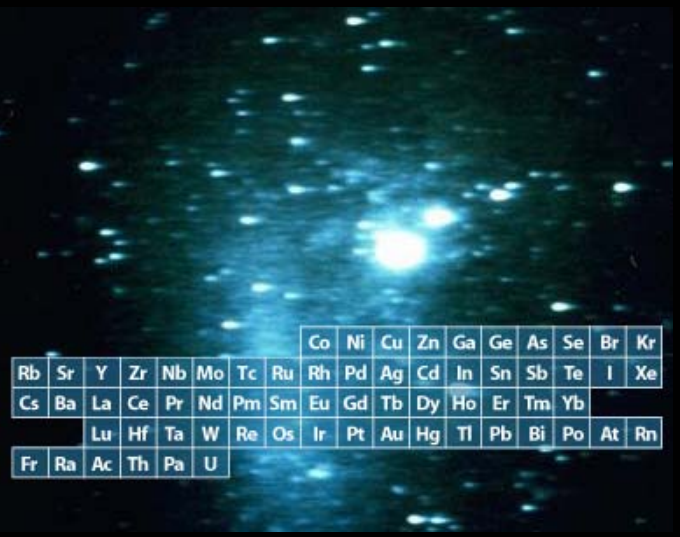
Astrobiology – Life and the Universe

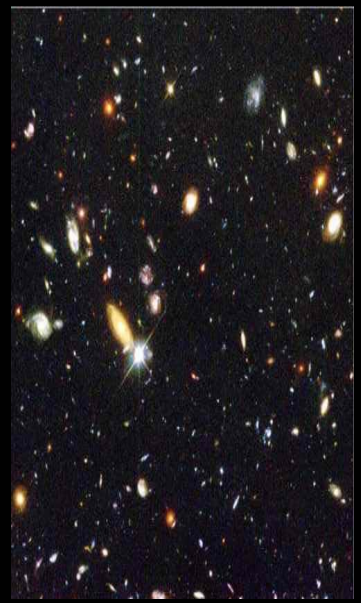
Guiding Questions

1. What role could comets and meteorites have played in the origin of life on Earth?
2. Have spacecraft found any evidence for life elsewhere in our solar system?
3. Do meteorites from Mars give conclusive proof that life originated there?
4. How likely is it that other civilizations exist in our Galaxy?
5. How do astronomers search for evidence of civilizations on planets orbiting other stars?
6. Will it ever be possible to see Earthlike planets orbiting other stars?

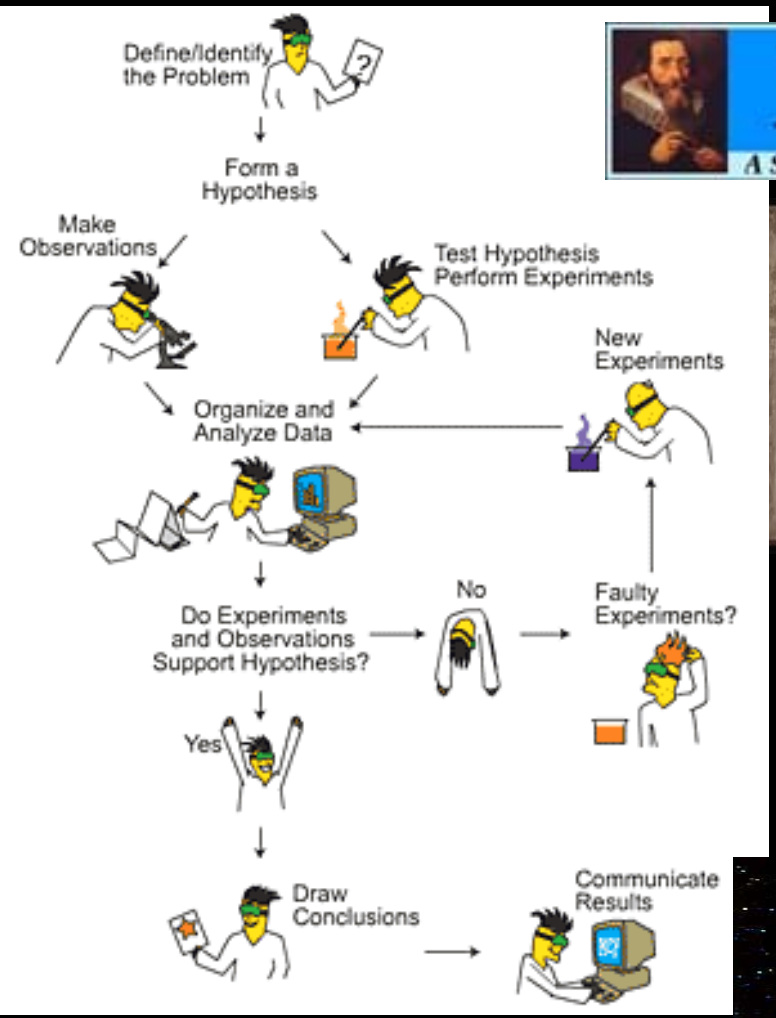
Life and the Universe



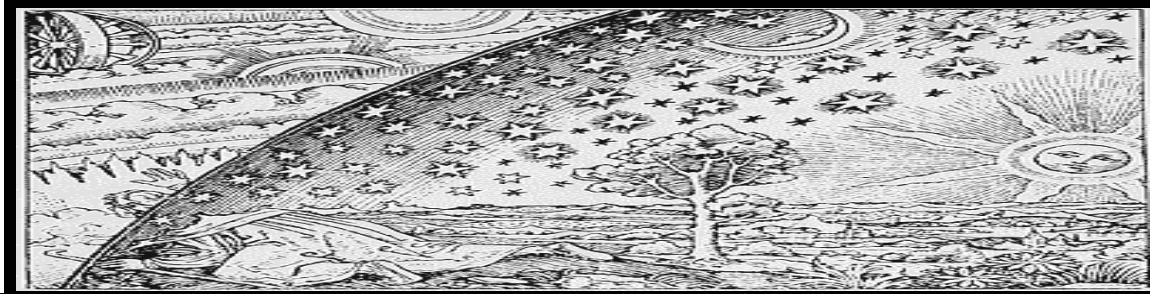
- Searching for life everywhere
- Planets, stars, galaxies, Big Bang
  - Conception of size and distance
- Stars and the origins of chemicals
- Formation of planets
- Defining astrobiology – the science

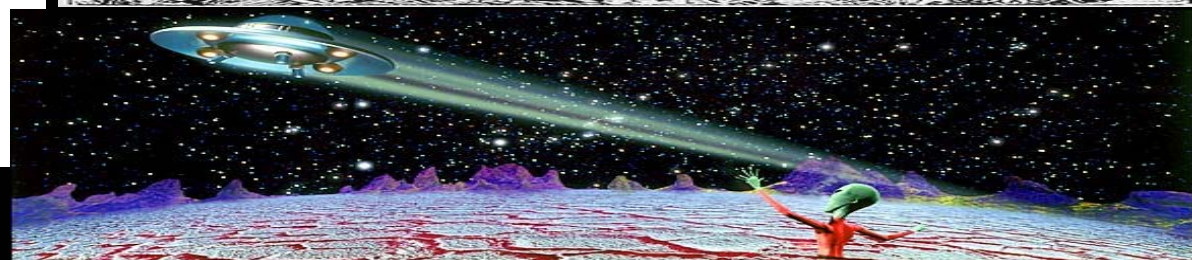


The Science of Life in the Universe



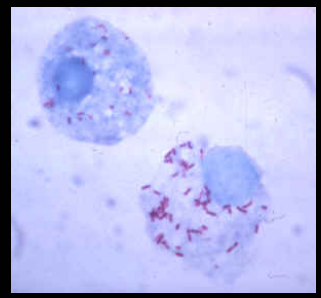
- Ancient cosmologies
- Science as a way of knowing
- Copernicus, Galileo, Kepler, Newton
- Pseudoscience and nonsense

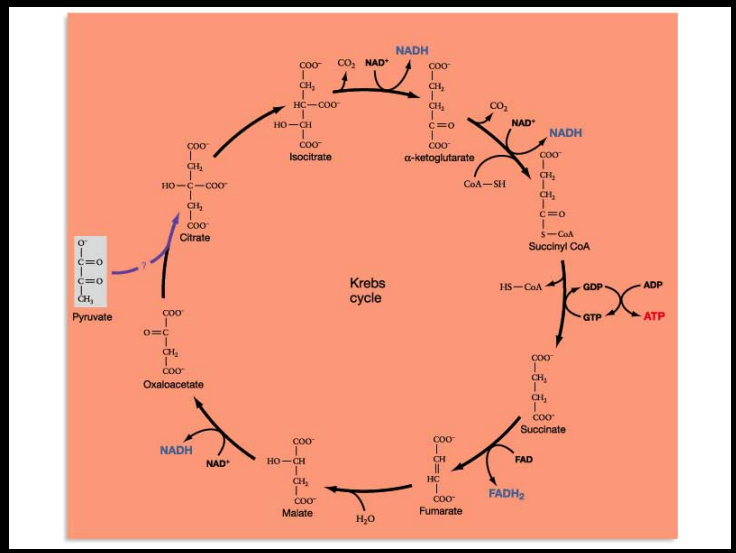




The Nature of Life

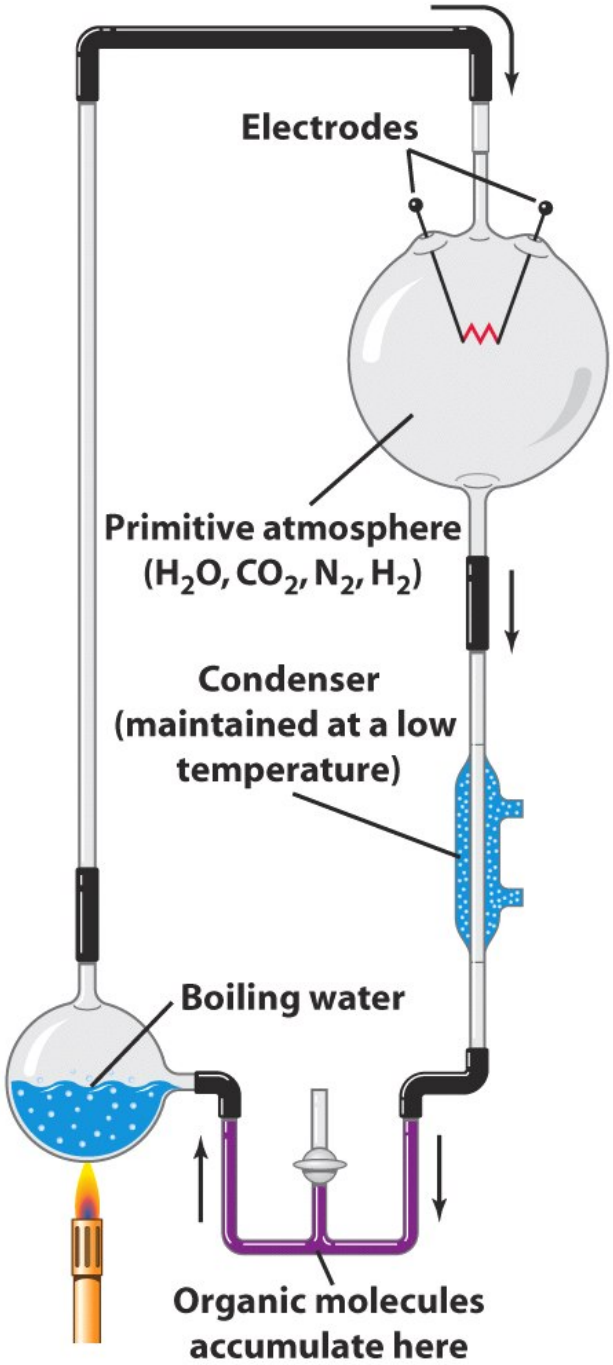
- What is it?
- Cells
- Metabolism
- DNA
- Extremophiles





