Anyone Out There?

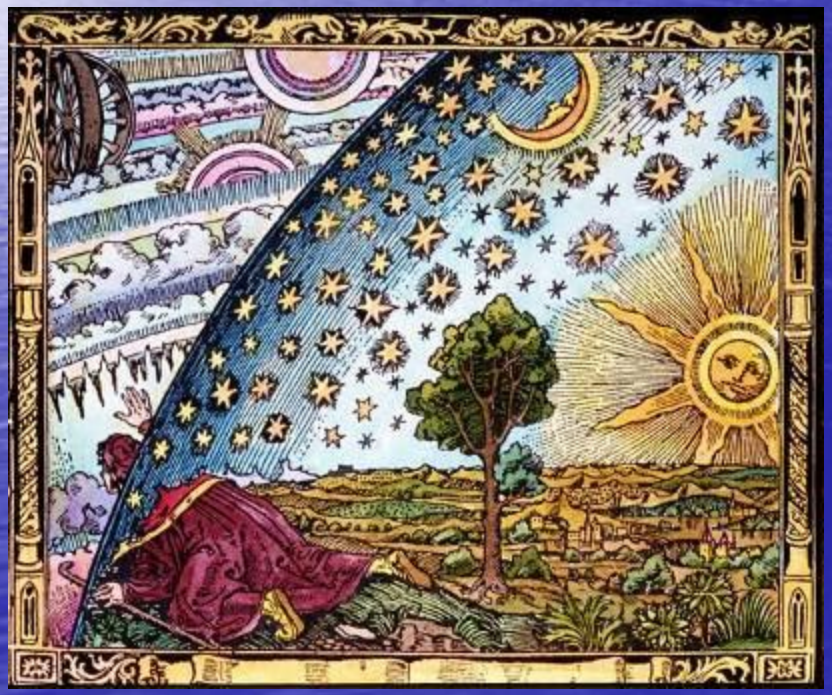
Exploring the questions and some of the Scientific Method in the Study of Life Existing Beyond Earth

Astronomy Course Outline

Week 1: The Sky | Week 2: The Planets | **Week 3: The Stars** | Week 4: History of Astronomy | Week 5: Telescopes | Week 6: Deep Sky Objects | Week 7: Cosmology | Week 8: Alien Worlds

Some Early thoughts On Life Beyond Earth

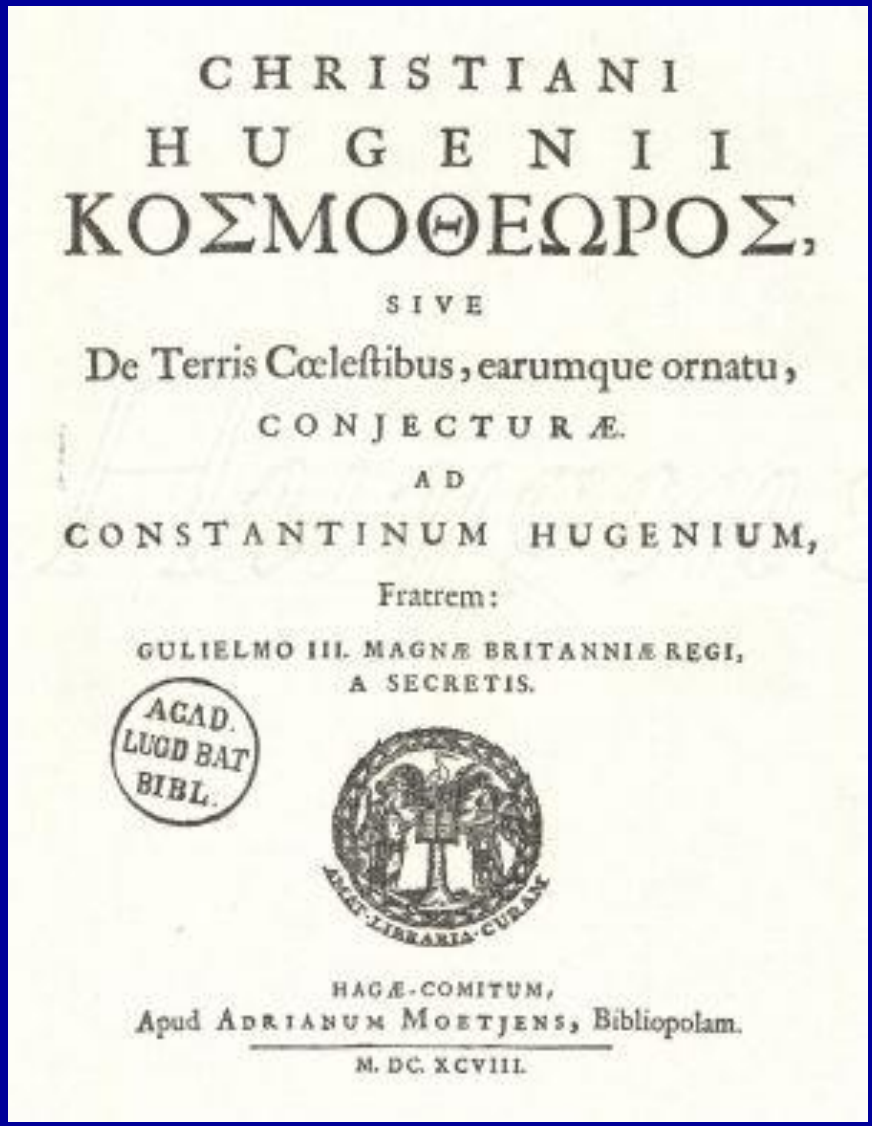
Humans have been asking since the beginning of recorded history.



"In the universe, nothing is the only of its kind. In other regions, surely there must be other Earths, other men, other beasts of burden."
Lucretius, 1st century BC

Christiaan Huygens' *Cosmotheoros* (1698)

- During the last years of his life, Christiaan Huygens worked on a "philosophical treatise", addressed to his brother Constantijn, which contained his speculations on the construction of the universe and the habitability of the planets as deduced from his own observations and those of other astronomers of his time.
- Using the powers of observation available to him, he theorized that the inhabitants of Jupiter and Saturn (he used the term "Planetarians") must possess "the Art of Navigation," especially "in having so many Moons to direct their Course…. And what a troop of other things follow from this allowance? If they have Ships, they must have Sails and Anchors, Ropes, Pillies, and Rudders…"


CHRISTIANI
HUGENII
KOΣMOΘEΩPOΣ,
SIVE
De Terris Cœleſtibus, earumque ornatu,
CONJECTURÆ.
AD
CONSTANTINUM HUGENIUM,
Fratrem:
GULIELMO III. MAGNÆ BRITANNIÆ REGI,
A SECRETIS.
ACAD. LUGD BAT BIBL.
HAGÆ-COMITUM,
Apud ADRIANUM MOETJENS, Bibliopolam.
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What is Earthly Life Itself?

- Is it a mechanical process?
- Is it supernatural?
- Or is it a complex system that "emerges" and how so? From laws of chemistry, genetics, evolution? What, if anything, "guides" life?

Digesting Duck

The Canard Digérateur, or Digesting Duck, was an automaton in the form of a duck, created by Jacques de Vaucanson and unveiled on 30 May 1739 in France. The mechanical duck appeared to have the ability to eat kernels of grain, and to metabolize and defecate them. Wikipedia

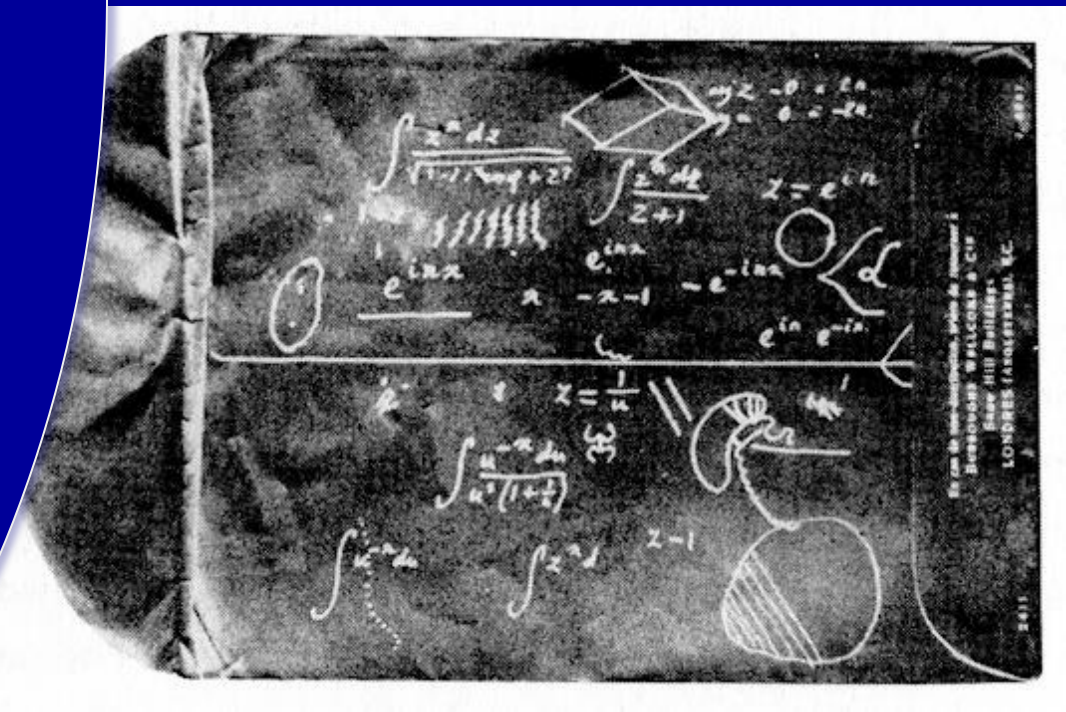
Some things to keep in mind

- We invariably fail to imagine what we fail to imagine
- The universe is not only stranger than we suppose but stranger than we can suppose
- The phenomenon in the universe are not a static collection of parts moving about on independent "tracks" so to speak but a dynamic, complex and often self-adaptive system.
- Life emerging may very well be an emergent feature given the right alignment of variables (heat, time, elements present, etc)

"Where is Everybody?" - The Fermi Paradox and Possibility of Extraterrestrial Life

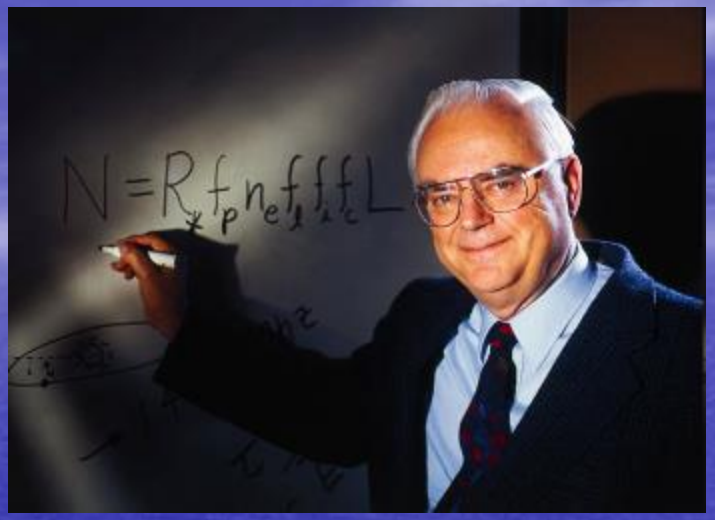
- 1950, Los Alamos National Laboratory New Mexico.

  A group of scientists, Enrico Fermi and Edward Teller among them, are sitting at a table, discussing the some of the deepest mysteries of physics. They are on a lunch break at the facility where the foundations of modern nuclear physics were formed. Suddenly during the conversation, in an apparent juxtaposition, Fermi asks "Where is Everybody?". Surprisingly, the rest of the scientists know exactly what he means, to quote Edward Teller "The result of his question was general laughter because of the strange fact that in spite of Fermi's question coming from the clear blue, everybody around the table seemed to understand at once that he was talking about extraterrestrial life."



