Thursday November 9, 2017

Upcoming Items

1. Read Ch. 12.5 by next class and do the self-study quizzes.
2. Homework #9 due Tuesday

Wonderful Job on Second Midterm!

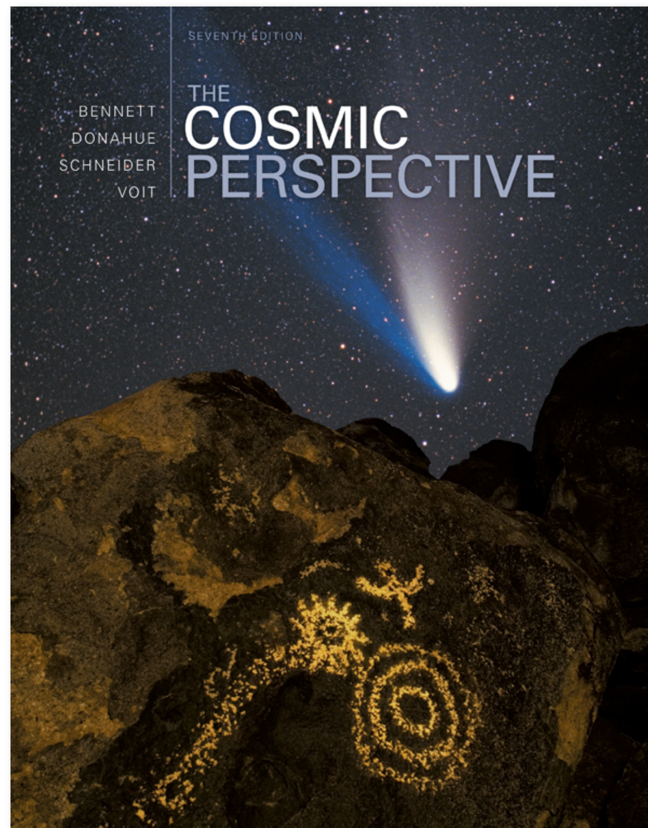
- Class average 123/150=82% (better than on first!)
- Class standard deviation 23/150
- Another outstanding performance!

SMALL SOLAR SYSTEM BODIES

Ch. 8.3, 12.1–12.3

You should be able to…

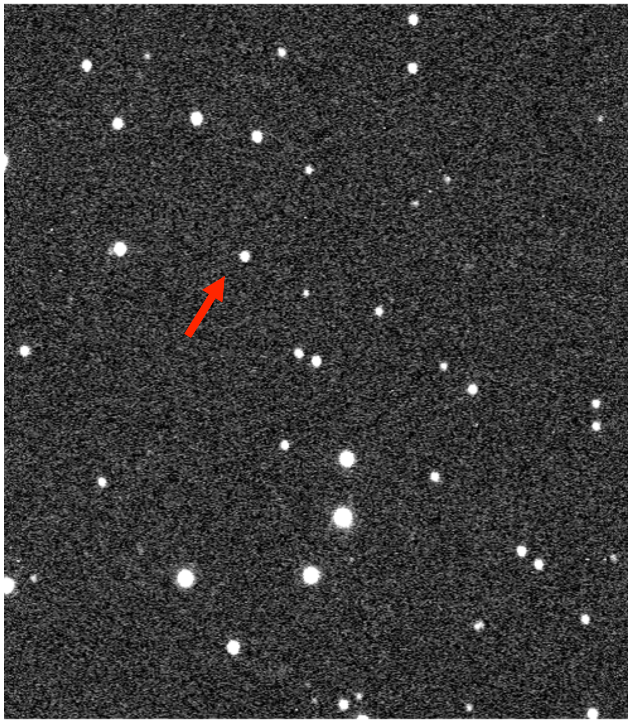
- … *explain why asteroids and comets are generally confined to specific regions of the solar system.*
- … *estimate the age of the solar system based on the proportion of the end-products of radioactivity present in a meteorite.*



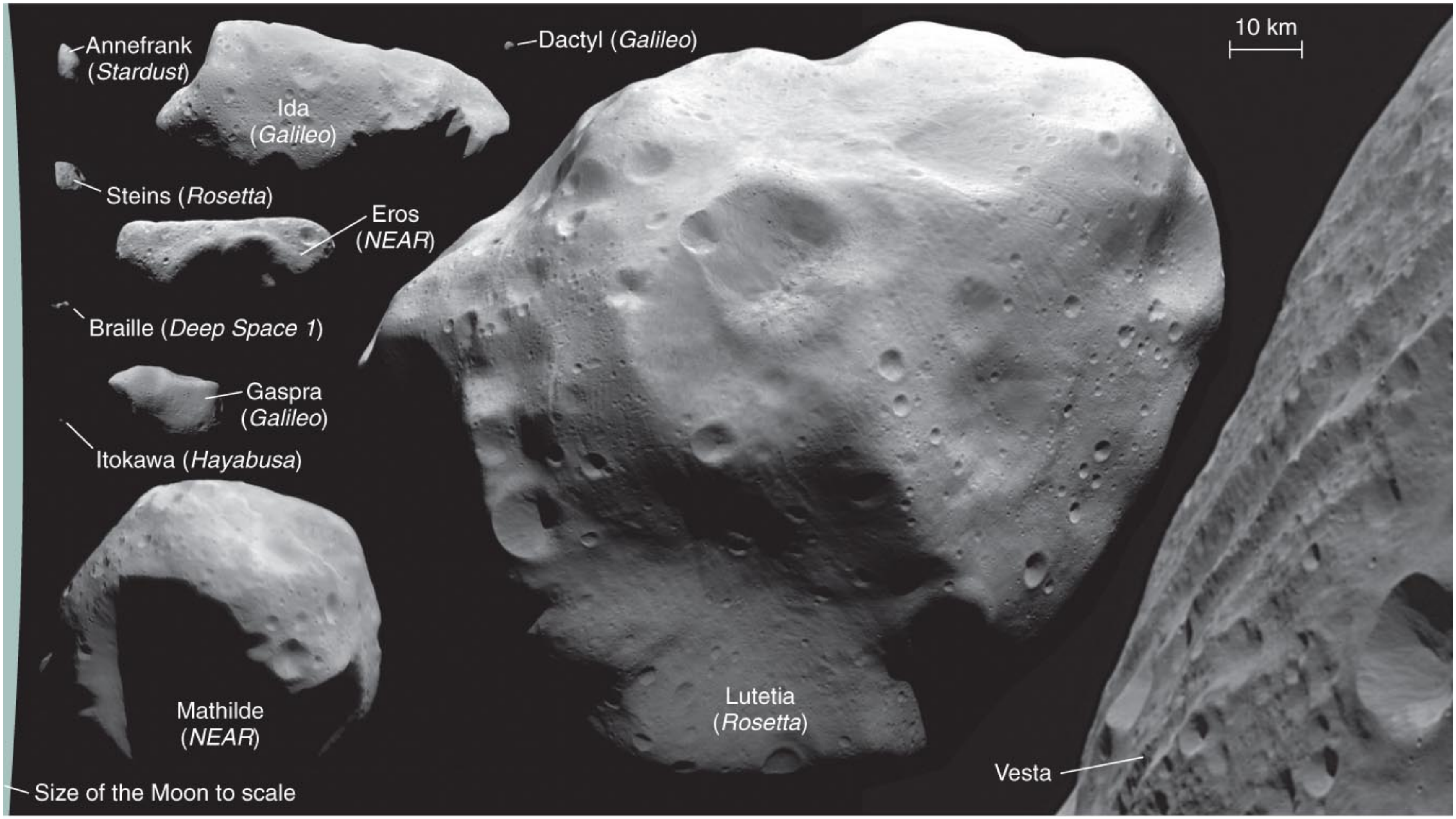
Any astro questions?

