

The History of the Earth



Origin of the Universe

The universe began about 14.4 billion years ago

The **Big Bang Theory** states that, in the beginning, the universe was all in one place

All of its matter and energy were squished into an infinitely small point, a singularity

Then it exploded



Origin of the Universe

The tremendous amount of material blown out by the explosion eventually formed the stars and galaxies

After about 10 billion years, our solar system began to form



Birth of the Solar System

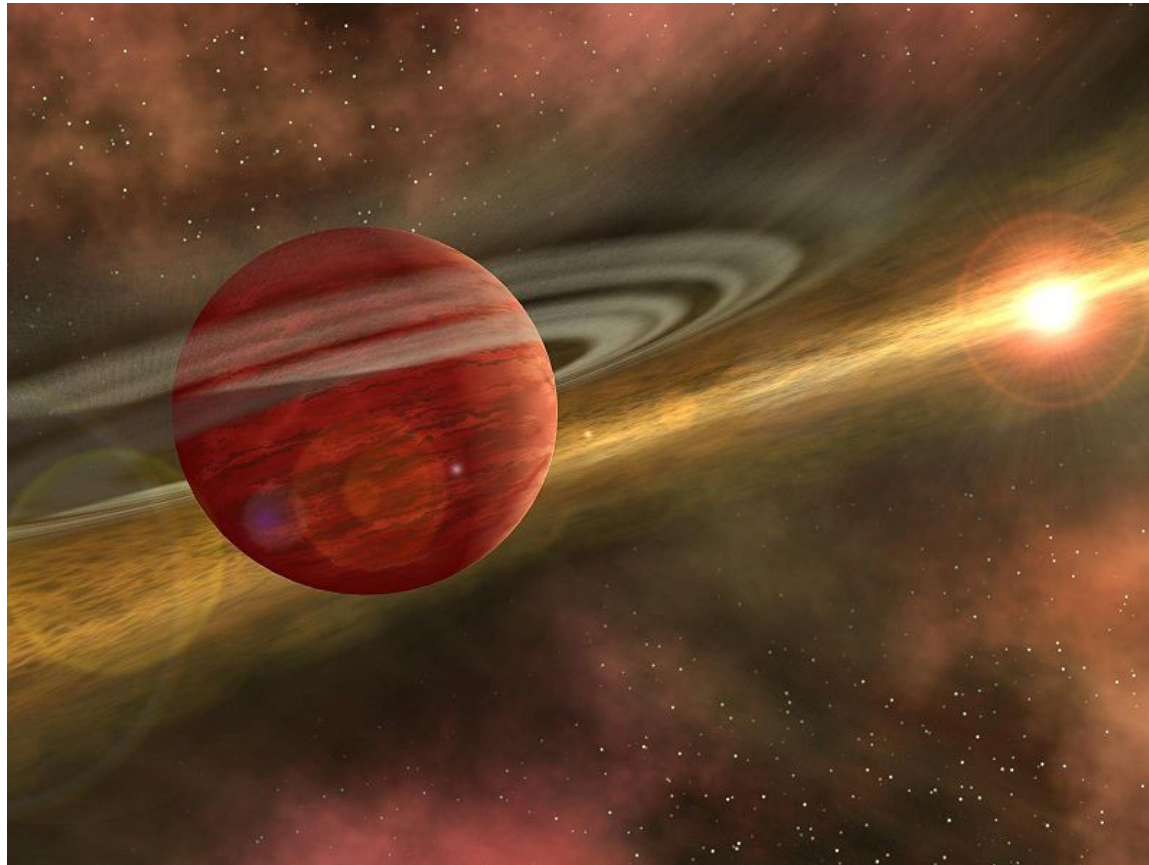
We know how the Earth and Solar System are today and this allows us to work backwards and determine how the Earth and Solar System were formed

Plus we can out into the universe for clues on how stars and planets are currently being formed



The Nebular Hypothesis

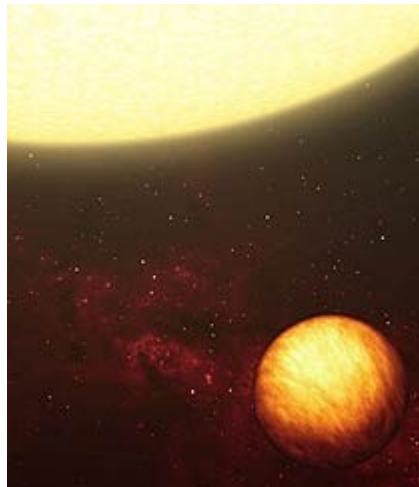
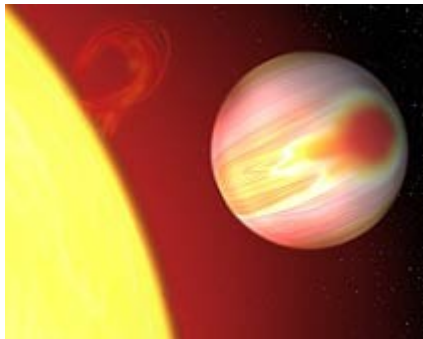
In cosmogony, the **Nebular Hypothesis** is the currently accepted argument about how a Solar System can form



Other Solar Systems

We have now discovered over two hundred planets orbiting other stars

The processes that created our solar system have also created an uncountable number of other solar systems



The Nebular Hypothesis

A large gas cloud (nebula) begins to condense

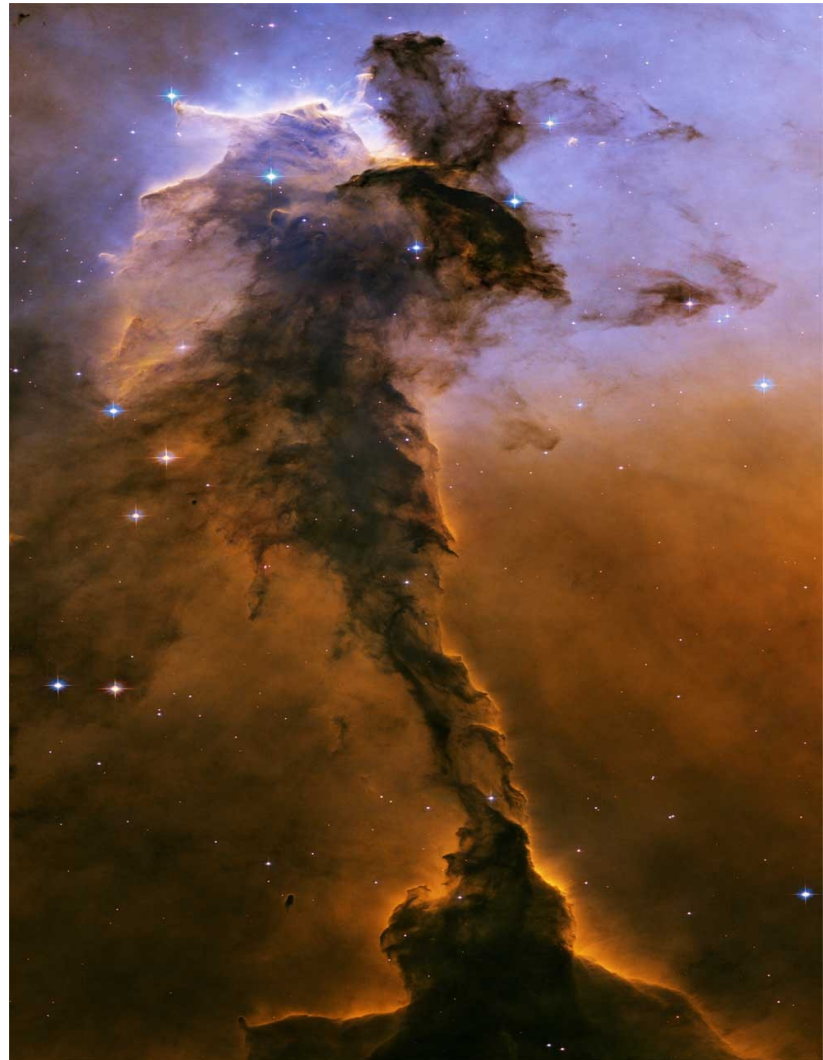
Most of the mass is in the center, there is turbulence in the outer parts



