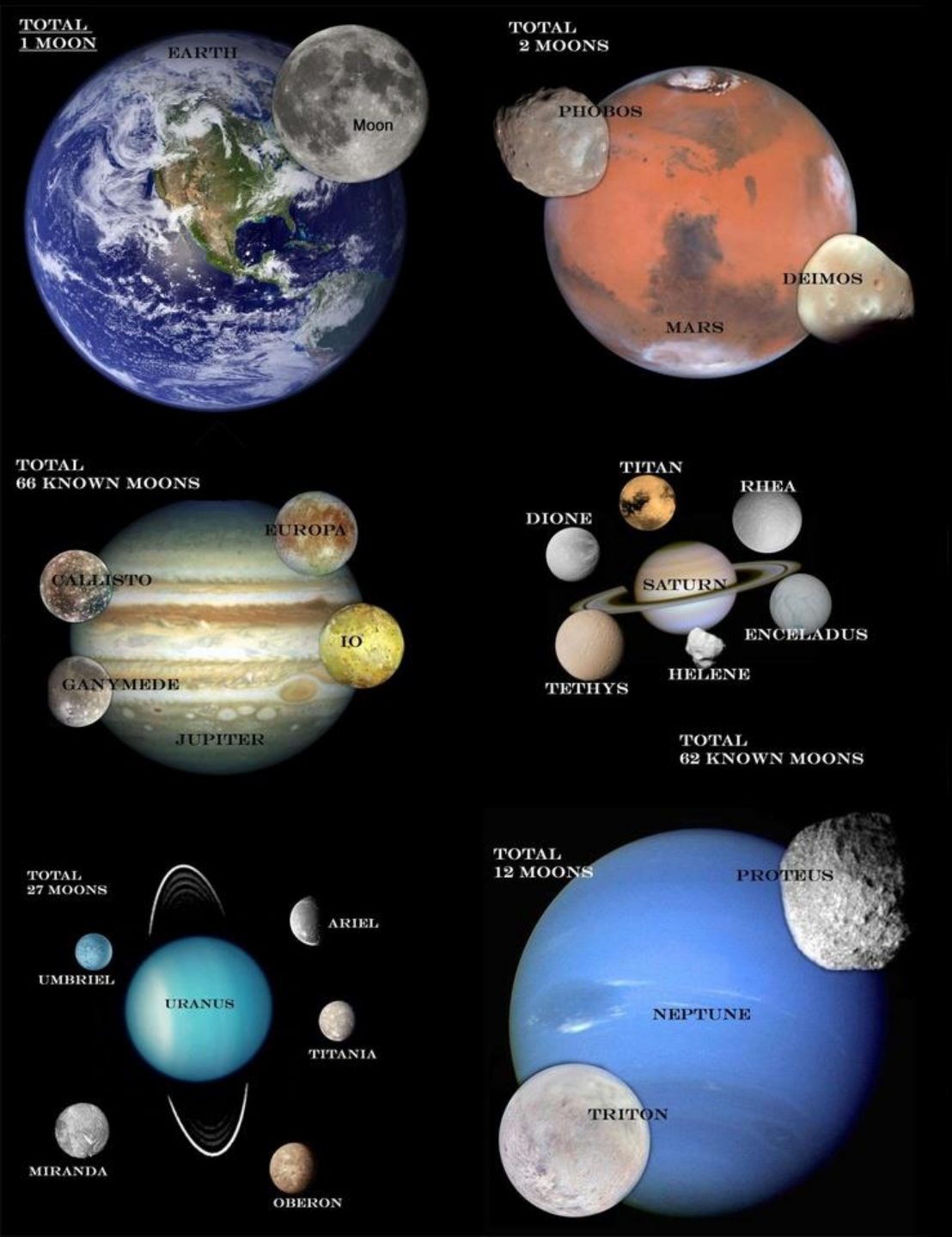
The History of the Earth



We have talked about how the universe and sun formed, but what about the planets and moons?

Review: Origin of the Universe

The universe began about 13.7 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 expanded.

Origin of our Solar System

About 10 billion years after the Big Bang, our solar system began to form.

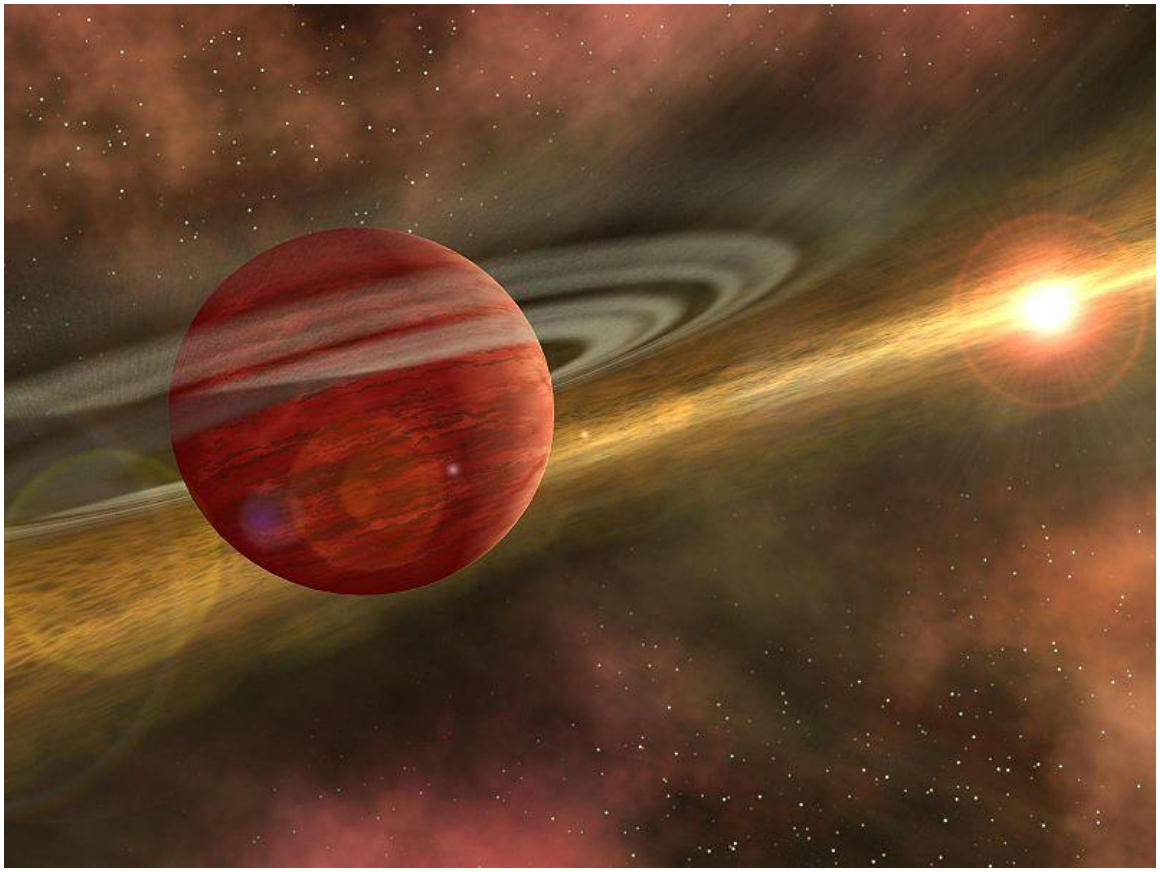
Birth of the Solar System

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 look out into the universe at how other stars and planets are currently being formed

The Nebular Hypothesis

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



***Cosmogony is the branch of science that deals with the origin of the universe, especially the solar system**

The Nebular Hypothesis

1. A large gas cloud called a **nebula** begins to condense Most of the mass is in the center, there is turbulence (violent movement) in the outer parts

