ASTR 150

- **Homework 1** due tonight!
- **Homework 2** due next Monday
- **Planetarium** shows this week
- Last time: Asteroids
- Today: Asteroids and Comets

Embarrassing moments in asteroid tracking.

Music: *3rd Planet* – Modest Mouse

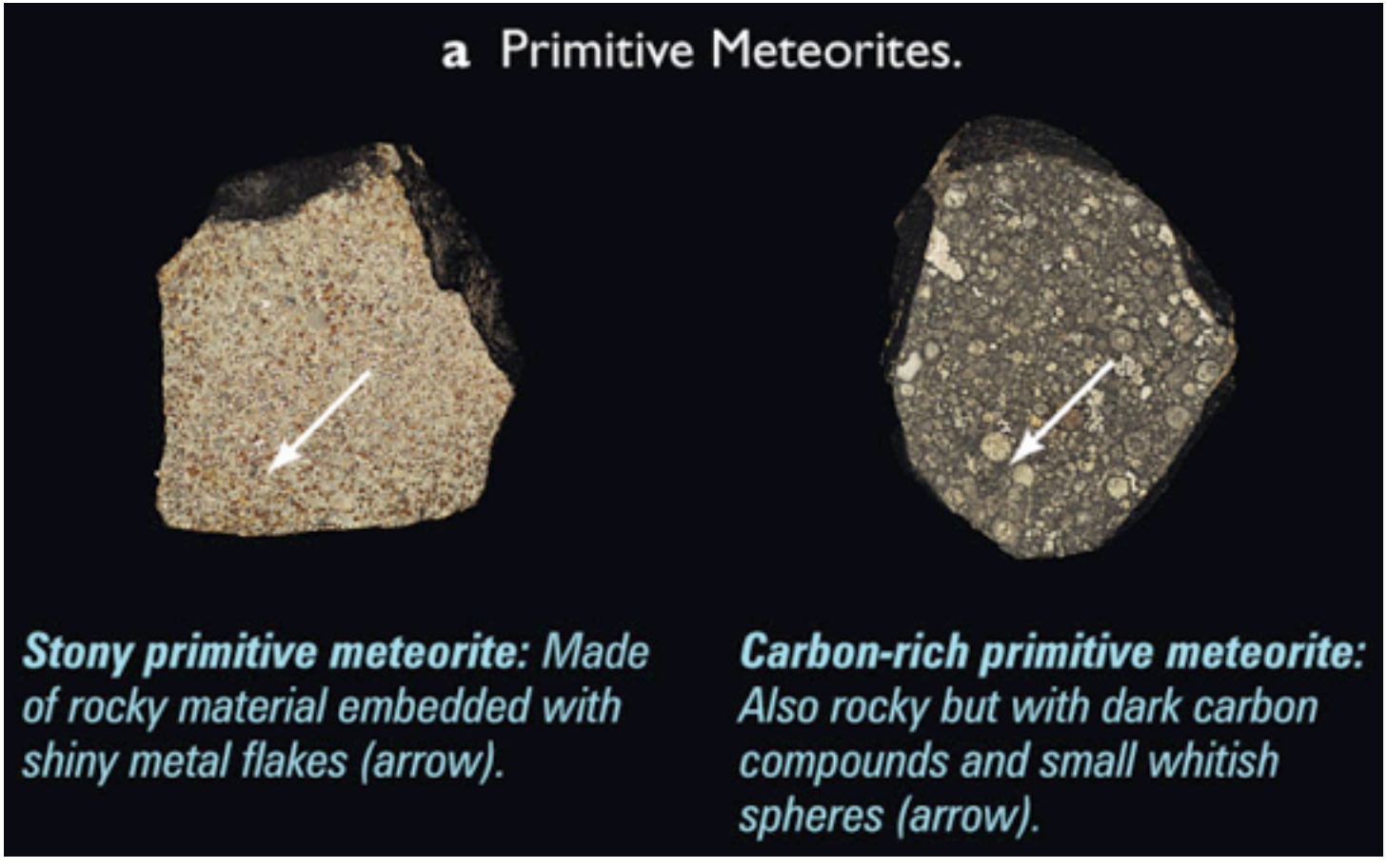
Review: Types of meteorites

- **Stonys**
  - 95% of meteorite falls
  - Rocky composition
- **Irons**
  - 4% of meteorite falls
  - Iron-nickel alloy
- **Stony-Irons**
  - 1% of meteorite falls
  - Mixtures of iron-nickel alloy and rocky material

Most meteors don't result in a meteorite – they are small bits of interplanetary dust
Meteorites will be asteroid fragments
40,000 tons of space debris falls to Earth each year
Iron meteorites are solid chunks of iron and nickel.
Stony meteorites are silicate masses that resemble Earth rocks.
Stony-iron meteorites are iron-stone mixtures.

