

Formation of Universe and Solar System



Course: Earth System Science

Programme: Five Year Integrated M.Sc., Geography

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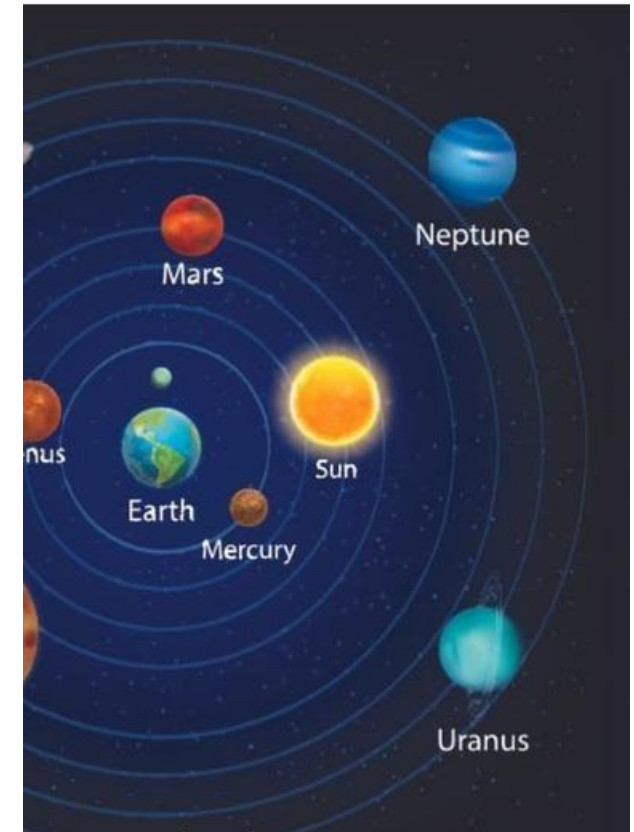
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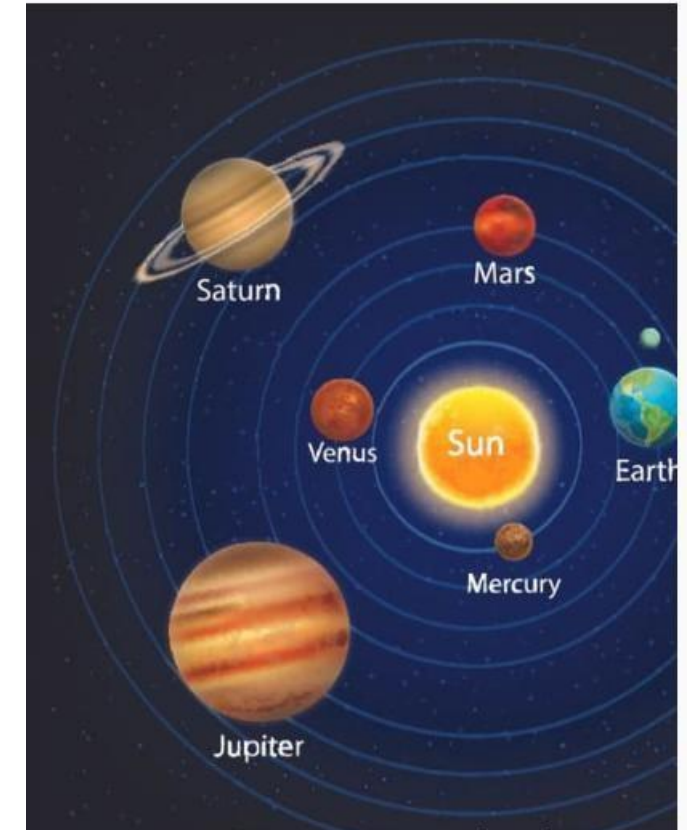
Geocentric Model

- ❖ Also known as the Earth-centered model.
- ❖ Historically, it was the dominant model for a long time, supported by ancient **Greek philosophers and accepted by the Church for centuries.**
- ❖ In this model, the Earth is stationary, and everything else in the universe, including the Sun, Moon, planets, and stars, revolves around it.
- ❖ To explain the observed motions of the planets, complex systems of epicycles (small circles on larger circles) were used to account for the apparent retrograde motion of planets.
- ❖ **The Ptolemaic system**, a geocentric model, was widely accepted for centuries.



Heliocentric Model:

- ❖ Also known as the **Sun-centered model**.
- ❖ It places the Sun at the center of the solar system, with the Earth and other planets orbiting around it.
- ❖ This model was proposed by **Aristarchus of Samos** in the 3rd century BC, but it didn't gain widespread acceptance until the 16th century.
- ❖ **Nicolaus Copernicus** is credited with reviving and popularizing the heliocentric model with his work in the 16th century.
- ❖ The heliocentric model explains the observed motions of planets more simply and accurately than the geocentric model.
- ❖ The heliocentric model was a major shift in scientific understanding and challenged long-held beliefs.
- ❖ **Galileo Galilei's** observations through his telescope, such as the moons of Jupiter orbiting Jupiter, provided further evidence supporting the heliocentric model and challenging the geocentric view.

