

**ASTR-1010: Astronomy I**  
**Course Notes**  
**Section X**

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## **Abstract**

These class notes are designed for use of the instructor and students of the course **ASTR-1010: Astronomy I** taught by Dr. Donald G. Luttermoser at East Tennessee State University.

## X. The Jovian Planets

### A. Jupiter

1. Jupiter is the fifth planet from the Sun. It is 318 times as massive as the Earth and its diameter is  $11.2 D_{\oplus}$  at the equator and  $10.4 D_{\oplus}$  at its poles  $\implies$  Jupiter is flattened due to its rapid rotation ( $P = 9^h50.5^m$ ).
  - a) Jupiter contains more mass than all of the other planets put together!
  - b) All of the planets could fit inside Jupiter's volume.
  - c) If Jupiter had 10 times more mass, it would have been a secondary star (a red dwarf) to the Sun.
2. Jupiter is a gas giant. There may be a small rocky core at the center, but it is surrounded by a large envelope of hydrogen and helium (similar composition to the Sun).
  - a) As one goes deeper into the planet, the hydrogen gas gets so dense that it becomes **metallic hydrogen**.
  - b) This metallic hydrogen is hot so it is ionized. This coupled with Jupiter's rapid rotation produces an enormous magnetic field surrounding the planet.
3. Jupiter's cloud tops are banded. In the southern hemisphere, a the **Great Red Spot** is often seen  $\implies$  Galileo discovered this feature, so it has been around for at least 400 years!
  - a) The Great Red Spot is actually a giant hurricane (it is twice the size of the Earth).

- b) The dark bands are called **belts** and represent low pressure areas in Jupiter's atmosphere (Jupiter spins so fast that these low pressure areas are stretched completely around the planet).
  - c) The brighter bands are called **zones** and are high pressure areas.
  - d) These clouds are composed primarily of ammonia and methane.
4. The first spacecrafts to visit Jupiter were **Pioneer 10** (Dec 1973) and **Pioneer 11** (Dec 1974).
5. Five years later, **Voyager 1** and **Voyager 2** sailed past the planet. The Voyagers had much better cameras and detectors than the Pioneers. The Voyagers rewrote the books on Jupiter:
- a) Jupiter has a ring made up of smoke sized particles — it can only be seen from the back side of Jupiter!
  - b) Io has volcanos! And many of them!
  - c) Europa may have a subterranean ocean (which may possibly have lifeforms in it) covered by a water ice surface.
  - d) Ganymede and Callisto also have water ice on their surfaces.
6. These earlier spacecraft were flybys, in the late 1990s and early 2000s the **Galileo** spacecraft was in orbit around Jupiter (it has since been "deorbited" into Jupiter's atmosphere to avoid any possible future contamination of Europa) — it launched a probe into the atmosphere of Jupiter and found that Jupiter's atmo-

sphere is a lot drier than was anticipated.

7. All of these spacecraft have taught us a great deal about the 4 Galilean moons of Jupiter:
  - a) Jupiter's closest large moon, **Io**, has volcanos that are caused by tides being continuously raised and lowered within the moon as it orbits the planet in an eccentric orbit.
  - b) The large number of volcanos on Io regenerates a new surface in a few decades  $\implies$  the most geologically active body in the solar system.
  - c) The second-closest large moon, **Europa**, has one of the smoothest surfaces of any large body in the solar system. Its water ice crust and average density suggests that Europa has a large, planet-wide, liquid ocean beneath the surface. Since tides are also raised on Europa, this liquid ocean may have volcanic vents on its floor which may support primitive life.
  - d) **Ganymede**, the 3rd-closest large moon, is the largest moon in the solar system ( $D = 1.5 D_{\text{Moon}} = 1.1 D_{\text{Mercury}}$ ). It also has water ice on its surface which is covered with many craters.
  - e) **Callisto**, the farthest of the Galilean moons from Jupiter is a bit smaller than Ganymede and has even a higher density of craters on its surface. Both Callisto and Ganymede may also have subterranean liquid water oceans, but much deeper than Europa's.

