

AGISETI: ARDC-supported GNU radio Interactive SETI Curriculum

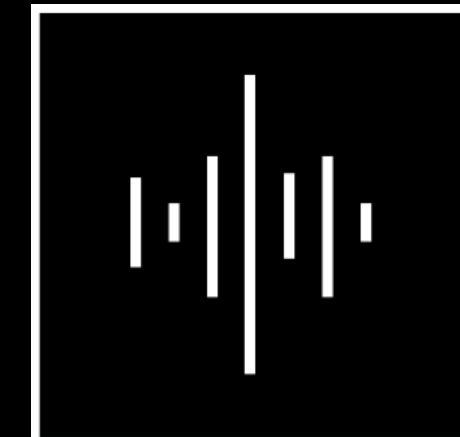
Vishal Gajjar (SETI Institute) and Joel Earwicker (SETI Institute)

29th May 2024



gajjarvishal.com

Supported by:



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AMATEUR RADIO DIGITAL COMMUNICATIONS

Some of the challenges in STEM education

- Motivating Student Interest and Participation
- Bridging Theory and Practice
- Utilizing Cutting-Edge Technology
- Interdisciplinary Approach
- Updating Curriculum Content

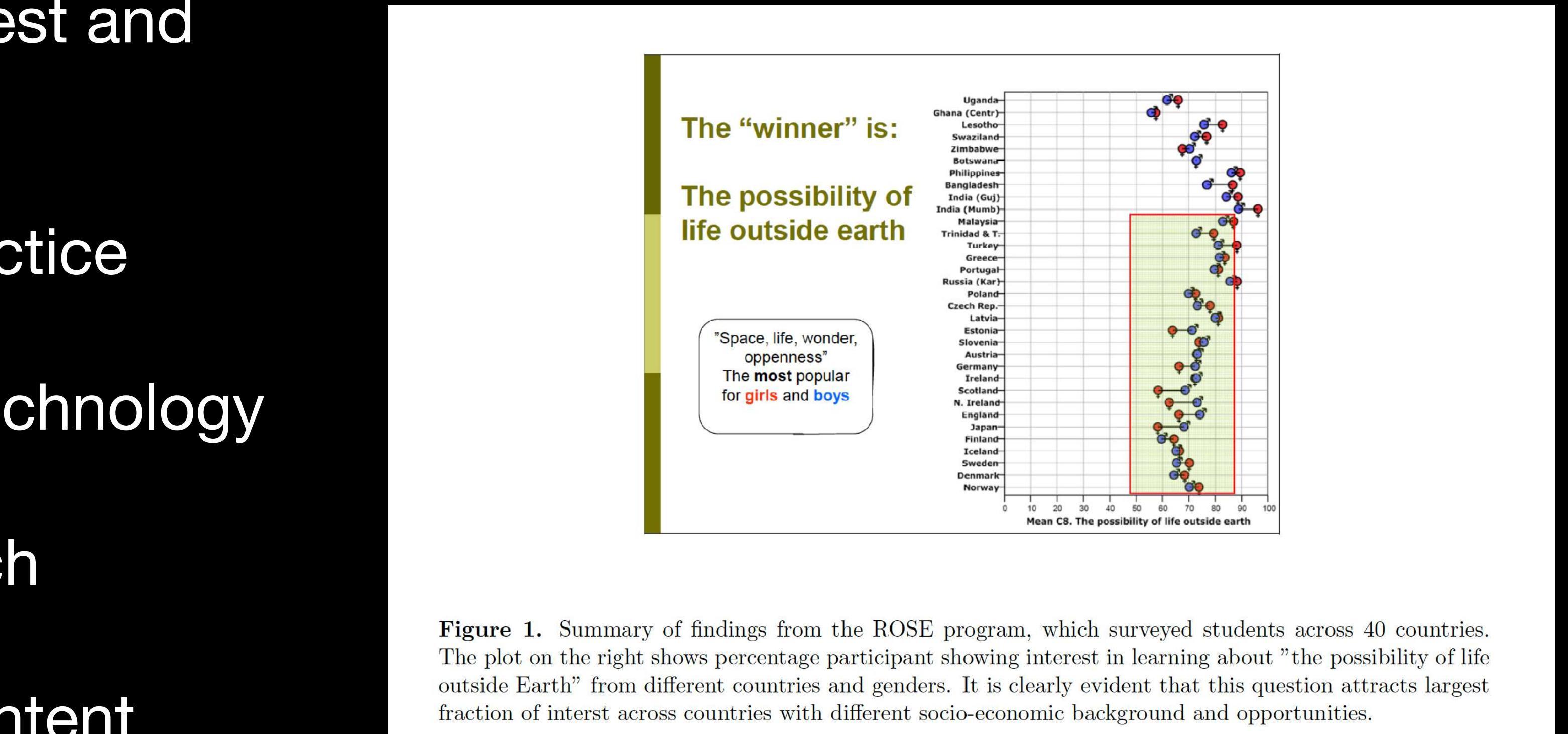
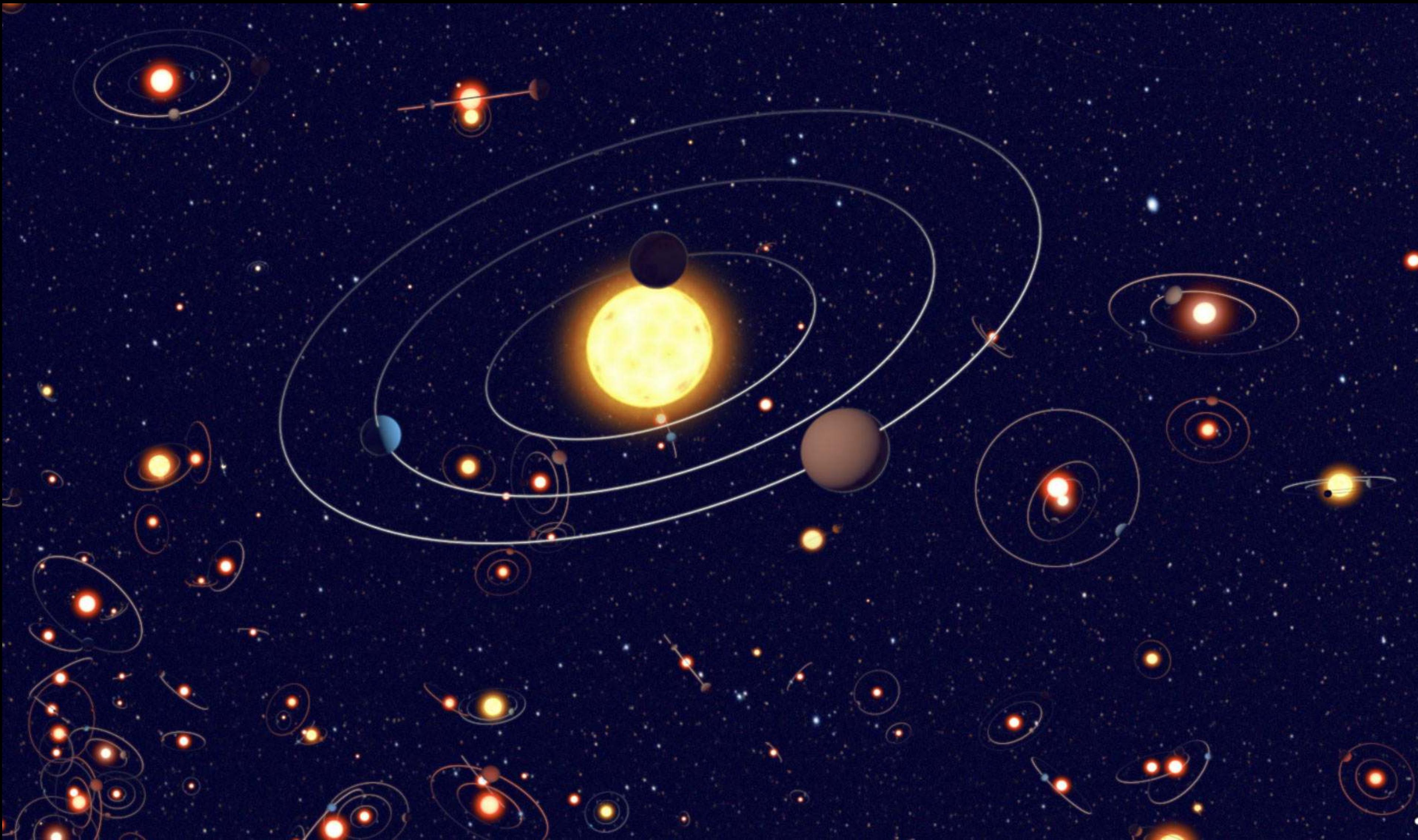


Figure 1. Summary of findings from the ROSE program, which surveyed students across 40 countries. The plot on the right shows percentage participant showing interest in learning about "the possibility of life outside Earth" from different countries and genders. It is clearly evident that this question attracts largest fraction of interest across countries with different socio-economic background and opportunities.

Search For Extra-Terrestrial Intelligence at Radio Frequencies



Scope of our work

1. SETI-Inspired Curriculum:

- Modular curriculum encompassing astronomy, electronics, electromagnetic wave fundamentals, radio antenna operations, digital signal processing, communication fundamentals with detailed hands-on lab tutorial developed under the framework of GNU radio.

2. ATA Telescope Access:

- User-friendly GUI for remote operation of the Allen Telescope Array.

3. Training Workshops:

- A hands on training workshop hosted at the ATA for instructors

4. Online Platform:

- Dedicated project website and collaboration with NASA's Community College Network for broad outreach.

GNU radio

Sine_wave.grc - /Users/vishalgajjar/Documents/ARDC/Week6_Hydrogen_line_ATA

File Edit View Run Tools Help

Simple_velocity Frequency_velocity_both amplitude_modulation Frequency_modulation Sine_wave

Options
Title: Not titled yet
Author: vishalgajjar
Output Language: Python
Generate Options: QT GUI

Variable ID: samp_rate Value: 3.84M

Variable ID: nfft Value: 4.096k

Variable ID: decimation Value: 937

Variable ID: integration_time Value: 1

Signal Source
Sample Rate: 3.84M
Waveform: Cosine
Frequency: 1k
Amplitude: 1
Offset: 0
Initial Phase (Radians): 0

