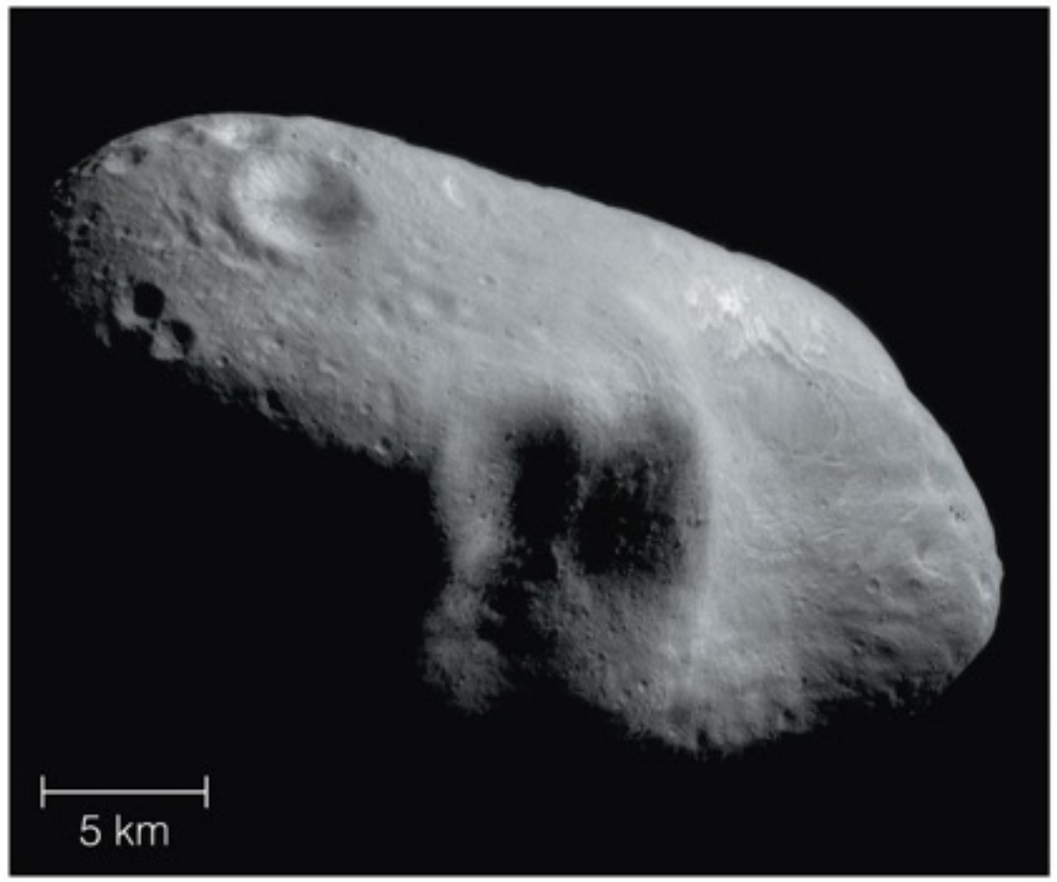
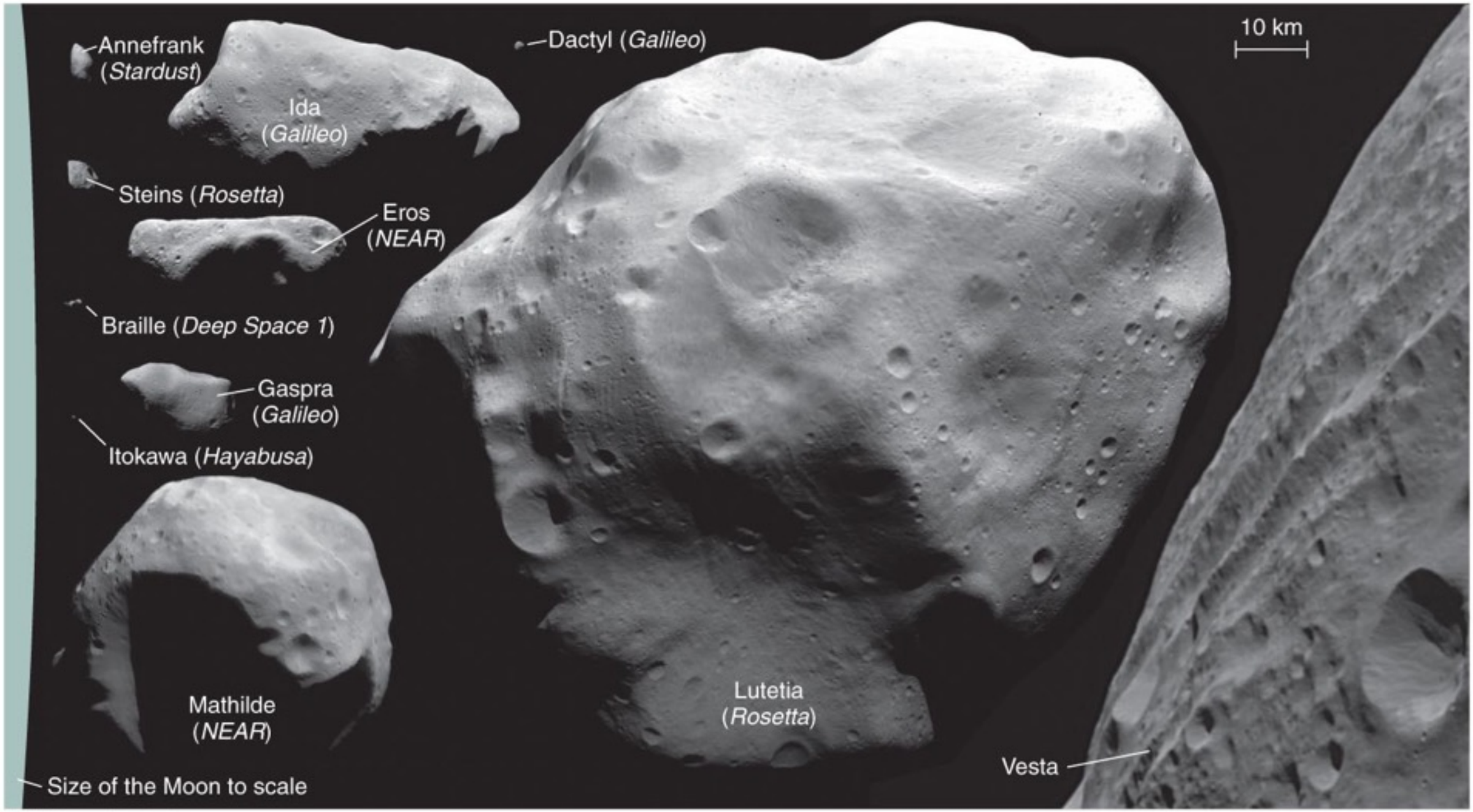
Asteroids, Comets, and Dwarf Planets: Their Nature, Orbits, and Impacts

Asteroid Facts

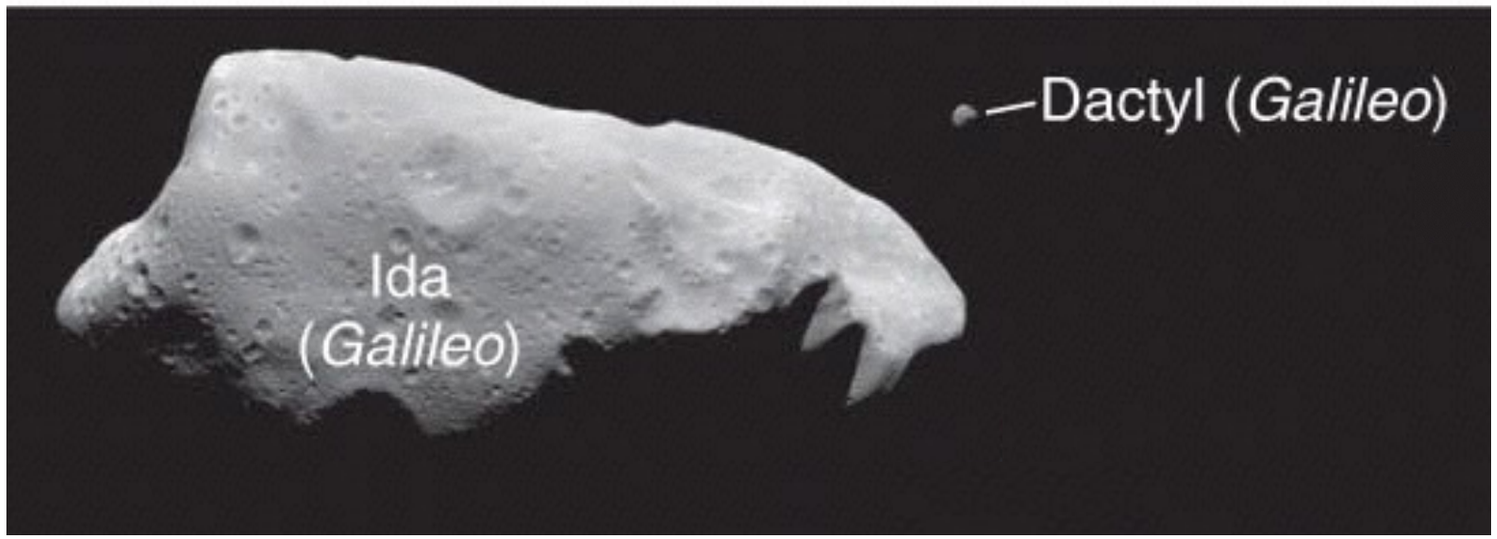


- Asteroids are rocky leftovers of planet formation.
- The largest is Ceres, diameter ~1000 kilometers.
- 150,000 in catalogs, and probably over a million with diameter >1 kilometer.
- Small asteroids are more common than large asteroids.
- All the asteroids in the solar system wouldn't add up to even a small terrestrial planet.



