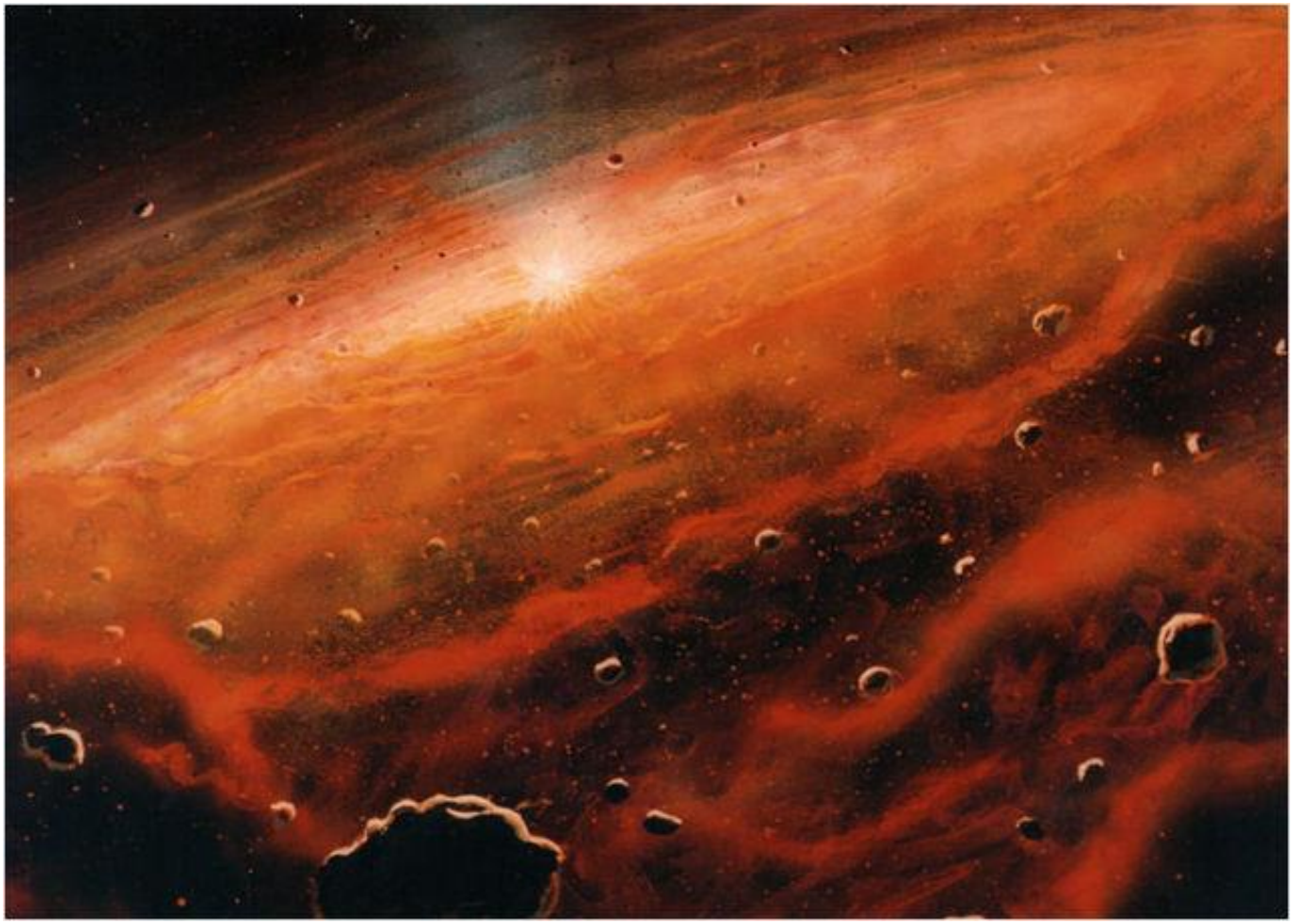
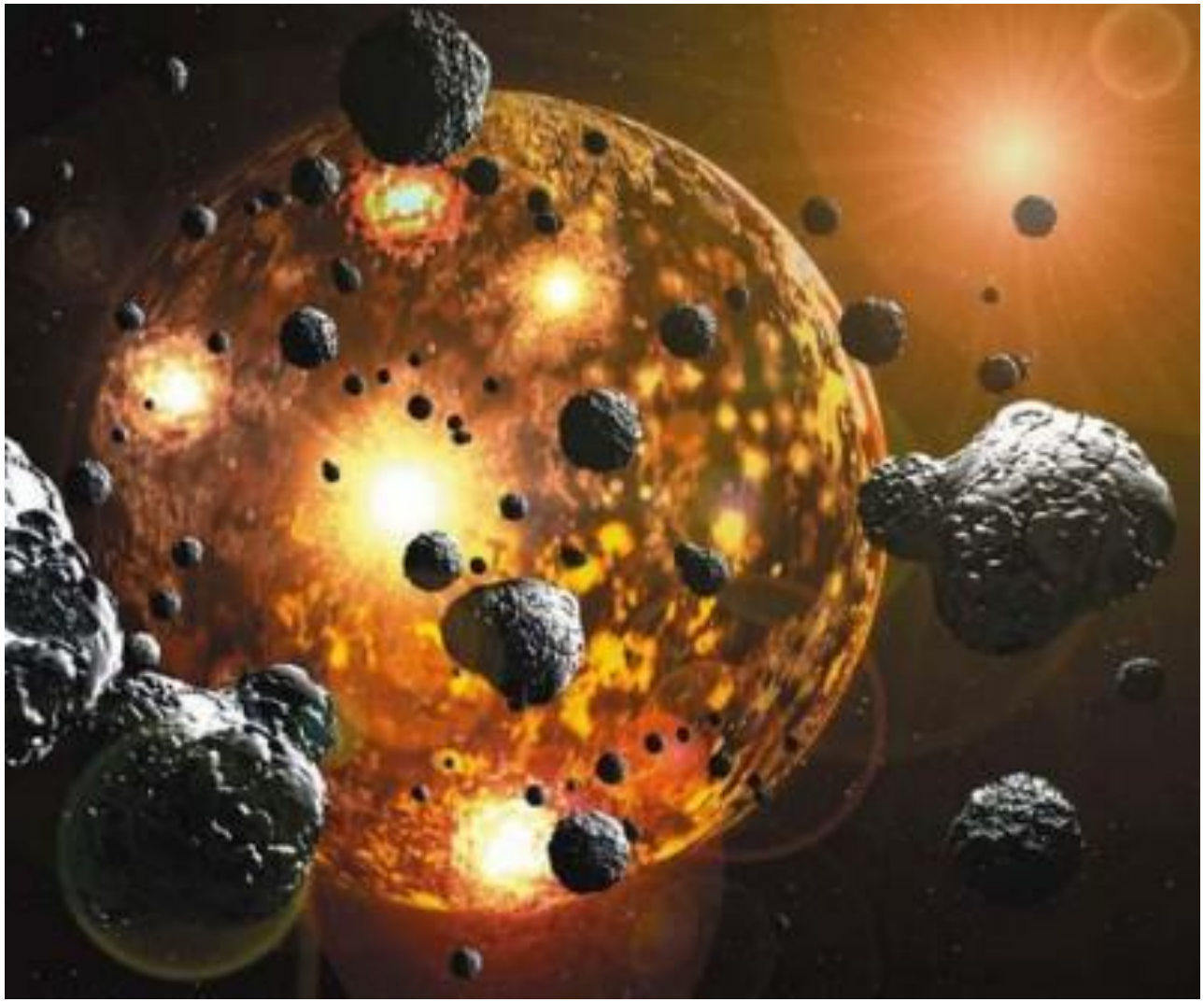
Lesson 15

