Astronomy 330

This class (Lecture 15):

Life in the Solar System

Next Class:

Biological Evolution

Music: *Life on Mars*– David Bowie

Extra Credit?

0.5 % added to final grade for attending Alex's talk on the 16th.

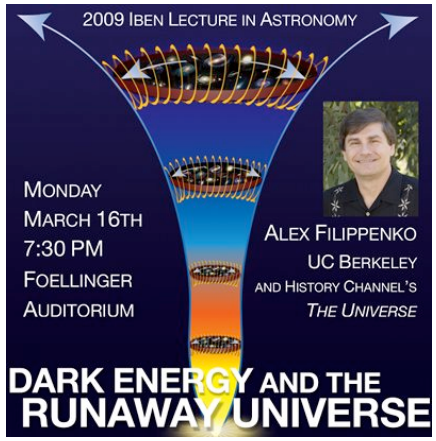
1 page typed report:

(1) Summary of talk

(2) Cool stuff you knew.

(3) Cool stuff you learned.

Due in discussion class on April 1st.



Outline

- Life in our Solar System?
  - Mars
  - Jupiter (Europa)
  - Saturn (Titan)

Drake Equation

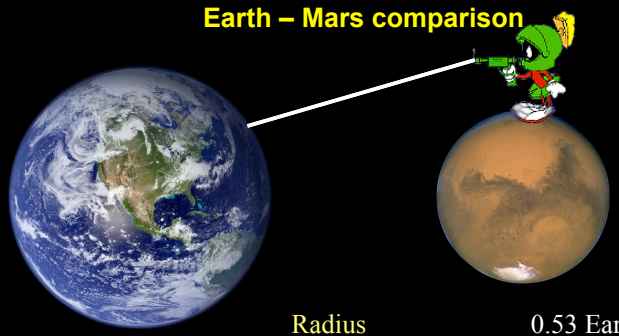
That's 0.36 Life-liking systems/year

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
	20 stars/ yr	0.12 systems/ star	1.25 x 0.12 = 0.15 planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Earth – Mars comparison



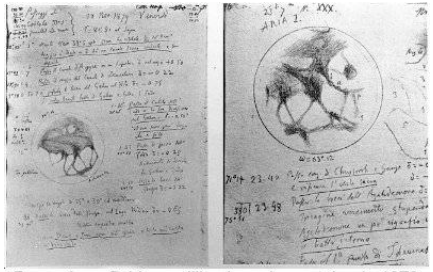
Radius	0.53 Earth
Surface gravity	0.38 Earth
Mass	0.11 Earth
Distance from Sun	1.5 AU
Average Temp	-63 C
Max Temp	20 C
Year	687 Earth days
Length of Day	24 hours 39 minutes
Atmosphere	CO_2 95%

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

What we used to think.

Giovanni Virginio Schiaparelli

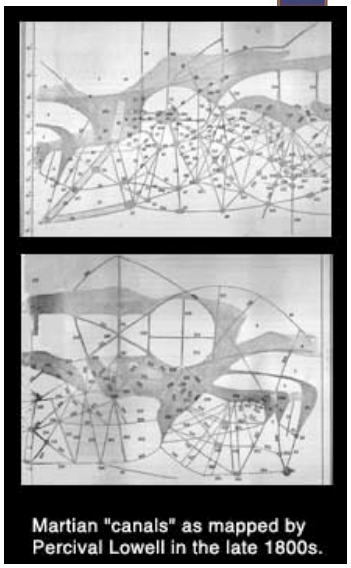
- Was thought to be similar to the Earth in many ways.
- Life was argued to exist on Mars by many astronomers.
- The astronomer Schiaparelli announced that he saw regular linear markings on the surface, which he named *canali*.
- Technically, in Italian means channels, but it was mistranslated to canals.



Pages from Schiaparelli's observing notebook, 1879

Percival Lowell's Canals

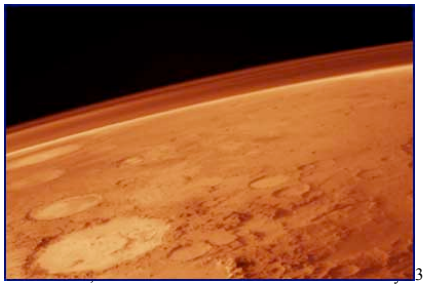
- Evidence for intelligent life?
- Mapped the civilization.
- Influenced culture.

