

Prospects for Intelligent Life in the Milky Way Galaxy

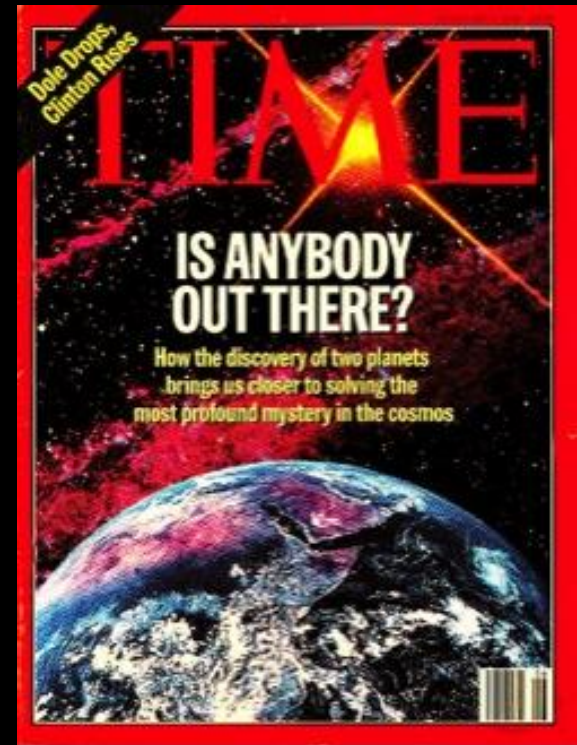


Geoff Marcy
University of California



Keck Observatory

Only Known Site of
Biology
in the Universe





Milky Way Galaxy

200 Billion Stars

*How common is Intelligent Life
In the Milky Way Galaxy ?*

Intelligent Life in the Milky Way Galaxy

* Science Fiction Books and Movies taught us . . .



A collage of science fiction spacecraft and alien ships against a starry background. The ships include a white Star Trek Enterprise-style vessel, a green alien ship with a long neck, a purple alien ship, and a green alien ship with glowing lights.

Intelligent Life in the Milky Way Galaxy

* Science Fiction Books and Movies influenced us.

Was Science Fiction Right?

Serious Concerns . . .

Non-Detections of Intelligent Life in the Galaxy:

- * Moon: No Alien Spacecraft, Crash Debris, Obelisk
- * Mars: No sign of debris left by alien visitors
- * Earth: Lovely planet, but *no aliens settled*.
- * 100's of Professional Telescopes: No Alien spacecraft
- * Night Sky: No Exotic Rocket Exhaust, i.e., gamma rays
- * No robotic probes orbiting Solar System
- * **No Radio Signals from aliens, despite radio telescopes.**
- * Some aliens will wander in the Galaxy,
and would colonize Earth..



Where *Is* Everybody?

Was Science Fiction overly optimistic?

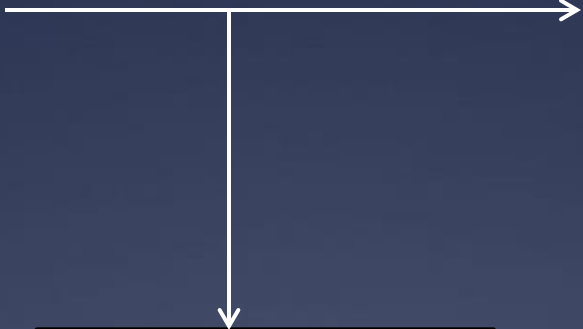
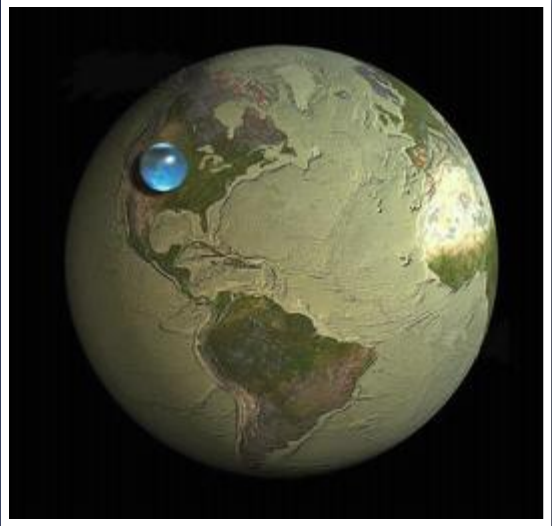
Where *Is* Everybody?

*Possible reasons that
Intelligent life may be rare
in the Galaxy . . .*

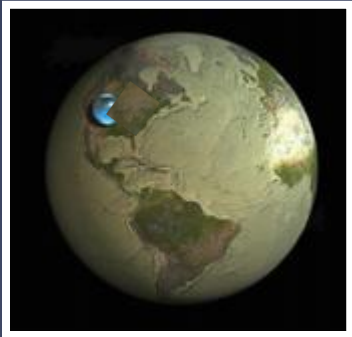
Earth: A Lucky Amount of Water

Earth is 0.06% water.

Lucky Delivery of Water
by Asteroids and Comets



**0.03% Water:
Desert World**



Other Earths:

Most Rocky Planets are
Desert or Water Worlds

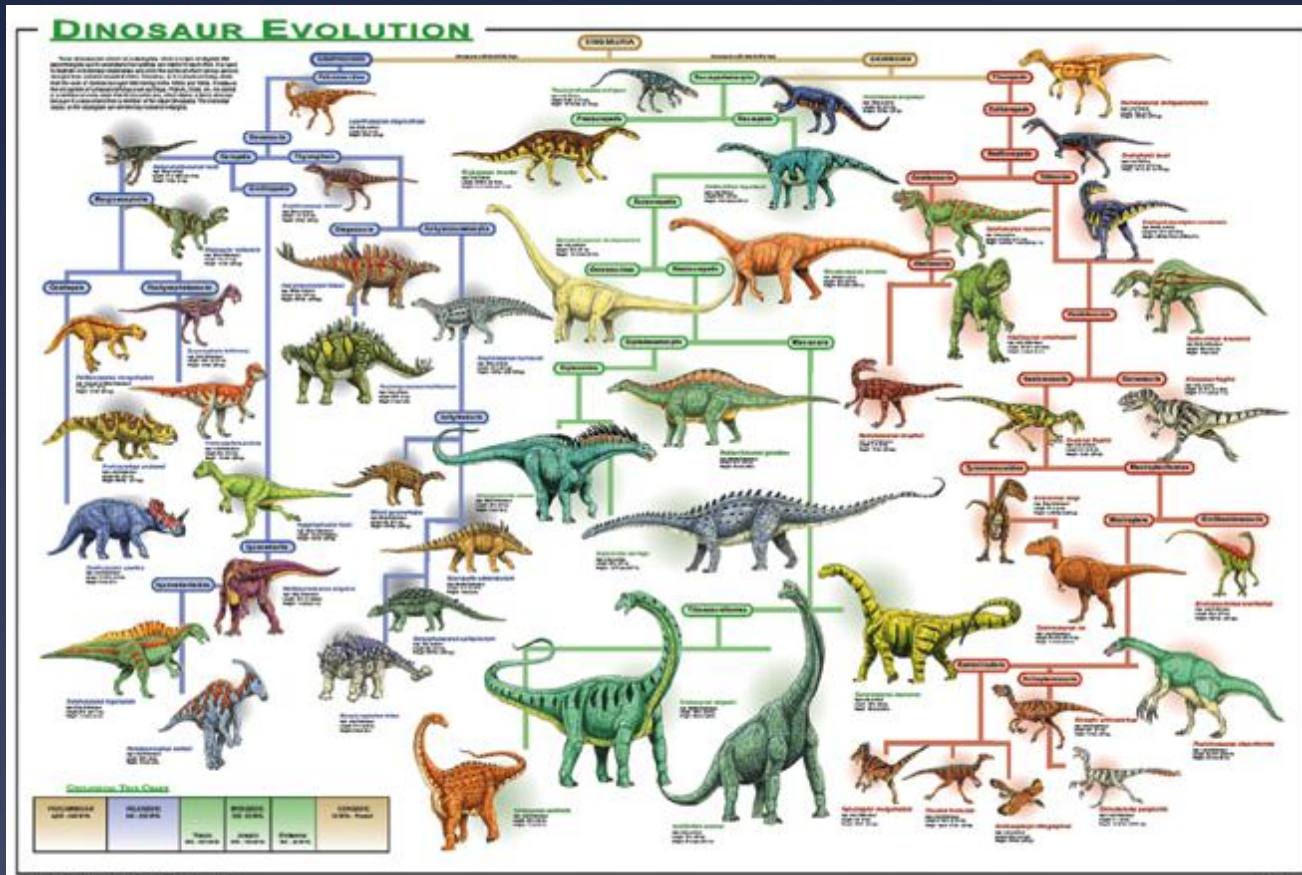
No Technological Life

**0.09% Water:
Water World**



Does Evolution Favor Intelligence ?

Test: Dinosaur brain evolution

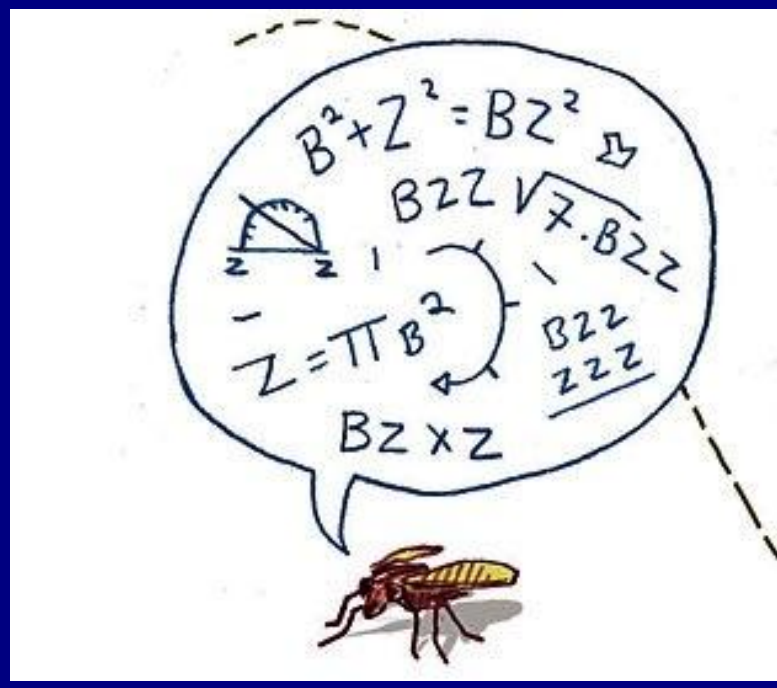


Paleontology:

- Walnut-size brains
- No tools
- Bird-like brains

200 Million Years of Dinosaur Evolution: A No-Brainer

Does Evolution Favor Intelligence?



