# 222nd AAS Meeting – Indianapolis, Indiana June, 2013

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# 101 – Kavli Foundation Lectureship: The Search for Habitable Worlds

## 101.01 – The Search for Habitable Worlds

*David W. Latham*[1]

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We live at a very special time in the history of astronomy. We are poised to discover and characterizes exoplanets enough like the Earth that we can imagine life as we know it could arise and be comfortable. We are seeking rocky planets at the right distances from their host stars for water to be liquid on the surface, and with a secondary atmosphere that might even show evidence for biogenic gases. Transiting planets are where the present action is, because they can provide masses and radii for planets, and thus the bulk properties such as density and surface gravity that constrain our models of their interior structure and composition. Are they ice giants like Uranus and Neptune, or rocky worlds like the terrestrial planets, or maybe something in between with lots of water or extended atmospheres of hydrogen and helium? NASA's Kepler mission has provided lots of small planet candidates, but the bottleneck for characterizing them is the ultra-precise radial velocities needed for confirming and characterizing the planets with mass determinations. HARPS-N has recently come into operation at the Telescopio Nazionale Galileo on La Palma and is now contributing to the follow up of Kepler candidates, but we need better ways to correct for astrophysical effects that distort the radial velocities, and still better velocity precision if we hope to reach the level of 9 cm/s induced by a true Earth twin in a one-year orbit around a star like the Sun. Kepler looks at only one four hundreth of the sky. We need all-sky surveys for transiting planets to find the nearest and brightest examples for radial-velocity follow up and studies of planetary atmospheres with missions like the James Webb Space Telescope and G-CLEF spectrograph on the Giant Magellan Telescope. Our long-range goal is to see if the atmospheres of any potentially habitable planets actually show evidence for biogenic gases that have been produced in large enough quantities to impact the biosphere and be detected remotely. If we detect spectroscopic biomarkers that can only be present if they are continually replenished by life, then we can point at that star and speculate that we may not be alone in the universe.

# 102 – Bridging Laboratory and Astrophysics: Atoms

## 102.01 – Atomic Data Applications for Supernova Modeling


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The modeling of supernovae (SNe) incorporates a variety of disciplines, including hydrodynamics, radiation transport, nuclear physics and atomic physics. These efforts require numerical simulation of the final stages of a star's life, the supernova explosion phase, and the radiation that is subsequently emitted by the supernova remnant, which can occur over a time span of tens of thousands of years. While there are several different types of SNe, they all emit radiation in some form. The measurement and interpretation of these spectra provide important information about the structure of the exploding star and the supernova engine. In this talk, the role of atomic data is highlighted as iit pertains to the modeling of supernova spectra. Recent applications [1,2] involve the Los Alamos OPLIB opacity database, which has been used to provide atomic opacities for modeling supernova plasmas under local thermodynamic equilibrium (LTE) conditions. Ongoing work includes the application of atomic data generated by the Los Alamos suite of atomic physics codes under more complicated, non-LTE conditions [3]. As a specific, recent example, a portion of the x-ray spectrum produced by Tycho's supernova remnant (SN 1572) will be discussed [4]. [1] C.L. Fryer et al, Astrophys. J. 707, 193 (2009). [2] C.L. Fryer et al, Astrophys. J. 725, 296 (2009). [3] C.J. Fontes et al, Conference Proceedings for ICPEAC XXVII, J. of Phys: Conf. Series 388, 012022 (2012). [4] K.A. Eriksen et al, Presentation at the 2012 AAS Meeting (Austin, TX). (This work was performed under the auspices of the U.S. Department of Energy by Los Alamos National Laboratory under Contract No. DE-AC52-06NA25396.)

## 102.02 – Photoionized Plasmas in the Z Facility and in Astrophysics


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Many astrophysical environments such as x-ray binaries, active galactic nuclei, and accretion disks of compact objects have photoionized plasmas. Detailed x-ray spectral observations performed with the Chandra and XMM-Newton orbiting telescopes provide critical information on the state of photoionized plasmas. However, the complexity of the astrophysical environment makes the spectral analysis challenging, and thus laboratory experiments are important for data interpretation and testing of modeling codes. The Z facility at Sandia National Laboratories is a powerful source of x-rays to produce and study in the laboratory photoionized plasmas relevant for astrophysics under well characterized conditions. We discuss an experimental and theory/modeling effort in which the intense x-ray flux emitted at the collapse of a z-pinch implosion conducted at the Z pulsed-power machine is employed to produce a neon photoionized plasma. The broadband x-ray radiation flux from the z-pinch is used to both create the photoionized plasma and provide a source of backlighting photons to study the atomic kinetics through K-shell line absorption spectroscopy. The plasma is contained in a cm-scale gas cell that can be located at different distances from the z-pinch, thus effectively controlling the x-ray flux producing the plasma. Time-integrated and gated transmission spectra are recorded with a spectrometer equipped with two elliptically-bent KAP crystals and a set of slits to record up to six spatially-resolved spectra per crystal in the same shot. The transmission data shows a rich line absorption spectrum that spans over several ionization stages of neon including Be-, Li-, He- and H-like ions. Modeling calculations are used to interpret the transmission spectra recorded in the Z experiments with the goal of extracting the charge- state distribution, electron temperature and the radiation flux driving the plasma, as well as to determine the ionization parameter of the plasma. This work is sponsored in part by the National Nuclear Security Administration under the High Energy Density Laboratory Plasmas grant program through DOE Grant DE-FG52-09NA29551, and the Z Facility Fundamental Science Program of SNL.

## 102.03 – Spectroscopic Measurements of Collision-less Coupling Between Laser-Produced, Super-Alfvénic Debris Plasmas and Magnetized, Ambient Plasmas


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Emission spectroscopy is currently being utilized in order to assess collision-less momentum and energy coupling between super-Alfvénic debris plasmas and magnetized, ambient plasmas of astrophysical relevance. In a recent campaign on the Large Plasma Device (LAPD) utilizing the Phoenix laboratory Raptor laser (130 J, 25 ns FWHM), laser-ablated carbon debris plasmas were generated within magnetized, ambient helium plasmas ($n_{elec}$ ? $3\times10^{12}$ $cm^{-3}$, $T_{elec}$ ? 5.5 eV, $B_0$ = 200 G), and prominent spectral lines of carbon and helium ions were studied in high resolution (? 0.01 nm). Time-resolved Doppler shift and width measurements of a C V ion spectral line reveal significant deceleration as the ions stream through the background plasma, which may indirectly indicate momentum coupling. Spectral lines of He II ions are observed to intensify by orders of magnitude and broaden, indicating energy transfer from the debris plasma to the background plasma.

# 103 – Cosmology and Associated Topics

## 103.01 – Cosmic Microwave Background Polarization Measurements from Three Years of BICEP Observations

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*Contributing teams: BICEP Collaboration*

In an era of precision cosmology, the initial conditions of the Universe remain a puzzle. Inflation, an exponential expansion in the first $10^{-36}$s, is the leading explanation for the origin of structure. A generic prediction of inflation is odd-parity (B-mode) polarization in the cosmic microwave background (CMB) at degree angular scales. No experiment has detected B-mode polarization yet. The BICEP (Background Imaging of Cosmic Extragalactic Polarization) telescope has provided the best constraints on B-mode polarization so far. This talk describes new results from BICEP. BICEP observed the CMB from the South Pole for three seasons from 2006 to 2008. The design incorporated polarization-sensitive bolometers, a cryogenic refracting telescope, absorptive forebaffle, reflective ground screen, fast azimuth scanning, and boresight rotation to optimize sensitivity to the CMB polarization and minimize systematic contamination. We published the first results from BICEP in Chiang et al. (2010) which used only the first two seasons' data to place the best limits on inflationary B-mode polarization. Now we report new results from the full three-year data including an improved B-mode limit. We improved the analysis method with a new deprojection technique that removes contamination from the dominant sources of calibration uncertainty. Based on the success of BICEP, a series of more sensitive experiments including BICEP2, the Keck Array, and BICEP3 is continuing the search for B-mode polarization from the South Pole. The analysis techniques presented here will be critical for their success.

## 103.02D – New Techniques in Dark Matter Mapping

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We have developed a new pipeline for mapping dark matter associated with clusters of galaxies via weak gravitational lensing. This method will be useful both with current datasets and future large optical survey telescopes, such as the Large Synoptic Survey Telescope (LSST). We use a novel source finding technique using a wavelet detection method. We then find known photometric and spectroscopic redshifts associated with our sources and measure the ellipticities of galaxies using a second moment technique. The ellipticity and photometric redshift distribution are then converted to a dark matter map. We have represented the dark matter as smoothed particles to invert the ellipticity map. This had yielded dark matter distributions when applied to our Subaru archive image of Abell 2218.

## 103.03 – Evidence for Supporting the Black Hole Universe Model

*Tianxi Zhang*[1]
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According to Zhang's recently proposed black hole universe model, the universe originated from a hot star-like black hole and grew up from a supermassive black hole to the present state by accreting ambient matter including radiation and merging with other black holes. With a single hypothesis that a black hole constructs its own spacetime or a spacetime encloses a black hole, this new cosmological model can explain all our observations of the universe to date with the well-developed physics. The observable and non-observable spaces of the universe are hierarchically layered instead of isotropically uniform. His previous work has explained various aspects of the black hole universe such as the origin, structure, evolution, expansion, and acceleration of the black hole universe; the cosmic microwave background radiation; the energy emission of quasars; and the black hole nucleosynthesis. This study explores more evidence for supporting the black hole universe model. We will investigate: (i) the emission of dynamic black holes to explain gamma ray bursts and X-ray flares of the massive black hole at the center of Milky Way, (ii) the structure of the black hole universe to explain the greater attractors and dark flows, and (iii) the evolution of the black hole universe to explain the discovery of old galactic clusters in the young universe and the enrichment of heavy elements around the distant quasars. We will also address other properties of the black hole universe and compare this new cosmological model with the big bang theory.

## 103.04D – Bayesian Analysis of Systematic Effects in Interferometric Observations of the Cosmic Microwave Background Polarization

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The detection of the primordial B-mode spectrum of the polarized cosmic microwave background (CMB) signal may provide a probe of inflation. However, observation of such a faint signal requires excellent control of systematic errors. Interferometry proves to be a promising approach for overcoming such a challenge. In this thesis we present a complete simulation pipeline of interferometric observations of CMB polarization, including systematic errors. We employ a method for Bayesian inference of power spectra and signal reconstruction from interferometric data of the CMB polarization signal by using the technique of Gibbs sampling. Several categories of systematic errors are considered: instrumental errors, consisting of antenna gain and antenna coupling errors, and beam errors, consisting of antenna pointing errors, beam cross-polarization and beam shape (and size) errors. In order to recover the tensor-to-scalar ratio, r, within a 10% tolerance level, which ensures the experiment is sensitive enough to detect the B-signal at r=0.01 in the multipole range 28 < l < 384, we find that, for a QUBIC-like experiment, Gaussian-distributed systematic errors must be controlled with precisions of |g_rms| = 0.1 for antenna gain, |e_rms| = 5e-4 for antenna coupling, d_rms ~ 0.7 degrees for pointing, z_rms ~ 0.7 degrees for beam shape, and m_rms = 5e-4 for beam cross-polarization.

## 103.05 – Eclipsing Binaries as Accurate Extragalactic Distance Indicators: Refining the Distance to the Triangulum Spiral Galaxy M33.

*Edward F. Guinan*[1], *Andrej Prsa*[1], *Edward L. Fitzpatrick*[1], *Alceste Z. Bonanos*[2], *Scott G. Engle*[1], *Edward J. Devinney*[1], *Glenn Recker*[1]
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For over decade we have been using eclipsing binaries (EBs) to determine accurate distances to Local Group Galaxies such as the Magellanic Clouds & M31 (cf. Fitzpatrick et al. 2003; Vilardell et al. 2010). We (and others) have demonstrated that carefully selected EBs can serve as excellent 'Standard Candles.' Distances measured from EBs are basically geometric and are essentially free from assumptions and uncertainties that complicate other less direct methods. The radii of the stars are determined to better than a few percent from the time-tested analyses of their light and radial velocity curves. With accurate determinations of radii, Teff (or calibrated flux SEDs) and ISM absorption, it is possible to calculate reliable distances with uncertainties of < 5%. M33 is an important face-on spiral galaxy that still has a large range in its measured distance of ~750 - 960 kpc. We carried out HST/COS and STIS FUV-Near-IR (1150 - 8500A) spectrophotometry & WFPC-2 photometry of the19th mag (O7V +O7V) eclipsing binary D33 J013346.2+304439.9 in M33 to try to improve its distance.This EB was used previously by Bonanos et al. (2006) to determine a distance = 964 +/- 54 kpc. Analysis of the HST FUV-NIR data will yield more accurate Teff, Av, and [Fe/H] measures. These quantities, when combined with the results from existing light and radial velocity curves of Bonanos et al. permit the refined distance to be found with more certainty. We discuss the results and compare them with other recent M33 distances. When a reliable distance is found, M33 could replace the LMC as the primary exgalactic distance calibrator since this Sa spiral has chemical and physical properties more in common with the galaxies used to determine the Hubble Law and Ho. This research supported by HST NASA grants HST-GO-10919 & HST-GO-11725.

# 104 – University of Arizona Astronomy Club

## 104.01 – The University of Arizona's Astronomy Club: Overview and Goals

*Jake Turner[1], Kevin Hardegree-Ullman[1], Allison P. Towner[1], Amanda Walker-LaFollette[1], Allison M. McGraw[1], Lauren I. Biddle[1], Amy Robertson[1], Carter-Thaxton Smith[1]*

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The University of Arizona Astronomy Club was started out of a desire to fulfill a dire need for peer support, both social and academic in the astronomy/physics (i.e. future astro grad students) undergraduate major at the University of Arizona. Early goals were simple peer support and networking. Subsequently, the club started research projects out of a desire for research experience for club members for two reasons: 1) research experience in general, esp. for REU and grad school applications, and 2) desire to have some background in observation and research for the observational-astronomy course. Current goals of the club are very similar: peer social and academic support, research experience, public outreach (EPO), professional support and experience (i.e. attendance at this conference)

## 104.02 – Research Projects and Undergraduate Retention at the University of Arizona

*Amanda Walker-LaFollette[1], Kevin Hardegree-Ullman[2, 1], Allison P. Towner[1], Allison M. McGraw[1], Lauren I. Biddle[1], Amy Robertson[1], Jake Turner[1], Carter-Thaxton Smith[1]*

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The University of Arizona's Astronomy Club utilizes its access to the many telescopes in and around Tucson, Arizona, to allow students to fully participate in a variety of research projects. Three current projects - the exoplanet project, the radio astronomy project, and the Kepler project - all work to give undergraduates who are interested in astronomy the opportunity to explore practical astronomy outside the classroom and in a peer-supported environment. The exoplanet project strives to teach students about the research process, including observing exoplanet transits on the Steward Observatory 61" Kuiper telescope on Mt. Bigelow in Tucson, AZ, reducing the data into lightcurves with the Image Reduction and Analysis Facility (IRAF), modeling the lightcurves using the Interactive Data Language (IDL), and writing and publishing a professional paper, and does it all with no faculty involvement. The radio astronomy project is designed to provide students with an opportunity to work with a professor on a radio astronomy research project, and to learn about the research process, including observing molecules in molecular clouds using the Arizona Radio Observatory 12-meter radio telescope on Kitt Peak in Arizona. The Kepler project is a new project designed in part to facilitate graduate-undergraduate interaction in the Astronomy Department, and in part to allow students (both graduate and undergraduate) to participate in star-spot cycle research using data from the Kepler Mission. All of these research projects and structures provide students with unique access to telescopes, peer mentoring, networking, and understanding the entire process of astronomical research.

## 104.03 – The Benefits of Peer-Mentoring in Undergraduate Group Research Projects at The University of Arizona

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According to the American Institute of Physics, the number of graduate students enrolled in astronomy programs in the US has been steadily increasing in the past 15 years. Research experience is one of the key factors graduate admissions committees look for when choosing students. The University of Arizona Astronomy Club is setting a new precedent in research by having students introduce other students to research. This eases the transition to research projects, and allows students to work in a comfortable setting without the sometimes-overwhelming cognitive disconnect between a professor and their students. The University of Arizona's research projects have many benefits to all students involved. It is well established that people learn a subject best when they have to teach it to others. Students leading the projects learn alongside their peers in a peer-mentoring setting. When project leaders move on in their academic career, other project members can easily take the lead. Students learn how to work in teams, practice effective communication skills, and begin the processes of conducting a full research project, which are essential skills for all budding scientists. These research projects also give students hands-on research experience that supplement and greatly expand on concepts taught in the classroom, and make them more attractive to graduate schools and REU programs.

## 104.04 – Undergraduate Social Support and Career Networking as a Result of Membership in the University of Arizona Astronomy Club

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Membership in formal or informal groups of students with similar interests provides many benefits to undergraduate astronomy majors at the University of Arizona. First and foremost, members benefit from peer social and academic support within the major. These benefits are both tangible and intangible: students form friendships with like-minded peers, which can sustain them through difficult periods of study, but these social networks are the basis of later professional networks as well. Students in the U of A Astronomy Club have received both informal and formal research positions at other institutions as a direct result of the support, peer mentoring, and connections of club members, and at least six also hold paid, non-research positions within the department as a result of their connection to the club. Finally, most Astronomy Club members take their first steps into professional astronomy, such as attendance at a AAS Meeting, as a result of Club membership and the encouragement of older club members.

## 104.05 – The University of Arizona Astronomy Club Outreaches out to the Public and Beyond

*Allison M. McGraw[1], Kevin Hardegree-Ullman[2], Allison P. Towner[1], Amanda Walker-LaFollette[1], Amy Robertson[1], Lauren I. Biddle[1], Jake Turner[1], Carter-Thaxton Smith[1]*

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The University of Arizona's Astronomy Club utilizes many outreach tools in order to make astronomy exciting and obtainable for all demographics of the public. Hands-on activities are integrated along with three-dimensional models to explain many different astronomical topics including star clusters, habitable zones, and the local stellar neighborhood. The club hosts free monthly star parties to provide the public a better opportunity to explore the Tucson night sky. Club members volunteer their time and provide telescopes in a darker location just outside the city. No limits exist to types, shapes, and forms of outreach and providing education for this club. From toddlers to senior citizens, the club is always ready for a new event or opportunity to engage any audience. This is a unique experience for members of the public, as all of the members of the club are undergraduates of astronomy. Furthermore, it is an excellent and effective bonding experience between the students involved as they construct the models and work together to reach out to all members of the Tucson community.

## 104.06 – Further Enhancement of the Astronomy Club at the University of Arizona

*Lauren I. Biddle[1], Allison P. Towner[1], Allison M. McGraw[1], Amanda Walker-LaFollette[1]*

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The University of Arizona Astronomy Club has progressed into what is now a thriving organization. The Astronomy Club has been successful in involving undergraduates in research and community outreach as well as building bonds between students. We have big plans for further development of the organization, while maintaining an exciting, informative, and enjoyable atmosphere for its members. One focus for the future of Astronomy Club is to develop a stronger professional presence within the astronomy department and community. In order to accomplish this goal, we will encourage member attendance at meetings such as the AAS and local talks given at Steward Observatory. Students will benefit from this learning more about subjects other than their own research. Students also benefit from social connections, and, to that end, we plan to continue and expand club social and outreach activities. Another advancement is the club web page, which provides both members, non-members, and the general public with useful resources such as programming guides, "how-to's," and links to online resources. A survey was distributed to the members of Astronomy Club to get feedback on how the organization can make their experience at the UofA both educational and fun. We have review the responses and make decisions based on what the members want. in activities is important to increase membership, maintain attendance, and sustain the club as a whole. The most important goal for the organization is that it will continue to evolve through years, long after the current members are graduated.

# 105 – WIYN Observatory - Building on the Past, Looking to the Future: Groundbreaking Science and Education

## 105.01 – WIYN Observatory: Past, Present, and Future

*Patricia Knezek*[1]

*1. NOAO/WIYN Observatory, Tucson, AZ, United States.*

I will present an overview of the history, performance, and capabilities of the WIYN 3.5-m and 0.9-m telescopes since the inception of the observatory. This will set the context for the rest of the meeting that highlights what has been accomplished by the WIYN partnership, what WIYN currently has to offer the community, and planning for the future of 4m-class telescopes, including WIYN, in the upcoming decade.

## 105.02 – Probing the Dynamics of Open Star Clusters with WIYN/Hydra

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The Hydra Multi-Object Spectrograph on the WIYN 3.5-m telescope is ideally suited for systematic radial-velocity studies of open star clusters. As part of the WIYN Open Cluster Study (WOCS) we are conducting comprehensive radial-velocity surveys (~0.5 km/s single-measurement precision) of the solar-type stars in a select sample of open clusters that span a wide range in age and metallicity using WIYN/Hydra. In this talk, I will focus on our most complete cluster: NGC 188. At an age of 7 Gyr, NGC 188 is dynamically evolved, having lived through tens of half-mass relaxation times. WIYN/Hydra data reveal a rich binary population amongst the solar-type main-sequence, red-giant and blue-straggler stars, and allow us to derive orbital solutions for the majority of our detected binaries (out to orbital periods of ~3000 days). This detailed knowledge of the NGC 188 binaries, and those in other WOCS clusters, enable us to develop a highly accurate N-body model of NGC 188, which reveals the dynamical history of the cluster's rich binary population. WIYN/Hydra data and N-body modeling have been particularly important for our understanding of the NGC 188 blue stragglers. Our WIYN observations show that the NGC 188 blue stragglers have a strikingly high binary frequency of (at least) 76%, most having periods near 1000 days, and a companion-mass distribution that is narrow and peaked at ~0.5 solar masses. These characteristics are significantly different from those of the normal main-sequence stars. The combination of WIYN/Hydra data, recent HST observations in the FUV, and sophisticated N-body modeling of the cluster, point to mass transfer as the dominant formation channel for the NGC 188 blue stragglers, addressing a decades-long theoretical debate about their origins.

## 105.03 – A WIYN-Hydra Study of Red Giant Branch Stars in the Globular Cluster M13: Linking Globular Cluster Formation Scenarios, Deep Mixing, and Post-RGB Evolution

*Christian I. Johnson*[1]

*1. University of California, Los Angeles, Los Angeles, CA, United States.*

The WIYN-Hydra fiber positioner and bench spectrograph system are an excellent platform for examining the chemical abundance patterns of Galactic globular cluster stars. In this talk I highlight recent work that employed Hydra to obtain oxygen and sodium abundances for 113 red giant branch (RGB) and asymptotic giant branch (AGB) stars in the globular cluster M13. The observations cover stars from the luminosity of the horizontal branch to the RGB-tip, and the results are examined in the context of recently proposed globular cluster formation scenarios. Some of the interesting results include: a central concentration of the most O-poor stars, the correlated decrease in [O/Fe] with increasing luminosity for the most O-poor stars, and a paucity of AGB stars with low [O/Fe] and high [Na/Fe]. These observations support the idea that some RGB stars in M13, perhaps aided by enhanced He abundances, undergo in situ deep mixing above the RGB-bump. The most He-rich (O-poor) giants may also evolve to populate the 'extreme' horizontal branch and terminate their evolution as AGB-manqué stars.

## 105.04 – WIYN Studies of Environmental Effects on Virgo Cluster Galaxies

*Jeffrey D. Kenney*[1]

*1. Yale University, New Haven, CT, United States.*

We present highlights of WIYN studies of environmentally disturbed Virgo cluster galaxies, done through various imaging and spectroscopy programs. The goal of these studies is to identify the mechanisms which transform cluster galaxies, and assess their impact on galaxy evolution. Imaging and kinematic studies allow one to distinguish between different transformation mechanisms, including ram pressure stripping and galaxy-galaxy collisions. Imaging of decoupled dust clouds and extraplanar HII regions provide signatures of ram pressure stripped galaxies. Stellar population studies reveal when galaxies were stripped, help us pinpoint the evolutionary stages of stripping, and provide evidence for ram pressure-induced starbursts. IFU studies of kinematics not only help distinguish between the different types of interactions, but allow for distance determinations based on stellar kinematics. The Sparesepak IFU has allowed kinematic mapping of the vast system of ionized gas filaments surrounding the elliptical M86 and the spiral NGC 4438 that has collided with it. We describe the recent WIYN H-alpha imaging of the spectacular fireballs in the gas tail of IC3418, a smoking gun example of a dwarf galaxy transforming from late to early type through the action of ram pressure stripping.

## 105.05 – Stellar Populations in External Galaxies with WIYN

*Katherine L. Rhode*[1]

*1. Indiana Univ., Bloomington, IN, United States.*

One of the WIYN 3.5-m telescope's greatest assets is that it can produce high-resolution, deep imaging with excellent image quality over a large field-of-view. This capability makes WIYN well-suited for studies of stellar populations in external galaxies. I will give an overview of two such projects. One is a wide-field survey of the globular cluster systems of a sample of giant spiral, S0, and elliptical galaxies. The target galaxies have distances of ~10 to 30 Mpc and are located in a range of environments. We use deep imaging in three broadband filters to identify point-source globular clusters out to large radii around the galaxies and derive robust measurements of the total number, specific frequency (number normalized by the galaxy luminosity or mass), spatial distribution, and color distribution of each galaxy's globular cluster system. The data allow us to investigate how these properties vary with galaxy morphology and environment, to test models of galaxy formation and evolution, and to constrain fundamental quantities like the redshift at which the first globular clusters formed in the Universe. The second project involves follow-up WIYN observations of low-mass galaxy halos (called ultra-compact high-velocity clouds, or UCHVCs) identified by the ALFALFA HI 21-cm line survey. We have begun a campaign of deep, optical (broadband and H-alpha) high-resolution wide-field imaging with WIYN pODI to identify possible stellar counterparts to the UCHVCs and detect any ongoing star formation. The first such UCHVC we observed with WIYN revealed a low-mass, gas-rich dwarf galaxy with active star formation and a distance of ~1.7+/-0.3 Mpc. I will discuss the status of both projects, highlight recent results, and mention future directions.

## 105.06 – A Search for the Lowest Metallicity Galaxies at z=0.8

*Isak Wold*[1], *Amy J. Barger*[1]

*1. University of Wisconsin Madison, Madison, WI, United States.*

I will describe how we are using WIYN+HYDRA to study ultra-strong emission line galaxies (rest-frame EW(Hbeta) > 30A). This population contains some of the lowest metallicity galaxies known (12+log(O/H)=7.1) and offers the potential for determining whether there is a metallicity floor on late forming galaxies.

## 105.07 – Mapping Dark Matter and the PSF: Weak Lensing Studies of Galaxy Clusters with pODI

*Ian P. Dell'Antonio*[1], *Jacqueline E. McCleary*[1]

*1. Brown Univ., Providence, RI, United States.*

We present first results from a science verification program to use the excellent delivered image quality of pODI in both direct imaging and coherent guiding modes to measure the PSF pattern and its stability across the full pODI field of view. We apply the results to observations of galaxy clusters to underscore the excellent potential of ODI for weak lensing science.

# 106 – SPD Hale Prize Lecture: Twisting and Writhing with George Ellery Hale

## 106.01 – Twisting and Writhing with George Ellery Hale

*Richard C. Canfield*[1]

*1. Montana State Univ., Bozeman, MT, United States.*

Early in his productive career in astronomy, George Ellery Hale developed innovative solar instrumentation that allowed him to make narrow-band images. Among the solar phenomena he discovered were sunspot vortices, which he attributed to storms akin to cyclones in our own atmosphere. Using the concept of magnetic helicity, physicists and mathematicians describe the topology of magnetic fields, including twisting and writhing. Our contemporary understanding of Hale's vortices as a consequence of large-scale twist in sunspot magnetic fields hinges on a key property of helicity: conservation. I will describe the critical role that this property plays, when applied to twist and writhe, in a fundamental aspect of global solar magnetism: the hemispheric and solar cycle dependences of active region electric currents with respect to magnetic fields. With the advent of unbroken sequences of high-resolution magnetic images, such as those presently available from the Helioseismic and Magnetic Imager on Solar Dynamics Observatory, the flux of magnetic helicity through the photosphere can be observed quantitatively. As magnetic flux tubes buoy up through the convection zone, buffeted and shredded by turbulence, they break up into fragments by repeated random bifurcation. We track these rising flux fragments in the photosphere, and calculate the flux of energy and magnetic helicity there. Using a quantitative model of coronal currents, we also track connections between these fragments to calculate the energy and magnetic helicity stored at topological interfaces that are in some ways analogous to the storage of stress at faults in the Earth's crust. Comparison of these values to solar flares and interplanetary coronal mass ejections implies that this is the primary storage mechanism for energy and magnetic helicity released in those phenomena, and suggests a useful tool for quantitative prediction of geomagnetic storms.

# 108 – Astronomy Education: Where Are We Now and Where Are We Going?

## 108.01 – Undergraduate-Level Astronomy Education: Where We Are Now and Where We Could be Going in the Future?

*Edward E. Prather*[1]

*1. Center for Astronomy Education (CAE), Univ. of Arizona, Tucson, AZ, United States.*

A brief history of research in astronomy education at the undergraduate level will be provided, along with a discussion of where the discipline is most likely to go next, and where I believe the most rewarding new frontier resides.

## 108.02 – K-12 Teacher Professional Development

*Mary Kay Hemenway*[1]

*1. Univ. of Texas-Austin, Austin, TX, United States.*

For many school subjects, teachers enlist in professional development activities to fulfill certification requirements to update themselves on recent developments in their field. For astronomy, in addition to certification, many teachers need to acquire basic knowledge and skills since their background is often deficient. Thus, a main goal of professional development workshops is to enhance the knowledge base of the participants. But their needs go beyond what can be acquired in a book or lecture. In response to guidelines of the National Science Education Standards (1996), the participants should actively investigate phenomena and interpret results, be introduced to resources that expand their knowledge, build on their current understanding, and incorporate reflection on the process and outcomes of understanding science through inquiry. Examples of how these elements are incorporated into workshops that emphasize activities and teacher-to-teacher interaction over lecture are offered in this presentation. Setting realistic goals for workshops of different lengths (from one day to one month) and evaluating the results are also components of teacher professional development.

## 108.03 – Using AER to Improve Teacher Education

*Randi R. Ludwig*[1]

*1. University of Texas, Austin, TX, United States.*

In many ways, the astronomy education community is uniquely poised to influence pre-service and in-service teacher preparation. Astro101 courses are among those most commonly taken to satisfy general education requirements for non-science majors, including 9-25% education majors (Deming & Hufnagel, 2001; Rudolph et al. 2010). In addition, the astronomy community's numerous observatories and NASA centers engage in many efforts to satisfy demand for in-service teacher professional development (PD). These efforts represent a great laboratory in which we can apply conclusions from astronomy education research (AER) studies in particular and science education research (SER) in general. Foremost, we can work to align typical Astro101 and teacher PD content coverage to heavily hit topics in the Next Generation Science Standards (http://www.nextgenscience.org/) and utilize methods of teaching those topics that have been identified as successful in AER studies. Additionally, we can work to present teacher education using methodology that has been identified by the SER community as effective for lasting learning. In this presentation, I will highlight some of the big ideas from AER and SER that may be most useful in teacher education, many of which we implement at UT Austin in the Hands-on-Science program for pre-service teacher education and in-service teacher PD.

## 108.04 – The Impact of the Next Generation Science Standards on Future Professional Development and Astronomy Education Research

*Sanlyn Buxner*[1, 2]

*1. University of Arizona, Tucson, AZ, United States. 2. Planetary Science Institute, Tucson, AZ, United States.*

The Next Generation Science Standards will have a profound impact on the future science education of students and professional development for teachers. The science and engineering practices, crosscutting concepts, and disciplinary core ideas laid out in the Framework for K-12 Science Education (NRC, 2011) will change the focus and methods of how we prepare teachers to meet these new standards. Extending beyond just the use of inquiry in the classroom, teachers will need support designing and implementing integrated experiences for students that require them to apply knowledge of content and practices. Integrating the three dimensions central to the new standards will pose curricular challenges and create opportunities for innovative space science projects and instruction. The science research and technology community will have an important role in supporting authentic classroom practices as well as training and support of teachers in these new ways of presenting science and technology. These changes will require a new focus for teacher professional development and new ways to research impacts of teacher training and changes in classroom practice. In addition, new and innovative tools will be needed to assess mastery of students' knowledge of practices and the ways teachers effectively help students achieve these new goals. The astronomy education community has much to offer as K-12 and undergraduate level science educators rethink and redefine what it means to be scientifically literate and figure out how to truly measure the success of these new ways of teaching science.

## 108.05 – Catalyzing Effective Science Education: Contributions from the NASA Science Education and Public Outreach Forums

*Denise A. Smith*[1], *Lindsay Bartolone*[2], *Bonnie Eisenhamer*[1], *Brandon L. Lawton*[1], *Gregory R. Schultz*[3], *Laura Peticolas*[4], *Theresa Schwerin*[5], *Stephanie Shipp*[6]

*1. STScI, Baltimore, MD, United States. 2. Adler Planetarium, Chicago, IL, United States. 3. Astronomical Society of the Pacific, San Francisco, CA, United States. 4. UC-Berkeley, Berkeley, CA, United States. 5. Institute for Global Environmental Strategies, Arlington, VA, United States. 6. Lunar and Planetary Institute, Houston, TX, United States.*

*Contributing teams: NASA Astrophysics E/PO Community, NASA Astrophysics Forum Team*

Advancing scientific literacy and strengthening the Nation's future workforce through stimulating, informative, and effective learning experiences are core principles of the NASA Science Mission Directorate (SMD) education and public outreach (E/PO) program. To support and coordinate its E/PO community in offering a coherent suite of activities and experiences that effectively meet the needs of the education community, NASA SMD has created four Science Education and Public Outreach Forums (Astrophysics, Planetary Science, Heliophysics, Earth Science). Forum activities include: professional development to raise awareness of the existing body of best practices and educational research; analysis and cataloging of SMD-funded education materials with respect to AAAS Benchmarks for Science Literacy; Working Groups that assemble needs assessment and best practices data relevant to Higher Education, K-12 Formal Education, and Informal Science Education audiences; and community collaborations that enable SMD E/PO community members to develop new partnerships and to learn and share successful strategies and techniques. This presentation will highlight examples of Forum and community-based activities related to astronomy education and teacher professional development, within the context of the principles articulated within the NRC Framework for K-12 Science Education and the Next Generation Science Standards. Among these are an emerging community of practice for K-12 educators and online teacher professional development and resources that incorporate misconception research and authentic experiences with NASA Astrophysics data.

# 109 – Bridging Laboratory and Astrophysics: Molecules

## 109.01 – Complex Organic Molecules in Protoplanetary Disks

*Catherine Walsh[1, 2], Tom J. Millar[2], Hideko Nomura[3], Eric Herbst[4, 5], Susanna Widicus-Weaver[6]*
*1. Leiden University, Leiden, Netherlands. 2. Queen's University Belfast, Belfast, United Kingdom. 3. Kyoto University, Kyoto, Japan. 4. University of Virginia, Charlottesville, VA, United States. 5. Ohio State University, Columbus, OH, United States. 6. Emory University, Atlanta, GA, United States.*

Protoplanetary disks are vital objects in star and planet formation. In addition to aiding mass accretion onto the central star and angular momentum dissipation, they also contain all material which may form an orbiting planetary system. Of great interest to the astrochemistry and astrobiology communities is the origin of prebiotic molecules, considered the 'building blocks' of Life. Is it possible for complex molecules to form in protoplanetary disks and survive assimilation into planets and other planetary system objects, such as, comets? We explore the synthesis of large complex organic molecules (COMs) in protoplanetary disks which encompass young stars. We use a chemical network primarily developed for use in hot core models to calculate the abundance and distribution of gas-phase and grain-mantle (ice) COMs and discuss the potential of observing the gas-phase form of these species with new facilities, such as, ALMA.

## 109.02 – Microwave to Submillimeter Observations of Molecules in the Laboratory and in Space

*DeWayne Halfen[1]*
*1. Steward Observatory, University of Arizona, Tucson, AZ, United States.*

The primary method of identifying molecular species in interstellar space is radio astronomy. Observations performed at radio telescopes are based on high-resolution laboratory measurements of the pure rotational spectrum of a molecule. With this technique, over 150 different chemical compounds have been securely detected in interstellar gas. High-resolution rotational spectra have accuracies of one part in $10^7$ - $10^8$, and provide the characteristic frequencies that are used to search for these species. Rotational spectra are typically recorded using direct absorption methods, Fourier transform microwave/millimeter-wave spectroscopy, and velocity modulation techniques. Also exotic synthesis methods, such as DC and AC glow discharges, pulsed supersonic jet expansions, laser ablation, and Broida-type ovens, are often required to produce these molecules. Recent laboratory and astronomical studies have expanded set of molecules that are now known in interstellar/circumstellar gas. The first negative molecular ions have been detected in cold, dark clouds and circumstellar envelopes. The iron-bearing species FeCN was also recently measured in the laboratory and discovered in the gas surrounding a carbon-rich AGB star, the first iron-containing species found in space. New observations of oxygen-rich stars have shown that metal-bearing oxides and hydroxides are also abundant circumstellar species in these environments. These new discoveries, as well as recent laboratory results for other potential interstellar species, will also be presented, in particular those for ScO, $ScC_2$, and $AlC_2$. In addition, the need for more measurements of metal-containing molecules will be discussed.

## 109.03 – Investigations of the Formation of Carbon Grains in Circumstellar Outflows

*Cesar Contreras[1, 2], Farid Salama[1]*
*1. NASA Ames Research Center, Oak Ridge Associated Universities, Moffett Field, CA, United States. 2. Bay Area Environmental Research Institute, Sonoma, CA, United States.*

The study of formation and destruction processes of cosmic dust is essential to understand and to quantify the budget of extraterrestrial organic molecules. Although dust with all its components plays an important role in the evolution of interstellar chemistry and in the formation of organic molecules, little is known on the formation and destruction processes of carbonaceous dust. PAHs are important chemical building blocks of interstellar dust. They are detected in interplanetary dust particles and in meteoritic samples. Additionally, observational, laboratory, and theoretical studies have shown that PAHs, in their neutral and ionized forms, are an important, ubiquitous component of the interstellar medium. Also, the formation of PAHs from smaller molecules has not been extensively studied. Therefore, it is imperative that laboratory experiments be conducted to study the dynamic processes of carbon grain formation from PAH precursors. Studies of interstellar dust analogs formed from a variety of PAH and hydrocarbon precursors as well as species that include the atoms O, N, and S, have recently been performed in our laboratory under conditions that simulate interstellar and circumstellar environments. The species formed in the pulsed discharge nozzle (PDN) plasma source are detected and characterized with a high-sensitivity cavity ringdown spectrometer (CRDS) coupled to a Reflectron time-of-flight mass spectrometer (ReTOF-MS), thus providing both spectroscopic and ion mass information in-situ. We report the first set of measurements obtained in these experiments and identify the species present in the experiments and the ions that are formed in the plasma process. From these unique measurements, we derive information on the size and the structure of interstellar dust grain particles, the growth and the destruction processes of interstellar dust and the resulting budget of extraterrestrial organic molecules. Acknowledgements: Support from NASA's Laboratory Astrophysics 'Carbon in the Galaxy's Consortium Grant (NNH10ZDA001N) is gratefully acknowledged.

## 109.04 – From Isolated Molecules to Clusters and Aggregates –Spectroscopic Properties dictate Photochemical Behavior: Applications to Astrophysics and Planetary Sciences

*Murthy Gudipati[1, 5], Isabelle Couturier-Tamburelli[2], Ronen Jacovi[1, 3], Antti Lignell[1, 4]*
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Non-symmetric linear polyynes are established to be abundant in the interstellar space – thanks to their large dipole moment that enables their observation using rotational spectroscopy in the millimeter wave region [Herbst and Leung; ApJSS 69, 271, 1989]. While the conditions under which such hydrogen and oxygen depleted, carbon and nitrogen rich molecules prevail still need a better understanding, some clues could be obtained by their detection in Saturn's organic-rich moon Titan's atmosphere. Titan's atmosphere is over 95% N2 and rest dominated by CH4 and minor amounts of larger hydrocarbons (containing C, N, and H elements). Lack of significant amount of Oxygen in Titan's atmosphere and dominant Nitrogen atmosphere seem to result in the photochemical formation of linear polyynes. Our interest is to connect the isolated molecular properties relevant to astrophysical conditions to properties of molecular aggregates that are relevant to planetary conditions with dense atmosphere such as on Titan. Spectroscopic properties of isolated molecules determine their photochemical pathways as well. However, in molecular aggregates, particularly involving large permanent dipole moment as well as transition dipole moments, spectroscopic properties of isolated molecules do not help to predict the aggregate photochemistry. Exciton interactions in aggregates would significantly alter the corresponding spectroscopic properties of aggregates and hence their photochemical behavior. Similarly, spin-orbit coupling opens up photoexcitation pathways involving change of spin that are otherwise forbidden in isolated molecules. We will discuss exciton and spin-orbit coupling interactions in reference to linear cyanopolyynes and demonstrate [Gudipati et al. Nat. Commun. 4, 1648, 2013] that new photochemical channels can be active in condensed molecular aggregates that are not accessible with isolated molecules.

# 110 – Interstellar Medium, Dust, Etc.

## 110.01 – The Effect of Composition on the Spectral Features of Silicate Glasses: The Effect of Aluminium

*Angela Speck[1], Alan G. Whittington[1], Anne M. Hofmeister[2]*
*1. Univ. of Missouri, Columbia, MO, United States. 2. Washington University, St Louis, MO, United States.*

Many astrophysical environments exhibit a mid-infrared (IR) spectral feature at around 10 microns, which has long been attributed to amorphous silicates. However, this feature varies from location to location, and even within a given object both spatially and temporally. While the major elemental components of amorphous silicates are expected to be magnesium, silicon, oxygen and possibly iron, aluminium has been invoked to explain a variety of observational phenomena with respect to silicate spectral features. Aluminium is known to occur in some extraterrestrial minerals, for example, Al is seen in CAI (Ca-Al inclusions) and in primitive meteorites. Aluminium is the fourth most abundant metal after Si, Mg, and Fe. Present athe laboratory spectra of a sample of silicates of known Al abundance and discuss how the Al affects these samples both physically and spectrally. Potential applications of these data are also discussed.

## 110.02D – Large Scale Two-Fluid Simulations of Molecular Clouds with Statistical Tracers of Magnetized Turbulence

*Chad Meyer[1], Dinshaw S. Balsara[1]*
*1. University of Notre Dame, Notre Dame, IN, United States.*

Observational and computational studies of molecular clouds are continuing to unveil the importance of magnetic fields and turbulence in the process of star formation. In this work, we present a set of high-resolution magnetohydrodynamic simulations of the turbulence typical of molecular clouds which separately trace both the ionized and neutral gasses. Recent observational results point to anisotropy in the turbulence which may be due to the presence of magnetic fields. It has also been proposed that we are able to see the effects of ambipolar diffusion in the line widths of ionized and neutral molecules. By examining the probability distribution function and the bispectrum of both the ion and neutral species in our simulations, we can characterize the clouds they represent based on the relative strengths of the magnetic fields and turbulent flows. We show that the sonic and Alfvénic Mach numbers are identifiable using these statistical methods, which can be applied to observations of molecular clouds. These methods provide a powerful tool for comparison of turbulence simulations with observable data.

## 110.03 – Interacting Galactic Neutral Hydrogen Filaments and Associated High-Frequency Continuum Emission

*Gerrit L. Verschuur[1]*
*1. University of Memphis, Lakeland, TN, United States.*

Galactic HI emission profiles in an area where several large-scale filaments at velocities ranging from -46 to 0 km/s overlap were decomposed into Gaussian components. Eighteen families of components defined by similarities of center velocity and line width were identified and related to small-scale structure in the high-frequency continuum emission observed by the WMAP spacecraft, as evidenced in the Internal Linear Combination (ILC}) map of Hinshaw et al. (2007). When the center velocities of the Gaussian families, which summarize the properties of all the HI along the lines-of-sight in a given area, are used to focus on HI channel maps the phenomenon of close associations between HI and ILC peaks reported in my published papers is dramatically highlighted. Of particular interest, each of two pairs of HI peaks straddles a continuum peak. The previously hypothesized model for producing the continuum radiation involving free-free emission from electrons is re-examined in the light of the new data. By choosing reasonable values for the parameters required to evaluate the model, the distance for associated HI-ILC features is of order 30 to 100 pc. No associated H? radiation is expected because the electrons involved exist throughout the Milky Way. The mechanism for clumping and separation of neutrals and electrons needs to be explored.

## 110.04D – 2010 BLASTPol Observations of the Magnetic Field of the Filamentary Galactic Cloud 'Lupus I'

*Tristan Matthews[1], Peter A. R. Ade[2], Francesco E. Angilè[3], Steven J. Benton[4], Nicholas L. Chapman[1], Mark J. Devlin[3], Bradley Dober[3], Laura M. Fissel[4], Yasuo Fukui[5], Natalie Gandilo[4], Joshua O. Gundersen[6], Peter Hargrave[2], Nicholas B. Galitzki[3], Jeffrey Klein[3], Andrei Korotkov[7], Lorenzo Moncelsi[8], Tony Mroczkowski[8], Calvin Barth Netterfield[4], Giles Novak[1], David Nutter[2], Luca Olmi[9, 10], Frédérick Poidevin[11], Giorgio Savini[11], Douglas Scott[12], Jamil Shariff[4], Juan D. Soler[4], Nicholas E. Thomas[6], Matthew Truch[3], Carole E. Tucker[2], Gregory S. Tucker[7], Derek Ward-Thompson[13]*
*1. Northwestern University, Chicago, IL, United States. 2. Cardiff Univ., Cardiff, Wales, United Kingdom. 3. Univ. of Pennsylvania, Philadelphia, PA, United States. 4. Univ. of Toronto, Toronto, ON, Canada. 5. Nagoya Univ., Chikusa-ku, Nagoya, Japan. 6. Univ. of Miami, Miami, FL, United States. 7. Brown Univ., Providence, RI, United States. 8. California Institute of Technology, Pasadena, CA, United States. 9. Univ. of Puerto Rico, San Juan, Puerto Rico, United States. 10. NAF, Osservatorio Astrofisico di Arcetri, Firenze, Florence, Italy. 11. Univ. College London , London, England, United Kingdom. 12. Univ. of British Columbia, Vancouver, BC, Canada. 13. University of Central Lancashire, Lancashire, England, United Kingdom.*

We present here 350 and 500 micron polarization observations of the Lupus I molecular cloud taken during the 2010 BLASTPol Antarctic flight. Lupus I is a nearby, isolated, young, and filamentary molecular cloud making it an ideal target to test magnetically regulated star formation models. In the presence of intermediate to strong magnetic fields (in comparison to turbulence), these models predict the formation of large filaments extended perpendicular to the local magnetic field direction as gas preferentially collapses along the field lines. We compare the BLASTPol polarization observations with previous optical polarimetry and find a uniform large-scale field direction from low to high density in Lupus I, consistent with magnetically regulated star formation models.

## 110.05 – Finding the True Metal Abundances in High Velocity Clouds

*Jeffrey Gritton[1], Robin L. Shelton[1], Kyujin Kwak[2]*
*1. University of Georgia, Athens, GA, United States. 2. Ulsan National Institute of Science and Technology, Ulsan, Korea, Republic of.*

As high velocity clouds (HVCs) pass through the gas in the Milky Way, the HVC and Galactic material mix. Mixing of hot, metal-enriched Galactic halo material with cooler, metal-poor clouds begins long before the clouds completely dissipate and long before they slow to the velocity of the Galactic material. As a result, we see HVCs that are not in their original state. In order to learn how to extract the true initial characteristics of the clouds from observations of real, somewhat mixed clouds, we made detailed 2 and 3 dimensional simulations of the hydrodynamics and time-dependent ionization levels of cloud-ISM interactions. Our simulations assume a hot, tenuous, solar metallicity halo and warm, low metallicity clouds. They reveal that the metallicity of the HVC is noticeably augmented as it passes through the Galaxy's halo. Furthermore they show that the quantity of metals in various parts of the cloud is correlated with the ionization state of the gas, such that the more highly ionized high velocity material has acquired more metal atoms than the intermediate and poorly ionized high velocity material. Highly ionized material is integrated into the high velocity gas as ablated material from the HVC encapsulates and mixes with the halo material. The encapsulated gas then cools and recombines over time to augment the metallicity of intermediate and poorly ionized material.

## 110.06 – Gas, Dust and Star Formation in Nearby Galaxies: The JCMT Perspective

*Jose R. Sanchez-Gallego[1]*
*1. Physics and Astronomy, University of Kentucky, Lexington, KY, United States.*

Star formation is the most important factor controlling the internal evolution of galaxies. In the last decades, numerous efforts have been made to understand the physical conditions triggering the star formation. In this talk I will present some of the main results of the Nearby Galaxies Legacy Survey which we are carrying out with the James Clerk Maxwell Telescope. The survey has mapped 156 local galaxies in the CO J=3-2 line to trace the dense molecular hydrogen, while covering the complete morphological spectrum. Additional Halpha imaging has been obtained for all the galaxies in the sample to constrain the properties of the massive star formation in the galaxies of the sample. 450 and 850 micron continuum observations are currently ongoing using SCUBA-2 and I will present some of the first results. We find a tight correlation between CO J=3-2 and infrared luminosities. While this correlation remains true for CO and Halpha luminosities, a number of galaxies show enhanced star formation rates that do not correspond with their observed molecular gas content. I will discuss several theories that could explain these results, including the possibility that these galaxies have suffered very recent bursts of star formation, only detected in the Halpha line. Finally, I will introduce a new theoretical model that enables us to calculate

the total hydrogen volume densities around photodissociation regions. This new method presents an alternative approach to measure the diffuse component of the molecular gas near Giant Molecular Clouds, which may play an important role in the fuelling of star formation in galaxies.

# 111 – WIYN Observatory - Building on the Past, Looking to the Future: pODI and Instrumentation

## 111.01 – The WIYN One Degree Imager – Status and Performance

*Todd A. Boroson*[1]

*1. NOAO, Tucson, AZ, United States.*

A preliminary version of the WIYN One Degree Imager (ODI) has been commissioned and put into scientific operation. ODI was designed to take advantage of the excellent image quality and wide field of view of the WIYN 3.5m telescope. It will do this by covering a one square degree focal plane with orthogonal transfer array (OTA) detectors, which have the capability to correct for image motion during the exposure in regions approximately the size of the isokinetic patch. The partial ODI (pODI) differs from the complete ODI in two ways – only 13 of the 64 OTAs populate the focal plane, and only coherent image motion correction is enabled. However, this implementation has allowed the commissioning of the instrument with all subsystems except the additional detectors in place. The 13 OTAs are configured as a 24 X 24 arcminute "science field", plus 4 outer OTAs, allowing the sampling of all radii within the one square degree field. pODI is now in use for science observations as we prepare to upgrade the focal plane. The performance of pODI is excellent. Image quality is site seeing limited, and, on good seeing nights, we can achieve images around 0.4 arcsec FWHM over the entire field. The guide signal, from selected regions in the outer OTAs, can be passed to the telescope exclusively, or the high frequency component can be applied as a global shift to the OTAs. We are still in the process of characterizing the gains from this coherent correction, but the detectors perform well in this mode. Data are immediately transferred to an archive at Indiana University, where they are pipeline-processed to remove instrumental signature. The OTA detectors perform adequately in terms of read noise, full well, sensitivity, and dark current. They show 2 anomalies: (1) regions in the circuitry outside the imaging area glow under certain circumstances, and (2) a low level degradation of charge transfer efficiency is present between the imaging area and the serial registers. We have found ways to address both of these effects in operation, calibration, and post-processing, and the instrument is producing valuable scientific observations.

## 111.02 – The WIYN One Degree Imager: First Operations and Future Upgrade Path

*Daniel R. Harbeck*[1]

*1. WIYN Observatory, Tucson, AZ, United States.*

*Contributing teams: ODI Team, PPA Team*

WIYN's latest instrument, the One Degree Imager with a partially populated focal plane (pODI), has started shared risk operations in the semester 2013A. pODI, with 13 out of 64 possible detector slots populated, offers a science field of view of 24' x 24' and has proven its capability to deliver excellent image quality of order of 0.4' over the entire field of view. I will present the first highlights from commissioning and the first half year of science operations. In the second part of the talk I will outline an upgrade path to add additional detectors to the instrument, which would significantly increase the usable field of view to about 48 x 48 arcminutes. With such an extended field of view, ODI will be a viable and competitive choice for large scale survey operations.

## 111.03 – The Pipeline, Portal and Archive (PPA) System for the WIYN Partial One Degree Imager

*Jayadev Rajagopal*[1]

*1. NOAO, Tucson, AZ, United States.*

*Contributing teams: ODI, PTI, NOAO-SDM*

The WIYN telescope has recently commissioned the partial One Degree Imager (pODI), which has already demonstrated very high image quality over a wide field. The PPA system was envisioned as the transport, archiving, reduction and discovery system for the complex and high-volume data from this instrument. The building blocks of the PPA are a high-speed transport conduit from the WIYN Observatory to Indiana where the archive resides, a pipeline data reduction system running on an NSF super computing facility (XSEDE) and a data access and discovery Portal. In many ways, the PPA is a forerunner of data systems for the extremely large data from the mega-surveys envisaged for the future. PPA has been designed and executed jointly by the WIYN partnership and Pervasive Technologies Institute (PTI) at IU. NOAO designed the pipeline algorithms and data transport, and PTI hosts the Archive, handles XSEDE computing and developed the Portal. The PPA was deployed for the first semester (2013A) of pODI shared-risk operation with essential services in place. When complete, the PPA will offer users, in addition to advanced data visualization tools, the option of generating pipeline re-runs and a virtual Desktop for limited custom analysis of reduced data. I will describe the development and report on the current status of the PPA system.

## 111.04 – The Hydra Multi-Object Spectrograph

*Patricia Knezek*[1]

*1. NOAO/WIYN Observatory, Tucson, AZ, United States.*

Hydra is a multi-object spectrometer that utilizes fiber optics placed in the focal plane to simultaneously transmit the light from numerous objects to a bench mounted spectrograph that records the spectrum of each object onto a CCD detector. This is a very versatile instrument, and I will summarize its capabilities. I will also highlight some scientific areas where this instrument has and/or will contribute to our understanding.

