

IS THERE LIFE OUT THERE?

Larry Haug

Former NASA Contractor

- Apollo Moon Landing Team Member
- Hubble Space Telescope Ground Data Systems Manager

SOURCES

- **“The Search for Life in the Universe”**
by Neil deGrasse Tyson, Director, Hayden Planetarium in NYC
- **“The Search for Life Across the Universe”**
by Amy Crawford, Science Journalist for Smithsonian Magazine
- **“Would We Know Alien Life If We Saw It?”**
by Trudy E. Bell, Science Journalist for Scientific American
- **“Life Among the Gas Giants”**
by Craig Mellow, American biologist and professor of molecular medicine at the University of Massachusetts Medical School
- **“Astrobiology: Possibility of Life Out There”**
by Dr. Tim Kral, Associate Professor of Microbiology at U of A

In order to determine if extraterrestrial life exists we need to answer three questions:

- What is life?**
- What is needed for life to exist?**
- Where do we look for extraterrestrial life?**



WHAT IS LIFE?





What Is Life?

- **Species # 1**
- **Species # 2**
- **Species # 3**
- **Species # 4**

SPECIES #1

- **Can exist in extreme hot and cold environments**
- **Can live in water**
- **Has no arms or legs or any other external appendages but is able to move on the ground at speeds up to 2 feet/second**
- **Can swallow other creatures up to 5 times the size of its mouth**
- **Some kill their prey with a poisonous excretion and then eat their poisoned victims**
- **Periodically sheds their outer covering which protects them from their environment**

What Is Life?

- **Species # 1 - Snake**
- Species # 2
- Species # 3
- Species # 4



SPECIES #2

- Can exist in extreme environments
- Some species live next to hydrothermal vents in the deepest part of the ocean under extreme pressures
- Can survive at temperatures exceeding 600° F
- They can replicate photosynthesis using only chemicals and can live off of the H_2SO_4 gases from the vents
- Some species live many kilometers deep in the earth's crust and mantle where there is no water and feed on Iron, Potassium and Sulphur

What Is Life?

- Species # 1 - Snake



- **Species # 2 - Extremophiles**



- Species # 3

- Species # 4

SPECIES #3

- These creatures are only 1 mm long and are found in Lichen and Moss, everywhere from mountaintops to the deep sea, from tropical rain forests to the Antarctic
- They are an ancient group, with fossils dating from 530 million years ago
- They can exist in temperatures close to Absolute Zero (minus 459.67° Fahrenheit) and up to 300° F
- They can exist is pressures about six times greater than those found in the deepest ocean trenches
- Can survive 30 years without food or water
- Can survive in the vacuum of space
- Can survive up to 1,000 times more radiation than other animals

What Is Life?

- Species # 1 - Snake
- Species # 2 - Extremophiles
- Species # 3 – Tardigrades
aka Water Bears
- Species # 4



SPECIES #4

- **Creature consists of 60% water but cannot survive immersed in water**
- **Cannot survive in extreme hot or cold environments**
- **Breathes an explosive gas and cannot survive without it**
- **Depends on over 10 million microscopic creatures living inside of them to survive**

What Is Life?

- Species # 1 - Snake
- Species # 2 - Extremophiles
- Species # 3 – Tardigrades
aka Water Bears
- Species # 4 - Homo Sapiens



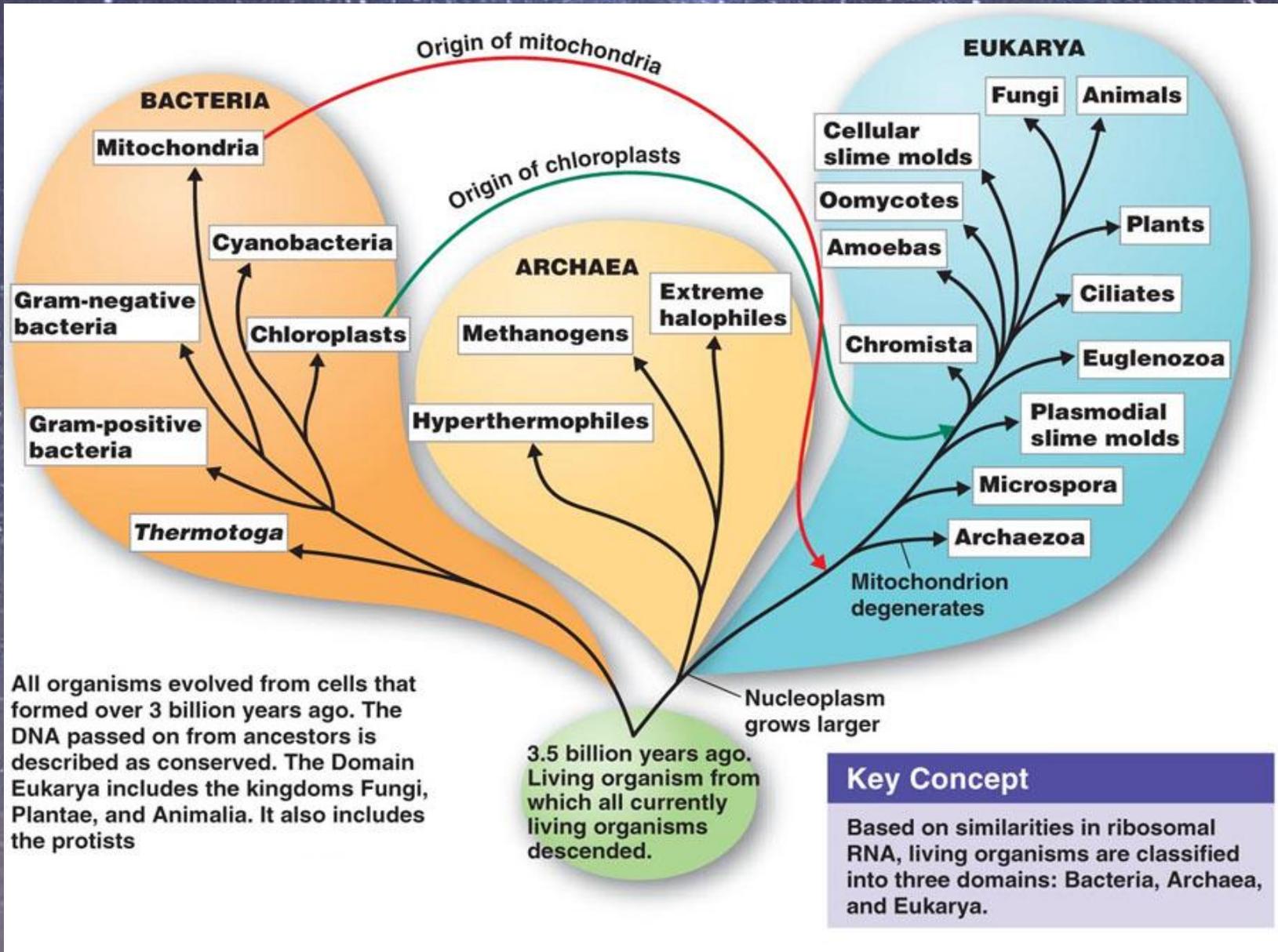
What are the characteristics that we use to define life?

- **Container (Cellular Membrane)**
- **Template (DNA and/or RNA)**
- **Catalyst (Metabolic Enzyme)**
- **Ability to Reproduce**
- **Ability to Produce Energy**
- **Ability to evolve**

NASA Definition of Life

**A self-sustaining chemical system
capable of Darwinian evolution.**

What Constitutes Life On Earth?



What Species Live On Earth?

- There are approximately 10 to 14 Million Species currently on Earth
- They range from single cell microbes to large living creatures
- 86% have yet to be described
- More than 99 percent of all species, amounting to over five billion species, that ever lived on Earth are estimated to be extinct



WHAT IS NEEDED FOR LIFE TO
EXIST?

What Elements are Needed For Life to Exist?

The Elements of Life*			
Element	Symbol	Atomic Number	Approximate Atomic Weight
Hydrogen	H	1	1
Carbon	C	6	12
Nitrogen	N	7	14
Oxygen	O	8	16
Sodium	Na	11	23
Magnesium	Mg	12	24
Phosphorus	P	15	31
Sulfur	S	16	32
Chlorine	Cl	17	35
Potassium	K	19	39
Calcium	Ca	20	40
Iron	Fe	26	56
Iodine	I	53	127
*Hydrogen, carbon, nitrogen, and oxygen are the most abundant chemical elements in living organisms.			

Biogenic Elements

- Carbon
- Hydrogen
- Oxygen
- Nitrogen
- Sulfur
- Phosphorus

What Do We Think Is Needed For Life to Exist in the Universe?