The Nebular Hypothesis

The turbulent eddies collect matter measuring meters across

Small chunks grow and collide, eventually becoming large aggregates of gas and solid chunks



The Nebular Hypothesis

Pictures from the Hubble Space Telescope show newborn stars emerging from dense, compact pockets of interstellar gas called evaporating gaseous globules



The Nebular Hypothesis

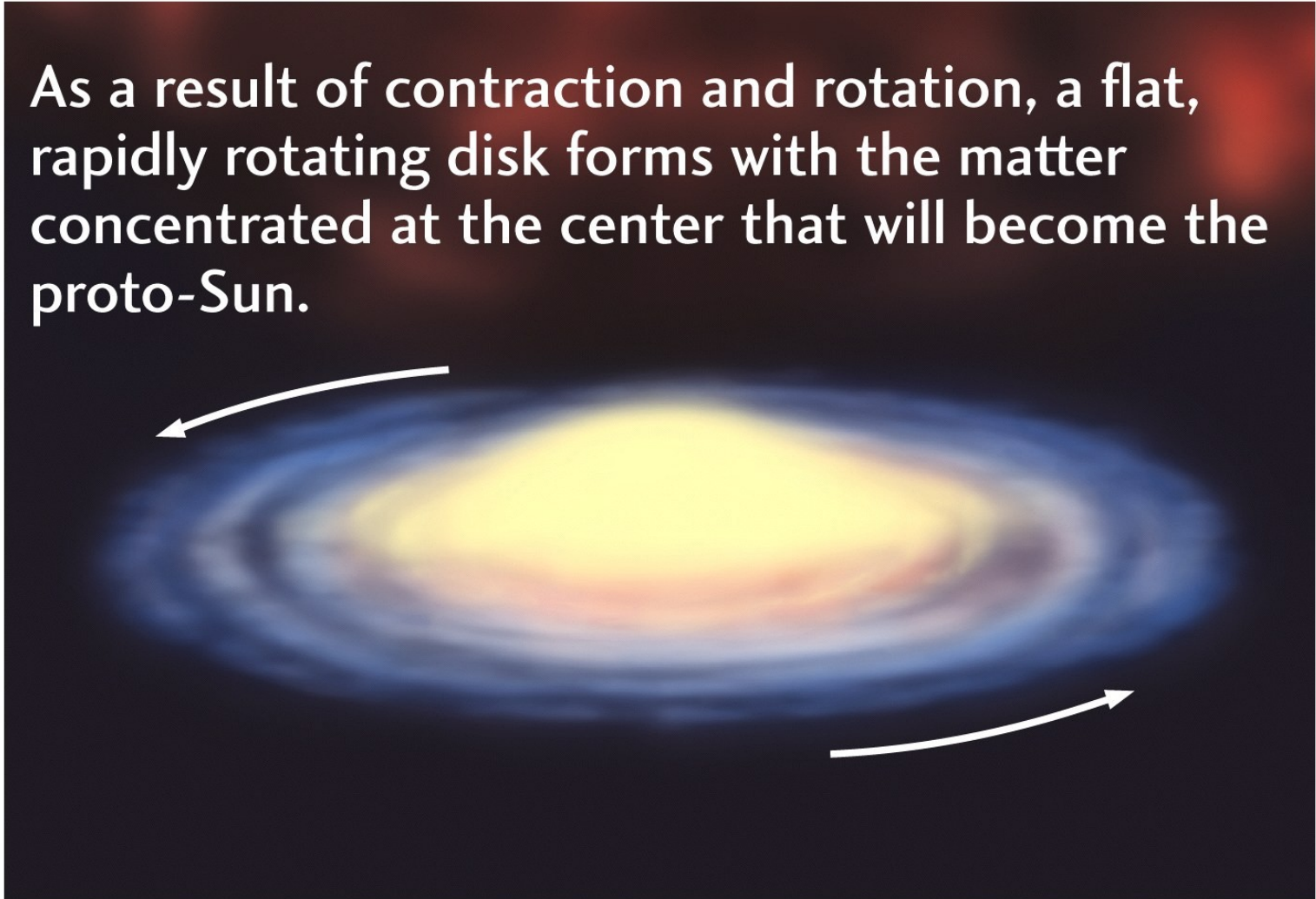
Gravitational attraction causes the mass of gas and dust to slowly contract and it begins to rotate

The dust and matter slowly falls towards the center

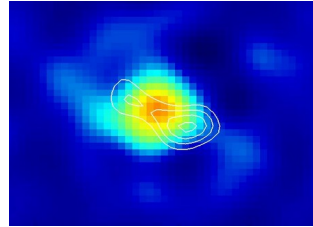


Protostar

As a result of contraction and rotation, a flat, rapidly rotating disk forms with the matter concentrated at the center that will become the proto-Sun.



False Color Image of Protostar



The multi-colored area shows a dust disk surrounding a newborn star

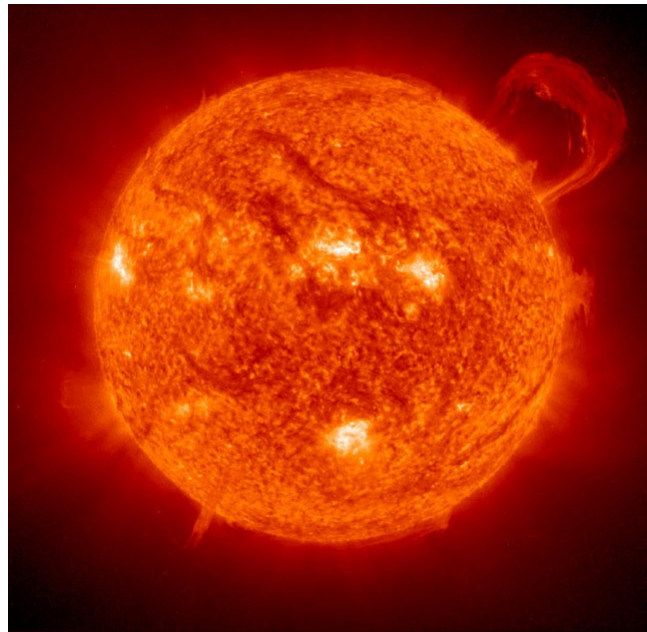
The red-orange area at the center represents the brightest region, which contains the young star

It is surrounded by the cooler, dusty disk, which appears as yellow, green and blue

