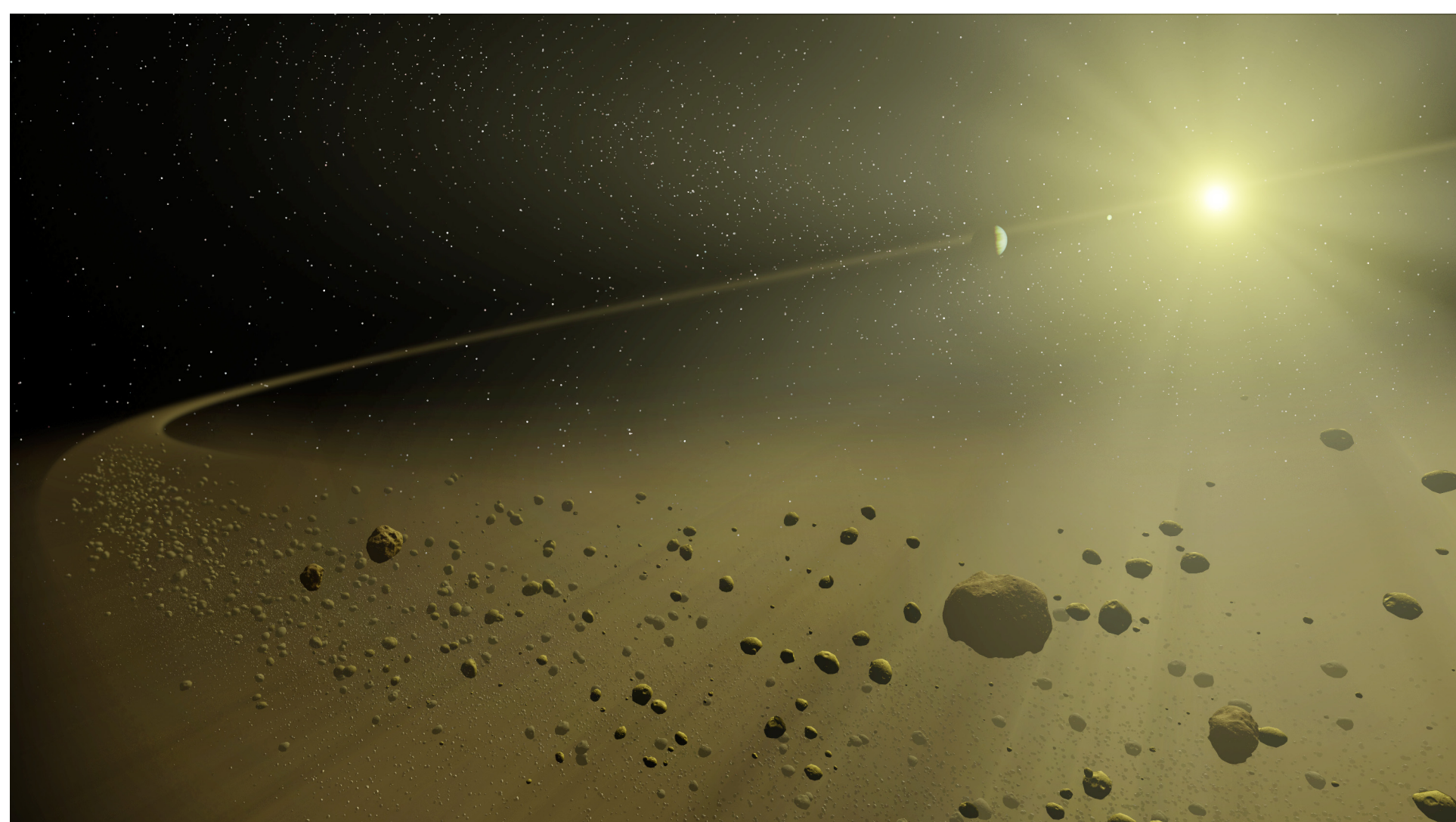


EARTH FORMATION — 4.6 BILLION YEARS AGO

Earth and all the planets of our solar system formed, 4.6 billion years ago, from the accretion of gas and dust that was orbiting the newly forming Sun. For the first 10-20 million years after the main period of planet formation, most of the remaining debris in the solar system was swept up by the newly formed planets. The collisions of the debris with the newly formed planets were explosive. The impacts created the cratered surfaces of the moon, Mars, Venus, and Mercury. Earth was also struck, but the craters produced by the impacts have mostly been erased by erosion and plate tectonics.



