

# THE SEARCH FOR EXTRATERRESTRIAL INTELLIGENT LIFE

Ramiro Saide

DARA TRAINING



MANCHESTER  
1824

The University  
of Manchester

# WE ARE NOT ALONE



THE QUESTION OF WHETHER WE ARE ALONE IN THE UNIVERSE,  
**HAS BEEN ANSWERED.**

03.2019

FLEEING CHAOS IN  
EL SALVADOR

CARNIVAL  
CELEBRATIONS

EXPLORING  
BORNEO'S CAVES

## NATIONAL GEOGRAPHIC

# WE ARE NOT ALONE

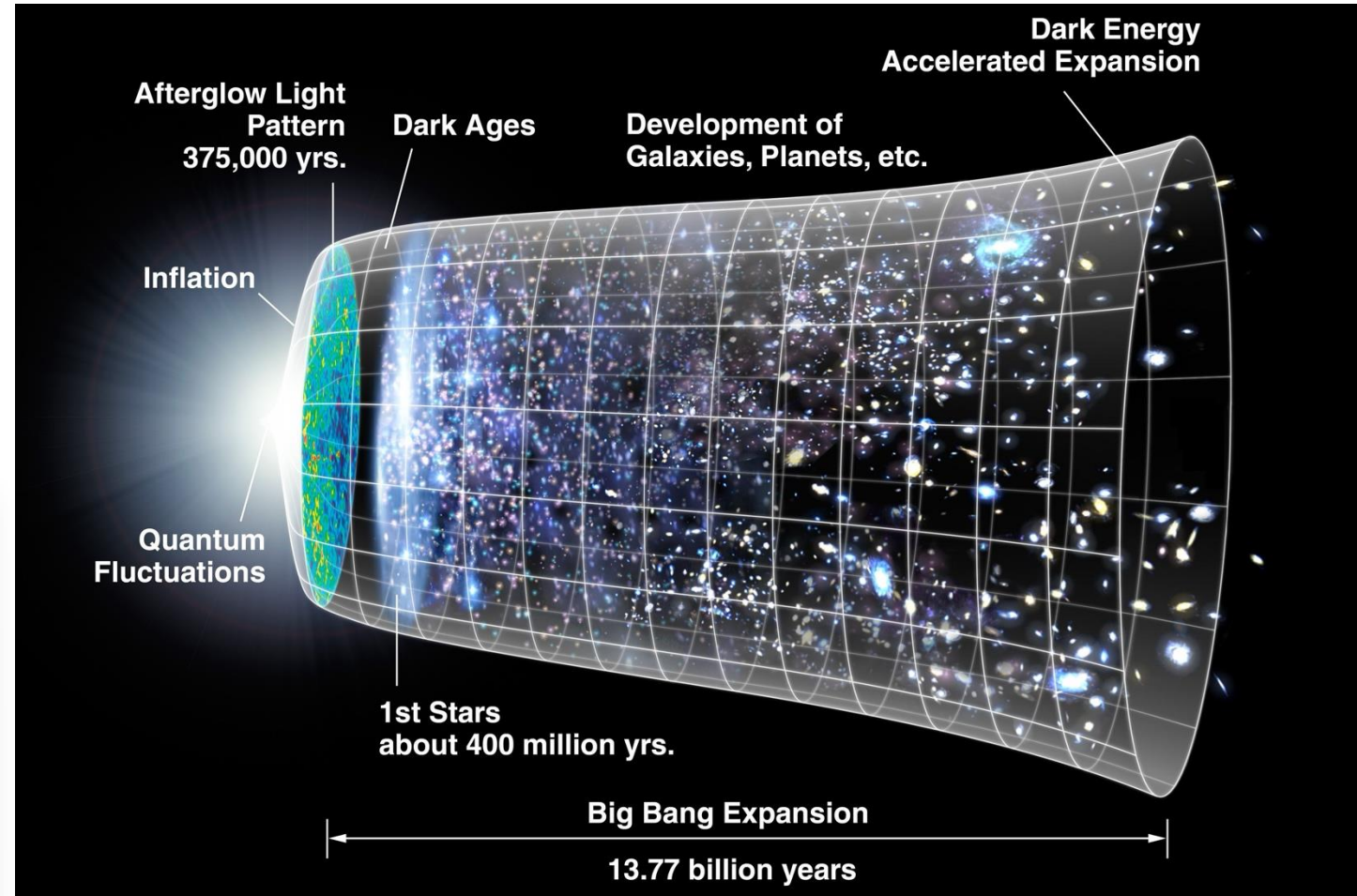
Scientists say there must be other life in the universe.  
Here's how they're searching for it.



*"Something great is  
around those stars."*

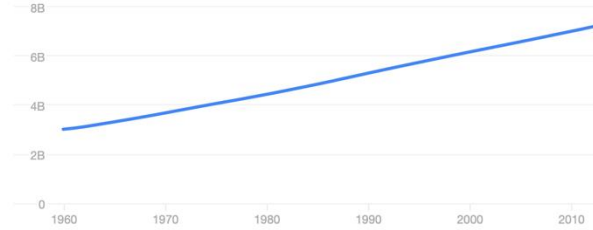
SARA SEAGER,  
ASTROPHYSICIST

# The Journey for Life



World / Population

8.142 billion (2024)



Explore more >

Sources include: World Bank

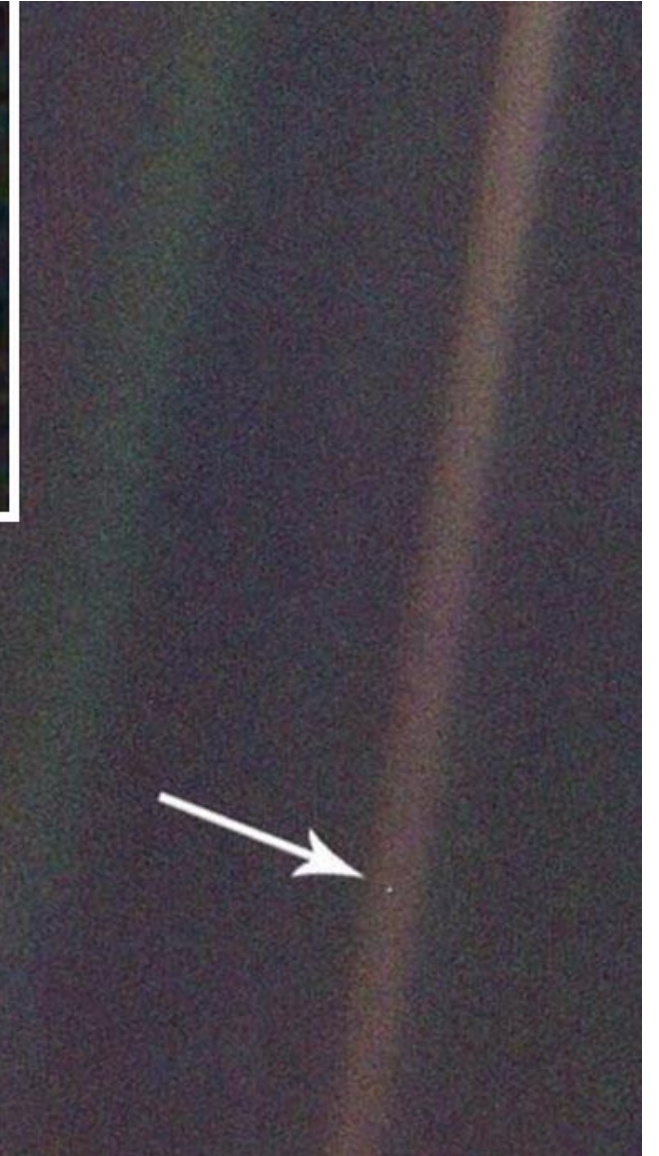


Worldometer

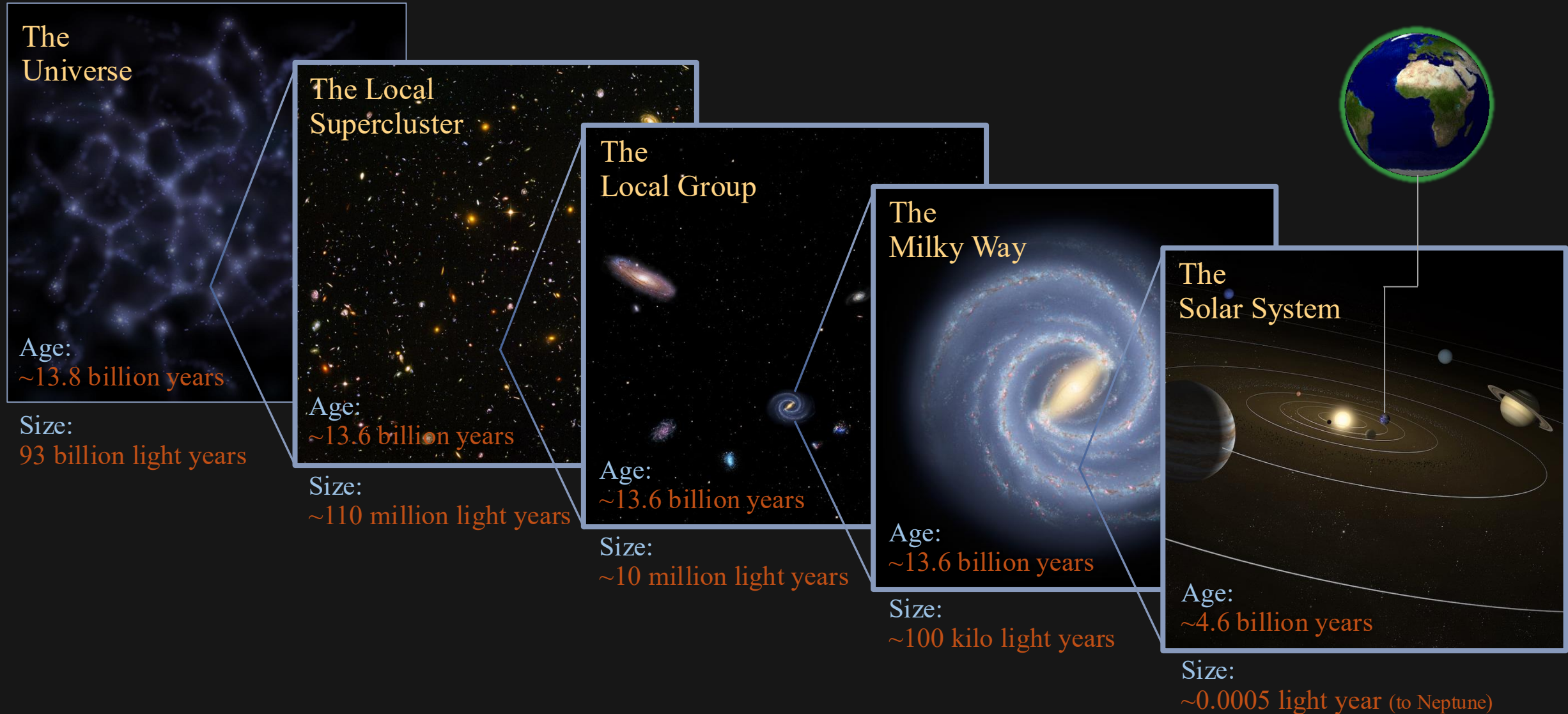
<https://www.worldometers.info/world-population>

World Population Clock: 8.2 Billion People (LIVE, 2025)

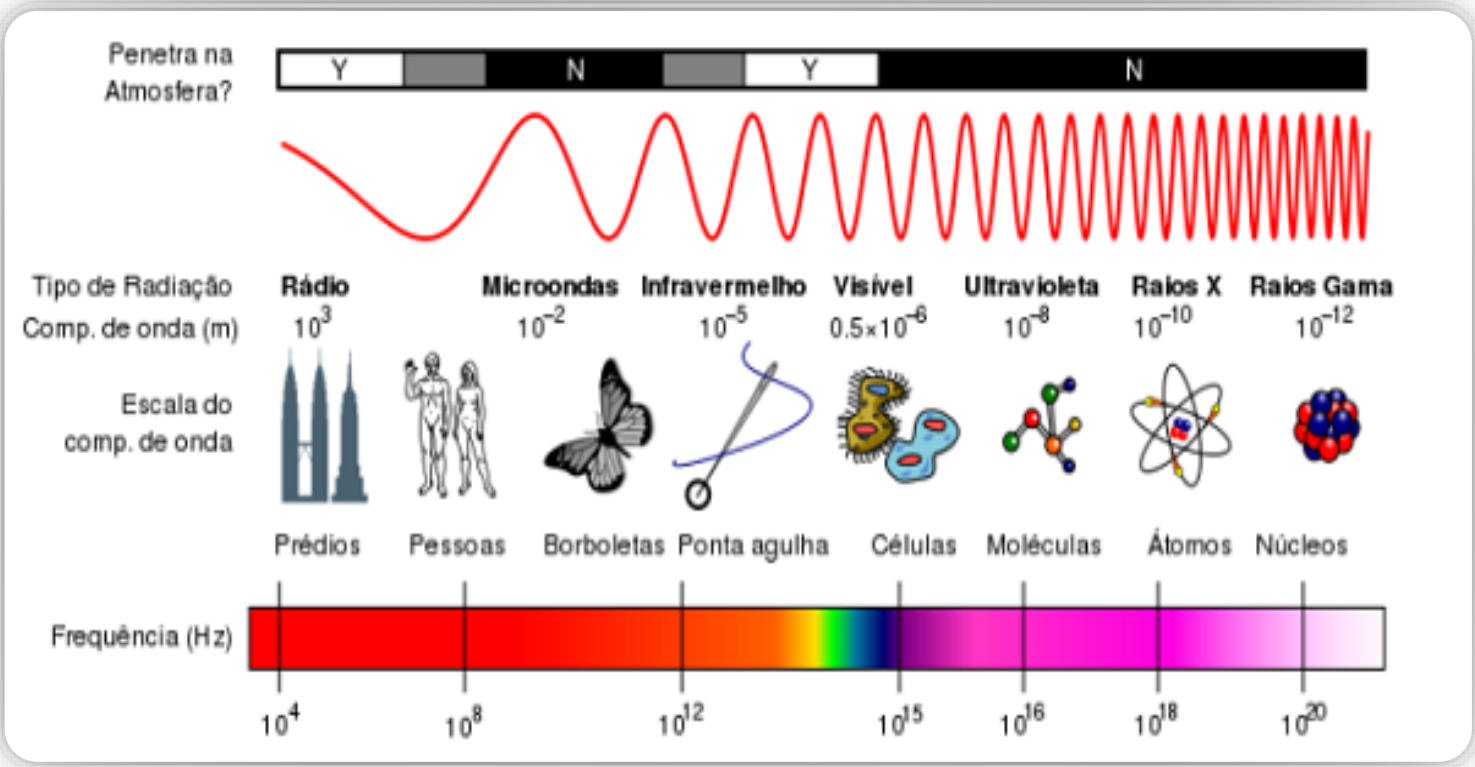
The current world population is 8,247,087,524 as of Friday, September 19, 2025 according to recent United Nations estimates [1] elaborated by ...



# Where are we in the Universe?



# How does the universe communicate with us?



# SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI\* and PHILIP MORRISON†

Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation ; (2) origin of life ; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known ; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

\* Now on leave at CERN, Geneva.

† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be ?

## The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

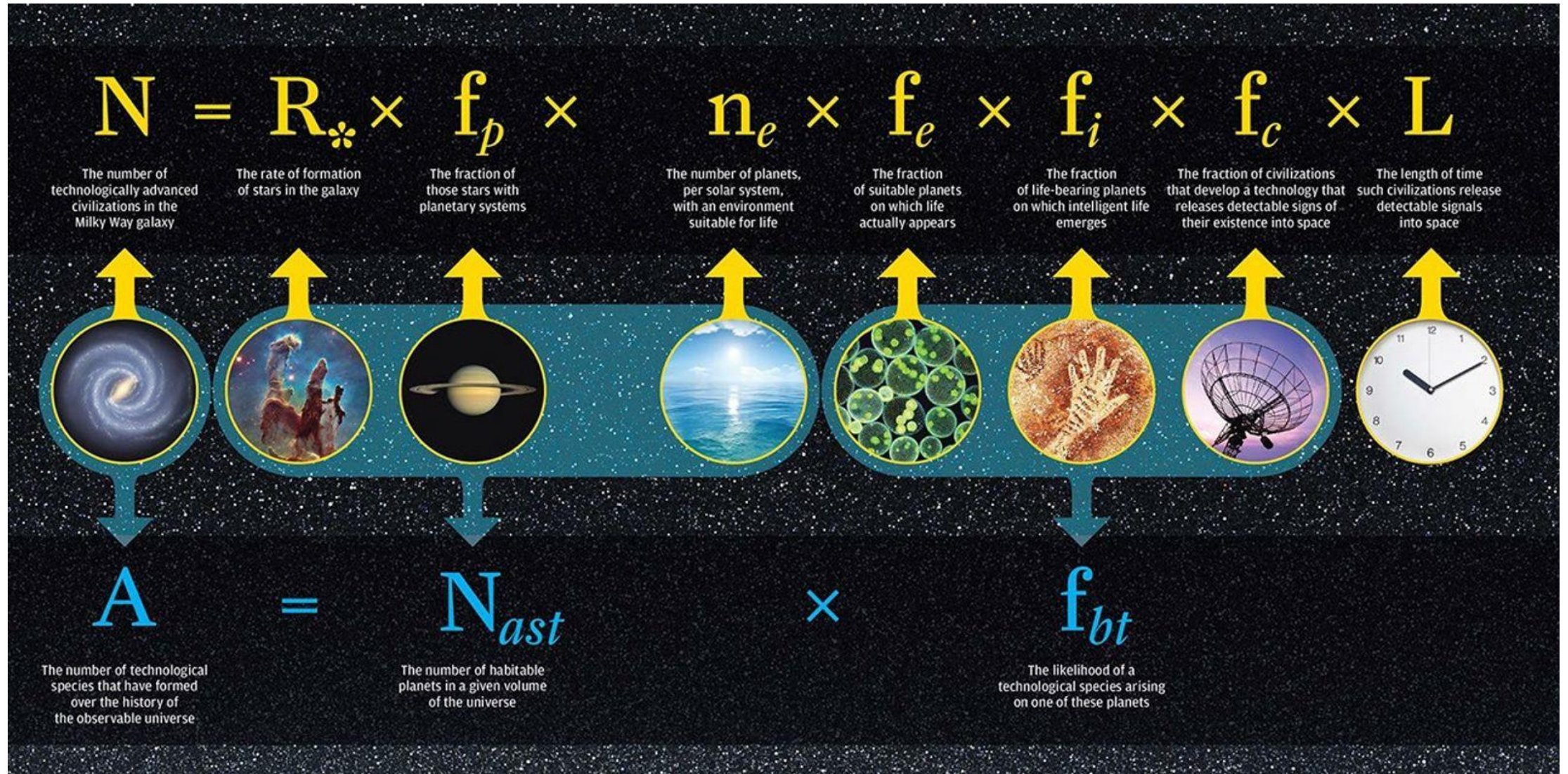
Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-

# Project Ozma

- In 1960 Dr Frank Drake performed the first world's SETI experiment.
- Dr Drake and his team observed the stars Tau Ceti (~12 ly) and Epsilon Eridani(~11 ly).
- The observation was conducted at 21 cm (1420 MHz) – 200 hours in total at 100Hz BW.
- 2000\$ for the narrowband filters.
- **No signs of ETI were detected.**

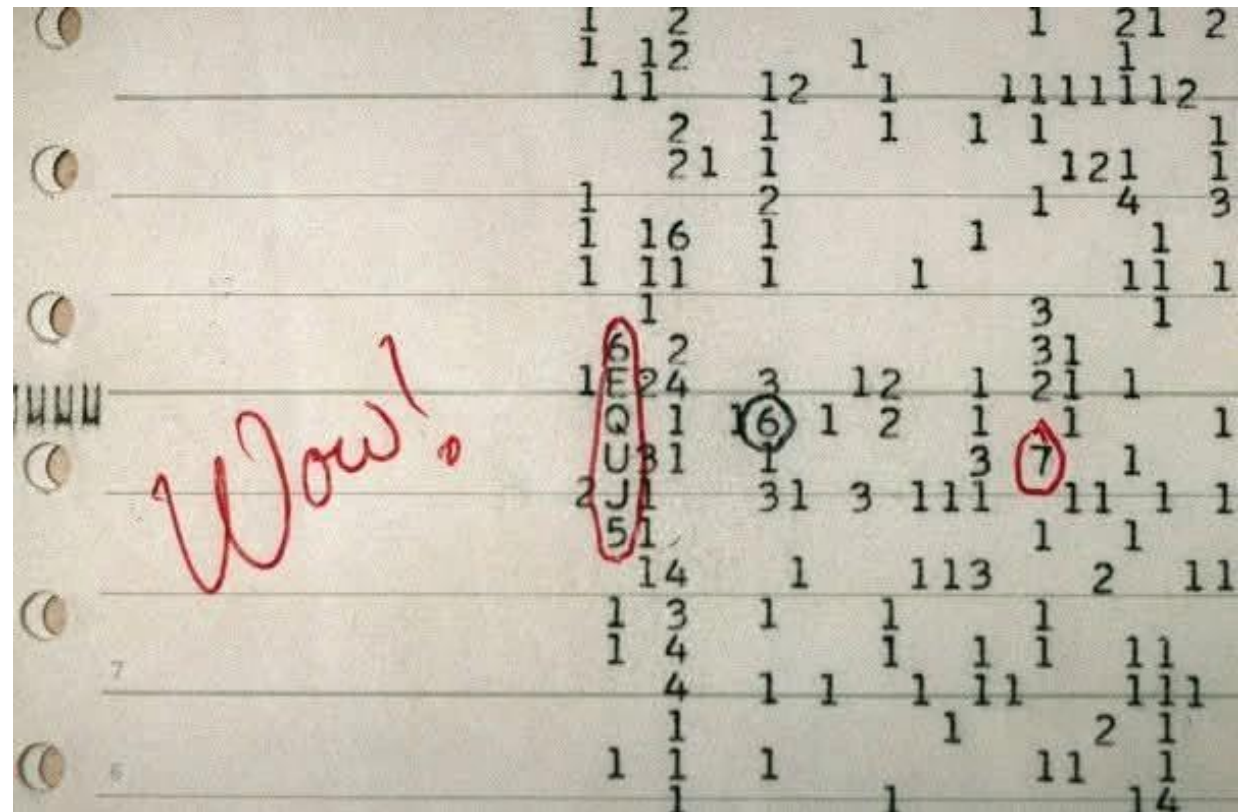


# The Drake Equation



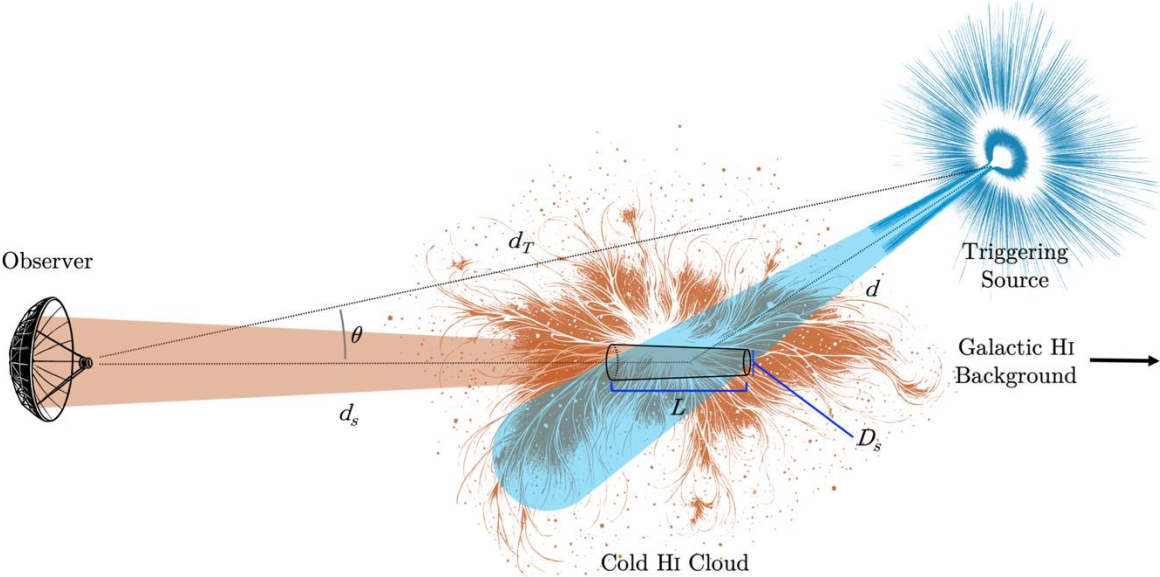


# The Wow! Signal



# The Wow! Signal

The Wow! Signal was caused by a sudden brightening of the hydrogen line in the clouds triggered by a strong transient radiation source, such as a magnetar flare or a soft gamma repeater (Mendez et., 2024).



| Parameter                                     | Value                                                          |
|-----------------------------------------------|----------------------------------------------------------------|
| Date                                          | August 15, 1977                                                |
| Time                                          | 22:16:01s (10:16:01 PM) EST (02:16 UTC, August 16)             |
| Location                                      | Sagittarius Constellation                                      |
| Frequency                                     | $1420.4556 \pm 0.005$ MHz                                      |
| Observation Frame                             | Galactic Center of Rest (GCR)                                  |
| Bandwidth                                     | narrowband ( $\leq 10$ kHz)                                    |
| Signal Strength                               | $30.5 \pm 0.5$ times background noise (SNR $\approx 30$ to 31) |
| Duration                                      | 72 seconds                                                     |
| Positive (West) Horn Coordinates (Equatorial) | RA: 19h 25m 31s $\pm$ 10s, Dec: -26d 57m $\pm$ 20m (J2000)     |
| Negative (East) Horn Coordinates (Equatorial) | RA: 19h 28m 22s $\pm$ 10s, Dec: -26d 57m $\pm$ 20m (J2000)     |
| Positive (West) Horn Coordinates (Galactic)   | lon: 11d 39.0m $\pm$ 0.9m, lat: -18d 53.4m $\pm$ 2.1m          |
| Negative (East) Horn Coordinates (Galactic)   | lon: 11d 54.0m $\pm$ 0.9m, lat: -19d 28.8m $\pm$ 2.1m          |
| Estimated Intensity                           | $\approx 54$ or 212 Jy                                         |

# Why Radio?

**Distinct from nature:** coherent radio signatures (e.g., narrowband,  $\sim$ Hz resolution, precisely drifting tones) are rare in natural astrophysical sources.

**Favorable propagation:** signals in the radio window ( $\sim$ 1–10 GHz) transverse interstellar medium with comparatively low attenuation and scattering.

**Information-rich:** radio photons can carry high-bit-rate information across vast distances.

**Energy-efficient:** radio waves are cheap to generate; high ERP is achievable with modest transmitter power and antenna gain.



# Different windows



| Industrial activity                      | Possible technosignature                                 | Ref. |
|------------------------------------------|----------------------------------------------------------|------|
| Antimatter reactor                       | Pionic gamma rays & neutrinos, positronic gamma rays     | [10] |
| Antimatter rocket                        | Annihilation gamma rays, high proper motion              | [9]  |
| Dark matter reactor                      | Possible gamma spectral line, neutrinos, other particles | [32] |
| Nuclear energy usage                     | Sub-MeV to MeV antineutrinos, isotopic signatures        | [11] |
| Particle accelerators                    | Ultrahigh-energy neutrinos, possible GRB-like transients | [18] |
| Primordial black hole reactor            | High-energy electromagnetic radiation from evaporation   | [25] |
| Radioactive ISM tracers                  | Gamma-ray lines, nuclides on ocean floor                 |      |
| Relativistic shrapnel                    | Apparent ultrahigh-energy cosmic rays in atmosphere      |      |
| Stellar engineering via neutrino heating | Stray pionic emission                                    | [23] |
| Ultrarelativistic craft                  | Boosted reflected starlight, interaction gamma-rays      | [8]  |
| XRB Dyson sphere                         | X-ray occultations, too dim in X-rays, infrared excess   | [16] |
| XRB stellar engines                      | XRB with unusual proper motion                           | [30] |

Table 1: Examples of hypothetical high-energy industrial technosignatures.

(Lacki & DiKerby, 2025)



# Types of Civilizations

## Type I: Planetary Civilization ( $10^{16}$ W)

- Harnesses all available energy on its home planet such as solar, wind, and geothermal power.

