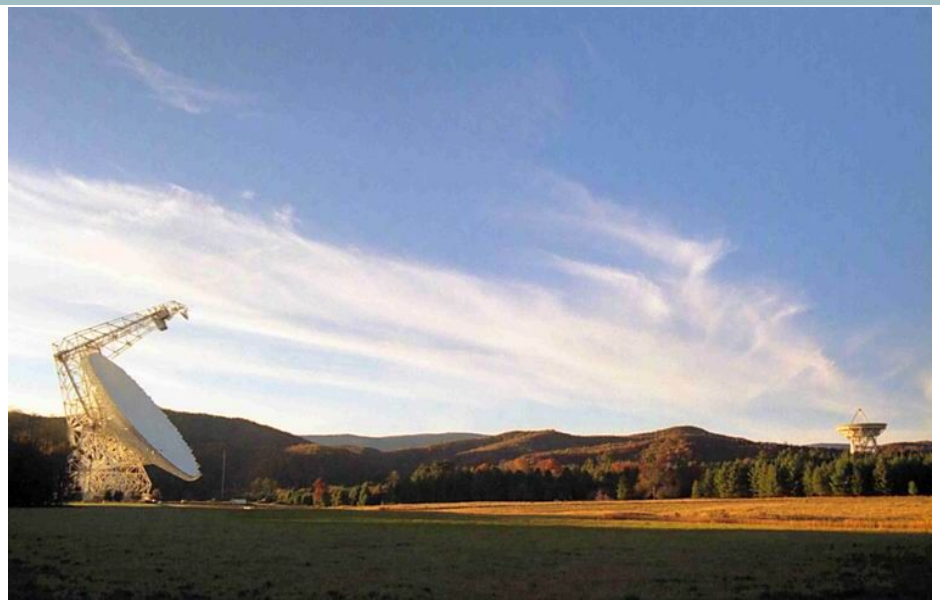
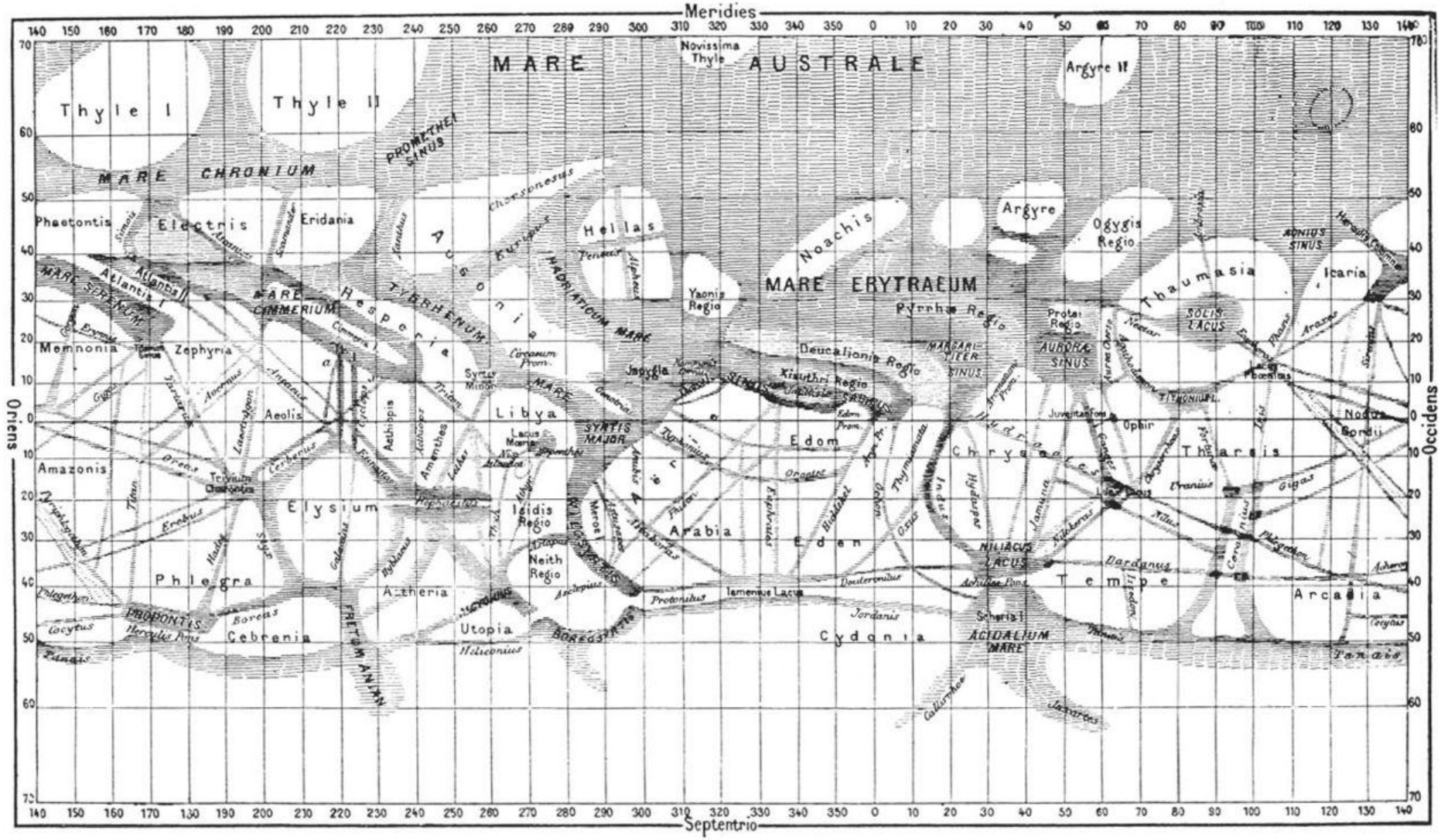
The Quest for Extraterrestrial Intelligence



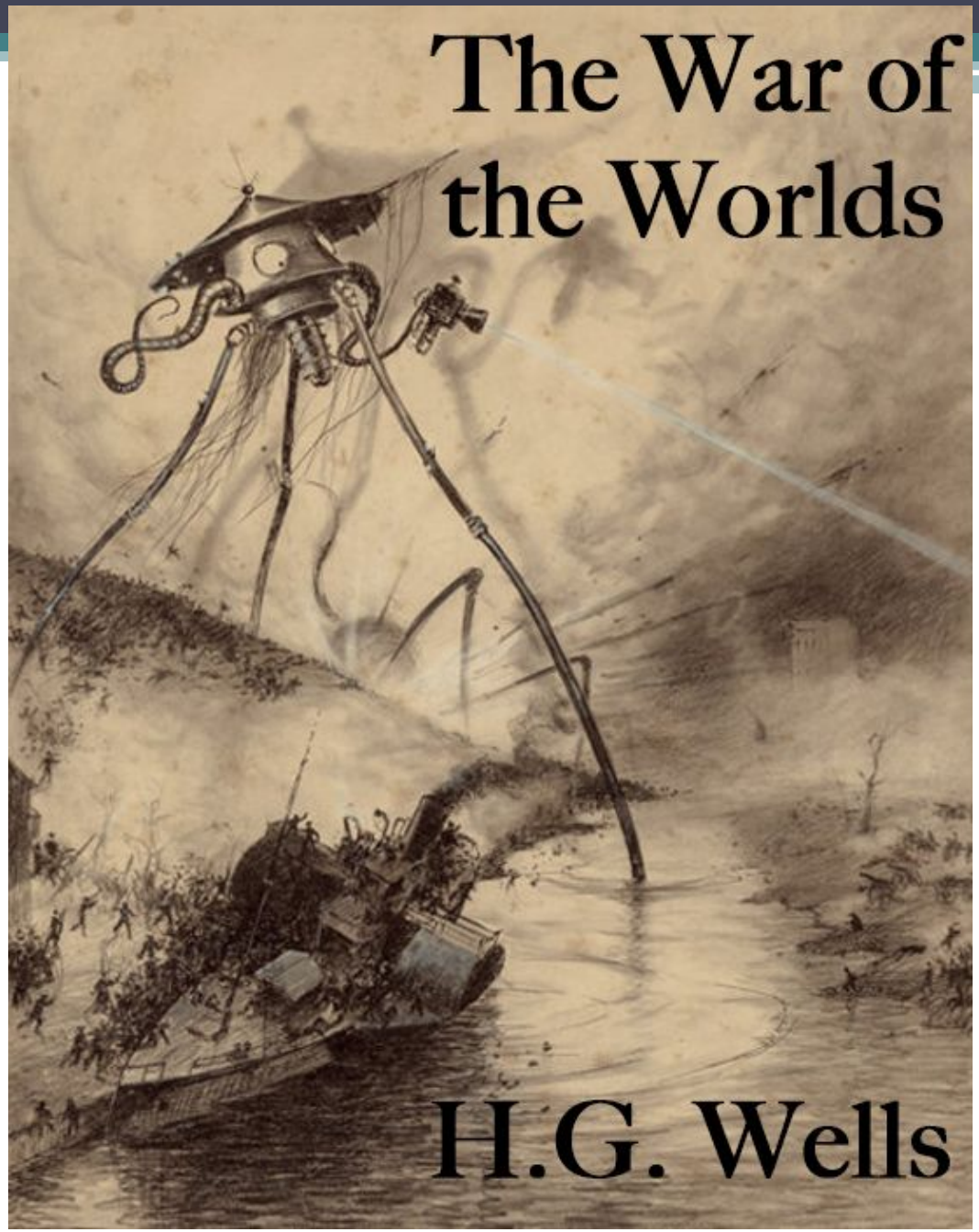
Jay Frothingham (they/he)
Green Bank Observatory
Green Bank, WV

Extraterrestrial Life Debate – Not New

- Philosophy/Cosmology/World-View inspired:
  - Atomist (Epicurus) – 5th century BC
  - Lucretius – 1st century AD
  - Giordano Bruno (heretic) – 16th century
  - Voltaire (Micromegas -- aliens) – 18th century
  - Thomas Paine
- Scientists:
  - Kepler (Moon) – 16th century
  - Sir John Herschel (Moon & Sun) – 19th century
  - Percival Lowell (Mars) – 1894/95



Giovanni Schiaparelli 1877



1898

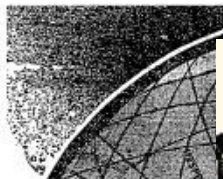
https://www.gutenberg.org/files/36/36-h/36-h.htm

Percival Lowell & Martian Canals

THERE IS LIFE ON THE PLANET MARS

Prof. Percival Lowell, recognised as the greatest authority on the subject, declares there can be no doubt that living beings inhabit our neighbor world.

