

Homework Issues

Two significant figures are enough!

You can round your calculations to 2 significant figures. Hopefully this will prevent some of the sloppy mistakes.

The speed of light is 299,792,458 m/s. Make life easy on yourself and write 3.0×10^8 m/s

One AU is 1.495978×10^{11} m, but just write 1.5×10^{11} m

Pluto, Comets, and Other Solar System Debris

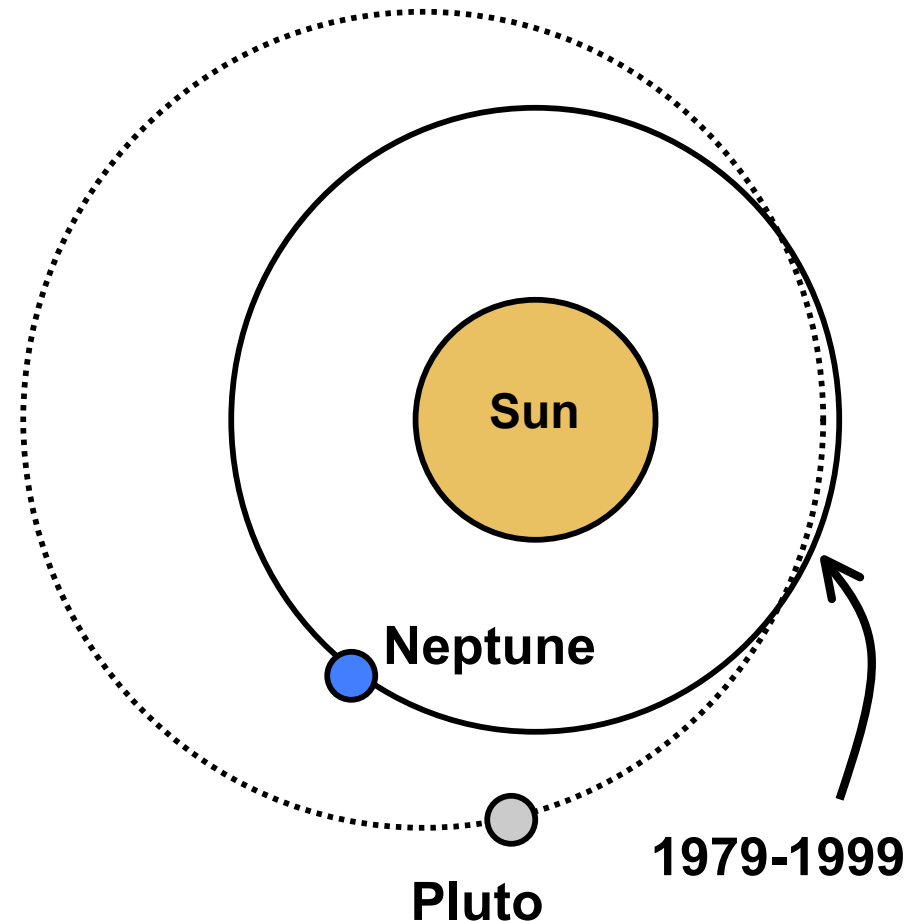
Today's Lecture:

