Small Bodies

11/25/2009

Opening Discussion

- http://www.wired.com/geekdad/2009/11/earth-destr
- Have you seen anything interesting in the news?
- http://www.space.com/missionlaunches/091123-ma
- What did we talk about last time?

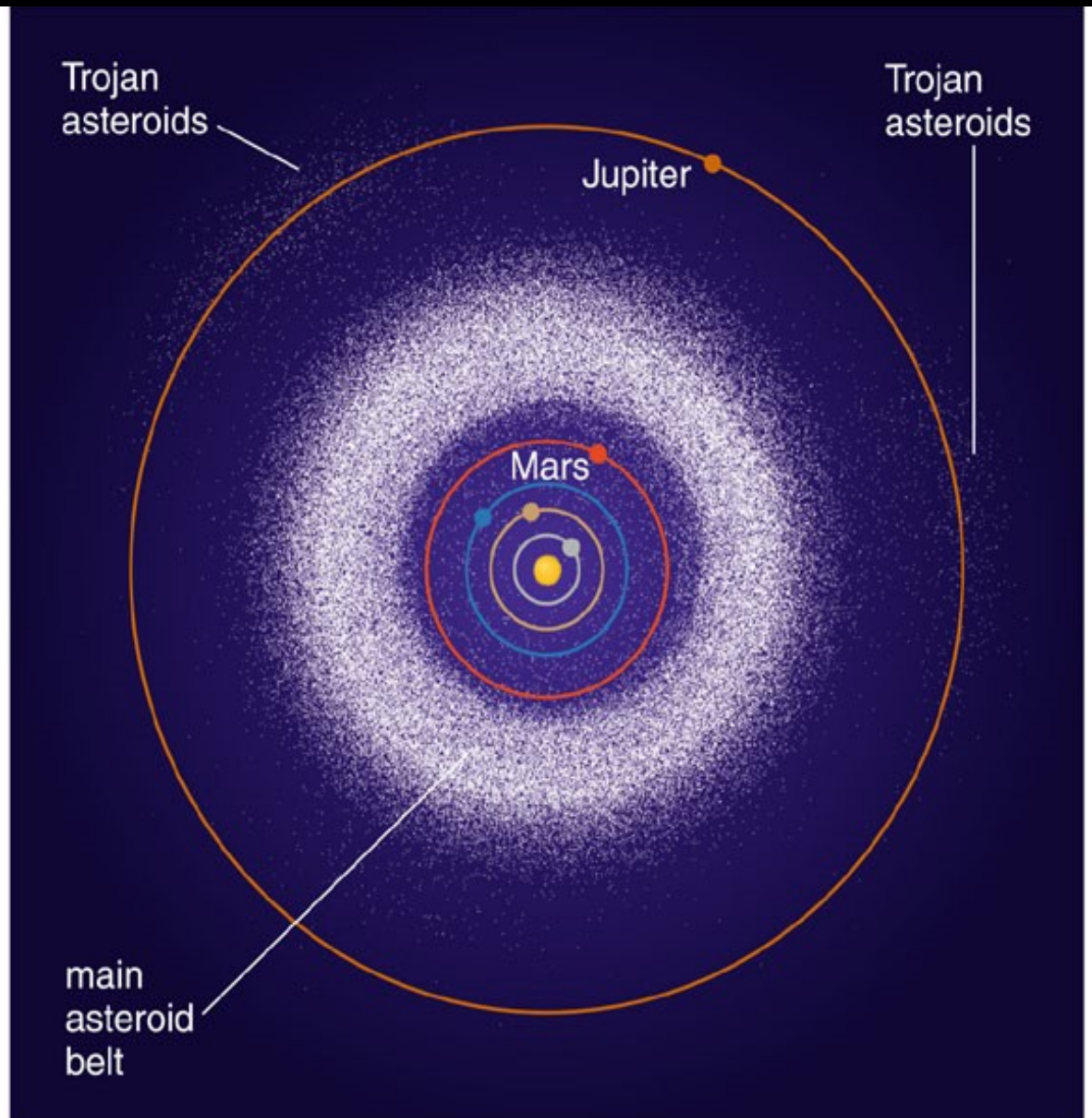
Small Bodies in our Solar System

- There are three major populations of small bodies in our Solar System. We care about these small bodies because they are our best link to the early history of our Solar System.
- Asteroids mostly orbit between Mars and Jupiter with lower inclinations in the normal direction. They are typically rocky or carbonatious.
- Kuiper belt objects orbit close to the plane of the Solar System out beyond the orbit of Neptune. These bodies are icy.
- Oort cloud objects have huge orbits going in all directions.