Formation of the Earth

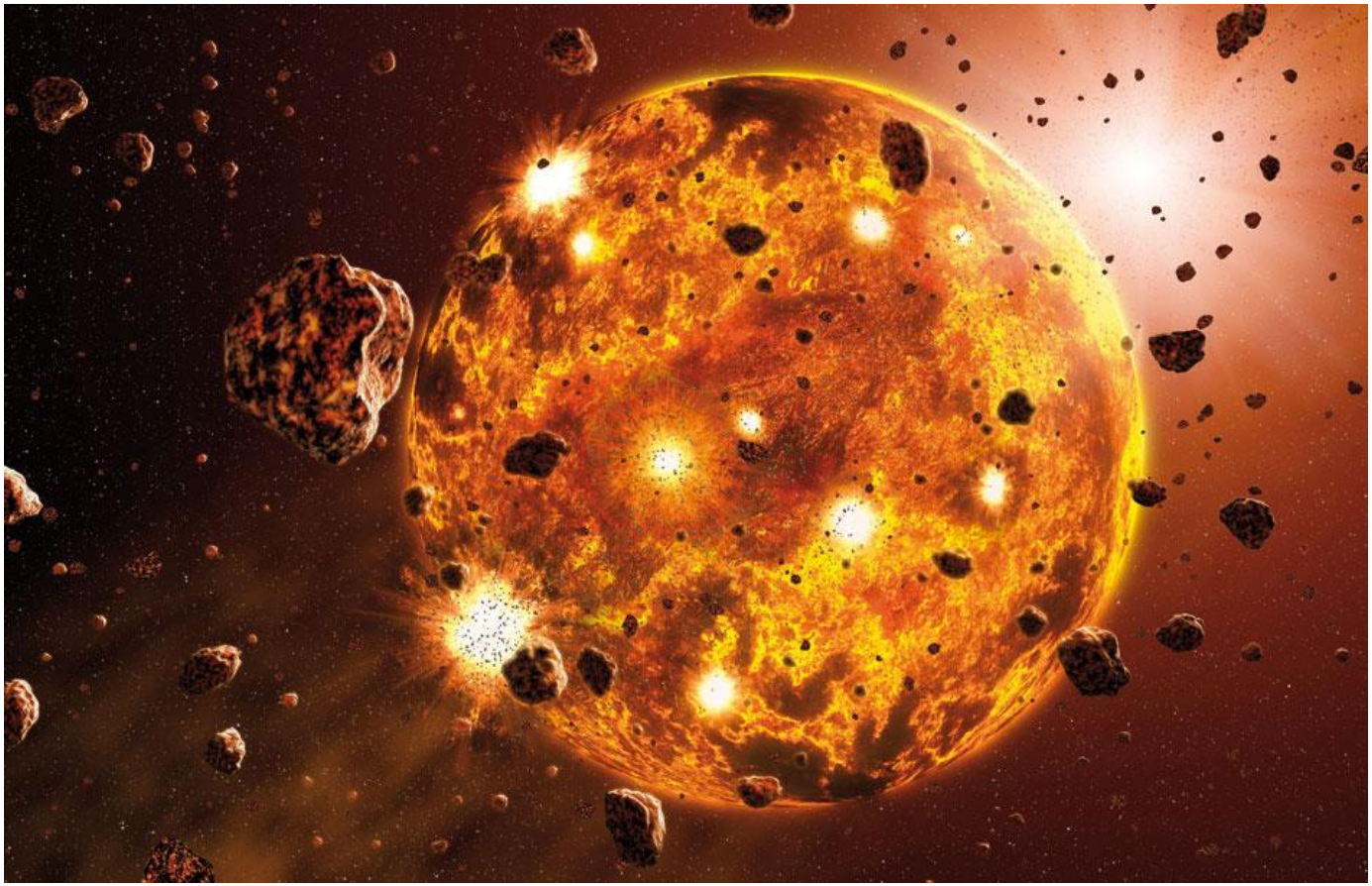


In the rotating cloud of the protostellar disk, millions of **planetesimals** form and grow larger and larger as they collect more and more dust, gas, and asteroids from the cloud.

The planetesimals then collect together under gravity building larger and larger **protoplanets**. This process is called **accretion**.



