BREAKTHROUGH LISTEN

Humanity's largest search for cosmic company

Steve Croft, UC Berkeley

with Andrew Siemion and colleagues
and support from the Breakthrough Prize Foundation

BERKELEY SETI RESEARCH CENTER

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UFO Sighting? No, Just Google's 'Rogue' Balloon

By Nola Taylor Redd, Space.com Contributor | May 28, 2014 02:02pm ET

MORE

On Oct. 16, 2012, residents of Pike County, Ky., looked high in the sky to find a strange sight. Amateur astronomer Allen Epling described it to a local reporter as looking "like two fluorescent bulbs, side by side, parallel, shining very brightly." The Earthly source of the UFOs has been found.

Credit: East Kentucky Broadcasting (via YouTube)

Two years ago, a Google balloon launched to test the feasibility of delivering the Internet to people around the world achieved notoriety when it was identified as a UFO in Pike County, Kentucky.

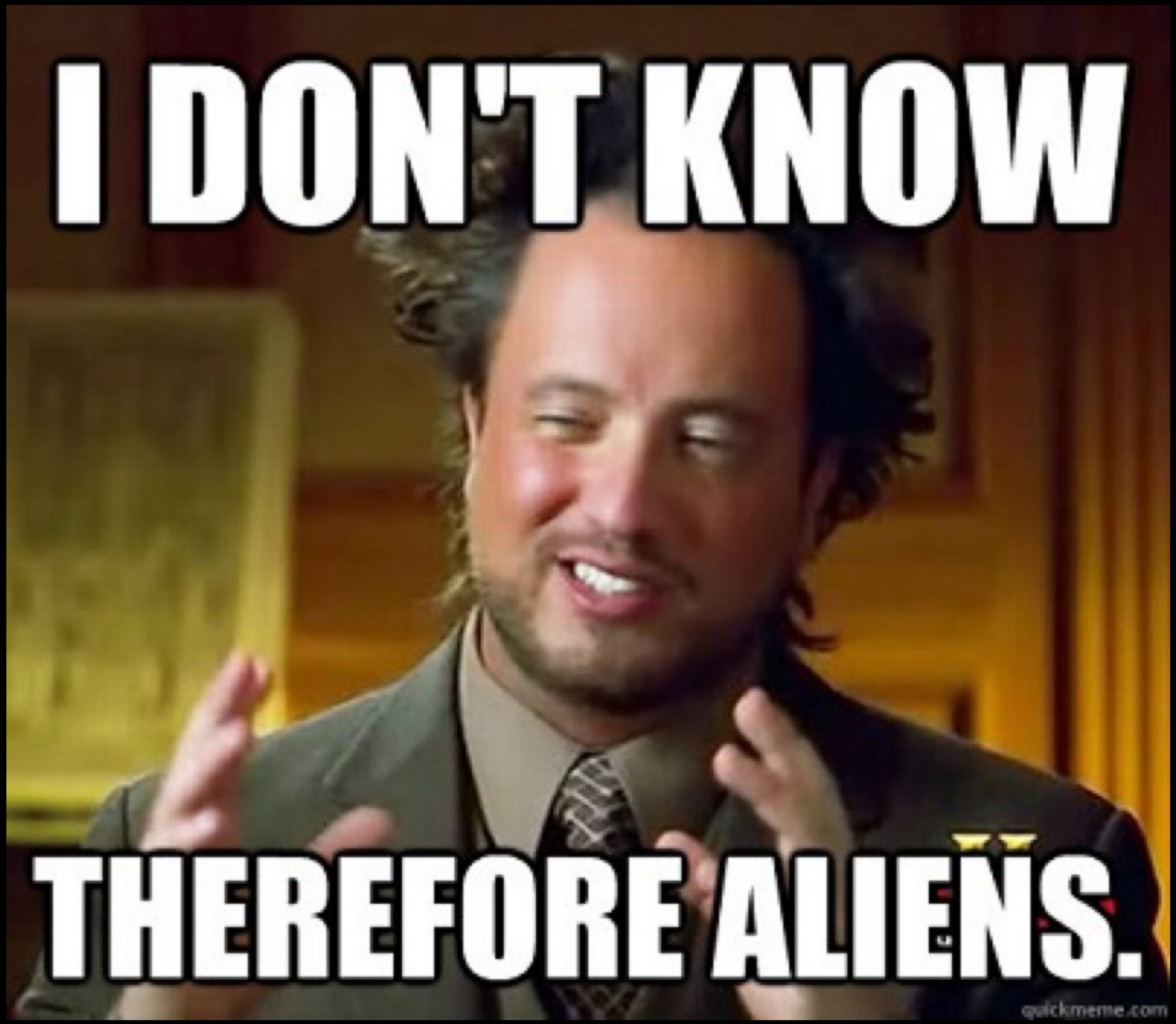
Turns out, the balloon responsible for the mass UFO sightings was not only a prototype, but one that wasn't following the plans of its designers.

"This is a balloon that went rogue," said Google X Rapid Evaluation team leader Rich DeVaul at Smithsonian magazine's "The Future is Here" festival in Washington, D.C., on May 17. "No one outside Google X knows this," DeVaul added. [Where to Spot 'UFOs' (Infographic)]

Do you believe alien life exists elsewhere in the universe?

- Yes - We may not have found them yet, but they're out there.
- No - Aliens are just part of science fiction.

Launched in California in 2012, the new Falcon 11 model was supposed to take a short-duration test flight. However, while in the air, the balloon malfunctioned, and controllers were unable to land it, leading to its cross-country trip.


I DON'T KNOW
THEREFORE ALIENS.
quickmeme.com

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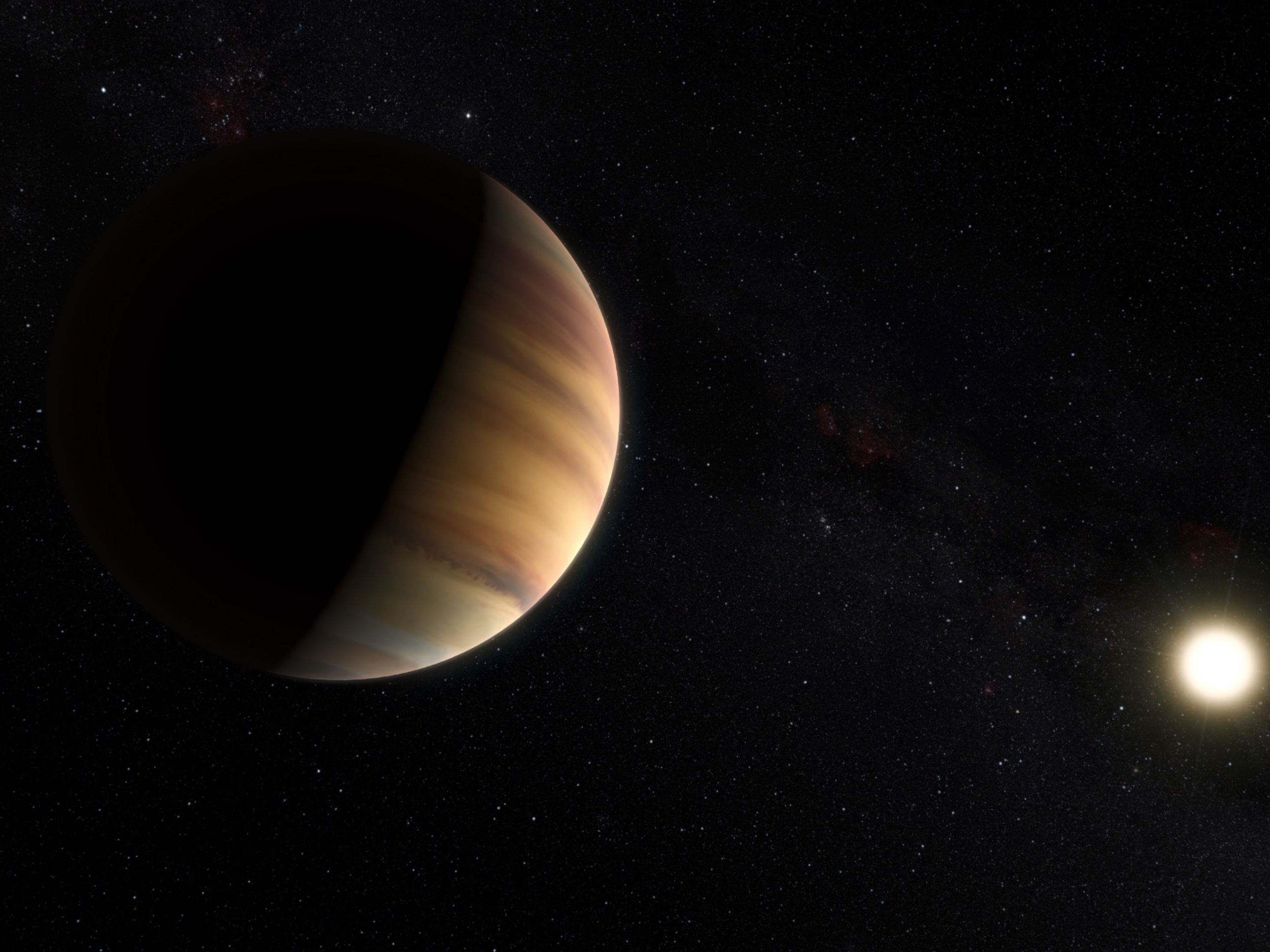

