

Astronomy 330



This class (Lecture 12):

Life in the Solar System

Next Class:

Life in the Solar System

HW 5 is due Wednesday

Music: *We Are All Made of Stars*— Moby

Presentations



- **Daniel Borup**
[Futurama](#)

HW 2



- **Stanley Swat**
<http://www.ufohowto.com/>
- **Lucas Guthrie**
<http://www.crystalinks.com/abduction.html>

Outline

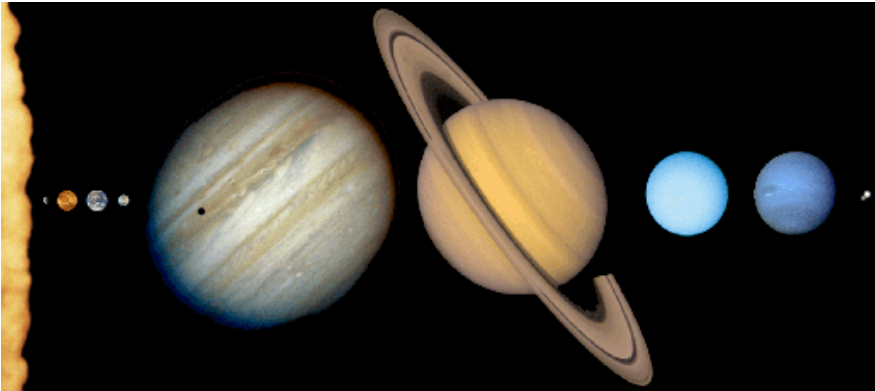


- Life on Venus?
- Life on Mars?

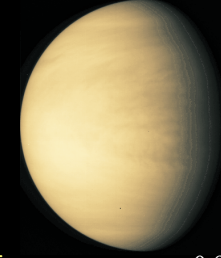
Life in the Solar System?



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



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.

Turns Out that Venus is Hell



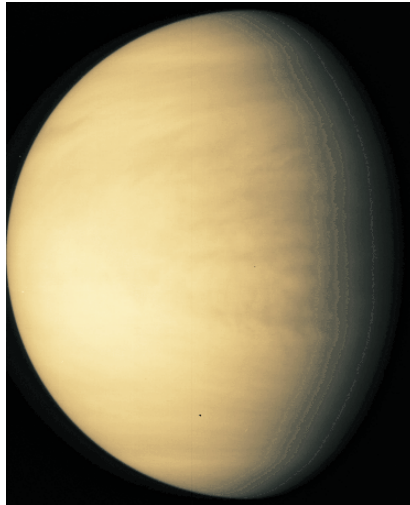
- The surface is hot enough to melt lead
- There is a runaway greenhouse effect
- There is almost no water
- There is sulfuric acid rain
- Not a place to visit for Spring Break.



Our “Twin”



- Always covered in thick clouds of CO₂, 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

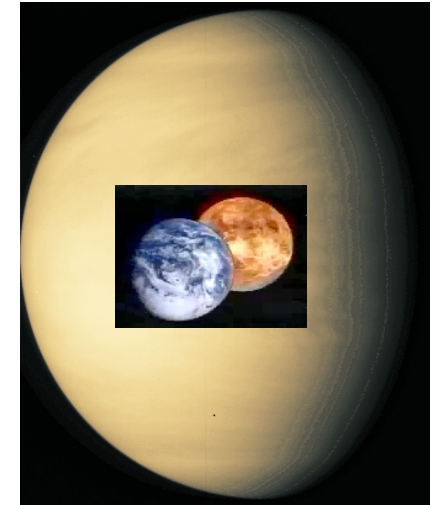


<http://antwpr.gsfc.nasa.gov/apod/ap960923.html>

Our “Twin”



- Often called the morning star or the evening star. 3rd brightest object in the sky.
- Often mistaken for a UFO.
- Retrograde rotation – Sun rises in west
- No moons, no magnetic field



<http://antwpr.gsfc.nasa.gov/apod/ap960923.html>

Soviet Satellites on Venus



Color as seen on the surface of Venus

Venera 13

Color with atmospheric effects removed



USSR Academy of Sciences / Brown University

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

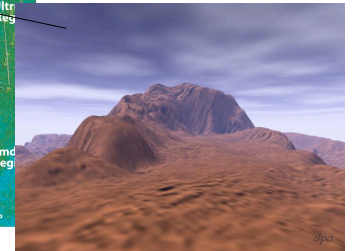
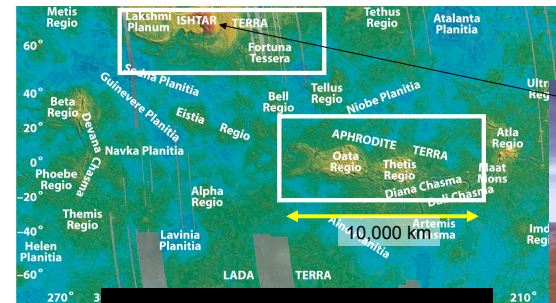


Surface of Venus: Radar



<http://www.solarviews.com/cap/venus/vidven1.htm>

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>

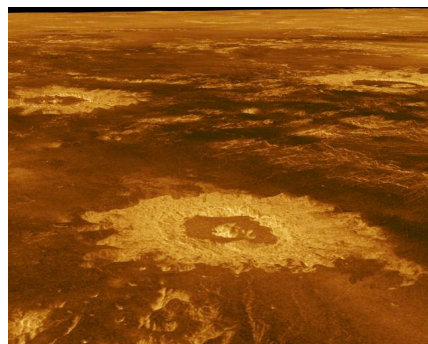
Images of Venus

from radar data collected by the
NASA Magellan Spacecraft

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?