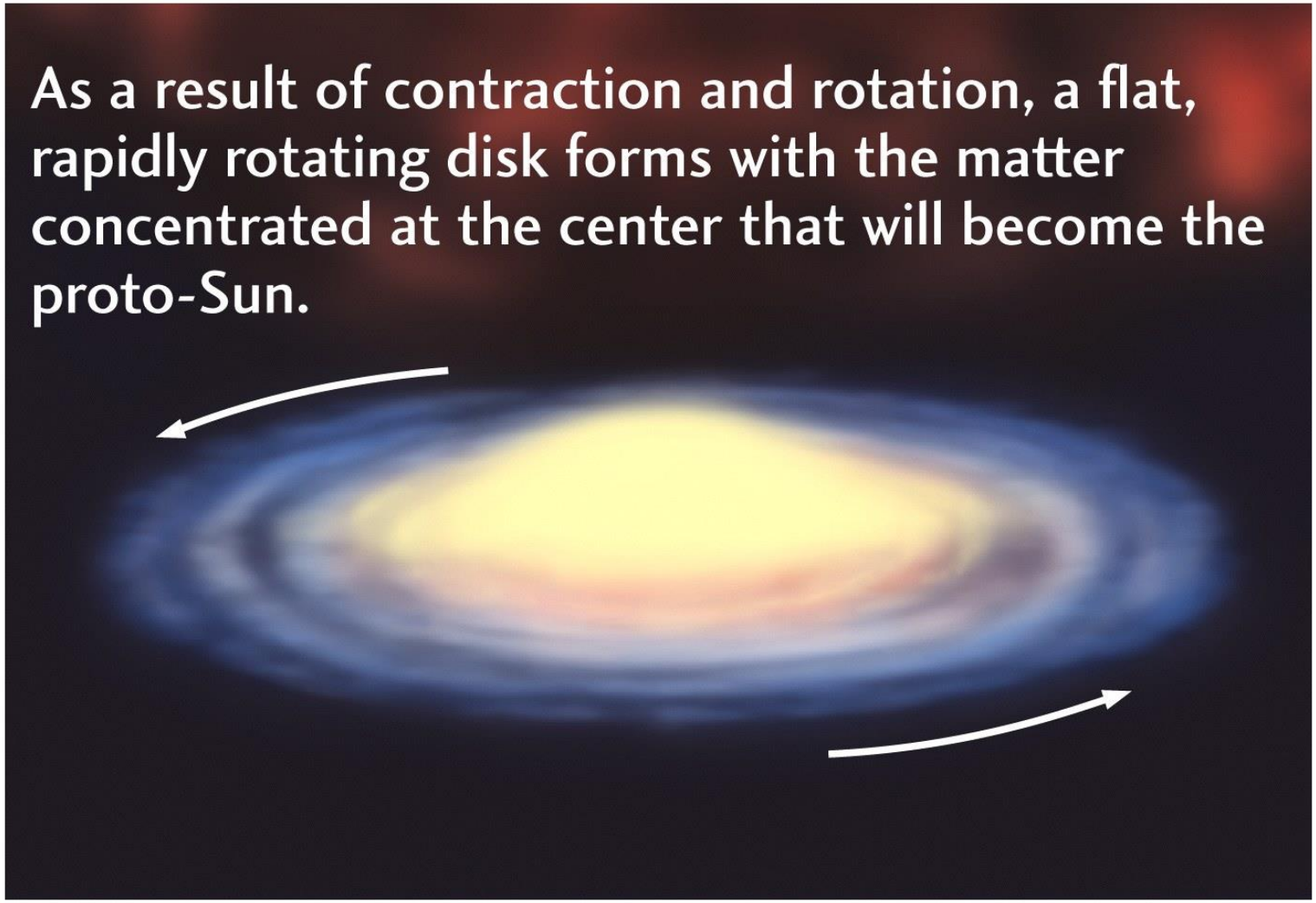
The Nebular Hypothesis

2. Gravity causes the mass of gas and dust to slowly contract and it begins to rotate.

The majority of the dust and matter slowly falls towards the center.

Protostar

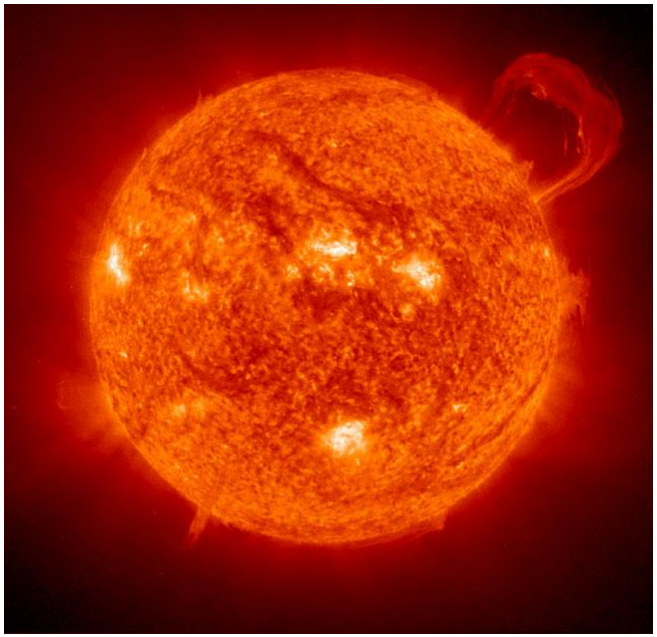
3. As a result of contraction and rotation, a flat, rapidly rotating disk forms with the matter concentrated at the center that will become the proto-Sun.



The sun is formed.

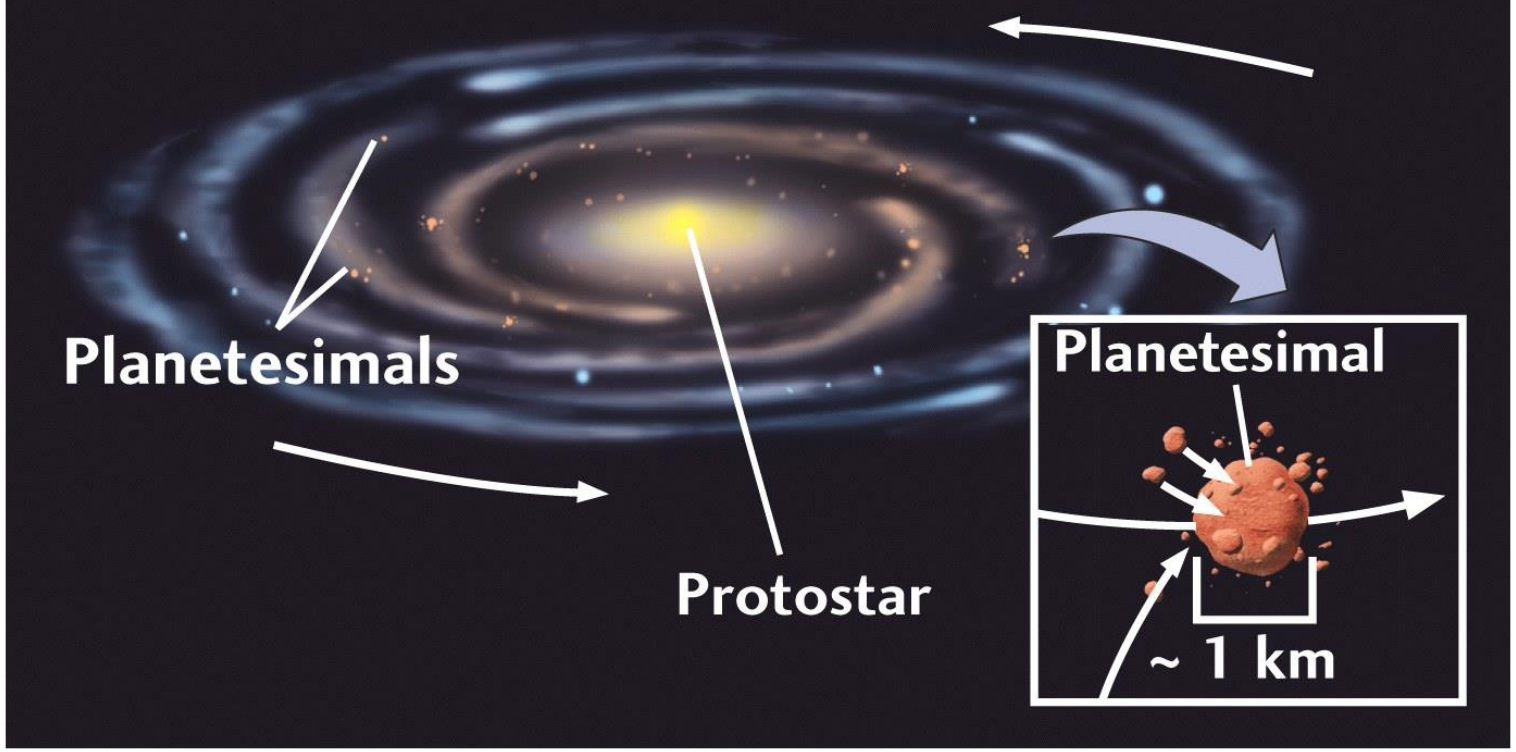
4. <u>Nuclear fusion</u> begins in the sun.