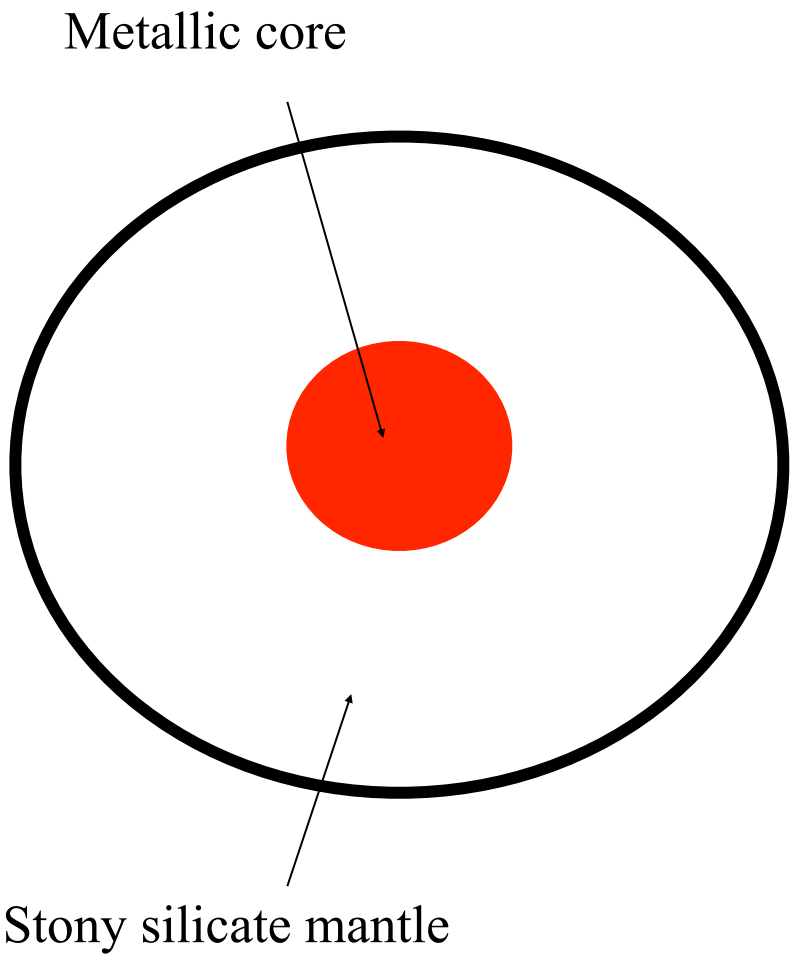
Types of meteorites derived from asteroids - primitive

- Small asteroids are primitive - unchanged since they solidified ~4.6 billion years ago