## 111.05 – Integral Field Spectroscopy on the 3.5-m WIYN Telescope

*Marsha J. Wolf*[1]

*1. Univ. of Wisconsin, Madison, Madison, WI, United States.*

The instrumentation suite of the 3.5-m WIYN Telescope includes an integral field unit (IFU) called SparsePak that feeds the Bench Spectrograph. SparsePak exploits the A-omega advantage of large fibers to enable deep spectroscopic observations of low surface brightness extended sources. It contains 82, 4.7 arcsec diameter fibers arranged in a configuration with an inner core of 17 densely packed fibers, with angular extent of 24 x 39 arcsec, that are surrounded by a sparser grid of fibers subtending 72 x 71 arcsec. Additionally, 7 sky fibers are arranged approximately 25 arcsec away from the "object" grid, along 2 adjacent edges. I will describe performance characteristics of the SparsePak IFU and highlight UW science programs that are utilizing it.

## 111.06 – The WIYN 0.9-meter Consortium and the Half Degree Imager

*Constantine P. Deliyannis*[1]

*1. Indiana Univ., Bloomington, IN, United States.*

The composition of the WIYN 0.9m Consortium will be described, as well as the various observing modes employed at the WIYN 0.9m telescope. The capabilities of the new Half Degree Imager (HDI) will be reviewed, and observing opportunities for the NOAO community will be highlighted.

## 111.07 – The WHIRC near-IR Camera

*Jayadev Rajagopal*[1]

*1. CTIO, Tucson, AZ, United States.*

WHIRC is a near-IR (0.9-2.5 micron) camera for the WIYN 3.5m telescope. WHIRC frequently delivers seeing limited performance of approximately 0.5-0.6' FWHM. When the seeing is very good, applying tip-tilt first-order AO corrections with the WIYN-Tip-Tilt-Module(WTTM) can produce near diffraction-limited images (0.20') in the Ks band. A suite of broad and narrow-band filters are available. These capabilities have seen WHIRC rapidly become one of the most popular and productive instruments on WIYN.

# 112 – The Secret Life of Globular Clusters

## 112.01 – The Secret Life of Globular Clusters

*Catherine A. Pilachowski*[1]

*1. Indiana University, Bloomington, IN, United States.*

Over the last three decades, the increasing complexity of the observed properties of globular star clusters has led to greater and greater disparity with the classical view of globular clusters as simple stellar populations. High precision photometry with the Hubble Space Telescope, combined with both large spectroscopic surveys enabled by multi-object instruments and advances in our theoretical understanding of stellar evolution, have finally resulted in a new paradigm for understanding globular clusters as complex systems that experienced multiple star formation events. The chemical evolution of globular clusters differs significantly from that of Galactic field populations, and the dynamical evolution of globular clusters as complex systems now informs both our understanding of the initial dynamical conditions of the clusters themselves and of the formation of the halo.

# 113 – Supernovae and Their Diversity

## 113.01 – Supernovae and Their Diversity

*Peter M. Garnavich*[1]

*1. Univ. of Notre Dame, Notre Dame, IN, United States.*

The number of supernovae discovered annually has exploded and this has led to a growing diversity in observed supernova luminosities and properties. Stripped core-collapse supernovae show a range of expansion velocities with the broad-line events associated to gamma-ray bursts. Several types of extremely luminous supernovae have been identified in the past five years. Some may result from a pair-production instability in very massive stars while others appear to come from less massive progenitors and have an uncertain power source. Thermonuclear (type Ia) events are often thought of as uniform in their properties and that is what makes them good distance indicators. But type Ia supernovae are diverse in subtle and not so subtle ways that may reveal the nature of their explosion mechanism and progenitors. Wider, deeper time-domain sky surveys such as DES and LSST are likely to find even more variety in stellar explosions.

# 114 – Laboratory Astrophysics

## 114.01 – Uncertainties in Atomic Data and Their Propagation Through Spectral Models

*Manuel Bautista[1], Vanessa Fivet[1, 3], Pascal Quinet[3], Claudio Mendoza[1], Timothy R. Kallman[2]*
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We present a method for computing uncertainties in spectral models, i.e. level populations, line emissivities, and emission line ratios, based upon the propagation of uncertainties originating from atomic data. We provide analytic expressions, in the form of linear sets of algebraic equations, for the coupled uncertainties among all levels. These equations can be solved efficiently for any set of physical conditions and uncertainties in the atomic data. We illustrate our method applied to spectral models of O III and Fe II and discuss the impact of the uncertainties on atomic systems under different physical conditions. As to intrinsic uncertainties in theoretical atomic data, we propose that these uncertainties can be estimated from the dispersion in the results from various independent calculations. This technique provides excellent results for the uncertainties in A-values of forbidden transitions in [Fe II].

## 114.02 – AtomPy: A Cloud Atomic-data Service for Astrophysical Applications

*Claudio Mendoza[1], Josiah S. Boswell[1], Manuel Bautista[1]*
*1. Physics, Western Michigan University, Kalamazoo, MI, United States.*

Apart from our long-term commitment to the computing of accurate atomic data for astrophysical applications, we have also been interested in the problems of data access and dissemination. In this respect, one of us took part in the developments of TIPTOPbase [1, 2, 3], the astrophysical opacity server referred to as OPserver [4, 5], and, more recently, of the Virtual Atomic and Molecular Data Center [6, 7]. Our present effort is now with the establishment of a cloud atomic data web service, AtomPy, implemented by means of SOAP web services, Google Drive spreadsheets and Python modules. In the present poster we will describe the outline of this ambitious project, illustrated with some prototypes that are already operational.

## 114.03 – Modeling Laser-Driven Laboratory Astrophysics Experiments Using the CRASH Code

*Michael Grosskopf[1], Paul Keiter[1], Carolyn C. Kuranz[1], Guy Malamud[1, 2], Matt Trantham[1], R. Paul Drake[1]*
*1. University of Michgan, Ann Arbor, MI, United States. 2. Nuclear Research Center, Negev, Israel.*

Laser-driven, laboratory astrophysics experiments can provide important insight into the physical processes relevant to astrophysical systems. The radiation hydrodynamics code developed by the Center for Radiative Shock Hydrodynamics (CRASH) at the University of Michigan has been used to model experimental designs for high-energy-density laboratory astrophysics campaigns on OMEGA and other high-energy laser facilities. This code is an Eulerian, block-adaptive AMR hydrodynamics code with implicit multigroup radiation transport and electron heat conduction. The CRASH model has been used on many applications including: radiative shocks, Kelvin-Helmholtz and Rayleigh-Taylor experiments on the OMEGA laser; as well as laser-driven ablative plumes in experiments by the Astrophysical Collisionless Shocks Experiments with Lasers (ACSEL) collaboration. We report a series of results with the CRASH code in support of design work for upcoming high-energy-density physics experiments, as well as comparison between existing experimental data and simulation results. This work is funded by the Predictive Sciences Academic Alliances Program in NNSA-ASC via grant DEFC52- 08NA28616, by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-NA0000850.

## 114.04 – An Experimental Concept to Measure Opacities Under Solar-relevant Conditions

*Paul Keiter[1], Katie Mussack[2], Sallee Klein[1]*
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Recent solar abundance models (Asplund 2009) use a significantly lower abundance for C, N, O compared to models used roughly a decade ago. Although the models used now are much more sophisticated than before, a discrepancy still exists between the abundances in the models and the abundances determined by helioseismic inferences. Agreement can be obtained by ad hoc adjustments to the opacity of high-Z ($Z > 2$) elements ranging from a few percent in the solar interior to as much as 30% just below the convection zone (CZ). Although many of the opacity models are thought to agree within a few percent, a recent element-by-element study (Blancard 2012) indicates a larger disagreement between models for certain elements. Experimental opacity measurements for these elements in the regimes of interest will provide valuable information to help resolve these discrepancies. We will present an experimental platform designed to measure the opacity of C, N, and O and discuss the achievable parameter regime. We will also briefly discuss how this platform can be extended to include other high-Z elements.

## 114.05 – Single-Mode, Supersonic Kelvin-Helmholtz Instability Experiment on OMEGA-EP

*Wesley Wan[1], Guy Malamud[1], Carlos Di Stefano[1], Carolyn C. Kuranz[1], R. Paul Drake[1]*
*1. University of Michigan, Ann Arbor, MI, United States.*

Laboratory laser experiments are able to produce and study phenomena that occur in astrophysical systems, allowing us to study mechanisms relevant to the formation, interaction, and destruction processes of stars and planets. These dynamic processes are strongly affected by hydrodynamic instabilities such as the Kelvin-Helmholtz instability, which arises when shear flow at an interface causes mixing between fluid layers. This instability is commonly observed at the boundary of cloud bands among gas planets, and can act as an atmospheric loss mechanism on planets with little to no intrinsic magnetic field. It is also observed in simulations of astrophysical systems including supernovae and wind-driven clumps. This poster discusses an upcoming experiment for the OMEGA-EP system that will produce a supersonic Kelvin-Helmholtz instability in the high-energy-density regime. This experiment will use a long laser pulse to create a sustained shock through two stratified layers separated by a seeded, single-mode perturbation. A high Mach number is believed to suppress the growth of the Kelvin-Helmholtz instability and, if sufficiently high, prevent growth entirely. We will be quantifying these effects using x-ray radiography. This work is funded by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-NA0000850, with additional support provided under Cooperative Agreement No. DE-FC52-08NA28302 through the Laboratory for Laser Energetics, University of Rochester.

## 114.06 – Storage Ring Measurements of Electron Impact Ionization for Astrophysics

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Understanding astrophysical plasmas and interpreting their spectra requires knowledge of their charge state distributions (CSD). The CSD is determined by the rates of ionization and recombination in the plasma. Thus, accurate electron impact ionization (EII) data are needed to calculate the CSD for electron ionized objects such as stars, supernovae, galaxies, and clusters of galaxies. We are studying EII for astrophysically important ions using the TSR storage ring located at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. Storage ring measurements are largely free of the metastable contamination found in other experimental geometries, resulting in unambiguous EII data. We have found discrepancies of about 10% - 30% between our measured cross sections and those commonly used in CSD models. Because it is impractical to perform experimental measurements for every astrophysically relevant ion, theory must provide the bulk of the necessary EII data. These experimental results provide an essential benchmark for such EII calculations.

## 114.07 – Dissociative Recombination of Molecular Ions for Astrochemistry

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Dissociative recombination (DR) of molecular ions is a key chemical process in the cold interstellar medium (ISM). DR affects the composition, charge state, and energy balance of such environments. Astrochemical models of the ISM require reliable total DR cross sections as well as knowledge of the chemical composition and excitation states of the neutral DR products. Theory cannot reliably provide these data. We have systematically measured DR for many astrophysically relevant molecular ions utilizing the TSR storage ring at the Max-Planck-Institute for Nuclear Physics in Heidelberg, Germany. We used the merged ion-electron beam technique combined with an energy- and position-sensitive imaging detector and are able to study DR down to plasma temperatures of 10 K. The DR count rate is used to obtain absolute DR rate coefficient. Additionally we determine the masses of the DR products by measuring their kinetic energy. This allows us to assign particular DR fragmentation channels and to obtain their branching ratios. Moreover, the distribution of detected fragment distances provides information on the kinetic energy released in DR and thus also on the internal excitation of the DR products. All this information is particularly important for understanding DR of heteronuclear polyatomic ions. We will present DR results for several ions recently investigated at TSR. This work is supported in part by NASA and the NSF.

## 114.08 – Laboratory Investigations Into The Origins Of Organic Chemistry

*Nathalie de Ruette[1], Kenneth A. Miller[1], Aodh O'Connor[1], Julia Stuetzel[1], Xavier Urbain[2], Daniel W. Savin[1]*
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The chain of chemical reactions leading towards life is thought to begin in molecular clouds when atomic carbon is fixed into molecules, initiating the synthesis of complex organic species. Spectroscopic observations, combined with sophisticated astrochemical models to interpret the collected spectra, provide much of our knowledge of this process. However, uncertainties in the underlying chemical data in these models limit our understanding of the molecular universe. Theory provides little insight as fully quantum mechanical calculations for reactions with four or more atoms are too complex for current capabilities. Measurements of rate coefficients for reactions of C with molecular ions are extremely challenging. This is due to the difficulty in producing a sufficiently intense and well characterized beam of neutral carbon atoms. We have developed a novel merged beam apparatus to study reactions of neutral atomic C with molecular ions. A $C^-$ beam is created in a cesium ion sputter source and accelerated to 28 keV. A series of apertures and electrostatic optics create a collimated beam. Using an 808 nm (1.53 eV) laser beam, ~4% of the $C^-$ beam is neutralized via photodetachment. We produce a pure ground term neutral C beam by electrostatically removing the remaining $C^-$. A velocity matched, co-propagating $H_3^+$ beam at 7.05 keV, created with a duoplasmatron source, is then merged with the C beam. The merged beams method allows us to use fast beams, which are easy to handle and monitor, while being able to achieve relative collision energies down to some tens of meV. An electrostatic energy analyzer separates and detects the charged end products of the different reaction channels. The reactions rate coefficients are determined by measuring all the relevant currents, beam shapes, energies, signal counts and background rates. We have measured the absolute rate coefficients for $C + H_3^+$ ? $CH^+ + H_2$ and $C + H_3^+$ ? $CH_2^+ + H$. Since $H_3^+$ is ubiquitous in molecular clouds, these reactions are some of the first steps leading to the formation of complex organic molecules within such clouds. Our reaction studies will help to provide a better basis for astrochemical models and benchmarks for future theoretical development.

## 114.09 – Oscillator Strengths and Predissociation Rates for Rydberg Transitions between 92.7 and 97.5 nm in $^{13}C^{16}O$ and $^{12}C^{18}O$

*Steven R. Federman[1], Michele Eidelsberg[2], Jean Louis Lemaire[2], Lisseth Gavilan[2], Glenn Stark[3], Alan Heays[3], Jean-Hugues Fillion[4], James R. Lyons[5], Nelson de Oliveira[6]*
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As part of our ongoing studies related to the photochemistry of carbon monoxide, we present results for *W* – *X* (*v*?=0-3, 0) bands seen in absorption spectra of $^{13}C^{16}O$ and $^{12}C^{18}O$ and compare them with earlier determinations. Comparison is also made with our recently published results on $^{12}C^{16}O$. The experiments were performed on the DESIRS beam-line at the SOLEIL Synchrotron. A VUV Fourier Transform Spectrometer provided a resolving power of about 300,000, allowing us to discern individual lines in these electronic transitions. CO photochemistry plays an important role in many astrophysical environments, including photon-dominated regions in interstellar clouds, circumstellar disks around newly formed stars, and the envelopes surrounding stars near the end of their lives. It controls the CO abundance and the ratio of its isotopologues. The measurements described here provide the necessary data for modeling CO in these environments.

## 114.1 – Abundances of Neutral and Ionized PAH Along The Lines-of-Sight of Diffuse and Translucent Interstellar Clouds

*Farid Salama[1], Gazinur Galazutdinov[2], Jacek Krelowski[3], Ludovic Biennier[4], Yuri Beletsky[5], In-Ok Song[6]*
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The spectra of neutral and ionized PAHs isolated in the gas phase at low temperature have been measured in the laboratory under conditions that mimic interstellar conditions and are compared with a set of astronomical spectra of reddened, early type stars. The comparisons of astronomical and laboratory data provide upper limits for the abundances of neutral PAH molecules and ions along specific lines-of-sight. Something that is not attainable from infrared observations. We present the characteristics of the laboratory facility (COSmIC) that was developed for this study and discuss the findings resulting from the comparison of the laboratory data with high resolution, high S/N ratio astronomical observations. COSmIC combines a supersonic jet expansion with discharge plasma and cavity ringdown spectroscopy and provides experimental conditions that closely mimic the interstellar conditions. The column densities of the individual PAH molecules and ions probed in these surveys are derived from the comparison of the laboratory data with high resolution, high S/N ratio astronomical observations. The comparisons of astronomical and laboratory data lead to clear conclusions regarding the expected abundances for PAHs in the interstellar environments probed in the surveys. Band profile comparisons between laboratory and astronomical spectra lead to information regarding the molecular structures and characteristics associated with the DIB carriers in the corresponding lines-of-sight. These quantitative surveys of neutral and ionized PAHs in the optical range open the way for quantitative searches of PAHs and complex organics in a variety of interstellar and circumstellar environments. Acknowledgements: F.S. acknowledges the support of the Astrophysics Research and Analysis Program of the NASA Space Mission Directorate and the technical support provided by R. Walker at NASA ARC. J.K. acknowledges the financial support of the Polish State. The authors are deeply grateful to the ESO archive as well as to the ESO staff members for their active support.

## 114.12 – A Need for Modeling N-rich, C-, O-poor Chemistry

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Stars exceeding 60 solar masses experience an interrupted CNO-cycle, caused by transport of nuclear products from the stellar interior into the extended atmosphere. The result is excess N at the expense of C and O. Such is the situation for Eta Car that experienced two major eruptions in the 19th century and continues to experience major mass loss by interacting winds from its massive primary and secondary. At least ten, possibly forty, solar masses were ejected and prove to be greatly enriched in N. C and O are only a few percent in abundance relative to N in the Sun. Many atomic species are found in neutral or ionic state, such as Fe, Ni, Mg, Mn, Ti, Sr, Sc, V. The presence of the latter three, having never before been detected in interstellar space, is suggestive that insufficient C and O are present to form oxides and carbides. Yet dust is present in the Homunculus as demonstrated by the reflected starlight that turns out to be highly polarized at optical wavelengths, implying small dust grains. Today the massive binary is cloaked by 4 magnitudes of primary wind. A less massive, high velocity wind carves a cavity out of the primary wind with high modulation of 5.54-years due to the eccentric orbit. While color-dependent changes occur across each periastron, a secular brightening of one stellar magnitude continues for the past fifteen years and is grey, or non-color dependent, implying a decrease in formation of large dust grains. 3D hydrodynamic models with radiative transfer are providing increasing information on the physical conditions in the winds with a long term effort to understand under what conditions molecules and dust form. Herschel observations of the Homunculus have

revealed many molecular and H I lines in the submm spectral region. The molecules, byproducts from the formation of dust in the Great Eruption, provide clues to the formation of the dust in this rather adverse environment.

## 114.14 – Ion Heating During Magnetic Reconnection in a High Temperature Toroidal Plasma

*Darren Craig[1], M. Cartolano[1], D. J. Den Hartog[2], S. T. Kumar[2], R. Magee[2], M. D. Nornberg[2]*
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Ions are strongly heated during spontaneous magnetic reconnection events in the Madison Symmetric Torus (MST), a large toroidal plasma experiment at the University of Wisconsin - Madison. Nonlinear mechanisms active in the plasma result in states that are strongly self-organized; ion heating is a major macroscopic result of the self-organization process. During reconnection events the ion temperature doubles (or more) in ~100 microseconds, and can reach temperatures >1 keV. The heating is stronger for ions with higher charge and/or mass and is also anisotropic, favoring energization perpendicular to the large scale magnetic field. Collisions between the different ion species are important for redistributing the energy between different species and for relaxing the anisotropy of the heating in MST. The ion heating is proportional to the decrease in global magnetic energy during the reconnection event and correlates with the amplitudes of several coupled tearing mode fluctuations that underlie much of physics of the reconnection event. While ion heating is observed globally throughout the plasma volume, the increase in ion temperature is not uniform but instead depends on both the distance from the plasma center and on the toroidal location of the various coupled reconnection sites. Several theories have been proposed to explain the heating but none so far has emerged as clearly satisfying the full range of experimental observations. Work Supported by U.S.D.O.E and N.S.F.

## 114.15 – Investigation of Plume Dynamics in Pulsed Infrared Laser Ablation of Interstellar and Solar System Ice Analogs

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We recently developed in-situ analysis of chemical composition of radiation processed astrophysical and planetary ice analogs [Gudipati and Yang, ApJL 756, L24, 2013]. This method is similar to the well-established MALDI (matrix-assisted laser desorption and ionization) method, except that we use two lasers – the first an infrared (IR) laser for desorption/ablation of ice and the second an ultraviolet (UV) laser for multiphoton ionization of the plume atoms, molecules, and clusters. With this two-color matrix-assisted laser desorption/ablation and laser ionization (2C-MALDI) method we demonstrated that even at 5 K, ices containing polycyclic aromatic hydrocarbons (PAHs) under UV irradiation result in hydrogenation and oxygenation of the PAHs. In order to better understand the dynamics of the ablation vs. desorption process upon firing a focused infrared laser on to the ice we carried out further detailed studies that will be presented. In brief, matrix-assisted ablation of water ices was initiated by an IR laser that was tuned to an absorption band of water ice (?=2948 nm; 5 ns pulse duration), and the ejected material was ionized with a second UV pulse (?=266 or 355 nm; 5 ns pulse duration). Ions produced during this process were detected using a 100 cm time of flight mass spectrometer. The delay between the ablating IR and ionizing UV laser pulses was varied between 0 and 50 ?s for cross-sectional analysis of plume composition at a variety of time points. A variety of molecular species were incorporated into the frozen water matrix to determine their effect on plume composition and evolution over time. Among the additives studied, toluene proved to be particularly useful. Toluene is hydroxylated upon irradiation with a Ly-alpha photons generated by hydrogen flow-discharge lamp. The nonpolar toluene and the polar photoproduct (cresol) exhibited different dynamics in the plume. Cresol-water clusters were also observed in the irradiated spectra, and the relative abundances of these species at a range of IR-UV pulse delay times were compared to those of water monomers and small water clusters.

## 114.16 – X-Ray powder diffraction of cosmic dust analogues.

*Sarah Day[1, 2], Stephen P. Thompson[2], Aneurin Evans[1], Julia E. Parker[2]*
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We use synchrotron X-Ray powder diffraction (SXPD) at the Diamond Light Source, UK, to study the formation and structural evolution of cosmic dust analogues as they are thermally cycled. The SXPD measurements are complemented by Raman and FTIR spectroscopy. Amorphous Ca-rich silicates are produced using a sol-gel method; SEM shows that the grains produced in this way have a diameter <10?m. Infrared spectroscopy confirms the amorphous nature of the grains, exhibiting broad features at 10 and 18?m. SXPD data are obtained for a range of samples at elevated temperatures, from ambient to 1200K, with and without exposure to gaseous CO2. These experiments have relevance to the formation of carbonate dust species in circumstellar and protostellar environments, where the processes governing their formation are not well understood; they may also be relevant to carbonate formation on planetary surfaces. We have also investigated the formation and dissociation of clathrate hydrates using SXPD. The results of some of these experiments will be presented.

## 114.17 – Atomic and Molecular Wavelength Calibration Sources for Astronomy

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We have measured atomic emission wavelengths and molecular absorption wavelengths for several sources, including thorium, uranium, acetylene, hydrogen cyanide, and two isotopes of carbon monoxide. The atomic sources provide calibration standards throughout the optical and near-infrared, while the molecular sources can be used as standards in the near-infrared H-band (1500 nm to 1650 nm). We have implemented several of these sources on the CRyogenic high-resolution InfraRed Echelle Spectrograph (CRIRES) on the Very Large Telescope (VLT) in Chile, and used the molecular standards to measure radial velocities of standard stars.

## 114.18 – Laboratory Molecular Ion Spectroscopy in an Ion Beam

*Michael Porambo[1], Jessica Pearson[1], Craig Riccardo[1], Benjamin J. McCall[1]*
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Laboratory spectroscopy is needed to decipher the wealth of observational spectra obtained from such missions and observatories as *Herschel*, SOFIA, and ALMA. Spectra of interstellar molecular ions in particular are of great interest, as molecular ions are thought to be key reactants and intermediates of interstellar chemical reactions in the gas phase. However, spectra of molecular ions are particularly difficult to acquire in the laboratory, due to high reactivity and confusion with neutral molecules. To acquire highly precise spectra that can be used to identify astronomical transitions, we are developing a novel ion beam spectrometer called Sensitive, Cooled, Resolved, Ion BEam Spectroscopy (SCRIBES). SCRIBES combines highly sensitive cavity-enhanced spectroscopy with ion-neutral separation, mass spectrometry, and a supersonic expansion ion source to produce rotationally cool molecular ions. Frequency calibration of spectra with an optical frequency comb allows for determination of precise linecenters of molecular transitions, with an uncertainty on the order of 1 MHz. Results of near-infrared spectroscopy with a hot ion beam and work implementing mid-infrared spectroscopy are presented. When completed, this system will be used to study molecular ions of astrophysical significance.

## none | none | 114.11 | none|114.11 – The ORGANIC Experiment on EXPOSE-R on the ISS: A Space Exposure Experiment

*Kathryn Bryson[1, 3], Zan Peeters[2], Farid Salama[3], Bernard Foing[4], Pascale Ehrenfreund[5, 6], Antonio Ricco[7], Elmar K. Jessberger[8], Addi Bischoff[8], Michel Breitfellner[9], Werner Schmidt[10], François Robert[11]*
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Aromatic networks are among the most abundant organic material in space. PAHs and fullerenes have been identified in meteorites and are thought to be among the carriers for numerous astronomical absorption and emission features. Thin films of selected PAHs and fullerenes have been subjected to the low Earth orbit environment as part of the ORGANIC experiment on the multi-user facility EXPOSE-R onboard the ISS. The ORGANIC experiment monitored the chemical evolution, survival, destruction, and chemical modification of the samples. EXPOSE-R was mounted on the outside of the ISS from March 10, 2009 to January 21, 2011. The samples were returned to Earth and

inspected in spring 2011. The 682-day period outside the ISS provided continuous exposure to the cosmic-, solar-, and trapped-particle radiation background and >2500 h of unshadowed solar illumination. All trays carry both solar-irradiation-exposed and dark samples shielded from the UV photons, enabling discrimination between the effects of exposure to solar photons and cosmic rays. The samples were analyzed before exposure to the space environment with UV-VIS spectroscopy. Ground truth monitoring of additional sample carriers was performed through UV-VIS spectroscopy at regular intervals at NASA Ames Research Center. During the exposure on the ISS, 2 control sample carriers were exposed with a slight time shift in a planetary simulation chamber at the Microgravity User Support Center at DLR. Vacuum, UV radiation, and temperature fluctuations are simulated according to the telemetry data measured during flight. The spectroscopic measurements of these two carriers have been performed together with the returned flight samples. We report on the scientific experiment, the details of the ground control analysis, and preliminary flight sample results.

# 114 – Laboratory Astrophysics

**Poster Session – – 26 May 2013 05:38 PM to 05:38 PM**

This session includes the same abstracts from the previous session.

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# 115 – Binaries, Variable Stars and White Dwarfs

## 115.01 – Pulsational Light Variability in a Sample of Carbon-rich Post-AGB Stars in the Magellanic Clouds

*Bruce J. Hrivnak[1], Wenxian Lu[1], Igor Soszynski[2], Ryszard Szczerba[3], Kevin Volk[4]*

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A sample of 17 carbon-rich post-AGB stars has been identified based on Spitzer spectra of candidate objects in the Magellanic Clouds (Volk et al. 2011, ApJ, 735, 127). We have studied the light variability of these using Ogle II and III data for 15 of these that have such data. We find periodic variability in three, with periods of 74, 96, and 158 days; these have F spectral types. These three we compare with the pulsation properties of carbon-rich post-AGB objects (proto-planetary nebulae) in the Galaxy (Hrivnak et al. 2010, ApJ, 709, 1042). The others all vary, but generally with a shorter timescale. The pulsation amplitudes of the variables range from 0.1 to 0.5 mag in I, and are larger in V. In addition, several show long-term, monotonic changes in brightness. Only a few of these have spectra from which to determine spectral types. Based on our study of post-AGB objects in the Galaxy, we would expect the short-term variables to be objects that have evolved to higher temperatures (B stars) on the HR diagram. This research has been supported by the NSF (AST 1009974).

## 115.02 – A Study of Light Variability in a Sample of Proto-planetary Nebula Candidates

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We are continuing our long-term observational study of light variability in proto-planetary nebulae (PPNe) and PPN candidates. In this poster, we present preliminary results from a five-year study of a subset of 18 objects. All were observed using the 0.4-m telescope at the Valparaiso University Observatory. We find that they all varied in brightness, by 0.12 to 0.74 mag in V. Periods have been found for 8 out of 18 objects, and they range from 27 to 125 days. These variations are due to the pulsation of the stars. The goal is to find the amplitude and period of the variations, which can be used to investigate the internal structure of the stars. We present the results of this study and show some sample light curves. Funding is acknowledged from the NSF (AST 1009974) and the Indiana Space Grant Consortium.

## 115.03 – Disk Properties in Taurus Binary Systems

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We present results from an imaging survey of pre-main-sequence Taurus binaries and their protoplanetary disks taken during Cycle 0 at ALMA. All systems have projected separations of 100 AU or larger; thus we can resolve the pair and characterize the individual disk properties. The overall goals of the study are to compare the properties of disks around stars in binary systems with their single star counterparts and to test models of binary formation. While previous observations have detected only the primary's disk in most systems, our observations at 1.3 and 0.85 mm have detected a number of previously undetected secondary disks. We present preliminary estimates of the disk properties and comparisons of the single and binary populations. This research was conducted at the NASA Exoplanet Science Institute, Caltech and makes use of the following ALMA data: ADS/JAO.ALMA#2011.0.00150.S. 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.

## 115.04 – Fundamental Properties of the LMC Eclipsing Binary Macho* J053648.7-691700

*Frank P. Maloney[1], Eduard Bachmakov[1], Gal Matijevic[1], Edward F. Guinan[1], Edward L. Fitzpatrick[1], Andrej Prsa[1]*

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We present preliminary results for the fundamental properties of the eccentric eclipsing/spectroscopic binary system MACHO* J053648.7-691700 in the Large Magellanic Cloud (LMC). This is a detached system consisting of two similar late-O or early-B components with a 3.85 day orbital period. Previously published CCD u, $V_J$, and $I_C$ photometry (Bayne et al. 2004), and HST/STIS spectroscopy obtained by us were used to analyze the system. The modeling of the light curve reveals the temperature ratio and relative radii of the component stars, as well as the orbital inclination, longitude of periastron, and eccentricity. The radial velocity study, when combined with the photometry, reveals the temperatures, radii, reddening, and masses of the stars. Of particular importance is the distance to this system, obtained from a knowledge of the radii, temperatures, and reddening, since the location of the system is within 7 arc-min of SN 1987A, whose distance is thought to be known accurately.

## 115.05 – Photometric Observations of the Totally Eclipsing, Solar Type Eclipsing Binary, DK Andromedae

*Ronald G. Samec[1], Danny R. Faulkner[2], Walter V. Van Hamme[3], James Kring[1]*

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We present the first precision BVRI light curves, synthetic light curve solutions and a period study for the Sonneberg variable, DK And. Observations were taken with the NURO 0.81-m Lowell reflector on 24, 25 and 27 September and 26 October and 01 November 2011 with the SARA 0.9-m reflector. Our light curves were premodeled with Binary Maker 3.0, and solved with the Wilson-Devinney program. Our observations included 374 B, 372 V, 392 R and 394 I individual and calibrated observations. These were taken with the NURO, Lowell 2KX2K NASACAM, and the SARA 1KX1K Apogee camera. Six mean times of minimum light were determined, includingHJDMin I= 2455866.8222(±0.0003), 2455828.6632(±0.0001), 2455829.6405(±0.0097), and HJDMin II=2455866.5782(±0.0007), 2455860.6970(±0.0053) and 2455828.9081(±0.0004). Thirty-one timings taken over 73 years are included in our ephemeris calculation: J.D. Hel Min I = 2451435.4330(±0.0011)d + 0.48922346(±0.00000015)×E + 2.4(±0.4)×$10^{-11}$×$E^2$ For conservative mass transfer, the positive quadratic term means that the more massive star is the gainer. Our light curves shows a time of constant light in the secondary eclipse of 28 minutes making this an A-type W UMa system. The amplitude of the light curves are about 0.5 mags in V. The light curve solution reveals a rather extreme mass ratio of 0.32, a component temperature difference of ~300K, and an inclination of 82.5°. The curves show the effects of dark spot activity. We thank USC, Lancaster for their support of our membership in NURO for the past 8 years, the American Astronomical Society for its support through its small research program and Arizona Space grant for the partial support for our student’s travel.

## 115.06 – Photometric Study of the Solar Type Pre-Contact Binary, V2421 Cygni

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*1. Bob Jones University, Taylors, SC, United States. 2. Florida International University, Miami, FL, United States. 3. University of South Carolina, Lancaster, SC, United States.*

We present the first precision BVRI light curves, and synthetic light curve solutions and a period study for the 14th magnitude (V) pre-contact W UMa Binary, V2421 Cygni. Observations were taken with the NURO 0.81-m Lowell reflector on 30 September, 1 and 2 October. Our light curves were premodeled with Binary Maker 3.0, and solved with the Wilson-Devinney program. The observations included 140 B, 149 V, 139 R and 135 I individual and calibrated observations. These were taken with the Lowell CRYOTIGER cooled (-100k) 2KX2K NASACAM. Three mean times of minimum light were determined, including HJDMin I = 2455469.82375±0.00037, and 2455471.72232±0.0012 and HJDMin II = 2455470.77149±0.0012. Eight eclipse timings were taken from the the literature for our calculation of its first precision ephemeris: JD Tmin I = 2455469.8238± 0.0047 + 0.6331290 ± 0.0000015 d*E The light curve has the appearance of an Algol (EA) type, however it is made up of dwarf solar type components in a detached mode with a period of only 0.6331 days. The light curve solution gives a mass ratio of ~0.5, an inclination of 86° and amplitudes of 1.3, 1.1, 0.98, and 0.87 in B,V,R and I, respectively. Flare-like disruptions occur in the light curves following the primary and secondary eclipses. The fill-outs are 83% and 98% for star one (hotter more massive component) and star two, respectively. The model includes two hot spots, possibly, stream spots (one a direct hit and the second, a splash spot). Further observations are needed to determine its orbital evolution. We thank USC, Lancaster for their support of our membership in NURO for the past 8 years, the American Astronomical Society for its support through its small research program and Arizona Space grant for the partial support for our student’s travel.

## 115.07 – A Spectroscopic Investigation of the Interaction of Delta Scorpius with its Companion

*Mary McDaniel[1], Melvin Blake[1], Taylor C. Garber[1], Michael W. Castelaz[2]*

*1. University of North Alabama, Florence, AL, United States. 2. Pisgah Astronomical Research Institute, Balsam Grove, NC, United States.*

In July of 2011, the highly-eccentric Be star system Delta Scorpius was predicted to have an interaction between its companion star and its circumstellar disk during its periastron passage which takes place every eleven years. During previous passages the circumstellar disk was not present, so the 2011 passage presented a unique opportunity to study such an encounter. We conducted a spectroscopic study with a 1200 line/mm grating Cassegrain spectrograph on the 0.40m telescope at Pisgah Astronomical Research Institute of Delta Scorpius to determine any effects that may have been caused by the companion star and disk interacting with each other. We will present our resulting images from before and after the close-periastron encounter to discuss the possible causes of our results.

## 115.08 – Investigation of the Orbital Properties of Intermediate-Mass Eclipsing Binary Star Systems

*Sierra Obryan[1], Wes T. Ryle[1], Stephen Williams[2]*
*1. Thomas More College, Crestview Hills, KY, United States. 2. Georgia State University, Atlanta, GA, United States.*

This research examines the orbital properties of intermediate-mass eclipsing binary stars. A binary eclipsing star system consists of two stars which orbit their common center of mass and pass in front of one another from our point of view. Many intermediate-mass eclipsing binary systems have been identified from the All Sky Automated Survey. However, this survey fails to produce well resolved data on each individual eclipse. This study overcomes this issue with dedicated observations from small aperture telescopes. By measuring the brightness of the system during an eclipse, light curves for each system can be generated. This information can then be combined with spectroscopic data to determine important physical parameters of the system. In particular, a new data analysis software package will be used to find revised mass and radius estimates for these stars. Refined physical parameters are vital due to these stars being used as astronomical distance indicators and comparison standards. This study currently focuses on star systems BD +11 3569, TYC 5933-142-1, and V448 Mon.

## 115.09 – A New Eclipsing Binary Discovered in a Crowded Star Field

*Jessica A. Larson[1], Emily Ranquist[1], Andrew Hernandez[1], Emily Stoker[1], Clement Gaillard[1]*
*1. Pysics-Astronomy, Brigham Young University, Provo, UT, United States.*

Using the 0.9 meter telescope on West Mountain to follow-up possible transiting planets with ground based photometry, we discovered a previously unknown eclipsing binary system. This eclipsing binary is located in a crowded star field and so could not be reduced using photometry. In order to figure out which object in our field of view is the eclipsing binary, we learned how to use DAO phot. By using DAO phot we hope to be able to learn more about the individual stars that make up the binary system and their parameters.

## 115.1 – A Calibrated H-alpha Index to Monitor Emission Line Objects

*Eric G. Hintz[1], Michael D. Joner[1]*
*1. Brigham Young Univ., Provo, UT, United States.*

Over an 8 year period we have developed a calibrated H-alpha index, similar to the more traditional H-beta index, based on spectrophotometric observations (Joner & Hintz, 2013) from the DAO 1.2-m Telescope. While developing the calibration for this filter set we also obtained spectra of a number of emission line systems such as high mass x-ray binaries (HMXB), Be stars, and young stellar objects. From this work we find that the main sequence stars fill a very tight relation in the H-alpha/H-beta plane and that the emission line objects are easily detected. We will present the overall location of these emission line objects. We will also present the changes experiences by these objects over the course of the years of the project.

## 115.11 – Those Crafty Cepheids: Surprises From Ground-Based Photometry and HST-COS FUV Spectra

*Scott G. Engle[1], Edward F. Guinan[1], Hilding Neilson[2], Richard P. Wasatonic[1], Graham Harper[3]*
*1. Villanova Univ., Villanova, PA, United States. 2. East Tennessee State University, Johnson City, TN, United States. 3. Trinity College Dublin, Dublin, Ireland.*

Several years ago the Secret Lives of Cepheids (SLiC) program was initiated to look for unexpected or exotic behaviors from Cepheids. Regular photometric monitoring of Cepheids already possessing robust historical datasets was started to better understand long-term pulsation period changes, but to look for possible amplitude changes as well. At the time, only two “unusual” Cepheids were known to have undergone amplitude changes - Polaris and V473 Lyr. To date, however, the SLiC program has found evidence for amplitude changes in seven other Cepheids, raising the possibility that a 'Blazhko effect' could be at work in certain Cepheids, as exists in a subset of RR Lyr stars. As the program expanded, we found that previous International Ultraviolet Exporer (IUE) studies showed certain Cepheids to have UV emissions from warm-to-hot stellar atmospheres. On top of that, the emissions were variable and well-phased to the stellar pulsation period, indicating that the mechanism heating the Cepheid atmosphere was influenced by these pulsations, if not linked to them. With the installation of the Cosmic Origins Spectrograph (COS) onboard the Hubble Space Telescope (HST), a modern, high-quality UV spectrograph was now operating that could efficiently obtain high-resolution spectra of the Cepheids. We have been fortunate to observe four Cepheids to date with COS, and the results are well beyond anything IUE had led us to expect. Here we will present the current optical and UV results of the SLiC program, the implications of the results, and the future direction and expansion of the program. We gratefully acknowledge support for this program from HST grants HST-GO-11726.01-A, HST-GO-12302.01-A and HST-GO-13019.01-A, as well as NSF/RUI grant AST-1009903.

## 115.12 – Fourier Decomposition and Physical Parameters of the RR Lyrae Stars in the Globular Cluster NGC 4833

*Brian W. Murphy[1], Andrew N. Darragh[1]*
*1. Butler University, Indianapolis, IN, United States.*

We present a preliminary analysis of the RR Lyrae stars in the Globular Cluster NGC 4833. Images were obtained from January through June 2011 with the Southeastern Association for Research in Astronomy 0.6-meter telescope located at Cerro Tololo Interamerican Observatory. The image subtraction method of Alard & Lupton (1998) was used to both search for variable stars in the cluster and to produce light curves of each of the variables stars found. In total 17 RR Lyrae variables we found in our 10'X10' field of view, these included 10 variables of type RRab and 7 of type RRc. Using Fourier decomposition of the light curves of these variables we found the mean iron abundance to be [Fe/H]=-1.67+/-0.13. The mean absolute V-magnitude and log of effective temperature of the RRab variables were 0.65+/-0.07 and 3.8088+/-0.0045, respectively. For the RRc variables we found the mean absolute V-magnitude, log of the effective temperature, and helium abundance to be 0.67+/-0.03, 3.8560+/-0.0014, and 0.243+/-0.005, respectively. The cluster was also found to be of the Oosterhoff type II.

## 115.13 – Timescale Measures for Irregularly Sampled, Aperiodic Light Curves

*Krzysztof Findeisen[1], Lynne Hillenbrand[1]*
*1. Caltech, Pasadena, CA, United States.*

We present preliminary results of a project to determine the most robust methods for identifying the characteristic timescale(s) of an aperiodic signal given noise and uneven sampling. While periodograms have been a staple of the analysis of periodic signals for decades, the analogous situation for aperiodic signals involves a mixture of competing heuristic techniques. We present both theoretical and empirical characterizations of the accuracy, precision, and robustness of a variety of techniques, and outline recommendations for the most practical timescale measures.

## 115.14 – Measuring Gravitational Redshifts of White Dwarfs in Wide Binaries: Which Method is the Best?

*Trisha Mizusawa[1], Terry D. Oswalt[1], Jay B. Holberg[2], Jingkun Zhao[3]*
*1. Florida Institute of Technology, Melbourne, FL, United States. 2. Lunar and Planetary Laboratory, Tucson, AZ, United States. 3. National Astronomical Observatories, Beijing, China.*

We present a preliminary sample of gravitational redshift measurements for hydrogen-rich (DA) white dwarfs that have widely separated main sequence companions. In such wide pairs orbital velocities are negligible and the differences between the apparent radial velocities of components are essentially the gravitational redshifts of the white dwarfs. Published gravitational redshifts for many systems have been inconsistent over the years, probably because several methods have been used, yet a single method has not yet been demonstrated to be the most accurate. Here we report our efforts to determine the optimal method for measuring apparent radial velocities and gravitational redshifts of DA white dwarfs. Several different techniques for measuring the H? 6562 absorption line core were used to measure apparent radial velocities in both the white dwarfs and their main sequence companions. A template-matching algorithm was also used for the latter components where more lines are available. Comparisons of our gravitational redshifts obtained using each of the fitting routines and our recommendation for the best method will be presented. Funding from the National Science Foundation from grant AST-0807919 to Florida Institute of Technology, NSF grant AST-1008845 to the University of Arizona and NASA Astrophysics Data Program grant NNX1OAD76 to the University of Arizona are gratefully acknowledged. We also thank the allocation committees and support personnel of the Apache Point 3.5m, Cerro Tololo 4m, Kitt Peak 4m, MMT 6.5m and SOAR 4.2m telescopes for the observing time that supported this project.

# 116 – Stars, Stellar Evolution and Atmospheres, Circumstellar Disks

## 116.01 – Photometric Parallaxes and Subdwarf Identification for M Stars

*Dayna L. Thompson[1], Thomas H. Robertson[1], Sarah K. Thompson[1]*
*1. Ball State University, Muncie, IN, United States.*

Advances have been made in the detection of M dwarf stars over the last two decades giving more complete CMDs and therefore more accurate photometric parallaxes. Distance estimations that are obtained using these photometric parallaxes are essential when modeling the spatial distribution of stars in our Galaxy. This is especially important for M-type stars, as they make up more than half of the mass of the Milky Way. Photometric data on the Kron-Cousins photometric system have been obtained for new late K to middle M-type stars with known distances. These data have been used to obtain absolute red magnitudes, to construct a CMD, and to compute a polynomial function for disk dwarf stars in the color range 1.5 ? R-I < 2.0, which can be used to compute absolute red magnitudes to be used for photometric parallaxes. Subdwarf stars that lie close to the disk dwarf sequence have higher systematic velocities and proper motions than disk dwarf stars. This makes them key targets for the proper-motion surveys, and although approximately 99.7% of stars in the Milky Way make up the disk main sequence, statistically there will be more subdwarfs in the sample. Therefore, intermediate-band CaH observations have been obtained to distinguish subdwarf stars from disk dwarfs for 0.9 < R-I < 1.4.

## 116.02 – Identifying Subluminous M Stars Using Three Color Photometry

*Thomas H. Robertson[1], Sarah K. Thompson[1], Dayna L. Thompson[1]*
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Subdwarf stars are stars that appear below the main sequence in a color-magnitude diagram for the most common stars which make up the disk of our galaxy. The present criteria for identifying red subdwarfs vary based on the observational data. Typically, stars have been classified as subdwarfs if they were faint with high proper motions. It is also known that subdwarfs are metal poor and can be identified by visual inspection of their spectra as well. By examining a red star's relative TiO5 and CaH abundances in digital spectra, it can be classified as subdwarf. Such classification requires the acquisition and analysis of digital spectra which is very time consuming. This project attempted to determine if these stars can be objectively identified using three-color photometry. The three-color photometry compares broad band R and I colors and intermediate-band CaH observations. This photometry, developed at Ball State University, has been shown to be effective and efficient in luminosity classification (distinguishing between giant and dwarf stars) and in estimating distances to red dwarf stars. Observations of red dwarfs and subdwarfs made using the 0.9-m telescope of the Southeastern Association for Research in Astronomy (SARA) showed that stars in the color range 0.9 < R-I < 1.4 can be identified as subluminous using their position in the (R-CaH) – (R-I) two-color diagram. This information can be very helpful in identifying subdwarf stars in photometric surveys for red dwarf stars and in reducing systematic errors in their photometric parallaxes.

## 116.03 – Multithermal Analysis of Coronal Loops Using SDO-AIA Data

*Joan T. Schmelz[1], Sankaet Pathak[1]*
*1. Univ. of Memphis, Memphis, TN, United States.*

The Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory is designed to provide an unprecedented view of the solar corona. The six coronal filters peak at different temperatures and cover the entire active region temperature range, making AIA ideal for multi-thermal analysis. Temperature analysis relies on the instrument response functions, sensitivity of each filter with respect to temperature. These response functions are constructed by convolving the instrument effective areas with a synthetic coronal spectrum calculated at each relevant temperature. Each coronal spectrum relies on the data tabulated in the CHIANTI atomic physics database. Recent upgrades to CHIANTI have resulted in more complete calculations of the synthetic spectra in the AIA wavelength bands, especially near 94 and 131 angstroms. These advances have led to improved results for the Differential Emission Measure analysis of coronal loop cross-field temperatures calculated from AIA data. These improved results will be presented.

## 116.04 – The Young Solar Analogs Project: Initial Photometric Results

*Jon M. Saken[1], Richard O. Gray[2], Christopher J. Corbally[3]*
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Since 2007 we have been conducting spectroscopic monitoring of the Ca II H & K lines and G-band for a sample of 31 YSAs in order to better understand their activity cycles and variations, as well as the effects of young stars on their solar systems. The targets cover the spectral range of stars most likely to contain Earth analogs, F8-K2, and a broad enough range of ages, 0.3 Gyr - 1.5 Gyr, to investigate how activity level changes with stellar age. These studies are already showing possible evidence for activity cycles, large variations in starspot activity, and flaring events. In order to obtain a more complete picture of the nature of the stars' activity and examine the correlations between stellar brightness and chromospheric activity, we have started a complimentary campaign of photometric monitoring of these targets in Johnson B, V, and R, Stromgren v and H-alpha, with the use of a small robotic telescope dedicated to this project. This poster will present some results from the first year of photometric monitoring, focusing on the correlations between the photometric bands, and between the photometric and spectroscopic data, as well as an investigation of short-term (1-2 minutes) spectroscopic variations using data obtained earlier this year on the 1.8 m Vatican Advanced Technology Telescope (VATT).

## 116.05 – Upcoming Microlensing by Proxima Centauri: A Rare Opportunity for Mass Determination and Planet Detection

*Kailash C. Sahu[1], Howard E. Bond[1], Jay Anderson[1], Martin Dominik[2]*
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Proxima Centauri will pass close to two background stars in 2014 and 2016, with impact parameters of about 1.6 and 0.5 arc seconds. Because Proxima is so nearby, its angular Einstein ring radius is large (~28 milli arc sec) and will lead to detectable relativistic deflections of the images of the background stars even at those angular separations. Measurement of the astrometric shifts offers a unique opportunity for an accurate determination of the mass of Proxima. Although the background stars are >8.5 mag fainter than Proxima, the large contrast is mitigated by the relatively large separations at which the gravitational deflection is still detectable, and well within the capabilities of the Hubble Space Telescope. The upcoming events also offer the opportunity to detect and determine the masses of planetary companions, either through additional astrometric shifts, or in rare circumstances through a photometric microlensing event, leading to a brightening of the source star. These events would have durations of a few hours to several days.

## 116.06 – White Light Flares and Spots on an L1 Dwarf

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We report on more than one year of monitoring the nearby field L1 dwarf WISEP J190648.47+401106.8 with the Kepler mission. Supporting ground-based observations show that it is magnetically active with quiescent radio and H alpha emission. The rotation rate is 8.9 hours with a long-lived large surface feature, possibly a starspot or cloud. We report new constraints on the surface features from simultaneous spectroscopy and photometry. Short-cadence Kepler observations detect white light flares with estimated energy 10^31 ergs that occur at least once a month; the flare rise times are a few minutes and the most powerful last for hours. We discuss simultaneous Gemini spectroscopy of these flares that confirm white light and atomic emission lines. Despite the low effective temperature (~2300K) and size (<1 Jupiter radius) of this L dwarf, it has a flare rate comparable to the Sun.

## 116.07 – Stellar Rotation and the Chronology of the Galaxy

*Donald M. Terndrup[1]*
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The observed slow spindown of main-sequence stars in open clusters has led to the suggestion that stellar rotation can be used as a clock for determining the ages of cluster and field stars. In this paper, I analyze available cluster and field-star rotation periods and rotation rates (v sin i), along with well-calibrated evolutionary models incorporating angular momentum loss and core/surface mixing, to evaluate the accuracy of

gyrochronology under various illustrative cases. The presence of a range of rotation rates at any given mass in young and intermediate-age clusters sets strong limits on the accuracy of gyrochronology. Furthermore, magnitude-limited time-series photometric surveys will contain a variety of degeneracies and other confusions that require additional information, such as spectroscopic or asteroseismic determinations of gravity, in order to yield ages with sufficiently small errors to address unresolved issues in galactic structure and evolution.

## 116.08 – Luminous and Variable Stars in M31 and M33. I. The Warm Hypergiants and Post-Red Supergiant Evolution

*Roberta M. Humphreys[1], Kris Davidson[1], Skyler Grammer[1], John C. Martin[3], Kerstin Weis[2]*
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The progenitors of the Type IIP supernovae have an apparent upper mass limit of ~ 20 solar masses suggesting that the most massive red supergiants evolve to warmer temperatures before their terminal explosion. But very few post-red supergiants are known. We have identified a small group of luminous stars in M31 and M33 that are candidates for post-red supergiant evolution. These stars have A -- F-type supergiant absorption line spectra and strong hydrogen emission, hence the warm hypergiant name. Their spectra are also distinguished by the Ca II triplet and [Ca II] doublet in emission formed in a low density circumstellar environment. They all have significant near- and mid-infrared excess radiation due to free-free emission and thermal emission from dust. We discuss their wind parameters and mass loss rates which range from a few times 10^-6 to 10^-4 solar masses per year. On an HR Diagram, these stars will overlap the region of the LBVs at maximum light, however the warm hypergiants are not LBVs. Their winds are not optically thick and they have no significant variability. We suggest, howvwr, that the warm hypergiants may be the progenitors of the ``less luminous" LBVs such as R71 and even SN1987A.

## 116.09 – High Resolution Spectroscopy of Two Anomalous Groups in M67

*Courtney McGahee[1], Jeremy R. King[1], Constantine P. Deliyannis[2], Ryan M. Maderak[2]*
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We present results concerning two anomalous sub-groups of near-turnoff stars in M67, blue stragglers and bright subgiants. Observations were conducted using the WIYN 3.5 m telescope in conjunction with the HYDRA spectrograph at Kitt Peak National Observatory. We include a low precision radial velocity survey and the preliminary results of an abundance study which may lead to new insights into the evolution of such objects. Support for this was provided by NSF grant AST 09-08342.

## 116.1 – The Abundance of Fluorine in Open Cluster Giants

*Kristie A. Nault[1], Catherine A. Pilachowski[1]*
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We present the chemical abundance of fluorine in 11 red giant stars in three open clusters, NGC 752, M67, and the Hyades, as part of a larger study to investigate the chemical enrichment of fluorine in the galactic disk. This project utilizes data obtained at 2.3 microns with the Phoenix infrared spectrometer on the 2.1-m telescope at the Kitt Peak National Observatory, with a moderate resolution (R=50,000) and high signal-to-noise ratio (>100). While weak, the hydrogen fluoride feature is present in several of the stars; abundances and upper limits are derived using spectrum synthesis.

## 116.11 – The Massive Star Population in M101

*Skyler Grammer[1], Roberta M. Humphreys[1]*
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Evolved massive stars including luminous blue variables and hypergiants are the likely progenitor class of giant eruptions or supernova impostors (SN impostors). Motivated by the small number of progenitors positively associated with SN impostors, we present a survey of the massive star population in M101. Regions of massive star formation, ranging from 0.05 $kpc^2$ to 50 $kpc^2$, were identified using *GALEX* FUV and NUV imaging across the face of M101. The resolved stellar populations within each region were extracted from sixteen archival multicolor *HST* ACS WFC observations and color-magnitude-diagrams (CMD) were created. We have identified red supergiant (RSG) and blue supergiant (BSG) candidates using color and luminosity criteria. The RSG and BSG candidates identified represents the population of stars in M101 likely to be the SN impostor progenitor class. Furthermore we have determined the star formation histories (SFH) for the massive star populations within each region using two methods: CMD modeling, and spectral-energy-distribution fitting. We find that there has been a continuous buildup of massive stars over the last 100 Myr with a sharp increase in star formation rate within the last 20 Myr. Evidence for a decrease in mean stellar ages for regions with increasing radii has also been observed and is consistent with previously observed color gradients in optical and UV.

## 116.12 – Hubble Space Telescope IR Surface Brightness Fluctuation Color Measurements in the Virgo and Fornax Clusters

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We have measured infrared surface brightness fluctuations (SBF) in a sample of 16 elliptical, S0, and dwarf galaxies in the Virgo and Fornax clusters using the WFC3 IR channel on the Hubble Space Telescope. SBF measurements in the F110W and F160W filters were used to compute the fluctuation color, a distance-independent quantity that, when combined with stellar population models and optical SBF data from ACS, breaks the age-metallicity degeneracy and illuminates the star formation histories of these galaxies. We also present the F110W SBF absolute magnitude calibration as a function of optical (g-z) color, and compare the color dependence of that calibration to the F160W calibration that is commonly used for extragalactic distance measurements.

