

# Astronomy 330



## This class (Lecture 12):

Life in the Solar System  
Dave Dreiser  
Feifei Lian

## Next Class (Thursday):

Life in the Solar System  
Maura Walsh  
Carolyn Buesing

**HW 4 is due tonight**

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

# HW 2



- Daniel Cohen  
<http://www.newscientist.com/article/dn9943-top-10-controversial-pieces-of-evidence-for-extraterrestrial-life.html>
- Katherine Woodruff  
<http://www.abduct.com>

# Presentations



- Dave Dreiser  
[Star Lies](#)
- Feifei Lian  
[Extremophiles](#)

# Outline



- Life on Venus?
- Life on Mars?

## Drake Equation

That's 9.75 planetary systems/year

Frank Drake



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

# 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

15 stars/yr

0.65 systems/star

planets/system

life/planet

intel./life

comm./intel.

yrs/comm.

## 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- exist in the clouds.
  - So, something may be producing them.
- Hardly any carbon monoxide, which should be there.
  - So something may be removing CO.

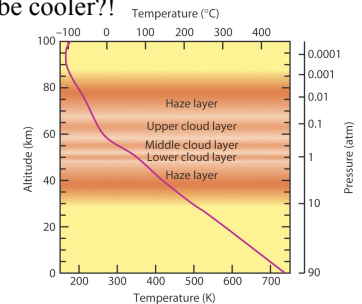


[http://www.manson-valley.de/fotogalerie/manson/images/acss/acss\\_32.jpg](http://www.manson-valley.de/fotogalerie/manson/images/acss/acss_32.jpg)

## Life on Venus?



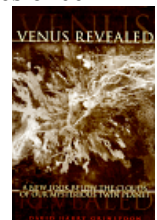
- Surface is far too hot
  - If lead is liquid, think of what heat would do to complex organic polymers
  - No cooler polar regions exist
    - Heat is uniform!
    - But, high in the clouds it should be cooler?!
- Maybe life can still exist in the clouds?
- At 50 km up, the temperature is not too hot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



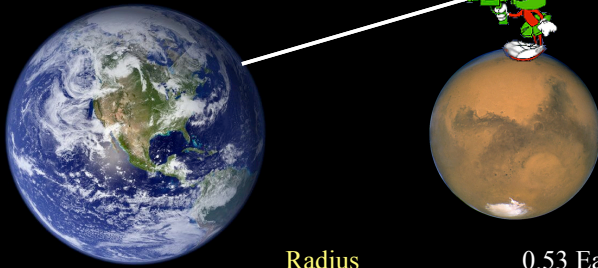
## Life on Venus?



- 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 terrestrial micro-organisms (extremophiles).
- 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

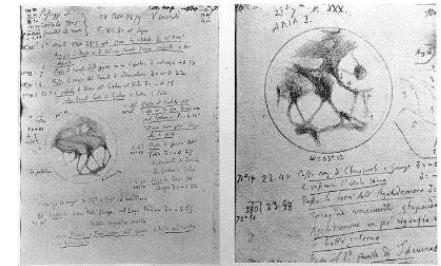


Mars has the Solar System's largest Volcano, Olympus Mons – 27 km tall.

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 <sub>2</sub> 95%

## What we used to think.

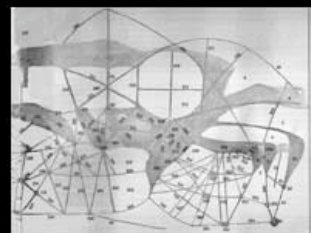
- Similar to the Earth in many ways.
- Life was argued to exist on Mars.
- The astronomer Schiaparelli announced that he saw regular linear markings on the surface, which he named canali.
- Technically, in Italian means channels, but it was mistranslated to canals.



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.

