Astronomy 330

This class (Lecture 13):
Life in the Solar System
Se-Joon Chung
Nicholas Langhammer

Next Class (Thursday!):
Origin of Life
Anna Dorn
Praneet Sahgal

HW 5 due Tuesday
Midterm due next Thursday.

Music: *Life on Mars*– David Bowie

Take Home Midterm

- Will email it to everyone after class today.
  - 50%: 4 short (few paragraphs) essays
  - 50%: 1 larger (~1-2 page) essay (with definition terms)
- Must be typed, not handwritten.
- Will cover material up to and including Thursday.
- It is a closed notes exam (honor system!).
- You can make 1 page of notes for use during the exam.
- Due at the start of class next Thursday (March 8th)

HW 2

- Mary Heaton
  http://alien-ufo-research.com/news/

2012 Transit of Venus

- http://www.transitofvenus.org/faq/113-when-is-the-next-transit-of-venus-after-2012
- http://www.transitofvenus.org/

Presentations

- Se-Joon Chung
  Space Travel

- Nicholas Langhammer
  Rethinking Life

Outline

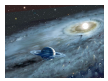
- Life on Mars
- Life on the outer planets

Drake Equation

Frank Drake

That's 16 planetary systems/year








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

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	0.8 systems/ star	planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

n_e

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

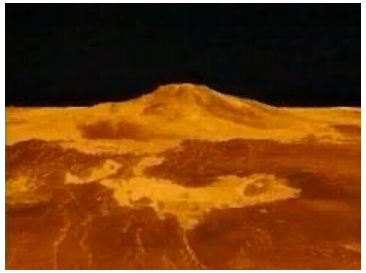
- n_p: number of planets suitable for life per planetary system
- f_s: fraction of stars whose properties are suitable for life to develop on one of its planets

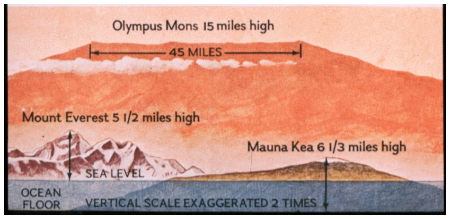
$$n_e = n_p \times f_s$$

http://nike.cecs.csulb.edu/~kjlivio/Wallpapers/Planets%2001.jpg

Olympus Mons

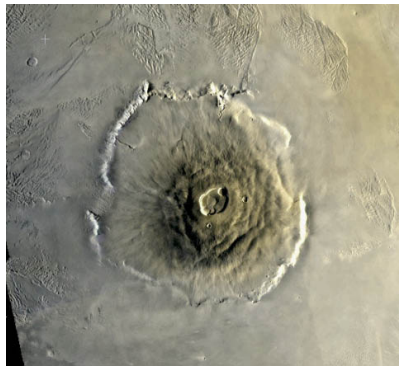
- The largest mountain in the Solar System rising 26 km high
- A shield volcano, like Hawaii on Earth
- Its caldera is 90 km across





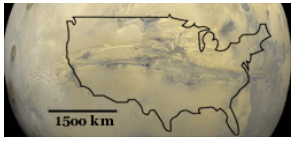
Olympus Mons

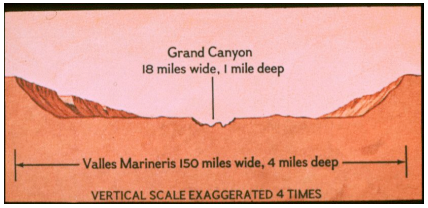
- Its base is more than 500 km in diameter
- As long as the entire Hawaiian island chain
- Rimmed by a 6 km high cliff
- Last erupted 25 million years ago
- Probably so big, due to lack of plate tectonics



Valles Marineris

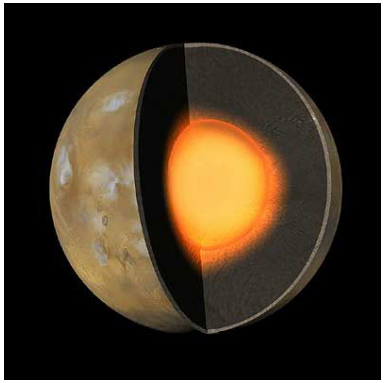
- A series of fault canyons
- 5000 km long
  - A big as the U.S.!
- A giant crack in the crust of Mars
  - Formed as the planet cooled
  - Expanded by water flow





