

Astronomy 210

Section 1 – MWF 1500-1550
134 Astronomy Building



This Class (Lecture 23):

Giant Planets

**Night Observation Report and
HW 7 due on Friday**

Next Class:

Debris

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Earth – Mars Comparison



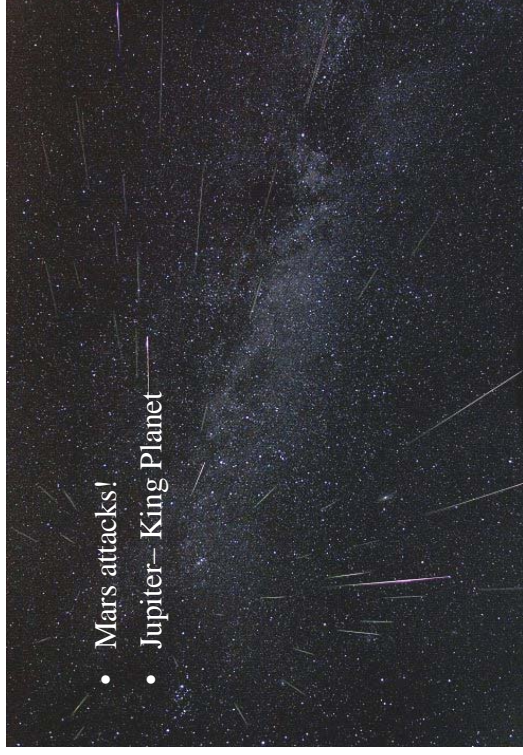
Mars has the
Solar System's
largest Volcano, –
Olympus Mons –
26 km tall



Radius	0.53 Earth
Surface gravity	0.38 Earth
Mass	0.11 Earth
Distance from Sun	1.5 AU
Eccentricity	0.09
Tilt	25°
Year	687 Earth days
Solar day	24 hours 39 minutes

Outline

- Mars attacks!
- Jupiter– King Planet



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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

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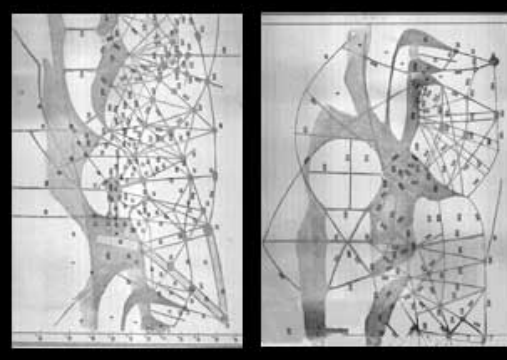
Percival Lowell's Canals



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



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

The "Canals" of Mars

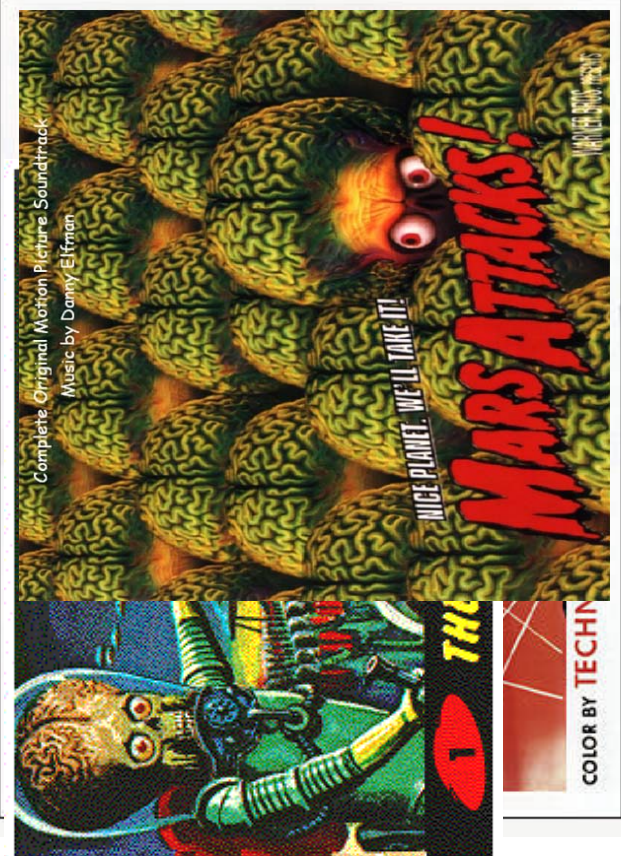


- Mars' color suggested a desert world.
- Mars is the only planet we can see the surface of with a telescope
- "Canals" thought to irrigate the desert with water from ice caps
- No doubt Martians would want to conquer Earth for its abundant resources
- Spawned many sci-fi stories

Of course, modern telescopes show no canals on Mars

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The Martian Atmosphere



- 95% CO₂, 3% N₂, 2% Ar
 - Composition similar to Venus
 - Except there is some water vapor (0.03%)
- Sparse atmosphere
 - Less than 1% Earth's (like 40km alt on Earth)
 - Mars is too small
 - Not enough gravity to hold a thick atmosphere