Intelligence is not strongly favored.



Prediction:

1000 Civilizations in 5 Billion Years

For contemporaneous civilizations,

Their Lifetimes Must Overlap:

Need: Lifetime > 5 Million yr

**What is the
Typical Lifetime
of a Civilization ?**



The background of the slide is a dark space filled with stars. Several pieces of science fiction technology are scattered across the scene. In the upper left, there is a white, saucer-shaped spacecraft with a long neck and a smaller probe-like object attached. To its right is a green, elongated, segmented alien vessel. In the center, a small, purple, insect-like alien creature is visible. At the bottom, there are two more green alien vessels, one of which is larger and more complex, resembling a multi-segmented probe or lander.

Intelligent Life in the Milky Way Galaxy

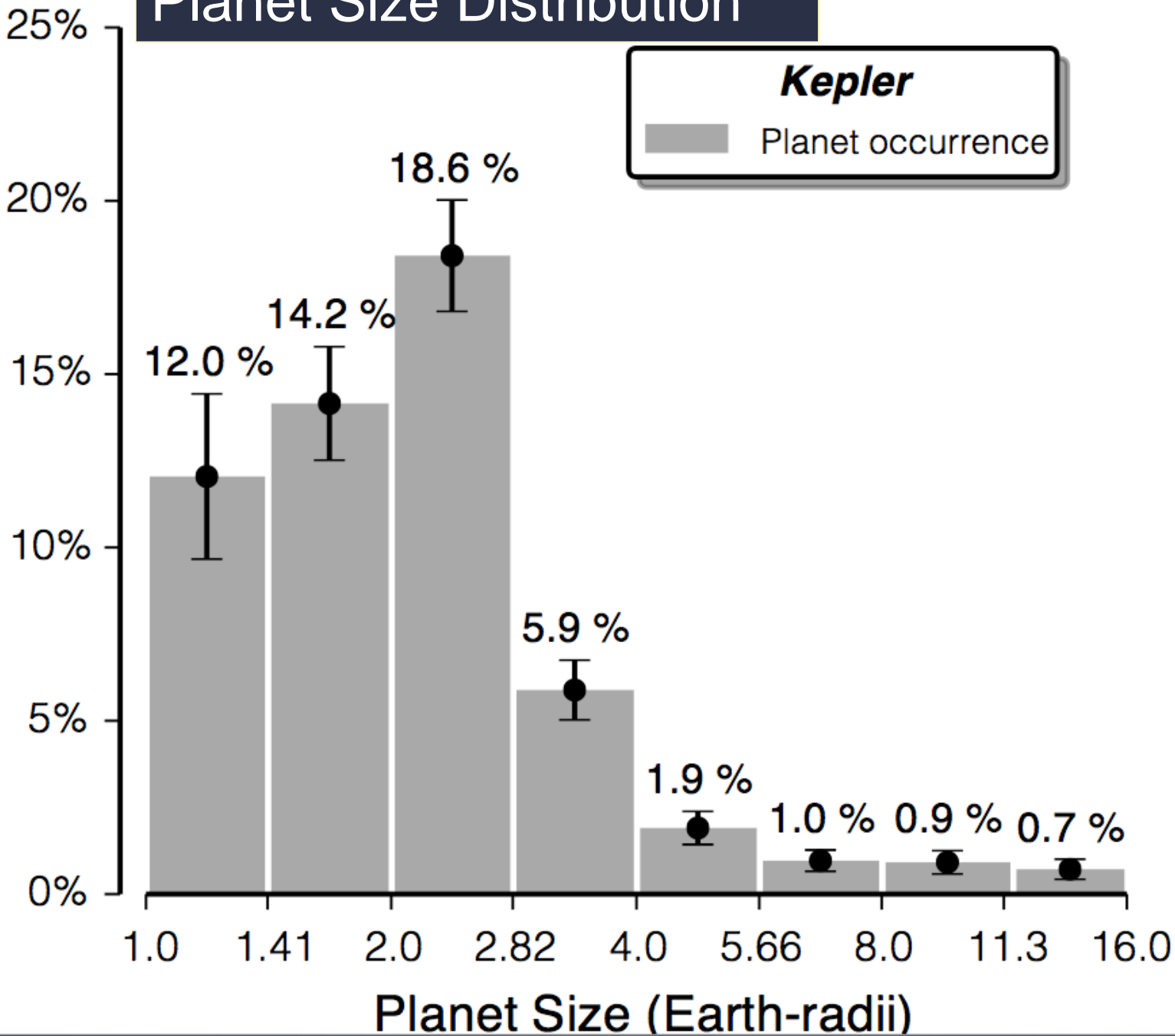
* Science Fiction books and movies influenced us . . .

Was Science Fiction Right?

Cause for Optimism . . .