## Type II: Stellar Civilization ( $10^{26}$ W)

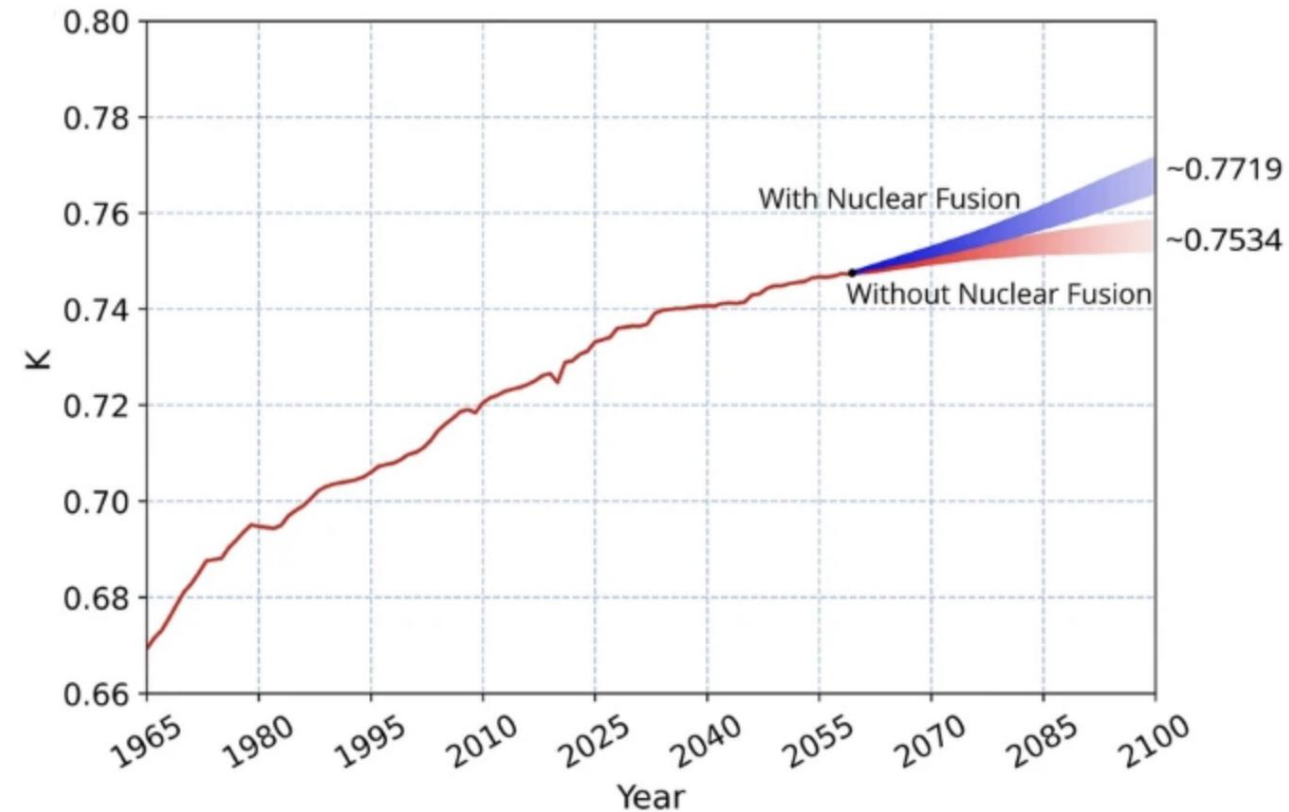
- Harnesses the total energy output of its host star, possibly using structures like Dyson spheres.

## Type III: Galactic Civilization ( $10^{36}$ W)

- Harnesses the energy of its entire host galaxy, potentially by controlling supermassive black holes.

$$K = \frac{\log P - 6}{10}$$

*Earth,  $K = \sim 0.7276$*



(Zhang et al., 2023)

# Did We Really Find Dyson Spheres?

Science / Space

‘Dyson spheres’ were theorized as a way to detect alien life. Scientists say they’ve found potential evidence

By Jacopo Prisco, CNN  
9 minute read · Published 7:00 AM EDT

NewScientist

Space

Dozens of stars show signs of hosting advanced alien civilisations

Sufficiently advanced aliens would be able to capture vast quantities of energy from their star using a massive structure called a Dyson sphere. Such a device would give off an infrared heat signature - and astronomers have just spotted 60 stars that seem to match

By Jonathan O’Callaghan  
10 May 2024

METRO

NEWS ENTERTAINMENT SPORT LIFESTYLE

Mysterious objects in space could be proof of alien life

Hiyah Zaidi  
Published May 15, 2024 3:11pm Updated May 15, 2024 6:22pm

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Project Hephaistos – II. Dyson sphere candidates from Gaia DR3, 2MASS, and WISE

ABSTRACT

ALIEN MEGASTRUCTURES?

NEW STUDY FINDS POTENTIAL ‘DYSON SPHERES’

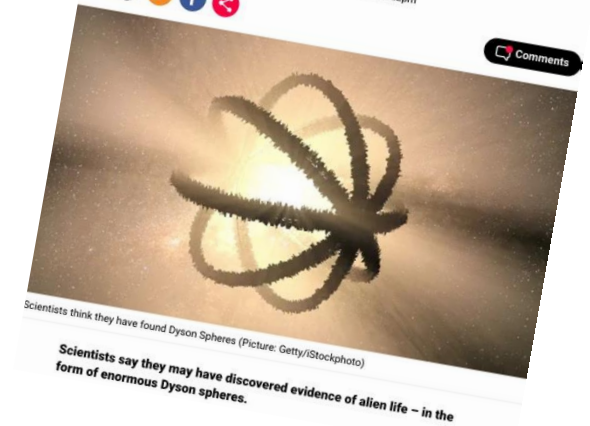
NBC NEWS NOW

New study finds potential alien mega-structures known as ‘dyson spheres’

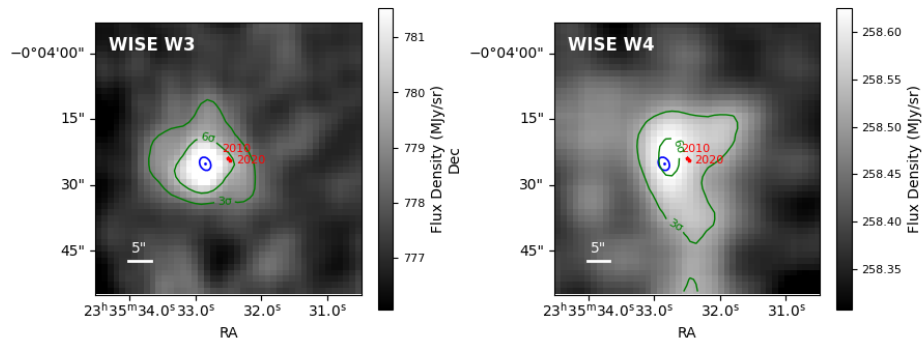
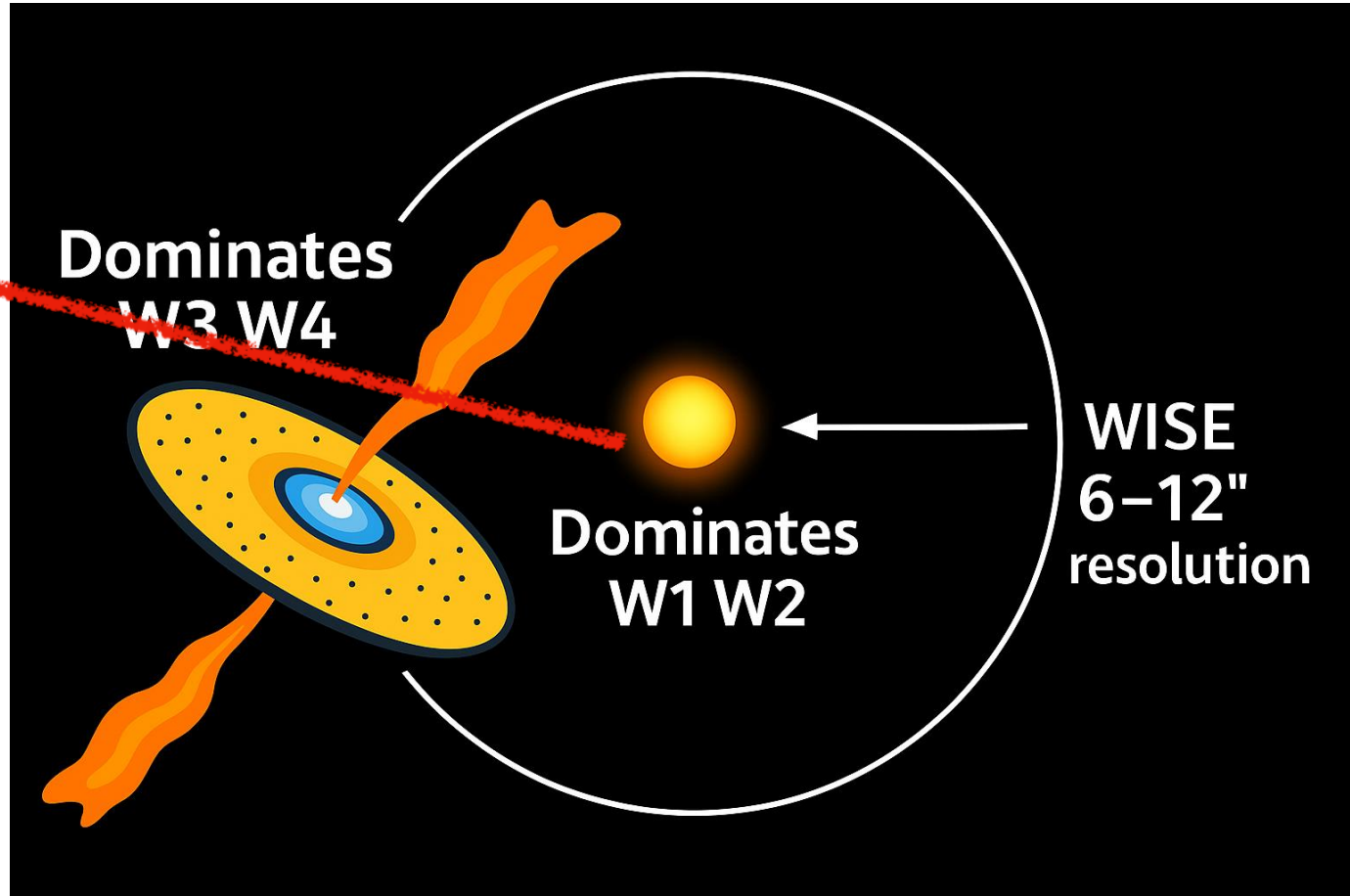
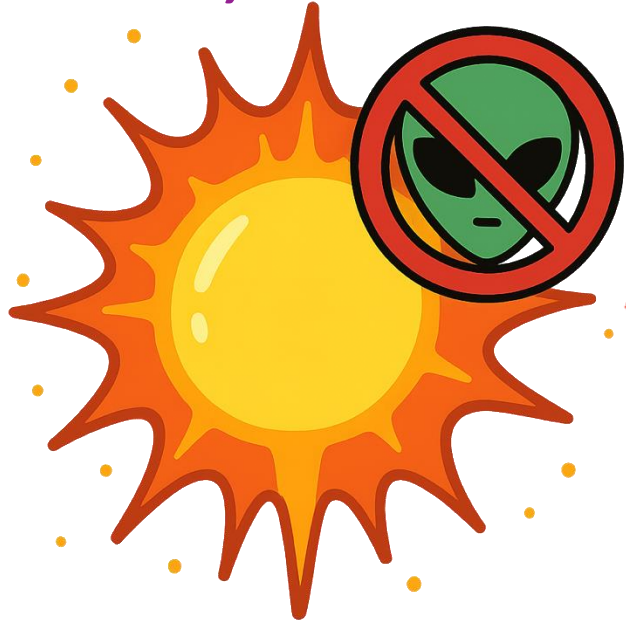
A group of researchers have identified at least seven stars that might be surrounded by advanced alien mega-structures known as “dyson spheres.” NBC News’ Ellison Barber speaks with Janna Levin, a professor of physics and astronomy at Barnard College, about the findings and whether the truth is out there.

June 14, 2024

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# So, no ETs?



The mid-infrared light once thought to be the ET's industrial waste heat, is actually from a nearby Hot, Dust-Obscured Galaxy (**Hot DOG**).

Credit: Ren et al., 2025)

# Panspermia Theory

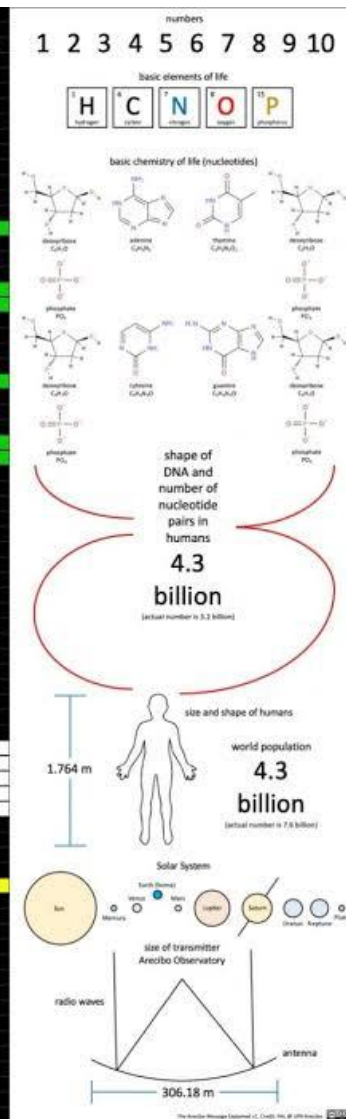
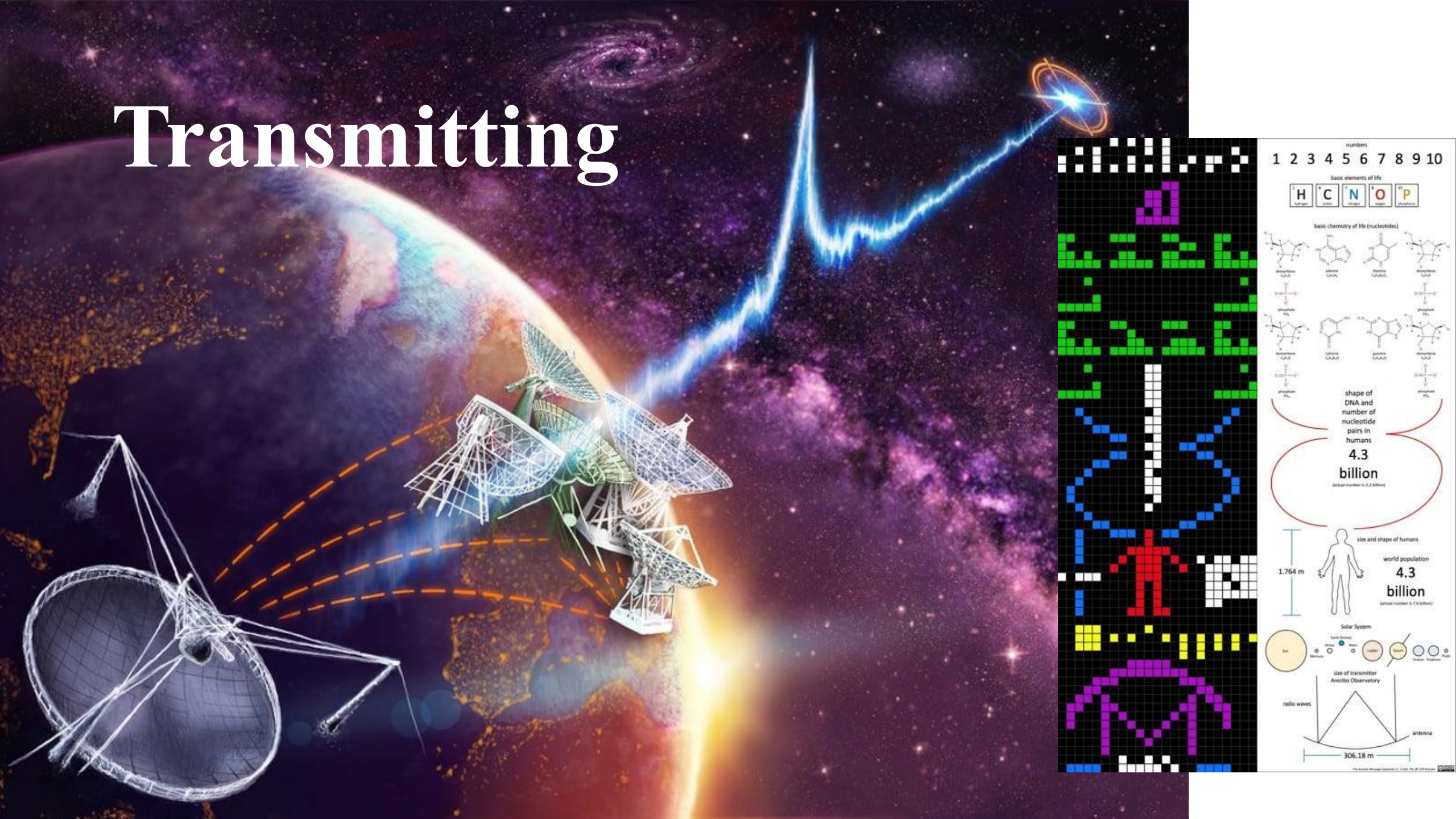




# Listening

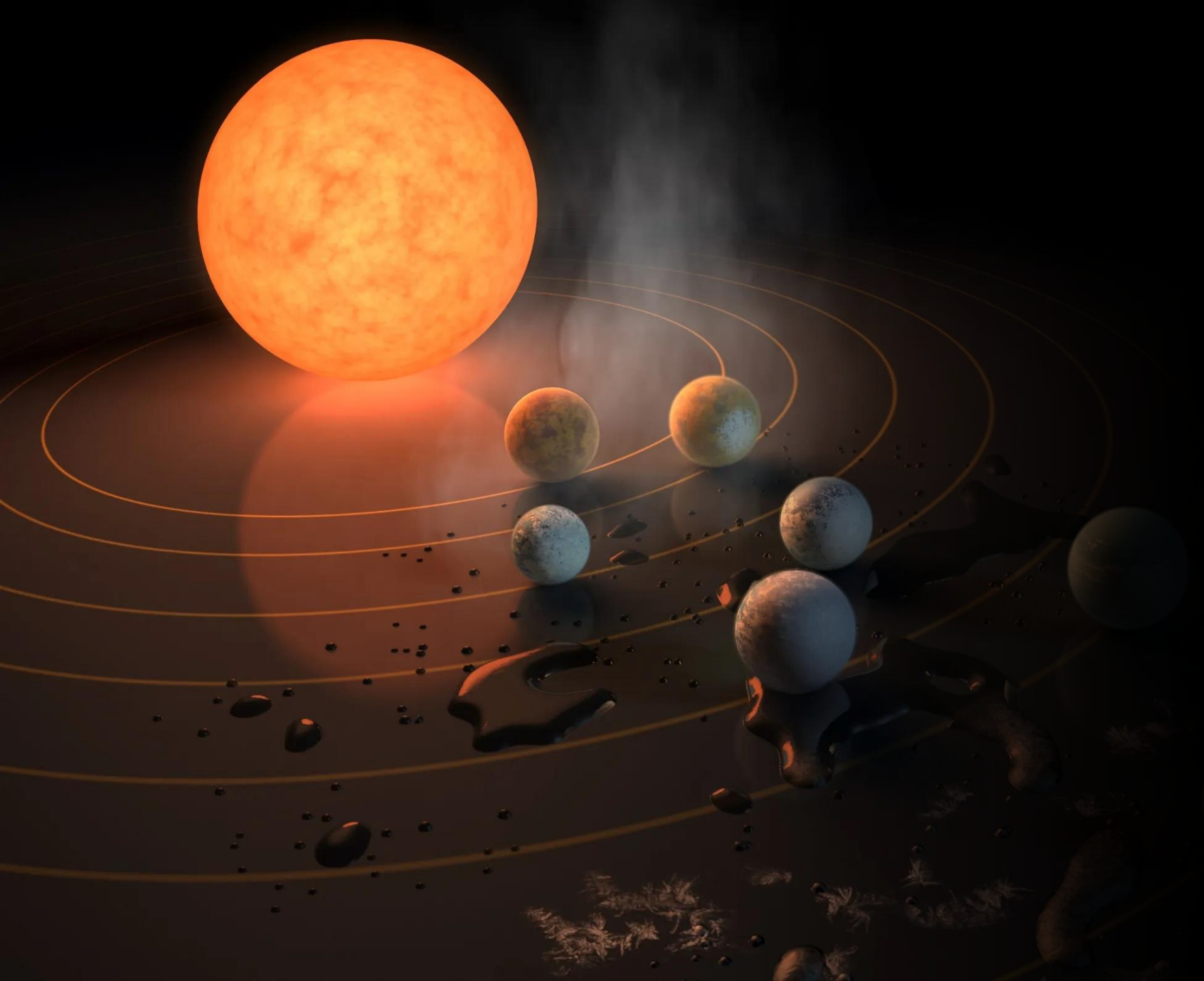


# Transmitting



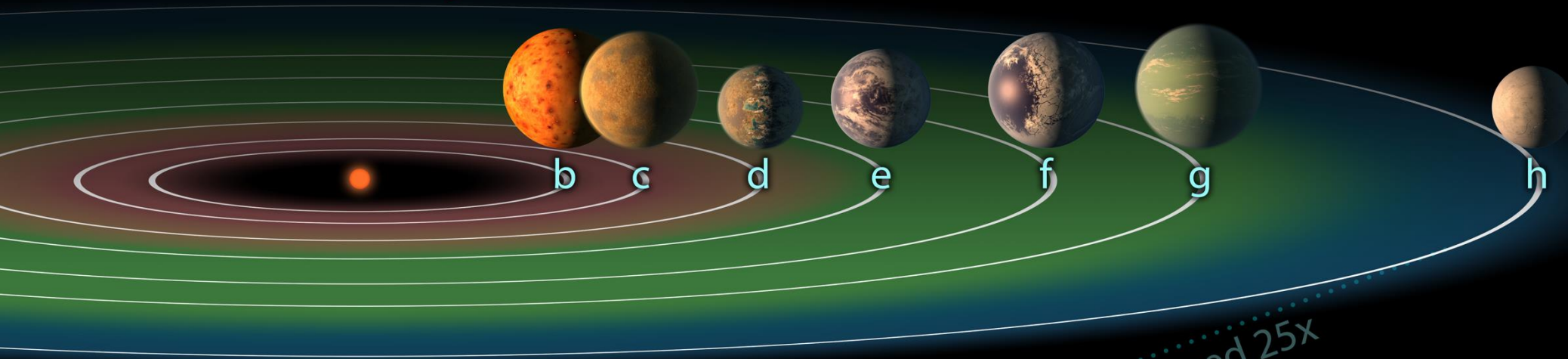
# Direct Sampling



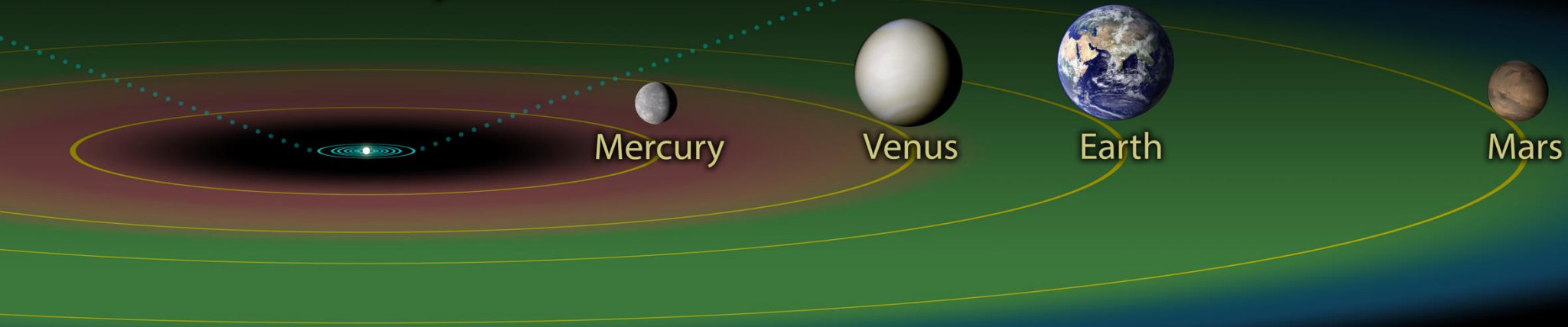


# Life in our Solar System

## TRAPPIST-1 System



## Inner Solar System



Enlarged 25x

# Mars

- Evidence shows that Mars once had long-lived surface water.
- Mars once had a thicker, warmer atmosphere.
- Essential bio-elements are present such as C, H, O, N, S — building block of biomolecules.
- Earth day length aids environmental rhythms.

nature

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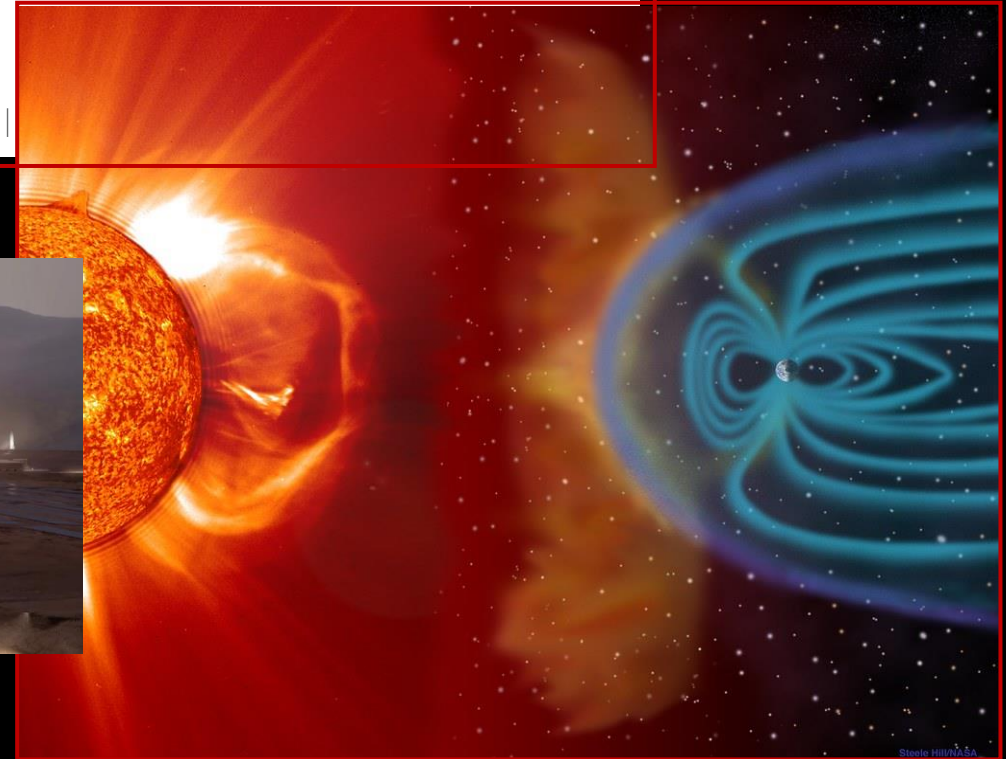
Article | [Open access](#) | Published: 10 September 2025

## Redox-driven mineral and organic associations in Jezero Crater, Mars

[Joel A. Hurowitz](#) , [M. M. Tice](#), [A. C. Allwood](#), [M. L. Cable](#), [K. P. Hand](#), [A. E. Murphy](#), [K. Uckert](#), [J. F. Bell III](#), [T. Bosak](#), [A. P. Broz](#), [E. Clavé](#), [A. Cousin](#), [S. Davidoff](#), [E. Dehouck](#), [K. A. Farley](#), [S. Gupta](#), [S.-E. Hamran](#), [K. Hickman-Lewis](#), [J. R. Johnson](#), [A. J. Jones](#), [M. W. M. Jones](#), [P. S. Jørgensen](#), [L. C. Kah](#), [H. Kalucha](#), ... [Z. U. Wolf](#) [+ Show authors](#)

[Nature](#) **645**, 332–340 (2025) | [Cite this article](#)

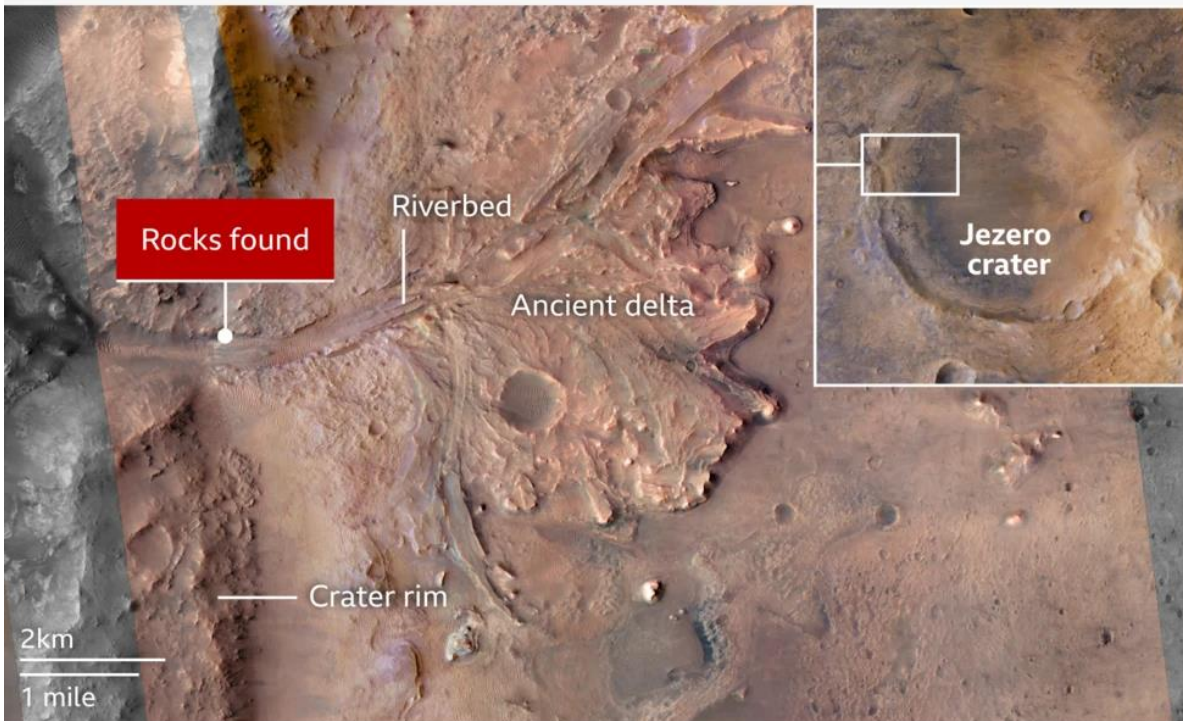
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# Mars

- Perseverance found organic-carbon-bearing mudstones with iron-phosphate (vivianite) and iron-sulfide (greigite).
- These minerals formed through low-temperature redox reactions involving organic matter after the sediments were deposited.
- Samples on Earth are needed to further analysis.