Frank Drake

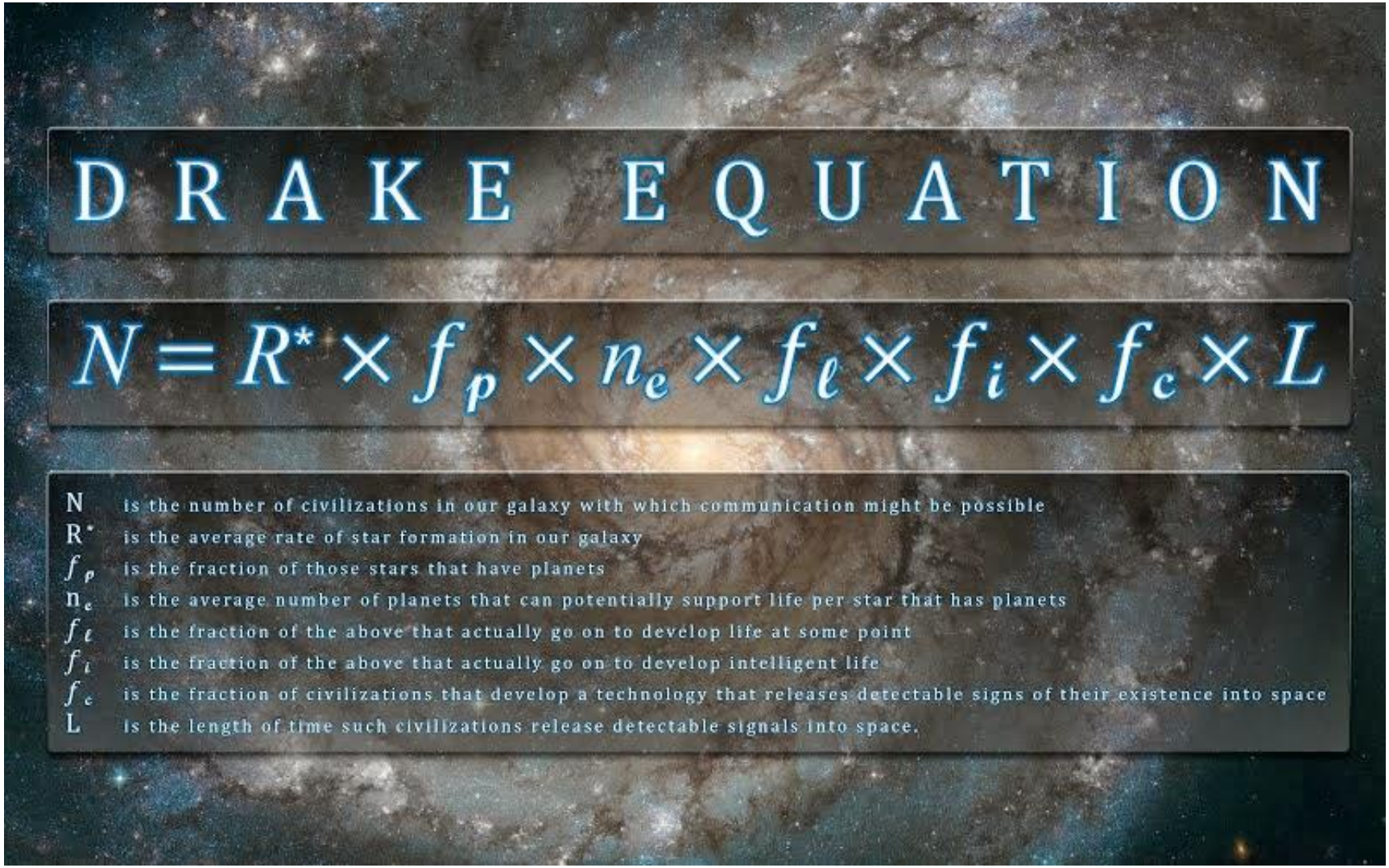
In the 1960's ET stepped out of science fiction



Drake presented a thought experiment,

not a scientific equation.

It is designed to inspire thought, dialogue and quantify expectations based on things we can observe with certainty (I.e. not counting UFO sightings etc)


DRAKE EQUATION
$N = R^* \times f_p \times n_e \times f_\ell \times f_i \times f_c \times L$
N is the number of civilizations in our galaxy with which communication might be possible
R^* is the average rate of star formation in our galaxy
f_p is the fraction of those stars that have planets
n_e is the average number of planets that can potentially support life per star that has planets
f_ℓ is the fraction of the above that actually go on to develop life at some point
f_i is the fraction of the above that actually go on to develop intelligent life
f_c is the fraction of civilizations that develop a technology that releases detectable signs of their existence into space
L is the length of time such civilizations release detectable signals into space.

"The Drake Equation"

- 7 variables that allow us to get an estimate of probability of intelligent, communicating life in our galaxy (N)

- Important to note, this is just a guess!

$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

N* Number of Stars in the Milky Way Galaxy

- This is the factor we actually have a decent handle on
- For scientists, that means we are fairly certain that there are between 100-500 billion stars in the Milky Way

$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

Extra Criterion for Stars

Easy to find

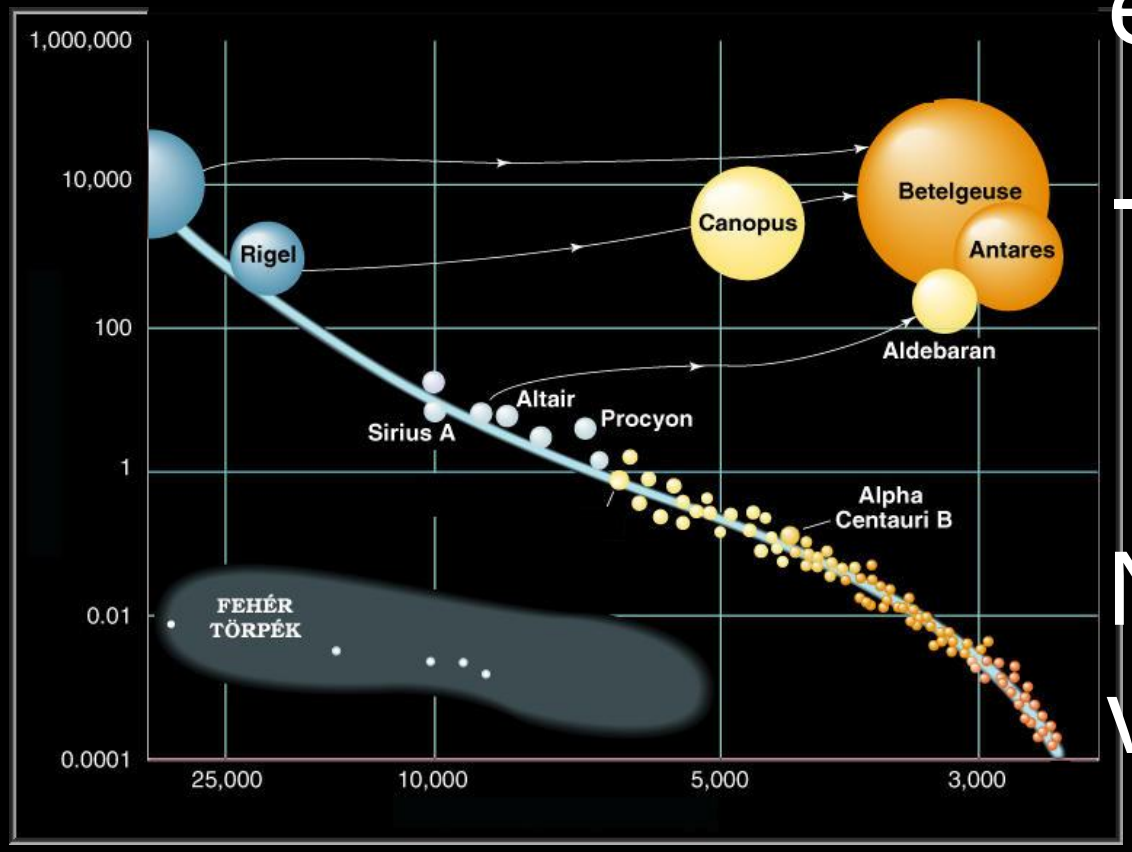
Not too Bright

(as to hide

Potential

planets in glare)

Not all stars are suitable



Last long enough

-not Giants

Not hugely variable

-not Dwarves

f_p What Fraction of Stars Have at Least One Planet?

- Current estimates:

  about 10% to 50%
  of all stars have at least 1 planet

- Scientists are refining this estimate all the time with missions like Kepler

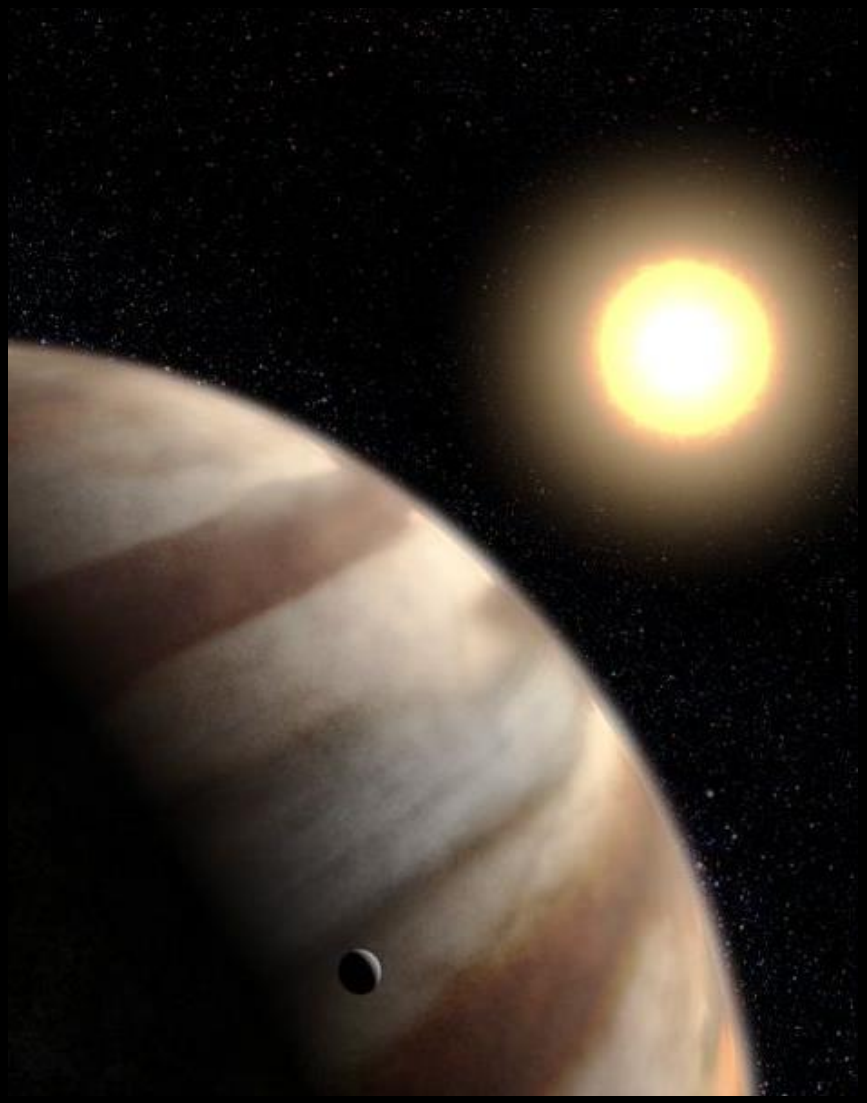
$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

Habitable exoPlanets

Smaller than Neptune

Hard to find

Don't generate light and are more affected by host stars glare



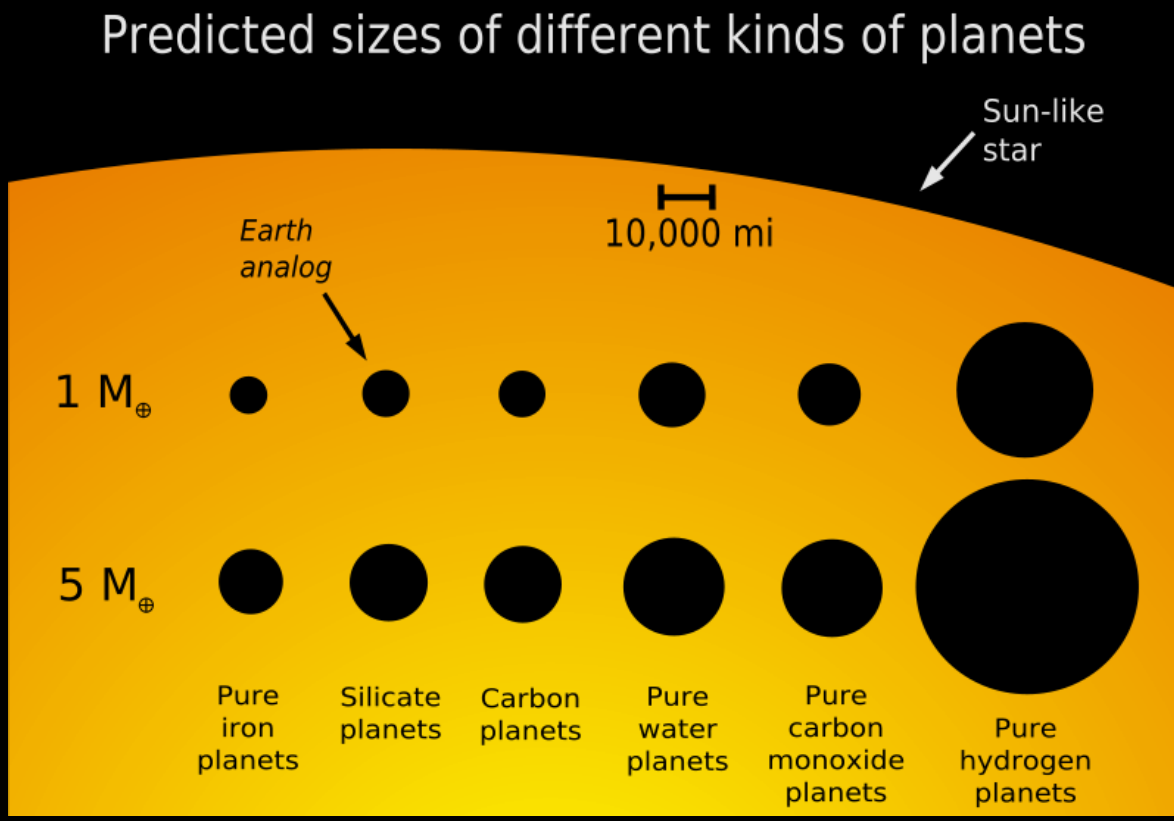
Planets – Transit

Planet moves between us and star

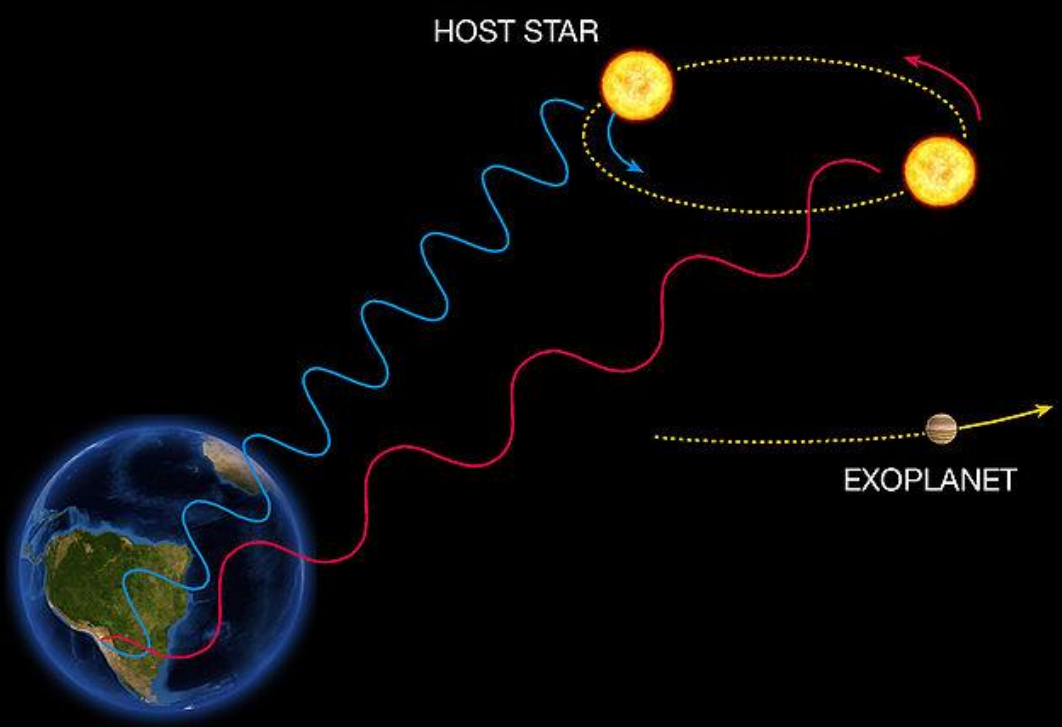
Faint dip in brightness – star still a point!