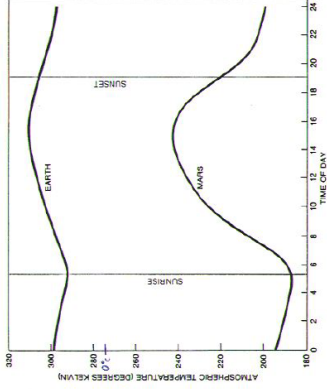
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Temperatures on Mars



- Daily temperature variations like Earth
 - Coldest at sunrise
 - Warmest a few hours after noon
- But **much** colder
 - Farther away - less solar radiation
 - Greenhouse effect only raises the temperature 5 K
 - Typically, 170 K at night to 240 K during the day (~103 to -33 C)
 - It can get up to 0 C in the southern summer!



DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE in the *Viking 1* landing site. The temperature in the atmosphere is about 100 K warmer at noon than at sunrise or sunset. The daily range, however, is about three times greater on Mars than it is on the earth. At the Chama Lake range in 18 degrees, from 225 to 318 degrees K, (109 to 37 degrees C).

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Seasons on Mars

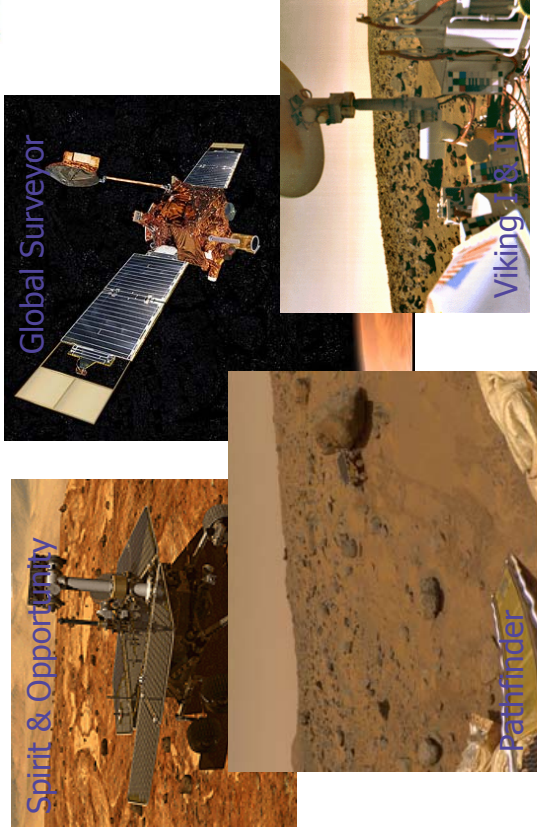


- A Martian day is about 24 hours
- Mars' spin axis is tilted to its orbit by 25°
- So, Mars has Earth-like seasons! But...
 - The Martian year is 1.88 Earth years
 - Seasons are almost twice as long
 - Mars' orbit is more eccentric than Earth's
 - Enough to make a difference in temperatures
 - Southern summer shorter and hotter than northern summer
 - Southern winters are long and cold!

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Exploring Mars



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Missions to Mars



- Mankind has sent about 35 missions to explore Mars
 - More than any other planet
 - Mainly from the U.S. and Russia
- Only about 1/3 are successful in completing their missions (some are partly successful)
- We have learned a great deal from both the successes and failures

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The Surface of Mars



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



View of “Twin Peaks” from Mars Pathfinder

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

The Martian Sky



- The Martian sky does not appear blue, why?
- Mars’ atmosphere contains fine dust
 - Absorbs blue light
 - What is left appears “butterscotch yellow” or pinkish
- If Mars’ atmosphere were cleansed of dust, the sky would be blue like Earth

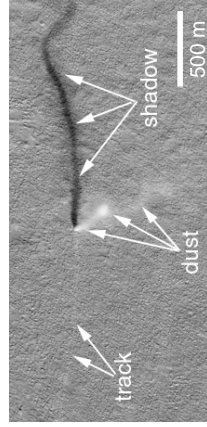
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Dust Storms and Dust Devils Mars vs. Earth



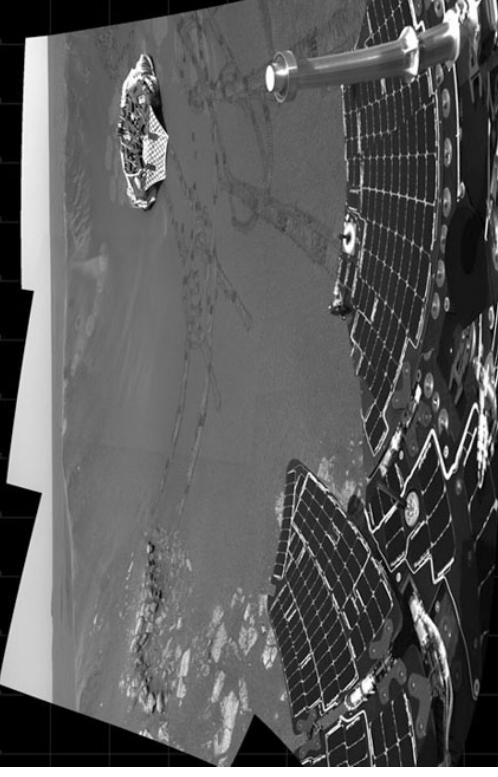
Dust devil on Earth (D. Catling)



