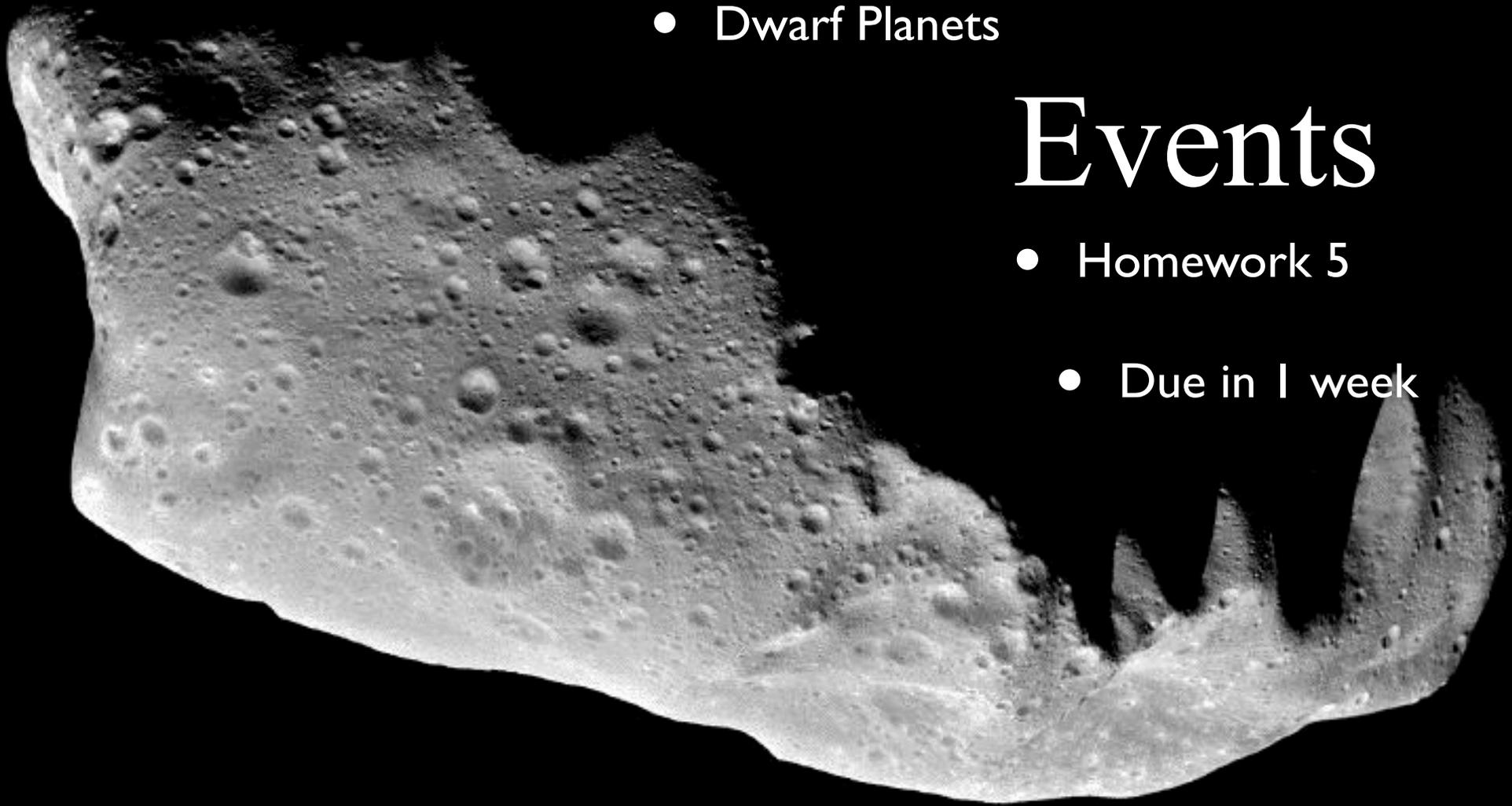


Today

- The Little Things
 - Asteroids & Comets
 - Dwarf Planets

Events

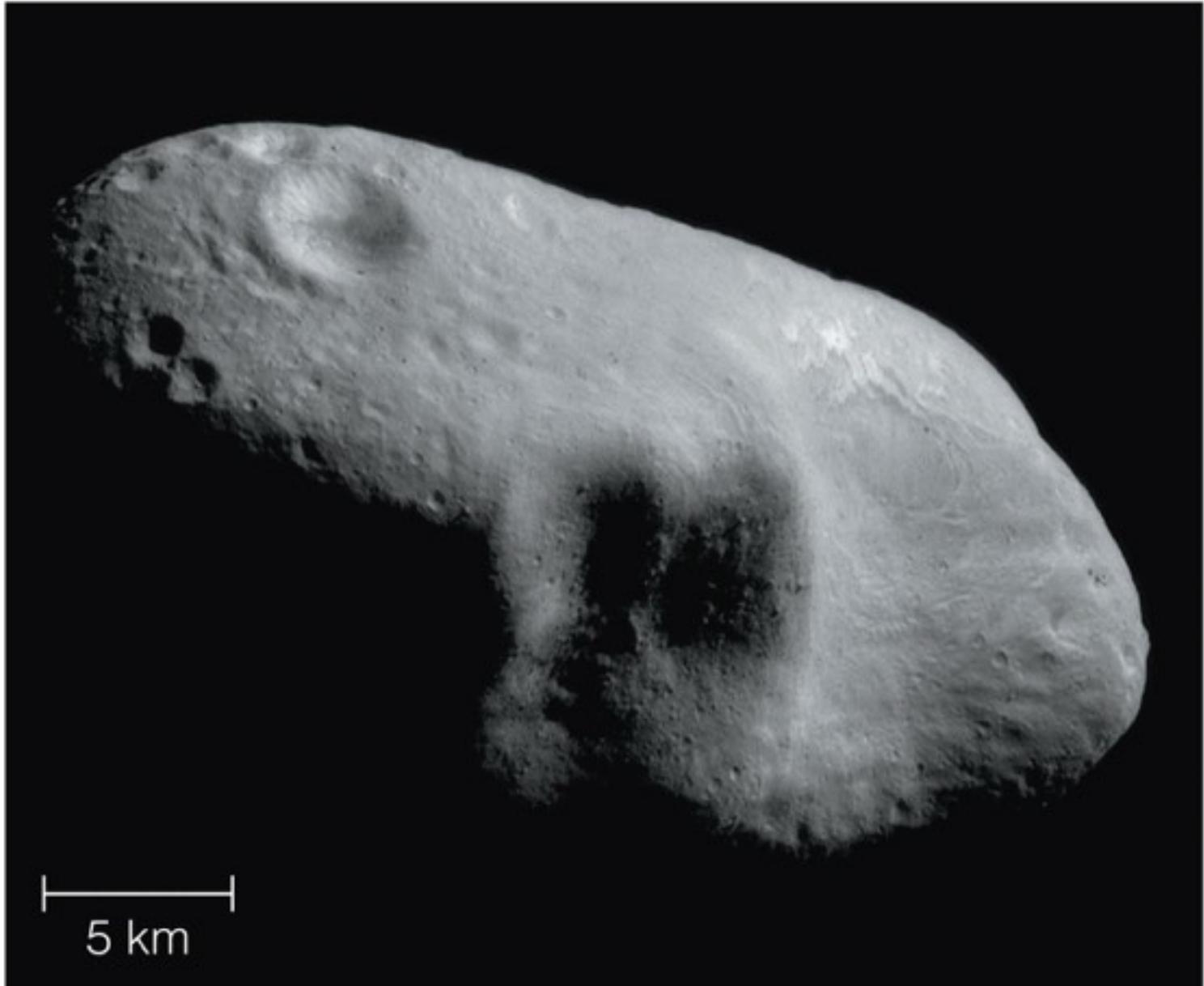
- Homework 5
 - Due in 1 week



