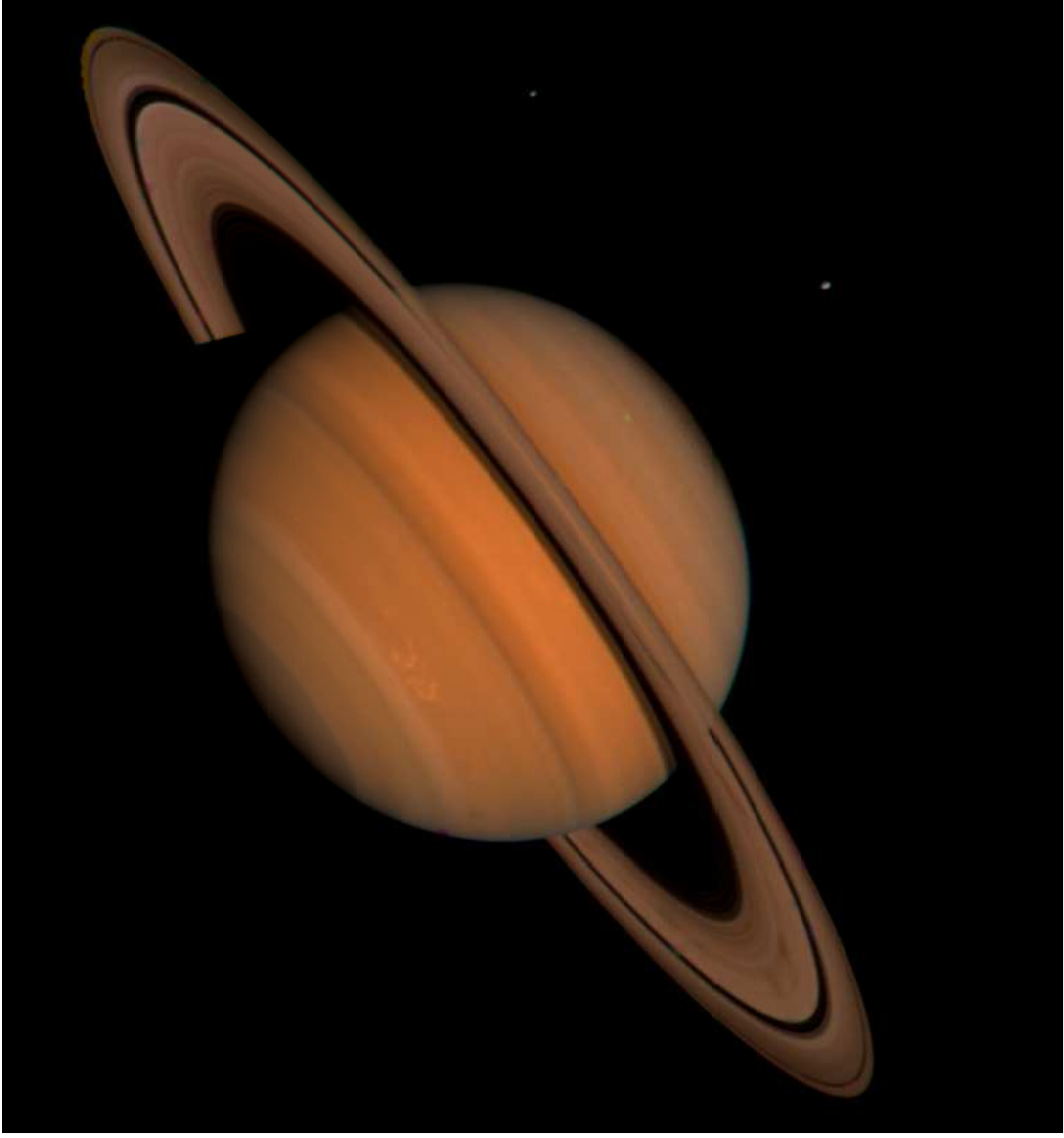




“The scientific theory I like best is that the rings of Saturn are composed entirely of lost airline luggage.”

Mark Russell

What We Will Learn Today

- Why does Saturn have such a low density and how does that affect its shape?
- What do we know about Saturn's interior and weather?
- How did Saturn's rings form and how do we explain their observed patterns?
- How is Saturn unique in our Solar System?

