



Lecture Outlines

Chapter 12

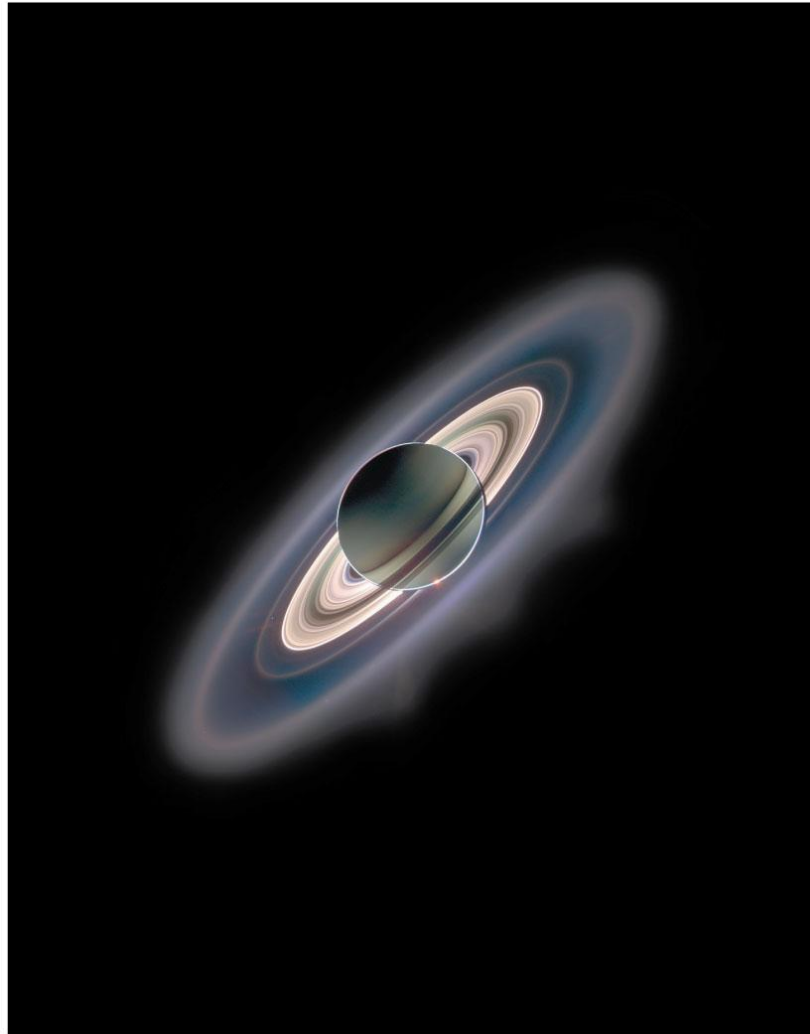
Astronomy Today

7th Edition

Chaisson/McMillan

Chapter 12

Saturn



Units of Chapter 12

12.1 Orbital and Physical Properties

12.2 Saturn's Atmosphere

12.3 Saturn's Interior and Magnetosphere

12.4 Saturn's Spectacular Ring System

12.5 The Moons of Saturn

Dancing Among Saturn's Moons

12.1 Orbital and Physical Properties

Mass: 5.7×10^{26} kg

Radius: 60,000 km

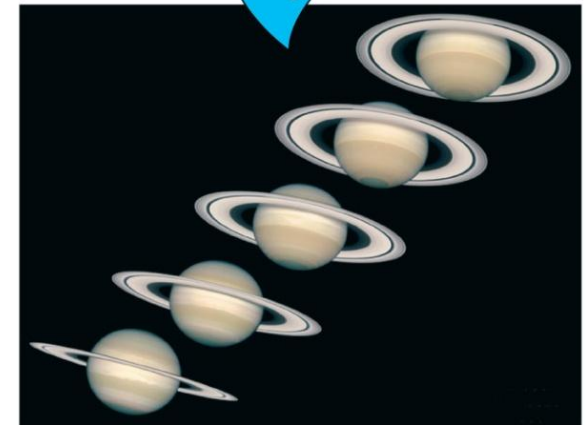
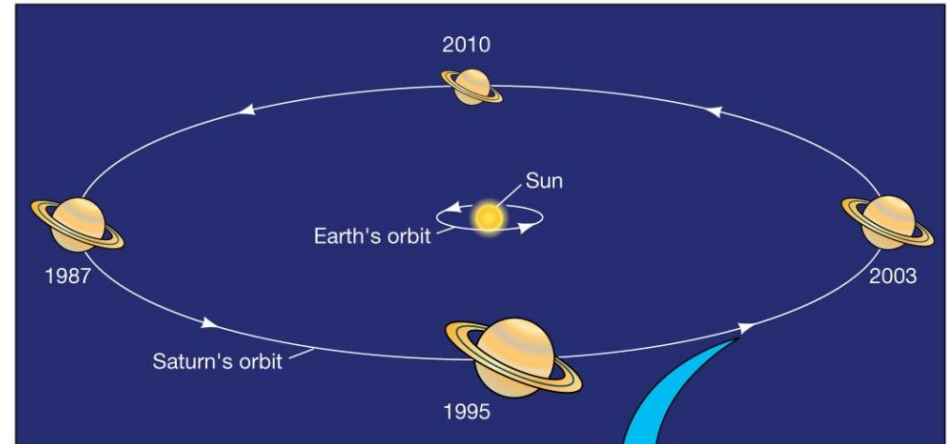
Density: 700 kg/m³—less than water!

Rotation: Rapid and differential, enough to flatten Saturn considerably

Rings: Very prominent; wide but extremely thin

12.1 Orbital and Physical Properties

View of rings from Earth changes as Saturn orbits the Sun



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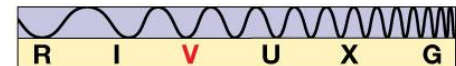
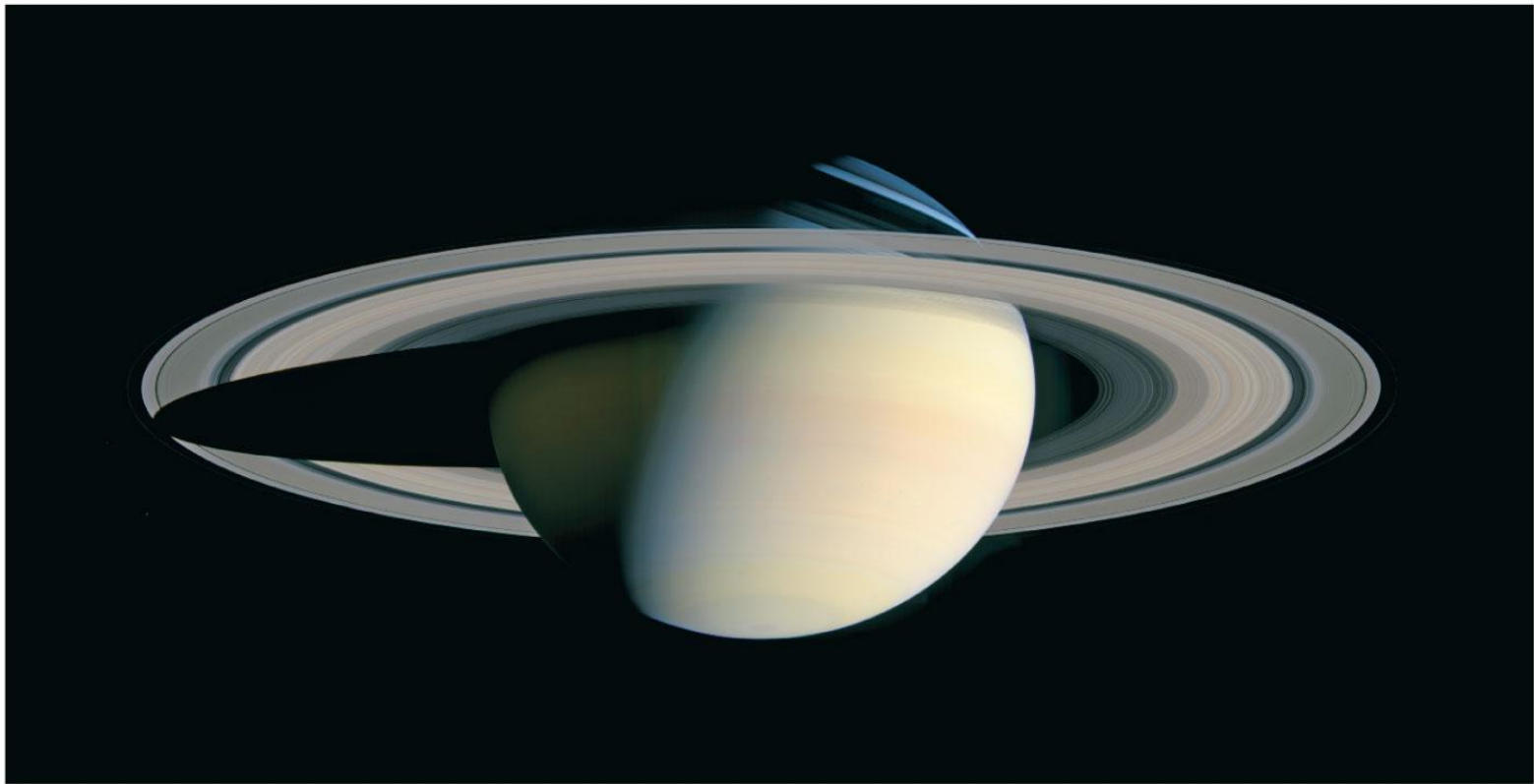
12.2 Saturn's Atmosphere

Saturn's atmosphere also shows zone and band structure, but coloration is much more subdued than Jupiter's

Mostly molecular hydrogen, helium, methane, and ammonia; helium fraction is much less than on Jupiter

12.2 Saturn's Atmosphere

This true-color image shows the delicate coloration of the cloud patterns on Saturn