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



What are asteroids like?



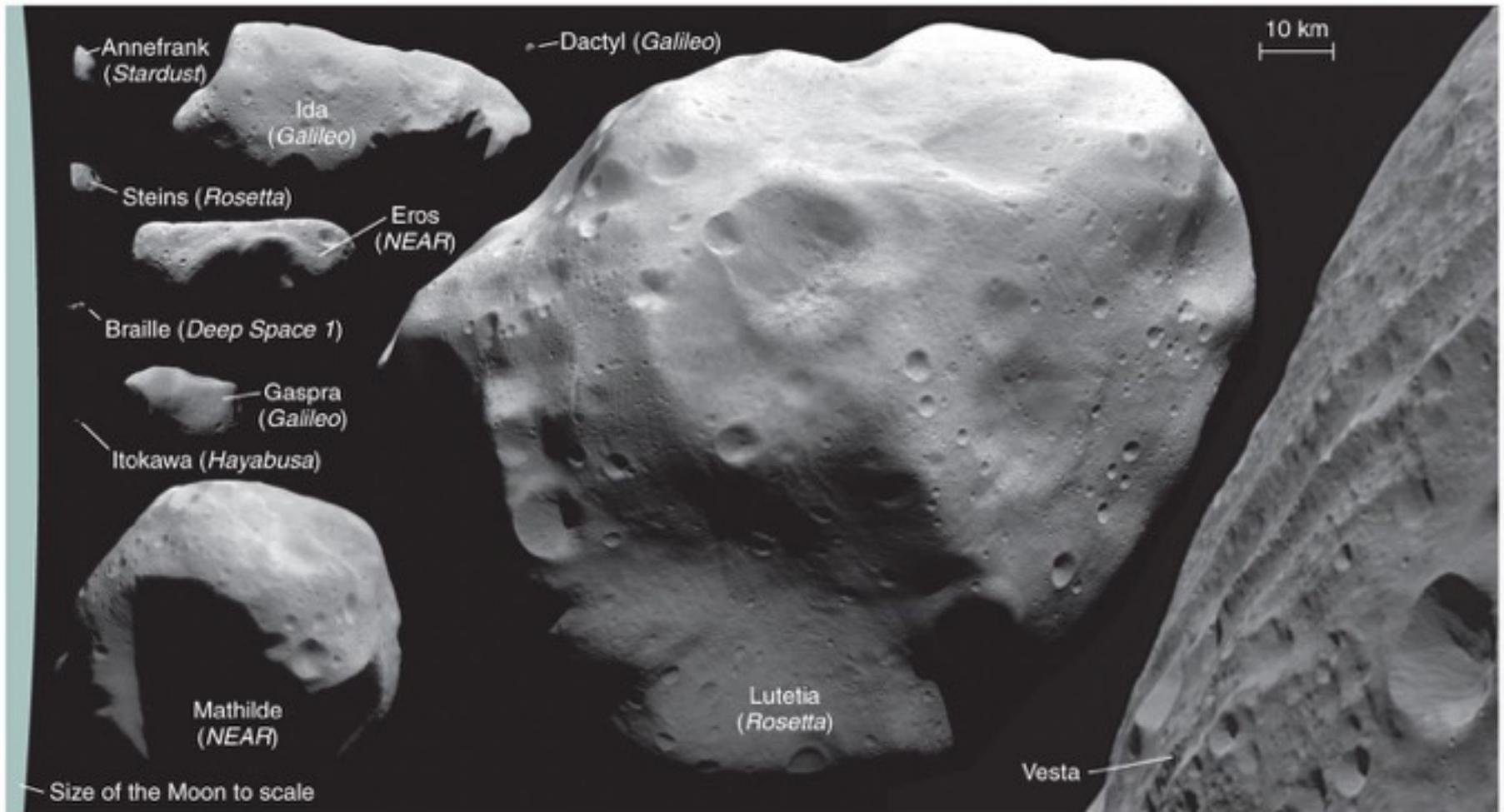
Asteroid
traversing
sky due to
orbital
motion
(time lapse)