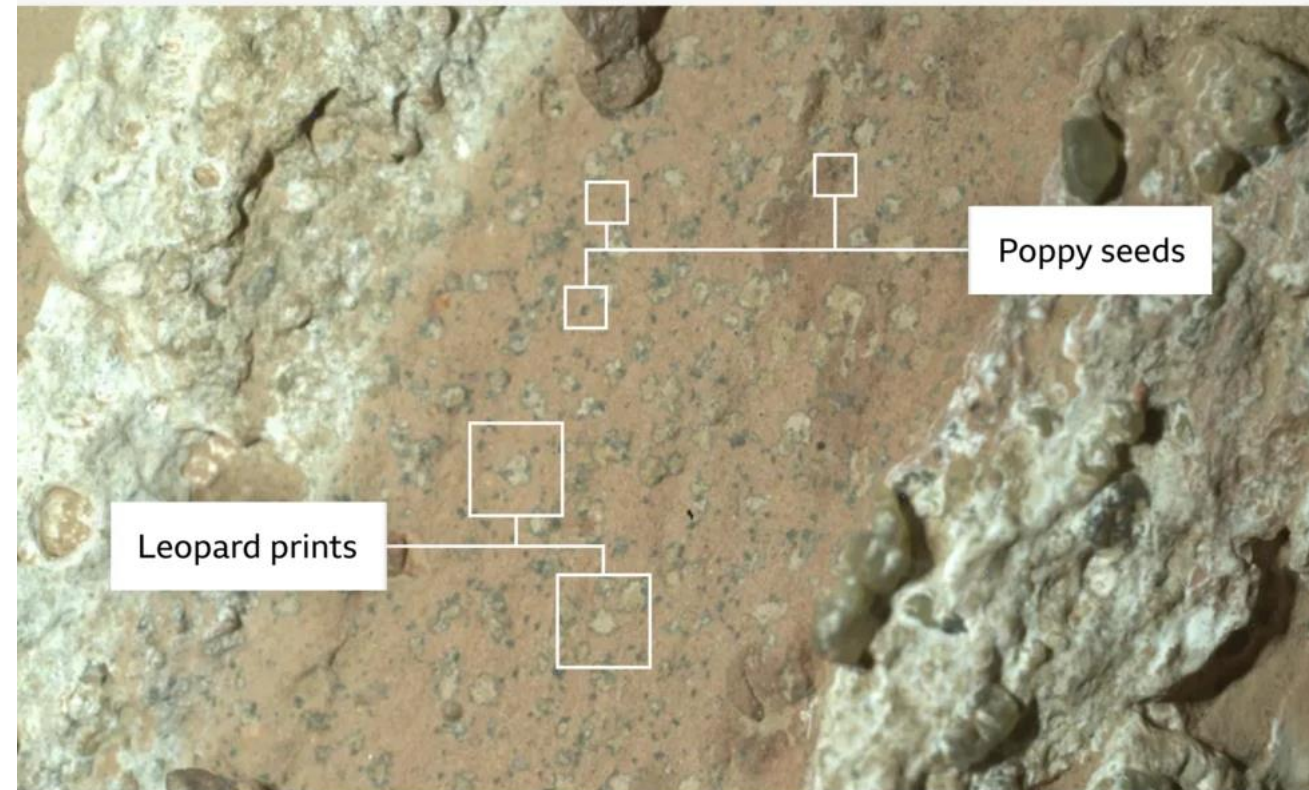
Inside Mars' Jezero crater



Source: Aster Cowart/NASA/ESA

BBC

Mineral rock markings may have been made by microbes



Source: Nasa

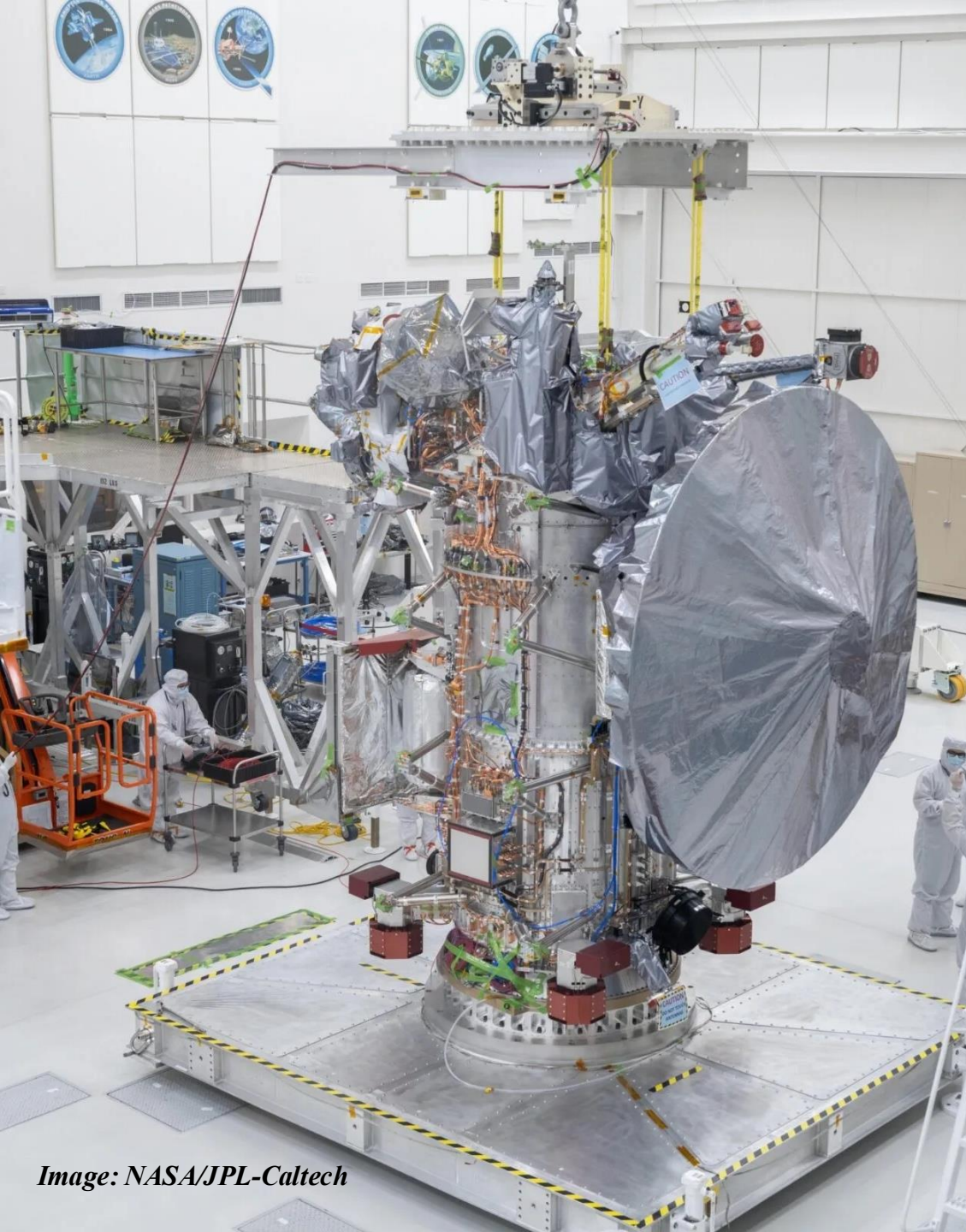
BBC

# Europa

---



- Tidal forces squeeze and heat Europa's interior allowing liquid water to exist.
  - Europa's subsurface oceans are thought to contain twice as much water as all of Earth's oceans combined.
  - Measurements of magnetic field suggest salt water, hinting contact with rocky seabed — potential source of life-giving energy.
-



*Image: NASA/JPL-Caltech*

# Nasa Europa Clipper

- **Ice-penetrating radar:** Maps Europa's ice and possible internal lakes.
- **Europa Clipper Magnetometer + Plasma Instrument for Magnetic Sounding:** Measure magnetic properties to provide strong evidence of a subsurface ocean; help determine the depth of the icy shell and ocean.
- **Europa Thermal Emission Imaging System + Europa Imaging System (EIS):** Two camera sets at different wavelengths to map the surface and search for plumes.
- **Surface Dust Analyser:** Detects small particles ejected from Europa that could trace potential plumes.
- **Europa-UVS, MISE, MASPEX (3 spectrometers):** Measure the composition of Europa's surface and atmosphere to infer the makeup of its hidden ocean.

# Enceladus



- South pole is covered in a series of fissures through which plumes of water have been observed shooting up into space.
- Cassini flew thorough Enceladus plumes several times between 2007–2015 to analyse the water composition (phosphorus).
- Enceladus Life Finder was proposed to investigate habitability and internal ocean.

Letter | Published: 27 June 2018

## Macromolecular organic compounds from the depths of Enceladus

Frank Postberg [✉](#), Nozair Khawaja, Bernd Abel, Gael Choblet, Christopher R. Glein, Murthy S. Gudipati, Bryana L. Henderson, Hsiang-Wen Hsu, Sascha Kempf, Fabian Klenner, Georg Moragas-Klostermeyer, Brian Magee, Lenz Nölle, Mark Perry, René Reviol, Jürgen Schmidt, Ralf Srama, Ferdinand Stolz, Gabriel Tobie, Mario Trieloff & J. Hunter Waite

*Nature* **558**, 564–568 (2018) | [Cite this article](#)

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### Abstract

Saturn's moon Enceladus harbours a global water ocean<sup>1</sup>, which lies under an ice crust and above a rocky core<sup>2</sup>. Through warm cracks in the crust<sup>3</sup> a cryo-volcanic plume ejects ice grains and vapour into space<sup>4,5,6,7</sup> that contain materials originating from the ocean<sup>8,9</sup>. Hydrothermal activity is suspected to occur deep inside the porous core<sup>10,11,12</sup>, powered by tidal dissipation<sup>13</sup>. So far, only simple organic compounds with molecular masses mostly below 50 atomic mass units have been observed in plume material<sup>6,14,15</sup>. Here we report observations of emitted ice grains containing concentrated and complex macromolecular organic material with molecular masses above 200 atomic mass units. The data constrain the macromolecular structure of organics detected in the ice grains and suggest the presence of a thin organic-rich film on top of the oceanic water table, where organic nucleation cores generated by the bursting of bubbles allow the probing of Enceladus' organic inventory in enhanced concentrations.

# Venus



nature  
astronomy

ARTICLES

<https://doi.org/10.1038/s41550-020-1174-4>



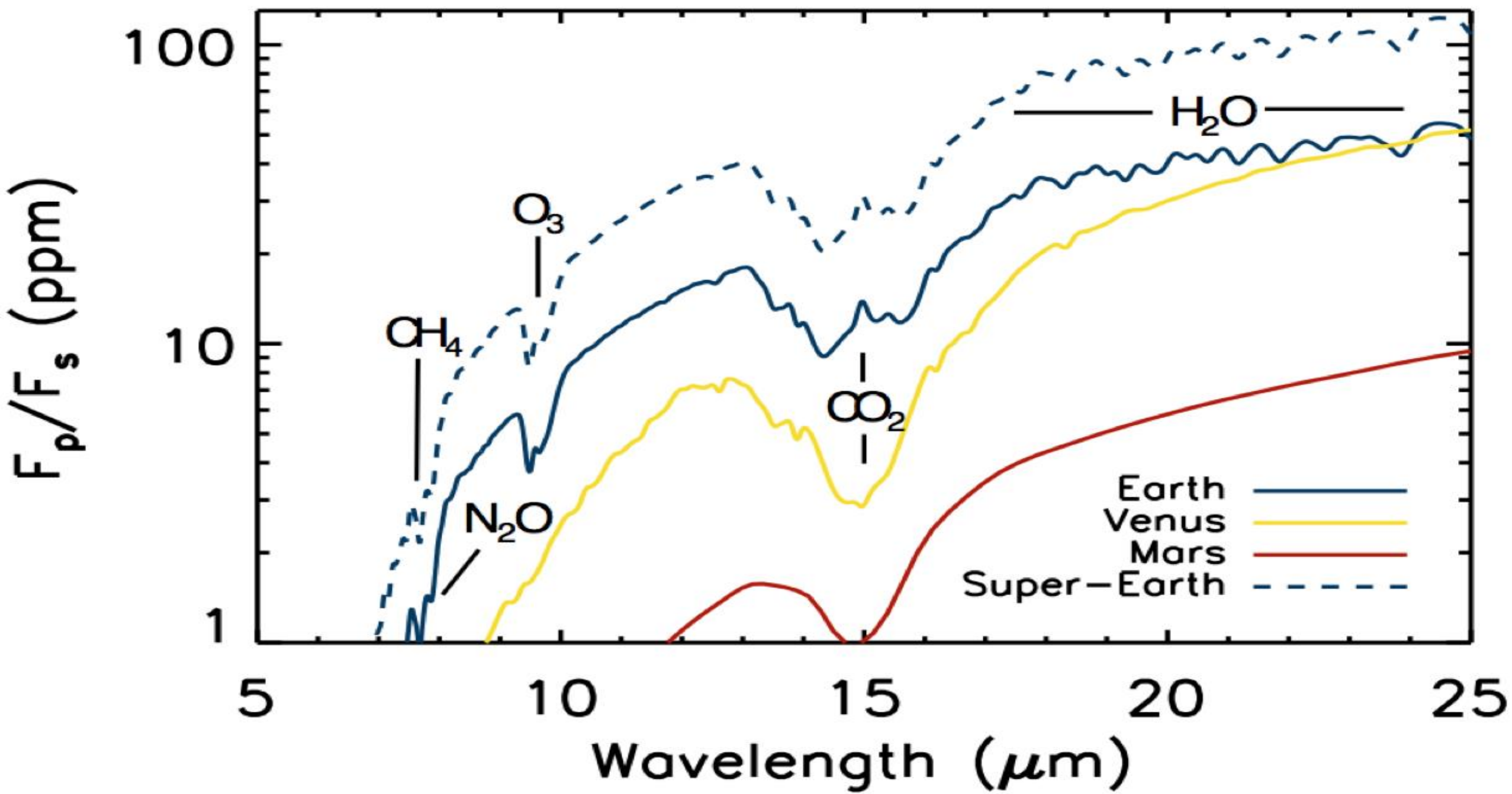
## Phosphine gas in the cloud decks of Venus

Jane S. Greaves<sup>1,2</sup>✉, Anita M. S. Richards<sup>3</sup>, William Bains<sup>4</sup>, Paul B. Rimmer<sup>5,6,7</sup>, Hideo Sagawa<sup>8</sup>, David L. Clements<sup>9</sup>, Sara Seager<sup>4,13,14</sup>, Janusz J. Petkowski<sup>4</sup>, Clara Sousa-Silva<sup>4</sup>, Sukrit Ranjan<sup>4</sup>, Emily Drabek-Maunder<sup>1,10</sup>, Helen J. Fraser<sup>11</sup>, Annabel Cartwright<sup>1</sup>, Ingo Mueller-Wodarg<sup>9</sup>, Zhuchang Zhan<sup>4</sup>, Per Friberg<sup>12</sup>, Iain Coulson<sup>12</sup>, E'lisa Lee<sup>12</sup> and Jim Hoge<sup>12</sup>

Measurements of trace gases in planetary atmospheres help us explore chemical conditions different to those on Earth. Our nearest neighbour, Venus, has cloud decks that are temperate but hyperacidic. Here we report the apparent presence of phosphine ( $\text{PH}_3$ ) gas in Venus's atmosphere, where any phosphorus should be in oxidized forms. Single-line millimetre-waveband spectral detections (quality up to  $\sim 15\sigma$ ) from the JCMT and ALMA telescopes have no other plausible identification. Atmospheric  $\text{PH}_3$  at  $\sim 20$  ppb abundance is inferred. The presence of  $\text{PH}_3$  is unexplained after exhaustive study of steady-state chemistry and photochemical pathways, with no currently known abiotic production routes in Venus's atmosphere, clouds, surface and sub-surface, or from lightning, volcanic or meteoritic delivery.  $\text{PH}_3$  could originate from unknown photochemistry or geochemistry, or, by analogy with biological production of  $\text{PH}_3$  on Earth, from the presence of life. Other  $\text{PH}_3$  spectral features should be sought, while in situ cloud and surface sampling could examine sources of this gas.

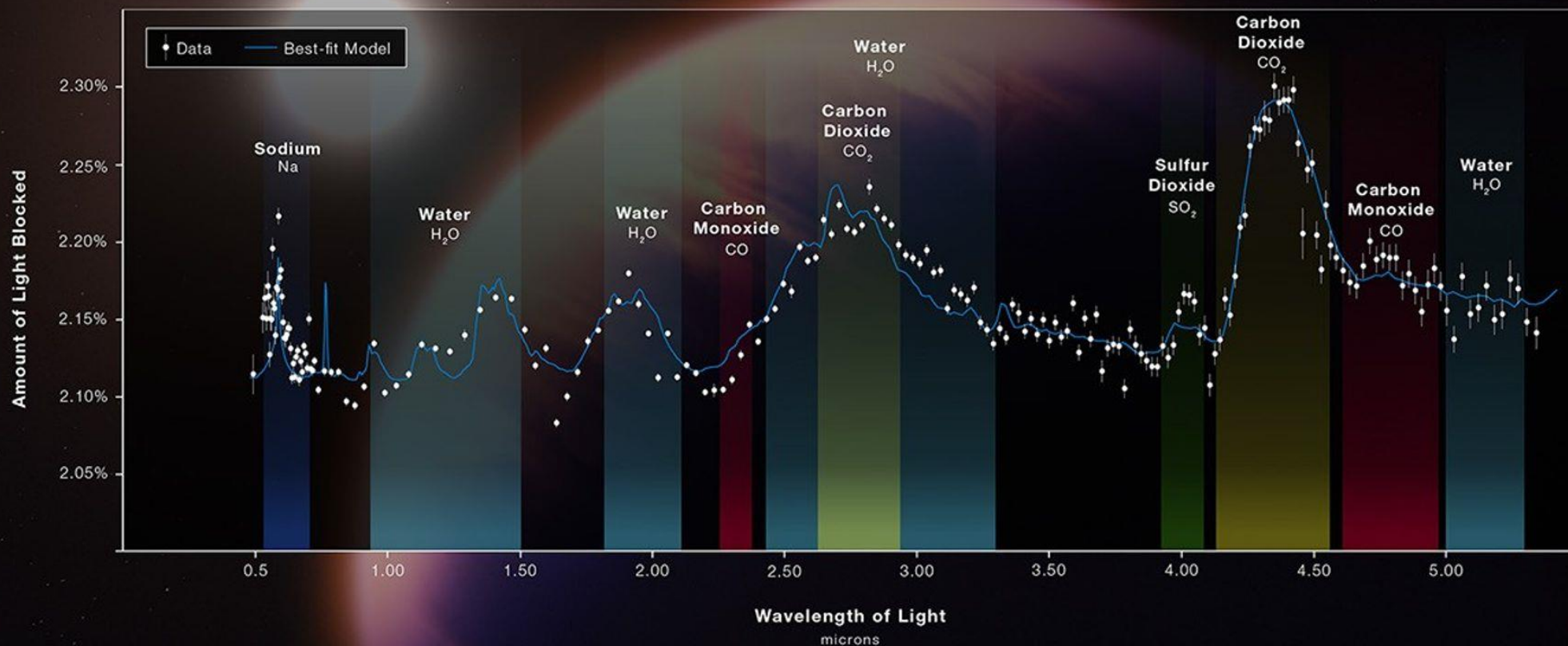
- The hottest planet surface in the solar system (470 degree Celsius).
- Fifty-four times more dense than Earth's — it is the densest terrestrial atmosphere in the solar system.
- The atmospheric pressure on the surface is  $\sim 92$  bar.
- In 2020 scientists detected Phosphine in the clouds on Venus, using JCMT in Hawaii and ALMA in Chile.

M5V :  $T_{\text{eff}}=2800$



# HOT GAS GIANT EXOPLANET WASP-39 b ATMOSPHERE COMPOSITION

NIRSpec PRISM



**WEBB**  
SPACE TELESCOPE

GAMMA

X-RAY

ULTRAVIOLET

VISIBLE

INFRARED

MICROWAVE

RADIO



FERMI



CHANDRA



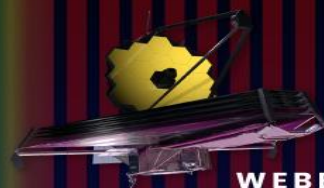
HUBBLE



ROMAN



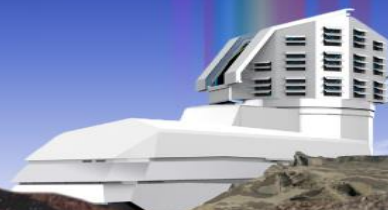
EUCLID



WEBB



SOFIA



RUBIN and ELTs



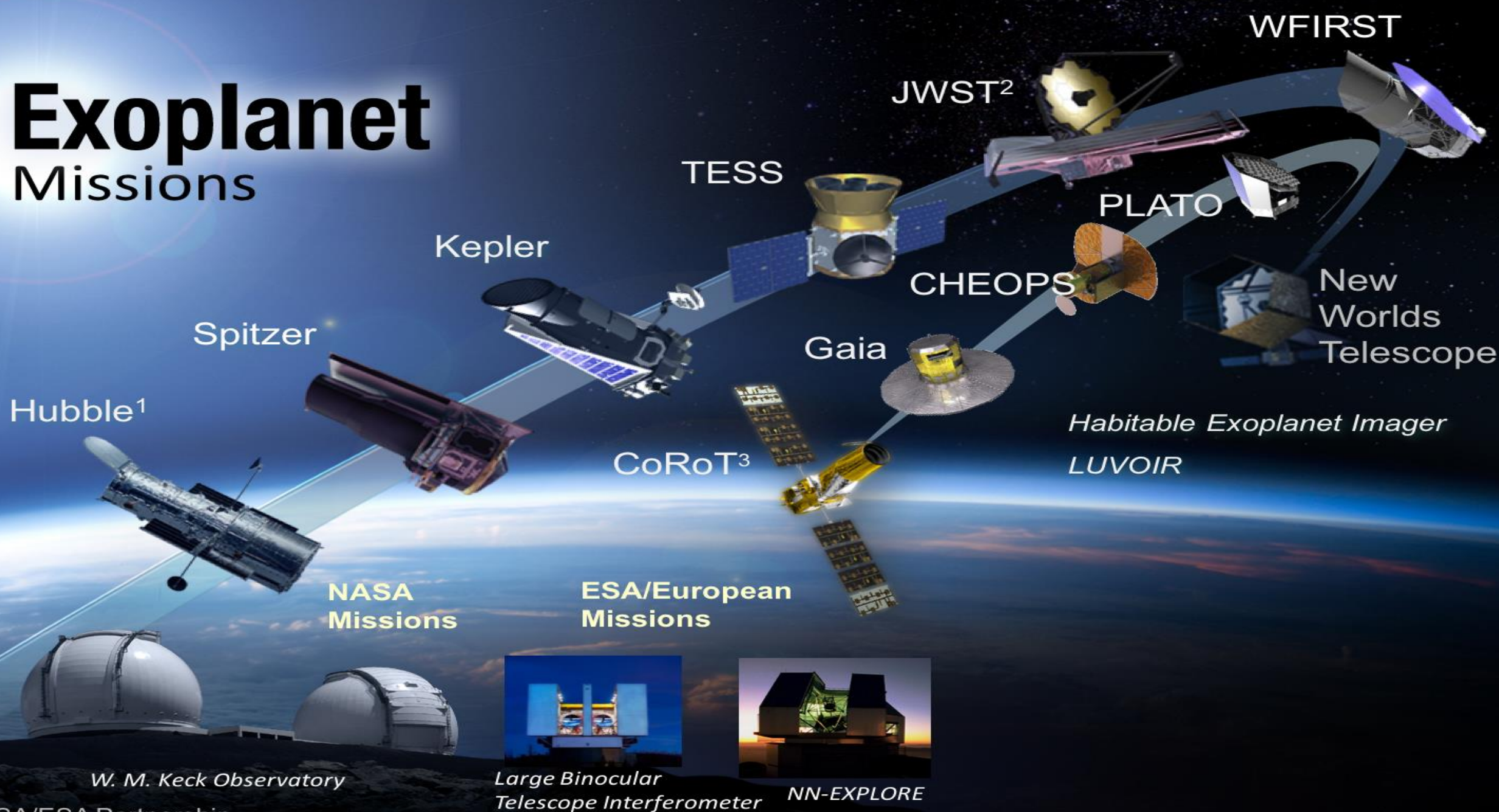
ALMA



SKA

ATMOSPHERE

# Exoplanet Missions



<sup>1</sup> NASA/ESA Partnership

<sup>2</sup> NASA/ESA/CSA Partnership

<sup>3</sup> CNES/ESA

**Ground Telescopes with NASA participation**

# Radial velocity method (1140)



nature

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Articles | Published: 01 November 1995

## A Jupiter-mass companion to a solar-type star

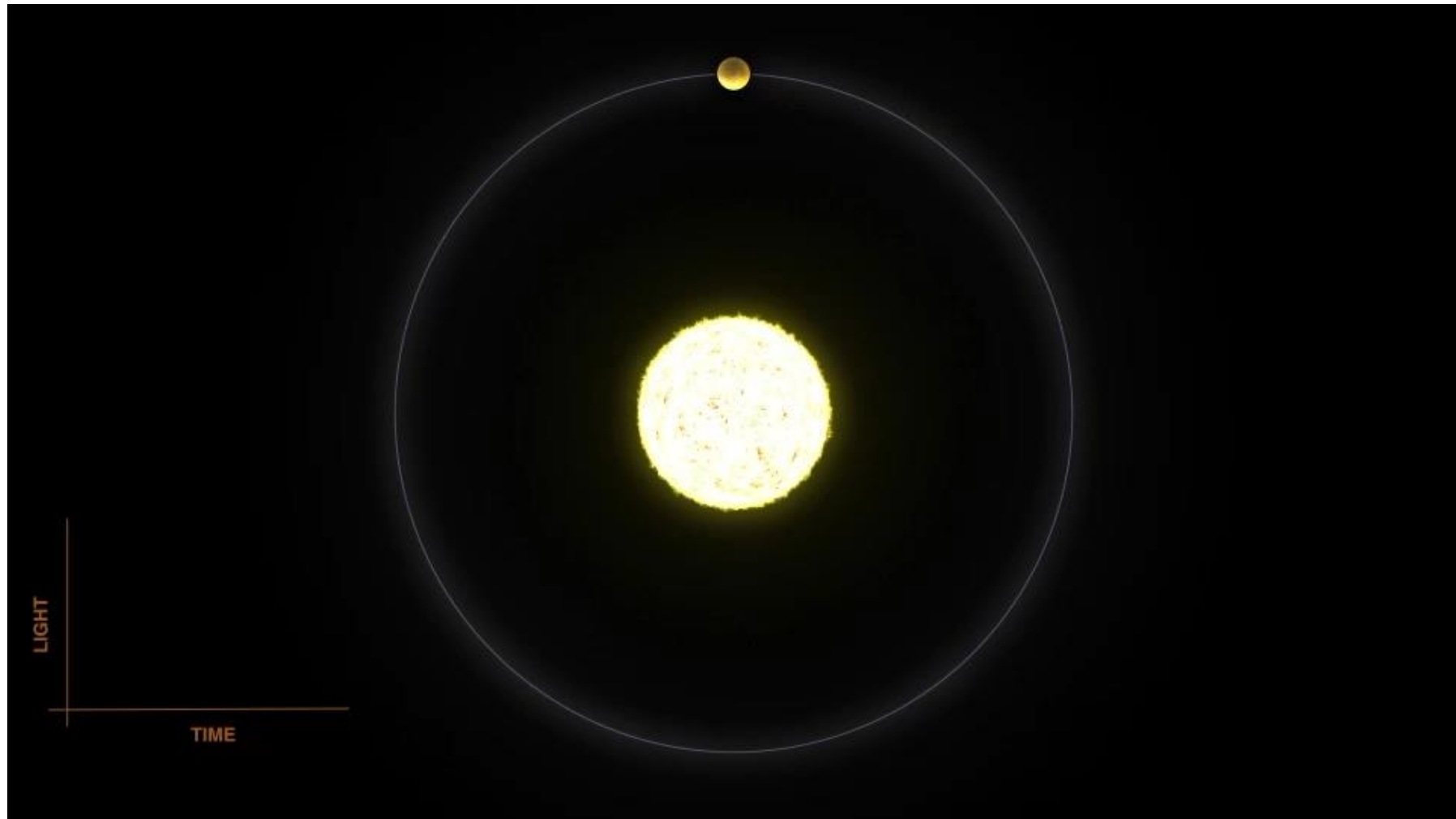
[Michel Mayor](#) & [Didier Queloz](#)

[Nature](#) **378**, 355–359 (1995) | [Cite this article](#)

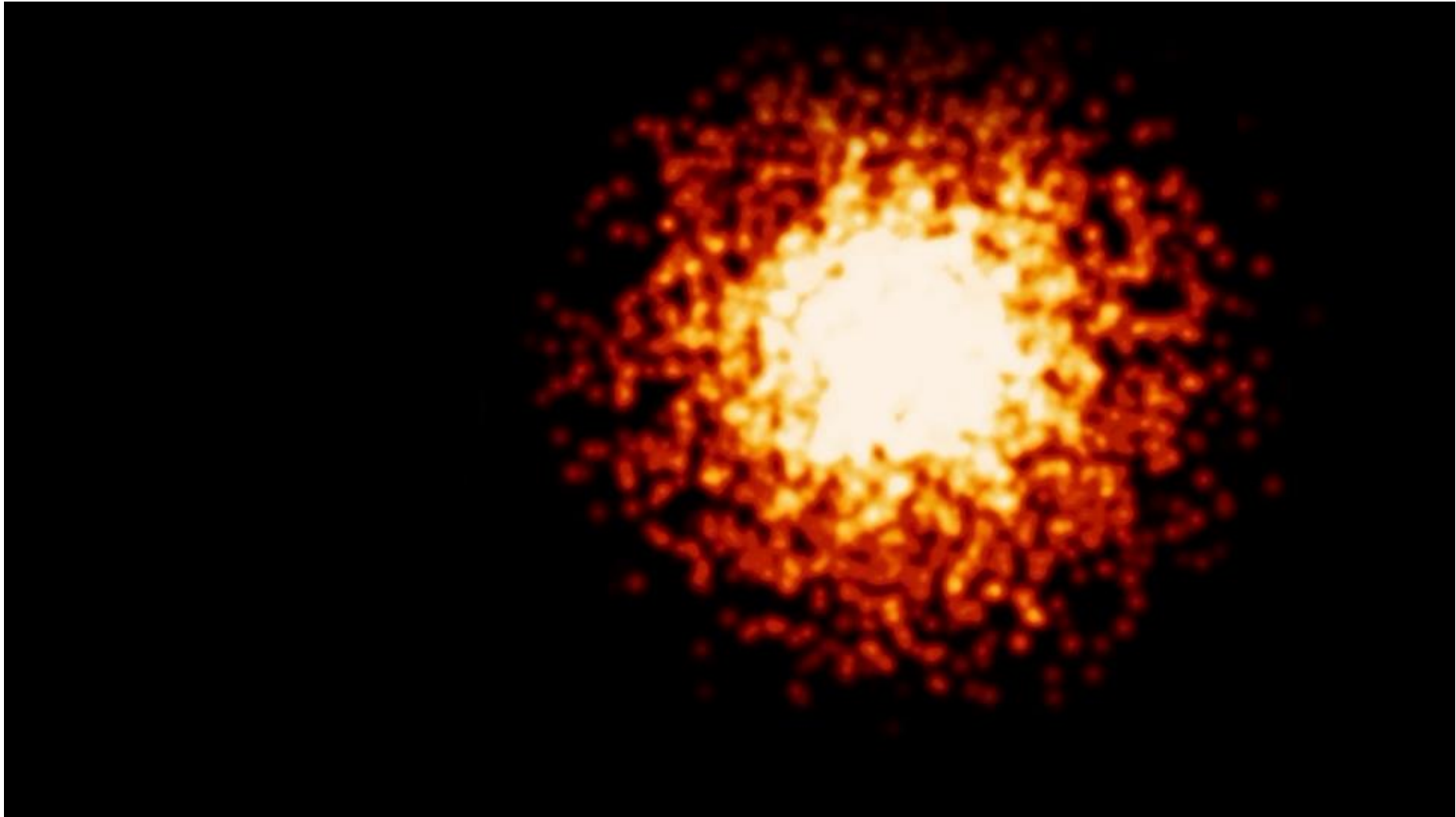
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The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.