By Lilian Whiting.



THE legions of canals on Mars, forming a colossal and a wisely planned system designed to irrigate the oases of the vast deserts which make up the surface of this planet, are an unanswerable argument for the existence of conscious, intelligent life. A thing made predicates a maker. This truism, of course, was Paley's favorite assertion, but it is none the worse for that. Schiaparelli discovered 104 canals; Prof. Percival Lowell and his staff of the Lowell Observatory at Flagstaff, Arizona, have discovered over 350, and they regard this number as no limit. The larger and more obvious are, like the larger asteroids, discovered first; but in each opposition of the planet the trained sight and skill of the great astronomer who is now held to be the specialist on Mars—the Martian expert, as it were—discovers new and smaller ones.

yet safe to assume that the professional tea-taster can so distinguish." In fact, Prof. Lowell lays emphasis on the fact that the astronomer must see with his mind as well as with his eyes.

In consultation with Prof. W. H. Pickering and other eminent counselors the site of the new observatory, whose supreme mission was to be the study of Mars, was selected in Arizona, on account of the steadiness of the air. Flagstaff is on a plateau oasis some 7,000 feet above sea level, with the purple peaks

...r York Times.

...DAY, AUGUST 30, 1907.—SIXTEEN PAGES.

WATTERSON'S PAPER BURNED.

Fire Early This Morning in the Courier-Journal Building.

LOUISVILLE, Ky., Friday, Aug. 30.—Fire started early this morning in the building of the Louisville Courier-Journal, of which Henry Watterson is editor. At 1 o'clock it seemed that the building was doomed. All the employes escaped.

SHUT OFF LA FOLLETTE.

Teachers Wouldn't Let Him Speak on Partisan Politics.

Special to The New York Times.

PITTSBURG, Aug. 29.—United States Senator Robert A. La Follette of Wisconsin, was prevented from discussing partisan politics at the teachers' institute here this afternoon by Superintendent of

MARS INHABITED, SAYS PROF. LOWELL

Declares the Planet to Be the Abode of Intelligent, Constructive Life.

THE RECENT OBSERVATIONS

Changes in Canals Confirm Former Theory—Splendid Photographs Were Obtained.

Special Cable to THE NEW YORK TIMES.

LONDON, Aug. 29.—In answer to a

REBUKE BY KING

He Walks Out of a Ca... Nature of the Pe...

MARIENBAD, Aug. 2... has administered a rebu... of indelicate songs in ... amusement, and his ac... taken publicly, has cre... citement in Marienbad.

His Majesty entered ... to-night, and, after listen... items on the programme ... as a protest against the ... ure of the performance. ... pany was playing. His ... lowed by the Duke of Te... members of his suite, a... icans and Englishmen p...

"This is horrible, app...

1920 – Marconi & Tesla

MARCONI SURE MARS FLASHES MESSAGES

Regularity of Signals, London Expert Says, Eliminates Atmospheric Disturbance Theory.

WAVES TEN TIMES OURS

J. H. C. Macbeth Declares It Would Be Simple Matter to Arrange a Code.

RADIO HEARS THINGS AS MARS NEARS US

A 24-Tube Set in England Picks Up Strong Signals Made in Harsh Dots.

VANCOUVER ALSO FAVORED

At Washington the Translator of McLean Telegrams Stands by to Decode Any Message.

LONDON, Aug. 23 (Associated Press). —An attempt by British wireless experts to "listen in" on Mars resulted in strange noises being heard at 1 o'clock this morning. The source of the noises could not be ascertained by the experts. The attempt was made on a twenty-four tube set erected on a hill at Dul-

Project Ozma - 1960

Observed Tau Ceti and Epsilon Eridani at 1.42 GHz (150 hours)

(Left) Frank Drake with the Tatel 85-ft telescope in Green Bank

Fun fact : The project was named after ”Princess Ozma” the fictional ruler of the Land of Oz.

Drake Equation from meeting in Green Bank in November 1961

An informal, private gathering convened by the Space Science Board, in November 1961, on the subject of "Intelligent Extraterrestrial Life." Following the publication of Cocconi and Morrison's seminal paper.

The attendees were J. Pearman, Dana Atchley, Melvin Calvin, Giuseppe Cocconi, Frank Drake, Su-Shu Huang, John Lilly, Philip Morrison, Bernard Oliver, Carl Sagan, and Otto Struve.

The group whimsically constituted itself "The Order of the Dolphin" because of Lilly's work on dolphin communication. During the conference, Calvin was awarded the Nobel Prize in Chemistry

Big Questions

a. Are other solar systems common?
b. Are other Earth-like planets common?
c. Do you believe that extraterrestrial life is common?
d. Do you believe that extraterrestrial intelligent life is common?
e. Do you believe intelligent life tries to communicate its existence to other worlds?
f. Do you believe that intelligent life colonizes other solar systems?

The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- *N* = the number of civilizations in our galaxy for which communication might be possible

The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

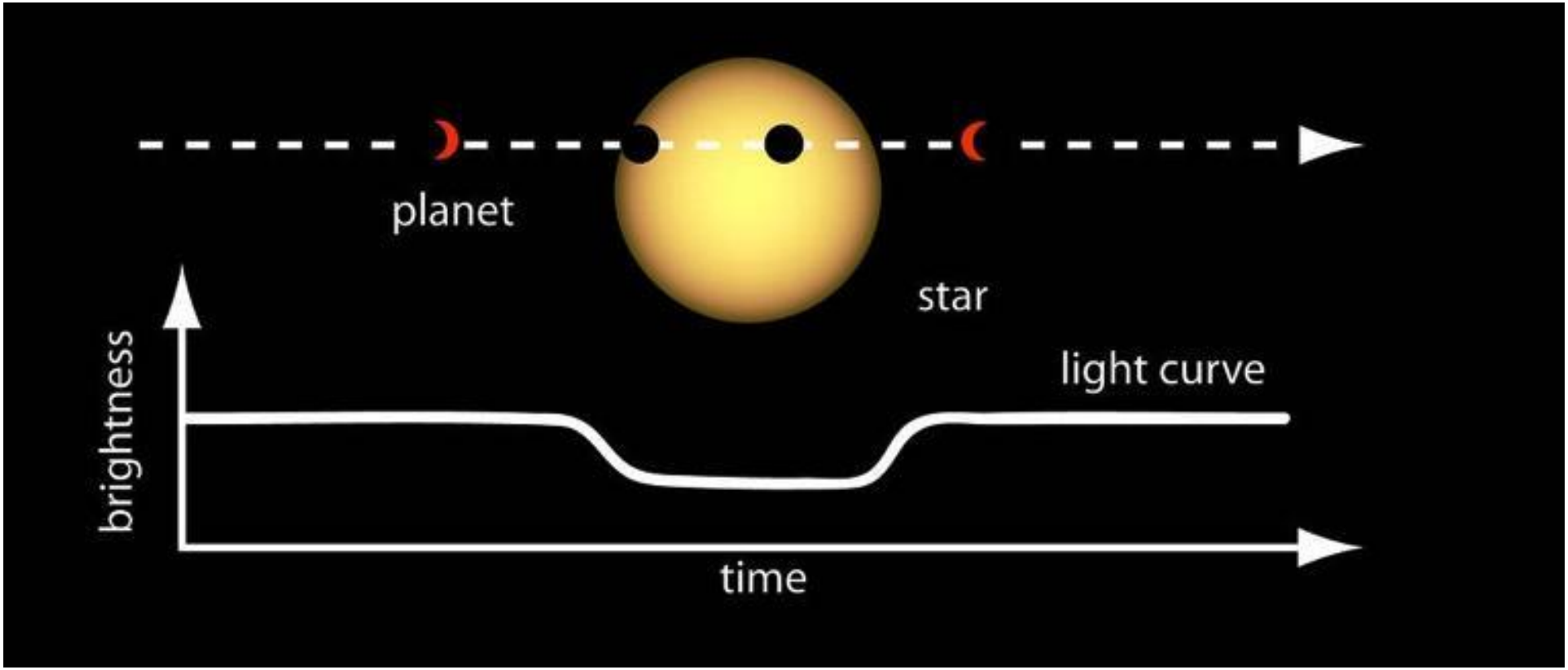
- *N* = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life.

The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- *N* = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life.
- f_p = The fraction of those stars with planetary systems.

