1

Observing the Moon, Planets & Stars
Osher Spring 2009, SCU

Meeting 5
More on Moon & Saturn

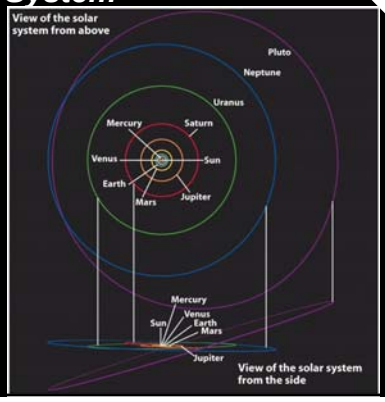
May 6, 2009
7:30-9:30 pm
Kenna 109

"Dr. Bill" Pezzaglia
www.clifford.org/~drbill
http://www.clifford.org/drbill/osher

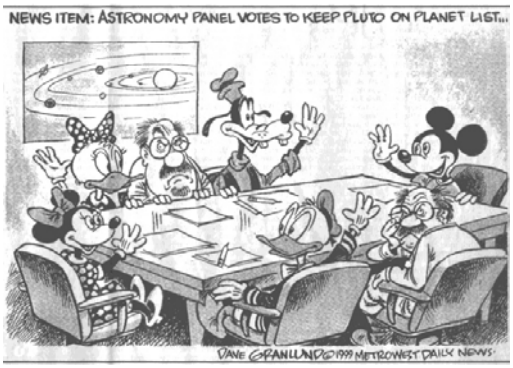
The Solar System

2

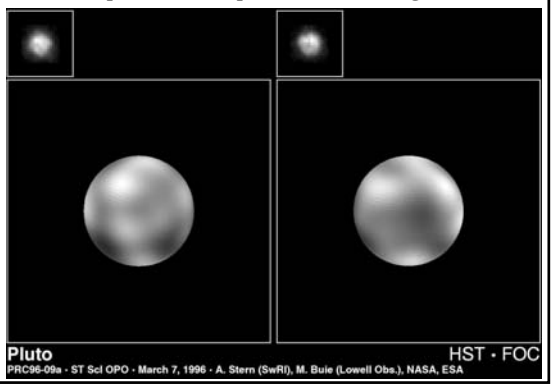
All planets lie in the ecliptic plane (except pluto)



A.4 What about Pluto ?



Hubble Space Telescope: Our best image of Pluto



Pluto and the ***New Horizons*** Mission

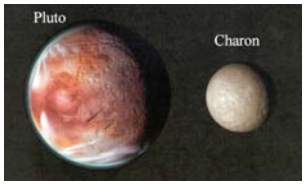


TABLE 6.1 *Mass of Members of the Solar System*

Object	Percentage of Total Mass
Sun	99.80
Jupiter	0.10
Comets	0.05
All other planets	0.04
Satellites and rings	0.00005
Asteroids	0.000002
Cosmic dust	0.0000001

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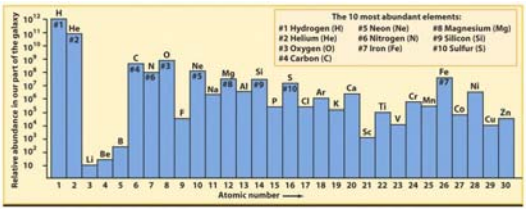
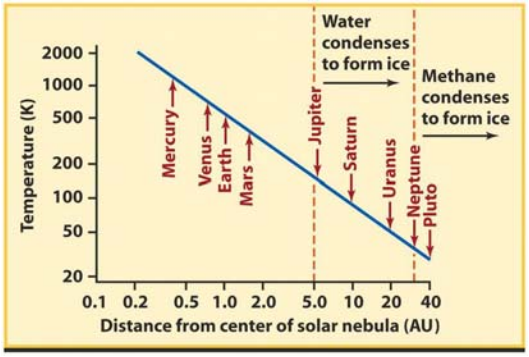
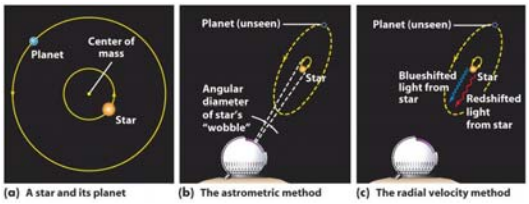
Table 6-1, p.136

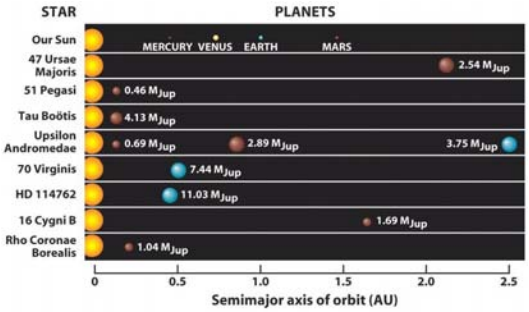
Elements in the Solar system





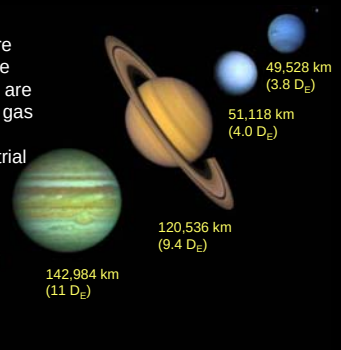
Discovery of Planets around other stars!