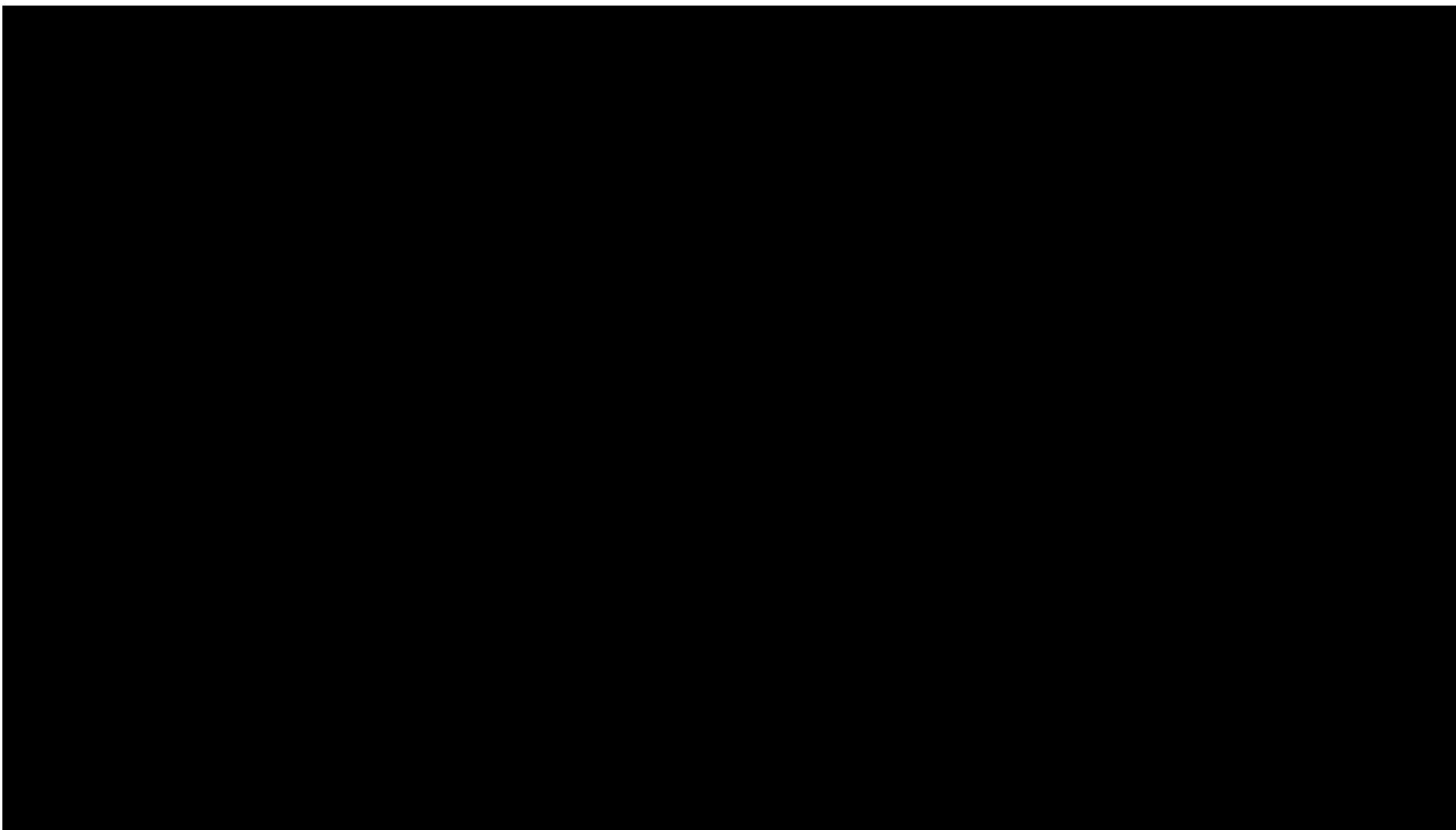
# Transit Method (4446)



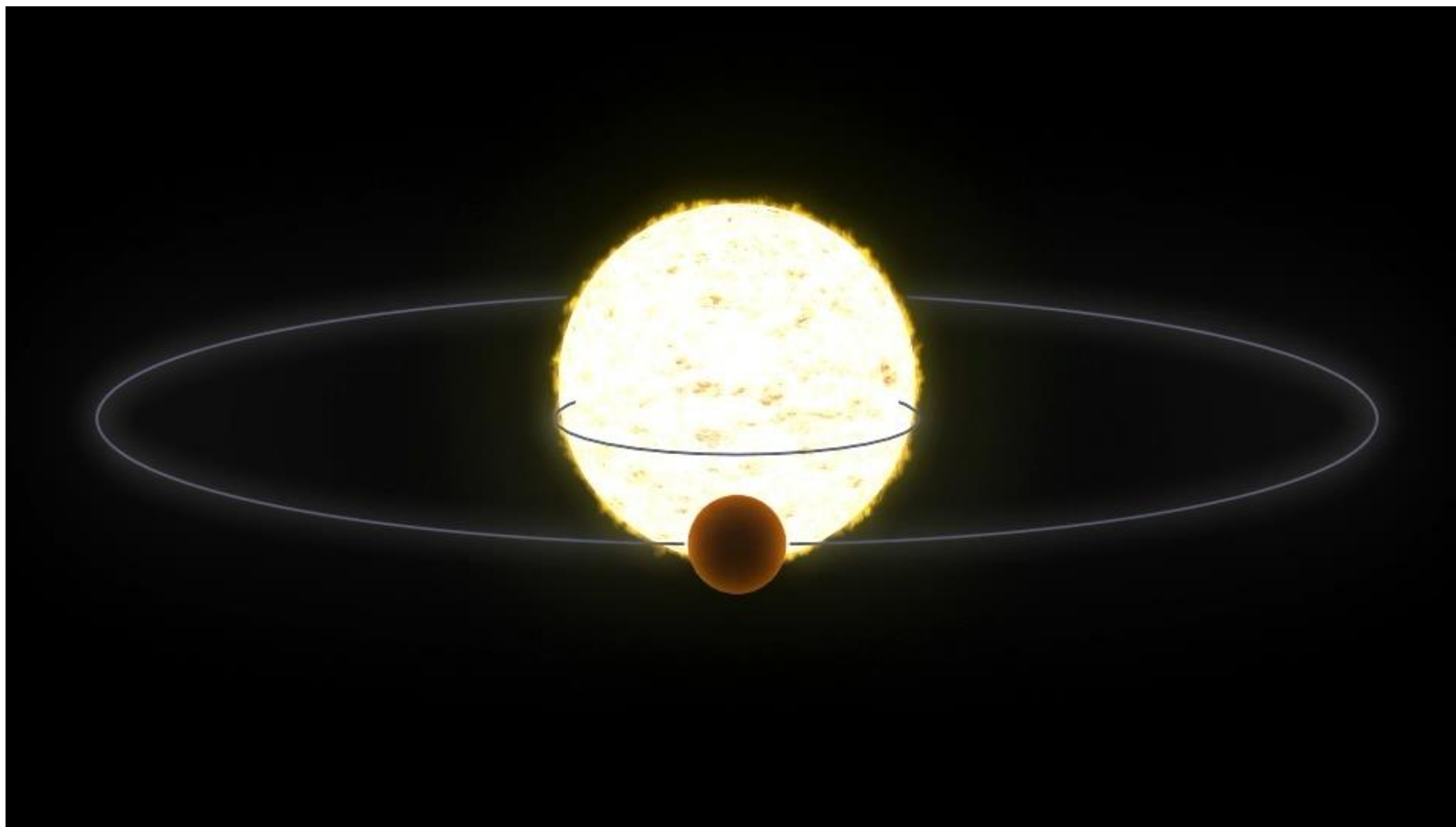
## Direct imaging (87)



# Gravitational Microlensing (253)



# Astrometry (5)



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08/06/2026**919**TESS Confirmed Planets  
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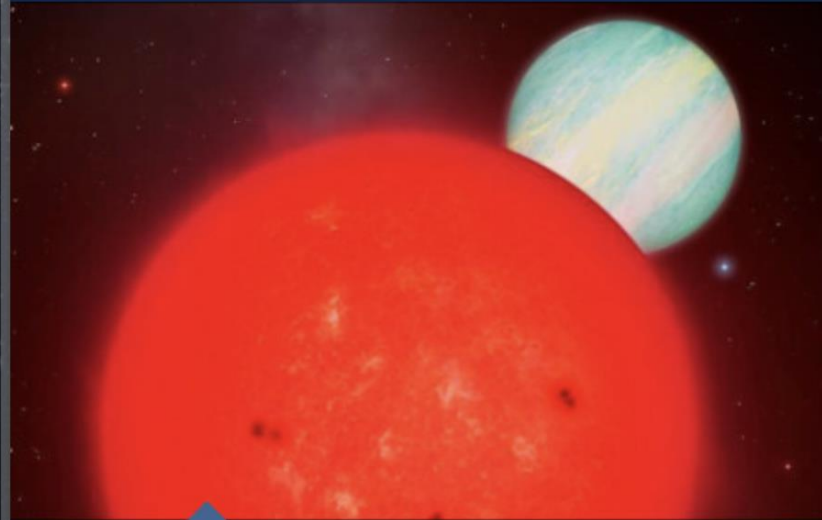
JWST uses precision transmission and eclipse spectroscopy and direct imaging to deliver spectra from the near-infrared to the mid-infrared.

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## Three's Company

**August 6, 2026 • New Data**

This week's new planets include TOI-5628 A b, a rare giant planet orbiting an M dwarf with an associated white dwarf companion, and HD 60779 b & c, a pair of planets orbiting a bright, Sun-like star.

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# The Breakthrough Listen Search for Intelligent Life: Public Data, Formats, Reduction, and Archiving

Matthew Lebofsky<sup>1</sup>, Steve Croft<sup>1</sup>, Andrew P. V. Siemion<sup>1,2,3,4</sup>, Danny C. Price<sup>1,5</sup>, J. Emilio Enriquez<sup>1,3</sup>, Howard Isaacson<sup>1,6</sup>, David H. E. MacMahon<sup>1</sup>, David Anderson<sup>7</sup>, Bryan Brzycki<sup>1</sup>, Jeff Cobb<sup>7</sup>, Daniel Czech<sup>1</sup>, David DeBoer<sup>1</sup>, Julia DeMarines<sup>1</sup>, Jamie Drew<sup>8</sup>, Griffin Foster<sup>1,9</sup>, Vishal Gajjar<sup>1</sup>, Nectaria Gizani<sup>1,10</sup>, Greg Hellbourg<sup>11</sup>, Eric J. Korpela<sup>7</sup>, Brian Lacki<sup>12</sup>, Sofia Sheikh<sup>13</sup>, Dan Werthimer<sup>1</sup>, Pete Worden<sup>8</sup>, Alex Yu<sup>14</sup>, and Yunfan Gerry Zhang<sup>1</sup>

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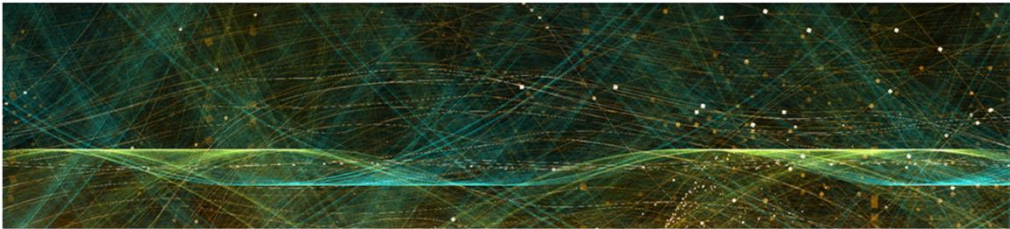
Received 2019 April 17; accepted 2019 August 27; published 2019 November 5

## Abstract



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Search



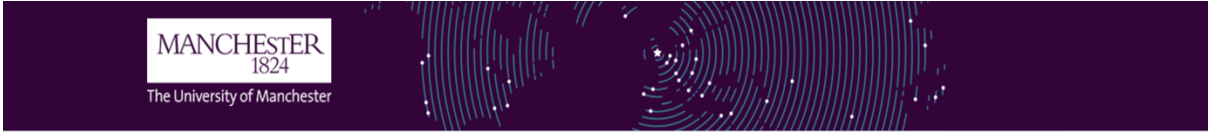
## Open Data Archive

Breakthrough Listen data are stored in technical formats that require specialized software to analyze, and file sizes can be several gigabytes. Before downloading files from our public archive, we recommend you familiarize yourself with how the data are stored. A good place to start is with the educational materials provided by [Berkeley SETI Research Center](#).

Access analysis results and description from [The Breakthrough Listen Search for Advanced Life: 1.1-1.9 GHz observations of 692 Nearby Stars](#).

A beta interface with additional search options is also available at [seti.berkeley.edu/opendata](https://seti.berkeley.edu/opendata).

## Search Form



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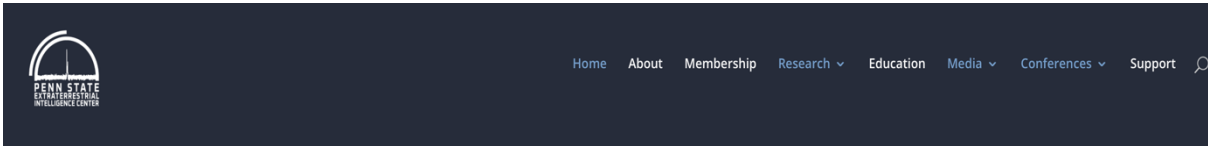
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## SETI (Search for Extraterrestrial Intelligence) Institute (External organisation)

Garrett, M. (Academic expert member)

[Astronomy and Astrophysics Theory Group](#)

Activity: [Membership](#) > [Membership of committee](#) > [Research](#)





# The Breakthrough Listen Search for Intelligent Life: Public Data, Formats, Reduction, and Archiving

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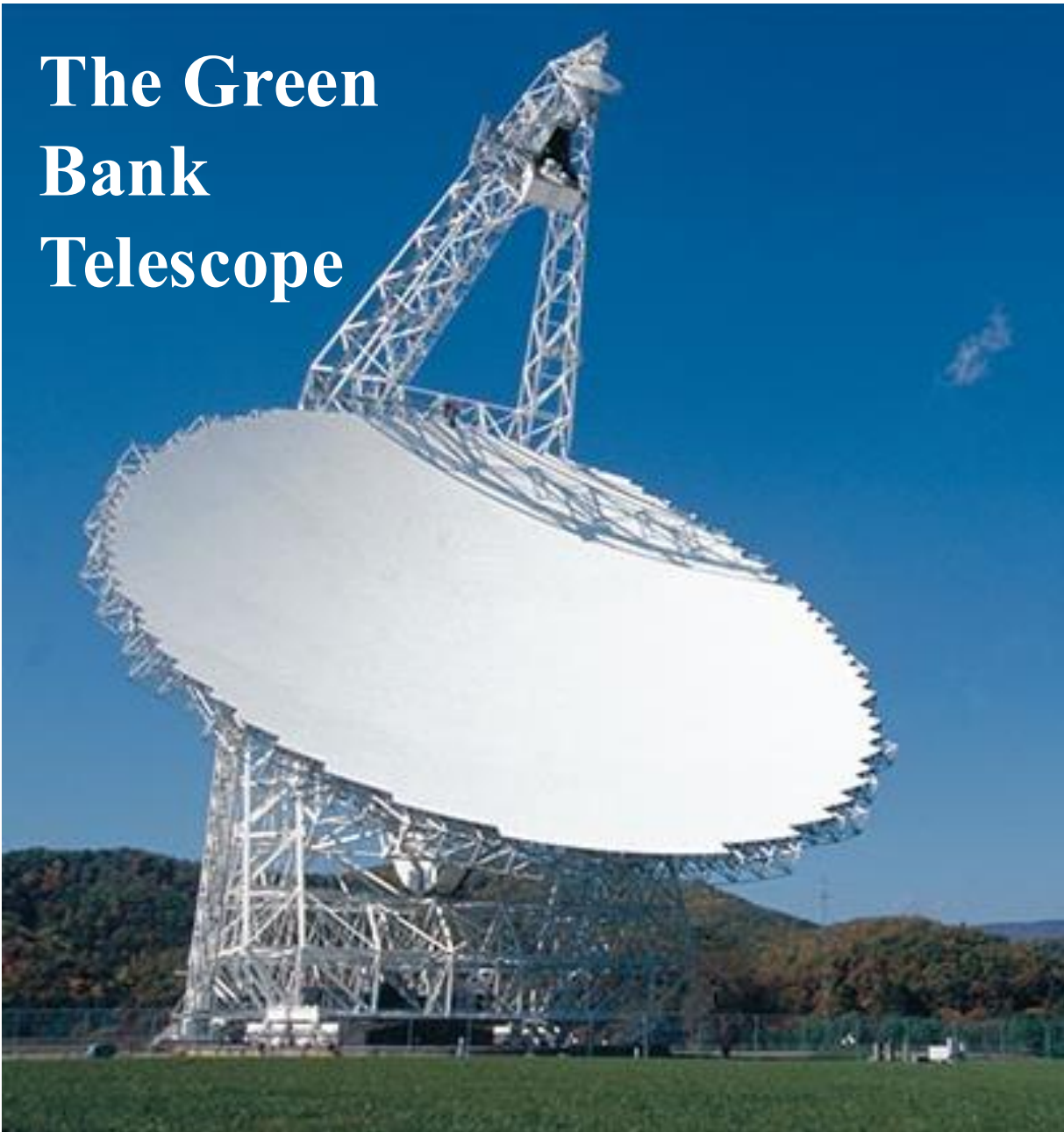
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*Received 2019 April 17; accepted 2019 August 27; published 2019 November 5*

## Abstract

*Breakthrough Listen* is the most comprehensive and sensitive search for extraterrestrial intelligence (SETI) to date,

**The Green  
Bank  
Telescope**



**Automated  
Planet  
Finder**



**Parkes  
Telescope**





# The Breakthrough Listen Search for Intelligent Life: 1.1–1.9 GHz Observations of 692 Nearby Stars

J. Emilio Enriquez<sup>1,2</sup> , Andrew Siemion<sup>1,2,3</sup> , Griffin Foster<sup>1,4</sup> , Vishal Gajjar<sup>5</sup> , Greg Hellbourg<sup>1</sup>, Jack Hickish<sup>6</sup> , Howard Isaacson<sup>1</sup> , Danny C. Price<sup>1,7</sup> , Steve Croft<sup>1</sup> , David DeBoer<sup>6</sup>, Matt Lebofsky<sup>1</sup>, David H. E. MacMahon<sup>6</sup>, and Dan Werthimer<sup>1,5,6</sup>

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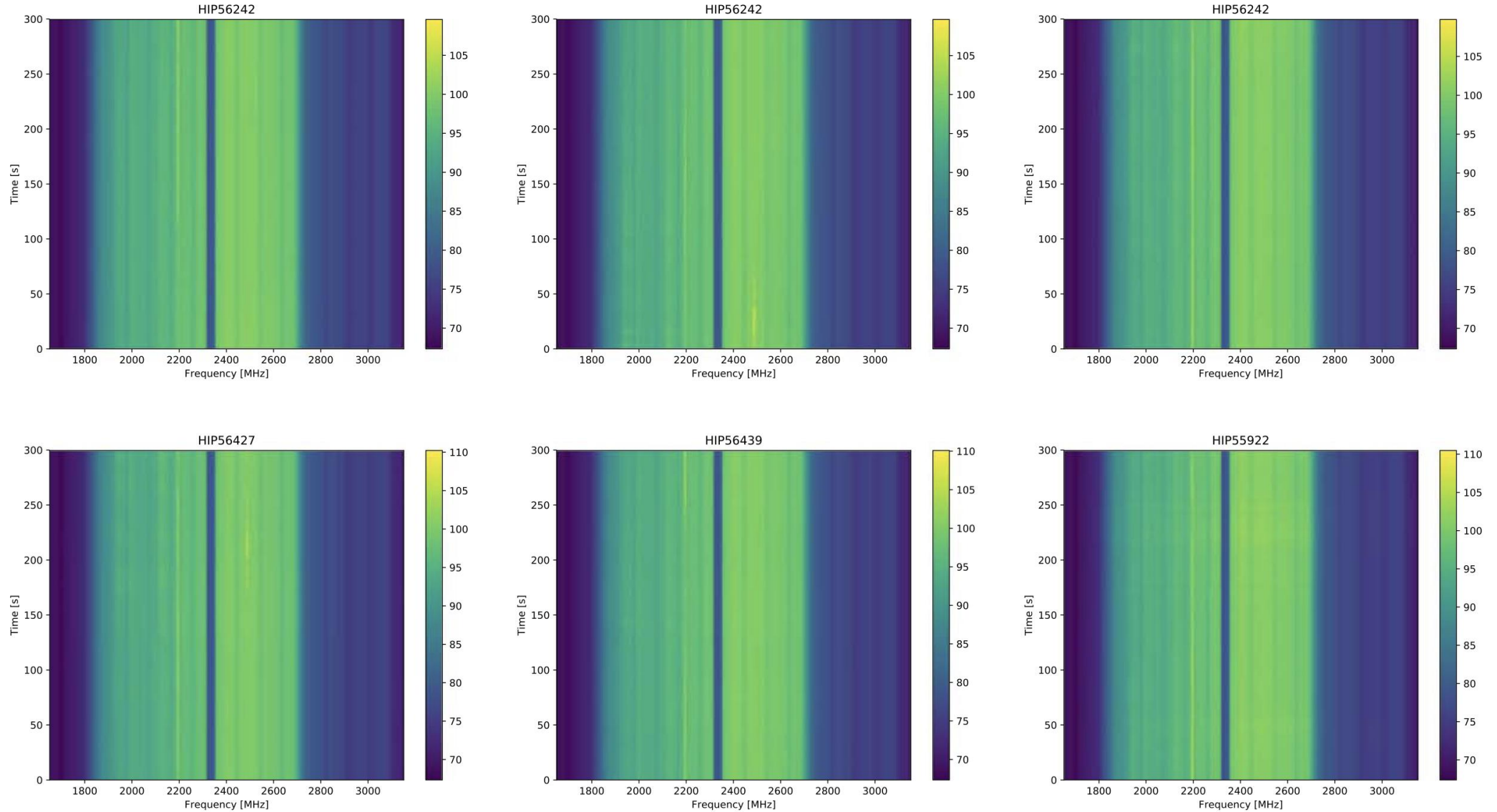
<sup>7</sup> Centre for Astrophysics & Supercomputing, Swinburne University of Technology, PO Box 218, Hawthorn, VIC 3122, Australia

*Received 2017 April 20; revised 2017 September 5; accepted 2017 September 8; published 2017 November 6*

## Abstract

We report on a search for engineered signals from a sample of 692 nearby stars using the Robert C. Byrd Green Bank Telescope, undertaken as part of the *Breakthrough Listen Initiative* search for extraterrestrial intelligence. Observations were made over 1.1–1.9 GHz (L band), with three sets of five-minute observations of the 692 primary targets, interspersed with five-minute observations of secondary targets. By comparing the “ON” and “OFF” observations, we are able to identify terrestrial interference and place limits on the presence of engineered signals from putative extraterrestrial civilizations inhabiting the environs of the target stars. During the analysis, 11 events passed our thresholding algorithm, but a detailed analysis of their properties indicates that they are consistent with known examples of anthropogenic radio-frequency interference. We conclude that, at the time of our observations,

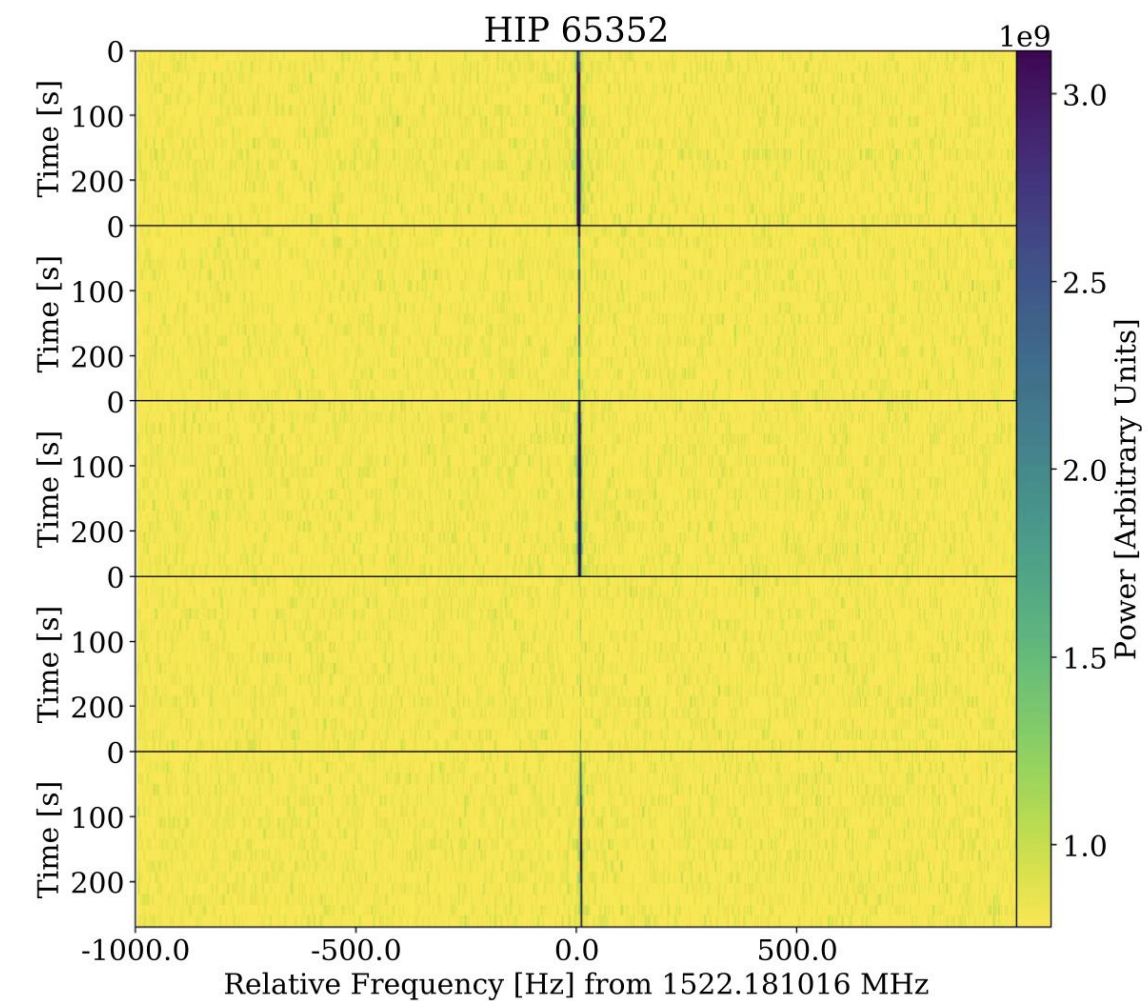
# Observation strategy



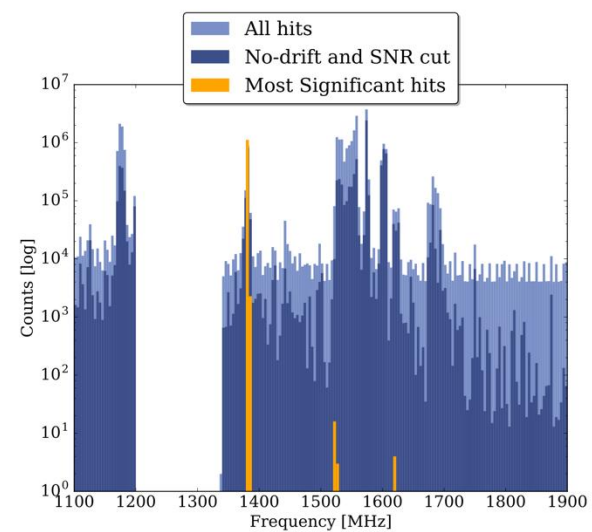
# TurboSETI



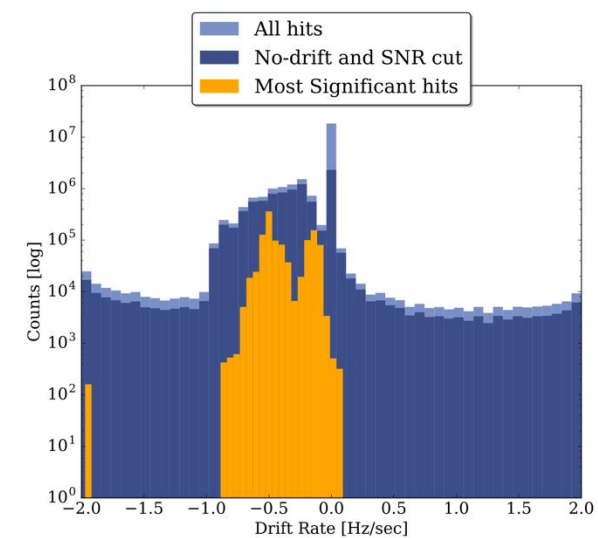
[www.spacetelescope.org](http://www.spacetelescope.org)



THE ASTROPHYSICAL JOURNAL, 849:104 (13pp), 2017 November 10



Enriquez et al.



