

Asteroids, Comets, and Dwarf Planets: Their Nature, Orbits, and Impacts

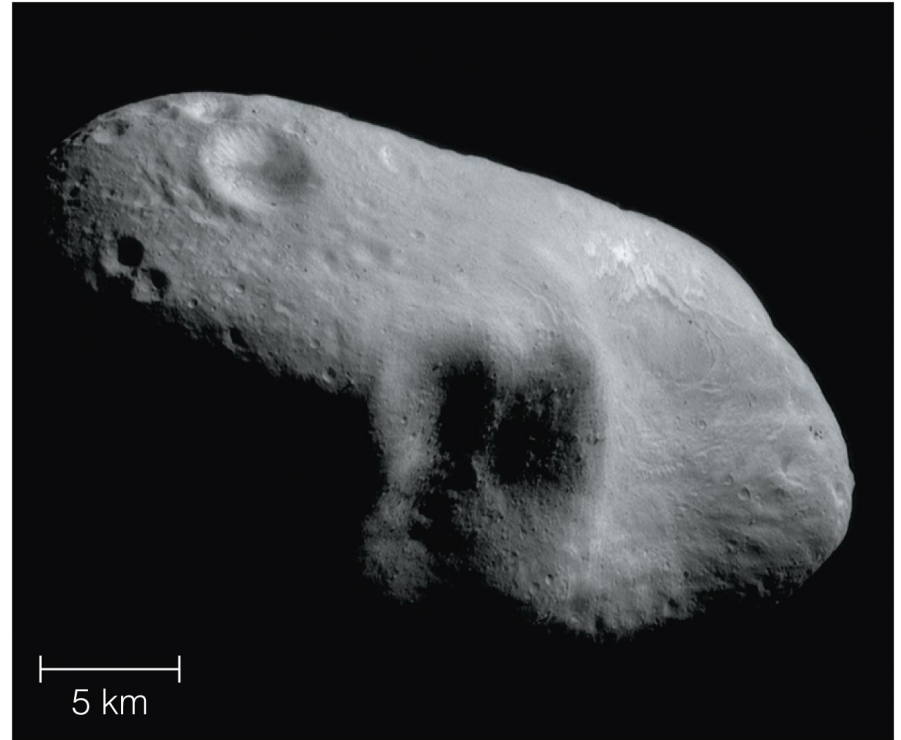


What are asteroids like?

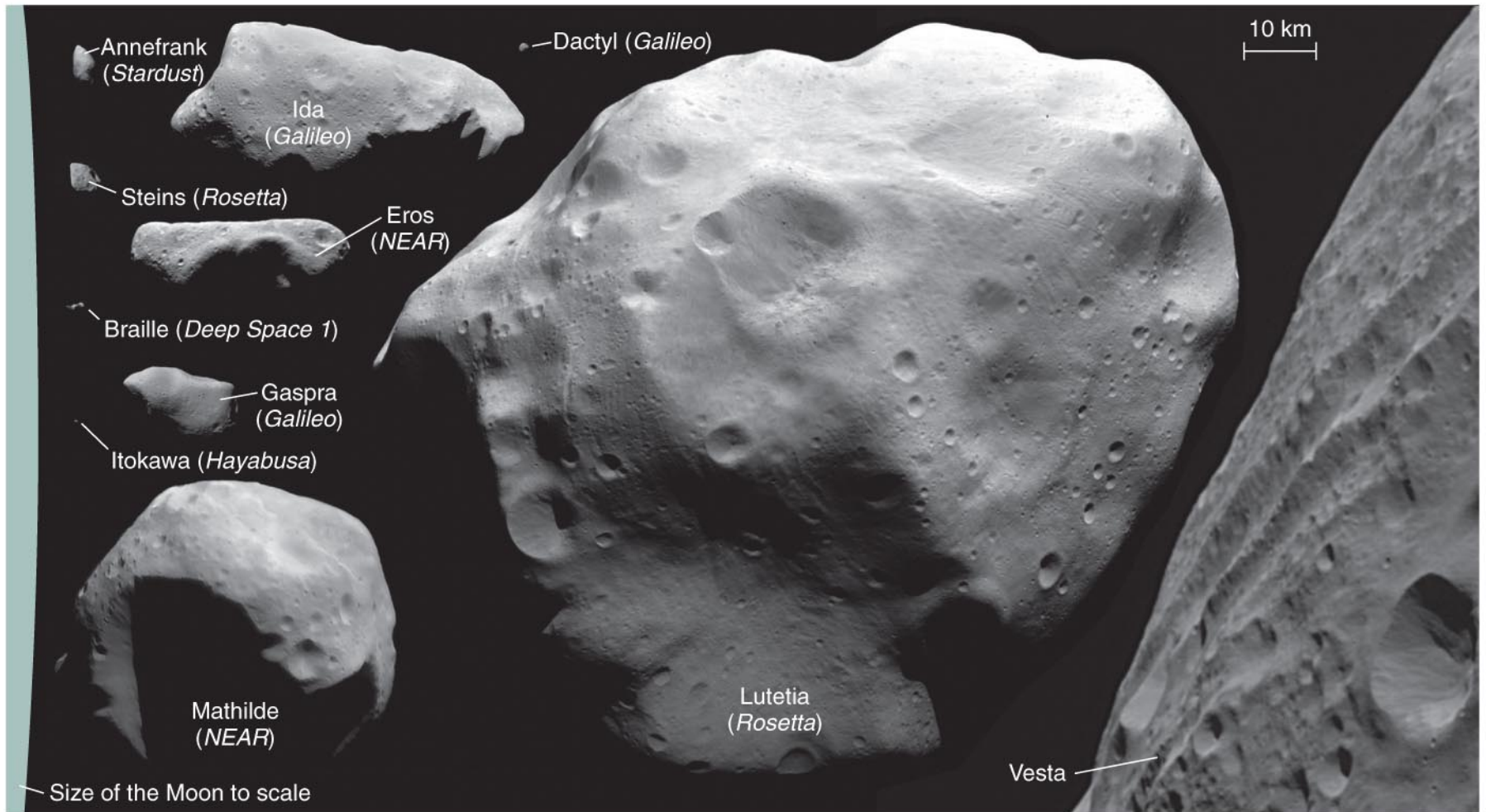
Asteroids are rocky leftovers of planet formation.

The largest is Ceres, diameter ~ 1000 kilometers.

150,000 in catalogs, and probably over a million with diameter >1 kilometer.

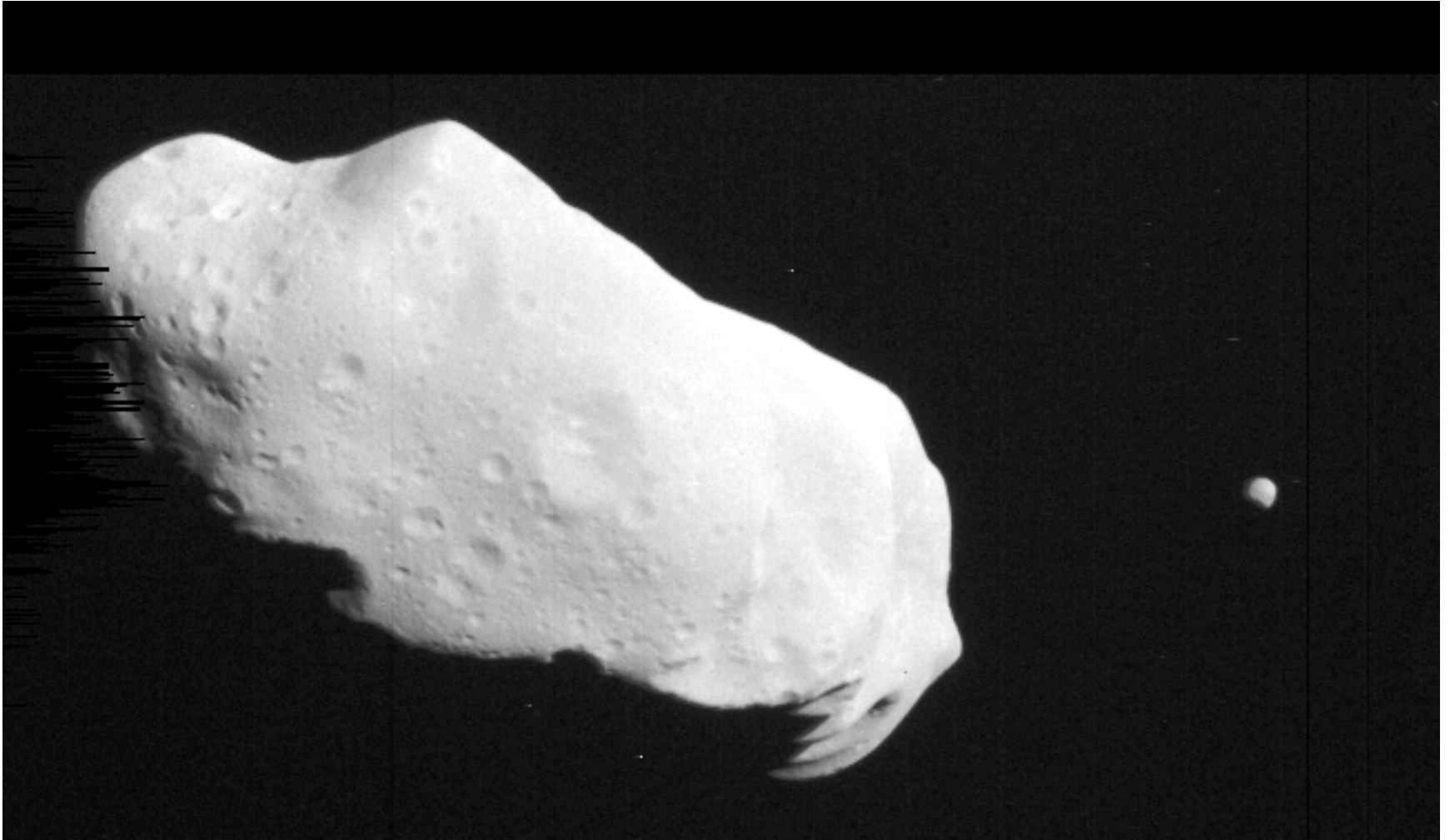


Small asteroids are more common than large asteroids.
All the asteroids in the solar system wouldn't add up to even a small terrestrial planet.



