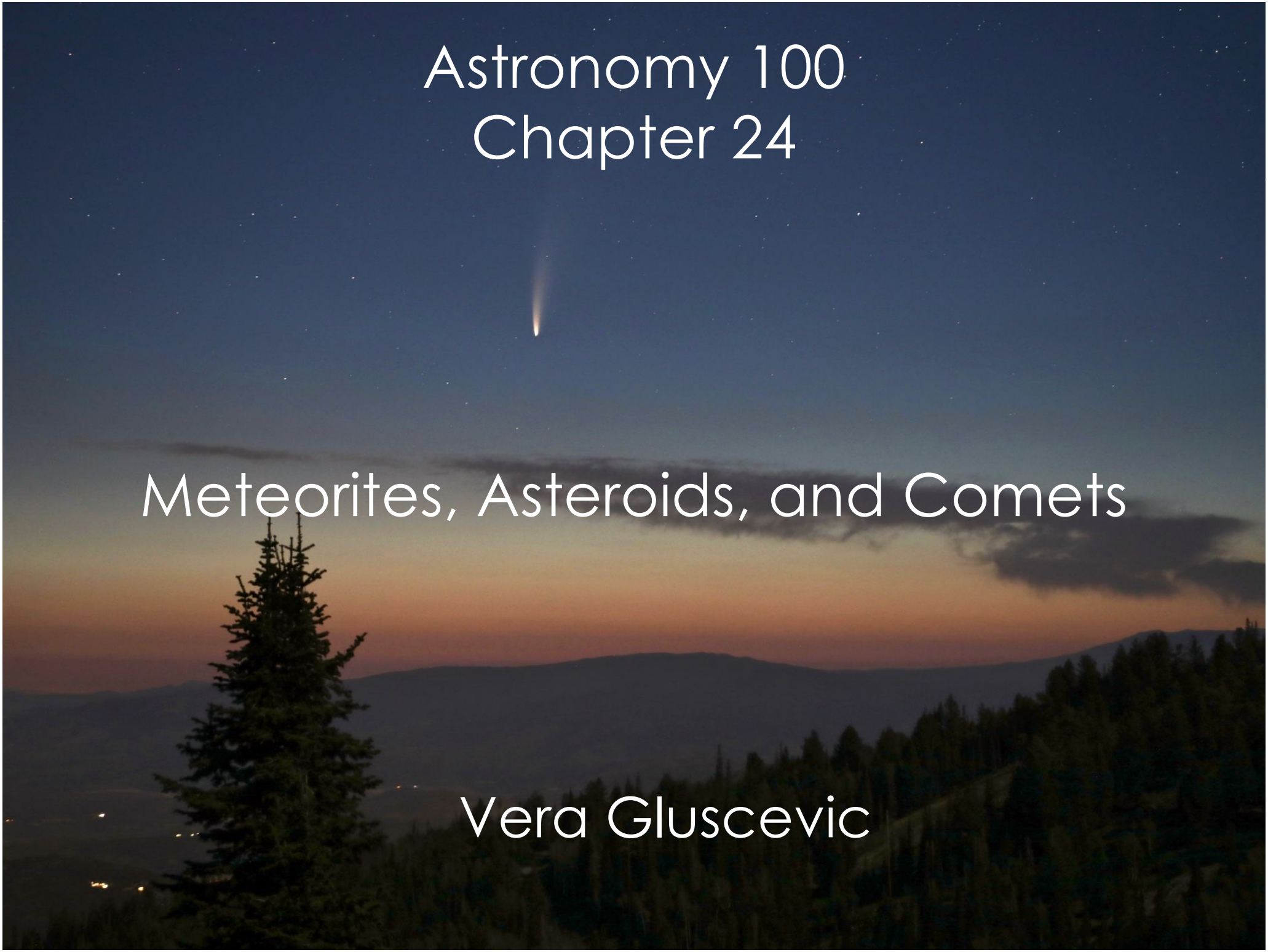


Astronomy 100
Chapter 24

Meteorites, Asteroids, and Comets

Vera Gluscevic

Plan for this lesson:

Planetesimals
Asteroids
Comets
Meteors and Meteorites

Planetesimals

Two types of planetesimals in solar system, leftovers from its formation:

- Asteroids – rocky planetesimals that formed in the inner solar system.
- Comets – icy planetesimals that formed beyond the frost line.

Currently accepted definitions

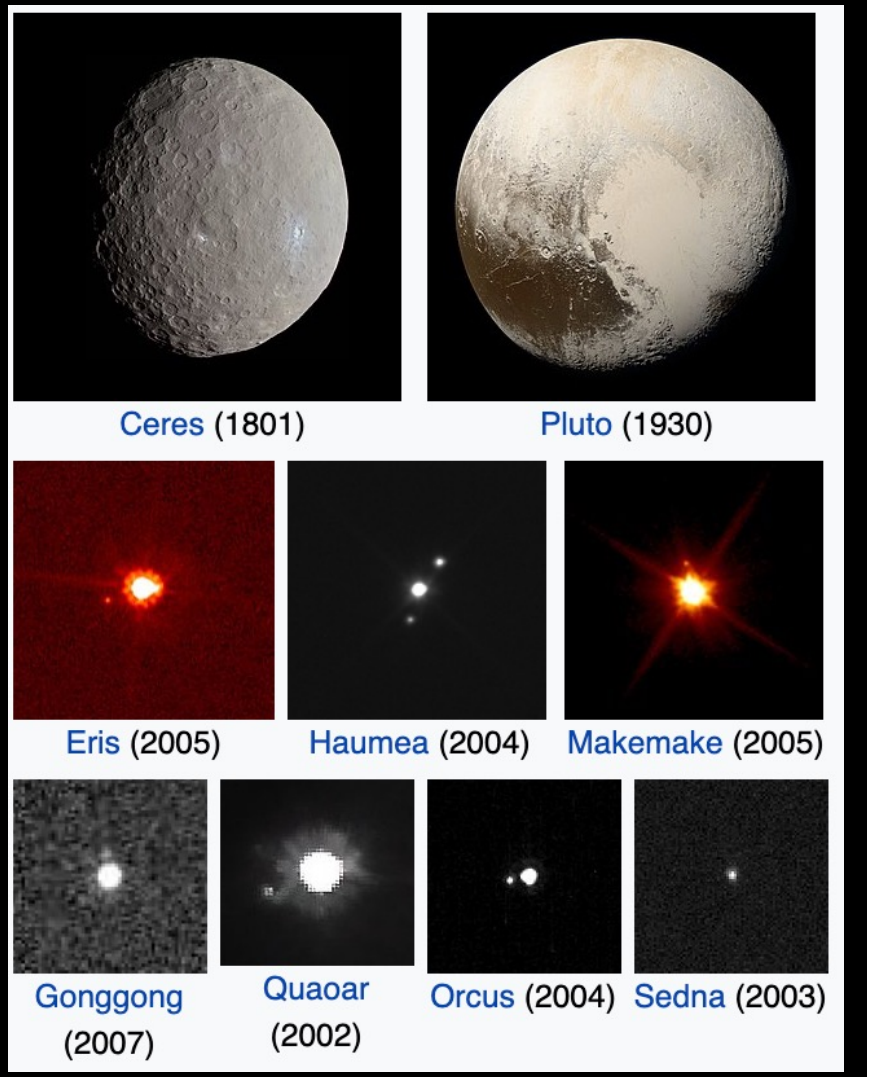
- ✓ **Meteoroid:** 1 mm to 1 m across (grains of dust, rocks, and boulders)
- ✓ **Asteroid / minor planet:** larger than 1 m, too small to be a planet or a dwarf planet.
- ✓ **Dwarf planet:** orbits the Sun, large enough to assume spherical shape, too small to clear its orbit.
- ✓ **Meteors** ("shooting stars"): amospheric phenomena, tracks of meteoroids that enter our atmosphere at high speed and burn up.
- ✓ **Meteorites:** pieces of meteoroids that hit the Earth, surviving the fall through the atmosphere (we find them on the ground).