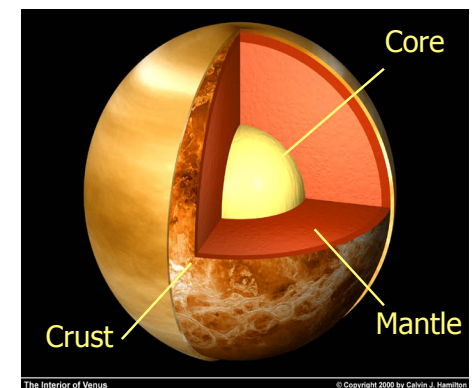


- Possibility: Extreme temperatures soften rock, making the surface subject to catastrophic volcanic upheaval

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



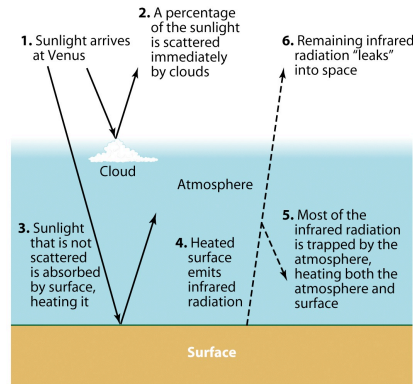
The Interior of Venus

© Copyright 2000 by Calvin J. Hamilton

Runaway Greenhouse



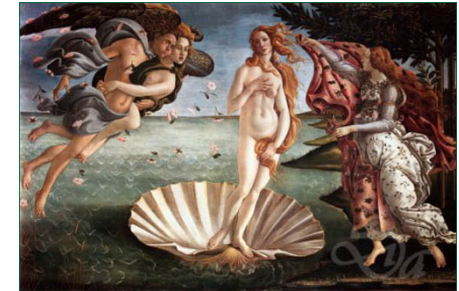
- On Earth, greenhouse gasses insulate us
 - Keep Earth 35 K warmer than it would be otherwise
- On Venus, massive amounts of CO₂ keep it incredibly hot
 - Almost 300 K warmer!
 - The hottest planet in the Solar System



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...

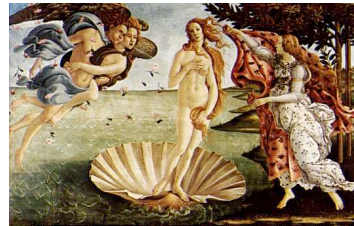


<http://www.digitalart.ab.ca/art/ren/images/birth-of-venus.jpg>

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.

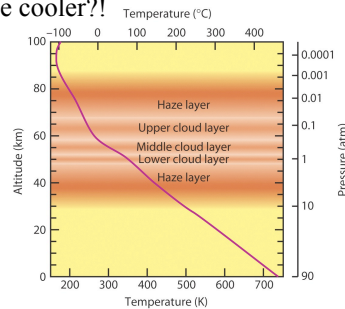


<http://photos1.blogger.com/blogger/4103/1148/1600/Venus%20Wimbledon05.jpg>

Life on Venus?



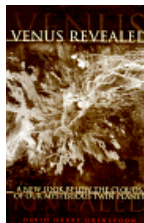
- Surface is far too hot
 - If lead is liquid, think of what heat would do to complex organic polymers
 - No cooler polar regions exist
 - Heat is uniform!
 - But, high in the clouds it should be cooler?!
- Maybe life can still exist in the clouds?
- At 50 km up, the temperature is not too hot and the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



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?



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

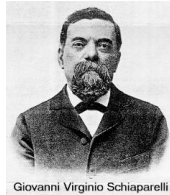
Earth – Mars comparison

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%

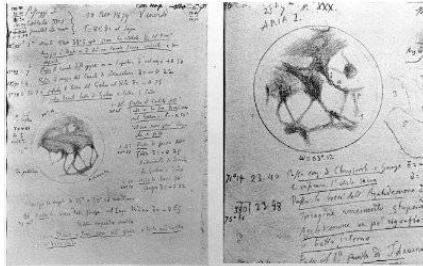
Mars has the Solar System's largest Volcano, Olympus Mons – 27 km tall.

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.



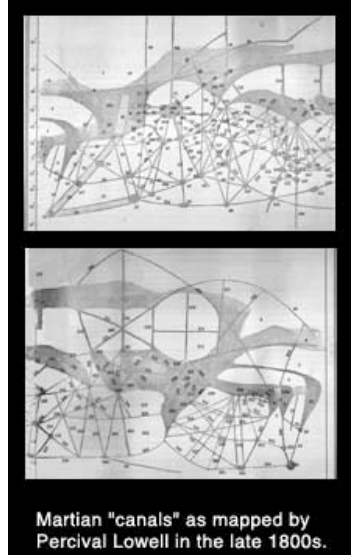
Giovanni Virginio Schiaparelli



Pages from Schiaparelli's observing notebook, 1879

Percival Lowell's Canals

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

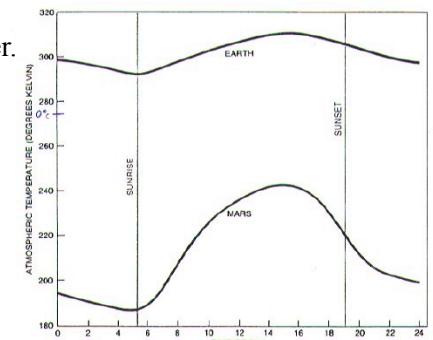


Martian "canals" as mapped by Percival Lowell in the late 1800s.