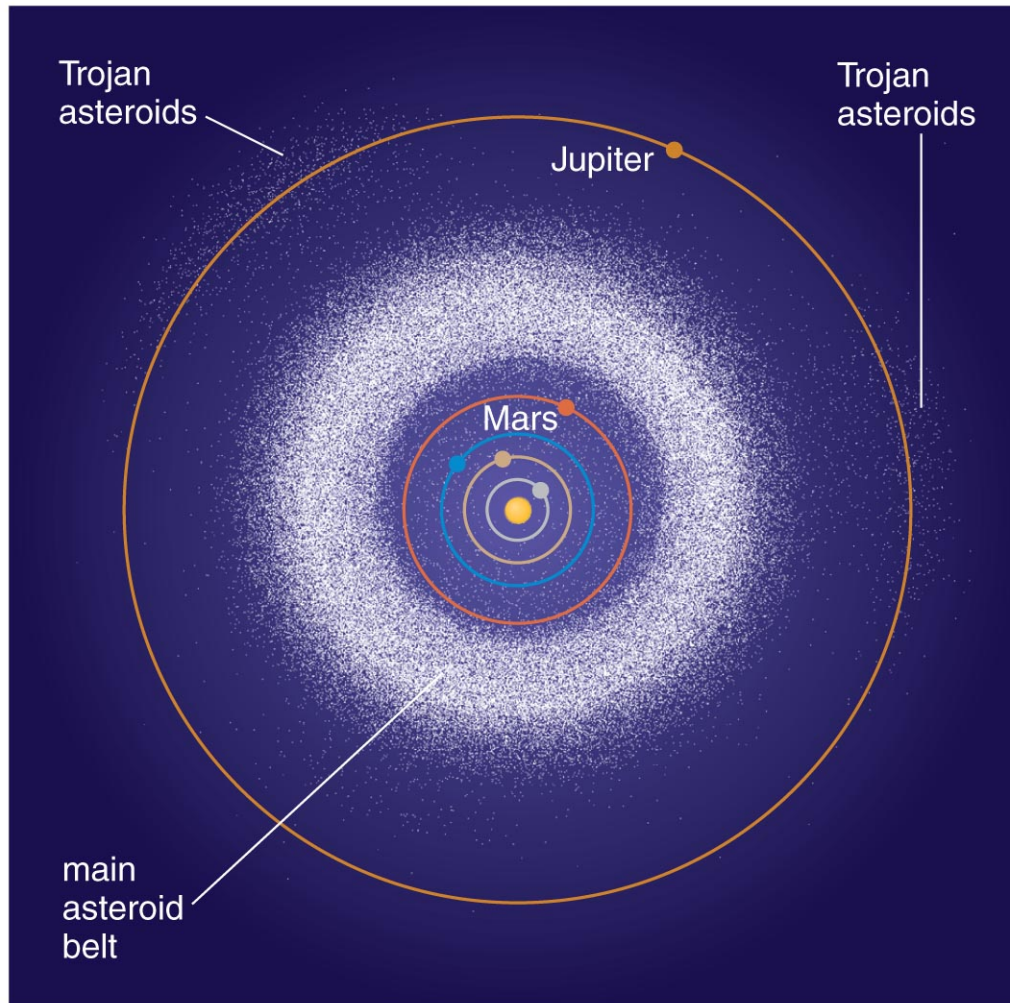
- Asteroids are cratered and not round.

Asteroids with Moons



Ida and Dactyl (imaged by Galileo probe)

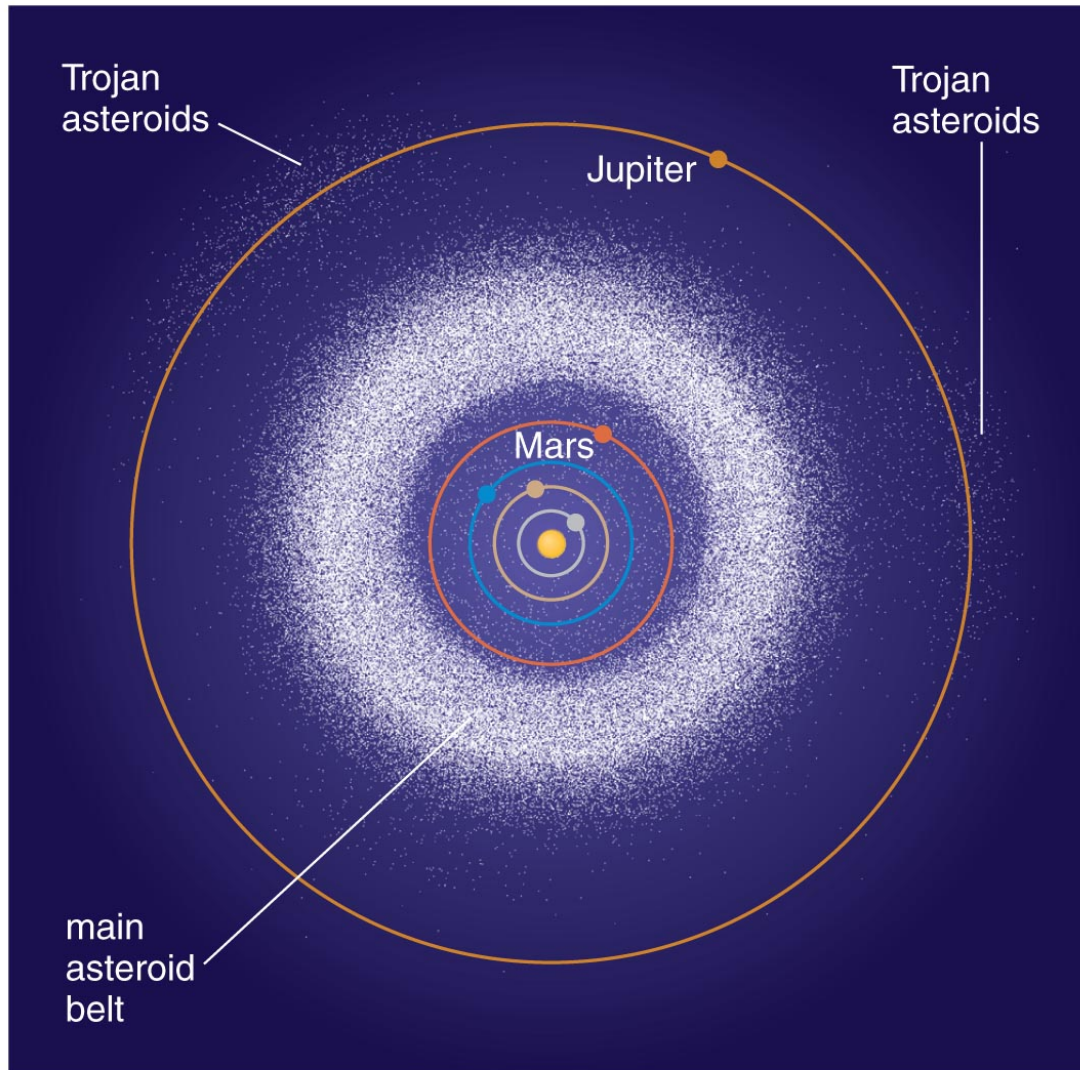
Asteroid Orbits



- Most asteroids orbit in the *asteroid belt* between Mars and Jupiter.
- *Trojan asteroids* follow Jupiter's orbit.
- Orbits of *near-Earth asteroids* cross Earth's orbit.

Why are there relatively few asteroids beyond Jupiter?

But why is there an asteroid belt?



Rocky planetesimals between Mars and Jupiter did not accrete into a planet.

Jupiter's gravity stirred up asteroid orbits and prevented them from accreting.

So what happened to asteroids closer to the Sun than the asteroid belt?

How are meteorites related to asteroids?



Meteor Terminology

- **Meteoroid:** a rock in space
- **Meteorite:** a rock from space that falls through Earth's atmosphere
- **Meteor:** the bright trail left by a meteorite

Meteorite Impacts

Small impacts
not uncommon.

But only one
known story of a
person getting
hit, [in 1954](#).



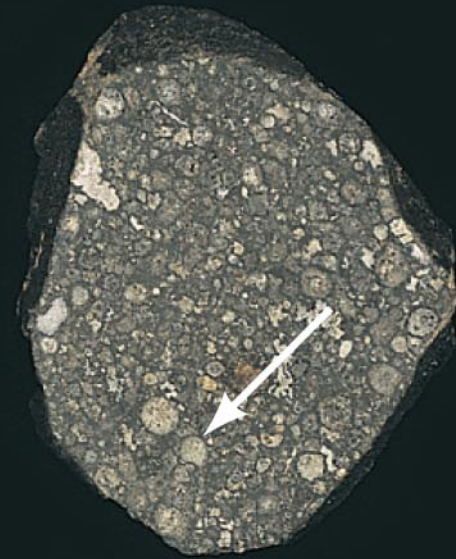
Meteorite Types

- 1) Primitive: unchanged in composition since they first formed 4.6 billion years ago
- 2) Processed: younger; have experienced processes like volcanism or differentiation

Primitive Meteorites



Stony primitive meteorite: Made of rocky material embedded with shiny metal flakes (arrow).



Carbon-rich primitive meteorite: Also rocky but with dark carbon compounds and small whitish spheres (arrow).

a Primitive meteorites.