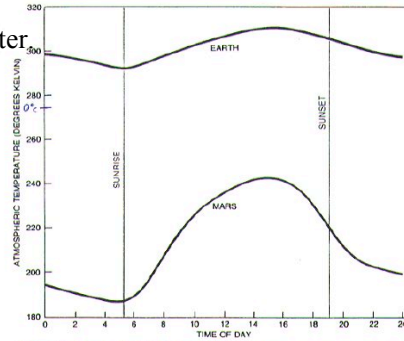
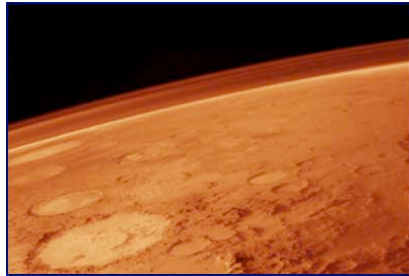




## The Martian Atmosphere



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

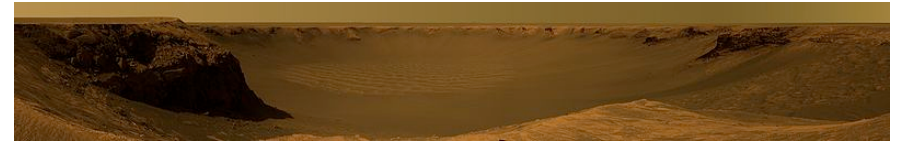


DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the Viking 1 landing site (color) are quantitatively similar to those at China Lake, Calif., a desert site (black). In both cases the temperature touches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is about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



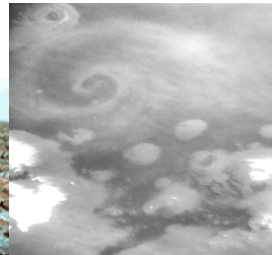
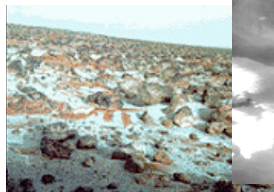
- Mars is a desert!
- Iron oxide in soil gives reddish cast.



## Water on Mars



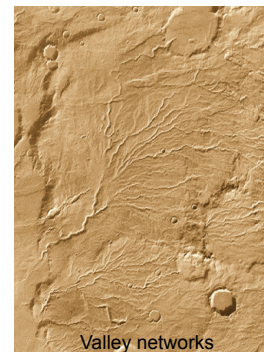
- There **is** water on Mars
  - North and south polar caps (mostly CO<sub>2</sub>)
  - Some water vapor in the air
  - Frost on rocks
  - Clouds (ice crystals)
- No *liquid* water now



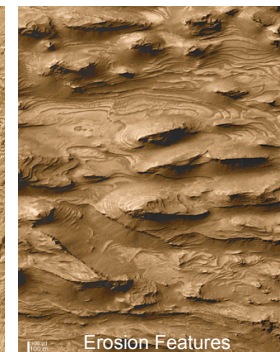
## Liquid water on Mars?



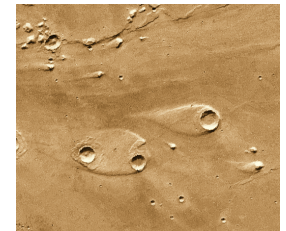
- Water erosion features visible from space
- Atmospheric pressure too low for liquid water to exist
- Perhaps at some point in the past?



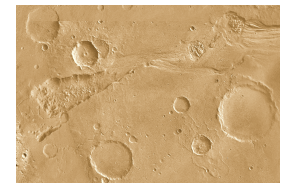
Valley networks



Erosion Features



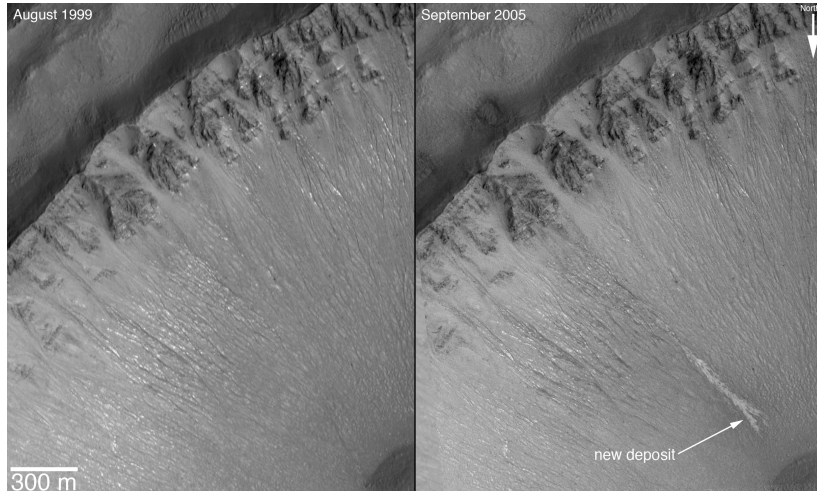
"Islands"