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



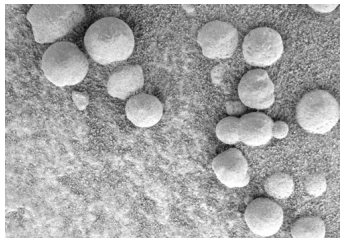
Mars' Watery Past

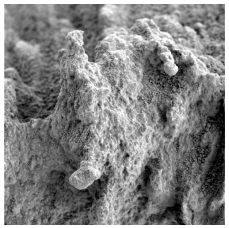
Mars' Past

- 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 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?

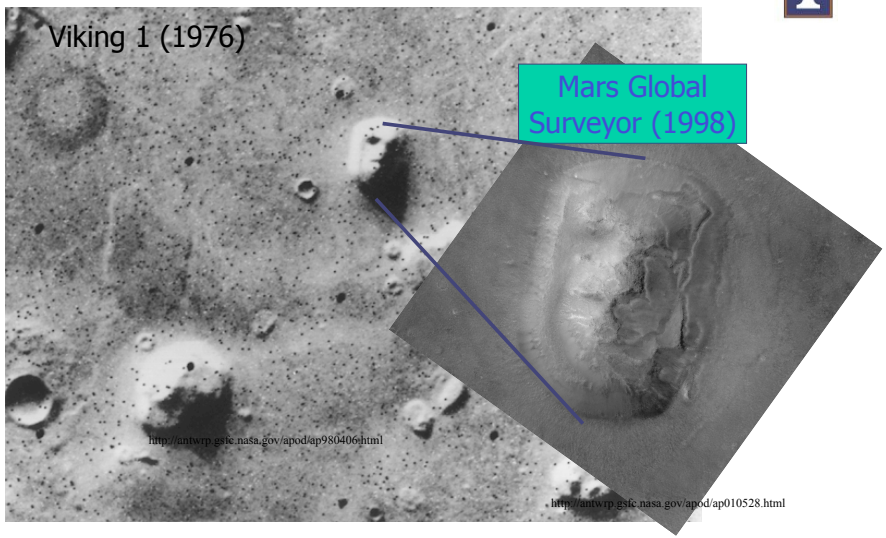




What Happened?

- 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 evolve and then move underground?

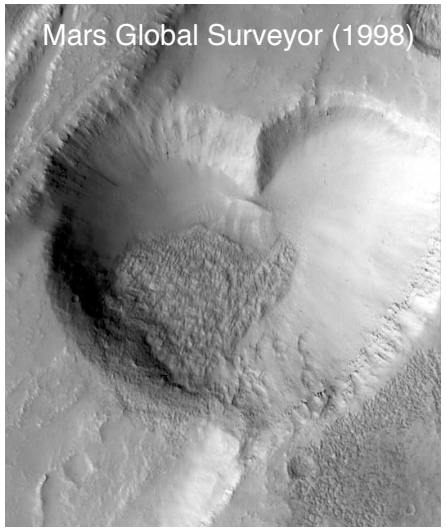
The "Face" of Mars?



Other Faces

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

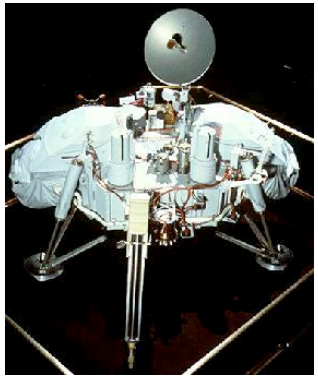
Other Places



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

The Search for Mars Life

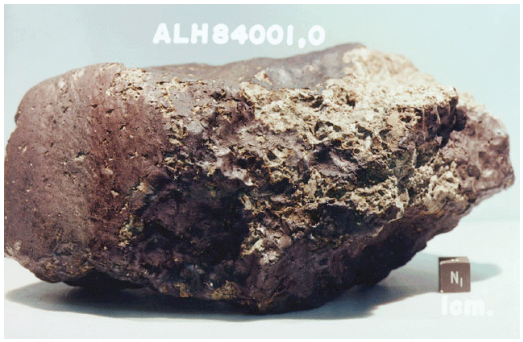
- Viking 1 and 2 carried several experiments to detect life
- The results were ambiguous. The soil reacted vigorously with the Viking nutrients, then tapered off in activity.
- The conclusion of most scientists is that the reactions were due to inorganic chemical reactions.
- It has been suggested that Mars might harbor peroxide-based life forms that 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