Planet Saturn's Details

Property	Value
Semi-major axis	9.5 AU
Size (radius)	9.4 R _{Earth}
Mass	95.2 M _{Earth}
Average density	0.70 g/cc
Composition	Mostly Hydrogen & Helium
Average cloud-top temperature	95 K
Moons	> 47
Orbital period	29.4 years
Rotation period (sidereal)*	10.6 hours
Axis tilt	26.7°
Orbital inclination	2.5°
Orbital eccentricity	0.056

* Measured based on rotation of magnetic field lines

Saturn Would Float in Water!

- Lowest density planet
 - 0.7 g/cc, vs. water at 1 g/cc
- Initial core of $\sim 10 M_{\text{Earth}}$
 - Hydrogen compound ices
 - H_2O , NH_3 , CH_4
- Gathered substantial atmosphere (H, He)
 - Not as much as Jupiter ($\sim 300 M_{\text{Earth}}$)
 - Much more than Neptune & Uranus ($\sim 15 M_{\text{Earth}}$)
- Did not compact as much as Jupiter
 - Farther from the Sun, gathered less H & He

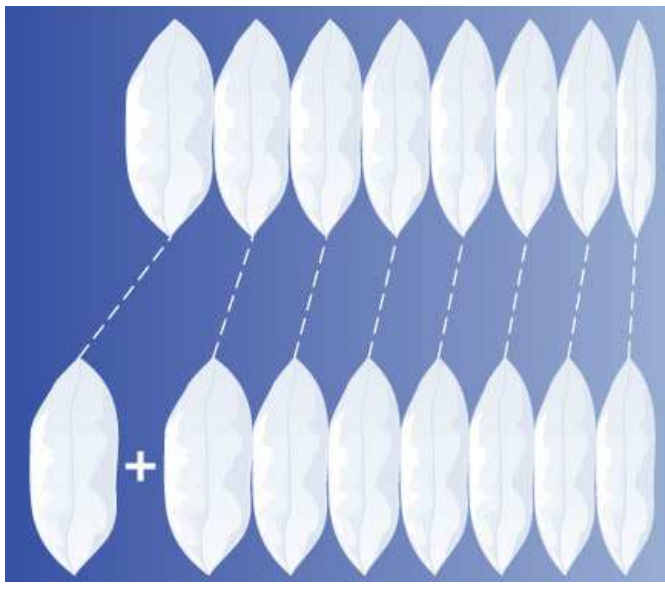
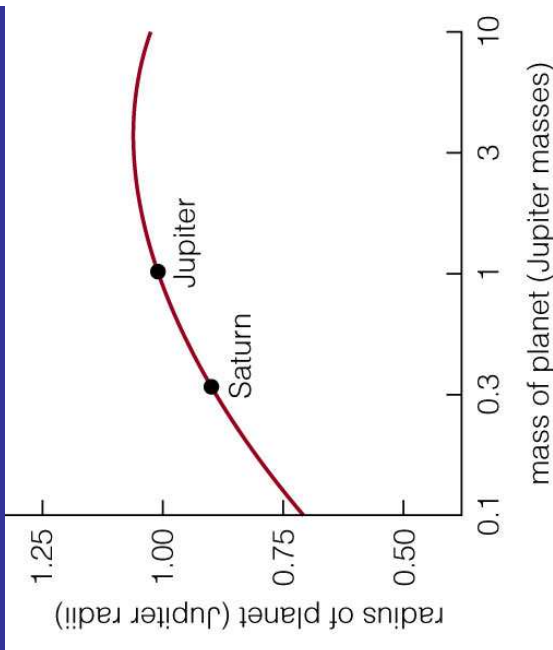


Fig 11.2

Saturn's Shape: Flattened Sphere

- Gravity alone would roll Saturn into a perfect sphere
- But, low density and fast rotation distorts it
 - Bulge at the equator
 - Flattened at the poles

