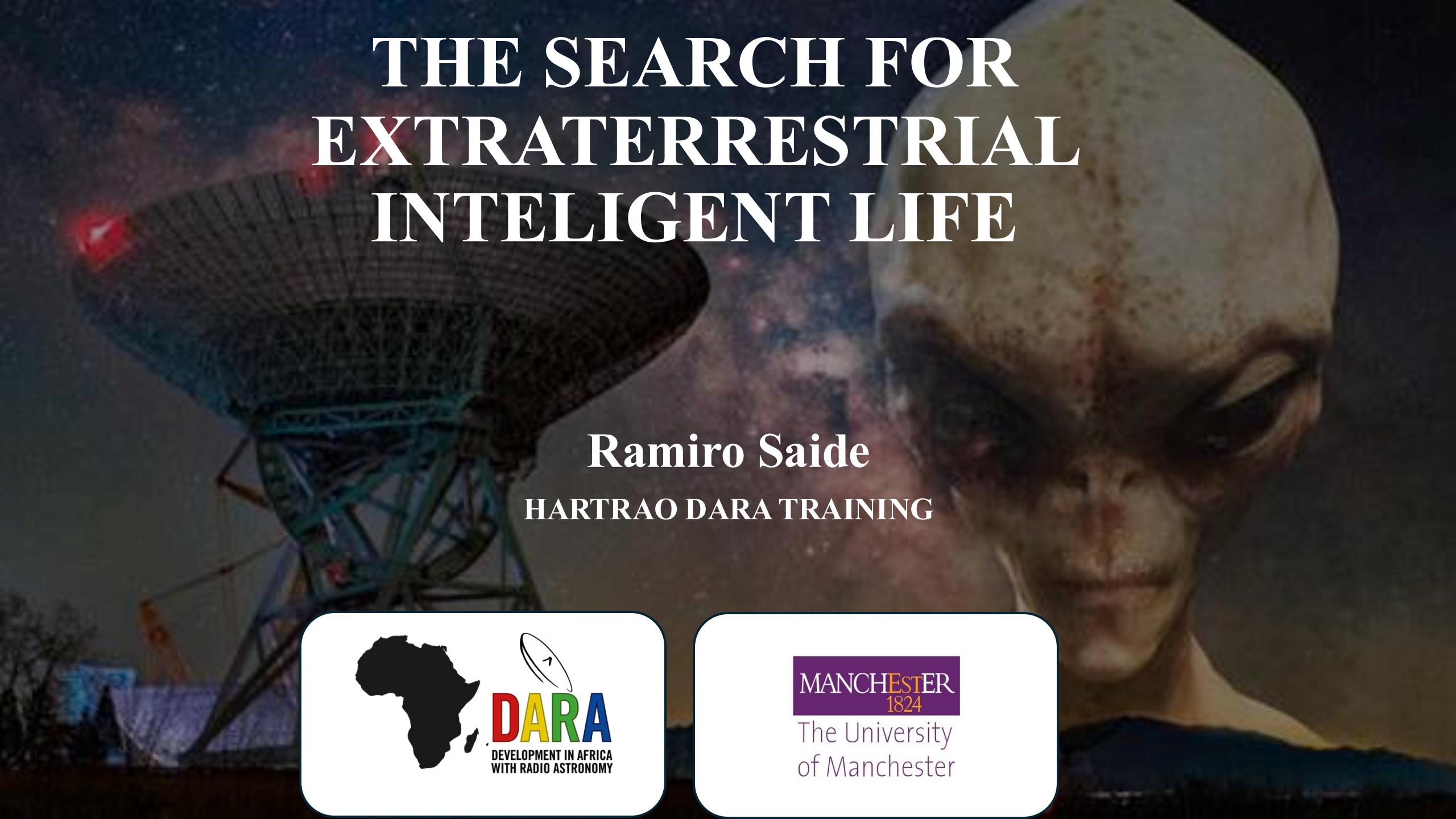


THE SEARCH FOR EXTRATERRESTRIAL INTELIGENT LIFE

Ramiro Saide

HARTRAO DARA TRAINING

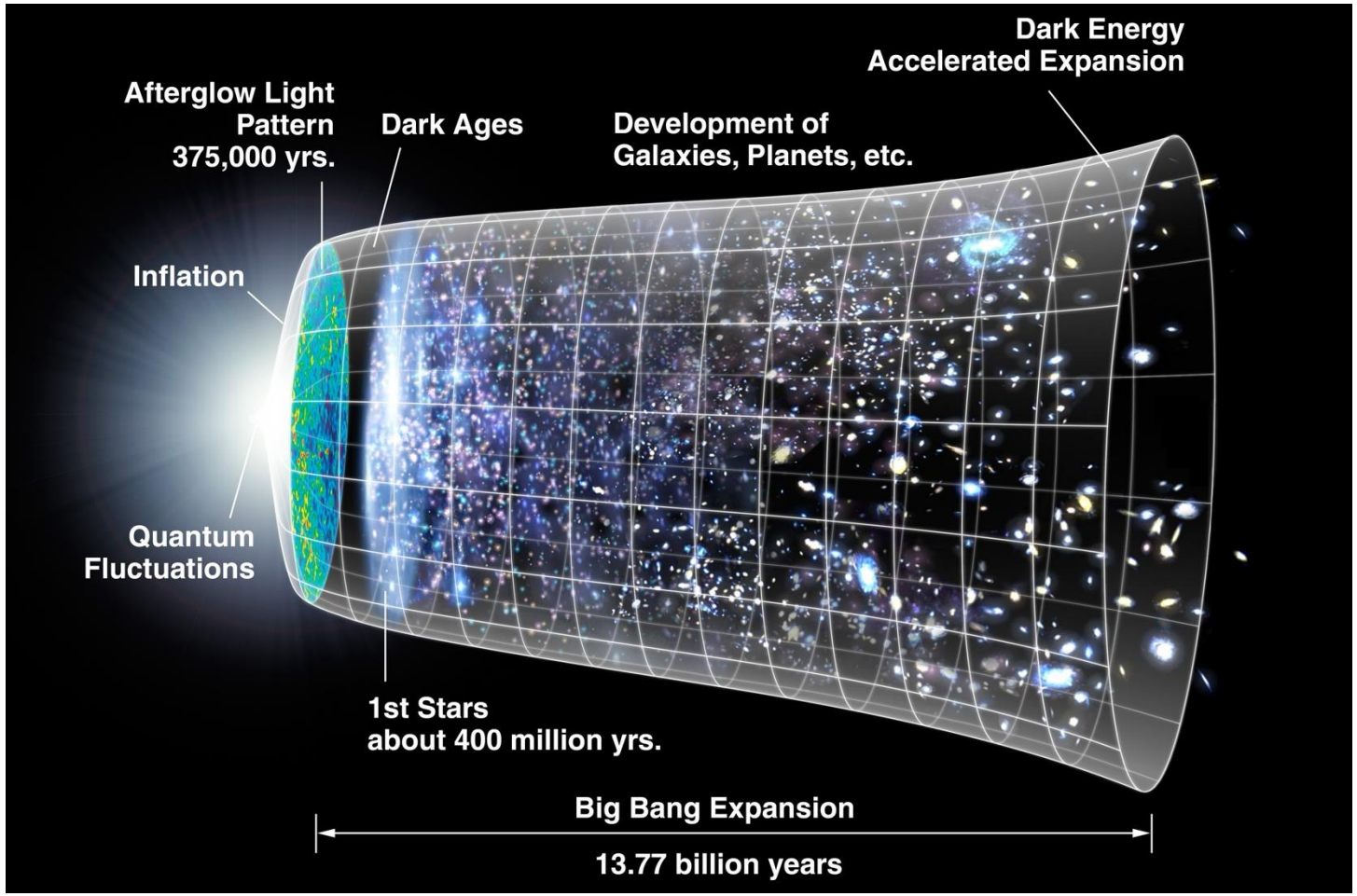
DARA
DEVELOPMENT IN AFRICA WITH RADIO ASTRONOMY

MANCHESTER 1824
The University of Manchester


WE ARE NOT
ALONE
THE QUESTION OF WHETHER WE ARE ALONE IN THE UNIVERSE,
HAS BEEN ANSWERED.

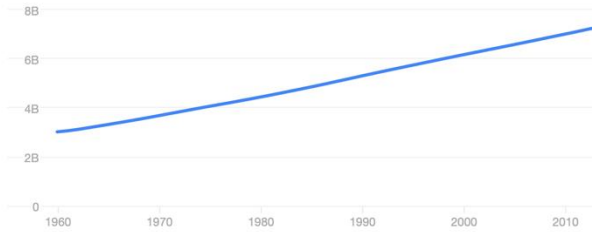

03.2019
FLEEING CHAOS IN EL SALVADOR
CARNIVAL CELEBRATIONS
EXPLORING BORNEO'S CAVES
NATIONAL GEOGRAPHIC
WE ARE NOT ALONE
Scientists say there must be other life in the universe. Here's how they're searching for it.
"Something great is around those stars."
SARA SEAGER, ASTROPHYSICIST

The Journey for Life



World / Population

8.142 billion (2024)



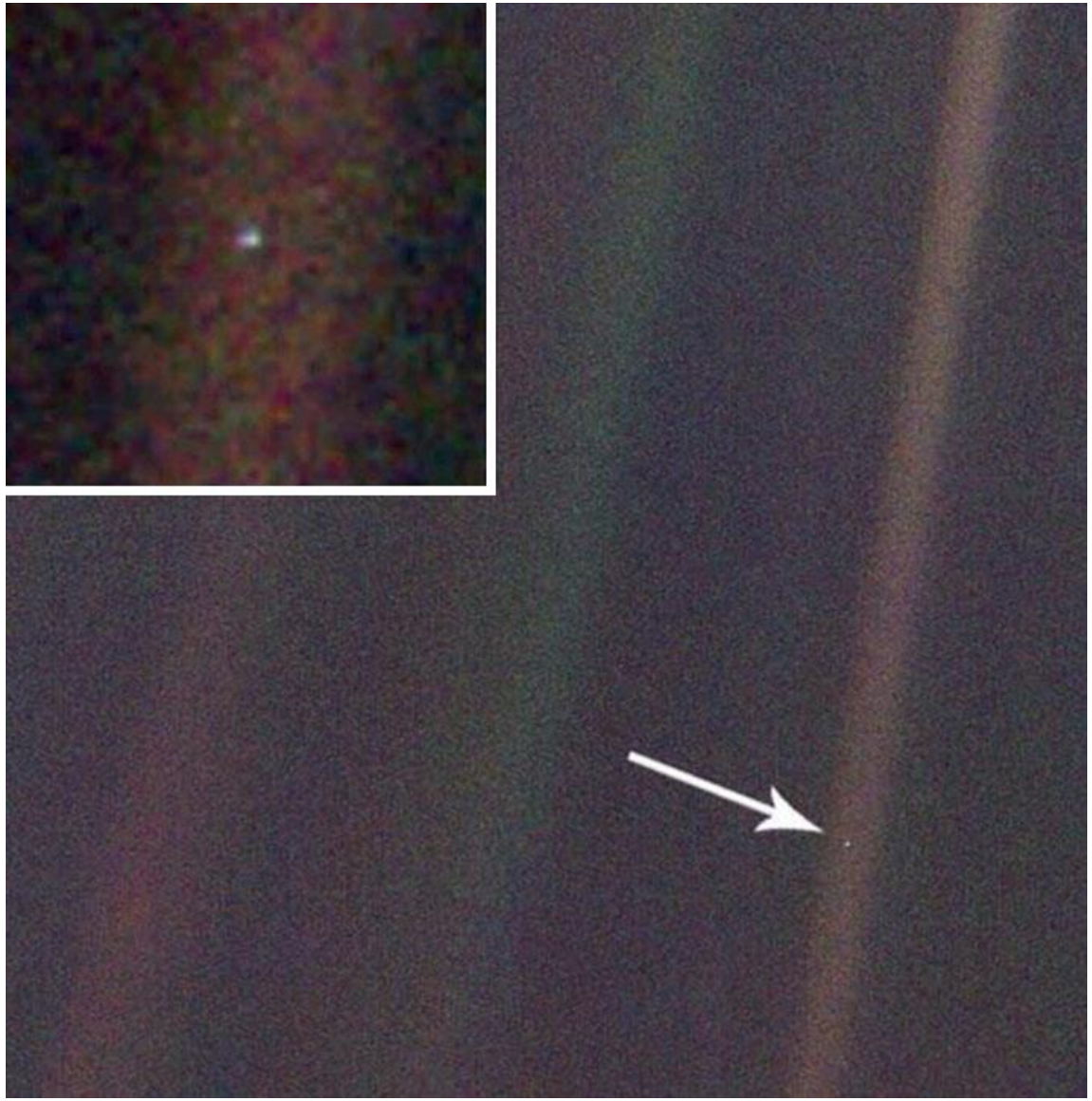
Explore more >

Sources include: World Bank

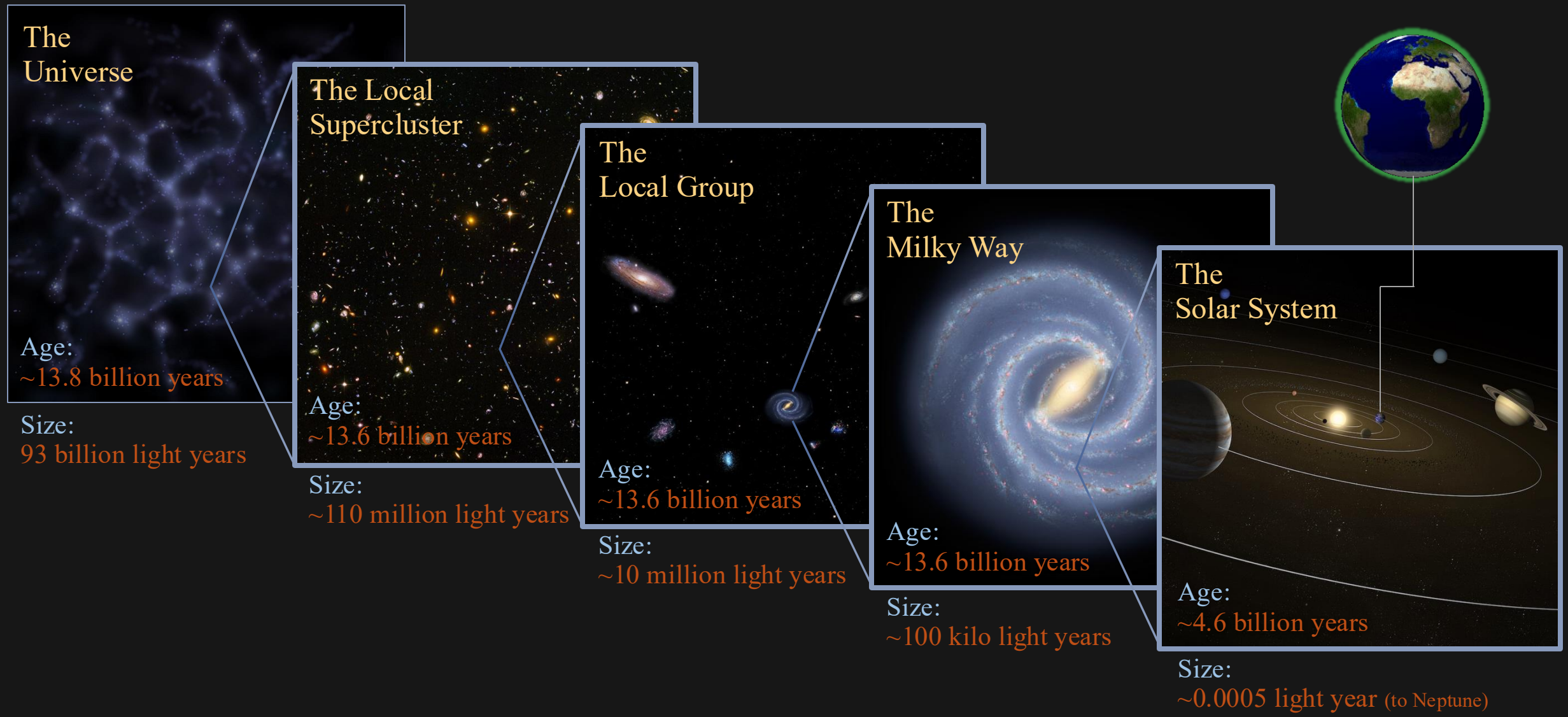
Worldometer
https://www.worldometers.info › world-population

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

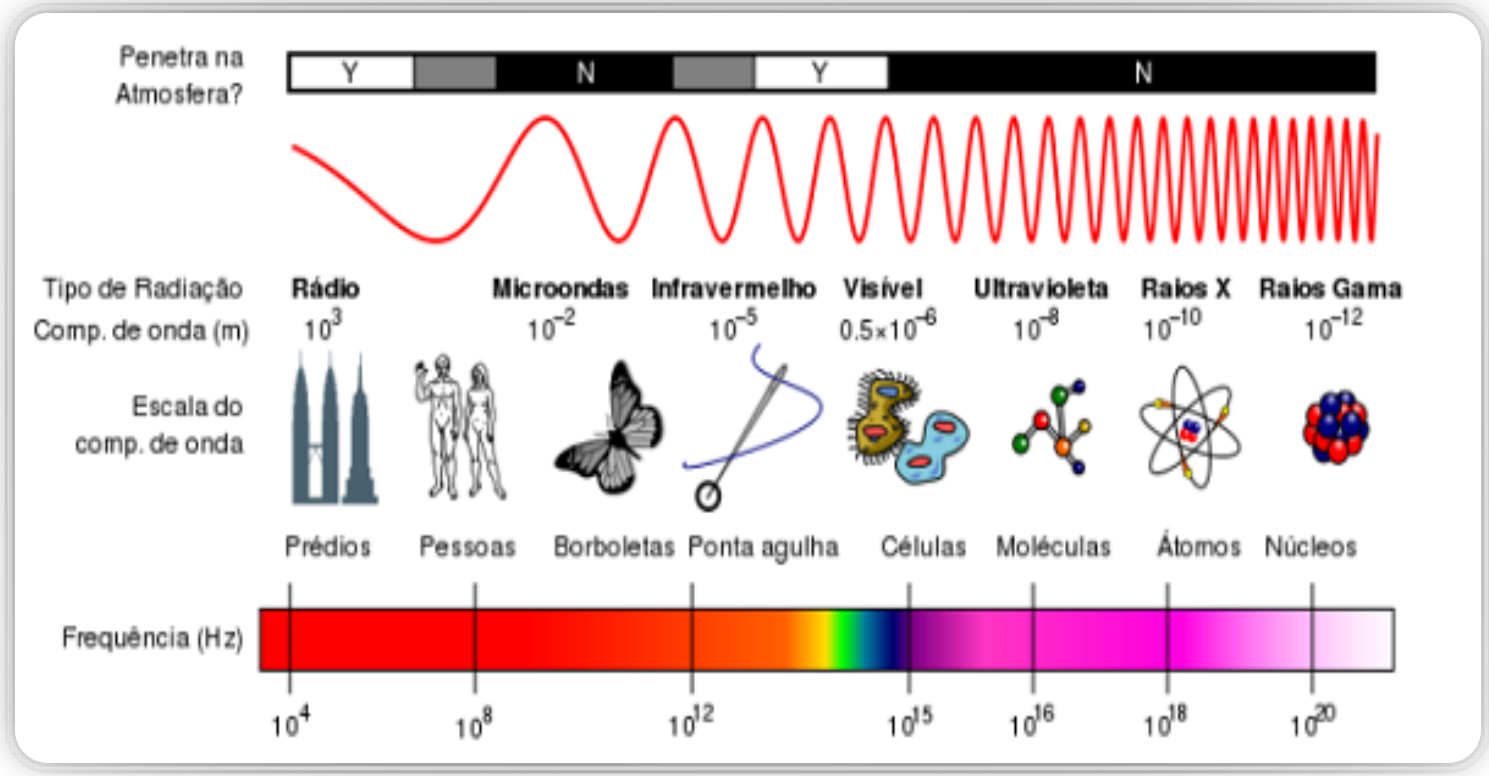
The current world population is **8,247,087,524** as of Friday, September 19, 2025 accc recent United Nations estimates [1] elaborated by ...

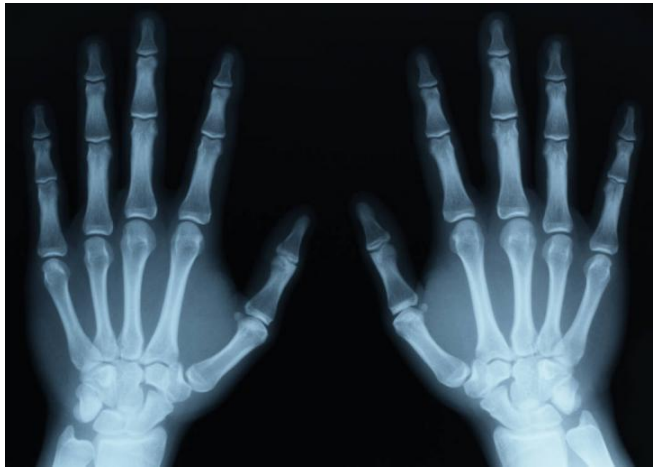


Where are we in the Universe?



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-

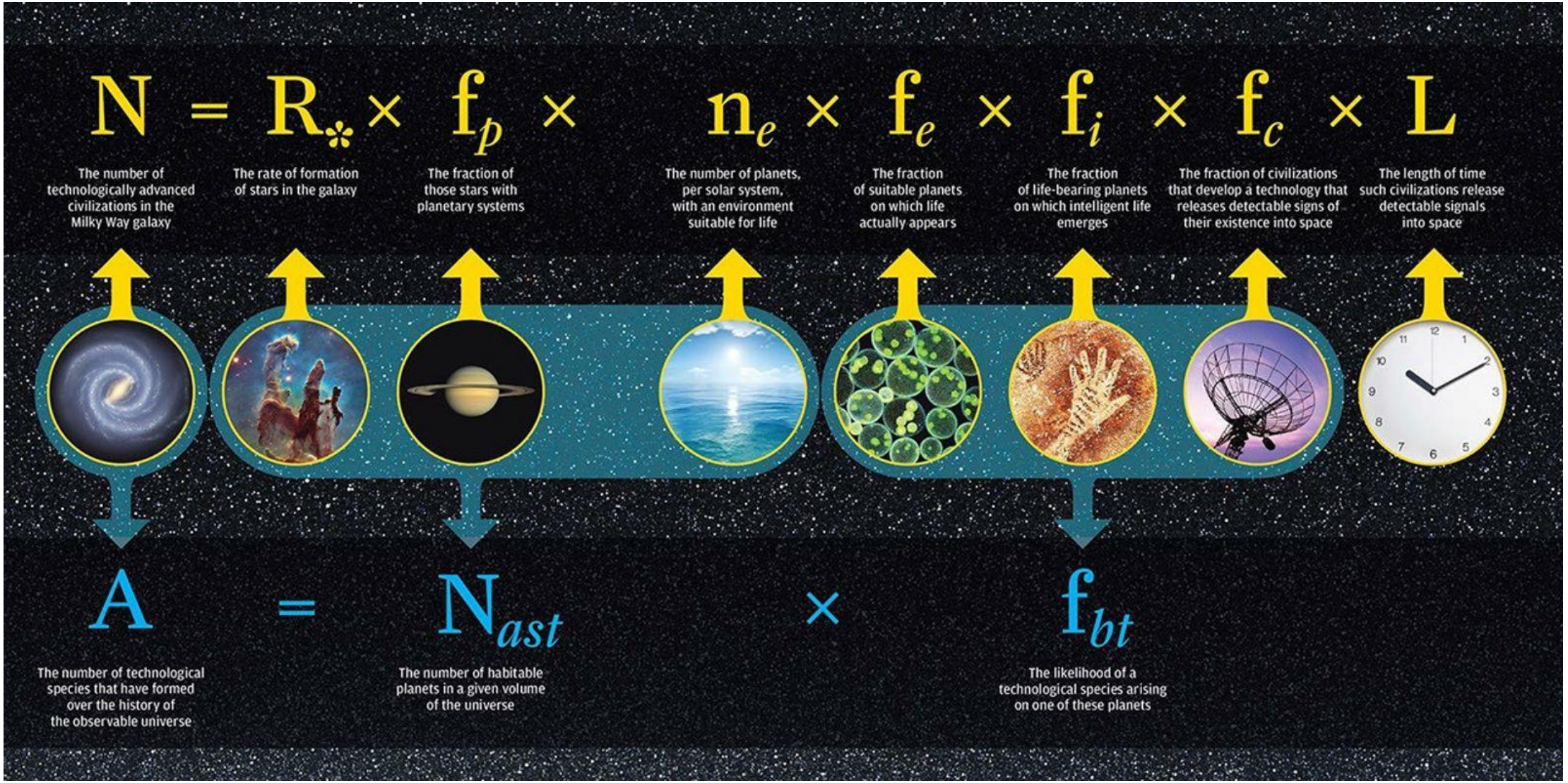
Project Ozma

- 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.

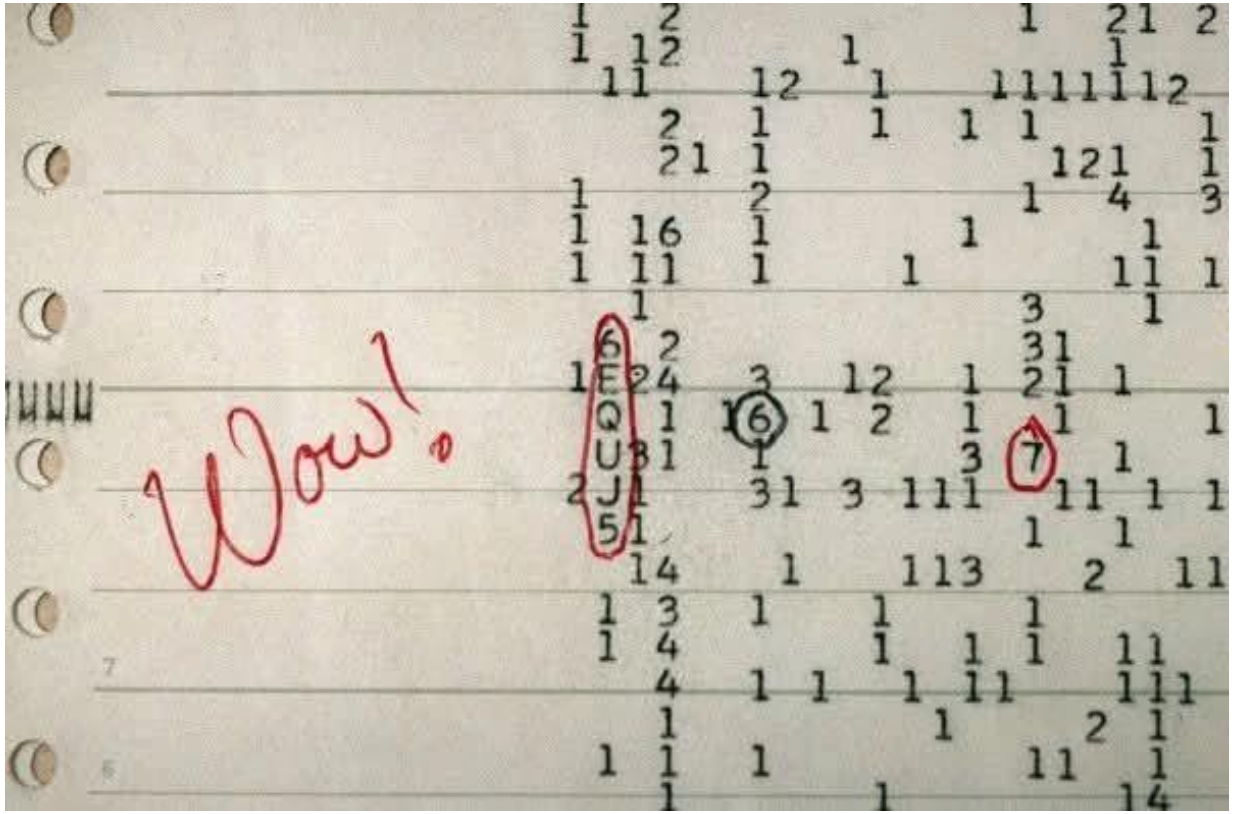
- No signs of ETI were detected.