Learn a lot from a transit

Will also have



Planets – Radial Velocity

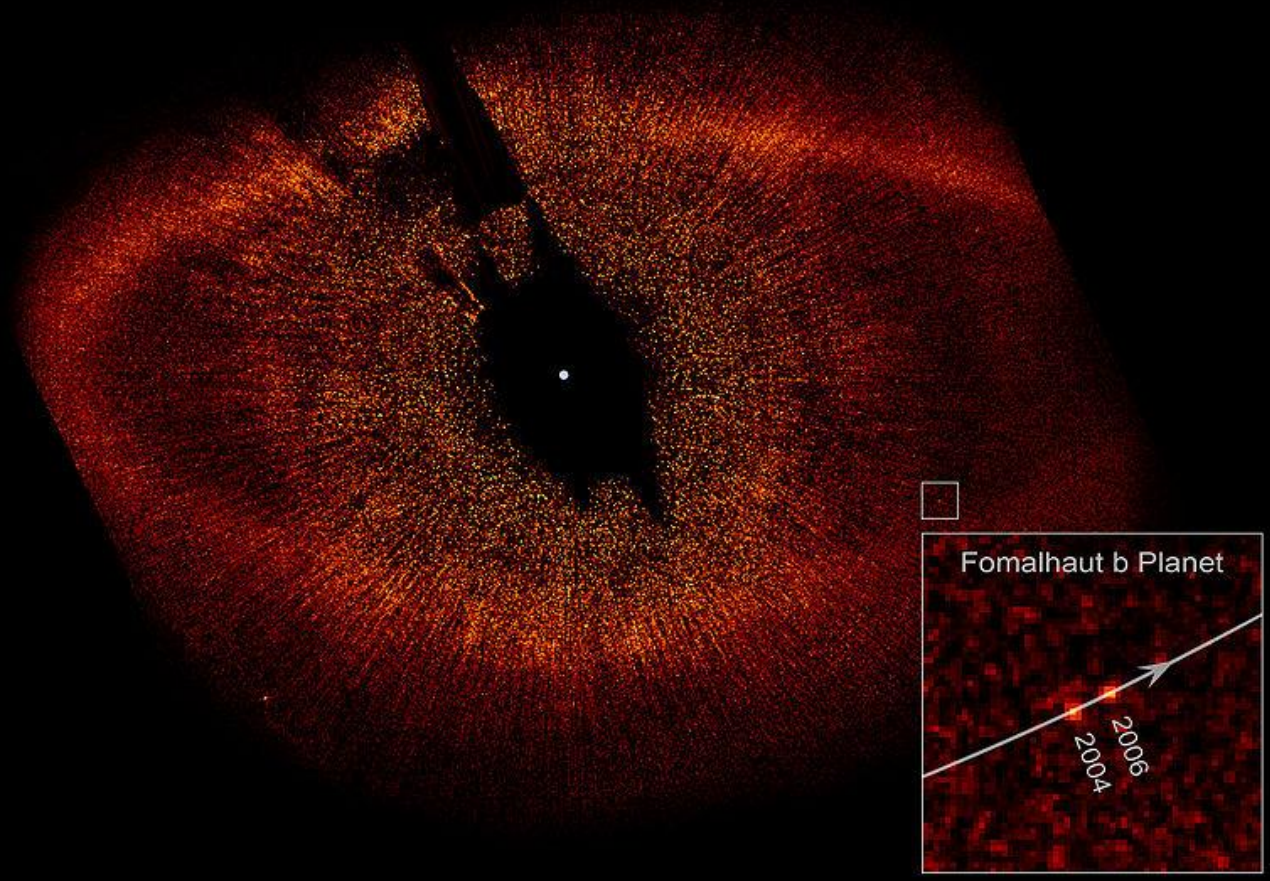


The Radial Velocity Method

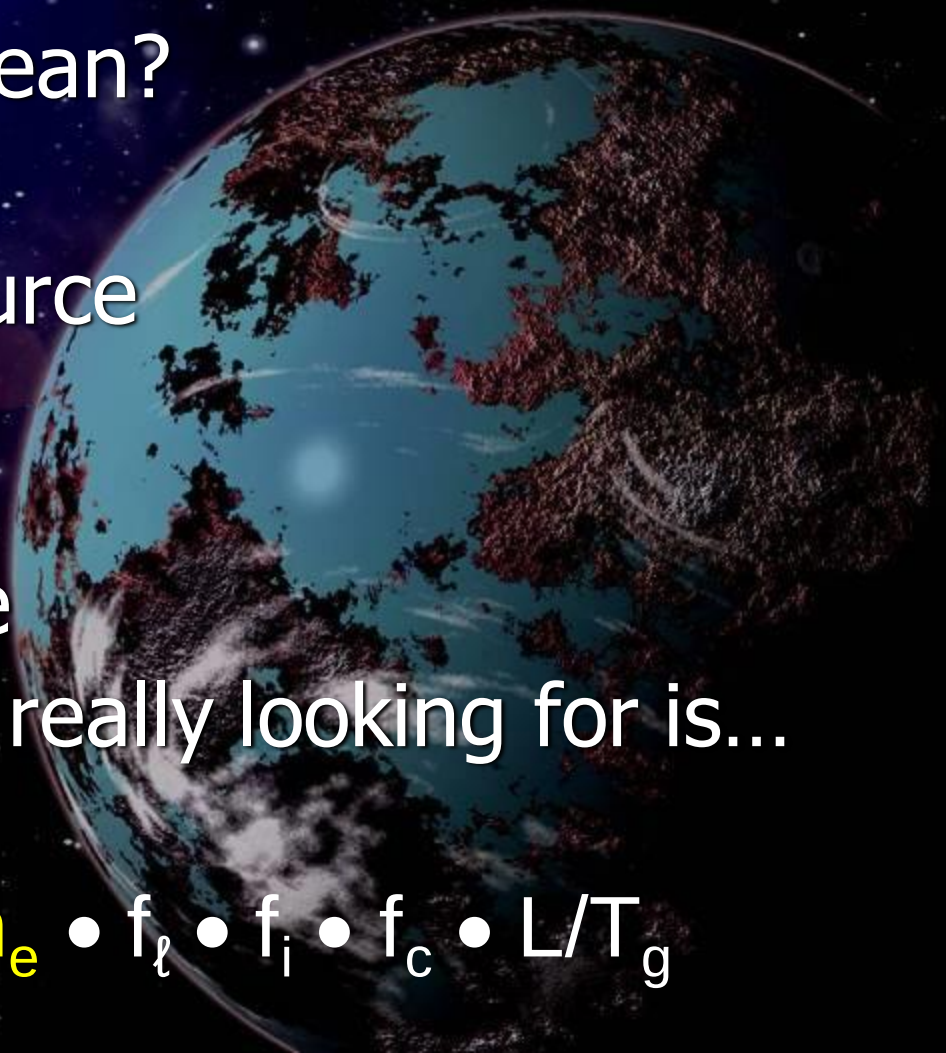
ESO Press Photo 22e/07 (25 April 2007)

- As planet orbits tar, star also noves
- oppler shift can e observed
- ery small notion
- 12.7m/s for upiter

Planets - Direct Imaging



n_e How Many of These Worlds Have the "Right" Environment?

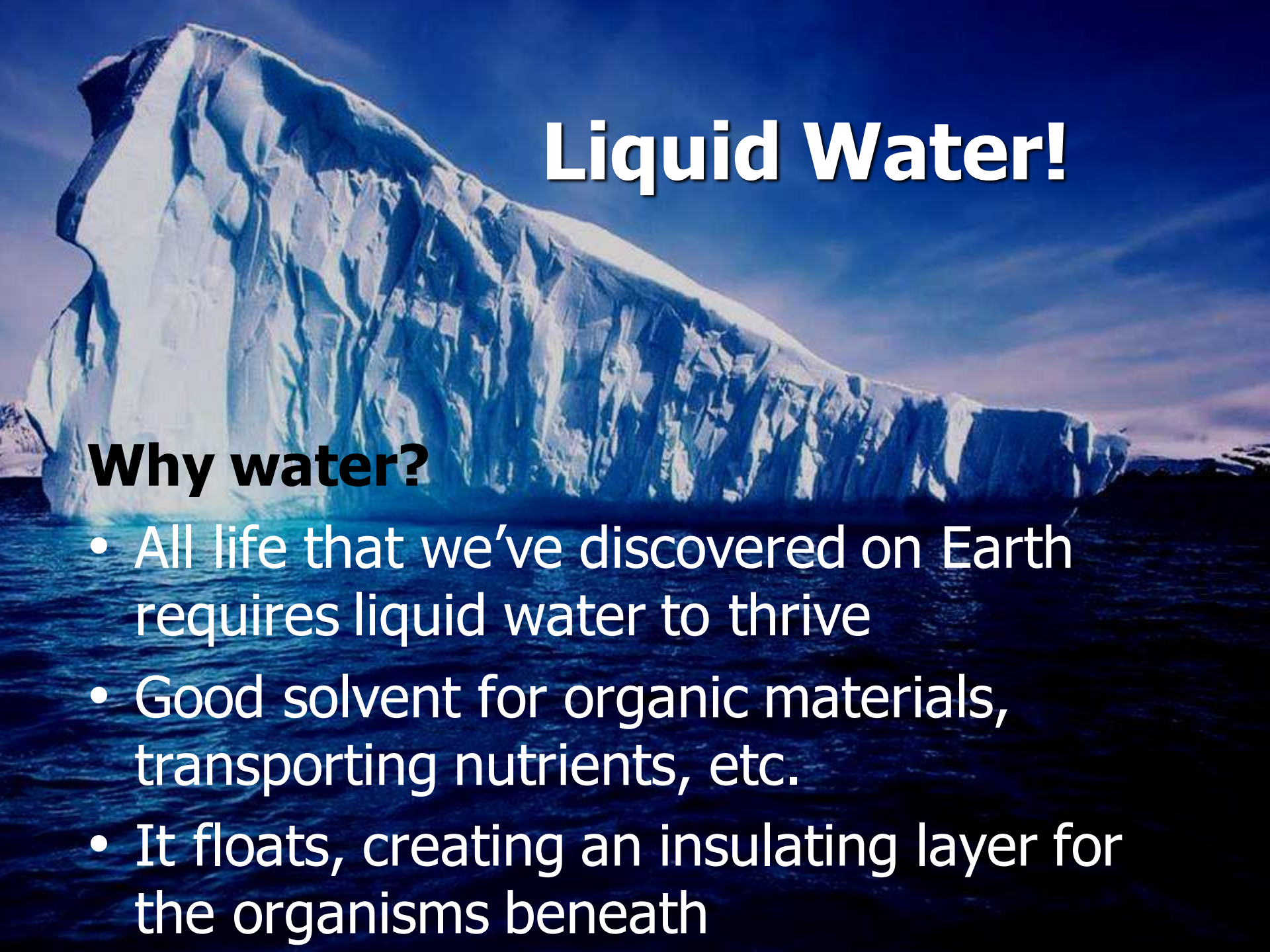


What does "Right" mean?