Asteroid Facts

- Rocky leftovers of planet formation.
- Largest: Ceres, diameter 1,000 km.
- 150,000 in catalogs, and probably over a million with diameter >1 km.
- Small asteroids are more common than large ones.
- All the asteroids in the solar system wouldn’t add up to even a small terrestrial planet.
  What does that suggest about their formation?

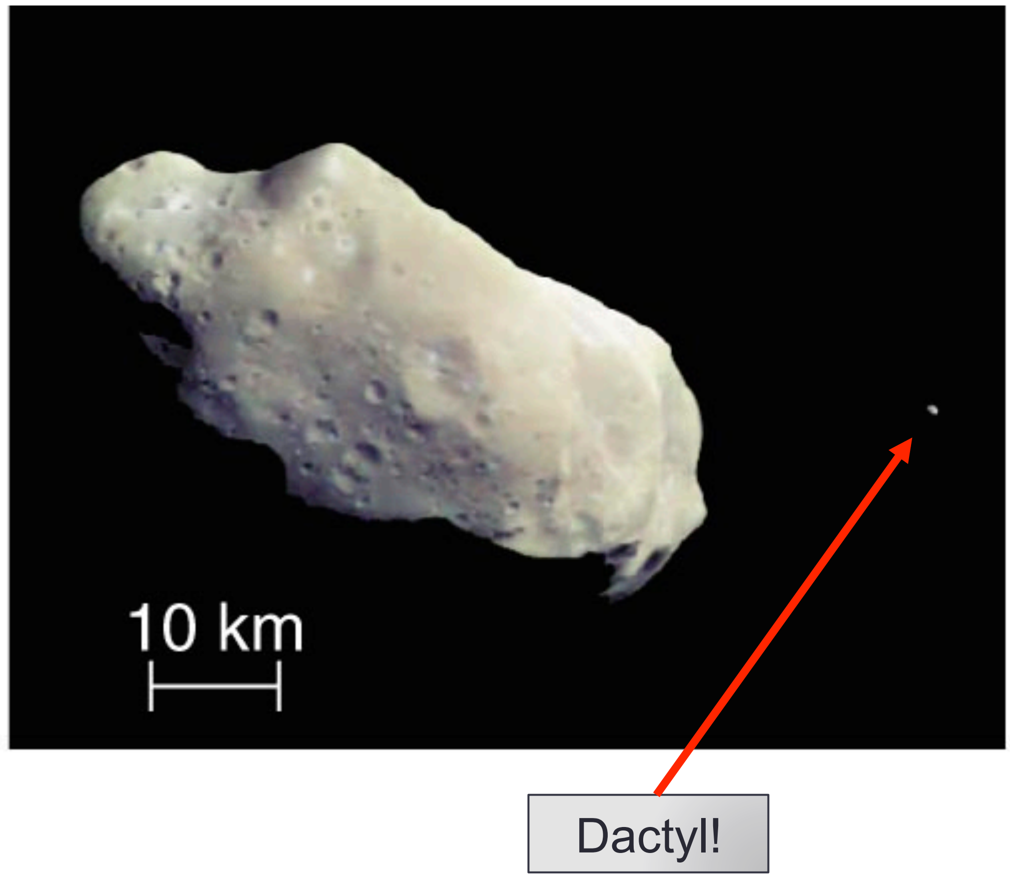


Asteroid 12566 Derichardson!



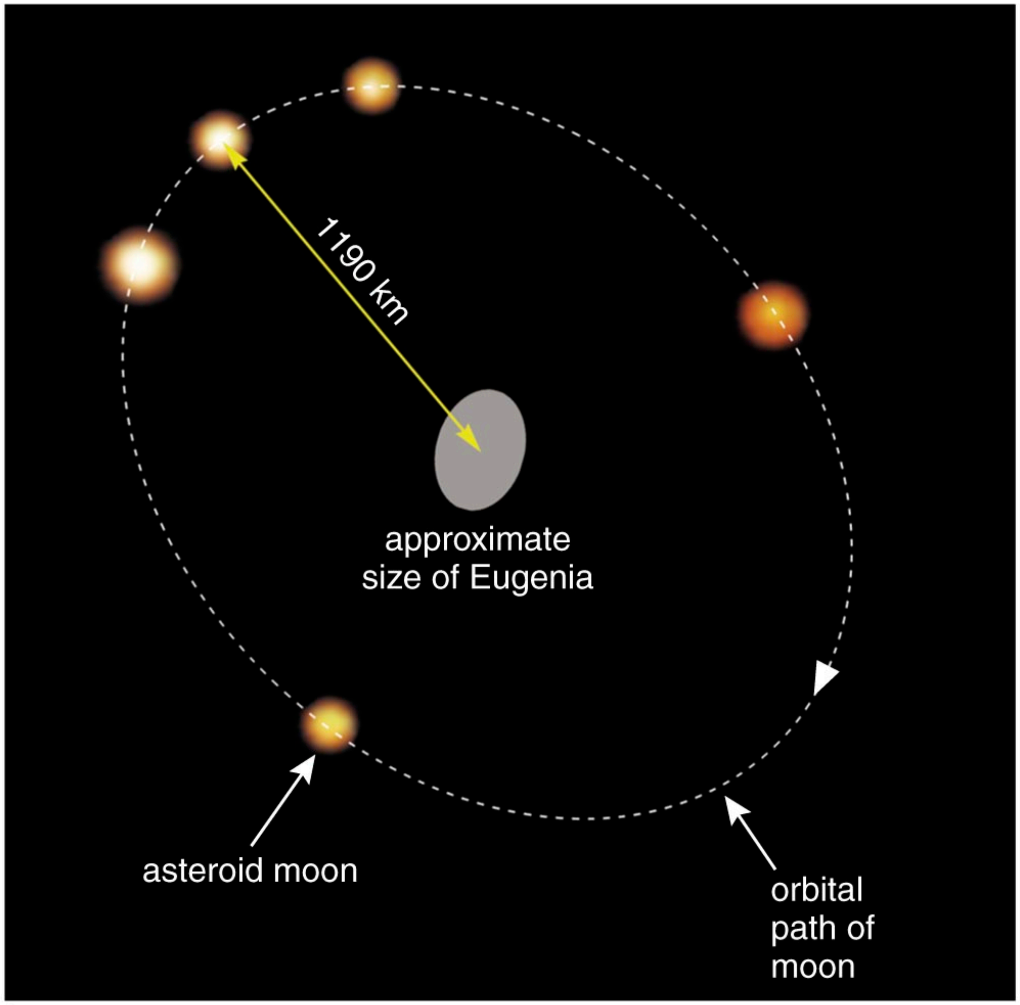
- Asteroids are usually cratered and not round. What does that say about their size?