Dust devil seen by Mars Global Surveyor

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The Surface of Mars: Opportunity

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

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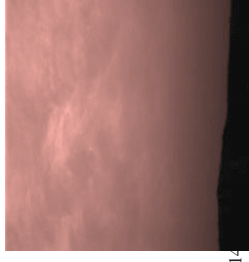
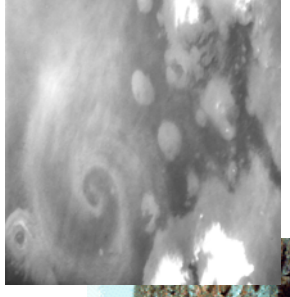
Earth – Mars Comparison



Mars has the largest Volcano, Olympus Mons – 26 km tall	Radius 0.53 Earth
	Surface gravity 0.38 Earth
	Mass 0.11 Earth
	Distance from Sun 1.5 AU
	Eccentricity 0.09
	Tilt 25°
	Year 687 Earth days
	Solar day 24 hours 39 minutes

Water on Mars

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



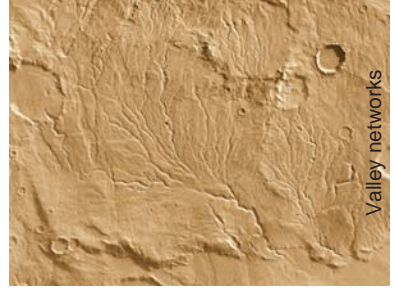
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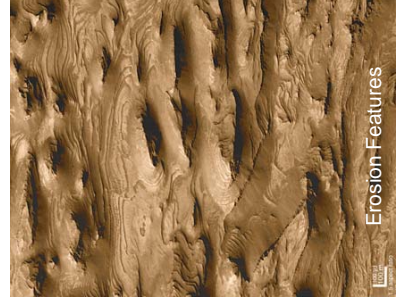
Liquid water on Mars?

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



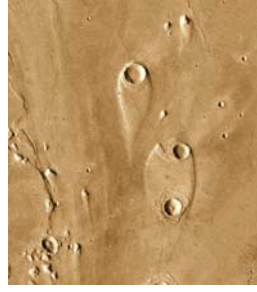
Valley networks

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Erosion Features

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"Islands"

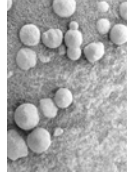


Flood erosion



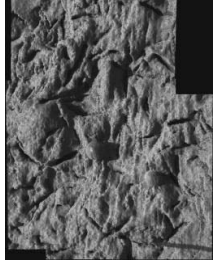
Standing Water on Mars

- 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?



El Capitan

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Mars' Watery Past



Image Courtesy of Kees Weenenbos

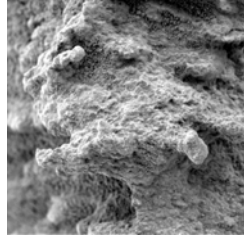
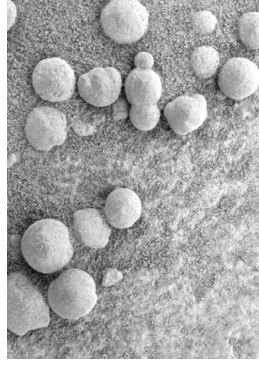
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What Happened to the Water?

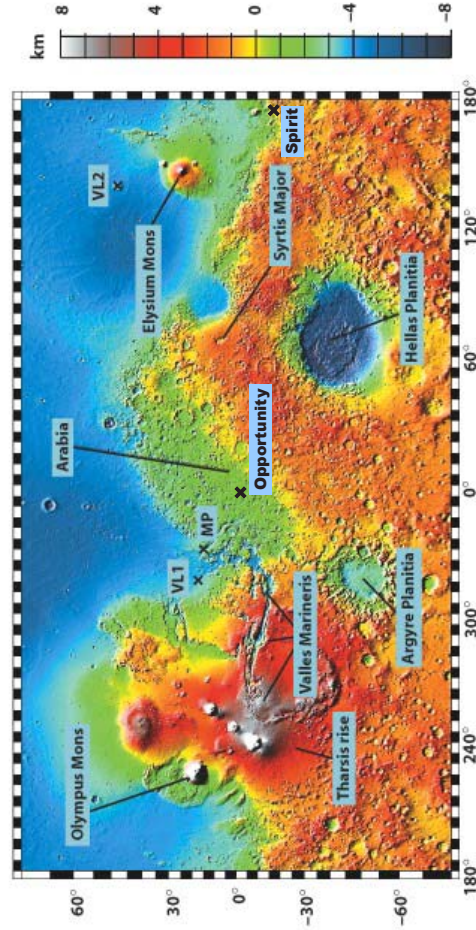
- That is the big question
 - Both Opportunity and Spirit have found evidence of water
 - Did the water escape to space with the air?
 - Is it frozen beneath the surface?
- The rovers are continuing their exploration
- More missions are planned



