

Astronomy 330



This class (Lecture 13):

Life in the Solar System

Next Class:

Life in the Solar System

HW 5 is due Wednesday

Music: *Life on Mars*– David Bowie

Question



How were the first presentations?

- a) Good. I learned something.
- b) Good. It was nice to see different ideas.
- c) Okay.
- d) Bad. Quality was low.
- e) Bad. Just boring mostly.

Outline



- Life on Venus?
- Life on Mars?

Drake Equation



Frank Drake

That's 2.6 planetary systems/year



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

# 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 communicate	Lifetime of advanced civilizations
	9 stars/yr	0.29 systems/star	planets/system	life/planet	intel./life	comm./intel.	yrs/comm.

n_e 

Complex term, so let's break it into two terms:

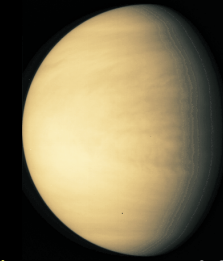
- n_p : number of planets suitable for life per planetary system
- f_s : fraction of stars whose properties are suitable for life to develop on one of its planets

$$n_e = n_p \times f_s$$

<http://mike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg>



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

Question



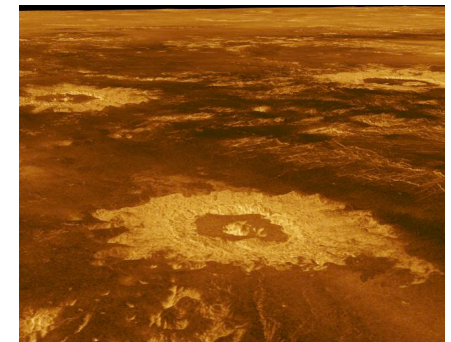
Why is Venus the hottest planet?

- It's the goddess of love.
- Closest to the Sun.
- Greenhouse effect.
- Clouds absorb more sunlight than any other planet.
- Interior is hotter than other planets due to the tidal forces of the Sun.

Impacts on Venus



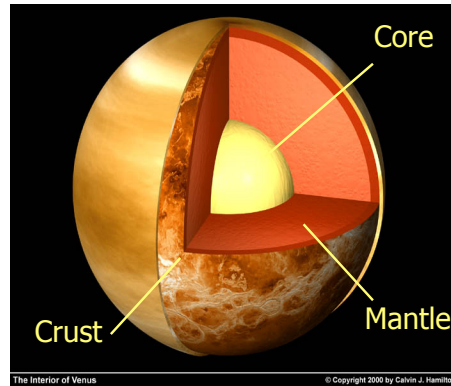
- Venus has about 1,000 craters, often clustered
- No trace of heavy bombardment
- Cratering rate indicates Venus' surface about 500 million yrs old
- Why?
 - Possibility: Extreme temperatures soften rock, making the surface subject to catastrophic volcanic upheaval



Venus' Interior



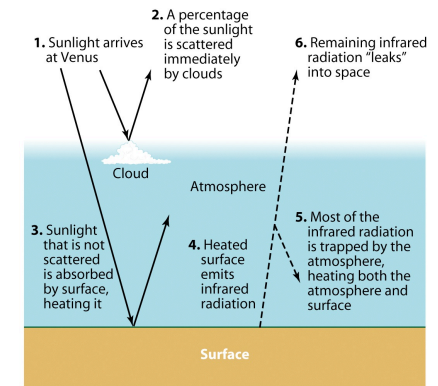
- Venus' size and density are roughly equal to Earth's
 - Indicates iron core of similar size
- No magnetic field
 - Very slow rotation: 243 Earth days



Runaway Greenhouse



- On Earth, greenhouse gasses insulate us
 - Keep Earth 35 K warmer than it would be otherwise
- On Venus, massive amounts of CO₂ 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 O₂ from life, but early Earth was N.
- Earth and Venus have similar amounts of carbon & nitrogen, but...

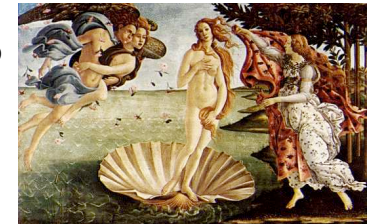


<http://www.digitalart.ab.ca/art/ren/images/birth-of-venus.jpg>

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 H₂O— 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.

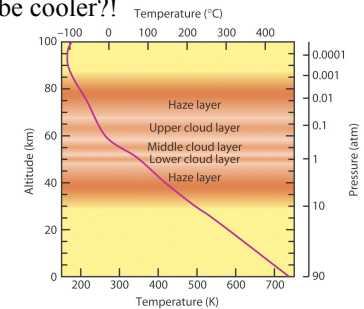


<http://photos1.blogger.com/blogger/4103/1148/1600/Venus%20Wimbledon05.jpg>

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.

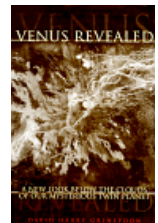


http://www.manson-valley.de/fotogalerie/manson/images/acss/acss_32.jpg

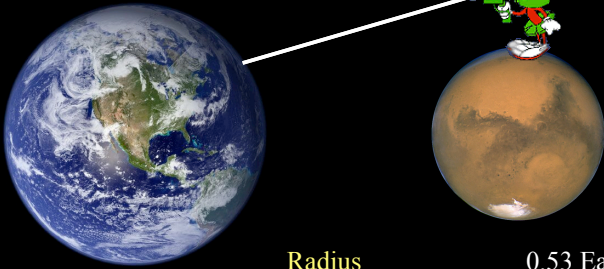
Life on Venus?



