Astronomy 230

This class (Lecture 14):

Life in the Solar System

Next Class:

Midterm!!!

Oct 17:
Amanda Schultz &
Joel Bonasera

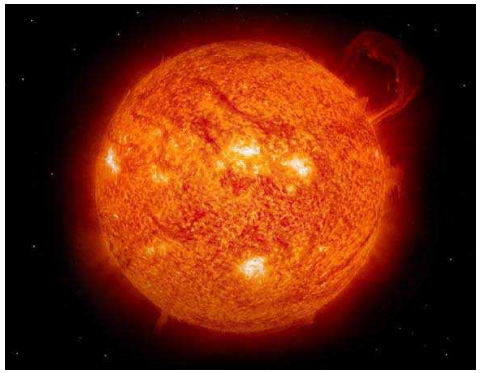
Music: *For Science* – They Might Be Giants

Midterm

- 1 hour exam in this classroom.
- It will cover material up to, but not including, "Life in the Solar System". It **will** include all discussion about f_l.
- Will consist of 17 multiple choice/ true-false questions (worth 40 points) and 2 essay questions (25 and 40 points each) .
- A total of 105 points, so 5 extra credit points.
- You can bring a normal-sized sheet of paper with notes on both sides.

Our Sun

- Is a fairly typical star
  - Has lived for 5 billion years
  - Will probably live another 5 billion

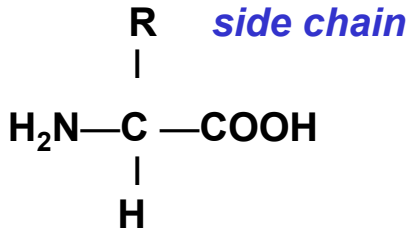


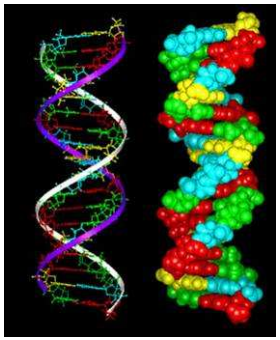
Proto-Earth

- The hot proto-Earth heated up the ices on dust grains– mostly water, carbon dioxide, and nitrogen– the Earth's first atmosphere.
- The water condensed to form oceans and much of the CO_2 was dissolved in the oceans, unlike Venus and Mars.
- No oxygen, no ozone layer.
- UV light, lightning, radioactivity, and geothermal heat, provided energy for chemical reactions.
- Perfect place for carbon chemistry.

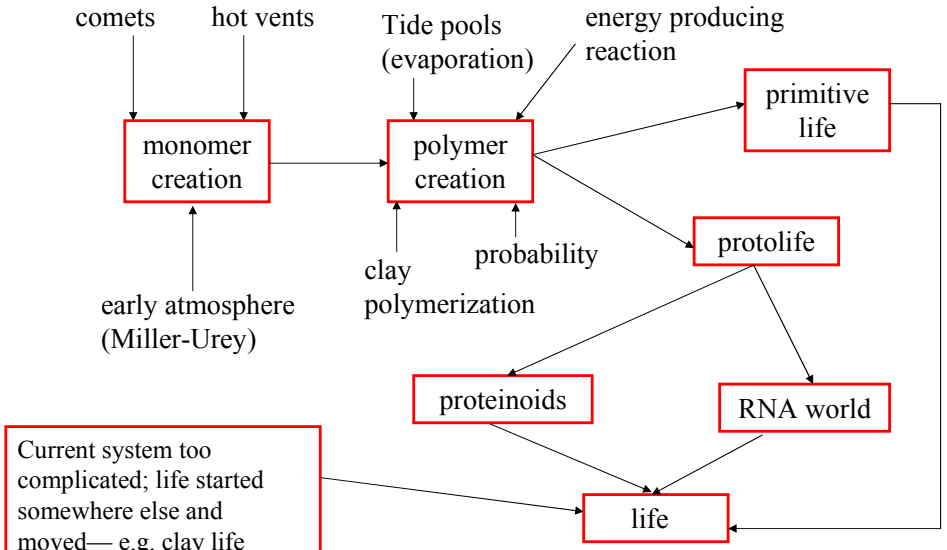
Life on Earth

- Most important components are
  - Proteins/enzymes
    - Polymers made of amino acids strung together.
  - Nucleic Acids (DNA or RNA)
    - Polymers made of sugars (deoxyribose or ribose), a phosphate, and nitrogenous bases.
- In life on Earth, they are so closely linked that it is hard to figure out which came first.
- We do know that life began about 3.8 billion years ago, soon after the large bombardment.





Pathways on Earth



Review

- What are the five biological attributes of life, and what do they mean?
- Compare the chemical composition of life to the chemical composition of: a) the crust of the Earth; b) Earth's oceans; and c) the Sun.
- What is the Drake Equation, and what do the terms mean?
- What is the origin and use of the four main biological elements H, O, N, and C?
- Describe the Early Universe. Why do we believe in the Big Bang?
- What stages did the Universe go through?
- What do we think will happen to the Universe? Explain the role of Dark Energy.
- What are the properties of a first generation star? In particular, describe which heavy elements they made and how they did it. How are they different than stars today?
- What are the properties of a second generation star? In particular, describe which heavy elements they made and how they did it.
- What does the presence of complex molecules in interstellar space tell us?
- Describe the techniques that astronomers use to search for planets around stars? What are the limitations?

Review

- Describe the processes for forming a star and its planets.
- The planets and the Sun formed from the same interstellar cloud. Discuss reasons why the chemical abundances of the inner planets are different than the outer planets.
- What determines if a planet is in the Habitable Zone?
- What is HONC and how are they used?
- What does “left-handed” life mean?
- What are monomers and polymers? Examples?
- Discuss DNA and RNA. How do they function to assemble proteins that carry the genetic code?
- What are possible scenarios for synthesis of monomers and polymers?
- What was the Miller-Urey experiment and why is it thought to be important for life? Include the role of a reducing atmosphere in your discussion.

HW #3

- **Joe Coletta:** http://www.iwasabducted.com/
- **Jake O'Keefe:** http://www.space.com/searchforlife/seti_newplanet_050616.html
- **Adam Molski:** http://www.geocities.com/area51/nebula/2768/main.html
- **Steven Novak:** http://greenzilla.tripod.com/index3.htm

Outline

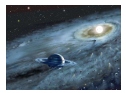
- Life in our Solar System?
  - Venus
  - Mars
  - Jupiter

Drake Equation

That's 2.6 life-arising systems/decade

Frank Drake





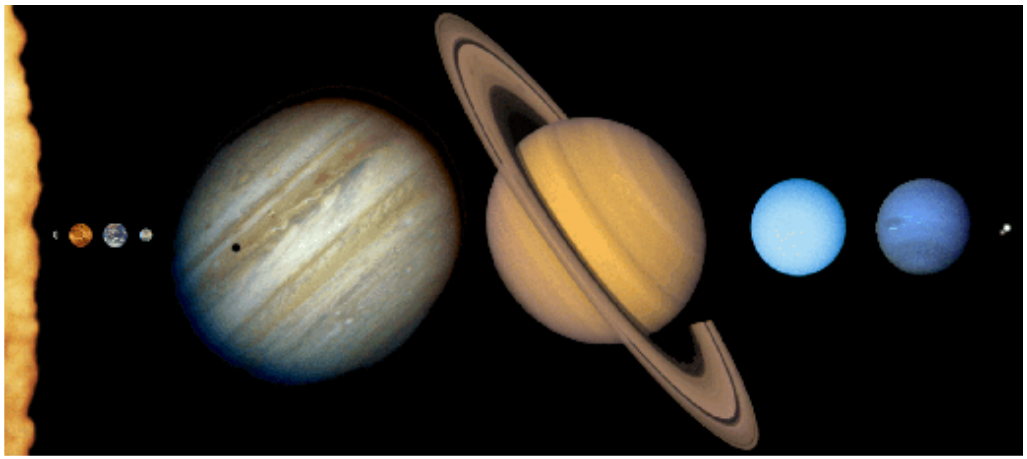



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

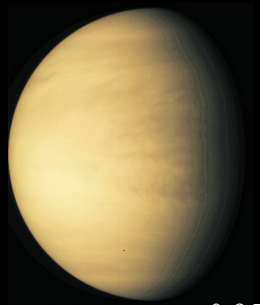
N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	15 stars/ yr	0.5 systems/ star	2.7 x 0.134 = 0.36 planets/ system	0.095 life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Life in the Solar System?

