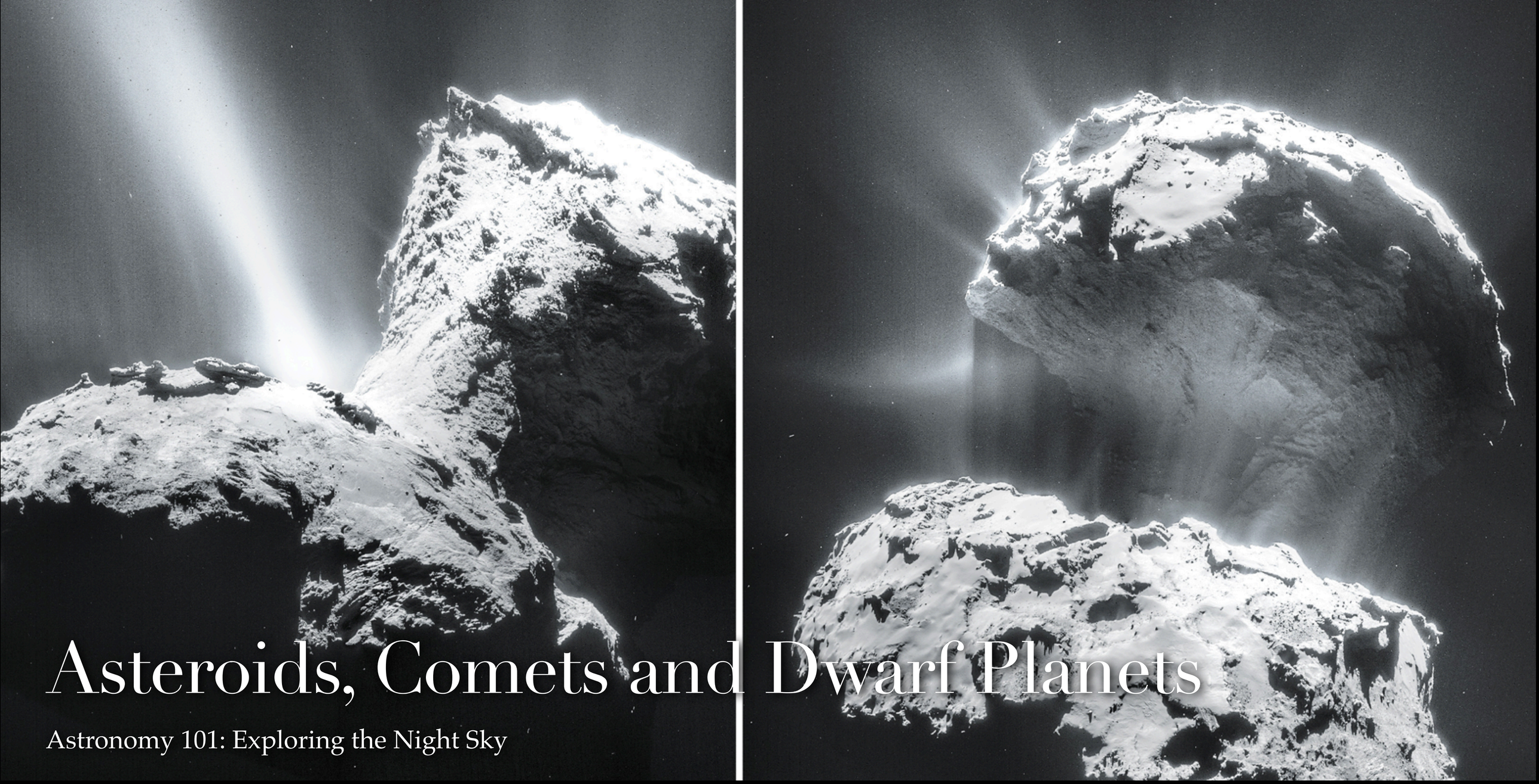


Asteroids, Comets and Dwarf Planets

Astronomy 101: Exploring the Night Sky

January, 2018

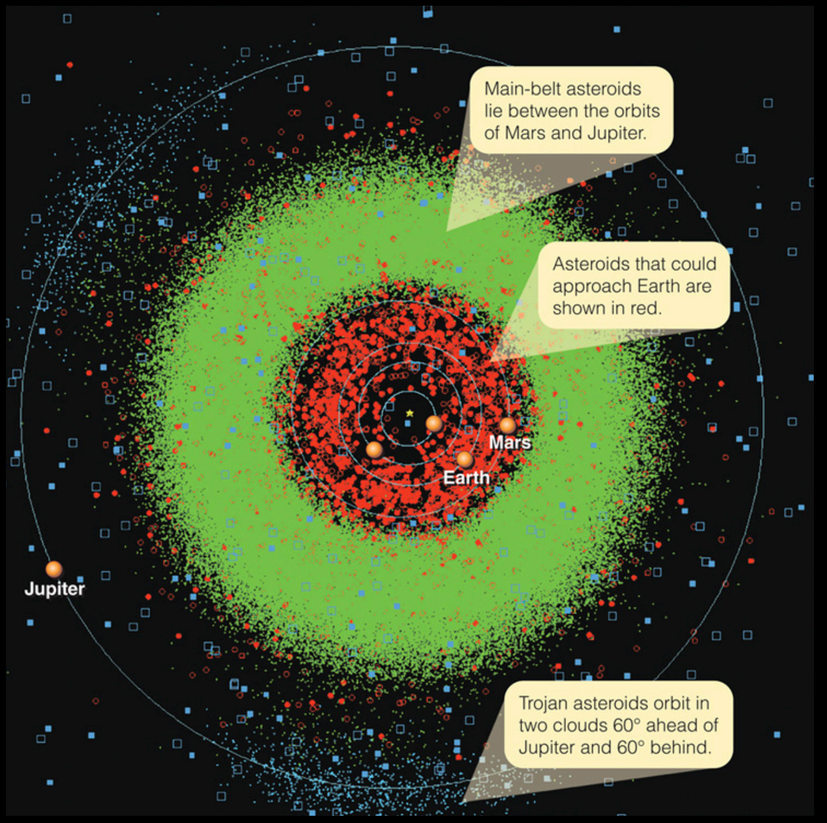
Asteroids

Discovery of Asteroids

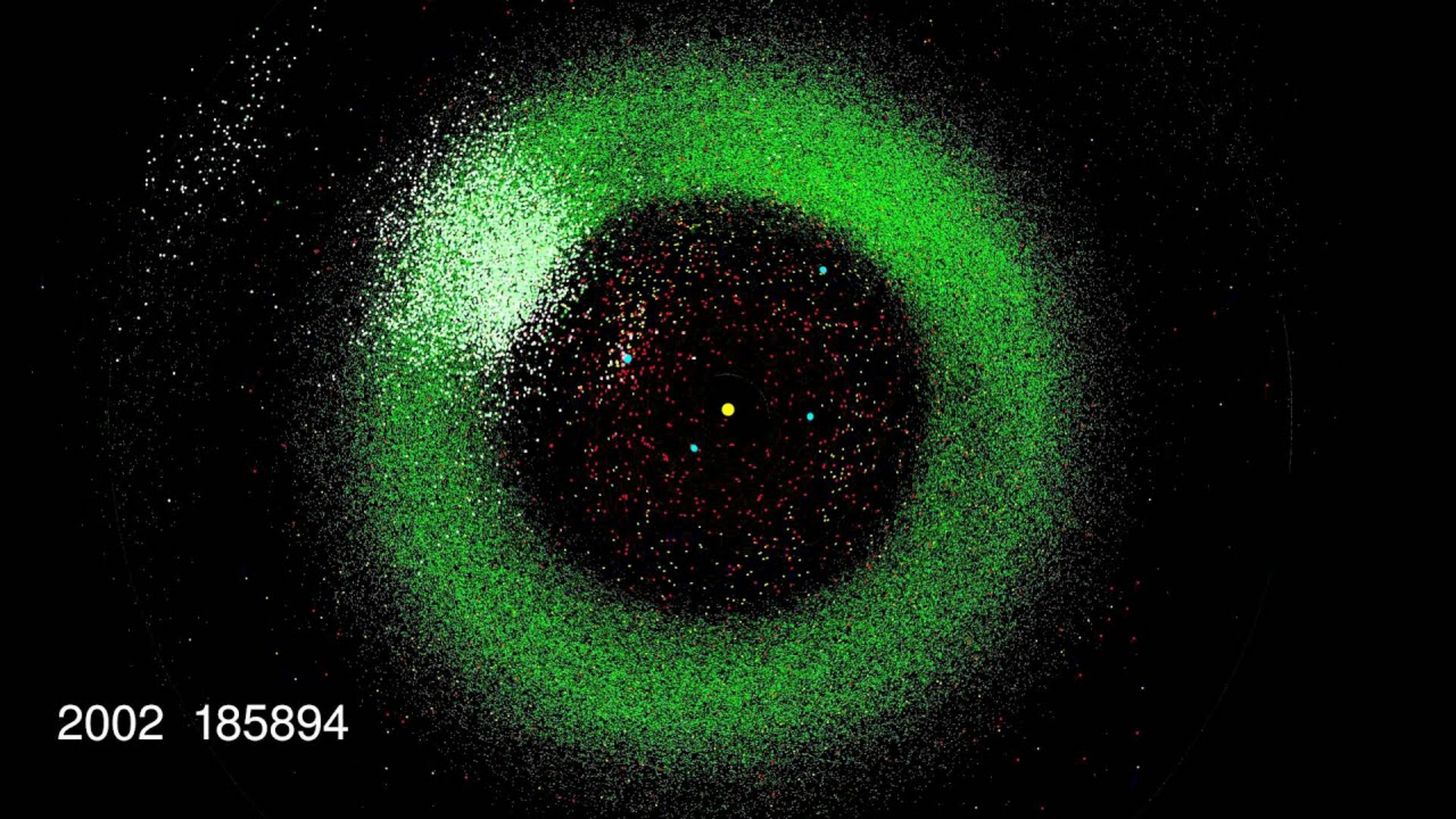
Finding asteroids and comets has rapidly advanced in the past few decades.

Until 1970, we only knew of a few thousand objects in our solar system.

That number has rapidly increased over the last few decades due to advances in telescopes and dedicated efforts by individual researchers.