- 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



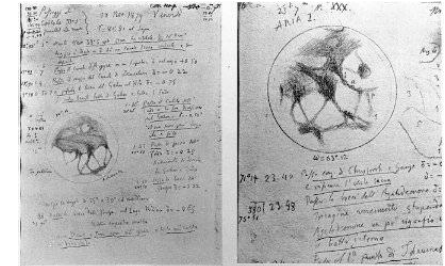
Mars has the Solar System's largest Volcano, Olympus Mons – 27 km tall.

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.



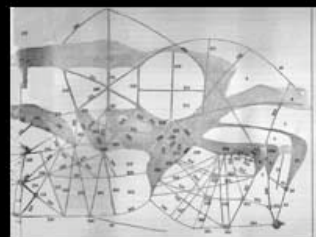
- Was thought to be similar to the Earth in many ways.
- Life was argued to exist on Mars by many astronomers.
- The astronomer Schiaparelli announced that he saw regular linear markings on the surface, which he named canali.
- Technically, in Italian means channels, but it was mistranslated to canals.



Pages from Schiaparelli's observing notebook, 1879

Percival Lowell's Canals

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



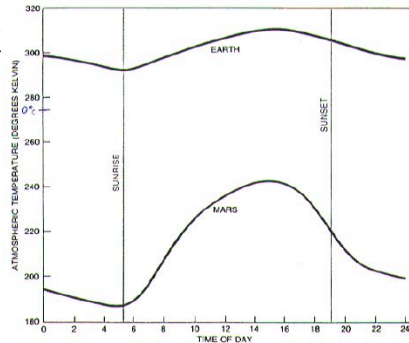
Martian "canals" as mapped by Percival Lowell in the late 1800s.



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



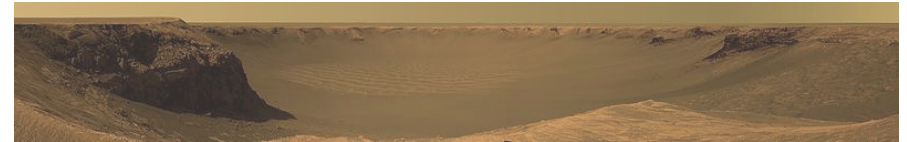
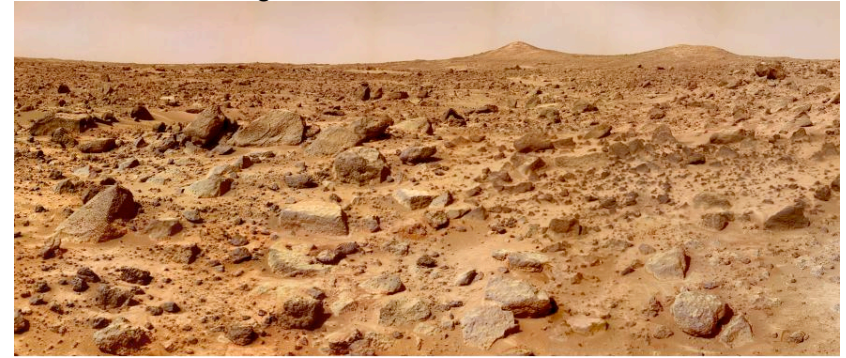
DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the *Viking 1* landing site (color) are qualitatively similar to those at China Lake, Calif., a desert site (black) in both cases the temperature touches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is about three times greater on Mars than it is on the earth. At Viking site range is 55 degrees, from about 187 to 242 degree Kelvin (-16 to -31 degree Celsius). At China Lake range is 18 degrees, from 292 to 310 degree K. (19 to 37 degree C).



The Surface of Mars



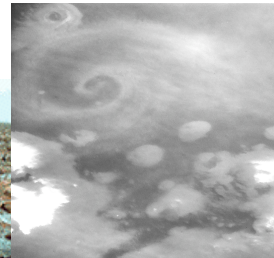
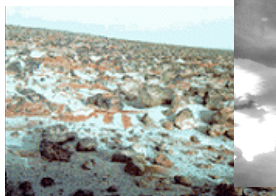
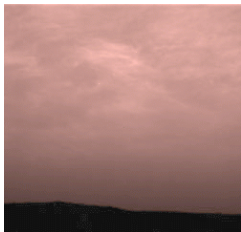
- Mars is a desert!
- Iron oxide in soil gives reddish cast.



Water on Mars



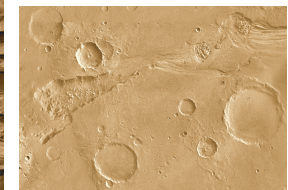
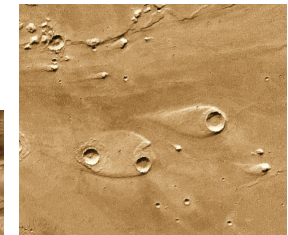
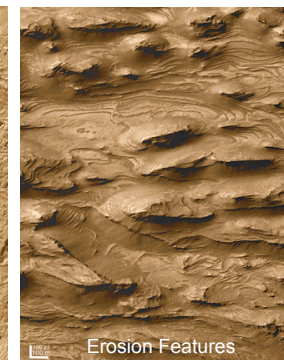
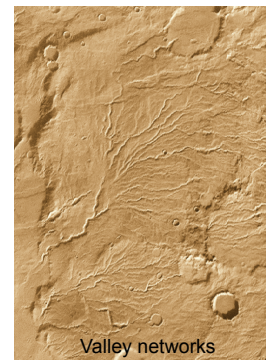
- There **is** water on Mars
 - North and south polar caps (mostly CO₂)
 - Some water vapor in the air
 - Frost on rocks
 - Clouds (ice crystals)
- No *liquid* water now



Liquid water on Mars?