## 116.13 – Variability in Optical Spectra of ? Orionis

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We present the results of a time-series analysis of 130 échelle spectra of ? Ori (B0 Ia), acquired over seven observing seasons between 1998 and 2006 at Ritter Observatory. The equivalent widths of H? (net) and He I ?5876 were measured and radial velocities were obtained from the central absorption of He I ?5876. Temporal variance spectra (TVS) revealed significant wind variability in both H? and He I ?5876. The He I TVS have a double-peaked profile consistent with radial velocity oscillations. A periodicity search was carried out on the equivalent width and radial velocity data, as well as on wavelength-binned spectra. This analysis has revealed several periods in the variability with time scales of 2-7 d. Many of these periods exhibit sinusoidal modulation in the associated phase diagrams. Several of these periods were present in both H? and He I, indicating a possible connection between the wind and the photosphere. Due to the harmonic nature of these periods, stellar pulsations may be the origin of some of the observed variability. Periods on the order of the rotational period were also detected in the He I line in the 98-99 season and in both lines during the 04-05 season. These periods may indicate rotational modulation due to structure in the wind.

## 116.14 – Signatures of Rotational Modulation of Magnetic 'Active Regions' in Hybrid and Non-coronal Cool Giant Stars

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Observations of the variations in the fluxes, non-thermal broadening, and shifts of selected UV chromospheric emission lines provide a powerful diagnostic tool to characterize the total unsigned magnetic flux and its rotational modulation in cool giant stars, as well as the energy dissipation and momentum deposition in their atmospheres. We utilize a new empirical method, based on our 2.5D MHD model of Alfvén wave-driven winds from evolved stars, to detect and characterize the signatures of the rotational modulation of magnetic 'active regions' in two evolved giant stars, representative of both hybrid and non-coronal (K5 III) stars. Specifically, we derive the properties of chromospheric motions and heating rates at two or more epochs for each star. We use archival HST/GHRS and HST/STIS observations to address a fundamental question in the evolution of magnetic dynamos in late-type giant stars, namely: what is the inter-relationship between chromospheric turbulence, magnetic flux, and the wind properties in cool, evolved stars?

## 116.16 – Variable Circumstellar Disks of “Classical” Be Stars

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Circumstellar disks are common among many stars, all spectral types, and at different stages of their lifetimes. Among the near-main sequence “Classical” Be stars, there is growing evidence that these disks can form, dissipate, and reform, on timescales that are differ from case to case. We present data for a subset of cases where observations have been obtained throughout the different phases of the disk cycle. Using data

obtained with the SpeX instrument at the NASA IRTF, we examine the IR spectral line variability of these stars to better understand the timescales and the physical mechanisms involved. The primary focus in this study are the V/R variations that are observed in the sample. The second stage of our project is to examine a sample of star clusters known to contain Be stars, with the goal to develop a more statistically significant sample of variable circumstellar disk systems. With a robust multi-epoch study we can determine whether these Be stars exhibit disk-loss or disk-renewal phases. The larger sample will enable a better understanding of the prevalence of these disk events.

## 116.17 – Ultracool Dwarf Spectroscopic Templates, Bolometric Fluxes, and ? Factors

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We present new spectroscopic templates, bolometric corrections, and ? factors (the ratio of H? continuum flux to bolometric flux) for ultracool dwarfs. Using spectra from a combination of the Sloan Digital Sky Survey (SDSS) and the APO 3.5-m telescope, we have calculated spectroscopic templates for L0-L8 dwarfs. These templates can be used as spectroscopic standards in addition to radial velocity standards with a precision of 50 km/s. We also present bolometric fluxes for over a hundred late-M and L dwarfs based on a fit of BT-Settl models to photometry from SDSS, 2MASS and WISE. Bolometric corrections for the z and K band are included as a function of z-J and J-K color, respectively. We calculate a ? factor for late-M and L dwarfs from bolometric fluxes combined with measurements the continuum surrounding the H? region. The new ? factor is significantly larger than previous calculations, in part due to the updated models used to measure the bolometric fluxes. The ratio of L dwarf H? emission to bolometric flux is stronger than was previously thought.

# 117 – Young Stellar Objects, Star Formation, and Star Clusters

## 117.01 – Fundamental Parameters of Nearby Young Stars

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We present high resolution (R ~ 60,000) spectroscopic data of F and G members of the nearby, young associations AB Doradus and ? Pictoris obtained with the Cross-Dispersed Echelle Spectrograph on the 2.7 meter telescope at the McDonald Observatory. Effective temperatures, log(g), [Fe/H], and microturbulent velocities are first estimated using the TGVIT code, then finely tuned using MOOG. Equivalent width (EW) measurements were made using TAME alongside a self-produced IDL routine to constrain EW accuracy and improve computed fundamental parameters. MOOG is also used to derive the chemical abundance of several elements including Mn which is known to be over abundant in planet hosting stars. Vsin(i) are also computed using a ?2 analysis of our observed data to Atlas9 model atmospheres passed through the SPECTRUM spectral synthesis code on lines which do not depend strongly on surface gravity. Due to the limited number of Fe II lines which govern the surface gravity fit in both TGVIT and MOOG, we implement another ?2 analysis of strongly log(g) dependent lines to ensure the values are correct. Coupling the surface gravities and temperatures derived in this study with the luminosities found in the Tycho-2 catalog, we estimate masses for each star and compare these masses to several evolutionary models to begin the process of constraining pre-main sequence evolutionary models.

## 117.02 – Early Evolution of Rotating Star Clusters - Homogeneous Initial Conditions

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An increasing number of young star clusters are being observed to have significant internal rotation. In this respect, it is crucial to understand the role of angular momentum during the initial stages of star cluster dynamical evolution. Driven by these motivations, we explored the dynamics of the dissipationless collapse in the presence of non-vanishing initial angular momentum. We present here the preliminary results of an extended survey of N-body simulations, designed to investigate the early dynamical evolution of stellar systems with different amounts of total angular momentum, initially characterized by uniform density and solid body rotation. The structural and kinematical properties of the systems resulting from such 'violent relaxation' scenario will be described, with emphasis on the dynamical interplay between internal rotation and pressure support.

## 117.03 – Early Evolution of Rotating Star Clusters - Inhomogeneous Initial Conditions

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Recent spectroscopic observational studies have provided evidence that young massive star clusters can be characterized by a significant amount of internal rotation. Such evidence calls for renewed efforts in the investigation of the role of angular momentum in the formation and early stages of dynamical evolution of star clusters. We performed a survey of N-body simulations to follow the dynamics of the collapse of stellar systems with different initial values of total angular momentum and global virial ratio. We present here the preliminary results of simulations starting from initial conditions characterized by different degrees of departure from spatial homogeneity and approximate solid-body rotation. We describe the dynamical properties of the final equilibrium configurations, with particular attention to the effects of internal rotation on the dynamical evolution of the early substructures.

## 117.04 – The Mass of the Most Massive Star in Stellar Clusters Determined from 25 Million MASSCLEAN Monte Carlo Simulations

*Bogdan Popescu[1], Margaret M. Hanson[1], Jura Borissova[2], Radostin Kurtev[2], Valentin Ivanov[3], Soeren S. Larsen[4], Marcio Catelan[5], Dante Minniti[5], Philip Lucas[6]*
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Is there a maximum universal stellar mass, or might the maximum stellar mass in a cluster be tied to the mass of the associated cluster? Direct measurements of the maximum stellar mass of hundreds of young stellar clusters would help us to answer this fundamental question. However, such information does not presently exist. We are mindful that the most massive star in a stellar cluster can have a strong influence on the integrated magnitudes and colors of their host stellar cluster, especially clusters in the low-mass range. Thinking strategically, this color variation provides us with a mechanism for divulging the properties of that most massive star. We performed 25 million MASSCLEAN Monte Carlo simulations of stellar clusters in the 200-1000 M_Sun range in the U, B, and V bands. These simulations were then used to estimate the mass of the most massive star for 40 young, low-mass LMC clusters. In a similar way, the integrated colors and magnitudes in VISTA's Z, Y, J, H, and Ks bands can also be used to estimate the mass of the most massive star in VISTA-identified stellar clusters. Is the IMF for one hundred young 1000 solar mass clusters the same at the high end as ten young 10,000 solar mass clusters? Using the VISTA's clusters, we intend to answer the question, 'Does the lower mass of a stellar cluster artificially steepen the high-mass IMF?'.

## 117.05 – A Search for Variable Stars in Open Clusters: NGC 7654 and More

*Adam Pierce[1], Eric G. Hintz[1]*
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We will present results from an examination of the open cluster NGC 7654, and other clusters, that have been examined at both long cadence (single observation per night) and short cadence (many observations per night). Data were obtained from both the Tenagra 0.8-m telescope and the BYU David Derrick 0.4-m Telescope. Our primary objective was the discovery of short period variable stars and to see if we could recover the same stars at both cadence rates.

## 117.06 – Kinematics and Colors of Star Clusters in M101

*Lesley A. Simanton[1], Rupali Chandar[1], Bryan Miller[2]*
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Star formation is an ongoing process in the universe and one of the main drivers of change in galaxies. Most stars are born in clusters, and the properties of the cluster population of a galaxy can reveal information on the formation history of the galaxy itself. Here, we look at properties of the cluster population of the nearby, late-type spiral galaxy M101. We have identified a few thousand star clusters, including approximately 90 candidate ancient globular clusters (GCs), from multi-band Hubble Space Telescope images. We obtained follow-up low-resolution (R approximately 2000) optical spectroscopy from Gemini-GMOS for 43 total clusters, of which 18 are old GCs and 25 are young massive clusters (YMCs). Properties assessed include radial velocities (derived from spectra) and color distributions (derived from photometry). From the radial velocities, we find that GCs do not show evidence for rotation and have a much higher velocity dispersion than the YMCs, suggesting that the GCs are part of a stellar halo or thick disk in M101. We compare the color distributions to those in elliptical galaxies and other spirals such as our Milky Way.

## 117.07 – H-alpha/H-beta Index Measurements for Stars in Open Clusters

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We are building upon the work of Joner & Hintz (2013) and calibrating the H-alpha and H-beta indexes for a number of open clusters to provide a large sample of secondary standards. In the original work the indexes were determined from spectroscopic observations taken with the 1.2-m telescope of the Dominion Astrophysical Observatory. A number of these stars were members of open clusters. We used these primary standards to zero point photometric observations made with the BYU West Mountain Observatory 0.9-m telescope. We will report observations of NGC 884, NGC 869, NGC 188, NGC 752, M67, M36, M37, and M38.

## 117.08 – Identification of Faint Chandra X-ray Sources in the Core-Collapsed Globular Cluster NGC 6752

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We have searched for optical identifications for 39 Chandra X-ray sources that lie within the 1.9? half-mass radius of the nearby, core-collapsed globular cluster, NGC 6752,

using deep Hubble Space Telescope ACS/WFC imaging in H?, R, and B. Photometry of these images allows us to classify candidate counterparts based on color-magnitude diagram location. In addition to recovering 13 previously detected optical counterparts, we propose a number of new optical IDs. There are as many as 17 cataclysmic variables, a number of chromospherically active binaries, and one active galaxy. We will discuss the spatial distribution of these optical counterparts and the interpretation of the distributions based on simulations of the cluster dynamical evolution.

## 117.09 – Spatial Mixing of Multiple Stellar Populations in Globular Clusters

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We present here the results of a survey of N-body simulations aimed at exploring the long-term dynamical evolution of globular clusters with multiple stellar populations and the spatial mixing of first-generation (FG) and second-generation stars (SG). Our previous investigations on the formation and evolution of multiple population clusters suggested that SG stars formed from the ejecta of FG AGB stars are expected initially to be concentrated in the cluster inner regions. Our simulations show that until mixing is complete and the radial profile of the ratio of the number of SG/FG number ratio, NSG/NFG, is flat over the entire cluster, the radial profile of NSG/NFG is characterized by three regions: 1) a flat inner part; 2) a declining part in which FG stars are increasingly dominant; and 3) an outer region where the NSG /NFG profile flattens again (the NSG /NFG profile may rise slightly again in the outermost cluster regions). The distance from the cluster center at which the local value of NSG/NFG equals the global value of this number ratio is approximately between 1 and 2 cluster half-mass radii. We have studied the dependence of the mixing timescale on the SG initial concentration and our simulations suggest that in many Galactic globular clusters the SG should still be more spatially concentrated than the FG.

# 118 – Supernovae and Supernova Remnants

## 118.01 – Cosmology Biases in the Analysis of Future Supernova Surveys

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We present the results of a study of selection criteria to identify Type Ia supernovae photometrically in a simulated mixed sample of Type Ia supernovae and core collapse supernovae. The simulated sample is a mockup of the expected results of the Dark Energy Survey. The results of Gjergo et al. 2013 are presented, which studied the Dark Energy Task Force Figure of Merit (modified to include core collapse supernovae systematics) as a function of sample purity. The Figure of Merit is optimized at 98% purity. Additional selection criteria such as measured color-magnitude, fitted SALT2 SNIa x1 and color, and the photometric typing algorithm PSNID are then applied to significantly improve the expected SNIa statistics, while maintaining near 98% purity. However, it is not obvious that the quality of the additional supernovae gained in this analysis is high enough to be useful for cosmology. For example, we will demonstrate that the distance modulus of the excess supernovae can be biased.

## 118.02 – Comparison of Supernovae Data Sets with Modified Gravity and Dark Energy Models

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We compare three supernovae data sets with a variety of modified gravity and dark energy models. The supernovae data sets in this study are: (1) the current Union2.1 compilation; (2) a simulated sample from the Dark Energy Survey, whose final data set is expected within 6 years and will contain ~10 times more Type Ia supernovae than the Union2.1 compilation; and (3) a hypothetical sample of very high-precision supernovae going up to redshifts of 2.0, called for in the recent DOE/HEP Dark Energy Science Program report. The dark energy models include time-independent and time-dependent parametrizations. The modified gravity models, implemented in the CosmoMC and MGCAMB packages, include f(R) models and Chameleon models with Yukawa-like couplings to matter.

## 118.03 – Spectroscopy of Sloan Digital Sky Survey II Supernovae Host Galaxies

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We report the results of host galaxy spectra from supernovae (SNe) and other transient events from the Sloan Digital Sky Survey (SDSS-II). 3879 spectra were obtained serendipitously during SDSS and an additional 2693 host galaxy spectra were obtained with an ancillary project of the Baryon Oscillation Spectroscopic Survey (BOSS). The spectroscopic targets are found in Stripe 82 and represent the first systematic, unbiased, magnitude limited spectroscopic survey of SN host galaxies. We describe the target selection, the data, and the redshift distribution of the SN host galaxies. With these new galaxy redshifts, we report absolute magnitudes of the host galaxies and use the data to report the spectroscopic features of the sample including velocity dispersion, specific star formation, and photometric galaxy mass. We further reclassify the SN candidates using the photometric light curves using the spectroscopic redshift as a prior. Finally, we report efficiency and purity of the photometric SN Ia sample using different criteria on light curve quality and SALT2 parameters.

## 118.04 – The Detection of a Light Echo from Type Ia SN 2007af in NGC 5584

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We report the discovery of a light echo (LE) at t ~1000 days past maximum from the normal Type Ia supernova (SNe Ia) SN 2007af in the spiral galaxy NGC 5584. The presence of a LE is supported by photometric data and analysis of the images acquired during the Cepheid campaign using the Hubble Space Telescope (HST) Wide Field Camera 3 (Riess et al. 2011). The F350 and F555 images show a distinct ring-like structure with an additional central source. The images, taken months apart, show an evolution of the ring structure, which is consistent with a growing light echo in time. We find an angular radius of the outer echo to be ~0.29" – 0.36". Using the Cepheid distance to NGC 5584 of 24 Mpc, we find the dust illuminated by the light echo to be at a distance ~800 pc from the supernova. This rare discovery adds to the select few light echoes found in Type Ia SNe: SN 1572, SN 1991T, SN 1995E, SN 1998bu, and SN 2006X. Light echoes are powerful tools that probe the environment around supernovae, determine dust properties and characteristics, and could provide constraints on the progenitors, which are not fully understood for SN Ia.

## 118.05 – Late-2012 Photometry of SN 2009ip

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The object designated SN 2009ip was first noted in NGC 7259 in August 2009. There was evidence of photometric variability in the years preceding discovery and when it brightened again in July 2010 it was classified as a SN impostor. The latest pair of outbursts in July 2012 and September 2012 may have been a terminal SN explosion. We present V, Rc, and Ic-band photometry following the September 2012 event along with an analysis of periodic brightness fluctuations that were recorded during its decline in brightness.

## 118.06 – The Mid-Infrared and Optical Decay of SN 2011fe

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We measure the decay rate of the mid-IR luminosity from the type Ia supernova 2011fe, the brightest type Ia in decades. We observe 2011fe between six months and one year after explosion using Spitzer/IRAC observations. The fading in the 3.6 micron channel is 1.48+/-0.02 mag/100d, which is similar to that seen in blue optical bands. The supernova brightness fades at 0.78+/-0.02 mag/100d in the 4.5 micron channel which is close to that observed in the near-IR. We argue that the difference is a result of doubly ionized iron-peak elements dominating the bluer IRAC band while singly ionized species are controlling the longer wavelength channel. To test this, we use Large Binocular Telescope spectra taken during the same phases to show that doubly ionized emission lines do fade more slowly than their singly ionized cousins. We also find that [Co III] emission fades at more than twice the radioactive decay rate due to the combination of decreasing excitation in the nebula, recombination and cobalt decaying to iron. The nebular emission velocities of [Fe III] and [Co III] lines show a smaller blue-shift than emission from singly ionized atoms. The Si II velocity gradient near maximum light combined with our nebular velocity measurements suggest SN 2011fe was a typical member of the 'low velocity gradient' class of type Ia. Analyzing IRAC photometry from other supernovae we find that mid-IR color of type Ia events is correlated with the early light curve width and can be used as an indicator of the radioactive nickel yield.

## 118.07 – Polarization and the Evolution of Expansion Velocity in Type Ia Supernovae

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Spectropolarimetric observations of Type Ia supernovae (SNIa) have been increasing in an effort to explore the asymmetric outermost ejecta of these explosive objects. Low continuum polarization measurements with slightly higher detections across certain spectral lines point to approximately spherical photospheres with chemical enrichments in the overlying layers. As each SN's photosphere recedes through this clumpy ejecta, a spectral line displays a unique velocity gradient in time. Previous studies suggest a

SNIa's velocity gradient is well-correlated to the polarization of the Si II 6355Å line. However the gradient is derived at a time when the polarization of the SN is declining or at a minimum. We investigate the relationship between the expansion velocity's temporal evolution and the polarization of specific features at similar epochs of observations to determine the impact on this correlation.

## 118.08 – The Fundamental Metallicity Relation Reduces Type Ia Supernova Hubble Residuals More Than Host Mass Alone

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Type Ia supernova Hubble residuals have been shown to correlate with host galaxy mass, imposing a major obstacle for their use in measuring dark energy properties. Here, we calibrate the fundamental metallicity relation (FMR) of Mannucci et al. for host mass and star formation rates measured from broad-band colors alone. We apply the FMR to the large number of hosts from the SDSS-II sample of Gupta et al. and find that the scatter in the Hubble residuals is significantly reduced when compared with using only stellar mass (or the mass-metallicity relation) as a fit parameter. Our calibration of the FMR is restricted to only star-forming galaxies and in the Hubble residual calculation we include only hosts with log(SFR) > -2. Our results strongly suggest that metallicity is the underlying source of the correlation between Hubble residuals and host galaxy mass. Since the FMR is nearly constant between z = 2 and the present, use of the FMR along with light-curve width and color should provide a robust distance measurement method that minimizes systematic errors.

## 118.09 – 3-D Rendering of the Supernova Remnant 1E0102.2-7219 in the SMC

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Recent papers suggest that the young, oxygen-rich supernova remnant 1E 0102.2-7219 (E0102) in the Small Magellanic Cloud has an asymmetric bipolar structure. Using data from the Rutgers/CTIO Fabry-Pérot interferometer, we examine the kinematics and structure of this intriguing object in the light [O III]5007 emission. (Some aspects of these data were previously discussed by Eriksen et al. 2001.) The data cube consists of 72 isovelocity slices covering the complete velocity range of the optical emission and separated by 100 km/s with seeing limited spatial resolution. The data can be rendered by PINGsoft 2, an IDL Integral Field Spectroscopy Software package designed to visualize, analyze, and manipulate spectroscopy 3-D datasets. We examine the spatio-kinematic structure of E0102 and compare our conclusions to recent analyses by other investigators, such as Vogt & Dopita (2010).

## 118.1 – On the Hard X-ray Emission Detected from the Northwestern Rim of the Galactic Supernova Remnant G156.2+5.7

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The Galactic supernova remnant (SNR) G156.2+5.7 has been proposed to be a member of the class of Galactic SNRs that feature a significant hard component to their observed X-ray emission: prior X-ray observations have suggested that this X-ray emission is localized to the center and northwestern rim of this SNR. Recently, it has been argued that the observed hard X-ray emission detected from this SNR (specifically from the northwestern rim of the SNR) actually originates from a background cluster of galaxies seen in projection toward this rim. Therefore, it would appear that this SNR does not produce a significant amount of hard X-ray emission after all and its classification as a hard X-ray emitting SNR is misguided. To investigate the true nature of the observed X-ray emission, we have conducted a joint spectral analysis of ROSAT, ASCA and RXTE observations of this northwestern rim: we find an excess of hard X-ray emission beyond that expected from models for the emission from the background cluster and the diffuse X-ray background. We investigate whether this excess is produced by other background sources seen in the RXTE field of view or if the excess is produced by the SNR itself. Our spectral analysis and our initial results will be presented and discussed.

## 118.11 – UV and Optical Spectroscopy of SNR E0102 in the SMC

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We present a new ultraviolet spectrum and supporting optical spectra of the young supernova remnant 1E 0102.2-7219 (E0102) in the Small Magellanic Cloud, obtained with the Cosmic Origins Spectrograph aboard the Hubble Space Telescope and the R-C spectrograph mounted on the 4-m Blanco telescope at CTIO. E0102 is a member of the rare oxygen rich SNRs, with strong oxygen emission but lacking hydrogen and helium. The COS observation has yielded the highest signal-to-noise far-UV spectrum of this remnant, and displays strong UV lines in O, C and possibly Si. The optical spectra also show strong O emission over a large ionization range, including the O I recombination lines at 7774A, 8446A, and 9263A, along with Ne and faint S emission in our blue and red spectra, respectively.

# 119 – Cosmology and Associated Topics

## 119.01 – Precision Cosmology with a New Probabilistic Photometric Redshifts Approach

*Matias Carrasco Kind[1], Robert J. Brunner[1]*
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A complete understanding of both dark energy and dark matter remains one of most important challenges in astrophysics today. Recent theoretical and numerical computations have made important progress in quantifying the role of these dark components on the formation and evolution of galaxies through cosmic time, but observational verification of these predictions and the development of new, more stringent constraints has not kept pace. It is in this context that, photometric redshifts have become more important with the growth of large imaging surveys, such as DES and LSST, that have been designed to address this issue. But their basic implementation has not changed significantly from their original development, as most techniques provide a single photometric redshift estimate and an associated error for the an extragalactic source. In this work, we present a unique and powerful solution that leverages the full information contained in the photometric data to address this cosmological challenge with a new approach that provides accurate photometric redshift probability density functions (PDF) for galaxies. This new approach, which scales efficiently to massive data, efficiently combines standard template fitting techniques with powerful machine learning methods. Included in this framework is our recently developed technique entitled Trees for PhotoZ (TPZ); a new, robust, parallel photometric redshift code that uses prediction trees and random forests to generate photo-z PDFs in a reliable and fast manner. In addition, our approach also provides ancillary information about the internal structure of the data, including the relative importance of variables used during the redshift estimation, an identification of areas in the training sample that provide poor predictions, and an accurate outlier rejection method. We will also present current results of this approach on a variety of datasets and discuss, by using specific examples, how the full photo-z PDF can be incorporated into galaxy clustering analysis enhancing the cosmological measurements, such as the angular power spectrum or the galaxy redshift distribution, to accelerate the cosmological discovery process and improve our knowledge of the Universe.

## 119.02 – Diagnostic Tests for Systematic Effects on Large Scale Structure

*Yiran Wang[1], Robert J. Brunner[1]*
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With the growth in current and future large photometric surveys, the quantification and mitigation of systematic effects that might bias clustering measurements has become more acute than ever. Therefore, we present specific diagnostic tests that we developed and tested on the SDSS DR7. Specifically, we present results that quantify, in a consistent manner, the effects due to variations in seeing, Galactic extinction, and stellar contamination. Our approach is based on pixelizing the data, in a similar manner to Scranton et l (2002), below the physical scale of the different systematics and comparing the cross-correlation of a specific systematic with the target population to identify the optimal systematic cut to minimize the effect on the desired signal. In our analysis, we found that by using HEALPix, we recovered a less biased measurement than by using SDSSPix, but SDSSPix was optimal in recovering the density variation within a stripe due to its consistency with the survey geometry.

## 119.03 – The Evolution of the Distribution of Enriched Material in Large Scale Structure from z=3 to z=0

*Ali Snedden[1], Lara A. Phillips[1], Grant J. Mathews[1], Jared Coughlin[1], Aparna Bhattacharya[1], In-Saeng Suh[1]*
*1. University of Notre Dame, Notre Dame, IN, United States.*

The local cosmic environment influences the formation and evolution of galaxies. This environment is composed of many galaxies, immersed in an intricate web of dark matter, forming extensive clusters and filaments with vast voids between them. A history of this evolution is preserved as a relic in intergalactic medium (IGM) permeating this structure. Using a computer vision algorithm, adapted to identify clusters, filaments and voids, we characterize the large-scale structure and its constituent galaxies in our GADGET-2 simulations. Once these regions of interest are identified, all the constituent gas and dark matter particles forming this structure are traced back in redshift. The selected region of interest is then re-run at higher resolution. With metal cooling and feedback enabled, we follow the evolution of the member galaxies and the enrichment of the structures as a function of redshift.

## 119.04 – The Metallicity Distribution of the Circumgalactic Medium Traced by Optically-Thick Lyman Limit Systems

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The circumgalactic medium (CGM) of galaxies is the interface between galaxies and the intergalactic medium (IGM). In this region, the flows that drive galaxy evolution – outflows from galaxies and infall from the IGM – collide (perhaps quite literally). The metallicity distribution of gas in the cool (T ~ few x 10^4 K) CGM can shed light on the balance of infalling and outflowing material about galaxies. Because of the typical densities and sizes involved, many of the flows in the CGM have H I column densities typical of Lyman limit systems (LLSs). The sample collected by Lehner et al. (2013) were dominated by optically thin LLSs [16 < log N(HI) < 17.2], and were shown to have a bimodal metallicity distribution with low- and high-metallicity branches centered at ~3% and 40% of the solar metallicity. We present a survey of the metallicity in a sample of 0.25 < z < 1 LLSs selected on the basis of their Lyman break optical depth from a snapshot survey with the Cosmic Origins Spectrograph (COS) on board HST. We combine the H I column densities of these systems with ground-based measurements of Mg II strength from LBT/MODS, Magellan/MagE, and Keck/HIRES observations. We use these observations to assess what fraction of optically-thick LLSs [log N(HI)>17.2] are metal poor, comparing it with the Lehner et al. results and the unimodal distribution of damped Lyman-alpha abundances at these redshifts. We comment on the implications of our measurements for understanding the cold-mode accretion phenomenon.

## 119.05 – Coasting Universe From z=50 till Now

*David F. Bartlett[1], John P. Cumalat[1]*
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For some time we have been finding evidence in the local universe that both Newtonian gravity and Maxwellian electromagnetism need modification: specifically a massive photon ($mc^2=10^{-25}$ eV) and a graviton of the same, but imaginary mass. The non-relativistic equations for gravity and electricity share a common factor, $k_o$=2?m /h c=400 pc: $?^2$ ?+ $k_o^2$? = 4 ? G ?; ?=-GMCos[$k_o$R]/R $?^2$ ?- $k_o^2$? =- 4 ? ?; ?=-QExp-[$k_o$R]/R We have proposed a relation between 400 pc and the structure in clusters of galaxies at about 128 $h^{-1}$ Mpc as observed by Broadhurst(1990) and in red galaxies by Ryabinkov, Kaurov, and Kamaniker(2012). What was 400 pc at a lookback z of $10^{5.63}$ is 170 Mpc now, . Further at a z= $10^{5.63}$, the energy stored in baryons is the same as that stored in gravity: $?_m$= $?_g$=(1/2) ?$?_m$=k $_o^2$/2?G.(Here we use natural units c=h-bar=1). Additionally this energy density is 8 $R_?^4$, where $R_?$= 13.6 eV. We now propose that this triple numerical coincidence indicates a cosmological reality. Structure really begins to form at this early time. We suggest a universe that has been retarded by a massive photon (a(t) ? $t^{1/2}$) from the time of nucleosynthesis till z=50 when the first stars form. Since then, it has been coasting (a ? t). We will show how this cosmology helps explain the association that Verschuur has found between WMAP peaks and HI maxima and minima. References to our previous work may be found at http://www-hep.colorado.edu/Cosinusoidal/ and in the article, 'Analogies between electricity and gravity', Metrologia 41 (2004) S115-S124.

## 119.06 – Early Results from the First Year of Observations by the Atacama B-mode Search (ABS)

*Sara M. Simon[1]*
*1. Princeton University, Princeton, NJ, United States.*
*Contributing teams: ABS Collaboration*

The Atacama B-mode Search (ABS) instrument, which began observation in February of 2012, is a crossed-Dragone telescope located at an elevation of 5100 m in the Atacama Desert in Chile. The primary scientific goal of ABS is to measure the B-mode polarization spectrum of the Cosmic Microwave Background (CMB) from multipole moments of about l=50 to l=500, a range that includes the primordial B-mode peak. Unlike most current polarization experiments, ABS features a cryogenic telescope and a warm half-wave plate used to modulate the polarization of the incoming light. The ABS focal plane array consists of 240 pixels designed for observation at 150 GHz by the TRUCE collaboration. Each pixel has its own individual, single-moded feedhorn and contains two transition-edge sensor (TES) bolometers sensitive to orthogonal polarizations. The detectors are read out using time domain multiplexing so that the thermal loading of the readout electronics does not heat the focal plane. I will present early results from the first year of ABS data.

## 119.07 – The E and B EXperiment EBEX

*Kyle Helson[1], Asad M. Aboobaker[2], Peter Ade[3], Francois Aubin[4], Carlo Baccigalupi[5], Kevin Bandura[4], Chaoyun Bao[2], Julian Borrill[6], Bikramjit Chandra[2], Daniel Chapman[7], Joy Didier[7], Matt*

*Dobbs[4], Ben Gold[2], Julien Grain[8], Will Grainger[3], Shaul Hanany[2], Seth N. Hillbrand[7], Gene Hilton[9], Hannes Hubmayr[9], Kent Irwin[9], Bradley Johnson[7], Andrew Jaffe[10], Terry J. Jones[2], Theodore Kisner[6], Jeffrey Klein[2], Andrei Korotkov[1], Samuel Leach[5], Adrian T. Lee[11], Lorne Levinson[12], Michele Limon[7], Kevin MacDermid[4], Amber D. Miller[7], Michael Milligan[2], Enzo Pascale[3], Cong-Xin Qiu[2], Kate Raach[2], Britt Reichborn-Kjennerud[7], Carl Reintsema[9], Ilan Sagiv[12], Graeme Smecher[4], Radek Stompor[13], Matthieu Tristram[14], Gregory S. Tucker[1], Benjamin Westbrook[11], Amit P. Yadav[15], Matias Zaldarriaga[15], Kyle Zilic[2]*

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We report on the status of EBEX, a NASA-funded balloon-borne polarimeter designed to measure the polarization of the Cosmic Microwave Background radiation. The instrument employs a 1.5 meter Gregorian-type telescope with three bands centered on 150, 250, and 410 GHz with 8' resolution. A fixed polarizing grid and a rotating achromatic half wave plate on a superconducting magnetic bearing make each individual detector a polarimeter. The two polarizations are distributed to separate focal planes, totaling over 1000 transition edge sensor bolometers. EBEX was launched from the Antarctic in December 2012 on a 12-day long-duration balloon flight. Flight hard disks and other elements of the payload were recovered in January 2013 and analysis is in progress.

## 119.08 – A Search for Dark Matter Annihilation from Dwarf Galaxies using VERITAS

*Ben Zitzer[1]*

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Current cosmological models and data suggest the existence of a Cold Dark Matter (DM) component, however the nature of DM particles remains unknown. A favored candidate for DM is a Weakly Interacting Massive Particle (WIMP) in the mass range of 50 GeV to greater than 10 TeV. Nearby dwarf spheroidal galaxies (Dsph) are expected to contain a high density of Dark Matter with a low gamma-ray background, and are thus promising targets for the detection of secondary gamma rays at very high energies (VHE, $E > 0.1$ TeV) through the annihilation of WIMPs into standard model particles. The VERITAS array of Cherenkov Telescopes, sensitive to gamma rays in the 100GeV to 10 TeV range, carries out an extensive observation program of Dsphs. Presented here are results of the observations and new statistical techniques for constraining the dark matter physics from these objects.

## 119.09 – Deep Images of a 2 deg Large Quasar Group Field

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Large quasar groups (LQGs) comprise structures on the 100-200 Mpc scale at redshifts $z>0.8$. Constraining their matter content is vital if we are to interpret them as structure markers, which requires deep, wide field images as a first step. We present a deep (AB~24) multi-band imaging survey of UV and optical data covering 2 square degrees toward the Clowes-Campusano LQG field which contains structures at $z\sim0.8$ and $z\sim1.4$, and preliminary results.

# 120 – Astronomy Education & Public Outreach

## 120.01 – EduBites: Cliffs Notes for EPO

*Carolyn Brinkworth[1], Lindsay Bartolone[2], Mathew Wenger[3], Ann Martin[4], Michelle Nichols-Yehling[2], Jacob Llamas[1], Robert L. Hurt[1], Gordon K. Squires[1]*

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We present a new resource for the astronomy education community, with the goal of improving our community's knowledge and understanding of the educational research papers pertinent to our work. When launched, EduBites will be a searchable database of summaries of peer-reviewed education papers, written by astronomy educators and posted for the entire community to use. While we are all aware that we should be basing our E/PO work on a solid research foundation, many people in the community are pushed for time when it comes to staying on top of the educational literature. EduBites aims to reduce that workload for the benefit of the entire community. Our database will ultimately tackle papers across the whole of the astronomy education spectrum, including formal and informal education, outreach, grades K-16, pedagogy, evaluation, and many other topics. We are keen to hear from anyone on the community who would be interested in joining our review team, and will welcome feedback on the EduBites user experience. EduBites is still currently under development but, when launched, it will be found at edubites.ipac.caltech.edu

## 120.02 – An Update on the AAS Astronomy Ambassadors Program

*Richard T. Fienberg[1], Suzanne Gurton[2], Andrew Fraknoi[3], Edward E. Prather[4], Anna Hurst[2], Dennis L. Schatz[5]*

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The American Astronomical Society, partnering with organizations active in science education and public outreach (EPO), has launched a series of professional-development workshops and a community of practice designed to help improve early-career astronomers' ability to effectively communicate with students and the public. Called Astronomy Ambassadors, the program provides mentoring and training experiences for young astronomers, from advanced undergraduates to beginning faculty; it also provides access to resources and a network of contacts within the astronomy EPO community. By learning how to implement effective education and outreach strategies, Astronomy Ambassadors become better teachers, better presenters at meetings, and better representatives of our science to the public and to government. And because young astronomers are a more diverse group than those who currently do the majority of outreach, they help the astronomical community present a more multicultural and gender-balanced face to the public, enabling members of underserved groups to see themselves as scientists. Ambassadors are provided with a large library of outreach activities and materials that are suitable for a range of venues and audiences and that will grow with time. For much of this library we are using resources developed by organizations such as the Astronomical Society of the Pacific, the Pacific Science Center, and the Center for Astronomy Education for other outreach programs, though some resources have been created by one of us (AF) specifically for this program. The first Astronomy Ambassadors workshop was held at the 221st meeting of the AAS in January 2013 and served 30 young astronomers chosen from more than 75 applicants. Incorporating feedback from workshop participants and lessons learned from the reports they've submitted after conducting their own outreach events, we are now planning the second annual workshop to be held 4-5 January 2014 at the 223rd AAS meeting in National Harbor, Maryland.

## 120.03 – Partnerships: The Key to Sustainability and Reach for E/PO

*Bonnie Eisenhamer[1], Dan McCallister[1], Holly Ryer[1]*

*1. STScI, Baltimore, MD, United States.*

The Space Telescope Science Institute (STScI) is the home institution for the E/PO activities of the Hubble and future James Webb space telescopes. Over time, STScI's Office of Public Outreach has established the infrastructure needed for an E/PO program that reaches various audiences at the local, regional, and national levels. Partnerships are a critical element of this infrastructure, and sustainability of our E/PO program is ensured through our ongoing partnerships with organizations and institutions with staying power and reach. We have learned from past efforts that strategic partnerships can foster innovation, support diversity initiatives, and increase impact in a cost-effective way while providing target audiences with greater access to NASA SMD science and resources. Partnerships are utilized to field-test educational products and programs, disseminate materials and initiatives, and support professional development activities. Partners are selected based upon specific criteria such as potential for reach, the percentage of underrepresented educators and students served, complementary program goals, and willingness to collect and share evaluation data and results with us. This poster will highlight examples and benefits of strategic partnerships over time.

## 120.04 – Out in Space: A True Musical Collaboration Between an Astronomer and a Music Producer

*James R. Webb[1], Keith Morrison[2]*

*1. Florida International Univ., Miami, FL, United States. 2. Kokopelli Studios, Homestead, FL, United States.*

The collaboration between a professional astronomer who is also an amateur musician and songwriter, and an accomplished musician/music producer to produce a CD of astronomy music that not only carries messages of intellectual value, but is also musically compelling is very rare. The authors have formed such a collaboration. Dr. Webb (professor, astronomer, observatory director, and musician) took his original astronomy songs to Keith Morrison (music producer, audio engineer, arranger, studio owner) and together they reworked the original astronomy songs to form a unique musical experience, blending ideas, science, philosophy, guitars, and rhythms that covers many genres of music. This music is intended for public consumption by distribution to science centers, planetariums, the internet and through more traditional channels. The details of the recording, uses for teaching, and the outreach potential are examined in this paper.

## 120.06 – New Observatory Outreach Programs for Students in Grades 3-12

*Bhasker K. Moorthy[1], Joe Kabbes[1], Kelly A. Page[1], Kevin Cole[1]*

*1. William Rainey Harper College, Palatine, IL, United States.*

The Henize Observatory at Harper College, a community college in suburban Chicago, has conducted biweekly public viewing sessions from March to November for over ten years. Recently, we developed two complementary public education programs for primary and secondary school students. The Cosmic Explorers program allows students in Grades 3-6 to observe and identify night sky objects and receive small rewards for completing four "seasons" of observing in their Night Sky Passport. The Henize Docent program gives students in Grades 7-12 the opportunity to assist with observatory operations, including the Cosmic Explorers program, and learn about astronomy and nature interpretation methods. Together, these two programs have rejuvenated our public viewing sessions and generated a real excitement in the community. The success of these programs has presented new challenges for the observatory. Innovative solutions for crowd control and expanded training for volunteer staff were necessary to support the increased visitor load. Students in the docent program have been highly motivated and require training and challenges to keep them engaged. One unexpected benefit was increased interest in Harper College's Astronomy Club as students, particularly those in education, participate in these informal education opportunities. Both programs can be adapted to any venue with night time observing and access to telescopes. We will discuss the programs, their costs, program materials and marketing, challenges and solutions, and future plans. This work is supported by a Harper College Resource for Excellence Grant.

## 120.07 – Celebrating Ten Years of Progress at The Bank of Kentucky Observatory of Thomas More College

*Wes T. Ryle[1]*

*1. Thomas More College, Crestview Hills, KY, United States.*

The Bank of Kentucky Observatory at Thomas More College is celebrating its tenth year of operation. Despite being a modest facility with small aperture telescopes, the observatory is a very active through classroom instruction, student research, and public outreach. We present a synopsis of recent activity over the past five years, including undergraduate research on active galactic nuclei, eclipsing binaries, and proper motion, a glimpse at how the observatory plays a role in student laboratories, and a discussion of a public outreach program that is currently hosting more than 1,000 attendees per year. We also present future goals for the observatory, including increased collaboration with other facilities in the region.

## 120.08 – Evaluating Middle School Students' Spatial-scientific Performance in Earth-space Science

*Jennifer Wilhelm[1], Christa Jackson[1], Michael D. Toland[1], Merryn Cole[1], Ronald J. Wilhelm[1]*

*1. University of Kentucky, Lexington, KY, United States.*

Many astronomical concepts cannot be understood without a developed understanding

of four spatial-mathematics domains defined as follows: a) Geometric Spatial Visualization (GSV) - Visualizing the geometric features of a system as it appears above, below, and within the system's plane; b) Spatial Projection (SP) - Projecting to a different location and visualizing from that global perspective; c) Cardinal Directions (CD) - Distinguishing directions (N, S, E, W) in order to document an object's vector position in space; and d) Periodic Patterns - (PP) Recognizing occurrences at regular intervals of time and/or space. For this study, differences were examined between groups of sixth grade students' spatial-scientific development pre/post implementation of an Earth/Space unit. Treatment teachers employed a NASA-based curriculum (Realistic Explorations in Astronomical Learning), while control teachers implemented their regular Earth/Space units. A 2-level hierarchical linear model was used to evaluate student performance on the Lunar Phases Concept Inventory (LPCI) and four spatial-mathematics domains, while controlling for two variables (gender and ethnicity) at the student level and one variable (teaching experience) at the teacher level. Overall LPCI results show pre-test scores predicted post-test scores, boys performed better than girls, and Whites performed better than non-Whites. We also compared experimental and control groups' by spatial-mathematics domain outcomes. For GSV, it was found that boys, in general, tended to have higher GSV post-scores. For domains CD and SP, no statistically significant differences were observed. PP results show Whites performed better than non-Whites. Also for PP, a significant cross-level interaction term (gender-treatment) was observed, which means differences in control and experimental groups are dependent on students' gender. These findings can be interpreted as: (a) the experimental girls scored higher than the control girls and/or (b) the control group displayed a gender gap in favor of boys while no gender gap was displayed within the experimental group.

## 120.09 – Exploring the Relationships Between Student Moon Observations and Spatial-Science Reasoning

*Merryn Cole[1], Jennifer Wilhelm[1], Christa Jackson[1], Hongwei Yang[1], Ronald J. Wilhelm[1]*
*1. STEM Education, University of Kentucky, Lexington, KY, United States.*

Relationships between student moon observation journaling and sixth-grade students' spatial-scientific reasoning after implementation of an Earth/Space unit were examined. Teachers followed the NASA-based REAL (Realistic Explorations in Astronomical Learning) curriculum. As part of this curriculum, students kept daily moon observation journals for 5 weeks, recording position and appearance of the moon as well as noting patterns. An extensive search was conducted in both the multilevel model (Hierarchical Linear Modeling) space and the single level model space. The final model identified for this data set is a single level linear model. The model shows that students performing better on moon observation journals, both in terms of overall score and number of entries, score higher on LPCI (Lunar Phases Concept Inventory) post-tests. For every 1 point increase in the overall moon journal score, participants are expected to score 0.18 points or nearly 1% point higher on the LPCI post-test when holding constant the effects of the other two predictors, LPCI pre-test score and number of moon journal entries. An examination of the quality of moon journal entries demonstrates that students who put more time and effort into their moon journals notice more patterns in the appearance (percentage of illumination) and location of the moon in the sky. These patterns additionally relate to their development of spatial skills as they are describing the apparently changing location of celestial objects in relation to their single position on Earth. This study is unique in the purposeful link created between student moon observations and spatial skills. The use of moon journals distinguishes this study further by fostering scientific observation along with skills from across STEM fields and other disciplines. We believe that future work will show a strong link between these improved spatial skills and performance in mathematics and science.

## 120.1 – CosmoQuest Year 1.5: Citizen Scientist Behaviors and Site Usage Across Multiple Projects

*Nicole E. Gugliucci[1], Pamela L. Gay[1], Georgia Bracey[1]*
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*Contributing teams: CosmoQuest Team*

CosmoQuest launched as a citizen science portal in January 2012 and has since expanded to include three projects in planetary surface mapping, one completed project searching for KBOs, and several more on the way with various astrophysical science goals. We take a close look at how our users move through the site, how much time they spend on various tasks, project retention rate, and how many use multiple projects on the site. We are also piloting a citizen science motivation survey given to random site users to find out why citizen scientists join new projects and continue to participate. This is part of a larger project using online and real-life interactions to study citizen scientist behaviors, motivations, and learning with a goal of building better community with researchers, volunteers, educators, and developers.

## 120.11 – SkyGlowNet as a Vehicle for STEM Education

*K. M. Flurchick[1], Eric R. Craine[3, 4], Roger B. Culver[2, 4], Shanel Deal[1], Christopher Foster[1]*
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SkyGlowNet is an emerging network of internet-enabled sky brightness meters (iSBM) that continuously record and log sky brightness at the zenith of each network node site. Also logged are time and weather information. These data are polled at a user-defined frequency, typically about every 45 seconds. The data are uploaded to the SkyGlowNet website, initially to a proprietary area where the data for each institution are embargoed for one or two semesters as students conduct research projects with their data. When released from embargo, the data are moved to another area where they can be accessed by all SkyGlowNet participants. Some of the data are periodically released to a public area on the website. In this presentation we describe the data formats and provide examples of both data content and the structure of the website. Early data from two nodes in the SkyGlowNet have been characterized, both quantitatively and qualitatively, by undergraduate students at NCAT. A summary of their work is presented here. These analyses are of utility in helping those new to looking at these data to understand how to interpret them. In particular, we demonstrate differences between effects on light at night and sky brightness due to astronomical cycles, atmospheric phenomena, and artificial lighting. Quantitative characterization of the data includes statistical analyses of parsed segments of the temporal data stream. An attempt is made to relate statistical metrics to specific types of phenomena.

## 120.12 – What Non-science Majors Gain from Participating in Authentic Scientific Research: The Results from a Decade-long Assessment Program

*Michelle Wooten[1], Travis A. Rector[1], Andrew W. Puckett[1], Kimberly A. Coble[2]*
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The results of pre- post- analysis of students' responses to assessments based on their participation in 'Research-Based Science Education' (RBSE) curriculum will be presented. Students participating in RBSE curriculum are non-science majors who participate in authentic scientific research as part of laboratory instruction. The results of this study comprise students' responses from four universities from 2003 - 2013. To gauge changes in students' perception of the process of scientific research and their confidence in their skills in performing science-oriented tasks, a variety of assessments were used: concept maps (n=130), attitudinal surveys (n=130), journal responses (n =50), and interviews (n=17). Analyses of matching pre- post- responses reveal significant gains in some predicted forms, but not in others. Possible reasons for students' changes in response, or lack thereof, will be discussed.

## 120.13 – Mars: A Freshmen Year Seminar of Science and Science-fiction

*Michael Svec[1], David A. Moffett[1], Michael Winiski[1]*
*1. Education, Furman University, Greenville, SC, United States.*

'Mars: On the shoulder of giants' is a freshmen year seminar developed collaboratively between the physics, education, and center for teaching and learning. This course focuses on how scientific knowledge is developed through the lens of our changing view of Mars throughout history. Analyses of current studies of Mars are juxtaposed against historical understanding and perceptions of the planet found in scientific and popular literature of the day, as well as the movies. Kim Stanley Robinson's 'Red Mars' provides a unifying story throughout the course complimented by Fredrick Taylor's 'The Scientific Exploration of Mars' and Hartmann's 'A Traveler's Guide to Mars.' Based on the three-years of experience, the authors advocate the use of the speculative science-fiction novel and argue for its use in high school and undergraduate courses including those for science majors. Many of the students who selected this seminar went on to major in science and in subsequent interviews discussed the influence of science fiction on their decision to major in science. Science fiction provided story, science, and speculation that became a rich medium for critical-thinking skills and critical literacy. Student reflections indicated that science fiction served as a reminder of why they study science, a source for imagination, and exploration of science as a human endeavor. Based on this experience, we propose five elements for selecting science-fiction for inclusion in science classes: 1) Provides a deep description of the science content or technologies, 2) Describes science and technologies are plausible or accurate to the time period, 3) Contains a novum or plausible innovation that plays a key element in the speculation, 4) Exploration of the impact on society or humanity, and, 5) Shows science and technology as human endeavors.

## 120.14 – An Experiment with Open-Source Introduction to Astronomy

*Geoffrey S. Burks[1]*
*1. Tennessee State Univ., Nashville, TN, United States.*

The cost of higher education is going up at the same time that federal support for higher education is going down. The cost of buying text books is becoming a major hardship at

schools who have a large number of students from non-privileged backgrounds. In an attempt to reach more students, we are starting a project to provide freely downloadable texts and labs using the a modified wiki model. The content will be primarily submitted by users of the texts. Proposed content will be submitted to an editor, and chapters will be peer reviewed.

## 120.15 – TeachAstronomy.com - Digitizing Astronomy Resources

*Kevin Hardegree-Ullman[1, 2], Chris D. Impey[2], Carmen Austin[2], Anand Patikkal[2], Mithun Paul[2], Naresh Ganesan[2]*
*1. University of Toledo, Toledo, OH, United States. 2. University of Arizona, Tucson, AZ, United States.*

Teach Astronomy—a new, free online resource—can be used as a teaching tool in non-science major introductory college level astronomy courses, and as a reference guide for casual learners and hobbyists. Digital content available on Teach Astronomy includes: a comprehensive introductory astronomy textbook by Chris Impey, Wikipedia astronomy articles, images from Astronomy Picture of the Day archives and (new) AstroPix database, two to three minute topical video clips by Chris Impey, podcasts from 365 Days of Astronomy archives, and an RSS feed of astronomy news from Science Daily. Teach Astronomy features an original technology called the Wikimap to cluster, display, and navigate site search results. Development of Teach Astronomy was motivated by steep increases in textbook prices, the rapid adoption of digital resources by students and the public, and the modern capabilities of digital technology. This past spring semester Teach Astronomy was used as content supplement to lectures in a massive, open, online course (MOOC) taught by Chris Impey. Usage of Teach Astronomy has been steadily growing since its initial release in August of 2012. The site has users in all corners of the country and is being used as a primary teaching tool in at least four states.

## 120.16 – First Steps Toward Exploring NITARP's Impacts on Teachers' Knowledge, Attitudes, and Teaching

*Debbie French[1, 2], Timothy F. Slater[1], Andrea C. Burrows [1]*
*1. University of Wyoming and CAPER Center for Astronomy & Physics Education Research, Laramie, WA, United States. 2. New Philadelphia City Schools, New Philadelphia, OH, United States.*

Few high school science teachers have had opportunities to engage in authentic scientific research. As a result, many may find it difficult to communicate to their students how science is done. Moreover, without relevant experience, teachers have few pathways to be able to successfully implement scientific research and inquiry into the classroom. In response, astronomers created the NASA-IPAC Teacher Archive Research Program - NITARP, originally funded by NASA as part of the Spitzer Space Telescope Public Engagement Program, and more recently as an NSF-sponsored Research Experience for Teachers program (NSF 0742222). This project partners teachers and their students with a mentor scientist to work on a unique research project using Spitzer Space Telescope data. The year-long project culminates by having teachers and students present their scientific methods and findings at a professional conference, such as the American Astronomical Society. To determine how teachers' attitudes toward science and scientific inquiry changed after participating in NITARP, five NITARP alumni teachers completed open-ended survey and interview questions describing how their experience changed how they thought about astronomy and what happened in their classroom as a direct result of their NITARP experiences. Teachers reported increasing their astronomy content knowledge, implementing new skills and computer programs into their curriculum, incorporating the use of real data, and are implementing, or are planning to implement research in their classrooms. Teachers also stated they feel more comfortable speaking the language of science and communicating with scientists. They also felt more confident in teaching how science is done. The results of this exploratory study showing positive impacts motivate us to more deeply study the underlying mechanisms in this and similar programs best poised to improve science education.

## 120.17 – Where Students Get Their Information about Science and Technology and Assessment of That Knowledge

*Sanlyn Buxner[1], Jenna Llull[1], Chris D. Impey[1], Kitina Tijerino[1]*
*1. University of Arizona, Tucson, AZ, United States.*
*Contributing teams: Collaboration of Astronomy Teaching Scholars (CATS)*

The changing landscape of where people get information has created challenges and opportunities for undergraduate science instructors. The perception that students are relying less on their textbooks and more on online content has created questions about how to engage with students in science courses. We report on our work investigating where undergraduate non-major astronomy students report getting their information about science as well as their general interest in science and technology. Through pilot surveys and in-depth interviews, we have refined a survey that asks students about their general interest in science, where they get their information about science, and what it means to study something scientifically. Our work shows that our students report getting a lot of information about science from in-class presentations but turn first to the internet when they want to learn something new about science. Overall, students rate their knowledge of science higher than their knowledge of technology due to coursework that covers science but not technology. Students who are more interested in science in general also self-report higher knowledge in science and are rated higher in their understanding about how to study something scientifically. Students who are less interested in science and rate themselves less knowledgeable about science turn first to online sources when learning something new related to science. Our work has implications for instructors who engage non-science major students and those working to improve science literacy of those students. This work is supported in part through an Arizona/NASA Space Grant Consortium Undergraduate Research Internship. This material is based in part upon work supported by the National Science Foundation under Grant No. 0715517, a CCLI Phase III Grant for the Collaboration of Astronomy Teaching Scholars (CATS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

# 200 – SPD Harvey Prize Lecture: Modeling Solar Eruptions: Where Do We Stand?

## 200.01 – Modeling Solar Eruptions: Where Do We Stand?

*Tibor Torok*[1]

*1. Predictive Science Inc., San Diego, CA, United States.*

Solar flares and coronal mass ejections involve massive releases of energies into the heliosphere and are the main driver of space weather disturbances near Earth. It is now well accepted that these enigmatic events are manifestations of a sudden and violent disruption of the Sun's coronal magnetic field. However, although such eruptions have been studied for many years, the detailed physical mechanisms by which they are initiated and driven are not yet fully understood; primarily because of our present inability to accurately measure magnetic fields in the corona. Numerical models have become a powerful tool to help us overcome this limitation. Global simulations of solar eruptions are particularly challenging, because of the enormous disparity of the relevant scales. While the steady advance of computational power has enabled us to model eruptions with ever increasing detail and realism, many questions remain unanswered. In this talk, I review what we have learned from numerical modeling about the physical processes associated with solar eruptions and I will discuss the current limitations and future prospects of models.