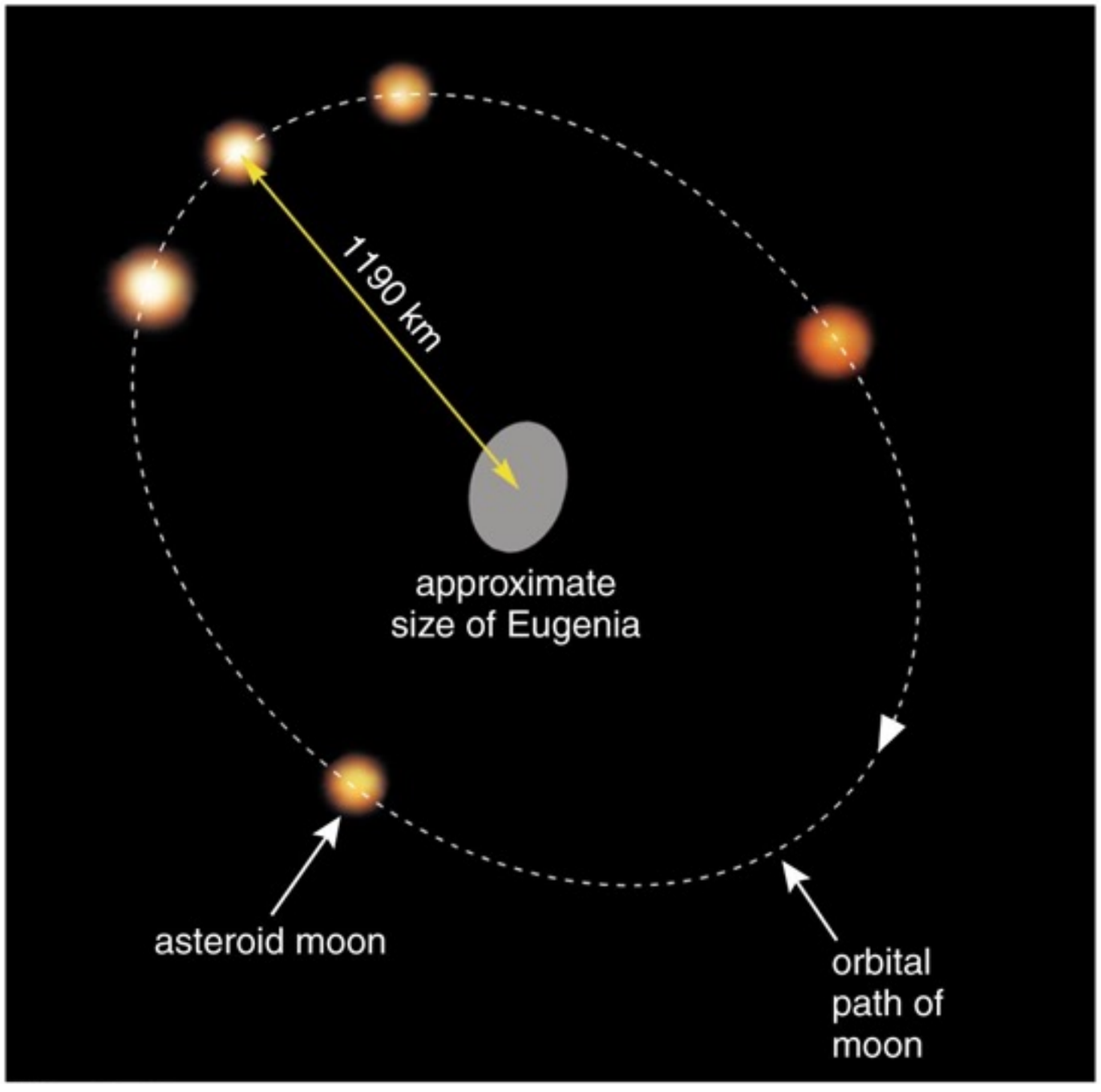
- Asteroids are cratered and not round.

Asteroids with Moons



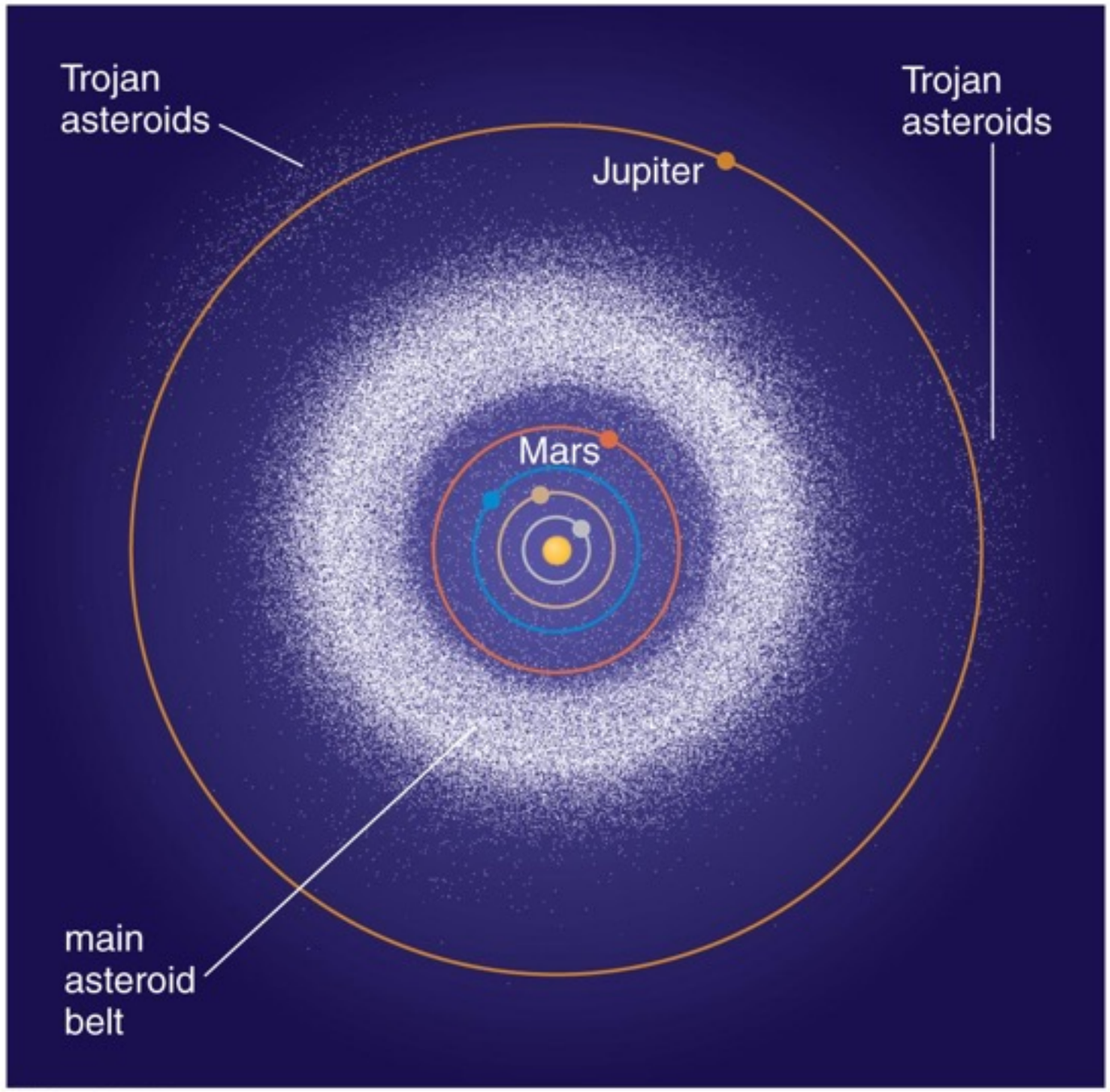
- Some large asteroids have their own moon.
- Asteroid Ida has a tiny moon named Dactyl.

Density of Asteroids



- Measuring the orbit of asteroid's moon tells us an asteroid's mass.
- Mass and size tell us an asteroid's density.
- Some asteroids are solid rock; others are just piles of rubble.