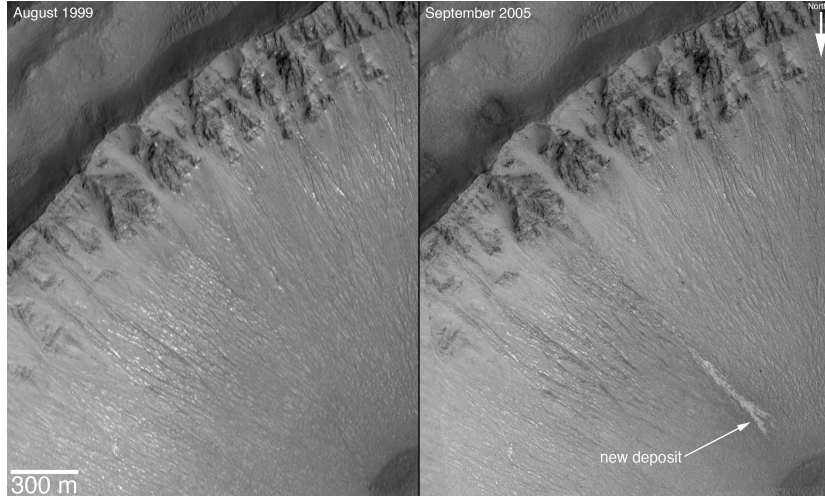


- Water erosion features visible from space
- Atmospheric pressure too low for liquid water to exist
- Perhaps at some point in the past?

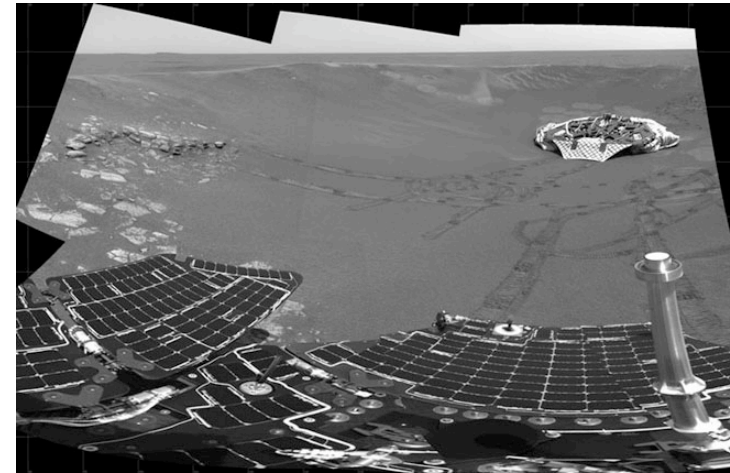


Flood erosion

New Water?



The Surface of Mars: Opportunity



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

Roving on Mars



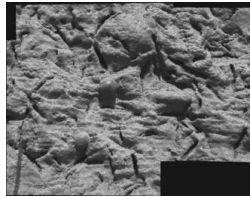
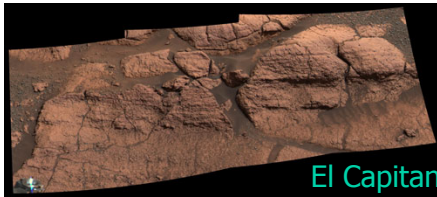
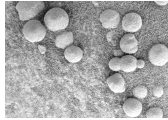
Roving on Mars:
Spirit and Opportunity
find evidence of ancient
liquid water

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

Standing Water on Mars



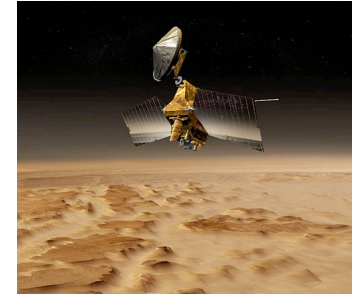
- The new data from the rovers are highly suggestive of ancient standing water on the Meridiani Planum.
- 3 pieces of evidence:
 - Physical appearance of rocks
 - Rocks with niches where crystals appear to have grown
 - Rocks with sulfates left after the water evaporated
- Is it a former sea floor or just an area that had ground-water?