The chemical building blocks of life are found throughout space

- All life on Earth, and possibly on other worlds, depends on organic (carbon-based) molecules
- These molecules occur naturally throughout interstellar space
- The organic molecules needed for life to originate were probably brought to the young Earth by comets or meteorites



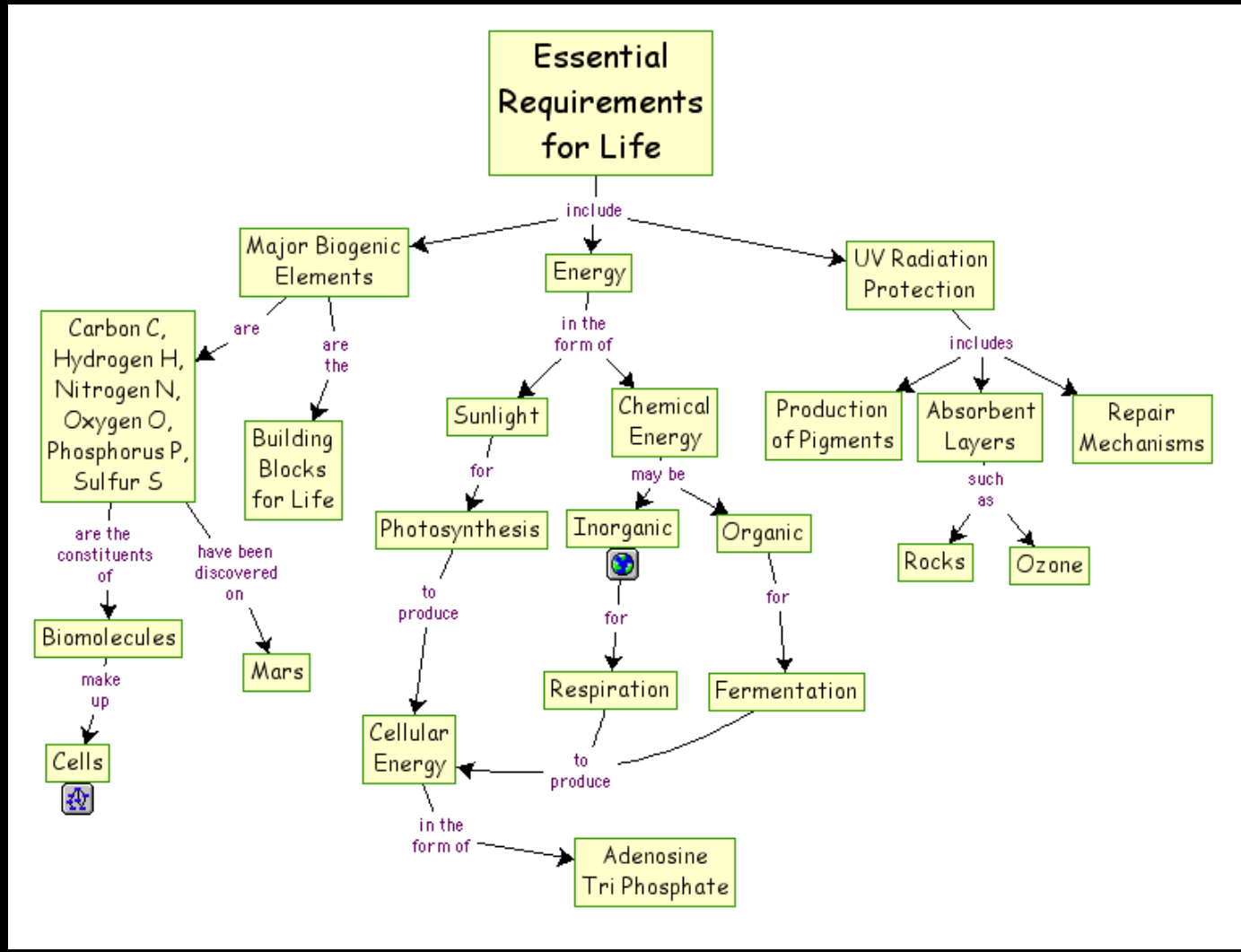
- Another likely source for organic molecules is chemical reactions in the Earth's primitive atmosphere
- Similar processes may occur on other worlds

The Origin and Evolution of Life on Earth

- Origin of Life
- Prokaryotes
- Eukaryotes
- Oxygen in Air
- Impacts & Extinctions
- Human Evolution

Searching for Life in the Solar System

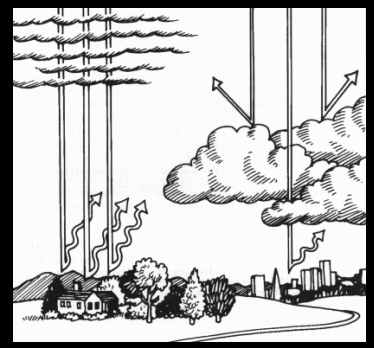
- Environmental Needs
- In the Solar System

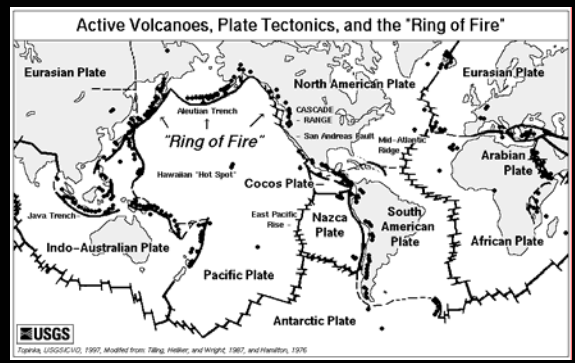


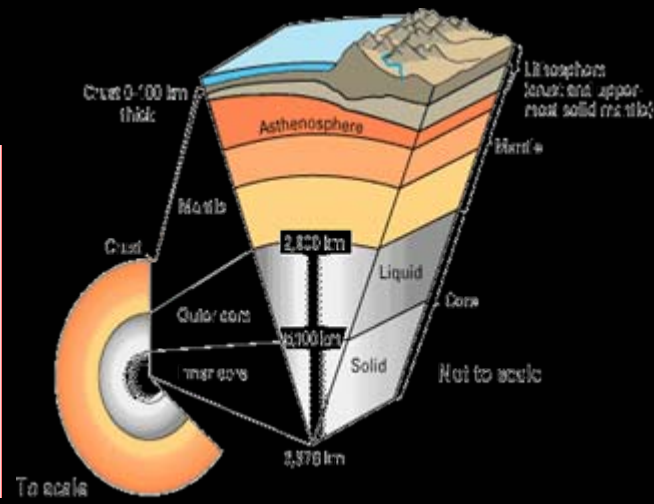
The Geological History of the Earth

EON	ERA	PERIOD		EPOCH		Ma
Phanerozoic	Cenozoic	Quaternary		Holocene		0.01
				Pleistocene	Late	0.8
					Early	1.8
		Tertiary	Neogene	Pliocene	Late	3.6
					Early	5.3
				Miocene	Late	11.2
					Middle	16.4
					Early	23.7
				Oligocene	Late	28.5
					Early	33.7
			Paleogene	Eocene	Late	41.3
					Middle	49.0
					Early	54.8
				Paleocene	Late	61.0
					Early	65.0
	Mesozoic	Cretaceous		Late		99.0
				Early		144
		Jurassic		Late		159
				Middle		180
				Early		206
		Triassic		Late		227
				Middle		242
				Early		248
	Paleozoic	Permian		Late		256
				Early		290
		Pennsylvanian				323
		Mississippian				354
		Devonian		Late		370
				Middle		391
				Early		417
		Silurian		Late		423
				Early		443
		Ordovician		Late		458
				Middle		470
				Early		490
		Cambrian		D		500
				C		512
				B		520
				A		543
Precambrian	Proterozoic	Late				900
		Middle				1600
		Early				2500
	Archean	Late				3000
		Middle				3400
		Early				3800?