Processed Meteorites



Metal-rich processed meteorite:
Made of iron and other metals that came from a shattered asteroid's core.



Rocky processed meteorite:
Resembles volcanic rocks found on Earth. This meteorite probably came from Vesta's south pole.

b Processed meteorites.

Meteorites from Moon and Mars

- A few meteorites arrive from the Moon and Mars.
- Composition differs from the asteroid fragments.
- A cheap (but slow) way to acquire Moon rocks and Mars rocks

What have we learned?

- **What are asteroids like?**
 - They are rocky, small, potato-shaped leftovers from the era of planet formation.
- **Why is there an asteroid belt?**
 - Jupiter's gravity prevented planetesimals between Jupiter and Mars from forming a planet.

What have we learned?

- **How are meteorites related to asteroids?**
 - Primitive meteorites are remnants from solar nebula.
 - Processed meteorites are fragments of larger bodies that underwent differentiation.

12.2 Comets

- Our goals for learning:
 - **What are comets like?**
 - **Where do comets come from?**

What are comets like?

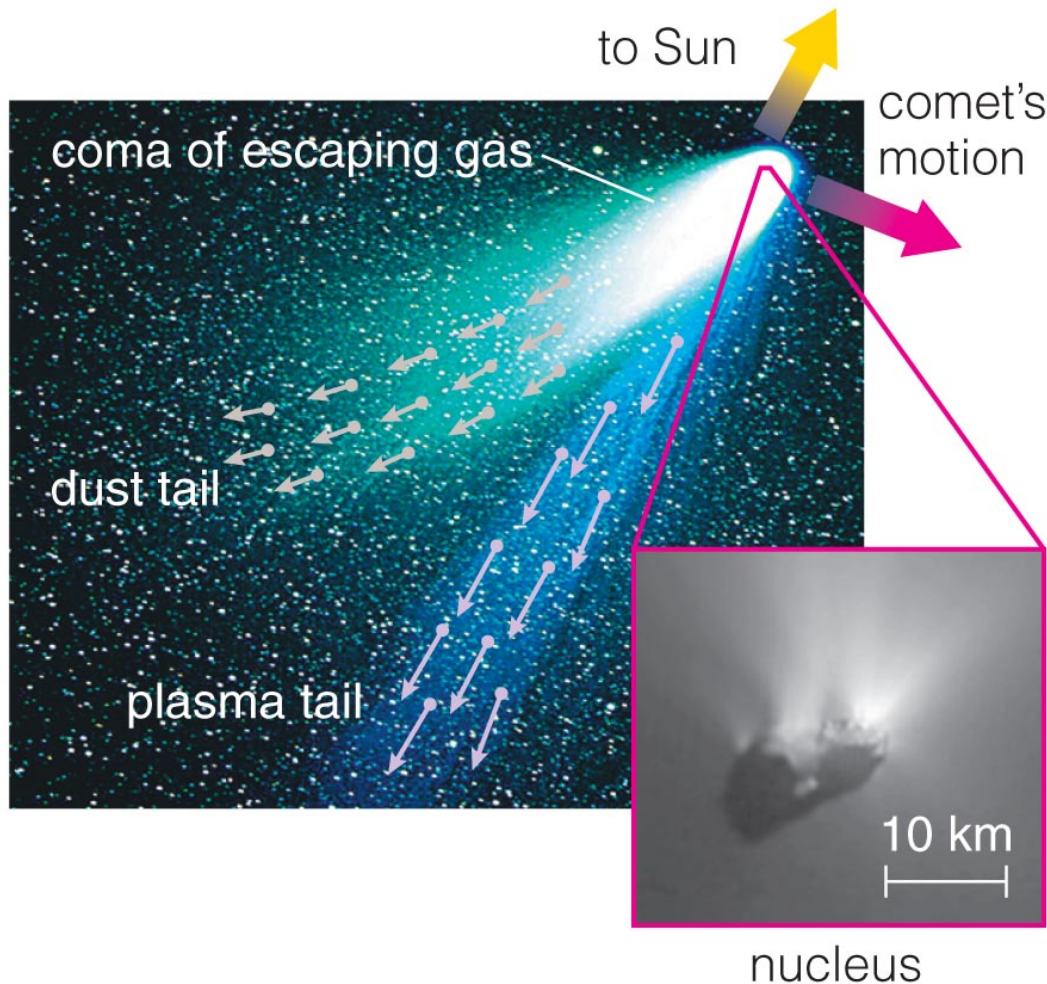


a Comet Hyakutake.

Comet Facts

- Formed beyond the frost line, comets are icy counterparts to asteroids.
- Nucleus of comet is a "dirty snowball."
- Most comets do not have tails.
- Most comets remain perpetually frozen in the outer solar system.
- Only comets that enter the inner solar system grow tails.

Anatomy of a Comet

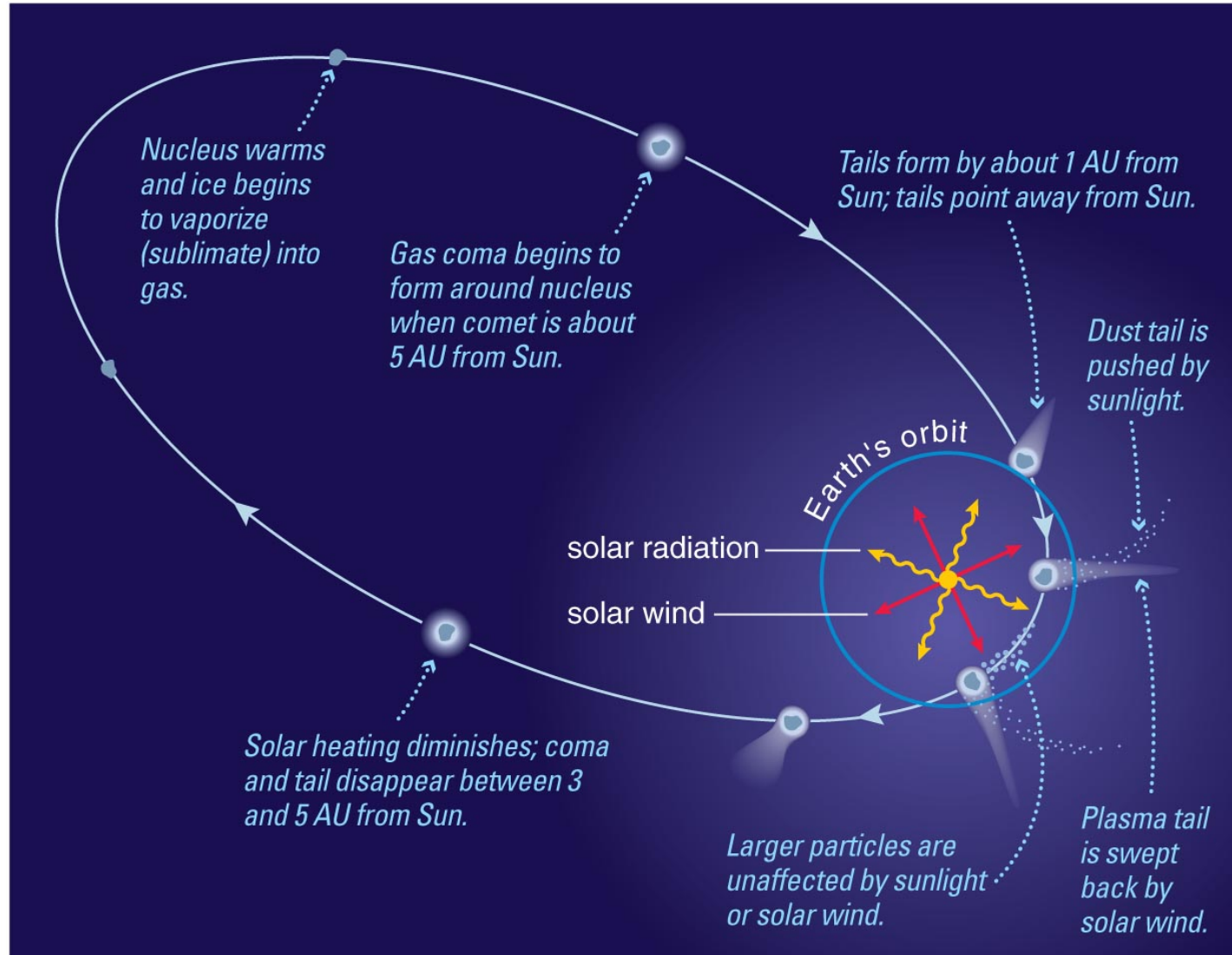


A *coma* is the atmosphere that comes from a comet's heated nucleus.

A *plasma tail* is gas escaping from coma, pushed by the solar wind.

A *dust tail* is pushed by photons.

