BREAKTHROUGH LISTEN

AND THE FUTURE OF THE SEARCH FOR INTELLIGENT LIFE

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05/10/2017

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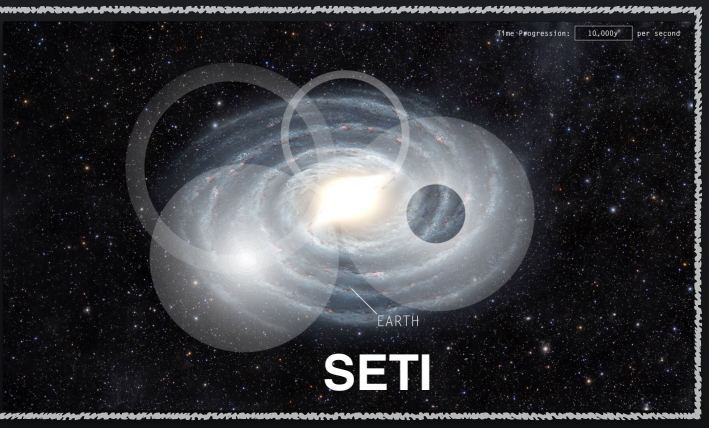
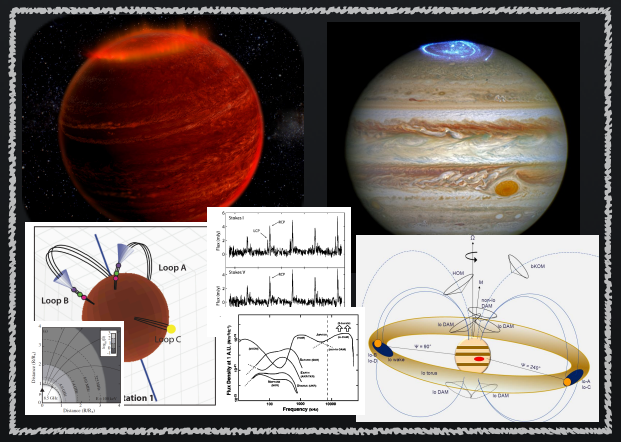
Danny Price, Dan Werthimer

BERKELEY SETI
RESEARCH CENTER

Radboud Universiteit Nijmegen

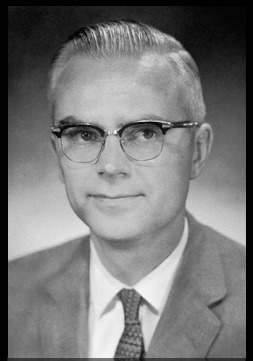

Time Progression: 10,000y per second
EARTH
SETI


BREAKTHROUGH
LISTEN
BREAKTHROUGH INITIATIVES


Loop A
Loop B
Loop C
Frequency (MHz)

How common is intelligent life in the galaxy?

How common is intelligent life in the galaxy?


Frank Drake, 1961

The Drake Equation

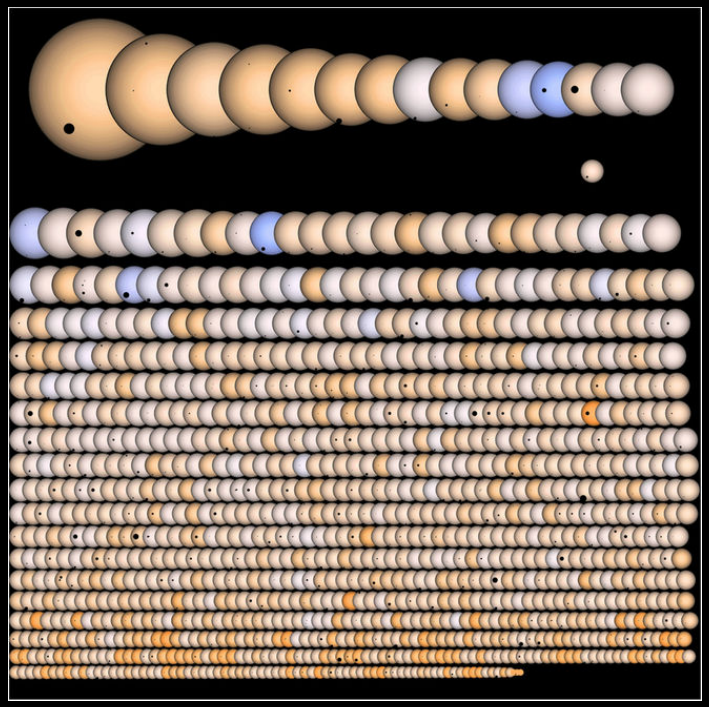
$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- R^* = the average rate of star formation in the galaxy
- f_p = the fraction of those stars that have planets
- n_e = the average number of planets that can potentially support life per star that has planets
- f_l = the fraction of the above that actually go on to develop life at some point
- f_i = the fraction of the above that actually go on to develop intelligent life
- f_c = the fraction of civilizations that develop a technology that releases detectable signs of their existence into space
- L = the average lifetime of a civilization

$f_p * n_e$ hints towards common…

Based on *Kepler* ~5-50% of FGKM stars host an Earth-like planet.

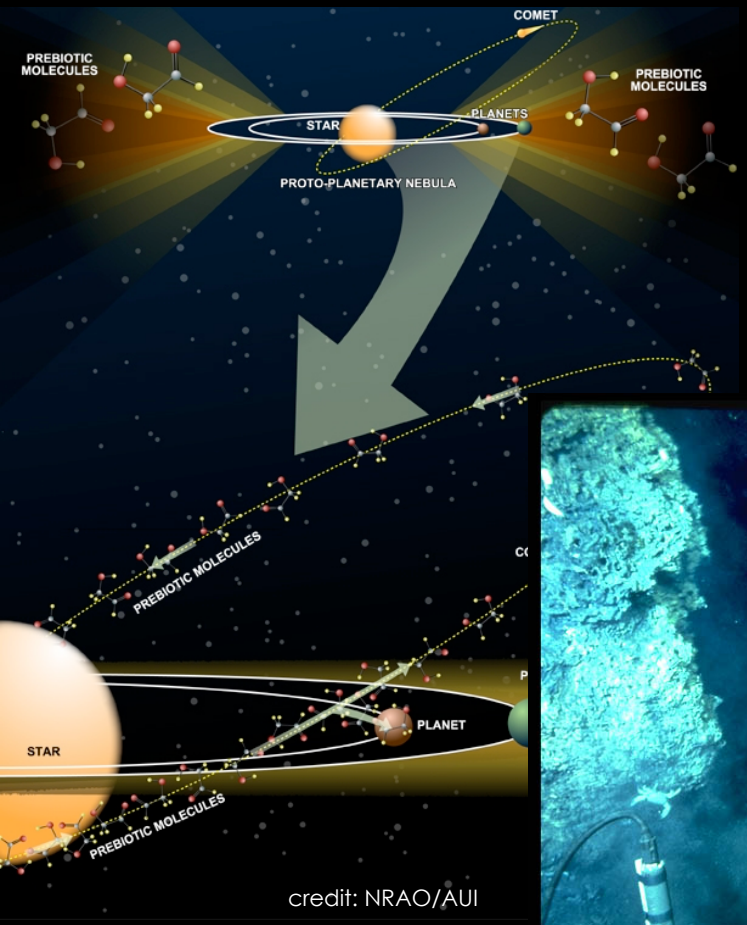
e.g. Dressing et al 2013, Kopparapu 2013, Petigura et al. 2013



… but what about $f_l * f_i * f_c * L$?

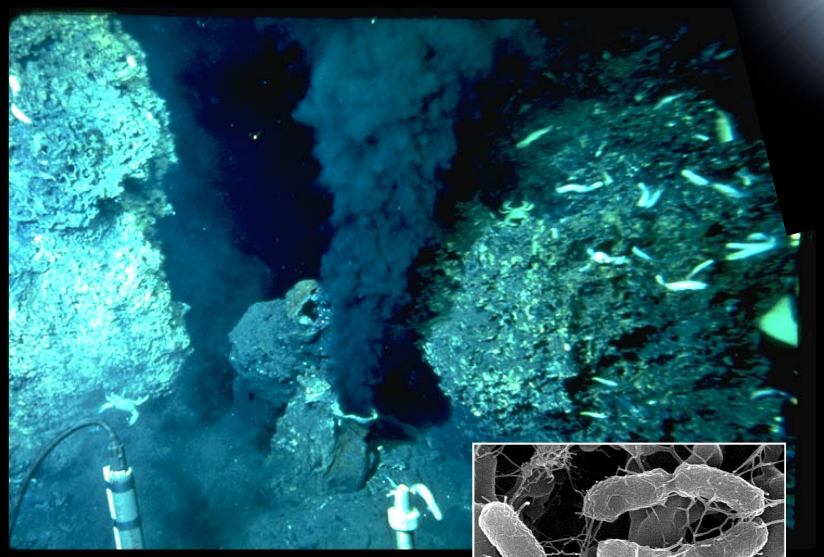
Life in the Universe

Complex Chemistry

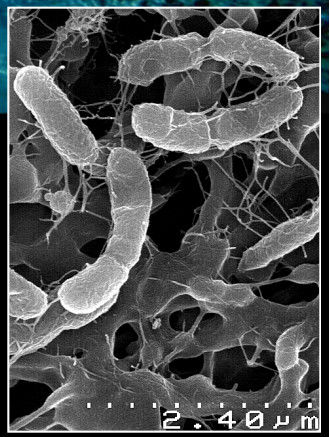


credit: NRAO/AUI

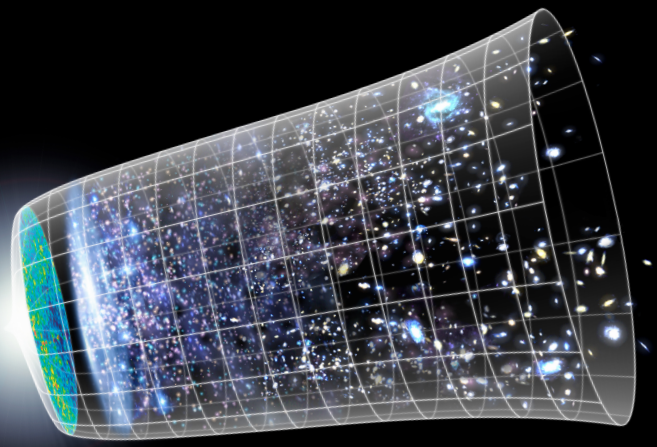
Extreme Life



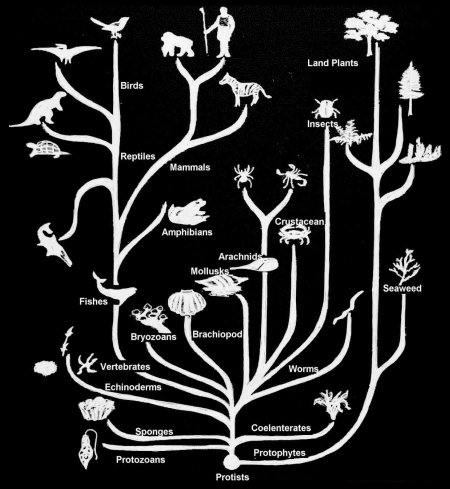
"Black Smoker" - Mariana Trench



Cosmological times



Role of Evolution?



… but what about $f_l * f_i * f_c * L$?

- From the lack of constraints, it is equally likely that we are the only civilization in the galaxy or that there are thousands of them.

Carl Sagan: "…the only significant test of the existence of extraterrestrial intelligence is an experimental one."

