

Meteorites: rocks from Outer Space



Olivenza - Stone, chondrite (ordinary, LL) Meteorite Copyright © 2007 Calvin J. Hamilton

Nature cooperates with us....the meteor last night

[Youtube video of meteor from Iowa](#)

Meteorites...when the piece of solid matter causing the meteor makes it to the ground

- Were noticed in deep antiquity
- There is probably one in the Kaaba Shrine in Saudi Arabia
- A knife made of meteoric iron was found in the tomb of Pharaoh Tutankhamun



Types of meteorites

- Stony meteorites (about 94%), usually *chondrites*
- Iron-nickel (about 5%)
- Relatively rare but extremely important *carbonaceous chondrites* ("objects that have the consistency of dirt clods")



Tagish Lake meteorite

A piece of the Tagish Lake meteorite

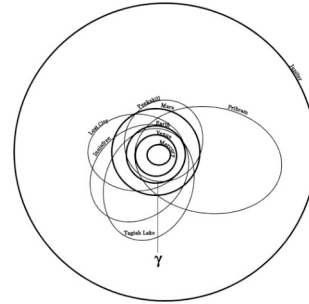


(Image courtesy of Mike Zolensky, NASA/JSC)

Best preserved carbonaceous chondrite found

Orbits of meteorites: where do they come from?

A powerful hint as to the nature of meteorites: stay tuned



Ages of meteorites

- Age of formation (how determined?): almost all around 4.60 Gyr
- Cosmic ray exposure ages (how long they were out in outer space unshielded): millions to tens of millions of years.
- Last number suggests they were broken off a bigger object fairly recently

Things you should be thinking about

- How do meteorites fit into the other objects we have discussed all semester?
- Are they pieces broken off of planets? Which planets?

Presentation of the *hagioliths*

A picture is worth a thousand words, and a real thing is worth a thousand pictures



The next type of small solar system object: asteroids

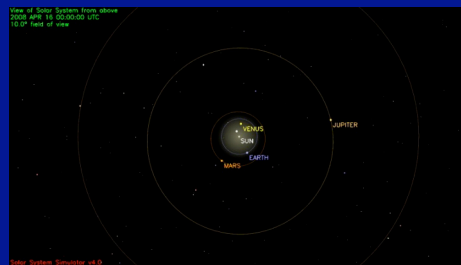


There is a big gap between the orbits of Mars and Jupiter. Shouldn't there be a planet in there?

First such object was found on Jan. 1, 1801...Ceres

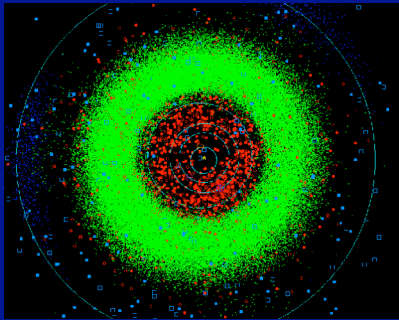
- Others found in following years:
- Vesta
- Pallas
- Juno
- The fact that it took so long to find them means that they are much smaller than major planets
- They are called *minor planets* or *asteroids*

What the solar system looks like without asteroids



Seems a big jump between Mars and Jupiter

Include the asteroids and it looks like this

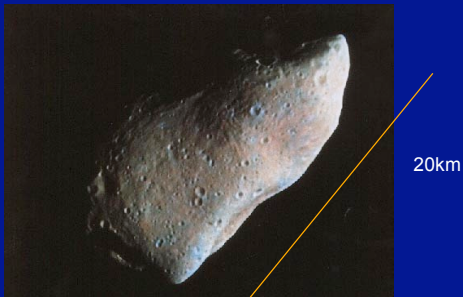


Each dot is an asteroid

A description of asteroids

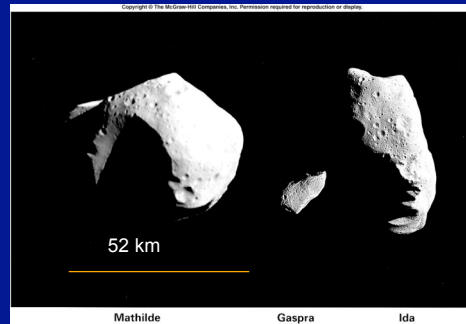
- Little worlds (minor planets)
- Big rocks (largest 600 miles in diameter)
- Red things on previous plot: *near-Earth asteroids* (scary name, isn't it?)
- What do they look like? No idea before 1993