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

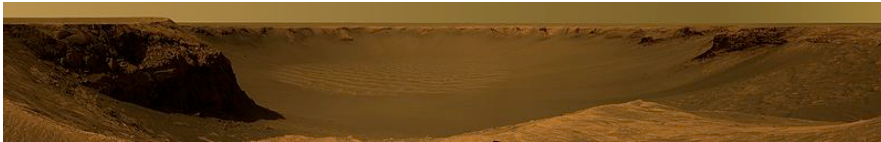
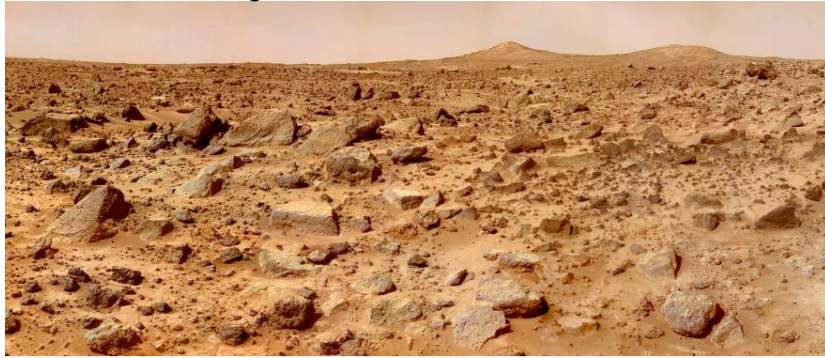


DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the Viking 1 landing site (color) are qualitatively similar to those at China Lake, Calif., a desert site (black). In both cases the temperature touches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is about 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 (–16 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



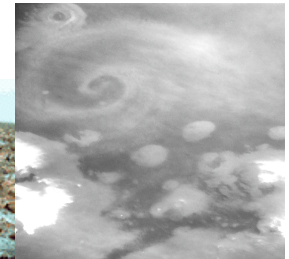
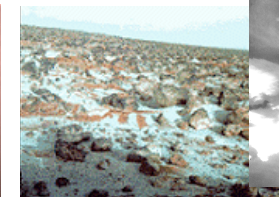
- Mars is a desert!
- Iron oxide in soil gives reddish cast.



Water on Mars



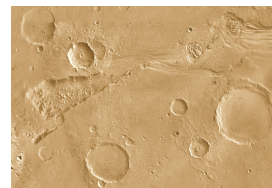
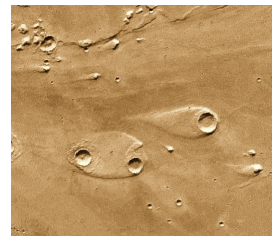
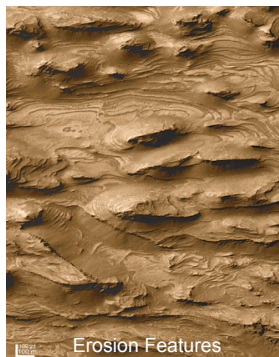
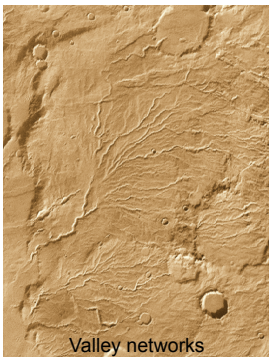
- There **is** water on Mars
 - North and south polar caps (mostly CO₂)
 - Some water vapor in the air
 - Frost on rocks
 - Clouds (ice crystals)
- No *liquid* water now



Liquid water on Mars?

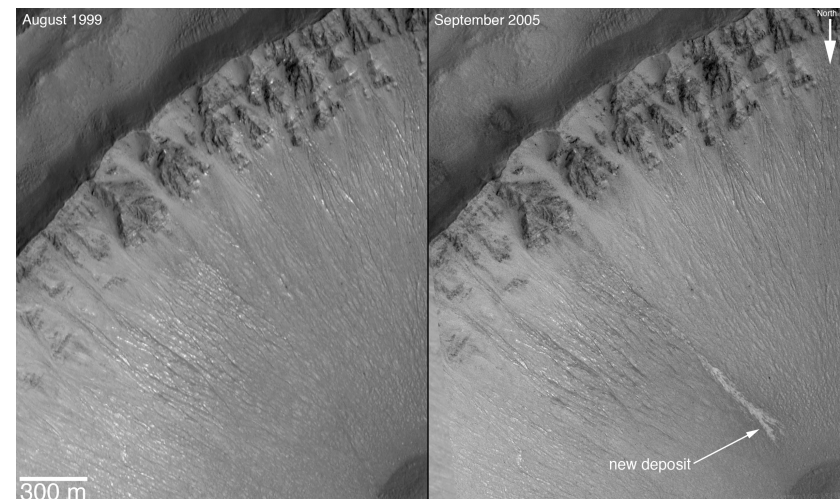


- Water erosion features visible from space
- Atmospheric pressure too low for liquid water to exist
- Perhaps at some point in the past?

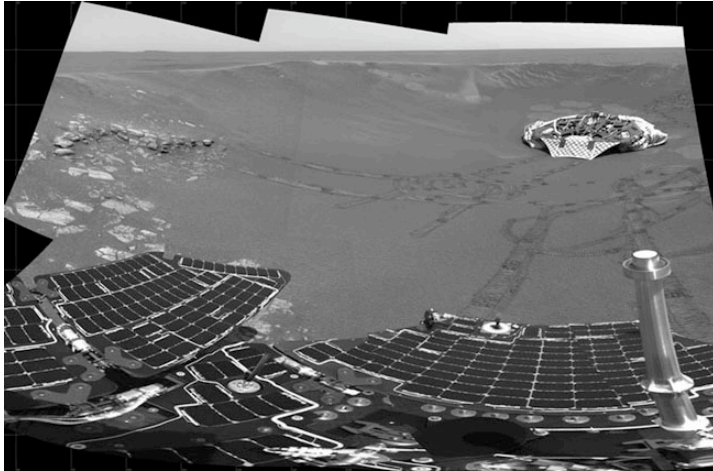


Flood erosion

New Water?