Detectable Signatures of Intelligence

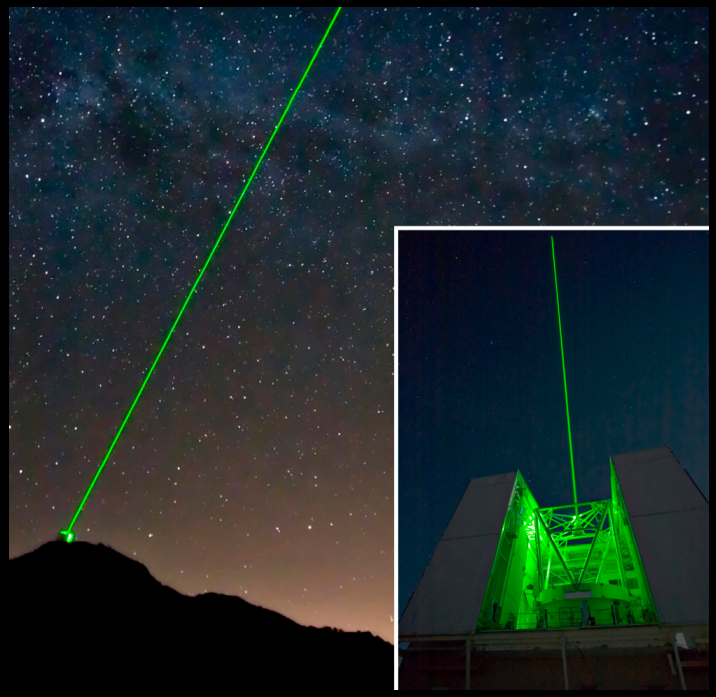
High-power TV and Radio

Hundreds of transmitters detectable at a few lightyears

Planetary Radar Systems

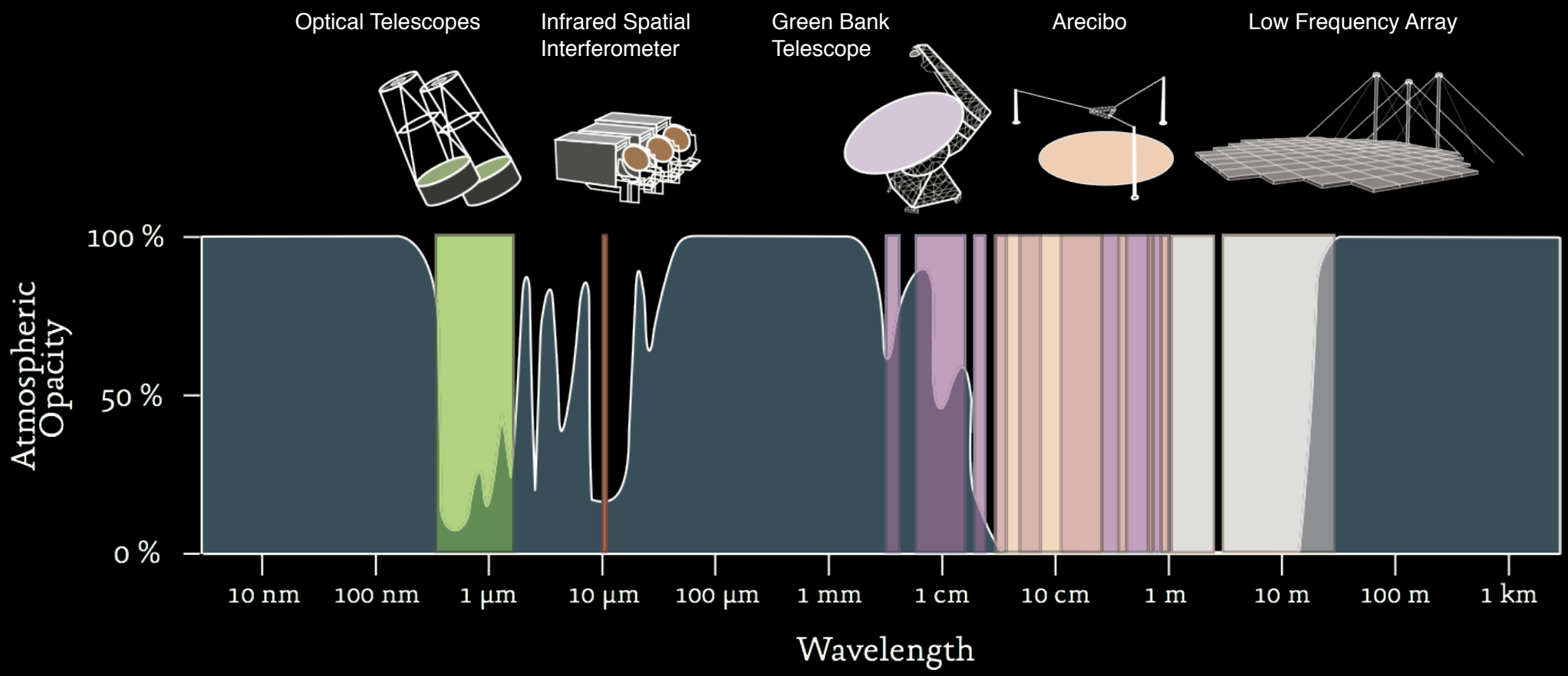
A few radar systems on Earth detectable across the galaxy

High-power Lasers

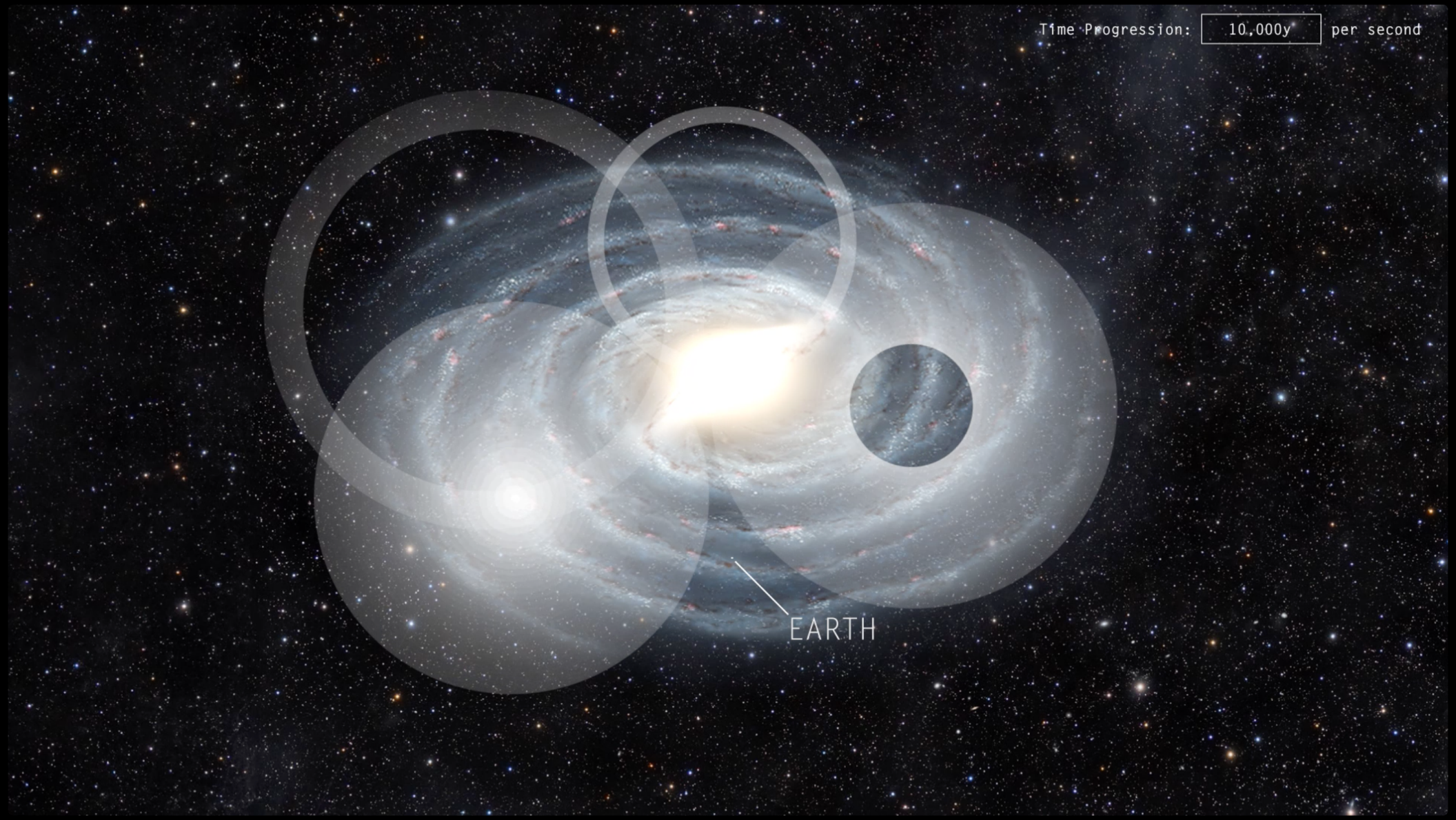


Lasers can outshine the Sun by thousands of times

Searching Across the Electromagnetic Spectrum



Using multiple telescopes, we can search across the electromagnetic spectrum for indicators of advanced technology.


Time Progression: 10,000y per second
EARTH

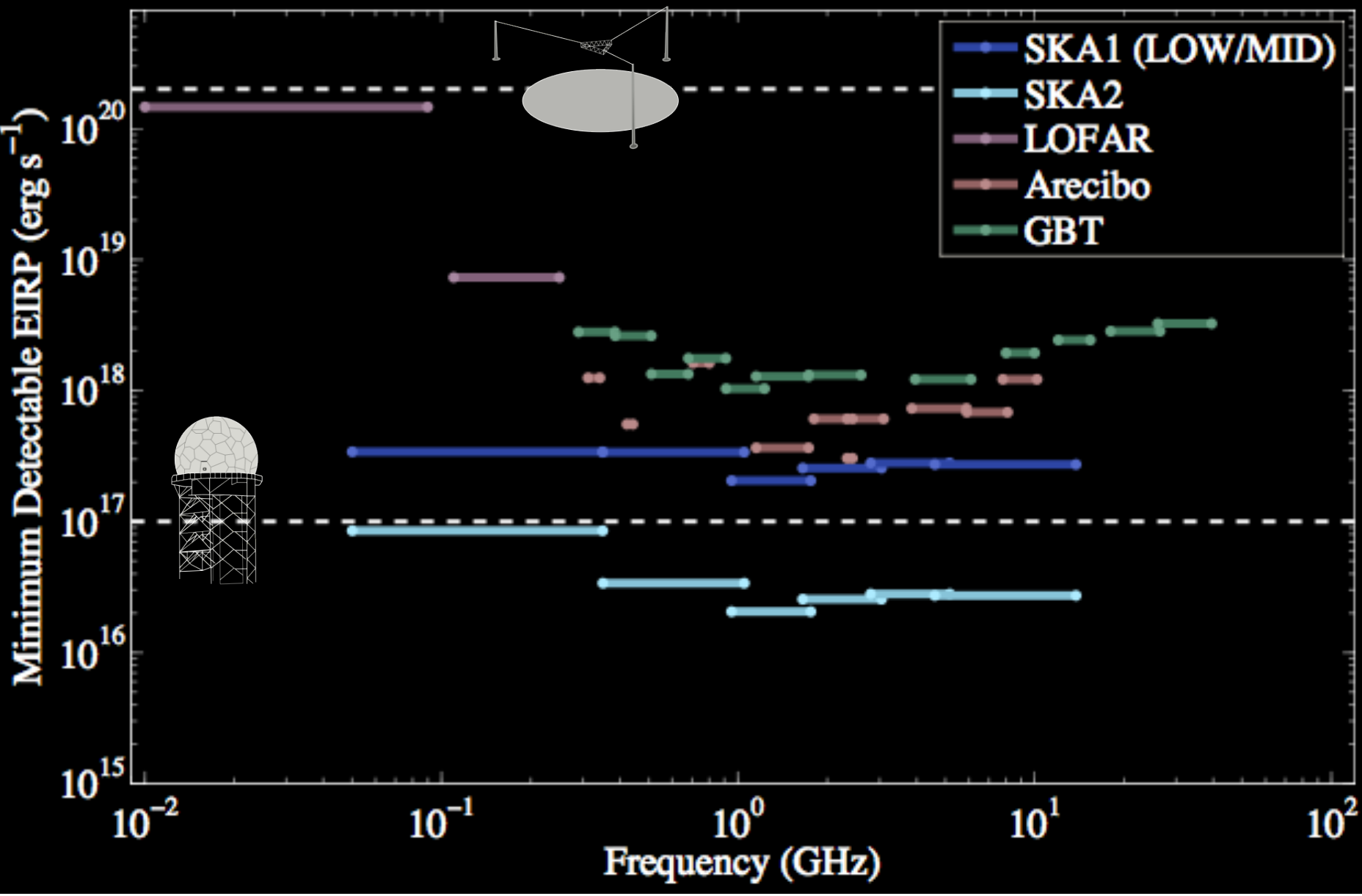
THE SQUARE KILOMETRE ARRAY

One of the World's Largest Scientific Instruments

SETI ON THE SKA
SQUARE KILOMETRE ARRAY

FOR AN EXTRATERRESTRIAL TRANSMITTER @ 50 LY

($t_{integration}$ = 10 min, SNR = 15)



BREAKTHROUGH LISTEN

BREAKTHROUGH LISTEN

Board of Advisors

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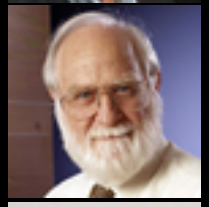

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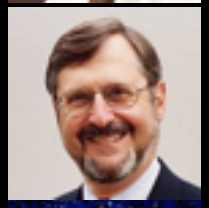

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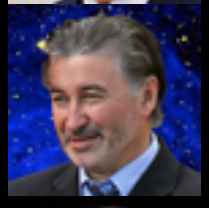

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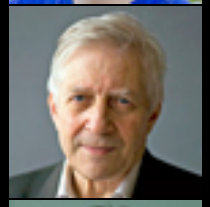

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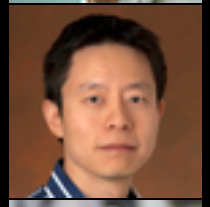

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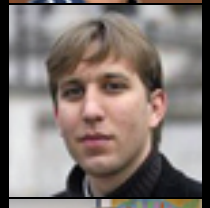

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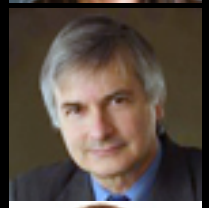

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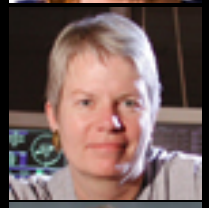