H atom + H atom = He atom + energy



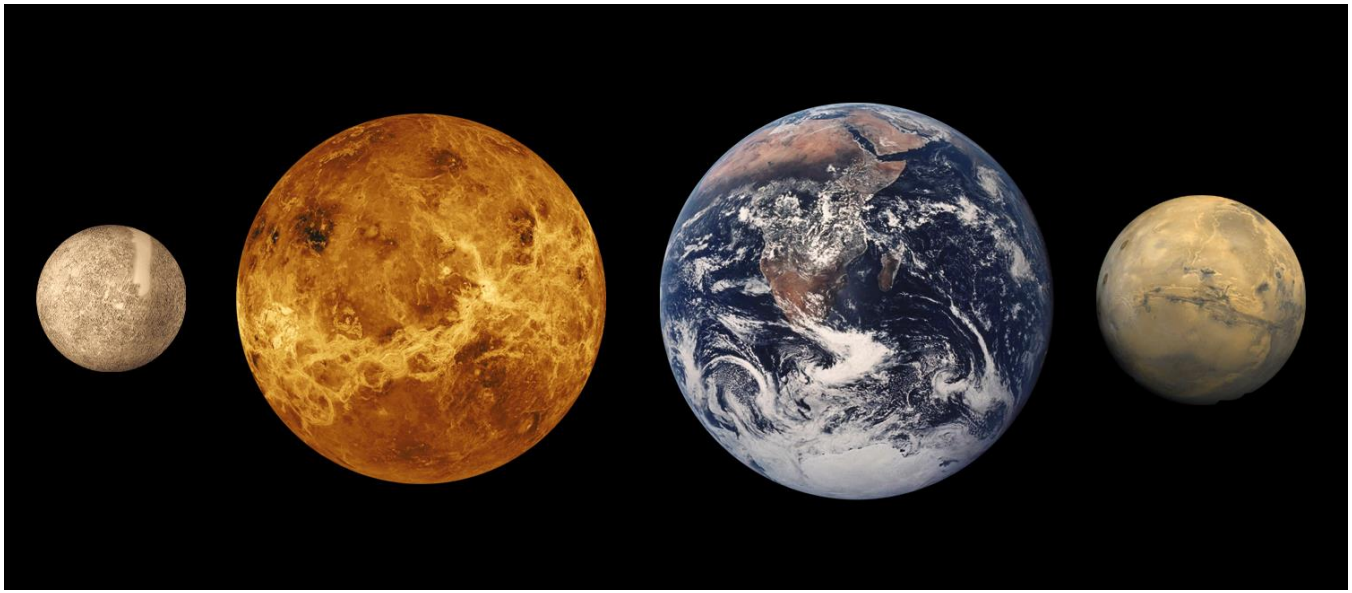
Birth of the Solar System

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



Inner Planets

6. Because **gravitational** forces are greater nearer the sun, the **inner** planets accrue and compact heavier solid matter. The inner planets (also called **terrestrial**) are **rocky** and composed mostly of silicates and **metals.** The inner planets are relatively **small, hot, rocky**, have few **moons** and no **rings**.