Asteroids

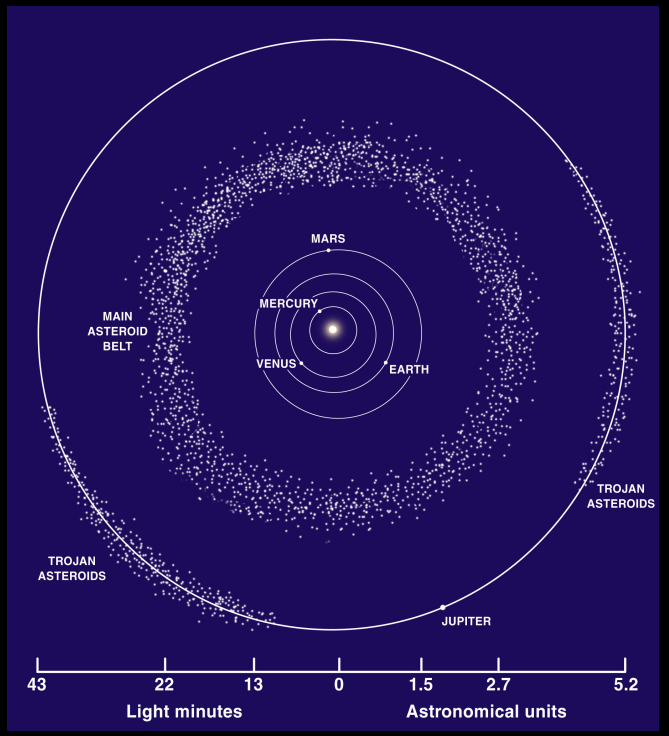
The discovery

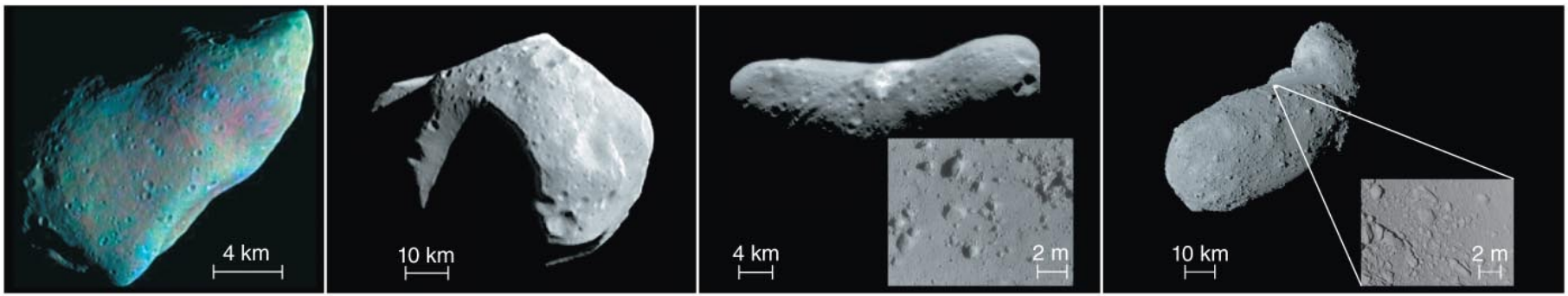
- 1700s: **Titius-Bode law** stated that each successive planet approximately twice as far as previous planet from the Sun. Worked for planets known at the time, and predicted the correct position for Uranus, discovered in 1781.
- Astronomers began searching for a planet at 2.8 AU.
- **Ceres discovered by Piazzi in 1801** (first asteroid discovered, now one of five dwarf planets in the Solar System).
- After several other (but much smaller) objects were discovered in the region between Mars and Jupiter, Herschel proposed the term "**asteroid**" (star-like).



Asteroids (minor planets)

- **Main asteroid belt located between the orbits of Mars and Jupiter** (where a planet never formed)
- Largest is Ceres (diameter ~1000 km), now a **dwarf planet**.
- More than 1 million catalogued to date.
- Collective mass is likely half the mass of our Moon.





a Gaspra, photographed by the *Galileo* spacecraft. Colors are exaggerated to show detail.

b Mathilde, photographed by the *Near-Earth Asteroid Rendezvous* (*NEAR*) spacecraft on its way to Eros.

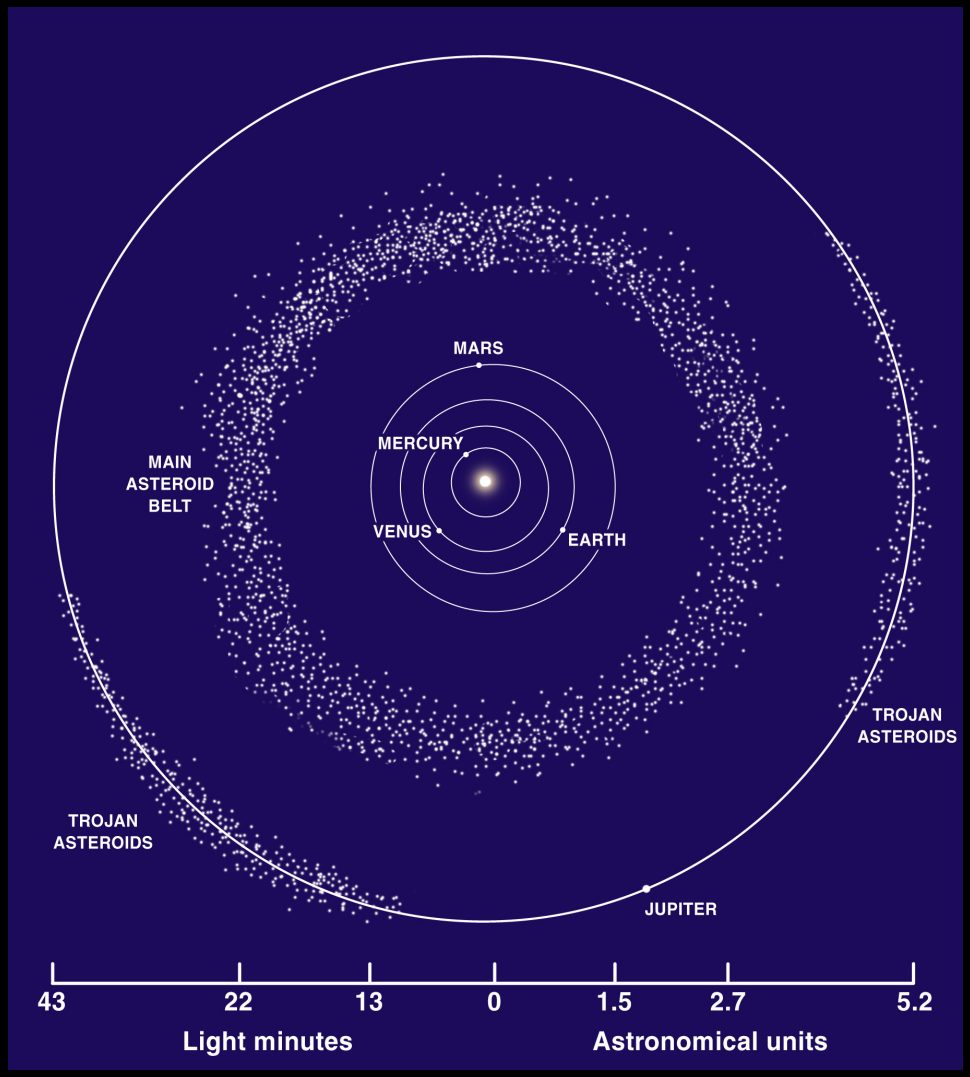
c Eros, photographed by the *NEAR* spacecraft, which orbited Eros for a year before ending its mission with a soft landing on the asteroid's surface.

d Itokawa, photographed by the Japanese *Hayabusa* mission, which landed on the surface and attempted to capture a sample for return to Earth.