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The Geology of Mars

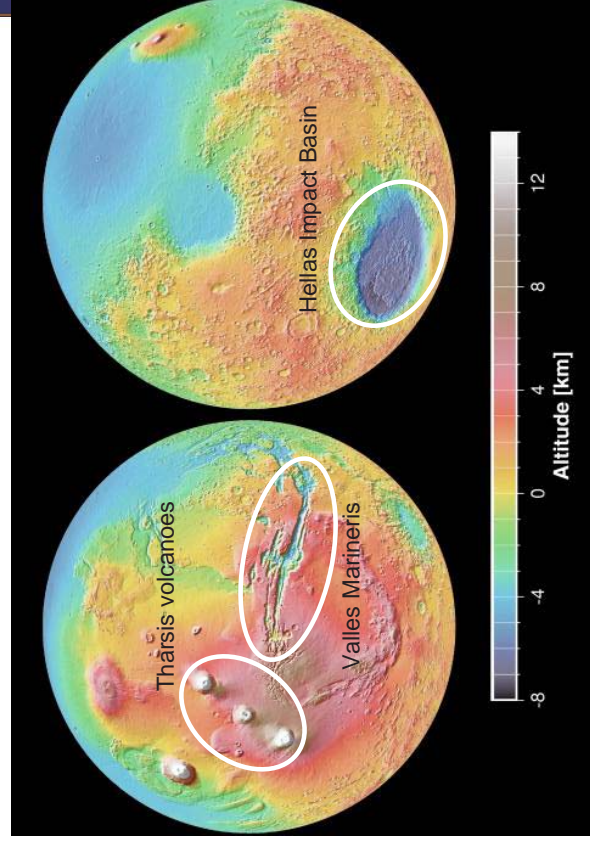


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The Surface of Mars



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Mars Global Surveyor

The Geology of Mars



- Mars' surface has two distinct regions
- Southern region is mostly heavily cratered highlands
 - Ancient surface
 - Craters from the heavy bombardment 4 billion years ago
- Northern region is volcanic lowland plains
 - Few craters - younger surface!
 - Dominated by large volcanoes

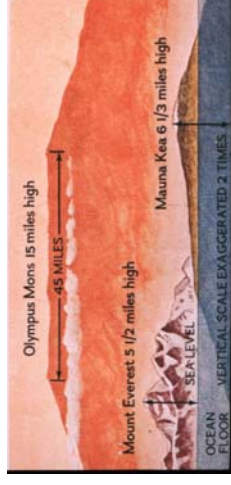
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Olympus Mons



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



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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

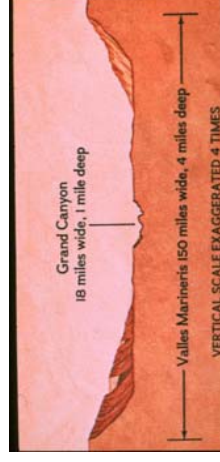
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Valles Marineris



- 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



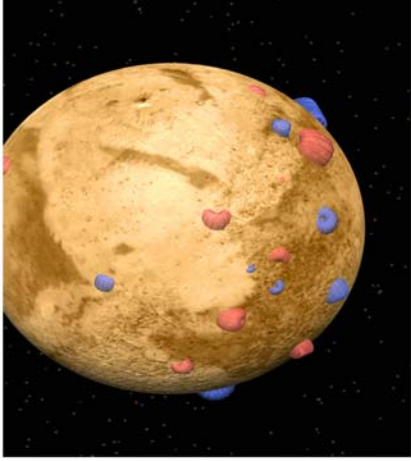
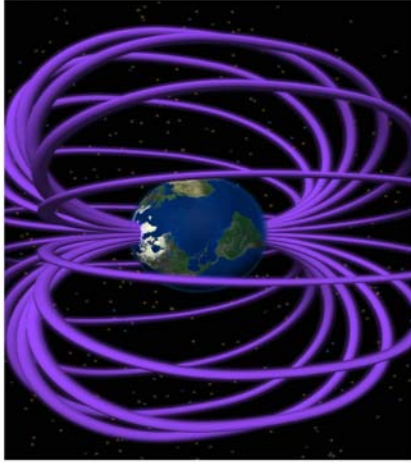
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Magnetic Field



- Mars' magnetic field is extremely weak



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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



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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?



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What Happened?