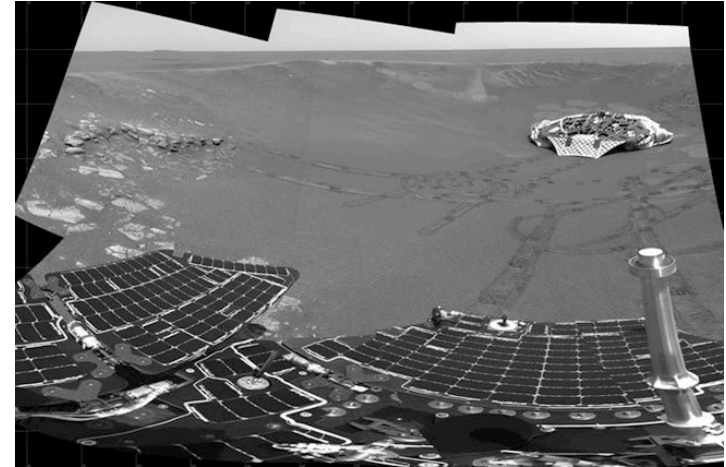
Flood erosion



## New Water?



## The Surface of Mars: Opportunity



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

## Roving on Mars



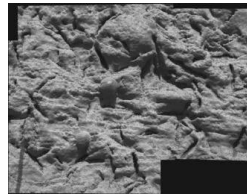
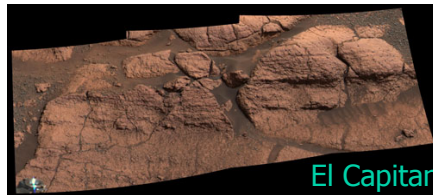
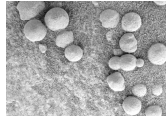
**Roving on Mars:**  
Spirit and Opportunity  
find evidence of ancient  
liquid water

[http://antwrp.gsfc.nasa.gov/apod/image/0403/emptyest\\_opportunity\\_big.jpg](http://antwrp.gsfc.nasa.gov/apod/image/0403/emptyest_opportunity_big.jpg)

## Standing Water on Mars



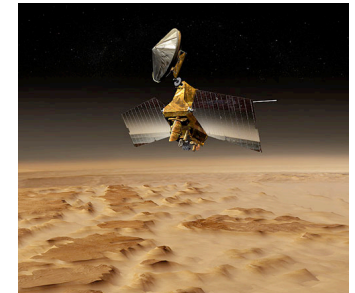
- The new data from the rovers are highly suggestive of ancient standing water on the Meridiani Planum.
- 3 pieces of evidence:
  - Physical appearance of rocks
  - Rocks with niches where crystals appear to have grown
  - Rocks with sulfates left after the water evaporated
- Is it a former sea floor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



## Mars Missions Now



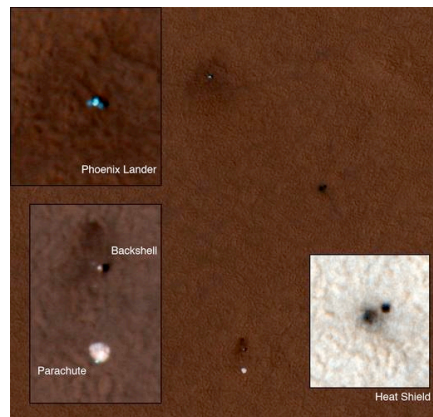
- Mars Reconnaissance Orbiter
  - Studying the geology and climate of Mars
  - Look for ancient sea shores
  - Survey potential landing sites