The diameter of the disk is about 20 times larger than our entire solar system

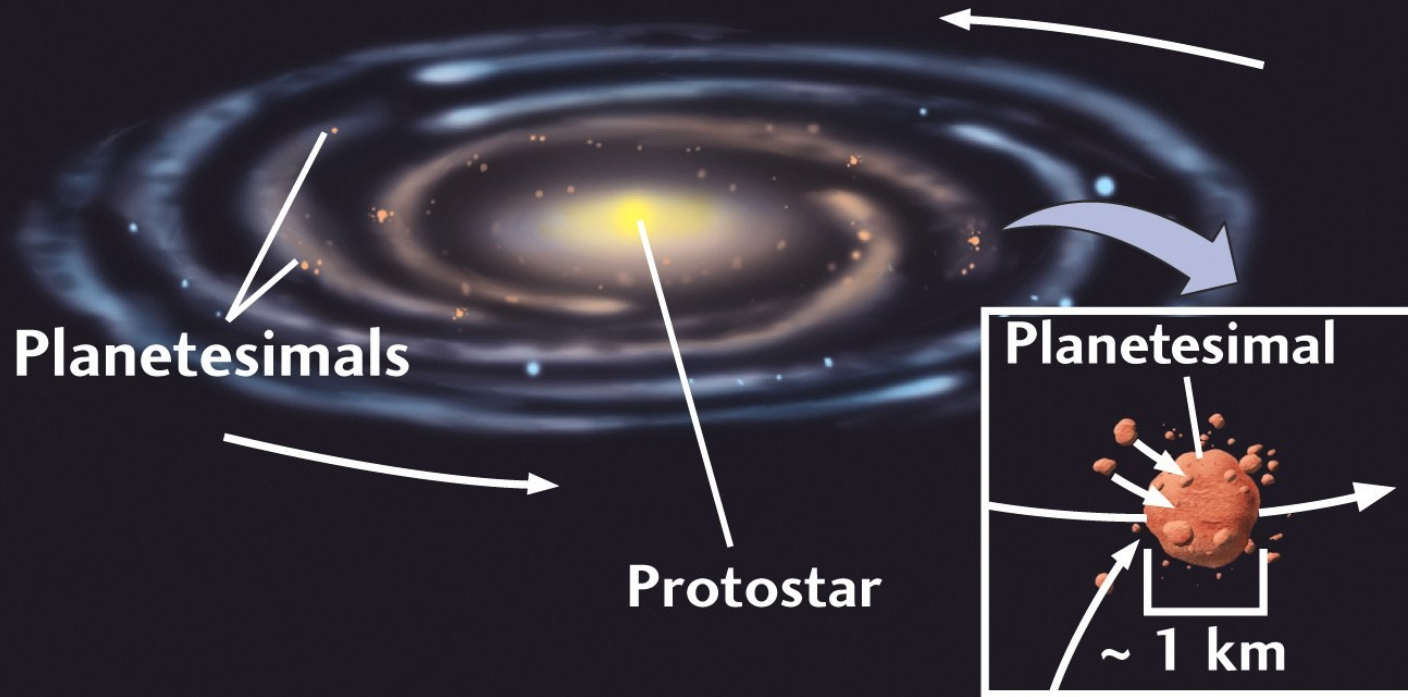
The Sun

After sufficient mass and density was achieved in the Sun, the temperature rose to one million °C, resulting in thermonuclear fusion.



Birth of the Solar System

The enveloping disk of gas and dust forms grains that collide and clump together into small chunks or planetesimals.



Protoplanets

Gravitational forces allow the inner planets to accrue and compact solid matter (including light and heavy atoms)

Solar radiation blew gases (primarily hydrogen, helium) away from inner planets

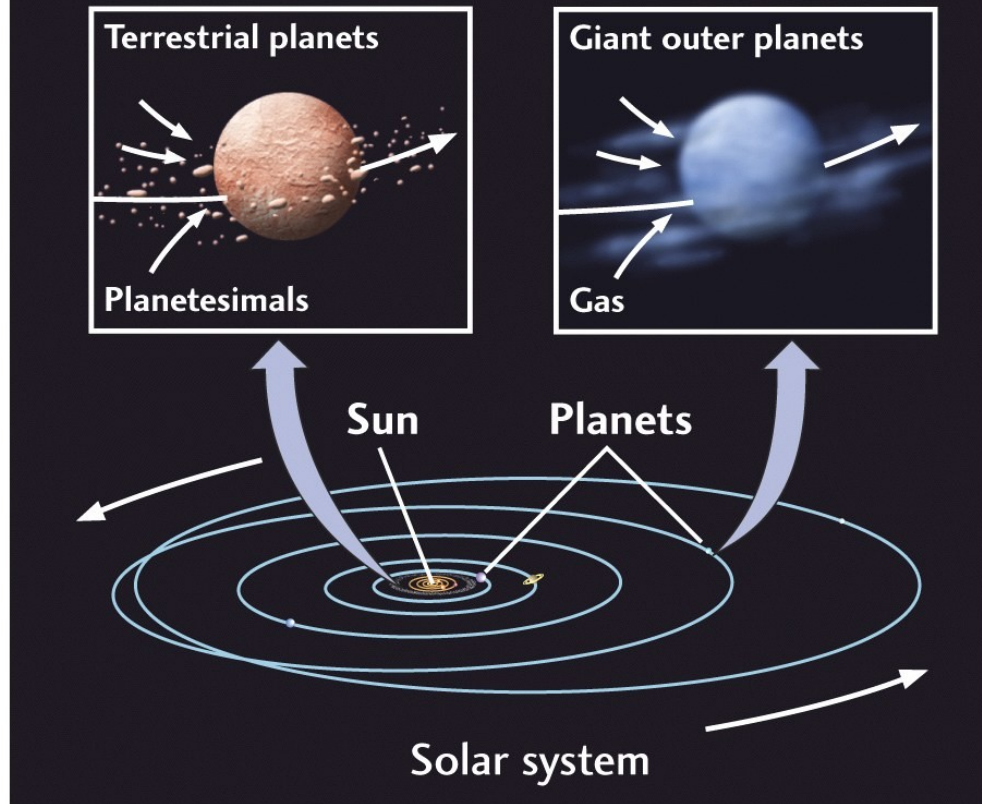
These gases were collected and condensed into the gas giants (Jupiter, Saturn, Uranus, Neptune)

Beyond Neptune, ice and frozen gases form Pluto, Sedna and the Kuiper Belt Objects