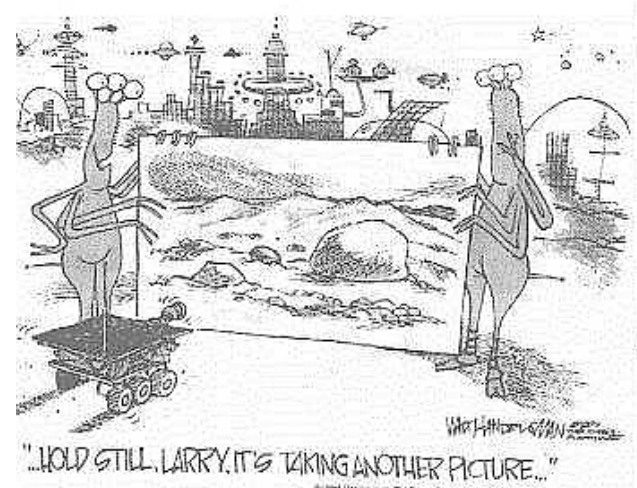


The Surface of Mars: Opportunity



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

Roving on Mars



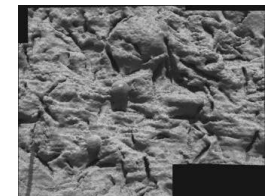
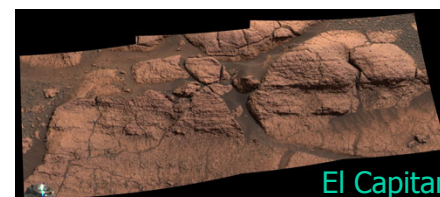
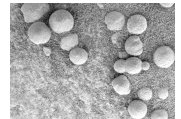
Roving on Mars: Spirit and Opportunity find evidence of ancient liquid water

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

Standing Water on Mars



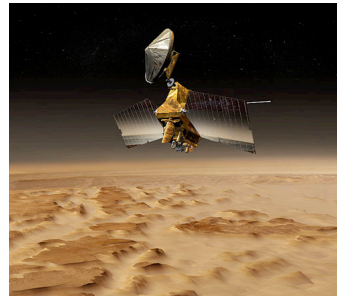
- The new data from the rovers are highly suggestive of ancient standing water on the Meridiani Planum.
- 3 pieces of evidence:
 - Physical appearance of rocks
 - Rocks with niches where crystals appear to have grown
 - Rocks with sulfates left after the water evaporated
- Is it a former sea floor or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



Mars Missions Now



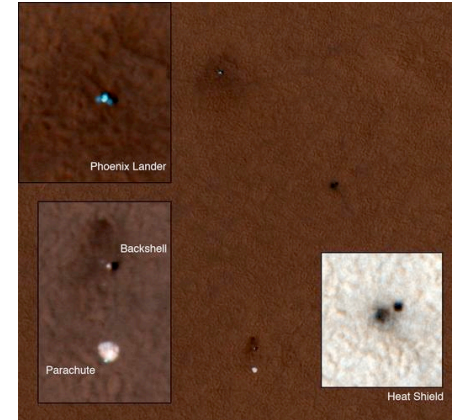
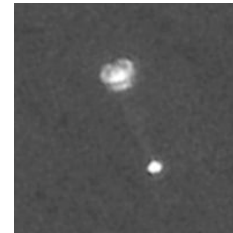
- Mars Reconnaissance Orbiter
 - Studying the geology and climate of Mars
 - Look for ancient sea shores
 - Survey potential landing sites



Mars Missions Now



- Phoenix
 - Analyze water ice at Mars' north pole

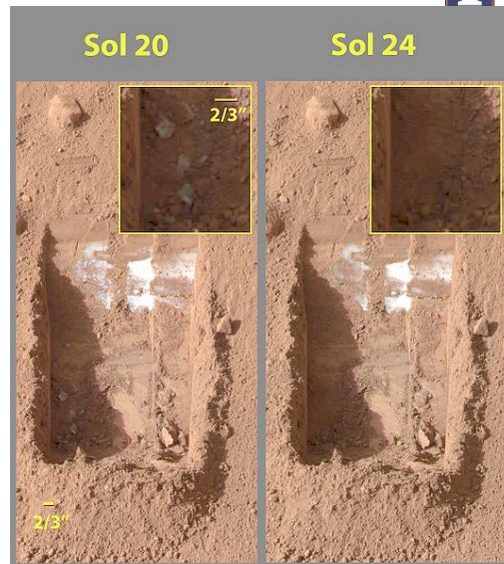


http://www.nasa.gov/mission_pages/phoenix/images/press/PSP_008591_2485_RGB_Lander_Inserts.html

Mars Missions Now



- Phoenix
 - Confirmed water ice on the surface of Mars
 - Sublimates too slowly for dry ice (CO_2)



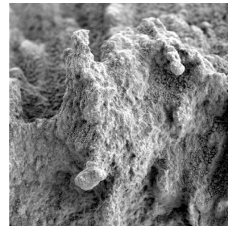
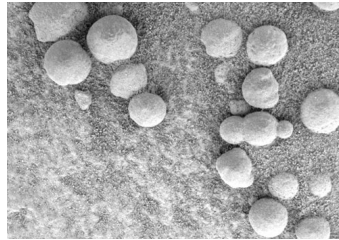
Mars' Watery Past



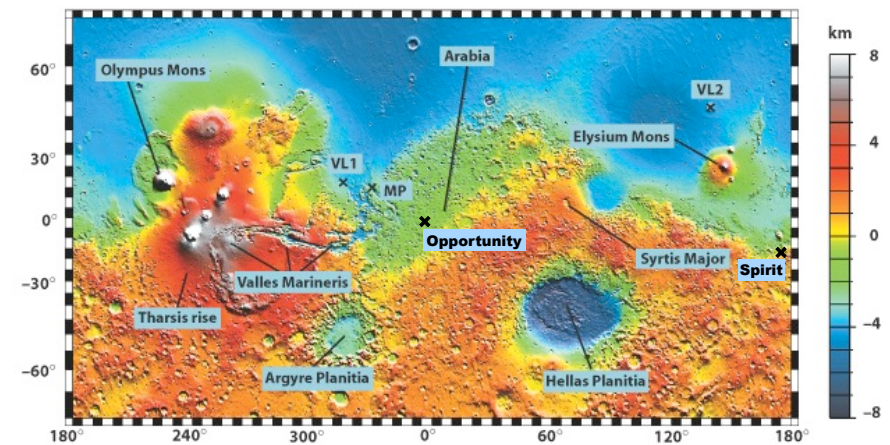
Image Courtesy of Kees Veenbos

What Happened to the Water?