Currently known asteroids

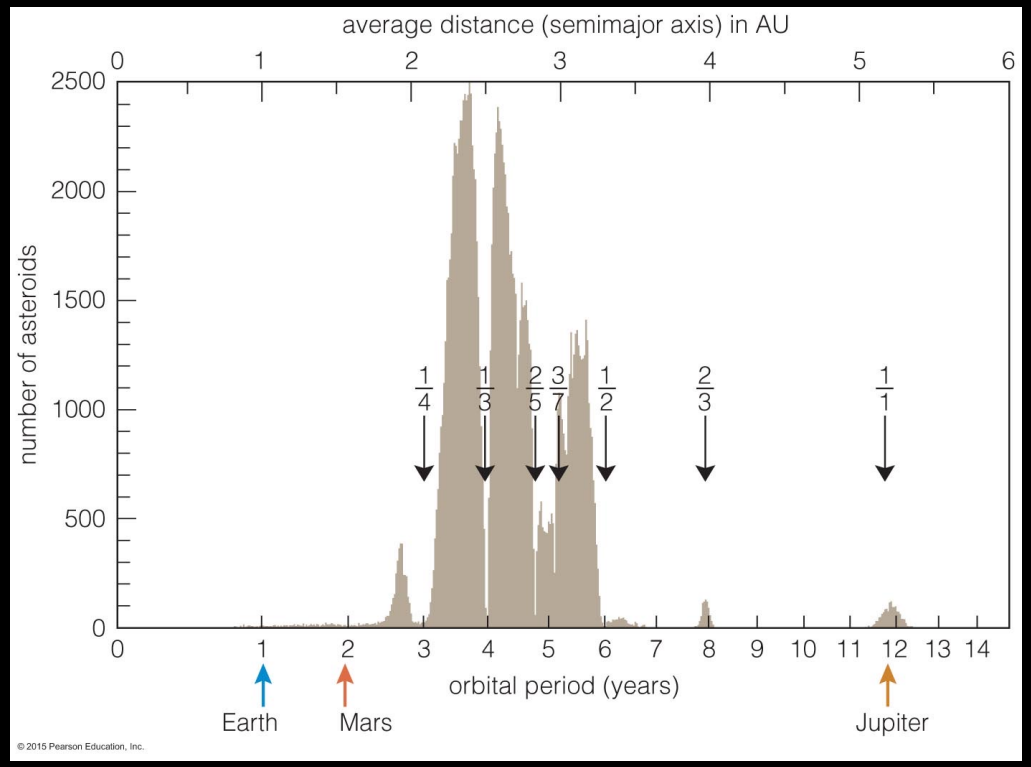
The animation represents a map of the increased count of all known asteroids in the solar system between Jan. 1, 1999 and Jan. 31, 2018. (Blue represents near-Earth asteroids. Orange represents main-belt asteroids between the orbits of Mars and Jupiter.)

Why did a planet never form from the main asteroid belt?



Jupiter is the culprit yet again!

- Orbital **resonance** with Jupiter clears certain regions of the asteroid belt: **Kirkwood gaps**.
- Kirkwood gaps apear where asteroid's orbital period times a whole number equals Jupiter's orbital period times another whole number.



question for you

Which statement is true?

A. Comets we see in the sky are colder than asteroids.
B. Asteroids can be dwarf planets, while comets cannot.
C. Meteors always fall onto the Earth and are then called meteorites.
D. Meteors get much closer to us than comets.

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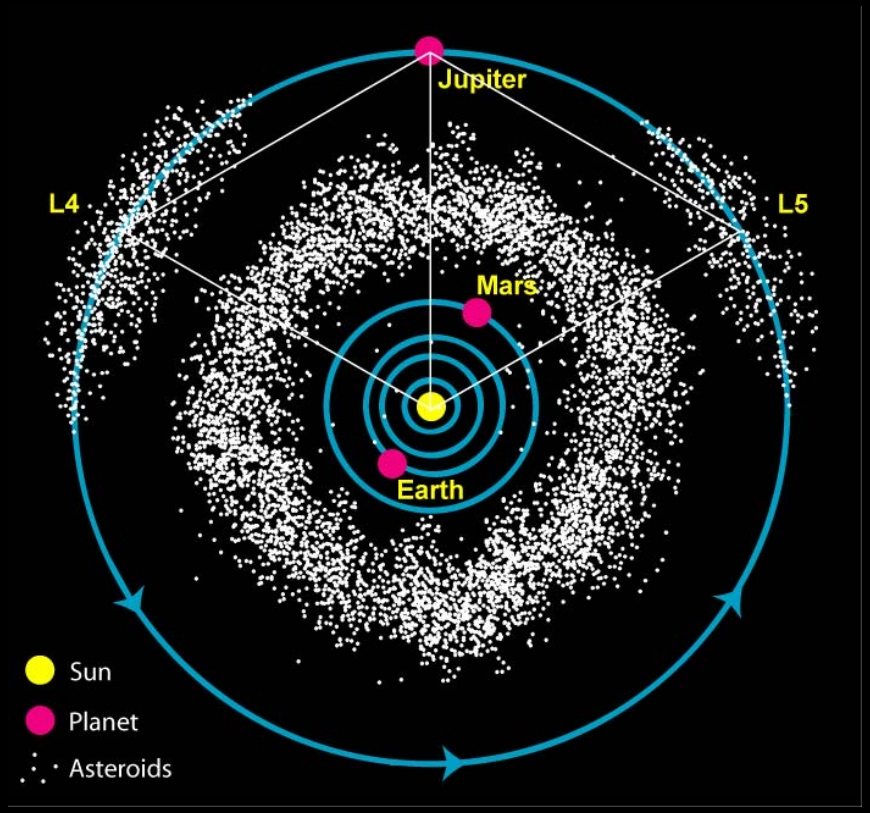
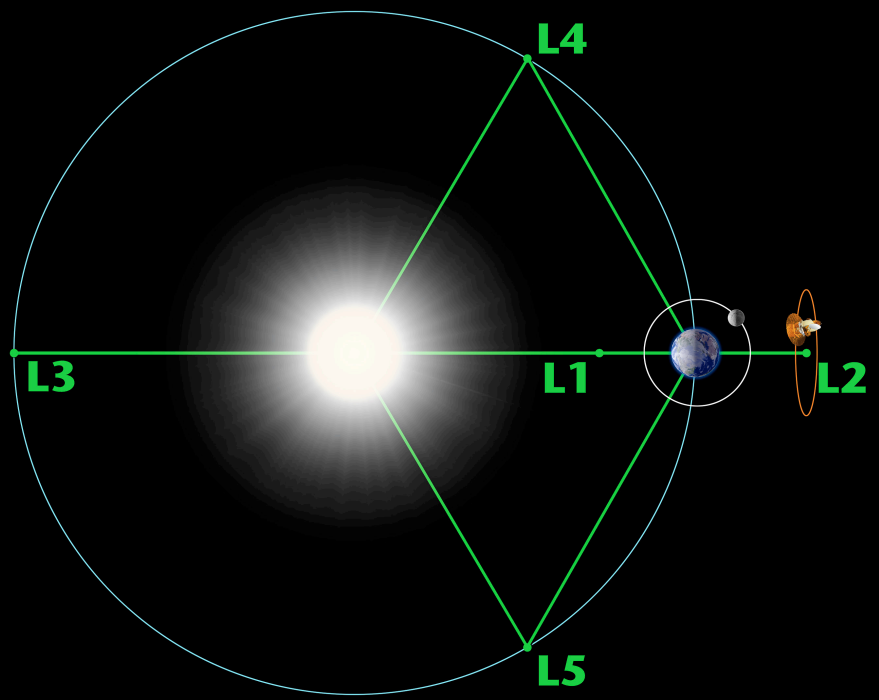
The Trojan Asteroids