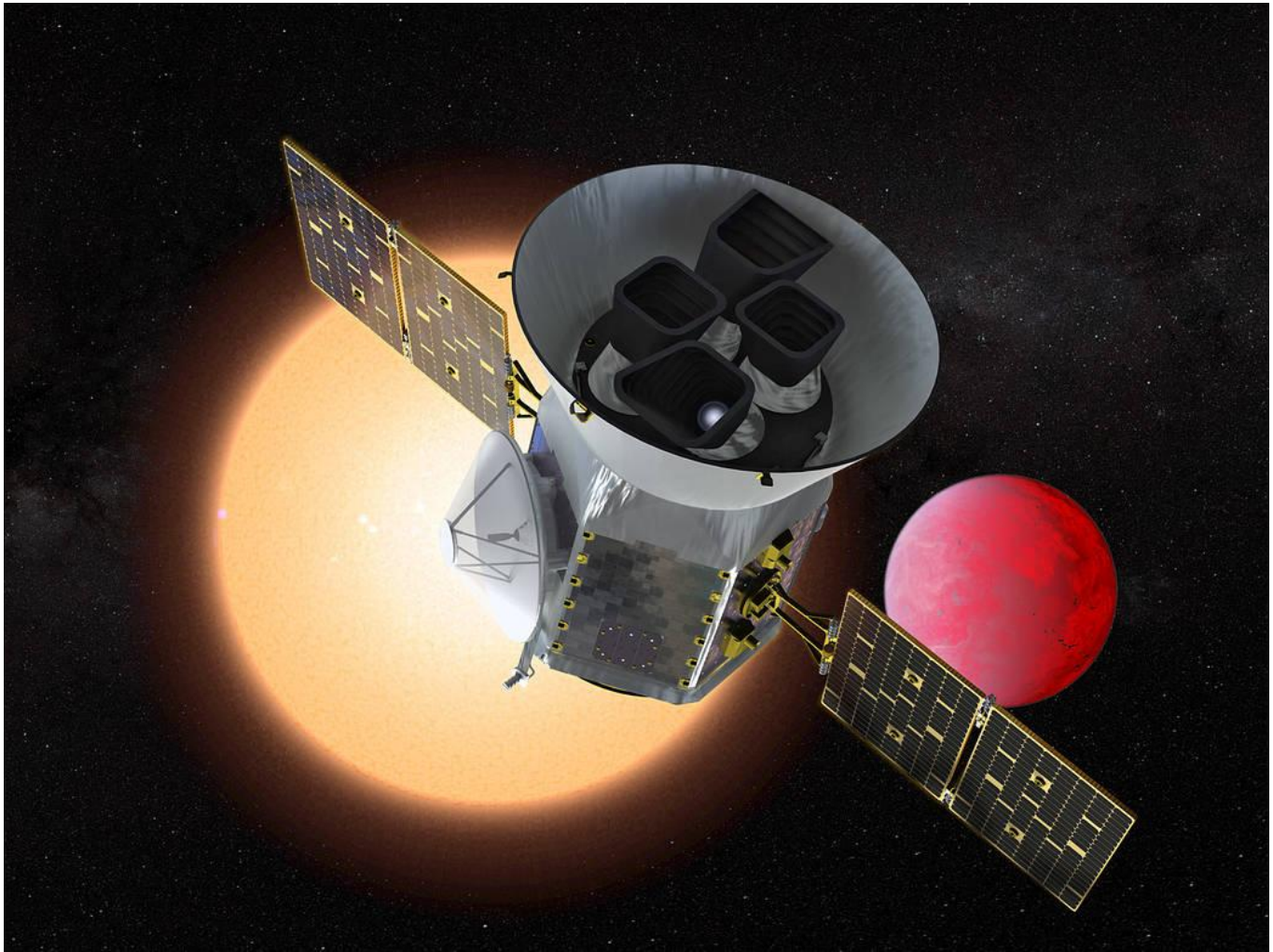
Kepler and TESS Spacecrafts looking for planets that pass in front of a star



https://www.zooniverse.org/projects/mschwamb/planet-hunters-ngts

TESS spacecraft

- Transiting exoplanet survey satellite
- After 3 years, 5500 candidates, 200 confirmed

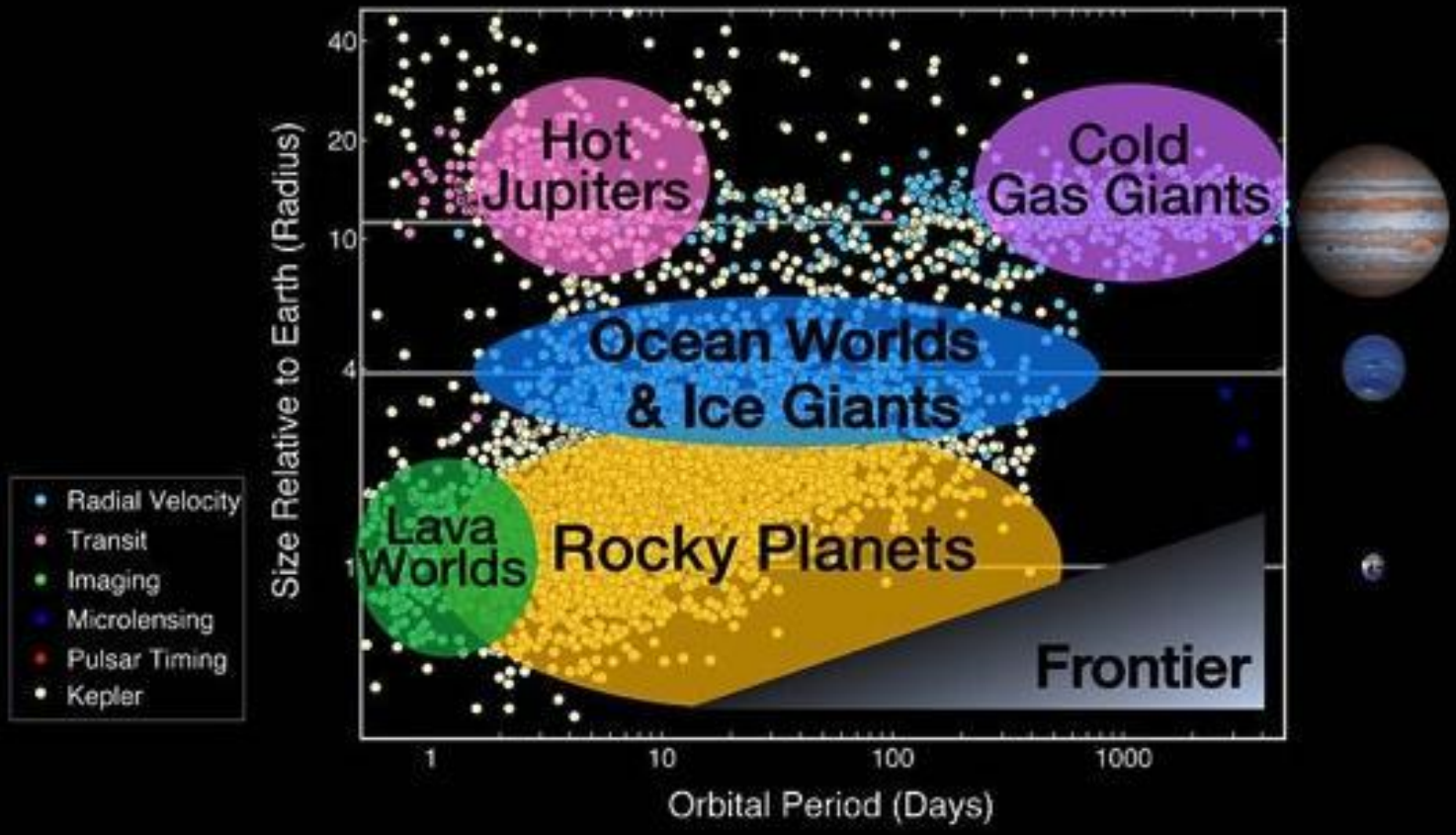


The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- N = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life.
- f_p = The fraction of those stars with planetary systems.
- n_e = The number of planets, per planetary system, with an environment suitable for life.

Exoplanet Populations



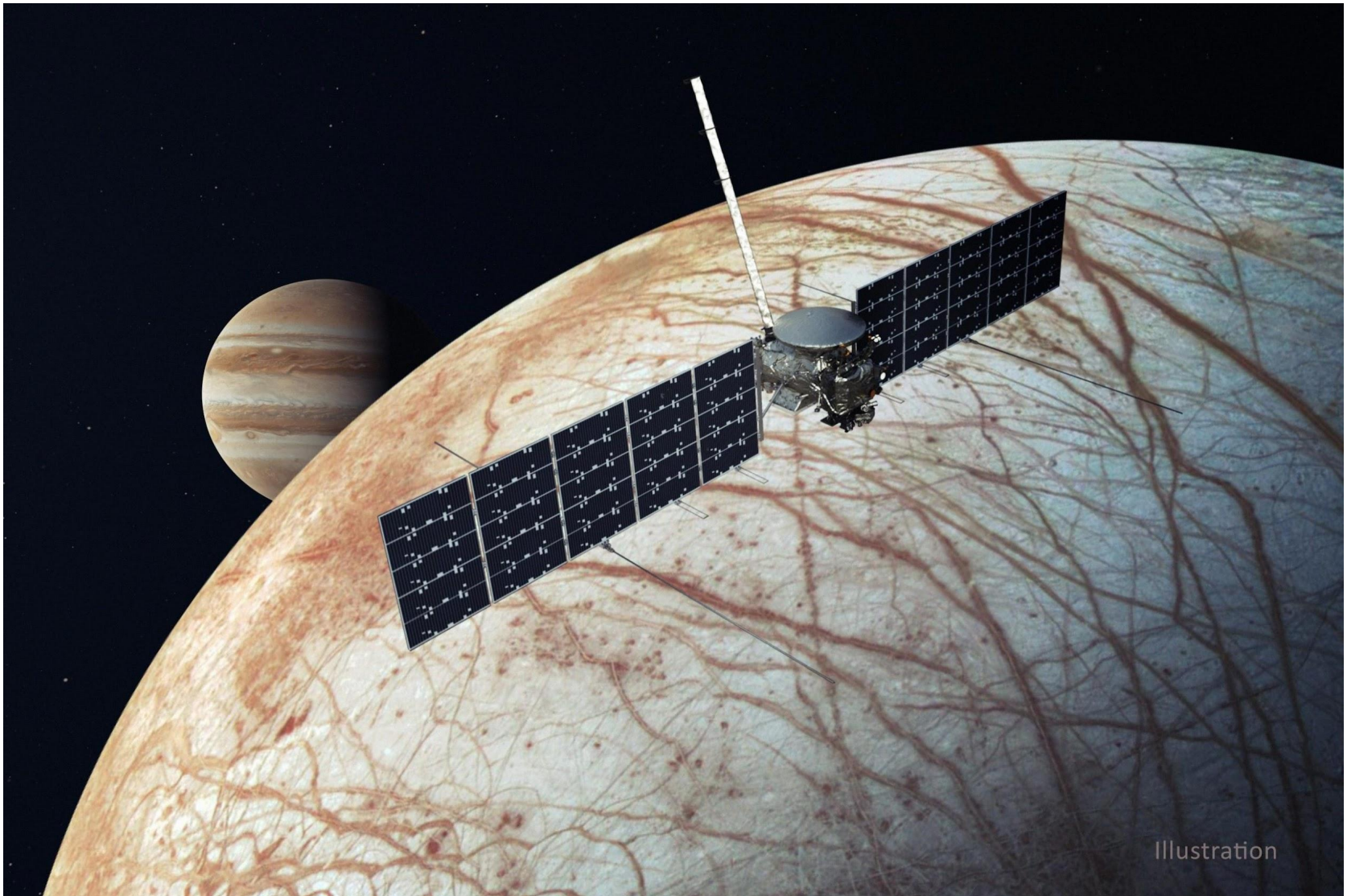
The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- N = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life.
- f_p = The fraction of those stars with planetary systems.
- n_e = The number of planets, per planetary system, with an environment suitable for life.
- f_l = The fraction of suitable planets on which life actually appears.