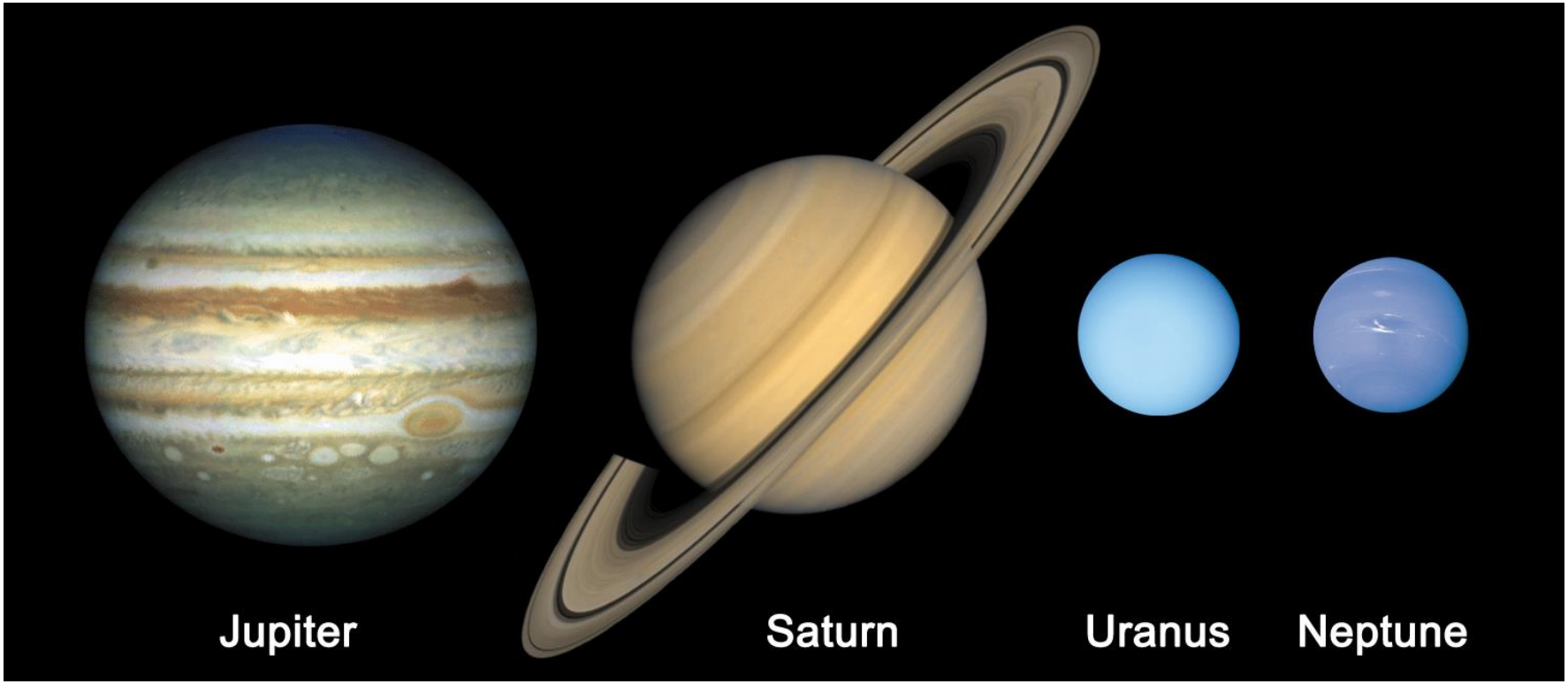


Mercury Venus Earth Mars

7. The Outer Planets

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

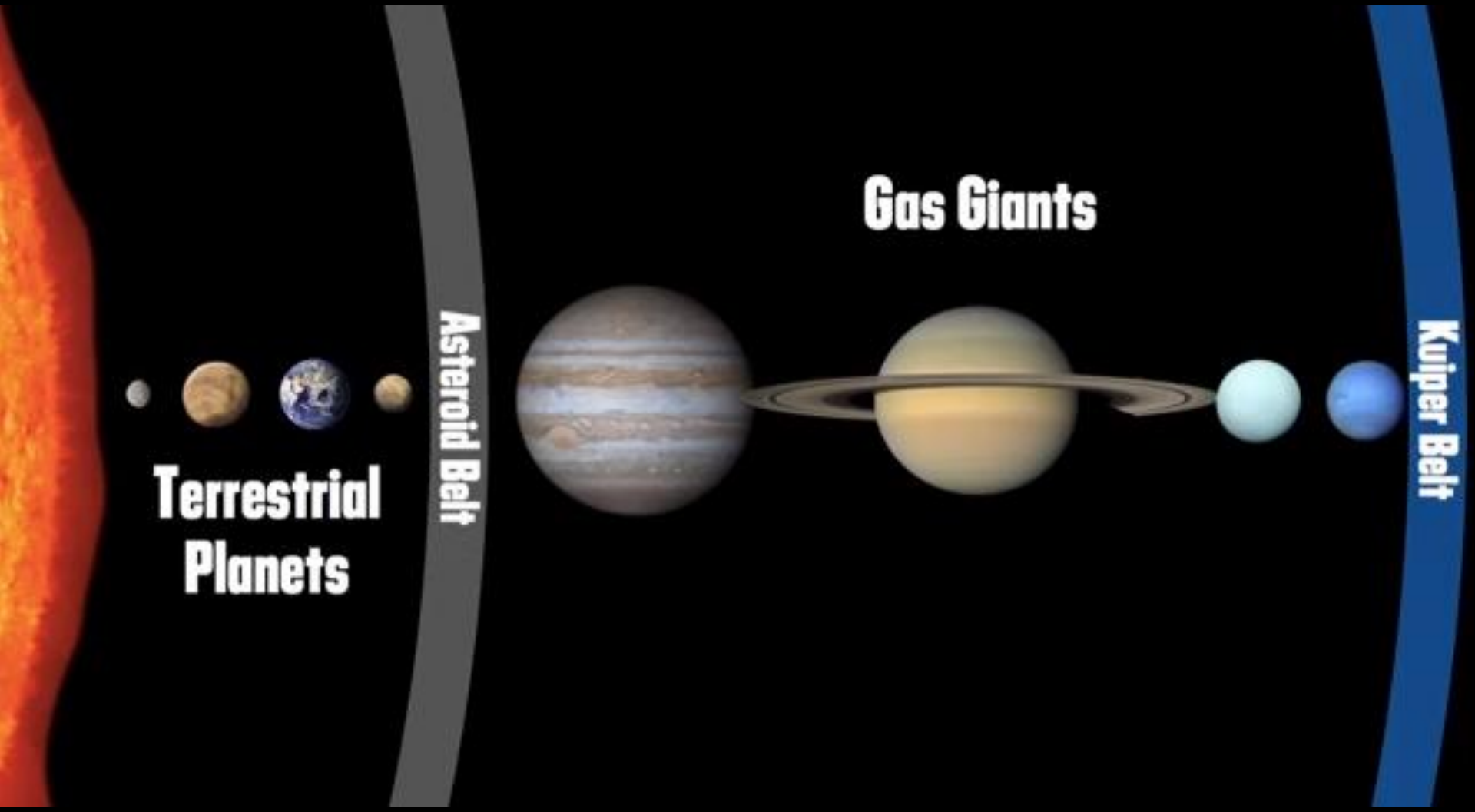
These gases were collected and condensed into the gas giants (Jupiter, Saturn, Uranus, Neptune)



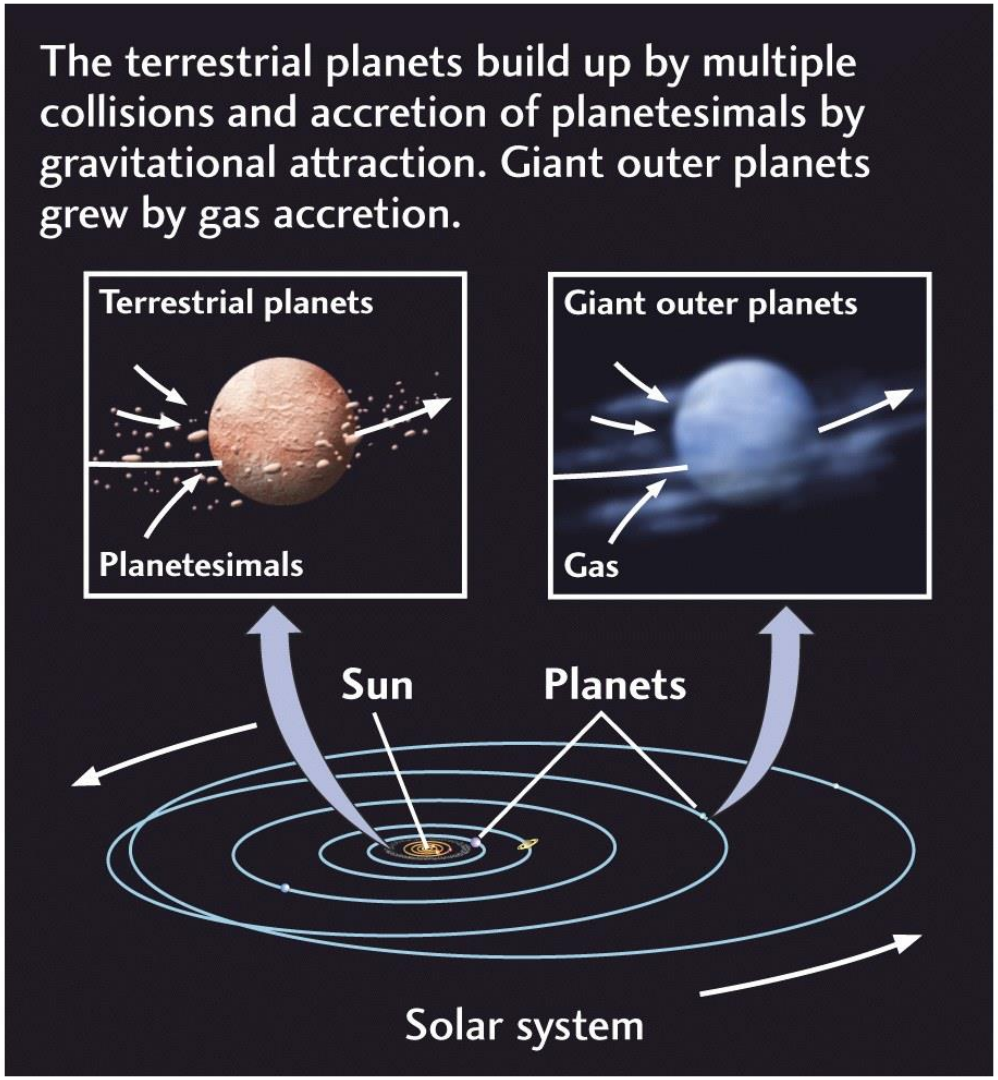
8. Beyond Neptune, ice and frozen gases form Pluto, Sedna and the Kuiper Belt Objects

9. Left-over debris forms comets and asteroids

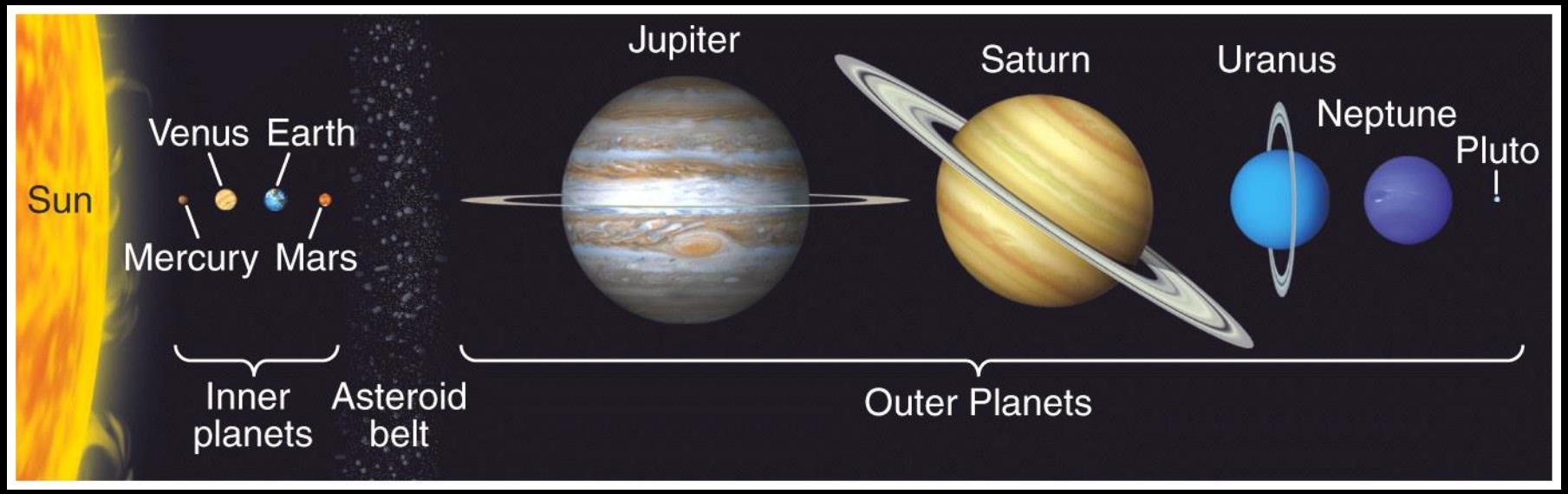
- Kuiper Belt Video Clip (5mins)