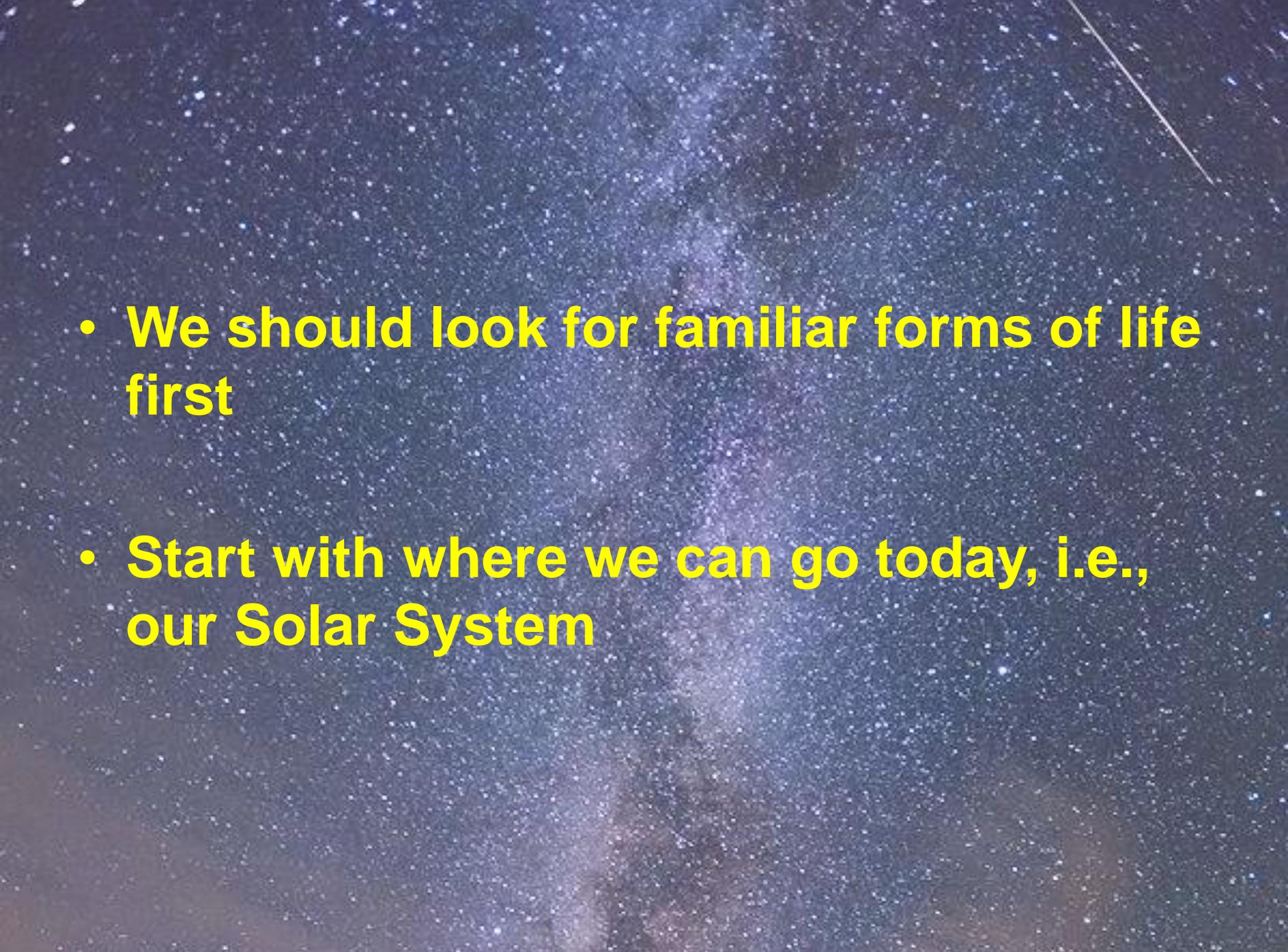
- Four most common elements in the Universe are Hydrogen, Helium, Carbon and Oxygen
- Helium is an inert gas
- Most abundant, chemically active ingredients in the cosmos are also the top three ingredients of life on Earth and account for over 95% of the atoms in humans and in all known life
- Therefore, any other life should be made up of a similar mix of elements

What Are the Processes Needed For Life to Exist?

- Life arose on Earth because of fundamentals in biochemistry whose processes are universal
- This strain of life has existed on Earth for billions of years
- Chemistry has had a chance to do other things, i.e., life based on silicon, if they really worked
- For life to exist, we think that you need liquid water, organic molecules, an energy source, a catalytic surface to kick start a biological process and time
- Therefore, other life in the Universe will, in all probability, be based on the same processes



WHERE DO WE LOOK FOR
EXTRATERRESTRIAL LIFE?

- 
- **We should look for familiar forms of life first**
 - **Start with where we can go today, i.e., our Solar System**

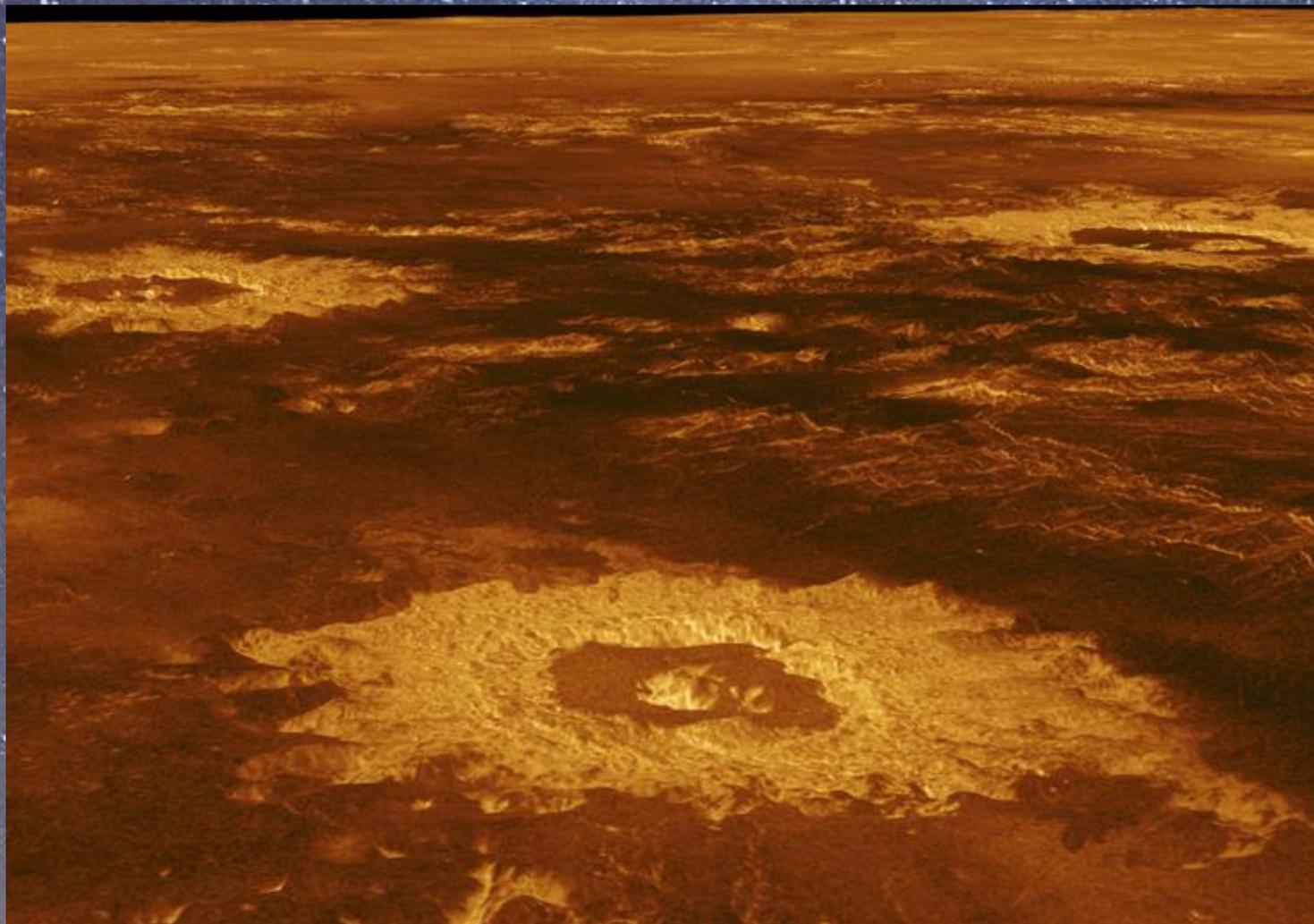
VENUS

- 90 bars of CO₂ in its atmosphere
- Ground temperature is 800°F
- Melting point of Lead is 621.5°F
- Too hot for liquid water to exist at any pressure
- The surface of Venus is just too inhospitable for life to exist
- But what about the clouds of Venus?
- The clouds we see on Venus are made up of sulfur dioxide and drops of sulfuric acid