- Geologic Timescale
- Plate Tectonics
- Solid Earth
- Greenhouse Effect
- Relative/Absolute Dating



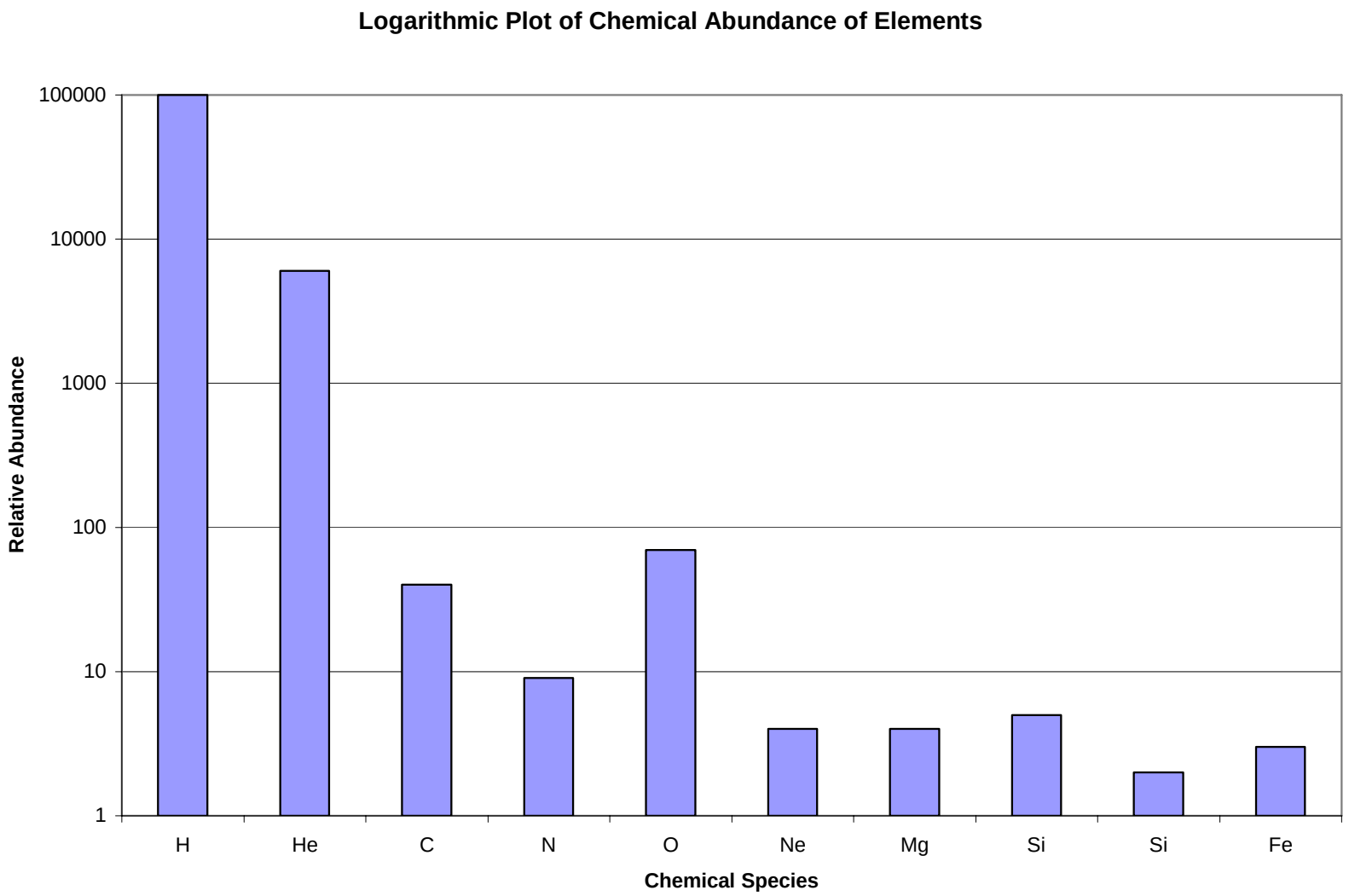




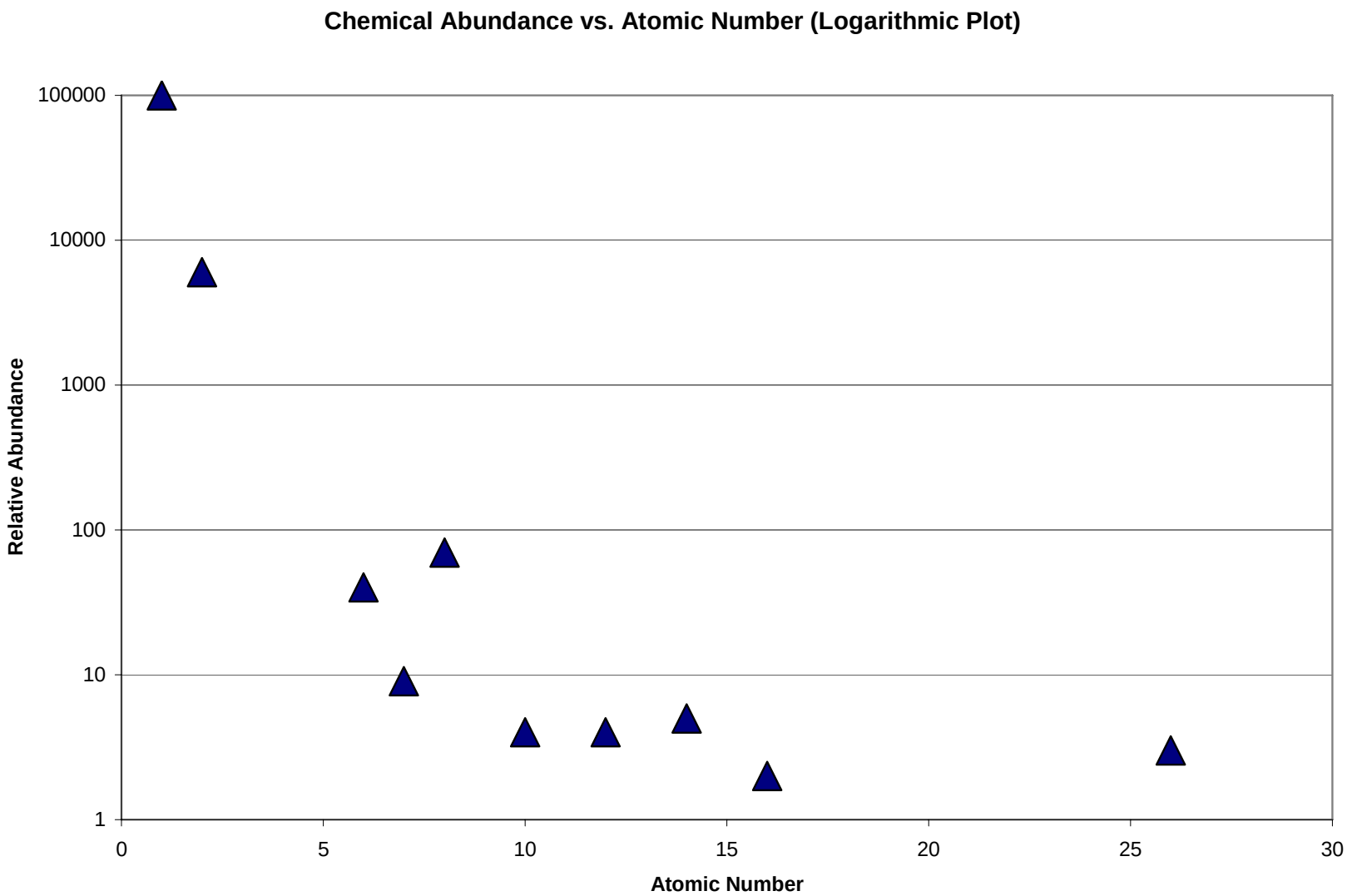
Abundance of the Chemical Elements

- NOTE WELL
  - Abundance in many textbooks is plotted on a logarithmic scale
    - this allows for the different elements to actually appear on the same scale as hydrogen and helium
    - it does show relative differences among higher atomic weight elements better than linear scale
  - Abundance of elements on a linear scale is very different