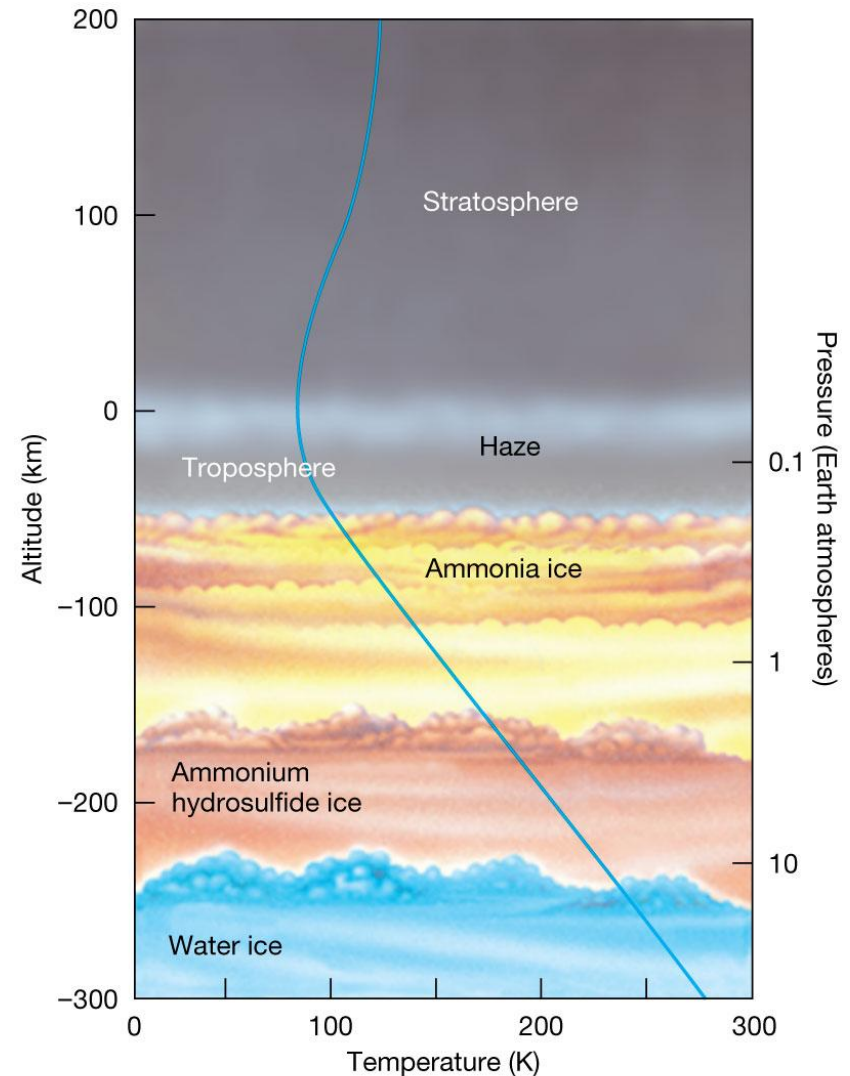


12.2 Saturn's Atmosphere

Similar to Jupiter's, except
pressure is lower

Three cloud layers

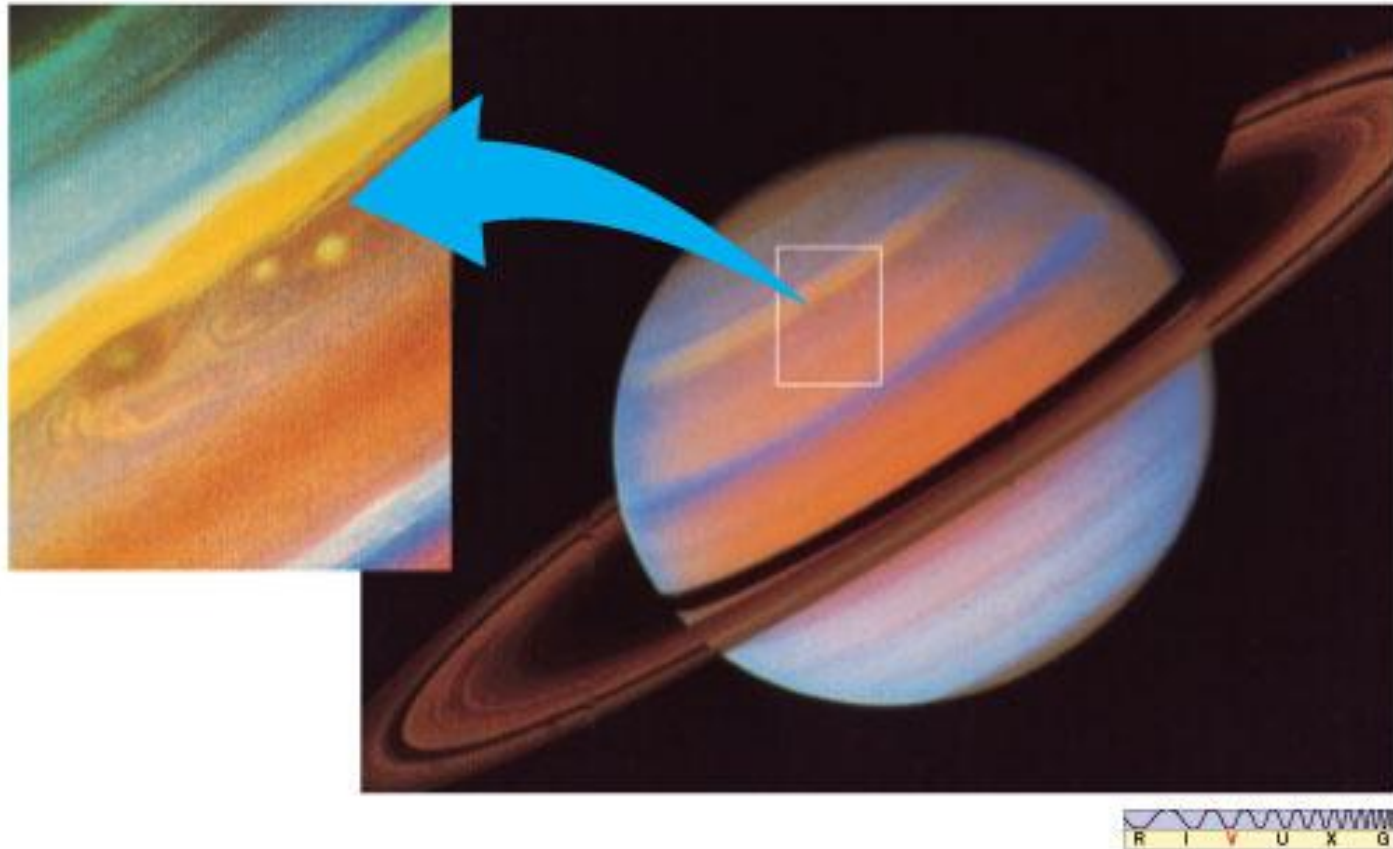
Cloud layers are thicker than
Jupiter's; see only top layer



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12.2 Saturn's Atmosphere

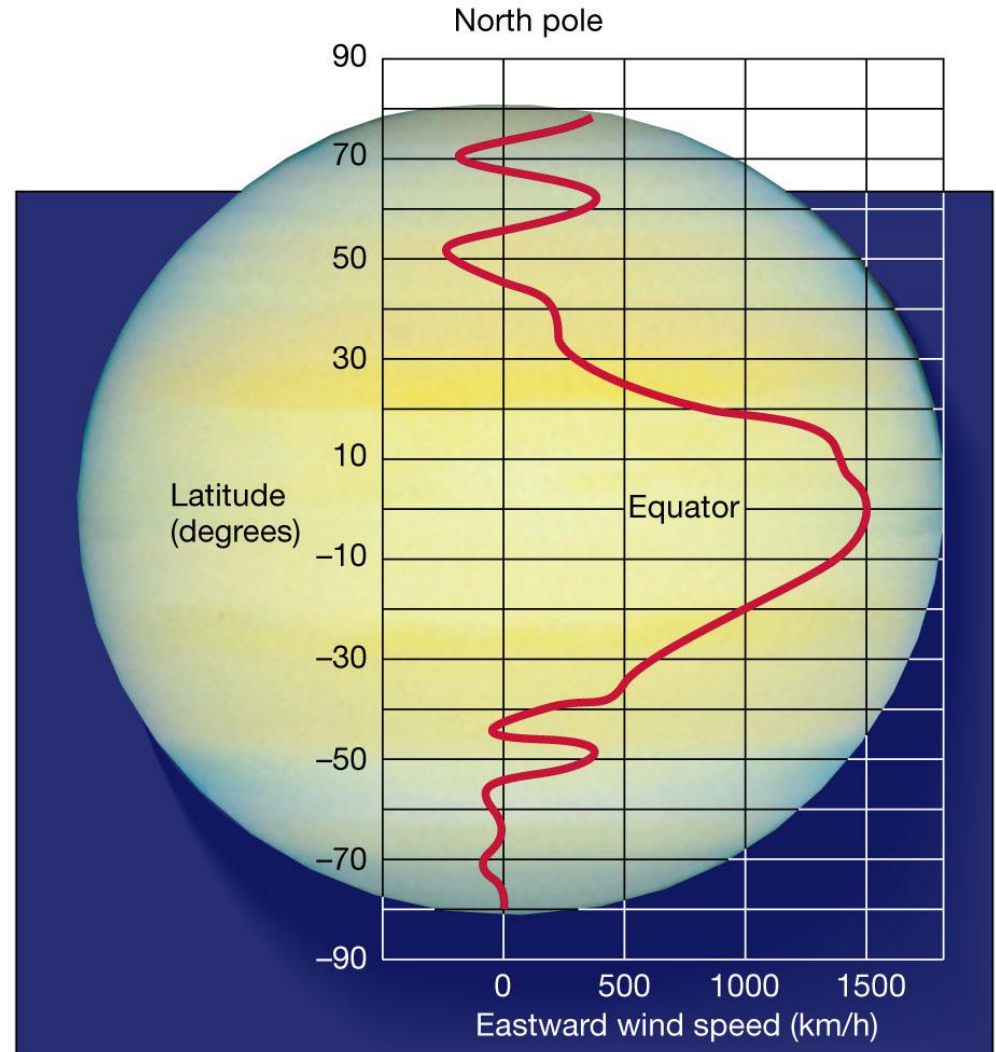
Structure in Saturn's clouds can be seen more clearly in this false-color image



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12.2 Saturn's Atmosphere

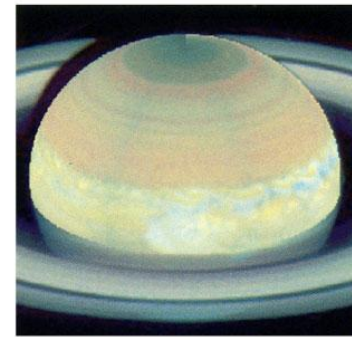
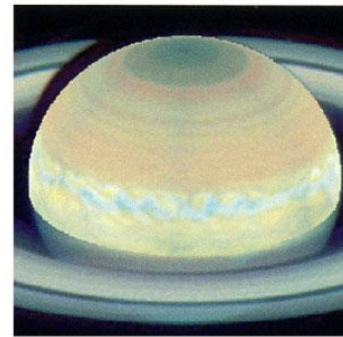
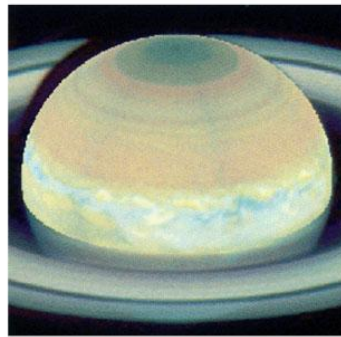
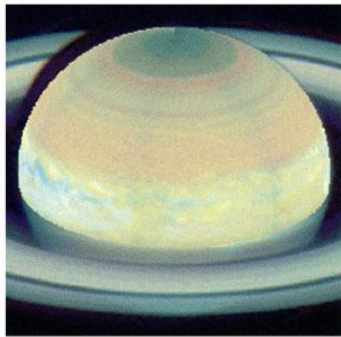
Wind patterns on Saturn are similar to those on Jupiter, with zonal flow