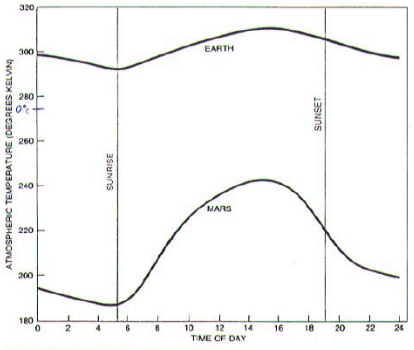


Martian "canals" as mapped by Percival Lowell in the late 1800s.

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





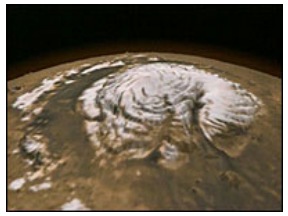
DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the *Viking 1* landing site (*color*) are qualitatively similar to those at China Lake, Calif., a desert site (*black*). In both cases the temperature reaches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is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

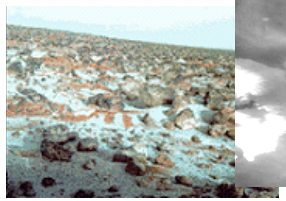
The Surface of Mars

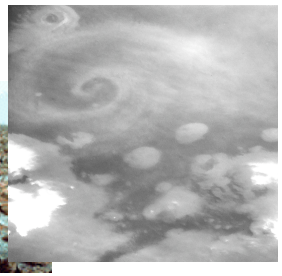
- Mars is a desert!
- Iron oxide in soil gives reddish cast.

Water on Mars

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

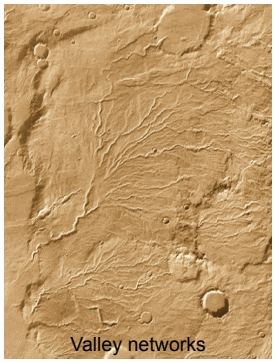


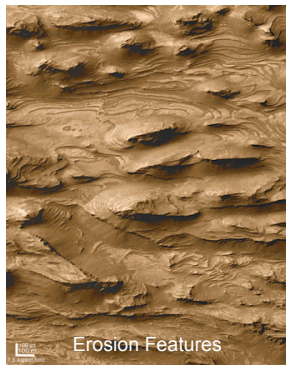


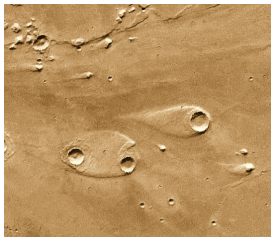


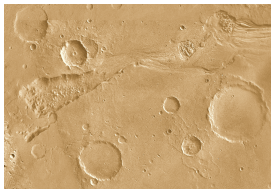
Liquid water on Mars?