## Mars Missions Now



- Phoenix
  - Analyze water ice at Mars' north pole

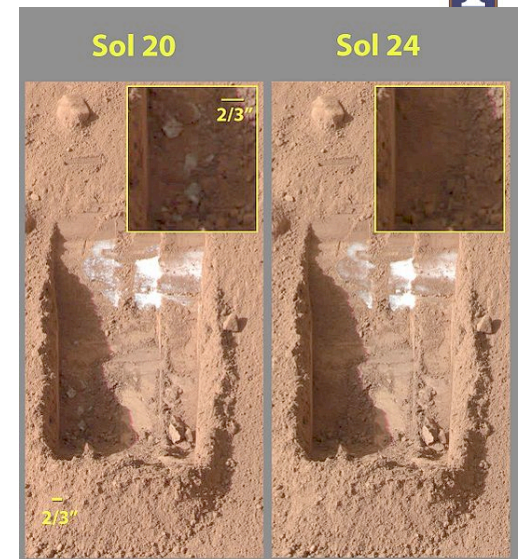


[http://www.nasa.gov/mission\\_pages/phoenix/images/press/PSP\\_008591\\_2485\\_RGB\\_Lander\\_Inserts.html](http://www.nasa.gov/mission_pages/phoenix/images/press/PSP_008591_2485_RGB_Lander_Inserts.html)

## Mars Missions Now



- Phoenix
  - Confirmed water ice on the surface of Mars
  - Sublimates too slowly for dry ice ( $\text{CO}_2$ )

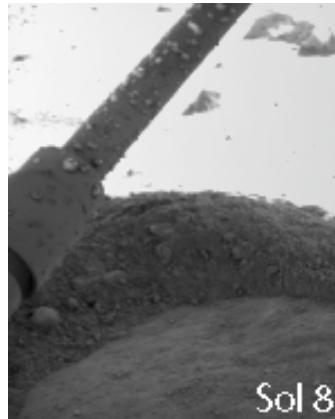
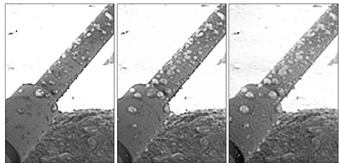




## Mars Missions Now



- Phoenix
  - Blobs on lander legs
  - Blobs merge (Sol 8 & 31)
  - Liquid!
  - Saltwater most likely



<http://www.planetary.org/blog/article/00001890/>

## Mars' Watery Past

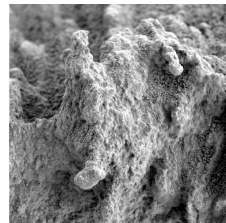
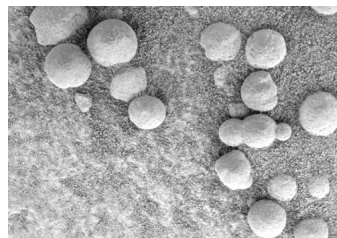


Image Courtesy of Kees Veenenbos

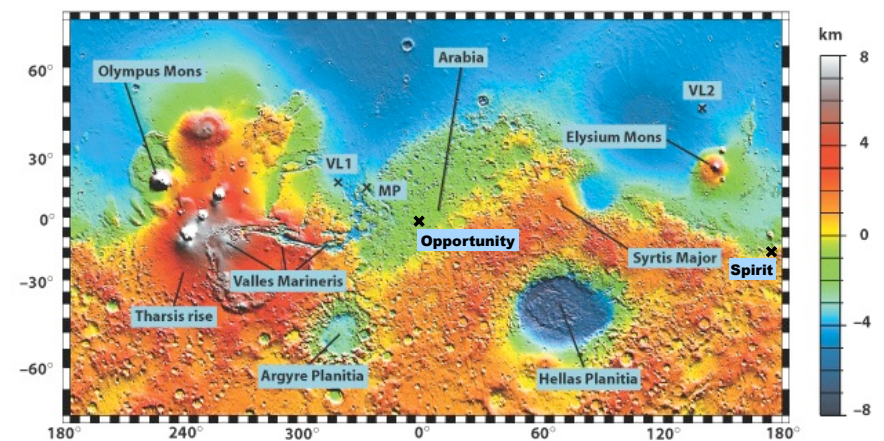
## What Happened to the Water?



- 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?

