105 Chapter 6 Review Notes

- The gaseous giant planets of our solar system include Jupiter, Saturn, Uranus, and Neptune
- These planets are composed primarily of gaseous H and He, with various amounts of other volatile or "icy" materials (not necessarily cold, but able to freeze out under low-T conditions in the outer solar system) including:
    - Ammonia
    - Methane
    - Water
    - Ethyne/acetylene
- Most of our data on these planets has been gathered by a small number of spacecraft since the 1970s including:
    - Pioneer 10 (first to Jupiter)
    - Pioneer 11 (first to Saturn)
    - Voyager 1 (first good color images of Jupiter and Saturn and their moons)
    - Voyager 2 (Jupiter, Saturn; first and only spacecraft to fly by Uranus and Neptune)
    - Galileo (first and only orbiter around Jupiter; first atmospheric probe of gas giant/Jupiter)
    - Cassini (first and only orbiter around Saturn; first probe to land on moon of another planet – Titan) – ongoing mission
    - Hubble Space Telescope (capable of producing images showing atmospheric storms/details of all 4 gas giants)
- Interior models of the gas giants are consistent with observed data on planetary masses and the compositions of their outer atmospheres and uppermost cloud decks, but are by no means certain
- Masses of planets can (and have been) determined by observing the distance and orbital period of natural satellites/moons in a nearly circular orbit around the planet (and by the gravitational forces on passing spacecraft) using the following equation:

$$M_{planet} = 4\pi^2a^3/GP^2$$

  where a is the average radius of the moon's orbit around the (center of the) planet, G is the gravitational constant, and P is the period of the moon's orbit around the planet. Note that the size of the satellite or moon need not be known, so long as it is *much* smaller than the planet it is orbiting.

- Once the mass is known, the average density can be calculated by dividing the mass by the volume of the planet, where Volume = $4/3\pi r^3$ (with r being the *average* radius for the somewhat flattened gas giants)

- The average density and some educated guesses about the bulk compositions of the planets can be used to formulate models of how much H and He gas, icy materials (methane, ammonia, water, etc.), and rocky materials are found within each planet.
- Whereas the high proportion of hydrogen gas can be directly detected from it's absorption spectrum, percentages of helium in each gas giant are extrapolated from the assumption that nearly all of the remaining gas (albeit nearly impossible to identify directly) is He, in nearly solar abundances. Percentages of icy and rocky components are based on the same solar abundance assumption, which is the best guess available with our current data sets.
- Hydrogen will be compressed to its liquid metallic state in the deep interiors of both Jupiter and Saturn, due to the high pressures produced by the planets' high masses and strong gravitational fields
- The circulation of liquid metallic H by convective heat loss in both Jupiter and Saturn produces magnetic dipole fields for both planets, with Jupiter's field some 20,000 times the strength of that generated in the interior of the Earth
- All of the gas giants except for Uranus are releasing significant internal heat. The primary sources of this heat vary from planet to planet
    - Jupiter's internal heat source is likely to be primarily primordial (heat of original accretion) in nature due to it's lowest surface area to volume ratio (ratio = 3/r)
    - Saturn's internal heat is perhaps generated by gravitational potential energy being released by droplets of liquid helium dropping through the lighter hydrogen; **recent Cassini data seem to show the He depletion expected if this mechanism is occurring (atmosphere about 96% H and 4% He)**
    - Uranus' lack of detectable internal heat source (as well as it's interior structure) is problematic (because the nearly identical Neptune *has* a detectable heat release), but may result from difficulty in convective heat loss resulting from it's tipped over orientation and uneven solar heating of the atmosphere during it's orbit. The internal heat source in both planets could be continued differentiation of icy and/or rocky materials in the deep interior, but with our currently sparse data sets, this is speculative, at best
- Storms and high velocity atmospheric winds have been detected for all 4 gas giants, with maximum wind speeds from 100-200 m/s (Jupiter and Uranus) to 400 or even 500 m/s (Neptune and Saturn, respectively). The energy for such atmospheric motions comes primarily from the internal heat of the planets
- The color of the clouds (yellows, oranges, browns) on Jupiter and Saturn is not completely understood, but may result from small amounts of sulfur-bearing compounds
- The dark and light bands in the atmosphere of Jupiter are known as belts and zones, respectively, and represent areas with less or more bright clouds where gases are convectively rising and falling, respectively
- The Great Red Spot is a long-lived (hundreds of years) storm in Jupiter's atmosphere, but the reason for it's reddish color is not yet clear

- Bright cloud layers of icy clouds have been detected as being (from top downward) ammonia, ammonium hydrogen sulfide and water ice on Jupiter; a similar set of cloud decks should exist in Saturn's atmosphere, with only the uppermost ammonia ice clouds having been directly detected so far
- Lightning and thunderstorms have been detected in the atmospheres of Jupiter and Saturn (and these probably occur on Uranus and Neptune, as well)
- The bright (white) icy clouds in the atmospheres of Neptune and Uranus (detected more recently in Hubble Space Telescope images) are composed primarily of methane ice; the atmospheres of Jupiter and Saturn are not cold enough (and so don't have sufficiently high methane partial pressures) for the methane there to condense into clouds
- The green-blue and bluish colors of Uranus and Neptune, respectively, are produced by the absorption of red light in their atmospheres by methane gas; Neptune's atmosphere appears bluer because it has a higher methane content
- All 4 gas giants have magnetic fields, resulting in magnetospheres and aurorae; the aurorae are strongest at Jupiter (because of its massive magnetic field strength), but are now being regularly observed in the UV at Saturn by the HST
- The magnetic fields of Uranus and Neptune are off-center and greatly rotated from their rotational poles for reasons that are not yet understood
- Jupiter's massive plasma belts produce aurorae in the tenuous atmosphere produced by volcanic gas eruptions on Io, as well