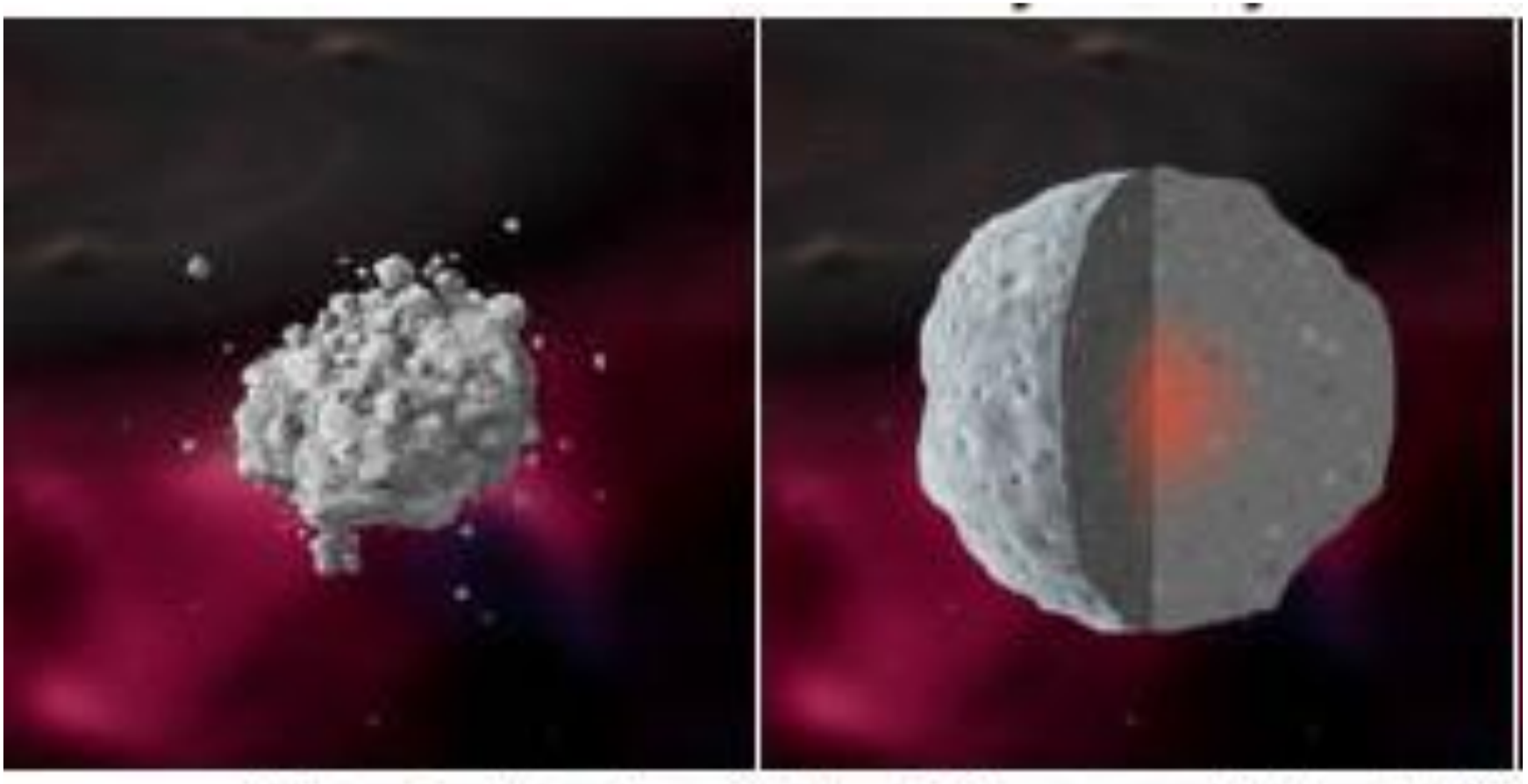
Accretion: The collision and clumping together of billions of asteroids and planetesimals to make larger and larger bodies. The new planets in our solar system gained their materials and grew larger and larger with time as asteroids clumped together under the influence of gravity.