Meteors and Meteorites

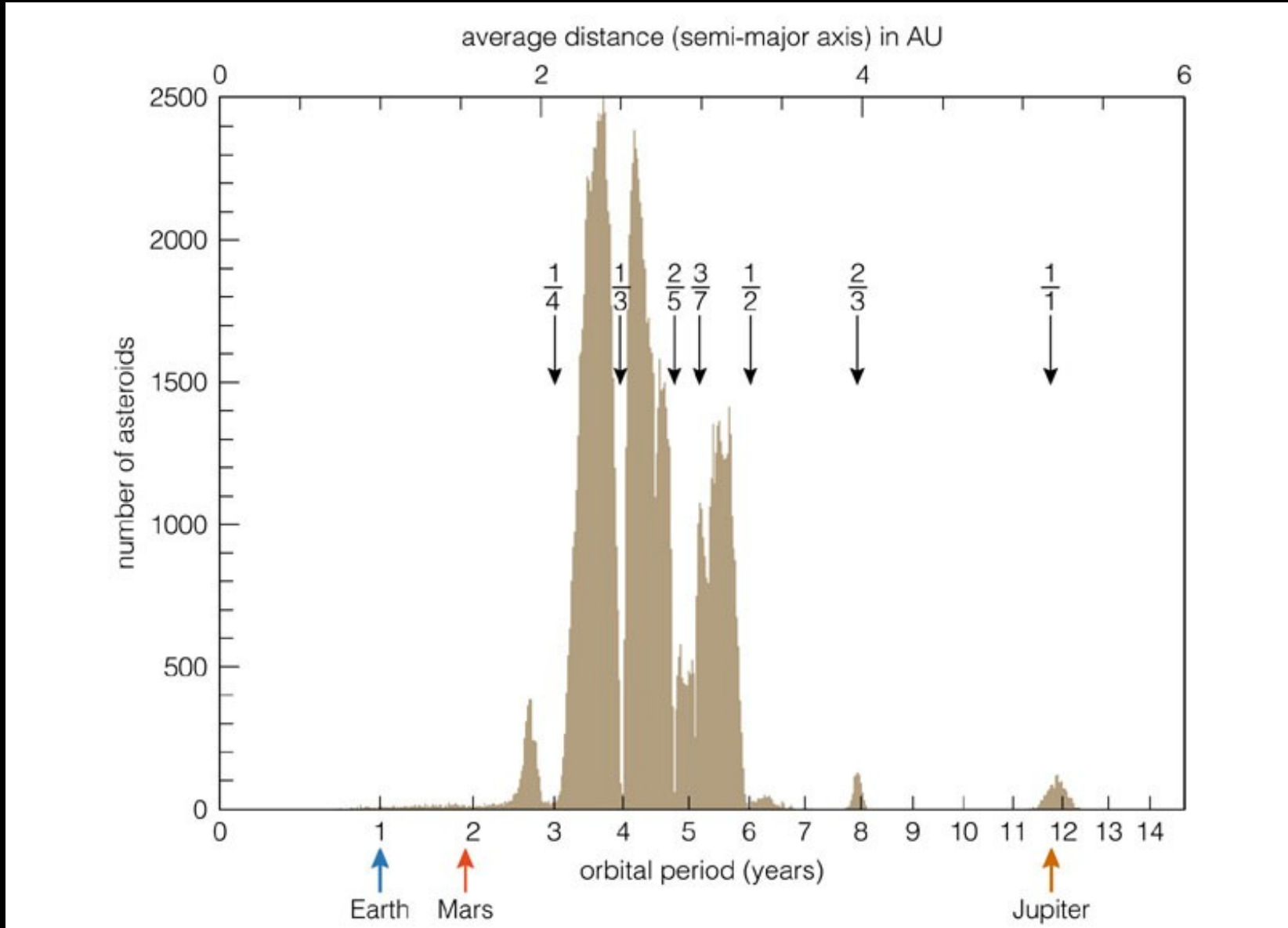
- Just to be clear on terms, a meteor is the bright streak out see going through the air that is often called a shooting star. A meteorite is the chunk that hits the ground assuming it is big enough to get that far.
- In general, asteroids are small rocky objects and comets are small icy objects. Comets only have tails when they are near the Sun, but we will still call them comets even without the tails based on composition.
- Basically, asteroids formed inside the frost line while comets formed outside of it.