https://www.youtube.com/watch?v=BKKg4lZ_o-Y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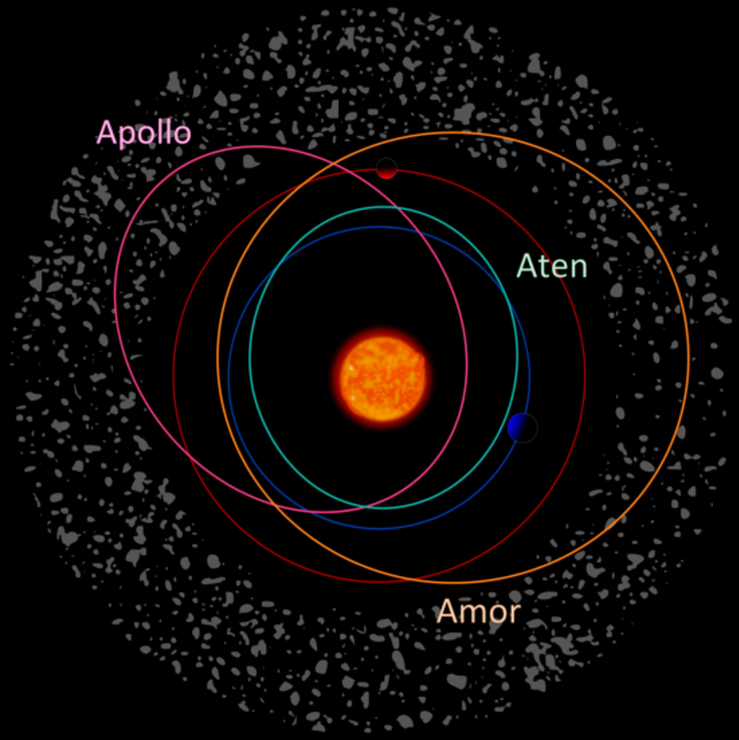
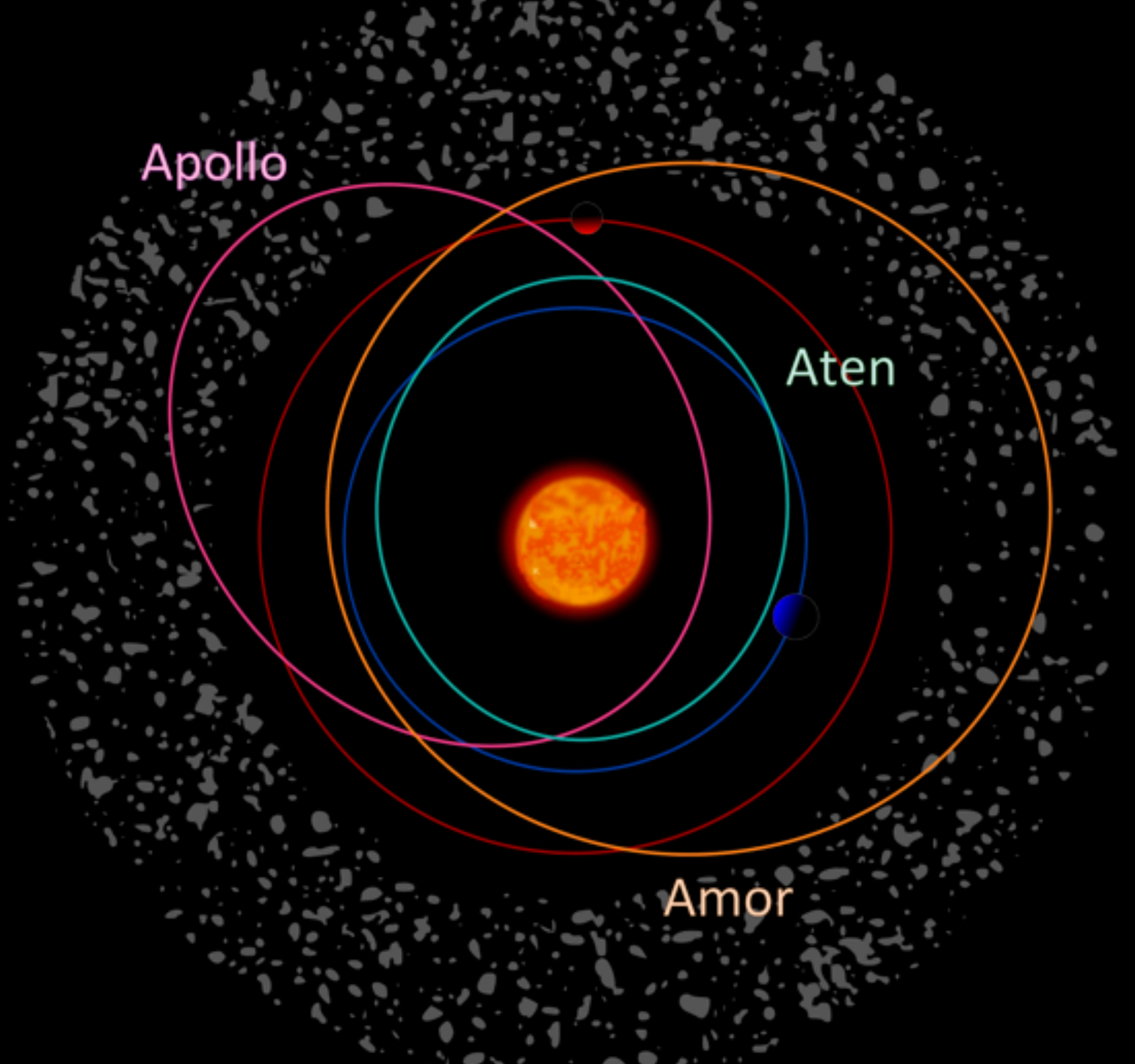
Families of Asteroids

There are three main groups of asteroids: Near-Earth, Main Belt and Trojan.

Trojan asteroids are stuck orbiting in Jupiter's Lagrange points, while main belt asteroids orbit in mostly circular orbits in the asteroid belt.

The Near-Earth asteroids are sub-classified into:
Amor - objects that orbits do not cross Earth's path
Apollo - objects that cross Earth's path (mostly out)
Aten - objects that cross Earth's path (mostly inside)
Apollo and Aten objects are of danger to Earth.




Apollo
Aten
Amor

Asteroid Belt

Asteroids are rocky objects within the inner solar system.

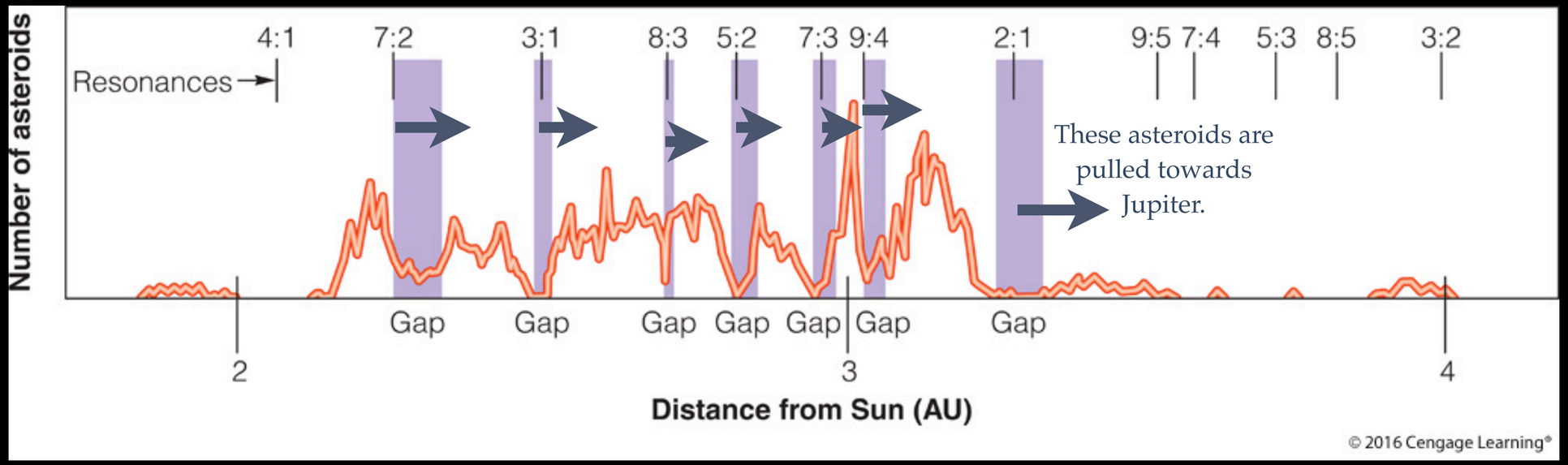
These are likely objects that were never accreted into a planet - a failed planet instead of a broken planet.

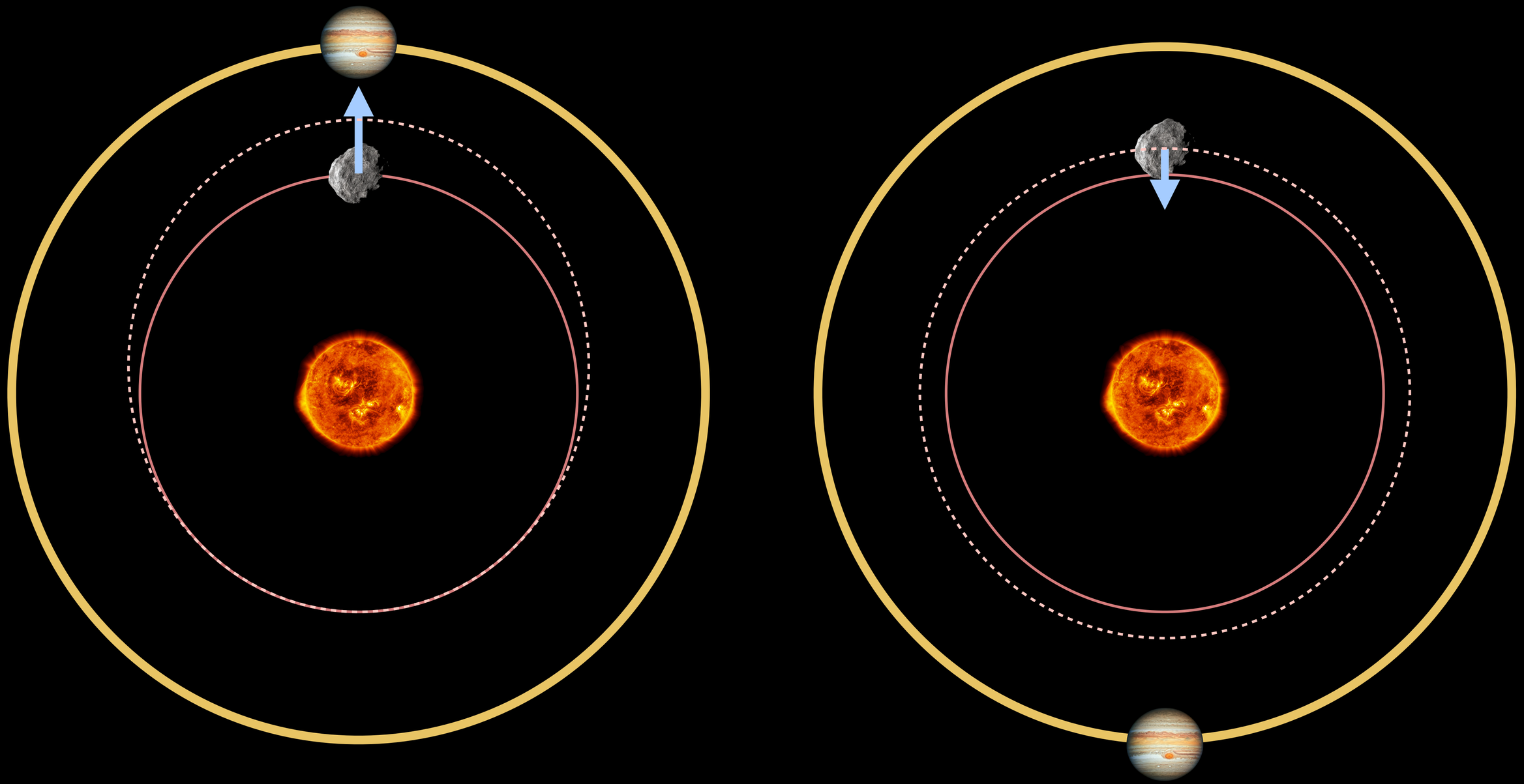
These are some of the oldest objects in our solar system!

Asteroid Orbits

The Main Belt shows clear signs of orbital resonances with Jupiter.

An asteroid with a semimajor orbit of 3.28 AU would go around the Sun exactly twice for each of Jupiter's orbits. The cumulative effect of this resonance would be to pull the asteroid closer to Jupiter.





