Beyond the realm of Planets

Comets, Kuiper Belt and Oort Cloud

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Historical interpretation of Comets

- In earlier times, comets were regarded as ghostly apparitions where pale luminous patches or streaks of light in the night time sky that would mysteriously appear, remain for few days or weeks and then vanish.

- Aristotle considered the comets to be atmospheric phenomena rather than astronomical objects and this view prevailed until Middle Ages.

- In 16th century, **Tycho Brahe** a Danish astronomer compared sightings of comets made by observers at different sites and found to similar everywhere unlike the atmospheric phenomena like clouds whose appearance and location in the sky are different to observers located many miles away from each other.

- **Hence concluded that comets are astronomical objects, not atmospheric phenomena.**

The Comets

- Comets are frozen leftovers from the formation of the Solar System composed of dust, rock, and ices adrift in the frigid outer reaches of the Solar System.

- Comet nuclei can be seen only when they come deep enough into the inner Solar System to suffer destructive heating from the Sun.

- When they are close enough to show the effects of solar heating, we call them **active comets**.

- Most comets are too small and far away to be seen and counted by telescopes on Earth, total number ranges as high as a trillion comet nuclei- more than all the stars in the Milky Way Galaxy. The current number of known comets is about **3910**.

The Comets

- Comets are divided into two groups:
    - ***Kuiper Belt*** comets
    - ***Oort Cloud*** comets.
- These two populations of comet nuclei are named after scientists **Gerard Kuiper** and **Jan Oort,** who first proposed their existence in the mid-20th century.

The Kuiper Belt and Oort Cloud are reservoirs of comets

Kuiper Belt

- The Kuiper Belt is a doughnut-shaped region of icy planetesimals extending far beyond the orbit of Neptune. It is home to Pluto, several dwarf planets.

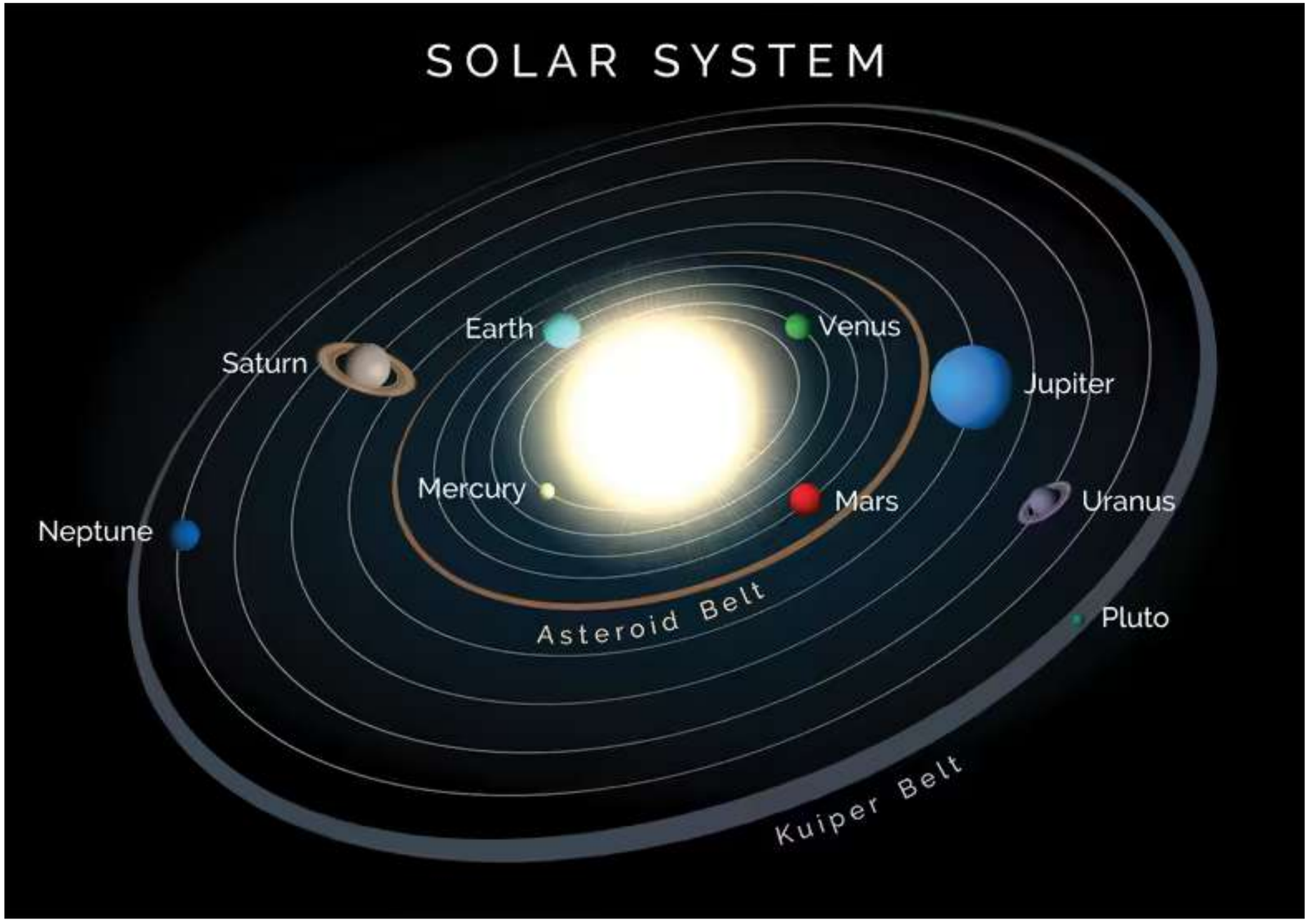
- There may be millions of other icy planetesimals in the Kuiper Belt that were left over from the formation of our solar system.