- Small, rocky planet
- That has a heat source
  - Habitable Zone
  - Tidal heating
- And an atmosphere

What we're really looking for is…

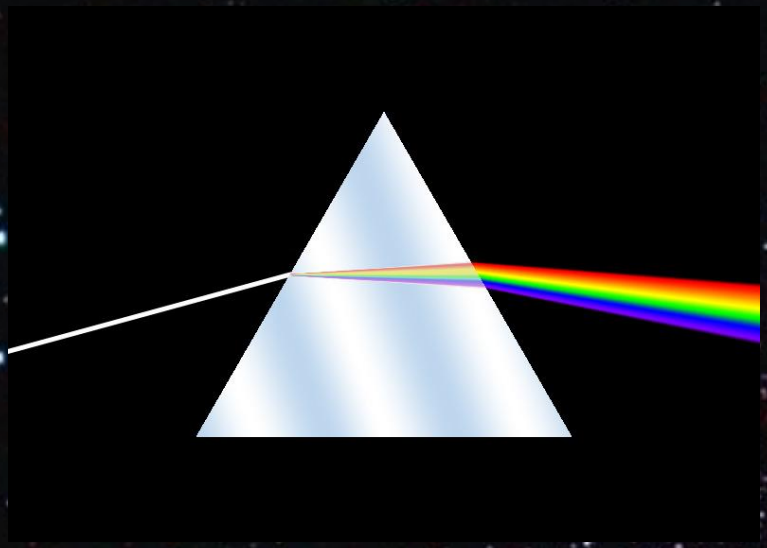
$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

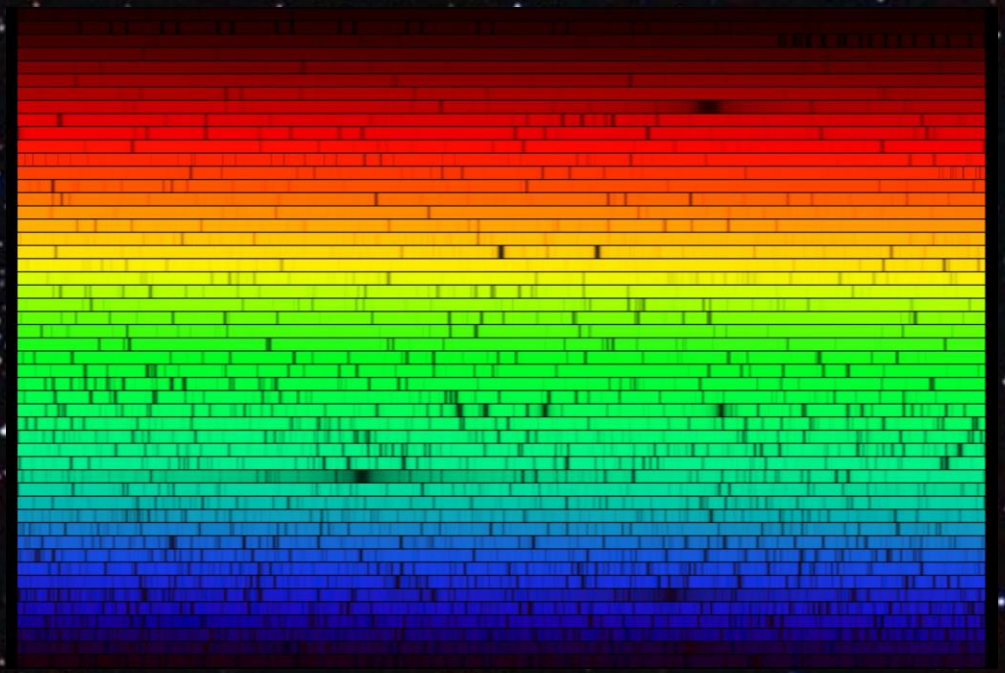


Liquid Water!

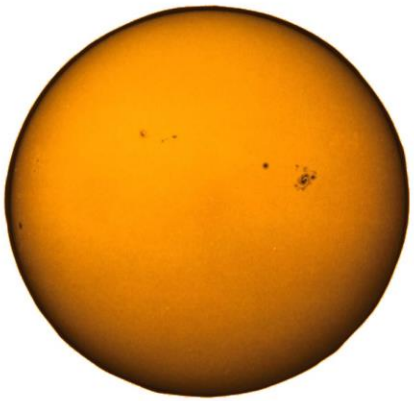
Why water?

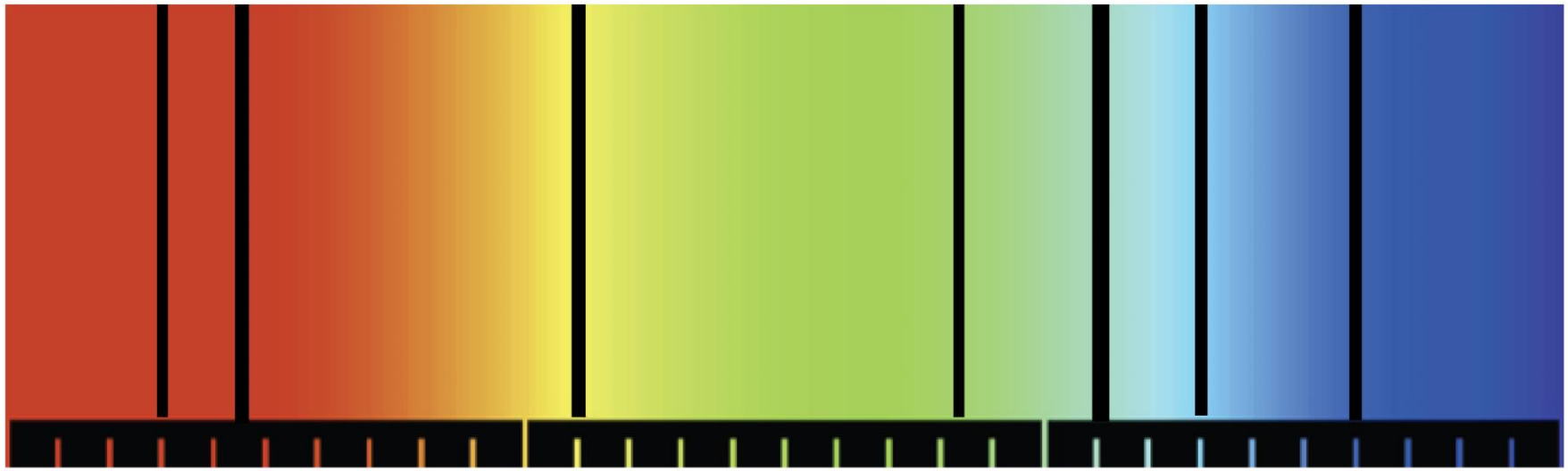
- All life that we've discovered on Earth requires liquid water to thrive
- Good solvent for organic materials, transporting nutrients, etc.
- It floats, creating an insulating layer for the organisms beneath