Growth of Tail



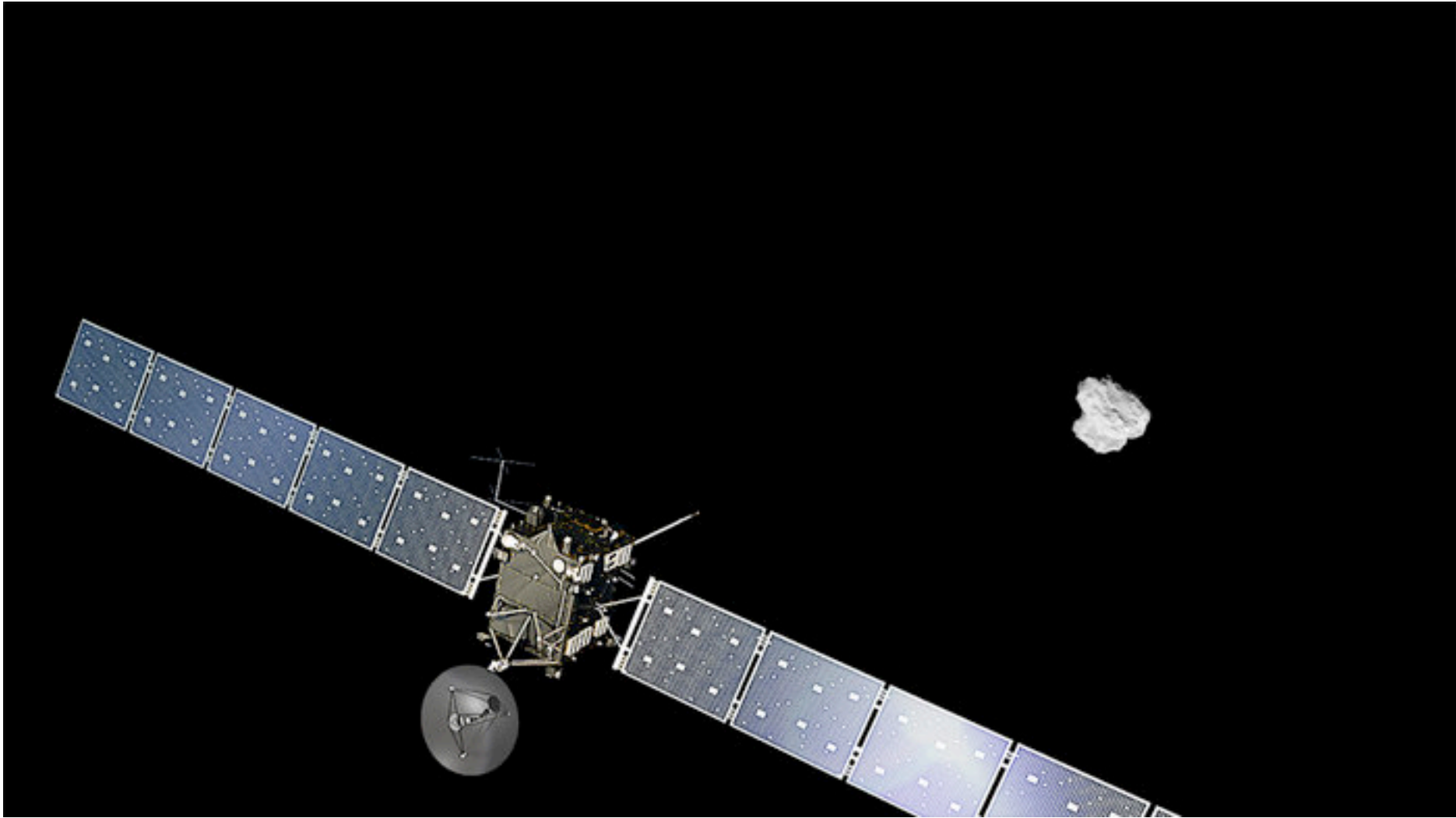
a This diagram (not to scale) shows the changes that occur when a comet's orbit takes it on a passage into the inner solar system.



b This digital composite photo, taken in Australia during the 2001 Leonid meteor shower, shows meteors as streaks of light. The large rock is Uluru, also known as Ayers Rock.

- Comets eject small particles that follow the comet around in its orbit and cause meteor showers when Earth crosses the comet's orbit.

What does a comet nucleus look like?



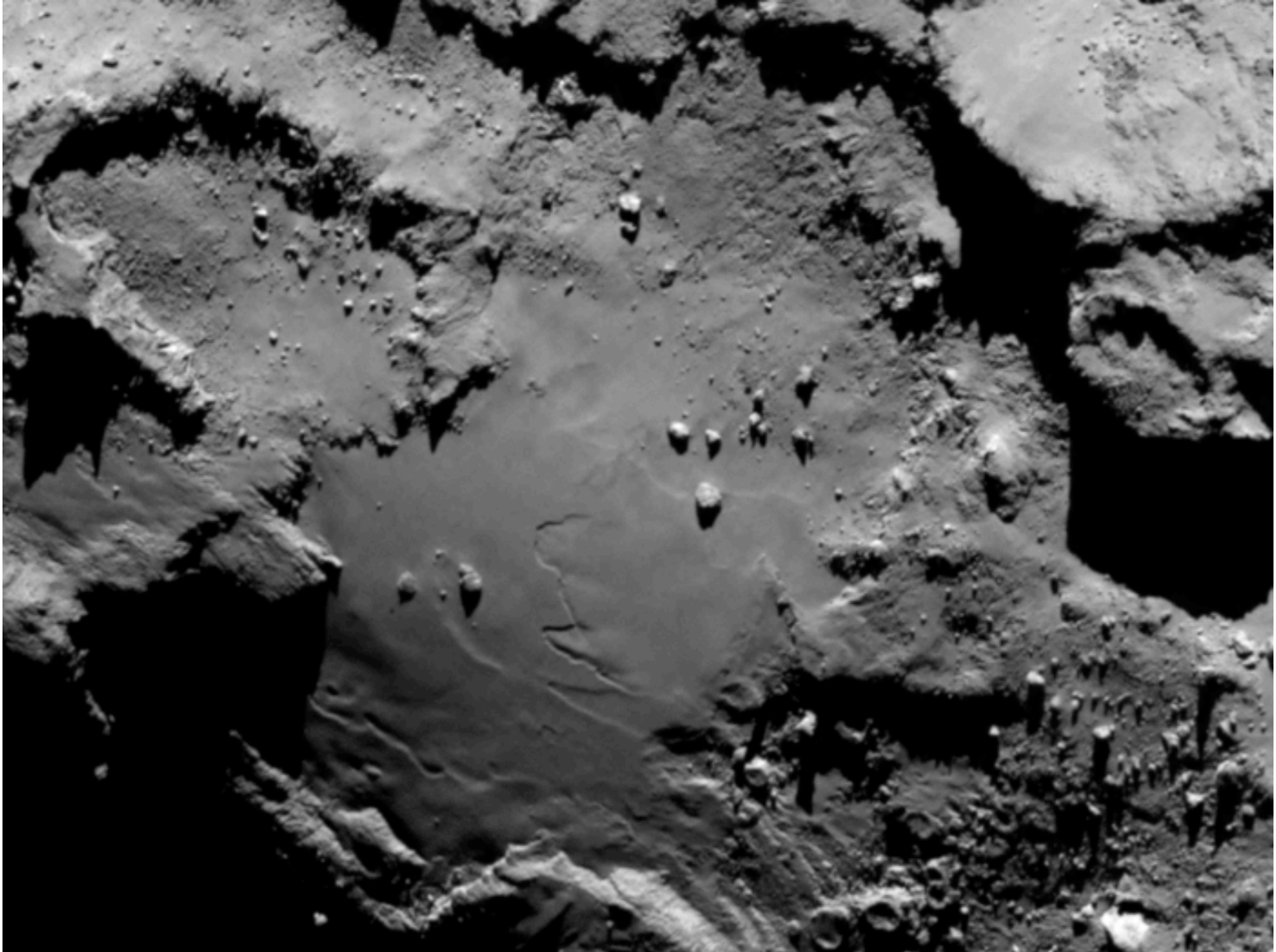
Rosetta and Comet 67P/Churyumov-Gerasimenko

What does a comet nucleus look like?



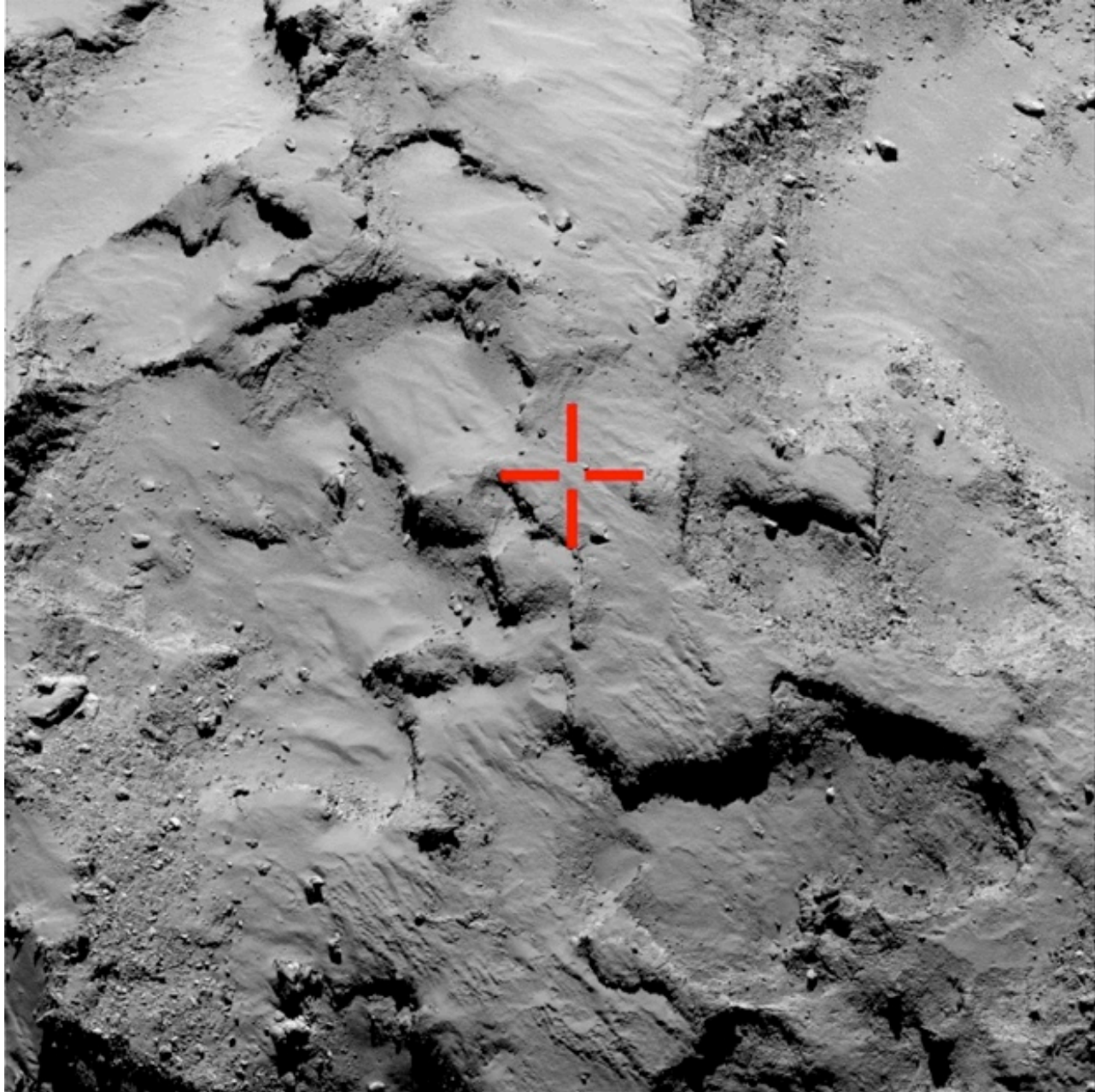
Rotating View

What does a comet nucleus look like?