Jill Tarter
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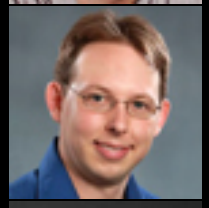

Jason Wright
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Shelley Wright
UC San Diego

The Berkeley team

The Breakthrough Listen Initiative: Telescopes

Automated Planet Finder (Lick Observatory)

- Search for extremely narrow emission lines from artificial lasers
- Extremely high resolution “Levy Spectrometer”
  374 - 950 nm, $\lambda/\Delta\lambda = 10^5$
- 10%

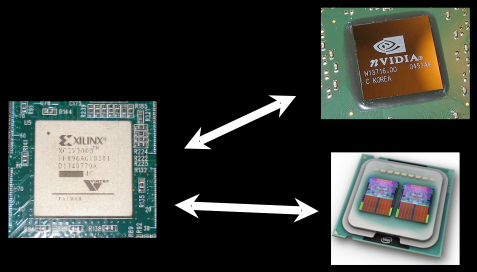
Green Bank Telescope (Green Bank, WV)

- Radio search focusing on targeted and raster observations
- Nearly continuous frequency coverage 300 MHz - 100 GHz
- Flexible IF system can deliver up to 10 GHz dual-pol analog bandwidth
- Extremely radio quiet (Federally protected radio quiet zone)
- ~20%

Parkes Telescope (New South Wales, Australia)

- Radio search focusing on surveys
- Southern hemisphere location gives great access to galactic plane
- Multi-beam receiver allows very efficient L-band (1.2 - 1.5 GHz) galactic plane surveys (Parkes Multibeam Receiver)
- Wide-band single-pixel and Phased Array Feed upgrades possible.
- ~20%

The Breakthrough Listen Initiative: Timeline



August 2015
Instrumentation development and observation planning

November 2015
APF Observations Begin

January 2016
GBT Observations Begin

October 2016
Parkes Observations Begin

The Breakthrough Listen Initiative: Overview

Publications of the Astronomical Society of the Pacific, 129:054501 (11pp), 2017 May https://doi.org/10.1088/1538-3873/aa5800

The *Breakthrough Listen* Search for Intelligent Life: Target Selection of Nearby Stars and Galaxies

Howard Isaacson[1], Andrew P. V. Siemion[1,2,3,4], Geoffrey W. Marcy[5], Matt Lebofsky[1], Danny C. Price[1], David MacMahon[1], Steve Croft[1], David DeBoer[1], Jack Hickish[1], Dan Werthimer[1], Sofia Sheikh[1], Greg Hellbourg[1], and J. Emilio Enriquez[1]
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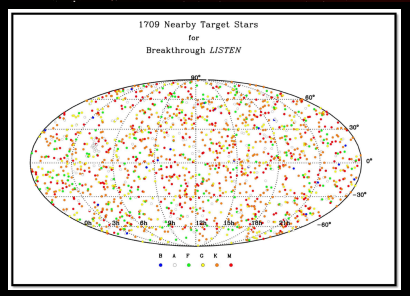
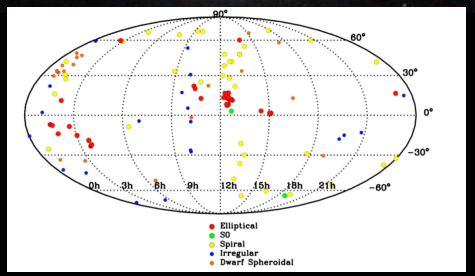
Received 2016 December 6; accepted 2017 January 4; published 2017 March 24

1 Million Stars

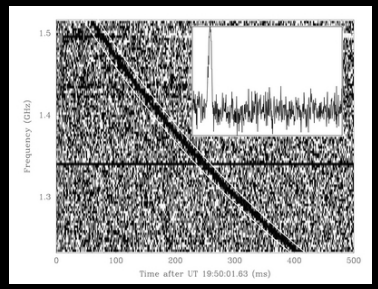


Milky Way Galactic Plane Survey

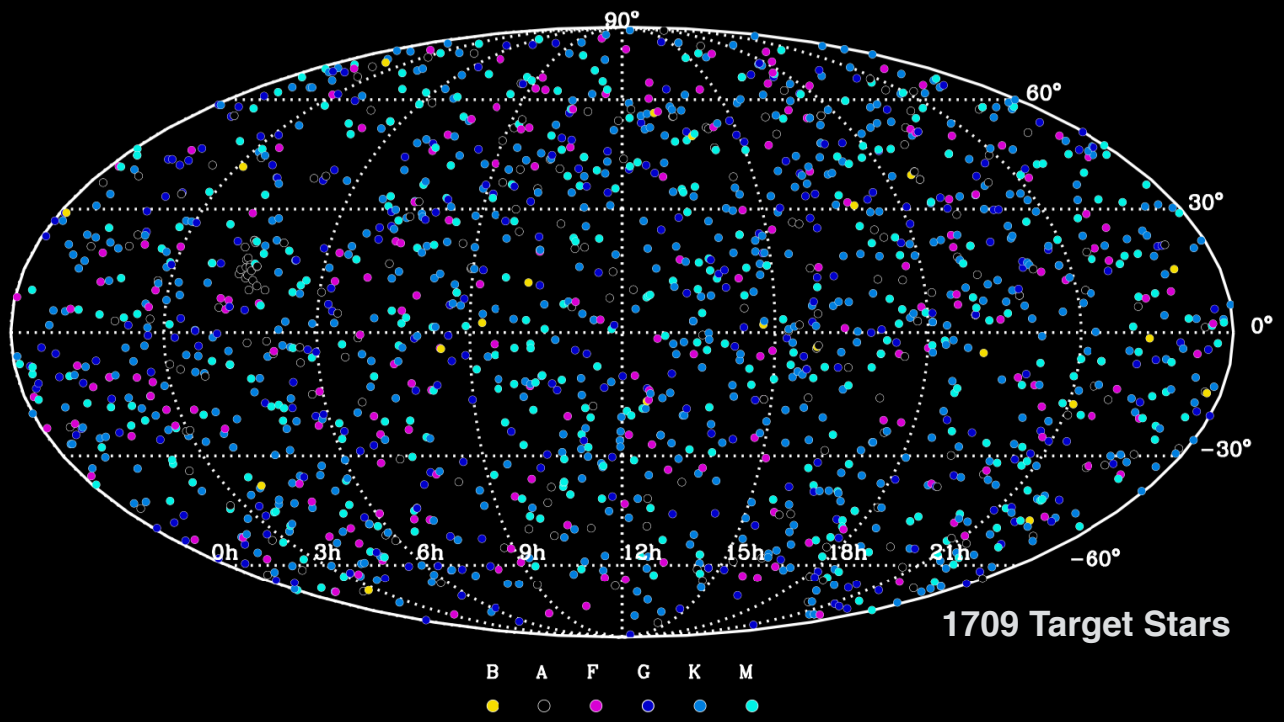
100 Galaxies



Exotica



R.TSS - O.TSS



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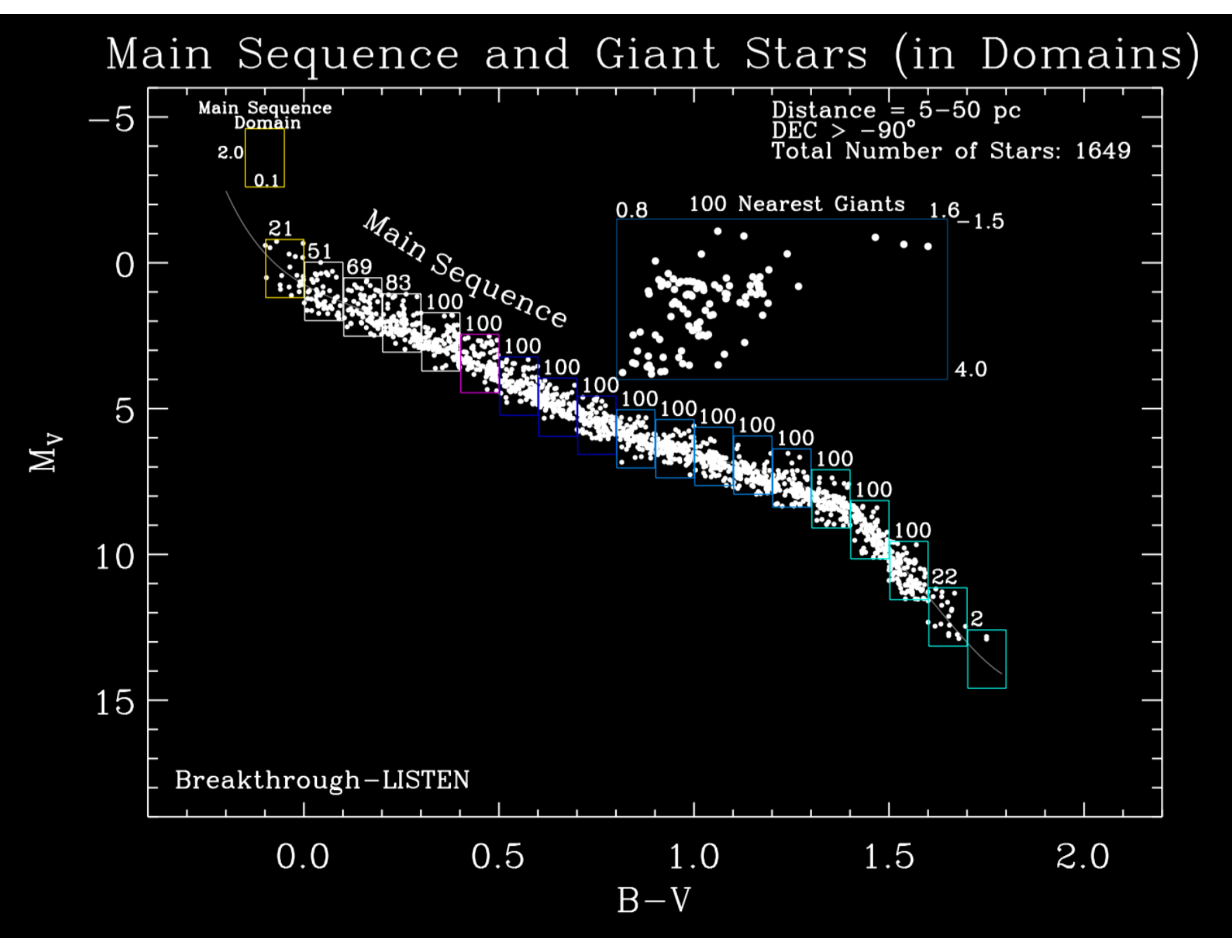

Main Sequence and Giant Stars (in Domains)
Main Sequence Domain
2.0
0.1
Distance = 5–50 pc
DEC > −90°
Total Number of Stars: 1649
0.8
100 Nearest Giants
1.6
−1.5
4.0
Main Sequence
21
51
69
83
100
100
100
100
100
100
100
100
100
100
100
22
2
−5
0
5
10
15
M_V
0.0
0.5
1.0
1.5
2.0
B−V
Breakthrough−LISTEN

The Breakthrough Listen Search for Advanced Life: 1.1-1.9 GHz observations of 692 Nearby Stars

Enriquez et. al. *Submitted to ApJ*

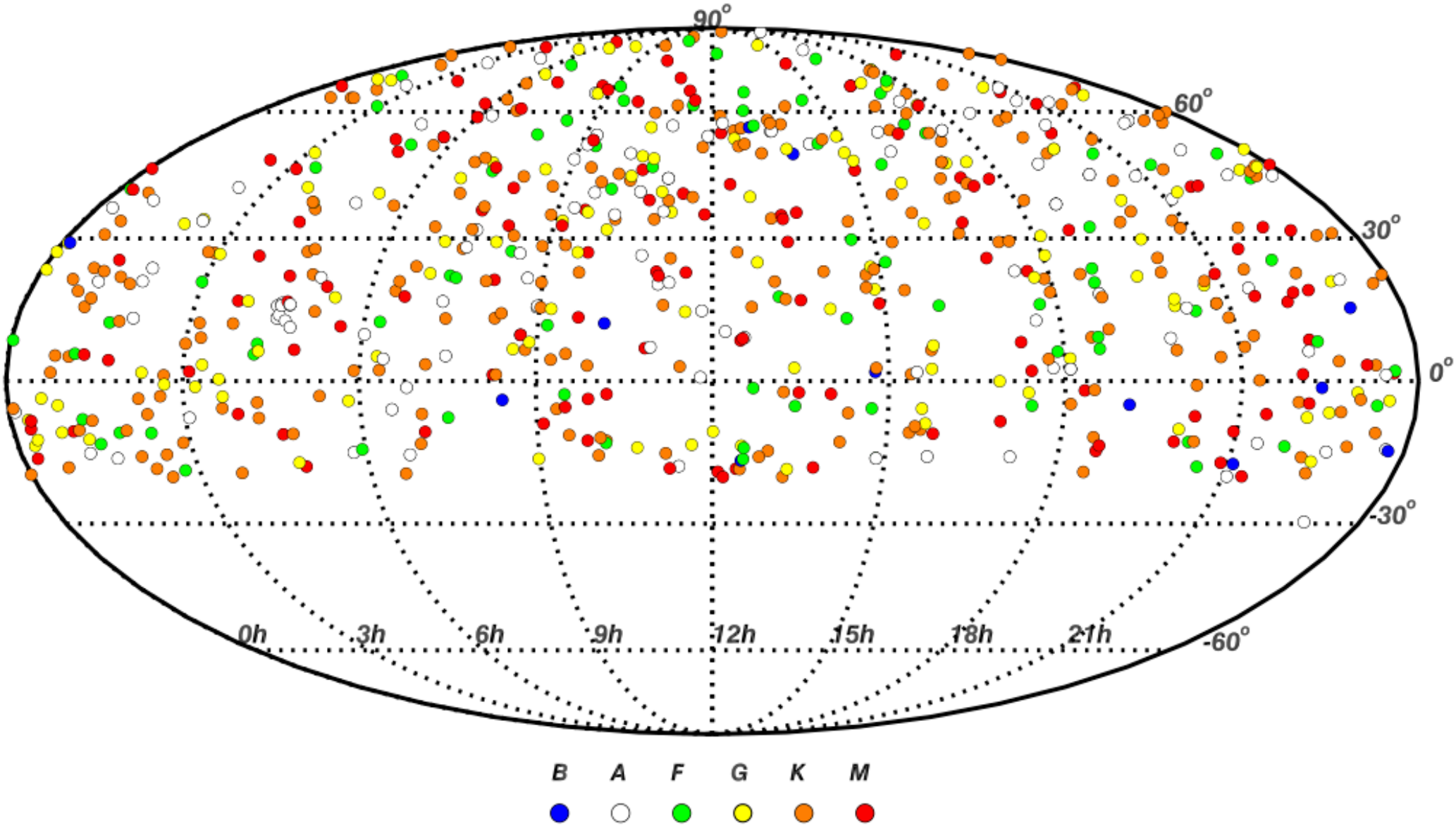
THE BREAKTHROUGH LISTEN SEARCH FOR ADVANCED LIFE: 1.1-1.9 GHZ OBSERVATIONS OF 692 NEARBY STARS