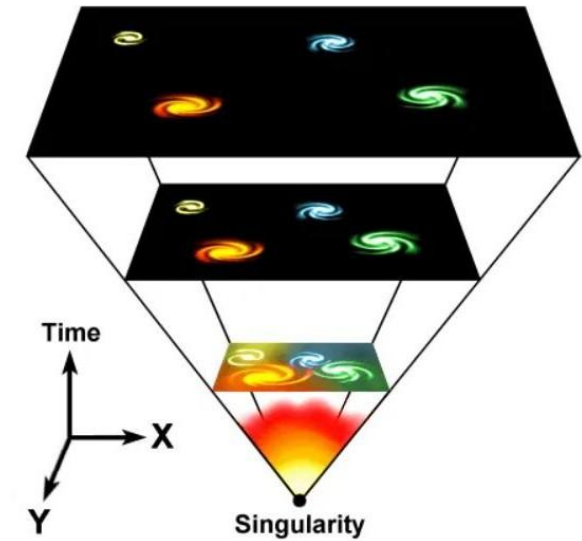


Theories of Origin of Universe and solar system

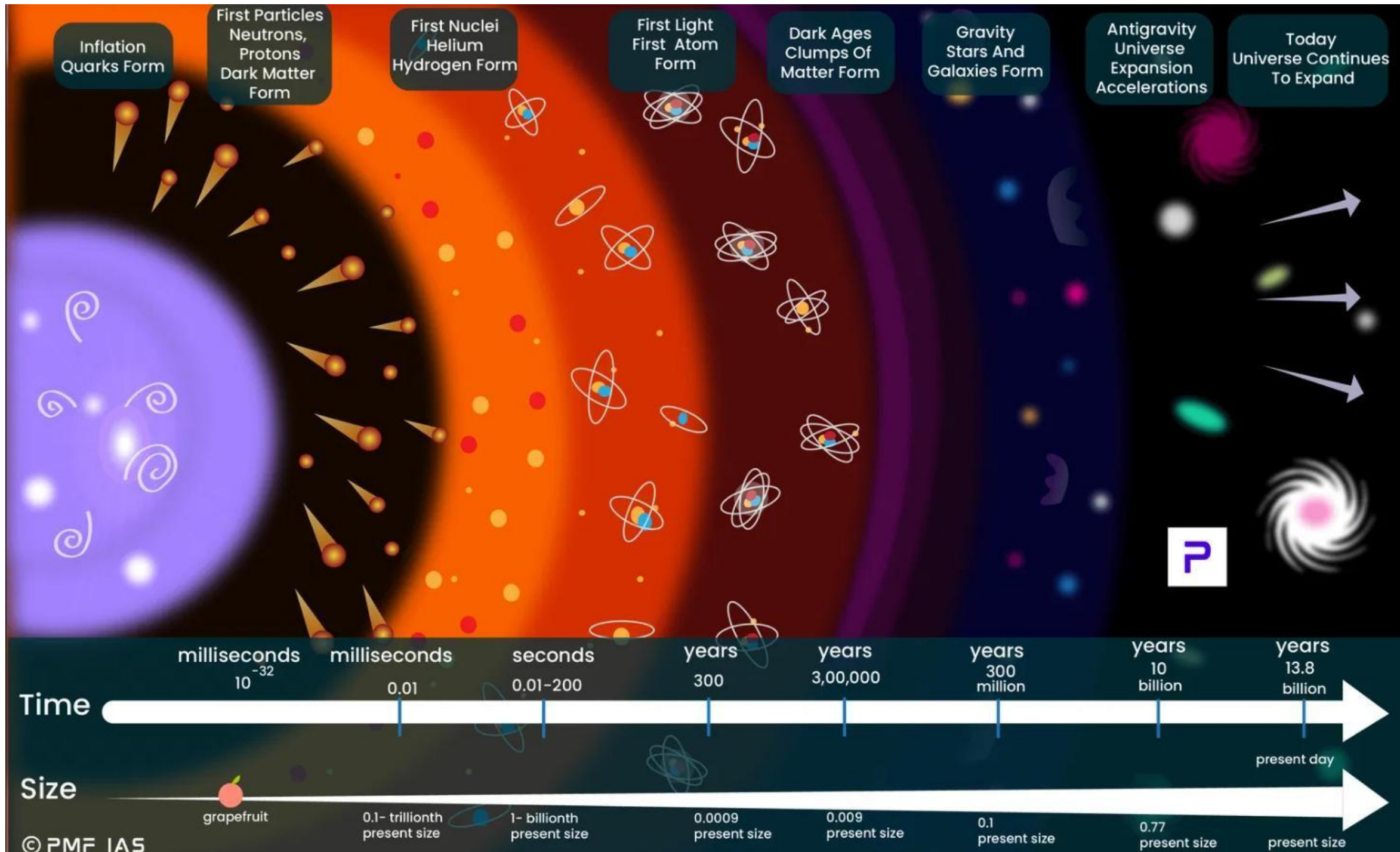
- German philosopher Immanuel Kant's **Nebular Hypothesis (Theory) of Laplace (1796)** tried to explain the formation of the solar system. But it had many drawbacks as the theory was based on scientifically erroneous assumptions. But one assumption it got right was that the solar system was born from a giant interstellar cloud called **nebula (a vast, swirling cloud of gas and dust)**.
- In **1900, Chamberlain and Moulton** considered that a wandering star approached the sun. As a result, a cigar-shaped extension of material was separated from the solar surface. As the passing star moved away, the material separated from the solar surface continued to revolve around the sun and slowly condensed into planets. **Sir James Jeans and later Sir Harold Jeffrey** supported this argument.
- In 1950, **Otto Schmidt in Russia and Carl Weizsacker in Germany** somewhat revised the Nebular Hypothesis. They considered that the sun was surrounded by solar nebula containing mostly **hydrogen and helium** along with what may be termed as dust. The friction and collision of particles led to the formation of a disk-shaped cloud and the planets were formed through the process of accretion.
- The most popular argument is the **Big Bang Theory (expanding universe hypothesis (Edwin Hubble, in 1920, provided evidence that the universe is expanding))**. It was followed up by the **Nuclear Disc Model (Neo-Laplacian model)** which dealt primarily with the formation of the solar system.

