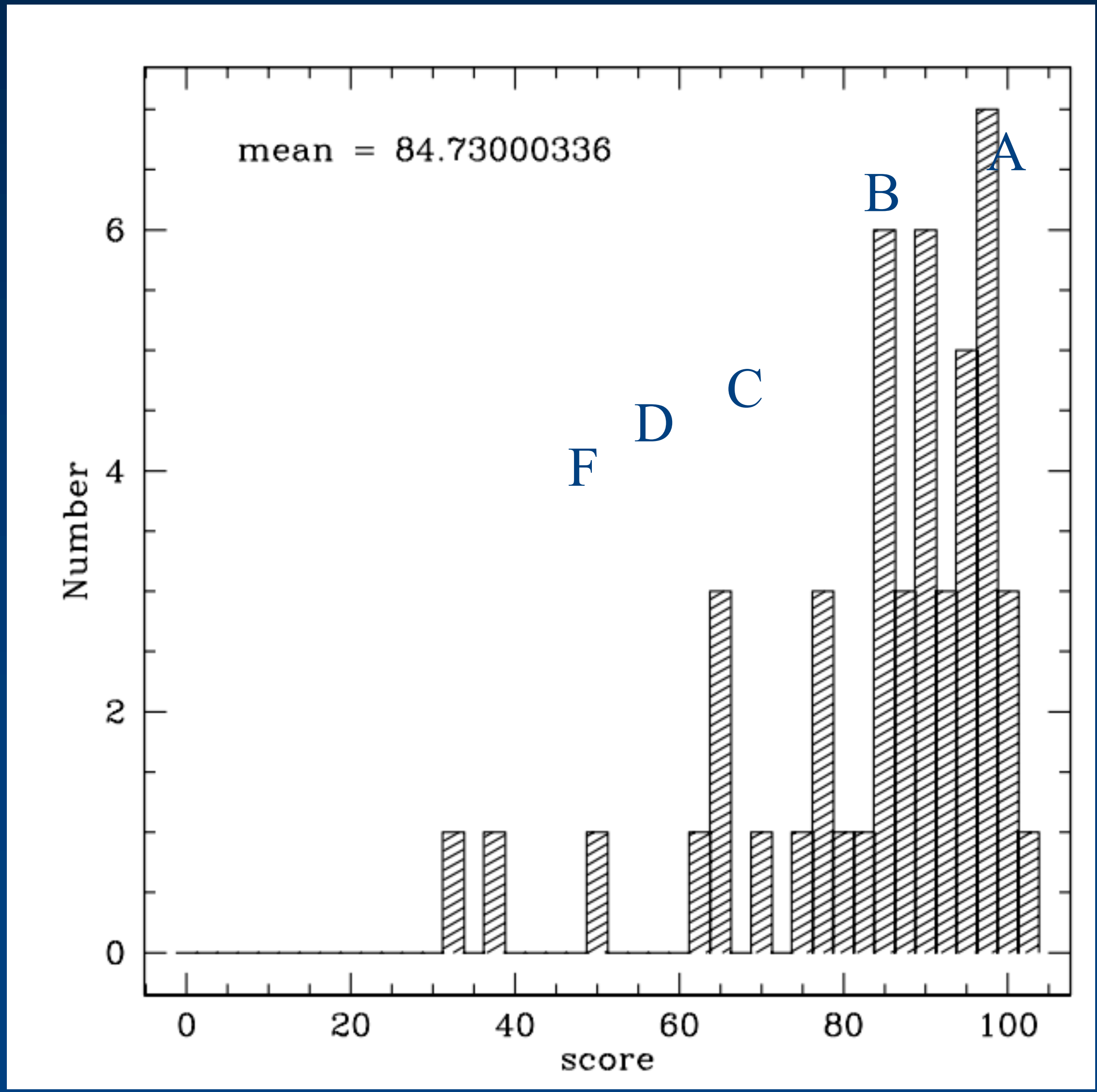
Test #2 Results

90 – 100: A
80 – 89: B
60 – 79: C
50 – 59: D
< 49 : F



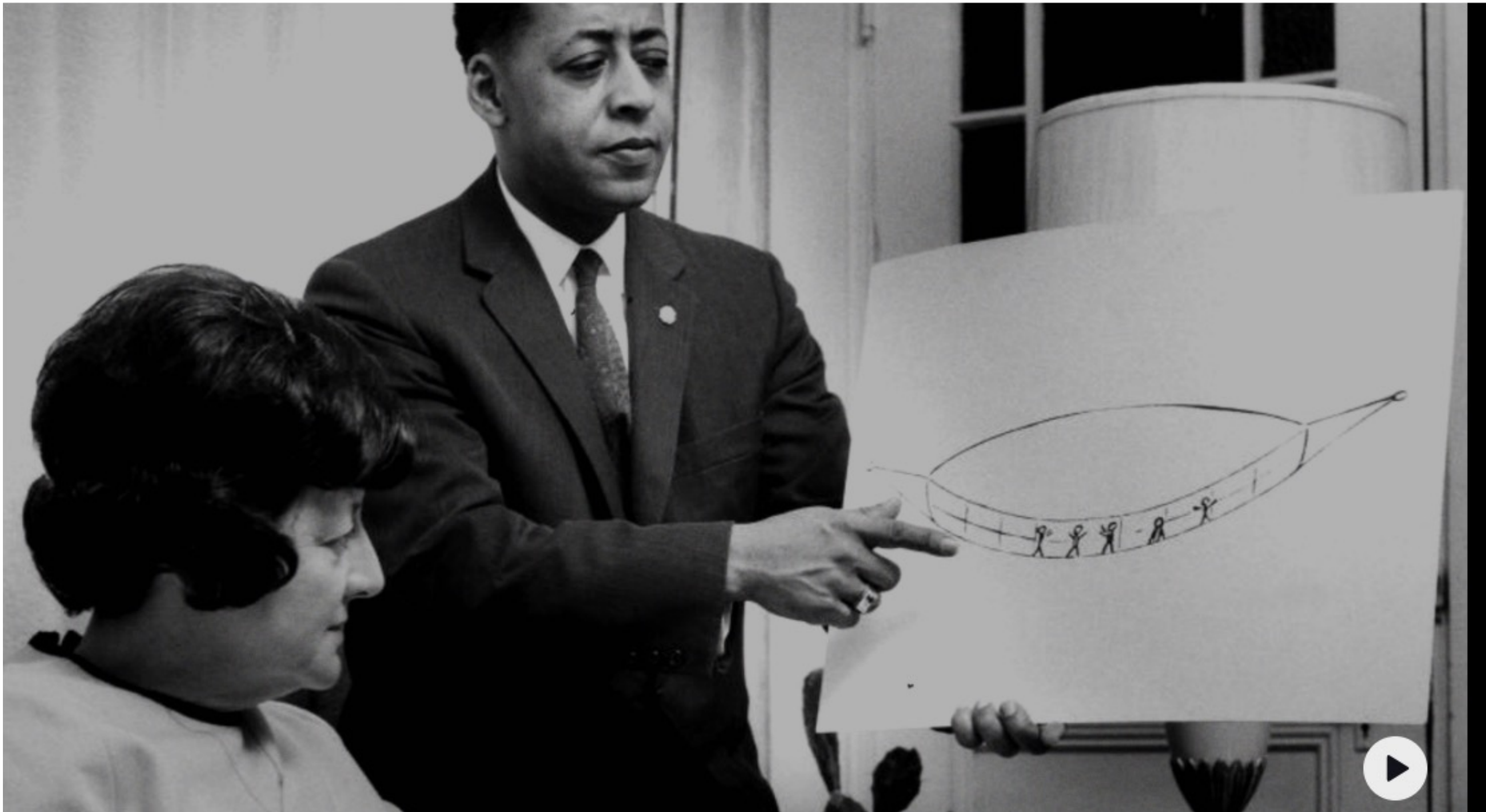
Announcements

- Planet Data sheet available
- Final Project due May 2nd
- Planet viewing 1-2pm Tuesday May 7th in RH114

Life in the Universe

Are we alone? What might other forms of life look like? What about intelligent life? What do we mean by "living"? What do we mean by "intelligent"?

Life in the Universe



Barney and Betty Hill describe their abduction by aliens in 1961.

Will 2020 Be the Year We Find Intelligent Alien Life?

By Leonard David 6 days ago Search For Life

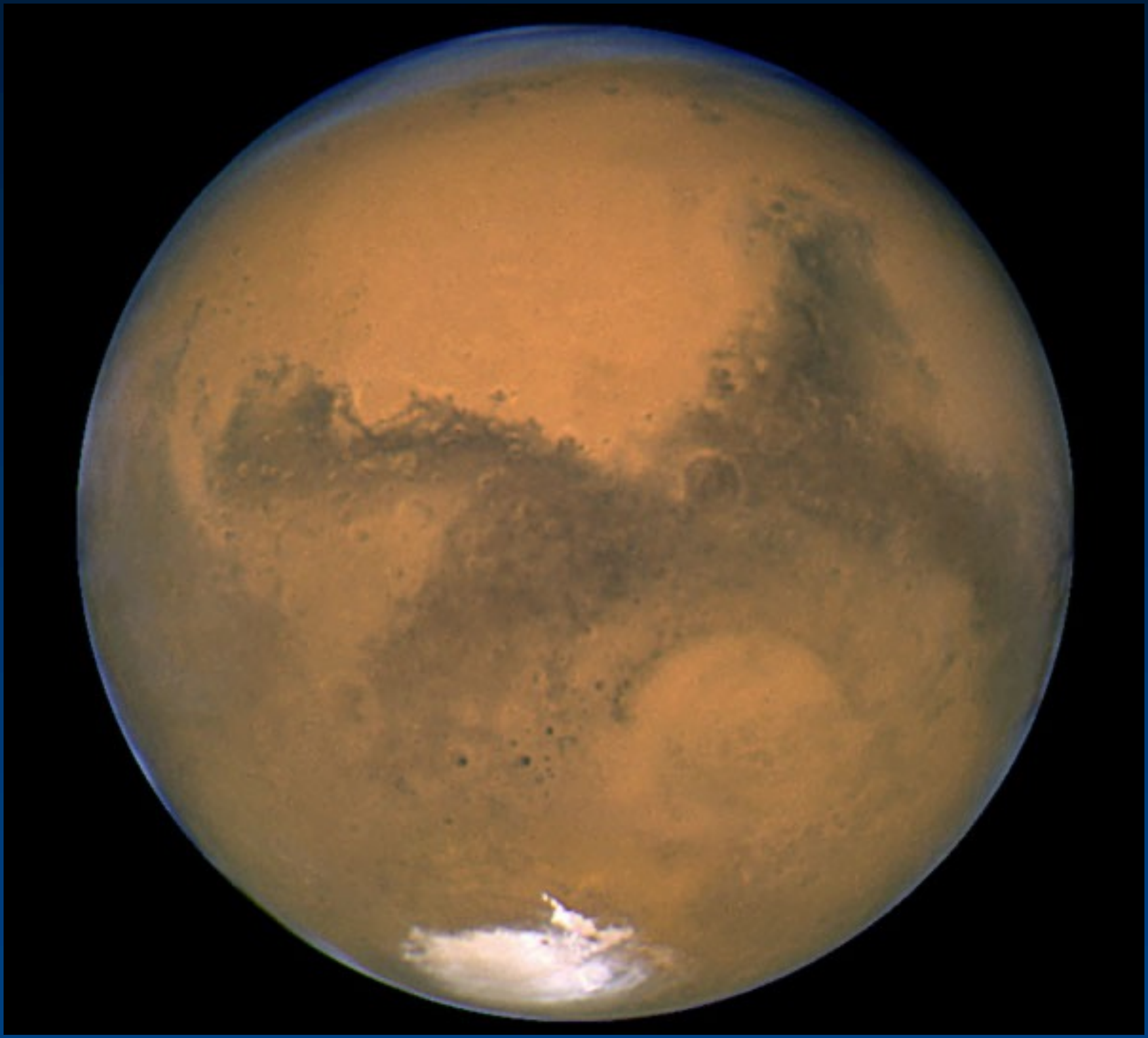
Probably not, but there are reasons to be optimistic about our near-future prospects.