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

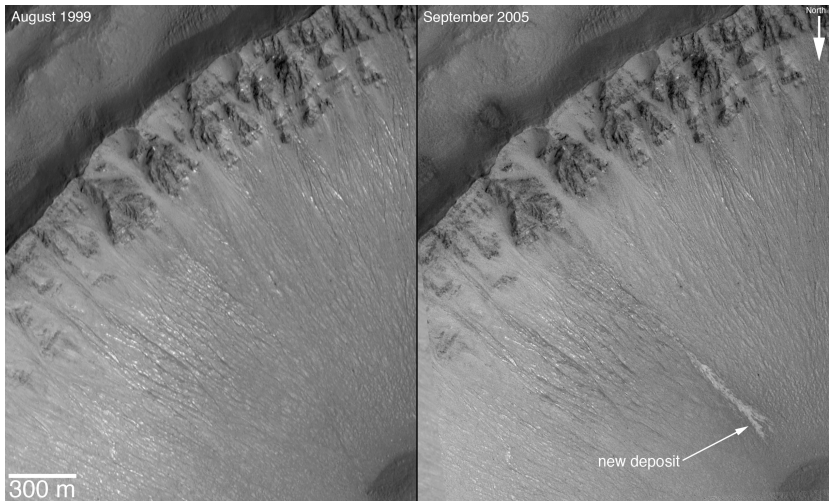

Valley networks


Erosion Features

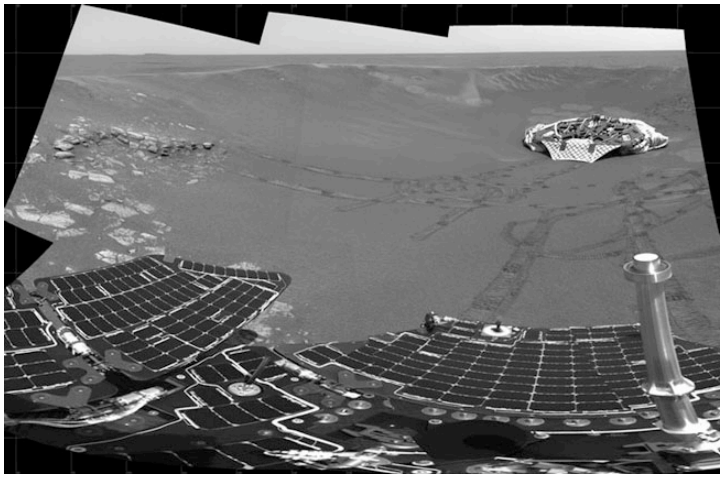

"Islands"


Flood erosion

New Water?



The Surface of Mars: Opportunity



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

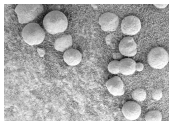
Roving on Mars

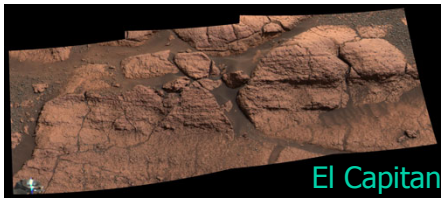
Roving on Mars:
Spirit and Opportunity find evidence of ancient liquid water

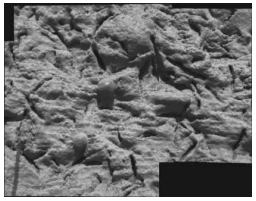
http://antwrp.gsfc.nasa.gov/apod/image/0403/emptynest_opportunity_big.jpg

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?

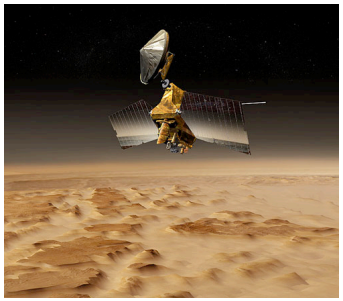






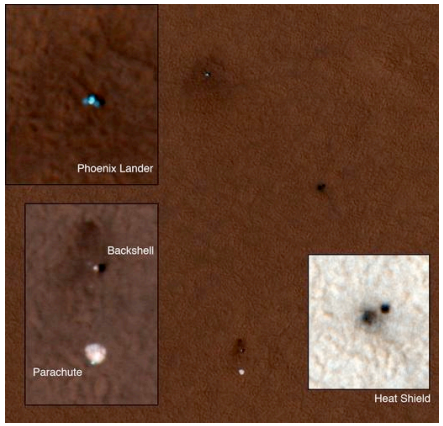
Mars Missions Now

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



Mars Missions Now

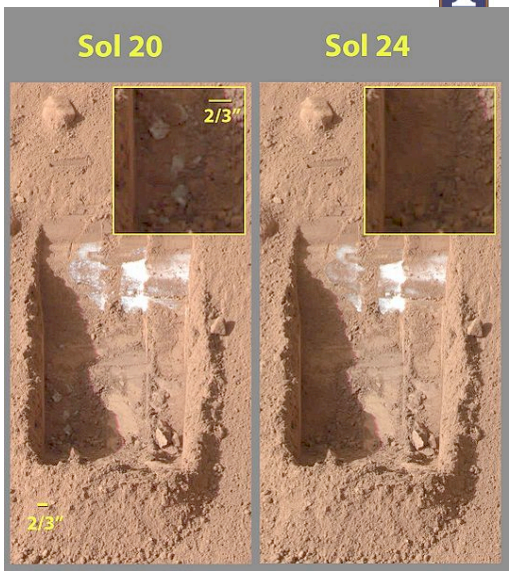
- Phoenix
  - Analyze water ice at Mars' north pole