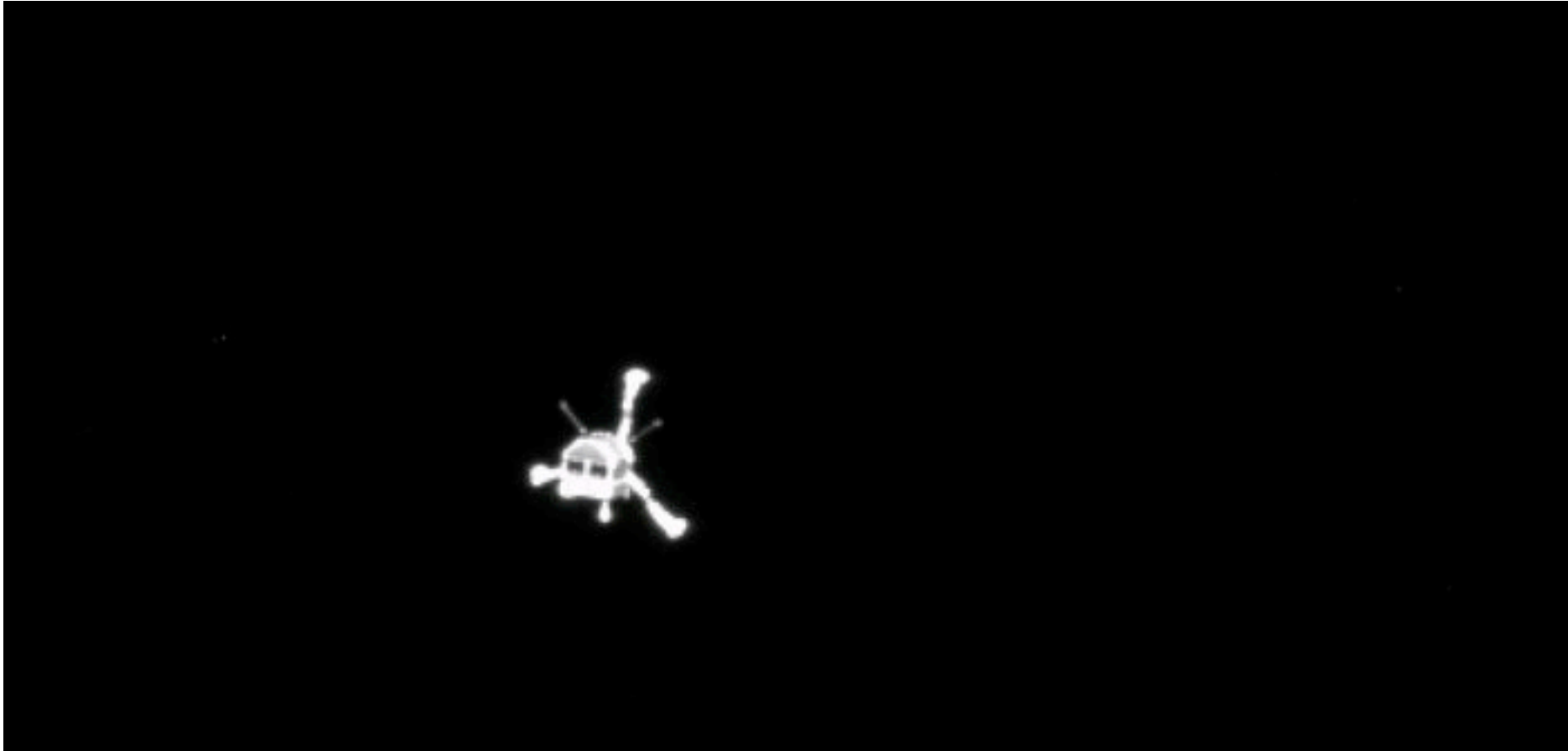


[Rosetta images of comet](#)

How does one land on a comet?



How does one land on a comet?



Rosetta's view of the Philae descent

How does one land on a comet?

3 km away

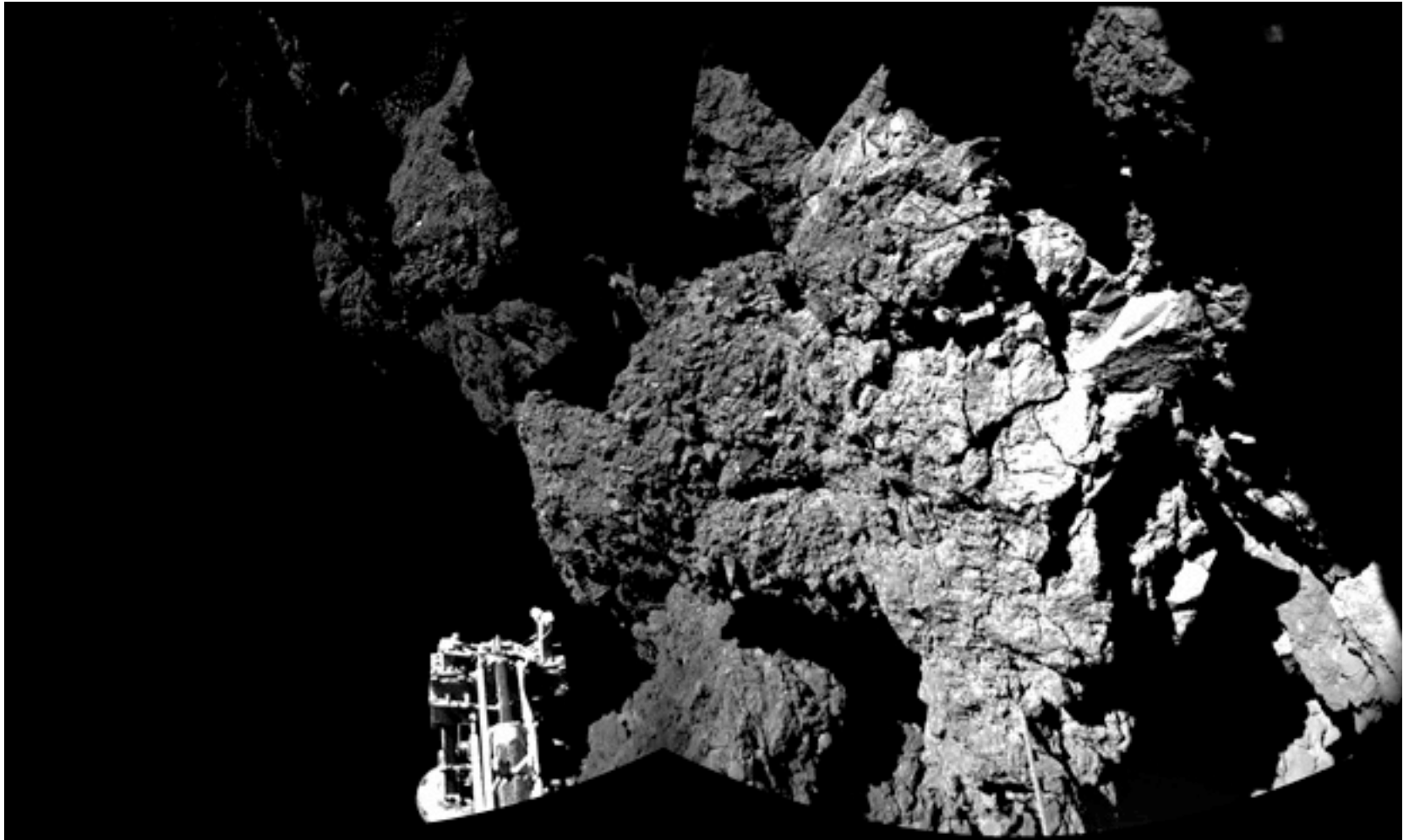


How does one land on a comet?