- It extends out to several thousand astronomical units from the Sun.

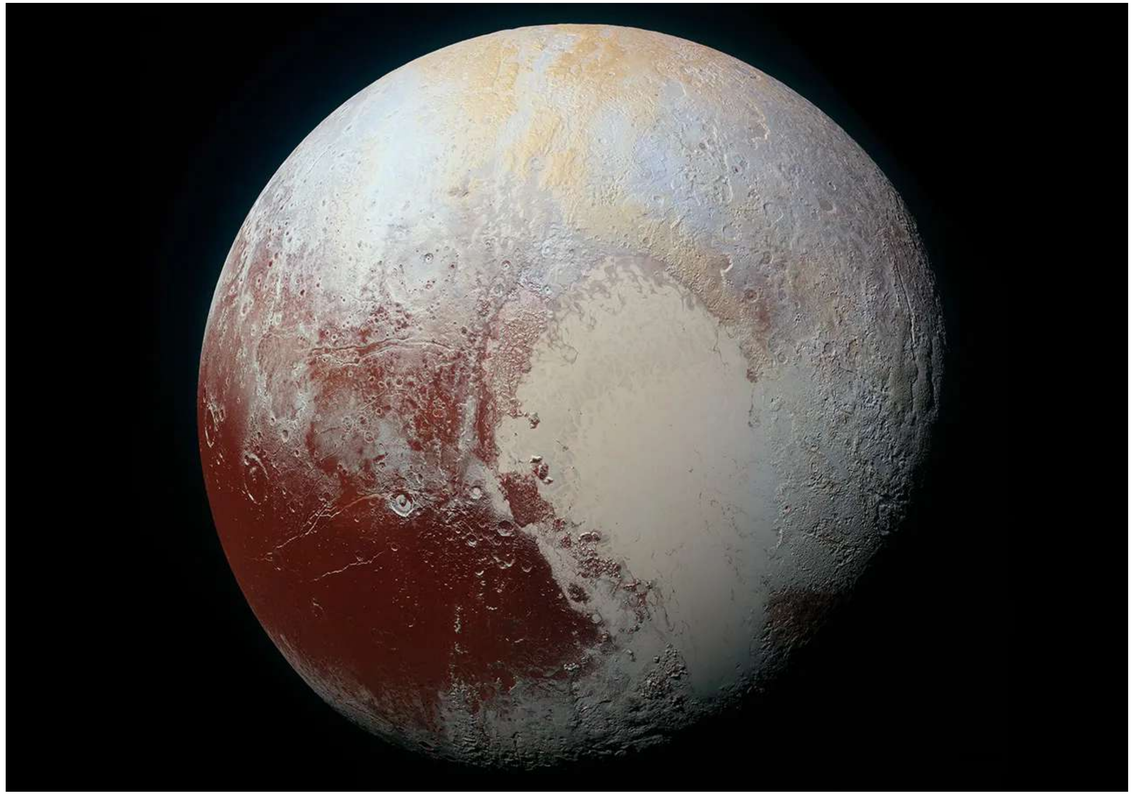
- The innermost part of the Kuiper Belt appears to contain tens of thousands of icy planetesimals, called **Kuiper Belt objects** (KBO).The largest KBOs are over a thousand kilometres across, and the closest of these are just within the range of ground based telescopes.

- Many smaller KBOs must be there beyond the reach of our telescopes and too far from the sun to be active and it seems that these planetesimals are comet nuclei.