Life in the Universe

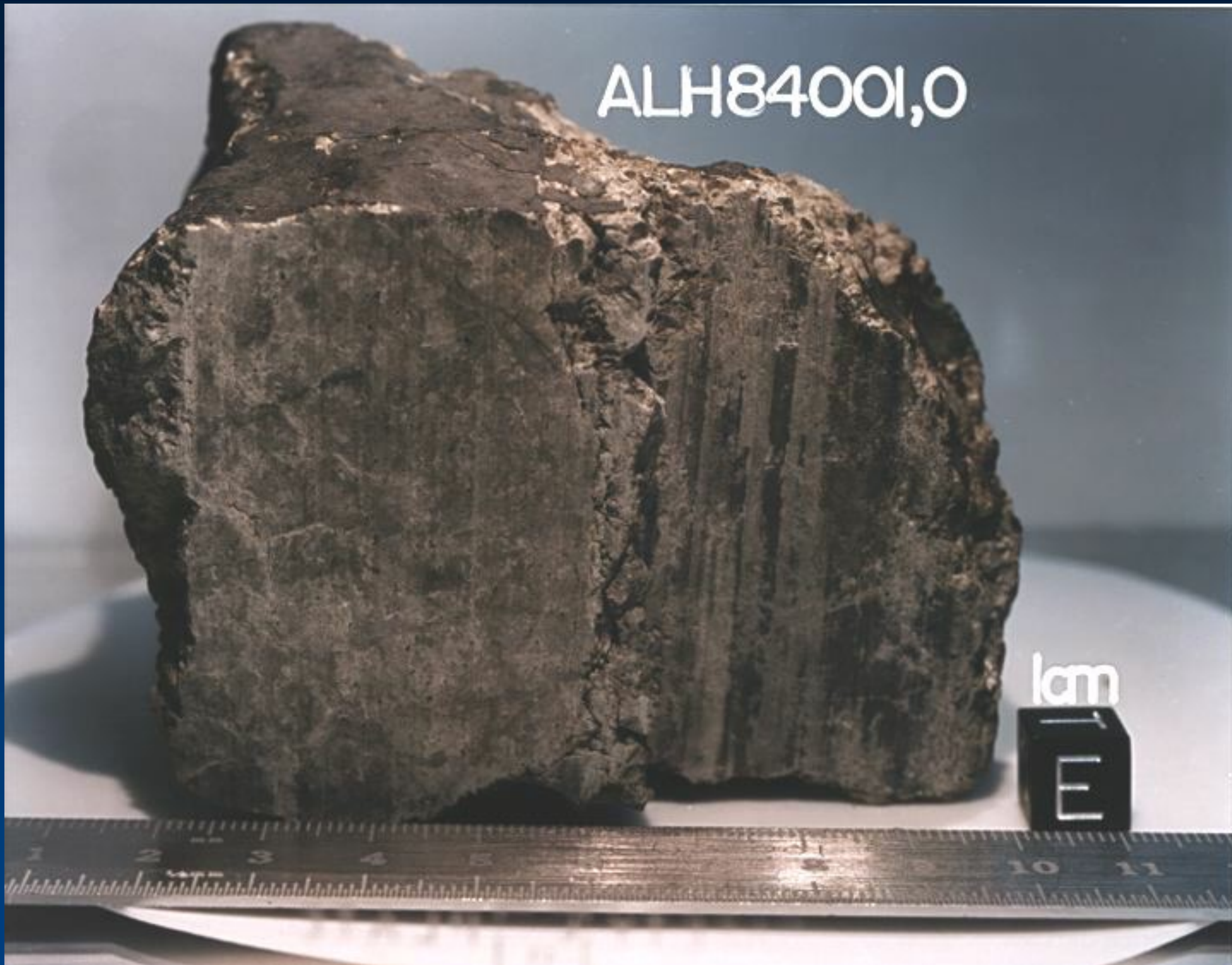
View from Apollo 17

Pale Blue Dot

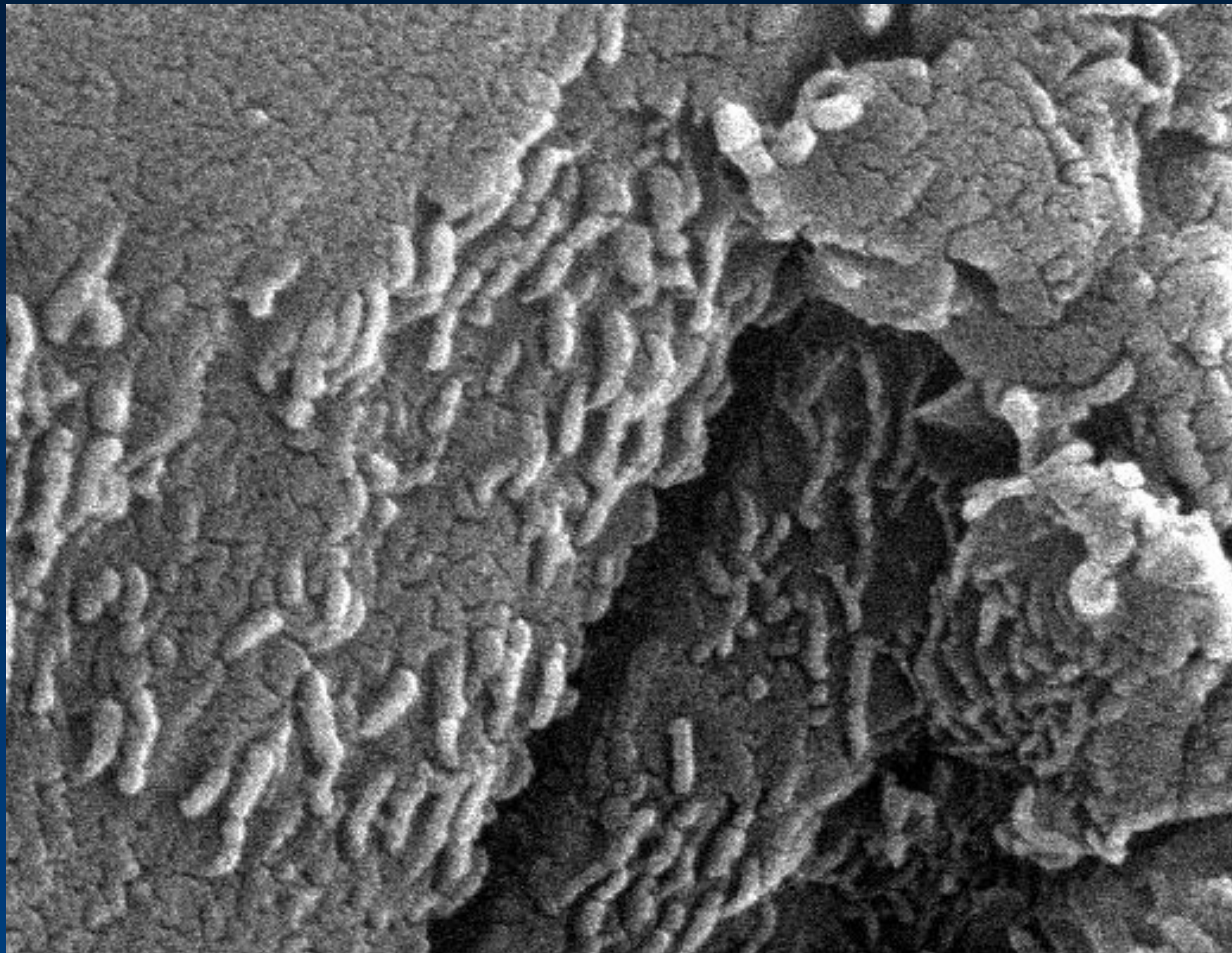
Earth as seen from Voyager 1, when it was 6 billion km from home.



HST image of Mars taken August 2003

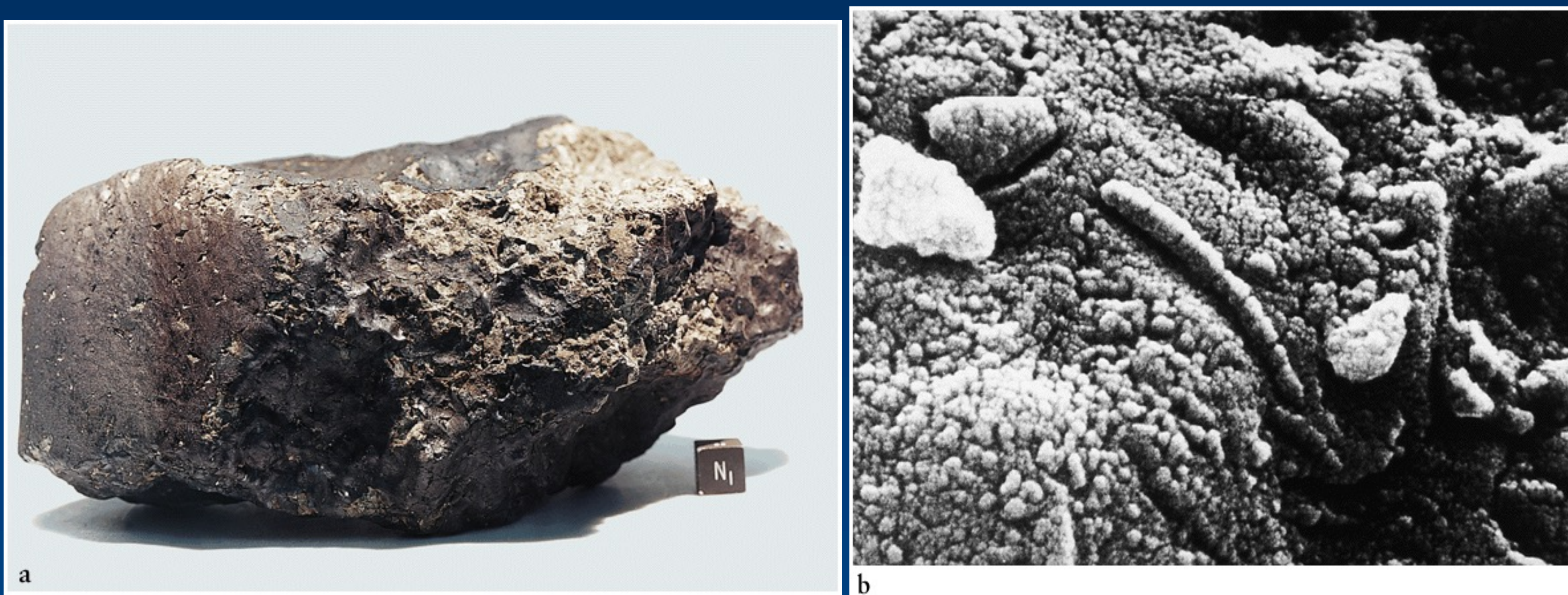


Found in Antarctica 1984. Chemically identified from Mars (rare)



Microscopic fossil remains in a meteorite thought to have originated from Mars (1997).

ALH84001 which shows odd shaped features that are reminiscent of bacteria. General consensus is - not life.