How the Earth Grew in Size by Accretion

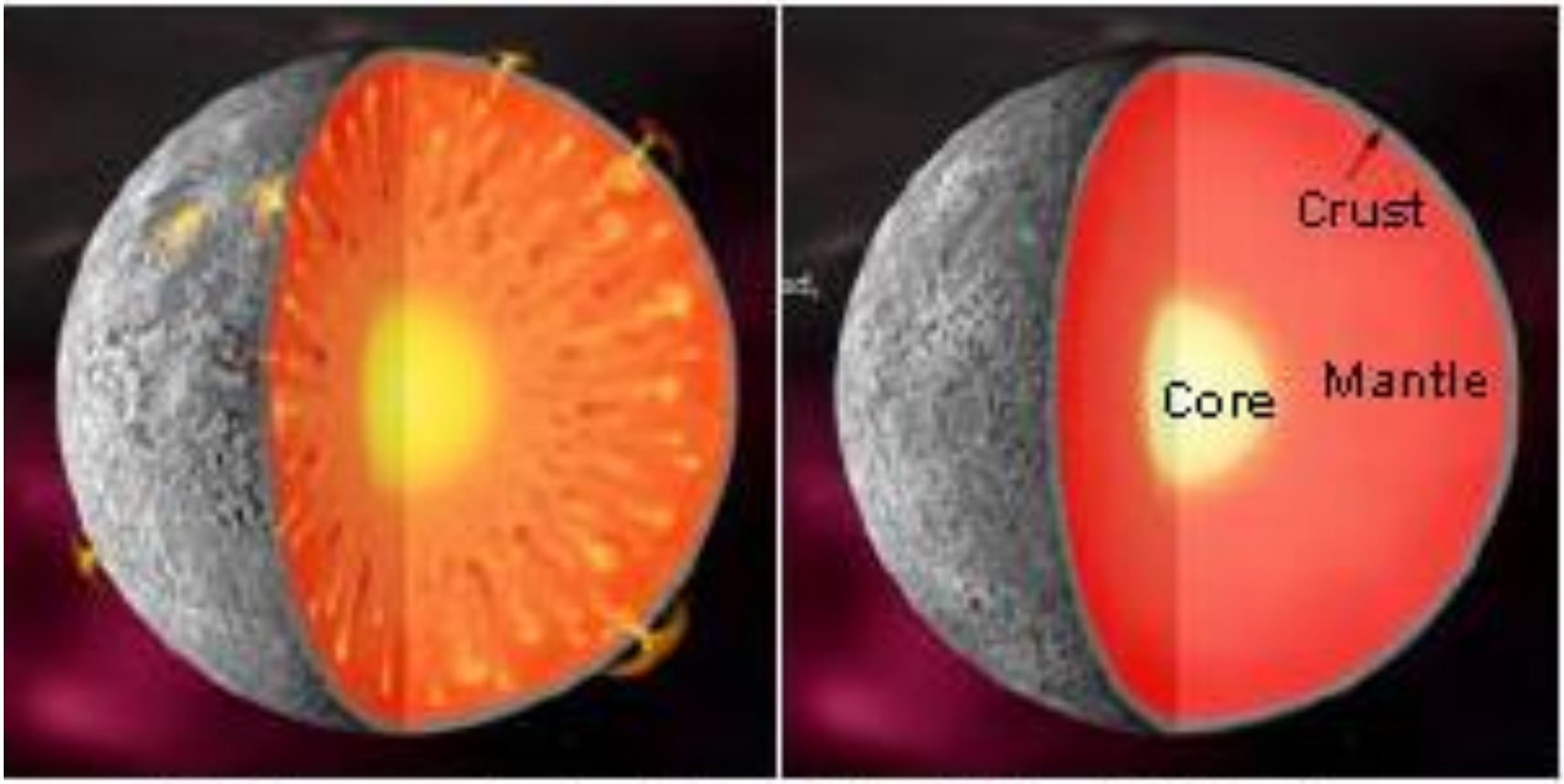
Asteroids and planetesimals clump together by gravity. The mass gets bigger forming a **protoplanet** (early planet)

As the **protoplanet** grows larger, gravity pulls the material into a sphere shape (round ball shape).

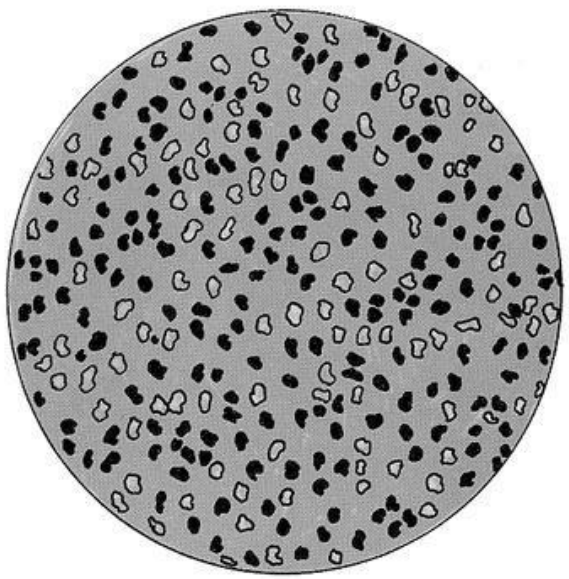


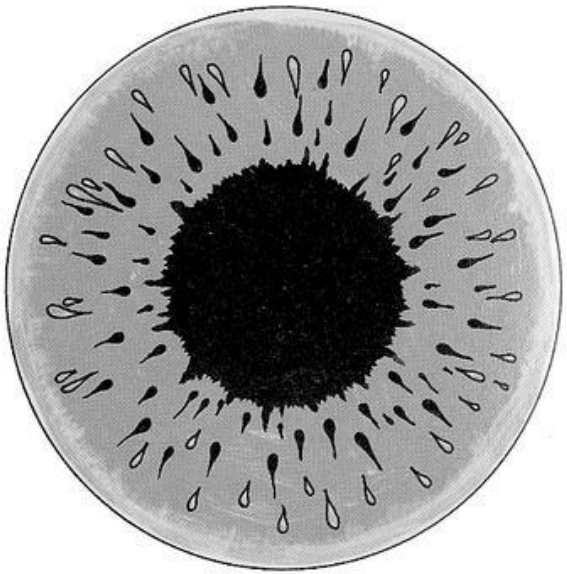
As the **protoplanet** gets bigger, it gets hotter and hotter in the interior. The planetary materials become molten (melted).

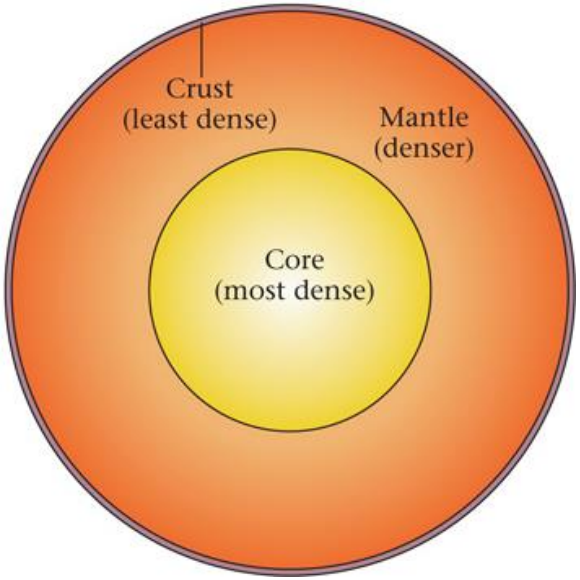
When accretion ends, the planet (Earth) begins to cool. The molten rock and minerals separate into layers and by density and by temperature.



Differentiation: The very hot molten materials that make up new planets separate into layers as the net planet cools. The layers differ in density, temperature, and thickness.



