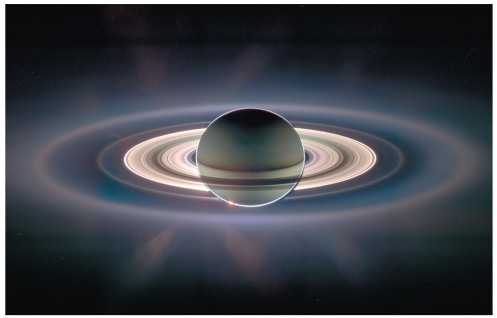
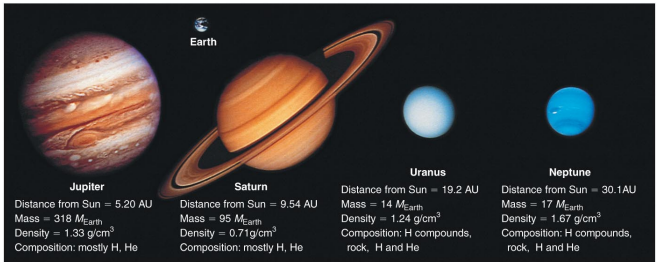
Chapter 11
Jovian Planet Systems



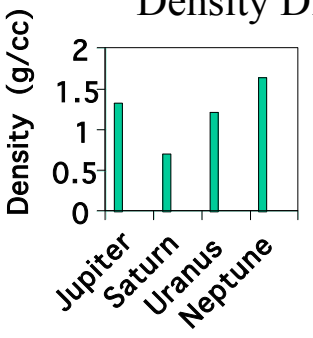
Are jovian planets all alike?



Jovian Planet Composition

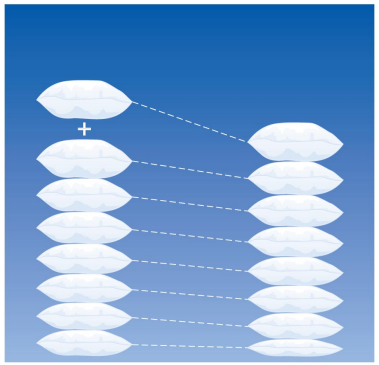
- Jupiter and Saturn
  - Mostly H and He gas
  - Rocky Core
- Uranus and Neptune
  - Mostly hydrogen compounds: water (H_2O), methane (CH_4), ammonia (NH_3)
  - Some H, He
  - Rocky core

Density Differences



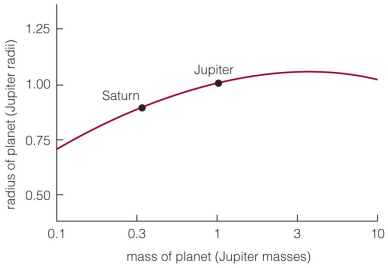
- Uranus and Neptune are denser than Saturn because they have less H/He, proportionately
- But that explanation doesn't work for Jupiter….

Sizes of Jovian Planets



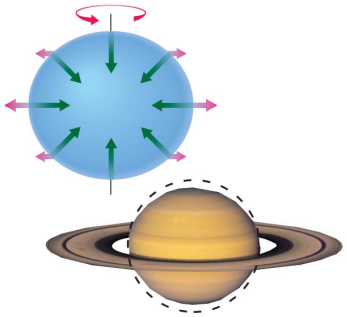
- Adding mass to a jovian planet compresses the underlying gas layers

Sizes of Jovian Planets



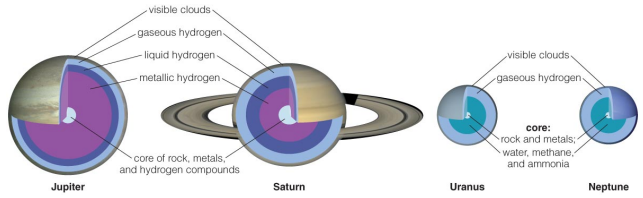
- Greater compression is why Jupiter is not much larger than Saturn even though it is three times more massive
- Jovian planets with even more mass can be smaller than Jupiter

Rotation and Shape



- Jovian planets are not quite spherical because of their rapid rotation

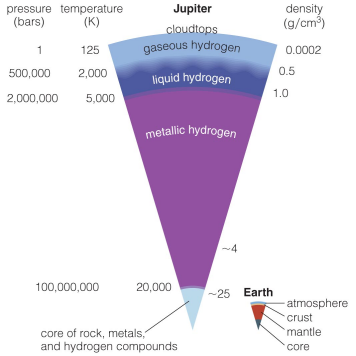
What are jovian planets like on the inside?