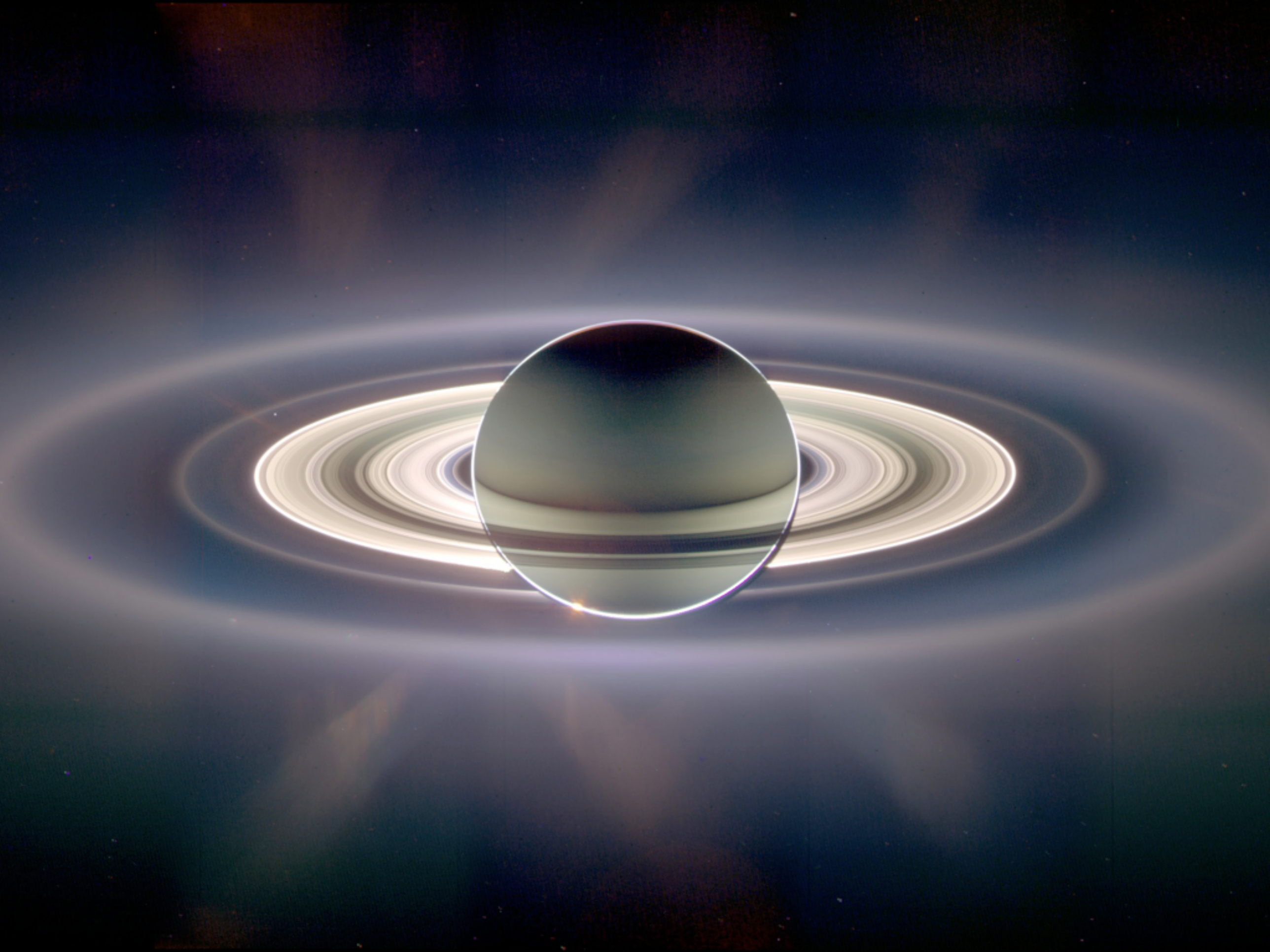

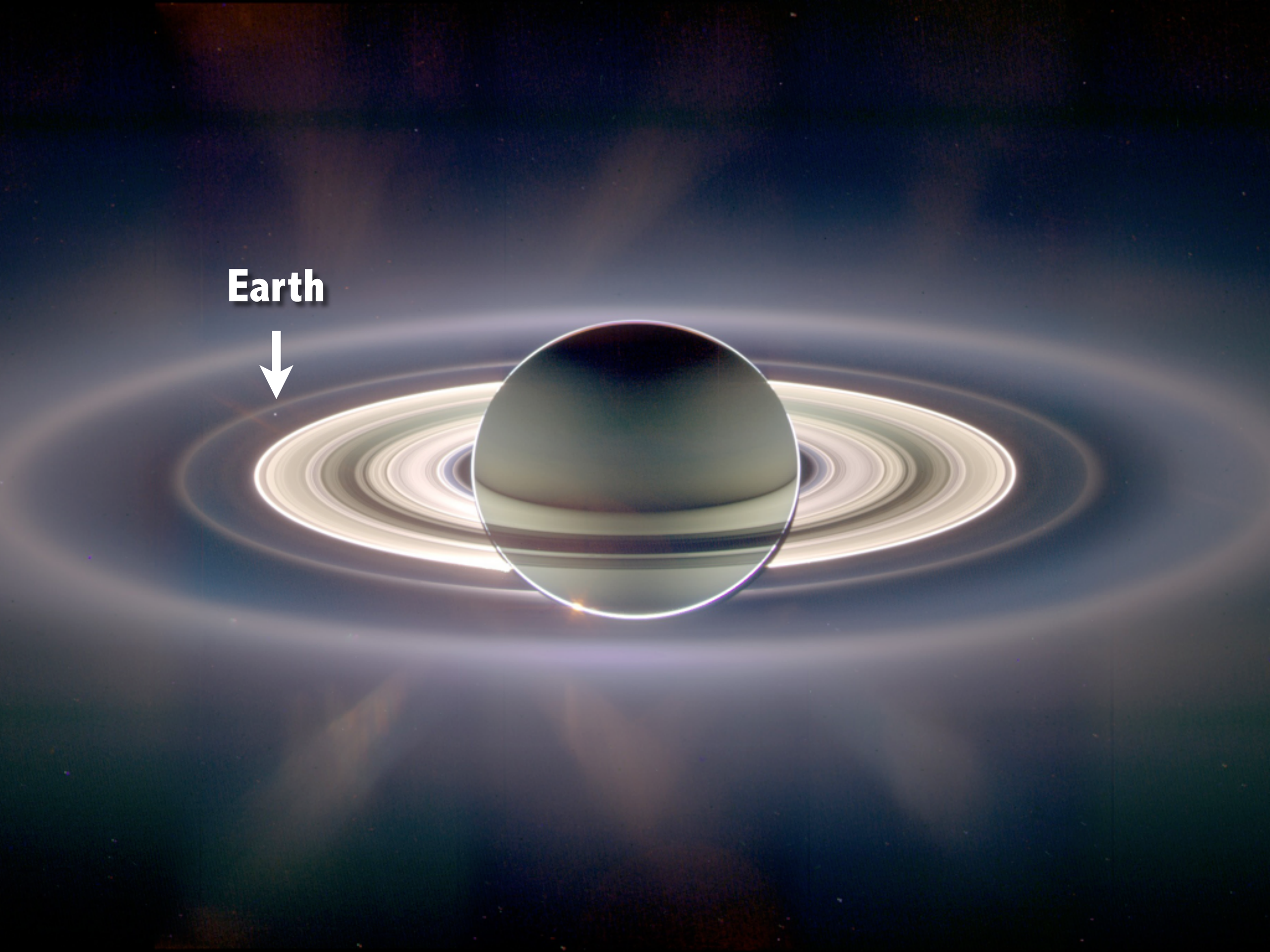
Earth

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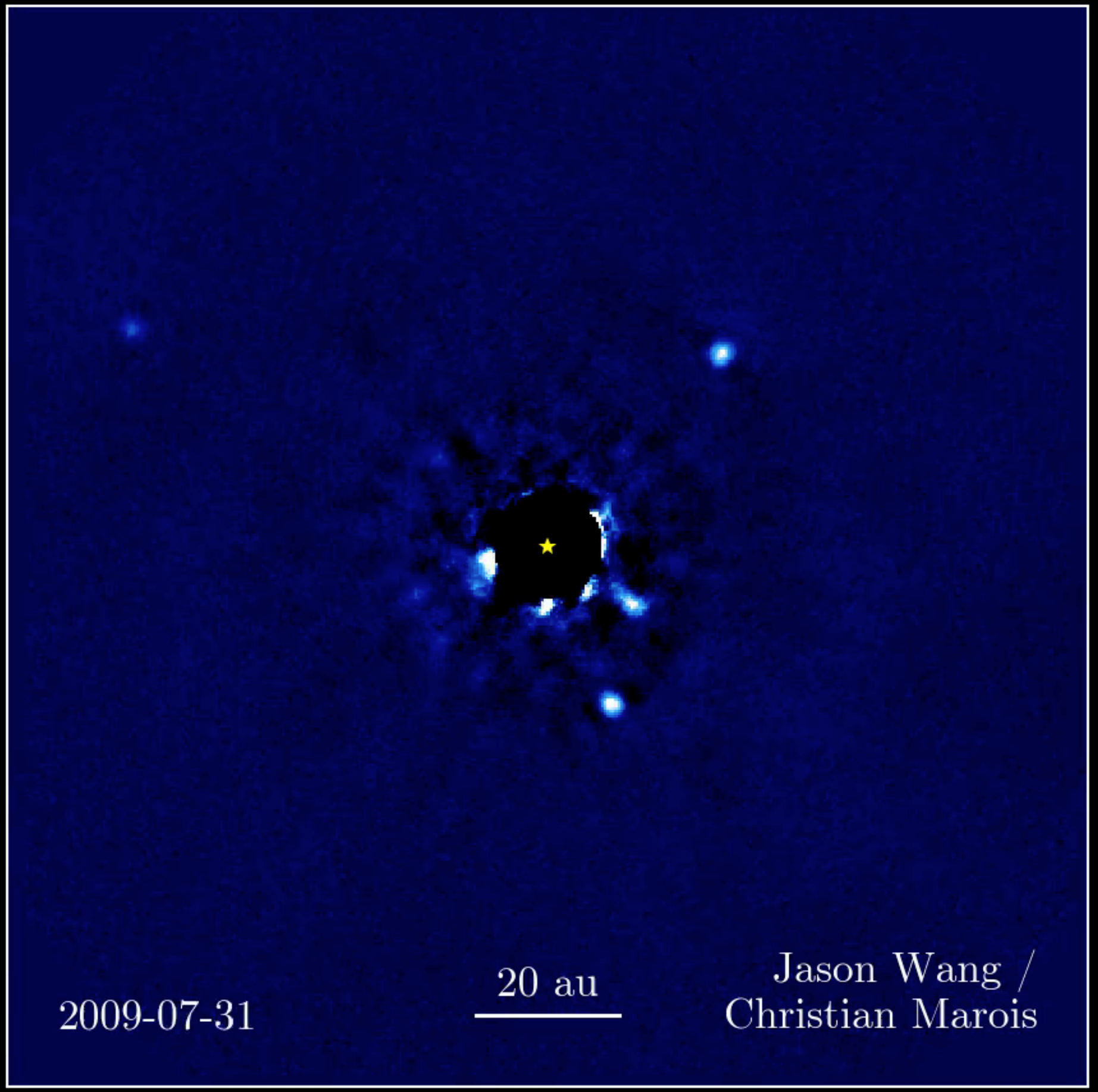
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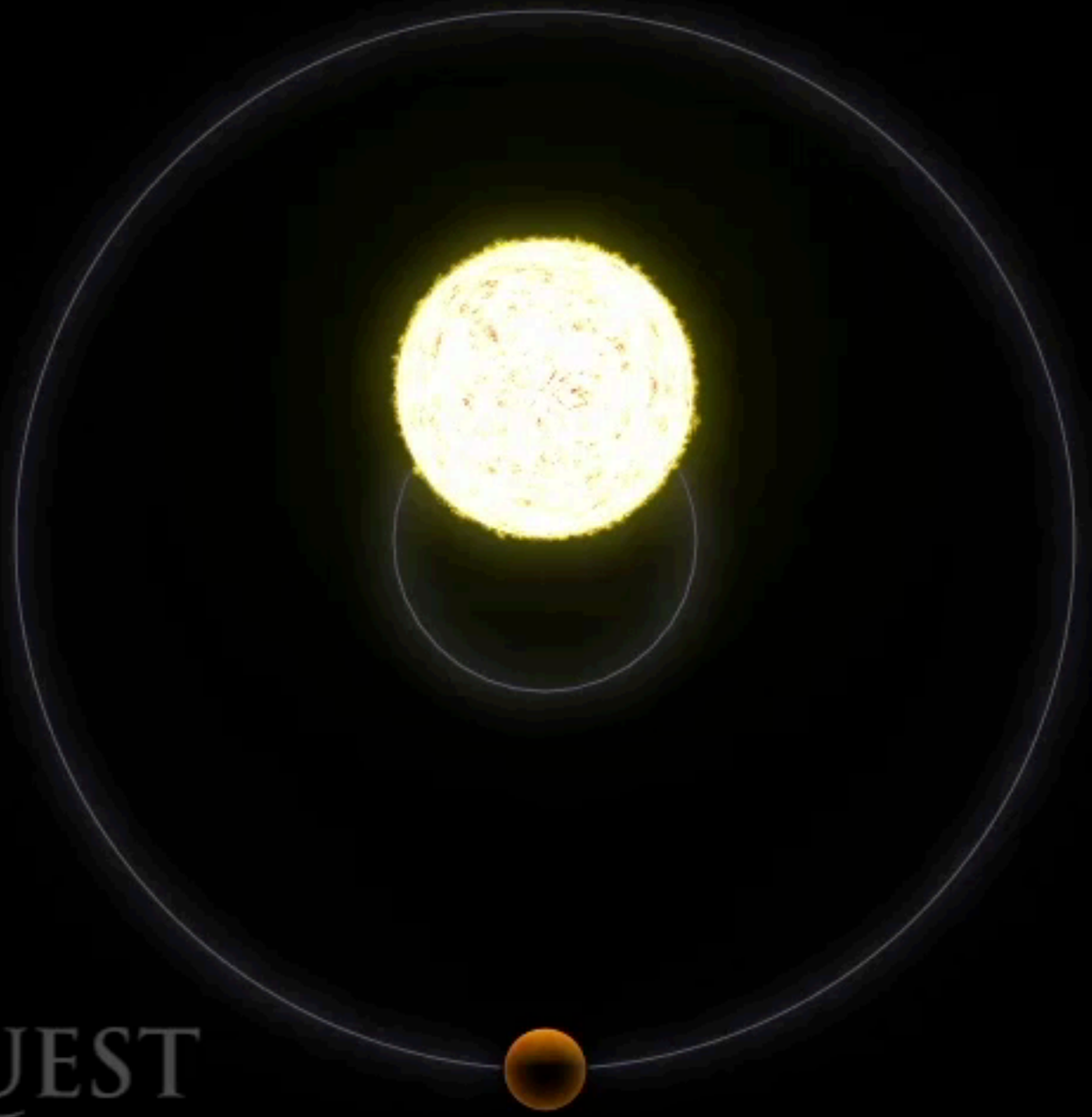
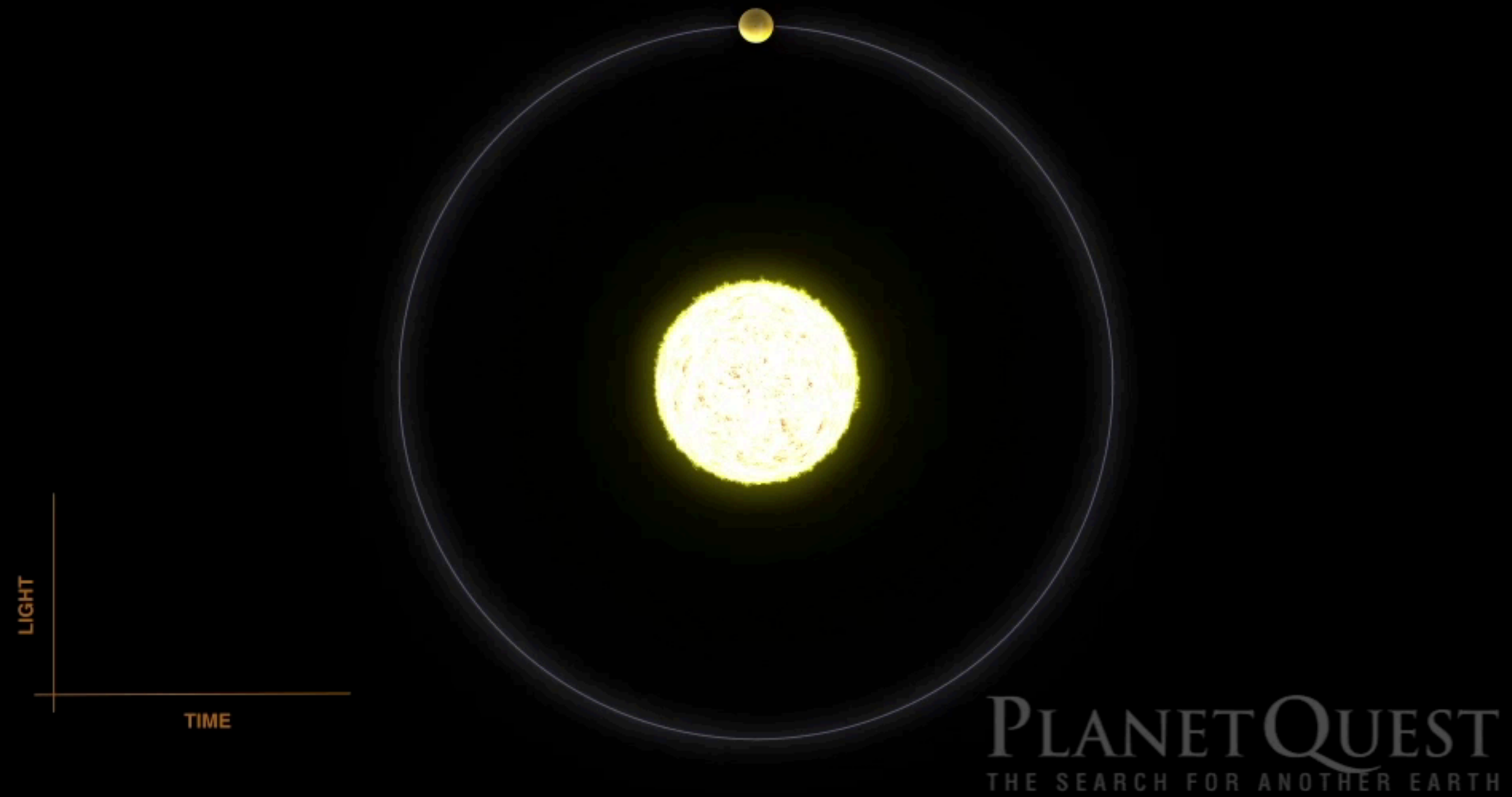
Jason Wang /
Christian Marois


PLANET QUEST
THE SEARCH FOR ANOTHER EARTH


LIGHT
TIME
PLANETQUEST
THE SEARCH FOR ANOTHER EARTH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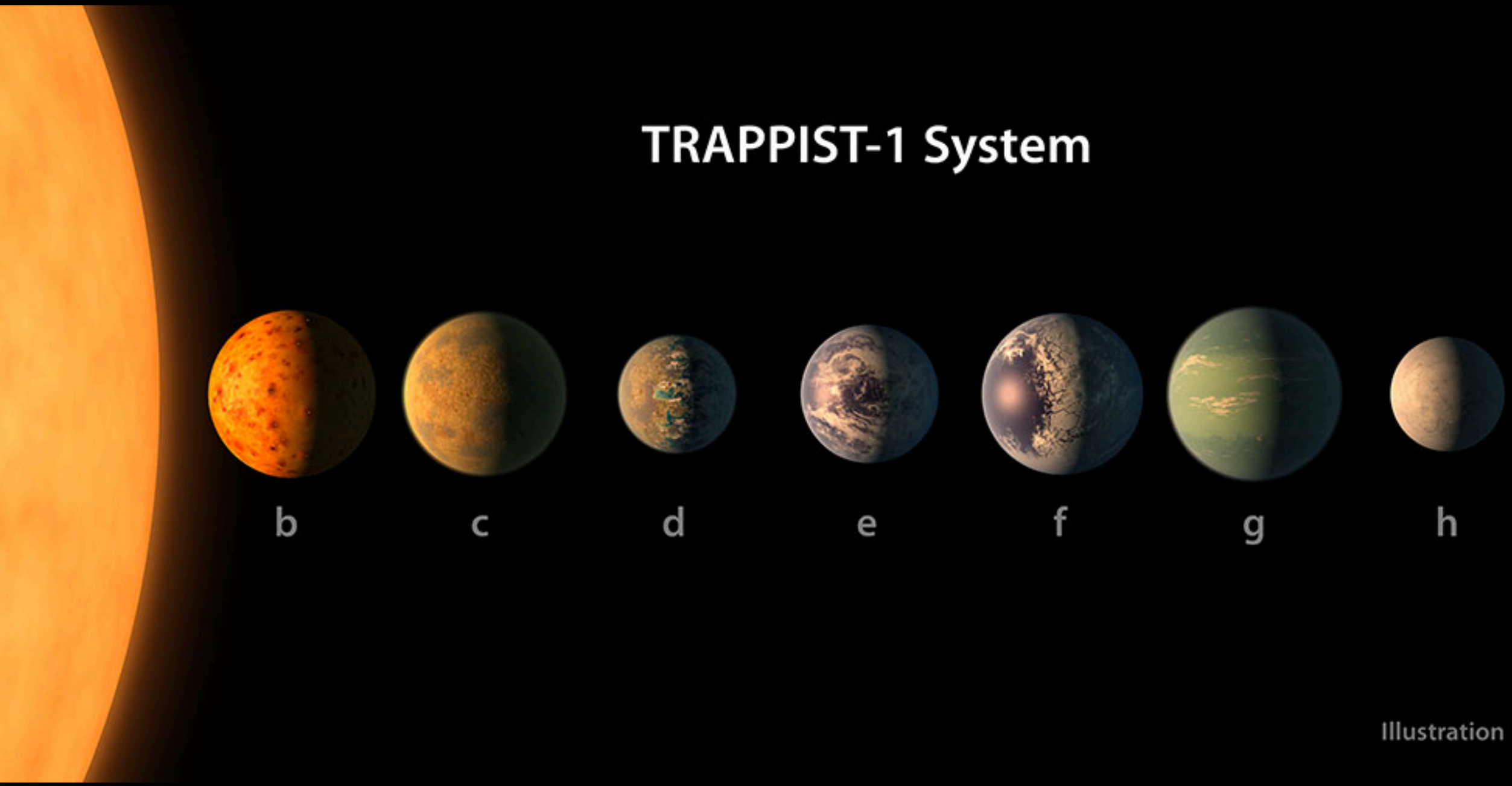
http://extrasolar.spaceart.org



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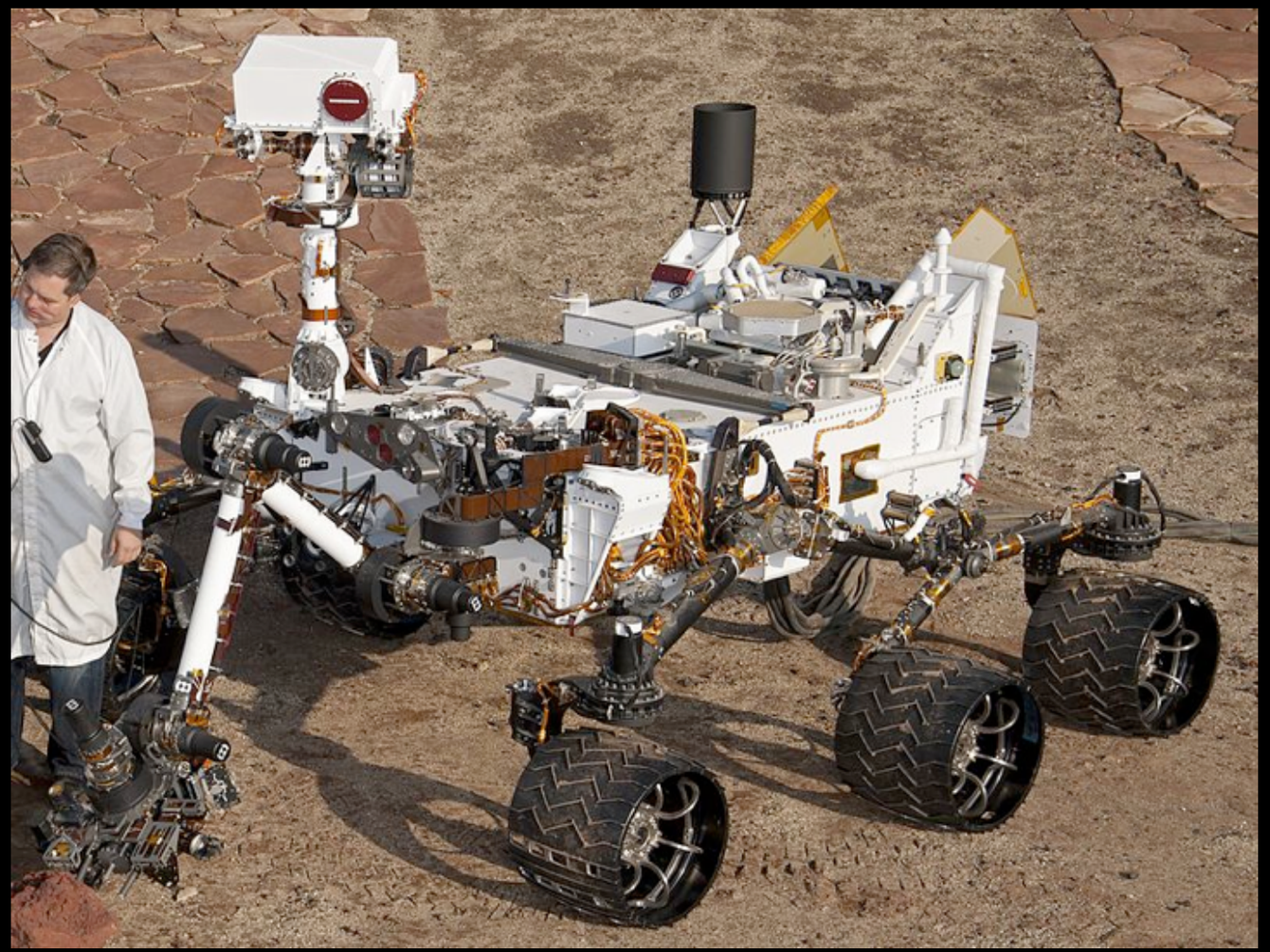
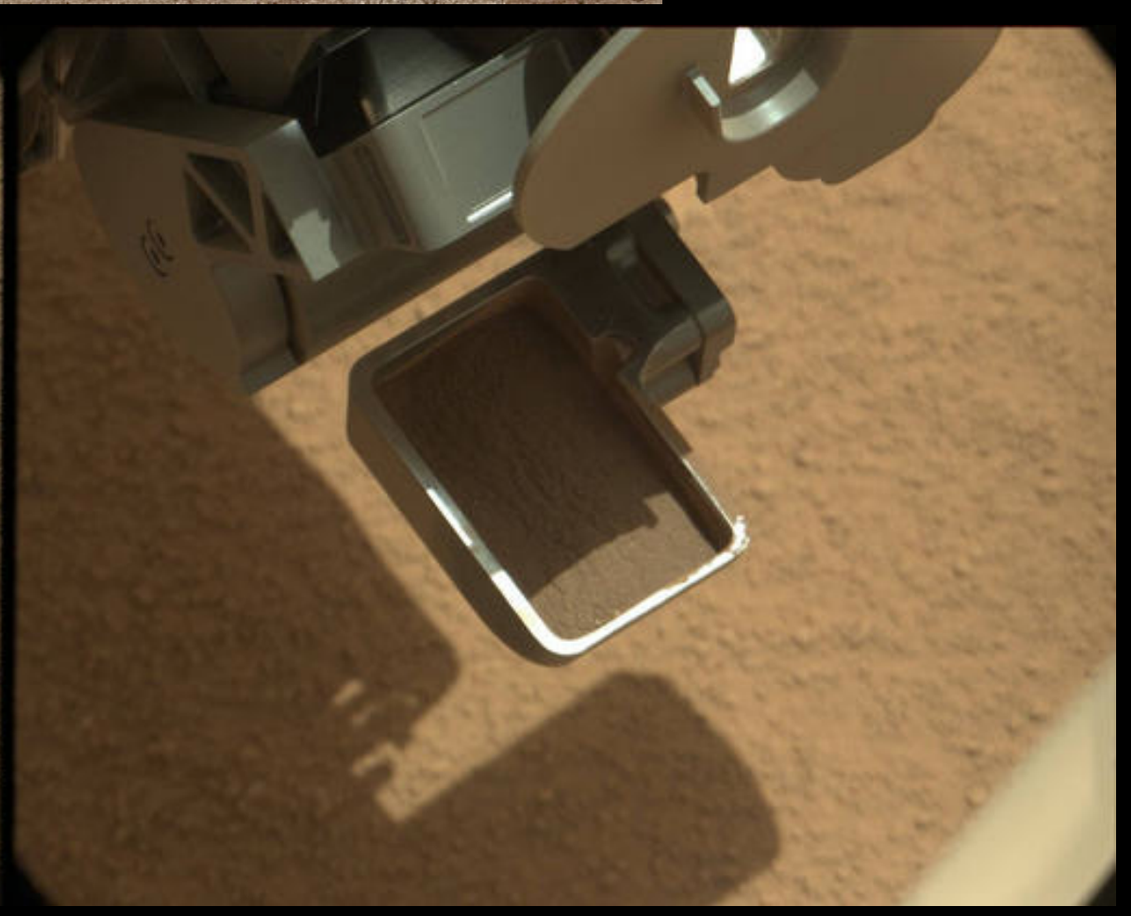
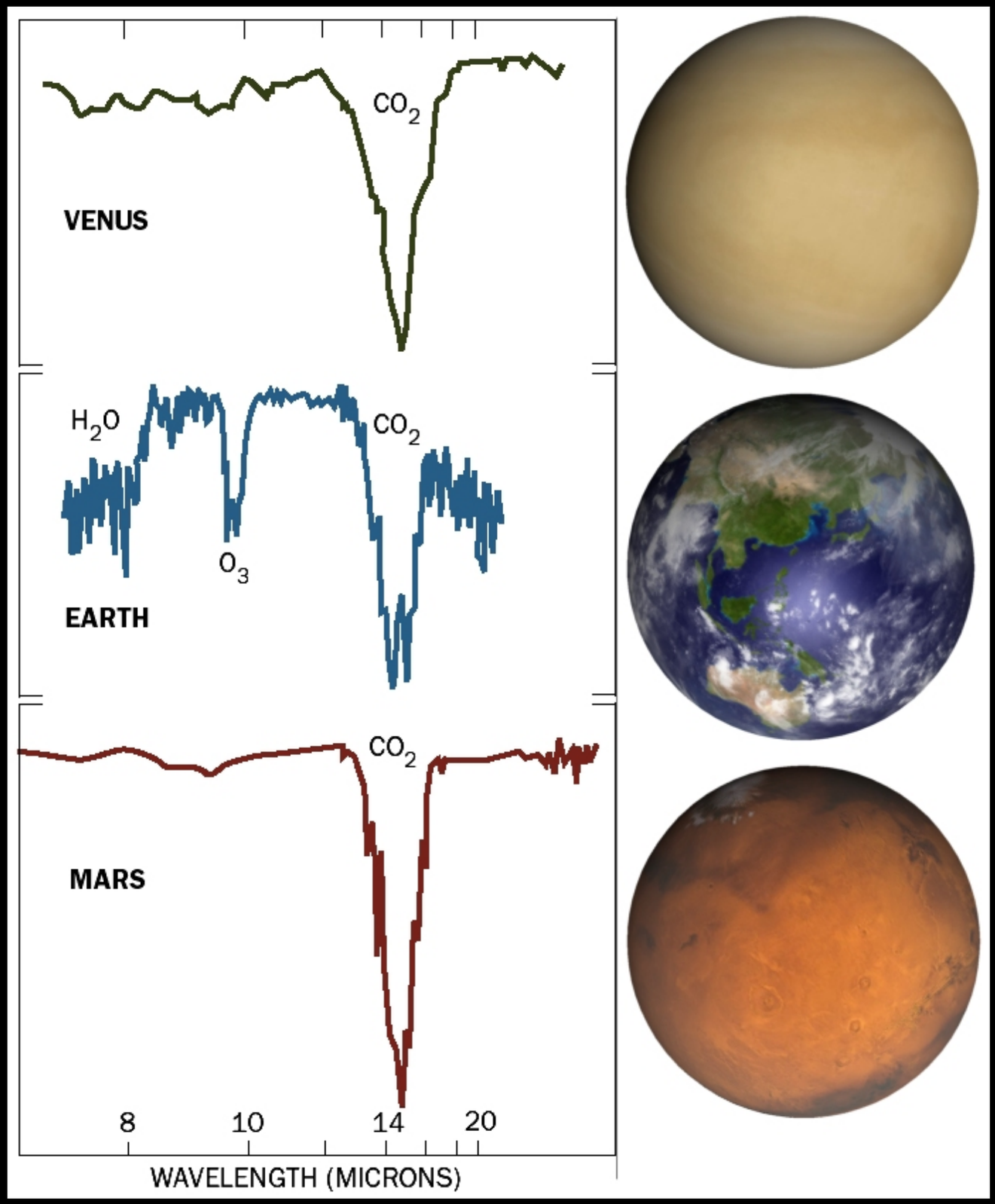
HUDF (NASA)

Where is everybody?