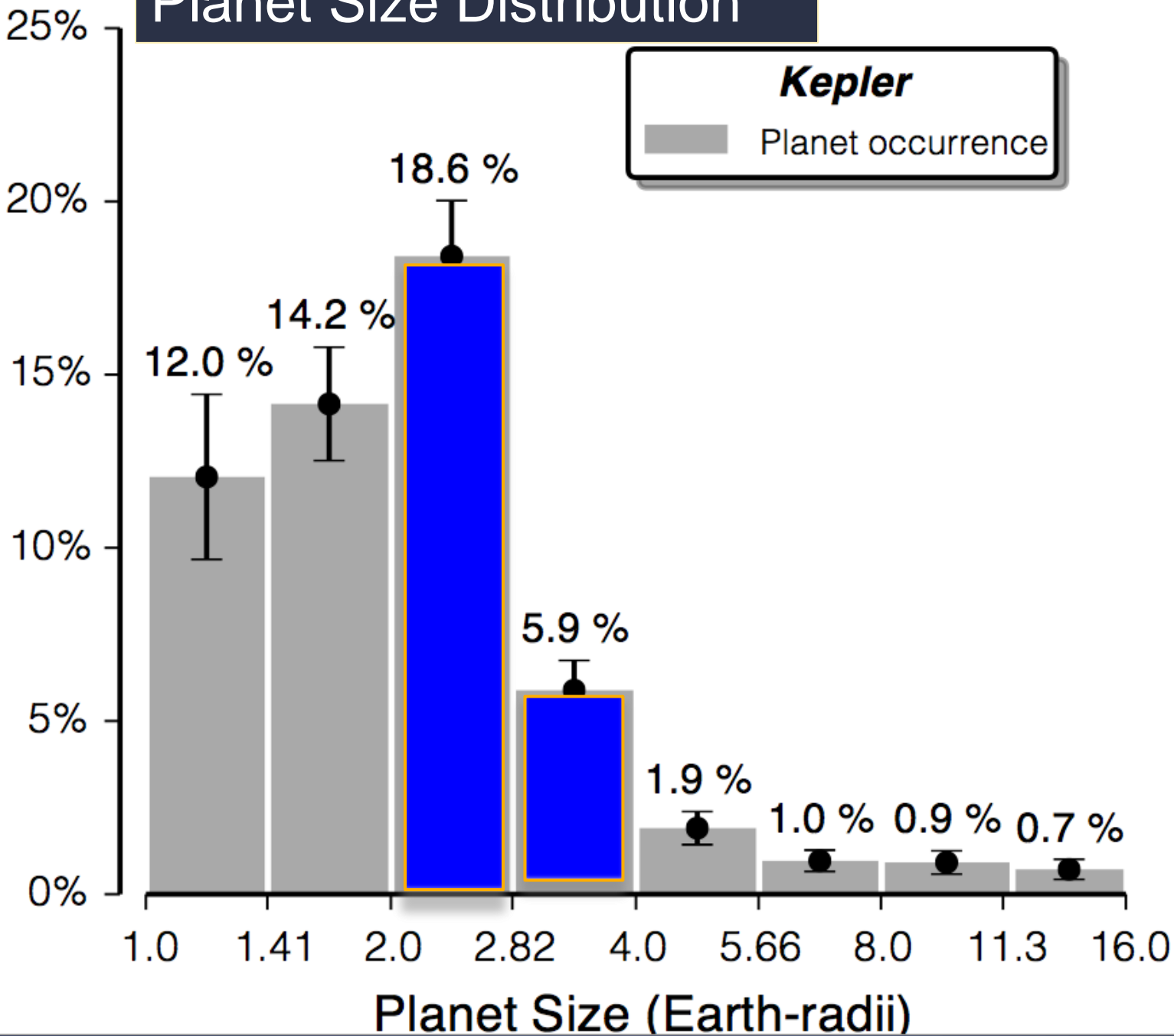
Planet Size Distribution

Fraction of Stars with Planets
having $P = 5-100$ days

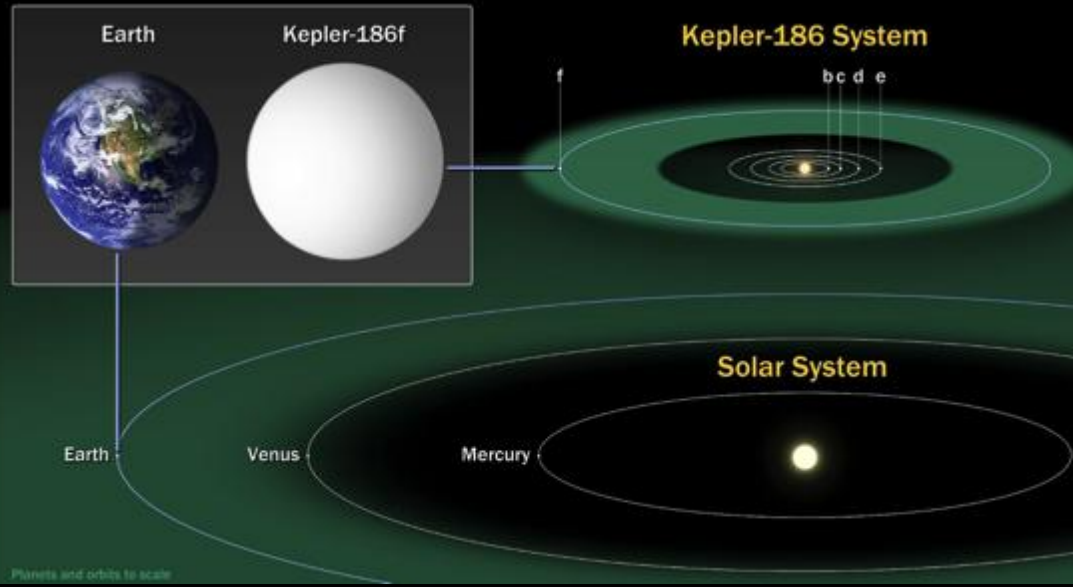
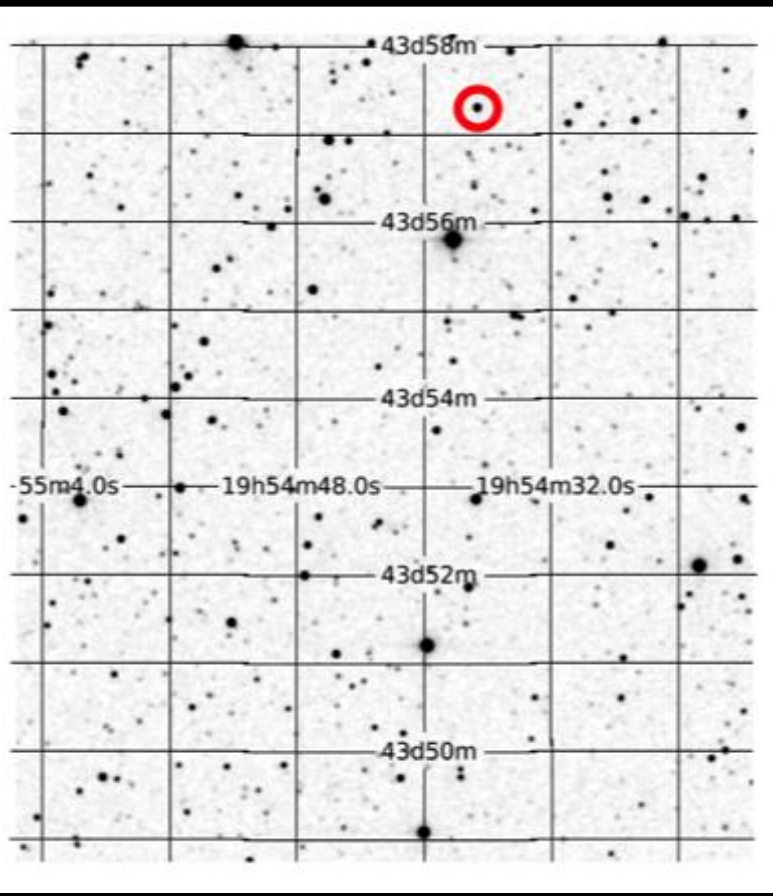


Planet Size Distribution

Fraction of Stars with Planets
having $P = 5-100$ days



Kepler-186 f Planet in Habitable Zone

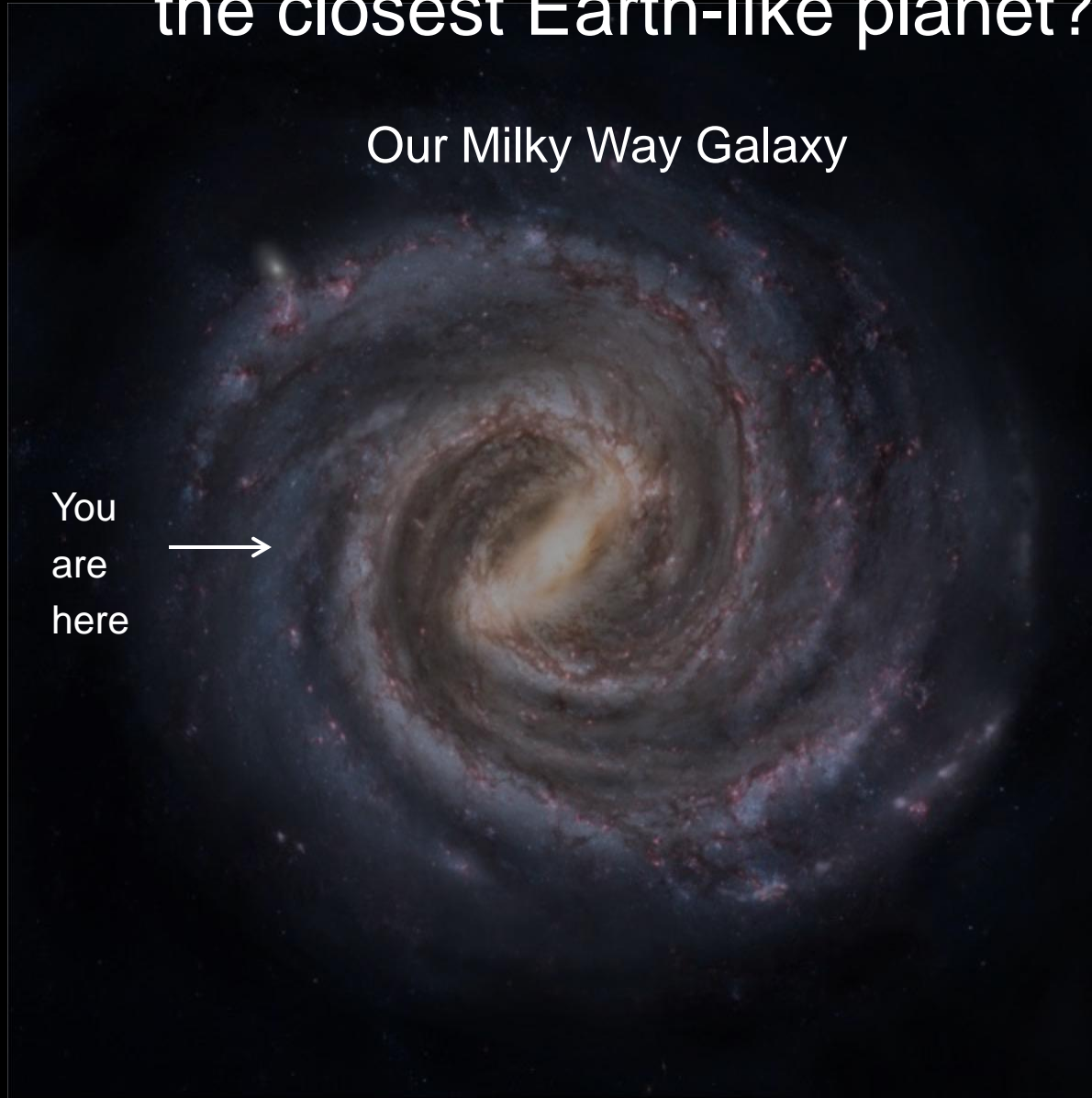


Kepler-186f orbits a star with about 4% of the Sun's luminosity with an orbital period of 129.9 days and an orbital distance of 40% times that of Earth's.

How far away is the closest Earth-like planet?

Our Milky Way Galaxy

You
are
here



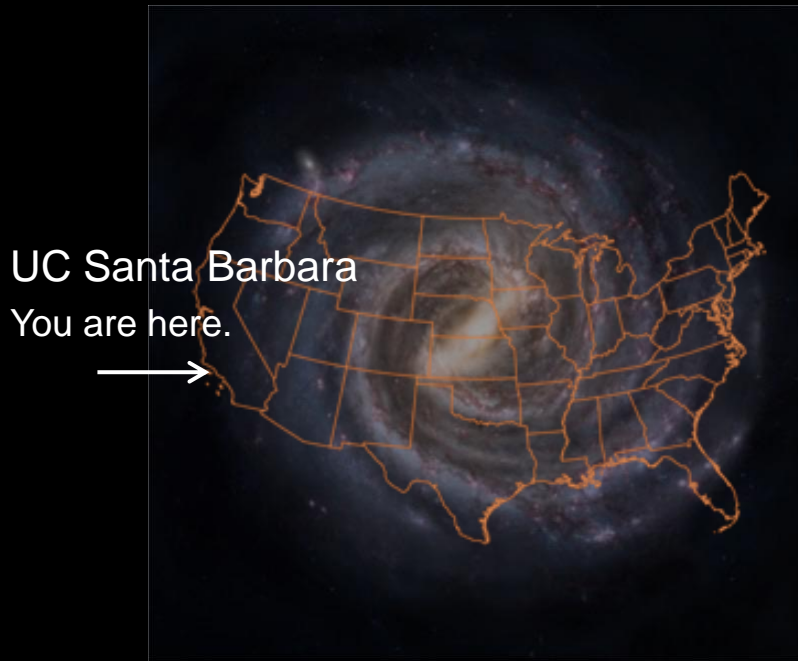
Shrink the Milky Way Galaxy to the size of the U.S. - - -

UC Santa Barbara
You are here.



Shrink the Milky Way Galaxy to the size of the U.S. - - -

How far away is the nearest habitable planet?



The nearest habitable planet
is across campus.



Intelligent Life in the Milky Way Galaxy



I could be wrong hereafter.
But I don't think so.

Estimate the number of
Intelligent Civilizations
in the Milky Way Galaxy

40 Billion Earth-size planets
in habitable zone.

What fraction have
Intelligent Life ?