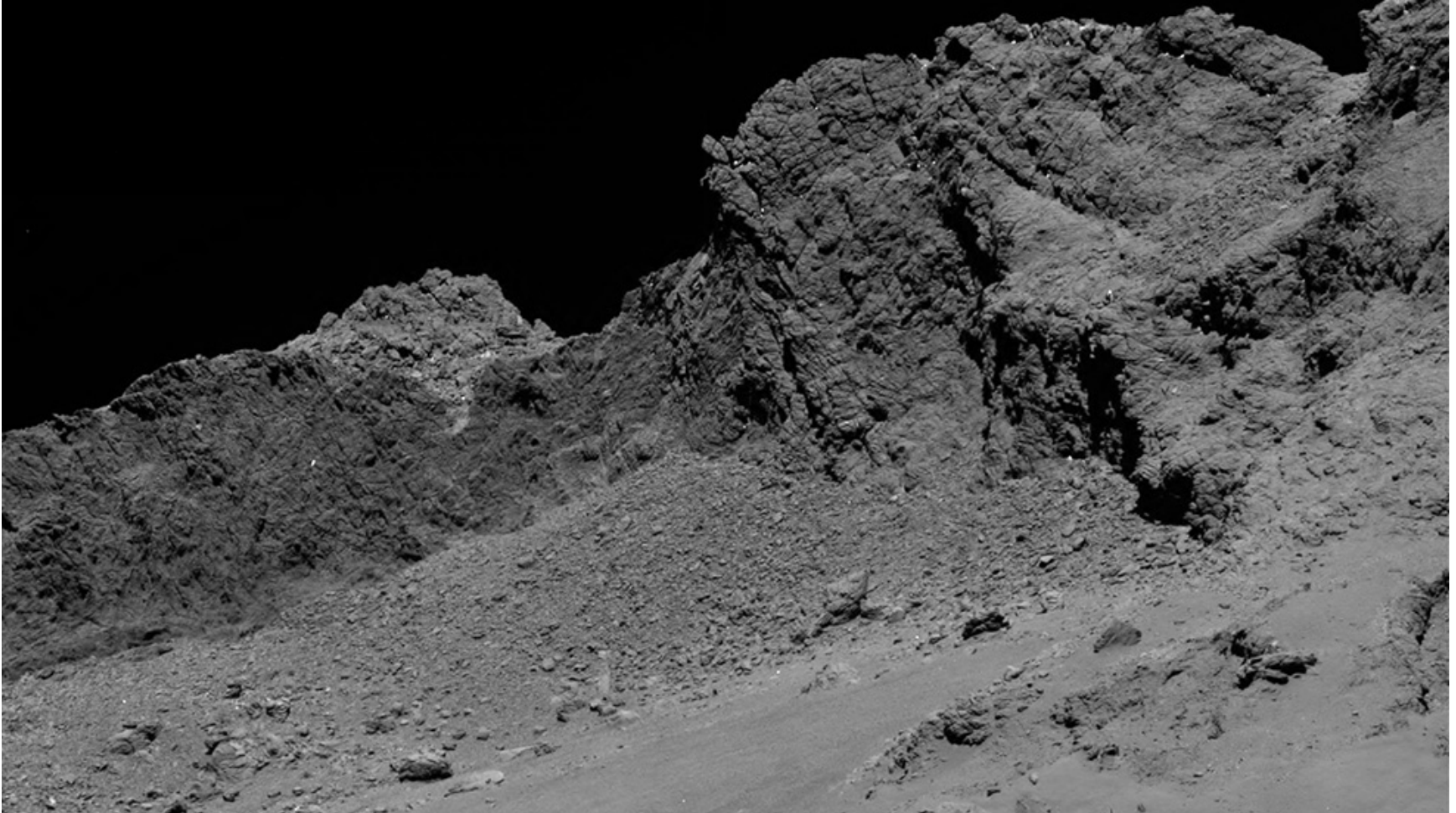
40 meters away.....

How does one land on a comet?



First image from surface

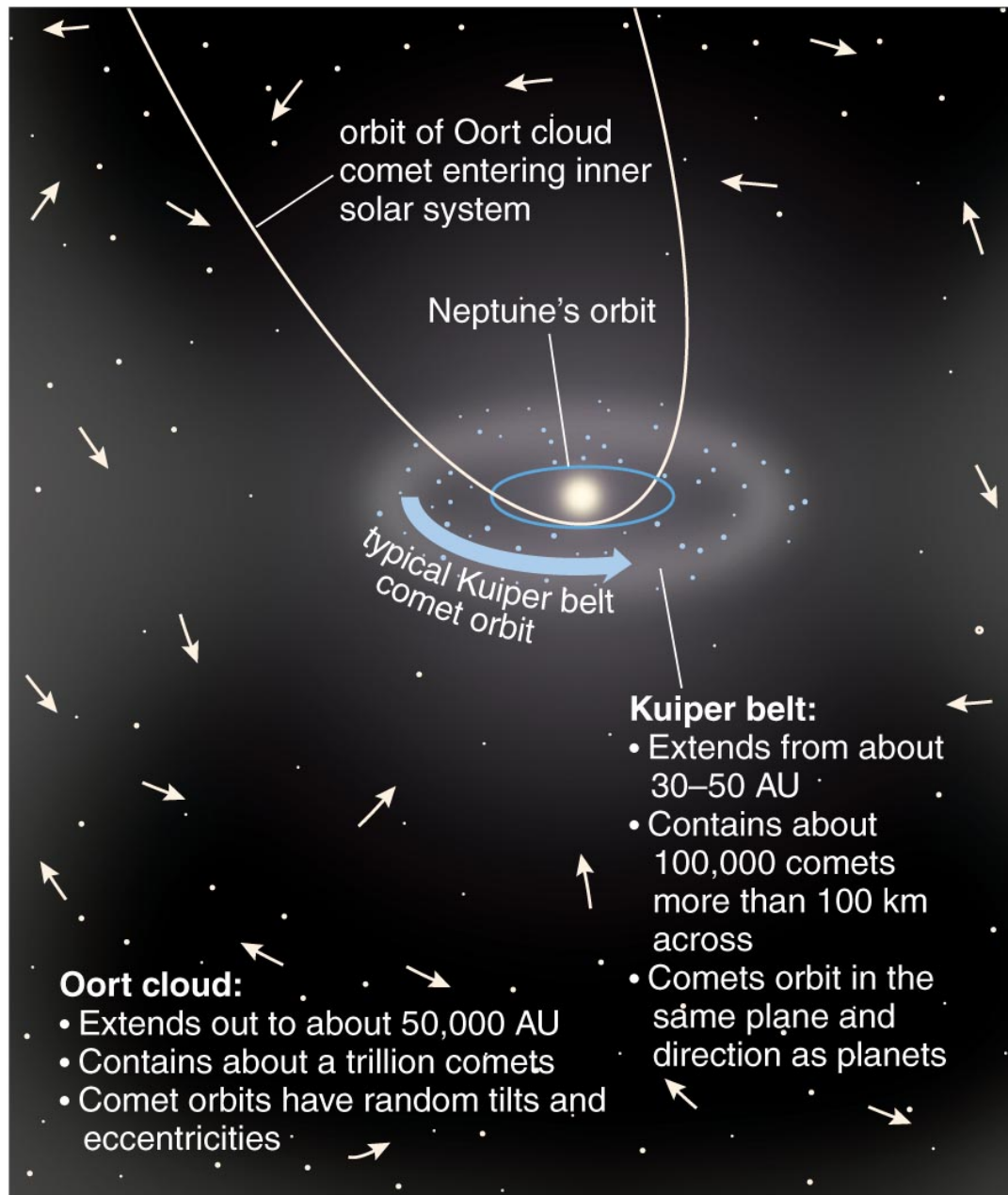
Rosetta's final descent



Where do comets come from?



b Comet Hale-Bopp, photographed over Phoenix.



- Only a tiny number of comets enter the inner solar system. Most stay far from the Sun.
- ***Oort cloud:***
on random orbits extending to about 50,000 AU
- ***Kuiper belt:***
on orderly orbits from 30–100 AU in disk of solar system

How did they get there?

- Kuiper belt comets formed in the Kuiper belt: flat plane, aligned with the plane of planetary orbits, orbiting in the same direction as the planets
- Oort cloud comets were once closer to the Sun, but they were kicked out there by gravitational interactions with jovian planets: spherical distribution, orbits in any direction

What have we learned?

- **What are comets like?**
 - Comets are like dirty snowballs.
 - Most are far from Sun and do not have tails.
 - Tails grow when comet nears Sun and nucleus heats up.
- **Where do comets come from?**
 - Comets in plane of solar system come from Kuiper belt.
 - Comets on random orbits come from Oort cloud.