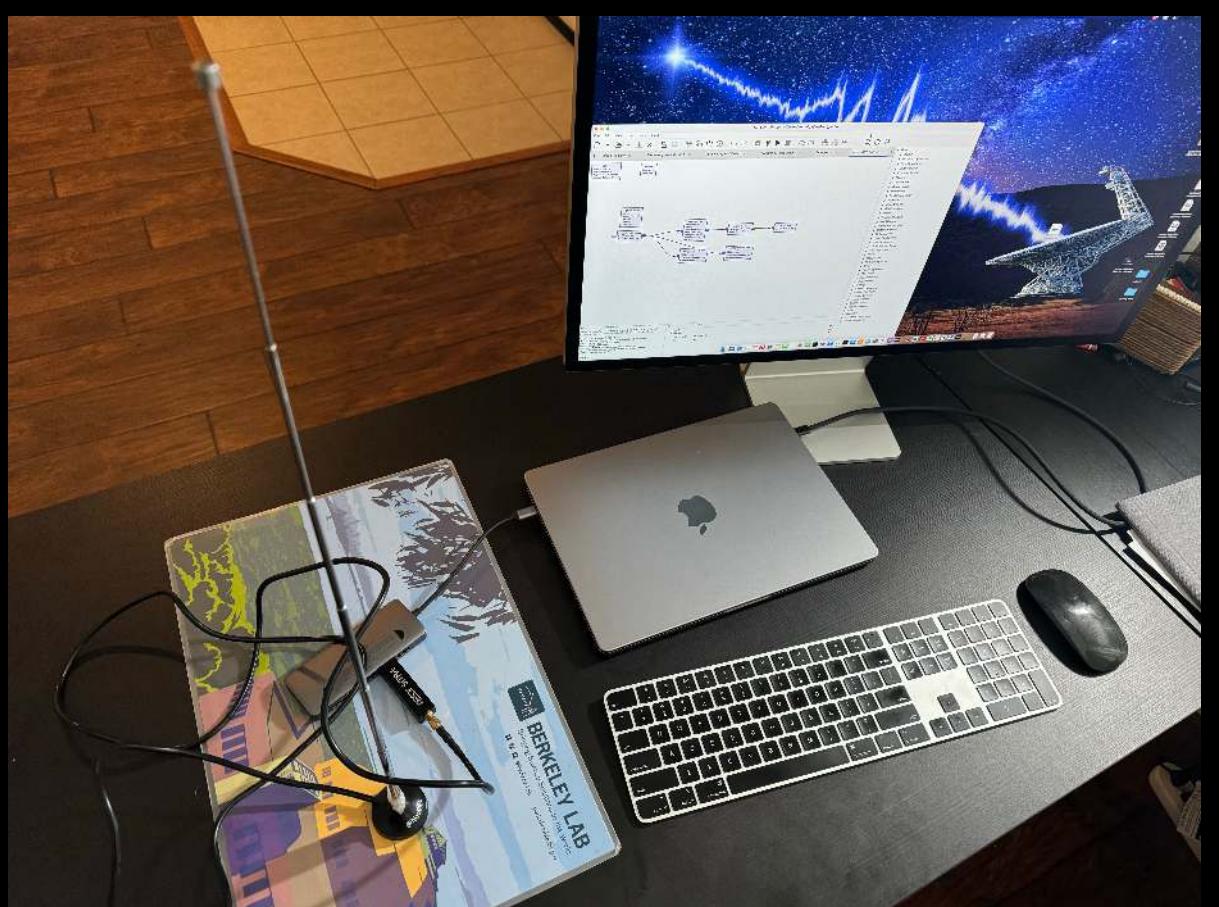
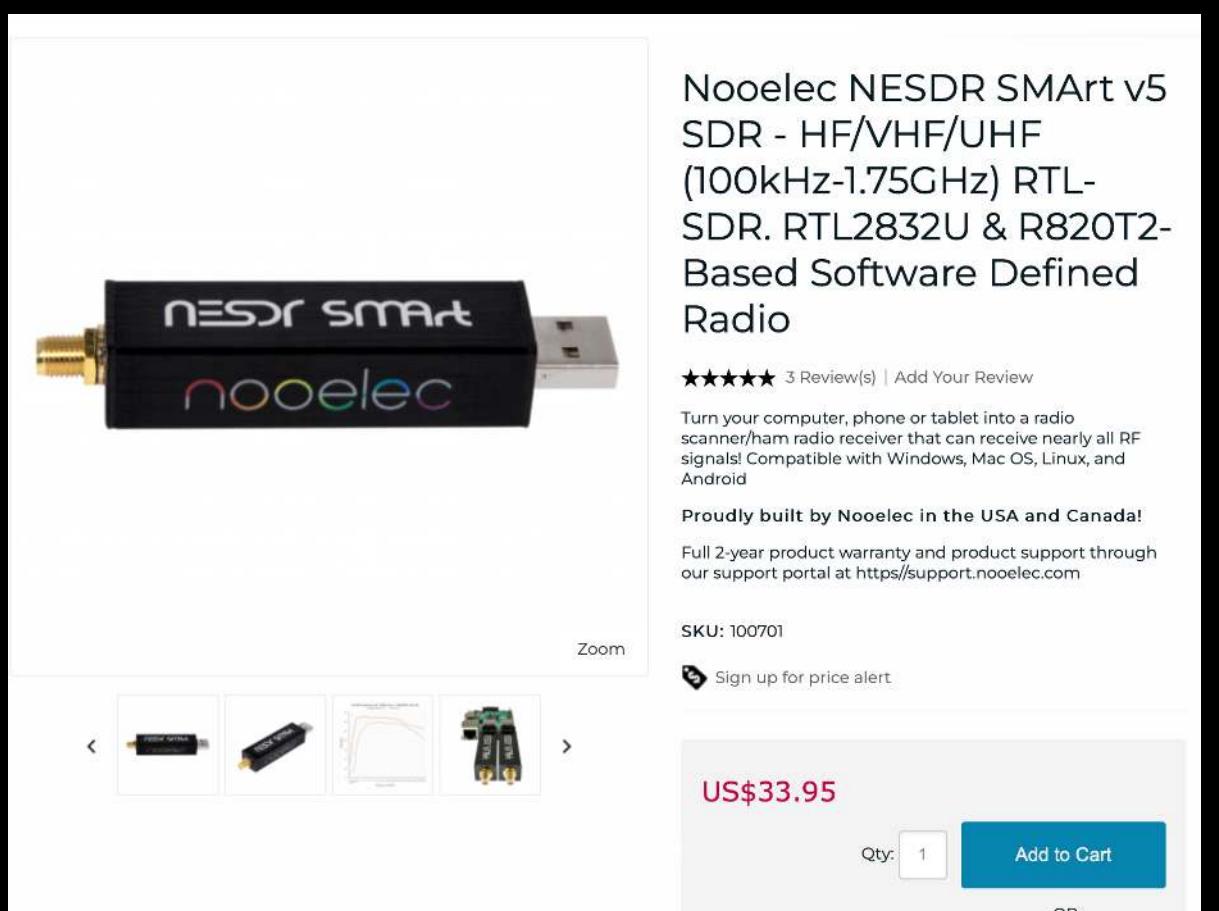
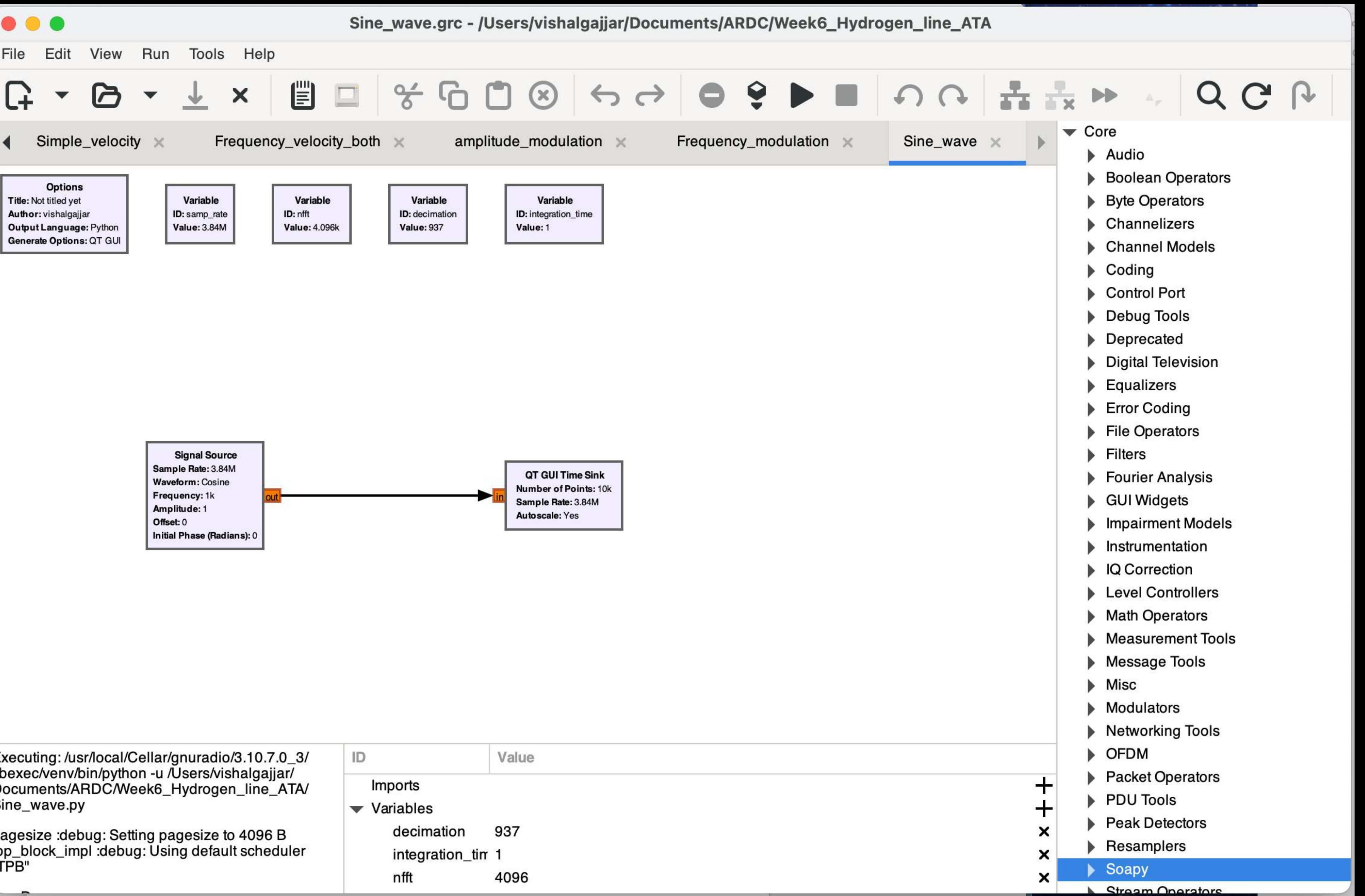
QT GUI Time Sink
Number of Points: 10k
Sample Rate: 3.84M
Autoscale: Yes

Executing: /usr/local/Cellar/gnuradio/3.10.7.0_3/libexec/venv/bin/python -u /Users/vishalgajjar/Documents/ARDC/Week6_Hydrogen_line_ATA/Sine_wave.py

pagesize :debug: Setting pagesize to 4096 B
top_block_impl :debug: Using default scheduler "TPB"

ID	Value
Imports	
Variables	
decimation	937
integration_time	1
nfft	4096

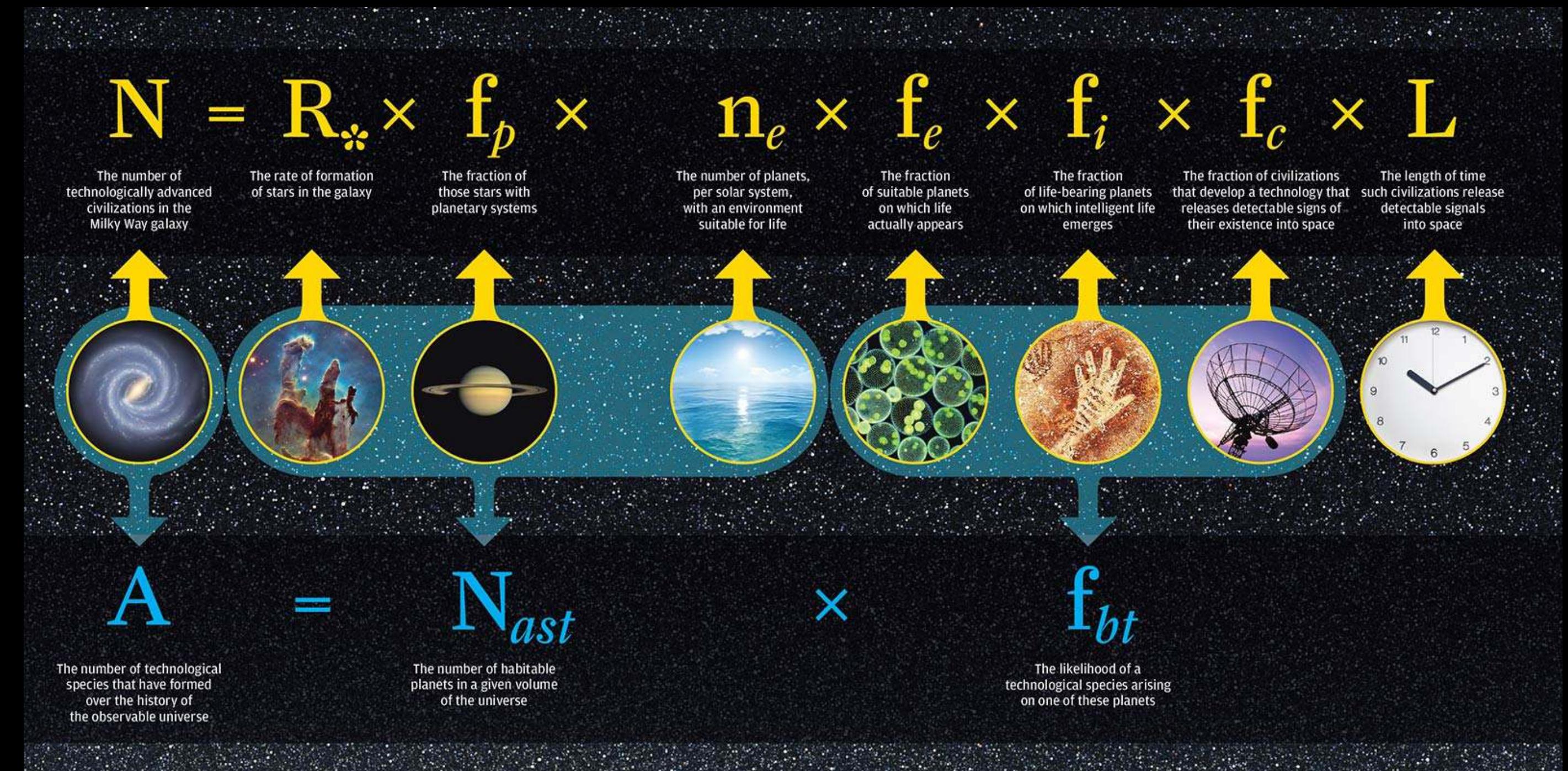
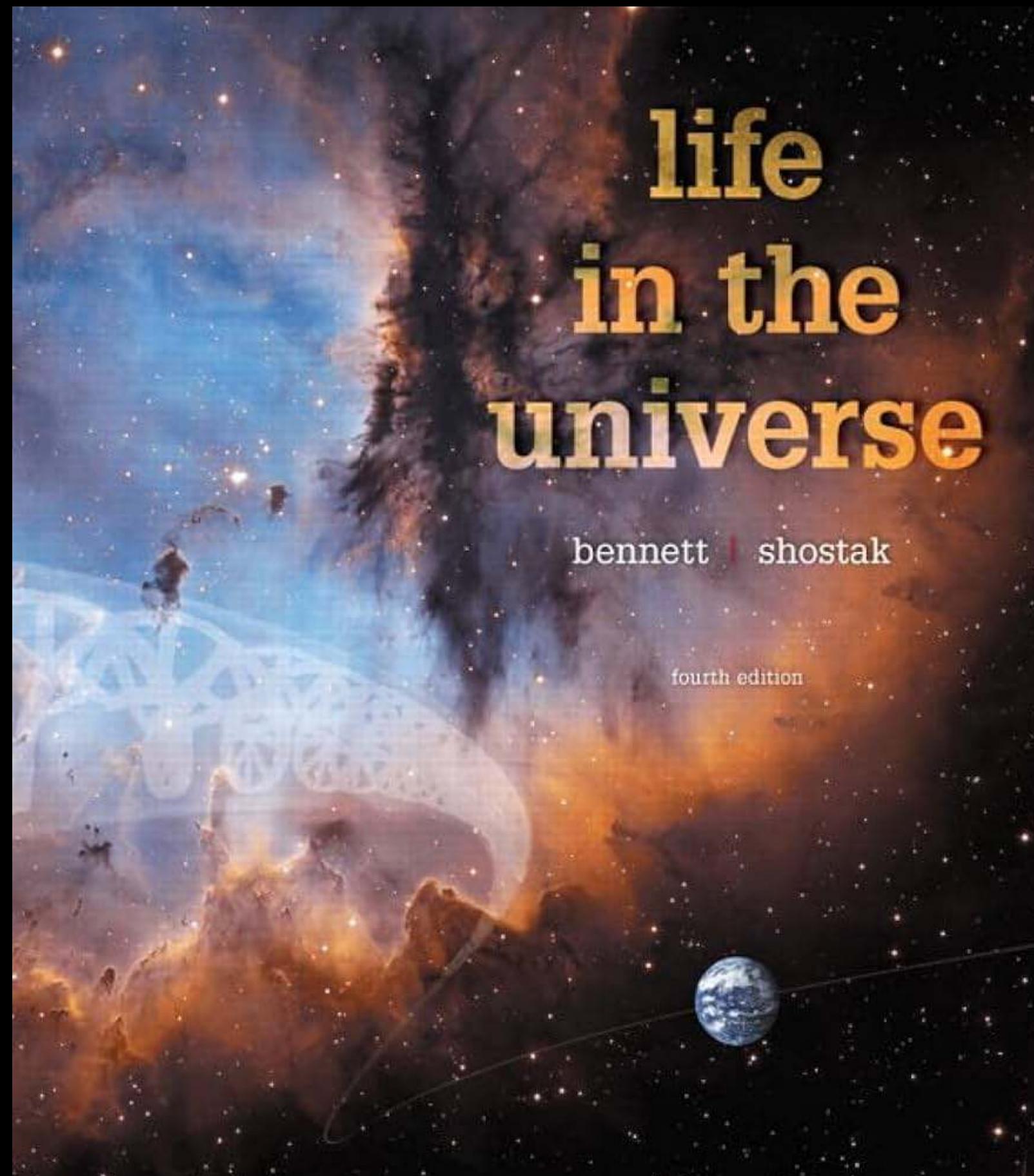
Core
▶ Audio
▶ Boolean Operators
▶ Byte Operators
▶ Channelizers
▶ Channel Models
▶ Coding
▶ Control Port
▶ Debug Tools
▶ Deprecated
▶ Digital Television
▶ Equalizers
▶ Error Coding
▶ File Operators
▶ Filters
▶ Fourier Analysis
▶ GUI Widgets
▶ Impairment Models
▶ Instrumentation
▶ IQ Correction
▶ Level Controllers
▶ Math Operators
▶ Measurement Tools
▶ Message Tools
▶ Misc
▶ Modulators
▶ Networking Tools
▶ OFDM
▶ Packet Operators
▶ PDU Tools
▶ Peak Detectors
▶ Resamplers
▶ Soapy
▶ Stream Operators