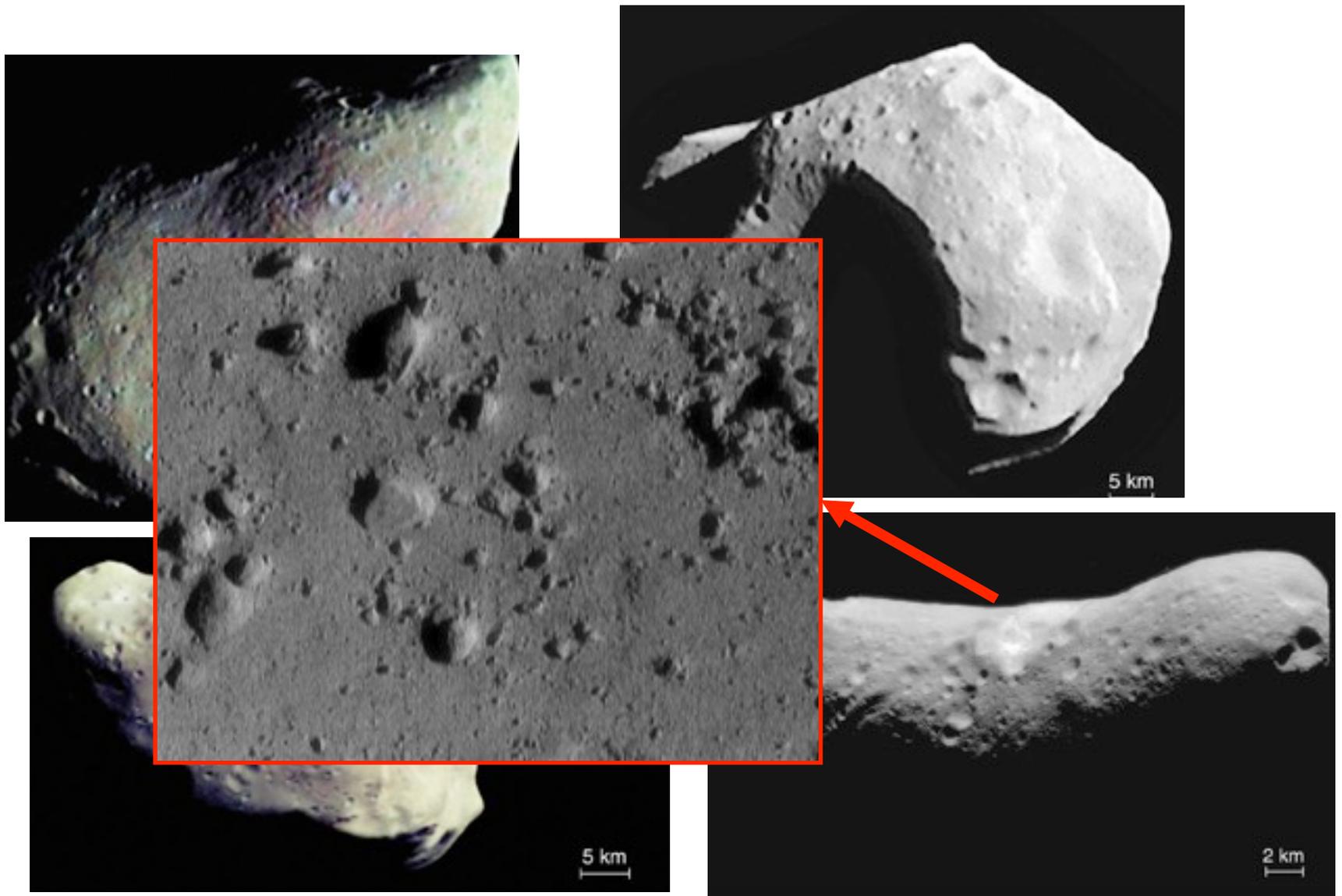
Asteroid Facts

- Asteroids are rocky leftovers of planet formation.
- “Rubble Piles”
 - loose collection of rocks; not one big one.
- The largest is Ceres, diameter $\sim 1,000$ km.
- There are 150,000 in catalogs, and probably over a million with diameter >1 km.
- 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.

Lots of small bodies, but not much mass.



- Asteroids are cratered and not round.



Asteroids are cratered and not round.