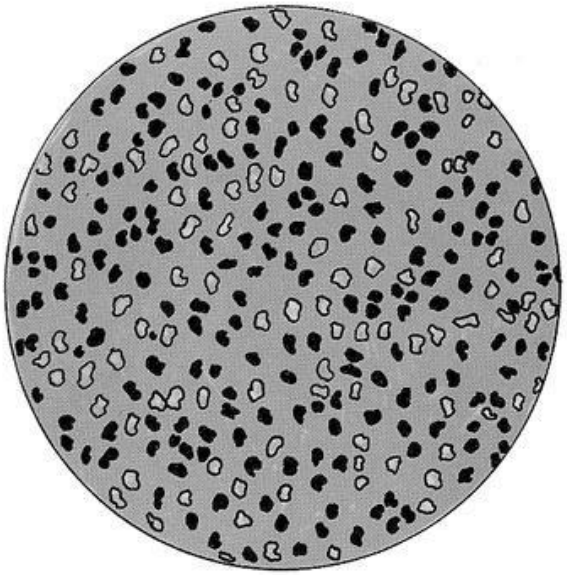


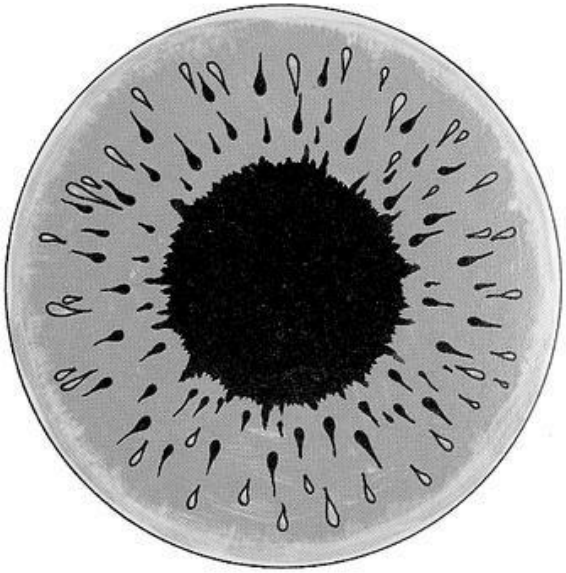


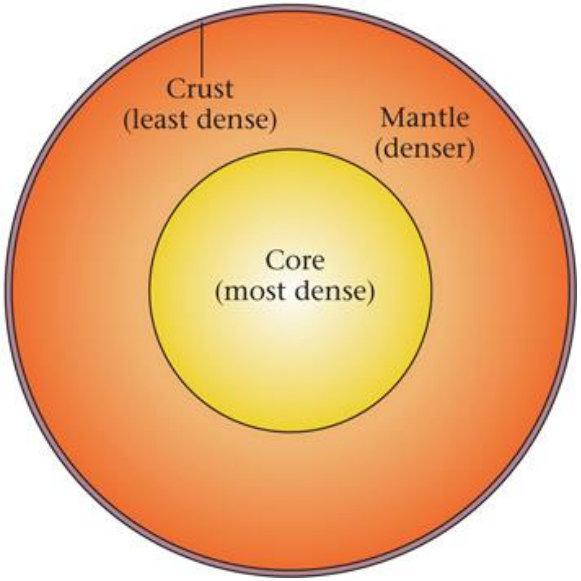
Totally molten and uniformly mixed

Separation of rock and metals by density

Layers in the interior of the Earth.