Extremophiles are organisms that live in "extreme environments," under high pressure and temperature. Bacteria often form on the rocks near the hydrothermal vents. Pictured is the Sully Vent in the Main Endeavour Vent Field, NE Pacific. A bed of tube worms cover the base of the black smoker.

Europa – satellite of Jupiter, has a subsurface ocean ”Europa Clipper” to launch in October 2024



- JUICE (JUpiter ICy moons Explorer) will explore Jupiter and three of its icy moons in depth.
- Launched April 2023; expected to reach Jupiter in July 2031.

The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- N = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life.
- f_p = The fraction of those stars with planetary systems.
- n_e = The number of planets, per planetary system, with an environment suitable for life.
- f_l = The fraction of suitable planets on which life actually appears.
- f_i = The fraction of life-bearing planets on which intelligent life emerges.

The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- N = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life.
- f_p = The fraction of those stars with planetary systems.
- n_e = The number of planets, per planetary system, with an environment suitable for life.
- f_l = The fraction of suitable planets on which life actually appears.
- f_i = The fraction of life-bearing planets on which intelligent life emerges.
- f_c = The fraction of civilizations that develop a technology that releases into space detectable signs of their existence.

Detectable Signatures of Intelligence

High-power TV and Radio

Hundreds of transmitters detectable at a few lightyears

Planetary Radar Systems

A few radar systems on Earth detectable across the galaxy

High-power Lasers

Lasers can outshine the Sun by thousands of times

The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- N = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life.
- f_p = The fraction of those stars with planetary systems.
- n_e = The number of planets, per planetary system, with an environment suitable for life.
- f_l = The fraction of suitable planets on which life actually appears.
- f_i = The fraction of life-bearing planets on which intelligent life emerges.
- f_c = The fraction of civilizations that develop a technology that releases into space detectable signs of their existence.
- L = The length of time such civilizations release detectable signals into space.

The Drake Equation (DRAKE)

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

- N = the number of civilizations in our galaxy for which communication might be possible
- R^{*} = The rate of formation of stars suitable for the development of intelligent life. About 1 / year
- f_p = The fraction of those stars with planetary systems. 0.5
- n_e = The number of planets, per planetary system, with an environment suitable for life. 5
- f_l = The fraction of suitable planets on which life actually appears. 1
- f_i = The fraction of life-bearing planets on which intelligent life emerges. 1
- f_c = The fraction of civilizations that develop a technology that releases into space detectable signs of their existence. 0.2
- L = The length of time such civilizations release detectable signals into space. 100,000,000 years

The Drake Equation (JAY ESTIMATE)

$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

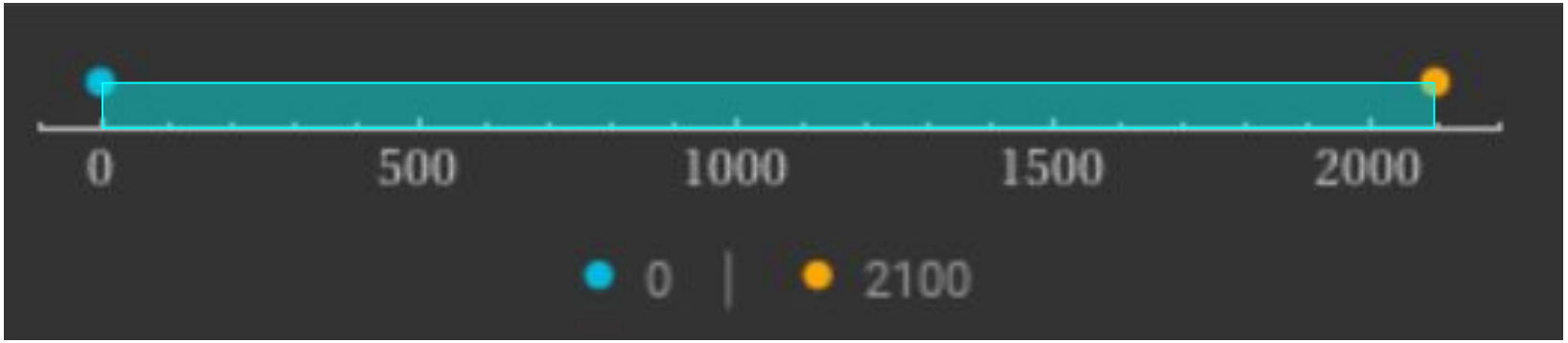
- *N* = the number of civilizations in our galaxy for which communication might be possible
- R^* = The rate of formation of stars suitable for the development of intelligent life. About 3 / year
- f_p = The fraction of those stars with planetary systems. 1
- n_e = The number of planets, per planetary system, with an environment suitable for life. About 0.1
- f_l = The fraction of suitable planets on which life actually appears. 0.7
- f_i = The fraction of life-bearing planets on which intelligent life emerges. 0.1
- f_c = The fraction of civilizations that develop a technology that releases into space detectable signs of their existence. 1
- *L* = The length of time such civilizations release detectable signals into space. 100,000 years ?

The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

N **= the number of civilizations in our galaxy for which communication might be possible**

= 2 thousand civilizations (Jay estimate)



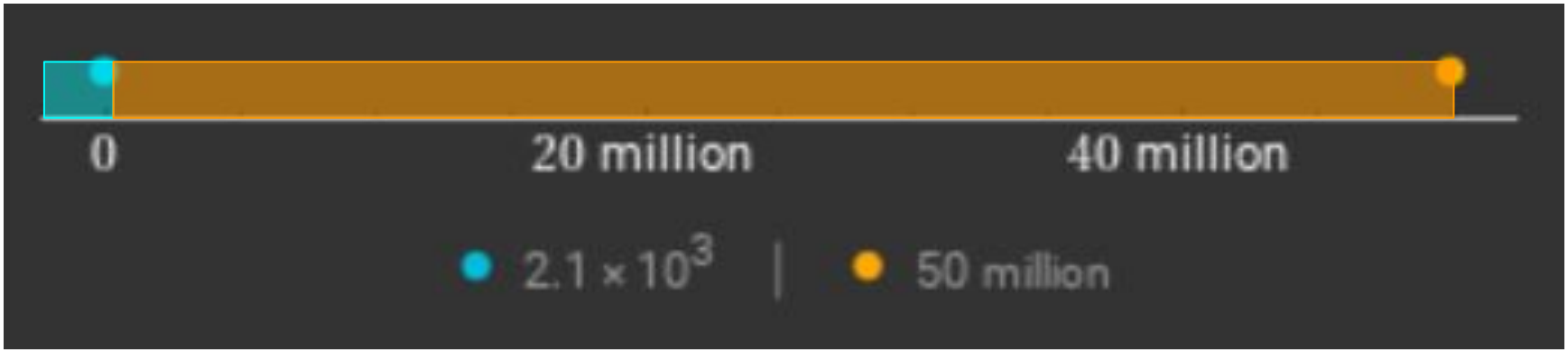
The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

N **= the number of civilizations in our galaxy for which communication might be possible**

= 50 million civilizations (Drake estimate)

= 2 thousand civilizations (Jay estimate)



The Drake Equation

$$N = R^{*} \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

"Space is big, but time is bigger." - Dr. Jay Lockman

Dictionary

Definitions from Oxford Languages · Learn more

light year

/ˈlīt ˌyir/

noun

noun: **light year**; plural noun: **light years**; noun: **lightyear**; plural noun: **lightyears**

ASTRONOMY

a unit of astronomical distance equivalent to the distance that light travels in one year, which is 9.4607×10^{12} km (nearly 6 trillion miles).

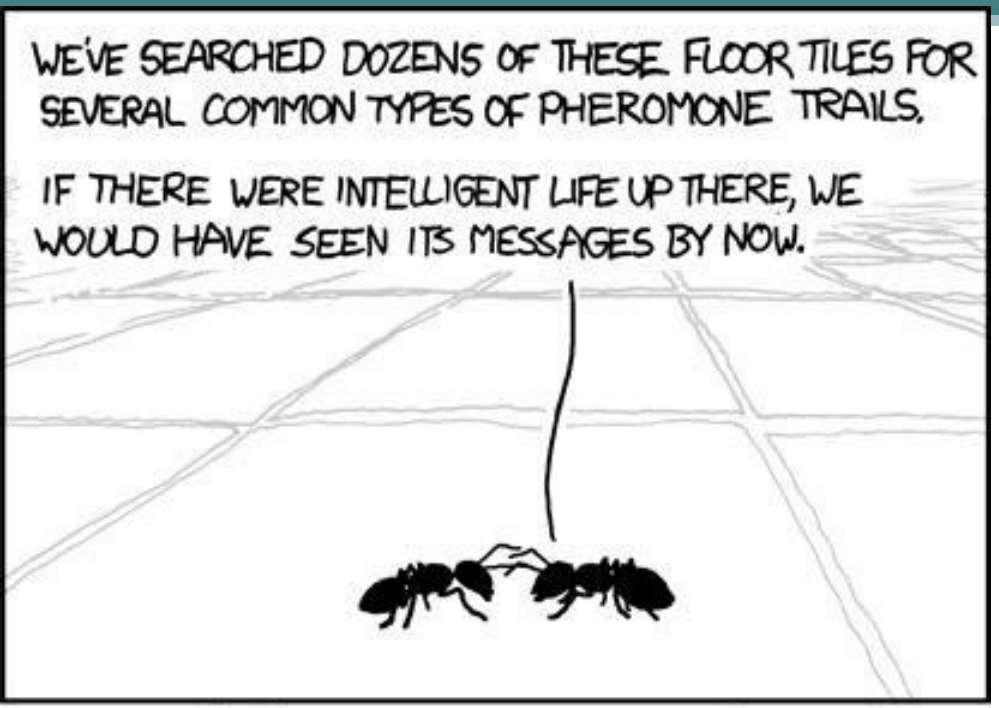
- **INFORMAL**

  a long distance or great amount.