Trojan asteroids lead and follow Jupiter in its orbit at the "Lagrange" points.



Lagrange Points: A Gravitational Balance

- There are 5 Lagrange points occurring in system of two objects orbiting a common center of mass.
- An object placed at a Lagrange point will tend to stay there, orbiting the Sun while keeping the same position with respect to Earth in its orbit.
- Of the five Lagrange points, three are unstable (L1, L2, L3) and two are stable (L4, L5). James Webb lives in L2.



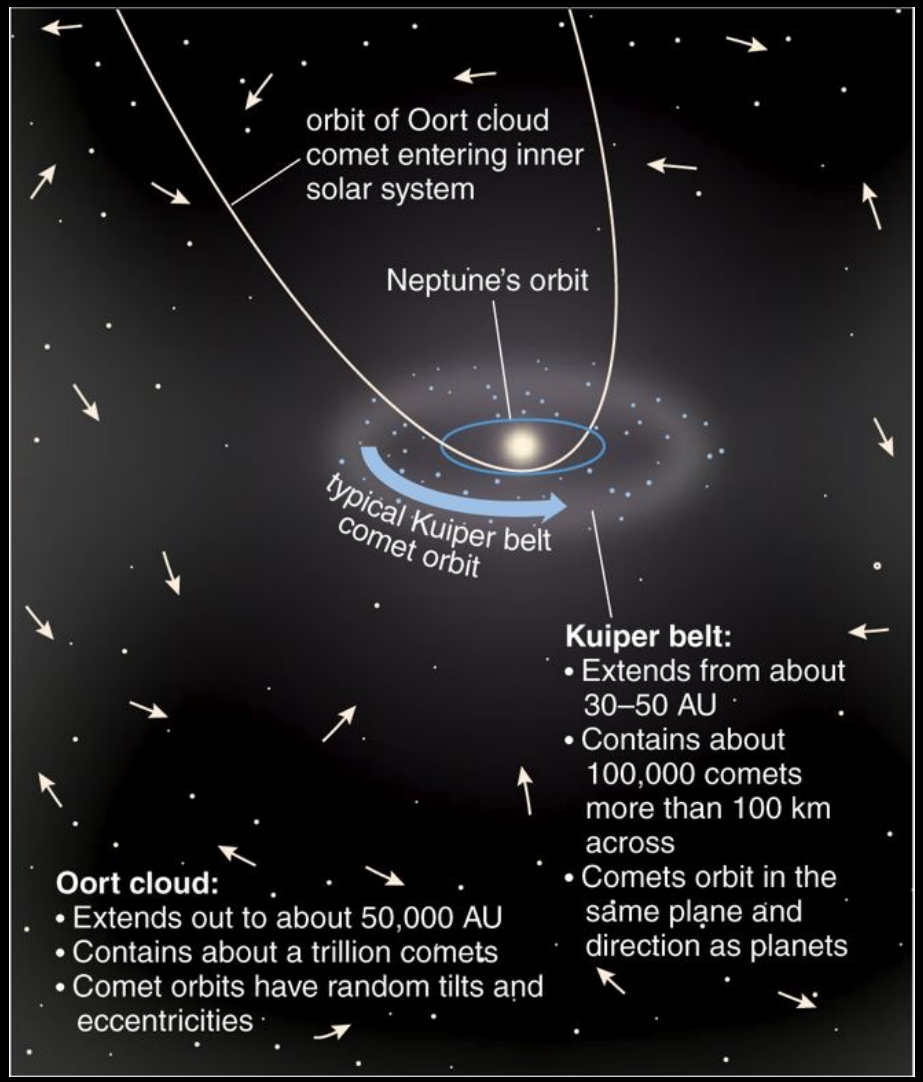
Comets

Comets

- Icy planetesimals are called comets, regardless of size, whether they ever appear with tails, or where they came from.
- Typically ~10km nucleus.