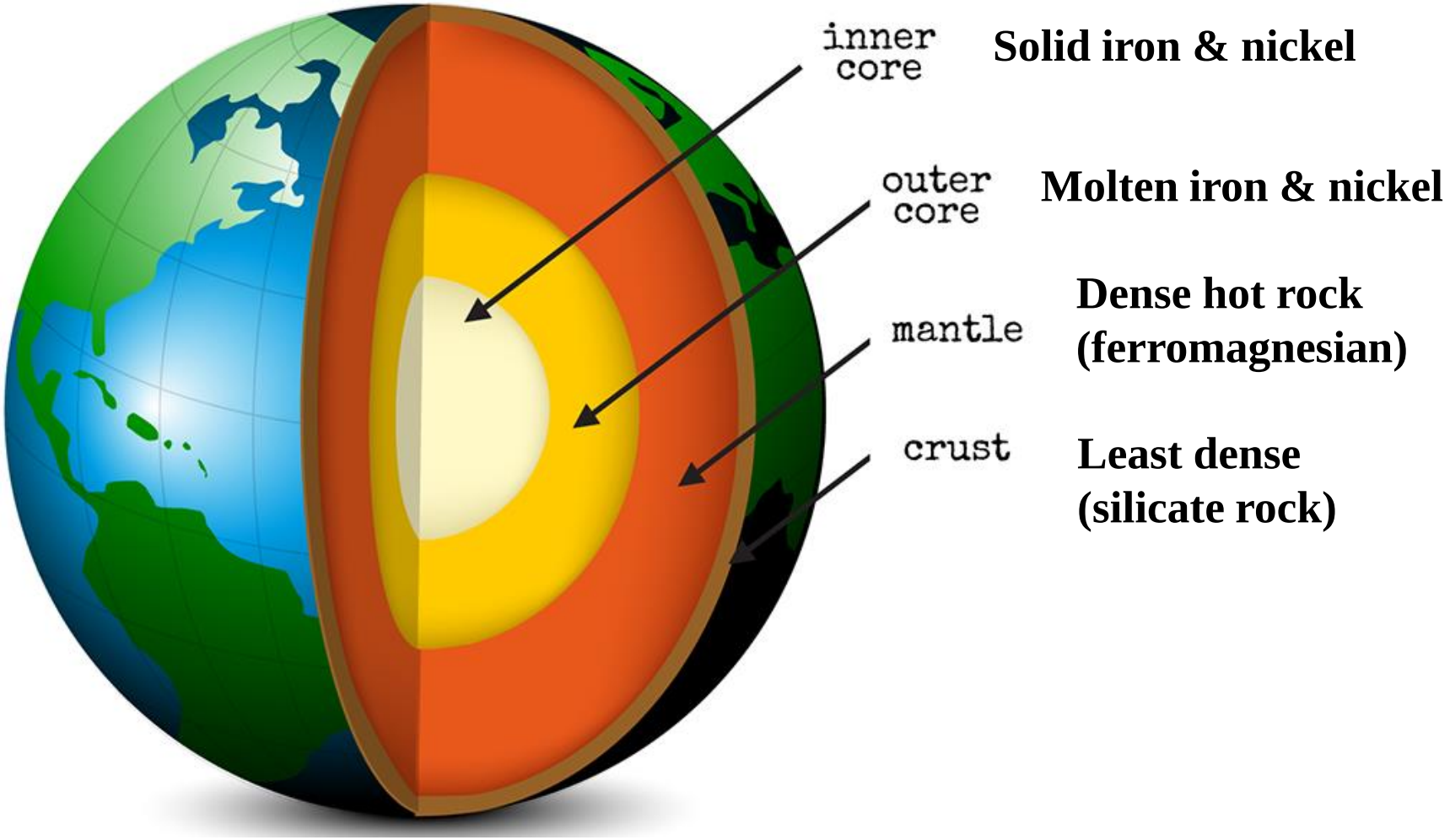


The hot molten Earth. All planetary materials were mixed uniformly.

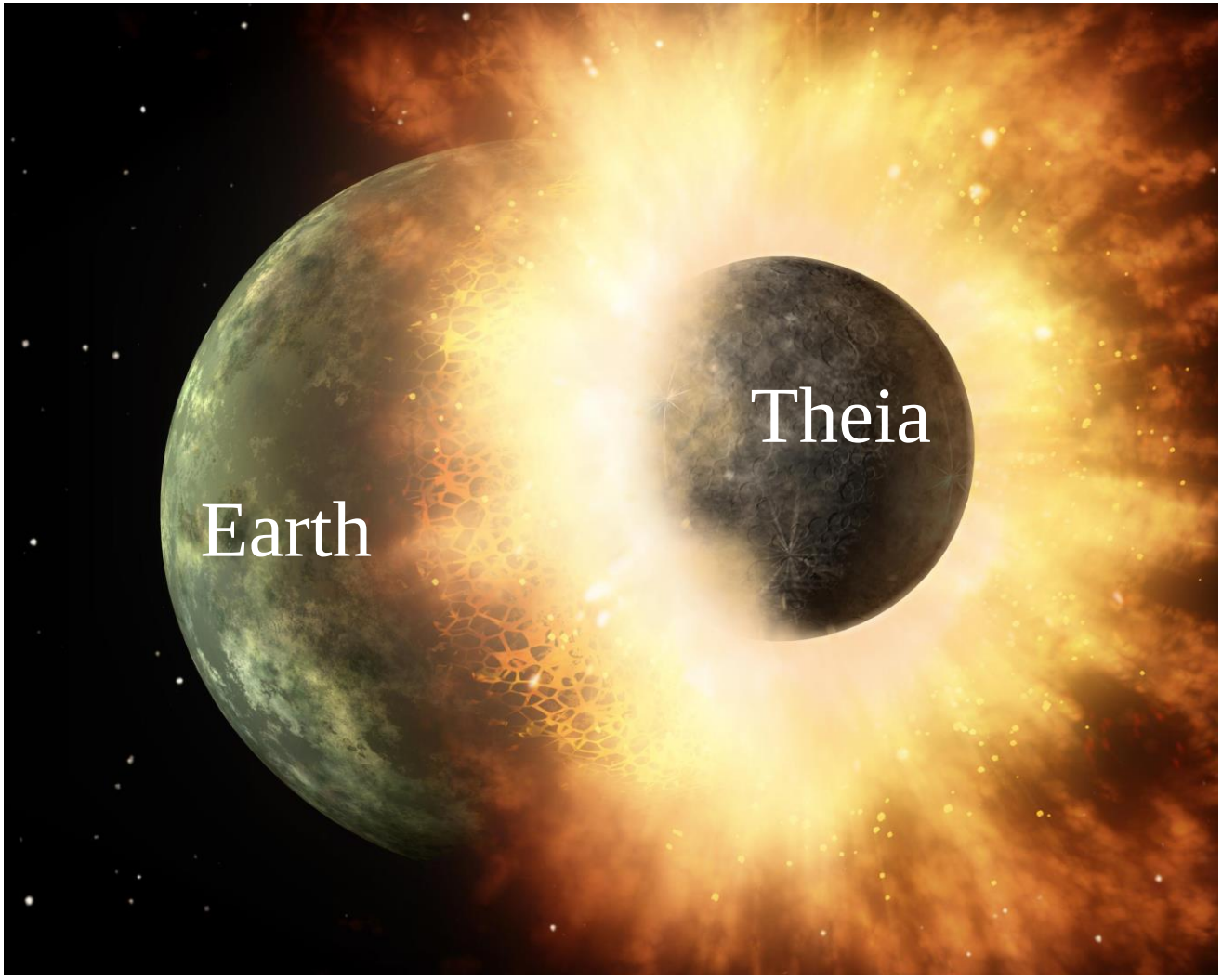
As the molten Earth cooled, planetary materials separated by density. More dense sinks to the center. Less dense move to outside.

Modern Earth. The interior of the Earth is differentiated into layers.