# 201 – Astronomy Education & Public Outreach

## 201.01 – My Sky Tonight: Nurturing a Scientific Frame of Mind in Early Childhood

*Jim Manning[1], Jim Manning[1], Gregory R. Schultz[1], Suzanne Gurton[1], Julia Plummer[2], Maureen Callanan[3], Jennifer Jipson[4], Sasha Palmquist[5]*

*1. Astronomical Society of the Pacific, San Francisco, CA, United States. 2. Penn State University, University Park, PA, United States. 3. UC Santa Cruz, Santa Cruz, CA, United States. 4. Cal Poly San Luis Obispo, San Luis Obispo, CA, United States. 5. Palmquist & Associates, Wshington, DC, United States.*

The Astronomical Society of the Pacific (ASP), in collaboration with a team of researchers, evaluators, and informal education institutions, has embarked on an NSF-funded project designed to build capacity in informal science education (ISE) practitioners by supporting development of their understanding of early childhood astronomy knowledge and the building of pedagogical skills and tools supportive of early childhood learning in informal settings. While preschool–aged children have long been considered too young and too cognitively immature to benefit from science learning, a growing body of recent research shows that children's curiosity about science topics begins in the years prior to school, and that a child's early years lay a powerful foundation for subsequent learning. Further, informal science educator and learning researchers argue that more effectively building on young children's inherent curiosity about the natural world could lead to stronger science learning outcomes than waiting to introduce science in classroom settings. Consequently, using the domain of astronomy as a basis, the ASP and its partners are embarking on a project to: 1) advance the knowledge base concerning astronomy conceptions and curiosities of young children and how they can be built upon to position children for later learning, 2) develop interactive learning experiences to be used by ISE practitioners and families with small children to nurture children's science curiosity and reasoning, 3) increase participation in astronomy by families in general and underserved families in particular, and 4) improve practice by engaging ISE practitioners in the research and development of effective practices, providing implementation tools and methods. The presenter will share project status as it gets underway.

## 201.02 – Inclusive Design for Learning – Making Your Classroom Accessible

*Angela Speck[1], Gina Ceylan[1]*

*1. Univ. of Missouri, Columbia, MO, United States.*

As science educators, our shared purpose of communicating and cultivating essential content and skills in all learners calls for continual re-evaluation of materials and approaches in the context of increasingly diverse classrooms. Lack of enrollment and retention of under-represented groups in science courses necessitates improvement of current science curricula design and teaching techniques in order to provide equitable educational experiences. We have developed an Inclusive Design for Learning course for STEM graduate students with the aim of improving the instructional approaches of our future STEM faculty in higher education. We will present the background and techniques used in this course and offer preliminary analysis of its first semester in action.

## 201.03 – Continued Testing of Head-Mounted Displays for Deaf Education in a Planetarium

*Eric G. Hintz[1], Michael Jones[1], Jeannette Lawler[1], Nathan Bench[1], Fred R. Mangrubang[2]*

*1. Brigham Young Univ., Provo, UT, United States. 2. Gallaudet University, Washington, DC, United States.*

For more than a year now we have been developing techniques for using Head-Mounted Displays (HMD) to help accommodate a deaf audience in a planetarium environment. Our target audience is primarily children from 8 to 13 years of age, but the methodologies can be used for a wide variety of audiences. Applications also extend beyond the planetarium environment. Three tests have been done to determine if American Sign Language (ASL) can be delivered to the HMD and the student view both the planetarium show and the ASL 'sound track'. From those early results we are now at the point of testing for comprehension improvement on a number of astronomical subjects. We will present a number of these early results.

## 201.04 – Using Attendance Worksheets to Improve Student Attendance, Participation, and Learning

*Edward Rhoads[1]*

*1. , Indianapolis, IN, United States.*

As science instructors we are faced with two main barriers with respect to student learning. The first is motivating our students to attend class and the second is to make them active participants in the learning process once we have gotten them to class. As we head further into the internet age this problem only gets exacerbated as students have replaced newspapers with cell phones which can surf the web, check their emails, and play games. Quizzes can motivated the students to attend class but do not necessarily motivate them to pay attention. Active learning techniques work but we as instructors have been bombarded by the active learning message to the point that we either do it already or refuse to. I present another option which in my classroom has doubled the rate at which students learn my material. By using attendance worksheets instead of end of class quizzes I hold students accountable for not just their attendance but for when they show up and when they leave the class. In addition it makes the students an active participant in the class even without using active learning techniques as they are writing notes and answering the questions you have posed while the class is in progress. Therefore using attendance worksheets is an effective tool to use in order to guide student learning.

## 201.05 – Two Eyes, 3D Early Results: Stereoscopic vs 2D Representations of Highly Spatial Scientific Imagery

*Aaron Price[1, 2]*

*1. Museum of Science and Industry, Chicago, Chicago, IL, United States. 2. AAVSO, Cambridge, MA, United States.*

'Two Eyes, 3D' is a 3-year NSF funded research project to study the educational impacts of using stereoscopic representations in informal settings. The first study conducted as part of the project tested children 5-12 on their ability to perceive spatial elements of slides of scientific objects shown to them in either stereoscopic or 2D format. Children were also tested for prior spatial ability. Early results suggest that stereoscopy does not have a major impact on perceiving spatial elements of an image, but it does have a more significant impact on how the children apply that knowledge when presented with a common sense situation. The project is run by the AAVSO and this study was conducted at the Boston Museum of Science.

## 201.06 – Operationalizing the 21st Century Learning Skills Framework for the NASA Mission to Mars Program

*Burgess Smith[1]*

*1. Evaluation & Research, Museum of Science and Industry Chicago, Chicago, IL, United States.*

*Contributing teams: MSI Research & Evaluation Team, MSI Interactive Videoconferences Team*

Internal evaluators working with the NASA Mission to Mars program, an out-of-school collaborative videoconferencing program at the Museum of Science and Industry Chicago (MSI), developed an observation protocol to collect evidence about the collaborative learning opportunities offered by the program's unique technology. Details about the protocol's development are discussed, along with results of the pilot observations of the program.

## 201.07 – Peer-to-Peer Instruction with Interactive Demonstrations in Upper Level Astronomy Courses

*Richard Gelderman[1]*

*1. Western Kentucky Univ., Bowling Green, KY, United States.*

Spectral and polarization properties of light are topics that most intro physics courses barely touch. Students therefore rarely have any useful experience to draw on when those topics come up in an upper level astronomy class. This means that they approach problems dealing with spectra or polarization as plug-and-chug mathematics applications, devoid of physical context. We have been addressing such dilemmas by using interactive demonstrations in the lecture meeting to give students direct experience with polarization filters, diffraction gratings, spectral sources, and situations requiring them to analyze sources based on the observed polarization of spectral properties. Each student individually predicts the outcomes for a demonstration. Students then collaborate within in a group of three to discuss their prediction, reporting the group's consensus prediction. After observing the demonstration, students in the group compare their predictions to the results, and attempt to explain the phenomena. Based on curricular reforms in physics education, these methods have provided our students with the ability to much more than just manipulate equations related to spectroscopic and polarization analysis.

## 201.08 – Astrobites: The Online Astronomy Research Digest for Undergraduates

*Christopher Faesi[1]*

*1. Harvard Univ., Cambridge, MA, United States.*

*Contributing teams: Astrobites Collaboration*

Astrobites (http://astrobites.org) is an innovative science education initiative developed by graduate students in astrophysics for an undergraduate audience. Our goal is to help

undergraduates make the transition from the classroom to careers in research by introducing them to the astronomical literature in a pedagogical, approachable, and comprehensible way. Every day we select one new journal article posted to the astrophysics preprint server (http://arXiv.org/astro-ph) and prepare a brief summary describing methods and results, explaining jargon, and providing context. We also write regular blog posts containing career advice, such as tips for applying for graduate school, how to install astronomical software, or demystifying the publishing process. The articles are written by a team of about 30 graduate students in astrophysics from throughout the US and Europe. Since its founding in 2010, Astrobites has grown dramatically, now reaching more than 1000 daily readers in over 100 countries worldwide. Our audience includes not only undergraduates, but also interested non-scientists, educators, and professional researchers. More broadly, Astrobites is interested in fostering the development of vital communication skills that are crucial to a successful science career, yet not formally taught in most astronomy PhD programs. In addition to providing our graduate student authors with valuable opportunities to practice these skills through writing and editing articles, we organize events such as the upcoming workshop Communicating Science 2013, at which graduate students in all science fields from around the country will learn from and interact with panelists who are experts in science communication.

# 202 – Bridging Laboratory and Astrophysics: Dust and Ices

## 202.01 – The Importance of Dust for Astrophysics

*Stephen Rinehart*[1]
*1. NASA's GSFC, Greenbelt, MD, United States.*

For over 40 years, astronomers have known that dust is common in the universe. With advances in infrared astronomy, astronomical dust has been discovered within our own solar system, in star formation regions, disks around stars, and in distant galaxies. This dust comprises less than one percent of the mass of the interstellar medium in galaxies, but it plays several important roles within astrophysics, such as reprocessing of radiative outputs from stars and AGNs. Understanding dust, therefore, is necessary to understand a number of key astrophysical processes, and laboratory investigations have been crucial for gaining insight into the composition and optical properties of these dust grains. Recent work has further improved the state of our understanding of astronomical dust, but much work still remains if we are to be able to properly interpret data from future facilities such as JWST.

## 202.02 – Interstellar Ice Chemistry: From Water to Complex Organics

*Karin I. Oberg*[1], *Edith Fayolle*[2], *Harold Linnartz*[2], *Ewine van Dishoeck*[2], *Jean-Hugues Fillion*[3], *Mathieu Bertin*[3]
*1. University of Virginia, Charlottesville, VA, United States. 2. Leiden University, Leiden, Netherlands. 3. UPMC univ Paris 6, LPMAA, Paris, France.*

Molecular cloud cores, protostellar envelopes and protoplanetary disk midplanes are all characterized by freeze-out of atoms and molecules (other than H and H2) onto interstellar dust grains. On the grain surface, atom addition reactions, especially hydrogenation, are efficient and H2O forms readily from O, CH3OH from CO etc. The result is an icy mantle typically dominated by H2O, but also rich in CO2, CO, NH3, CH3OH and CH4. These ices are further processed through interactions with radiation, electrons and energetic particles. Because of the efficiency of the freeze-out process, and the complex chemistry that succeeds it, these icy grain mantles constitute a major reservoir of volatiles during star formation and are also the source of much of the chemical evolution observed in star forming regions. Laboratory experiments allow us to explore how molecules and radicals desorb, dissociate, diffuse and react in ices when exposed to different sources of energy. Changes in ice composition and structure is constrained using infrared spectroscopy and mass spectrometry. By comparing ice desorption, segregation, and chemistry efficiencies under different experimental conditions, we can characterize the basic ice processes, e.g. diffusion of different species, that underpin the observable changes in ice composition and structure. This information can then be used to predict the interstellar ice chemical evolution. I will review some of the key laboratory discoveries on ice chemistry during the past few years and how they have been used to predict and interpret astronomical observations of ice bands and gas-phase molecules associated with ice evaporation. These include measurements of thermal diffusion in and evaporation from ice mixtures, non-thermal diffusion efficiencies (including the recent results on frequency resolved UV photodesorption), and the expected temperature dependencies of the complex ice chemistry regulated by radical formation and diffusion. Based on these examples I will argue that the combination of laboratory experiments and observations is crucial to formulate and to test hypotheses on key processes that regulate the interstellar ice chemistry.

## 202.03 – New Laboratory-Based Optical Functions of Cosmic Abundance Glass: Comparison to “Astronomical Silicates” and Application to Post-AGB Object HD 161796

*Angela Speck*[1, 4], *Karly M. Pitman*[2], *Anne M. Hofmeister*[3], *Alan G. Whittington*[4]
*1. Physics & Astronomy Department, University of Missouri, Columbia, MO, United States. 2. Planetary Science Institute, Alhambra, CA, United States. 3. Earth & Planetary Science, Washington University, St Louis, MO, United States. 4. Geological Sciences, University of Missouri, Columbia, MO, United States.*

Complex refractive indices (optical functions) for amorphous silicates are used to model and interpret a wide variety of astrophysical environments including H II regions, circumstellar dust around evolved stars and in disks around young stellar objects (YSOs), and active galactic nuclei (AGN). However, the most widely-used optical functions in the literature have been derived using compositionally and structurally disparate materials, and were prepared with inconsistent methodology, kludging observational data and laboratory data with different experimental methods to populate the wavelength space. Furthermore, these previous optical functions often include portions derived from astronomical observations rather than laboratory spectra. New quantitative laboratory data are available to build up wavelength coverage for amorphous silicates in a more systematic way. We present optical functions and extinction cross-sections derived from mid-UV to far-IR laboratory transmission spectra of cosmic abundance silicate glass. The advantages of using these data are that our glass sample was synthesized especially with cosmic (solar) abundances in mind and excludes iron. We compare these results to other popular optical functions used to model amorphous silicates (e.g., “astronomical” or “cosmic” silicate by Draine & Lee 1984, Draine 2003, Ossenkopf et al. 1992), both directly and in application to HD 161796, a spherically symmetric, O-rich system with a visible central star, optically thin dust shell, and radiation field intermediate to AGB and PN class targets. The new cosmic silicate optical functions have much lower UV-vis and NIR opacity than the traditionally used functions necessitating significantly more dust (1 or 2 orders of magnitude for mass) to model an object like HD 161796. Furthermore, the lower opacity has an impact on the fraction of crystalline material needed to match the observed spectrum. Previous models produced using older optical functions will underestimate the dust mass and overestimate the importance of crystalline silicates. This work is supported through NSF AST-1009544 and NASA APRA04-000-0041.

## 202.04 – Experimental Investigation of Charging Properties of Interstellar Type Silica Dust Grains by Secondary Electron Emissions

*Dragana Tankosic*[1], *Mian M. Abbas*[2]
*1. NASA Postdoctoral Program, NASA/MSFC, Huntsville, AL, United States. 2. NASA/MSFC, Huntsville , AL, United States.*

The dust charging by electron impact is an important dust charging process in astrophysical and planetary environments. Incident low energy electrons are reflected or stick to the grains charging the dust grains negatively. At sufficiently high energies electrons penetrate the grains, leading to excitation and emission of electrons referred to as secondary electron emission (SEE). Available classical theoretical models for calculations of SEE yields are generally applicable for neutral, planar, or bulk surfaces. However, these models are not valid for calculations of the electron impact charging properties of electrostatically charged micron/submicron-size dust grains in astrophysical environments. Rigorous quantum mechanical models are not yet available, and the SEE yields have to be determined experimentally for development of more accurate models for charging of individual dust grains. At the present time, very limited experimental data are available for charging of individual micron-size dust grains, particularly for low energy electron impact. Our laboratory measurements on individual, positively charged, micron-size dust grains levitated carried out in a unique facility at NASA-MSFC, based on an electrodynamic balance, indicate that the SEE by electron impact is a complex process. The electron impact may lead to charging or discharging of dust grains depending upon the grain size, surface potential, electron energy, electron flux, grain composition, and configuration (Abbas et al, 2010, 2012). In this paper, we discuss SEE charging properties of individual micron-size silica microspheres that are believed to be analogs of a class of interstellar dust grains. The measurements indicate charging of the 0.2 micron silica particles when exposed to 25 eV electron beams and discharging when exposed to higher energy electron beams. Relatively large size silica particles (5.2-6.82 micron) generally discharge to lower equilibrium potentials at both electron energies. These measurements conducted on silica microspheres are qualitatively similar in nature to our previous SEE measurements on lunar Apollo missions dust samples.

# 203 – Outer Limits of the Milky Way I: Overview and Theories of Galactic Structure

## 203.01 – Dynamics of Spirals and Warps

*Jerry Sellwood*[1]
*1. Rutgers Univ., Piscataway, NJ, United States.*

Like many galaxies, the Milky Way, has spiral patterns and a warp, but our location within the disk makes spirals, in particular, much harder to identify. I give a very brief summary of the believed mechanism that creates spirals, and explain how this understanding may help us to unravel the recent spiral history of the outer Milky Way. Warps are another form of collective oscillation of galaxy disks, although unlike spirals they probably would not arise without external influence.

## 203.02 – Old Stars in the Outer Disk of the Galaxy: Results from SEGUE

*Constance M. Rockosi*[1]
*1. University of California, Santa Cruz, Santa Cruz, CA, United States.*

The chemical abundances of old stars in the Milky Way disk trace its star formation history, and the kinematics and orbital properties of these stars evolve through dynamical interactions in the disk. These processes can be internal, such as encounters with spiral structure, or could be external interactions which are a defining feature in hierarchical galaxy growth. Correlations between stellar kinematics and chemistry, as are found in the solar neighborhood, are the signature of those processes that shape the formation and growth of our Galaxy's disk. With SEGUE survey spectroscopy we can investigate those same properties in the outer Galaxy. I will review results of several investigations that used SEGUE data to determine how the radial and vertical density profiles, metallicity distribution, eccentricity and rotation velocity of stars in the outer disk vary with stellar metallicity and the abundance of alpha elements. I will also discuss studies of the outer disk using the SEGUE data that revealed large-scale velocity and density asymmetries and kinematic clustering that may be the result of past dynamical encounters.

## 203.03 – Deciphering the Dynamical Echoes of Dwarf Galaxies on the Milky Way Disk

*Sukanya Chakrabarti*[1]
*1. Rochester Institute of Technology, Rochester, NY, United States.*

The Milky Way satellites are sensitive probes of galaxy interactions -- through tidal streams, which trace the past influence of dark matter halos on satellites, and through the tidal effects of the satellites on galactic disks, both stellar and gaseous. Recent surveys of the Milky Way have revealed large scale planar disturbances and a warp in the gas distribution, and stellar tidal streams as seen in deep infrared surveys. I will discuss our earlier prediction of a putative new dwarf galaxy from analysis of disturbances in the outer HI disk of the Milky Way. We have begun to build on our recent work on developing the Tidal Analysis method, which yields the mass and location of the satellites that are responsible for producing the observed distortions in the outer HI disks of spirals. We are now combining this inverse method with a forward morphological analysis that accounts for contributions of all known satellites. Our aim is not simply to study satellite interactions in an assumed potential for the DM halo but rather, to infer constraints on its shape and radial profile in an integral manner. A critical examination of the effects of known satellites, taking into account the uncertainties, will also allow us to determine whether dark satellites are needed to understand the structure of the Milky Way disk.

## 203.04 – Poster Summaries I

*Barbara Whitney*[1]
*1. University of Wisconsin, Madison, WI, United States.*

Poster authors each have about 1 minute and 1 slide to advertise their posters, which will be presented on day 2 of the meeting. The afternoon of day 2 will be free for extensive discussions at the poster session!

# 204 – WIYN Observatory - Building on the Past, Looking to the Future: Partnerships

## 204.01 – WIYN Observatory: Partnerships

*John S. Gallagher*[1]
*1. Univ. of Wisconsin, Madison, WI, United States.*
*Contributing teams: Dept of Astronomy, University of Wisconsin-Madison*

As part of its 'meeting-in-a-meeting' highlighting the scientific contributions and the new instrumentation available at WIYN, the Observatory partners are providing a forum for discussion of potential partnership arrangements for national 4-meter class telescopes. In this session, WIYN and other operators of 4-meter class telescopes will join in a panel discussion that features their plans for the future, possible strategies for broadening the user base from the community, and potential synergies and partnerships with existing and planned large survey projects and facilities. This session is intended to facilitate a conversation within the national community that explores potential future partnership arrangements to provide stable operational models for moderate aperture facilities that currently serve a large user base in the US.

## 204.02 – Panel Discussion: WIYN Observatory: Partnerships

*Buell Jannuzi*[1, 2]
*1. Steward Observatory, Tucson, AZ, United States. 2. University of Arizona, Tucson, AZ, United States.*

As part of its 'meeting-in-a-meeting' highlighting the scientific contributions and the new instrumentation available at WIYN, the Observatory partners are providing a forum for discussion of potential partnership arrangements for national 4-meter class telescopes. In this session, WIYN and other operators of 4-meter class telescopes will join in a panel discussion that features their plans for the future, possible strategies for broadening the user base from the community, and potential synergies and partnerships with existing and planned large survey projects and facilities. This session is intended to facilitate a conversation within the national community that explores potential future partnership arrangements to provide stable operational models for moderate aperture facilities that currently serve a large user base in the US.

## 204.03 – WIYN Observatory: Partnerships

*Timothy C. Beers*[1]
*1. NOAO, Tucson, AZ, United States.*

As part of its 'meeting-in-a-meeting' highlighting the scientific contributions and the new instrumentation available at WIYN, the Observatory partners are providing a forum for discussion of potential partnership arrangements for national 4-meter class telescopes. In this session, WIYN and other operators of 4-meter class telescopes will join in a panel discussion that features their plans for the future, possible strategies for broadening the user base from the community, and potential synergies and partnerships with existing and planned large survey projects and facilities. This session is intended to facilitate a conversation within the national community that explores potential future partnership arrangements to provide stable operational models for moderate aperture facilities that currently serve a large user base in the US.

## 204.04 – WIYN Observatory: Partnerships

*Suzanne L. Hawley*[1, 3]*, Rene A. Walterbos*[2, 3]*, Bruce A. Gillespie*[3]
*1. Univ. of Washington, Seattle, WA, United States. 2. New Mexico State University, Las Cruces, NM, United States. 3. Apache Point Observatory, Sunspot, NM, United States.*

As part of its 'meeting-in-a-meeting' highlighting the scientific contributions and the new instrumentation available at WIYN, the Observatory partners are providing a forum for discussion of potential partnership arrangements for national 4-meter class telescopes. In this session, WIYN and other operators of 4-meter class telescopes will join in a panel discussion that features their plans for the future, possible strategies for broadening the user base from the community, and potential synergies and partnerships with existing and planned large survey projects and facilities. This session is intended to facilitate a conversation within the national community that explores potential future partnership arrangements to provide stable operational models for moderate aperture facilities that currently serve a large user base in the US.

## 204.05 – WIYN Observatory: Partnerships

*John J. Salzer*[1]
*1. Indiana University, Bloomington, IN, United States.*

As part of its 'meeting-in-a-meeting' highlighting the scientific contributions and the new instrumentation available at WIYN, the Observatory partners are providing a forum for discussion of potential partnership arrangements for national 4-meter class telescopes. In this session, WIYN and other operators of 4-meter class telescopes will join in a panel discussion that features their plans for the future, possible strategies for broadening the user base from the community, and potential synergies and partnerships with existing and planned large survey projects and facilities. This session is intended to facilitate a conversation within the national community that explores potential future partnership arrangements to provide stable operational models for moderate aperture facilities that currently serve a large user base in the US.

# 205 – The Atacama Large Millimeter/submillimeter Array: A New Window on the Universe

## 205.01 – The Atacama Large Millimeter/submillimeter Array: A New Window on the Universe

*Anthony J. Beasley*[1]
*1. National Radio Astronomy Observatory, Charlottesville, VA, United States.*

The Atacama Large Millimeter/submillimeter Array (ALMA) is the largest ground-based global astronomy endeavor in history. Composed of 66 high-precision antennas located on an excellent site at 5000m+ elevation on the Chajnantor plateau in northern Chile, ALMA is delivering the astronomy community orders of magnitude improvements in millimeter-wavelength sensitivity, frequency coverage, resolution, imaging, and spectral capabilities, impacting most fields of astrophysics and opening multiple new scientific frontiers. ALMA's capabilities span wavelengths from 9.6 to 0.3 mm (31-950 GHz), a key part of the electromagnetic spectrum for observing the first stars and galaxies, directly imaging planetary formation, and studying the energy output from supermassive black holes in starburst galaxies. ALMA's inauguration on 13 March 2013 marked the Project's transition to operation as a fully-fledged Observatory. This session will review ALMA's origins and history, current technical capabilities, and describe its primary scientific goals. Innovative aspects of its design, construction, operation, and governance will be highlighted, including the key roles of the North American ALMA Science Center at the National Radio Astronomy Observatory in Charlottesville, Virginia and the Joint ALMA Observatory in Chile. Development of the state-of-the-art technologies that are enabling the highest impact science will be described. Science operations were initiated 30 September 2011, and research results will be presented from both the Cycle 0 and Cycle 1 Early Science opportunities. This session will conclude with the vision for the Development Program that will maintain ALMA's capabilities at the forefront of modern astronomy. ALMA is a partnership of North America, Europe, and East Asia in cooperation with the Republic of Chile. ALMA is funded in North America by the U.S. National Science Foundation, in cooperation with the National Research Council of Canada, and the National Science Council of Taiwan.

# 208 – Galaxies and AGN I

## 208.01 – Determination of Physical Parameter Estimates for Metal-Poor Stars from the HK and HES Surveys

*Timothy C. Beers[1], Young Sun Lee[2], Vinicius Placco[3], Daniela Carollo[4], Norbert Christlieb[5], Stephanie Fiorenza[6]*

*1. NOAO, Tucson, AZ, United States. 2. New Mexico State University, Las Cruces, NM, United States. 3. University of Sao Paulo, Sao Paulo, Brazil. 4. Macquarie University, Sydney, NSW, Australia. 5. University of Heidelberg, Heidelberg, Germany. 6. City University of New York, New York City, NY, United States.*

Over the past quarter century, well over ten thousand metal-poor star candidates selected during the course of the HK survey of Beers, Preston, and Shectman and the Hamburg/ESO survey of Christlieb and collaborators have had medium-resolution (R ~ 2500-3000) spectroscopy obtained, using a host of telescopes and spectrographs. During that time, we have refined the analysis tools at our disposal, and collected broadband photometry for many of these stars. Here we report on an application of the recently refined non-SEGUE Stellar Parameter Pipeline (n-SSPP) to obtain estimates of effective temperatures (Teff), surface gravities (log g), and metallicities ([Fe/H]) for many of these stars. In the case of some of the follow-up spectra, the wavelength coverage and S/N ratios also permit the determination of [C/Fe] and [alpha/Fe] ratios. Ongoing detailed analyses of the chemistry and kinematics of these stars will be described.

## 208.02 – The Origin of the Diffuse UV Light from Spiral Disks: The Case of M101

*Alison F. Crocker[1], Rupali Chandar[1]*

*1. University of Toledo, Toledo, OH, United States.*

Active star formation sites in the arms of spiral galaxies distinctly stand out in UV images, however, UV emission is also detected within inter-arm regions. Three sources for this emission are possible: 1) in-situ star formation, at a low specific SFR or with a top-light IMF 2) a quiescently aging young stellar population and 3) UV light scattered off dust grains. The possibility of substantial emission from these latter two sources calls into question the applicability of standard star-formation recipes to inter-arm regions as done in studies of resolved star-formation laws. Using HST FUV images of two inter-arm regions in M101, we use the FUV luminosity function of individual stars to constrain the recent star-formation histories of these regions. One of the two regions shows a recent SFH that must have quenched in the past 10-15 Myr, while the other region may have some ongoing star-formation. We also measure the amount of non-stellar UV luminosity (after a correction for sub-detection stars based on the derived star-formation history) and this accounts for a minimal fraction in one field (< 20%), but a substantial fraction in the other field (approximately 70%). This emission is likely to be scattered light from more actively star-forming regions; indeed, a higher surface density of this diffuse emission is observed in the field closer to an actively star-forming arm. Both the lack of current star-formation (confirmed in one field) and the sizable contribution from scattered UV light indicates that UV emission may not ideal for constraining the current SFR in all inter-arm regions of spiral galaxies.

## 208.03 – Chemical Abundances Of Spirals (CHAOS): A Spectroscopic Survey of HII Regions in Nearby Spiral Galaxies

*Kevin V. Croxall[1], Richard W. Pogge[1], Evan D. Skillman[2], Danielle Berg[2], John Moustakas[3]*

*1. Ohio State University, Columbus, OH, United States. 2. University of Minnesota, Minneapolis, MN, United States. 3. Siena College, Loudonville, NY, United States.*

While nebular abundances of the interstellar medium can be determined via the analysis of emission line spectra of ionized gas (HII) regions, decades of observations have failed to remove unacceptably high uncertainties in the true chemical abundances. In order to definitively establish the nebular abundances of spiral galaxies, we have undertaken a large survey of ~1000 HII region spectra in 13 galaxies drawn from the Spitzer Infrared Nearby Galaxy Survey (SINGS) using the MODS spectrograph on the LBT. We present the first results of this survey, which aims to increase, by more than an order of magnitude, the number of HII regions in spiral galaxies with high quality spectra that extend from the 3200A to 1 micron. In this presentation we focus on results from NGC 628 and NGC 6946, for which we have obtained spectra of ~70 and ~50 HII regions, respectively, spanning the radius of each galaxy. We detect, and compare, numerous temperature indicators, including several detections of the nebular Balmer discontinuity. These spectra enable us to accurately determine the physical conditions necessary to derive the absolute and relative abundances of the ISM.

## 208.04 – Transformation of the Virgo Dwarf Irregular Galaxy IC3418 by Ram Pressure Stripping

*Jeffrey D. Kenney[1]*

*1. Yale University, New Haven, CT, United States.*

We present optical imaging and spectroscopy of the Virgo Cluster dwarf irregular galaxy IC3418, which appears to be a 'smoking gun' example of the transformation of a dwarf irregular (dI) into a dwarf elliptical (dE) by ram pressure stripping. GALEX UV and WIYN optical images show a spectacular 1-sided, 17 kpc length tail of UV-bright knots, head-tail, and linear stellar features. The only H$\alpha$ emission arises from a few HII regions in the outer half of the tail, the brightest of which are at the heads of head-tail UV sources, whose tails point back toward the galaxy. In several of the elongated tail sources the H$\alpha$ peaks are outwardly offset from the UV peaks. The head-tail (``fireballs'') and linear stellar features in the stripped tail are likely formed from dense gas clumps which continue to accelerate through ram pressure, leaving behind streams of newly formed stars which are not affected by ram pressure. Kinematics of HII regions in the tail show that the tail gas has experienced only modest acceleration, as the knots have velocities much closer to the galaxy than the cluster. Neither H-alpha nor HI emission are detected in the main body of the galaxy, despite structure in optical images resembling star forming regions and spiral arms, and several bright supergiants. Deep optical images show a relatively undisturbed stellar body and no smooth stellar component to the tail, but only clusters and streams of young stars, properties inconsistent with a tidal interaction. Keck optical spectra indicate star formation in the main body stopped ~200 Myr ago, with a radial gradient in quenching time of less than 100 Myr, indicating rapid stripping from the outside in. A starburst occurred prior to quenching, perhaps due to ram-pressure induced star formation. In IC3418, we propose that we are witnessing a critical stage in the transformation of a dI into a dE, the removal of nearly all of the ISM by ICM ram pressure stripping.

## 208.07 – Nurturing Lyman Break Galaxies: Observed Links Between Environment and Spectroscopic Features

*Jeff Cooke[1], Yuuki Omori[2], Emma Ryan-Weber[1]*

*1. Swinburne University, Hawthorn, VIC, Australia. 2. McGill University, Montreal, QC, Canada.*

I will present detailed two-point correlation functions determined from large (~10,000-60,000) samples of z ~ 3 Lyman break galaxies (LBGs) in the Canada-France-Hawaii Telescope Legacy Survey Deep Fields that reveal a strong relationship between their environment and restframe ultraviolet spectroscopic properties. We examine LBG subsets based on their color, magnitude, and spectroscopic features. For the latter, we use broadband color-magnitude criteria, tested using ~1000 Keck spectra, to isolate >95% pure subsets of LBGs with dominant Lya in absorption (aLBGs) and LBGs with dominant Lya in emission (eLBGs). The net Lya equivalent width of LBGs traces many other key ultraviolet properties such as morphology, ISM line-widths, star formation rates, and estimated galactic outflows. The auto-correlation functions reveal that magnitude has a significant effect on small scales (<~1 Mpc, the so-called one-halo term) and color has more influence on larger scales, (>~1 Mpc, the so called two-halo term), however, we see the largest diversity in the aLBG and eLBG auto-correlation functions. The aLBG auto-correlation function shows a strong amplitude on all scales, indicative of parent halos having M_DM ~10^13 M_solar, whereas the eLBG auto-correlation function shows a weaker amplitude, indicating average parent halos of M_DM ~10^11 M_solar, and exhibits a curious ``hump'' at intermediate scales which we isolate to the faintest, bluest LBGs. We find that a ``shell'' model, in which a significant fraction of eLBGs are located on shells, provides a good representation of the form of the eLBG auto-correlation function. Moreover, the aLBG-eLBG cross-correlation function shows an anti-correlation reinforcing an intrinsic difference in the physical distribution of the two LBG subsets in space. The results show that aLBGs prefer massive, group-like environments and that eLBGs are found on group outskirts and in the field, thus revealing an environment effect on ultraviolet properties and indicating that the mechanisms behind the morphology-density relation at low-redshift are active at z ~ 3.

# 209 – Supernovae and Neutron Stars

## 209.01 – Three-Dimensional Simulations of Core-Collapse Supernovae

*Sean M. Couch*[1]

*1. University of Chicago, Chicago, IL, United States.*

Core-collapse supernovae (CCSNe) are the luminous explosions that herald the death of massive stars. Despite the importance of CCSNe to our understanding of many aspects of the universe the mechanism that reverses stellar core collapse and drives supernova explosions is not fully understood. The CCSN mechanism is one of the most important challenges for modern computational astrophysics. I will discuss the current state-of-the-art of CCSN theory and simulation, with an emphasis on my recent work on three-dimensional CCSN simulations. I will highlight some of the most interesting and important questions supernova theorists are currently wrestling with, in particular the importance of fully three-dimensional simulations.

## 209.02 – Supernova Simulations with a Quark-Gluon Plasma Phase Transition in the NDL Equation of State

*J. Pocahontas Olson*[1], *Matthew Meixner*[1], *Grant J. Mathews*[1], *Lan Nguyen*[2], *Hollis E. Dalhed*[3]

*1. University of Notre Dame, Notre Dame, IN, United States. 2. Hanoi National University of Education, Hanoi, Viet Nam. 3. Lawrence Livermore National Laboratory, Livermore, CA, United States.*

Recent studies have shown that a transition to a quark-gluon plasma during a core-collapse supernovae could provide a mechanism to revitalize a stalled accretion shock. The neutron star that cools from this explosion could also contain quark matter, which would alter the relationship between its mass and radius, as well as its cool down rate. An Equation of State (EoS) to describe the properties of matter in extremes of density and temperature would allow us to incorporate these phases of matter in simulation. I will discuss the effects of a phase transition to quark-gluon matter in the new Notre Dame Livermore Equation of State (NDL EoS). I demonstrate the consequences of varying the QCD bag constant and the strong coupling constant on the mass-radius relationship. The observation of a 1.97 ± 0.04 M? neutron star provides a stringent limit on the parameter space of a quark-gluon plasma phase in simulating supernovae collapse. Finally, I will compare simulations of the old Bowers & Wilson EoS and various settings of the NDL EoS using our spherically symmetric supernova simulation.

## 209.03 – A Sterile Neutrino and its Consequences for Core-Collapse Supernovae

*MacKenzie Warren*[1], *Matthew Meixner*[1], *Grant J. Mathews*[1], *Jun Hidaka*[2], *Toshitaka Kajino*[2]

*1. Department of Physics, University of Notre Dame, Notre Dame, IN, United States. 2. National Astronomical Observatory of Japan, Tokyo, Japan.*

Despite significant advancements in modeling core-collapse supernovae, there are still phenomena that we do not understand. The existence of a right-handed sterile neutrino may provide a means of solving some of the issues related to the lepton fraction, neutrino spectrum and energy transport within the collapsing core. Recent anomalous reactor results and cosmological constraints provide some bounds on the sterile neutrino mass m_{s} and mixing angle sin^{2} 2 theta. We have included the effects of a coherent active-sterile conversion for a ~keV mass sterile neutrino with sin^{2} 2 theta ~ 10^{-9}, including matter effects through the MSW mechanism, into a self-consistent supernova model. Preliminary results show that a few milliseconds prior to the core bounce there is a coherent conversion of electron neutrinos to sterile neutrinos, which alters the neutrino spectrum and dynamics of the collapse.

## 209.04 – A Light Echo Candidate from Supernova 2009ig

*Peter M. Garnavich*[1], *Peter Milne*[2], *Ginger L. Bryngelson*[3], *Mark D. Leising*[4]

*1. Univ. of Notre Dame, Notre Dame, IN, United States. 2. University of Arizona, Tucson, AZ, United States. 3. Francis Marion University, Florence, SC, United States. 4. Clemson University, Clemson, SC, United States.*

Deep imaging of the nearby type Ia supernova 2009ig shows that its optical light curve stopped fading about 700 days after B-band maximum light. The photometry was obtained by the Large Binocular Telescope (LBT) starting a year after the explosion. Normally, type Ia at late-times are powered by radioactive decay and their broad-band light curves continuously fade at between 1.0 and 1.5 mag/100 days. The continued visibility of SN 2009ig suggests that the emission is now dominated by a light echo or an existing faint source that was present along the site line. From the early light curve, SN 2009ig appears to be a normal type Ia with minimal host dust extinction. The candidate light echo is 10 V-band magnitudes fainter than the supernova at peak, and this means it is slightly more luminous than other light echoes seen from type Ia events such as SN 1991T, 1995E, and 1998bu. However, the estimated light-of-sight extinction to SN 2009ig is unusually low for a supernova showing a light echo.

## 209.05 – EQ Lyn and V455 And: Contrasts in Post-Outburst Behavior

*Paula Szkody*[1], *Anjum S. Mukadam*[1], *Boris T. Gaensicke*[2]

*1. Univ. of Washington, Seattle, WA, United States. 2. Univesity of Warwick, Coventry, United Kingdom.*

Cataclysmic variables (CVs) that contain accreting, pulsating white dwarfs provide a unique means to study how cooling of the white dwarf affects the pulsation spectrum. In contrast to non-accreting white dwarfs which cool through evolution on timescales of millions of years, the white dwarfs in CVs are heated by infrequent dwarf nova outbursts and then cool on timescales of 3-5 years. Thus, following the cooling and pulsations is very feasible and allows a comparison of how the accretion (which alters the composition, temperature and rotation of the white dwarf) affects the interior of the star. We have followed the pulsation changes of EQ Lyn (SDSSJ070745+45) for 6 years following its outburst in October 2006 and of V455 And (HS2331+39) for 5 years after its September 2007 outburst. While the pulsations disappeared for the year after outburst in each system, the return to quiescent states were quite different in each object. At one year past outburst, EQ Lyn had returned to optical quiescence while the UV showed the white dwarf was still 2000K hotter than quiescence. Pulsations at precisely the same periods as quiescence returned by 3.3 yrs after outburst but they then disappeared the following year, to again return in 2012. The unchanged period combined with the quick return to quiescence imply little accretion happened during outburst with little effect on the white dwarf interior. However, the reason for the disappearance of the pulsations in 2011 is not understood. V455 And did not fully return to optical quiescence until 4 yrs after outburst, even though after 3 yrs it was only 600K above its quiescent temperature. The pulsations that were apparent near 340 sec at quiescence were shifted to shorter periods near 255 sec at 2 years past outburst and gradually lengthened to about 325 sec at the end of 2012. This shortening of the pulsation period at hotter temperatures is similar to what is observed in ZZ Ceti stars in their instability strip. Further cooling sequences are needed to understand what the common behavior pattern is following outbursts. This research was partially funded by NSF grant AST-1008734 and NASA grants HST-GO11163.01A, HSTGO-11639.01A and HST-GO12231.01A.

## 209.06 – Gravitational and Electromagnetic Emission from Binary Neutron Star Mergers

*Patrick M. Motl*[1], *Carlos Palenzuela*[2], *Luis Lehner*[3], *Marcelo Ponce*[4], *Steven L. Liebling*[5], *Matthew Anderson*[6], *David Neilsen*[7]

*1. Indiana University Kokomo, Kokomo, IN, United States. 2. CITA, Toronto, ON, Canada. 3. Perimeter Institute, Waterloo, ON, Canada. 4. University of Guelph, Guelph, ON, Canada. 5. Long Island University, Brookville, NY, United States. 6. Indiana University, Bloomington, IN, United States. 7. Brigham Young University, Provo, UT, United States.*

The inspiral of a neutron star – neutron star binary is a leading candidate for strong emission of gravitational waves. The interaction between the stellar magnetospheres may also give rise to electromagnetic emissions accompanying the gravity waves as the neutron stars inspiral and merge. We present results from a set of resistive magnetohydrodynamic simulations of mergers computed with full general relativity. We vary the initial magnetic field of the neutron stars including cases where the fields are initially aligned, anit-aligned and where one star's field dominates over its companion. This presentation is based upon work supported by the National Aeronautics and Space Administration under grant No. NNX13AH01G through the astrophysics theory program.

## 209.07 – Search for an X-ray Counterpart to VER J2019+407

*Mark F. Theiling*[1], *Vikram Dwarkadas*[3], *Amanda Weinstein*[2]

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VER J2019+407 is a very high energy gamma-ray source detected by the VERITAS observatory and lying within the angular extent of the gamma-Cygni supernova remnant (SNR). We present here the results of a 50ks Chandra observation, taken with the intention of elucidating the nature of the source and its relationship (if any) with the

SNR. Imaging and spectral analysis are presented, and scenarios for the reconciliation of X-ray and gamma-ray findings are discussed.

## 209.08 – Pulsars in the Laboratory: Practical Superluminal Emitters Mimic Their Galactic Cousins

*John Singleton[1], Andrea C. Schmidt[2], John Middleditch[2], Simon Redman[2], James Wigger[2], Houshang Ardavan[3], Arzhang Ardavan[4]*

*1. National High Magnetic Field Laboratory, Los Alamos, NM, United States. 2. Los Alamos National Laboratory/UNM, Los Alamos, NM, United States. 3. Cambridge University, Cambridge, United Kingdom. 4. Oxford University, Oxford, United Kingdom.*

Maxwell's equations establish that polarization currents can be animated to travel faster than the speed of light *in vacuo*, and that these superluminal distribution patterns emit tightly focused packets of electromagnetic radiation that are fundamentally different from those emitted by conventional means. A polarization current occurs when a polarized region moves or is changed with time *t*; its density is ?*P*/?*t* and it has the same dimensions as a conventional current density of electrons. If a polarization current oscillates or accelerates, it will emit electromagnetic radiation, just as an accelerated or oscillating current of electrons does. However, unlike electrons, which possess rest mass and are therefore limited to speeds less than *c*, the speed of light, polarization currents may travel arbitrarily fast, as the displacement of their constituent elements is minimal; while the radiation source travels faster than *c*, the individual massive particles' speeds remain subluminal. In the past few years, several superluminal light sources have been built in the laboratory, generating polarization currents that move at up to 20 times the speed of light. Here we compare the emitted radiation from these well-characterized, ground-based experiments to observational pulsar data. Comparisons are also made with theoretical predictions of the Superluminal Model for Pulsars, which invokes emission by polarization currents that travel faster than light in a circular orbit through the pulsar's plasma "atmosphere." Using this single, dominant emission mechanism, which accounts for the properties of the laboratory-based sources, we show that many of the most enigmatic features of pulsar radiation are merely qualities intrinsic to a faster- than-light source: (i) the apparent radiation temperature and pulse shape; (ii) the unusual polarization properties (e.g. swing in position angle); and (iii) the broadband radiation spectrum.

## 209.09 – On the Anatomy of a Point-charge in Superluminal Rotation and Its Relevance to Pulsar Radiation

*Andrea C. Schmidt[1], John Singleton[2], John Middleditch[1], Houshang Ardavan[3], Arzhang Ardavan[4]*

*1. LANL/UNM, Los Alamos, NM, United States. 2. National High Magnetic Field Laboratory, Los Alamos, NM, United States. 3. Cambridge University, Cambridge, United Kingdom. 4. Oxford University, Oxford, United Kingdom.*

Recent theoretical work and data gathered from ground-based astrophysics experiments have shown unambiguously that most salient features of pulsar emission can be explained in terms of superluminal (faster than light in vacuum) polarization currents whose distribution pattern follows a circular orbit. A generic, simplified model of this kind has been found to approximate quantitatively the spectrum of the Crab pulsar as well as a variety of other pulsars for which multi-wavelength observations are available over 16 to 18 orders of magnitude of frequency with very few adjustable parameters. Here, we study the emission of a localized charge, e.g., a polarization-current element of infinitesimal volume, in constant superluminal rotation to simulate a typical pulsar's emitting region. We set out by applying basic methods introduced by Huyghens and Fresnel to gain phase information and find that radiation sources that travel not only faster than light, but are also subject to acceleration, possess a two-sheeted envelope and a cusp – a region of intense concentration of energy. Moreover, careful analysis of the relationship between emission and observation time reveals that this need not be monotonic and one-to-one, as multiple retarded times – or even extended periods of source time – can contribute to a single instant of reception. To introduce amplitude in addition to phase information, we derive and numerically evaluate the correct *formulae* for the Liénard-Wiechert potentials and fields excited by a point charge travelling arbitrarily fast along a given trajectory. Finally, we compare these findings to the radiation emitted by pulsars and find that virtually all of the enigmatic features of pulsar radiation – the polarization properties, image structure, apparent radiation temperature and peak spectral frequencies – can be explained using a single, elegant model with few input parameters and no external assumptions.

# 210 – Bridging Laboratory and Astrophysics: Plasmas

## 210.01 – Laboratory Studies of Supersonic Magnetized Plasma Jets and Radiative Shocks

*Sergey Lebedev*[1]

*1. Imperial College, London, United Kingdom.*

In this talk I will focus on laboratory plasma experiments producing magnetically driven supersonic plasma jets and on the interaction of these jets with ambient media. The experiments are scalable to astrophysical flows in that the critical dimensionless numbers such as the plasma collisionality, the plasma beta, the Reynolds number and the magnetic Reynolds number are all in the astrophysically appropriate ranges. The experimental results will be compared with computer simulations performed with laboratory plasma codes and with astrophysical codes. In the experiments the jets are driven and collimated by the toroidal magnetic fields and it is found that the level of MHD instabilities in the jets strongly depends on the strength of the field represented by the ratio of the thermal to magnetic field pressures (plasma beta). The experiments show the possibility of formation of episodic outflows, with periodic ejections of magnetic bubbles naturally evolving into a heterogeneous jet propagating inside a channel made of self-collimated magnetic cavities [1,2]. We also found that it is possible to form quasi-laminar jets which are “indirectly” collimated by the toroidal magnetic fields, but this requires the presence of the lower density halo plasma surrounding the central jet [3]. Studies of the radiative shocks formed in the interaction of the supersonic magnetized plasma flows with ambient plasma will be also presented, and the development of cooling instabilities in the post-shock plasma will be discussed. This research was sponsored by EPSRC Grant No. EP/G001324/1 and by the OFES DOE under DOE Cooperative Agreement No. DE-SC-0001063. References 1. A. Ciardi, S.V. Lebedev, A. Frank et al., The Astrophysical Journal, 691: L147–L150 (2009) 2. F.A. Suzuki-Vidal, S.V. Lebedev, S.N. Bland et al., Physics of Plasmas, 17, 112708 (2010). 3. F.A. Suzuki-Vidal, M. Bocchi, S.V. Lebedev et al., Physics of Plasmas, 19, 022708 (2012).

## 210.02 – First-Principles Computer Simulations of Dense Plasmas and Application to the Interiors of Giant Planets

*Burkhard Militzer*[1]

*1. Earth and Planetary Science, Astronomy, University of California, Berkeley, Berkeley, CA, United States.*

This presentation will review three recent applications of first-principles computer simulation techniques to study matter at extreme temperature-pressure conditions that are of relevance to astrophysics. First we report a recent methodological advance in *all-electron path integral Monte Carlo* (PIMC) that allowed us to extend this method beyond hydrogen and helium to elements with core electrons [1]. We combine results from PIMC and with density functional molecular dynamics (DFT-MD) simulations and derive a coherent equation of state (EOS) for *water and carbon plasmas* in the regime from 1-50 Mbar and $10^4$-$10^9$ K that can be compared to laboratory shock wave experiments. Second we apply DFT-MD simulations to characterize superionic water in the interiors of Uranus and Neptune. By adopting a thermodynamic integration technique, we derive the Gibbs free energy in order to demonstrate the existence of a phase transformation from body-centered cubic to face-centered cubic superionic water [2]. Finally we again use DFT-MD to study the interiors of gas giant planets. We determine the EOS for hydrogen-helium mixtures spanning density-temperature conditions in the deep interiors of giant planets, 0.2-9.0 g/cc and 1000-80000 K [3]. We compare the simulation results with the semi-analytical EOS model by Saumon and Chabrier. We present a revision to the mass-radius relationship which makes the hottest exoplanets increase in radius by ~0.2 Jupiter radii at fixed entropy and for masses greater than 0.5 Jupiter masses. This change is large enough to have possible implications for some discrepant *inflated giant exoplanets*. We conclude by demonstrating that all materials in the *cores* of giant planets, ices, MgO, $SiO_2$, and iron, will all dissolve into metallic hydrogen. This implies the cores of Jupiter and Saturn have been at least partially eroded. [1] K. P. Driver, B. Militzer, Phys. Rev. Lett. 108 (2012) 115502. [2] H. F. Wilson, M. L. Wong, B. Militzer, http://arxiv.org/abs/1211.6482. [3] B. Militzer, Phys. Rev. B 87 (2013) 014202; http://arxiv.org/abs/1302.4691. [4] H. F. Wilson, B. Militzer, Astrophys. J. Lett. 745 (2011) 54; Phys. Rev. Lett. 108 (2012) 111101.

## 210.03 – Laser-Driven Magnetic Pistons Relevant to the Formation of Magnetized Collisionless Shocks

*Erik Everson*[1], *Anton Bondarenko*[1], *Derek Schaeffer*[1], *Carmen Constantin*[1], *Steve Vincena*[1], *Bart Van Compernolle*[1], *S. Eric Clark*[1], *Dan Winske*[2], *Christoph Niemann*[1]

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To study the dynamics that lead to magnetized collisionless shock formation, laboratory experiments were performed at the University of California at Los Angeles (UCLA) that utilize the Large Plasma Device (LAPD) and the Phoenix Laboratory Raptor laser to drive sub- and super-Alfvénic laser-plasma explosions through the uniform, magnetized ambient-plasma of the LAPD. The 130 J, 25 ns FWHM, 1053 nm Raptor laser pulse ablates a graphite target that produces a debris-plasma capable of driving diamagnetic cavities ?55 cm (?3 c/?$_{pi}$) for ?6 gyro-periods in the low-density (2-5×$10^{12}$ $cm^{-3}$), magnetized (200-275 G) Hydrogen (or Helium) plasma of the LAPD. With the deployment of magnetic flux probes, the evolution and growth of the magnetic piston can be measured across the experimental volume, as well as the wave dynamics parallel to the background magnetic field.

## 210.04 – A Two-dimensional Multimode RM Experiment on OMEGA-EP

*Carlos Di Stefano*[1], *Guy Malamud*[1, 2], *Carolyn C. Kuranz*[1], *Sallee Klein*[1], *Michael Grosskopf*[1], *Paul Keiter*[1], *R. Paul Drake*[1]

*1. University of Michigan, Ann Arbor, MI, United States. 2. Nuclear Research Center - Negev, Beer-Sheva, Israel.*

The Richtmyer-Meshkov (RM) process occurs when a shock wave crosses an interface between two materials of different densities and deposits vorticity on it due to interface and/or shock-front structure, causing this initial structure to grow in time. This process also occurs when astrophysical shock waves cross density gradients. It has been suggested that RM is responsible for observed structure in the Tycho supernova remnant. Previous HED RM experiments using machined interfaces have examined only single-mode behavior, often in the regime of high Mach number and large amplitude, such that interaction between the RM spikes and the shock is significant. In the case of a multimode initial perturbation, the non-linear bubble-competition process is dominant. This causes the average wavelength of the perturbation to increase with time, and the width of the overall mixing zone to grow faster than in the case of a single-mode interface. At late time, the mixing-zone growth is theorized to become self-similar. Although there have been studies of RM using uncharacterized three-dimensional multimode perturbations, none of this previous work has examined the evolution of a well-characterized multimode interface and its spectral structure in the bubble-merger regime. In the present study, we discuss an experimental design, to be implemented on Omega EP, meant to measure two-dimensional multimode RM evolution at late times with well-characterized initial conditions. This work is funded by the NNSA-DS and SC-OFES Joint Program in HEDLP, by the NLUF in NNSA-DS and by the PSAAP in NNSA-ASC. The corresponding grant numbers are DE- FG52-09NA29548, DE-FG52-09NA29034, and DE-FC52-08NA28616.

# 211 – Outer Limits of the Milky Way II: Star Formation

## 211.01 – Star Formation Beyond the Solar Circle: A Survey of Surveys

*Charles R. Kerton*[1]

*1. Iowa State University, Ames, IA, United States.*

This talk will review and distill the results of major radio, infrared, and combined radio/IR, surveys that have focused on the identification and characterization of active regions of star formation in the outer Galaxy. These surveys reveal that, in terms of star formation activity, the Milky Way beyond the solar circle is not a vast wasteland, but rather it is an area containing numerous regions of star formation well placed for detailed individual study, for large-scale studies of star formation within spiral arms, and for comparative studies with star formation occurring in different environments such as the inner Galaxy and Galactic center.

## 211.02 – The BeSSeL Survey and the Outer Milky Way

*Alberto Sanna*[1], *Mark J. Reid*[2], *Karl Menten*[1]

*1. Max Planck Institute for Radio Astronomy, Bonn, Germany. 2. Harvard-Smithsonian CfA, Cambridge, MA, United States.*

*Contributing teams: BeSSeL Survey Team*

Astrometric Very Long Baseline Interferometry (VLBI) observations of maser sources in the Milky Way provide measurements of the trigonometric parallaxes and full space motions of massive star-forming regions throughout the Galactic disk. Currently, one can measure absolute parallaxes with accuracies of about 0.01 mas. This information can be used to map the spiral structure of our Galaxy and to constrain fundamental parameters such as the circular rotation at the Solar circle ($?_0$), rotation curve, and the distance to the Galactic center ($R_0$). Here, we review the measurement of about a hundred sources spread along the first three Galactic quadrants up to a heliocentric distance of 12 kpc. These parallaxes come from the *Bar and Spiral Structure Legacy* (BeSSeL) survey, a key project of the NRAO Very Long Baseline Array (VLBA), as well as from the Japanese VERA and European VLBI Network. This talk will focus on results for sources outside the Solar circle, including the Local, Perseus, and Outer arms of the Milky Way.