- We want to examine in more detail the backyard of humans.
- What we find may change our estimates of n_e or even f_l.



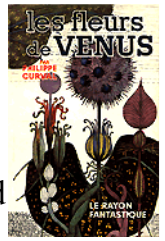
Earth – Venus comparison



Venus is the hottest planet, the closest in size to Earth, the closest in distance to Earth, and the planet with the longest day.

Radius	0.95 Earth
Surface gravity	0.91 Earth
Mass	0.81 Earth
Distance from Sun	0.72 AU
Average Temp	475 C
Year	224.7 Earth days
Length of Day	116.8 Earth days
Atmosphere	96% CO_2

What We Used to Think



Venus must be hotter, as it is closer the Sun, but the cloud cover must reflect back a large amount of the heat.

In 1918, a Swedish chemist and Nobel laureate concluded:

- Everything on Venus is dripping wet.
- Most of the surface is no doubt covered with swamps.
- The constantly uniform climatic conditions result in an entire absence of adaptation to changing exterior conditions.
- Only low forms of life are therefore represented, mostly no doubt, belonging to the vegetable kingdom; and the organisms are nearly of the same kind all over the planet.

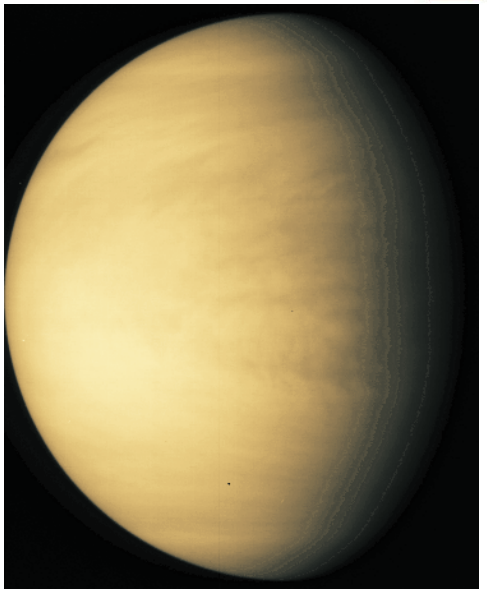
http://www.daviddarling.info/encyclopedia/V/Venuslife.html

Turns Out that Venus is Hell

- The surface is hot enough to melt lead
- There is a runaway greenhouse effect
- There is almost no water
- There is sulfuric acid rain
- Not a place to visit for Spring Break.

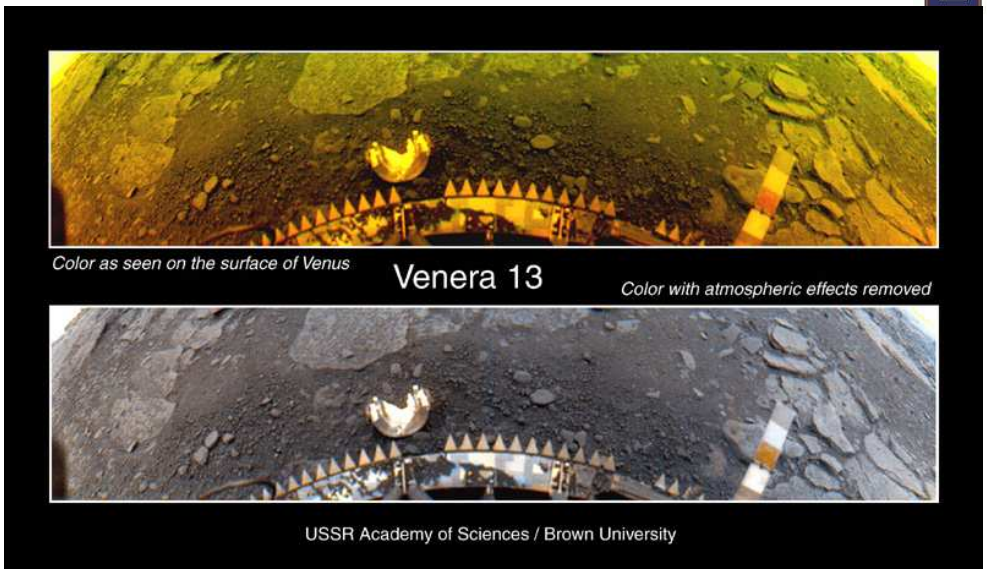
Our "Twin"

- Always covered in thick clouds of CO_2, which make it the hottest planet in the Solar System.
- Pressure on surface is 90 times that on Earth– like 1 km under the sea
- Often called the morning star or the evening star. 3rd brightest object in the sky. Often mistaken for UFO.
- Retrograde rotation – Sun rises in west
- No moons, no magnetic field



http://antwrp.gsfc.nasa.gov/apod/ap960923.html

Soviet Satellites on Venus

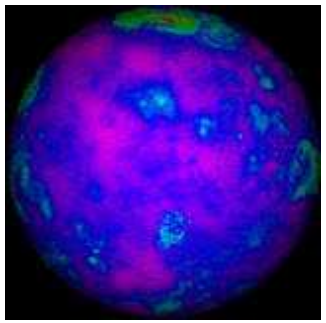


Mostly Basalts-like rocks, indicative of volcanoes

The Venusian Surface Revealed

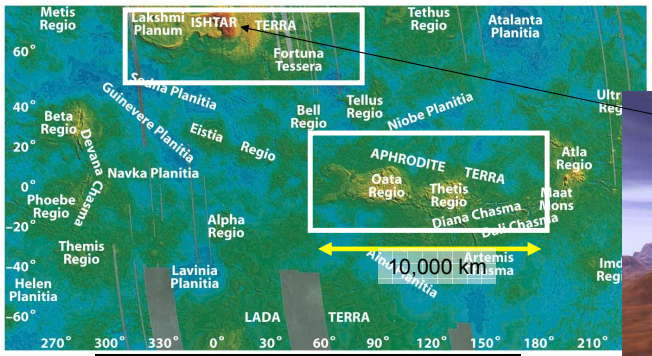
- We can't see Venus' surface in visible light, clouds block the view
- Magellan's Radar showed the surface
- Most of surface is smooth lava flows
- Many large volcanoes
- Probable ongoing volcanism

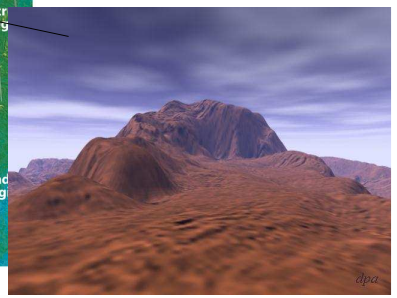
Surface of Venus: Radar



http://www.solarviews.com/raw/venus

Venus: surface features



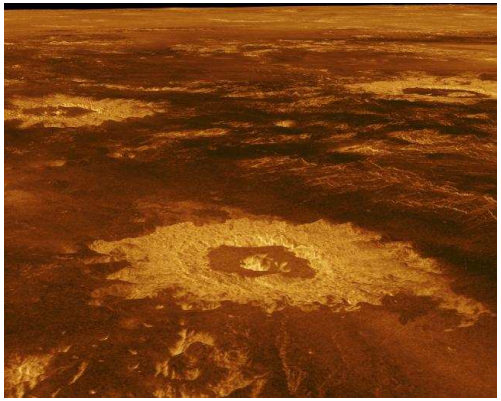


Maxwell Montes (65N 5E)
(Highest mountain range in the solar system
11km high– Everest is 8km)

http://www.geology.smu.edu/~dpa-www/venus.html

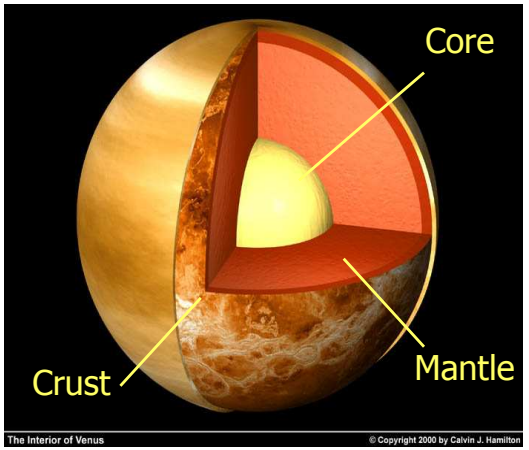
Impacts on Venus

- Venus has about 1,000 craters, often clustered
- No trace of heavy bombardment
- Cratering rate indicates Venus' surface about 500 million yrs old
- Why?
  - Possibility: Extreme temperatures soften rock, making the surface subject to catastrophic volcanic upheaval