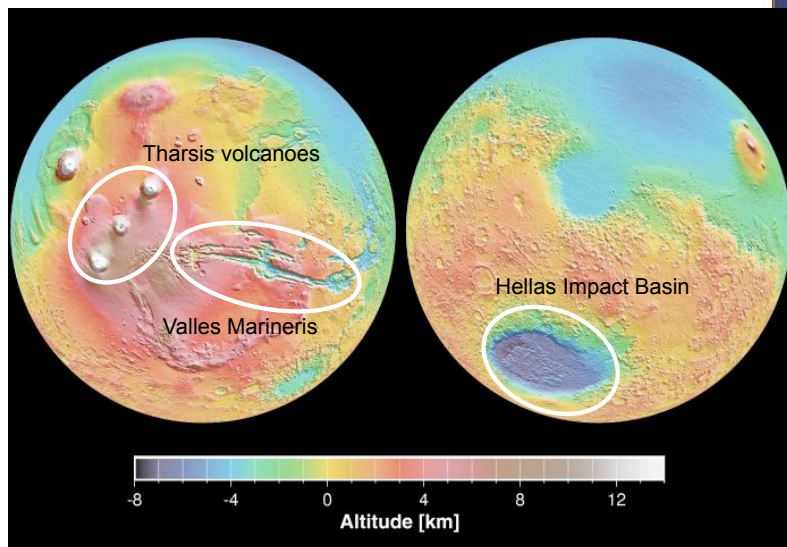
- That is the big question
 - Quite a lot of evidence for water now and in the past.
 - Did the surface water escape to space with the air?
 - How much is still frozen beneath the surface?



The Geology of Mars



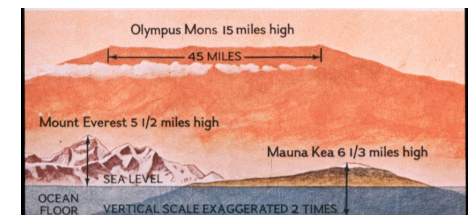
The Surface of Mars



Mars Global Surveyor

Olympus Mons

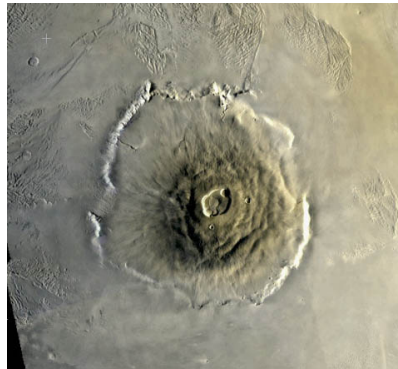
- The largest mountain in the Solar System rising 26 km high
- A shield volcano, like Hawaii on Earth
- Its caldera is 90 km across



Olympus Mons



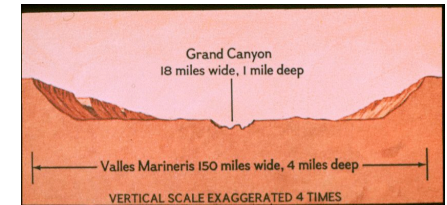
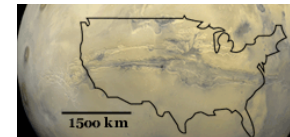
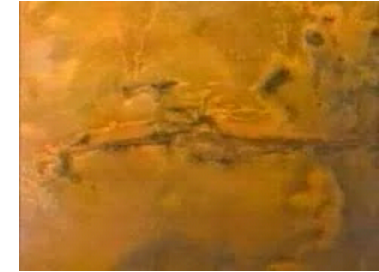
- Its base is more than 500 km in diameter
- As long as the entire Hawaiian island chain
- Rimmed by a 6 km high cliff
- Last erupted 25 million years ago
- Probably so big, due to lack of plate tectonics



Valles Marineris



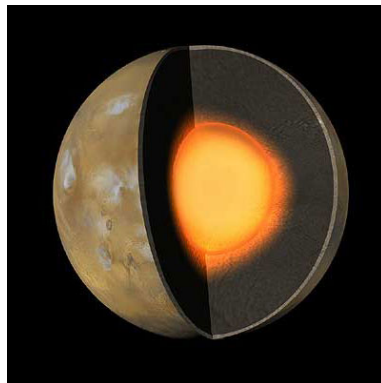
- A series of fault canyons
- 5000 km long
 - A big as the U.S.!
- A giant crack in the crust of Mars
 - Formed as the planet cooled
 - Expanded by water flow



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?



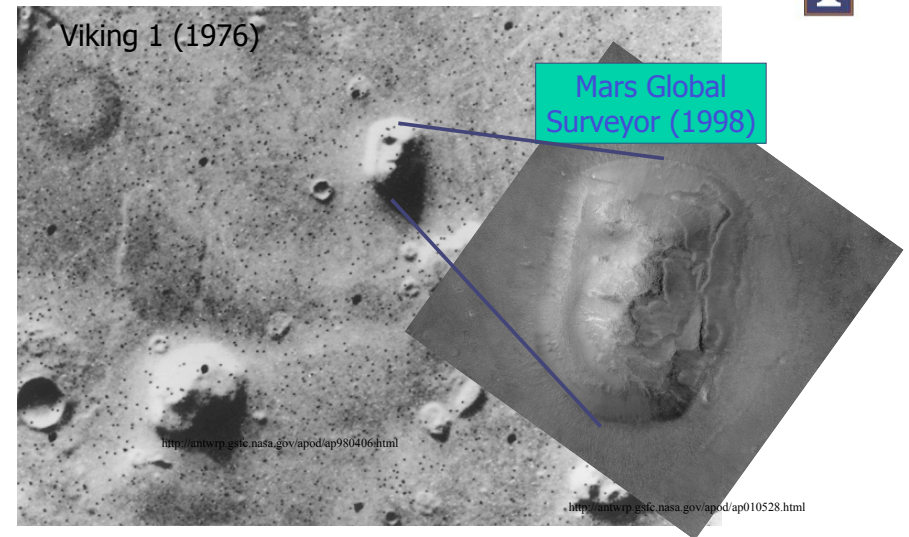
What Happened?