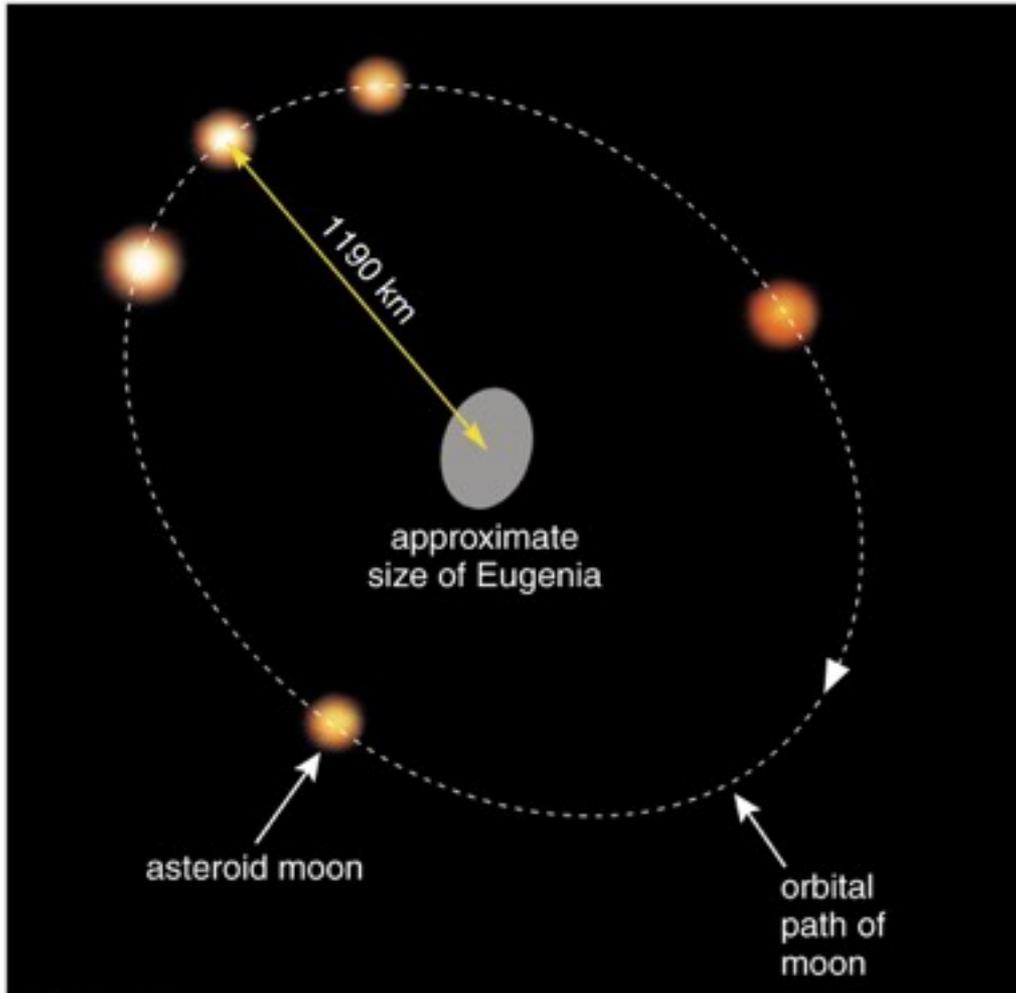
NEAR movie

Asteroids with Moons



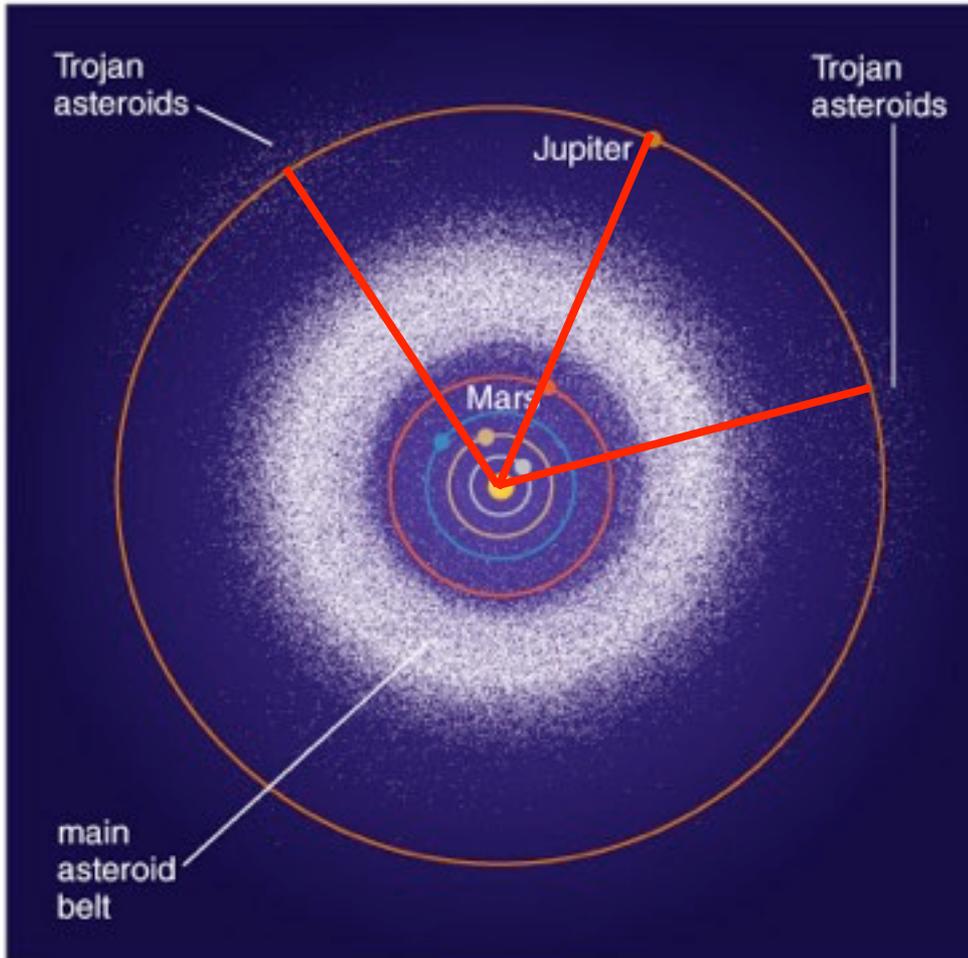
- Some large asteroids have their own moon.
- Asteroid Ida has a tiny moon named Dactyl.
- Sometimes asteroids are binary, with two roughly equal size partners.

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.
- Typical densities ~ 2 g/cc - rock with gaps - "rubble piles"