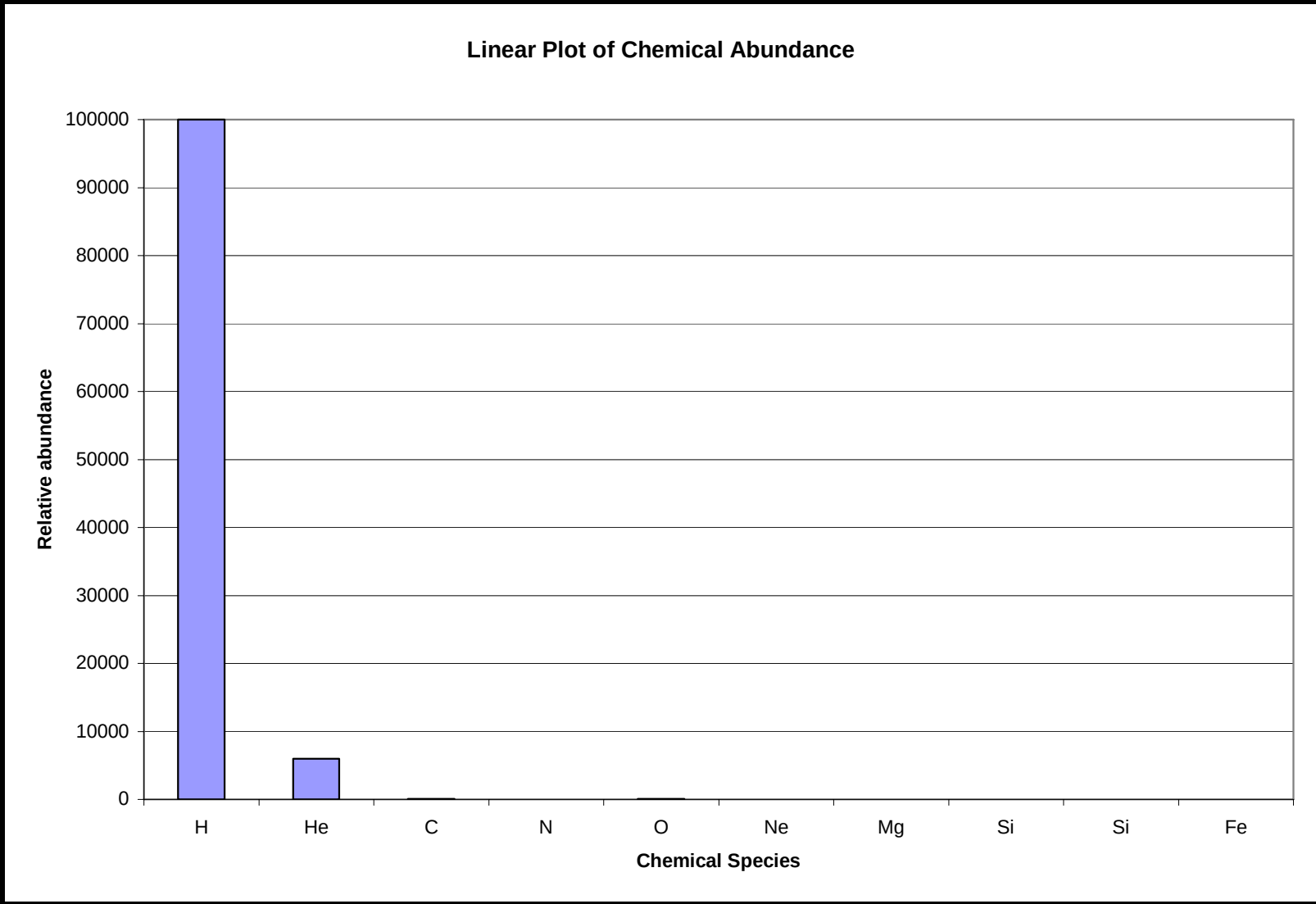
Log Plot of Abundance



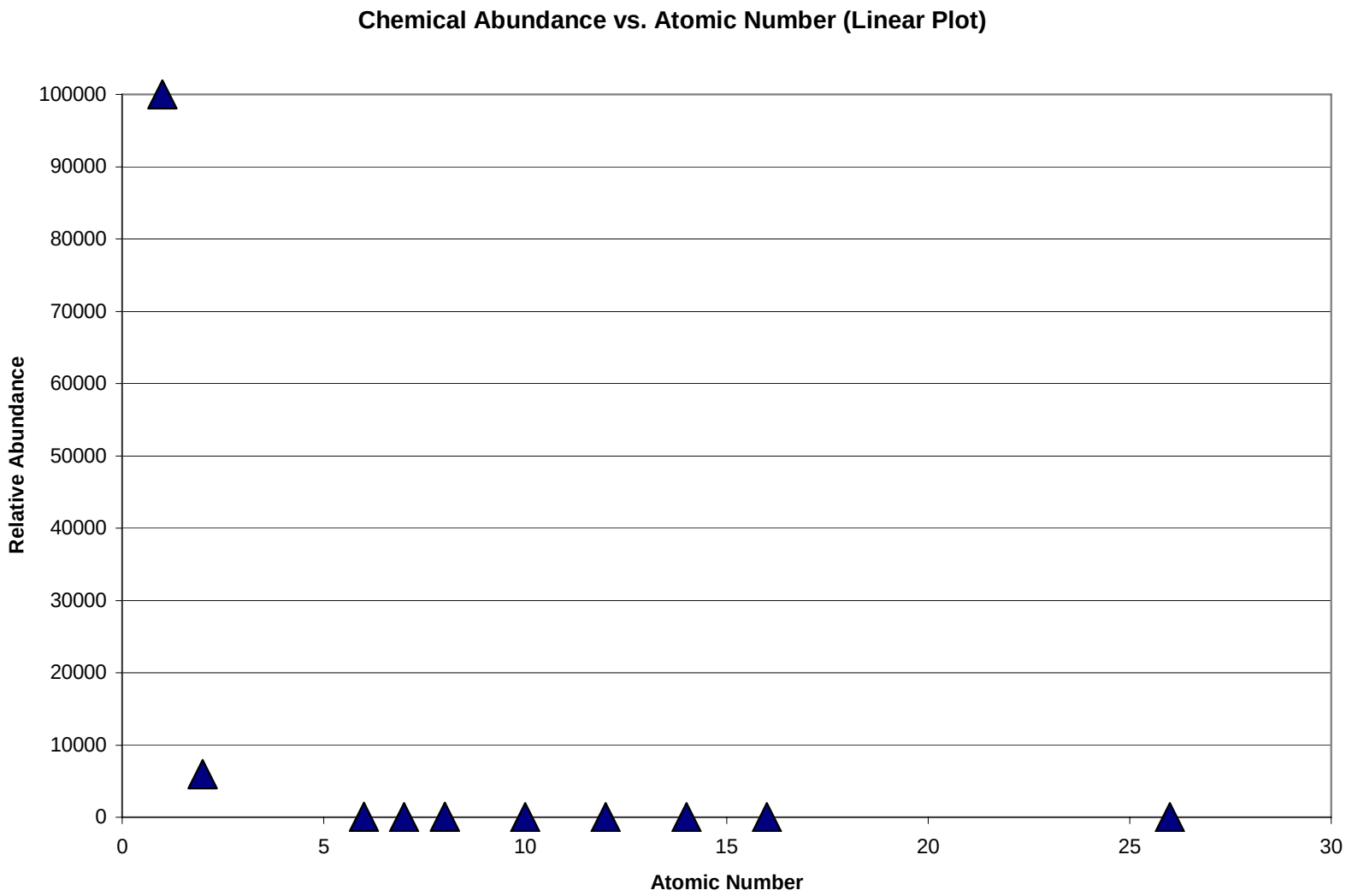
Another Log View



A Linear View of Abundance



Another Linear View



Other Observations

- Radioactive dating of solar system rocks
  - Earth ~ 4 billion years
  - Moon ~4.5 billion years
  - Meteorites ~4.6 billion years
- Most orbital and rotation planes confined to ecliptic plane with counterclockwise motion
- Extensive satellite and rings around Jovians
- Planets have more of the heavier elements than the sun

Planetary Summary

Planet	Mass (Earth=1)	Density (g/cm^3)	Major Constituents
Mercury	0.06	5.4	Rock, Iron
Venus	0.82	5.2	Rock, Iron
Earth	1.00	5.5	Rock, Iron
Mars	0.11	3.9	Rock, Iron
Jupiter	318	1.3	H, He
Saturn	95	0.7	H, He
Uranus	14	1.3	Ices, H, He
Neptune	17	1.7	Ices, H, He

Other Planet Observations

- Terrestrial planets are closer to sun
  - Mercury
  - Venus
  - Earth
  - Mars
- Jovian planets furthest from sun
  - Jupiter
  - Saturn
  - Uranus
  - Neptune

Some Conclusions

- Planets formed at same time as Sun
- Planetary and satellite/ring systems are similar to remnants of dusty disks such as that seen about stars being born (e.g. T Tauri stars)
- Planet composition dependent upon where it formed in solar system

Nebular Condensation Model

- Most remnant heat from collapse retained near center
- After sun ignites, remaining dust reaches an equilibrium temperature
- Different densities of the planets are explained by condensation temperatures
- Nebular dust temperature increases to center of nebula

Nebular Condensation Physics

- Energy absorbed per unit area from sun = energy emitted as thermal radiator
- Solar Flux = Lum (Sun) / 4 x distance^2
- Flux emitted = constant x T^4 [Stefan-Boltzmann]
- Concluding from above yields
  - T = constant / distance$^{0.5}$

Nebular Condensation Chemistry

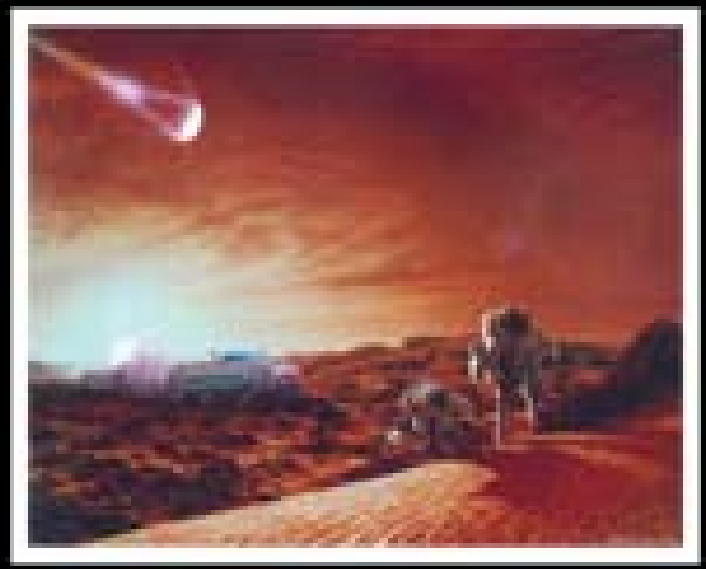
Molecule	Freezing Point	Distance from Center
H_2	10 K	>100 AU
H_2O	273 K	>10 AU
CH_4	35 K	>35 AU
NH_3	190 K	>8 AU
$FeSO_4$	700 K	>1 AU
SiO_4	1000 K	>0.5 AU

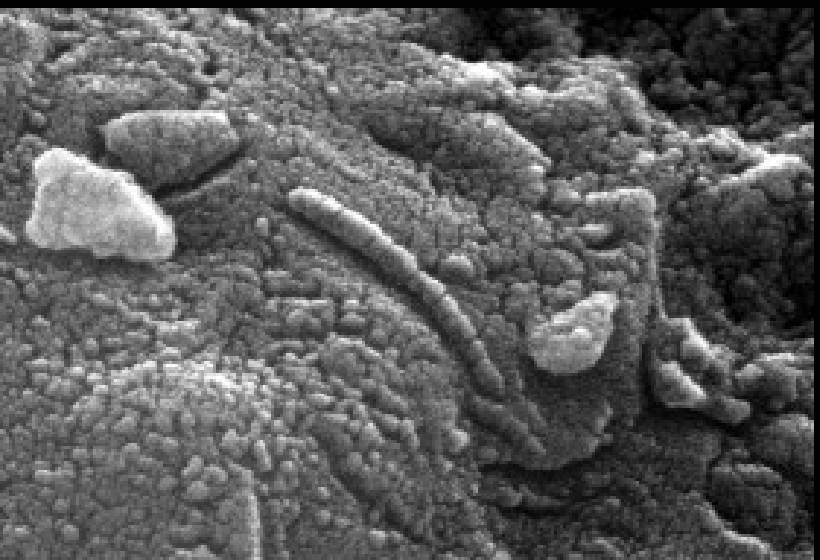
Nebular Condensation Summary

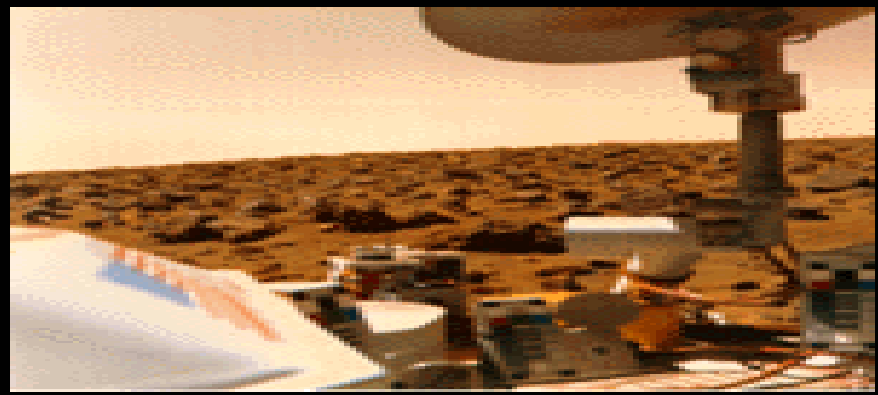
- Solid Particles collide, stick together, sink toward center
  - Terrestrials -> rocky
  - Jovians -> rocky core + ices + light gases
- Coolest, most massive collect H and He
- More collisions -> heating and differentiating of interior
- Remnants flushed by solar wind
- Evolution of atmospheres