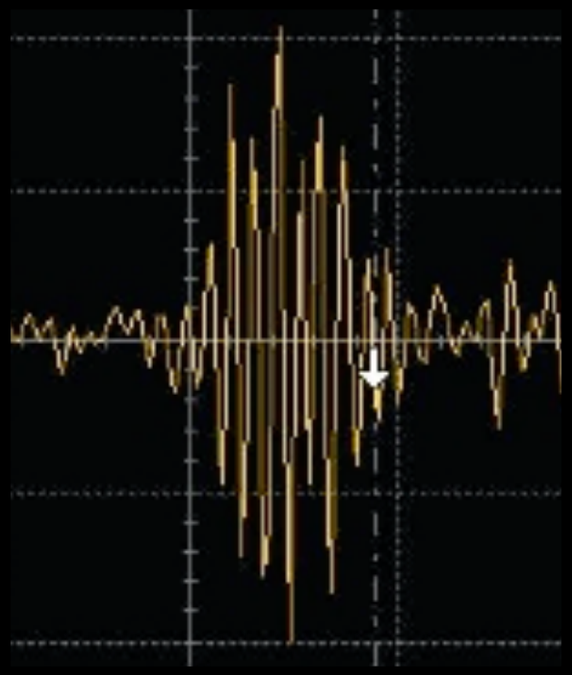


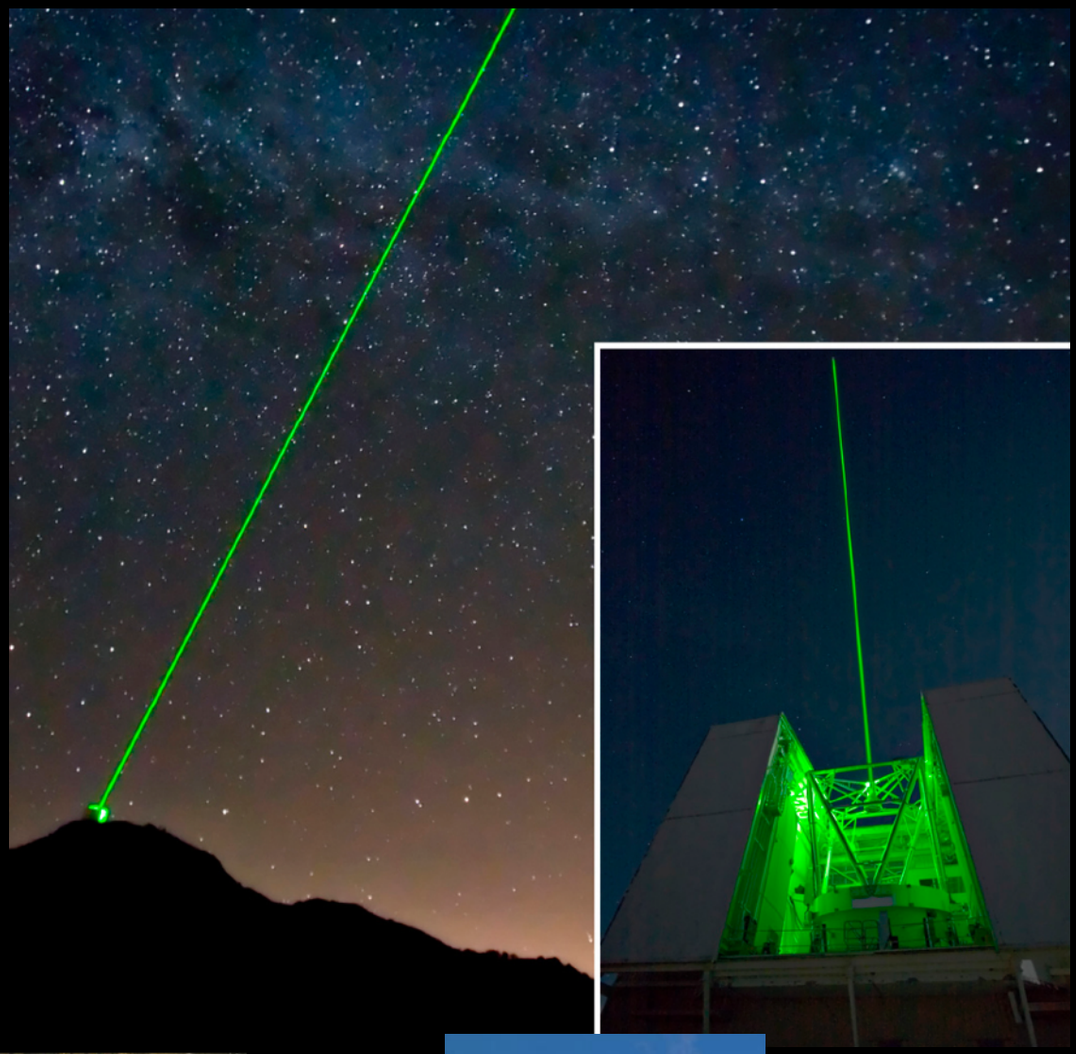


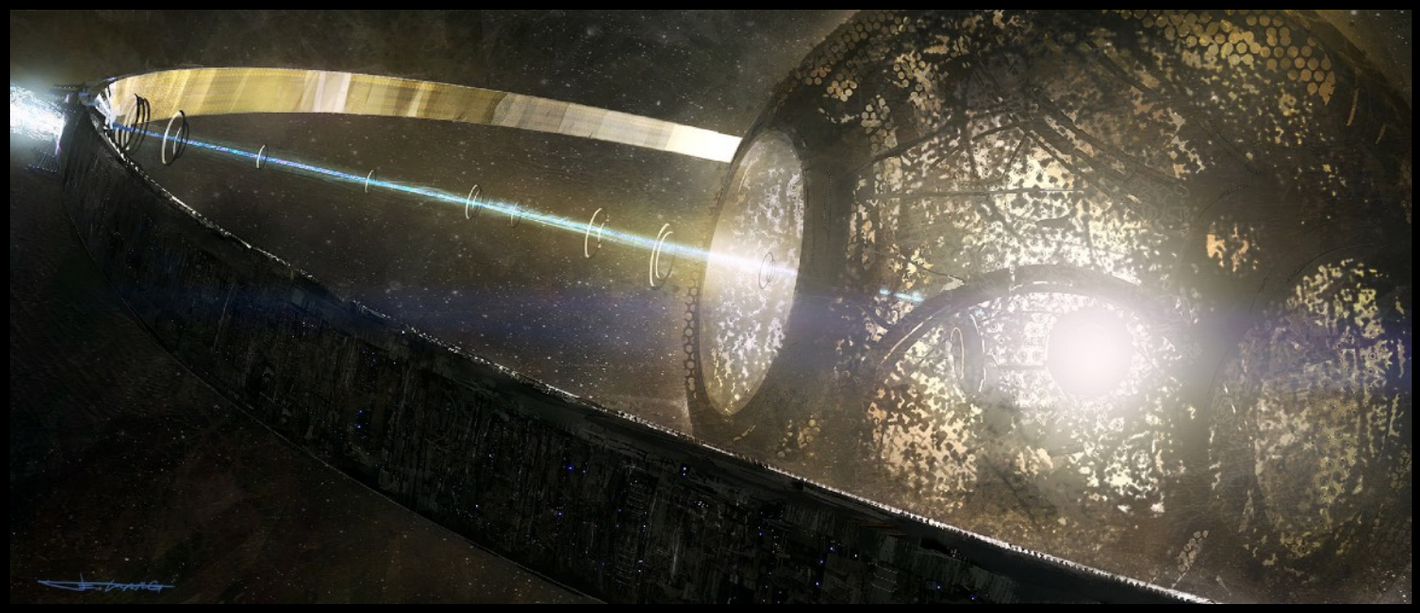
Biosignatures



Technosignatures







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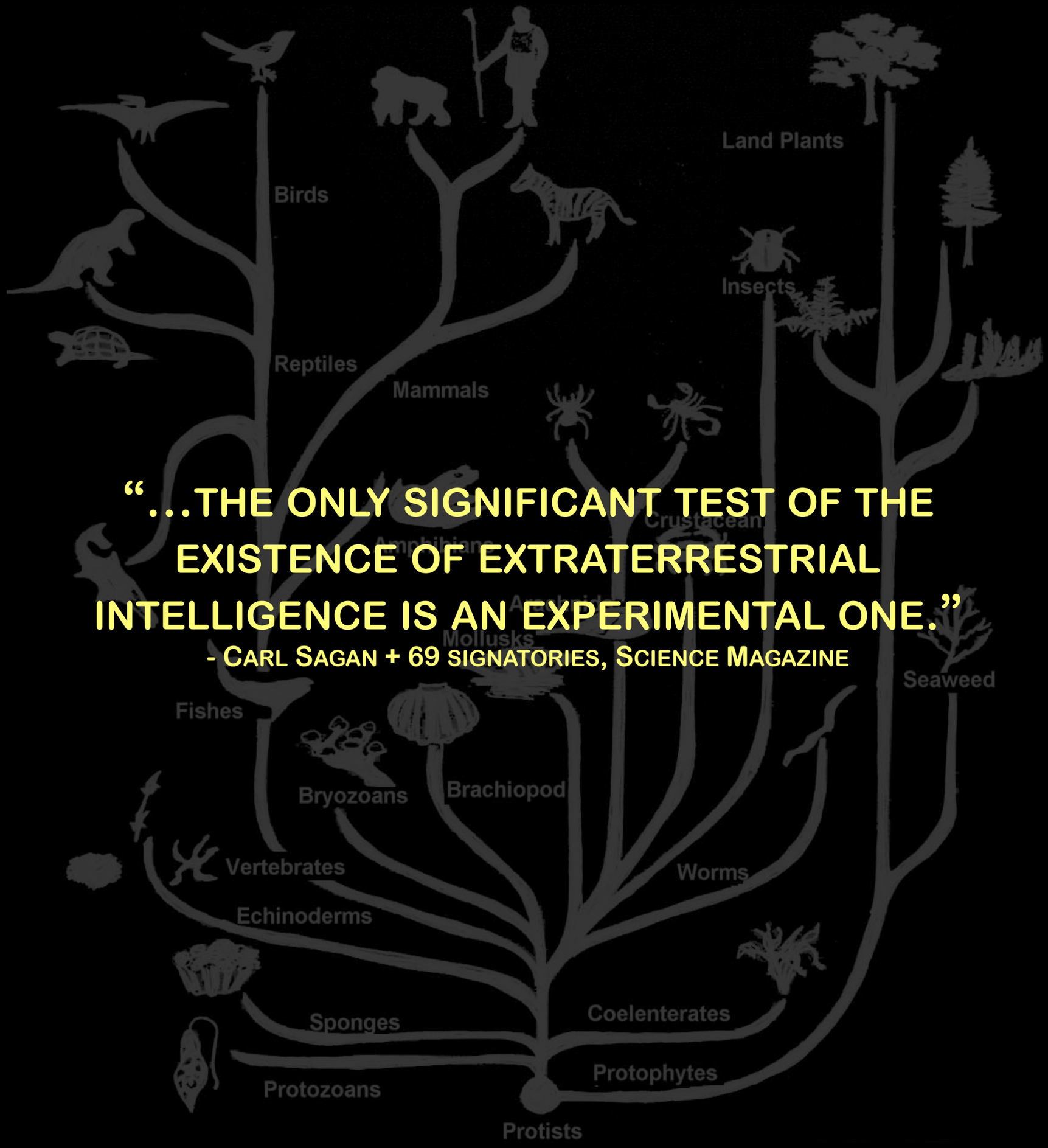

“…THE ONLY SIGNIFICANT TEST OF THE EXISTENCE OF EXTRATERRESTRIAL INTELLIGENCE IS AN EXPERIMENTAL ONE.”

- CARL SAGAN + 69 SIGNATORIES, SCIENCE MAGAZINE

Sale

Zoom




NooElec NESDR Mini+ Al - 0.5PPM TCXO USB RTL-SDR Receiver (RTL2832 + R820T) w/ Antenna and Remote Control, Installed in Aluminum Enclosure

★★★★★ 1 Review(s) | Add Your Review

NooElec NESDR Mini+ 0.5PPM TCXO-based RTL-SDR USB set installed in a special edition black aluminum enclosure. R820T tuner is guaranteed.

Full 2 Year Warranty! Assembled in the USA.

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Orders usually **shipped in business day!**
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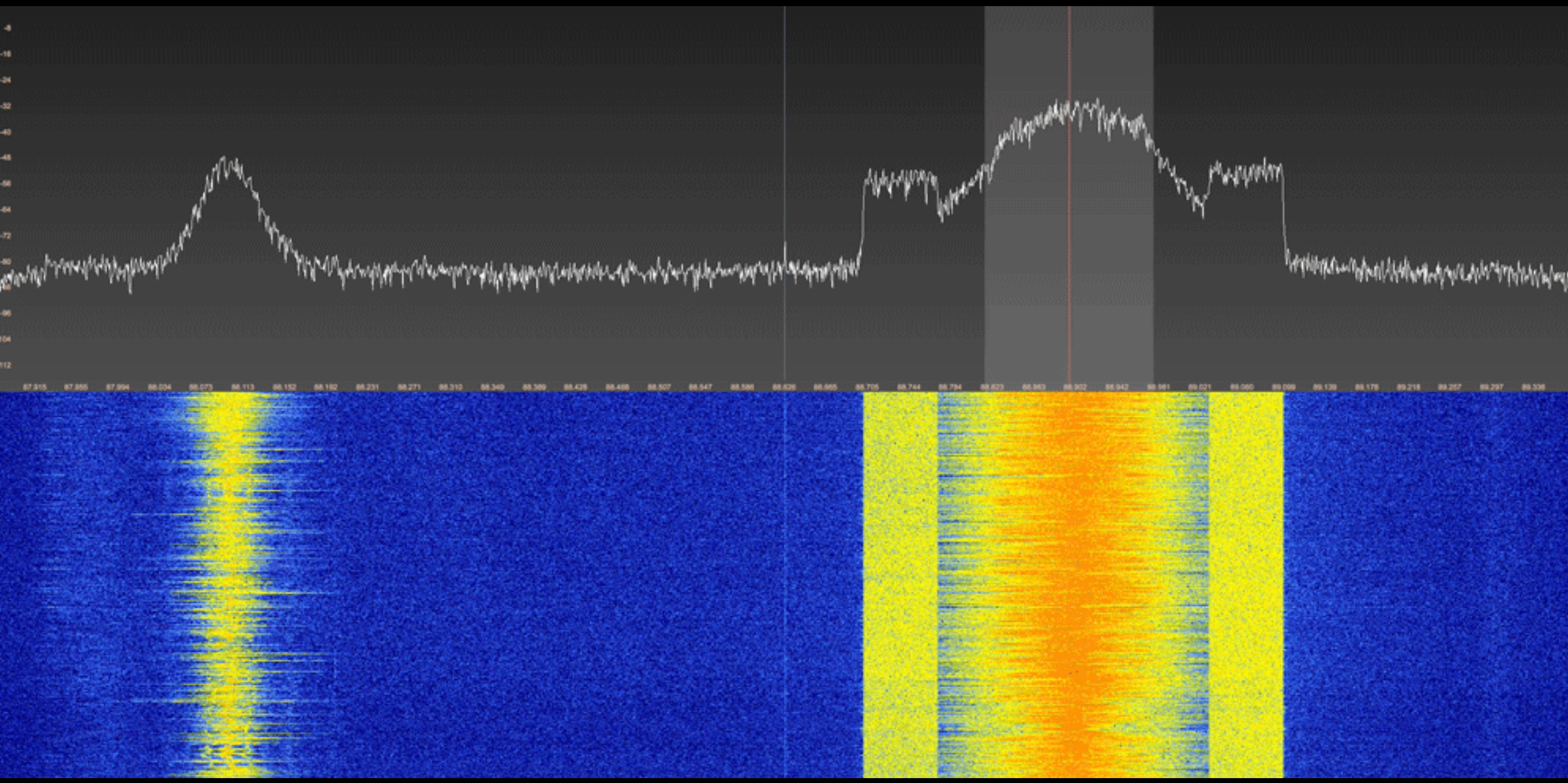

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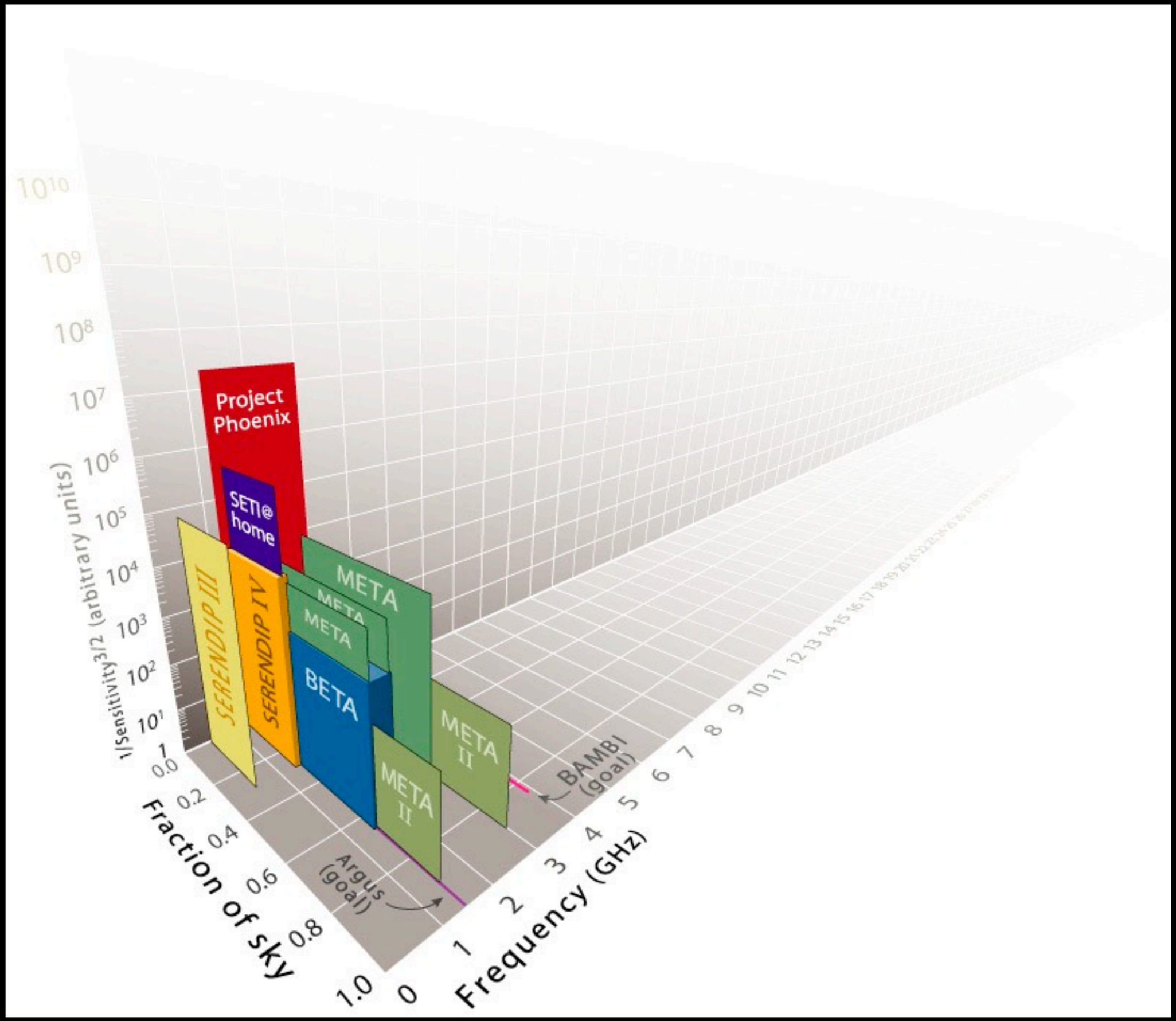
BL Radio Infrastructure

arxiv.org/abs/1707.06024

arxiv.org/abs/1804.04571

- 6 GHz bandwith
- 4 PB storage
- 200 TFLOPS
- ~750 MB/sec/compute node
- Observing ~5 hours a day (20% time)
- Hundreds of TB/day raw data per day since 1/1/16 - reduced to dynamic spectra at 0.5 TB / hr



