Astronomy 150:

Killer Skies

HW1 due tonight, but allowing submission up until next week. HW2 is available now. Have to access Nat History Building, so don't wait.

This Class (Lecture 4):
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 by September 13th.
  - Register with first part of your illinois email (NetID
- Grade points lost if not registered by that date.
- If you can't read your iclicker ID, you can go the Illini bookstore (at the bag-check counter), "vote" with your clicker, and your clicker ID will be displayed on the base unit.

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

HW2

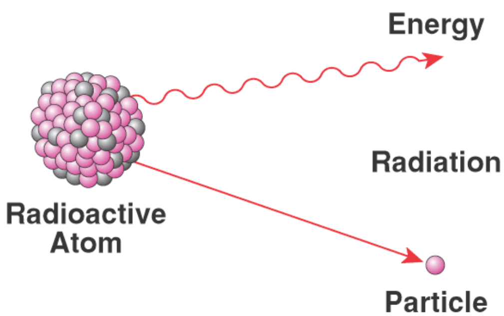
- Look at assignment on Compass before you go.
  - Not timed. Can look at it as much as you want.
- Do not submit though.
- Can print it out, write down relevant points, etc.
- Then go to Nat History building.
  - Take notes or whatever.
- Then, come back bring up HW again, fill it in, then submit.

Outline

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

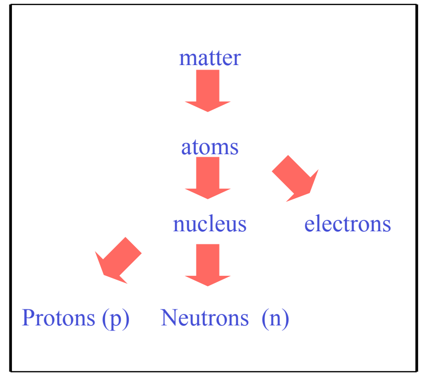
Radioactive Decay Examples

http://www.colorado.edu/physics/2000/isotopes/radioactive_decay3.html



Radioactivity is a good clock!

Radioactive Dating



Example 1: Carbon C=6p

- Carbon-12: 6p+6n, stable
- Carbon-14: 6p + 8n, unstable (1/2 life of 5730 years)
- **$^{14}C \rightarrow ^{14}N$ (nitrogen)**
- Nitrogen-14: 7p + 7n, stable

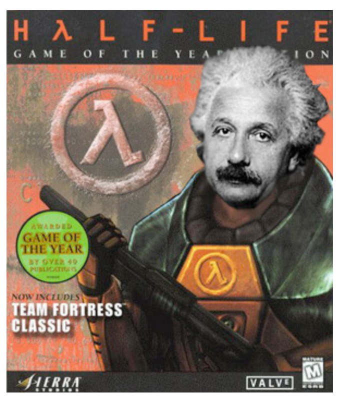
Example 2: Uranium U=92p

- Uranium-238: 92 p + 146 n (1/2 life of 4.5 billion years)

$^{238}U \rightarrow$ chain of decays $\rightarrow ^{206}Pb$ (lead)

Carbon-14

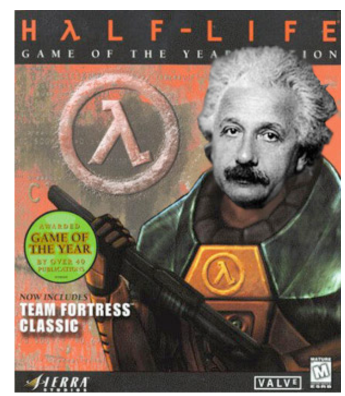
- Carbon-14 dating is the best known example, it can only be used for organic processes over a short time period.
- Not for metorites
- Cosmic rays from space are constantly hitting the Earth.
- React with ^{14}N in atmosphere to create ^{14}C.



http://bbspot.com/Images/News_Features/2003/12/half-life.jpg

Carbon-14

- Decays back to ^{14}N with half life of 5730 years.
- But, there is an equilibrium in abundance
- In atmosphere, the ^{14}C is mostly in $^{14}CO^2$.
- Plants take in $^{14}CO^2$ with the $^{12}CO^2$ and other animals eat the plants.



http://bbspot.com/Images/News_Features/2003/12/half-life.jpg

Carbon-14

- So, every living creature has a equilibrium ratio of $^{14}CO^2/^{12}CO^2$.
- When the organism dies, the ^{14}C decays to ^{14}N. By measuring how much ^{14}C remains, you can date the fossil.
- This works well to about 60,000 years.
  - Viking remains in Newfoundland– 500 yrs before Columbus.
  - Shroud of Turin to 1330 AD
  - Can't be used for meteorites

http://web.mit.edu/smcguire/www/newfoundland/newf16.html

Interesting Question

Half-life of a radioactive element is

a) The time it takes for half a radioactive sample to decay.
b) The time it takes for half the human population to die.
c) The time it takes for half of the class to get the idea of radioactivity,
d) The time it takes for rocks to turn into amorphous solids.
e) The time it takes to eat cake.