Mars

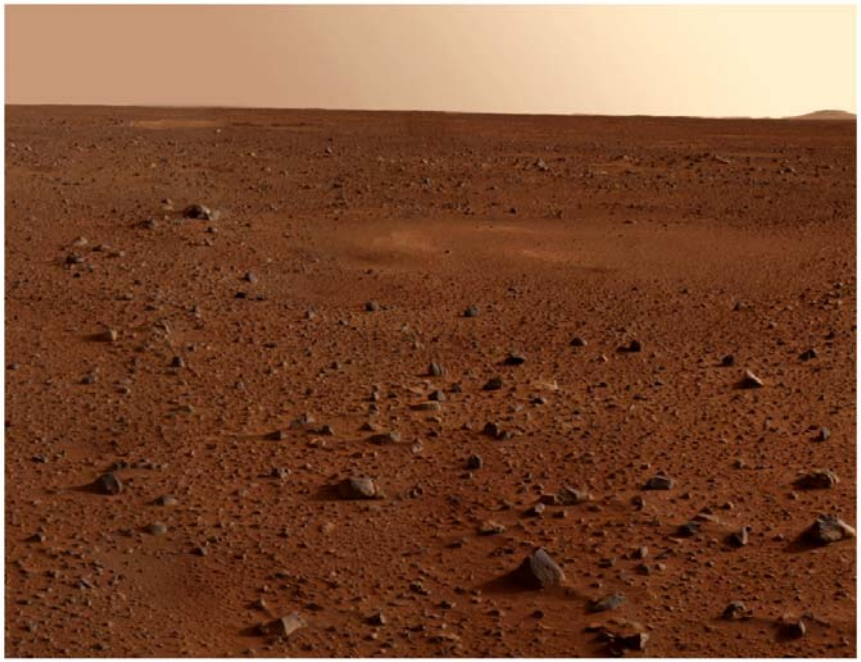
- Science Fiction
- Search for Life
- Martian Meteorites
- Exploration







Both of the NASA rovers that reached Mars in 2004 landed at locations that may once have been covered in water

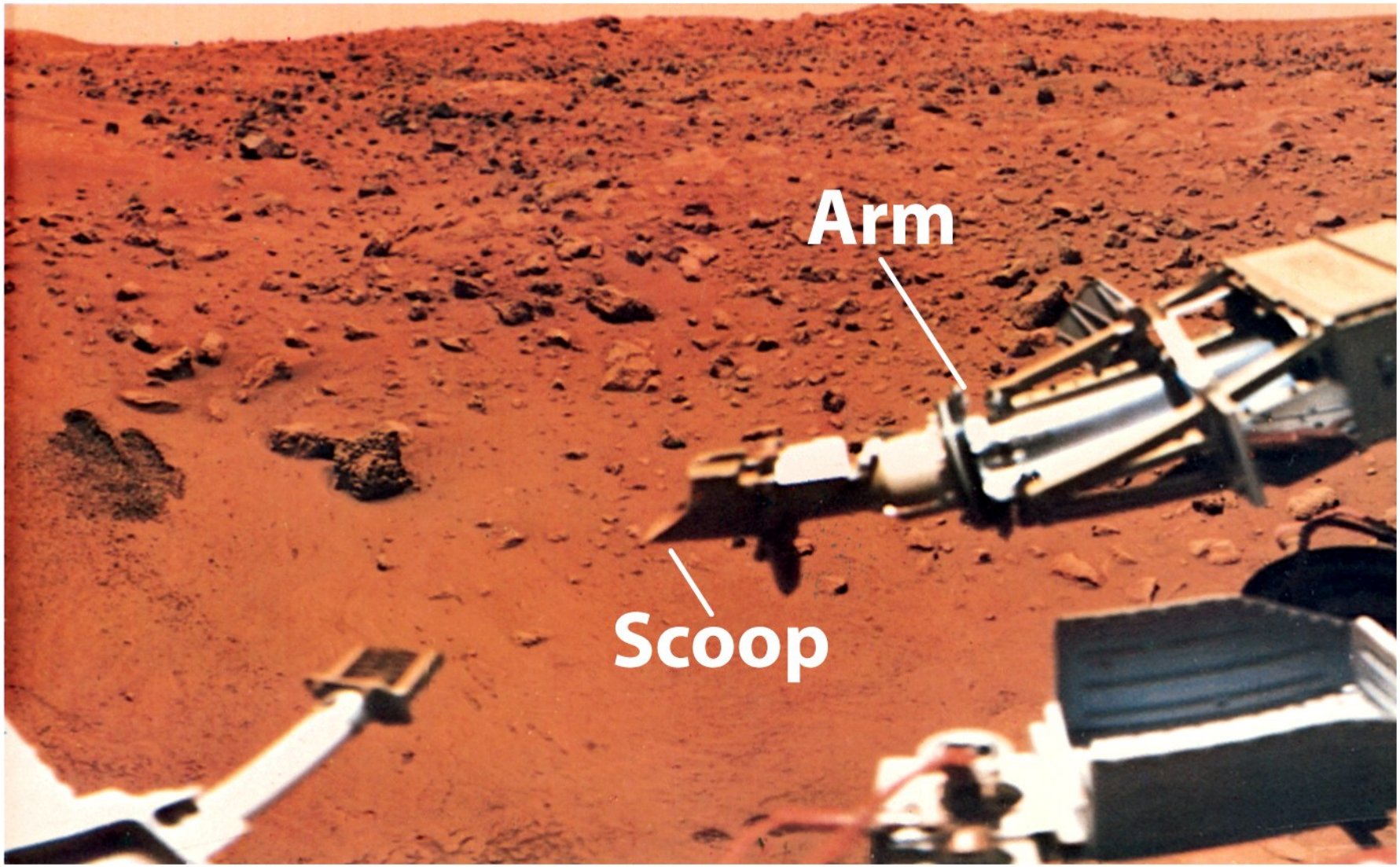


***Spirit* landing site in Gusev Crater**

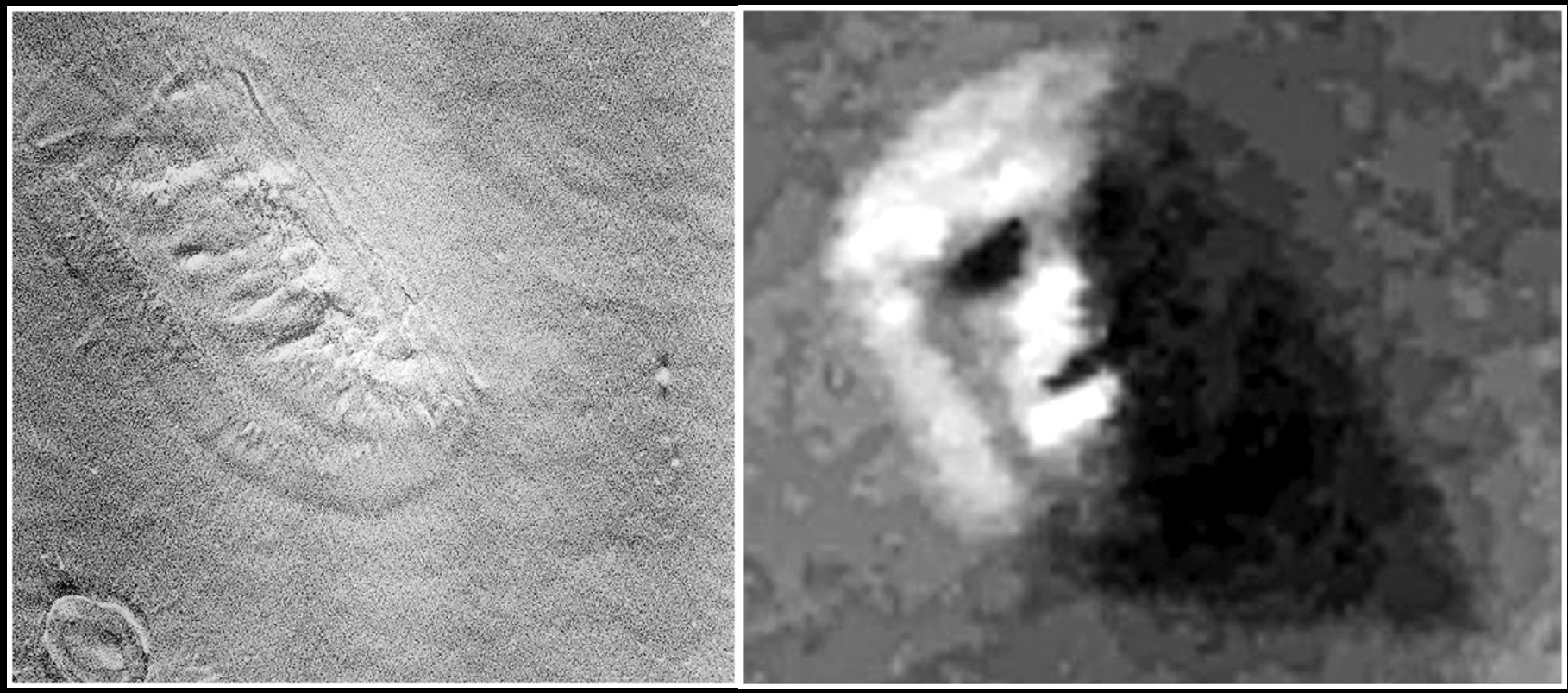
***Opportunity* landing site in Meridiani Planum**

- The unsuccessful *Beagle 2* mission to Mars was to carry out a different set of biological experiments on samples taken from the interiors of rocks
- These experiments may be attempted again on a future mission

The *Viking Lander* spacecraft searched for microorganisms on the Martian surface, but found no conclusive sign of their presence