- 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?

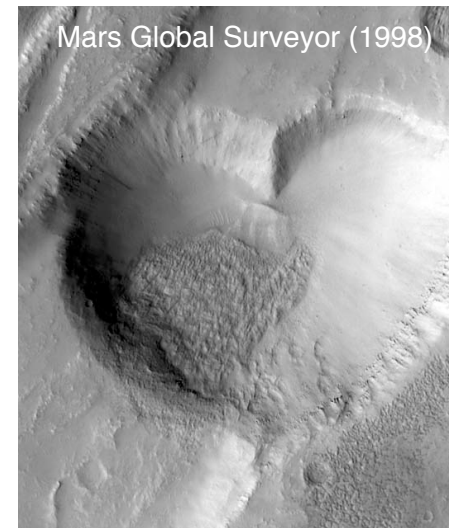


Other Faces



<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.
- 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?



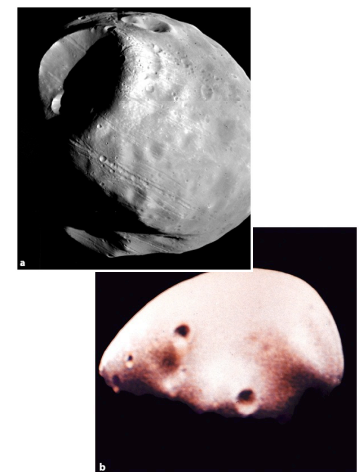
- Microscopic shapes that resemble living and fossil bacteria on Earth—nanobacteria, but much smaller than on Earth.
- Microscopic mineral grains like some produced by living and fossil bacteria on Earth
- Organic chemical compounds that resemble the decay products of bacteria on Earth.
- In the end,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



Phobos & Deimos



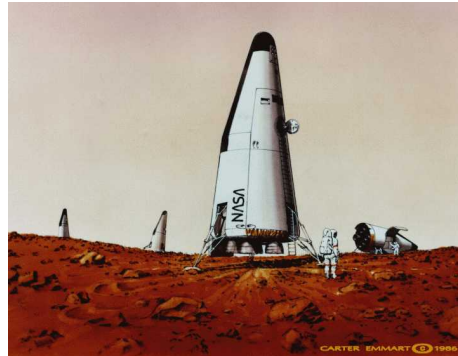
- Mars' moons
- Likely captured asteroids
- Very small
 - About 15-25 km in size
 - Shaped like potatoes