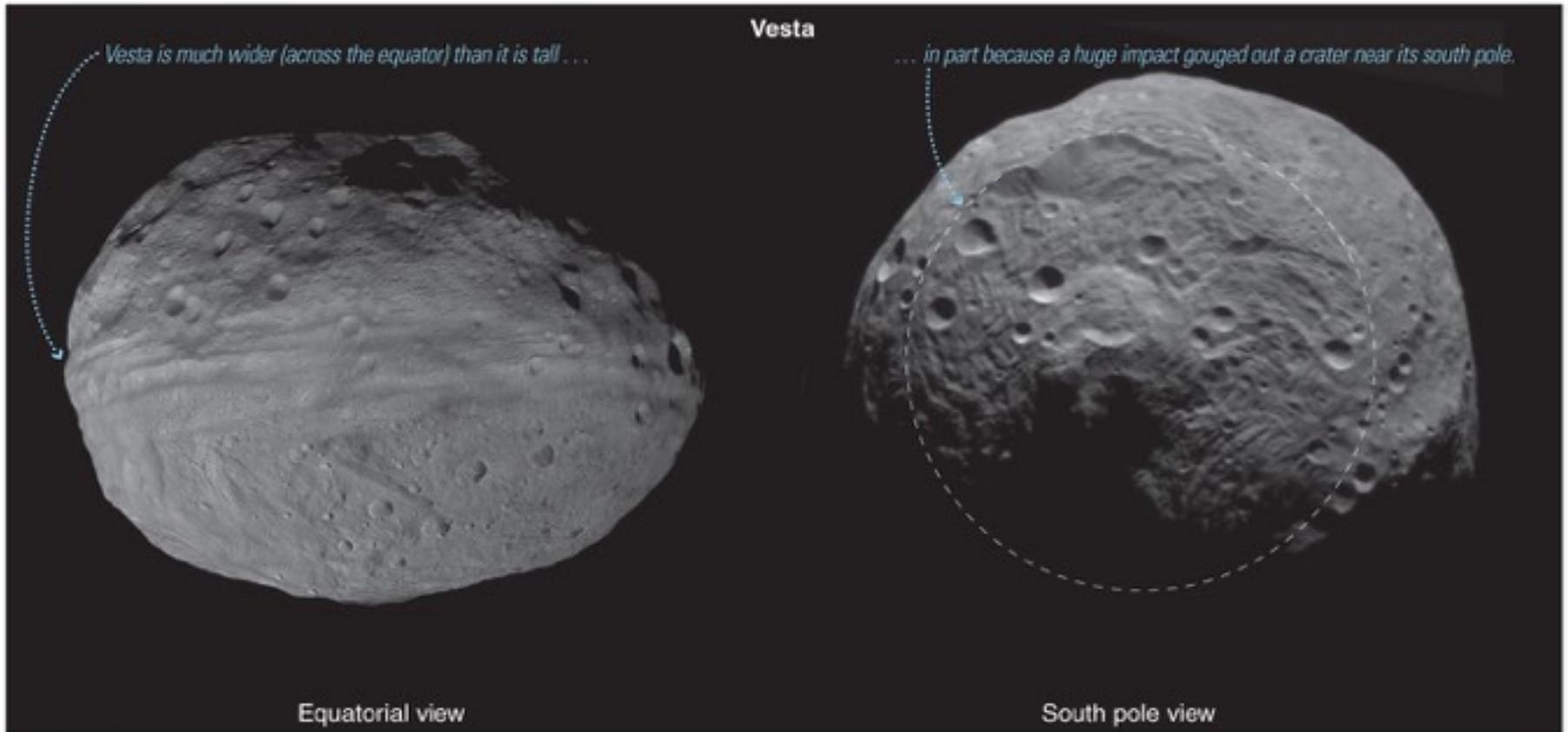
Asteroid Orbits



- Most asteroids orbit in a **belt** between Mars and Jupiter.
- *Trojan asteroids* follow Jupiter's orbit.
 - 60 degrees ahead or behind
- *Apollo asteroids* cross Earth's orbit