A “Face” on Mars

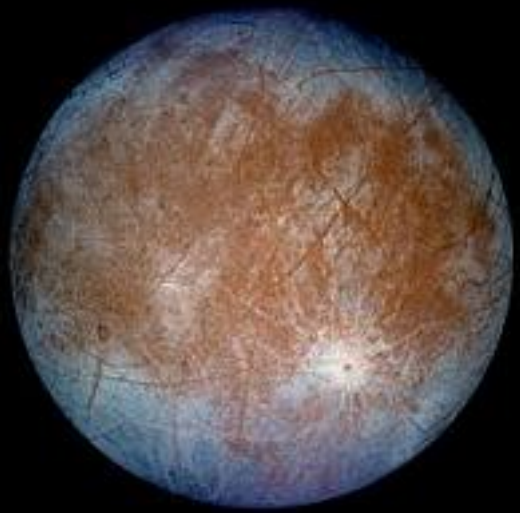


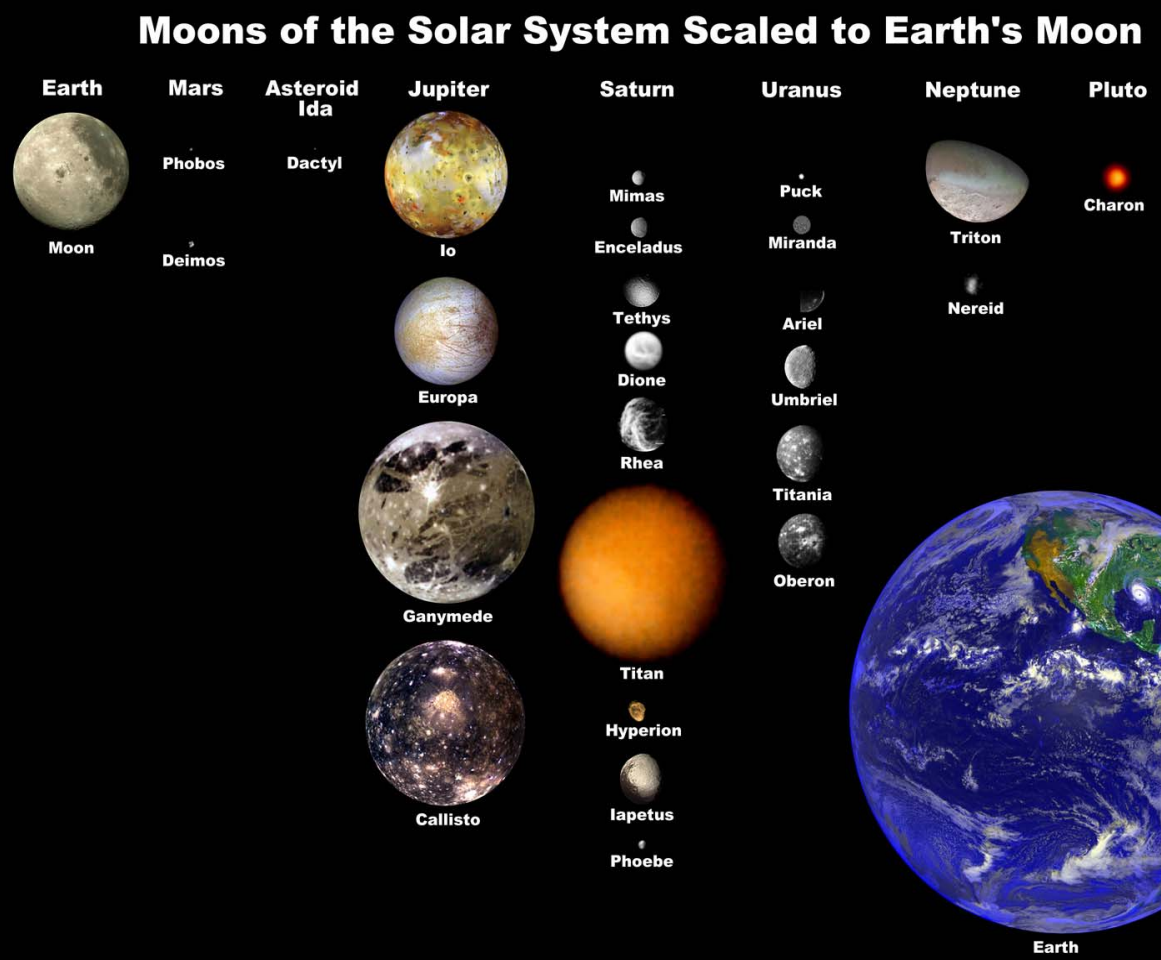
Meteorites from Mars have been scrutinized for evidence of past life

- A Martian rock that came to Earth as a meteorite was examined for circumstantial evidence that microorganisms once existed on Mars
- The science community does is skeptical, and more samples are needed for additional evidence

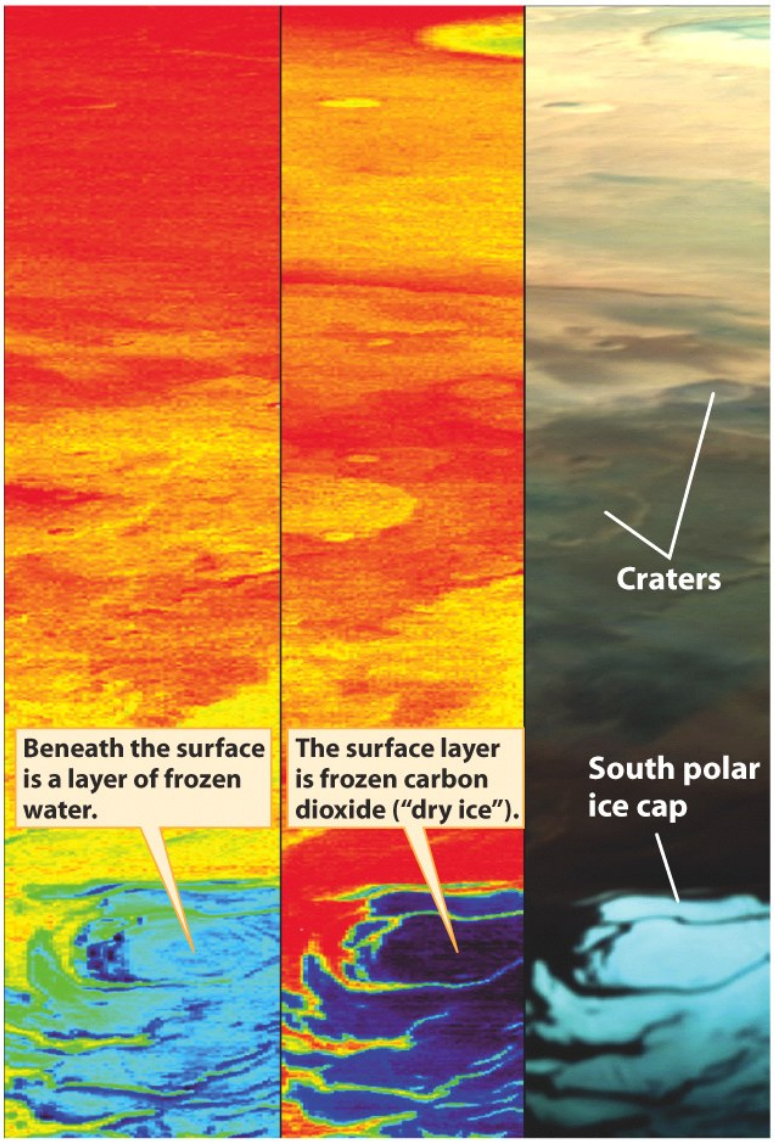
Life on Jovian Moons

- Europa
- Titan
- Others



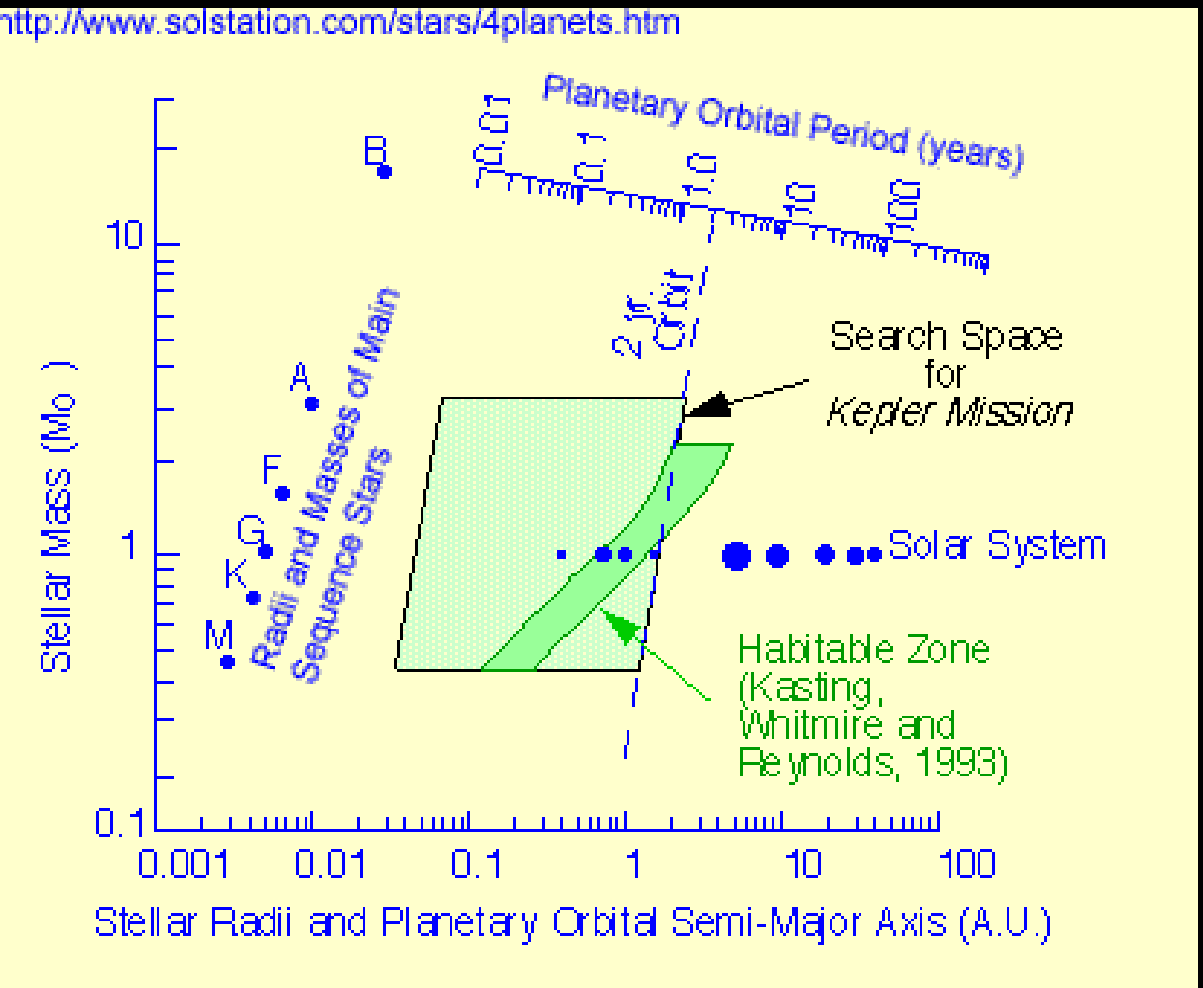


Europa and Mars have the potential for life to have evolved



- Besides Earth, there are two worlds in our solar system—the planet Mars and Jupiter's moon Europa—may have had the right conditions for the origin of life
- Mars once had liquid water on its surface, though it has none today
- Life may have originated on Mars during the liquid water era
- Europa may have extensive liquid water beneath its icy surface
- A future mission to search for the presence of life on Europa has been cancelled