Where is everybody?

1. There has never been a detection of an ET signal
2. We have never encountered ET

- Some term in the Drake Equation may be a barrier to the formation of intelligent life.
- Some of our assumptions about the Drake Equation may be flawed.
- Civilizations get efficient too fast: detectable signals only emitted for a short time
- Dark Forest hypothesis: other civilizations don't want to be found out
- SETI paradox: everyone is listening, but no one is "speaking"
- Rare Earth hypothesis: complex life is much less common than we think
- Water World hypothesis: intelligent life in other planets would not develop the same tools as humans on Earth (e.g., dolphins)



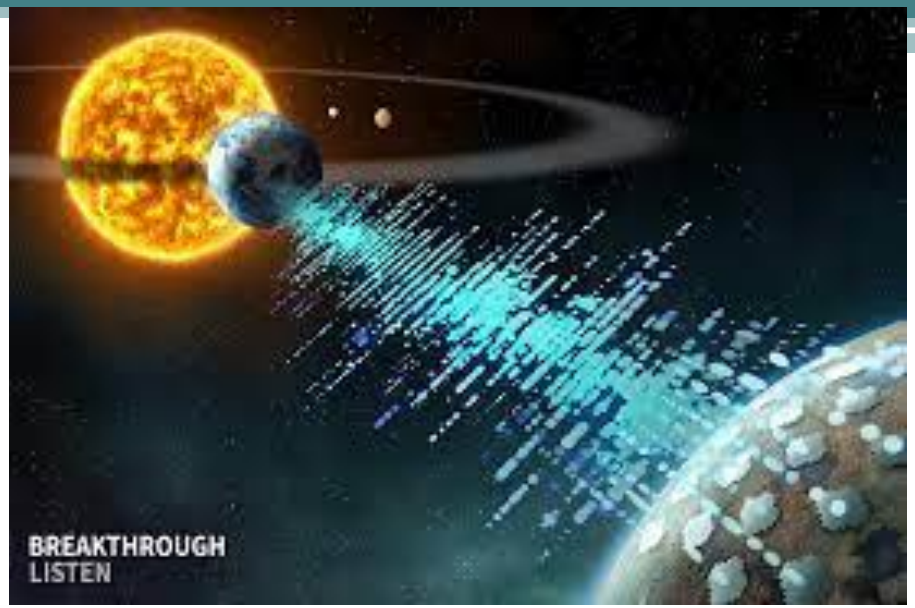
THE WORLD'S FIRST ANT COLONY TO ACHIEVE SENTIENCE CALLS OFF THE SEARCH FOR US.

"The probability of success is difficult to estimate, but if we never search the chance of success is zero."

Guiseppe Cocconi, Philip Morrison
Searching for Interstellar Communications, Nature, 1959

What are SETI searches like?

- Optical – encoded messages on collimated light beams
- Infrared – the signature of Dyson spheres (Soviet Union/Russians)
- Radio (US)
  - High time resolution
  - High frequency resolution
  - Pointed observations toward particular stars
  - Commensal/Piggy-back experiments
  - **Breakthrough Listen Project**



Breakthrough Listen

Observing Plan for 2016

1. Green Bank Radio Telescope: 5-year Contract – 1300 hours/year

World's Deepest SETI Surveys of Five Key Samples (Northern Hemisphere):

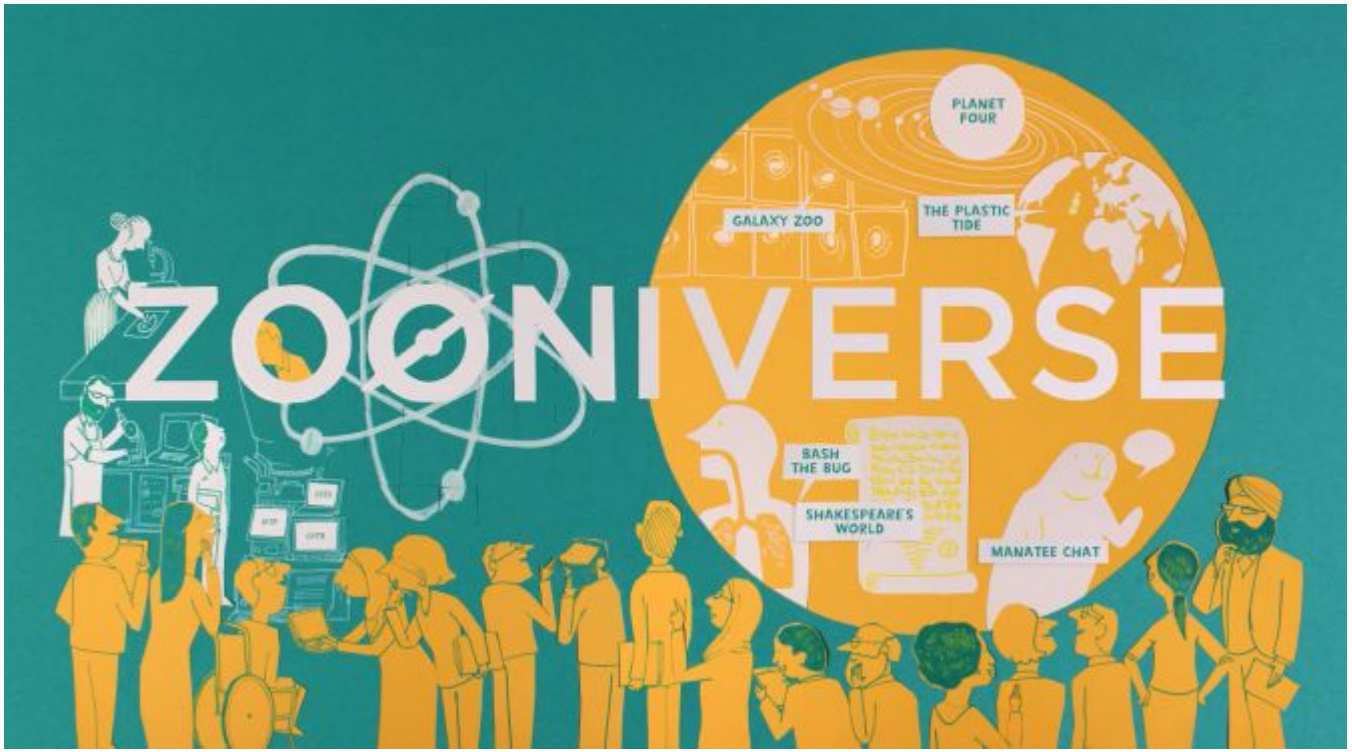
- ***All 43 stars within 5 parsecs***, at 1-15 GHz. First-ever complete SETI survey within 5 parsecs. Sensitive to "Earth-leakage" levels of radio transmission. (Targets: Appendix 1)
- ***1000 stars of all spectral-types*** (OBAFGKM). Within 50 parsecs. 1-15 GHz (Appendix 1).
- ***One Million Nearby Stars.*** In 2016, first 5,000 stars; 1 minute exposure (1-15 GHz)
- ***Centers of 100 nearby galaxies***: spirals, ellipticals, dwarfs, irregulars (1-15 GHz)
- ***Exotic Stars:*** 20 White Dwarfs, 20 Neutron stars, 20 black holes

- All stars within 15 light years
- One thousand stars within 150 light years
- One million nearby stars
- 100 galaxies

- 1 day of Breakthrough = 1 year of any previous survey

SETI: Not just for scientists!

- Participate in citizen science initiatives (https://www.zooniverse.org/projects)



SETI: Not just for scientists!

- Create and inspire - will your sci-fi novel motivate the next Frank Drake?

ON THE LINKS BETWEEN ASTRONOMY, ASTRONOMERS AND SCIENCE FICTION

S. Boissier[1]

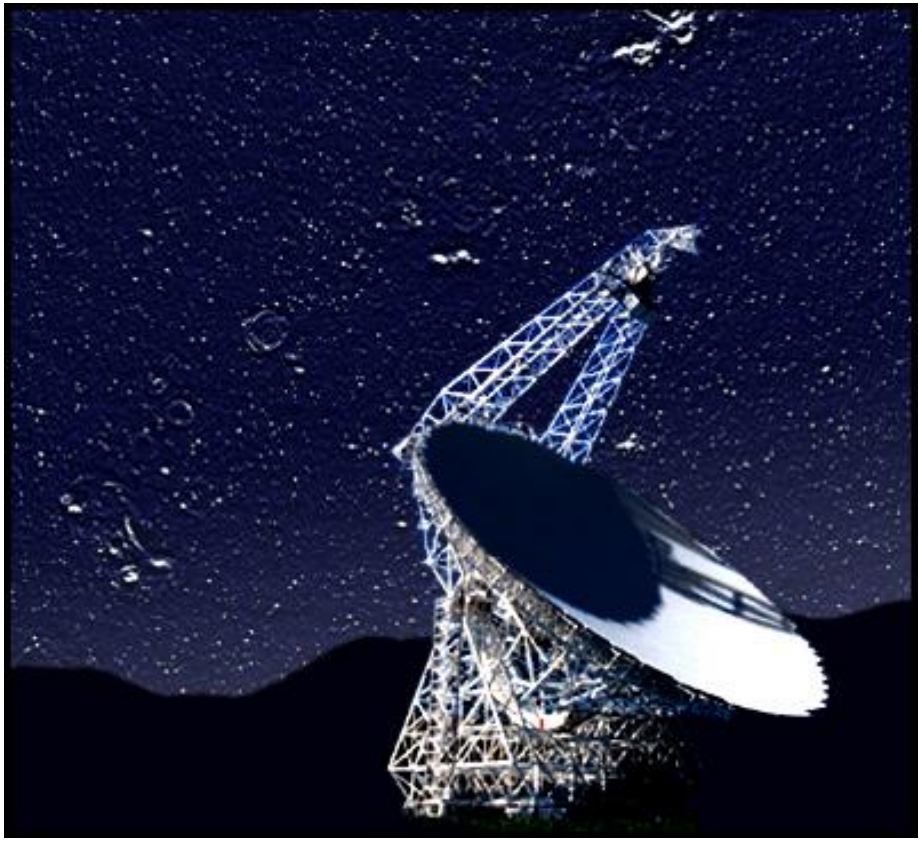
Abstract. Science Fiction is using astronomy to offer to the public blockbusters at the movies (e.g. Interstellar), series or movies in streaming media (Don't Look Up, The Expanse), many books from classic authors (I. Asimov, A.C. Clarke) or more moderns ones (K.S. Robinson), comics (the adventures of Valerian and Laureline), or video games (Mass Effect, No Man's sky) that have a very large cumulated audience.

