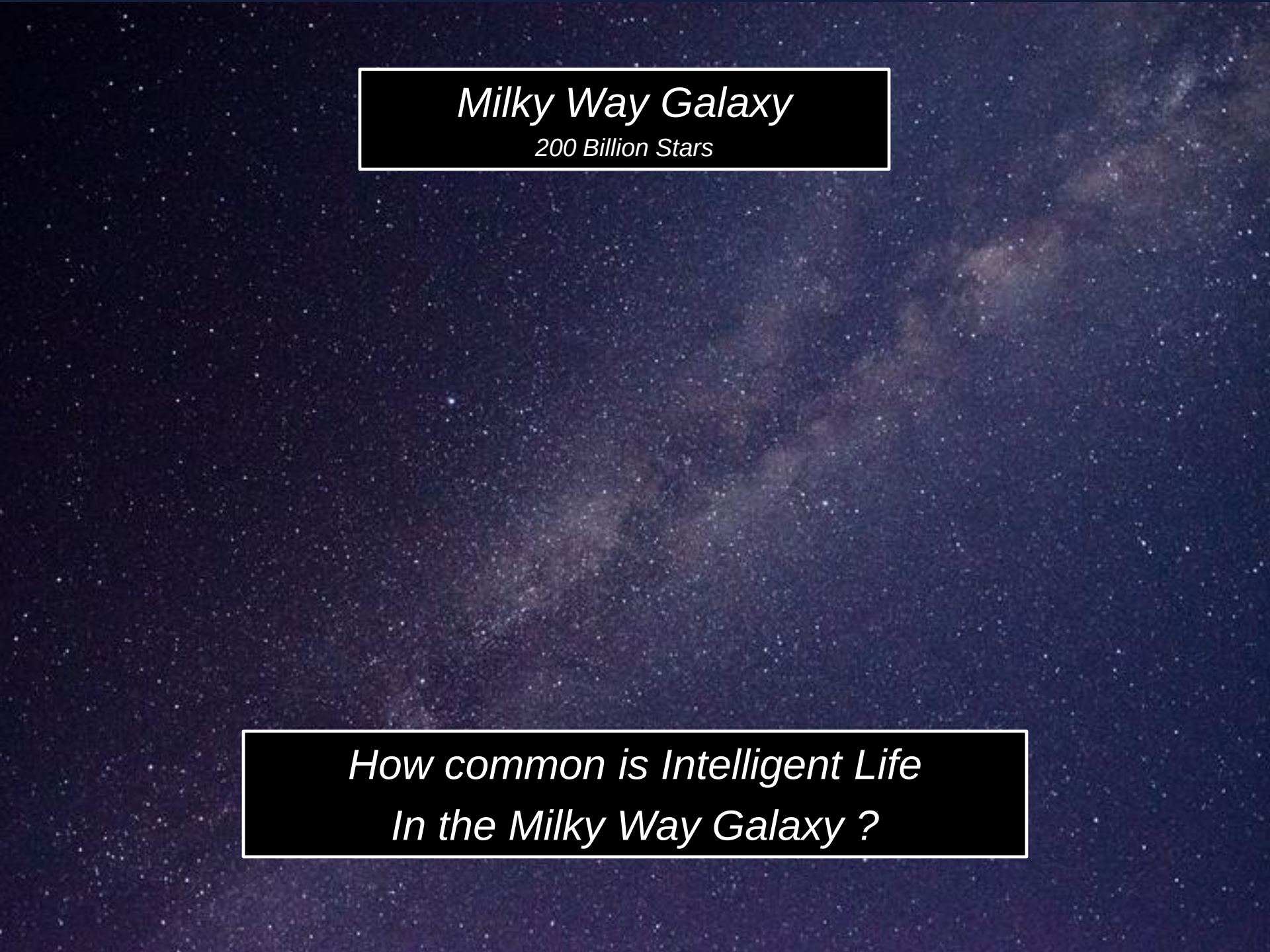
Prospects for

Intelligent Life in the Milky Way Galaxy

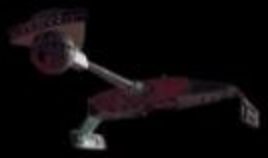
Geoff Marcy
University of California

Only Known Site of Biology in the Universe

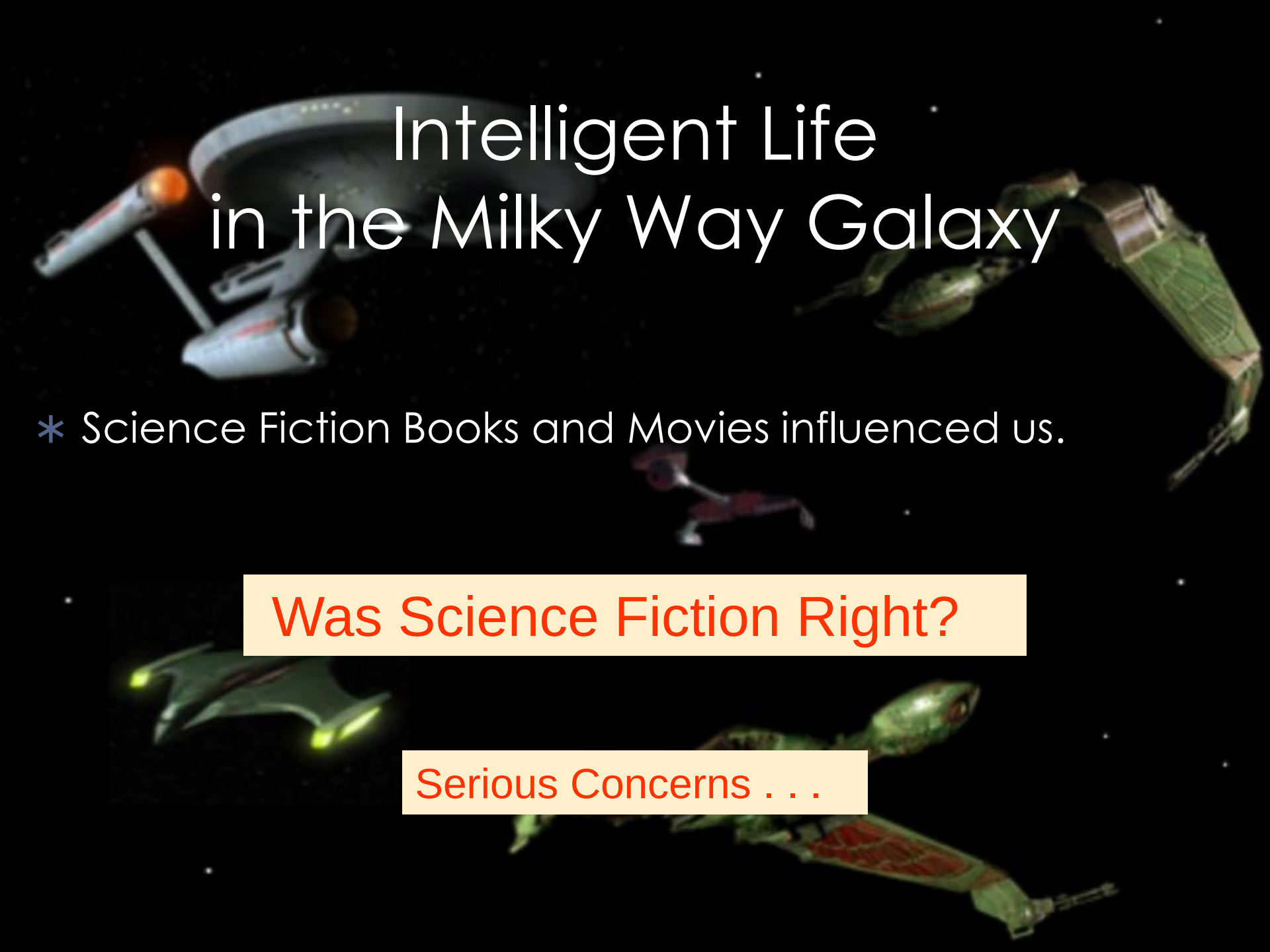

Milky Way Galaxy
200 Billion Stars
How common is Intelligent Life
In the Milky Way Galaxy ?

Intelligent Life in the Milky Way Galaxy

* Science Fiction Books and Movies taught us . . .



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?

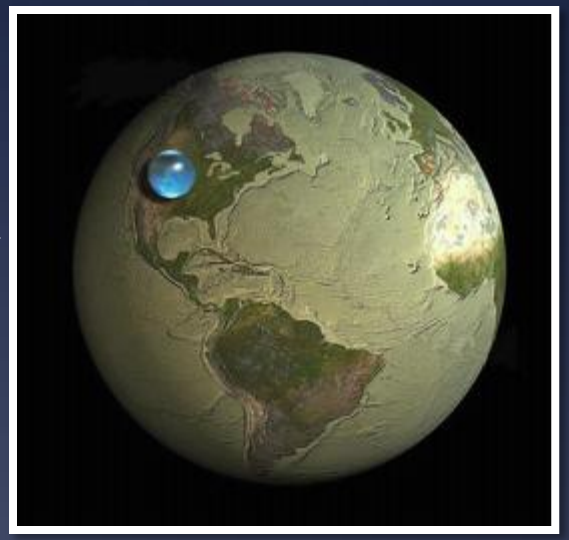
Where *Is* Everybody?

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

Earth: A Lucky Amount of Water

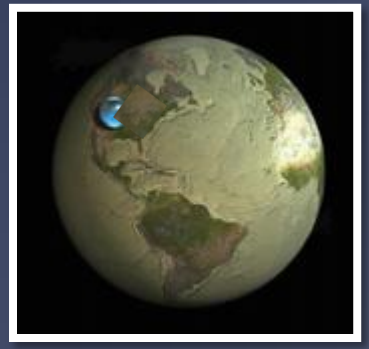
Earth is 0.06% water.

Lucky Delivery of Water
by Asteroids and Comets



Other Earths:

0.03% Water: Desert World



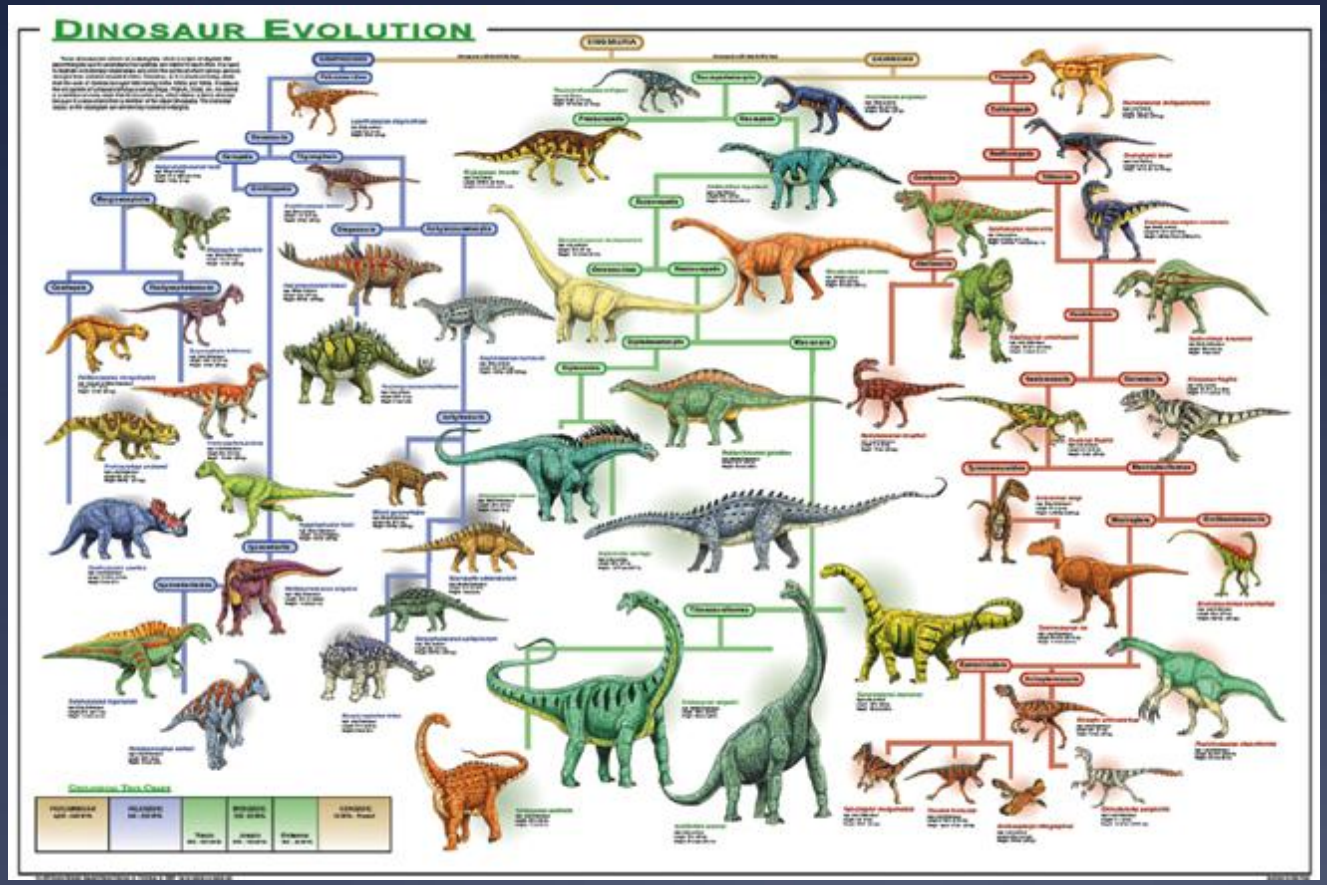
Most Rocky Planets are
Desert or Water Worlds

No Technological Life

0.09% Water: Water World

Does Evolution Favor Intelligence ?