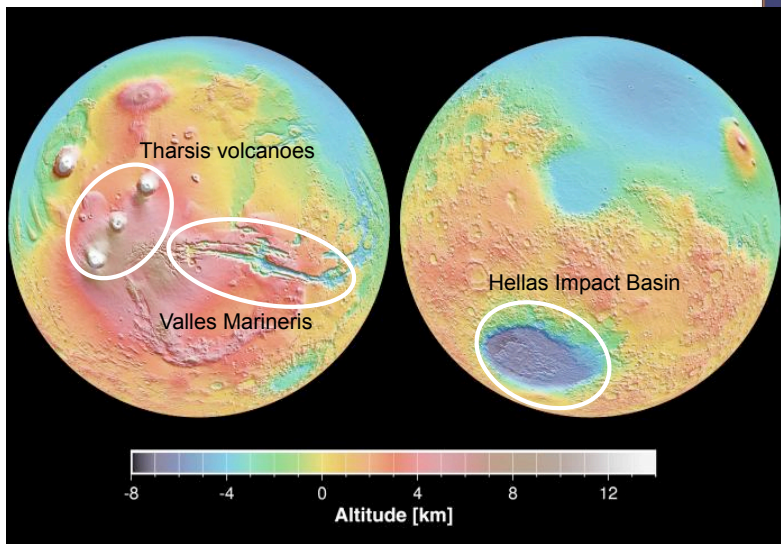


## The Geology of Mars





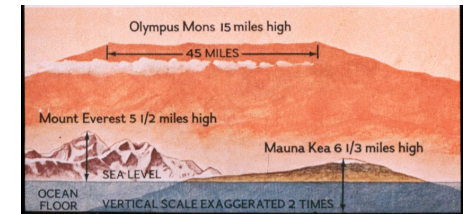
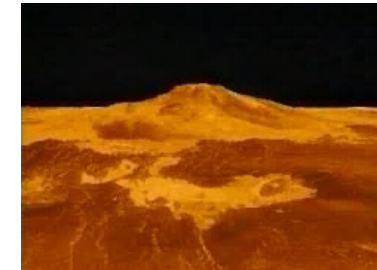
## The Surface of Mars



Mars Global Surveyor

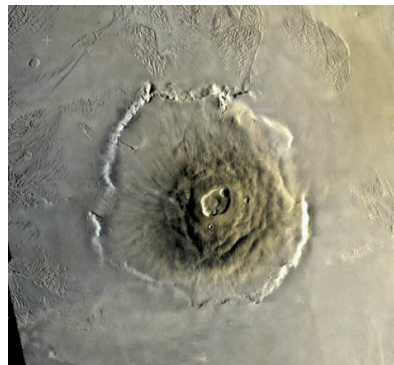
## Olympus Mons

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



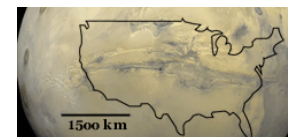
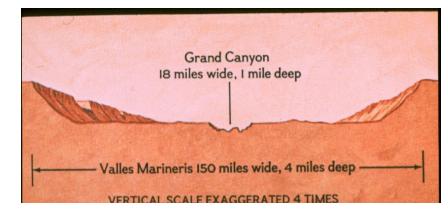
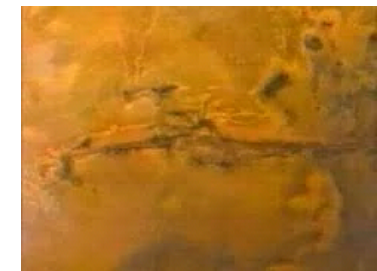
## Olympus Mons

- 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

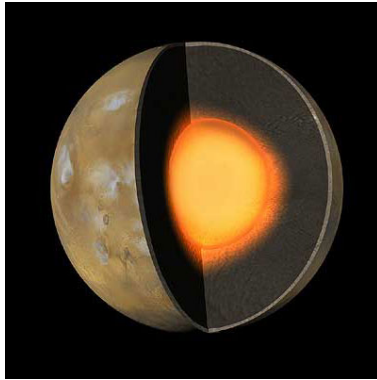
- A series of fault canyons
- 5000 km long
  - A big as the U.S.!
- A giant crack in the crust of Mars
  - Formed as the planet cooled
  - Expanded by water flow



## 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



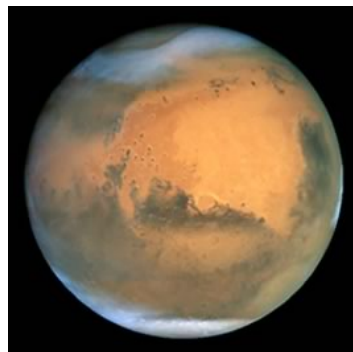
- Early in Mars' history it was likely more Earth-like
  - Geologically active
  - Volcanic eruptions created a thick carbon dioxide, nitrogen atmosphere
  - Greenhouse effect made it warm enough for liquid water
  - Oceans? Rivers? Glaciers by the poles?
  - Life?