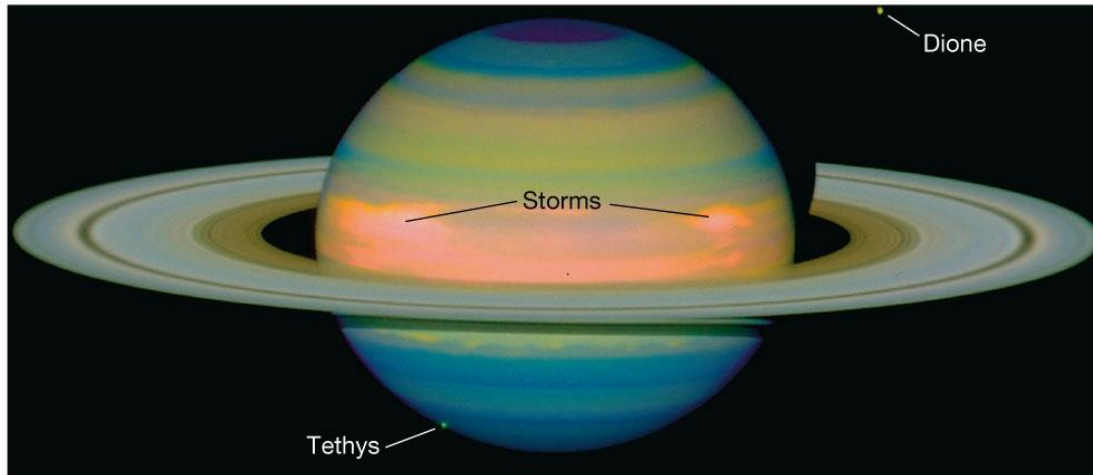
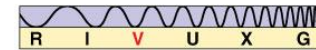
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12.2 Saturn's Atmosphere

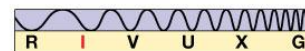
Jupiter-style “spots” rare on Saturn; don't form often and quickly dissipate if they do



(a)

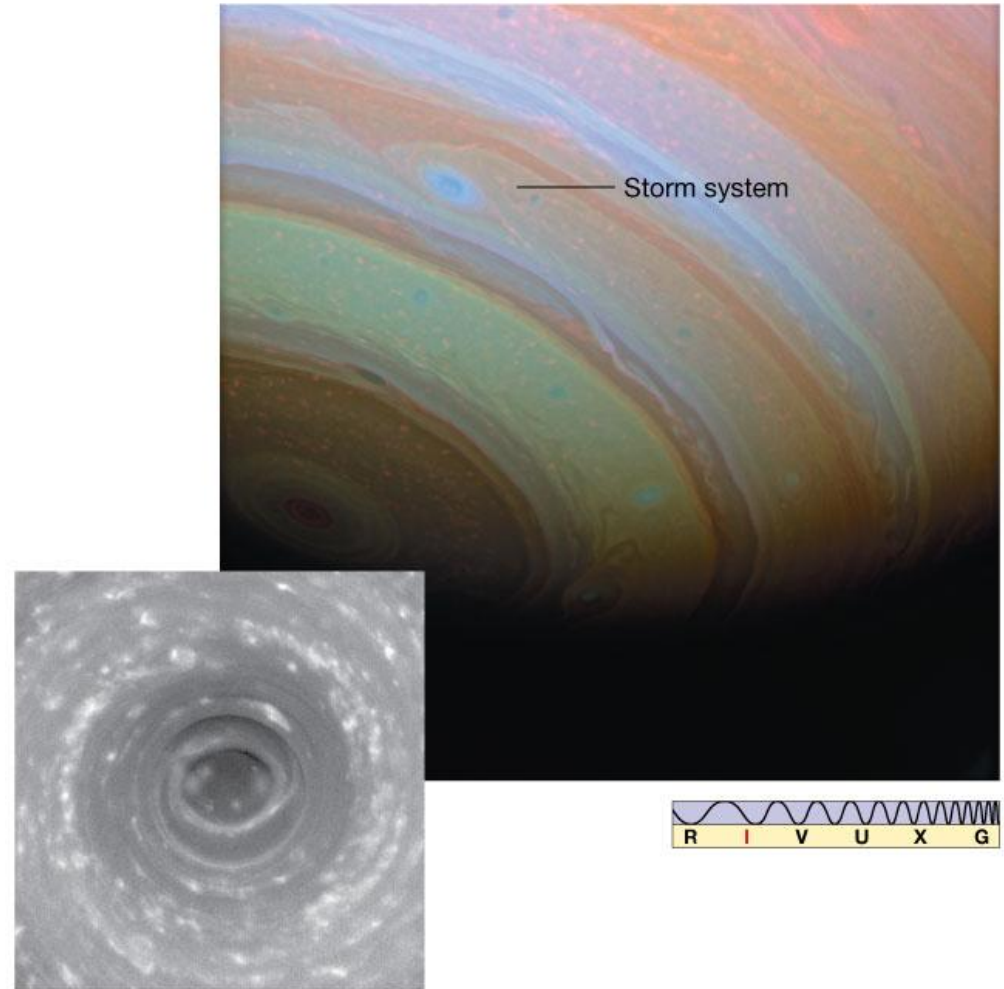


(b)



12.2 Saturn's Atmosphere

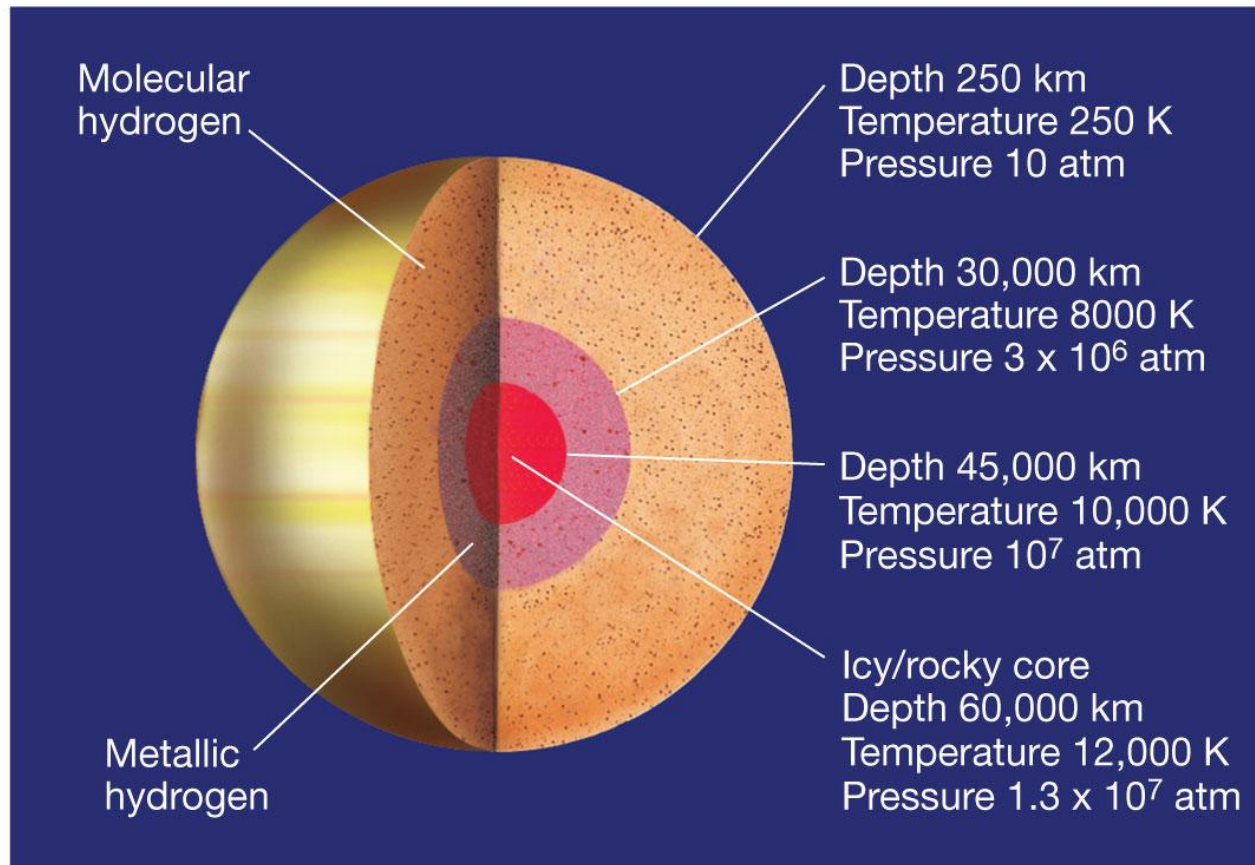
This image shows what is thought to be a vast thunderstorm on Saturn, as well as the polar vortex at Saturn's south pole.