Asteroids with Moons



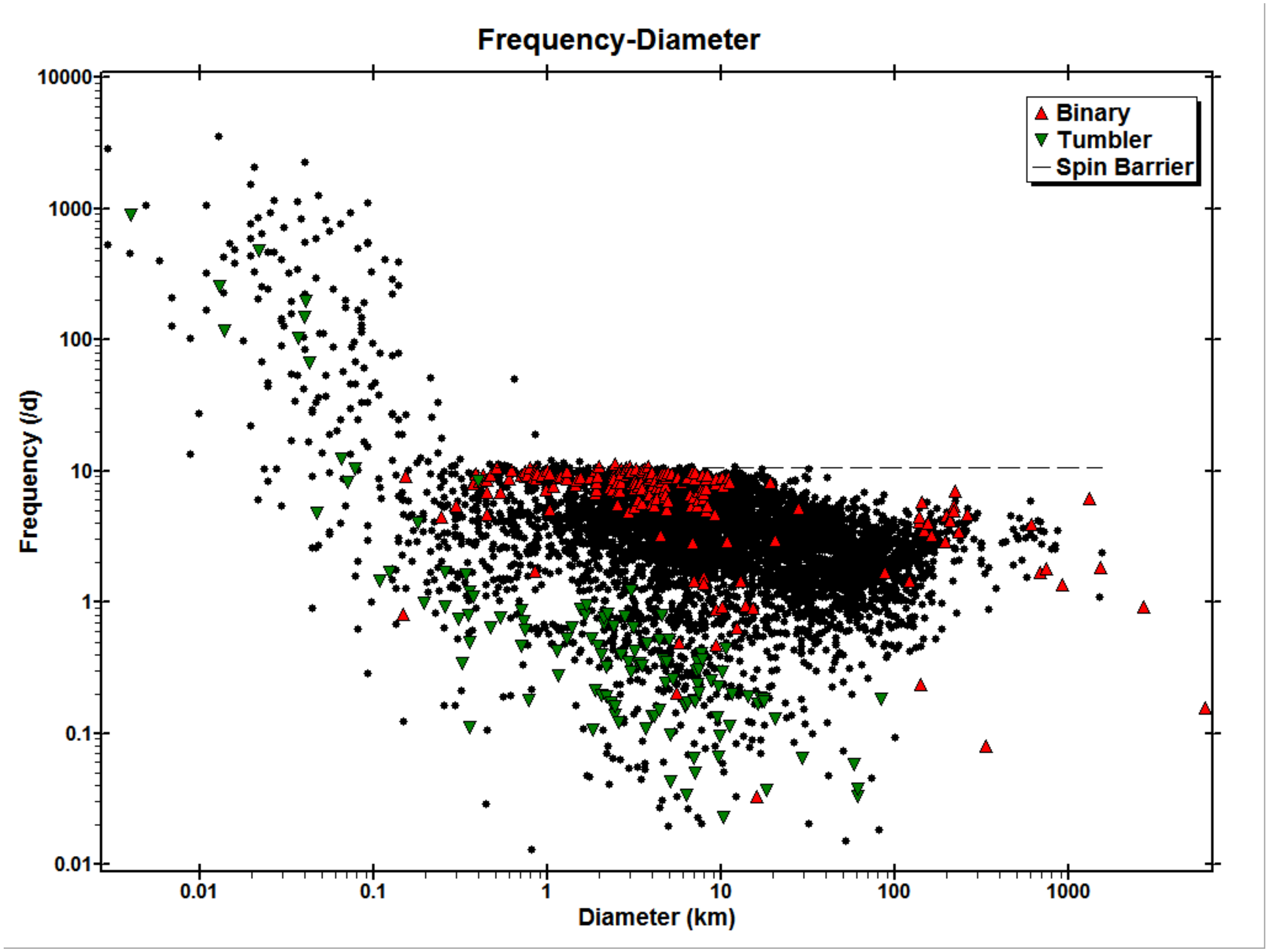
- Some asteroids have their own moon(s).
- Asteroid Ida has a tiny moon named Dactyl.

Density of Asteroids



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

Asteroid rotation rates; comments?