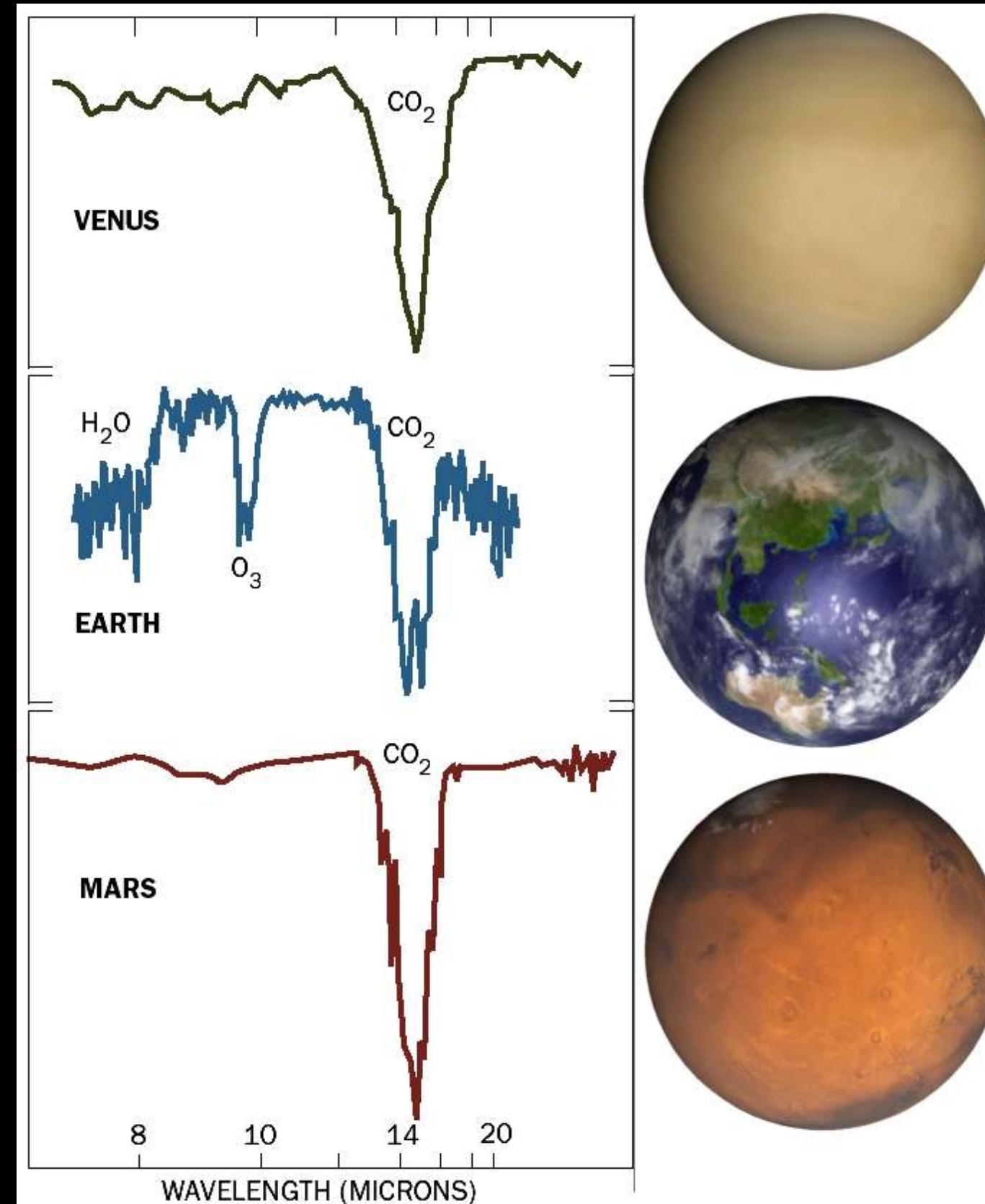
(Optional) Hardware for more involved Lab experiments

Free Software to create flowgraphs and save them as .grc files

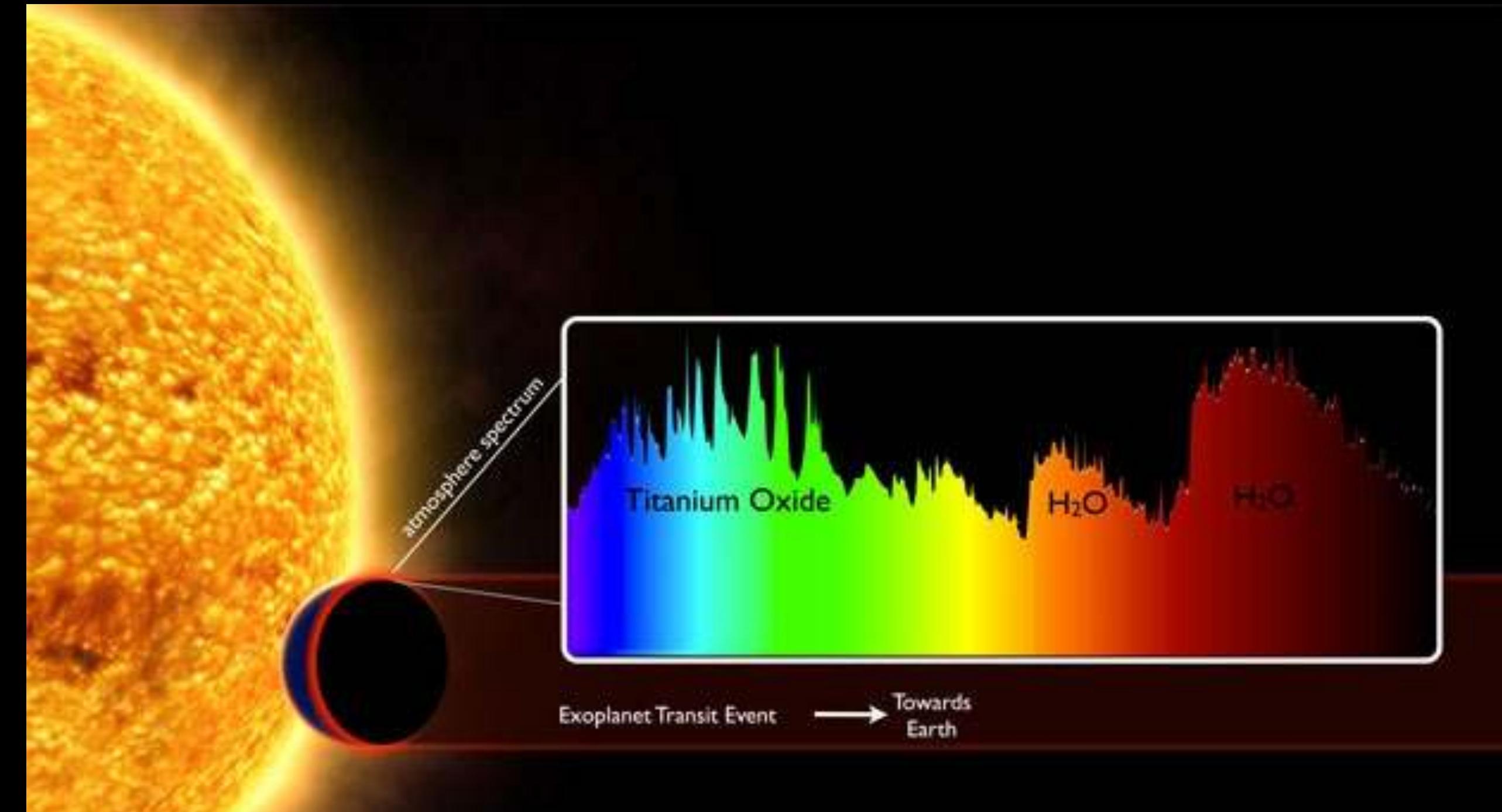
Life in the Universe!



