Summary of Lecture 12

Key points include:

1. Asteroids and comets are members of the Solar System that are smaller than planets but not in orbit around planets.
2. Roughly, asteroids are rocky and comets are icy, and asteroids tend to be a lot closer to the Sun than comets, on average. But there are examples of each that blur the distinction.
3. The largest asteroid, Ceres, has a diameter of $\sim 1,000$ km and is considered a "dwarf planet" (like Pluto). There are more than a million asteroids with diameter > 1 km, but all of the asteroids combined don't even add up to the Moon's mass.
4. The "main belt" of asteroids orbits between Mars and Jupiter. Despite their large number, there is a *ton* of space between them; not like in the movies! There are also "Trojan" asteroids that follow Jupiter's orbit.
5. Asteroids in the main belt that are in resonance with Jupiter's orbit (so that their orbital periods are in a small integer ratio with Jupiter's orbital period, e.g., the asteroid might go around the Sun 3 times for every 2 times that Jupiter does) get periodic nudges that kick them out of those orbits, leaving gaps in the belt.
6. Terminology: a *meteor* burns up in our atmosphere, whereas a *meteorite* survives to land on Earth.
7. Meteorites can give us information about the primitive Solar System.
8. **Important conceptual point:** inside the *frost line*, about 3.5 au from the Sun, it is too hot to have ices that have hydrogen. Most of the mass of ordinary stuff in the universe is hydrogen, so inside the frost line you only get rocky stuff, which can't have as much mass as the stuff further out, which *can* include hydrogen.
9. Comets, which are largely ice, have a *nucleus* (the actual object), a *coma* (the much larger atmosphere that comes from the nucleus heated by the Sun), at a *tail* (the stuff pushed away from the comet).
10. When the comet is close enough to the sun, there are actually two tails, the *dust tail*, which is pushed by light from the Sun, and the *plasma tail*, which is pushed by the much slower solar wind.
11. Both the solar wind and the light move much faster than the comet in its orbit. That has the weird effect that the tails *always* point *away* from the Sun, so that although the tail trails the comet as the comet approaches the Sun it *precedes* the comet as the comet

moves away from the Sun. Thus you should not think of this like something moving through the atmosphere, where the tail would always trail the direction of motion.

12. Meteor showers are associated with small particles (*meteoroids*) ejected by particular comets.

13. Some comets come from very far out in the Solar System, so that their orbital periods are millions of years. But others have had enough gravitational interactions with planets (especially Jupiter) to be brought into closer orbits, with periods of years to centuries.

14. There is a collection of objects past Neptune called *Kuiper belt objects*, like Pluto. The largest of these, which are big enough to be crushed into rough spheres by their own gravity, are called (like Ceres) "dwarf planets".

15. Comets and asteroids hit planets from time to time. For example, comet Shoemaker-Levy 9 hit Jupiter (in > 20 fragments) in 1994, in 1908 a comet or asteroid caused the Tunguska event in Siberia, in 2013 Chelyabinsk hit Russia,and 66 million years ago an asteroid hit the Earth and helped cause a mass extinction.