Mars Missions Now



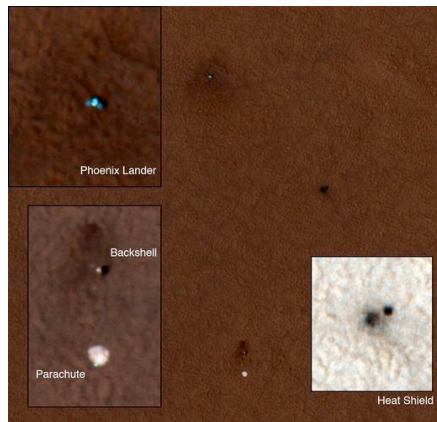
- Mars Reconnaissance Orbiter
 - Studying the geology and climate of Mars
 - Look for ancient sea shores
 - Survey potential landing sites



Mars Missions Now



- Phoenix
 - Analyze water ice at Mars' north pole

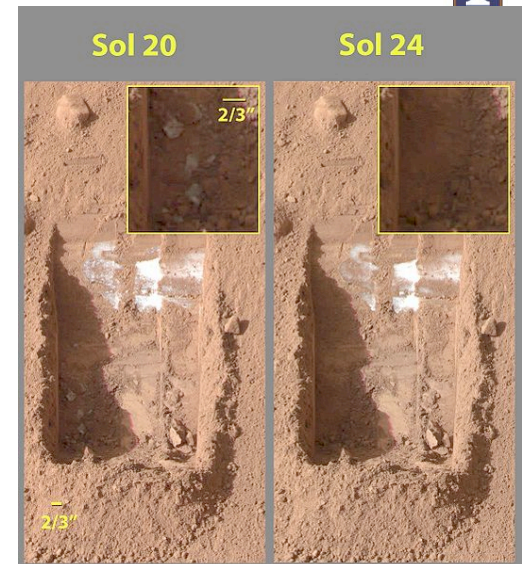


http://www.nasa.gov/mission_pages/phoenix/images/press/PSP_008591_2485_RGB_Lander_Inserts.html

Mars Missions Now



- Phoenix
 - Confirmed water ice on the surface of Mars
 - Sublimates too slowly for dry ice (CO₂)



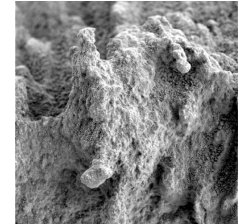
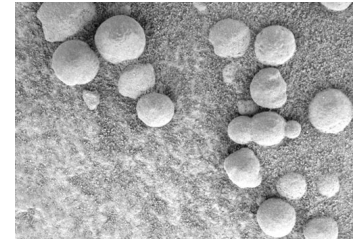
Mars' Watery Past



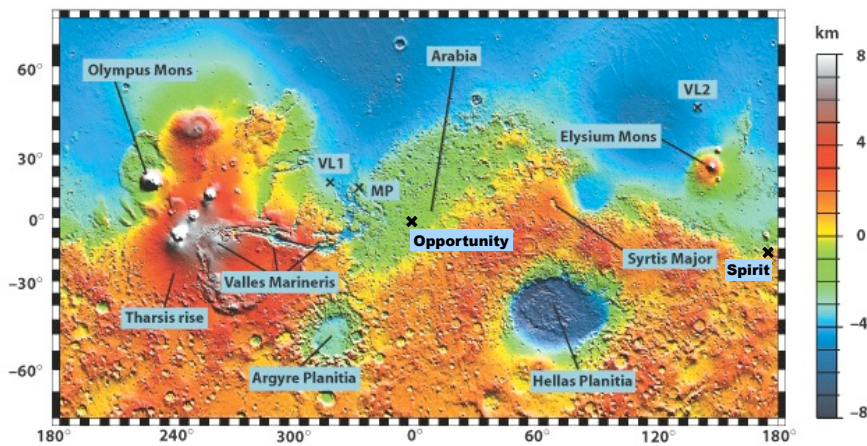
What Happened to the Water?



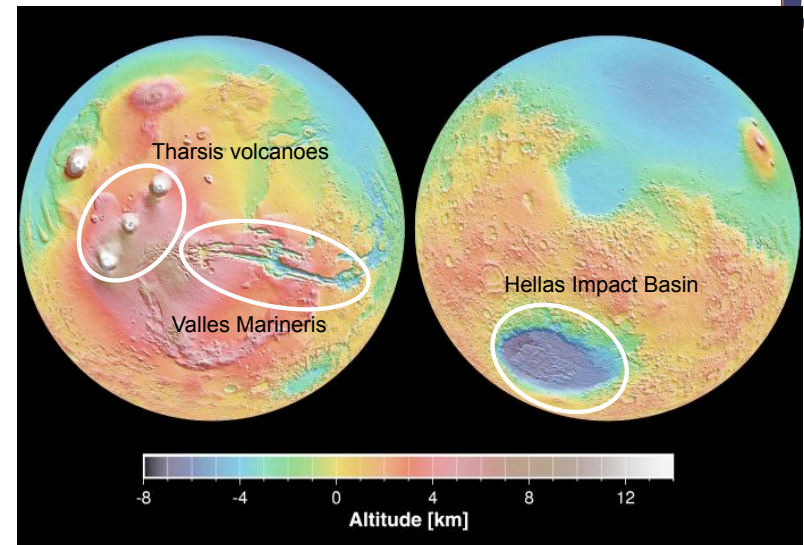
- That is the big question
 - Quite a lot of evidence for water now and in the past.
 - Did the surface water escape to space with the air?
 - How much is still frozen beneath the surface?