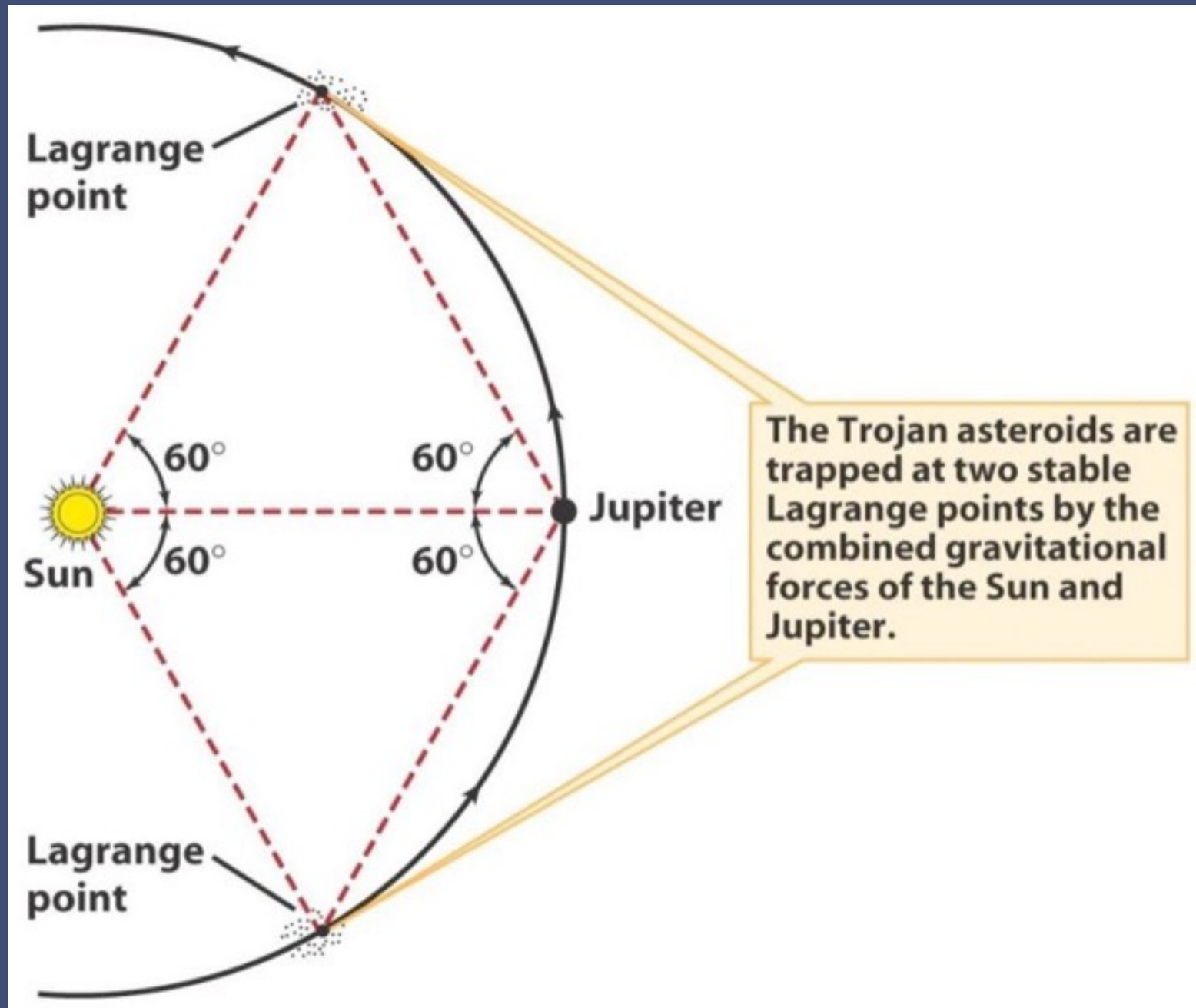
Asteroid Orbits



- 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.

Locations of Asteroids

- "Trojan asteroids"
  - –collections of asteroids at the 2 stable Lagrange points of Jupiter
  - –Over 450 asteroids orbit in the L4 & L5 Lagrange points of Jupiter



Thought Question

Which explanation for the belt seems the most plausible?

A. The belt is where all the asteroids happened to form.
B. The belt is the remnant of a large terrestrial planet that used to be between Mars and Jupiter.
C. The belt is where all the asteroids happened to survive.

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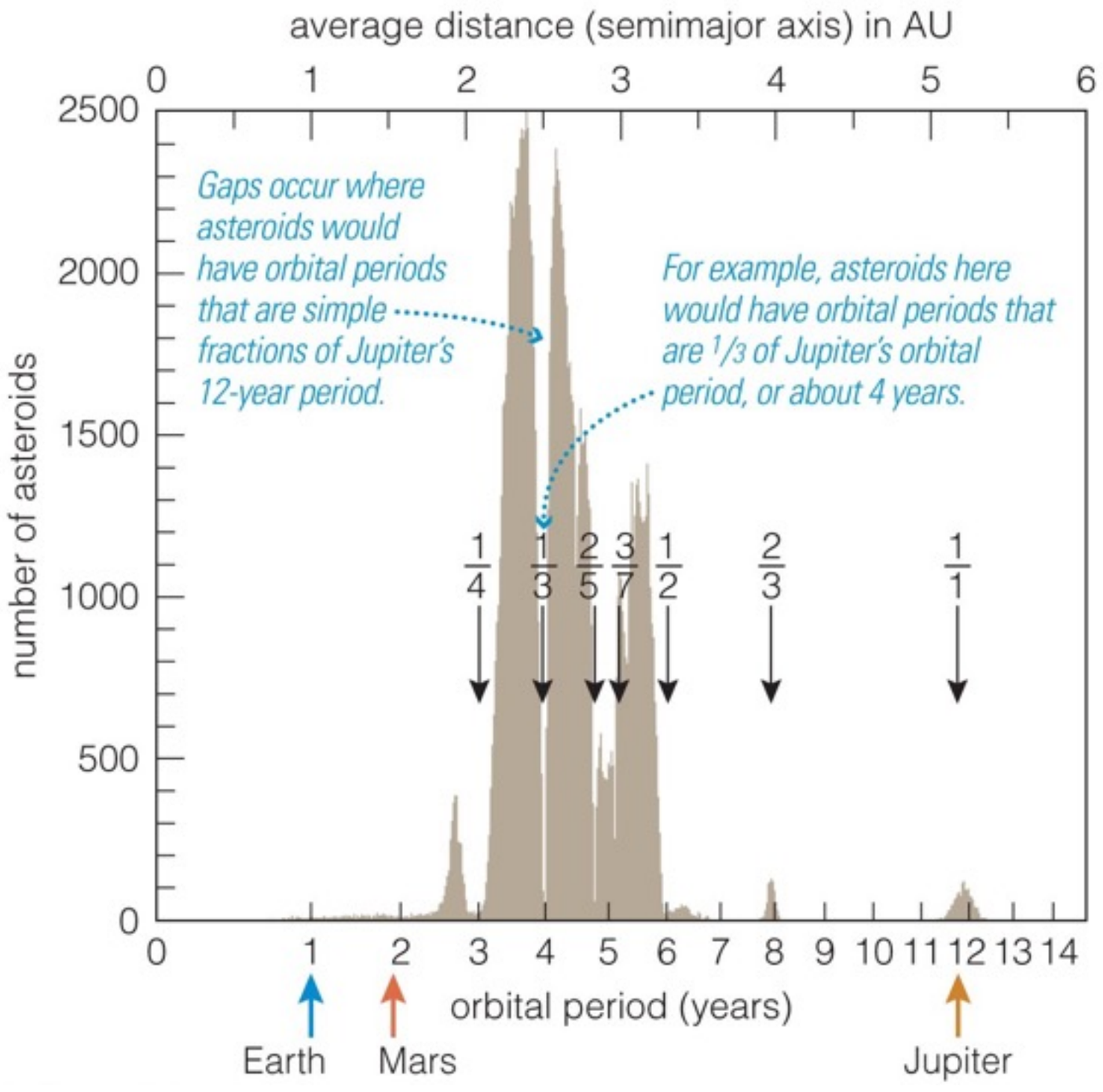
C. **The belt is where all the asteroids happened to survive.**

But WHY didn't they form a planet?

Orbital Resonances



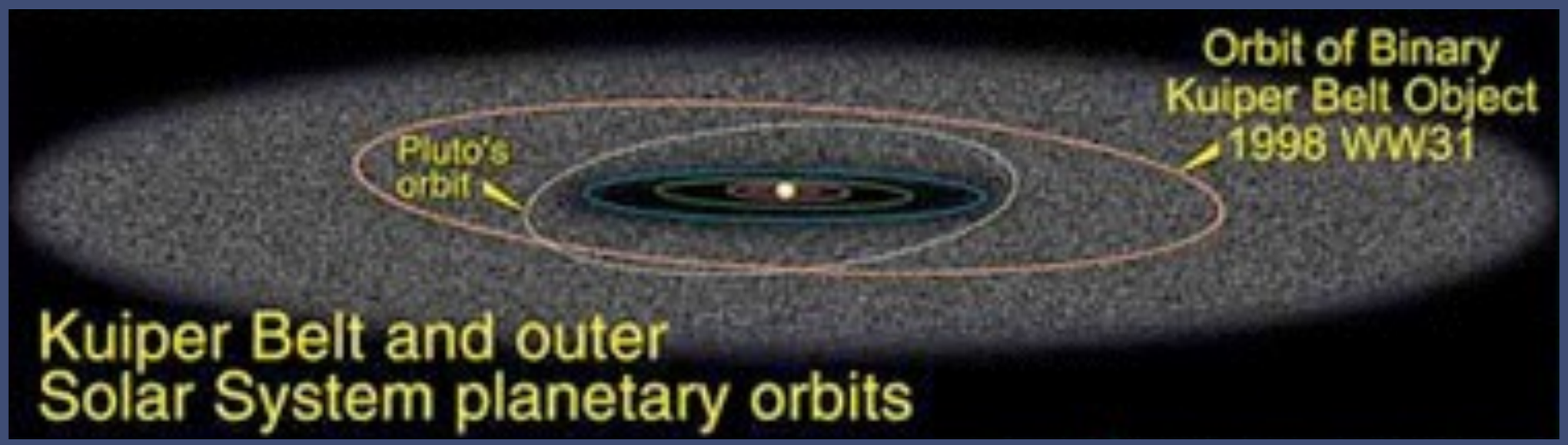
- Asteroids in orbital resonance with Jupiter experience periodic nudges.
- Eventually, those nudges move asteroids out of resonant orbits, leaving gaps (Kirkwood gaps) in the asteroid belt.

