Spectroscopy at Magellan: Searching for Exoplanets in Star Clusters

The Michigan/Magellan Fiber System (M2FS) is a new multi-object spectrograph for the Magellan/Clay 6.5 m telescope at the Las Campanas Observatory in Chile. M2FS is capable of attaining 35 - 100 m/s radial velocity (RV) precision while also measuring T^{eff} and other stellar parameters for for 256 targets simultaneously to about V = 15. In November 2013 we began a study of the open clusters NGC 2422 and NGC 2516 to test the precision capabilities of M2FS; study their internal kinematics, binaries, and stellar activity; and begin a search for hot gas giant companions. We present an overview of the diverse capabilities of M2FS and report preliminary results for both clusters. Finally, we describe a planed survey of about 1500 stars in eight nearby open clusters spanning ages from 100 Myr to 1 Gyr. This survey is designed to help constrain exoplanet formation and migration theories by identifying a significant sample hot gas giants with a range of well known ages.

Author(s): John Ira Bailey[3], Mario L. Mateo[3], Russel J. White[2], Jeffrey D. Crane[1]
Institution(s): *1. Carnegie Observatories, 2. Georgia State University, 3. University of Michigan*

438.06 – Next Generation Visible Nulling Coronagraph

We present efforts to advance an approach to broadband, high-order, starlight suppression for enabling direct detection and characterization of exoplanetary systems with arbitrary telescope apertures using a single nuller. The techniques being advanced include phase-occulting optics and a wavefront control strategy modified to incorporate achromatic phase shifters. Both polarization components are nulled simultaneously. Science yield with future large aperture telescopes is discussed.

Author(s): Brian Hicks[1], Richard Lyon[1], Mark Clampin[1], Matthew R Bolcar[1], Udayan Mallik[1], Eric Mentzell[1], Peter Petrone[2]
Institution(s): *1. NASA/GSFC, 2. Sigma Space Corporation*

438.07 – First Semester Science Operations with the Gemini Planet Imager

The Gemini Planet Imager (GPI) has now gone through its first six months of operations at Gemini South, starting in August 1st, 2014 and finishing in January 31st, 2015. We present here the experiences in integrating and operating the instrument in mixed queue and classical modes. A total of 72 hours of observations was accepted out of a total of proposed 266 hours, out of a total of 2469 hours for all instruments at Gemini South. The 72 hours were distributed over 12 programs from almost all partner countries. In addition to the standard classical and queue time 140 hours was assigned to the GPIES campaign.

Author(s): Fredrik Tord Rantakyro[1], Pascale Hibon[1], Andrew Cardwell[1], Naru Sadakuni[1], Carlos Quiroz[1], Rene Rutten[1], Gaston Gausachs[1], Ramon Galvez[1]
Institution(s): *1. Gemini Observatory*
Contributing team(s): GPI Commissioning Team, GPIES team

438.08 – Measuring the Mass of Kepler-78b Using a Gaussian Process Model

Kepler-78b is a transiting planet that is 1.2 times the size of Earth and orbits a young K dwarf every 8 hours. Howard et al. (2013) and Pepe et al. (2013) independently reported the mass of Kepler-78b based on radial velocity measurements using the HIRES and HARPS-N spectrographs, respectively. In this study, a nonparametric model of the stellar activity observed in radial velocity measurements is made using Gaussian process regression, a novel technique in the field of radial velocity analysis, allowing the planetary Doppler signal to be modeled more accurately. By fitting the stellar activity with various Gaussian process regression models, we find a more precise measurement of the planet Doppler amplitude. We identify a superior Gaussian process model, and reanalyze both radial velocity datasets acquired by Howard et al. (2013) and Pepe et al. (2013) with this new technique. The Doppler amplitude of Kepler-78b is measured to be 1.92 +/- 0.25 m s^{-1}, which corresponds to a mass of 1.93 +/- 0.27 M^E, a 2.5-sigma improvement on the measurement of Howard et al (2013). This corresponds to a density of 6.1+1.9/-1.4 g cm^{-3}, and an iron mass fraction of 0.32 +/- 0.26, assuming a two component rock-iron composition. This is consistent with an Earth-like composition, with uncertainties ranging from Moon-like to Mercury-like. Better understanding of the composition of Kepler-78b is an integral part of understanding rocky planet formation.

Author(s): Samuel Kai Grunblatt[1], Andrew Howard[1], Raphaëlle Haywood[2]
Institution(s): *1. University of Hawaii-Manoa, 2. University of St. Andrews*

438.09 – Thermal Structure of WASP-43b from Phase-Resolved Emission Spectroscopy

Previous exoplanet phase-curve observations have revealed day-night temperature contrasts and hot-spot offsets relative to the substellar point. However, the interpretation of these broadband photometry measurements were limited due to an inherent degeneracy between the atmospheric composition and thermal structure. We will present the first spectroscopic phase-curve measurements for the hot-Jupiter exoplanet WASP-43b spanning three full planet rotations using the Hubble Space Telescope. With these data, we will show a 2D map of the planet's atmospheric thermal structure, discuss its day-night heat redistribution, and demonstrate an altitude dependence in the hot-spot offset relative to the substellar point. We will also present new results from a recent phase-curve measurement of WASP-43b using the Spitzer Space Telescope.

Author(s): Kevin B. Stevenson[3], Jean-Michel Desert[4], Michael R. Line[1], Jacob Bean[3], Jonathan J. Fortney[1], Adam P. Showman[2], Tiffany Kataria[2], Laura Kreidberg[3]
Institution(s): *1. UC Santa Cruz, 2. University of Arizona, 3. University of Chicago, 4. University of Colorado*

438.10 – Super earth interiors and validity of Birch's Law for ultra-high pressure metals and ionic solids

Super Earths, recently detected by the Kepler Mission, expand the ensemble of known terrestrial planets beyond our Solar System's limited group. Birch's Law and velocity-density systematics have been crucial in constraining our knowledge of the composition of Earth's mantle and core. Recently published static diamond anvil cell experimental measurements of sound velocities in iron, a key deep element in most super Earth models, are inconsistent with each other with regard to the validity of Birch's Law. We examine the range of validity of Birch's Law for several metallic elements, including iron, and ionic solids shocked with a two-stage light gas gun into the ultra-high pressure, temperature fluid state and make comparisons to the recent static data.

Author(s): Lucas Andrew Ware[1]
Institution(s): *1. Seattle University*

438.11 – Building massive, tightly packed planetary systems by in-situ accretion of pebbles

The distribution of mass in planetary systems is one of the most important constraints available for understanding the process of planet formation. One particularly interesting observation is the large number of super-Earth sized planets in short period orbits and tightly packed systems. The amount of mass in these systems is about ten times what would be expected if they had surface density disributions similar to the solar system (i.e. the minimum mass solar nebula) extrapolated inwards of half an AU. This observation raises the question: how and when did all that mass get there? In this work we explore the idea that the radial drift and eventual accretion of small, centimeter sized pebbles leads to massive inner planetary systems.

Author(s): John Moriarty[1], Debra Fischer[1]
Institution(s): *1. Yale University*

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439 – Galaxy Clusters Posters

439.01 – Dynamical Properties of Clusters Identified in Large Surveys Using the HectoMap Redshift Survey

Large surveys of clusters can yield tight constraints on cosmological parameters if systematic effects are well understood. Here, we use the dense redshift survey HectoMap to measure the dynamical properties of clusters and groups associated with either ROSAT X-ray sources or red-sequence selected clusters from SDSS imaging. HectoMap covers 50 square degrees with a median redshift of z=0.34 and samples dense systems better than other surveys at this depth (e.g., 10x denser than BOSS). We use the entire HectoMap survey to quantify the significance of redshift peaks associated with the entries in cluster catalogs such as redmapper and AMF. We show that some of the optically selected clusters are superpositions of multiple systems. For many of the clusters, we are able to extract estimates of velocity dispersions. By stacking clusters by estimated richness, we show that the dynamics can be probed by more sophisticated

methods such as the caustic technique.
Our results will provide an independent assessment of systematic effects present in large cluster surveys such as redMapper and help build to stronger cosmological constraints from clusters. In addition, our results can be applied to large cluster surveys to improve our understanding of the evolution of galaxies and intracluster gas within clusters.

Author(s): David Mark Reiman[4], Kenneth J. Rines[4], Margaret J. Geller[2], Antonaldo Diaferio[3], Ho Seong Hwang[1]
Institution(s): *1. Korean Institute for Advanced Studies, 2. Smithsonian Astrophysical Observatory, 3. Universita degli Studi di Torino, 4. Western Washington University*

439.02 – Cooling, AGN Feedback and Star Formation in Cool-Core Galaxy Clusters

The feedback from active galactic nuclei (AGNs) is widely considered to be the major heating source in cool-core galaxy clusters to prevent a classical cooling flow. Numerical simulations with AGN feedback have successfully suppressed radiative cooling, but generally fail to reproduce the right amount of cold gas and the expected cyclical AGN activities. We perform adaptive mesh simulations including both momentum-driven AGN feedback and star formation to study the interplay between cooling, AGN heating and star formation over ~ 6.5 Gyr time in an isolated cool-core cluster. Cold clumps first cool out of the ICM due to the non-liner perturbation driven by the AGN jets. These cold clumps feed both star formation and the supermassive black hole (SMBH), triggering an AGN outburst which increases the entropy of the ICM and reduces its cooling rate. Within 1-2 Gyr, star formation completely consumes the cold gas, which leads to a brief shutoff of the AGN. The ICM quickly cools and develops multiphase gas again, followed by another cycle of star formation/AGN outburst. Within 6.5 Gyr, we observe three such cycles. The average star formation rate is ~40 solar mass/yr. The black hole accretion rate shows a large scatter, but the average correlates well with the star formation rate and is roughly one order of magnitude lower.

Author(s): Yuan Li[2], Greg Bryan[1], Mateusz Ruszkowski[2]
Institution(s): *1. Columbia University, 2. University of Michigan*

439.03 – Hot Halo Emission Detected at Outskirts of Two Poor Galaxy Groups Using *Suzaku*

We present *Suzaku* off-center observations of two poor galaxy groups, NGC 3402 and NGC 5129, with temperatures below 1 keV. Through spectral decomposition, we measure their surface brightnesses and temperatures out to 420 and 300 times the critical density of the universe for NGC 3402 and NGC 5129, respectively. These quantities are consistent with extrapolations from existing inner measurements of the two groups. With the refined X-ray luminosities, the two groups prefer L^X-T relations without a break in the group regime. Furthermore, we measure the electron number densities and hydrostatic masses at these radii. We find that the electron number density profiles require three β-model components, including one with a flat slope, for both groups. Adding the gas mass measured from the X-ray data and stellar mass from group galaxy members, we measure baryon fractions of f^b = 0.120 and 0.116 for NGC 3402 and NGC 5129, respectively. Combining other poor groups with well measured X-ray emission to the outskirts, we find an average baryon fraction of $f^{b,ave}$ = 0.111 for X-ray bright groups with temperatures between 0.8-1.3 keV, extending existing constraints to lower mass systems.

Author(s): Jenna Nugent[2], Xinyu Dai[2], Ming Sun[1]
Institution(s): *1. University of Alabama, 2. University of Oklahoma*

439.04 – New Limits on Gamma-Ray Emission from Galaxy Clusters

Galaxy clusters are predicted to produce gamma-ray emission, through cosmic ray interaction and/or dark matter annihilation, potentially detectable by the Fermi Large Area Telescope (Fermi-LAT). Specifically, cosmic ray interactions with the intra-cluster gas results in neutral pion decay, producing gamma-rays. As yet, this emission has not been detected using small samples of clusters. We present a new, independent stacking analysis of Fermi-LAT photon count maps using the 78 richest nearby clusters (z < 0.12) from the Two Micron All-Sky Survey (2MASS) cluster catalog. Our initial search yields non-detections of gamma-ray emission from galaxy clusters but we achieve the lowest upper limits on the photon flux to date. Scaling to recent cosmic ray acceleration and gamma-ray emission models, we find that cosmic rays represent a negligible contribution to the intra-cluster energy density and gas pressure. Furthermore, either merger shocks must have lower Mach numbers than inferred from radio emission, so < 2 − 4, or significantly less than 50% of the baryon mass has been processed through such shocks, and thus, the majority of baryons should be assembled through minor mergers or through cold accretion.

Author(s): Rhiannon Danae Griffin[2], Xinyu Dai[2], Christopher S. Kochanek[1]
Institution(s): *1. Ohio State University, 2. University of Oklahoma*

439.05 – Examining the Center: Positions, Dominance, and Star Formation Rates of Most Massive Group Galaxies at Intermediate Redshift

The group environment is believed to be the stage for many galaxy transformations, helping evolve blue star-forming galaxies to red passive ones. In local studies of galaxy clusters, the central member is usually a single dominant giant galaxy at the center of the potential with little star formation thought to be the result of galaxy mergers. In nearby groups, a range of morphologies and star formation rates are observed and the formation history is less clear. Further, the position and dominance of the central galaxy cannot be assumed in groups, which are less massive and evolved than clusters. To understand the connections between global group properties and properties of the central group galaxy at intermediate redshift, we examine galaxy groups from the Group Environment and Evolution Collaboration (GEEC) catalog, including both optically- and X-ray-selected groups at redshift z~0.4. The sample is diverse, containing a range in overall mass and evolutionary state. The number of groups is significant, membership is notably complete, and measurements span the IR to the UV allowing the properties of the members to be connected to those of the host groups. Having investigated trends in the global group properties previously, including mass and velocity substructure, we turn our attention now to the galaxy populations, focusing on the central regions of these systems. The most massive and second most massive group galaxies are identified by their stellar mass. The positions of the most massive galaxies (MMGs) are determined with respect to both the luminosity-weighted and X-ray center. Star formation rates are used to explore the fraction of passive/quiescent versus star-forming MMGs and the dominance of the MMGs in our group sample is also tested. Determinations of these characteristics and trends constitute the important first steps toward a detailed understanding of the relationships between the properties of host groups and their most massive galaxies and the environmental effects involved in the evolution of such objects.

Author(s): Jennifer L. Connelly[4], Laura C. Parker[3], Sean McGee[5], John S. Mulchaey[1], Alexis Finoguenov[6], Michael Balogh[7], David Wilman[2]
Institution(s): *1. Carnegie Institution of Washington, 2. Max Planck Institute for Extraterrestrial Physics, 3. McMaster University, 4. Rochester Institute of Technology, 5. University of Birmingham, 6. University of Helsinki, 7. University of Waterloo*
Contributing team(s): Group Environment Evolution Collaboration

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440 – Gravitational Waves Posters

440.01 – Computing the Influence of a Gravitational Wave on an Electromagnetic Field

General Relativity applied to electromagnetism: what happens to an electromagnetic field when the spacetime it is embedded in is oscillating? I present a numerical model that answers this question for any arbitrary boundary conditions and properties of the gravitational wave. This is particularly useful as this problem cannot be solved analytically for all but the simplest boundary conditions. The model can be used to determine a gravitational wave’s signature without being restricted to simple boundary conditions like LIGO's interferometers.