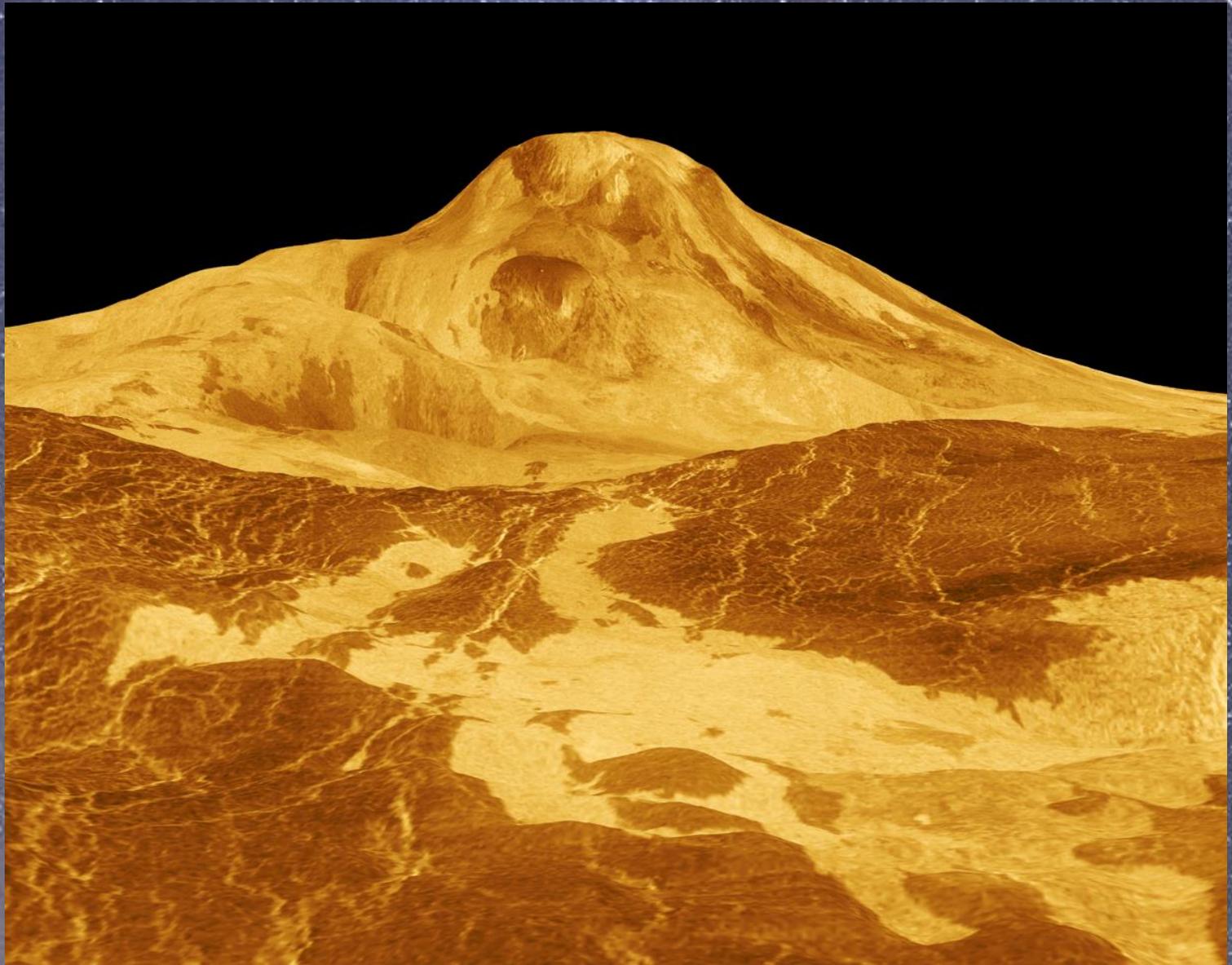
VENUS



VENUS



VENUS



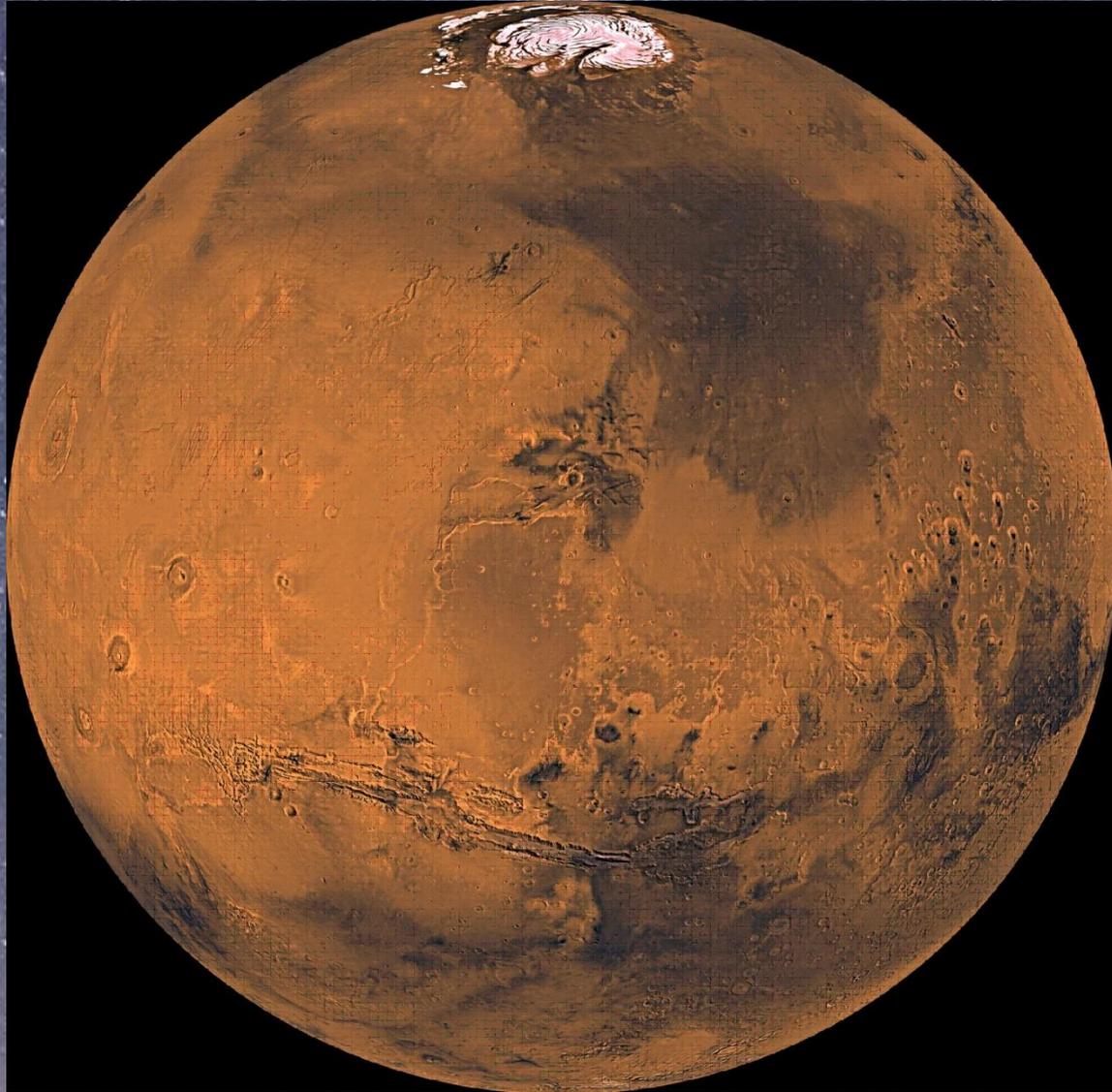
MARS

- **Argument for water-based and carbon-based life is never stronger than on Mars**
- **Water still flows on Mars today – at or very near the surface**
- **Mars' Curiosity Rover discovered two types of complex organic molecules from inside a mudstone at Gale Crater**
- **One resembled a fatty acid found in the cell walls of terrestrial organisms**
- **If life exists on Mars it will probably be sub-surface**

Conditions on the Surface of Mars

- **Cold (- 67° F average)**
- **Dry (0.03% water vapor)**
- **Very Thin Atmosphere (6 mbar)**
- **No Detectable Organics**
- **Lethal Radiation**
- **Oxidants in the Soil**
- **No Magnetic Field**

MARS





**12,756 km
Diameter**



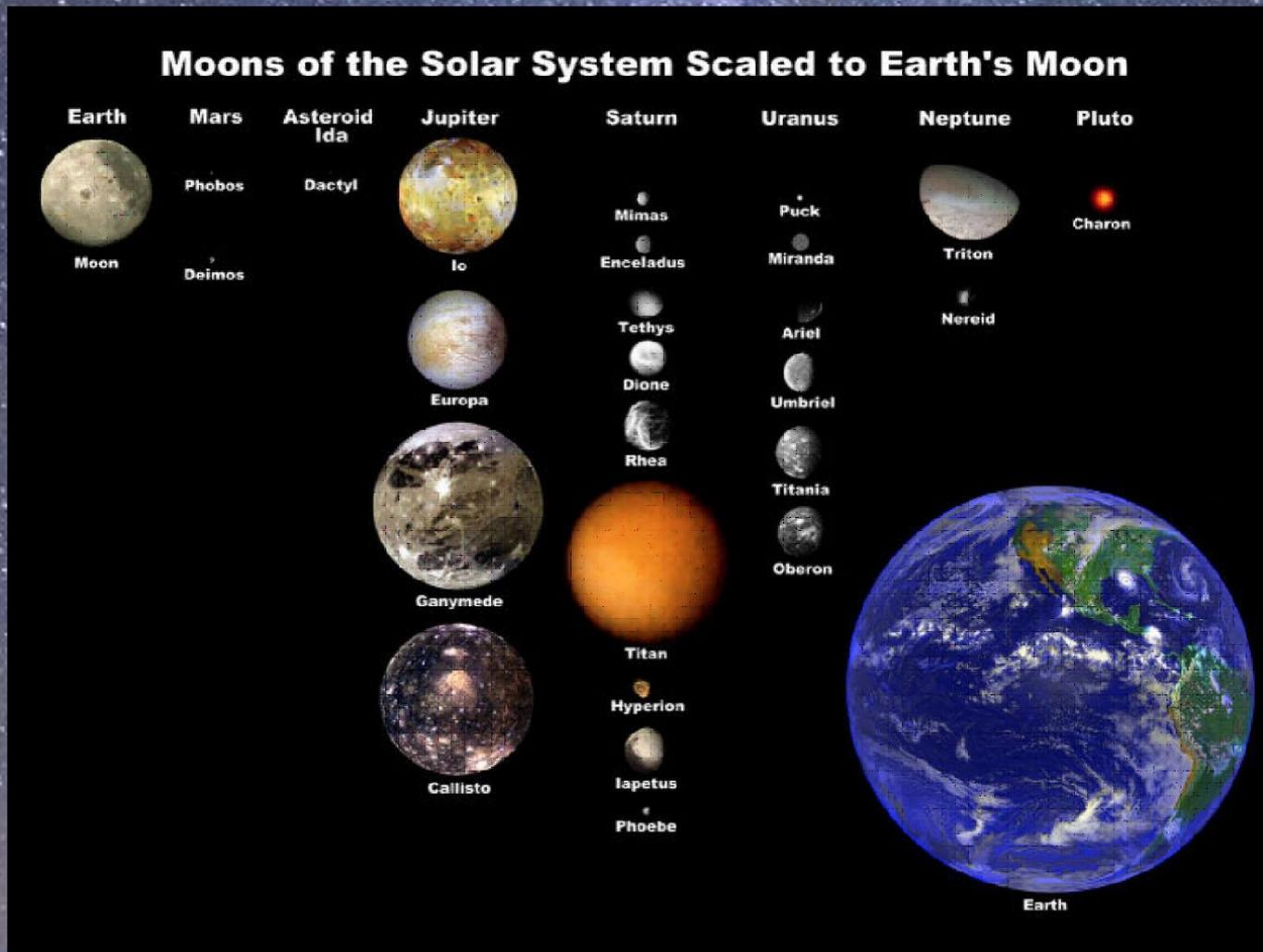
**6,794 km
Diameter**

MARS



MOONS OF THE OUTER SOLAR SYSTEM

Moons of the Gas Giants in our Solar System may have environments suitable for life