Credit: NRAO/AUI/NSF\

The Drake Equation

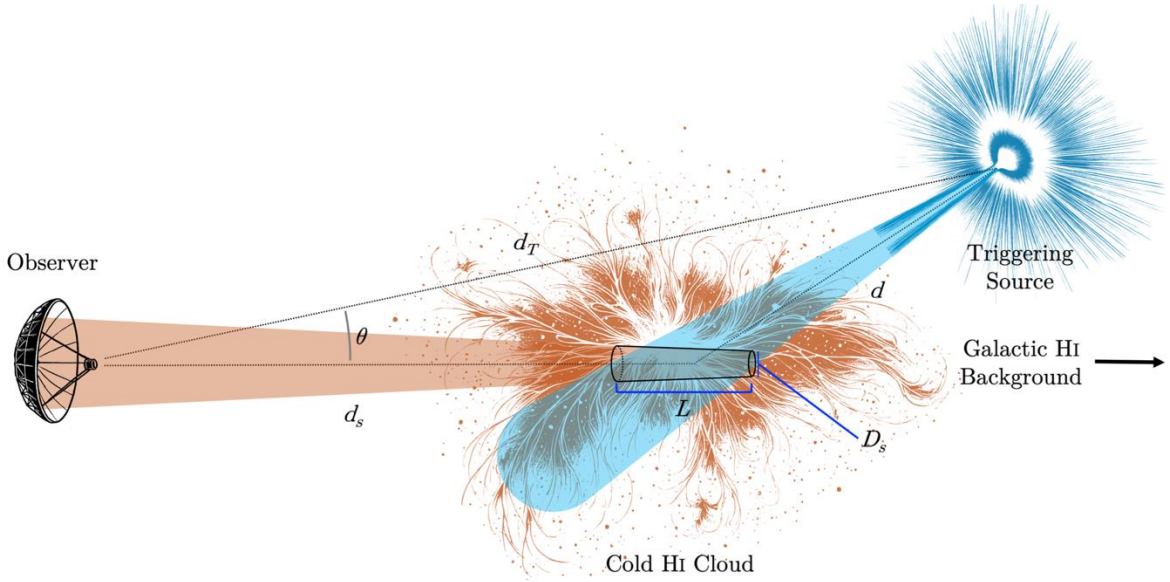


The Wow! Signal



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 ± 0.005 MHz
Observation Frame	Galactic Center of Rest (GCR)
Bandwidth	narrowband ($\leq$ 10 kHz)
Signal Strength	30.5 ± 0.5 times background noise (SNR $\approx$ 30 to 31)
Duration	72 seconds
Positive (West) Horn Coordinates (Equatorial)	RA: 19h 25m 31s ± 10s, Dec: -26d 57m ± 20m (J2000)
Negative (East) Horn Coordinates (Equatorial)	RA: 19h 28m 22s ± 10s, Dec: -26d 57m ± 20m (J2000)
Positive (West) Horn Coordinates (Galactic)	lon: 11d 39.0m ± 0.9m, lat: -18d 53.4m ± 2.1m
Negative (East) Horn Coordinates (Galactic)	lon: 11d 54.0m ± 0.9m, lat: -19d 28.8m ± 2.1m
Estimated Intensity	$\approx$ 54 or 212 Jy

Why Radio?

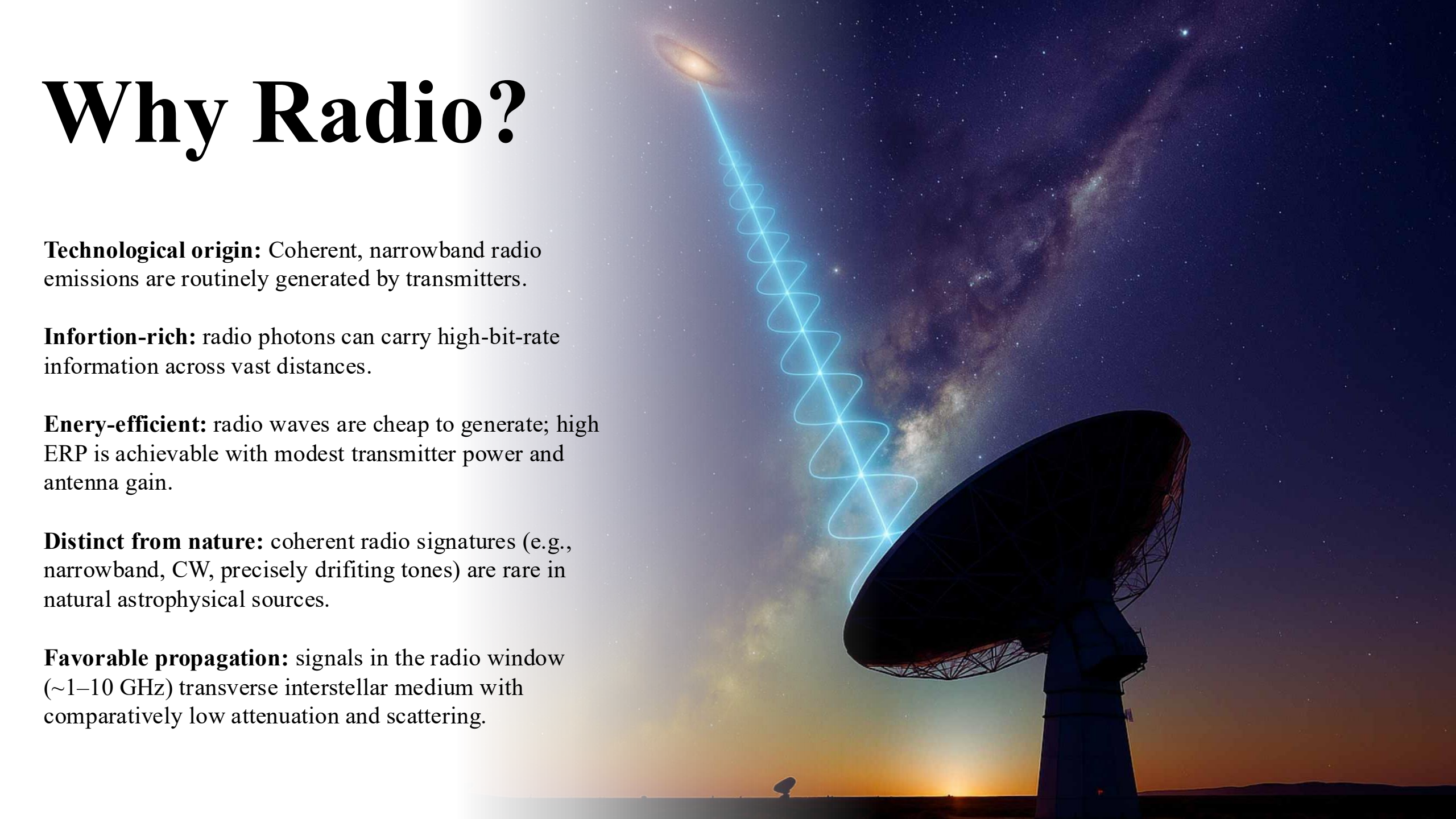
Technological origin: Coherent, narrowband radio emissions are routinely generated by transmitters.

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

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

Distinct from nature: coherent radio signatures (e.g., narrowband, CW, precisely drifiting tones) are rare in natural astrophysical sources.

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



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)

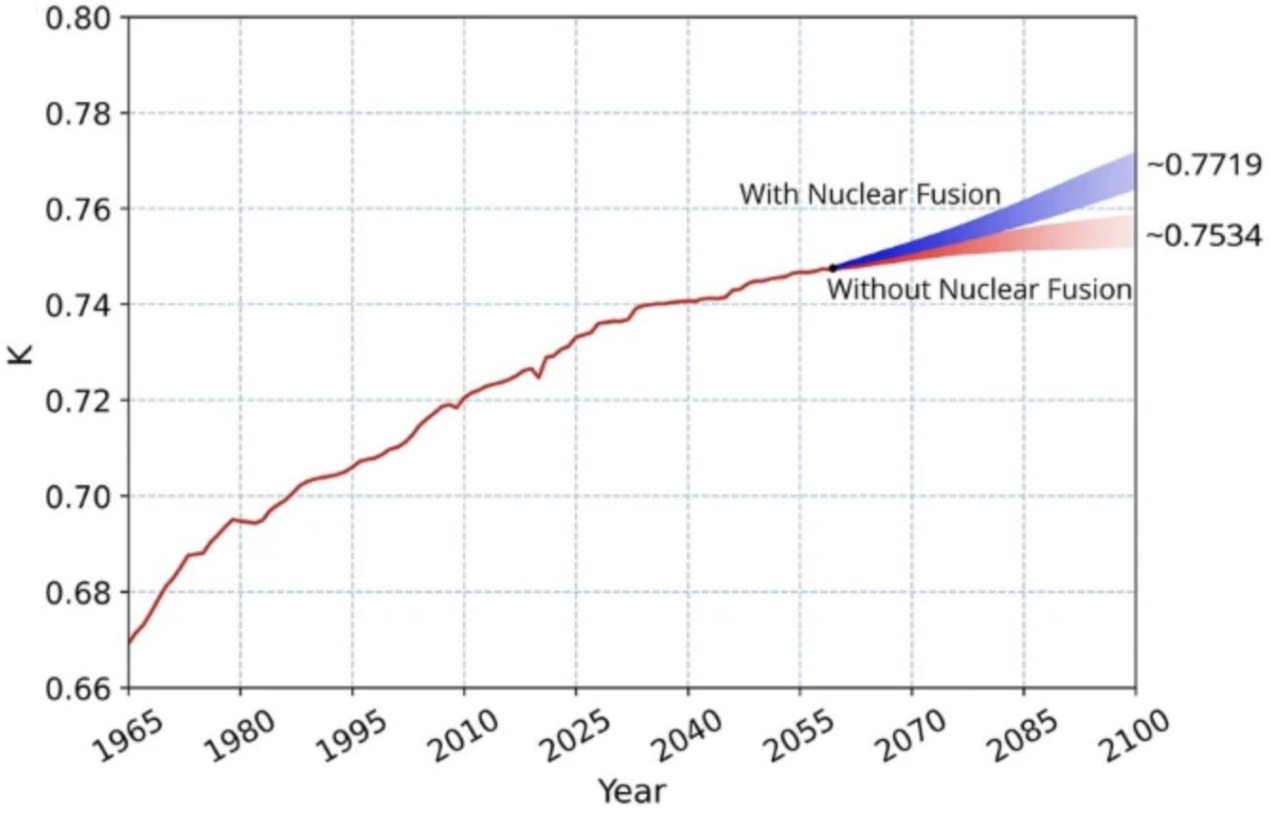
- Harnesses the total energy output of its host star, possibly using structures like Dyson spheres.

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, $K = \sim 0.7276$

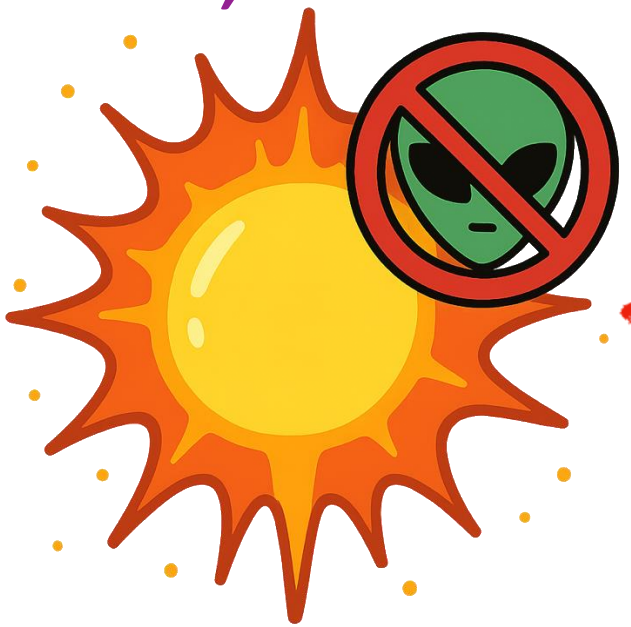


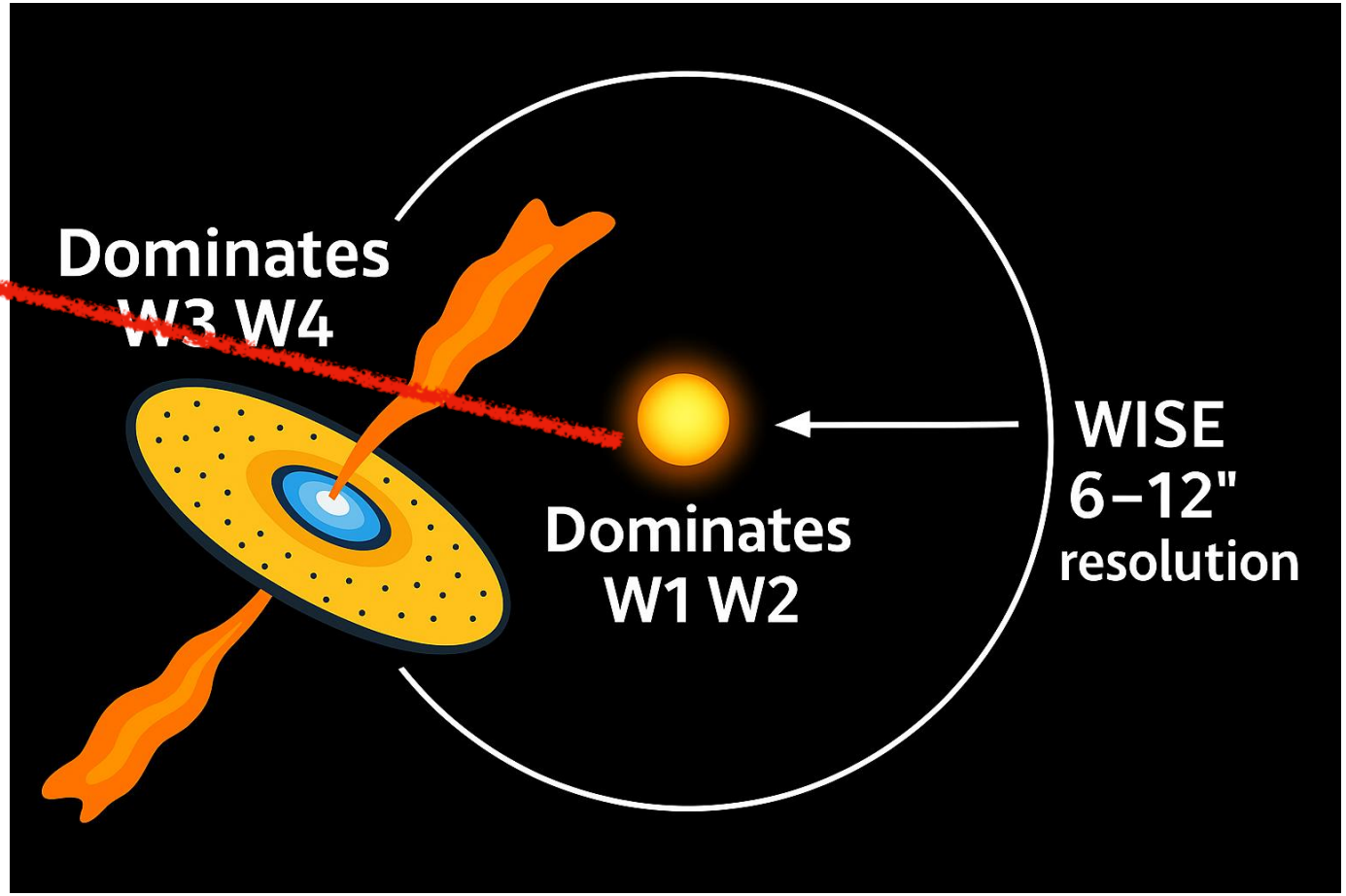
(Zhang et al., 2023)

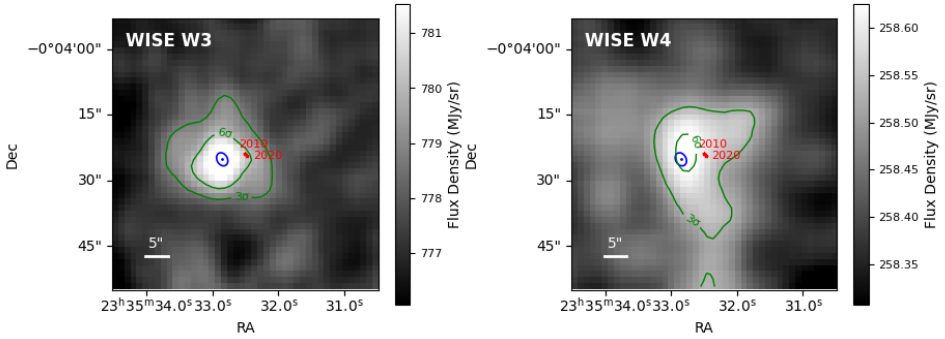
Did We Really Find Dyson Spheres?

Credit: Ren et al., 2025)

So, no ETs?







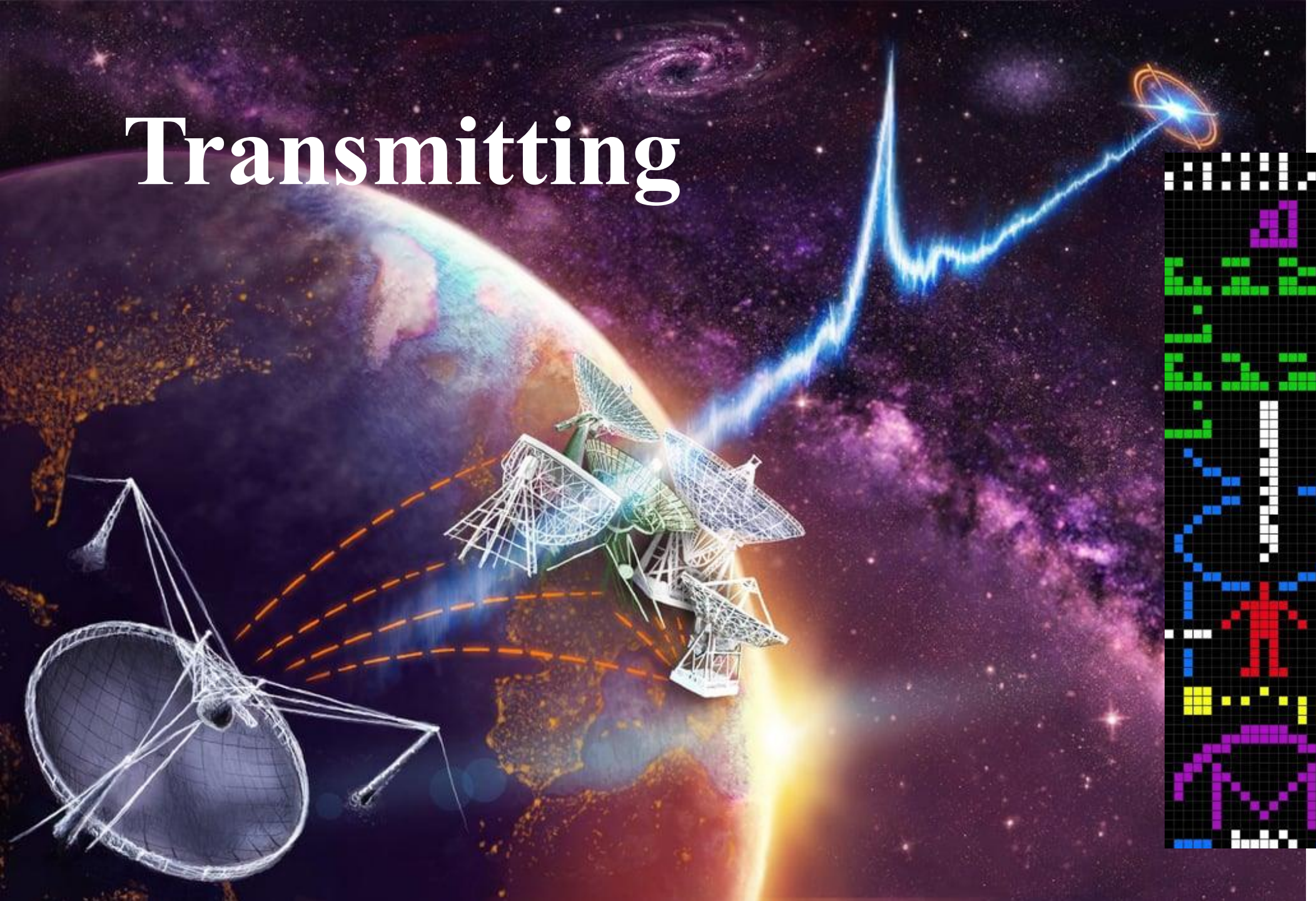
The mid-infrared light once thought to be the ET's industrial waste heat, is actually from a nearby Hot, Dust-Obscured Galaxy (Hot DOG).

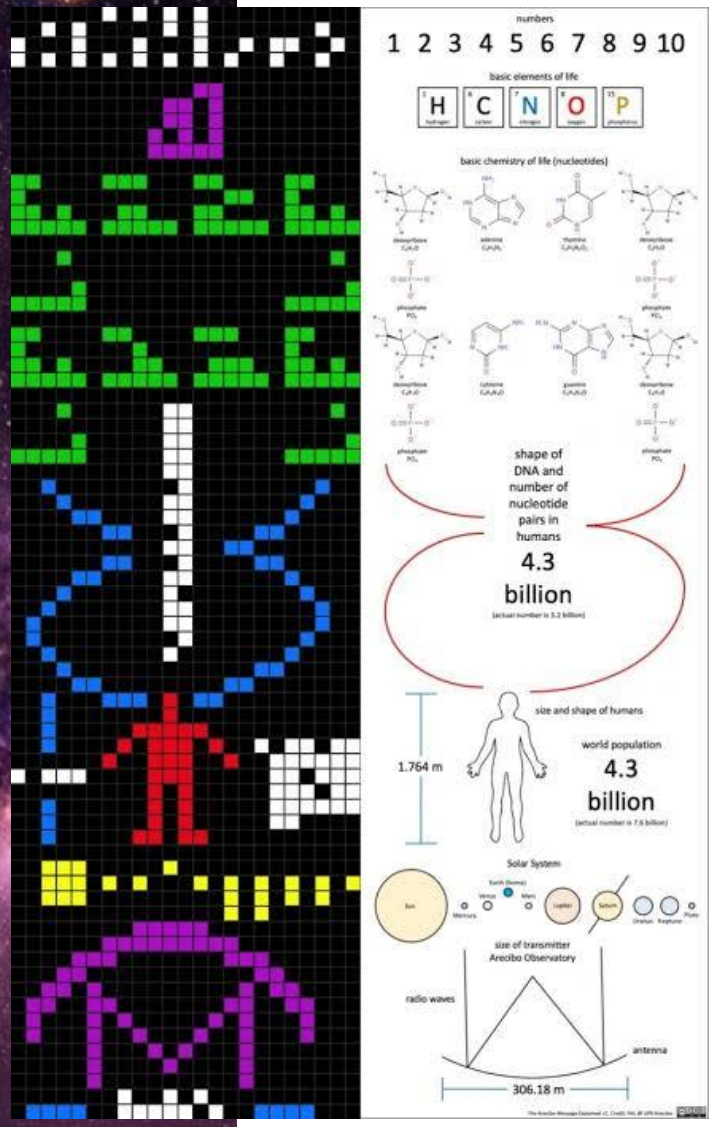
Credit: Ren et al., 2025)

Panspermia Theory

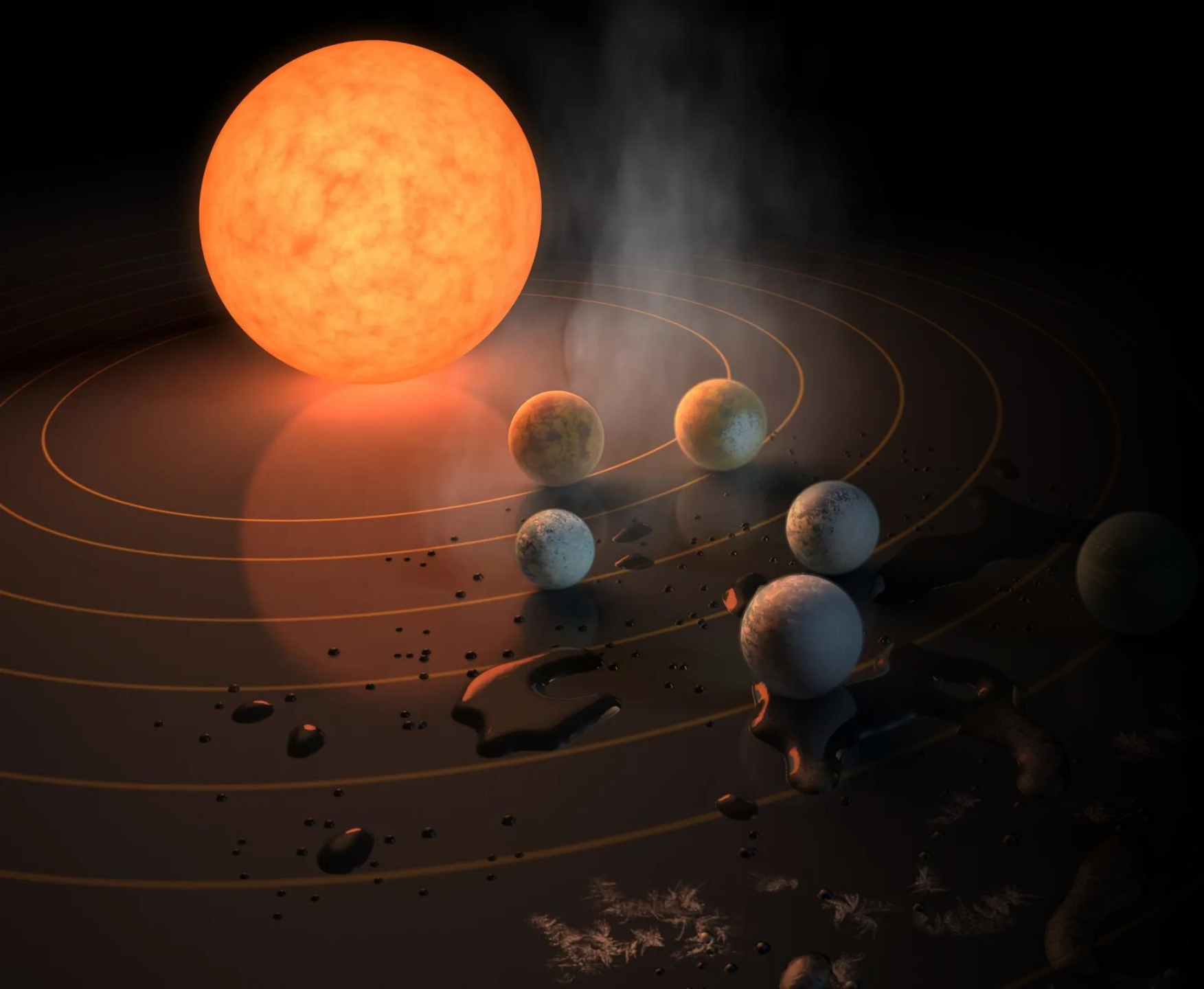
Listing

Transmitting

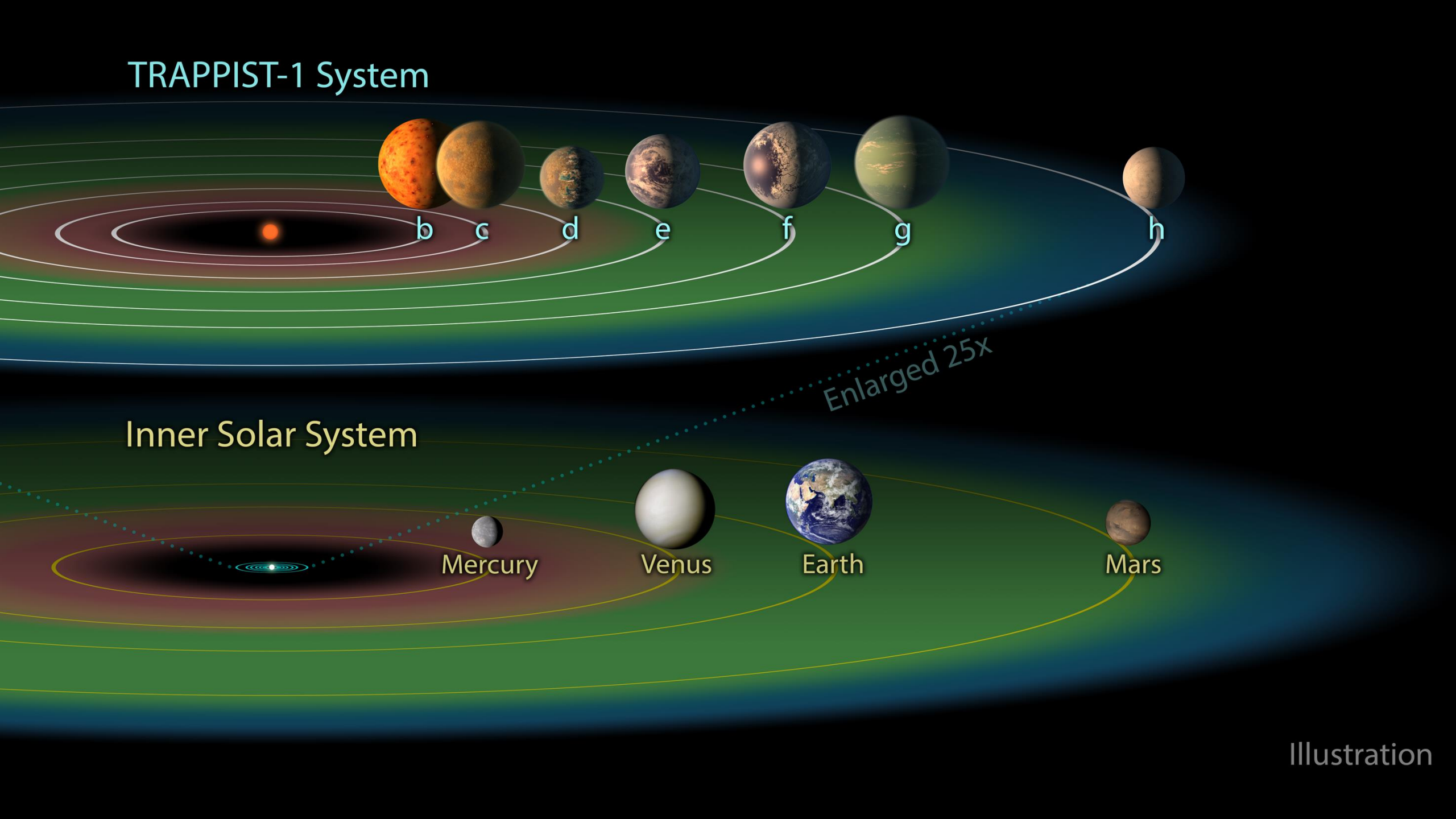




Direct Sampling



Life in our Solar System


TRAPPIST-1 System
b
c
d
e
f
g
h
Enlarged 25x
Inner Solar System
Mercury
Venus
Earth
Mars
Illustration

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 — bulding block of biomolecules.
- Earth day length aids environmental rhythms.