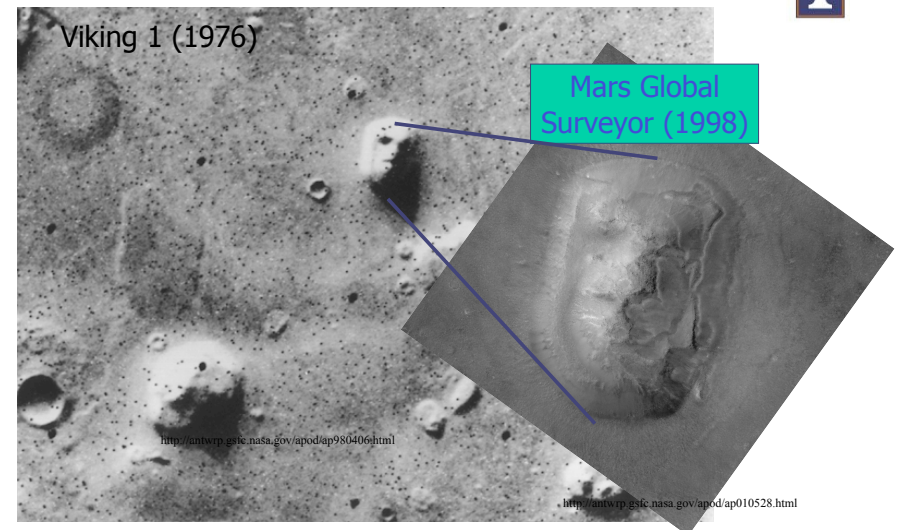
## What Happened?



- 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?





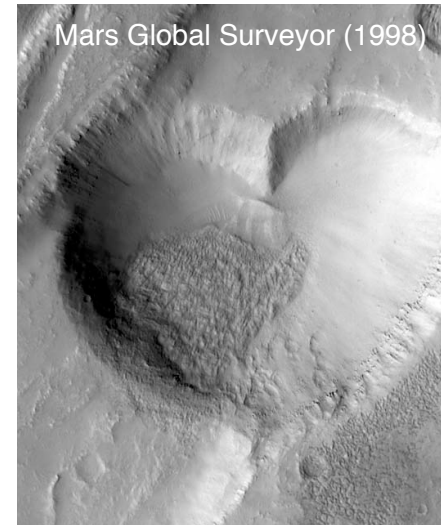
## Other Faces



Mars Global Surveyor (1998)

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

## Other Places



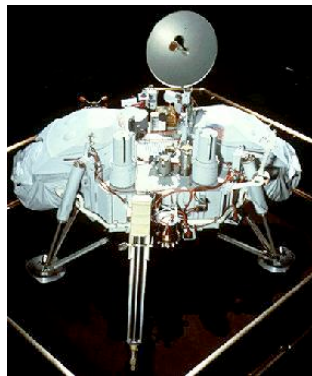
Mars Global Surveyor (1998)

<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 fossil 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





## Martian Microbe Fossils?



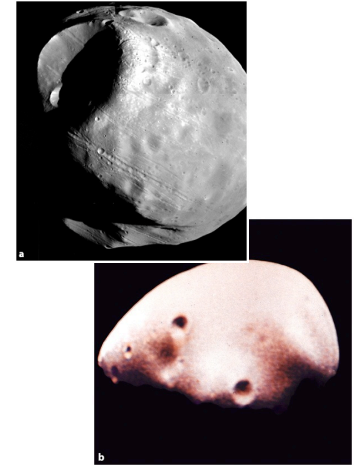
- Microscopic shapes that resemble living and fossil bacteria on Earth—nanobacteria, but much smaller than on Earth.
- Microscopic mineral grains like some produced by living and fossil bacteria on Earth
- Organic chemical compounds that resemble the decay products of bacteria on Earth.
- In the end, 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
- Obama estimated a manned orbit to Mars in mid 2030's with a landing soon after.
- Russia and Europe are discussing options
- China may be considering it too.