Jovian Planets (Gas Giants)

The outer planets are much bigger than the terrestrial ones, and are gigantic low-density gas balls unlike the high density rocky terrestrial planets.



Jupiter: Atmosphere 1

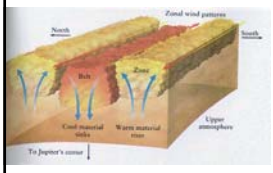
- Horizontal stripes
  - Zones "light"
  - Belts: "dark", lower level
- Great Red Spot
  - large storm
- Smaller white spots
  - smaller storms
- With spacecraft, lots of other cloud features

Jupiter: Atmosphere 2

- Differential Rotation
  - Observe rotation period by tracking atmospheric features
    - 9h 50m 28s at equator (fastest rotation of all planets in SS)
    - 9h 55m 41s at poles
  - Solid bodies must have same rotation everywhere

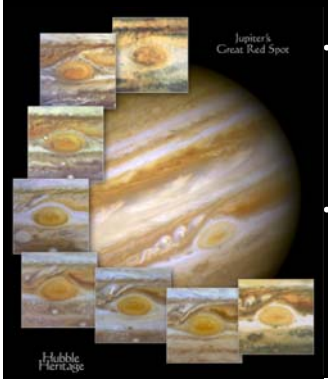
=> evidence that Jupiter is not a solid body

Jupiter: Belts and Zones



- Alternating light/dark stripes in atmosphere
- Convection – warm air rises from below, cools off, then sinks (same as Earth's troposphere)
- Rapid rotation stretches these convection cells across the planet

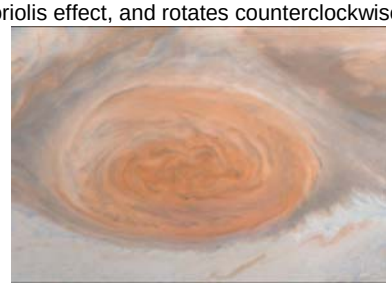
Jupiter: Storms



- Great Red Spot
  - about size of Earth
  - At largest, has been seen at 3x Earth size
  - Rotates ccw
  - more than 300 yrs old
- White ovals
  - smaller, less long-lived
  - also rotate ccw

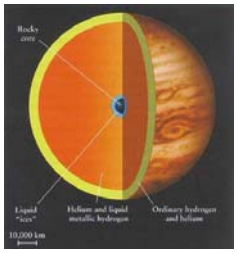
Great Red Spot = high pressure system.

Air flows outward, is deflected to the left by the Coriolis effect, and rotates counterclockwise.



Great Red Spot was first seen in 1664!

Jupiter: Internal Structure



- Core ~ 7,000 km thick
  - 8x Earth mass, smaller size

  => very dense (also high T,P)

  "rocky"= Fe, Si, O, but in different forms than we're used to
- Liquid ices ~ 7,000 km thick
- He & liquid metallic H ~ 45,000 km thick
  - electrons free to move
- Gaseous H and He ~ 12,000 km thick
  - cloud layers in top 100km of this layer

Saturn: History / Early Observations

- Visible without telescope
- 1610 – Galileo first sees rings
- 1665 – Huygens discovers Titan

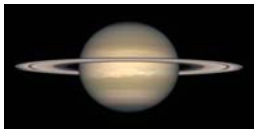
Density

- 0.69 g/cm3 (lowest of planets in SS)
  - slightly smaller size
  - significantly smaller mass

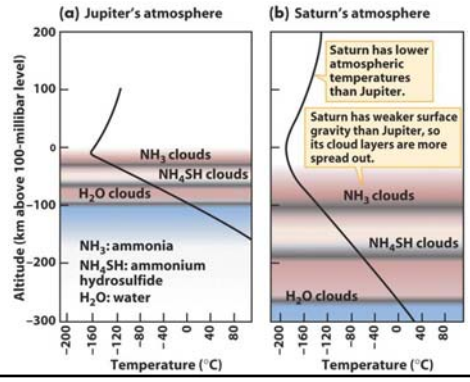
13 inch telescope from Earth
http://www.stellafane.com/schupmann/schupmann.html

Saturn: Atmosphere 1

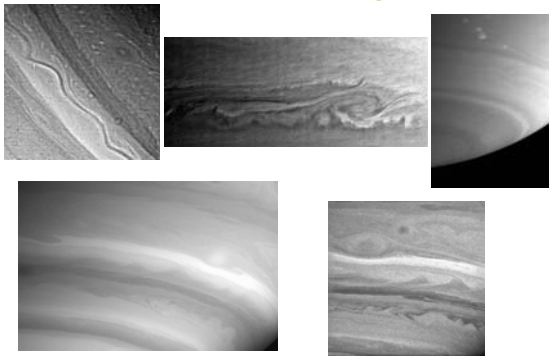
- Similar basic atm structure and colors as Jupiter
  - Belts and zones
  - Storms
    - No long-lived analog to great red spot
    - several analogs to white spots
  - Many other cloud features