Author(s): Varadarajan Srinivasan[1]
Institution(s): *1. Columbia University*

440.02 – Assessing the Detectability of Gravitational Waves from Coalescing Binary Black Holes with Precessing Spin

The Advanced LIGO and Virgo gravitational wave detectors will come online within the year and are expected to outperform the strain sensitivity of initial LIGO/Virgo detectors by an order of magnitude and operate with greater bandwidth, possibly to frequencies as low as 10 Hz. Coalescing binary black holes (BBH) are anticipated to be among the most likely sources of gravitational radiation observable by the detectors. Searches for such systems benefit greatly from the use of accurate predictions for the gravitational wave signal to filter the data. The component black holes of these systems are predicted to have substantial spin, which greatly influences the gravitational waveforms from these sources; however, recent LIGO/Virgo searches have made use of banks of waveform models which neglect the effects of the component spins. The inclusion of spinning components is relatively simplified when the spins are taken to be aligned with the orbital angular momentum, though the difficult task of including precession (allowing for mis-aligned component spins) remains a goal of this work. We aim to assess the ability of the GSTLAL gravitational wave search pipeline using IMR aligned-spin template waveforms to recover signals from generically spinning black hole binaries injected into simulated Advanced LIGO and Virgo detector noise. If black holes are highly spinning as predicted, use of aligned-spin template banks in upcoming searches could increase the detection rate of these systems in Advanced LIGO and Virgo data, providing the opportunity for a deeper understanding of the sources.

Author(s): Sara Frederick[3], Stephen Privitera[2], Alan J. Weinstein[1]
Institution(s): *1. California Institute of Technology, 2. Max Planck Institute for Gravitational Physics (Albert Einstein Institute), 3. University of Rochester*
Contributing team(s): LIGO Scientific Collaboration

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441 – GRBs Posters

441.01 – Exploring biases in the measurement of Isotropic Equivalent Energies of Gamma-ray Bursts with the Fermi Telescope

This study is being performed to determine if isotropic equivalent energies, E^{iso}, measured for gamma-ray bursts are significantly biased by lack of high-energy gamma-ray photon data, leading to inconsistent best-fit spectral models which diverge at high energies. Isotropic equivalent energies are often measured between energies of 10 keV to 10 MeV and prior to the 2008 launch of Fermi, the BATSE gamma-ray burst telescope was limited to observable energies below 700 keV, missing ~90% of the integrated energy band. The brightest bursts often peak at energies exceeding previous detector thresholds, therefore missing large portions of a burst's fluence and leading to incorrect modeling of the spectral shape. Despite these limitations on accurately measuring the full energy output, correlations have emerged, treating E^{iso} as an intrinsic property with physical application to gamma-ray burst physics rather than an observational quantity. We explore the impact of detector truncation on E^{iso} by performing time-integrated analysis both with and without spectra from Fermi's high-energy Large Area Telescope (LAT). Preliminary results show that multiple models, providing good statistics, measure inconsistent isotropic equivalent energies for the same burst, and consistently underestimate the energy output when LAT data is excluded from the analysis. Exclusion of the LAT data leads to unconstrained high-energy spectral slopes of the Band function allowing for observer influence on the choice of how to constrain the slope or to accept a cutoff power-law as the better fit. This proves that correlations involving E^{iso} are currently biased by detector limitations and the true meaning of E^{iso} has yet to be determined.

Author(s): Kimberly Zoldak[2], Judith L. Racusin[1], Julia D. Kennefick[2]
Institution(s): *1. NASA/GSFC, 2. University of Arkansas*

441.02 – Relativistic Shear Flows and Applications to Gamma-ray Burst and Blazar Jets

Using Particle-in-Cell simulations we have demonstrated efficient creation of macroscopic ordered magnetic fields and nonthermal particle energization at the boundary layers of relativistic shear flows. In a jet geometry the fields are preferentially toroidal. Electrons are energized to form a peak around the ion kinetic energy plus a power-law tail of slope ~ -3. The highly anisotropic electrons will emit synchrotron and synchro-self-Compton radiation narrowly beamed along the jet axis. Such radiation may be relevant to the observed spectra of GRB and Blazar jets.

Author(s): Edison P. Liang[2], Markus Boettcher[1], Wen Fu[2], Parisa Roustazadeh[1]
Institution(s): *1. northwest university, 2. Rice Univ.*

442 – Instrumentation: Space and Ground Posters

442.01 – Performing Fowler Sampling and Removing Cosmic Ray Hits to Reduce Noise Numerically from Long-Infrared Detector Images

The University of Rochester Long-Infrared Astrophysics group works with 1024x1024 HgCdTe detector arrays to be developed for a passively cooled infrared space mission. The near-earth object camera (NEOCam) is a proposed infrared space mission for the purpose of discovering and characterizing potentially hazardous objects such as asteroids that are larger than 140 meters in diameter that orbit near the Earth. The tests that were performed in the numerical reduction were called Fowler Samplings. The Fowler images that were produced took average samples of data of sample up the ramp (SUTR) points. The images have the readout noise corrected. Readout noise is a consequence of the imperfect operation of any physical electronic device and occurs from a voltage being induced by the charge of electrons transferred to a capacitor. The results led to a significant decrease in electrons per second that fluctuate throughout the images. These results were consistent across multiple infrared detector arrays and promising for the development of NEOCam.

Author(s): Chelsea Lynn Jean[1]
Institution(s): *1. University of Rochester*
Contributing team(s): Craig McMurtry, Meghan Dorn, Judy Pipher, University of Rochester

442.02 – NASA Astrophysics Cosmic Origins (COR) and Physics of the Cosmos (PCOS) Strategic Technology Development Program

The COR and PCOS Program Offices (PO) reside at the NASA Goddard Space Flight Center (GSFC), serving as the NASA Astrophysics Division's implementation arm for matters relating to the two programs. One aspect of the PO's activities is managing the COR and PCOS Strategic Astrophysics Technology (SAT) program, helping mature technologies to enable and enhance future astrophysics missions.
The PO is guided by the National Research Council's "New Worlds, New Horizons in Astronomy and Astrophysics" Decadal Survey report, and NASA's Astrophysics Implementation Plan. Strategic goals include dark energy; gravitational

waves; X-ray observatories, e.g., US participation in ATHENA; Inflation probe; and a large UV/Visible telescope.
To date, 51 COR and 65 PCOS SAT proposals have been received, of which 11 COR and 18 PCOS projects were funded. Notable successes include maturation of a new far-IR detector, later adopted by the SOFIA HAWC instrument; maturation of the H4RG near-IR detector, adopted by WFIRST; development of an antenna-coupled transition-edge superconducting bolometer, a technology deployed by BICEP2 that allowed measurement of B-mode polarization in the CMB signal, a possible signature of Inflation; and finally, the REXIS instrument on OSIRIS-REx is incorporating CCDs with directly deposited optical blocking filters developed by another SAT-funded project.
We discuss our technology development process, with community input and strategic prioritization informing calls for SAT proposals and guiding investment decisions. We also present results of this year's technology gap prioritization and showcase our current portfolio of technology development projects. These include five newly selected projects, kicking off in FY 2015.
For more information, visit the COR Program website at cor.gsfc.nasa.gov and the PCOS website at pcos.gsfc.nasa.gov.

Author(s): Thai Pham[1], Bernard D. Seery[1]
Institution(s): *1. NASA Astrophysics PCOS and COR*

442.03 – The SAPHIRA Near-Infrared Avalanche Photodiode Array: Telescope Deployments and Future Developments

We present our recent achievements of the Selex SAPHIRA APD arrays, which this year have seen deployment at three different telescopes, most notably demonstrating tip-tilt wavefront sensing in conjunction with the Palomar 1.5-m Telescope's Robo-AO system. A cooperative effort to provide enhanced speckle nulling capability to the SCExAO instrument on the Subaru telescope is also underway. We present the progress and development timeframe for the SAPHIRA and expected future applications, including targets and observational parameter space we expect the detectors to open to the astronomical community.

Author(s): Dani Eleanor Atkinson[1], Donald Hall[1], Christoph Baranec[1]
Institution(s): *1. University of Hawai'i*

442.04 – Dome Flat Stability of the Gemini South Adaptive Optics Imager (GSAOI)

We characterize the stability of GSAOI dome flats taken during the period from December 2012 to June 2014. This period includes 16 separate laser runs and 5 instrument changes. All 22 filters, 6 broad band and 16 narrow band, are considered. Dome flats are taken twice per run to examine short term variability. Additionally, lamp-off flats in the longer wavelength filters (> 1.5 μ) began in February 2013 and we compare lamp-on flats to the difference of lamp-on and lamp-off flats.

Author(s): Joanna E. Thomas-Osip[1], Eleazar Rodrigo Carrasco Damele[1]
Institution(s): *1. Gemini Observatory*

442.05 – Update on the Gemini High-Resolution Optical SpecTrograph (GHOST)

The Gemini High-Resolution Opitcal SpecTrograph (GHOST) is under development for the Gemini telescopes in collaboration with the Austrailian Astronomical Observatory (AAO), the NRC-Herzberg in Canada, and the Australian National University (ANU). The latest design and project plan will be presented and the scientific role of the instrument will be discussed.

Author(s): Steven J. Margheim[1]
Institution(s): *1. Gemini Obs.*
Contributing team(s): GHOST Instrument Team

442.06 – Northop Grumman/Xinetics Deformable Mirrors: Enabling Reliable Advanced Imaging for 20 Years and Beyond

Adaptive Optics Xinetics (AOX), a wholly-owned subsidiary of Northrop Grumman, has manufactured and delivered more than 300 deformable mirrors (DMs) since 1995. With more than 32 gigacycles of use, these mirrors have significantly increased the scientific return of ground based astronomical telescopes by removing atmospheric distortion from the image plane. AOX deformable mirrors exhibit little or no hysteresis, aging or creep, making them highly reliable and predictable. A range of space -based applications are currently in development or under consideration as key enablers for future astronomical missions. We will review a variety of AOX DMs and discuss a number of their real world applications and results.

Author(s): Russ Matijevich[1]
Institution(s): *1. Northrop Grumman*
Contributing team(s): Jeff Cavaco, Northrop Grumman Xinetics

443 – Large Scale Structure and Cosmological Topics Posters

443.01 – Quantifying the statistical and systematic uncertainties in galaxy group catalogues

Dark matter is not visible to us and there are no known methods to directly detect it; therefore, we must rely on different methods to indirectly identify dark matter (DM) halos. We use a Friends-of-Friends algorithm to identify galaxy groups in mock galaxy catalogues from different magnitude samples obtained from N-body simulations by the Large Suite of Dark Matter Simulations (LasDamas), and assign masses to each of these groups by abundance matching. We also compute a group mass that depends on the contribution of galaxies from each DM halo in the galaxy group, and compare it to the mass obtained using abundance matching. We show that the abundance-matched mass is greater than the mass determined by the contributions of DM halos to the group. We also look at the purity and completeness of the galaxy group catalogues, and determine that for each of the magnitude samples, the purity and completeness levels are above 80 percent on average for central and satellites galaxies. We define a pointing fraction for a group-halo system that depends on the number of galaxies in the DM halo and in the galaxy group. We use this fraction to define good and bad group-halo matches, and conclude that more than 90 percent of the galaxy groups found in the mock galaxy catalogues are good matches with their preferred DM halo. We finalize by examining the scatter in the group mass as function of abundance-matched mass, and determine that this scatter ranges from 0.2 dex to 0.6 dex for all magnitude samples.

Author(s): Victor Calderon[1], Andreas A. Berlind[1], Manodeep Sinha[1]
Institution(s): *1. Vanderbilt University*

443.02 – A search for ultra-light axions using precision cosmological data

Ultra-light axions (ULAs) with masses in the range 10^{-33} eV $< m <$ 10^{-20} eV are motivated by string theory and might contribute to either the dark-matter or dark-energy density of the Universe. ULAs could suppress the growth of structure on small scales, or lead to an enhanced integrated Sachs-Wolfe effect on large-scale cosmic microwave-background (CMB) anisotropies. In this work, cosmological observables over the full ULA mass range are computed, and then used to search for evidence of ULAs using CMB data from the Wilkinson Microwave Anisotropy Probe (WMAP), Planck satellite, Atacama Cosmology Telescope, and South Pole Telescope, as well as galaxy clustering data from the WiggleZ galaxy-redshift survey. In the mass range 10^{-32} eV $< m <$ $10^{-25.5}$ eV, the axion relic-density Ω_{a} (relative to the total dark-matter relic density Ω_{d}) must obey the constraints $\Omega_{a}/\Omega_{d} < 0.05$ and $\Omega_{a}h^{2} < 0.006$ at 95%-confidence. For $m > 10^{-24}$ eV, ULAs are indistinguishable from standard cold dark matter on the length scales probed, and are thus allowed by these data. For $m < 10^{-32}$ eV, ULAs are allowed to compose a significant fraction of the dark energy.

Author(s): Daniel Grin[4], Renee Hlozek[3], David Marsh[2], Pedro Ferreira[1]
Institution(s): *1. Oxford University, 2. Perimeter Institute, 3. Princeton University, 4. University of Chicago*

443.03 – Effects of massive neutrinos on the properties of cluster scale halos

The presence of massive neutrinos affects the growth of large scale structure in the Universe leaving an imprint on the abundance and properties of massive dark matter-dominated halos. When studying upcoming surveys, quantitatively understanding the impact of massive neutrinos is important to estimate neutrino masses as well as to disentangle the impact of the physics of the accelerating universe from effects of massive neutrinos from such observations. In this paper, we use a suite of gravity-only N-body gravity simulations incorporating the effects of massive neutrinos on the growth of large scale structure. Our main approximation, that the sourcing of the growth of density fluctuations due to massive neutrinos can be neglected, is justified in the case of low neutrino masses, within the range suggested from current observations. We compare results for the halo mass function using our simulations to expectations from the universal behavior of the mass function and interpret the appropriate prescription for universality ideas in cases with non-zero neutrino mass. We show the suppression of the mass function predicted by our prescription, and estimate the accuracy of our approximate approach, if one assumes
universality to be valid.

Author(s): Rahul Biswas[3], Katrin Heitmann[1], Salman Habib[1], Adrian Pope[1], Hal Finkel[1], Amol Upadhye[4], Nicholas Frontiere[2]
Institution(s): *1. Argonne National Laboratory, 2. University of Chicago, 3. University of Washington, 4. University of Wisconsin*

443.04 – Weak Lensing Mass Calibration of the RBC X-ray Galaxy Cluster Catalog

In order to fully realize the potential of galaxy clusters as a cosmological probe, we must understand the mass function of the galaxy clusters we observe. Weak gravitational lensing provides a valuable tool for measuring the cluster masses because it is a direct probe of the gravitational field of the cluster, without assumptions about cluster structure. Here we present a weak lensing measurement of the masses of clusters in the RBC catalog. Our clusters are drawn from the ROSAT All-Sky Survey, an X-ray selected catalog, with a well-understood selection function. We compare our results to simulation outputs to probe the impact of substructure and three-dimensional shape not captured by simple analytical models, and discuss the relationship between the galaxy cluster masses we measure and the masses inferred based on assumptions of hydrostatic equilibrium.

