

Chapter 11. Creation and Its Debris

Meteorites

- A *meteor* is the fireball (shooting star) seen in the sky. A meteor is caused by a *meteoroid* moving along a solar orbit and colliding with the Earth. The fast motion heats and ionizes the surrounding air, producing the visible light. Meteoroids that survive and strike the ground become *meteorites*.
- Each day, about 800 meteorites with masses >10 g fall on the Earth. The larger ones are rarer. The large ones can be up to a few meters across and weigh several tons.
- Table 11.1. Three types of meteorites: stones, stony irons, and irons. Stones are the most common meteorites, but are usually hard to distinguish from ordinary rocks. Stones are further divided into three subtypes - carbonaceous chondrites, chondrites, and achondrites. Carbonaceous chondrites are the most primitive and the oldest, ~ 4.56 billion years, which represent the age of the solar system.
- Some meteorites contain tiny bits of diamonds that were produced by shock waves from exploding stars acting on interstellar dust. Some meteorites contain organic compounds including amino acids! Meteorites brought the origin of life?

Asteroids

- Bode's law predicted a "planet" between Mars and Jupiter. The asteroid belt was later found there at 2-3 AU from the Sun.
- The first asteroid, Ceres, was found in 1801. With a radius of 475 km, it is also the largest asteroid. More than 20,000 asteroids have been found, more than 6,000 have known orbits, and several hundred new ones are discovered each year.
- Many asteroids group into families with similar orbits. The Amos, Apollos, Atens families have perihelia less than 1 AU from the Sun. None of these AAAOs (AAA objects) intersect the Earth's orbit. However, perturbations by planets may change AAAOs orbits. Four meteorites have their meteoroid orbits calculated, and they are all AAAOs.
- Asteroids are believed to be remnants of planetesimals, the original small bodies out of which the planets formed. Collisions break up planetesimals into asteroids.
- The masses of a few asteroids have been estimated from their perturbations on Mars or among themselves. The mass of Ceres is $2 \times 10^{-4} M_{earth}$. The mass of all asteroids together is $10^{-3} M_{earth}$.
- Different types of meteorites can be related to different types of asteroids. Carbonaceous chondrites are at the outer edge of the asteroid belt.

Comets

- A typical comet has three parts, a nucleus, a coma, and two tails (a gas tail and a dust tail). The gas tail shows emission lines of ionized gas; its blue color is from the emission of carbon molecules. The dust tail reflects sunlight and is yellowish.
- Comets are “dirty snowballs”. The nucleus contains frozen water and dust. As a comet approaches the Sun, it is heated by the sunlight and the ices in the nucleus start to evaporate into gas, carrying dust along and forming the coma. The gas, partially ionized by the ultraviolet radiation from the Sun, is blown by the solar wind into a *gas tail*, which always points away from the Sun. The dust in the coma can be accelerated by the solar radiation and form a *dust tail*. Dust particles lag behind the comet in the orbit, and the dust tail can spread into a great fan.
- Comet nuclei lose 1% of mass at each solar passage. Short-period (<200 yr period) comets, having lost more mass, are fainter. Comets eventually lose all their volatiles and disintegrate. Up to 1/2 of the AAAs are dead comets.
- In 1950, Jan Oort suggested that trillions of comets were contained in the *Oort comet cloud*, which extends to 100,000 AU outward, and provides long-period comets. In 1951, Gerard Kuiper suggested another reservoir of comets aligned with the ecliptic plane, stretching from just beyond Neptune to 200 AU in radius. This *Kuiper belt* provides short-period comets.
- The Oort comet cloud has never been detected. The Kuiper belt objects (KBOs) were first detected in 1992. The asteroid 1992 QB1 was detected with a semimajor axis of 41 AU, confirming the existence of the Kuiper belt. Subsequently, more KBOs are detected.
- Comets may break up and become meteors. Meteor showers and meteor storms occur when the Earth crosses the orbit of a disintegrated comet. Usually we can see 3 meteors per hour; during a meteor shower we see 10-100 per hour.
- The dusty debris produced by comets and asteroid collisions spreads out into the Solar system in the ecliptic plane. The dust scatters sunlight and produces a faint glow, the *zodiacal light*, which is best seen after the evening twilight or before the morning twilight.

The Creation of the Solar System

- The creation of the solar system started with the contraction of a slowly-spinning interstellar molecular cloud under the force of its own gravity. Being subjected to the law of conservation of angular momentum, it spun faster as it contracted, flattening into a disk called the *solar nebula*. The gas in the disk formed the planets eventually.
- At first the least volatile material condensed into solid grains. The grains collided and fused together to form larger particles, which could accrete more grains. This snowball effect created bodies large enough to gravitationally accrete more mass. “Planetesimals” were then produced. The planetesimals collided and fused together to form planets.