Asteroids & Comets

- Asteroids
  - –rocky or metallic
  - –found mostly in the inner solar system
    - asteroid belt
    - Trojan asteroids in orbit with Jupiter (& Mars)
- Comets
  - –composed of ice, dust & rock
  - –found mostly in the outer solar system
    - Kuiper belt
    - Oort cloud

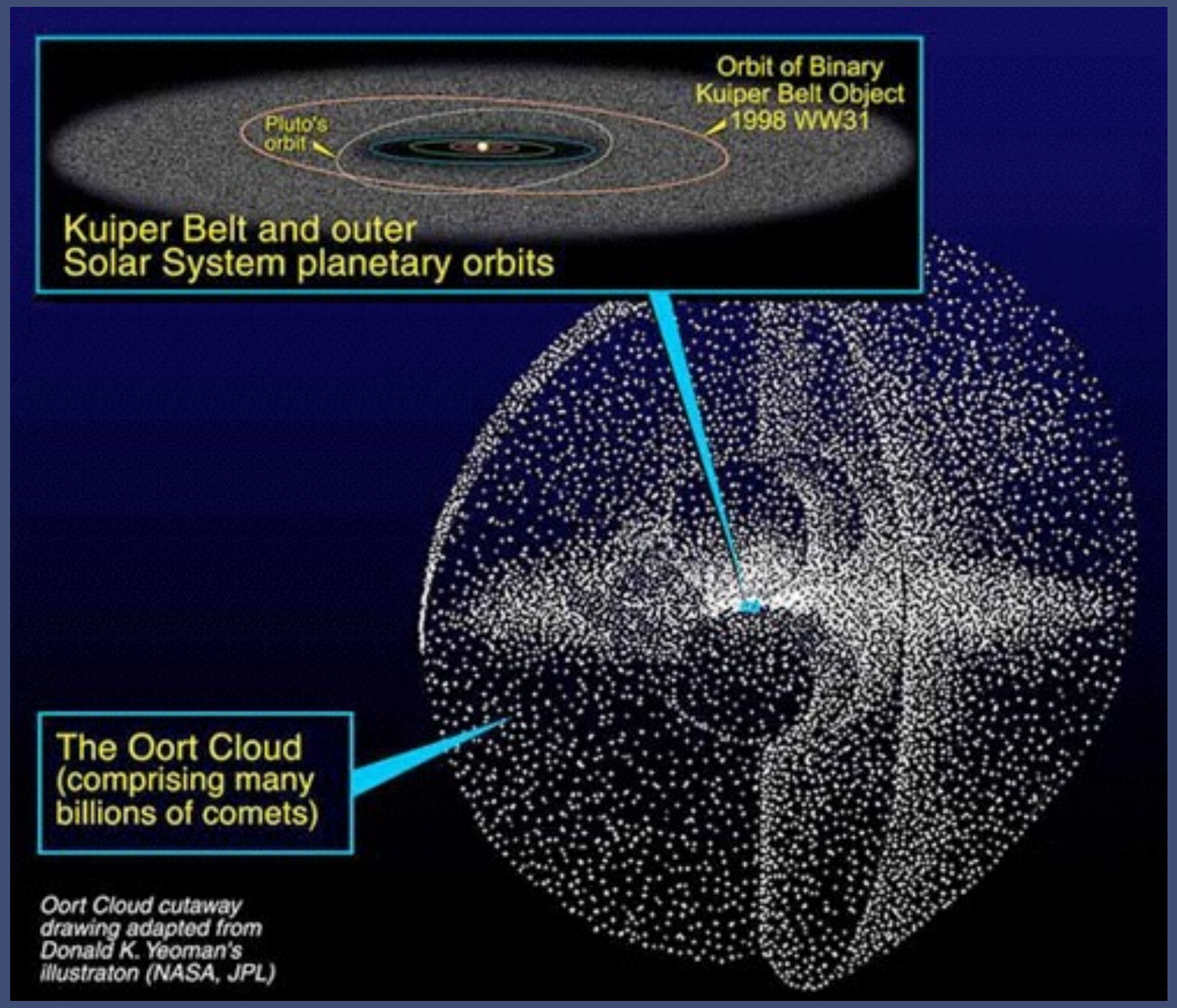
Locations of Comets

- Kuiper Belt
  - –lies in ecliptic plane
  - –extends from orbit of Neptune out to 50 AU
  - –contains 10,000-1,000,000 comet-like bodies



Locations of Comets

- Oort cloud
  - –spherical cloud of comets & debris
  - –extends from Kuiper belt out to 50,000 AU



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

When Comets Approach the Sun

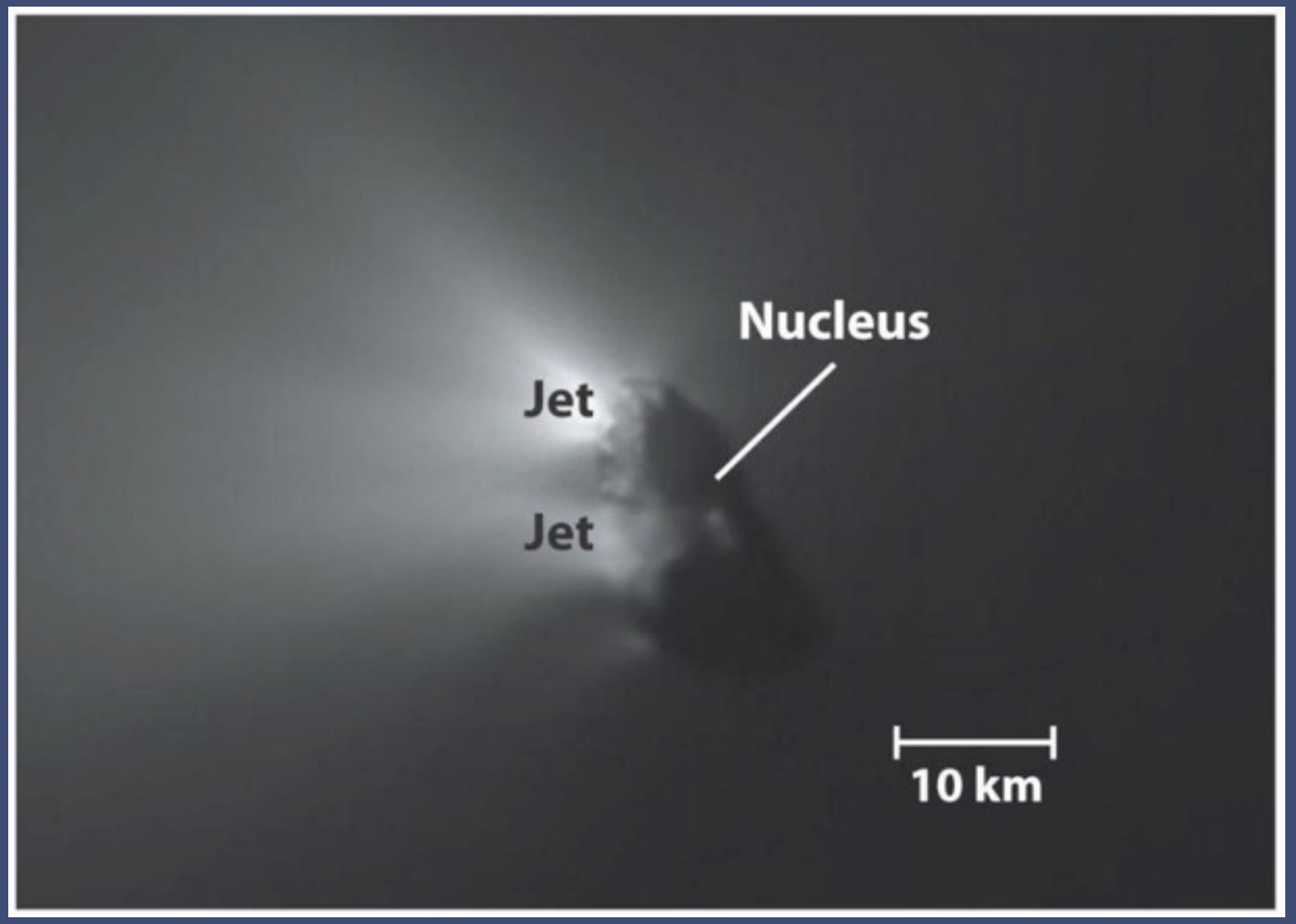
- Far from Sun comets are just frozen chunks of ice and dust, maybe 10-100 km in size
- Nearly impossible to see without a very large telescope
- When a comet approaches the Sun on a highly elliptical orbit, the heat and radiation pressure from the Sun transforms the cold, dark chunk of ice into something spectacular

Metamorphosis of Comet

- Heat from Sun melts some of the ice in the comet
- Liberates gas & dust from the comet
- Gas & dust released from comet create 4 identifiable components

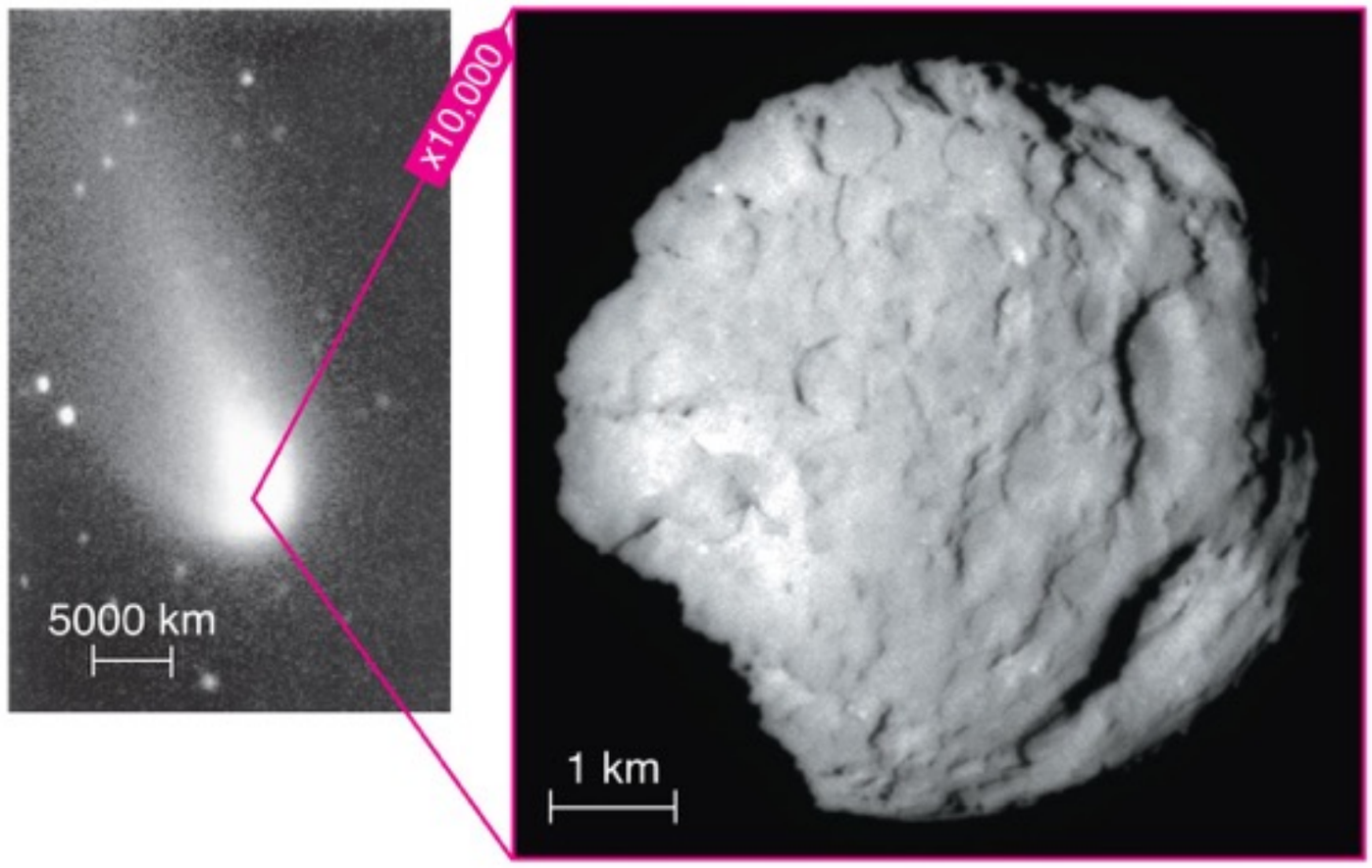
1. Nucleus
   - heart of the comet
   - the unmelted core