Chapter 8, pages 184-209

- Pluto
- Comets
- Meteoroids
- Cosmic Collisions

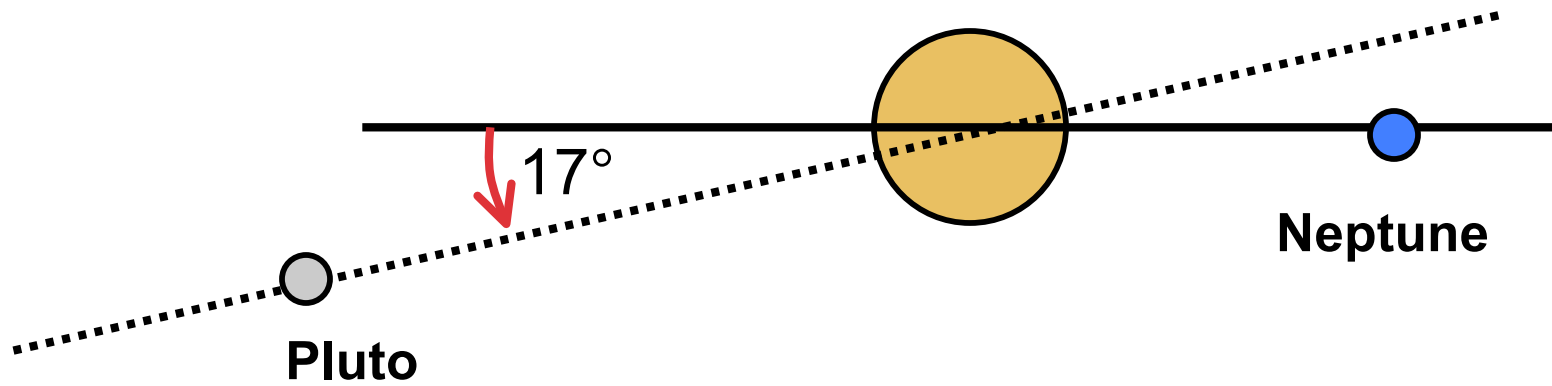
Pluto: The Former Planet

- Discovered in 1930 by C. Tombaugh, incredibly (it was predicted in the right place by a flawed calculation)
- The 9th planet from 1930-2006. Now considered a “dwarf planet”
- Actually the 10th largest object circling the Sun, and the 2nd largest dwarf planet (1/500 the Earth’s mass)
- Weird orbit--sometimes closer than Neptune, very eccentric ($e=0.25$), and inclined by 17°



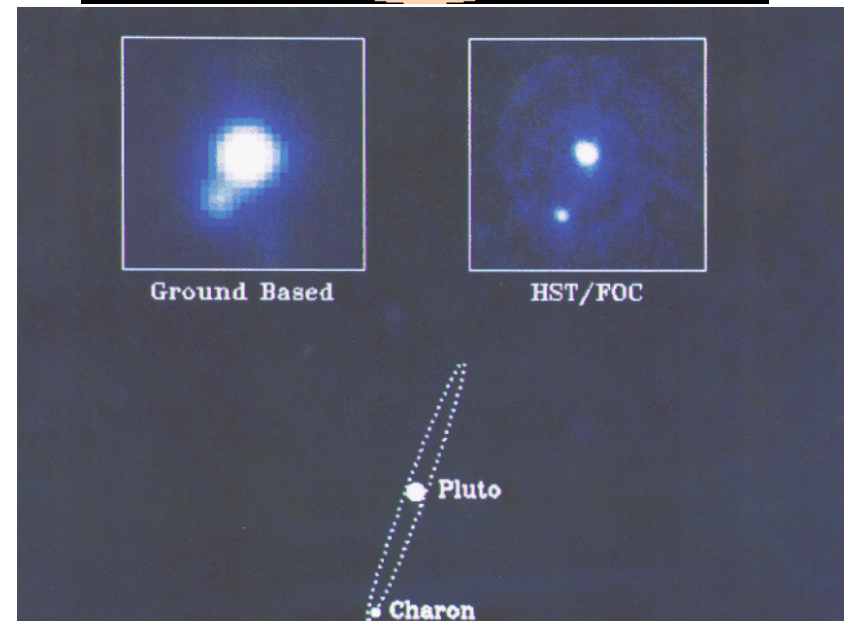
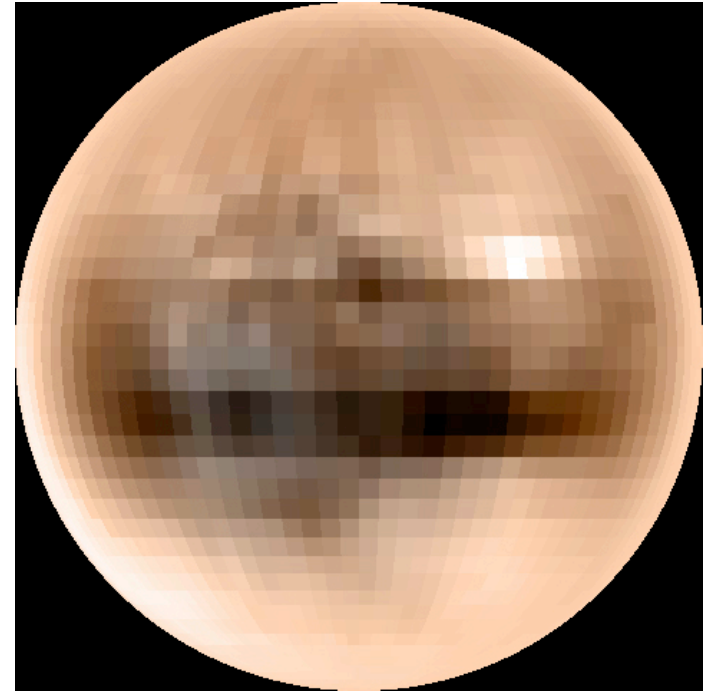
- Weird density 2 g/cm^3 ! Less than terrestrial planets, but more than jovian!

