Lecture 15

1. Solar System

The Solar System is made up of the Sun, 9 planets, asteroids (small rocky, or metallic objects), comets (icy objects) and a lot of empty space.

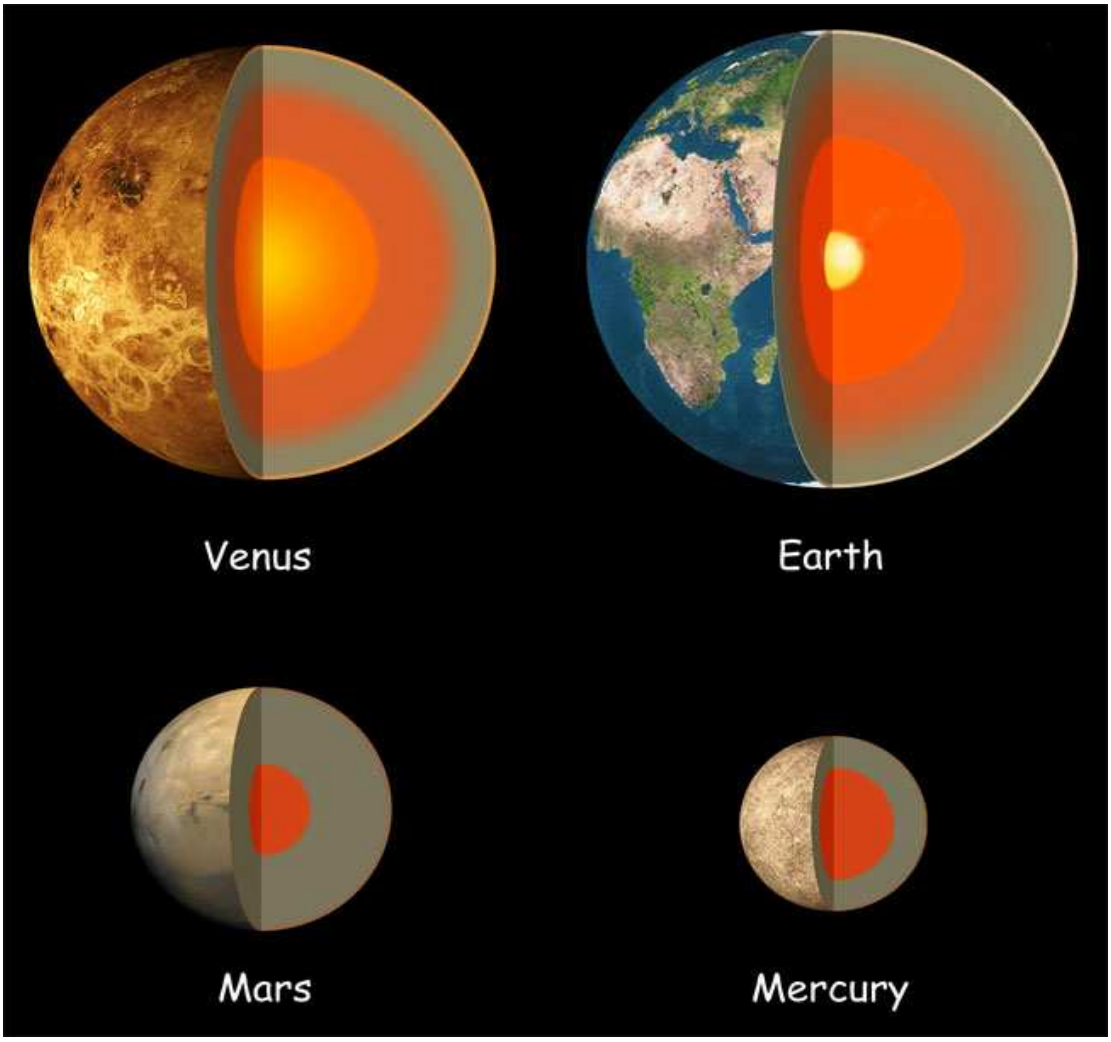
The nine planets move around the Sun in paths called orbits. Moons, like our own Moon orbit most of the planets.

Nearest the Sun are the rocky or terrestrial planets (Mercury, Venus, Earth and Mars). Further away from the Sun are the gas giants, or Jovian planets (Jupiter, Saturn, Uranus, Neptune, and Pluto). Terrestrial planets are relatively small, have few moons, have iron core and made mostly of rock and iron. Jovian planets are relatively large, have a lot of moons, have liquid hydrogen core and much smaller density. Their surfaces are extremely cold.