Author(s): Melanie Simet[1], Nicholas Battaglia[2], Rachel Mandelbaum[1], Uros Seljak[3]
Institution(s): *1. Carnegie Mellon University, 2. Princeton University, 3. University of California, Berkeley*

443.05 – Radio and Gamma-Ray Monitoring of Strongly Lensed Quasars and Blazars

We observed six strongly lensed, radio-loud quasars (MG 0414+0534, CLASS B0712+472, JVAS B1030+074, CLASS B1127+385, CLASS B1152+199, and JVAS B1938+666) in order to identify systems suitable for measuring cosmological parameters using time delays between their multiple images. Two separate monitoring campaigns were carried out using the VLA. We found evidence for variability in a majority of the lightcurves. B0712 and B1030 had particularly strong variations, exhibiting linear flux trends. These results show that most of these systems should be targeted with followup monitoring campaigns, especially B0712 and B1030. In additional to these follow-up campaigns, future work will involve searching for and performing time delay measurements on lensed blazars using the Fermi gamma-ray telescope, following the proof of concept by Cheung et al. 2014. Discrepancies between gamma-ray and radio time delays of B0218 suggest physically separated emissions sources. We plan to extend study of emission regions to other lensed blazars.

Author(s): Nick Rumbaugh[5], Chris Fassnacht[5], John McKean[2], Leon Koopmans[3], Matthew Auger[6], Sherry Suyu[1], Philip J. Marshall[4]
Institution(s): *1. ASIAA, 2. ASTRON, 3. Kapteyn Astronomical Institute, 4. SLAC National Accelerator Laboratory, 5. University of California, Davis, 6. University of Cambridge*

443.06 – Current state of the final cosmology analysis of the Supernova Legacy Survey (SNLS)

We review the recent progress made in the analysis of supernovae from the Supernova Legacy Survey (SNLS). This corresponds to the final cosmology analysis of the SNLS, as it will include the complete 5 year data set. We begin with a brief summary of the methodology behind supernova cosmology, as well as a review of the current state of constraints on dark energy. We then move on to describing the improvements that the final SNLS analysis will bring forth. The improvements we will focus on are threefold. We begin by describing the new photometric calibration which greatly reduces the systematic uncertainty on the cosmological parameters. We will then go over improvements in the photometry method itself. Finally, we consider the impact of adding new data to the construction of spectrophotometric templates of type Ia supernovae. We conclude with a tentative estimate of the expected uncertainty on the equation of state parameter of dark energy in the context of the final SNLS analysis as well as an outlook on potential further improvements of the analysis method.

Author(s): Patrick El-Hage[1]
Institution(s): *1. CNRS/IN2P3*
Contributing team(s): SNLS Collaboration

443.07 – Inferring the Intrinsic Ellipticity Distribution of Galaxies

The unknown distribution of intrinsic galaxy shapes is a primary source of systematic error in the measurement of the gravitational lensing distortion of galaxy images, or cosmic shear. By simultaneously inferring the distribution of galaxy morphologies disambiguated from lensing, we can achieve gains in gravitational lensing precision and learn about the evolution of galaxy morphologies over cosmic time. We present a flexible statistical model to perform this joint inference and demonstrate the implementation with simulated data.

Author(s): Michael Schneider[2], William Dawson[2], David W. Hogg[3], Philip J. Marshall[4], Joshua Meyers[4], Deborah J. Bard[4], Dustin Lang[1]
Institution(s): *1. CMU, 2. Lawrence Livermore Natl Lab, 3. NYU, 4. SLAC*

443.08 – Sensitivity of a Dark Matter Search with the Micro-X and XQC Rocket Payloads

Rocket borne high-resolution X-ray spectrometers provide the ability to generate high-resolution spectra from an observation over a wide field of view. This type of observation is especially useful in searches of potential dark matter signals from the Milky Way, where the large field of view and high spectral resolution leads to much higher signal to background ratios than with Chandra and XMM. In spite of the decreased exposure time associated with a sounding rocket observation, these other factors lead to significantly increased sensitivity to sterile neutrino decay (or other line-emitting dark matter models) when compared with existing observations. We calculate the sensitivity limits that would be set by an observation of the galactic center with the Micro-X and XQC sounding rocket payloads to emission lines in the soft x-ray band resulting from possible sterile neutrino decay.

Author(s): David Goldfinger[1], Enectali Figueroa-Feliciano[1], Daniel Castro[1], Adam Anderson[1]
Institution(s): *1. Massachusetts Institute of Technology*

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444 – Not Quite and Brand New Stars Posters

444.01 – A Catalog of Low-Mass Star-Forming Cores Observed with SHARC-II at 350 µm

This paper presents a catalog of low-mass protostellar cores observed with the SHARC-II instrument at 350 µm. The catalog includes 82 maps covering a total of 166 detected sources. For each source, we include basic source properties such as position, flux density, and radius. We also present quantification of the sensitivity of SHARC-II 350 µm observations to extended emission and to the observing mode used on the telescope.

Author(s): Akshaya Suresh[1], Hector G. Arce[1], Michael Dunham[1]
Institution(s): *1. Yale University*

444.02 – A M2FS Spectroscopic Study of Low-mass Young Stars in Orion OB1

Surveys of pre-main sequence stars in the ~4-10 Myr range provide a window into the decline of the accretion phase of stars and the formation of planets. Nearby star clusters and stellar associations allow for the study of these young stellar populations all the way down to the lowest mass members. One of the best examples of nearby 4-10 Myr old stellar populations is the Orion OB1 association. The CIDA Variability Survey of Orion OB1 (CVSO – Briceño et al. 2001) has used the variability properties of low-mass pre-main-sequence (PMS) stars to identify hundreds of K and M-type stellar members of the Orion OB1 association, a number of them displaying IR-excess emission and thought to be representative of more evolved disk-bearing young stars. Characterizing these young, low-mass objects using spectroscopy is integral to understanding the accretion phase in young stars. We present preliminary results of a spectroscopic survey of candidate and confirmed Orion OB1 low-mass members taken during November 2014 and February 2014 using the Michigan/Magellan Fiber Spectrograph (M2FS), a PI instrument on the Magellan Clay Telescope (PI: M. Matteo). Target fields located in the off-cloud regions of Orion were identified in the CVSO, and observed using the low and high-resolution modes of M2FS. Both low and high-resolution spectra are needed in order to confirm membership and derive masses, ages, kinematics and accretion properties. Initial analysis of these spectra reveal many new K and M-type members of the Orion OB1 association in these low extinction, off-cloud areas. These are the more evolved siblings of the youngest stars still embedded in the molecular clouds, like those in the Orion Nebula Cluster. With membership and spectroscopic indicators of accretion we are building the most comprehensive stellar census of this association, enabling us to derive a robust estimate of the fraction of young stars still accreting at a various ages, a key constraint for the end of accretion and the formation of giant planets.

Author(s): Catherine C. Kaleida[2], Cesar Briceno[2], Nuria Calvet[3], Mario L. Mateo[3], Jesus Hernandez[1]
Institution(s): *1. Centro de Investigaciones de Astronomía (CIDA), 2. Cerro Tololo Inter-American Observatory, 3. University of Michigan*

444.03 – ClassLess: A Comprehensive Database of Young Stellar Objects

We have designed and constructed a database housing published measurements of Young Stellar Objects (YSOs) within ~1 kpc of the Sun. ClassLess, so called because it includes YSOs in all stages of evolution, is a relational database in which user interaction is conducted via HTML web browsers, queries are performed in scientific language, and all data are linked to the sources of publication. Each star is associated with a cluster (or clusters), and both spatially resolved and unresolved measurements are stored, allowing proper use of data from multiple star systems. With this fully searchable tool, myriad ground- and space-based instruments and surveys across wavelength regimes can be exploited. In addition to primary measurements, the database self consistently calculates and serves higher level data products such as extinction, luminosity, and mass. As a result, searches for young stars with specific physical characteristics can be completed with just a few mouse clicks.

Author(s): Lynne Hillenbrand[1], Nairn Baliber[1]
Institution(s): *1. California Institute of Technology*

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445 – Pulsars, Black Holes and Their Environments Posters

445.01 – Characterization of the Inner Knot of the Crab: The Site of the Gamma-ray Flares?

One of the most intriguing recent discoveries has been the detection of powerful γ-ray flares from the Crab Nebula. Such events, with a recurrence time of about once per year, can be so dramatic to make the system the brightest source in the gamma-ray sky as occurred, e.g. in April 2011. These flares challenge our understanding of how pulsar wind nebulae work and defy current astrophysical models for particle acceleration. We present here our study of the inner knot located within a fraction of an arcsecond from the pulsar with the aim of characterizing the feature and asking if this might be the site of the origin of the γ-ray flares. We took data using Keck, HST, and Chandra obtained as part of our multi-wavelength campaign to identify the source of the enigmatic flares. We set an upper limit as to the x-ray flux from the knot. We also find that the dimensions, surface brightness, flux, etc. of the optical and infrared knot are all correlated with distance of from the pulsar. This distance, in turn, varies with time. In addition to this most thorough characterization of the inner knot's properties, we examine the hypothesis that the knot may be the site of the flares by examining the knot separation versus the Fermi/LAT γ-ray flux. Finally, as part of this research, we make use of a new approach employing singular value decomposition (SVD) for analyzing time series of images and compare the approach to more traditional methods. Our conclusions are only refined but not impacted by using the new approach.

Author(s): Martin C. Weisskopf[1]
Institution(s): *1. NASA/MSFC*
Contributing team(s): On behalf of the Chandra/HST/Keck gamma-ray flare team

445.02 – The Binary Companion of Young, Relativistic Pulsar J1906+0746

PSR J1906+0746 is a young pulsar in the relativistic binary with the second-shortest known orbital period, of 3.98 hours. We will present a timing study based on five years of observations, conducted with the 5 largest radio telescopes in the world, aimed at determining the companion nature.

Through the measurement of three post-Keplerian orbital parameters we find the pulsar mass to be 1.291(11) M_sol, and the companion mass 1.322(11) M_sol respectively. These masses fit well in the observed collection of double neutron stars, but are also compatible with other white dwarfs around pulsars that are young like PSR J1906+0746. Neither radio pulsations nor dispersion-inducing outflows that could have further established the companion nature were detected. We derive an HI-absorption distance, which indicates that an optical confirmation of a white dwarf companion is very challenging.

The pulsar is fading fast due to geodetic precession, limiting future timing improvements. We conclude that young pulsar J1906+0746 is likely part of a double neutron star, or is otherwise orbited by an older white dwarf, in an exotic system formed through two stages of mass transfer.

Author(s): Joeri van Leeuwen[1], Laura Kasian[2], Ingrid H. Stairs[2]
Institution(s): *1. ASTRON, the Netherlands Institute for Radio Astronomy, 2. UBC*
Contributing team(s): PALFA Team

445.03 – EXPLORING THE TIME EVOLUTION OF LUMINOSITY AND PULSE PROFILE IN X-RAY PULSARS.

We report progress in our effort to analyze and model the large collection of observations made by RXTE, XMM-Newton and Chandra of X-ray Binary Pulsars in the Magellanic Clouds. There are >2000 individual RXTE PCA, and > 200 XMM-Newton and Chandra observations of the Magellanic clouds. Each observation covers a large fraction of the whole SMC (or LMC) population, and we are able to deconvolve the often simultaneous signals to create a 20 year record of individual pulsar's activity. Together, these datasets cover the entire range of variability timescales and accretion regimes in High Mass X-ray Binaries. We are compiling a library of energy-resolved pulse profiles covering the entire luminosity and spin-period parameter space. In parallel we are developing a suite of computational models to parameterize the pulse profile morphology. We begin with a pair of isotropically emitting poles with general relativity, and then add complexity in the form of fan and pencil beam components. The initial goal is to discover the ratio of the beam components as a function of accretion rate and luminosity, and ultimately the distribution of offsets between magnetic and spin axes. These products are needed for the next generation of advances in neutron star theory and modeling. This unique dataset enables us to determine the upper and lower limits of accretion powered luminosity in a large statistically complete sample of neutron stars, and hence make several direct tests of fundamental NS parameters and accretion physics.

Author(s): Silas Laycock[4], Dimitris Christodoulou[4], Rigel Cappallo[4], Wynn Ho[5], Malcolm Coe[5], Robin Corbet[3], Helen Klus[5], Demosthenes Kazanas[1], Jose Luis Galache[2], Samuel Fingerman[4], Jun Yang[4], Scott Norton[4]
Institution(s): *1. NASA/GSFC, 2. Smithsonian Astrophysical Observatory, 3. UMBC, 4. University of Massachusetts, 5. University of Southampton*

445.04 – Calculating a Lensing Rate for the Supermassive Black Hole at the Galactic Center

An important observable effect from the supermassive black hole at the Galactic center is the relativistic lensing of stars passing in the vicinity of the black hole. This leads to the generation of multiple unresolved stellar images and an increase in brightness of the source. Detection and analysis of lensing events give information regarding the nature of the black hole and the workings of general relativity. We calculated an updated rate of observable lensing events for K-Band emitting stars present in the innermost few parsecs of the Galactic center, for contemporary observational limits, specifically, those for Keck Observatory and its current adaptive optics system, as well as the limits for the Thirty Meter Telescope. We can expect to detect one lensing event per 5 years for unresolved lensing under Keck Adaptive Optics. The new generation of telescopes will have even greater detection potential, as projected detection rates are one event every 1-2 years.