J. Emilio Enriquez [1,2], Andrew Siemion[1,2,3,4], Danny C. Price[1], David MacMahon[1], Matt Lebofsky[1], Howard Isaacson[1], Greg Hellbourg[1] Vishal Gajjar[5], Steve Croft[1],

ABSTRACT

We report on a search using the Robert C. Byrd Green Bank Telescope (GBT) for engineered signals from a sample of 692 nearby stars. This was undertaken as part of the *Breakthrough Listen* project to search for extraterrestrial intelligence. Observations were made in *L*-band, with three sets of 5-minute observations of the 692 primary targets, interspersed with 5-minute observations of secondary targets. By comparing the "ON" and "OFF" observations we are able to place limits on the presence of engineered signals from putative extraterrestrial civilizations inhabiting the environs of these stars. During the analysis, eleven events passed our thresholding algorithm, but detailed analysis of their properties indicates they are consistent with known examples of radio frequency interference. We conclude that none of the observed stars host high-duty-cycle radio transmitters emitting between 1.1 to 1.9 GHz with an EIRP of $\sim 10^{13}$ W, which is achievable by our own civilization.

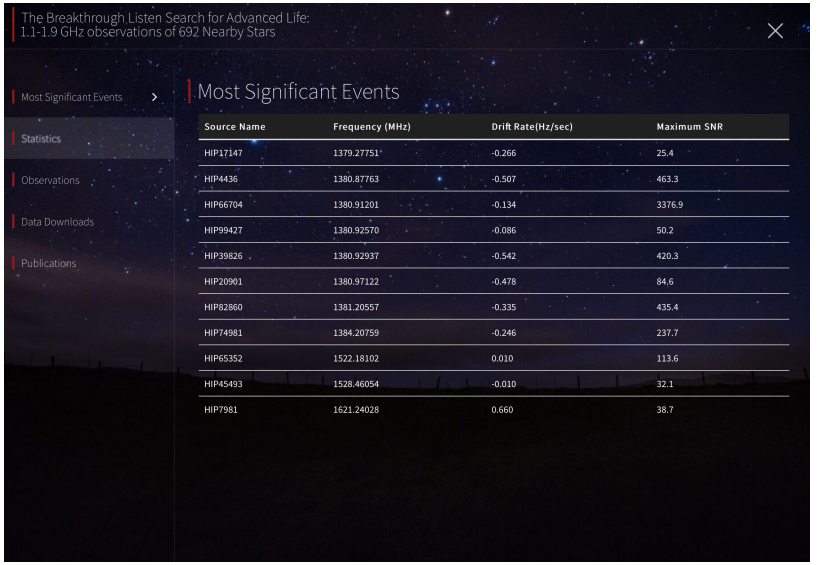
THE 692 STAR SAMPLE

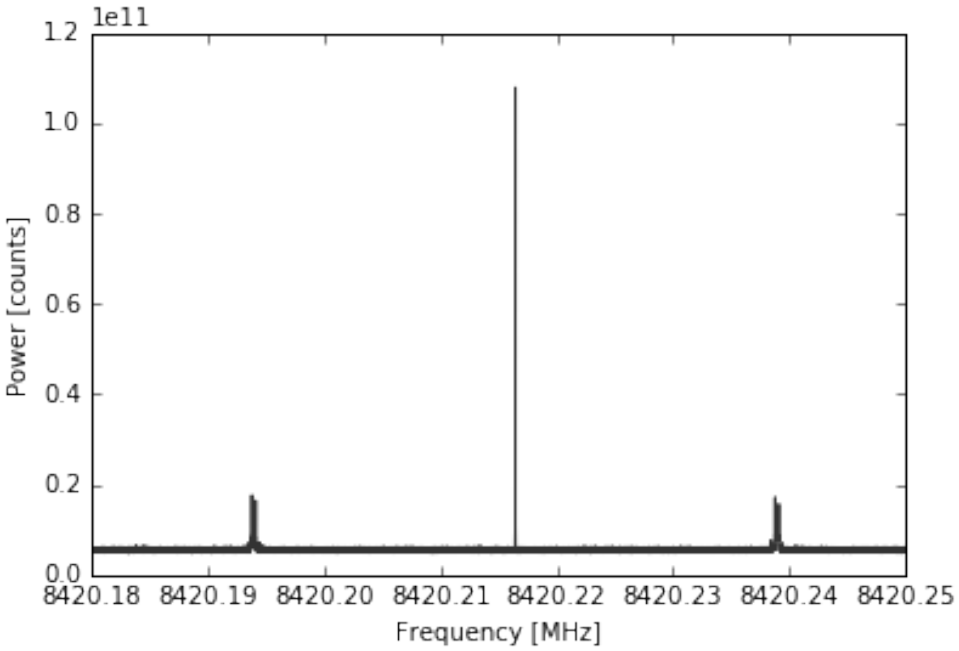


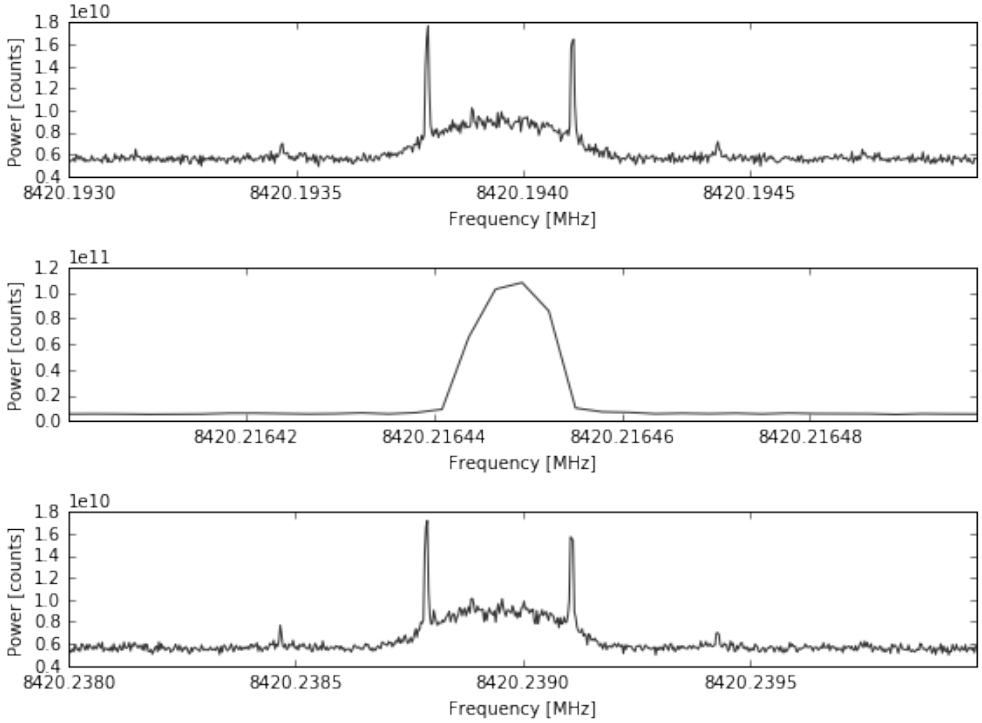
OBSERVATIONS OF 692 NEARBY STARS

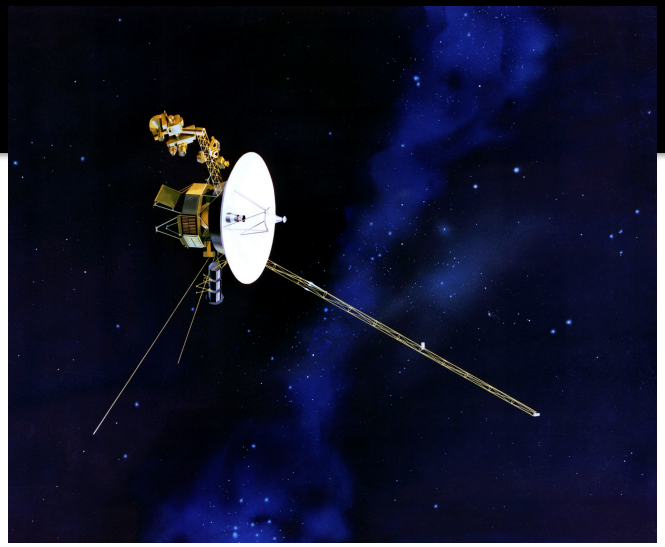
- L-band 1.1-1.9GHz
- Total of 400 hrs
- Lots of data!

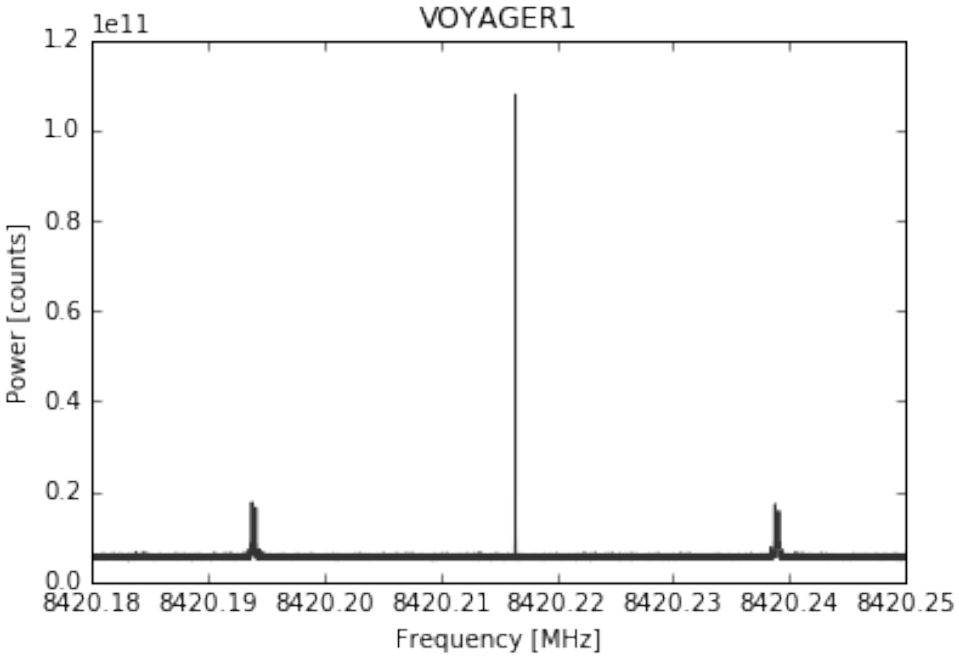
- https://seti.berkeley.edu/lband2017

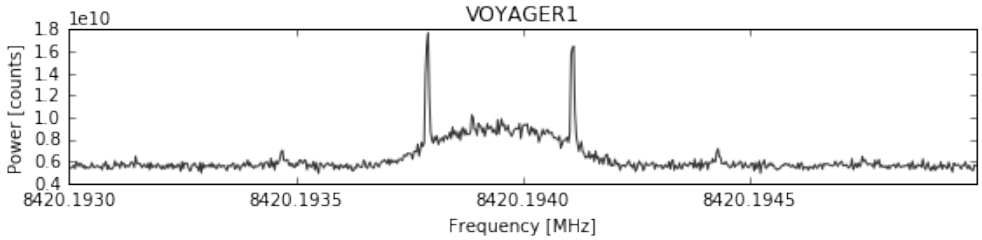


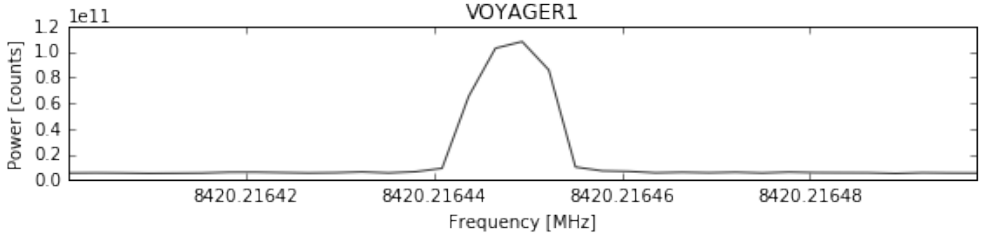

1e11
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Power [counts]
8420.18
8420.19
8420.20
8420.21
8420.22
8420.23
8420.24
8420.25
Frequency [MHz]