Test: Dinosaur brain evolution

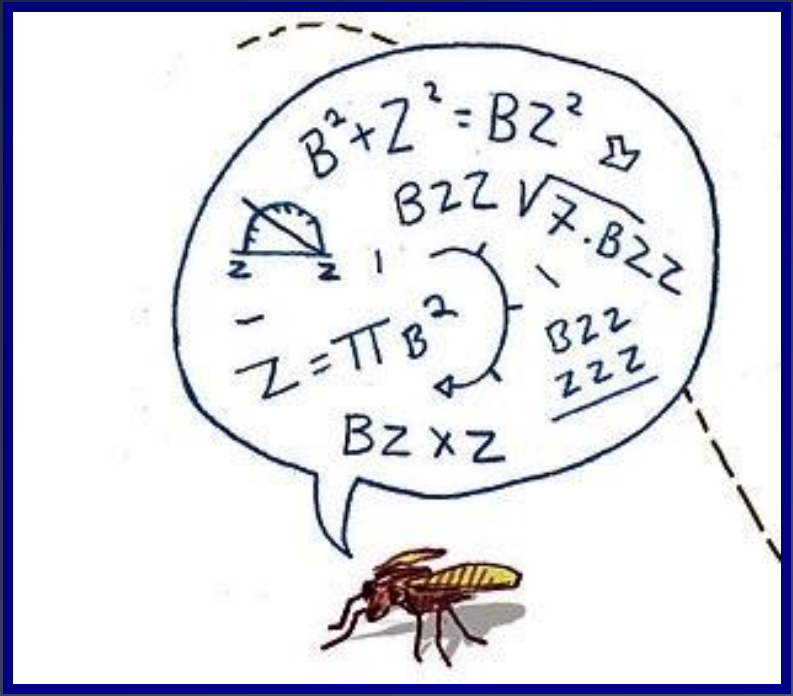


Paleontology:

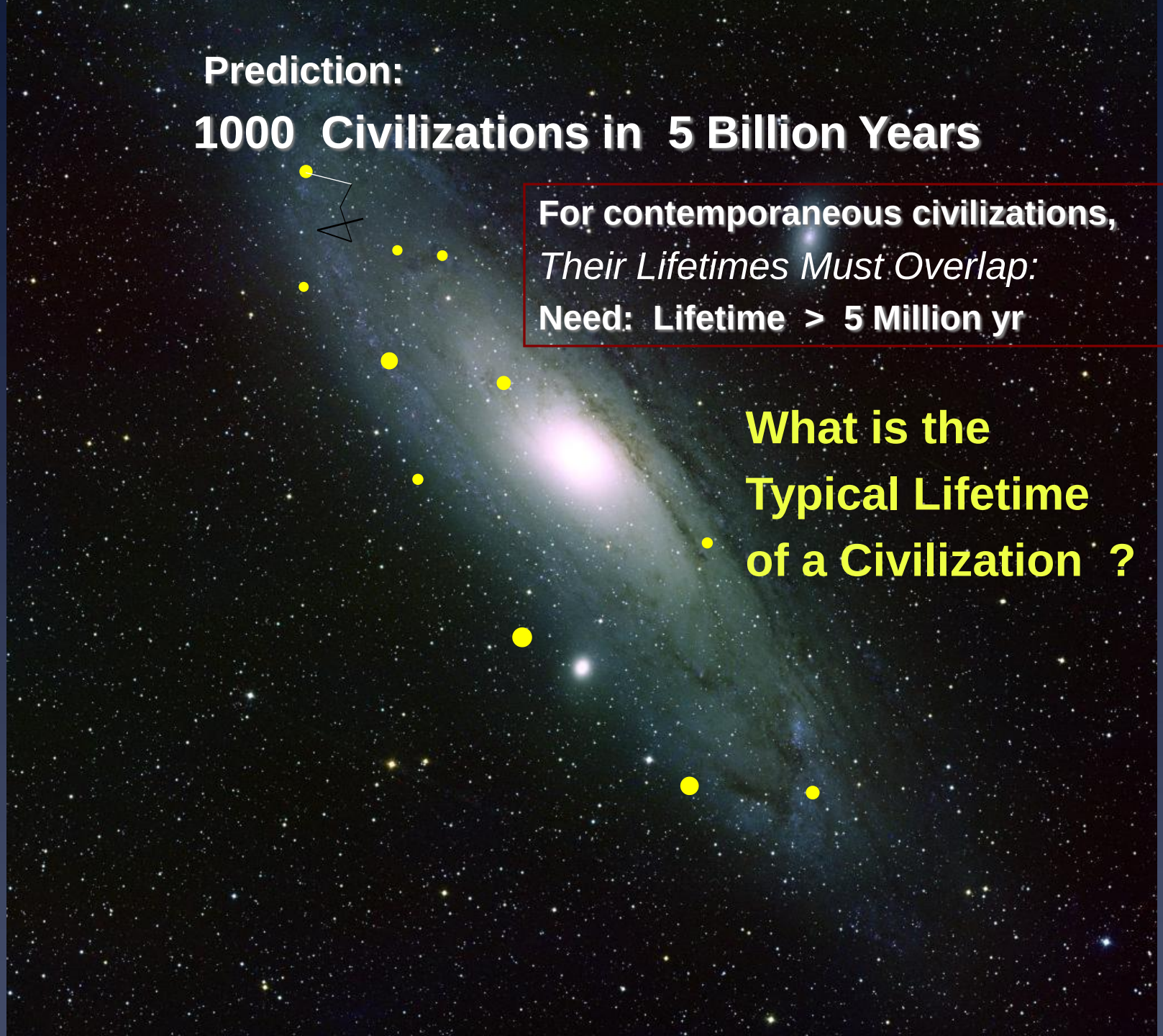
- Walnut-size brains
- No tools
- Bird-like brains

200 Million Years of Dinosaur Evolution: A No-Brainer

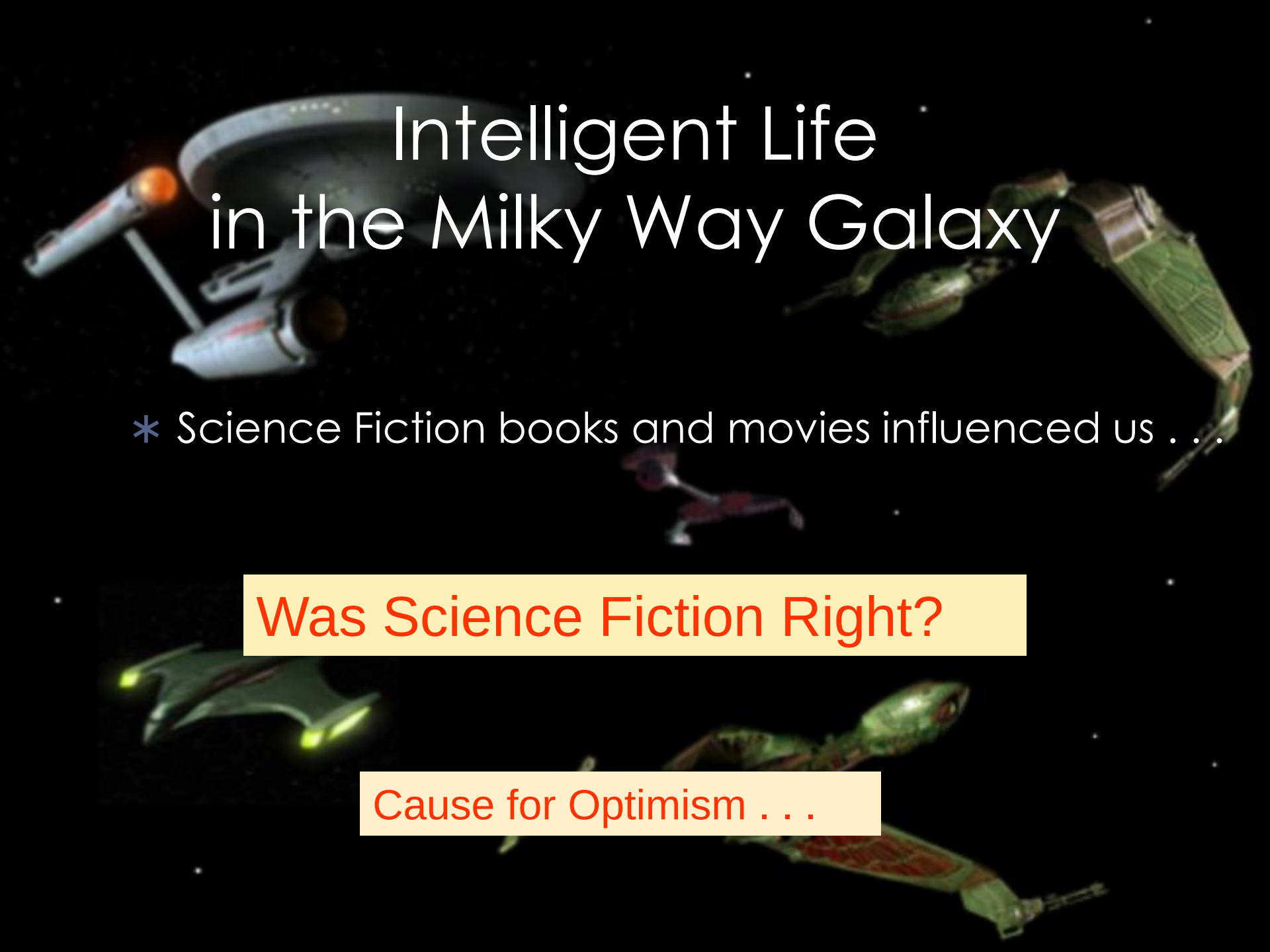
Does Evolution Favor Intelligence?



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 ?

Intelligent Life in the Milky Way Galaxy

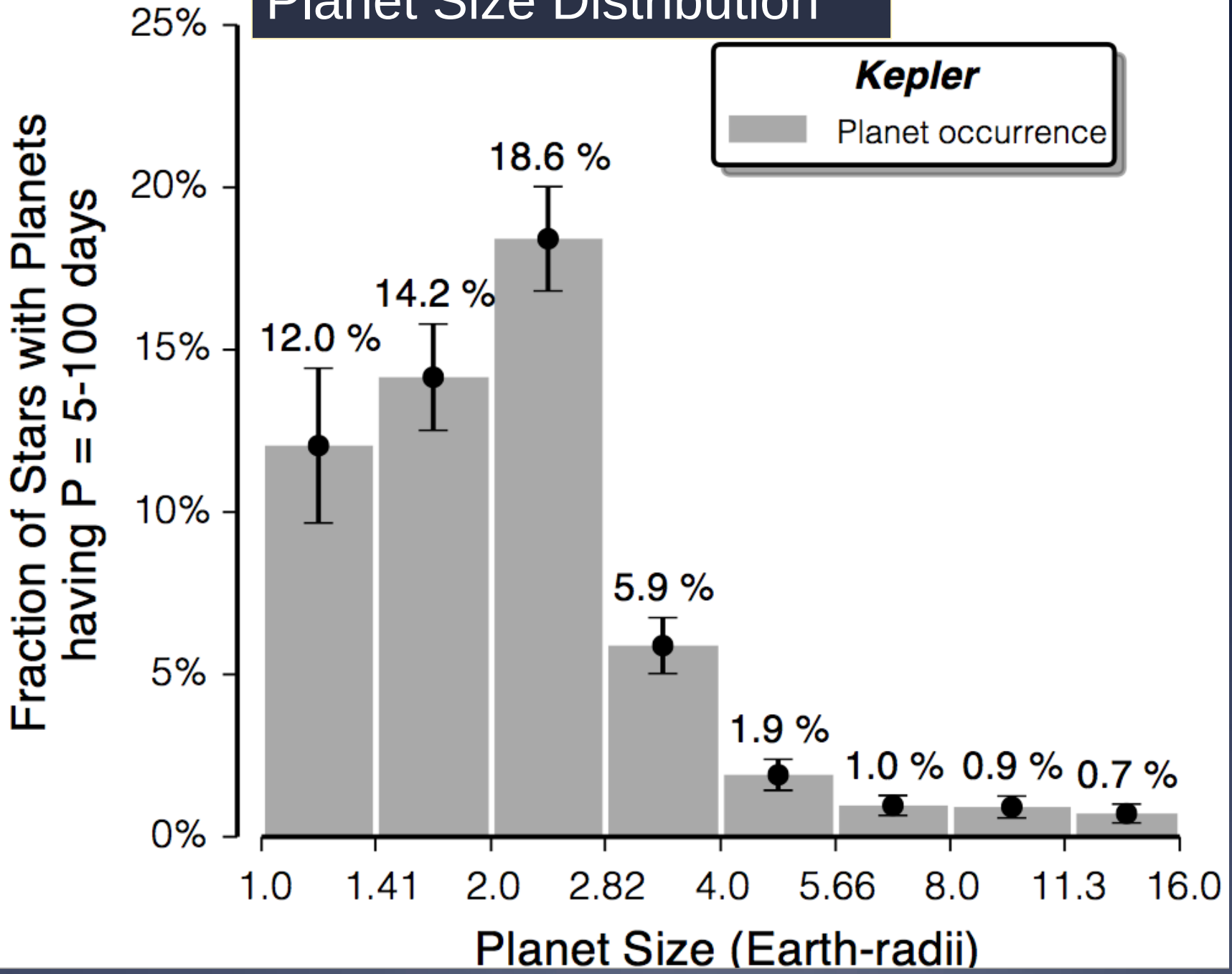


* Science Fiction books and movies influenced us . . .