Astronomers can use Science Fiction to illustrate physics or astronomical facts. It might be a good way to talk about our work, our methods, by comparing them to examples with which a large audience is familiar. A few examples are provided in this contribution.

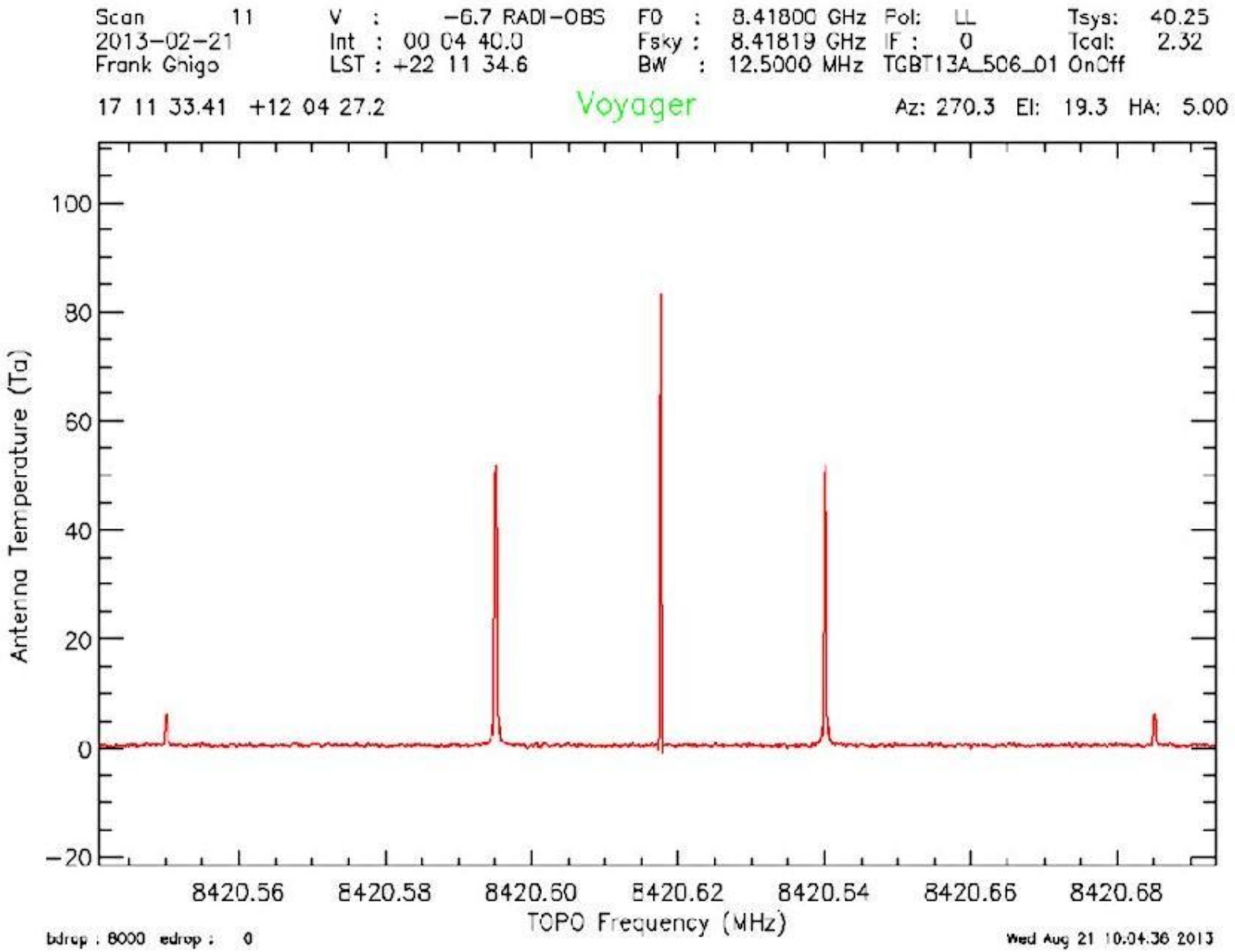
In a recent study (Stanwey, 2022), it was shown that 93 percent of British professional astronomers have an interest for Science Fiction, and 69 percent consider that Science Fiction influenced their career or life choice. I am presenting a similar study made for French astronomers, performed during and just after the 2024 French astronomer meeting (Journées de la SF2A).

SETI: Not just for scientists!

- Keep looking (and listening) to the sky!



EXTRA SLIDES


Scan 11
2013-02-21
Frank Ghigo
V : -6.7 RADI-OBS
Int : 00 04 40.0
LST : +22 11 34.6
F0 : 8.41800 GHz
Fsky : 8.41819 GHz
BW : 12.5000 MHz
Pol: LL
IF : 0
TGBT13A_506_01
Tsys: 40.25
Tcal: 2.32
OnOff
17 11 33.41 +12 04 27.2
Voyager
Az: 270.3 El: 19.3 HA: 5.00
Antenna Temperature (Ta)
100
80
60
40
20
0
-20
8420.56
8420.58
8420.60
8420.62
8420.64
8420.66
8420.68
TOPO Frequency (MHz)
bdrop : 8000 edrop : 0
Wed Aug 21 10:04:36 2013

Rare Earth Hypothesis

Add terms to the Drake Equation

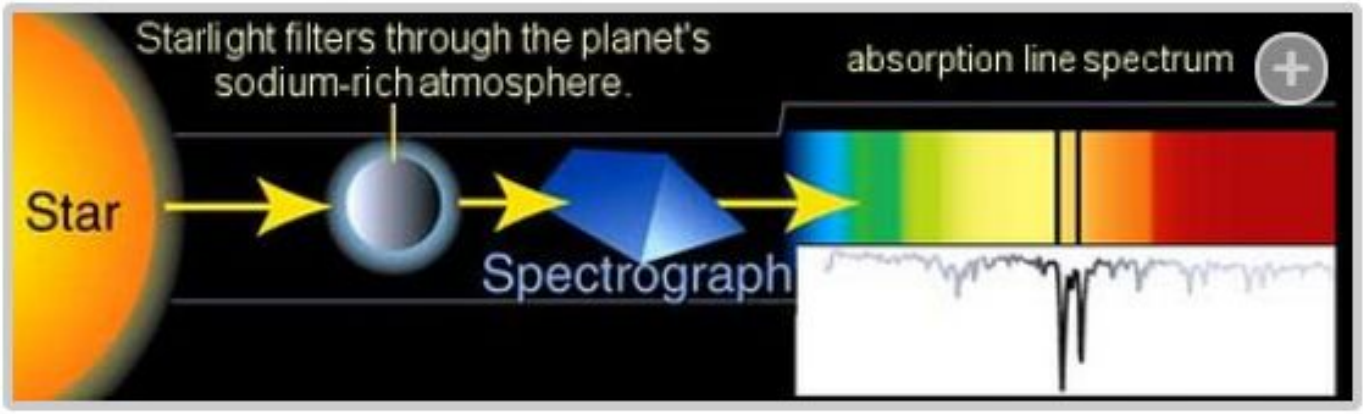
- Right kind of star
- Stable orbit
- Stable Solar System
- Large Moon- stabilizes Earth's axis; tides
- Outer planets such as Jupiter – protects from asteroids
- Fast rotating planet – requires a collision with another planet-sized object
- Magnetic field
- Plate tectonics and a tilted axis to promote evolution

Q: What is inside of a dark cloud?

H_2O (water)
H_2CO* (formaldehyde)
NH_3 (ammonia)
CO (Carbon monoxide)

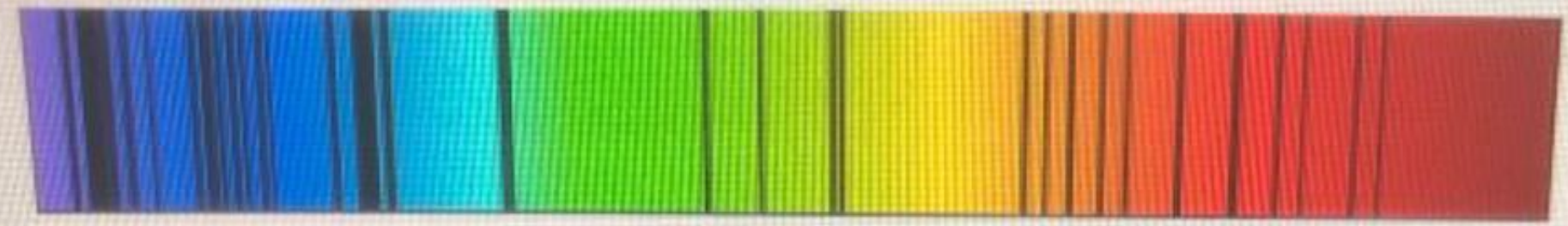
HCOOH* (formic acid)
CH_3OH* (methanol)
CH_2CHCN (vinyl cyanide)
$HOCH_2CH_2OH$ (ethylene glycol)
CH_3CO_2H (acetic acid)
CH_3CH_2OH (ethyl alcohol)
CH_2OHCHO (glycolaldehyde)
C_6H^-