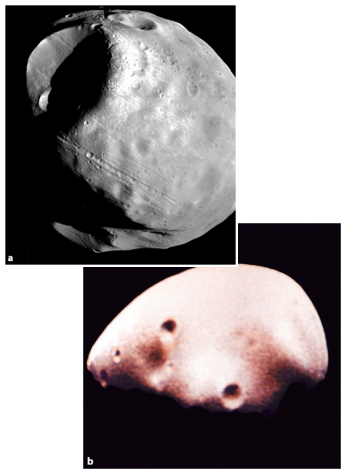


Martian Microbe Fossils?

- 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 compelling 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.

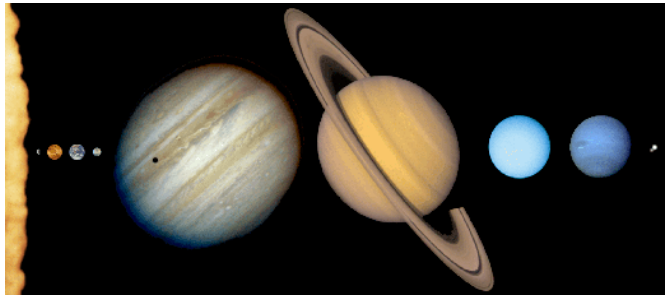
Question

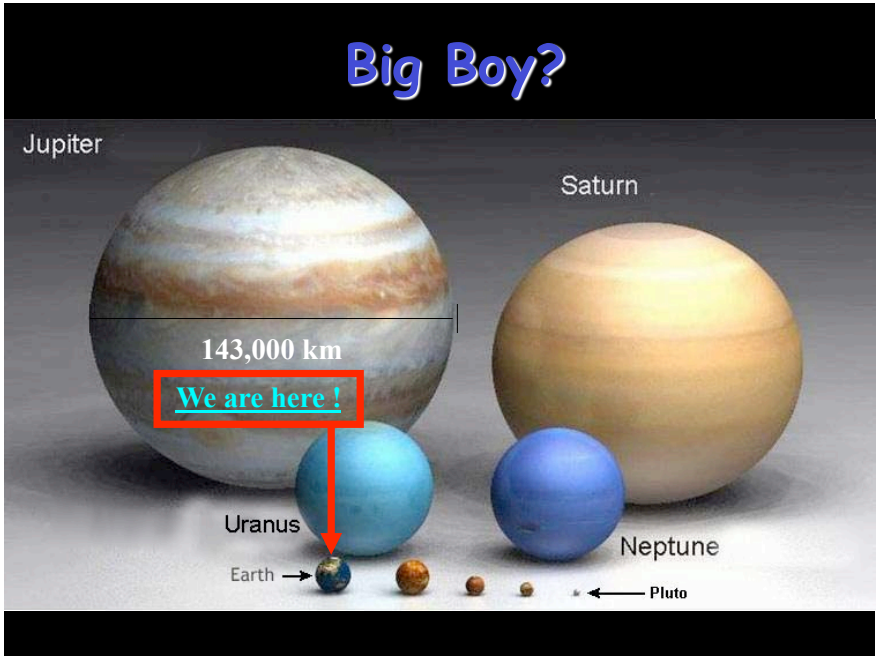
The face on Mars

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 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.

