Astronomy 150:
Killer Skies

HW1 due on Sun. As you have to access Nat History Building, you can't wait until the last minute.

This Class (Lecture 3):
Asteroids/Comets

Next Class:
Star Formation

Music: *Asteroid* – Killing Joke

You need to Register You Clicker

- Go to **link on syllabus** to register your clicker ASAP.
- **Bring it to class every day.**

https://online-s.physics.uiuc.edu/cgi/courses/shell/iclicker.pl

Outline

- These "death rocks" are old.
- Do you know the Solar System?
- What are comets and asteroids?

Meteorite Dating

Radioactive "clocks" extremely useful!

Procedure:
- Collect radioactive nuclei from meteor
- Measure both parent and daughter
- Find out how long since sample formed!

Meteorite Dating

$t_{1/2}(^{238}\text{U}) = 4.5 \times 10^{9}$ years = 4.5 billion years

Example

- If a meteorite has 50% ^{238}U, and 50% ^{206}Pb
  How old is it?
  Exactly 1 half-life = 4.5 billion years!

Experimental Results: meteorites are oldest known objects:

- Oldest meteorites:
  - **4.6 billion years = age of solar system!**

Meteorites are Ancient

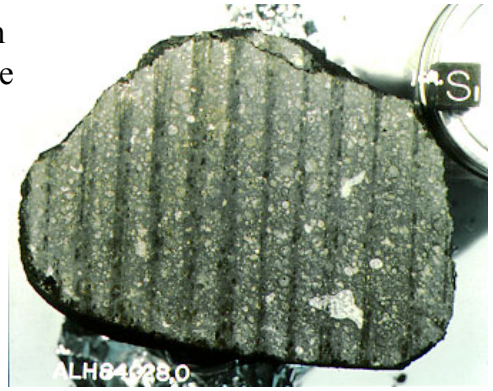
- Meteorites are the oldest objects in the Solar System
- Remnants of the Solar System's formation
- The oldest are the carbonaceous chondrites (a type of stony)
  - Abundant in carbon and water
  - Contain amino acids - building blocks of life!
  - 4.56 billion years old
- Some have diamonds produced by interstellar shock waves!

Carbonaceous chondrite

Stony Meteorites (94% of all meteorites)

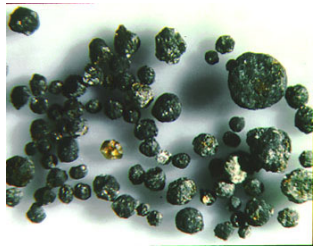
- Two types:
- Chondrites…contain chondrules…they are very old and primitive
- Achondrites…no chondrules

Photo of a carbonaceous chondrite (carbon-bearing)



Chondrules

- Little over a mm in size.
- Formed from molten drops in space– very quicky.
- About 1 minute heating to 1500-1900 Celsius.
- Most pristine material in the Solar System.
- Interesting daughter species suggest that we likely formed near a supernova!



Ordinary Chondrites

Iron meteorites (5%)

- These consist of nearly pure metallic nickel and iron
- First source of iron for early humans
- Although rare, more easily recognized as non-terrestrial.
- More likely to survive through atmosphere intact.

Gibeon Iron

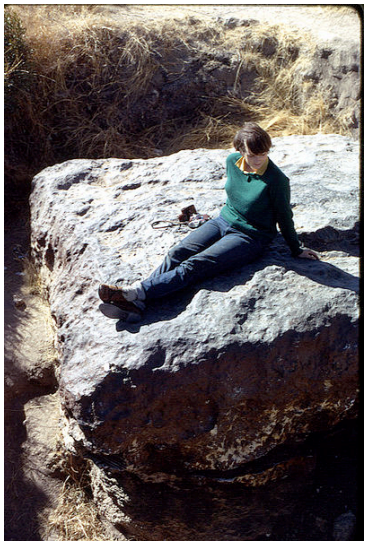
- 3 kg full slice
- Distinctive Widmanstätten pattern of intergrown iron-nickel alloys
  - This proves space origins, as it takes very slow cooling (1 to 100 degrees/ 1 million years) to make this pattern.
- Found Namibia, 1836
- Strewn field with over 50 tons of ‘irons’

Hoba Iron Meteorite

- 3m x 3m x 1m and 66 tons of iron (largest natural piece known on Earth)
- Found 1920, Namibia
- Probably hit 80,000 years ago
- No crater

Hoba Iron Meteorite

- Meteorite is now about 60 tons, so it has lost 6 tons in the last 90 years.
- Why?