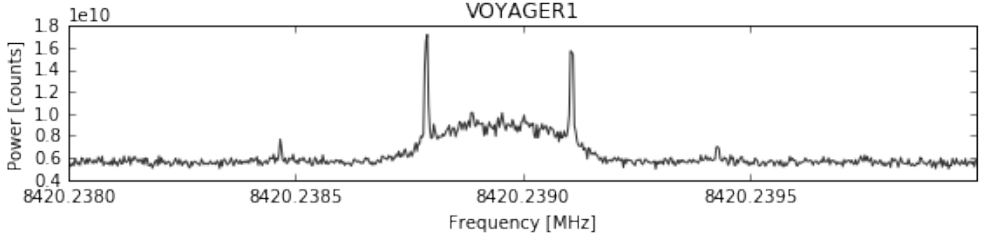

1e10
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
Power [counts]
8420.1930
8420.1935
8420.1940
8420.1945
Frequency [MHz]
1e11
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Power [counts]
8420.21642
8420.21644
8420.21646
8420.21648
Frequency [MHz]
1e10
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
Power [counts]
8420.2380
8420.2385
8420.2390
8420.2395
Frequency [MHz]



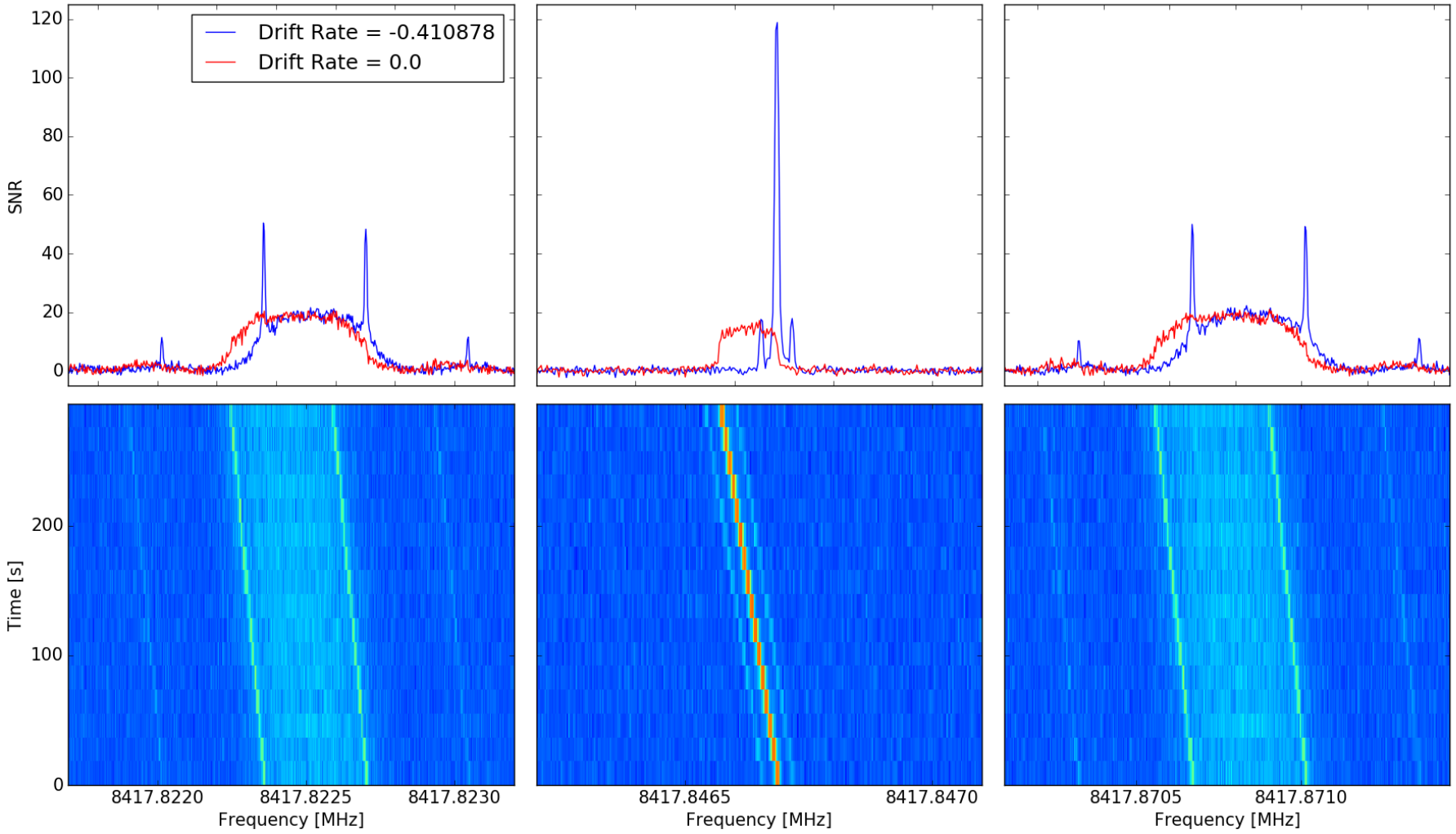

VOYAGER1
1e11
Power [counts]
Frequency [MHz]
8420.18
8420.19
8420.20
8420.21
8420.22
8420.23
8420.24
8420.25


VOYAGER1
1e10
Power [counts]
Frequency [MHz]
8420.1930
8420.1935
8420.1940
8420.1945

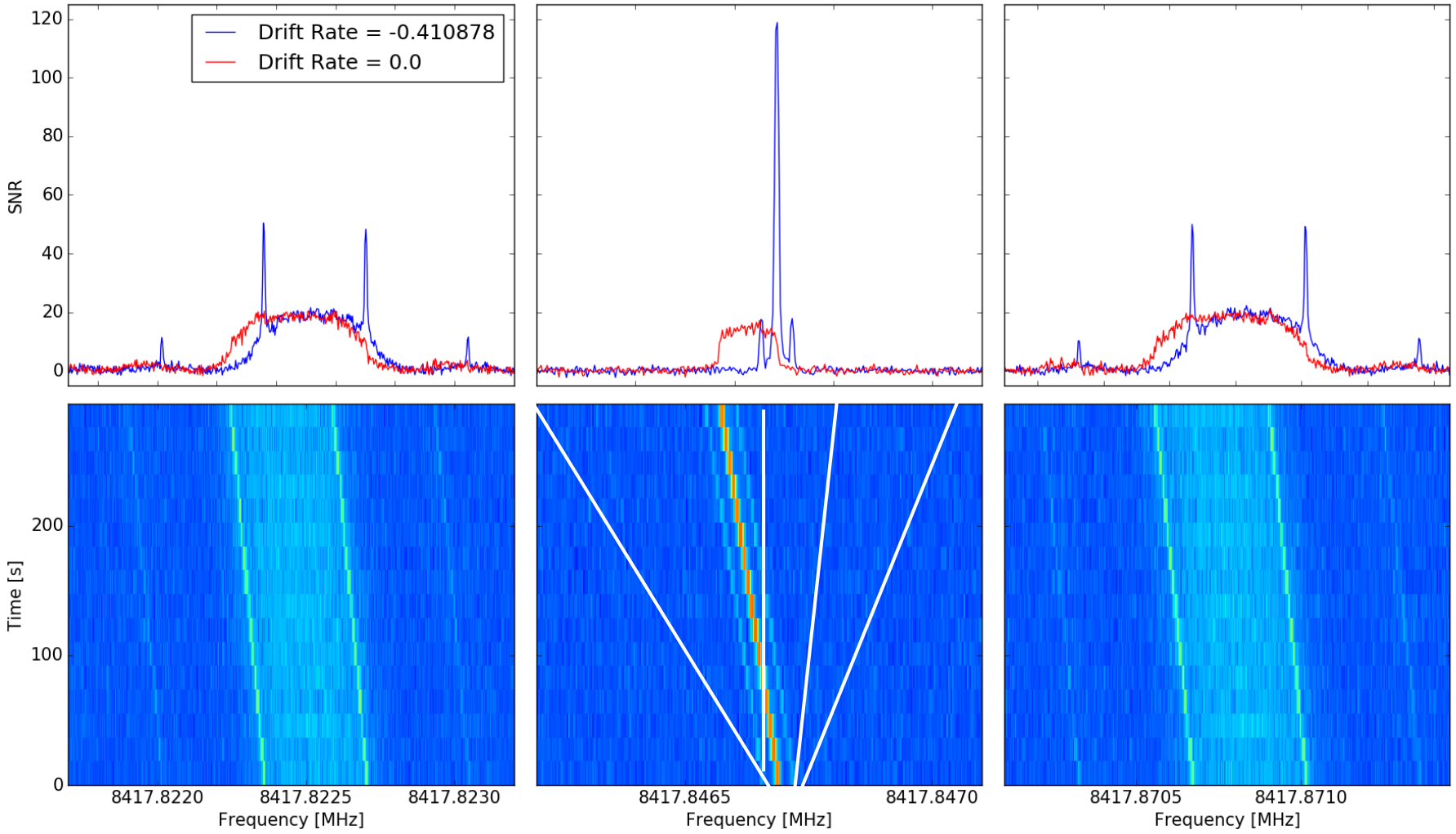

VOYAGER1
1e11
Power [counts]
Frequency [MHz]
8420.21642
8420.21644
8420.21646
8420.21648


VOYAGER1
1e10
Power [counts]
Frequency [MHz]
8420.2380
8420.2385
8420.2390
8420.2395