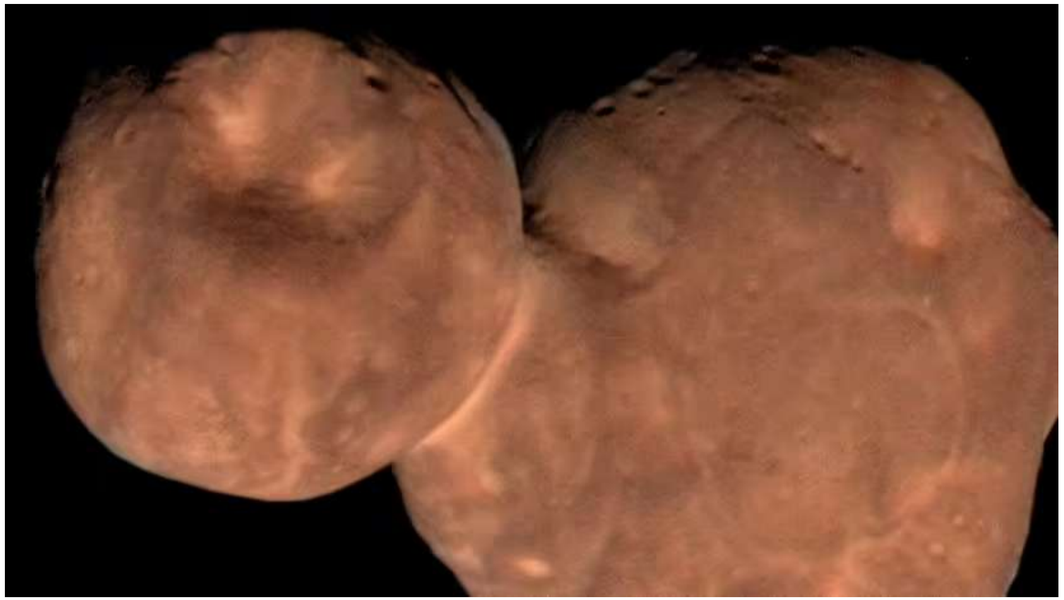
Kuiper Belt


SOLAR SYSTEM
Saturn
Earth
Venus
Jupiter
Mercury
Mars
Uranus
Neptune
Asteroid Belt
Pluto
Kuiper Belt

Kuiper Belt Objects (KBOs)



NASA’s New Horizons spacecraft captured this high-resolution enhanced colour view of Pluto, which resides in the Kuiper Belt, in 2015



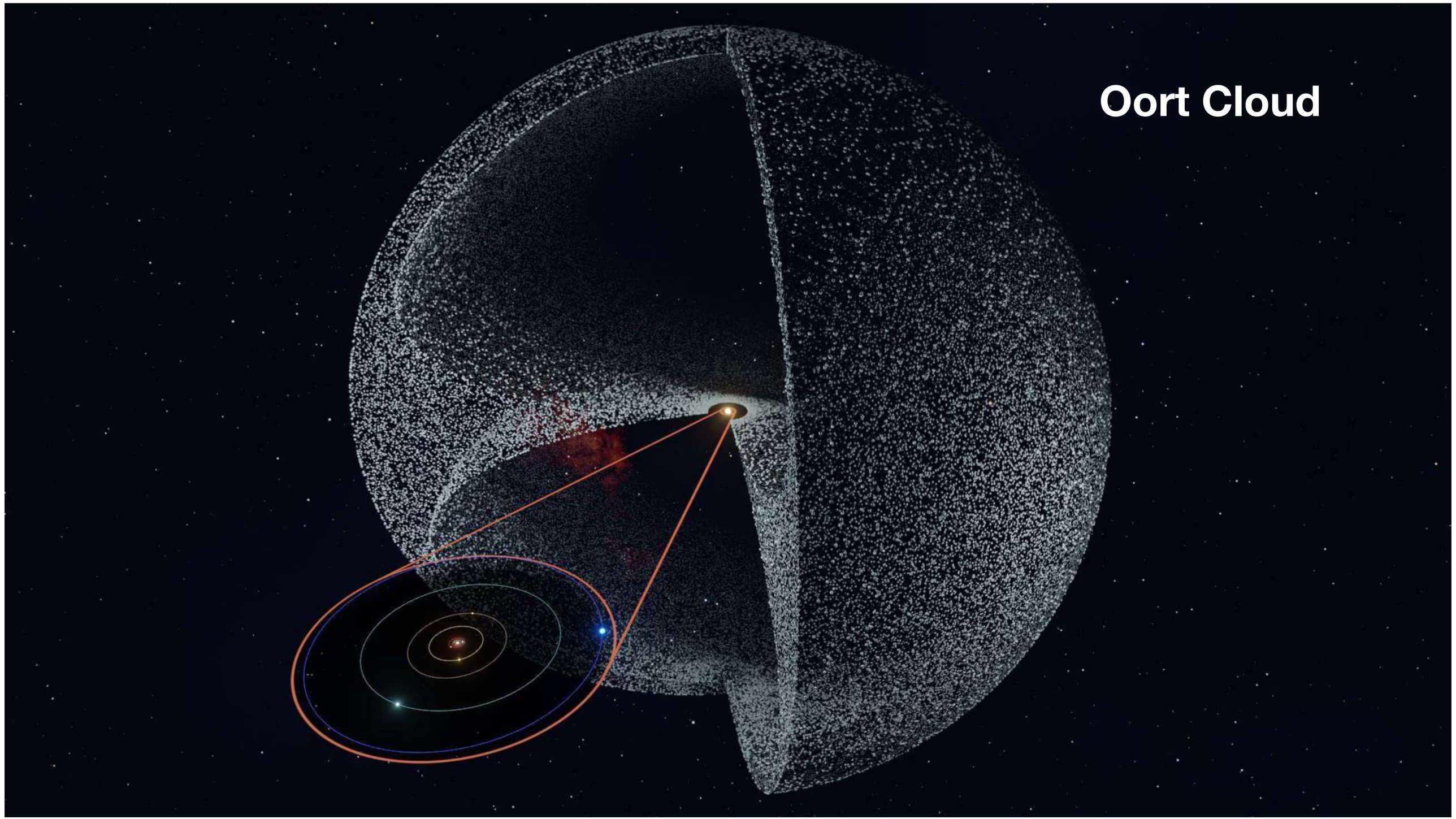
This composite image of the primordial Kuiper belt object 2014 MU69 (now called Arrokoth) was compiled from data obtained by NASA's New Horizons spacecraft as it flew by the object Jan. 1, 2019.