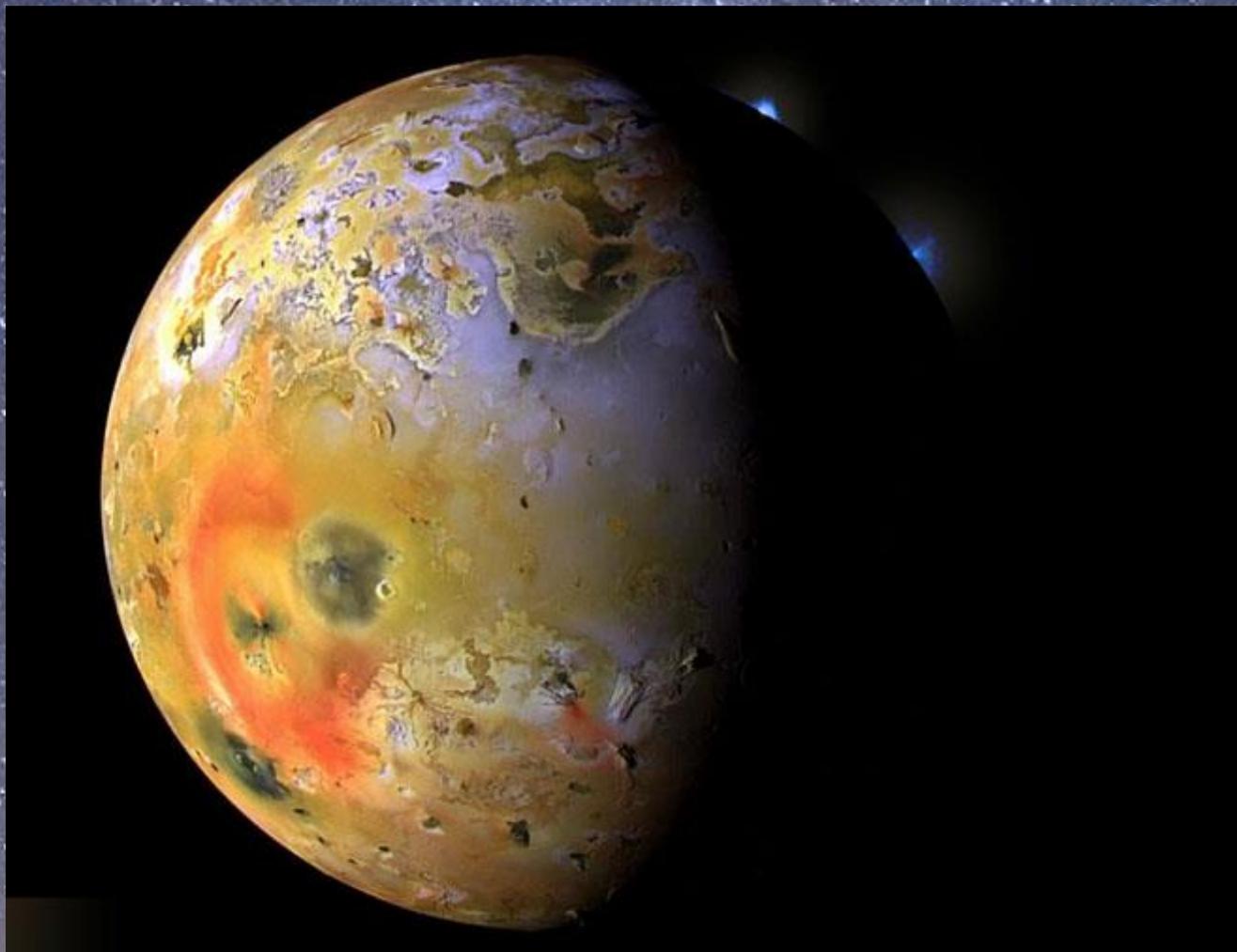


IO

(Moon of Jupiter)

- **With over 400 active volcanoes, IO is the most geologically active object in the Solar System**
- **Several volcanoes produce plumes of sulfur and sulfur dioxide that climb as high as 500 km (300 mi) above the surface**
- **IO's surface is also dotted with more than 100 mountains that have been uplifted by extensive compression at the base of IO's silicate crust. Some of these peaks are taller than Mount Everest**
- **Unlike most satellites in the outer Solar System, which are mostly composed of water ice, IO is primarily composed of silicate rock surrounding a molten iron or iron-sulfide core**
- **Most of IO's surface is composed of extensive plains coated with sulfur and sulfur-dioxide frost**
- **Not much chance of life on IO**