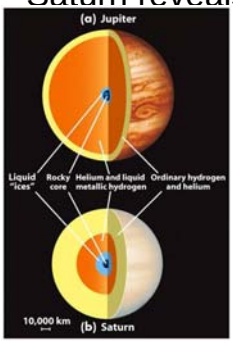
Saturn: Atmosphere 2



Saturn storm images



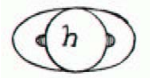
The oblateness of Jupiter and Saturn reveals their rocky cores



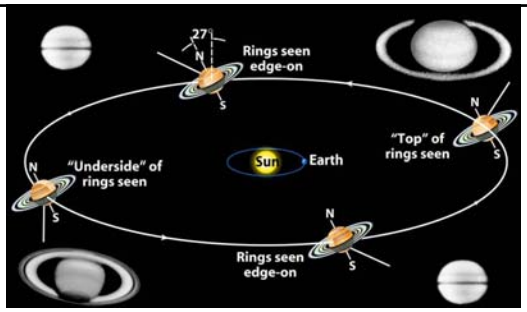
- Jupiter probably has a rocky core several times more massive than the Earth
- The core is surrounded by a layer of liquid "ices" (water, ammonia, methane, and associated compounds)
- On top of this is a layer of helium and liquid metallic hydrogen and an outermost layer composed primarily of ordinary hydrogen and helium
- Saturn's internal structure is similar to that of Jupiter, but its core makes up a larger fraction of its volume and its liquid metallic hydrogen mantle is shallower than that of Jupiter

Saturn's Rings

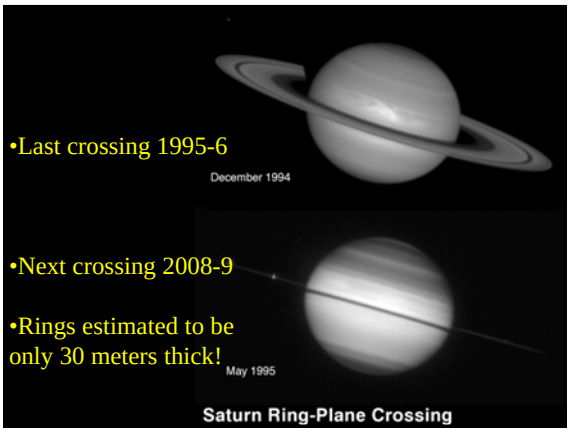
- 1610: Galileo looks at Saturn, notices it is not circular.
- Bulges on sides disappear in 1612, reappear in 1613



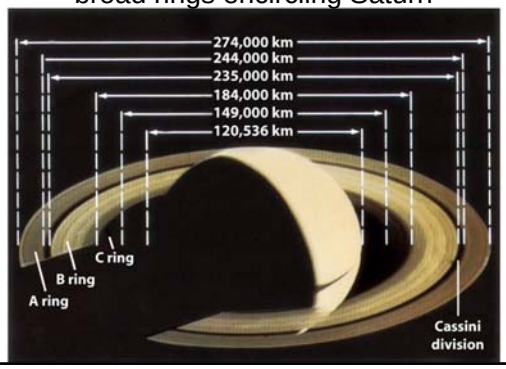
- 1655: With a better telescope, Huygens discovers ring, tilted by 27°



- Huygens explains why the rings disappear. They are very thin, and when seen edge twice a saturn year, they vanish!



Earth-based observations reveal three broad rings encircling Saturn

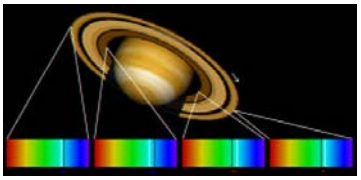


Encke Division (1838)

A more subtle division is found in the "A" ring

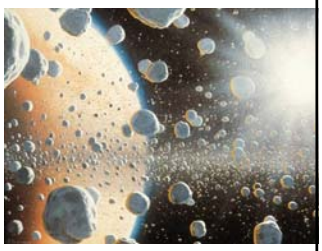
Rings are not solid!

- 1857 Maxwell argues cannot be solid (centrifugal forces would tear it apart)
- 1895 Keeler measures Doppler velocities, each "ringlet" has different speed
- Rings consist of many "moonlets", each orbiting the central planet.
- 80% reflectivity implies they are icy particles



1970 Voyager Probes

- From scattering of radio signals through the rings, estimate average particles are 10 cm in size
- Some are as small as 1 cm, some as big as 5 meters.
- In comparison the ring particles of the other planets are:
  - Jupiter's are small dust particles smaller than 1 mm
  - Uranus particles are perhaps 1 meter in size
  - Neptune size unknown (similar to Uranus?)