Where and Why of Asteroids

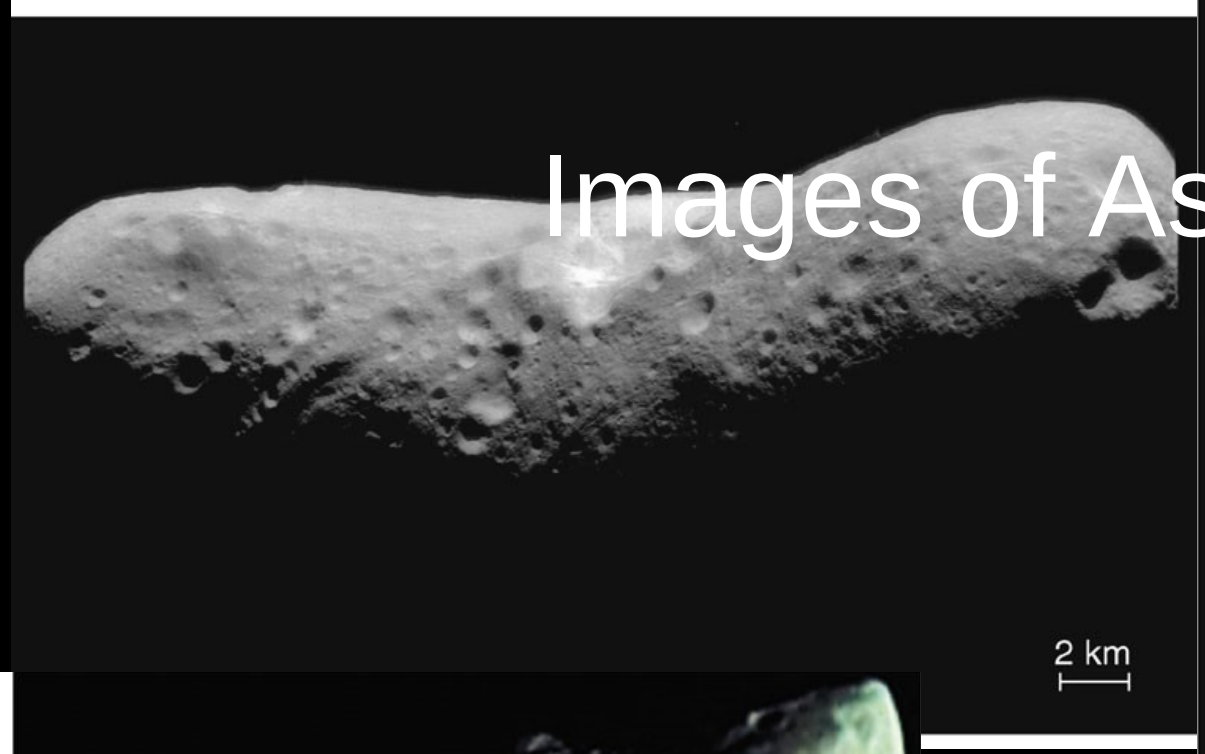


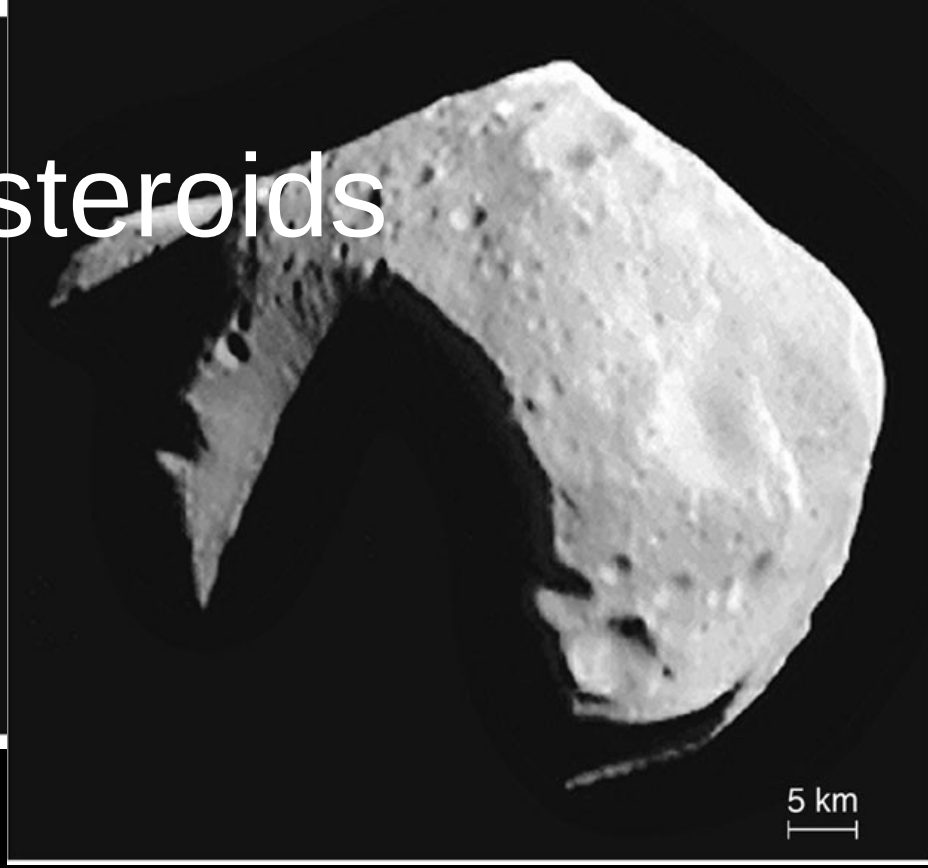
- Why is there an asteroid belt instead of another planet? The reason is likely Jupiter which made collisions more destructive.
- Ceres, the largest asteroid, is only 1000 km in diameter. Most others are much smaller. All together they would make a body less than 2000 km in diameter.