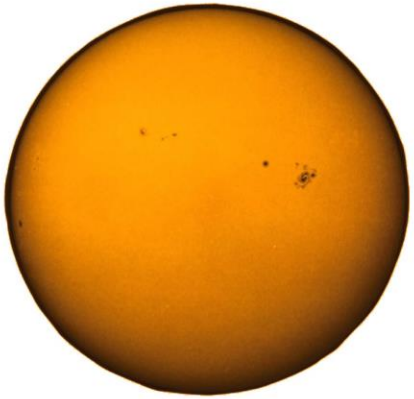




Star



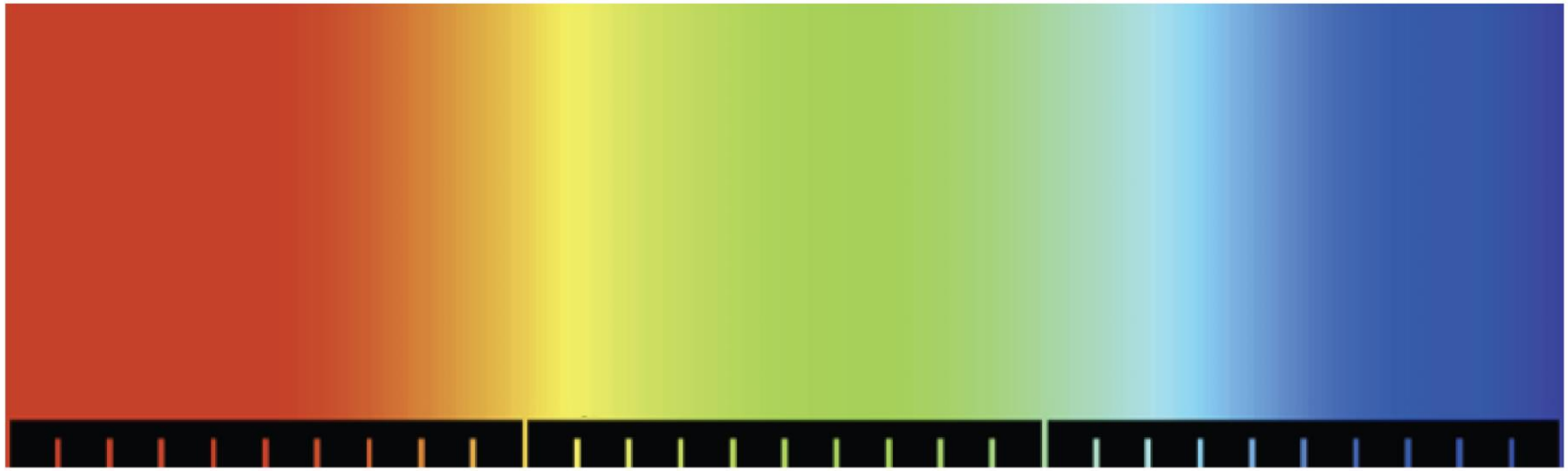


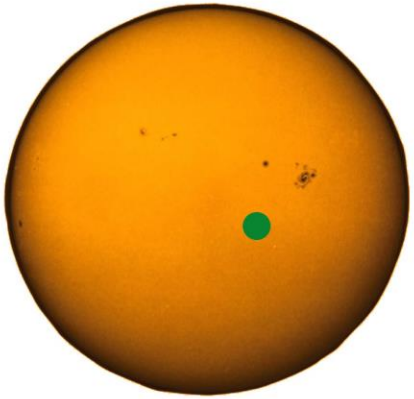


STAR

HYDROGEN

HELIUM

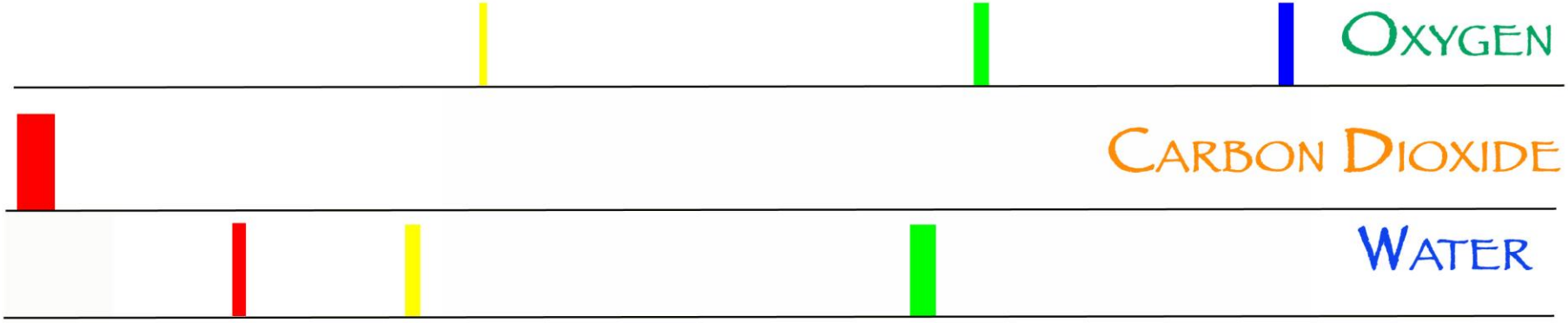


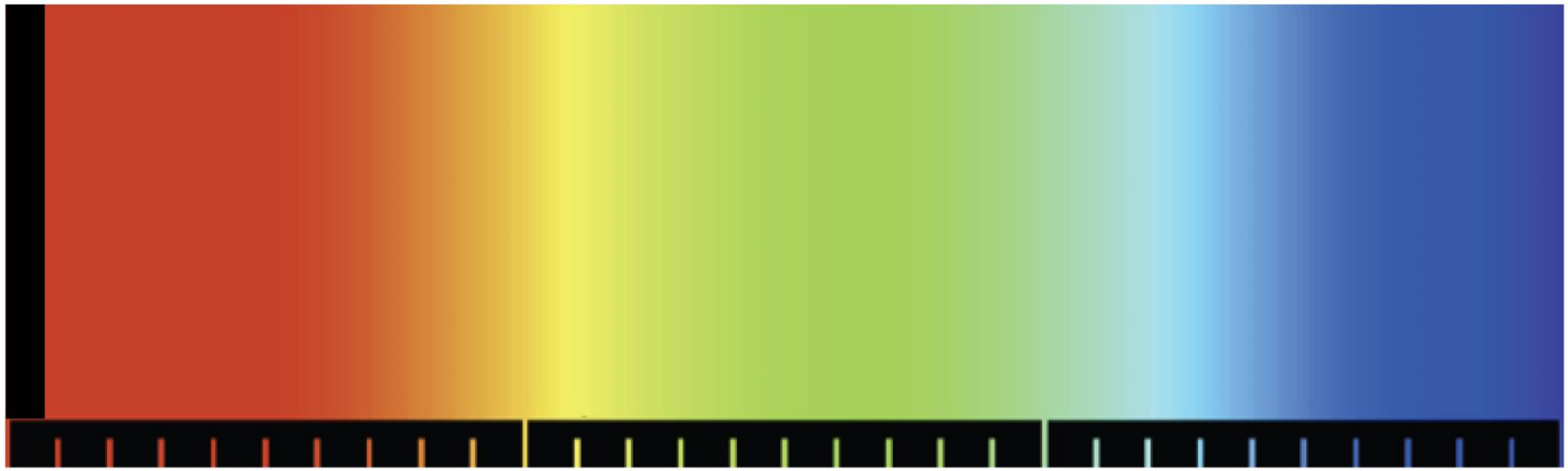


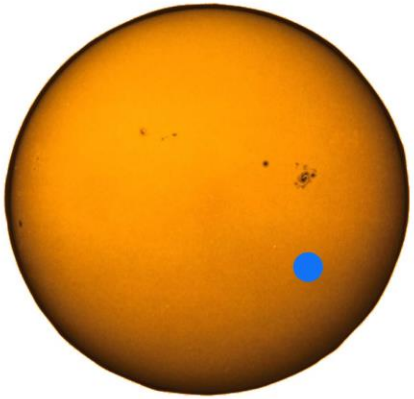
STAR

PLANET A

HYDROGEN HELIUM



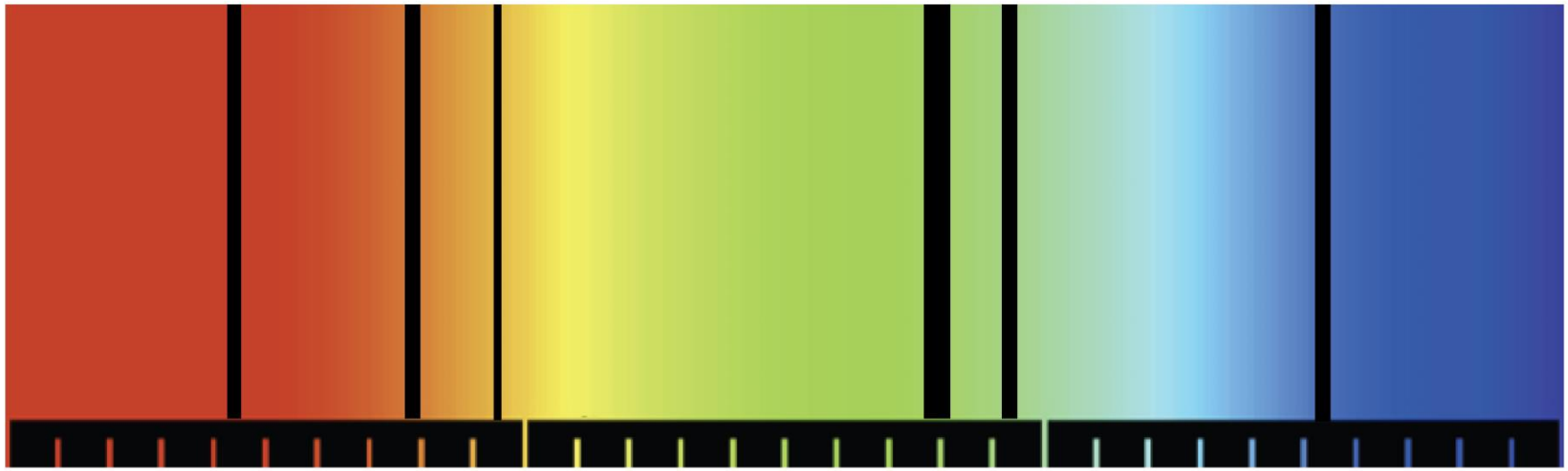


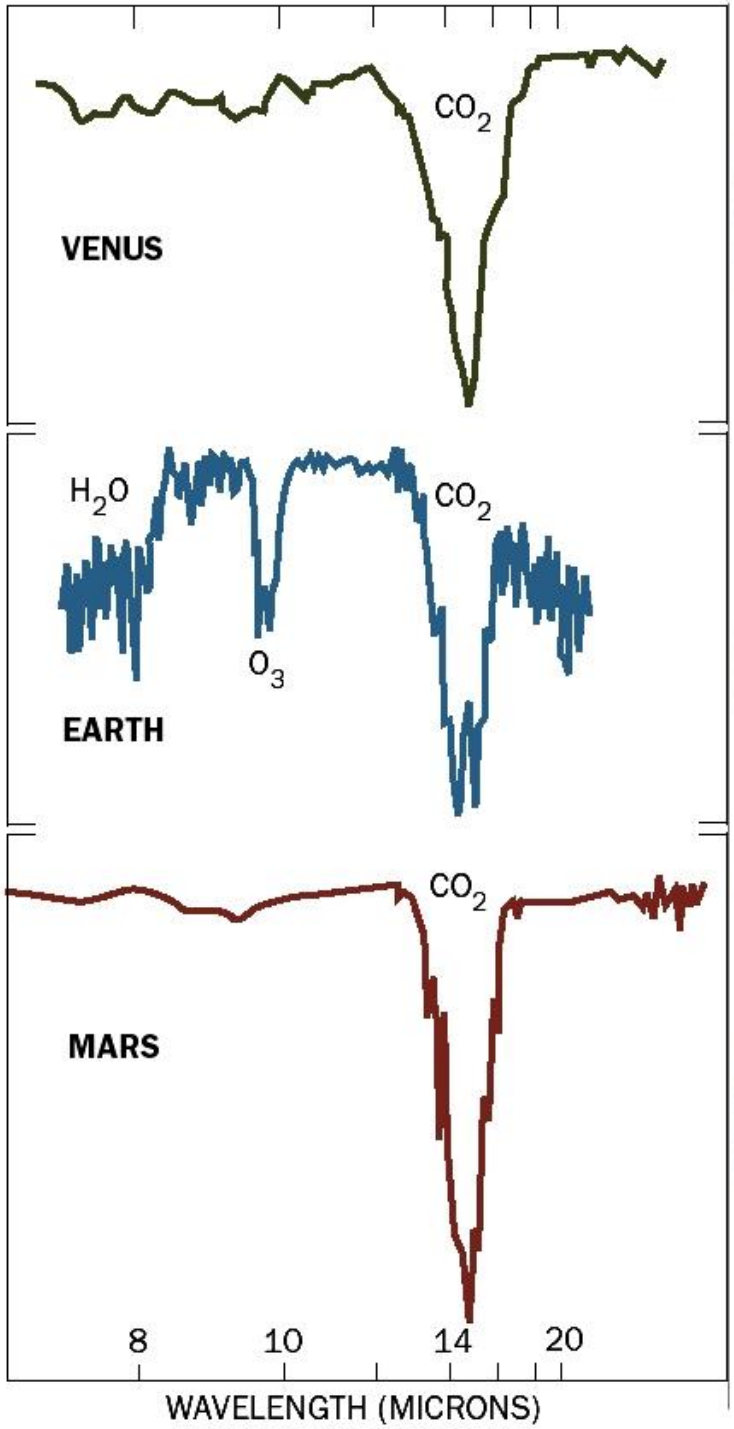


STAR

PLANET B

HYDROGEN HELIUM

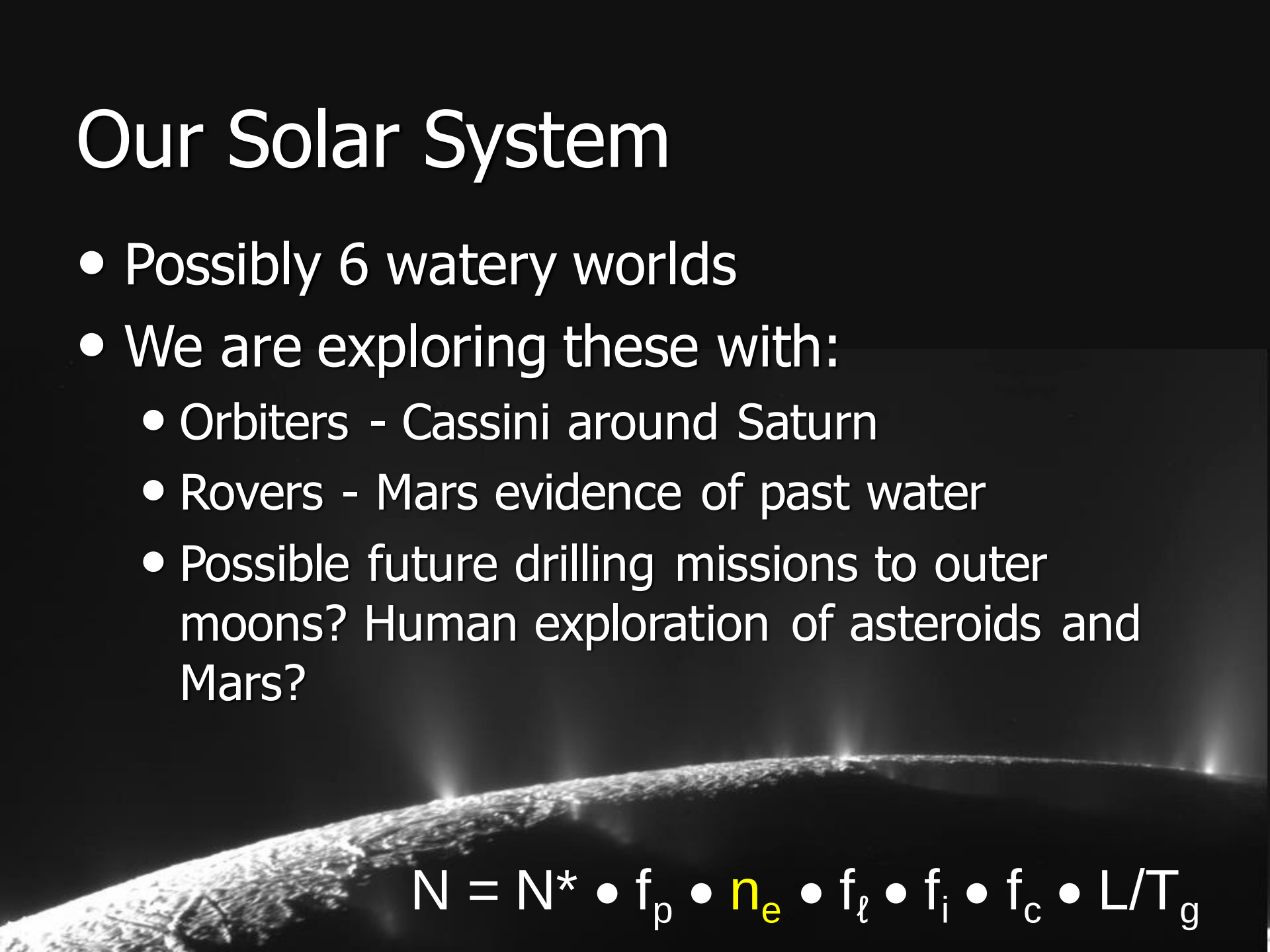




Comparing Planetary atmospheres as a metric of habitability

Our Solar System

- Possibly 6 watery worlds
- We are exploring these with:
  - Orbiters - Cassini around Saturn
  - Rovers - Mars evidence of past water
  - Possible future drilling missions to outer moons? Human exploration of asteroids and Mars?



$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

f_ℓ How Many Habitable Planets Develop Any Life Forms?

(at any point)

Start with what we know:

Our Solar System

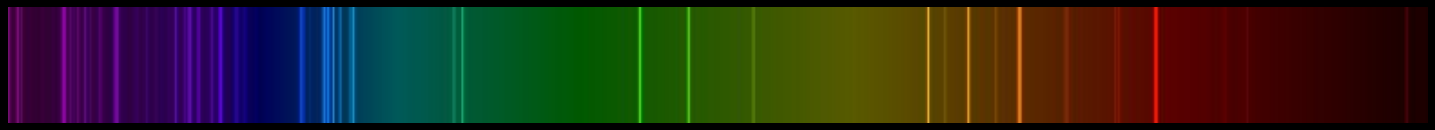
Just 1 that we know of

- Earth!

$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

Life - Spectroscopy

Watch spectrum for lines



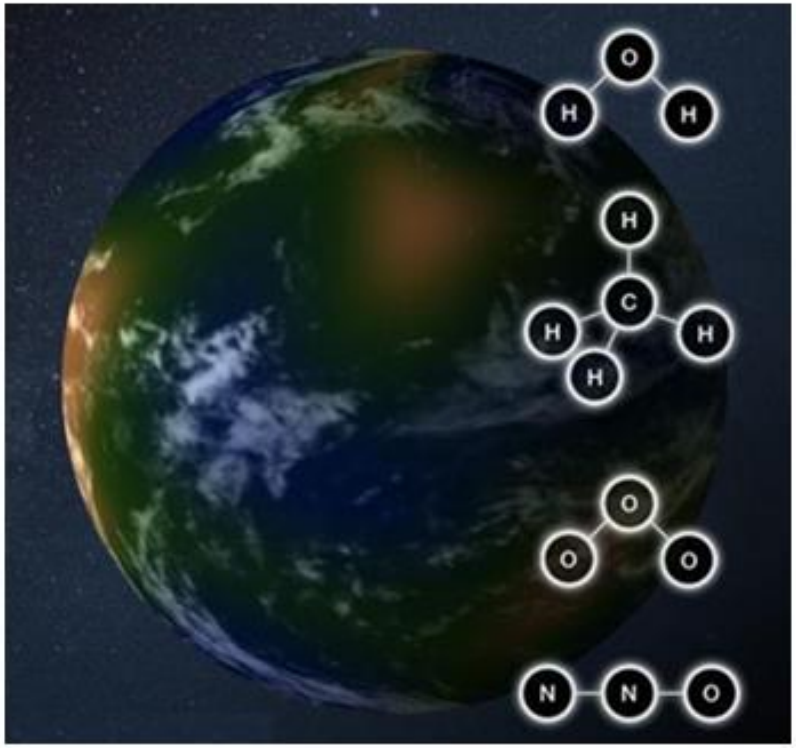
Oxygen – only exists because of plants

Observe during transit

Some light passes through atmosphere

$f_l \approx 13 – 100\%$

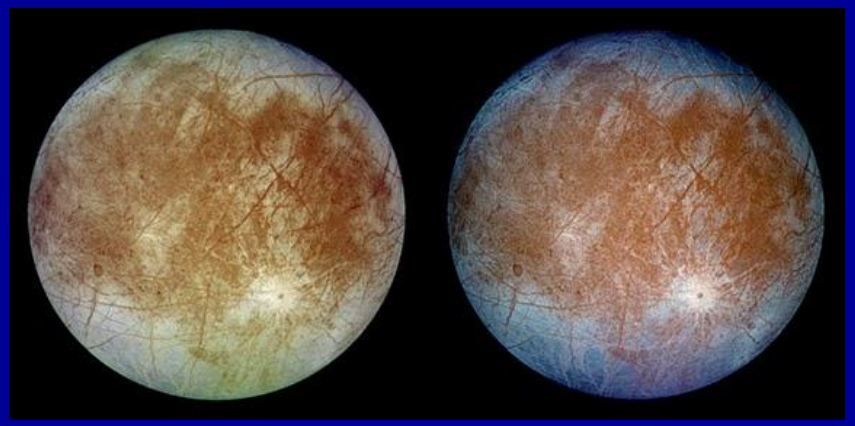
Imaging Spectroscopy – Biosignatures on Earth-like Exoplanets