## 211.03 – Distant HII Regions in the Outer and Outer Scutum Centaurus Arms

*Loren D. Anderson*[1], *Thomas M. Bania*[2], *Dana S. Balser*[3], *Trey Wenger*[2]

*1. West Virginia University, Morgantown, WV, United States. 2. Boston University, Boston, MA, United States. 3. NRAO, Charlottesville, VA, United States.*

Galactic HII regions are the formation sites of massive OB stars and, as such, are the archetypical tracers of Galactic spiral structure. They are the brightest objects in the Galaxy at radio an infrared wavelengths and can be located across the entire Galactic disk. Therefore, we argue that HII regions are the best indicators of ongoing massive star formation in the outer Galactic disk. Here, I will discuss our efforts to identify distant HII regions using mid-infrared data from WISE or Spitzer, and to follow up with radio recombination line spectroscopic measurements with the Green Bank Telescope. In the first Galactic quadrant, we have found over 30 HII regions in the Outer Arm, and two in the Outer Scutum-Centaurus arm. Prior to our work almost nothing was known about massive star formation in this part of the Galaxy. The Outer Scutum-Centaurus arm detections are the most distant known Galactic HII regions, up to 24 kpc from he Sun and 17 kpc from the Galactic center. In the second and third Galactic quadrants, we have measured the recombination line emission from ~150 newly idenfified HII regions. We will discuss star formation rates and efficiencies in the outer Galactic disk, as well as the completeness of our census of massive star formation.

## 211.04 – Poster Sumaries II

*Barbara Whitney*[1]

*1. University of Wisconsin, Madison, WI, United States.*

Poster authors each have about 1 minute and 1 slide to advertise their posters, which will be presented on day 2 of the meeting. The afternoon of day 2 will be free for extensive discussions at the poster session!

## 212 – Computation as a Bridge between the Laboratory and Astrophysics

### 212.01 – Computation as a Bridge between the Laboratory and Astrophysics

*Robert Rosner[1], Fausto Cattaneo[1]*
*1. Univ. of Chicago, Chicago, IL, United States.*

Over the past decade, the many deep connections between terrestrial laboratory studies and astrophysics have been powerfully supported by modern numerical simulation: These calculations are able to make contact with modeling of both physically complex astrophysical phenomena and related phenomena observed in far greater detail in terrestrial laboratories. We will describe several examples that illustrate the power of numerical simulations to bridge laboratory and astrophysical studies.

# 213 – The X-ray Background and the Cosmic History of Black Hole Growth

## 213.01 – The X-ray Background and the Cosmic History of Black Hole Growth

*Guenther Hasinger[1]*

*1. University of Hawaii, Honolulu, HI, United States.*

The X-ray sky is dominated by a diffuse extragalactic background radiation, which was resolved almost completely into discrete sources using the X-ray satellites ROSAT, Chandra and XMM-Newton - we observe the growth phase of the population of supermassive Black Holes throughout the history of the Universe. Indeed, the mass distribution of Black Holes in local galaxies is well traced by the evolution of the accreting Black Hole luminosity function. However, the maximum of high-luminosity objects occurs significantly earlier in the history of the universe (at redshifts 2-3), than that of low-luminosity objects, which have a peak at redshifts below unity. This anti-hierarchical evolution is similar to the down-sizing effect observed in the optical galaxy population and requires different feeding modes in the early and late Universe. Galaxy mergers are likely responsible for the early growth of black holes and bulges, while a different feeding mode - the re-juvenation of Black Holes in galaxies by the accretion of fresh gas from their environment – may be responsible for the late evolution of both the star formation and AGN activity. This is also confirmed by spatial correlation analyses, showing that AGN up to redshifts of z=2 live in relatively massive, non-evolving dark matter haloes. Recently the excitement has shifted to even higher redshifts where the objects are so faint that again only studies of their integrated emission - the background - can be performed. At this new X-ray background frontier, a correlation between the unresolved emission observed by Chandra with the residual near-infrared background observed by the Spitzer space telescope has revealed a significant signal which may well be emission of the first generation of Black Holes in the Universe. Prospects for future development in this field will be discussed.

# 214 – WIYN Observatory - Building on the Past, Looking to the Future

## 214.01 – Wind Variability in BZ Cam

*R. K. Honeycutt[1], Styliani Kafka[2], Jeff W. Robertson[3]*
*1. Indiana Univ., Bloomington, IN, United States. 2. Carnegie Institute, Washington, DC, United States. 3. Arkansas Tech University, Russellville, AR, United States.*

Results from a long-term study of outflow from the nova-like cataclysmic variable (CV) BZ Cam are described. Spectroscopic data was acquired in 2005-2006 and photometry is available 1990-2012. The wind is concentrated in episodes lasting 15-45 min. The systematic evolution of the wind profiles during an episode are interpreted as due to the transverse component of wind motion across the disk. An orbital period of 0.15353(4) is derived, and is used to demonstrate that the wind episodes are concentrated near the times of superior conjunction of the secondary star. This orbital dependence of the wind, along with other evidence, argues that the radiation-driven wind receives an initial boost from the accretion stream/disk impact.

## 214.02 – The Shell-Shocked Interstellar Medium Near Cygnus X-1

*Paul Sell[1], Sebastian Heinz[1], Emily E. Richards[2], Dave Russell[3], Elena Gallo[4], Sera Markoff[3], Rob Fender[5], Michael Nowak[6]*
*1. The University of Wisconsin-Madison, Madison, WI, United States. 2. University of Indiana-Bloomington, Bloomington, IN, United States. 3. University of Amsterdam, Amsterdam, Netherlands. 4. University of Michigan, Ann Arbor, MI, United States. 5. University of Southampton, Southampton, United Kingdom. 6. Massachusetts Institute of Technology, Cambridge, MA, United States.*

We present observations of the outflowing shockwave north of the microquasar (X-ray binary with jets), Cygnus X-1. We use Westerbork Synthesis Radio, Chandra X-ray, and WIYN Hydra optical spectroscopic observations to probe the limb-brightened shell where the jet of the microquasar seems to be driving a parsec-scale shock into a nearby HII region. In particular, the unique ability of WIYN-Hydra to place fibers in specified positions in between stars in a relatively crowded, large field on the sky makes it a powerful instrument for carrying out these observations. We then compare our multiwavelength observations to the detailed MAPPINGSIII shock models to place the most robust constraints to date on the density and velocity of the outflow and the power needed to drive it. Our analysis of the jet driven outflow from this microquasar leads us to revisit our understanding of dominant physical mechanisms involved in jet-driven, parsec-scale shocks in the ISM.

## 214.03 – The WIYN Open Cluster Study: A 15-Year Report

*Robert D. Mathieu[1]*
*1. Univ. of Wisconsin, Madison, WI, United States.*
*Contributing teams: WOCS Collaboration*

The WIYN 3.5m telescope combines large aperture, wide field of view and superb image quality. The WIYN consortium includes investigators in numerous areas of open cluster research. The combination spawned the WIYN Open Cluster Study (WOCS) over a decade ago, with the goals of producing 1) comprehensive photometric, astrometric and spectroscopic data for new fundamental open clusters and 2) addressing key astrophysical problems with these data. The set of core WOCS open clusters spans age and metallicity. Low reddening, solar proximity and richness were also desirable features in selecting core open clusters. More than 50 WIYN Open Cluster Study papers have been published in refereed journals. Highlights include: deep and wide-field photometry of NGC 188, NGC 2168 (M35), and NGC 6819 (WOCS I, II, XI and LII); deep and wide-field proper-motion studies of the old open clusters NGC 188, NGC 2682 (M67) and NGC 6791 (WOCS XVII, XXXIII and XLVI); comprehensive radial-velocity surveys of NGC 188, NGC 2168 and NGC 6819 (WOCS XXXII, XXIV, and XXXVIII); metallicity and lithium abundances in NGC 2168 (WOCS V); comprehensive definition of the hard-binary populations of NGC 188 and NGC 2168 (WOCS XXII and XLVIII); rotation period distributions in NGC 1039 (M34) and NGC 2168 (WOCS XXXV, XLIII, and XLV); study of chromospheric activity in NGC 2682 (WOCS XVIII); photometric variability surveys in NGC 188 and NGC 2682 (IX and XV); new Bayesian techniques for determination of cluster parameters (WOCS XXIII); a new infrared age-diagnostic for open clusters (WOCS XL); theoretical studies of stellar rotation (WOCS XIII and XIV); sophisticated N-body simulations of NGC 188 (WOCS LI); and the discovery of a high binary frequency and white dwarf companions among NGC 188 blue stragglers. While the WIYN 3.5m telescope remains at its heart, today the WIYN Open Cluster Study collaboration extends beyond both the WIYN observatory and consortium, and continues as a vital and productive exploration into these fundamental stellar systems. Publication list can be found at http://www.astro.ufl.edu/~ata/wocs/pubs.html. The WIYN Open Cluster Study has been continuously supported by grants from the National Science Foundation.

## 214.04 – WIYN Open Cluster Study: Radial Velocity Membership of the Evolved Population of Open Cluster NGC 6791

*Benjamin M. Tofflemire[1], Natalie M. Gosnell[1], Robert D. Mathieu[1]*
*1. University of Wisconsin - Madison, Madison, WI, United States.*

The open cluster NGC 6791 has been the focus of much recent study due to its intriguing combination of old age and high metallicity (~8 Gyr, [Fe/H]=+0.30), and its location within the Kepler field. As part of the WIYN Open Cluster Study (WOCS), we present precise (~0.5 km/s) radial velocities for proper-motion candidate members of NGC 6791 from Platais et al. 2011. The WIYN 3.5m telescope and Hydra Multi-Object Spectrograph offer the ideal facility for making definitive cluster membership measurements via radial velocities. Our survey, extending down to V~16.5, probes the evolved cluster population, including blue straggler and horizontal branch (HB) candidates. Of the 156 proper-motion selected stars above our magnitude limit, all have at least one radial-velocity measurement and 82% have three measurements, sufficient for secure radial-velocity-determined membership of non-velocity-variables. The Platais et al. 2011 proper-motion catalog includes twelve HB candidates, of which we find only four to be cluster members. Three fall slightly blueward of the red clump and the fourth confirms membership of a blue-HB star from Green and Liebert 1996. This star is also consistent with being a blue straggler. We will include an analysis of the evolved cluster membership and identify radial-velocity-variable objects. Support for this program is provided by NSF grant AST-0908082.

## 214.05 – Surface Abundances of NGC 188 Blue Stragglers as a Clue to Formation History

*Katelyn Milliman[1], Robert D. Mathieu[1], Simon C. Schuler[2]*
*1. University of Wisconsin-Madison, Madison, WI, United States. 2. University of Tampa, Tampa, FL, United States.*

Studies of the old open cluster NGC 188 have discovered a blue straggler binary frequency nearly three times the binary fraction of main-sequence stars, and a secondary mass distribution peaking at 0.5 solar masses for long-period blue stragglers. These features suggest that asymptotic giant branch mass transfer in binary stars dominates the production of blue stragglers in open clusters. However, sophisticated N-body simulations point toward stellar collisions being the dominant formation process. These two mechanisms are expected to result in measurably different blue straggler surface abundances. Blue stragglers resulting from stellar collisions of main-sequence stars are predicted to retain roughly the same surface abundance as the more massive star in the collision. On the other hand, blue stragglers formed by mass transfer from an evolved companion will have a surface abundance altered by the nucleosynthesis that occurred within the evolved donor star. We present first results of a surface abundance study of 21 blue stragglers in NGC 188 using the Hydra multi-object spectrograph on the WIYN 3.5 m telescope. These results include measurements of barium, oxygen, and carbon and offer a clue to the formation history of blue stragglers in open clusters. We gratefully acknowledge funding from the National Science Foundation under grant AST-0908082.

## 214.06 – Radial Velocities of Three Relatively Unstudied Open Clusters

*Christian R. Hayes[1], Eileen D. Friel[1]*
*1. Indiana University, Bloomington, IN, United States.*

We present radial velocities for stars in the field of the open star clusters Berkeley 44, Berkeley 81, and NGC 6802 from spectra obtained using the Wisconsin Indiana Yale NOAO (WIYN) 3.5m telescope. These open clusters are of intermediate age (1-3 Gyr), located within the solar Galactocentric radius, and are relatively unstudied, with no previous radial velocity measurements. For Berkeley 44, we found 32 potential members out of 50 stars with a mean radial velocity of -9.6 ± 3.0 km/s (standard deviation). For Berkeley 81, we found 17 possible cluster members out of 46 stars with a mean radial velocity of 48.1 ± 2.0 km/s. For NGC 6802, we found 25 possible members out of 36 stars with a mean radial velocity of 12.4 ± 2.8 km/s. In addition we present an analysis of the kinematics of 134 open clusters (with ages from a few Myr to some of the oldest open clusters on the order of 10 Gyr) using data obtained in this study and from the literature.

## 214.07 – Deep Near-infrared Photometry of Little-studied Old Open Clusters

*Zachary Catlin[1], Eileen D. Friel[1], Heather R. Jacobson[2]*
*1. Indiana University, Bloomington, IN, United States. 2. Massachusetts Institute of Technology, Cambridge, MA, United States.*

Open clusters, especially those older than 1 Gyr, serve as probes of the Galaxy's

chemical and dynamical history. We present JHK photometry of a number of known or suspected old open clusters near the galactic plane, obtained using the WHIRC near-infrared imager on the WIYN 3.5-m telescope, with a focus on newly-identified or little-studied clusters. This photometry extends well into the main sequence for many of the clusters and is several magnitudes fainter than the corresponding 2MASS data, and allows for more accurate determination of cluster age, distance, and metallicity.

## 214.08 – A Study of Evolved Stars in the Open Cluster NGC 7789

*Jamie C. Overbeek[1], Eileen D. Friel[1], Heather R. Jacobson[2], Catherine A. Pilachowski[1]*
*1. Astronomy, Indiana University, Bloomington, IN, United States. 2. MIT, Cambridge, MA, United States.*

We present an analysis of a large sample of evolved stars in the open cluster NGC 7789 based on data from the Hydra multi-object spectrograph on the Wisconsin Indiana Yale NOAO (WIYN) 3.5m telescope. High-resolution spectra over the region ~6050-6400Å have been measured for radial velocities and abundances. The 34 determined cluster members have an average heliocentric radial velocity of -55.0±3.0 km/s, and measured iron abundances give an <[Fe/H]> of -0.15±0.1 in good agreement with Pilachowski (1985). We have investigated the effects of two different line lists – one used in previous studies based on astrophysical log(gf) values derived from Arcturus, and another with laboratory-derived log(gf) values being used in the GAIA-ESO spectroscopic survey – on the determination of stellar parameters $T_{eff}$, log(g), microturbulent velocity, and [Fe/H]. This large sample of members will allow us to investigate the level of intrinsic abundance variations and trends in abundance of light elements with evolutionary state among the red giants in the cluster.

## 214.09 – A Kinematical Study of M13

*Maria J. Cordero[1], Catherine A. Pilachowski[1], Christian I. Johnson[2], Constantine P. Deliyannis[1]*
*1. Indiana University, Bloomington, IN, United States. 2. University of California at Los Angeles, Los Angeles, CA, United States.*

We investigate the kinematics of a sample of ~200 red giant stars in the globular cluster M13 using moderate-resolution WIYN-Hydra spectra with published chemical abundances. Hydrodynamical simulations show that globular clusters form multiple generations with a characteristic chemical imprint and internal kinematical differences. For instance, a second generation, which is Na-enhanced and O-depleted, rotates more rapidly and is more centrally concentrated than its progenitor in the early stages of a globular cluster. These initial differences can be smoothed by two-body interactions in old globular clusters. Despite its old age, M13 has a centrally concentrated O-depleted population. The aim of this study is to assess for the first time whether different stellar populations in M13 present kinematical differences.

## 214.1 – Kinematics of the Globular Cluster System of the Sombrero Galaxy

*Jessica L. Windschitl[1], Katherine L. Rhode[1], Terry J. Bridges[2], Stephen E. Zepf[3], Karl Gebhardt[4], Kenneth C. Freeman[5]*
*1. Indiana University, Bloomington, IN, United States. 2. Queen's University, Kingston, ON, Canada. 3. Michigan State University, East Lansing, MI, United States. 4. University of Texas at Austin, Austin, TX, United States. 5. Australian National University, Mount Stromlo Observatory, Weston Creek, ACT, Australia.*

Using spectra from the Hydra spectrograph on the 3.5m WIYN telescope and from the AAOmega spectrograph on the 3.9m Anglo-Australian Telescope, we have measured heliocentric radial velocities for >50 globular clusters in the Sombrero Galaxy (M104). We combine these new measurements with those from previous studies to construct and analyze a total sample of >360 globular cluster velocities in M104. We use the line-of-sight velocity dispersion to determine the mass and mass-to-light ratio profiles for the galaxy using a spherical, isotropic Jeans mass model. In addition to the increased sample size, our data provide a significant expansion in radial coverage compared to previous spectroscopic studies. This allows us to reliably compute the mass profile of M104 out to ~43 kpc, nearly 14 kpc farther into the halo than previous work. We find that the mass-to-light ratio profile increases from the center to a value of ~20 at 43 kpc. We also look for the presence of rotation in the globular cluster system as a whole and within the red and blue subpopulations. Despite the large number of clusters and better radial sampling, we do not find strong evidence of rotation.

## 214.11 – Deep Halpha Imaging of Nearby Starbursting Dwarf Galaxies

*Liese van Zee[1], Kristen B. McQuinn[2], Evan D. Skillman[2], Patricia L. Moravec[1]*
*1. Indiana Univ., Bloomington, IN, United States. 2. University of Minnesota, Minneapolis, MN, United States.*

We present results from new deep Halpha imaging observations of nearby starbursting dwarf galaxies with the WIYN 3.5m, KPNO 4m, and Bok 2.3m telescopes. We highlight the advantages of superb seeing conditions and throughput of pODI on the WIYN 3.5m telescope. Our observations are designed to detect faint ionized gas outflows and allow us to compare directly the luminosity and structure of the ionized gas with the spatial and temporal distribution of recent star formation activity. We discuss the nature and extent of the diffuse Halpha emission in these systems and the implications for mass loss via galactic winds in low mass galaxies.

## 214.12 – Optical Imaging of Extended Star Formation in Nearby Spiral Galaxies with the One Degree Imager

*Jenna E. Ryon[1], Ralf C. Kotulla[2], John S. Gallagher[1]*
*1. University of Wisconsin - Madison, Madison, WI, United States. 2. University of Wisconsin - Milwaukee, Milwaukee, WI, United States.*

We present initial results from a deep u and i-band imaging campaign using the One Degree Imager (ODI) on the WIYN 3.5-m telescope. We obtained images of several galaxies known to harbor extended regions of star formation beyond their optical disks, including NGC 2146, NGC 2403, NGC 2841, NGC 4254, and NGC 5055. We investigate the stellar component of these extended star-forming regions on large (>1 kpc) and small (~50 pc) scales. We will compare the large-scale spatial structures, e.g. spiral arms or tidal features, found in our optical images to those found in GALEX UV images. Because we reach a finer resolution (0.8-1.2') as compared to the GALEX PSF, we will also determine the properties of small-scale structures, e.g. star clusters or individual stars, that exist in extended star-forming regions.

## 214.13 – The Evolutionary Status of Blue Compact Dwarf Galaxies: I. Surface Photometry

*Steven Janowiecki[1], John J. Salzer[1]*
*1. Indiana Univesity, Bloomington, IN, United States.*

We are interested in the role and context of Blue Compact Dwarf Galaxies (BCDs) in dwarf galaxy evolution, in particular whether all gas-rich dwarf galaxies could evolve to or from a BCD-like phase, or if BCDs are truly a distinct type of dwarf galaxy, even when they are not starbursting. For our sample of 20 BCDs, we use multi-wavelength photometry to construct Spectral Energy Distributions from the UV to IR which we fit with models to determine physical properties and star formation histories. We also use our deep, high-resolution observations in the B and H filters to probe the structure of the starburst and underlying host galaxy. We fit and decompose the surface brightness profiles in multiple filters and compare the host structure to other dwarf galaxies. We find that the host galaxies of BCDs have brighter central surface brightnesses and smaller exponential scale lengths than ordinary dwarf irregulars, favoring the idea that BCDs are a distinct type of galaxy rather than a phase common to all gas-rich dwarf irregulars.

## 214.14 – Probing Galaxy Evolution with Spatially Resolved Spectral Energy Distribution (SED) Fitting Techniques

*John S. Gallagher[1], Ralf C. Kotulla[2]*
*1. Univ. of Wisconsin, Madison, WI, United States. 2. University of Wisconsin, Milwaukee, WI, United States.*

The morphology of a galaxy and the stellar populations within it are both closely linked to its past evolutionary history. Combining these two aspects therefore allows a more detailed investigation of the physical processes that govern galaxy evolution than obtained from an analysis based only on the colors of the stellar population. We present results of a prototype study fitting multi-wavelength photometry of galaxies pixel-by-pixel, allowing us to compute maps of stellar population physical properties that can typically be derived via SED fitting in combination with fits to surface brightnesses. These maps allow us to investigate the spatial correlation between physical parameters, such as stellar mass densities, star formation rate densities and dust extinctions. We will present preliminary examples from our study based on imaging with the WIYN telescopes demonstrating the power of this approach.

## 214.15 – The ALFALFA H? Survey

*Angela Van Sistine[1], John J. Salzer[1], Steven Janowiecki[1], Arthur Sugden[2], Martha P. Haynes[3], Riccardo Giovanelli[3], Eric M. Wilcots[4]*
*1. Indiana University, Bloomington, IN, United States. 2. Brown University, Providence, RI, United States. 3. Cornell University, Ithaca, NY, United States. 4. University of Wisconsin, Madison, WI, United States.*

The ALFALFA H? survey uses a volume-limited sample of HI-selected galaxies from the ALFALFA survey to study star formation in the local universe. When complete, this survey will have narrow-band H? images of over 1500 HI-selected galaxies with velocities between 1500 km/s and 7500 km/s. ALFALFA detects galaxies with HI masses as low as ~3x10^7 M_sol in our survey volume, probing well into the flat portion of the HI mass function. With our unique data set we are able to study star formation in a sample of galaxies selected to be capable of making stars and are unbiased to the optical properties of the galaxies. Our primary science goal is to produce the best possible measurement of the local star-formation rate density. We also use our data set to study star formation as a function of galaxy environment and compare UV and H? star-formation rates (using GALEX). The ALFALFA H? survey is ongoing, but is complete in the fall sky. Here we present an overview of the entire survey and results based on the fall sample.

## 214.16 – Optical Imaging of HI-selected Local Group Galaxy Candidates with pODI

*Elizabeth A. Adams[1], John M. Cannon[2], Riccardo Giovanelli[1], Martha P. Haynes[1], Ricardo Munoz[3], Katherine L. Rhode[4], John J. Salzer[4]*

*1. Cornell University, Ithaca, NY, United States. 2. Macalester College, St. Paul, MN, United States. 3. Universidad de Chile, Santiago, Chile. 4. Indiana University, Bloomington, IN, United States.*

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 Group. 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 Group (Adams et al. 2013). At distances of ~1 Mpc, the UCHVCs have HI masses of ~10^5 Msun and indicative dynamical masses of ~10^7 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. We are undertaking an imaging campaign using pODI on the WIYN 3.5m telescope to search for resolved stellar counterparts to these UCHVCs. The central coverage region of pODI is well matched to the HI size of the UCHVCs and the outlying detectors allow a constraint on foreground and background contamination. Our g'- and i'-band observations allow us to probe to ~1.5 magnitude below the tip of the red giant branch out to distances of ~1 Mpc. We present preliminary results from the broadband imaging and discuss constraints on the stellar population of these objects. This work has been supported by NSF grants AST-0607007 and AST-1107390, grants from the Brinson Foundation, and a NSF GRFP.

## 214.17 – Stellar Populations of Quasar Host Galaxies Using WIYN

*Gregory Mosby[1], Emily Moravec[2], Ralf C. Kotulla[3]*

*1. University of Wisconsin, Madison, Madison, WI, United States. 2. St. Olaf College, Northfield, MN, United States. 3. University of Wisconsin, Milwaukee, Milwaukee, WI, United States.*

We now know that most galaxies have supermassive black holes (SMBH) in their centers, and somewhat unexpectedly, there are relationships—such as the M-sigma relation—between the mass of the central black hole and the velocity dispersion of the host galaxy's stellar spheroid (bulge), even though they lie outside the black hole's influence. Galaxy merger models show reasonable evidence for coevolution of the bulge and black hole since the merging process initiates simultaneous growth of the black hole and galaxy by supplying gas to the nucleus for accretion onto the black hole and triggering bursts of star formation. The merging process truncates the growth of both by removing the gas reservoir via feedback from these processes. But recently, it's been shown that this relation could arise from central limit-like arguments alone. To really judge connections between SMBH and their host, it's crucial to study these galaxies at the peak of black hole growth—during the quasar phase. Using 3-d spectroscopy methods, namely Sparsepak, an integral field units (IFU) on WIYN, it is possible to successfully recover information about the host galaxy's integrated star formation history that can be used to check merger-induced galaxy evolution predicted by the models. However, it is critical to have a robust and careful analysis of the stellar population modeling. The research presented in this poster focuses on new results from Sparsepak and preliminary WHIRC H-band light profiles of select quasar host galaxies. The stellar populations are derived using a new statistical method called diffusion k-means, and the WHIRC data are analyzed using a Python code written by Ralf Kotulla.

## 214.18 – Gas and Galaxies in the Cosmic Web: A WIYN/HYDRA Galaxy Redshift Survey around HST/COS Target Sight Lines

*Brian A. Keeney[1], John T. Stocke[1], David Syphers[1], Helen Yamamoto[1], Bart P. Wakker[2], Blair D. Savage[2], Steven V. Penton[1, 3], James C. Green[1]*

*1. Univ. of Colorado, Boulder, CO, United States. 2. Univ. of Wisconsin, Madison, WI, United States. 3. STScI, Baltimore, MD, United States.*

The unprecedented far-UV throughput of the Cosmic Origins Spectrograph (COS) is revolutionizing studies of the local intergalactic medium (IGM). In particular, COS is allowing us to refine estimates of the baryon content and metallicity of the IGM, as well as the relationship of IGM absorbers to galaxies. For the past several years we have been using WIYN/HYDRA to obtain spectra of all galaxies brighter than g=20 that are within 20 arcminutes of the ~25 AGN targeted by the COS Science Team that are accessible from the northern hemisphere. When combined with the COS spectra of these AGN, this galaxy redshift survey is enhancing our understanding of the composition and topology of the nearby Universe in both gas and galaxies, allowing us to assess the extent of metal transport away from galaxies, the filling factor of gas and metal-enriched gas in galaxy filaments, and the metallicity of gas in galaxy voids. Here we present estimates of the completeness of our survey along these sight lines and examples of close galaxy-absorber associations discovered by our survey.

## 214.19 – Broad- and Narrow-Band Wide-Field Imaging with pODI

*John J. Salzer[1], Steven Janowiecki[1]*

*1. Indiana University, Bloomington, IN, United States.*

We present preliminary results of two distinct 'science verification' observing programs that make use of the pODI instrument on the WIYN 3.5m telescope. This new camera covers a ~0.2 square degree field of view, has a fine pixel scale (0.11'/pixel), and delivers excellent image quality across the entire one-degree field. The first program consisted of observations of an extremely low HI-mass object to search for an optical counterpart (using gri filters) and signs of current star formation (using an H? filter). This object was detected in 21-cm HI emission by the ALFALFA survey and appears as a blue low-surface-brightness galaxy in our deep observations. Second, we have used multiple narrow-band filters to carry out wide field surveys for emission-line sources at various redshifts. We surveyed fields with existing spectroscopic follow-up (COSMOS, DEEP2) and also new fields to detect previously unknown emission-line sources at high redshift. Finally, we demonstrate our use of the ODI Pipeline Portal and Archive system in customizing the reduction and performing some of the data analysis in these projects.

## 214.2 – Imaging Main Belt Comets and Asteroids with the WIYN pODI Camera

*Jayadev Rajagopal[1], David Jewitt[2], Susan E. Ridgway[1]*

*1. NOAO, Tucson, AZ, United States. 2. UCLA, Los Angeles, CA, United States.*

The 3.5 m WIYN telescope on Kitt Peak has just commissioned the partial One Degree Imager (pODI), an instrument that promises high quality wide-field imaging. To demonstrate the capabilities of this new camera, we obtained deep, wide-field images of Main Belt Comets (asteroids which show transient, comet-like morphologies resulting from significant mass loss). We present initial results from two such targets, P/2010 A2 and 300163. The data, although preliminary, demonstrate the advantages of the sharp images and large field offered by pODI. The full extent of the A2 tail is revealed for the first time and we have begun to study deep images of other asteroids in the field. The latter is the first step in a main thrust of our program, to look for evidence of pervasive low-level activity in main belt asteroids.

## 214.21 – A Fast On-the-fly Data Reduction Pipeline for Rapid Inspection of pODI Data

*Ralf C. Kotulla[1]*

*1. University of Wisconsin - Milwaukee, Milwaukee, WI, United States.*

*Contributing teams: One Degree Imager Commissioning Working Group*

I present a fast data reduction software for pODI, optimized for a first data inspection during acquisition at the the telescope. The pipeline is coded in pure python with minimal additional requirements. It is installed on the ODI observer's interface and publicly available from the author's webpage. It performs all basic reduction steps including overscan subtraction, bias- and dark-correction and flat-fielding, making use of multiple CPU-cores wherever possible, resulting in an execution time of only a few seconds per frame. Additional capabilities include adding an accurate WCS solution based on the 2MASS reference system as well as photometric zeropoints for frames covered by the SDSS foot-print. As such this quickreduce pipeline offers the ODI observer a convenient way to closely monitor data quality, a necessity to optimize the observing strategy during the night.

## 214.22 – pODI at WIYN: Instrument Performance and

## Upgrade Path

*Daniel R. Harbeck[1], Todd A. Boroson[2], Jayadev Rajagopal[2]*
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*Contributing teams: ODI Team, PPA Team*

A preliminary version of the WIYN One Degree Imager (ODI) has been commissioned throughout the semester 2012B, and has been put into scientific operation February 2013. ODI was devised to take advantage of the excellent image quality and wide field of view of the WIYN 3.5m telescope. To further improve delivered image quality, ODI uses Orthogonal Transfer Array (OTA) detectors that have the capability to electronically correct for image motion in the detectors during an exposure. The partial ODI (pODI) populates 13 out of the 64 OTAs in the focal plane, and coherent image motion correction is enabled. The 13 OTAs are configured as a 24 x 24 arcminute central "science field", plus 4 outer OTAs, allowing the sampling of all radii within the one square degree field. Guide star signals from the outer detectors are either directed to the telescope only, or additionally used to calculate a global, coherent shift correction that is sent to the OTAs. The performance of pODI is excellent. Image quality is site seeing limited, and, on good seeing nights, we can achieve images around 0.4 arcsec FWHM over the entire field. We are still in the process of characterizing the gains from active image motion correction, but the detectors perform well in this mode. Data are immediately transferred to an archive at Indiana University, where they are pipeline-processed to remove instrumental signature. In this poster we summarize the current performance of the pODI instrument and outline a path towards a future, expanded version of ODI with a 6x6 central detector array, or a field of view of 48 x 48 arcminutes.

## 214.23 – The Contributions of the WIYN Telescope to Advanced Degrees

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Over its nearly 20 year history the WIYN telescope has provided crucial data for numerous masters and doctoral degrees at the partner institutions (University of Wisconsin-Madison, Indiana University, and Yale University) plus others who access the telescope via national time from NOAO. The topics of this work range widely; e.g., single and binary stars, galaxy stellar populations and kinematics, large scale structure, etc. Students have made wide use of WIYN's long established suite of facility instruments, which currently includes the Hydra multi-object fiber spectrograph, the SparsePak integral field unit fiber spectrograph, and the WHIRC near-infrared imager. In addition, the new large format imager pODI is entering shared risk science observations; graduate students are already planning dissertation work that will utilize it.

# 215 – AGN, QSO, Blazars

## 215.01 – Reddening and Absorption in Mrk 231

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Mrk 231 is the nearest ultraluminous infrared galaxy. It has the optical spectrum of a quasar with a well-known broad absorption line complex observed in NaID. We present new IRTF and MDM TIFKAM near-infrared, and KPNO optical spectra of Mrk 231. The near-IR spectra reveal HeI*?10830 broad absorption lines, similar in shape and depth to the well-known NaID absorption, including components with outflow velocities of ~4500, 6000, and 8000 km/s. The 4500 km/s component has a flat bottom, similar to NaID, suggesting fill-in by red supergiant emission associated with the 100-300 Myr old starburst contributing to the short wavelengths in the KPNO spectrum. The starburst appears to be resolved on the scale of the slit width, making the precise depth difficult to determine. While the low-velocity side of the 4500 km/s component matches that of NaID, the high-velocity side is about ~350 km/s faster. The KPNO spectrum includes the well-known HeI*?3889 and CaII components at ~4500 km/s, although the HeI* feature is broader and lies at a higher velocity (~70 km/s) than the CaII lines. Subtracting the starburst emission reveals the higher velocity components at 6000 and 8000 km/s in HeI*?3889 as well. Partial covering analysis of CaII H&K lines results in a covering fraction of ~80% for the principal absorption component. However, the depth of the HeI*?10830 precludes step-function partial covering, and an inhomogeneous absorber is required. The unusually steep extinction observed in the near-UV is simply explained by scattering in a dust shell rather than in a slab in the line of sight, and is modelled using $A_V$~1.5 and Milky Way scattering and absorption opacities. After making these corrections, the near-UV through near-IR spectral energy distribution resembles that of an ordinary quasar with an enhanced hot dust continuum. Additional results will be presented.

## 215.02 – An Exceptional Radio Flare in Markarian 421

*Joseph Richards[1], Talvikki Hovatta[2], Tuomas Savolainen[3], Matthew L. Lister[1], Anthony C. Readhead[2], Margo F. Aller[4], Hugh D. Aller[4], Lars Fuhrmann[3], Emmanouil Angelakis[3], Marcello Giroletti[5]*

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In September 2012, the high-spectral-peaked (HSP) blazar Mkn 421 underwent a rapid wideband radio flare, reaching nearly twice its brightest level in over three decades of monitoring by the University of Michigan Radio Astronomy Observatory (UMRAO). Rapid radio variations are unprecedented in this object and are surprising in an HSP BL Lac object. In this flare, the 15 GHz flux density measured by the Owens Valley Radio Observatory (OVRO) blazar monitoring program increased by about a factor of two with an exponential doubling time of about 9 days, comparable with the fastest large-amplitude cm-band radio variability observed in any blazar. Similar increases were detected at radio frequencies up to mm-band by the F-GAMMA program. This radio flare followed about two months after a similarly unprecedented GeV gamma-ray flare (reaching a daily E>100 MeV flux of (1.2+/-0.7)x10^-6 ph cm^-2 s^-1) reported by the Fermi collaboration, which was accompanied by a tentative near-simultaneous TeV detection by ARGO-YBJ. In response to this radio flare, we carried out a five epoch cm- to mm-band multifrequency Very Long Baseline Array (VLBA) monitoring campaign to investigate possible changes in parsec-scale kinematics, structural variations, and polarization behavior in the aftermath of this emission event. Preliminary results show significant brightening in the compact core region. The OVRO 40-m monitoring program is supported in part by NSF grants AST-0808050 and AST-1109911, and NASA grants NNX08AW31G and NNX11A043G. UMRAO was supported in part by NSF grant AST-0607523, and NASA Fermi GI grants NNX09AU16G, NNX10AP16G, and NNX11AO13G. Funds for operation of the UMRAO were provided by the University of Michigan. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

## 215.03 – Interpretation of Blazar Micro-Variability as Turbulent Jets

*James R. Webb[1], Douglas Laurence[1], Gopal Bhatta[1], Sarah M. Dhalla[1], Olga Harrington[1]*

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We present a model for Blazar Micro-variability where the rapid, low amplitude fluctuations are the result of a shock passing through a turbulent section of the relativistic jet. As the shock encounters the turbulent cells, the plasma in the cells is accelerated and emit a pulse of Synchrotron emission. We show several well sampled micro-variability curves de-convolved and out model applied to determine the distribution of cell sizes and other physical parameters of of the turbulent flow.

## 215.05 – Quasar Composite Spectra With BOSS

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The Baryon Oscillation Spectroscopic Survey (BOSS) has collected over 100,000 $z>2$ quasar spectra since 2009. Using this unprecedented sample, we have created a composite spectrum at a signal-to-noise ratio of well over 500 per pixel. Using subsamples of BOSS spectra, we have also generated composite quasar spectra binned by luminosity and redshift. We present an analysis of quasar evolution, systematic lineshifts with luminosity, and line equivalent widths from these composite spectra.

## 215.06 – X-ray Emission from Black Holes at the Centers of Nearby Dwarf Galaxies

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As part of a search for intermediate-mass black hole candidates in the local universe, we have assembled a new sample of nearby ($d$ < 80 Mpc) AGNs in dwarf galaxies with stellar masses less than $10^{10}$ $M_?$. Collectively, these 28 objects are the least massive galaxies known to contain central black holes. Surprisingly, only two of them show clear evidence of broad emission lines in their optical spectra, indicating a much higher incidence of narrow-line (type 2) AGNs in our low-mass sample than in samples of classical Seyfert galaxies. There are two possible explanations for this. First, our objects may have the same basic structure as luminous Seyfert galaxies but a higher probability that their broad-line regions (BLRs) are obscured along the line of sight (e.g., due to a larger covering factor of the nuclear torus). Alternatively, theoretical work suggests that the BLR becomes increasingly difficult to detect (or may even cease to exist) as luminosity or black-hole mass decreases. Some of our objects, if they are in the relevant mass/luminosity range, could actually be unobscured. To investigate which scenario is more plausible, we have observed a subset of 8 galaxies from our sample with *Chandra* and *XMM-Newton*. We find that the ratios of their observed X-ray luminosities and their [O III] emission-line luminosities are very low compared to the intrinsic ratios measured for luminous AGNs, suggesting that our objects are heavily absorbed. Consistent with this conclusion, one well-detected object (NGC 4117) has a typical Seyfert 2 X-ray spectrum with an absorption column density of $N_H$ ? 4 × $10^{23}$ $cm^{-2}$. However, the modest spectral evidence available for the remaining objects indicates that their observed X-ray emission is extremely soft, which is not expected in the absorption scenario. We note, though, that the weak fluxes of the soft-spectrum objects ($L_X$ ? $10^{38}$–$10^{39}$ erg $s^{-1}$) could easily be associated with sources in the host galaxy (e.g., diffuse hot gas), leaving open the possibility that the active nuclei are in fact heavily absorbed.

## 215.07 – Statistical Analysis of the Long Baseline Variability Properties of a Large Gamma-Ray Selected Blazar AGN Sample

*Chris R. Shrader[1]*

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The Fermi Gamma-Ray Space Telescope has cataloged over 1800 gamma-ray (>100 MeV) point sources of which more than 1100 are identified with AGN. These AGN, and a large number of unidentified high-latitude objects of which a large fraction are also likely AGN, are predominantly representative of the radio-loud “blazar” subclass. The emission from these objects is well known to be beaming dominated and is almost always variable, often exhibiting high-amplitude flaring. To date there have been numerous studies of individual objects including multi-wavelength campaigns in some cases including parsec-scale radio jet morphological study. Collectively, this has led to new insight in to our understanding of the blazar phenomena and jet propagation in general. However, there remains a dearth of information on the collective variability characteristics of the population as a statistical ensemble. What, for example, are the distributions of flare amplitudes, durations, temporal profiles and recurrence histories among the gamma-ray blazar subclasses? Given the unprecedented sky coverage of

Fermi – the full sky is observed approximately every two orbits leading to an approximate one part in 6 monitoring duty cycle for any point on the sky – we have begun to explore this issue. A light curve database compiled and maintained (weekly) by the Fermi Science Support Center contains flux histories for every source in the Fermi 2FGL catalog. In this contribution, we present our analysis of the statistical properties of the high-latitude component of this light curve database.

## 215.08 – Highlights from the VERITAS Blazar Observation Program

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*Contributing teams: VERITAS Collaboration*

The Very Energetic Radiation Imaging Telescope Array System (VERITAS) is an array of four 12-meter imaging atmospheric Cherenkov telescopes located in southern Arizona. VERITAS devotes a major portion of its observing budget to active galactic nuclei (AGNs), and has detected 24 of them at at very-high-energies (VHE; E >100 GeV). In Summer 2012, the cameras of VERITAS were successfully upgraded, decreasing the energy threshold of observations and increasing the array sensitivity. VERITAS continues to detect VHE AGNs and the collaboration has a large emphasis on acquiring significant multi-wavelength observations. These efforts ensures the production of exciting scientific results revealing the nature of these sources, their emission mechanism, jet physics, and the density of extra-galactic background light. Recent observational results for AGNs from the VERITAS Collaboration will be presented.

## 215.09 – MOJAVE: Parsec-Scale Kinematics Analysis of AGN Jets from 1994 to 2011

*Matthew L. Lister[1]*
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*Contributing teams: MOJAVE Collaboration*

We present a kinematics analysis of 200 parsec-scale radio jets associated with AGNs, based on 15 GHz VLBA data obtained between 1994 Aug 31 and 2011 May 1. The jets were drawn from complete samples of gamma-ray and radio-selected AGNs, and also include a set of lower-luminosity jets associated with radio galaxies that are viewed at larger angles to the line of sight. We have identified and tracked nearly 900 well-defined moving jet features, one third of which had sufficient epochs to define their acceleration properties. We confirm our previous result that accelerations parallel to the velocity of jet features are larger on average than perpendicular accelerations, indicating that changes in the Lorentz factors of the features, rather than simple jet bending, are required to explain much of the observed accelerations. We have examined the vector motion directions and apparent velocities of features within individual jets, and find a significant spread in these quantities. In general, for each jet, there is typically a characteristic speed at which new features emerge, with a moderately large dispersion about that value. In some jets, subsequent features emerge at progressively increasing sky position angles, implying that at any given time, only a portion of the full, broad jet outflow is sufficiently energized to produce detectable compact synchrotron radiation. The inferred spread in viewing angle is insufficiently large, however, to fully account for the distribution of apparent speed, implying that features in an AGN jet also have a moderate range of bulk Lorentz factors. The distribution of characteristic jet speeds in our sample spans a large range, ranging from 38 c for the fastest quasar feature, to subluminal apparent velocities for the lower power radio galaxies.

## 216 – The ISM and Objects Therein

### 216.01 – Si IV Column Densities Predicted from Non-Equilibrium Ionization Simulations of Turbulent Mixing Layers and High-Velocity Clouds

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We present the column densities of Si IV predicted from hydrodynamic simulations of turbulent mixing layers (TMLs) and high velocity clouds (HVCs). By using non-equilibrium ionization calculations, we traced the ionization states of silicon at each hydrodynamic time step in the simulations. The Si IV ions become abundant in the mixed gas that forms via mixing of cool cloud gas with hot ambient gas. Most of our TML models underpredict low-velocity Si IV column densities so that multiple layers are required to explain the observed column densities. However, the high-velocity Si IV column densities predicted from our HVC simulations overlap the observed ones. The ratios between the Si IV column densities presented here and the C IV and O VI column densities presented in Kwak & Shelton (2010) and Kwak et al. (2011) for the same hydrodynamic models are generally in better agreement with observations than are predictions from other models such as thermal conduction and shock heating. In time, the mixed material decelerates to the speed of the environmental gas and may contribute to the numbers of high ions observed at normal velocities in the Milky Way's halo. Following Henley et al. (2012), we estimate contributions to the observed normal-velocity high ions in the halo from four scenarios including decelerated HVC gas, extraplanar supernova remnants, galactic fountains, and photoionization by external radiation fields. We find that additional processes that produce more Si IV ions relative to other high ions are required in order to account for all of the observed normal-velocity Si IV ions in the halo.

### 216.02 – Detecting the Rapidly Expanding out Shell of the Crab Nebula: Where to Look

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We present a range of steady-state photoionization simulations, corresponding to different assumed shell geometries and compositions, of the unseen postulated rapidly expanding outer shell to the Crab Nebula. The properties of the shell are constrained by the mass that must lie within it, and by limits to the intensities of hydrogen recombination lines. In all cases the photoionization models predict that the NIR [Ne VI] ?7.65 ?m line should be the strongest line emitted by the shell. This line is predicted to be dramatically brighter than the optical lines commonly used in searches. The C IV ?1549Å doublet is predicted to be the strongest absorption line from the shell, which is in agreement with HST observations. However we show that the cooling timescale for the fast shell is much longer than the age of the Crab, due to the low density. This means that the temperature of the shell will actually “remember” its initial conditions. The recombination time is much shorter than the age of the Crab, so the predicted level of ionization should approximate the real ionization. In any case, it is clear that IR observations present the best opportunity to detect the fast shell and so guide future models that will constrain early events in the original explosion.

### 216.04 – $OH^+$ in Diffuse Molecular Clouds

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We are conducting a comprehensive survey of absorption from diffuse molecular clouds from archival UVES/VLT data. Here we focus on $OH^+$ and OH results, which indicate these molecules prefer different environments. The dominant absorption feature in $OH^+$ arises from a main component seen in $CH^+$, while OH absorption follows CN absorption. This distinction provides useful constraints on OH chemistry in diffuse molecular clouds. Since $CH^+$ detections favor low-density gas with small fractions of molecular hydrogen, this must be true for $OH^+$ as well, confirming $OH^+$ and $H_2O^+$ observations with the *Herschel Space Telescope*. Our observed correspondence indicates that the cosmic ray ionization rate derived from these measurements pertains to atomic gas. The association of OH absorption with gas rich in CN is attributed to the need for high enough density and molecular fraction before detectable amounts of OH are seen. Thus, while $OH^+$ leads to OH production, chemical arguments suggest that their abundances are controlled by different sets of conditions and coexist with different sets of observed species. Of particular note is that non-thermal chemistry appears to play a limited role in the synthesis of OH in diffuse molecular clouds.

### 216.05 – Determining the Nonmetastable Ammonia Populations in NGC 7538 Using the Green Bank Telescope

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As part of an ongoing maser study, we have a campaign on the Green Bank Telescope of the National Radio Astronomy Observatory to observe the nonmetastable transitions of ammonia in NGC 7538. To date, we have observed 31 transitions of 14NH3 and 15NH3, some for the first time in astronomy. We report on the (J,K) = (4,3), (5,3), (6,3), (7,3), (11,3), (12,3), (6,6), (7,6), (8,6), (9,6), (13,6), (14,6), (10,9), (11,9), (12,9), (15,9), (16,9), and (15,12) transitions of ortho-14NH3; the (6,5), (7,5), (9,8), (10,8), (11,8), (14,8), and (15,8) transitions of para-14NH3; the (3,3), (4,3), (5,3), (6,3), and (6,6) transitions of ortho-15NH3; and the (2,2) transition of para-15NH3. We summarize our ongoing effort to quantify the level populations as they pertain to competing pumping schemes for the known ammonia masers in the region, with particular focus on multiple transitions within the same rotational ladder of common azimuthal quantum number K. We have multiple epochs of observation for the 14NH3 (9,6) and (9,8) masers for which we present variability constraints. This work is supported by Wittenberg University through the Physics Department and the Student Development Board.

### 216.06 – The Dissipation Range of Interstellar Turbulence

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Turbulence may play an important role in a number of interstellar processes. One of these is heating of the interstellar gas, as the turbulent energy is dissipated and changed into thermal energy of the gas, or at least other forms of energy. There have been very promising recent results on the mechanism for dissipation of turbulence in the Solar Wind (Howes et al, Phys. Plasm. 18, 102305, 2011). In the Solar Wind, the dissipation arises because small-scale irregularities develop properties of kinetic Alfven waves, and apparently damp like kinetic Alfven waves. A property of kinetic Alfven waves is that they become significantly compressive on size scales of order the ion Larmor radius. Much is known about the plasma properties of ionized components of interstellar medium such as HII regions and the Diffuse Ionized Gas (DIG) phase, including information on the turbulence in these media. The technique of radio wave scintillations can yield properties of HII region and DIG turbulence on scales of order the ion Larmor radius, which we refer to as the dissipation scale. In this paper, we collect results from a number of published radio scattering measurements of interstellar turbulence on the dissipation scale. These studies show evidence for a spectral break on the dissipation scale, but no evidence for enhanced compressibility of the fluctuations. The simplest explanation of our result is that turbulence in the ionized interstellar medium does not possess properties of kinetic Alfven waves. This could point to an important difference with Solar Wind turbulence. New observations, particularly with the Very Long Baseline Array (VLBA) could yield much better measurements of the power spectrum of interstellar turbulence in the dissipation range. This research was supported at the University of Iowa by grants AST09-07911 and ATM09-56901 from the National Science Foundation.

### 216.07 – Arecibo Spectral Line Scan of the Hot Molecular Core in W51: Results from the C-Band High Frequency Range

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In 2010 we began an ambitious project with the 305m Arecibo Telescope: a spectral line scan of the W51 hot molecular core covering all available frequency bands, from 1 to 10 GHz. The observations were taken in the summers of 2010, 2011, and 2012. All frequency bands were observed with the Mock spectrometer, which allowed simultaneous observations of 14 adjacent spectral windows, 8192 channels each, ~0.3 km/s channel width. In this update report we concentrate on results from the C-Band High frequency range, from 6.0 to 8.2 GHz. We achieved a typical rms of ~15 mJy. We report detection of more than 70 spectral lines; among the most prominent are radio recombination lines, including alpha, beta, gamma, delta and epsilon hydrogen lines;

emission and absorption lines of excited hydroxyl transitions at 6.030, 6.035 and 6.049 GHz; and methanol masers and absorption of the 6.67 GHz transition.

## 216.08 – Multispectral Imaging and Analysis of the Rosette Nebula

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With the goal of understanding the three dimensional structure and fundamental physical processes of the Rosette Nebula and its associated cluster NGC 2244, we have acquired flux-calibrated, 4-degree field, deep exposures of the Rosette region through 3 nm bandwidth H? (656.3 nm) as well as H? (486.1nm), O[III] (500.7 nm) and S[II] (671.6 nm) filters with 4.5 nm bandwidth. The 4 arcsec/pixel images are supplemented with 4 degree field slit spectra and combined with archival WISE data in the 3.4, 4.6, 12, and 22 micron bands, published single dish radio data of the hydrogen continuum at 1410, 2700, and 4750 MHz, and Chandra X-ray data to form a data array allowing comparison and analysis of this important star forming region across the electromagnetic spectrum. The new observational data also allow the development of useful new image maps. The H? to H? ratio yields extinction in the visible spectrum by dust across the region, and the 1410 MHz hydrogen continuum to H? line ratio reveals structure obscured in the optical bands. A radial profile analysis of large scale H? emission from the Rosette is found to be inconsistent with an assumption of a simple spherically symmetric region, and suggests a partially unobstructed view of the central cluster. These data are the basis for work in progress to develop a comprehensive model of the structure and radiative processes in the Rosette region with CLOUDY and CLOUDY-3D.

## 216.09 – Cooling Function in Wide Range of Density and Metallicity

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This work focuses on how the plasma cooling function changes with density and metallicity over a wide range of temperature ($10^4$ K10 K), density (1cm$^{-3}$10 cm$^{-3}$) and metallicity (0Z??). We assume that the plasma is optically thin and in collisional ionization equilibrium (CIE). We first review some important cooling processes and investigate the effects of density and metallicity on the level of ionization. We found that high densities enhance the ionization of elements such as hydrogen until they reach local thermodynamic equilibrium. The metallicity (mainly the abundance of Mg) changes the ionization of hydrogen when H is partially ionized. This is due to charge transfer, in which $Mg^0$ neutralizes $H^+$, and $H^0$ neutralizes other elements like oxygen. This dependence of metallicity changes the electron density for temperatures where H is partially ionized, $T<2\times10^4$ K. We find that the cooling function's dependence on density and metallicity is coupled and very complex at low temperature ($T<2\times10^4$ K), but, above this temperature, the metallicity and density dependence can be treated separately. We second separate the metallicity dependence and the density dependence for the low-density solar abundance cooling function. Increased metallicity enhances the bremsstrahlung and other cooling due to the electrons provided by metals. High densities strongly suppress the cooling for ($10^4$ K6 K) due to collisionally de-excitation of line coolants and changes in the ionization. We develop a series of correction functions for $T>2\times10^4$ K that describe the different dependencies and can be applied to other cooling functions. We finally present our fitting results that can be used in hydrodynamics code easily, along with tables that can be used when greater precision is used.

## 216.1 – A Systematic Search for Infall Signatures Towards the Starless Core Population in the Perseus Molecular Cloud

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We present the results of a survey searching for infall signatures toward 61 starless cores in the Perseus molecular cloud. Observations of the ground state transitions of HCN, HNC, and H13CN were carried out using the 12-m radio telescope on Kitt Peak operated by the Arizona Radio Observatory. All three molecules are tracers of dense molecular gas. HCN 1-0 is an excellent infall tracer, with its three hyperfine lines probing different optical depths. We examined the spectra for signs of infall by comparing observed line asymmetries with the velocity peak of the optically thin isotopologue H13CN. We find that there is an excess of blue asymmetries, but clearly self-absorbed profiles are rare (< 20%). We compare the observed molecular properties with physical properties such as mass, temperature, and location within Perseus. This project was observed by The University of Arizona Undergraduate Astronomy Club and is the main component of Amanda Walker-LaFollette's NASA Space Grant internship research.

## 216.11 – Computational and Observational Studies of Interstellar Thioformaldehyde Masers

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Interstellar spectroscopy of thioformaldehyde (H2CS) holds considerable promise because of the close relationship between the H2CS molecule and the well-studied formaldehyde (H2CO) molecule. In particular, the well-known J(Ka,Kc) = 1(1,0) to 1(1,1) transition of H2CO at 6 cm (4.8 GHz) has an analogous H2CS transition at 1046 MHz. However, the 1046-MHz line of H2CS has never been detected astronomically. We present here a summary of: (1) a computational investigation of H2CS level populations related to known H2CO 6-cm masers, and (2) an observational campaign of four isotopologues of H2CS. Maser emission from H2CO has been observed at 6 cm for which Boland and de Jong (1981) have developed a pump model. We have extended this model to H2CS and we present preliminary calculations for a 1046-MHz maser. We intend to develop a quantitative tool for interpreting H2CS observations toward Galactic and extragalactic locations of H2CO maser emission by constructing a radiative-transfer maser model for H2CS. Thioformaldehyde has been detected in a few Galactic sources via J>1 transitions. However, interpretation of these results has two outstanding problems: the H2CS/H2CO abundances do not agree with known sulfur-to-oxygen ratios nor do the J>1 populations have the expected Boltzmann relationship to the J=1 states. A detection of the 1046-MHz transition of H2CS with J=1 would alleviate many of the ambiguities in the interpretation of existing observational results. We describe our forthcoming experiment to search in a Galactic star-forming region for thermal and nonthermal emission and absorption from four thioformaldehyde isotopologues: H2(12C)(32S), H2(13C)(32S), H2(12C)(34S), and D2(12C)(32S). Taken together, both parts of this research effort will provide valuable and novel constraints on H2CS and H2CO. New observations of H2CS isotopologues will yield new measurements of deuterium-to-hydrogen and sulfur-to-oxygen ratios in star-forming environments. Also, the application of the H2CO maser pump model to H2CS will provide new insights on the rare and enigmatic H2CO masers in the Galaxy. This work is supported by Wittenberg University through the Physics Department and the Student Development Board.

