Lecture Fifteen

A Myriad of Moons

Scope: The Moon is a dominant fixture in our night sky, and it is one of the seven large moons of the solar system. Over 160 other moons have been discovered, from thousands of kilometers in diameter to just a few kilometers. While impacts have played a dominant role in shaping moons' surfaces, the icy outer moons also show tectonic and volcanic activity at cryogenic temperatures. Some moons' size and orbit indicate that they formed along with the planet, while others appear to have been captured into orbit afterward. One anomaly is Triton—it is the largest moon of Neptune, yet could not have formed in situ. Even more puzzling is why Earth's Moon, one of the largest in the solar system, orbits such a small planet.

Outline

I. Our Moon plays a pivotal role in shaping our view of the universe.

- **A.** The Moon is ingrained in our culture, from calendars to folklore to romance.
- **B.** The Moon as a destination fueled both our imagination of the universe and the technology to get there.

II. The Moon is one of the seven large moons of the solar system.

- **A.** The Moon is about one-fourth the size of Earth and is located about 30 Earth diameters away.
- **B.** The large moons, in decreasing order of size, are Ganymede, Titan, Callisto, Io, our Moon, Europa, and Triton.
- **C.** Ganymede and Titan are larger than the planet Mercury, and all are larger than Pluto.
- **D.** Ganymede is ice covered and heavily cratered.
- **E.** The Huygens probe landed on Titan and revealed its frozen features in detail.

III. Over 160 moons of other planets have been discovered so far.

- **A.** After the 7 large moons (several thousand km in diameter), there are 9 medium-sized moons (>1000 km), about 20 small moons (>100 km), and about 50 tiny moons (>10 km).

- **B.** Several moons of Saturn show very large impact craters.
  1. Rhea and Tethys have impact basins whose size is a significant fraction of the moons' diameters.
  2. Mimas is commonly referred to as the *Death Star* moon.
  3. Iapetus has at least nine large impact basins. It also has one hemisphere as bright as snow and the other hemisphere as dark as coal.
- **C.** Uranus's moons show lots of icy geologic features.
  1. Titania has canyons that are thought to indicate expansion, contraction, and fracturing of its icy surface.
  2. Ariel's canyons are filled in with cryovolcanic flows.
  3. Miranda's jumbled terrain seems to indicate extensive ice tectonics.
- **D.** Tiny moons have irregular shapes that resemble asteroids.
- **E.** Even asteroids can have moons.

IV. Moons can also be classified on the basis of their orbits.

- **A.** All of the giant planets have both regular and irregular moons.
  1. Regular satellites have generally circular orbits near the equatorial plane of their planet.
  2. Irregular satellites have orbits with a wide range of inclinations and eccentricities, and they are found in the outer parts of the moon systems.
  3. Regular moons are considered to have formed along with the planet, while irregular moons are thought to have been captured.
- **B.** Some moon systems show intriguing features.
  1. Mars's two irregular moons, Phobos and Deimos, are tiny and must surely be captured asteroids.
  2. Neptune's large moon Triton is on a retrograde orbit that indicates it must be a captured object.
  3. Charon is not really a moon: Pluto and Charon orbit their common center of mass, and they are orbited by two smaller moons.

V. When viewed in context of the solar system, Earth's large moon is perhaps the biggest anomaly of all.

- **A.** The Earth-Moon system is close to being considered a double system, as the center of mass is significantly displaced from the center of Earth.

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.