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12.3 Saturn's Interior and Magnetosphere

Interior structure **similar to Jupiter's**



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12.3 Saturn's Interior and Magnetosphere

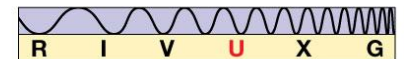
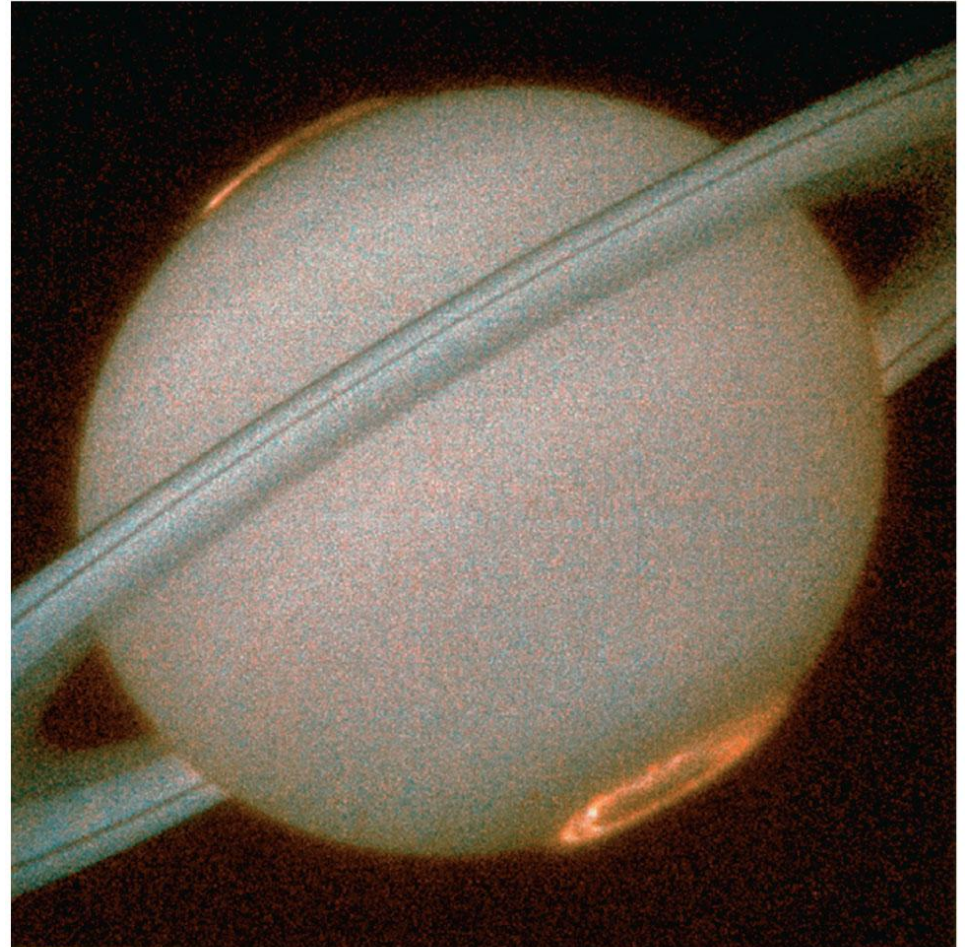
Saturn also radiates more energy than it gets from the Sun, but not because of cooling:

- Helium and hydrogen are not well mixed; helium tends to condense into droplets and then fall
- Gravitational field compresses helium and heats it up

12.3 Saturn's Interior and Magnetosphere

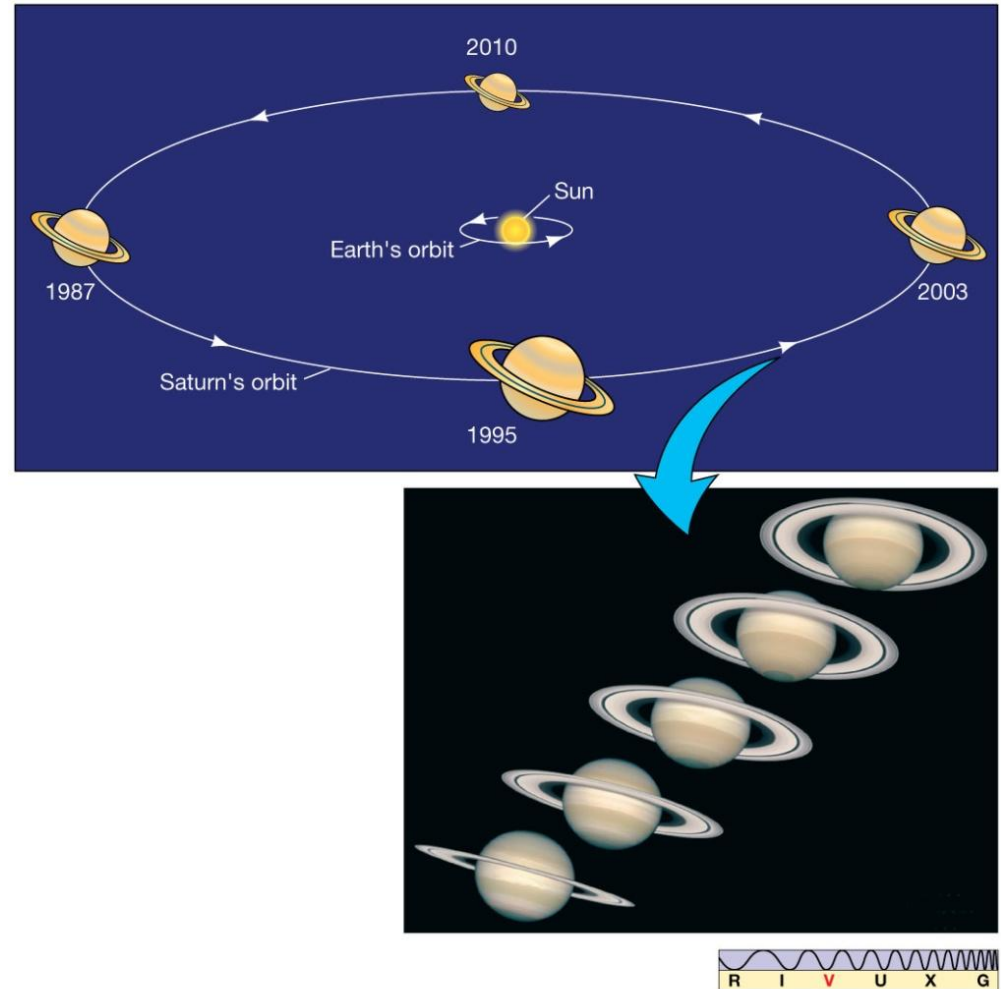
Saturn also has a strong magnetic field, but only 5% as strong as Jupiter's

Creates aurorae



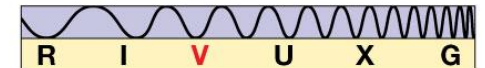
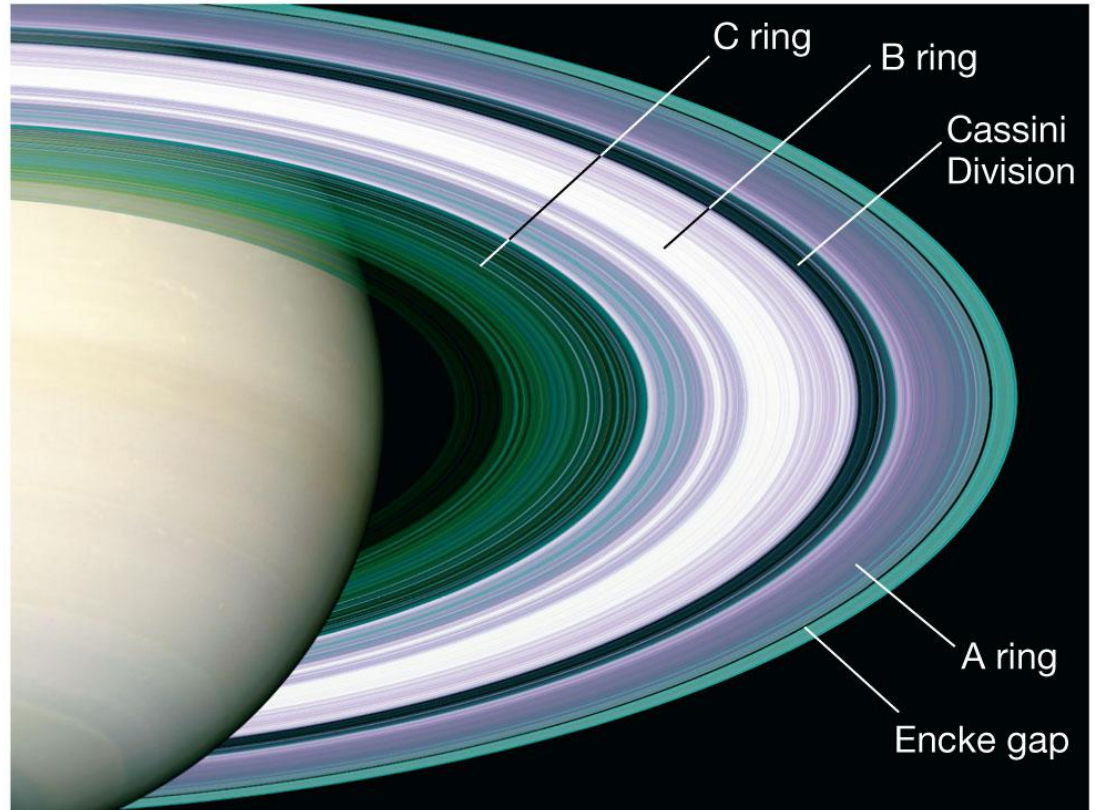
12.4 Saturn's Spectacular Ring System

Saturn has an extraordinarily large and complex ring system, which was visible even to the first telescopes



12.4 Saturn's Spectacular Ring System

Overview of the
ring system



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12.4 Saturn's Spectacular Ring System

Ring particles range in size from fractions of a millimeter to tens of meters

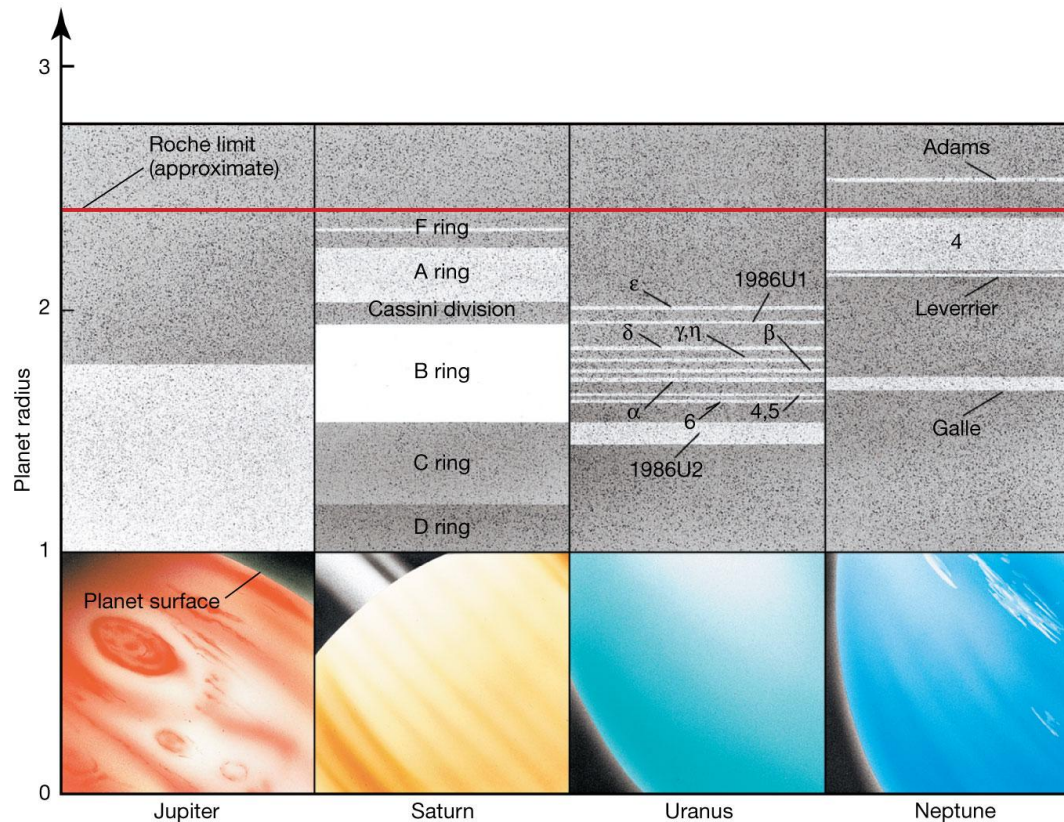
Composition: Water ice—similar to snowballs

Why rings?