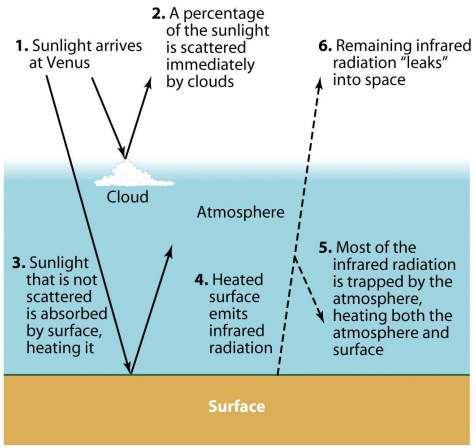
Venus' Interior

- Venus' size and density are roughly equal to Earth's
  - Indicates iron core of similar size
- No magnetic field
  - Very slow rotation - 243 Earth days



Runaway Greenhouse

- On Earth, greenhouse gasses insulate us
  - Keep Earth 35 K warmer than it would be otherwise
- On Venus, massive amounts of CO_2 keep it incredibly hot
  - Almost 300 K warmer!
  - The hottest planet in the Solar System



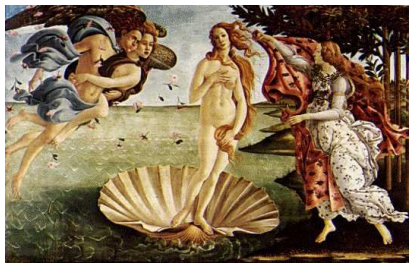
What Happened to Venus?

- It really should have been more like Earth, but the atmosphere is much different.
- Earth's atmosphere is mostly O_2 from life, but early Earth was N.
- Earth and Venus have similar amounts of carbon & nitrogen, but Venus's carbon is loose in the atmosphere.

http://www.digitalart.ab.ca/art/ren/images/birth-of-venus.jpg

Why So Different?

- Earth's carbon is locked up
  - Dissolved in the oceans
  - Locked into rocks and life



- Venus' carbon is in its atmosphere
  - Too close to the Sun for liquid water
  - No oceans to trap the carbon dioxide
  - No life to process the carbon into sedimentary rocks

http://www.edgechaos.com/MECA/WALLART/VR89/venus.jpeg

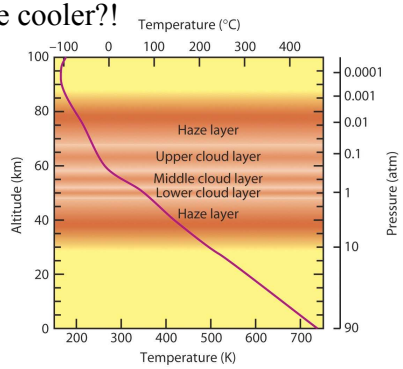
What Happened to Venus?

- Apparently Venus lost its H_2O– no oceans and no sediments.
- Probably the atmospheric temperature was hot enough for water to travel high enough to be broken apart by UV radiation, the H was lost and the O reacted with something else.
- Irreversible procedure!
- Which is why greenhouse effect is worrisome here too!
- The Earth traps water vapor in the cool tropopause at 14km.

http://photos1.blogger.com/blogger/4103/1148/1600/Venus%20Wimbeldon05.jpg

Life on Venus?

- Surface is far too hot
  - If lead is liquid, think of what heat would do to complex organic polymers
  - No cooler polar regions exist
    - Heat is uniform!
    - But, high in the clouds it should be cooler?!
- Maybe life can still exist in the clouds?
- At 50 km up, the temperature is not too hot and the pressure is 1 atmosphere.



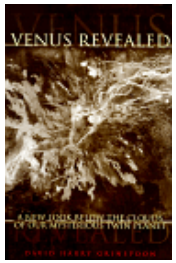
Chemical Disequilibrium

- High clouds in the atmosphere contain chemicals that hint at the presence of some kind of biological activity.
- Hydrogen sulfide and sulfur dioxide - two gases that react with each other– exists in the clouds.
- Something is probably producing them.
- Hardly any carbon monoxide. So something is perhaps removing the gas.

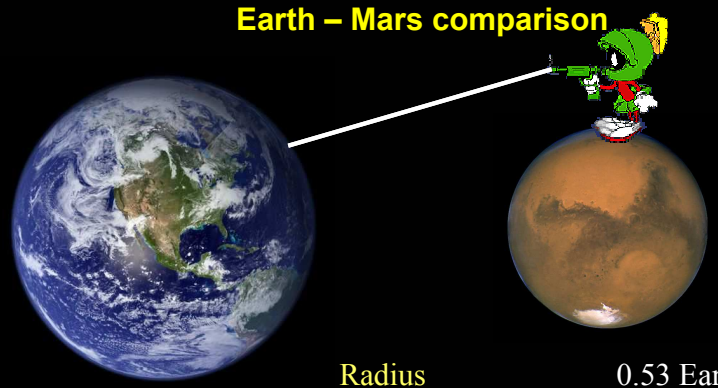
http://www.manson-valley.de/fotogalerie/manson/images/acss/acss_32.jpg

Life on Venus?

- One possibility is that microbes living in the clouds could be combining sulfur dioxide with carbon monoxide and possibly hydrogen sulphide or carbonyl sulphide in a metabolism similar to that of some early terrestrial micro-organisms.
- Given that the temperature on Venus was once much cooler, there may once have been oceans on the planet. Life could have started there and retreated to stable niches once the runaway greenhouse effect began.
- Maybe a mission to scoop up some atmosphere?



Earth – Mars comparison



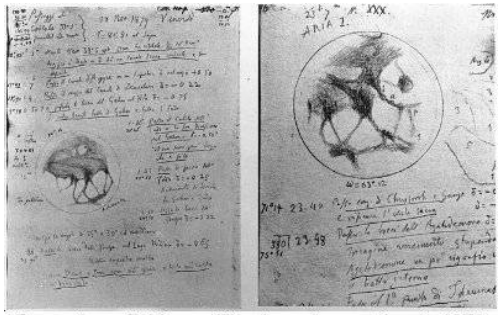
Mars has the Solar System's largest Volcano, Olympus Mons – 27 km tall.

Radius	0.53 Earth
Surface gravity	0.38 Earth
Mass	0.11 Earth
Distance from Sun	1.5 AU
Average Temp	-63 C
Max Temp	20 C
Year	687 Earth days
Length of Day	24 hours 39 minutes
Atmosphere	CO_2 95%

What we used to think.

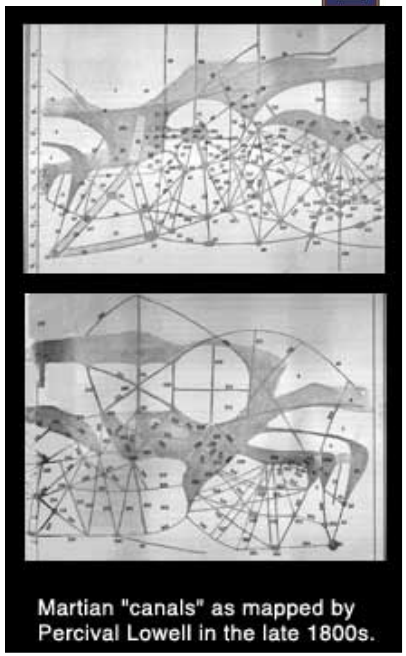

Giovanni Virginio Schiaparelli

- Was thought to be similar to the Earth in many ways.
- Life was argued to exist on Mars by many astronomers.
- The astronomer Schiaparelli announced that he saw regular linear markings on the surface, which he named *canali*.
- Technically, in Italian means channels, but it was mistranslated to canals.