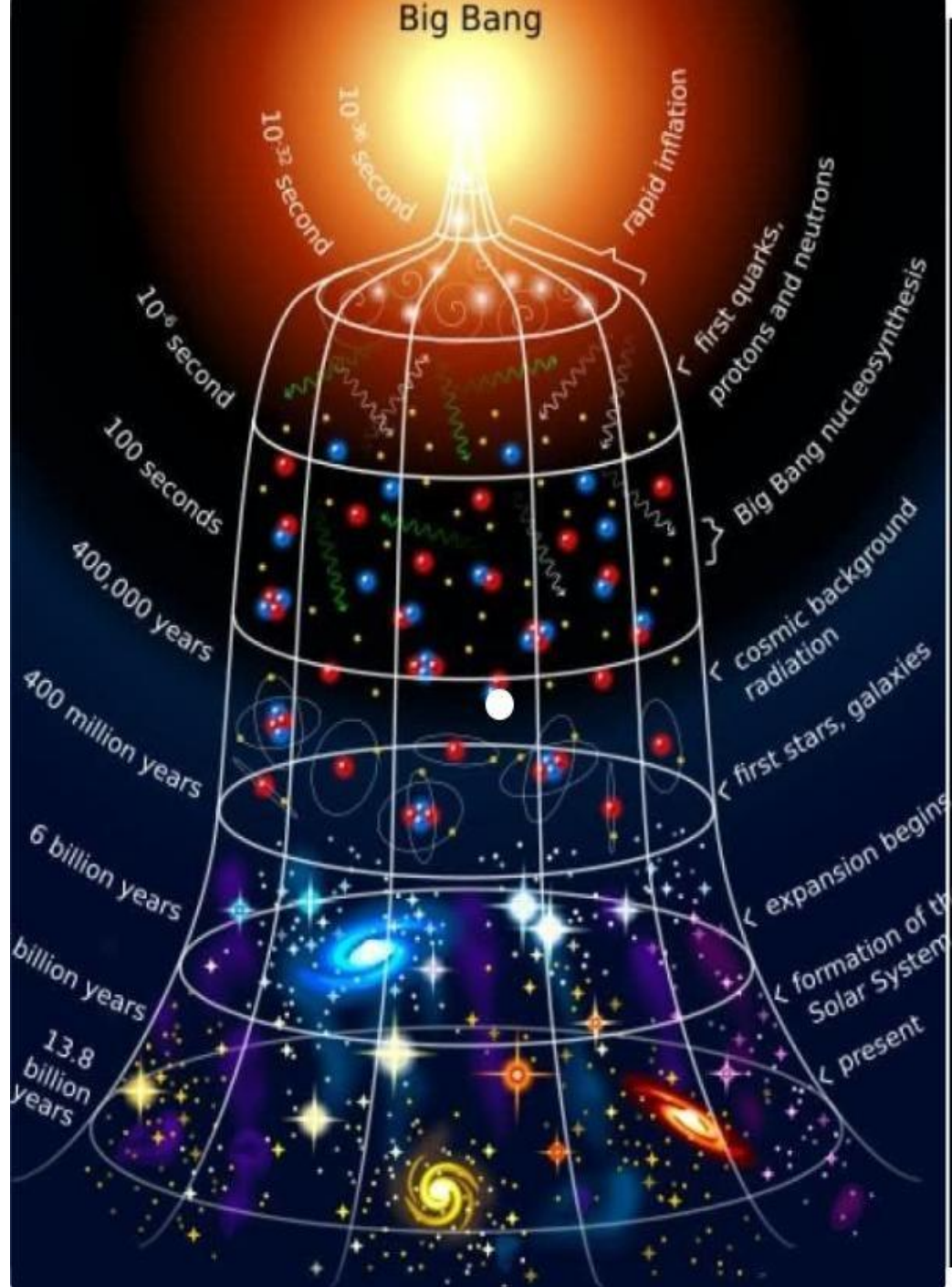
The Universe, Big Bang Theory and The Evolution of The Universe

- The **Big Bang Theory** is the prevailing cosmological model for the universe's birth. It states that **13.8 billion years ago**, all of space was contained in a **single point** of very **high-density** and **high-temperature** state from which the universe has been **expanding in all directions** ever since.
- The Universe is all existing matter & space. It is incomprehensively large (beyond mental grasp). It consists of both physical (subatomic particles like electrons, protons to galactic super-clusters) and non-physical (light, gravitation, space etc.) components.
- The universe, at present, is said to possess about **100 billion galaxies**, each comprising an average of **100 billion stars**. In comparison, **Milky Way Galaxy** is believed to possess **100 billion to 400 billion stars**. (1,000,000 = 1 Million = 10 Lakhs; 1,000,000,000 = 1 Billion = 100 Crore; 1,000,000,000,000 = 1 Trillion)
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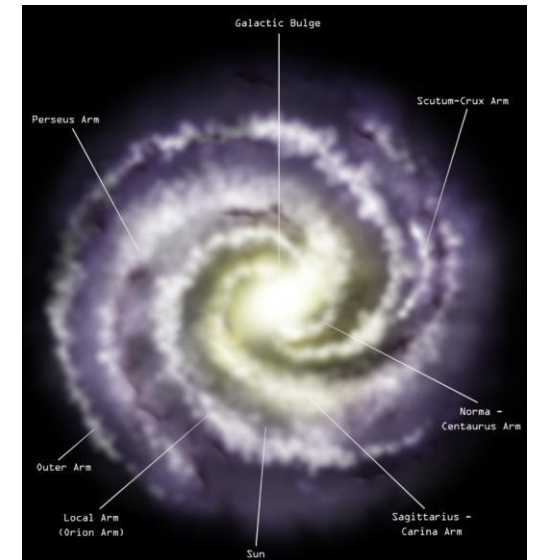


Singularity: Singularities were first predicated as a result of Einstein's Theory of General Relativity, which resulted in the theoretical existence of black holes....