- Too close to planet for moon to form—tidal forces would tear it apart

12.4 Saturn's Spectacular Ring System

Closest distance that moon could survive is called Roche limit; ring systems are all inside this limit

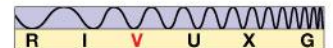
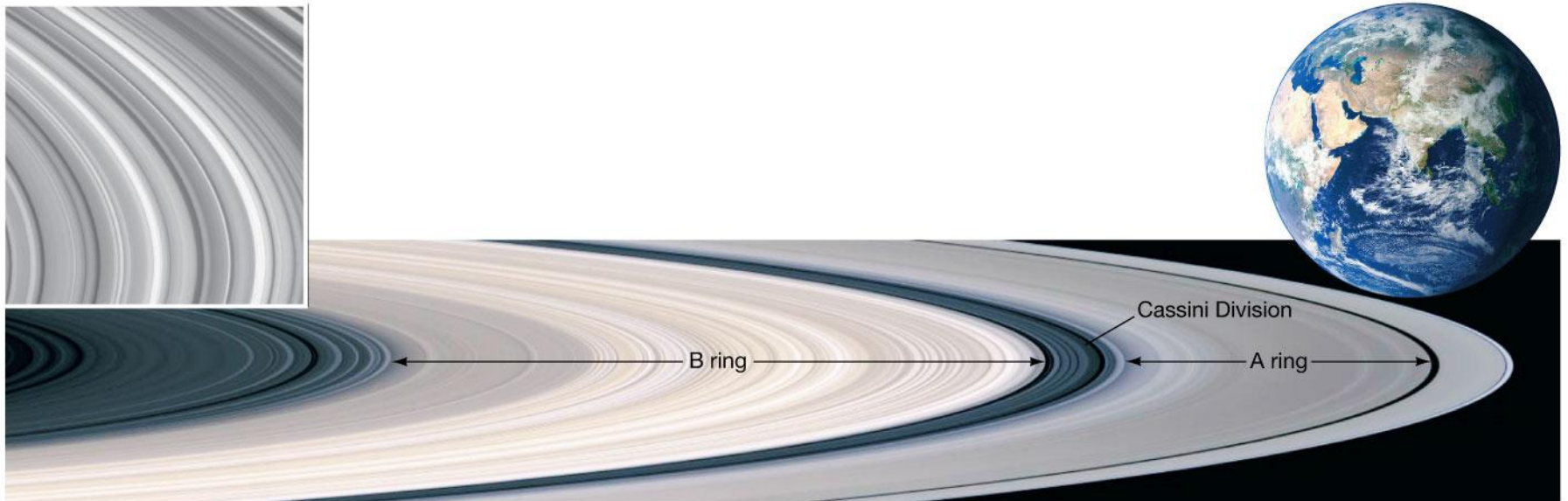


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12.4 Saturn's Spectacular Ring System

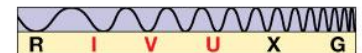
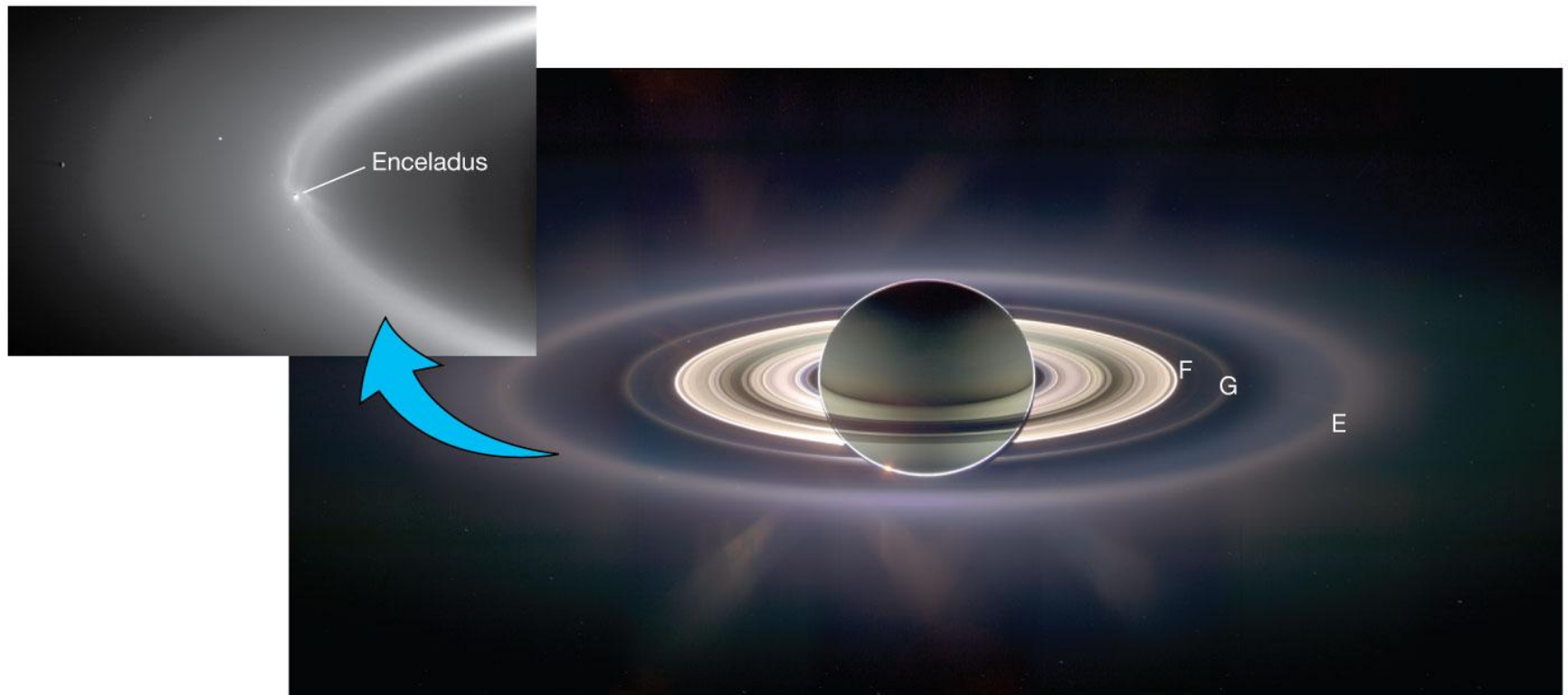
Voyager probes showed Saturn's rings to be much more complex than originally thought

(Earth is shown on the same scale as the rings)



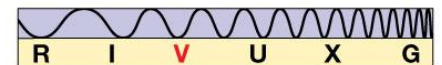
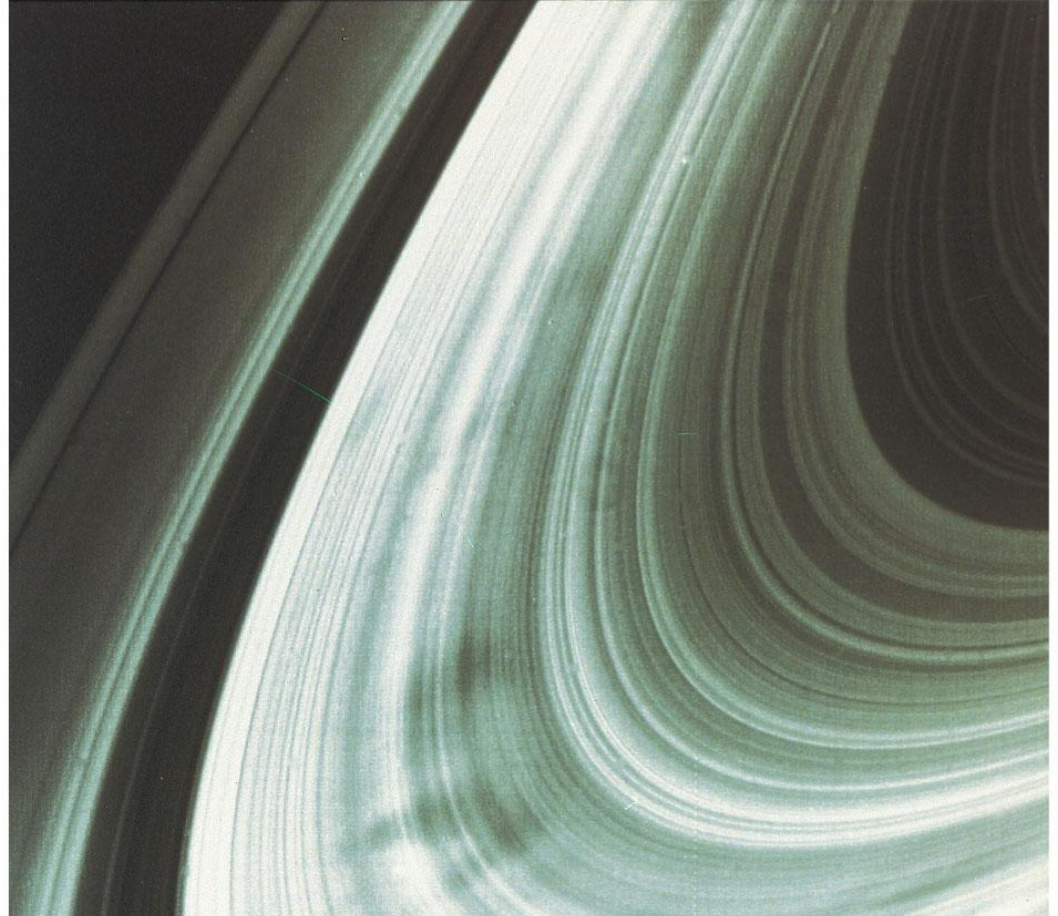
12.4 Saturn's Spectacular Ring System