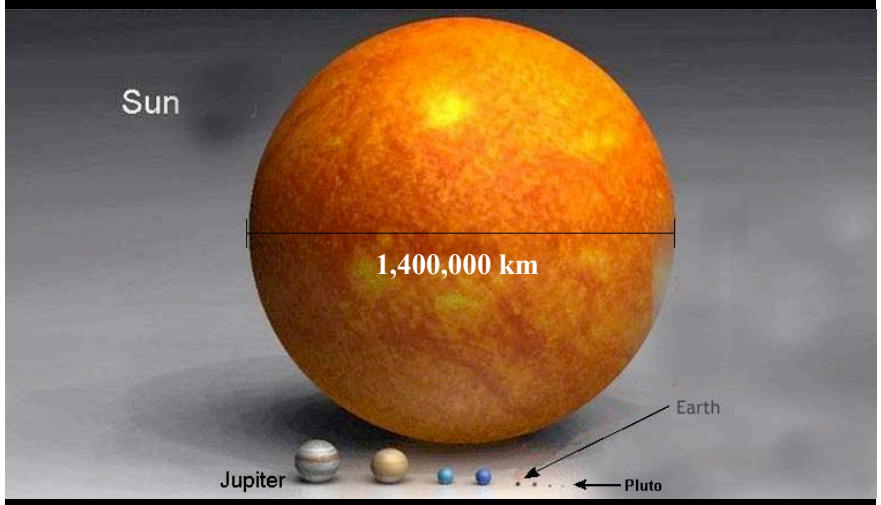
Life in the Solar System

- 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.





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

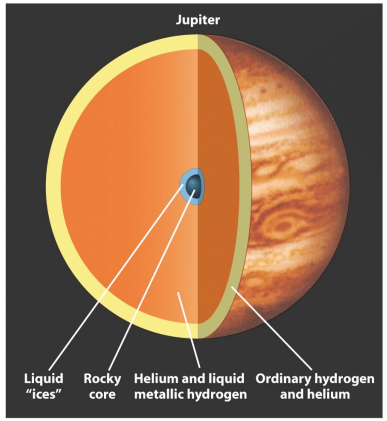
Causes a bulge at the equator.

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

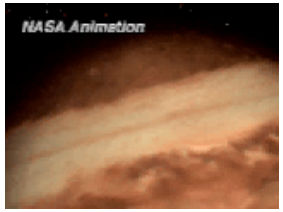
Jupiter's Interior

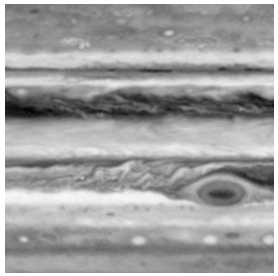
- Average density only 30% greater than water
- 25% that of the Earth's average density
- By 20,000 km, the pressure is 3 million times that on the Earth's surface!
  - Hydrogen becomes a liquid metal
- Core of rock & "ice" 10-12 Earth masses



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.





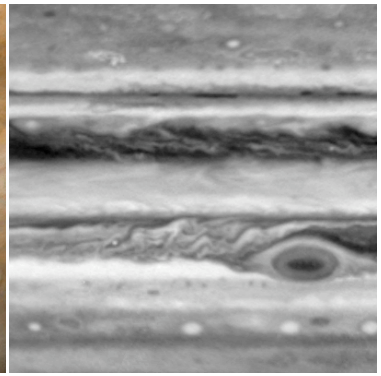
Driving Jupiter's Weather

- 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

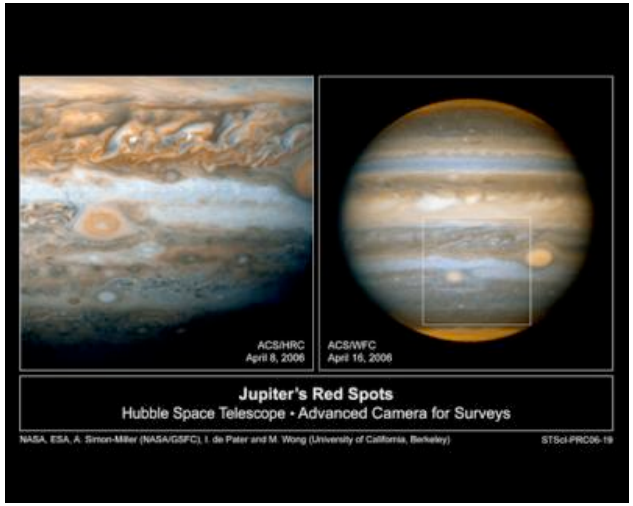
- A huge storm 25,000 km across – twice size of the Earth!
- First observed > 300 years ago!