http://alcdef.org/images/lcdb_all.png

Group Q: Maximum Rotation Rate

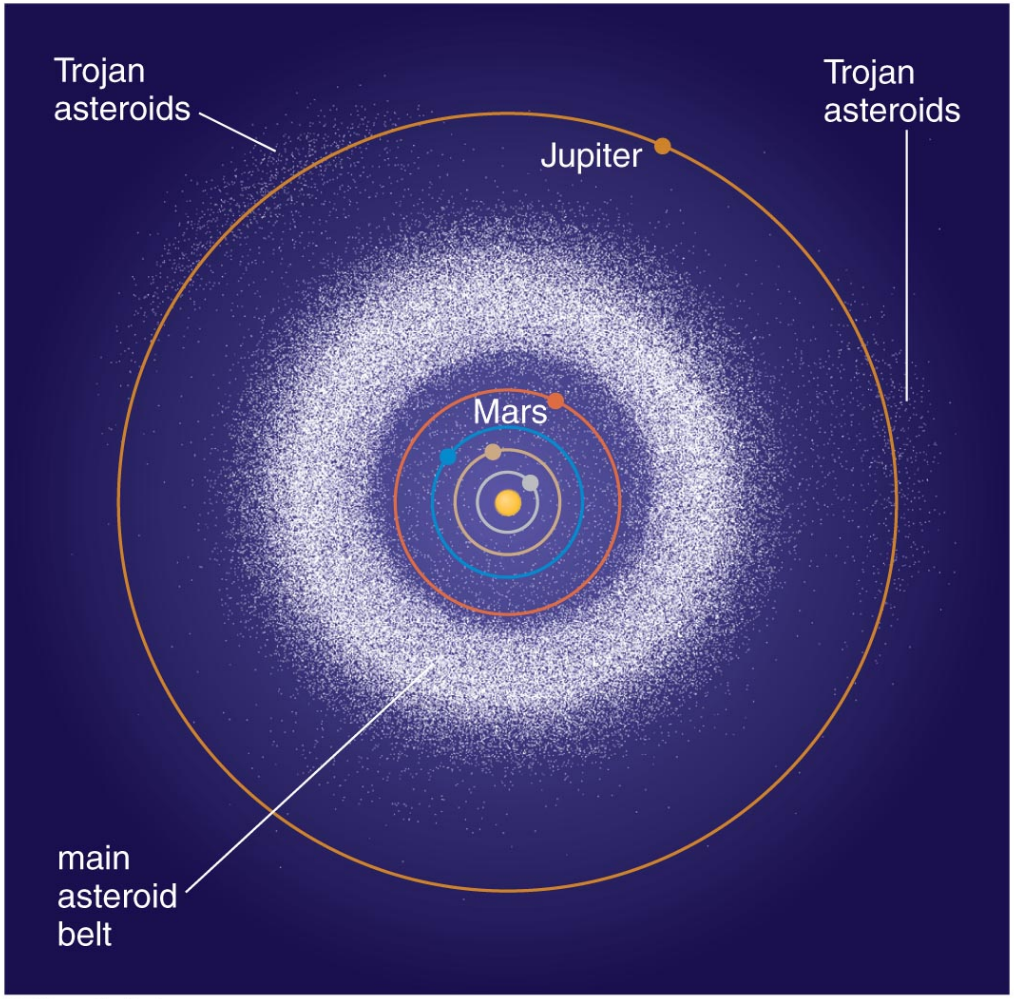
- Suppose that an asteroid is held together only by its own gravity (no material strength)
- Assume asteroid is a sphere of mass M and radius R
- Say the asteroid spins at an angular rate of Ω radians/sec
- At what Ω_{crit} would a particle on the surface be moving at the orbital angular velocity?
- That's the limit; particle would fly off at higher rates
- Your group Q: derive Ω_{crit}!

Maximum Rotation Rate

- Suppose that an object is held together by self-gravity
  I.e., no material strength
- Then it can't rotate more rapidly than a circular gravitational orbit at its surface
  Would fly apart at faster rates!
- How fast is that? Say asteroid is sphere, mass M, rad R:
  $\Omega_{max}=(GM/R^3)^{1/2}$
- But density = ρ = $M/V=M/[(4\pi/3)R^3]$
  Thus $M/R^3=(4\pi/3)\rho$
  $\Omega_{max}=[(4\pi/3)G\rho]^{1/2}$; Ω_{max} depends *only* on average density
- For rock, r = 2000 kg m^{-3}, $P_{min}=2\pi/\Omega_{max}$=2.3 hours
  Faster than this means significant material strength!