## 216.12 – The WISE Catalog of Galactic HII Regions

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All-sky data from the WISE satellite are sensitive enough to detect the emission from all Galactic HII regions. HII regions have a characteristic mid-infrared morphology, namely ~10 micron emission surrounding ~20 micron emission, that allows for their identification at mid-infrared wavelengths. Using data from WISE, we have created a catalog of ~8000 visually identified HII regions and HII region candidates. This catalog contains ~2000 known HII regions, ~2000 HII region candidates that have detected radio continuum emission, and ~4000 HII region candidates that do not have detected radio continuum emission. The catalog is unbiased in the sense that it is sensitive to HII regions of all sizes and distances, including new detections in the Outer Scutum-Centaurus arm. These detections are the most distant massive star forming regions known in the Milky Way. As in previous studies, we find that star formation in the central molecular zone is inefficient relative to the rest of the Galaxy.

## 216.13 – Modeling the Extended Dust Shell Around AFGL 618

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ISO observations of the carbon-rich post-AGB object AFGL 618 have found an extremely extended (r >1 pc) circumstellar dust shell. This shell contains a fossil record of mass loss that occurred during the ascent of the asymptotic giant branch. We analyze previous far-infrared observations of AFGL 618 to estimate the mass of the dust shell, and thus place a lower limit on the mass of the progenitor star. We present a new sub-millimeter (350 m) map of AFGL 618, and place limits on the temperature and crystal structure of the dust grains. The analysis incorporates radiative transfer (RT) modeling of AFGL 618 using the 1-d code DUSTY. The models suggest that previous estimates of the inner radius of the dust shell were too small by a factor of 5-10. This discrepancy may be due to clumping in the HII region close to the central star. Our models show that the dust within » 10000 of the central star is dominated by crystalline material, while the far-infrared and sub-millimetre observations suggest that the dust at larger distances is amorphous, implying that the properties of the dust grains change with the evolution of the star. Finally, we show that the existing data do not lead to a unique model: good models have been achieved by assuming either constant or increasing mass-loss rate for the last few hundred years of AGB evolution. Increased mass loss at the end of the AGB requires the overall optical depth to be increased. The increasing mass-loss phase cannot have a duration longer than »500 yrs.

## 216.14 – Investigating the Variance of Mid-infrared Dust Spectral Features of Oxygen-rich AGB Stars

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Asymptotic Giant Branch (AGB) stars, are major contributors of cosmic dust to the interstellar medium. Understanding the cosmic dust ejected from these stars is essential to understanding the broader topics of evolution and composition of stellar objects in our universe. Oxygen-rich AGB stars have been classified according to the shapes of their spectral features in the mid-infrared (IR). We have studied the dust around sixteen Oxygen rich AGB stars via infrared spectroscopy. These sixteen objects were chosen for our sample because they represent a group with similarly shaped mid-IR feature. Using spectral data from the Infrared Space Observatory (ISO), and the Infrared Astronomical Satellite (IRAS) we investigated variations in the spectral parameters of these stars to find correlations.

## 216.15 – Modeling the Mineralogy of Dust Around Obscured, Oxygen-rich AGB Star, IRAS 17495-2534

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The oxygen-rich, highly obscured, asymptotic giant branch (AGB) star, IRAS 17495-2534 has been shown to exhibit a crystalline silicate spectral absorption feature alongside a strong classic 10-micron amorphous silicate absorption feature. We present a series of simple models designed to determine the composition of the optically thick dust shell around this star and distinguish between competing hypotheses to explain its unusual spectral features. We find that diopside ($CaMgSi_2O_6$) composition glass gives the best fit to the amorphous feature but this is by no means the only possible fit. We rule out the inclusion of (most) crystalline pyroxene minerals; and constrain the composition of the crystalline olivine minerals that can match the observed features. Finally we include silica-rich minerals to explain residual emission at ~9 microns. Our findings conflict with standard models for dust formation.

# 217 – Extrasolar Planets & Tools

## 217.01 – Transit Observations of Venus's Atmosphere in 2012 from Terrestrial and Space Telescopes as Exoplanet Analogs

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We extensively observed the 8 June 2012 transit of Venus from several sites on Earth; we provide this interim status report about this and about two subsequent ToVs observed from space. From Haleakala Obs., we observed the entire June transit over almost 7 h with a coronagraph of the Venus Twilight Experiment (~B filter) and with a RED Epic camera to compare with simultaneous data from ESA's Venus Express, to study the Cytherean mesosphere; from Kitt Peak, we have near-IR spectropolarimetry at 1.6 µm from the aureole and during the disk crossing that compare well with carbon dioxide spectral models; from Sac Peak/IBIS we have high-resolution imaging of the Cytherean aureole for 22 min, starting even before 1st contact; from Big Bear, we have high-resolution imaging of Venus's atmosphere and the black-drop effect through 2nd contact; and we had 8 other coronagraphs around the world. For the Sept 21 ToV as seen from Jupiter, we had 14 orbits of HST to use Jupiter's clouds as a reflecting surface to search for an 0.01% diminution in light and a differential drop that would result from Venus's atmosphere by observing in both IR/UV, for which we have 170 HST exposures. As of this writing, preliminary data reduction indicates that variations in Jovian clouds and the two periods of Jupiter's rotation will be too great to allow extraction of the transit signal. For the December 20 ToV as seen from Saturn, we had 22 hours of observing time with VIMS on Cassini, for which we are looking for a signal of the 10-hr transit in total solar irradiance and of Venus's atmosphere in IR as an exoplanet-transit analog. Our Maui & Sac Peak expedition was sponsored by National Geographic Society's Committee for Research and Exploration; HST data reduction by NASA: HST-GO-13067. Some of the funds for the carbon dioxide filter for Sac Peak provided by NASA through AAS's Small Research Grant Program. We thank Rob Ratkowski of Haleakala Amateur Astronomers; Rob Lucas, Aram Friedman, Eric Pilger, Stan Truitt, and Steve Bisque/Software Bisque for Haleakala support/operations; Vasyl Yurchyshyn and Joseph Gangestad '06 of The Aerospace Corp. at Big Bear Solar Obs; LMSAL and Hinode science/operations team.

## 217.02 – Flying Toasters: Heating Exoplanets Via The Stellar Wind

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As is now well-known, hot Jupiters close to their host planets generally display inflated radii relative to expectations based on the equation of state and the incident stellar radiation field. A number of models have been proposed to supply additional internal heating and thus account for this effect. It has recently been shown that the interaction of the stellar wind and the planetary magnetosphere may be a significant contributor to the required heating, by driving an electric circuit through the planetary interior. I present preliminary models of this effect, focusing on the magnitude and location of the induced heating in the planetary interior, and showing that both are in accord with requirements. I also suggest observational tests which may be able to distinguish between this and other proposed models for internal heating.

## 217.03 – Habitability in Binary Systems: The Role of UV Reduction and Magnetic Protection

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The number of planets found in binary systems is growing rapidly and the discovery of many more planets in binary systems appears inevitable. We use the newly refined and more restrictive, single star habitable zone (HZ) models of Kopparapu et al. (2013) and include planetary magnetic protection calculations in order to investigate binary star habitability. Here we present results on circumstellar or S-type planets, which are planets orbiting a single star member of a binary. P-type planets, on the other hand, orbit the center of mass of the binary. Stable planetary orbits exist in HZs for both types of binaries as long as the semi-major axis of the planet is either greater than (P-type) or less than (S-type) a few times the semi-major axis of the binary. We define two types of S-type binaries for this investigation. The SA-type is a circumstellar planet orbiting the binary's primary star. In this case, the limits of habitability are dominated by the primary being only slightly affected by the presence of the lower mass companion. Thus, the SA-type planets have habitability characteristics, including magnetic protection, similar to single stars of the same type. The SB-type is a circumstellar planet orbiting the secondary star in a wide binary. An SB-type planet needs to orbit slightly outside the secondary's single star HZ and remain within the primary's single star HZ at all times. We explore the parameter space for which this is possible. We have found that planets lying in the combined HZ of SB binaries can be magnetically protected against the effects of stellar winds from both primary and secondary stars in a limited number of cases. We conclude that habitable conditions exist for a subset of SA-type, and a smaller subset of SB-type binaries. However, circumbinary planets (P-types) provide the most intriguing possibilities for the existence of complex life due to the effect of synchronization of binaries with periods in the 20-30 day range which allows for planets with significant magnetic protection.

## 217.04 – The University of Arizona Astronomy Club Follow-up Observations of Transiting Extra-solar Planet HAT-P-36b

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We observed 5 primary transits of exoplanet HAT-P-36b with the Steward Observatory 1.55 meter Kuiper Telescope in the U and R photometric bands. With our results, we have been able to produce a more complete light curve and refine previously published values for the planet's mass, radius, density, surface gravity, Safronov number, equilibrium temperature, orbital distance, orbital inclination. We developed a modeling package that uses the Levenberg-Marquardt minimization algorithm to find the least-squares best fit to the light curve. The errors were generated using a bootstrap Monte Carlo method. The red noise of the transit was determined by using the permutation "rosary bead" method, which constrains the red noise in our transits better than the publicly available modeling package, TAP.

## 217.05 – Optical Observations of the Transiting Exoplanet GJ 1214b

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We observed nine primary transits of the super-Earth exoplanet GJ 1214b in several optical photometric bands from March to August 2012, with the goal of constraining the short wavelength slope of the spectrum of GJ 1214b. Our observations were conducted on the Kuiper 1.55 m telescope in Arizona and the STELLA-I robotic 1.2 m telescope in Tenerife, Spain. From the derived light curves we extracted transit depths in R , V , and g? bands. We originally fit our data using the publically available modeling software, Transit Analysis Package (TAP). However, we found that TAP overestimates the amount of red noise in our transits and unnecessarily inflates our error bars for the transit depth. Therefore, we reanalyzed our full dataset and developed a modeling package called EXOMOP that uses the analytic equations of Mandel & Agol (2002) to generate a model transit, the Levenberg-Marquardt non-linear least squares minimization algorithm to find the best fit, the bootstrap Monte Carlo technique to calculate robust errors of the fitted parameters, and the residual permutation "rosary bead" method to access the importance of red noise. From our reanalysis of the data we find that our error bars on the transit depth are not overestimated. We find that our results overlap within errors the short-wavelength observations of de Mooij et al. (2012), but are also consistent with a spectral slope of zero in GJ 1214b in the optical wavelength region. Our observations thus allow for a larger suite of possible atmosphere compositions, including those with a high-molecular-weight and hazes.

## 217.07 – Using Proxy Stars to Reduce Radius and Temperature Estimates for Low-Mass Kepler Objects of Interest

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The number of exoplanets being found around low-mass stars continues to increase, but study of these planets is complicated by the difficulty of characterizing their host stars. While empirical metrics and synthetic spectra enable stellar characterization for cooler and hotter stellar types, respectively, stars in the range between M1 and K5 are especially challenging. Since nearly all exoplanets are discovered indirectly by the effect they produce on their host stars, the errors in these stellar parameters for low-mass stars result in correspondingly large errors in the size and temperature of the planets around them. For planets near their stellar habitable zones, this uncertainty is especially salient. We improve this accuracy for a sample of planet candidates discovered by the Kepler Space Telescope by assigning the temperatures and radii of nearby 'proxy' stars, which have had their radii measured directly, to our target stars. We identify these proxy stars by using spectral typing software to compare the spectra of planet hosting stars to the spectra of similar nearby stars. By assigning them the parameters of the proxy stars, we reduce the uncertainties in size and temperature for the planet hosting stars. This also reduces the uncertainties in the size and temperature of the exoplanets, and thus allows us to better characterize their habitability.

## 217.08 – Measuring the Magnetic Field Strength of the Transiting Extra-solar Planet TrES-2b Using Near-UV Observations

*Ian Cates[1], Jake Turner[1], Kyle Pearson[1]*
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By measuring the magnetic field of an extra-solar planet we can learn about properties such as its internal structure, rotation period, and atmospheric retention. It is also theorized that magnetic fields can contribute to the habitability of a planet (Grie?meier et al. 2005). By observing the asymmetries in the near-UV and optical light curve of a transiting extra-solar planet it is possible to detect a magnetic field (Vidotto et al. 2011). We observed the primary transit of TrES-2b using a near-UV filter with the Steward Observatory 61' Kuiper Telescope, and compared it with available optical data in an attempt to detect this asymmetry. Analysis of the data does not show any asymmetries. Furthermore, we found that the upper limit of the magnetic field strength ranges from 0.022 to 0.46 Gauss. Future observations of the planet's radio emissions generated by electron–cyclotron maser interactions are encouraged to confirm this low magnetic field.

## 217.09 – Near UV Observation of HAT-P-16b

*Kyle Pearson[1], Jake Turner[1]*
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We observed the primary transit of the hot Jupiter HAT-P-16b in the near-UV photometric band on December 29, 2012 in an attempt to detect its magnetic field. Vidotto, Jardine & Helling (2011) postulate that the magnetic field of HAT-P-16b can be constrained if its near-UV light curve shows an early ingress compared to its optical light curve, while its egress remains unswayed. Predicted magnetic fields of Jupiter-like planets should range between 8 G (Reiners & Christensen 2010) and 40 G (Sanchez-Lavega 2004). However, we derived an upper limit of the magnetic field strength of HAT-P-16b to range between 0.0082 and 0.82 G (for a 1--100 G magnetic field strength range for the host star, HAT-P-16). Using these magnetic field values and an assumed B* of 100 G, the Vidotto, Jardine & Helling (2011) method predicts a timing difference of 19--38 mins. We did not detect an early ingress in our night of observing when using a cadence of 45 seconds and an average photometric precision of 2.25 mmag. We present the first near-UV light curve of HAT-P-16b and find a near-UV planetary radius of 1.242+-0.056 (R_Jup) which is consistent with its near-IR radius of R=1.289+-0.066 (R_Jup) (Buchhave 2010). We developed an automated reduction pipeline and a modeling package to process our data. The modeling package utilizes the Levenberg-Marquardt minimization algorithm to find a least-squares best fit and a differential evolution Markov Chain Monte Carlo to find the best fit to the light curve, and uses both the residual permutation (rosary bead) method and time-averaging method (Pont 2006) to constrain the red noise in both fitting methods.

## 217.1 – A Systematic Search for Secondary Eclipses in the Kepler Dataset

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Studying secondary eclipses of transiting exoplanets offers a means for characterizing these important systems. The primary transit occurs when the planet passes in front of its host star, causing a dip in the star's brightness. A secondary eclipse is the smaller decrease in the light of a system when the planet goes behind the star. This phenomenon can help with the characterization of the planet and its atmosphere. For example, depending on the wavelengths observed, the depth of the secondary eclipse can reveal the albedo of the planet; also the timing and width of the secondary eclipse can help determine the orbital parameters of the planet. We studied the Kepler light curves of stars with close-in Neptune and Jupiter class planets to search for secondary eclipses. Among our targets, we re-analyzed some systems studied by Coughlin et al. (2012), including ones that were discarded for being too variable. We present our most interesting findings of sources containing up to 14 quarters of data from the Kepler mission.

## 217.11 – Transit Planet Spectrophotometry with a Contaminated Target

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Slitless spectroscopy of transiting exoplanets has for some time now been shown to yield the transmission spectrum of the planetary atmosphere, as well as other planetary characteristics, such as its radius. However, due to operational considerations, in some cases the target spectrum can be contaminated by flux from nearby objects on the detector. We describe our efforts to remedy this situation by performing transit planet spectroscopy using both aXeSIM simulations and Hubble Space Telescope (HST) observations of a system in which a nearby star contaminated the target. This work is an intermediate step towards devising a technique to obtain transmission spectra for exoplanet systems in more crowded fields.

## 217.12 – Exoplanet Observations in SOFIA's Cycle 1

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The NASA/DLR Stratospheric Observatory for Infrared Astronomy (SOFIA), a 2.5-meter infrared telescope on board a Boeing 747-SP, will conduct 0.3 - 1,600 micron photometric, spectroscopic, and imaging observations from altitudes as high as 45,000 ft. The airborne-based platform has unique advantages in comparison to ground- and space-based observatories in the field of characterization of the physical properties of exoplanets: parallel optical and near-infrared photometric and spectrophotometric follow-up observations during planetary transits and eclipses will be feasible with SOFIA's instrumentation, in particular the HIPO-FLITECAM optical/NIR instruments and possible future dedicated instrumentation. Here we present spectrophotometric exoplanet observations that were or will be conducted in SOFIA's cycle 1.

## 217.13 – Testing a Method of Detecting a Magnetic Field of Transiting Hot-Jupiter CoRot-1b

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In October of 2011 and December of 2012, exoplanet CoRot-1b was observed on the Steward Observatory 61" Kuiper Telescope using the Bessel-U filter to detect a possible magnetic field. In addition, the primary transit of CoRoT-1b was observed January 29, 2012 and February 2, 2012 using the medium resolution spectrograph on the 6.5 meter MMT Observatory. It is suggested by Vidotto et. al. (2011), that it is possible to detect a magnetic field of a transiting exoplanet in the near-UV photometric band by comparing asymmetry between the ingress and egress of the light curve. This effect is believed to be caused by a bow shock being formed in front of the planet as it transverses through the coronal plasma of its host star. CoRot-1b is a candidate for demonstrating this effect. We do not observe an early ingress in our near-UV broad-band light curves from the 61' Kuiper Telescope. We find an unexpected upper limit of 0.087-1.4 Gauss for the magnetic field strength of CoRoT-1b. This result is consistent with the near-UV observations by Turner et al. 2013 of another exoplanet predicted to show this effect, TrES-3b. It was suggested Vidotto et al 2011 and the finding of Turner et al. 2013 that an early near-UV might only happen at certain spectral resonance lines. Our observations from the MMT observatory hope to shed light on this possibly. Our spectral observations can constrain the composition of a possible bowshock and also investigate potential molecular features in the atmosphere of CoRoT-1b. To find the best fit to the light curves we used a modeling package called EXOMOP that uses the analytic equations of Mandel & Agol (2002) to generate a model transit, the Levenberg-Marquardt non-linear least squares minimization algorithm to find the best fit, the bootstrap Monte Carlo technique to calculate robust errors of the fitted parameters, and the residual permutation "rosary bead" method to access the importance of red noise. Several other parameters to confirm and amend can be derived from the light curve including the planet's mass, radius, density, surface gravity, distance, and orbital inclination.

## 217.14 – Eclipsing Binaries and the Search for Circumbinary Exoplanets in Kepler Data

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The Kepler Space Telescope has delivered light curves for about 2700 eclipsing binary star systems. Already six circumbinary planets have been discovered in the first four quarters of these data, and since then an additional ten quarters have been made public. Studying circumbinary planets can provide important clues about the planet formation process. Our project aims to improve knowledge of previously identified circumbinary planets and to conduct a search for new candidates in the Kepler data, looking for

eclipses produced by the transit of the planet in front of the binary star system. We developed data reduction pipelines using PYKE and IDL to increase the signal-to-noise of the light curves and fold them with the periodicity of the binary system in order to improve our ability to detect the (diluted) signal from any planets. Here we present a few interesting objects analyzed using these pipelines.

## 217.15 – A Search for Exoplanets in Short-Period Eclipsing Binary Star Systems

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More than 800 confirmed exoplanets are currently known. However, the number of exoplanets known in binary star systems is far less. These planets are in wide binaries with stellar orbital periods of decades or longer. The planets can be either circumbinary (P-type) or circumstellar (S-type). Most of the known binaries with planets are S-type systems. The existence of planets in binary star systems tests models of planet formation. In the case of S-type orbits the protoplanetary disk surrounding one star is tidally and thermally perturbed by the companion star. Theoretical studies have indicated that planet formation may be impossible if the stars are closer than 20-100 AU. But Gamma Cep and HD196885 have planets that are at 20 AU. HR 7162 has a planet inside this limit (19 AU). This paper reports the progress of a search for exoplanets with S-type orbits in short-period binary star systems. The selected targets have stellar orbital periods of just a few days. These systems are eclipsing binaries so that exoplanet transits, if planets exist, will be highly likely. Furthermore, the possible range of planetary orbital periods can be predicted. From this it is possible to establish when the orbital phases of all possible planetary period have been sufficiently sampled. So by this technique null detections can establish a lack of planets above a certain size, set by photometric precision. We report the results for 8 binary star systems

## 217.16 – Innovations for Exoplanet Data Acquisition

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Extra-solar planets are detected through the analysis of light fluctuations from a star. During a planetary transit, a star's magnitude decreases slightly, which, when plotted against the time, appears as a small dip in its light curve. In order to find the stars' magnitudes over time and plot light curves, one must go through a time consuming process called photometry on each image for every star. Through the use of the Image Reduction and Analysis Facility (IRAF) command language and scripting tools, I have been able to develop a program, called brightER, that greatly reduces the amount of time spent gathering this information. It combines the entire photometric process into one compact package, automates multiple steps of that process, and has guided instructions throughout. Through the use of brightER, we can spend less time acquiring magnitudes and more time analyzing them.

## 217.17 – Differential Photometry with OSCAAR: Open Source Differential Photometry Code for Amateur Astronomical Research

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*Contributing teams: OSCAAR Team*

We present a cross-platform, open-source differential photometry package written in Python, called OSCAAR (Open Source differential photometry Code for Amateur Astronomical Research). The code is intended for use by undergraduate students or small observatories, or to be used as a scaffolding to be built upon and refined by more advanced users. OSCAAR can be controlled with a graphical user interface for those unfamiliar with Python. OSCAAR makes extensive use of existing astronomical software packages, and the implementation of classes and methods within OSCAAR is designed to be highly modular and interchangeable. The aim of OSCAAR is to provide a free, practical differential photometry toolkit with which users can easily create light curves, and also to encourage the users to work with the source code and refine it for their own purposes.

## 217.18 – WCO Observations of KELT Candidates

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*Contributing teams: KELT*

We present the light curves of several KELT exoplanet candidates observed from the Westminster College Observatory (WCO) in Pennsylvania. WCO is one of several observatories belonging to the KELT-North photometric follow-up network. While KELT is optimized for wide-field single-band synoptic surveys, WCO is optimized for narrow-field multi-band observations at higher photometric precision. As such, light curves obtained at WCO (and other follow-up observatories) serve the important complementary functions of both vetting exoplanet false-positives and enabling better fits to exoplanetary system parameters.

# 218 – Pulsars and Neutron Stars

## 218.01 – The Motion of Cassiopeia A's Neutron Star

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We used data from the High Resolution Camera on the Chandra X-ray Observatory to measure the proper motion of the neutron star in Cassiopeia A over a baseline of 10 years. Due to a lack of external registration sources, we used the slow-moving quasi-stationary flocculi (QSFs) for registration. Using a number of different techniques (centroiding, Gaussian fitting, chi-square, Cash statistic), we find that our measurement is dominated by the morphology changes of the QSFs over the 10-yr period. Our measurement indicates that the neutron star is moving at 450 +/- 200 km/s in the south-southeast direction. Given the measurement difficulties, we are pleased that our measurement is completely consistent with the inferred proper motion of the neutron star based on its offset from the center of expansion of the optical ejecta. The neutron star motion does not seem to align with any of the major structures in Cas A, such as the jets and the Fe-rich ejecta to the north and southeast.

## 218.02 – New Radio Pulsars in the Large Magellanic Cloud

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We present the discovery of eight new radio pulsars located in the Large Magellanic Cloud. These pulsars were found as a result of reprocessing the Parkes Multibeam Survey data of the Magellanic Clouds, as well as an ongoing new survey at Parkes with high-resolution data acquisition systems. Although no millisecond pulsars have been found, these discoveries have increased the known rotation powered pulsar population in the Large Magellanic Cloud to 23, an increase of more than 50%.

## 218.03 – Limits on Lorentz Invariance Violation from VERITAS Using the Crab Pulsar Profile

*John P. Finley*[1]
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*Contributing teams: VERITAS Collaboration*

Quantum gravity (QG) theories over the past fifty years have sought to understand the relationship between the four fundamental forces of nature. A major feature of the theoretical ideas is that the energy dependence of the interactions possibly unify at the Planck scale of ~10^19 GeV. A potential consequence of the unification of gravity and the other three forces would be a breaking of Lorentz symmetry. Using time of flight (ToF) measurements gamma-ray telescopes have been able to put constraints on the energy scale of Lorentz Invariance Violation (LIV). The Crab Pulsar, the only pulsar detected at very high energies (VHE, E>100GeV), presents a unique opportunity to put new constraints on LIV. We present the results of observations of the Crab Pulsar with VERITAS and describe the statistical methods used to measure LIV effects in the Crab Pulsar.

## 218.04 – Search for Very High Energy Radiation in Black-Widow Type Millisecond Pulsar Systems

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*Contributing teams: VERITAS Collaboration*

Millisecond pulsars are old neutron stars that have been spun up to high angular frequencies by the accretion of matter from a companion star. High-energy photons have been detected from this region, including gamma rays in the Fermi energy band. It is anticipated that the injection of high-energy particles into shocks between the pulsar and its companion star, could produce a significant flux of gamma rays above 150 GeV. VERITAS (the Very Energetic Radiation Imaging Telescope Array System) is an array of four Air Cherenkov telescopes in southern Arizona that is sensitive to radiation between 150 GeV and 25 TeV. Recently this instrument was used to observe the black-widow type millisecond pulsar PSR J0023+09 in binary with a low mass companion. An analysis of the data from this source, while preliminary, did not show the system to be a significant source of very high-energy gamma rays. Even so, this non-detection can be used to constrain models of wind interactions between millisecond pulsars and their companions.

# 300 – The Latest Results from the NASA Kepler Mission: Exoplanets and Astrophysics

## 300.01 – The Latest Results from the NASA Kepler Mission: Exoplanets and Astrophysics

*Steve B. Howell*[1]

*1. NASA ARC, Moffett Field, CA, United States.*

The NASA Kepler mission was launch just over four years ago. The Exoplanet results have been astounding and have changed out view of our place in the Universe. Kepler has also provide unique and paradigm changing results in the field of Astrophysics. The asteroseismology work is well known and a large fraction of the stellar results to date. Variable stars of all kinds and even extragalactic astrophysics are also well represented by Kepler science. I will provide an overview of the mission status and the latest new discoveries in Exoplanets. The talk will also highlight the many areas of astrophysical research enabled by Kepler and some of the most exciting new scientific results. The talk will end with a view to the future of the Kepler mission into its second year of extended operations.

# 301 – Bridging Laboratory and Astrophysics: Planetary

## 301.01 – Water Ice in Comets: A Comparative Study

*Silvia Protopapa[1], Jessica Sunshine[1], Lori M. Feaga[1], Michael S. Kelley[1], Michael F. A'Hearn[1], Tony Farnham[1]*
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*Contributing teams: DIXI Team*

Processes involving the sublimation of volatiles dominate cometary activity and drive the release of ancient material from within the nucleus into the coma. As comets are kept cold for most of their history, they contain the least processed primordial materials that accumulated into the giant planets. In addition, comets may have delivered their ices and organics to the primitive Earth. The Deep Impact eXtended Investigation (DIXI) to comet Hartley 2 revealed a highly active comet with bright icy-rich jets. We present a detailed characterization of the composition and texture of the ices and refractories in the inner-most coma of Hartley 2, closer than a few kilometers from the surface. This analysis is conducted using laboratory measurements of optical constants of cometary analog materials. We also discuss the implications of these findings on the accretion process that led to the formation of cometary nuclei and therefore of planets. The physical makeup of the ice grains in comet Hartley 2 is compared with that of water ice in the interior, surface, and coma of other comets (e.g., 9P/Tempel 1, C/2002 T7 (LINEAR), 17P/Holmes). Through this comparative study, we investigate how ice is redistributed from the interior to the surface and ultimately into the coma of comets.

## 301.02 – The Importance of Accurate Atomic and Molecular Line-lists for Characterizing Exoplanetary Atmospheres

*Nikku Madhusudhan[1], Richard Freedman[2, 3], Jonathan Tennyson[4]*
*1. Yale University, Princeton, NJ, United States. 2. SETI Institute, Mountain View, CA, United States. 3. NASA Ames Research Center, Moffett Field, CA, United States. 4. University College London, London, United Kingdom.*

Recent advancements in exoplanet observations are placing unprecedented constraints on the physical and chemical properties of exoplanetary atmospheres. Statistically significant constraints have been placed on the abundances of atomic and molecular species, elemental abundance ratios, temperature profiles, energy circulation, presence of hazes/clouds, and non-equilibrium chemistry, in several exoplanetary atmospheres, including gas giants, ice giants, as well as super-Earths, over a wide temperature range. The chemical constraints have also motivated new paradigms for classifying exoplanets and new efforts to constraint their formation conditions. Central to all interpretations of exoplanet spectra, however, is the accuracy of fundamental inputs in the models, primarily, the atomic and molecular opacities, which are derived from laboratory experiments and/or ab initio numerical calculations. In this talk, we will review the state-of-the-art in atomic and molecular line-lists as applied to studies of exoplanetary atmospheres. We will discuss examples where advances in laboratory astrophysics, experimental and computational, have addressed important problems in the area of exoplanetary atmospheres, as well as outstanding questions requiring new experiments and/or theoretical calculations. For example, recent studies are suggesting that high-temperature line-lists of hydrocarbons (CH4, C2H2, HCN, etc.), and several metal hydrides, in addition to refined line-lists of several well-studied molecules, are important to accurately interpret exoplanetary spectra. We will highlight several fundamental questions in the area that require new efforts in laboratory astrophysics. Besides their importance in interpreting observations with current instruments, the refined parameters are also critical in the assessment of future facilities for exoplanet characterization, such as JWST, GMT, etc.

## 301.03 – Investigating Titan's Atmospheric Chemistry at Low Temperature in Support of the NASA Cassini Mission

*Ella Sciamma-O'Brien[1], Farid Salama[1]*
*1. NASA Ames Research Center, Moffett Field, CA, United States.*

Titan's atmosphere, composed mainly of N2 and CH4, is the siege of a complex chemistry induced by solar UV radiation and electron bombardment from Saturn's magnetosphere. This organic chemistry occurs at temperatures lower than 200 K and leads to the production of heavy molecules and subsequently solid aerosols that form the orange haze surrounding Titan. The Titan Haze Simulation (THS) experiment has been developed on the COSmIC simulation chamber at NASA Ames in order to study the different steps of Titan's atmospheric chemistry at low temperature and to provide laboratory data in support for Cassini data analysis. The chemistry is simulated by plasma in the stream of a supersonic expansion. With this unique design, the gas mixture is adiabatically cooled to Titan-like temperature (~150 K) before inducing the chemistry by plasma discharge. Different gas mixtures containing N2, CH4, and the first products of the N2-CH4 chemistry (C2H2, C2H4, C6H6…) but also heavier molecules such as PAHs or nitrogen containing PAHs can be injected. Both the gas phase and solid phase products resulting from the plasma-induced chemistry can be monitored and analyzed. Here we present the results of recent gas phase and solid phase studies that highlight the chemical growth evolution when injecting heavier hydrocarbon trace elements in the initial N2-CH4 mixture. Due to the short residence time of the gas in the plasma discharge, only the first steps of the chemistry have time to occur in a N2-CH4 discharge. However by adding acetylene and benzene to the initial N2-CH4 mixture, we can study the intermediate steps of Titan's atmospheric chemistry as well as specific chemical pathways. These results show the uniqueness of the THS experiment to help understand the first and intermediate steps of Titan's atmospheric chemistry as well as specific chemical pathways leading to Titan's haze formation. Aknowledgements: This research is supported by NASA SMD (PATM). E.S.O. acknowledges the support of the NASA Postdoctoral Program (NPP). The authors acknowledge the technical support of R. Walker.

# 302 – Extrasolar Planets & Tools

## 302.01 – Astrometry with the Kepler Planet Finder – A Progress Report

*G. F. Benedict*[1]

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We wish to derive proper motion and parallax for targets of interest within the Kepler field of view. Kepler as a photometer reads out target star postage stamp subsets of the entire CCD focal plane mosaic once every 30 minutes. The postage stamps are 4x5 to 8x8 pixels, with 3.98 arcsec pixel size. Every 90 days the telescope rotates 90°. Consequently, each field is observed by four different CCDs. The 30-minute cadence generates approximately 4700 postage stamps for each star, for each 90-day quarter. Theoretically the astrometric precision in the absence of systematic error is inversely proportional to sqrt(N). Potentially, with an entire quarter's observations, even with 4 arcsec pixels, one might conceivably approach HST/FGS per observation precision, 1 millisecond of arc. Unfortunately Kepler pixel data is seriously afflicted with systematics. This report presents a rogue's gallery of such systematics, identifies some spacecraft-specific and target-specific causes, offers a few solutions to some, and outlines possible future efforts at amelioration. At this stage in the investigation by collapsing the middle of three quarter's set of positions to a catalog of relative positions and modeling these catalogs (all for the same CCD) as a function of time one can obtain relative proper motions with a little better precision than the PPMXL, but only for a subset of the Kepler targets. Parallaxes will require modeling the same field with differing CCDs. Pixel phase corrections may assist this effort.

## 302.02 – The Atmospheric Circulation of the Eccentric Hot-Jupiter HAT-P-2b

*Nikole Lewis*[1]*, Adam P. Showman*[2]*, Jonathan J. Fortney*[3]*, Heather Knutson*[4]*, Mark S. Marley*[5]

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The hot-Jupiter HAT-P-2b has become a prime target for Spitzer Space Telescope observations aimed at understanding the atmospheric response of exoplanets on highly eccentric orbits. Here we present a suite of three-dimensional atmospheric circulation models for HAT-P-2b that investigates the effects of assumed atmospheric composition and rotation rate on global scale winds and thermal patterns. We compare and contrast atmospheric models for HAT-P-2b which assume one and five times solar metallicity, both with and without TiO/VO as atmospheric constituents, along with models which assume a rotation period half and twice the nominal pseudo-synchronous rotation period. We find that changes in assumed atmospheric metallicity and rotation rate do not significantly affect model predictions of the planetary flux as a function of orbital phase. However, models in which TiO/VO are present in the atmosphere develop a transient temperature inversion between the transit and secondary eclipse events that results in significant variations in the timing and magnitude of the peak of the planetary flux compared with models in which TiO/VO are omitted from the opacity tables. We find that no one single atmospheric model can reproduce the recently observed full and partial orbit phase curves at 3.6, 4.5 and 8.0 microns, which is likely due to non-equilibrium chemical processes not captured by our current atmospheric models for HAT-P-2b.

## 302.03 – KELT-6b: A Transiting Mildly-Inflated Saturn with a Metal-Poor Host

*Karen A. Collins*[1, 2]*, Robert Siverd*[3]*, Thomas G. Beatty*[4]*, Jason Eastman*[6, 7]*, B. S. Gaudi*[4]*, Joshua Pepper*[3, 25]*, Keivan Stassun*[3, 5]*, David W. Latham*[8]*, Allyson Bieryla*[8]*, Mark Manner*[12, 23]*, Eric L. Jensen*[11]*, John F. Kielkopf*[1]*, Joao Gregorio*[20]*, Benjamin J. Fulton*[16]*, Lars A. Buchhave*[9, 10]*, Kaloyan Penev*[13]*, Justin R. Crepp*[14]*, Phillip Cargile*[3]*, Claude E. Mack*[3]*, Thomas E. Oberst*[21]*, Ryan L. Avril*[21]*, Sam Mellon*[21]*, Kim K. McLeod*[22]*, Saurav Dhital*[3, 15]*, Robert P. Stefanik*[8]*, Michael L. Calkins*[8]*, Gilbert Esquerdo*[8]*, Perry L. Berlind*[8]*, Rachel Street*[6]*, Roberto Zambelli*[24]*, Qingqing Mao*[3]*, Alexander J. Richert*[17]*, Andrew Gould*[4]*, Darren L. Depoy*[18]*, Jennifer L. Marshall*[18]*, Richard W. Pogge*[4]*, Mark Trueblood*[19]*, Patricia Trueblood*[19]

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We present the discovery of KELT-6b, a mildly inflated transiting Saturn, orbiting a metal-poor star. A joint analysis of the spectroscopic, radial velocity, and photometric data indicates the planet has a mass of 0.5 M_J, radius of 1.3 R_J, and an orbital period of ~8 days. The bright (V~10) host is a slightly evolved, metal-poor F star with [Fe/H]~-0.3 and an inferred mass and radius of ~1.2 M_sol and ~1.7 R_sol. Although KELT-6 is more evolved than HD209458, the orbital period of KELT-6b is longer than HD209458b, resulting in almost identical incident flux at both planets. Thus, KELT-6b is a metal-poor twin of HD209458b, one of the best understood exoplanets, and offers the unique opportunity to perform a comparative measurement of two similar planets in similar environments around stars of very different metallicities in order to test theories of exoplanetary atmospheres, in particular the causes of atmospheric temperature inversions, and to test theories of planet formation. High resolution radial velocity data indicate a possible longer period third body in the system. No companions are detected in Keck adaptive optics imagery, allowing constraints on the mass and period of the putative companion.

## 302.04 – Measuring Masses and Densities of Small Planets found by NASA's Kepler Spacecraft with Radial Velocity Measurements from Keck/HIRES

*Howard T. Isaacson*[1]*, Geoff Marcy*[1]*, Jason Rowe*[2]

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*Contributing teams: Kepler Team*

We use the Keck telescope and HIRES spectrometer to measure the masses of Kepler planet candidates. Analysis of 22 Kepler-identified planetary systems, holding 42 transiting planets (candidates) and 8 newly discovered non-transiting planets are presented herein. Combining the planet radius measurements from Kepler with mass measurements from Keck, we constrain the bulk density of short period planets that range in size from 1.0 to 3.0 Earth radii. Extensive ground based observations made by the Kepler Follow-up Program (KFOP) have provided extensive details about each KOI. Reconnaissance spectroscopy was used to refine the stellar and planet properties of each KOI at an early stage. SME spectral analysis and asteroseismology, when available, are used to obtain the final stellar properties. Adaptive Optics and speckle imaging constrain the presence of background eclipsing binaries that could masquerade as transiting planets. By combining ground based follow-up observations with Kepler photometry, a false positive probability is calculated for each KOI. An MCMC analysis that combines both Kepler photometry and Keck radial velocity measurements determines the final orbital parameters and planet properties for each system. The resulting mass vs. radius diagram for the planets reveals that radii increase with mass monotonically, well represented by a power law for the smallest planets. This M-R relationship offers key insights about the internal composition of the planets and the division between rocky and gaseous planets.

## 302.05 – Habitability in Binary Systems

*Paul A. Mason*[1, 3]*, Joni Clark*[3]*, Pablo A. Cuartas*[2]*, Jorge I. Zuluaga*[2]*, Sebastian Bustamante*[2]

*1. Univ. Of Texas at El Paso, Las Cruces, NM, United States. 2. Universidad de Antioquia, Medellín, Colombia. 3. New Mexico State University, Las Cruces, NM, United States.*

Progress towards understanding factors that contribute to habitability on planets in binary systems is summarized. In wide binaries, habitable zones (HZ) may contain so called S-type planets, a planet orbiting one of the stellar components. For most stable planetary orbits the HZ is dominated by the star being orbited, especially if it is the more luminous star. In circumbinary, P-type planets, UV may be reduced and planetary magnetic protection may be significantly enhanced, for orbital periods greater than 20 days, due to the rapid synchronization of the stellar rotation with the binary orbit. We suggest that estimates of the number of planets capable of sustaining complex life should include a significant number of potentially habitable circumbinary planets.

# 303 – Outer Limits of the Milky Way III: Mapping Galactic Structure in Stars and Dust

## 303.01 – Exploring Substructure in the Milky Way's Midplane

*David L. Nidever[1, 2], Steven R. Majewski[2], Gail Zasowski[3]*
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*Contributing teams: APOGEE*

A host of new Galactic spectroscopic surveys are enabling explorations of structure and substructure of the Milky Way's midplane (thin and thick disks and bar/bulge) in greater detail than previously possible. In this talk I will present results of several new discoveries in this area. First, using commissioning data from the Apache Point Observatory Galactic Evolution Experiment (APOGEE), we discovered a previously unknown population of high-velocity stars in the bulge of the Milky Way. Comparison to various Galactic models suggests that these high RVs are best explained by stars in orbits of the Galactic bar potential. These observations should help us characterize the properties of the prominent bar at the center of our galaxy. Second, we discovered a new retrograde-moving stellar stream in the southern hemisphere spectroscopic data of the Grid Giant Star Survey (GGSS). N-body simulations and chemical fingerprinting show that this stream originates in the 'star cluster' Omega Centauri that is likely the remnant of an accreted dwarf galaxy. Finally, I will preview some initial results on the search for kinematical and chemical substructure in the Milky Way's disk from the APOGEE survey.

## 303.02 – Exploring the Milky Way Disk Through Stellar Clusters and Diffuse Interstellar Bands

*Gail Zasowski[1]*
*1. The Ohio State University, Columbus, OH, United States.*

The continuing influx of high-quality photometric and spectroscopic infrared (IR) data has opened new approaches for studying the properties of the dustiest regions of the Milky Way, which include the outer midplane. In this talk, I will discuss two ongoing projects. The first focuses on visually identifying highly reddened and embedded open cluster candidates in the new GLIMPSE-360 mid-IR imaging data and obtaining the follow-up photometric and spectroscopic observations necessary to confirm the existence of genuine clusters and derive their properties. This program is augmenting the census of characterized open clusters in the relatively poorly studied outer disk. In the second section, I will present early results from the detection and characterization of H-band diffuse interstellar bands (DIBs), as observed in high-resolution spectra from the APOGEE survey. These long-wavelength DIBs were first observed very recently by Geballe et al. (2011, Nature) along a handful of sightlines. This work expands the number of detections by more than three orders of magnitude and traces the feature throughout as much of the Galaxy as is accessible by APOGEE, including the outer disk. The spatial distribution of the DIB features and the correlation of their strength and kinematics with various ISM tracers give new insights into the environment and properties of the feature carriers and the ISM in which they reside.

## 303.03 – GLIMPSE360: Completing the Mid-Infrared View of the Galactic Disk

*Robert A. Benjamin[1, 2]*
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*Contributing teams: GLIMPSE360 Team*

GLIMPSE (the Galactic Legacy Infrared Survey Midplane Survey Extraordinaire) is an ongoing Spitzer Space Telescope program to obtain large-scale mid-infrared coverage of the Galactic mid-plane. As measured by publications, it has been the most successful of the Spitzer Legacy programs: over 515 refereed publications have used GLIMPSE data. We present the complete mid-infrared Spitzer/GLIMPSE panoramic coverage of the Galactic mid-plane, with a focus on the recently completed Warm Spitzer GLIMPSE360 survey. GLIMPSE360 consists of 3.6 and 4.5 images covering the 187 degrees of the Galactic plane not covered in previous Spitzer programs: Galactic longitude l=65-265 with a variable latitude range that follows the HI and star-formation warp of the Galaxy. Three visits on each sky position with 0.6 and 12 s High Dynamic Range frames provides a sensitivity range that provides a significant improvement over both WISE and the original GLIMPSE survey. We describe the point source catalog, archive, image sets and the data distribution schedule. We then highlight some of the key scientific results from the survey so far, including the discovery of a large number of previously unknown star forming regions, stellar clusters and stellar outflows, some at very large Galactocentric radius. We use GLIMPSE360 data to map the distance to the truncation/warp of the stellar disk of the Galaxy, and show how the combination of GLIMPSE and 2MASS can be used to created a detailed map of the three-dimensional structure of the warping, truncating Galactic disk. We compare this map of the warped stellar disk with maps of the HI warp and summarize their similarities, differences, and implications.

## 303.04 – Meeting Summary and Discussion

*Barbara Whitney[1]*
*1. University of Wisconsin, Madison, WI, United States.*

What interesting questions remain, and how should we address them?

# 304 – Stars, Cool Dwarfs, and Brown Dwarfs

## 304.01 – RECONS Answers Fundamental Questions in the Solar Neighborhood

*Todd J. Henry[1], Sergio Dieterich[1, 2], Philip A. Ianna[1, 3], Wei-Chun Jao[1, 2], David W. Koerner[1, 4], Adric R. Riedel[5, 6], Kenneth J. Slatten[1], John P. Subasavage[1, 7], Jennifer G. Winters[1, 2]*
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*Contributing teams: RECONS*

Comprehensive surveys are often the best way to answer fundamental questions about the Universe, but it is typically difficult to get reliable results unless great care is taken to develop and understand the sample. By observing a complete sample of red and brown dwarfs (spectral types mid-M to mid-L) in the southern sky within 15 pc --- defined by trigonometric parallax --- the RECONS (www.recons.org, REsearch Consortium On Nearby Stars) team is searching for answers to three basic questions: (1) where are the breaks in the luminosity and mass functions at the stellar/substellar border? (2) what are the populations of stellar, brown dwarf, and Jovian planets orbiting the red dwarfs that account for 75% of all stars? and (3) do the smallest stars exhibit long-term activity cycles like our Sun? We identify a sample of more than 300 of the nearest red and brown dwarfs using a combination of astrometry (parallaxes, proper motions, orbits), and photometry (plate BRI from SuperCOSMOS, VRI from our CCD observations, JHK from 2MASS, and new WISE data). Our observing program, now in its 14th year, is carried out at the CTIO/SMARTS 0.9m telescope. This is the largest long-term study of members of the solar neighborhood in the southern hemisphere, so it provides unparalleled astrometric and photometric time coverage for the nearest red and brown dwarfs. By focusing on a carefully vetted sample of the Sun's neighbors, we can hope to reveal the real answers to the three questions posed above. This effort is supported by the NSF through grants AST-0908402 and AST-1109445, and via observations made possible by the SMARTS Consortium.

## 304.02D – A Pathway to Earth-like Worlds: Overcoming Astrophysical Noise due to Convection

*Heather M. Cegla[1, 2], Chris Watson[1], Sergiy Shelyag[3, 1], Mihalis Mathioudakis[1]*
*1. Queen's University Belfast, Belfast, North Ireland, UK, United Kingdom. 2. Vanderbilt University , Nashville, TN, United States. 3. Monash University , Melbourne, VIC, Australia.*

One of the consequences of the plasma motions within the convective envelopes of low-mass stars (i.e. potential planet hosting stars) are the radial velocity (RV) shifts due to variable stellar line profile asymmetries, known as astrophysical noise (or stellar jitter). This can pose a major problem for planet hunters because RV follow-up is mandatory for most planet confirmation and characterization. Furthermore, as the net RV shifts produced from these photospheric convective motions are around the m/s level this is especially troublesome for confirmation of Earth-analogs that induce Doppler-wobbles on the cm/s level. The currently implemented noise removal technique for granulation rests on adapting observational strategies to average out such noise. However, this technique is extremely observationally intensive and does not provide information on the nature of jitter. We aim to go beyond these previous techniques by understanding the physical processes involved in granulation and removing the actual RV signature from granulation. We outline our techniques to characterize photospheric granulation as an astrophysical noise source. The backbone of this characterization is a state-of-the-art 3D magnetohydrodynamic solar simulation, coupled with detailed wavelength-dependent radiative transfer. Due to the time-intensive nature of these simulations, we use a short time-series to parameterize the granulation signal. This parameterization is then used to create full Sun-as-a-star observations from which we examine the convective noise. We present the results of this study, as well as the identification of variable gravitational redshift as a potential source of stellar jitter, both of which could impact the RV follow-up and confirmation of low-mass terrestrial planets and Earth-like worlds.

## 304.03 – A Theory on the Possible Convective Origins of Active Longitudes on Solar-like Stars

*Maria A. Weber[1, 2], Yuhong Fan[1], Mark S. Miesch[1]*
*1. High Altitude Observatory, Boulder, CO, United States. 2. Colorado State University, Fort Collins, CO, United States.*

Using a thin flux tube model in a rotating spherical shell of turbulent, solar- like convective flows, we find that the distribution of emerging flux tubes in our simulation is inhomogeneous in longitude, with properties similar to those of active longitudes on the Sun and other solar-like stars. The large-scale pattern of flux emergence our simulations produce exhibits preferred longitudinal modes of low order, drift with respect to a fixed reference system, and alignment across the Equator at low latitudes between ±15 degrees. We suggest that these active-longitude- like emergence patterns are the result of columnar, rotationally aligned giant cells present in our convection simulation at low latitudes. If giant convecting cells exist in the bulk of the solar convection zone, this phenomenon, along with differential rotation, could in part provide an explanation for the behavior of active longitudes.

## 304.04 – A Fundamental Photometric Variability Sequence Tracing the Evolution of Sun-like Stars

*Fabienne A. Bastien[1], Keivan Stassun[1, 2], Gibor S. Basri[3], Joshua Pepper[4]*
*1. Vanderbilt University, Nashville, TN, United States. 2. Fisk University, Nashville, TN, United States. 3. University of California, Berkeley, CA, United States. 4. Lehigh University, Bethlehem, PA, United States.*

The brightness variability of Sun-like stars -- from long-timescale variations attributed to the rotational modulation of spots to high-frequency acoustic oscillations -- change as they spin down on the main-sequence and then as they evolve to become subgiants and red giants. Here, we use Kepler long-cadence light curves to present a unified picture of how the photometric behavior of Sun-like stars at intermediate timescales (hours to days) evolves with time. We show that stars exhibit clear evolutionary sequences in diagrams of three simple photometric variability measures; these measures thus provide a 'fundamental plane' of stellar evolution akin to the Hertzsprung-Russell diagram, but involve only simple measures of photometric variability. We observe that the light curves of these stars become 'quieter' as they age and spin down, but that the light curves become suddenly and significantly more complex as they approach their evolution off the main-sequence. Using an asteroseismically analyzed sample of stars, we show that the sequences in our fundamental plane correlate strongly with stellar surface gravity, thereby providing a simple tool to accurately measure this quantity to better than 0.1 dex with just the long-cadence light curve. We find that the Sun itself obeys these new-found relationships; its surface gravity is correctly predicted to within 0.1 dex using only simple measures of its photometric variability. We suggest that the brightness variations we observe trace a mixture of both granulation and global oscillations, akin to that traced in astroseismic analyses, but manifested in a remarkably simpler fashion than previously appreciated.

## 304.05 – Prospects for Unprecedented Imaging of Stellar Surfaces with the NPOI

*Anders M. Jorgensen[1], Henrique R. Schmitt[2], David Mozurkewich[3], Gerard van Belle[4], Donald J. Hutter[5], J. T. Armstrong[2], Ellyn K. Baines[2]*
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We present the design of a low-cost approach to making high-resolution images with the Navy Precision Optical Interferometer (NPOI) with resolution and fidelity better than any stellar images published to date. The capability combines several existing advances and infrastructure at NPOI with modest enhancements. For optimal imaging there are several requirements that should be fulfilled. The observatory should be capable of measuring visibilities on a wide range of baseline lengths and orientations, providing complete UV coverage in a short period of time. It should measure visibility amplitudes with good SNR on all baselines as critical imaging information is often contained in low-amplitude visibilities. It should measure the visibility phase on all baselines. The technologies which can achieve this are the NPOI Y-shaped array with (nearly) equal spacing between telescopes and an ability for rapid configuration. Placing 6-telescopes in a row makes it possible to measure visibilities into the 4th lobe of the visibility function, and coherent integration techniques can be used to obtain good SNR on very small visibilities. Coherently integrated visibilities can be used for imaging with standard radio imaging packages such as AIPS. The commissioning of one additional station, the use of new hardware installed, and software enhancements can make this a reality. In this presentation we will give an overview of this potential new capability at NPOI and what it takes to get there.

# 305 – Recent Advances in Our Understanding of Star Formation

## 305.01 – Recent Advances in Our Understanding of Star Formation

*Bruce Elmegreen*[1]

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Our understanding of star formation in the cores of molecular clouds has steadily improved over the last decade as new telescopes covering a wide range of wavelengths have become available and as computer simulations have grown in size and complexity to include the most important physical processes during core collapse. Star formation generally appears to be linked to compressive turbulent flows in an environment with strong self-gravity, and to the resulting segmentation and collapse of stream-fed filaments and cores into multiple stellar systems. At the same time, new surveys on galactic scales covering ultraviolet to millimeter wavelengths, and new galaxy-scale simulations, have given an increasingly coherent picture in which the areal-average star formation rate depends mostly on the surface density of molecules, with many of the small-scale details either averaged out or unimportant. How these two frameworks join together is still a mystery that drives considerable research on such topics as the origin of the initial stellar mass function, analytical approximations to star formation rates that are useful at sub-grid levels in cosmological simulations, cluster formation and the fraction of young stars born in bound clusters, and stellar feedback that powers gas heating and motions in the interstellar medium and galactic halo. This review will highlight recent results and future directions in the broad field of star formation research.

# 308 – Bridging Laboratory and Astrophysics: Nuclear

## 308.01 – Late Time Signatures of Core Collapse Supernovae and Their Interplay with Nuclear Physics

*Luke Roberts*[1]

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After a successful core collapse supernova explosion, a neutron star is often left as a compact remnant. During the first minute of the neutron star's life, it cools and contracts by emitting a prodigious number of neutrinos. Additionally, a significant amount of matter is ejected The properties of the neutrino signal depend on the properties of dense matter inside the neutron star, which are beginning to be strongly constrained by terrestrial laboratory experiments. I will discuss recent advances in modelling this environment and how this work has been informed by experimental data.

## 308.02 – Understanding Cosmic Explosions in the Laboratory

*Fernando Montes*[1, 2]

*1. National Superconducting Cyclotron Laboratory, East Lansing, MI, United States. 2. Joint Institute for Nuclear Astrophysics, Notre Dame, IN, United States.*

Unstable isotopes and nuclear reactions play a critical role establishing the chemical composition of the universe and the properties of stellar explosions. Progress in astronomical observations and the chemical evolution of the Galaxy needs to be accompanied with similar progress in understanding the relevant properties of rare isotopes through experiments. I will review the important role that rare isotopes play in understanding stellar explosions, show some examples of recent laboratory measurements and give an outlook of future facilities that will be well suited for astrophysics studies.