Pessimist: 1 in a Million

Advanced

There must be Thousands of Civilizations
In the Milky Way Galaxy. . .



The Drake Equation:

N_{Civil} : Number of Advanced Civilizations in the Galaxy



Number of Earths in Milky Way Galaxy

200 billion stars

20% of all Stars have Earth-size planets in the habitable zone.

→ 40 Billion Earth-Size Planets

What about “Earth-Like” Planets?

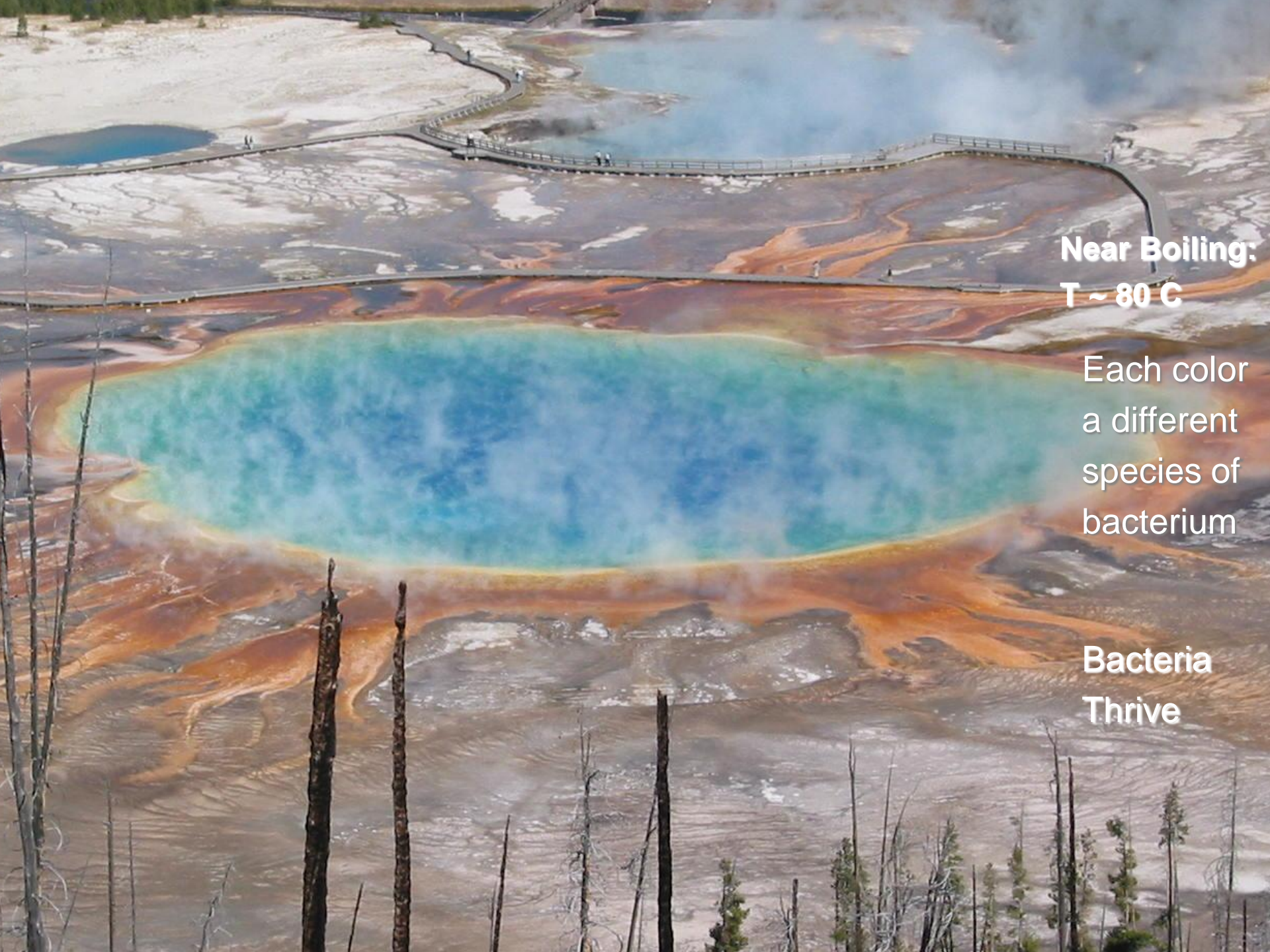
What properties make a planet suitable for life?

One of the Least Hospitable Places on Earth:
Yellowstone National Park

- Boiling Geysers
- Freezing winter
- Sulfuric acid

Suitable for Life ?





**Near Boiling:
T ~ 80 C**

Each color
a different
species of
bacterium

**Bacteria
Thrive**

Yellowstone

Life at High Temperature and High Acidity



Temp = 65 C
pH = 2



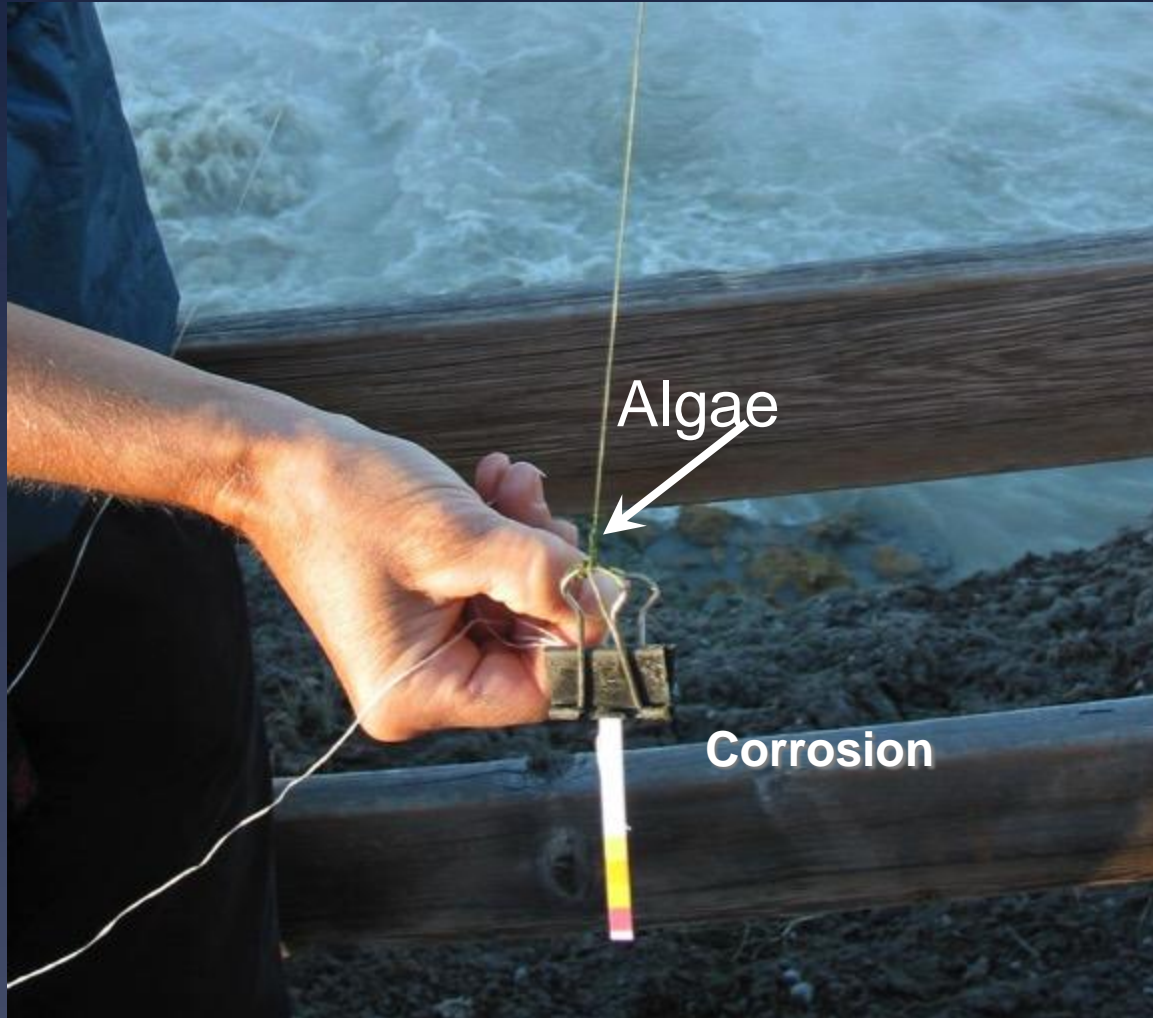
Filamentous bacteria thriving in pH=2.

Yellowstone Churning Cauldron



Boiling Temp

Yellowstone Churning Cauldron Hot Spring



Near Boiling
Temperature

pH = 2

**Bacteria &
Algae Thrive**

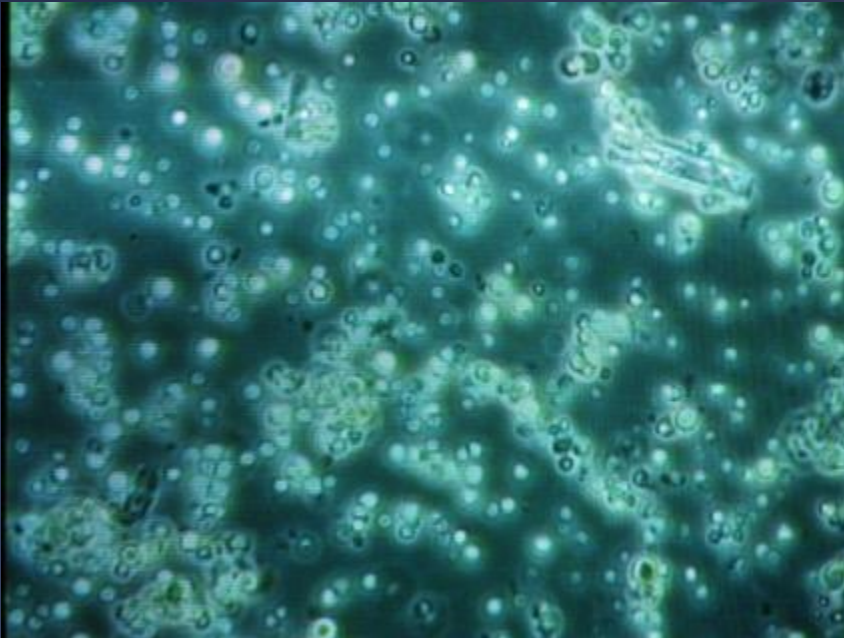
pH = 2

Life Thrives at:

Temp = 0 - 75 C

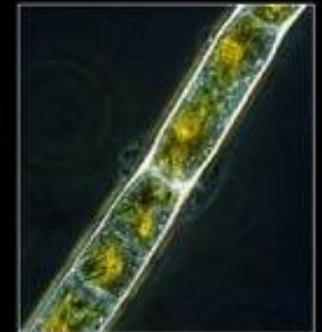
Wide Range of Acidity

Cyanidium Calderium



Lives at Temp > 65 C

Zygonium sp.