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

Mars Missions Now

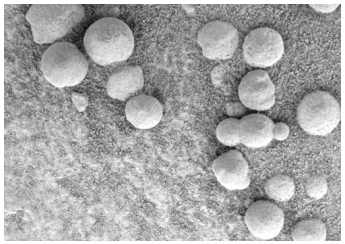
- Phoenix
  - Confirmed water ice on the surface of Mars
  - Sublimates too slowly for dry ice (CO_2)

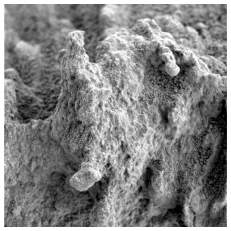


Mars' Watery Past

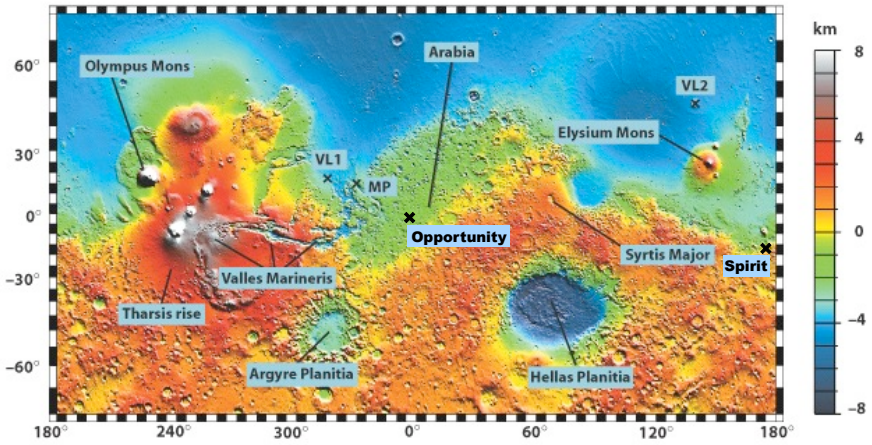
What Happened to the Water?

- 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?