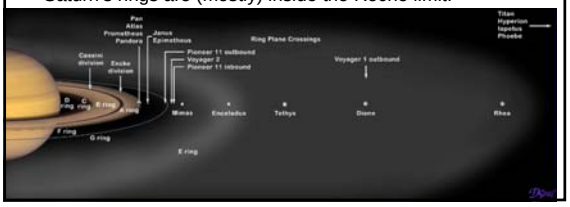


Source of Saturn's Rings

- The ice in Saturn's rings would make a moon about 100 km across. Where had all that ice come from?
- Leading hypothesis: the rings were originally a moon that was pulled apart by Saturn's tides.
- Rings are temporary, they will dissipate unless refreshed
- Rings get "dirty" over time, less reflective
- Saturn's rings must be very young (100 million years?)

Roche Limit (2.4 Saturn Radii)

- The moon's own gravity tends to **hold it together.**
- Tidal forces from planet tend to pull it apart
- The "Roche Limit" is the critical distance where the two balance
- Saturn's moons are (mostly) outside of Roche Limit
- Saturn's rings are (mostly) inside the Roche limit.

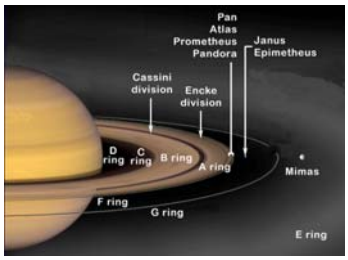


Saturn's Rings: Natural Color

Gaps in Saturn's Rings

Gaps in the rings are caused by ***resonances*** with the satellites
Example: Mimas causes the Cassini Division

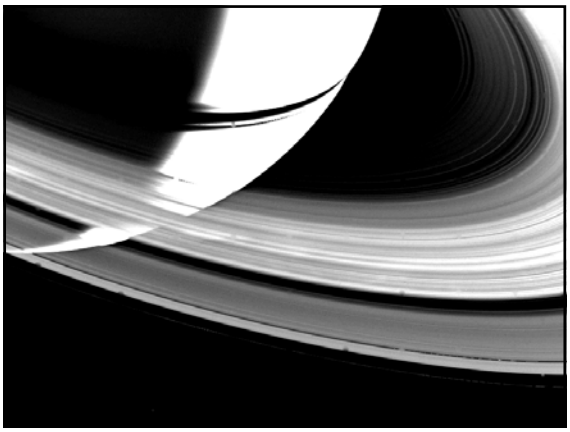
Mimas makes one revolution in 23 hours. A ring particle in The Cassini Division makes one revolution in 11 ½ hours, or two revolutions in one Mimas period. This is ***resonance.***



What is "resonant motion"?

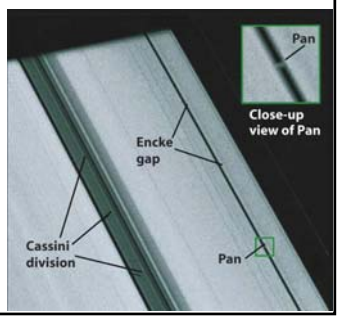
When you push someone in a swing, each time they come back, you give a new push to keep them going. This is ***resonant motion***.

Each time a ring particle comes between Saturn and Mimas, it gets a <u>pull from Mimas</u>, causing its orbit to become ***eccentric***. This increases the likelihood that it will collide with another particle and be destroyed.

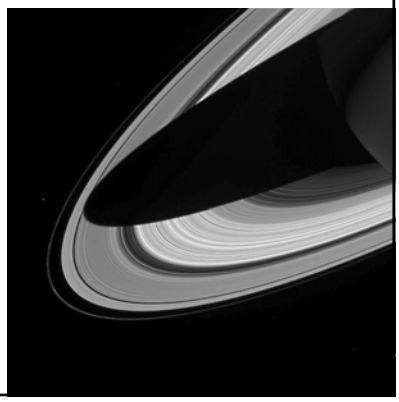


Encke Division

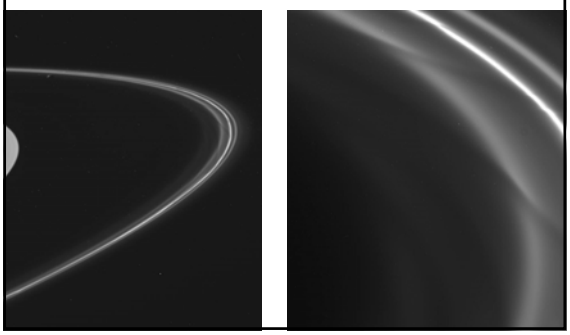
Probably created not by resonance, but by the small moon "Pan" which shares the orbit.