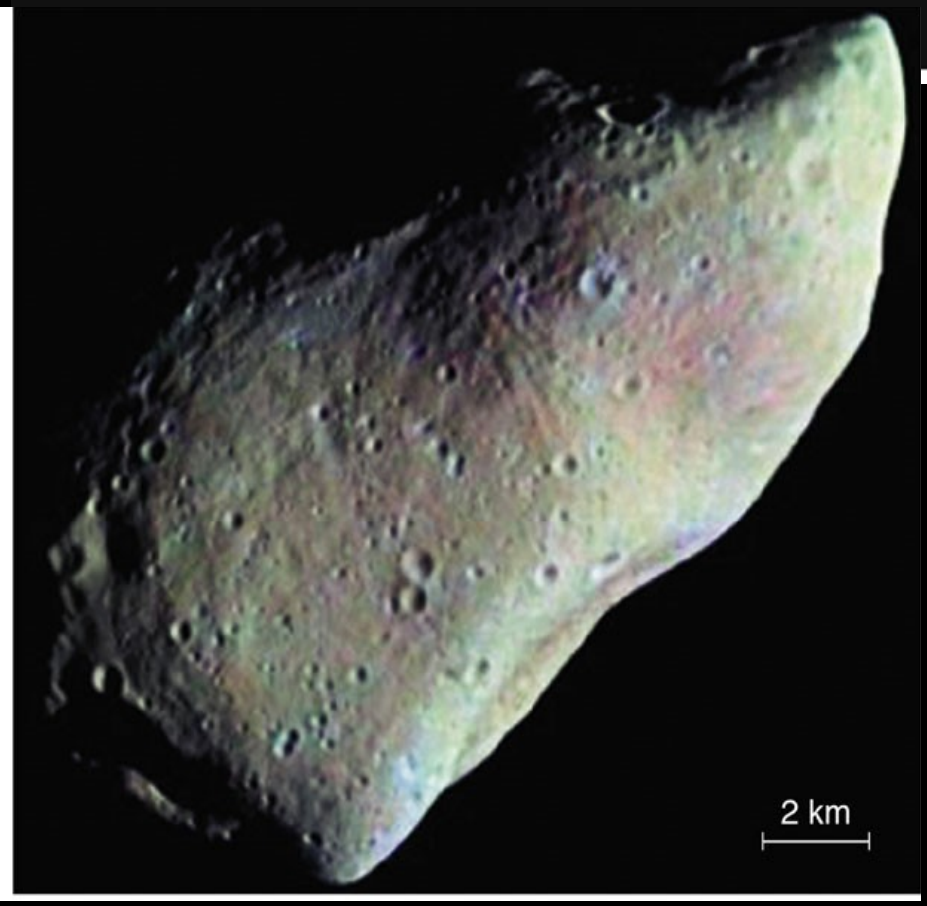
Resonances



Images of Asteroids







Measuring Asteroid Properties

- Spacecraft have only gone near a select few asteroids. Even with the biggest ground telescopes most asteroids are little more than tiny dots. Because of this, some ingenuity is required to determine their properties.
- Orbit – repeated observations of asteroids allow us to determine their orbits. This gives us semimajor axis, eccentricity and inclination.
- Size and reflectivity – If we know the orbit we know how far the asteroid is from us. Measuring how bright it is tells us a combination of size and reflectivity. Observing brightness in IR lets us separate the two.

More Properties

Masses and densities – Measuring the mass of asteroids is hard. We have to measure their gravitational effect on another body. It really helps us understand composition. Mathilde has a density of 1.5 g/cm^3. Eros has a density of 2.4 g/cm^3.

Shapes – Light curves and radio observations can tell us shape. Ceres is the only asteroid that is round from gravity. Hence it is classified as a dwarf planet.

Compositions – Spectroscopy can tell us surface composition. Most distant asteroids are dark and carbon rich. Nearer asteroids have rocky composition. Some asteroids appear to made of metals.