This backlit view shows the fainter F, G, and E rings



12.4 Saturn's Spectacular Ring System

Voyager also found radial “spikes” that formed and then dissipated; this probably happens frequently

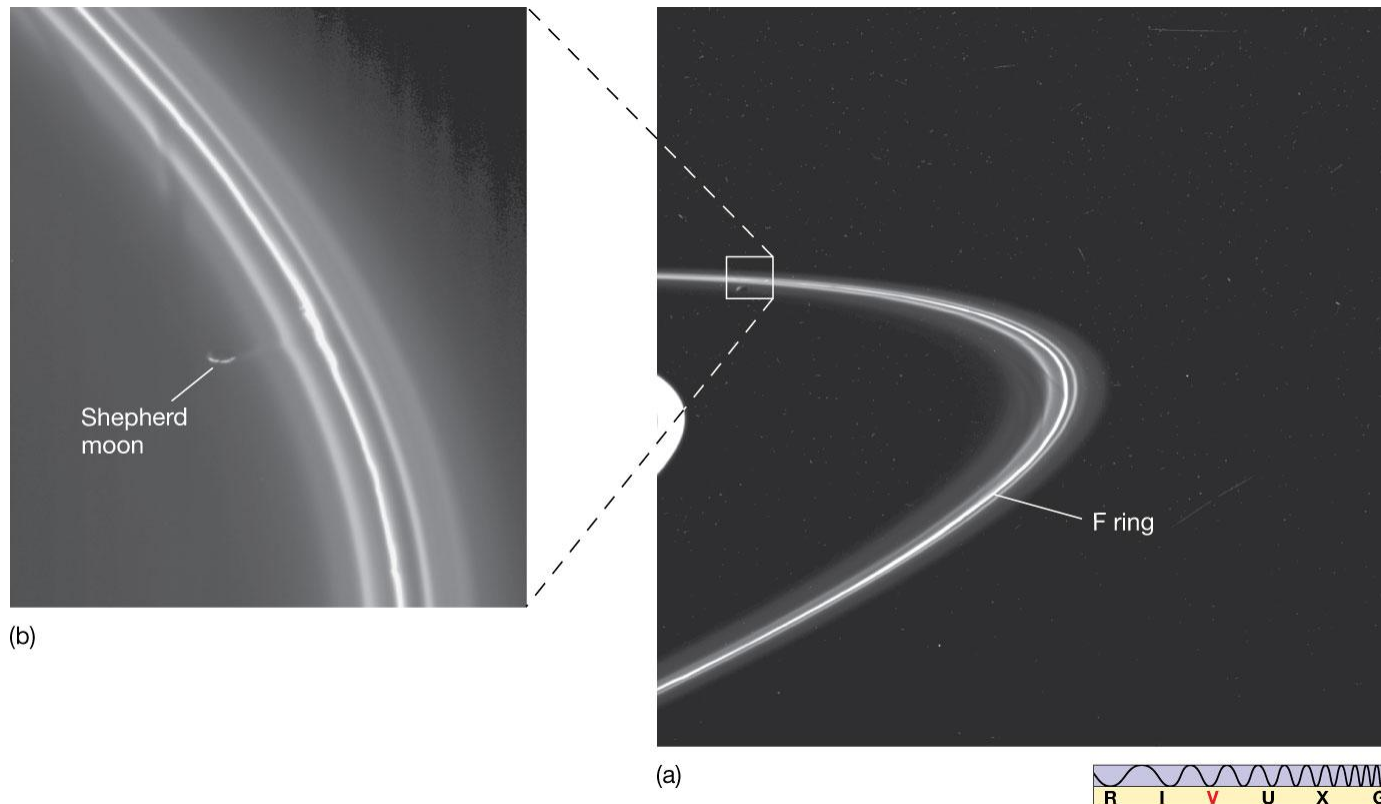


12.4 Saturn's Spectacular Ring System

- Other edges and divisions in rings are also the result of resonance
- “Shepherd” moon defines outer edge of A ring through gravitational interactions

12.4 Saturn's Spectacular Ring System

Strangest ring is outermost, F ring; it appears to have braids and kinks



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12.4 Saturn's Spectacular Ring System

Details of formation are unknown:

- Probably too active to have lasted since birth of solar system
- Not all rings may be the same age
- Either must be continually replenished, or are the result of a catastrophic event

12.5 The Moons of Saturn

Saturn's many moons appear to be made of water ice

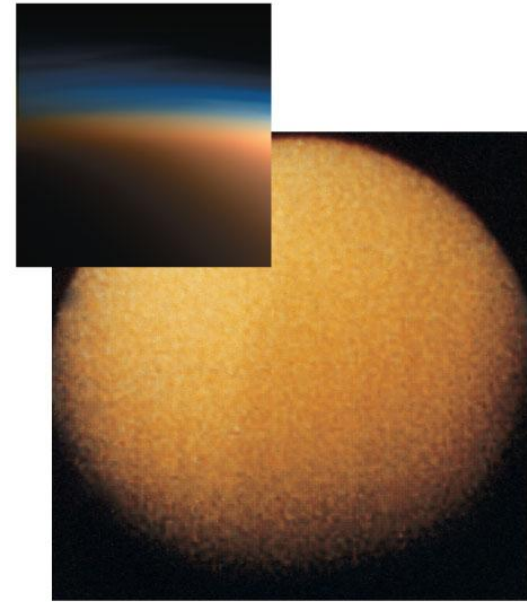
In addition to the small moons, Saturn has

- Six medium-sized moons (Mimas, Enceladus, Tethys, Dione, Rhea, and Iapetus)
- One large moon (Titan), almost as large as Jupiter's Ganymede

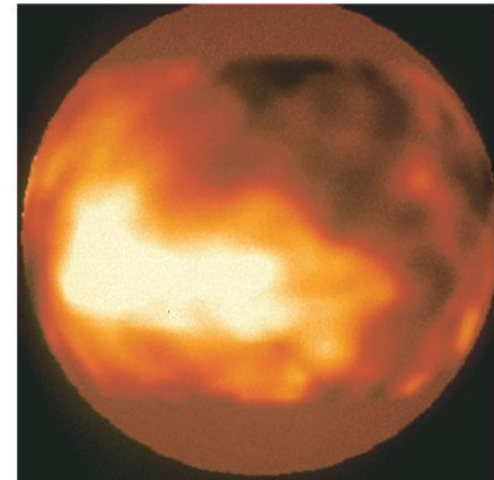
12.5 The Moons of Saturn

Titan has been known for many years to have an atmosphere thicker and denser than Earth's; mostly nitrogen and argon

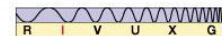
Makes surface impossible to see; the upper picture at right was taken from only 4000 km away



(a)

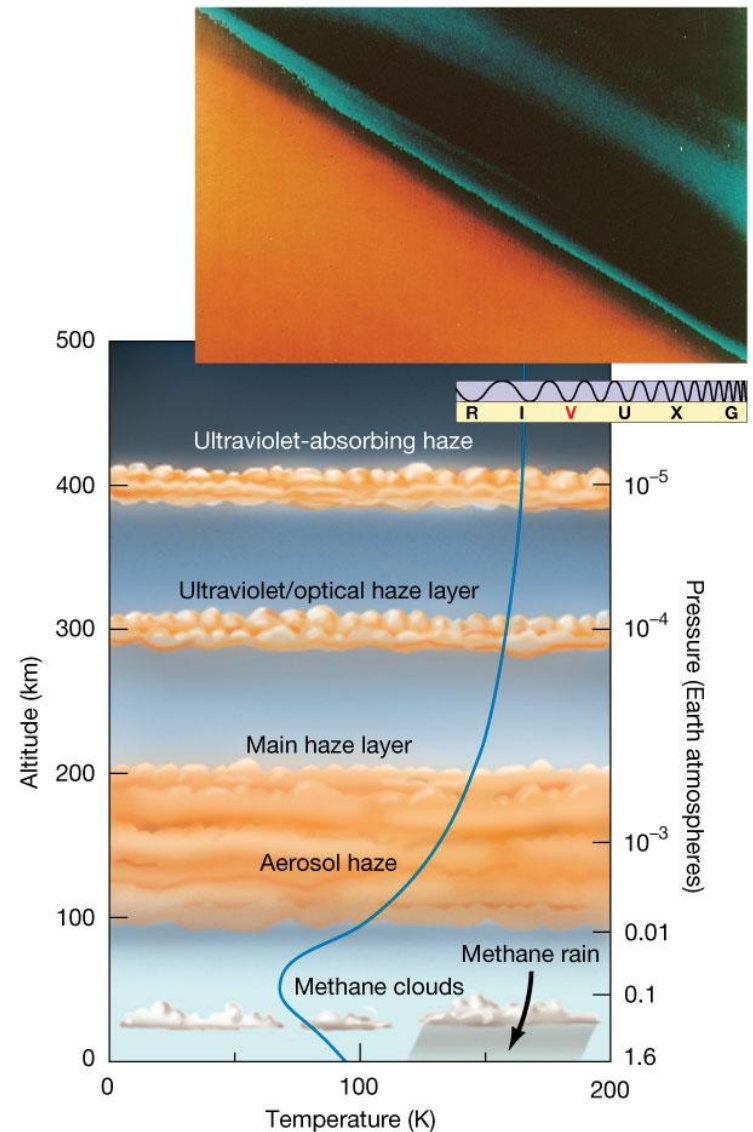


(b)