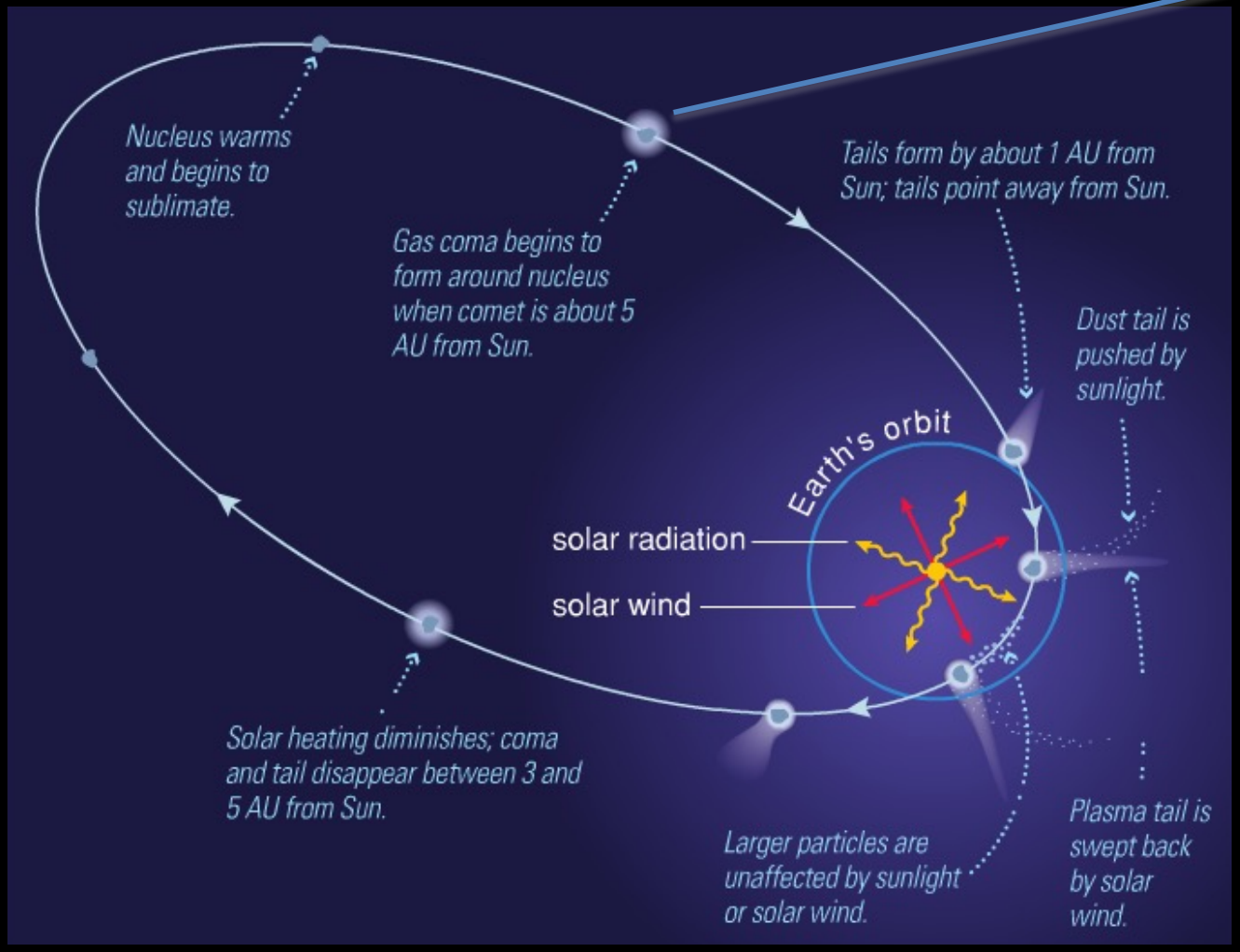
The Realm of Comets

Comets originate from the Kuiper Belt and Oort Cloud (long period).



The Realm of Comets

Life of a Comet

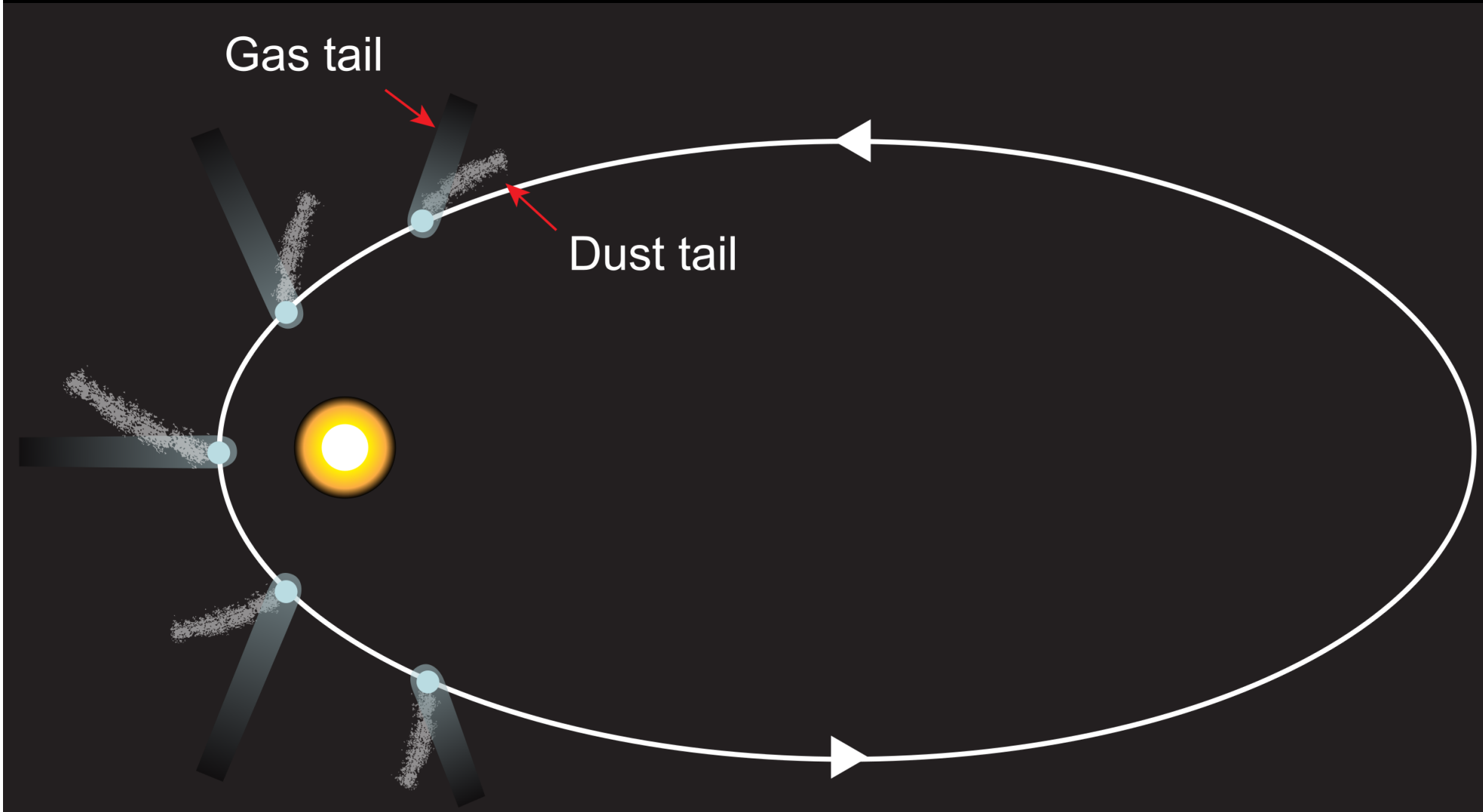


Cometary tails

Comets coming close to the Sun develop two tails:

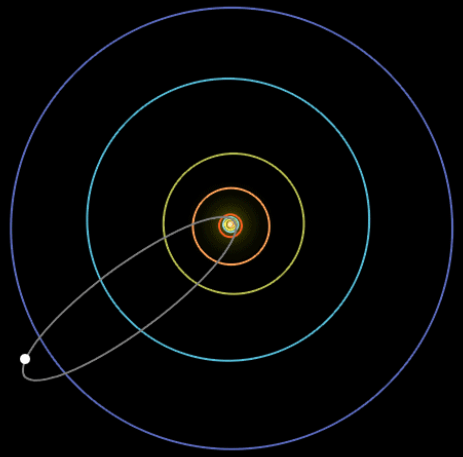
- **Plasma tail**: gas ionized by ultraviolet light, swept straight back by solar wind
- **Dust tail**: dust escaping from coma, swept back by pressure from sunlight, curved in the direction comet came from.

Cometary tails



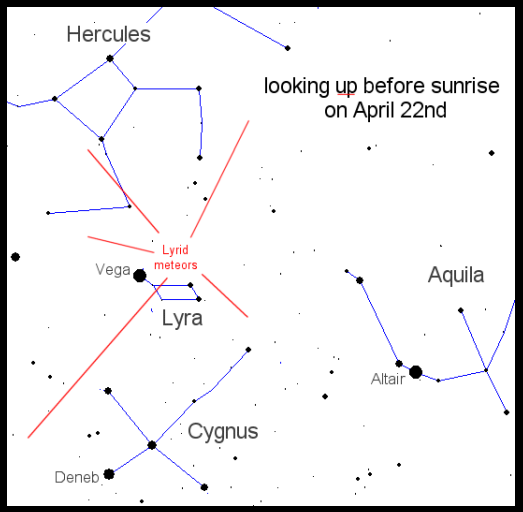
The most famous comet

- Observations of Halley's comet date back to 240 B.C. in nearly every civilization.
- Aristotle: Comets are disturbances in Earth's atmosphere.
- 1577: Tycho Brahe used parallax measurements to show that comets are farther away than the Moon.
- 1705: Edmond Halley realized that three previous comets (1532, 1607, 1682) are all recurrences of the same comet and predicted its return in 1758.