F Ring from Cassini probe close approach, July 3, 2004

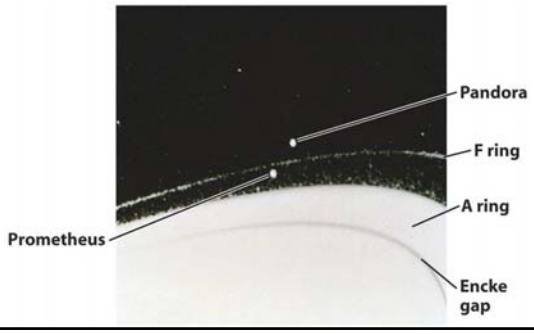


Saturn's F-ring from Cassini

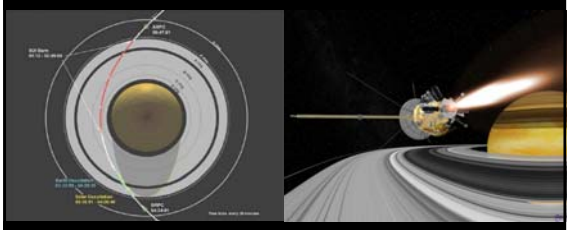


F Ring Shepherd Moons

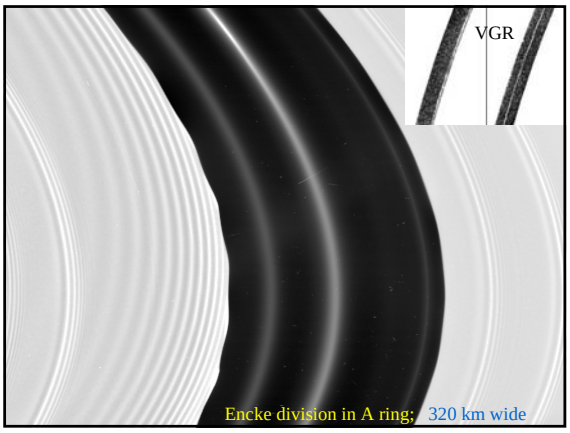
These two moons keep the narrow F ring in place.



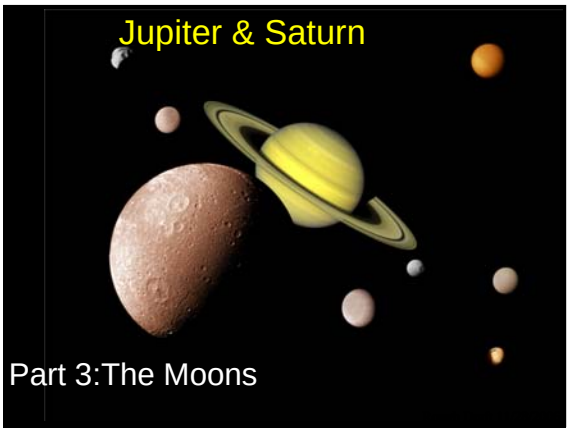
Cassini Saturn Orbit Insertion (SOI)



June 30, 2004, 7:30 - 9:15 PDT

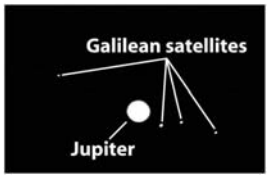


Jupiter & Saturn



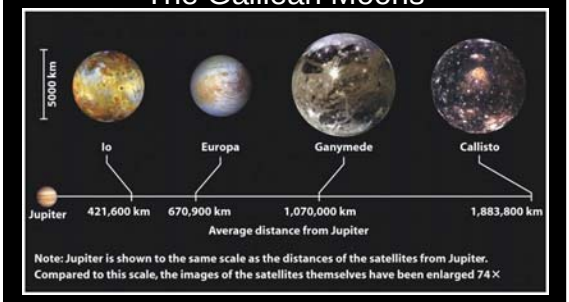
Part 3:The Moons

Jupiter's Galilean satellites are easily seen with Earth-based telescopes



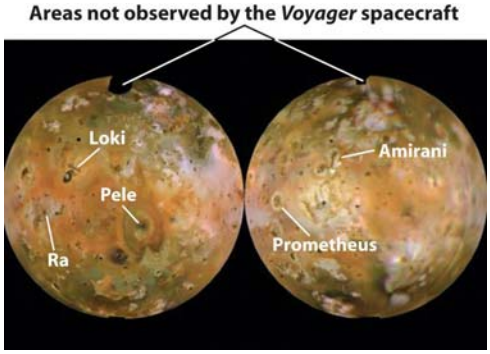
- The four Galilean satellites orbit Jupiter in the plane of its equator
- All are in synchronous rotation
- The orbital periods of the three innermost Galilean satellites, Io, Europa, and Ganymede, are in the ratio 1:2:4