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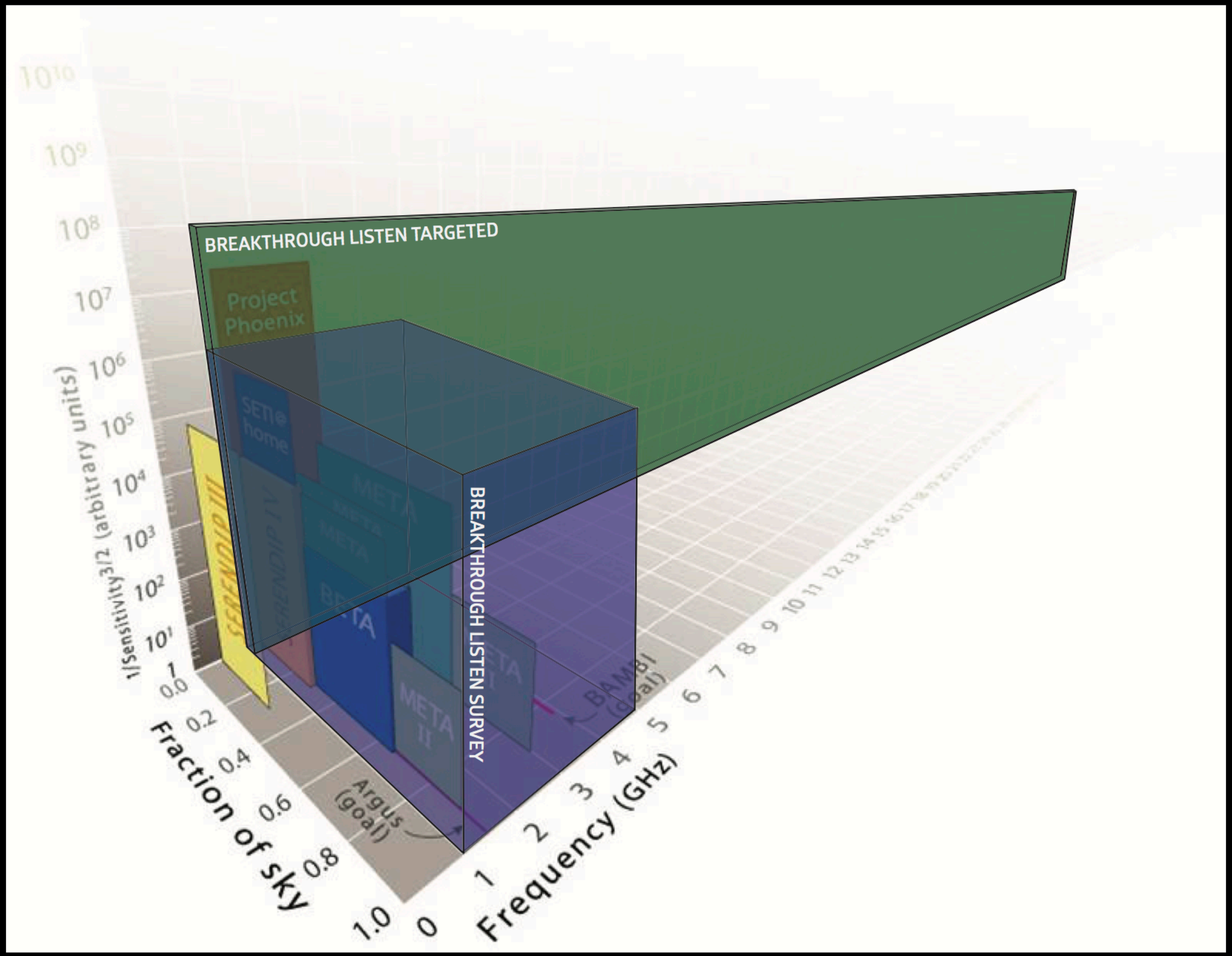

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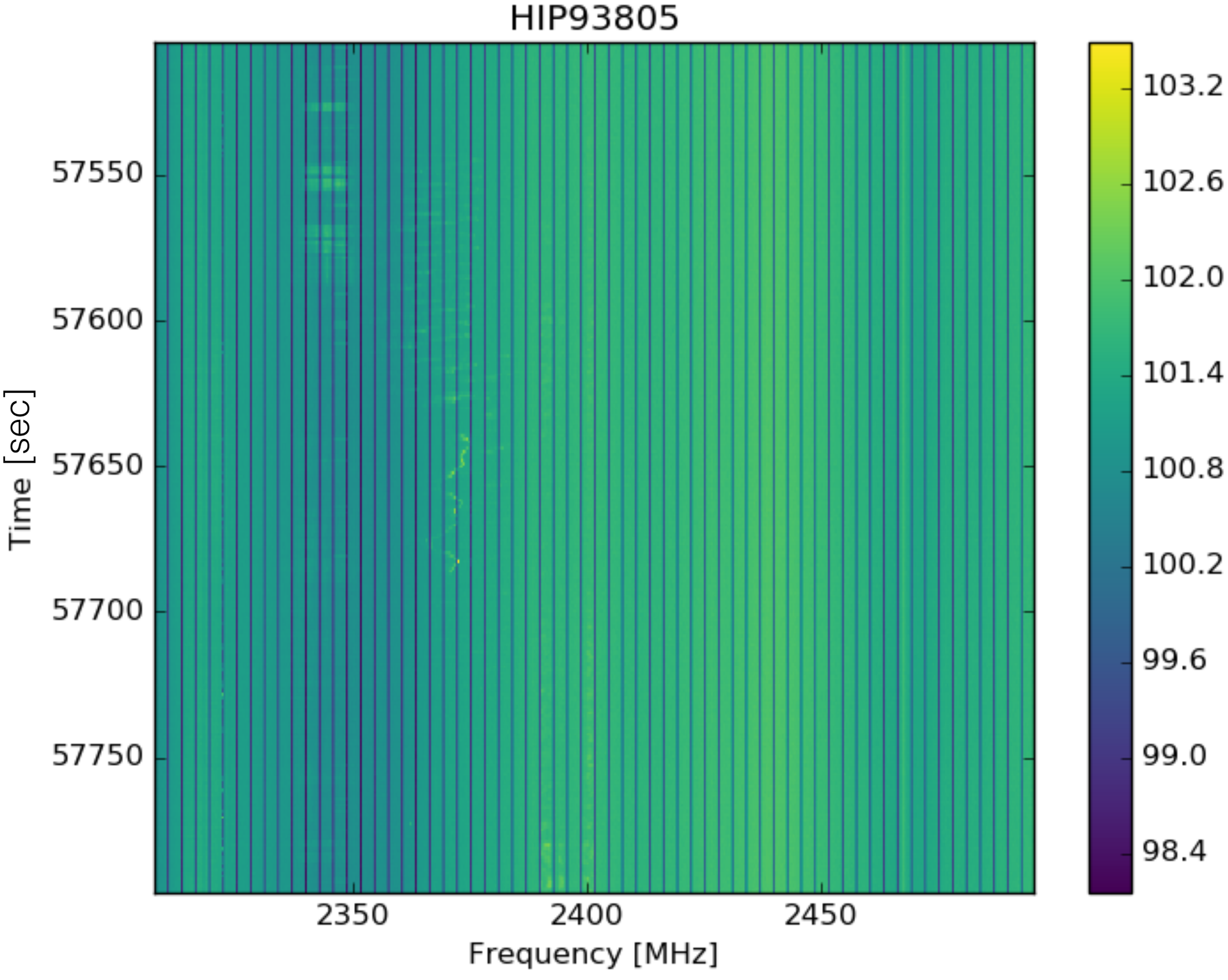
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UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

AERONAUTICAL MOBILE
AERONAUTICAL MOBILE SATELLITE
AERONAUTICAL RADIONAVIGATION
AMATEUR
AMATEUR SATELLITE
BROADCASTING
BROADCASTING SATELLITE
EARTH EXPLORATION SATELLITE
FIXED
FIXED SATELLITE
INTER-SATELLITE
LAND MOBILE
LAND MOBILE SATELLITE
MARITIME MOBILE
MARITIME MOBILE SATELLITE
MARITIME RADIONAVIGATION
METEOROLOGICAL
METEOROLOGICAL SATELLITE
MOBILE
MOBILE SATELLITE
RADIO ASTRONOMY
RADIODETERMINATION SATELLITE
RADIOLOCATION
RADIOLOCATION SATELLITE
RADIONAVIGATION
RADIONAVIGATION SATELLITE
SPACE OPERATION
SPACE RESEARCH
STANDARD FREQUENCY AND TIME SIGNAL
STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

GOVERNMENT EXCLUSIVE
GOVERNMENT/NON-GOVERNMENT SHARED
NON-GOVERNMENT EXCLUSIVE

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and NTIA. As such, it does not completely reflect all aspects, i.e. footnotes and recent changes made to the Table of Frequency Allocations. Therefore, for complete information, users should consult the Table to determine the current status of U.S. allocations.

U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

August 2011

For sale by the Superintendent of Documents, U.S. Government Printing Office
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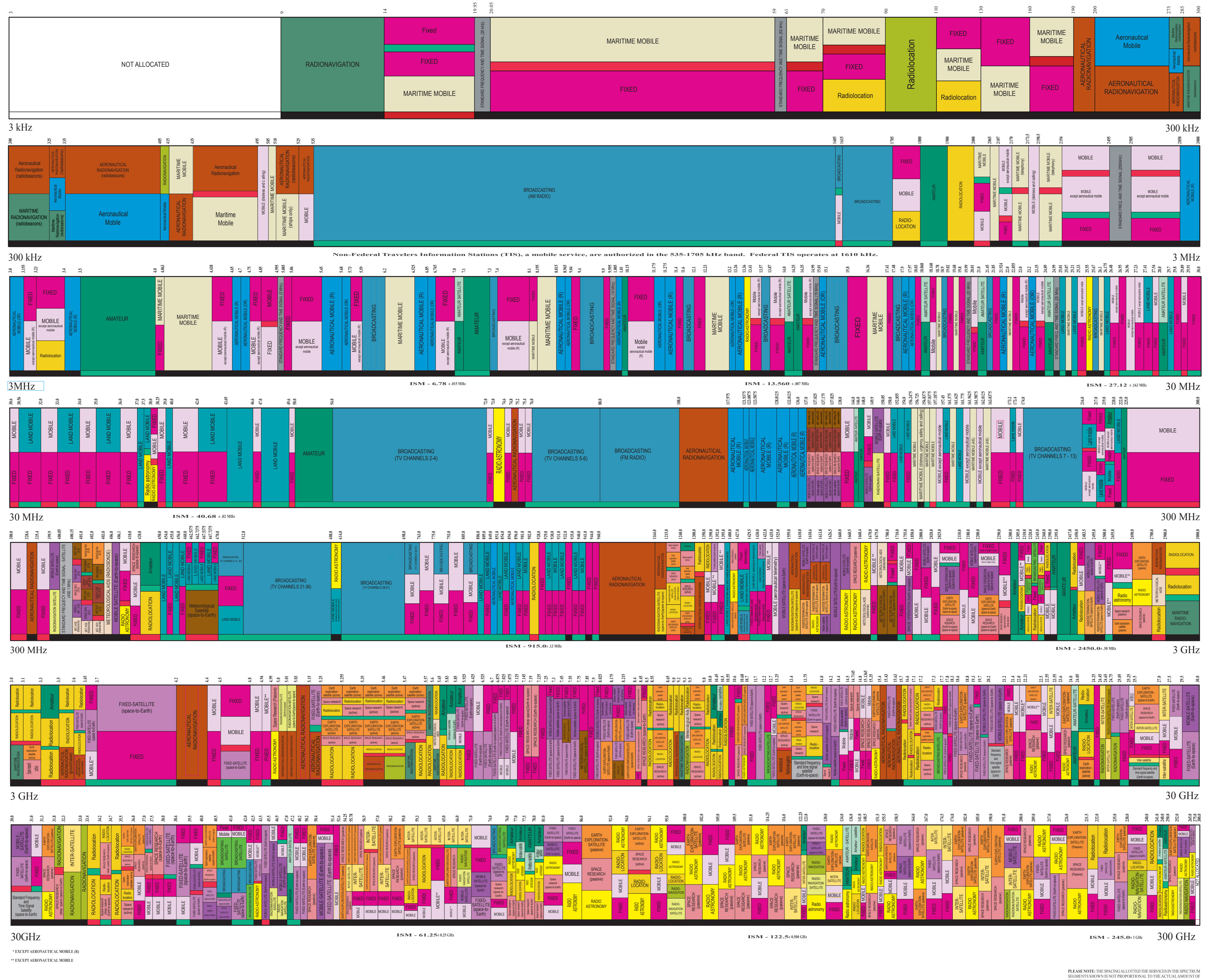

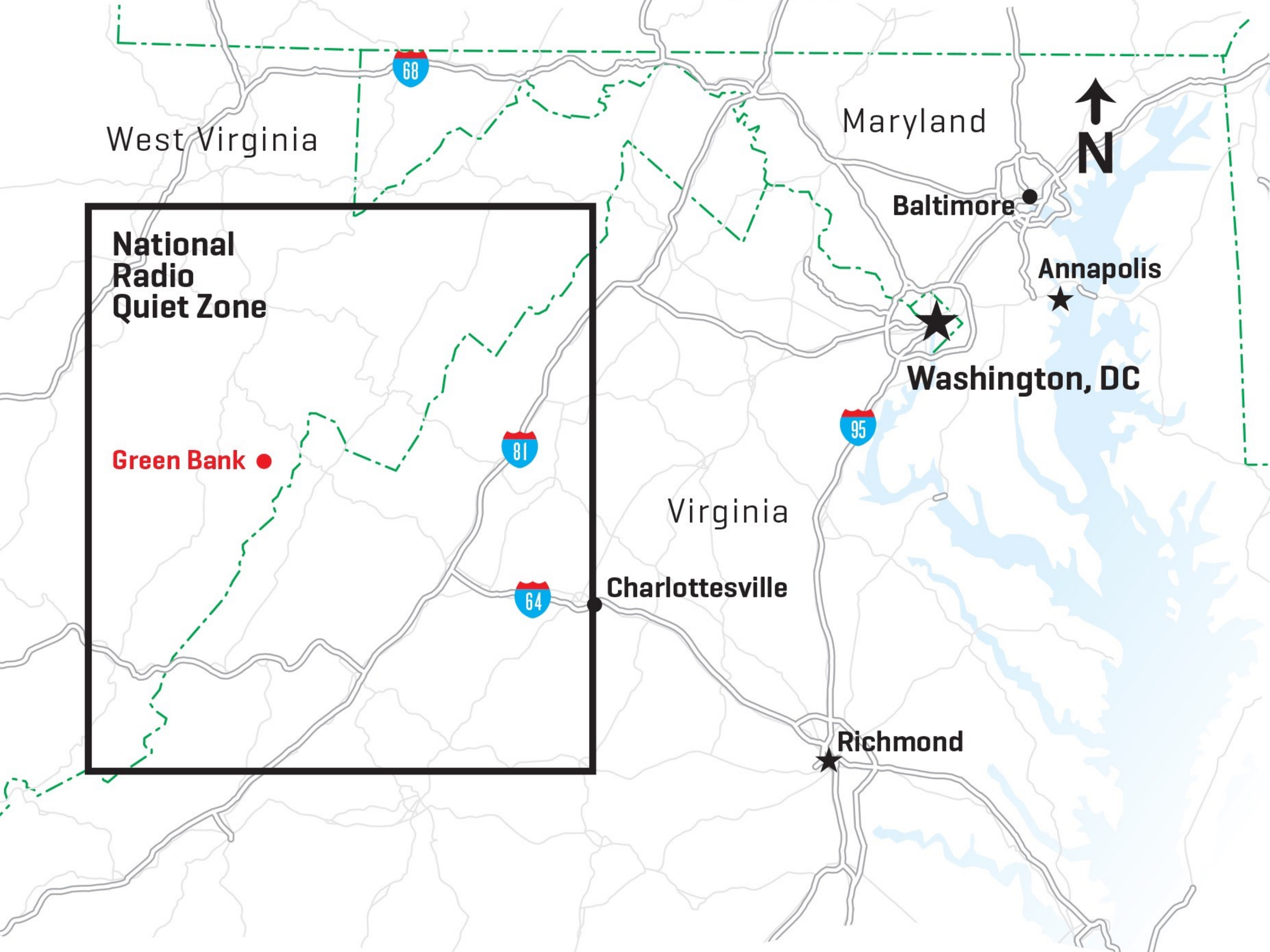
West Virginia
Maryland
Virginia
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National
Radio
Quiet Zone
Green Bank
Baltimore
Annapolis
Washington, DC
Charlottesville
Richmond
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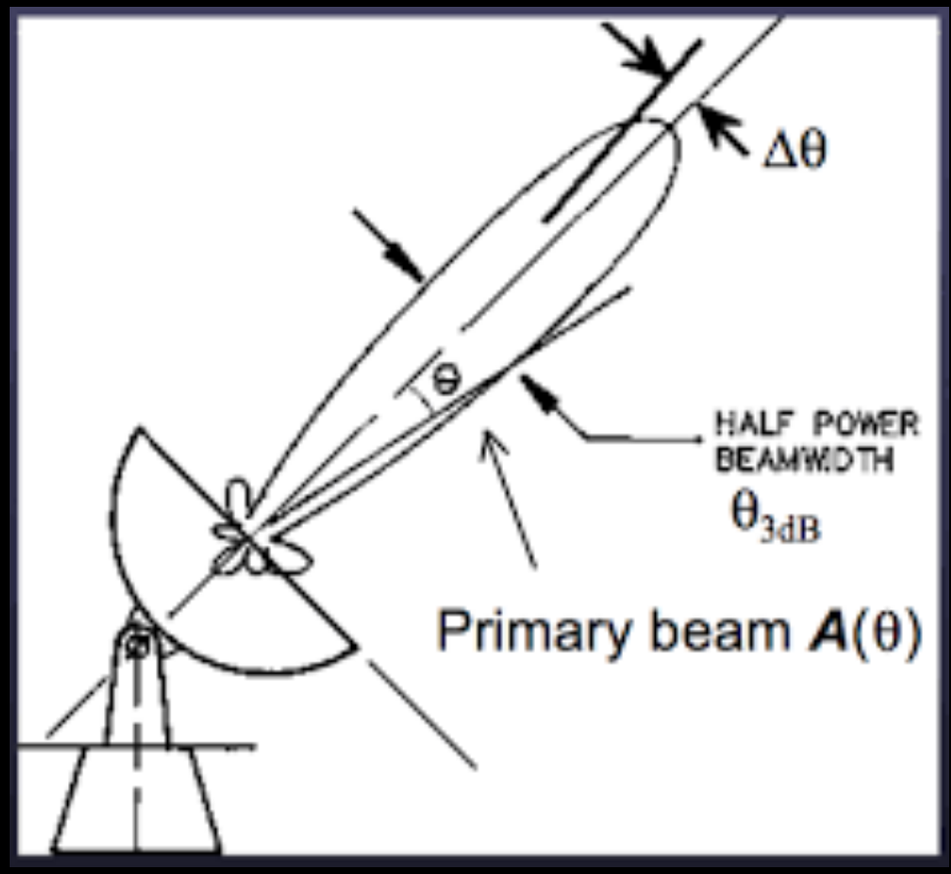
64
95


NETGEAR


9:41
Tuesday, September 12


12:08
Galanz


Δθ
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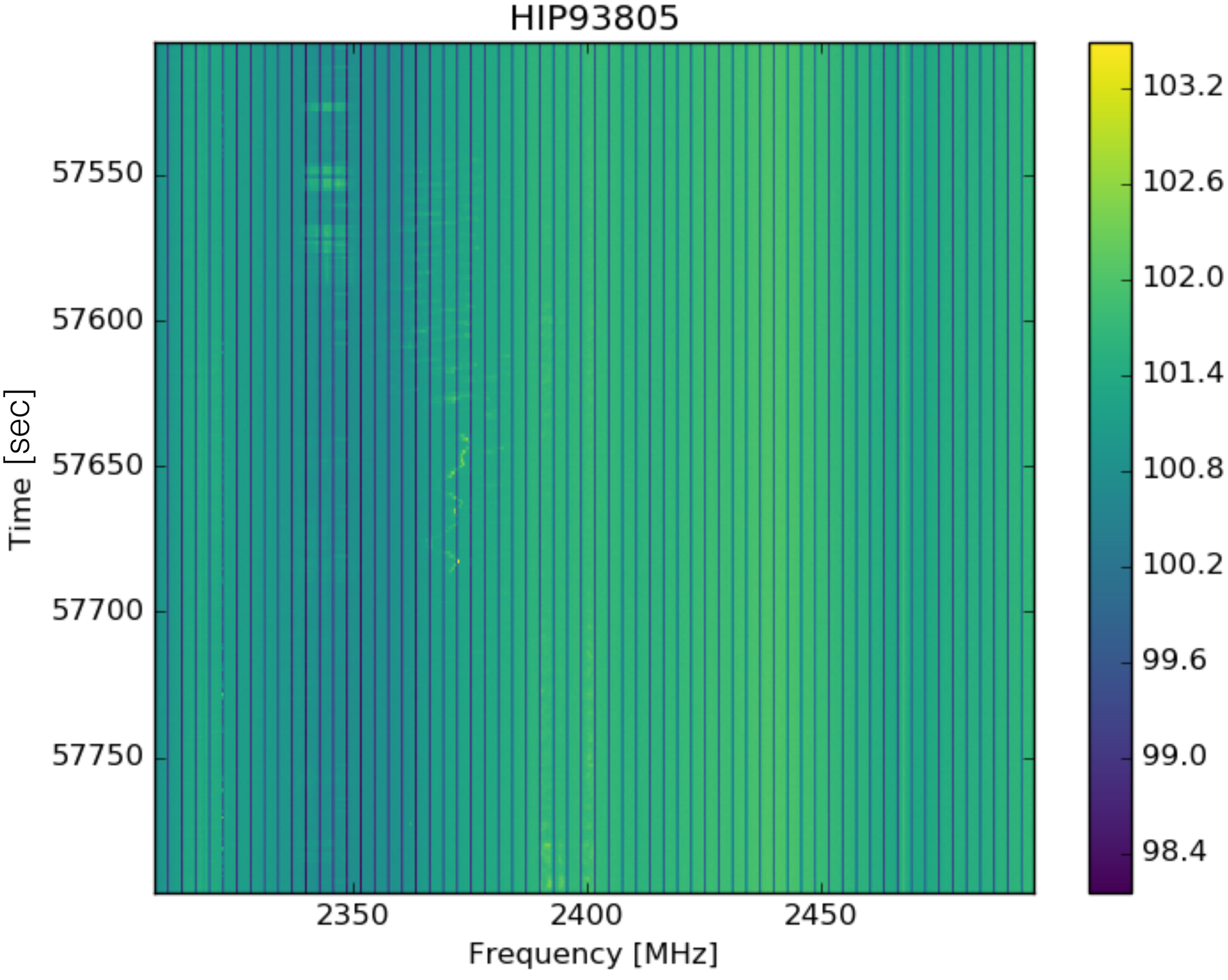
HALF POWER
BEAMWIDTH
θ_{3dB}
Primary beam $A(\theta)$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Frequency [MHz]