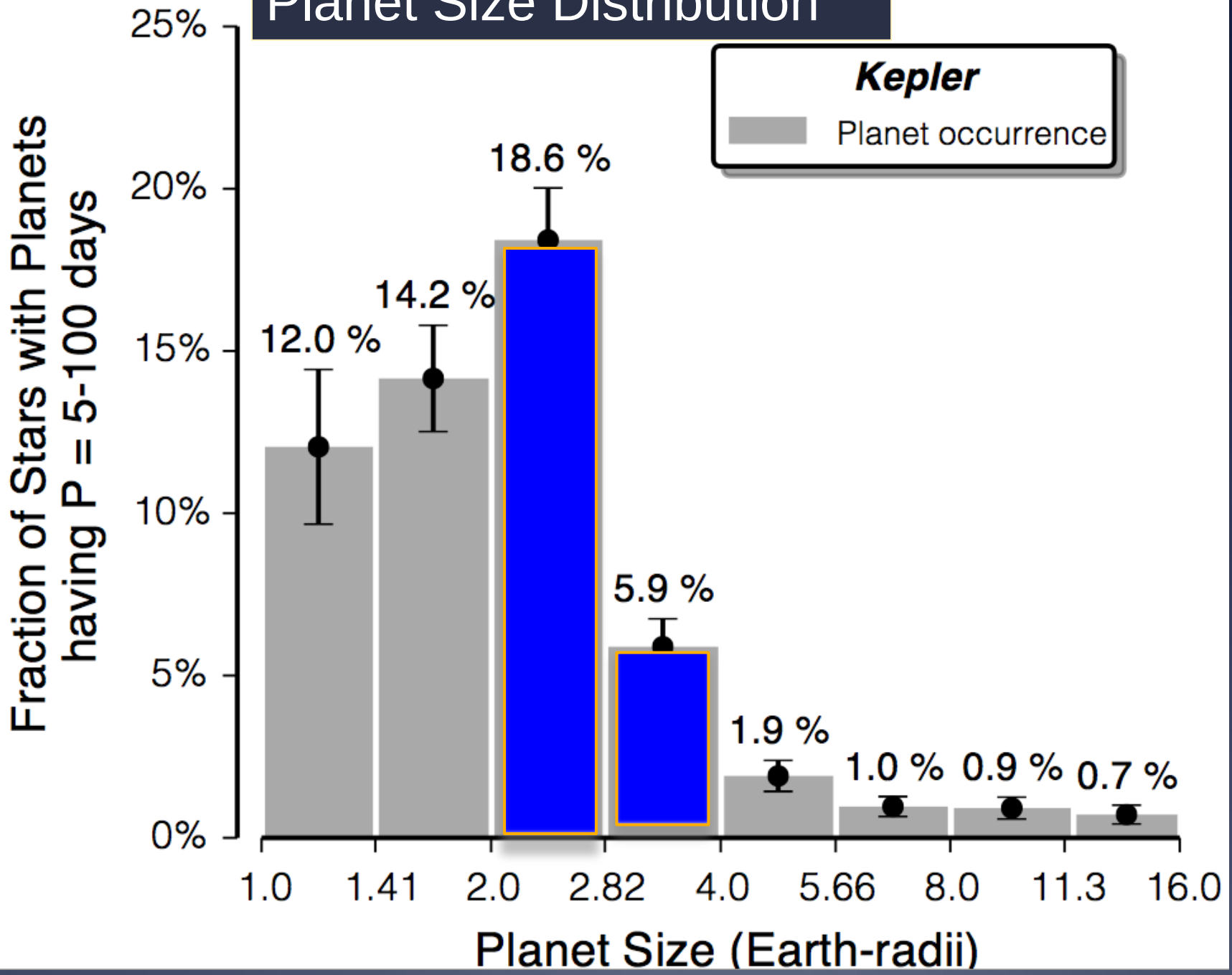
Was Science Fiction Right?

Cause for Optimism . . .

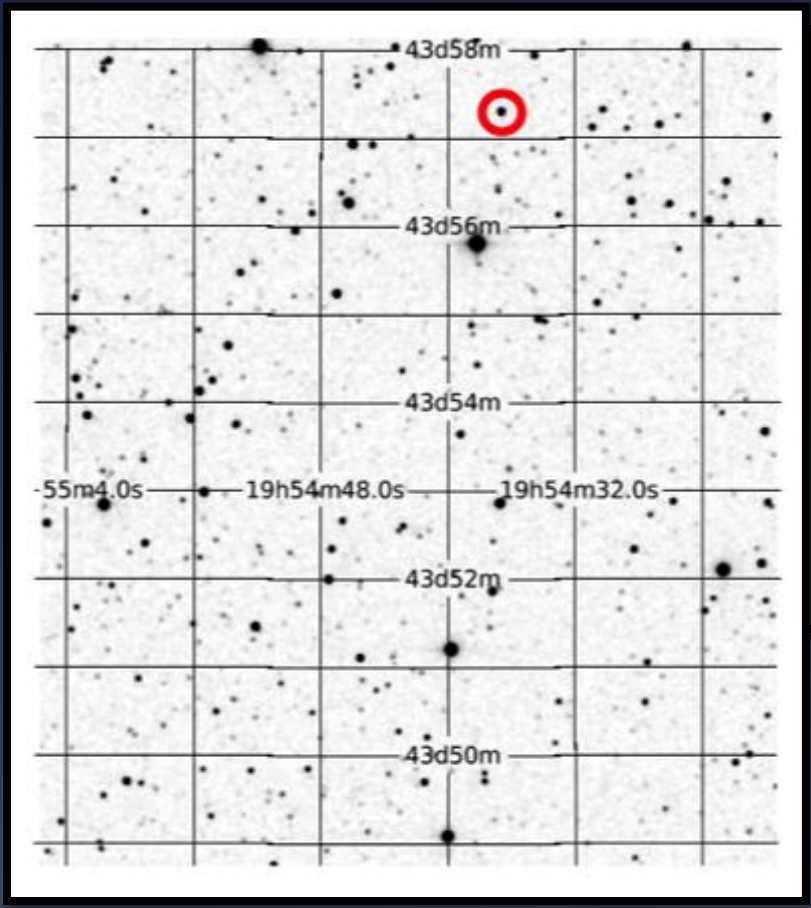
Planet Size Distribution

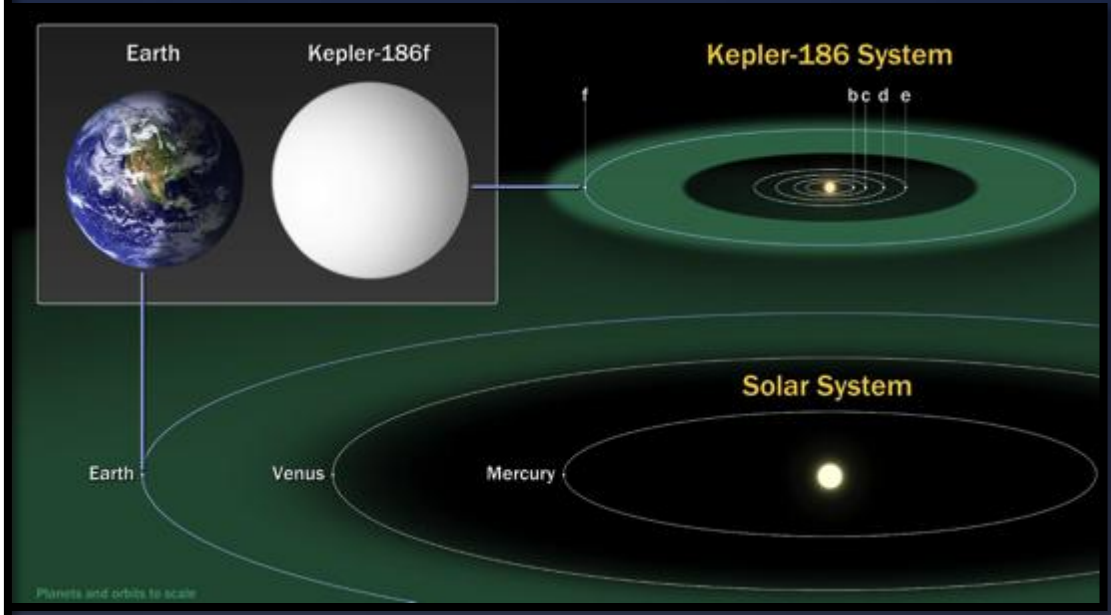


Planet Size Distribution



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

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

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.