Zygonium is a genus of filamentous green algae. This species is acidophilic.

Extremophiles Teach us that Life:

- Tolerates heat or cold
- Thrives in acidic or alkaline environments
- Takes food from a variety of sources
 - Copes with Intense Solar Radiation - - or none!

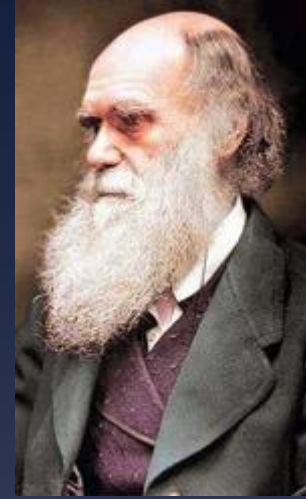
Liquid Water



Life

Primitive Life: *Common in the Universe*

Darwinian Evolution



Individuals with traits that best allow them to survive and reproduce will on average produce the greatest number of surviving offspring.

Advantageous traits are passed on.

Intelligence is occasionally an “advantage”

(we humans like to think . . .)

SETI:

Search for Extraterrestrial Intelligence

SETI:

Search for Extraterrestrial Intelligence

Method 1:

Search for Visible (Optical) Light
from Advanced Civilizations

Optical SETI: R.Schwartz & C.Townes 1961

nature

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article

Nature **190**, 205 - 208 (15 April 1961); doi:10.1038/190205a0

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Interstellar and Interplanetary Communication by Optical Masers

R. N. SCHWARTZ & C. H. TOWNES*

Institute for Defense Analyses, Washington, D.C.

*On leave from Columbia University, New York.

1. Cocconi, G. , and Morrison, P. , *Nature*, **184**, 844 (1959). | [ISI](#) |
2. Purcell, E. M. , talk at Professional Group on Microwave Theory and Techniques, *Inst. Rad. Eng.*, (June 1959).
3. Struve, O. , K. T. Compton Lecture, Mass. Inst. Tech., November 1959.
4. Schawlow, A. L. and Townes, C. H. , *Phys. Rev.*, **112**, 1940 (1958). | [Article](#) | [ISI](#) | [ChemPort](#) |

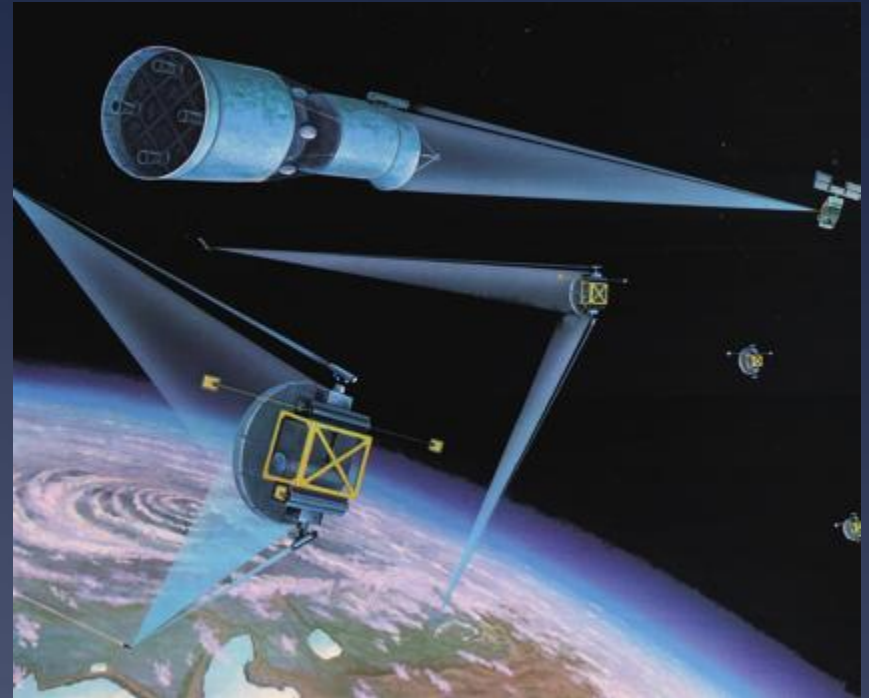
* "A civilization out there could be a thousand years ahead of us," Townes said. "It seems possible that some being on a planet orbiting a nearby star could send a bright enough beam that we could see..."

Laser Communication



Laser technology now allows for high-bandwidth, long-range communication. Advancing rapidly.

Advantages of Laser Communication



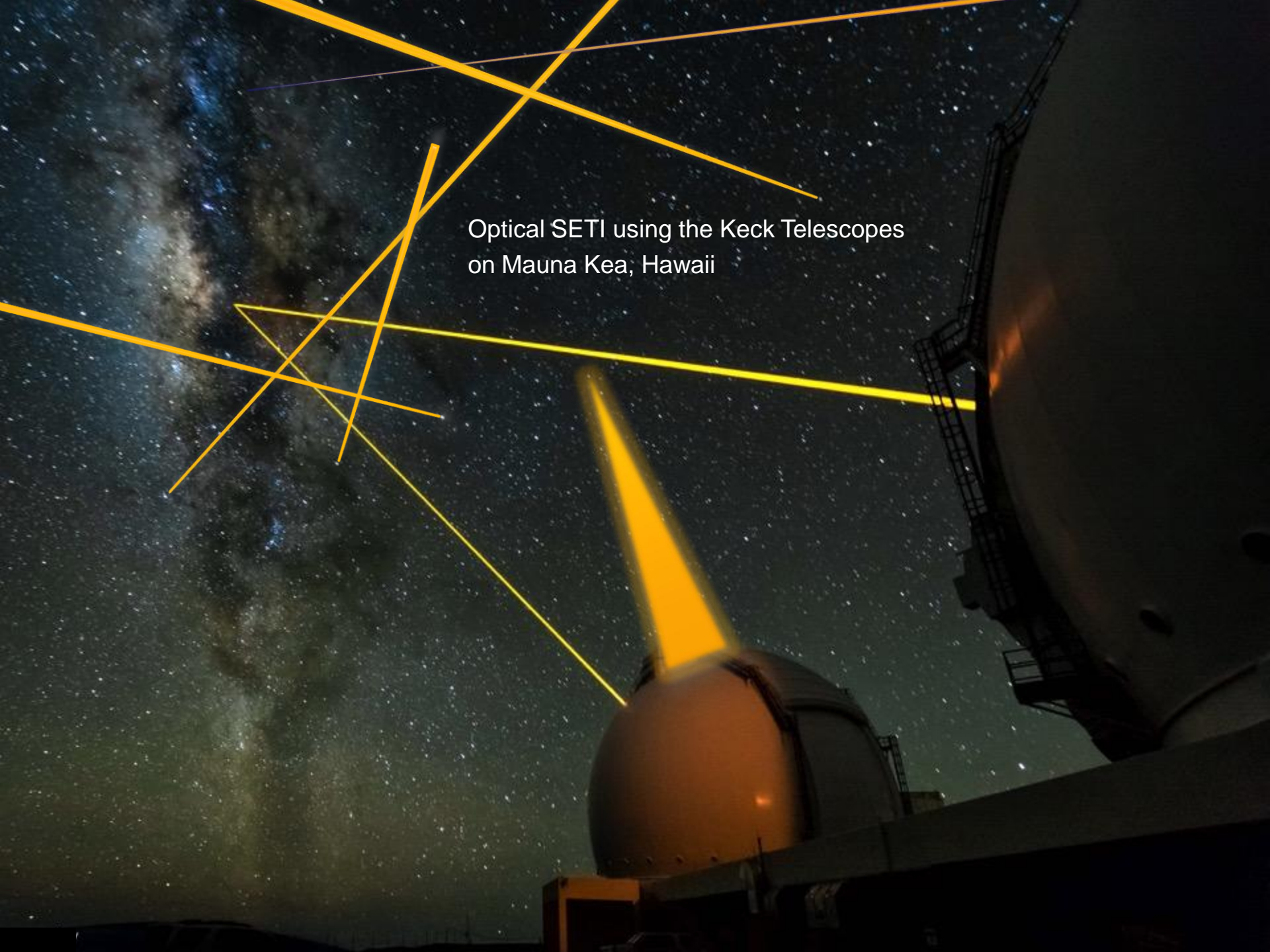
Laser-based data transmission advantages over radio links:

- Shorter wavelengths can achieve higher data rates than radio
- Laser beams are inherently less divergent than radio:
Less power & More privacy.

Laser Guide Stars: Lasers Pointed at Objects of Interest



Innocent Astronomers pointing lasers at the nearby stars and planets. Worldwide, every night.

A night-time photograph of the Keck Telescopes on Mauna Kea, Hawaii, with the Milky Way galaxy visible in the background. Several bright yellow laser beams are directed from the telescopes into the sky, creating a complex pattern of intersecting lines. One beam is particularly prominent, originating from a telescope in the foreground and pointing towards the upper left. The sky is filled with stars, and the Milky Way's structure is clearly visible as a dense band of light. The telescopes themselves are dark, with some structural elements and ladders visible against the starry background.