12.5 The Moons of Saturn

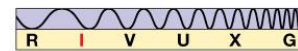
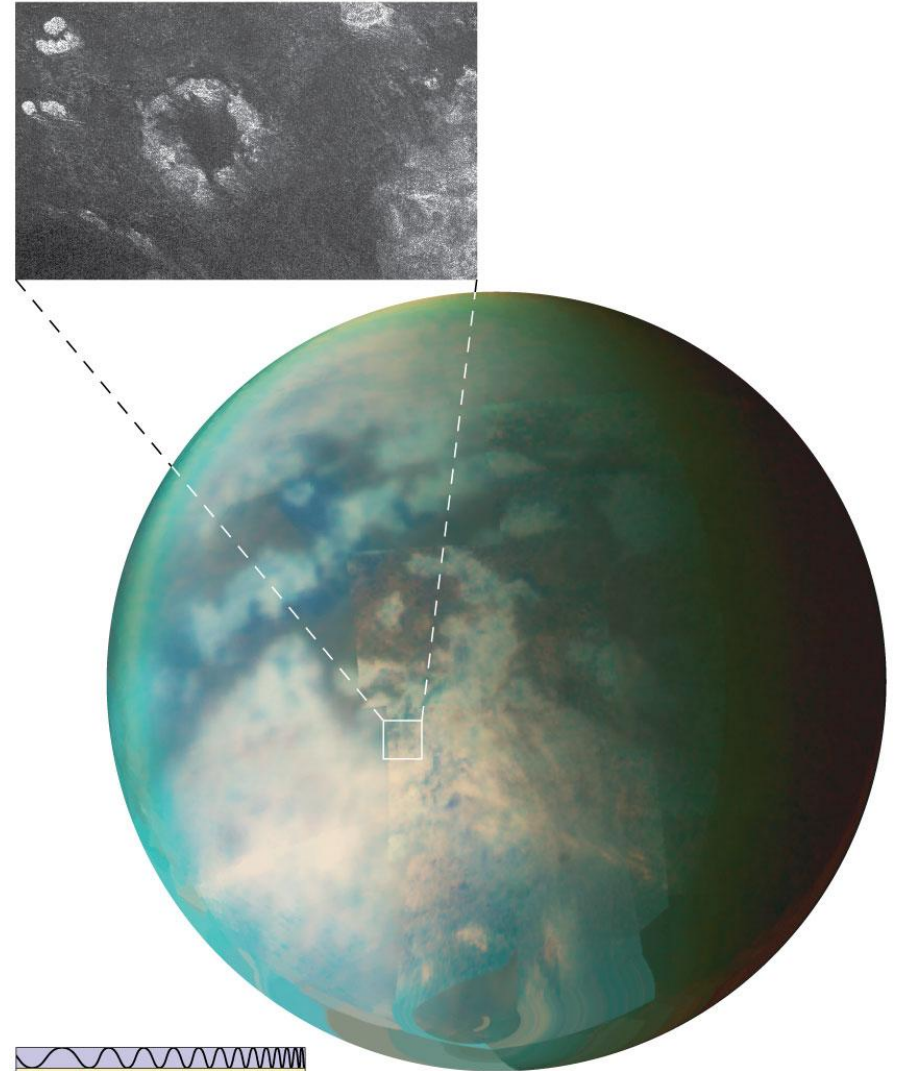
Trace chemicals in Titan's atmosphere make it chemically complex



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12.5 The Moons of Saturn

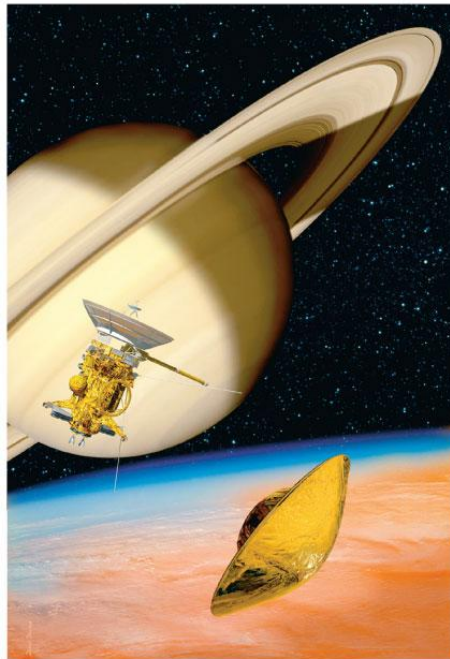
Some surface features on Titan are visible in this *Cassini* infrared image



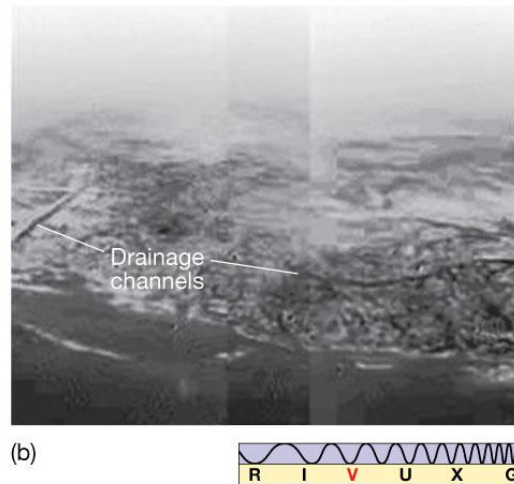
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12.5 The Moons of Saturn

The *Huygens* spacecraft has landed on Titan and returned images directly from the surface



(a)



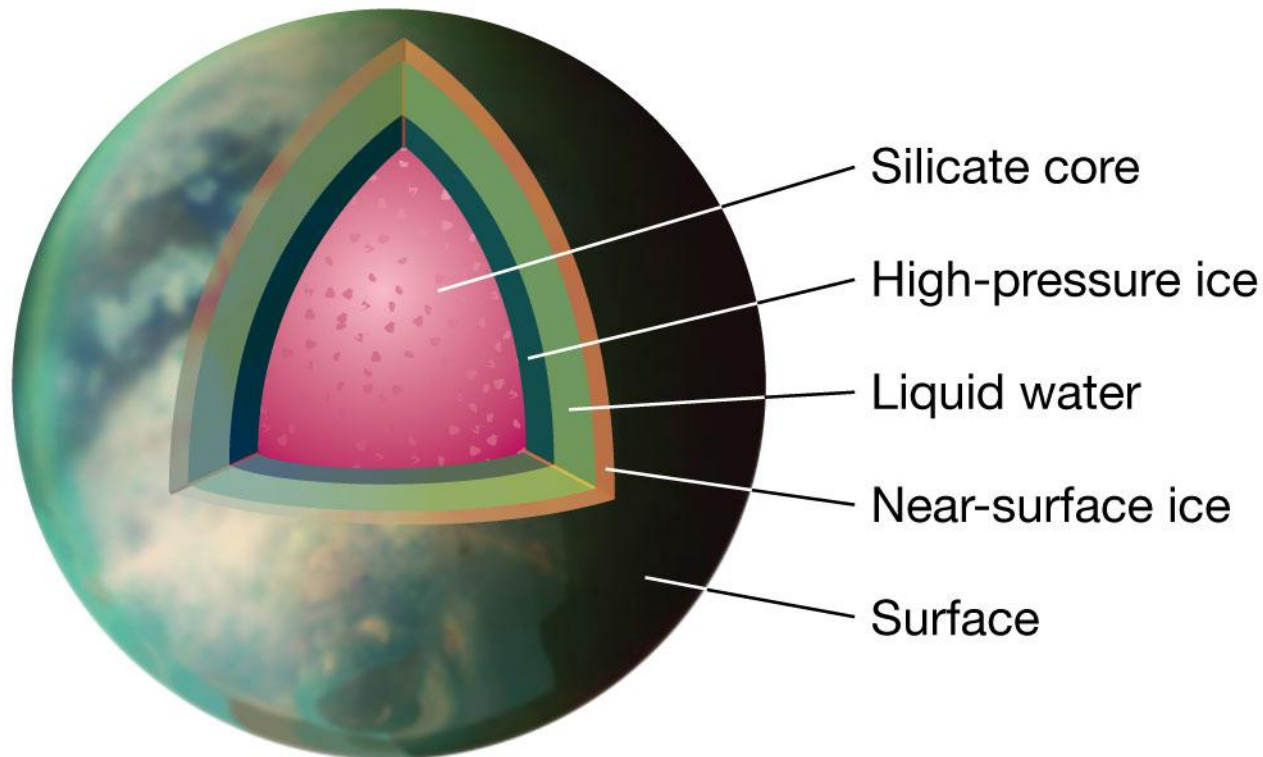
(b)



(c)

12.5 The Moons of Saturn

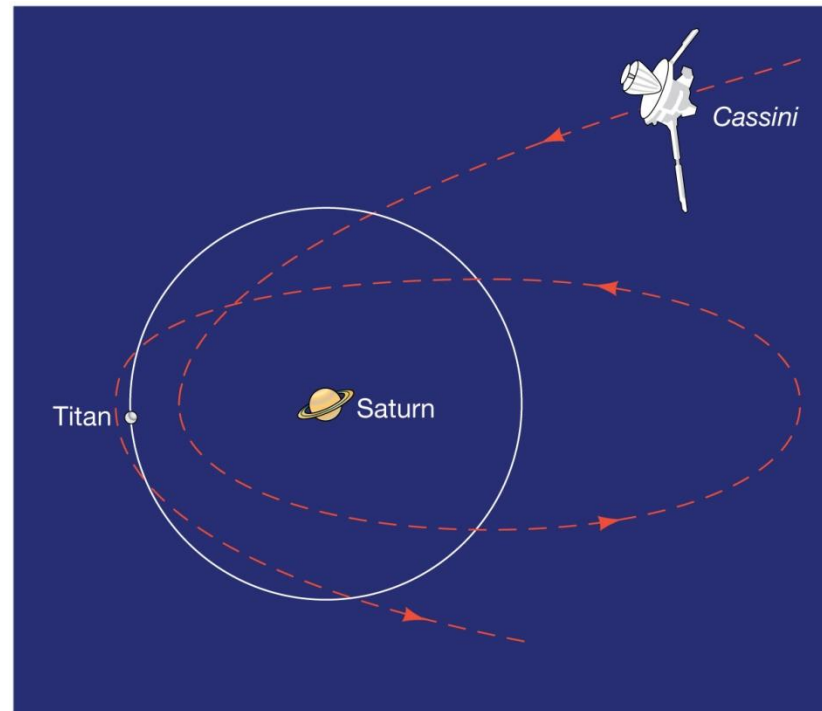
Based on measurements made by *Cassini* and *Huygens*, this is the current best guess as to what the interior of Titan looks like



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Discovery 12-1: Dancing Among Saturn's Moons

The *Cassini* spacecraft uses multiple “gravitational slingshots” to make multiple close passes around Saturn’s moons. Precise orbits are decided on the fly.