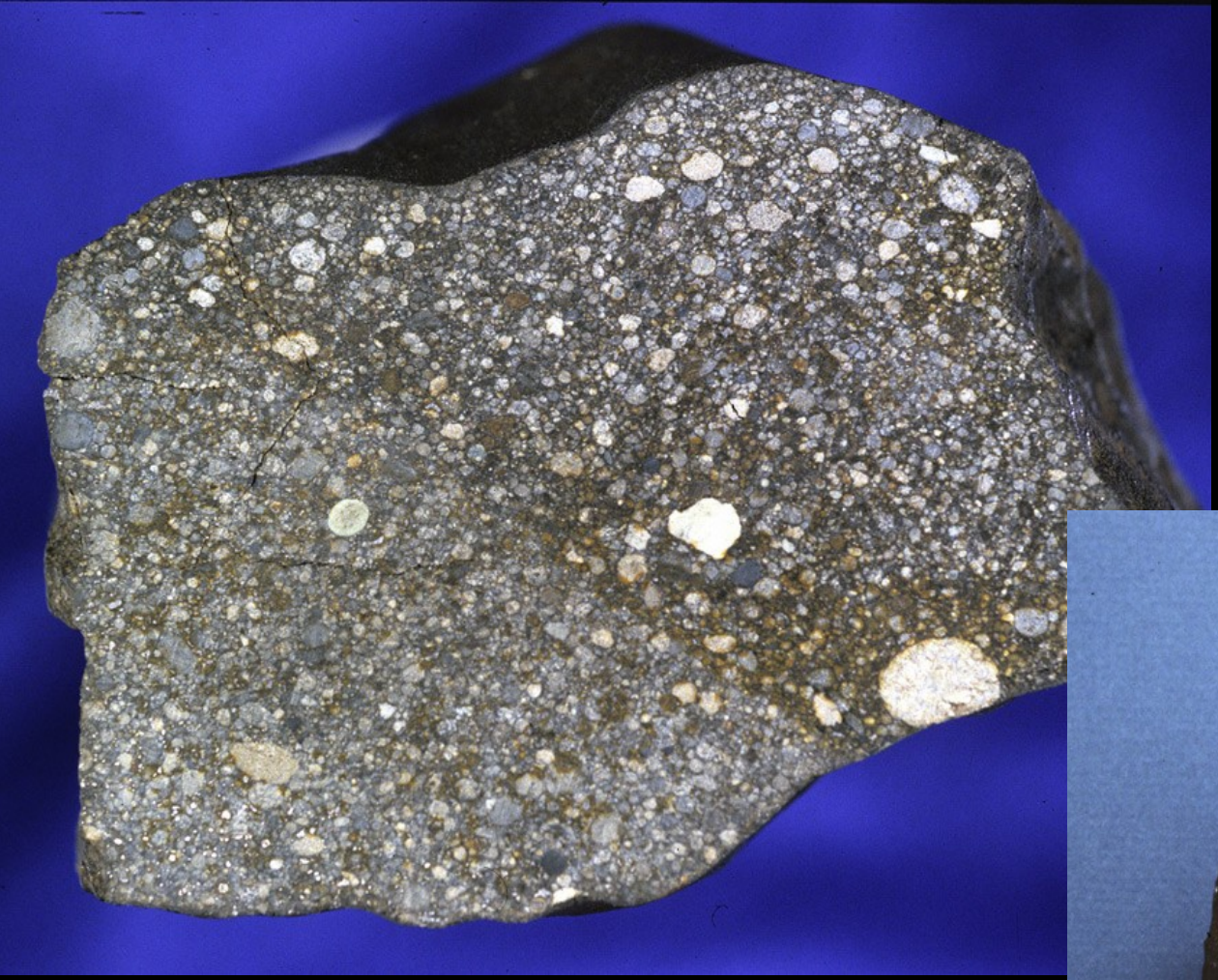
Meteorites

- The fact that meteors are space debris streaking through the atmosphere and that meteorites are rocks from space hasn't been accepted all that long.
- We now know that meteorites are indeed fragments of asteroids that have run into the Earth and were big enough to survive the passage through the atmosphere. These objects help tell us a lot about early composition because many of them are made from the same stuff that originally accreted in the early Solar System. All of these can be identified by higher levels of materials rare on Earth.