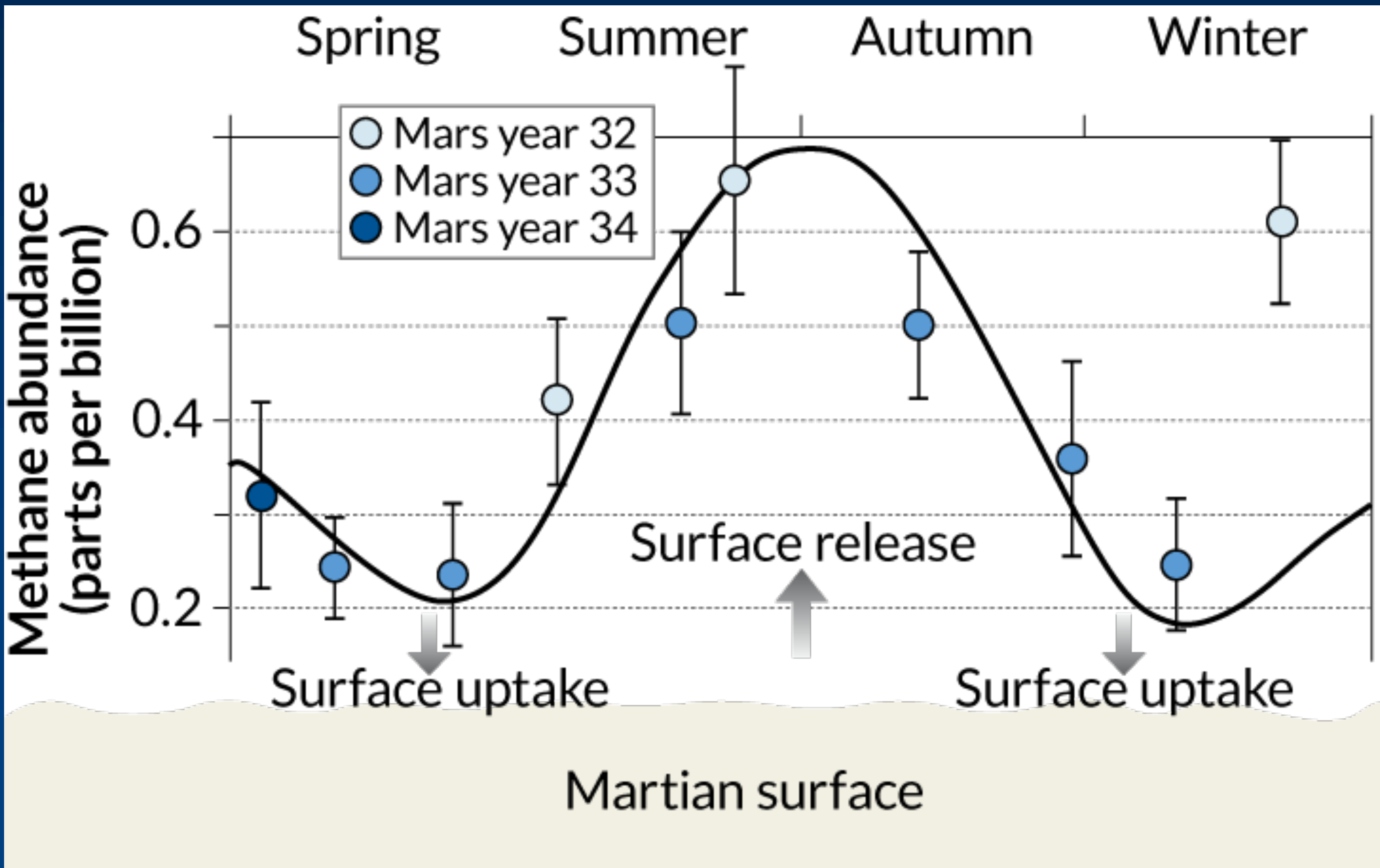


Methane on Mars?

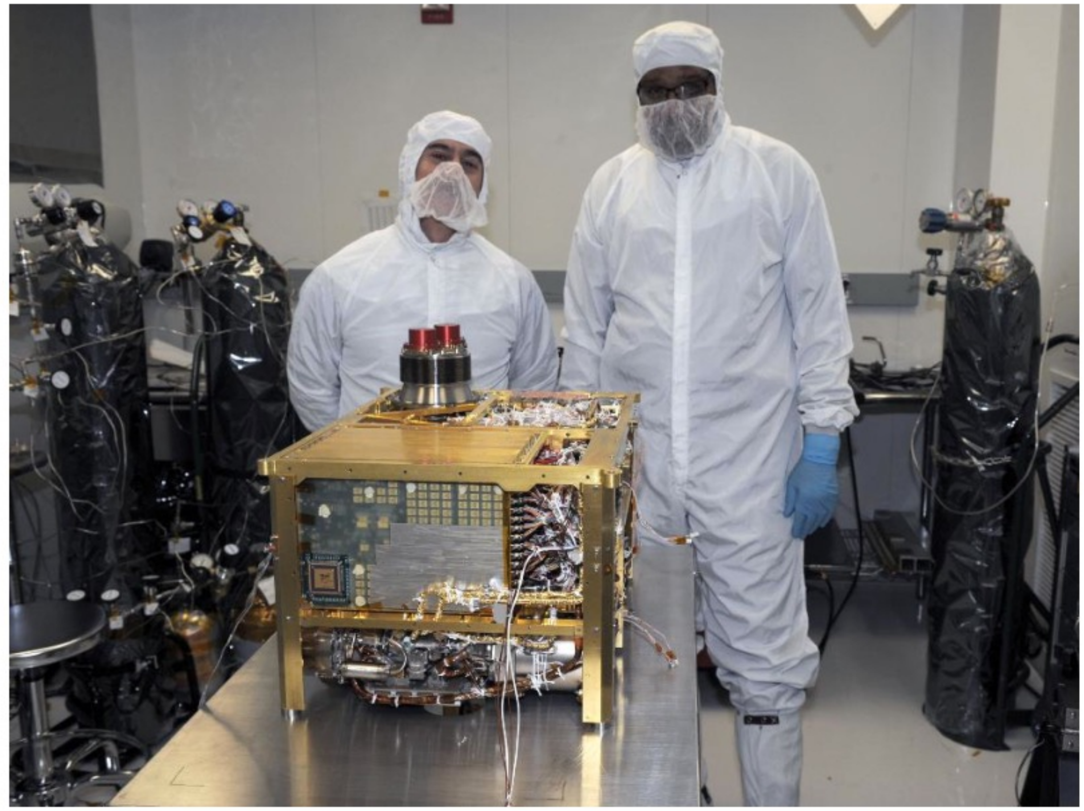
- On Earth 90% of methane comes from living organisms, rest is geological/chemical
- Some critters can live in the sand on Earth and outgas methane
- Atmospheric methane is destroyed in ~600 years
- 2009: Methane plumes reported on Mars
  - Up to 45 ppb in some regions
- 2018: Curiosity reports seasonal variations of Methane and in 2019 Oxygen

Methane on Mars?

- 2018: Curiosity reports seasonal dependence:



Curiosity

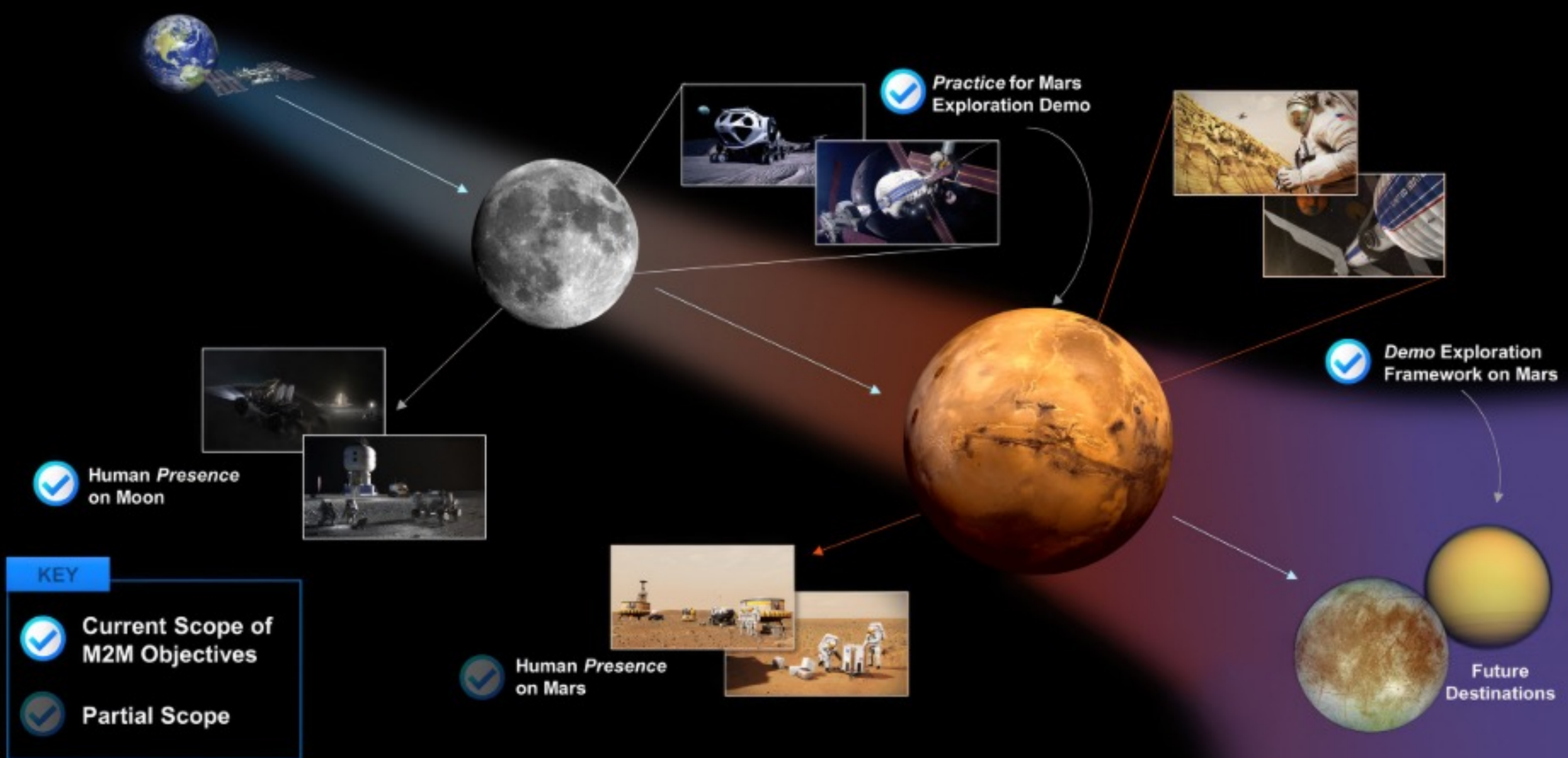


The Sample Analysis at Mars (SAM) instrument for NASA's Mars Science Laboratory mission will study chemistry of rocks, soil and air as the mission's rover, Curiosity, investigates Gale Crater on Mars. SAM was built at the NASA Goddard Space Flight Center, Greenbelt, Md., where this image was taken. Image credit: *NASA*

3 experiments searching for life on Mars:

1) Gas metabolism: look for changes in the atmosphere induced by metabolism in the Martian soil.
2) Labeled Release: Add nutrients tagged with radioactive ^{14}C and then look for release of radioactive $^{14}CO_2$ by metabolism from organic material in martian soil.
3) Mass Spectrometer: Search directly in Martian soil for organic compounds known to be essential to Earth life. Gale crater has sediments that could contain organic compounds.

CURRENT MOON TO MARS SCOPE



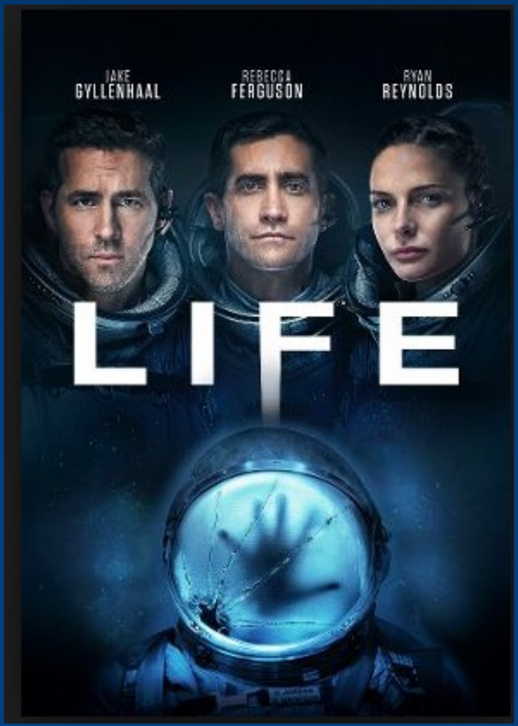
Identified goals and objectives are designed to first achieve the Moon to Mars endeavor, which will strategically position space exploration to extend beyond these destinations, reaching farther into the solar system to achieve the blueprint vision.

Courtesy: NASA

A thought for discussion:

Mars Sample Return has been proposed to bring back soil samples from Mars to test more carefully for life.

Should we do this?



What is Life?