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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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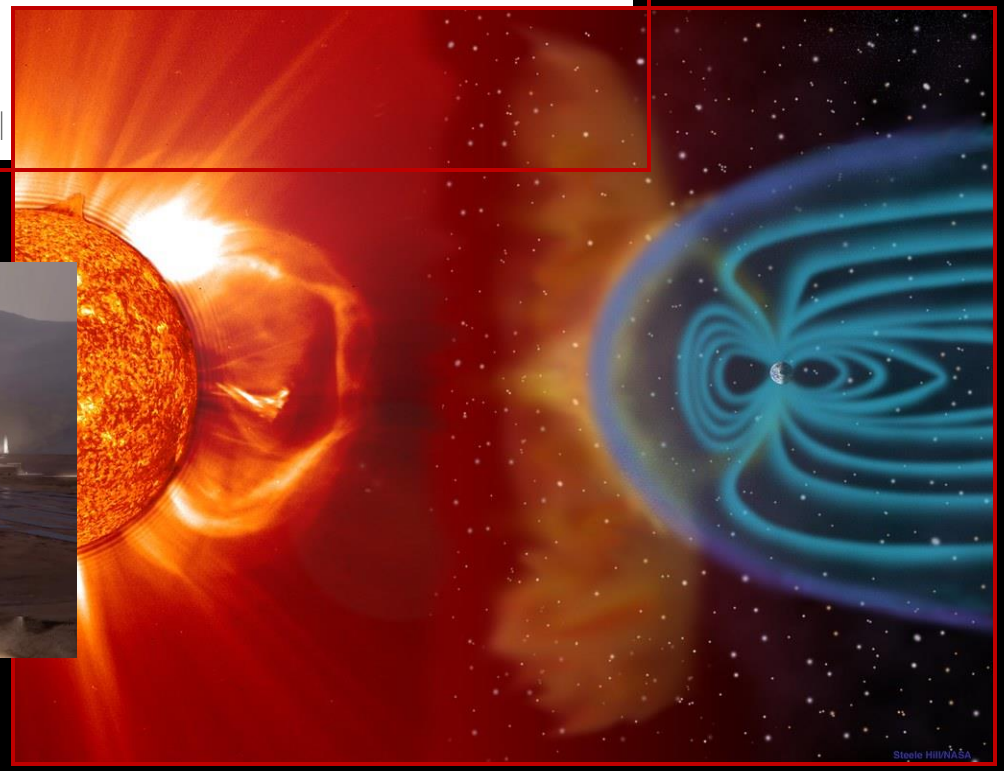
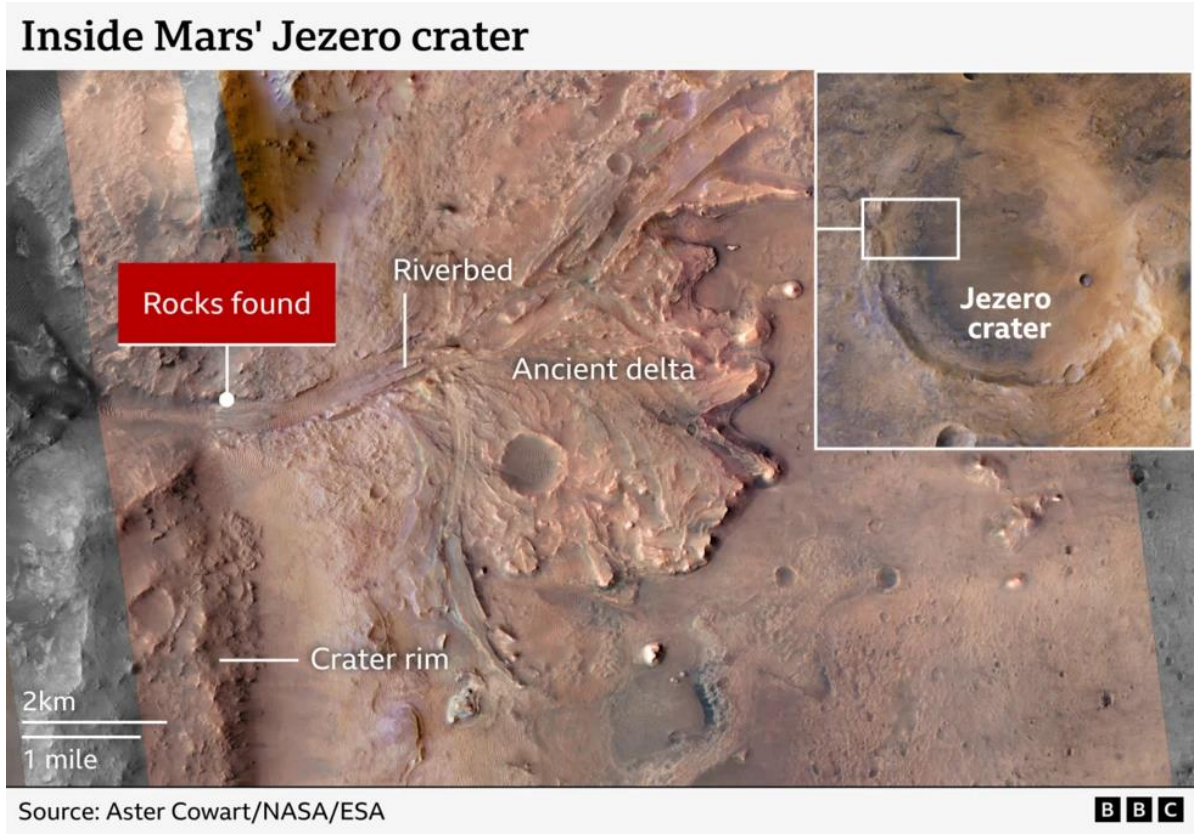
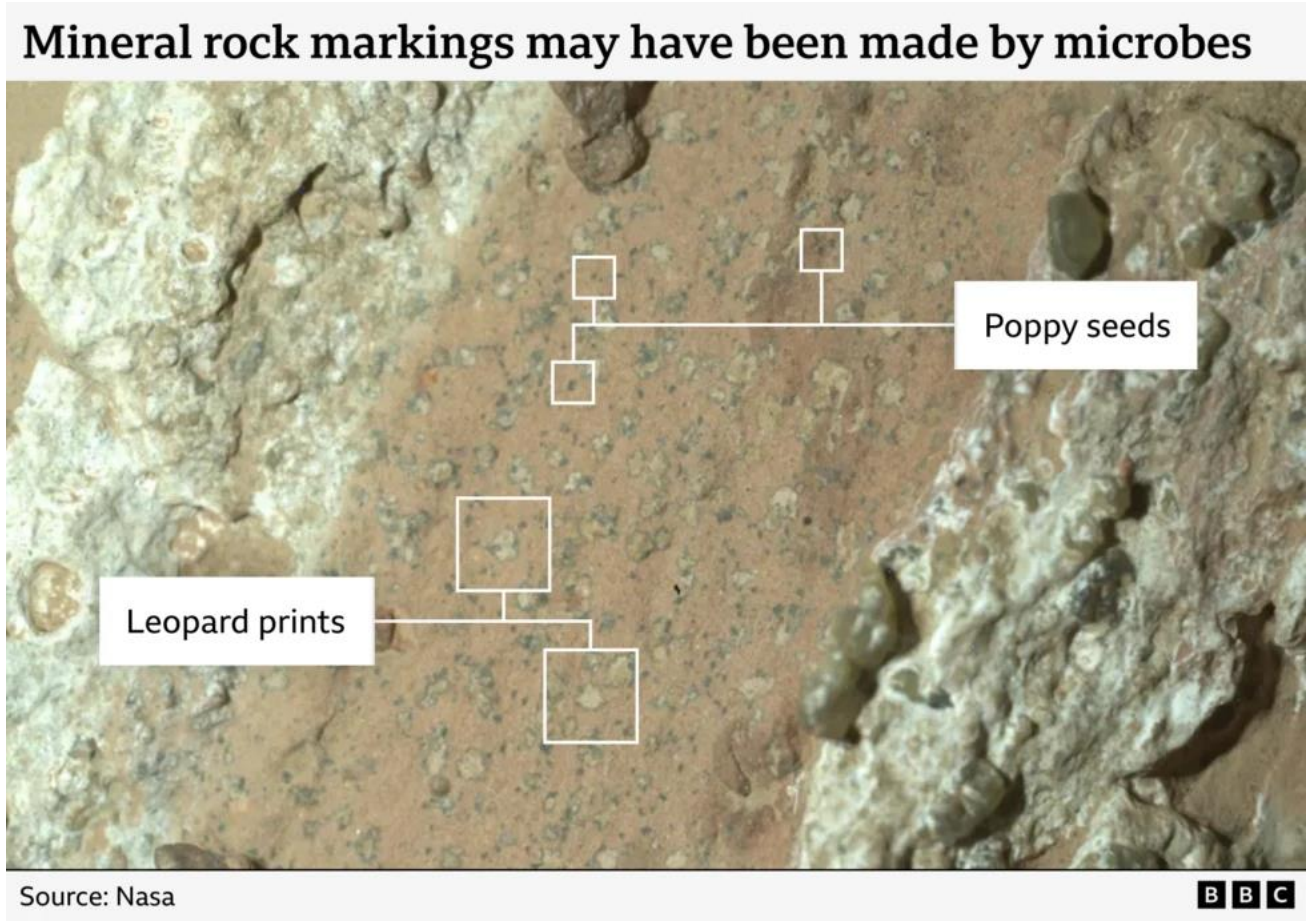


Mars

- 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.





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[1], which lies under an ice crust and above a rocky core[2]. Through warm cracks in the crust[3] a cryo-volcanic plume ejects ice grains and vapour into space[4,5,6,7] that contain materials originating from the ocean[8,9]. Hydrothermal activity is suspected to occur deep inside the porous core[10,11,12], powered by tidal dissipation[13]. So far, only simple organic compounds with molecular masses mostly below 50 atomic mass units have been observed in plume material[6,14,15]. 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.

nature astronomy

ARTICLES

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

Check for updates

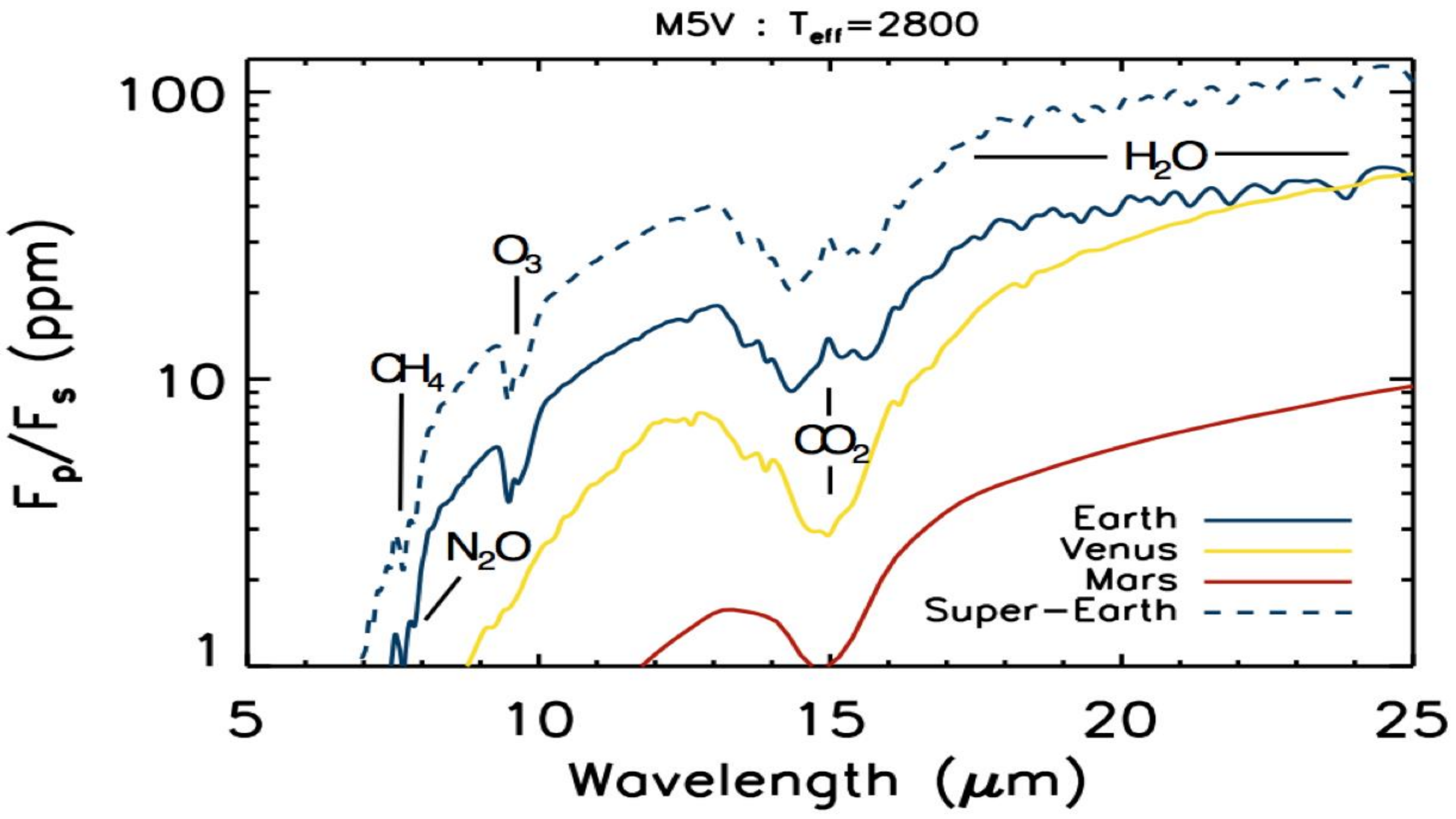
Phosphine gas in the cloud decks of Venus

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

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 (PH_3) gas in Venus's atmosphere, where any phosphorus should be in oxidized forms. Single-line millimetre-waveband spectral detections (quality up to ~15σ) from the JCMT and ALMA telescopes have no other plausible identification. Atmospheric PH_3 at ~20 ppb abundance is inferred. The presence of 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 subsurface, or from lightning, volcanic or meteoritic delivery. PH_3 could originate from unknown photochemistry or geochemistry, or, by analogy with biological production of PH_3 on Earth, from the presence of life. Other PH_3 spectral features should be sought, while in situ cloud and surface sampling could examine sources of this gas.

Venus

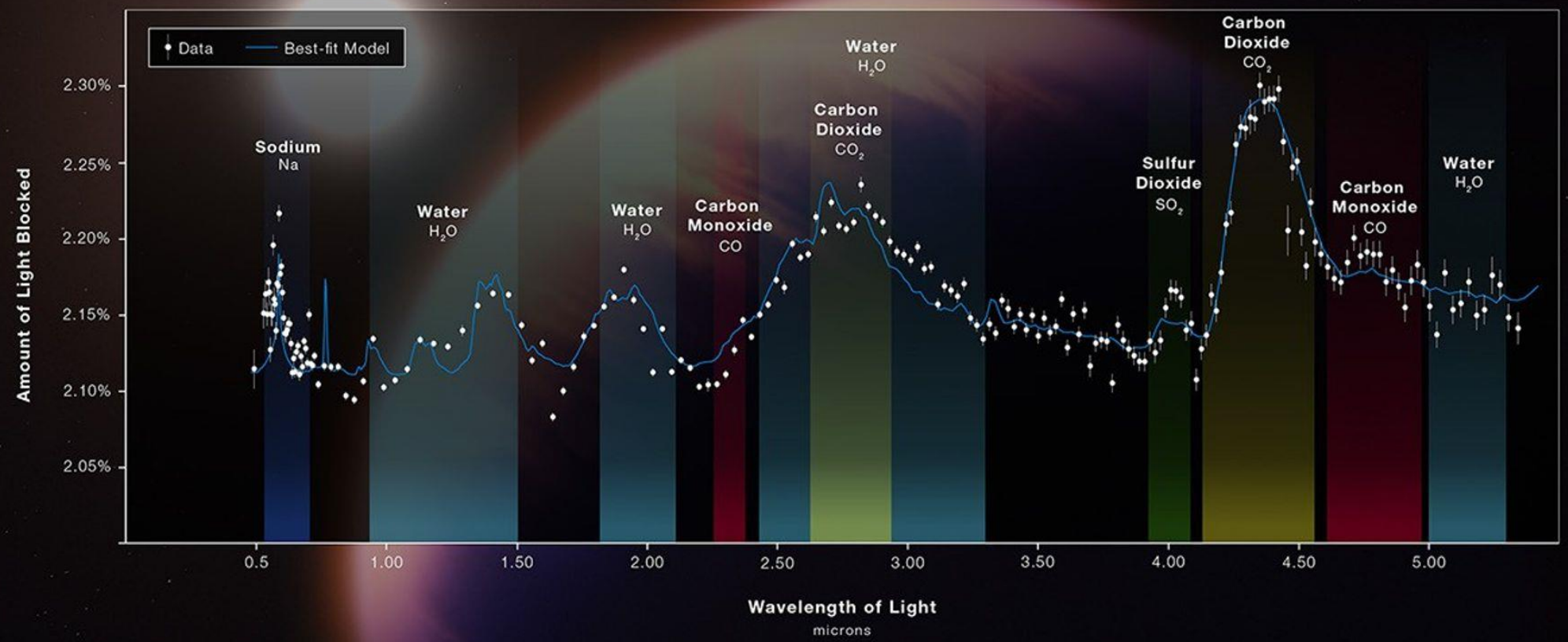
- The hottest planet surface in the solar system (470 degree Celsius).
- Fifty-four times more dense than Earth's — it is the densest terrestrial atmosphere in the solar system.
- The atmospheric pressure on the surface is ~ 92 bar.
- In 2020 scientists detected Phosphine in the clouds on Venus, using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


M5V : T_{eff}=2800
100
10
1
F_p/F_s (ppm)
H_2O
O_3
CH_4
CO_2
N_2O
Earth
Venus
Mars
Super−Earth
5
10
15
20
25
Wavelength (μm)

HOT GAS GIANT EXOPLANET WASP-39 b

ATMOSPHERE COMPOSITION

NIRSpec PRISM



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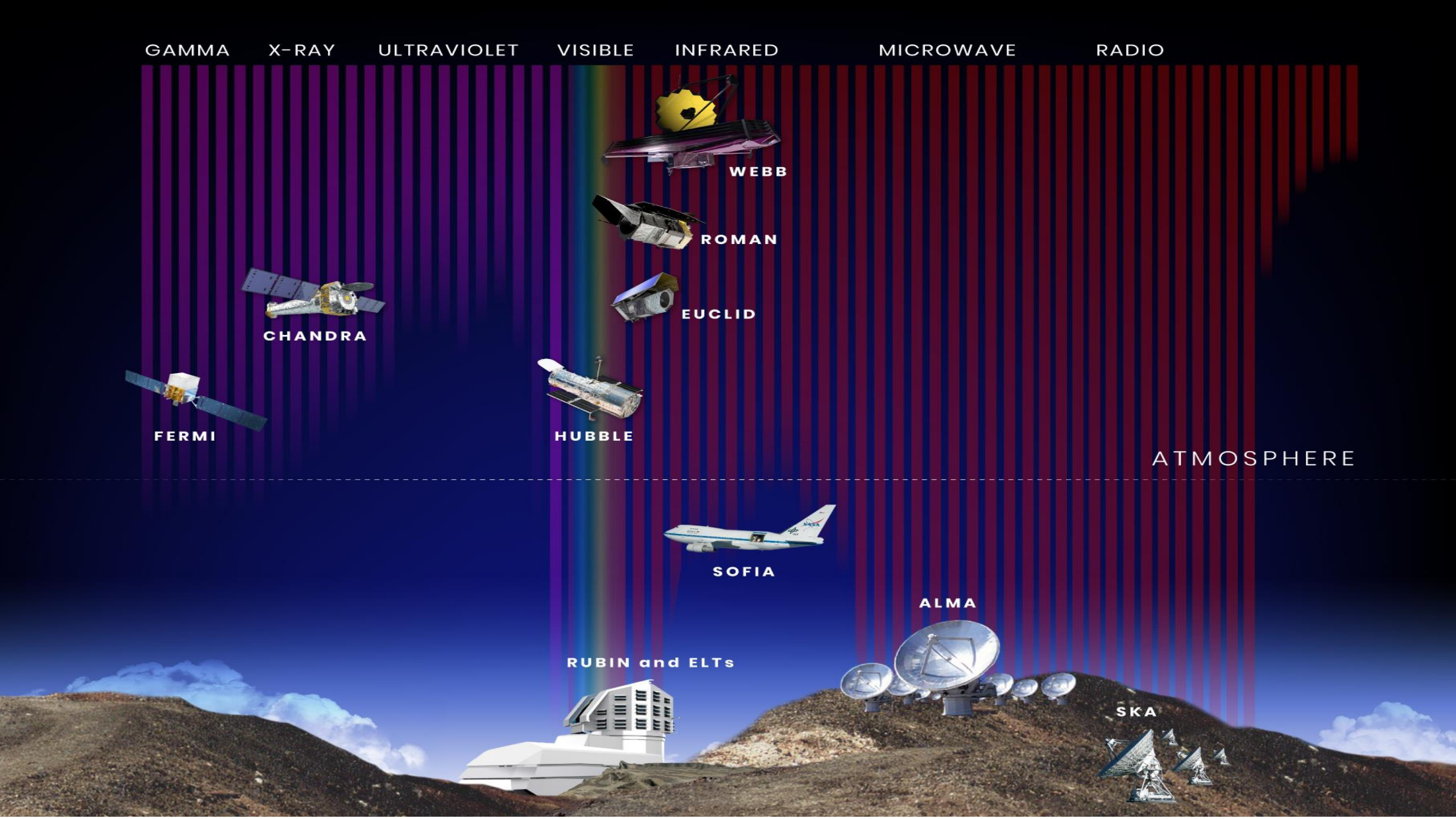
SPACE TELESCOPE


GAMMA
X-RAY
ULTRAVIOLET
VISIBLE
INFRARED
MICROWAVE
RADIO
WEBB
ROMAN
EUCLID
CHANDRA
FERMI
HUBBLE
ATMOSPHERE
SOFIA
ALMA
RUBIN and ELTs
SKA

Exoplanet Missions

WFIRST

JWST[2]

TESS

PLATO

Kepler

CHEOPS

New Worlds Telescope

Spitzer

Gaia

Hubble[1]

Habitable Exoplanet Imager

LUVOIR

CoRoT[3]

NASA Missions

ESA/European Missions

Large Binocular Telescope Interferometer

NN-EXPLORE

W. M. Keck Observatory

[1] NASA/ESA Partnership
[2] NASA/ESA/CSA Partnership
[3] CNES/ESA

Ground Telescopes with NASA participation

Radial velocity method (1140)