Hoba Iron Meteorite

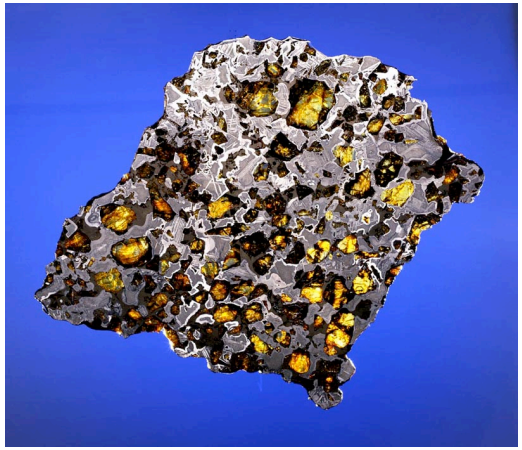
Why has the meteorite lost 6 tons over 90 years?

a) Erosion
b) Rust
c) Stolen
d) Removed to make sitting arrangements
e) Aliens

Stony-iron meteorites (1%)

- These are a mixture of the previous two types
- Often they are fragmental, suggestive of violent processes

Glorietta Mountain New Mexico Pallasite (full slice)

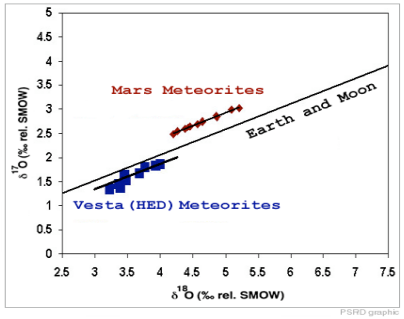


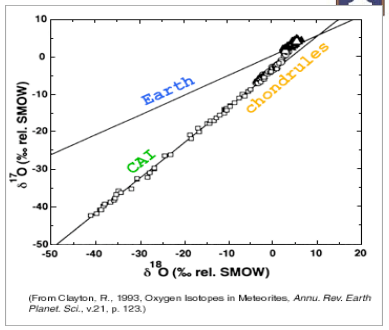
- Stony-iron meteorite
- Suspended in an iron matrix
- Etched iron shows Widmanstatten pattern
- Olivines with very uniform composition
- Likely source: core-mantle boundary region of a once differentiated and since-shattered asteroid

They're From Outer Space!

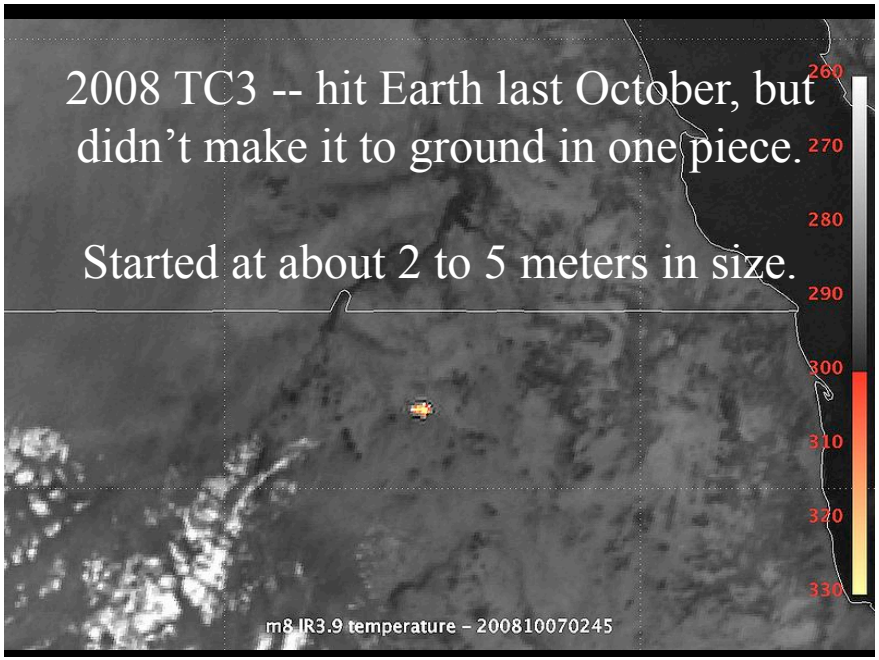
- Ernst Chladni, a German physicist, proposes an extraterrestrial origin for meteorites in 1794, previous thought to be volcanic in nature, while meteors were thought to be atmospheric.
- Numerous witnessed meteorite falls occur in the 1790s, especially at Siena, Italy in 1794 and at Wold Cottage, England, in 1795
- Jean-Baptiste Biot's chemical analysis on many 'fallen stones' during 1802-1803, establishes their chemical similarity to each other, and distinctive differences from terrestrial rocks