Asteroid Classifications

C-type: (carbonaceous) low reflectivity due to high amounts of carbon

S-type: (silicate) high reflectivity due to high amounts of silicon

M-type: (metallic) high amounts of metals

C-type more common further from the Sun

C-type

S-type

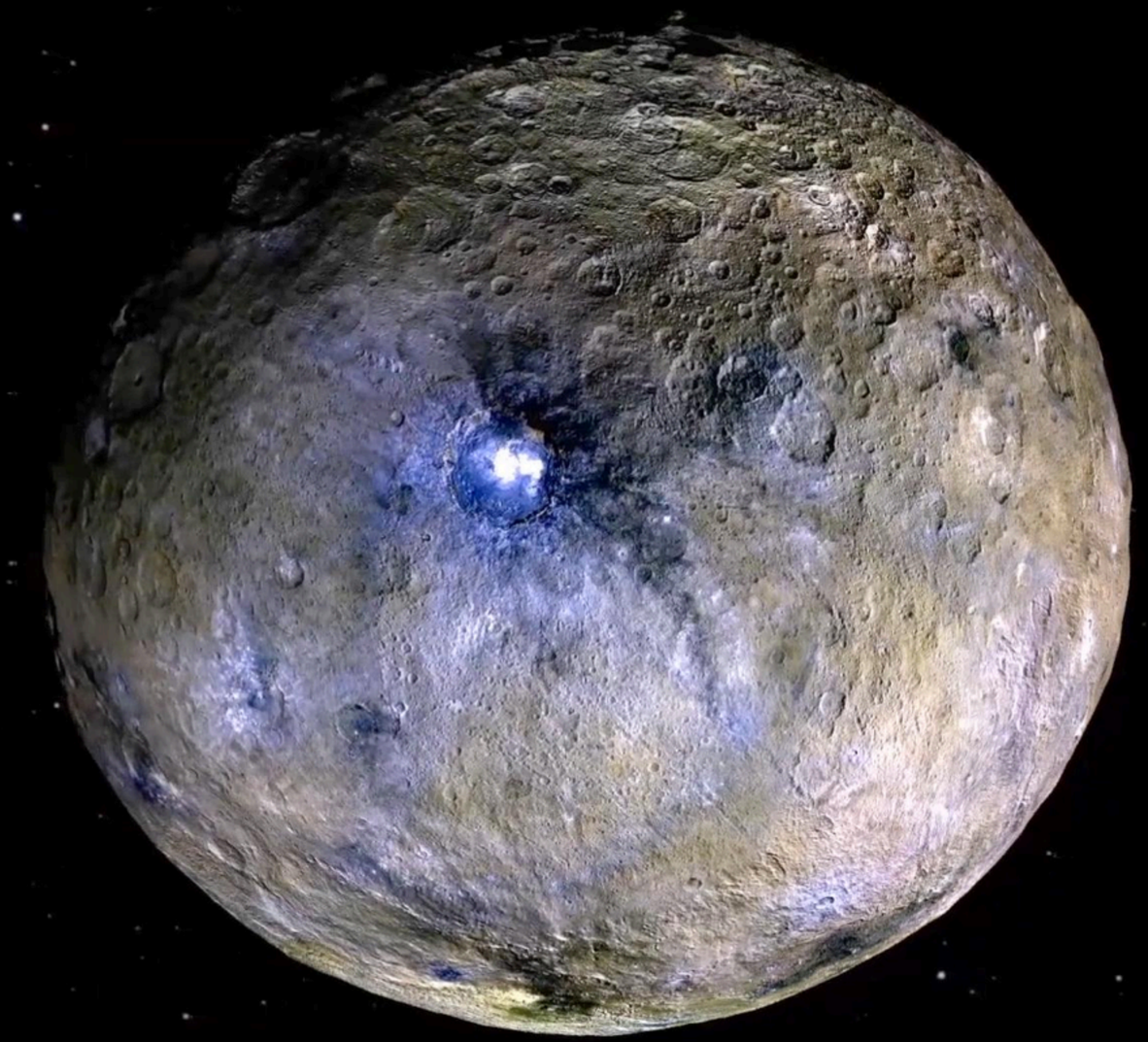
M-type

Largest Asteroid

Ceres is a dwarf planet in the asteroid belt - the largest one, and shares more in common with Mars than with the other asteroids.

It has a somewhat differentated core, and a sizeable amount of water.

Ceres’s diameter is about as wide as Ontario.



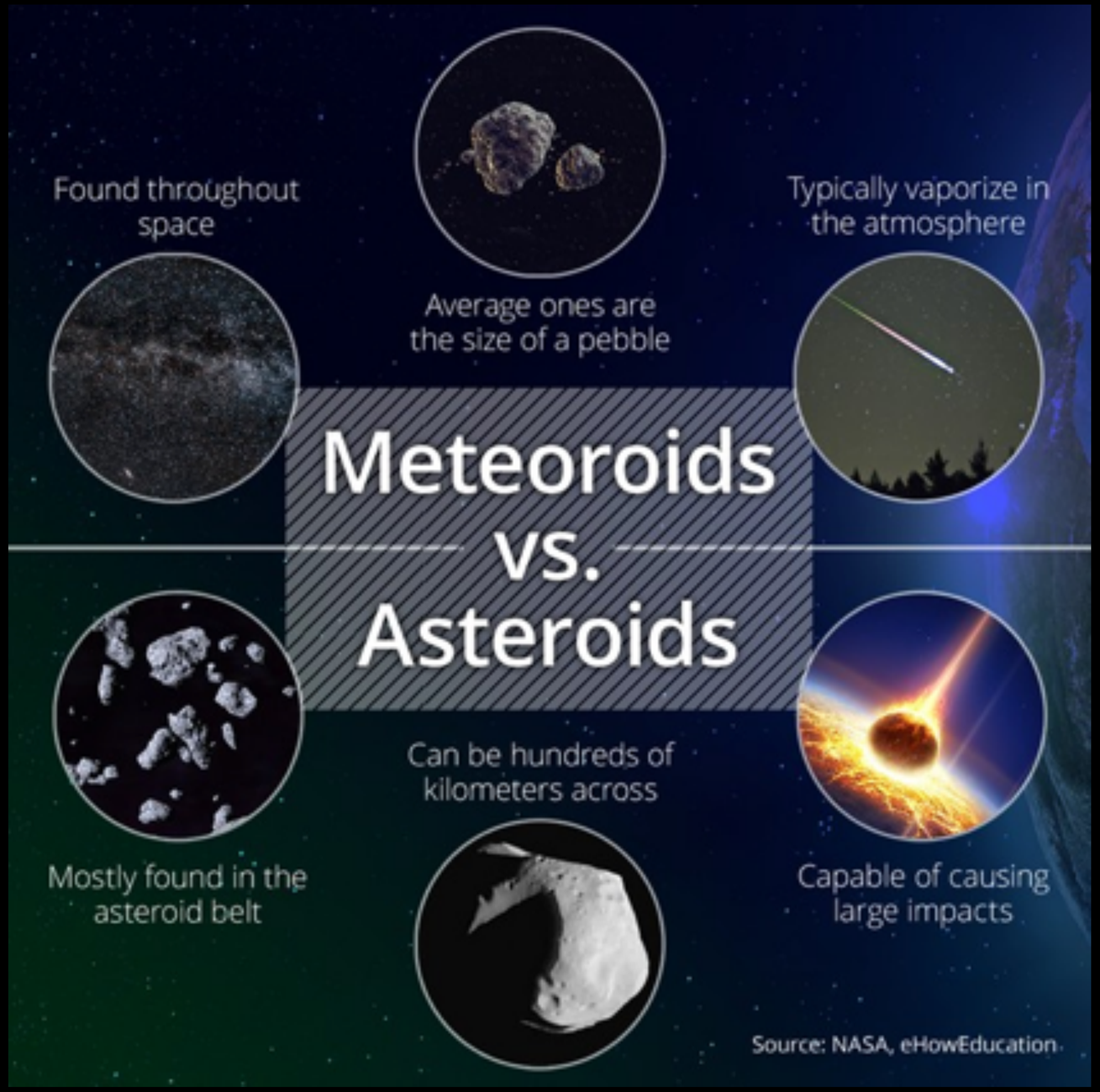
Meteoroids

Meteoroids vs Asteroids

Both are space-faring objects,
but the real distinction is size.

A meteoroid is something that will likely burn up in our atmosphere: less than 1m in diameter.

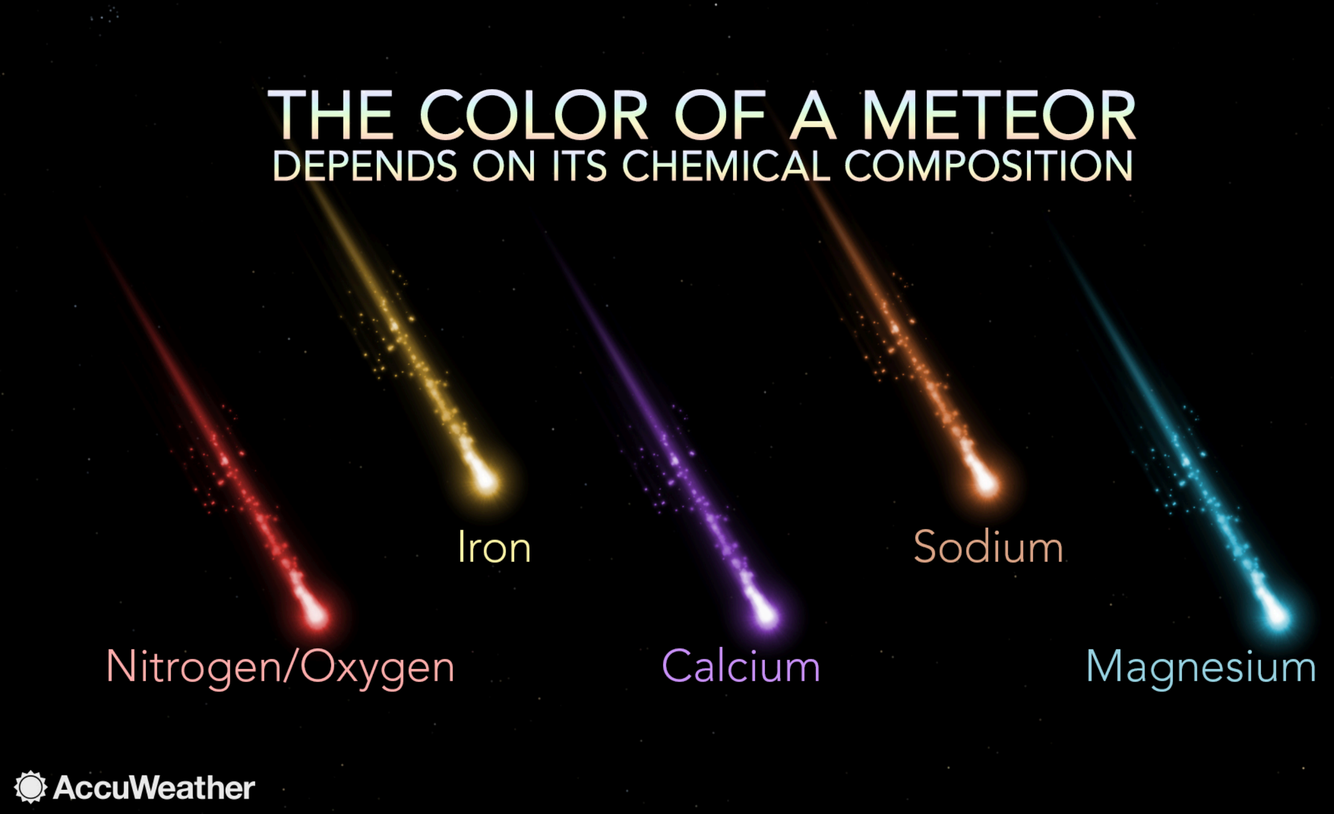
Asteroids are larger than 1m, but do not have enough mass to form a spherical shape.



Meteoroids vs Asteroids

Both meteoroids and asteroids are comprised primarily of rock: metals and silicates.

Determining their composition is difficult from a distance - but easy when they enter our atmosphere.



As meteoroids enter our atmosphere, they burn up with a distinctive colour.

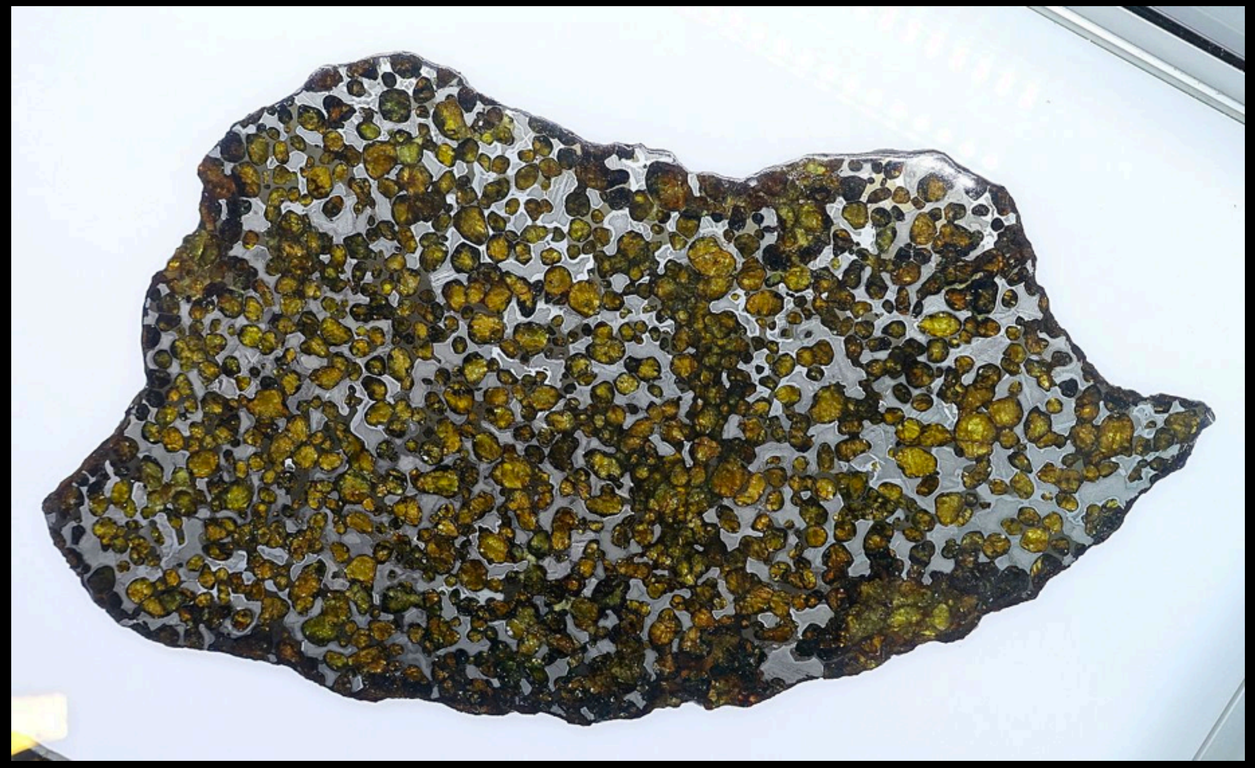
Meteoroid, Meteor, Meteorite

The difference is terminology:

Asteroid / Meteoroid is what it is called in space.