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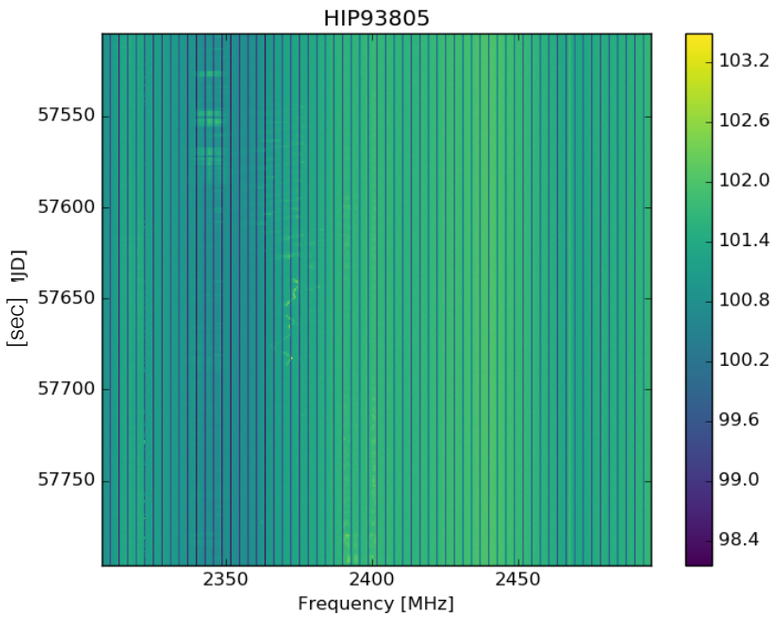
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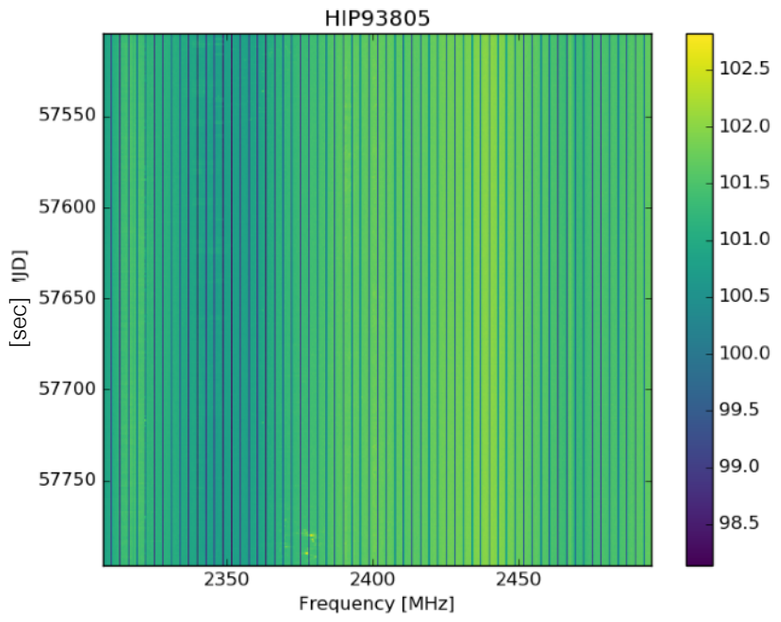
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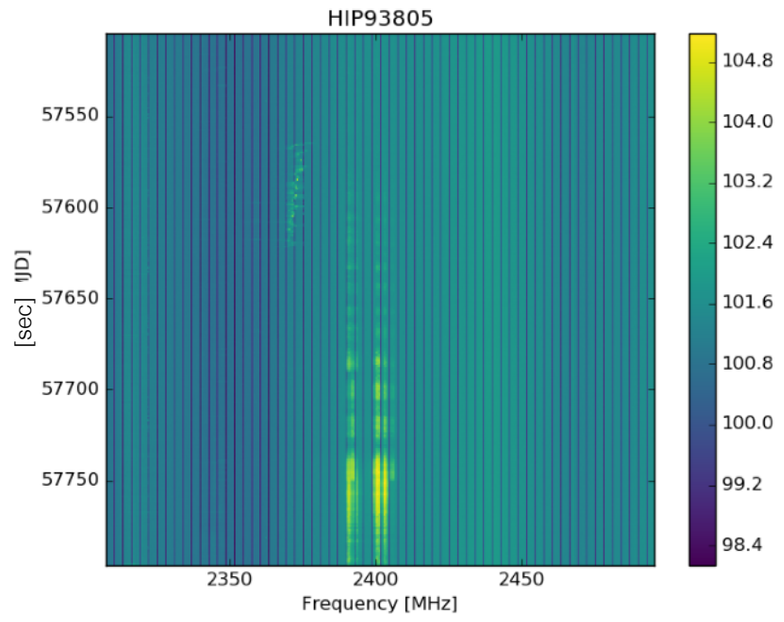
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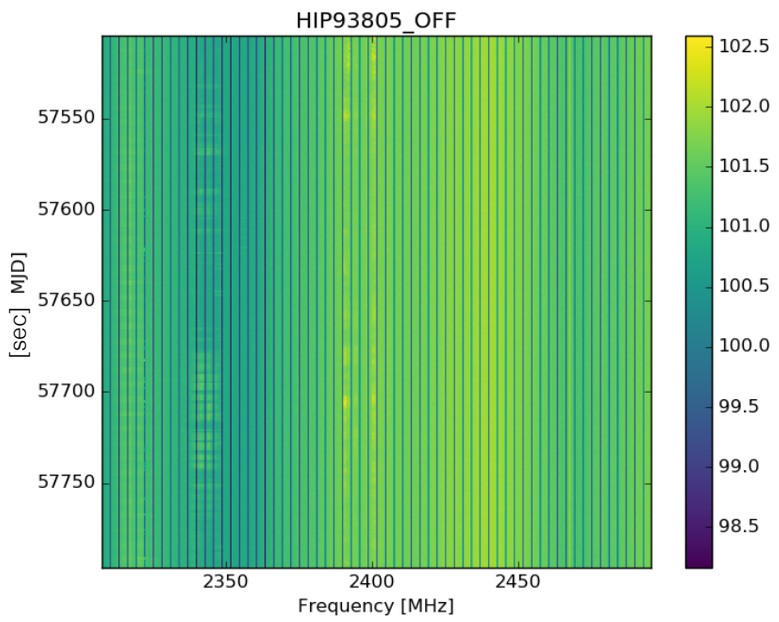
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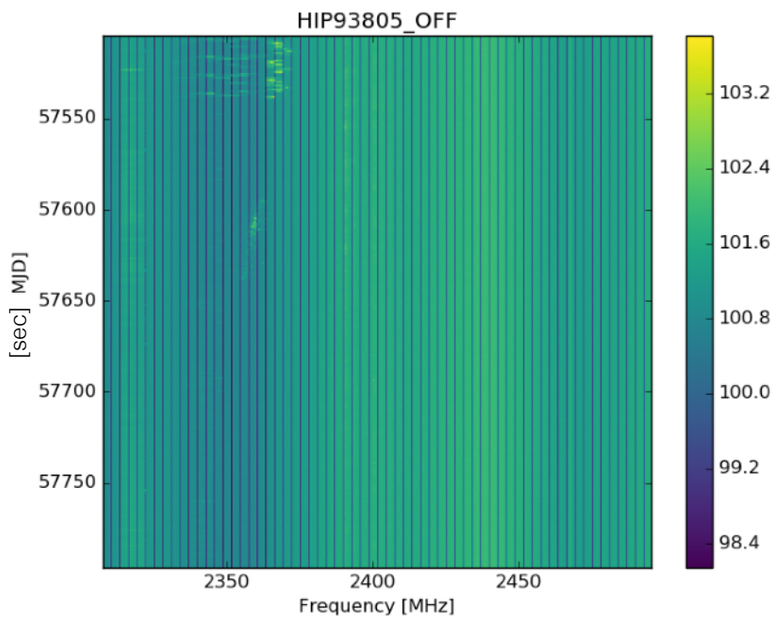
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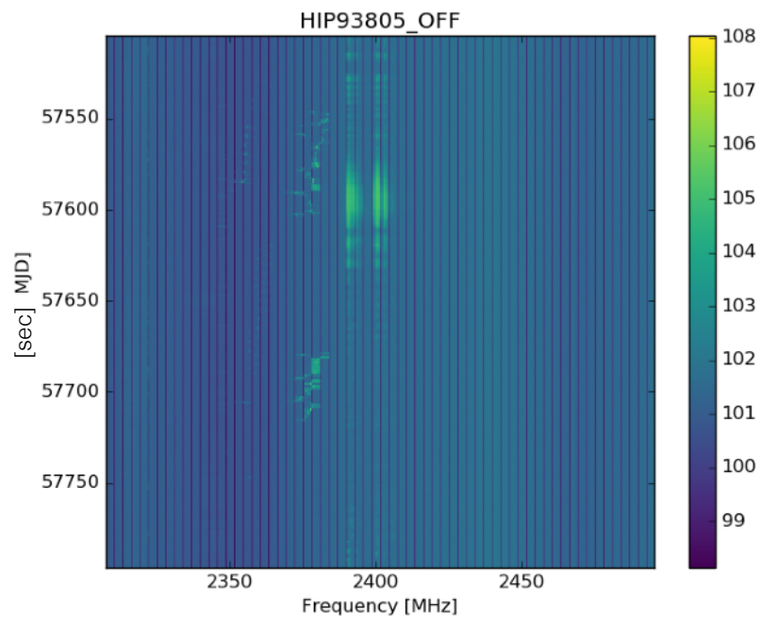
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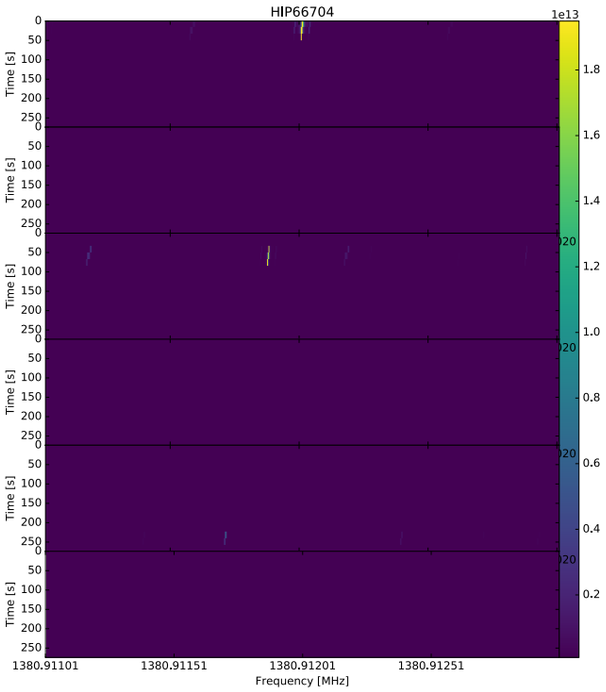
99

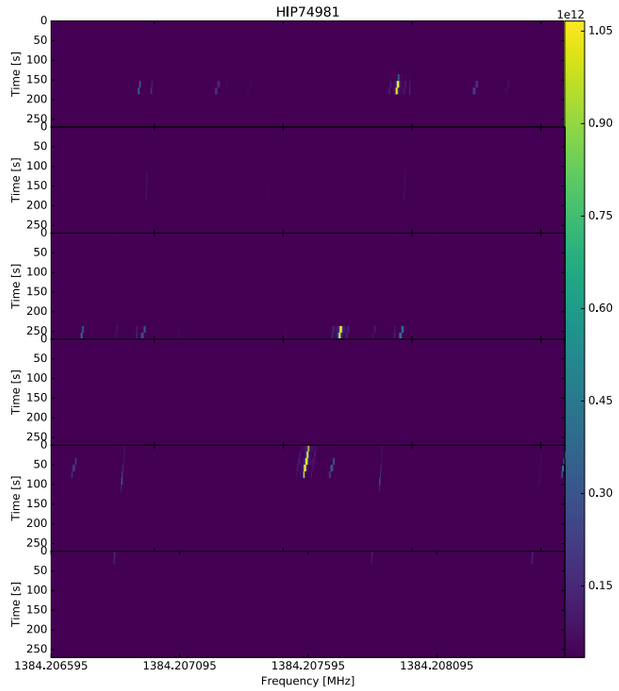
Green Bank Data Products

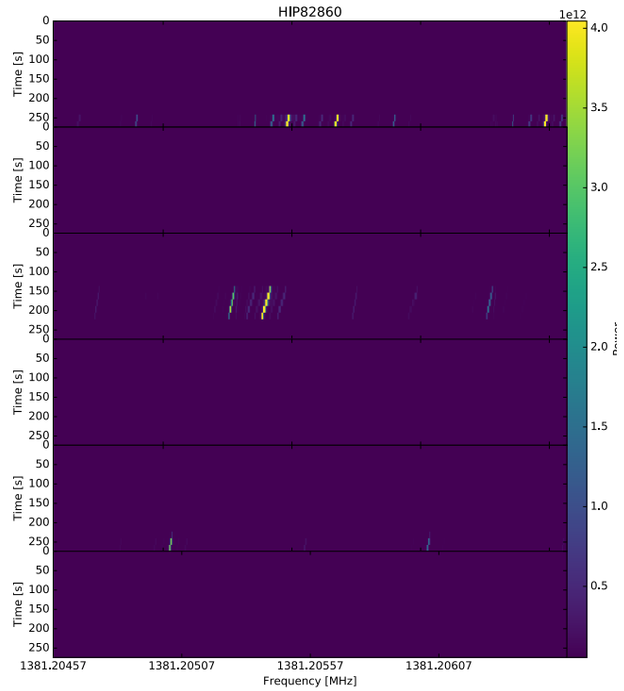
Some GUPPI raw (IQ) data, some hdf5 / filterbank spectrograms publicly available - working on more

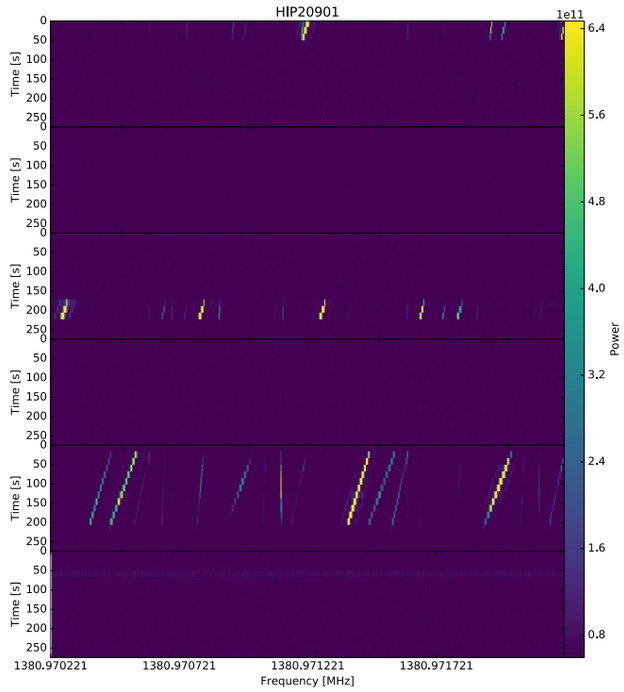
High freq. resolution	~3 Hz frequency bin resolution, ~18 second sample time (SETI)
Medium resolution	~3 kHz frequency bin resolution, ~1 second sample time (spectral line)
High time resolution	~366 kHz frequency bin resolution, ~349 us sample time (pulsar)

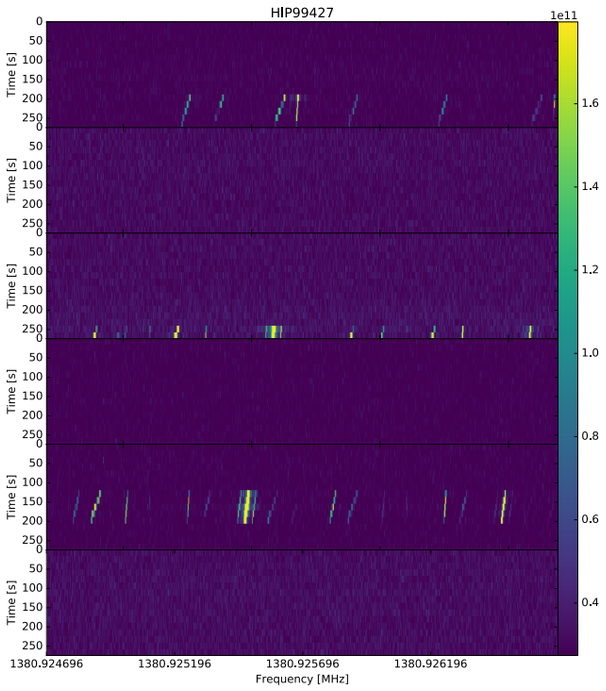
MULTIPLE HIT EVENTS (ENRIQUEZ ET AL. 2017)

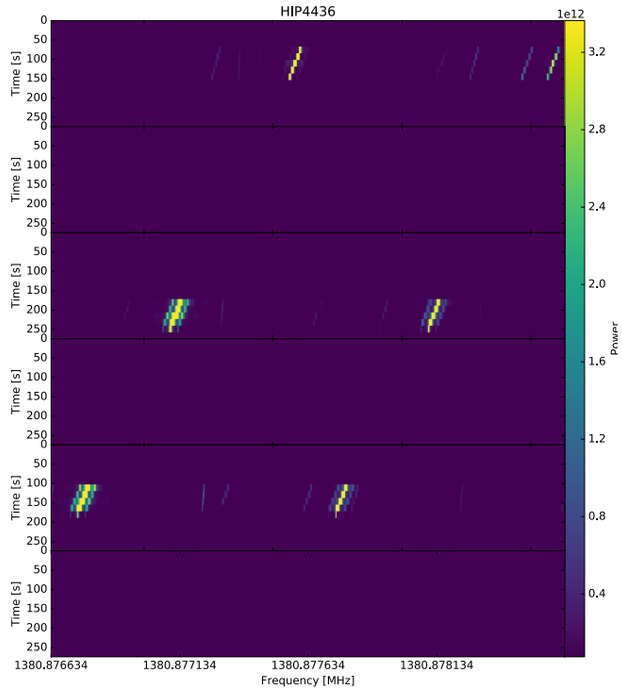


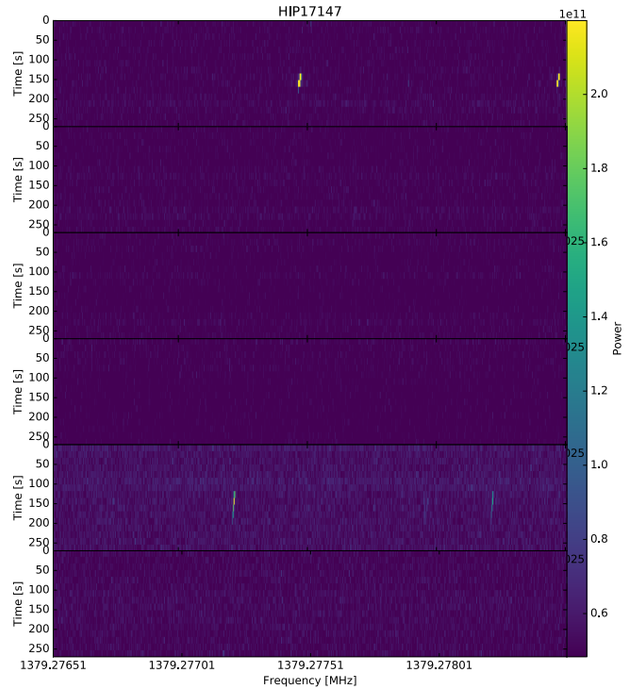


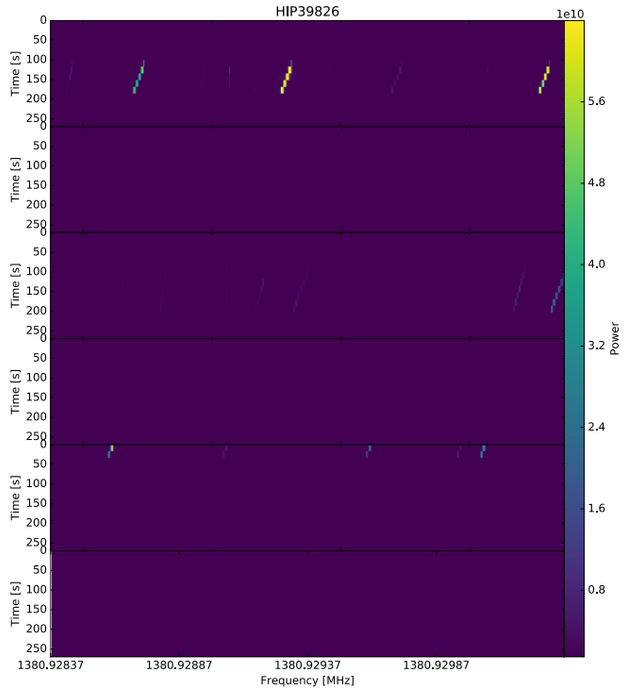












HTTPS://SETI.BERKELEY.EDU/LBAND2017

BERKELEY SETI RESEARCH CENTER

Alien shock as scientists reveal 11 mysterious 'signals' hailing Earth are probed for UFOs

ALIENS could be hailing Earth say scientists hunting for life as 11 signals from space were discovered.