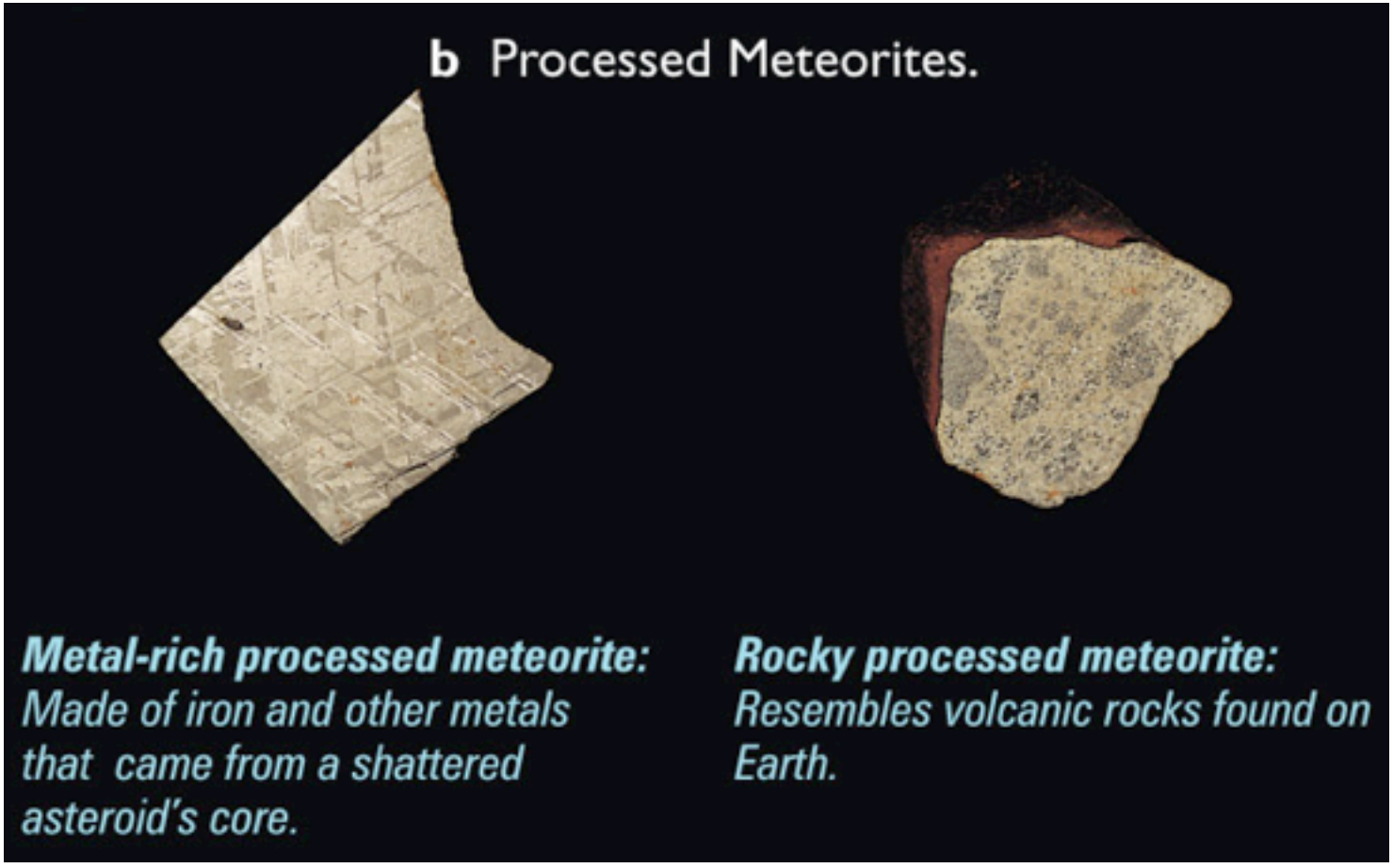
Types of meteorites derived from asteroids - processed

- Larger asteroids are differentiated -
  - in past, were melted
  - metals sink to center
  - have a metallic core and rocky mantle
- As asteroids fragment, both metallic and rocky pieces are produced
- Called processed meteorites



Processed Meteorites

- All irons and stony-irons are processed
- Some stonys are processed, most are primitive



i>clicker question

Primitive meteorites:

A. Are approximately 4.6 billion years old
B. Give us clues to what the early solar system was like
C. May be iron or stony
D. A and B
E. A, B, and C