## Question



We know for sure that

- a) Mars used to have water.
- b) Mars has life.
- c) The people of Mars need soap.
- d) The atmosphere of Mars is gone.
- e) Mars has water just under the surface now and used to have surface water.

## Question



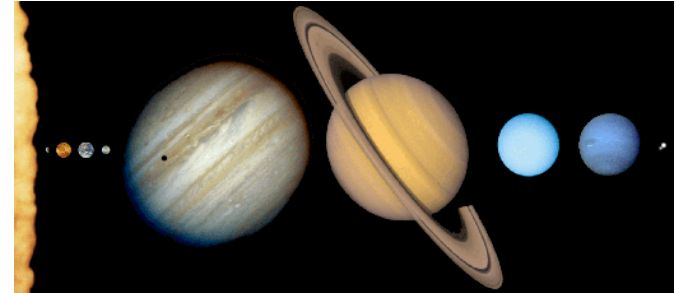
The face on Mars

- 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.

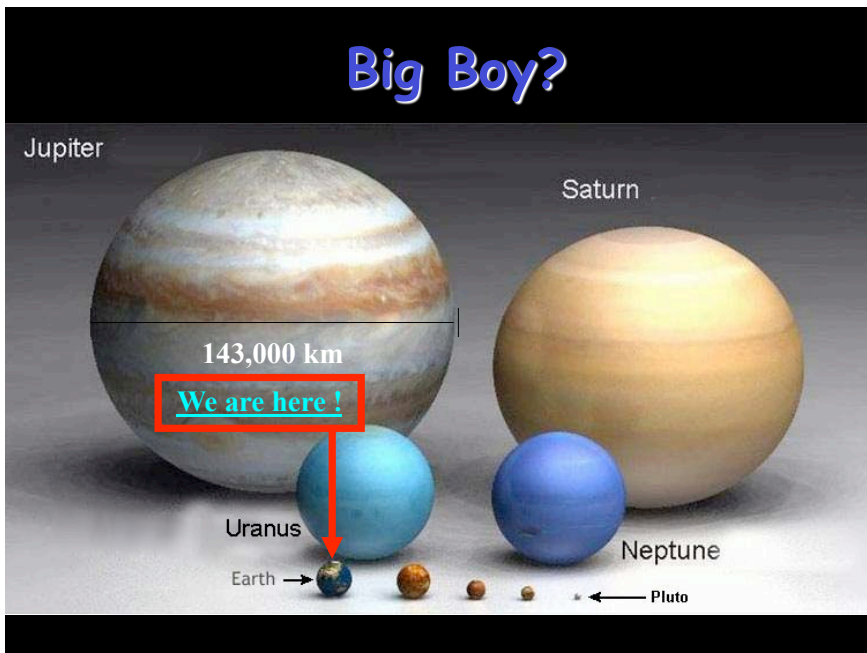
## Life in the Solar System



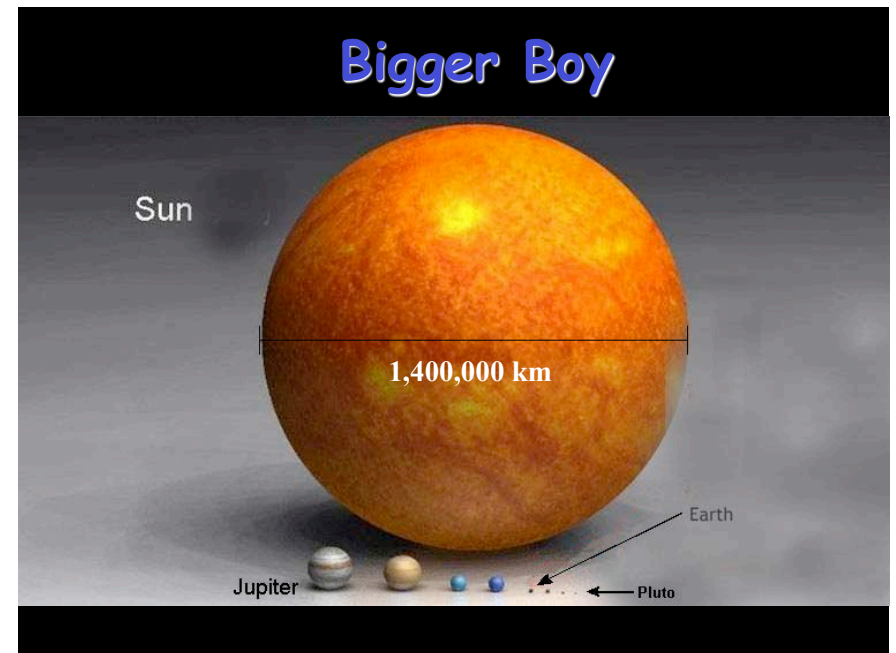
- Venus may have life in the clouds.
- Mars might still have life under the soil.
- But what about the outer solar system?
- It isn't in our definition of the habitable zone, but it still is interesting.
- We will now focus on Jupiter, Io, Europa, and Titan.