Voyager 1 image



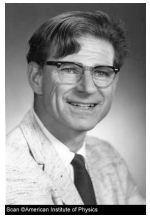
Cassini images

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?

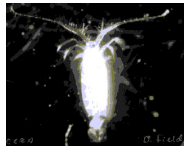


http://tierra.rediris.es/merge/Carl_Sagan/192a.jpg

http://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

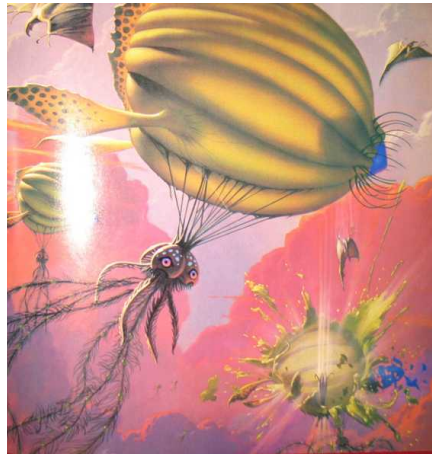
Floating Life

- 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

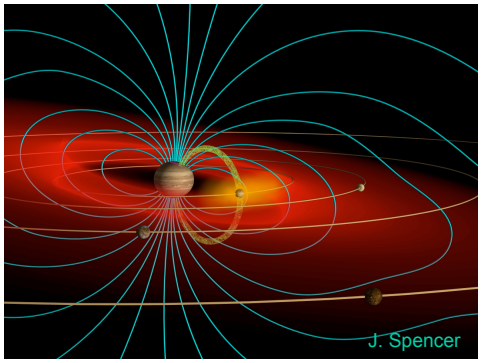
Floating Life

- 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

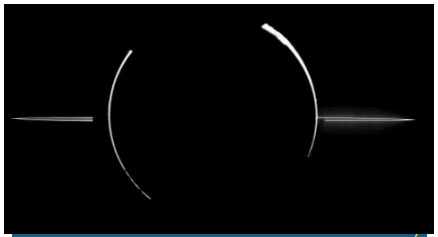
Jupiter's Magnetosphere

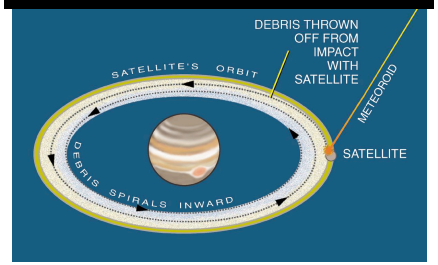
- Liquid metal hydrogen generates a magnetic field
  - 14x stronger than Earth's field
  - Over 4 million km across
- A ring of ionized particles surrounds Jupiter
  - Stripped from Jupiter's moon Io



Jupiter's Rings

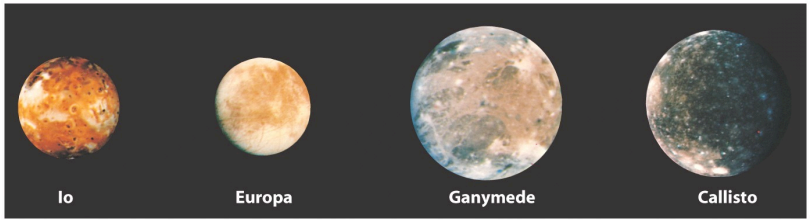
- Jupiter has rings!
- Discovered by the Voyagers
- Not prominent like Saturn's
- Dusty disk of debris, probably from meteoroid impacts with small moons