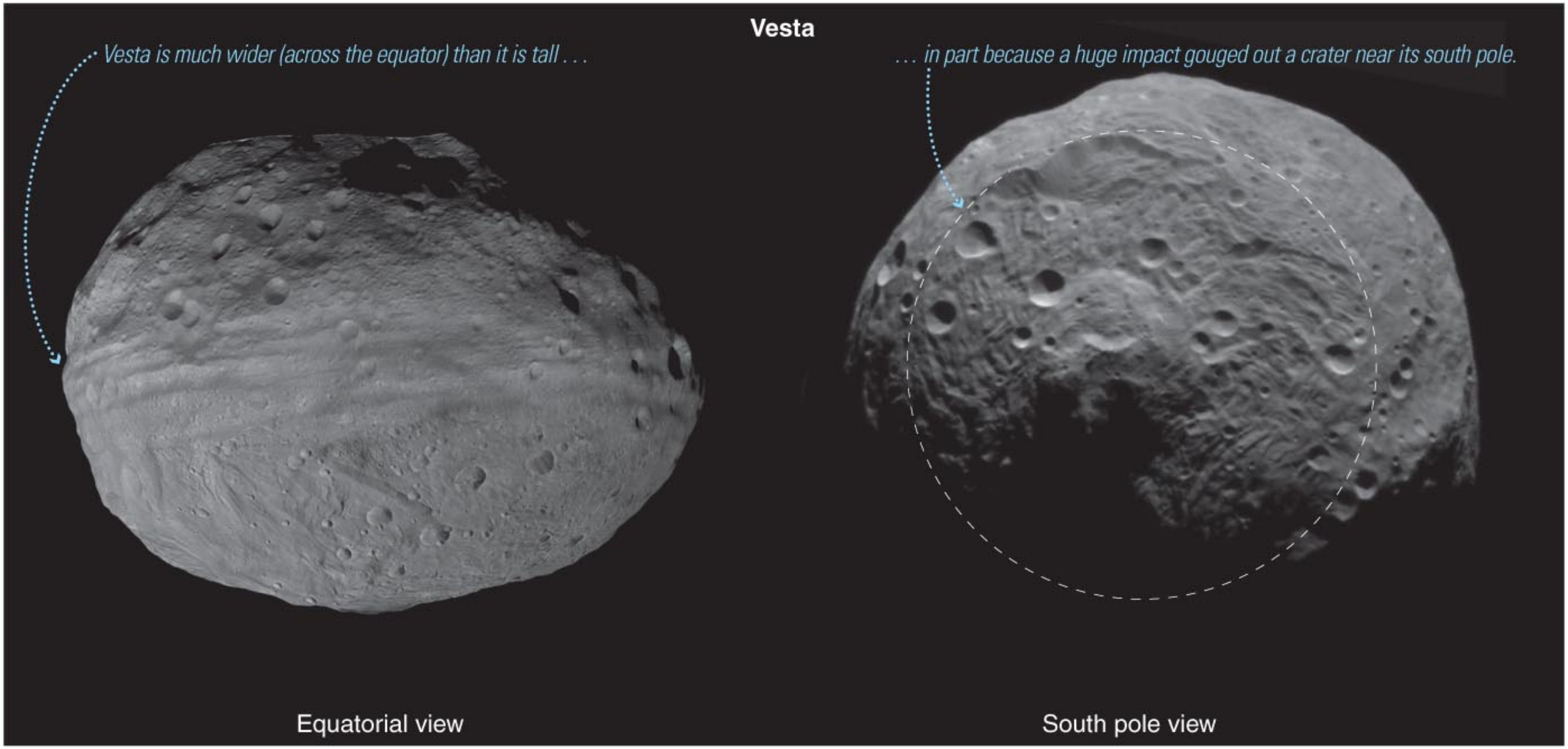
Movie From Drew’s Research

Asteroid Orbits

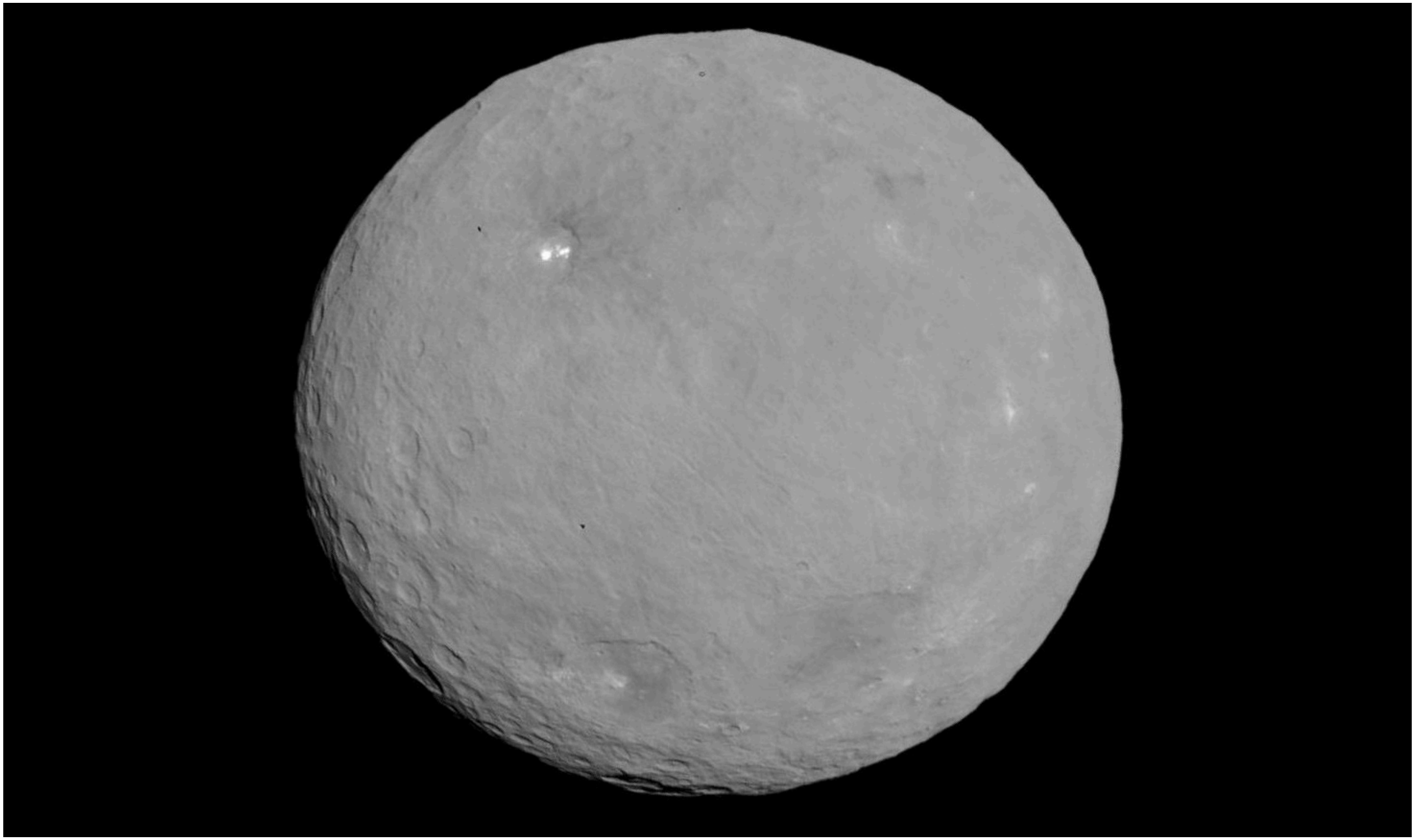


- Most asteroids orbit in a belt between Mars and Jupiter.
- *Trojan asteroids* follow Jupiter's path.
- Orbits of *near-Earth asteroids* approach or cross Earth's orbit.