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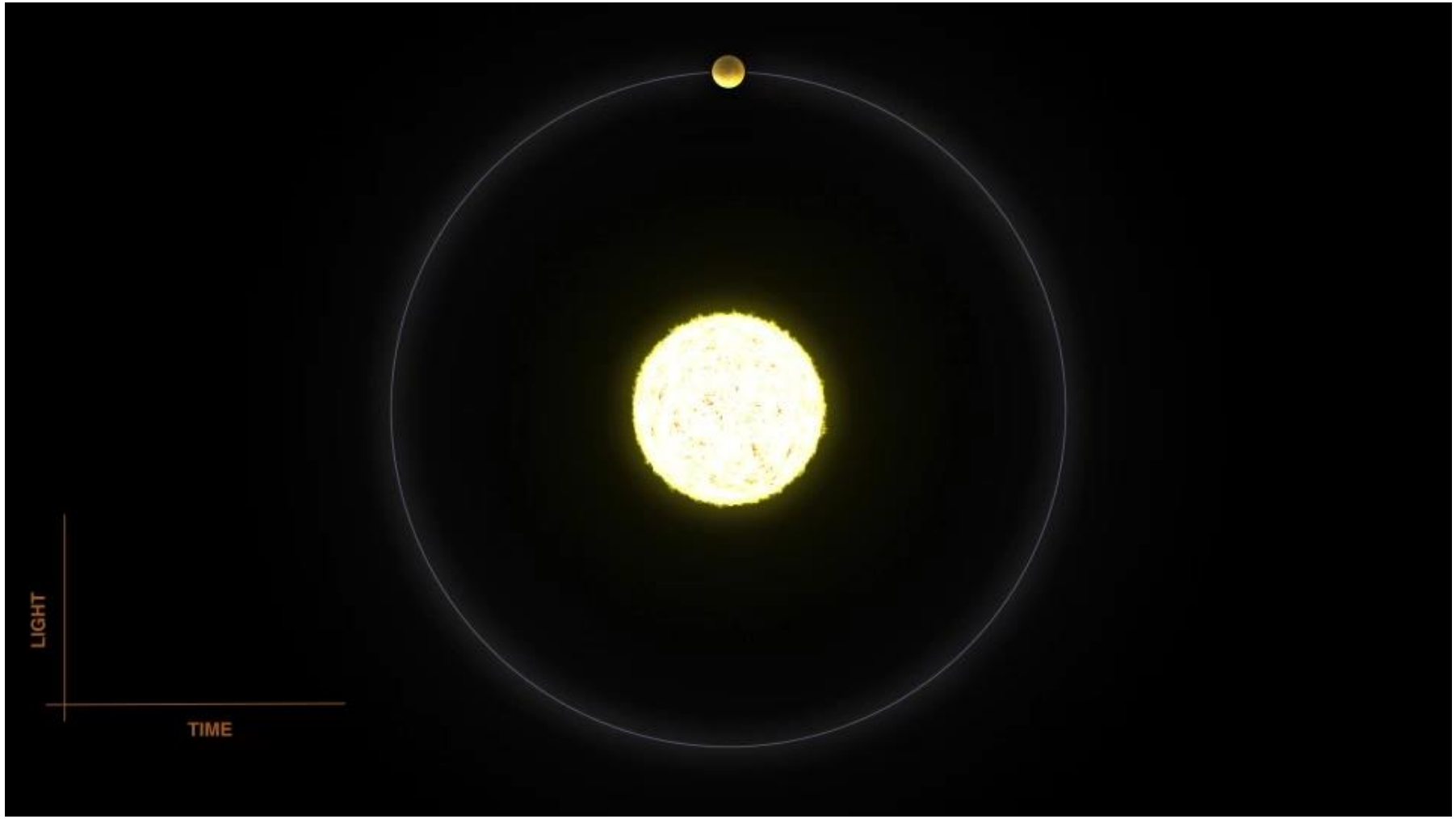
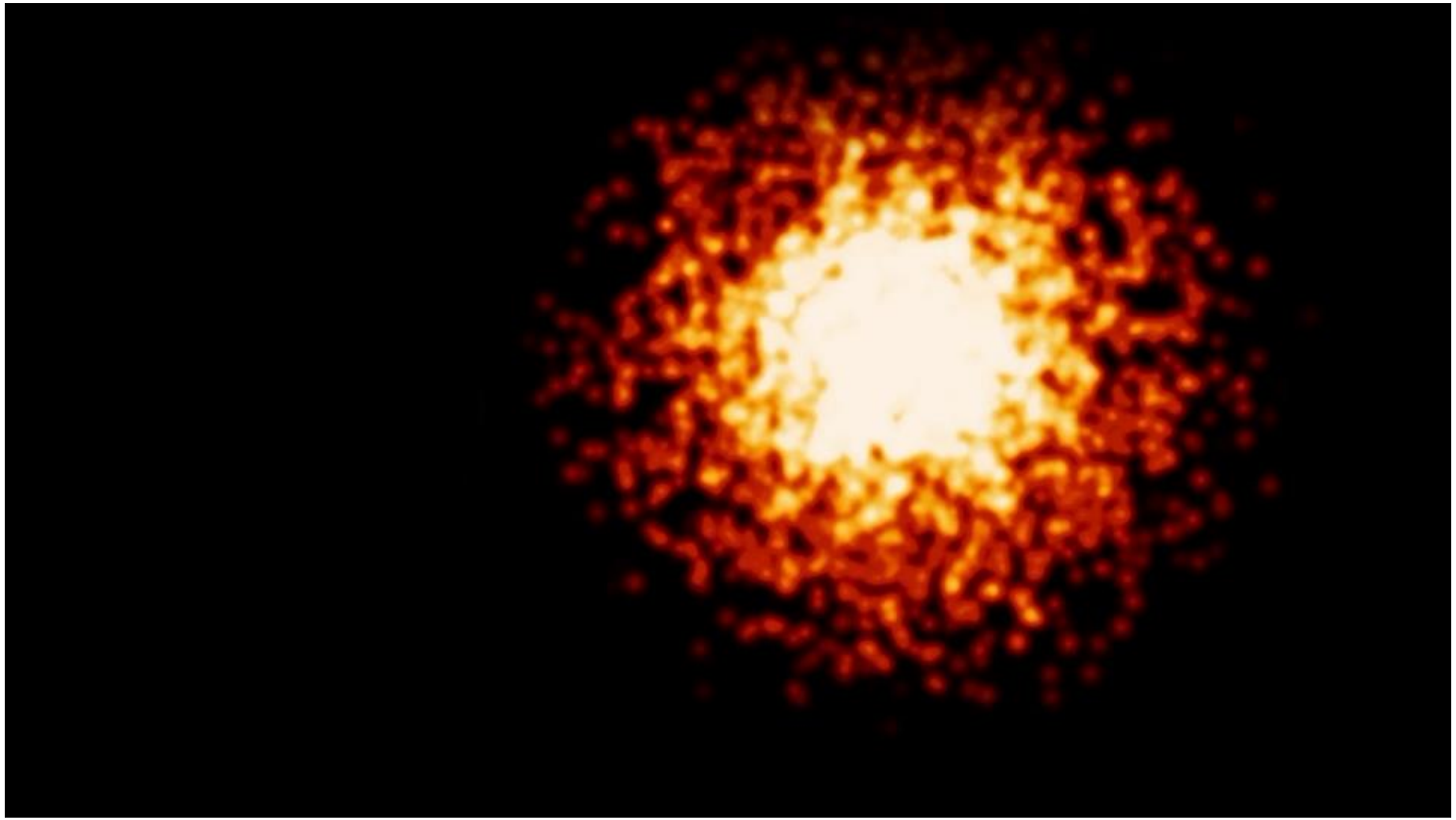
The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might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

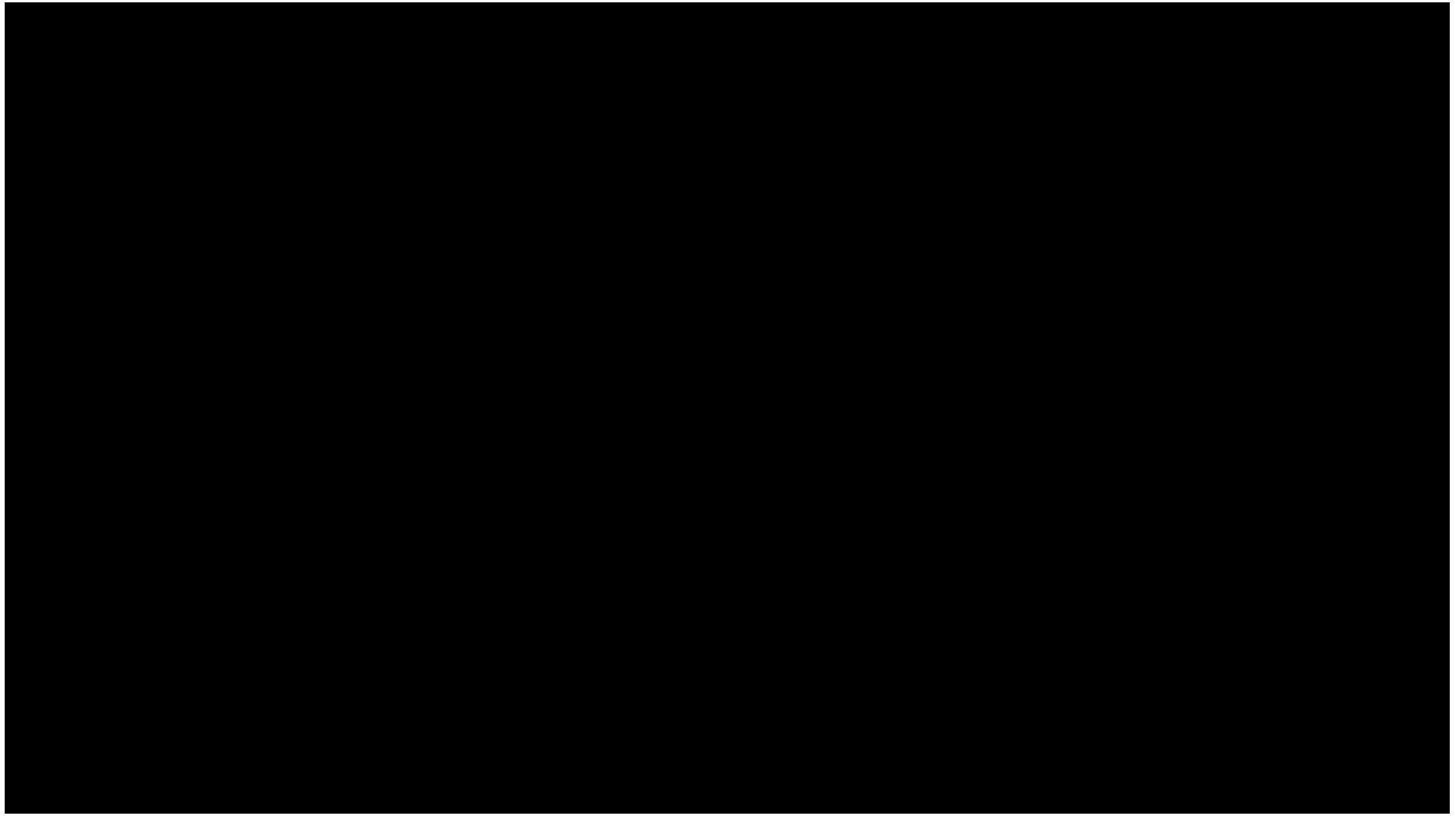
Transit Method (4446)



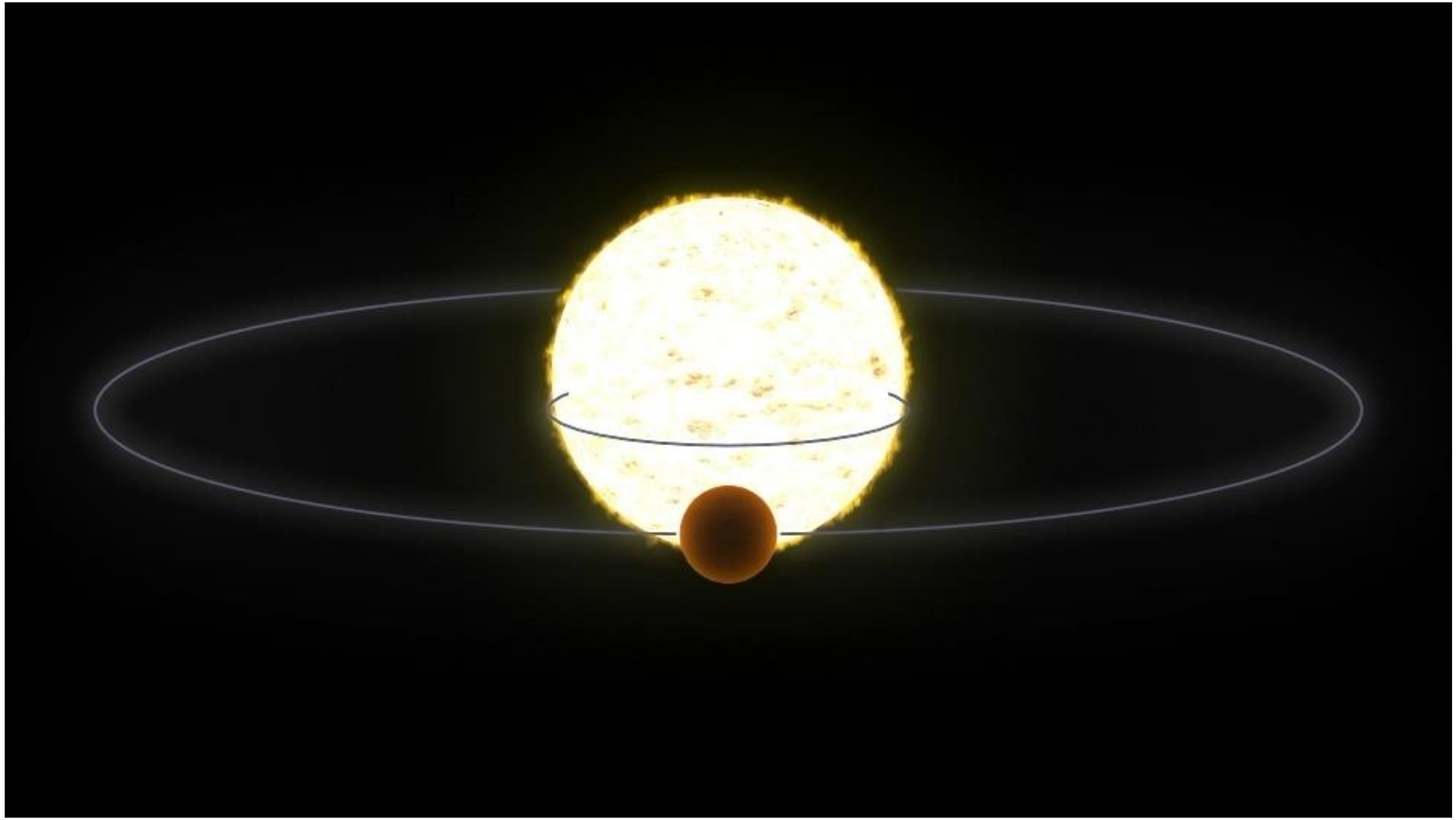
Direct imaging (87)



Gravitational Microlensing (253)



Astrometry (5)



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693
TESS Confirmed Planets
09/17/2025

7,668
TESS Project Candidates
09/02/2025

View more Planet and Candidate statistics

Explore the Archive

Name or Coordinates | Search

Optional Radius (arcsec)

Advanced Search

Transit Surveys — 130,041,578 Light Curves

Launched in April 2018, TESS is surveying the sky for two years to find transiting exoplanets around the brightest stars near Earth.

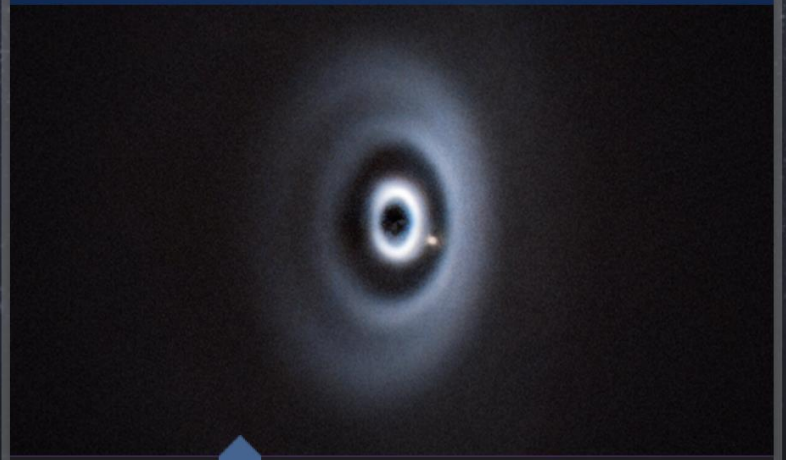
- Confirmed Planets
- ExoFOP-TESS
- Project Candidates
- Community Candidates

TESS | Kepler | K2 | KELT | UKIRT

New Data: Eighteen Planets and 10 Spectra

September 17, 2025 • New Data

The 18 new planets that tipped our counter to *6,007* this week include WISPIT 2 b, a young planet directly imaged in a gap of a multi-ringed disk, which means the planet is actively clearing its gap while forming in the protoplanetary disk. We've also added four JWST spectra of TRAPPIST-1 e.



News → 1 2 3 4 | Plots → 1 2 3 4


TUNING
MHz
KHz
MHz

Publications of the Astronomical Society of the Pacific, 131:124505 (23pp), 2019 December https://doi.org/10.1088/1538-3873/ab3e82

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

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

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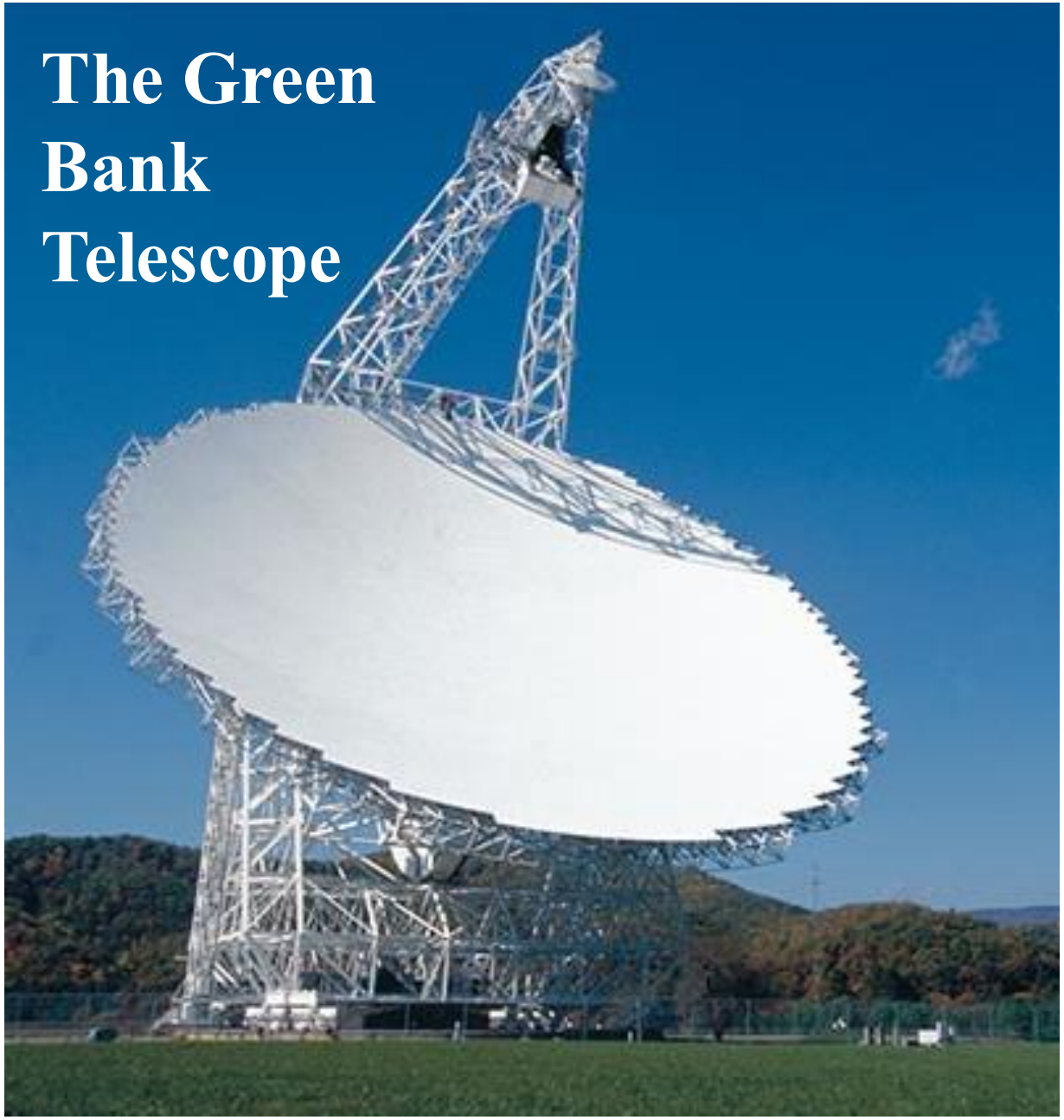
[14] Department of Electrical Engineering and Computer Sciences, University of California Berkeley, Berkeley, CA 94720, USA
Received 2019 April 17; accepted 2019 August 27; published 2019 November 5

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 Astrophysical Journal, 849:104 (13pp), 2017 November 10 https://doi.org/10.3847/1538-4357/aa8d1b

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

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

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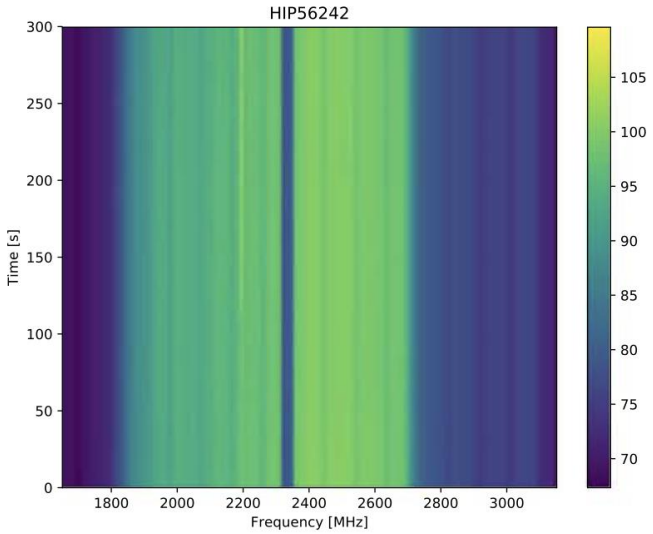
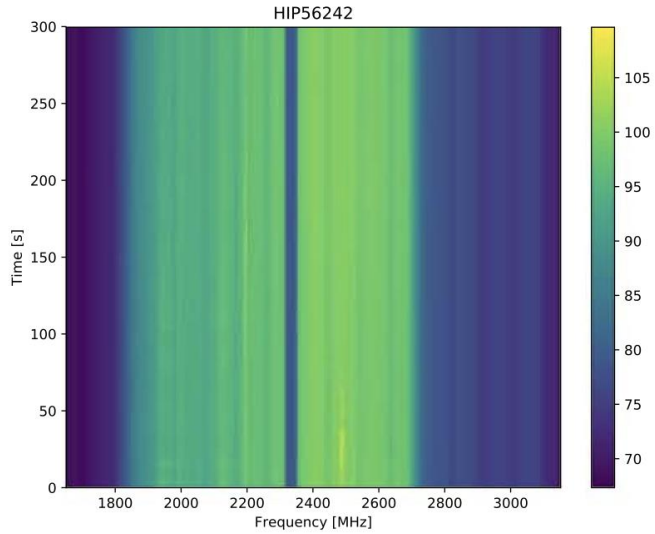
Received 2017 April 20; revised 2017 September 5; accepted 2017 September 8; published 2017 November 6

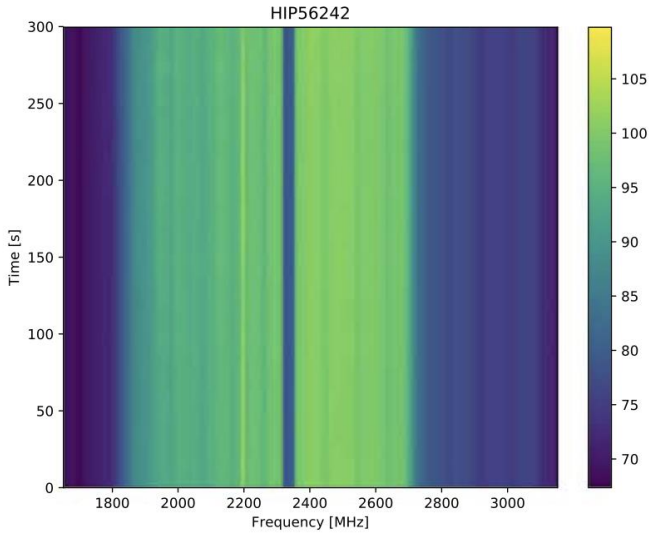
Abstract

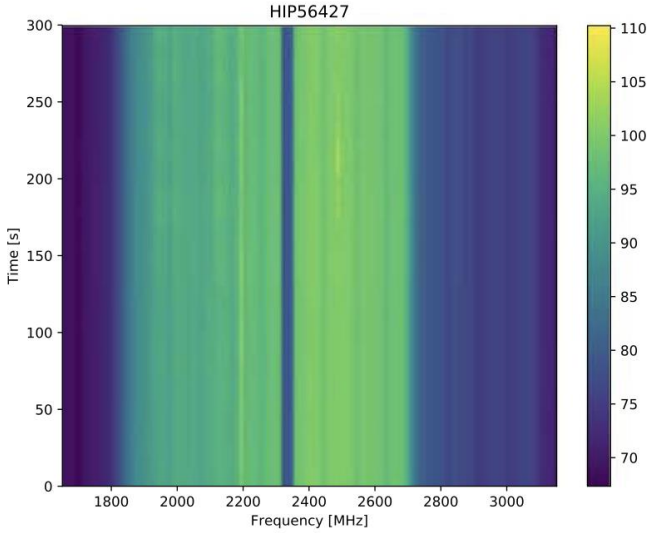
We report on a search for engineered signals from a sample of 692 nearby stars using the Robert C. Byrd Green Bank Telescope, undertaken as part of the *Breakthrough Listen Initiative* search for extraterrestrial intelligence. Observations were made over 1.1–1.9 GHz (L band), with three sets of five-minute 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,