Oort Cloud

- Oort Cloud is the most distant region in our solar system and home of Long-Period comets.

- Unlike the flat disk of the Kuiper Belt, the **Oort Cloud** is a spherical distribution of comet nuclei that are too remote to be seen by even the most powerful telescopes.

- Comet nuclei from the Oort Cloud approach the inner Solar System from random directions in the sky, and follow orbits that bring them in from as far as 50,000 AU from the Sun, or about a fifth of the way to the nearest star. This gives an estimated idea about the size and shape of the Oort Cloud.

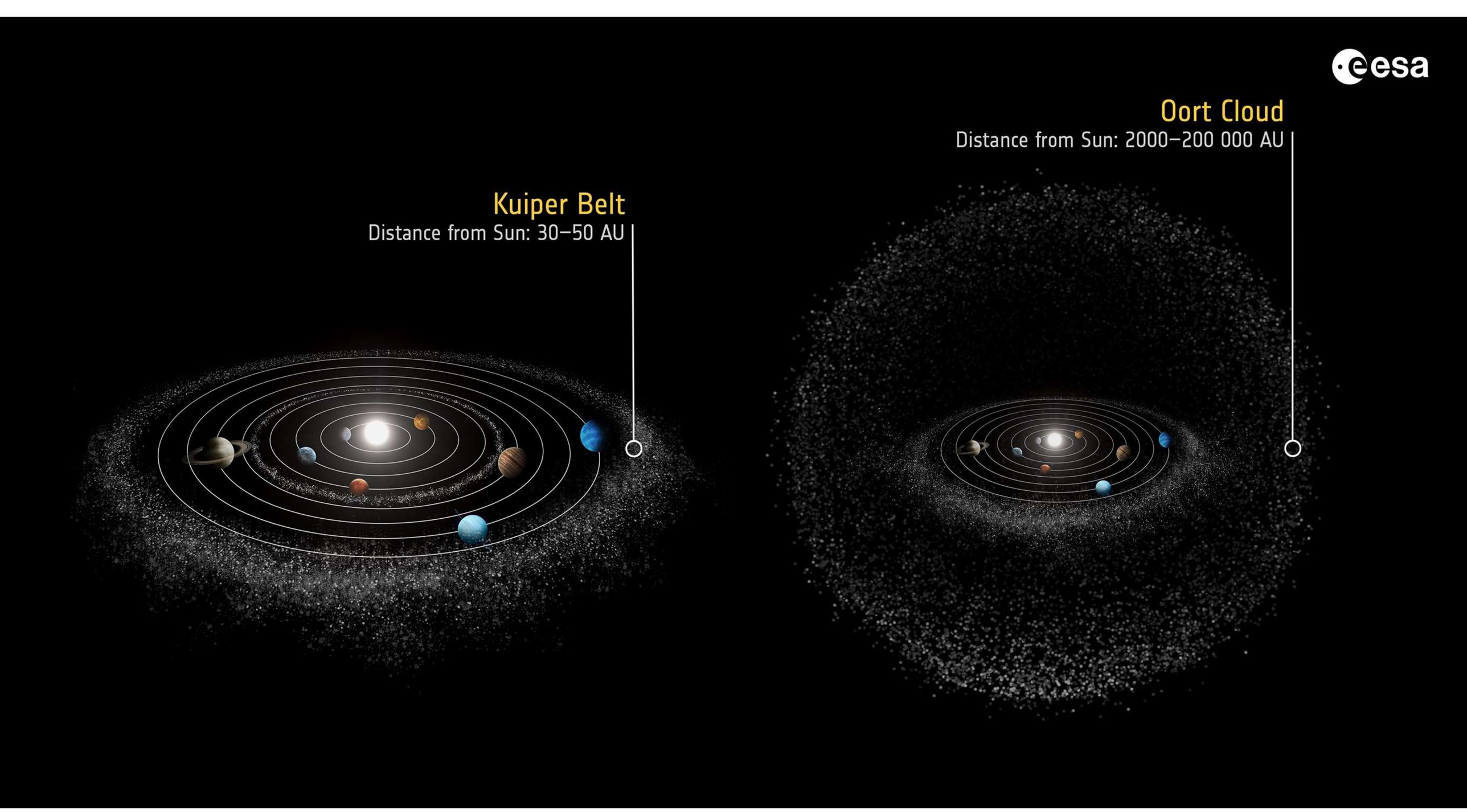

Oort Cloud

Formation of Oort Cloud

- After the planets formed 4.6 billion years ago, the region in which they formed still contained lots of leftover chunks called planetesimals. Planetesimals formed from the same material as the planets did. The gravity of the planets (primarily Jupiter) then scattered the planetesimals in every directions.

- Some planetesimals were ejected from the solar system entirely, while others were flung into eccentric orbits where they were still held by the Sun's gravity, but were far enough out that galactic influences also tugged on them.

- Gravity from the planets shoved many icy planetesimals away from the Sun, and gravity from the galaxy likely caused them to settle in the borderlands of the solar system, where the planets couldn't perturb them anymore. And they became what we now call the Oort Cloud. Again, that's the leading idea, but the Oort Cloud could also capture objects that didn't form in the solar system.


esa
Oort Cloud
Distance from Sun: 2000–200 000 AU
Kuiper Belt
Distance from Sun: 30–50 AU

How does the comets reach inner Solar System?

From the Kuiper Belt

- The comet nuclei in Kuiper Belt are packed close enough to interact gravitationally from time to time. In such events, one nucleus gains energy while the other loses it. The ‘winner’ may gain enough energy to be sent into an orbit that reaches far beyond the boundary of Kuiper Belt. It seems likely that the Oort Cloud was populated in this way. Whereas, the ‘loser’ comet nuclei fall inward toward the Sun if enough orbital energy is lost.

How does the comets reach inner Solar System?

From the Oort Cloud

- Because of the immense volume of this region the distances between comet nuclei are very large (at least 10 AU), making collisions between comet nuclei extremely uncommon events.

- The Sun’s gravitational force on the Oort Cloud comet nuclei is so feeble that they are just barely bound to the Sun at all. The effect of a slowly passing star or interstellar cloud can compete with Sun’s gravity, significantly changing the orbits of the Oort Cloud objects.

How does the comets reach inner Solar System?