10



10

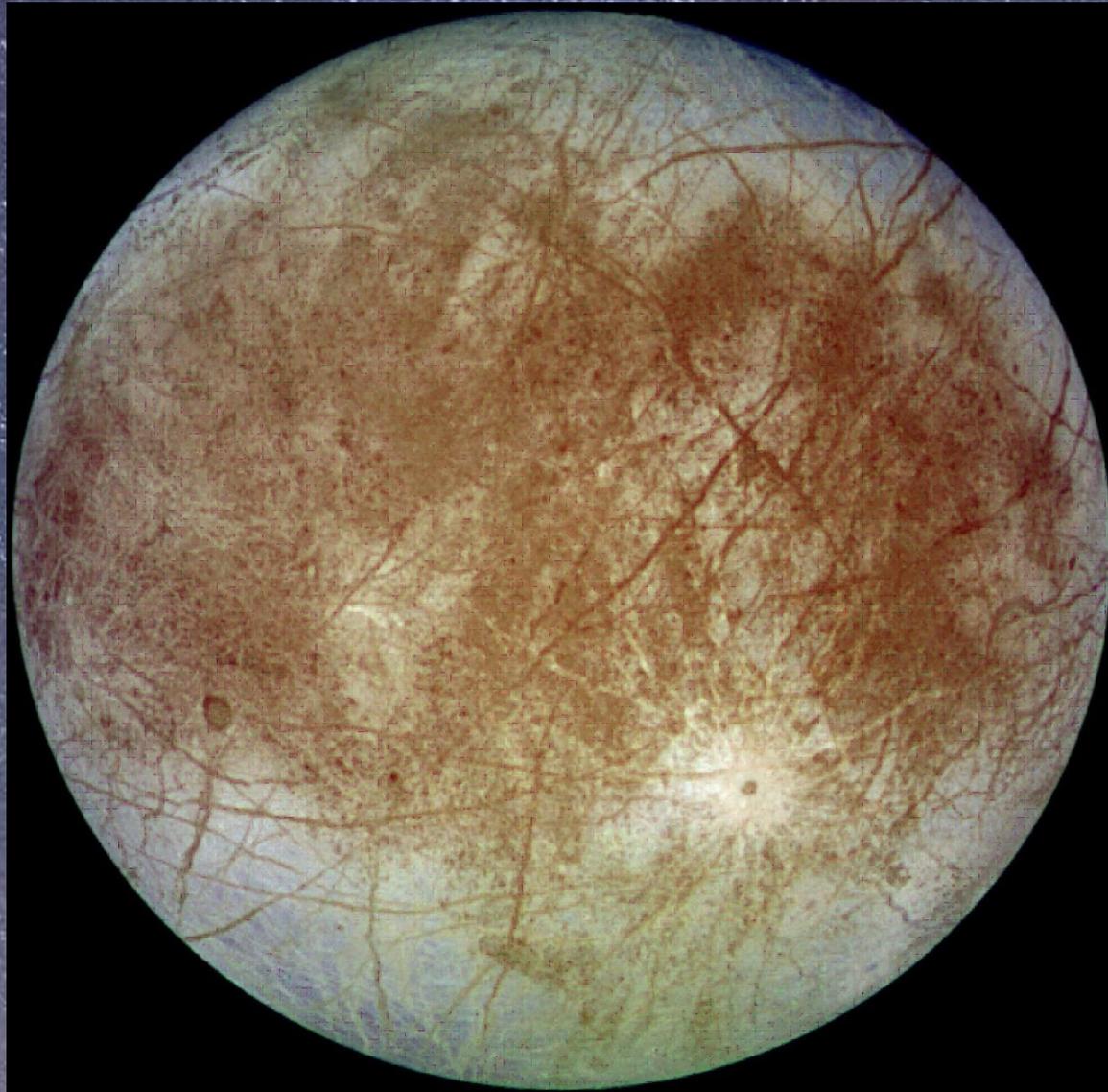


EUROPA

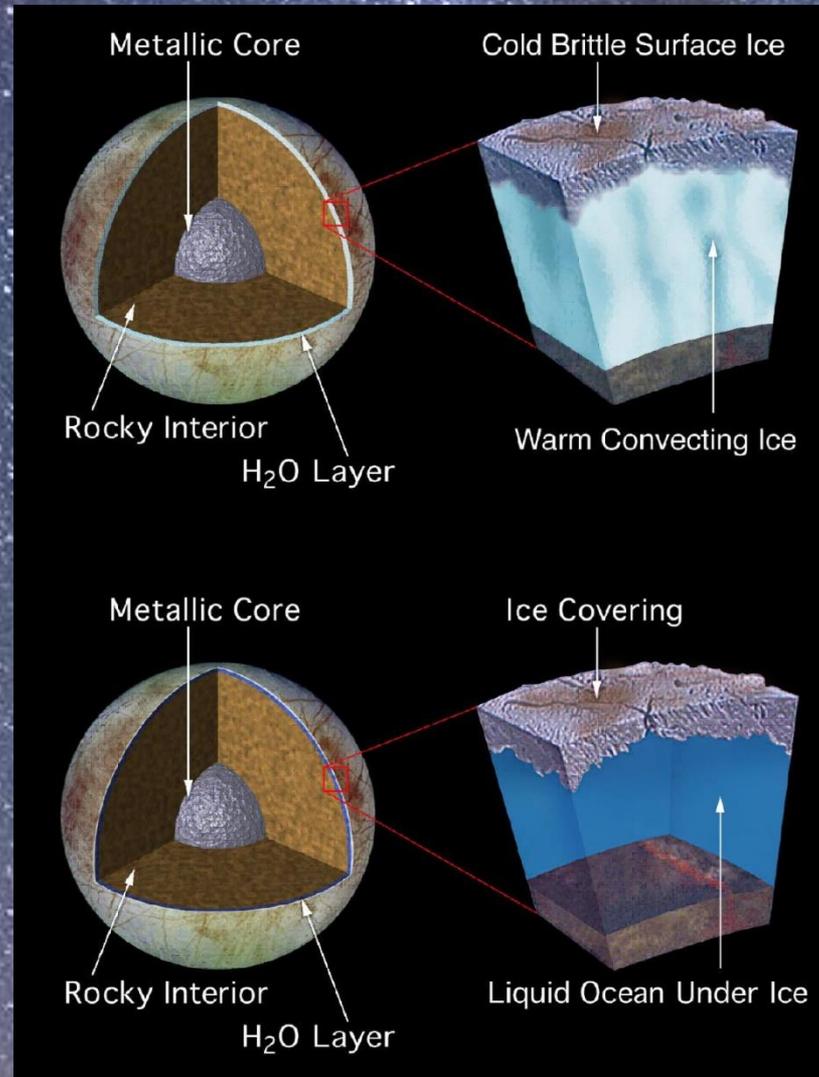
(Moon of Jupiter)

- Tidal forces from Jupiter heat Europa enough to keep liquid the salt-water ocean believed to be hidden under the smooth crust of ice on the surface
- Has a tenuous atmosphere composed primarily of oxygen
- Has the smoothest surface of any known solid object in the Solar System
- Hubble Space Telescope has detected water vapor plumes
- Life would probably not exist on the surface because of the radiation
- 10 cm down to a few meters probably enough sunlight for photosynthesis – but too cold
- Hydrothermal vents at the bottom of the ocean might be the best bet (Chemosynthesis)
- However, there is no evidence yet for this at all

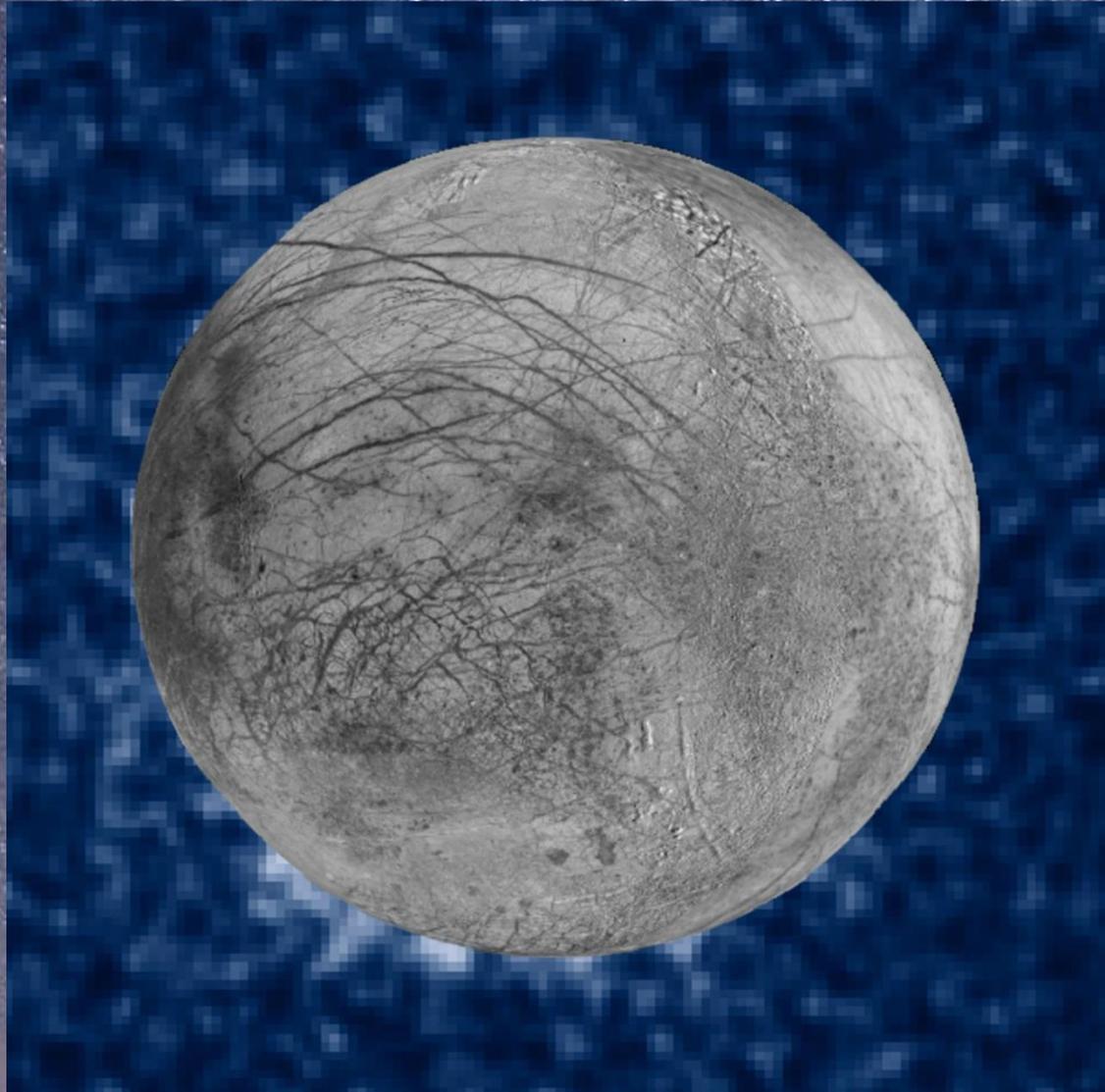
EUROPA



EUROPA



EUROPA WITH PLUMES (7 o'clock)