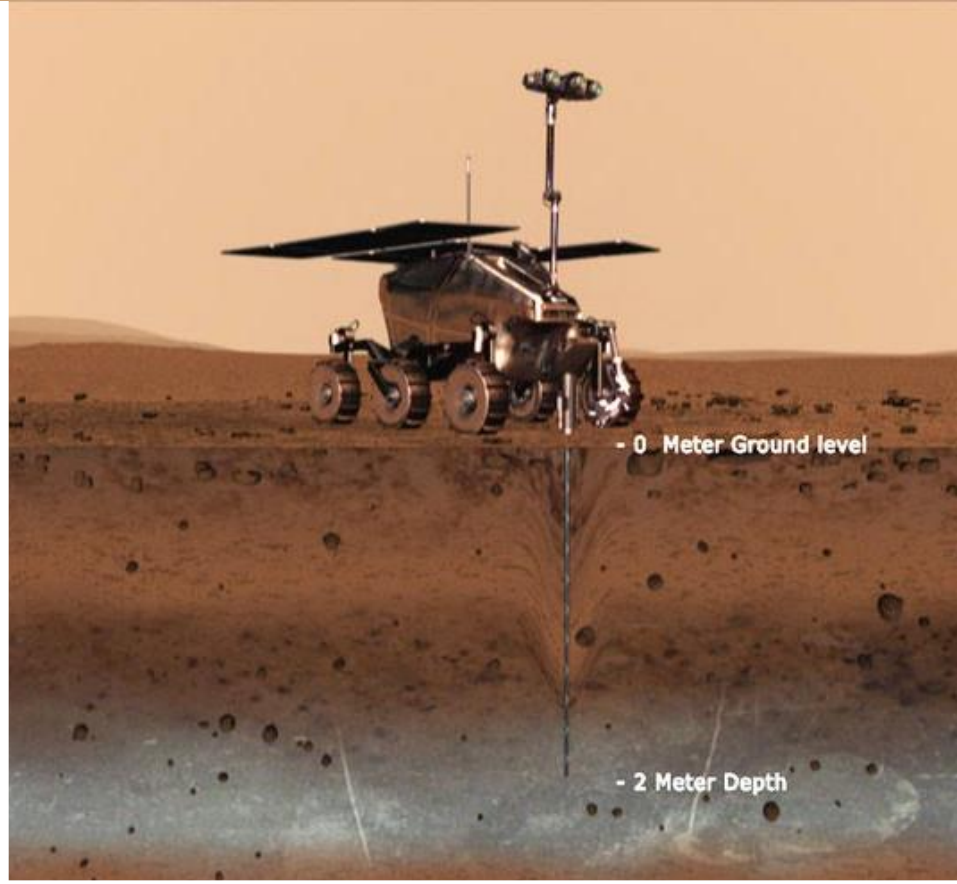


A hypothetical earth-like planet that shows water, ozone, nitrous oxide, and methane in its spectrum could be inhabited by plant life, bacterial life, and intelligent life. The presence of ozone indicates that oxygen must also exist in the atmosphere, since ozone is created from UV radiation reacting with oxygen.

A hypothetical planet showing methane and water in its atmosphere suggest that the planet is a good candidate for the evolution of life, assuming it does not already exist. Both plant life and bacterial life would be expected based on the biosignatures.

Possibility of Simple, i.e. single-celled, Life, could create remotely sensed biomarkers

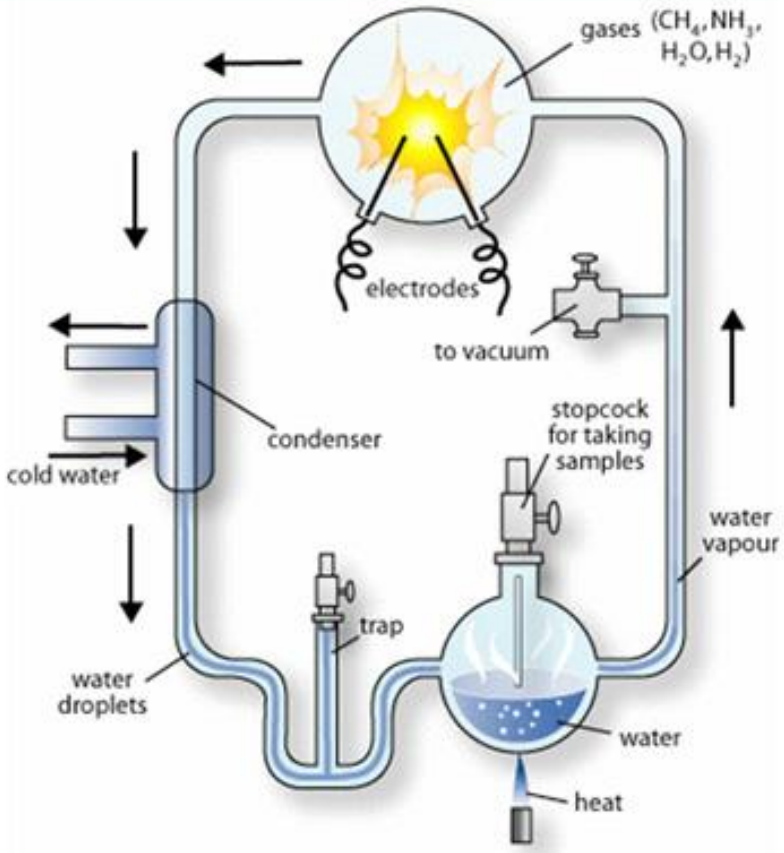


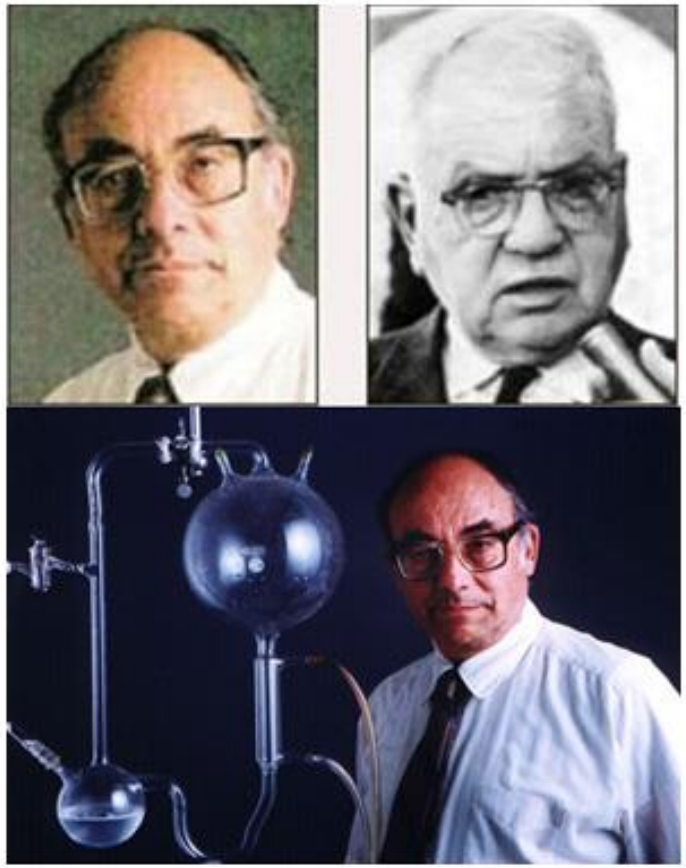


Projects to explore for microbes on Mars (either alive or extinct)

Urey and Miller Experiment

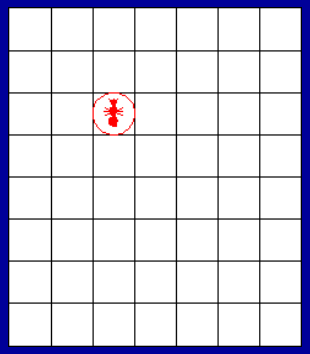
RAJU'S BIOLOGY



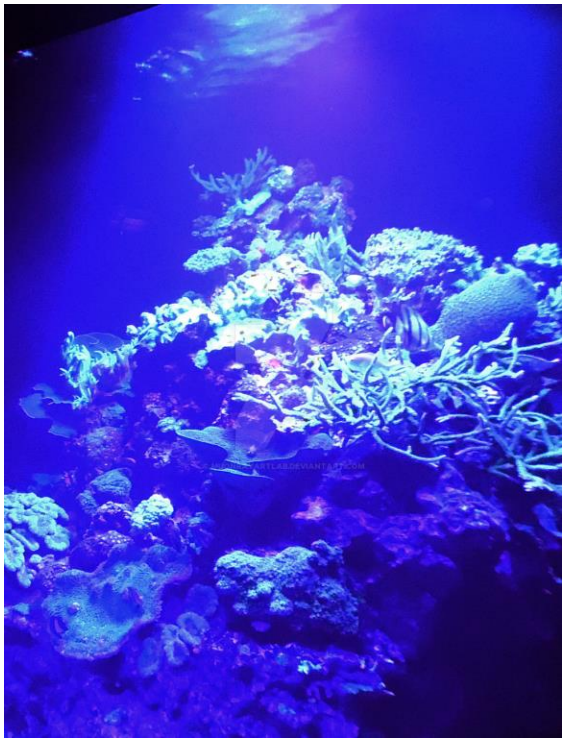


Comparing remotely sensed cosmic chemistry with Earth biochemistry experiments to replicate the origin of biomolecules, amino acids, nucleic acids, lipids for cell membranes, etc.

Using Space science to help develop theories and refine models for life on Earth – especially concerning Living Networks and Ecosystems



Life as seen from space represents complex living networks

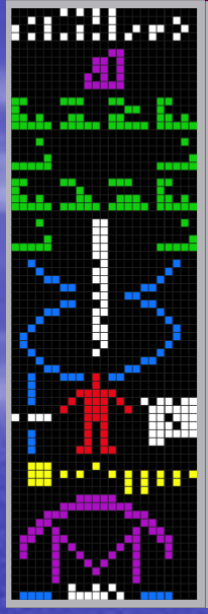


f_i How Often Does Simple Life Become Intelligent?

- Billions of species have existed on Earth. Many Species have developed very complex brains.
- Only one seems to have looked out into the galaxy for company – perhaps a fluke of circumstance!
- This part could ask Does life always become more complex over time?

$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

f_c How Many Intelligent Civilizations/Species Communicate?



- These civilizations/species are able and willing to communicate
- Is it possible that they are out there in listen-only mode?

$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

L Average Lifetime of a Communicating Civilization

We have been communicating for less than a century

How long will we survive?

$$N = N^* \bullet f_p \bullet n_e \bullet f_\ell \bullet f_i \bullet f_c \bullet L/T_g$$

Looking at past civilizations

Civilizations have a habit of emerging but also collapsing

Same in nature with insect "societies"

Range of Estimates

Pessimistic	Factors	Optimistic
100 billion	N^*	500 billion
One quarter	f_p	Half
1 in 1000	n_e	1
1 in 1000	f_ℓ	1 in 10
1 in 1000	f_i	1 in 10
1 in 100	f_c	1 in 10
1,000 years	L	1 billion years
We are alone		**Millions of civilizations**