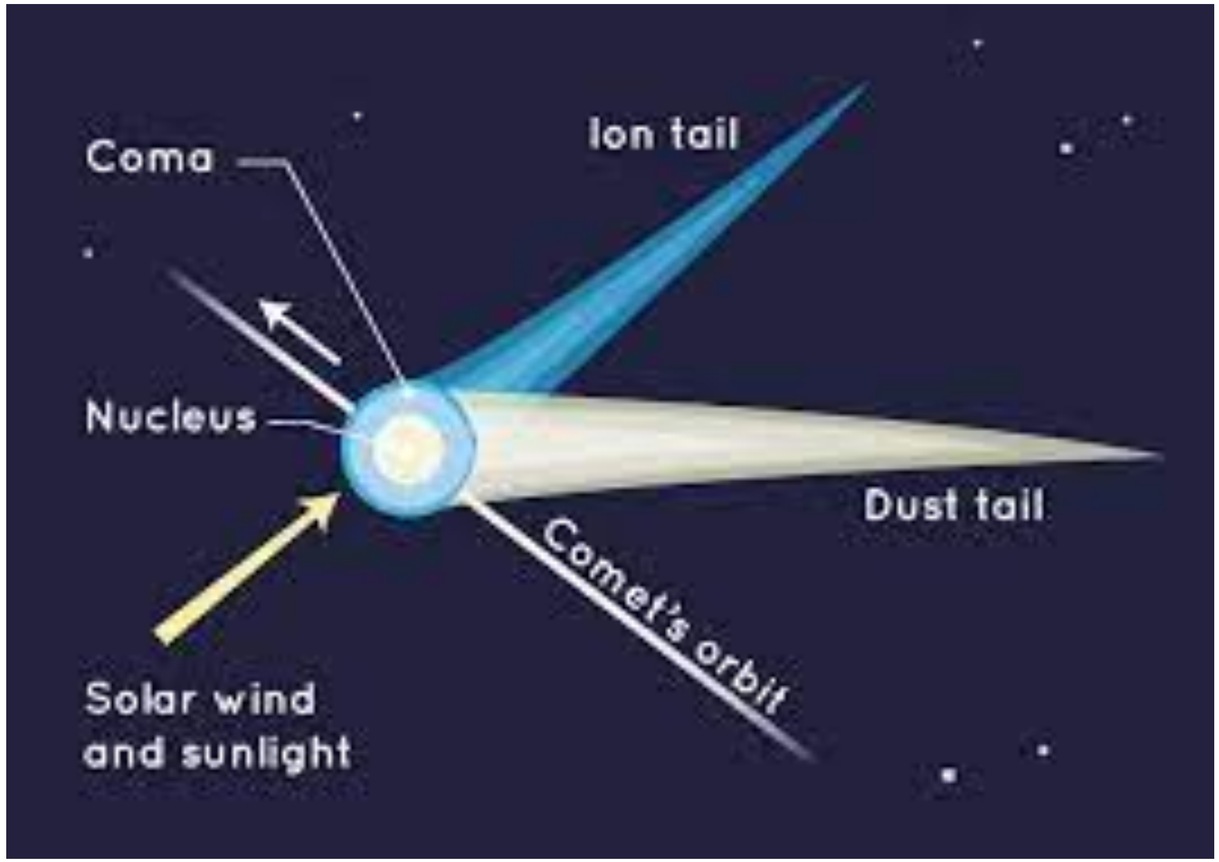
From the Oort Cloud

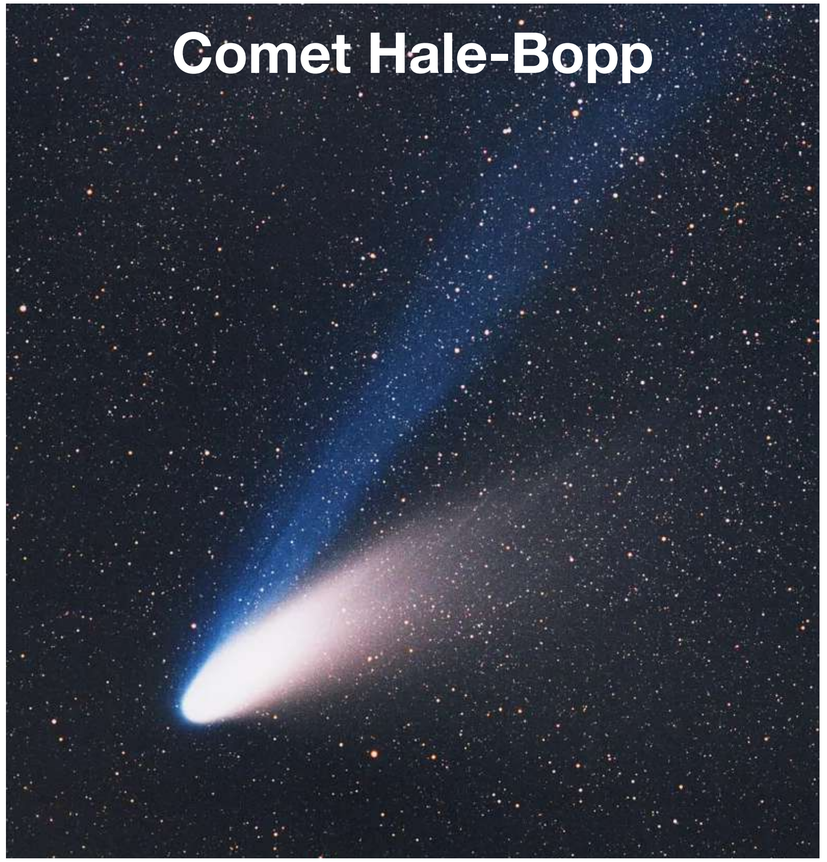
- If the interaction adds to the orbital energy of a comet nucleus, it may move outward to an even more distant orbit, or escape from the Solar System completely to begin its journey through interstellar space.

- On the other hand, a comet nucleus that loses orbital energy falls inward. Some of these come all the way into the inner Solar System, where they may appear briefly in our skies as active comets before returning once again to the Oort Cloud.

Anatomy of an Active Comet

The principal components of a fully developed active comet are **nucleus**, **the coma**, and two types of tails called the **dust tail** and the **ion tail**. Together, the nucleus and coma are called the **head**.





Anatomy of an Active Comet

- The nucleus is the smallest component of a comet, but it is the source of all the mass that we see stretched across the skies as the comet nears the Sun.

- Comet nucleus ranges from few tens of meters to several hundred kilometres across.

- Most comet nuclei have been preserved over the past 4.6 billion years by the “deep freeze” of the outer Solar System. Comet nuclei are made of the most nearly pristine material remaining from the formation of the Solar System.

- As a comet nucleus nears the Sun, sunlight heats its surface, turning volatile ices into gases, which then stream away from the nucleus, carrying embedded dust particles along with them. This process of conversion from solid to gas is called ***sublimation***.