Author(s): Isabel A Lipartito[1]
Institution(s): *1. University of California, Los Angeles*
Contributing team(s): UCLA Galactic Center Group

445.05 – SMBH Measurements and Host-Galaxy Correlations: Ellipticals, Bulges, Pseudobulges, and Composite Bulges

We present and discuss VLT-SINFONI AO measurements of supermassive black hole masses via stellar kinematics and dynamical modeling for a number of nearby galaxies, mostly lenticular and spiral galaxies with modest bulges and low velocity dispersions. We combine these with our previous elliptical-galaxy measurements and measurements from the literature to construct a database of ~ 100 galaxies with carefully vetted parameters; in disk galaxies, we distinguish between classical bulges, (disky) pseudobulges, and composite systems containing both. This large dataset allows us to explore correlations between SMBH mass and several bulge and pseudobulge parameters -- stellar mass, central velocity dispersion, half-mass radius, and mean central stellar-mass density -- for a variety of systems. Although most pseudobulges do not follow the general elliptical/classical-bulge--SMBH relations, we find evidence that SMBH masses may correlate with pseudobulge properties when the latter are sufficiently compact and dense. We also find evidence that SMBHs correlate with the classical-bulge component of composite-bulge galaxies

Author(s): Peter Erwin[1], Roberto Saglia[1], Jens Thomas[1], Michael Opitsch[1], Maximilian Fabricius[1], Nina Nowak[2], Ralf Bender[1], Michael John Williams[1], Ximena Mazzalay[1]
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445.06 – A Highly Ordered Magnetic Field in a Crushed Pulsar Wind Nebula in G327.1-1.1

A significant fraction of a pulsar's spin-down luminosity is in the form of a relativistic magnetized particle outflow known as a pulsar wind. Confinement of the wind by the ambient medium creates a synchrotron-emitting bubble called a pulsar wind nebula (PWN). Studies of PWNe is important for understanding the physics of relativistic shocks and particle acceleration. Simulations suggest that a PWN will be crushed by the reverse shock of its surrounding supernova remnant at an age of ~10^4 yr, resulting in a turbulent environment. However, given the short timescale of the interaction stage, only a few such systems are observed.
We present radio polarization observations of the PWN in supernova remnant G327.1-1.1, taken with the Australia Telescope Compact Array. Previous works suggest that this system has recently interacted with the supernova reverse shock, providing a rare example for the study of magnetic field in a crushed PWN. We found a highly ordered magnetic field in the PWN, which is unexpected given the presumed turbulent interior of the nebula. This suggests that the magnetic pressure in the PWN could play an important role in the interaction with supernova reverse shock.
The Australia Telescope Compact Array is part of the Australia Telescope National Facility which is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO.YKM and CYN are supported by a ECS grant of the Hong Kong Government under HKU 709713P

Author(s): Yik Ki Ma[5], Chi-Yung Ng[5], Niccolò Bucciantini[2], Bryan M. Gaensler[4], Patrick O. Slane[1], Tea Temim[3]
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446 – Spiral Galaxies Thursday Posters

446.01 – A Method for Measuring the Transverse Velocity Vector and the Geometric Distance of the Andromeda Galaxy Using Water Masers

Water masers have been observed in five star forming regions in the Andromeda galaxy (M31). The masers are excellent astrometric point sources for measuring the transverse velocity and geometric distance (via proper rotation) of M31. We present an algorithm to determine the geometric distance and proper motion of M31 assuming a tilted ring model and a sparse maser network. The observed proper motion of each water maser includes contributions from the proper rotation of the spiral disk, the systemic proper motion of M31, and any peculiar motion (commonly exhibited by water masers). We place constraints on water maser peculiar motions using observations of molecular gas (CO, HCN, and HCO+) at the water maser sites in M31. Given a set of maser proper motion measurements, our Bayesian algorithm can construct a maximum likelihood and podterior distribution of the transverse velocity and geometric distance of M31 that can be generally applied to proper motion measurements in disk galaxies. This research was performed with support from the NSF grant AST-1109078.

Author(s): Nikta Amiri[1], Jeremiah K. Darling[1]
Institution(s): *1. University of Colorado Boulder*

446.02 – Constraints on the Efficiency of Radial Migration in Spiral Galaxies

A transient spiral arm can permanently rearrange the orbital angular momentum of the stellar disk without inducing kinematic heating. This phenomenon is called radial migration because a star's orbital angular momentum determines its mean orbital radius. Should radial migration be an efficient process it could cause a large fraction of disk stars to experience significant changes in their individual orbital angular momenta on dynamically short timescales. Such scenarios have strong implications for the chemical, structural and kinematic evolution of disk galaxies. We have undertaken an investigation into the physical dependencies of the efficiency of radial migration on stellar kinematics and spiral structure. In order for a disk star to migrate radially, it must first be "trapped" in a particular family of orbits, called horseshoe orbits, that occur near the radius of corotation with a spiral pattern. Thus far, the only analytic criterion for horseshoe orbits has been for stars with zero random orbital energy. We present our analytically derived "capture criterion" for stars with some finite random orbital energy in a disk with a given rotation curve. Our capture criterion predict that trapping in a horseshoe orbit is primarily determined by whether or not the position of a star's mean orbital radius (determined by its orbital angular momentum) is within the "capture region", the location and shape of which can be derived from the capture criterion. We visualize and confirm this prediction via numerically integrated orbits. We then apply our capture criterion to snap shot models of disk galaxies to determine (1) the radial distribution of the fraction of stars initially trapped in horseshoe orbits, and (2) the dependence of the total fraction of captured stars in the disk on the radial component of the stellar velocity dispersion (σR) and the amplitude of the spiral perturbation to the underlying potential at corotation. We here present a model of an exponential disk with a flat rotation curve where the initial fraction of stars trapped in horseshoe orbits falls with increasing velocity dispersion as exp[-σR^2].

Author(s): Kathryne J Daniel[1], Rosemary F. G. Wyse[1]
Institution(s): *1. Johns Hopkins University*

446.03 – Extending the Surface Brightness Profile of the Andromeda Galaxy Using Spitzer-IRAC Observations

We present the first results from an extended survey of the Andromeda galaxy (M31) using 41.1 hours of observations by Spitzer-IRAC at 3.6 µm and 4.5 µm. This survey extends previous observations to the outer disk and halo, covering total lengths of 4.4° and 6.6° along the minor and major axes, respectively. We have produced surface brightness profiles by combining the integrated light from background-corrected maps with stellar counts from a new catalog of point sources. Using auxiliary catalogs we have carried out a statistical analysis in colour-magnitude space to discriminate M31 objects from the foreground Milky Way stars. We discuss our preliminary results on constraining the stellar mass and characterizing point sources in the outer radii.

Author(s): Masoud Rafiei Ravandi[4], Pauline Barmby[4], Matthew Ashby[2], Tim Davidge[1], Seppo J. Laine[3], Jenna Zhang[2]
Institution(s): *1. Dominion Astrophysical Observatory, National Research Council of Canada, 2. Harvard-Smithsonian Center for Astrophysics, 3. Spitzer Science Center, California Institute of Technology, 4. University of Western Ontario*

446.04 – Evidence of Interactions or Minor Merger from Neutral Gas Observations of NGC 3521

We present CO (J=1-0) observations of spiral galaxy NGC 3521. At first glance, NGC 3521 appears to be a fairly typical, fairly symmetric disk galaxy with a weak two arm spiral pattern. However, deeper observations revealed asymmetries in the distributions of both stars and gas in the outermost regions of the galaxy. We analyze CO and HI data cubes to determine if NGC 3521 is undergoing galaxy-galaxy interactions or perhaps experienced a minor merger recently.

Author(s): Christopher L. Taylor[1]
Institution(s): *1. California State Univ. Sacramento*

446.05 – Effects of Spiral Arms on Gaseous Structures and Mass Drift in Spiral Galaxies

Stellar spiral arms play a key role in the formation and evolution of gaseous structures in disk galaxies as well as mass drift in the radial direction. Using hydrodynamic simulations, we investigate nonlinear responses of self-gravitating gas to an imposed stellar spiral potential in galactic disks. By considering various models with different arm strength and pattern speed, we find that the physical properties of imposed spiral potential have profound influences on the shapes and extent of gaseous arms as well as the related mass drift rate. To produce quasi-steady spiral shocks, the gas has to not only move faster than the local sound speed relative to the perturbing potential, but also have sufficient time to respond to one arm before encountering the next arm. From our numerical results, we provide a simple expression for the existence of quasi-steady spiral shocks depending on the pitch angle and pattern speed of stellar spiral arms, which appears consistent to the previous study. We also measure the mass drift rates which are in the range of ~0.5-3.0 $M^{\odot}$/yr inside the corotation radius, and further quantify the relative contribution of shock dissipation (~50%), external torque (~40%), and self-gravitational torque (~10%) to them. The offset between the pitch angles of stellar and gaseous arms is larger for smaller arm strength and larger pattern speed, since a deeper potential tends to form shocks closer to the potential minima of the arms. We demonstrate that the distributions of line-of-sight velocities and spiral shock densities can be a diagnostic tool in distinguishing whether the spiral pattern rotates fast or not.

Author(s): Yonghwi Kim[1], Woong-Tae Kim[1]
Institution(s): *1. Seoul National University*

446.06 – Nature of the Wiggle Instability of Galactic Spiral Shocks

Gas in disk galaxies interacts nonlinearly with a underlying stellar spiral potential to form galactic spiral shocks. Numerical simulations typically show that these shocks are unstable to the wiggle instability, producing non-axisymmetric structures with high vorticity. While previous studies suggested that the wiggle instability may arise from the Kelvin-Helmholtz instability or orbit crowding of gas elements near the shock, its physical nature remains uncertain. It was even argued that the wiggle instability is of numerical origin, caused by the inability of a numerical code to resolve a shock that is inclined to numerical grids. To clarify this issue, we perform a normal-mode linear stability analysis of galactic spiral shocks as a boundary-value problem. We find that the wiggle instability originates physically from the potential vorticity (PV) generation at a distorted shock front. As the gas follows galaxy rotation, it periodically passes through multiple shocks, successively increasing its PV. The accumulated PV sets up a normal-mode that grows exponentially, with a growth rate comparable to the orbital angular frequency. We show that the results of our linear stability analysis are in good agreement with the those of local hydrodynamic simulations of the wiggle instability. Magnetic fields play a stabilizing role due tension that tends to reduce PV.

Author(s): Woong-Tae Kim[1], Yonghwi Kim[1], Jeong-Gyu Kim[1]
Institution(s): *1. Seoul National Univ.*

446.07 – Can Spiral Arms Affect Star Formation in Nuclear Rings of Barred-spiral Galaxies?

We use hydrodynamic simulations to study star formation occurring in nuclear rings of barred-spiral galaxies in the presence of outer spiral arms. We find that spiral arms can drive gas toward the bar region from outside only if the arms rotate more slowly than the bar. The inflowing gas enhances the surface density in dust lanes as well as the star formation rate (SFR) in the nuclear ring at late time. The enhanced ring-SFR is larger by a factor of ~3–20 than in no-arm counterpart. The total stellar mass formed is larger for models with stonger and/or slower-rotating arms. On the other hand, spiral arms rotating faster than the bar do not affect the ring star formation much. When the SFR is large, star formation is distributed throughout the ring, with no appreciable age gradient of star clusters in the azimuthal direction. When the SFR is low, on the other hand, star formation occurs preferentially in the the contact points between the dust lanes and the ring, exhibiting an azimuthal age gradient.

Author(s): Woo-Young Seo[1], Woong-Tae Kim[1]
Institution(s): *1. Seoul National University*

446.08 – Short GMC lifetimes: an observational estimate with the PdBI Arcsecond Whirlpool Survey (PAWS)

The lifetimes of giant molecular clouds (GMCs) set a natural limit to the timescale over which gas is converted into stars. Yet very little is directly observationally known about the cloud lifecycle outside the Local Group. I will present a novel approach to estimate cloud lifetimes from high spatial resolution and sensitivity observations of nearby star-forming galaxies, using the crossing time between spiral arms as a fiducial clock. I will present results focussed on the cloud population in the zone between the two main spiral arms in M51, where cloud destruction via shear and star formation feedback dominates over cloud formation processes. By monitoring the change in cloud number densities and ensemble properties from one side of the interarm to the other, we find that cloud lifetimes are very short, 10-30Myr on average. Such short lifetimes suggests that clouds are highly sensitive to their environment, in which processes are suficient to disrupt clouds afer a few free-fall times.

Author(s): Sharon Meidt[3], Annie Hughes[2], Clare L. Dobbs[8], Jerome Pety[1], Todd A. Thompson[6], Santiago Garcia-Burillo[5], Adam K. Leroy[4], Eva Schinnerer[3], Dario Colombo[7], Miguel Querejeta[3], Carsten Kramer[1], Karl Schuster[1], Gaelle Dumas[1]
Institution(s): *1. IRAM, 2. IRAP, 3. Max Planck Institute for Astronomy, 4. NRAO, 5. OAN, 6. OSU, 7. University of Alberta, 8. University of Exeter*

446.09 –
Environmental dependence of GMCs in M83

We present results of giant molecular clouds formed in a hydrodynamical model of the barred spiral galaxy, M83. Our global model resolves down to 1.5 pc and explores the properties of the clouds forming in the bar, spiral and disc environments. The property distributions of the GMCs show only a small dependence based on their environment, however we notice three distinct different cloud types emerging, whose relative number is environment dependent. These cloud types consist of typical clouds (ones whose mass and radius agrees well with observations), massive clouds (with radii larger than 30 pc and mass above 10^7 Msun) and transient clouds who are typically unbound with short life times. We discuss the environment dependence of these cloud types, their evolution and looks at the expected star formation rate from different models.

Author(s): Yusuke Fujimoto[1]
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447 – Star Clusters and Associations Posters

447.01 – The Open Cluster NGC 6811: An Eclipsing Binary, the Turnoff, and Age

Thanks to its extended study during the original *Kepler* mission, we have an abundance of new data on the intermediate age (~1 Gyr) cluster NGC 6811. NGC 6811 is currently the oldest cluster with a fully studied population of rotating stars being used to calibrate gyrochronology relations. The cluster's turnoff also falls completely within the instability strip, and the majority of the brightest main sequence stars have now been identified as δ Scuti pulsators. The eclipsing binary KIC 9777062/Sanders 195 is a cluster member slightly fainter than the turnoff, containing one star that falls within the instability strip. A thorough study of the binary can therefore calibrate the masses and luminosities of the cluster's pulsating stars. We use the characteristics of the binary star components in concert with a re-examination of the photometric properties of the cluster's turnoff and giant stars to produce an improved age determination.

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Author(s): Eric L. Sandquist[5], Jens Jessen-Hansen[1], Matthew D. Shetrone[4], Karsten Brogaard[1], Soren Meibom[2], Marika Leitner[3], Dennis Stello[6], Jerome A. Orosz[5], Frank Grundahl[1], Soren Frandsen[1]
Institution(s): *1. Aarhus University, 2. Harvard-Smithsonian Center for Astrophysics, 3. Humboldt State University, 4. McDonald Observatory/University of Texas, 5. San Diego State University, 6. University of Sydney*

447.02 – The Structure and Stellar Populations of Nuclear Star Clusters in Late-type Spiral Galaxies From HST/WFC3 Imaging

Luminous, compact stellar systems known as nuclear clusters (NCs) are commonly found in the centers of galaxies across the entire Hubble sequence. We present a detailed analysis of the two-dimensional (2D) structure of of ten of the nearest and brightest NCs residing in late-type spiral galaxies, using imaging data from Hubble Space Telescope Wide Field Camera 3 in seven bands that span the near-ultraviolet to the near-infrared. The intrinsic shapes and sizes of the NCs, disentangled from the effects of point spread function (PSF) blurring, were measured by fitting PSF convolved, 2D surface brightness profiles to each image using GALFIT. The clusters exhibit a wide range of structural properties, with F814W absolute magnitudes that range from −11.2 mag to −15.1 mag and F814W effective radii that range from 1.4 to 8.3 pc. For six of the ten NCs in our sample, we find changes in the effective radius with wavelength, which suggests that many NCs contain radially varying stellar populations. We also find a general trend of increasing roundness of the NCs at longer wavelengths, suggesting that the youngest stars in NCs typically form in disks.