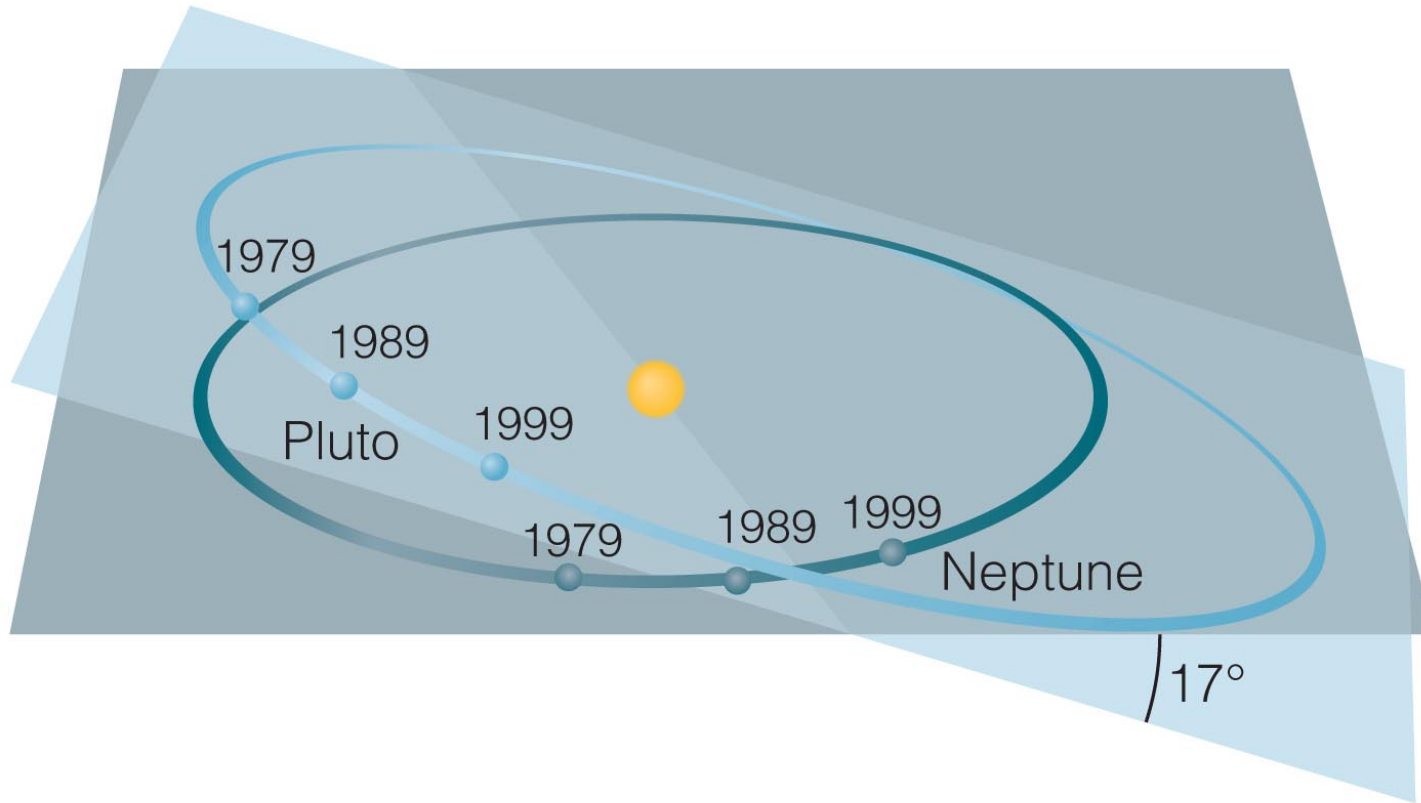
12.3 Pluto: Lone Dog No More

- Our goals for learning:
 - **How big can a comet be?**
 - **What are the large objects of the Kuiper belt like?**

How big can a comet be?



Pluto's Orbit



Pluto will never hit Neptune, even though their orbits cross:

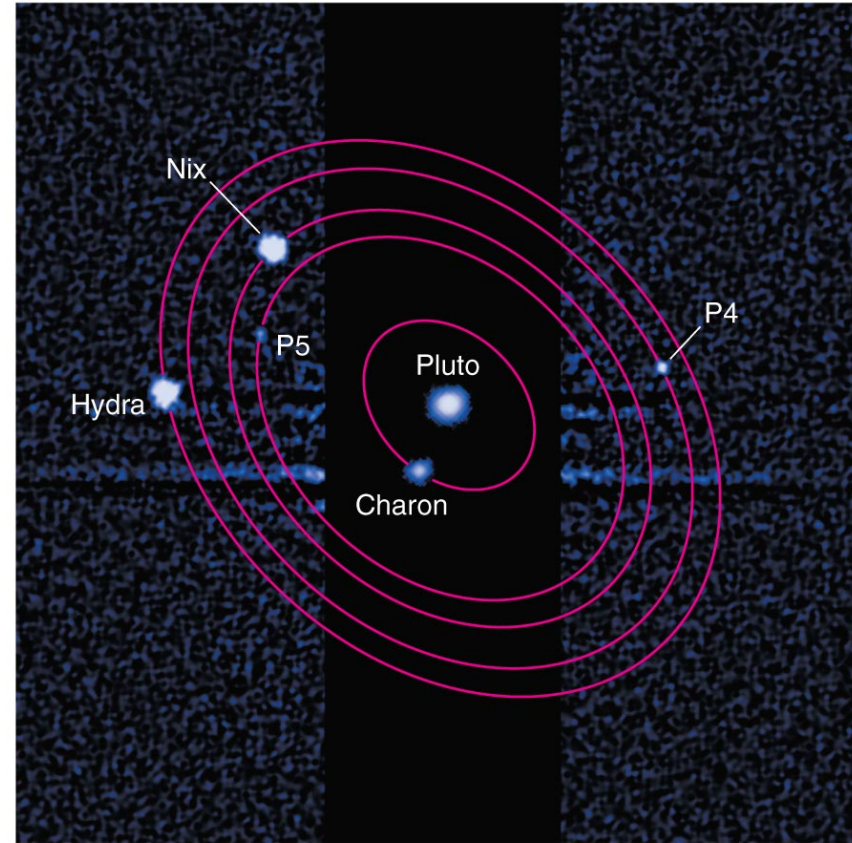
- Because of the tilt of Pluto's orbit, and
- Because their 3:2 orbital resonance (*Neptune orbits three times during the time Pluto orbits twice*) keeps the two safely away from one another.

What is Pluto like?

Its moon Charon is nearly as large as Pluto itself (probably made by a major impact).

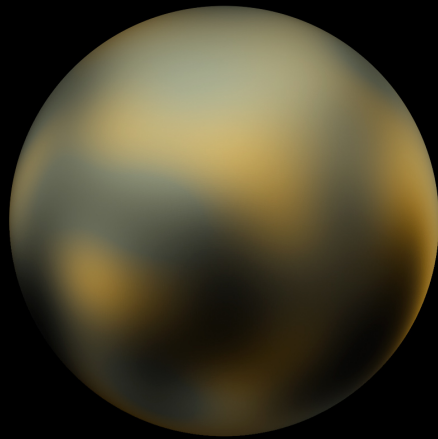
Pluto is very cold (40 K).

Pluto has a thin nitrogen atmosphere that will refreeze onto the surface as Pluto's orbit takes it farther from the Sun.

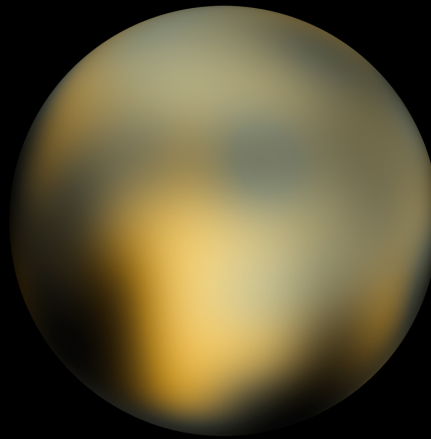


a This Hubble Space Telescope photo shows Pluto and its five known moons, along with orbital paths for the moons. Horizontal stripes are scattered light from Charon and Pluto in the long exposure.

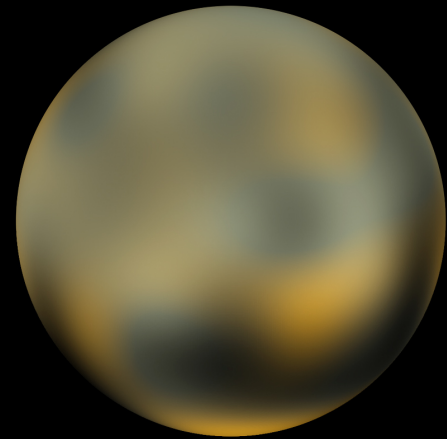
Pluto Images from Hubble Space Telescope



90°



180°



270°

Pluto Faces
Hubble Space Telescope • ACS/HRC

NASA, ESA, and M. Buie (Southwest Research Institute)

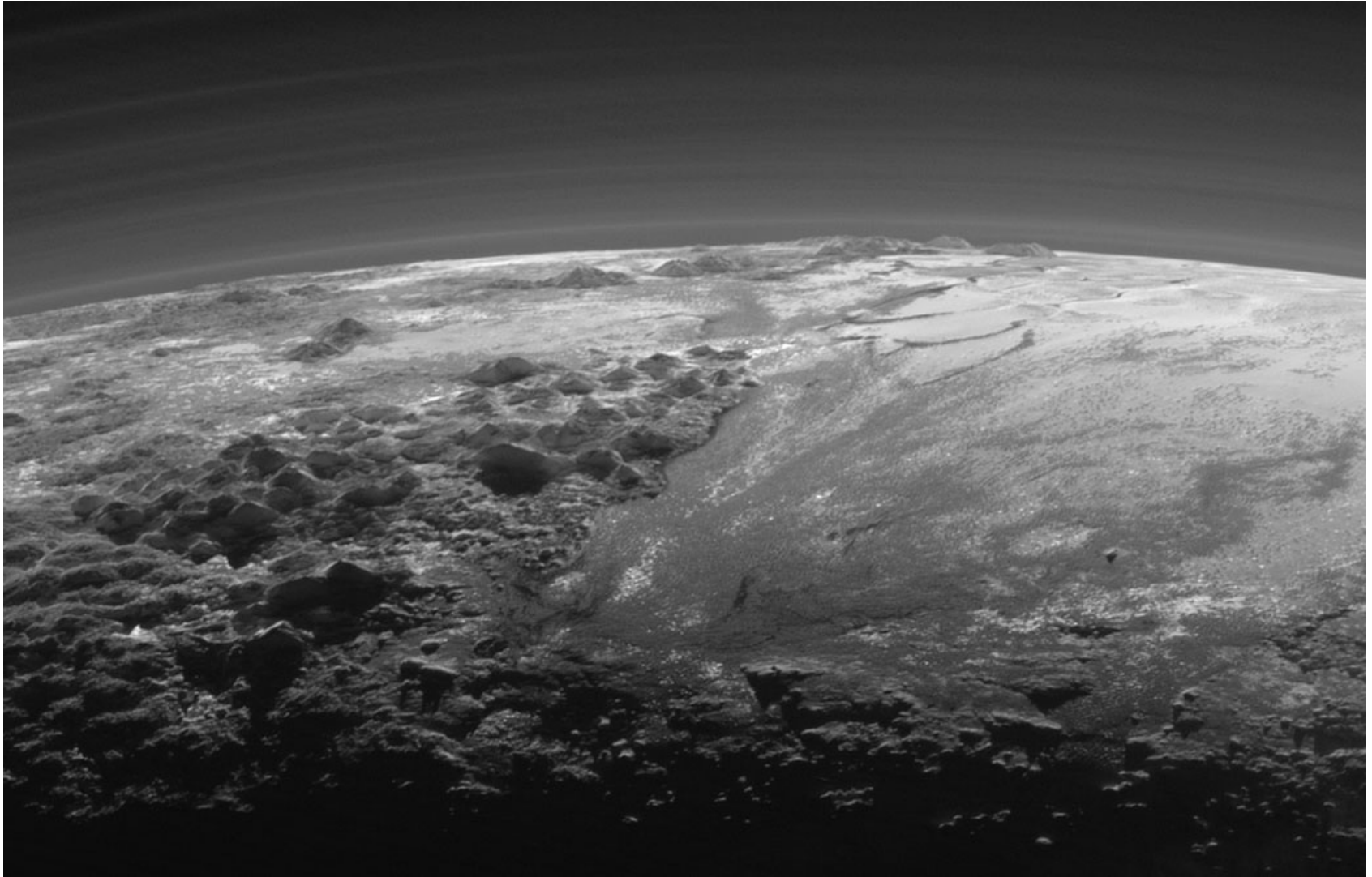
STScI-PRC10-06a

Pluto New Horizons (2015)

