Chapter 9. Great Worlds

• Jupiter and Saturn are the two largest planets in the solar system. Jupiter's mass is 0.001 that of the Sun and twice that of all other planets put together.

• Voyager 1 and Voyager 2 were launched in 1977 to probe Jupiter, Saturn, Uranus, and Neptune. These missions provided the best close-up pictures of these outer planets. Galileo, launched in 1989, went into orbit about Jupiter in 1995 and dropped a probe into its atmosphere.

A Profile of Jupiter

• Jupiter is the largest and the most massive planet in the solar system. Its mass is 318 times the Earth's mass and its radius 11.2 times the Earth's radius. Its low mean density, 1.33 g/cm^3, indicates that its composition is dominated by light elements, i.e., H and He.

• Jupiter is noticeably oblate because of its fast rotation. Images of Jupiter in visible wavelengths show lighter zones and darker belts with alternating prograde and retrograde motions. The most prominent feature is the Great Red Spot.

Radiation Emitted by Jupiter

• Jupiter absorbs the sunlight, and emits blackbody radiation that peaks in the infrared. The observed blackbody temperature of Jupiter, 124 K, is 15 K higher than expected if it is heated by the sunlight only. The extra heating is provided by the gradual contraction of Jupiter, converting gravitational energy into heat.

• Jupiter has a strong magnetic field. Charged particles spiraling along magnetic field will emit synchrotron radiation that peaks in radio wavelengths. The radio emission from Jupiter is dominated by synchrotron radiation, also called nonthermal radiation.

Rotation of Jupiter

• Jupiter's rotation cannot be measured using its surface features because the clouds are blown by high-velocity winds. Jupiter's rotational period is best measured with radio observations of its synchrotron radiation because the associated magnetic field is anchored deep in Jupiter's core.

Jupiter's Atmosphere

• The optical appearance of zones and belts on Jupiter depends on the reflective properties, depths in the atmosphere, and temperatures.

• The Great Red Spot of Jupiter is a high pressure region floating high in the atmosphere. It has been present since its discovery 300 years ago.

Jupiter's Interior

• The interior of Jupiter cannot be probed directly. We can only model it theoretically using the concept of *hydrostatic equilibrium*, which requires the upward pressure to balance the downward

weight so that no motion sets in. It is possible to model the temperature, density, and state of matter in Jupiter's interior.

• The center of Jupiter contains a "rock" core enveloped by a layer of "ice". Surrounding these is a mantle of liquid metallic hydrogen, which is responsible for generating Jupiter's magnetic field.

Jupiter's Satellites

• Jupiter has 16 satellites. The four largest ones, Io, Europa, Ganymede, and Callisto were discovered by Galileo. These four are all synchronous rotators.

• Io is the most volcanic body in the Solar system because of the strong tidal effects from the other three Galilean satellites and Jupiter itself.

• Jupiter is surrounded by rings.

Saturn's Atmosphere

• Saturn's atmosphere is similar to that of Jupiter, showing brighter zones and darker belts with alternating prograde and retrograde winds. The wind speed at the equator reaches 1,700 km/hr!

• The Great White Spot on Saturn appears every ∼30 yr (Saturn's orbital period). It is caused by a bubble of ammonia (NH_3) heated by the summer Sun and rising to an altitude above the cloud tops. The ammonia gas crystallizes into bright reflective clouds, forming the Great White Spot, moves north, and dissipates in the winds.

Saturn's Rings

• Saturn has seven main rings (A – G), most of which are resolved into hundreds of ringlets.

• The dark band between the A ring and the B ring is called the Cassini division, which still contains many ringlets. The dark band within the A ring is called the Encke division, which does not contain any ringlet.

• The thinknesses of the rings increase from a few tens of meters to ∼1,000 km outwards. At 270,000 km across, Saturn's ring system is the thinnest astronomical structure known.

• The opaqueness of a ring at different wavelengths can be measured to determine the sizes of particles in the ring. The occultation of starlight by the rings indicates that Saturn's rings contain fine dust and particles of sizes ranging from 1 cm to 10 m.

• Many interesting phenomena are observed in Saturn's rings, and many of these phenomena are caused by dynamic interactions with small moons. For example:
– The Cassini division is caused by a perturbing resonance with the moon Mimas.
– The Encke division is swept clean by a moon.
– The delicate, braided F-ring is kept together by two shepherd moons.