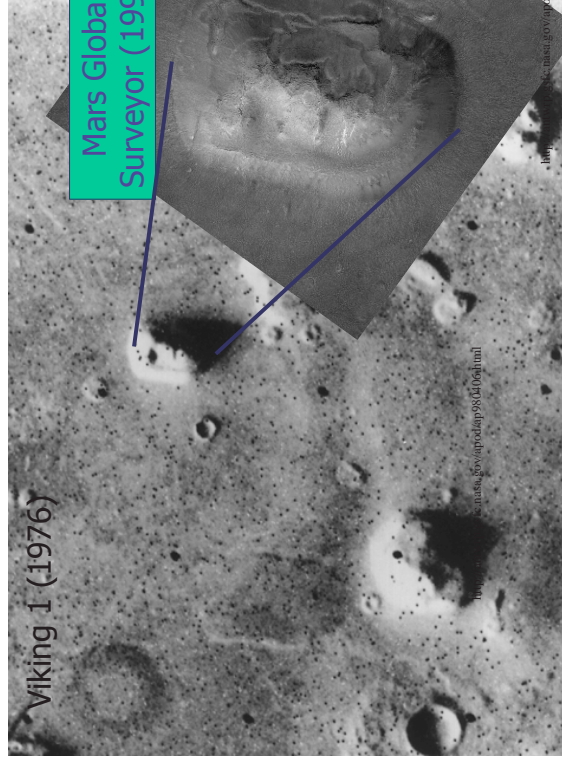
- Mars was too small
 - Not enough internal heat
- Plate tectonics stopped
 - Volcanoes sat over "hotspots" grew to immense sizes
- Volcanic activity slowed as the interior cooled
- The atmosphere escaped
- The planet froze



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The "Face" of Mars?



Viking 1 (1976)

Mars Global Surveyor (1998)

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<http://www.nasa.gov/pdf/opp981064.html>

<http://www.nasa.gov/pdf/opp010528.html>

Other Faces



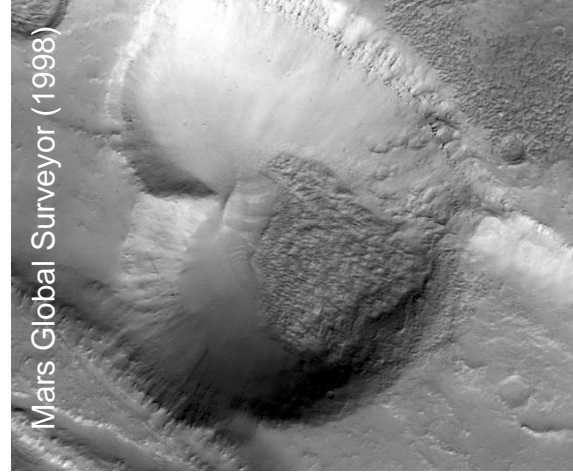
Mars Global Surveyor (1998)

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<http://antwvp.gsfc.nasa.gov/spot/opp990315.html>

Other Places



Mars Global Surveyor (1998)

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<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.

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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.



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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



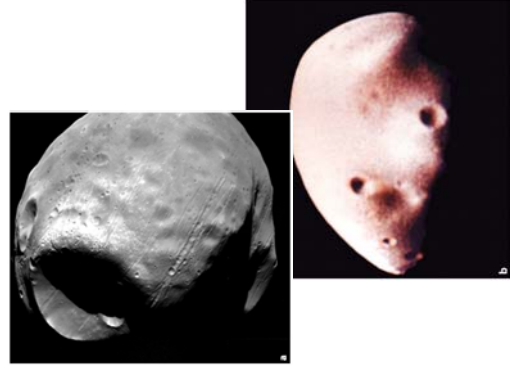
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Phobos & Deimos



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



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Future Mars Missions



- Mars Reconnaissance Orbiter (2005)
 - Will study the geology and climate of Mars
 - Look for ancient sea shores
 - Survey potential landing sites
- Phoenix (2007)
 - Will analyze water ice at Mars' north pole



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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



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Jupiter, King of the Planets



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

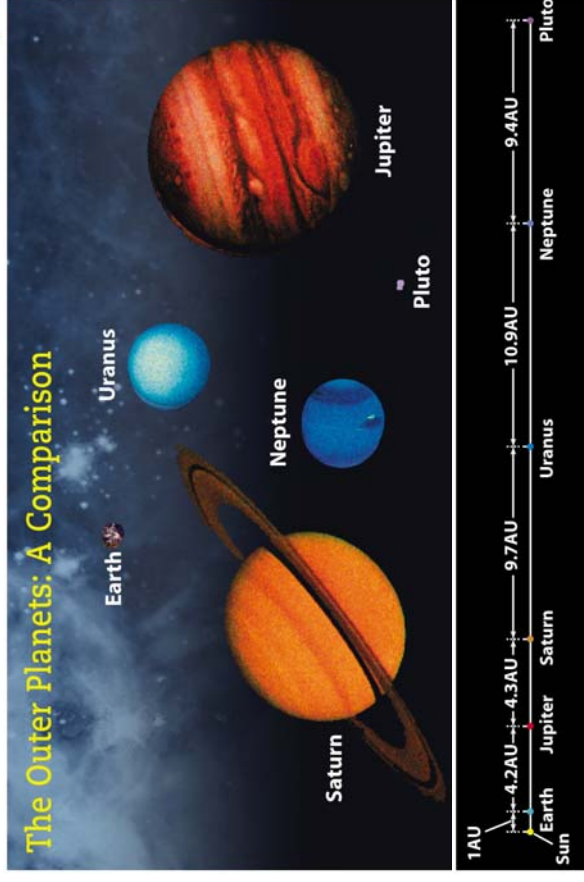
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The Outer Planets