# The Wow! Signal of Our Generation

nature  
astronomy

ARTICLES

<https://doi.org/10.1038/s41550-021-01508-8>



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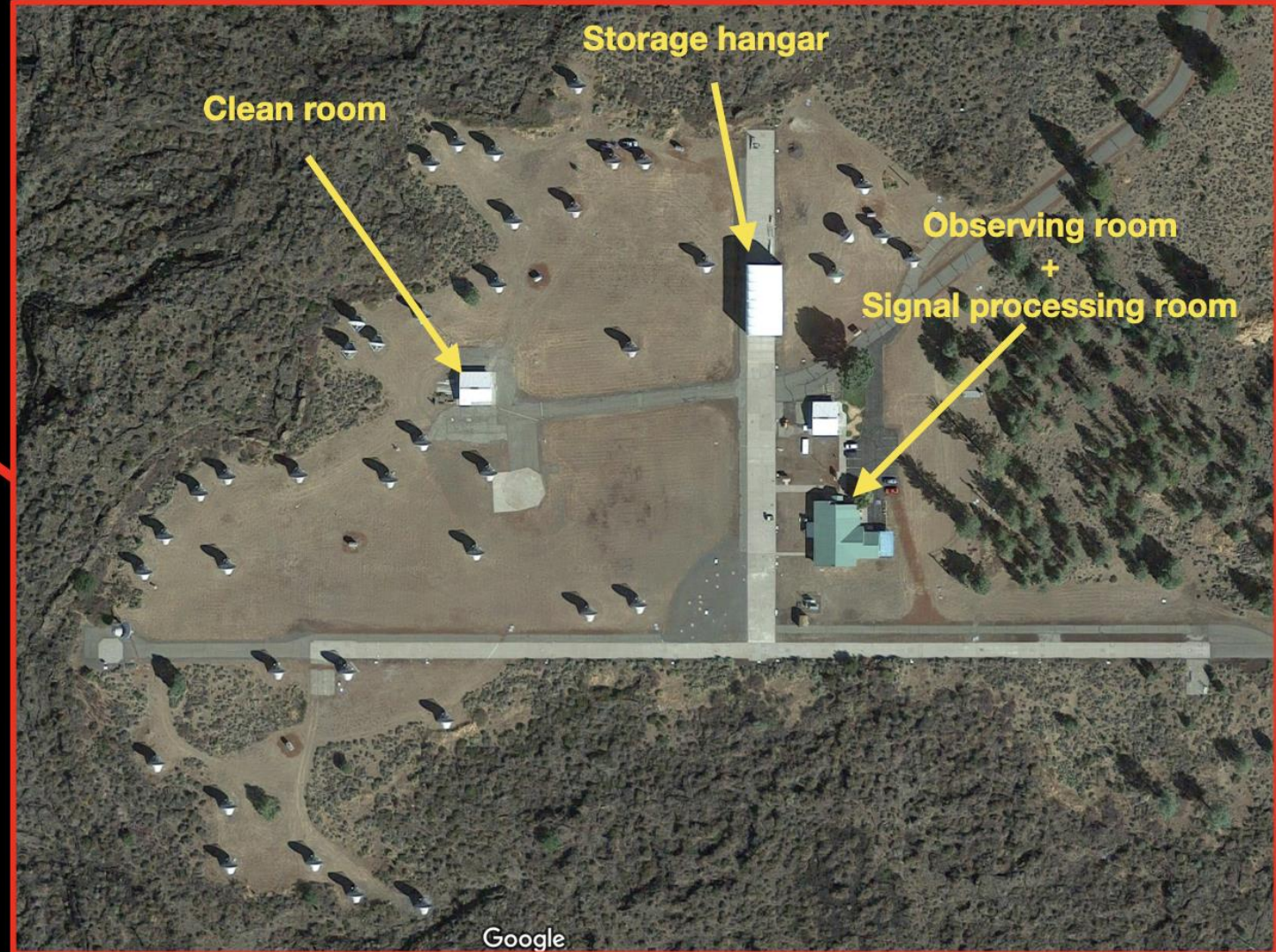
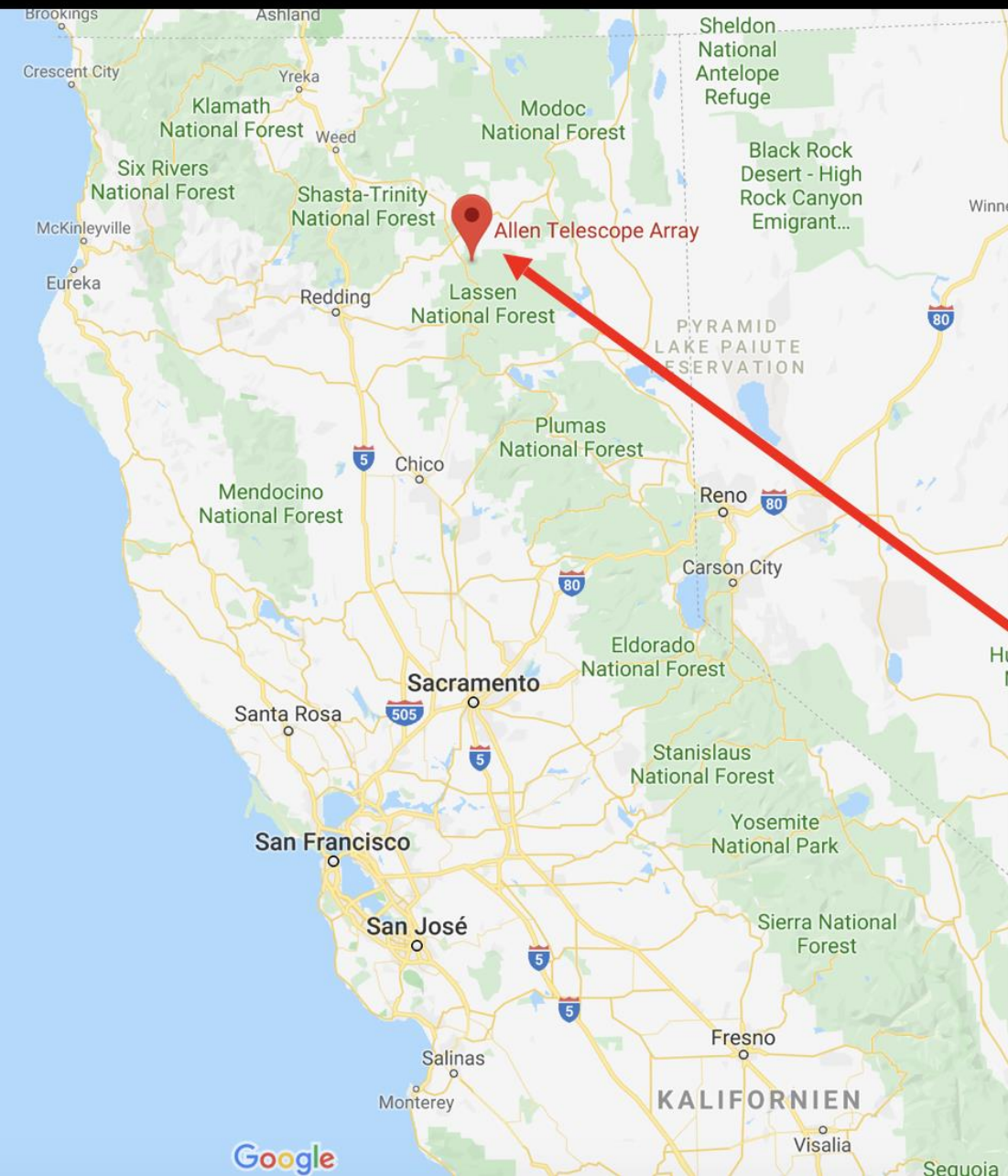
## Analysis of the Breakthrough Listen signal of interest blc1 with a technosignature verification framework

Sofia Z. Sheikh <sup>1</sup>✉, Shane Smith <sup>1,2</sup>, Danny C. Price <sup>1,3</sup>, David DeBoer <sup>4</sup>, Brian C. Lacki <sup>1</sup>, Daniel J. Czech <sup>1</sup>, Steve Croft <sup>1,5</sup>, Vishal Gajjar <sup>1</sup>, Howard Isaacson <sup>1,6</sup>, Matt Lebofsky <sup>1</sup>, David H. E. MacMahon<sup>1,4</sup>, Cherry Ng <sup>1,5,7</sup>, Karen I. Perez <sup>8</sup>, Andrew P. V. Siemion <sup>1,5,9</sup>, Claire Isabel Webb<sup>1,10</sup>, Andrew Zic <sup>11,12</sup>, Jamie Drew<sup>13</sup> and S. Pete Worden<sup>13</sup>

The aim of the search for extraterrestrial intelligence (SETI) is to find technologically capable life beyond Earth through their technosignatures. On 2019 April 29, the Breakthrough Listen SETI project observed Proxima Centauri with the Parkes ‘Murriyang’ radio telescope. These data contained a narrowband signal with characteristics broadly consistent with a technosignature near 982 MHz (‘blc1’). Here we present a procedure for the analysis of potential technosignatures, in the context of the ubiquity of human-generated radio interference, which we apply to blc1. Using this procedure, we find that blc1 is not an extraterrestrial technosignature, but rather an electronically drifting intermodulation product of local, time-varying interferers aligned with the observing cadence. We find dozens of instances of radio interference with similar morphologies to blc1 at

Blc1 is not an extraterrestrial technosignature, but rather an electronically drifting intermodulation product of local, time-varying interferers aligned with the observing cadence. They found dozens of similar morphologies to blc1.

# Hat Creek Radio Observatory- Allen Telescope Array



# An Interferometric SETI Observation of Kepler-111 b

Kelvin Wandia<sup>1</sup>, <sup>★</sup> Michael A. Garrett<sup>1,2</sup>, Jack F. Radcliffe<sup>1,3</sup>, Simon T. Garrington<sup>1</sup>, James Fawcett<sup>1</sup>, Vishal Gajjar<sup>4</sup>, David H. E. MacMahon<sup>4</sup>, Eskil Varenius<sup>5</sup>, Robert M. Campbell<sup>6</sup>, Zsolt Paragi<sup>6</sup>, Andrew P. V. Siemion<sup>1,4,7,8</sup>

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<sup>7</sup> *SETI Institute, Mountain View, CA 94043, USA*

<sup>8</sup> *University of Malta, Institute of Space Sciences and Astronomy, Malta*

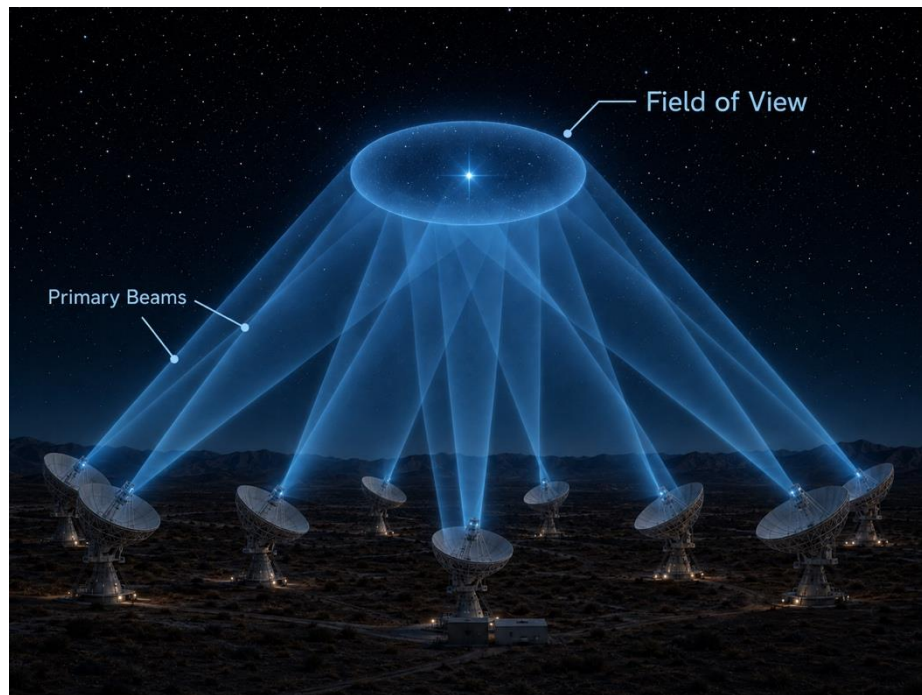
13 April 2023

## ABSTRACT

The application of Very Long Baseline Interferometry (VLBI) to the Search for Extraterrestrial Intelligence (SETI) has been limited to date, despite the technique offering many advantages over traditional single-dish SETI observations. In order to further develop interferometry for SETI, we used the European VLBI Network (EVN) at 21 cm to observe potential secondary phase calibrators in the Kepler field. Unfortunately, no secondary calibrators were detected. However, a VLBA primary calibrator in the field, J1926+4441, offset only  $\sim 1.88'$  from a nearby exoplanet Kepler-111 b, was correlated with high temporal (0.25 s) and spectral ( $16384 \times 488$  Hz channels) resolution. During the analysis of the high-resolution data, we identified a spectral feature that was present in both the auto and cross-correlation data with a central frequency of  $1420.424 \pm 0.0002$  MHz and a width

- **Offset Gregorian Dish**
- **Each of the 42 antennas (6.1 m) in diameter.**
- **Produces ~1.5 GHz of bandwidth/polarization (~3.0 GHz in total).**
- **The entire telescope equates to ~84 GHz or ~1.4 Tbps at 8 bits per sample.**
- **1 – 10 GHz wide band**





# Multi-beam Search for technosignatures on RECONS targets with the Allen Telescope Array

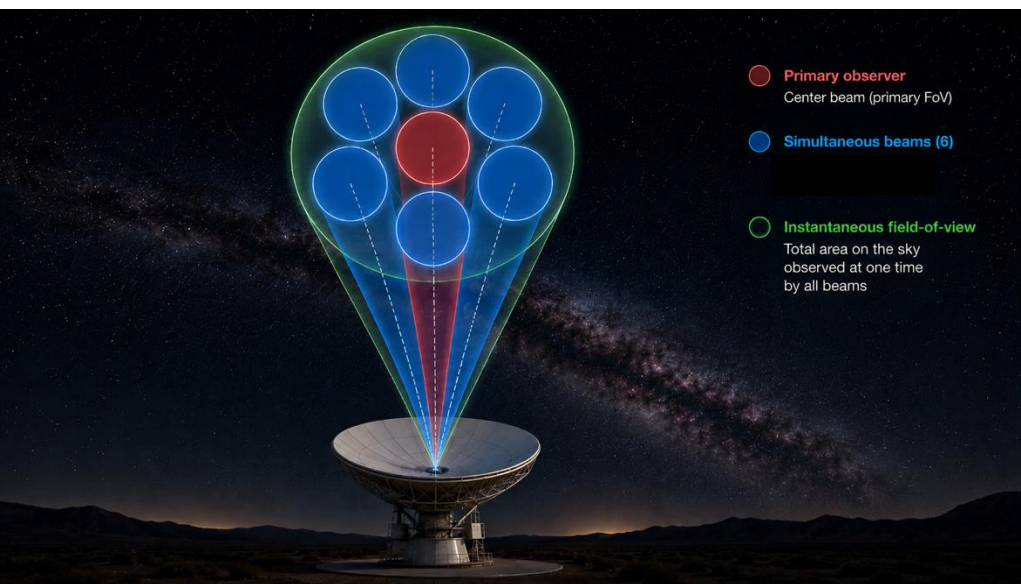
Ramiro C. Saide,<sup>1</sup>  Wael Farah,<sup>1,2</sup> Sofia Z. Sheikh<sup>1,2,4</sup> Alexander W. Pollak<sup>1</sup> Andrew P. V. Siemion<sup>1,2,3</sup> Others

<sup>1</sup>SETI Institute, 339 Bernardo Ave Suite 200 Mountain View, CA 94043

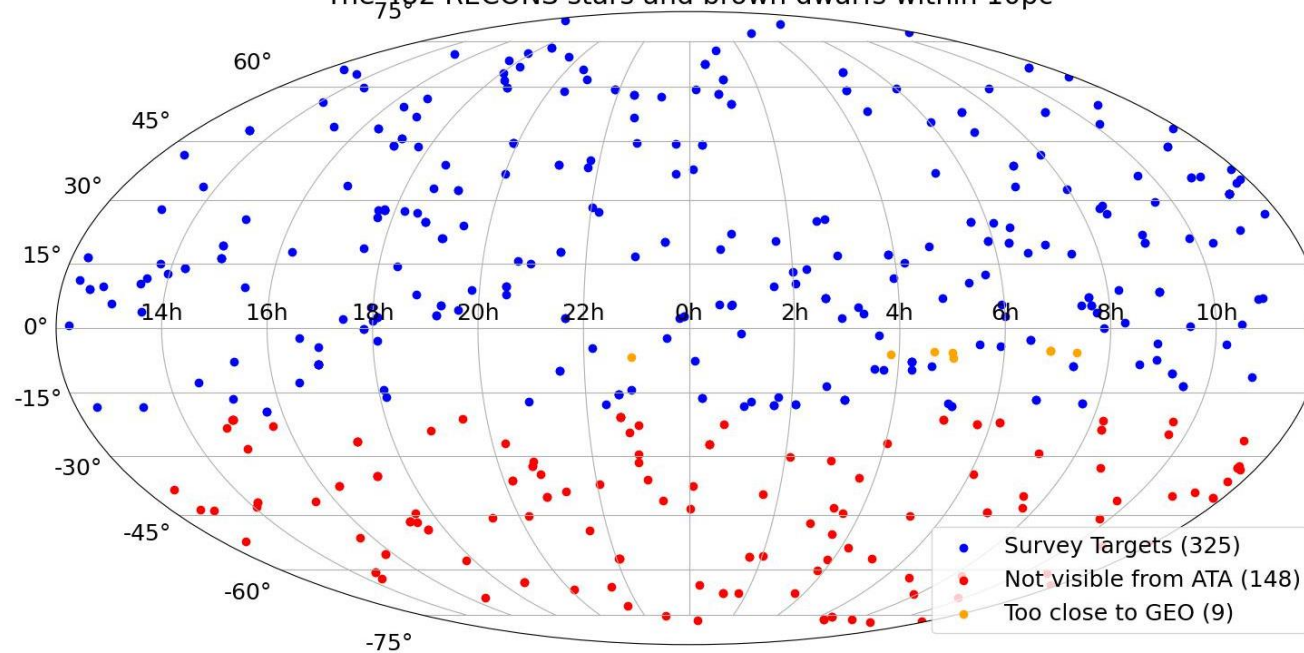
<sup>2</sup>Berkeley SETI Research Center, University of California, Berkeley, CA 94720, USA

<sup>3</sup>University of Malta, Institute of Space Sciences and Astronomy

<sup>4</sup>Penn State Extraterrestrial Intelligence Center, Pennsylvania State University, University Park PA 16802



The 482 RECONS stars and brown dwarfs within 10pc



# HYCEAN EXOPLANETS AS CANDIDATES FOR TECHNOSIGNATURE DETECTION: A CASE STUDY OF K2-18 B IN THE 3–10 GHz BAND

Ramiro C. Saide,<sup>1</sup> Wael Farah,<sup>1,2</sup> Sofia Z. Sheikh,<sup>1,2,3</sup> Alexander W. Pollak,<sup>1,2</sup> Andrew P. V. Siemion,<sup>1,2,4</sup> Luigi F. Cruz,<sup>1</sup> Roy H. Davis,<sup>1</sup> David R. DeBoer,<sup>1,2</sup> Vishal Gajjar,<sup>1,2</sup> Phil Karn,<sup>1</sup> Mark Masters,<sup>1</sup> Carol Shumaker,<sup>1</sup> Gurmehar Singh,<sup>1,5</sup> and Michael Snodgrass<sup>1</sup>

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<sup>5</sup>Purdue University, West Lafayette, IN 47907, USA

## ABSTRACT

Recently the James Webb Space Telescope (JWST) performed near-infrared spectroscopic observations of the atmosphere of a potential Hycean exoplanet, K2-18 b. These spectra provided evidence of the presence of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) in its atmosphere, along with potential signs of dimethyl sulfide (DMS), a plausible biomarker. In this work, we present triggered narrow-band radio observations of K2-18 b conducted using the Allen Telescope Array (ATA) across a frequency range of 3–10 GHz, in search of signs of artificially produced radio emissions (radio technosignatures). We do not find any spatially isolated signals in the direction of K2-18 b, establishing



in x f

Strongest hints yet of  
biological activity  
outside the solar system

## New Constraints on DMS and DMDS in the Atmosphere of K2-18 b from JWST MIRI

Nikku Madhusudhan<sup>1</sup>, Savvas Constantinou<sup>1,6</sup>, Måns Holmberg<sup>2,6</sup>, Subhjit Sarkar<sup>3,6</sup>, Anjali A. A. Piette<sup>4</sup>, and Julianne I. Moses<sup>5</sup>

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<sup>3</sup>School of Physics and Astronomy, Cardiff University, The Parade, Cardiff, CF24 3AA, UK

<sup>4</sup>School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

<sup>5</sup>Space Science Institute, Boulder, CO 80301, USA

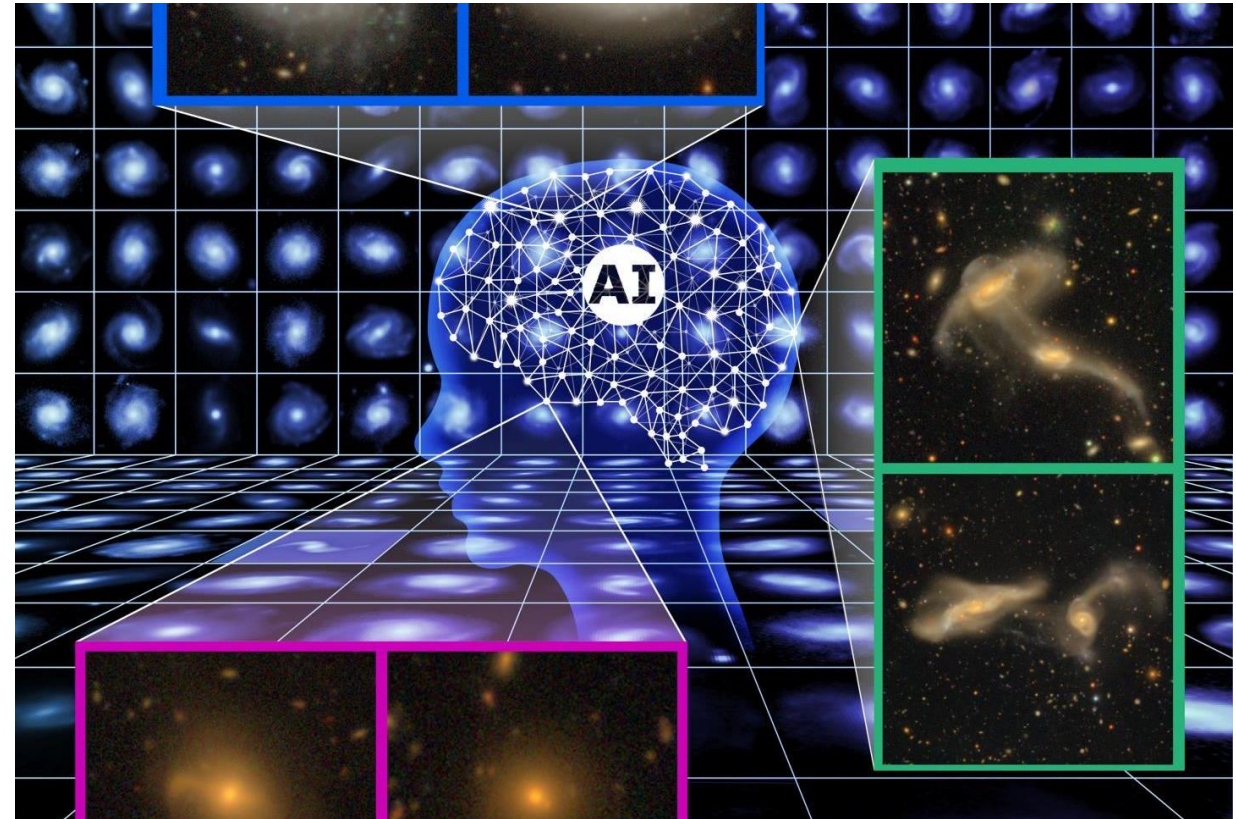
Received 2024 December 13; revised 2025 March 14; accepted 2025 March 15; published 2025 April 17

## Abstract

The sub-Neptune frontier has opened a new window into the rich diversity of planetary environments beyond the solar system. The possibility of hycean worlds, with planet-wide oceans and H<sub>2</sub>-rich atmospheres, significantly expands and accelerates the search for habitable environments elsewhere. Recent JWST transmission spectroscopy of the candidate hycean world K2-18 b in the near-infrared led to the first detections of the carbon-bearing molecules CH<sub>4</sub> and CO<sub>2</sub> in its atmosphere, with a composition consistent with predictions for hycean conditions. The observations also provided a tentative hint of dimethyl sulfide (DMS), a possible biosignature gas, but the inference was of low statistical significance. We report a mid-infrared transmission spectrum of K2-18 b obtained using the JWST MIRI LRS instrument in the ~6–12 μm range. The spectrum shows distinct features and is inconsistent with a featureless spectrum at 3.4σ significance compared to our canonical model. We find that the spectrum cannot be explained by most molecules predicted for K2-18 b, with the exception of DMS and dimethyl disulfide (DMDS), also a potential biosignature gas. We report new independent evidence for DMS and/or DMDS in the atmosphere at 3σ significance, with high abundance (≥10 ppmv) of at least one of the two molecules. More observations are needed to increase the robustness of the findings and resolve the degeneracy between DMS and DMDS. The results also highlight the need for additional experimental and theoretical work to determine accurate cross sections of important biosignature gases and identify potential abiotic sources. We discuss the implications of the present findings for the possibility of biological activity on K2-18 b.

Unified Astronomy Thesaurus concepts: Exoplanets (498); Biosignatures (2018); Habitable planets (695)

# Artificial Intelligence in SETI



# Big Data in Astronomy

| Sky Survey                                                                    | Volume | Velocity       | Variety                     |
|-------------------------------------------------------------------------------|--------|----------------|-----------------------------|
| SDSS<br><i>Sloan Digital Sky Survey</i>                                       | 50 TB  | 200 GB per day | images, catalogs, redshifts |
| GAIA                                                                          | 100 TB | 40 GB per day  | more than 100 parameters    |
| Pan-STARRS<br><i>Panoramic Survey Telescope<br/>and Rapid Response System</i> | 5 PB   | 5 TB per day   | images, catalogs            |
| LSST<br><i>Large Synoptic Survey Telescope</i>                                | 60 PB  | 10 TB per day  | images, catalogs            |
| SKA<br><i>Square Kilometer Array</i>                                          | 3 ZB   | 150 TB per day | images, catalog, redshifts  |

*Notes:*  
The column Volume refers to raw data produced at the end of the experiment.  
Values regarding Pan-STARRS, LSST, and SKA surveys refer to expected Volume and Velocity values.