# 309 – Galaxies and AGN II

## 309.02 – Companion Galaxies of Radio AGN: Insights into AGN Fueling and Feedback

*Cameron Pace[1], Samir Salim[1]*

*1. Indiana University, Bloomington, IN, United States.*

Powerful radio jets from AGN may affect nearby galaxies. There is observational evidence of both enhanced and suppressed star formation in satellite galaxies of radio AGN. Theoretical models have also been developed which explain both suppressed and enhanced star formation as a result of jet interaction. Our investigation aims to examine whether radio jet interactions commonly enhance or suppress star formation in satellite galaxies. We compared the satellites of a large, statistical sample of 7,220 radio AGN to the satellites of a control sample of non-radio AGN. Galaxies in the control sample match the radio AGN in redshift, r magnitude and u-r color. Data for the satellites were drawn from the Sloan Digital Sky Survey (SDSS). A catalog of galaxy clusters was used to classify galaxies in both samples as field galaxies, cluster members, or brightest cluster galaxies. Preliminary results suggest that for galaxies in all three of these environments, radio AGN have more satellites within 100 kpc than non-radio AGN. These excess satellites tend to be red, which suggests they are not the result of jet-induced star formation. Since the excess in red satellites of radio AGN is not accompanied by a decrease in the number of blue satellites, we suggest that AGN jets do not usually suppress star formation.

## 309.05 – AGN Prospects for the Cherenkov Telescope Array

*Markus Boettcher[1, 2], Anita Reimer[3]*

*1. Centre for Space Research, North-West University, Potchefstroom, North-West Province, South Africa. 2. Ohio University, Athens, OH, United States. 3. University of Innsbruck, Innsbruck, Tirol, Austria.*

In this talk, I will present an overview of the science prospects for very-high-energy gamma-ray observations of AGN by the planned Cherenkov Telescope Array. Progress is expected in a variety of science questions, including the physics of particle acceleration in relativistic jets, the unification between blazars and radio galaxies and the blazar sequence, population studies and questions of cosmological evolution of AGN, and explorations of signatures of gamma-gamma absorption both by the Extragalactic Background Light and by IR - UV radiation fields intrinsic to the AGN.

# 310 – Young Stellar Objects, Star Formation and Star Clusters

## 310.01 – A Wide-Field Census of Young Stars in NGC 6334

*Sarah Willis[1, 2], Massimo Marengo[1], Lori Allen[3], Giovanni G. Fazio[2], Howard A. Smith[2]*
*1. Iowa State University, Ames, IA, United States. 2. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. National Optical Astronomical Observatory, Tucson, AZ, United States.*

NGC 6334 is a giant molecular cloud with high far-infrared luminosity and a complex history of star formation located approximately 1.6 kpc away in the plane of the Milky Way Galaxy. We have obtained and analyzed near- and mid-infrared observations using deep J,H,K observation and Spitzer and Herschel datasets of this region which uncovered over 2,000 young stars nestled within the intricate structure of the cloud complex. We have used this YSO census to estimate the overall rate and efficiency of star formation in this region. By comparing these with other Galactic star forming regions and other galaxies, we have identified NGC 6334 as a potential 'mini-starburst' with SFE > 0.15 and ?$_{SFR}$ > 40 M? Myr$^{-1}$ pc$^{2}$. We have also compared the YSO population to the previously identified cold dust clumps and filaments to search for the youngest clusters and massive stars within this region.

## 310.02 – Characterizing a Herschel-detected Sample of Very Red Protostars in Orion

*John J. Tobin[1], Amelia M. Stutz[2], Manoj Puravankara[3], S. Thomas Megeath[4], William J. Fischer[4], Roland Vavrek[5], Dan M. Watson[3]*
*1. National Radio Astronomy Observatory, Charlottesville, VA, United States. 2. MPIA, Heidelberg, Germany. 3. University of Rochester, Rochester, NY, United States. 4. University of Toledo, Toledo, OH, United States. 5. ESA, Madrid, Spain.*
*Contributing teams: HOPS Team*

We have detected a sample of the reddest, and potentially youngest, protostars in the Orion molecular clouds using data obtained with the PACS instrument onboard the Herschel Space Observatory as part of the Herschel Orion Protostar Survey (HOPS). A total of 55 new protostar candidates are detected at 70 um and 160 um that are either undetected or too faint in the Spitzer/MIPS 24 um band to be reliably classified as protostars. We find that the 11 reddest new protostar candidates are free from extra-galactic contamination and can thus be reliably explained as protostars. We combine our sample with the previsouly identified Spitzer protostar sample to select the reddest sources in Orion; we find 18 sources (11 of which are new) that have extremely red 70/24 um colors. We name these sources 'PACS Bright Red sources', or PBRs. We conclude that the red colors of the PBRS can only be explainded by high envelopedensities, the highest Class 0 envelope densities / masses of all the observed protostars in Orion. We have obtained follow-up observations toward a sub-sample of the PBRs using the PACS spectrometer onboard Herschel, observing the full spectral range between 55 and 190 microns to characterize the high-J CO and water emission which is indicative of shock-heating in the outflows. We detect CO and water lines in 5 of 9 observed sources; only those with bolometric luminosities greater than 1.7 L_sun show detectable lines. We have also obtained CARMA CO (J=1-0) maps toward some of the reddest sources and detect evidence of compact outflows in some cases and non detections in others. While sample overlap is not complete, we do not detect outflow activity toward sources that do not have detected lines in the PACS spectra. The compact outflows are consistent with the PBRs being very young sources with recently launched outflows and creating shocks strong enough to produce high-J water and CO lines. Those sources without outflow detections may simply have outflows that are too weak to produce detectable lines in the current data.

## 310.03 – Probing the Early Evolution of Dust Grains Through Detailed YSO Models

*Erica Rodgers[1], Angela Cotera[2], Barbara Whitney[3, 1]*
*1. Space Science Institute, Boulder, CO, United States. 2. SETI Institute, Mountain View, CA, United States. 3. University of Wisconsin, Madison, WI, United States.*

Young stellar objects (YSOs) evolve from being dominated by a circumstellar envelope, which overtime collapses onto a circumstellar disk and disperses via jets and outflows, while the disk material accretes onto the forming star. Planets form in the circumstellar disks from dust grains that begin with an interstellar medium (ISM) grain size distribution, and grow from sizes typically less than 1um to planets with radii greater than 6000 km. Light from the forming central star scatters off of the small dust grains in the disk, envelope and outflow regions resulting in polarization at near-infrared wavelengths. Studying the polarized light in these regions provides insight into the size and distribution of the dust grain population, which changes as the YSO evolves; thus facilitating our understanding of both stellar and planetary formation. We model high-resolution Hubble Space Telescope Near Infrared Camera and Multi-Object Spectrometer (NICMOS) imaging and polarimetry for a group of four (IRAS04302+2247, IRAS04016+2610, CoKu Tau/1, DG Tau B) Taurus-Auriga YSOs known to span the earliest stellar evolutionary phases (Class I - Class I/II). We use both well-developed 3-D radiative transfer codes and variable dust grain models to sensitively constrain not only the geometry and optical depth of the scattering medium, but also the grain size distribution. We simultaneously fit multi-wavelength (submicron to millimeter) spectral energy distributions (SEDs) for our objects to further constrain the model results. Scattered light from neither ISM nor spherical small grains provides enough polarization to reproduce the NICMOS observations. Non-spherical aligned grains may produce a larger polarization depending on the orientation of the magnetic field. We present data and model YSO polarization, image morphology, and SEDs for varying dust grain models.

## 310.04 – X-ray Measurements of Variable Accretion onto the Young Star TW Hydrae

*Nancy S. Brickhouse[1], Steven R. Cranmer[1], Andrea K. Dupree[1], Scott J. Wolk[1], Hans M. Guenther[1]*
*1. Harvard-Smithsonian, CfA, Cambridge, MA, United States.*

We report X-ray line ratio diagnostics of the electron temperature, electron density and hydrogen column density observed from the classical T Tauri star (CTTS) TW Hydrae using the High Energy Transmission Grating (HETG) spectrometer onboard Chandra. Applying a classical model of magnetically channeled flow from an accretion disk onto the stellar surface, and making the assumption that the absorber of the X-ray shock is the accreting stream itself, we are able to determine all the properties of the accretion, namely the mass accretion rate, stellar magnetic field strength, disk truncation radius, and surface filling factor. We find that the diagnostic ratios, and thus the accretion parameters, are variable, lending support to the absorption assumption. We also report X-ray and optical signatures that respond to the variable accretion, with timescales suggesting the response of the stellar atmosphere to the impact of accretion.

## 310.05 – ALMA SiO (5-4) Observations: Protostellar Outflows near Sgr A*

*Farhad Yusef-Zadeh[1], Marc Royster[1], M. Wardle[8], R. Arendt[2], Howard A. Bushouse[3], Dariusz C. Lis[4], Marc W. Pound[5], D. A. Roberts[1], Barbara Whitney[6], Al Wootten[7]*
*1. Northwestern University, Evanston, IL, United States. 2. Crest/UMBC/NASA, Greenbelt, MD, United States. 3. STScI, Baltimore, MD, United States. 4. Cal Tech, Pasadena, CA, United States. 5. U. of Maryland, College Park, MD, United States. 6. Space Science Institute, Boulder, CO, United States. 7. NRAO, Charlottesville, MD, United States. 8. Macquarie University, Sydney, NSW, Australia.*

ALMA observations of the Galactic center resulted in the detection of a number of SiO (5-4) clumps of molecular gas in the 2-pc molecular ring orbiting Sgr A*. Eleven clumps of SiO (5-4) are also found within 0.6pc (15") of Sgr A*. The three SiO (5-4) clumps closest to Sgr A* show the largest central velocities of ~150 km/s and broadest asymmetric linewidths with full width zero intensity (FWZI) 110-147 km/s. Other clumps beyond the inner 15" show narrow linewidths (FWZI ~18-56 km/s. Using CARMA SiO (2-1) data, LVG modeling of the broad velocity clumps, constrain the H2 gas density (3-9)x10^5 cm^-3 for an assumed kinetic temperature 100-200K. The SiO clumps combined with evidence of YSO candidates are interpreted as highly embedded protostellar outflows, signifying an early stage of massive star formation near Sgr A* in the last 10^4-10^5 years. Star formation near Sgr A* is forbidden, unless the gas density is large enough for self-gravity to overcome the strong tidal shear of the back hole. We discuss different mechanisms that increase the gas density so that star formation can take place in this tidally stressed environment.

## 310.06 – New Computational Techniques to Determine Ages of LMC Star Clusters from Their Integrated Spectra

*Randa Asa'd[1], Margaret M. Hanson[2], Andrea V. Ahumada[3]*
*1. American University of Sharjah, Sharjah, United Arab Emirates. 2. University of Cincinnati, Cincinnati, OH, United States. 3. Observatorio Astronomico de la Universidad Nacional de Córdoba,, Argentina, Argentina.*

We are introducing a method of using integrated spectra which will be useful for determining ages in more distant unresolved stellar clusters and galaxies. Using the SOAR and Blanco 4 m telescopes, we obtained the integrated spectra of 20 stellar clusters that did not have integrated spectra in the optical range, or had never been

observed before (but have CMDs). Using this sample and 7 other stellar clusters from the literature, we show that for our sample, the statistical Kolmogorov-Smirnov (KS) test can better find the closest match between the observed spectrum and theoretical model than the traditional ?^2 minimization.

## 310.07 – The Role of Angular Momentum in the Dynamical Evolution of Star Clusters

*Anna Lisa Varri[1], Enrico Vesperini[1], Stephen L. McMillan[2], Bertin Giuseppe[3]*
*1. Indiana University, Bloomington, IN, United States. 2. Drexel University, Philadelphia, PA, United States. 3. Universita' degli Studi di Milano, Milano, Milano, Italy.*

New high precision spectroscopic observations and proper motion studies of thousands of stars in selected Galactic globular clusters are beginning to reveal detailed information about the three-dimensional kinematics of this class of stellar systems. Such a complete view of the velocity space calls for a much more complex dynamical interpretation with respect to the traditional paradigm, in which, for simplicity, the effects of internal rotation are often neglected. In view of this, we present the results of an extensive survey of N-body simulations designed to investigate the long-term dynamical evolution of star clusters characterized by a broad range of different initial structural and kinematical properties, including the presence of differential rotation. We will discuss in detail the role of angular momentum in the evolution toward core collapse by comparing the evolution of rotating and non-rotating stellar systems with similar initial structure. Particular attention will be given to the analysis of the evolution of pressure anisotropy and its radial variation in the simulated star clusters.

# 311 – Curiosity on Mars: The Latest Results from an Amazing Mission

## 311.01 – Curiosity on Mars: The Latest Results from an Amazing Mission

*Dawn Sumner*[1]

*1. University of California, Davis, Davis, CA, United States.*
*Contributing teams: Mars Science Laboratory Team*

Since August 2012, the Mars Science Laboratory (MSL) team has used the Curiosity rover to explore Gale Crater, Mars. Curiosity's science instruments were chosen to assess whether or not environments on Mars had conditions that could have supported life, e.g. whether environments were or are habitable. The 155-km diameter Gale crater was chosen as Curiosity's field site because it contains kilometers of layered rock that record the history of early environments when Mars was warmer and wetter, and thus more likely to be habitable. In addition, the landing ellipse contains evidence for alluvial fan deposits that indicate past flowing water. To date, Curiosity has been exploring within the landing ellipse by imaging rocks and land forms; characterizing the chemistry and physical properties of the atmosphere; monitoring radiation doses; and measuring the elemental composition, mineralogy, and adsorbed gases in soil and rock. Results have already led to insights into diverse modern and ancient processes that influenced the landing site, some of which have global implications. In my presentation, I will present an overview of results from the mission that have been approved by the team for release at the time of the AAS conference, with a specific focus on those with the most significant implications for the history of Mars as a planet.

# 313 – Outer Limits of the Milky Way

## 313.01 – The Vertical Structure, Ionization, and Kinematic Structure of Spiral Arm Outflows Inside and Outside the Solar Circle

*Martin Gostisha[1], Robert A. Benjamin[1], L. M. Haffner[2], Alex S. Hill[3], Kat A. Barger[4]*
*1. University of Wisconsin-Whitewater, Whitewater, WI, United States. 2. University of Wisconsin-Madison, Madison, WI, United States. 3. CSIRO, Highett, VIC, Australia. 4. University of Notre Dame, Notre Dame, IN, United States.*

Velocity-resolved surveys of the Galactic plane with the Wisconsin H-alpha Mapper indicate a thick distribution of ~1 kpc for the ionized gas layer of the Galaxy, but also show that the emission is enhanced in the vicinity of spiral arms. We characterize the vertical scale-heights of the Perseus Arm and Scutum-Centaurus Arm as a function of azimuth and compare the structure of these arms in ionized gas (from WHAM) and neutral gas (from the Leiden-Argentina-Bonn survey). We then explore the hypothesis that these arms are the sources of correlated outflow from the Galactic disk and compare the observed velocity structure of the arms with different predictions for outflow kinematics.

## 313.02 – A PanSTARRS-1 Panoramic View of the Galactic Anticenter Structure

*Eric F. Bell[1], Colin T. Slater[1], Eric Morganson[2], Eddie Schlafly[2], Douglas P. Finkbeiner[3], Mario Juric[4], Nicolas Martin[2, 5], Hans-Walter Rix[2]*
*1. University of Michigan, Ann Arbor, MI, United States. 2. Max-Planck-Institut fuer Astronomie, Heidelberg, Germany. 3. Harvard-Smithsonian CfA, Cambridge, MA, United States. 4. LSST Corporation , Tucson, AZ, United States. 5. Strasbourg Observatory, Strasbourg, France.*
*Contributing teams: PanSTARRS-1 Consortium*

The Galactic Anticenter Structure (or Monoceros ring) has been interpreted as a Galactic warp, a flare, an outer disk structure caused by the accumulated damage on the thin disk by interactions with dark matter subhalos, or as the debris from a satellite disruption on a near-circular orbit well-aligned with the plane of the Milky Way. We present a new panoramic view of the Galactic Anticenter Structure from the PanSTARRS-1 survey derived from color-selected main sequence turn-off stars. The Galactic Anticenter Structure is prominent both north and south of the plane, and extends for more than 100 degrees in galactic latitude in both hemispheres. The feature is asymmetric, extends to higher galactic latitude in the north compared to the south, and is more substructured in the north. In both hemispheres, the density of stars drops off quickly at the edge of the feature, particularly so in the south. We present a preliminary comparison with three models, highlighting areas of qualitative agreement and disagreement: a smooth Galactic flare, a model of a disrupting dwarf on a near-circular orbit (Penarrubia et al. 2005; ApJ, 626, 128), and a model of the impact of subhalo interactions on the thin disk (Kazantzidis et al. 2008; ApJ, 688, 254).

## 313.03 – The Effects of Drag and Tidal Forces on the Orbits of High-Velocity Clouds

*Alexandre Fernandes[1], Robert A. Benjamin[1]*
*1. University of Wisconsin - Whitewater, Whitewater, WI, United States.*

Over the past several years, orbital constraints have been obtained for several high velocity cloud complexes surrounding the Milky Way: Complex GCP (Smith Cloud), Complex A, Complex H, Complex GCN, and the Magellanic Stream. We summarize what is known about the orbits of these clouds and and discuss how well each of these complexes fits a balistic trajectory, and discuss how the length of a complex across the sky is related to the inital 'fragmentation' and velocity dispersion of the clouds. We then introduce gas drag into the simulation of the orbits of these complexes. We present analytical tests of our numerical method and characterize the departure of the clouds from the ballistic trajectory as a function of drag parameters (ambient gas density and velocity and cloud column density). Using the results of these simulations we comment on the survivability and ultimate fate of HVC in the context of the different models of drag forces.

## 313.04 – A Search for New Galaxies Hidden Behind the Plane of the Outer Milky Way

*Ashton Falduto[1], Loryn A. Zachariasen[1], Stephanie Bessler[1], Robert A. Benjamin[1]*
*1. University of Wisconsin-Whitewater, Whitewater, WI, United States.*
*Contributing teams: GLIMPSE360 Team*

We report the results of a visual search for galaxy candidates in a region covered by the GLIMPSE-360 Warm Spitzer Exploration program. Each section of the sky was imaged for 36 seconds in the 3.6 and 4.5 µm bands using IRAC on the Spitzer Space Telescope. We present a catalog of galaxies and highlight some of the more interesting examples. We examine the recovery rate of Galaxies along the Galactic plane, tabulate the physical parameters of the galaxies, discuss their clustering properties, and note which have been previously detected in other wavebands and surveys.

## 313.06 – A Sampling from the Spitzer Mapping of the Outer Galaxy

*Sean J. Carey[1], Joseph L. Hora[2], Donald R. Mizuno[3], Sachindev S. Shenoy[4], Kathleen E. Kraemer[3], Mark H. Heyer[5], Alberto Noriega-Crespo[1]*
*1. IPAC / Caltech, Pasadena, CA, United States. 2. Smithsonian Center for Astrophysics, Cambridge, MA, United States. 3. Boston College, Chestnut Hill, MA, United States. 4. SOFIA Science Center, Moffet Field, CA, United States. 5. University of Massachusetts, Cambridge, MA, United States.*
*Contributing teams: SMOG Collaboration*

We present some highlights of the 21 square degree imaging survey of a region in the 2nd quadrant from 3.6 to 160 microns using the IRAC and MIPS instruments aboard the Spitzer Space Telescope. The area surveyed, centered on l = 105.5 and b = 1.5, probes both arm and interarm regions including 1 kiloparcsec of the Perseus arm. In addition to panoramic images, we will display color-color diagrams of sources identified in the field providing some classification of the observed protostellar content and the arm versus interarm contrast in star formation. These data in conjunction with existing survey data from FCRAO (CO J=1-0), UKIDSS (near-IR), and HiGal (far-IR and submm) provide a wealth of information for studying star formation out to the edge of the Galactic disk and the energetics of the interstellar medium in the periphery of our Galaxy. This work is based 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.

## 313.07 – An Investigation of Mid-Infrared Selected Star Clusters in the Outer Galaxy

*Stephanie Bessler[1], Loryn A. Zachariasen[1], Ashton Falduto[1], Robert A. Benjamin[1]*
*1. University of Wisconsin-Whitewater, Whitewater, WI, United States.*
*Contributing teams: GLIMPSE360 Team*

GLIMPSE360 is a Warm Spitzer mission to survey the outer Galactic plane in the mid-infrared band at 3.6 and 4.5 microns over the Galactic longitude l=65-265. We have searched a section of this data for extended objects, including star formation regions and stellar clusters. Here we present a list of cluster candidates, along their location, sizes, and near and mid-IR color magnitude diagrams. We compare our list of objects to catalogs of confirmed and candidate clusters in order to determine whether our clusters are distinguished in their physical properties. We also present optical images of selected star clusters obtained with the WIYN 0.9m telescope, finding that some of our candidate clusters could have previously been detected in optical wavelenghts but were, for some reason, not already discovered. The possibility of using these new clusters for studies of the structure and kinematics of the Galactic disk is discussed.

## 313.08 – A Study of HII regions and Star Formation in the Far Outer Galaxy

*Jeonghee Rho[1], Hans Zinnecker[2], Barbara Whitney[3]*
*1. SETI Institute and NASA Ames Research Center, Mountain View, CA, United States. 2. DSI/SOFIA Science Center, Mountain View, CA, United States. 3. U. of Wisconsin, Madison, WI, United States.*

Is there a star formation 'edge' to the Galaxy, where stars are no longer capable of forming? Are the star formation rates and initial mass functions different in the Outer Galaxy, where the metallicity, gravitational potential, and interstellar pressure are lower? To answer such fundamental questions of Galactic astrophysics, we present a study of HII regions and associated young stellar objects (YSOs) located in the Far Outer Galaxy. We used GLIMPSE360 IRAC and WISE observations with which the high angular resolution images are ideal to identify star formation activities by separating

individual, bright HII regions and YSOs. We also investigate radiative transfer models applied to the spectral energy distributions of YSOs, and the properties of clouds associated with HII regions and star formation using existing high resolution CO and H I data.

## 313.09 – The Mid-Infrared View of Star Formation Regions in the Outer Galaxy

*Marta M. Sewilo[1, 2], Barbara Whitney[3, 2], Marilyn Meade[3], Brian L. Babler[3], Edward B. Churchwell[3], Robert A. Benjamin[4]*
*1. The Johns Hopkins University, Baltimore, MD, United States. 2. Space Science Institute, Boulder, CO, United States. 3. University of Wisconsin - Madison, Madison, WI, United States. 4. University of Wisconsin - Whitewater, Whitewater, WI, United States.*

Based on the 3.6 and 4.5 micron images from the Spitzer GLIMPSE360 survey, combined with the WISE 12 micron image, we identified a sample of star formation regions in the outer Galaxy. We study their correlation with the CO clouds from 'The Outer Galaxy Molecular Cloud Catalog' (Brunt et al. 2003; based on the FCRAO survey), as well as with known H II regions and masers. We investigate the CO and mid-IR properties as a function of distance and the association with various dynamical features in the Galaxy.

## 313.11 – A Search for Star Formation in the Outer Milky Way Galaxy

*Loryn A. Zachariasen[1], Stephanie Bessler[1], Ashton Falduto[1], Robert A. Benjamin[1]*
*1. University of Wisconsin - Whitewater, Whitewater, WI, United States.*
*Contributing teams: GLIMPSE360 Team*

Stars form inside clouds of dense interstellar gas and dust known as molecular clouds. In these clouds, the high density and low temperature allow atoms to bind together into molecules. This continues until the gas clump into regions of such high density that one reaches a point where a star begins to form. We describe the first results of a search for star-formation in the GLIMPSE360 survey, a survey of the Milky Way using the Infrared Array Camera on the Spitzer Space Telescope. We have visually inspected approximately 100 square degrees to create a catalog of 'objects of interest' consisting principally of galaxies, star forming regions, jets and outflows, bowshocks, and stellar clusters. Here we describe the candidate star forming regions, presenting the GLIMPSE360 and WISE images of a few dozen objects. We divide these objects into three classes: previously known, not previously known but correlated with known objects, and previously unknown, and present information on a representative sample of each. Ultimately, this data can be used to map out the locations of star formation regions in our galaxy to get a better understanding of the distribution and physics of star formation across the Milky Way.

# 313 – Outer Limits of the Milky Way

**Poster Session – – 26 May 2013 05:38 PM to 05:38 PM**

This session includes the same abstracts from the previous session.

# 314 – Evolution of Galaxies

## 314.01 – The Structure and Star Formation History of the New Milky Way Satellites and Beyond

*David J. Sand*[1]

*1. Texas Tech Unversity, Lubbock, TX, United States.*

The recent discovery of faint Milky Way (MW) satellites, along with faint companions to M31, has led to a confrontation between the expected number of satellite galaxies seen in Cold Dark Matter (CDM) simulations with those observed in recent very wide-field surveys. However, connecting simulations with observations is not trivial and only once we have a deep observational understanding of these new objects (e.g. their star formation history, structure, mass, internal dynamical state and gravitational interaction with the MW) can we robustly answer the question: Do the observed satellites fit into the standard CDM picture of structure formation? Thus motivated, we have undertaken a large, wide-field imaging program to study the new MW satellites with 6-8 meter class telescopes in order to measure their structural properties and star formation history via color-magnitude diagram fitting techniques, and will present our sample results here. We will also present initial results of a new survey using Magellan/Megacam to search for faint satellites around our next nearest neighbors -- NGC 253 and NGC 5128.

## 314.02 – Nebular Abundances of Fifteen KISS Star-Forming Galaxies

*Alec S. Hirschauer*[1], *John J. Salzer*[1]

*1. Indiana University, Bloomington, IN, United States.*

We present high S/N spectroscopy of 15 emission-line galaxies (ELGs) selected from the KPNO International Spectroscopic Survey (KISS). These targets were selected as having high equivalent width [O III] lines despite possessing strong emission line (SEL) abundance estimates suggesting higher abundances. Our hope with this sample was to derive direct-method ($T_e$) abundances for use in constraining the upper-metallicity branch of the $R_{23}$ relation. The spectra cover the full optical region from [O II]??3726,3729 to [S III]??9069,9531 and include measurement of [O III]?4363 in 13 objects. From these spectra, we determine abundance ratios of helium, nitrogen, oxygen, neon, sulfur, and argon. We find these galaxies to predominantly inhabit the ambiguous $R_{23}$ turnaround region (8.0 < 12+log(O/H) < 8.3), representative of medium-abundance sources. Further inspection of galaxy spectra reveals inhomogeneity of target type (e.g., two targets show evidence for AGN contamination), which weakens somewhat the utility of this sample in exploring accurate upper-branch abundances. Finally, we present a comparison of direct-method abundances with empirical SEL techniques, revealing some discrepancies.

## 314.03 – Spectroscopic Analysis of H? Dots

*Jesse Feddersen*[1], *John J. Salzer*[1], *Caryl Gronwall*[2]

*1. Indiana University, Bloomington, IN, United States. 2. Pennsylvania State University, University Park, PA, United States.*

We present spectroscopic measurements of ~200 faint point sources of emission - called H? dots - found in narrow-band images taken for the ALFALFA H? project. Our image analysis catalogs emission-line sources that are not optically associated with the target ALFALFA galaxy. Analyzing spectra of these sources, we find isolated extragalactic HII regions, ultra-low luminosity dwarf galaxies, background (higher redshift) galaxies, and QSOs. We give a summary of the photometric and spectroscopic properties of the full sample of H? dots discovered to date. We also illustrate why these objects are of astrophysical interest. For example, using coarse oxygen abundance measurements of the low luminosity dwarf galaxies, we detect signs of a possible flattening in the local Luminosity-Metallicity relation. We also find luminous [O III]-detected star-forming galaxies at z ~ 0.32 with unusually low oxygen abundances.

## 314.04 – Baryonic Distributions in the Dark Matter Halo of NGC3992

*Emily E. Richards*[1], *Liese van Zee*[1], *Daniel C. Wavle*[1], *Kate L. Barnes*[1], *Shawn Staudaher*[2], *Daniel A. Dale*[2], *Daniela Calzetti*[3], *Julianne Dalcanton*[4], *James Bullock*[5], *Rupali Chandar*[6]

*1. Indiana University, Bloomington, IN, United States. 2. University of Wyoming, Laramie, WY, United States. 3. Univeristy of Massachusetts, Amherst, MA, United States. 4. University of Washington, Seattle, WA, United States. 5. University of California, Irvine, Irvine, CA, United States. 6. University of Toledo, Toledo, OH, United States.*

A dynamical analysis of the spiral galaxy NGC3992 is carried out using 21 cm line observations of neutral hydrogen from the VLA and Spitzer 3.6?m observations of the underlying stellar component. A rotation curve is derived from the 21 cm line data and is decomposed into dark and luminous (baryonic) components using the gas surface density and stellar mass distribution inferred from the Spitzer 3.6?m image. Optical B, R, and H? observations are used to derive structural properties and the current star formation rate (SFR). Correlations between the distribution of dark matter and transitions in the stellar properties can provide insight into galaxy disk formation. Similarly, the connection between SFR and dark matter content will highlight the role of dark matter in suppressing or supporting star formation.

## 314.05 – Extraplanar Star Formation in Edge-on Spiral Galaxies: H II Region Abundances

*Katherine M. Rueff*[1], *J. C. Howk*[1]

*1. University of Notre Dame, Notre Dame, IN, United States.*

Recent observations have shown the thick disks of edge-on spiral galaxies contain dense material capable of fueling star formation (Rueff et al. 2013). We present spectroscopic confirmation of two extraplanar H II regions using MODS on the LBT and LRIS on Keck in the edge-on spiral galaxies NGC 891 and NGC 4013. These H II regions trace recent star formation located at distances z ? 650 pc and z ? 850 pc from the midplanes of NGC 891 and NGC 4013, respectively. Extraplanar H II regions provide a probe of the properties of the interstellar medium (ISM) as well as what physical processes may be taking place in the disk-halo interface. We discuss metallicity diagnostics derived from our spectroscopic data for these thick disk H II regions and the implications for the origins of the gas in the thick disks of these galaxies.

## 314.06 – PNe in M31 as Tracers of the History of the Disk of M31

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Luminous PNe have been mapped at radii Rgal well beyond the disk radius (R25) and the HI warp of M31 and beyond 50 kpc. Theory suggests that luminous PNe are the descendants of stars more massive than about 2 Msun, which raises questions of their formation at these distances where most stars are ancient. We have measured the abundances of He, N. O, Ne and other light alphas from the optical spectra of the sample. O/H is uniformly solar and its gradient is surprisingly shallow. The locations of the central stars on an H-R diagram confirm that they have indeed evolved from stars of about 2 Msun. This rules out their origin from dwarf galaxies that may have been assimilated as the outer disk of M31 formed. Instead, the results support the suggestion of Bernard et al (2012) that the ISM from which the central stars formed was tidally extracted from an M31-M33 encounter in which a burst of star formation occurred ~2 GY ago.

## 314.07 – Oxygen Abundance Measurements of SHIELD Galaxies

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We have derived oxygen abundances for 8 galaxies from the Survey for HI in extremely low-mass dwarfs (SHIELD). The SHIELD survey is an ongoing study of 12 very low-mass galaxies with HI-masses between $10^6$ and $10^7$ solar masses, detected by the Arecibo Legacy Fast ALFA (ALFALFA). H-alpha images from the WIYN 3.5m show that these galaxies each appear to be dominated by one or two star-forming regions that we targeted with long slit spectral observations using the Mayall 4m telescope at KPNO. We were only able to obtain a direct measurement of the electron temperature by detection of the weak [O III]?4363 line in 4 of the HII-regions, so oxygen abundances for the other HII-regions were estimated using the strong-line method of McGaugh (1991). Despite the very low HI and stellar masses of these galaxies, our derived abundances are not exceptionally low as would be expected based in empirical mass-metallicity relationships. Rather, we find the oxygen abundances for HII-regions in these systems to be typical of intermediate-mass dwarf irregulars.

## 314.09 – Mass Dependent Galaxy Transformation Mechanisms In The Complex Environment Of SuperGroup Abell 1882

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We have constructed a detailed photometric and spectrometric map of the SuperGroup environment of Abell 1882, using multi-wavelength data from MMT, SDSS, NED, GAMA, GMOS, Spitzer and GALEX. We have traced transformations in color, morphological properties, specific star formation rate and birthrate parameter for 526 spectrometrically classified galaxies in a wide range of density and radial locations in Abell 1882. Our results show that the system exhibits mass dependent evolutionary mechanisms primarily along the feeding filaments in the SuperGroup environment. The behavior in color and galaxy density suggests that the post-starburst galaxies with stellar masses above and below $10^{9.5}$ solar masses show different environmental mechanisms. We see the galaxy transformations as far out as 11 Mpc from the assumed center of this complex structure, still leaving the dominant transformation process ambiguous at least for galaxies with mass > $10^{9.5}$ solar masses.

## 314.1 – Understanding Polar Ring Galaxies Using the Cosinusoidal Potential

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Using the Cosinusoidal Potential as an alternative to the Newtonian Gravitational Potential, one is able to reproduce the flat rotation curves observed in disk galaxies without the introduction of dark matter. One naturally explains the thinness of the disk and the central bulge. Further, the Cosinusoidal Potential can also be used to explain the stability of orbits and why some stars orbit around the z-axis in disk galaxies. In addition, the potential generates stronger tidal forces than anticipated in Newtonian gravity. Here we present the long range behavior of the potential and show how it can provide an explanation for the observation of polar ring galaxies.

## 314.11 – Changes in Mass, Density and Energy in Galaxy-Galaxy Interactions

*Robert C. Berrington[1], Shawn D. Slavin[2]*
*1. Ball State University, Muncie, IN, United States. 2. Purdue University, Calumet, Hammond, IN, United States.*

We present numerous N-body simulations to investigate the change in mass, energy and structure of galaxies through mutual interactions. Galaxy models are selected to span a range of large-radius power-law density slopes. Collisional orbits are described by impact parameter and velocity at impact. We span a large range of impact parameters and velocities. We discuss our investigation into the dependency of the mass and energy change with galaxy structural parameters. Angular momentum transfer and changes in galaxy density profiles are characterized by the galaxy orbital collision parameters. We suggest that these models can be used to look for secular trends in the observational properties of elliptical galaxies in clusters of galaxies. We discuss the results of these models, and future directions of this study.

## 314.12 – Kinematic Analysis of Nine Low Mass Gas-rich Galaxies

*Daniel Wavle[1], Liese van Zee[1], Emily E. Richards[1], Kate L. Barnes[1], Shawn Staudaher[2], Daniel A. Dale[2], Daniela Calzetti[3], Julianne Dalcanton[4], James Bullock[5], Rupali Chandar[6], Joannah L. Hinz[7]*
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We present results from an optical, near-IR, and neutral gas study of a sample of 9 nearby gas-rich low mass galaxies. Half of the galaxies in this sample were previously known to host unusually extended gaseous disks (D_HI > 5xD_25). We trace the stellar distribution using new deep, wide field-of-view Spitzer 3.6micron images and use archival data from the VLA to trace the gas distribution and kinematics. Rotation curves have been derived by interactively fitting tilted-ring models to observed velocity fields from the neutral hydrogen synthesis observations. We derive a dark matter halo profile by fitting the observed rotation curve to the sum in quadrature of the baryonic components (stars and gas) and an isothermal dark matter halo. The stellar mass-to-light ratio is calculated for each galaxy in both the optical and near-IR. As is typical for low mass galaxies, these systems appear to be dark matter dominated throughout their stellar disk. We discuss the extent of their neutral gas disk, stellar distribution, and dark matter fraction in the context of galaxy formation and evolution.

## 314.13 – The First Look at the Rest-Frame Optical Morphology of the Most UV-Luminous Star-Forming Galaxies at High Redshift

*Christian Wilson[1], Kyoung-Soo Lee[1]*
*1. Purdue University, West Lafayette, IN, United States.*

We present preliminary results of comparative morphological studies of high-redshift star-forming galaxies observed over a wide range of UV luminosities. Our main sample represents the most actively star-forming (thus most UV-luminous; L>L*) galaxies selected over a 5.3 square-degree area in the Bootes field of the NOAO Deep Wide-Field Survey. On the other hand, the control sample derives from similarly selected, but significantly less UV-luminous, galaxies observed by the CANDELS program. Based on the HST imaging data (CANDELS + existing archival data) available for the two samples, we employ both visual inspection and quantitative classification techniques to investigate whether or not the galaxy morphology varies significantly with UV luminosity (or star formation rates).

## 314.14 – Investigating the Dependence of the Rest-Frame Optical Morphology of High-Redshift Star-Forming Galaxies on Stellar Masses

*Gregory Neeser[1], Kyoung-Soo Lee[1], Suzanne Lorenz[1]*
*1. Purdue University, West Lafayette, IN, United States.*

We present a morphological study of high-redshift galaxies observed in the CANDELS fields. Using the available deep optical and mid-infrared data, which sample the rest-frame far-UV and optical portion of the galaxy SEDs respectively, we first measure the stellar masses and star formation rates for galaxies in our samples. Based on these information, we investigate how the sizes, light profiles, and clumpiness of the galaxies (measured from the HST data) vary across the range of star formation rates and stellar masses.

## 314.15 – On the Light Element Homogeneity of Terzan 7

*Michael M. Briley[1], Sarah L. Martell[3], Graeme H. Smith[2]*
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Terzan 7 is one of a handful of globular clusters believed to have been stripped from the nearby Sagittarius dwarf galaxy. Having an origin in a dwarf galaxy rather than the Milky Way and a lower mass, Terzan 7 offers an opportunity to test hierarchical scenarios for the origin of the Milky Way's globular clusters and the role of environment and age in establishing the light element homogeneity of globulars. Here we report on an analysis of low resolution blue VLT spectra of more than 20 Terzan 7 ([Fe/H] ~ -0.7) red giants believed to be cluster members. Observed CN and CH band strengths were converted into [C/Fe] and [N/Fe] abundances through comparison with synthetic spectra based on indices. The resulting abundances exhibit: 1) A trend of decreasing C and increasing N with luminosity among the brightest stars in the sample (Mv < +1). While a well known phenomena among the more metal poor globulars, Galactic clusters of similar metallically to Ter 7 do not exhibit significant deep mixing. However, as Ter 7 is a few Gyr younger than its Milky Way counterparts, its red giants are some 20% more massive, and thus possibly more efficient at deep mixing despite their high metallicity. 2) The range of N abundances among the Ter 7 giants is considerably smaller than that found in 47 Tuc and M71 (archetypical Milky Way clusters of similar metallicity). Most notably, no significant bimodal distribution of N abundances is present. Moreover, the overall abundance of C is also some 0.5 dex lower. If further observations of Ter 7 prove it to be as moderately homogeneous as the present analysis indicates, then there are implications for the origin of the Milky Way's globular clusters. Most of the Milky Way GCs that have metallicities similar to Ter 7 are members of the thick disk or bulge populations. Such clusters that have been studied to date show large populations of CN-rich giants that are more extreme than what is seen here. If Ter 7 proves to be typical of the most metal-rich clusters that originated within dwarf galaxies of the Local Group, then the implication would be that the disk and bulge clusters of the Milky Way were not acquired from accreted satellites.

## 314.16 – Properties of the Ancient Stellar Populations in the Two Sculptor Group Dwarf Satellite Galaxies : Revealed by RR Lyrae Variable Stars

*Soung-Chul Yang[1], Rachel A. Wagner-Kaiser[2], Ata Sarajedini[2], Sang Chul Kim[1], Jeamann Kyeong[1]*
*1. Korea Astronomy and Space Science Institute, Deajeon, Korea, Republic of. 2. University of Florida, Gainesville, FL, United States.*

RR Lyrae variable stars are well known old (>10Gyr) and metal-poor population II distance indicator. However due to their low brightness compared to other bright distance indicators (e.g. TRGB or Cepheids; i.e. RR Lyraes are as low as 4 mag fainter than TRGB), the distance measurements using the RR Lyrae variables have been limited within the Local Group. Here we report the results of our analyses on the RR

Lyrae variable stars detected beyond the Local Group. We have used deep archival images taken with Advanced Camera for Surveys (ACS) onboard the Hubble Space Telescope (HST) to investigate legitimate RR Lyrae candidates in the Sculptor Group dwarf galaxies, ESO290-G010 and ESO410-G005. The presence of these stars in these two transition type dwarf galaxies strongly supports the idea that although the Sculptor Group galaxies have a considerably different environment from the Local Group, they also share a common epoch of the early star formation with the Local Group galaxies.

## 314.17 – New HErshel Multi-wavelength Extragalactic Survey of Edge-on Spirals

*Benne Holwerda[1], Simone Bianchi[7], Julianne Dalcanton[2], David J. Radburn-Smith[2], Roelof S. de Jong[6], Maarten Baes[4], Pieter C. van der Kruit[8], Karl D. Gordon[3, 4], Manolis Xilouris[5], Torsten Boeker[1]*

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Edge-on spiral galaxies are a unique perspective on the vertical structure of spiral disks, showing both stars and the iconic dark dust-lanes. The thickness of these dust-lanes can now be resolved for the first time with Herschel in far-infrared and sub-mm emission. First and foremost, these Herschel observations will settle whether or not there is a phase change in the vertical structure of the ISM with disk mass. Previously, a dramatic change in dust-lane morphology was observed as the dust disk collapses into a thin lane in massive spirals. In lower-mass spirals, the dust remains distributed vertically throughout the stellar disk. NHEMSES specifically targets lower mass nearby edge-ons to complement existing Herschel observations of high-mass edge-on spirals (the HEROES project) to verify this change in dust disk structure. Our second goal is to provide a multi-wavelength survey of edge-on spirals to drive a new generation of spiral disk Spectral Energy Distribution models. These model how dust reprocesses starlight to thermal emission but the geometry of the dust disk remains the critical unknown. We present the full NHEMESES sample of Herschel observations and discuss their vertical and radial scales, general morphology, and near-infrared colors.

## 314.18 – On The Offset of Barred Galaxies From the Black Hole $M_{BH}$-? Relationship

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We use collisionless *N*-body simulations of barred and non-barred galaxies to determine how the growth of a point mass representing a supermassive black hole (SMBH) influences the nuclear stellar kinematics in both pure disk systems, and in systems composed of a disk and spheroidal bulge. We show that the presence of a bar enhances the effect that the growth of an SMBH has on the stellar velocity dispersion (?) within the effective radius. In the presence of a bar, the increase in ? due to the growth of an SMBH is on average ?10%, whereas the increase is only ~4% in an axisymmetric disk. The increase results from a combination of three separate factors (a) streaming motions along the bar which result in an enhancement of ? by ~5% for close-to-end-on orientations of the bar; (b) angular momentum transport by the bar that results in an increase in the central mass density and consequent enhancement of ? of ~5% above the corresponding axisymmetric system; (c) an increase in the vertical and radial velocity anisotropy of stars in the vicinity of the SMBH which results in an inclination dependent increase in ?. In contrast, in axisymmetric systems, the growth of the SMBH causes the velocity distribution in the inner part of the nucleus to become less radially anisotropic. We conclude that the growth of a black hole in the presence of a bar could be partially responsible for an offset of ~15% observed for barred galaxies and pseudo bulges from the $M_{BH}$-? relation for unbarred galaxies, if the black hole grows significantly *after* the formation of the bar.

## 314.19 – Dust Properties of Star Forming Galaxies at z~2

*Matthew T. Nichols[1], Jennifer L. Wojno[1], Lutz Haberzettl[1], Gerard M. Williger[1], Matthew Lenhert[2], Nicole Nesvadba[3]*

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Lyman-break galaxies (LBGs) are tracers of star formation in the Universe with their characteristic break at 912Å. They are easy to identify over a large redshift range from z~3 to 9. That makes them the benchmark against which other samples of high redshift galaxies have been compared over the last few years. However, the epoch around z~2 is still not well explored. At this epoch, the Lyman break is still located in the rest frame UV and makes space-based observation necessary. With GALEX and HST WFC3, the observational tools became available, allowing for the selection of samples of true LBGs. Using deep GALEX FUV+NUV imaging data, our group identified a sample of 73 LBGs and IR-luminous LBGs at z~2 in the GOODS-S. Here we present preliminary results of a study of the dust properties of a subsample of these LBGs which could be identified in the far-IR. Using Herschel data, we analyze the far-IR SEDs of these star forming galaxies. By fitting dust models, we make predictions for examples of the dust temperature and masses for our sample galaxies.

## 314.2 – Chandra Observational Constraints on the X-ray Mass-Temperature Relation of Galaxy Clusters and Groups out to z~1.4

*Jingying Wang[1], Haiguang Xu[1]*

*1. Shanghai Jiao Tong University, Shanghai, China.*

Mass-temperature relation of galaxy clusters and groups is an important indicator for examining our understanding of the evolution and thermal history of such systems. We present a systematic analysis on the largest sample so far, which consists of more than 300 clusters and groups from the Chandra archival data. We show that the mass-temperature relation of the high- and low-mass parts of the sample can be described with power-law relations with different slopes. We also find that there is a clear trend for cooler systems to have a smaller mass fraction of X-ray emitting gas, which is evident within both r500 and r200. Both phenomena demonstrate that the effects of energy injection are more pronounced in less massive (i.e., cooler) systems.

## 314 – Evolution of Galaxies

**Poster Session – – 26 May 2013 05:38 PM to 05:38 PM**

This session includes the same abstracts from the previous session.

# 315 – Ground Based, Airborne Observations

## 315.01 – Measurement of the Rotation Rate of Jovian Planets with Doppler Spectroscopy

*Piper Reid*[1]
*1. Dripping Springs High School, Dripping Springs, TX, United States.*

Jupiter and Saturn are the two gas giants in our solar system. These huge planets rotate very quickly and are composed of gas with no rock or ice surface like many of the other planets in our solar system. Determining the rotational velocity of these planets is of interest to scientists as this information can help in the understanding of the origins of these gas giants and the formation of our solar system. With an amateur astronomer's telescope in a backyard observatory, is it possible to determine the speed of rotation of Jupiter and Saturn by measuring the Doppler shift of the Hydrogen-? emission lines from each side of the planet? Two Jovian planets, Jupiter and Saturn were studied. The rotational velocity was calculated by aligning the spectroscope slit with the equatorial axis of the Jovian planet and capturing a spectrum that shows tilt in the characteristic emission lines then analyzing the tilt of the emission lines and calculating the amount of Doppler shift implied by this spectral shift. By careful use of consumer grade astronomical equipment it is possible for an amateur astronomer to determine the rotational velocity of the Jovian planets from a backyard home observatory in a suburban setting.

## 315.02 – Asteroid Rotation Studies

*Xianming L. Han*[1], *Wenjuan Liu*[3, 4], *Luming Sun*[3, 4], *Shan Gao*[3, 4], *Jingjing Shi*[3, 4], *Shufen Wang*[3, 4], *Xiang Pan*[3, 4], *Peng Jiang*[3], *Hongyan Zhou*[3, 4], *Bin Li*[2], *Haibin Zhao*[2]
*1. Butler University, Indianapolis, IN, United States. 2. Purple Mountain Observatory, Nanjing, Jiangsu, China. 3. University of Science and Technology of China, Hefei, Anhui, China. 4. Polar Research Institute of China, Shanghai, China.*

During winter of 2012-2013, we measured the rotation periods of seven asteroids using the 0.9-m SARA North telescope located at the Kitt Peak National Observatory in Arizona and at the 0.6-m SARA South telescope located at the Cerro Tololo Inter-American Observatory in Chile. The asteroids that we carried out photometry studies include: 1614 Goldschmidt, 1727 Mette, 2207 Antenor, 2616 Lesya, 2972 Niilo, 4387 Tanaka, 34898 (2622 P-L). We will present their rotation periods, and compare with previous results where available.

## 315.03 – The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII): Progress Towards High Angular Resolution in the Far-Infrared

*Stephen Rinehart*[1], *Richard Barclay*[1], *Richard K. Barry*[1], *Dominic J. Benford*[1], *Dale J. Fixsen*[2], *Eric Gorman*[1], *Michael Jackson*[1], *Christine Jhabvala*[1], *David Leisawitz*[1], *Eric Mentzell*[1], *Lee G. Mundy*[2], *Maxime Rizzo*[2], *Robert F. Silverberg*[1], *Johannes Staguhn*[3], *Allison Willingham*[1]
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*Contributing teams: BETTII Team*

The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII) is an 8-meter baseline far-infrared (30-90 microns) interferometer designed to fly on a high altitude balloon. BETTII uses a double-Fourier Michelson interferometer to simultaneously obtain spatial and spectral information on science targets; the long baseline permits subarcsecond angular resolution, a capability unmatched by other far-infrared facilities. The first BETTII flight will make use of this unique capability to address key questions about star formation. Here, we present the overall design of the BETTII gondola and science instrument, and provide an overview of the current status of the project.

## 315.04 – GBT 3mm Observations in the ALMA-Era

*David T. Frayer*[1], *Brian S. Mason*[2], *Ronald J. Maddalena*[1]
*1. NRAO, Green Bank, WV, United States. 2. NRAO, Charlottesville, VA, United States.*

We discuss the current capabilities and instrumentation under development covering the 3mm atmospheric window from 67--115.3 GHz for the Robert C. Byrd Green Bank Telescope (GBT). The current GBT 4mm receiver operates from 67 GHz to 93 GHz and has comparable sensitivity to ALMA Cycle-1 at 84-90 GHz. Within the 3mm window below 84 GHz (ALMA has no frequency coverage below 84 GHz), no facility in the world comes close to matching the GBT sensitivity. The development of 3mm multi-pixel cameras such as Argus and Mustang will greatly improve the spectral-line and continuum mapping capabilities of the GBT. Although ALMA will provide excellent sensitivity at sub-arcsec resolution over small areas, multi-pixel cameras on the GBT will greatly improve the available mapping speeds for large areas at 3mm. The GBT surveys will provide targets for detailed follow-up ALMA studies, and the GBT could provide sensitive short-spacing data for GBT+ALMA imaging. The GBT is operated by the National Radio Astronomy Observatory and is currently a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

## 315.05 – Precision Differential Photometry from a Non-Precision Site (Expanding Undergraduate Research Potential)

*Joseph H. Jones*[1]
*1. University of North Georgia, Dahlonega, GA, United States.*

More than a decade ago the first exo-planet transit light curve was observed with modest instruments. This inspired the idea that it might be possible to develop observational and data reduction techniques using our venerable, but ancient 16" Boller & Chivens telescope to achieve the milli-magnitude precision differential photometry necessary for such a project. Such capability with a small instrument in the very "non-photometric" environment of our region (SE USA) greatly expands the potential observational projects available to undergraduate (and faculty) researchers. A brief description of the techniques developed to achieve this capability at the University of North Georgia will be presented. The state of our telescope is such that if these techniques work for us, they should be more than applicable to other researchers at institutions in similar regions with similar sized but more modern instruments.

## 315 – Ground Based, Airborne Observations

**Poster Session – – 26 May 2013 05:38 PM to 05:38 PM**

This session includes the same abstracts from the previous session.

# 316 – Instrumentation: Space Missions

## 316.01 – Study of the Evolution of the ACS/WFC Sensitivity Loss

*Leonardo Ubeda*[1], *Jay Anderson*[1]
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We present a study of the sensitivity loss of the ACS/WFC CCDs for one medium-band, eight broad-band, and three narrow-band filters using a calibration field located 6.7 arcmin West of the center of globular cluster 47 Tucanae. For pre-SM4 images, a comparison of the sensitivity loss rates found in this research with those calculated using standard white dwarf stars by Bohlin, R. et al. (ISR ACS 2011-03) shows excellent agreement within the uncertainties of the two methods. We found that the sensitivity losses are less than ?0.0004 mag/year. We also have a baseline of at least three years of post-SM4 observations of the 47 Tucanae calibration field. Our study shows that, on average, the sensitivity loss post-SM4 is negligible.

## 316.02 – Study of Evolution of the ACS/SBC Sensitivity

*Roberto J. Avila*[1]
*1. Space Telescope Science Institute, Baltimore, MD, United States.*
*Contributing teams: ACS Team*

The Solar Blind Channel (SBC) on the Hubble Space Telescope has been in orbit for over 11 years and it is one of the older far ultraviolet imagers on the telescope. In anticipation of the UV campaign for cycle 21, we present the first study of the evolution of the sensitivity of the camera. A long baseline has been established by observing a calibration field (NGC6681) every year since launch in all six SBC filters (five long and one medium pass). From these observations we derive and report the sensitivity curves from launch to present.

## 316.03 – Surveying Resources for CTE-loss Mitigation in ACS/WFC

*Josh Sokol*[1], *Marco Chiaberge*[1]
*1. STScI, Baltimore, MD, United States.*
*Contributing teams: ACS Team*

Since it's launch in 2002, Hubble's Advanced Camera for Surveys (ACS) has been subject to the punishing radiation environment of space. As a result, the charge-transfer efficiency (CTE) of the ACS CCDs is being slowly degraded. The ACS team has spent its last few years developing strategies and software to allay this problem, but new users may have trouble finding or availing themselves of our resources. This poster overviews the tools ACS observers have at their disposal to combat CTE losses – including the new online CTE-correcting calculator – and presents the circumstances in which they should be applied.

## 316.04 – Flagging Bad Data in the COS FUV Detectors: Improving the Data Quality by Discarding Events

*David J. Sahnow*[1], *Justin Ely*[1], *Philip Hodge*[1], *Svea Hernandez*[1]
*1. Space Telescope Science Institute, Baltimore, MD, United States.*

The Far Ultraviolet (FUV) detector of the Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope includes a microchannel plate detector with a Cross Delay-Line anode. The detector is subject to both constant and evolving non-uniformities that impact the quality of the data; these include dead spots, detector edge effects, and regions affected by microchannel plate gain sag. Although flat fielding techniques can, in principle, be used to compensate for some of these effects, it is often necessary to exclude data that cannot be properly corrected. Data quality flags are used by the COS pipeline to identify regions containing questionable data. We will describe the routine monitoring of the detector, our criteria for identifying events to be excluded, and how the use of the appropriate data collection techniques, such as the FP-POS procedure, can be used to minimize the effects of the discarded data.