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



We know for sure that

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

Question



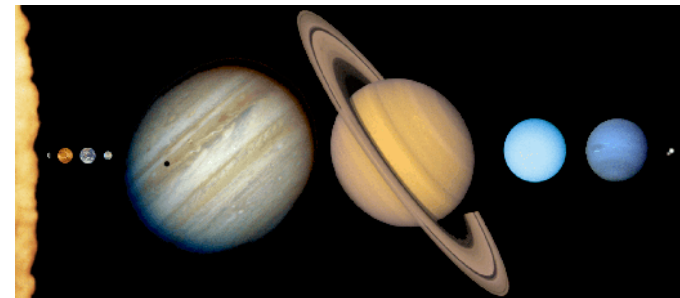
The face on Mars

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

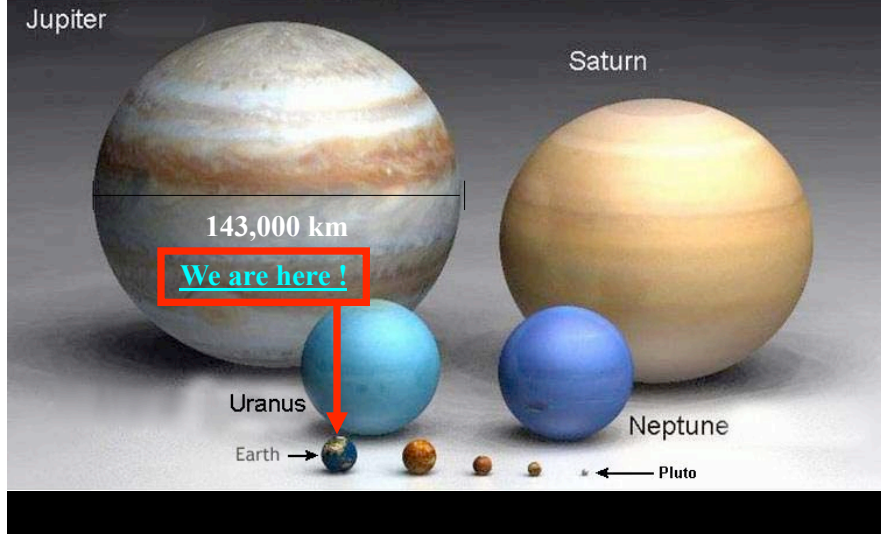
Life in the Solar System



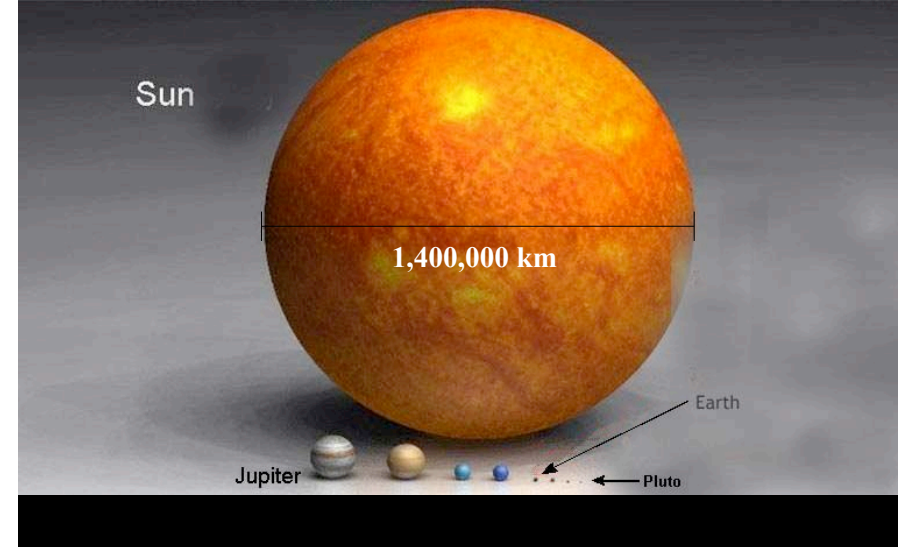
- Venus may have life in the clouds.
- Mars might still have life under the soil.
- But what about the outer solar system?
- It isn't in our definition of the habitable zone, but it still is interesting.
- We will now focus on Jupiter, Io, Europa, and Titan.



Big Boy?



Bigger Boy



Earth – Jupiter comparison



Jupiter, King of the Planets

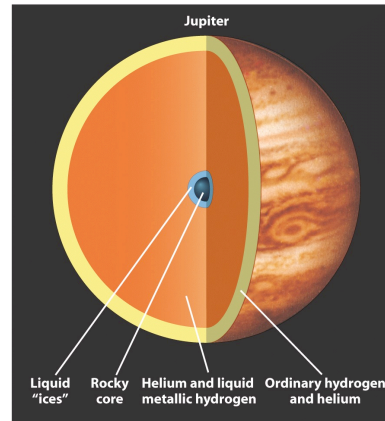


- Named for the king of the Roman gods
- A truly immense planet
 - Over 11 times the diameter of Earth
 - Over 300 times the mass of Earth
 - Over twice the mass of all the other planets combined!
 - Has over 63 moons, its own mini-solar system!
- Visited by 4 spacecraft
 - Pioneer 11 - Flyby in 1979
 - 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



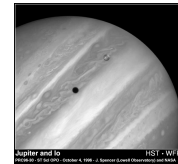
Driving Jupiter's Weather



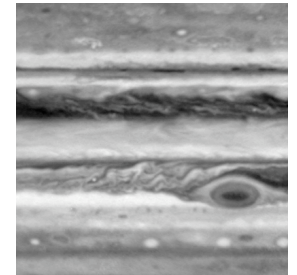
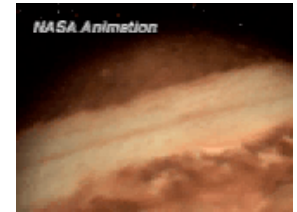
- On Earth, solar heating drives weather
- On Jupiter, internal heat drives weather
 - Winds maintain speeds to great depths
 - Jupiter radiates 70% more heat than it receives from the Sun
 - The heat is from Jupiter contracting under its own powerful gravity
 - As it contracts, the gas is squeezed,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



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.



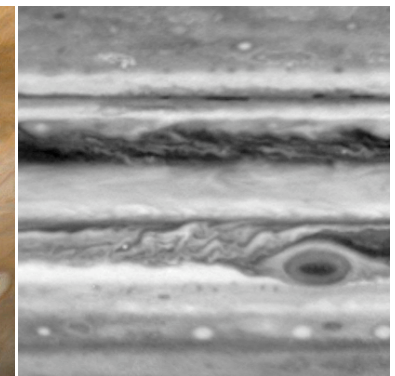
The Great Red Spot



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

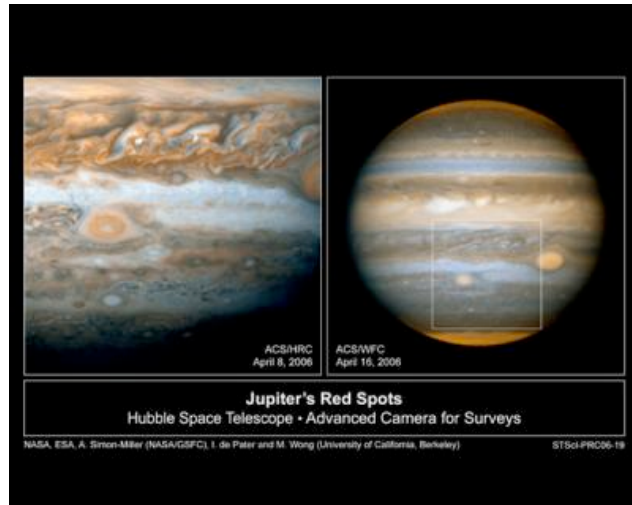


Voyager 1 image



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

Floating Life



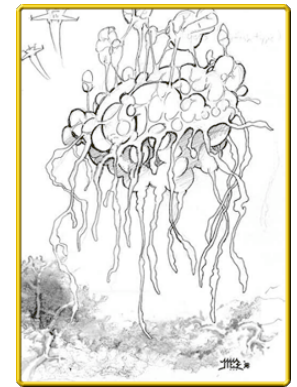
- The problem is that any life in the clouds that sank too far down would be destroyed by the temperature or pressure.
- They proposed a simple life form like oceanic plankton called “sinkers”.
- Small (0.1 cm) life that grew and fell, but then replicated by “splitting-up” and getting circulated back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



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.



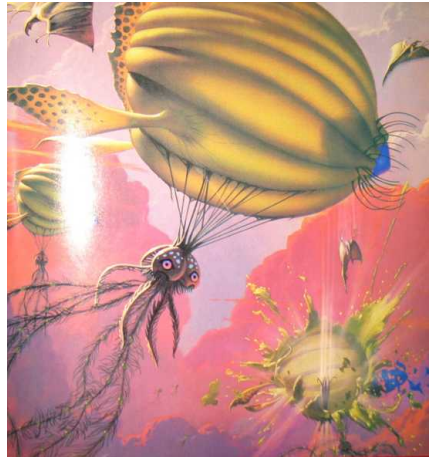
<http://www.wackerbaits.com/sf/media/bellsinker.jpg>
<http://www.mantapacific.org/mantapacific/information/images/plankton.jpg>

<http://www.firaxis.com/smac/native-life.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/superminymc/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.