Meteor is what it is called as it is burning up in the atmosphere.

Meteorite is the rock that is left over after it strikes the ground.



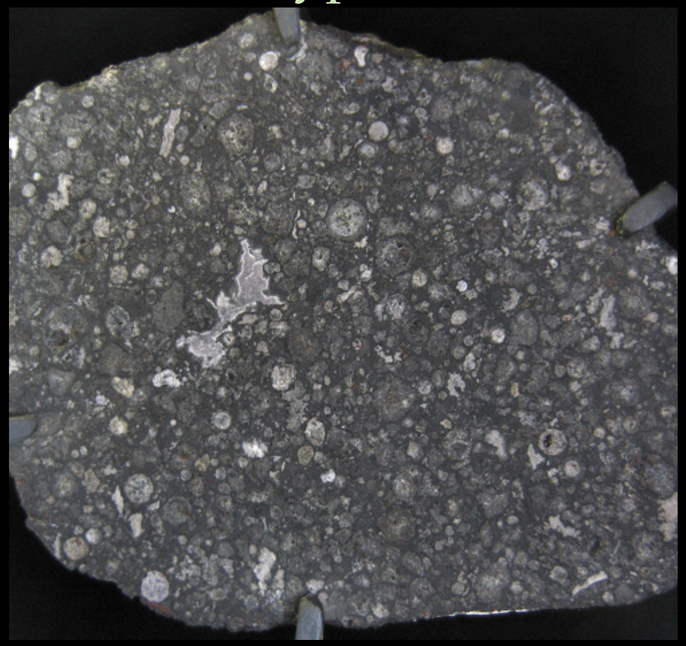
This is the iron-rich Springwater meteorite.

Only 6% of meteors have high iron content, but 50% of meteorite finds have high iron content. Why?

Meteorites up close

Pallasite

Type M



Type C

Meteor Showers

Meteoroids are not visible with telescopes.

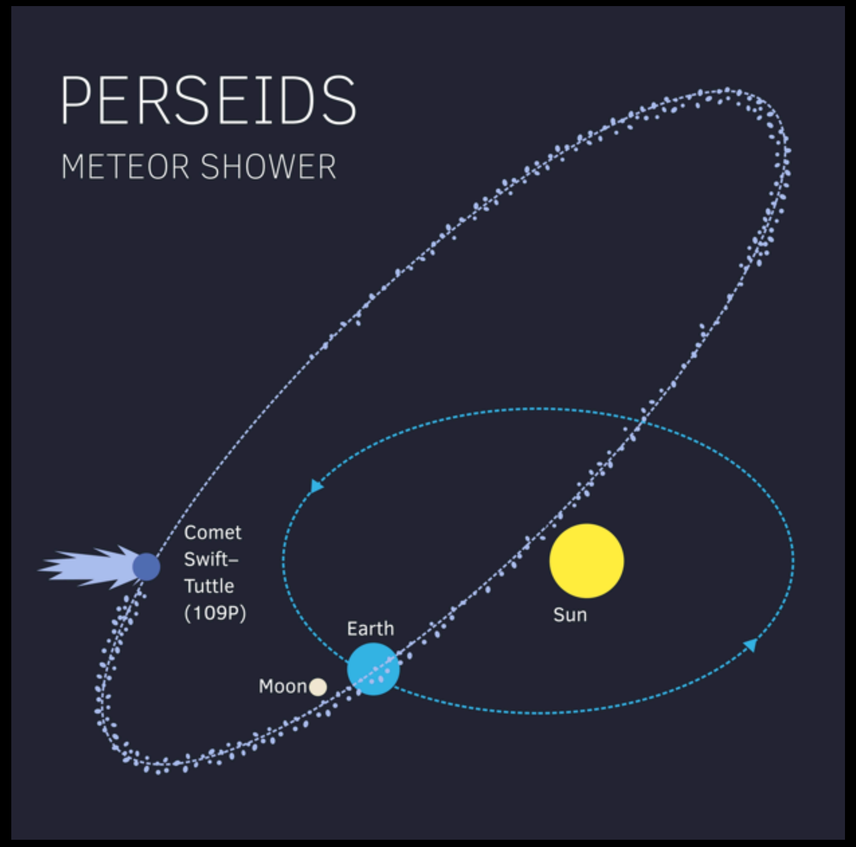
We see them when they burn up in our atmosphere, and use the trail and speed to track back to their orbits.

A meteor shower is a grouping of meteors that all appear to come from one position: the radiant of the shower.

Meteor Showers

A meteor shower indicates a common origin for all of the meteors.

From tracking these objects, we now recognize that the common origins are the comets that orbit our sun.



2018 Meteor Shower List

Shower name	Activity Period	ZHR at Max
Quadrantid	Jan. 4	25
Lyrid	Apr. 22	10
Eta Aquarid	May 4	10
Delta Aquarid	July 30	10
Perseid	Aug. 11–13	50
Draconid	Oct. 9	6
Orionid	Oct. 21–22	15
Taurid	Nov. 9	3
Leonid	Nov. 17–18	10
Andromedid	Nov. 25–27	5
Geminid	Dec. 13–14	75
Ursid	Dec. 22	5

Meteor Fireballs

In 2013, a 20 m wide meteor exploded above Russia, releasing as much energy ~6 modern nuclear bombs.

Many modern fireball images come from Russia: is Russia more commonly targetted?

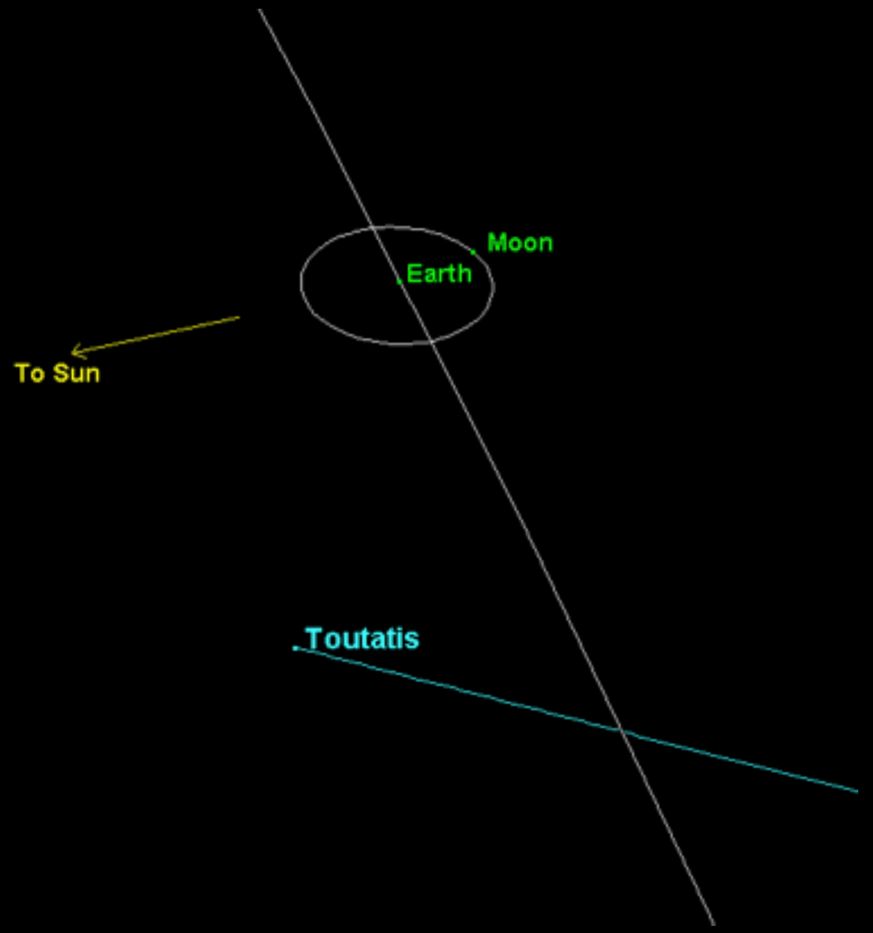
Dangers to Earth

>10 000 Earth-cross asteroids are known, and about 1400 are “hazardous”

Hazardous: larger than 150m across & orbit within 0.05 AU of Earth

In 2004, 3 km wide Toutatis passed within 1.5M km of Earth

It was detected 3 days AFTER it passed by Earth



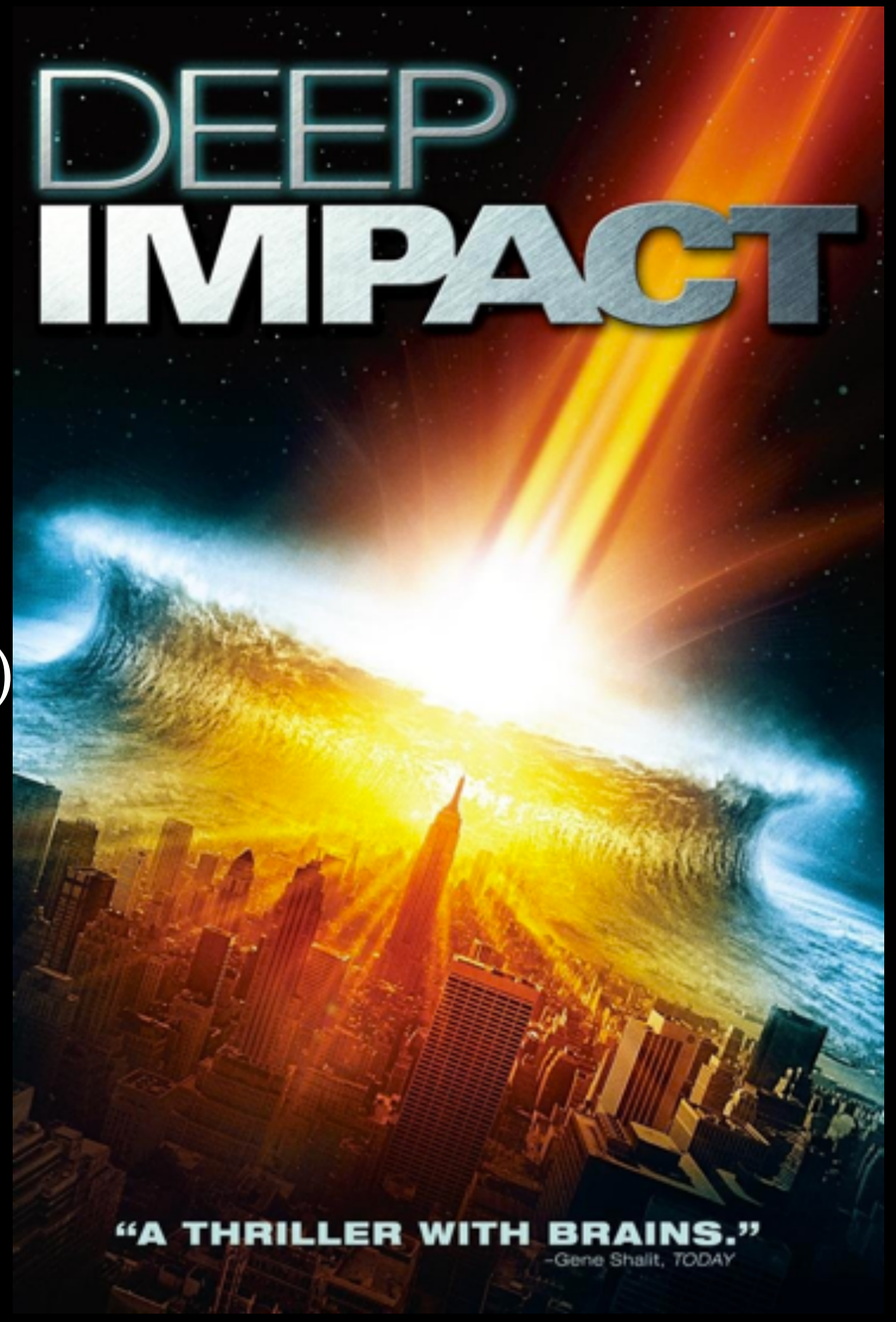
Dangers to Earth

Should I worry?