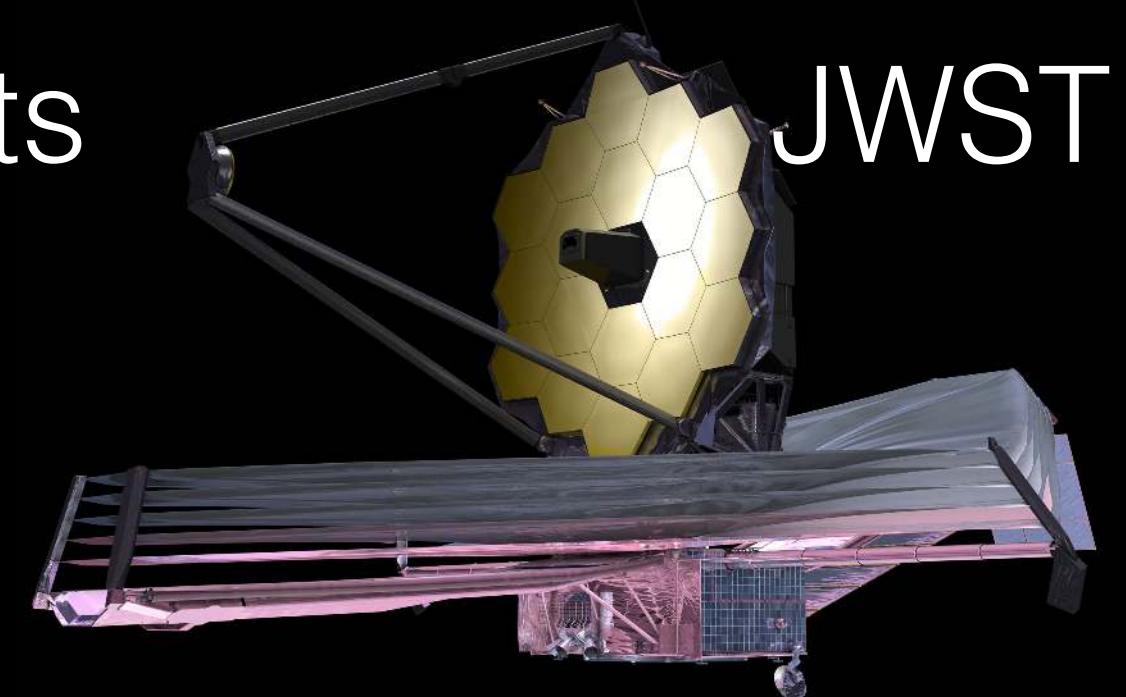
Searching for Biosignature



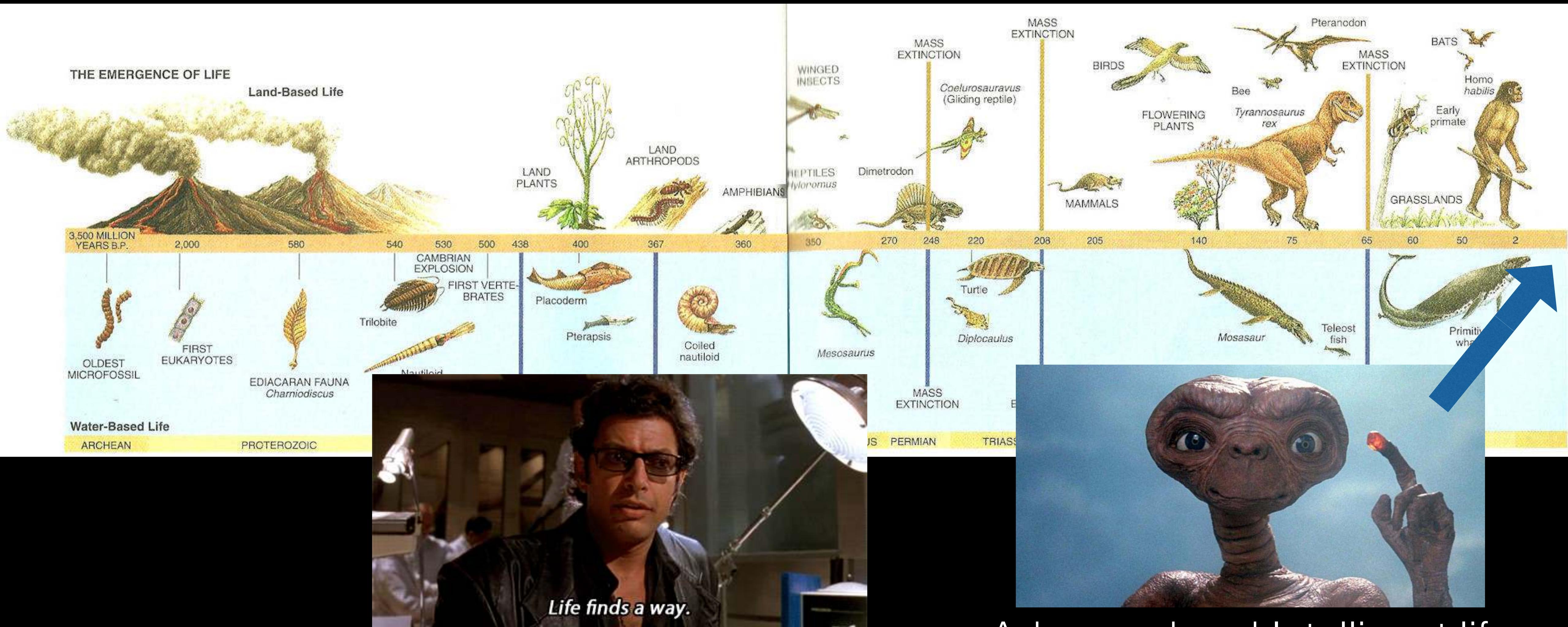
Detecting signs of life



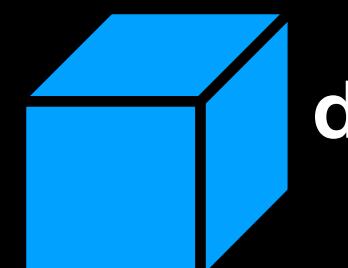
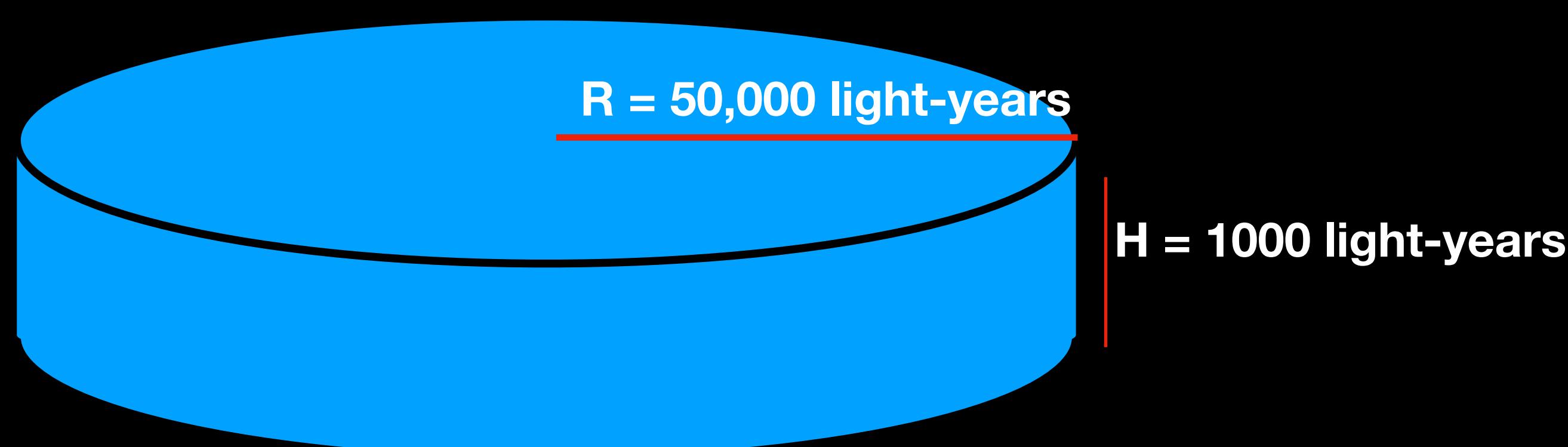
Detecting atmospheres of exoplanets



Evolution of life



Estimating distance to the nearest technologically-advanced life in our Milky Way



$$V = \pi R^2 \times H$$

$$N = N_{HB} \times f_{life} \times f_T \times f_{now}$$

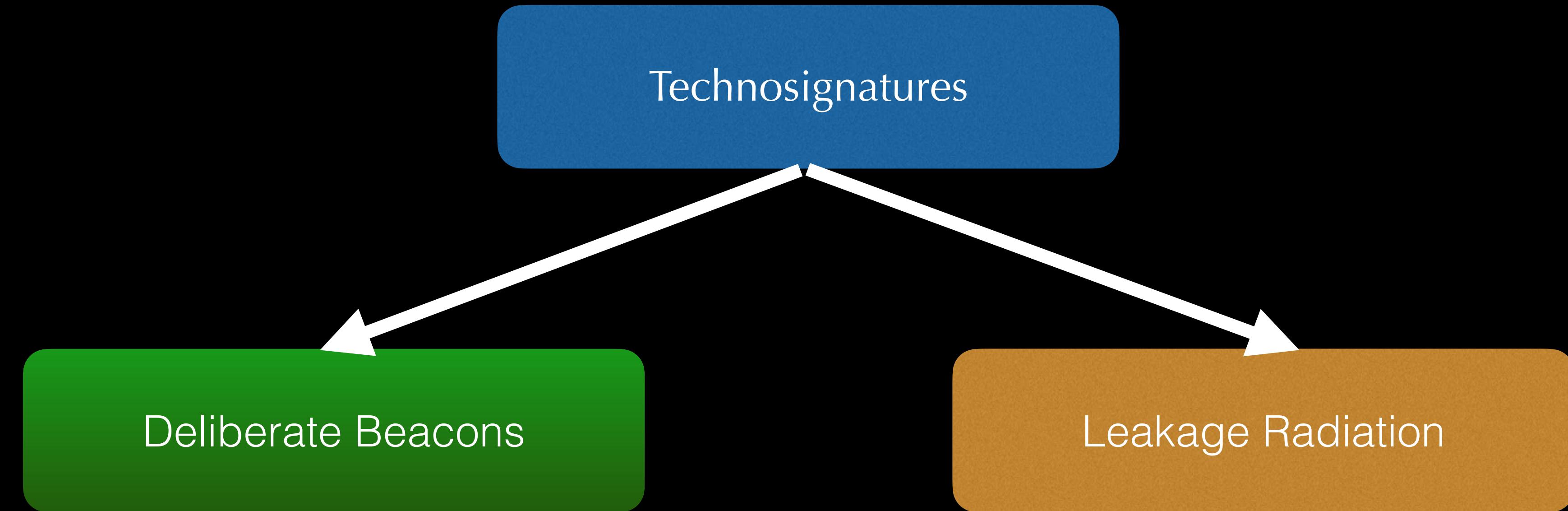
$$d = \left(\frac{V}{N} \right)^{1/3}$$

Optimistic: 1 million civilization with average distance between them <200 lightyears

Reserved: 10 civilizations with average distance between them >10,000 lightyears

Search For Extra-Terrestrial Intelligence at Radio Frequencies





- Easy to identify
- Energetically efficient
- Bright enough to be detectable across interstellar distances
- Likely to be rare in numbers but should be detectable with moderate sensitivity

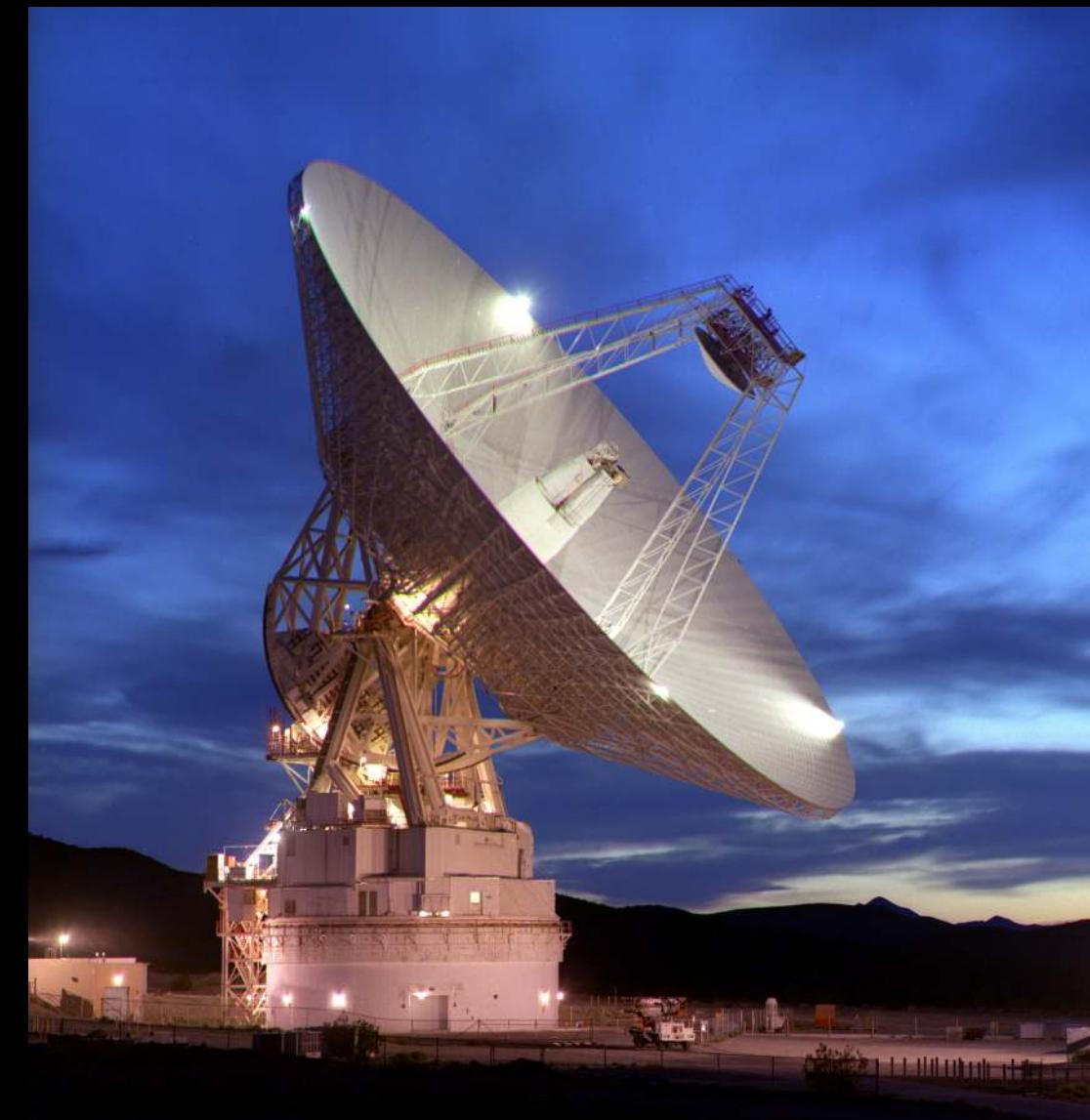
- Anomalous and defy our understanding of astrophysical phenomena
- May carry information, hence allowing identification of their artificiality
- May be transmitted isotropically
- Relatively weaker and require sensitive, deep searches
- Likely to be large in numbers

Examples of Radio Technosignatures we produce

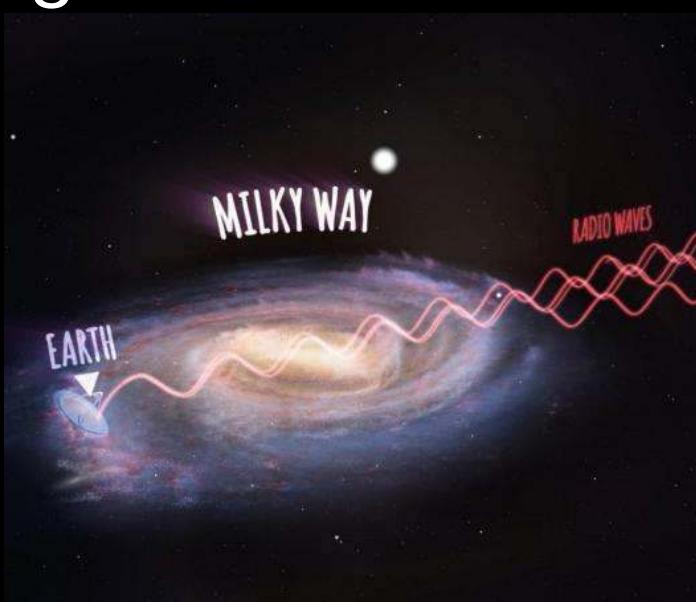
PLANETARY RADAR SYSTEMS



Such signals are likely to be easily distinguishable from the natural occurring signals