Nucleus of Comet



- Picture of nucleus of comet Halley
- Taken by a spacecraft flown past the nucleus

Nucleus of Comet



b The first image shows Comet Wild 2 photographed from Earth, and the inset shows its nucleus photographed by the *Stardust* spacecraft. The irregular surface probably shows effects from a combination of impacts and uneven vaporization rates in different regions.

Interactive Figure

- A "dirty snowball"
- Source of material for comet's tail

Deep Impact

Interactive Figure

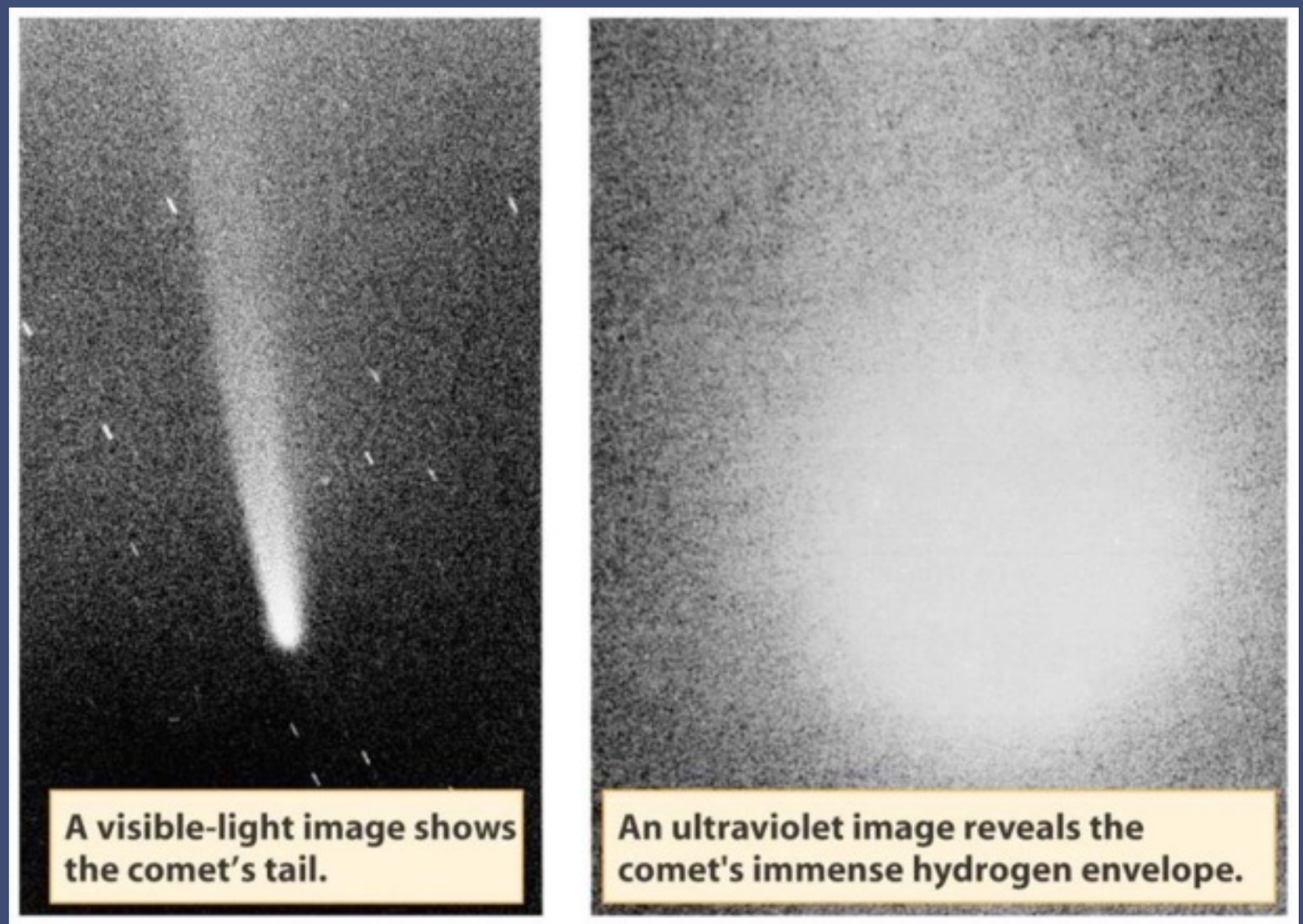
- Mission to study nucleus of Comet Tempel 1
- Projectile hit surface on July 4, 2005.
- Many telescopes studied aftermath of impact.

Metamorphosis of Comet

2. Coma
   - glowing ball of gas surrounding nucleus
   - about 1,000,000 km in diameter
   - this is the bright head of the comet visible at optical wavelengths

Metamorphosis of Comet

3. Hydrogen envelope
   - very large envelope of Hydrogen surrounding nucleus
   - not visible in optical wavelengths
   - very apparent in UV



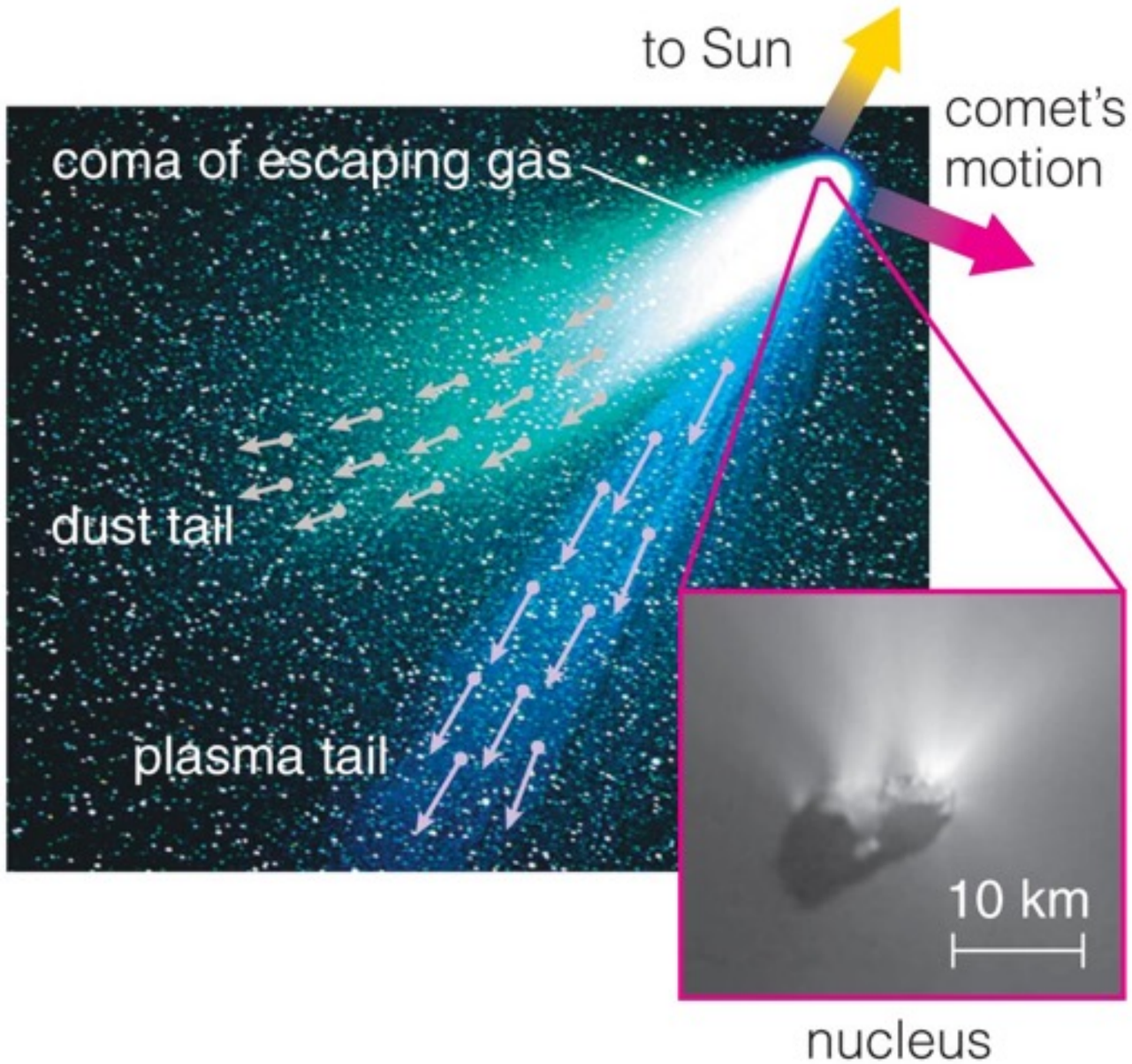
Metamorphosis of Comet

4. Comet tail
   - comets really have 2 tails
     - ion tail
     - dust tail

Comet Tails

- Plasma (or ion) tail
  - –composed of electrically charged particles (called ions)
  - –pushed away from the nucleus by electrically charged particles in the solar wind
  - –plasma tail always points away from Sun
- Dust tail
  - –mostly composed of dust
  - –electrically neutral
  - –pushed away from nucleus by pressure of photons of light (radiation pressure)
  - –follows Kepler's laws
    - orbits more slowly as it gets further from Sun
    - dust tail lags behind the ion tail

