Chapter 12
Saturn
Units of Chapter 12

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12.1 Orbital and Physical Properties

Mass: $5.7 \times 10^{26}$ kg

Radius: 60,000 km

Density: 700 kg/m$^3$—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.
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
Similar to Jupiter’s, except pressure is lower

Three cloud layers

Cloud layers are thicker than Jupiter’s; see only top layer
12.2 Saturn’s Atmosphere

Structure in Saturn’s clouds can be seen more clearly in this false-color image.
12.2 Saturn’s Atmosphere

Wind patterns on Saturn are similar to those on Jupiter, with zonal flow.
12.2 Saturn’s Atmosphere

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

This image shows a huge storm on Saturn; it is expected to last at least two years. Smaller storms dissipate more quickly due to extremely high wind speeds.
12.3 Saturn’s Interior and Magnetosphere

Interior structure similar to Jupiter’s

- Molecular hydrogen
  - Depth 250 km
  - Temperature 250 K
  - Pressure 10 atm
- Depth 30,000 km
  - Temperature 8000 K
  - Pressure $3 \times 10^6$ atm
- Depth 45,000 km
  - Temperature 10,000 K
  - Pressure $10^7$ atm
- Icy/rocky core
  - Depth 60,000 km
  - Temperature 12,000 K
  - Pressure $1.3 \times 10^7$ atm
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
Saturn also has a strong magnetic field, but only 5% as strong as Jupiter’s.

Creates aurorae
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
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.
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
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
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
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.
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.
Trace chemicals in Titan’s atmosphere make it chemically complex.
12.5 The Moons of Saturn

Some surface features on Titan are visible in this Cassini infrared image
12.5 The Moons of Saturn

The *Huygens* spacecraft has landed on Titan and returned images directly from the surface.
Based on measurements made by Cassini and Huygens, this is the current best understanding as to what the interior of Titan looks like.
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.
12.5 The Moons of Saturn

This image shows Saturn’s mid-sized moons.
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.
Surface of Enceladus seems oddly youthful; inset shows active geysers
12.5 The Moons of Saturn

Masses of small moons not well known

Two of them share a single orbit
Two more moons are at the Lagrangian points of Tethys
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
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