Interiors of Jovian Planets

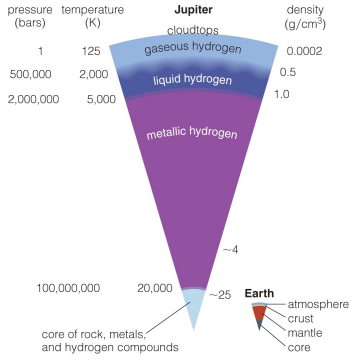
- No solid surface.
- Layers under high pressure and temperatures.
- Cores (~10 Earth masses) made of hydrogen compounds, metals & rock

Inside Jupiter



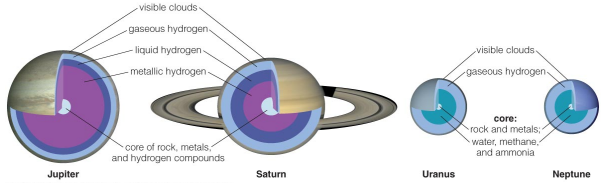
- High pressures inside Jupiter cause phase of hydrogen to change with depth
- Hydrogen acts like a metal at great depths because its electrons move freely

Inside Jupiter



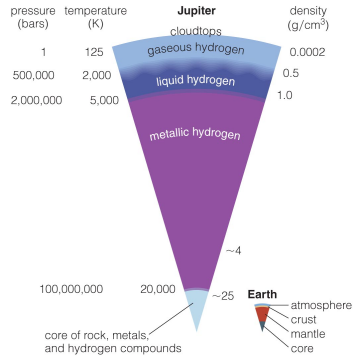
- Core is thought to be made of rock, metals, and hydrogen compounds
- Core is about same size as Earth but 10 times as massive

Comparing Jovian Interiors



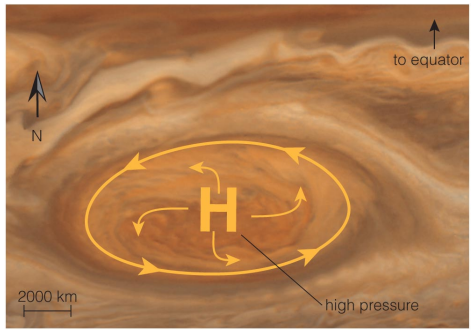
- Models suggest cores of jovian planets have similar composition
- Lower pressures inside Uranus and Neptune mean no metallic hydrogen

Jupiter's Internal Heat

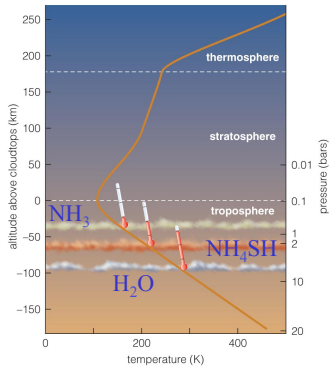


- Jupiter radiates twice as much energy it receives from Sun
- Energy probably comes from slow contraction of interior (releasing potential energy)

What is the weather like on jovian planets?

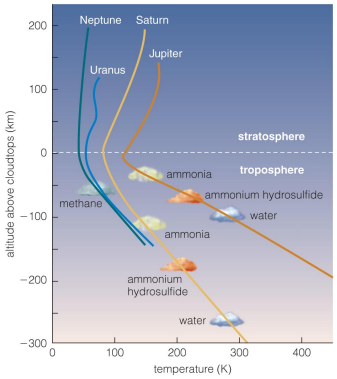


Jupiter's Atmosphere



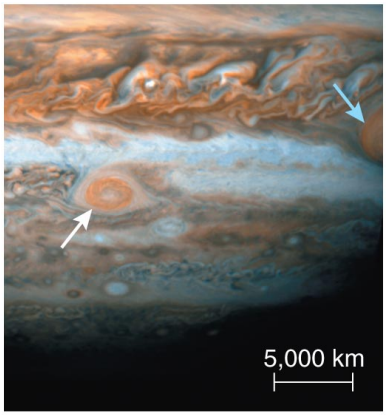
- Hydrogen compounds in Jupiter form clouds
- Different cloud layers correspond to freezing points of different hydrogen compounds

Jovian Planet Atmospheres



- Other jovian planets have cloud layers similar to Jupiter's
- Different compounds make clouds of different colors

Jupiter's colors

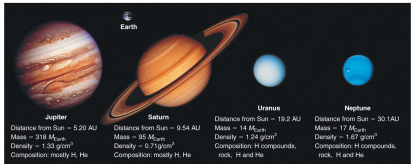


- Ammonium sulfide clouds (NH_4SH) reflect red/brown.
- Ammonia, the highest, coldest layer, reflects white.

Saturn's colors

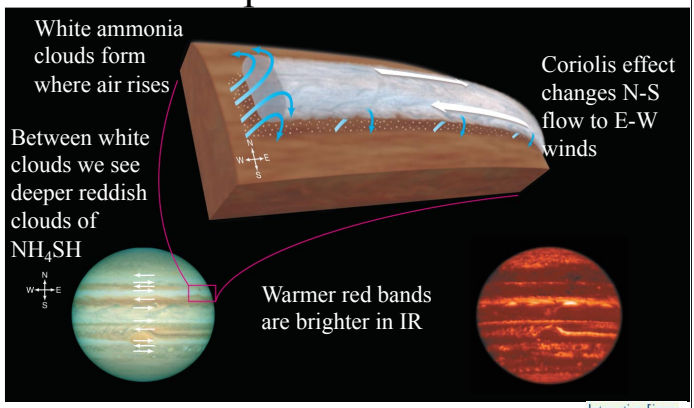
- Saturn's layers are similar, but deeper in and farther from the Sun --- more subdued.