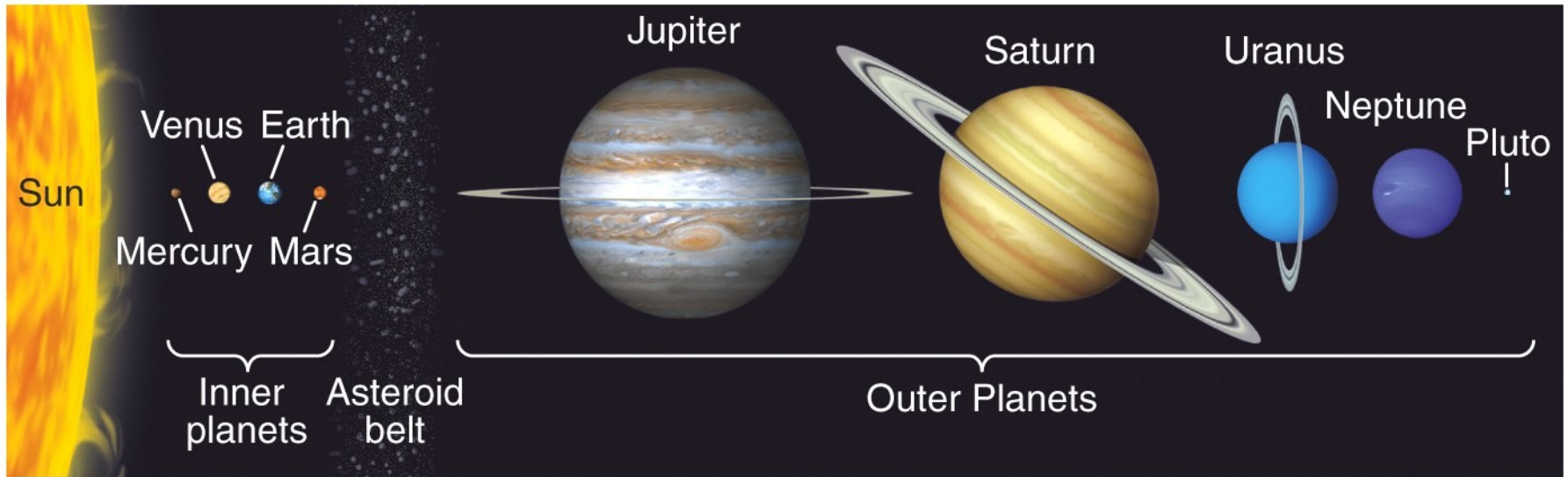
Left-over debris form comets and asteroids

Birth of the Solar System

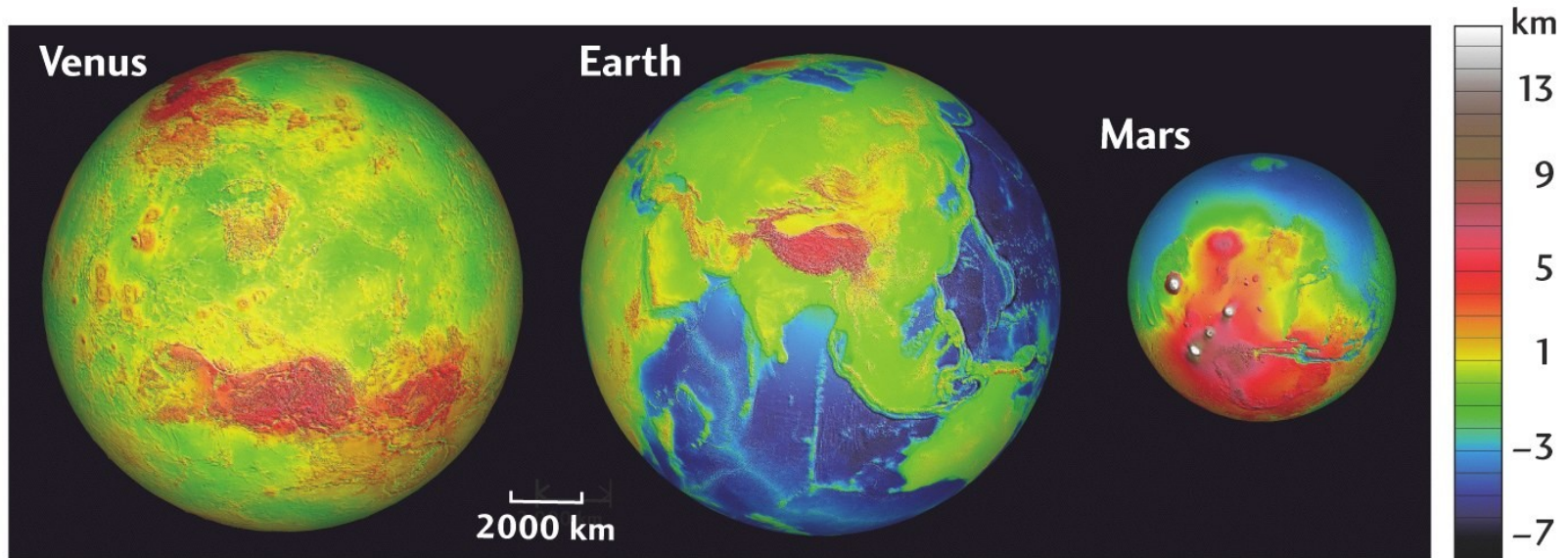
The terrestrial planets build up by multiple collisions and accretion of planetesimals by gravitational attraction. Giant outer planets grew by gas accretion.



Size of the Planets



Venus, Earth and Mars



These maps are color coded to display different elevations on the surface of each planet