Pluto and Charon

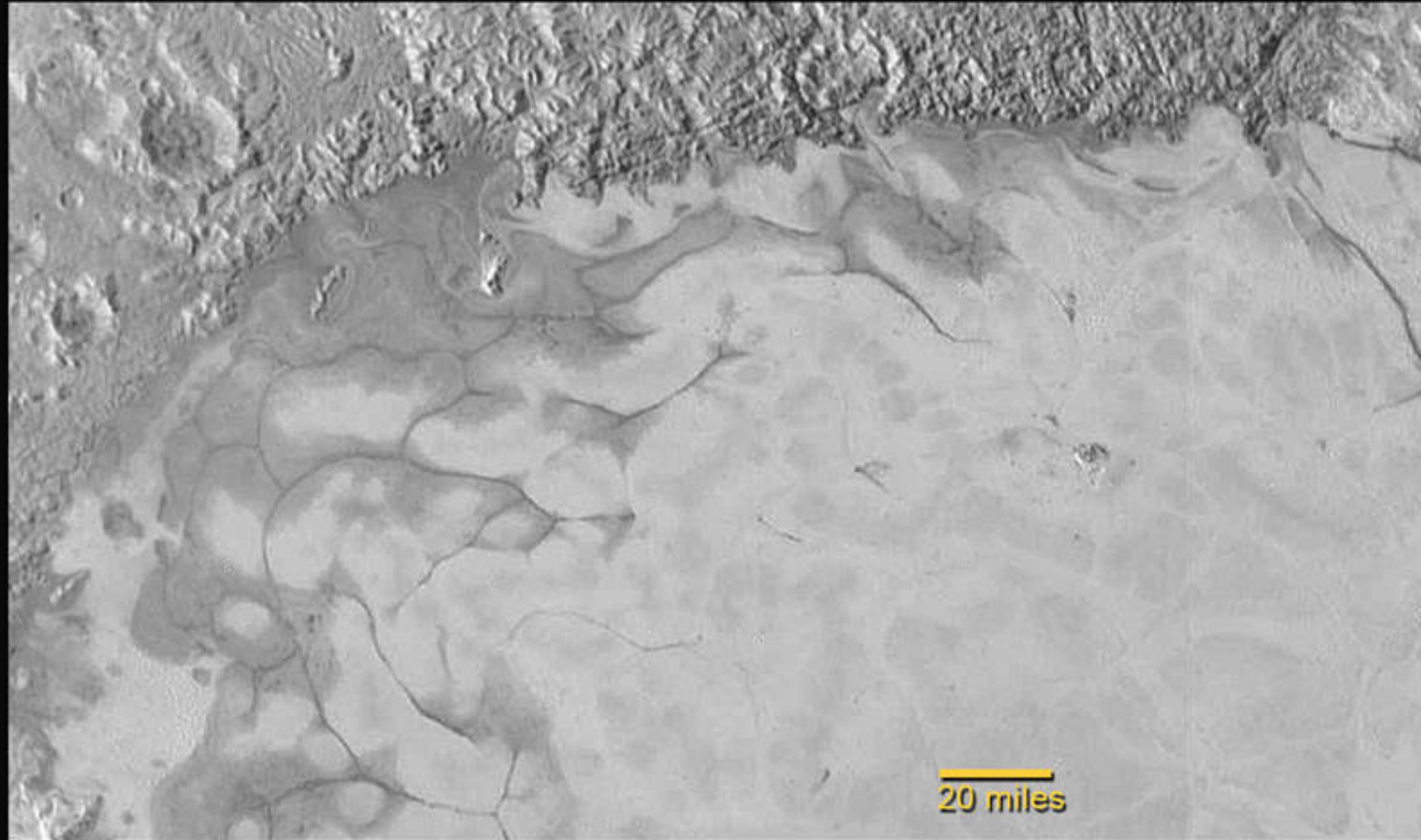


Pluto New Horizons



Icy mountains and flat ice plains

Pluto New Horizons



Glacial Flows

Is Pluto a Planet?

- Much smaller than the terrestrial or jovian planets
- Not a gas giant like other outer planets
- Has an icy composition like a comet
- Has a very elliptical, inclined orbit
- Has more in common with comets than with the eight major planets

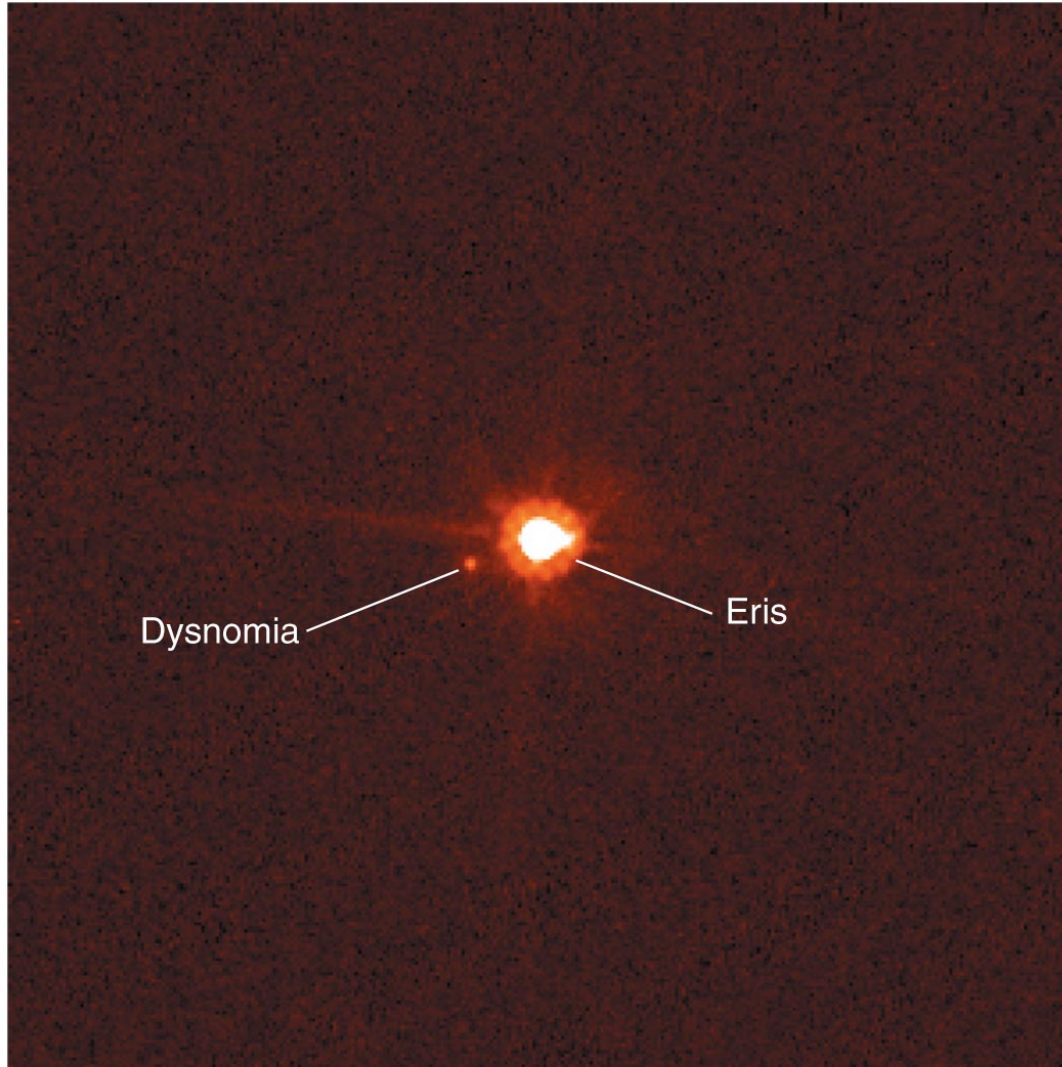
Other Icy Bodies



There are many icy objects like Pluto on elliptical, inclined orbits beyond Neptune.

The largest of these, Eris, was discovered in summer 2005, and is even larger than Pluto.

Kuiper Belt Objects



- These large, icy objects have orbits similar to the smaller objects in the Kuiper belt that become short period comets.
- So are they very large comets or very small planets?

Pluto and Eris

- Pluto's size was overestimated after its discovery in 1930, and nothing of similar size was discovered for several decades.
- Now other large objects have been discovered in Kuiper belt, including Eris.
- The International Astronomical Union (IAU) now classifies Pluto and Eris as ***dwarf planets***.
- Dwarf planets have not cleared most other objects from their orbital paths.

What have we learned?

- **How big can a comet be?**
 - The Kuiper belt from which comets come contains objects as large as Pluto.
- **What are the large objects of the Kuiper belt like?**
 - Large objects in the Kuiper belt have orbits and icy compositions like those of comets.