Pluto has an inclined orbit



Pluto (continued)

- Large distance makes it very difficult to study
- Mass known from the orbital period of its moon, Charon (6.4 days, discovered in 1978)
- Size and surface albedo mapped from occultations with Charon (1985-1990)
- Weird orbit--sometimes closer than Neptune, very eccentric ($e=0.25$), and inclined by 17°
- New Horizons probe launched in 2006 and will reach Pluto in 2015. Stay tuned!

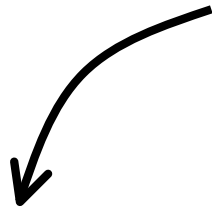


Pluto: King of the Kuiper Belt

- Pluto's unique properties have made astronomers uneasy about the planet designation for many years
- Since 1992, over 1000 of Kuiper Belt Objects (KBOs) (also called "Trans-Neptunian Objects")
- Pluto is one of the largest and brightest (because it has a high "albedo"), but it is nothing special
- In 2005, a KBO was found with a mass **greater** than Pluto
- In 2006, the new designation "dwarf planet" was created, and Pluto was downgraded to a dwarf planet.

Dwarf Planet: Celestial body orbiting the Sun that is massive enough to be rounded by its own gravity but has not cleared its neighboring region of its orbit and is not a satellite.

Initially named “Xena” when discovered in 2005
Later given the name “Eris”
10% larger than Pluto!!!



Comets: Dirty Snowballs

- Comets appear as diffuse, luminous patches, often with **long tails**
- They are basically “dirty snowballs” that evaporate as they approach the Sun
- The tail consists of dust and gas that is pushed by the Sun’s radiation pressure and solar wind

THE TAIL ALWAYS POINTS AWAY FROM THE SUN!

Comets (continued)

- Most comets are NOT periodic. They visit the Sun once then zoom away (or hit Sun)
- They come from the **Kuiper belt** and the “**Oort cloud**” (a sphere of perhaps 10^{12} comets, about 50,000 AU from the Sun)
- Sometimes perturbed by a passing star and deflected into the Solar System
- Made of **primitive material** that is important for understanding the early Solar System
- So we are very interested in studying comets (“Deep Impact” collision of 2005)

Asteroids

- Asteroids (“minor planets”) occupy a belt at ~ 2.8 AU from the Sun, where there could be a planet.
- First one (Ceres) found in 1801; several others found shortly thereafter (1802, 1804)
- Thousands are now known (10^5 or more?)
- About 6 are larger than 300 km, but most are small (< 10 km).
- **3 types:** rocks, iron/nickel, carbon rich
- **Jupiter’s gravity** probably prevented planet formation at that location in the Solar System
- Provide important clues to the Solar System’s origin!