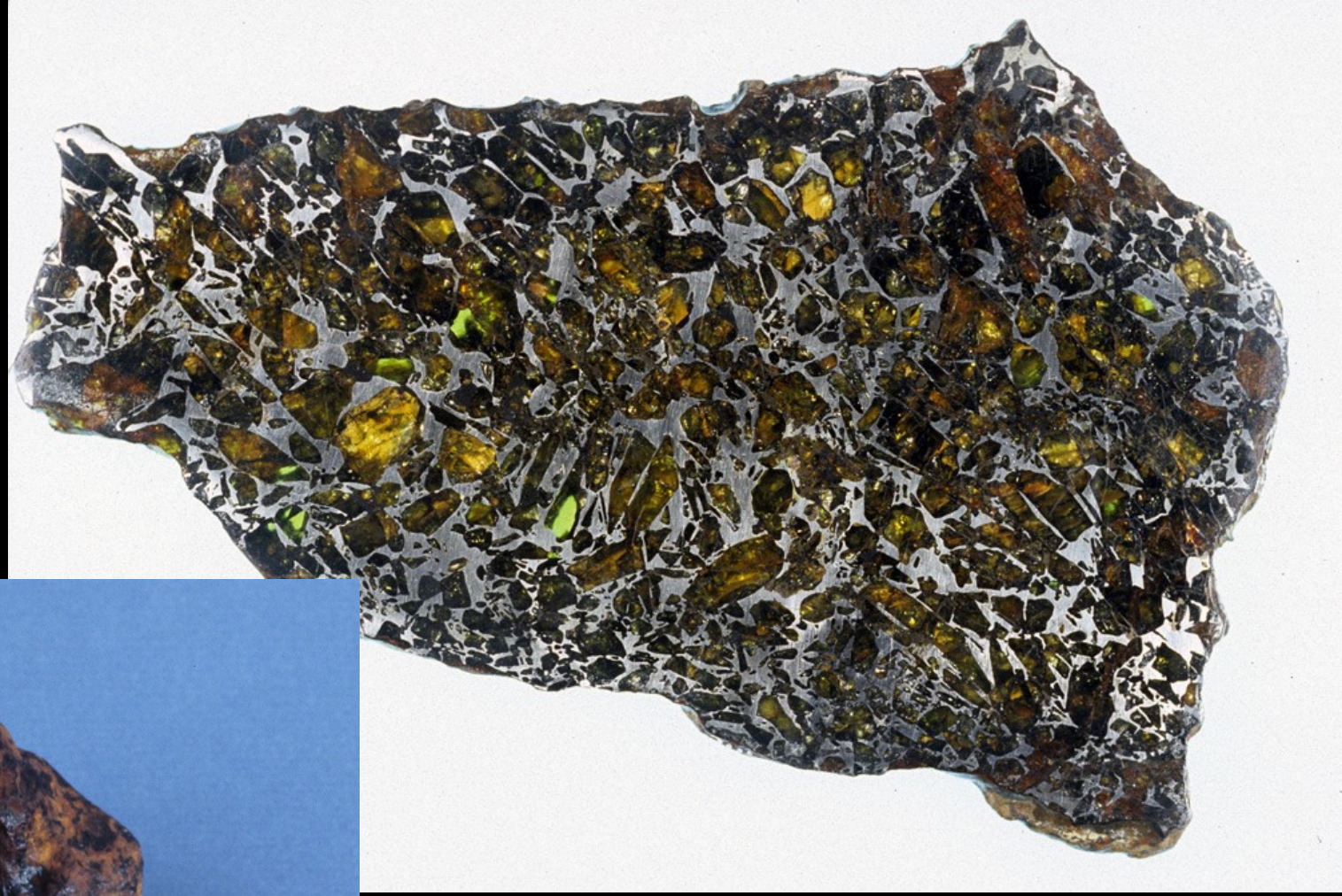
Types of Meteorites

- Meteorites come in two primary types with two subtypes for each.
  - Primitive meteorites (chondrites) date from 4.6 billion years ago and clearly have different components that are stuck together in some matrix. They are either stony with metal flakes or have a significant carbonatious component.
  - Processed meteorites look much like crust, mantle, or core of a planet. They likely came from larger asteroids that had differentiated and were broken apart.