Biggest asteroids: Vesta & Ceres

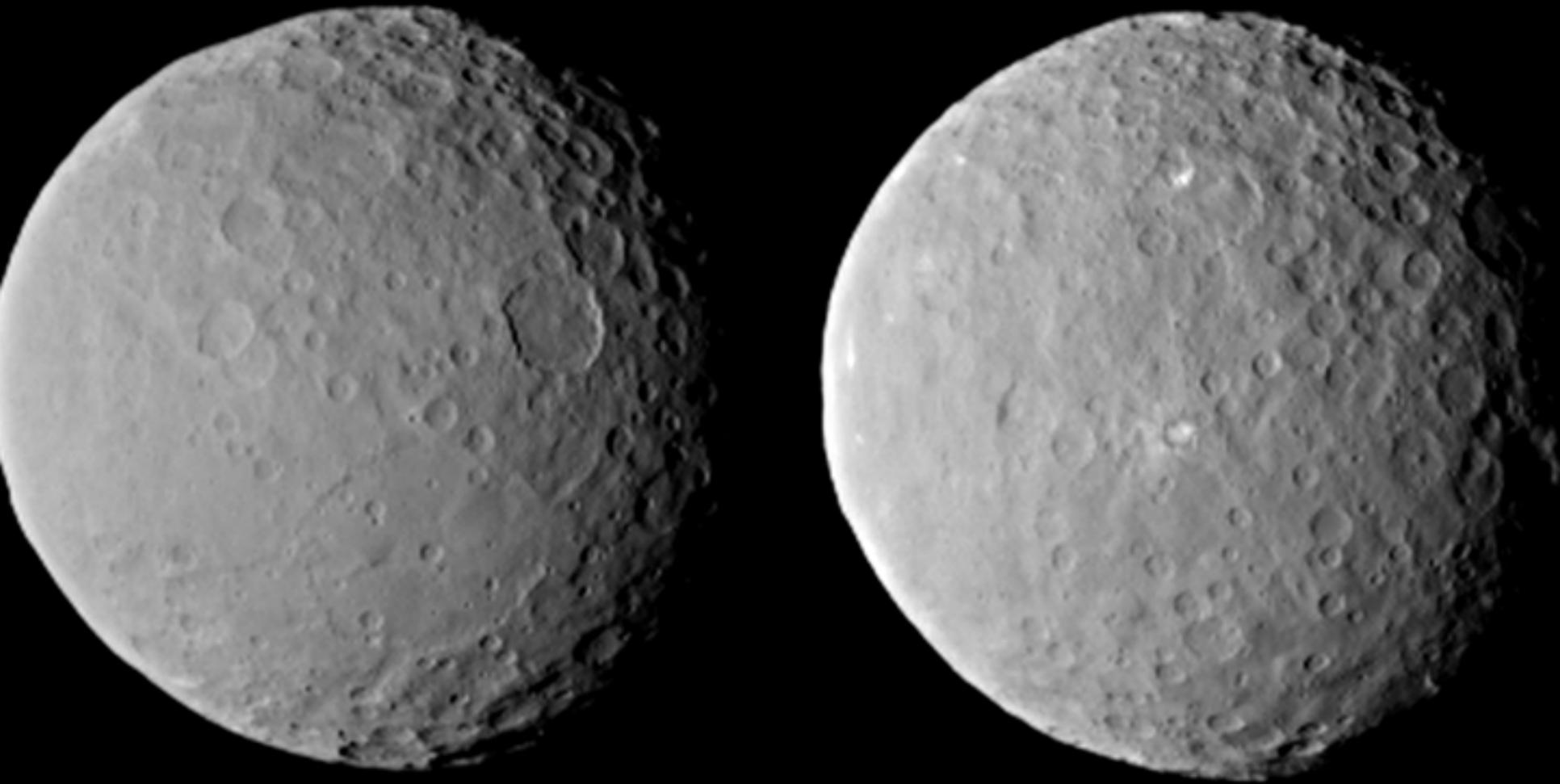
Vesta as seen by the *Dawn* Spacecraft



<https://www.youtube.com/watch?v=84vz6J8cnc8>

<http://vestatrek.jpl.nasa.gov/>

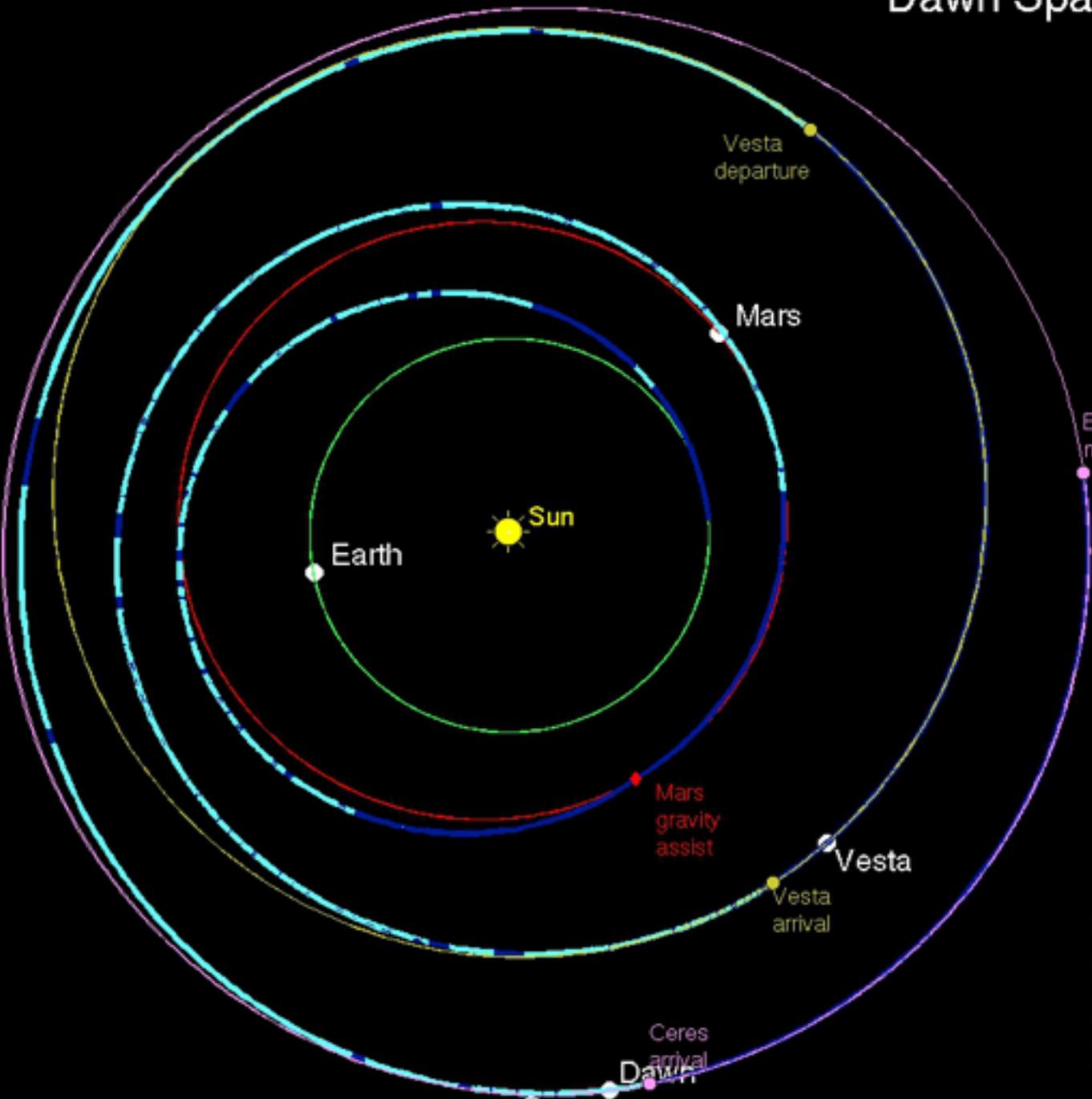
Ceres



Largest asteroid in solar system (~1000 km diameter);
qualifies as a dwarf planet

Dawn Spacecraft Current Location

Apr.01,2015 20:46:10 UT

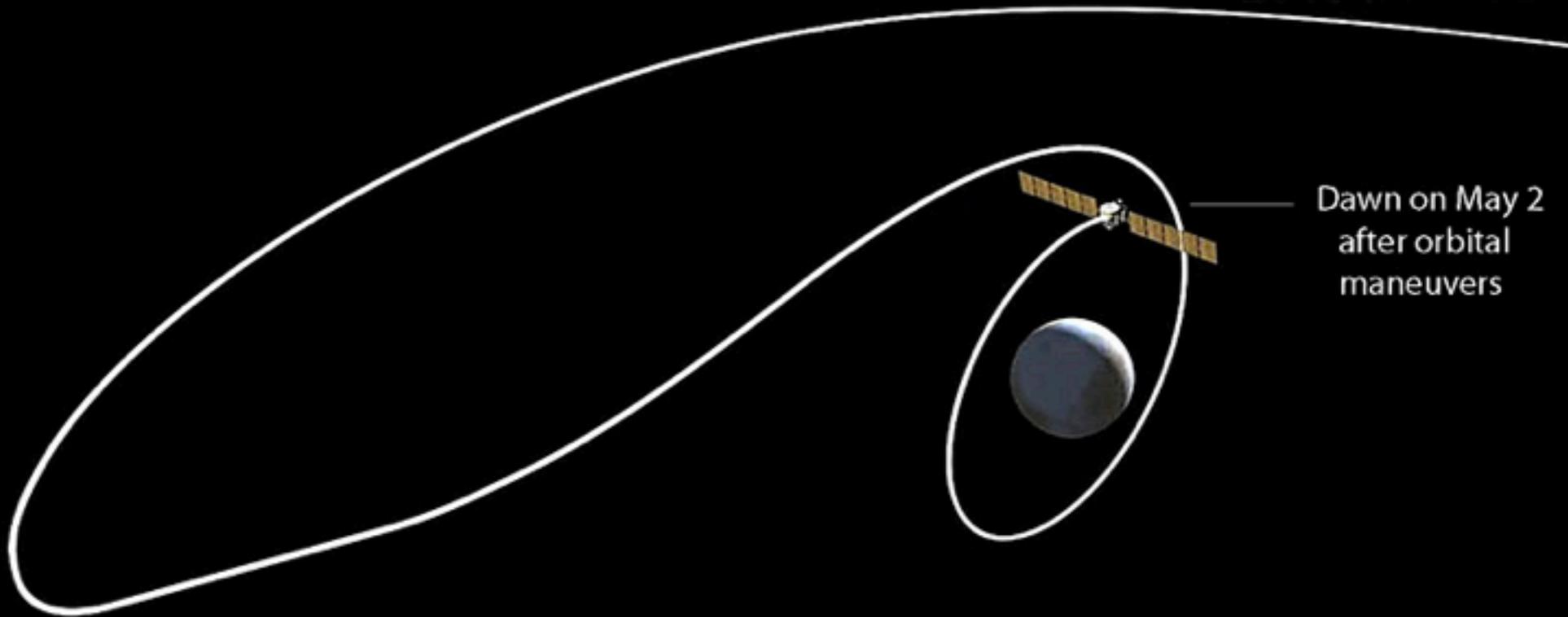


- Dawn trajectory thrust on
- Dawn trajectory thrust off
- Earth's orbit
- Mars's orbit
- Vesta's orbit
- Ceres' orbit