But how do we know?!

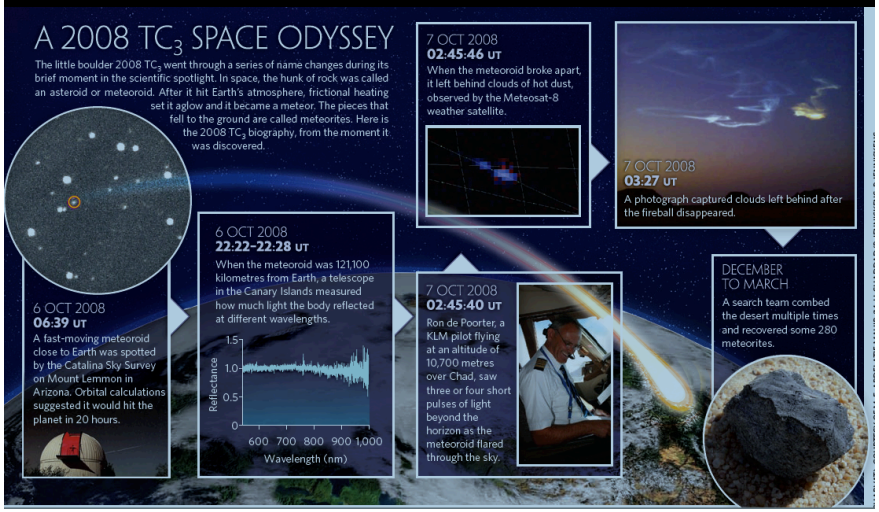




- Oxygen isotope ratios distinguish among solar system materials chemically; Earth and Moon plot together
- Planetary processes 'smear' O isotopes along a trend within one world; different initial ratios for each world



Significance: First asteroid detected before it was going to hit Earth. First meteorite recovered from such an asteroid.



Where From?

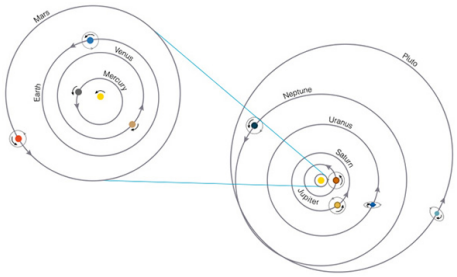
- Okay, so know we need to take a step back.
- Where do these rocks come from?
- How do they connect to our Solar System?
- What do they tell us about the history of our Solar System?
- Are we doomed?

So You Think You Know the Solar System?

- Six families of the solar system
  - Star
  - Rocky planets
  - Asteroid belt
  - Gas giant planets
  - Kuiper belt
  - Oort cloud

Planetary Orbits

- Orbital (and most rotational) motions in solar system are counter clock-wise in a flattened disk
- Orbits are actually close to circles, except Mercury.



http://www.youtube.com/watch?v=NrODEmei-wA&feature=PlayList&p=E09ABAE8A7C8BD40&index=0&fmt=18

Planets Dance

http://janus.astro.umd.edu/javadir/orbits/ssv.html

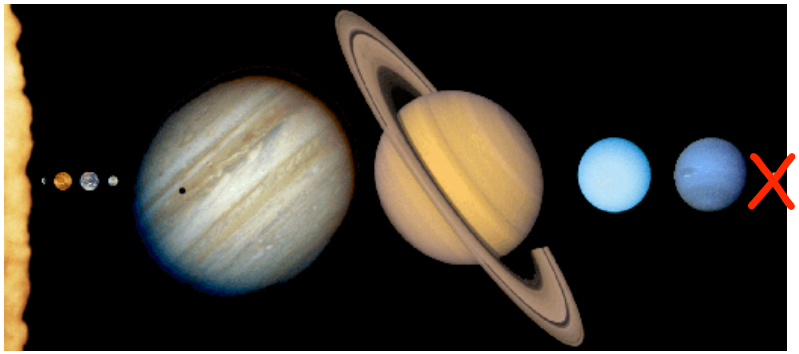
Question

What can we say about the planets' motion around the Sun?