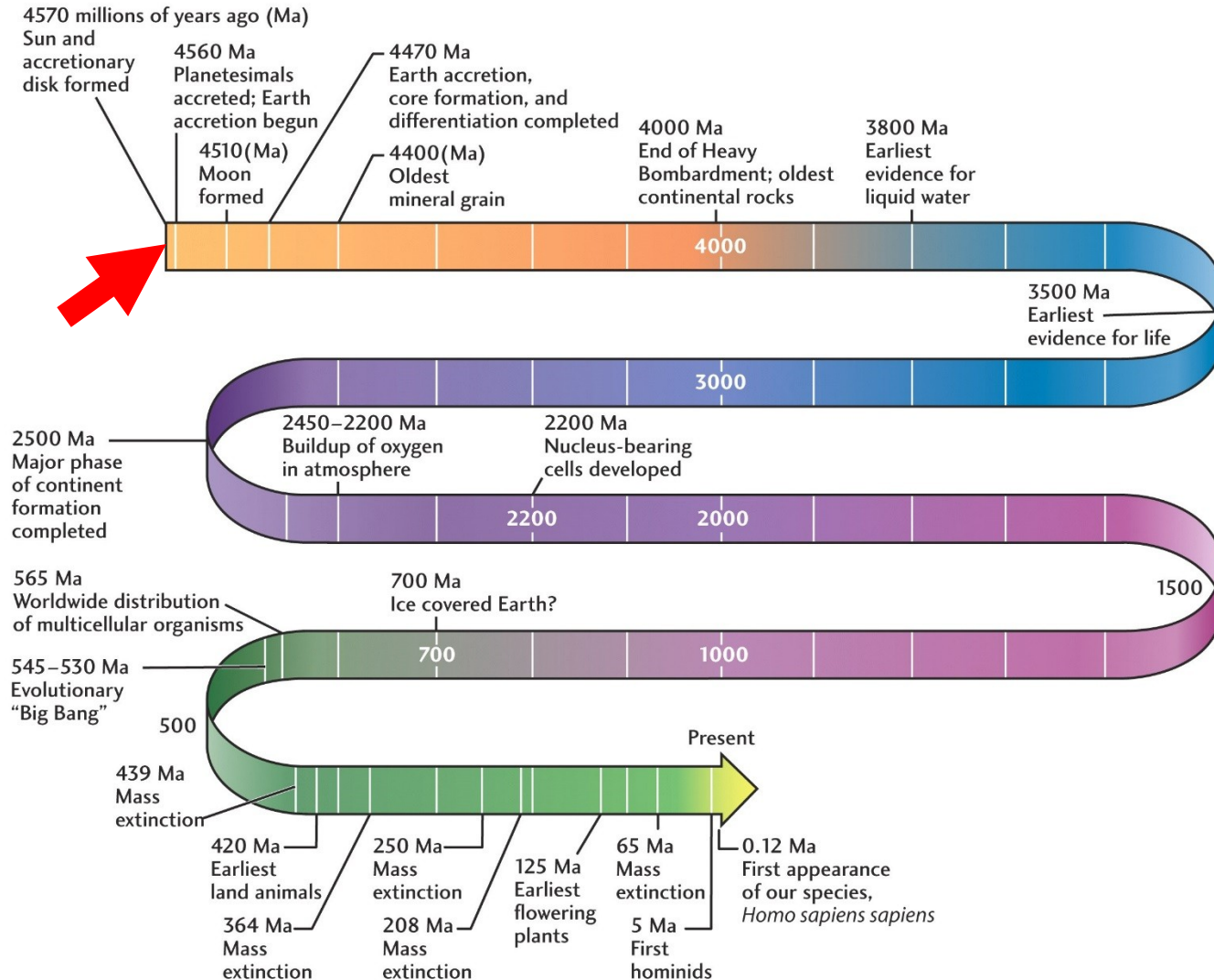
The Age of the Earth

Earth is ~ 4,570,000,000 years old

Meteorites give us access to debris left over from the formation of the solar system
We can date meteorites using radioactive isotopes and their decay products



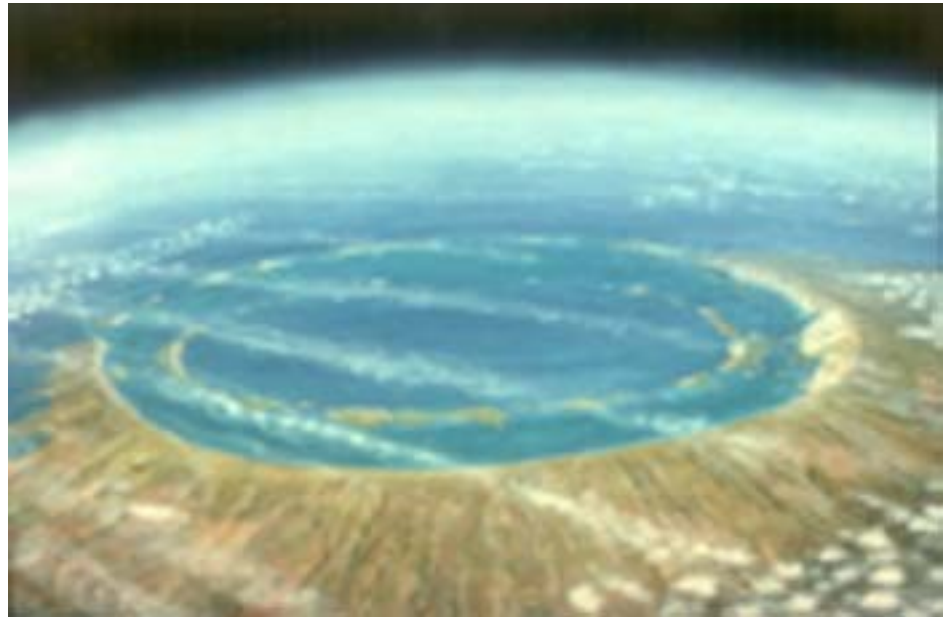
Geologic Time



Bombardment From Space

For the first half billion years of its existence, the surface of the Earth was repeatedly pulverized by asteroids and comets of all sizes

One of these collisions formed the Moon



Formation of the Moon

The **Giant Impact Hypothesis** predicts that around 50 million years after the initial creation of Earth, a planet about the size of Mars collided with Earth

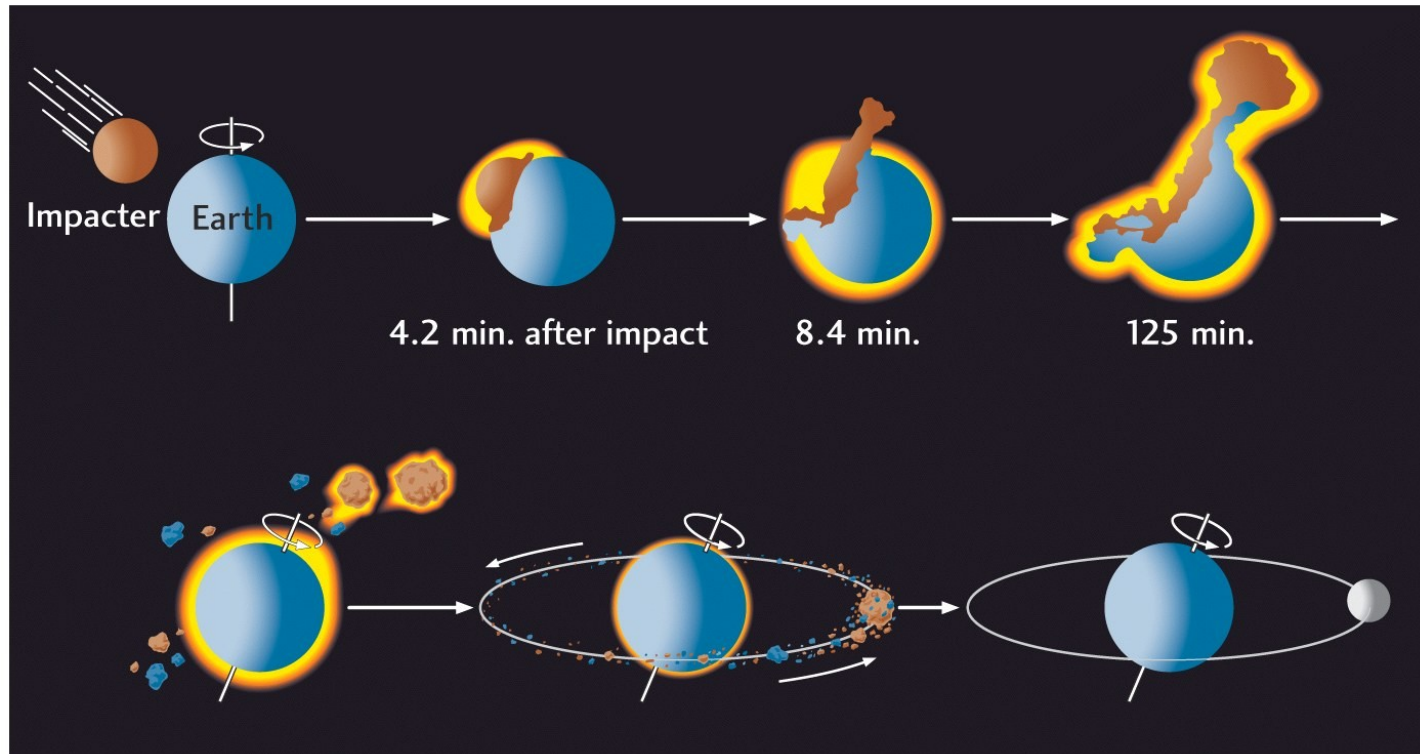
This idea was first proposed about 30 years ago, but it took calculations by modern high-speed computers to prove the feasibility



Formation of the Moon

This collision had to be very spectacular!