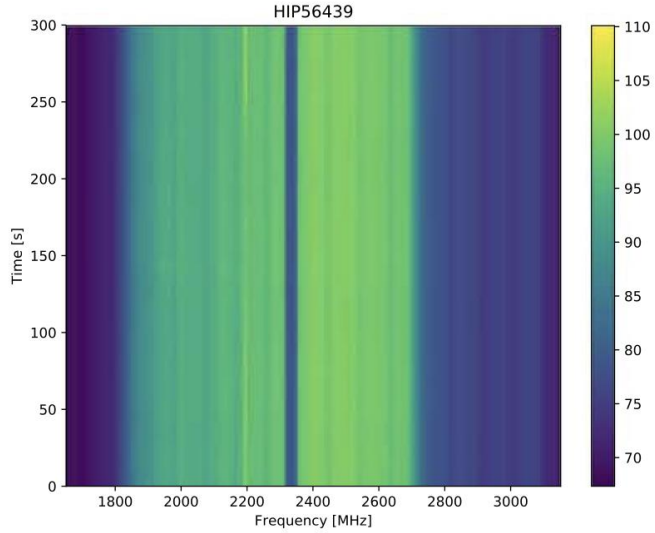
Observation strategy

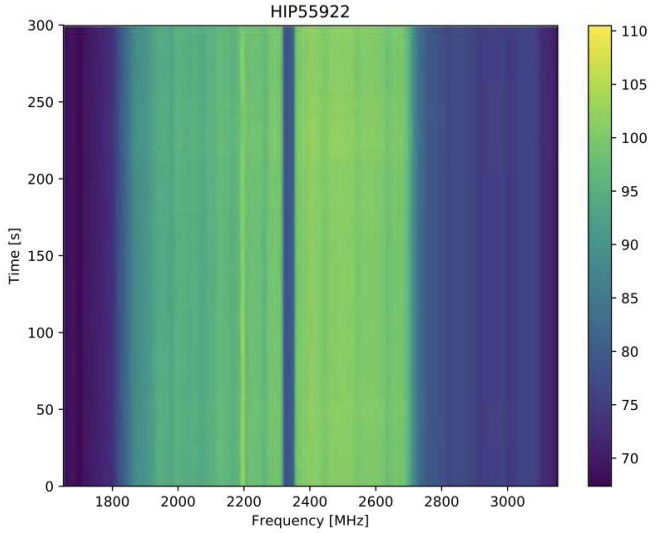




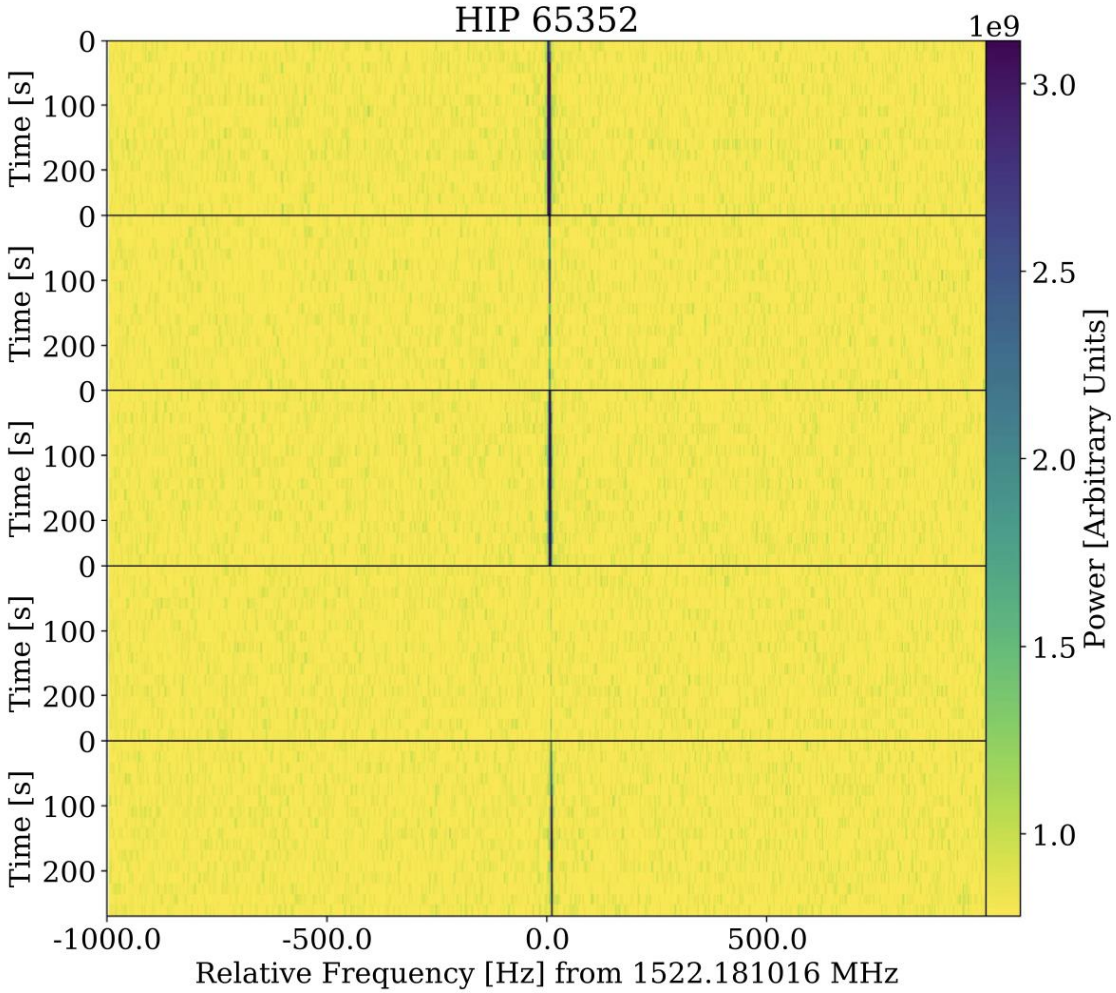


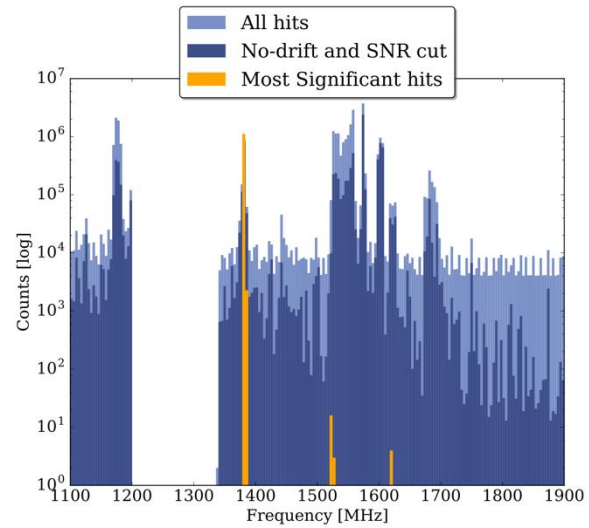


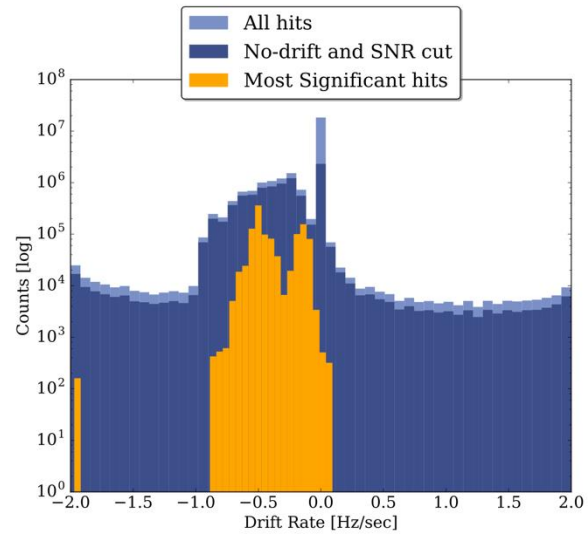




TurboSETI


HIP 65352
1e9
Time [s]
Power [Arbitrary Units]
Relative Frequency [Hz] from 1522.181016 MHz


All hits
No-drift and SNR cut
Most Significant hits
Counts [log]
Frequency [MHz]


All hits
No-drift and SNR cut
Most Significant hits
Counts [log]
Drift Rate [Hz/sec]

The Wow! Signal of Our Generation

nature astronomy

ARTICLES

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

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OPEN

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

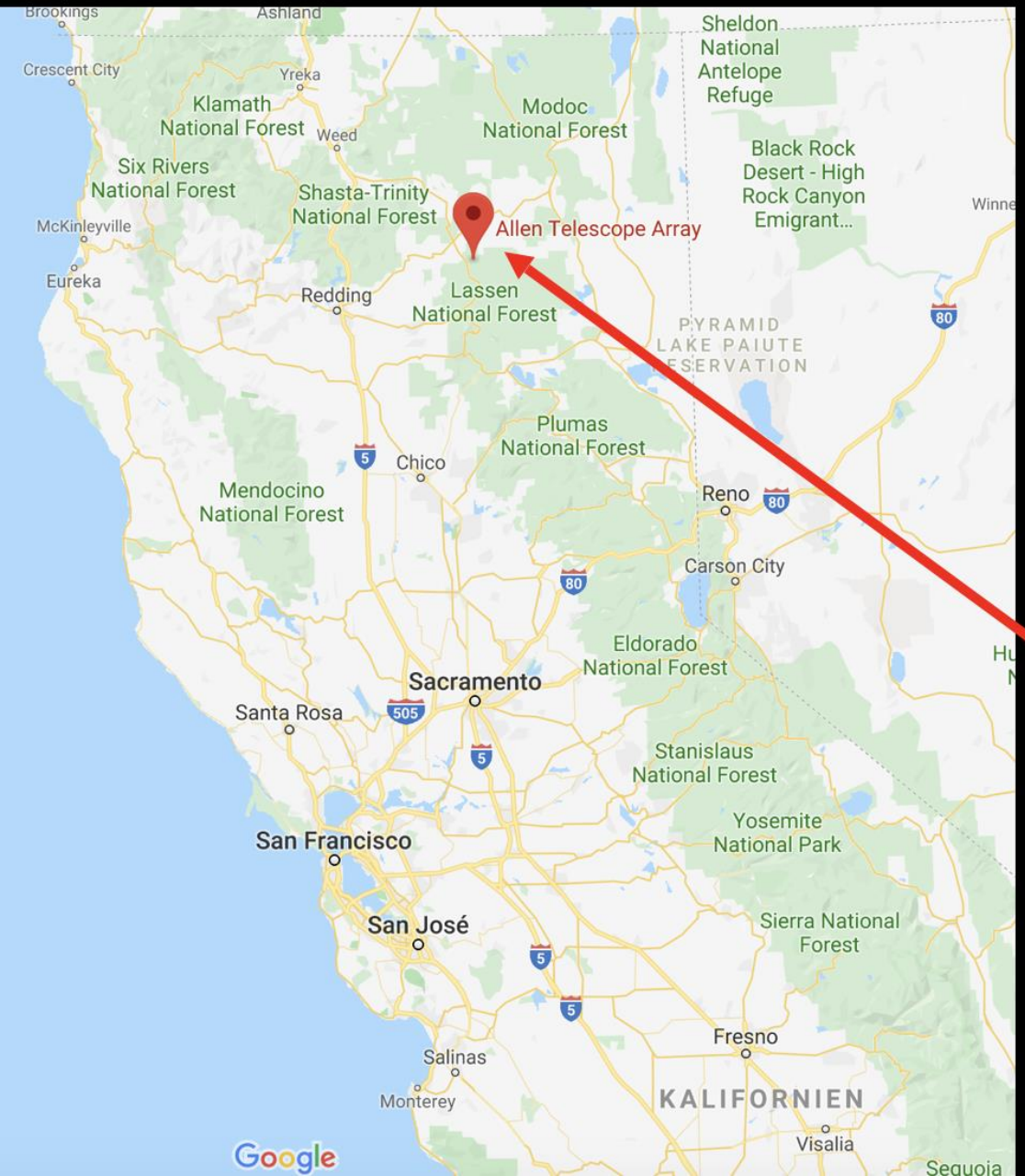
Sofia Z. Sheikh[1]✉, Shane Smith[1,2], Danny C. Price[1,3], David DeBoer[4], Brian C. Lacki[1], Daniel J. Czech[1], Steve Croft[1,5], Vishal Gajjar[1], Howard Isaacson[1,6], Matt Lebofsky[1], David H. E. MacMahon[1,4], Cherry Ng[1,5,7], Karen I. Perez[8], Andrew P. V. Siemion[1,5,9], Claire Isabel Webb[1,10],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

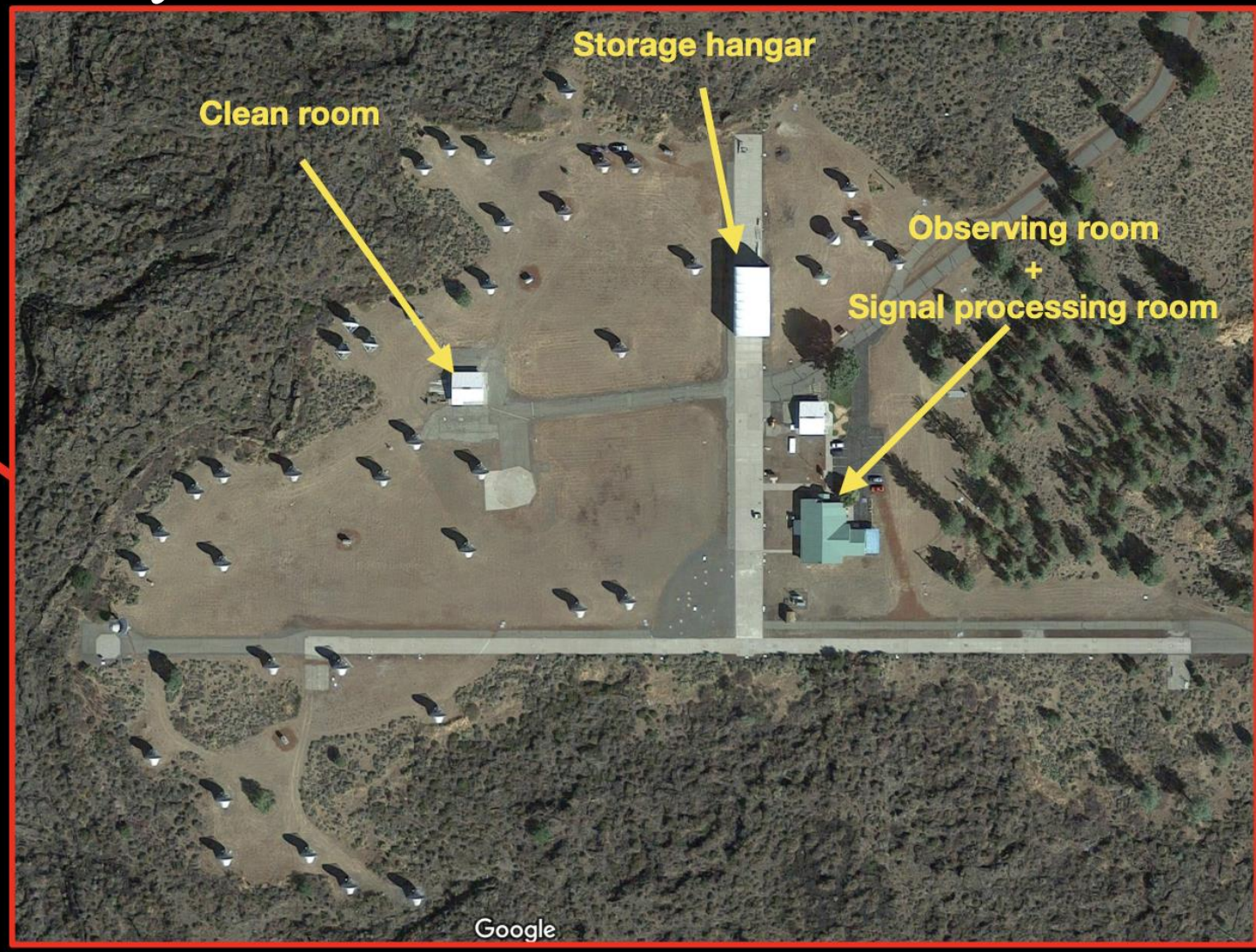
The aim of the search for extraterrestrial intelligence (SETI) is to find technologically capable life beyond Earth through their technosignatures. On 2019 April 29, the Breakthrough Listen SETI project observed Proxima Centauri with the Parkes 'Murriyang' radio telescope. These data contained a narrowband 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

SETI INSTITUTE





An Interferometric SETI Observation of Kepler-111 b

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

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[2] *Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands*
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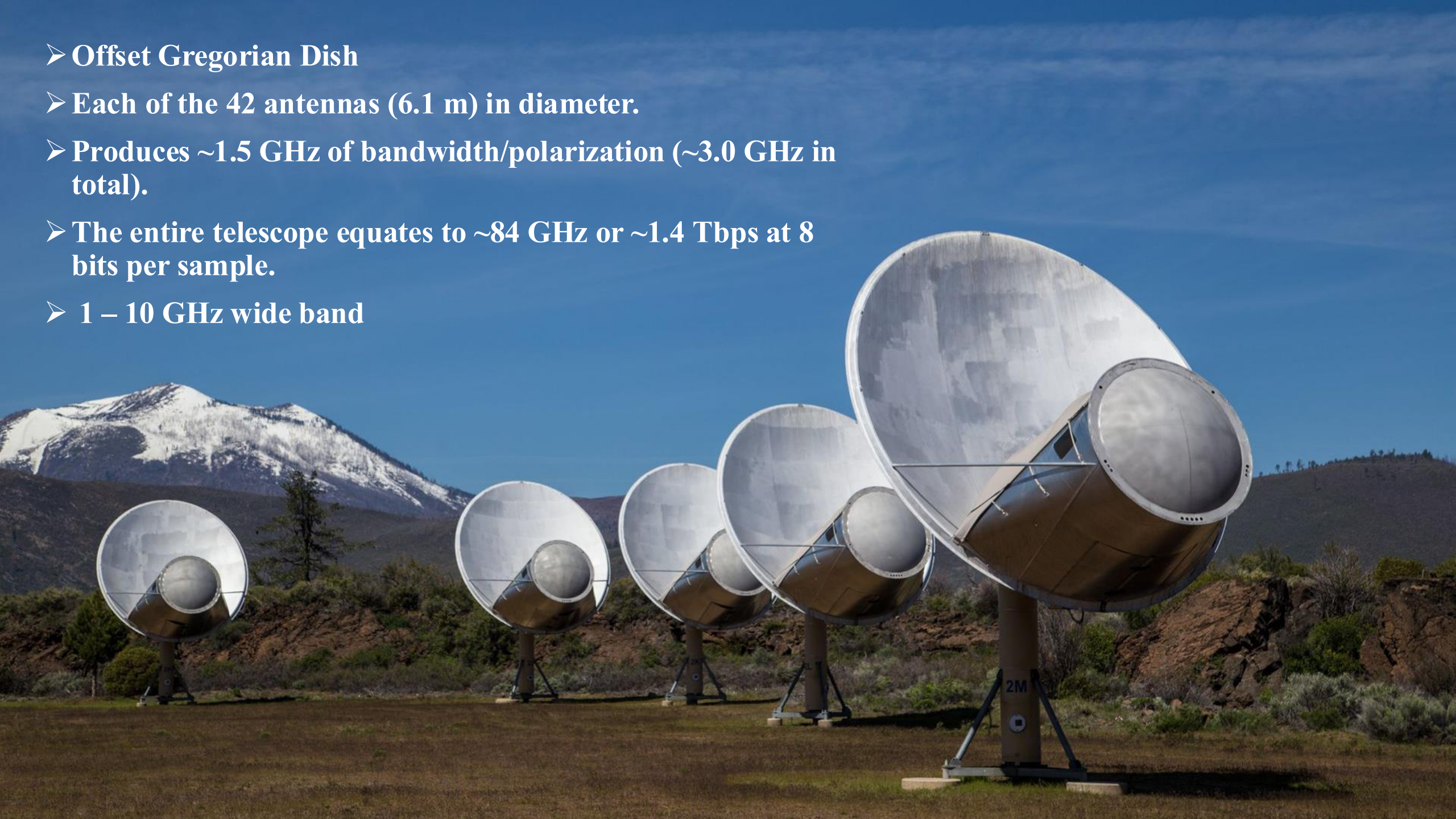
[5] *Department of Space, Earth and Environment, Chalmers University of Technology, Onsala Space Observatory, 439 92 Onsala, Sweden*
[6] *Joint Institute for VLBI in Europe, Oude Hoogeveensedijk 4, 7991 PD, Dwingeloo, The Netherlands*
[7] *SETI Institute, Mountain View, CA 94043, USA*
[8] *University of Malta, Institute of Space Sciences and Astronomy, Malta*

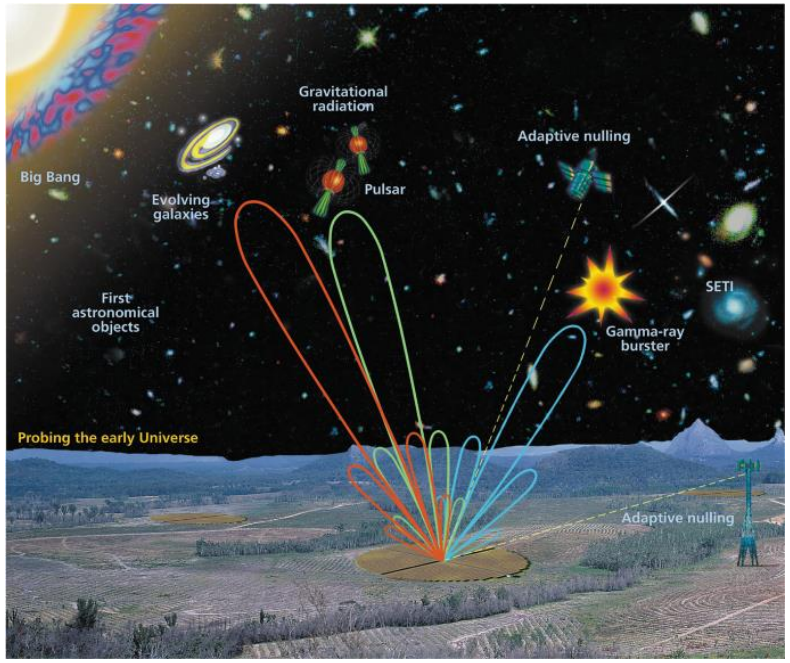
13 April 2023

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 ~ 1.88′ from a nearby exoplanet Kepler-111 b, was correlated with high temporal (0.25 s) and spectral (16384 × 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 ± 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,[1]★ Wael Farah,[1,2] Sofia Z. Sheikh[1,2,4] Alexander W. Pollak[1] Andrew P. V. Siemion[1,2,3] Others

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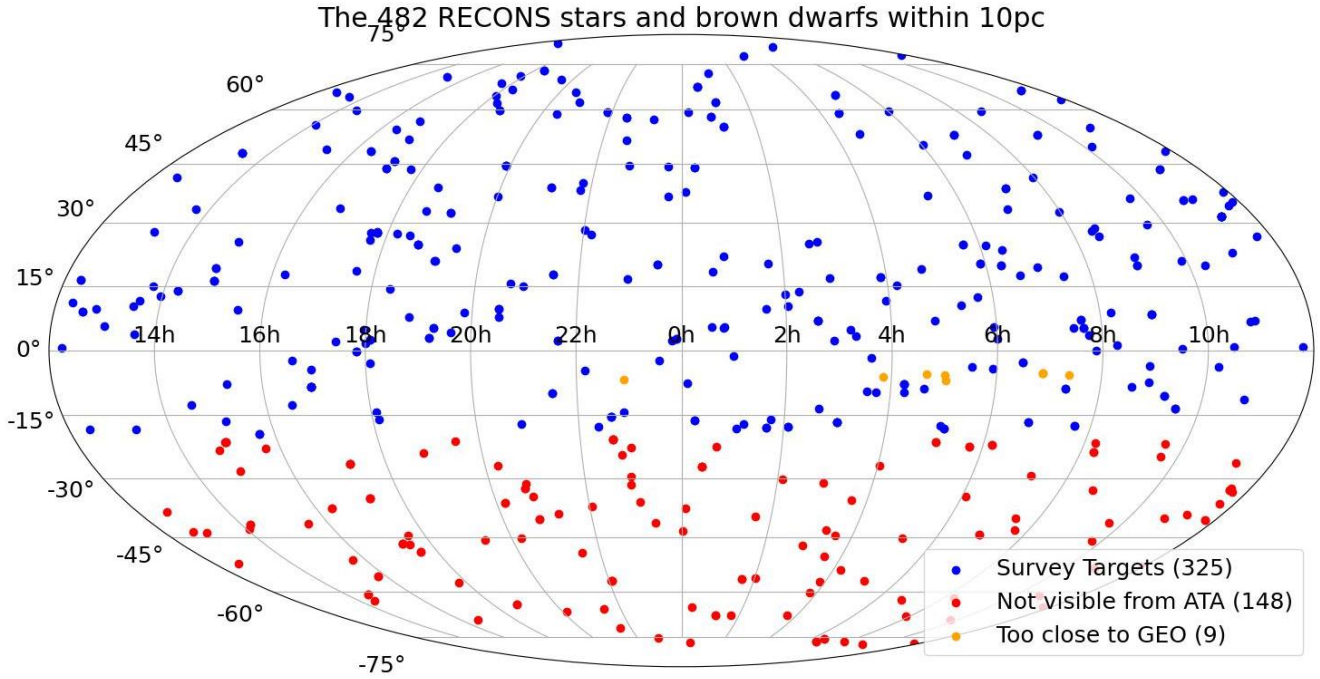
[2]*Berkeley SETI Research Center, University of California, Berkeley, CA 94720, USA*
[3]*University of Malta, Institute of Space Sciences and Astronomy*
[4]*Penn State Extraterrestrial Intelligence Center, Pennsylvania State University, University Park PA 16802*

- **Frequency range:** 3350 MHz to 9650 MHz.
- **Sample:** 266 stars from The Research Consortium On Nearby Stars (RECONS), a database established in 1994 to discover "missing" members of the solar neighborhood and to characterize the complete sample of nearby star systems and their environment.



Hycean Exoplanets as Candidates for Technosignature Detection: A Case Study of K2-18 b in the 3–10 GHz Band

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

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[5] *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_4) and carbon dioxide (CO_2) 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

UNIVERSITY OF CAMBRIDGE

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

Nikku Madhusudhan[1], Savvas Constantinou[1,6], Måns Holmberg[2,6], Subhajit Sarkar[3,6], Anjali A. A. Piette[4], and Julianne I. Moses[5]

[1] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK; nmadhu@ast.cam.ac.uk
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[5] 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_2-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_4 and CO_2 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 ($\gtrsim$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)

Big Data in Astronomy

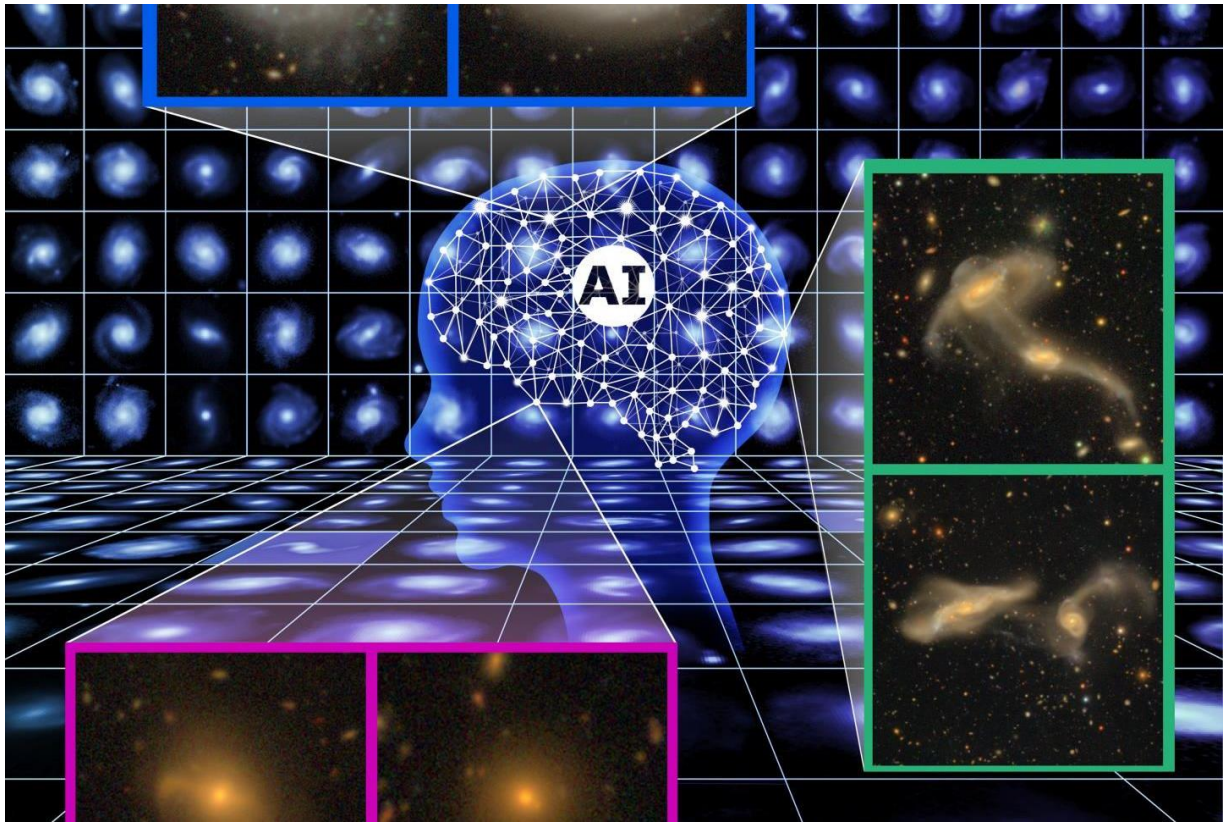
Sky Survey	Volume	Velocity	Variety
SDSS *Sloan Digital Sky Survey*	50 TB	200 GB per day	images, catalogs, redshits
GAIA	100 TB	40 GB per day	more then 100 parameters
Pan-STARRS *Panoramic Survey Telescope and Rapid Response System*	5 PB	5 TB per day	images, catalogs
LSST *Large Synoptic Survey Telescope*	60 PB	10 TB per day	images, catalogs
SKA *Square Kilometer Array*	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.
- Computing Power: 135 quadrillion of computations/s, would take 600 K years for a humam being to perform manually.
- 700 petabytes/year — 140 million HD movies –one would need 383 K years watching one per day.

