How Did Our Moon Form?

Many theories have been proposed for how our Moon formed. Any valid scientific model must explain several observations:

- Relative to Earth and other terrestrial planets, the Moon has less iron and few components that evaporate easily, such as water — volatiles — but it is enriched in aluminum and titanium.
- Rocks collected by the Apollo astronauts tell us that the Moon has essentially the same oxygen-isotope signature as Earth (isotopes are varieties of an element that have different masses).
- The plane in which our Moon orbits Earth is slightly tilted relative to Earth's plane of orbit around the Sun — the ecliptic.
- The Earth-Moon system has a large amount of mass, spin, and orbital motion — angular momentum — compared to other planets and moons.

Scientists developed different theories to explain these observations, but none could explain all of them. One theory was that Earth "captured" the Moon as it passed by, but this did not explain their similar isotopic compositions. Another theory was that Earth "threw off" the Moon, but calculations suggest that there was not enough angular momentum to do so. The third theory proposed that Earth and the Moon formed separately but close to each other. If this was true, however, they should have very similar compositions; this model cannot explain the differences in volatiles, iron, titanium, and aluminum between Earth and the Moon.

After the Apollo missions, a new model was proposed: the "giant impact theory." In this model, an impactor, half the size of Earth, collided with Earth during the early stages of solar system formation, about 4.5 billion years ago. The impactor was obliterated. Rocky debris, primarily from the impactor and some of Earth's outer layer, was hurled out into orbit around Earth. This material came together — accreted — to form the Moon.

The giant impact theory explains the Moon's relative lack of iron. Earth's iron core was untouched and much of the impactor's metallic core is thought to have been mixed into the Earth. Scientists still debate why the Moon is enriched in aluminum and titanium. Perhaps the impactor was enriched in these elements, or enrichment occurred as the materials condensed after impact. Scientists also debate why Earth and the Moon have similar oxygen-isotope signatures. Either the impactor had a similar isotopic composition, or the heat from the impact and accretion caused the isotopes to equilibrate between Earth and the debris band. Volatiles such as water and gases were driven out of the system by high temperatures caused by the impact. The theory also explains the tilt of the Moon's orbital plane and the greater angular momentum; the impactor struck Earth at an angle and added its own momentum to the system.

The giant impact theory best explains the current scientific evidence. Future planetary scientists — the students of today — may refine this model or even propose new models as new data are collected!