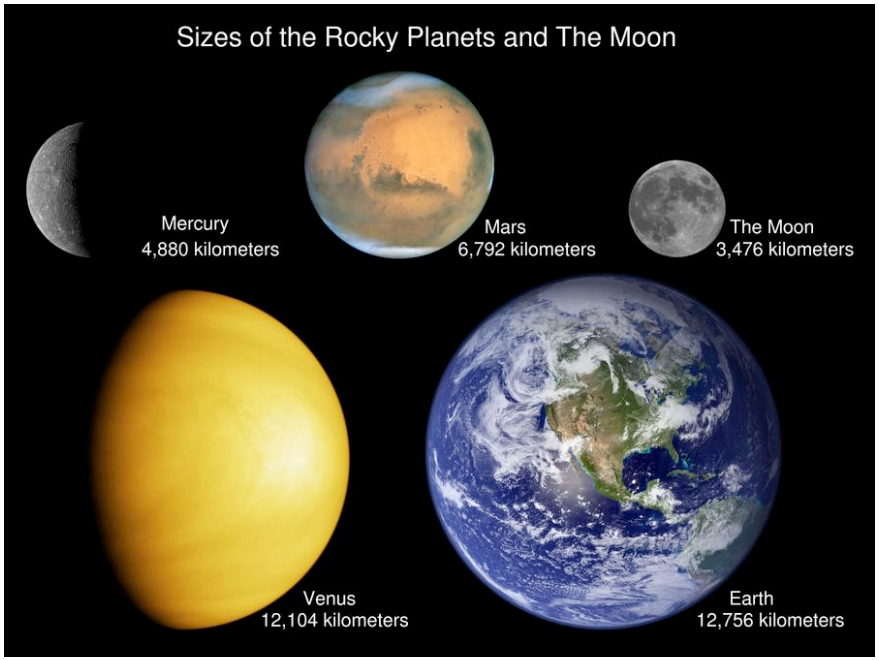
a) Random
b) They orbit the same direction in a flat plane.
c) They orbit the same direction in a uniform sphere.
d) They orbit in opposite directions in a flat plane.
e) Uniform motion, like a rotating disk (DVD?).