A considerable amount of material was blown off into space, but most fell back onto the Earth



Formation of the Moon

Part of the material from the collision remained in orbit around the Earth

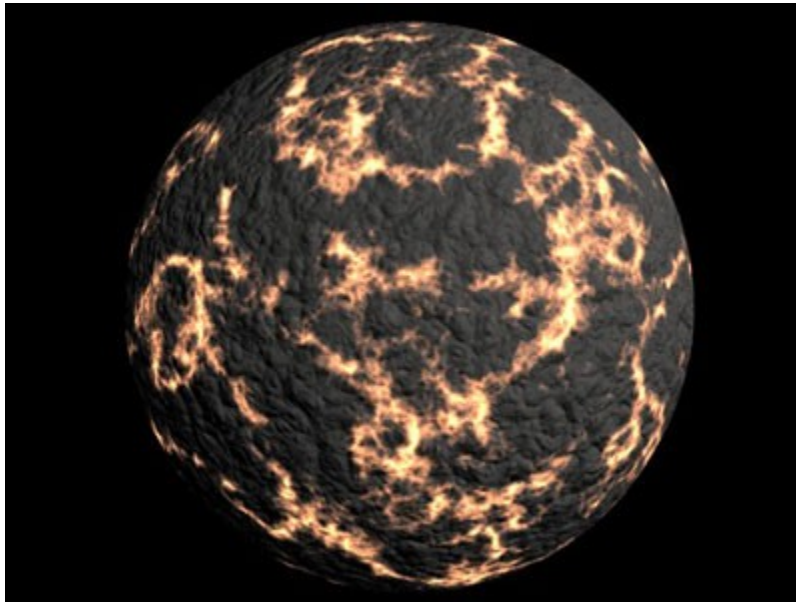
By the process collision and accretion, this orbiting material coalesced into the Moon

The early Moon orbited very close to the Earth



The Early Earth Heats Up

Three major factors that caused heating and melting in the early Earth's interior:

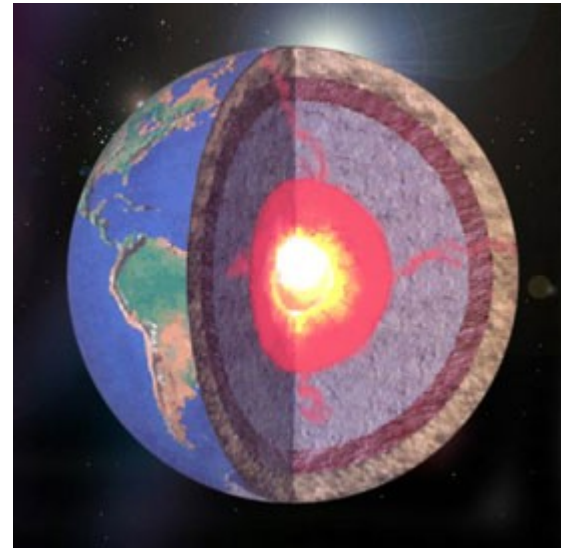


1. Collisions (Transfer of kinetic energy into heat)
2. Compression
3. Radioactivity of elements (e.g. uranium, potassium, or thorium)

The Core

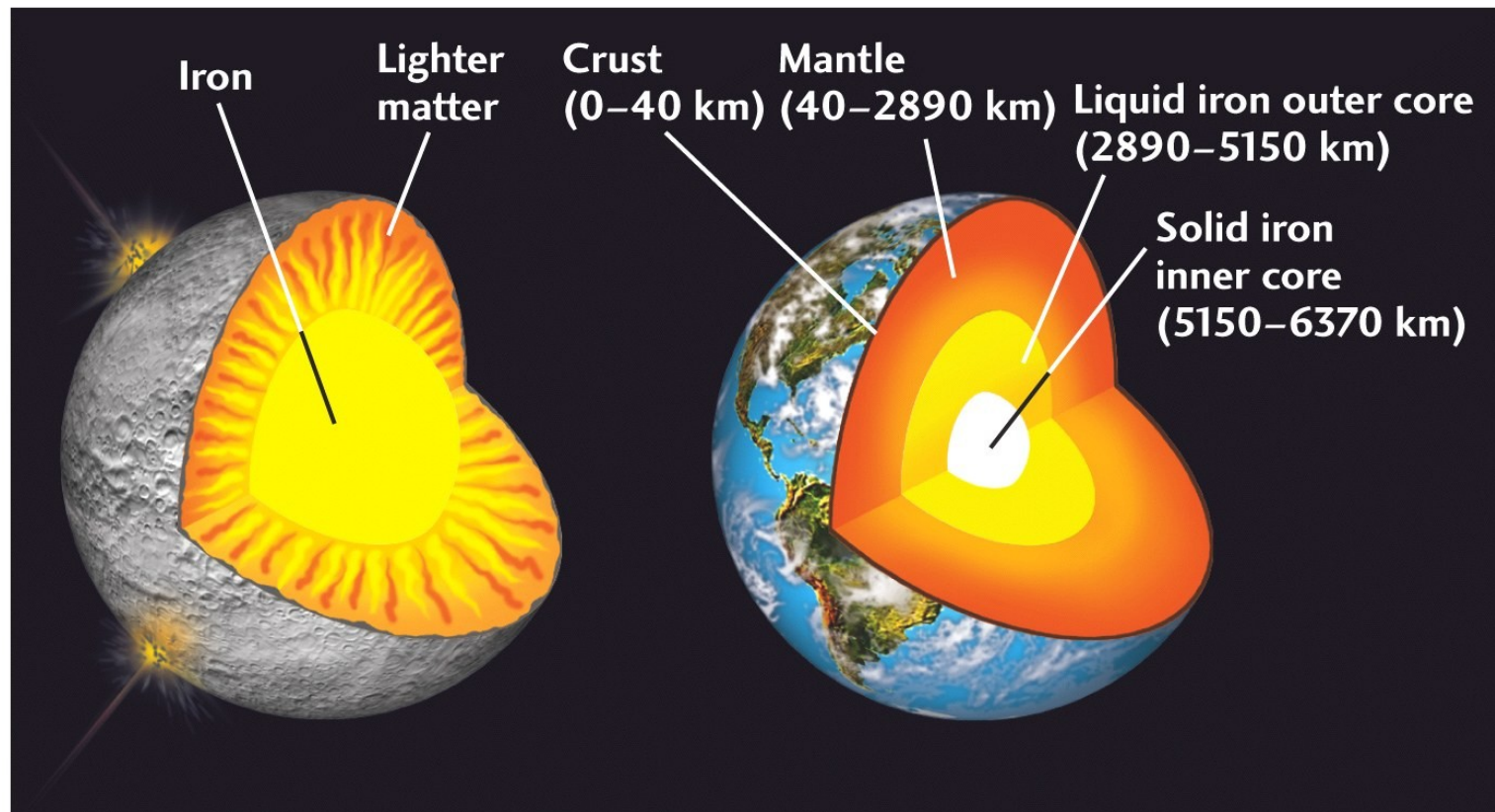
About 100 million years after initial accretion, temperatures at depths of 400 to 800 km below the Earth's surface reach the melting point of iron

In a process called **global chemical differential**, the heavier elements, including the melted iron, began to sink down into the **core** of the Earth, while the lighter elements such as oxygen and silica floated up towards the surface



Global Chemical Differentiation

This global chemical differentiation was completed by about 4.3 billion years ago, and the Earth had developed a **inner** and **outer core**, a **mantle** and **crust**