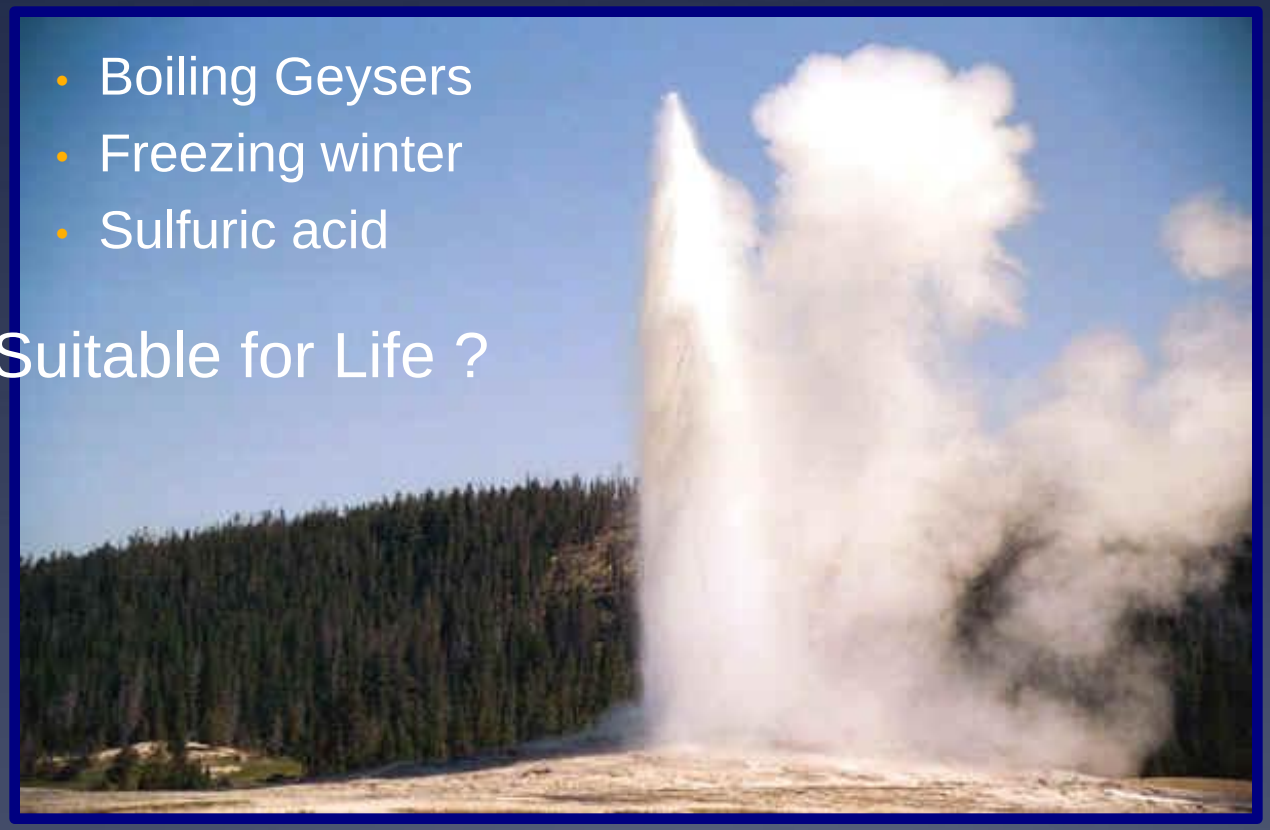
➔ **40 Billion Earth-Size Planets**

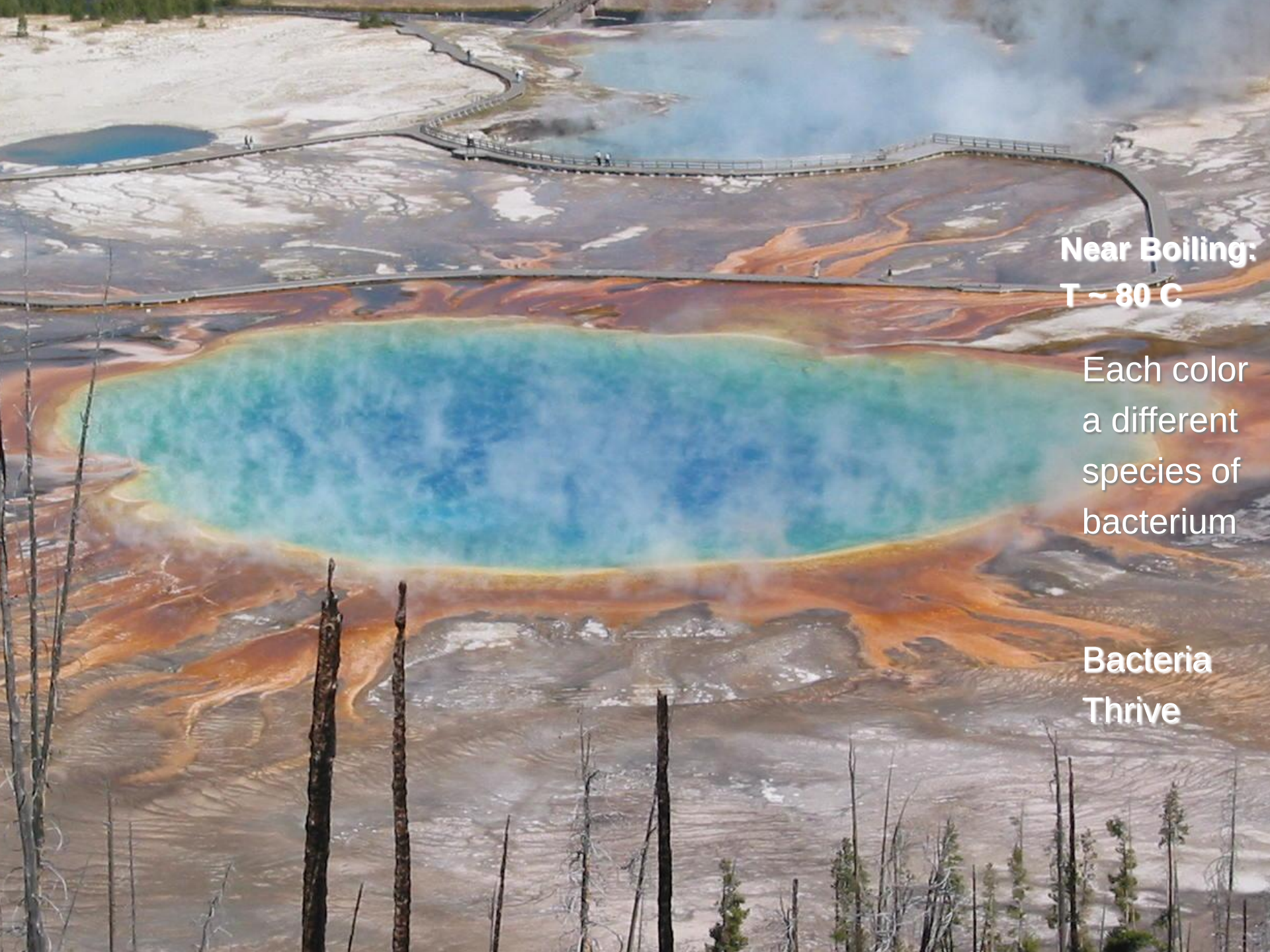
What about "Earth-Like" Planets ?

What properties make a planet suitable for life?

One of the Least Hospitable Places on Earth:

Yellowstone National Park




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

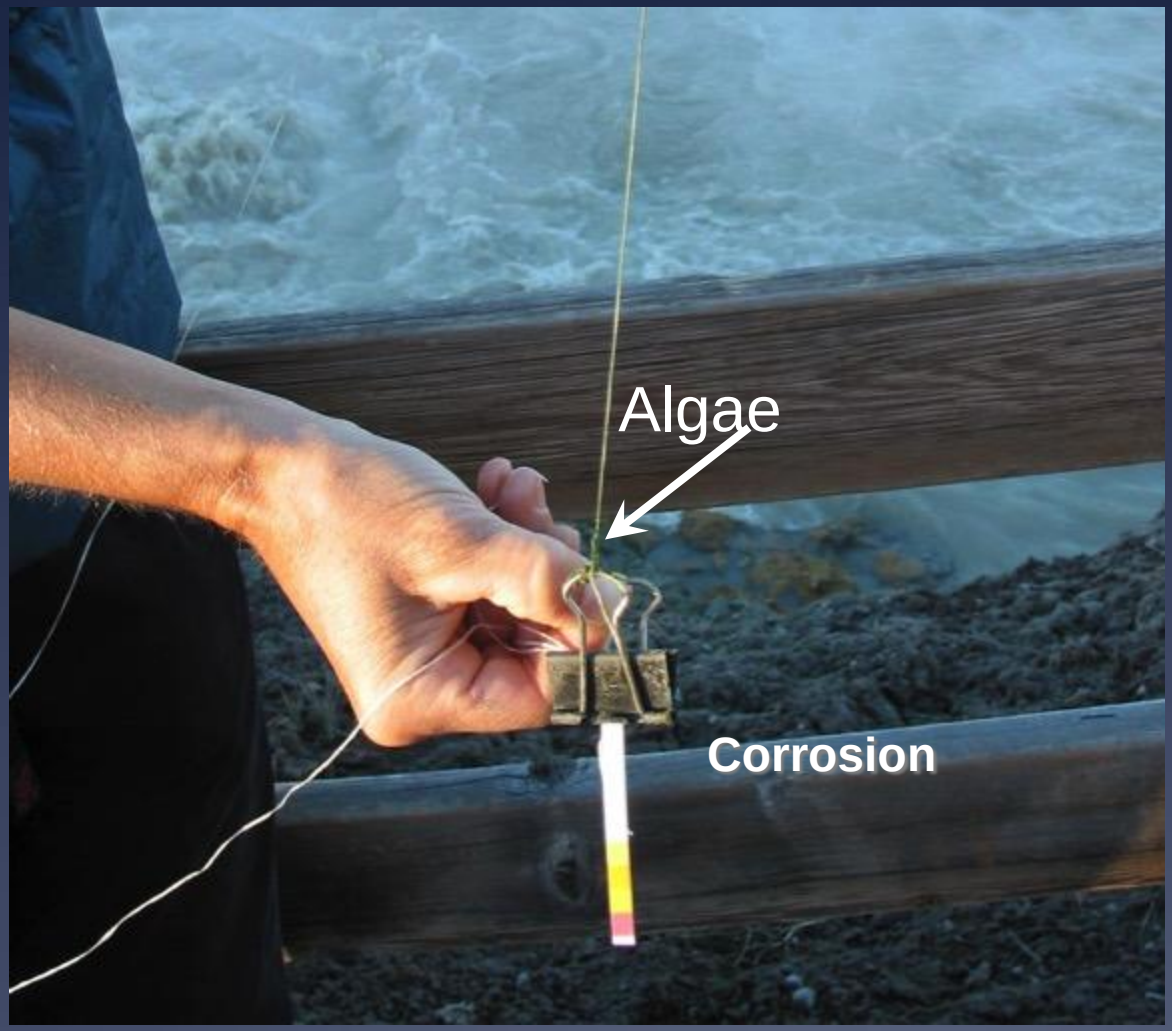
pH = 2

Filamentous bacteria thriving in pH=2.

Yellowstone
Churning Cauldron

Boiling Temp

Yellowstone
Churning Cauldron Hot Spring



pH = 2

Near Boiling Temperature

pH = 2

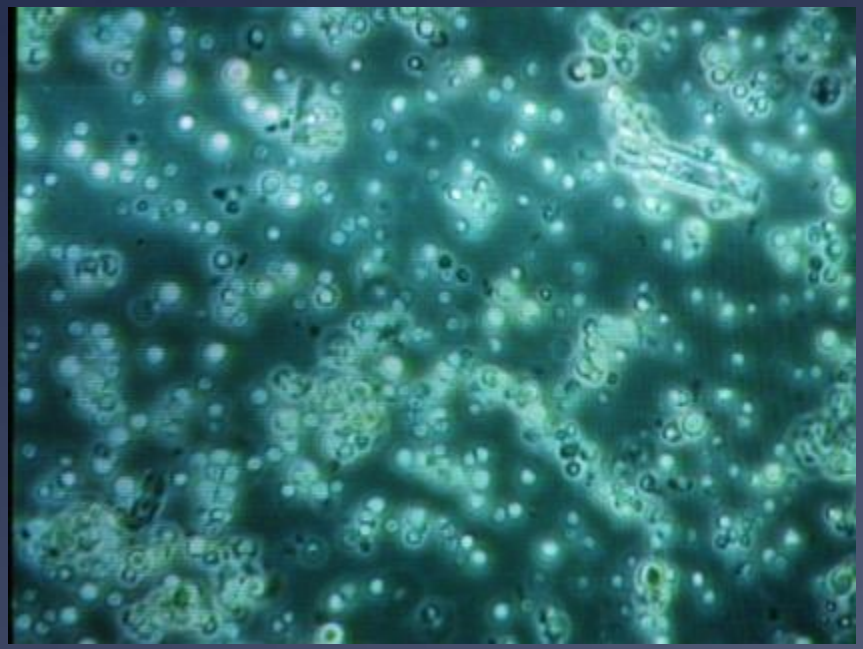
Bacteria & Algae Thrive

Life Thrives at:

Temp = 0 - 75 C

Wide Range of Acidity

Cyanidium Calderium



Lives at Temp > 65 C

Zygogonium sp.

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

Lynn J. Rothschild, 1998

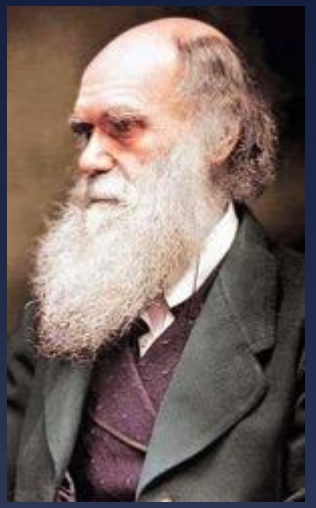
Extremophiles Teach us that Life:

- 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

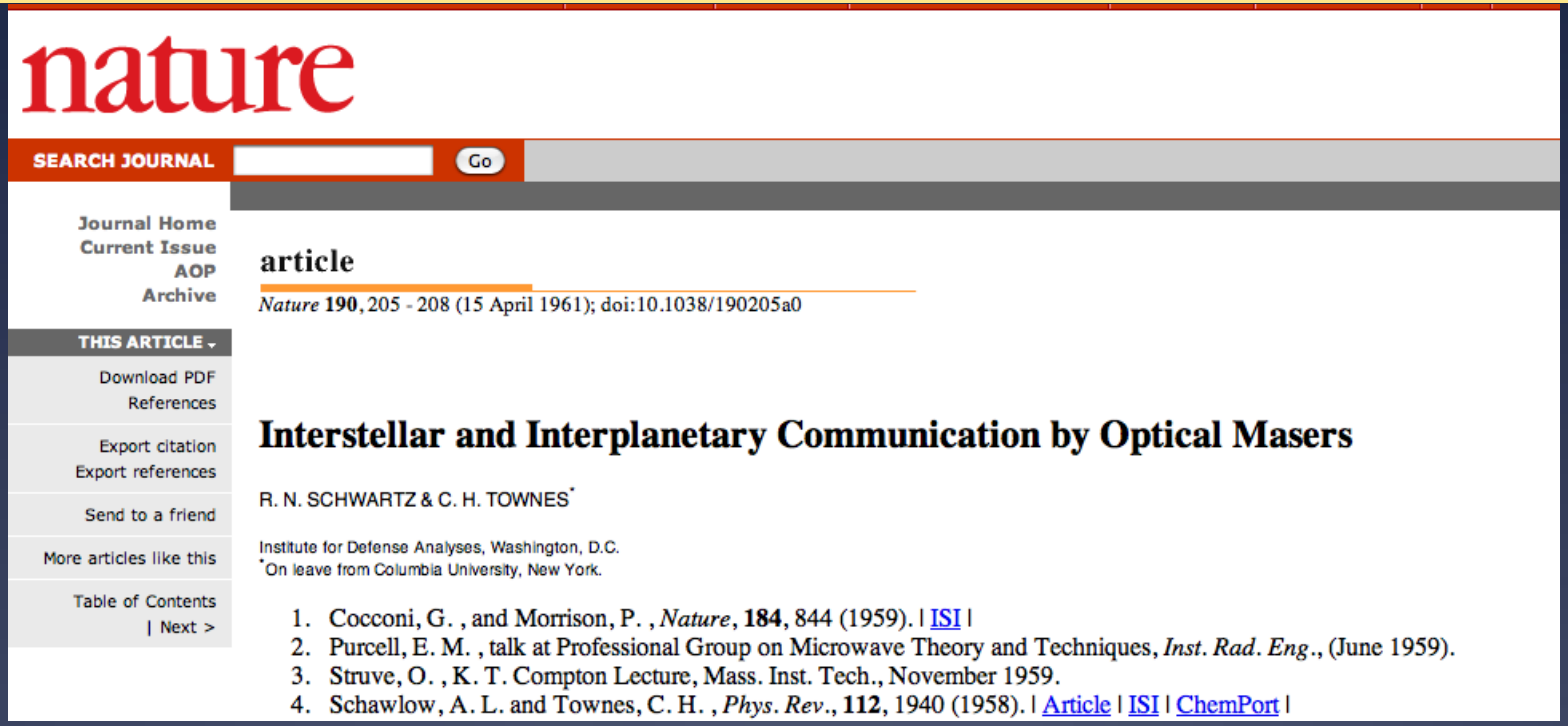
SETI:

Search for Extraterrestrial Intelligence

Method 1:

Search for Visible (Optical) Light
from Advanced Civilizations

Optical SETI:
R.Schwartz & C.Townes
1961



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

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.