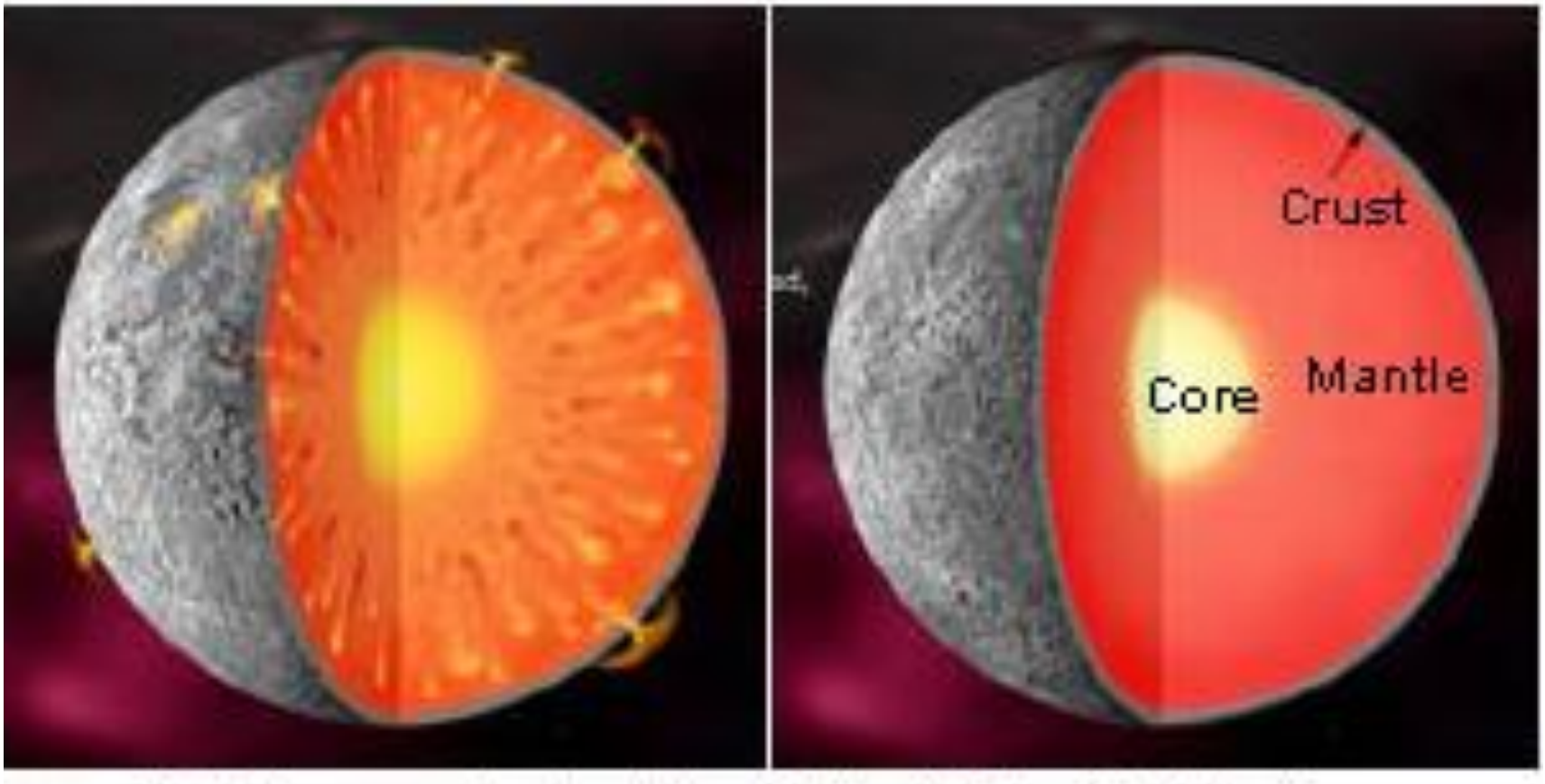
Layers of the Earth: Densest heaviest materials (iron and nickel) are in the center of the Earth (deepest). Lightest least dense materials (silicate rock) rise to the top.



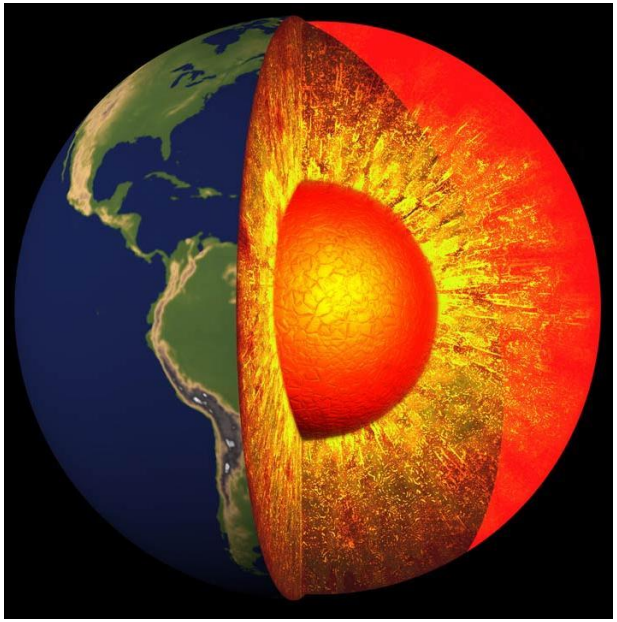
Sometime between 4.4 and 4.5 billion years ago, the theoretical protoplanet Theia collided with protoplanet Earth. This is the modern theory of the moon's formation.

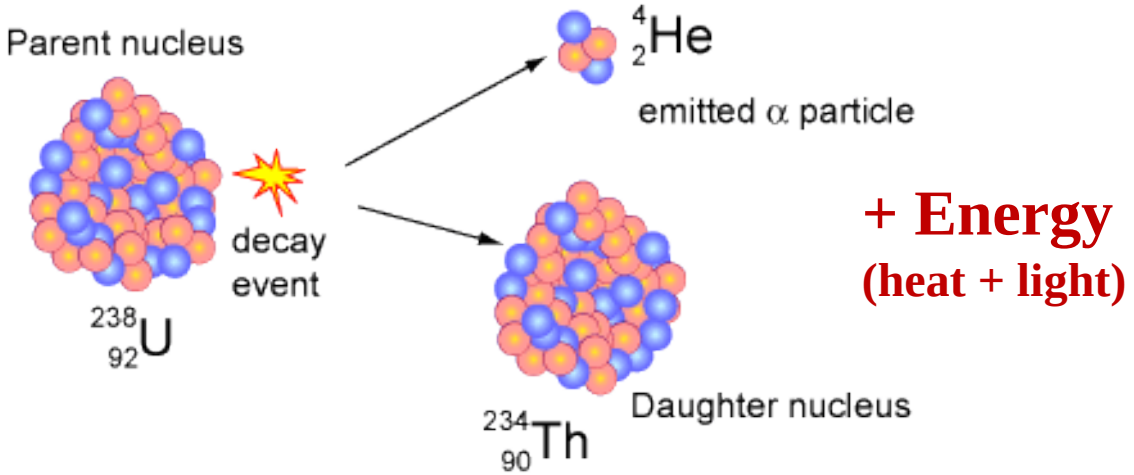


A small fraction of the Earth's heat is leftover heat from when the Earth was molten and differentiated into layers 4.5 billion years ago. The Earth is slowly cooling off. This **leftover heat** is called "**primordial heat**" (heat from the beginning).