2. Sun

The Sun is by far the largest object in the solar system. It contains more than 99.8% of the total mass of the Solar System (Jupiter contains most of the rest). It is often said that the Sun is an "ordinary" star. That's true in the sense that there are many others similar to it. But there are many more smaller stars than larger ones; the Sun is in the top 10% by mass. The median size of stars in our galaxy is probably less than half the mass of the Sun. The Sun is personified in many mythologies: the Greeks called it Helios and the Romans called it Sol. The Sun is, at present, about 70% hydrogen and 28% helium by mass everything else ("metals") amounts to less than 2%. This changes slowly over time as the Sun converts hydrogen to helium in its core.

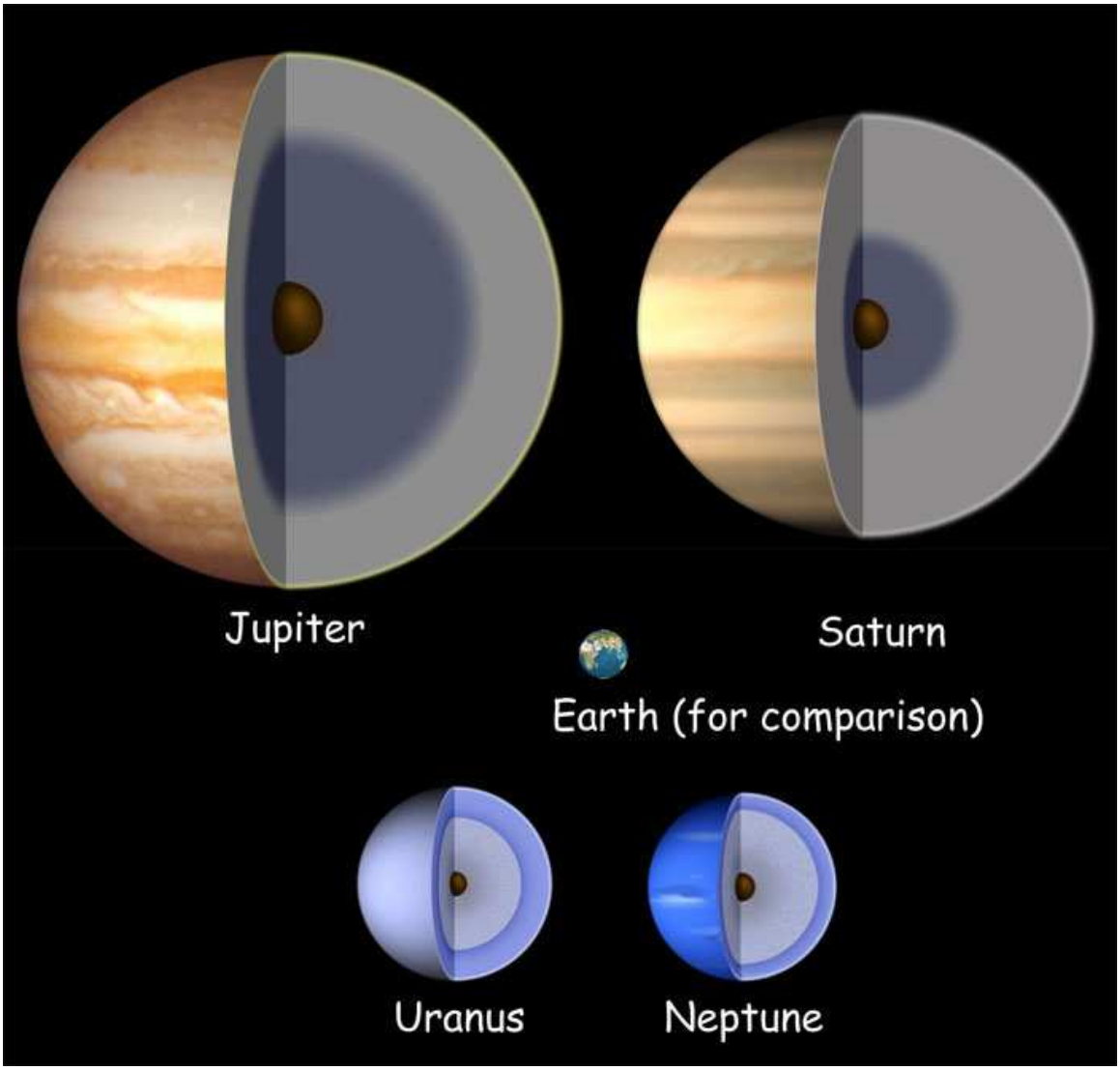
3. Terrestrial Planets



The four planets closest to the Sun—Mercury, Venus, Earth, and Mars—are called the terrestrial planets because they have solid rocky surfaces. Generally speaking they are