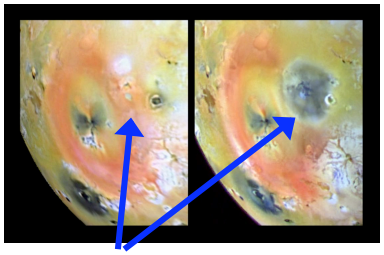
The Galilean Moons

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

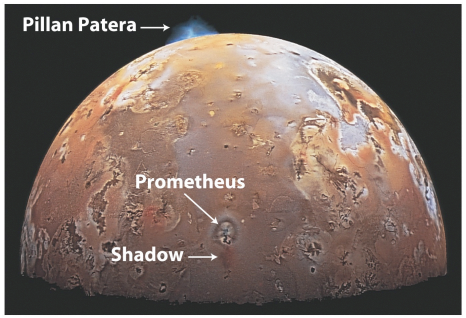


Io

- 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

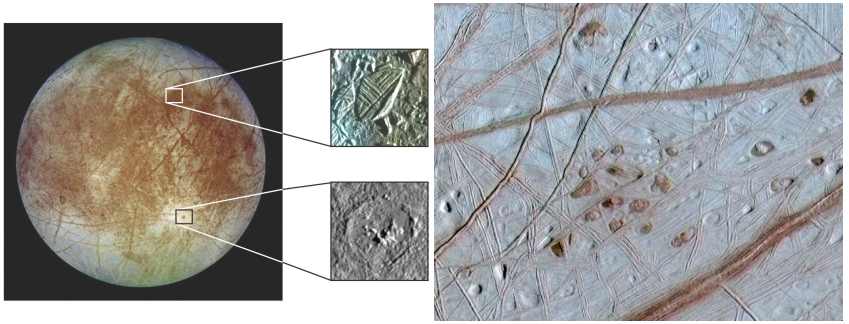


Pillan Patera eruption
Before & after



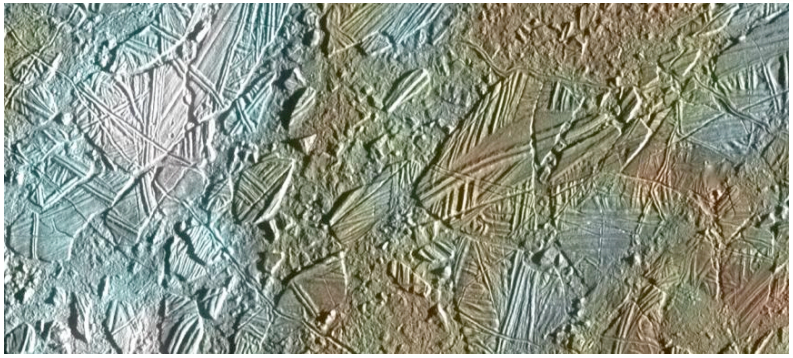
Europa

- 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

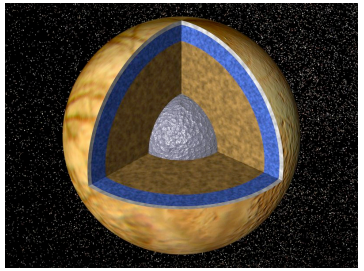
Europa



- 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 how thick the ice is yet.
- Future missions, will have to employ melting or smash and dive spacecraft.



Ganymede

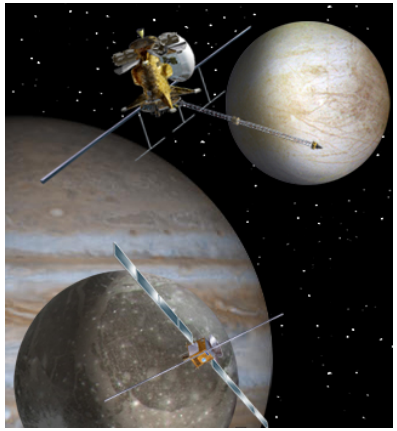
- Largest of the Galilean Moons
- Partly ancient surface, partly younger surface
  - Younger surfaces about the age of the Moon's maria
- Compared to our Moon:
  - 50% larger
  - 100% more massive
  - 40% less dense
- Interior more differentiated than Callisto, probably has an iron core
- May have a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

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

Europa Jupiter System Mission

- Early planning stages of NASA/ESA/JAXA mission.
- Two or three orbiters
  - Launch date around 2020