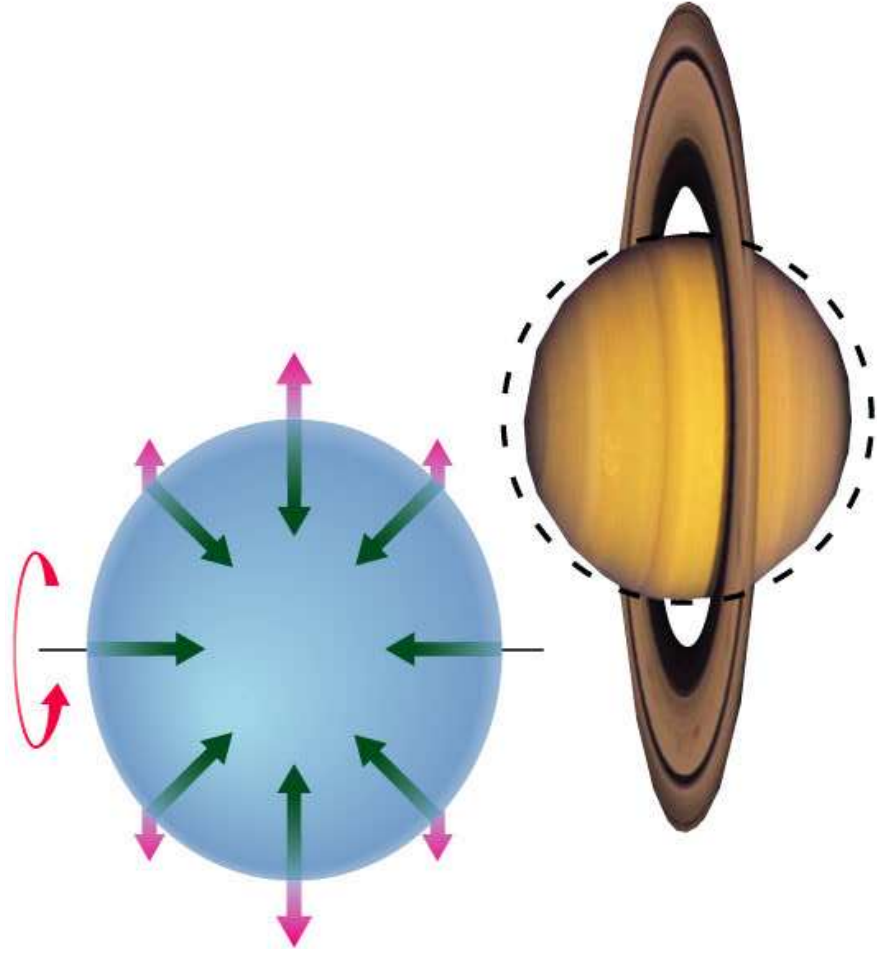


Fig 11.3

Saturn's Interior

- Outer layers are thicker than Jupiter
 - Lower mass implies greater depth for similar pressure change