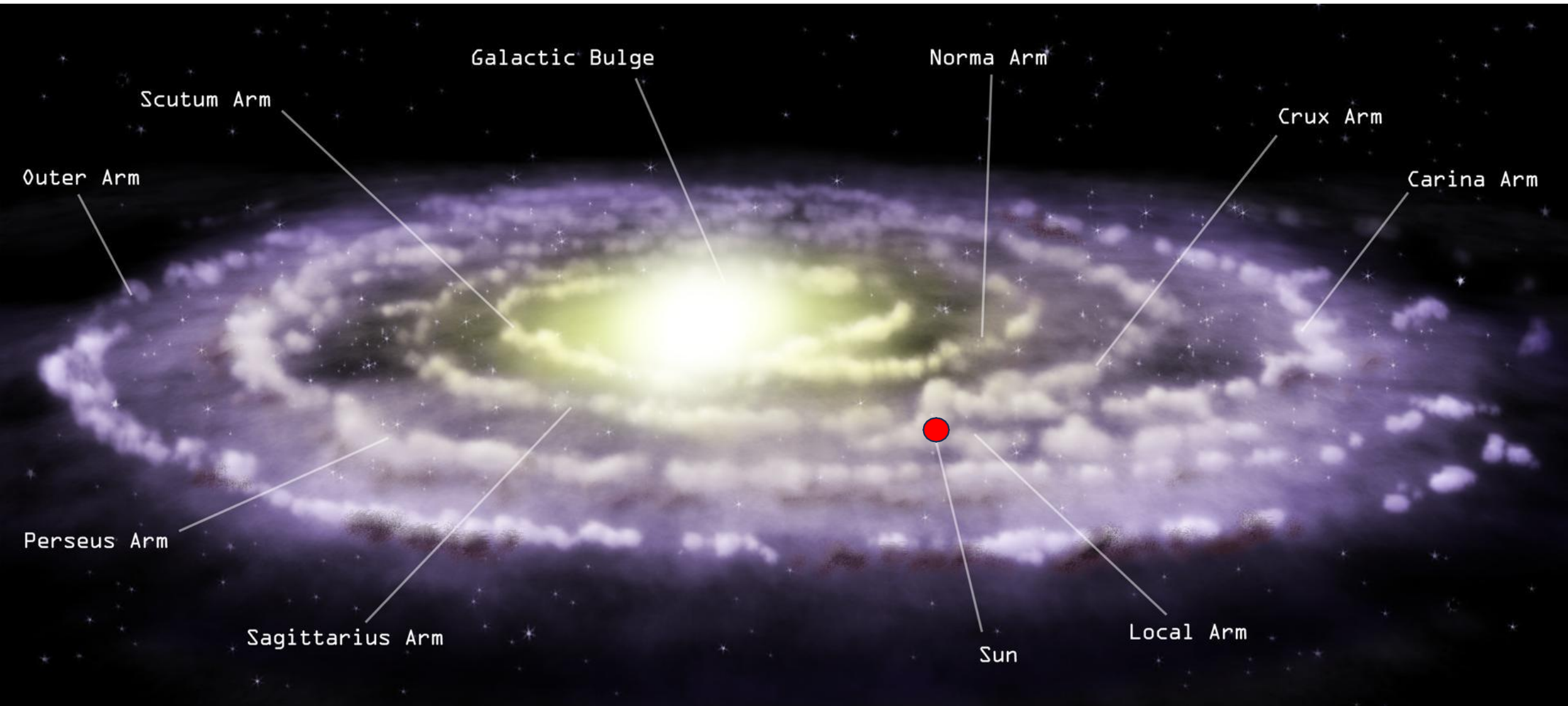




- It is the observation that the expansion of the universe is such that the velocity at which a galaxy is moving away from the observer is continuously **increasing** with time (**Hubble's law**). It implies that the universe will get increasingly **colder** as matter spreads across space.
- The accelerated expansion of the universe is thought to have begun since the universe entered its dark-energy-dominated era — roughly 5 billion years ago.
- **Dark energy** is an *unknown form of energy* that is hypothesised to permeate (spread throughout) all of space, tending to **accelerate the universe's expansion**