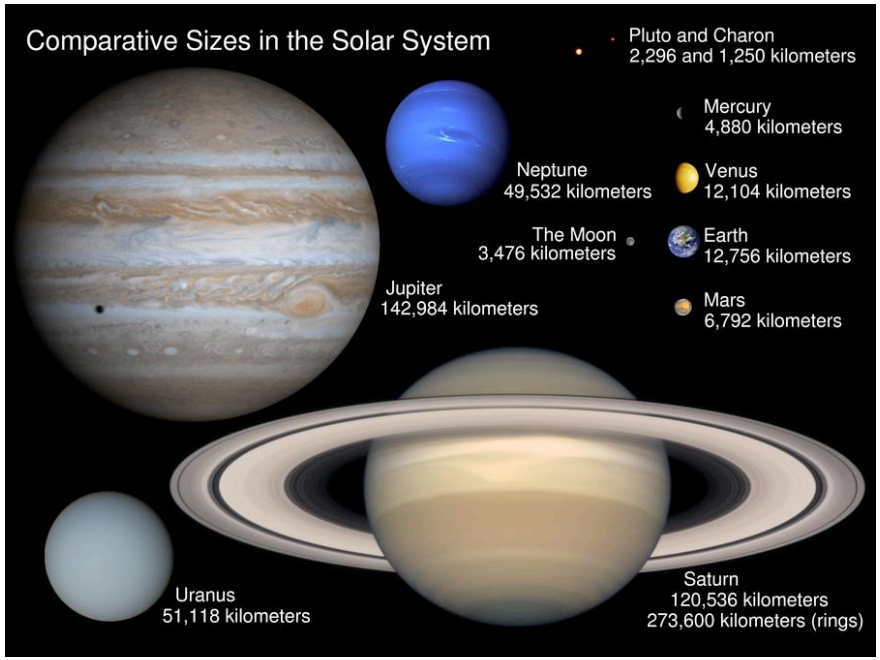
A Sense of Scale

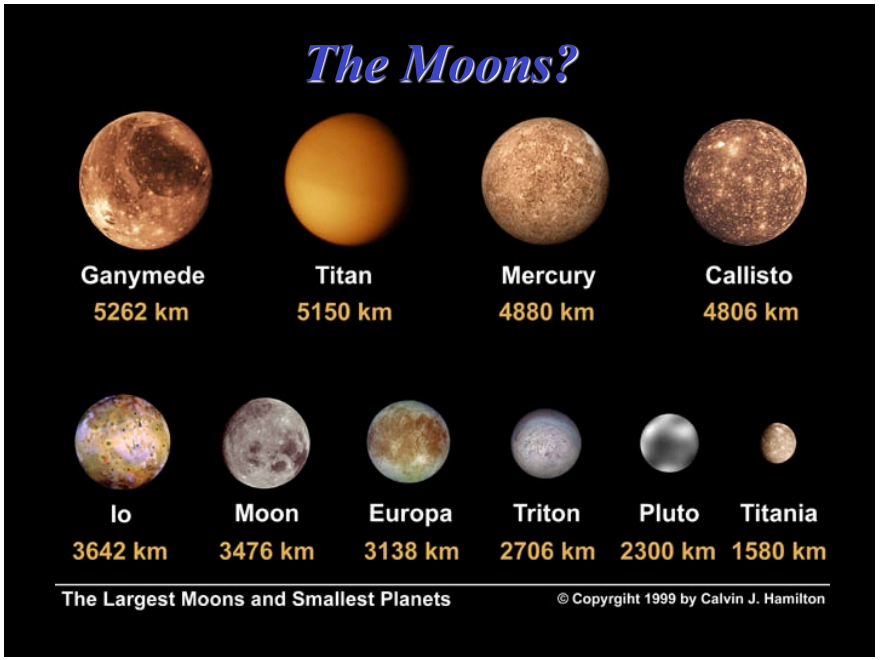
- Most pictures of the Solar System look something like this…



http://www.jpl.nasa.gov/galileo/sepo/education/nav/ss2.gif





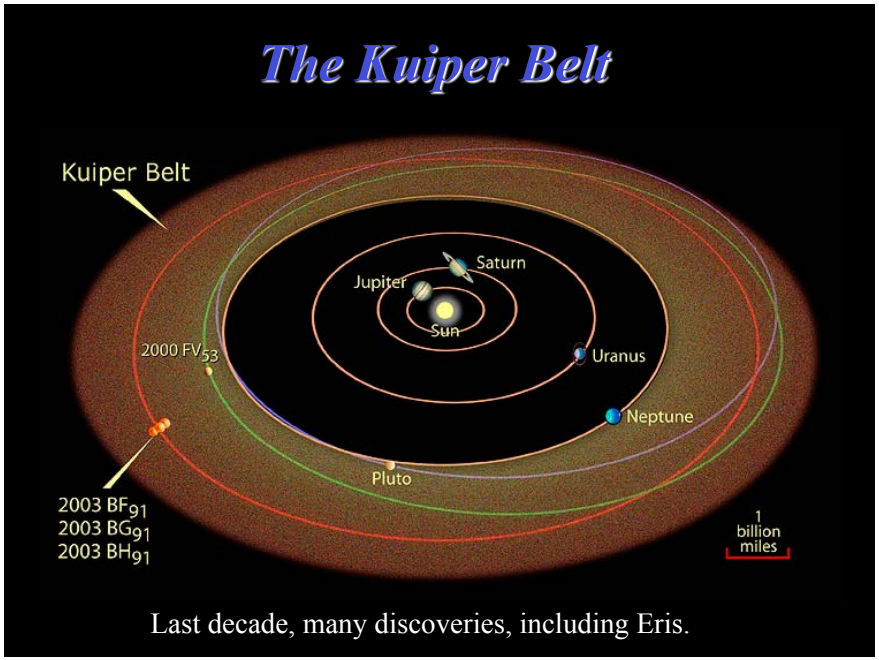


Do we know of all of the Bodies in our Solar System?

a) Yes.
b) No.