Pages from Schiaparelli's observing notebook, 1879

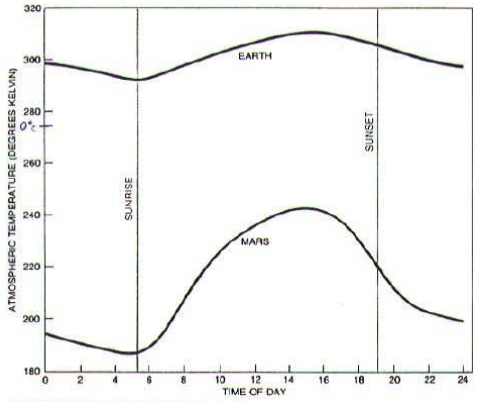
Percival Lowell's Canals

- Evidence for intelligent life?
- Mapped the civilization.
- Influenced culture.


Martian "canals" as mapped by Percival Lowell in the late 1800s.

The Martian Atmosphere

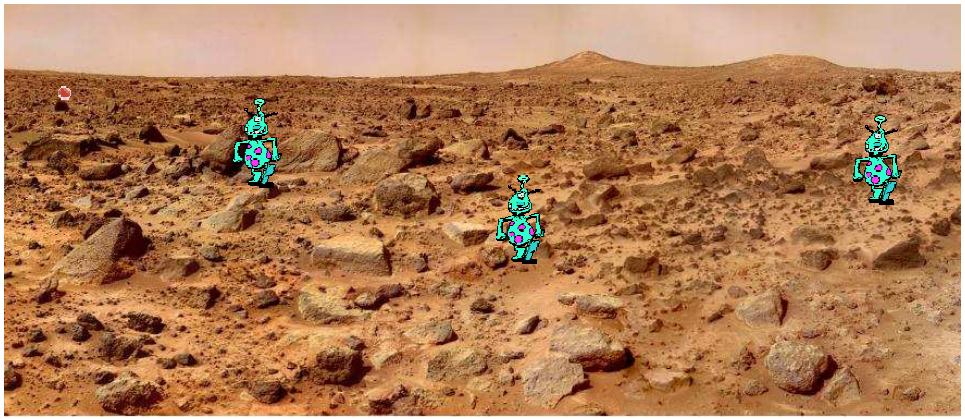
- 95% carbon dioxide
- Atmospheric pressure 0.6% of Earth's – like 40 km altitude on Earth
- But too thin for significant greenhouse effect.
- Pressure is too low for liquid water.
- Not protected by a global magnetosphere like Earth's
- Large daily and seasonal swings in surface temperature



DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the *Viking 1* landing site (*color*) are qualitatively similar to those at China Lake, Calif., a desert site (*black*). In both cases the temperature touches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is about three times greater on Mars than it is on the earth. At Viking site range is 55 degrees, from about 187 to 242 degrees Kelvin (−86 to −31 degrees Celsius). At China Lake range is 18 degrees, from 292 to 310 degrees K. (19 to 37 degrees C.).

The Surface of Mars

- Mars is a desert!
- Iron oxide in soil gives reddish cast.

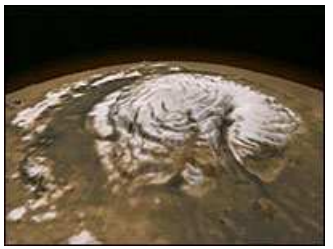


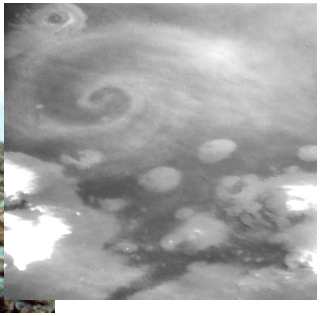
View of "Twin Peaks" from Mars Pathfinder

http://www.grc.nasa.gov/WWW/PAO/html/marspath.htm

Water on Mars

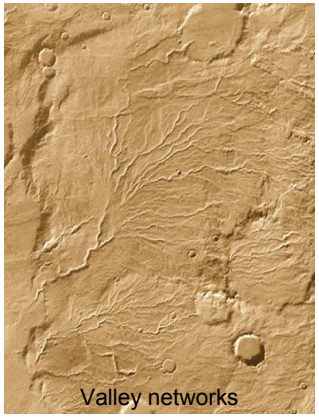
- There **is** water on Mars
  - North and south polar caps (mostly CO_2)
  - Some water vapor in the air
  - Frost on rocks
  - Clouds (ice crystals)
- No *liquid* water now

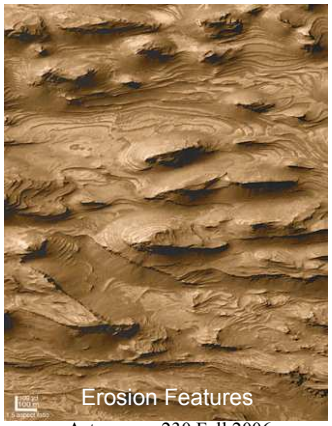


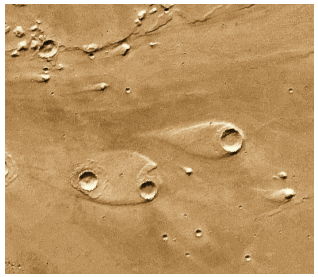


Liquid water on Mars?

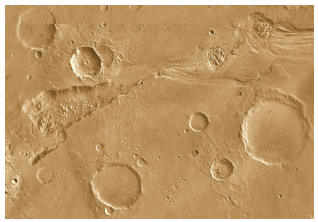
- Water erosion features visible from space
- Atmospheric pressure too low for liquid water to exist
- Perhaps at some point in the past?





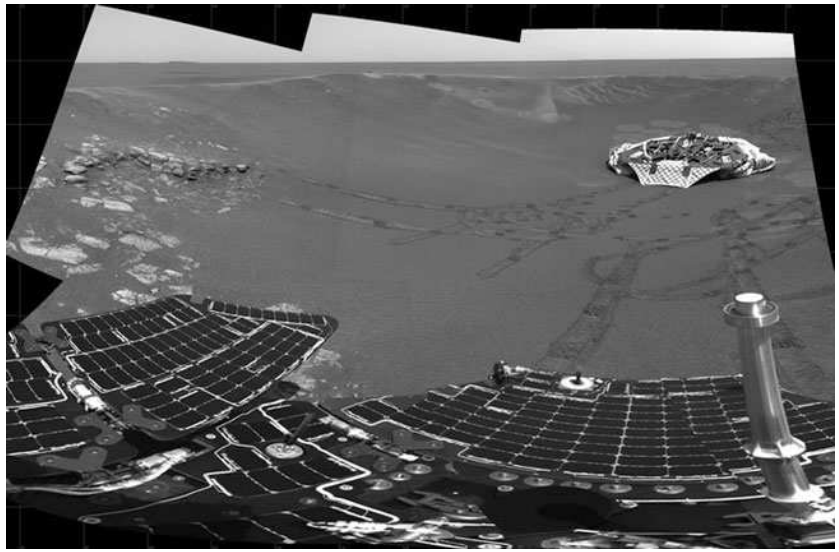


"Islands"