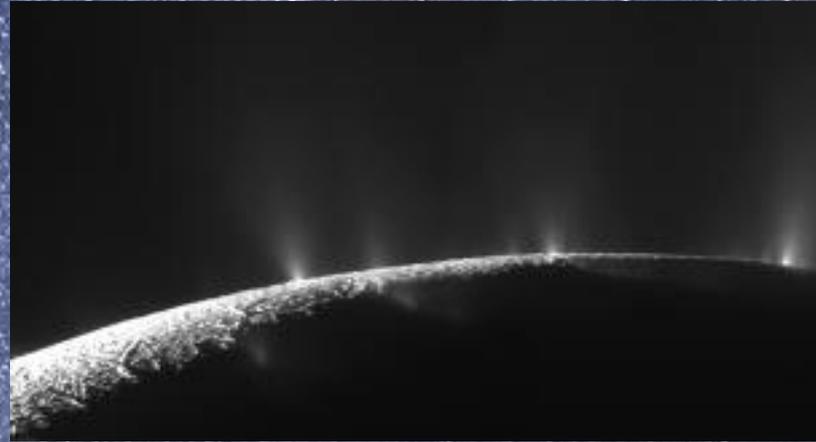


ENCELADUS

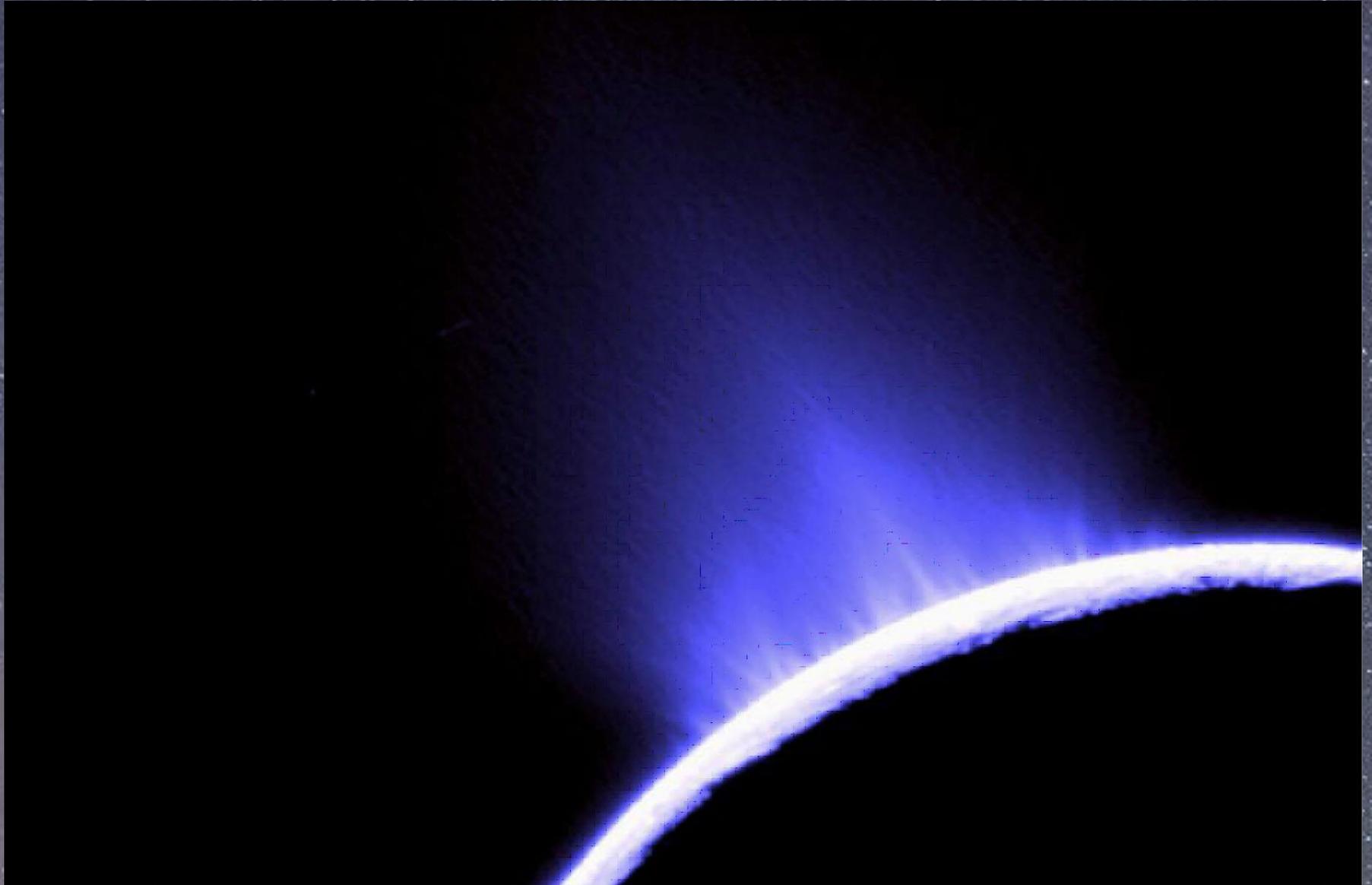
(Moon of Saturn)

- Enceladus, one of Saturn's moons, is shooting out plumes of icy particles consisting of briny water in the form of gas, liquid, and solid organic particles
- Some of the water vapor falls back as "snow"; the rest escapes, and supplies most of the material making up Saturn's E ring
- In 2014, NASA reported that *Cassini* found evidence for a large south polar subsurface ocean of liquid water with a thickness of around 10 km (6.2 mi)

ENCELADUS



ENCELADUS



ENCELADUS

Composition of the Gas Plumes (Geyser)

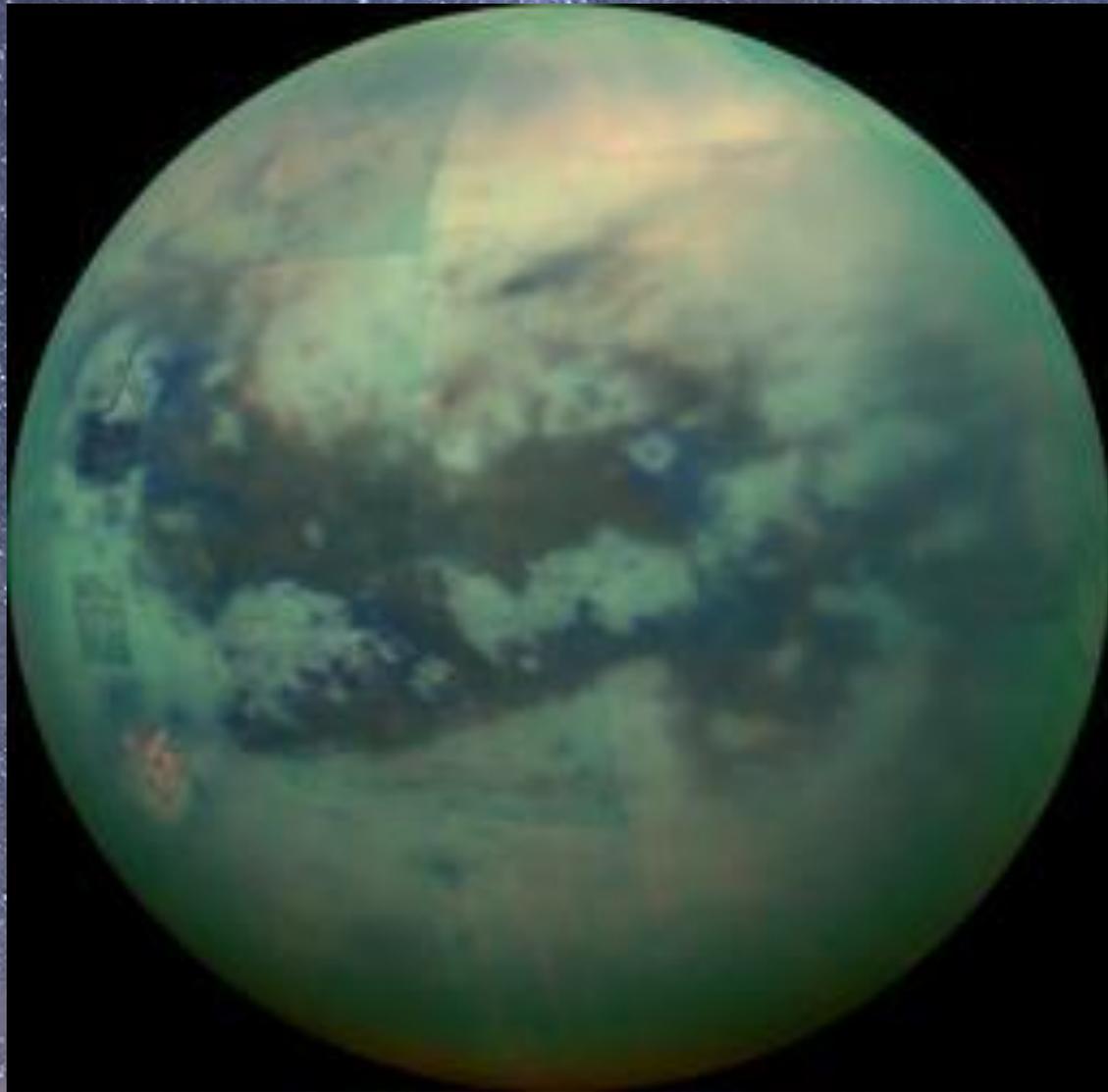
	min.	max.
H ₂ O	90.7%	91.5%
CO ₂	3.14%	3.26%
CO or N ₂	3.29%	4.27%
CH ₄	1.63%	1.68%

TITAN

(Moon of Saturn)

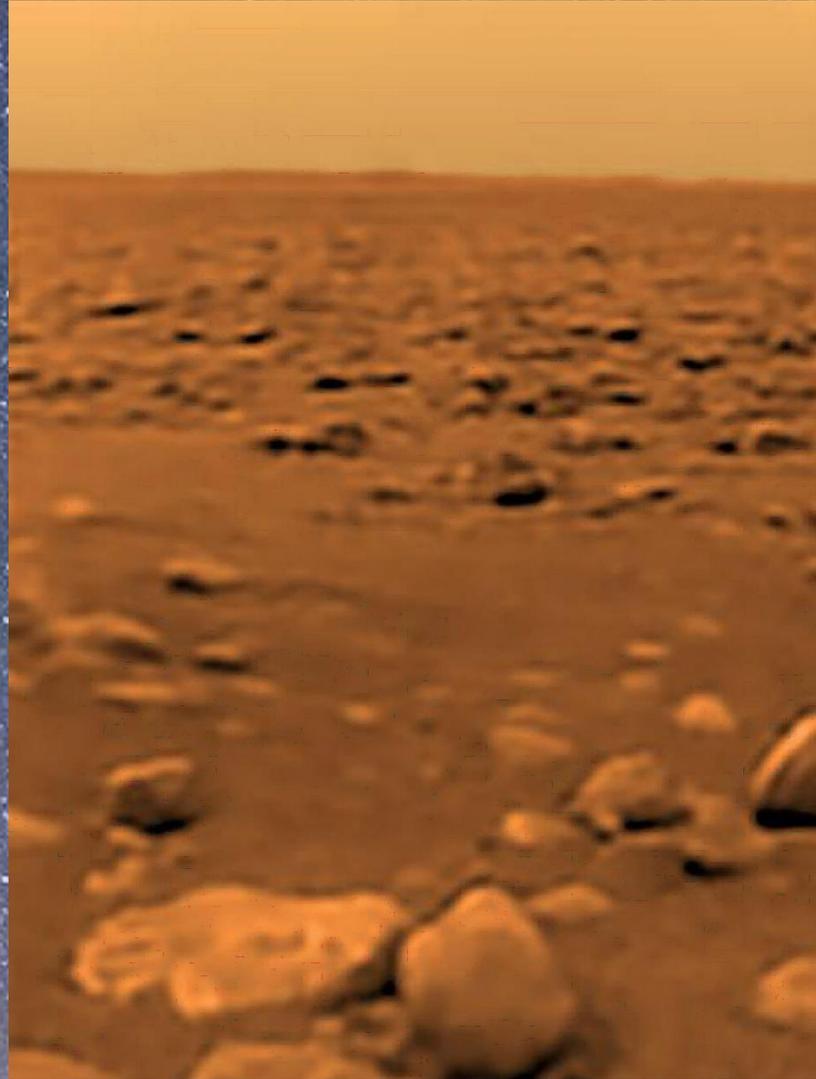
- Titan is the only one in our Solar system known to have an atmosphere rich in complex organic molecules
- Titan is the largest of at least 62 satellites of Saturn
- It is the second largest moon in the solar system, second to Ganymede
- Surface temperature is - 291°F at 1.467 bar
- Atmosphere is composed of 90-97% Nitrogen
- What look like rocks are believed to be water ice covered with a coating of tholin-type material
- At - 290.47°F, water ice behaves like silicate rock on Earth