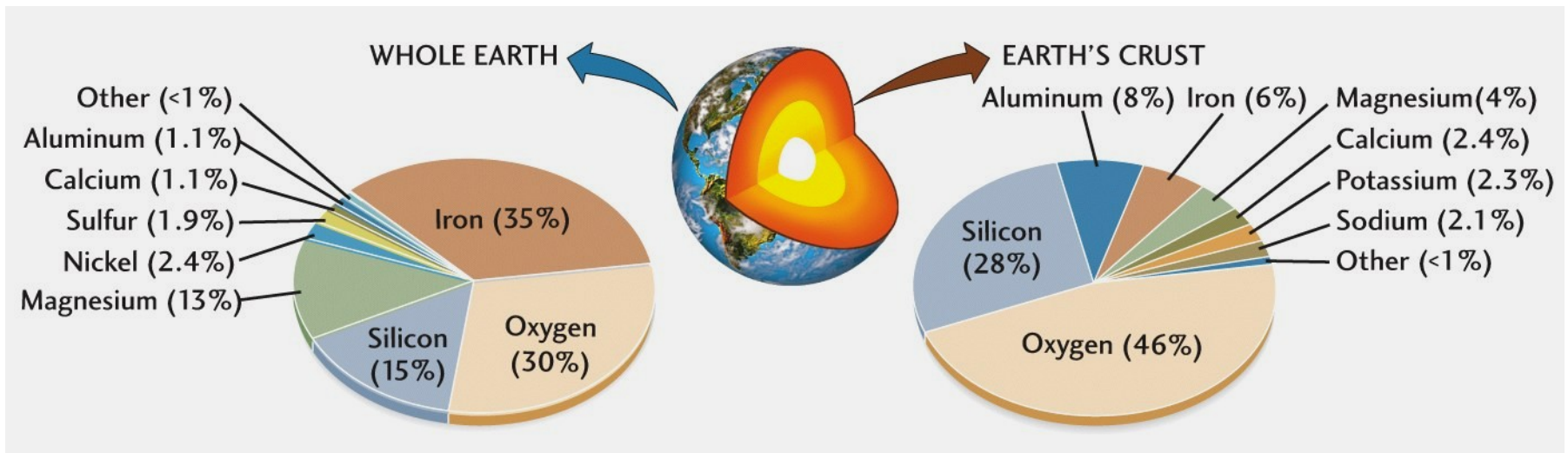


Chemical Composition of Earth

Each of the major layers has a distinctive chemical composition, with the crust being quite different from the Earth as a whole

Whole Earth:
Fe+O+Si+Mg = 93%

Crust:
Si+O+Al = 82%



Chemical Composition of Earth

Lithosphere: strong, rocky outer shell of the solid Earth including all the crust and the upper part of the mantle to a depth of ~100 km (forms the plates)

Asthenosphere: weak, ductile layer of the mantle beneath the lithosphere; deforms to accommodate the motions of the overlying plates

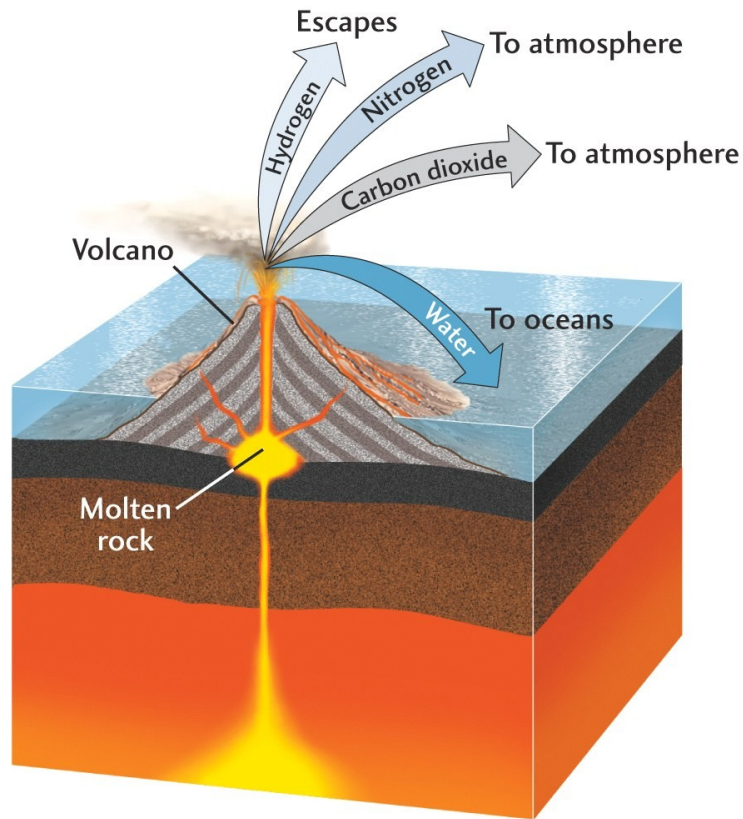
Deep Mantle: mantle beneath the asthenosphere (~400 to 2900 km in depth)

Outer core: liquid shell composed of mostly iron

Inner core: innermost sphere composed primarily of solid iron

Chemical Composition of Earth

Continents: Formed from solidified magma that floated up from the Mantle



Oceans and Atmosphere: Fluid and gaseous outer layers believed to have been created by out-gassing of gases and fluids from volcanic eruptions (in a process called **volatile transfer**)

The Evolving Atmosphere

Right after its creation, the Earth is thought to have had a thin atmosphere composed primarily of helium (He) and hydrogen (H) gases



The Earth's gravity could not hold these light gases and they easily escaped into outer space

Today, H and He are very rare in our atmosphere

The Evolving Atmosphere

For the next several hundred million years, volcanic out-gassing began to create a thicker atmosphere composed of a wide variety of gases

The gases that were released were probably similar to those created by modern volcanic eruptions



The Evolving Atmosphere



These would include:

Water vapor (H_2O)

Sulfur dioxide (SO_2)

Hydrogen sulfide (H_2S)

Carbon dioxide (CO_2)

Carbon Monoxide (CO)

Ammonia (NH_3)

Methane (CH_4)

Note that oxygen (O_2) gas is not created by volcanic eruptions

Creating the Oceans

It is hypothesized that water vapor escaping from the interior of the Earth via countless volcanic eruptions created the oceans (this took hundreds of millions of years)