Gas Giants
Terrestrial Planets
Asteroid Belt
Kuiper Belt

Birth of the Solar System



Size of the Planets



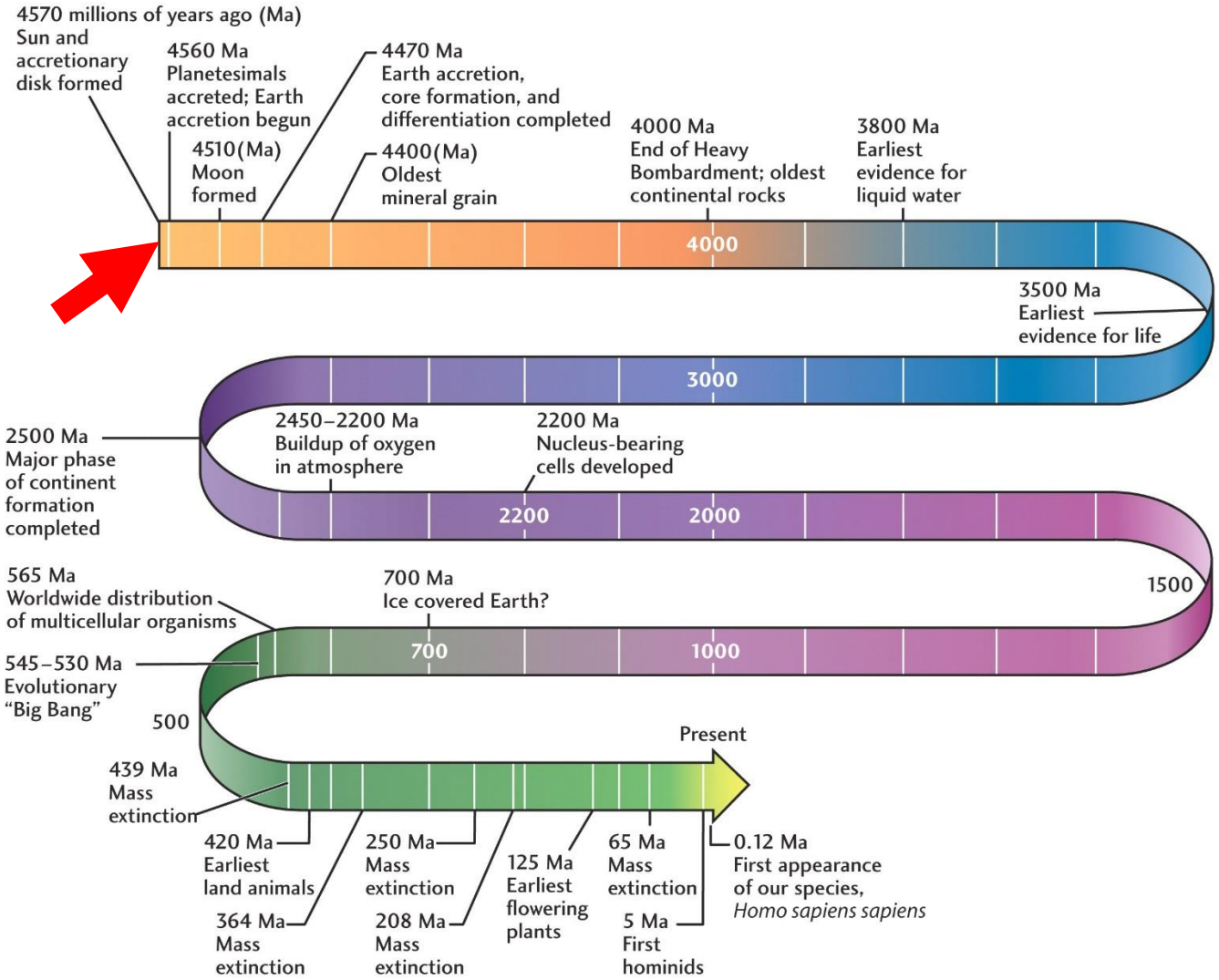
The Age of the Earth

Earth is ~ 4.6 BILLION years old (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