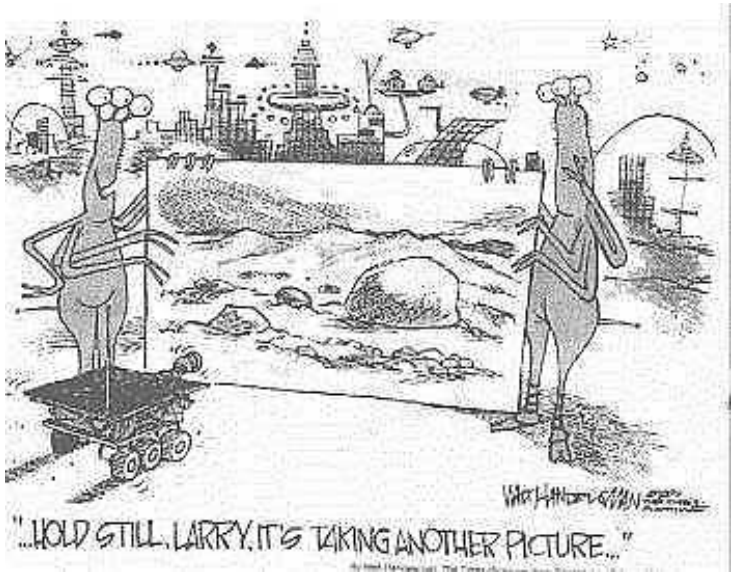
Flood erosion

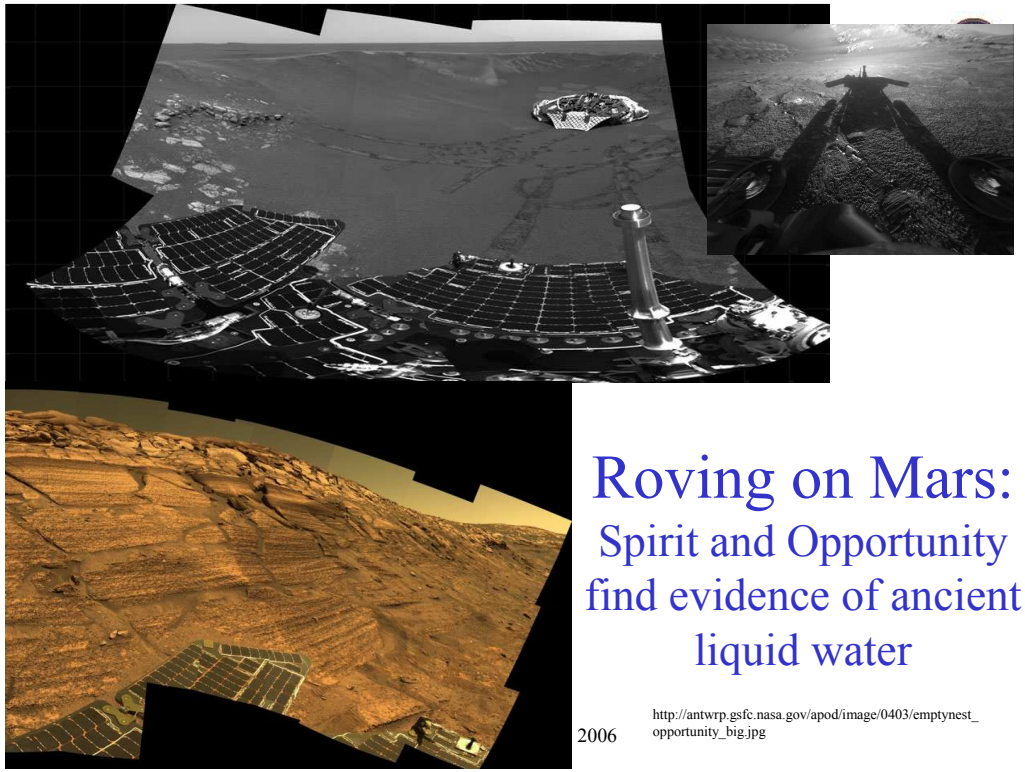
The Surface of Mars: Opportunity



http://antwrp.gsfc.nasa.gov/apod/ap040303.html

Roving on Mars





Roving on Mars:

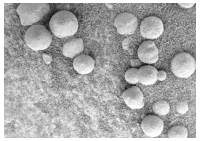
Spirit and Opportunity find evidence of ancient liquid water

2006

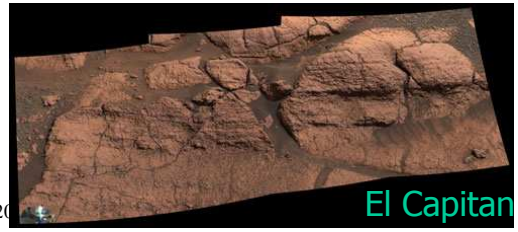
http://antwrp.gsfc.nasa.gov/apod/image/0403/emptynest_opportunity_big.jpg

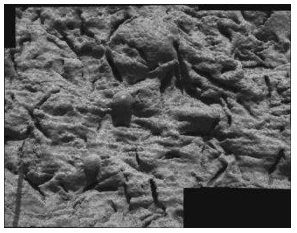
Standing Water on Mars

- The new data from the rovers are highly suggestive of ancient standing water on the Meridiani Planum.



- 3 pieces of evidence:
  - Physical appearance of rocks
  - Rocks with niches where crystals appear to have grown
  - Rocks with sulfates left after the water evaporated
- Is it a former sea floor or just an area that had ground-water?

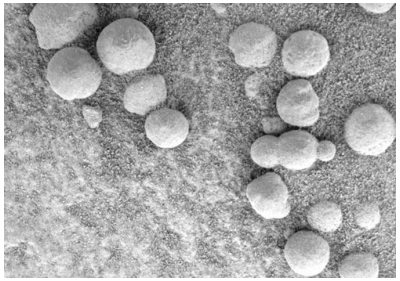


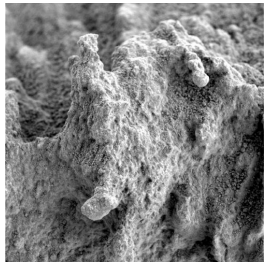


Mars' Watery Past

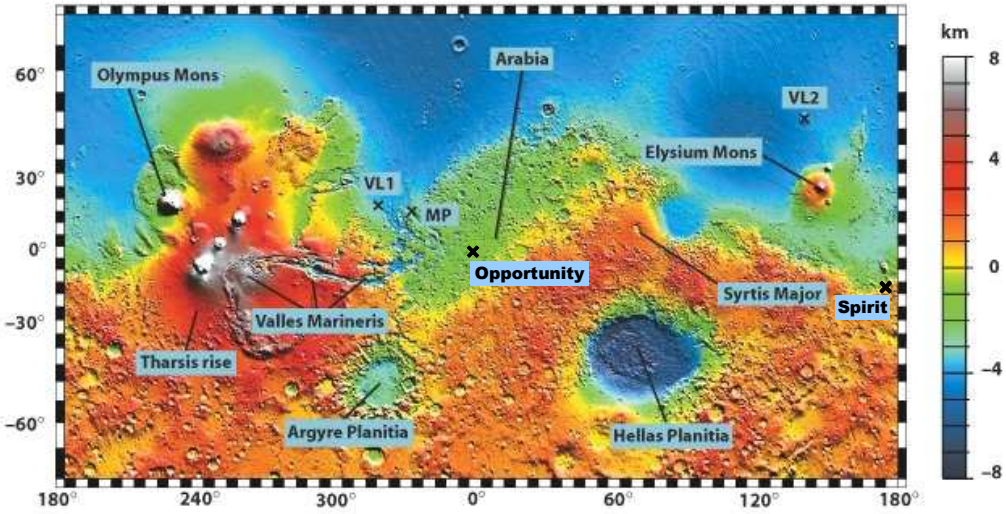
What Happened to the Water?