Methane on Uranus and Neptune

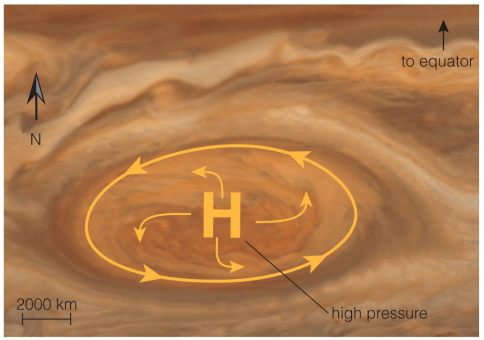


- Methane clouds of Neptune and Uranus absorb red light but reflect blue light, making those planets look blue

Jupiter's Bands



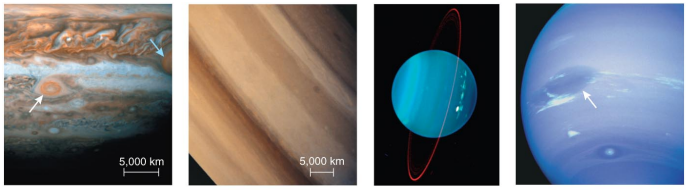
Jupiter's Great Red Spot



Interactive Figure

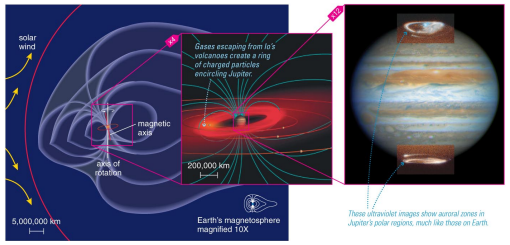
- A storm twice as wide as Earth
- Has existed for at least 3 centuries

Weather on Jovian Planets



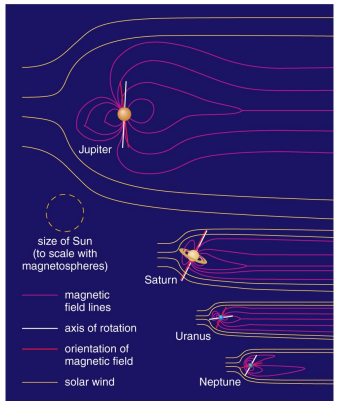
- All the jovian planets have strong winds and storms

Jupiter's Magnetosphere



- Jupiter's strong magnetic field gives it an enormous magnetosphere
- Gases escaping Io feed the donut-shaped Io torus

Other Magnetospheres



- All the jovian planets have substantial magnetospheres, but Jupiter's is largest by far

Thought Question

Jupiter does *not* have a large metal core like the Earth. How can it have a magnetic field?

a) The magnetic field is left over from when Jupiter accreted

b) Its magnetic field comes from the Sun

c) It has metallic hydrogen inside, which circulates and makes a magnetic field

d) That's why its magnetic field is weak

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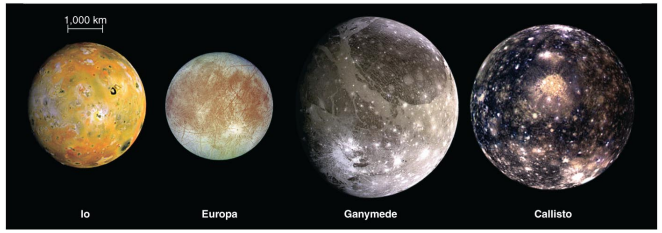
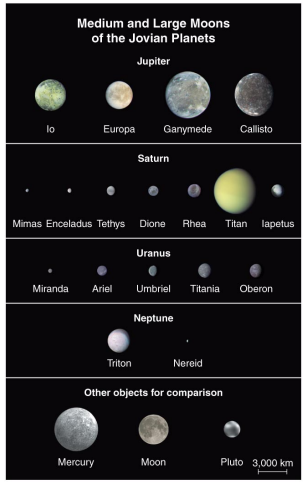
What kinds of moons orbit the jovian planets?



Sizes of Moons

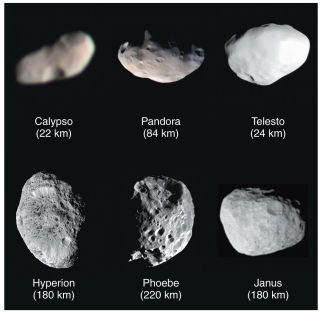
- Small moons (< 300 km)
  - No geological activity
- Medium-sized moons (300-1,500 km)
  - Geological activity in past
- Large moons (> 1,500 km)
  - Ongoing geological activity



Medium & Large Moons

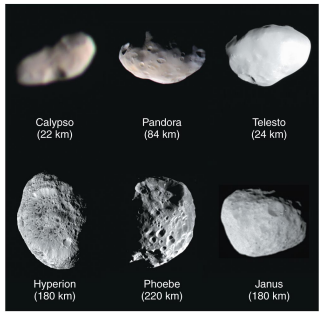
- Enough self-gravity to be spherical
- Have substantial amounts of ice.
- Formed in orbit around jovian planets.
- Circular orbits in same direction as planet rotation.