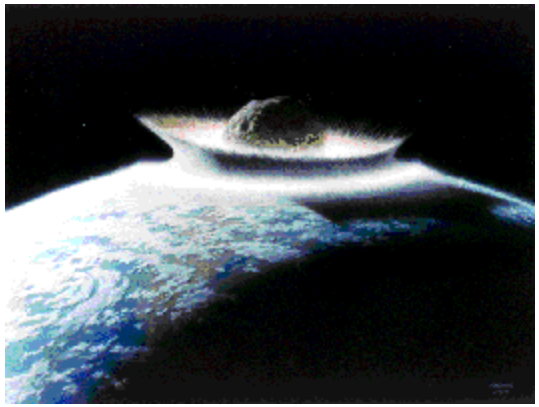
Geologic Time

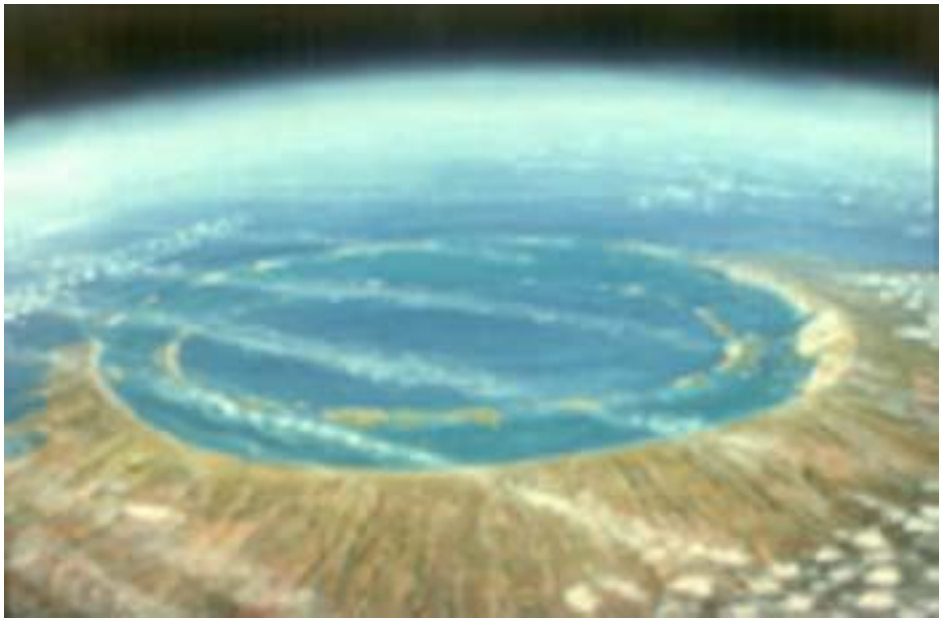


Bombardment From Space

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

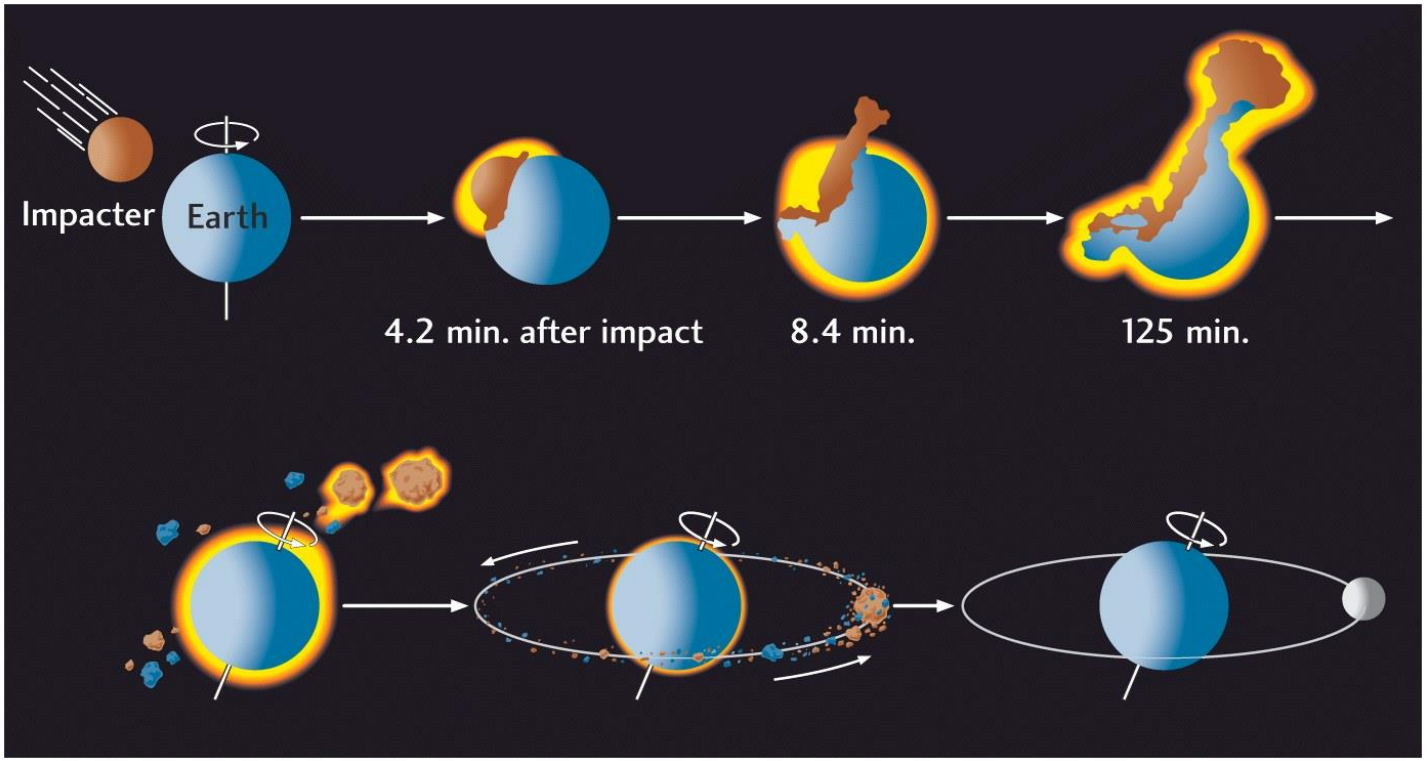
This idea was first proposed about 30 years ago, but it took calculations by modern high-speed computers to prove the feasibility

Video: Formation of the Moon

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

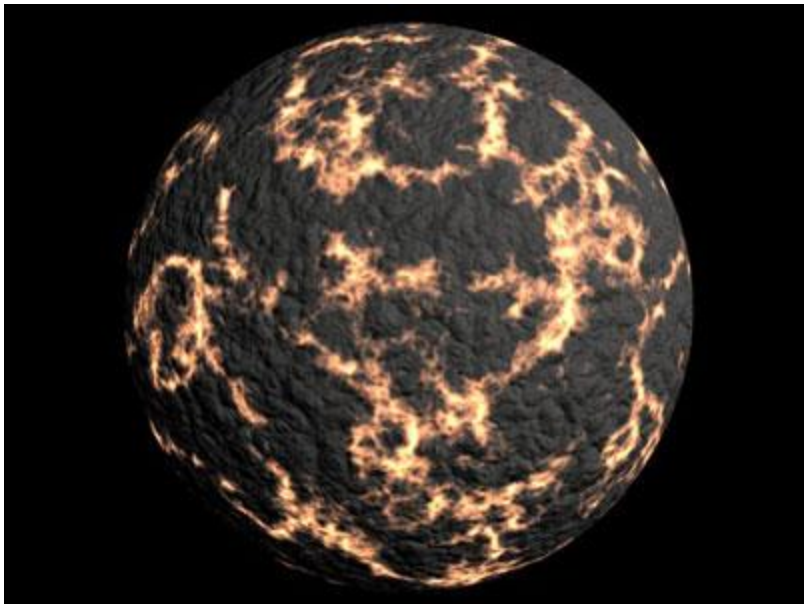
The early Moon orbited very close to the Earth

Accretion - the process of growth or increase, typically by the gradual accumulation of additional layers or matter.

Formation of the Solar System **Video Clip**

The Early Earth Heats Up

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

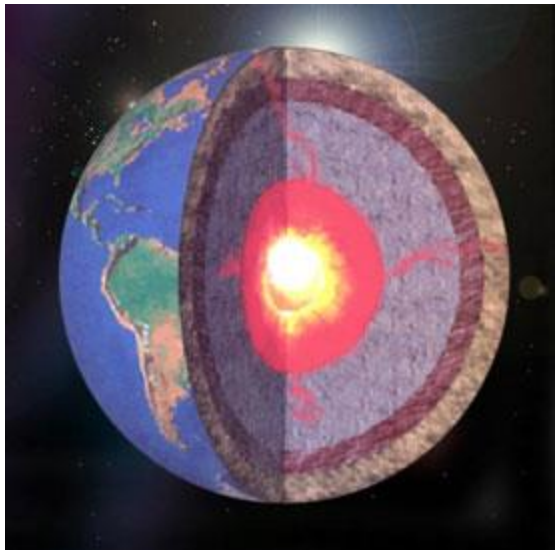


1. **Collisions (Transfer of kinetic energy into heat)**
2. **Compression**
3. **Radioactivity of elements (e.g. uranium, potassium, or thorium)**

The Core

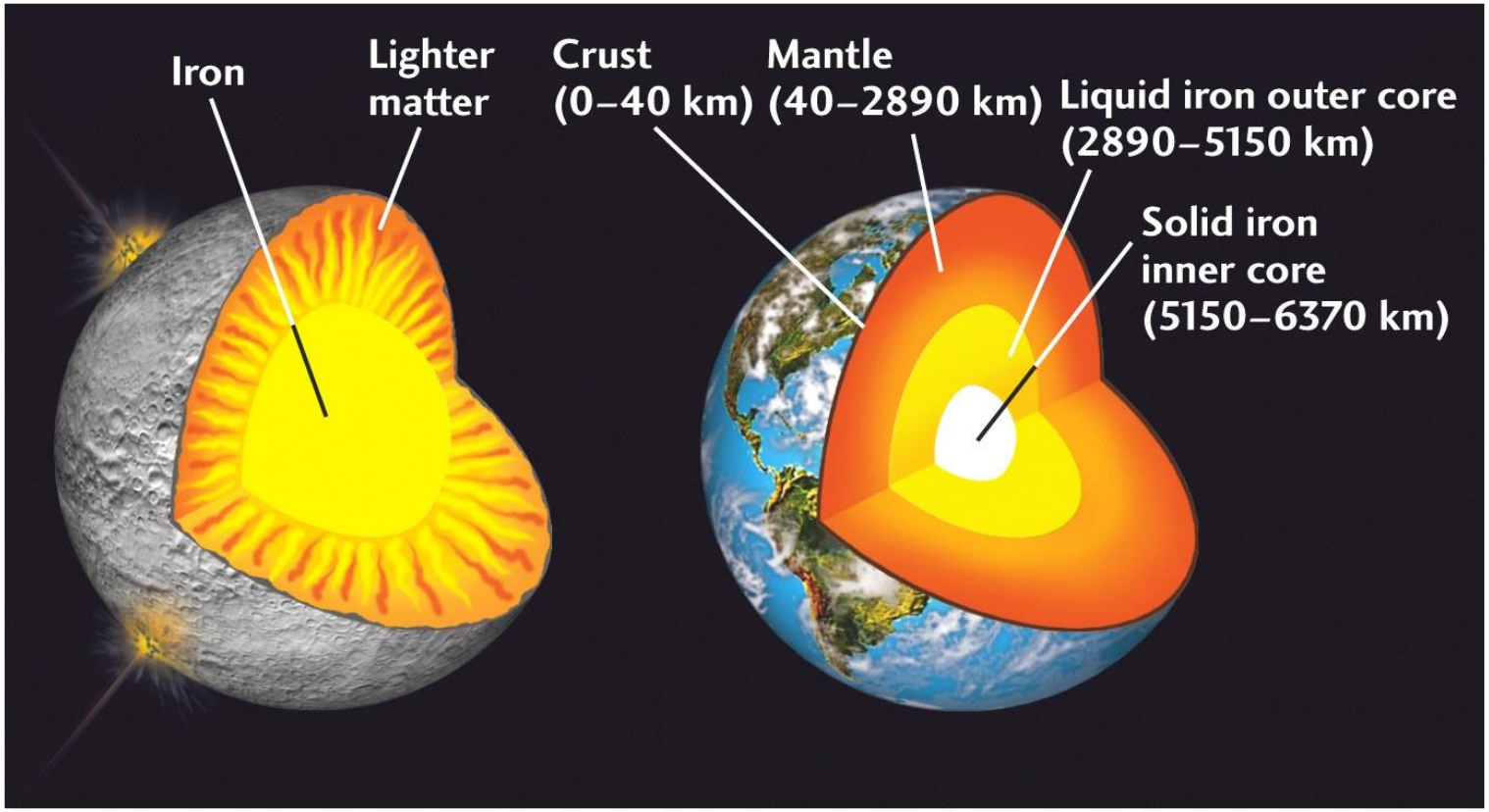
About 100 million years after initial accretion, temperatures at depths of 400 to 800 km below the Earth's surface reach the melting point of iron