The stellar populations of the clusters were studied by comparing their observed colors to simple stellar population (SSP) models. In color-color diagrams spanning the near-UV through the near-IR, most of the clusters lie far from single-burst evolutionary tracks, showing evidence for complex star formation histories. Most of the NCs have integrated colors consistent with the presence of both an old population (> 1 Gyr) and a young population (~100−300 Myr). The wide wavelength coverage of our data provides a sensitivity to populations with a mix of ages that would not be possible to achieve with imaging in optical bands only.

Author(s): Daniel Carson[4], Aaron J. Barth[4], Anil Seth[6], Mark den Brok[6], Michele Cappelari[5], Jenny E. Greene[3], Luis C. Ho[1], Nadine Neumayer[2]
Institution(s): *1. Kavli Institute for Astronomy and Astrophysics, 2. Max Planck Institute for Astronomy, 3. Princeton University, 4. University of California Irvine, 5. University of Oxford, 6. University of Utah*

447.03 – Distinguishing radio properties of the galactic and extragalactic sources towards the Orion Molecular Clouds

The goal of the Gould's Belt Distances Survey is to obtain accurate distances to star forming regions using VLBA measurements of non-thermally emitting young stars. Toward that end we have detected 374 objects at 4.5 and 7.5 GHz towards the Orion Molecular Clouds using the VLA. A subset of these sources that emit non-thermally are being monitored with VLBA in order to obtain stellar parallaxes and proper motion. In this contribution we report on current progress from 2 epochs of VLBA observations. While this is not sufficient for solution of distances and velocities, we can begin to distinguish between galactic and extragalactic sources. In this poster we look at the difference in the radio properties of these two populations, as well as whether or not the objects that were previously considered to be young stars are indeed members of the Orion Molecular Clouds. Our program will not only produce more accurate distances for constraining stellar ages, but the proper motions will be combined with radial velocities which we are also obtaining to determine the dynamical state of the Orion Nebula Cluster and other regions.

Author(s): Marina Kounkel[2], Lee W. Hartmann[2], Laurent Loinard[1], Gisela Ortiz-Leon[1]
Institution(s): *1. CRyA, 2. Univ. of Michigan*
Contributing team(s): Gould's Belt Distances Survey Group

448 – Starburst Galaxies Thursday Posters

448.01 – Probing the ISM of High-Redshift Gravitationally Lensed Dusty Star Forming Galaxies

The "Herschel Lensing Survey" (HLS; E. Egami et al. 2010) is a survey of massive galaxy clusters designed to detect gravitationally lensed dusty star forming galaxies in the submillimeter with Herschel. I will focus on results from the spectroscopic survey of the most luminous lensed dusty star forming galaxies discovered by HLS. We used optical/near-infrared spectrographs at LBT, Magellan, and VLT to detect multiple rest-frame optical nebular emission lines, which reveal the conditions of a galaxy's ISM; specifically ionization, star formation, metallicity, AGN activity, and dust attenuation. By targeting the most luminous sources further enables multi-wavelength (e.g. UV and Radio) follow-up of individual sources providing a glimpse into the nature of dusty star forming galaxies at redshifts z = 2 - 5.

Author(s): Gregory Walth[1]
Institution(s): *1. University of Arizona*
Contributing team(s): Herschel Lensing Survey

448.02 – Variations of the ISM conditions accross the Main Sequence of star forming galaxies: observations and simulations.

A significant amount of evidence has been gathered that leads to the existence of a main sequence (MS) of star formation in galaxies. This MS is expressed in terms of a correlation between the SFR and the stellar mass of the form SFR $\propto M^*$ and spans a few orders of magnitude in both quantities. Several ideas have been suggested to explain fundamental properties of the MS, such as its slope, its dispersion, and its evolution with redshift, but no consensus has been reached regarding its true nature, and whether the membership or not of particular galaxies to this MS underlies the existence of two different modes of star formation. In order to advance in the understanding of the MS, here we use a statistically robust Bayesian SED analysis method (CHIBURST) to consistently analyze the star-forming properties of a set of hydro-dynamical simulations of mergers, as well as observations of real mergers, both local and at intermediate redshift. We find a remarkable, very tight correlation between the specific star formation rate (sSFR) of galaxies, and the typical ISM conditions near their inernal star-forming regions, parametrized via a novel quantity: the compactness parameter (*C*). The evolution of mergers along this correlation explains the spread of the MS, and implies that the physical conditions of the ISM smoothly evolve between on-MS (secular) conditions and off-MS (coalescence/starburst) conditions. Furthermore, we show that the slope of the correlation can be interpreted in terms of the efficiency in the conversion of gas into stars, and that this efficiency remains unchanged along and across the MS. Finally, we discuss differences in the normalization of the correlation as a function of merger mass and redshift, and conclude that these differences imply the existence of two different modes of star formation, unrelated to the smooth evolution across the MS: a disk-like, low pressure mode and a compact nuclear-starburst mode.

Author(s): Juan R. Martinez Galarza[3], Howard Alan Smith[3], Lauranne Lanz[1], Christopher C. Hayward[1], Andreas Zezas[3], Chao-Ling Hung[3], Lee Rosenthal[2], Aaron Weiner[3]
Institution(s): *1. California Institute of Technology, 2. Haverford College, 3. Smithsonian Astrophysical Observatory*

448.03 – Age dating Star Clusters in Starburst Galaxy Merger NGC3256

Luminous infrared galaxies are systems undergoing rapid bursts of star formation triggered by the merging of molecular gas-rich galaxies. These galaxies can form more than 100 solar masses of stars per year. Here, an HST ACS/WFC study of optically-visible star formation in the late-stage merger NGC3256 is presented. This galaxy is clearly undergoing a starburst, with many young clusters visible in the HST far-ultraviolet and optical (F140LP, F435W and F814W) images of the merger. Estimates of optically-visible star cluster ages are summarized. These broad-band photometric age estimates are compared with those determined spectroscopically with Keck LRIS.

Author(s): Tamar Lambert-Brown[1]
Institution(s): *1. University of Maryland College Park*

448.04 – Probing Star Formation in the Early Universe with Far-IR Spectroscopy using ZEUS-2

ZEUS-2 is a long slit, direct detection, grating spectrometer for submillimeter wavelengths between 200-850 µm. At present, ZEUS-2 employs a single TES bolometer array that addresses only the 350 and 450 µm windows. Here we report the first science obtained with this array on the Atacama Pathfinder Experiment (APEX) telescope, and our progress towards implementing a second TES array that will open up the 200, 230, 640, 850 µm windows for direct detection spectroscopy on APEX.

Our investigations focus on detecting faint and broad far-infrared (FIR) fine structure lines of ionized carbon [CII] at 158 µm, nitrogen [NII] at 122 and 205 µm and doubly ionized oxygen [OIII] at 52 and 88 µm from distant galaxies as the lines are redshifted into the submm telluric windows. We are primarily interested in the redshift 1 to 4 interval which encompasses the epoch of maximum star formation rate per unit co-moving volume in the Universe. These far infrared lines are important gas coolants, and powerful probes of the physical conditions of the interstellar medium and the starlight that heats the gas. Here we report detections of the [CII] and [OIII] 88 µm lines from sources at redshift 1.8 to 4.3, and show how the lines can be used to trace both the spatial extent of the star formation and the hardness of the ambient radiation fields.

Author(s): Amit Vishwas[2], Carl Ferkinhoff[2], Thomas Nikola[2], Stephen Parshley[2], Justin Paul Schoenwald[2], Gordon J. Stacey[2], James L. Higdon[6], Sarah Higdon[6], Drew Brisbin[2], Aprajita Verma[8], Dominik A. Riechers[2], Steve Hailey-Dunsheath[1], Karl Menten[9], Rolf Güsten[9], Axel Weiss[9], Kent Irwin[7], Hsiao-Mei Cho[10], Michael D. Niemack[2], Mark Halpern[5], Mandana Amiri[5], Matthew Hasselfield[3], Donald V. Wiebe[5], Peter A. R. Ade[4], Carole E Tucker[4]
Institution(s): *1. California Institute of Technology, 2. Department of Astronomy, Cornell University, 3. Department of Astrophysical Sciences, Princeton University, 4. Department of Physics and Astronomy, Cardiff University, 5. Department of Physics and Astronomy, University of British Columbia, 6. Department of Physics, Georgia Southern University, 7. Department of Physics, Stanford University, 8. Department of Physics, University of Oxford, 9. Max-Planck-Institut für Radioastronomie, 10. NIST Boulder*

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449 – Stars and Friends Posters

449.01 – A Detailed Spectroscopic Analysis of The EQ Pegasi System

EQ Pegasi (GJ 896, HIP 116132) is a resolved binary system comprised of mid-M dwarfs at a distance of only 6.2 pc. The system has been studied extensively over a broad range of wavelengths from the X-ray to the radio. These observations reveal both components are variable, flare, and exhibit high levels of magnetic activity. The pair were recently proposed as members of a nearby young kinematic association on the basis of consistent Galactic kinematics, strong X-ray emission, and color-magnitude diagram position. Thus, they may be the closest pre-main-sequence system to the Sun. Here we present a detailed analysis of EQ Peg A and B using medium resolution spectra covering ~0.5-2.5 microns. We investigate spectral types, chromospheric activity indicators, lithium depletion, and gravity sensitive alkali lines and molecular bands to characterize the system and place constraints on its age.

Author(s): Joshua E. Schlieder[3], Simon Murphy[1], Adric R. Riedel[2]
Institution(s): *1. ARI/Heidelberg University, 2. CUNY/Hunter College, 3. NASA Ames Research Center*

449.02 – The Ages of Early-Type Stars: Strömgren Photometric Methods Calibrated, Validated, Tested, and Applied to Hosts and Prospective Hosts of Directly Imaged Exoplanets

Age determination is undertaken for nearby early-type (BAF) stars, which constitute attractive targets for high-contrast debris disk and planet imaging surveys. Our analysis sequence consists of: acquisition of *uvby*β photometry from catalogs, correction for the effects of extinction, interpolation of the photometry on to model atmosphere grids from which atmospheric parameters are determined, and finally, comparison to the theoretical isochrones from pre-main sequence through post-main sequence stellar evolution models, accounting for the effects of stellar rotation. We calibrate and validate our methods at the atmospheric parameter stage by comparing our results to fundamentally determined T^{eff} and log(g) values. We validate and test our methods at the evolutionary model stage by comparing our results on ages to the accepted ages of several benchmark open clusters (IC 2602, α Persei, Pleiades, Hyades). Finally, we apply our methods to estimate stellar ages for 3493 field stars, including several with directly imaged exoplanet candidates.

Author(s): Trevor J. David[1], Lynne Hillenbrand[1]
Institution(s): *1. California Institute of Technology*

449.03 – Time-Resolved Near-Ultraviolet Flare Spectra with the Hubble Space Telescope / Cosmic Origins Spectrograph

A large amount of the radiated energy during solar and stellar flares is emitted as white-light continuum emission, extending through the ultraviolet and optical wavelength regimes. Broadband photometry and optical spectral observations of M dwarf flares suggest that the white-light peak is located in the near-ultraviolet wavelength regime similar to a blackbody with T ~ 10,000 K, whereas radiative-hydrodynamic models using a solar-type flare heating mechanism (nonthermal electrons with a flux ~ 10^{11} erg / s / cm^2 accelerated in the corona) predict that the peak lies at redder wavelengths at the head of the Balmer continuum. We have completed a successful flare monitoring campaign on the dM4e star GJ 1243, in order to constrain the time-evolution of the peak of the white-light continuum. The campaign took place over 12 hours on Aug 31/Sept 1, 2014, and included optical monitoring from nine ground-based telescopes as the Hubble Space Telescope recorded time-tagged spectra in the near-ultraviolet (2450-2840 Å) with the Cosmic Origins Spectrograph. Two flares occurred during the HST observations, and we show preliminary results relating the continuum and line (Fe II and Mg II) emission to the simultaneous ground-based optical spectra and photometry. This dataset provides new constraints for radiative-hydrodynamic modeling of the lower flaring atmosphere in addition to input for models of the effects of flares on biomarkers and habitability around M dwarfs.

Author(s): Adam F Kowalski[4], Suzanne L. Hawley[13], Christopher M. Johns-Krull[8], Sarah J. Schmidt[10], Alexander Brown[11], John P. Wisniewski[12], James R. A. Davenport[13], Cecilia Farina[3], Nicola Pietro Gentile Fusillo[3], Manolis Xilouris[5], Mihalis Mathioudakis[7], Rachel A. Osten[9], Jon A. Holtzman[6], Ngoc Phan-Bao[1], Jeff A. Valenti[9], Lucianne Walkowicz[2]
Institution(s): *1. Academia Sinica, 2. Adler Planetarium, 3. Isaac Newton Group of Telescopes, 4. NASA Goddard Space Flight Center, 5. National Observatory of Athens, 6. New Mexico State University, 7. Queen's University of Belfast, 8. Rice University, 9. Space Telescope Science Institute, 10. The Ohio State University, 11. University of Colorado, 12. University of Oklahoma, 13. University of Washington*

449.04 – M-Dwarf Metallicity through Analysis of Binary Partner

We present work on determining the metallicity of M-dwarfs through analysis of M-star containing binary pairs and discuss its potential use with regards to exoplanet host star population studies. It is notoriously difficult to directly measure the metallicity of M-dwarf stars via their spectra due to the complexity of their composition; by study of the spectra of M-dwarfs and their binary partners, a technique to determine the metallicity of M-dwarfs via spectra analysis can be developed. Assuming that the metallicity of two stars in a binary pair is similar, by studying the metal content of the more easily measured solar type star and correlating that to various spectra line indices in the accompanying M-dwarf, we can indirectly measure the metal content of the M-dwarf. We use both high and low resolution spectra of 50+ halo binary stars in the northern hemisphere collected at McDonald Observatory to perform this analysis.

Author(s): Daniel Nagasawa[1], Jennifer L. Marshall[1], Ting Li[1]
Institution(s): *1. Texas A&M University*

449.05 – Using PSF fitting to Identify Possible Unresolved Binary Systems in the HST Archives

During the life of its mission, the Hubble Space Telescope (HST) has observed a fair number of brown dwarfs which, in ground based images, appear to be single objects, but frequently, are revealed to be binary systems with the higher angular resolution of HST. The very small angular separation of these binaries hints to the fact that many more of the apparently single brown dwarfs. With PSF fitting, it is possible to identify binary brown dwarf candidates in the HST archives which are not resolved according to the Rayleigh criterion. By fitting a double PSF to each filter and camera for which data exists, we can determine a range of probable magnitudes for the primary and secondary component of a possible binary system. These magnitudes can then be used to constrain model spectra of brown dwarfs to find a range of possible temperatures and spectral types for the primary and secondary objects.

In this poster, we will present the results for one possible binary and several apparently single objects and discuss how we go about determining the probability that an apparently single brown dwarf may be a binary system and find the magnitudes for each component.