The Geology of Mars



The Surface of Mars

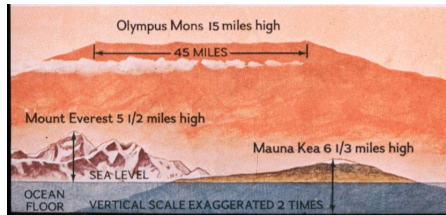
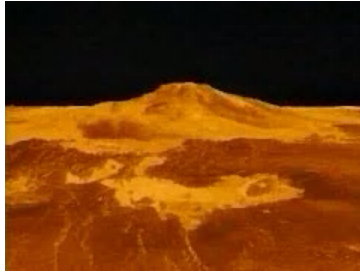


Mars Global Surveyor

Olympus Mons



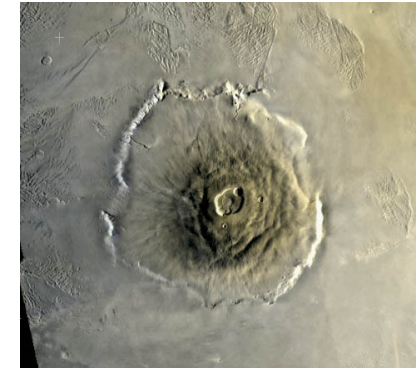
- The largest mountain in the Solar System rising 26 km high
- A shield volcano, like Hawaii on Earth
- Its caldera is 90 km across



Olympus Mons



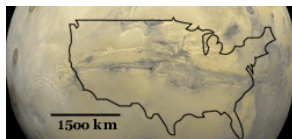
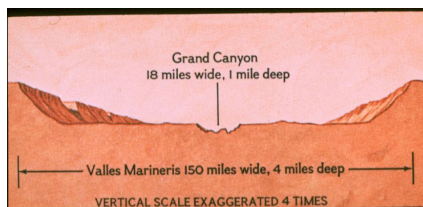
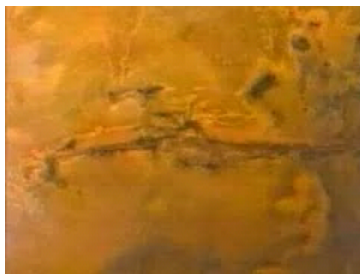
- Its base is more than 500 km in diameter
- As long as the entire Hawaiian island chain
- Rimmed by a 6 km high cliff
- Last erupted 25 million years ago
- Probably so big, due to lack of plate tectonics



Valles Marineris



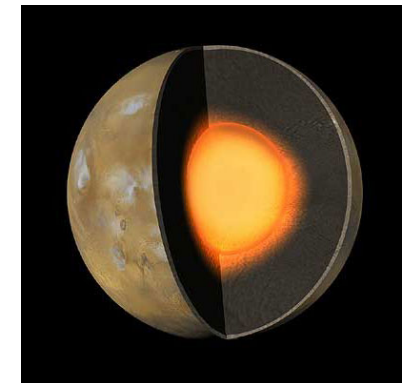
- A series of fault canyons
- 5000 km long
 - As big as the U.S.!
- A giant crack in the crust of Mars
 - Formed as the planet cooled
 - Expanded by water flow



Mars' Interior



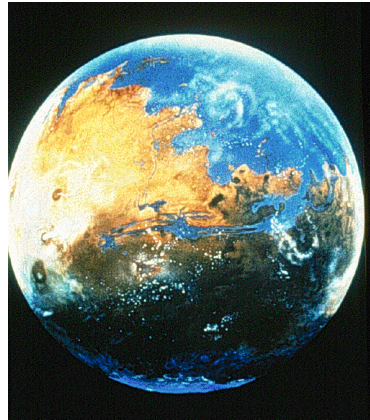
- Like Earth, Mars has an iron core
 - About half of the planet's radius in size
 - Heavily contaminated with sulfur
 - Weak magnetic field suggests a thin layer of liquid iron, mostly solid



Mars' Past



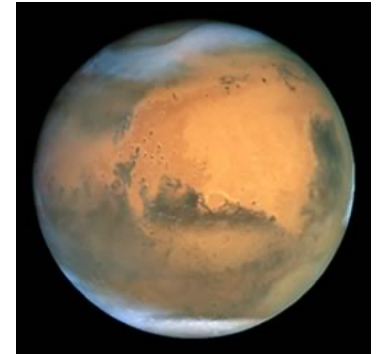
- Early in Mars' history it was likely more Earth-like
 - Geologically active
 - Volcanic eruptions created a thick carbon dioxide, nitrogen atmosphere
 - Greenhouse effect made it warm enough for liquid water
 - Oceans? Rivers? Glaciers by the poles?
 - Life?



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?



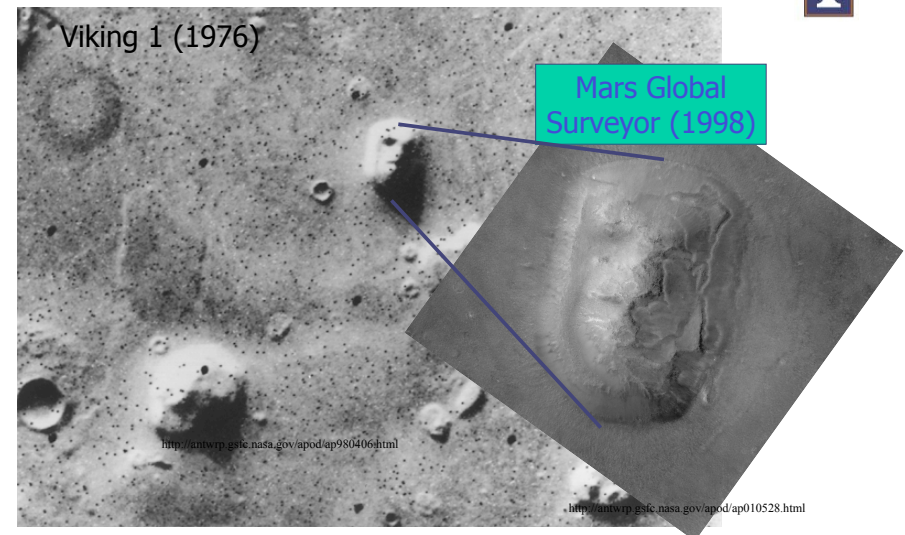
Question



We know for sure that

- Mars used to have liquid water on the surface.
- Mars has life.
- The people of Mars need soap.
- The atmosphere of Mars is gone.
- Mars has life under the surface.