End of prime mission

Distance to Vesta 1.662 AU
Distance to Earth 3.028 AU
Distance to Ceres 0.000397 AU
Distance to Sun 2.885 AU

Dawn closing in



First mission to use ion propulsion
allows slow but steady, long term thrust,
permitting it to meet both Vesta and Ceres

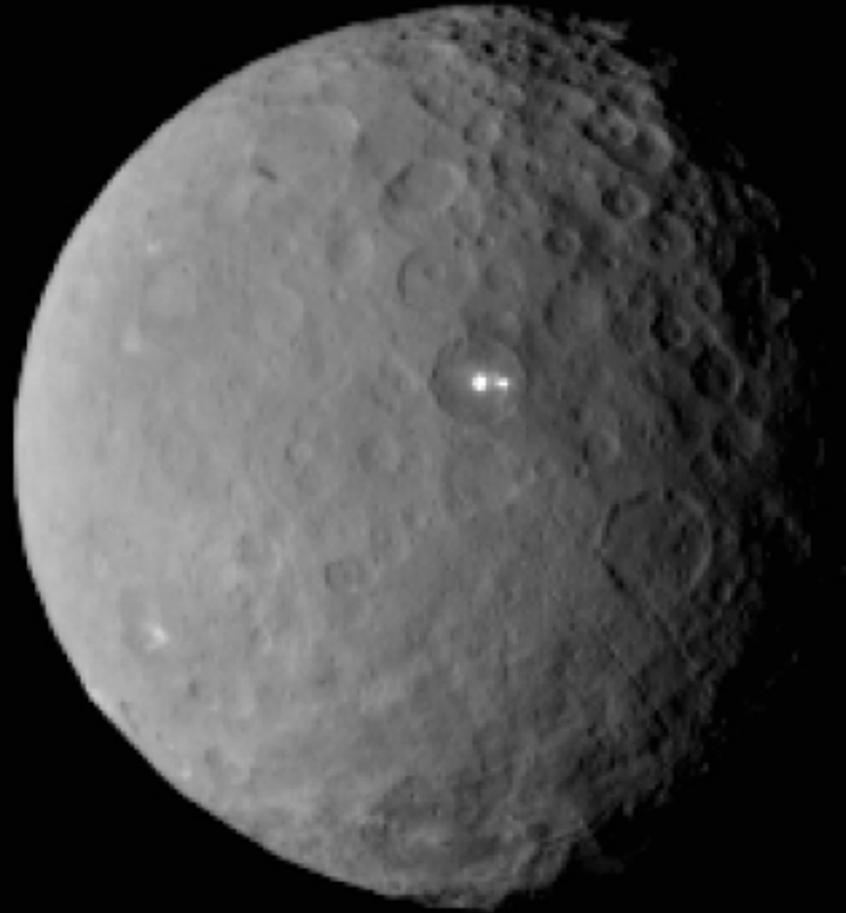
White spots
discovered by
Dawn spacecraft

high albedo $> 40\%$

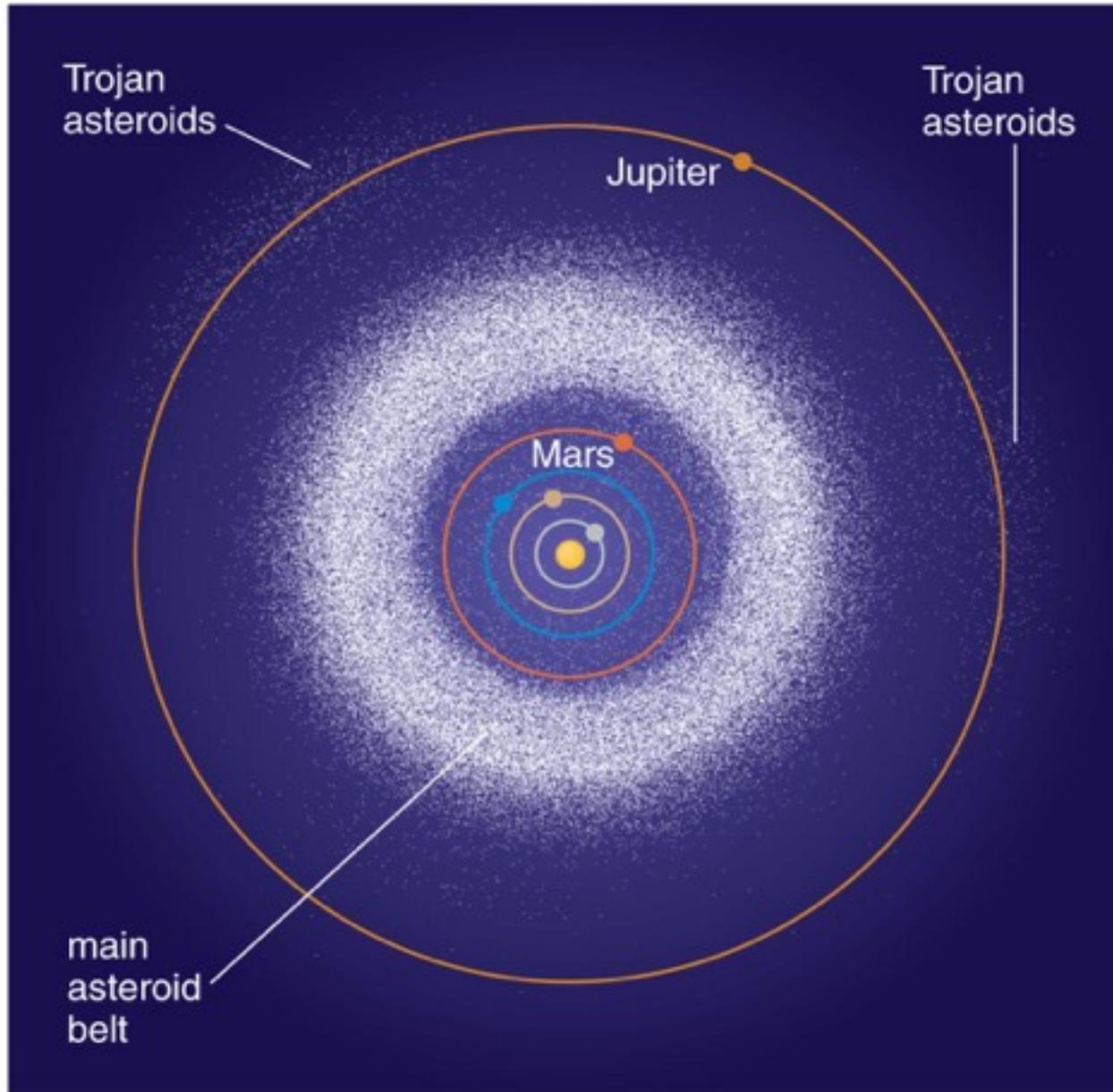
low albedo
surroundings $< 10\%$

Salty ice?
A hint of
subsurface water?