Gaspra: our first view of an asteroid

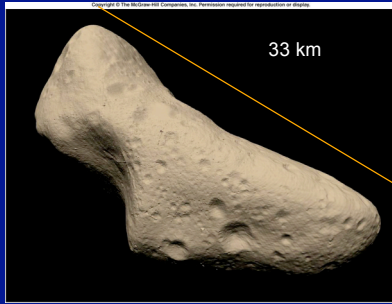


Not spherical: why not? ←

"Family picture" of several asteroids

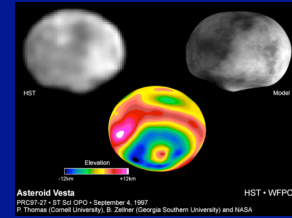


Eros...an asteroid with a lander (NEAR)

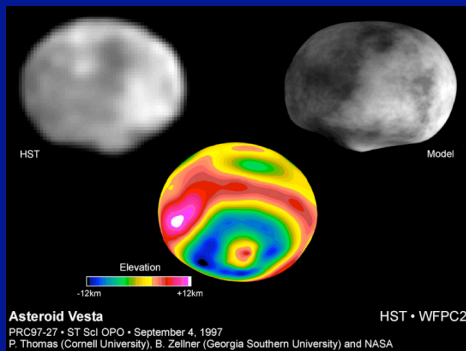


The big asteroids (none visited yet by spacecraft)

- Ceres 930 km
- Vesta 520 km
- Pallas 520 km
- Juno 480 km



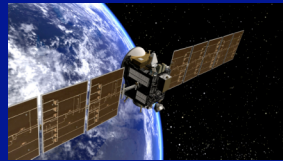
Vesta as seen by the HST



Aspects of Vesta

- At opposition is almost naked eye brightness (was at opposition in February)
- Go visit it at the Smithsonian Museum of Natural History (!#*)
- HST has observed it [rotation of Vesta](#)

The Dawn spacecraft...mission to Vesta and Ceres



Mission timeline:
Launch: September 27, 2007
Arrival at Vesta: August 2011
Arrival at Ceres: February 2015

Classes of asteroids (hey, this is a science course, you've got to have classes!)

- S type; albedo of 7-23 percent; main class in inner and middle belt
- C type; albedos of 2-7 percent (or less); main type in outer belt
- M type: metallic (mainly in central belt)
- V for Vesta; albedo of 38 percent, reflectance spectrum of pyroxine

Geology of asteroids determined by collisions

- Surfaces are cratered, but not as much as would be expected for an unaltered object
- Images show stress fractures on the object
- Collisional fracturing of a *differentiated* object could account for the different classes
- There are lots of double asteroids

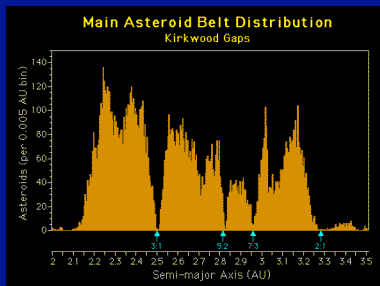
The orbits of asteroids

What do we see if we study the distribution of semimajor axes of asteroids



Think about what we might
Expect to see

What we do see



Kirkwood's Gaps: orbital resonances with Jupiter

The physics of orbital resonance...like Cassini's Division in Saturn's ring

➡ Remember demo with forced oscillator

What happens to the asteroids which were in resonant orbits?