Artificial Intelligence



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Article | Published: 30 January 2023

A deep-learning search for technosignatures from 820 nearby stars

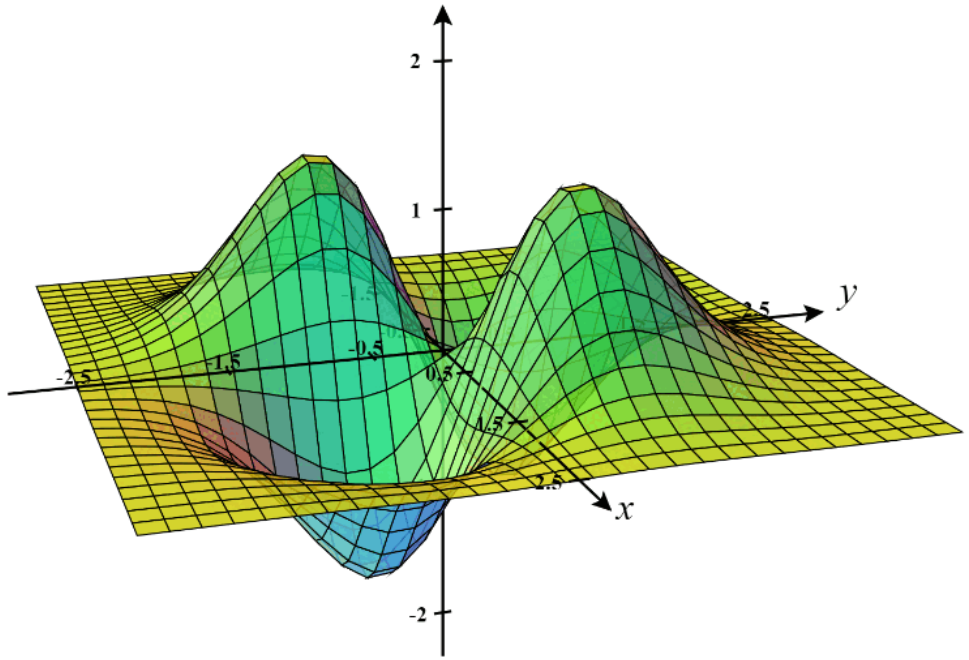
Peter Xiangyuan Ma ✉, Cherry Ng, Leandro Rizk, Steve Croft, Andrew P. V. Siemion, Bryan Brzycki, Daniel Czech, Jamie Drew, Vishal Gajjar, John Hoang, Howard Isaacson, Matt Lebofsky, David H. E. MacMahon, Imke de Pater, Danny C. Price, Sofia Z. Sheikh & S. Pete Worden

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

4906 Accesses | **31** Citations | **1740** Altmetric | Metrics

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

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[4] University of Malta, Institute of Space Sciences and Astronomy, Malta, Italy
[5] The Breakthrough Initiatives, NASA Research Park, Bld. 18, Moffett Field, CA, 94035, USA
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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 [illegible] for signals in spectrograms of intensity as a

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

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

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

27 January 1978, Volume 199, Number 4327 SCIENCE

Eavesdropping: The Radio Signature of the Earth

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

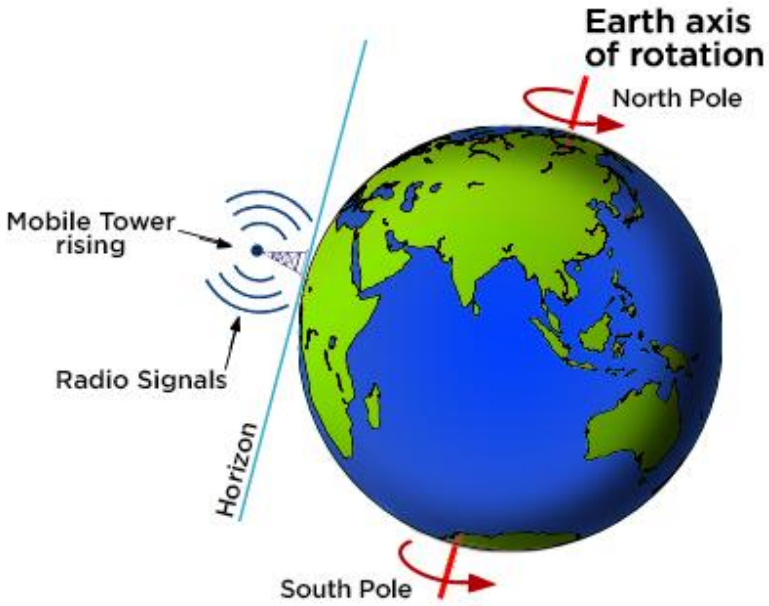
W. T. Sullivan III, S. Brown, C. Wetherill

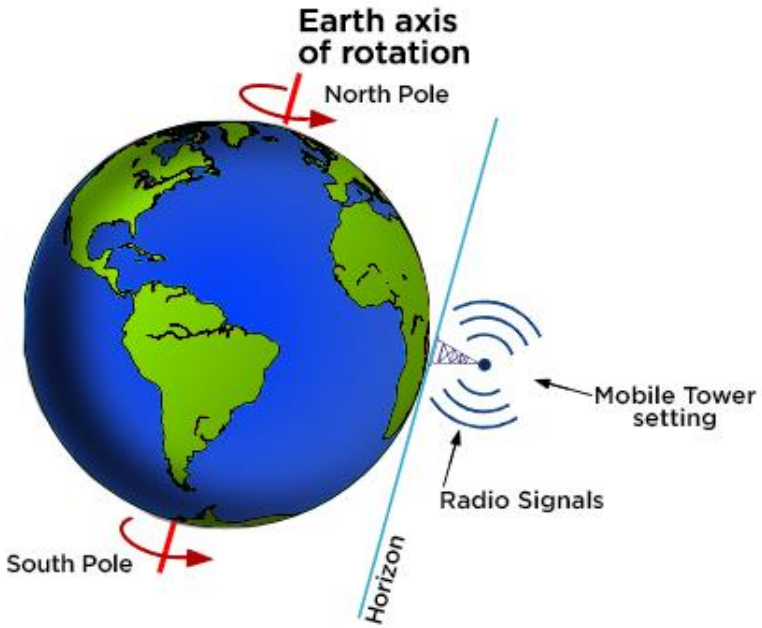
sult of the complex communications and transportation network spread over our globe. Of course, we do not know how applicable our present situation is to the more general case of all galactic civilizations over all time. It may be that our present "leaky" state will soon be terminated by advancing technology, 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.

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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June 2023

Article Contents

ABSTRACT

JOURNAL ARTICLE

Simulation of the Earth's radio-leakage from mobile towers as seen from selected nearby stellar systems FREE

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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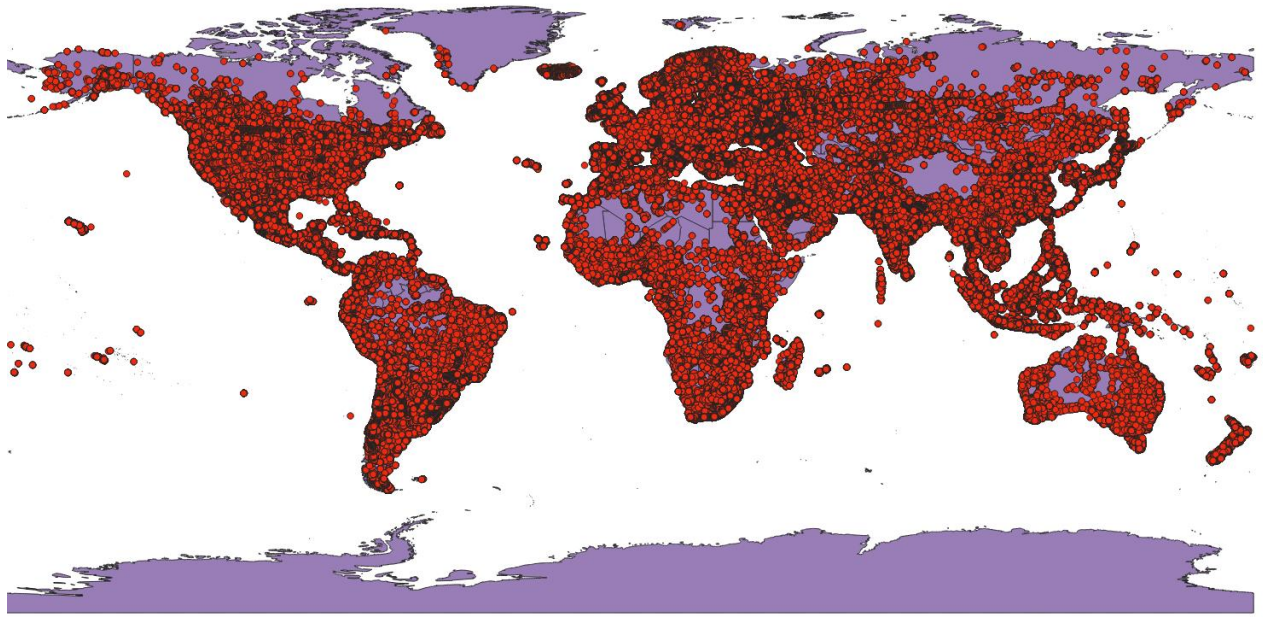
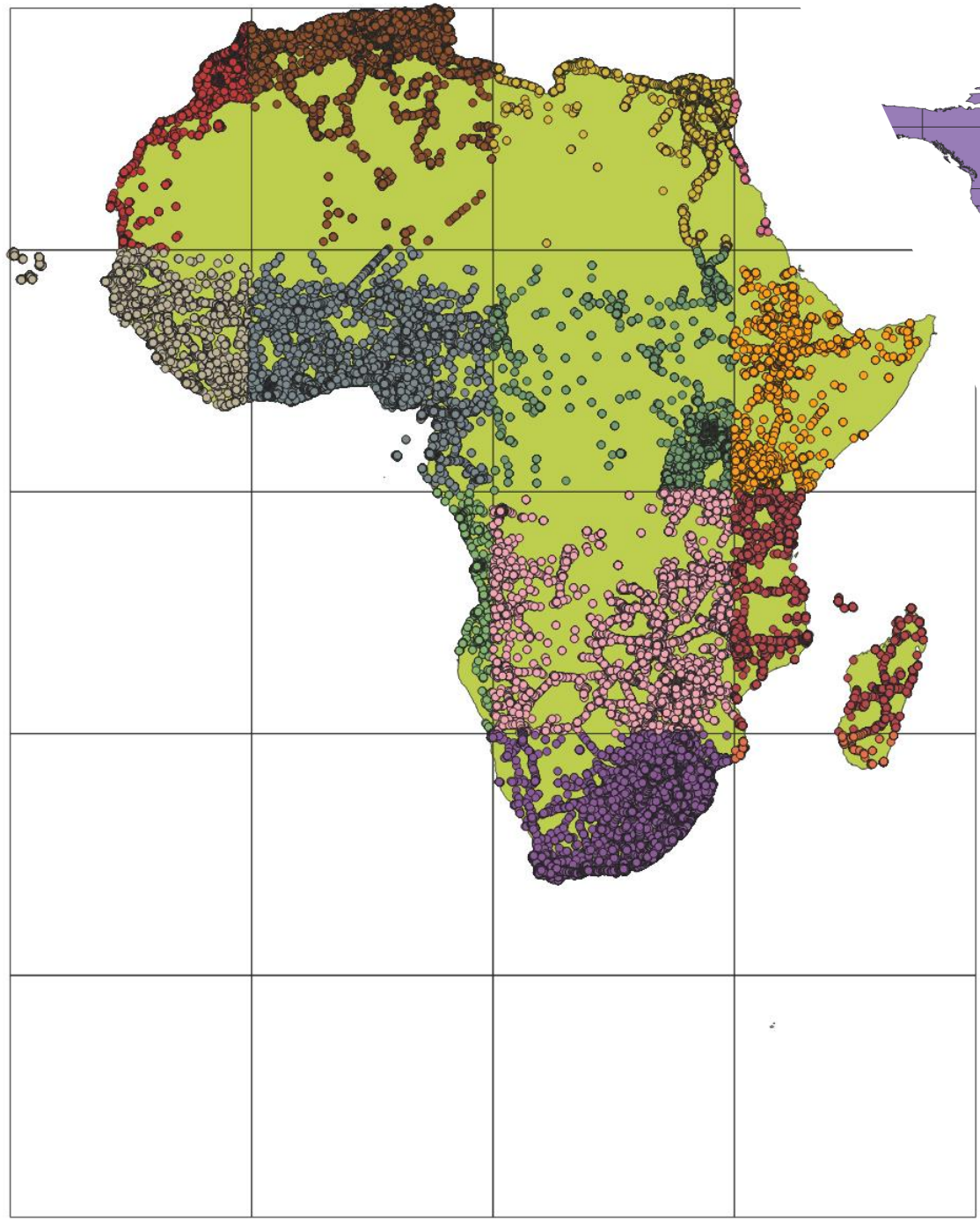


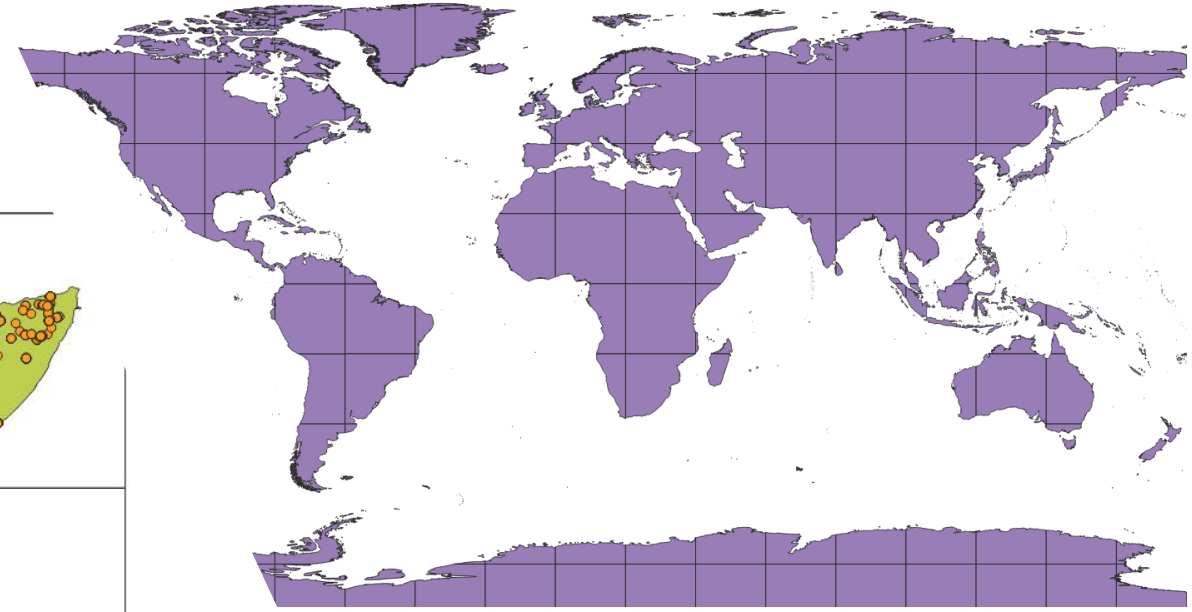
Timeline | X Demographics | Mendeley readers | Attention Score in Context

This research output has an **Altmetric Attention Score** of **920**. This is our high-level measure of the quality and quantity of online attention that it has received. This Attention Score, as well as the ranking and number of research outputs shown below, was calculated when the research output was last mentioned on **17 May 2024**.

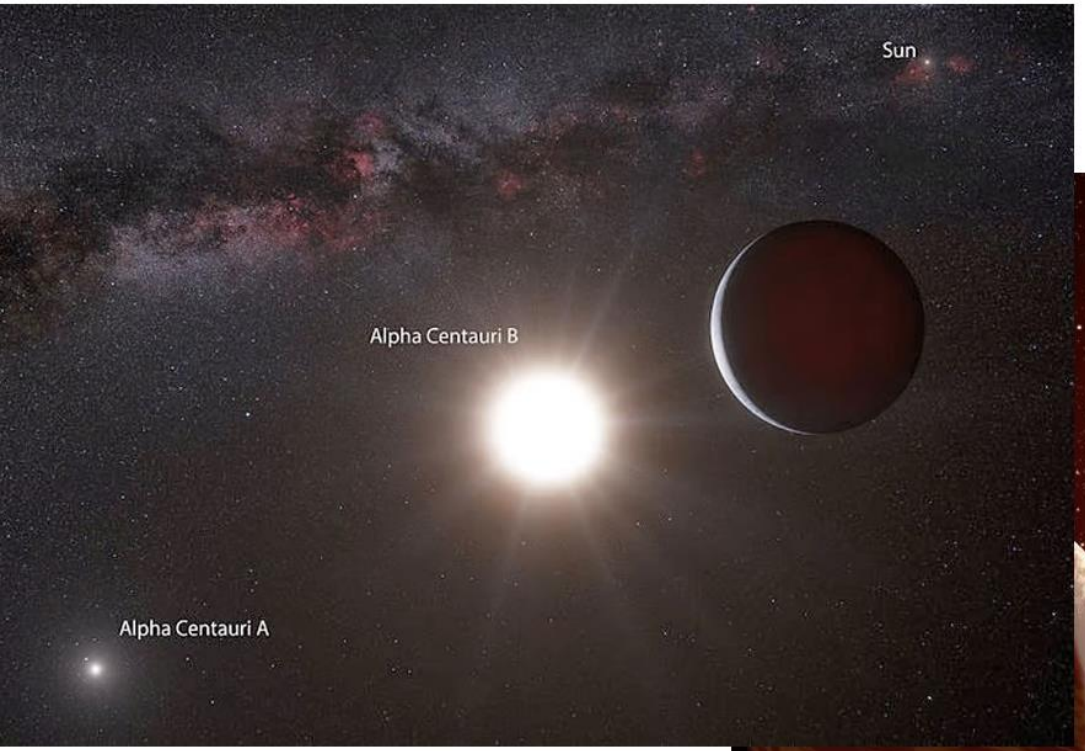
ALL RESEARCH OUTPUTS	OUTPUTS FROM MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY	OUTPUTS OF SIMILAR AGE	OUTPUT
#20,506	#31	#608	
of 27,993,746 outputs	of 41,477 outputs	of 499,604 outputs	

Altmetric has tracked 27,993,746 research outputs across all sources so far. Compared to these this one has done particularly well and is in the 99th percentile: it's **in the top 5% of all research outputs ever tracked** by Altmetric.