Optical SETI using the Keck Telescopes
on Mauna Kea, Hawaii

Searching for Laser Transmissionf from Extraterrestrial Intelligent Life

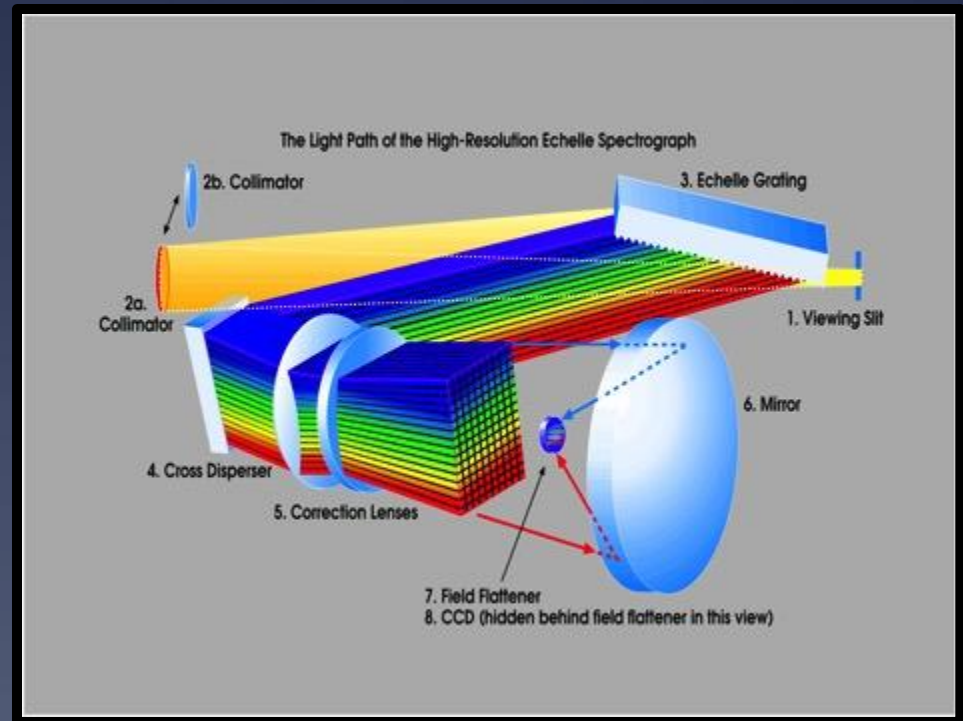
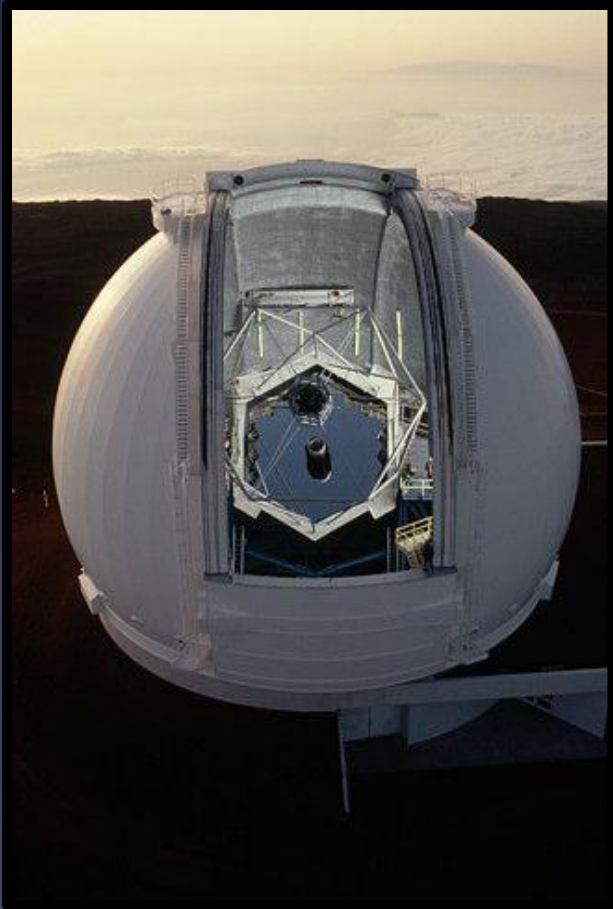
Keck Telescope
Mauna Kea, Hawaii



10-meter Keck Telescope

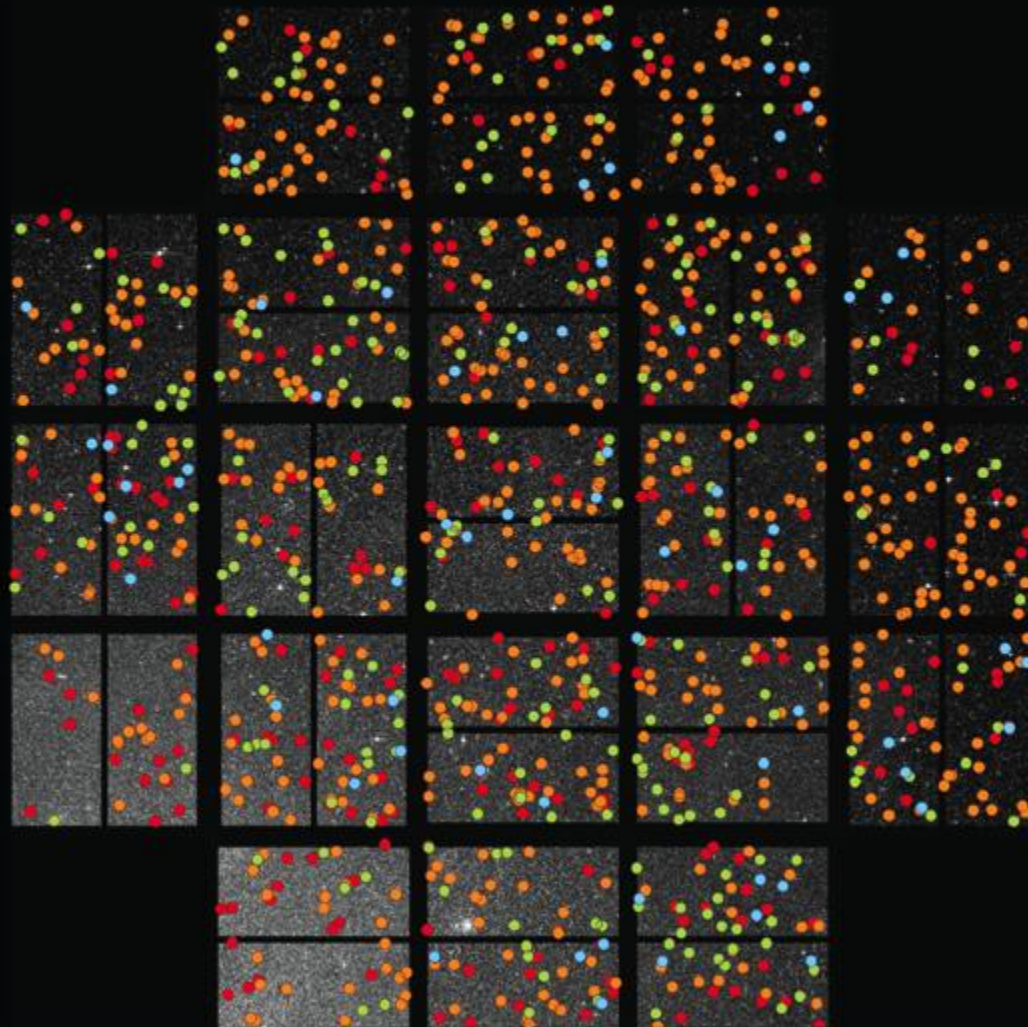
HiRES Spectrometer:

Search for Galactic Laser Internet



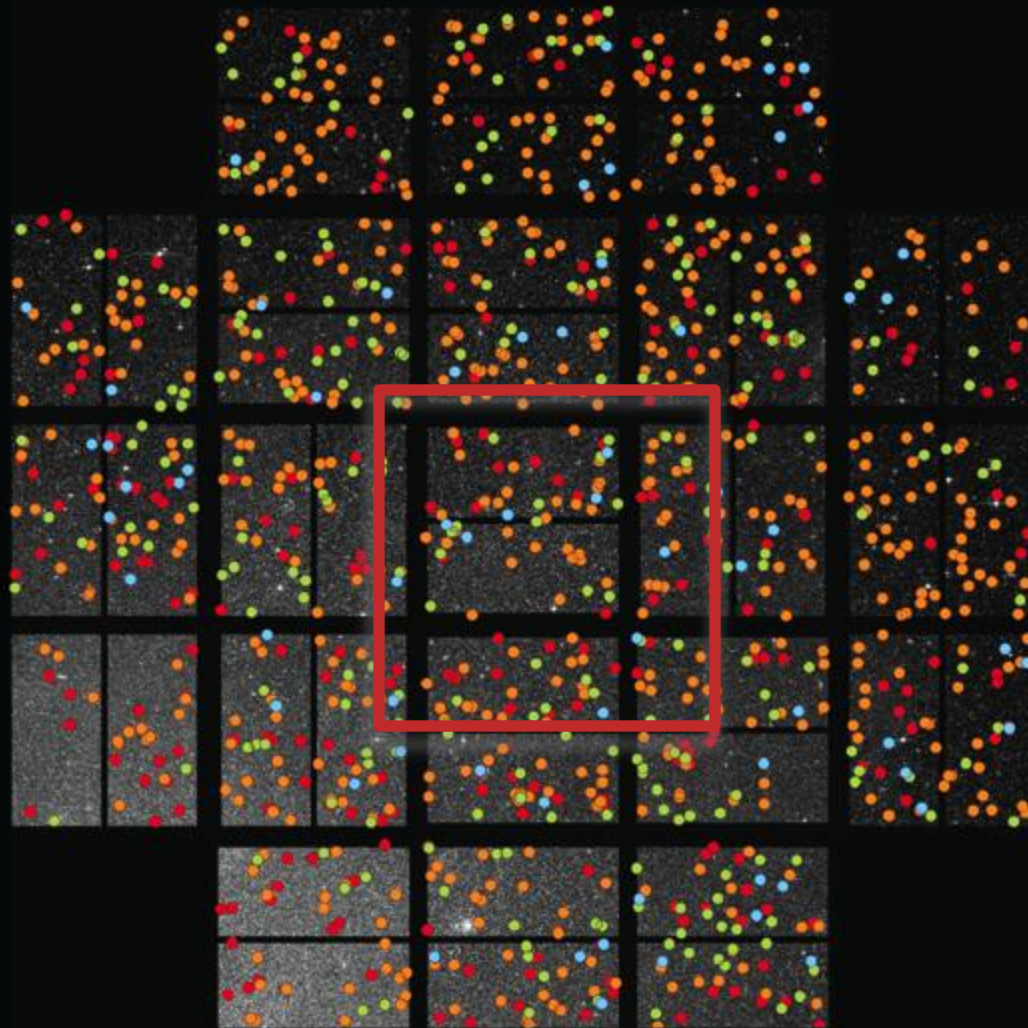
Targets: 1500 Kepler Planets including 400 Multi-Planet Systems