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12.5 The Moons of Saturn

This image shows Saturn's mid-sized moons



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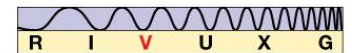
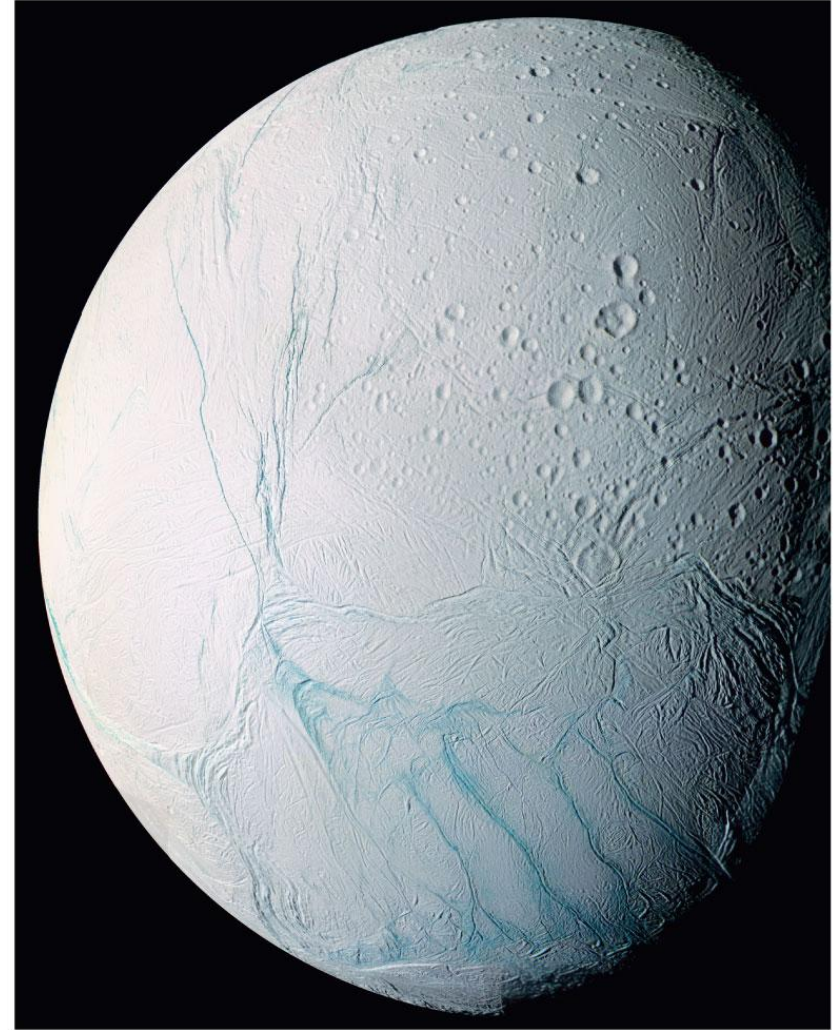


12.5 The Moons of Saturn

- Mimas, Enceladus, Tethys, Dione, and Rhea all orbit between 3 and 9 planetary radii from Saturn, and all are tidally locked—this means they have “leading” and “trailing” surfaces
- Iapetus orbits 59 radii away and is also tidally locked

12.5 The Moons of Saturn

Surface of Enceladus seems
oddly youthful

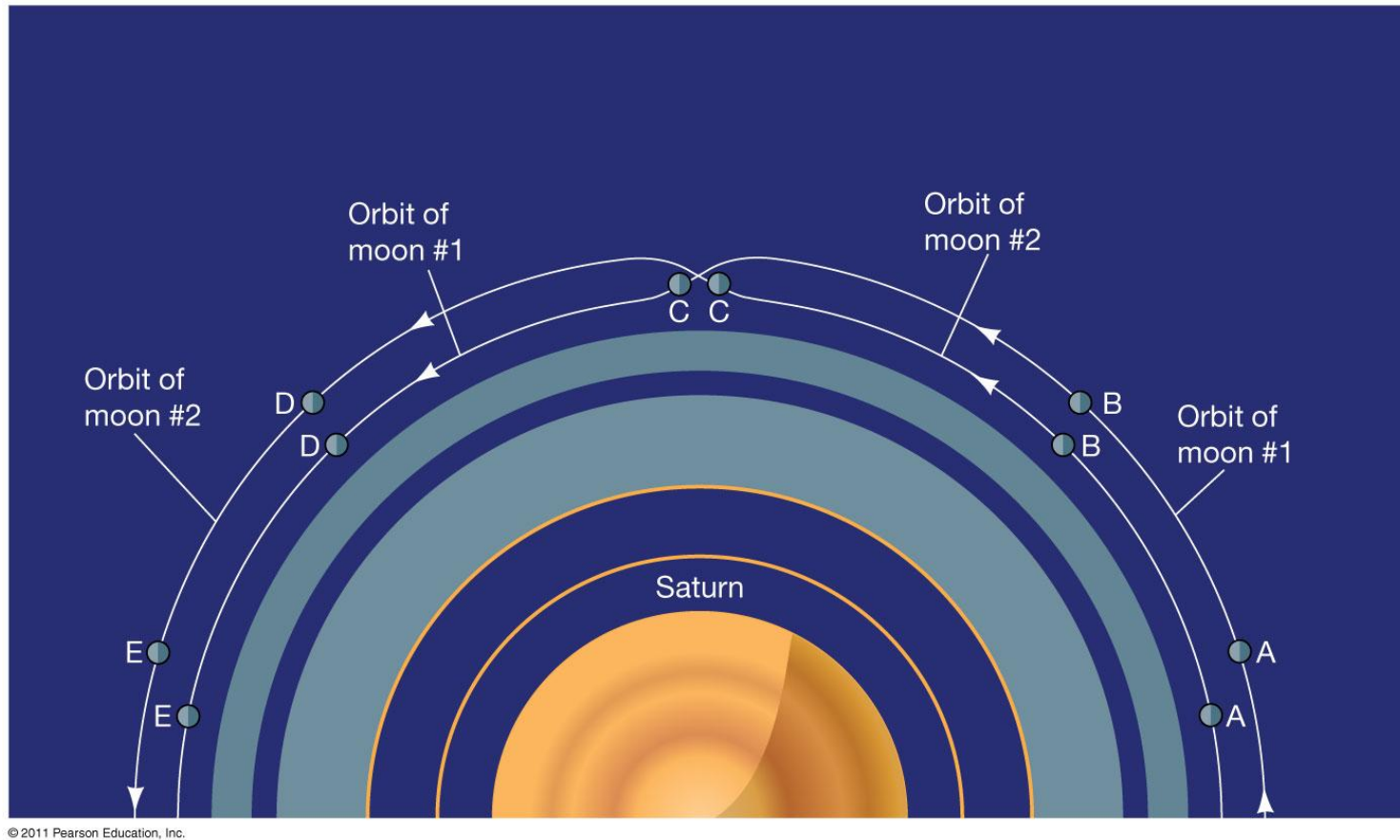


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12.5 The Moons of Saturn

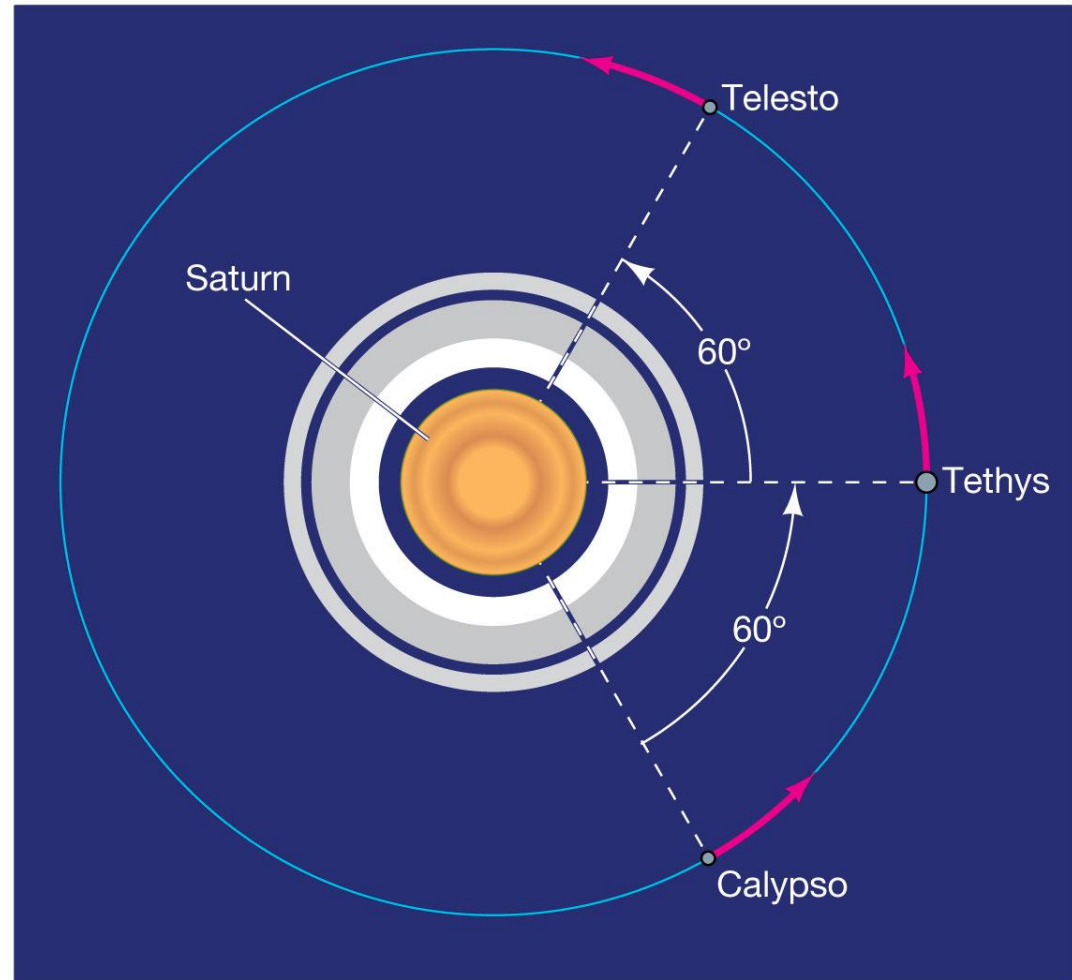
Masses of small moons not well known

Two of them share a single orbit



12.5 The Moons of Saturn

Two more moons are
at the Lagrangian
points of Tethys



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Summary of Chapter 12

- Saturn, like Jupiter, rotates differentially and is significantly flattened
- Saturn's weather patterns are in some ways similar to Jupiter's, but there are far fewer storms
- Saturn generates its own heat through the compression of "helium raindrops"
- Saturn has a large magnetic field and extensive magnetosphere

Summary of Chapter 12

(cont.)

- Saturn's most prominent feature is its rings, which are in its equatorial plane
- The rings have considerable gross and fine structure, with segments and gaps; their particles are icy and grain- to boulder-sized
- Interactions with medium and small moons determine the ring structure
- The rings are entirely within the Roche limit, where larger bodies would be torn apart by tidal forces

Summary of Chapter 12 (cont.)

- Titan is the second-largest moon in the solar system
- Titan has an extremely thick atmosphere, and little is known about its surface or interior
- Medium-sized moons are rock and water ice; their terrains vary
- These moons are tidally locked to Saturn
- Several of the small moons share orbits, either with each other or with larger moons