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

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

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

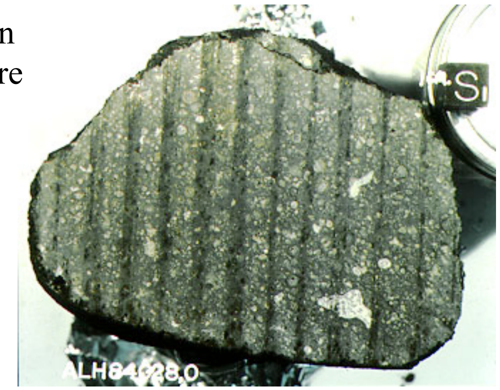
- Meteorites are the oldest objects in the Solar System
- Remnants of the Solar System's formation
- The oldest are the carbonaceous chondrites (a type of stony)
  - Abundant in carbon and water
  - Contain amino acids - building blocks of life!
  - 4.56 billion years old
- Some have diamonds produced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

Carbonaceous chondrite

Stony Meteorites (94% of all meteorites)

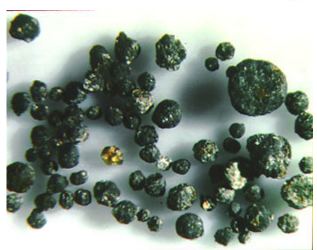
- Two types:
- Chondrites…contain chondrules…they are very old and primitive
- Achondrites…no chondrules

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

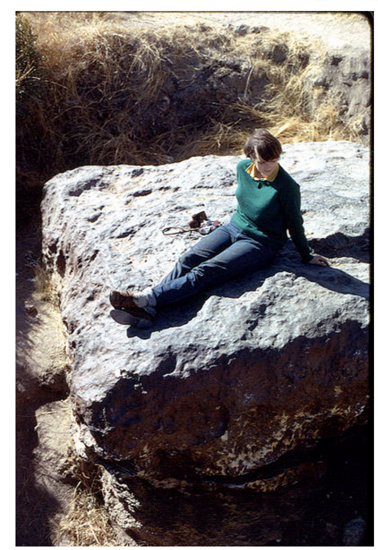
- Found Namibia, 1836
- Strewn field with over 50 tons of 'irons'
- This example: 3 kg
- Distinctive Widmanstätten pattern of intergrown iron-nickel alloys
  - This proves space origins, as it takes very slow cooling (1 to 100 degrees/ 1 million years) to make this pattern.

Hoba Iron Meteorite

- 3m x 3m x 1m and 66 tons of iron (largest natural piece of iron 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?



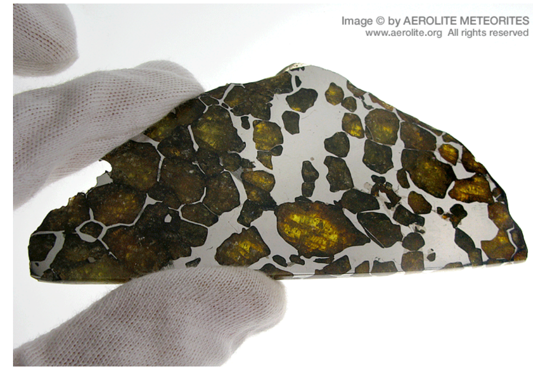
Hoba Iron Meteorite

Why has the meteorite lost 6 tons over 90 years?

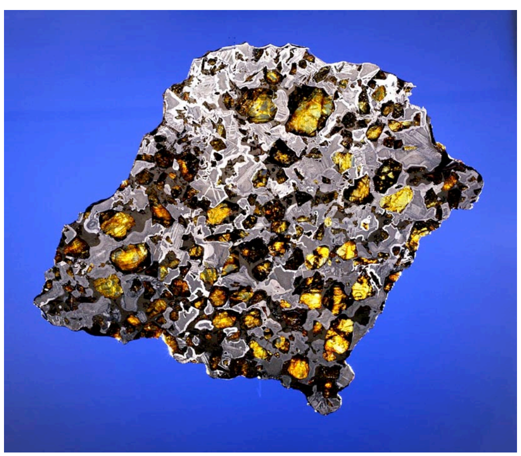
a) Erosion
b) Rust
c) Stolen
d) Removed to make sitting arrangements
e) Aliens