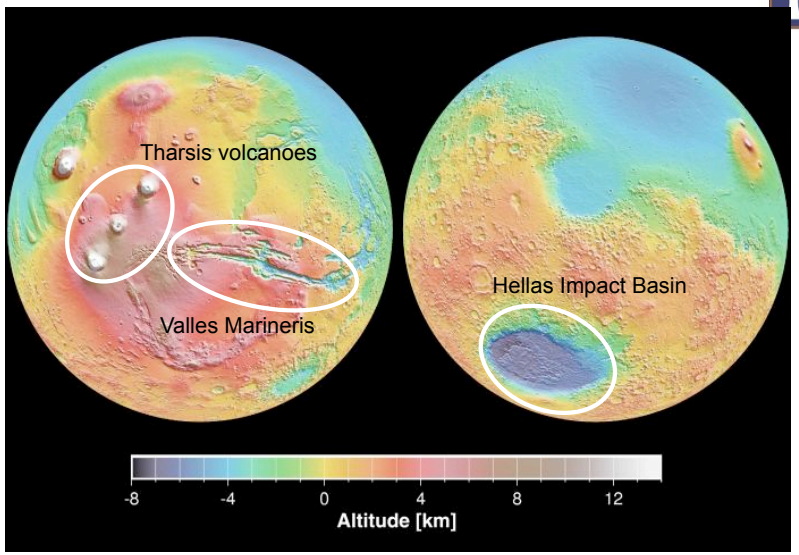




The Geology of Mars



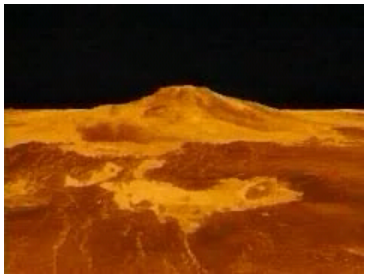
The Surface of Mars

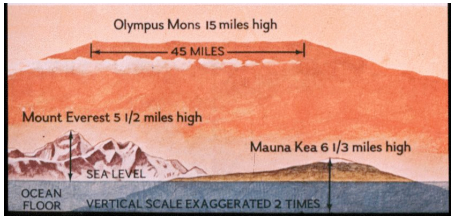


Mars Global Surveyor

Olympus Mons

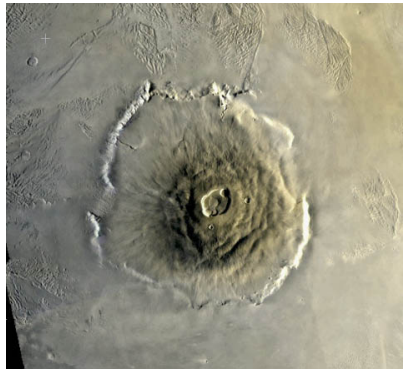
- The largest mountain in the Solar System rising 26 km high
- A shield volcano, like Hawaii on Earth
- Its caldera is 90 km across





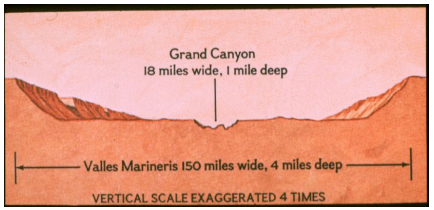
Olympus Mons

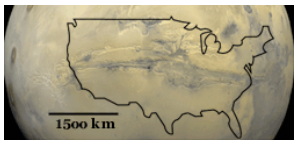
- Its base is more than 500 km in diameter
- As long as the entire Hawaiian island chain
- Rimmed by a 6 km high cliff
- Last erupted 25 million years ago
- Probably so big, due to lack of plate tectonics



Valles Marineris

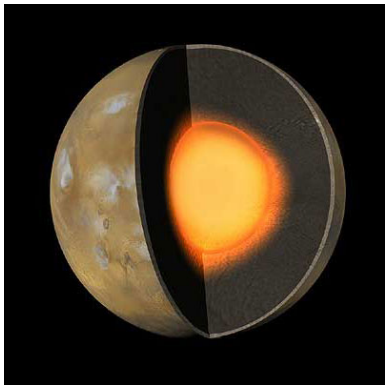
- A series of fault canyons
- 5000 km long
  - A big as the U.S.!
- A giant crack in the crust of Mars
  - Formed as the planet cooled
  - Expanded by water flow





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



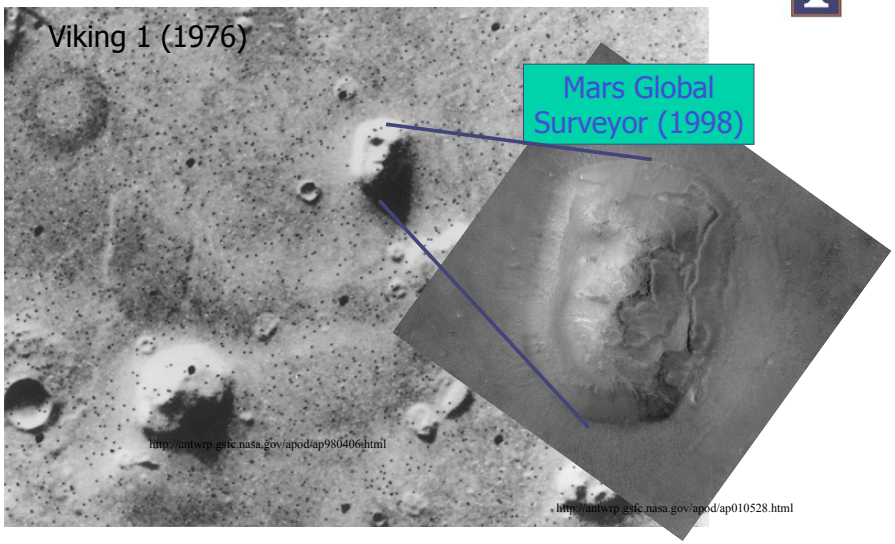
Mars' Past

- 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?