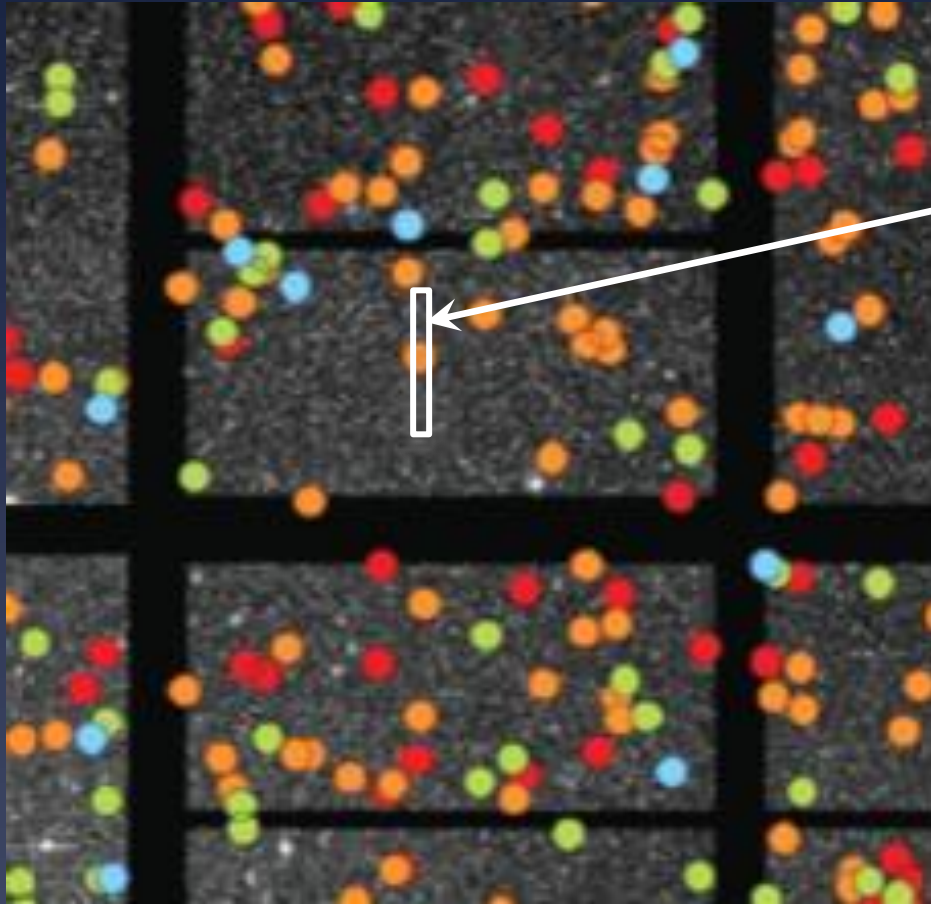
- Earth-size
- Super-Earth size
1.25 - 2.0 Earth-size
- Neptune-size
2.0 - 6.0 Earth-size
- Giant-planet size
6.0 - 22 Earth-size



Targets:
1500 Kepler Planets
including 400 Multi-Planet Systems

- Earth-size
- Super-Earth size
1.25 - 2.0 Earth-size
- Neptune-size
2.0 - 6.0 Earth-size
- Giant-planet size
6.0 - 22 Earth-size