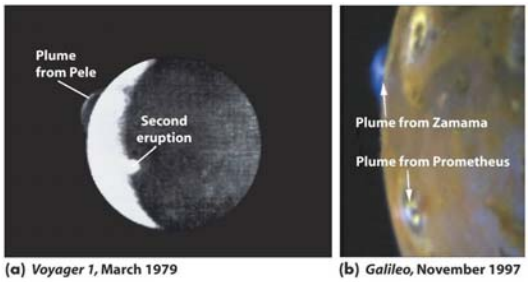
The Galilean Moons



Io is covered with colorful sulfur compounds ejected from active volcanoes

Areas not observed by the *Voyager* spacecraft



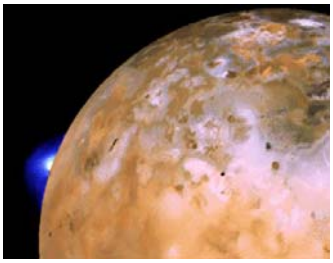


(a) *Voyager 1*, March 1979 (b) *Galileo*, November 1997

Io

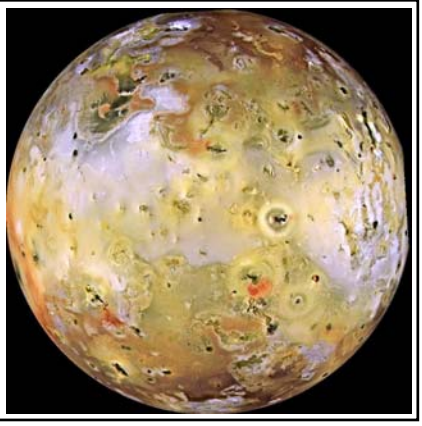
Active volcanoes were found on Io in 1979 by the Voyager Spacecraft.

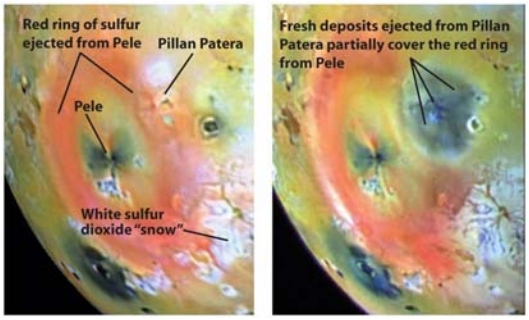
They were studied in greater detail by the Galileo spacecraft, which orbited Jupiter for about 10 years.

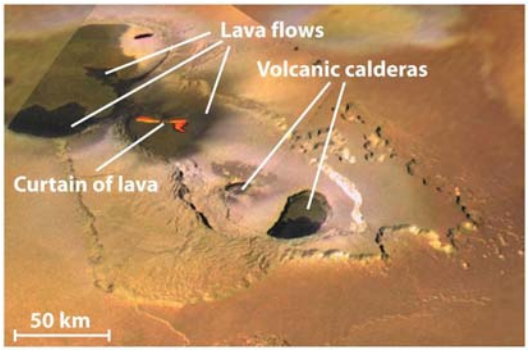


Io

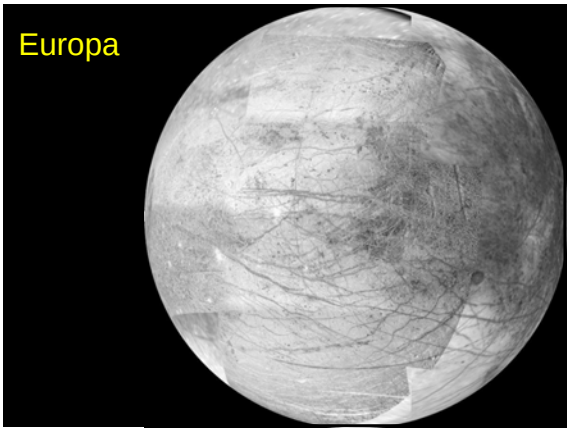
How can a small body like Io remain hot enough inside to produce such vigorous volcanic activity ?????







Europa

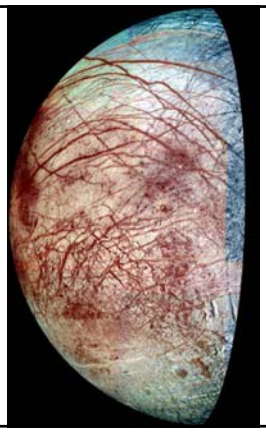


Europa

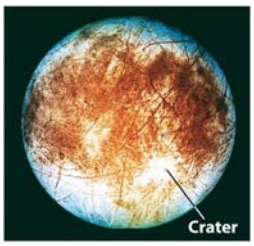
Europa has no impact craters. It's icy surface shows an intricate network of crossing cracks, similar to cracks in the Arctic ice pack on Earth.

There is very little vertical relief (no mountains or deep valleys).

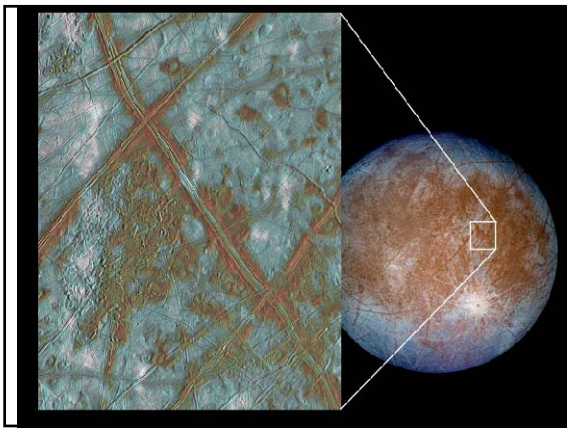
Europa's surface is very young.

