

- B. The standard hypothesis is that a giant impact on Earth led to the formation of the Moon.
- C. The existence of the Moon may be due to random chance, but it was a happy accident, as it has had a significant impact on the development of life on Earth.

Suggested Readings:

Beatty, Petersen, and Chaikin, *The New Solar System*, chaps. 22–23.

Benson, *Beyond: Visions of Interplanetary Probes*.

Comins, *What If the Moon Didn't Exist?*

Hey, *Solar System*.

Mackenzie, *The Big Splat*.

McFadden, Weissman, and Johnson, *Encyclopedia of the Solar System*, chaps. 12, 19.

Questions to Consider:

1. How many moons were completely disrupted by large impact events?
2. Why is it that, of the rocky planets, only Earth has a significant moon?
3. Why is it that, of the giant planets, Uranus is the only one without a large moon?

Lecture Sixteen

Intricate Ring Systems of the Giant Planets

Scope: Saturn's magnificent ring system is a wonder to behold, yet it also provides an extensive natural laboratory for studying gravitational and other interactions. The system contains several bright and faint rings, comprising thousands of ringlets, and is ultimately composed of icy particles both large and small. The other giant planets also have rings, but theirs are few, thin, and dark. The gravitational influence of moons both outside and within the ring systems creates gaps, clumps, waves, and other structures. Some moons are the proximate source of dust-sized particles in the rings, while other moons disrupted long ago may be the initial source of the large particles. The rings, combined with the moons, are dynamic systems that provide valuable clues and constraints on planetary histories.

Outline

- I. Saturn's magnificent ring system is a wonder to behold.
 - A. The simple silhouette of Saturn is an immediately recognizable iconic representation of all astronomy.
 - B. The overall structure is composed of rings and ringlets.
 1. From Earth one can see three main rings (A, B, C) and two empty regions called the Cassini Division (between the A and B rings) and the Encke Gap (within the A ring).
 2. Higher-resolution images from satellites show that each ring is composed of thousands of individual ringlets and reveal several smaller gaps.
 - C. The rings are composed of icy particles from dust sized to boulder sized.
 1. The scattering of light by these particles means that the rings can appear quite different depending on the viewing angle with respect to the Sun.
 2. Saturn's main rings are about 280,000 kilometers across yet less than a kilometer thick.
 3. Collisions among the ring particles help enforce uniform motion and produce a very thin structure.

- II.** In contrast to Saturn, rings of the other giant planets are few and dark.
- A.** Jupiter has one thin main ring and two much fainter and more diffuse rings.
 - B.** Uranus's rings, like the main ring of Jupiter, are very small and thin.
 - C.** There are about five ring structures in Neptune's rings.
 - D.** These planets' rings are difficult to see because the ring particles are as dark as charcoal.
- III.** The ring systems of the giants are closely tied to their moons.
- A.** Gravitational interactions with moons create many features in the rings.
 - 1.** The regular moons and rings share the same orbital plane.
 - 2.** Some gravitational resonances with moon orbits create gaps in the rings, some appear to have no effect, and some seem to gather ring particles.
 - 3.** Several gaps in the rings are created by moons orbiting within the gap.
 - 4.** Pairs of moons, called shepherd satellites, orbit on opposite sides of and maintain the thin structure of Uranus's epsilon ring and Saturn's F ring.
 - 5.** The bright arcs in Neptune's Adams Ring are produced by a high-order resonance with the small moon Galatea.
 - B.** Moons can be the sources of ring particles.
 - 1.** Particle bombardment of moons can release dust-sized particles into space.
 - 2.** Faint rings around Jupiter and Saturn are observed to be made from such ejected dust of moons.
 - 3.** The ice geysers on Enceladus spew forth the particles that create Saturn's E ring.
 - 4.** A continuing supply from the moons is necessary, as the small particles in these faint rings will be swept out of the ring system in thousands of years.
- IV.** The question of how the bright rings formed is not yet fully answered.
- A.** One hypothesis is that the rings formed with the planet, out of excess material that did not form moons.

- B.** The main problem with this original formation idea is that the ring systems we see today would dissipate in much less than 4 billion years.
- C.** An alternative hypothesis is that the tidal breakup of moons and comets provides the particles for the bright rings.
- D.** In the tidal breakup scenario, when the supply of objects runs out, the rings will eventually disappear.
- E.** Mars's moon Phobos has a decaying orbit, and in 50 million years Phobos may break apart and create a ring.

Suggested Readings:

Beatty, Petersen, and Chaikin, *The New Solar System*, chap. 16.

Benson, *Beyond: Visions of Interplanetary Probes*.

De Pater and Lissauer, *Planetary Sciences*, chap. 11.

Hey, *Solar System*.

Lovett, Horvath, and Cuzzi, *Saturn*.

McFadden, Weissman, and Johnson, *Encyclopedia of the Solar System*, chap. 27.

Questions to Consider:

- 1.** How likely is it that sometime during the 4.5-billion-year history of the solar system, Jupiter, Uranus, or Neptune had a ring system as extensive as Saturn's is today?
- 2.** How would the capture of the large moon Triton by Neptune affect its ring system?
- 3.** If the Moon formed by a giant impact, might Earth have had rings for a short time thereafter?