Summary of Lecture 13

Key points include:

1. How did the Solar System form?
2. Clue #1: all large bodies in the Solar System orbit in the same direction and nearly the same plane. Most also rotate in that same direction (thus their rotation is *prograde*).
3. Clue #2: there are two major planet types. Terrestrial planets are small, rocky, and close to the Sun. Jovian planets are large, gaseous, and farther from the Sun. We also have a lot of smaller objects.
4. Best current explanation: the *nebular theory*, in which the matter that would become the Solar System was once a giant cloud of interstellar gas which contracted because of its own gravity. The cloud had at least a little rotation, and as it contracted it spun up because of conservation of angular momentum. Particles condensed out of the cloud, collided to form larger objects, and eventually most of the mass that didn't go into the Sun was swept up to become the planets.
5. Like any model of an astronomical phenomenon, there are always puzzling details that are being revealed and resolved by astronomers. But the nebular theory has a lot of support, including observations of disks around other stars.
6. Why are there two major types of planets? Because of the frost line, as we discussed. Most of the normal stuff in the universe is hydrogen. Far from the Sun (more than about 3.5 au), ices containing hydrogen (such as water, or methane) can form. Thus a lot of mass is available, the planet builds up, and eventually can gravitationally attract and hold the gas in the nebula. But closer to the Sun, it's too hot for ices to form. Thus instead the planets form from rock and metal. There is much less of this than there is of hydrogen, so the planets formed close to the Sun are small and rocky, whereas the ones formed far from the Sun are large and gaseous, although even they can have a rocky core because heavy stuff can sink.
7. As lumps formed in the disk of material around the Sun, they would bump into each other and stick together. Thus many smaller objects collected into just a few large ones. Eventually the mass in a given area was dominated by a few, and eventually by one, object. Those last collisions could be monumental; for example, a collision of a Mars-sized object (but not Mars itself!) with the proto-Earth is thought to have flung out some mass that eventually collected to form the Moon.
8. Asteroids and comets are thought to be the leftovers from this process: asteroids inside the frost line, comets outside the frost line.

9. Most of the action happened about 4.6 billion years ago, which we determine by looking at radioactive nuclei in meteorites among other things. Collisions were much more common in the early Solar System than they are now (fortunately for us!).

10. The explosion of detections of planets around other stars (i.e., *exoplanets*) has tested these ideas and forced people to refine them.

11. We have to be careful: it is much easier to see the effects of big exoplanets than small ones (e.g., as they block out part of the light of their host star, or as they gravitationally tug their host star). It is also much easier to see exoplanets that are close to their host star than those that are far from their host star. As a result, there are *selection effects*; even if we see lots of big planets or planets close to their host star, that doesn't mean that most are like that.