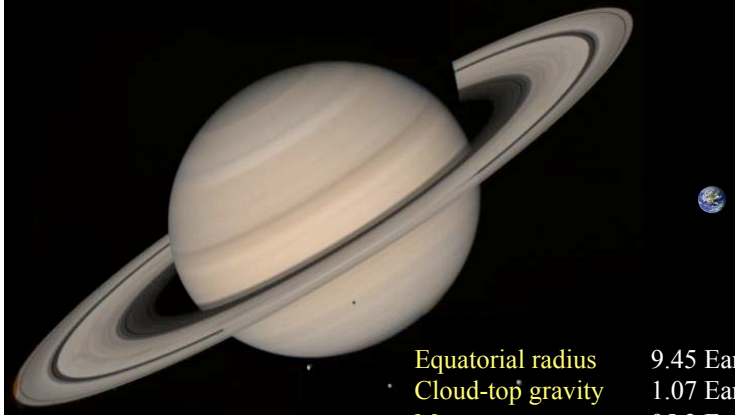


Question

The best place to look for life in the Jupiter system is

a) in the frozen oceans of Callisto.
b) in the frozen oceans of Ganymede.
c) in the upper atmospheres of Jupiter, floating life.
d) deep in the atmosphere of Jupiter, diamond bodied life to withstand the pressures.
e) under the ice on Europa.

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.

Jupiter-Saturn Comparison

Equatorial radius	0.84 Jupiter
Mass	0.30 Jupiter
Density	0.52 Jupiter

Almost as big as Jupiter, but Much less massive!

Saturn

- Named for the father of the Roman gods
- Saturn is very similar to Jupiter
  - Large planet
    - Mostly liquid hydrogen
  - Has a mini-solar system
    - At least 60 moons
    - Most are small

http://www.solarviews.com/cap/sat/saturn.htm

http://saturn.jpl.nasa.gov/cgibin/gs2.cgi?path=../multimedia/images/saturn/images/PIA05380.jpg&type=image

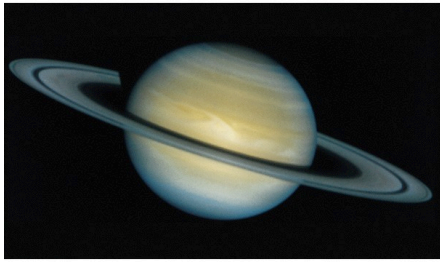
Missions to Saturn

- There have been 4 unmanned spacecraft missions to Saturn
- Pioneer 11
  - Flyby 1979
- Voyager 1
  - Flyby 1980
- Voyager 2
  - Flyby 1981
- Cassini-Huygens
  - Arrived 2004

The Cassini Mission

- Launched on October 15th, 1997
- Arrived at Saturn on July 1st, 2004
- Orbiting Saturn, making flybys of the planet, its rings, and some of its moons
- Contains 12 scientific instruments
- Also carries the Huygens probe, which was dropped onto Titan, Saturn's largest moon on Jan 2005. Remember?

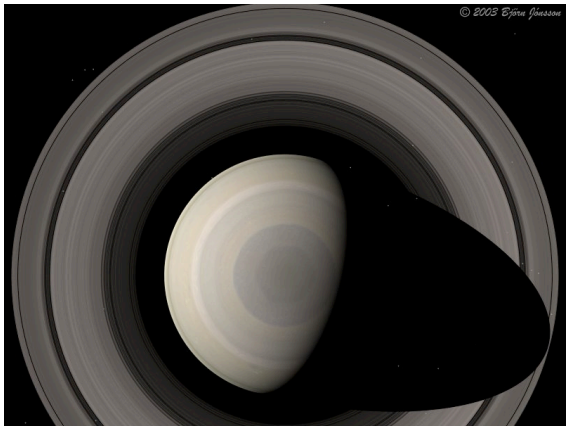
Saturn's Atmosphere



- Composition similar to Jupiter
  - Mostly hydrogen and helium
- Atmosphere more "spread out"
  - Less gravity
  - Contrast of cloud bands reduced
- Wind speeds fastest at the equator
  - 1000 km per hour!