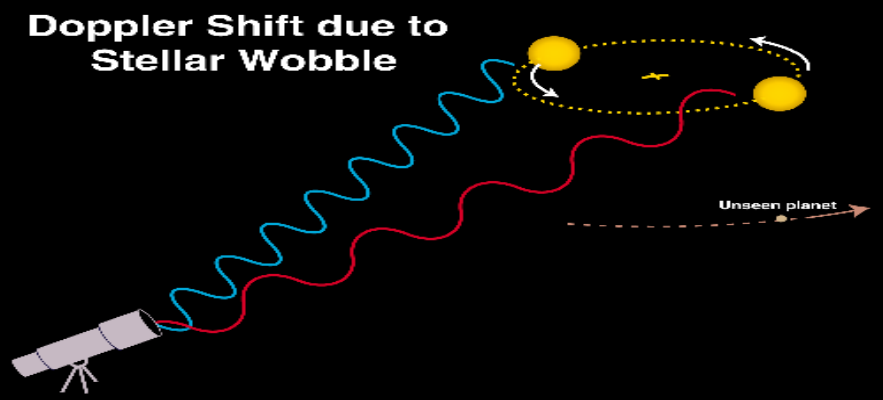
The Nature and Evolution of Habitability

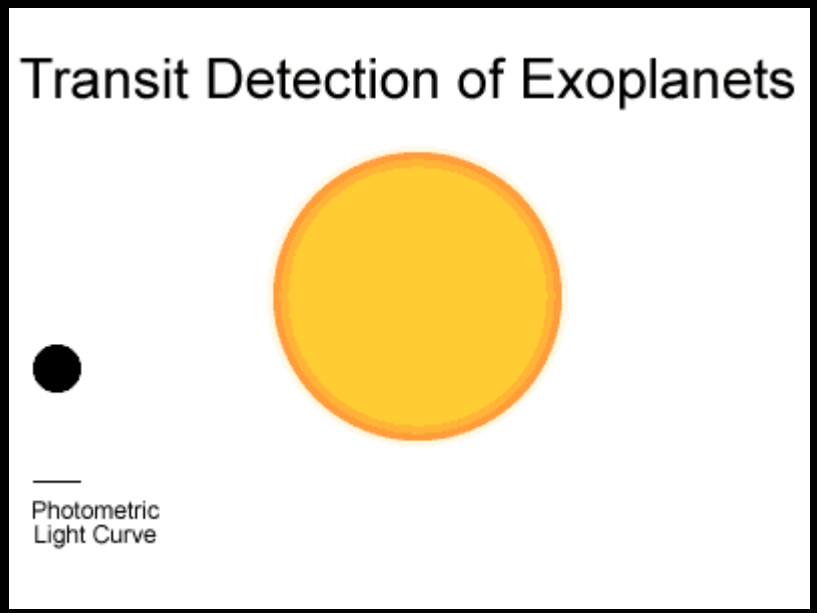


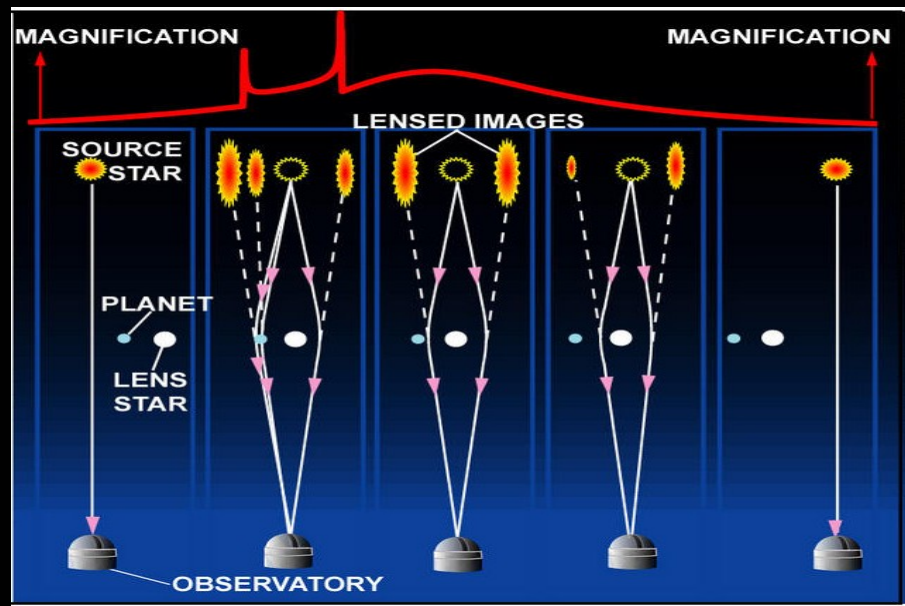
- Habitability Zone
  - Past, Present, Future

The Search for Habitable Worlds

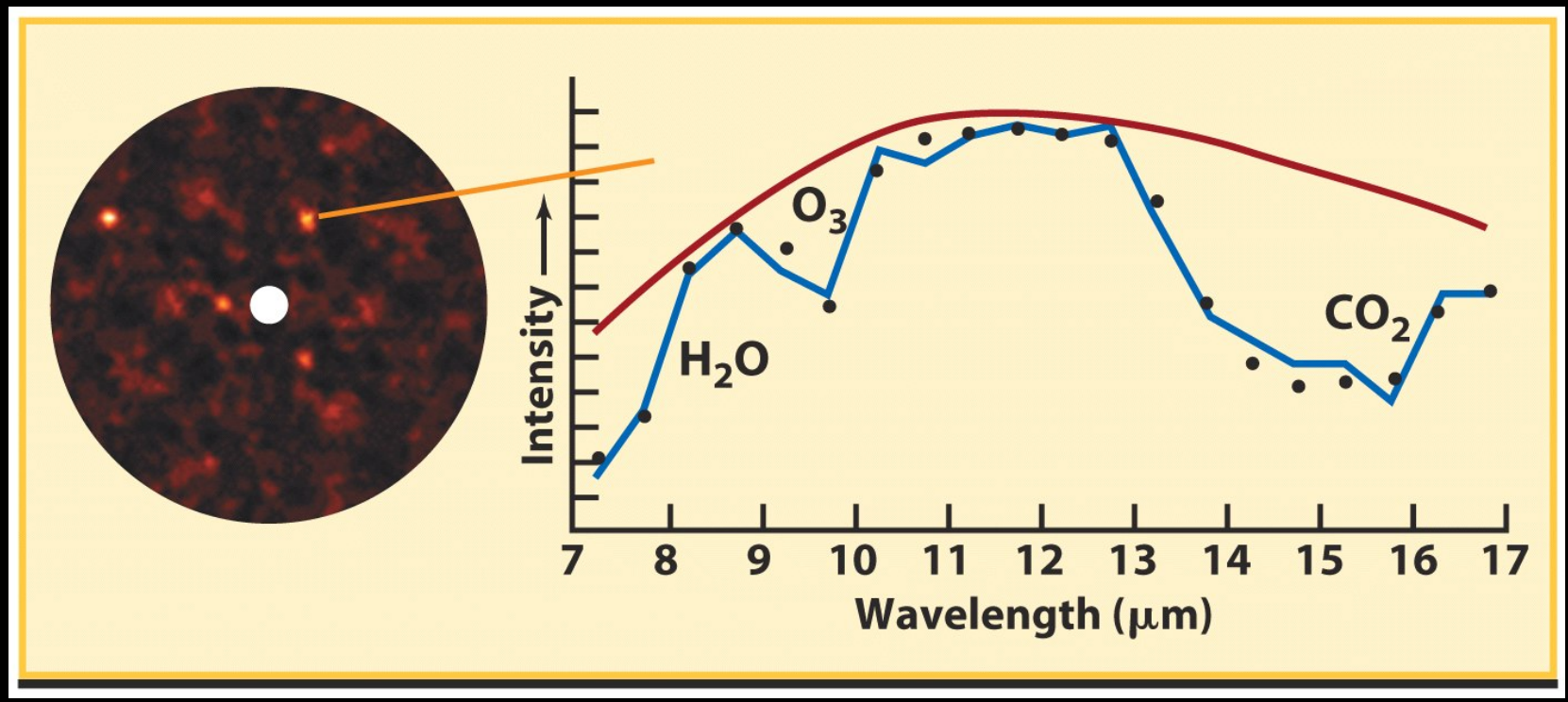
- Planet Formation
- Extrasolar Planets
  - Detection
- Earth-like Planets?







Infrared telescopes in space will soon begin searching for Earthlike planets



- A new generation of orbiting telescopes may be able to detect terrestrial planets around nearby stars
- If such planets are found, their infrared spectra may reveal the presence or absence of life

The Search for Extraterrestrial Intelligence

- SETI
- Drake Equation

$$N_C = N^* \times f_P \times n_{EZ} \times f_L \times f_I \times F$$

The Drake Equation

$$N_T = R_* f_p n_e f_l f_i f_t t_l$$

- N_T - number of communicative civilizations
- R_* - mean rate at which suitable stars are born 1-10/y
- f_p - fraction of stars with planetary systems 0.1-0.5
- n_e - number of Earth-like worlds per planetary system 1-3
- f_l - fraction of those Earths where life develops 0.1-1
- f_i - fraction of these on which intelligence develops 0.01-1
- f_t - fraction of intelligent beings who develop technology 0.1-1
- t_l - lifetime of a civilisation with ability to communicate 10^3-10^6

The Drake equation helps scientists estimate how many civilizations may inhabit our Galaxy

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

N = number of technologically advanced civilizations in the Galaxy whose messages we might be able to detect

R_* = the rate at which solar-type stars form in the Galaxy

f_p = the fraction of stars that have planets

n_e = the number of planets per solar system that are Earthlike (that is, suitable for life)

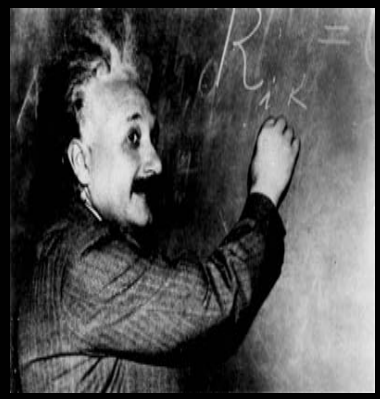
f_l = the fraction of those Earthlike planets on which life actually arises