(Botta, 2017)

- SKA-Low generate 5 zettabytes/year – equivalent to watch Netflix in HD for 5 billion years non-stop.
- SKA-Mid generate 62 exabytes/year – comparable to internet world traffic of few months.

**Table 1:** GPU compute resources and telescope data rates for two commensal SETI backends: BLUSE on MeerKAT and COSMIC on the VLA.

| System          | GPU hardware reported                                                      | Active / installed GPUs | Telescope data rate                   |
|-----------------|----------------------------------------------------------------------------|-------------------------|---------------------------------------|
| BLUSE / MeerKAT | 32 active AMD nodes × 4 RTX A4000<br>64 active Intel nodes × 1 RTX 2080 Ti | 192                     | 1.11–1.79 Tb/s raw, depending on band |
| COSMIC / VLA    | 22 GPU servers × 6 RTX A4000                                               | 132                     | 1.7 Tb/s in current 8-bit mode        |

- Computing Power: 135 quadrillion of computations/s, would take 600 K years for a human being to perform manually.
- 700 petabytes/year — 140 million HD movies —one would need 383 K years watching one per day.

Article | Published: 30 January 2023

# A deep-learning search for technosignatures from 820 nearby stars

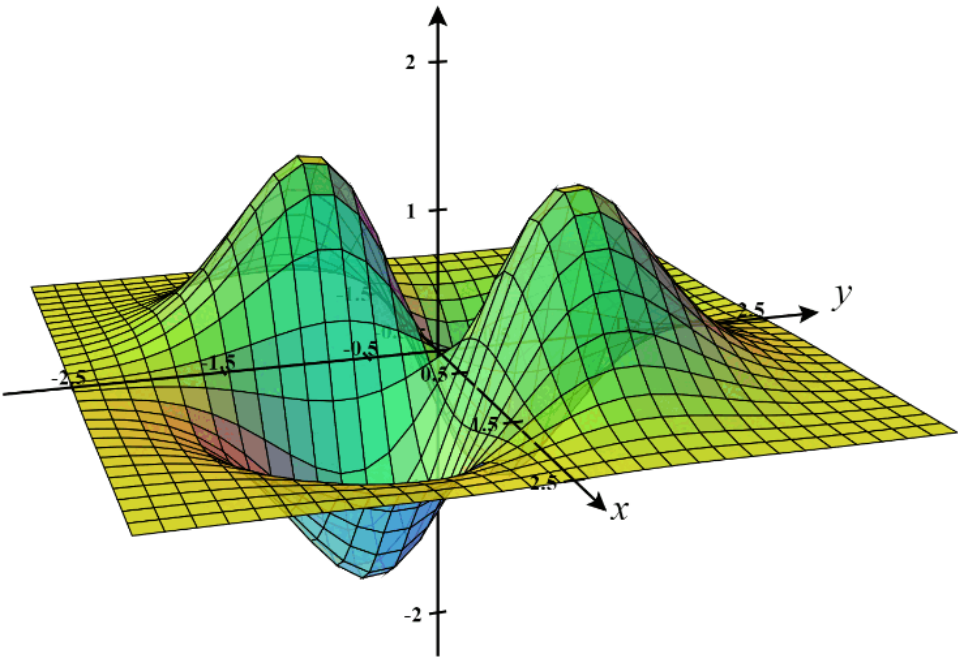
[Peter Xiangyuan Ma](#) , [Cherry Ng](#), [Leandro Rizk](#), [Steve Croft](#), [Andrew P. V. Siemion](#), [Bryan Brzycki](#), [Daniel Czech](#), [Jamie Drew](#), [Vishal Gajjar](#), [John Hoang](#), [Howard Isaacson](#), [Matt Lebofsky](#), [David H. E. MacMahon](#), [Imke de Pater](#), [Danny C. Price](#), [Sofia Z. Sheikh](#) & [S. Pete Worden](#)

*Nature Astronomy* **7**, 492–502 (2023) | [Cite this article](#)

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## Abstract

The goal of the search for extraterrestrial intelligence (SETI) is to quantify the prevalence of



No Prior INFO

## Narrow-band Signal Localization for SETI on Noisy Synthetic Spectrogram Data

Bryan Brzycki<sup>1</sup> , Andrew P. V. Siemion<sup>1,2,3,4</sup> , Steve Croft<sup>1,2</sup> , Daniel Czech<sup>1</sup> , David DeBoer<sup>1</sup> , Julia DeMarines<sup>1</sup>, Jamie Drew<sup>5</sup>, Vishal Gajjar<sup>6</sup>, Howard Isaacson<sup>1,7</sup>, Brian Lacki<sup>7</sup>, Matthew Lebofsky<sup>1</sup>, David H. E. MacMahon<sup>1</sup>, Imke de Pater<sup>1</sup>, Danny C. Price<sup>1,8</sup> , and S. Pete Worden<sup>8</sup>

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Received 2020 June 7; accepted 2020 July 30; published 2020 September 21

## Abstract

As it stands today, the search for extraterrestrial intelligence is highly dependent on our ability to detect interesting candidate signals, or technosignatures, in radio telescope observations and distinguish these from human radio frequency interference (RFI). Current signal processing techniques for signals in spectrograms of intensity as a

$$\nabla C \leftarrow \left\{ \begin{array}{l} \frac{\partial C}{\partial w_{jk}^{(l)}} = a_k^{(l-1)} \sigma'(z_j^{(l)}) \frac{\partial C}{\partial a_j^{(l)}} \\ \sum_{j=0}^{n_{l+1}-1} w_{jk}^{(l+1)} \sigma'(z_j^{(l+1)}) \frac{\partial C}{\partial a_j^{(l+1)}} \\ \text{or} \\ 2(a_j^{(L)} - y_j) \end{array} \right.$$

$$w_2 = w_1 - \alpha * dw$$

$$b_2 = b_1 - \alpha * db$$

## **Eavesdropping: The Radio Signature of the Earth**

Television leakage from the earth allows detection  
of our civilization at interstellar distances.

W. T. Sullivan III, S. Brown, C. Wetherill

sult of the complex communications and transportation network spread over our globe. Of course, we do not know how applicable our present situation is to the more general case of all galactic civilizations over all time. It may be that our present "leaky" state will soon be terminated by advancing technology, but on the other hand it may continue for a very long time, perhaps even longer than any period in which we might have the perseverance to send out purposeful messages. If we are at all typical, then we should perhaps be also looking for unintentional signals from others at least as diligently as for intentional ones.



Tech > News Tech

## **DISTANT HELLO** Hi-tech aliens may be watching Earth due to ‘radio leakage’ as scientists issue stark warning for ‘end of this decade’

**Ben Shimkus**

Published: 17:14 ET, May 2 2023 | Updated: 17:14 ET, May 2 2023

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Volume 522, Issue 2  
June 2023

## JOURNAL ARTICLE

### Simulation of the Earth's radio-leakage from mobile towers as seen from selected nearby stellar systems <sup>FREE</sup>

Ramiro C Saide ✉, M A Garrett ✉, N Heeralall-Issur

Monthly Notices of the Royal Astronomical Society, Volume 522, Issue 2, June 2023, Pages 2393–2402, <https://doi.org/10.1093/mnras/stad378>

Published: 06 February 2023 **Article history ▾**



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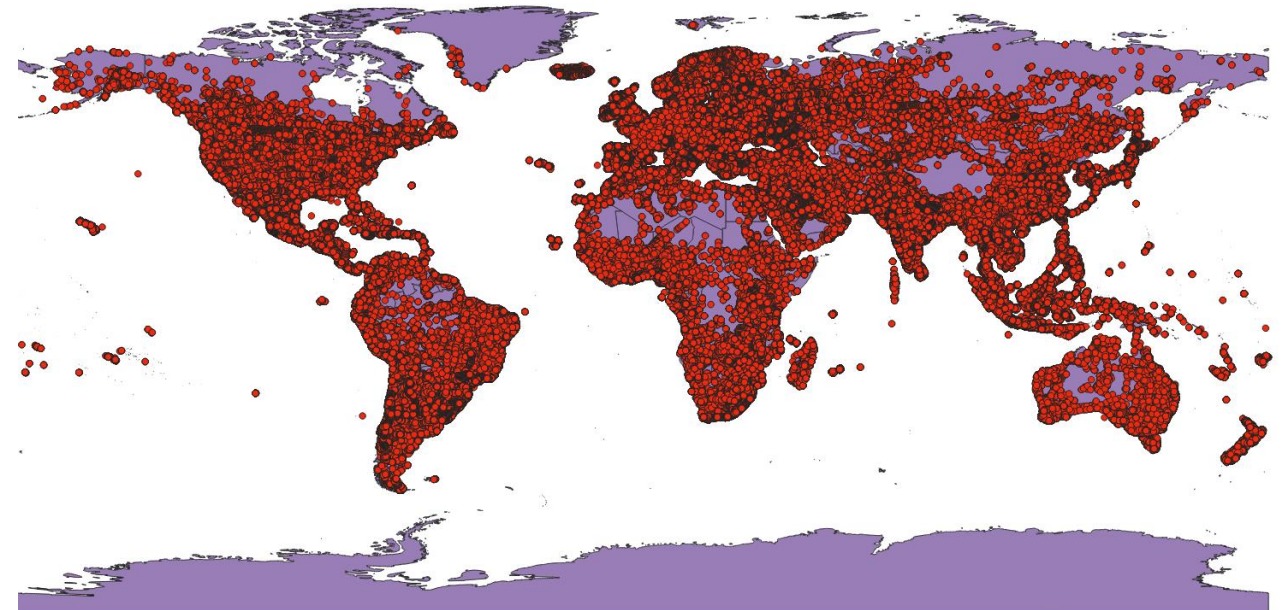
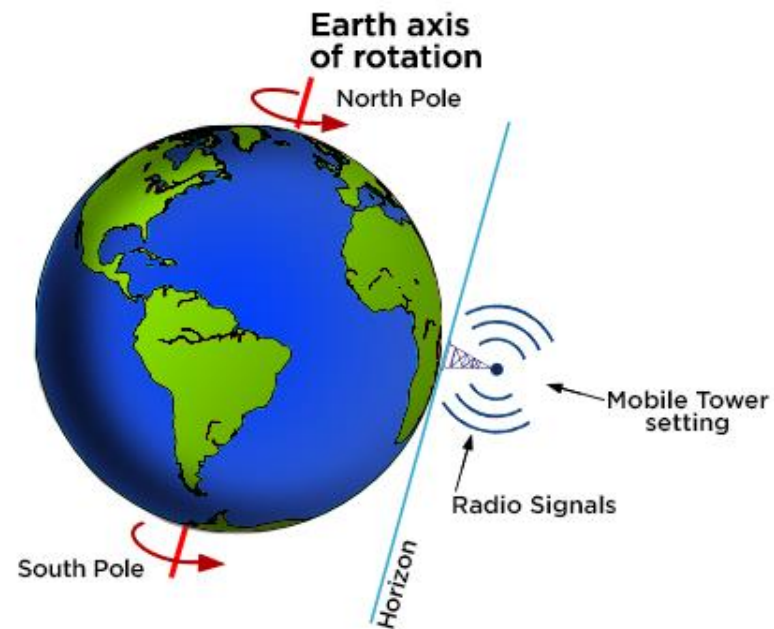
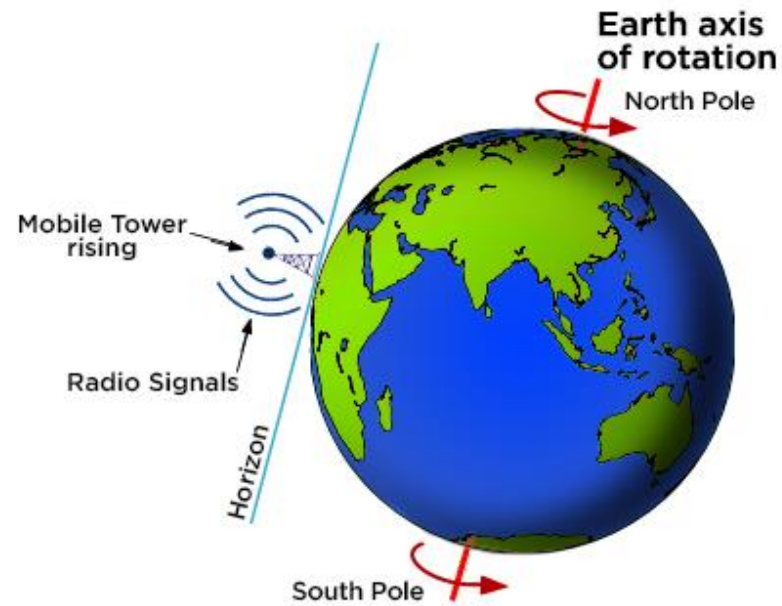
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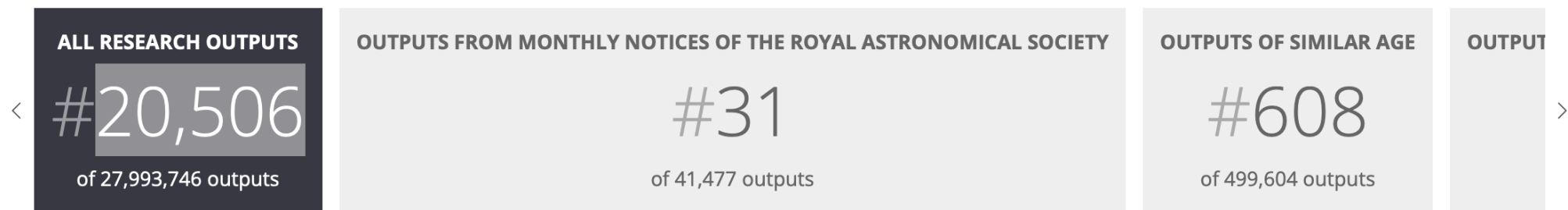
## Article Contents

ABSTRACT

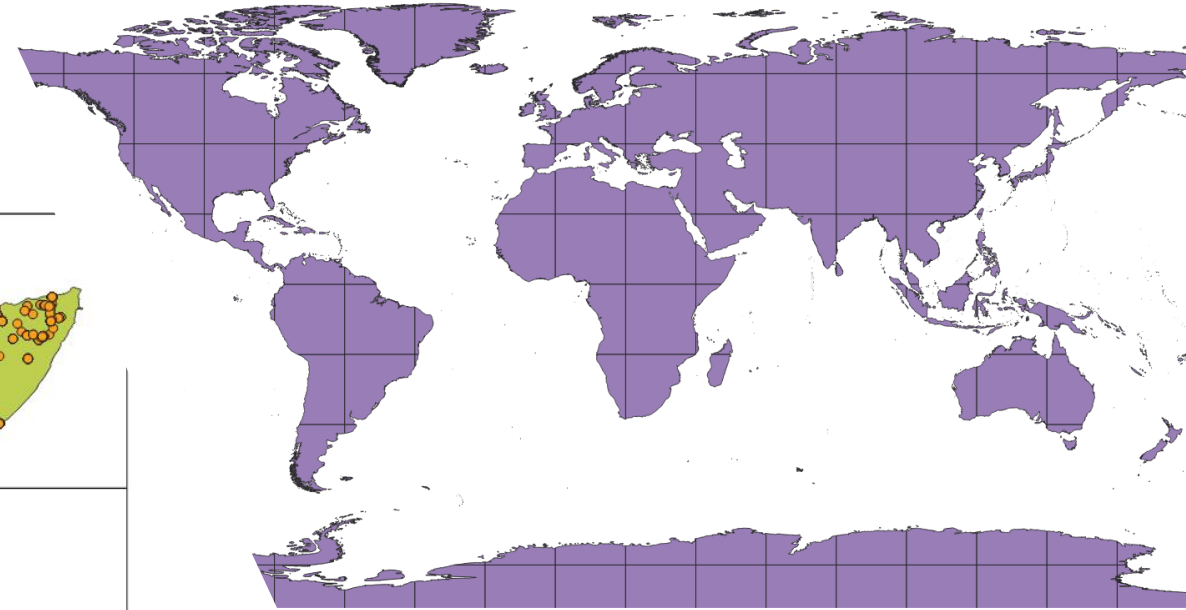
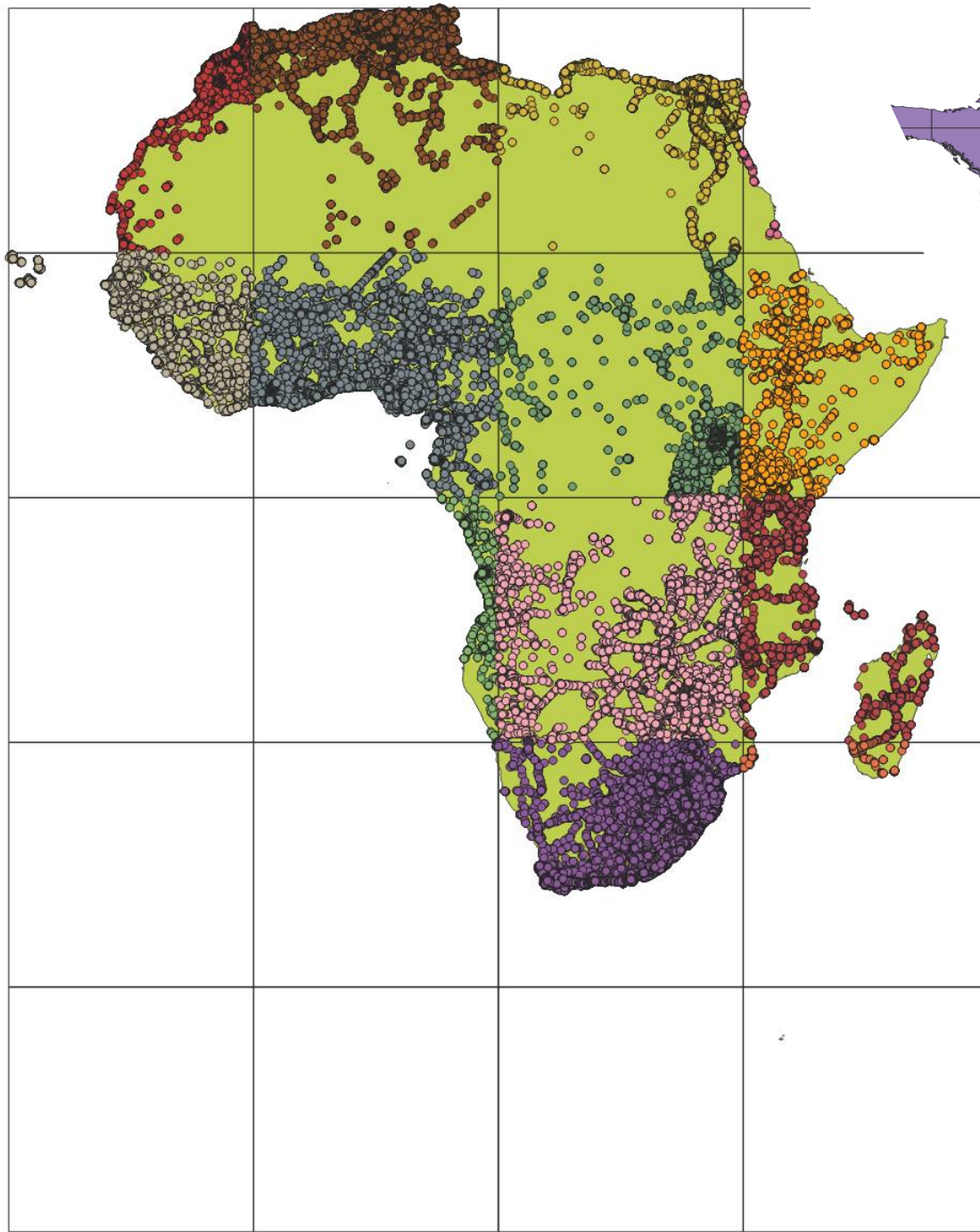




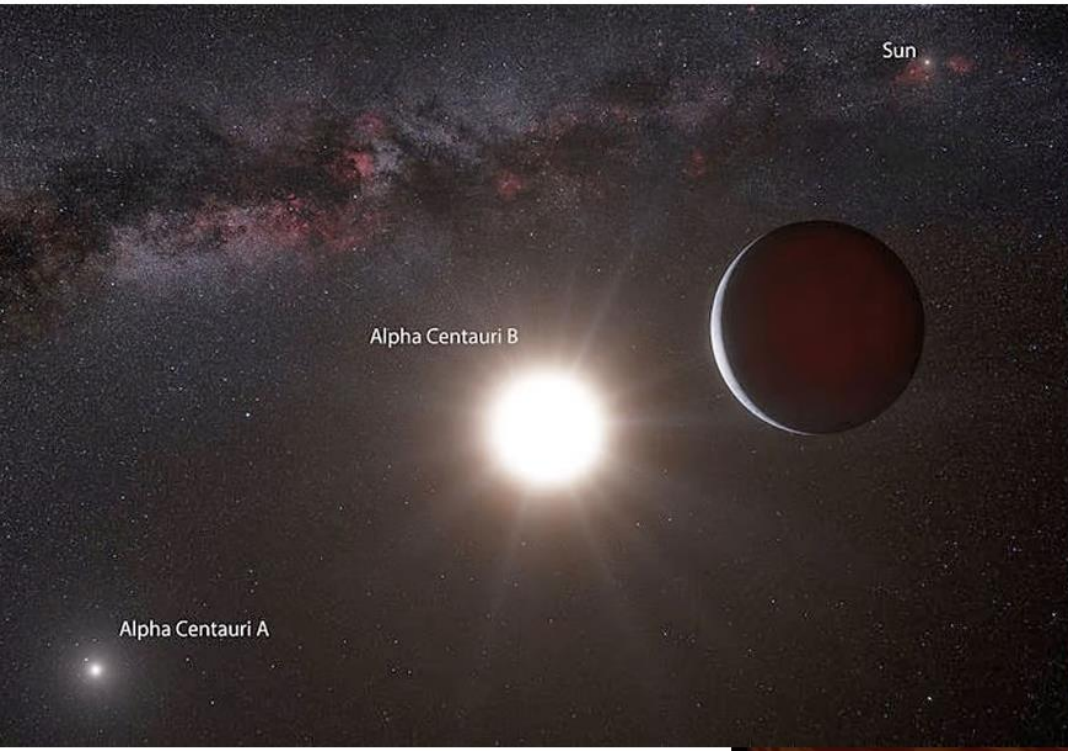
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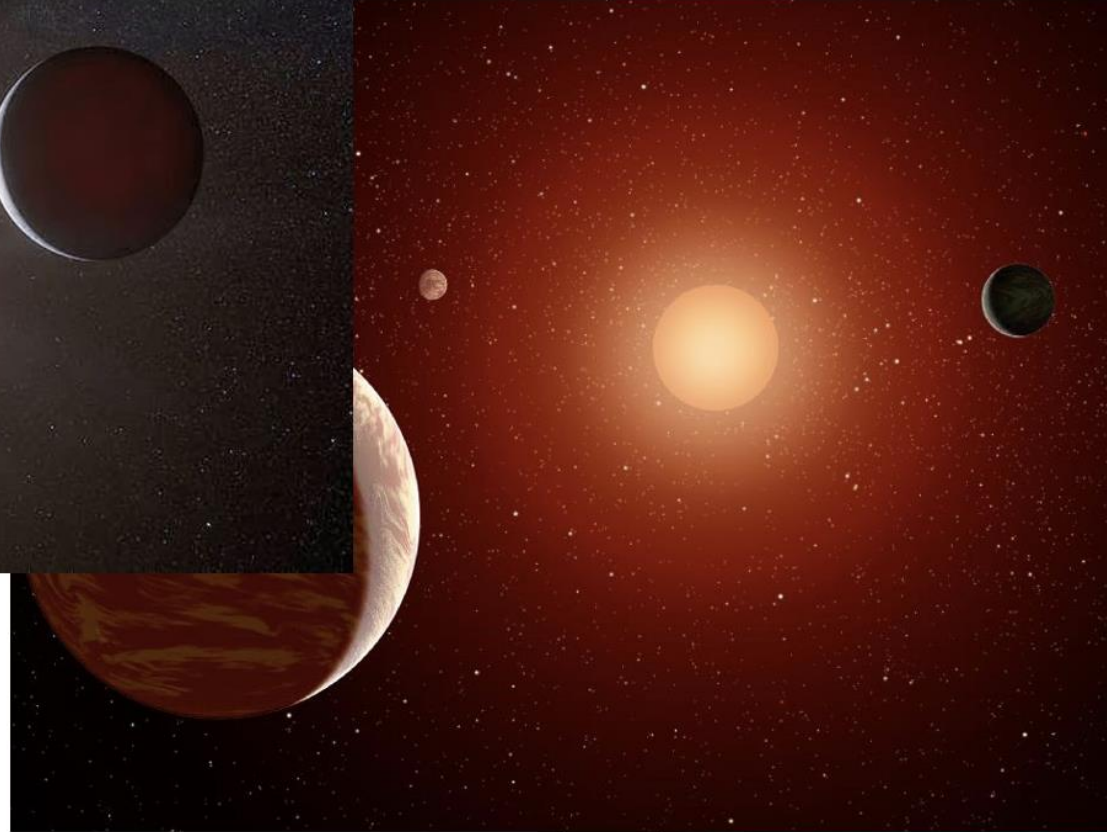
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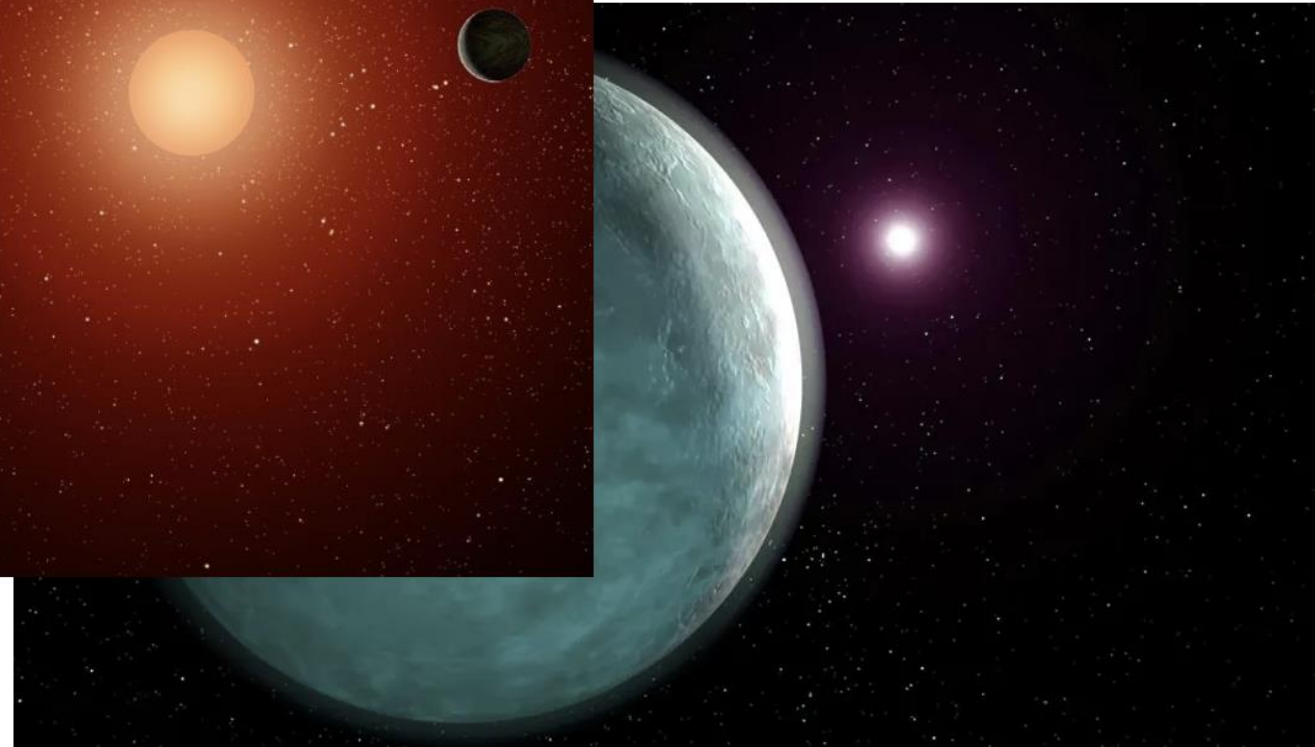
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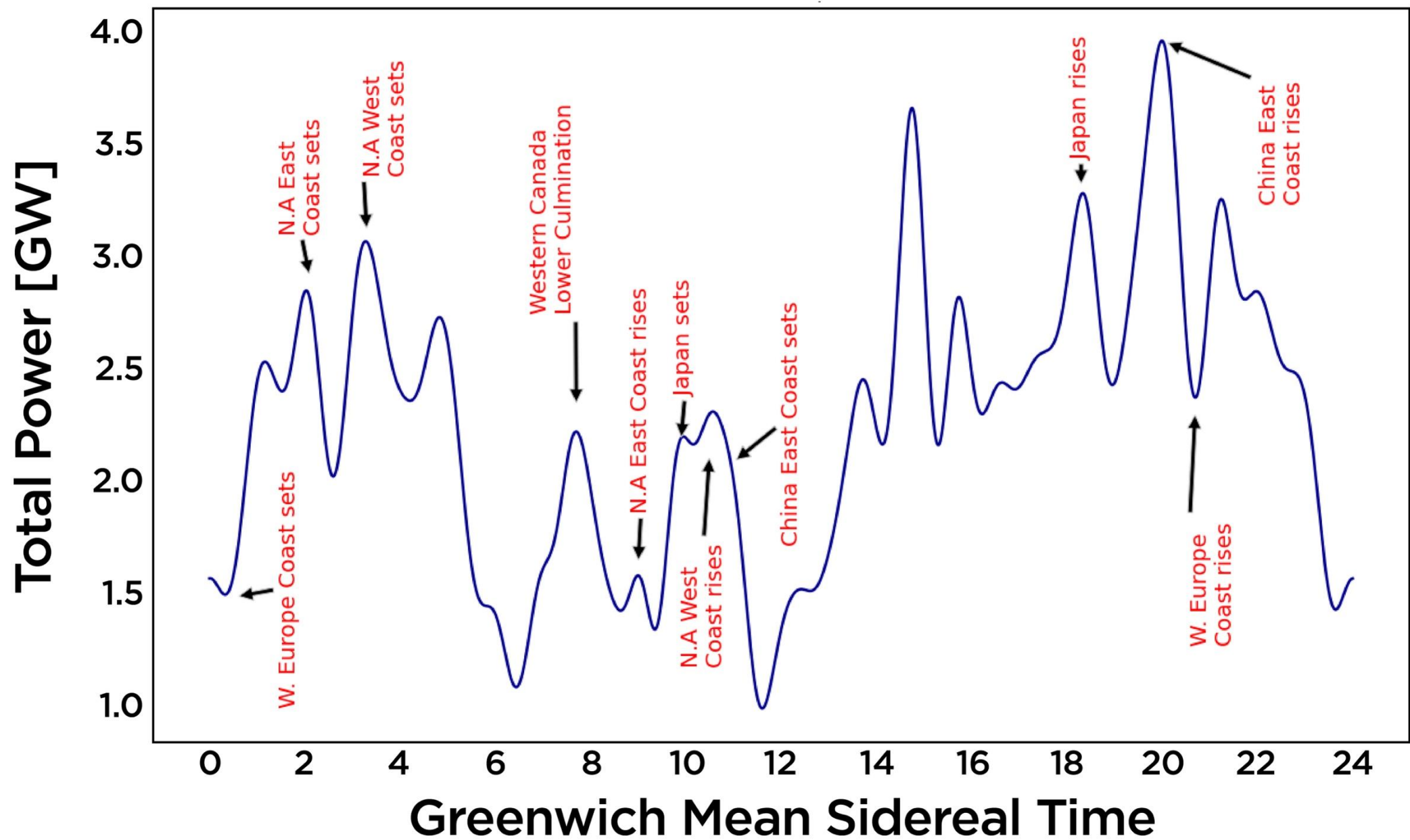
# Barnard Star