Most of the new heat that is keeping the Earth's interior hot is from the **radioactive decay** of heavy radioactive metal elements in the Earth's inner and outer cores.



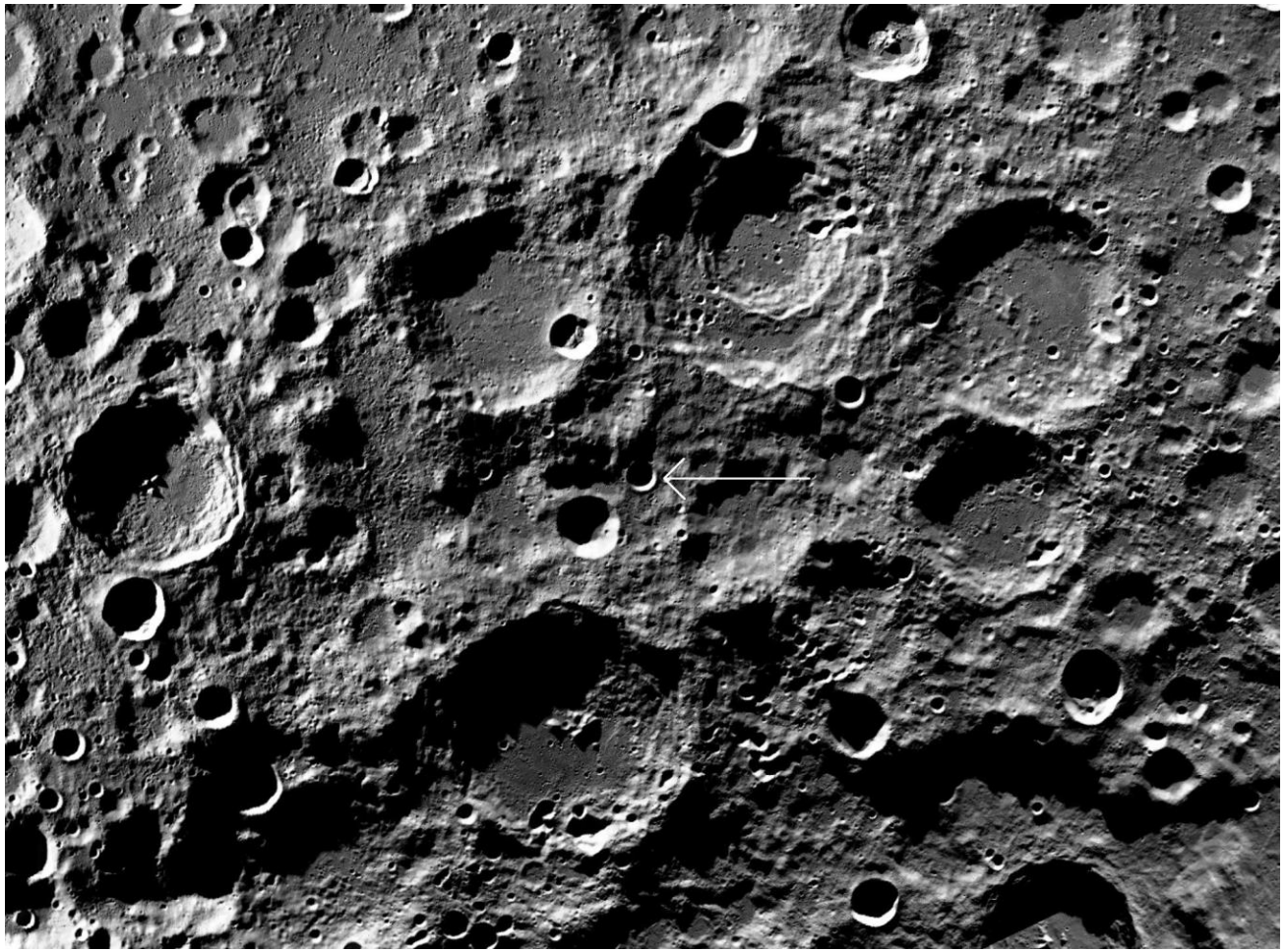


Uranium, **Thorium**, and most **Potassium** atoms are unstable and will undergo radiodecay. Most of these metals sank to the inner and outer core with the iron and nickel during differentiation. As they decay and break apart, they release energy that creates heat.

Between 3.8 and 4.0 billion years ago, the inner solar system planets and Earth's moon were subjected to the **Late Heavy Bombardment**.

- By 4.0 billion years ago (500 million years after the formation of the planets), the terrestrial planets and the Earth's surface had solidified into a solid rocky crust. The interiors were still molten and very hot.
- The gas giant planets disturbed clusters of comets and asteroids. These comets and asteroids were directed inward to the inner solar system.
- The comets and asteroids collided with the terrestrial planets and Earth's moon making most of the impact craters on those bodies.

The very high density of overlapping impact craters on Earth's moon and on Mercury imply each body in the inner solar system was potentially impacted by millions of large impactors (3.8 to 4.0 billion years ago).



The asteroids and comets carried traces of water, the lighter elements (nitrogen, sulfur, phosphorus), and organic compounds (made of carbon and hydrogen).

The **outgassing** of water vapor and gaseous compounds by the extreme volcanism coupled with the transport of water, light compounds, and organic compounds to Earth during the **Late Heavy Bombardment** provided enough elements and materials to create Earth's first atmosphere and eventually the water for the oceans.