Meteoroids

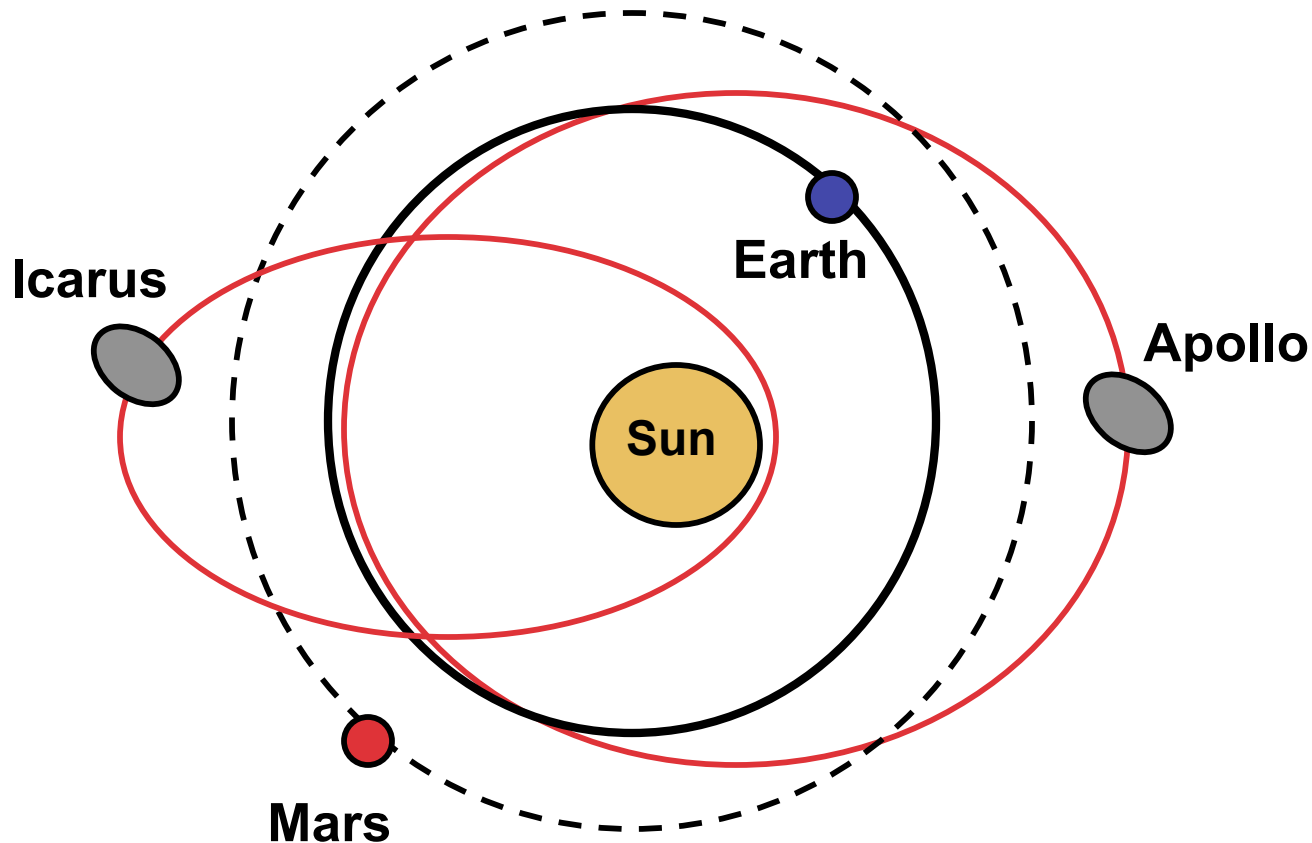
- **Meteoroids** are chunks floating through the Solar System, not in the asteroid belt.
- Most are small (< 10 m). They probably come from the asteroid belt produced by collisions
- When enter atmosphere of the Earth (< 100 km), they **burn** due to **friction**. This makes a **METEOR** (“shooting star”). Mostly little pebbles.
- Some actually reach the Earth’s surface: called **meteorites**.

Meteoroids (continued)

- Age = 4.6 billion years. The oldest known objects in the Solar System
- Chemical analysis shows that a few meteorites came from the Moon and Mars.
- Some carbon-rich meteorites have complex molecules, like amino acids: life precursors!
- Meteor showers occur when Earth passes through the orbit of an old disintegrating comet: occurs at the same time each year.

Collisions: Mass Extinctions

Some groups of asteroids have orbits that cross Earth's orbit. Eventually most of them can collide with Earth.



Also, sometimes random meteoroids and comets cross Earth's orbit.

Collisions have happened!

Recent collisions clearly have occurred.

- “Barringer meteor crater” in Arizona: 1.2 km in diameter, probably from a $d \sim 50$ m meteorite about 50,000 yrs ago.
- “Tunguska event,” 1908, Siberia - leveled 2000 km² forest; like 15 megatons of TNT. (The atomic bombs dropped on Japan were 20 kilotons or 0.02 megatons!)
- Despite erosion, >140 terrestrial craters have been found.

Collisions (continued)

- Over 300 near-Earth asteroids known with a diameter > 1 km (make craters of 10-20 km)
- Estimate: 2000-5000 of them exist in the Solar System
- Expect one collision per 300,000 years; 10^5 - 10^6 megatons of TNT (more than all the nuclear bombs we have put together)
- “Small” blasts (like Tunguska) are expected to happen 1 per roughly 1000 years

Collisions: Extinction

- Statistically, **averaged over tens of millions of years**, you are as likely to die from a cosmic collision as you are from an airplane crash, flood, or tornado.
- An asteroid or comet with $d \sim 10$ km hits roughly every 30 million
- One of these would probably mean the end of human civilization.