Small Moons



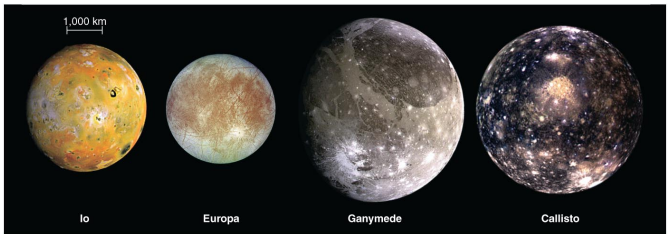
- Far more numerous than the medium and large moons.
- Not enough gravity to be spherical: "potato-shaped"

Small Moons

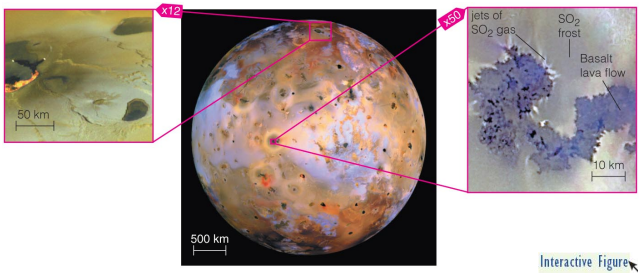


- Captured asteroids or comets, so orbits do not follow usual patterns.

Why are Jupiter's Galilean moons so geologically active?

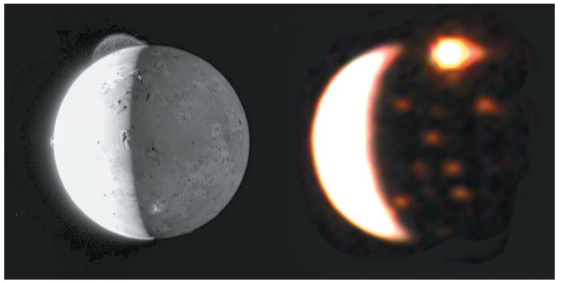


Io's Volcanic Activity



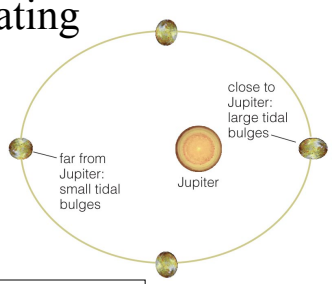
- Io is the most volcanically active body in the solar system, but why?

Io's Volcanoes



- Volcanic eruptions continue to change Io's surface

Tidal Heating

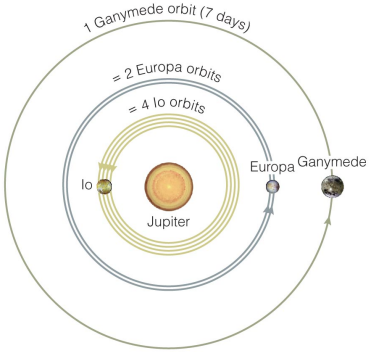


Io is squished and stretched as it orbits Jupiter

But why is its orbit so elliptical?

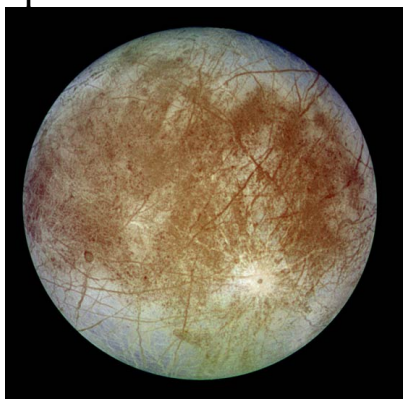
Orbital Resonances

The tugs add up over time, making all 3 orbits elliptical.

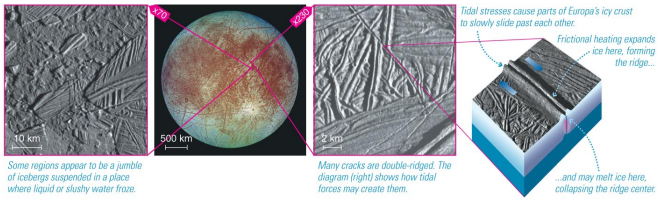


Every 7 days, these 3 moons line up.

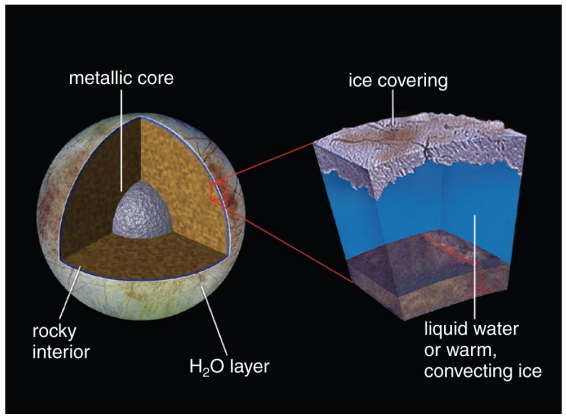
Europa's Ocean: Waterworld?