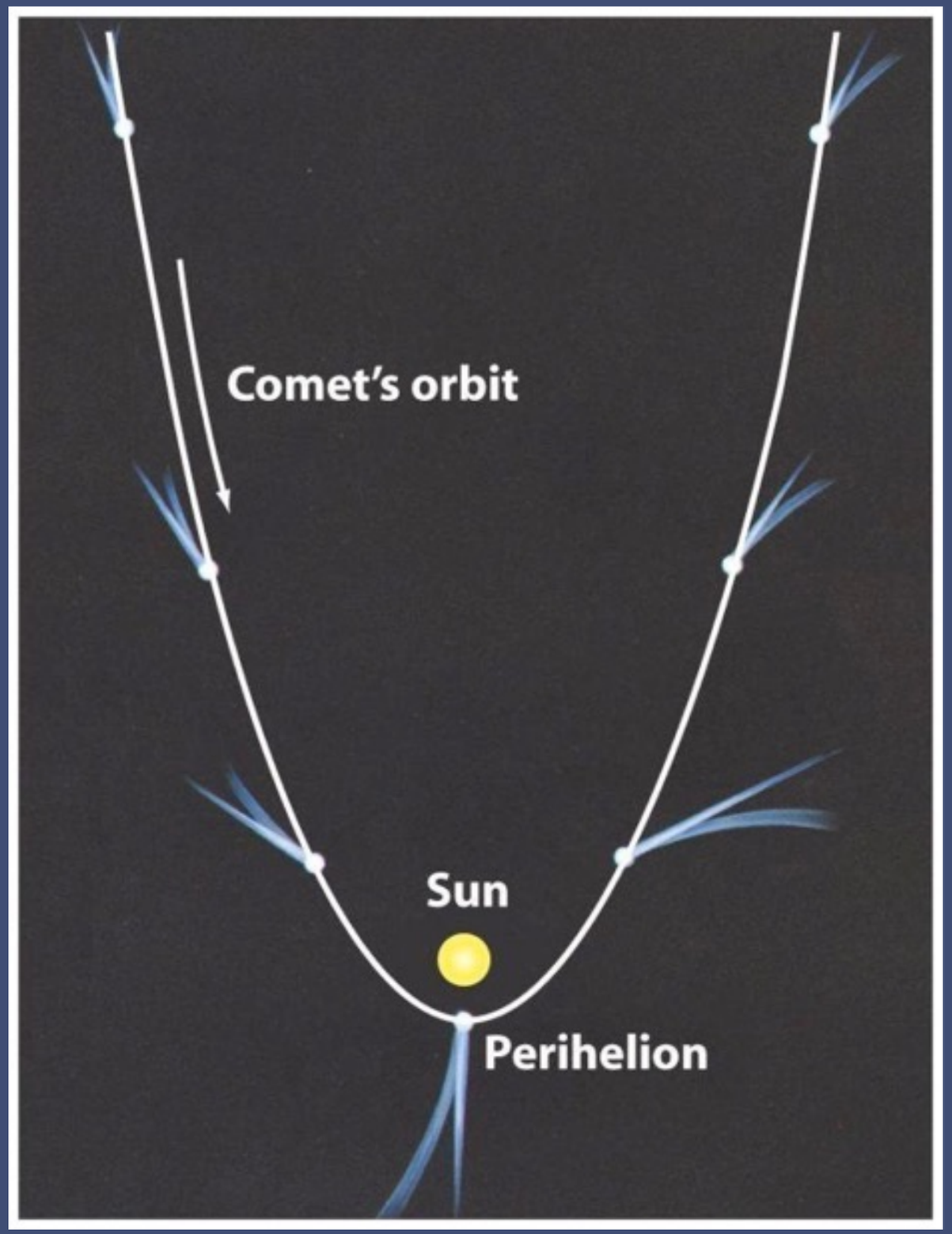
Anatomy of a Comet



- 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.

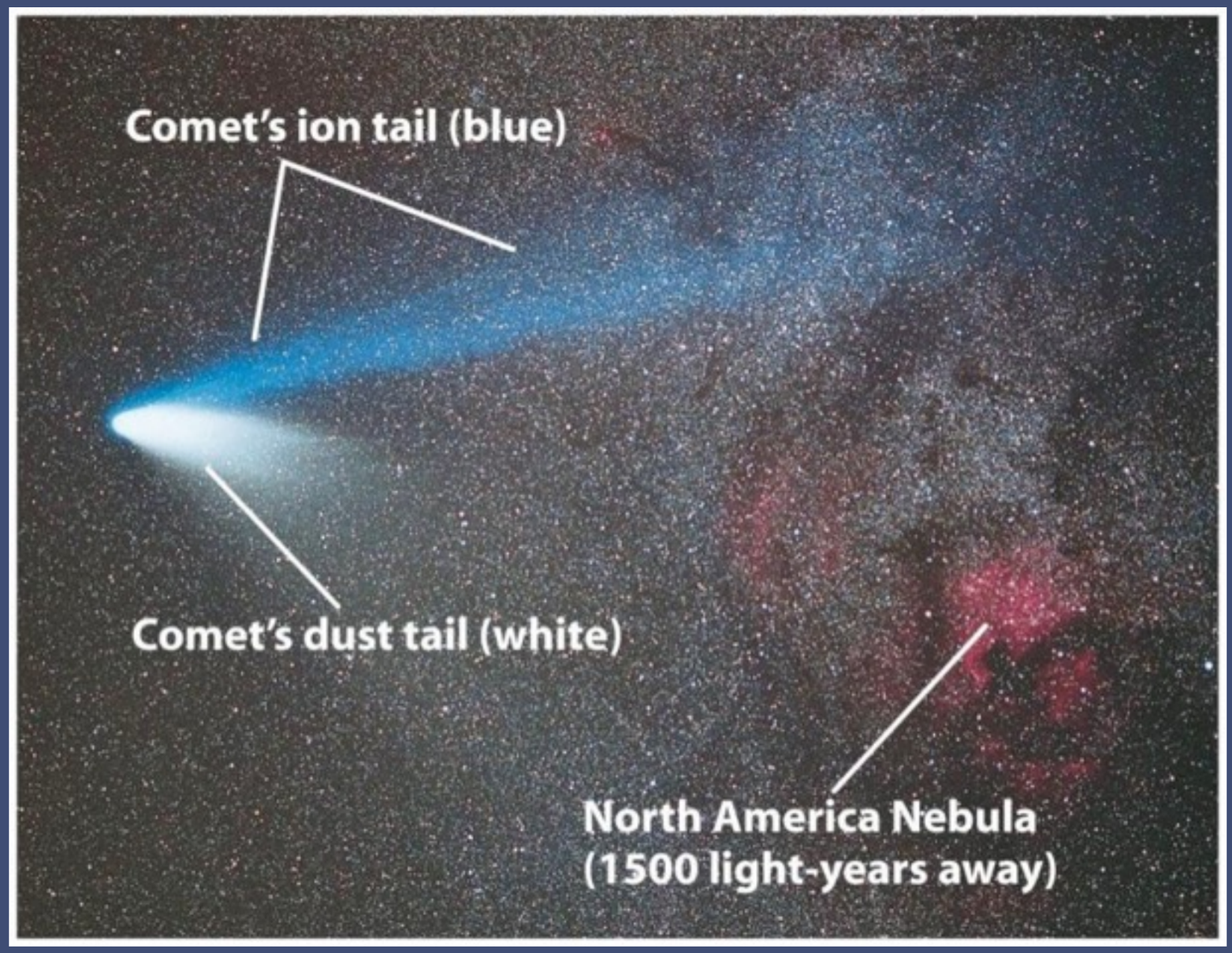
Comet Tails

- Plasma tail always points away from Sun
- Dust tail lags behind ion tail
- Tails are longest when comet is close to the Sun