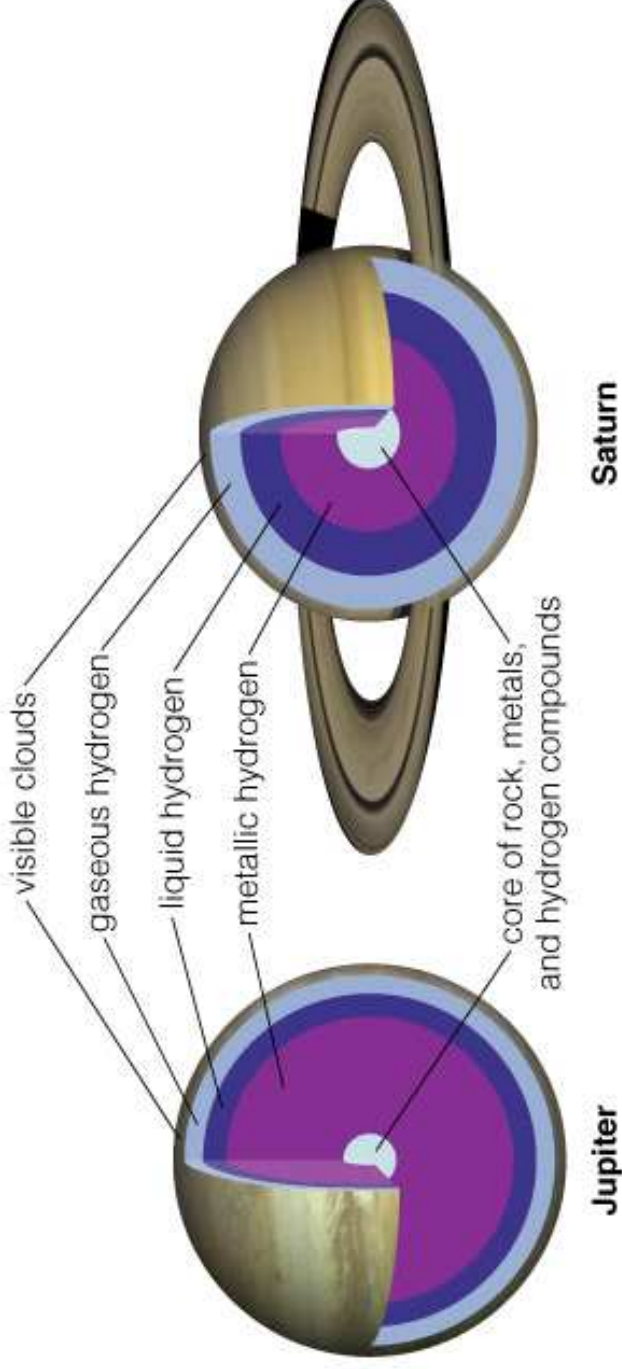


Fig 11.5

Source of Internal Heat

- Like Jupiter, Saturn emits twice the energy received from the Sun
 - What was the source of this energy for Jupiter?
- Pressure and temperature inside Saturn allow Helium to condense and “rain” down
 - This ongoing differentiation is the source of internal heat
 - Voyager & Cassini confirmed lower He abundance in Saturn’s atmosphere

Weather on Saturn

- Saturn is mostly H & He
- The traces of other compounds (CH_4 , NH_3 , H_2O) make it interesting
 - Whitish-yellow ammonia clouds
 - Brownish ammonium hydrosulfide clouds
 - White water clouds
- Similar layers as Jupiter, but deeper
 - Cooler temperatures due to distance from the Sun
 - Thus, Saturn's colors are more subtle than Jupiter's