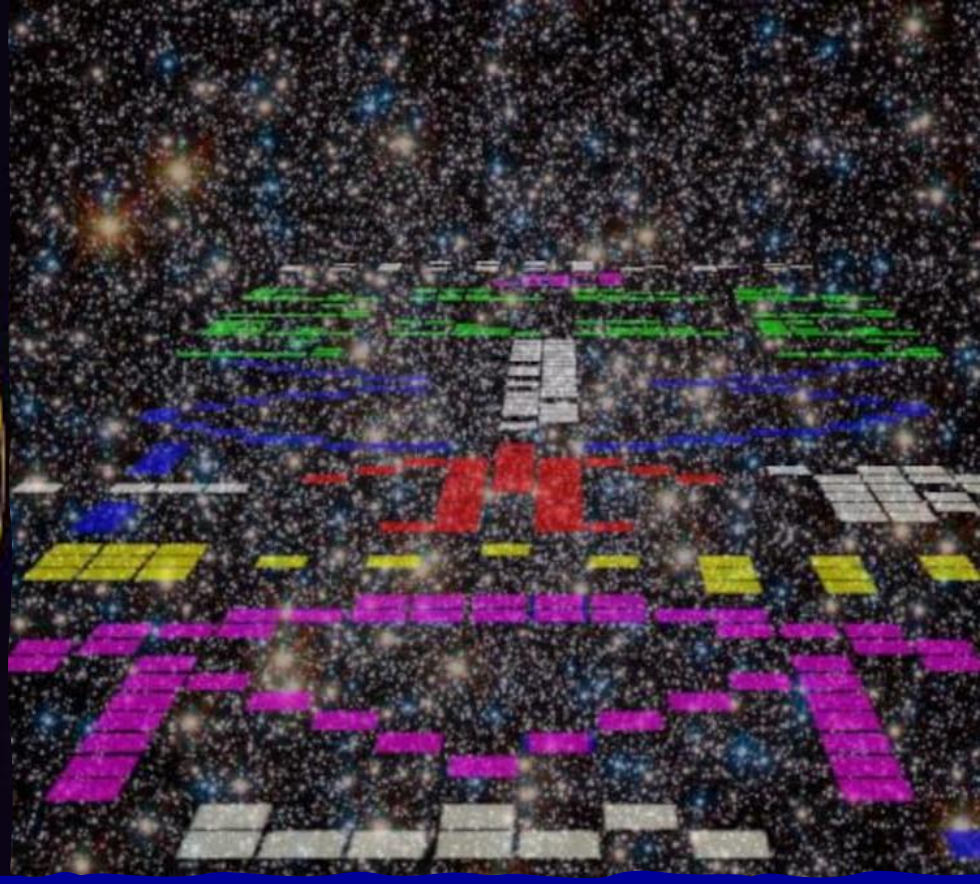
In the Meantime

We listen

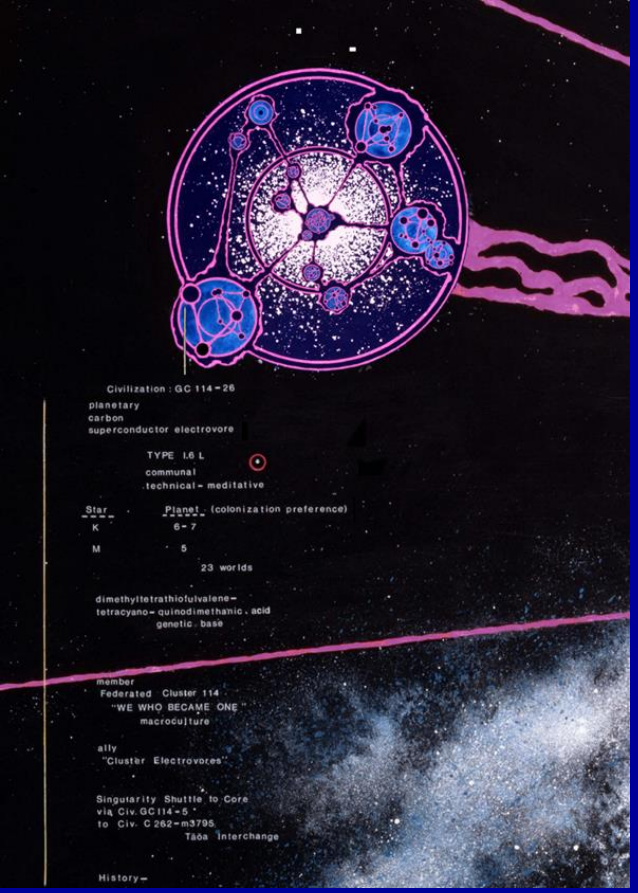
SETI HOME

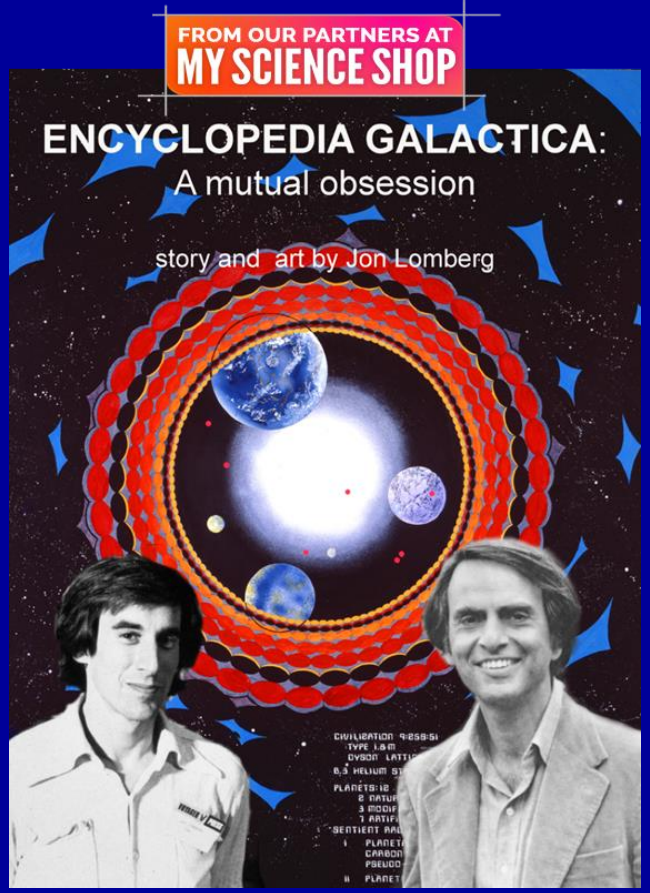
and

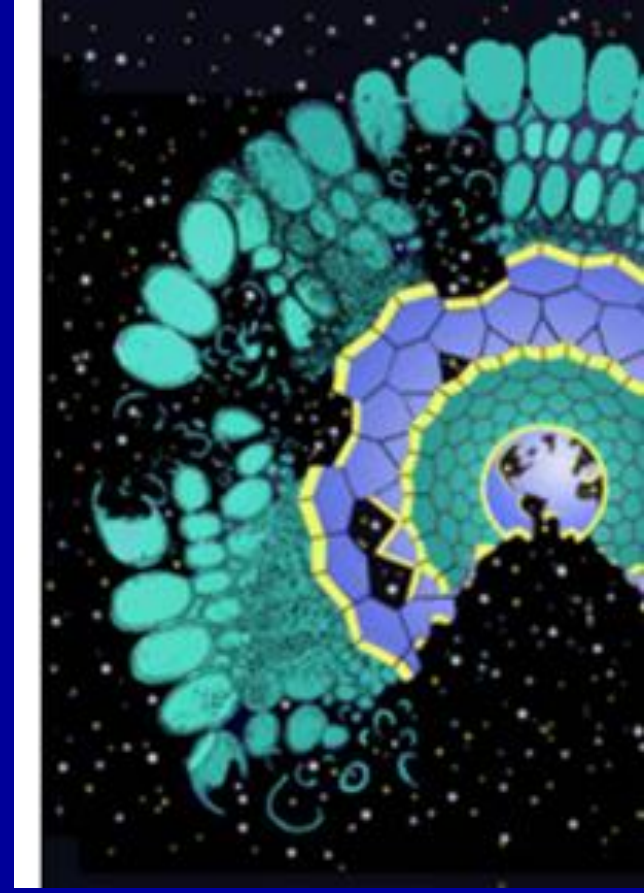
We watch



And we look into the future...sending messages







And speculate, imagine

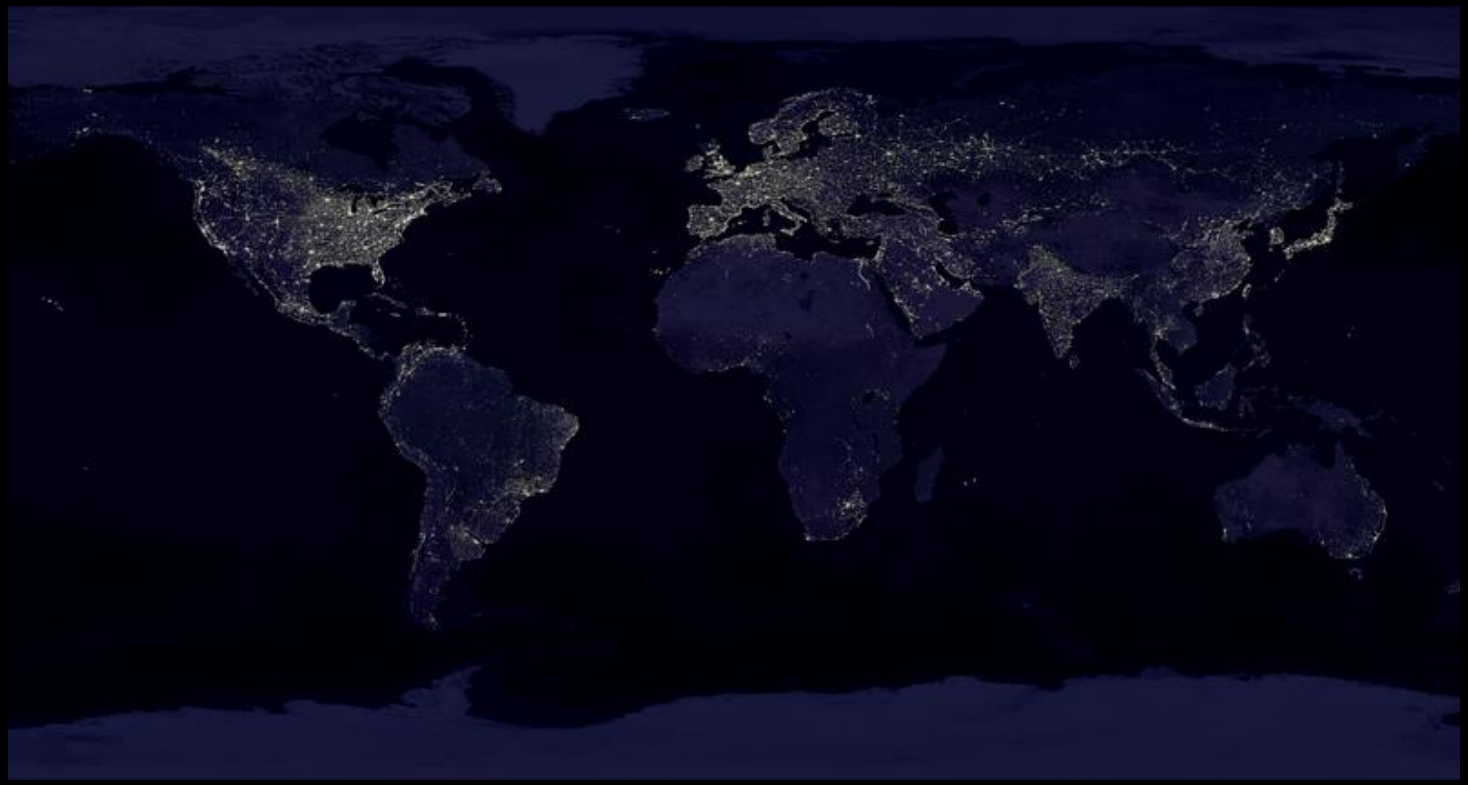
- Complex civiliaztions in space could create very obvious technosignures

Complex Life - Direct Observation of Technosignatures

Tiny planet-bound life forms

Individual cities are small (Dublin ~ 30km)

Large networks can become visible at scale



Similar to swarms of animals

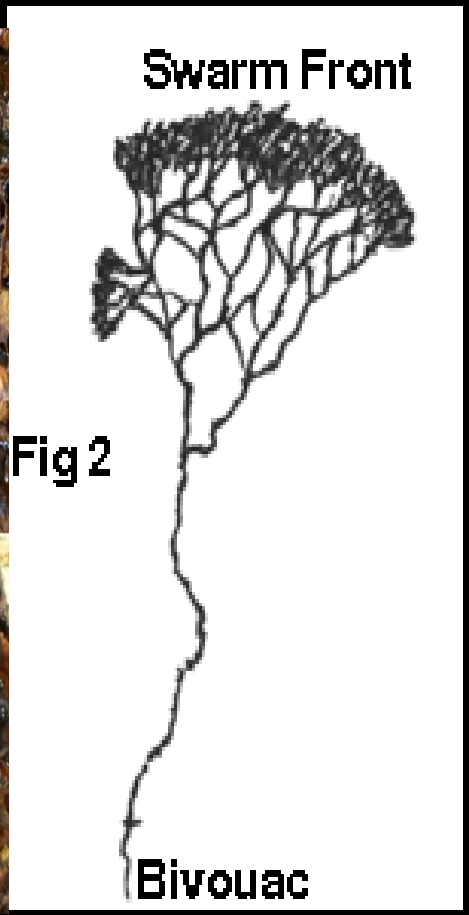
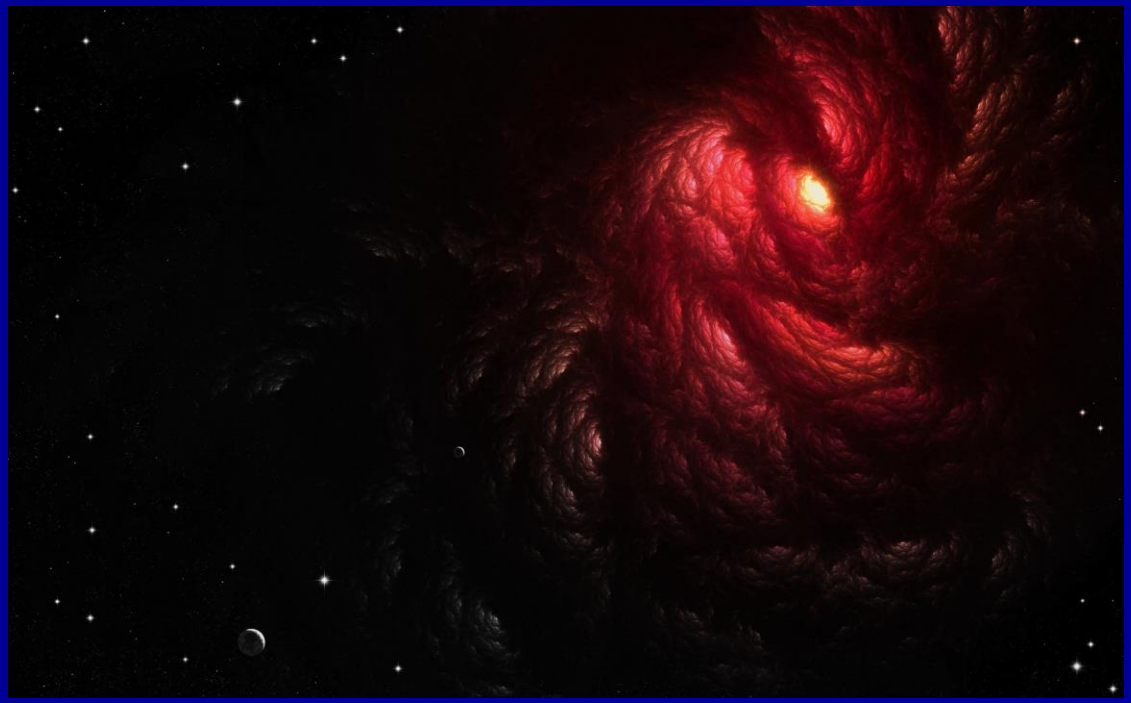