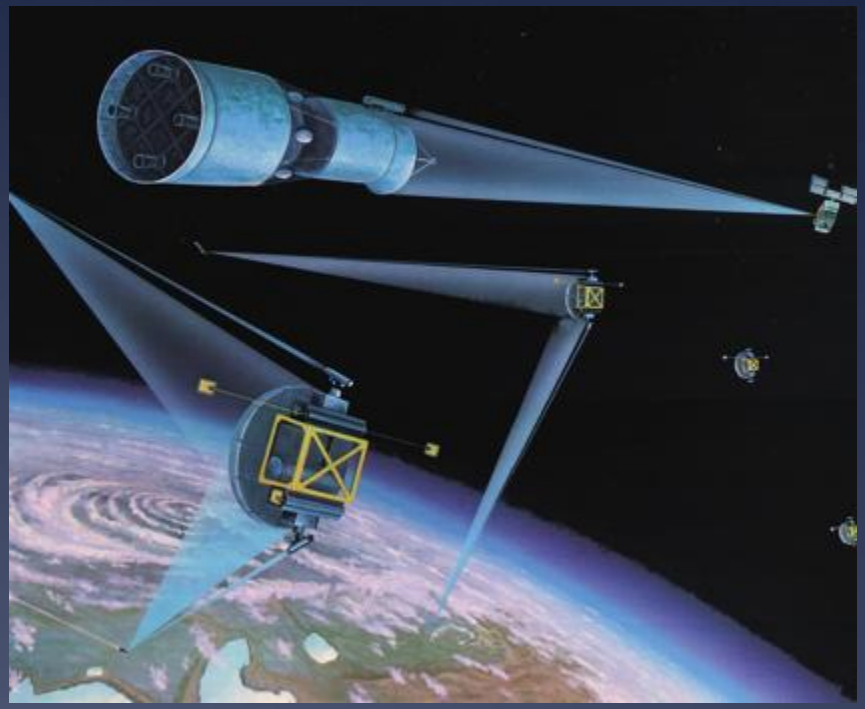
1. Cocconi, G. , and Morrison, P. , *Nature*, **184**, 844 (1959). | ISI |
2. Purcell, E. M. , talk at Professional Group on Microwave Theory and Techniques, *Inst. Rad. Eng.*, (June 1959).
3. Struve, O. , K. T. Compton Lecture, Mass. Inst. Tech., November 1959.
4. Schawlow, A. L. and Townes, C. H. ,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

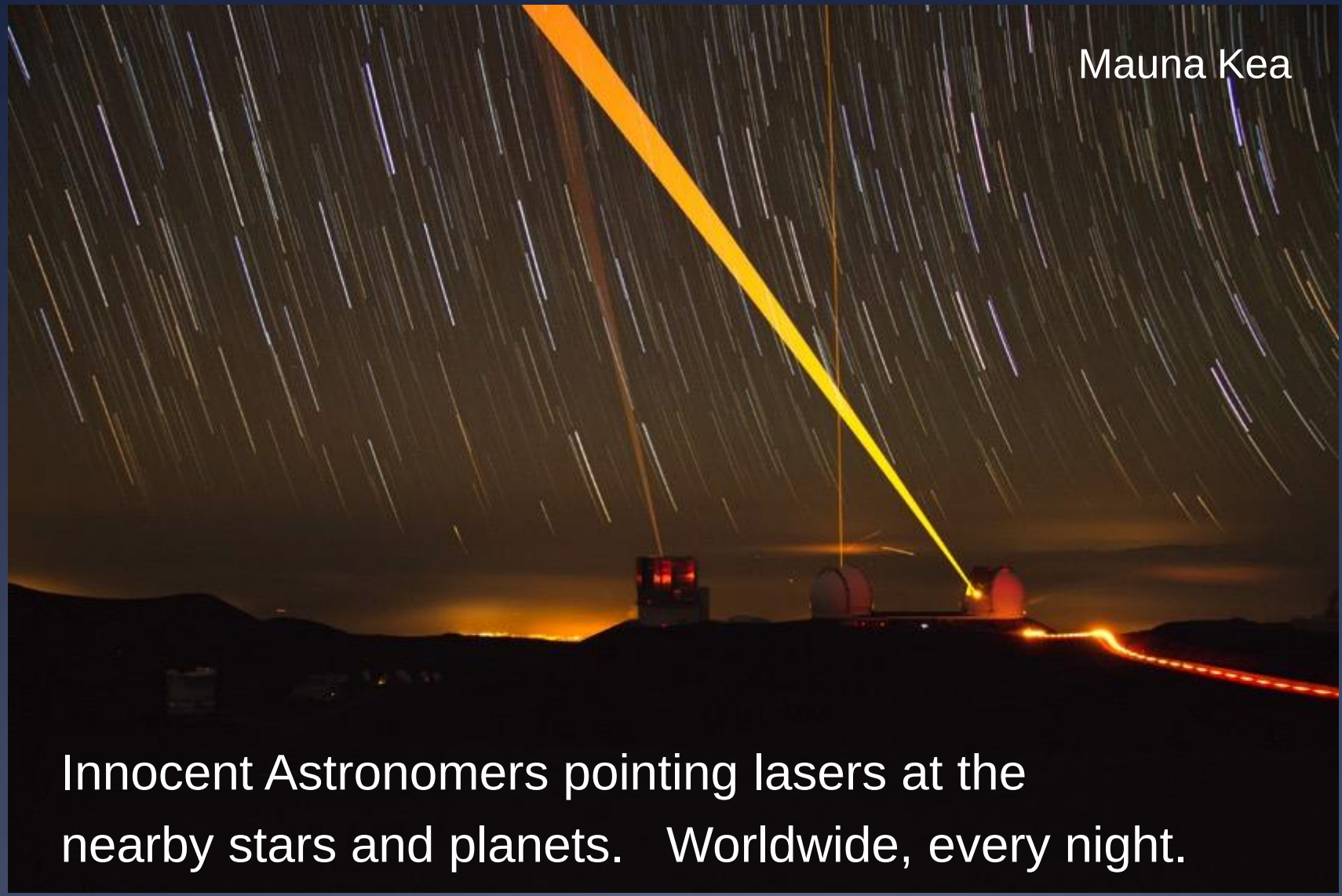


Laser-based data transmission advantages over radio links:

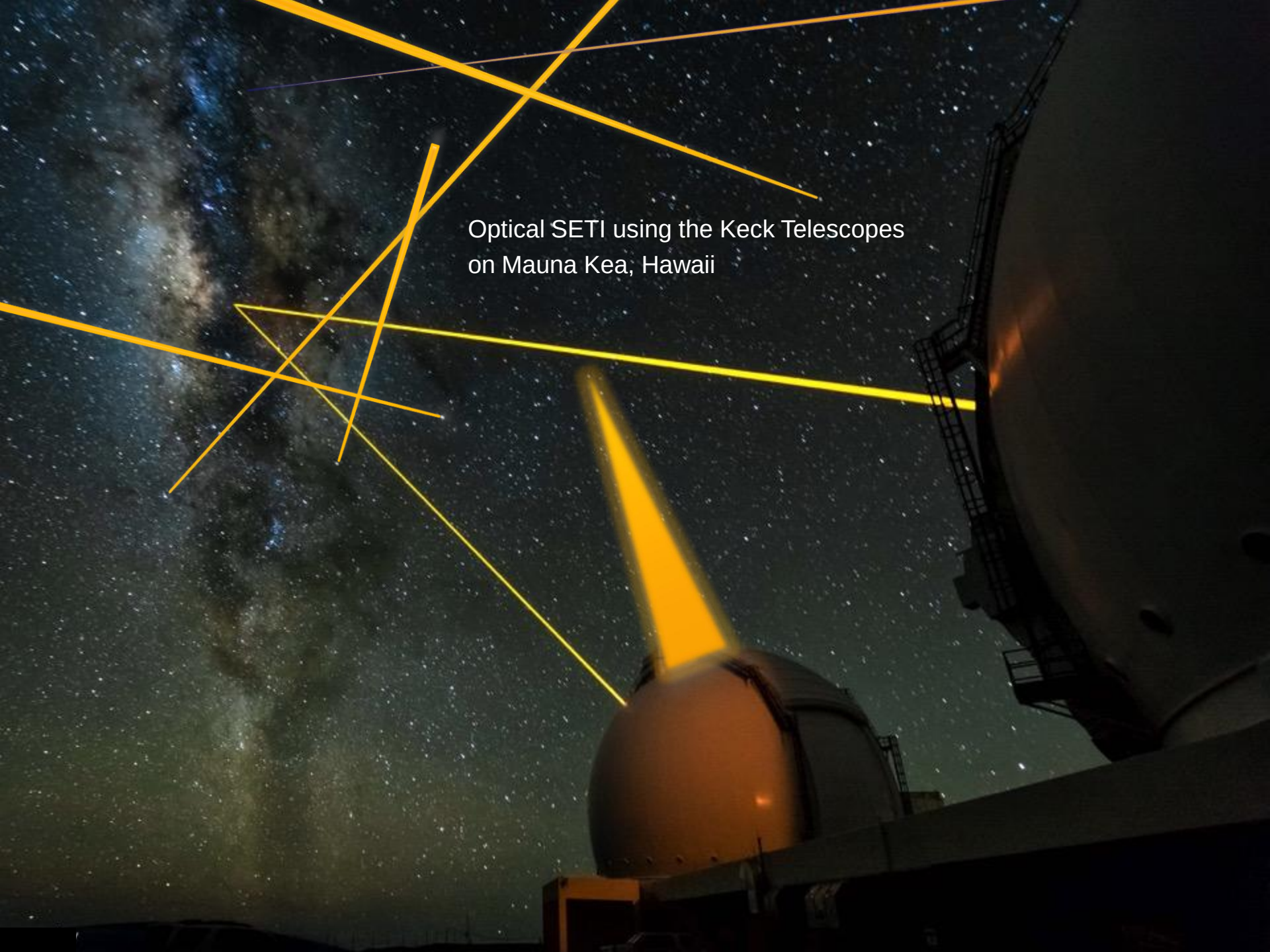
- Shorter wavelengths can achieve higher data rates than radio
- Laser beams are inherently less divergent than radio:

  Less power & More privacy.

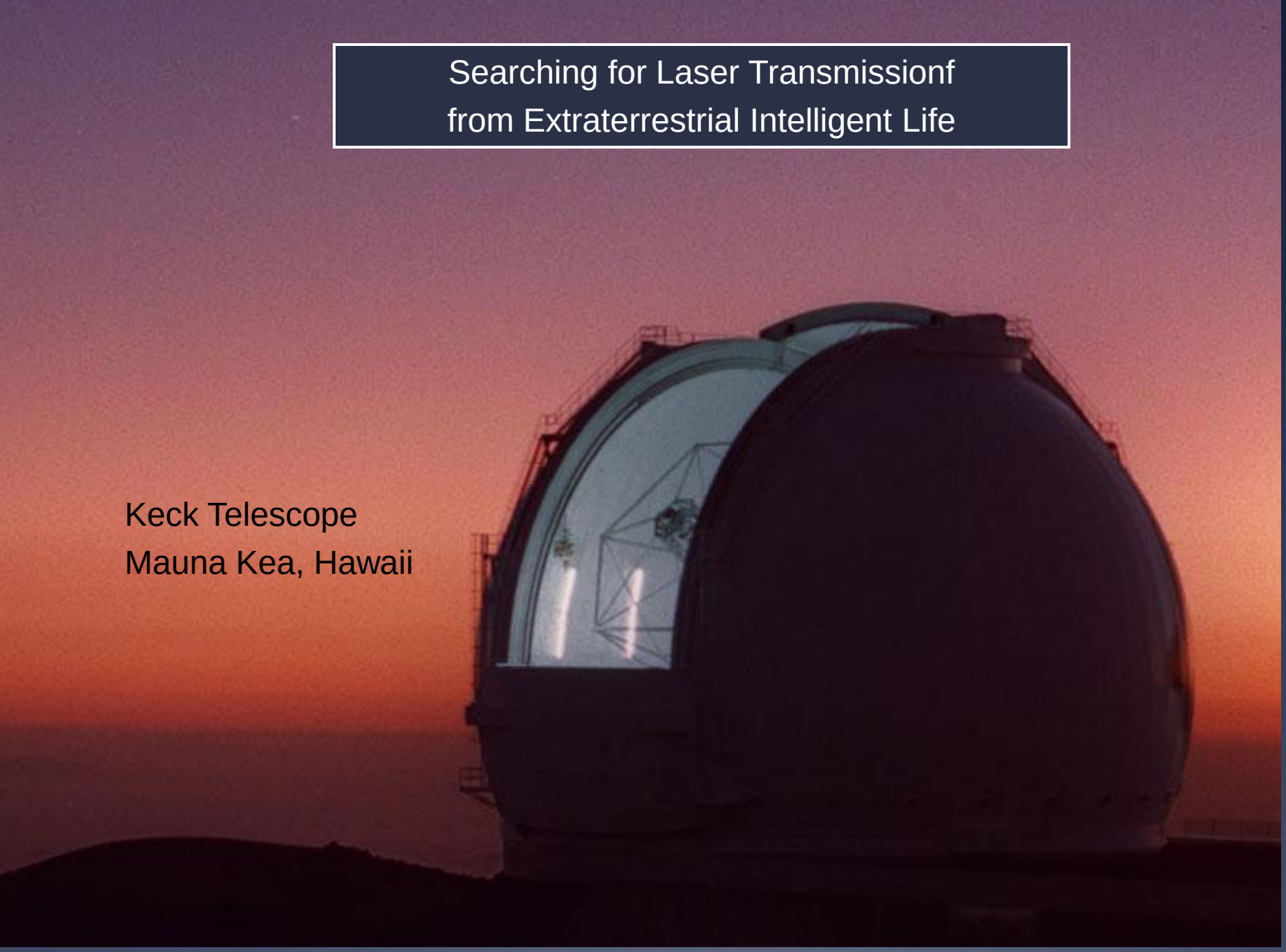
Laser Guide Stars:
Lasers Pointed at Objects of Interest