Do we know of all of the Bodies in our Solar System?

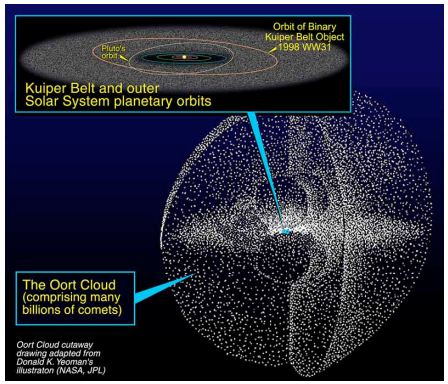
- No. Even at in the 21st century, we are still discovering new comets, or large asteroids, or even large planet-like objects?



Last decade, many discoveries, including Eris.

Oort Cloud

- Billions of icy minor planets – comet nuclei
- Roughly spherical out to 50,000 AU
- Predicted by Jan Oort
- Explains long-period comets
- No observations to date.



http://www.solarviews.com/browse/comet/kuiper3.jpg

Objects

- Most meteorites (i.e. survive the trip through the atmosphere) are from asteroids (or asteroid collisions and debris)
- Bigger than meteoroids (>50 meters), but smaller than planets.
- What is the difference between comets and asteroids?
  - Not much really, except comets have a coma or tails when they get close to the Sun– more ice.
  - Might have had a different formation mechanism
  - Some asteroids may be "extinct" comets.

Comets

- Comets come from the far reaches of the Solar System
- They have highly elongated, elliptical orbits, which bring them close to the Sun
- They mainly consist of ice and dust, thus are referred to as "dirty icebergs" or "dirty snowballs"
- They are held together very loosely: http://www.youtube.com/watch?v=tYc25Jt5RSk

Hyakutake
http://apod.nasa.gov/apod/ap980717.html

Junk in Space: Comets

Tails:

Sun's heat evaporates comet "atmosphere"

1. gas ionized (atoms stripped of electrons) like neon light– bluish
2. Dust released

Need sunlight: tail only appears when comet near the Sun

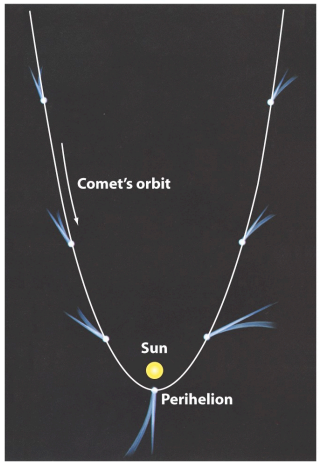
Where does gas tail point?

- Sunlight exerts force (pressure)
- "Solar wind": particles and magnetism driven from Sun

Thus: gas (ions) points ***away from Sun***

Dust has more mass, less easily accelerated, so

- Direction intermediate between comet motion and away from Sun



Life of a Comet

- Some comets crash into the Sun, a planet, or moon.
- Every time they orbit the Sun, they lose about 1% of their original mass.
- Torn apart by nearby planets– e.g. we'll see this later for comet Shoemaker-Levy

http://www.youtube.com/watch?v=3lE9UcPtlIQ

http://antwrp.gsfc.nasa.gov/apod/ap011109.html

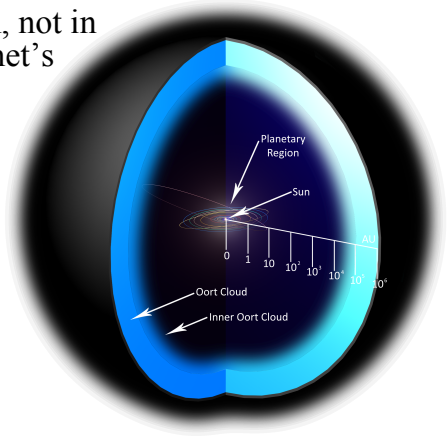
Where Do Comets Lurk?