No known hazardous asteroids will impact Earth in the next 100 years (likely longer, but our ability to predict beyond 100 years is limited)

Need multi-km size asteroid for extinction level event, which are easier to see and track.

Only a few extinction level asteroids cross our orbit now.

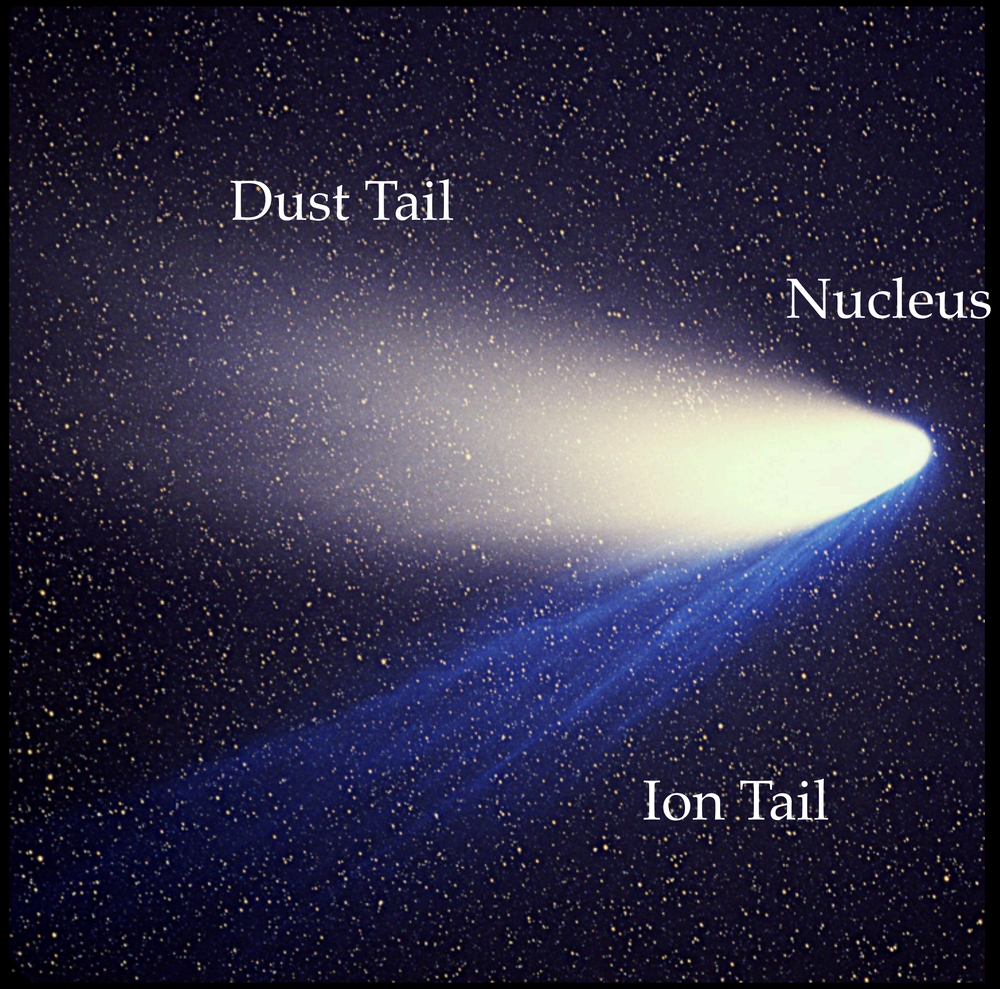


Comets

Comet Tails

Comets are rarely seen directly, but their tails are visible - long clouds of matter streaming off of the comet nucleus.

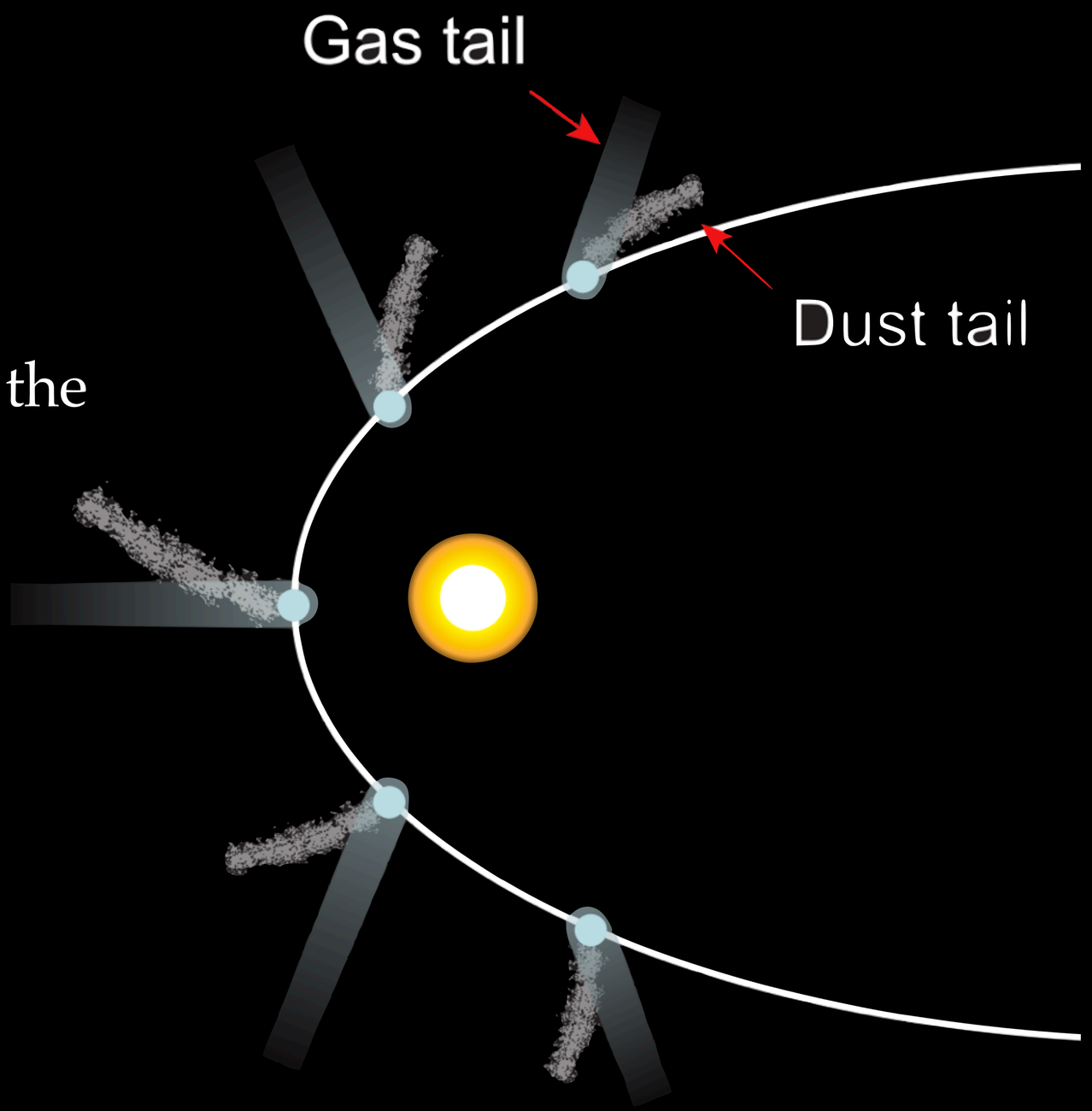
Both tails are produced from the radiation pressure and solar wind from the Sun - material on the surface of the comet is boiled off and separated into rocky dust particles and ionized gaseous particles.



Comet Tails

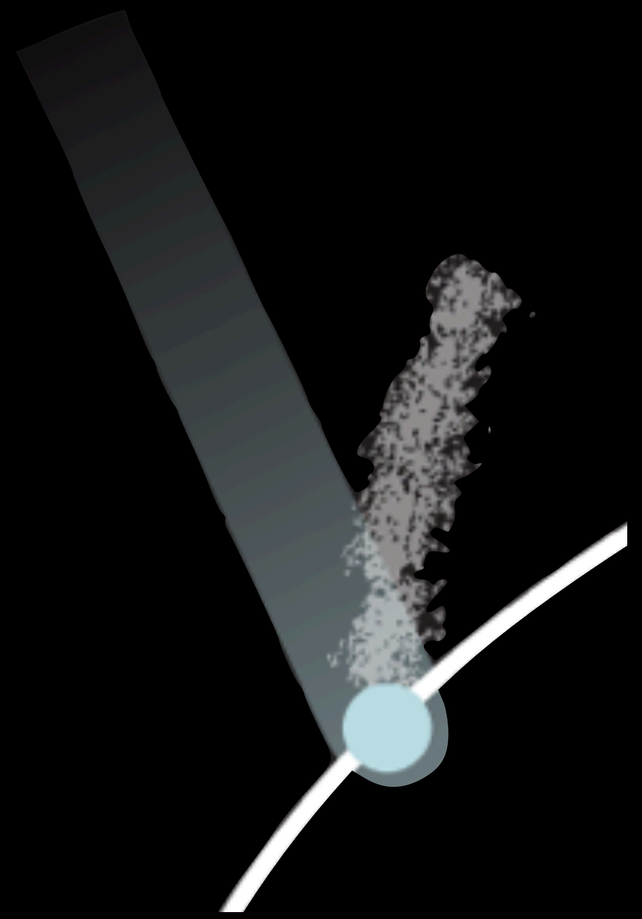
The lighter ionized particles move at higher speeds, and so they appear to form a nearly straight line away from the Sun.

The heavier dust particles move at slower speeds and so they trail in an arc that initially points towards the Sun, but curls behind the path of motion.



Comet Compositions

Gas Tail - Spectroscopy



Spectral measurements of comet tails suggest compositions of various ices of water and volatiles (CO, CO_2, methane, ammonia, etc).

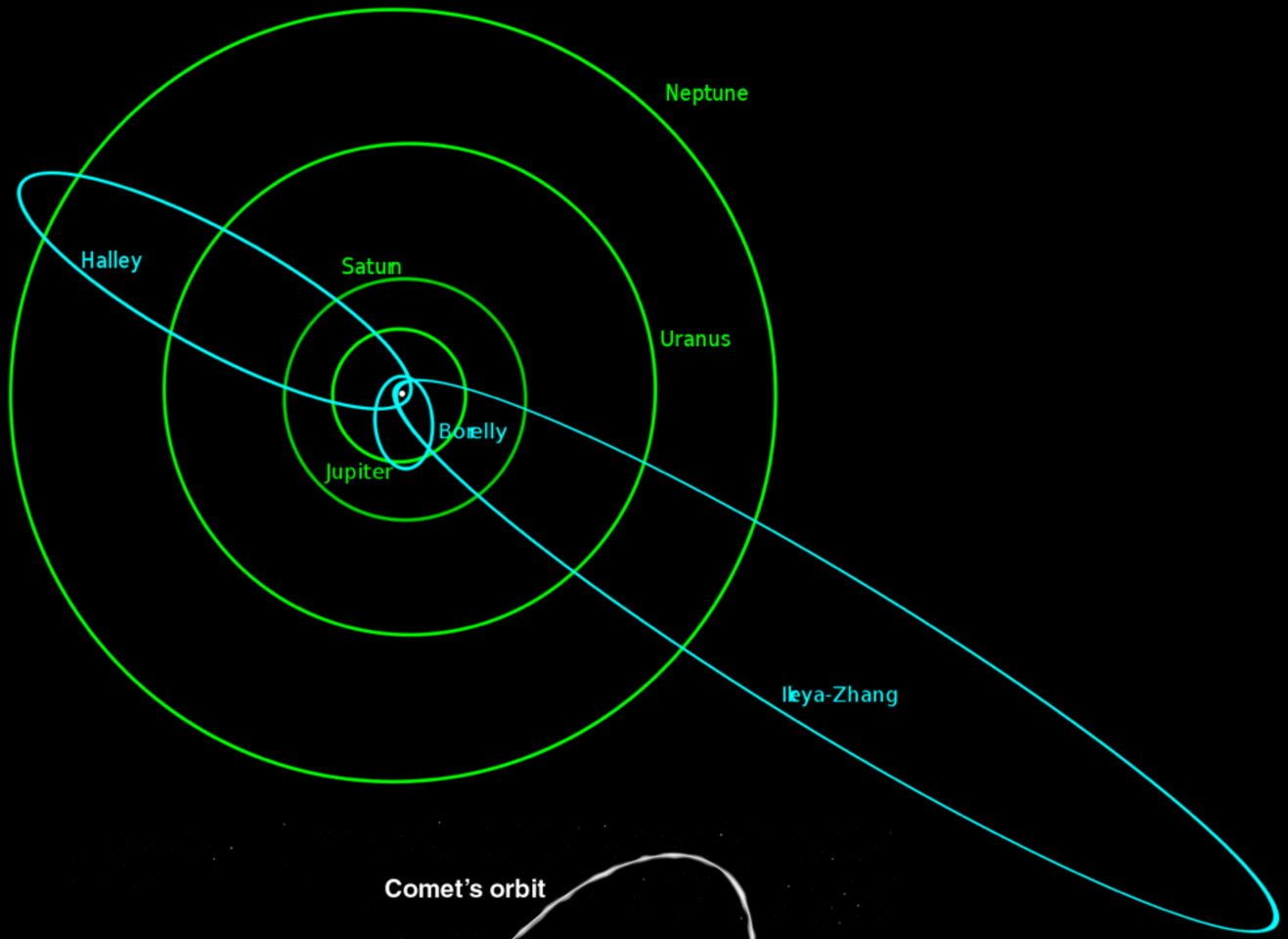
Densities are hard to determine, but estimates put the densities between 0.1 and 1.5g/cm^3, with many being lower than 0.5g/cm^3.