The “Face” of Mars?



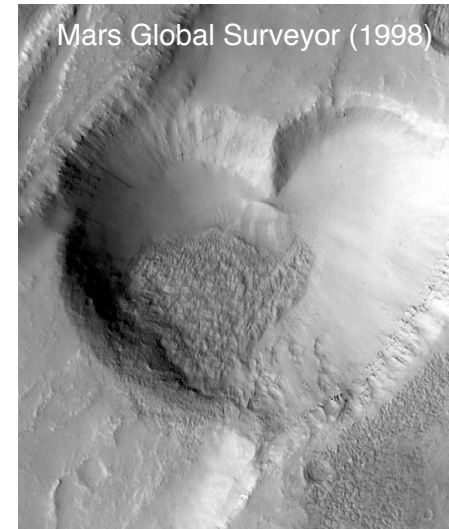
Other Faces



Mars Global Surveyor (1998)

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

Other Places



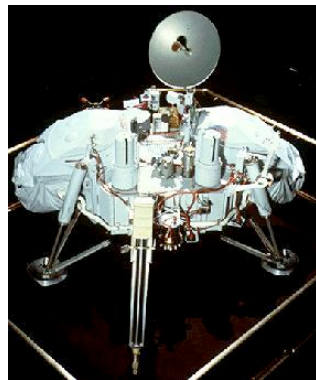
Mars Global Surveyor (1998)

<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.
- Dirk Schulze-Makuch suggested that Mars might harbor peroxide-based life forms which the landers could not detect



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



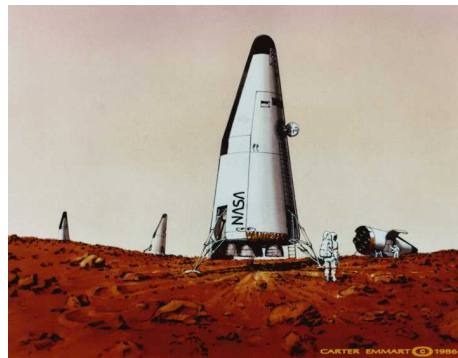
- Mars' moons
- Likely captured asteroids
- Very small
 - About 15-25 km in size
 - Shaped like potatoes