Chondrites



Achondrites



Stony-Irons and Iron Meteorites

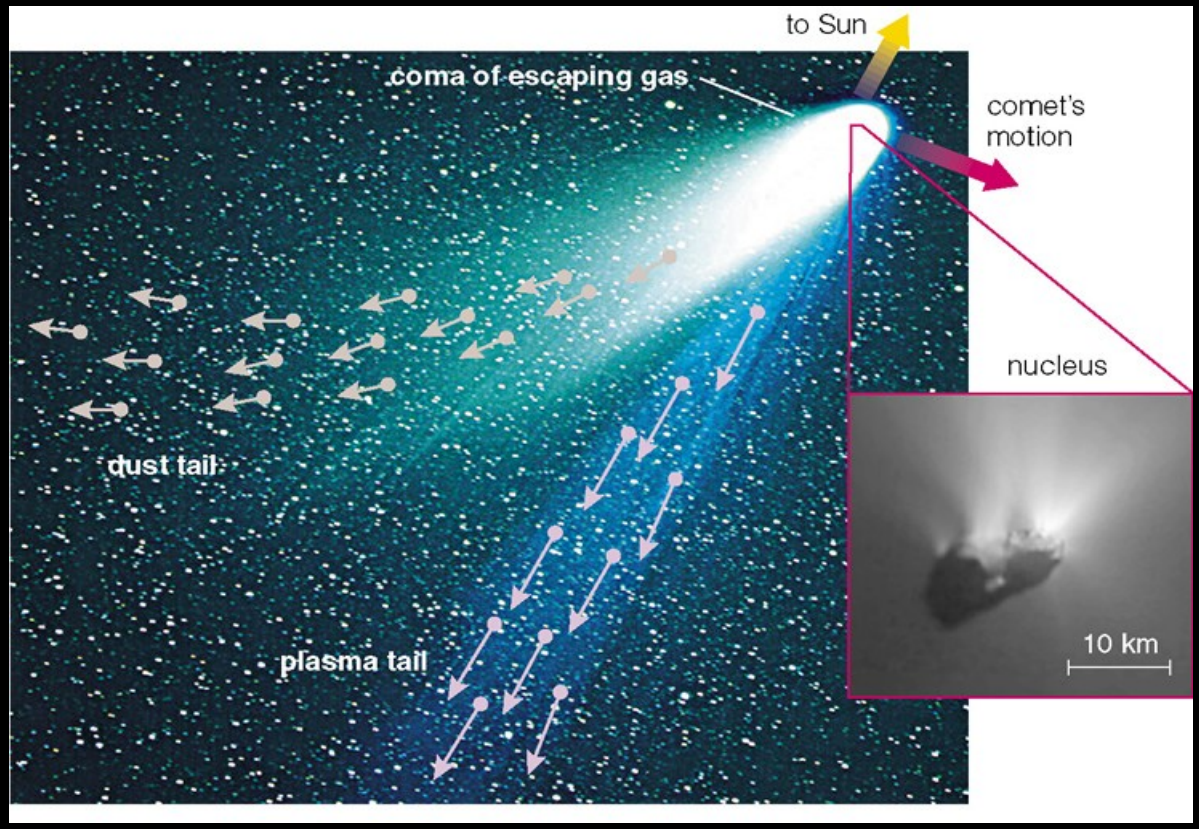
Non-Asteroid Meteorites

- Some meteorites don't have the composition of asteroids. Instead, they have the composition of the Moon or Mars. Likely these were ejected from those bodies in impacts and later struck the Earth.
- One of the meteorites that has a composition matching Mars factors in significantly in the debate about life on that planet.