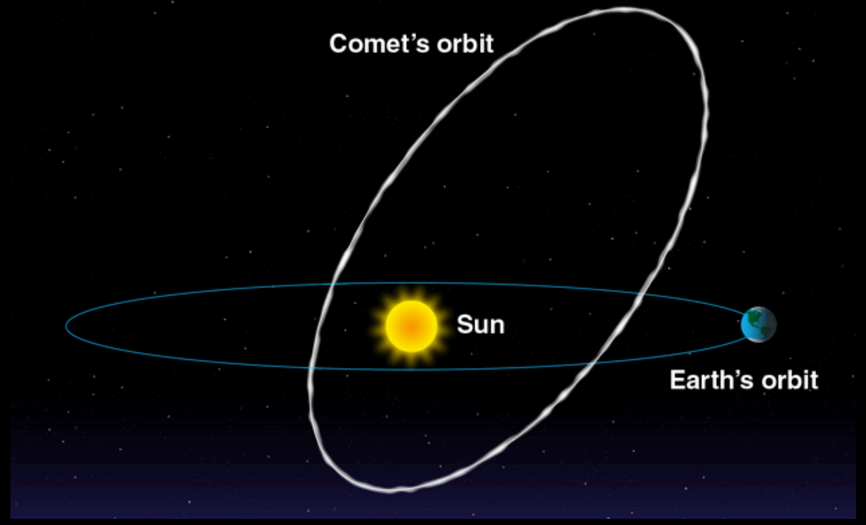
The metallicity observed in the meteor trails comes from trace amounts of these chemicals. Ices vapourize at lower temperature.

Comet Orbits

Comets typically have highly elliptical orbits that can take them out beyond the path of Neptune.

This belies their origins as Kuiper Belt objects that were diverted in their path by gravity assists from other planets.



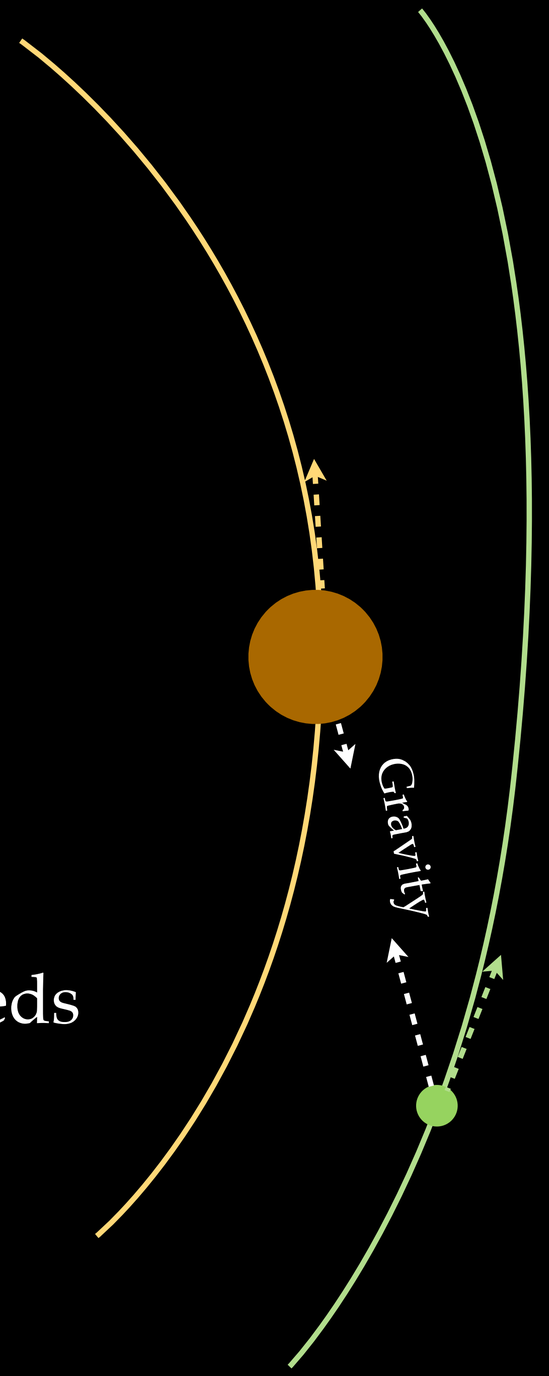


Gravity Assist

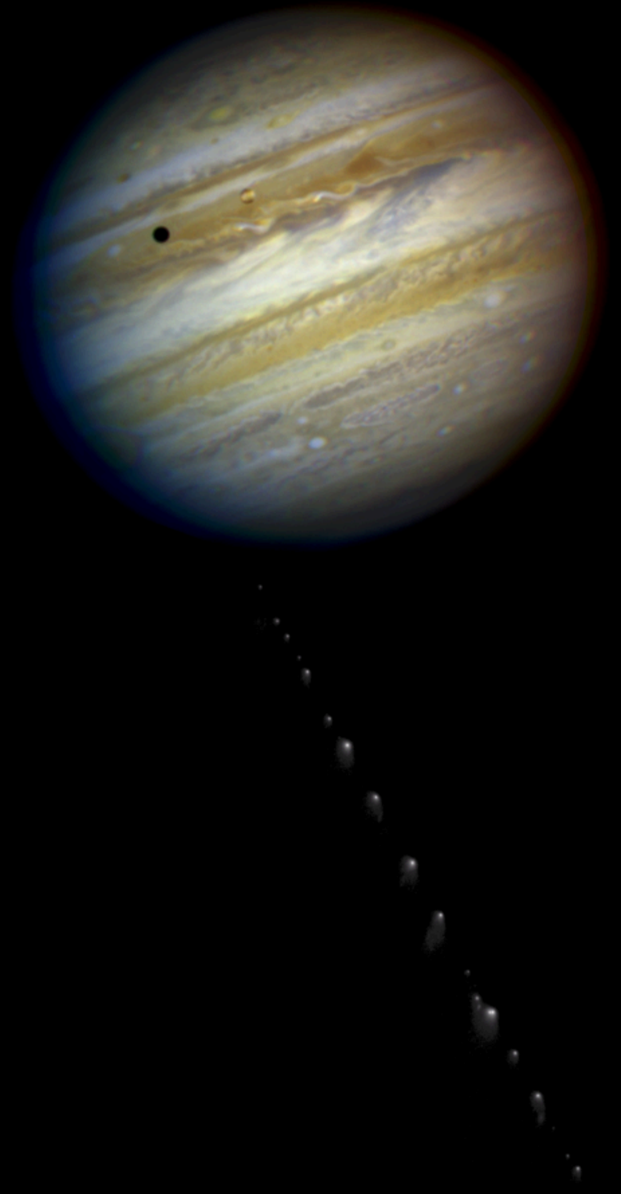
When the orbit of two objects brings them close to each other, the gravitational strength between them causes them to accelerate towards each other.

The leading object loses some orbital speed and the trailing object gains some orbital speed.

As their orbits take them apart again, the change in speeds remains - both objects change in eccentricity as their orbital velocities have forever been altered.



Comet Lifespans



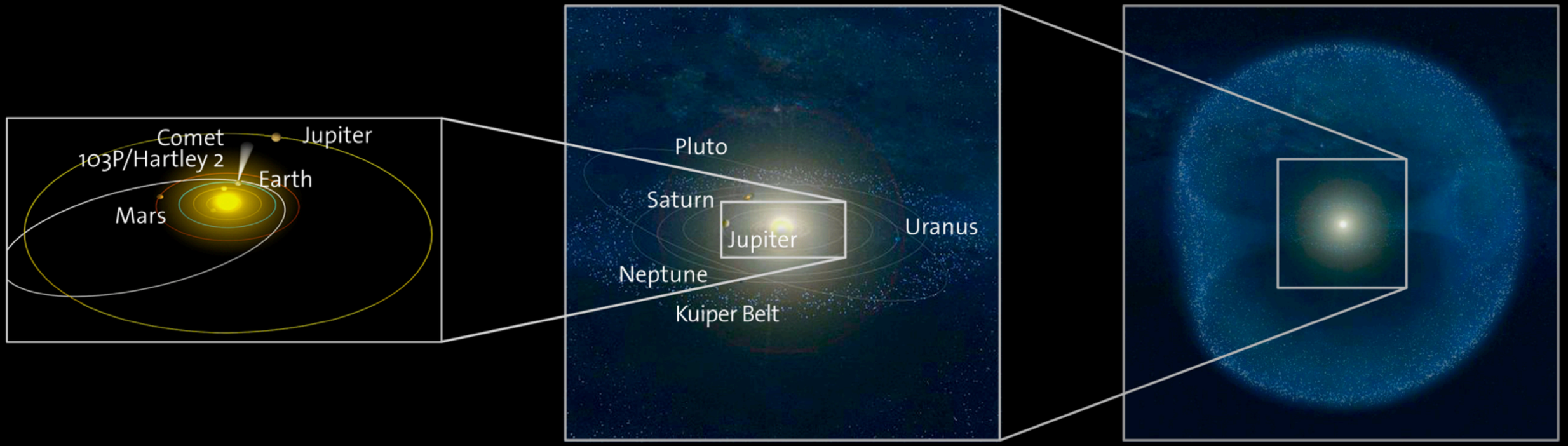
Long Period comets have periods of 200 years or greater - some can be up to 100ky+, taking them out into the Oort Cloud. Short Period comets have periods less than 200 years.

But comets can’t survive for long inside the solar system - either they are vapourized by the Sun or they are absorbed by Jupiter or deflected into the Sun by Jupiter.

There is a constant supply of new ones from the Kuiper belt or Oort cloud.

The Outer Reaches

The Kuiper Belt consists of a large number of trans-Neptunian objects that orbit with relatively low eccentricity. Total mass estimated at 30 Earths.