Creating the Oceans

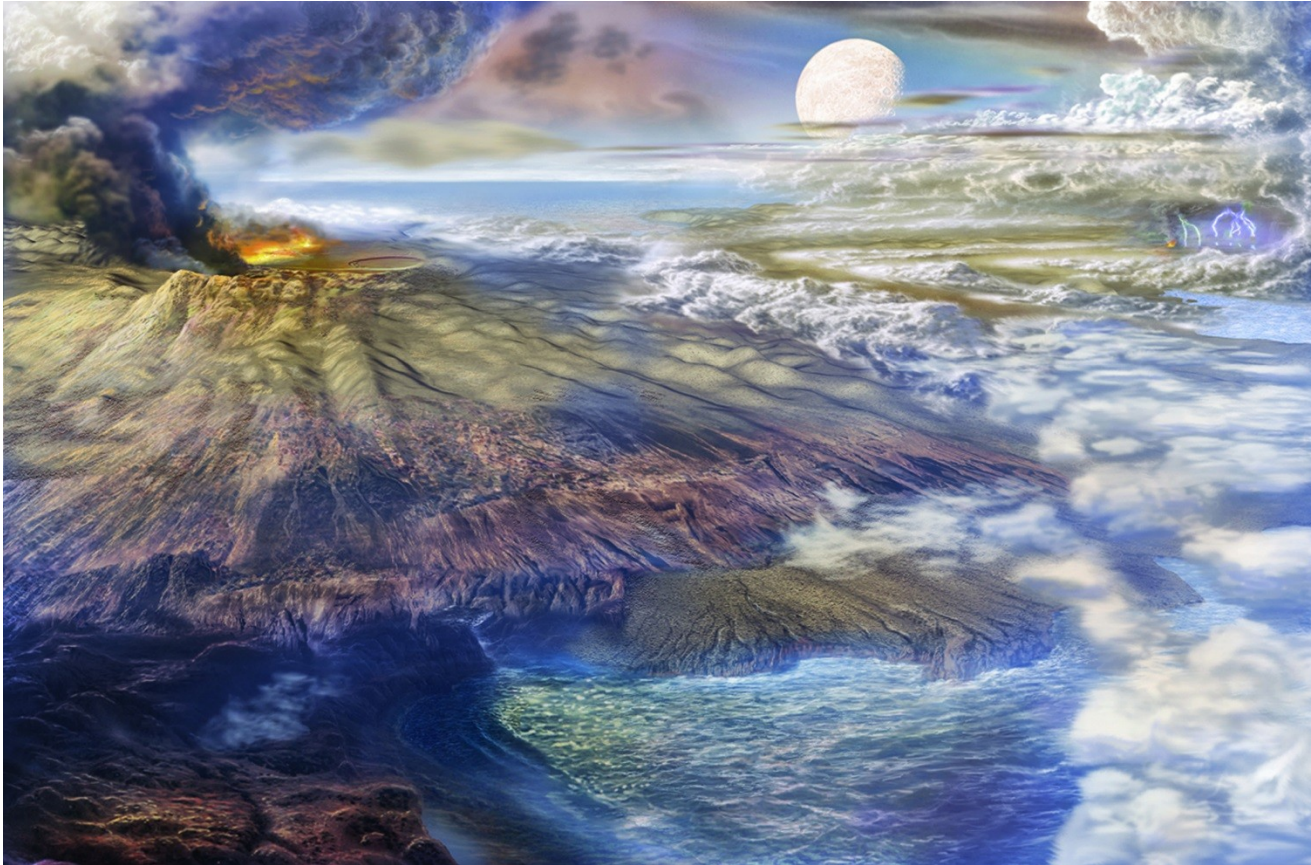


Astronomers also hypothesize that comets impacting the Earth were a major source of water that contributed to creation of the oceans

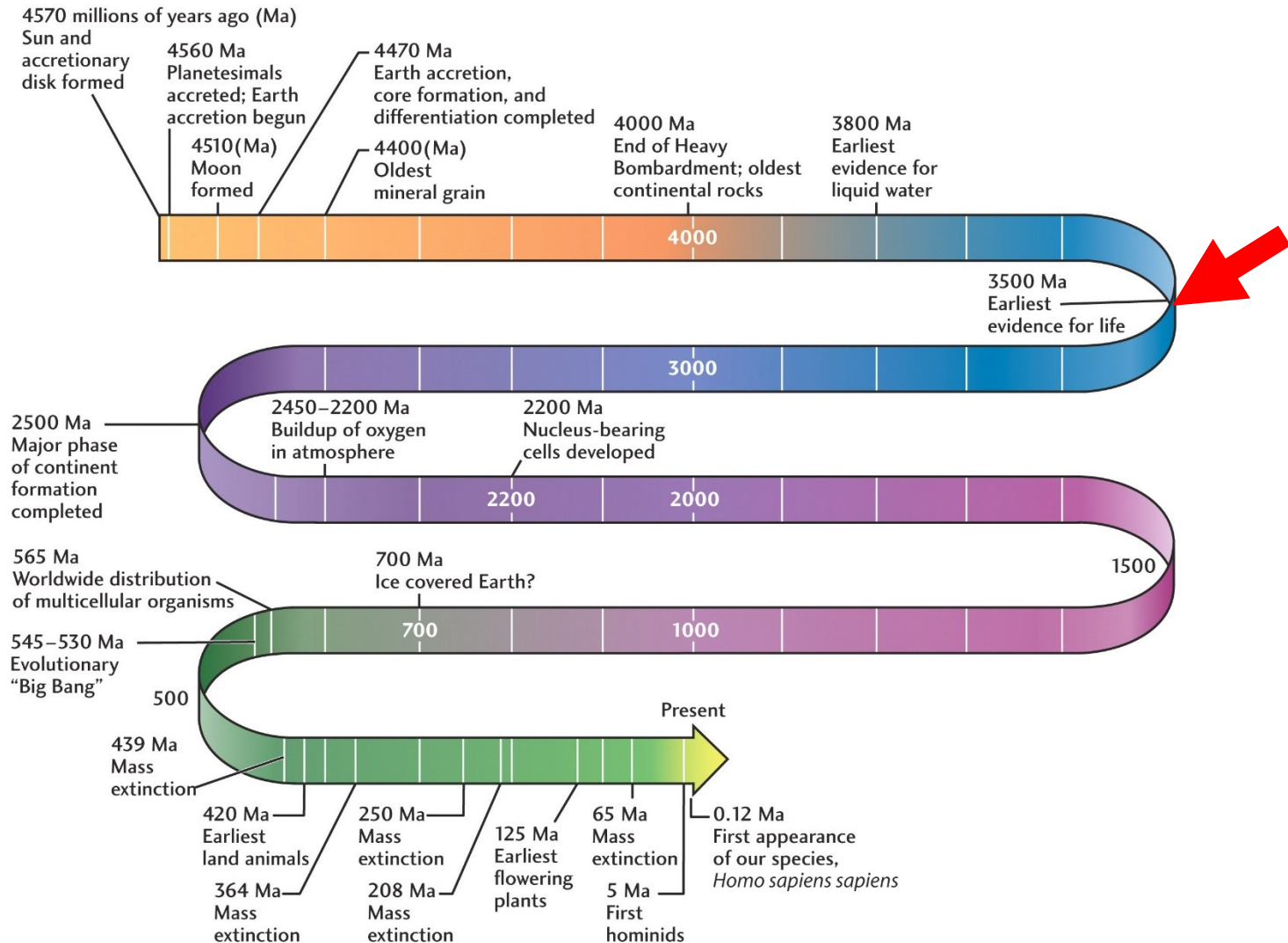
Remember, that comets are best described as “dirty ice balls”

Creating the Oceans

The earliest evidence of surface water on Earth dates back about 3.8 billion years



Geologic Time



A billion Year Old Earth

By 3.5 billion years ago, when the Earth was a billion years old, it had a thick atmosphere composed of CO₂, methane, water vapor and other volcanic gases



By human standards this early atmosphere was very poisonous

It contained almost no oxygen

Remember, today our atmosphere is 21% oxygen

A billion Year Old Earth

By 3.5 billion years ago, the Earth also had extensive oceans and seas of salt water, which contained many dissolved elements, such as iron



A billion Year Old Earth

But most important, by 3.5 billion years ago, there was life on Earth

The Continents



By 2.5 billion years ago, the continents had been formed

The density of the continental crust (2.8 gr/cm^3) is lighter than the crust found on ocean bottoms (3.2 gr/cm^3), so the continents rise above the ocean floor

A question that remains unanswered is, when did plate tectonics start?

Geologic Time