The Outer Planets: A Comparison



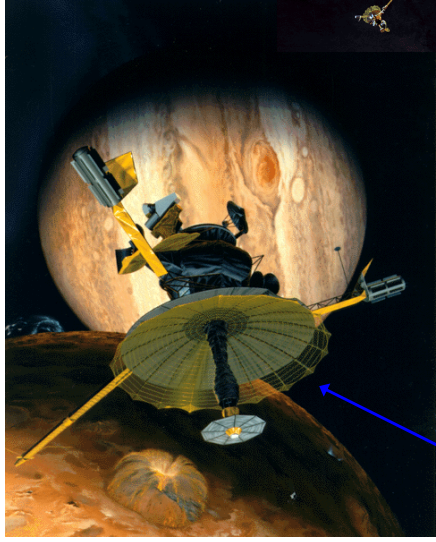
Earth – Jupiter Comparison



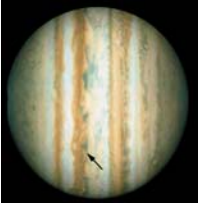
Biggest and most massive planet, more than the rest of the planets combined (0.1% M_{\oplus}), yet has the shortest day in Solar System

Radius	11.2 Earth
Cloud-top gravity	2.4 Earth
Mass	318 Earth
Distance from Sun	5.2 AU
Eccentricity	0.048
Tilt	3.1 °
Year	11.9 Earth years
Solar day	9 hours 55 minutes

The Galileo Spacecraft (1989 – 2003)



How the main antenna *should* have looked



First atmospheric probe



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What Did Galileo Experience?



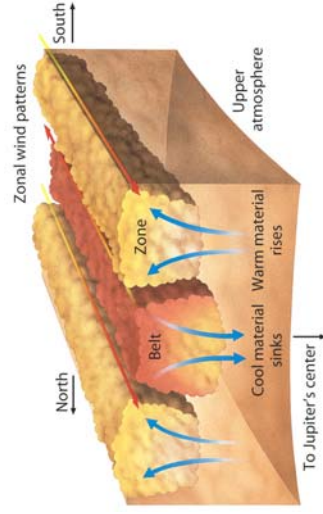
- An atmosphere unlike Earth's
 - 92% Hydrogen, 8% Helium, 0.1% other stuff
 - Very similar to the Sun's composition
 - Not too far from a binary star system
- Rich chemistry
 - Ammonia, methane, other hydrocarbons, water, phosphine, etc..
- 400 mph winds
- Incredible pressures
- Increasing temperatures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

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The Outer Atmosphere



- Alternating cloud bands parallel to Jupiter's equator
- Clouds mainly ammonia, methane, water
- Winds alternate direction (speeds of 600 km/hr!)
- Tremendous storms are created between the zones & belts



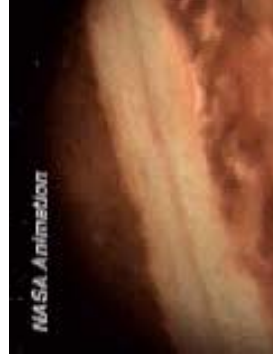
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Jupiter's Atmosphere



- Although mostly gas, by 20,000 km, 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.



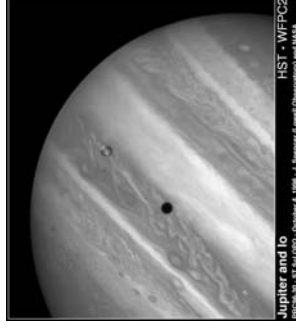
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Driving Jupiter's Weather



- 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 and Io
Photo: ST Scuderi, October 5, 1996. J. Alameri (Lunar Observatory) and MAA

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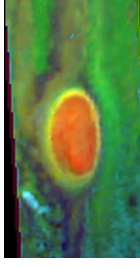
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The Great Red Spot

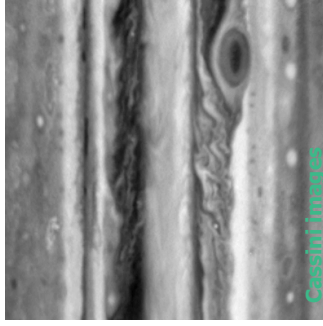


Icy ammonia (light blue) discovered by Galileo

- A huge storm 25,000 km across
- Twice size of the Earth!
- First observed over 300 years ago



Voyager 1 image



Cassini's images

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Floating Life

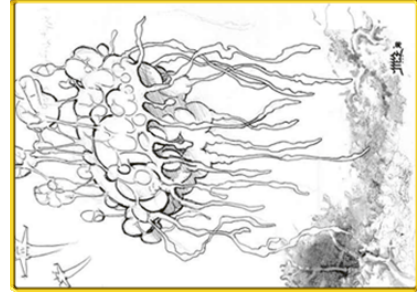


- Carl Sagan and Edwin Salpeter devised a scheme for life in the clouds of Jupiter.
- They argued that the atmosphere must be rich in organic chemistry, so why not expect Earth-like life?
- The problem is that any life in the clouds that sank too far down would be destroyed by the temperature or pressure.
- They proposed a simple life form like oceanic plankton called “sinters”.
- Small (0.1 cm) life that grew and fell, but then replicated by “splitting-up” and getting circulated back into the upper atmosphere.