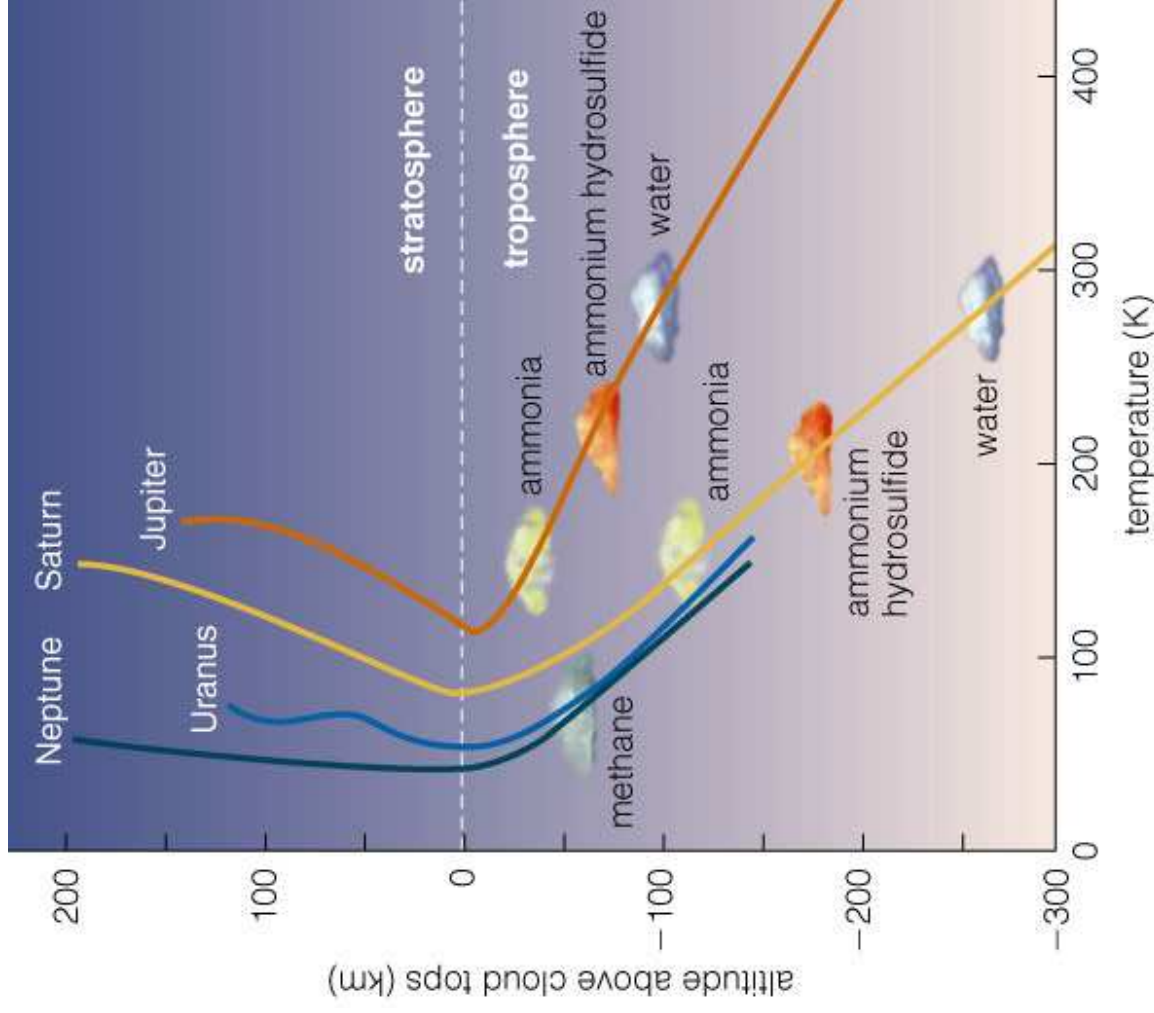


Fig 11.7

Seasons, Winds and Magnetism

- A pronounced tilt (27°) gives Saturn seasons
- Saturn's winds are stronger than Jupiter's
 - Not yet fully understood
 - Remember, Coriolis effect depends on size and rotation speed
- Saturn has a magnetic field, but weaker than Jupiter
 - Metallic hydrogen layer not as large
 - Less internal heat due to size and distance from the Sun, resulting in less convection