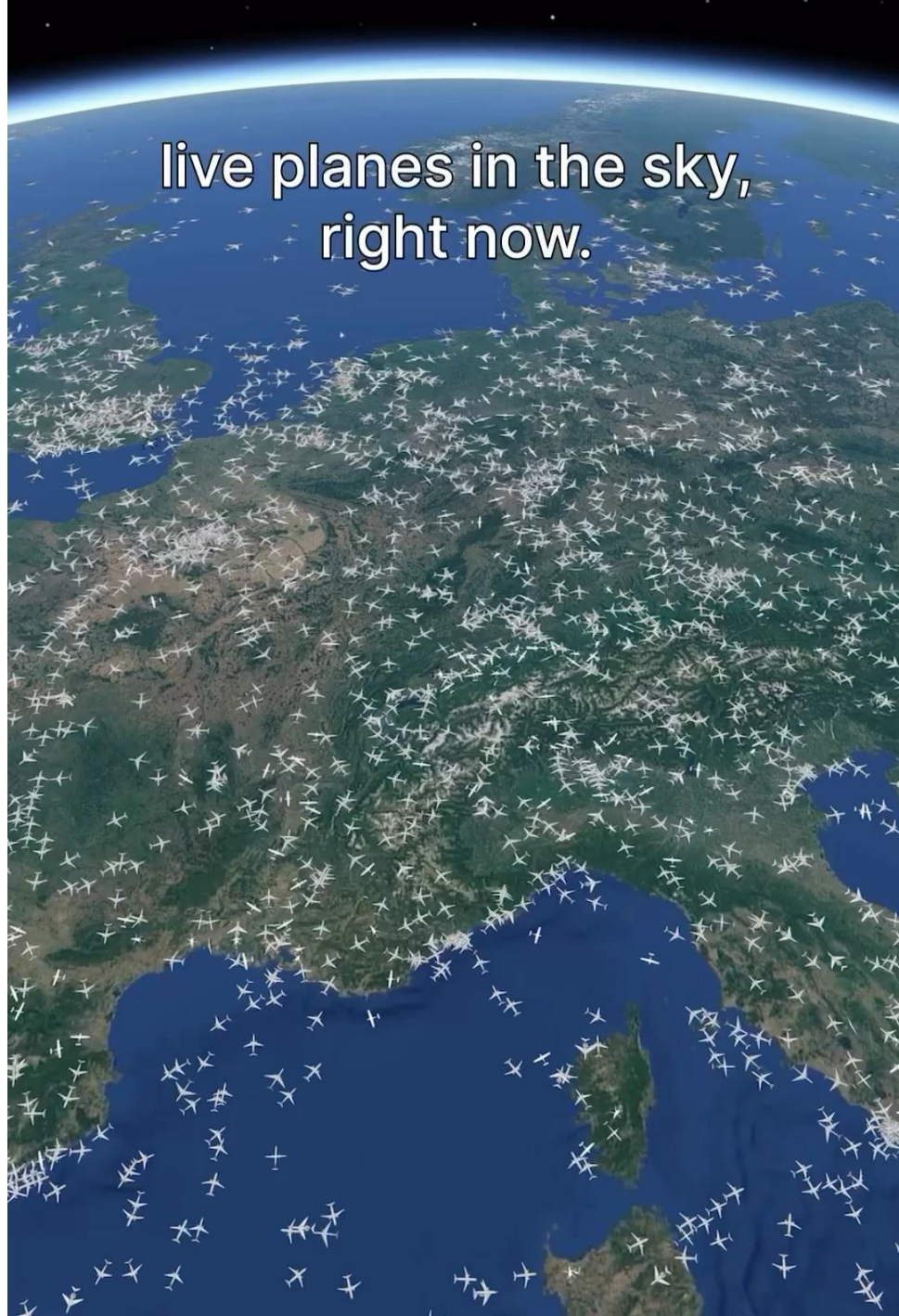
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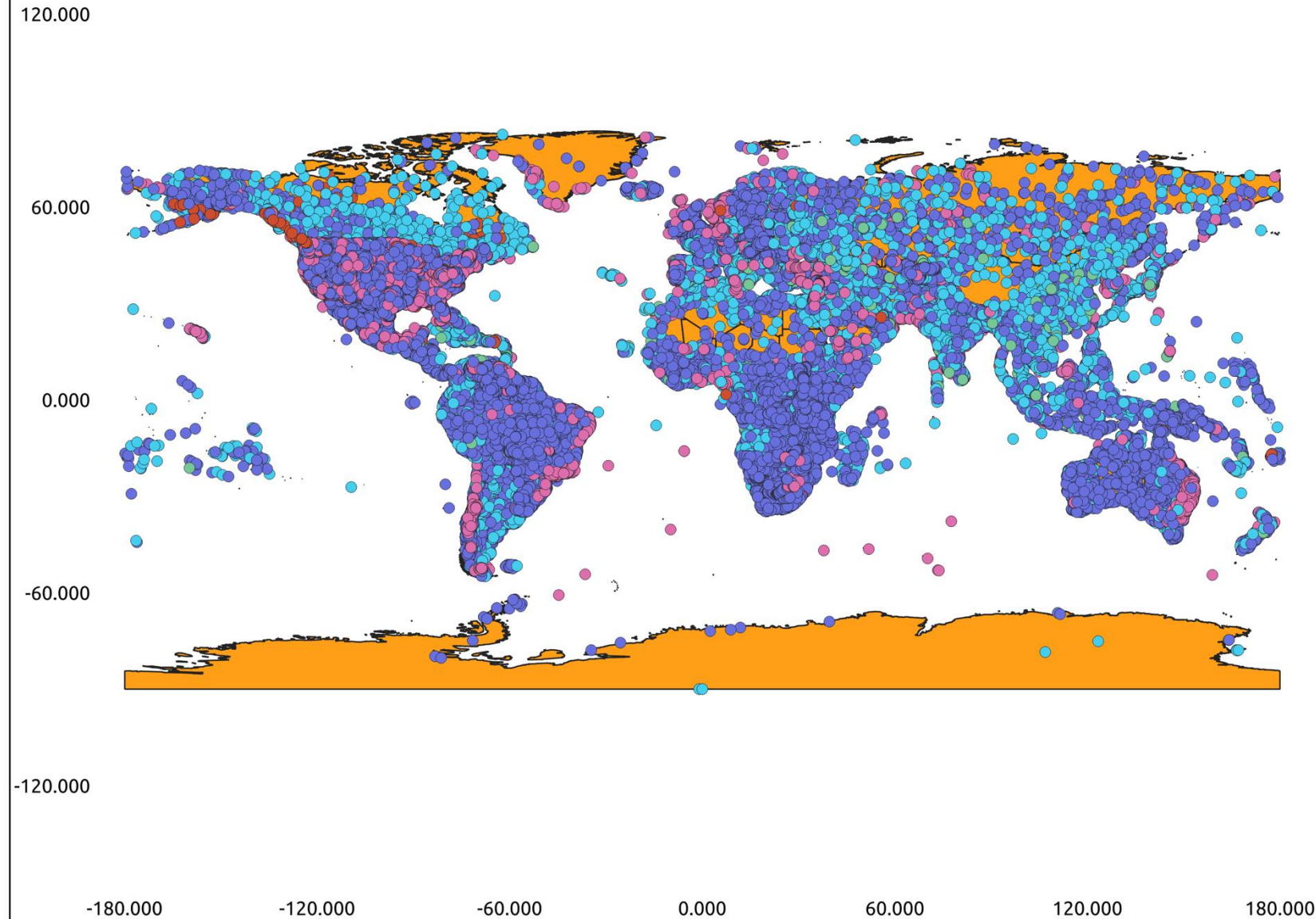
HD 95735: RA = 11.0558<sup>h</sup>, Dec = 35.96988°



live planes in the sky,  
right now.



# Map of Airports in the World



## Legend:

airports

- balloonport
- closed
- heliport
- large\_airport
- medium\_airport
- seaplane\_base
- small\_airport

Developed by:

Ramiro Caisse Saide

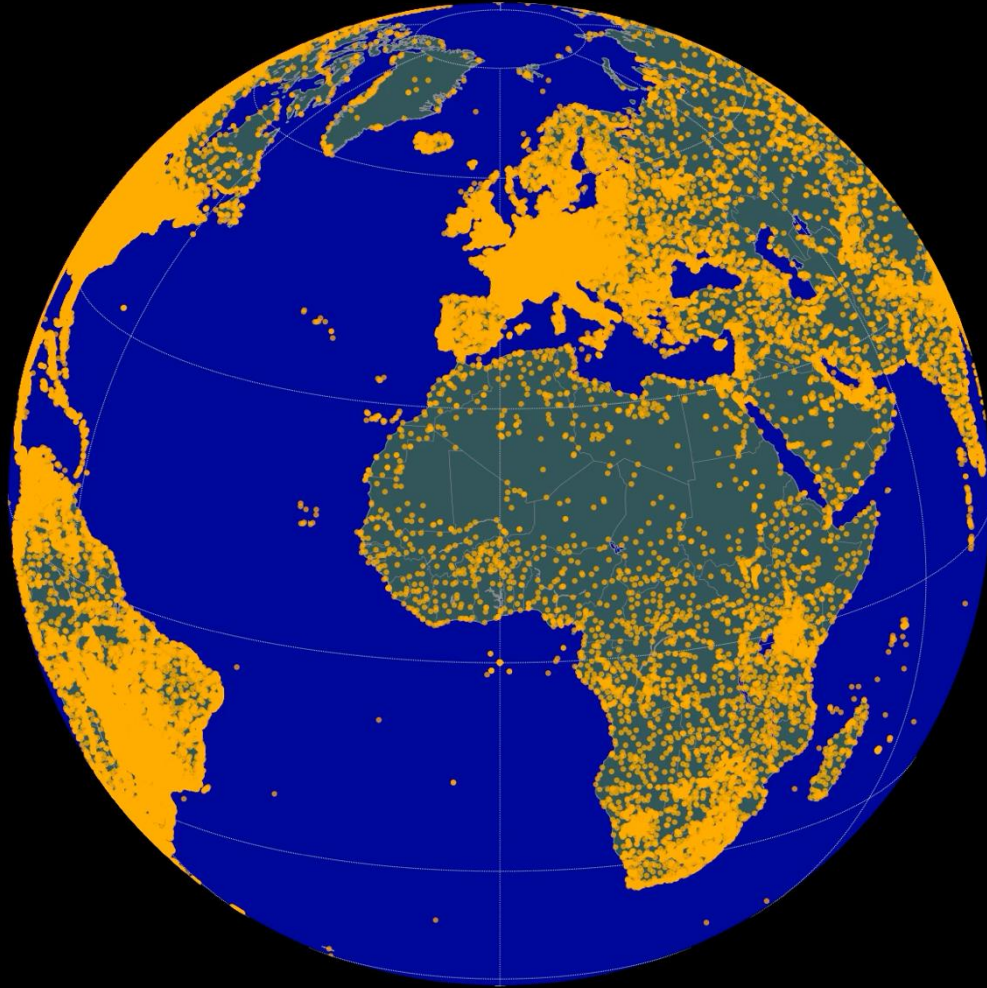


World Geodetic System  
(WGS) 84.

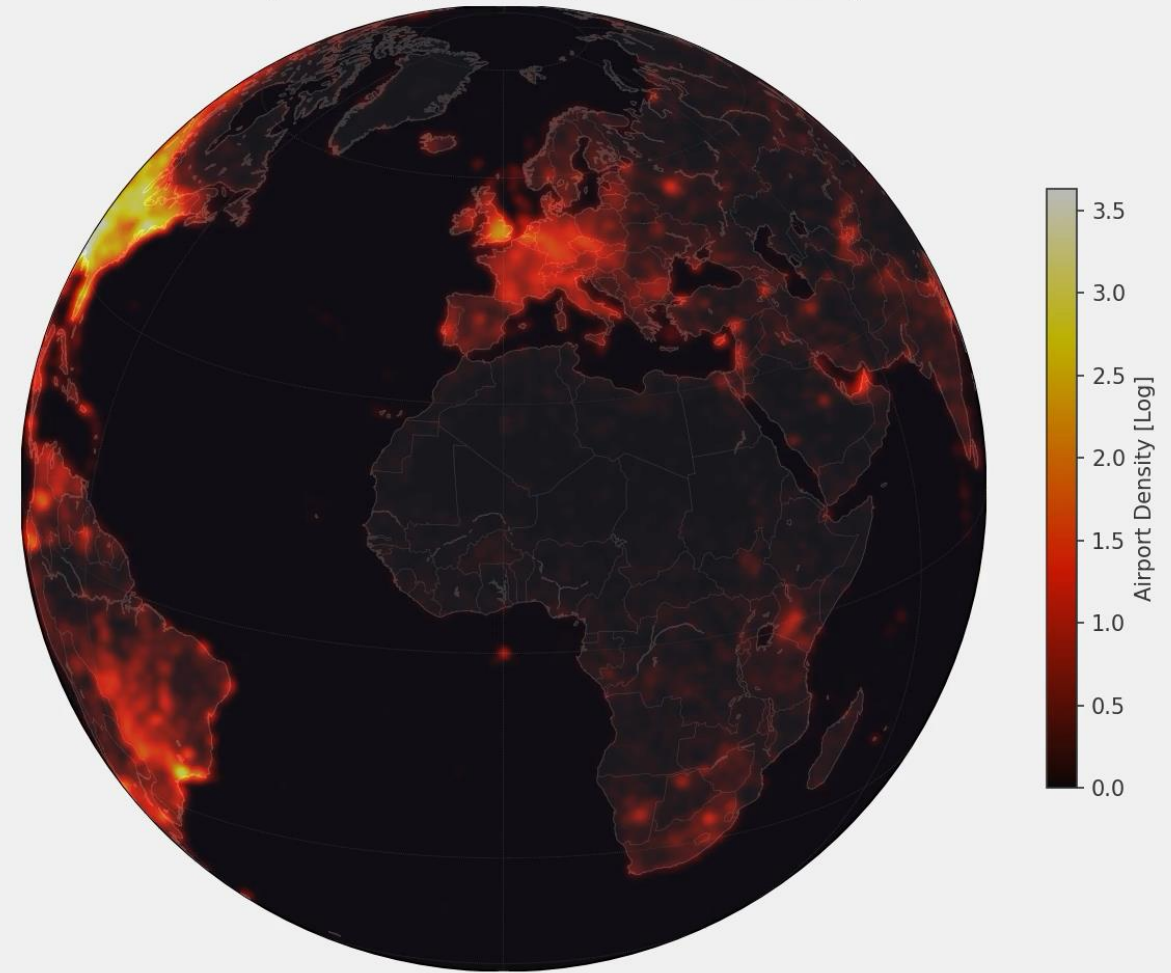
Natural Earth.

OurAirports dataset  
formats.

Global Airport Locations (View centered at 0°E)



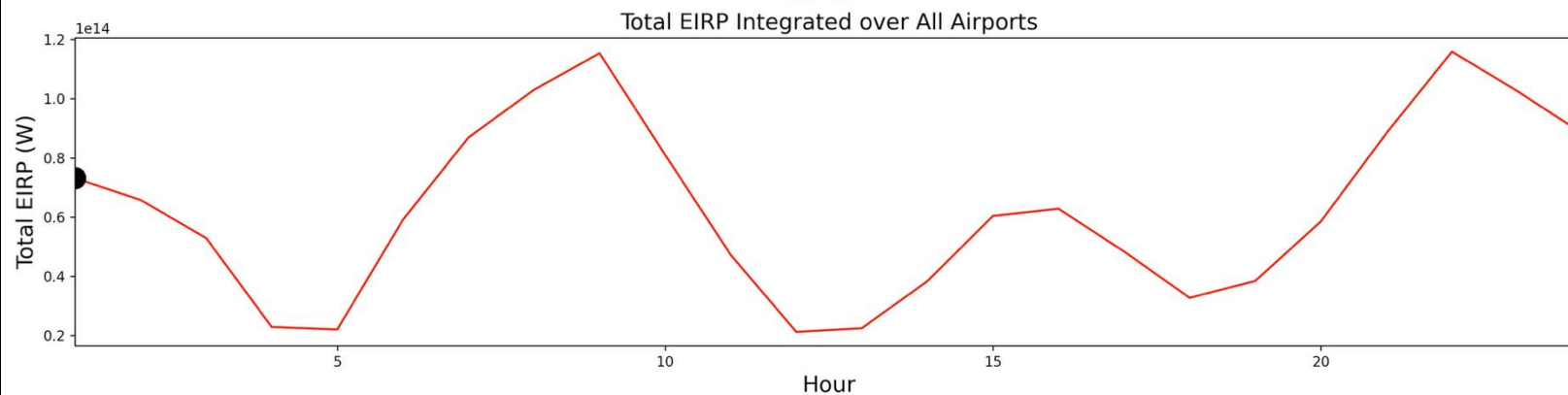
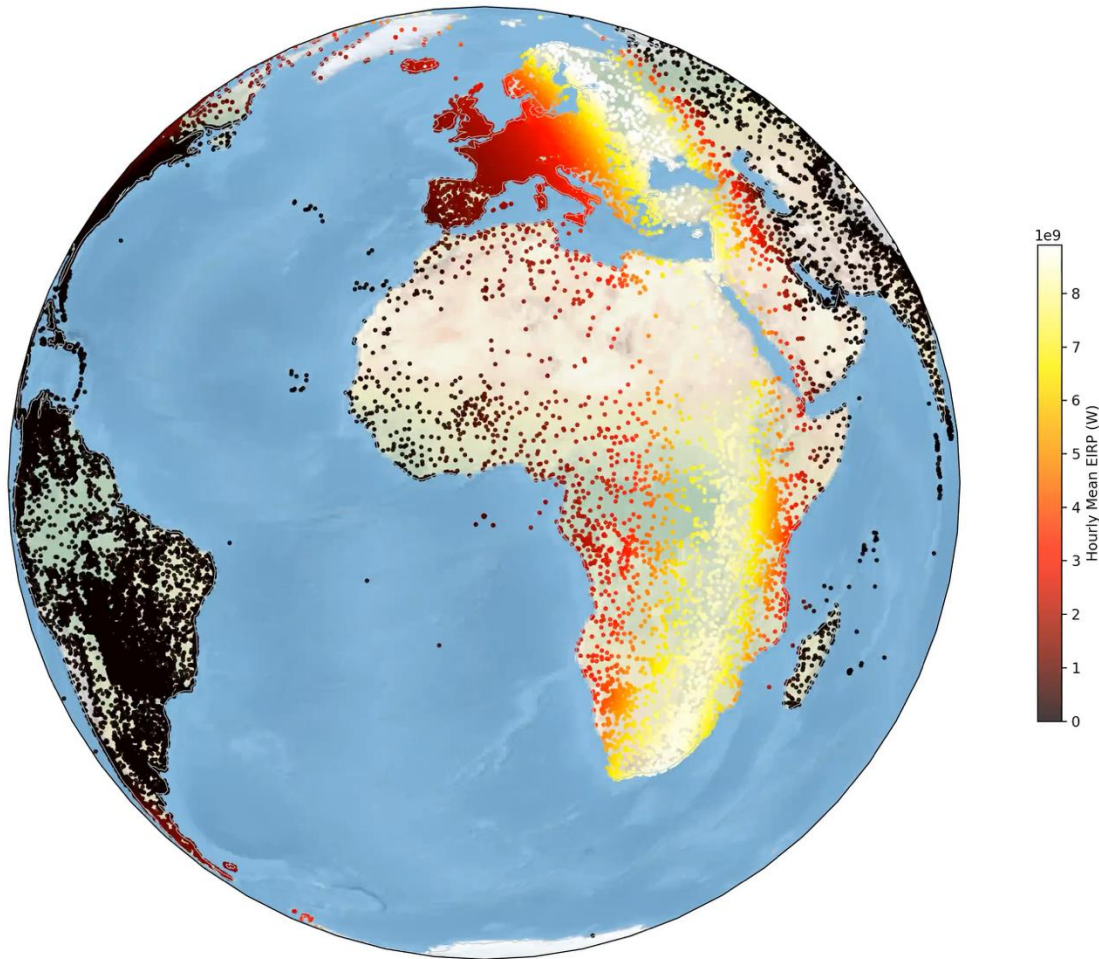
Global Airport Density Heatmap (View centered at 0°E)



# Target Selection

- Barnard's Star is the second closest stellar, at 6-ly system to our Sun.
- HD 48948 is a K-dwarf star located approximately 52.18-ly from Earth.
- HIP 57274 is a K-type star located about 84-ly from Earth.
- AU Microscopii is a young red dwarf star located 31.683-ly in the constellation Microscopium.
- HD 216520 is a K-type star, located in the northern celestial hemisphere, at 63.80-ly from our Earth.
- LHS 475 (also known as 2MASS J19205439-8233170) located at 40 ly for earth.



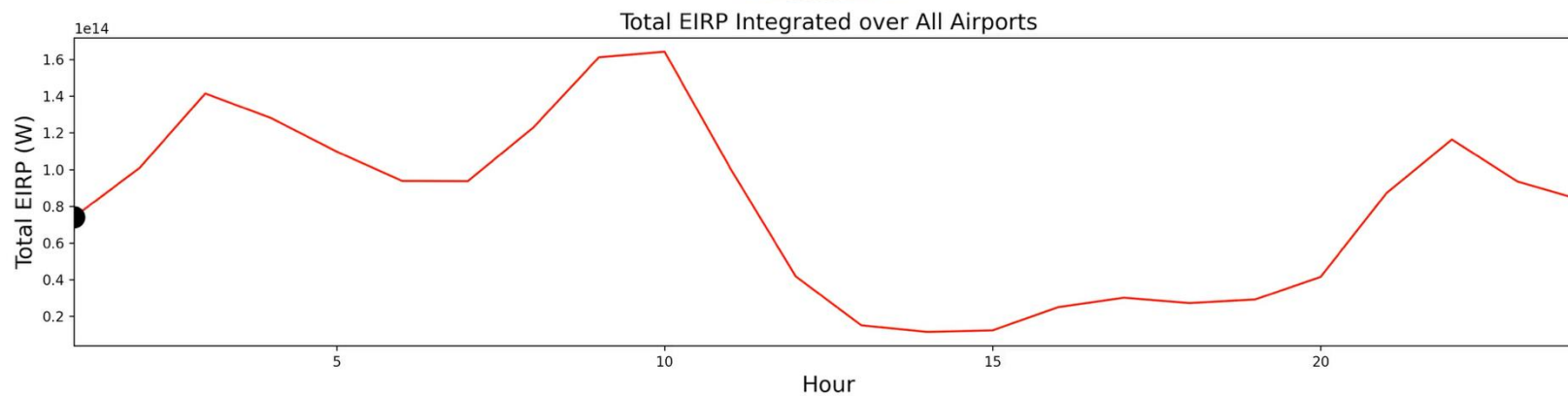
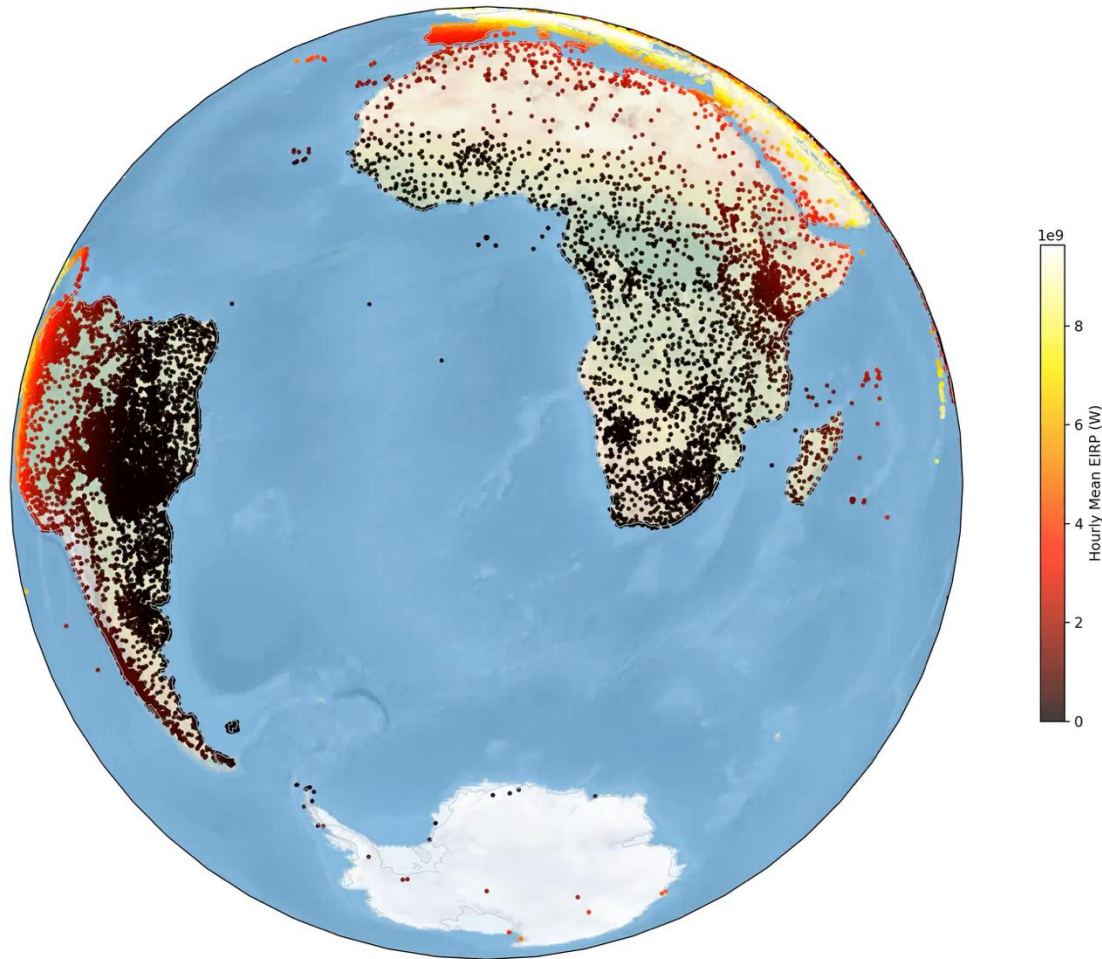


# Barnard Star

Right ascension: 17h 57m 47.648s

Declination: 4° 44' 21.912''

Barnard's Star (also known as GJ 699) is the second closest stellar (6 light-years) system to our Sun, with one sub-Earth-mass planet located inwards from the Habitable Zone.



# AU Microscopii

Right ascension: **20h 45m 9.885s**

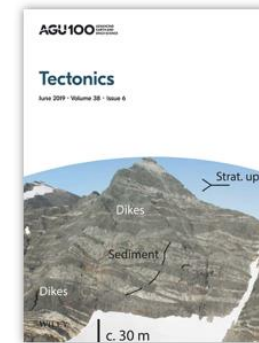
Declination: **-31° 20' 33"**

AU Microscopii is a young red dwarf star located 31.683 light-years, with three known planets and one exoplanet candidate.