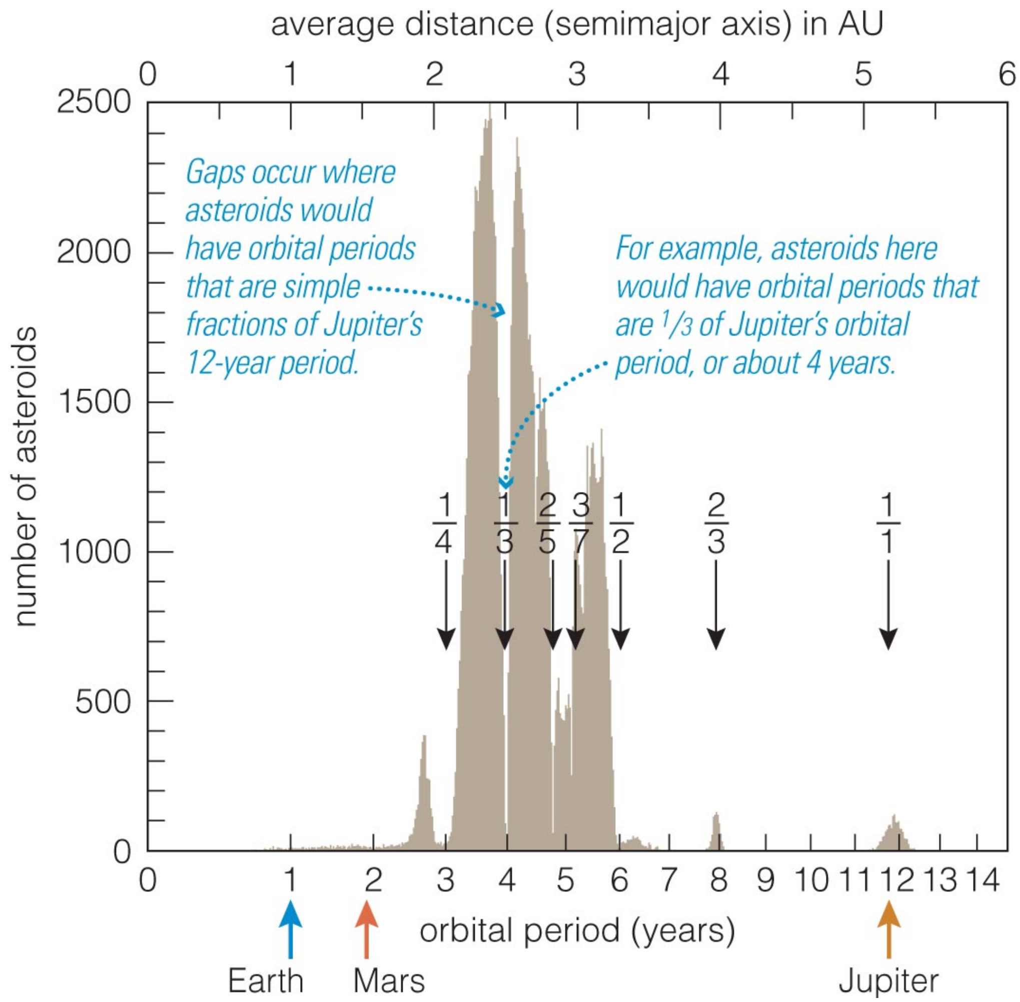
Vesta as seen by the *Dawn* Spacecraft



Ceres as seen by the *Dawn* Spacecraft

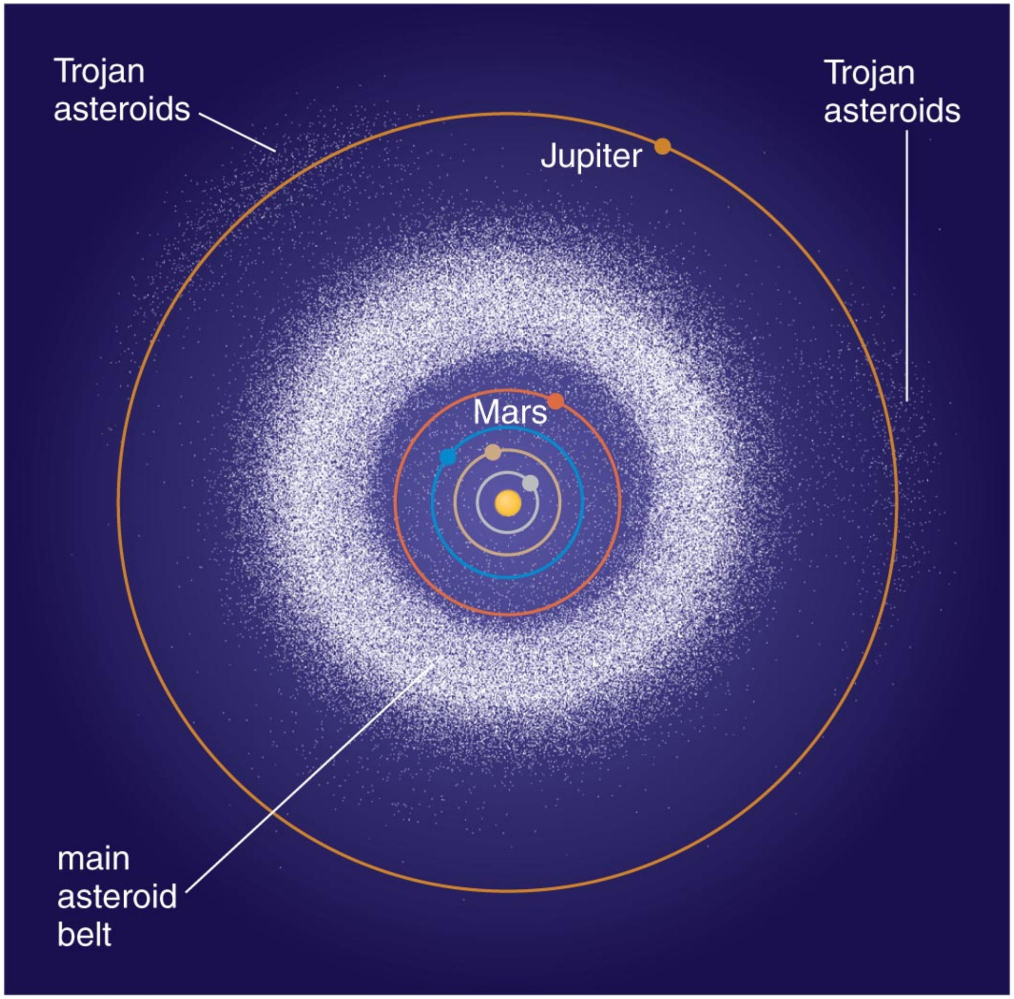


Orbital Resonances



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

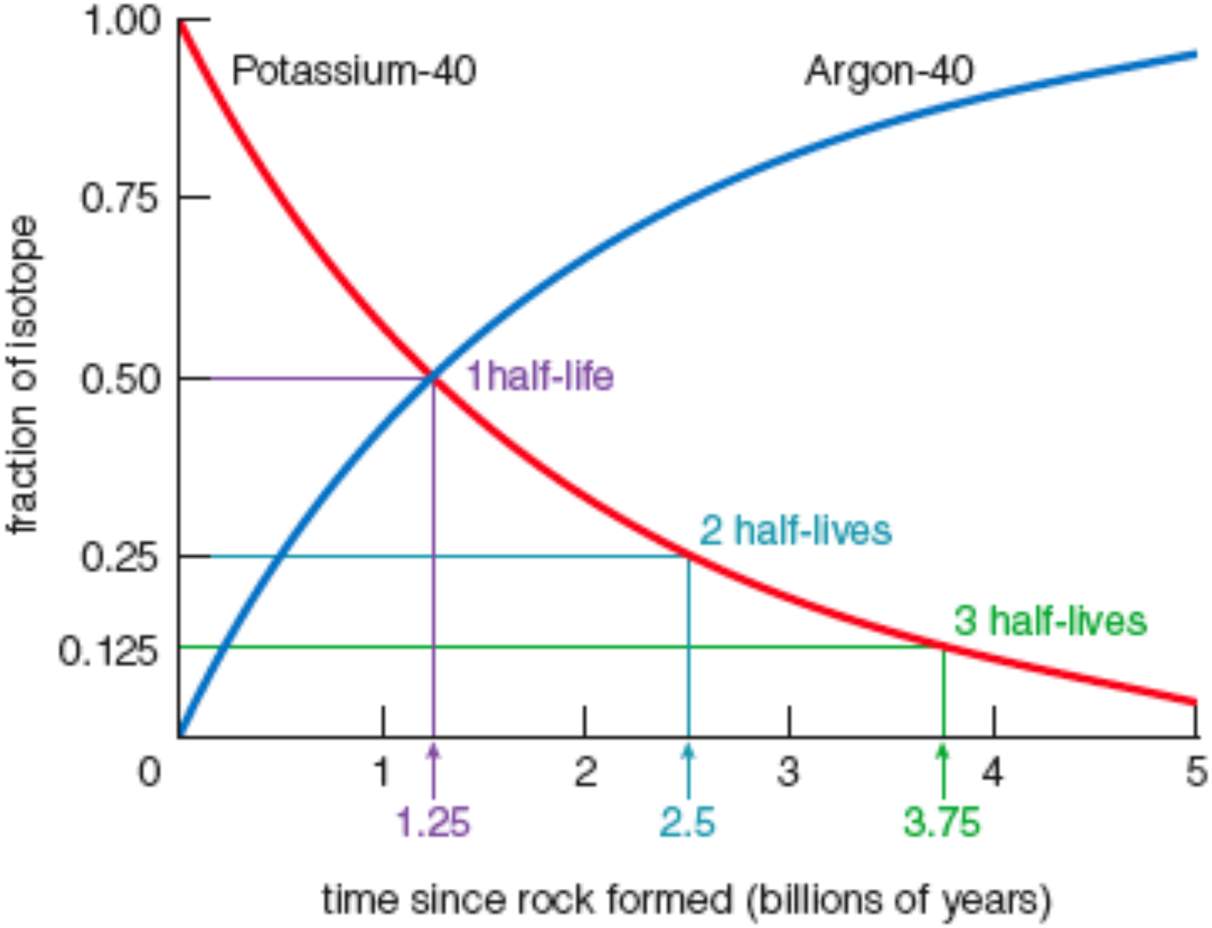
Origin of the Asteroid Belt



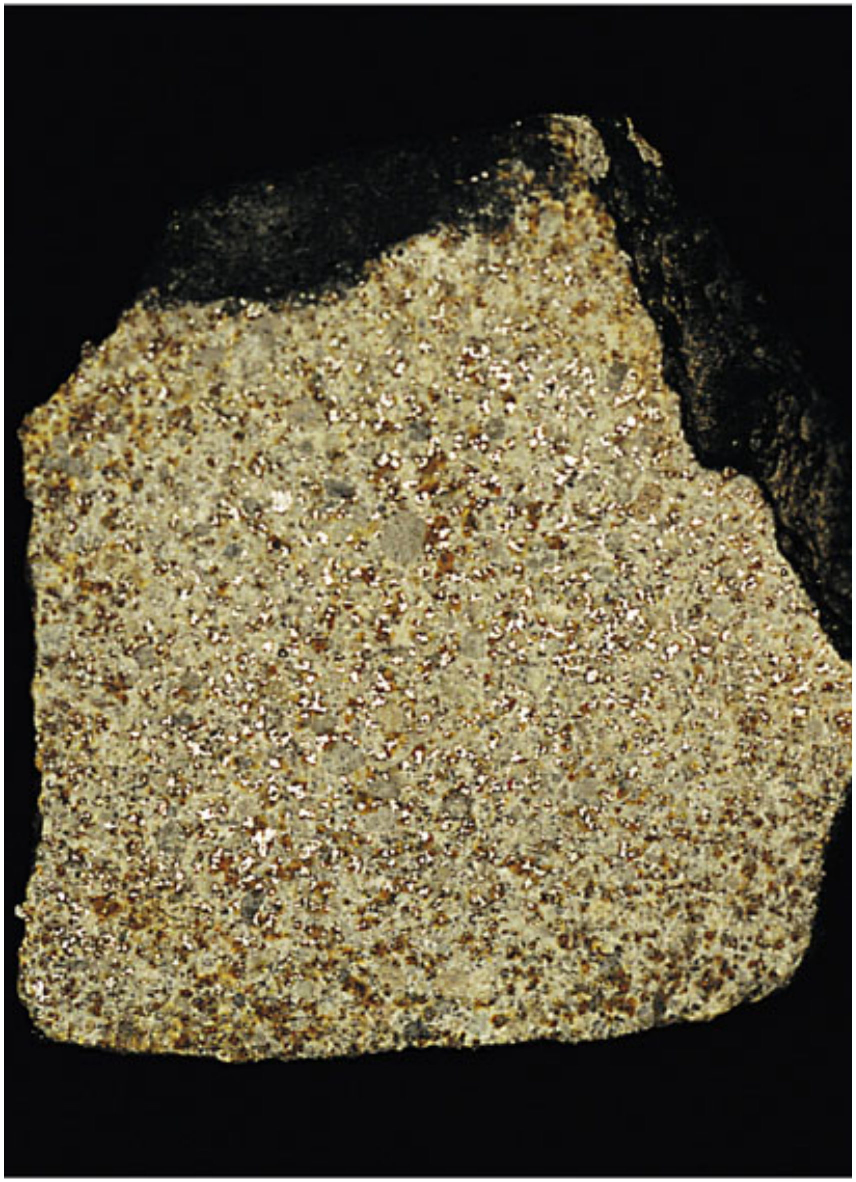
- Rocky planetesimals between Mars and Jupiter did not accrete into a planet.
- Jupiter's gravity, through influence of orbital resonances, stirred up asteroid orbits and prevented their accretion into a planet.

When did the planets form?

- We cannot find the age of a planet, but we can find the ages of the rocks that make it up.
- We can determine the age of a rock through careful analysis of the proportions of various atoms and isotopes within it.



- The decay of radioactive elements into other elements is a key tool in finding the ages of rocks.



- Age dating of meteorites that are unchanged since they condensed and accreted tells us that the solar system is about 4.6 billion years old.

Radioactive Dating

- For a sample containing 100% radioactive parent and 0% stable daughter at $t = 0$,

$$\text{fraction remaining } f = \left(\frac{1}{2}\right)^{t/t_{1/2}},$$

- where $t_{1/2}$ is the *halflife*.
- Exercise for the student: solve for t!

But what if we have some of the stable daughter around at t=0?

- Then there is a method called isochron dating that I encourage you to look up; needs a “non-radiogenic” isotope of the daughter element (doesn’t come from decay) for a comparison sample
- Net result: excellent agreement from many samples about the age of the Solar System!