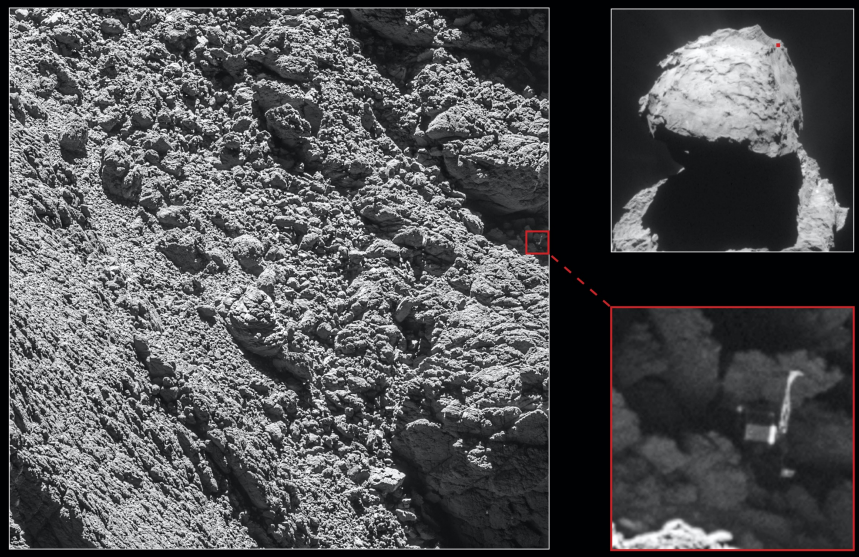
Comets pollute…

- Cometary orbits littered by dust blown off comet.
- **Meteor showers** occur when Earth sweeps through the remnants of a comet's tail:
  - Lyrids – late April
    Comet Thatcher
  - Perseids – August
    Comet Swift-Tuttle
  - Orionids – October
    Comet Halley
  - Leonids – November
    Comet Tempel-Tuttle
  - Geminids – December
    Comet Phaeton



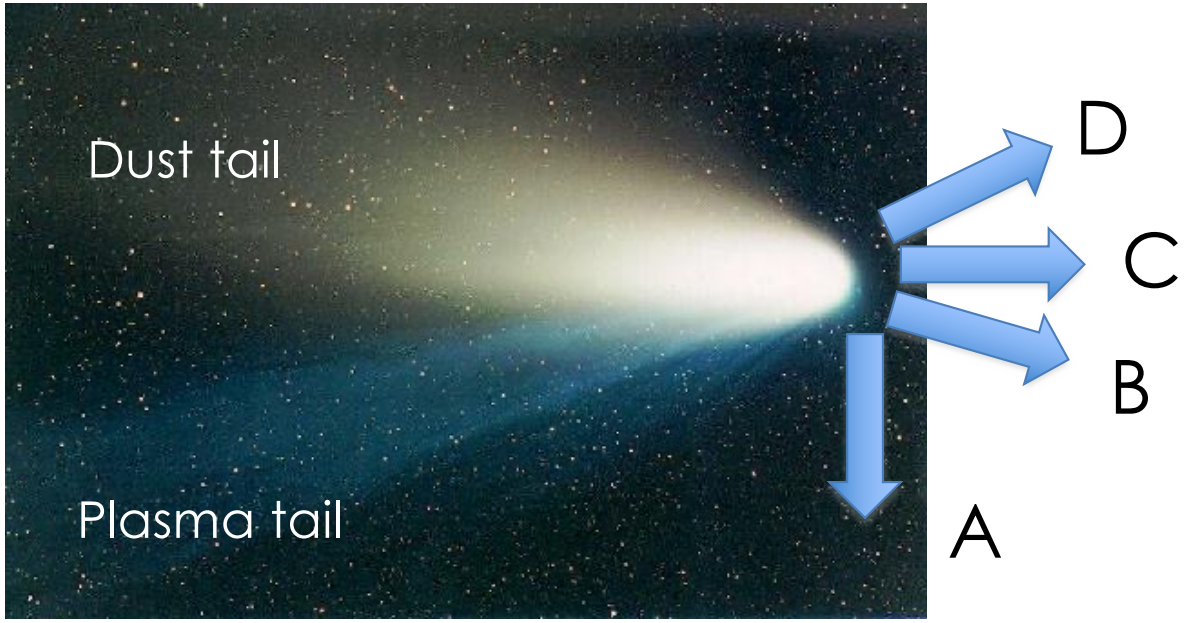
Rosetta and Philae

- ESA's Rosetta mission studied comet 67P/Churyumov–Gerasimenko from 2014 -2016.
- Philae probe is the first spacecraft to land on a comet.
- Last transmission from Philae in 2015.



question for you

Which direction is the Sun?



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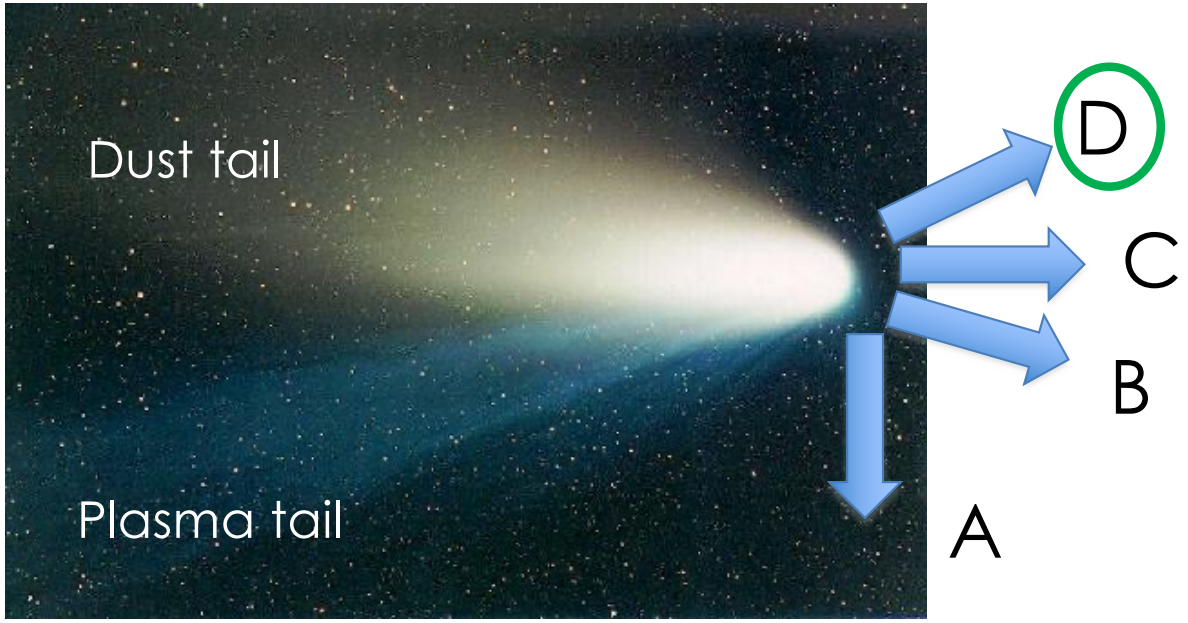