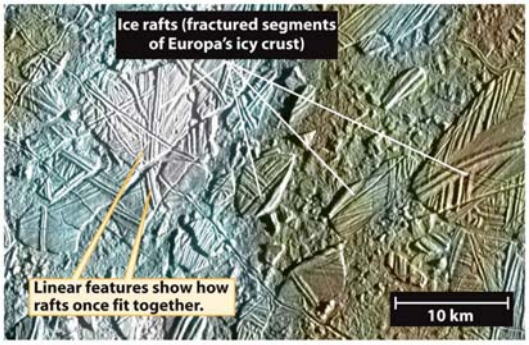


Europa is covered with a smooth layer of ice that may cover a worldwide ocean



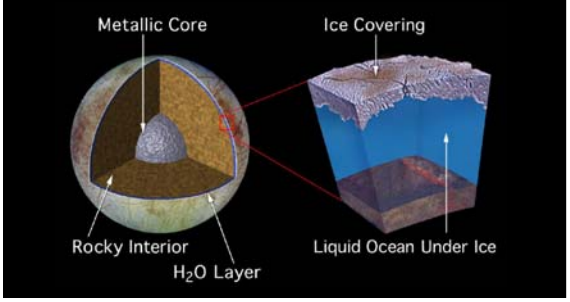
- While composed primarily of rock, Europa is covered with a smooth layer of water ice
- The surface has hardly any craters, indicating a geologically active history
- As for Io, tidal heating is responsible for Europa's internal heat
- Minerals dissolved in this ocean may explain Europa's induced magnetic field



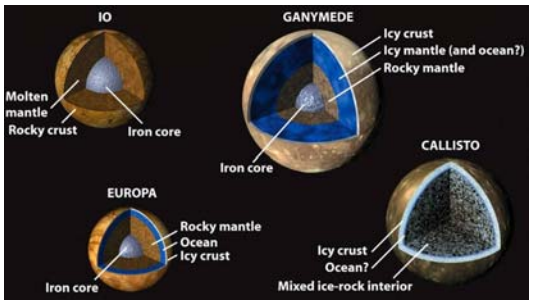


Ice rafts on Europa

Europa is heated by gravitational effects of Ganymede and Jupiter (like Io), and therefore it has an interior layer ("mantle") of liquid water.

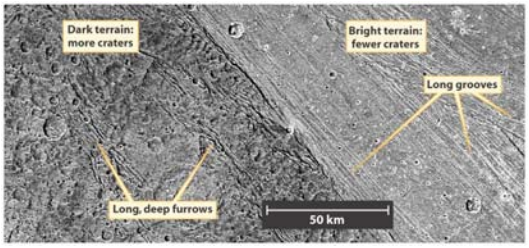


Liquid water may also lie beneath the cratered surfaces of Ganymede and Callisto

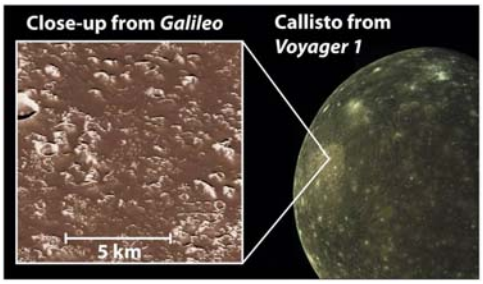


Ganymede

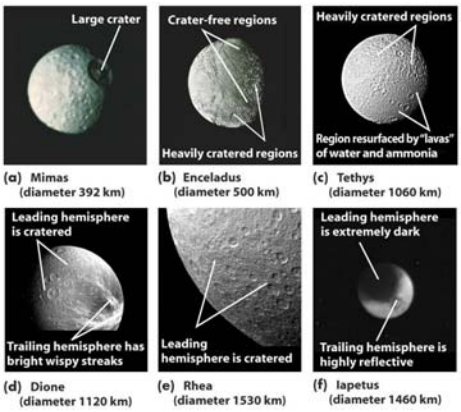
- Ganymede is highly differentiated, and probably has a metallic core
- It has a surprisingly strong magnetic field and a magnetosphere of its own
- While there is at present little tidal heating of Ganymede, it may have been heated in this fashion in the past
- An induced magnetic field suggests that it, too, has a layer of liquid water beneath the surface



- Two types of terrain are found on the icy surface of Ganymede:
  - areas of dark, ancient, heavily cratered surface
  - regions of heavily grooved, lighter-colored, younger terrain

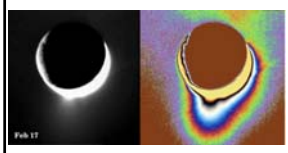


- Callisto has a heavily cratered crust of water ice
- The surface shows little sign of geologic activity, because there was never any significant tidal heating of Callisto
- However, some unknown processes have erased the smallest craters and blanketed the surface with a dark, dusty substance
- Magnetic field data seem to suggest that Callisto has a shallow subsurface ocean



Enceladus (Moon of Saturn)

Geysers of erupting liquid water announced in March 2006, discovered by the Cassini spacecraft



This is probably the source of the "E" ring

Titan: Largest Moon in the Solar System

Orbital period around Saturn is 16 days

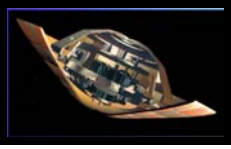
Thick atmosphere made mainly of N_2 (nitrogen) with a small amount of CH_4 (methane), which is a hydrocarbon.