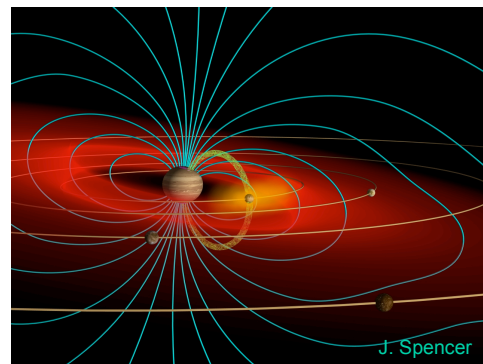


<http://www.epilogue.net/cgi/database/art/list.pl?gallery=3126>

Jupiter's Magnetosphere



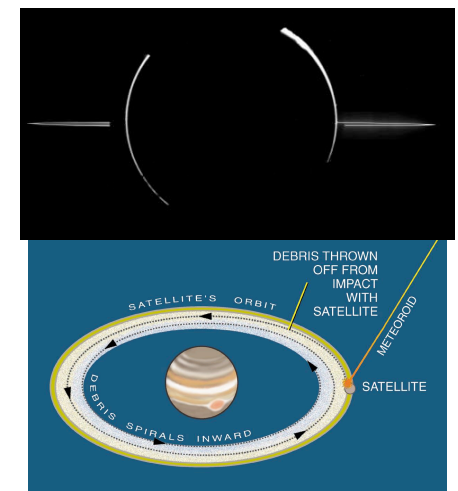
- Liquid metal hydrogen generates a magnetic field
 - 14x stronger than Earth's field
 - Over 4 million km across
- A ring of ionized particles surrounds Jupiter
 - Stripped from Jupiter's moon Io



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



The Galilean Moons



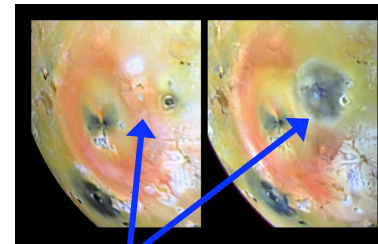
- Io is active.
- Europa is now thought to be the best option for life.
- But, Ganymede and Callisto are contenders perhaps for ancient life.



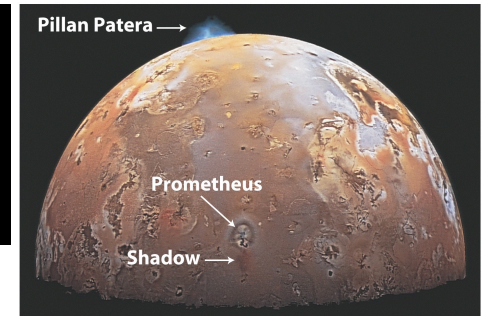
Io



- Innermost Galilean moon – the “pizza moon”
- The most volcanically active body in the solar system.
- Voyager 1 discovered presence of volcanoes
- Internal heating by Jupiter’s tides
- Atmospheric gases ripped off by Jupiter’s magnetic field – ion torus



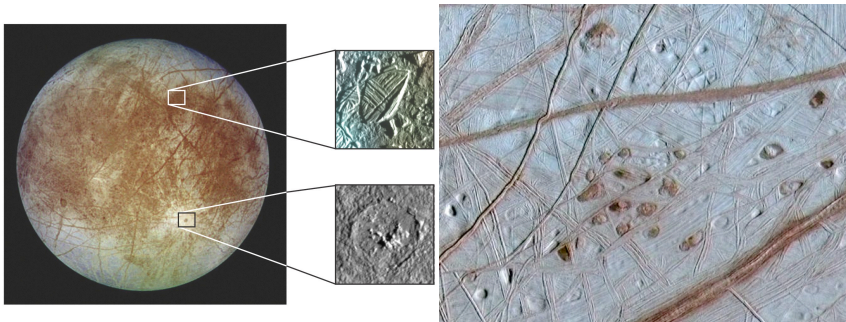
Pillan Patera eruption
Before & after



Europa

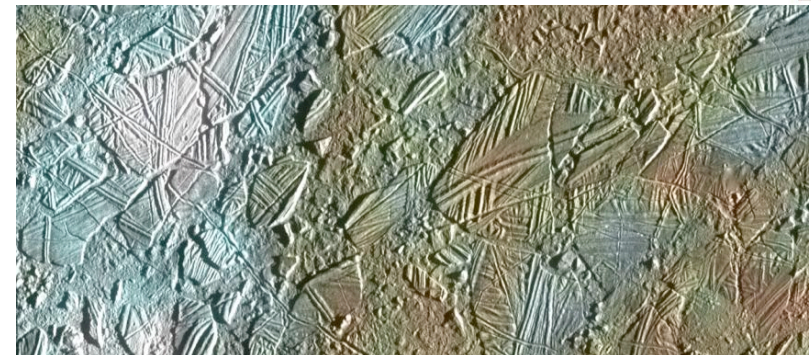


- Slightly smaller than our Moon.
- Icy crust 5 km thick. Can protect life against magnetic fields.
- Evidence for deep (50 km!) liquid water ocean beneath crust—remains liquid from tidal forces from Jupiter
- Cracks and fissures on surface – upwelling?



Galileo

Europa



- Young surface – few craters
- Tidal forces pull and push the ice
 - Like Io, it probably has strong tidal forces.

Europa



- Life would have to be below the surface, around hydrothermal vents.
- Very encouraging, as early life on Earth, might have been formed around such vents.
- We don't know how thick the ice is yet.
- Future missions, will have to employ melting or smash and dive spacecraft.