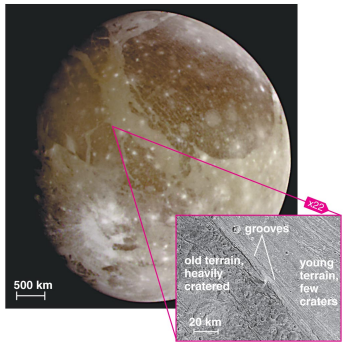
Tidal stresses crack Europa's surface ice.



Europa's interior also warmed by tidal heating

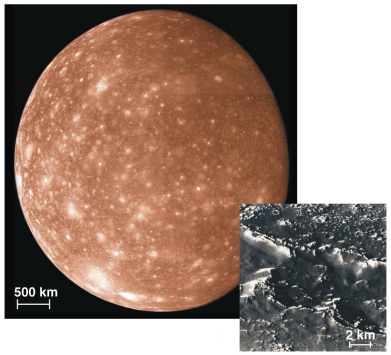


Ganymede



- Largest moon in the solar system
- Clear evidence of geological activity
- Tidal heating plus heat from radio-active decay?

Callisto



- "Classic" cratered iceball.
- No tidal heating, no orbital resonances.

Thought Question

How does Io get heated by Jupiter?

a) Auroras
b) Infrared Light
c) Jupiter pulls harder on one side than the other
d) Volcanoes

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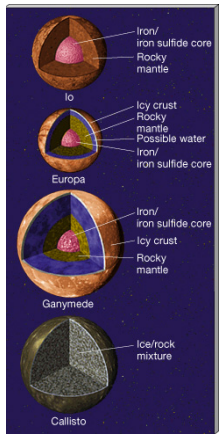
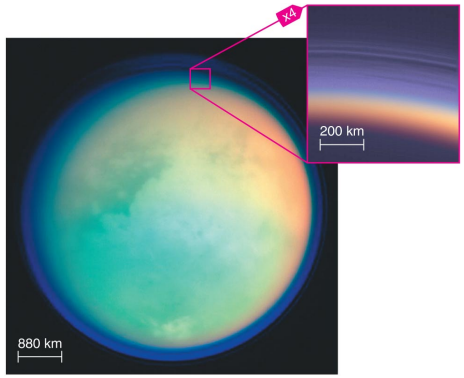
Galilean Moons – Internal Structure

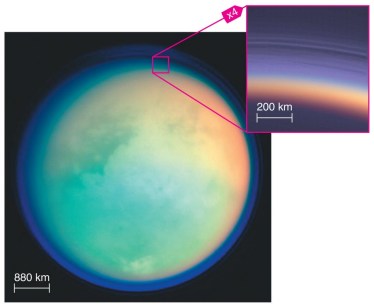


Density:	Ratio of ice/rock increases	No. of Craters increases
3.5 g/cm^3	↓	↓
3.0 g/cm^3		
1.9 g/cm^3		
1.9 g/cm^3		

What is remarkable about Titan and other major moons of the outer solar system?

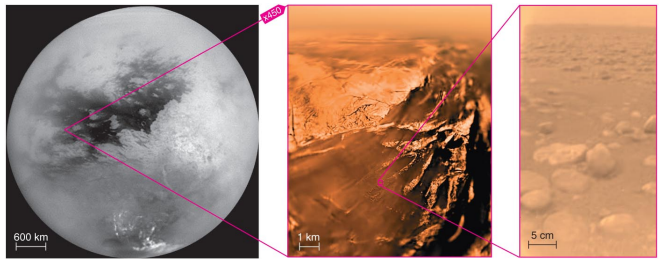


Titan's Atmosphere



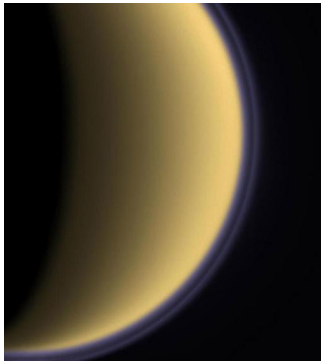
- Titan is the only moon in the solar system to have a thick atmosphere
- It consists mostly of nitrogen with some argon, methane
- Thick layer of smog: hydrocarbons (ethane, methane, propane)

Titan's Surface



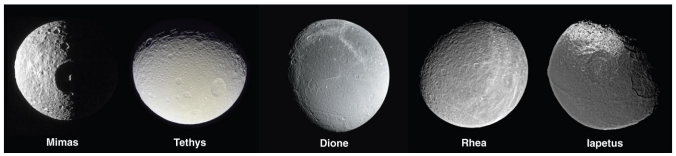
- *Huygens* probe provided first look at Titan's surface in early 2005
- Liquid methane on surface, "rocks" made of ice

Titan - Purple Haze



- The Sun's UV light breaks up CH_4 and N_2 in the atmosphere.
- These recombine to form a haze of hydrocarbons.