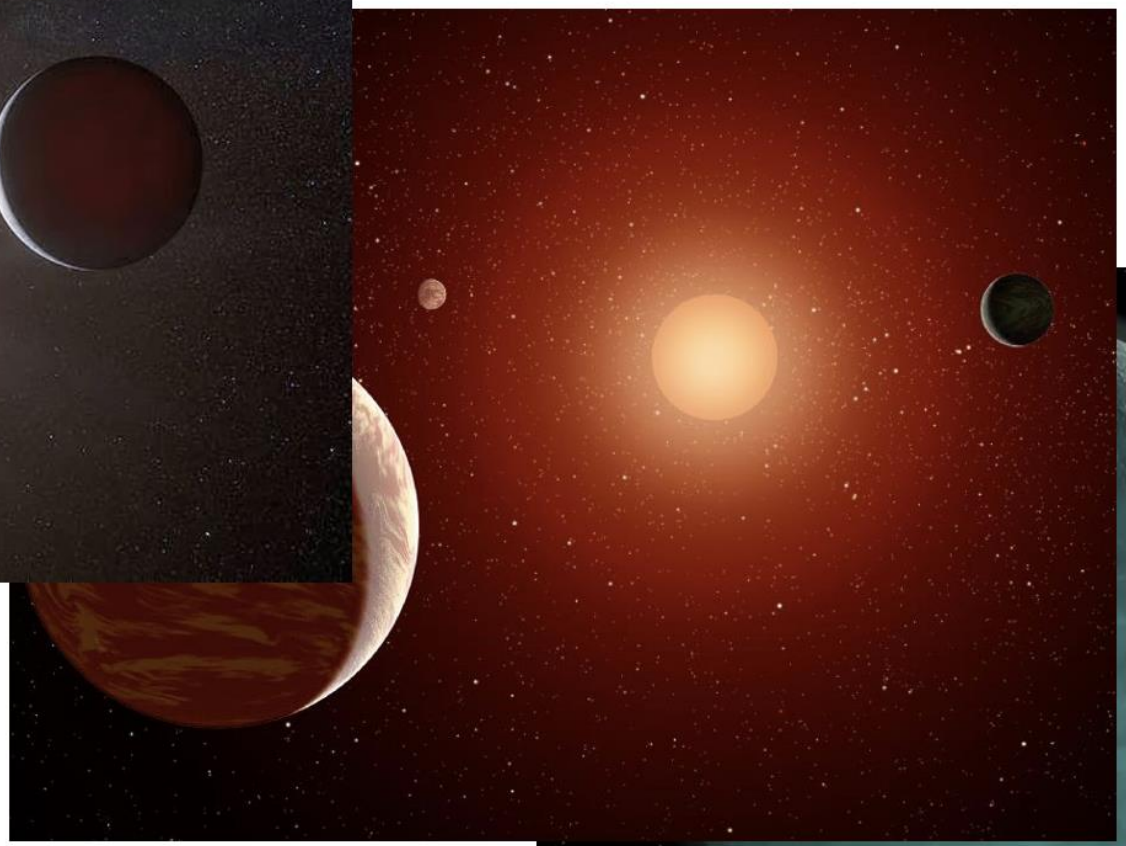




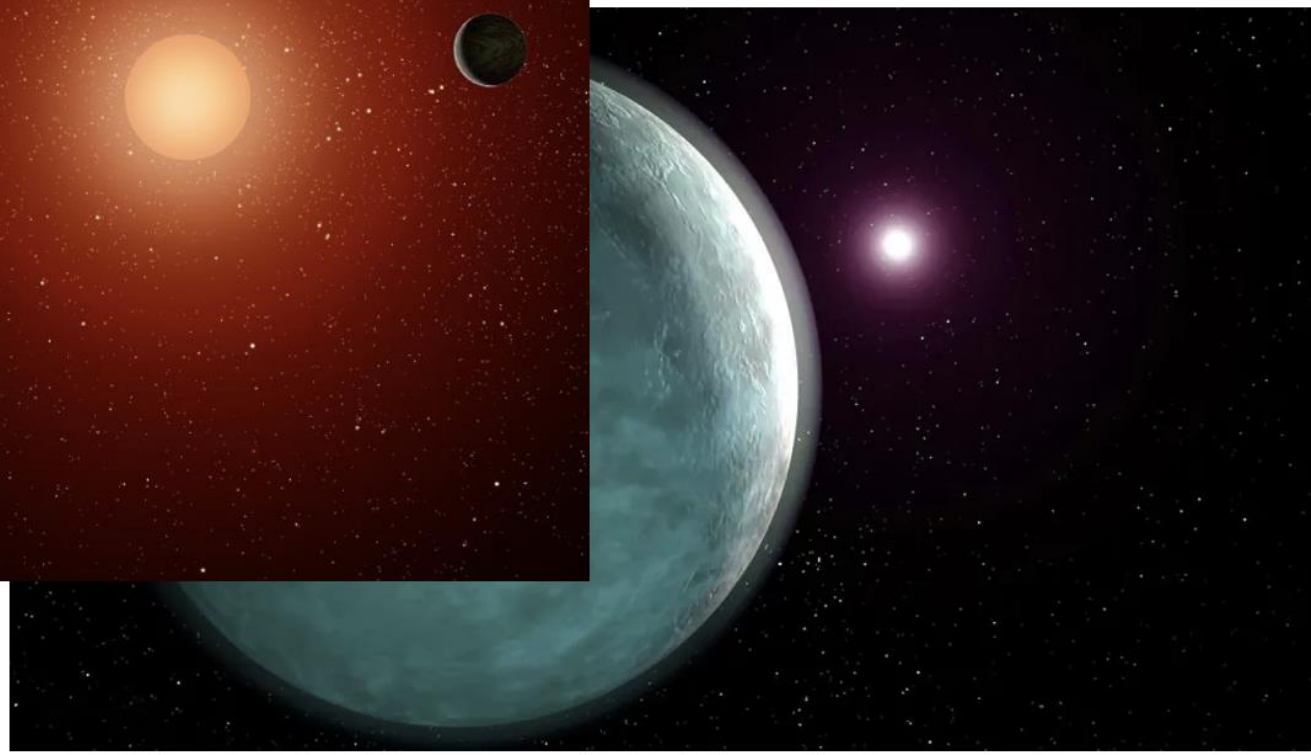
Alpha Centauri A

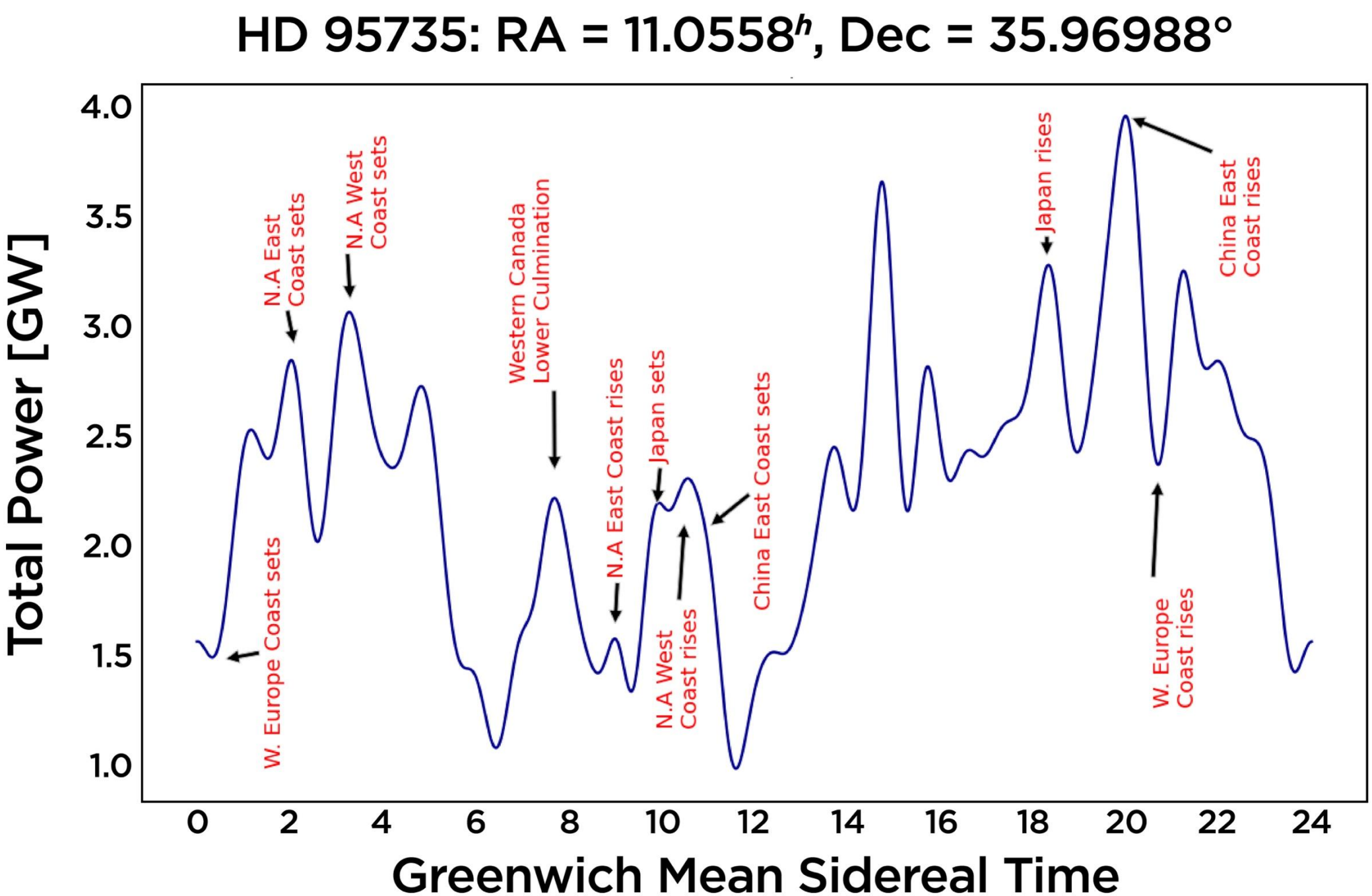


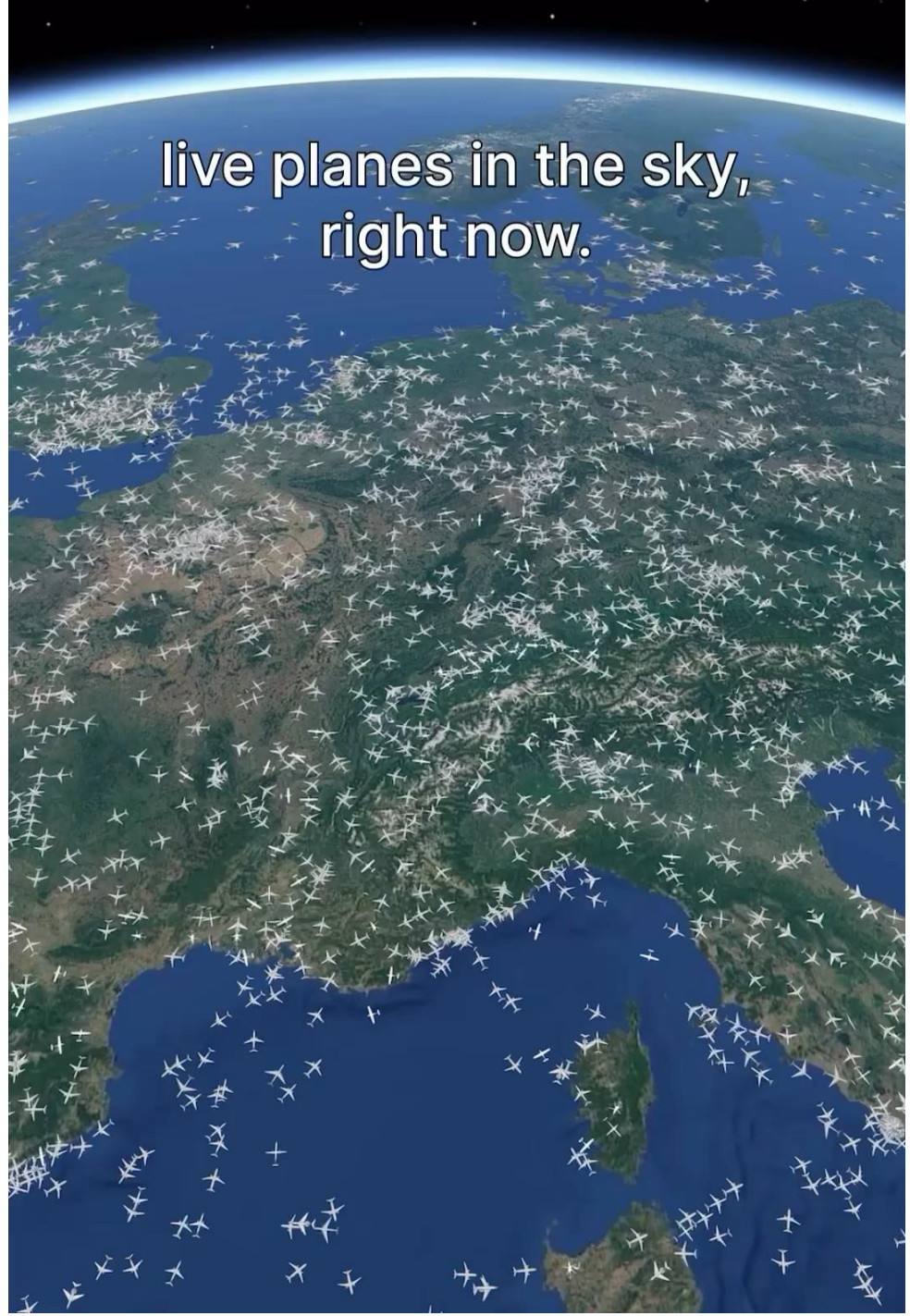
Barnard Star



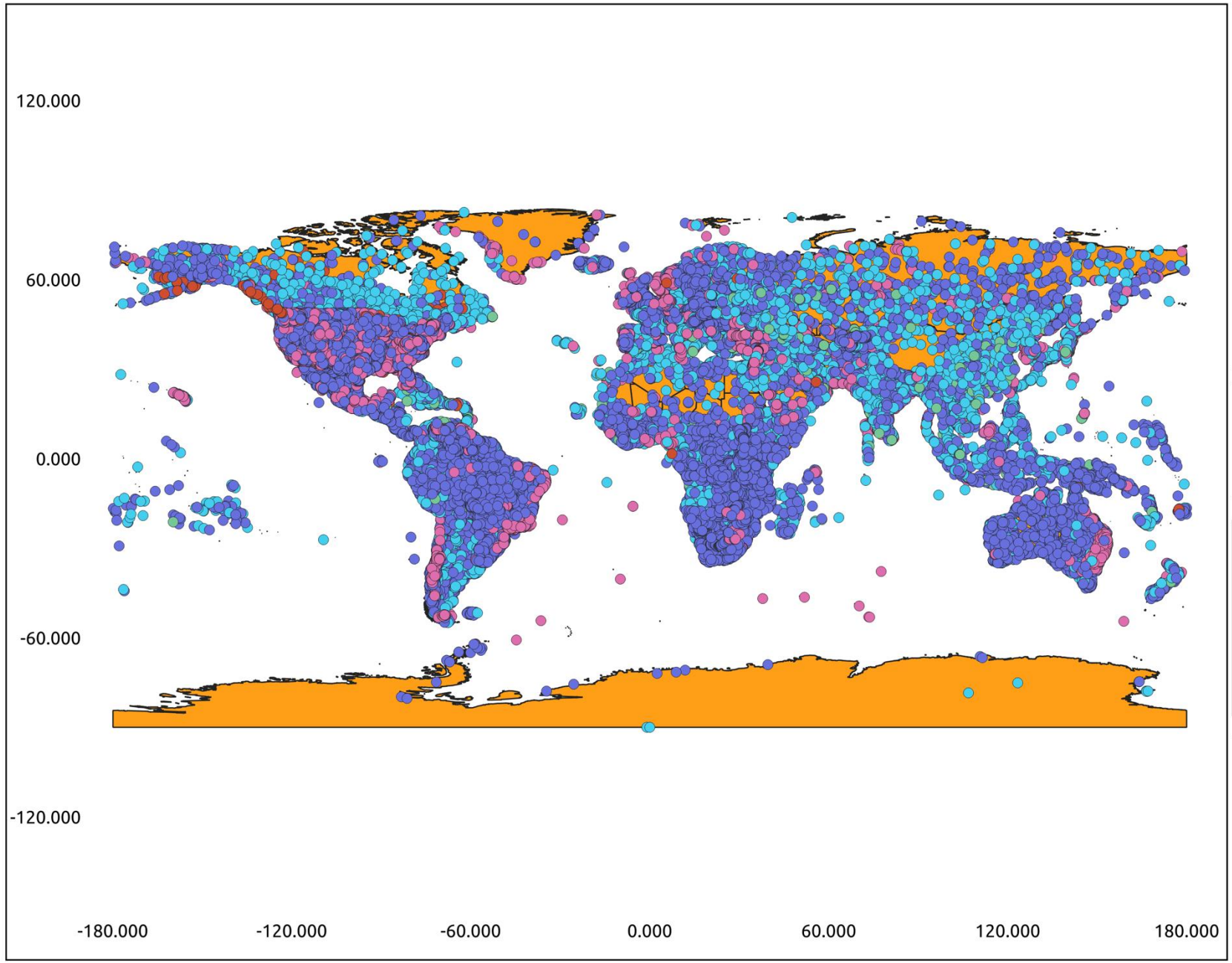
HD 95735




HD 95735: RA = 11.0558h, Dec = 35.96988°
Total Power [GW]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Greenwich Mean Sidereal Time
W. Europe Coast sets
N.A East Coast sets
N.A West Coast sets
Western Canada Lower Culmination
N.A East Coast rises
Japan sets
N.A West Coast rises
China East Coast sets
Japan rises
W. Europe Coast rises
China East Coast rises


live planes in the sky,
right now.

Map of Airports in the World



Legend:

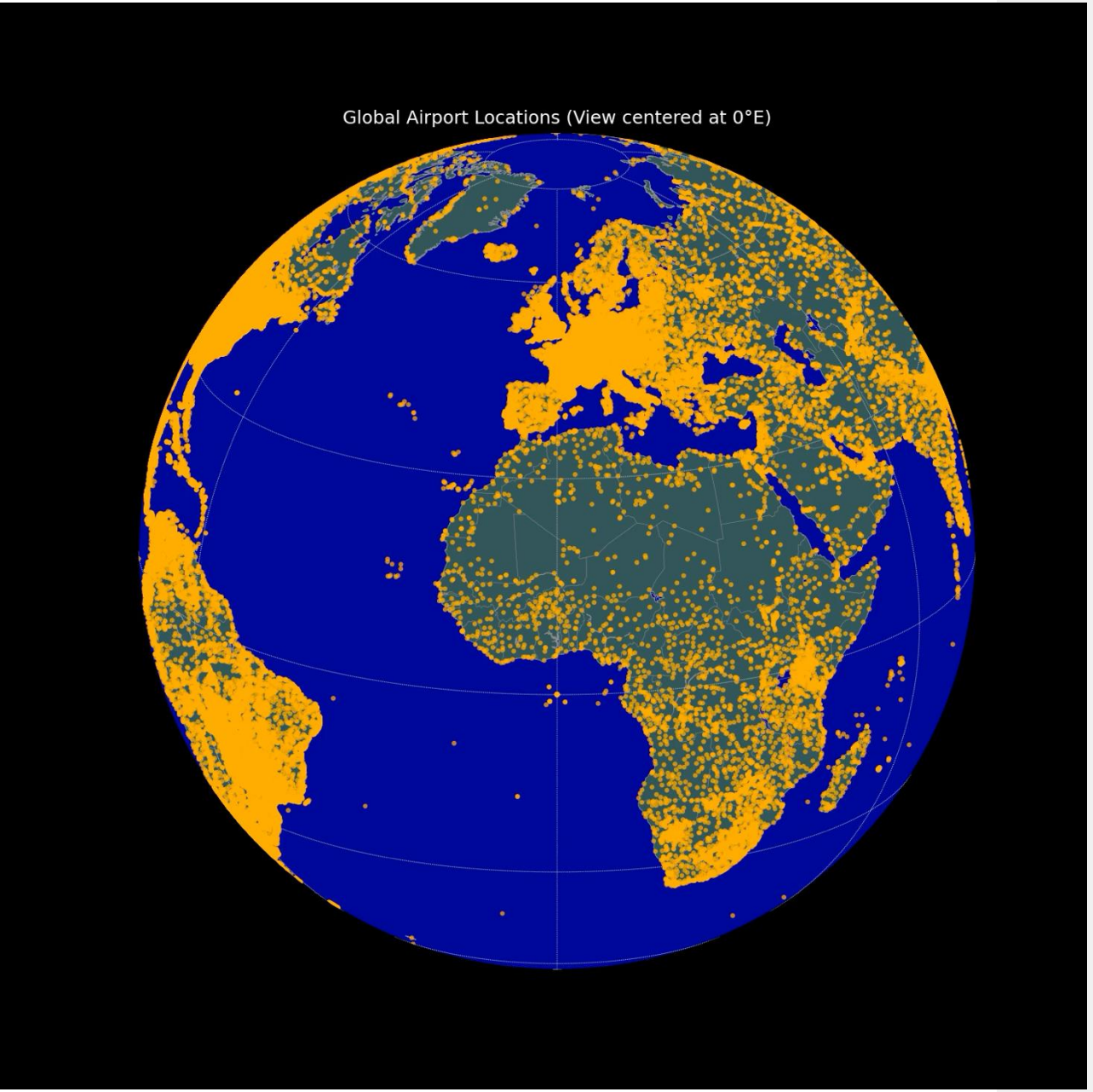
airports
- balloonport
- closed
- heliport
- large_airport
- medium_airport
- seaplane_base
- small_airport

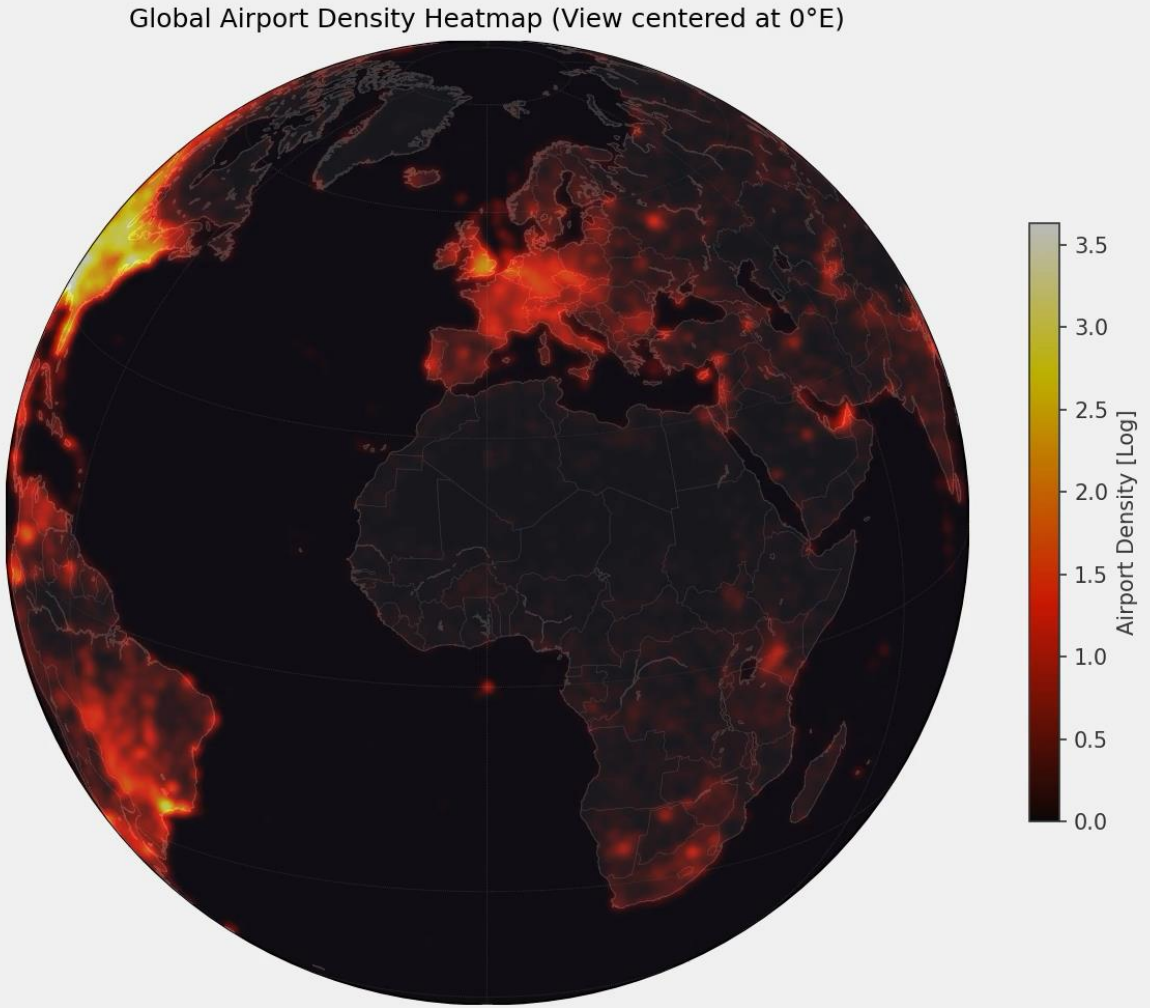
Developed by:

Ramiro Caisse Saide

0 35 70

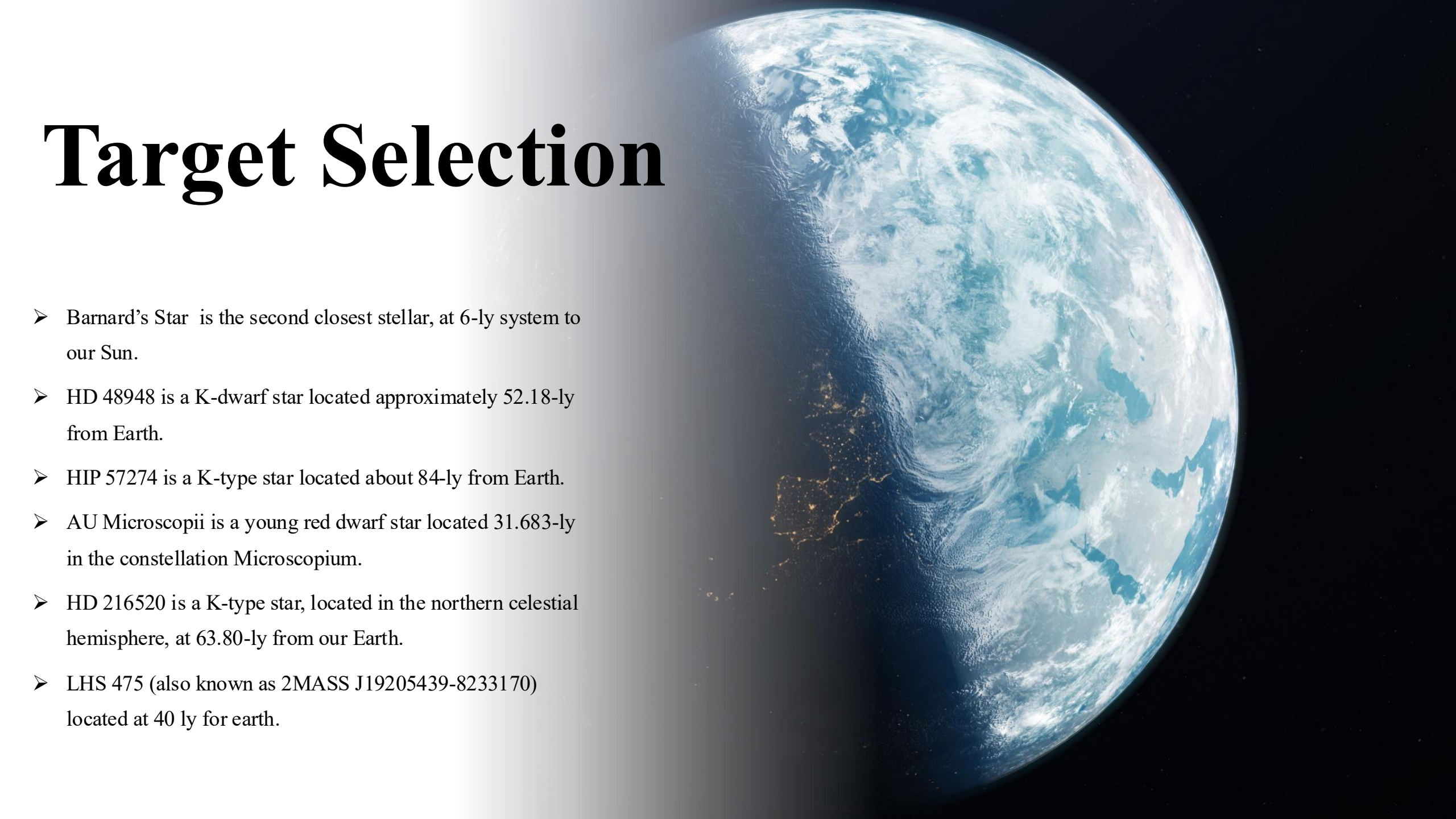
World Geodetic System (WGS) 84.
Natural Earth.
OurAirports dataset formats.

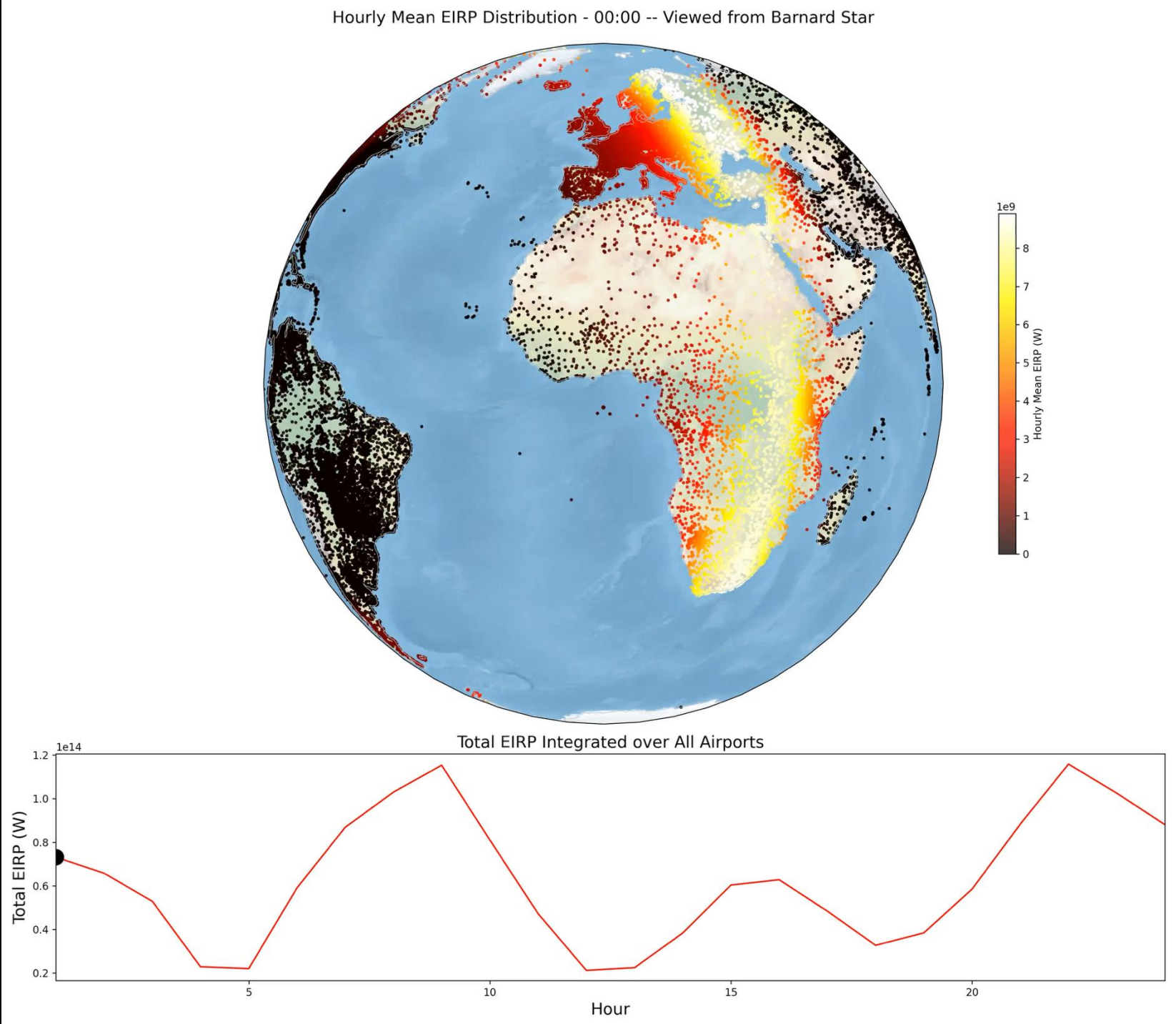

Global Airport Locations (View centered at 0°E)


Global Airport Density Heatmap (View centered at 0°E)
Airport Density [Log]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

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.



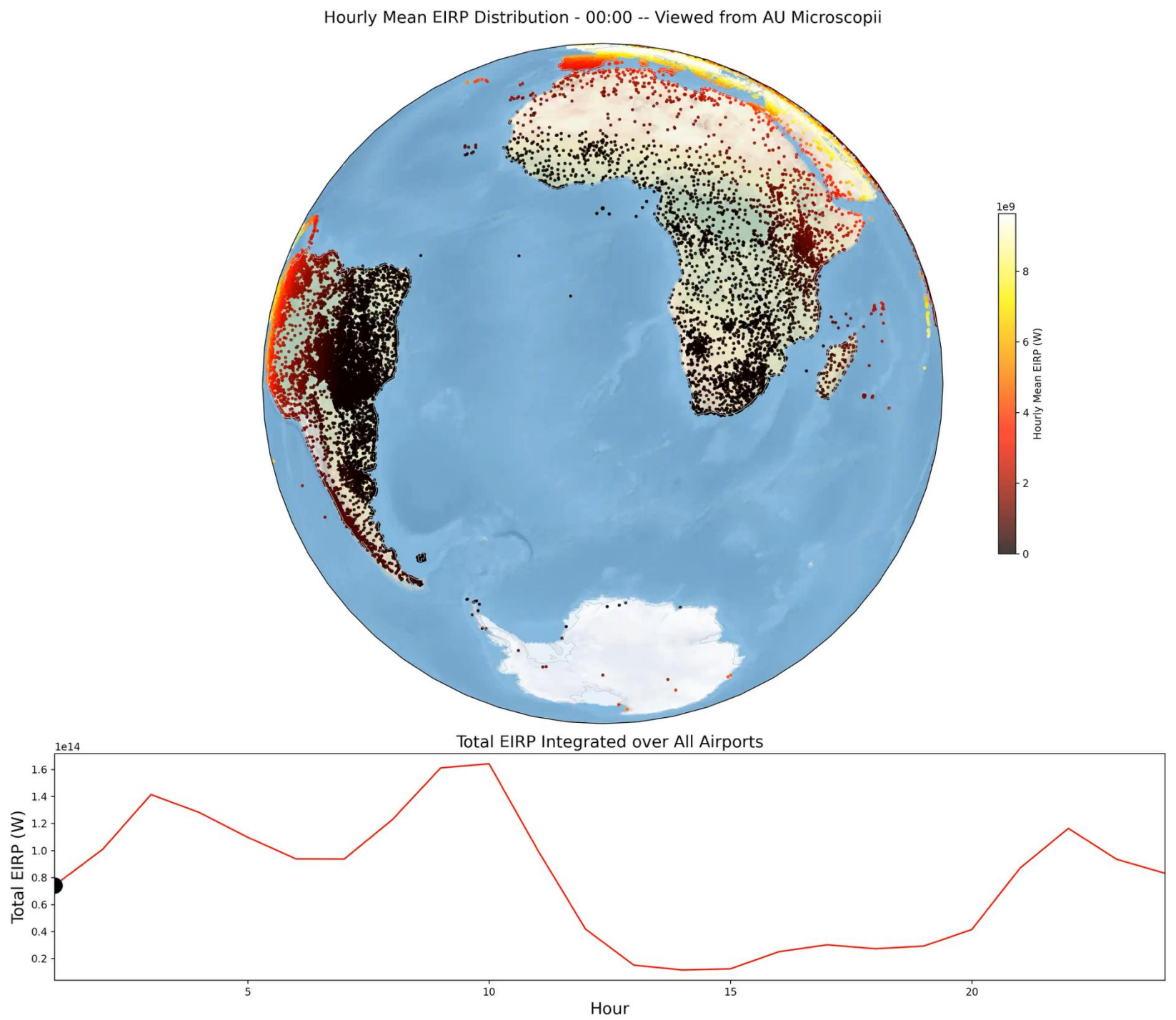


Barnard Star

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.