## Big Boy?



## Bigger Boy



## Earth – Jupiter comparison



Biggest and most massive planet, has the largest gravity, has the largest number of moons (>63), 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

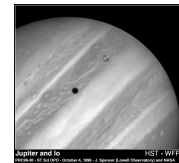
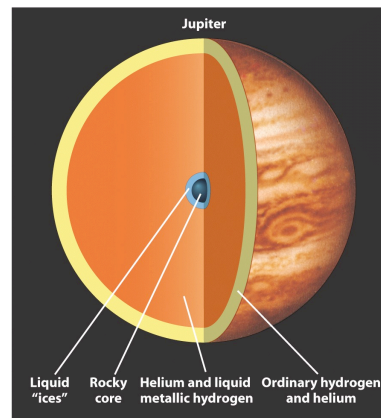


- Named for the king of the Roman gods
- A truly immense planet
  - Over 11 times the diameter of Earth
  - Over 300 times the mass of Earth
  - Over twice the mass of all the other planets combined!
  - Has over 63 moons, its own mini-solar system!
- Visited by 4 spacecraft
  - Pioneer 11 - Flyby in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



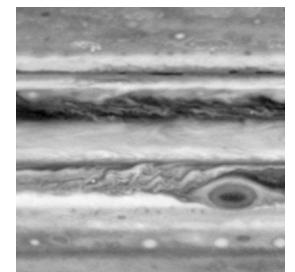
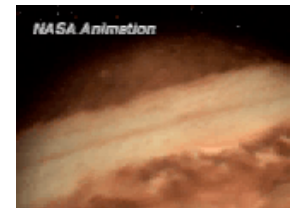
- Average density only 30% greater than water
- 25% that of the Earth's average density
- By 20,000 km, the pressure is 3 million times that on the Earth's surface!
  - Hydrogen becomes a liquid metal
- Core of rock & "ice" 10-12 Earth masses



## 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



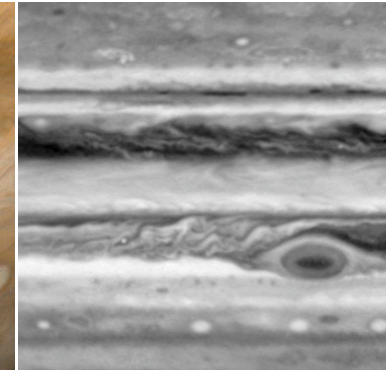
## The Great Red Spot



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

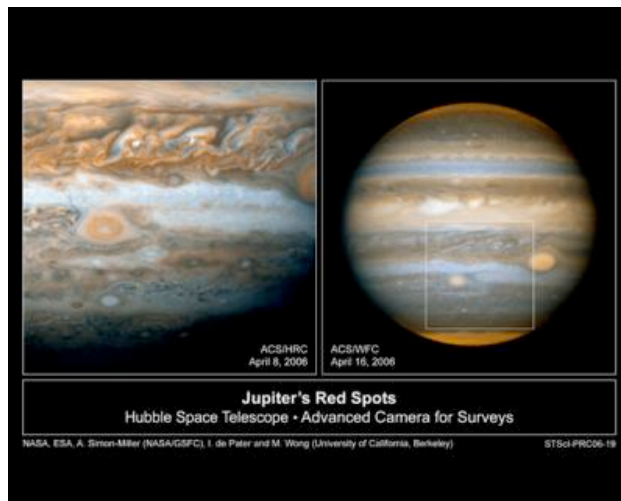


Voyager 1 image



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

[http://www.aip.org/history/esva/catalog/images/salpeter\\_edwin\\_a3.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.



<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/superminyme/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>