Seven tests for life

1. Complex Organization
2. Convert food to energy
3. Reproduce
4. Growth and Development
5. Respond to stimuli
6. Adapt to Environment
7. Show individual variation

Now Define Intelligent Life

Intelligent Life:

1. Ability to use tools
2. Language
3. Ability to learn

Geologic Time (The cosmic calendar)

January 1st Earth forms	February First oceans	March 20th First signs of Life	
April Early Life develops	May Early life develops	June Early life develops	
July Early life develops	August Early life develops	September Early life develops	
October Early life develops	November 15th primitive ocean life begins 28th life on land Rapid development	December 12th Dinosaurs 24th Dino's disappear 31st early evening - humanoids	December 31st 8–11:45pm - stone tools 11:54pm – first civilizations 11:59:46 – Christian era 11:59:59 – Declaration of Independence

Question:

Are there other intelligent life forms in our Galaxy that we could communicate with?

A: No, just 1 advanced civilization in the whole Milky Way

B: Yes, a few perhaps 100 in the Milky Way

C: Yes, many, 10000 in the Milky Way

D: Yes, lots, millions in the Milky Way

Question:

How long do high-tech civilizations last?

A: 1 year

B: 100 years

C: 10,000 years

D: millions of years

The Drake Equation

$$N = R_* f_p n_e f_l f_i f_c L$$

the number of civilizations in the Galaxy that can communicate across stellar distances

The Drake Equation

$$N = R_* f_p n_e f_l f_i f_c L$$

number of technological, intelligent civilizations in the Milky Way = rate at which new stars are formed x fraction of stars having planetary systems x average number of habitable planets within those planetary systems

x fraction of those habitable planets on which life arises x fraction of those life-bearing planets on which intelligence evolves x fraction of those planets with intelligent life that develop technological society x average lifetime of a technological civilization

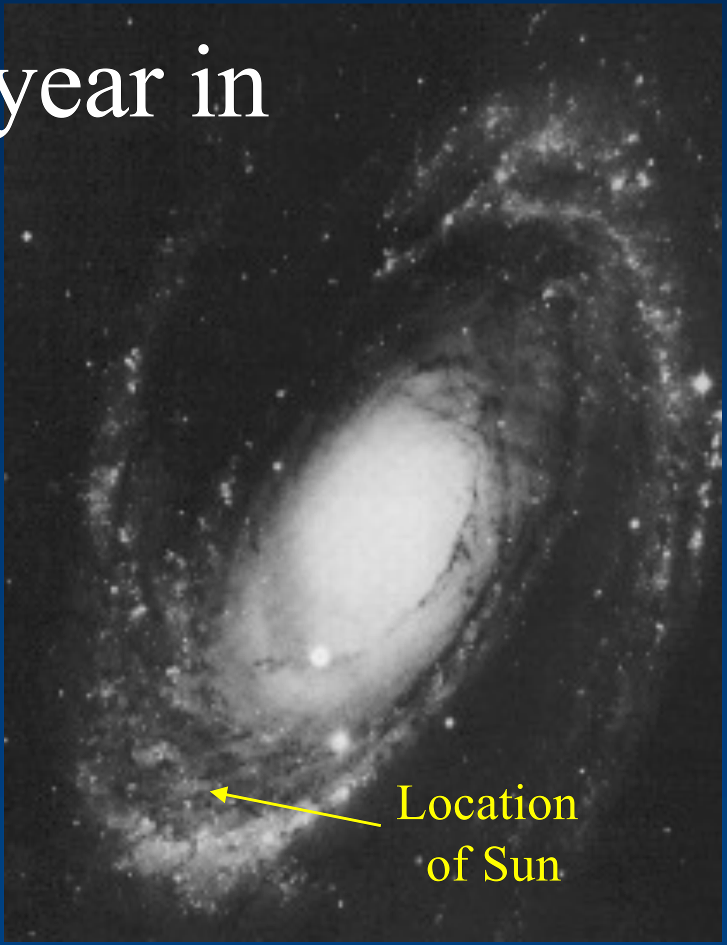
Each term is less certain than the preceding one!

$N = R_* f_p n_e f_l f_i f_c L$

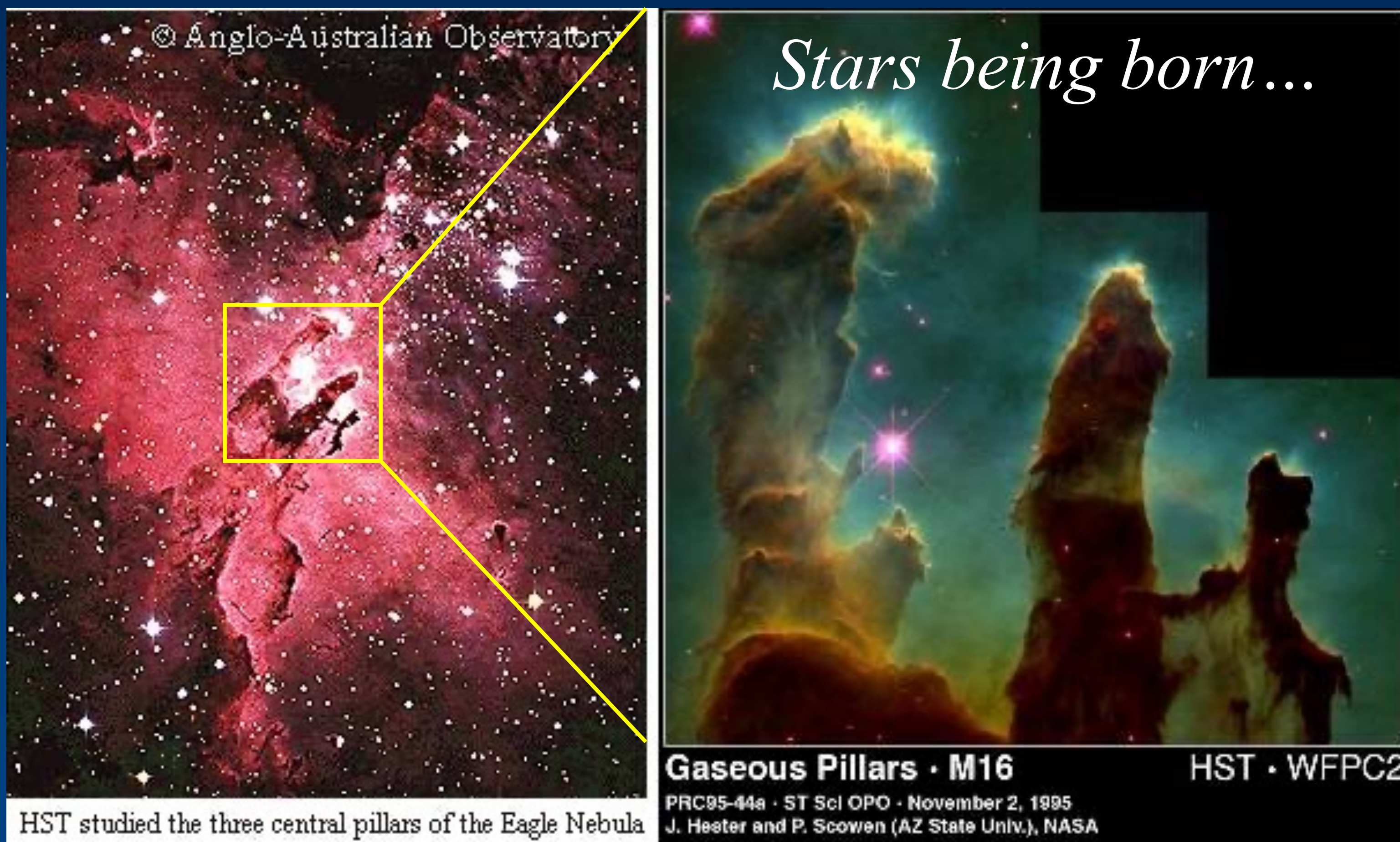
the ***rate*** at which suitable new ***stars are forming*** each year in the Galaxy

The Galaxy has ~***10^{11}*** stars, which are forming, living, and dying in billion year cycles-

Stars are the fundamental platforms and energy sources for life…



$N = R_* f_p n_e f_l f_i f_c L$



HST studied the three central pillars of the Eagle Nebula

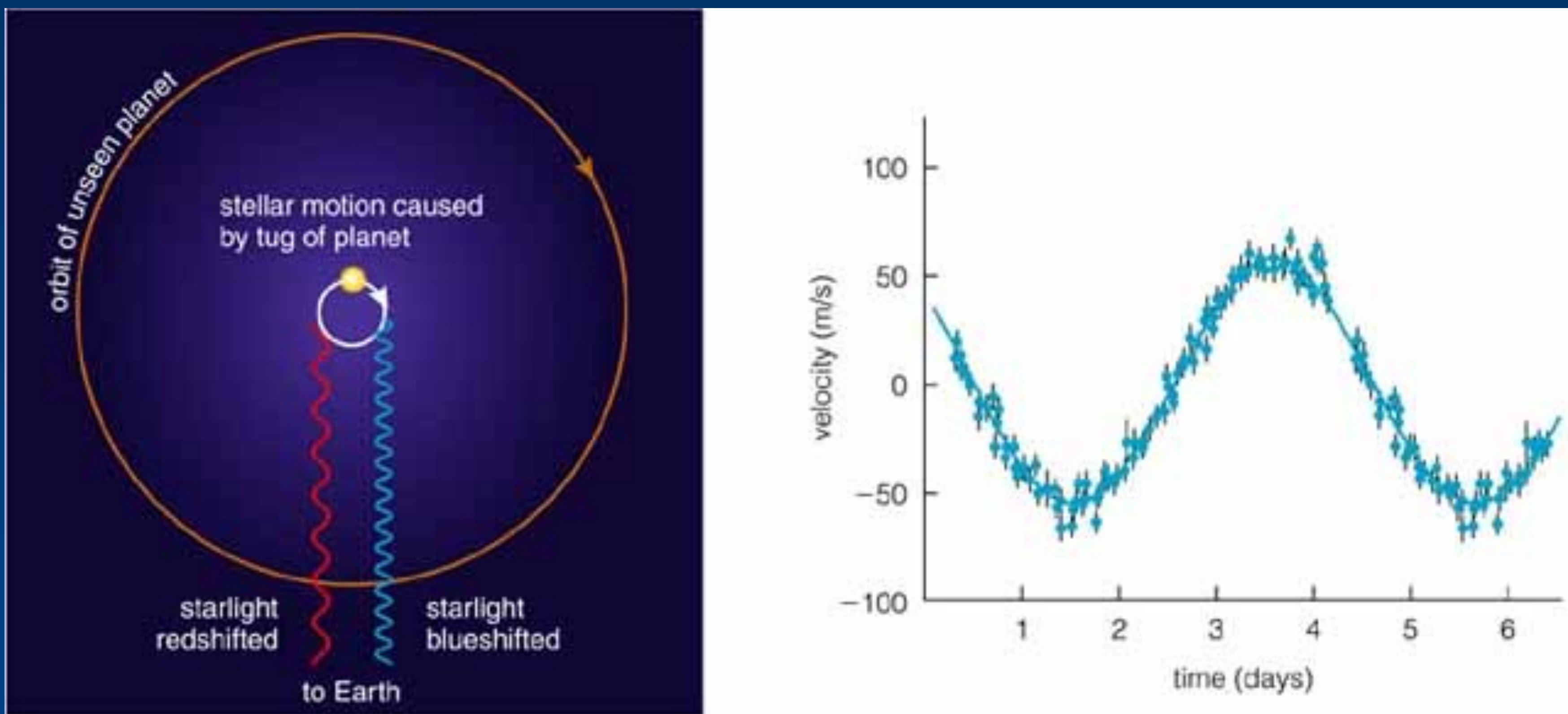
$$N = R_* f_p n_e f_l f_i f_c L$$

R_* is pretty well known because astronomical technology is up to the task of measuring it…