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Floating Life



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

<http://www.frnix.com/smac/hutivelfe.cfm>

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Floating Life



- Maybe similar to whales—mixture between jellyfish and birds?
- Big bags of hydrogen gas.
- 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/artlist.pl?gallery=3126>

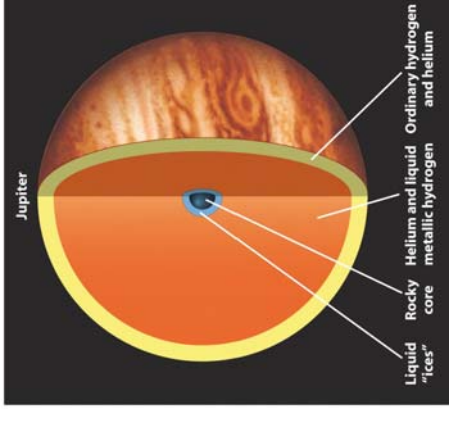
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Jupiter's Interior



- 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



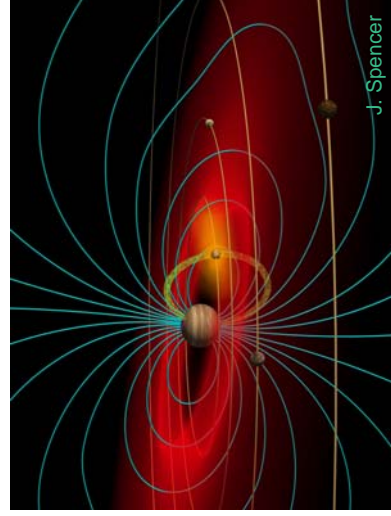
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Jupiter's Magnetosphere



- 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



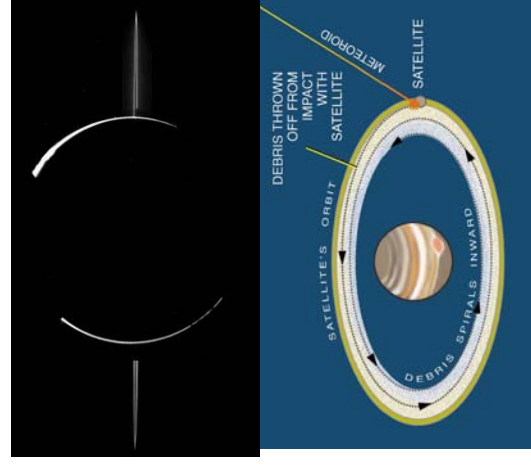
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Jupiter's Rings



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



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Jupiter's Moons



- Jupiter has a “mini-solar system” of moons
- Over 60 moons have been discovered
 - Most are small
 - Some are captured asteroids
- The 4 largest are the Galilean moons
 - Callisto, Ganymede, Europa, and Io
 - Discovered by Galileo with his telescope



Io

Europa

Ganymede

Callisto

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Callisto



- Furthest of the Galilean Moons from Jupiter
- Ancient surface, covered with craters
- Compared to our Moon:
 - 40% larger
 - 50% more massive
 - 45% less dense
- Surface is made of “dirty ice”
- Interior is rocky, mixed with ice



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Ganymede



- Largest of the Galilean Moons
- Partly ancient surface, partly younger surface
 - Younger surfaces about the age of the Moon's maria
- Compared to our Moon:
 - 50% larger
 - 100% more massive
 - 40% less dense
- Interior more differentiated than Callisto, probably has an iron core



NASA/JPL

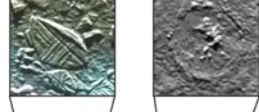
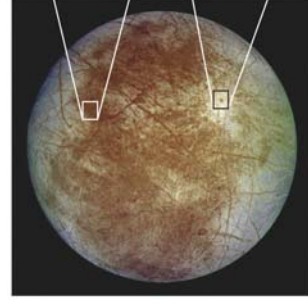
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Europa



- 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?



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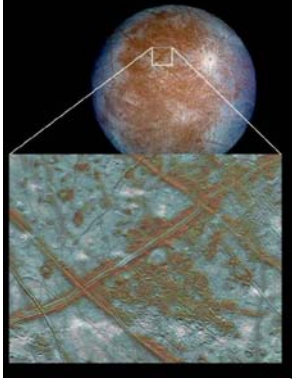
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Galileo

Europa



- Few impact craters indicate recent resurfacing.
- Life would have to be below the surface, around hydrothermal vents.
- Like Io, it probably has strong tidal forces.
- Very encouraging, as early life on Earth, might have been formed around such vents.
- We don't know how thick the ice is yet.
- To be continued.
- Future missions, will have to employ smash and dive spacecraft.