Dawn closing in -
more results soon



Why is there an asteroid belt?



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.

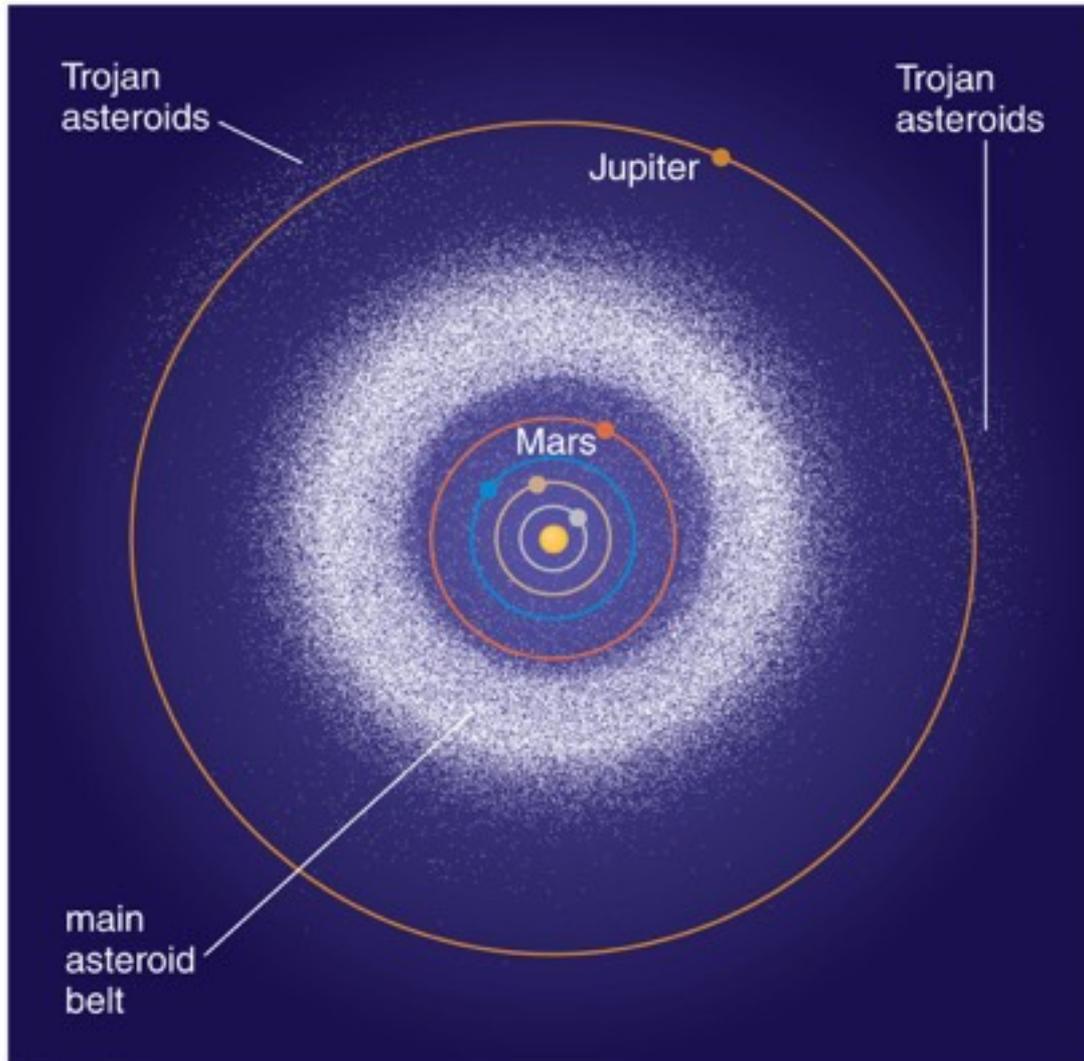
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- C. The belt is where all the asteroids happened to survive.**

But WHY didn't they form a planet?

Origin of Asteroid Belt



- Rocky planetesimals between Mars and Jupiter did not accrete into a planet.
- Jupiter's gravity, through influence of orbital resonances, stirred up asteroid orbits and prevented their accretion into a planet.

How are meteorites related to asteroids?



Rocks that fall from the sky...

- **Meteorite:** A rock from space that falls through Earth's atmosphere.
- **Meteor:** The bright trail seen as a shooting star.
Typically only a grain of sand.
- **Meteoroid:** A rock in space prone to become a meteor.

Meteorite Impact



Chicago, March 26, 2003

Meteorite Types

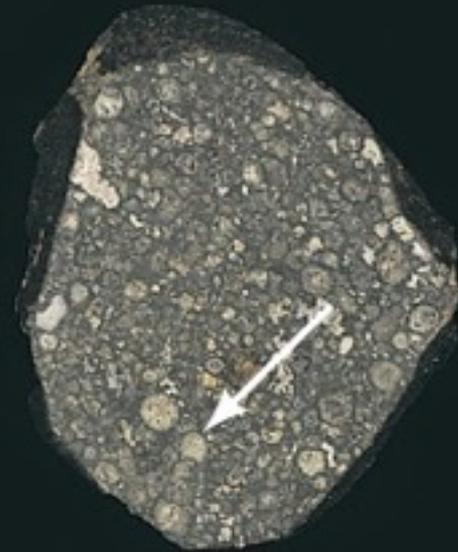
- 1) Primitive: unchanged in composition since they first formed 4.6 billion years ago
- 2) Processed: younger; have experienced processes like volcanism or differentiation

Primitive Meteorites

Primitive: Unchanged in composition since they first formed 4.5 billion years ago - key to measuring the composition of the solar system



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).

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.

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?**
 - Orbital resonances with Jupiter 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.