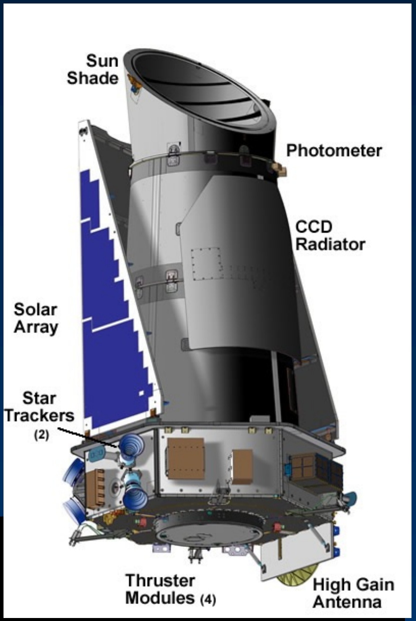
R_* ~ 10 stars per year

$$N = R_* f_p n_e f_l f_i f_c L$$

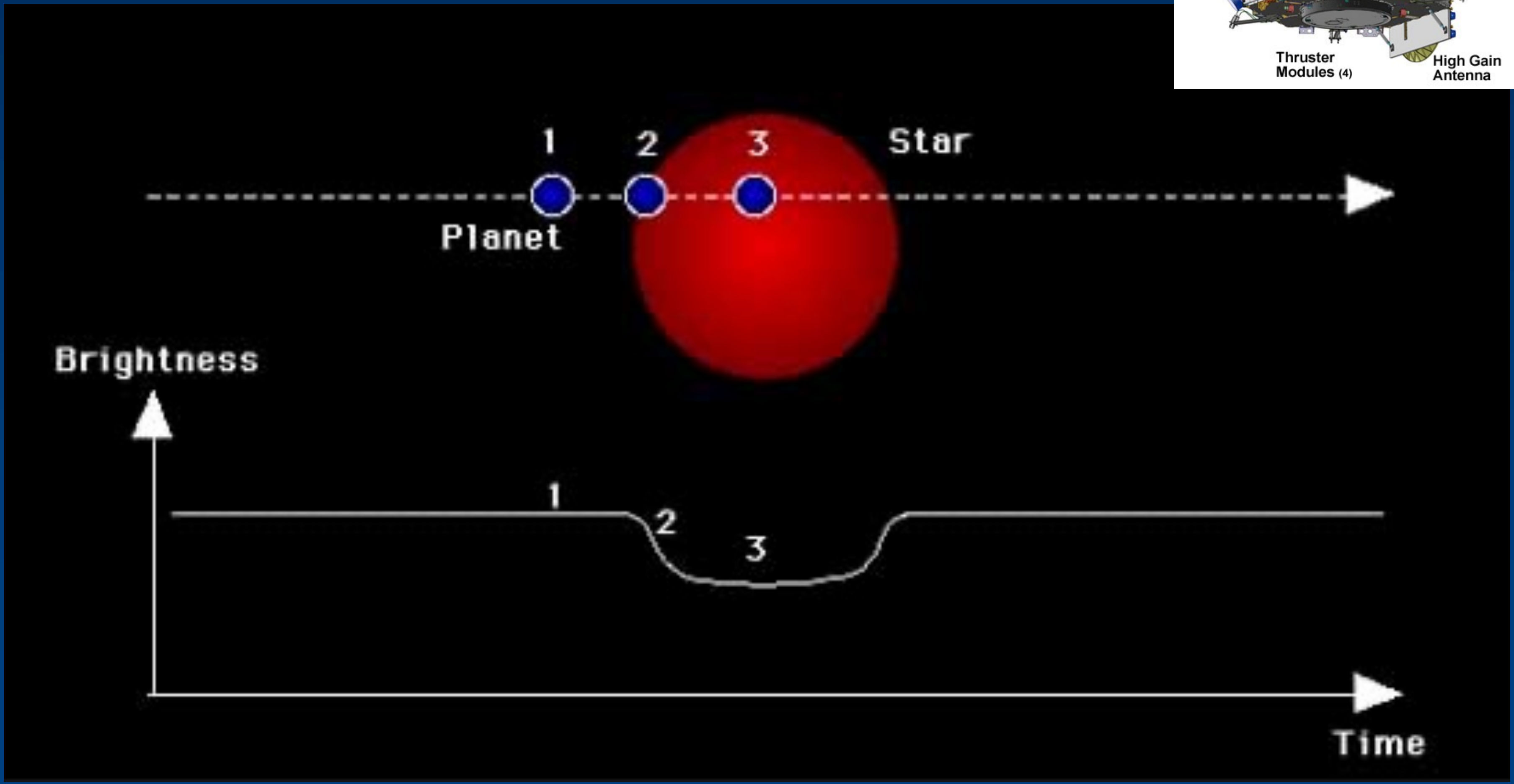
the fraction of suitable new stars around which ***planets form***



$$N = R_{*} f_p n_e f_l f_i f_c L$$



Another way to find planets…



$N = R_* f_p n_e f_l f_i f_c L$

f_p is becoming better known as we speak… long term Doppler programs and future space mission like TPF and Darwin will increase our knowledge.

$$f_p \sim 0.8$$

$N = R_* f_p n_e f_l f_i f_c L$

the number of planets residing in an ***ecosphere***, the shell of life

Direct energy: light from star

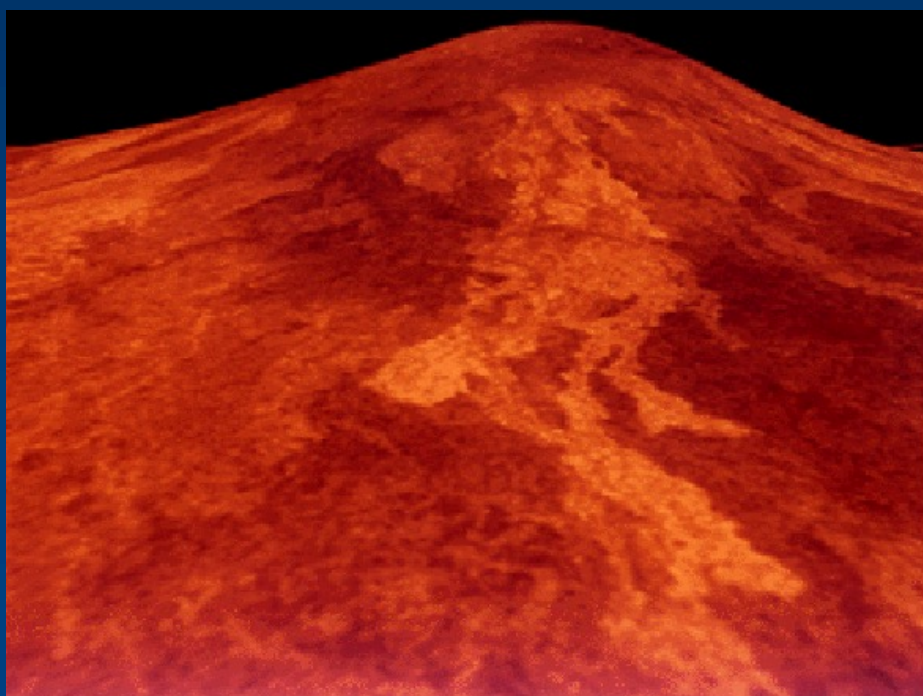
•Proximity to star (too close, too far, just right)
•Atmosphere of planet (climatic evolution)
•Ozone layer protects us from harmful UV-rays

Indirect energy: localized

•Solar wind + local magnetosphere
•Geothermal (radioactive decay)
•Central Planet (tidal forces on moons)

Requires stability for billions of years

$$N = R_* f_p n_e f_l f_i f_c L$$



Too close to the Sun

Venus suffers from a runaway Greenhouse effect, in which light energy from the star is trapped as heat by the atmosphere.

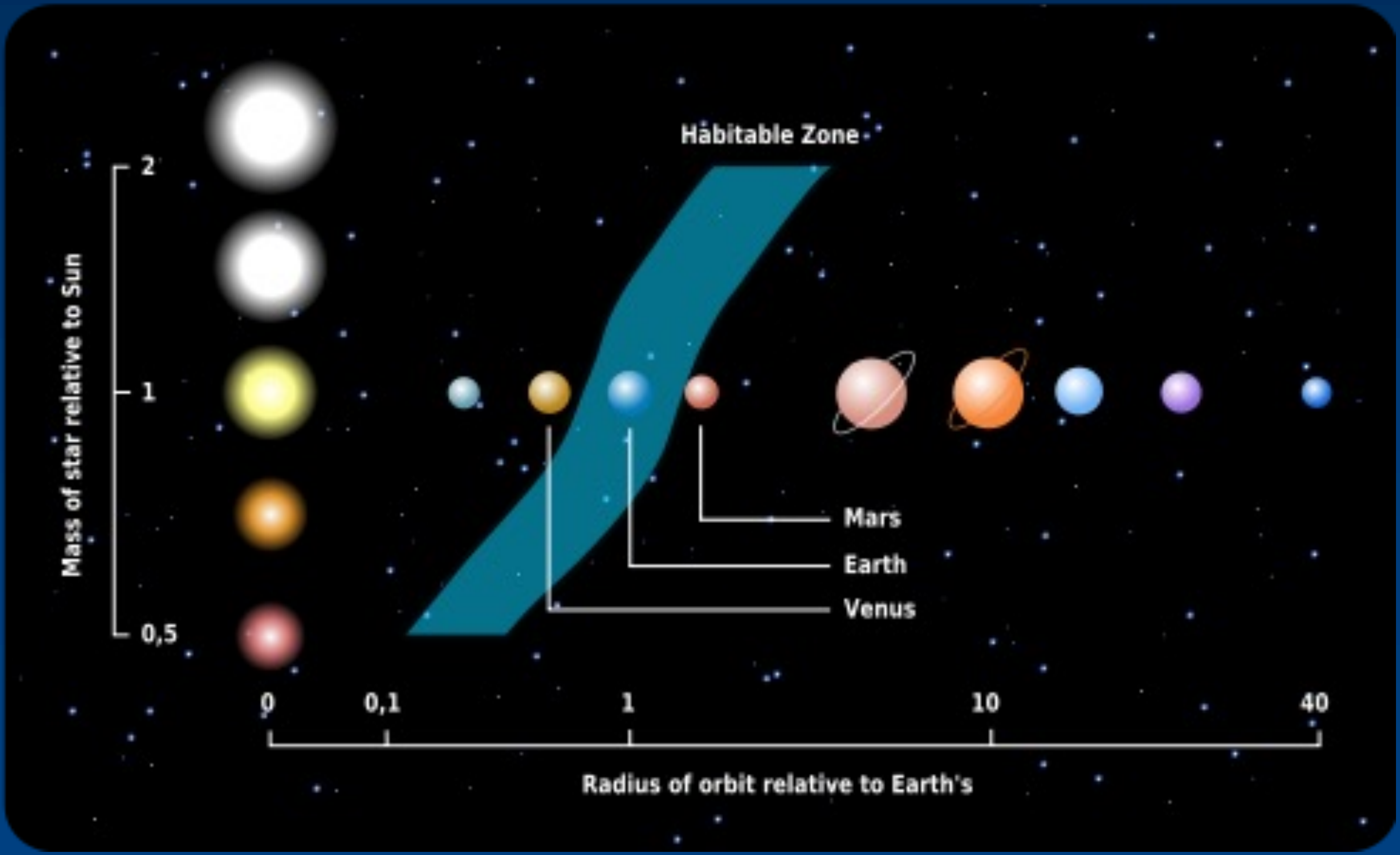
$N = R_* f_p n_e f_l f_i f_c L$

Too far from the Sun

Mars suffers from a runaway Ice Catastrophe, in which light energy from the star is reflected back into space.

$$N = R_* f_p n_e f_l f_i f_c L$$

In the zone …



$N = R_* f_p n_e f_l f_i f_c L$

n_e probably is zero in some planetary systems and is a few to several in others (ours?). We need to know what n_e is on average, its typical value.

n_e uncertain (~ 2?)

$$N = R_* f_p n_e f_l f_i f_c L$$

the fraction of ecosphere planets on which ***life arises***

Key Question: how readily does life arise?