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 differential was completed by about 4.3 billion years ago, and the Earth had developed a inner and outer core, a mantle and crust

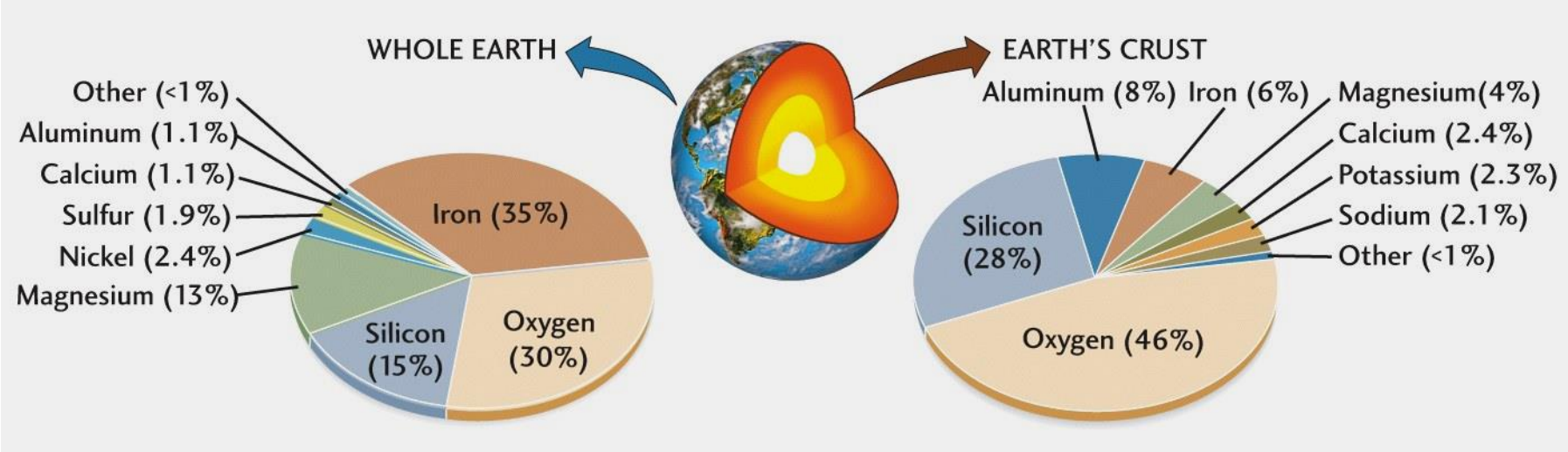


Chemical Composition of Earth

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

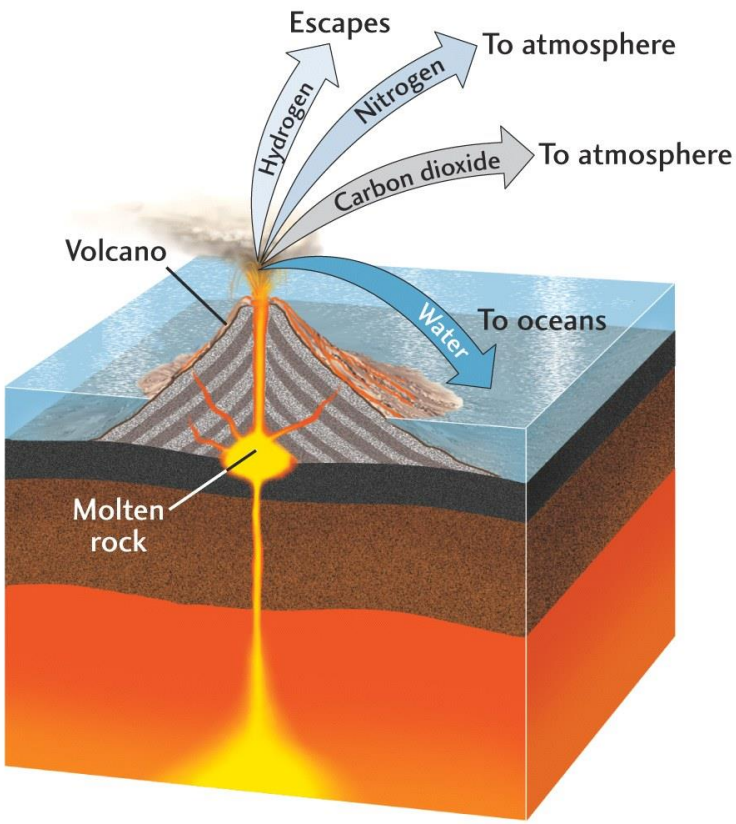
Deep Mantle: mantle beneath the asthenosphere (~400 to 2900 km in depth)

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 Earths 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)