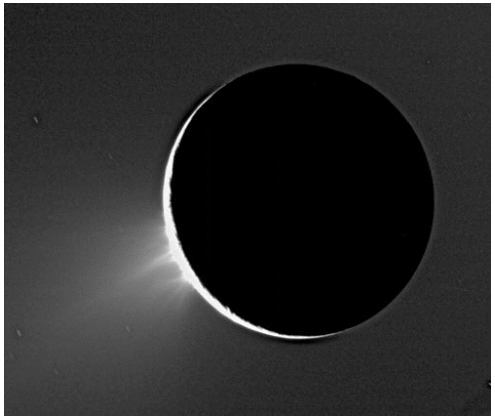
Medium Moons of Saturn



- Almost all show evidence of past volcanism and/or tectonics

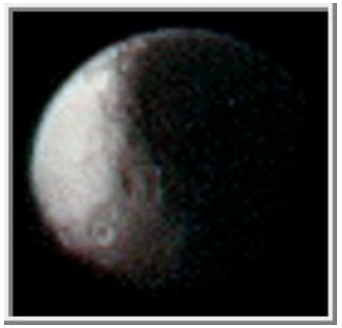
Enceladus

Reflects almost 100% of the light it receives
- covered with tiny ice crystals



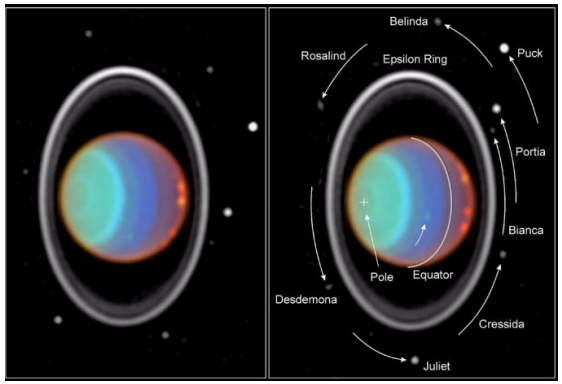
- Plumes of water ejected from holes in the ice

Iapetus

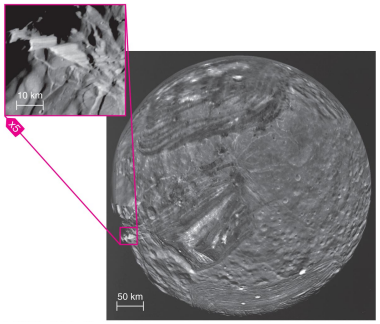


- Leading face in its orbit swept up dark particles

Uranus: IR Images

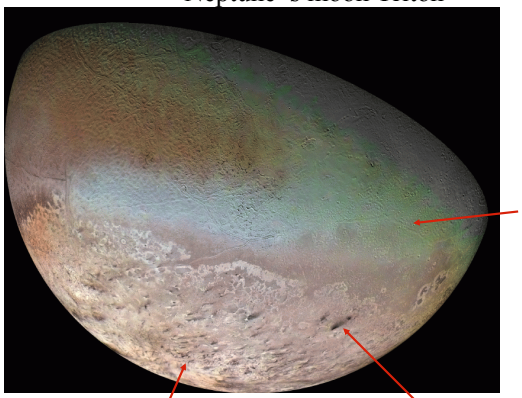


Medium Moons of Uranus

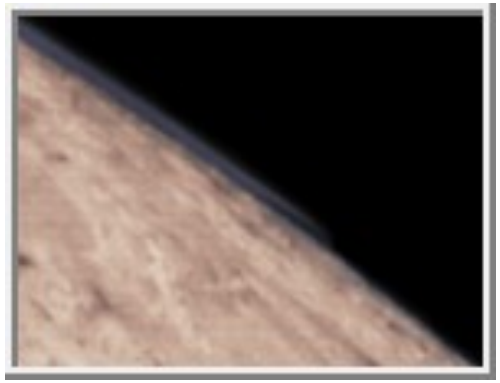


- Varying amounts of geological activity
- Moon Miranda has large tectonic features and few craters (episode of tidal heating in past)

Neptune's moon Triton

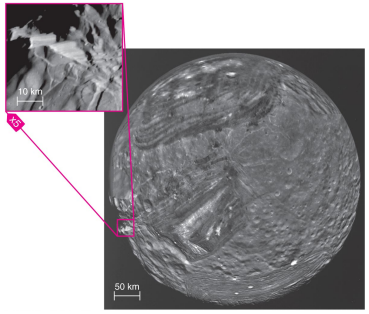


Triton – thin Nitrogen atmosphere

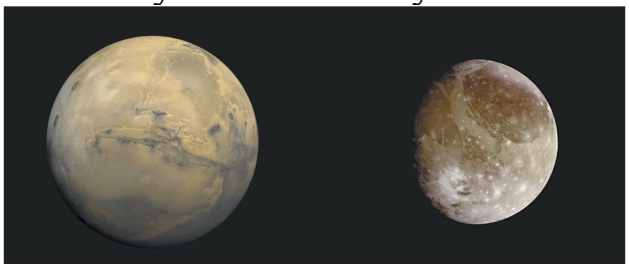


Frozen N is heated and ejected by geysers to form atmosphere

Why are small icy moons more geologically active than small rocky planets?