Meteorites

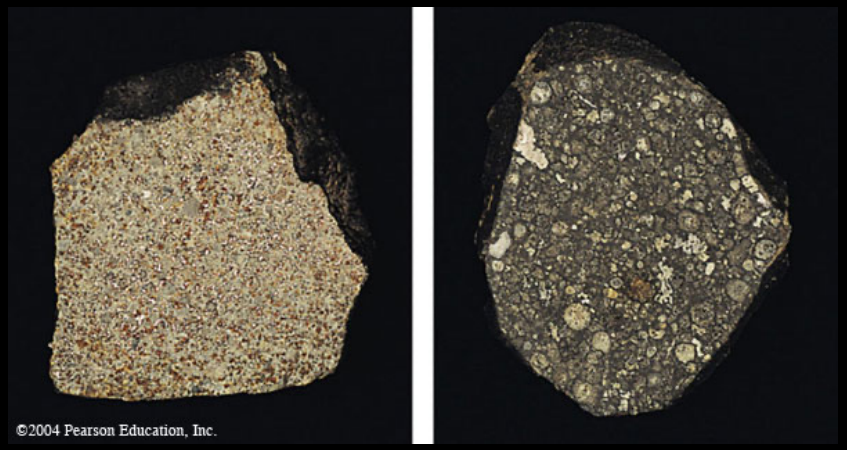
Types of meteorites

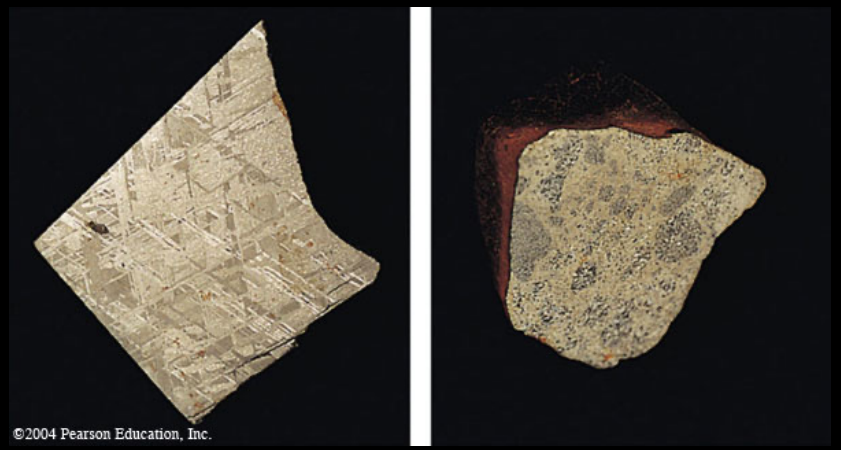
Primitive

- A planetesimal left from the formation of the Solar System.
- Mix of rock and metal flakes.
- ~4.6 billion years old

Processed

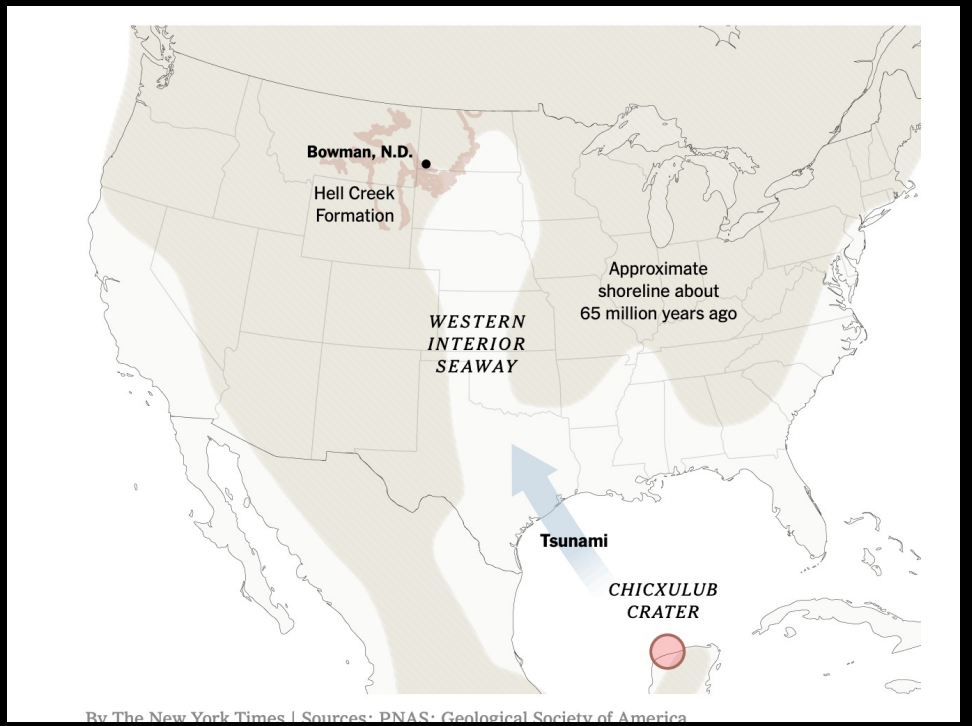
- Pieces broken off larger asteroid.
- Could be the metallic (from the core) or rocky (from crust).
- Younger than primitive.





What killed the dinosaurs?

- The boundary between rocks from the **Cretaceous and Tertiary** periods (now called the Cretaceous–Paleogene (K-Pg) boundary) is rich in iridium, common in meteorites and comets, but also showing evidence of:
  - High abundances of gold, platinum, osmium.
  - Shocked quartz, spherical rock droplets
  - Soot
- Chicxulub crater near Yucatan.
- Fosilized fish found in North Dakota.

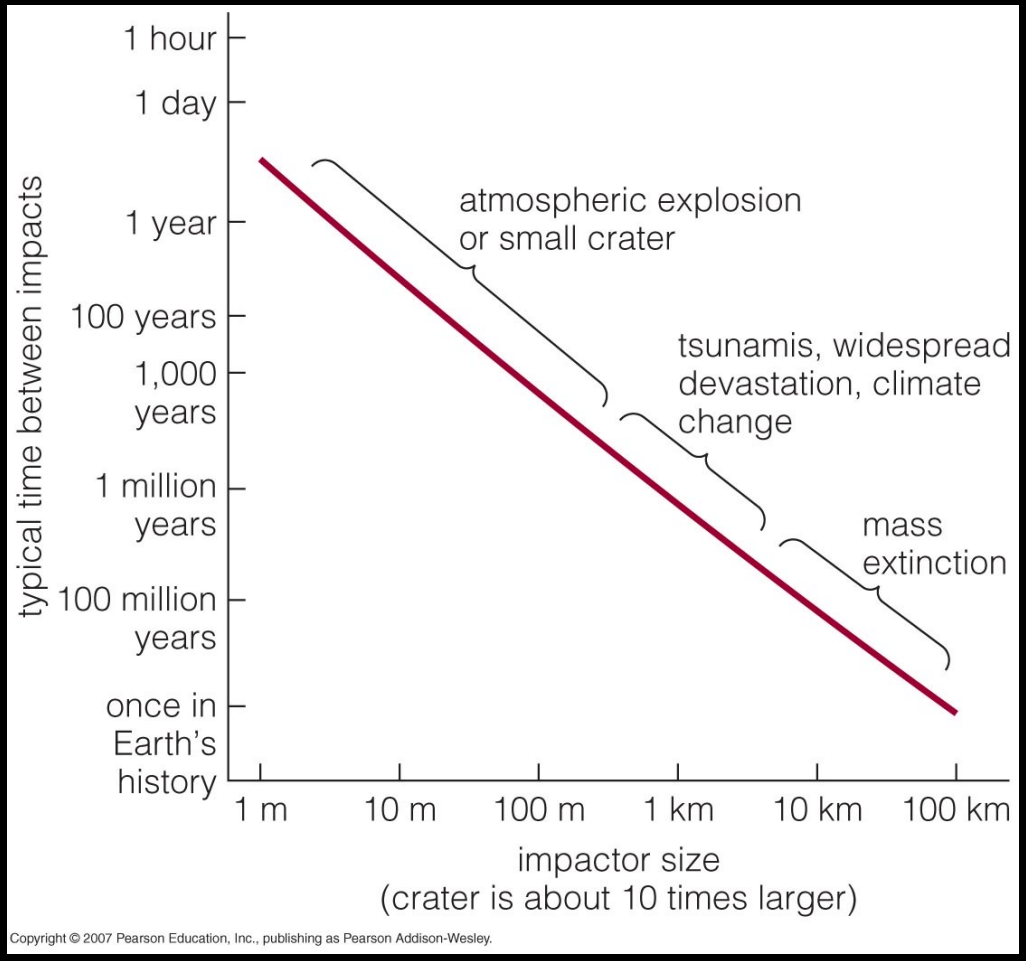


Barringer Crater, Arizona

Occurred ~50,000 years ago. Impactor 50 – 100 m in size.