Artist's depiction of the asteroid belt, between Jupiter and Mars. © NASA
Header image: Earth from space. © NASA

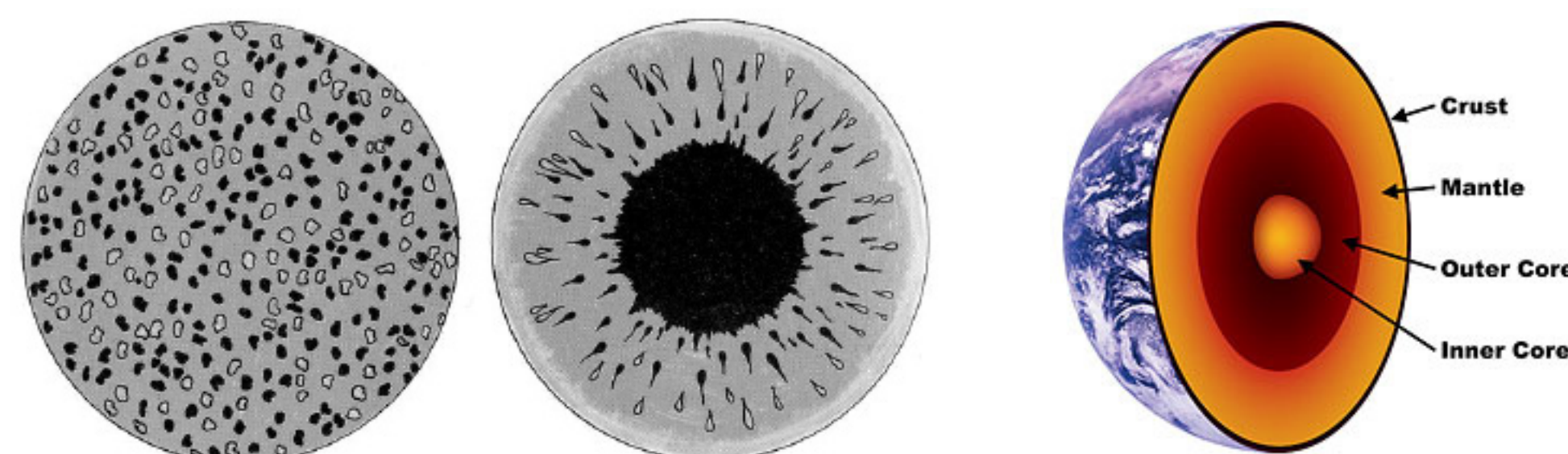
Dating Earth

Some debris never became part of the planets (such as the asteroids that reside in a protected belt between Jupiter and Mars). Fragments of asteroids occasionally collide with Earth and fall to the surface as meteorites. Because these asteroids formed at the same time and through the same processes as our planet, we can study them to learn Earth's age. Scientists use a process called **radiometric dating** to determine a meteorite's age. Radioactive elements decay at known rates into new stable elements. The ratio of these elements in a meteorite (or rock) tells us when it first formed.

For example, Uranium 238 decays to Lead 206. (There is no way to create ^{206}Pb except through ^{238}U decay, and no Pb existed in the original material.) Every 4.5 billion years, half of the ^{238}U turns into ^{206}Pb . So after 4.5 billion years, the ratio of ^{238}U : ^{206}Pb in the meteorite should be 1:1 (equal). After a total of 9 billion years, the ratio should be 1:3 ($\frac{1}{4}$ of the ^{238}U is left). The ratio of ^{238}U : ^{206}Pb in meteorites is just a little more than to 1:1, which sets the age of our Earth at a little more than one half life, or 4.6 billion years.