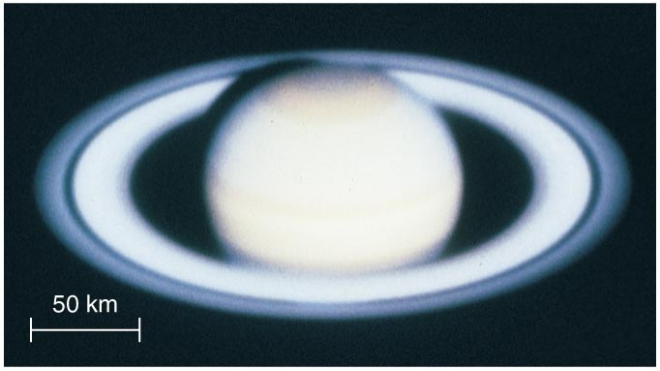


Rocky Planets vs. Icy Moons



- Rock melts at higher temperatures
- Only large rocky planets have enough heat for activity
- Ice melts at lower temperatures
- Tidal heating can melt internal ice, driving activity

What are Saturn's rings like?

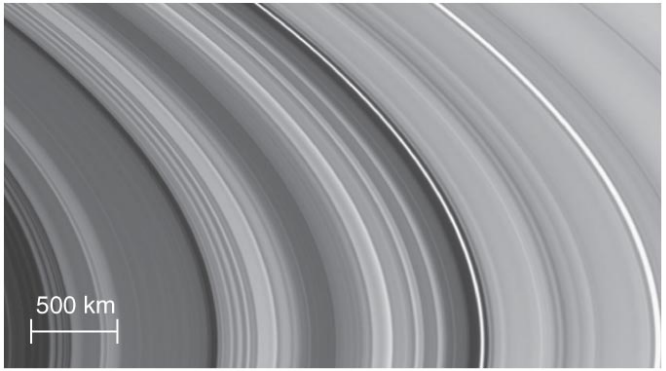


What are Saturn's rings like?

- They are made up of numerous, tiny individual particles
- They orbit over Saturn's equator
- They are very thin
- How do we know this?

  - Doppler effect from spectra show inner rings move faster than outer ring.

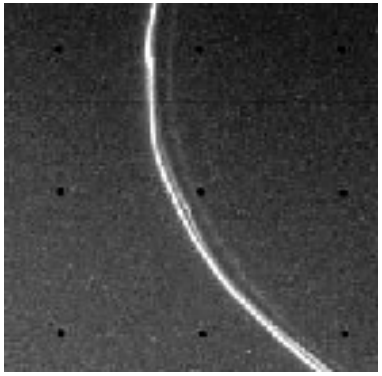
Spacecraft view of ring gaps



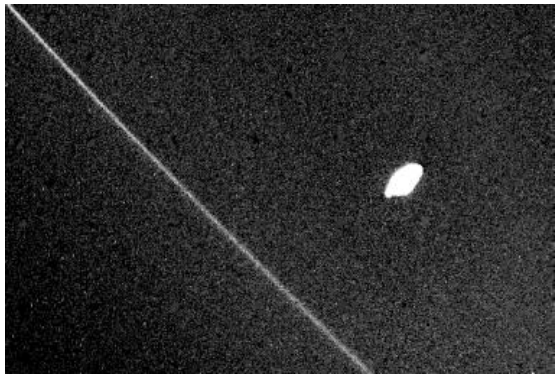
Rings – False color

Rings – "Backlit"