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



Question



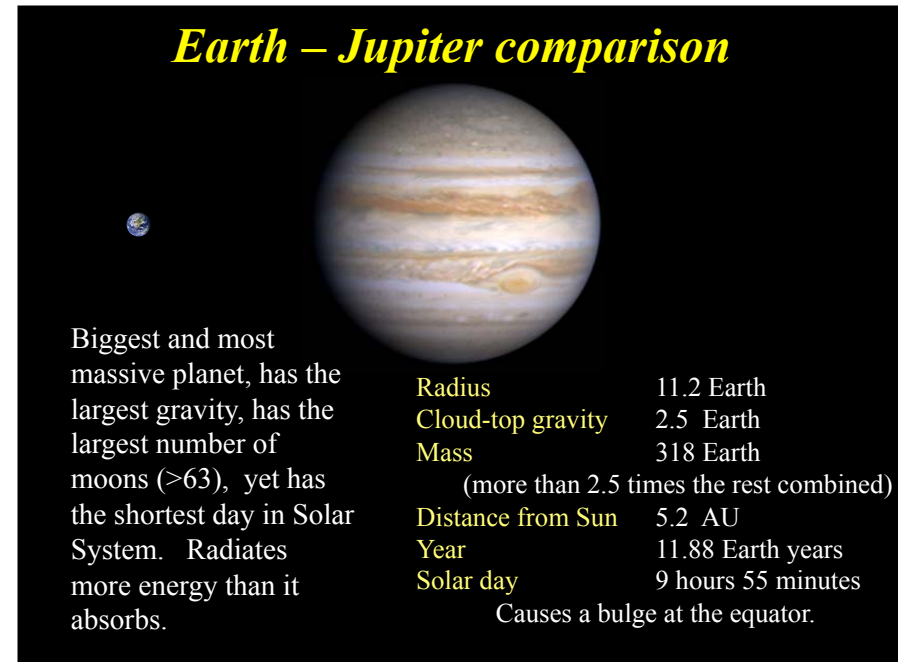
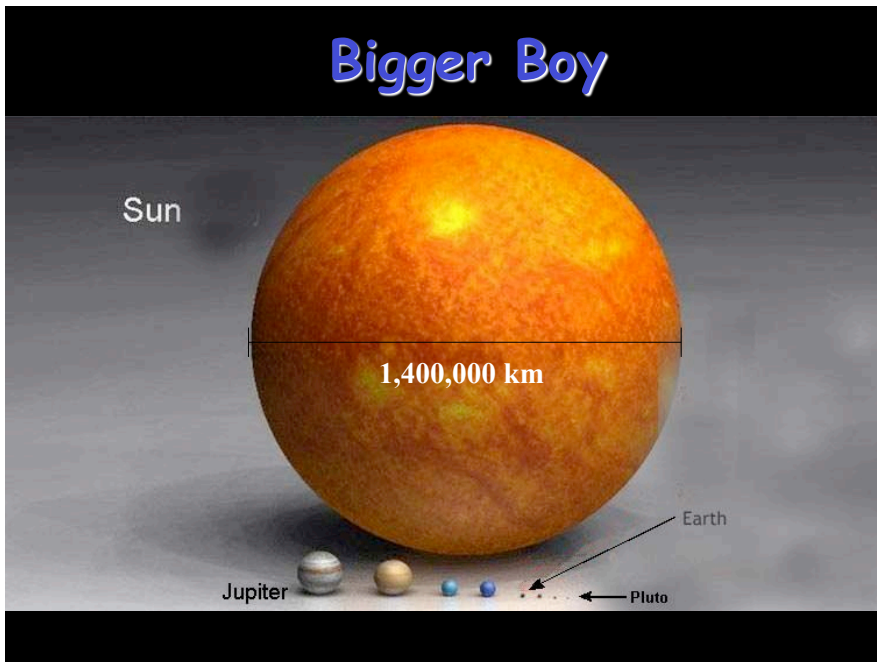
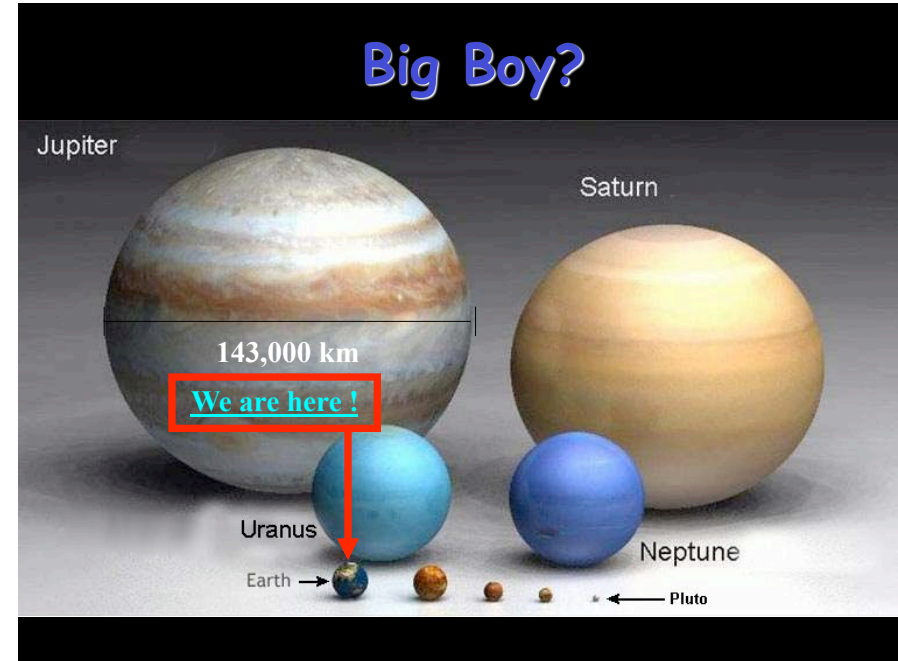
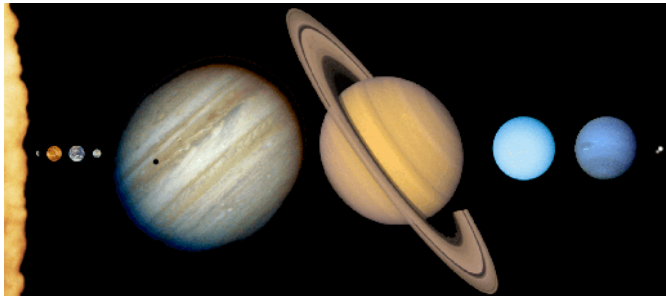
The face on Mars

- a) was a huge NASA cover-up.
- b) might have been created by Martians or ETs, but we'll never know for sure.
- c) was an optical illusion, like cloud shapes.
- d) will be the major focus of any follow-up rover missions.
- e) was really a statue that had fallen over.

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 now focus on Jupiter, Io, Europa, and Titan.



Jupiter, King of the Planets

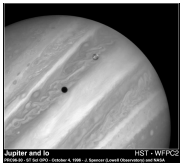
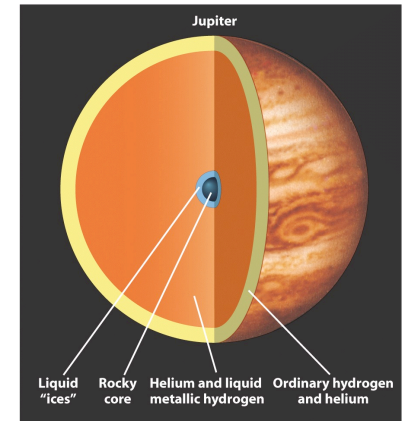


- Named for the king of the Roman gods
- A truly immense planet
 - Over 11 times the diameter of Earth
 - Over 300 times the mass of Earth
 - Over twice the mass of all the other planets combined!
 - Has over 63 moons, its own mini-solar system!
- Visited by 4 spacecraft
 - Pioneer 11 - Flyby in 1979
 - Voyagers 1 & 2 - Flybys in 1980 & 1981
 - Galileo - Went into orbit and dropped a probe into Jupiter's atmosphere, 1990-2003

Jupiter's Interior



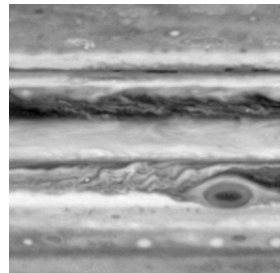
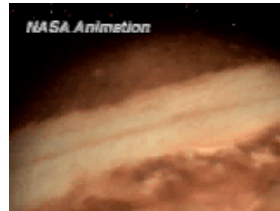
- Average density only 30% greater than water
- 25% that of the Earth's average density
- By 20,000 km, the pressure is 3 million times that on the Earth's surface!
 - Hydrogen becomes a liquid metal
- Core of rock & "ice" 10-12 Earth masses



Jupiter's 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.