DETECTION OF VOYAGER 1 WITH *TURBO*SETI

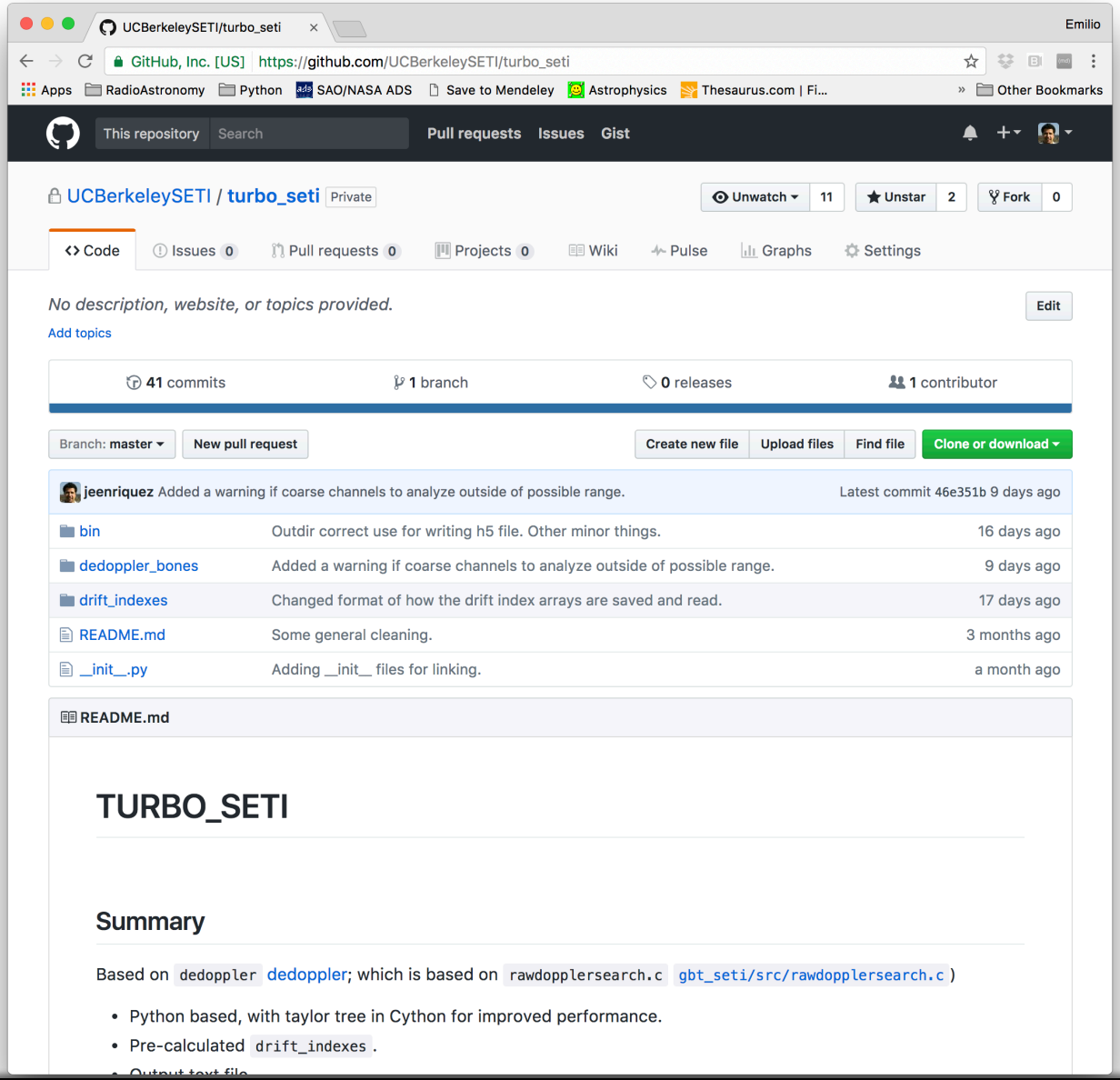


DETECTION OF VOYAGER 1 WITH *TURBO*SETI



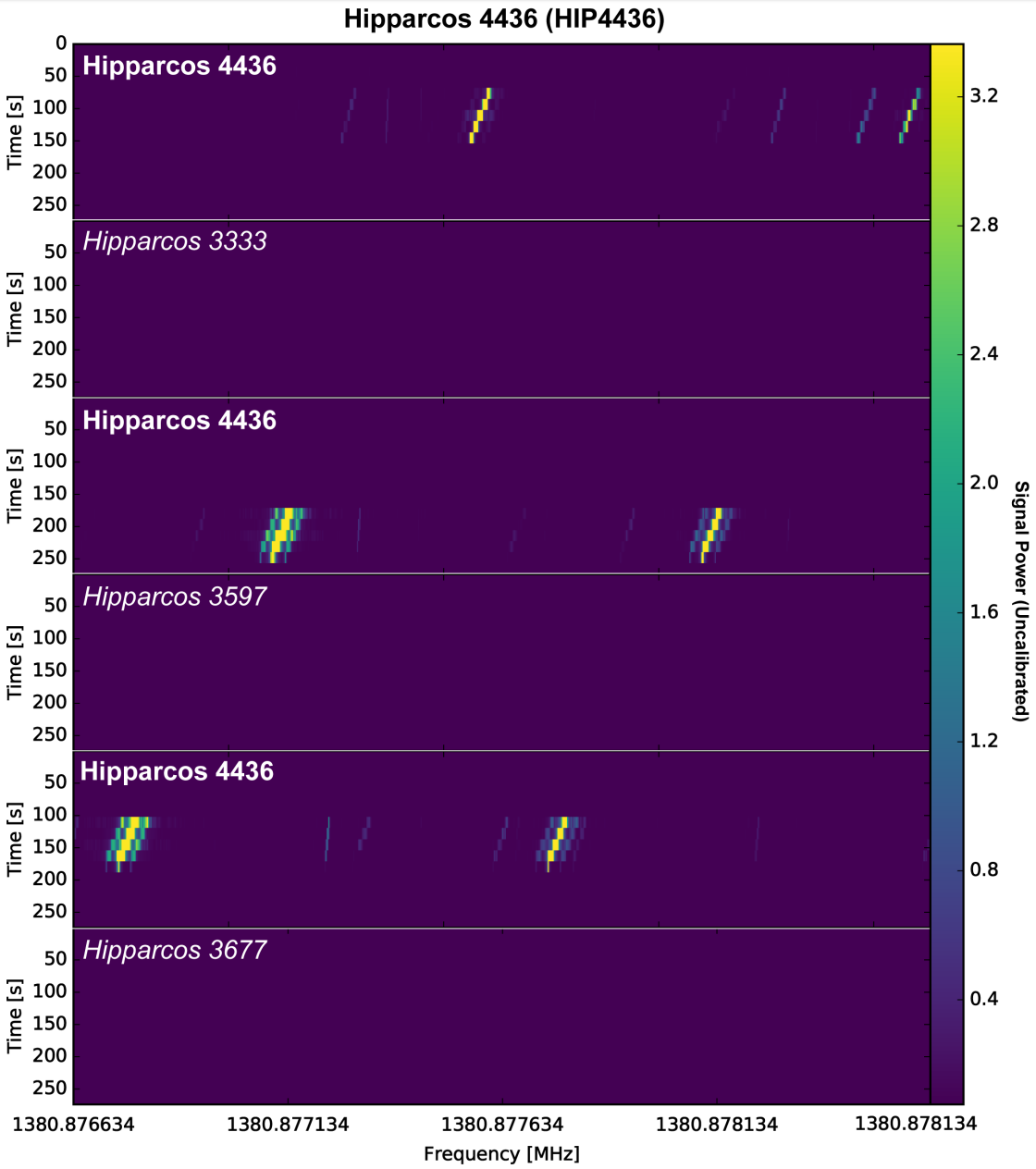
TURBOSETI

- https://github.com/UCBerkeleySETI/turbo_seti



- Tree search algorithm (Siemion2013 - Taylor 1974)
  - nlog(n)
- Python/Cython Based
- HDF5 input
- Flat output into csv or DataFrame (pandas)
- Potential real time (with appropriate parallelization).

Results from the Pipeline



- We observe these “A” stars with three nearby stars “B”, “C” and “D” as: ABACAD
- All signals are consistent with human-made RFI.
- Conclusion: We ruled out a continuos artificial signals between 1.1-1.9 GHz at brighter than 10^13 W.

"There's No Such Thing as Bad Publicity" ?

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No encounters: most ambitious alien search to date draws a blank

Only intelligent signals Breakthrough Listen project detected in first year are from mobile phones and other Earthly devices

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A $100m project to search for aliens is yet to find anything

TECH | 21 Apr 2017

Science geeks on the lookout for alien life: you're going to have to wait a little longer.

A $100m (£78m) project to search for signs of alien life is yet to find anything a year after launching.

The Breakthrough Listen project is made

Daily Mail .com | Science

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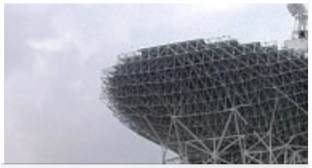
Breakthrough Listen reveals its first result: Alien hunting telescopes have found 11 strange signals - but NONE are believed to be extraterrestrial life

By Cheyenne Macdonald For
14:49 EDT 25 Apr 2017, updated 1
2017



EXPRESS

SECTIONS | LOGIN

SCIENCE

Have extraterrestrials been DISCOVERED? Eleven 'SIGNIFICANT' signals found in alien hunt

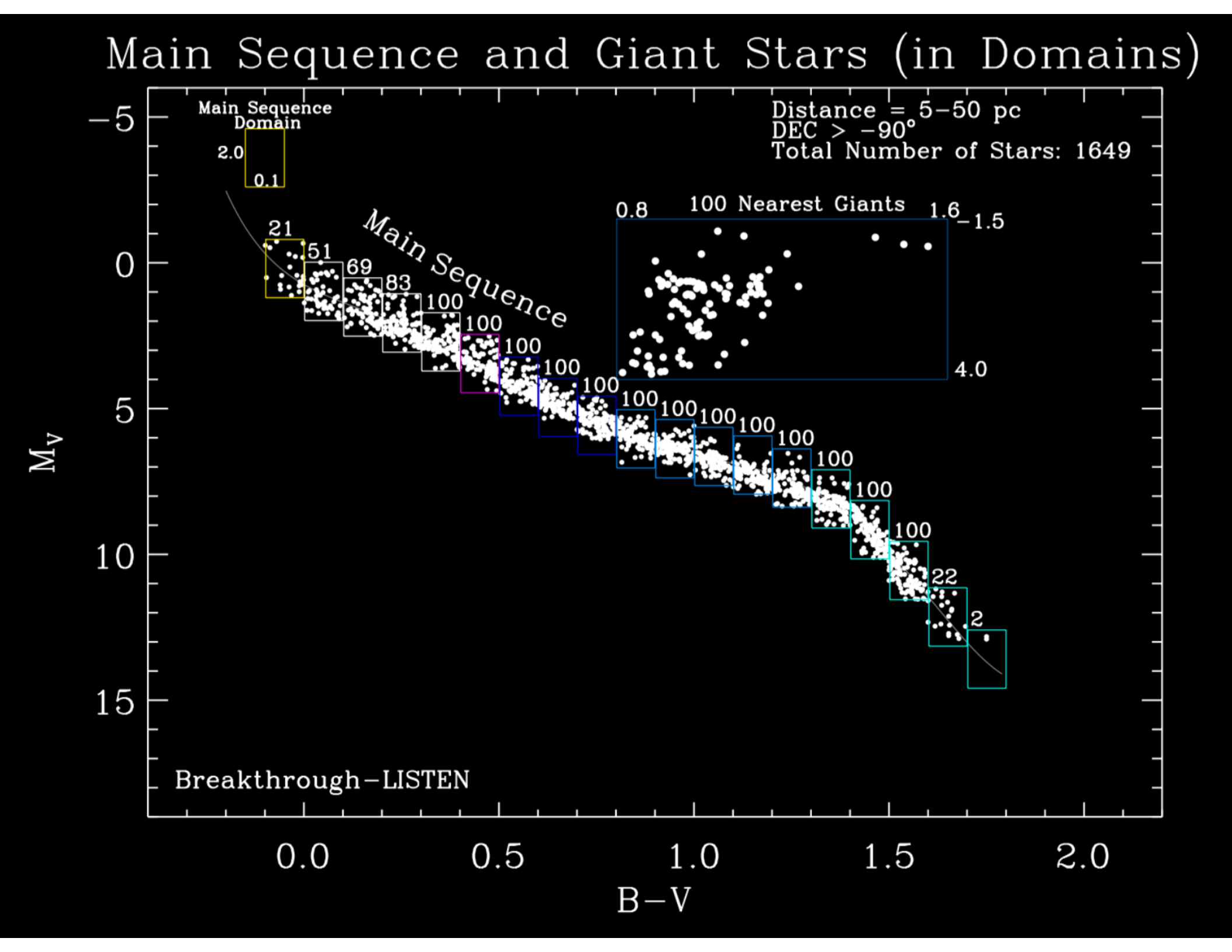
A STEPHEN Hawking-backed alien search campaign is in the process of reviewing 11 signals which could be of extraterrestrial origin.

By SEAN MARTIN
13:20, Sat, Apr 22, 2017 | UPDATED: 15:42, Sat, Apr 22, 2017

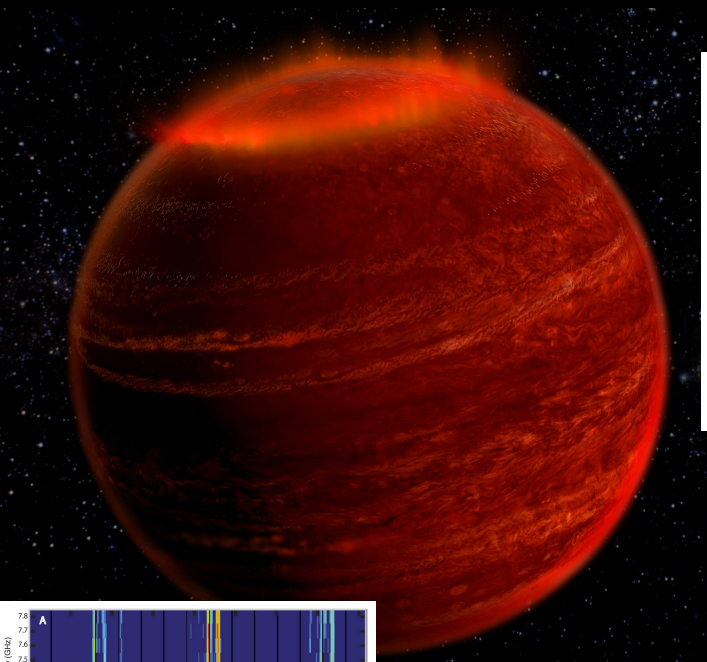
144 | 5

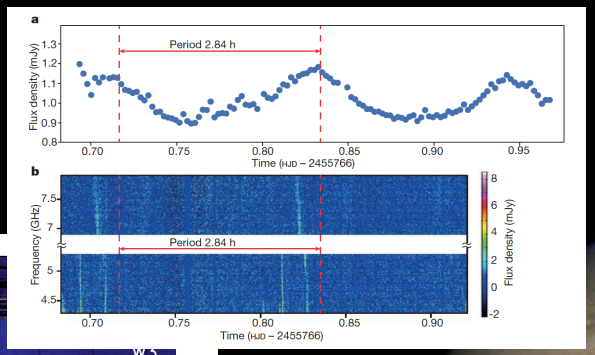
BERKELEY SETI RESEARCH CENTER

OTHER OPPORTUNITIES WITH BL DATA

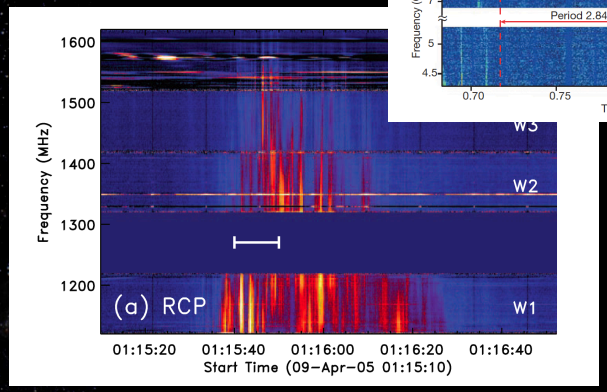

Main Sequence and Giant Stars (in Domains)
Main Sequence Domain
2.0
0.1
Distance = 5–50 pc
DEC > −90°
Total Number of Stars: 1649
0.8
100 Nearest Giants
1.6
−1.5
4.0
Main Sequence
21
51
69
83
100
100
100
100
100
100
100
100
100
100
100
22
2
−5
0
5
10
15
M_V
0.0
0.5
1.0
1.5
2.0
B−V
Breakthrough−LISTEN