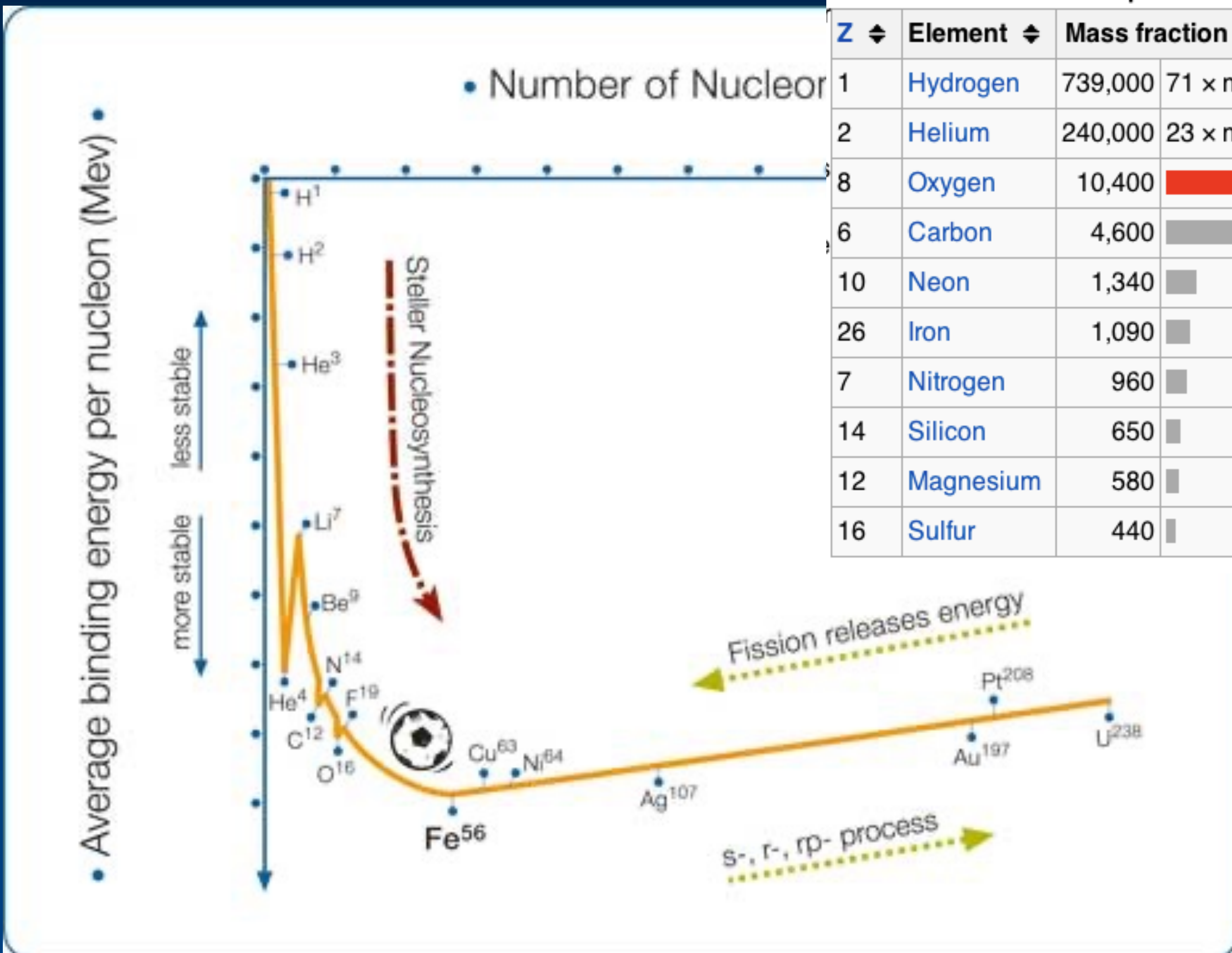
$N = R_{*} f_p n_e f_l f_i f_c L$

- All life (as we know it) is made of carbon based molecular chains
- Only 30 complex molecules comprised of only five (5) basic elements
- Urey-Miller experiment in 1953 showed that we could build amino acids

DNA molecule

C = carbon
H = hydrogen
N = nitrogen
O = oxygen
P = phosphorous

Binding Energy per nucleon



Ten most common elements in the Milky Way Galaxy estimated spectroscopically[1]

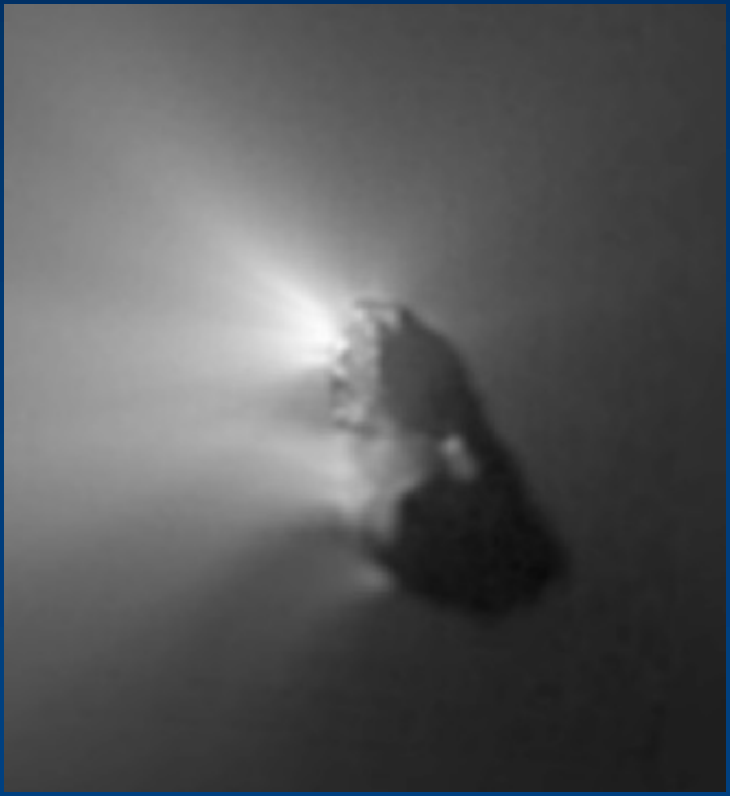
Z	Element	Mass fraction in parts per million	
1	Hydrogen	739,000	71 × mass of Oxygen (red bar)
2	Helium	240,000	23 × mass of Oxygen (red bar)
8	Oxygen	10,400	
6	Carbon	4,600	
10	Neon	1,340	
26	Iron	1,090	
7	Nitrogen	960	
14	Silicon	650	
12	Magnesium	580	
16	Sulfur	440	

$N = R_* f_p n_e f_l f_i f_c L$

- C, H, N, and O are among the seven most abundant elements is the universe
- The six elements of life (CHNOPS) are created in stars and supernovae explosions distributed them throughout the interstellar medium
- Organic molecules, such as amino acids, are commonly found in interstellar, molecular gas clouds, and in comets and meteorites

$N = R_* f_p n_e f_l f_i f_c L$

Comets, such as Halley, contain water ice and organic molecules, which are evaporated into interplanetary space



- Building blocks of planets during planet formation epoch
- Deposit water and organic molecules on planets
- Can alter course of evolution if impacting life bearing planet

$N = R_* f_p n_e f_l f_i f_c L$

Just how robust is life?

• Life persists in a wide range of terrestrial environments- from the high desert to frozen ice tundra, from the tropics to the black depths of the oceans…

Are there alternatives to photosynthesis?

• Life in the ocean depths exploits geothermal energy and survives *not* on sunlight, but on bacteria that metabolizes sulfuric acid outgasing from thermal vents

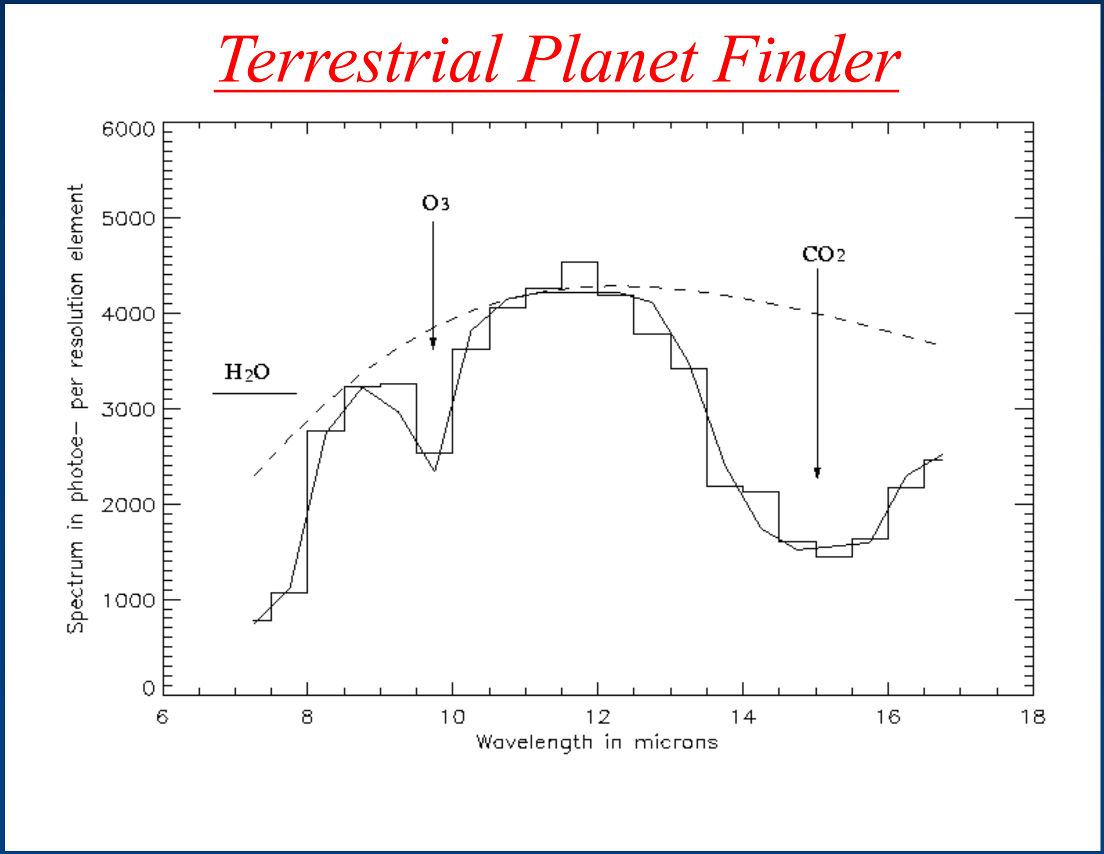
Life can arise in a range of environments and can survive on a variety of primary energy sources.

$N = R_* f_p n_e f_l f_i f_c L$

How will we detect signs of life on extrasolar planets?

Terrestrial Planet Finder would have taken spectra of earth sized planets up to 30 light years away!

Ozone, water, and carbon dioxide absorption features are indirect indicators of life processes (photosynthetic)



$N = R_* f_p n_e f_l f_i f_c L$

f_l , presently, can be guesstimated only by carefully studying our solar system, and in particular, Earth.

That life is a "language" with a 30 molecule "alphabet" and is comprised of the five most abundant elements is encouraging

$f_l \sim 0.1\text{-}1$ (?)

NOTE: f_l is likely <u>*not*</u> vanishingly small, say 10^{-8} or so

$N = R_* f_p n_e f_l f_i f_c L$

the fraction of life bearing planets upon which ***intelligence arises***

- How to define intelligence? (especially if you can' t give it an exam)

$$N = R_* f_p n_e f_l f_i f_c L$$

Defining intelligence…

Encephalization Quotient

Encephalization (E) is the ratio of brain mass to body "surface mass"