TITAN



TITAN

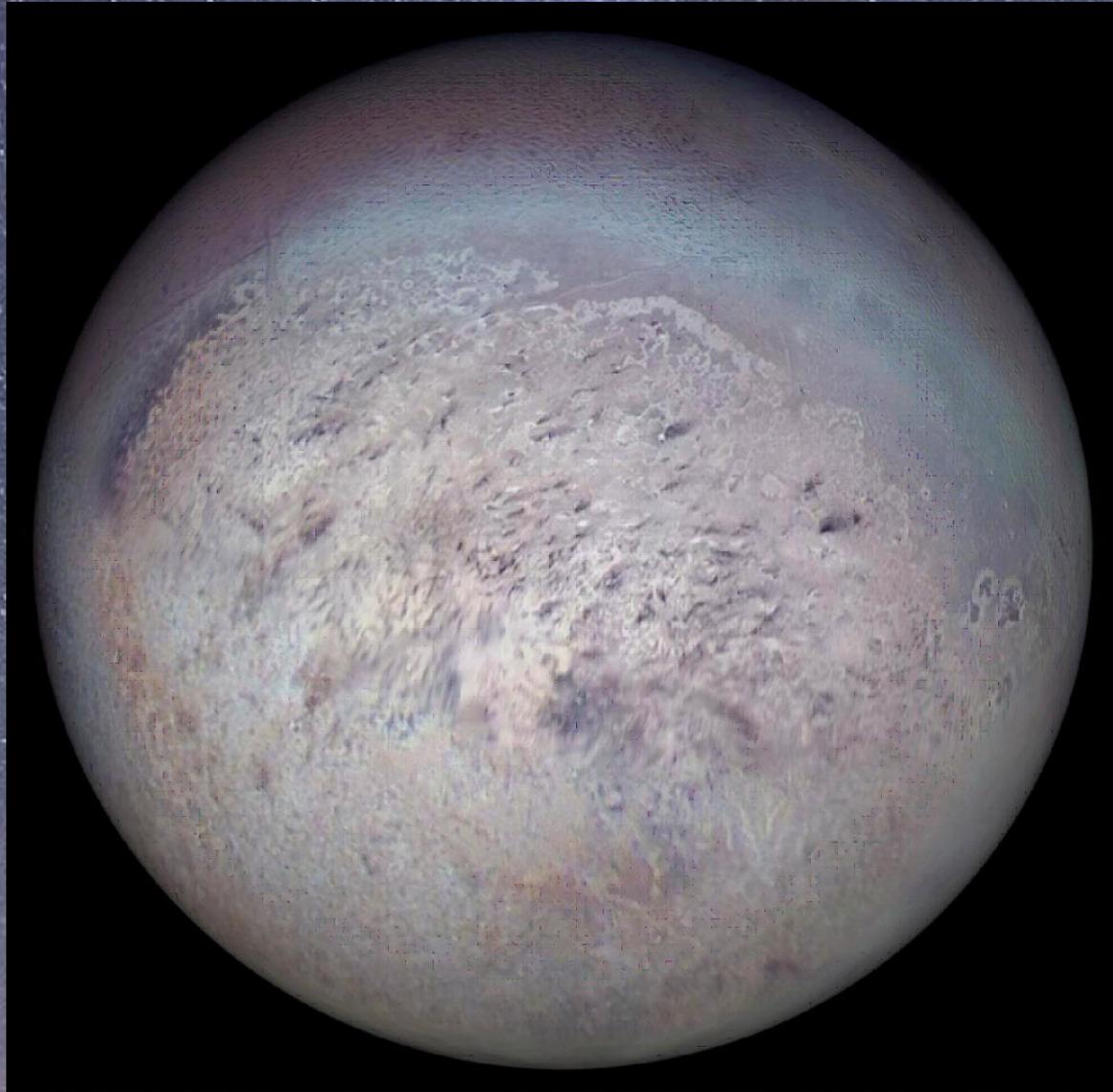
First color image of surface from Huygens Spacecraft



What about Triton or Charon?

- Triton is a moon of Neptune
- Charon is a moon of Pluto
- Both have frozen water
- Triton once had tidal heating
- Charon has tidal heating today

TRITON



CHARON



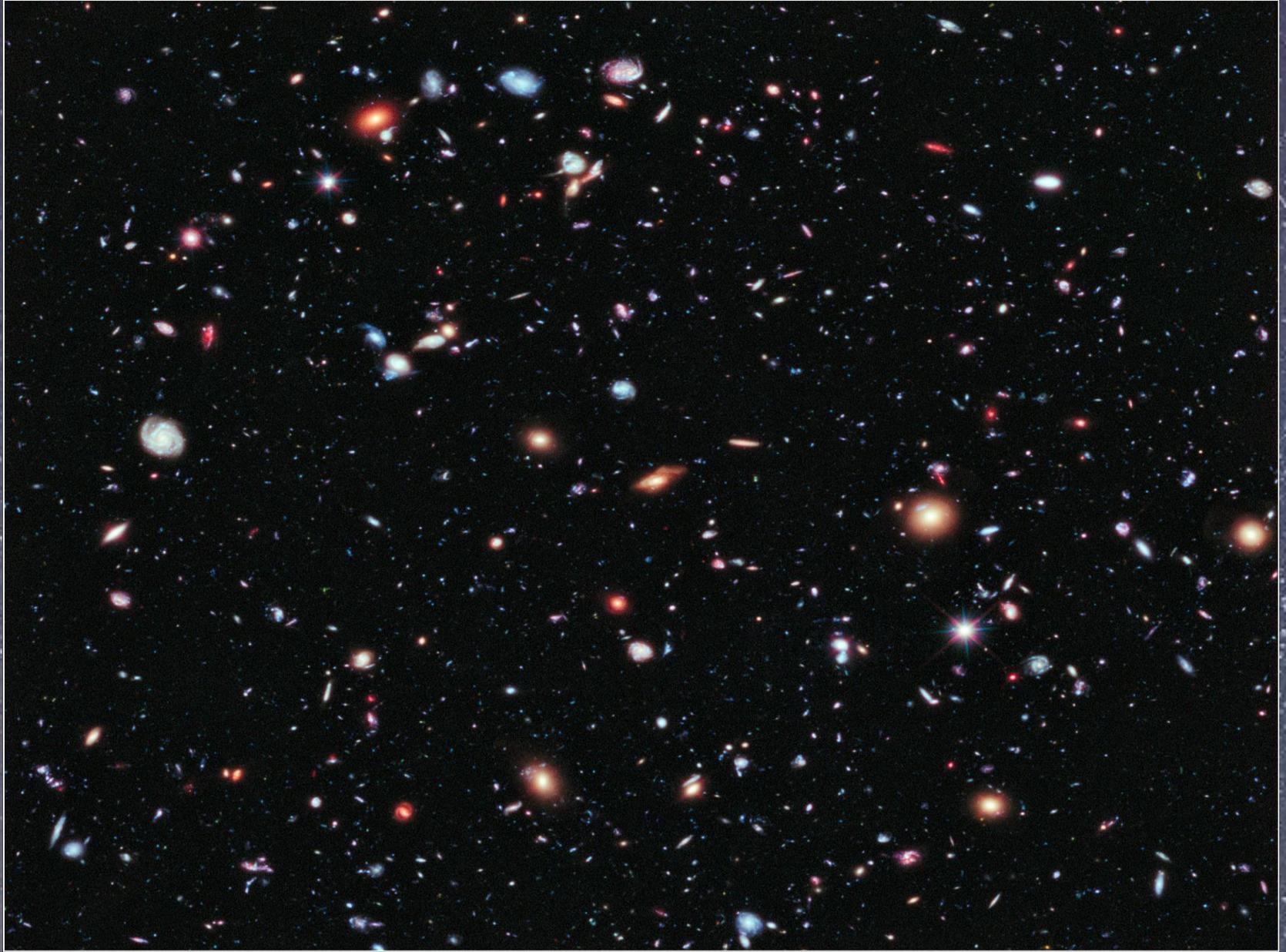
What About Outside of our Solar System?

- Our Galaxy, the Milky Way, is over 100,000 light years in size and consists of over 100 Billion Stars
- The known or observable Universe consists of 1 to 2 Trillion Galaxies and our current estimate is that it's edge is 46.5 B light years away
- Current laws of basic physics preclude us from visiting any of them in a lifetime
- Einstein's Special Theory of Relativity permanently tied mass and energy together in the simple yet fundamental equation $E=mc^2$
- This little equation predicts that nothing with mass can move as fast as light, or faster
- The reason particles of light, called photons, travel at light speeds is because they have no mass
- Therefore, our only way to search for extraterrestrial life outside of our Solar System is via observation

The Milky Way

You Are Here!





Hubble eXtreme Deep Field (XDF)
Hubble Space Telescope • ACS/WFC • WFC3/IR

Fermi Paradox

The basic points of the argument for the existence of extraterrestrial civilizations, made by physicists Enrico Fermi (1901–1954) and Michael H. Hart (born 1932), are:

- There are billions of stars in the galaxy that are similar to the Sun, many of which are billions of years older than Earth
- With high probability, some of these stars will have Earth-like planets, and if the Earth is typical, some might develop intelligent life
- Some of these civilizations might develop interstellar travel, a step the Earth is investigating now (ref. https://en.wikipedia.org/wiki/Interstellar_travel)
- Even at the slow pace of currently envisioned interstellar travel, the Milky Way galaxy could be completely traversed in a few million years

If a multitude of advanced extraterrestrial civilizations exists in the Milky Way galaxy, why is there no evidence such as spacecraft or probes?