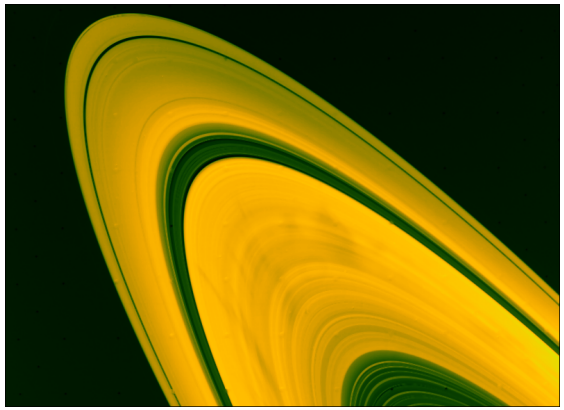
Braided F ring

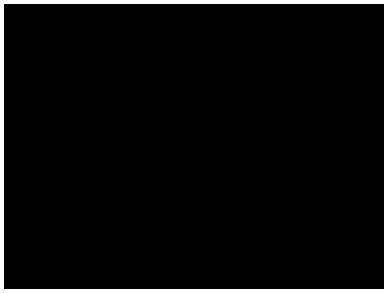


F ring and shepherd satellite



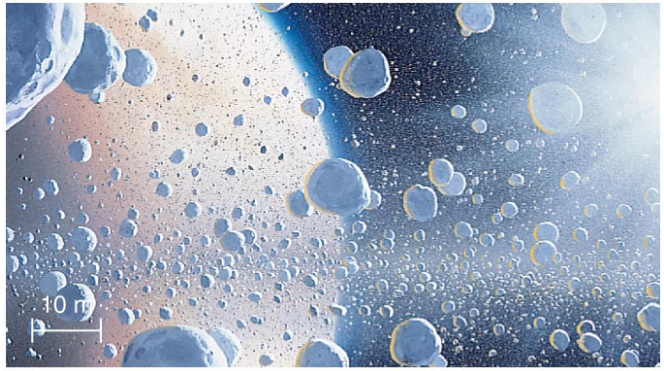
"Spokes" in the Rings





- charged dust particles elevated by magnetic field

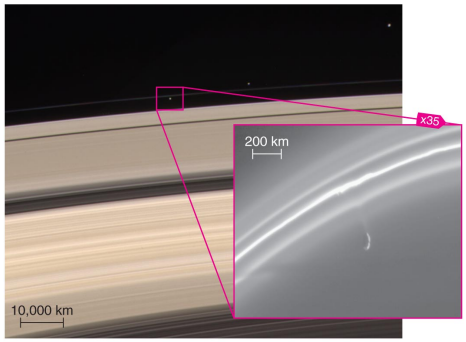
Artist's conception of close-up



Gap Moons

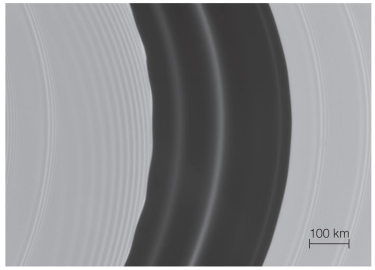
- Some small moons create gaps within rings

Shepherd Moons



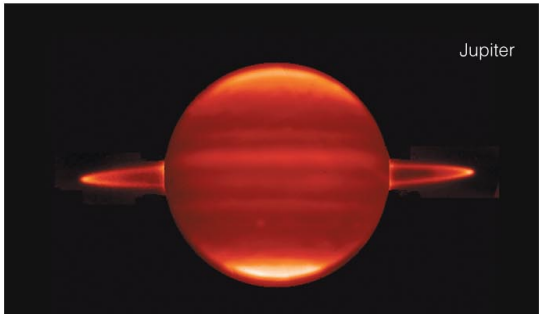
- Pair of small moons can force particles into a narrow ring

Resonance Gaps

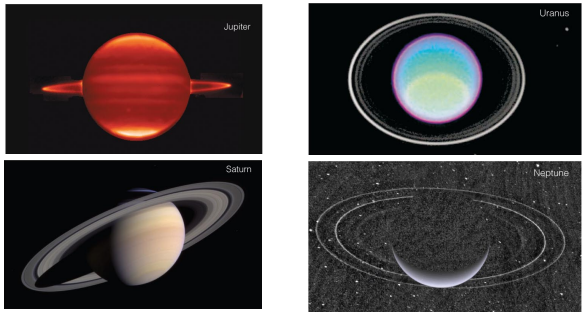


- Orbital resonance with a larger moon can also produce a gap

How do other jovian ring systems compare to Saturn's?

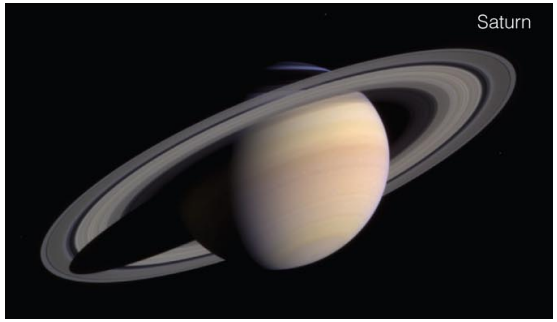


Jovian Ring Systems



- All four jovian planets have ring systems
- Others have smaller, darker ring particles than Saturn

Why do the jovian planets have rings?



Why do the jovian planets have rings?

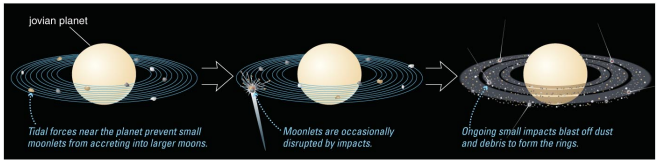
- They formed from dust and ice created in impacts on moons orbiting those planets

How do we know that?

How do we know?

- Rings aren't leftover from planet formation because the particles are too small to have survived this long. They would have spiraled down into planet.
- There must be a continuous replacement of tiny particles.
- The most likely source is impacts with the jovian moons.

Ring Formation



- Jovian planets all have rings because they possess many small moons close-in
- Impacts on these moons are random
- Saturn's incredible rings may be an "accident" of our time