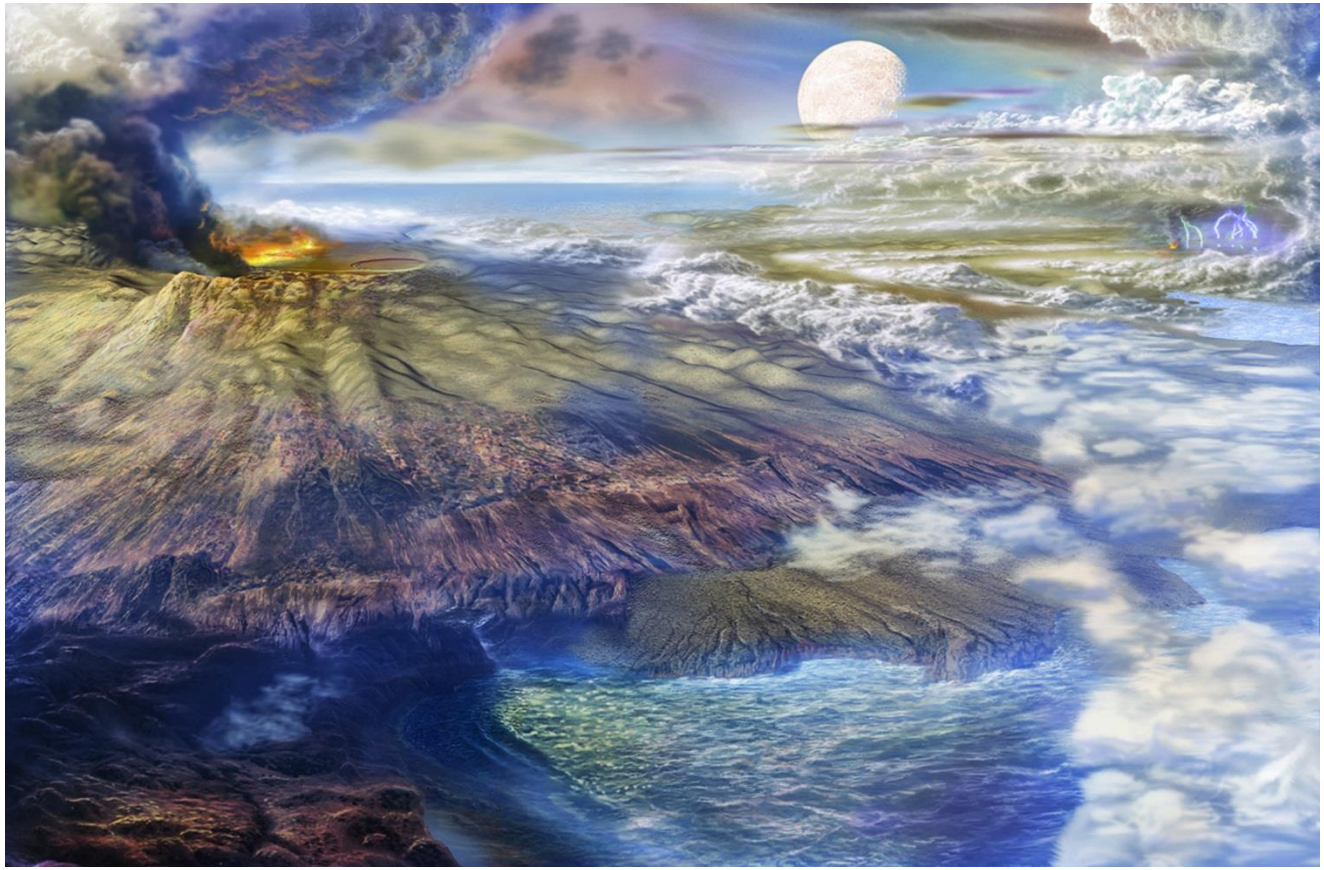
Creating the Oceans

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

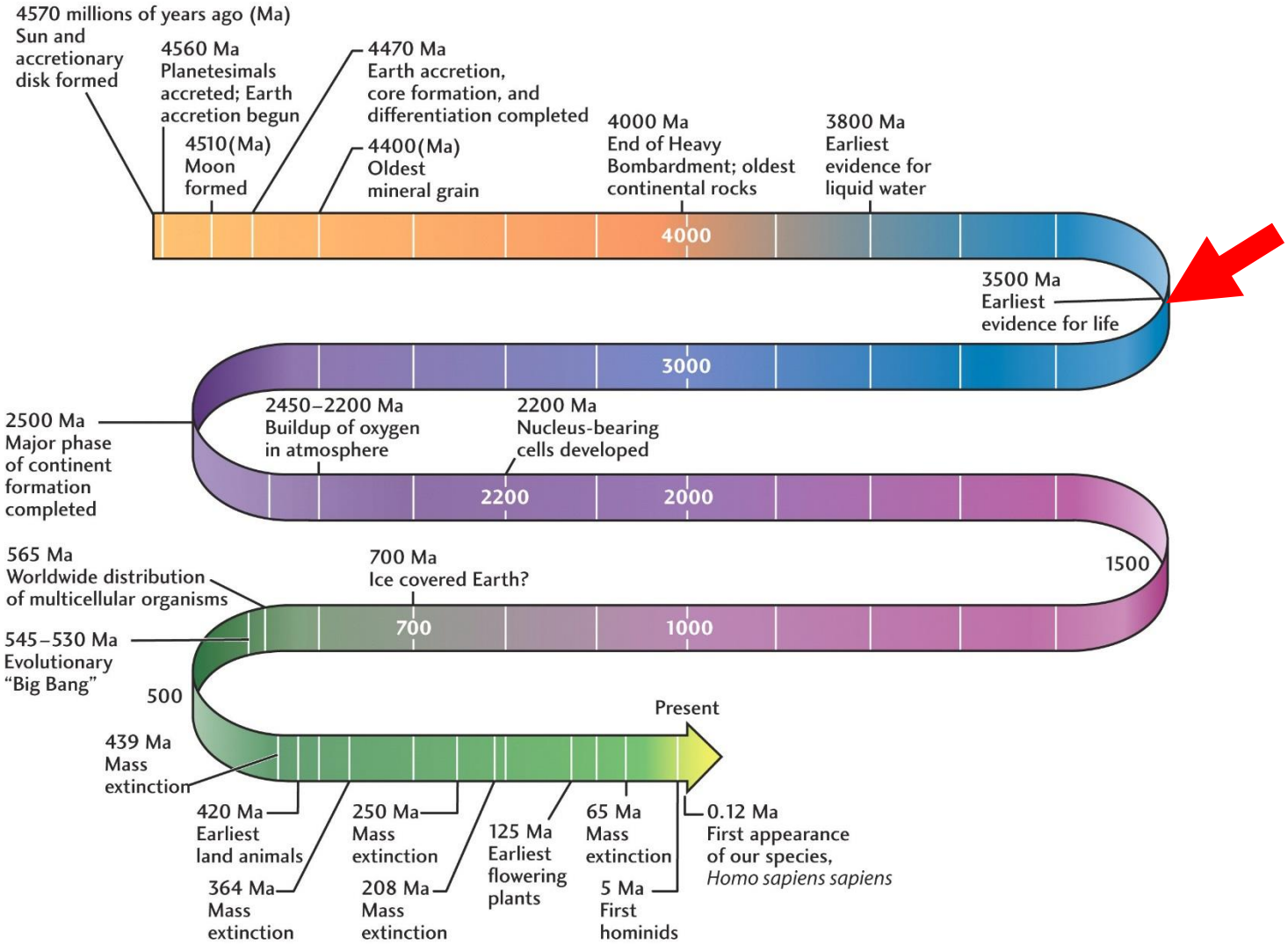
Remember, that comets are best described as “dirty ice balls”

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 CO_2, 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

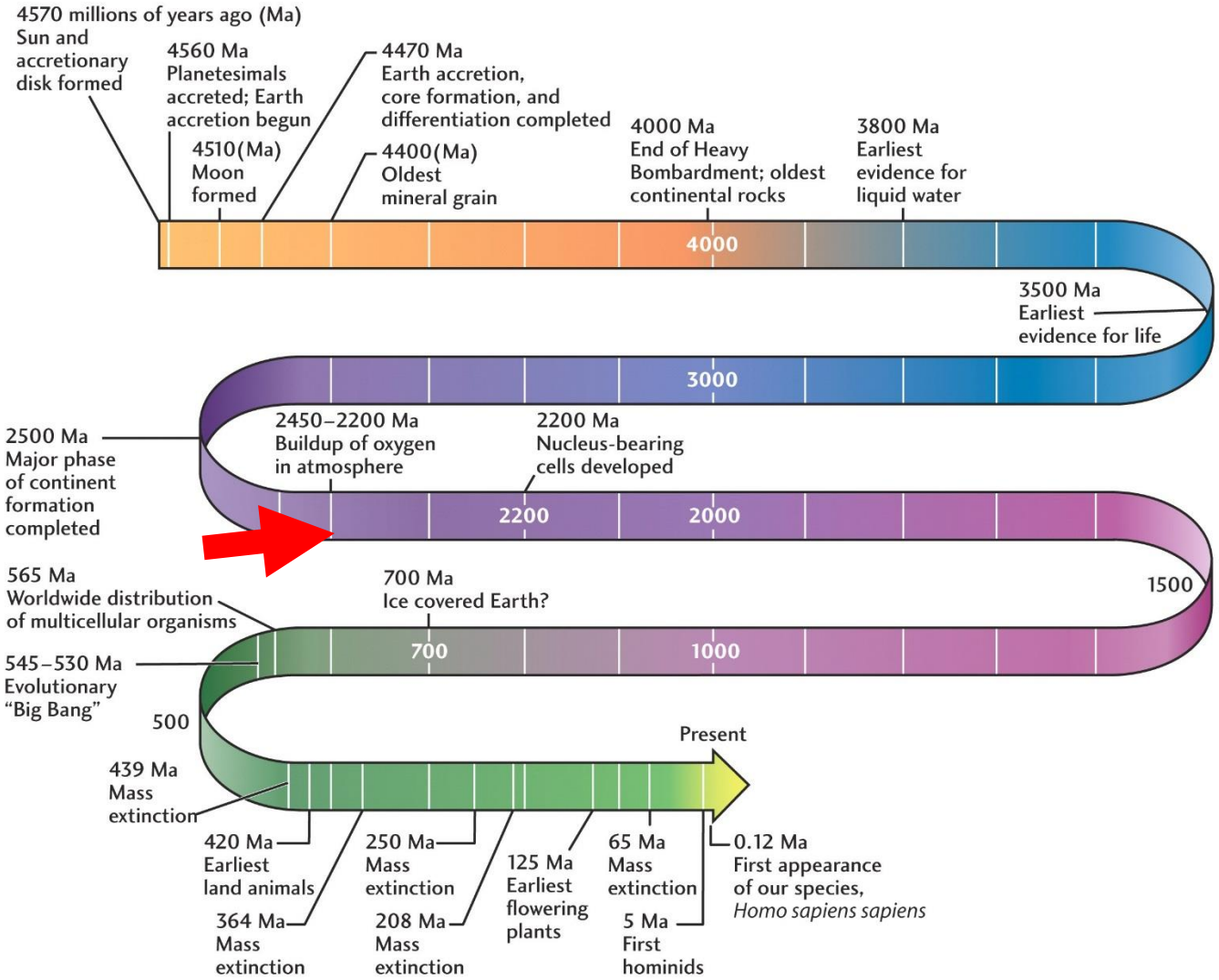
The Continents

By 2.5 billion years ago, the continents had been formed

The density of the continental crust (2.8 gr/cm^3) is lighter that 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



Other Solar Systems

As of 1 October 2016, there have been **3,532 exoplanets** in 2,649 planetary systems that have been confirmed.