Milky way Galaxy

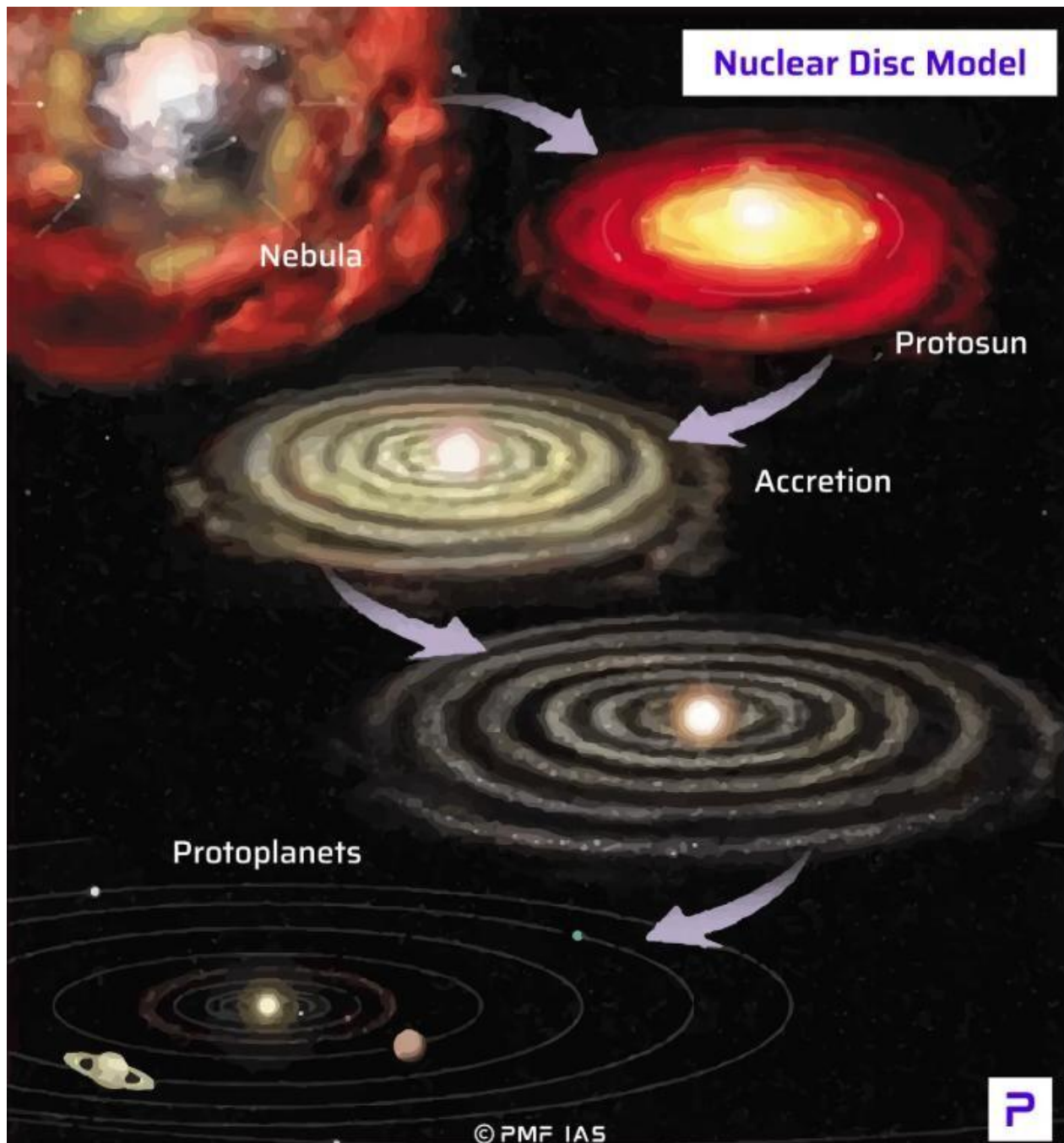


The Formation of the Sun

The **nebula** began to collapse (**gravitational collapse**) in on itself after becoming gravitationally unstable. This was possibly because of a nearby **supernova sending shock waves** rippling through space.

Gravity then caused dust and gas to coalesce to the centre of the nebular cloud. As more matter got pulled in, the centre got denser and hotter, increasing the gravity and pulling even more dust inwards causing a **snowball effect**.

About **99.9%** of the material fell into the centre and became the **protosun** (no sunlight yet). Once the centre of the cloud became hot enough it triggered **nuclear fusion**, and the Sun was born. The **0.1%** of matter that remained orbited around the Sun, causing the randomly shaped gas cloud to form a flat disc shape. This flat disc, called the **protoplanetary disc**, was where the planets formed.



Nebula

Gravitational Collapse

Super nova

Protosun

planetesimals

Protoplanets

Kuiper belt

Oort Cloud

The Formation of the Planets

Within the solar nebula, the dust particles in the gas occasionally collided and clumped together. Through this **accretion process**, the microscopic particles formed larger bodies that eventually became **planetesimals** (infant stage of a planet) with sizes up to a few kilometres across.

As the disc continued to cool, the planetesimals grew through accretion to form **protoplanets**. Gradually they got larger and larger, sweeping up all the leftover dust, other protoplanets, and planetesimals until they grew into the **planets**.

In the inner, hotter part of the solar nebula, planetesimals were composed mostly of silicates and metals. This hot, rocky material near the centre of the solar system gave rise to **terrestrial planets** with **metal cores** (mostly composed of iron and nickel): Mercury, Venus, Earth, and Mars.

In the outer, cooler portion of the nebula, water ice was the dominant component. This gave rise to the **gas and ice giants: Saturn, Jupiter, Neptune, and Uranus**.

Rocks that escaped the pull of planets were left as **asteroids**, scattered through the solar system. Many of these rocks orbit the Sun in an area **between Mars and Jupiter** known as the **asteroid belt**

Sir James Jeans, a British scientist, proposed his '**tidal hypothesis**' to explain the origin of the earth in **1919**, while **Harold Jeffreys**, another British scientist, **suggested modifications to the 'tidal hypothesis' in 1929**, making it more relevant and significant in the context of growing knowledge of the cosmogonic ideas of the first quarter of the twentieth century. The tidal hypothesis is a modern theory about the origins of the planet and solar system.

Assumptions of Tidal Hypothesis of Jeans and Jeffreys

- The sun and another invading star formed the solar system.
- The sun was once a massive incandescent gaseous mass of materials.
- Aside from the sun, there was another star in the universe known as an '**intruding star**.' This intruding star was much bigger in size than the primitive sun.
- The sun was stationary and rotated on its axis. The 'intruding star' was moving along a path in such a way that it was destined to come nearer to the primitive sun.
- The intruding star's tidal force had a significant impact on the surface of the primitive sun.
- According to James Jeans, a massive amount of matter was ejected from the primitive sun as a result of the intruding star's massive gravitational force, which later became the building material for future planets.
- Everyone in the universe attracts every other body with a force that is directly proportional to the product of the two bodies' masses and inversely proportional to the square of the distance between them, according to Newton's law of universal gravitation.

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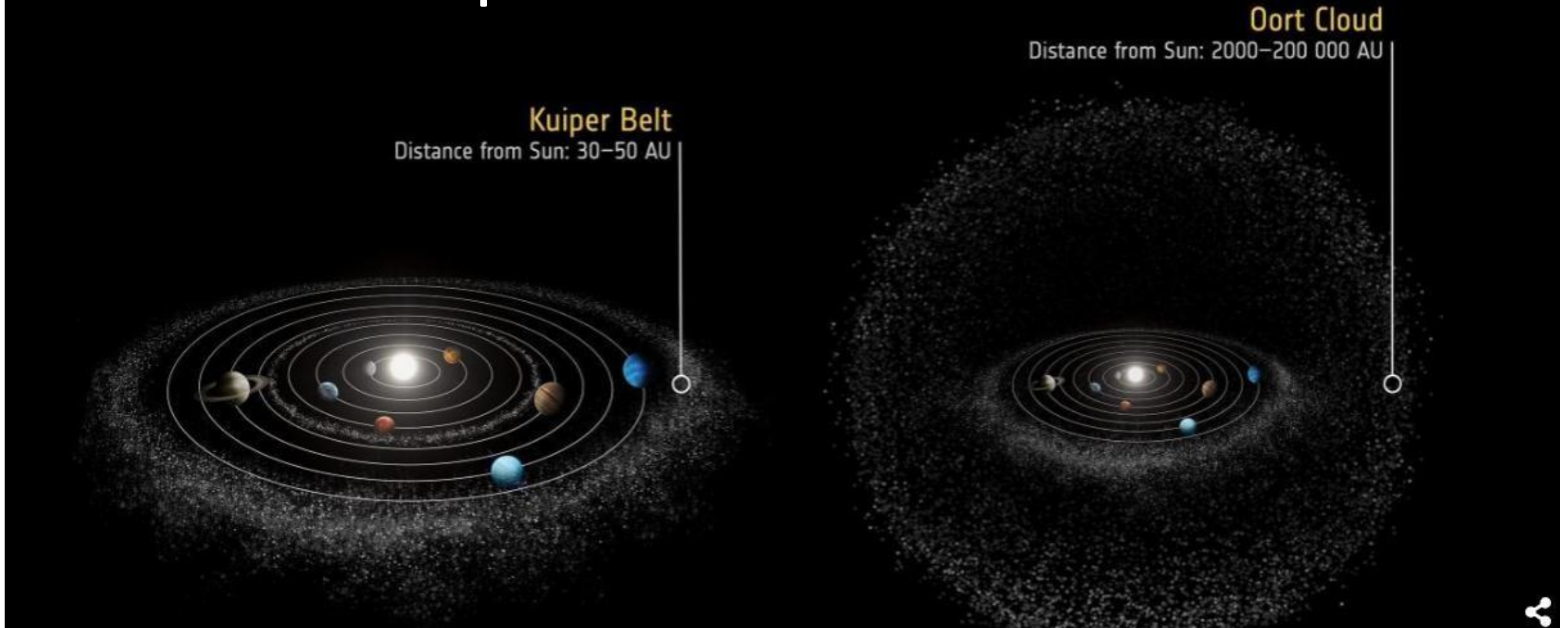
- According to James Jeans, the 'intruding star' was constantly moving closer to the primitive sun, exerting gaseous tidal force (gravitational pull) on its surface.
- As the 'intruding star' got closer to the 'primitive sun,' its gravitational attraction grew stronger, and the tidal force grew stronger as well.
- When the 'intruding star' got close enough to the 'primitive sun', its gravitational pull reached its maximum, causing a **massive cigar-shaped tide** to form on the 'primitive sun's outer surface,' with a massive mass of matter ejected from the 'primitive sun' in the shape of a cigar.
- This cigar-shaped substance, which was much thicker in the middle and thinner and sharper at the ends, was dubbed “**filament**” by James Jeans