Anatomy of an Active Comet

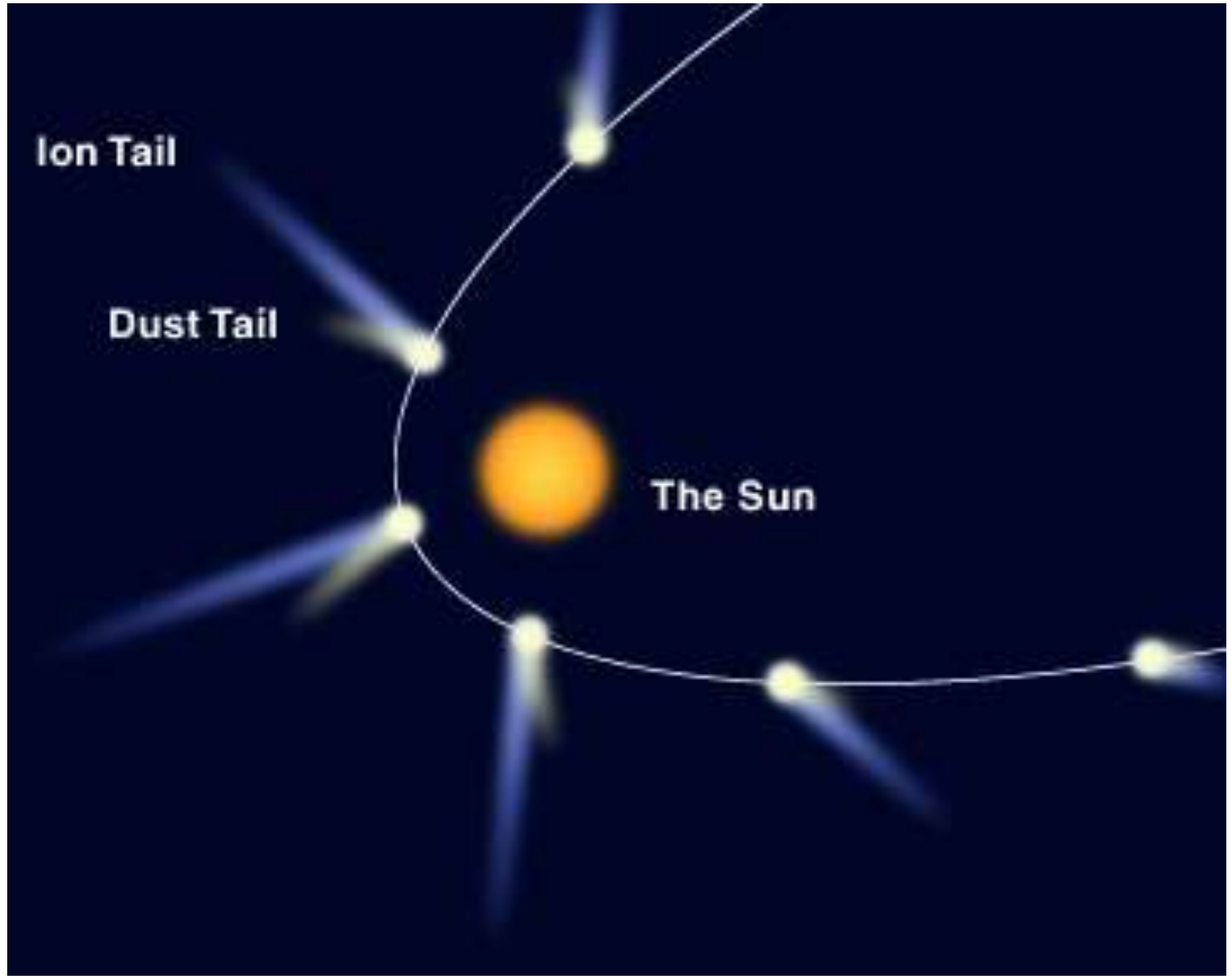
- The gases and dust driven from the nucleus of an active comet form a nearly spherical atmosphere cloud around the nucleus called the ***coma***.
- The nucleus and the inner part of the coma are collectively referred as the ***comet's head***.
- Pointing from the head of the comet in a direction away from the Sun are long streamers of dust, gas and ions called the ***tail.***

Tails of a comet

- A comet have two types of tails, i.e, **ion tail** and **dust tail**.

- Ions in the coma feel the effect of the solar wind that pushes on these ions, rapidly accelerating them to speeds of more than 100 km/s and sweeps them out into a long wispy structure.

- Solar wind quickly picks up the particles in the ion tail and appears straight pointing from the head of the comet directly away from the Sun.



Tails of a comet

- Dust particles in the coma can also have a net electric charge and feel the force of the solar wind. In addition, sunlight itself exerts a force on cometary dust.

- Dust particles being much more massive than individual ions, the acceleration is less as compared to the ions and do not reach such high relative speeds. As a result, the dust tail of a comet often appears to gently curve away from the head of the comet as the dust particles are gradually pushed from the comet’s orbit in the direction away from the Sun.

- Both tails always point away from the Sun, regardless of the direction in which the comet is moving. The tail extend ahead of the nucleus as it moves outward from the Sun.