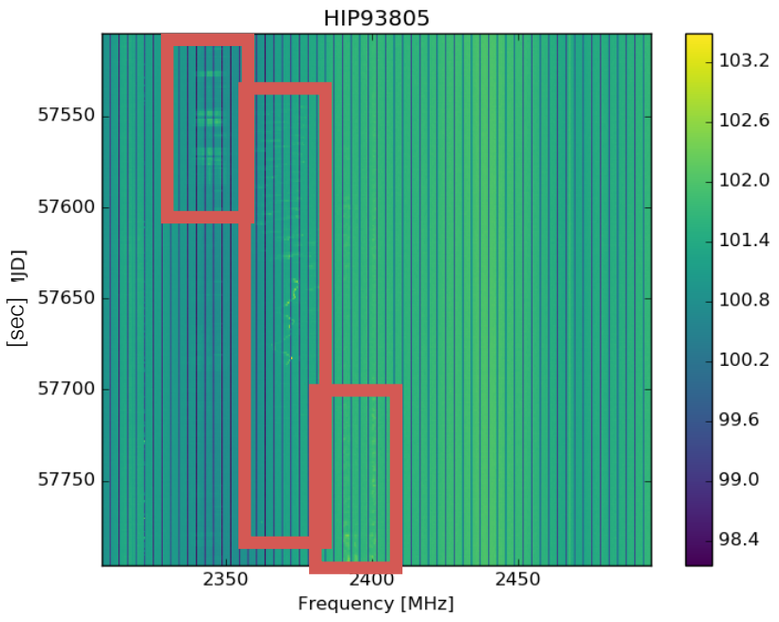
By Henry Holloway / Published 24th April 2017

ALIENS: SETI scientists revealed a string of signals detected by Breakthrough Listen project

The Breakthrough Listen project, an £80 million experiment to try and track down aliens, has revealed they have detected 11 promising signals.

Scientists running the giant listening scheme base dolled out the data to experts for analysis.

Nearly 700 stars have been buzzed by the Green Bank Telescope in West Virginia, US.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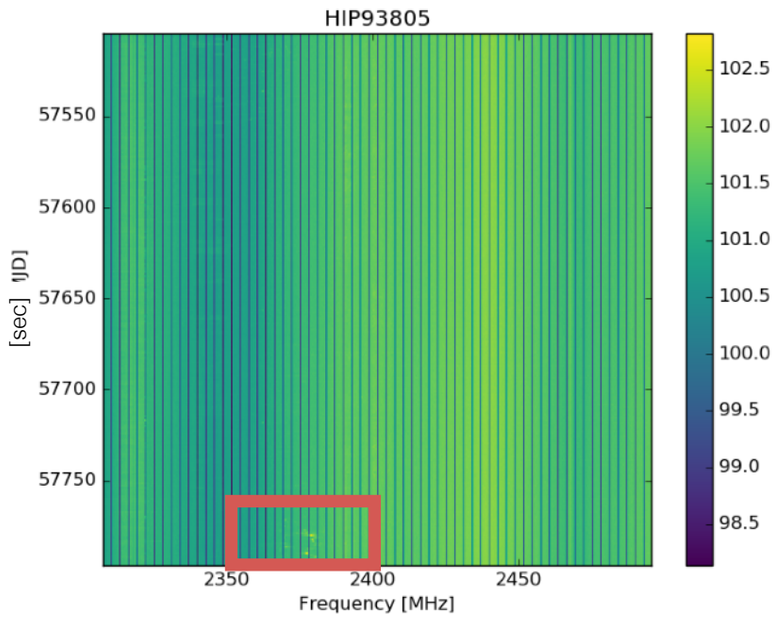
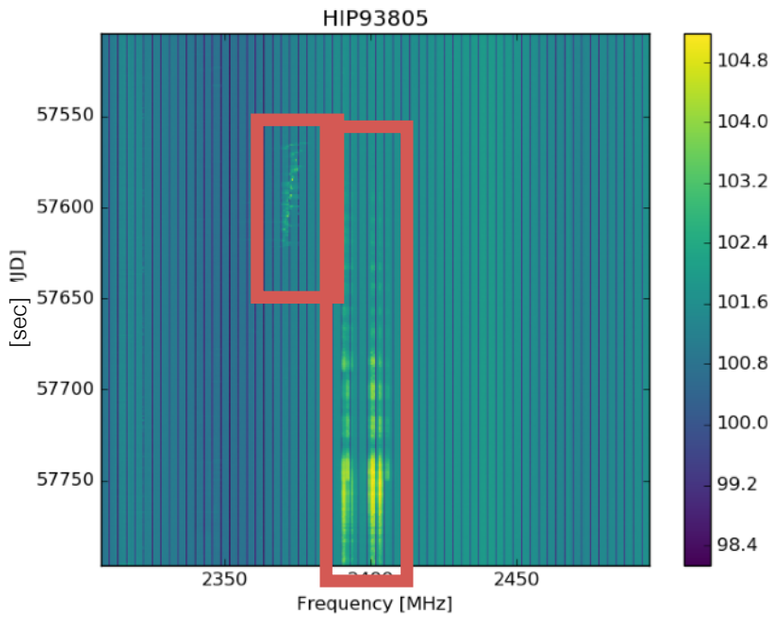
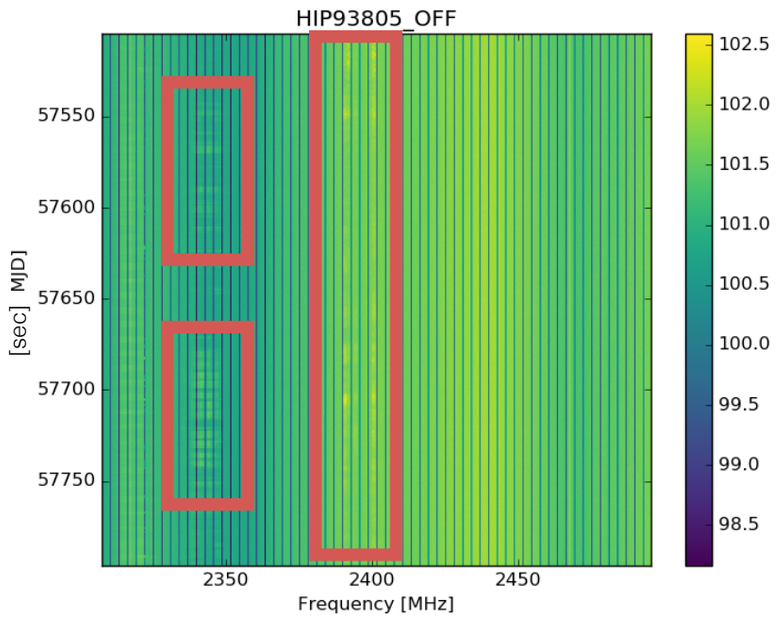
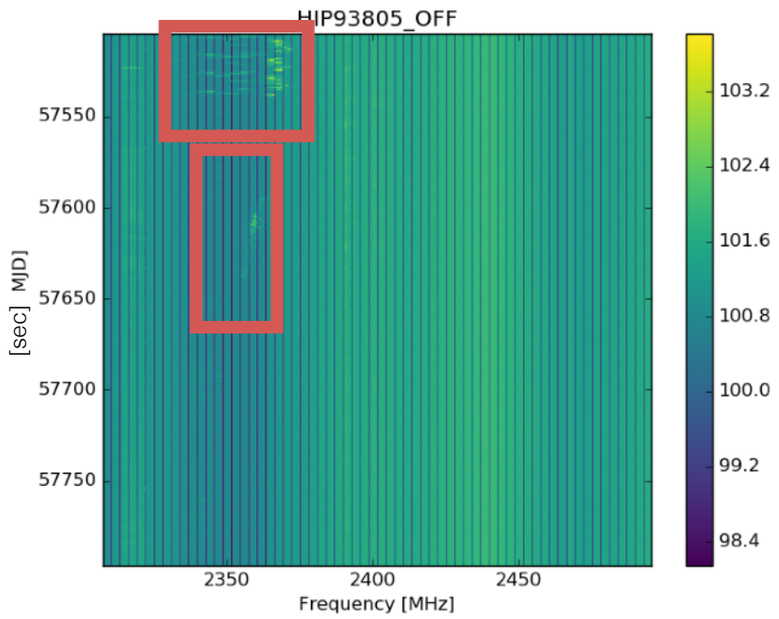
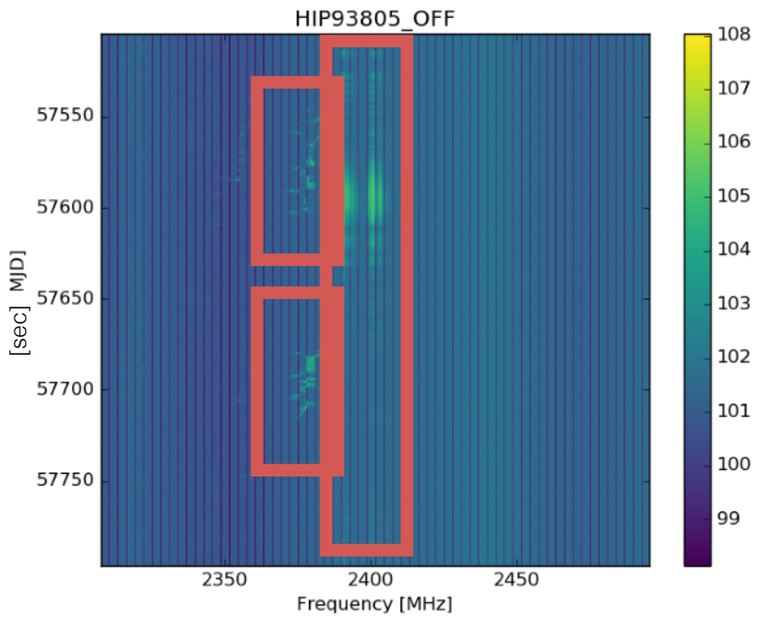
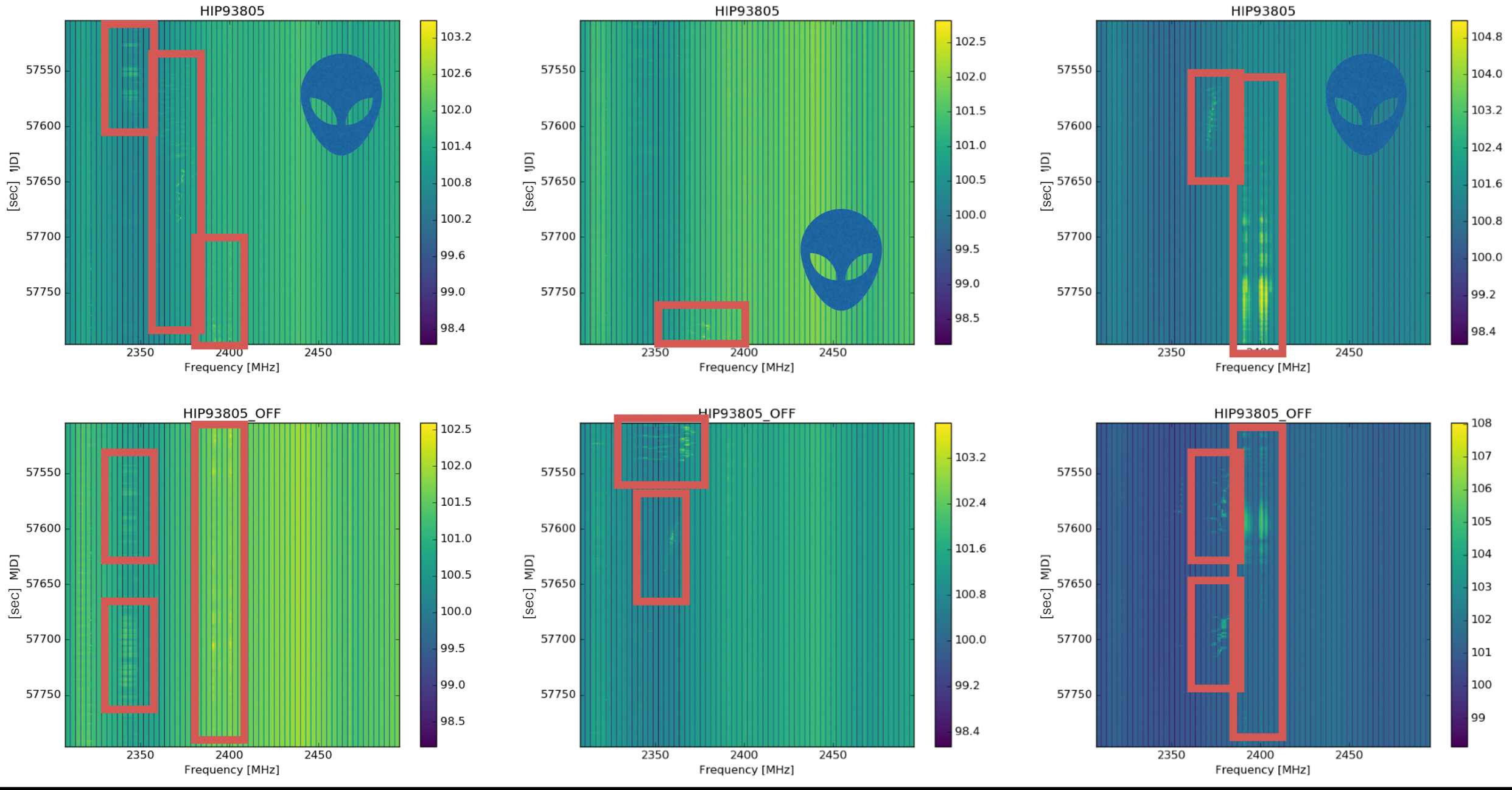

HIP93805
57550
57600
57650
57700
57750
[sec] MJD]
2350
2400
2450
Frequency [MHz]
102.5
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5


HIP93805
57550
57600
57650
57700
57750
[sec] MJD]
2350
2450
Frequency [MHz]
104.8
104.0
103.2
102.4
101.6
100.8
100.0
99.2
98.4


HIP93805_OFF
57550
57600
57650
57700
57750
[sec] MJD]
2350
2400
2450
Frequency [MHz]
102.5
102.0
101.5
101.0
100.5
100.0
99.5
99.0
98.5


HIP93805_OFF
57550
57600
57650
57700
57750
[sec] MJD]
2350
2400
2450
Frequency [MHz]
103.2
102.4
101.6
100.8
100.0
99.2
98.4


HIP93805_OFF
57550
57600
57650
57700
57750
[sec] MJD]
2350
2400
2450
Frequency [MHz]
108
107
106
105
104
103
102
101
100
99