OTHER OPPORTUNITIES WITH BL DATA

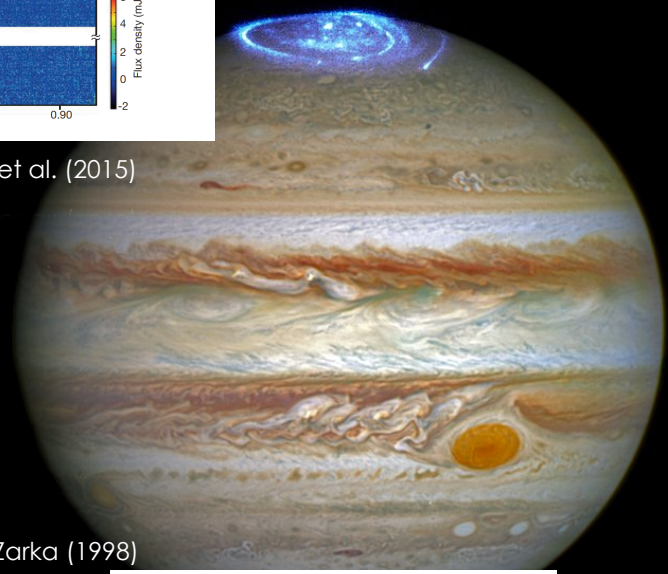




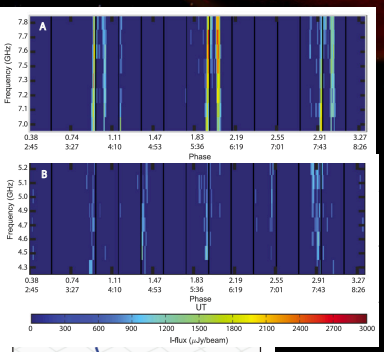
Hallinan et al. (2015)

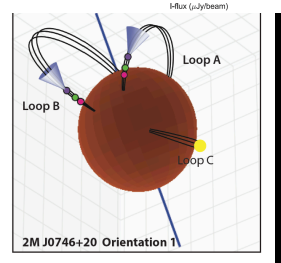


Osten (2007)



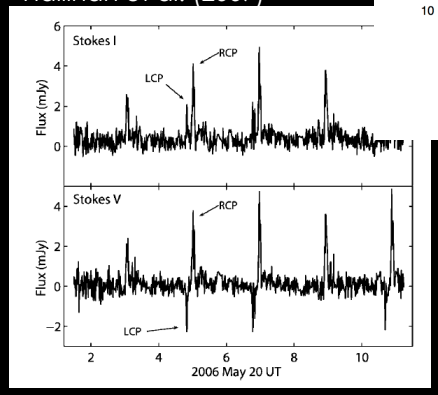
Zarka (1998)

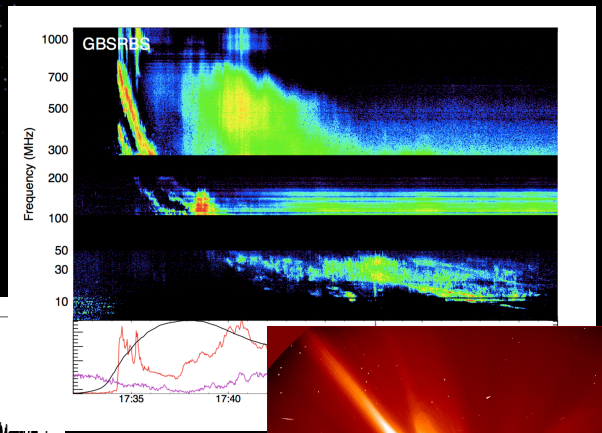


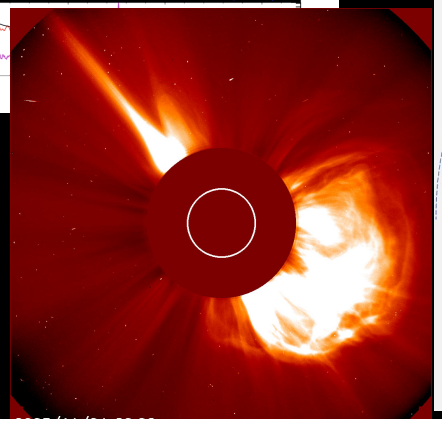


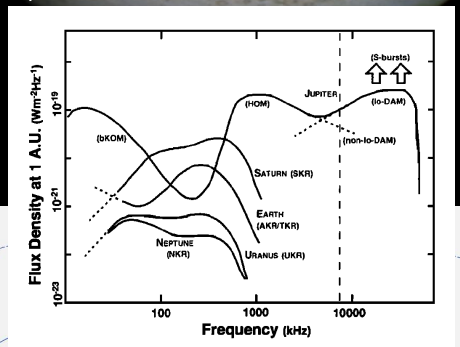
Lynch et al. (2015)

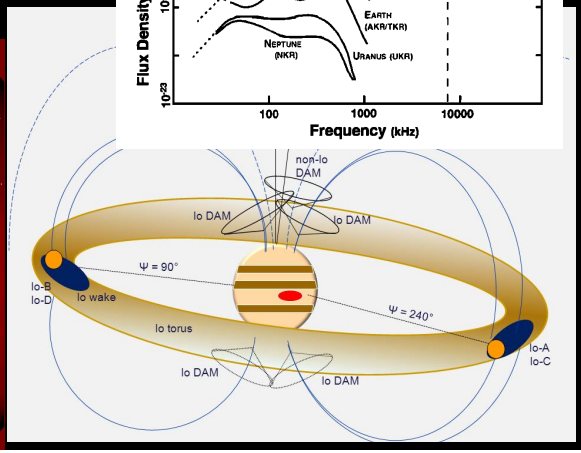
Hallinan et al. (2007)











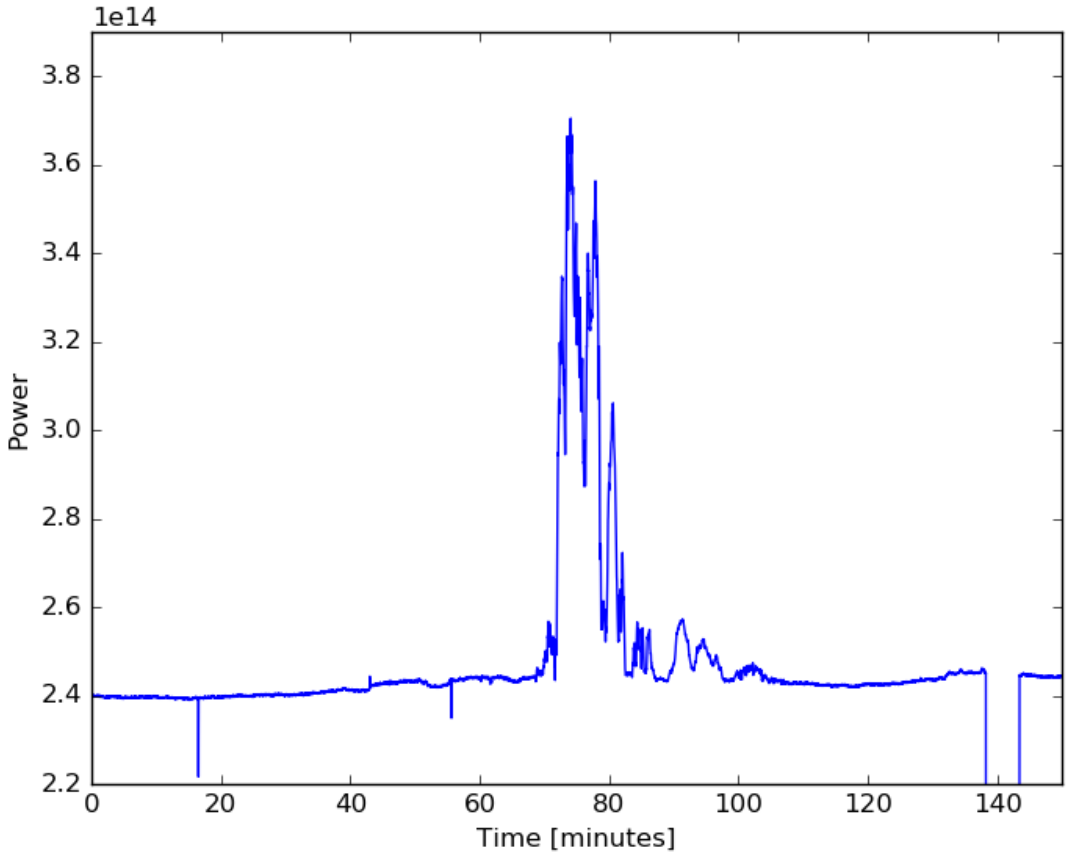
Open to Collaboration

- GBT Breakthrough Listen North American Community Workshop
  - (at Green Bank Observatory October, 2016)

- Engender a vibrant academic community furthering the search for intelligent life beyond the Earth, motivate the integration of that community with more traditional academic pursuits and share our work with the public.

BL Detection of 2MASS15+22 (TVLM513-56)?

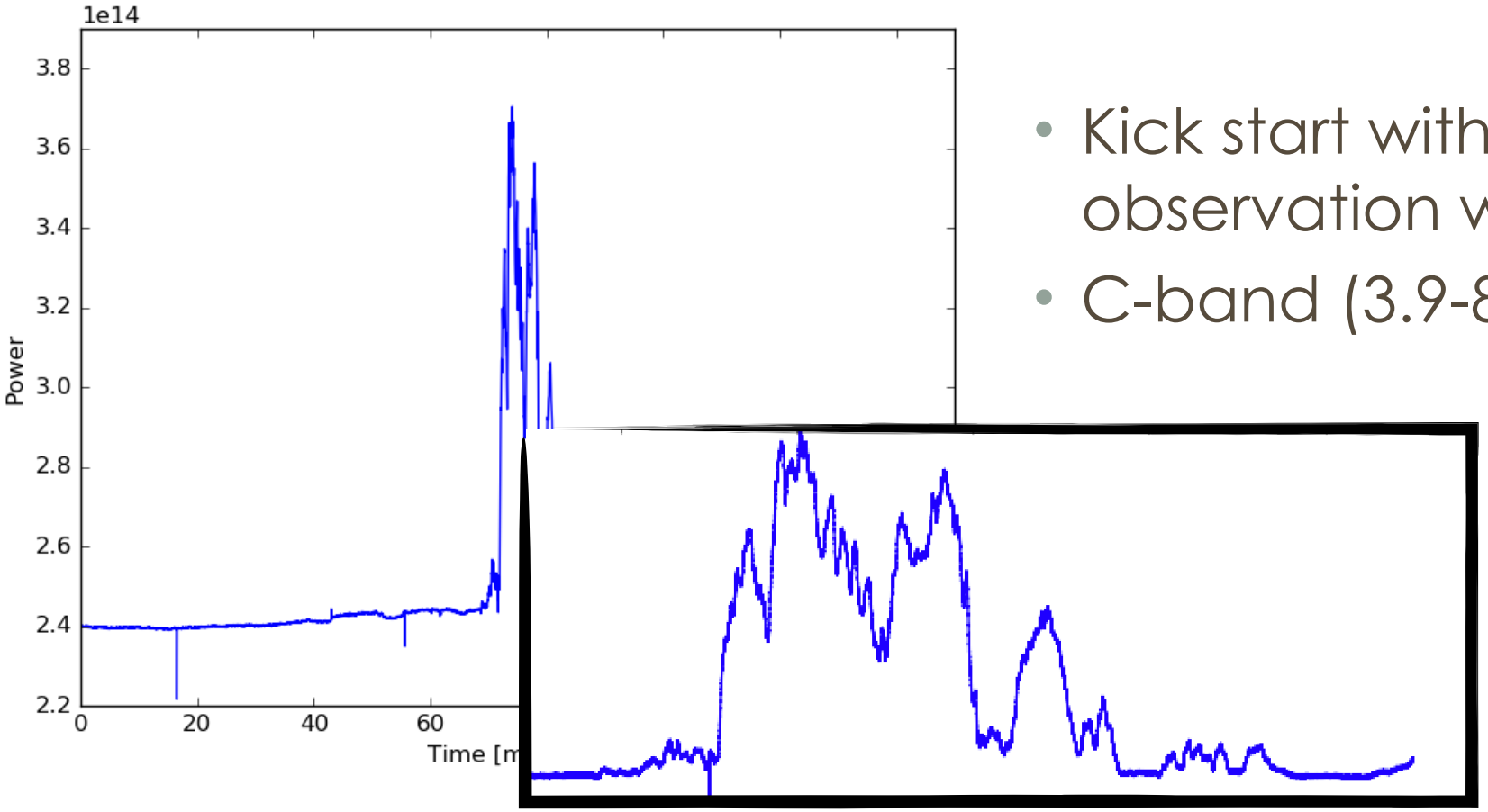
VERY Preliminary



- Kick start with a 2.5 hr observation with GBT
- C-band (3.9-8 GHz)

BL Detection of 2MASS15+22 (TVLM513-56)?