## A Global Plate Model Including Lithospheric Deformation Along Major Rifts and Orogens Since the Triassic

R. Dietmar Müller , Sabin Zahirovic, Simon E. Williams, John Cannon, Maria Seton, Dan J. Bower, Michael G. Tetley, Christian Heine, Eline Le Breton, Shaofeng Liu, Samuel H. J. Russell, Ting Yang, Jonathon Leonard, Michael Gurnis

First published: 05 May 2019 | <https://doi.org/10.1029/2018TC005462> | Citations: 423



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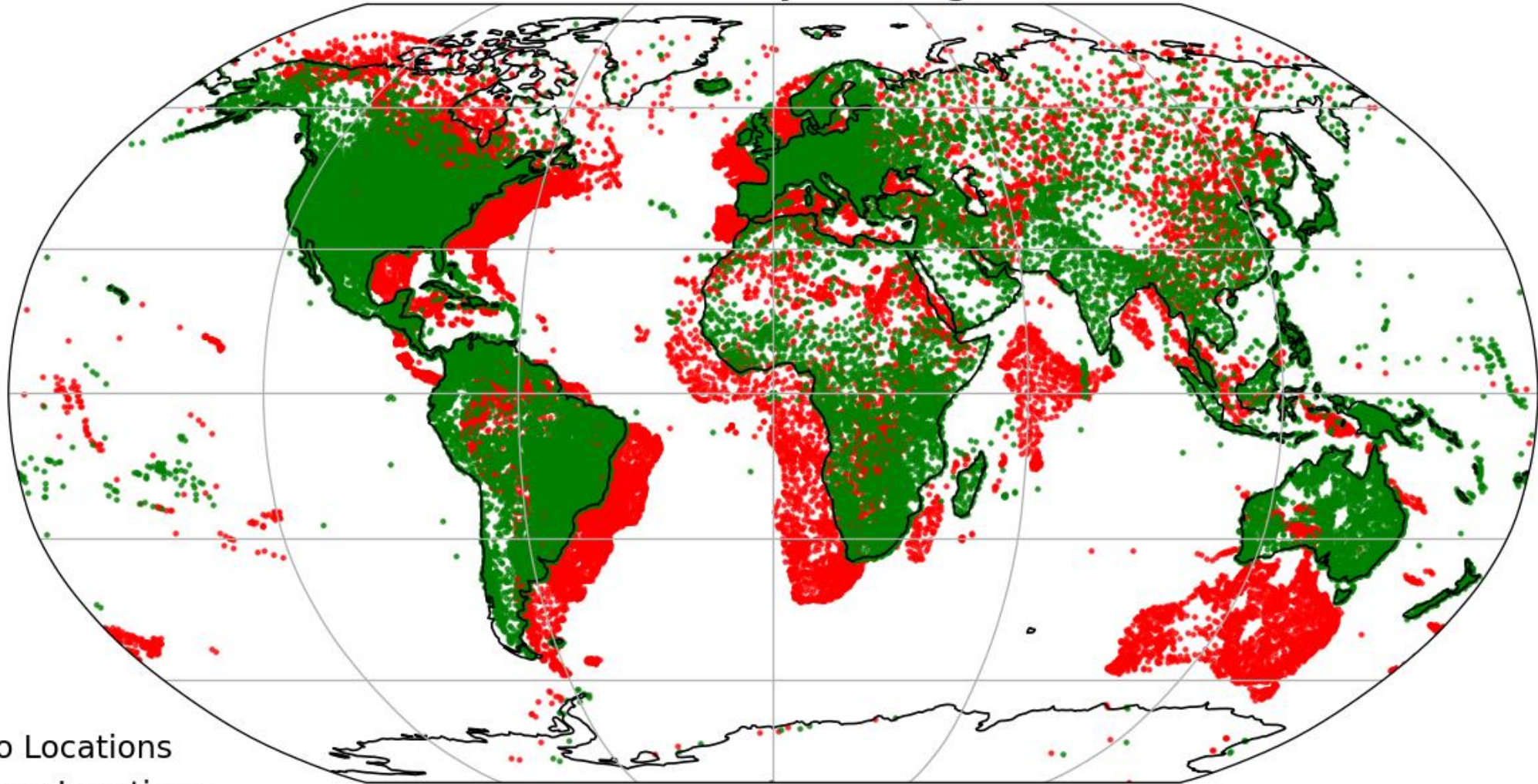
Volume 38, Issue 6

June 2019

Pages 1884-1907

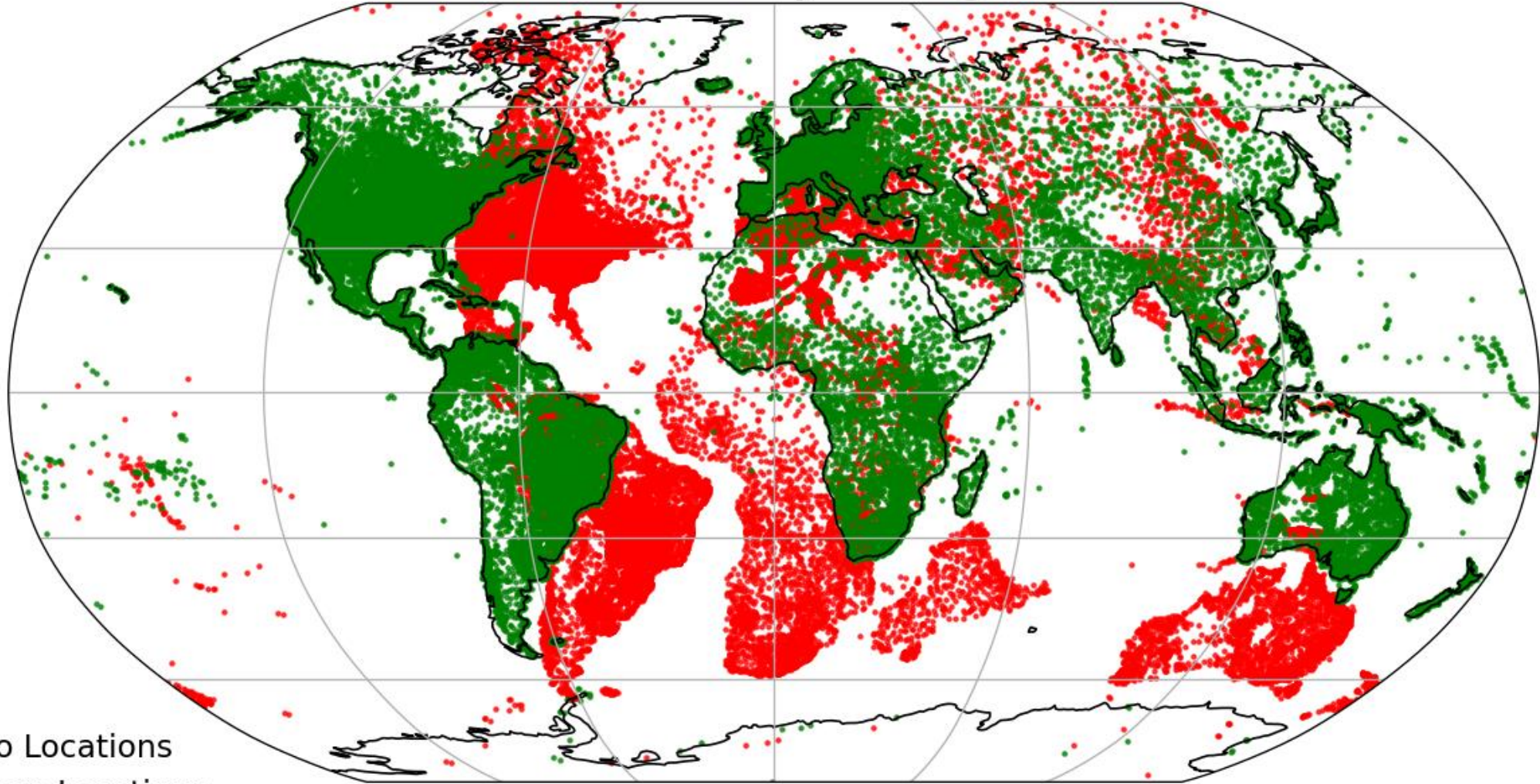
This article also appears in:  
**Fifty Years of Plate Tectonics:  
Then, Now, and Beyond**

50 Million years ago



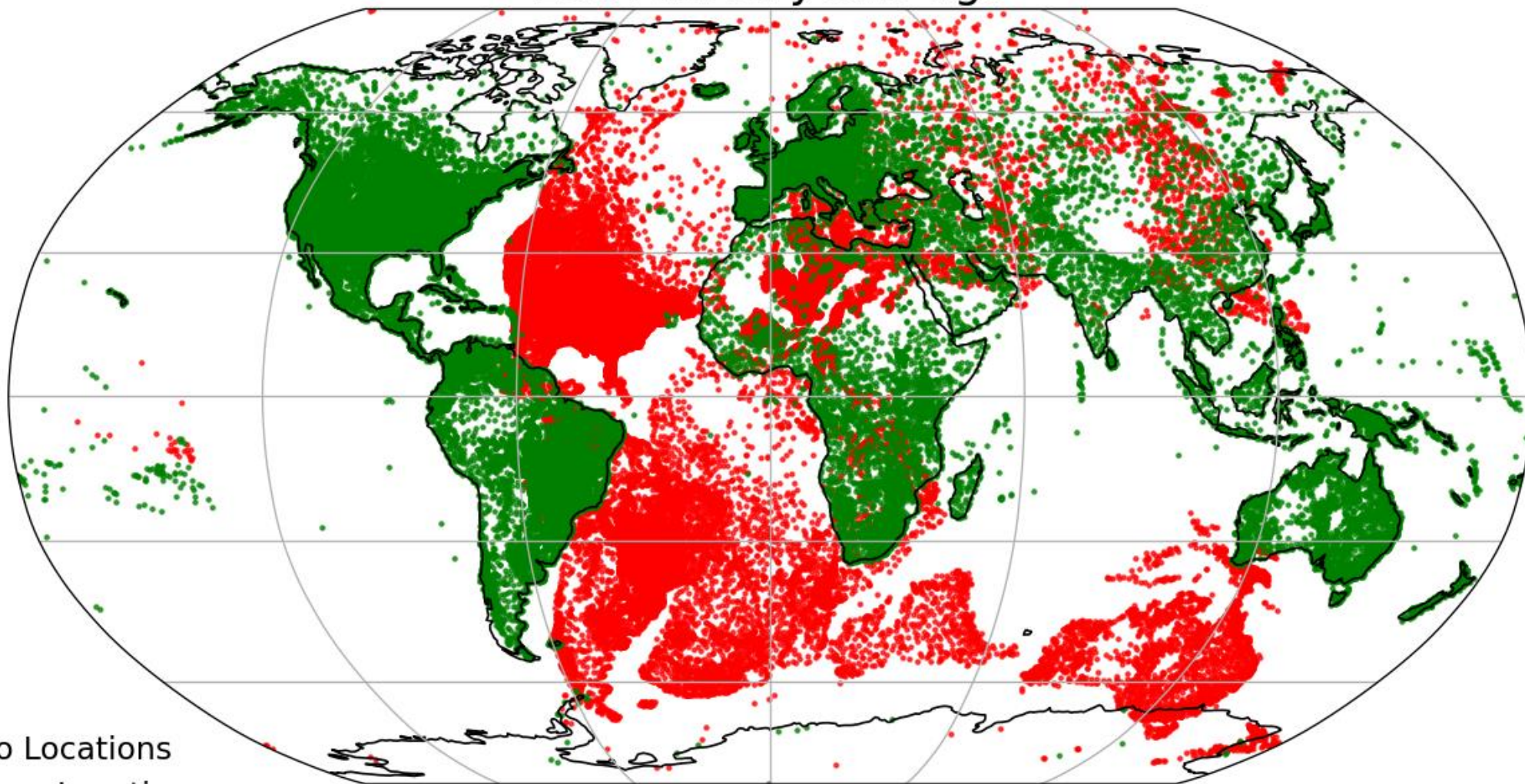
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- Modern Locations

100 Million years ago



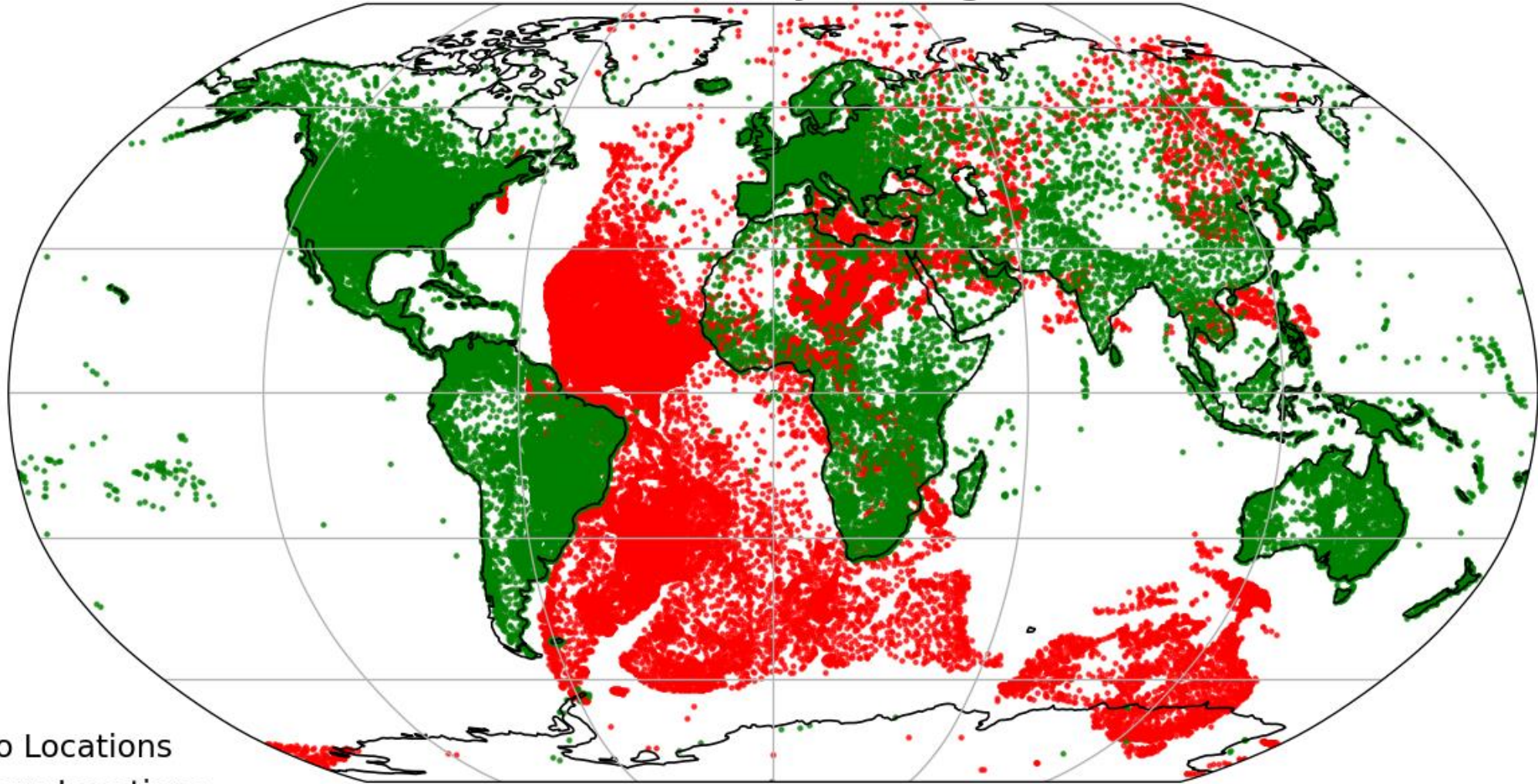
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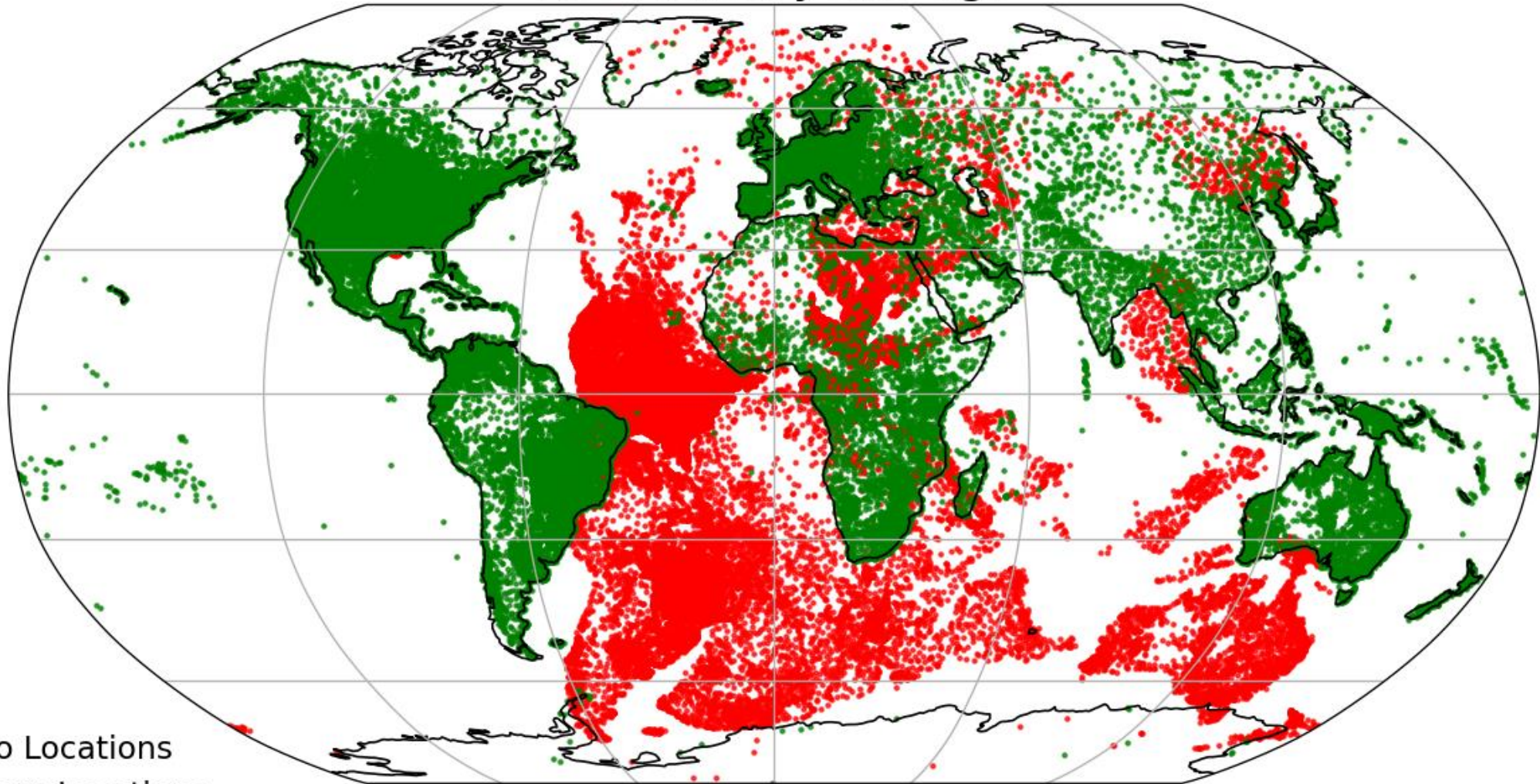
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200 Million years ago

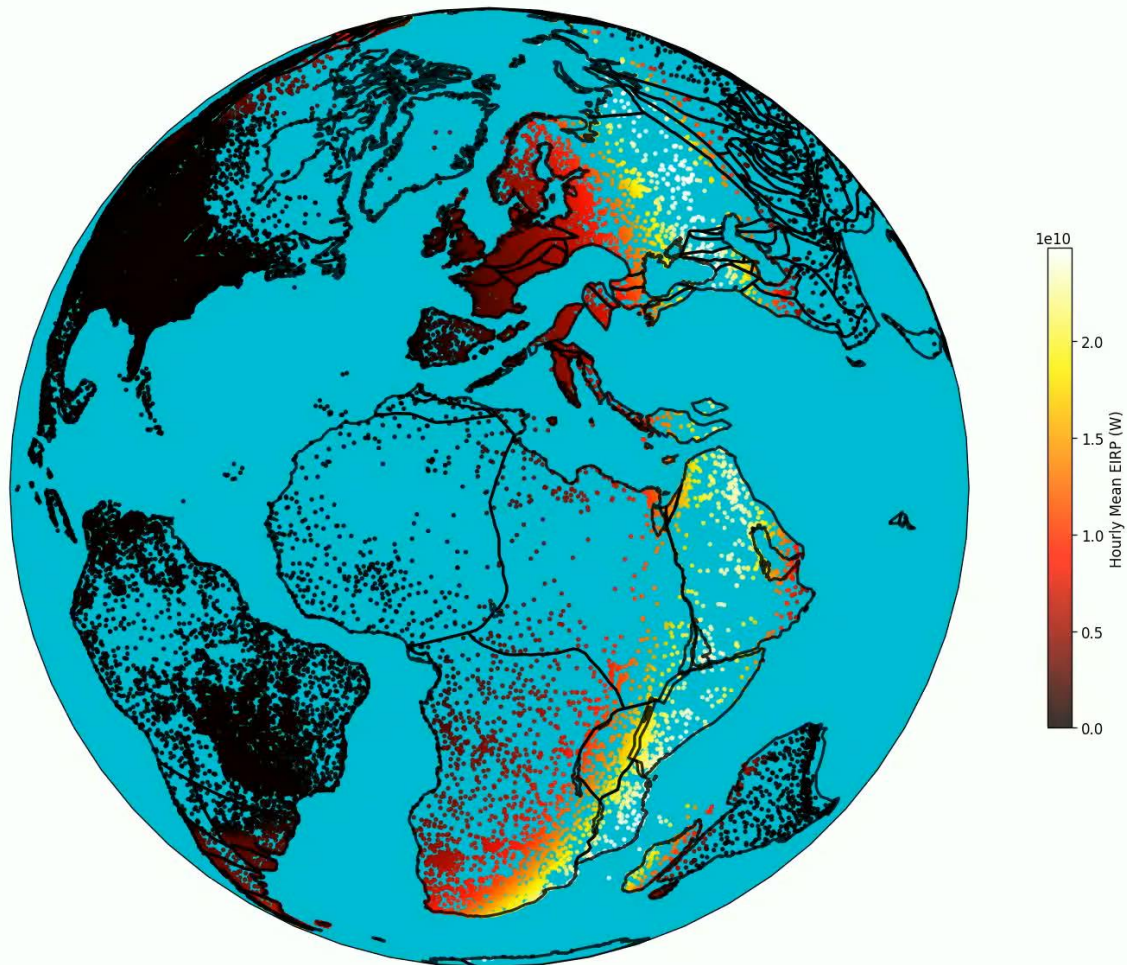


- Paleo Locations
- Modern Locations

250 Million years ago



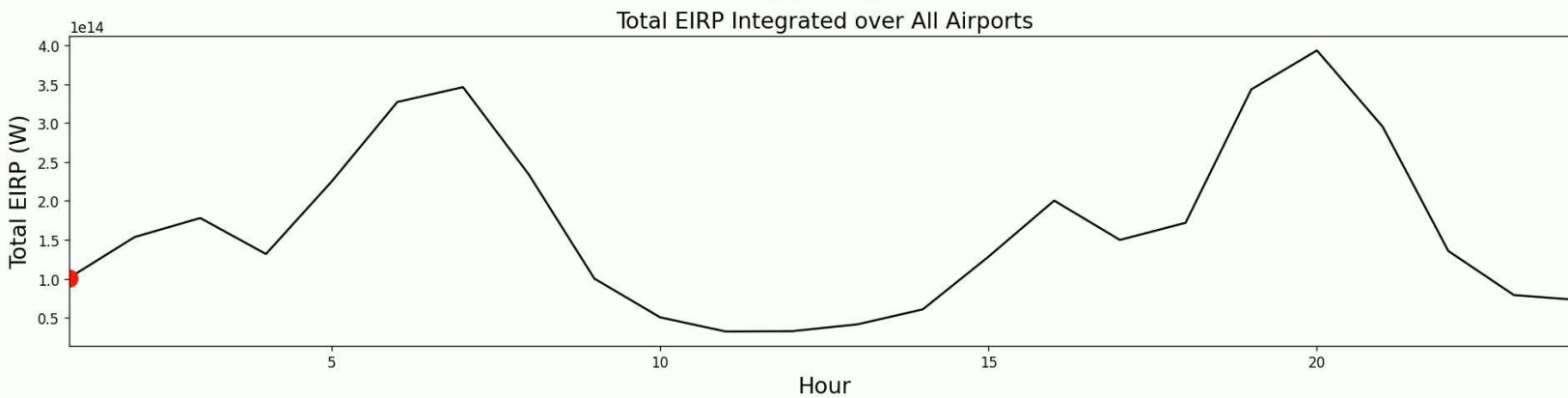
- Paleo Locations
- Modern Locations

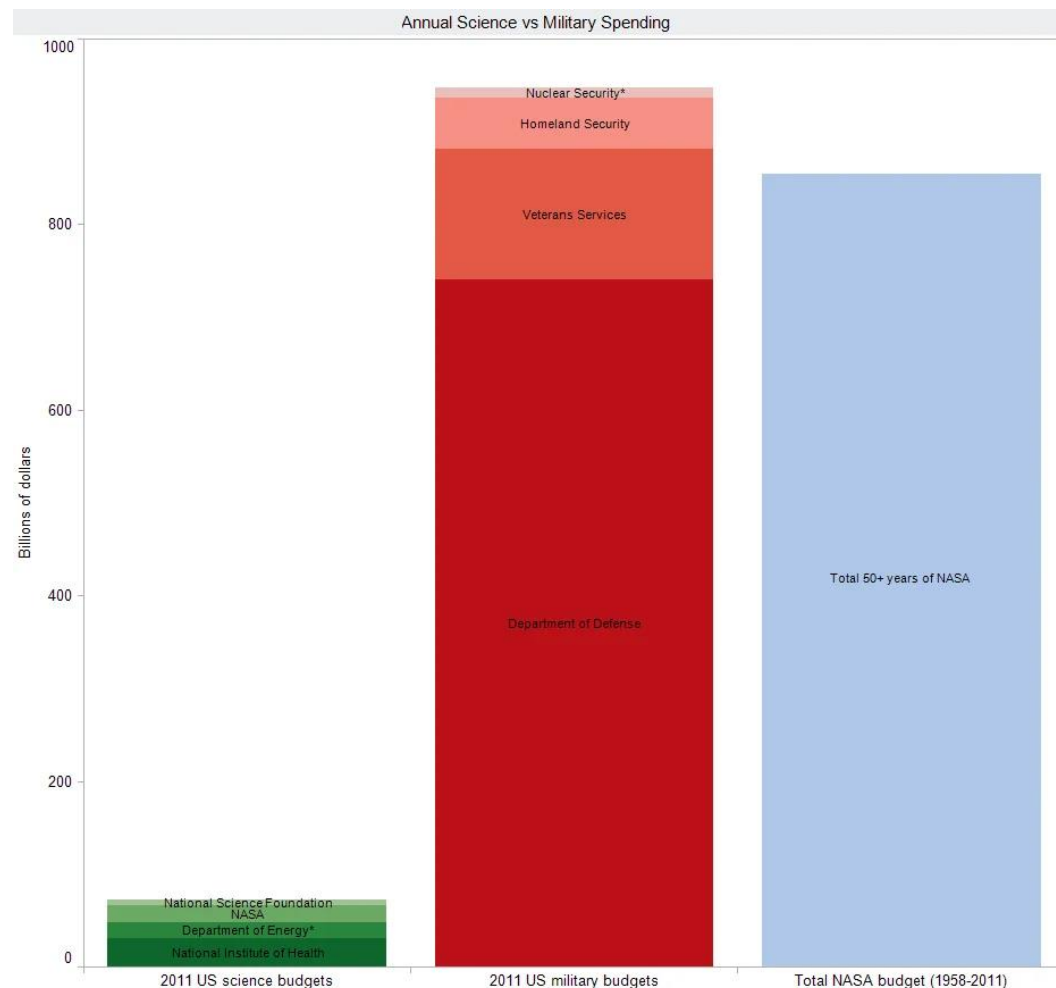


# Barnard Star

Right ascension: 17h 57m 47.648s

Declination: 4° 44' 21.912"





**Data Sources**  
 DHS - <http://www.dhs.gov/xlibrary/assets/budget-bib-fy2012.pdf>  
 DOD and veterans - <http://www.whitehouse.gov/sites/default/files/omb/budget/fy2012/assets/hist032.xls>  
 DOE - <http://www.eo.doe.gov/budget/13budget/ContentAppsum.pdf>  
 NASA - [http://www.nasa.gov/pdf/632697main\\_NASA\\_FY13\\_Budget\\_Summary-508.pdf](http://www.nasa.gov/pdf/632697main_NASA_FY13_Budget_Summary-508.pdf)  
 NIH - <http://www.nih.gov/about/aimanac/appropriations/index.htm>  
 NSF - [http://www.nsf.gov/about/congress/112/highlights/out1\\_0623.jsp](http://www.nsf.gov/about/congress/112/highlights/out1_0623.jsp)

\* Nuclear security is technically the responsibility of the DOE

Created by Steve Haroz



# \$2.113T

**TOTAL GLOBAL MILITARY SPENDING IN 2021,  
THE FIRST TIME IT HAS EXCEEDED \$2 TRILLION**

| REGION       | SPENDING (USD BILLIONS) | CHANGE        |
|--------------|-------------------------|---------------|
| Africa       | (39.7)                  | ↑ 1.2%        |
| Americas     | 883                     | -1.2% ↓       |
| Asia-Pacific | 586                     | ↑ 3.5%        |
| Europe       | 418                     | ↑ 3.0%        |
| Middle East  | (186)                   | -3.3% ↓       |
| <b>Total</b> | <b>\$2.113 trillion</b> | <b>↑ 0.7%</b> |

**“Absence of Evidence is not Evidence of Absence”**

**- Carl Sagan**

**any questions???**

**if not, just clap!**