8. Jupiter has a large number of smaller moons, many of the outer ones are probably captured asteroids.

## B. Saturn

1. Saturn is the sixth planet from the Sun. It is 95 times as massive as the Earth and its diameter is  $9.5 D_{\oplus}$  (equatorial).
  - a) Saturn rotates fast, but not as fast as Jupiter ( $P = 10^h 14.0^m$ ).
  - b) Saturn's density is  $690 \text{ kg/m}^3 \implies$  less than that of water ( $\rho = 1000 \text{ kg/m}^3$ )!
2. Saturn has a beautiful ring system. From Earth, it appears as though there are 3 main rings, **A** (farthest from planet), **B**, and **C** (closest to planet), with a large gap in between A and B called **Cassini's Division**. (There is a smaller division in the A-ring called **Encke's Division**.)
  - a) The rings are composed of ice particles that range in size from snowflakes (1 mm) to boulders (tens of meters across).
  - b) Saturn's rings fall within the **Roche lobe** of its gravitational field  $\implies$  anything of large size within such a lobe will be broken apart by severe tidal forces.
3. Saturn has a large moon system like Jupiter, the biggest are **Titan**, **Rhea**, **Iapetus**, **Dione**, and **Tethys**.
4. **Pioneer 11** flew past Saturn in 1979 and discovered a narrow ring just outside the A-ring which was called the **F-ring**.

5. The **Voyager 1** and **Voyager 2** spacecrafts flew past Saturn in 1980 and 1981, respectively. They made many discoveries!
  - a) The rings are actually composed of thousands of *ringlets*, like groves in a phonograph record.
  - b) The F-ring was discovered to be braided with 2 **shepherding moons** on either side of this ring.
  - c) *Black spokes* appear in the rings which rotate around the planet following the magnetic field.
  - d) Many small moons were found in orbit around the planet.
  
6. Saturn's internal structure is similar to Jupiter's with metallic hydrogen at the center.
  - a) It has higher wind speeds (500 m/s) than Jupiter.
  - b) Saturn's upper atmosphere contains fine aerosols which gives the atmosphere a hazy appearance and hides the cloud bands below.
  
7. Titan is the only moon in the solar system with an appreciable atmosphere  $\implies$  it's as thick as Earth's and composed of methane ( $\text{CH}_4$ ), nitrogen ( $\text{N}_2$ ), and hydrocarbons (the stuff that life is made of).
  
8. The **Cassini spacecraft** is on its way to Saturn and should arrive in 2004. Cassini will orbit the planet and study it in detail. It will also launch a probe into Titan's atmosphere to study its properties.

### C. Uranus

1. Uranus is the seventh planet from the Sun. It is 15 times as massive as the Earth and its diameter is  $4.0 D_{\oplus}$  (equatorial).
2. Uranus was discovered by accident by William Herschel on March 13, 1781.
3. Uranus's axis is tilted by  $98^{\circ} \implies$  Uranus also had an impact from a large planetesimal early in its history.
4. Uranus has 15 named moons and 5 recently discovered ones which as yet have not been given official names. Of these moons, 5 are fairly large: **Titania**, **Oberon**, **Umbriel**, **Ariel**, and **Miranda**.
5. In 1977 while Uranus was passing in front of a star, rings were discovered around Uranus.
6. In 1986, **Voyager 2** flew past the planet.
  - a) Discovered that the rings are made of dark particles (albedo of 0.01) around the size of a large lump of coal (1 m in diameter).
  - b) Miranda looks as though it was smashed apart by a large impact, and then later, the large pieces *fused* backed together.

### D. Neptune

1. Neptune is the eighth planet (on average) from the Sun. It is 17 times as massive as the Earth and its diameter is  $3.9 D_{\oplus}$  (equatorial).



2. Neptune has 8 known moons, the largest being **Triton**. (The other moons are fairly small.)
3. Neptune's discovery was made from theoretical calculations which were later confirmed by observations.
  - a) In 1843, a mathematician, John Adams, used perturbations found in Uranus's orbit to predict the location of an 8th planet.
  - b) There was some controversy about these calculations, but Adams was proven correct with the discovery of Neptune in 1845.
4. Little was known about Neptune until **Voyager 2** flew past the planet in 1989.
  - a) A **Great Dark Spot**, similar to Jupiter's Great Red Spot, was discovered on the planet's blue disk. (Note that recent Hubble Space Telescope observations of Neptune show that this "storm" no longer exists in the planet's atmosphere.)
  - b) Thin wispy white clouds of methane ice crystals were also found.
  - c) A thin atmosphere was found on Triton and methane geysers were also seen erupting!