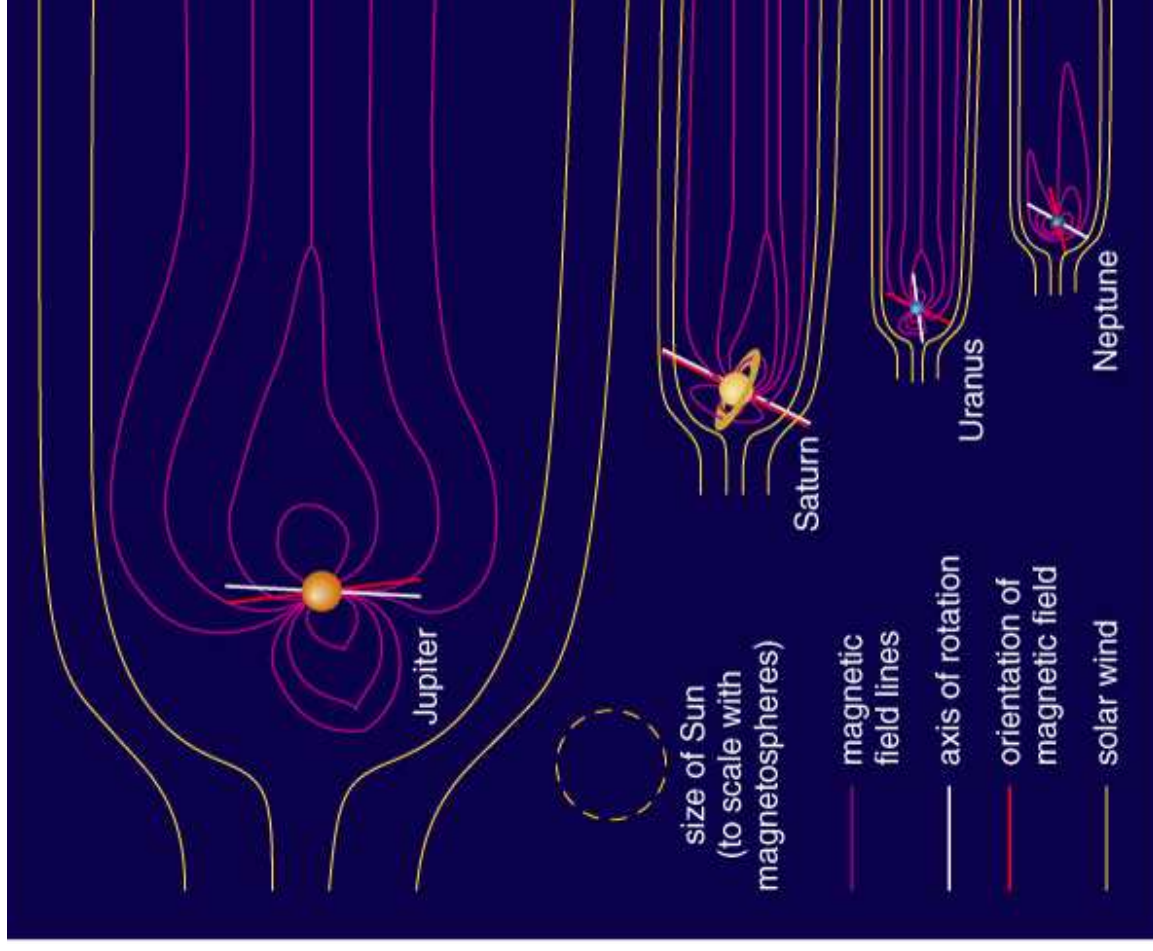


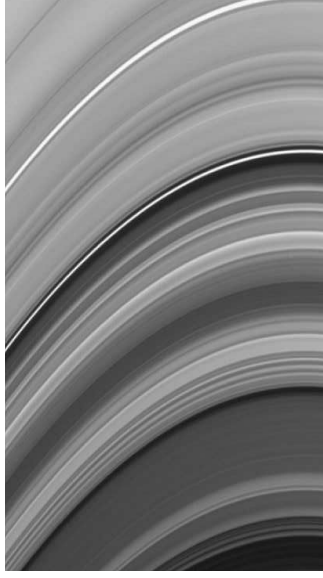
Fig 11.13

Saturn's Majestic Rings

- Easily seen with a backyard telescope
- Close-up spacecraft images reveal many gaps
- Appear as continuous sheets