Most comets in outer Solar System: **"Oort cloud"**

- Edge of Sun's gravitational influence
- Spherical distribution, not in ecliptic (plane of planet's orbits)

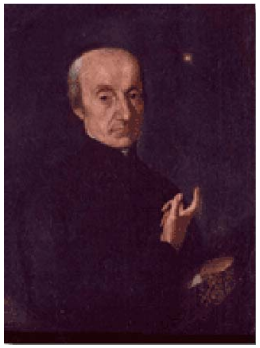
Comets are primitive material (never melted!)

- Clues to early Solar System



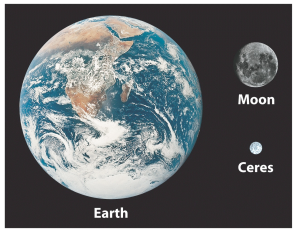
Discovery of the Asteroids

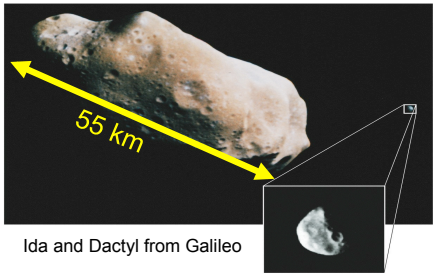
- In 1801, Giuseppe Piazzi noticed an uncharted "star" that shifted position among the stars over several nights
- Could it be another planet?
  - Its orbit was between Mars and Jupiter
  - Very dim, so it must be small
  - Too small to be a planet
- It was an *asteroid,* a "minor planet"



Asteroids

- Small sizes
  - Largest – Ceres: 940 km across
  - Only 3 more than 300 km
  - About 240 bigger than 100 km
  - Millions under 1 km
- Composition
  - Rocks (silicates) and iron/nickel

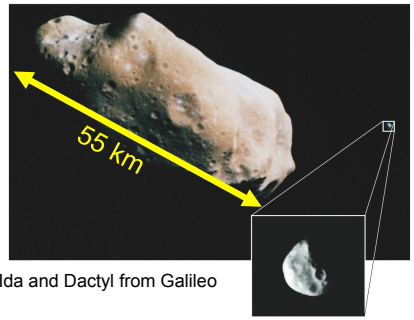




Ida and Dactyl from Galileo

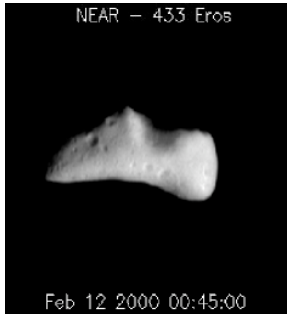
Asteroids

- Asteroids rotate– see Eros
- They can even have moons



Ida and Dactyl from Galileo

Eros from NEAR

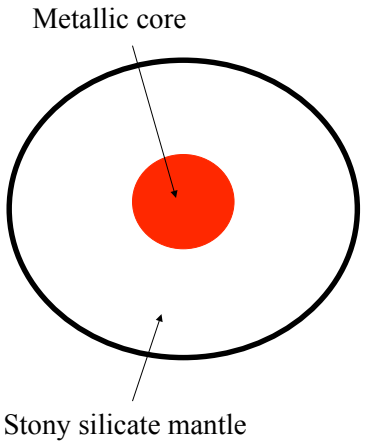


Asteroids

Eros from NEAR:http://near.jhuapl.edu/iod/20010205/index.html

Types of meteorites derived from asteroids

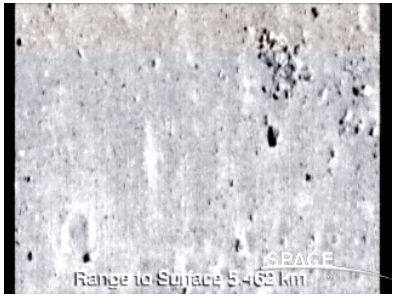
- Asteroids have a **metallic core** and **<u>stony silicate mantle</u>**
- As asteroids fragment, both metallic and silicate pieces are produced



Asteroids

- Because they are small, they are pretty much the same as when they formed– no differentiation, no internal heating: ancient 4.6 billion years old.
- Have regolith, some craters, some boulder
- Heavily cratered surface.