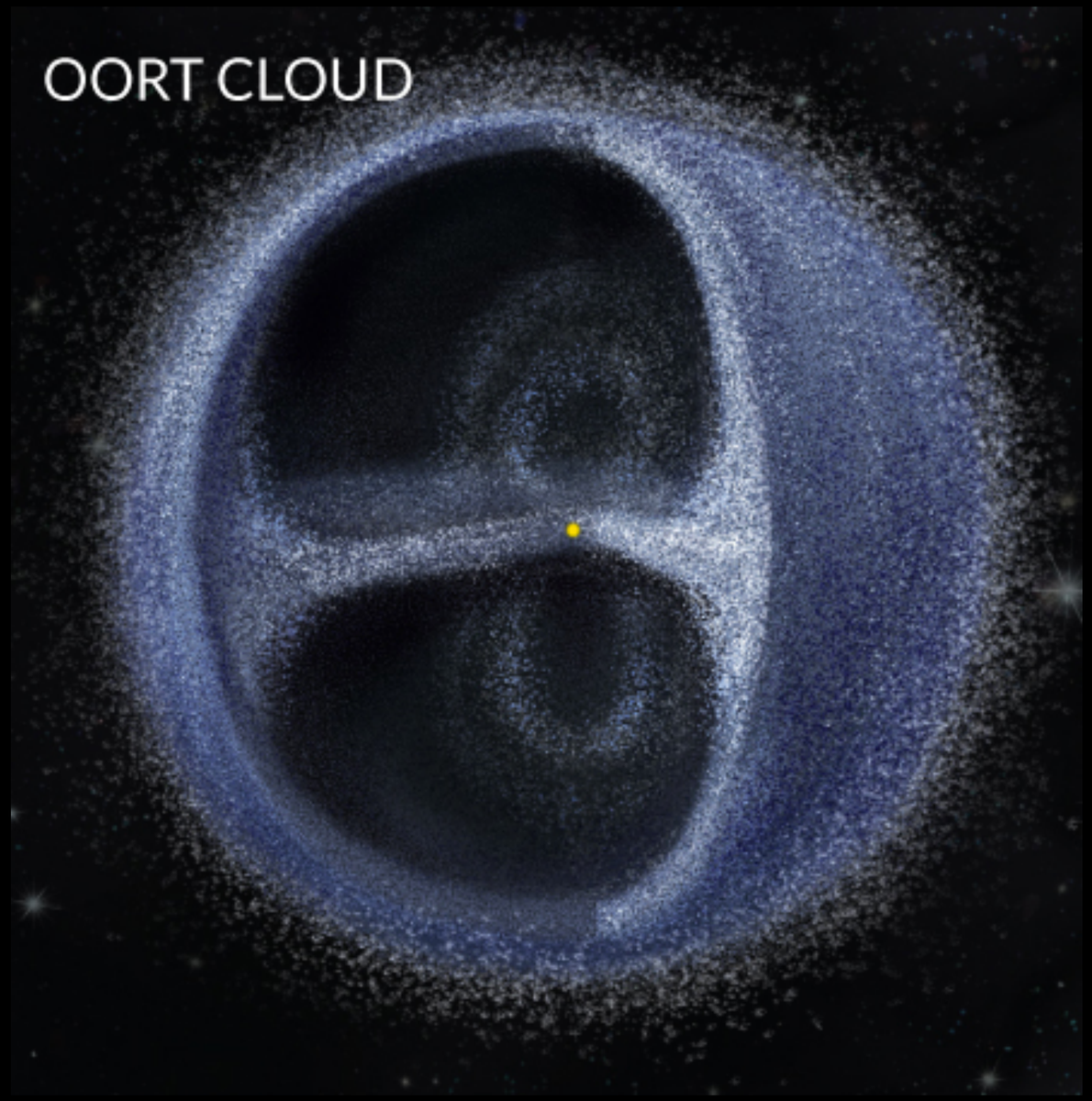


The Outer Reaches

The Oort Cloud is an icy cloud of material remaining from the solar nebula that never collapsed into the solar system.

Much of it orbits outside the eccliptic.

Estimates of mass: a few Earths.



Some notable objects

Comet Hale-Bopp

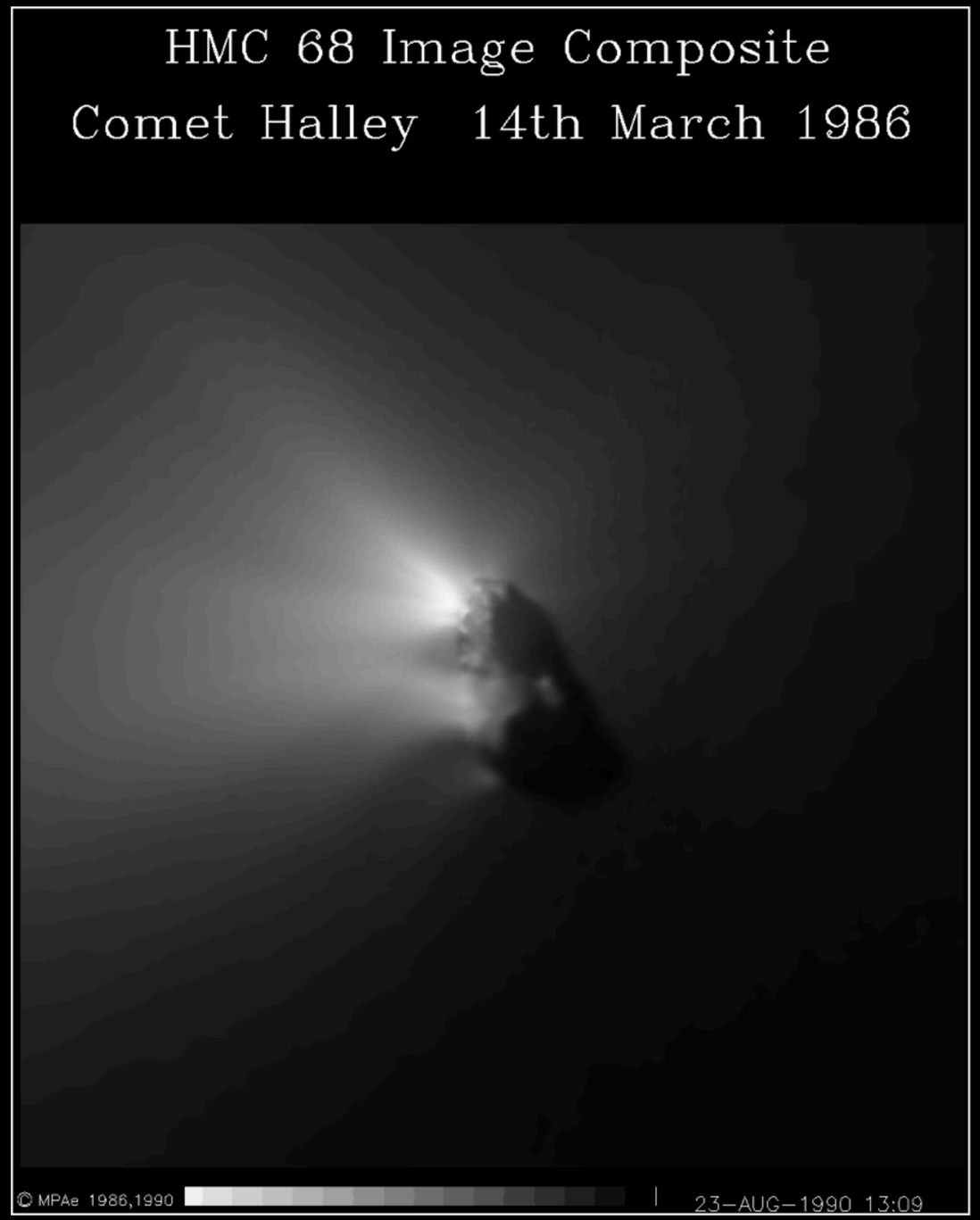
In 1995, two astronomers (Hale, Bopp) observed a comet long before it was visible by the naked eye.

For 18 months, Hale-Bopp was visible with the naked-eye in the night sky - the brightest and most widely observed of the 20th c.

Halley's Comet

Edmond Halley was the first to recognize that the object seen by astronomers every ~76 years was in fact the same thing!

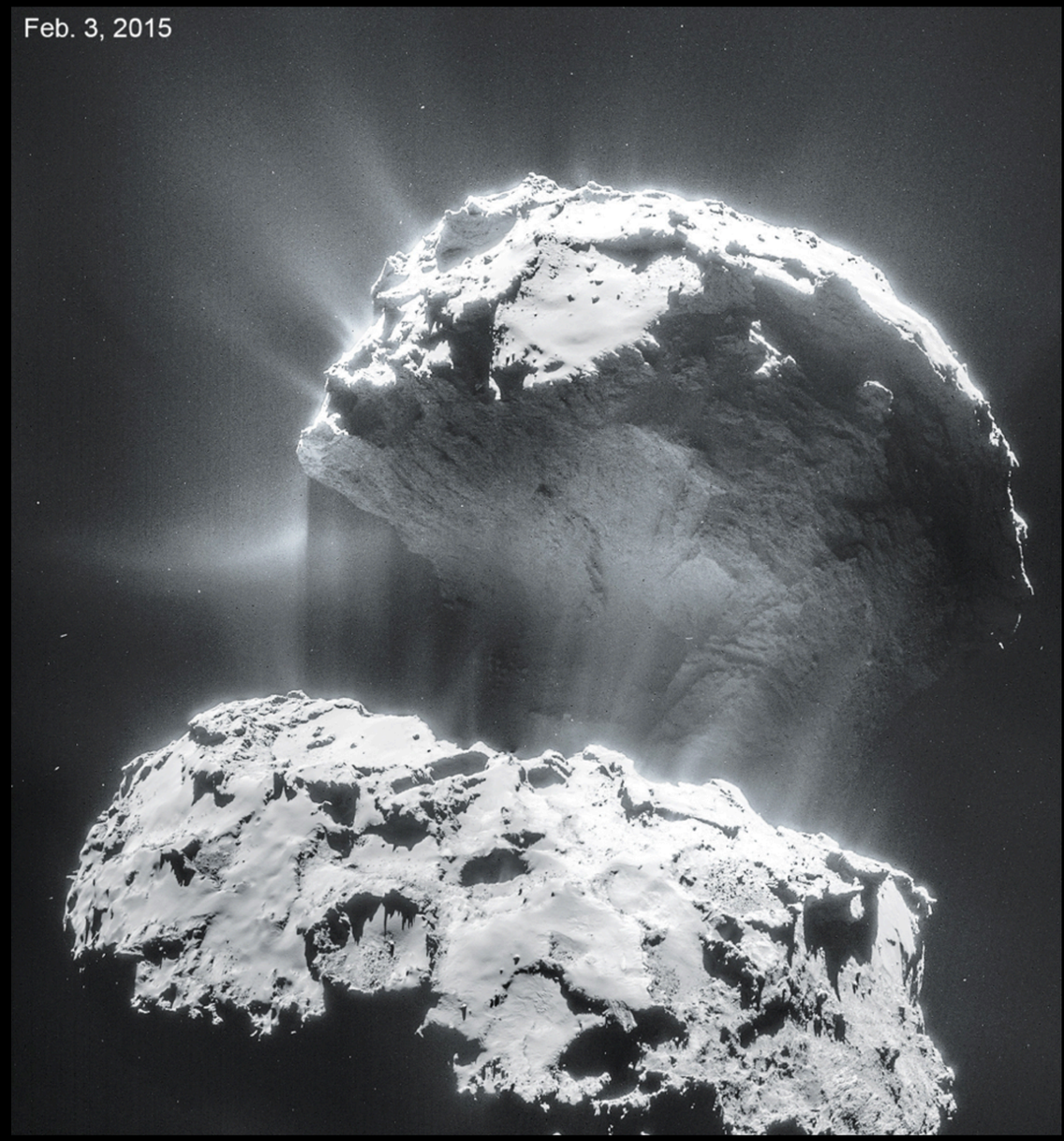
Halley's Comet had been observed for millennia as a harbinger of great events/ cataclysm because people didn't understand it.



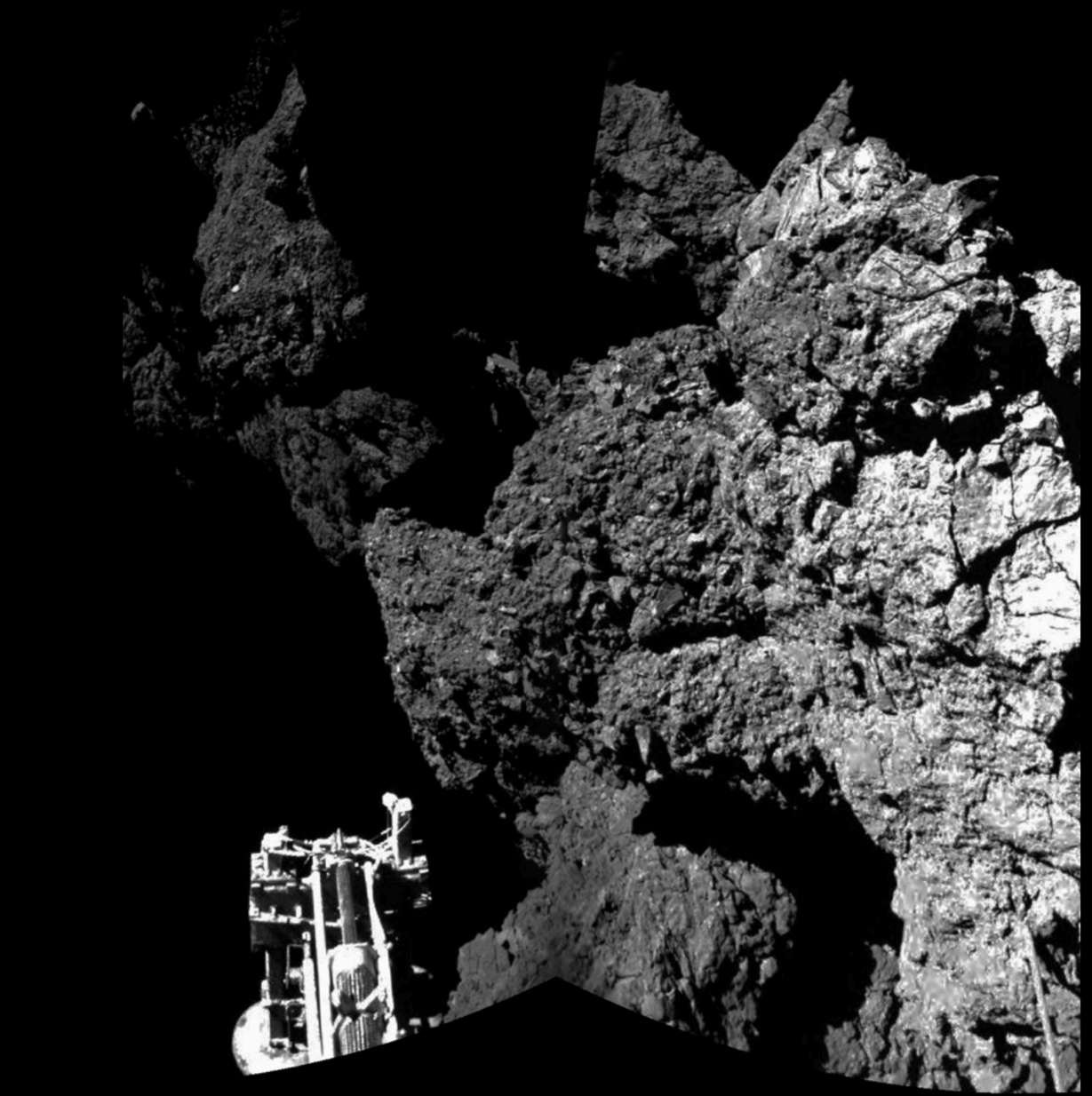
Churyumov-Gerasimenko (67P)