Driving Jupiter's Weather



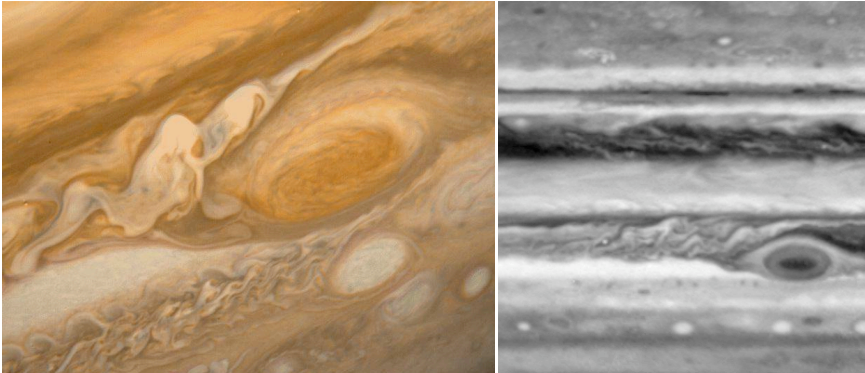
- On Earth, solar heating drives weather
- On Jupiter, internal heat drives weather
 - Winds maintain speeds to great depths
 - Jupiter radiates 70% more heat than it receives from the Sun
 - The heat is from Jupiter contracting under its own powerful gravity
 - As it contracts, the gas is squeezed,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



The Great Red Spot



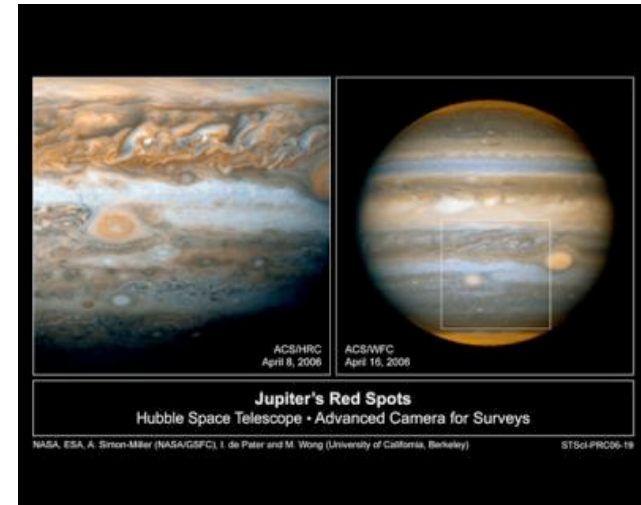
- A huge storm 25,000 km across – twice size of the Earth!
- First observed > 300 years ago!



Voyager 1 image

Cassini images

Little Red Spot



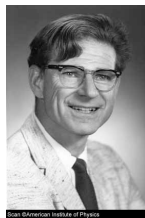
Life?



- 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



Edwin Salpeter, Institute of Physics

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.

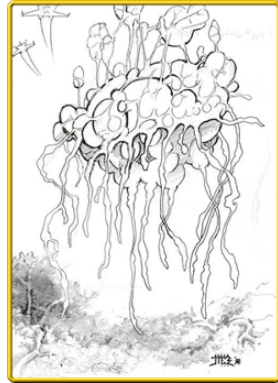


<http://www.wackerbaits.com/sf/media/bellsinker.jpg>
<http://www.mantapacific.org/mantapacific/information/images/plankton.jpg>

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.

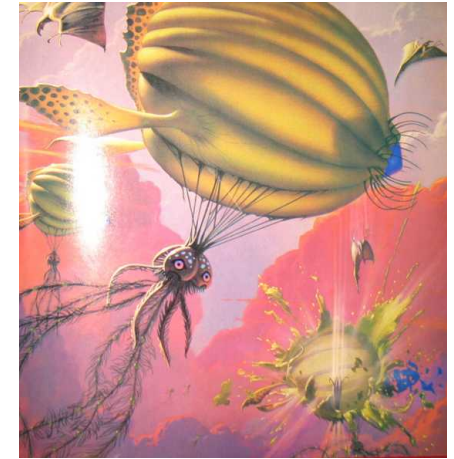


<http://www.firaxis.com/smac/nativelife.cfm>

Floating Life

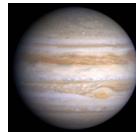


- They could be huge creatures, as large as 1 to 2 km in diameter.
- Maybe similar to whales – mixture between jellyfish and birds?
- Big bags of hydrogen gas.



<http://img.photobucket.com/albums/v154/superminymo/National%20Geographic%20Picture%20Atlas%20of%20Our%20Universe/Pg4JupiterPic.jpg>

Floating Life



- 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 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