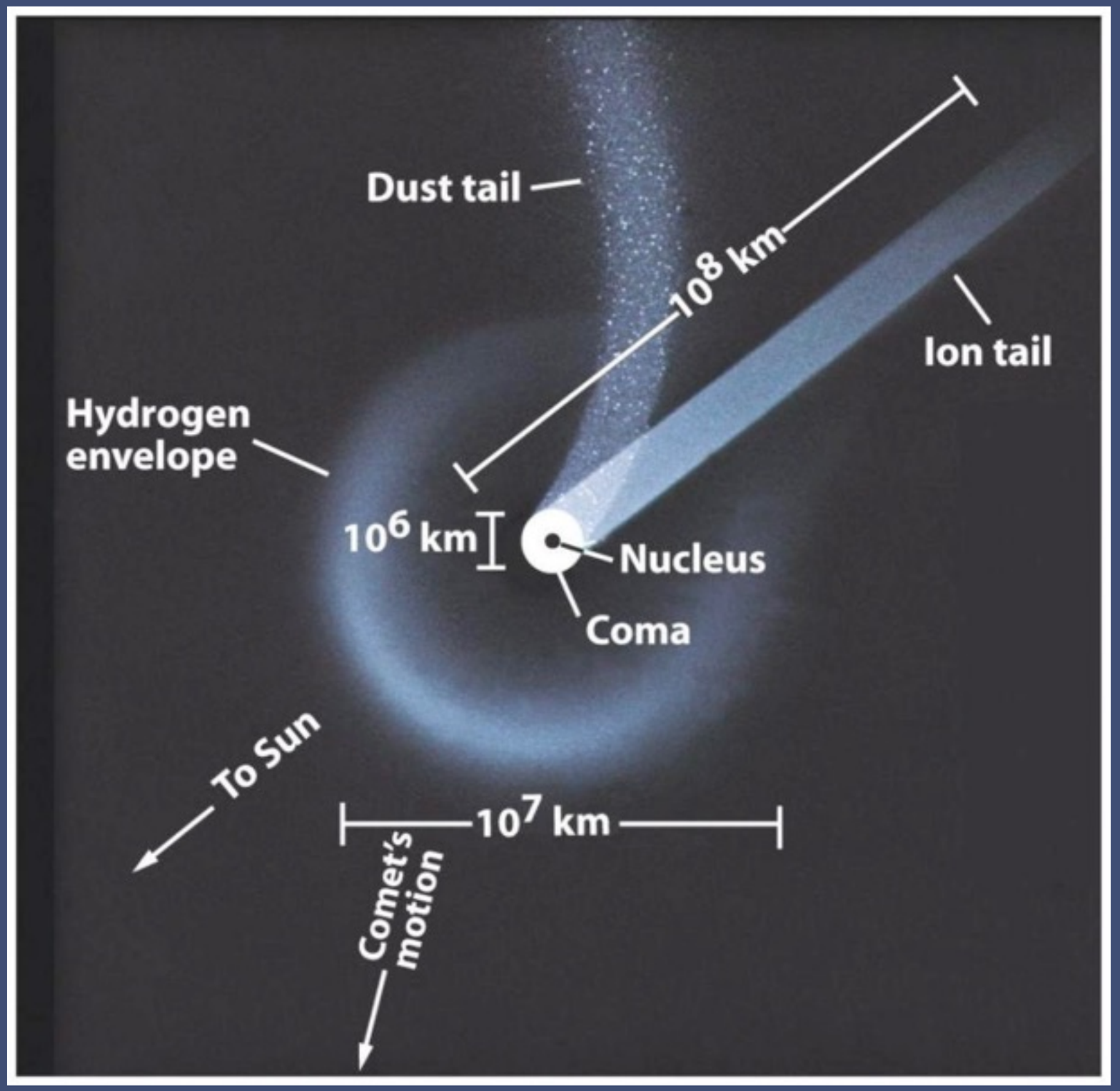
Comet Tails

- Plasma tail often glows blue because of presence of carbon-rich ions
- Dust tail often appears white



Comet Hale-Bopp

Comet Structure



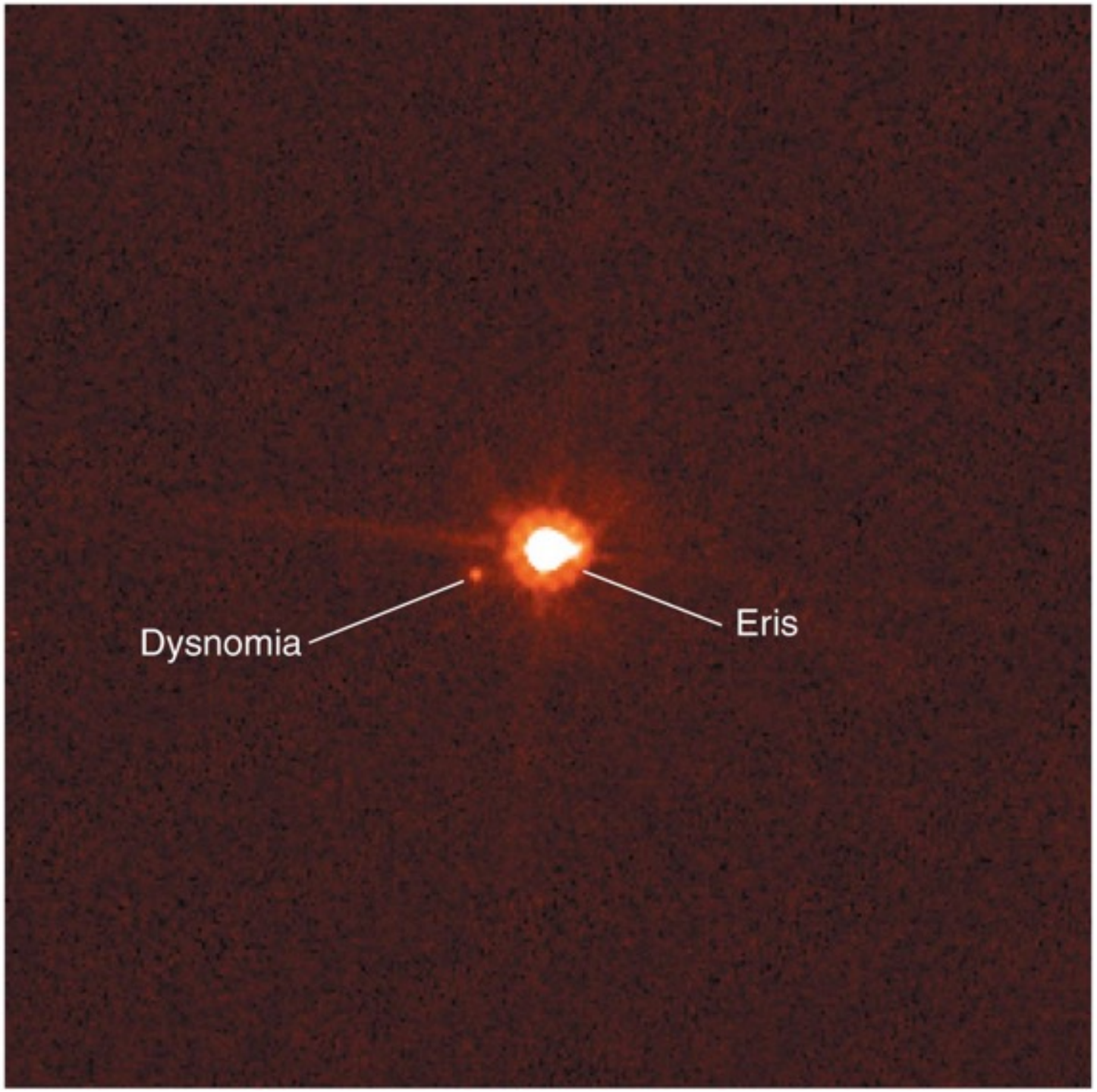
Halley's Comet

- recorded observations in 1531, 1607, and 1682
- In 1705 Edmond Halley predicted, using Newton's laws of motion, that the comet would return in 1758
- comet did indeed return as predicted and was later named in Halley's honor
- last visit to inner solar system in 1986
- will return again in 2061

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?

Meteor Terminology

- **Meteoroid:** a small rock drifting through space
- **Meteor:** the bright trail left by a meteoroid falling through Earth's atmosphere
- **Meteorite:** a rock that has survived the fall from space through Earth's atmosphere and reached the ground

Meteorite Impact

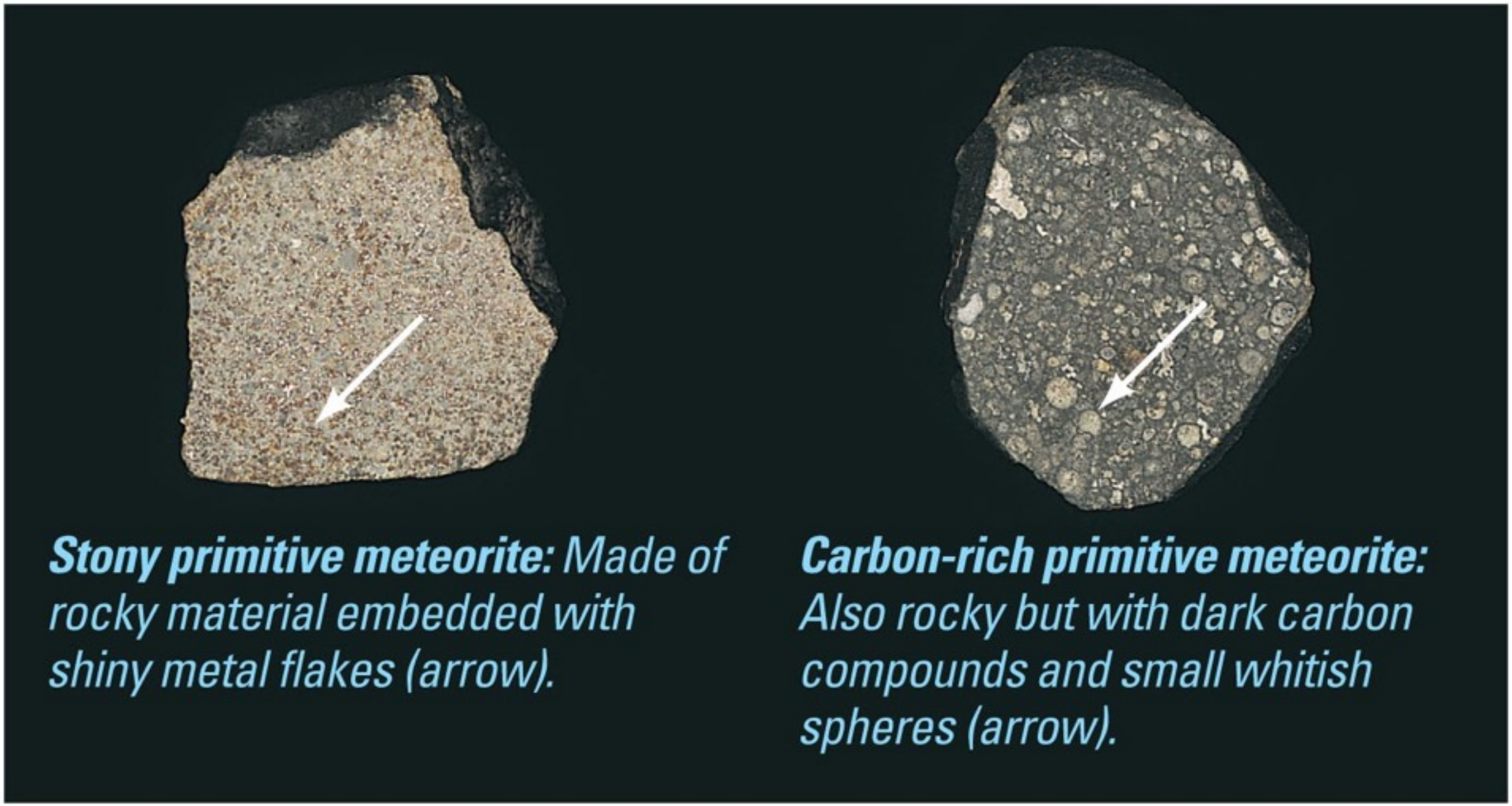
Chicago, March 26, 2003

Meteorite Types

1) Primitive: unchanged in composition since they first formed 4.6 billion years ago