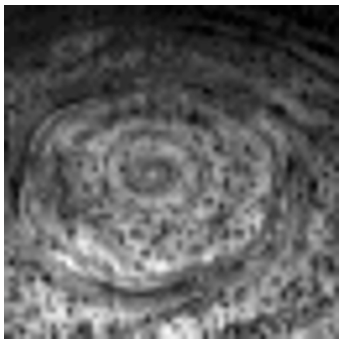
Driving Saturn's Weather

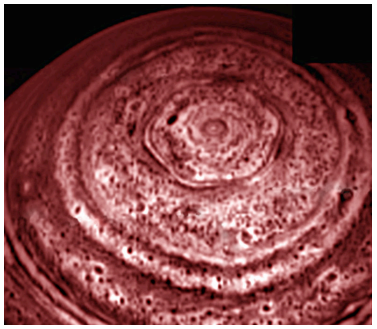
- As on Jupiter, Saturn's internal heat drives weather
  - Saturn radiates 80% more heat than it receives from the Sun
  - Like Jupiter, Saturn is still contracting!
  - As is contracts, heat is produced



Driving Saturn's Weather

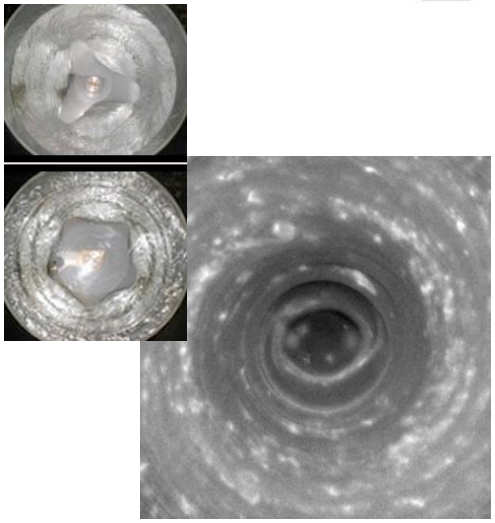
- As on Jupiter, storms are produced between cloud bands
  - No long lasting storm like the Great Red Spot, but hexagon cloud at pole has been stable for 20+ years.





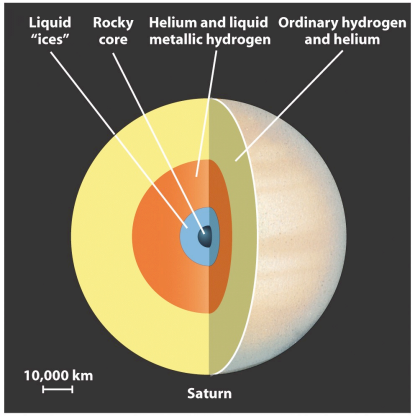
Driving Saturn's Weather

- Spinning water bucket experiments show similar features.
- Pseudoscience posit sound wave reflections.
- Saturn's South Pole also has an unusual structure.



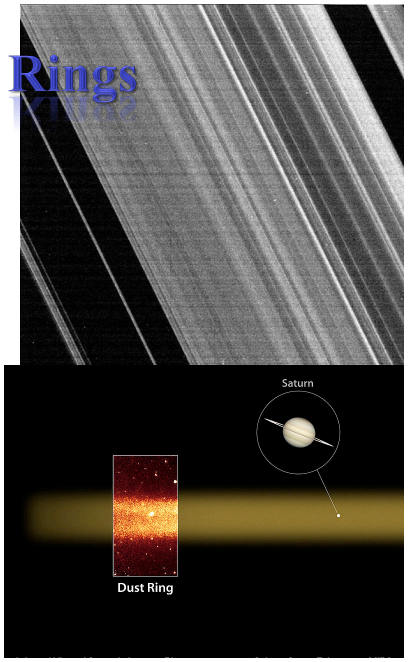
Saturn's Interior

- Similar structure to Jupiter's
  - But Saturn is less massive
  - The interior is less compressed
- Liquid metallic hydrogen creates a magnetic field
  - 30% weaker than Earth's



Saturn's Rings

- Two main rings
  - Several fainter rings
  - Each ring is divided into *ringlets*
- The rings are **thin**
  - Only a few tens of meters thick– razor thin!



Makeup of the Rings

- The rings of Saturn are **not** solid rings
  - Made of icy rocks
  - 1cm to 10m across
- New Cassini data shows ring particle size varies with distance from Saturn
  - Note the gap is filled with small particles