Author(s): Elora N. Salway[1], Denise C. Stephens[1], Douglas B. Gardner[1]
Institution(s): *1. Brigham Young University*

449.06 – Identifying New Fe I Levels from Stellar Spectra

The spectrum of the Fe I atom is critical to many areas of astrophysics and beyond. Measurements of the energies of its high-lying levels remain woefully incomplete, however, despite extensive laboratory and solar analysis. Here we discuss work by Peterson & Kurucz (2014, ApJS, in press) to identify such levels using high-resolution archival absorption-line ultraviolet and optical spectra of stars, whose warm temperatures favor moderate Fe I excitation. To date this analysis has provided the upper energies of 66 Fe I levels. Many are of higher excitation than is accessible to laboratory experiments; several exceed the Fe I ionization energy. These levels provide new identifications for over two thousand potentially detectable lines. We describe and illustrate our method, which is based on matching the strengths and positions of unidentified spectral features to the lines sharing a particular upper level in Kurucz's semi-empirical calculations. We also highlight the improvements these new identifications bring to the determination of the abundances of trace elements in individual stars, and to the ability of calculations of cool stellar spectra to match low-resolution observations of stars and old stellar systems.

Author(s): Ruth Peterson[2], Robert L. Kurucz[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. SETI Institute*

449.07 – Very low-luminosity Class I/Flat outflow sources in sigma Orionis: Clues to alternative formation mechanisms for very low-mass stars

We present an optical through sub-millimetre multi-wavelength study of two very low-luminosity Class I/Flat systems, Mayrit 1701117 and Mayrit 1082188, in the sigma Orionis cluster. We performed moderate resolution (R ~ 1000) optical (~0.4-0.9mu) spectroscopy with the TWIN spectrograph at the Calar Alto 3.5-m telescope. The spectra for both sources show prominent emission in accretion- and outflow-associated lines. The mean accretion rate measured from multiple line diagnostics is 6.4x10^{-10} Msun/yr for Mayrit 1701117, and 2.5x10^{-10} Msun/yr for Mayrit 1082188. The outflow mass loss rates for the two systems are similar and estimated to be ~1x10^{-9} Msun/yr. The activity rates are within the range observed for low-mass Class I protostars. We obtained sub-millimetre continuum observations with the Submillimetre Common-User Bolometer Array (SCUBA-2) bolometer at the James Clerk Maxwell Telescope. Both objects are detected at a >5-sigma level in the SCUBA-2 850mu band. The bolometric luminosity of the targets as measured from the observed spectral energy distribution over ~0.8-850mu is 0.18+/-0.04 Lsun for Mayrit 1701117, and 0.16+/-0.03 Lsun for Mayrit 1082188, and is in the very low-mass range. The total dust+gas mass derived from sub-millimetre fluxes is ~36 M_Jup and ~22 M_Jup for Mayrit 1701117 and Mayrit 1082188, respectively. There is the possibility that some of the envelope material might be dissipated by the strong outflows driven by these sources, resulting in a final mass of the system close to or below the sub-stellar limit. Given the membership of these objects in a relatively evolved cluster of ~3 Myr of age, we consider an alternate formation mechanism in the context of the `hybrid' model of disk fragmentation, followed by ejection of a gaseous clump.

Author(s): Basmah Riaz[4], E. Whelan[2], M. Thompson[3], E. Vorobyov[5], N. Lodieu[1]
Institution(s): *1. IAC, 2. Uni of Tuebingen, 3. Uni. of Hertfordshire, 4. Uni. of Maryland, 5. Uni. of Vienna*

449.08 – The Dearth of Lithium-Rich Red Giants in Globular Clusters

Roughly 90% of a star's lithium content is destroyed during mixing that occurs before a star reaches the red giant branch (RGB). Yet a few anomalous RGB stars have been reported with lithium orders of magnitude more than expected and are thus dubbed lithium-rich red giants. In this work, we compare medium-resolution spectra of red giants to synthetic model spectra using a least-squares fit to calculate lithium abundance detections and upper limits. The new results amend the 1% frequency of lithium-richness in red giants previously predicted by Brown et al. 1989, Ruchti et al. 2011, Lebzelter et al. 2012, and Kirby et al. 2012. The new measurement for lithium-richness, at most 0.56%±0.16%, explains the previously anomalous findings of Pilachowski et al. 2000 and Lind et al. 2012, where data was also collected from globular clusters. This downward revision of the predicted lithium-rich red giant fraction partially alleviates the discrepancy between most observations and canonical theory of stellar structure, which cannot explain the existence of Li-rich giants. This work debunks previous proposals for possible origins of abnormal lithium-enrichment in RGB stars.

Author(s): Andrew J Zhang[2], Evan N Kirby[1], Puragra Guhathakurta[3]
Institution(s): *1. California Institute of Technology, 2. The Harker School, 3. University of California, Santa Cruz*

449.09 – The Kepler Cluster Study: rotation period measurements for cool stars in the 2.5 billion year open cluster NGC 6819

The Kepler Cluster Study (KeCS) is a program to measure stellar rotation periods and search for planets around members of open star clusters within the field of view of NASA's Kepler mission. We present here the latest results from KeCS - measurements of stellar rotation periods in the 2.5 billion year open cluster NGC 6819 - and discuss their implications for a technique (gyrochronology) to determine stellar ages from stellar rotation.

Author(s): Soren Meibom[1], Sydney A. Barnes[3], Imants Platais[2], Ronald L. Gilliland[4], David W. Latham[1], Robert D. Mathieu[5]
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Contributing team(s): Kepler Science Team, Kepler Science Operations Center

449.10 – Herschel Observations of Protoplanetary Disks in Lynds 1641: Far IR Constraints on the Dust Distribution

We present Herschel Space Telescope observations of the star-forming region Lynds 1641 (L1641), a region in the Orion Molecular Cloud A with active star formation and a very young population. The observations were obtained by the Herschel OT Key Project “Herschel Orion Protostar Survey” (HOPS), using the Photodetector Array Camera and Spectrometer (PACS) at 70 and 160 microns, and were originally identified by the Spitzer Space Telescope. Our 64 sources comprise the largest Herschel sample of very young (< 2 Myr) protoplanetary disks studied so far. These observations were augmented by PACS 100 micron data from the Gould Belt Key Project. After combining optical photometry, Spitzer infrared photometry and spectroscopy, and the new PACS photometry at 70, 100 and 160 microns, we constructed Spectral Energy Distributions (SEDs) for all the sources. We used the SEDs to identify the full disks and the transitional disks in the sample, and to compare with theoretical models, aiming to estimate the degree of dust settling in this young population.

Author(s): Sierra Grant[7], Nuria Calvet[7], S. Thomas Megeath[8], William J. Fischer[5], Kyoung Hee Kim[6], Babar Ali[4], Laura Ingleby[1], Melissa McClure[3], Wen-hsin Hsu[7], Cesar Briceno[2]
Institution(s): *1. Boston University, 2. Cerro Tololo Inter-American Observatory, 3. European Southern Observatory, 4. NASA Herschel Science Center, 5. Oberlin College, 6. The Korea Astronomy and Space Science Institute, 7. University of Michigan, 8. University of Toledo*

449.11 – Ultraviolet Spectra of Star-Grazing Comets in the 49 Ceti Disk System

49 Ceti is a young star that hosts a debris disk with an unusually large amount of carbon monoxide gas. This excess gas has been attributed to frequent collisions of comets within the disk. (Zuckerman & Song, 2012). Since 49 Ceti disk is nearly edge-on to our line of sight, it is a prime target to observe disk gas and evaporated material from star-grazing comets using absorption spectroscopy, as shown by detection of time-variable circumstellar absorption in optical spectra of the star (Montgomery & Welsh 2012). Here we discuss ultraviolet spectra of 49 Ceti taken using the *Hubble Space Telescope* Space Telescope Imaging Spectrograph (STIS) during two separate visits six days apart. The spectra show time-variable and highly Doppler shifted absorption features from ionized gaseous species. The maximum velocity of the time-variable gas corresponds to a minimum distance from the star of 0.06 AU. These features very likely come from star-grazing comets. Lower limits on element abundances in the gas were found using the apparent optical depth method. The variable comet gas appears carbon rich, despite the disk gas as a whole showing strong absorption features from both carbon and oxygen (Roberge et al., 2014, in press).

Author(s): Brittany E. Miles[3], Aki Roberge[2], Barry Welsh[1]
Institution(s): *1. Eureka Scientific, 2. GSFC, 3. UCLA*

449.12 – Investigating Star-disk Interactions During Late-stage Circusmtellar Disk Evolution in the Nearby Pre-MS Stars T Cha and TWA 30

We investigate, via contemporaneous X-ray and optical/IR observations, the nearby, pre-main sequence star/disk systems T Chamaeleontis (T Cha; D ~ 110 pc, age 3-5 Myr) and TWA 30A and 30B (D ~ 40 pc; age ~ 8 Myr). All three of these systems present opportunities to probe pre-main sequence (pre-MS) star-disk interactions during late-stage circumstellar disk evolution. The classical T Tauri star T Cha is the closest known example of a highly inclined, actively accreting, solar-mass star/disk system; furthermore, T Cha may be orbited by a low-mass companion or massive planet that has cleared an inner hole in its disk. We analyze near-simultaneous Chandra high-resolution X-ray and optical H-alpha spectroscopy observations of T Cha and find a correlation between X-ray and optical extinction resulting from variable photospheric obscuration from a disk warp/clump. We search for signatures of accretion and infer the X-ray absorbing properties of the T Cha circumstellar disk.
We also present contemporaneous XMM-Newton X-ray and optical/IR spectroscopic observations of the nearby, actively accreting, very low-mass (mid-M) pre-MS star/disk/jet systems TWA 30A and 30B. Like T Cha, each component of this wide binary is viewed through a nearly edge-on circumstellar disk. We investigate potential X-ray accretion signatures, and compare the levels of magnetic activity in TWA 30A and 30B to those of other nearby, low-mass pre-MS stars near the H-burning limit. Both TWA 30A and 30B display large near-IR variability, suggestive of (respectively) variable obscuration of the stellar photosphere and a possible disk-rim warp. We detect only TWA 30A in X-rays and, similar to

the case of T Cha, find a correlation between optical/IR and X-ray extinction associated with variable photospheric obscuration. The proximity and highly-inclined viewing geometries of the TWA 30 pair and T Cha, combined with contemporaneous optical/IR and X-ray observations, afford a unique opportunity to investigate the composition of late-stage circumstellar disks orbiting pre-MS stars.

Author(s): David Principe[7], Joel Kastner[6], Juan Alcala[3], Michael S Bessell[1], David Huenemoerder[5], Giuseppe Sacco[2], Beate Stelzer[4]
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449.13 – Characterizing the Long-Term Variability of X-ray Binary 4U1705-44
Evidence for an Underlying Double-Welled Nonlinear Oscillator

4U 1705-44 is a bright low mass x-ray binary (LMXB) containing a neutron star and a close, low mass companion. The Rossi X-ray Timing Explorer (RXTE) All-Sky Monitor obtained approximately 14 years of daily monitoring on 4U 1705-44 in the 2-20 keV energy range. Understanding the x-ray variability of 4U1705-44 is critical to the study of all low mass x-ray binaries because they share many of the same global characteristics in their high-amplitude transitions and non-periodic variability. After comparing the longterm light curve and phase space trajectories of 4U1705-44 to various nonlinear oscillators, the Duffing Oscillator was revealed to be a strong candidate to describe these systems. The parameters of the Duffing equation were optimized and six solutions sharing the same characteristics as 4U1705-44 were found. Striking commonalities were revealed via a phase-space analysis of both 4U1705-44 and the six Duffing solutions: the low-order driving period is no less than 87 days and spans up to 180 days, which is seen and highlighted in the power spectra, zero-crossings and close returns analysis of 4U1705-44. Furthermore, the driving frequency of all six Duffing solutions tend to converge to a range of 3.6 – 4.5, corresponding to driving periods in the range from 130 to 175 days, in agreement with that found in 4U1705-44. Nonlinear analysis methods such as close returns and zero-crossings of the Duffing solutions also show the same trends. This strongly suggests that 4U1705-44 shares the same topological characteristics as the Duffing equation. With further analysis, we hope to develop a model to explain why 4U1705-44 shares the unique topology of the Duffing Oscillator specifically, rather than those of other families of nonlinear differential equations.

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Institution(s): *1. Colorado State University , 2. NASA's Goddard Space Flight Center*

449.14 – A Hyper Luminous X-ray Source Catalog Based on Chandra ACIS Data

Ultraluminous X-ray Sources(ULXs) were once considered to be good intermediate mass black hole (IMBH) candidates. People gradually realize most ULXs are just stellar mass black holes which have non spherical radiation or super Eddington luminosities. However X-ray sources with luminosities near or higher than several times $1\times10^{40} erg\,s^{-1}$ remains to be a grey land. Our nowadays radiation mechanism can not give that kind of X-ray luminosity for a stellar mass black hole. Are these kind of sources still stellar mass black holes? Or can higher x-ray luminosity be the key tracer of IMBHs? Their nature remain to be inconclusive. On the other hand, there are few promising IMBH candidates now and the best one is a hyper luminous X-ray source(HLX) with a consistent X-ray luminosity larger than $1\times10^{42} erg\,s^{-1}$. Previous luminous X-ray source catalog are far from exploiting the archival data thoroughly. Here we make a HLX survey using Chandra ACIS data to find X-ray sources like HLX-1 in $300 Mpc$. We directly analyse about 10000 ACIS observations and cross correlate the X-ray sources with a galaxy catalog we make. Our final catalog includes 86 HLX if we cut at $3\times10^{40} erg\,s^{-1}$. The log N-log S relation suggests a modest contamination by foreground or background sources. Follow up photometric and spectroscopical observations could reveal their nature. At last based on the limited archival data, we analyse one source particularly.

Author(s): Hang Gong[1], Jifeng Liu[1]
Institution(s): *1. NAOC*
Contributing team(s): CXC

449.15 – A Multi-band Extension of the Analysis of Variance Period Finding Algorithm

One of the largest challenges facing modern astronomical surveys is the automated classification of sources. In the case of variable stars, periods are among the most useful features for classification algorithms. In surveys such as the Dark Energy Survey, which cover a large area of the sky with relatively few visits, single band period finding algorithms can struggle due to poor phase coverage in any one band. However, these single band algorithms throw away data in the form of other bands that can potentially hold more information about the period of the variable source. We present here an extension of the Analysis of Variance single band period finding algorithm to include information about the period contained in other bands. We generate light curves of RR Lyrae stars in 5 bands and compare the performance of the multi-band algorithm to its single band implementation. By including these extra bands we show improved performance for poorly sampled light curves over long baselines in simulated data.