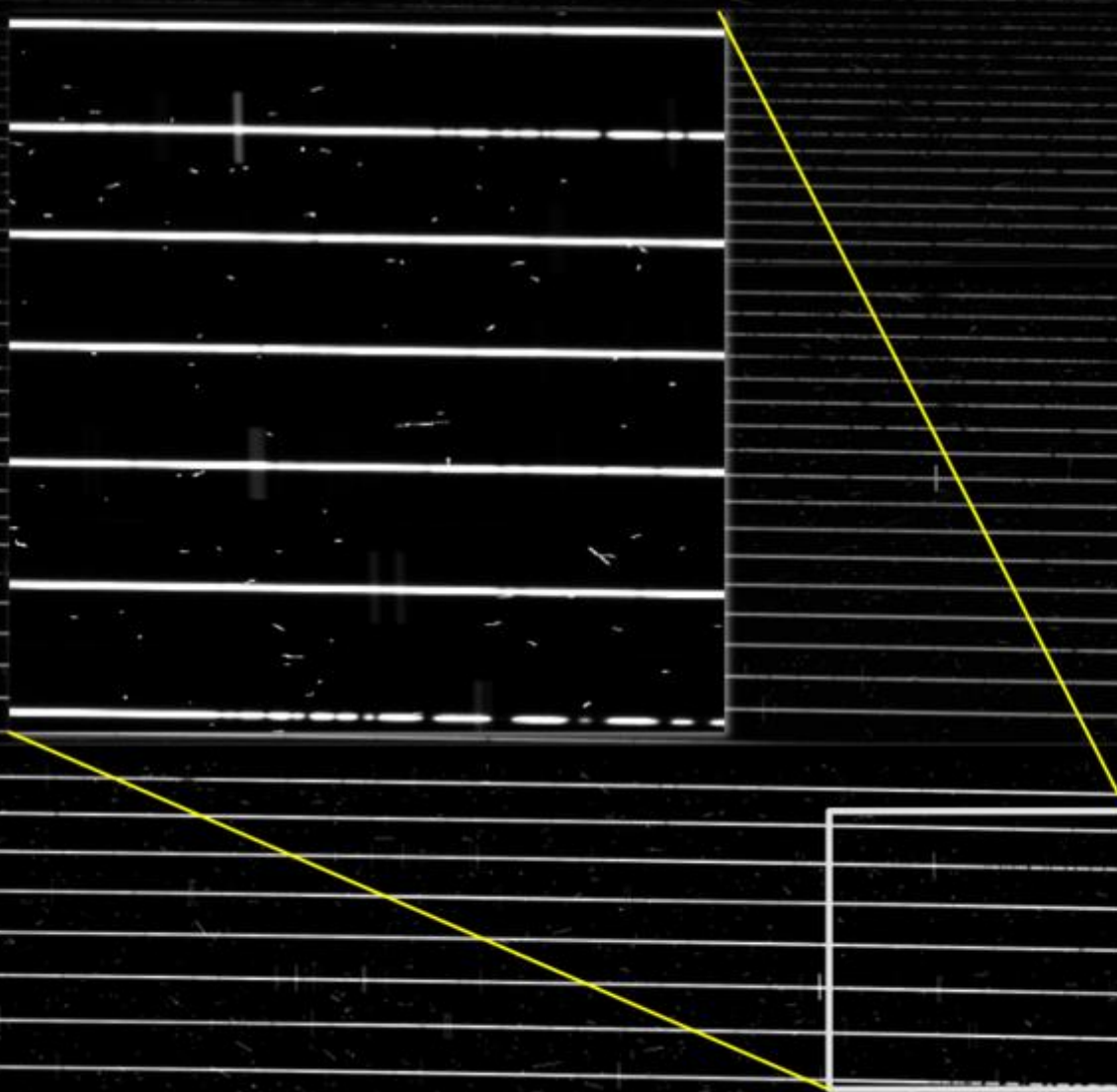




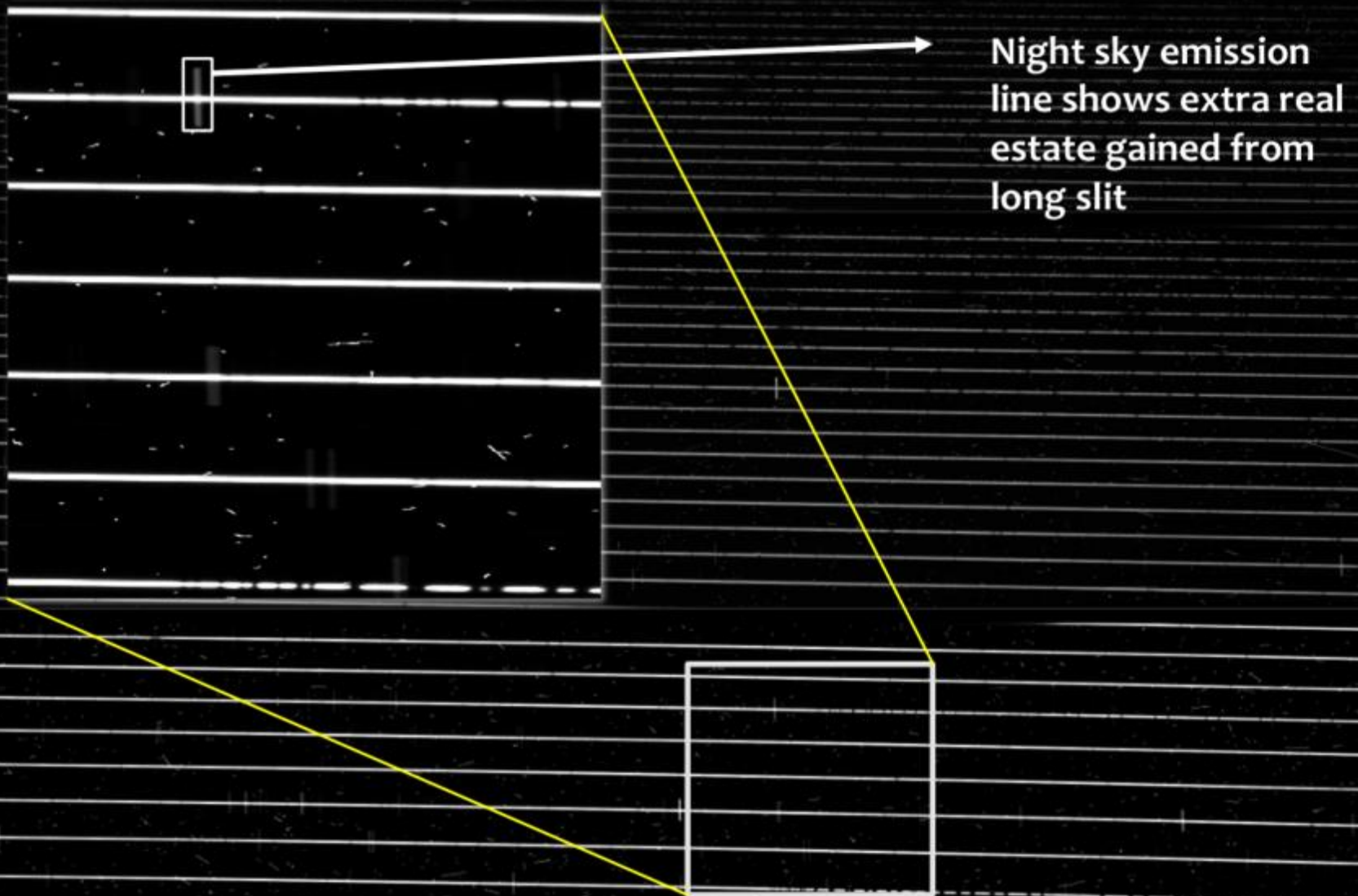
Long Entrance Slit
of Spectrometer

Long slit: 14 arcsec.
A Laser located anywhere along slit will be detected.

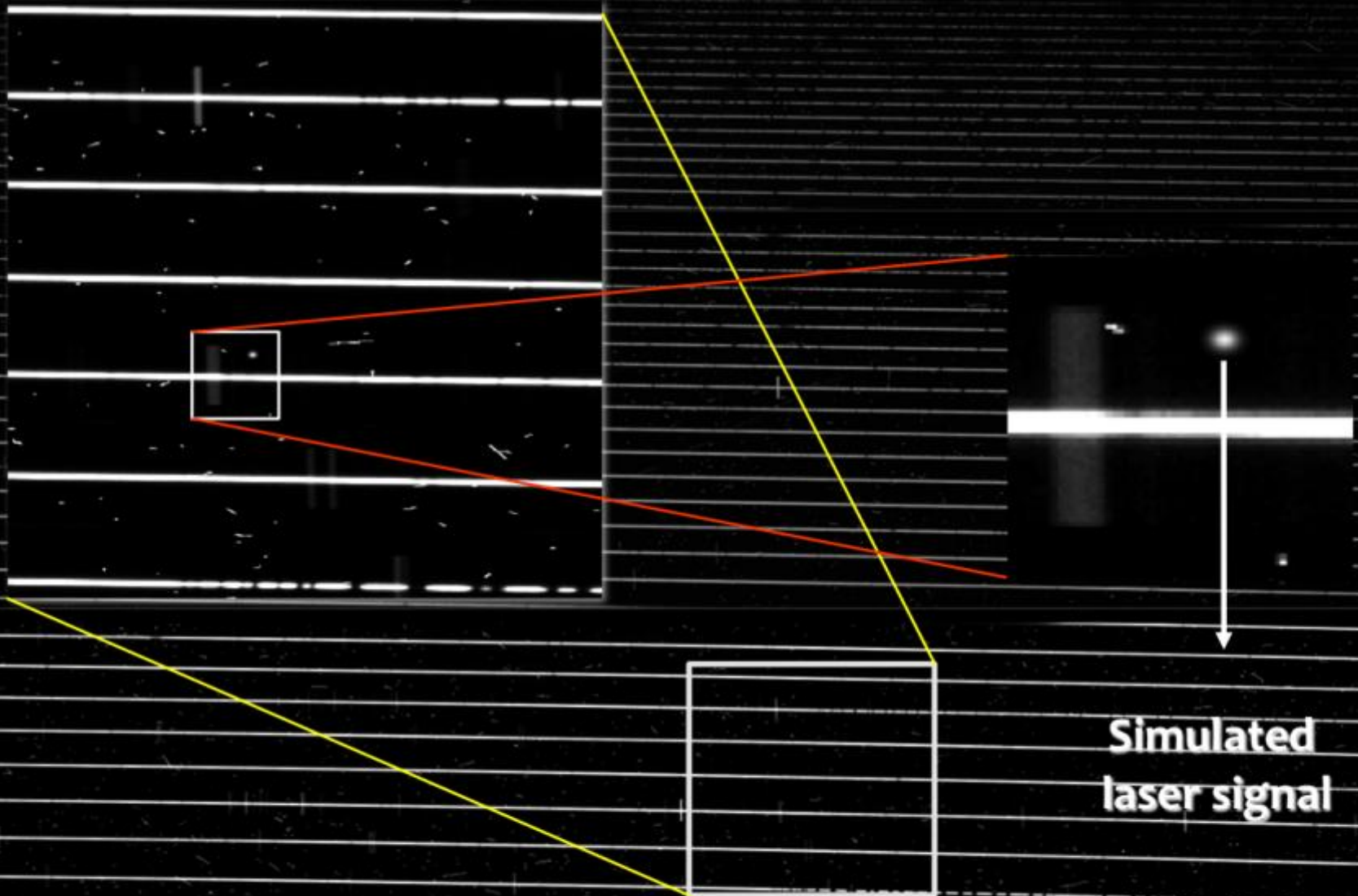
Raw Images from Spectrometer



Raw CCD Detector



Raw CCD Detector



SETI:

Search for Extraterrestrial Intelligence

Method 2:

Search for Radio Waves
from Advanced Civilizations

SETI: Picking up Radio Wave Transmissions

Green Bank
Radio Telescope



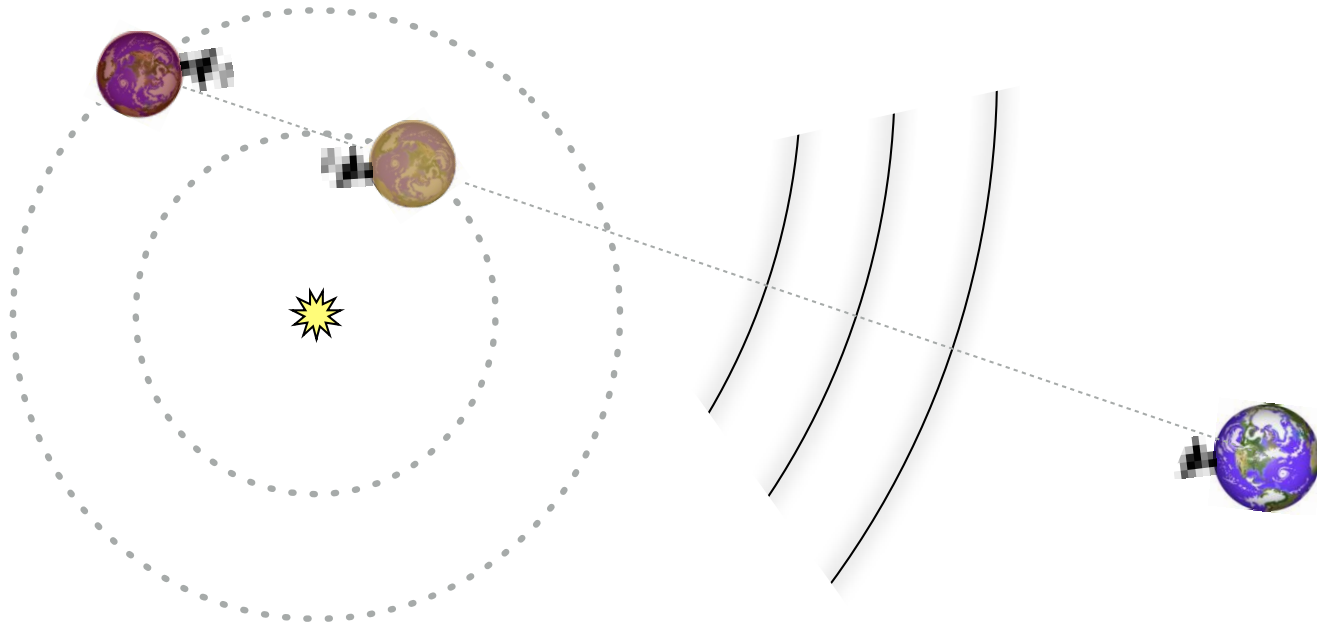
An aerial photograph of the Green Bank Radio Telescope, a large white parabolic dish mounted on a complex metal lattice structure. The telescope is situated in a valley surrounded by dense, green forested hills. The dish is tilted upwards and to the left. In the foreground, there are some buildings and a paved area. The overall scene is a mix of natural landscape and scientific infrastructure.

SETI: Picking up Radio Wave Transmissions

Green Bank
Radio Telescope

Available *now* for Purchase:
50% time for \$4 Million per year

Search for alien radio transmission when exoplanets line up with Earth



SETI_{with} MEERKAT



MeerKat::

Under construction: South Africa

7 Dishes already in place.

Most Sensitive SETI telescope ever

- Earth-size Planets are Common in the Milky Way Galaxy
- Simple Life: Probably Ubiquitous
- Intelligence: Precious, and May Be Rare in the Milky Way Galaxy