A few radar systems on Earth detectable across the galaxy



HIGH-POWER TV AND RADIO



Hundreds of transmitters detectable at a few lightyears

Mobile phone Transmission Leakage from Earth

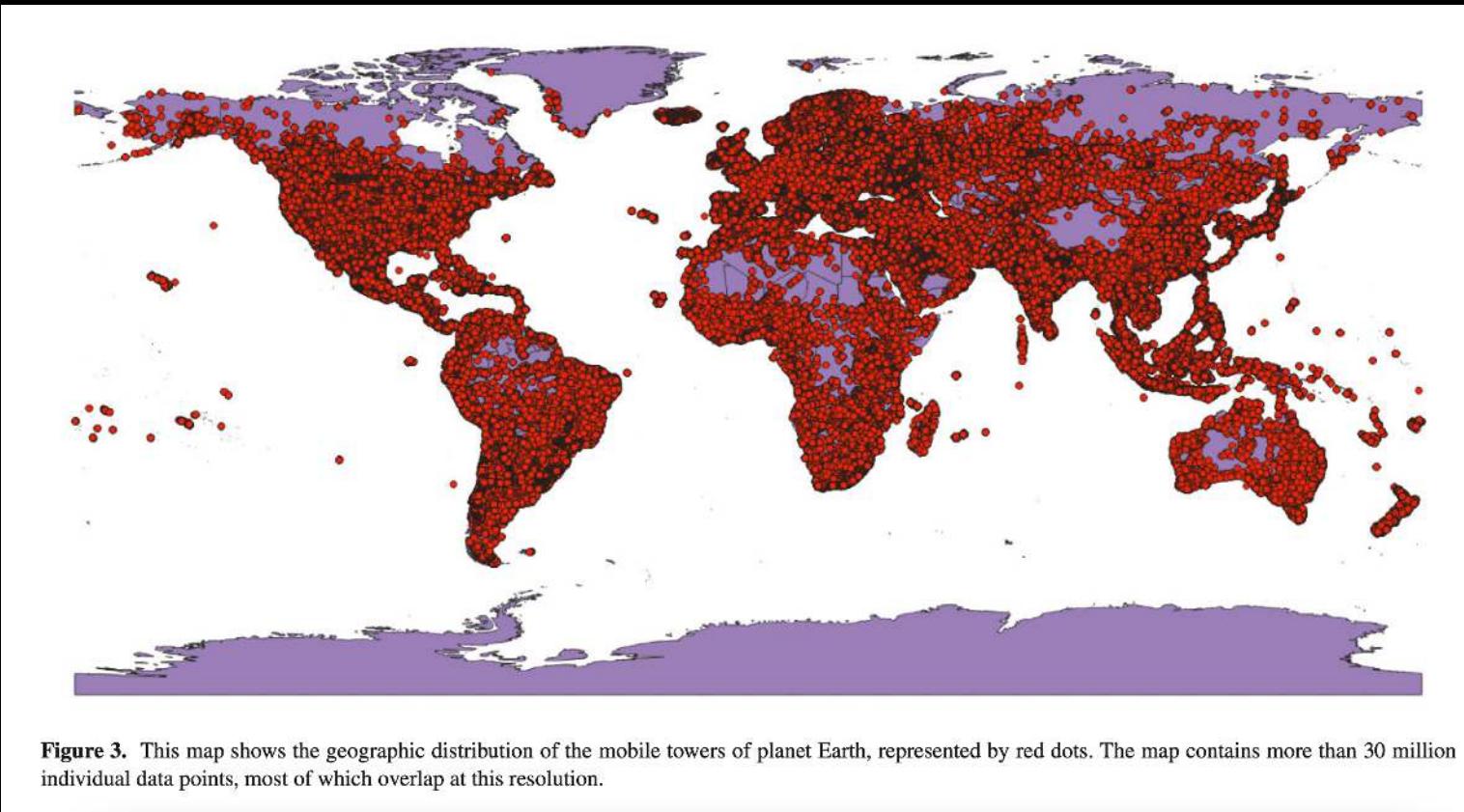
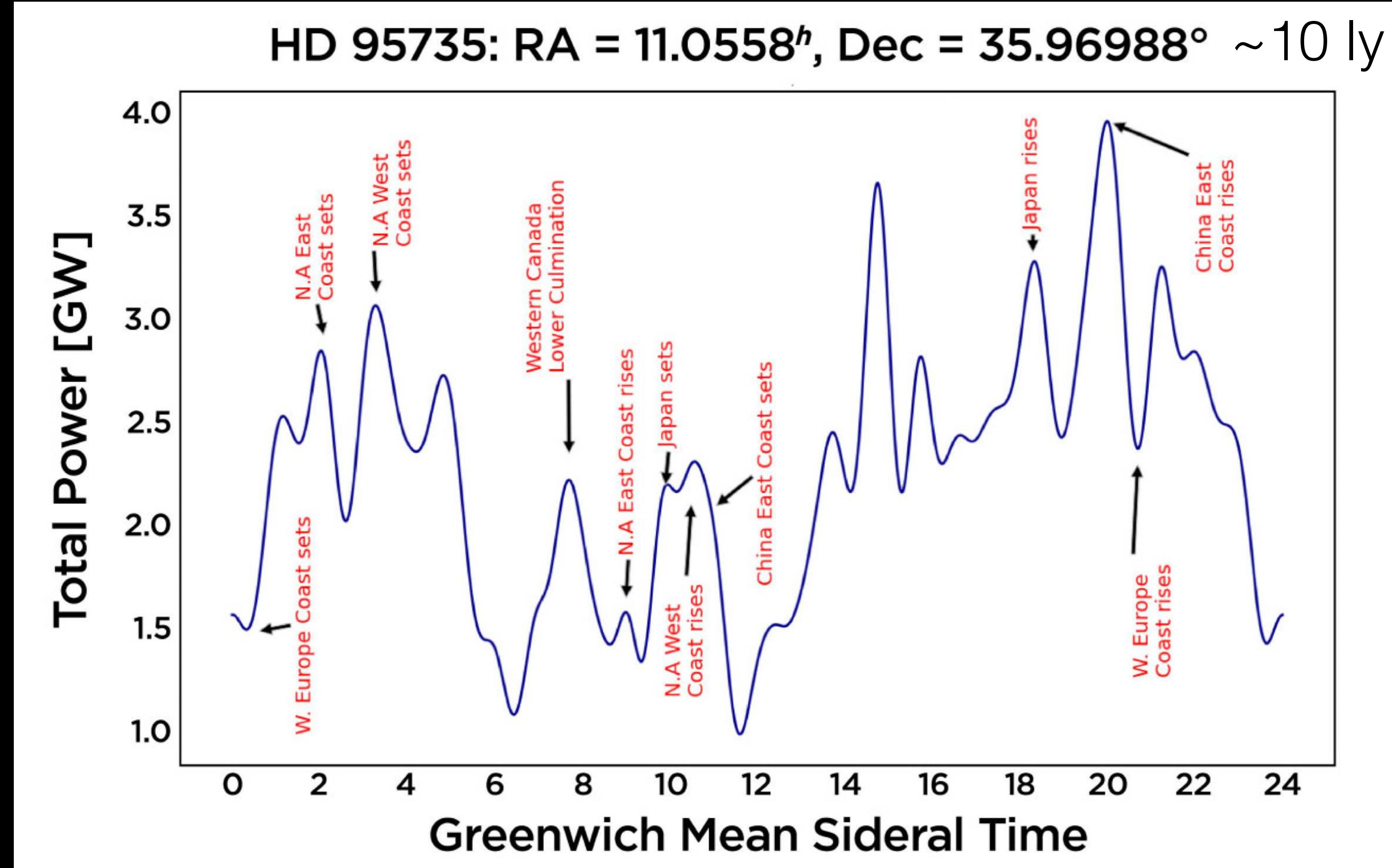


Figure 3. This map shows the geographic distribution of the mobile towers of planet Earth, represented by red dots. The map contains more than 30 million individual data points, most of which overlap at this resolution.

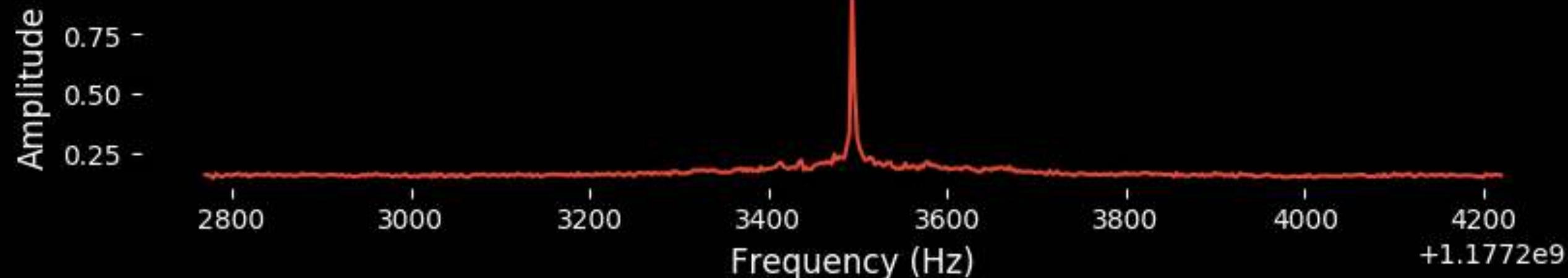


Narrowband Signals

Waterfall

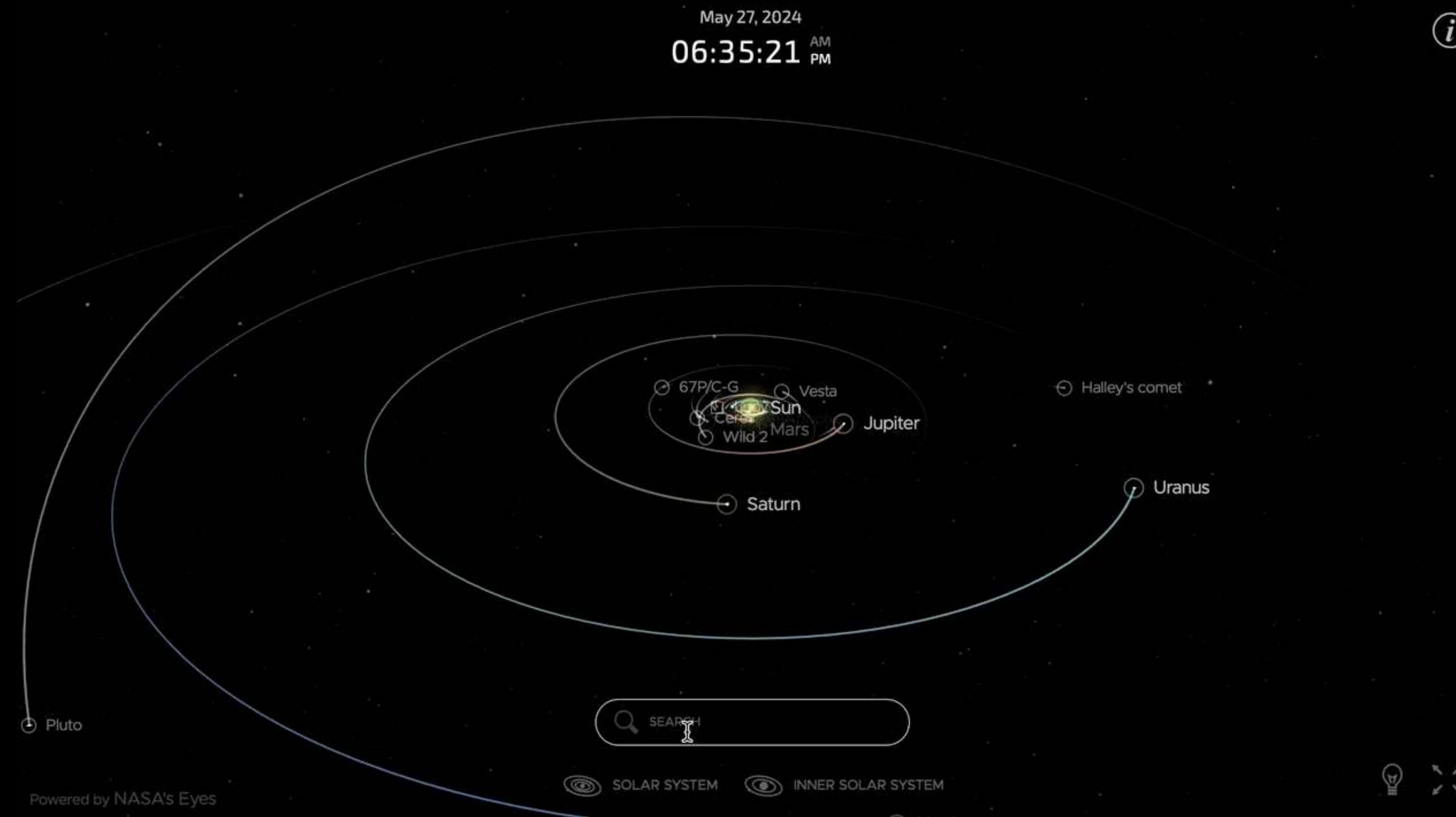


Average Spectra



- ✓ Easy to identify
- ✓ Energetically efficient
- ✓ Could be rare in number but bright enough to be detectable with shallow observations.
- ✓ May not carry information but could be associated with information carrying signals
- ✓ Could be large in numbers at a lower flux