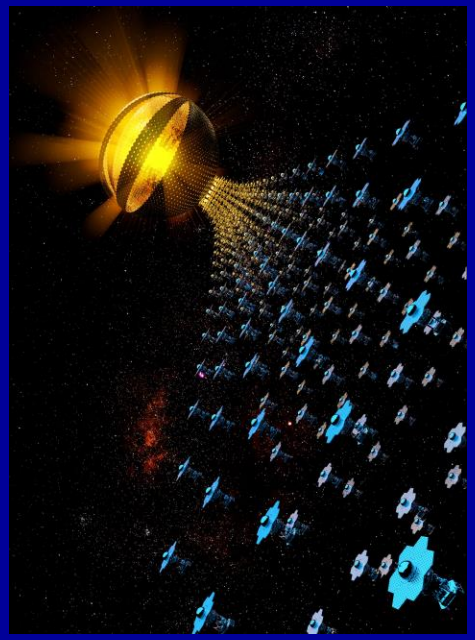
Fig 2

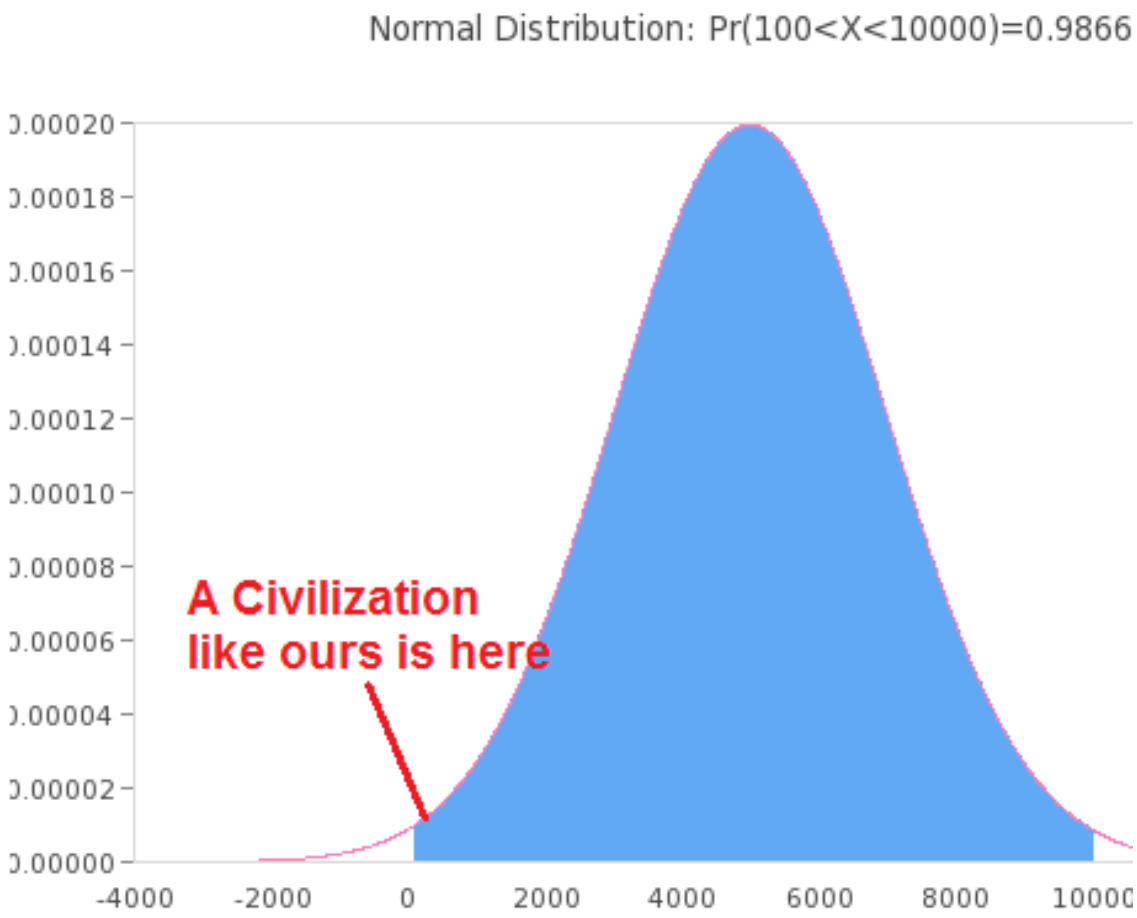
Speculative alien living structures

Swarms in space – a speculation

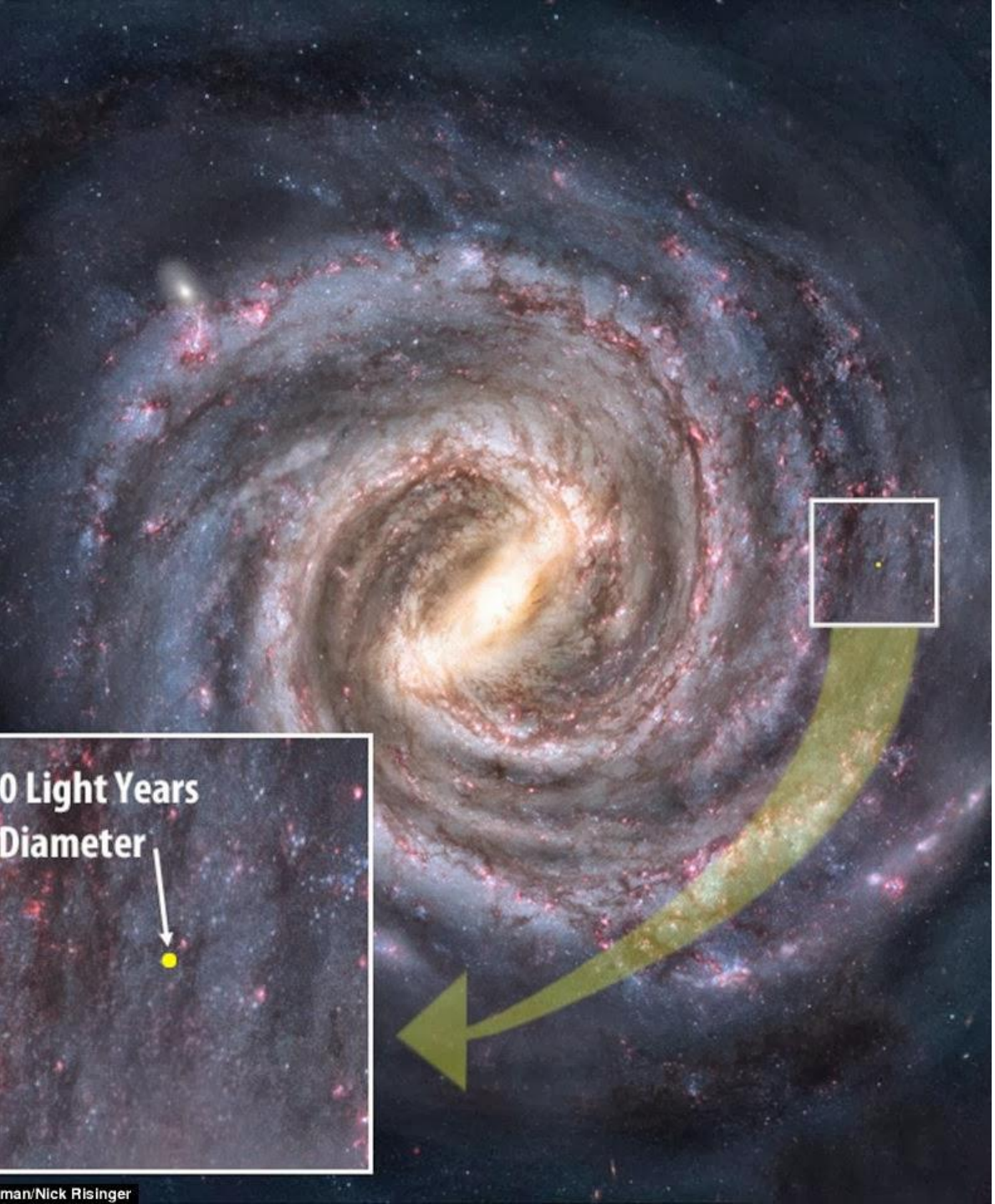


Dyson Swarms and Von Neumann Probes

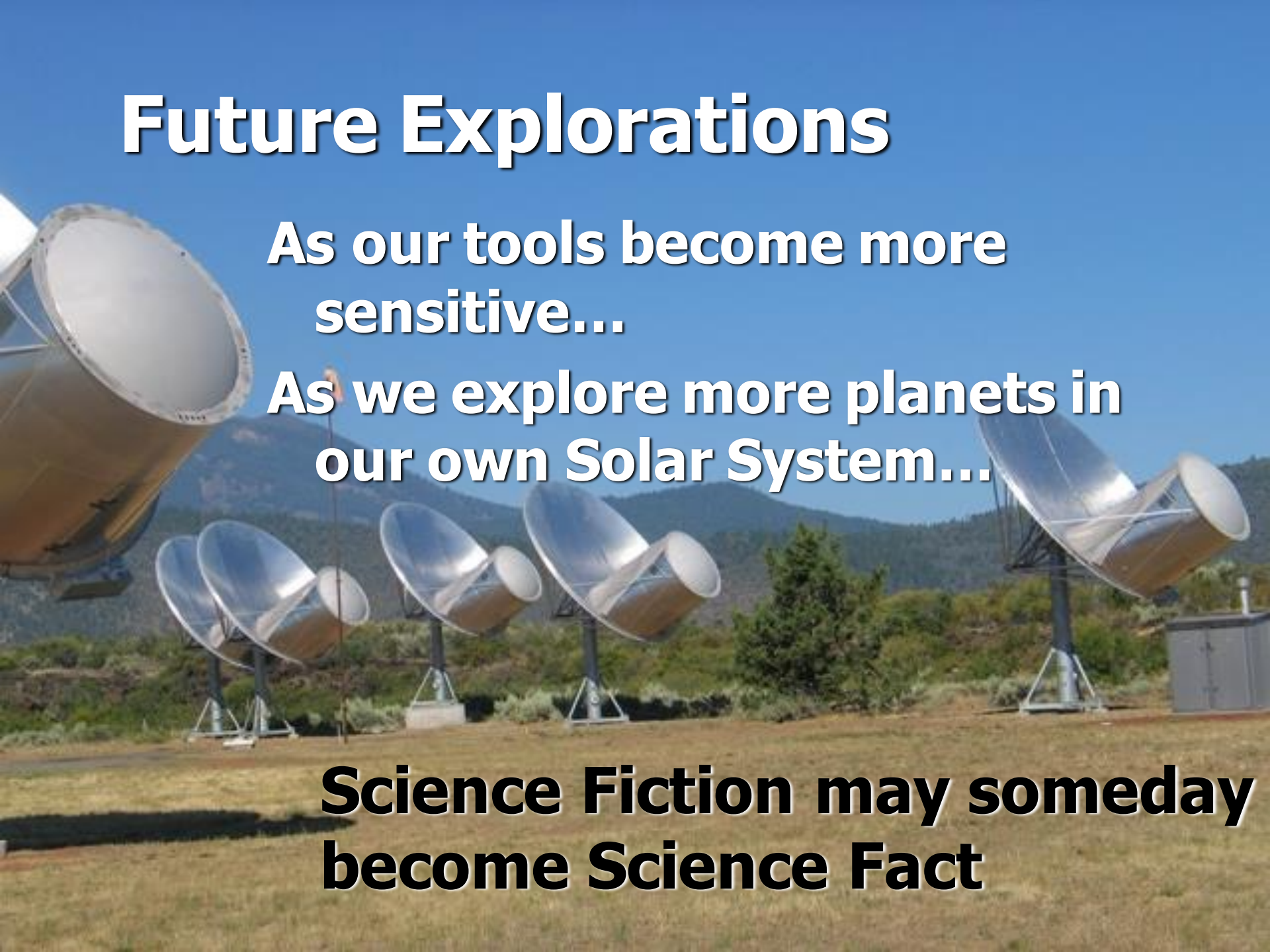




If self-replicating machines are in our technological "Future" then if we do make contact with them they would have been made by a more advanced society.
So why have we not seen them in more glaring detail?



Answer - because its a very big galaxy on the scale of even our radio transmissions



Future Explorations

As our tools become more sensitive…

As we explore more planets in our own Solar System…

Science Fiction may someday become Science Fact

The END!

Thanks! Merry Xmas
and New Year!