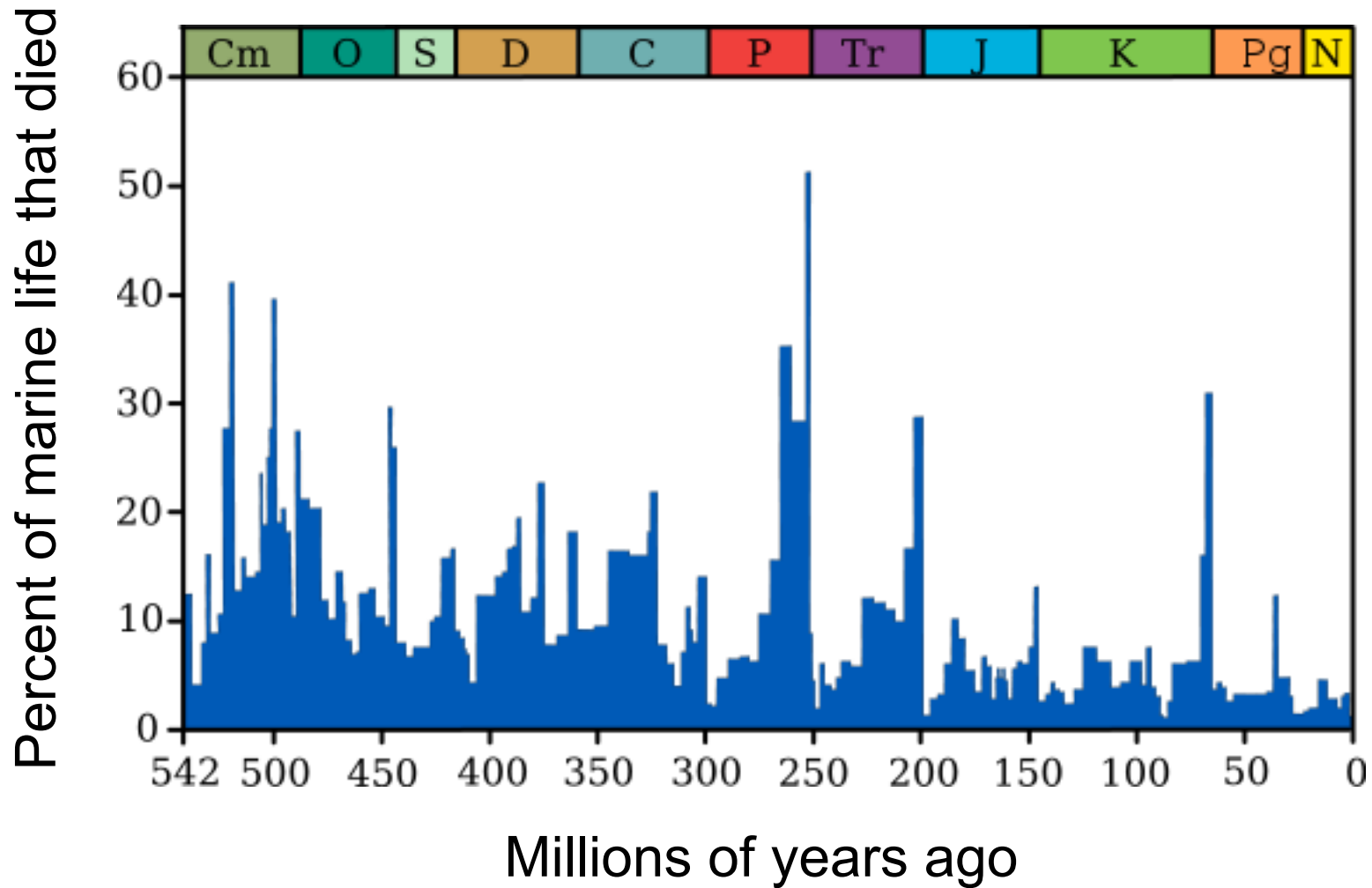
Collisions: Extinction (cont.)

- 10^8 - 10^9 megaton explosion devastates the surrounding area (~ 1000 km). The rest of the Earth is like an oven set to “broil.”
- This is followed by “impact winter” produced by dust in atmosphere; sunlight blocked; acid rain. Then long period (100-1000 years) of high temperature (greenhouse effect due to CO_2 in the atmosphere)

K-T Extinction

- Hypothesis: A comet impact caused the “Cretaceous-Tertiary (K-T) extinction” 65 million years ago, when the remaining dinosaurs died along with 2/3 of all other life.
- A layer of iridium was found in strata that formed 65 million years ago (1979).
- More recently, the probably impact site was identified near Yucatan peninsula.

Mass Extinctions Over Time



Comet crashed into Jupiter

- An awesome example of collisions in space was the collision of Comet Shoemaker-Levy 9 with Jupiter
- Comet (d~10 km) in orbit around Jupiter. It got torn apart by tidal forces during a close encounter in 1992. After one more orbit, chunks then crashed into Jupiter on July 16-22 1994.
- Each chunk released the equivalent of 6 million megatons of TNT