 - Actually are icy particles from dust grain sized to large boulders
- Particles are mostly water ice
- Collisions are frequent, but gentle – why?



Telescopic view from Earth



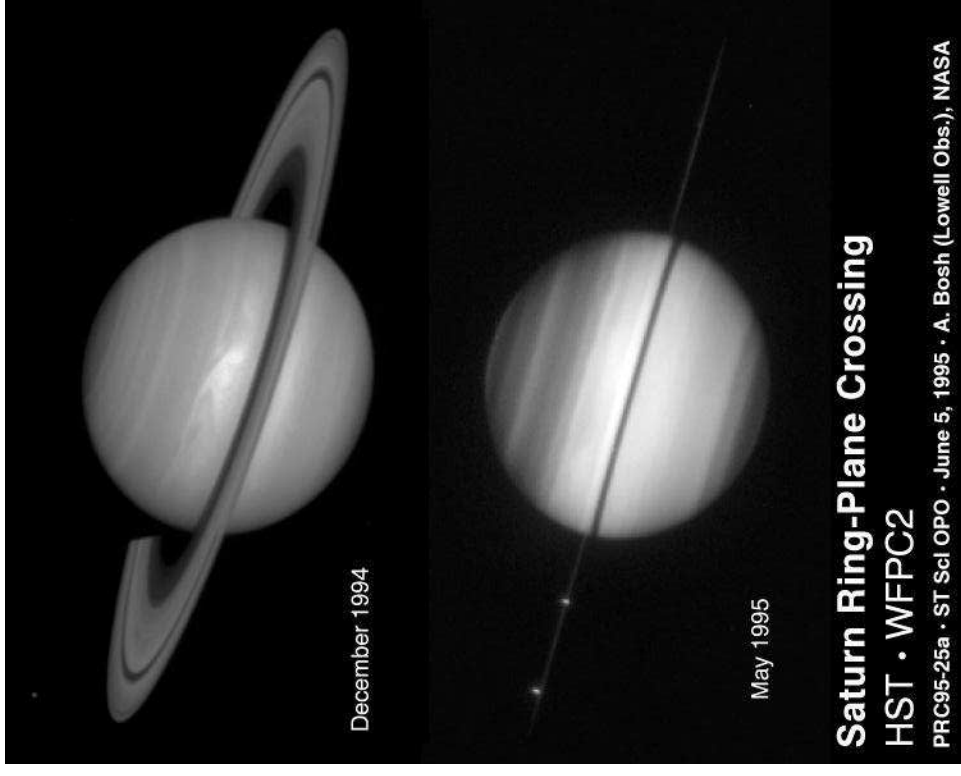
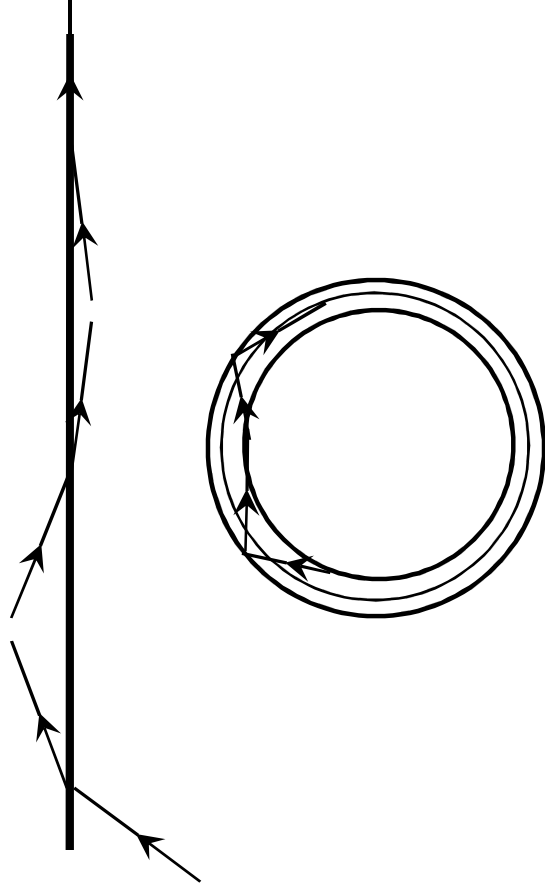
Cassini image