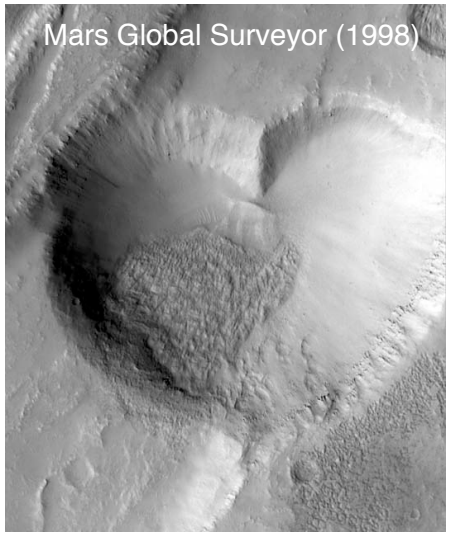
The "Face" of Mars?



Other Faces

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

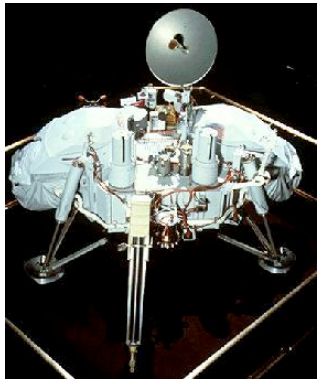
Other Places



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

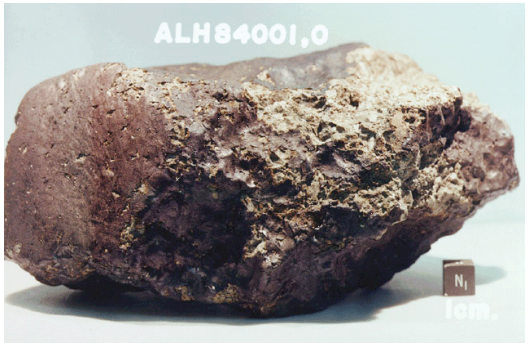
The Search for Mars Life

- 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



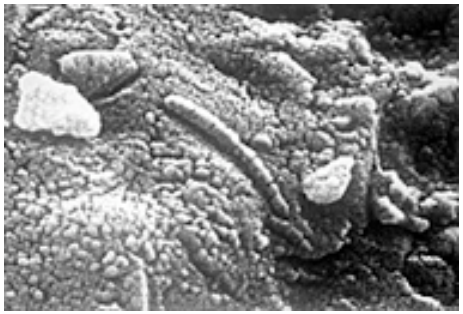
Martians?

- 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.



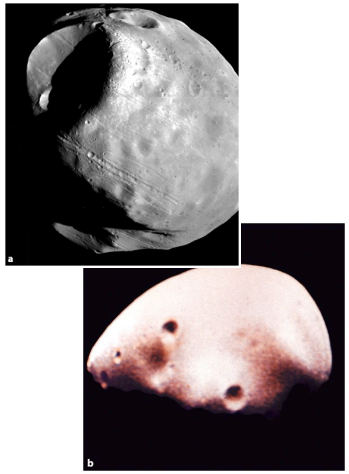
Martian Microbe Fossils?

- 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

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.