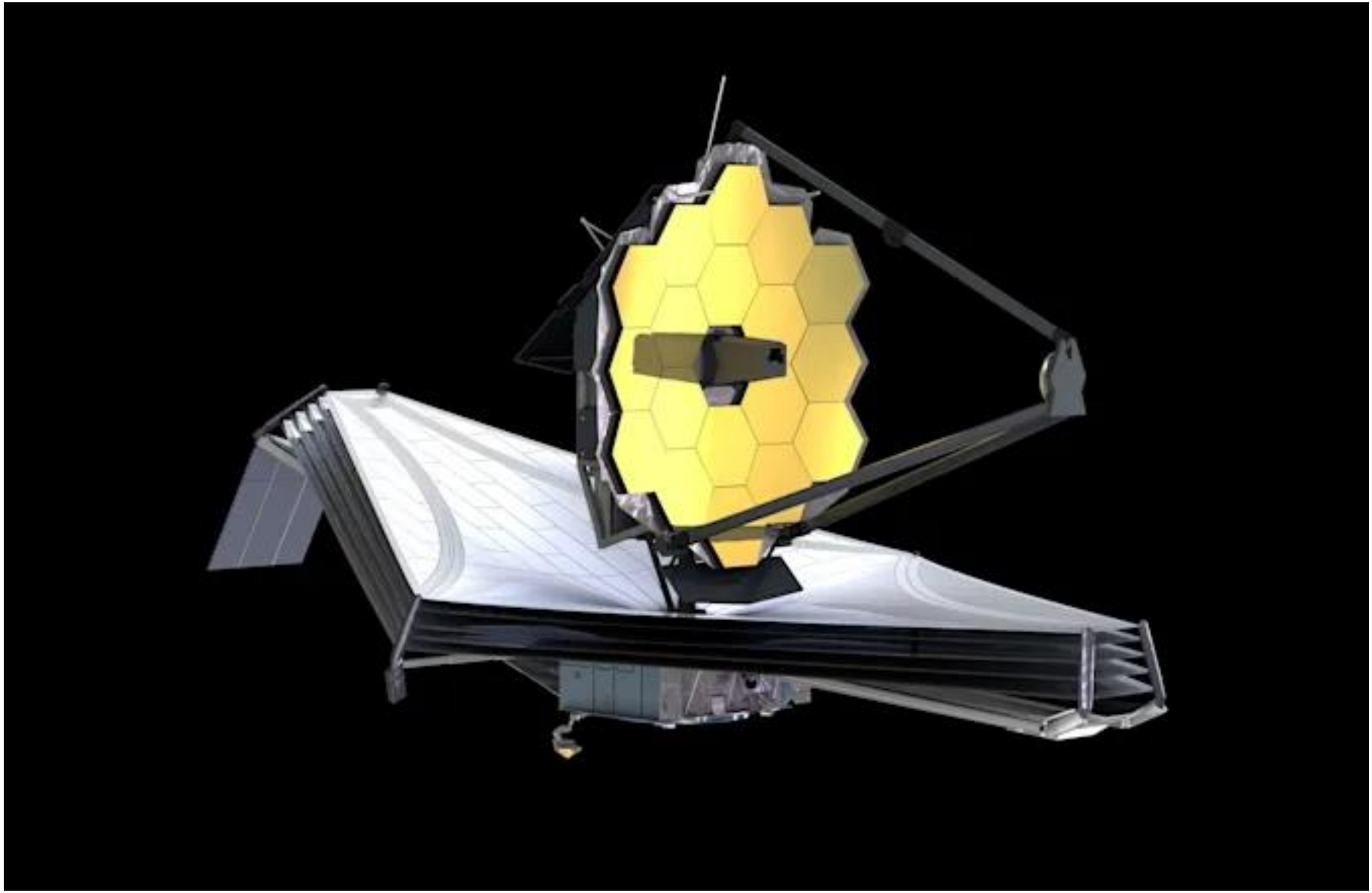
A: Organic Chemistry!

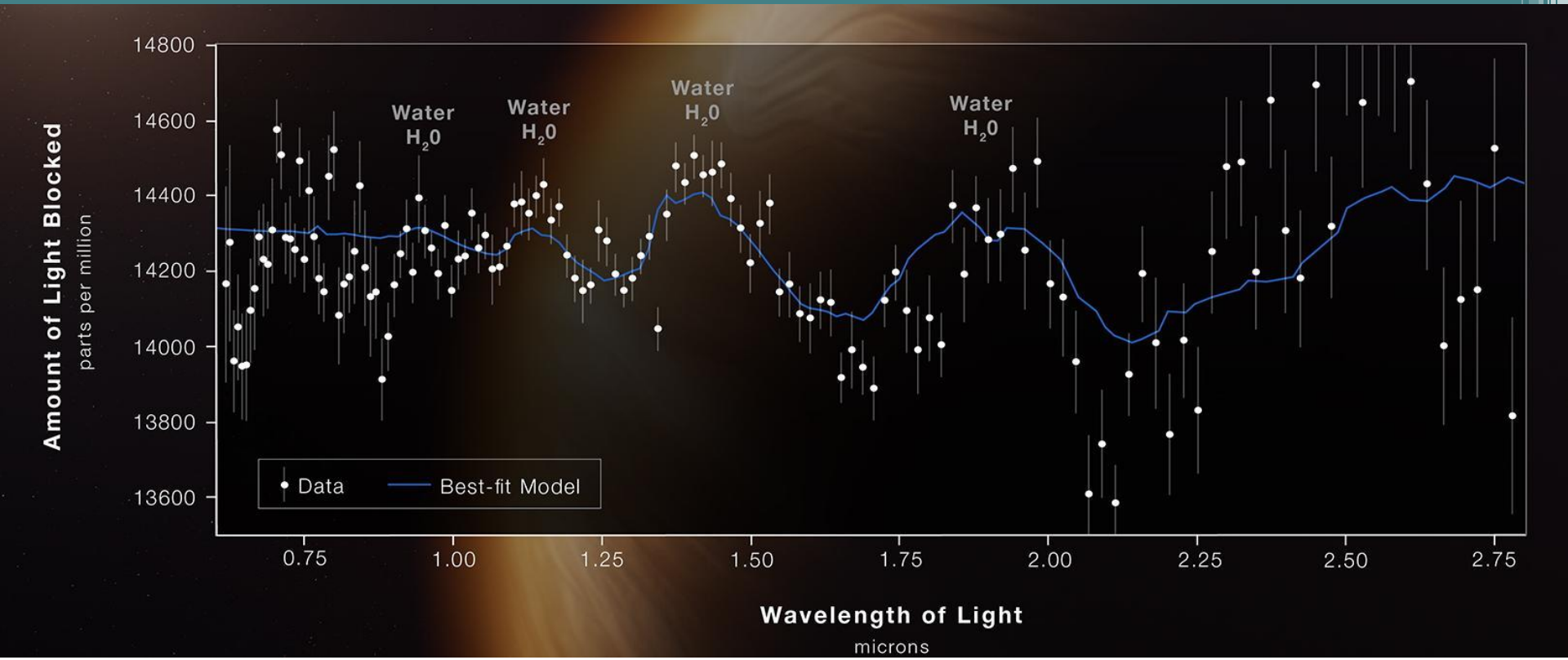


The presence of sodium in the atmosphere of Hot Jupiter exoplanet HD 209458 is measured by studying its spectrum.
Credit: A. Field, STScI

An absorption spectrum of oxygen is shown below.