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


Optical SETI using the Keck Telescopes
on Mauna Kea, Hawaii

Searching for Laser Transmissionf from Extraterrestrial Intelligent Life

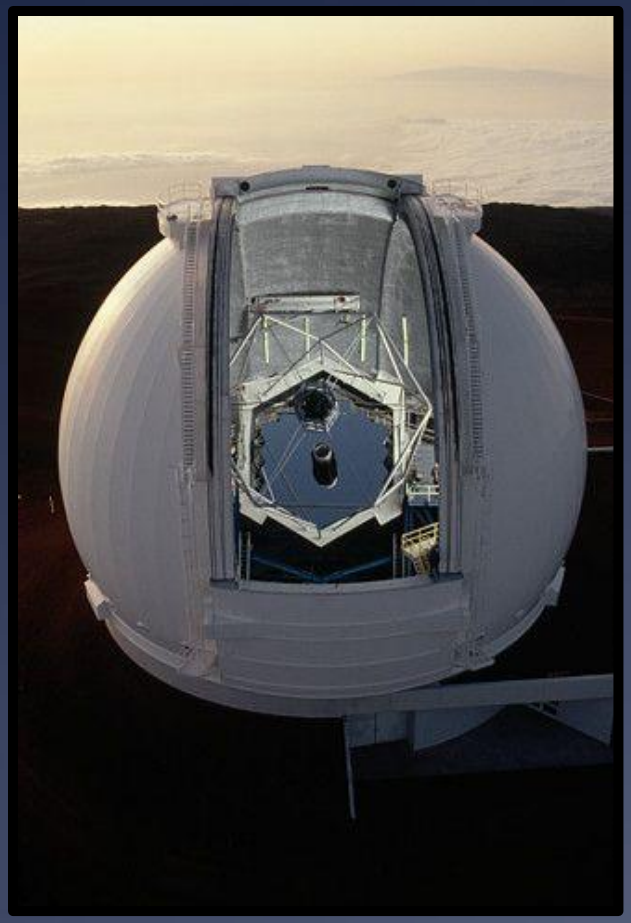


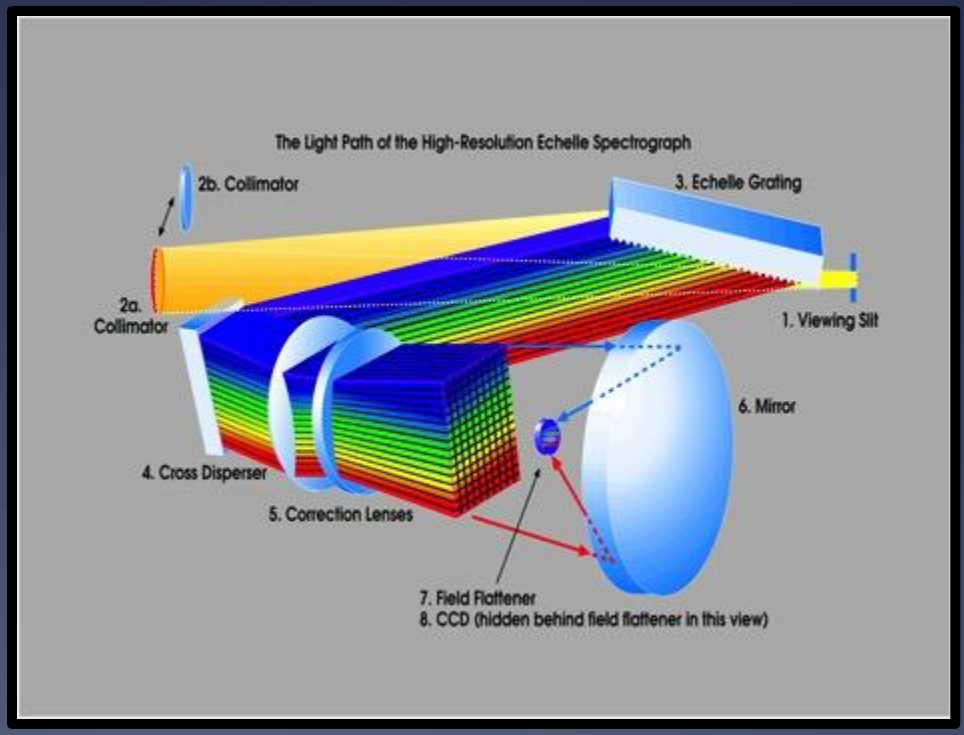
Keck Telescope
Mauna Kea, Hawaii

10-meter Keck Telescope

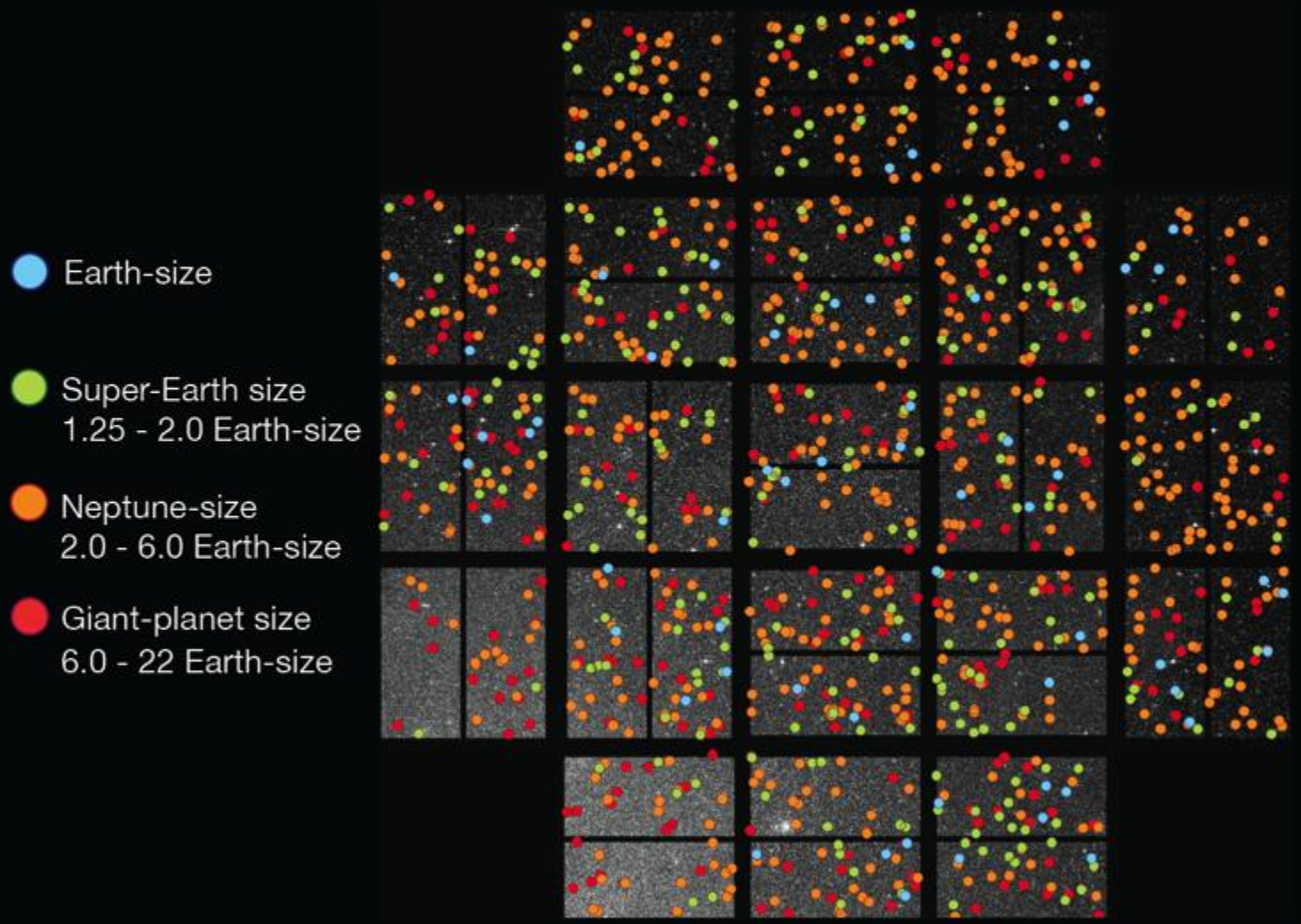
HiRES Spectrometer:

Search for Galactic Laser Internet





Targets:
1500 Kepler Planets
including 400 Multi-Planet Systems



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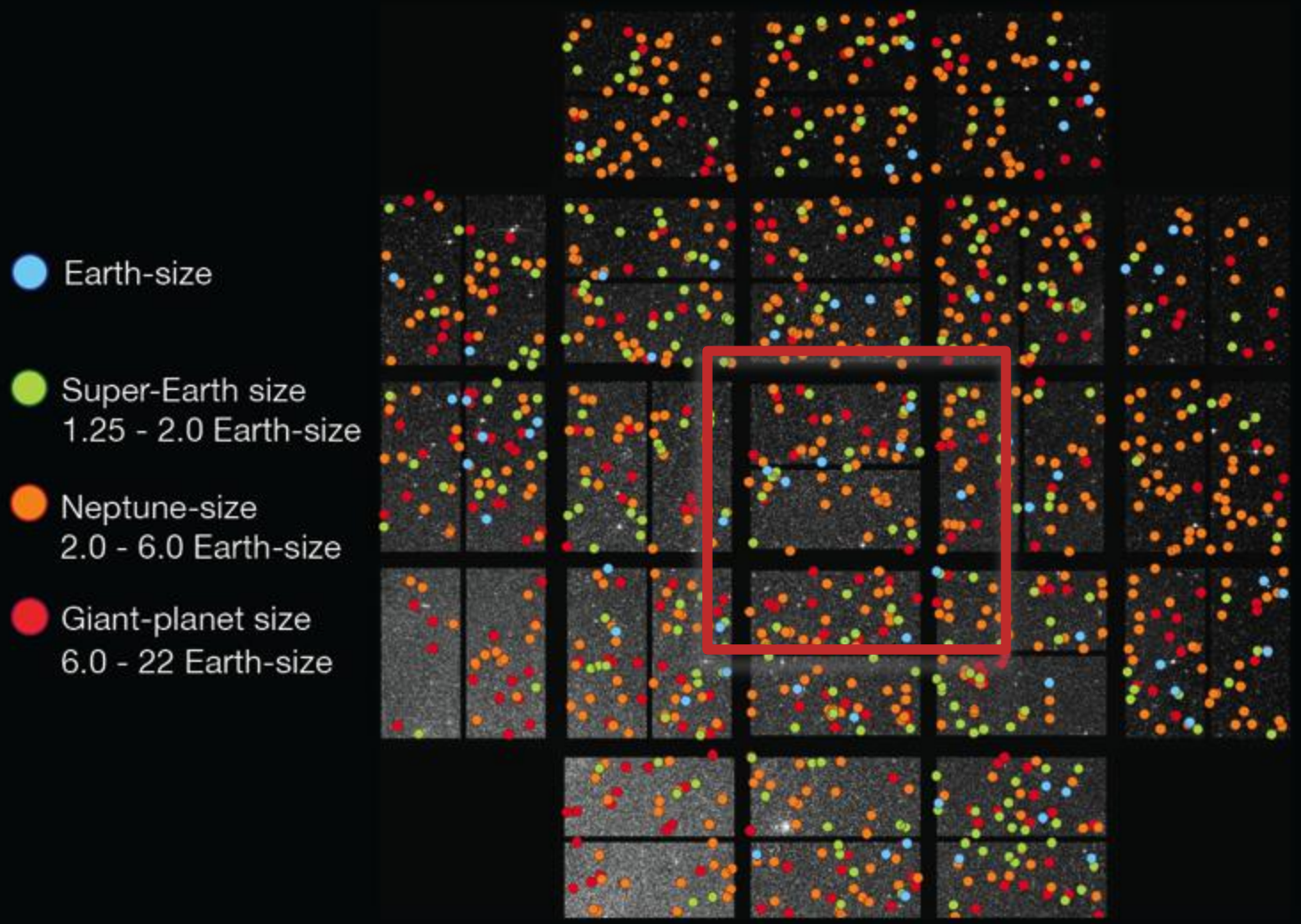
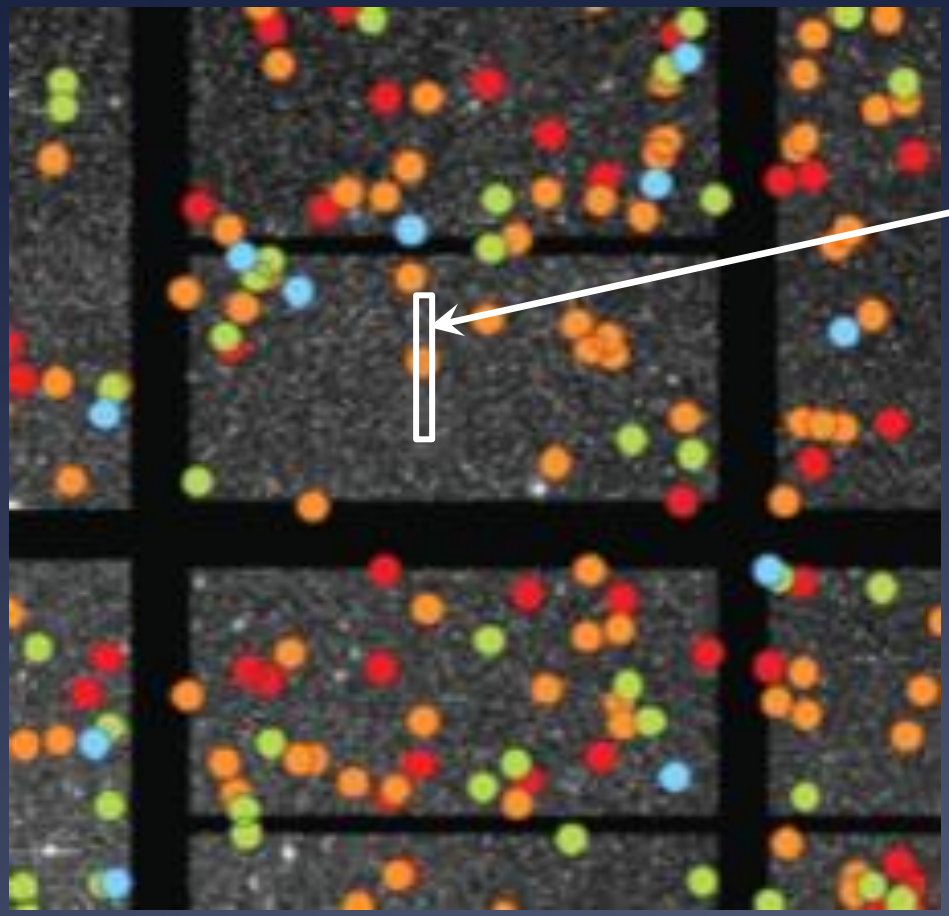
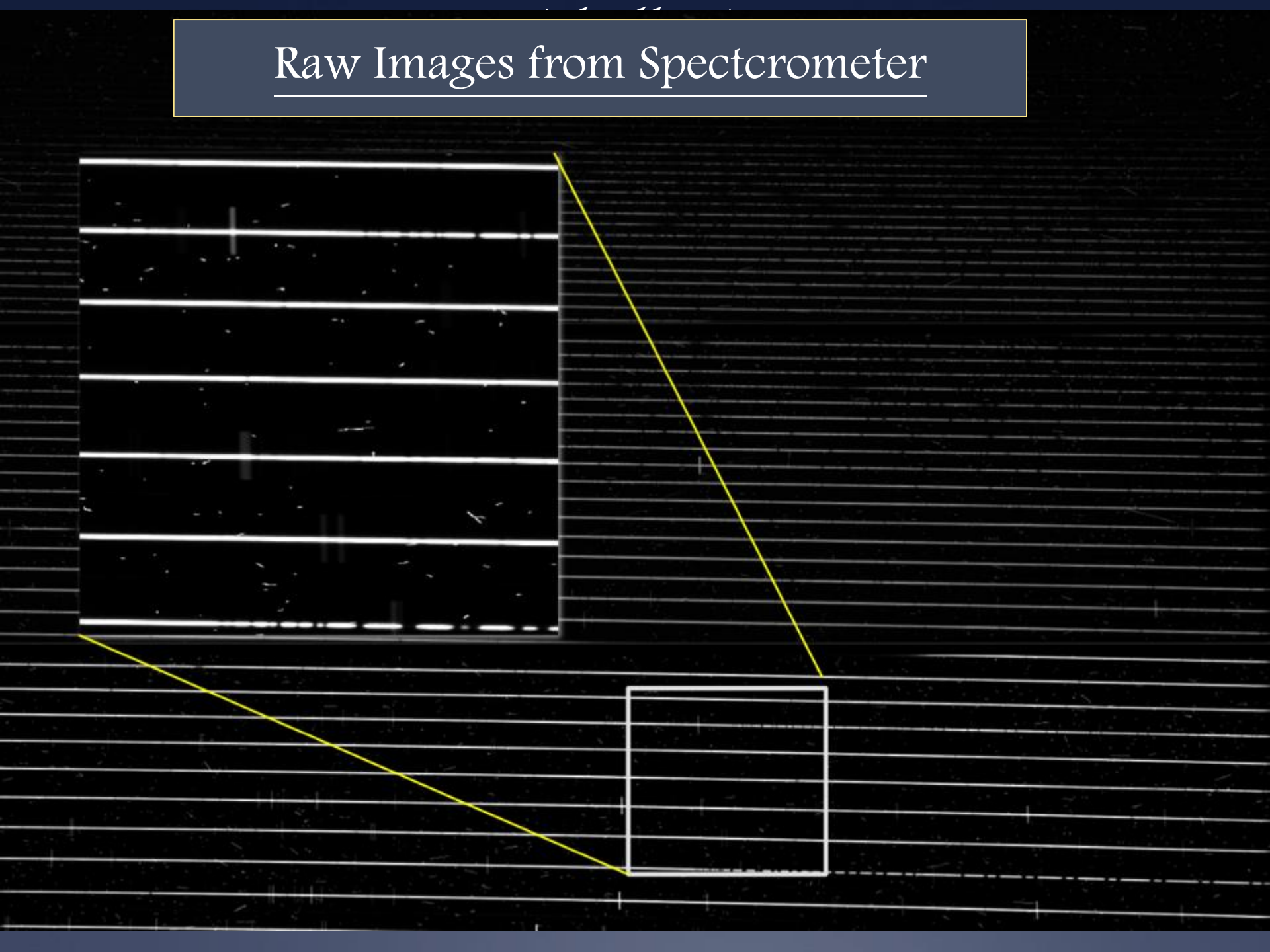




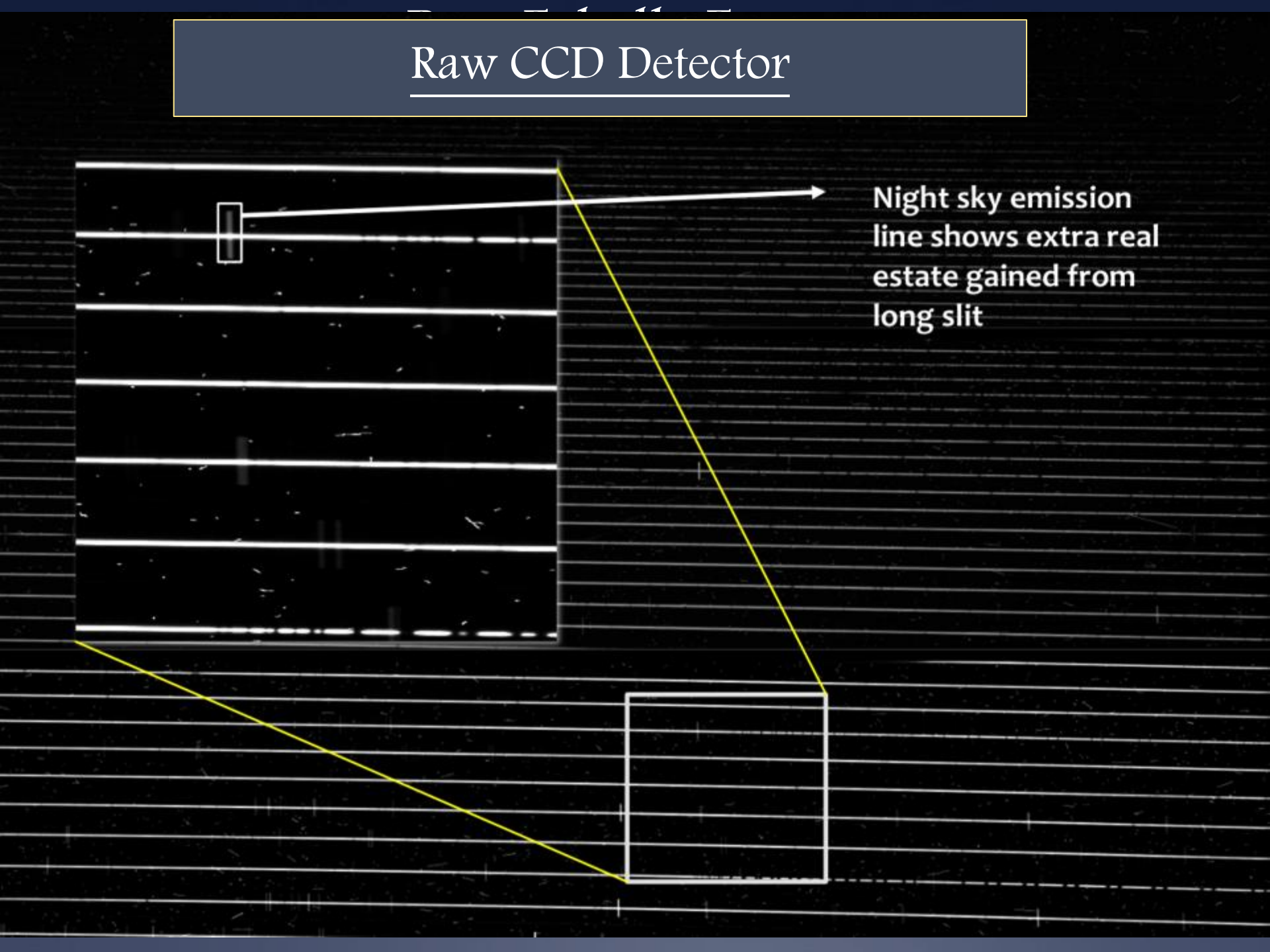
Long slit: 14 arcsec.

A Laser located anywhere along slit will be detected.