Comets

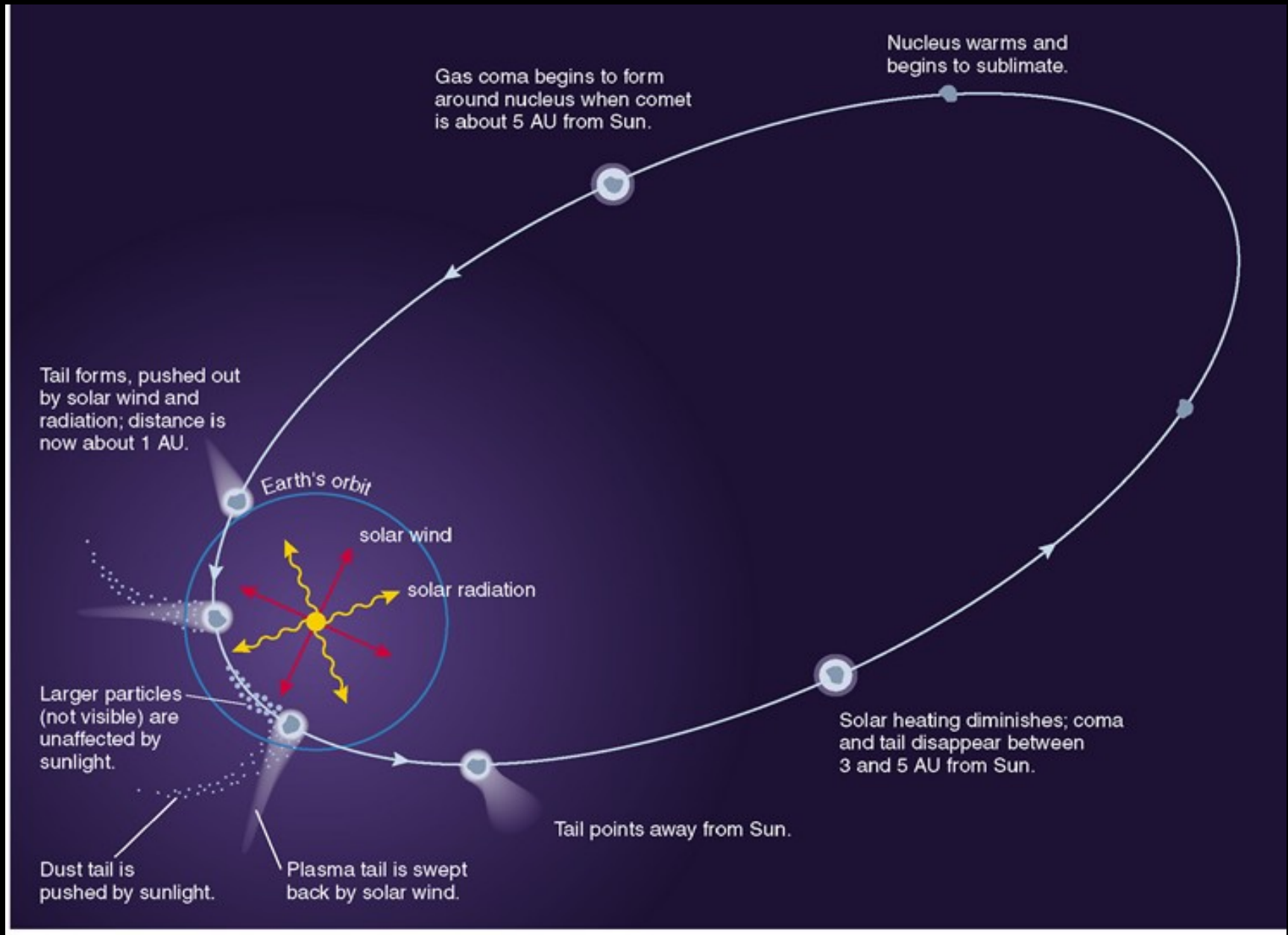
- Historically, comets have been known as bright objects in the sky with no real link to space. Edmund Halley became famous for realizing that several sightings were actually of one comet and predicted it would return 76 years after it's last appearance. The return of Halley sealed the fact that comets are bodies that orbit the Sun.
- Comets are really just large balls of ice and dust. When they come in close to the Sun the ices sublimate and throw up dust making them much more visible. Most comets are far from the Sun and look like nothing more than balls of dirty ice.

A Tale of Two Tails



- The comet itself is really a small core that we rarely see. When it comes close to the Sun the sublimation produces a larger coma.
- Dusty material in the coma is pushed by by radiation pressure. (dust tail)
- Gases in the coma are ionized and are swept back by the solar wind. (plasma tail)

Life of a Comet



Origins of Comets

- Imagine the early outer Solar System. Beginning around the frost line there are a vast number of small icy bodies orbiting the Sun and occasionally colliding. Some wind up going into the formation of the Jovian planets. Even after those planets form though, a large number of bodies are left behind.
- These bodies interact with the Jovian planets, often in close encounters. Passing close to a giant planet throws these objects into very different orbits, sometimes completely out of the Solar System.

Dynamical Friction and Planet Migration

- As we mentioned when we talked about planet formation, accretion can't build Neptune, or even Uranus, in 4.5 billion years with the density of material that should have been present. Most likely those planets formed closer to the Sun and moved outward.
- When a large body moves through smaller bodies a number of things happen. Dynamical friction/equipartition of energy tends to circularize the orbit of the large body while putting the small bodies onto more eccentric orbits.

More Migration

- There is rather strong evidence the Neptune actually formed well inside of its current orbit and migrated outward. This outward migration was caused by throwing more small objects in toward the Sun than it threw away from the Sun.
- The reason for the difference is that objects thrown in toward the Sun were likely to have a close encounter with Jupiter or Saturn and be removed from the system. Those thrown out returned for another encounter later.
- This same process also likely led to Jupiter migrating in.

Kuiper Belt

- Comets actually come from two sources. One source is a flat distribution beyond the orbit of Neptune called the Kuiper belt. These never passed very close to a planet. The Kuiper belt extends out to ~100 AU and likely contains ~100,000 comets 100 km across and a billion comets 10 km across.
- Evidence for the migration of Neptune comes from the fact that many of these bodies are trapped in resonances with Neptune. The lack of asteroids in the asteroid belt is likely evidence that Jupiter migrated inward as well.

Oort Cloud

- The small icy bodies that did pass close to planets (and helped to move the Jovian planets to where they are today) generally didn't stay in the plane of the Solar System. Instead, they were thrown in random directions on extremely high eccentricity orbits. Some were even put on unbound orbits.
- The ones that stayed bound orbit our Sun in the Oort cloud. Their orbits extend out to 50,000 AU where they can even be perturbed by other stars passing by. There are likely 10^{12} comets in the Oort cloud.

Minute Essay

- What are your plans for Thanksgiving?