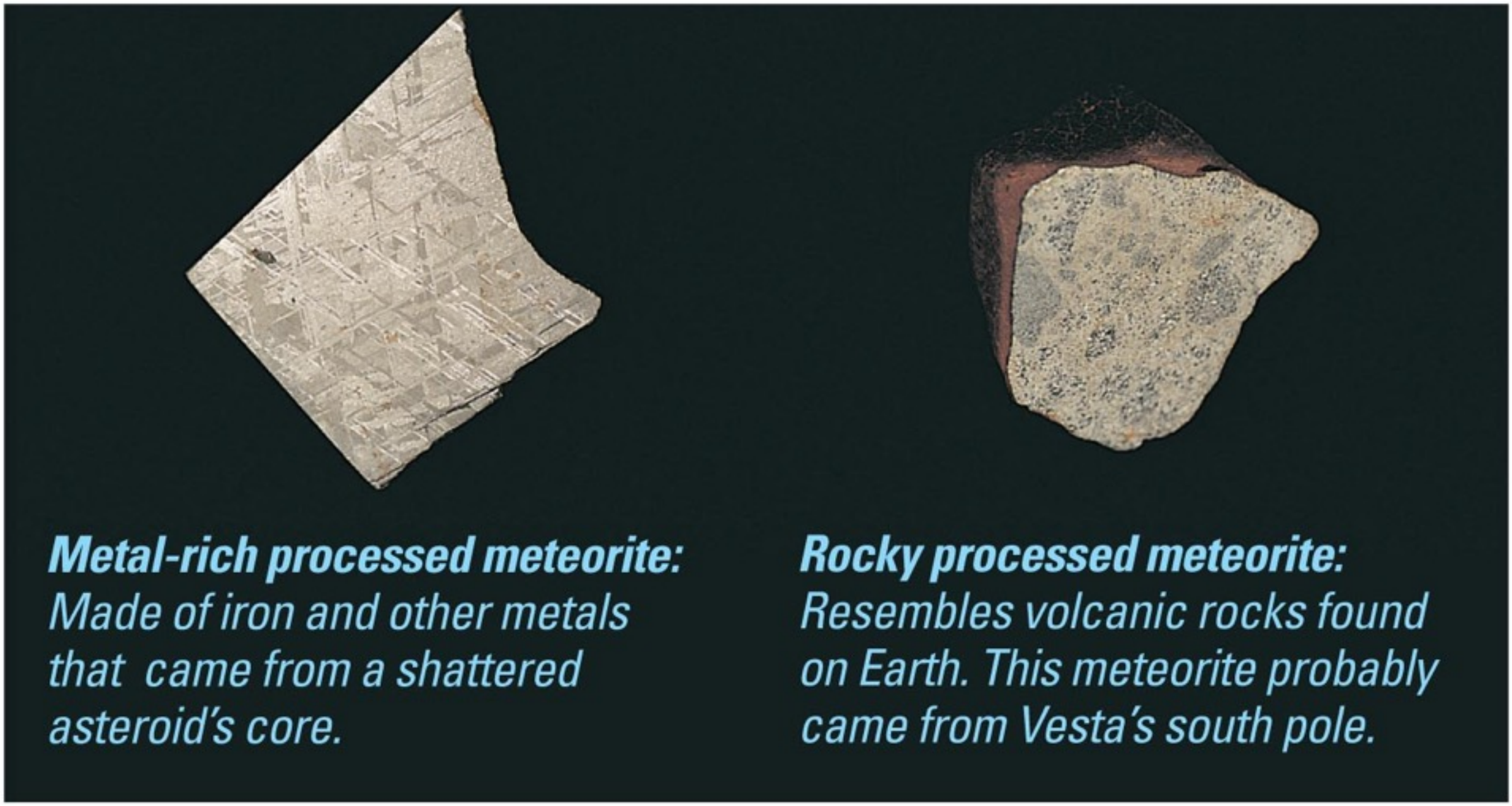
2) Processed: younger; have experienced processes like volcanism or differentiation

Primitive Meteorites



a Primitive meteorites.

Processed Meteorites



b Processed meteorites.

Collisions of Asteroids with Earth

- Barringer Crater
  - –Explosion equivalent to 20 megatons of TNT
  - –1.2 km (3/4 mi) wide crater
  - –formed approximately 50,000 years ago

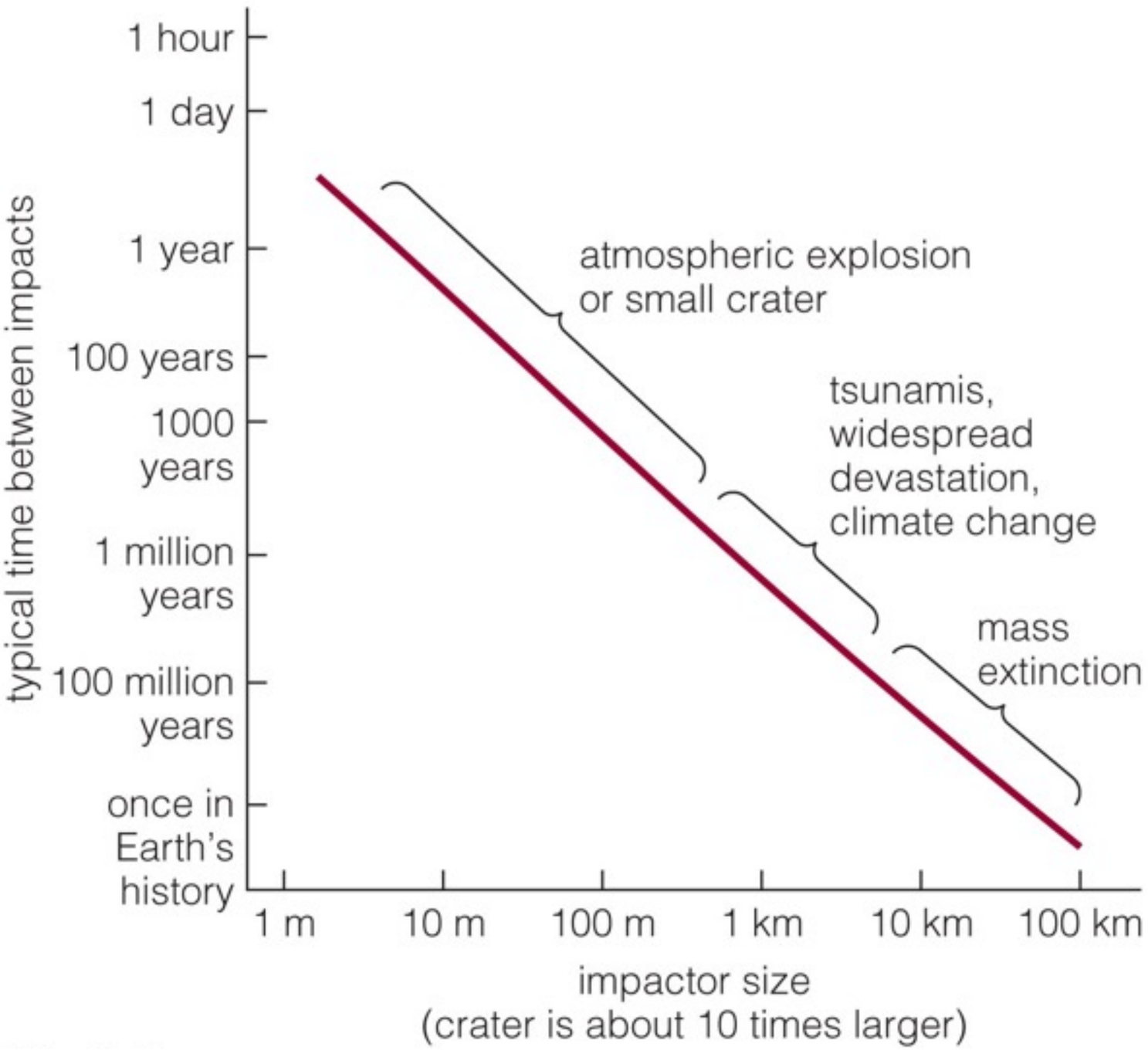
Collisions of Asteroids with Earth

- About 100 confirmed impact craters like Barringer's around the Earth
- Leading theory as to what caused the mass extinction of the dinosaurs

Shoemaker-Levy 9

- What would happen if Shoemaker-Levy 9 had hit Earth or if something like it hits us in the future?
  - –Mass extinction
    - mostly due to “nuclear winter”
      - –so much dust & debris would be kicked up into the atmosphere that we would be plunged into a period of near darkness lasting months or even years
      - –plants would die because of lack of sunlight
      - –animals would starve (plant eaters first, then meat eaters)
  - –Probably happen about once every 300,000 years

Frequency of Impacts



- Small impacts happen almost daily.
- Impacts large enough to cause mass extinctions happen many millions of years apart.