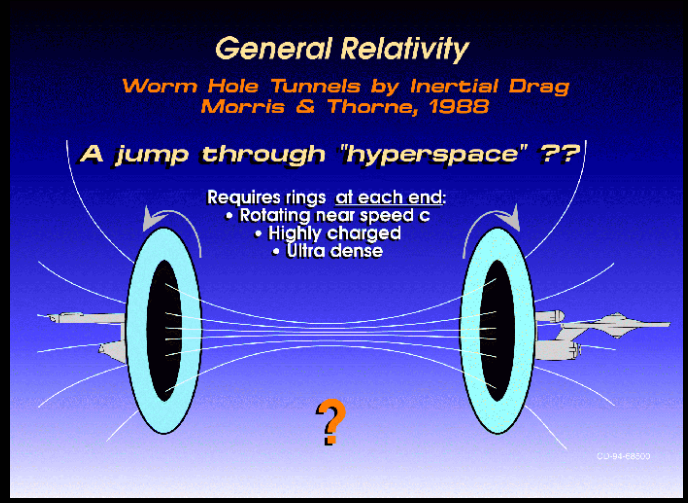
f_i = the fraction of those life-forms that evolve into intelligent species

f_c = the fraction of those species that develop adequate technology and then choose to send messages out into space

L = the lifetime of a technologically advanced civilization

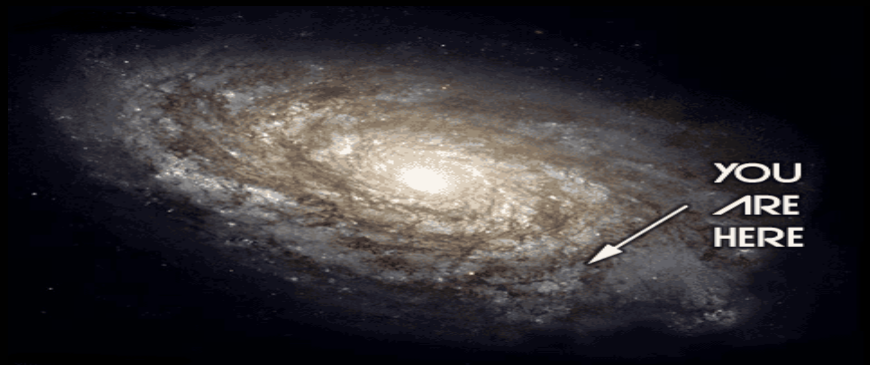
Interstellar Travel



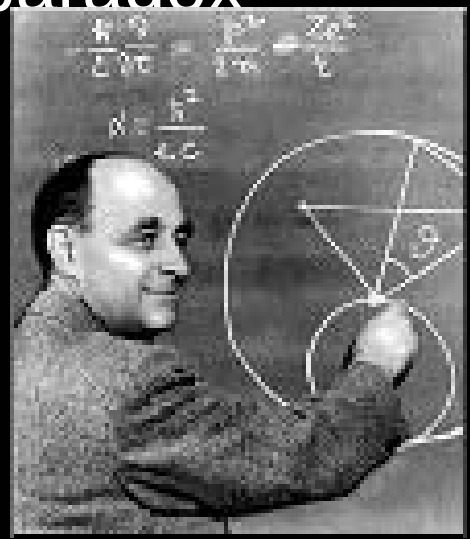


- How realistic?
  - Engineering
  - Limited by c
- Relativity and time dilation
- Wormholes and hyperspace?

The Fermi Paradox



- Where are the aliens?
- Galactic colonization
- Resolving the paradox

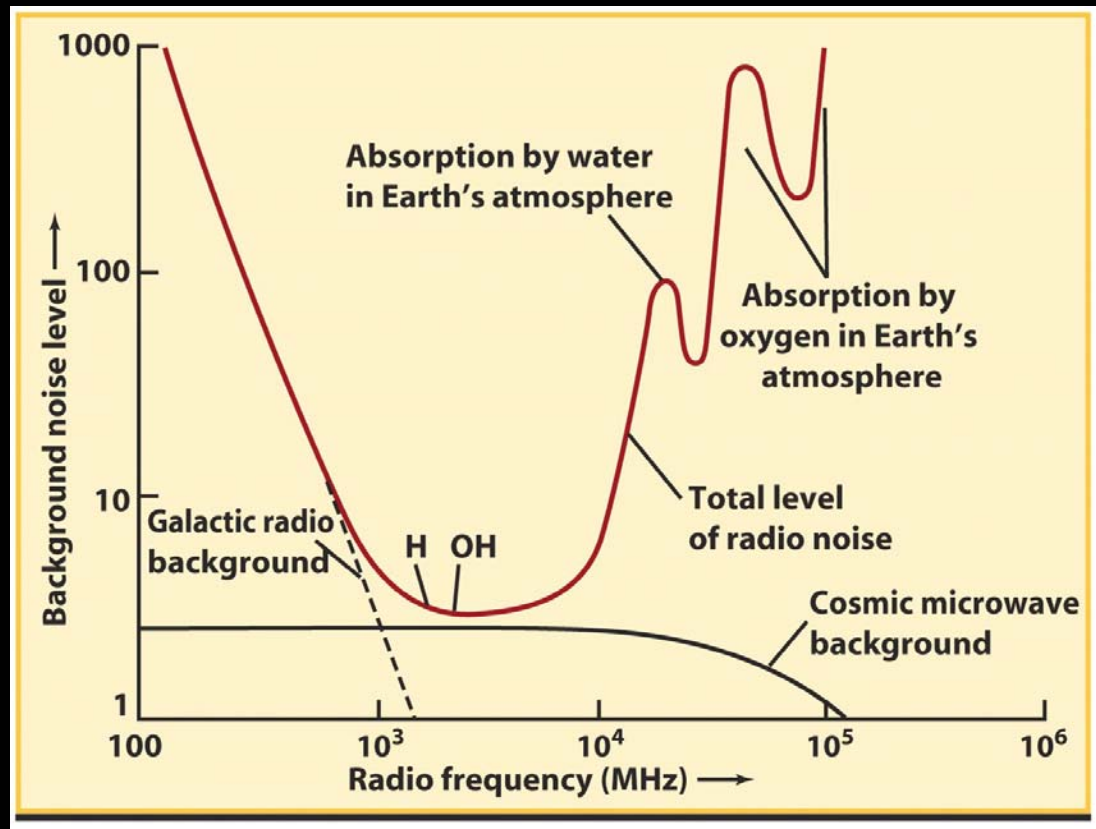


Contact – Implications of the Search and Discovery

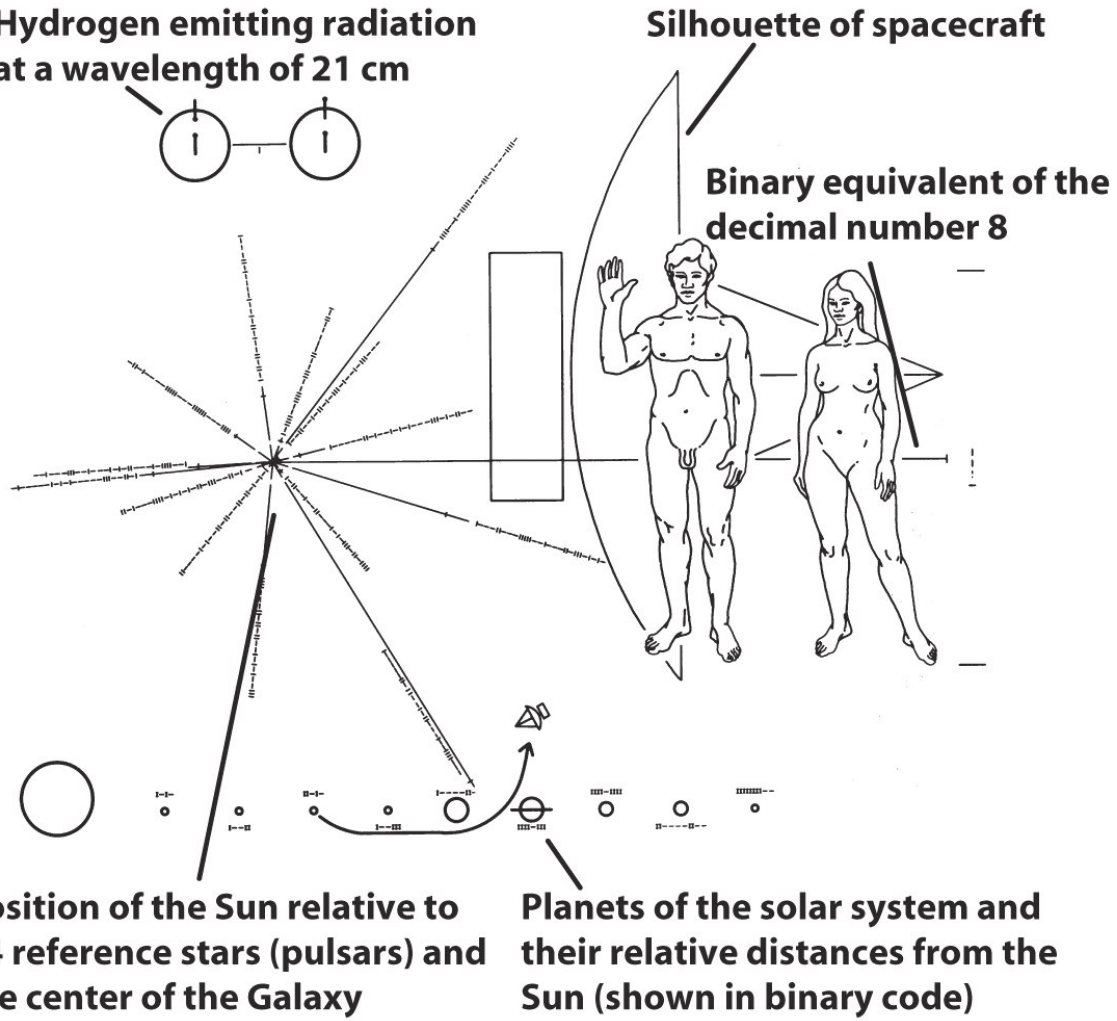
- Can we make contact
  - Which kind 1st, 2nd, 3rd
- Contact implications

Radio searches for alien civilizations are under way

- No signs of intelligent life have yet been detected, but searches continue and make increasing use of sophisticated techniques
- The so-called water hole is a range of radio frequencies in which there is little noise and little absorption by the Earth's atmosphere
- Some scientists suggest that this noise-free region would be well suited for interstellar communication



If an alien civilization were someday to find this message, which of the features on the plaque do you think would be easily understandable to them?



Universe in a Nutshell

- The universe is unimaginably large, and alive.
- You, me, we are not at the center of the universe.
- The way to know the universe is through science.

» Dr. Harold Geller

See you around the universe.