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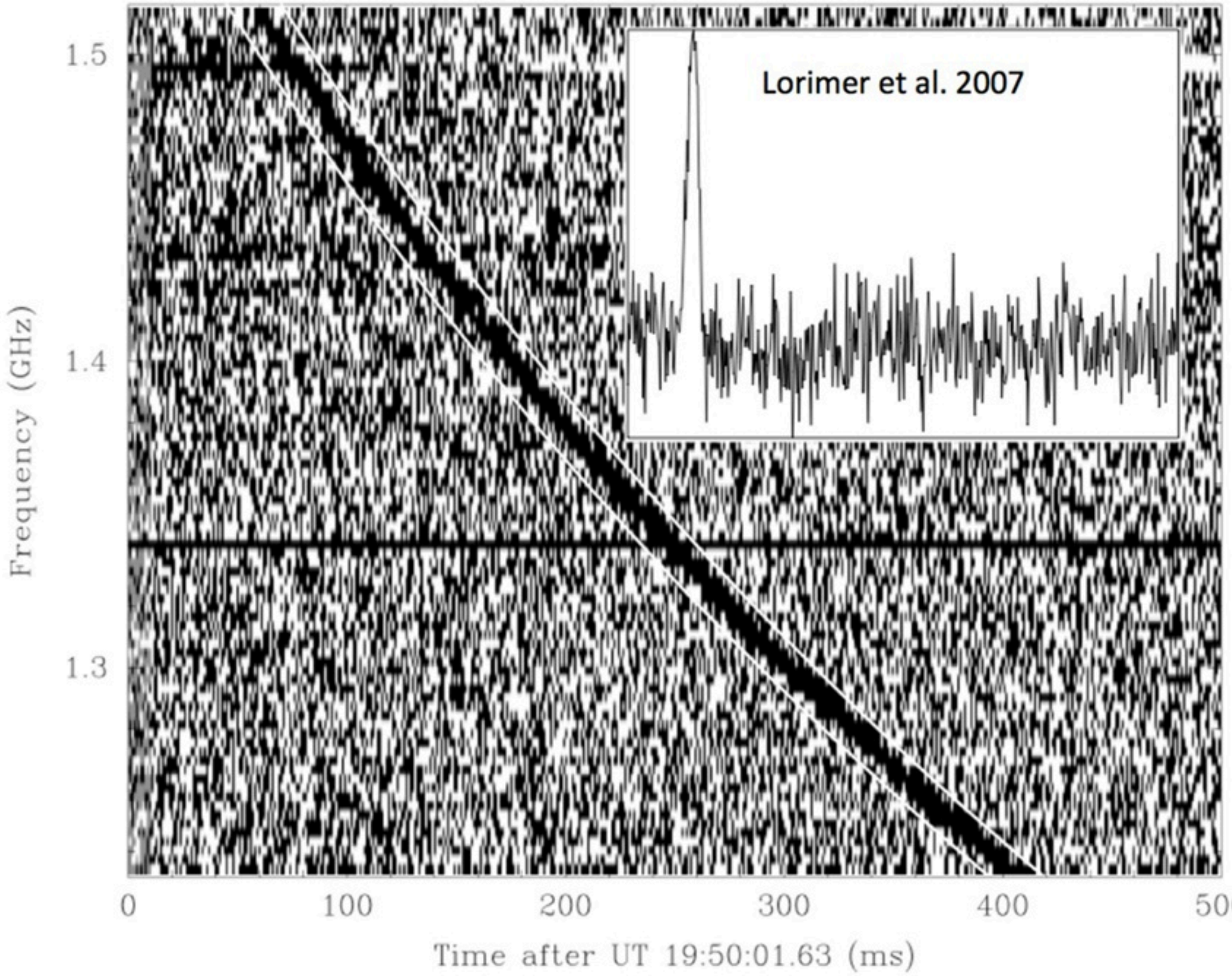
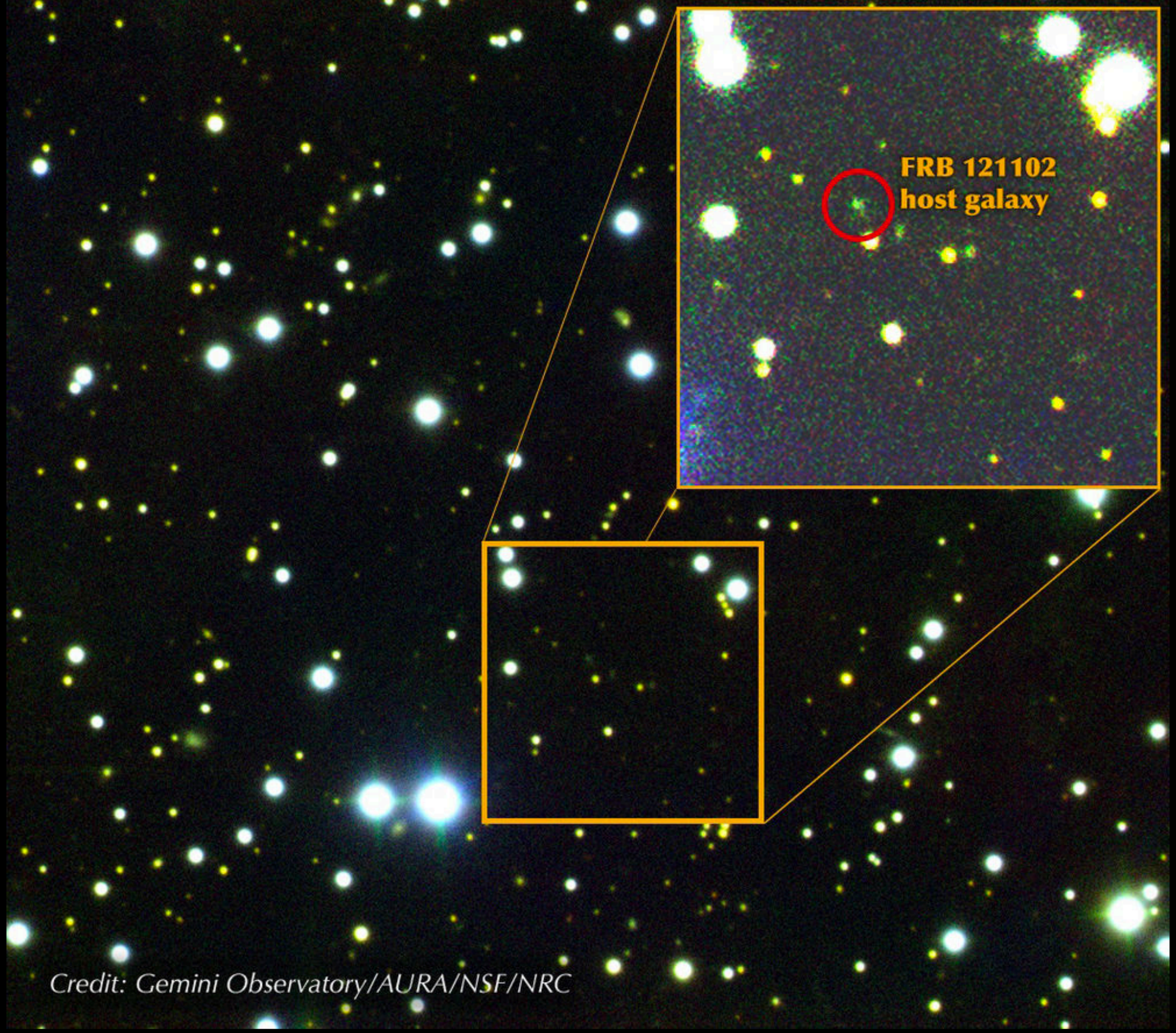
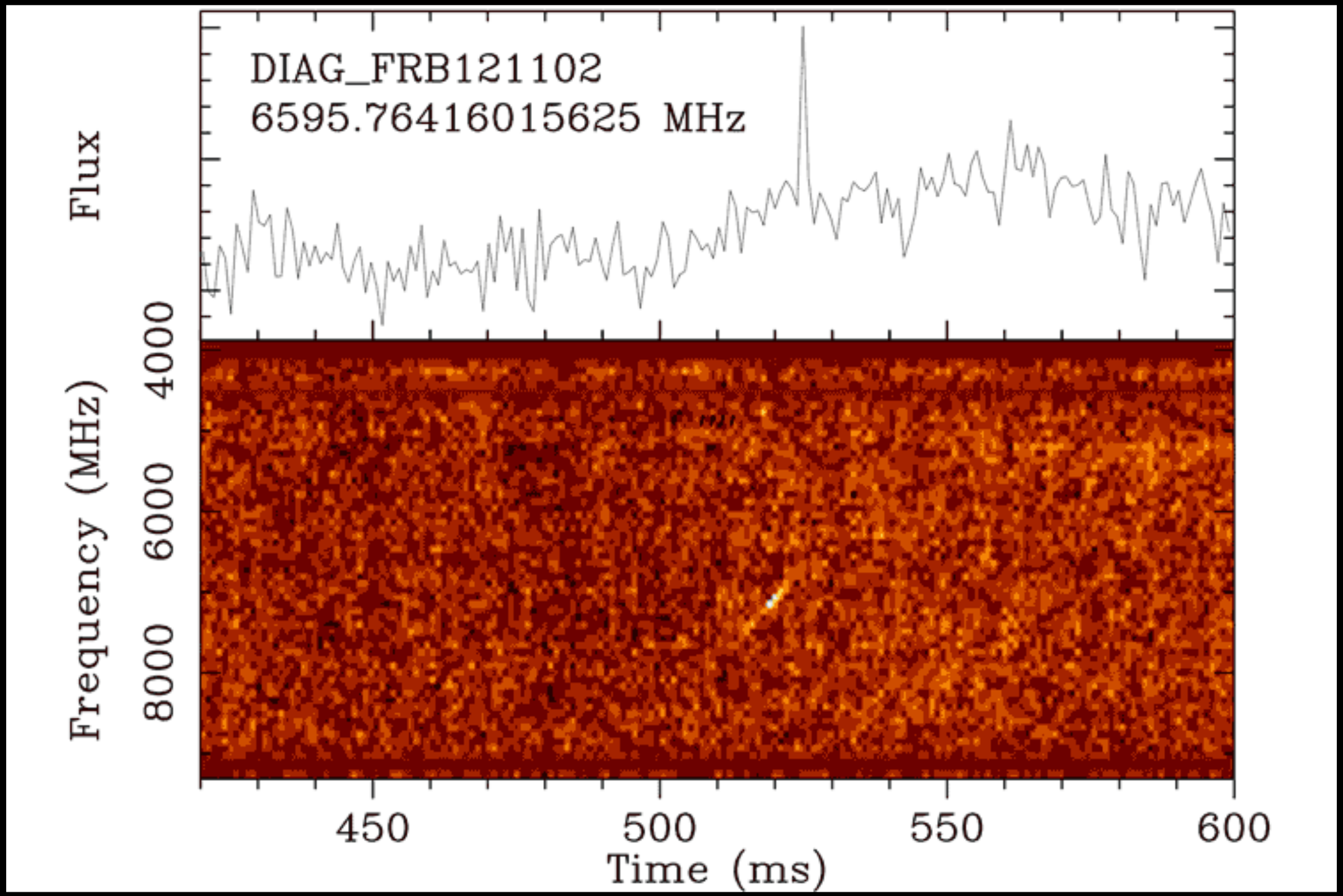

Lorimer et al. 2007
1.5
1.4
1.3
Frequency (GHz)
0
100
200
300
400
500
Time after UT 19:50:01.63 (ms)


FRB 121102
host galaxy
Credit: Gemini Observatory/AURA/NSF/NRC

HEIMDALL (GPU-ACCELERATED TREE DEDISPERSION)

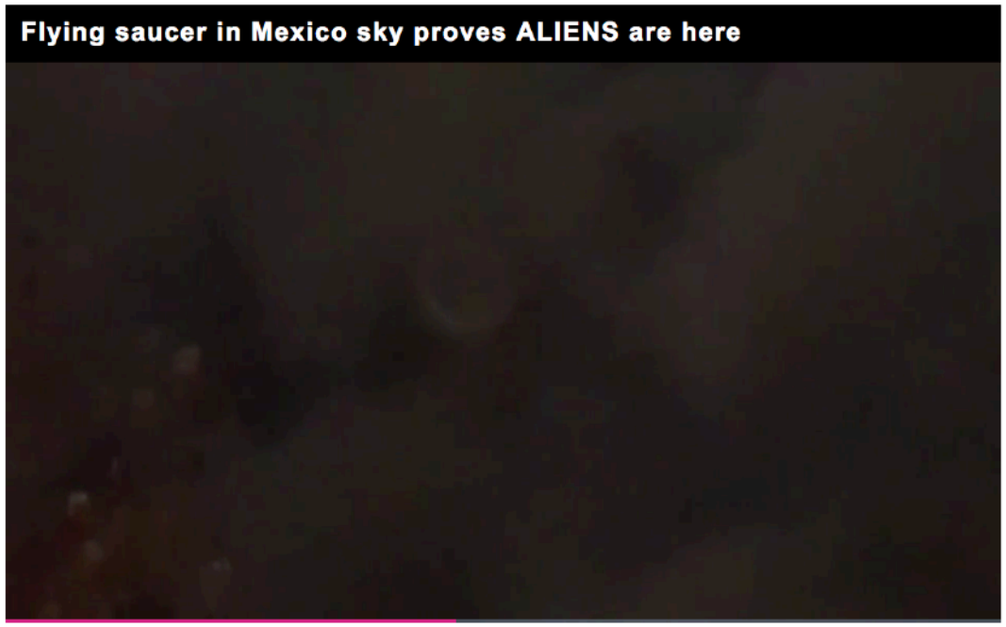
ARXIV.ORG/ABS/1804.04101



Scientists say 'MONSTROUS' energy bursts from space may be from ALIENS

MYSTERIOUS radio bursts may be being beamed to Earth by aliens, according to experts.

By Anders Anglesey / Published 11th January 2018



Boffins at Breakthrough Listen, a scientific research centre dedicated to finding intelligent life in the universe, confirmed it picked up the strange signals this week.

Radio bursts are not rare, but the FRB 121102 frequency is the only one that has been known to repeat itself.

The stunning details were revealed at this week's meeting of the American Astronomical Society in Washington DC.

Researchers said the burst releases a "monstrous" amount of energy each millisecond.

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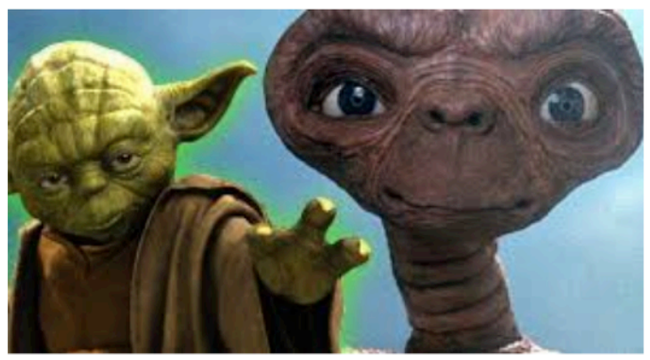
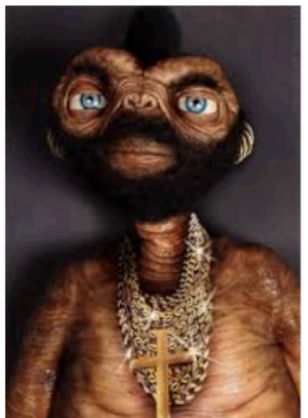
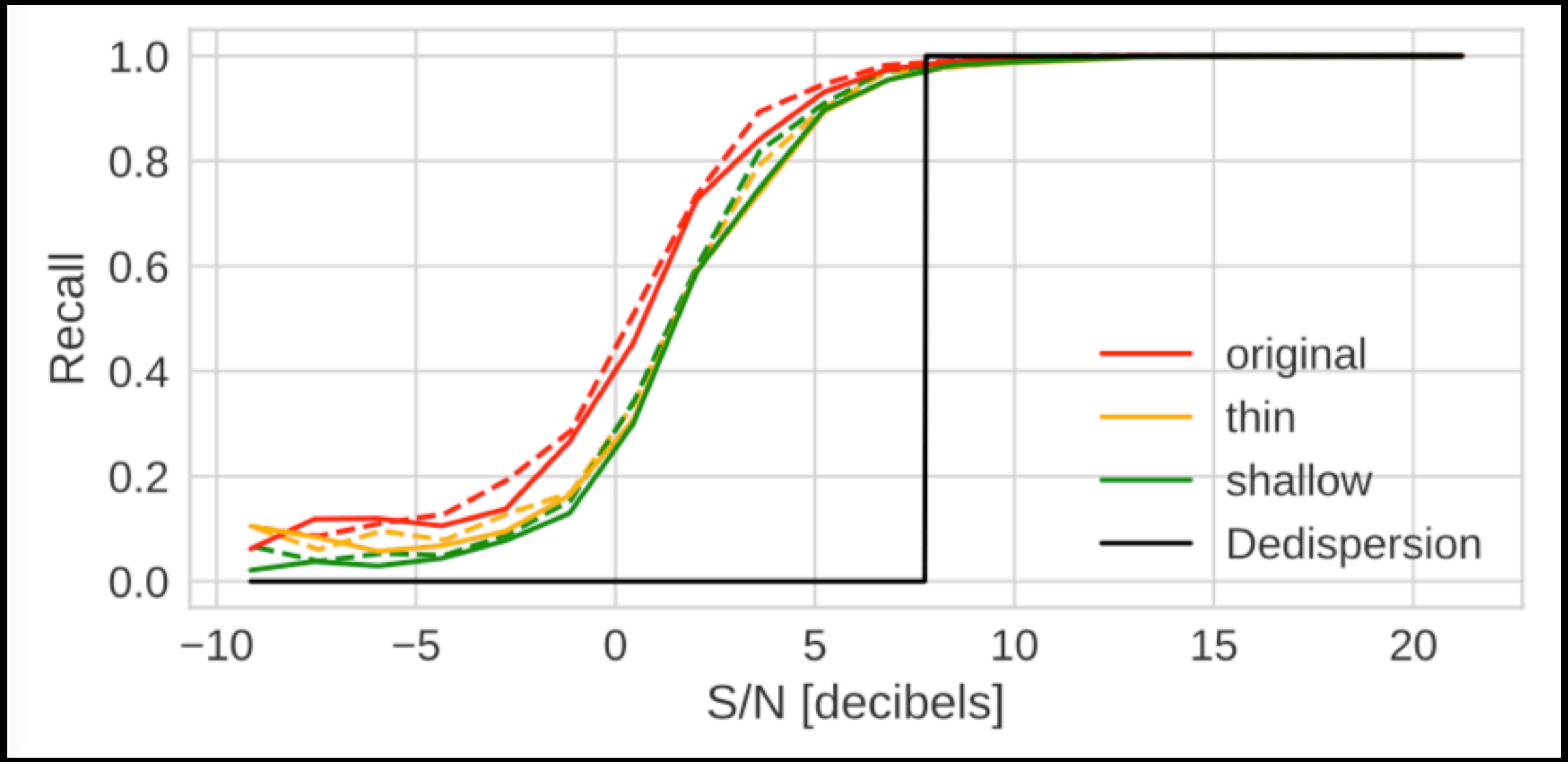




BL ML with CNNs (Gerry Zhang)

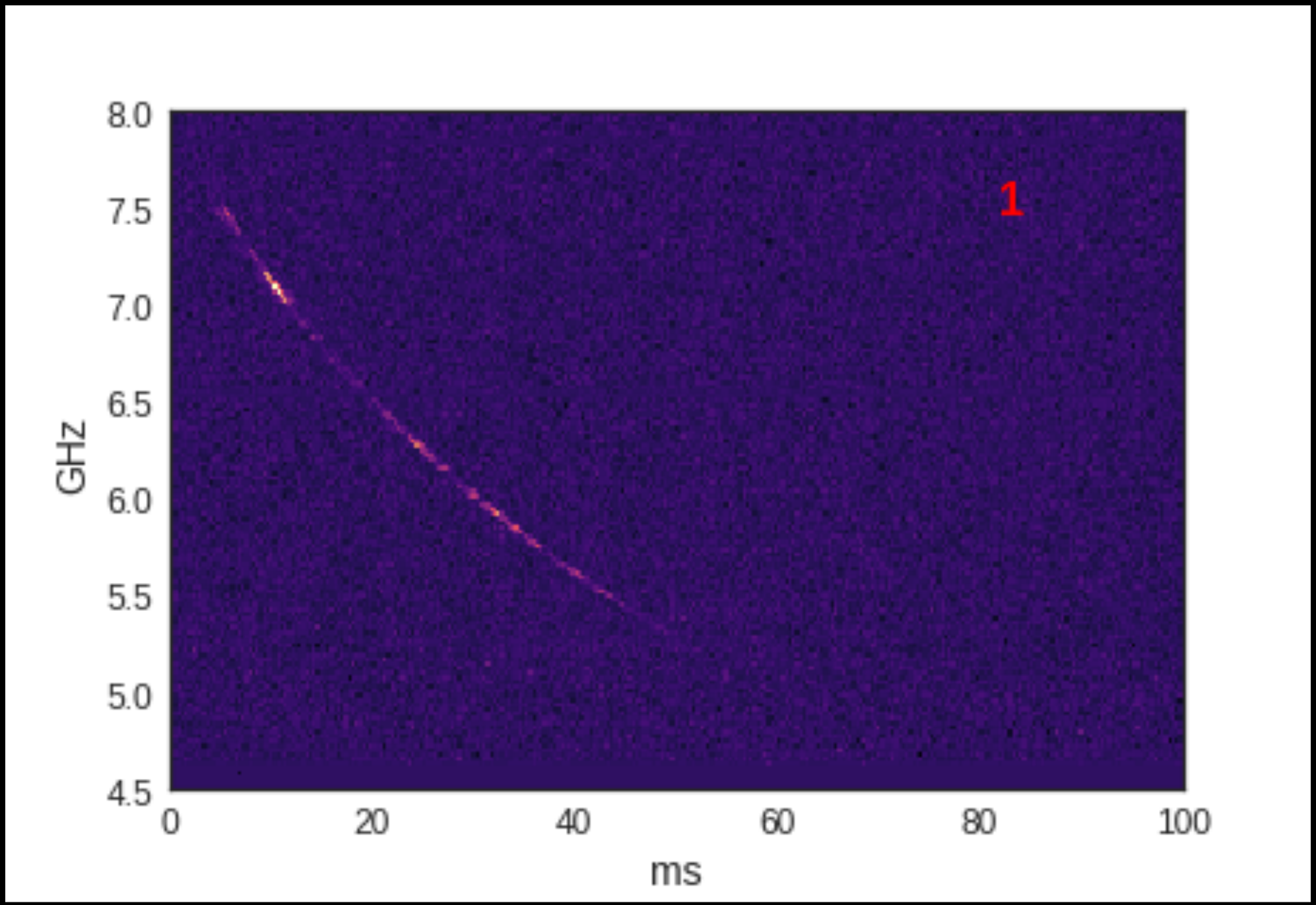
arxiv.org/abs/1809.03043



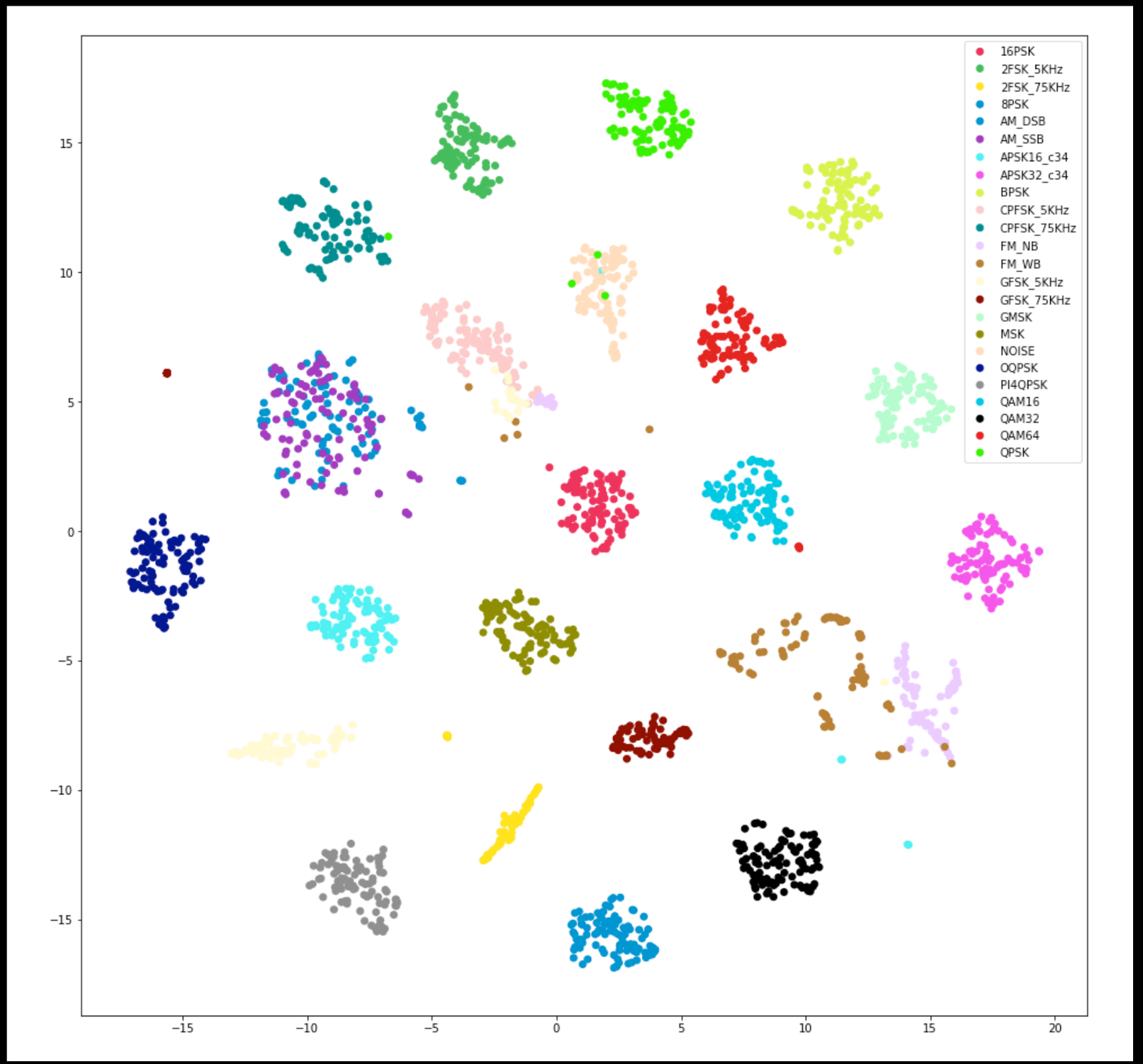
BL ML with CNNs (Gerry Zhang)