## 316.05 – Strategies for the Removal of Fixed-Pattern Noise in the COS FUV Detectors

*Justin Ely*[1], *Derck Massa*[1], *David J. Sahnow*[1], *Svea Hernandez*[1]
*1. STScI, Baltimore, MD, United States.*

Far Ultraviolet spectra taken with the Cosmic Origins Spectrograph on board the Hubble Space Telescope are subject to fixed-pattern noise introduced by both the detector and the illumination pattern. These features include artifacts such as shadows from the quantum efficiency grid-wires, hexagonal boundaries due to the multifiber bundles on the microchannel plates, and surface imperfections from production, assembly, and launch. Prior to on-orbit operations, the planned mitigation strategy for these features was to employ 2D flat-field images taken while on the ground. These ground-based flats were subsequently found to be inconsistent with data taken after launch, thus making it necessary to develop new flat-fielding strategies using on-orbit data. Discussed here are both the currently implemented corrections and those still under development. These include partial two dimensional flat fields to correct large-scale non-uniformities common to all modes, grating and position specific one-dimensional flats to correct smaller scale and grating-specific features, and enhanced flagging of questionable or uncorrectable data.

## 316.06 – Updated Status and Performance for the Cosmic Origins Spectrograph Onboard the Hubble Space Telescope

*Joanna M. Taylor*[1], *Alessandra Aloisi*[1], *John Bacinski*[1], *K. A. Bostroem*[1], *John H. Debes*[1], *Julia Roman-Duval*[1], *Justin Ely*[1], *Audrey DiFelice*[1], *Svea Hernandez*[1], *Gerard A. Kriss*[1], *Philip Hodge*[1], *Kevin Lindsay*[1], *Sean A. Lockwood*[1], *Derck Massa*[1], *Cristina M. Oliveira*[1], *Rachel A. Osten*[1], *Steven V. Penton*[1], *Charles R. Proffitt*[1], *David J. Sahnow*[1], *Paule Sonnentrucker*[1], *Thomas Wheeler*[1]
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The Cosmic Origins Spectrograph (COS) was installed on the Hubble Space Telescope in May 2009. Although COS was initially designed to perform high-sensitivity medium- and low-resolution spectroscopy of astronomical objects in the 1150-3200 Å wavelength range, new wavelength settings have recently become available that allow medium-resolution spectroscopy down to 900 Å, at effective areas comparable to those of FUSE. Here we provide an update on the implementation of the new short wavelength settings G130M/1222, 1096, and 1055. We discuss changes to the Far-Ultraviolet (FUV) and Near-Ultraviolet (NUV) dark rates, FUV pulse height filtering, new and improved flux calibrations for FUV Lifetime Positions 1 and 2, changes in sensitivity for both the NUV and FUV channels, and give a general overview of the calibration projects undertaken in Cycles 19 and 20.

## 316.07 – Update on the Status of the Space Telescope Imaging Spectrograph onboard the Hubble Space Telescope

*Svea Hernandez*[1], *Alessandra Aloisi*[1], *K. A. Bostroem*[1], *Colin Cox*[1], *John H. Debes*[1], *Audrey DiFelice*[1], *Julia Roman-Duval*[1], *Philip Hodge*[1], *Stephen Holland*[1], *Kevin Lindsay*[1], *Sean A. Lockwood*[1], *Elena Mason*[1], *Cristina M. Oliveira*[1], *Steven V. Penton*[1], *Charles R. Proffitt*[1], *Paule Sonnentrucker*[1], *Joanna M. Taylor*[1], *Thomas Wheeler*[1]
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The Space Telescope Imaging Spectrograph (STIS) has been on orbit for approximately 16 years as one of the 2nd generation instruments on the Hubble Space Telescope (HST). Its operations were interrupted by an electronics failure in 2004, but STIS was successfully repaired in May 2009 during Service Mission 4 (SM4) allowing it to resume science observations. The Instrument team continues to monitor its performance and work towards improving the quality of its products. Here we present updated information on the status of the FUV and NUV MAMA and the CCD detectors onboard STIS and describe recent changes to the STIS calibration pipeline. We also discuss the status of efforts to apply a pixel-based correction for charge transfer inefficiency (CTI) effects to STIS CCD data. These techniques show promise for ameliorating the effects of ongoing radiation damage on the quality of STIS CCD data.

## 316.08 – WFC3 Calibration Pipeline Update: Significant Changes and Improvements

*Megan L. Sosey*[1], *Sylvia M. Baggett*[1], *Bryan Hilbert*[1]
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*Contributing teams: WFC3 Team*

The CALWF3 processing software and its associated routines, such as WF3CCD and WF3IR, are now available independent of the IRAF environment as part of the HSTCAL package. The previous IRAF/PyRAF version, while still available within the current STSDAS/IRAF release, will no longer be maintained or updated. The STScI archive pipeline started running the updated HSTCAL-version of the software on Sept 26, 2012. Due to accompanying changes in pipeline-dependent keywords, anyone wishing to run the most recent version of the calibration pipeline on data retrieved prior to Sept 26,2012 should re-request the data from the STSCI archive. The routines may still be accessed from the PyRAF environment by importing the new WFC3TOOLS package (released as part of the latest stsci_python). This package may also be imported into any Python session. The calibration routines may also be called directly from the system command line prompt. The WFC3TOOLS package and the CALWF3

executable are included with the HSTCAL package released alongside the latest STSDAS public release and can be downloaded from http://www.stsci.edu/institute /software_hardware/stsdas/download-stsdas.

## 316.09 – Refined WFC3 Source Lists from the Hubble Legacy Archive (HLA)

*Kevin Lindsay[1], Michael A. Wolfe[1], Stefano Casertano[1], Rachel E. Anderson[1], Richard L. White[1], Lee Quick[1], Anton M. Koekemoer[1]*
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The Hubble Legacy Archive (HLA) provides a heightened level of Hubble Space Telescope (HST) archival data products, 'science-ready', to the astronomical community. We provide a general examination of the current strategy, and the steps being taken to produce source lists for the HST's Wide Field Camera 3 (WFC3) imaging data. These source lists are created from drizzled, combined, and astrometrically corrected WFC3 images. Providing both Source Extractor- and IRAF DAOPhot-based source lists requires that the HLA develop two unique sets of source list data products in order to facilitate the needs of the community. The HLA Data Release 6 (DR6) gave the community a first look at the HLA's high-level science image products for WFC3, while DR6.1 contributed a preliminary test suite of WFC3 source lists as a means of gaining user feedback. Since DR6.1, four flag-creating filters have been developed to refine both the Source Extractor and DAOPhot WFC3 source lists. These filters remove excess spurious artifact detections (e.g. saturated sources, cosmic rays, bleed line detections, etc…), so that more precise and complete data can be made available to the community. Although high-level science products are currently available for ACS and WFPC2 through the HLA interface, future plans include the adaptation of the WFC3 HLA image processing and source list creation pipelines for the processing of ACS and WFPC2 data. With the replacement of MultiDrizzle by AstroDrizzle, and the implementation of the newly developed and refined source list artifact flag filters, we expect to see an improvement in the quality of ACS and WFPC2 source lists and the relative astrometry of the image data.

## 316.1 – Simulating Wide-Field Slitless Spectroscopy with JWST/NIRISS

*William V. Dixon[1], Chris J. Willott[2], Roberto G. Abraham[3], Marcin Sawicki[4], John B. Hutchings[2], Alexander W. Fullerton[1]*
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The Near Infrared Imager and Slitless Spectrograph (NIRISS) aboard the James Webb Space Telescope (JWST) will offer wide-field slitless spectroscopy (WFSS) with a resolving power R = 150 over the wavelength range 0.8 to 2.25 microns. In this band, NIRISS will be sensitive to Lyman-alpha emission from galaxies with redshifts $6 < z < 17$. To explore its ability to observe such high-redshift galaxies, we have modeled a NIRISS observation of the massive galaxy cluster MACS J0647+7015. Using published images, photometry, and redshifts from the CLASH survey, we constructed a series of simulated direct and dispersed images in the six filters used for WFSS with NIRISS. To each image were added 180 high-redshift galaxies distributed uniformly in space, redshift, and magnitude. Using Source Extractor, we identified 7200 galaxies in the F200W direct image, including 165 of the high-redshift sources (the remainder were lost to bright foreground objects). From this catalog, we selected 1000 objects, including all 165 of the high-redshift sources. We performed photometry of these 1000 sources in each direct image and extracted their spectra (using the aXe software package) from each dispersed image. A subset of our team was given these data and asked to identify the high-redshift galaxies. We will present the results of this analysis and discuss their implications for the ability of NIRISS to detect and parameterize high-redshift galaxies in crowded fields. NIRISS is provided to the JWST project by the Canadian Space Agency under the leadership of René Doyon of the Université de Montréal. The prime contractor is COM DEV Canada.

## 316.11 – Wide Field Camera 3: Trends in the UVIS Detector

*Matthew Bourque[1], Jay Anderson[1], Sylvia M. Baggett[1], John A. Biretta[1], Susana E. Deustua[1], Derek Hammer[1], Kai Noeske[1], John W. MacKenty[1]*
*1. STScI, Baltimore, MD, United States.*
*Contributing teams: WFC3 Team*

The Hubble Space Telescope (HST) Wide Field Camera 3 (WFC3) is a fourth-generation imaging instrument that was installed during Servicing Missing 4 in May 2009 and has performed well on-orbit since then. The UVIS channel, named for its ultraviolet and visible light detecting capabilities, is comprised of two e2v CCDs and is one of two channels available on WFC3. We present the results of some of the monitoring programs used to regularly assess the performance and calibration of the UVIS detector. We discuss the long-term growth in the number of hot pixels and the effectiveness of the anneal procedures in controlling that growth as well as provide a summary of the long-term evolution in dark current. We also summarize the UVIS Charge Transfer Efficiency (CTE) monitoring accomplished using both external and internal observations and provide recommendations for CTE mitigation. We describe a program to check for detector hysteresis (quantum efficiency offset) in the detector and detail our method of successfully neutralizing any offset. Finally, we outline the routine photometric monitoring performed and provide an evaluation of the throughput stability of the UVIS channel. These and other trending programs will continue throughout and beyond HST's current proposal cycle as a means of evaluating the overall health and stability of WFC3/UVIS.

## 316.12 – Wide Field Camera 3: Phase II Proposal Update for Cycle 21

*Heather C. Gunning[1], Jay Anderson[1], Sylvia M. Baggett[1], Tomas Dahlen[1], Linda L. Dressel[1], Knox S. Long[1], John W. MacKenty[1]*
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*Contributing teams: WFC3*

Installed on the Hubble Space Telescope (HST) in May 2009, the Wide Field Camera 3 (WFC3) is a fourth-generation imaging instrument which has been performing well on-orbit. The most recent HST Call for Proposals ended on Friday March 1, 2013. For successful proposers - as determined by the Telescope Allocation Committee and approved by the Director of STScI - the next step is to convert the proposal into a 'Phase II' using the latest version of the Astronomer's Proposal Tool (APT 21.0.1). The Phase II contains the exposure specifications and details necessary for acquiring the data. To aid in this process, we summarize information which may be helpful to WFC3 observers preparing their Phase II. We discuss the available apertures and observing modes, the Charge Transfer Efficiency (CTE) mitigation options (post-flash and the CTE pixel-based correction algorithm), as well as strategies to optimize observations, e.g. useful dithering sequences, tips for packing orbits, and ways to minimize persistence in WFC3/IR images.

## 316.13 – The Large Observatory for X-ray Timing

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*Contributing teams: LOFT Collaboration*

The Large Observatory for X-ray Timing (LOFT) is a proposed European Space Agency M3 mission with US participation in the form of a proposed mission extension. The mission has two intstruments: a Large Area Detector with 20 times the collecting area of any previous X-ray telescope, and spectral resolution only slightly worse than that from CCDs; and a Wide Field Monitor which will provide the best combination of medium-energy X-ray sensitivity and field of view of any X-ray observatory to date, while also providing good spectral resolution. The proposed US contributions are Tanatalum collimators which will decrease the background in the LAD dramatically, and additional ground station support which will allow the full information from the WFM to be transmitted to Earth nearly all the time. The mission's core goals focus on understanding accretion in strong gravitational fields and the equation of state of dense matter, but the mission has the capability to contribute across nearly the whole of astrophysics.

## 316.14 – Properties of the Hubble Source Catalog

*Sahar S. Allam[1], Tamas Budavari[2], Stefano Casertano[1], Stephen H. Lubow[1], Lee Quick[1], Richard L. White[1], Bradley C. Whitmore[1]*
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The Hubble Source Catalog (HSC) is an initiative to combine tens of thousands of visit-based Hubble Legacy Archive (HLA) Source Extractor based source list into a single master catalog. The HSC is based on a newly developed crossmatching technique (Budavari & Lubow 2012) and includes ACS/WFC and WFPC2 detections from the HLA DR6 database. The astrometric residuals for the HCS individual objects are typically within 10 mas. An illustration of using the HSC will presented along with a comparisons of 'standard' photometric and astrometric catalogs. It is expected that the HSC will be a fundamental reference for JWST science and provide an essential research resource for many years, if not decades.

## 316.15 – Herschel - delivering cool science for years to come

*Stephan Ott[1]*
*1. ESA, Noordwijk, HE, Netherlands, Netherlands.*

The Herschel Space Observatory was launched 14th of May 2009. With a 3.5 m telescope, it is the largest space telescope ever launched. Herschel's three instruments (HIFI, PACS, and SPIRE) performed photometry and spectroscopy in the 55 - 671 micron range and delivered exciting science for the astronomical community since late

2009. Being a cryogenic mission Herschel's operational lifetime is consumable-limited by its supply of liquid helium; which is expected to run out in early April 2013. As a pioneering mission Herschel made extraordinary discoveries across a wide range of topics, from starburst galaxies in the distant Universe to newly forming planetary systems orbiting nearby young stars. At the time of this meeting the Herschel Science Ground Segment will undergo its transition period from the operational (observing) phase into its post-operational phase that will last until the end of 2017. It is expected that the peak of scientific productivity is still ahead of us, and in these years to come the Herschel Science Centre (HSC - located at ESAC, Madrid, Spain) and the NASA Herschel Science Center (NHSC - located at IPAC, Pasadena, U.S.A.) will continue to support the worldwide astronomical community in the analysis and exploitation of the Herschel data, enabling all astronomers to perform a vast amount of exciting science using the observatory's public data archive which provides access to 44000 observations taken in standard observing mode. Herschel data processing will continue to provide the astronomical community with high-quality data products, interactive analysis software and user documentation. These products and services are not only for the benefit of Herschel expert users; the Herschel Science Ground Segment actively pursues all avenues to expand the Herschel users community, with the final goal of making the treasure trove of Herschel data readily available to all astronomers as the definitive Herschel legacy. We will present the advanced state of Herschel's standard pipeline products, of HIPE, the Herschel Interactive Processing Environment, our documentation and outline our future development milestones and plans.

# 316 – Instrumentation: Space Missions

**Poster Session – – 26 May 2013 05:38 PM to 05:38 PM**

This session includes the same abstracts from the previous session.

# 317 – Stellar Evolution

## 317.01 – Any Density Changes Near the Inner Shell of the Planetary Nebula NGC 6803?

*Seong-Jae Lee[1], Siek Hyung[1]*
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Most recent high dispersion spectral data, secured at Lick Observatory in 1995 and 2001, suggested a large density increase near the inner shell boundary of the elliptical ring planetary nebula NGC 6803, e.g., Ne = 8900 (10^3.95) --> 14,400 (10^4.16)/cm^3 in [Ar IV] (Lee and Hyung 2013). We further analyzed high dispersion spectroscopic data observed in 2012 February with the Bohyunsan fiber-fed echelle spectrograph (BOES) attached to the Bohyunsan Observatory 1.8m telescope. The BOES diagnostic line ratios indicate a large change between 2001 & 2012 observations; -0.23, +0.39, +0.13, -0.28 dex for [S II], [O II], [N II], and [Cl III], respectively. For example, the 2012 BOES [Ar IV] line ratio implies a decreasing density of N=11,700 (10^4.07)/cm^3. We discuss the changes of physical conditions and kinematics of NGC 6803.

## 317.02 – Long Period Monitoring of the Superoutbursts of Two SU UMa-type Dwarf Nova Stars: FO And and IR Gem

*Aubrie A. Maxwell[1], R. K. Honeycutt[1]*
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Analysis of long-term observations for two SU UMa-type dwarf nova stars, FO And and IR Gem, are presented. Observations for FO And were obtained yearly from 1991 to 2005 and for IR Gem from 1991 to 2003 using Roboscope located at Indiana University. The long baseline has shown long term variation in both stars with a preliminary period of ~6000 +/-1000 days for FO And. A preliminary measurement for the nominal time between superoutbursts has been determined to be a minimum of ~80 days for FO And with an amplitude of ~3.2 mag above the quiescent magnitude. For IR Gem a minimum spacing of ~25 days with an amplitude of 3.4 mag above the quiescent magnitude is found. It is also observed that the maximum magnitudes during superoutbursts are relatively constant despite the variation in the quiescent magnitude. The time between normal outbursts for FO And and IR Gem are minimum of ~4 days and ~10 days respectively. FWHM values for both normal and superoutbursts as well as superoutburst decline rates are presented.

## 317.03 – Hubble Space Telescope Observations of the Light Echo from the Recent Outburst of T Pyxidis

*Stephen S. Lawrence[2], Jennifer L. Sokoloski[1], Arlin P. Crotts[1], Helena Uthas[1]*
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The recurrent nova T Pyxidis (T Pyx) is well known for its small binary separation, its unusually high luminosity in quiescence, and its optically emitting remnant. In 2011 April, T Pyx erupted for the first time since late 1966. We will describe Hubble Space Telescope observations of the `light echo' reflection of variable optical emission from the eruption scattered off of dust in the remnant from previous outbursts. These light echoes show that the remnant is dominated by a thick, clumpy ring with a radius of between roughly 4 and 5 arcseconds that is inclined by roughly 30° with respect to the plane of the sky. The delay time between the peak of the direct optical light from the outburst and its reflection from dust in the plane of the sky provides a distance to T Pyx of 4.8 +/- 0.5 kpc. We will discuss the interesting implications of the distance and the echoing structure on the velocities and morphology of the ejecta from earlier outbursts.

## 317.04 – High Resolution Near-IR Imaging of VY Canis Majoris with LBT / LMIRCam (2 - 5 ?m)

*Dinesh Shenoy[1], Terry J. Jones[1], Roberta M. Humphreys[1]*
*1. MN Institute for Astrophysics, University of Minnesota, Minneapolis, MN, United States.*
*Contributing teams: LMIRCam Instrument Team (PI: Mike Skrutskie)*

HST imaging of the famous red hypergiant VY Canis Majoris shows a complex circumstellar reflection nebula indicative of multiple asymmetric ejection episodes. Constructing a more complete picture of the mass loss mechanism compels extending high resolution imaging of massive stars such as VY CMa into the near-infrared, where the mechanism for emission from circumstellar ejecta transitions from scattering to thermal. We present LBT/LMIRCam observations of VY CMa at Ks (2.2 ?m), L' (3.8 ?m) and M (4.9 ?m) at sub-arcsecond resolution, comparable to the HST in the optical. The peculiar Southwest (SW) Clump, first identified as a highly reddened feature seen only at the longest wavelength (1 ?m) in the HST images, appears bright in the three LMIRCam filters. The SW Clump is found to be optically thick at all three wavelengths. A silicate grain model yields a lower limit mass on the order of 7E-4 M?

## 317.05 – What is Changing in Eta Car?

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Over the past fifteen years, the massive binary, Eta Car, has undergone a secular brightening of one stellar magnitude in addition to its 5.5-year periodic variations caused by the massive interacting winds influenced by the highly eccentric binary orbit. What is the cause of this brightening? Has the primary wind dropped? X-ray observations suggest that the hydrogen column density in LOS has dropped two-fold. The brightening is non-wavelength dependent in character. CMFGEN models of the primary stellar spectrum suggest that He I wind lines should brighten considerably and Fe II wind lines should fade. Such is not seen, but hydrogen broad lines have dropped two-fold in equivalent width. Has the secondary wind increased? The expected increase in excitation of the Weigelt Blobs is not present. Is this only an apparent brightening due to our unique LOS? Our 3D SPH models show that the LOS intersects the walls of the interacting winds. A small change in mass loss rate could be amplified to a large change in column density and a large drop in formation of large dust grains in LOS without major affect in other directions. We are pursuing observations and models to answer these questions.

## 317.06 – Photometric and Kinematic Analysis of ACS/HRC Ultraviolet Images of Eta Carinae

*Drew Rosen[1], Jon A. Morse[1]*
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We present an analysis of archival near-UV HST-ACS/HRC images of Eta Carina to search for spectrophotometric variations in, e.g., Mg II absorption/emission in inner regions of the Homunculus Nebula. Eta Carinae is a massive binary star system of approximately 150 solar masses, making it one of the most massive star systems that can be studied. The primary star appears to be approaching the end of its lifetime, and it is expected to go supernova (or hypernova) within the next million years, or possibly much sooner. The companion star, also apparently highly evolved, has a highly eccentric elliptical orbit with a period of 5.5 years that passes very close to, or even grazes, the photosphere of the larger primary star. Evidence suggests that periastron passage of the companion creates instabilities through the primary star that have resulted in the ejection of vast amounts of material in the Homunculus Nebulae, possibly at different epochs and in different directions.

## 317.07 – Novel, Young, Low-Mass Multiples from the *CASTOFFS* Survey

*Joshua E. Schlieder[1], Mickaël Bonnefoy[1], Niall Deacon[1], Tom Herbst[1], Katharine Johnston[1], Sebastien Lepine[2], Johan Olofsson[1], Emily L. Rice[3, 2], Thomas Henning[1]*
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Low-mass multiples are essential to understand stellar formation and evolution. Small separation, short period binaries provide a means to measure component masses via astrometric orbits. These masses are necessary for the calibration of widely used evolution models. Wide, hierarchical multiples provide a window into system evolution and constrain possible formation scenarios. We have identified two novel, low-mass multiple systems in the framework of the **C**ool **A**strometrically **S**elected **T**argets **O**ptimal **F**or **F**ollow-up **S**pectroscopy (*CASTOFFS*) survey. *CASTOFFS* aims to identify and characterize young, low-mass stars in the solar neighborhood. TYC 5241-986-1ABC is a hierarchical triple identified in a common proper motion companion search of the *CASTOFFS* sample. Optical spectroscopy of the components revealed a late-K primary with a pair of mid-M dwarf companions at an age of 20-120 Myr. *WISE* photometry of the primary suggested an excess in the mid-IR, which was verified by *Herschel* photometry at 70 ?m. The excess emission is characteristic of a ?150 K debris disk. TYC 5241-986-1A is a rare example of an intermediate age, late-type, debris disk host star. NLTT 33370AB is a nearby (16.4 pc), late-M binary with ?0.1? separation. Adaptive optics imaging revealed significant orbital motion since the discovery epoch in 2005. Our analyses of optical and near-IR spectra indicate that the system is ?100 Myrs old. We found the components have equal flux in the *J*-band and models predict preliminary masses at the star/brown dwarf boundary. NLTT 33370AB is one of only a few young, low-mass, binaries that can be used to calibrate evolution models.

## 317.08 – Light Element Abundance Inhomogeneities and Deep Mixing in Galactic Globular Clusters

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It was discovered years ago some thirty years ago that stars in Galactic globular clusters tend to decrease in carbon abundance with increasing luminosity on the red giant branch, particularly among the lower metallicity clusters. While such a phenomena is not predicted by canonical models of stellar interiors and evolution, it is widely believed to be the result of some “extra mixing” operating during red giant branch ascent which transports material exposed to the CN(O)-cycle to the surface. Here we present an analysis of observations to further explore the theories of deep mixing, most notably thermohaline circulation, in the evolving red giants of globular clusters within our own Galaxy. Building on the work of Martell, Smith, and Briley (2008, AJ, 136, 2522), we have used the KPNO 4-m and SOAR 4.1-m telescopes to extend the sample of clusters primarily at the high- and low-metallicity ends. The CH absorption features in these low resolution blue spectra will be analyzed via synthetic spectra in order to obtain [C/Fe] abundances. These abundances and the luminosities of the target stars will then be used to establish the rate at which C abundances are changing with time (i.e., the mixing efficiency). By establishing rates over a wide range of composition, the dependence of deep mixing on metallicity can be measured and used to better constrain theories of the underlying process.

## 317.09 – A Peculiar Class of Slow Speed Supernovae from the Palomar Transient Factory

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*Contributing teams: Palomar Transient Factory*

The Palomar Transient Factory has spectroscopically classified nearly two thousand supernovae. We mined this treasure trove of spectra to identify nine members of a peculiar, low-velocity class of transients. The physical origin of these slow, hydrogen-poor supernovae remains a matter of debate. Our systematic search shows evidence for two distinct subclasses based on their host galaxy, spectroscopic, and photometric properties: The 'SN 2002cx-like' supernovae are in late-type or dwarf hosts, have longer rise-times, and show cooler spectra (no Ti II trough) when compared to the 'SN 2002es-like' supernovae. Combining this with the literature sample, we discuss possible explosion mechanisms to explain these two channels.

## 317.1 – Signatures of Electron Capture and High Magnetic Fields in Late-Time NIR Spectra of SN 2005df

*Christopher L. Gerardy[1], Tiara Diamond[1], Peter Hoeflich[1]*
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We present late-time (200-400d) near-infrared spectral evolution for the moderately sub-luminous Type Ia SN 2005df. The spectra show numerous strong emission features of [Co II], [Co III] and [Fe II] through out the 0.8-2.5 micron region. The strong 1.64 micron [Fe II] feature exhibits a flattened core line profile similar to those seen in SN 2003du and SN 2003hv, although the width of the flattened core is only about half as wide as in these events. Interpreted as an emission hole due to high-density electron capture in the early stages of burning, this suggests that central density of the SN 2005df progenitor was somewhat less than in the other events. As the spectra age the cobalt features fade as would be expected from the decay of 56Co to 56Fe. However, the spectra otherwise show surprisingly little evolution despite spanning nearly a factor of two in post-maximum age. Comparisons with models of positron transport in late-time SN Ia ejecta suggest that the progenitor of SN 2005df may have had core magnetic fields as strong as 10^6 gauss or higher.

## 317.11 – Convergence Studies of Protostellar Disks with Gravitational Instabilities

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We report results of a convergence study of a protoplanetary disk susceptible to gravitational instabilities (GIs). The disk is primarily studied during its asymptotic state, a time of approximate balance between heating produced by the GIs and radiative cooling governed by realistic dust opacities. Local cooling times of ?5–20 orbital periods are found, with the longest times falling at those radii where the Toomre Q has its minimum value and the disk is most susceptible to GIs. An analytic explanation of this correspondence is presented. We examine cooling times, characterize GI-driven spiral waves and their resultant gravitational torques, evaluate how accurately mass transport can be represented by an ?-disk formulation, and discuss possible implications of our results for numerical convergence of fragmentation criteria in disk simulations. Results are compared with similar studies.

## 317.12 – Swift Ultraviolet Survey of the Magellanic Clouds

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While primarily being a Gamma-Ray Burst mission, Swift is spending a significant fraction of it's time observing non-GRB targets. We used the Swift Ultraviolet/Optical (UVOT) and X-Ray Telescopes (XRT) to seamlessly cover the Small and Large Magellanic Clouds in 50 (SMC) and 165 (LMC) individual pointings with 3 ks exposure time each (1 ks in each of the three UV filters at wavelengths of 192.8, 224.6, and 260 nanometers). The resulting mosaics provide the most detailed ultraviolet view of the Magellanic Clouds in terms of spatial resolution (~2 arc sec) and coverage (SMC: 3.4 square degrees, LMC: 9.2 square degrees). We detected tens of thousands of individual UV sources and have commenced detailed studies of its star formation history, initial mass function, UV extinction, and star forming regions.

## 317 – Stellar Evolution

**Poster Session – – 26 May 2013 05:38 PM to 05:38 PM**

This session includes the same abstracts from the previous session.

# 318 – Galaxy Observations

## 318.01 – Continuing L-Band Observations of Blazars with the 21-Meter Space Tracking Antenna at Morehead State University

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Radio observations of blazars are important for complementing observations made at other wavelengths, such as optical and X-ray. The 21-Meter Space Tracking Antenna (STA) at Morehead State University is well-suited for making precisely these complementary observations. During the 2012-2013 academic year the STA continued a campaign of monitoring observations of a sample of well known blazars. These observations were conducted at L-Band with remote observations of the STA now possible from the control room of the Space Science Center at Morehead State University. This research endeavor is mainly led by undergraduate students who lead in conducting observations and completing the associated data reduction. Results from observations from the 2012-2013 academic year will be presented and discussed.

## 318.02 – X-ray Observations of NGC 1068 using Suzaku

*Aaron T. Steffen[1]*
*1. UW - Marathon County, Wausau, WI, United States.*

We present a 41.6 ks X-ray observation of NGC 1068, a compton-thick, Seyfert 2 galaxy. The data were taken with the Suzaku X-ray Observatory using both the XIS (0.2 - 12 keV) and HXD (10 - 600 keV) instruments. We present best-fit spectral models and X-ray luminosities for these observations and compare them with previous X-ray data from both Chandra and XMM-Newton.

## 318.03 – Radio and Optical Polarimetry of M87 between 2003-2008

*Sayali S. Avachat[1], Eric S. Perlman[1], Frazer N. Owen[2], Steven C. Adams[3, 4], Mihai Cara[1, 5]*
*1. Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL, United States. 2. National Radio Astronomy Observatory, Socorro, NM, United States. 3. Department of Physics and Astronomy, Athens, GA, United States. 4. Department of Physics and Astronomy, Clemson, SC, United States. 5. Physics Department, Case Western Reserve University, Cleveland, OH, United States.*

We present optical and radio polarimetry of the M87 jet, obtained at sub-arcsecond resolution between 2003-2008. These observations have better angular resolution than previous work by factors 2-3, and in addition allow us to explore the time domain. Polarization variability was recently found in the highly variable, flaring knot HST-1, 0.86” from the nucleus, as well as in the nucleus itself, over the same time period by Perlman et al. (2011). Here we search for radio polarization variability from the nucleus, HST-1 and other jet components, and explore its relationship to the flux variability observed. We also compare the polarization characteristics of the jet in the optical and radio, both in terms of variability, as well as morphologically. We discuss the implications of our work in terms of jet models.

## 318.04 – Determining the Radial Locations of Dust Sources in FeLoBALs

*Jay P. Dunn[1]*
*1. Georgia Perimeter College, Dunwoody, GA, United States.*
*Contributing teams: Branden Wasik, Christin L. Holtzclaw, David Yenerall, Manuel Bautista, Nahum Arav, Daniel Hayes, Max Moe, Luis Ho*

We present 4 BAL quasars with blueshifted, absorption troughs attributed to MgII and FeII that also exhibit strong, narrow hydrogen Balmer emission lines out of a sample of 8510 quasars observed by the Sloan Digital Sky Survey (0.05% of the sample). Of the 70 and 15 quasars that demonstrate MgII and FeII absorption, respectively, we find that 32% and 27% have strong E(B-V) values (>0.1) for the continuum. In comparison, the objects with strong, narrow emission lines demonstrate E(B-V) values consistent with the continuum values, which suggests that the reddening sources in these objects are radially exterior to the NLR and likely at galactic scales.

## 318.05 – Centaurus A @ ALMA+ATCA: Molecular Gas toward the AGN of the nearest radio galaxy

*Juergen Ott[1], David S. Meier[2, 1], Mark McCoy[2]*
*1. National Radio Astronomy Observatory, Socorro, NM, United States. 2. New Mexico Institute for Technology, Socorro, NM, United States.*
*Contributing teams: CenA team*

Centaurus A and its associated host galaxy NGC 5128 are by far the most nearby radio galaxy. Its proximity provides us with the best opportunity to study the feeding of a supermassive, central black hole and the processing of accreting matter into large scale jets. In turn, jets have an impact on the interstellar medium that may inhibit or speed up star formation processes. We present Atacama Large Millimeter/submillimeter Array (ALMA) data toward the central ~300pc of CenA. We detect a large number of molecular species in emission and absorption. Line ratios, and eventually radiative transfer modeling, provides us with the best means to probe the molecular gas in the vicinity of the AGN. We characterize a number of absorption components that lie along the very warped disk structure of NGC5128, with very different linewidths ad velocities. We also obtained complementary Australia Telescope Compact Array observations that detect a water maser in the central nucleus, either directly emitted in the accretion disk or at the base of the emerging jets.

## 318.06 – Simulation and Separation for Signals in Low-Frequency Radio Sky

*Haiguang Xu[1], Jingying Wang[1]*
*1. Shanghai Jiao Tong University, Shanghai, China.*

We simulate the 50-200 MHz radio sky that is constrained in the field of view of the 21 Centimeter Array (21CMA), by carrying out Monte-Carlo simulations to model the strong contaminating foreground of the redshifted cosmological reionization signals, including emissions from our Galaxy, galaxy clusters, and extragalactic discrete sources (i.e., star-forming galaxies, radio-quiet AGNs, and radio-loud AGNs). By introducing a new approach designed on the basis of independent component analysis (ICA) and wavelet detection algorithm, we prove that, with a cumulative observation of one month with the 21CMA array, about 80% of bright galaxy clusters can be safely identified and separated from the overwhelmingly bright foreground. By examining the brightness temperature images and spectra extracted from these identified clusters, we find that the morphological and spectroscopic distortions are extremely small as compared to the input simulated clusters, even for the clusters that are fainter than the confusion limit. Furthermore, aiming to correctly restore the redshifted 21 cm signals emitted by the neutral hydrogen during the cosmic reionization processes, we re-examine the separation approaches based on the quadratic polynomial fitting technique in frequency space. At z = 8 and the noise level of 60 mK we find that a significant part of Mpc-scale components of the 21 cm signals is lost because it tends to be mis-identified as part of the foreground when single-narrow-segment separation approach is applied. The best restoration of the 21 cm signals can be obtained with the three-narrow-segment fitting technique as proposed in this paper. Similar results can be obtained at other redshifts.

## 318 – Galaxy Observations

**Poster Session – – 26 May 2013 05:38 PM to 05:38 PM**

This session includes the same abstracts from the previous session.

# 400 – Current Perspectives on the Spiral Structure of the Milky Way

## 400.01 – Current Perspectives on the Spiral Structure of the Milky Way

*Thomas M. Dame*[1]

*1. Harvard-Smithsonian CfA, Cambridge, MA, United States.*

Completion of the first Galactic 21 cm surveys almost 60 years ago was accompanied by great optimism that a face-on map of our Galaxy's spiral structure was at hand. We are still waiting. The only reliable "maps" of the atomic gas distribution that exist even today are those in the observed longitude-velocity diagram. Substantially more progress followed completion of the first CO surveys of the molecular gas some 30 years ago. Still, because distances to molecular clouds and other arm tracers are largely derived from their velocities, progress toward a face-on map has been slowed by both the kinematic distance ambiguity in the inner Galaxy and large errors on kinematic distances owing to noncircular motions. We are finally gaining traction on both of these problems. New interferometric 21 cm surveys are being used to resolve the distance ambiguity for hundreds of recently-discovered H II regions and their parent molecular clouds, and very long baseline interferometry is being used to measure direct parallax distances and proper motions for hundreds of maser sources throughout the Galaxy. The importance of these measurements for understanding the structure and kinematics of the Galaxy cannot be overemphasized. Some preliminary results based on the first 100 or so maser parallaxes will be presented. Even as our ability to sort out the Galaxy's spiral structure has been increasing substantially, hints have emerged that the structure itself might be simpler than long thought. Near-infrared surveys have shown that the Galaxy contains a fairly strong bar and they suggest that two dominant spiral arms, Sct-Cen and Perseus, originate at opposite ends of this bar. More direct evidence of a two-fold symmetry in the Galaxy has been provided by the discovery of the so-called Far 3-kpc Arm, which displays remarkable kinematic and structural symmetry with its near-side counterpart. In addition, a spiral feature recently identified in the distant outer Galaxy appears to be a large extension of the dominant Sct-Cen Arm and a symmetric counterpart of the nearby Perseus Arm. With such recent developments, many on-going surveys, and the planned launch of Gaia later this year, some renewed optimism in this field is justified.

# 401 – Bridging Laboratory and Astrophysics: Particles

## 401.01 – IceCube and Indirect Dark Matter Searches

*Carsten Rott*[2, 1]
*1. Ohio State University, Columbus, OH, United States. 2. Sungkyunkwan University, Seoul, Korea, Republic of.*

The study of high-energy neutrinos is a topic with rich connections across particle physics and astrophysics. It plays an essential role in answering fundamental questions about the nature of the cosmic ray sources, neutrino properties, and dark matter. Indirect searches for dark matter have seen tremendous progress over the last few years, which has been driven by new observational data, in particular with IceCube, new methodologies in searches, and new detection channels. After an overview of indirect dark matter searches and the major instruments involved, I will highlight advances in the field. The talk will summarize outstanding questions in indirect searches for dark matter and how those connect to laboratory astrophysics.

## 401.02 – GALPROP Code for Galactic Cosmic Ray Propagation and Associated Photon Emissions

*Igor Moskalenko*[1]
*1. Stanford University, Stanford, CA, United States.*
*Contributing teams: GALPROP Team*

Research in many areas of modern physics such as, e.g., indirect searches for dark matter and particle acceleration in supernova remnant shocks rely heavily on studies of cosmic rays (CRs) and associated diffuse emissions (radio, microwave, X-rays, gamma rays). The numerical Galactic CR propagation code GALPROP has been shown to reproduce simultaneously observational data of many kinds related to CR origin and propagation. We report on the latest updates of GALPROP, development of WebRun, a service to the scientific community enabling easy use of the GALPROP code via web browsers, and a library of evaluated isotopic production cross sections. We also report the results of a full Bayesian analysis of propagation parameters using nested sampling and Markov Chain Monte Carlo methods.

# 402 – Instrumentation, Data Handling, Surveys

## 402.01 – The WISE Survey of the Near-Earth Asteroids (NEOWISE)

*Tommy Grav[1], Amanda K. Mainzer[2], James M. Bauer[2, 3], Joseph R. Masiero[2], Rachel Stevenson[2], Nugent Carolyn[2, 6], Robert S. McMillan[4], Russell G. Walker[7], Timothy B. Spahr[5], Edward L. Wright[6]*
*1. Planetary Science Institute, Bloomington, IN, United States. 2. Jet Propulsion Laboratory, Pasadena, CA, United States. 3. Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA, United States. 4. Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, United States. 5. Minor Planet Center, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 6. UCLA Astronomy, Los Angeles, CA, United States. 7. Monterey Institute for Research in Astronomy, Marina, CA, United States.*
*Contributing teams: WISE Team, NEOWISE Team*

The Wide-field Infrared Survey Explorer (WISE) is a NASA Explorer class mission that has imaged the entire sky twice between January, 2010 and January, 2011 at four wavelengths spanning the near through mid-IR with sensitivities hundreds of times greater than previous surveys. Through a NASA funded project, called NEOWISE, we have systematically searched the WISE data for new and previously known asteroids, detecting over 158,000 objects (of which more than 30,000 were new discoveries). The NEOWISE project have resulted in a highly uniform survey of the near-Earth object (NEO) population at thermal infrared wavelengths ranging from 3 to 22 ?m, allowing us to refine estimates of their numbers, sizes, and albedos. The survey detected NEOs the same way whether they were previously known or not, subject to the availability of ground-based follow-up observations, resulting in the discovery of more than 130 new NEOs. The survey's uniform sensitivity, observing cadence, and image quality have permitted extrapolation of the 429 near-Earth asteroids (NEAs) detected by NEOWISE during the fully cryogenic portion of the WISE mission to the larger population. An additional 88 NEAs were observed in the post-cryogenic phase of the mission, with 12 of these being discoveries. Using the dataset and debiasing the results, we find that there are 981 ± 19 NEAs larger than 1 km and 20,500±3000 NEAs larger than 100 m [3]. We show that the Spaceguard goal of detecting 90% of all 1 km NEAs has been met, and that the cumulative size distribution is best represented by a broken power law with a slope of 1.32±0.14 below 1.5 km. This power-law slope produces about 13,200±1900 NEAs with diameter larger than 140 m. The results show that the overall number for the NEA population between 100 and 1000 m is somewhat lower than previous estimates. We also present the results of an analysis of the sub-populations within the near-Earth asteroids, including the Atens, Apollos, Amors, and those that are considered potentially hazardous objects (PHAs). Again using our debiasing techniques, we are able to place constraints on the number of potentially hazardous asteroids larger than 100 m and find that there are about 4700±1450 such objects.

## 402.02 – The PS1 Science Mission - Status and Results

*Kenneth C. Chambers[1]*
*1. Univ. of Hawaii, Honolulu, HI, United States.*

PS1, the Pan-STARRS1 Telescope is in its last year of the PS1 Science Mission. Operations of the PS1 System include the Observatory, Telescope, 1.4 Gigapixel Camera, Image Processing Pipeline , PSPS relational database and reduced science product software servers. The PS1 Surveys include: (1) A 3pi Steradian Survey, (2) A Medium Deep survey of 10 PS1 footprints spaced around the sky; (3) A solar system survey optimized for Near Earth Objects, (4) a Stellar Transit Survey; and (5) a Deep Survey of M31. The PS1 3pi Survey has now covered the sky north of dec=-30 with 8 to 12 visits in five bands: g,r,i,z and y or over ~45 epochs per point on sky. The performance of the PS1 system, sky coverage, cadence, and data quality of the surveys will be presented as well as progress in reprocessing of the data taken to date and plans for serving the data to the public. A summary of science highlights will be included. The PS1 Science Consortium consists of The Institute for Astronomy at the University of Hawai'i in Manoa, the Max Planck Institute for Astronomy, Heidelberg and the Max Planck Institute for Extraterrestrial Physics, Garching, The Johns Hopkins University, the University of Durham, the University of Edinburgh, the Queen's University Belfast, the Harvard-Smithsonian Center for Astrophysics, the Los Cumbres Observatory Global Telescope Network Incorporated, and the National Central University of Taiwan, NASA, and NSF.

## 402.03D – A New Era of Observational Capability at Ritter Observatory: Spectropolarimetry from Exoplanets to Circumstellar Disks and Beyond

*James W. Davidson[1], Karen S. Bjorkman[1]*
*1. The University of Toledo, Toledo, OH, United States.*

We will report on the current status of the University of Wisconsin's Halfwave Polarimeter (HPOL) instrument, currently installed on the 1-meter telescope of Ritter Observatory at the University of Toledo. HPOL is a medium resolution spectropolarimeter, providing wavelength coverage from 3200 angstroms to 1.05 microns with a 10 angstrom resolution. It was previously a facility instrument at the Pine Bluff Observatory of the University of Wisconsin, going off-line in October 2004. Our group began efforts to restore HPOL to operational condition, and relocate the instrument to Ritter Observatory with 'first light' on March 11th, 2012. We will review the restoration and relocation efforts, present the calibration work performed to demonstrate the instrument and telescope stability, and present selected preliminary results from the first year of observations. The refurbishment of HPOL has been partially funded by a Small Research Grant from the AAS, and also by the Scott E. Smith Fund for Research at Ritter Observatory.

## 402.04 – Vacuum-Ultraviolet Spectroscopy of H2O- and N2-Dominated Solids at Low Temperature

*Perry A. Gerakines[1], Amanda Hendrix[2]*
*1. NASA GSFC, Greenbelt, MD, United States. 2. Planetary Science Institute, Tucson, AZ, United States.*

The Ultraviolet Imaging Spectrograph (UVIS) instrument on the Cassini orbiter continues to produce reflectance measurements of icy surfaces in the vacuum ultraviolet (VUV) wavelength range from 110 to 190 nm. Prominent in the spectra of the Saturnian satellites are absorption features due to frozen H2O and possibly other volatile species present on their surfaces. In the lab, we have performed VUV transmission measurements of thin (?50-100 nm) films of frozen volatiles (CO2, CH4, and NH3) mixed with H2O and N2 at temperatures relevant to the interstellar medium and the outer Solar System. In this talk, we present preliminary results that will ultimately lead to optical constants for these films for use in surface scattering models applied to the interpretation of Cassini UVIS spectra.

## 402.05 – Optimization of Micro-Spec, an Ultra-Compact High-Performance Spectrometer for Far-Infrared Astronomy

*Giuseppe Cataldo[1, 2], Samuel H. Moseley[1], Edward Wollack[1], Wen-Ting Hsieh[1], Wei-Chung Huang[1], Thomas Stevenson[1]*
*1. NASA Goddard Space Flight Center, Greenbelt, MD, United States. 2. Universities Space Research Association (USRA), Columbia, MD, United States.*

Micro-Spec (μ-Spec) is a high-sensitivity direct-detection spectrometer operating in the far-infrared and submillimeter regime. When combined with a cryogenic telescope, it provides an enabling technology for studying the epoch of reionization and initial galaxy formation. As a direct-detection spectrometer, μ-Spec can provide high sensitivity under the low background conditions provided by cryogenic telescopes such as the space infrared telescope for cosmology and astrophysics SPICA. The μ-Spec modules use low-loss superconducting microstrip transmission lines implemented on a single 4-inch-diameter wafer. Such a dramatic size reduction is enabled by the use of silicon, a material with an index of refraction about three times that of vacuum, which thus allows the microstrip lines to be one third their vacuum length. Using a large number of modules as well as reducing the negative effects of stray light also contributes positively to the enhanced sensitivity of such an instrument. μ-Spec can be compared to a grating spectrometer, in which the phase retardation generated by the reflection from the grating grooves is instead produced by propagation through transmission lines of different length. The μ-Spec optical design is based on the stigmatization and minimization of the light path function in a two-dimensional diffractive region. The power collected through a broadband antenna is progressively divided by binary microstrip power dividers. The position of the radiators is selected to provide zero phase errors at two stigmatic points, and a third stigmatic point is generated by introducing a differential phase shift in each radiator. To optimize the overall efficiency of the instrument, the emitters are directed to the center of the focal surface. A point design was developed for initial demonstration. Because of losses to other diffraction orders, the efficiency of the design presented is about 30%. Design variations on this implementation are illustrated which can lead to near-unit efficiency and will be the basis of future instruments. Measurements are being conducted to validate the designs.

## 402.06 – Prototype Development of the GMT Fast Steering Mirror

*Young-Soo Kim[1], Ju Heon Koh[1], Hwa Kyoung Jung[1], Ho June Jung[1], Myung K. Cho[2], Won Hyun Park[3], Ho-Soon Yang[4], Ho-Sang Kim[5], Kyoung-Don Lee[5], Hyo-Sung Ahn[6], Byeong-Gon Park[1]*

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A Fast Steering Mirror (FSM) is going to be produced as a secondary mirror of the Giant Magellan Telescope (GMT). FSM is 3.2 m in diameter and the focal ratio is 0.65. It is composed of seven circular segments which match with the primary mirror segments. Each segment contains a light-weighted mirror whose diameter is 1.1 m. It also contains tip-tilt actuators which would compensate wind effect and structure jitter. An FSM prototype (FSMP) has been developed, which consists of a full-size off-axis mirror segment and a tip-tilt test-bed. The main purpose of the FSMP development is to achieve key technologies, such as fabrication of highly aspheric off-axis mirror and tip-tilt actuation. The development has been conducted by a consortium of five institutions in Korea and USA, and led by Korea Astronomy and Space Science Institute. The mirror was light-weighted and grinding of the front surface was finished. Polishing is in progress with computer generated hologram tests. The tip-tilt test-bed has been manufactured and assembled. Frequency tests are being performed and optical tilt set-up is arranged for visual demonstration. In this paper, we present progress of the prototype development, and future works.

## 402.07 – An Efficient and Optimal Technique for Identifying Point Sources in Millimeter/sub-millimeter Sky Maps

*Thushara Perera[1], Grant Wilson[2], Kimberly S. Scott[3], Jason Austermann[4], Alejandro Mancera[1]*

*1. Illinois Wesleyan University, Bloomington, IL, United States. 2. University of Massachusetts Amherst, Amherst, MA, United States. 3. National Radio Astronomy Observatory, Charlottesville, VA, United States. 4. University of Colorado Boulder, Boulder, CO, United States.*

In sub-millimeter and longer-wavelength observations, identification of point sources is important, either as the primary goal, or for the removal of foregrounds. A popular technique used in point source searches is to convolve the sky map with a 'Mexican-hat' kernel, also known as a *matched filter,* that takes into account the Fourier-domain noise properties of a map. In the process, variations in noise level across the map, usually represented by a *coverage map,* are either ignored or the sky map is truncated to include only a sub-region with near-uniform coverage. Simultaneously accounting for noise in the Fourier domain as well in map-space is traditionally considered a complex and computationally time-intensive problem. For the analysis of data from AzTEC, we have developed a new algorithm that accounts for both forms of noise in a mathematically sound, yet computationally efficient way. The basis of this method is a generalized least-squares fit of the PSF to every location (pixel) of the map. Computational efficiency is achieved by (1) exploiting the absence of sharp features in the noise power spectra of well designed observations and (2) the use of FFTs (Fast Fourier Transforms) for many of the calculations. We use results from AzTEC to demonstrate the advantages of such an analysis over the conventional matched-filter technique.

# 403 – Stellar Evolution and Binary Stars

## 403.02 – Occultation of the T Tauri Star RW Aurigae A by its Tidally Disrupted Disk

*Joseph E. Rodriguez[1, 2], Joshua Pepper[3, 2], Keivan Stassun[2, 1], Robert Siverd[2], Phillip Cargile[2], Thomas G. Beatty[4], B. S. Gaudi[4]*
*1. Fisk University, Nashville, TN, United States. 2. Vanderbilt University, Nashville, TN, United States. 3. Lehigh University, Bethlehem, PA, United States. 4. Ohio State University, Columbus, OH, United States.*
*Contributing teams: KELT Team*

RW Aur A is a classical T Tauri star, believed to have undergone a reconfiguration of its circumstellar environment by a recent fly-by of its stellar companion, RW Aur B. This interaction stripped away part of its circumstellar disk leaving a tidally disrupted ”arm” feature and a short truncated disk. We present photometric observations of the RW Aur system from the Kilodegree Extremely Little Telescope (KELT-North) showing a long and deep eclipse that occurred from September of 2010 until March of 2011. The eclipse has a depth ~2 magnitudes and a duration ~180 days. The eclipse was confirmed by archival observations from American Association of Variable Star Observers (AAVSO). We suggest that the eclipse is the result of a portion of the tidally disrupted disk occulting RW Aur A. Using simple kinematic and geometric arguments, we discount several other hypotheses for the cause of the eclipse. Additionally, we confirm a previously-reported 2.7 day out of eclipse periodic variation.

## 403.03 – Search for TeV Gamma Rays from Cygnus X-3

*Wei Cui[1]*
*1. Purdue Univ., West Lafayette, IN, United States.*
*Contributing teams: VERITAS Collaboration*

We report results from a systematic search for gamma-ray emission from Cygnus X-3 at TeV energies with VERITAS. The source is an enigmatic X-ray binary that has defied classification. Its short orbital period is typical of low-mass X-ray binaries, yet signatures of a Wolf-Rayet star are evident. Powerful jets seen are indicative of microquasar, but arguments for the existence of a neutron star are also compelling. Recently, Cygnus X-3 was detected at GeV gamma-ray energies with AGILE and Fermi LAT. There is strong evidence that GeV gamma-ray production is correlated with the radio/X-ray properties of the source. To this end, we have also carried out more focused searches for TeV gamma rays in the radio/X-ray states of interest.

## 403.04 – The Brightest X-ray Point Sources in M82

*Floyd Jackson[1, 2], Timothy P. Roberts[2], Andreas Zezas[3, 4], Roy E. Kilgard[5]*
*1. Physics and Astronomy, University of Toledo, Toledo, OH, United States. 2. Durham University, Durham, United Kingdom. 3. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States. 4. University of Crete, Crete, Greece. 5. Van Vleck Observatory, Wesleyan University, Middletown, CT, United States.*

The prototypical starburst galaxy M82 contains a large population of X-ray emitting sources. We report the results of a study of the brightest point-like X-ray emitters within this galaxy, based on ~ 0.5 Msec of observations taken with the Chandra X-ray Observatory. Four of these sources are previously studied ultraluminous X-ray sources (ULXs), including the famous M82 X-1.We find the temporal variations and spectral characteristics of these ULXs to be consistent with previous results. The remaining sources are heterogeneous, but all display X-ray properties typically observed in canonically accreting X-ray binaries (XRBs). Among these sources, we have discovered both a candidate transient and luminous accreting neutron star. We also see a possible difference in accretion modes between the brighter and fainter sources in this subset of our sample. The results presented in this work demonstrate both the importance and the rich potential for future studies of the physical properties of diverse XRB populations in nearby galaxies.

## 403.05 – Neutron-capture Nucleosynthesis in the First Stars

*Ian U. Roederer[1]*
*1. Carnegie Observatories, Pasadena, CA, United States.*

Recent studies suggest that members of the class of carbon-enriched metal-poor stars with no significant enhancement of neutron-capture elements (the CEMP-no stars) may be among the oldest stars in the Galaxy. As such, they may retain the chemical signatures of nucleosynthesis in the first generation of stars. I present the results of a study of the detailed neutron-capture abundance patterns present in the CEMP-no stars based on new high resolution spectra obtained with the MIKE spectrograph on the Magellan Telescopes. Contrary to what their classification might suggest, the CEMP-no stars do contain small amounts of elements heavier than the iron group. These heavy elements are thought to be produced by some combination of charged-particle and neutron-capture reactions. I will also highlight the implications of these abundance patterns regarding the nucleosynthesis mechanisms, their frequency of operation, and the nature of the first stars.

# 404 – The Bridged Gap: Transients in the Local Universe

## 404.01 – The Bridged Gap: Transients in the Local Universe

*Mansi M. Kasliwal*[1, 2]

*1. Carnegie Institution for Science, Pasadena, CA, United States.*

*2. Princeton University, Princeton, NJ, United States.*

*Contributing teams: Palomar Transient Factory*

The advent of wide-field synoptic imaging has re-invigorated the venerable field of time domain astronomy. Our framework of cosmic explosions no longer has a wide six-magnitude luminosity 'gap' between the brightest novae and faintest supernovae. Multiple new and distinct classes of very rare explosions have been uncovered just in the past few years. I review the surge of excitement (and debate) on the physics of these transients with unprecedented explosion signatures. 'Gap transients' represent missing pieces in two fundamental pictures: the fate of massive stars and the evolution of compact binaries. Calcium-rich gap transients may even hold the key to solving a long-standing abundance problem in the intra-cluster medium. I conclude with the next frontier in gap transients --- discovering elusive binary neutron star mergers, a goal which may soon be within reach with coordination between the next generation of synoptic surveys and advanced gravitational wave interferometers.