According to James Jeans, the cooling and condensation of the filament's incandescent mass of gaseous matter resulted in the formation of eight planets in our solar system

Modification by Jeffreys

- ❖ In 1929, Harold Jeffreys, a British physicist, updated James Jeans' initial tidal hypothesis and presented his concept as the '**collision hypothesis**.'
- ❖ Before the birth of our solar system, there were three stars in the universe, according to Jeffreys.
- ❖ The first was our **primitive sun**, the second was its '**companion star**,' and the third was an '**intruding star**' approaching the 'companion star.'
- ❖ As a result, the 'intruding star' collided with the 'companion star.' Due to head-on collision the companion star was completely smashed and shattered, some shattered portions were scattered in the sky while remaining debris started revolving around the primitive sun.
- ❖ However, the impact of the collision and explosion allowed the intruding star to break free from the original sun's gravitational pull and gradually fade away from the cosmos.
- ❖ The planets of our solar system were formed from the companion star's debris.
- ❖ It should be noted that Jeffreys proposed changes to James Jeans' tidal theory with the goal of removing key fundamental flaws in the tidal hypothesis so that it could survive modern scientific critique.

Kuiper Belt & Oort Cloud



Kuiper Belt : Lies beyond the orbit of Neptune, extending from roughly 30 to 55 AU (astronomical units) from the Sun

Oort Cloud A vast, spherical region that is thought to begin around 2,000 to 5,000 AU from the Sun and extend as far as 100,000 AU (or even further)