- That is the big question
  - Both Opportunity and Spirit have found evidence of water
  - Did the water escape to space with the air?
  - Is it frozen beneath the surface?
- The rovers are continuing their exploration
- More missions are planned

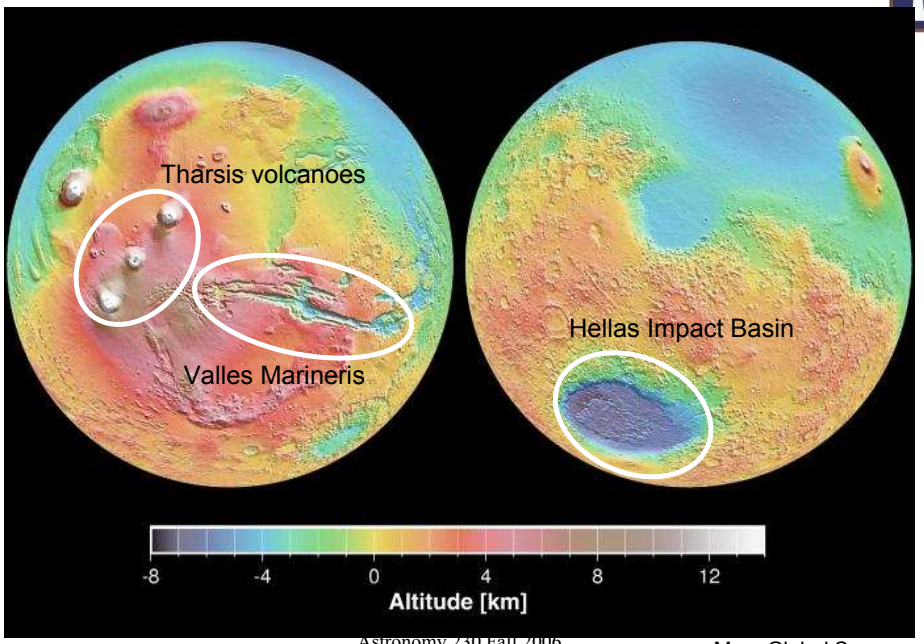




The Geology of Mars



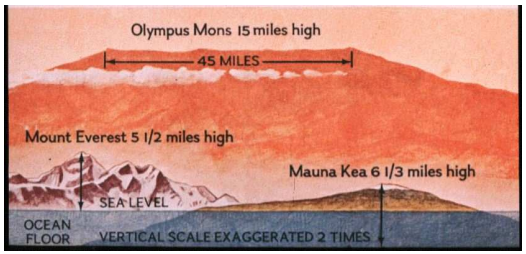
The Surface of Mars



Mars Global Surveyor

Olympus Mons

- The largest mountain in the Solar System rising 26 km high
- A shield volcano, like Hawaii on Earth
- Its caldera is 90 km across

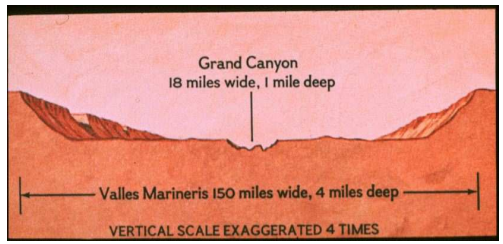


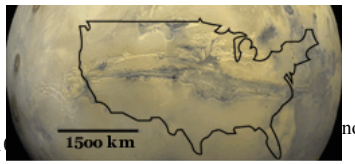
Olympus Mons

- Its base is more than 500 km in diameter
- As long as the entire Hawaiian island chain
- Rimmed by a 6 km high cliff
- Last erupted 25 million years ago
- Probably so big, due to lack of plate tectonics

Valles Marineris

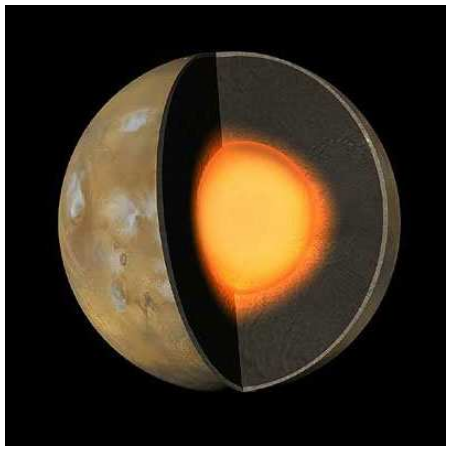
- A series of fault canyons
- 5000 km long
  - A big as the U.S.!
- A giant crack in the crust of Mars
  - Formed as the planet cooled
  - Expanded by water flow





Mars' Interior

- Like Earth, Mars has an iron core
  - About half of the planet's radius in size
  - Heavily contaminated with sulfur
  - Weak magnetic field suggests a thin layer of liquid iron, mostly solid



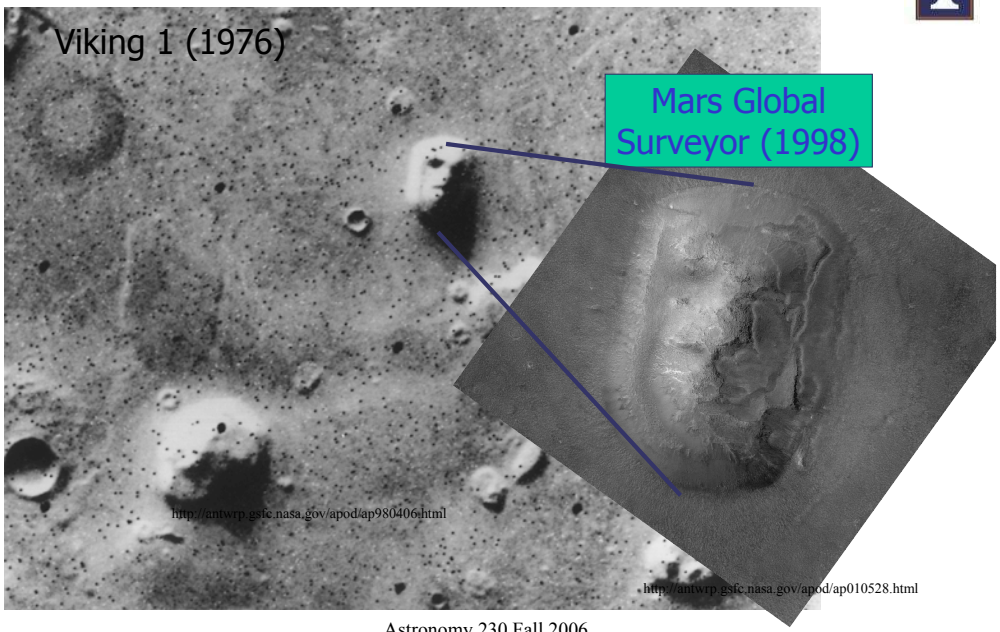
Mars' Past

- Early in Mars' history it was likely more Earth-like
  - Geologically active
  - Volcanic eruptions created a thick carbon dioxide, nitrogen atmosphere
  - Greenhouse effect made it warm enough for liquid water
  - Oceans? Rivers? Glaciers by the poles?
  - Life?

What Happened?

- Mars was too small
  - Not enough internal heat
- Plate tectonics stopped
  - Volcanoes sat over "hotspots" grew to immense sizes
- Volcanic activity slowed as the interior cooled
- The atmosphere escaped
- The planet froze
- Did life move underground?

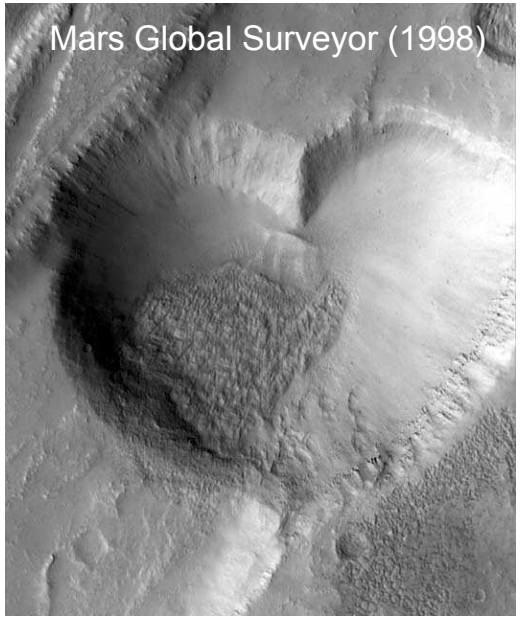
The "Face" of Mars?



Other Faces

http://antwrp.gsfc.nasa.gov/apod/ap990315.html

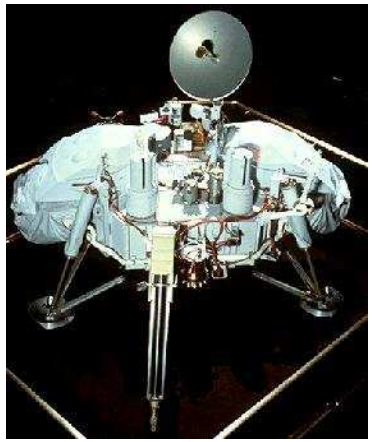
Other Places



http://www.solarviews.com/cap/mgs/heart.htm

The Search for Mars Life

- Viking 1 and 2 carried several experiments to detect life
- The results were ambiguous. The soil reacted vigorously with the Viking nutrients, then tapered off in activity.
- The conclusion of most scientists is that the reactions were due to inorganic chemical reactions.