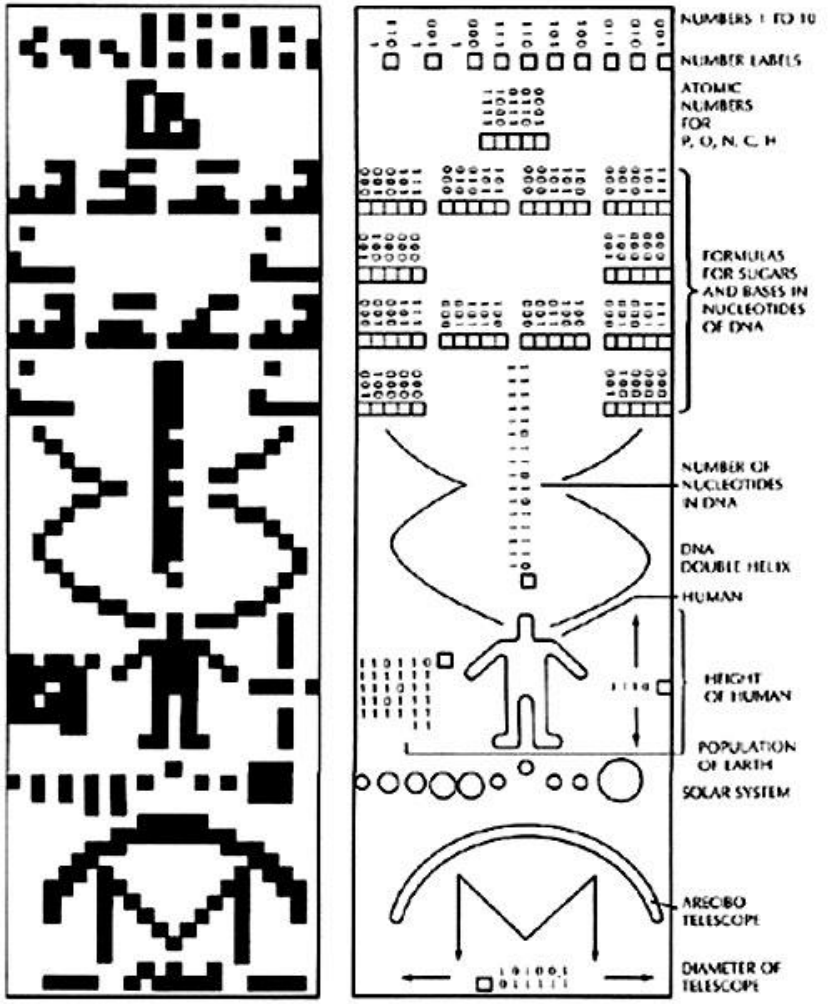




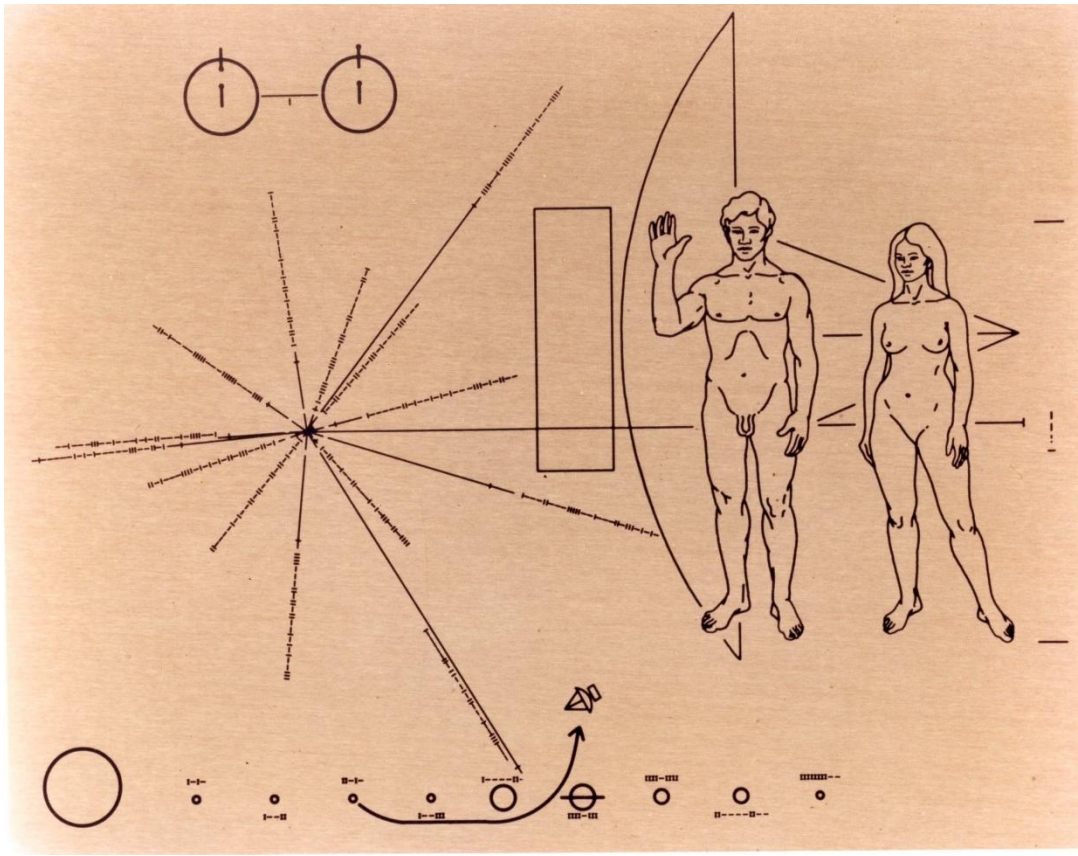


Planet “Wasp-96 b” – half the mass of Jupiter, 1.5 times the diameter; temperature about 1000 F. About 1100 l.y. away in the southern hemisphere.

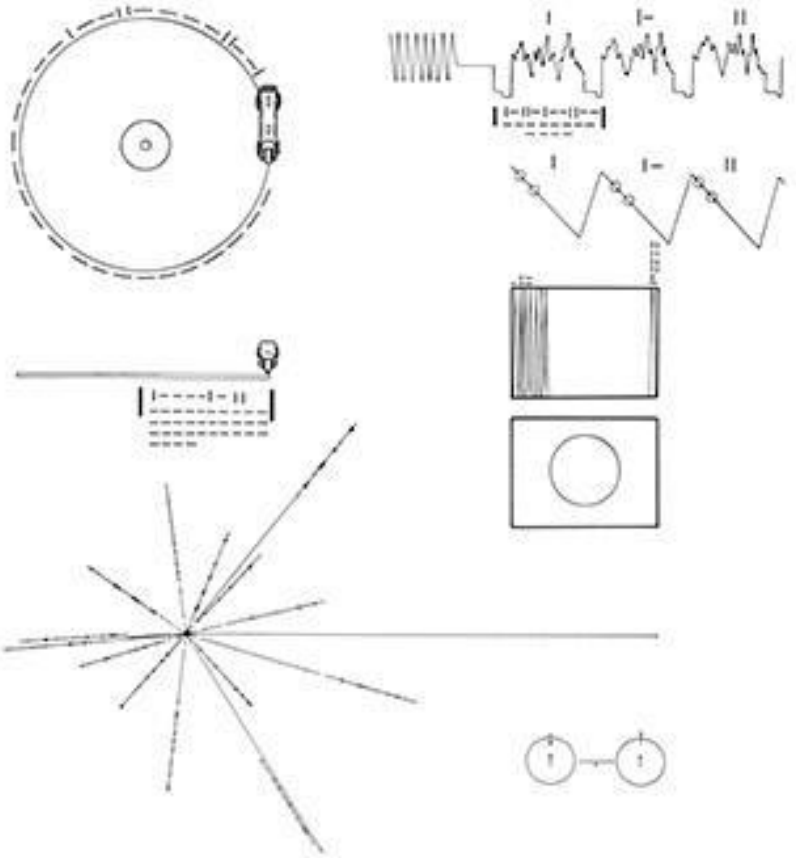
Arecibo 1974 message sent towards globular star cluster M13 (Drake & Sagan) – “Earth’s first and only attempt to phone ET”



NASA Pioneer 10 – Launched in 1972 and first man-made object to leave the solar system



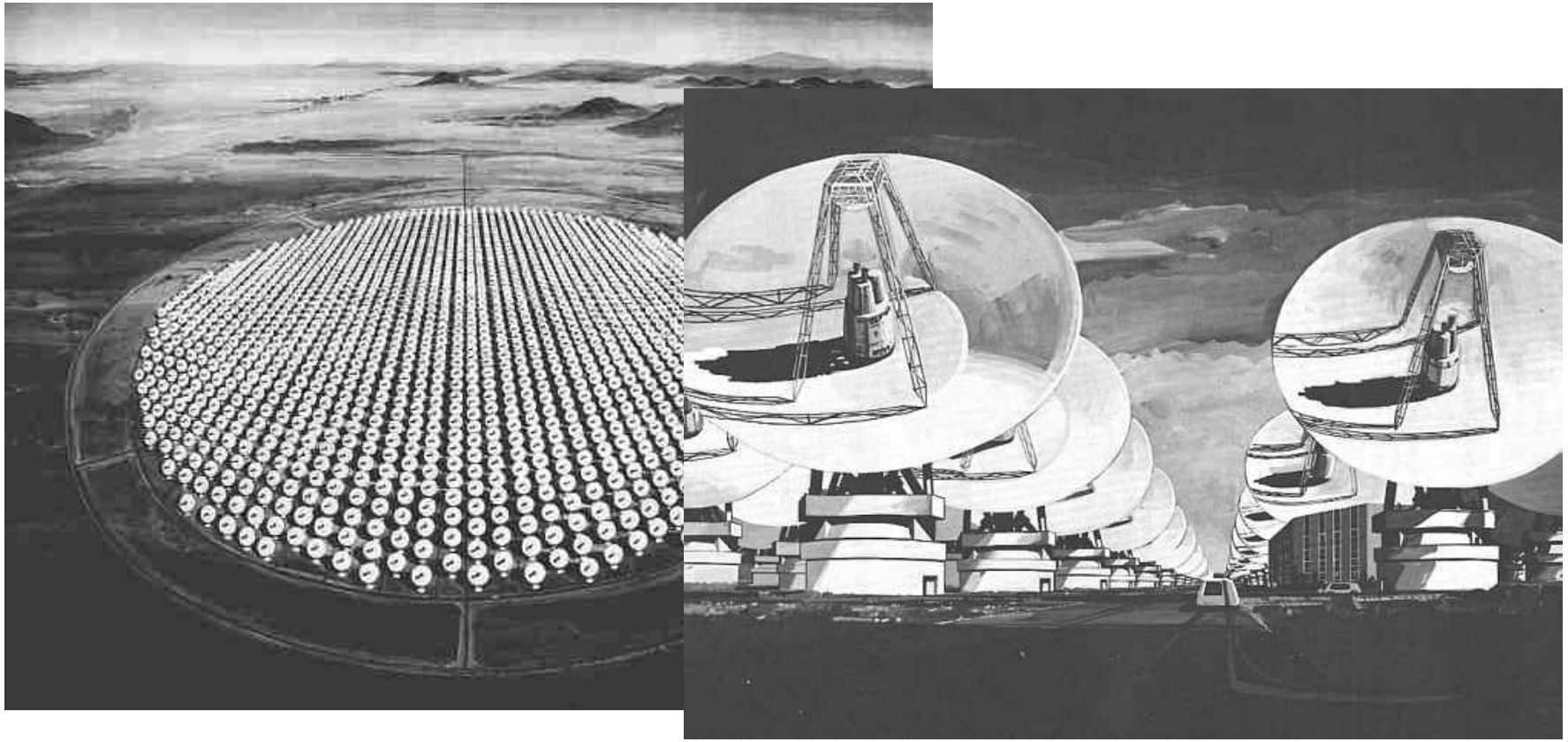
Voyager (launched in 1977)



“Oumuamua” asteroid from beyond our solar system,
was discovered Oct. 19, 2017
“a messenger from afar”

Project Cyclops - 1971

NASA funded project to explore how SETI should be conducted



No telescopes built, but it guided future SETI work

SETI Institute – Project Phoenix

Searched for radio emission (1-3 GHz) from 800 nearby stars.

Project leader forced to conclude “we live in a quiet neighborhood.”

SETI Institute – Allen Telescope Array

Searched for radio emission (0.5-10 GHz) from 800 nearby stars.

First 42 elements operational. Able to monitor multiple stars at once.