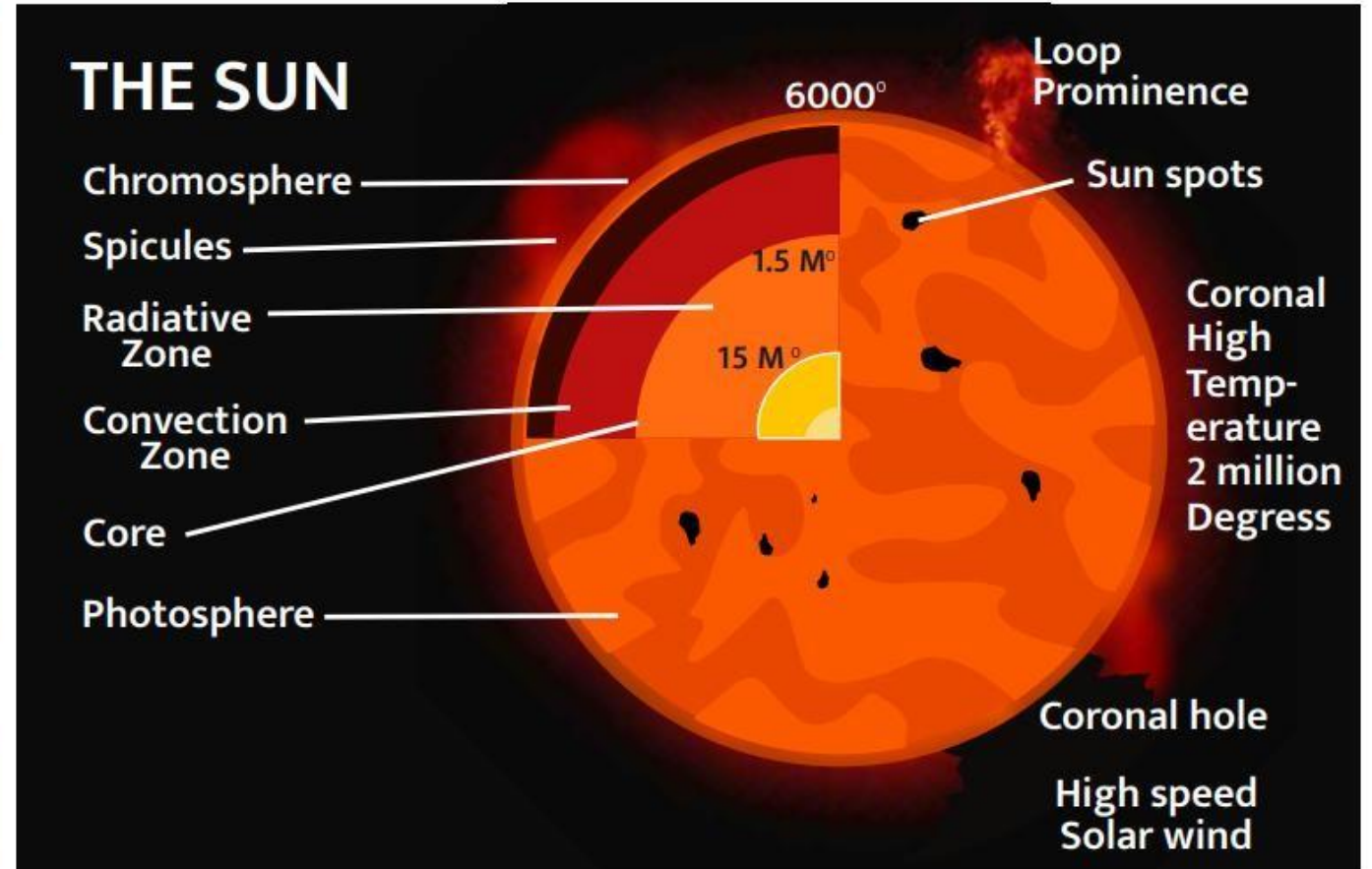
Planets

Sun is a ball of hot gases, mainly Hydrogen.

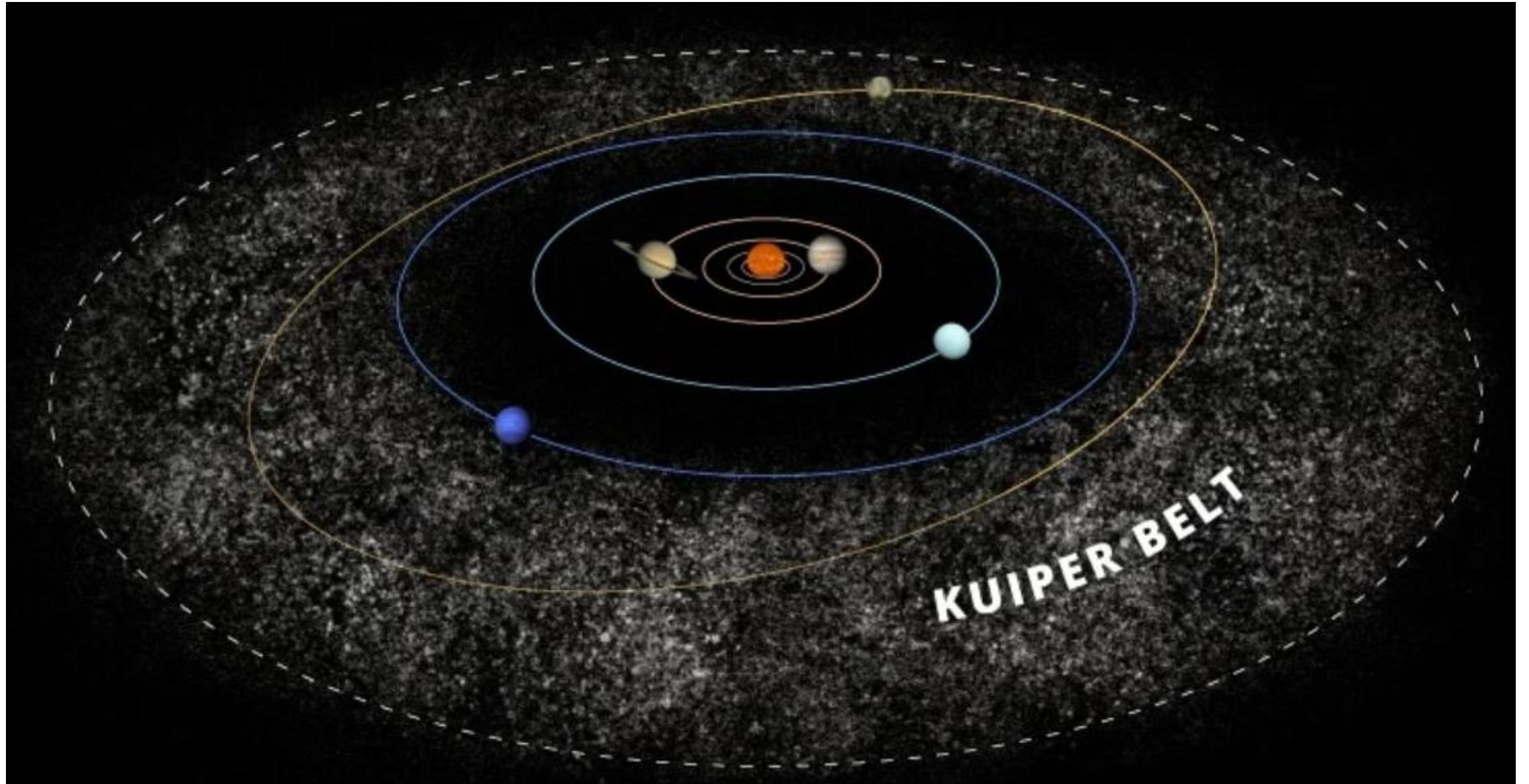
Shining surface of the Sun is called Photosphere.

The outer layer of the sun's atmosphere is made up of thin hot gases is called Corona.