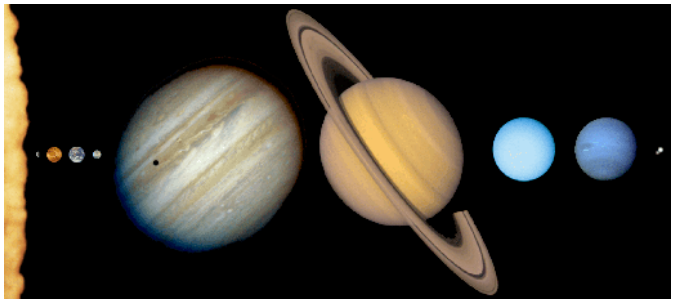
Question

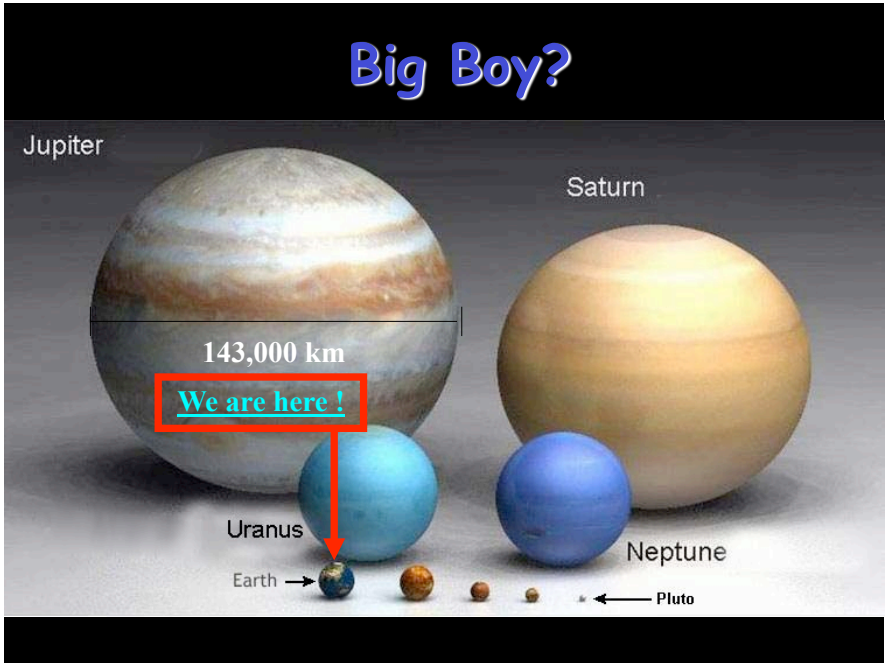
The face on Mars

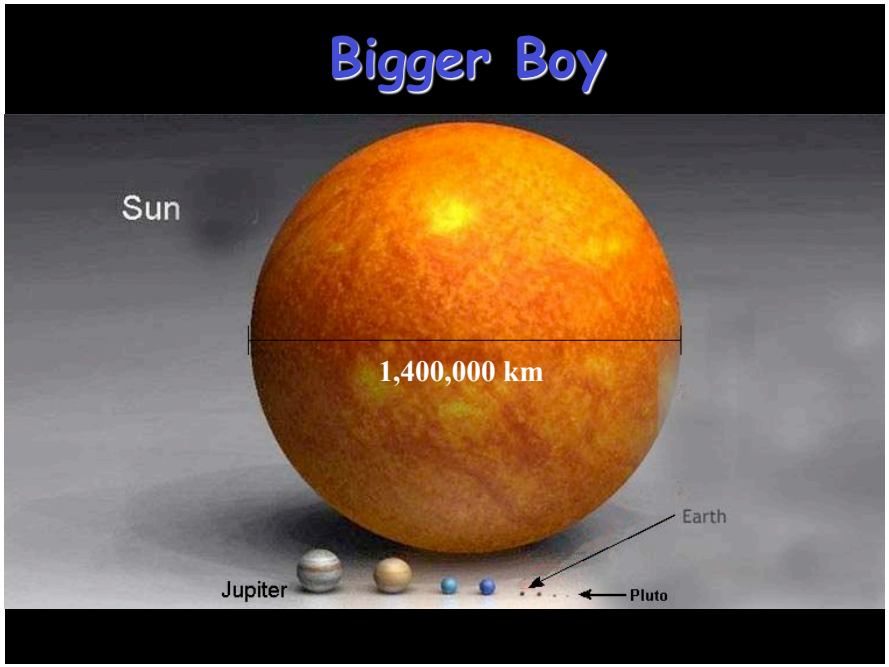
a) was a huge NASA cover-up.
b) might have been created by Martians or ETs, but we'll never know for sure.
c) was an optical illusions, like cloud shapes.
d) will be the major focus of any follow-up rover missions.
e) was really a statue that had fallen over.

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.







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

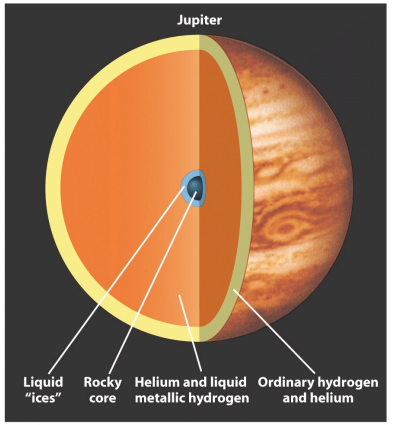
Causes a bulge at the equator.