$$E = \frac{\text{Brain Mass}}{(\text{Body Mass})^{2/3}}$$

$$N = R_* f_p n_e f_l f_i f_c L$$

Encephalization Quotient

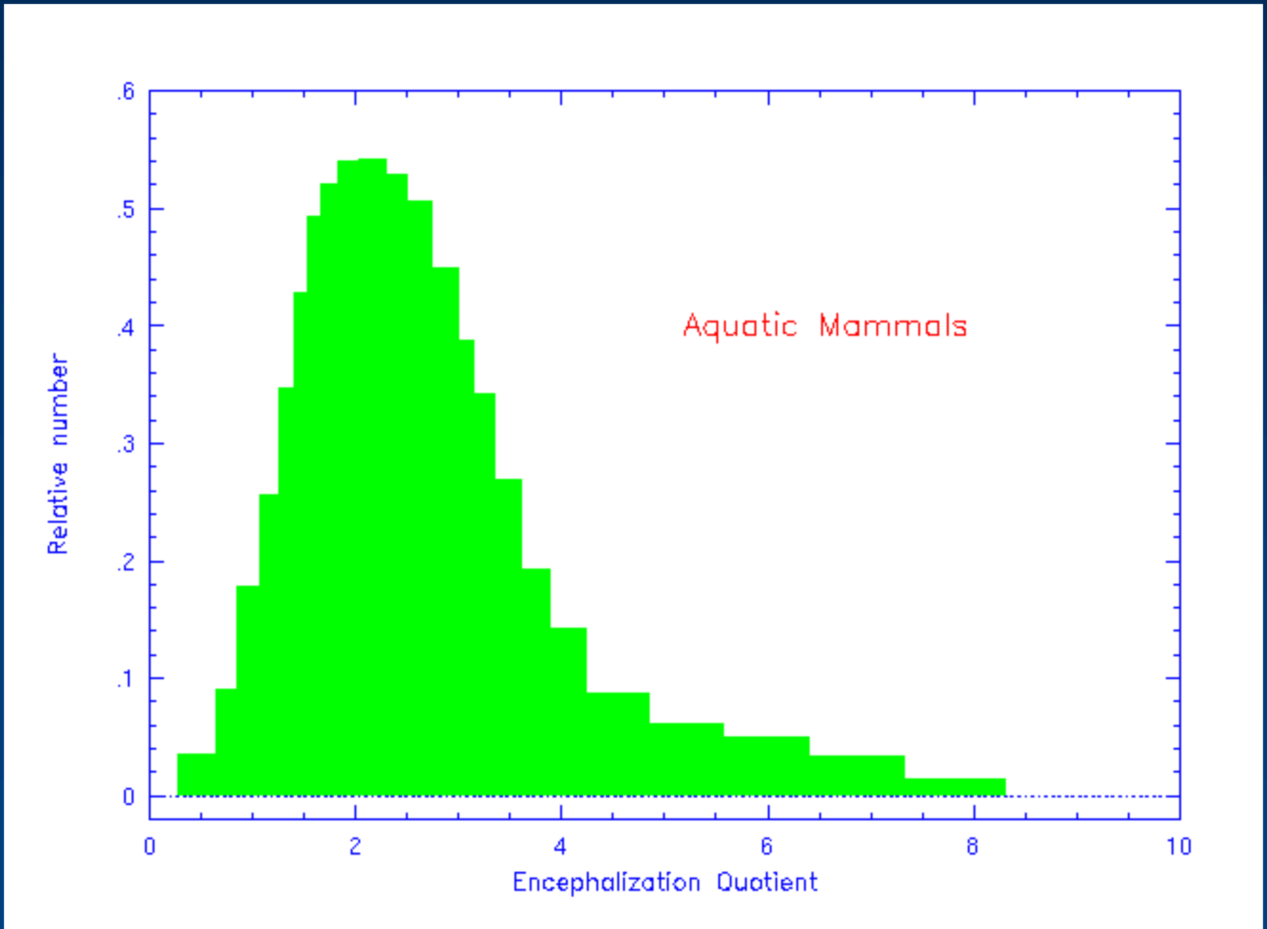
Encephalization Quotient (EQ) measures how "intelligent" a species is relative to other *comparable* life forms

$$EQ = \frac{E(actual)}{E(average)}$$

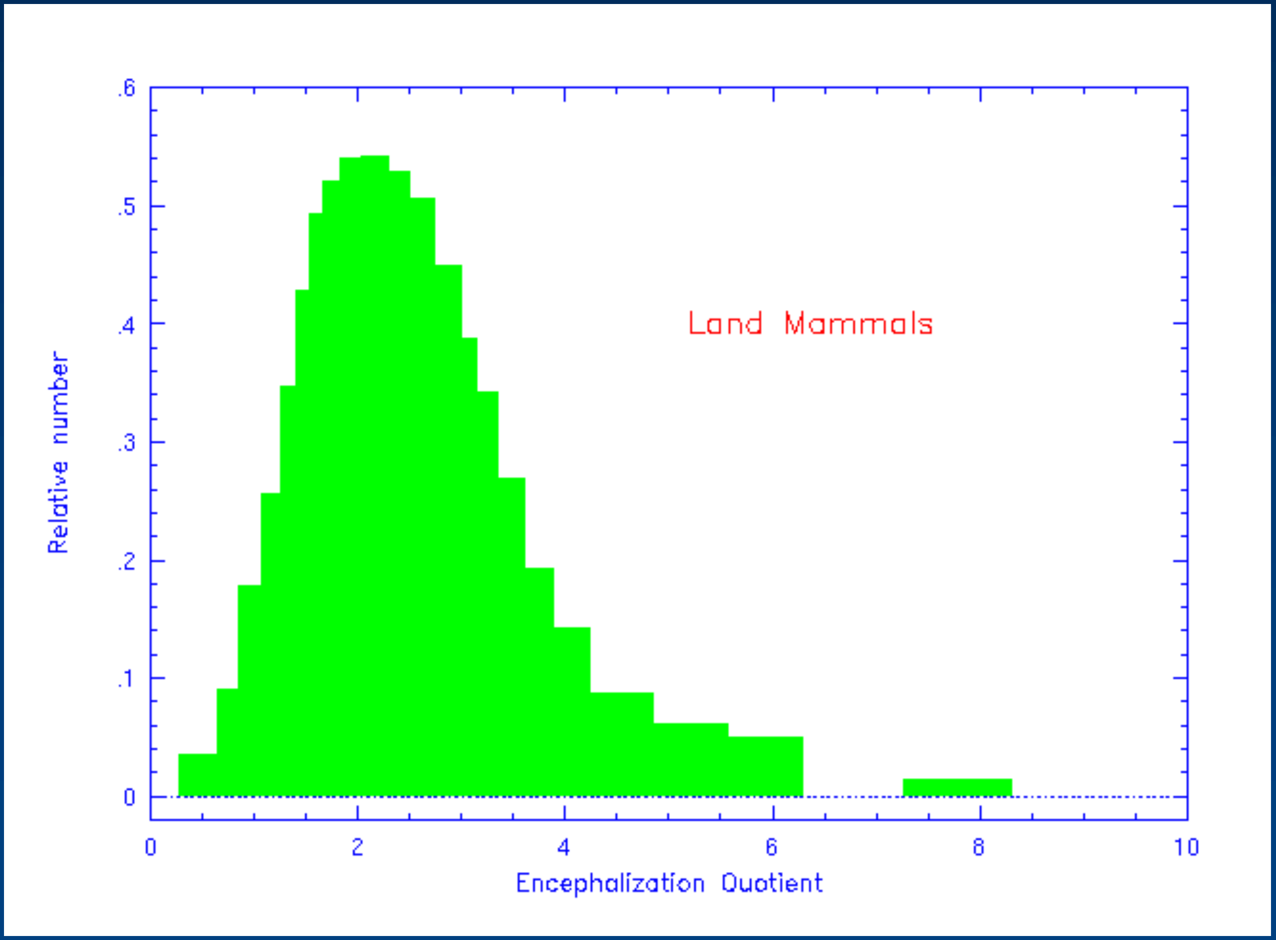
land mammals

EQ(cows) = 0.2
EQ(dogs) = 1
EQ(chimps) = 4
EQ(humans) = 8

$$N = R_* f_p n_e f_l f_i f_c L$$



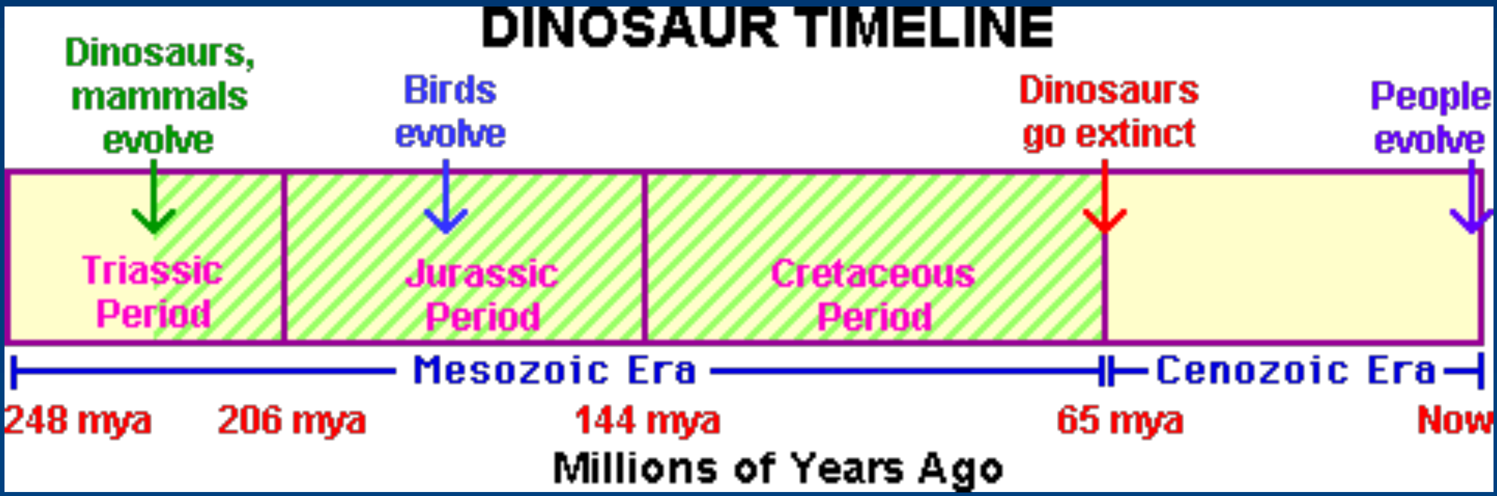
$N = R_* f_p n_e f_l f_i f_c L$



$$N = R_* f_p n_e f_l f_i f_c L$$

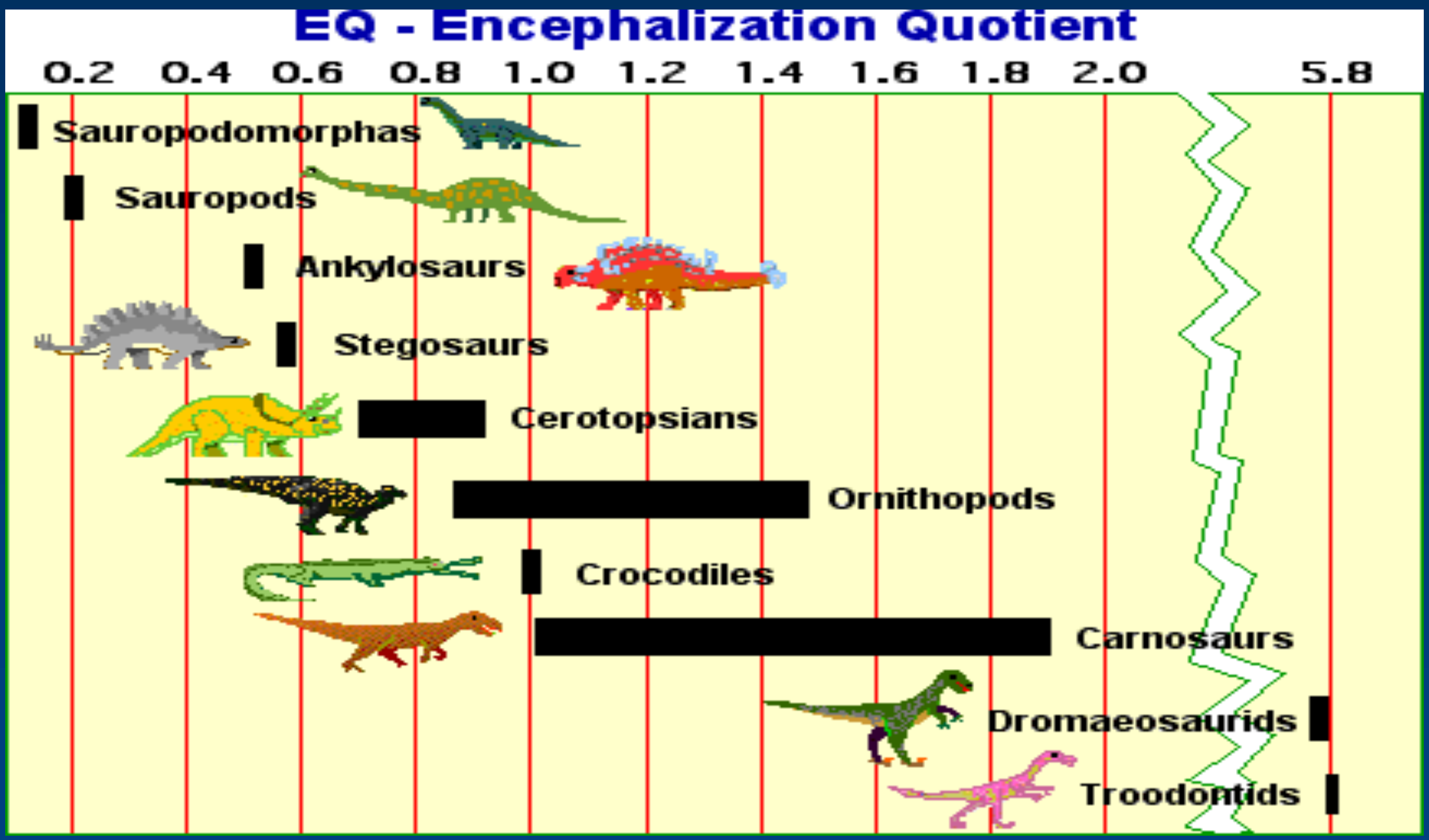
Were some dinosaurs smart?