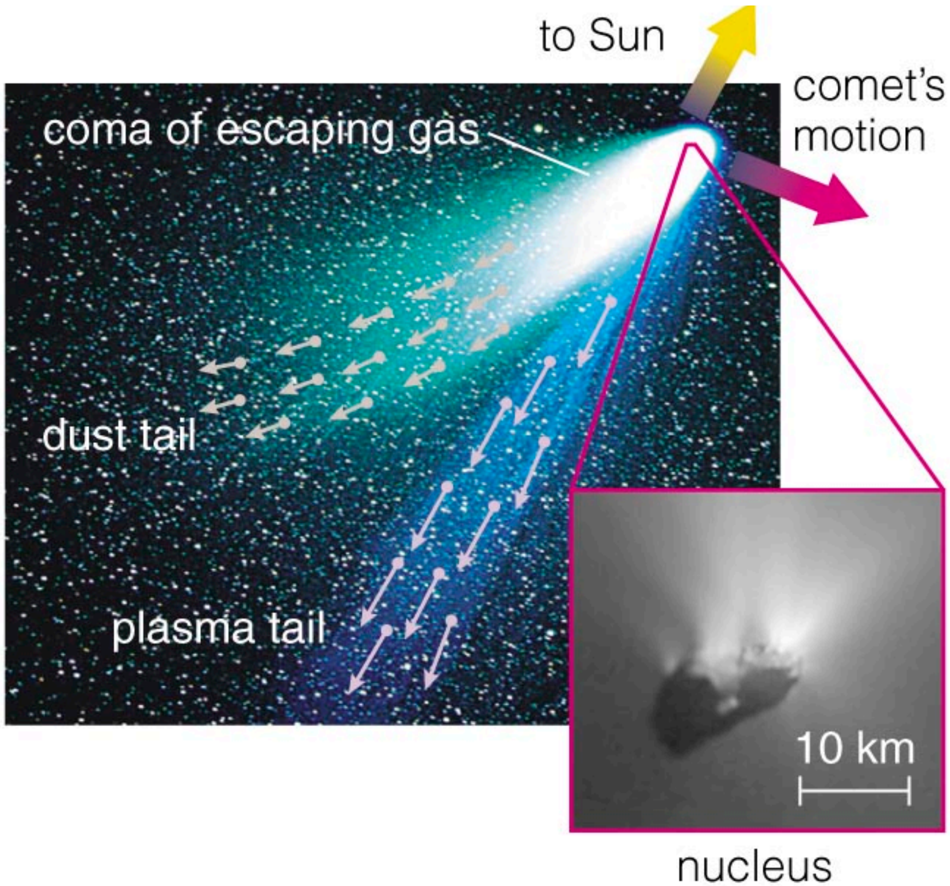
Non-gravitational Forces

- Solar wind.
  - Stream of charged particles from Sun, ~500 km/s.
  - Most effective at disturbing submicron-size particles.
- Radiation pressure.
  - Photon momentum = hf/c ➔ pressure $P = L/4\pi d^2 c$ (d = distance).
  - Most effective for micron-size particles.
- Poynting-Robertson drag.
  - Orbiting particles hit sunlight “headwind”, spiral in.
  - Most effective for centimeter-size particles.
- Yarkovsky effect.
  - Reradiation of sunlight results in thrust.
  - Most effective for meter-to-kilometer-size “particles.”

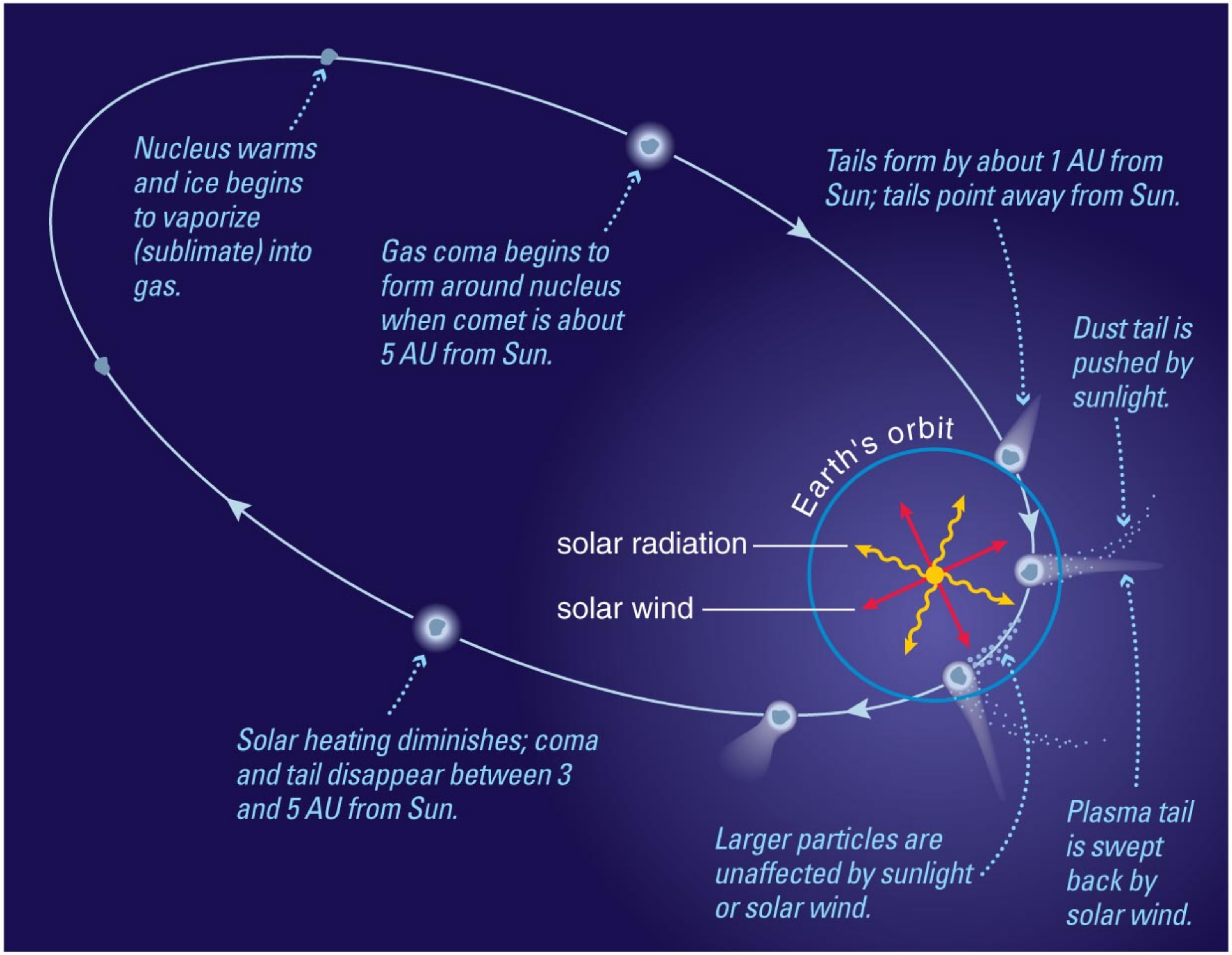
Comet Facts

- Formed beyond the frost line, comets are icy counterparts to asteroids.
  - Although we observe more and more “asteroids” with icy surfaces, e.g., (24) Themis…
- 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.



Tail always points away from the Sun. What does that tell us about the relative speed of the Solar wind to the speed of the comet's orbit?