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

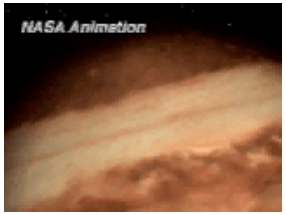
Jupiter's Interior

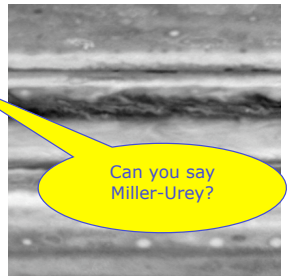
- Average density only 30% greater than water
- 25% that of the Earth's average density
- By 20,000 km, the pressure is 3 million times that on the Earth's surface!
  - Hydrogen becomes a liquid metal
- Core of rock & "ice" 10-12 Earth masses



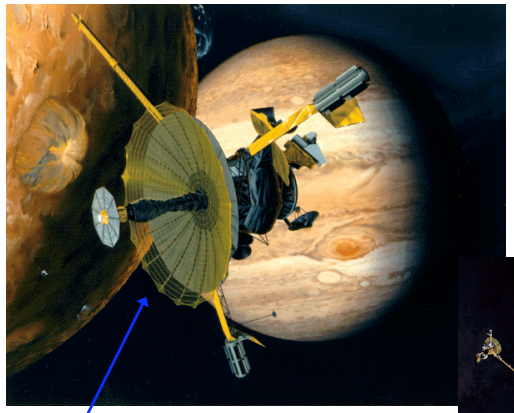
Jupiter's Atmosphere

- 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.

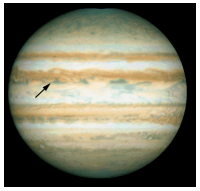




The Galileo Spacecraft (1989 – 2003)



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.

Probing the Atmosphere

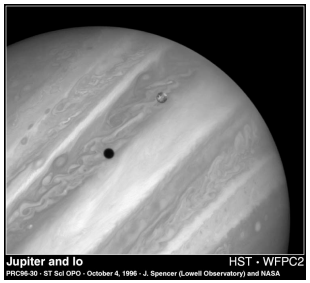
- Did not encounter the layers of clouds that was expected.
- The probe entered the least cloudy region of Jupiter.
- Did not rule out life, but did not support it.
- Later, the spacecraft Galileo was crashed into Jupiter.

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

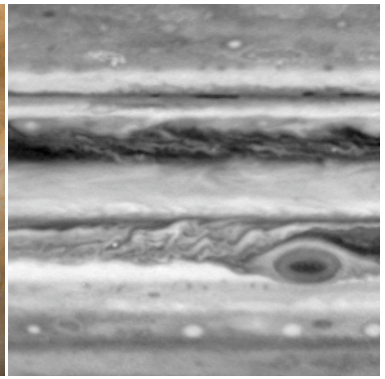
- On Earth, solar heating drives weather
- On Jupiter, internal heat drives weather
  - Winds maintain speeds to great depths
  - Jupiter radiates 70% more heat than it receives from the Sun
  - The heat is from Jupiter contracting under its own powerful gravity
  - As it contracts, the gas is squeezed,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



The Great Red Spot

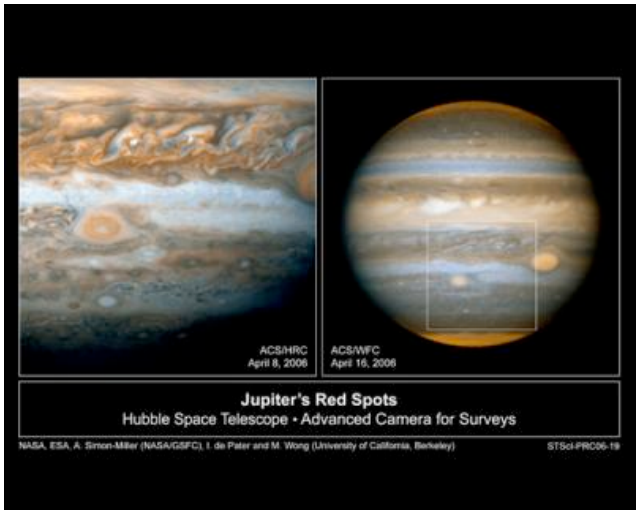
- A huge storm 25,000 km across – twice size of the Earth!
- First observed > 300 years ago!

Voyager 1 image



Cassini images

Little Red Spot



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