Author(s): Nicholas Mondrik[1], Jennifer L. Marshall[1], James Long[1]
Institution(s): *1. Texas A&M University*

449.16 – High-Cadence, Long-Baseline Light Curves of Red Giant Variable Stars

We investigate light curves of asymptotic giant branch (AGB) stars from a photometric survey with high cadence, baseline, and photometric precision. The KELT exoplanet transit survey uses small robotic telescopes to obtain light curves of stars over ~60% of the sky for stars with 8 < V < 12. Those light curves generally have 5,000 to 8,000 observations in a broad R-band filter at a 20-minute cadence over four to seven years. We identify AGB stars observed by KELT through the use of color cuts, and search for coherent variability and periodic behavior in the light curves. After identifying 16,252 candidate AGB stars observed by KELT, we find 151 of them showing strong periodic behavior.

Author(s): Robert Alexander Arnold[2], Joshua Pepper[1], Joseph E. Rodriguez[3]
Institution(s): *1. Lehigh University, 2. University of Central Arkansas, 3. Vanderbilt*
Contributing team(s): KELT Collaboration

449.17 – Deriving Precise Ages for Field White Dwarfs using Bayesian Techniques

We apply a self-consistent and robust Bayesian statistical approach along with a range of modern model ingredients to determine the ages, distances, and ZAMS masses of old field white dwarfs with hydrogen, helium, and mixed atmosphere types. We find that age, distance, and ZAMS mass are correlated in a manner that is too complex to be captured by traditional error propagation techniques. In cases where we can determine the composition of the atmosphere, our technique requires only quality optical and near-IR photometry to derive ages with < 15% uncertainties, often with little sensitivity to our choice of modern initial-final mass relation. We additionally predict the capabilities of this technique to derive WD ages and atmospheric types in the GAIA era, when thousands of WDs will have distances accurate to <2%.

Author(s): Aaron Webster[1], Ted von Hippel[1]
Institution(s): *1. Embry Riddle Aeronautical University*
Contributing team(s): Bayesian Analysis of Stellar Evolution (BASE)

449.18 – A Comprehensive Search for Cataclysmic Variables in 47 Tucanae

Most theoretic models typically predict the existence of ~100 cataclysmic variables (CVs) in the cores of massive globular clusters (GCs) such as 47 Tucanae. However, up to this point only 3 have been confirmed spectroscopically in 47 Tuc with only a handful more candidates. We present the most comprehensive search to date for erupting dwarf novae using every available epoch of archival Hubble Space telescope images in multiply-imaged visual through near-UV wide filters. These observations, covering 49 epochs, vastly improve upon the previous visual search by Shara et al. 1996. Here, we report that we have found no new erupting dwarf novae, severely limiting models for the formation of CVs or perhaps, suggesting CVs in GCs behave differently than those in the field.

Author(s): Matthew Wilde[1], Michael Shara[1]
Institution(s): *1. American Museum of Natural History*

449.19 – The Spatial Distribution of Novae in M31 : Bulge vs Disk Decomposition

Novae in Andromeda (M31) are believed to separate into two distinct populations (bulge/disk). The bulge seems to be more prolific nova producer as compared to the disk of M31, as per observations. These spatial distinctions appear to correlate with their spectral differences (Fe II in bulge , He/N in disk), which are thought to be evolved from two separate binary populations. However, recent observations of novae in the Milky Way have demonstrated spectral transformations from Fe II to He/N and vice-versa, which calls this distinction between two source classes into question. We construct a spatial distribution of novae in M31 based on the assumption that novae follow light. The comparison of our resulting model with observations has been discussed. We also construct a dust extinction model based on the observed dust distribution in M31 in order to investigate any possible effects that could play a role in the observed distribution.

Author(s): A. Kaur[1], Dieter Hartmann[1]
Institution(s): *1. Clemson University*

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450 – Supernovae Posters

450.01 – SN Hunt 248: a super-Eddington outburst from a massive cool hypergiant

We present observations of SN Hunt 248, a new supernova (SN) impostor in NGC 5806, which began a multi-stage outburst in May 2014. The "2014a" discovery brightening exhibited an absolute magnitude of $M \approx -12$ and the spectral characteristics of a cool dense outflow, with P-Cygni lines of Hα, Fe II, and Na I. The source rapidly climbed and peaked at $M \approx -15$ mag after two additional weeks. During this bright "2014b'' phase the spectrum became hotter, dominated by Balmer emission and a stronger blue continuum, similar to the SN impostor SN 1997bs. Archival images from the *Hubble Space Telescope* between 1997 and 2005 reveal a luminous (4×10^5 $L^{\odot}$) variable precursor star. Its location on the Hertzsprung-Russell diagram is consistent with a massive ($M^{init} \approx 30$ $M^{\odot}$) cool hypergiant having an extremely dense wind and an Eddington ratio (Γ) just below unity. At the onset of the 2014a brightening, however, the object was super-Eddington (Γ = 4 - 12). The subsequent boost in luminosity during the 2014b phase probably resulted from circumstellar interaction. SN Hunt 248 provides the first case of a cool hypergiant undergoing a giant eruption reminiscent of outbursts from luminous blue variable stars (LBVs). This lends support to the hypothesis that some cool hypergiants, such as ρCas, could be LBVs masquerading under a pseudo-photosphere created by their extremely dense winds. Moreover, SN Hunt 248 demonstrates that eruptions stemming from such stars can rival in peak luminosity the giant outbursts of much more massive systems like ηCar.

Author(s): Jon Mauerhan[4], Schuyler D. Van Dyk[1], Melissa Lynn Graham[4], WeiKang Zheng[4], Kelsey I. Clubb[4], Alexei V. Filippenko[4], Stefano Valenti[2], Peter Brown[3], Nathan Smith[5], Dale Andrew Howell[2], Iair Arcavi[2]
Institution(s): *1. IPAC, 2. LCOGT, 3. Texas A&M, 4. UC Berkeley, 5. University of Arizona*

450.02 – High-resolution Studies of Charge Exchange in Supernova Remnants with Magellan, XMM-Newton, and Micro-X

Charge exchange, the semi-resonant transfer of an electron from a neutral atom to an excited state in an energetic ion, can occur in plasmas where energetic ions are incident on a cold, at least partially neutral gas. Supernova remnants, especially in the immediate shock region, provide conditions conducive to charge exchange. The emission from post charge-exchange ions as the captured electron cascades down to the ground state, can shed light on the physical conditions of the shock and the immediate post-shock material, providing an important tool to understanding supernova explosions and their aftermath.
I present a study of charge exchange in the galactic supernova remnant G296.1-0.5 in two bands: the optical and the X-ray. The optical study, performed using both imaging and spectroscopy from the IMACS instrument on the Magellan Baade Telescope at Las Companas Observatory, seeks to identify `Balmer-dominated shocks' in the remnant, which occur when charge exchange occurs between hot, post-shock protons and colder neutral hydrogen in the environment. The X-ray study probes line ratios in dispersed spectral data obtained with XMM-Newton RGS from an X-ray lobe in the NW of the remnant to hunt for signatures of charge exchange. The dispersed data are degraded by the extended nature of the source, blending many of the lines.
We are working towards the future of spectroscopic studies in the X-ray for such extended sources with Micro-X: a sounding rocket-borne, high energy resolution X-ray telescope, utilizing an array of microcalorimeters to achieve high energy resolution for extended sources. I describe the design and commissioning of the payload and the steps toward launch, which is anticipated in the summer of 2015.

Author(s): Sarah N. Heine[1], Enectali Figueroa-Feliciano[1], Daniel Castro[1]
Institution(s): *1. Massachusetts Institute of Technology*

450.03 – High velocity features in Type Ia supernovae via interaction with circumstellar shell

Observations of Type Ia supernovae (SN Ia) in the weeks before B-band maximum (B^{max}) have shown the presence of Ca, Si, and Fe features with velocities of 8,000-14,000 km/s faster than that associated with the photospheric features (PSF). Suggestions for the source of the high velocity features include interaction of the ejecta with a circumstellar material. We perform hydrodynamic simulation of a supernova interacting with a shell consisting of 5×10^{-3} $M^{\odot}$ of material and an outer radius of 0.028 $R^{\odot}$ as well as a supernova in a low density circumstellar medium (LDCSM) without a shell. We present the synthetic spectra of the Ca II near-IR feature generated from both models fit to the observed features in SN 2011fe in the epoch before B^{max}. The shell interaction model consistently fits the observed spectra better than the LDCSM model at all times before B^{max}, and satisfies the observed velocity evolution of both the HVF and PSF.

Author(s): Brian W. Mulligan[1], J. Craig Wheeler[1]
Institution(s): *1. University of Texas at Austin*

450.04 – Polarized Light of SN 2014J

We present spectropolarimetric results of SN 2014J attained over several nights from February to May 2014 using the CCD Imaging/Spectropolarimeter (SPOL) at the 90” Bok and the 6.5-m MMT telescopes. Gathering multi-epoch data leads to a more complete picture of the time-dependent nature of this supernova’s polarized light. The continuum shows low polarization (~0.2%) thus confirming the small degree of global asymmetry typically seen in Type Ia supernovae. The near maximum light spectra show an evolving double-peaked Si II 6355Å line feature which reaches a polarization degree as high as ~0.7%.

Author(s): Amber L. Porter[1], Mark D. Leising[1], Peter Milne[2], Grant Williams[2], Paul S. Smith[2], Nathan Smith[2]
Institution(s): *1. Clemson University, 2. University of Arizona*

451 – The ISM and Its Denizens Posters

451.01 – A Search for Short-Term Variability in Diffuse Interstellar Bands

Modern electronic detectors allow for rapid observation of diffuse interstellar bands (DIB) than was possible with traditional photographic techniques. We have obtained moderate resolution (R=4000) spectra of two stars (HD 199478 and 183143) with strong DIB as described by Herbig (1995). We present the results of a comparison of these spectra over days and weeks to search for any significant temporal variability in the bands near 6200 A.
References:
Herbig (1995): "The Diffuse Interstellar Bands", Ann. Rev. Astro. Astrophys. 33: 19-73

Author(s): Alex Storrs[1], Stephanie McCubbin[1]
Institution(s): *1. Towson Univ.*

451.02 – Hydrogen Fluoride in the Local Universe

The Herschel Space Observatory has provided a unique opportunity to study hydride molecules with large rotational constant in the interstellar medium (ISM) within the nearby universe. Some of the key results from hydride studies with Herschel, and in particular with the Heterodyne Instrument for the Far-Infrared (HIFI), are the first detection at high spectral resolution of the fundamental J = 1 - 0 rotational transition of hydrogen fluoride (HF) at 1.232 THz, and the discovery of its ubiquitous nature within the ISM of the Milky Way galaxy and nearby galaxies. The remarkable Herschel/ HIFI results suggest, that the HF J = 1 – 0 transition promises to yield an extremely sensitive probe of the diffuse molecular gas along the lines of sight toward background far-infrared continuum sources and, as predicted earlier by chemical models, a valuable surrogate for molecular hydrogen in the nearby and high redshift universe. These and other interesting results on hydrogen fluoride from Herschel observations will be presented, as well as the results from follow-up studies from ground-base facilities on hydride molecules towards luminous lensed high-redshifted galaxies with strong submillimeter continuum.

Author(s): Raquel R. Monje[1], Dariusz C. Lis[1], Thomas G. Phillips[1]
Institution(s): *1. California Institute of Technology*

451.03 – What the Kinematics of Molecular Clouds Signify About Their Formation

We present a detailed analysis comparing the velocity fields in Galactic molecular clouds *and* the atomic gas that surrounds them in order to address the origin of the gradients. To that end, we present first-moment intensity-weighted velocity maps of the molecular clouds and surrounding atomic gas. The maps are made from high-resolution 13CO observations and 21 cm observations from the Leiden/Argentine/Bonn Galactic HI Survey. We find that (1) the atomic gas associated with each molecular cloud has a substantial velocity gradient—ranging from 0.02 to 0.07 km/s/pc —whether or not the molecular cloud itself has a substantial linear gradient. (2) If the gradients in the molecular and atomic gas were due to rotation, this would imply that the molecular clouds have less specific angular momentum than the surrounding HI by a factor of 1 – 6. (3) Most importantly, the velocity gradient position angles in the molecular and atomic gas are generally widely separated—by as much as 130 degrees in the case of the Rosette molecular cloud. This result argues against the hypothesis that molecular clouds formed by simple top-down collapse from atomic gas.

Author(s): Nia Imara[1], Leo Blitz[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. UC Berkeley*

451.04 – Carbon phases versus hydrogen phases: neutral gas in nearby galaxies

Due to its lower-than-hydrogen first ionization energy, atomic carbon is ionized throughout the diffuse ISM, tracing both regions of ioinized and neutral hydrogen gas. On the other hand, carbon monoxide (CO) exists and emits exclusively where hydrogen is in molecular form. Neutral atomic carbon is predicted to exist in between these phases, but recent evidence in our Galaxy and from simulations show it may be closely tied to the molecular gas than previously thought. Here, we investigate the gas in various carbon stages (evidenced through emission in [CII], [CI] and CO) compared to hydrogen stages (through α^{CO}-corrected CO for H^2 and HI emission). The observations are based upon the Beyond the Peak sample of 22 galaxies with data from the Herschel Space Observatory SPIRE FTS instrument, as well as relying on ground-based CO and HI observations. Based on these comparisons, [CI] does trace CO well and thus may provide a good way to trace molecular gas in external galaxies as well as in molecular clouds in the Milky Way.

Author(s): Alison Faye Crocker[1], Eric Pellegrini[2], John-David T. Smith[2]
Institution(s): *1. Reed College, 2. University of Toledo*
Contributing team(s): Beyond the Peak Team

451.05 – The environmental dependence of far-infrared dust emissivity variations in M31

In the framework of the Panchromatic Hubble Andromeda Treasury (PHAT) survey, we developed the Bayesian Extinction and Stellar Tool (BEAST), a probabilistic approach to modeling the dust attenuated photometric spectral energy distribution of an individual star (Gordon et al. 2015). Thus, we are able to infer the physical properties of every single source observed in the PHAT survey as well as constraining the extinction along each line of sight. The latter is of particular interest when studying the interstellar medium structure and the evolution of dust grains in a galaxy. Assuming a star geometry across M31, we build maps of both A(V) (dust surface density) and R(V) (grain size) parameters across large regions in M31. By combining these maps with the Herschel far-IR/submm emission maps, we highlight dust emissivity variations that are correlated with environment.

Author(s): Heddy Arab[1], Karl D. Gordon[1]
Institution(s): *1. Space Telescope Science Institute*
Contributing team(s): PHAT team

451.06 – TWILIGHT: A Cellular Framework for Three-Dimensional Radiative Transfer

We describe a new framework for solving three-dimensional radiative transfer of arbitrary geometries, including a full characterisation of the wavelength-dependent anisotropic scattering, absorption, and thermal reemission of light by dust. By adopting a cellular approach to discretising the light and dust, the problem can be efficiently solved through a fully deterministic iterative process. As a proof of concept we present TWILIGHT, our implementation of the cellular approach, in order to demonstrate and benchmark the new method. TWILIGHT simultaneously renders over one hundred unique images of a given environment with no additional slowdown, enabling a close study of inclination effects of three-dimensional dust geometries. In addition to qualitative rendering tests, TWILIGHT is successfully tested against two Monte-Carlo radiative transfer benchmarks, producing similar brightness profiles at varying inclinations. With the proof-of-concept established, we describe the improvements and current developments underway using the cellular framework, including a technique to resolve the subgrid physics of dust radiative transfer from micron-scale grain models to kiloparsec-sized dust environments.