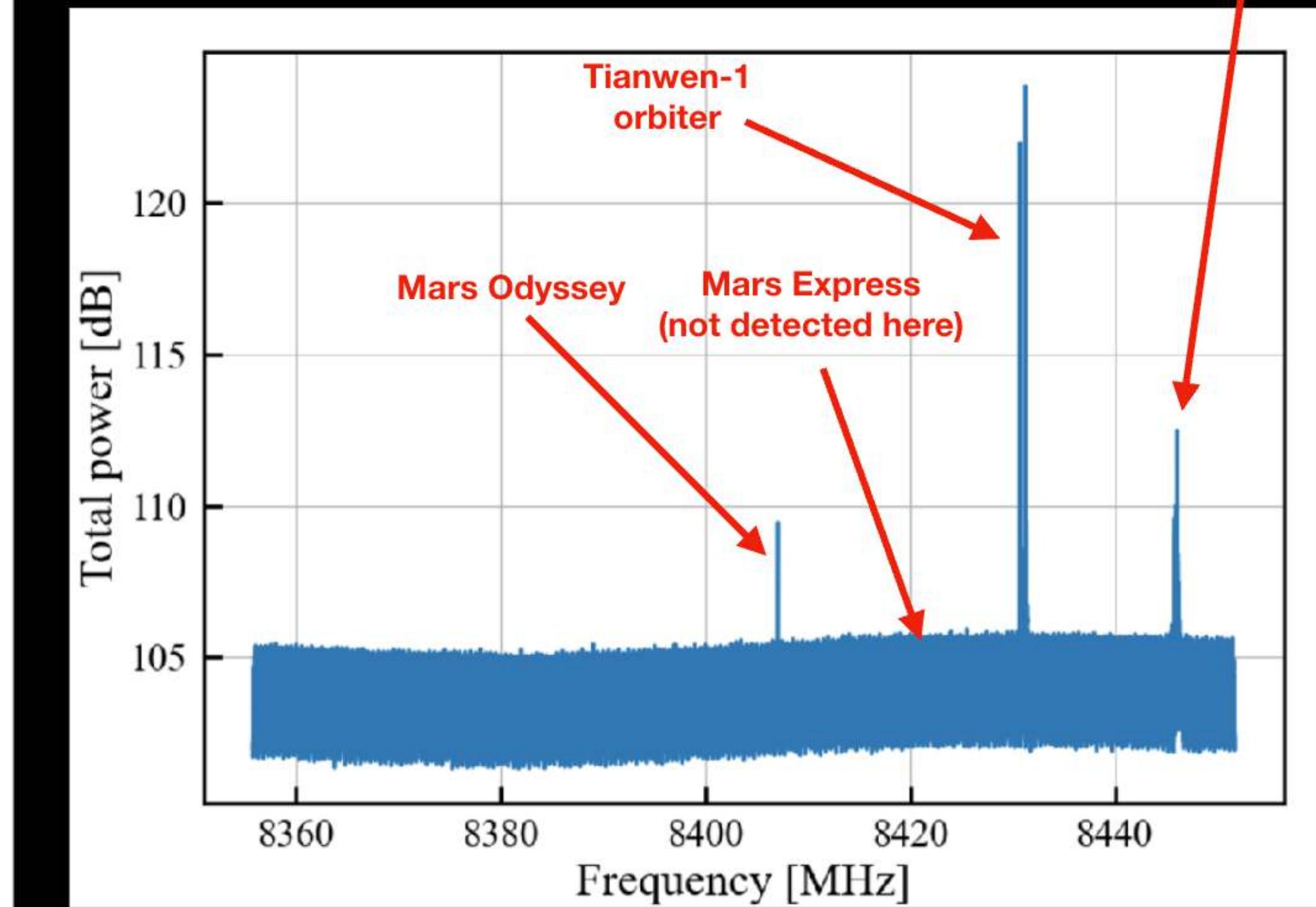
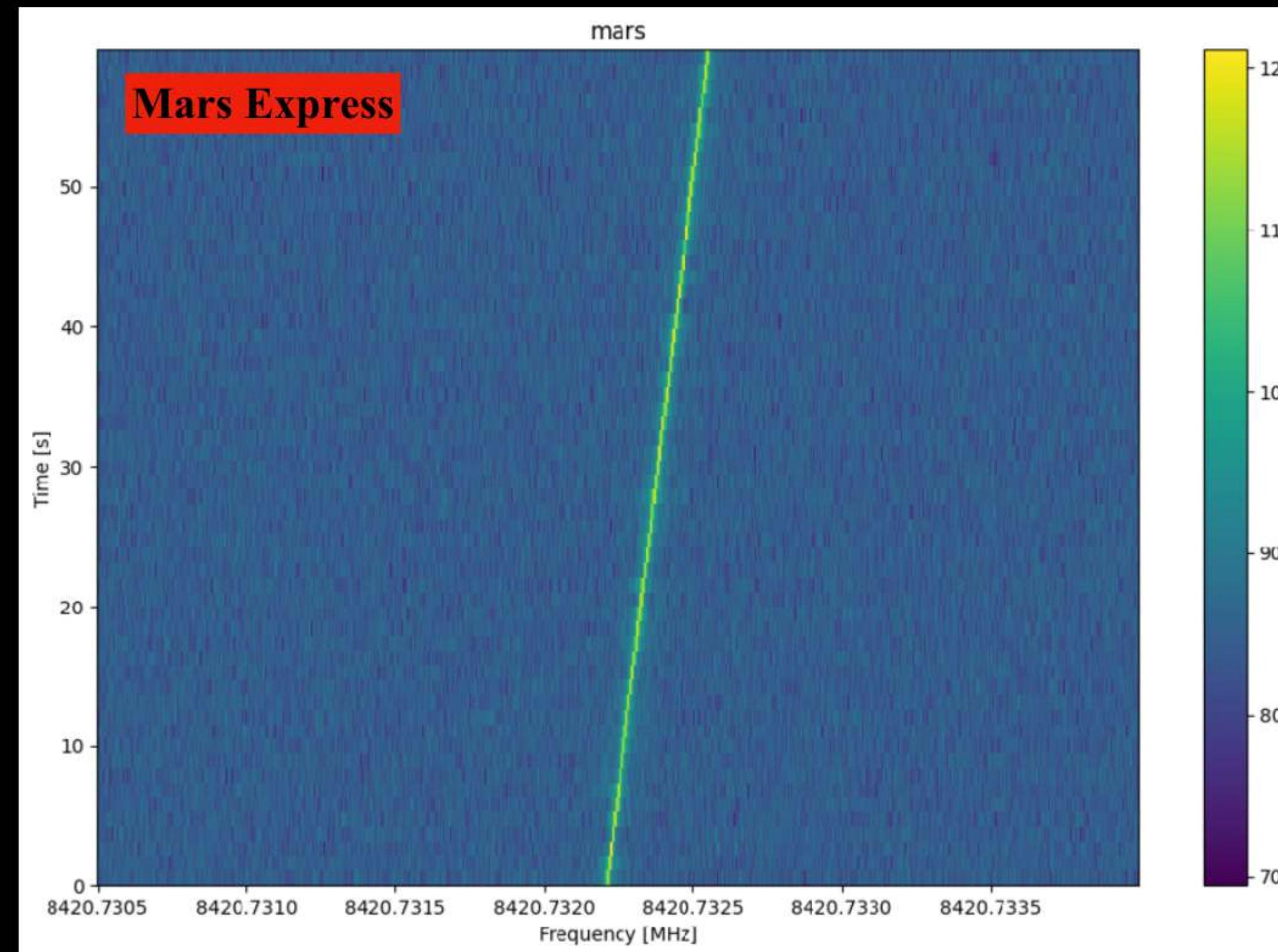
Narrowband signals from our Space probes, detection with the ATA



Narrowband signals from our Space probes, detection with the ATA



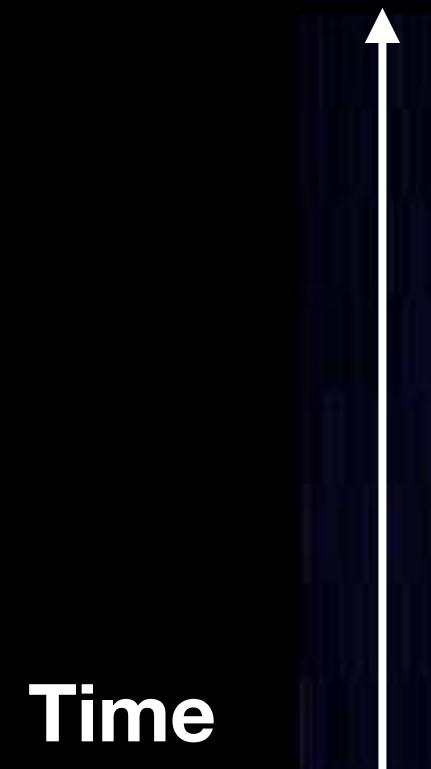
MAVEN



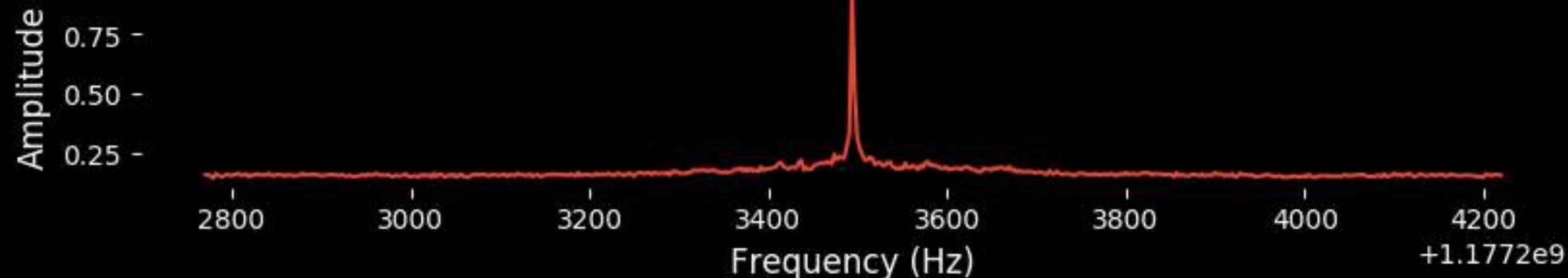
Credit: Wael Farah

Narrowband Signals

Waterfall

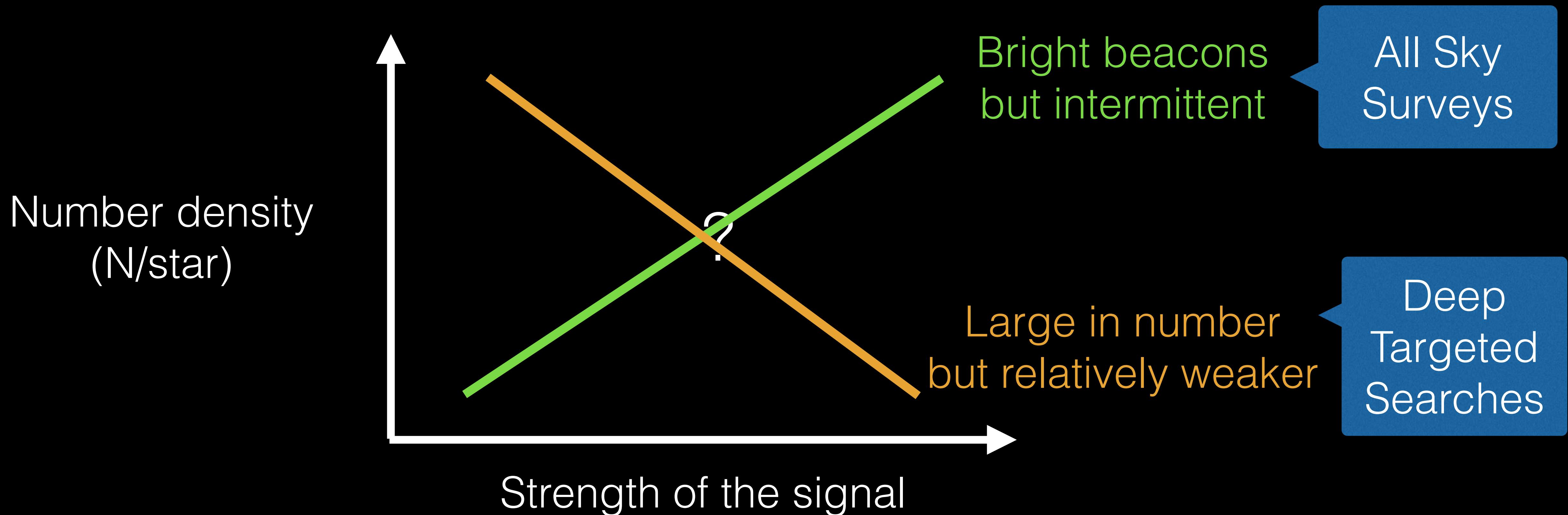


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Luminosity function of narrowband signals



Where are we searching?



1 Million Nearby Stars
Deep Searches for
beacons and leakage
radiations

Entire Galactic Plane and
Center for **beacons** and
leakage radiations

100 Galaxies
for powerful
beacons

Exotic astronomical
sources for leakage
radiations

BL OBSERVATIONAL FACILITIES FOR DEEP TARGETED AND LARGE SCALE SURVEY



GBT



Parkes



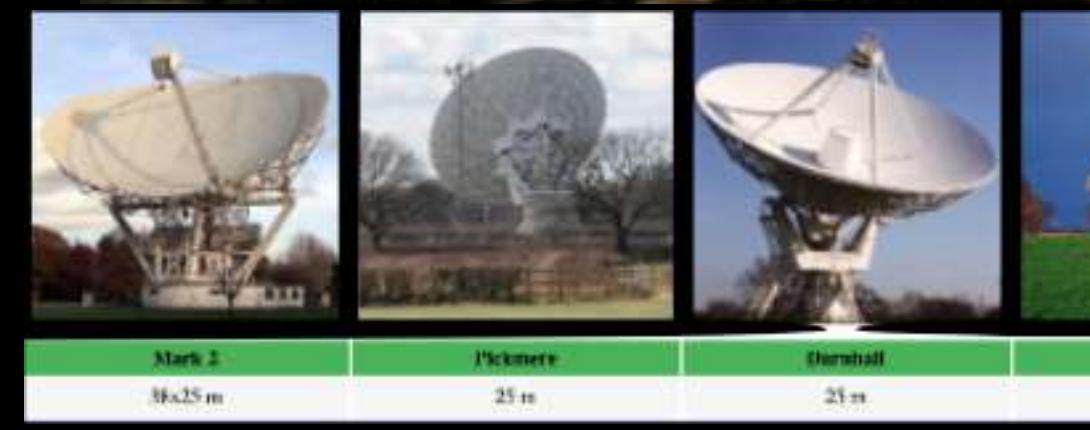
MeerKAT



APF



VERITAS



JBO and e-MERLIN



VLA



FAST



NenuFAR



LOFAR (international)