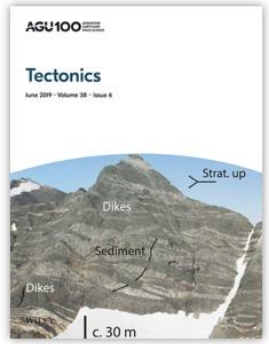
Tectonics®

Research Article | Open Access

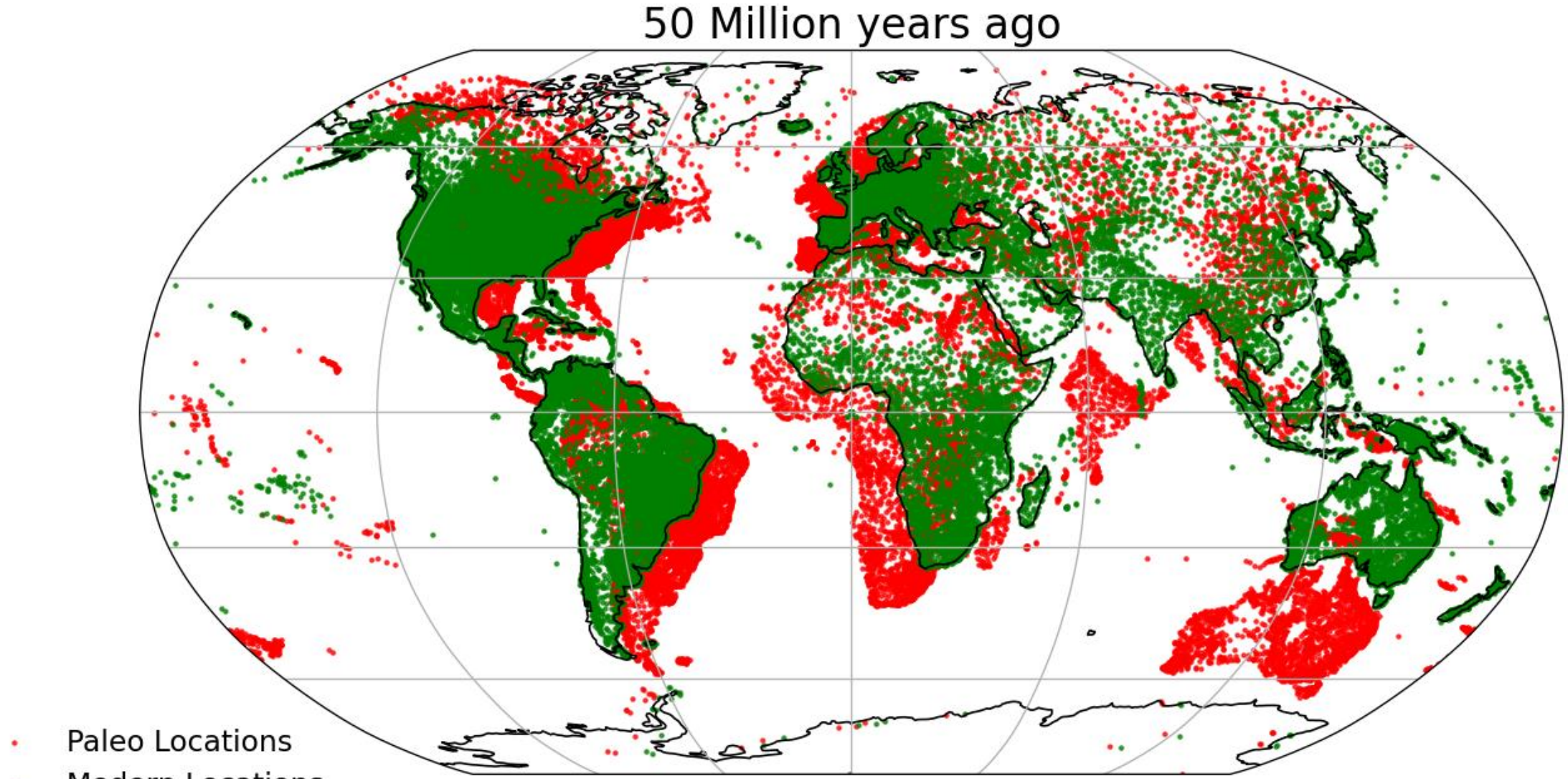
A Global Plate Model Including Lithospheric Deformation Along Major Rifts and Orogens Since the Triassic

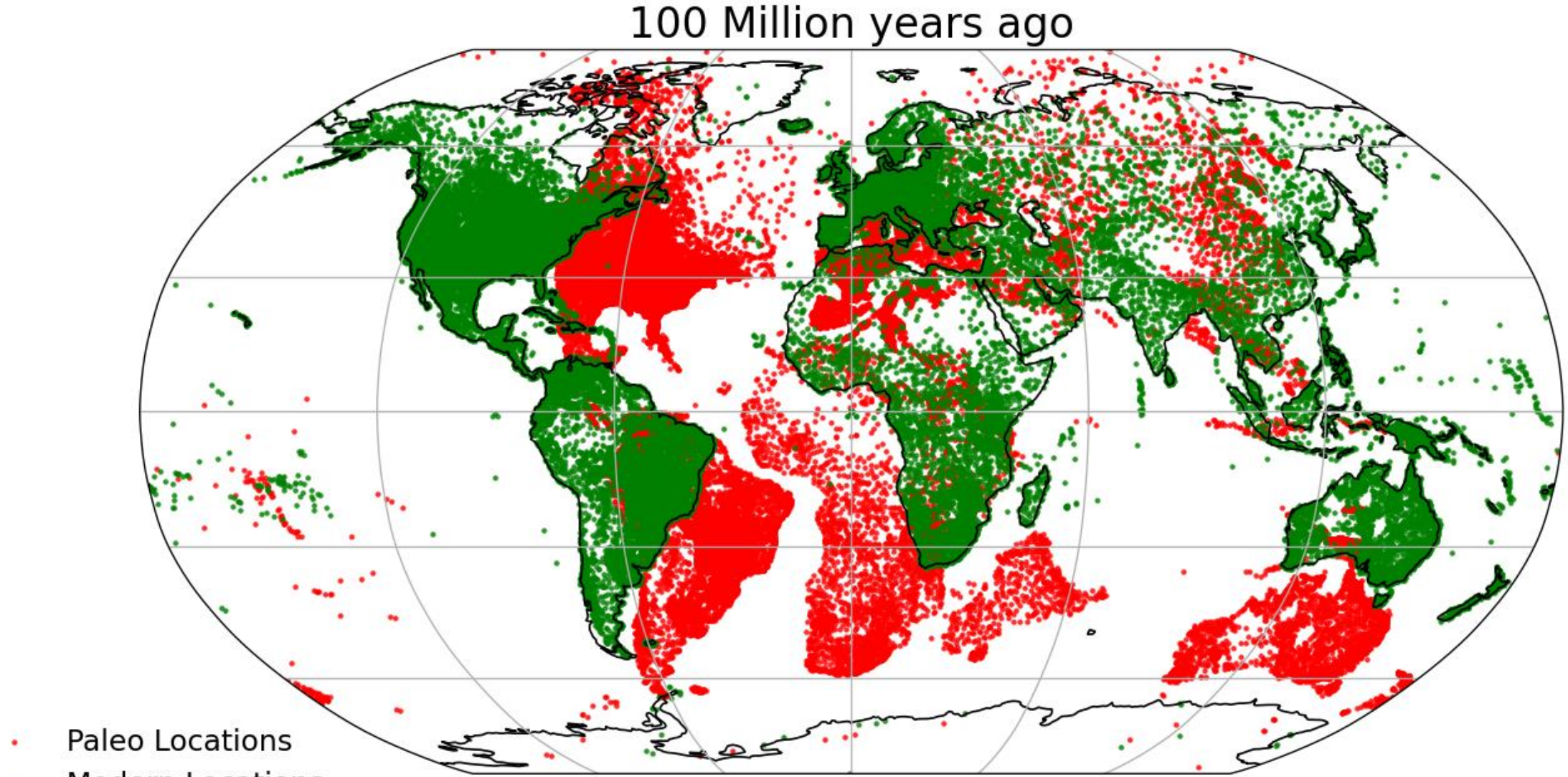
R. Dietmar Müller, Sabin Zahirovic, Simon E. Williams, John Cannon, Maria Seton, Dan J. Bower, Michael G. Tetley, Christian Heine, Eline Le Breton, Shaofeng Liu, Samuel H. J. Russell, Ting Yang, Jonathon Leonard, Michael Gurnis

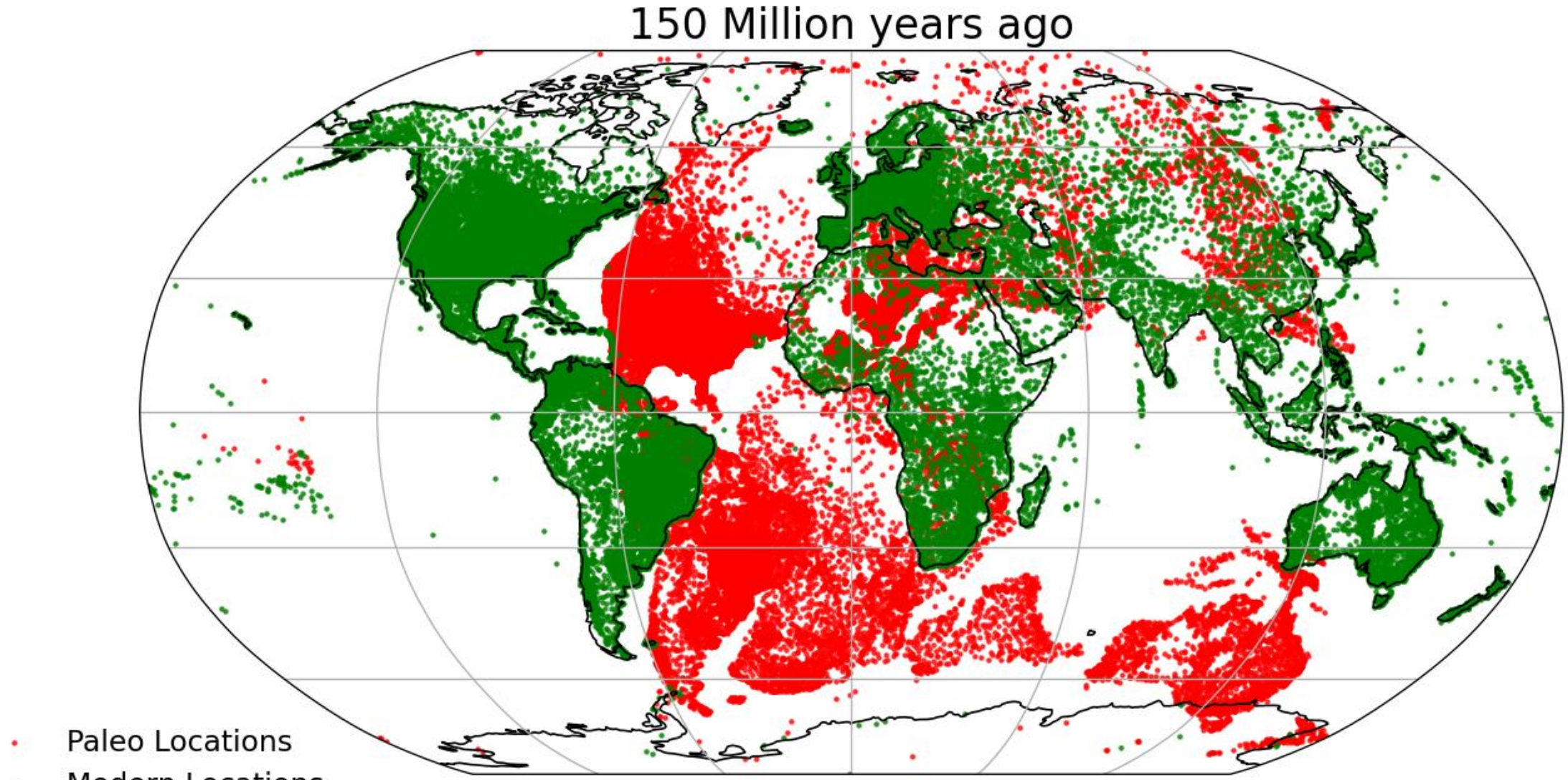
First published: 05 May 2019 | https://doi.org/10.1029/2018TC005462 | Citations: 423



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
Paleo Locations
Modern Locations


100 Million years ago
Paleo Locations
Modern Locations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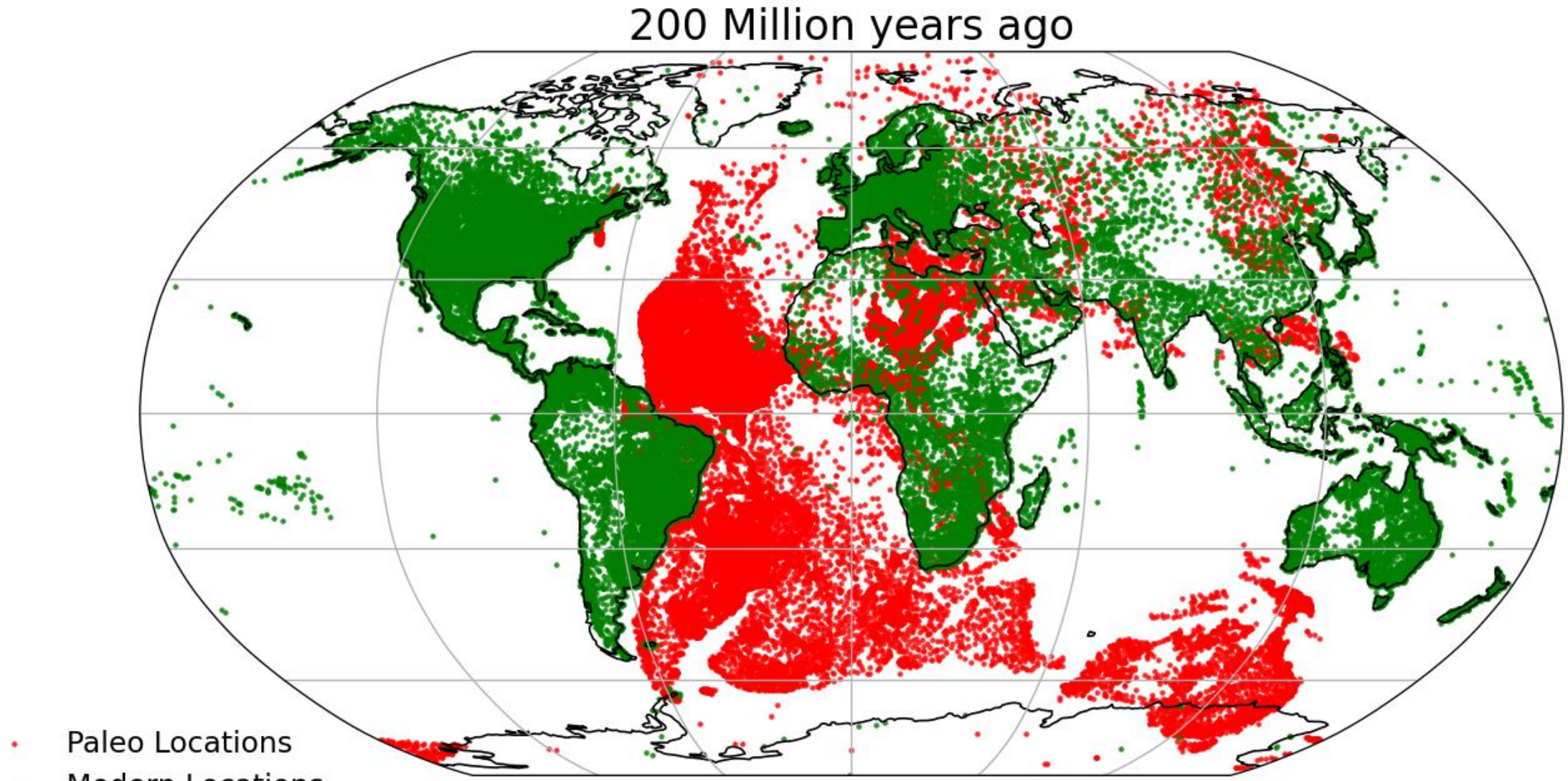
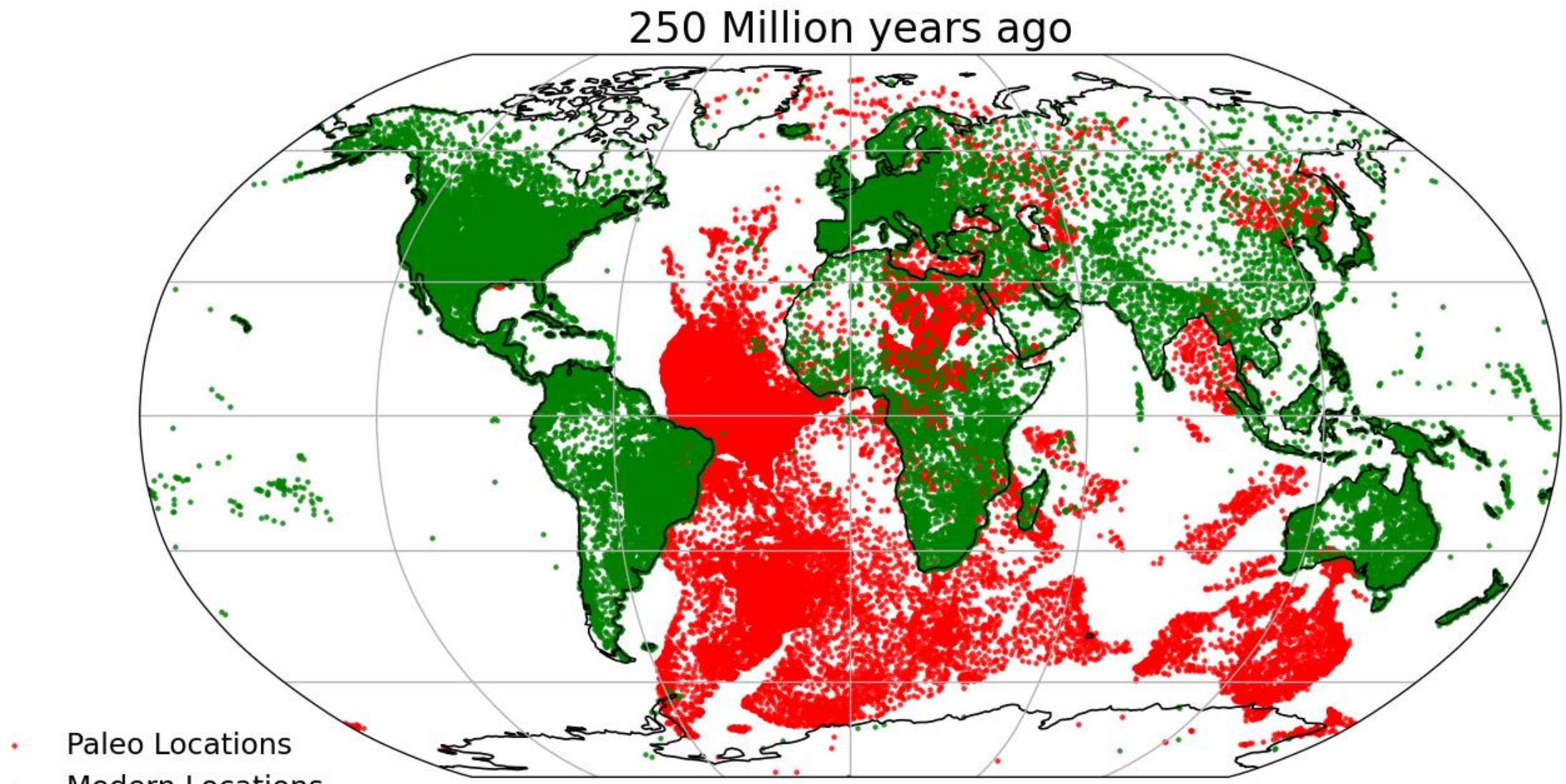
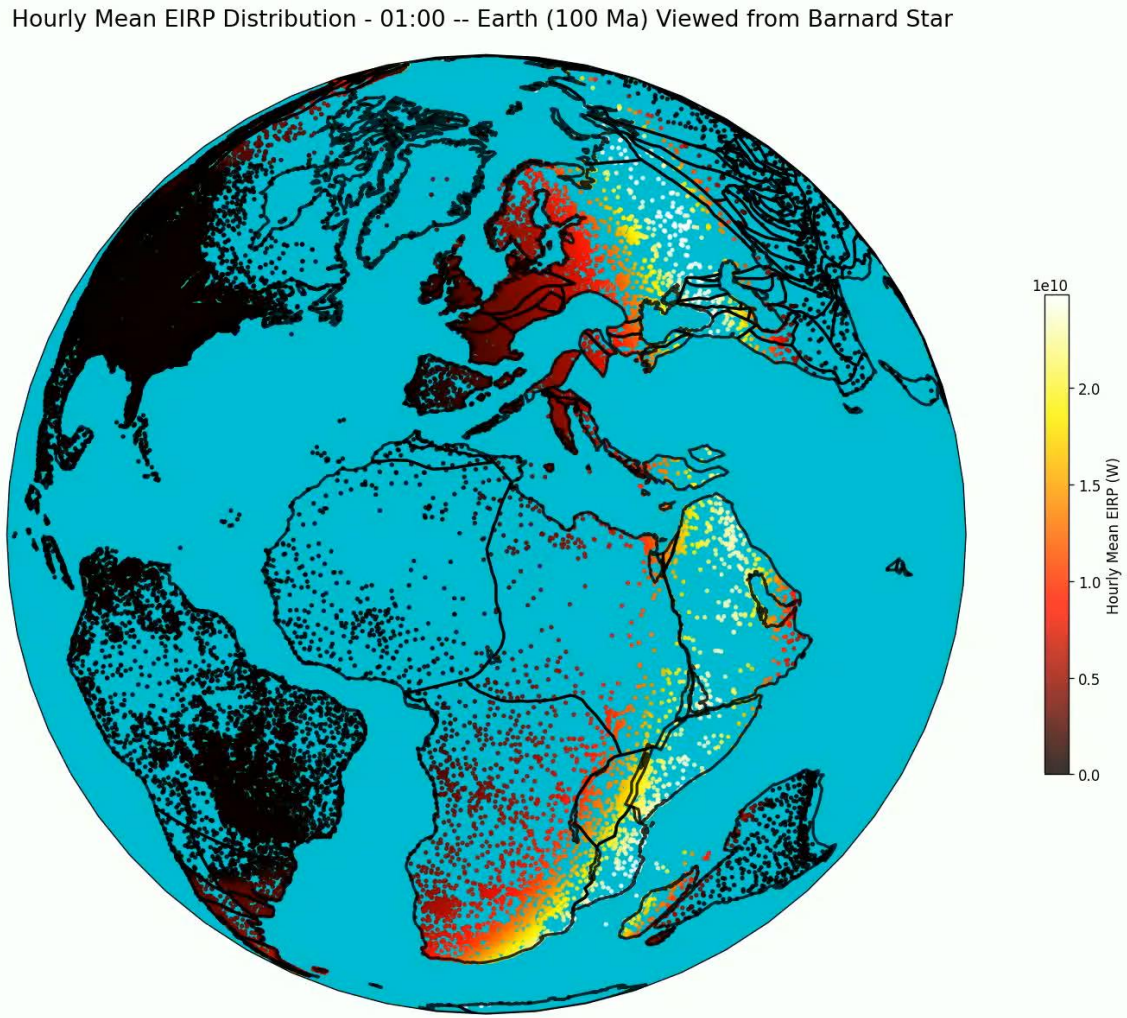
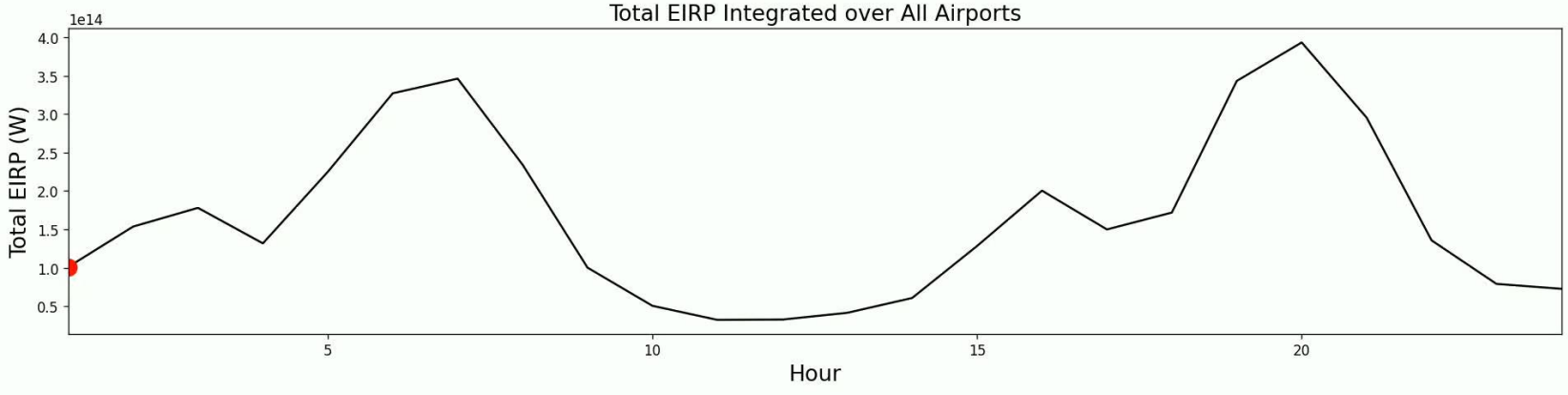
Modern Locations


200 Million years ago
Paleo Locations
Modern Locations


250 Million years ago
Paleo Locations
Modern Locations





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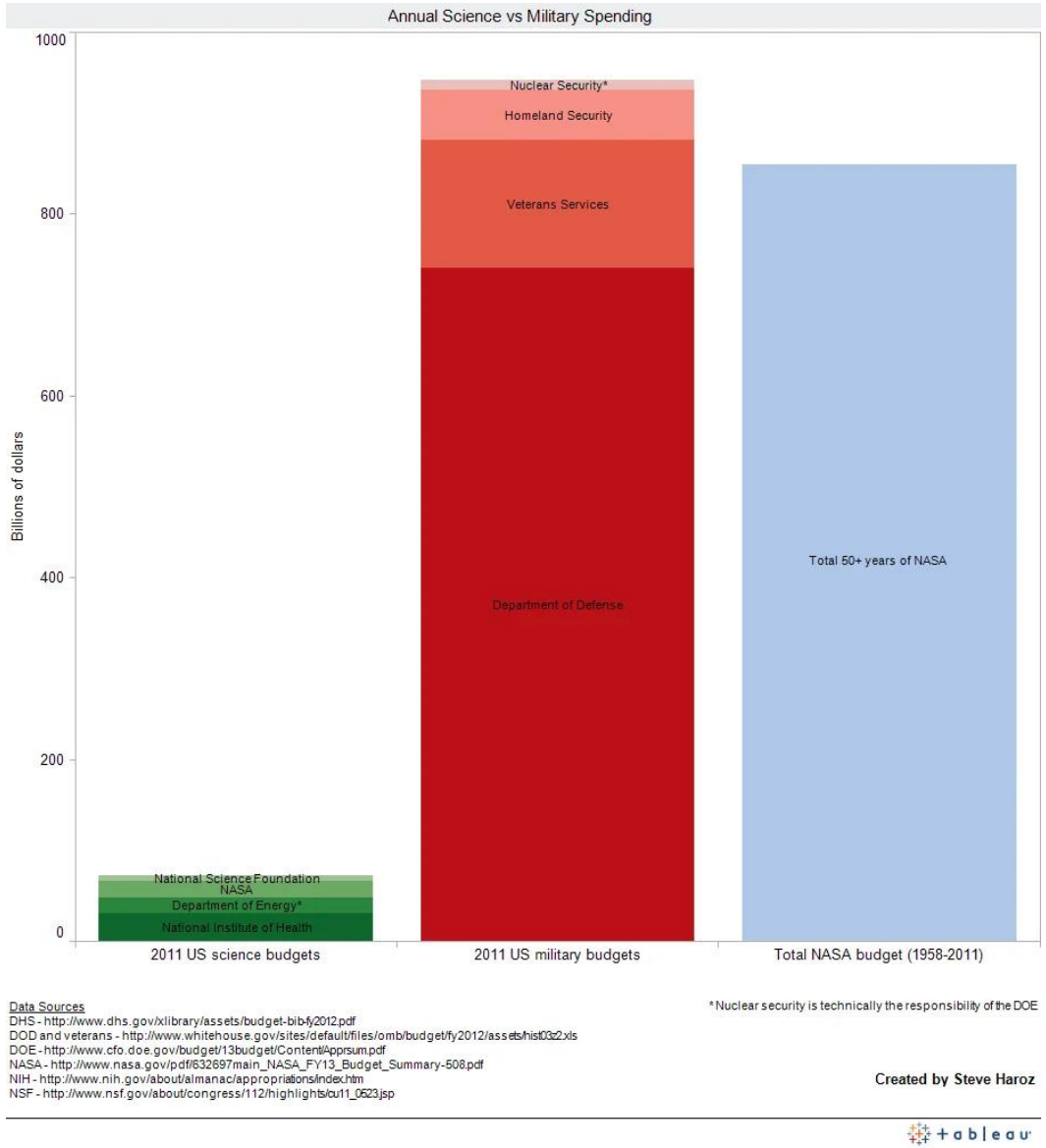
Annual Science vs Military Spending
1000
800
600
400
200
0
Billions of dollars
Nuclear Security*
Homeland Security
Veterans Services
Department of Defense
Total 50+ years of NASA
National Science Foundation
NASA
Department of Energy*
National Institute of Health
2011 US science budgets
2011 US military budgets
Total NASA budget (1958-2011)
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/hist03z2.xls
DOE - http://www.cfo.doe.gov/budget/13budget/Content/Apprsum.pdf
NASA - http://www.nasa.gov/pdf/632697main_NASA_FY13_Budget_Summary-508.pdf
NIH - http://www.nih.gov/about/almanac/appropriations/index.htm
NSF - http://www.nsf.gov/about/congress/112/highlights/cu11_0523.jsp
*Nuclear security is technically the responsibility of the DOE
Created by Steve Haroz
+ableau


$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%
Total
$2.113 trillion
0.7%

“Absence of Evidence is not Evidence of Absence”

- Carl Sagan


any questions???
if not, just clap!