Stony-iron meteorites (1%)

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



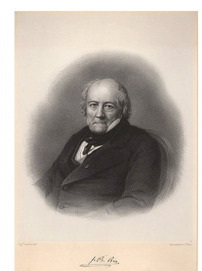
Glorietta Mountain New Mexico Pallasite (full slice)



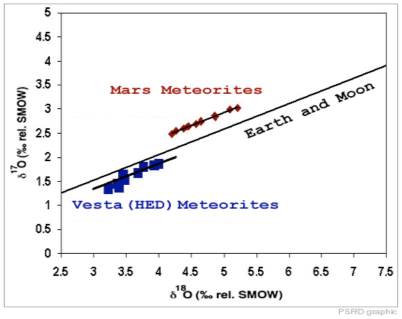
- Stony-iron meteorite
- Suspended in an iron matrix
- Etched iron shows Widmanstatten pattern
- Olivines with very uniform composition
- Likely source: core-mantle boundary region of a once differentiated and since-shattered asteroid

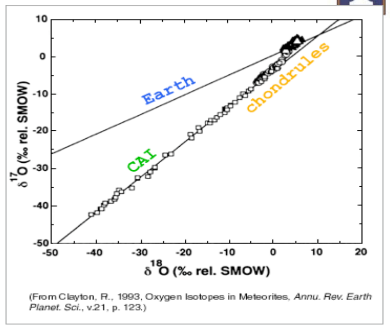
They're From Outer Space!

- 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?!

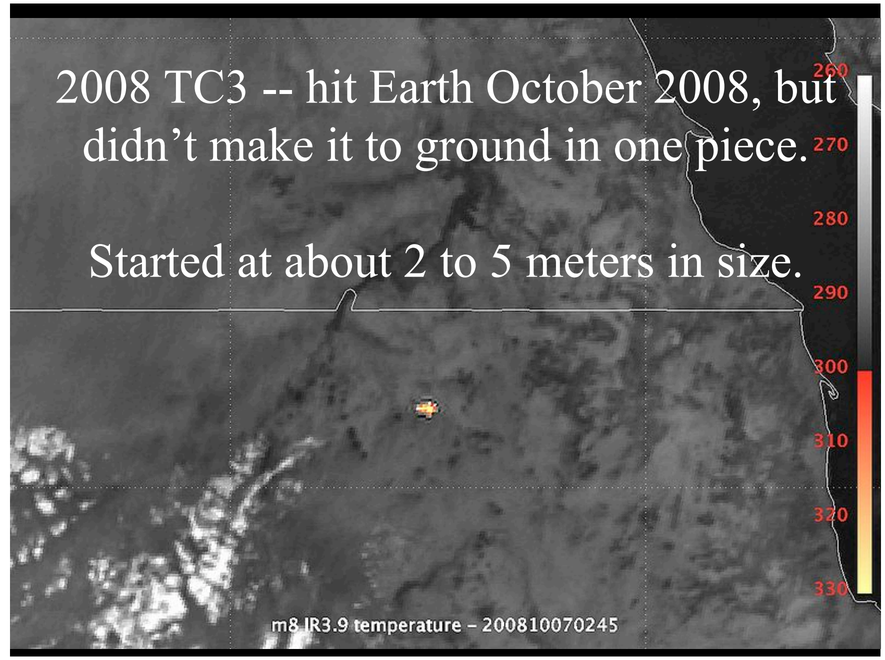




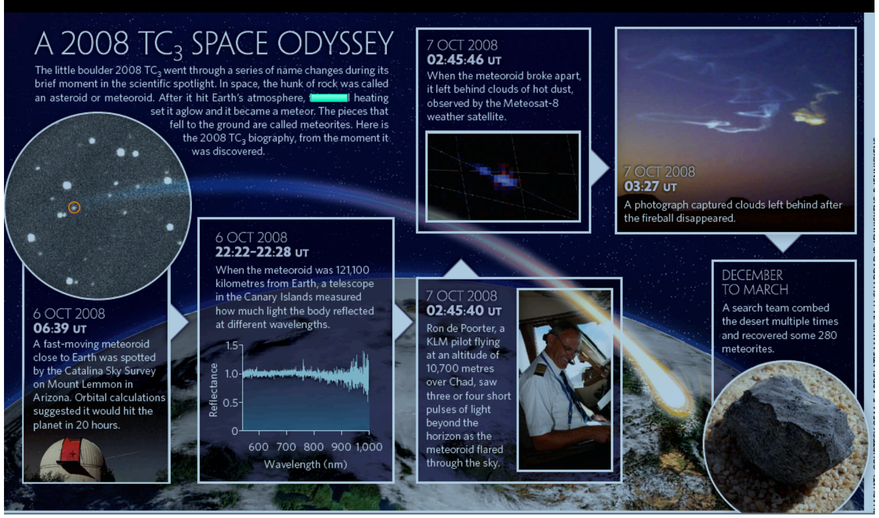
- Oxygen isotope ratios distinguish among solar system materials chemically; Earth and Moon plot together
- Planetary processes 'smear' O isotopes along a trend within one world; different initial ratios for each world

