Chapter 11
Jovian Planet Systems

11.1 A Different Kind of Planet

Our goals for learning:
• Are jovian planets all alike?
• What are jovian planets like on the inside?
• What is the weather like on jovian planets?
• Do jovian planets have magnetospheres like Earth’s?

Jovian Planet Composition

• Jupiter and Saturn
  – Mostly H and He gas

• Uranus and Neptune
  – Mostly hydrogen compounds: water (H₂O), methane (CH₄), ammonia (NH₃)
  – Some H, He, and rock
Density Differences

- Uranus and Neptune are denser than Saturn because they have less H/He, proportionately.

Density Differences

- 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.

Interiors of Jovian Planets

• No solid surface.
• Layers under high pressure and temperatures.
• Cores (~10 Earth masses) made of hydrogen compounds, metals & rock.
• The layers are different for the different planets. WHY?
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)

Internal Heat of Other Planets

- Saturn also radiates twice as much energy it receives from Sun
- Energy probably comes from differentiation (helium rain)
- Neptune emits nearly twice as much energy as it receives, but the source of that energy remains mysterious

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 (NH₄SH) 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 gas of Neptune and Uranus absorb red light but transmit blue light
- Blue light reflects off methane clouds, making those planes look blue

Jupiter’s Great Red Spot

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

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

What have we learned?

• Are jovian planets all alike?
  – Jupiter and Saturn are mostly H and He gas
  – Uranus and Neptune are mostly H compounds

• What are jovian planets like on the inside?
  – Layered interiors with very high pressure and cores made of rock, metals, and hydrogen compounds
  – Very high pressure in Jupiter and Saturn can produce metallic hydrogen

What have we learned?

• What is the weather like on jovian planets?
  – Multiple cloud layers determine colors of jovian planets
  – All have strong storms and winds

• Do jovian planets have magnetospheres like Earth’s?
  – All have substantial magnetospheres
  – Jupiter’s is largest by far
11.2 A Wealth of Worlds: Satellites of Ice and Rock

Our goals for learning:
• What kinds of moons orbit jovian planets?
• Why are Jupiter’s Galilean moons so geologically active?
• What is remarkable about Titan and other major moons of the outer solar system?
• Why are small icy moons more geologically active than small rocky 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.

Io’s Volcanic Activity

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

Ganymede

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

- “Classic” cratered iceball.
- No tidal heating, no orbital resonances.
- But it has magnetic field !?

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, and ethane

Titan’s Surface

- *Huygens* probe provided first look at Titan’s surface in early 2005
- Liquid methane, “rocks” made of ice
Medium Moons of Saturn

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

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

- Similar to Pluto, but larger
- Evidence for past geological activity
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 have we learned?

- What kinds of moons orbit jovian planets?
  - Moons of many sizes
  - Level of geological activity depends on size
- Why are Jupiter’s Galilean moons so geologically active?
  - Tidal heating drives activity, leading to Io’s volcanoes and ice geology on other moons

What have we learned?

- What is special about Titan and other major moons of the solar system?
  - Titan is only moon with thick atmosphere
  - Many other major moons show signs of geological activity
- Why are small icy moons more geologically active than small rocky planets?
  - Ice melts and deforms at lower temperatures enabling tidal heating to drive activity
11.3 Jovian Planet Rings

Our goals for learning:

• What are Saturn’s rings like?
• How do other jovian ring systems compare to Saturn’s?
• Why do the jovian planets have rings?

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

Why do the jovian planets have rings?

• They formed from dust 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.
- 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

What have we learned?

- What are Saturn’s rings like?
  - Made up of countless individual ice particles
  - Extremely thin with many gaps
- How do other jovian ring systems compare to Saturn’s?
  - Much fainter ring systems with smaller, darker, less numerous particles
- Why do the jovian planets have rings?
  - Ring particles are probably debris from moons