NEAR landing on Eros

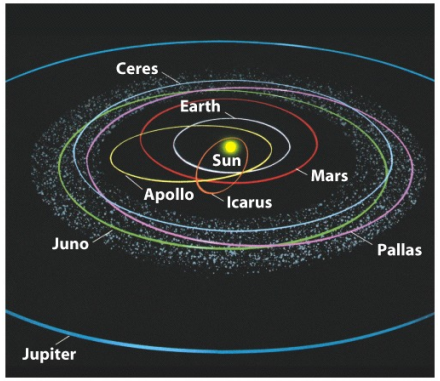


http://www.space.com/media/s010731_eros_landing_2.mov

http://www.youtube.com/watch?v=iiM7VHSRz4c

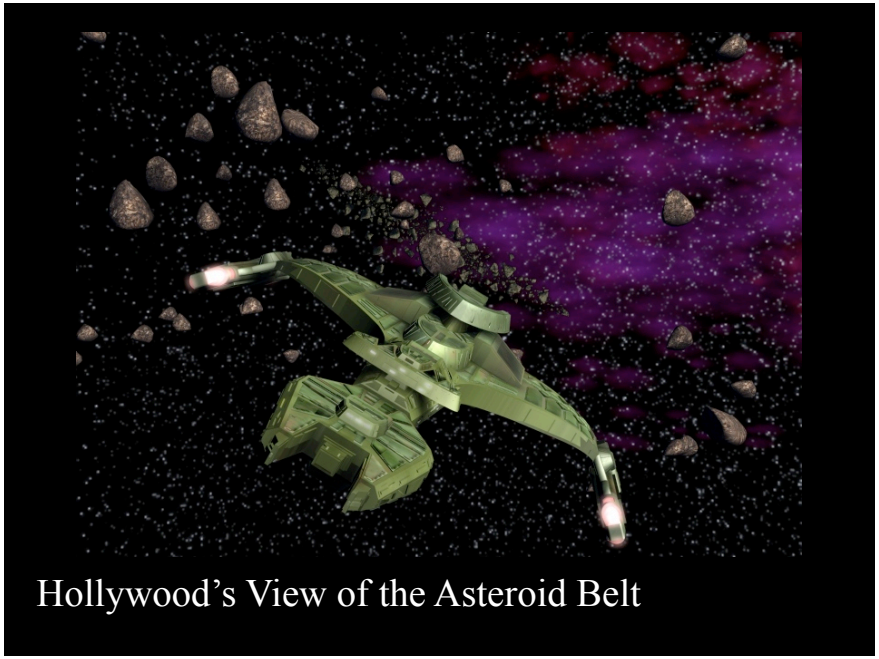
The Asteroid Belt

- Most, but not all, asteroids are found between 2-3.5 AU
  - Between Mars & Jupiter
  - Region is called the **Asteroid Belt**
- As asteroids collide with one another, they fragment and send pieces into near-Earth orbits

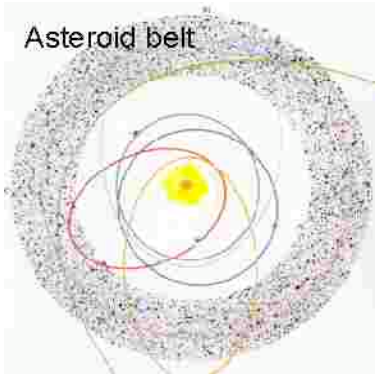


The possibility of successfully navigating an asteroid field…

- Actually, NASA has sent many space probes into and through the Asteroid Belt
- Unlike in Star Wars, the Asteroid Belt is not that crowded
- Average separation between sizable asteroids is 10 million km!



Hollywood's View of the Asteroid Belt

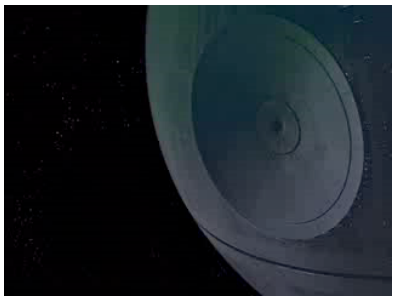


Thousands of asteroids …

On average, about a million miles apart!

Scientific View of the Asteroid Belt

Destroyed… by the Empire



- Are the asteroids a destroyed planet? **NO!**
  - Combined, the asteroids have a mass about 0.1% that of the Earth
  - Less than 10% that of our Moon
- The asteroids might be a *failed* planet
  - Jupiter's gravity kept the asteroids from coalescing into a planet
  - Jupiter probably ejected many asteroids from the Solar System