2008 TC3 -- hit Earth October 2008, but didn't make it to ground in one piece.

Started at about 2 to 5 meters in size.



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



2008 TC_3

- Size of 2-7 meters (7-16 ft)
- Exploded tens of km above ground
- Energy of 0.9 to 2.1 kilotons of TNT
- Caused a large fireball or bolide
- Meteoroids of this size hit Earth about two or three times

Where From?

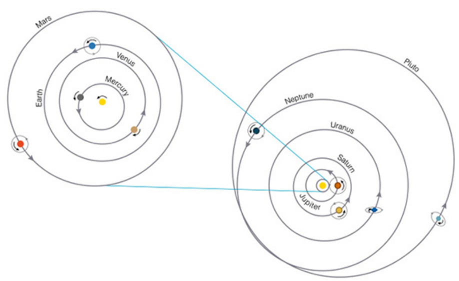
- Okay, so know we need to take a step back.
- Where do these rocks come from?
- How do they connect to our Solar System?
- What do they tell us about the history of our Solar System?
- Are we doomed?

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

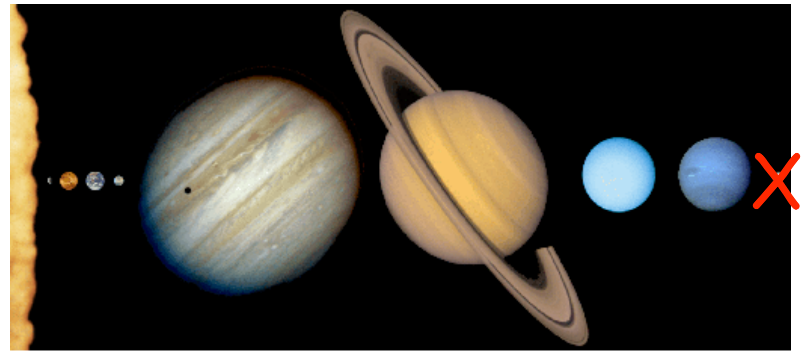
Question

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

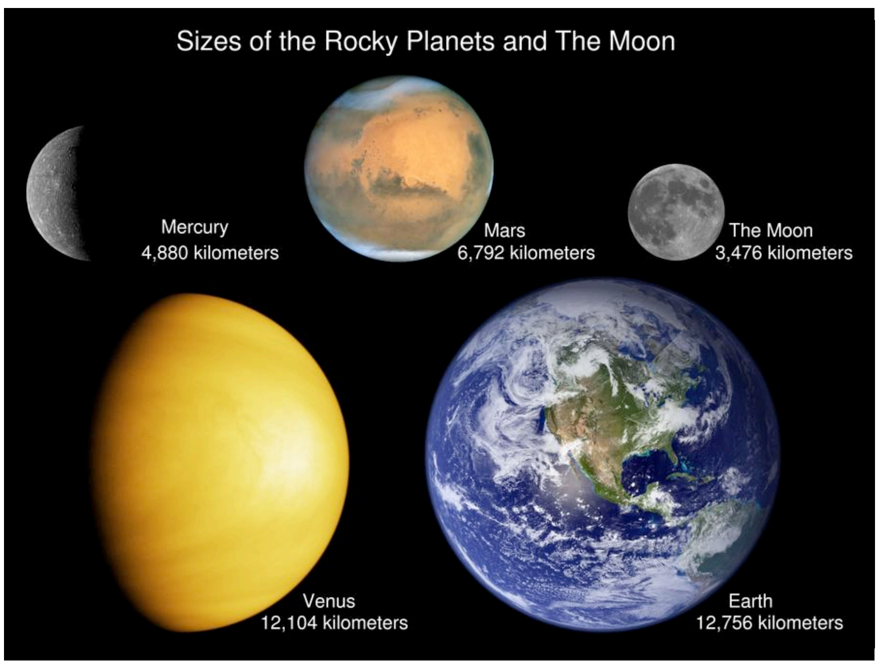
a) Random
b) They orbit the same direction in a flat plane.
c) They orbit the same direction in a uniform sphere.
d) They orbit in opposite directions in a flat plane.
e) Uniform motion, like a rotating disk (DVD?).