Martians?

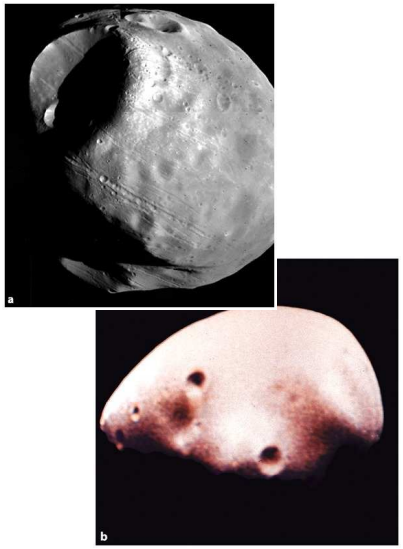
- In August 1996, evidence for microbial life was found in a Martian meteorite.
  - ALH84001 (3Gyrs): Found in Antarctica, composition suggests it was knocked from Mars
  - About 14 such Mars rocks have been found on Earth
- David McKay *et al.* suggested that there was fossil evidence for bacteria in the meteorite.

Martian Microbe Fossils?

- Microscopic shapes that resemble living and fossil bacteria on Earth– nanobacteria, but much smaller than on Earth.
- Microscopic mineral grains like some produced by living and fossil bacteria on Earth
- Organic chemical compounds that resemble the decay products of bacteria on Earth.
- In the end, not impelling enough. Non-biological processes can probably produce the observed features

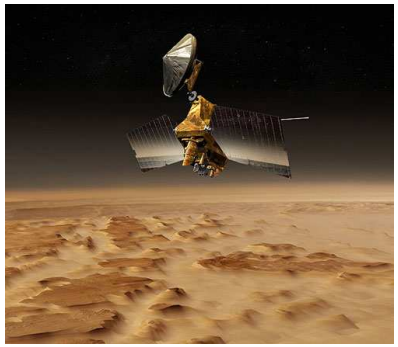
Phobos & Deimos

- Mars' moons
- Likely captured asteroids
- Very small
  - About 15-25 km in size
  - Shaped like potatoes



Mars Missions

- Mars Reconnaissance Orbiter (now)
  - Will study the geology and climate of Mars
  - Look for ancient sea shores
  - Survey potential landing sites
- Phoenix (2007)
  - Will analyze water ice at Mars' north pole

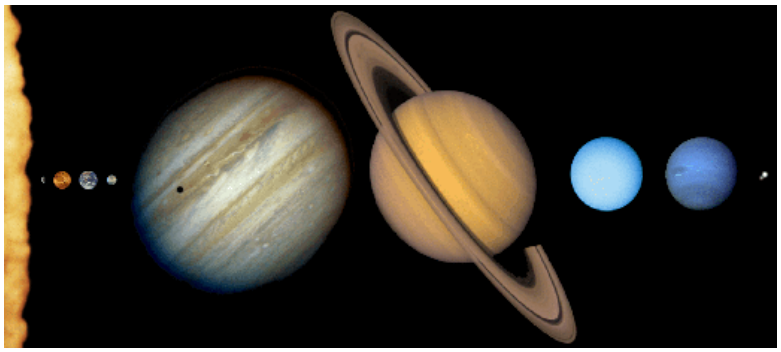


Manned Mars Exploration

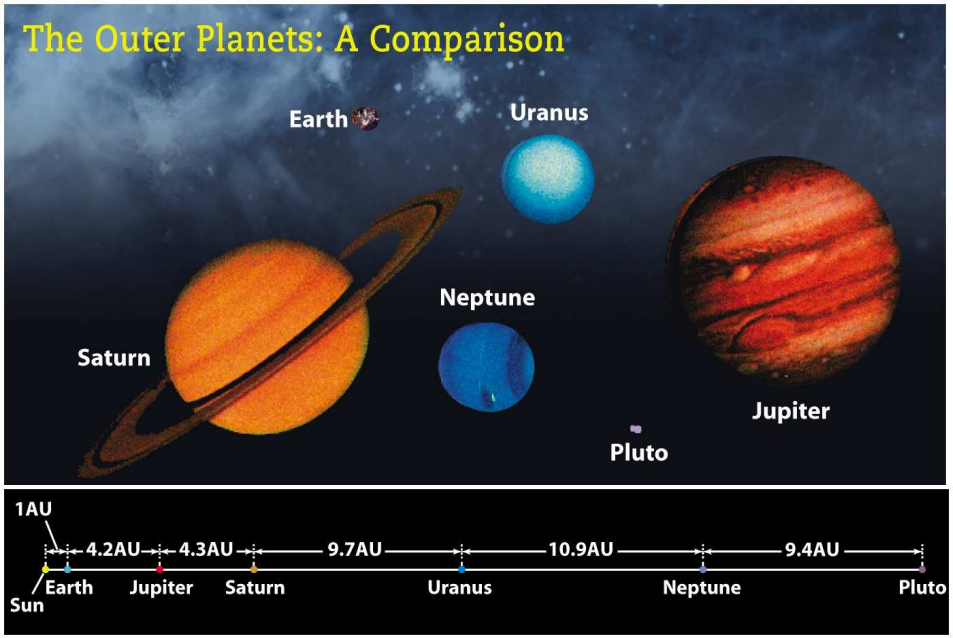
- NASA's plans to send a manned expedition to Mars
- Timetable:
  - Complete Space Station by 2010
  - Return to Moon by 2020
  - Then, on to Mars (no date)
- No cost estimates
  - Some funds from to-be-retired shuttle fleet

Life in the Solar System

- Venus may have life in the clouds.
- Mars might still have life under the soil.
- But what about the outer solar system?
- It isn't in our definition of the habitable zone, but it still is interesting.
- We will focus on Jupiter, Io, Europa, and Titan in this class.



The Outer Planets



Earth – Jupiter comparison

Biggest and most massive planet, has the largest gravity, has the largest number of moons (>61), yet has the shortest day in Solar System. Radiates more energy than it absorbs.

Radius	11.2 Earth
Cloud-top gravity	2.5 Earth
Mass	318 Earth
(more than 2.5 times the rest combined)	
Distance from Sun	5.2 AU
Year	11.88 Earth years
Solar day	9 hours 55 minutes

Causes a bulge at the equator.

Jupiter, King of the Planets

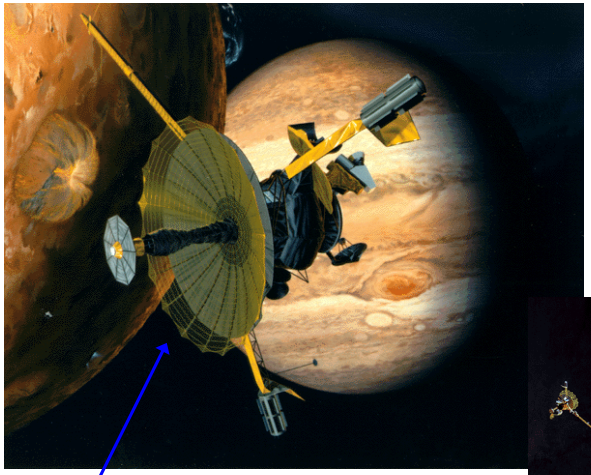
- Named for the king of the Roman gods
- A truly immense planet
  - Over 11 times the diameter of Earth
  - Over 300 times the mass of Earth
  - Over twice the mass of all the other planets combined!
  - Has over 60 moons, its own mini-solar system!
- Visited by 4 spacecraft
  - Pioneer 11 - Flyby in 1979
  - Voyagers 1 & 2 - Flybys in 1980 & 1981
  - Galileo - Went into orbit and dropped a probe into Jupiter's atmosphere, 1990-2003

Jupiter's Atmosphere

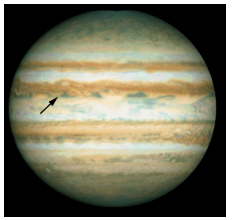
- Although mostly gas, by 20,000 km in, the pressure is 3 million atmospheres!
- Due to an internal heat source, the temperature rises as one penetrates the atmosphere.
- The outer atmosphere is made of freezing clouds of ammonia, methane, and ice.
- The swirling patterns are evidence of great storms.