MWA



ATA



SRT



NRT



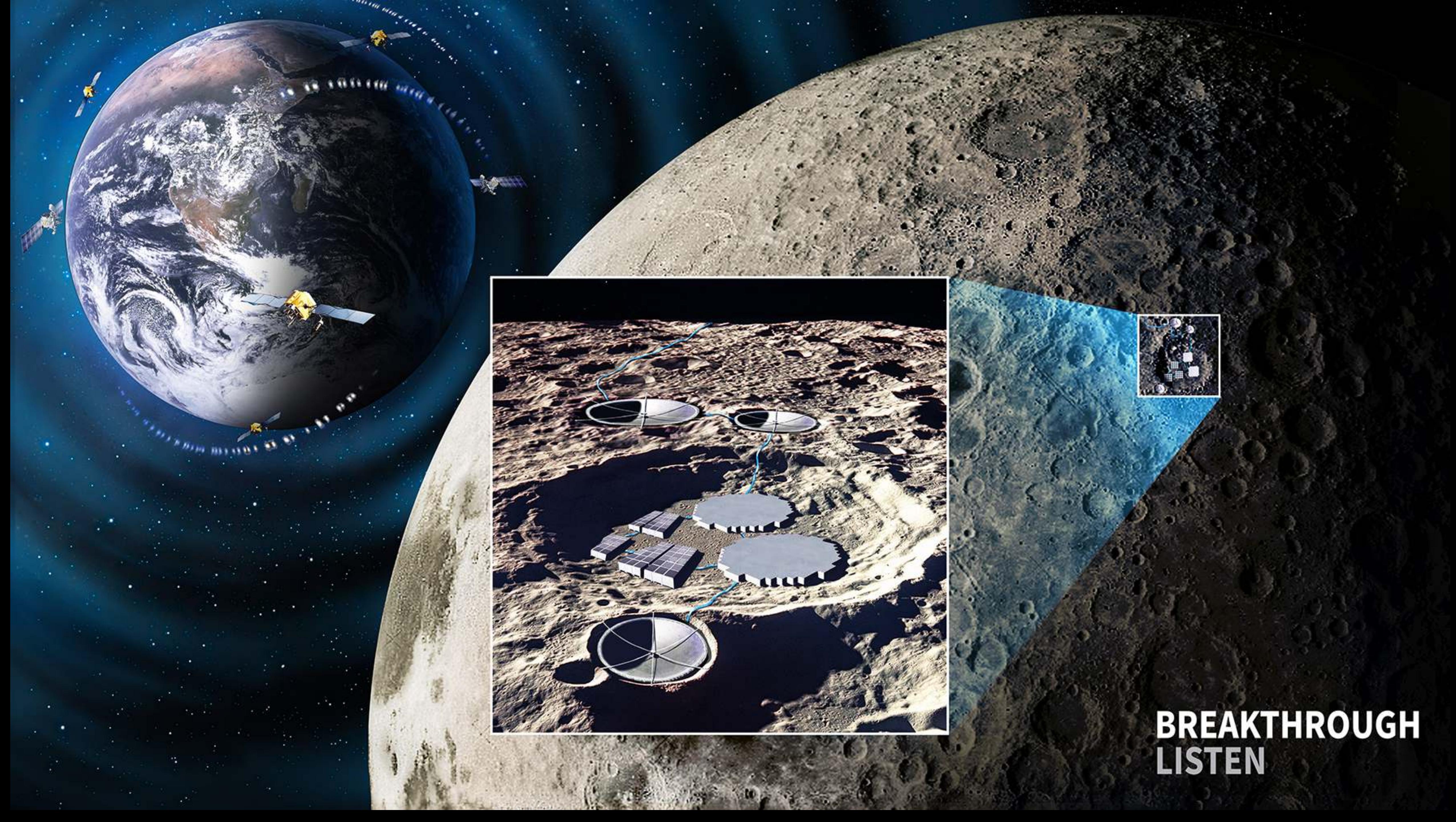
TESS



GMRT

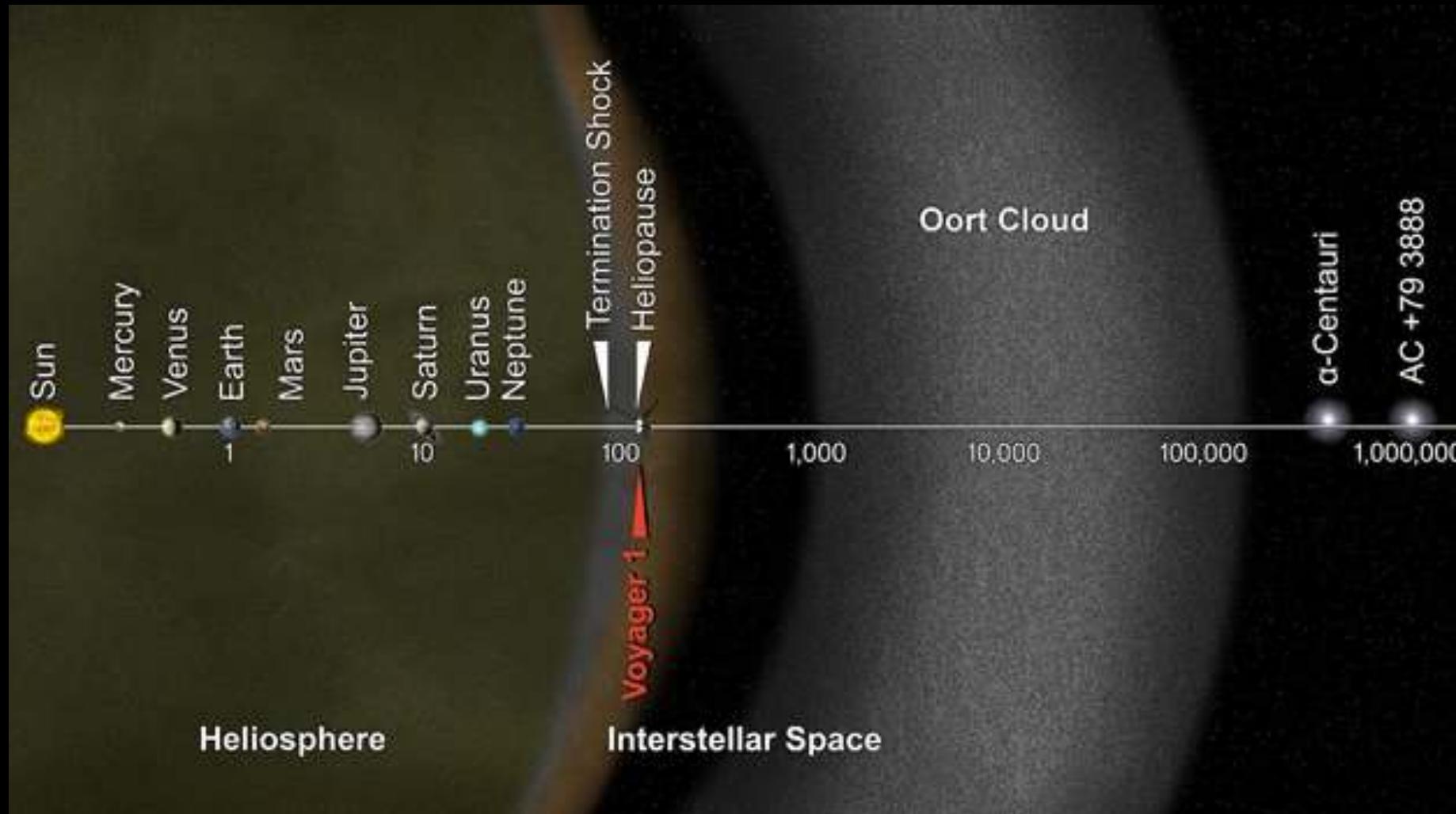


GAIA



**BREAKTHROUGH
LISTEN**

Hands-on Lab: Detecting Voyager 1



NASA Jet Propulsion Laboratory California Institute of Technology | Voyager

Home News Mission Golden Record Galleries Where Are They Now FAQs

Where are the Voyagers now?

Voyager 1 Flyby Spacecraft

Voyager 1 is the farthest human-made object from Earth and the first spacecraft to reach interstellar space. Scientists think it will reach the inner edge of the Oort Cloud in 300 years.

May 27, 2024 06:31:52 PM

READ MORE →

5 SEP. 1977 OUTER SOLAR SYSTEM

Launch Primary Target

FLYBY GOING INTERSTELLAR SINCE 2012

Type Status

15.13 billion mi 37,878 mph

Distance From Earth Powered by NASA's Eyes Speed (Relative To Sun)

SEARCH

SOLAR SYSTEM SPACECRAFT LOCATION

i

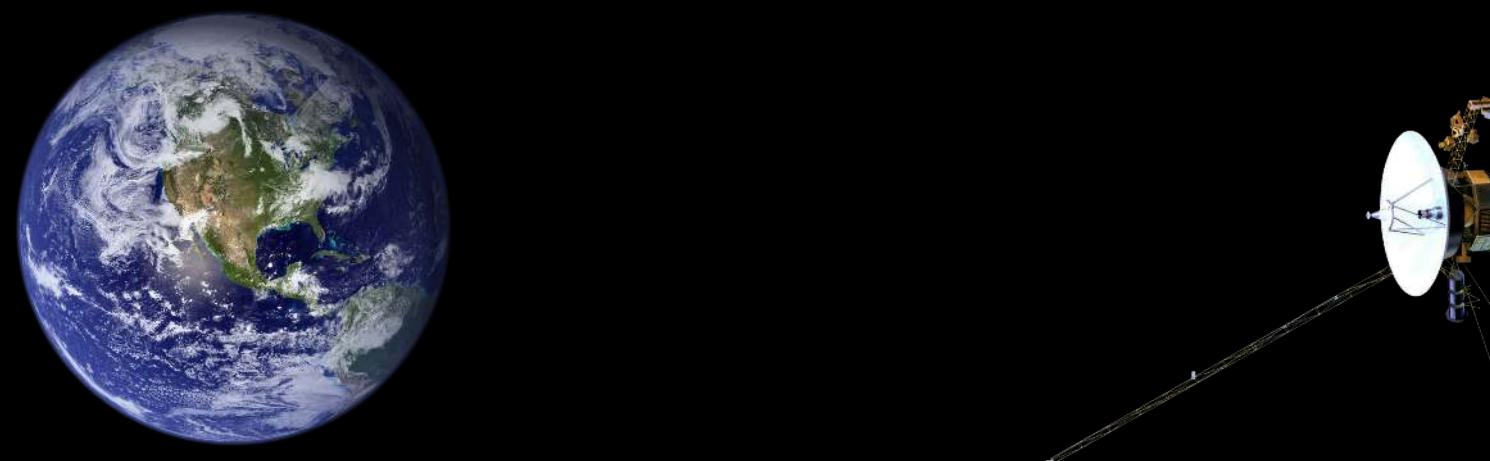
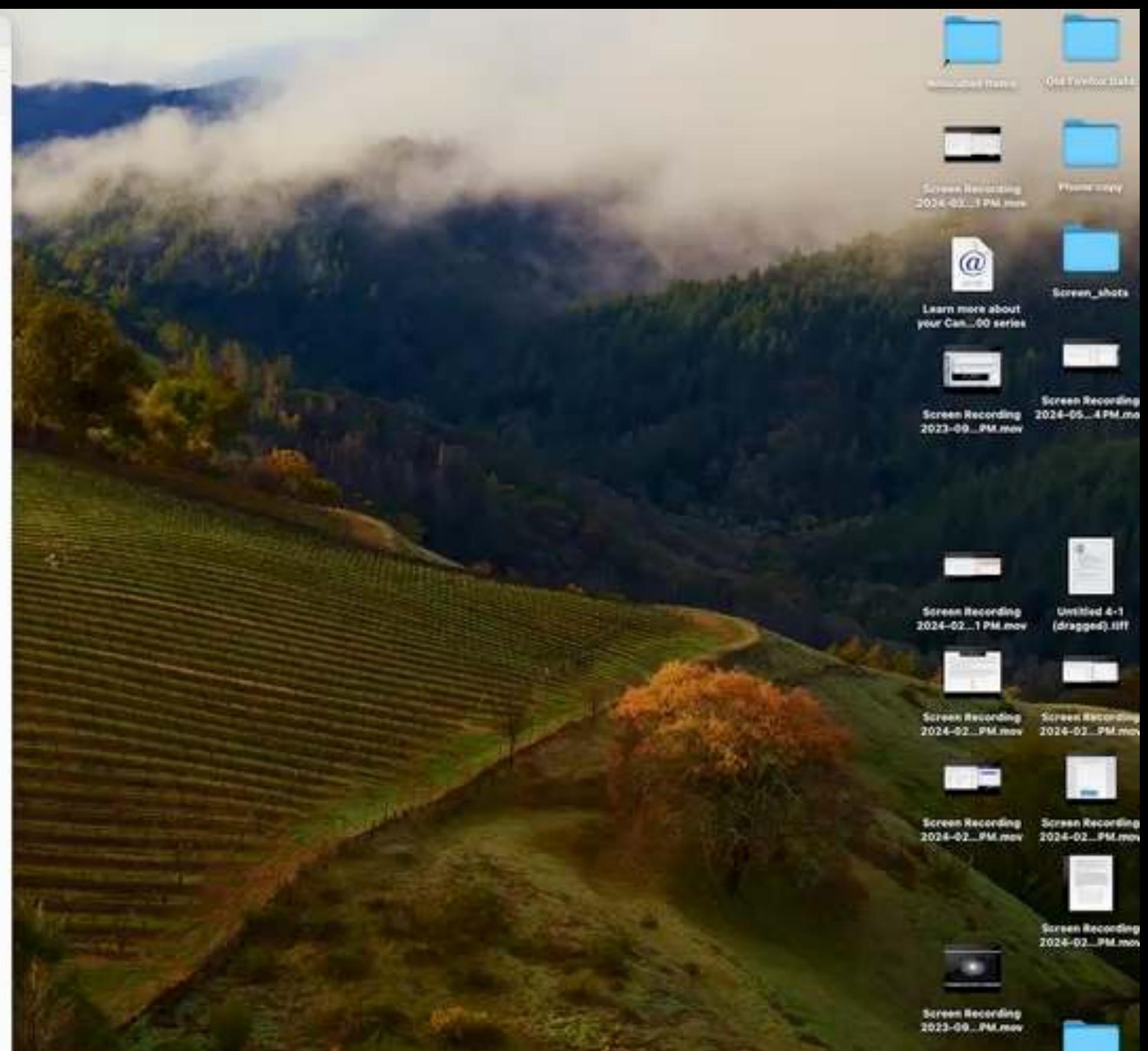
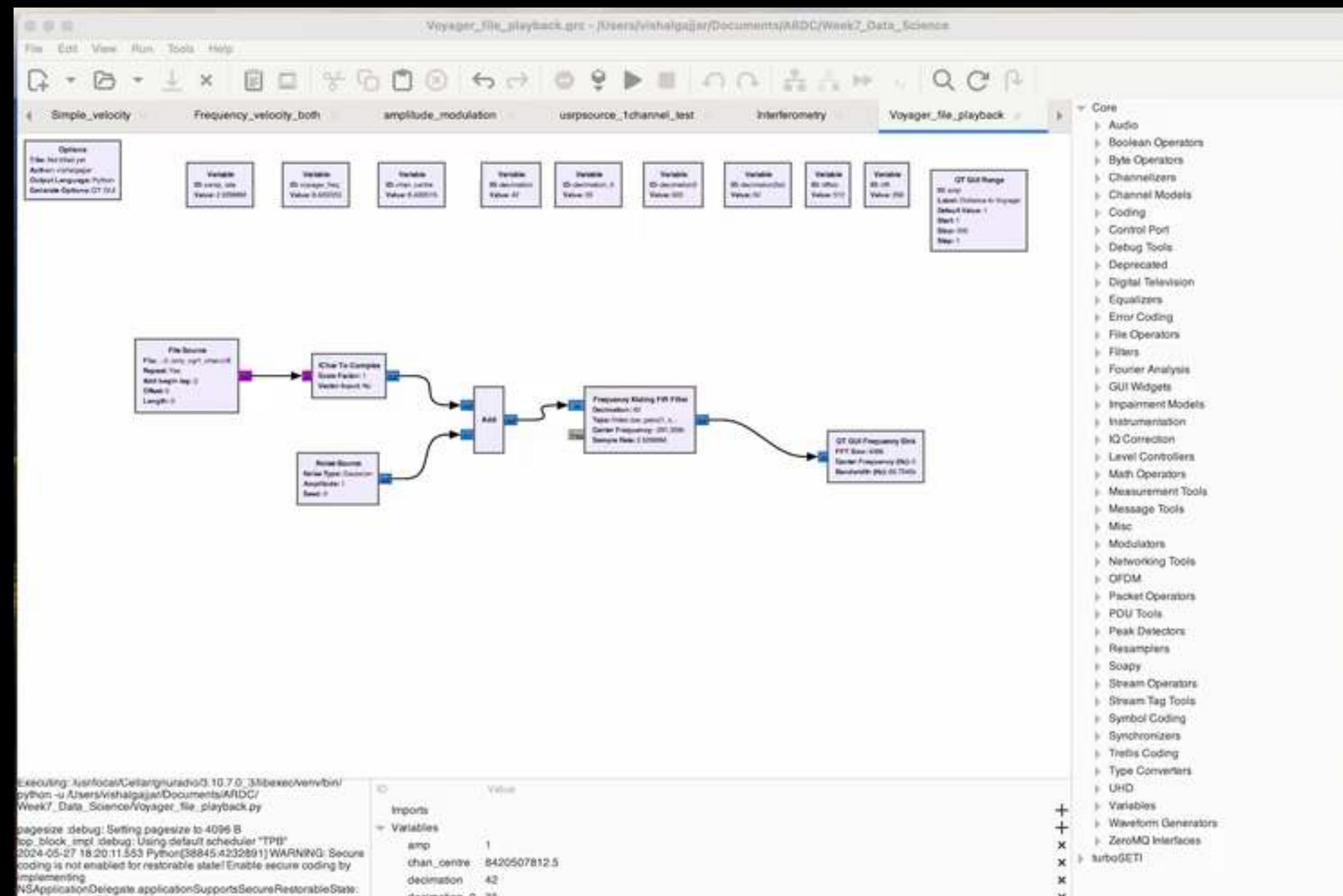
This screenshot shows the Voyager 1 status page on the JPL website. It displays the current position of Voyager 1 in interstellar space, having passed the Oort Cloud. The page includes details about its launch date (5 SEP. 1977), primary target (Outer Solar System), and current status (Going Interstellar Since 2012). It also provides the current distance from Earth (15.13 billion miles) and speed relative to the Sun (37,878 mph). The interface includes a search bar and links to the solar system and spacecraft location.