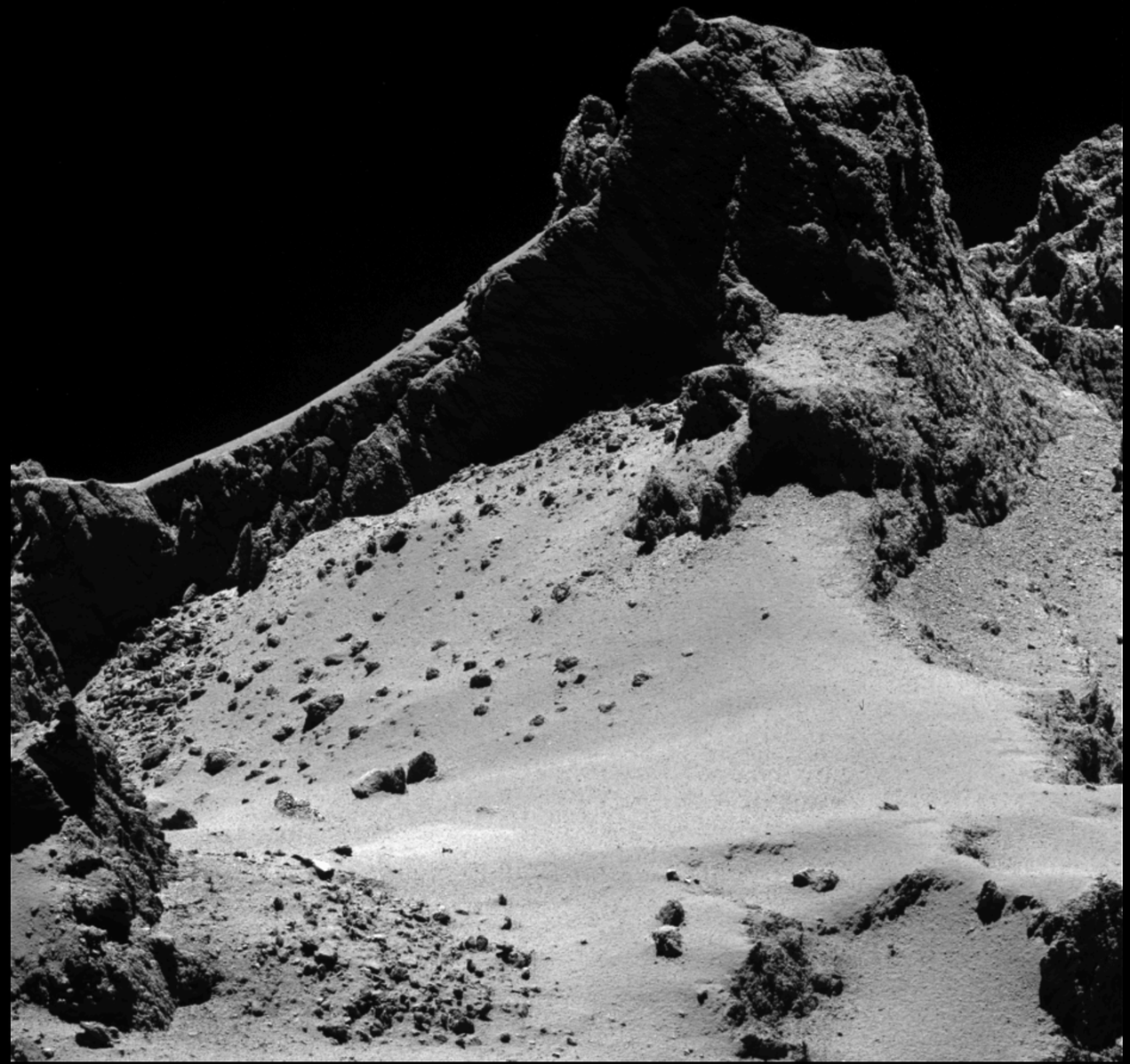
Launched in 2004, the Rosetta Mission set out to land on Comet 67P.

In 2016, it succeeded, providing the best pictures of any comet - an object that has remained mostly unchanged since the origin of our solar system.

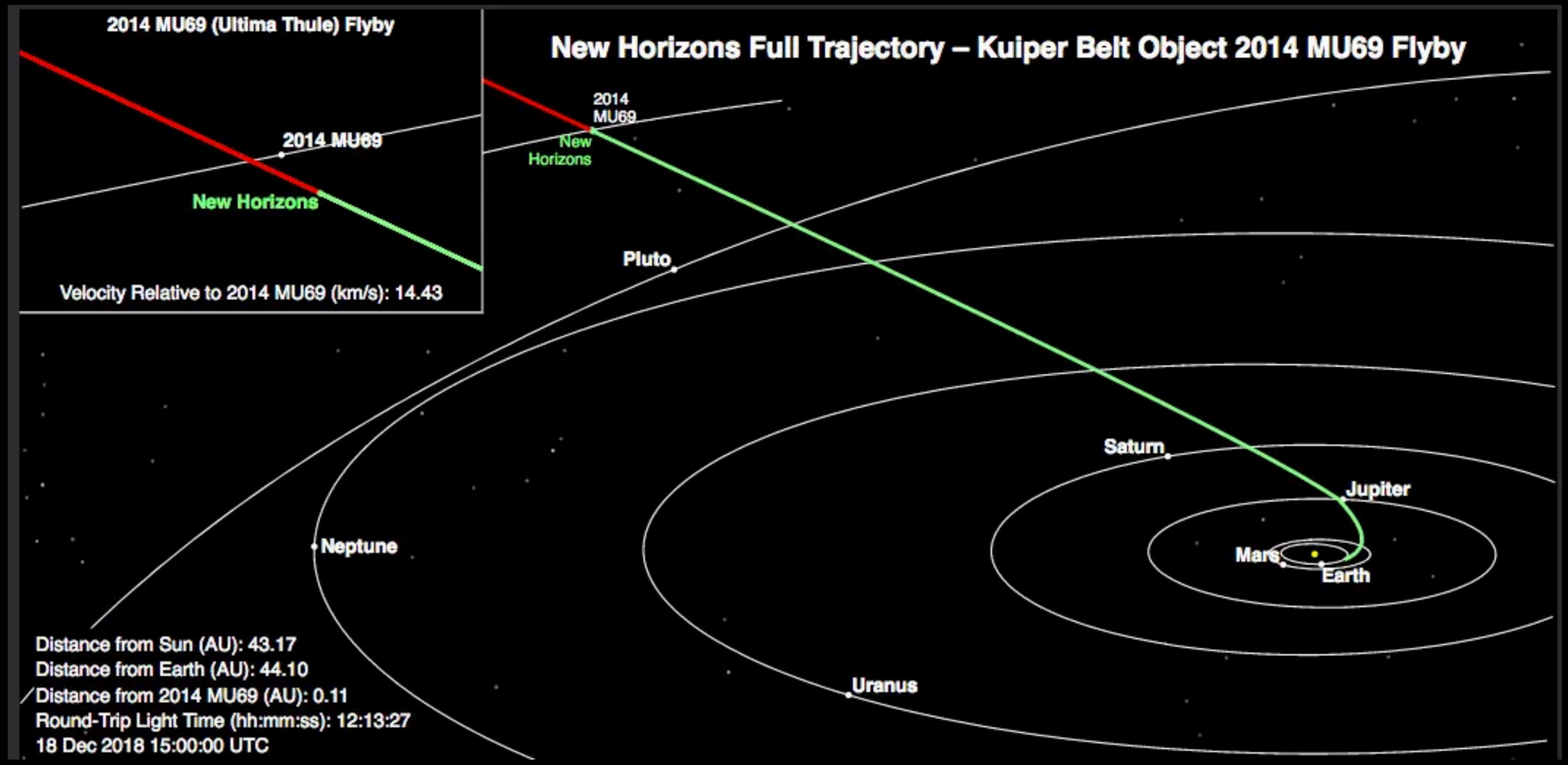


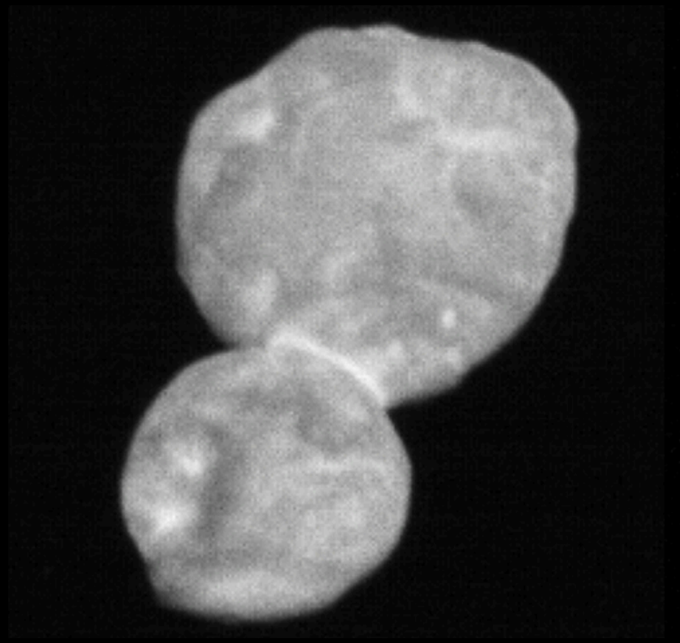
Churyumov-Gerasimenko (67P)

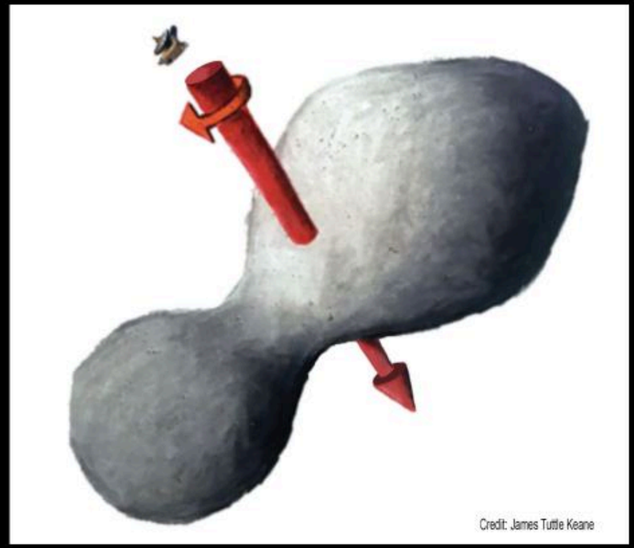




Ultima-Thule







Dwarf Planets


Nix
Kerberos
Styx
Charon
Hydra
Pluto
Dysnomia
Eris
Makemake
Namaka
Hi'iaka
Haumea
Sedna
2007 OR10
Weywot
Quaoar
Vanth
Orcus

Defining a Dwarf Planet

- Large enough for gravity to warp it into a spheroid.

- Must directly orbit the star, rather than another object.

- Has not cleared its orbital path of other debris.

5 official dwarf planets, but estimates put the total at around 200, and more than 100 candidates are currently being observed.

Pluto