small, rocky bodies (lots or materials made of the elements silicon, oxygen, aluminum, magnesium, sulfur and iron) with thin atmospheres. Internal structures of the terrestrial planets are very similar. For Venus, the core must be similar to that of the Earth in comparison to its size, but for Mercury, the core is relatively large in comparison to its size, and for Mars, the core is either relatively small, as shown here, or made of lighter than usual materials. Note that although Mercury's core is "large" in comparison to the size of the planet, it is not large compared to the Earth's core. The Earth's core is larger than Mars, and more than twice as massive as Mars and Mercury combined. (based on NASA image)

4. Jovian Planets



The structures of the Jovian planets (modified version of Lunar and Planetary Institute image; NASA) are quite different from the terrestrial planets. Jupiter consists mostly of liquid hydrogen, a large portion of which (shown in darker gray) is metallic hydrogen. Deep

inside, an icy core must overly a rocky and metallic core, but the size and mass of these cores is too small to significantly affect observations of Jupiter's properties, so we can only make educated guesses as to their size. The structure of Saturn is similar to that of Jupiter, but it is much less compressed under its weight, so it has far less metallic hydrogen. Uranus and Neptune have relatively small amounts of hydrogen -- just a few Earth masses -- above their icy and metallic cores, so we can be more confident about the structure of those cores. For Neptune, which has more mass than Uranus, but is smaller, the core must be most of the mass, while for Uranus, the hydrogen "mantle" must be more significant, and perhaps even exceed the mass of the core.

5. Pluto

Once known as the smallest, coldest, and most distant planet from the Sun, Pluto has a dual identity, not to mention being enshrouded in controversy since its discovery in 1930. On August 24, 2006, the International Astronomical Union (IAU) formally downgraded Pluto from an official planet to a dwarf planet. According to the new rules a planet meets three criteria: it must orbit the Sun, it must be big enough for gravity to squash it into a round ball, and it must have cleared other things out of the way in its orbital neighborhood. The latter measure knocks out Pluto and 2003UB313 (Eris), which orbit among the icy wrecks of the Kuiper Belt, and Ceres, which is in the asteroid belt.

(1) A "planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighborhood around its orbit.

(2) A "dwarf planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighborhood around its orbit, and (d) is not a satellite.

(3) All other objects except satellites orbiting the Sun shall be referred to collectively as "Small Solar-System Bodies".

Discovered by American astronomer Clyde Tombaugh in 1930, Pluto takes 248 years to orbit the Sun. Pluto's most recent close approach to the Sun was in 1989. Between 1979 and 1999, Pluto's highly elliptical orbit brought it closer to the Sun than Neptune, providing rare opportunities to study this small, cold, distant world and its companion moon, Charon. Most of what we know about Pluto we have learned since the late 1970s from Earth-based observations, the Infrared Astronomical Satellite (IRAS), and the Hubble Space Telescope. Many of the key questions about Pluto, Charon, and the outer fringes of our solar system await close-up observations by a robotic space flight mission.