Launched in 1977

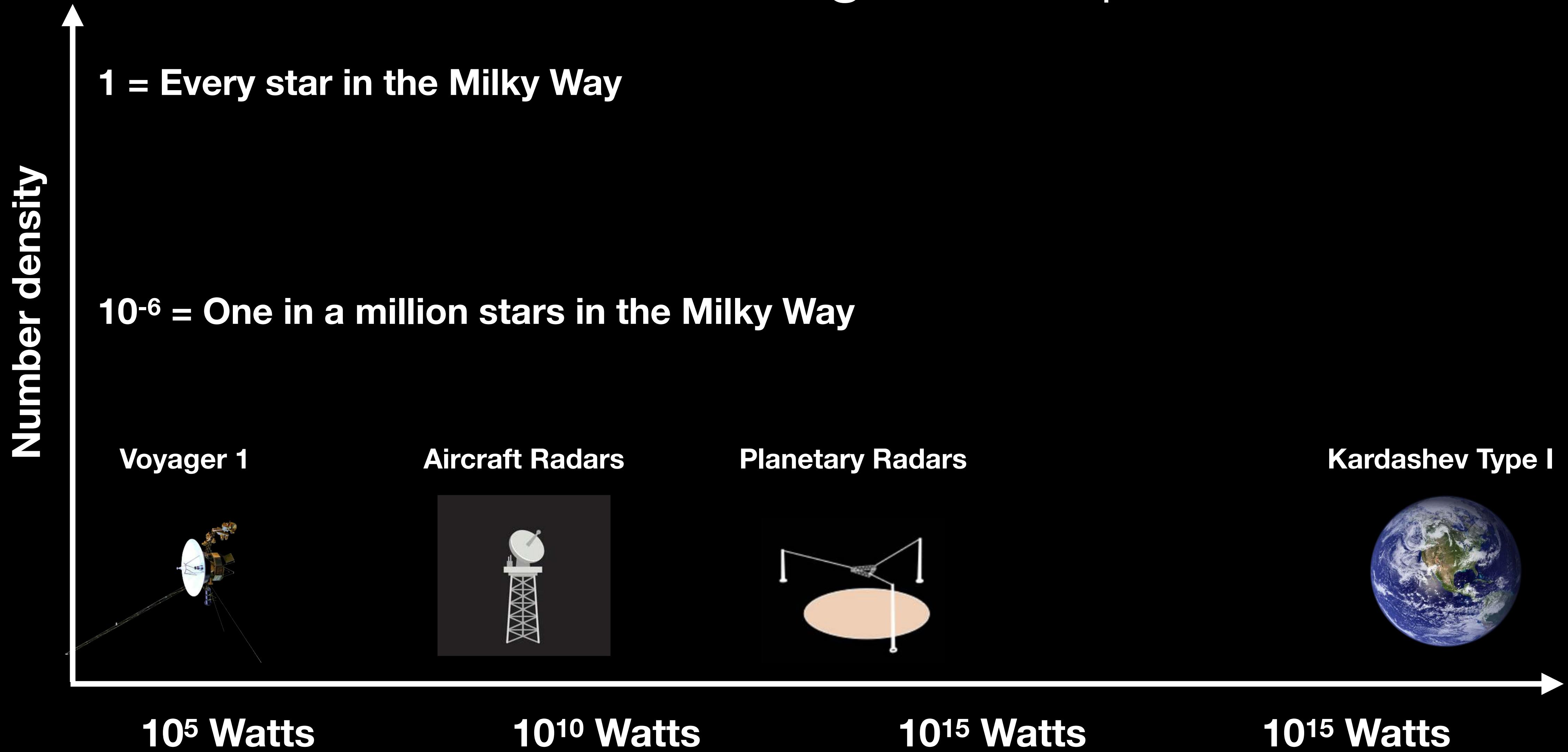
Furthest traveled human made object
Distance of about 24 billion kilometers

On-board transmitter power : 24 W (less than the refrigerator bulb)

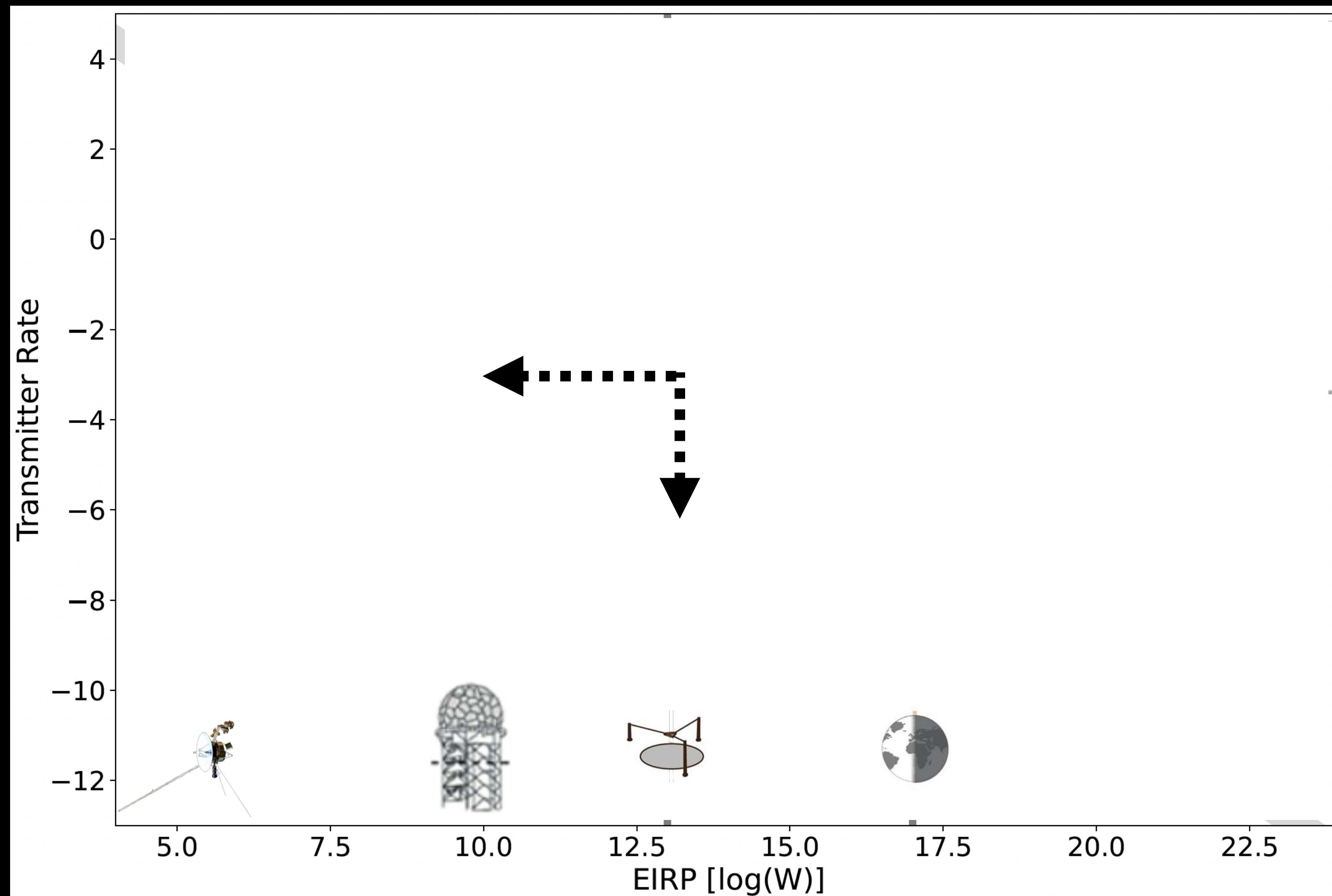
Hands-on Lab: Detecting Voyager 1



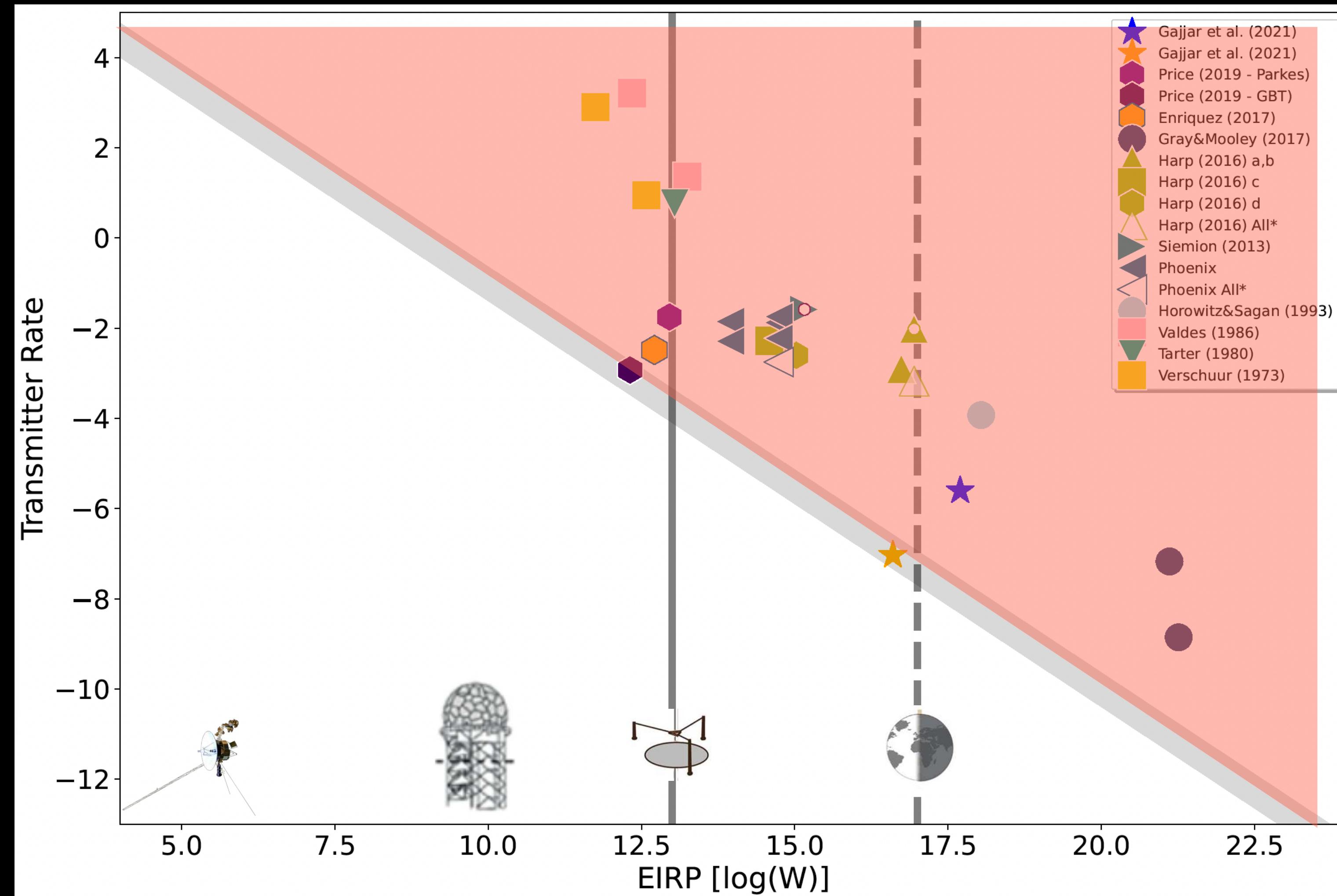
Can we detect Voyager-like signals from nearby stars with the existing telescopes?



Can we detect Voyager-like signals from nearby stars with the existing telescopes?



Can we detect Voyager-like signals from nearby stars with the existing telescopes?



Enriquez et al. 2017; Gajjar et al. 2021

Allen Telescope Array



- 42 Antenna
- Frequency covered from 1 to 10 GHz
- Primary focus: Searching for Extra-Terrestrial Intelligences

Credit: Luigi Cruz (HCRO)

HANDS-ON LAB?

- Estimating number of civilization that can communicate with us.
- Based on the detection of Voyager spacecraft signal from a 100m dish, how big telescope do we need to detect it from our nearest star systems.

Summary

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- Bridging Theory and Practice → • ATA Telescope Access
- Utilizing Cutting-Edge Technology → • Training Workshops with other instructors
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- Updating Curriculum Content →