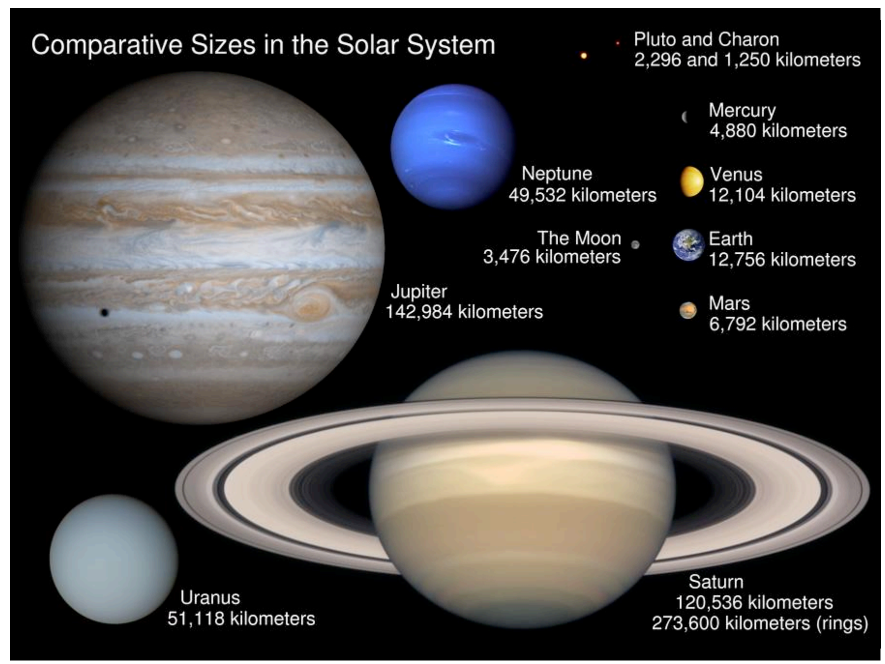
A Sense of Scale

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



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





The Moons?

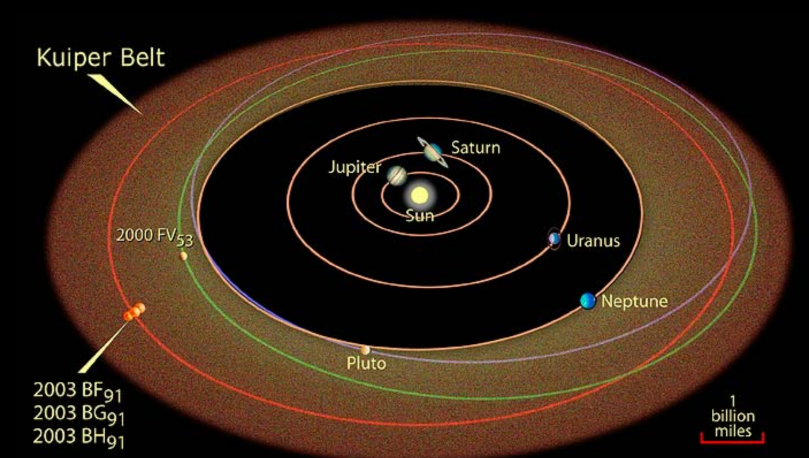
Do we know of all of the Bodies in our Solar System?

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?

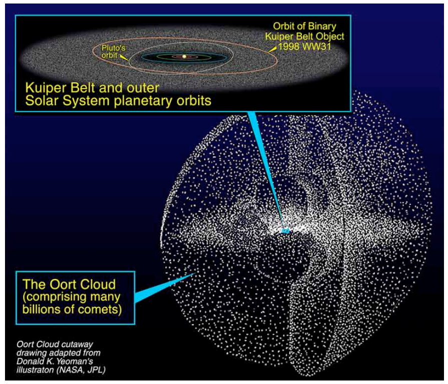
The Kuiper Belt



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

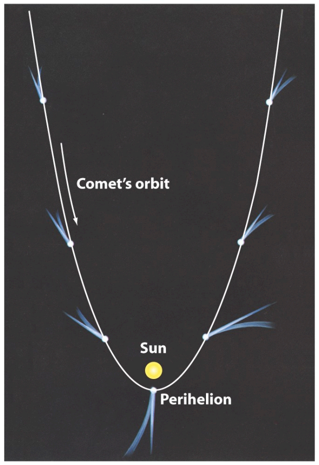
Where does gas tail point?

- 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