Many other hydrocarbons also present.

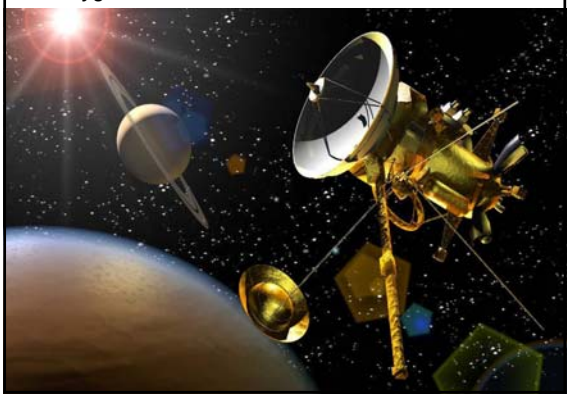
Titan is being explored by the Cassini spacecraft as it orbits Saturn.

The Huygens probe was detached from Cassini and entered Titan's atmosphere in January 2005.

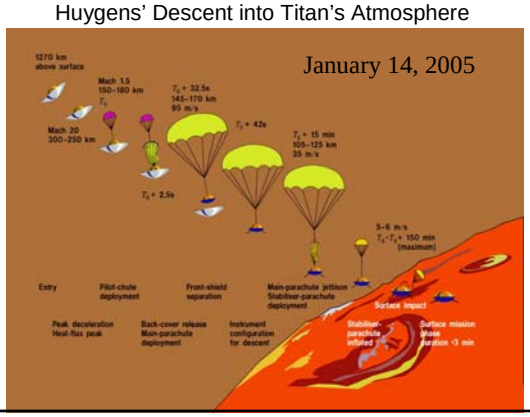
It descended through the atmosphere, making scientific measurements, and landed on Titan's surface, where it continued to make measurements for a few hours.

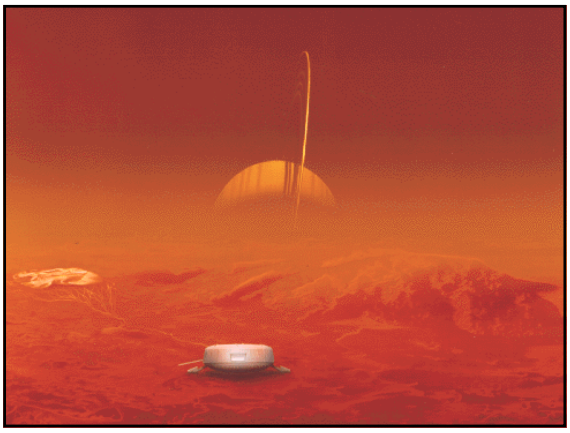


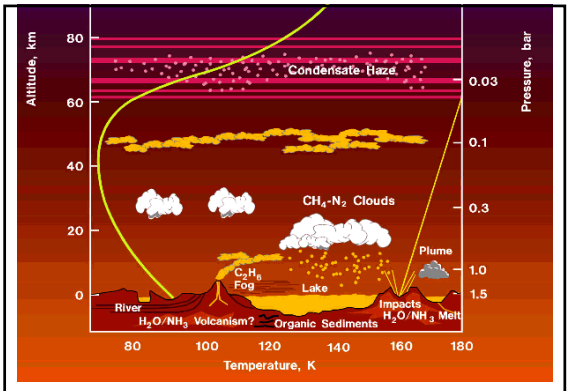
Huygens Probe Jettisoned, December 25, 2004



Huygens' Descent into Titan's Atmosphere





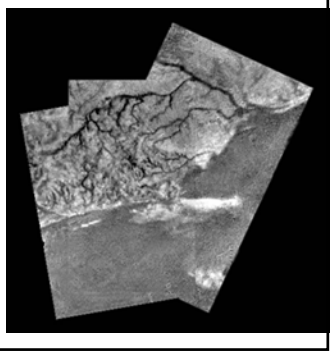


Titan's Atmosphere and Surface

Huygens finds flow channels on Titan

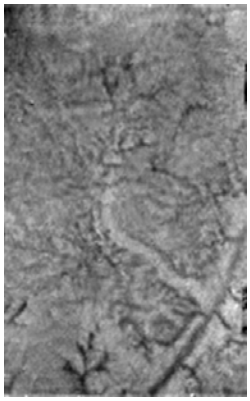
Images from the descent Probe cameras

- Hydrocarbon dust forms in atmosphere
- Dust settles on land (H_2O ice)
- Methane (CH_4) rains on Titan, washing hydrocarbon dust into streams and lakes



Titan's Surface

- Liquid methane may emerge from springs, forming channels as it flows downhill



- Titan landscape from Huygens lander, January 14, 2005
- Rounded boulders in foreground are about 4 - 15 cm across.
- The boulders are probably frozen H_2O.