They evolved over 160 million years, whereas humans have been around only 200 thousand years… what was different?



$$N = R_* f_p n_e f_l f_i f_c L$$

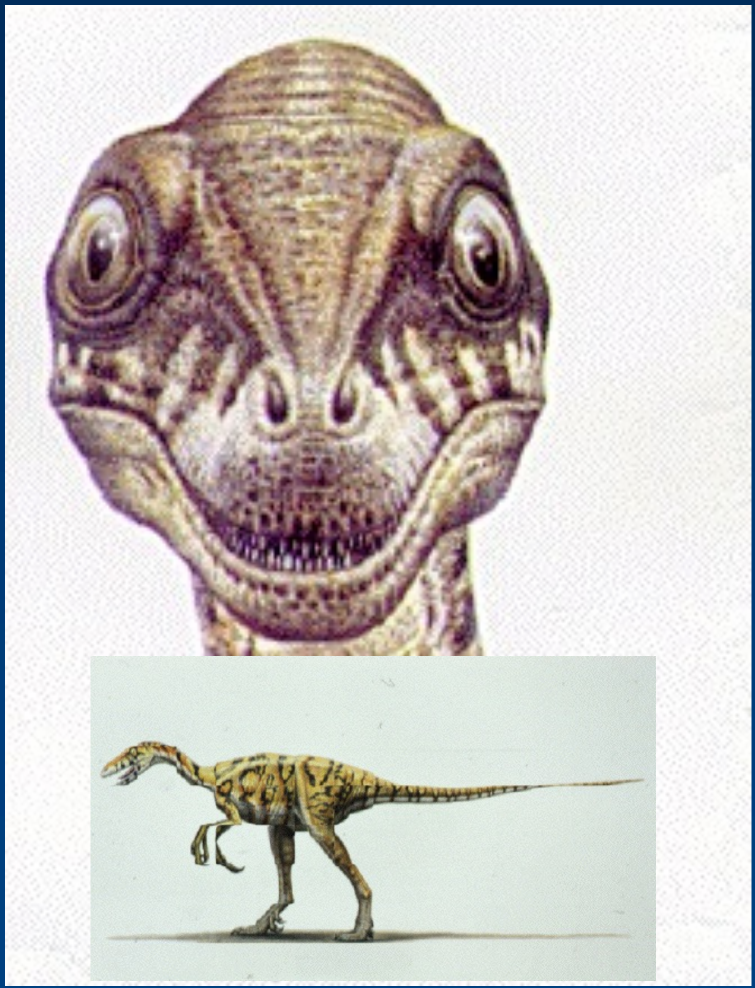
In fact, some dinosaurs were "intelligent", with EQ ~ 6 !



$$N = R_* f_p n_e f_l f_i f_c L$$

Tröodon

- Binocular Vision
- Stereoscopic Hearing
- Dexterous "Hands"
- Omniverous
- Largest EQ of dinosaurs



$N = R_* f_p n_e f_l f_i f_c L$

f_i can only be studied via the history of intelligence on Earth

• intelligence has always steadily increased with time, even with the repeated mass extinctions

$f_i \sim 0.1\text{-}1$ (?)

NOTE: f_i is likely *not* vanishingly small, say 10^{-8} or so except maybe in Congress

$N = R_* f_p n_e f_l f_i f_c L$

the fraction of planets hosting intelligent life where a *technological civilization* arises at least once

Must be able to communicate across stellar distances

Must be fast : Must be economical

➔ *electromagnetic radiation*

$N = R_* f_p n_e f_l f_i f_c L$

Technology. In the form of electromagnetic transmitters…

The physics is the same everywhere and is easily understood/developed

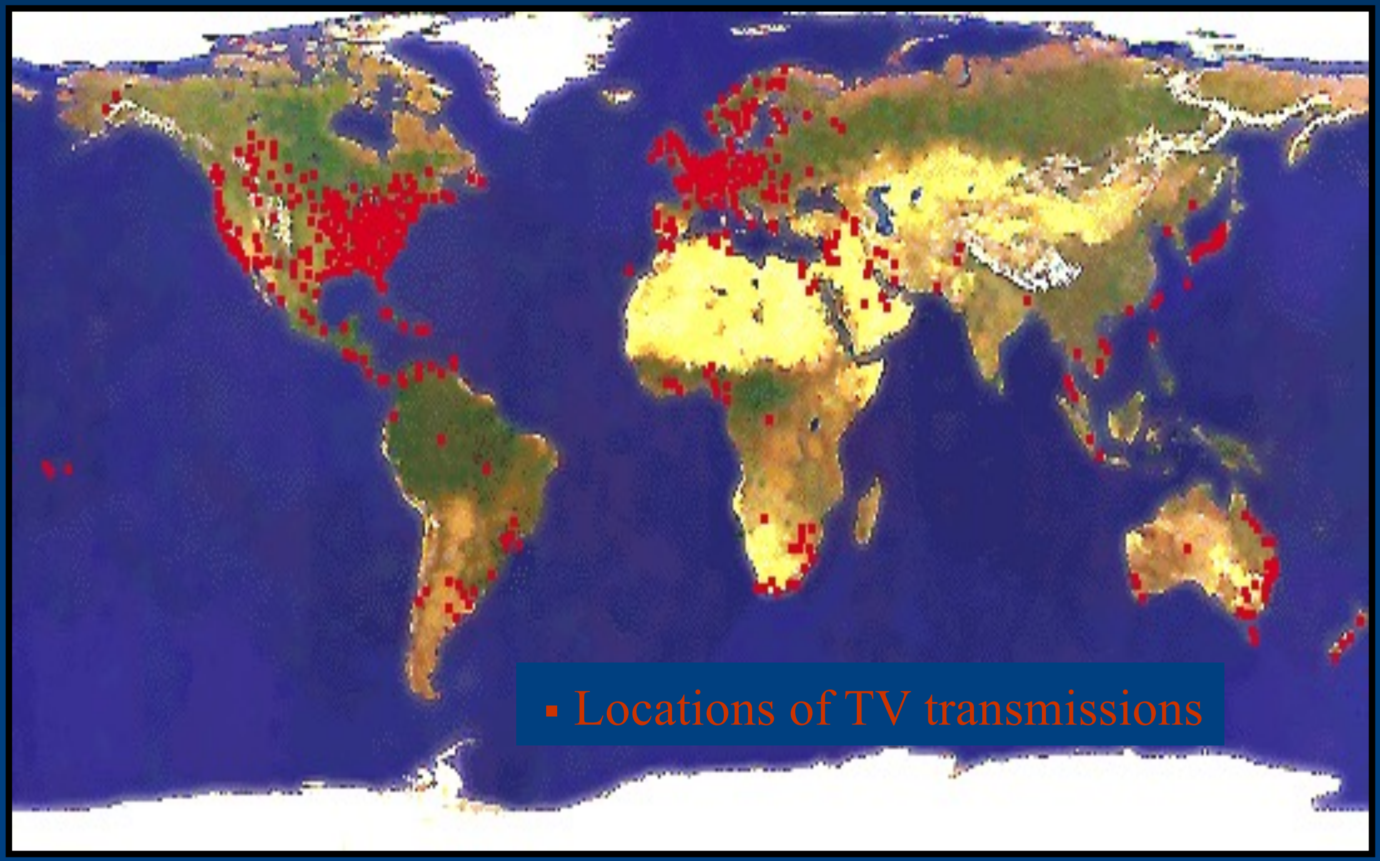
This simple technology was conceived and built only 5000 yrs after the pyramids and 10,000 yrs after writing appeared

The Very Large Array

Hello, Earth calling…

Powerful broadcast transmissions began ~ 1945

By 2021, the sphere has a 76 light year radius and has illuminated ~2100 stars!



$N = R_* f_p n_e f_l f_i f_c L$

The road to technology…

1. Ecological competitiveness and aggressive domination of habitat; frees species from "survive or die" centered consciousness
2. Living and working in groups; leads species to higher socialization stratification and communication skills
3. Control of fire (a technology)
4. Settlements and migrations; a ceasing of previous nomadic lifestyles
5. Development of agriculture and food storage

$N = R_* f_p n_e f_l f_i f_c L$

Why not dinosaurs?

Dinosaurs dominated Earth for 165 million years… why did they not develop radios and TVs?

No single type of dinosaur ever had complete dominion over its habitat in the way that modern humans have for some 30,000 years now.

Dinosaurs never surpassed a "survive or die" centered consciousness level, even though some were quite intelligent.

$N = R_* f_p n_e f_l f_i f_c L$

f_c can only be understood in terms of the human experience of technological development

- once humans dominated their habitat, the development of technology took only ~10,000 years, or 500 generations

$f_c \sim 0.1\text{-}1$ (?)

$$N = R_* f_p n_e f_l f_i f_c L$$

the <u>average</u> ***lifetime*** (in years), that technological civilizations remain in a *communicative* or *detectable* state

Do civilizations quickly destroy themselves, run out of natural resources, or after a brief time become quiet (i.e., dismantle or baffle their technology), or remain detectable for millions of years?

$N = R_* f_p n_e f_l f_i f_c L$

Evaluating N…

$R_* = 5\text{-}10$

$f_p = 0.5$

$n_e = 2$

$f_l = 0.1\text{-}1$

$f_i = 0.1\text{-}1$

$f_c = 0.1\text{-}1$

Maximum $N = 10\ L$

Moderate $N = L$

Minimum $N = 0.005\ L$

$N \sim L$

Take L ~ 10000, 1 civilization every 400 pc in the Milky Way

3e6 60 pc

Question:

Are there other intelligent life forms in our Galaxy that we could communicate with?

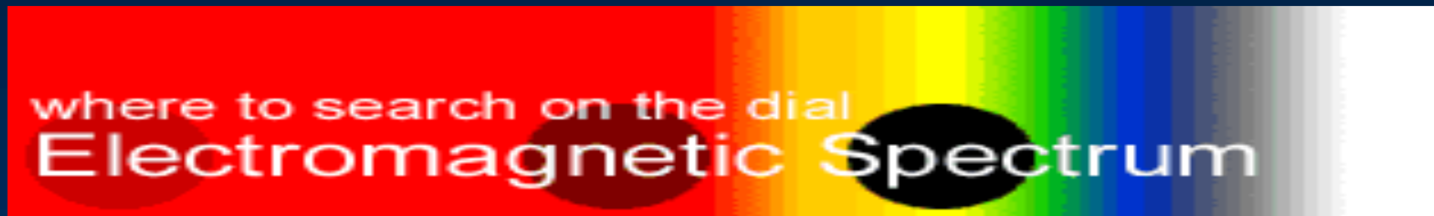
A: No, just 1 advanced civilization in the whole Milky Way

B: Yes, a few perhaps 100 in the Milky Way

C: Yes, many, 10000 in the Milky Way

D: Yes, lots, millions in the Milky Way

SETI: Search for Extraterrestrial Intelligence



Where the universe is quiet, of course!

where cosmic noise is minimal at ~3 gigahertz; *we exploit this window for our TV and satellite transmissions. ATA began operating Oct 2007.*

The Drake Equation

$$N = R_* f_p n_e f_l f_i f_c L$$

Why I don't have a girlfriend:
An application of the Drake Equation to love in the UK
Peter Backus

The Drake equation is used to estimate the number of highly evolved civilizations that might exist in our galaxy. The equation was developed in 1961 by Dr. Frank Drake at the National Radio Astronomy Observatory in Green Bank, West Virginia.