“Where are they and why haven’t they contacted us?”

How Long Will it Take to Reach Our Closest Neighbor?

- Nearest star system to Earth is Proxima Centauri, about 4.22 light-years away
- Light travels at 186,282.4 miles per second
- Light travels 5.88 trillion miles per year
- 2,480 trillion miles to Proxima Centauri
- Fastest Spacecraft was Helios 2, which orbited the sun and reached a speed of 157,078 mph
- Helios 2 would take approx. 19,000 years to reach Proxima Centauri

Spacecraft That Have Left the Solar System

Spacecraft	Distance from Earth (miles)	Speed (mph)	One-Way Light Time (Hours)	Still Functioning?	Constellation
• Pioneer 10	10.9 B	26,778.4	16.24	No	Taurus
• Pioneer 11	9.1 B	25,230.4	13.53	No	Scutum
• Voyager 1	12.8 B	38,014.5	19.12	Yes	Ophiuchus
• Voyager 2	10.6 B	34,370.5	15.82	Yes	Pavo
• New Horizons	3.6 B	31,968.1	5.33	Yes	Sagittarius

KEPLER MISSION

- The mission of the Kepler Space Telescope is to search for exoplanets orbiting around distant stars
- Lately NASA announced that its Kepler Space Telescope has identified over 1000 new exoplanets orbiting more than 300 stars, with five that are the right size and distance from their stars to support liquid water, and thus life as we know it
- How does Kepler find exoplanets?

<https://kepler.nasa.gov/multimedia/Interactives/HowKeplerDiscoversPlanetsElementary/flash.cfm>



SETI

Search for Extraterrestrial Intelligence

THE MISSION OF THE
SETI INSTITUTE

IS TO **EXPLORE, UNDERSTAND AND EXPLAIN**
THE ORIGIN, NATURE AND PREVALENCE
OF LIFE IN THE UNIVERSE..

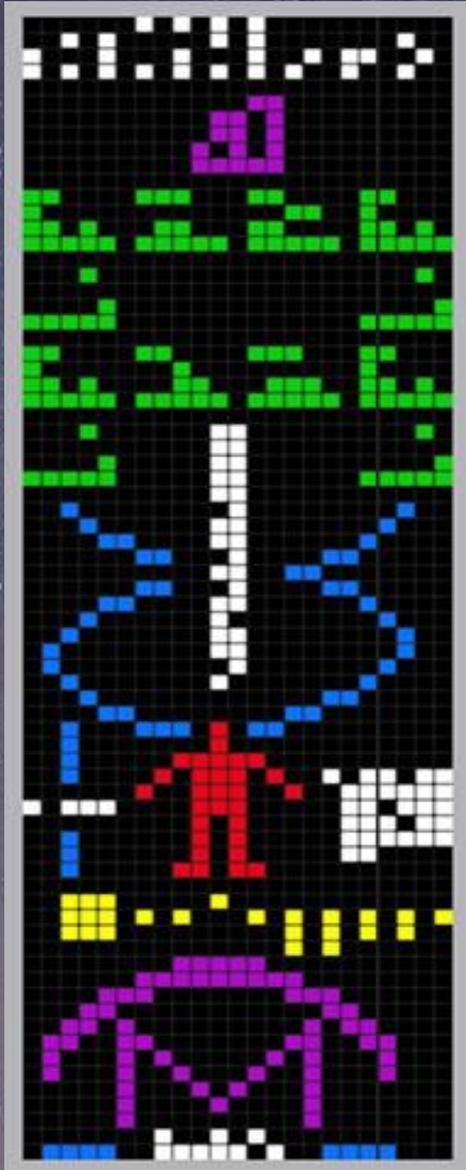
Arecibo Observatory

Radio Telescope



The Arecibo Message

1974



- The numbers one (1) to ten (10) (white)
- The atomic numbers of the elements hydrogen, carbon, nitrogen, oxygen and phosphorus, which make up deoxyribonucleic acid (DNA) (purple)
- The formulas for the sugars and bases in the nucleotides of DNA (green)
- The number of nucleotides in DNA, and a graphic of the double helix structure of DNA (white & blue)
- A graphic figure of a human, the dimension (physical height) of an average man, and the human population of Earth (red, blue/white, & white respectively)
- A graphic of the Solar System indicating which of the planets the message is coming from (yellow)
- A graphic of the Arecibo radio telescope and the dimension (the physical diameter) of the transmitting antenna dish (purple, white and blue)

The Communication Question

If extraterrestrials visited Earth or sent us a signal, would they be able to communicate with us?

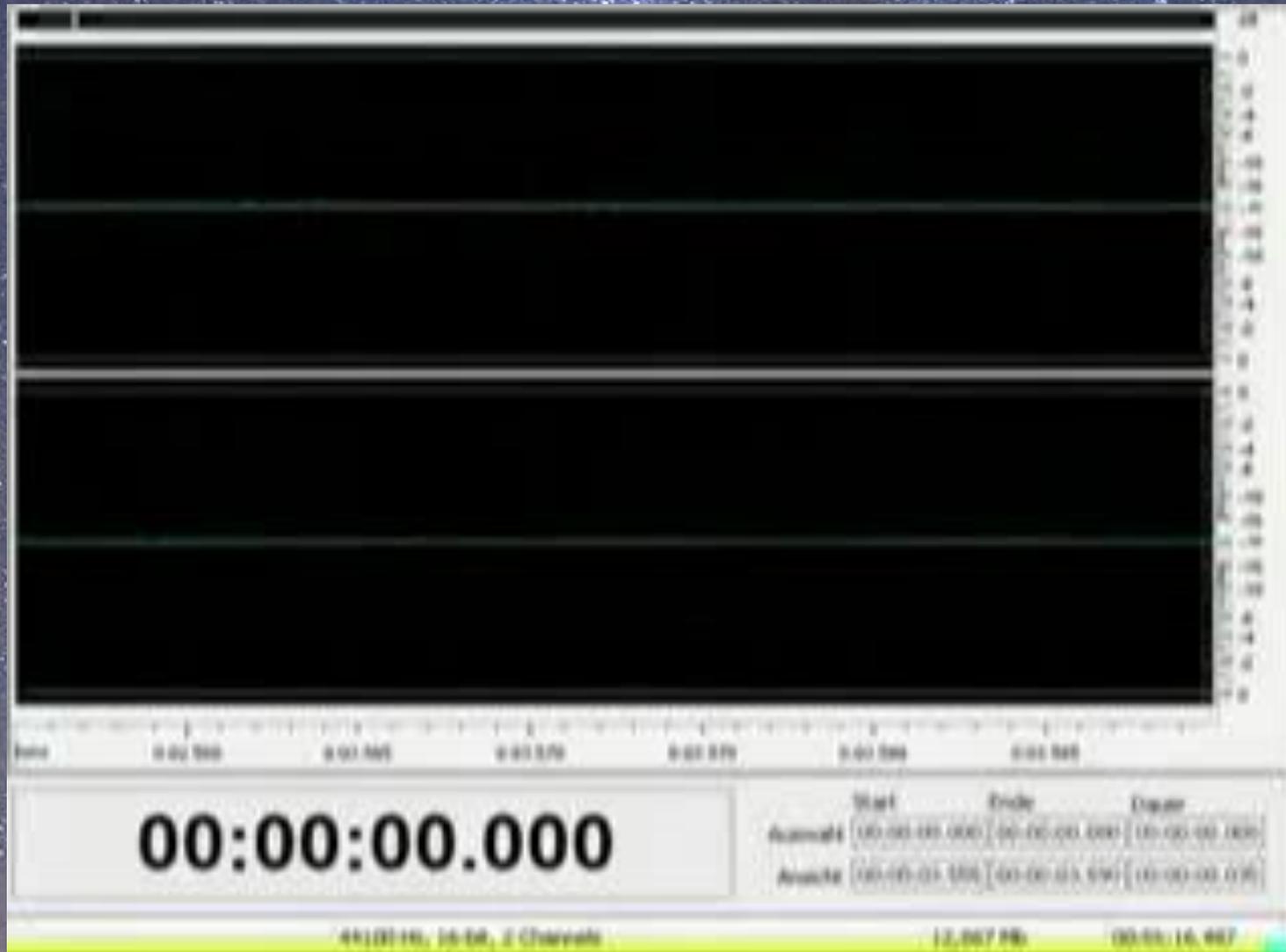
Possibly (probably) not!

How would they communicate with us?

The WOW! Signal

- On August 15, 1977, Jerry R. Ehman working on a SETI project at the Ohio State University telescope, detected a signal from what he surmised was of extraterrestrial origin
- The signal origin was northwest of the globular cluster of M55 in the constellation of Sagittarius, which is approximately 17,000 light years from Earth
- The signal was detected around 1420 MHz which is the radio frequency that Hydrogen naturally emits
- The signal lasted for 72 seconds and has not been heard again
- There are many theories about this signal but its true source is still unknown

The WOW! Signal



CONCLUSION

- **New spacecraft with more sophisticated instruments will be launched in the near future to explore Mars and the moons of Jupiter and Saturn looking for evidence of life**
- **The next generation of telescopes will be able to detect the atmospheres of exoplanets**
- **Any one with a detectable oxygen signature will betray bioactivity and thus, life**
- **A proposed project would send soap-size spacecraft to orbit Proxima Centauri at a speed of 4.6% the speed of light. It would take the spacecraft approximately 140 years to get there**
- **Nasa's chief scientist Ellen Stofan boldly predicted that we would find indications of life beyond Earth in the next 10 to 20 years**