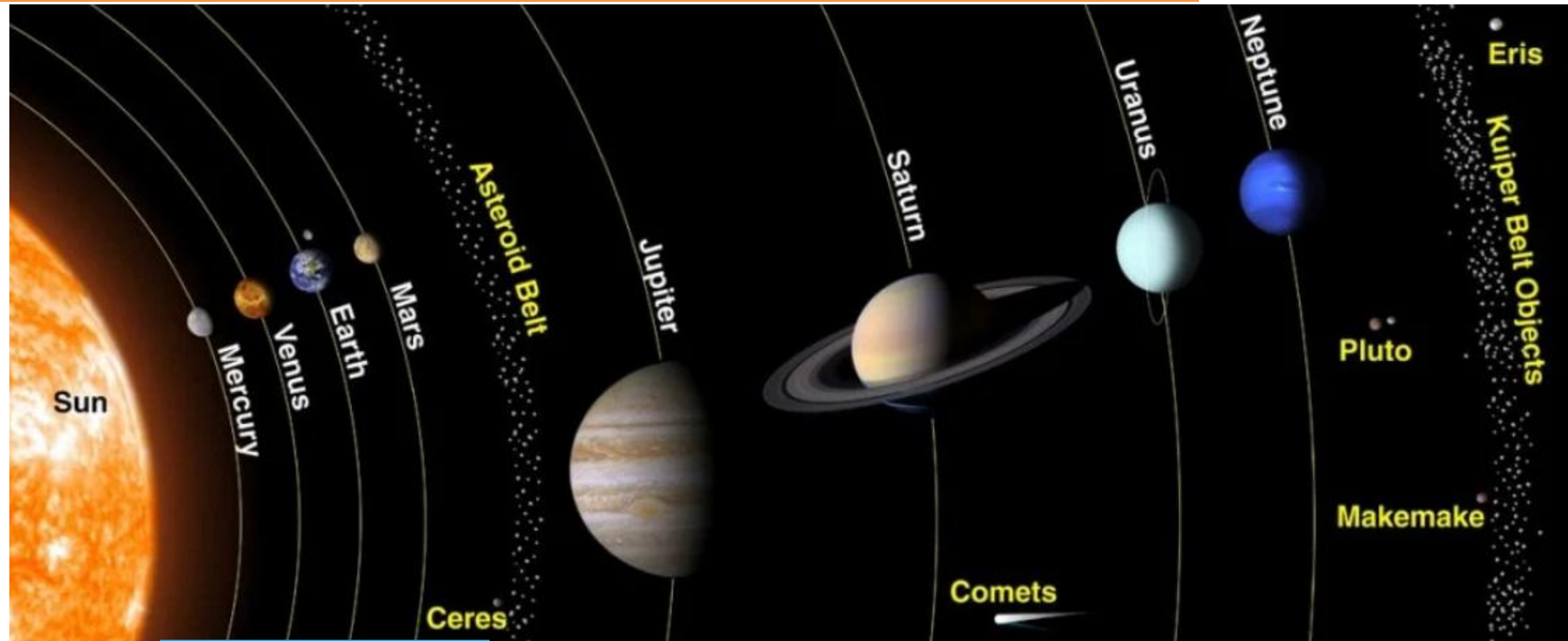
Corona is visible only during full eclipse.



Solar System



Planets

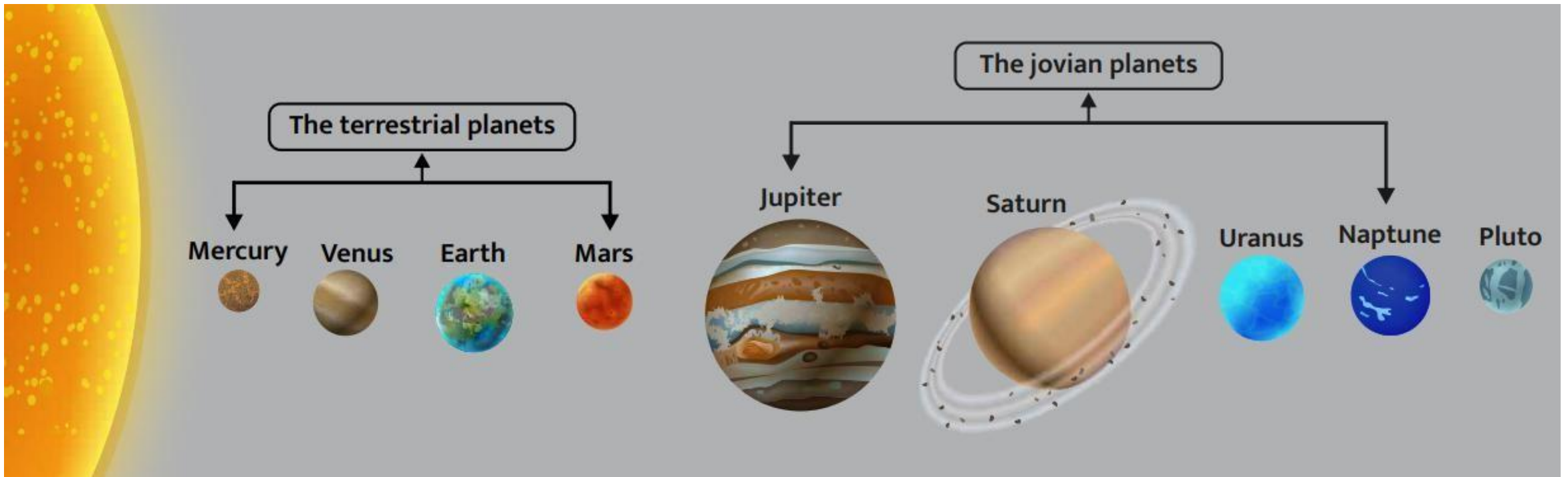


Inner Planets

Outer Planets

Planet	Surface Temp in° C	Period of Rotation	Period of Revolution	Diameter (km)	Size Rank	Moons
1. Mercury	+427	58 days	87 days	4,878	8	0
2. Venus	+480	243 days	224 days	12,104	6	0
3. Earth	+22	23:56 hrs	365 days	12,756	5	1
4. Mars	-23	1.025 days	687 days	6,787	7	2
5. Jupiter	-150	9.9 hrs	11.9 years	1,40,000	1	79
6. Saturn	-180	10.7 hrs	29 years	1,16,000	2	82
7. Uranus	-214	17 hrs	84 years	51,000	3	27
8. Neptune	-220	16 hrs	164 years	48,000	4	14
Pluto (dwarf)	-223	6.39 days	248 years	2,377	9	5

Planets are solid heavenly bodies which revolve round a star (e.g. the sun) in closed elliptical paths. A planet is made of rock and metal. It has no light of its own. A planet shines because it reflects the light of the sun. The planets move round the sun from west to east, so the relative positions of the planets keep changing day by day. There are **8** major planets including the earth



A **Satellite** (or moon) is a solid heavenly body that revolves round a planet. Except Mercury and Venus all other planets of solar system have satellites. The satellites have no light of their own. They shine because they reflect the light of the sun

Thank You