Impact Events

Frequency of large impacts is much less than that of smaller impacts.



Recent Impacts

Tunguska event in Siberia (1908) flattened a forest.

Recent Impacts

Comet Shoemaker-Levy 9 vs. Jupiter (1994).

question for you

If the last mass extinction caused by an impact of a comet on Earth happened 65 million years ago, when is the next such event going to happen?

A. 35 million years from now.
B. 65 million years from now.
C. Between 35 and 65 million years from now.
D. We cannot know for certain when individual impact events may occur.

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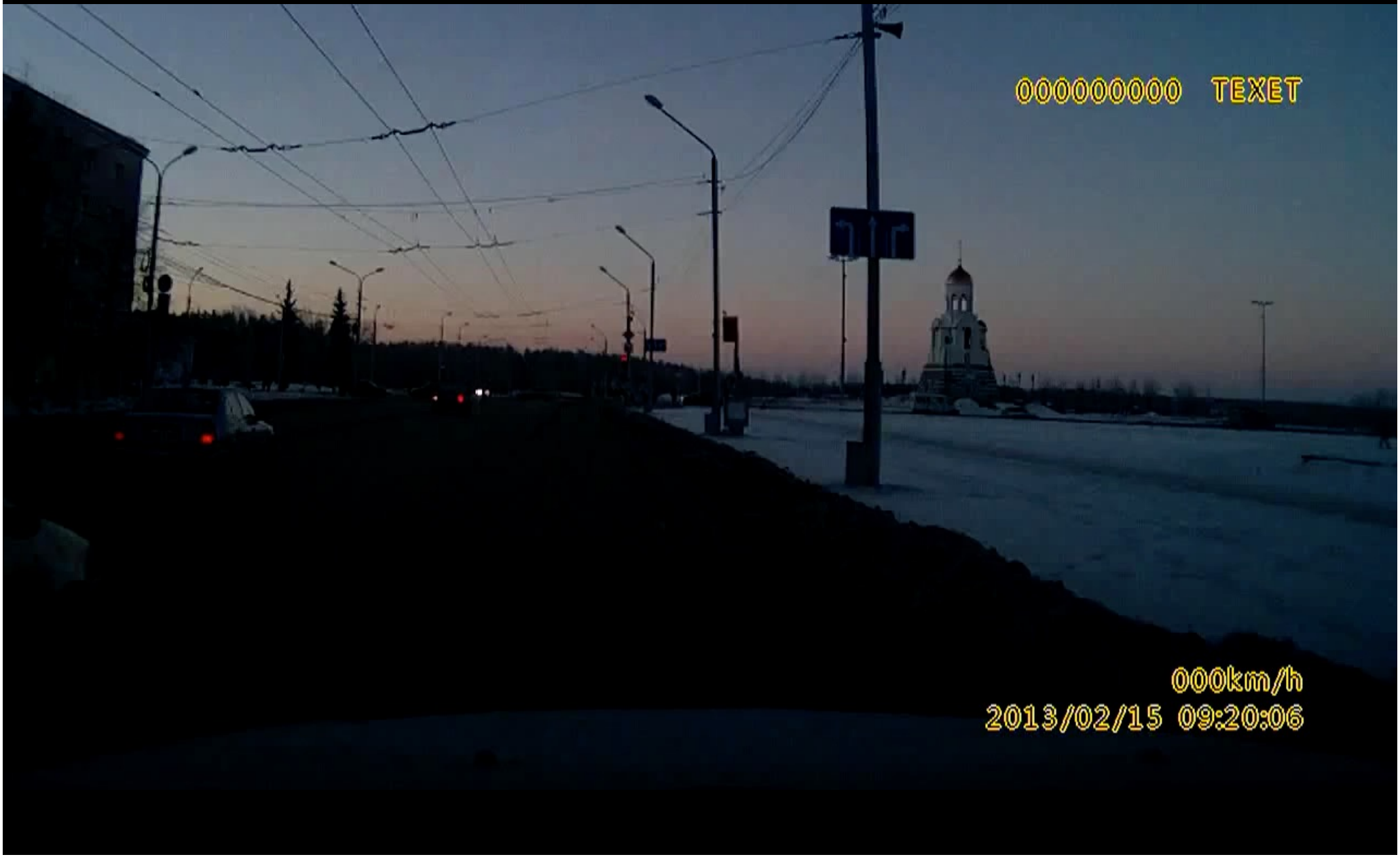
Recent Near-Impact: Feb. 15, 2013
Chelyabinsk, Russia



What did we learn in Chapter 24?

- Two types of planetesimals:
  - Asteroids are rocky planetesimals found up to and including Jupiter's orbit.
  - Comets are icy planetesimals found mostly in the outer solar system, especially in the Kuiper Belt and Oort cloud.
- Ceres, the largest asteroid, and the only one that is spherical in shape, is now a dwarf planet.
- The asteroid belt is located between the orbits of Mars and Jupiter.
- The Trojan asteroids are located at the L4 and L5 Lagrange points of Jupiter's orbit around the Sun.
- Kirkwood gaps in the asteroid belt are locations of orbital resonance with Jupiter.

What did we learn in Chapter 24?

- Meteoroids are grains of dust or small rocks in the solar system.
- A meteor is the streak left by a meteoroid entering Earth's atmosphere.
- A meteorite is the portion of a meteoroid that survives reentry and impacts the Earth's surface.
- Primitive meteorites are unchanged from the formation of the solar system and contain a mixture of rocks and metals.
- Processed meteorites are those broken off from larger asteroids, and may be purely metallic or purely rocky.

What did we learn in Chapter 24?

- Icy planetesimals are comets even if they never come close enough to the Sun to develop tails.
- A comet has two tails:
  - Plasma tail – ionized by UV light from the Sun, points straight back from the Sun.
  - Dust tail – This is from evaporating material, and is swept back due to radiation pressure.
- Meteor showers are caused by grains of dust left behind by comets entering the inner solar system.
- There are five official dwarf planets in our solar system: Ceres, Pluto, Eris, Haumea, Makemake.
- The Kuiper Belt dwarf planets are in highly inclined orbits.

What did we learn in Chapter 24?

- The impact of asteroids and comets with planets of the solar system, including the Earth, is not very common, but can lead to mass extinctions.
- The larger the size of the impactor, the more time between impacts:
  - Earth is impacted by a 10 m object (e.g. Chelyabinsk) every 100 years.
  - Impact of 1 km asteroid once every several million years.
- The size of the crater is approximately 10 times the size of the impactor.