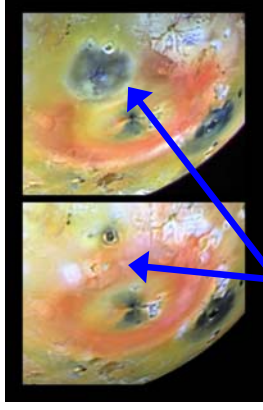


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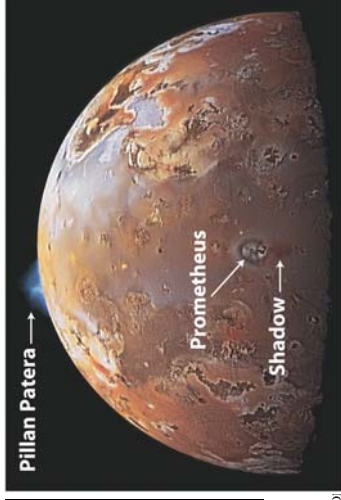
Io

- Innermost Galilean moon – the “pizza moon”
- The most volcanically active body in the solar system.
- Sulfur/sulfur dioxide on surface; silicate lava flows?
- Voyager 1 discovered presence of volcanoes
- Internal heating by Jupiter's tides
- Atmospheric gases ripped off by Jupiter's magnetic field – ion torus



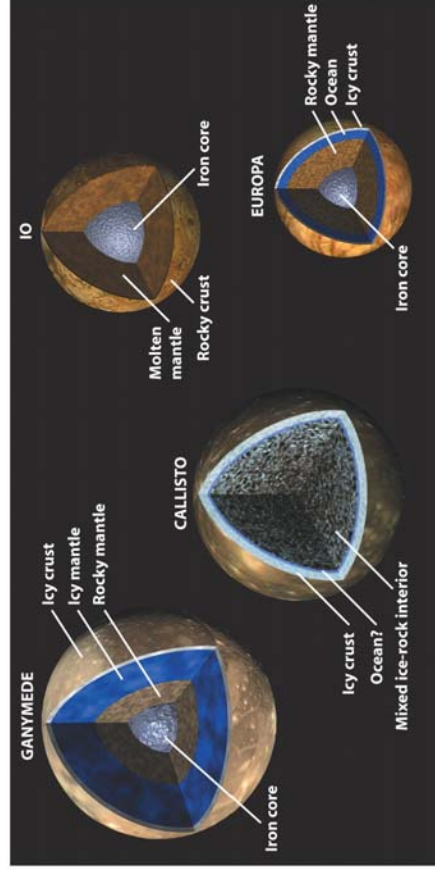
Pillan Patera eruption
Before & after

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The Galilean Moons



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All Stirred Up

- The Galileo spacecraft found the Galilean moons all have weak magnetic fields
- Tidal and magnetic forces from Jupiter act on its moons
- Stirs up their innards, makes them warm & liquid
 - Liquid conducting cores + rotation = magnetic fields
 - Also, this heating makes Io volcanic!

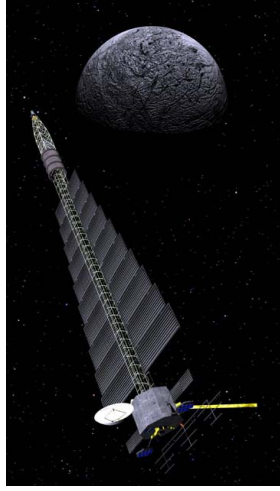
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Finding JIMO



- Jupiter Icy Moon Orbiter
 - To launch in 2015 or later
- Study Callisto, Ganymede, and Europa
 - Investigate makeup
 - Histories
 - Potential for sustaining life



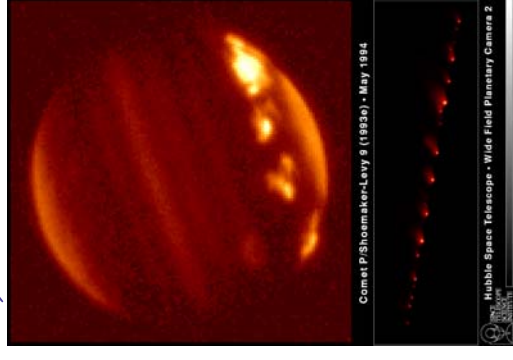
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Comet Shoemaker-Levy 9 (1993) - May 1994



- Impacts happen to Jupiter too!
- Comet SL9 broken up by repeated close approaches to Jupiter
- Huge fireballs ~ 10 km across
- Impact sites visible for months afterward



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Earth – Saturn comparison



Equatorial radius	9.45 Earth
Cloud-top gravity	1.07 Earth
Mass	95.2 Earth
Distance from Sun	9.53 AU
Year	29.5 Earth years
Solar day (equator)	10 hours 14 minutes

It floats. The least spherical planet.