The Orbits of Comets

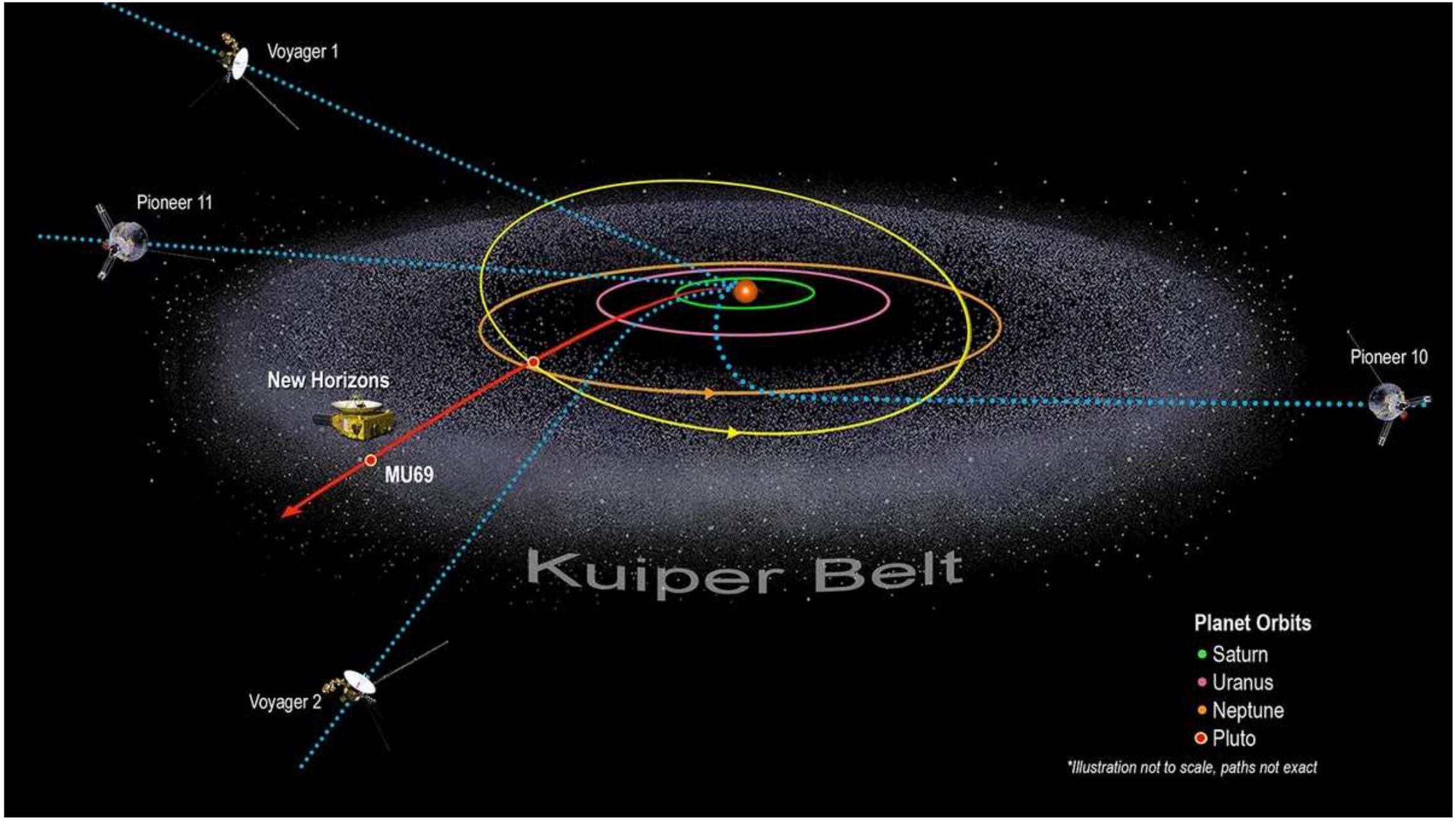
- Comets with periods of less than 200 years are called **short-period comets.**
- Comets with orbital period longer than 200 years are called **long-period comets.**
- When a comet nucleus first enters the inner Solar System, it must be on a very elongated orbit since one end of the orbit is close to the Sun while other end is in the distant parts of the Solar System. Because of this, it is expected that all comets seen in the inner Solar System have extremely elliptical orbits and extremely long orbital periods that carry them again and again back to the Oort Cloud or the Kuiper Belt.

Return of Comet Halley in March 1986.

Edmund Halley

In 1965 comet Ikeya-Seki was visible in broad daylight

In 1994, the Hubble Space Telescope observed the 21 pieces of Comet Shoemaker-Levy 9 slamming into Jupiter, leaving dark blemishes in the gas giant's swirling atmosphere.


Voyager 1
Pioneer 11
New Horizons
MU69
Pioneer 10
Kuiper Belt
Voyager 2
Planet Orbits
Saturn
Uranus
Neptune
Pluto
*Illustration not to scale, paths not exact

Thank You !