Can you say Miller-Urey?

The Galileo Spacecraft (1989 – 2003)



How the main antenna *should* have looked



First atmospheric probe

Probing the Atmosphere

- The probe lasted for 57 minutes before it was destroyed by temperature and pressure.
- Found a lot of turbulence, strong winds (330 mph), very little water ice, and no lightning.
- Did not encounter the layers of clouds that was expected.
- The probe entered the least cloudy region of Jupiter.
- Did not rule out life, but did not support it.
- Later, the spacecraft Galileo was crashed into Jupiter.

What Did Galileo Experience?

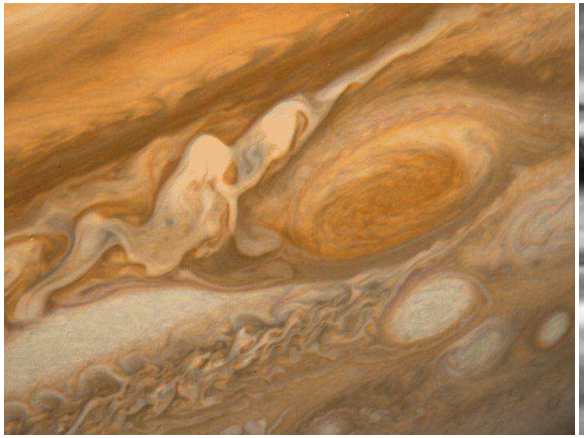
- An atmosphere unlike Earth's
  - 92% Hydrogen, 8% Helium, 0.1% other stuff
    - Very similar to the Sun's composition
    - Not too far from a binary star system
  - Rich chemistry
    - Ammonia, methane, other hydrocarbons, water, phosphine, etc..
- 400 mph winds
- Incredible pressures
- Increasing temperatures with depth

Driving Jupiter's Weather

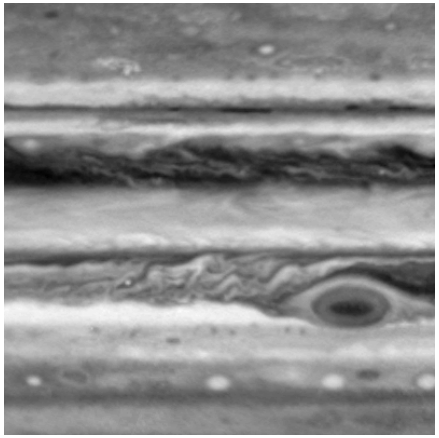
- On Earth, solar heating drives weather
- On Jupiter, internal heat drives weather
  - Winds maintain speeds to great depths
  - Jupiter radiates 70% more heat than it receives from the Sun
  - The heat is from Jupiter contracting under its own powerful gravity
  - As it contracts, the gas is squeezed, and the temperature increases

The Great Red Spot

- A huge storm 25,000 km across – twice size of the Earth!
- First observed > 300 years ago!



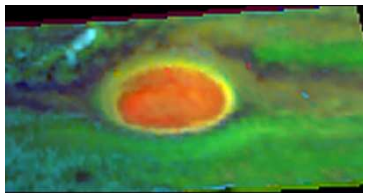
Voyager 1 image



Cassini images

Jupiter's Atmosphere

- The atmosphere resembles the conditions of the Miller-Urey experiment.
- The red bands and spots may be biological molecules.
  - The Miller-Urey experiment produces amino acids and **red polymers**.
  - Carl Sagan suggested that the atmosphere might be an optical photochemistry, like photosynthesis but more effective. Not much evidence for such a statement.
- But, constant churning of the atmosphere probably makes development of complex life nearly impossible.

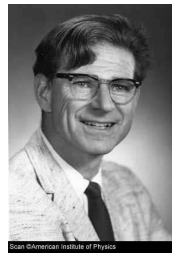


Icy ammonia (light blue) discovered by Galileo

Life?

- Carl Sagan and Edwin Salpeter devised a scheme for life in the clouds of Jupiter.
- They argued that the atmosphere must be rich in organic chemistry, so why not expect Earth-like life?

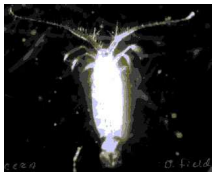
http://tierra.rediris.es/merge/Carl_Sagan/192a.jpg



http://www.aip.org/history/esva/catalog/images/salpeter_edwin_a3.jpg

Floating Life

- The problem is that any life in the clouds that sank too far down would be destroyed by the temperature or pressure.
- They proposed a simple life form like oceanic plankton called "sinkers".
- Small (0.1 cm) life that grew and fell, but then replicated by "splitting-up" and getting circulated back into the upper atmosphere.



http://www.wackerbaits.com/sf/media/bellsinker.jpg

http://www.mantapacific.org/mantapacific/information/images/plankton.jpg

Floating Life

- The sinkers became the basis of a proposed ecology.
- They also posited "floaters"– large hydrogen balloon-like life that "swim" in the Jovian atmosphere.
- They could be huge creatures, as large as 1 to 2 km in diameter.

http://www.firaxis.com/smac/nativelife.cfm

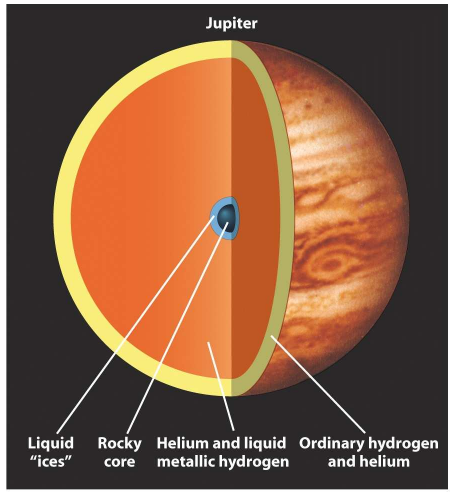
Floating Life

- Maybe similar to whales– mixture between jellyfish and birds?
- Big bags of hydrogen gas.
- Maybe there are also "hunters" that fed on the floaters?
- Of course, this is all speculative, and there is no way to detect such life.
- Science fiction from scientists really.

http://www.epilogue.net/cgi/database/art/list.pl?gallery=3126

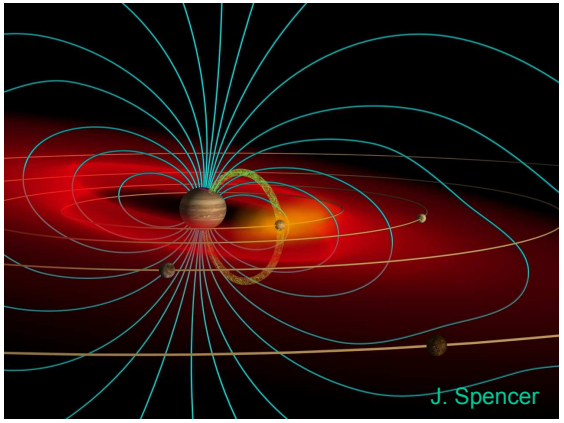
Jupiter's Interior

- Average density only 30% greater than water
- 25% that of the Earth's average density
- By 20,000 km, the pressure is 3 million times that on the Earth's surface!
  - Hydrogen becomes a liquid metal
- Core of rock & "ice" 10-12 Earth masses



Jupiter's Magnetosphere

- Liquid metal hydrogen generates a magnetic field
  - 14x stronger than Earth's field
  - Over 4 million km across
- A ring of ionized particles surrounds Jupiter
  - Stripped from Jupiter's moon Io



Jupiter's Rings

- Jupiter has rings!
- Discovered by the Voyagers
- Not prominent like Saturn's
- Dusty disk of debris, probably from meteoroid impacts with small moons