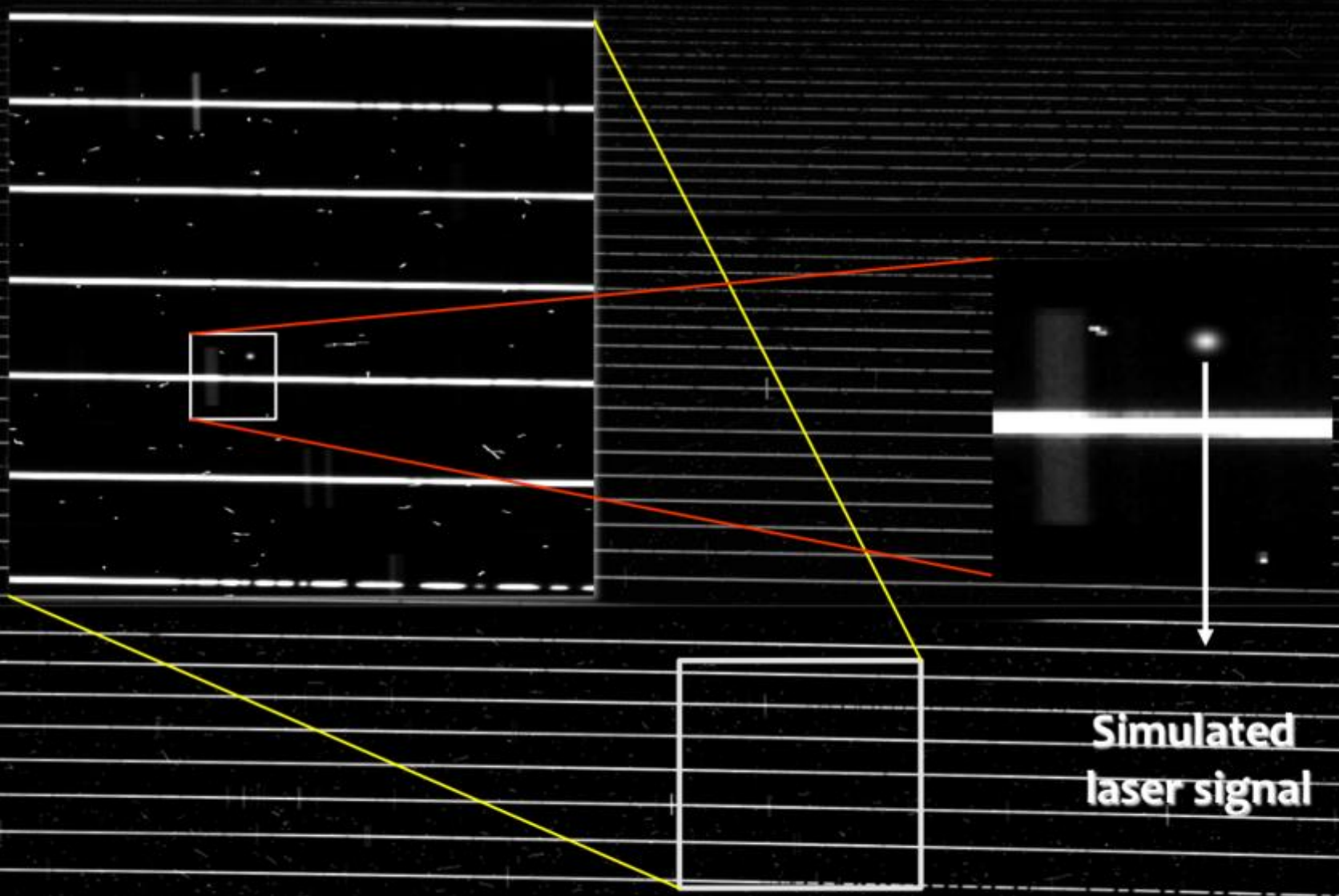
Raw Images from Spectcrometer



Raw CCD Detector



Raw CCD Detector



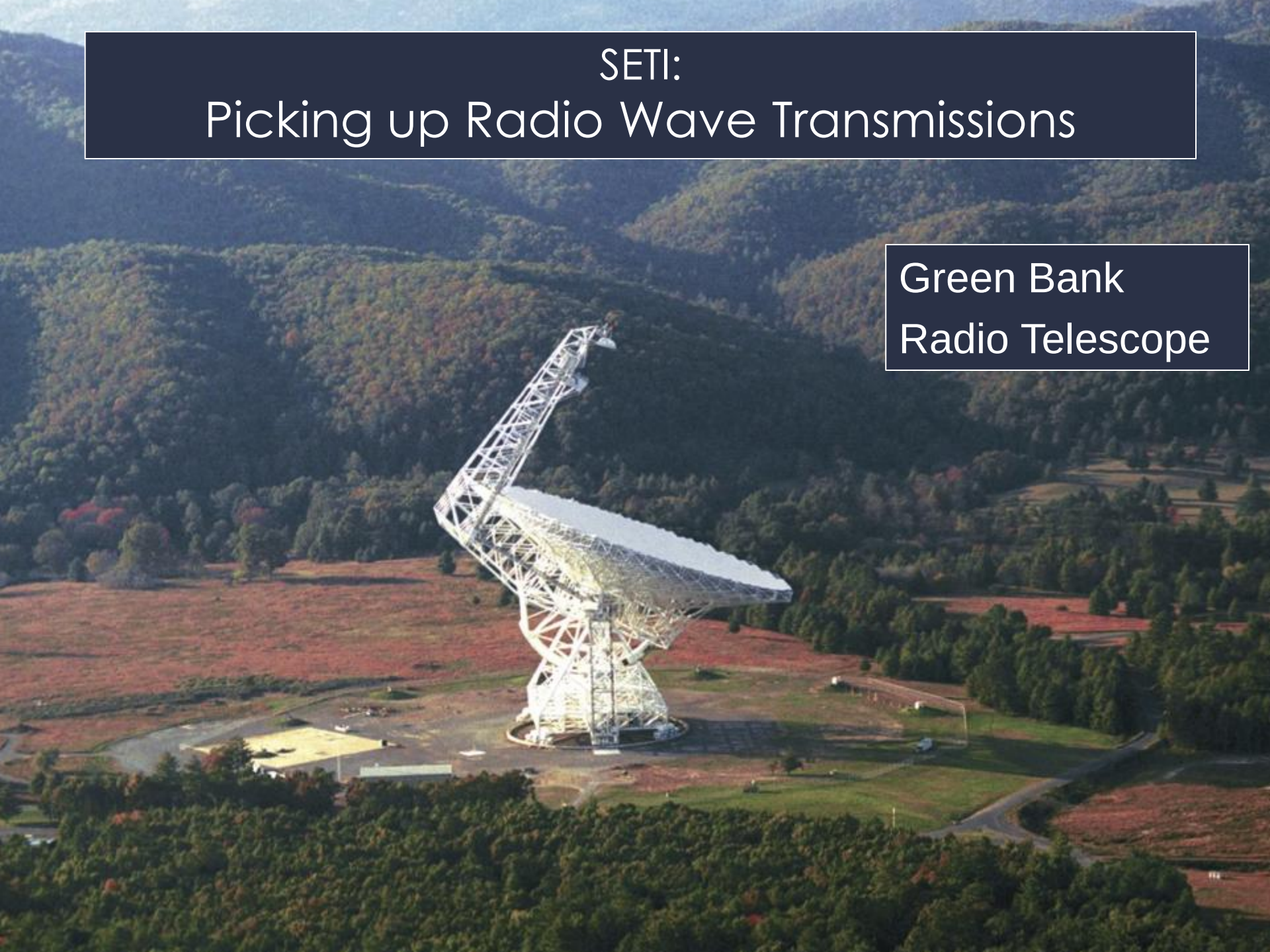
SETI:

Search for Extraterrestrial Intelligence

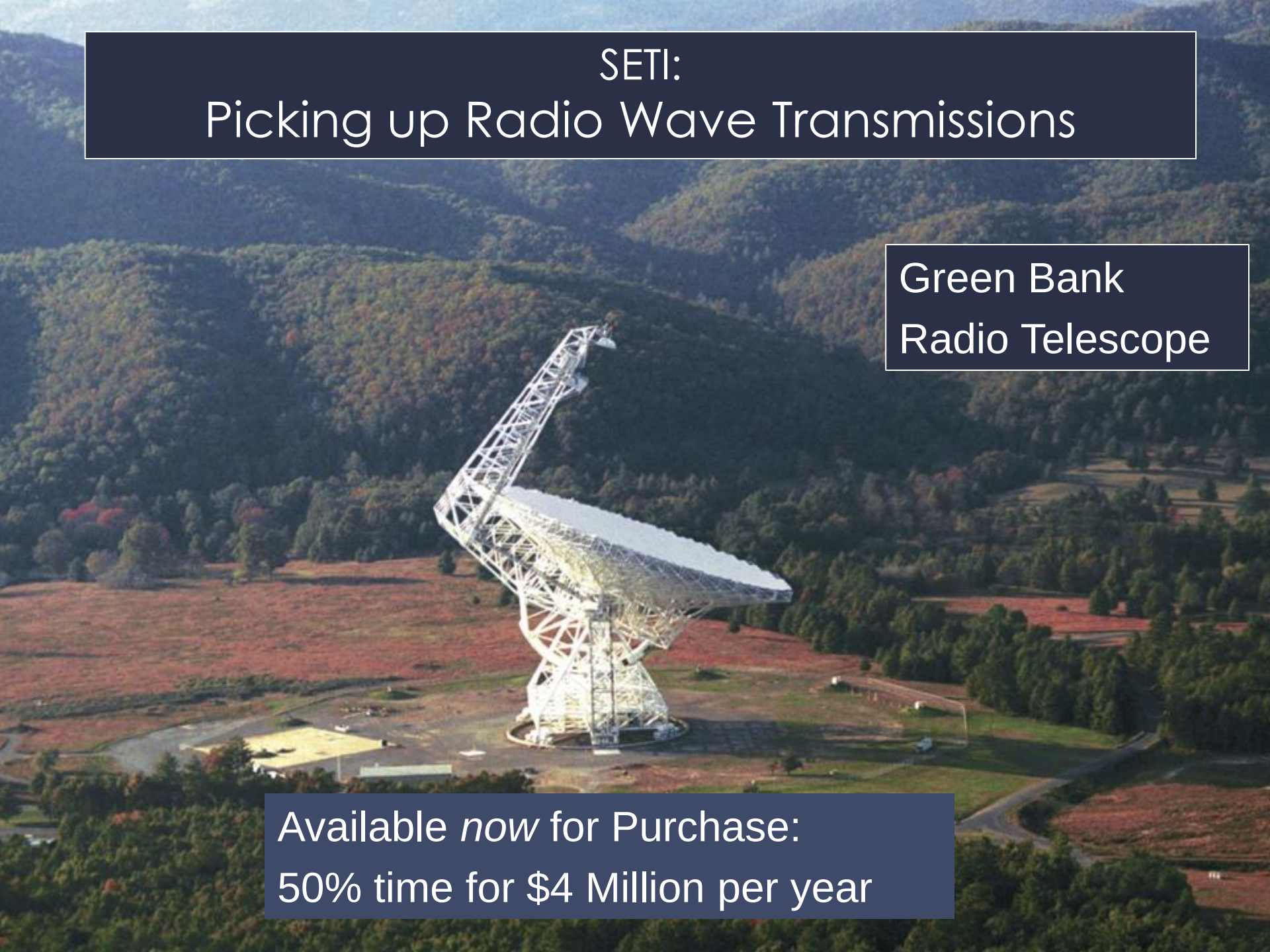
Method 2:

Search for Radio Waves
from Advanced Civilizations

SETI:
Picking up Radio Wave Transmissions



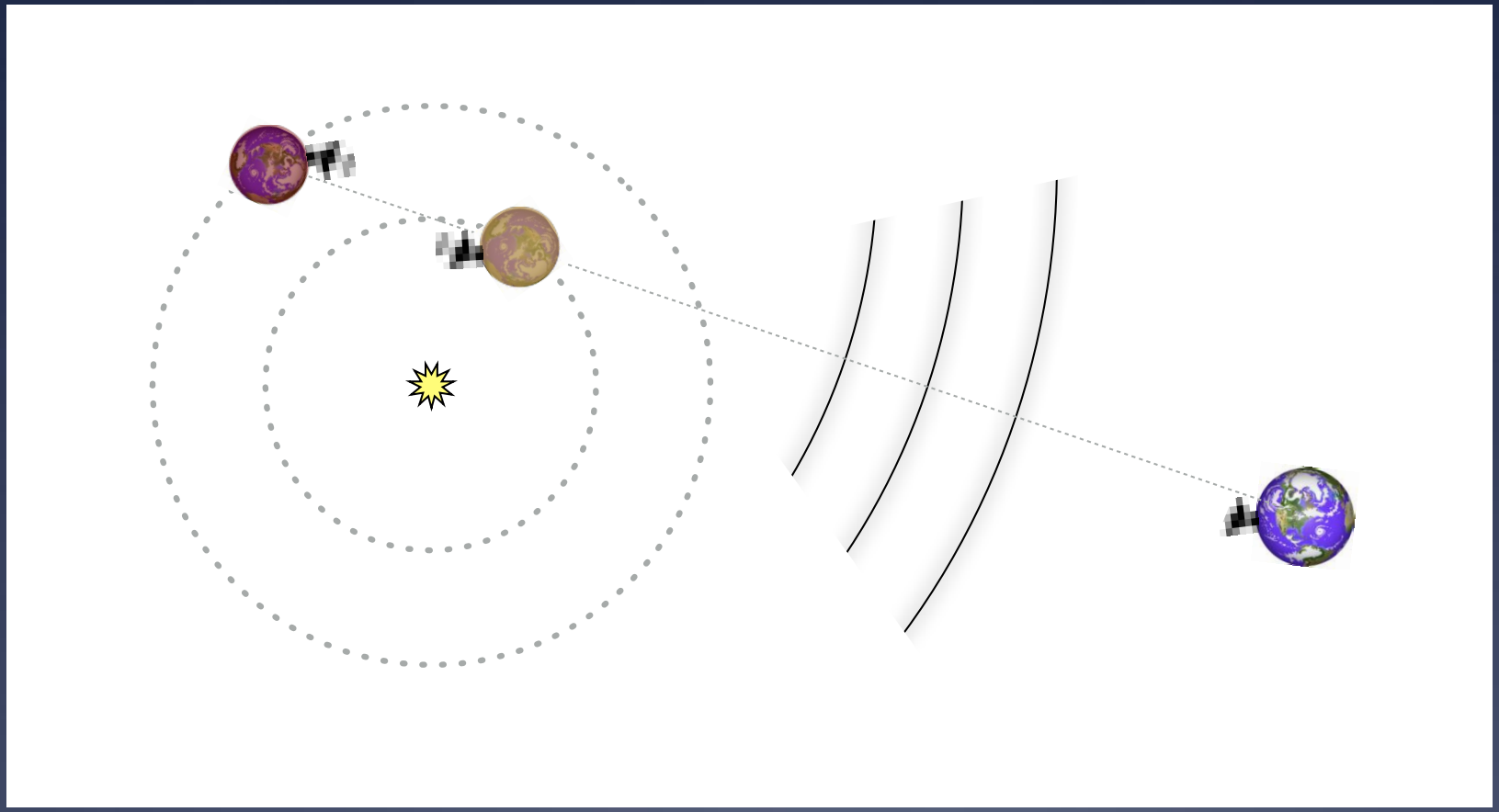
SETI:
Picking up Radio Wave Transmissions



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