VERY Preliminary



- Kick start with a 2.5 hr observation with GBT
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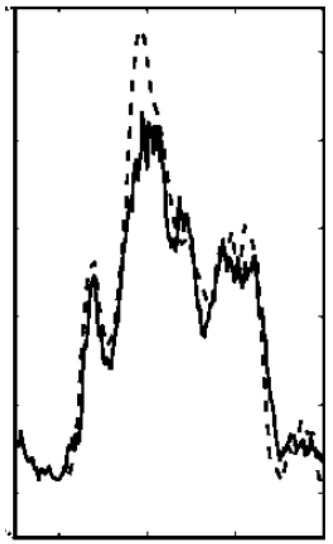

Hallinan et al. (2007)

BL Detection of 2MASS15+22 (TVLM513-56)?

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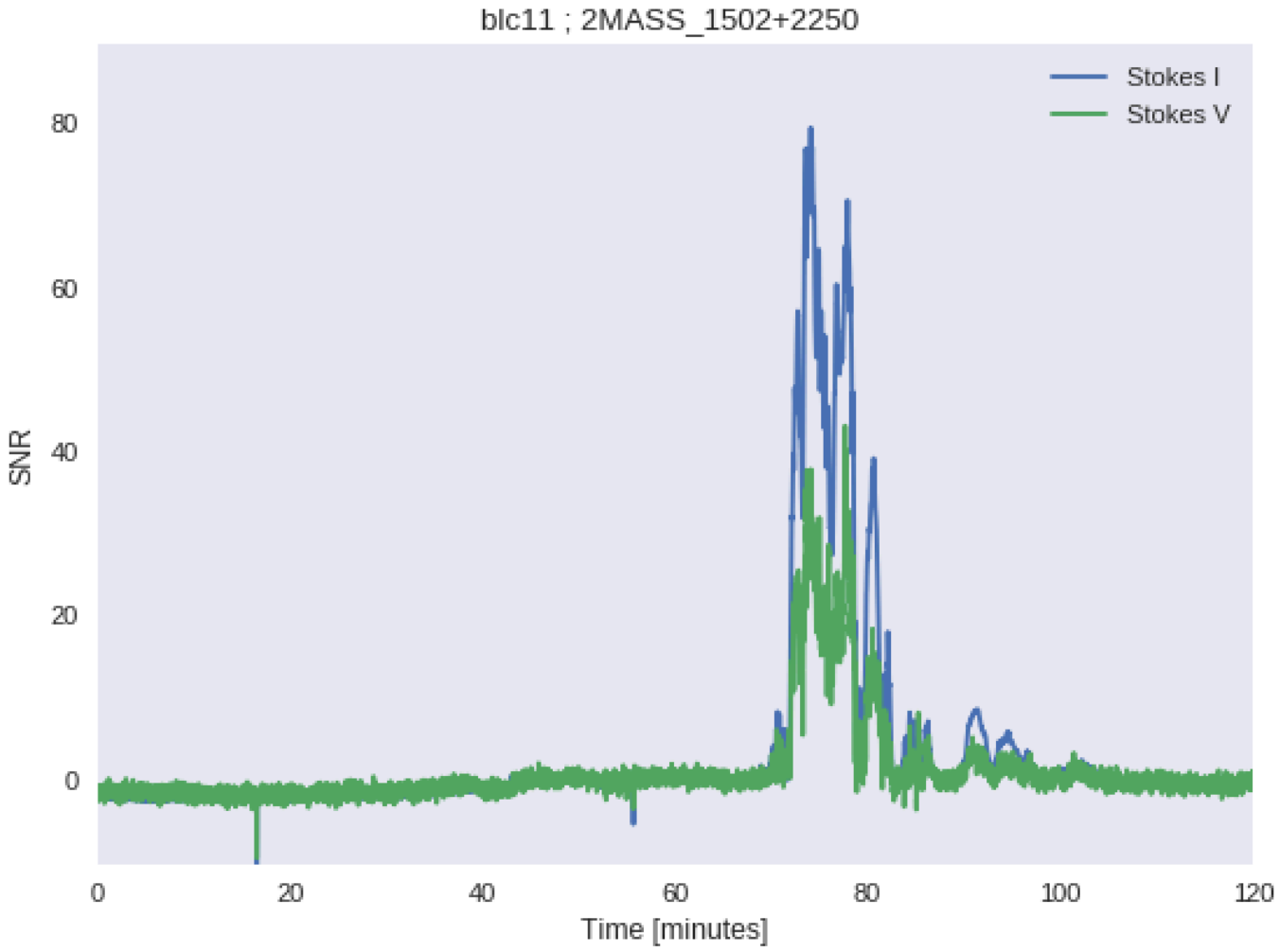
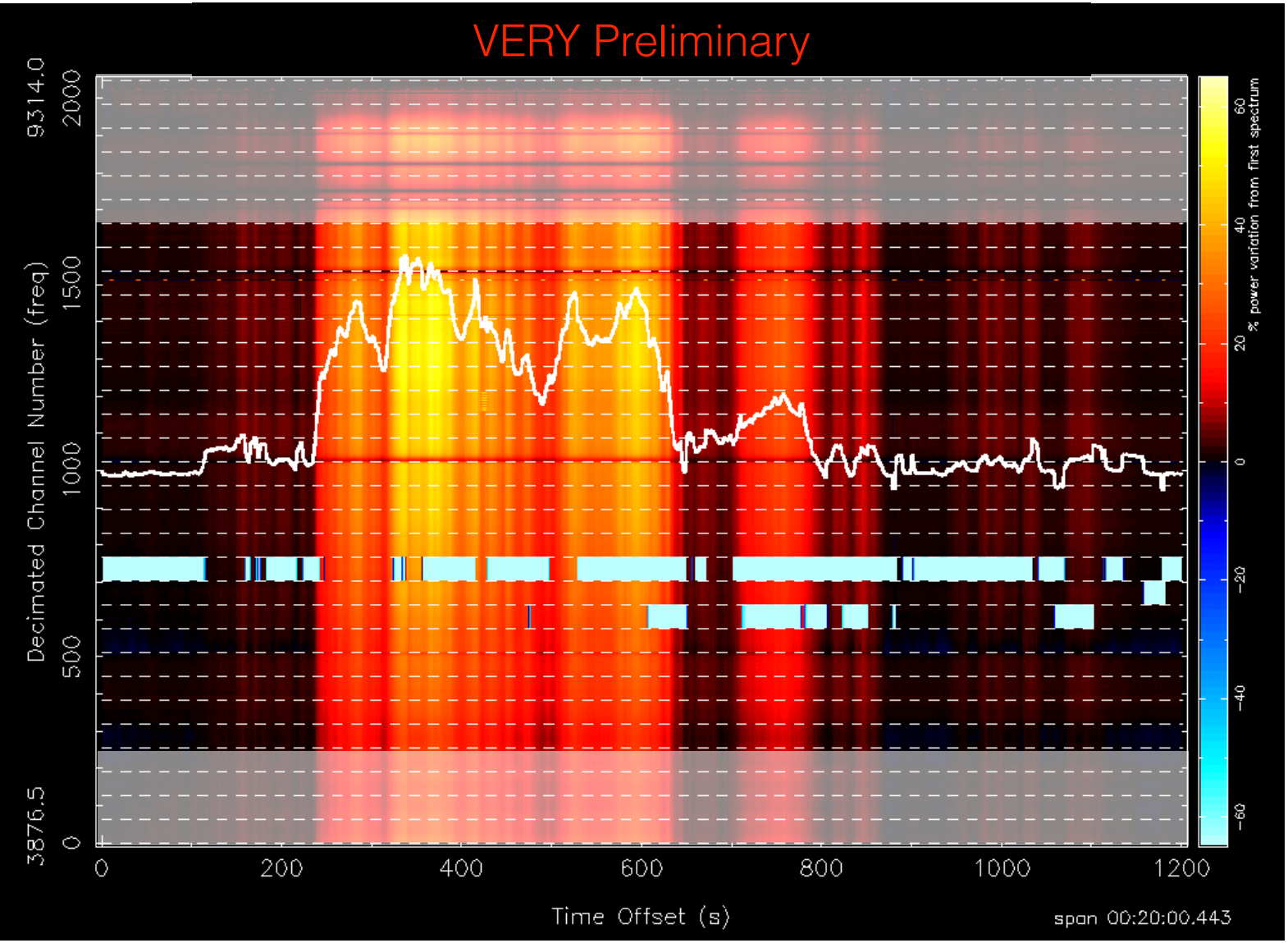


- Having crosstalk between polarizations
- Need proper Stokes V calibration!!

BL Detection of 2MASS15+22 (TVLM513-56)?



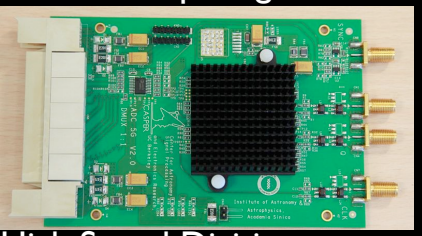
- Fractional bandwidth
  $\Delta\nu/\nu$ ~ 0.64
- Available Time*Frequency resolutions products
  - 1s * 3kHz
  - 350μs * 366 kHz

The Breakthrough Listen Initiative

BL Machine Learning Efforts

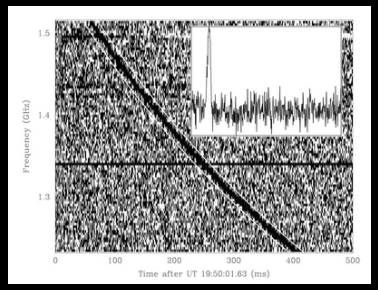
BL Instrumentation

FPGA Computing Boards

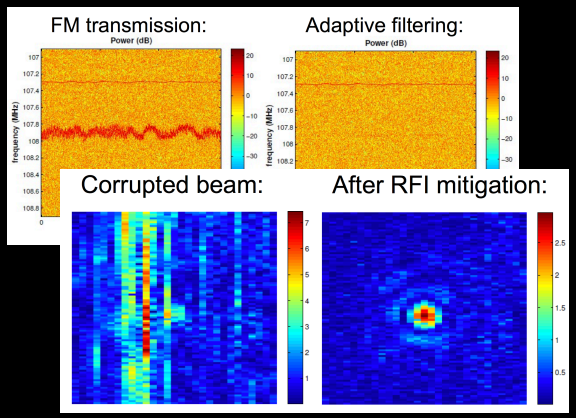


High Speed Digitizers

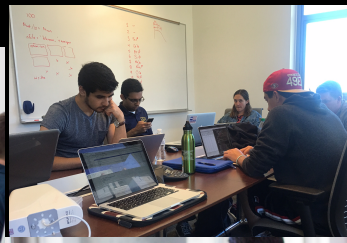
BL Collaborations



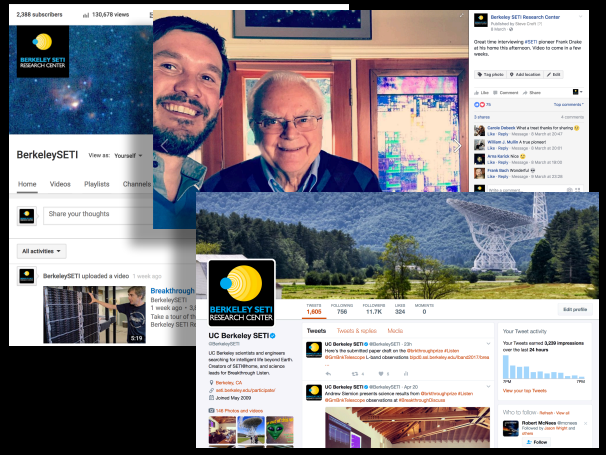
BL Advanced RFI mitigation



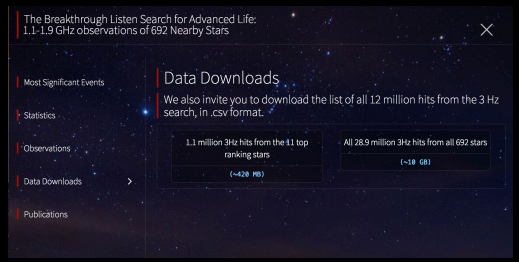
BL REU Program



BL Outreach



BL Public Data



SETI.BERKELEY.EDU | BREAKTHROUGHINITIATIVES.ORG

Open to Collaboration

- Monthly Collaborative SETI Meeting
  - Greg Hellbourg (gregory.hellbourg@berkeley.edu)
  - Next June 6th

- Want to know more:
  - https://seti.berkeley.edu/lband2017
  - https://seti.berkeley.edu