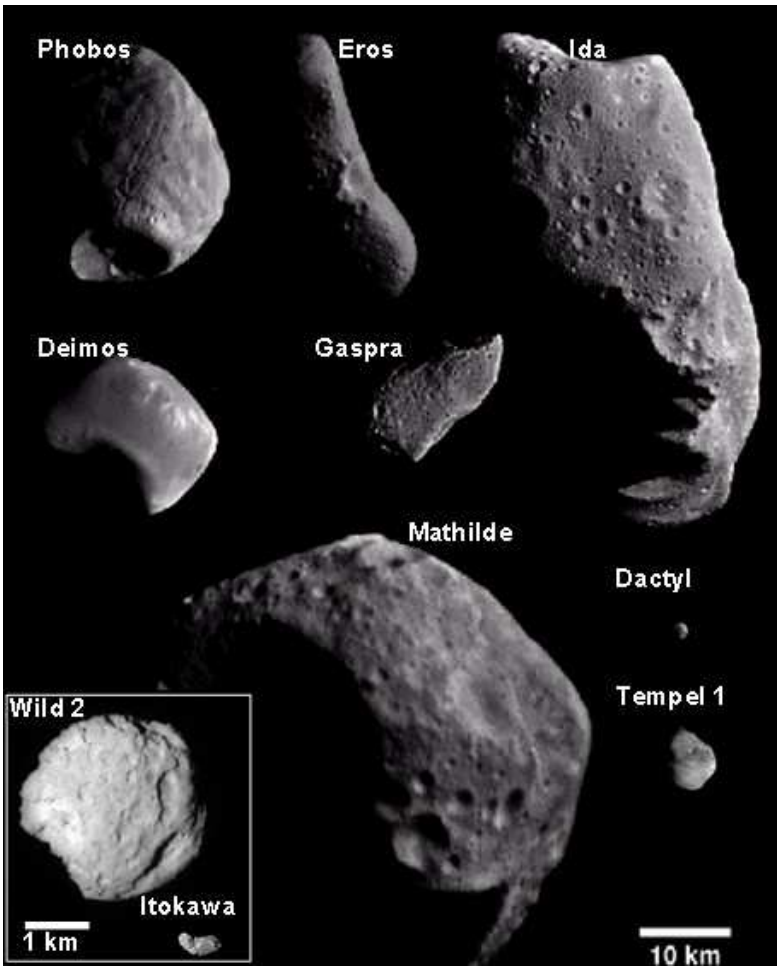
No spacecraft have yet visited Pluto. However, NASA launched a mission called New Horizons that will explore both Pluto and the Kuiper Belt region.

6. Asteroids

On the first day of January 1801, Giuseppe Piazzi discovered an object which he first thought was a new comet. But after its orbit was better determined it was clear that it was not a comet but more like a small planet. Piazzi named it Ceres, after the Sicilian goddess of grain. Three other small bodies were discovered in the next few years (Pallas, Vesta, and Juno). By the end of the 19th century there were several hundred.

Several hundred thousand asteroids have been discovered and given provisional designations so far. Thousands more are discovered each year. There are undoubtedly hundreds of thousands more that are too small to be seen from the Earth. There are 26 known asteroids larger than 200 km in diameter. Our census of the largest ones is now fairly complete: we probably know 99% of the asteroids larger than 100 km in diameter. Of those in the 10 to 100 km range we have cataloged about half. But we know very few of the smaller ones; there are probably considerably more than a million asteroids in the 1 km range. The total mass of all the asteroids is less than that of the Moon.

The largest asteroid by far is 1 Ceres. It is 933 km in diameter and contains about 25% of the mass of all the asteroids combined. The next largest are 2 Pallas, 4 Vesta and 10 Hygiea which are between 400 and 525 km in diameter. All other known asteroids are less than 340 km across.



There is some debate as to the classification of asteroids, comets and moons. There are many planetary satellites that are probably better thought of as captured asteroids. Mars's tiny moons Deimos and Phobos, Jupiter's outer eight moons, Saturn's outermost moon, Phoebe, and perhaps some of the newly discovered moons of Saturn, Uranus and Neptune are all more similar to asteroids than to the larger moons.

7. Comets

Unlike the other small bodies in the solar system, comets have been known since antiquity. There are Chinese records of Comet Halley going back to at least 240 BC. The famous Bayeux Tapestry, which commemorates the Norman Conquest of England in 1066, depicts an apparition of Comet Halley.

As of 1995, 878 comets have been cataloged and their orbits at least roughly calculated. Of these 184 are **periodic** comets (orbital periods less than 200 years); some of the remainder are no doubt periodic as well, but their orbits have not been determined with sufficient accuracy to tell for sure. Comets are sometimes called **dirty snowballs** or "icy mudballs". They are a mixture of ices (both water and frozen gases) and dust that for some reason didn't get incorporated into planets when the solar system was formed. This makes them very interesting as samples of the early history of the solar system.

Comets are invisible except when they are near the Sun. Most comets have highly eccentric orbits which take them far beyond the orbit of Pluto; these are seen once and then disappear for millennia. Only the short- and intermediate-period comets (like Comet Halley), stay within the orbit of Pluto for a significant fraction of their orbits.

After 500 or so passes near the Sun off most of a comet's ice and gas is lost leaving a rocky object very much like an asteroid in appearance. (Perhaps half of the near-Earth asteroids may be "dead" comets.) A comet whose orbit takes it near the Sun is also likely to either impact one of the planets or the Sun or to be ejected out of the solar system by a close encounter (esp. with Jupiter).