Artist conception of close-up view

The Rings are Incredibly Thin

- Over 270,000 km in diameter
- Only few tens of meters thick
 - Almost disappear when viewed edge-on
- Thinness explained by repeated collisions
- Collisions also responsible for near-circular orbits of ring particles



Patterns in Saturn's Rings

- Close-up images show gaps, ripples, other features
- Explained by
 - Gap moons
 - Shepherd moons
 - Orbital resonance

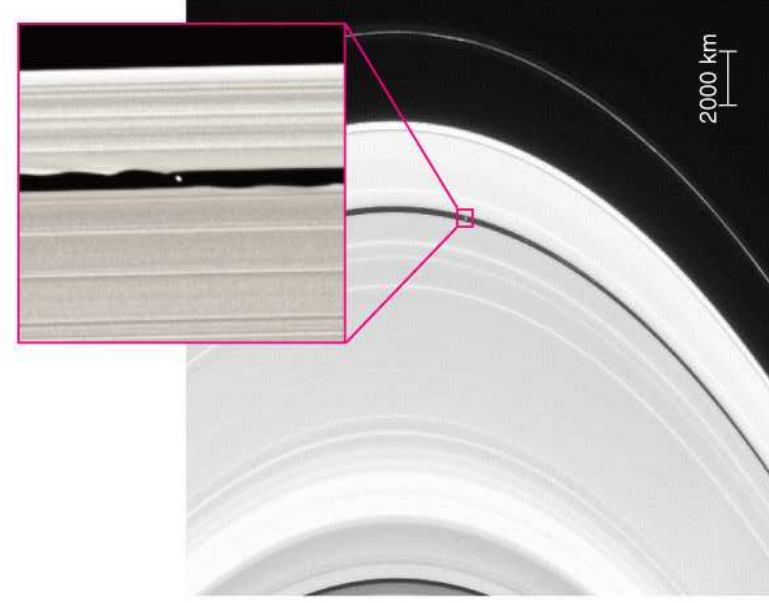


Fig 11.33

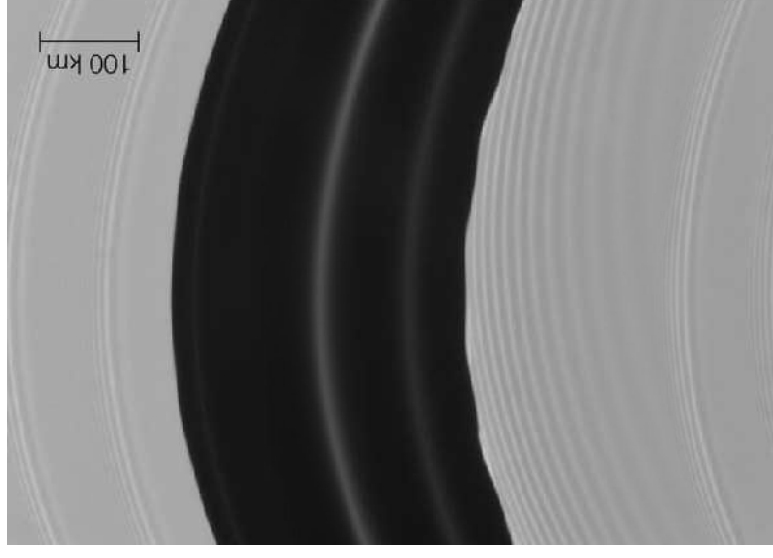
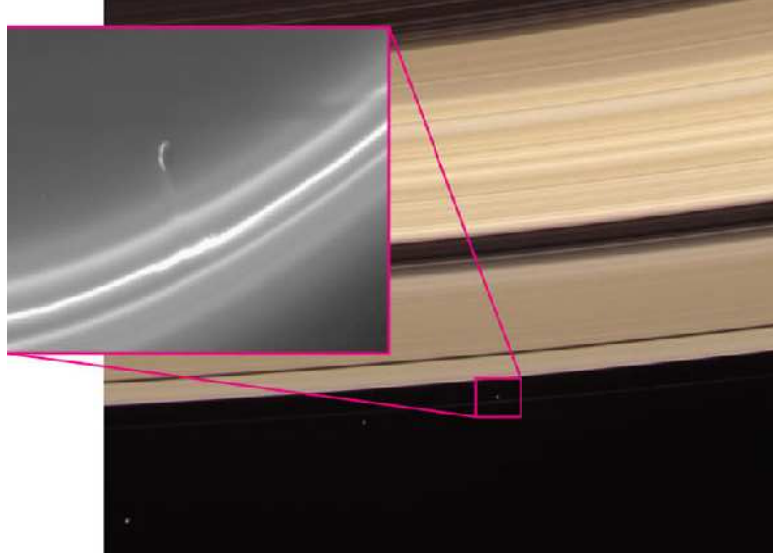
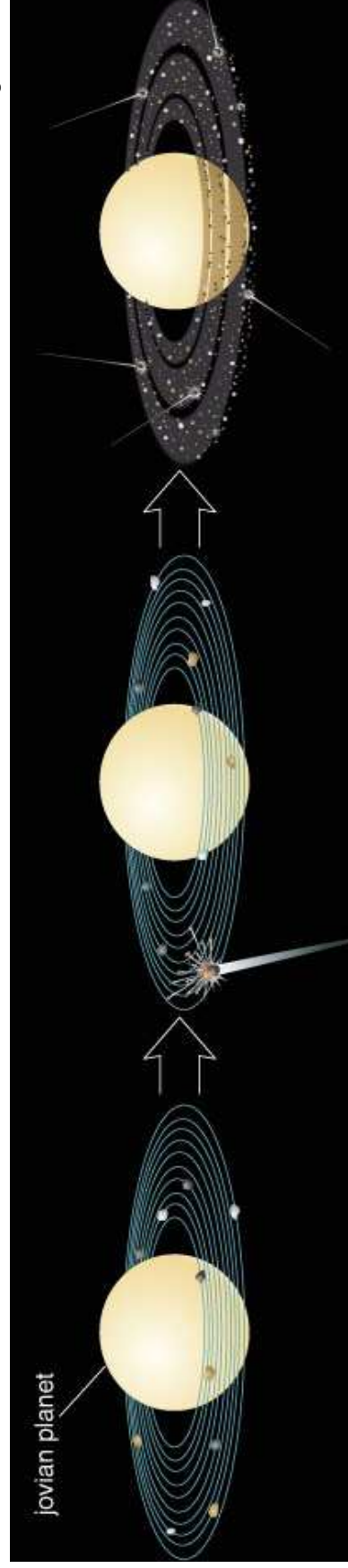


Fig 11.33

Where Did the Rings Come From?

- Rings did **not** form with the planets from the solar nebula
 - Particles are constantly ground up and would not survive billions of years
- Most rings seen in the Roche tidal zone
 - Area where tidal forces tearing objects apart become comparable to gravity, which holds them together
- Ring particles are pieces blasted off small moons, such as gap moons, or the remnants of infrequent collisions which can shatter the moons
- Saturn's magnificent rings are a temporary phenomenon and evolve over time scales of millions of years

Fig 11.35



Unique Features of Saturn

- Farthest planet seen by the ancient astronomers
- Least dense planet in the SS
 - Would float on water!
- Constant Helium rain
- Most impressive ring system
- “Flattest” planet