BREAKTHROUGH
LISTEN
AND THE FUTURE OF THE SEARCH
FOR INTELLIGENT LIFE

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05/10/2017
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How common is intelligent life in the galaxy?
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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

Frank Drake, 1961
$f_p^n e$ 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 $f_{l} \ast f_{i} \ast f_{c} \ast L$?
... but what about $f_l \times f_i \times f_c \times L$?

• 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**

A few radar systems on Earth detectable across the galaxy.

Hundreds of transmitters detectable at a few lightyears.

**Planetary Radar Systems**

**High-power Lasers**

Lasers can outshine the Sun by thousands of times.
Using multiple telescopes, we can search across the electromagnetic spectrum for indicators of advanced technology.
THE SQUARE KILOMETRE ARRAY

ONE OF THE WORLD’S LARGEST SCIENTIFIC INSTRUMENTS
FOR AN EXTRATERRESTRIAL TRANSMITTER @ 50 LY

(t_{\text{integration}} = 10 \text{ min}, \text{SNR} = 15)
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, $\frac{\lambda}{\Delta \lambda} = 10^5$
- 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 Search for Intelligent Life: Target Selection of Nearby Stars and Galaxies

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Received 2016 December 6; accepted 2017 January 4; published 2017 March 24
Main Sequence and Giant Stars (in Domains)

Distance = 5–50 pc
DEC > −90°
Total Number of Stars: 1649
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 $10^{15}$ W, which is achievable by our own civilization.
**Observations of 692 Nearby Stars**

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

- [https://seti.berkeley.edu/lband2017](https://seti.berkeley.edu/lband2017)

![Observation Equipment](image)
DETECTION OF VOYAGER 1 WITH TURBOSETI
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**TURBOSETI**

- [https://github.com/UCBerkeleySETI/turbo_seti](https://github.com/UCBerkeleySETI/turbo_seti)

- Tree search algorithm (Siemion2013 - Taylor 1974)
  - \(n \log (n)\)
- 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 continuous artificial signals between 1.1-1.9 GHz at brighter than $10^{13}$ W.
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

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
OTHER OPPORTUNITIES WITH BL DATA

Lynch et al. (2015)
Zarka (1998)
Hallinan et al. (2007)
Osten (2007)
Hallinan et al. (2015)
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)
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Hallinan et al. (2007)
BL DETECTION OF 2MASS15+22 (TVLM513-56)?

VERY Preliminary

- Having crosstalk between polarizations
- Need proper Stokes V calibration!!
BL DETECTION OF 2MASS15+22 (TVLM513-56)?

VERY Preliminary

• Fractional bandwidth $\Delta \nu/\nu \sim 0.64$

• Available Time*Frequency resolutions products
  - 1s * 3kHz
  - 350µs * 366 kHz
The Breakthrough Listen Initiative

BL INSTRUMENTATION
- FPGA Computing Boards
- High Speed Digitizers

BL COLLABORATIONS

BL ADVANCED RFI MITIGATION
- FM transmission:
- Adaptive filtering:
- Corrupted beam:
- After RFI mitigation:

BL MACHINE LEARNING

BL PUBLIC DATA
- The Breakthrough Listen Search for Advanced Life: 1.3-5 GHz observations of 100 nearby stars
- Data Downloads
- Statistics
- Observations
- Data Sources
- Publications

BL OUTREACH

BL REU PROGRAM

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