Earth's layers

Early Earth was hot due to the heat of accretion combined with the radioactive decay of elements trapped inside. As a result, it was almost entirely molten. As it started to release its heat and cool, crystals formed. Dense iron compounds sank toward Earth's center to form an iron **core**. Less dense material, like silicates and carbonates, rose to form the **crust**; the remainder became the **mantle**. This **differentiation** process (or density separation) likely affected almost all the inner rocky planets as well as the larger rocky moons of Jupiter and Saturn. In fact, some asteroids in the asteroid belt are large enough themselves to undergo differentiation, and we see evidence of this when we study asteroids fragments of their surface, after they have collided with Earth.

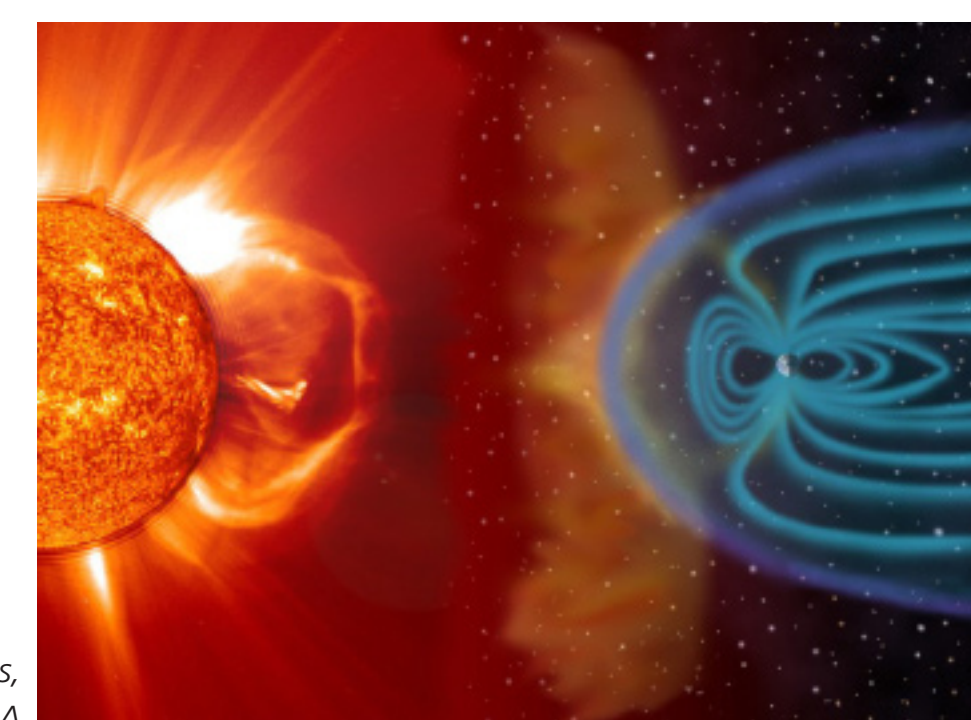


Simplified schematic of an early Earth formed primarily of two kinds of meteorites with low- and high-density materials in each. After melting, the planet undergoes differentiation: dense material sinks and less dense material rises to form Earth's layers. Image by T. Smith, University of Washington ©.

Earth's layers after differentiation (not to scale – crust is exaggerated). See large-scale model in hallway for correctly scaled image.

Earth's magnetic field

Much of Earth's first atmosphere would have been stripped away by strong solar winds that blew it to the outer solar system. Over time, Earth's iron core separated into two phases—a solid **inner core** and liquid **outer core**. Heat loss from the inner core drives convection of the outer core, which then creates a magnetic field. As convection increases and decreases speed, our magnetic field increases and decreases in strength. This magnetic field deflects solar winds. Once it had formed, it allowed an atmosphere to collect on our surface. (Over time the solar winds also diminished.) The north and south poles of our magnetic field align roughly with the rotational axis of Earth. They wander at a speed of approximately 40 km/year, necessitating the constant updating of navigational charts for individuals who still use compasses for navigation.



Artist's depiction of the solar winds, deflected by Earth's magnetic field. © NASA