Author(s): David Khatami[2], Barry Madore[1]
Institution(s): *1. Carnegie Observatories, 2. Pomona College*

451.07 – Probing the Role of Carbon in the Interstellar Ultraviolet Extinction

We model the ultraviolet/optical extinction curves between 0.3 to 8 μm-1 of 16 Galactic sight lines which exhibit variable strengths and widths of the 2175Å bump, in terms of the standard silicate/graphite interstellar grain model. We find that the C abundance required to be locked up in dust correlates with the strength of the 2175Å bump, while the abundance of Si depleted in dust shows no correlation with the 2175Å bump. This supports graphite or PAHs as the possible carrier of the 2175Å bump. We also see a weak correlation between the C depletion and 1/RV suggesting the far-UV extinction is more likely produced by small carbon dust.

Author(s): Ajay Mishra[1], Aigen Li[1]
Institution(s): *1. University of MIssouri-Columbia*

451.08 – Directly detecting exozodiacal dust and disk variability

Dust is common throughout stellar systems. The architecture of stellar systems may be typically comprised of a distant cold debris disk, a warm exozodiacal disk, and a hot inner disk. Dust in this exozodiacal region confounds exoplanet detections by scattering light or mimicking planetary emission. This environment must be well-modelled in order to find Earth-sized exoplanets. Interferometry at the Center for High Resolution Astronomy (CHARA) Array provides the angular resolution to directly detect near-infrared (NIR) excesses originating from warm and hot dust close to the host star. The recently upgraded Fiber-Linked Unit for Optical Recombination (JouFLU) is capable of measuring interferometric visibility contrasts to a precision of <0.1% and dust disk fluxes equal to 1% of the host star. There is likely a connection between these hot interferometrically detected dust disks and the harder-to-detect warm zodiacal dust analogues. In this way interferometric studies can observe the tip-of-the-iceberg of stellar system dust, providing details such as composition and grain size of dust, as well as statistics on the correlation of dust populations and stellar properties. These inner dust regions may exhibit a high degree of variability which should also be characterized and may give hint to the dust origin and replenishment mechanisms. JouFLU is currently involved in a large survey of exozodiacal dust stars of spectral types A through K with the aim to provide statistics about dust disk occurrence in relation to their host stars and the presence of cold dust reservoirs. Complementing this survey is a project of re-observing the earliest excess detections in order to determine their variability. In addition, NASA's InfraRed Telescope Facility (IRTF) provides a method for spectrophotometric detections of excess stellar flux corresponding to the presence of hot/warm exozodiacal dust. Multiple NIR interferometric instruments as well as medium resolution spectroscopy are a sensitive and affordable method of discovering inner disks and characterizing nearby habitable zone environments.

Author(s): Nicholas J. Scott[1]
Institution(s): *1. Georgia State University/ The CHARA Array*

451.09 – Herschel Galactic plane survey of ionized gas traced by [NII]

Far infrared and sub-/millimeter atomic & ionic fine structure and molecular rotational lines are powerful tracers of star formation on both Galactic and extragalactic scales. Although CO lines trace cool to moderately warm molecular gas, ionized carbon [CII] produces the strongest lines, which arise from almost all reasonably warm (T>50 K) parts of the ISM. However, [CII] alone cannot distinguish highly ionized gas from weakly ionized gas. [NII] plays a significant role in star formation as it is produced only in ionized regions; in [HII] regions as well as diffuse ionized gas. The ionization potential of nitrogen (14.5 eV) is greater than that of hydrogen (13.6 eV), therefore the ionized nitrogen [NII] lines reflect the effects of massive stars, with possible enhancement from X-ray and shock heating from the surroundings. Two far-infrared 122 um and 205 um [NII] fine structure spectral lines are targeted via Photodetector Array Camera and Spectrometer (PACS) onboard Herschel Space Observatory. The sample consists of 149 line-of-sight (LOS) positions in the Galactic plane. These positions overlap with the [CII] 158 um observations obtained with the GOT C+ survey. With a reasonable assumption that the emission from both 122 um and 205 um lines originate in the same gas; [NII] 122/205 um line ratio indicates the a good measure of the electron density of each of the LOS positions. [NII] detections are mainly toward the Galactic center direction and the [NII] electron densities are found between 7-50 cm^-3, which is enhanced WIM (Warm Ionized Medium). WIM densities are expected to be much lower (~1 cm-3), therefore non-detections toward the opposite side of the Galactic Center shows abundant of this gas. The pixel to pixel variation of the emission within a single Herschel pointing is relatively small, which is interpreted as the [NII] emission comes from an extended gas. It is important to quantify what fraction of [CII] emission arises in the ionized gas. Thus, with the present work of [NII] observations, it will be possible to resolve the different parts of the ISM leading to determine the total mass of the ISM.

Author(s): Umut Yildiz[1], Paul Goldsmith[1], Jorge Pineda[1], William Langer[1]
Institution(s): *1. Jet Propulsion Laboratory*

451.10 – Herschel/PACS photometry of transiting-planet host stars with candidate warm debris disks

Dust in debris disks is produced by colliding or evaporating planetesimals, which are remnants of the planet formation process. Warm dust disks, known by their emission at ≤24 µm, are rare (4% of FGK main sequence stars) and especially interesting because they trace material in the region likely to host terrestrial planets, where the dust has a very short dynamical lifetime. Statistical analyses of the source counts of excesses as found with the mid-IR Wide Field Infrared Survey Explorer (WISE) suggest that warm-dust candidates found for the Kepler transiting-planet host-star candidates can be explained by extragalactic or galactic background emission aligned by chance with the target stars. These statistical analyses do not exclude the possibility that a given WISE excess could be due to a transient dust population associated with the target. Here we report Herschel/PACS 100 and 160 micron follow-up observations of a sample of Kepler and non-Kepler transiting-planet candidates' host stars, with candidate WISE warm debris disks, aimed at detecting a possible cold debris disk in any one of them. No clear detections were found in any one of the objects at either wavelength. Our upper limits confirm that most objects in the sample do not have a massive debris disk like that in beta Pic. We also show that the planet-hosting star WASP-33 does not have a debris disk comparable to the one around eta Crv. Although the data cannot be used to rule out rare warm disks around the Kepler planet-hosting candidates, the lack of detections and the characteristics of neighboring emission found at far-IR wavelengths support an earlier result suggesting that most of the WISE-selected IR excesses around Kepler candidate host stars are likely due to either chance alignment with background IR-bright galaxies and/or to interstellar emission.

Author(s): David R. Ardila[5], Bruno Merin[2], Alvaro Ribas[1], Herve Bouy[1], Geoffrey Bryden[3], Karl R. Stapelfeldt[4], Deborah Padgett[4]
Institution(s): *1. Centro de Astrobiologia, 2. Herschel Science Centre / European Space Agency, 3. Jet Propulsion Laboratory, 4. NASA/Goddard Space Flight Center, 5. The Aerospace Corporation*

452 – The Milky Way Posters

452.01 – A Green Bank Telescope 21cm survey of HI clouds in the Milky Way's nuclear wind

Feedback processes such as large-scale galactic winds are thought to be responsible for distributing enriched gas throughout a galaxy and even into the IGM. Such winds have been found in many galaxies with active star formation near their center, and the Fermi bubbles provide evidence for such a nuclear wind in our own Milky Way. A recent 21 cm HI survey by the Australia Telescope Compact Array discovered a population of compact, isolated clouds surrounding the Galactic Center that may be entrained in the Fermi bubble wind. We present data from a survey of 21cm HI over an extended region around the Galactic Center using the Green Bank Telescope. These observations provide more strict constraints on neutral clouds in the Fermi bubble wind, and a more robust description of the parameters of HI clouds (i.e., mass, column density, and lifetime) near the Galactic Center.

Author(s): Sara Denbo[1], Ryan Endsley[3], Felix J. Lockman[2], Alyson Ford[2]
Institution(s): *1. Michigan State University, 2. National Radio Astronomy Observatory, 3. Washington University in St. Louis*

452.02 – A Python Pipeline for the Mercury N-body Code With First-Order GR Effects

We present a pipeline for use with the *Mercury* N-body code (Chambers 1999), which we make publicly available on *github*. We have modified the standard *Mercury* integrator to include first-order numerical relativistic effects and a smooth stellar potential for use in the near-Keplerian potential around a massive black hole. Python scripts generate the input files and perform analysis on hundreds of stars, including those in a disk around Sgr A* and in highly-eccentric remnants of disrupted binaries.
We use this code to simulate the dynamical effects of an intermediate-mass black hole on the stars in the Galactic center. Preliminary results indicate significant effects on the semi-major axis and eccentricity distribution. Using the h-statistic (Madigan et al. 2014) as a proxy for eccentricity, this should be observable in current observational data, allowing us to constrain the remaining parameter space available to an intermediate-mass black hole in the Galactic center (Gualandris & Merritt, 2009).

Author(s): Christopher AM Wieland[1], Ann-Marie Madigan[1]
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453 – The Sun and Solar System Thursday Posters

453.01 – Study of Photospheric Magnetic and Coronal Data in Solar Active Regions

We investigate the dynamical coupling between the photosphere and the corona in active regions by analyzing HMI magnetograms and AIA maps of coronal emission from the Solar Dynamics Observatory (SDO). The study consists of two main components, an spectral analysis and a correlation analysis. In the spectral analysis we characterized the spatiotemporal behavior of the line-of-sight (LOS) photospheric magnetic field and coronal intensity by determining the power-law decay of their Fourier spectra. Values of the power-law scaling exponents reflect the state of the turbulent photospheric plasma and capture field's transient changes that are related to the coronal emission. In particular, the scaling exponents were used to test the validity of Taylor's hypothesis for frozen-in-flow turbulence. For the correlation analysis we calculated the spatiotemporal autocorrelation and cross-correlation functions for the photospheric magnetic field and the coronal emission in different wavelengths. These multidimensional functions were reduced to a form that can be characterized by a single parameter such as the e-folding time or length. Our results suggest that parameters capturing the spatiotemporal complexity and dynamics can be used for monitoring the evolution of the active region towards a state of flare productivity. This type of parameters is often used for building flare prediction models, an essential of Space Weather forecasting.

Author(s): Jordan A Guerra[2], Antti A Pulkkinen[1], Vadim Uritsky[2]
Institution(s): *1. NASA GSFC, 2. The Catholic University of America*

453.02 – To the origin problem of the Moon

The work objective is to draw the astronomer's attention to the origin problem of the Moon on the new comparative basis of various chemical elements isotopes contained in both lunar and terrestrial rocks. At present time it is assumed that the Moon as the natural Earth satellite appeared about 4.2 milliards years ago after some celestial body as big as Mars had collided catastrophically with the Earth. If this hypothesis is correct, the Moon rocks isotopic composition must be identical both in contents and in abundance to that of the Earth. However as the lunar soil samples delivered by American astronauts from the Moon surface have shown it is not true.
For the unambiguous answer to the question of the Moon origin on base of lunar and terrestrial rocks isotopic content analysis only, it is necessary to compare both the isotopic content and abundance not of any chemical elements *in general*, but only of those *stable* isotopes which have 100 % relative abundance both on Earth and Moon. For this purpose we propose to introduce the characteristic of 100 % relative abundance of the stable isotopes (let it be named spectrum) for each celestial body.
Comparing the similar spectra for various planets one can draw a conclusion on the similarities and differences in their origin conditions. Thus if the Moon and the Earth arose out of one and the same progenitor body, they should have the

same spectra. For more perfect spectra identification the Moon soil samples have to be taken from its internal layers. So far we don't possess such samples.

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453.03 – Observation of new trans-Neptunian Objects in the Dark Energy Survey Supernova Fields

The Dark Energy Survey (DES) is a five-year optical imaging survey intended to measure the growth of structure and expansion history of the universe over a wide span of cosmic time. As part of this effort, the survey images ten separate 3 sq. deg. fields approximately weekly to search for Type Ia supernovae. These fields generate a rich time series of data that can be used to search for other interesting objects, such as moving transients. Among these are trans-Neptunian objects, including classical Kuiper Belt objects as well as scattered and detached disk objects. We have searched the data collected during DES's two and a half seasons for such objects. Our analysis revealed sixteen previously unknown outer solar system objects, including one Neptune trojan, several objects in mean motion resonances with Neptune, and a distant scattered disk object whose 1200-year orbital period is among the 50 longest known.

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453.04 – Comparative Imaging and Analysis of the Auroral Morphology of Ganymede

The Jovian satellite Ganymede is the largest moon in the solar system, and is the only known non-planetary object with its own magnetosphere. The magnetic field interacts with the magnetospheric plasma of Jupiter to create ultraviolet emissions at the 1356Å wavelength of atomic oxygen. Multiple unmanned missions to and beyond Jupiter are being developed by NASA and ESA, and require knowledge about the conditions they will encounter amongst the satellites and what phenomena should be studied. McGrath et al. (2013) processed and analyzed HST observations of the aurorae from four observing dates spanning 8.5 years. By comparing line-of-sight images and polar projections of the aurorae, McGrath et al. found evidence that the auroral oval on Ganymede is globally quite stable over time despite large localized brightness fluctuations, and is consistent with a magnetohydrodynamic model. Over the summer of 2014, two more recent sets of images were processed and analyzed using the same methods as the earlier work. Additionally, all the data were re-analyzed for comparison by brightness, by image polar projection, by repeating areas of bright emission, and when appropriate, by individual orbits' morphologies. Initial analysis is consistent with previous results of generally steady auroral ovals created by the Jovian magnetospheric plasma, and has revealed curious patterns of repeating areas of bright emission to be further studied.

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453.05 – A Diversity of Dust Properties in Oort Cloud Comets

Comets are near-pristine relics from our Solar System's epoch of planet formation. Thus, the properties of comets can be used to infer the environment in which they formed and to compare our Solar System to disks observed around other stars today. Specifically, the dust in comets is a record of the high temperature processes that occurred in the inner disk, and the large scale mixing that transported dust from the hot inner disk to the cold comet formation zones. However, comet dust may not be wholly pristine, as radiation from the Galatic environment likely process the surfaces of Oort cloud comets. Mid-infrared spectroscopy is sensitive to the dust properties of comets. We present a summary of Oort cloud comets observed in the mid-infrared, and discuss their inferred dust properties. Targets include recent comets C/2009 P1 (Garradd), C/2011 L4 (PanSTARRS), C/2012 F6 (Lemmon), and C/2012 K1 (PanSTARRS). A wide range of spectra are seen, and we discuss the possibility that irradiated mantles on dynamically new comets affect their observed infrared spectra.

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