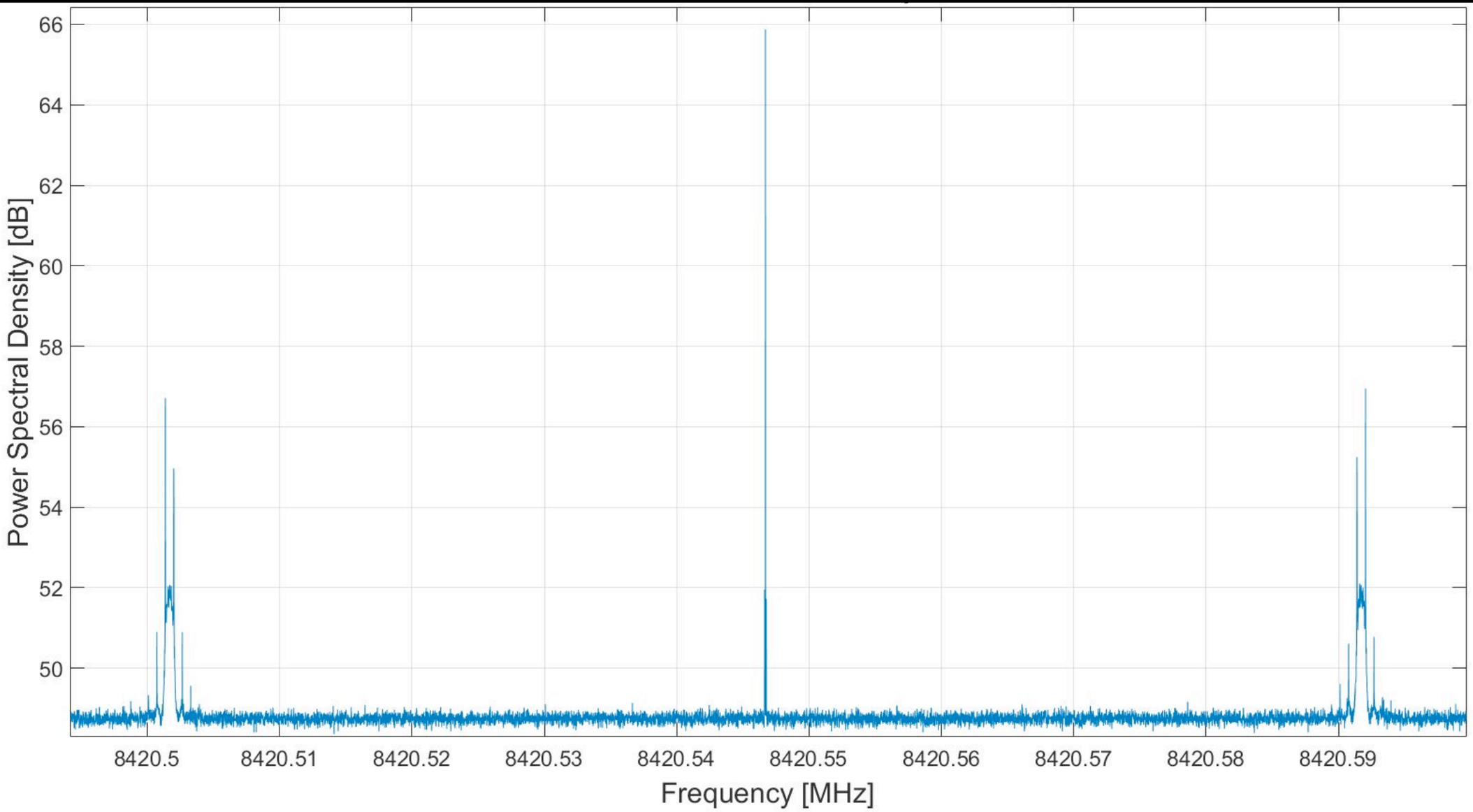
arxiv.org/abs/1809.03043

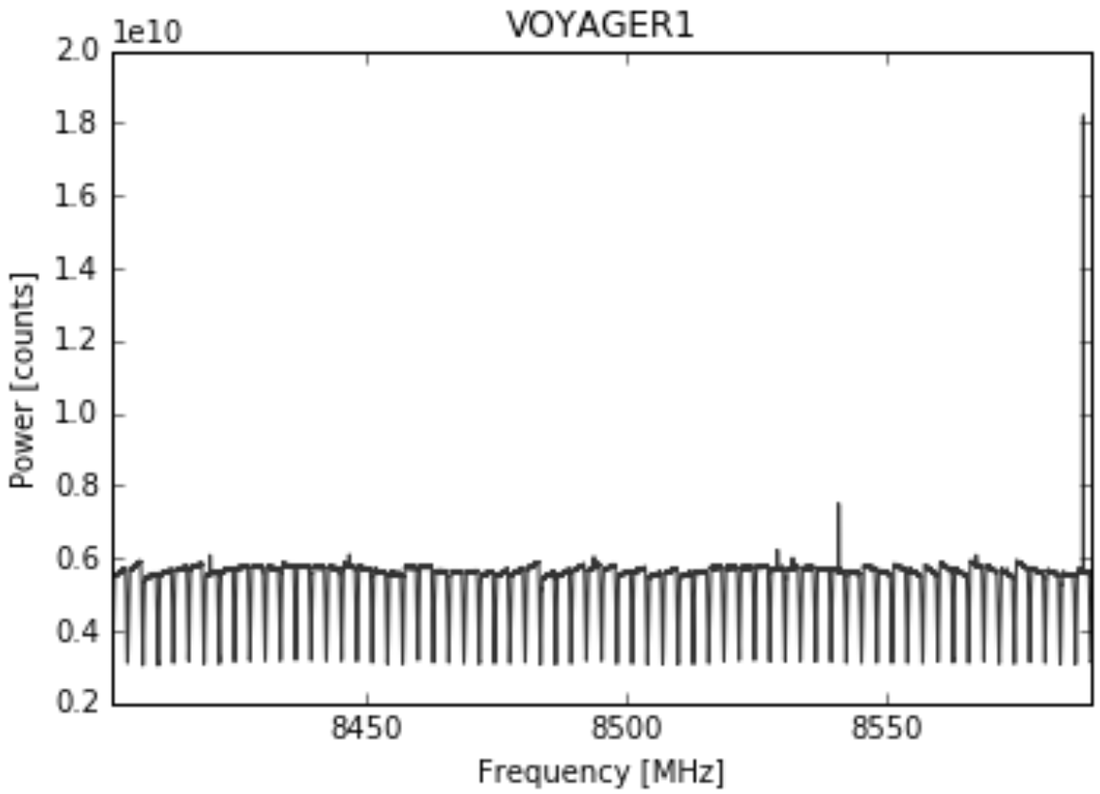
seti.berkeley.edu/frb-machine

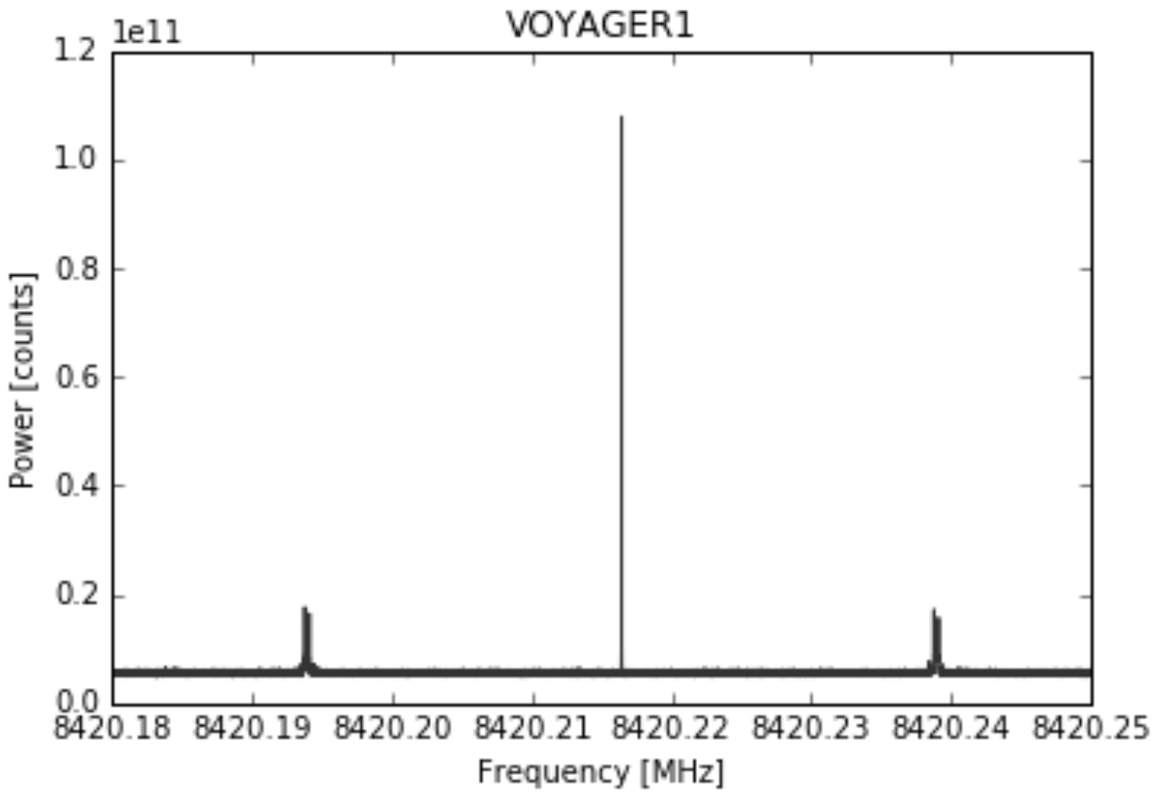


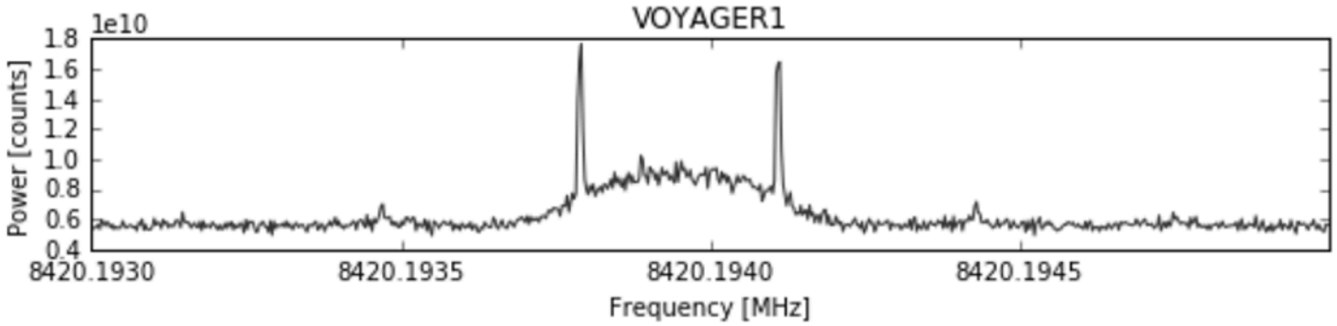
TSNE for modulation classification (Gerry Zhang and Morad Shefa)

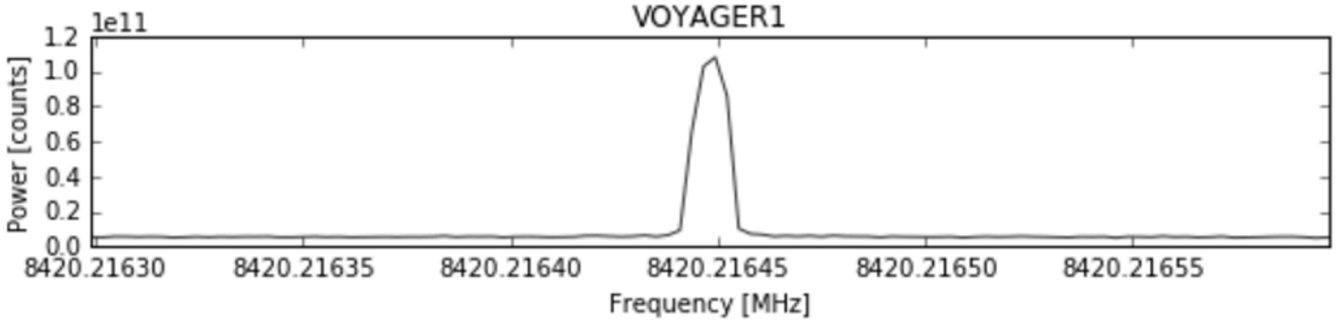


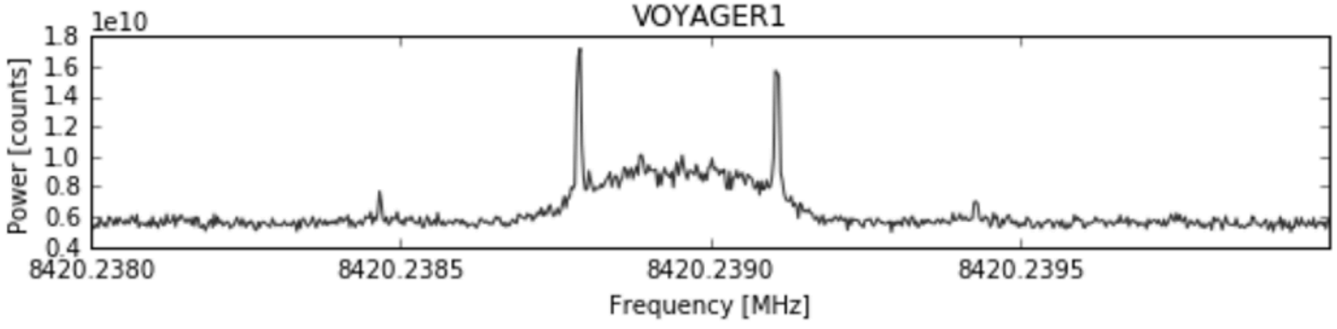

Power Spectral Density [dB]
66
64
62
60
58
56
54
52
50
8420.5
8420.51
8420.52
8420.53
8420.54
8420.55
8420.56
8420.57
8420.58
8420.59
Frequency [MHz]











http://bit.do/BL_voyager

Breakthrough Listen: Voyager 1 Observations

Voyager 1 is the most distant man-made object from Earth. Launched by NASA in 1977, it has travelled at fantastic speed (roughly 17,000 m/s), past the outer boundaries of our Solar System and into interstellar space (>12.5 billion miles from the Sun).

Remarkably, 38 years on, Voyager 1 is still sending telemetry data from the depths of interstellar space. This makes it a great systems test for the Breakthrough Listen signal processing pipeline.

In this tutorial, we load, read, and plot some Breakthrough Listen (BL) observations of Voyager 1. The data were taken using the Robert C. Byrd Greenbank Telescope in West Virginia.

About this tutorial

This tutorial introduces you to BL filterbank data. It is intended for intermediate to advanced users, who have experience with Python, Numpy and basic astronomy. You'll need to have Jupyter installed, along with a scientific Python installation (numpy, scipy, matplotlib, and astropy).

About the data

We used the Greenbank X-band receiver (8.0-11.6 GHz) on December 30, 2015, to observe the known position of Voyager 1. The BL digital signal processing system saves digitized data in a 'raw' format, which we have converted into 'filterbank' format using our `gpuspec` code (see guppi2spectra.c in https://github.com/UCBerkeleySETI/gbt_seti/tree/master/src). For *advanced users* who want to start from scratch, the specific command is:

```
time /gbt_seti/bin/gpuspec -i ./blc3_2bit_guppi_57386_VOYAGER1_0004.0000.raw \
    -B 2 -f 1032192 -t 15 -V -o /datax2/scratch/dprice/
```

For the purposes of this tutorial, we suggest that you download the 504 MB file `voyager_f1032192_t300_v2.fil` from the BL data archive.

Filterbank format

The voyager data is stored in *filterbank format*, a simple binary file format that is detailed in the SIGPROC user guide. For this tutorial, we've provided a simple Python class to load and interpret the filterbank file into a numpy array.

Let's get started!

Firstly, let's setup the notebook and import the `Filterbank()` class to read the data.

In [1]:
```
%matplotlib inline
```

In [3]:
```
import pylab as plt
from filterbank import Filterbank
```

Now, let's read the observation data using `Filterbank()`:

`Oumuamua

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Breakthrough Listen Observations of 1I/'Oumuamua with the GBT

J. Emilio Enriquez,[1,2] Andrew Siemion,[1,2,3] T. Joseph W. Lazio,[4] Matt Lebofsky,[1] David H. E. MacMahon,[1] Ryan S. Park,[4] Steve Croft,[1] David DeBoer,[1] Nectaria Gizani,[1,5] Vishal Gajjar,[6] Greg Hellbourg,[1] Howard Isaacson,[1] and Danny C. Price[1,7]

We conducted a search of the data for narrow-band (3Hz resolution) drifting sinusoids as described by Enriquez et al. (2017), over a drift rate range of ±2 Hz/s. This range includes any acceleration in the geocentric and barycentric frames, as well as accommodating a transmitter located anywhere on the body itself. Our preliminary results show no narrow band radio emission from the direction of 1I/'Oumuamua at any rotational phase.

The object was at ∼ 2 AU when observed, and given an approximate SEFD of 20 Jy, with a 300 s observation, and a 5σ threshold, these observations were sensitive to a hypothetical transmitter with an EIRP of ∼ 0.08 W (∼3,000 times weaker than the Dawn spacecraft communication down-link.).

Based on the possibility that 1I/'Oumuamua could be in fact a dormant comet with delayed outgassing, we also searched for any indication of hydroxyl emission at the four transitions between 1612 MHz and 1720 MHz. We searched the L-band data taken during quadrant Q2 by stacking the three 5-min observations. No emission was detected, confirming previous observations during closer approach that the nature of the object is consistent with an asteroid-like composition (Park 2017 in prep).

No transmitters brighter than 0.1 W between 1 - 12 GHz

Mystery 'cigar' asteroid in our solar system probed for 'ALIEN technology' THIS WEEK

ALIEN-hunting scientists are set to examine a "peculiar" 1,300ft-long asteroid hurtling through our solar system for signs of extraterrestrial technology this week.

By Joshua Nevett / Published 11th December 2017

SPACRE PROBE: Scientists are set to examine the Oumuamua asteroid this week

The mysterious cigar-shaped object, dubbed "Oumuamua" by astronomers, soared past Earth last month after entering our solar system.

Astronomers spotted the strange object – the size of New York's Empire State Building – through the Pan-STARR telescope in Hawaii on October 19.

As Oumuamua, the first interstellar object in our solar system, sped away through space, researchers gathered as much data as possible.

How to get access to the data

Some, but not all, of the data are available in the BL archive at http://breakthroughinitiatives.org/OpenDataSearch

To access GBT data, select "BL at Green Bank" from the projects drop-down, and optionally a target name. Note that this will return large numbers of files with filetype listed as "baseband data". These are the raw voltage files. Until you already have extensive experience using filterbank files, it would be best to avoid these baseband files at first, and stick to some of the example filterbank files (those with a .fil extension) at http://setiathome.berkeley.edu/~mattl/ml/

If you are developing pipelines to compare features between filterbank files, you may wish to test these with a larger set of data. We've made a subsample of the filterbank files from our analysis in Enriquez et al. (2017) available at http://blpd0.ssl.berkeley.edu/Lband/ - there's a total of 16 TB of high frequency resolution filterbanks here. We recommend only downloading these if you have fully explored a smaller subset of the filterbank data. We can provide more filterbank data where these came from on request, and will be making more of the data available online in due course.

How to read in a filterbank file

As noted above, the file format is pretty simple, a header plus a data array. We are moving towards HDF5 for data storage, which, among other things, makes it easier to access portions of a file without reading the whole thing into memory. You can read both filterbank and HDF5 files using https://github.com/UCBerkeleySETI/blimpy

There's also a fun Jupyter notebook that uses blimpy to read in and display one of our observations of the Voyager I spacecraft. Despite being 20 million kilometers from Earth and having a transmitter that only uses the same power as a refrigerator light, it's clearly detectable by our observations:
https://github.com/UCBerkeleySETI/breakthrough/blob/master/GBT/voyager/voyager.ipynb

This is a nice illustration of the capabilities of our instruments to detect signatures of technology even for very distant targets, and observations like the ones of Voyager, or others with artificially inserted "birdie" signals, could be used as a training set for machine learning or other approaches.

bit.do/HowToFindET

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Towards an All-Sky Radio SETI Telescope

Monday 29 October - Wednesday 31 October 2018
Jodrell Bank Centre for Astrophysics
University of Manchester

scroft@berkeley.edu

seti.berkeley.edu

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These slides: bit.do/croft_gnu

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