Answer: D

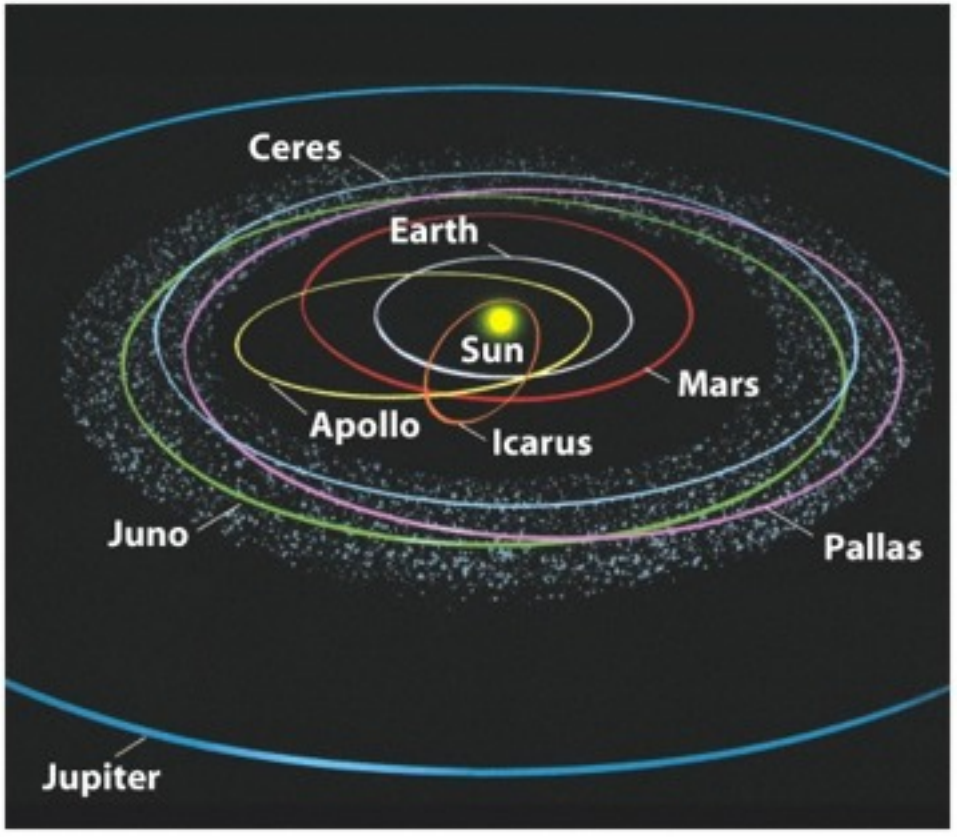
The Asteroid Belt

Most, but not all, asteroids are found between the orbits of Mars & Jupiter

Region is called the Asteroid Belt

Orbits in same direction as planets, orientations near same plane (Ecliptic)

As asteroids collide with one another, they fragment and send pieces into near-Earth orbits



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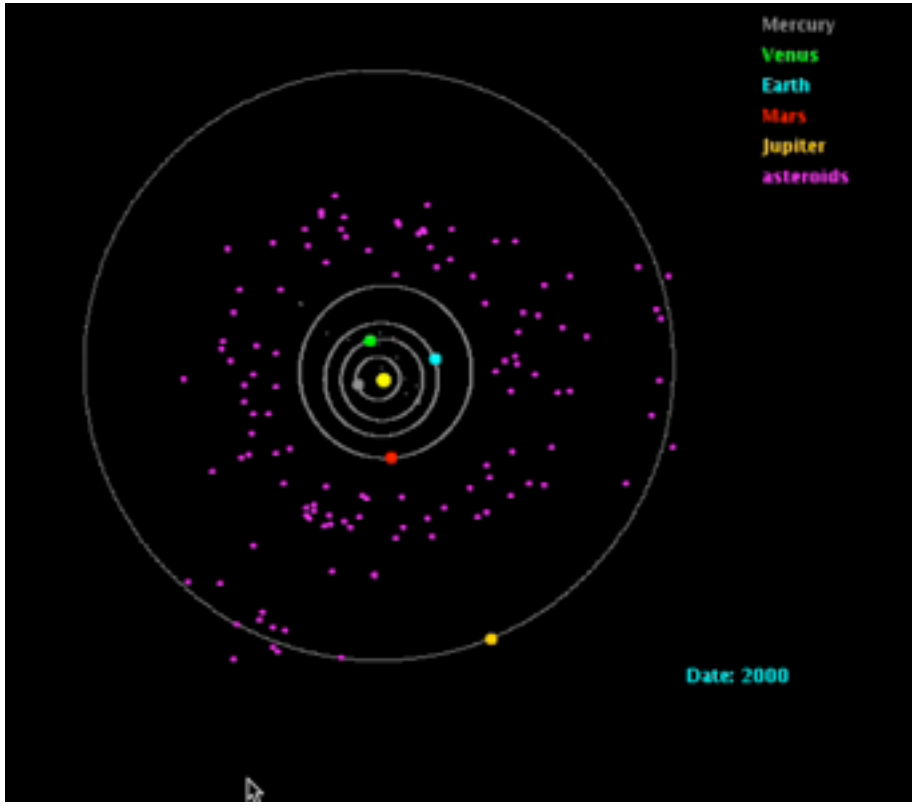
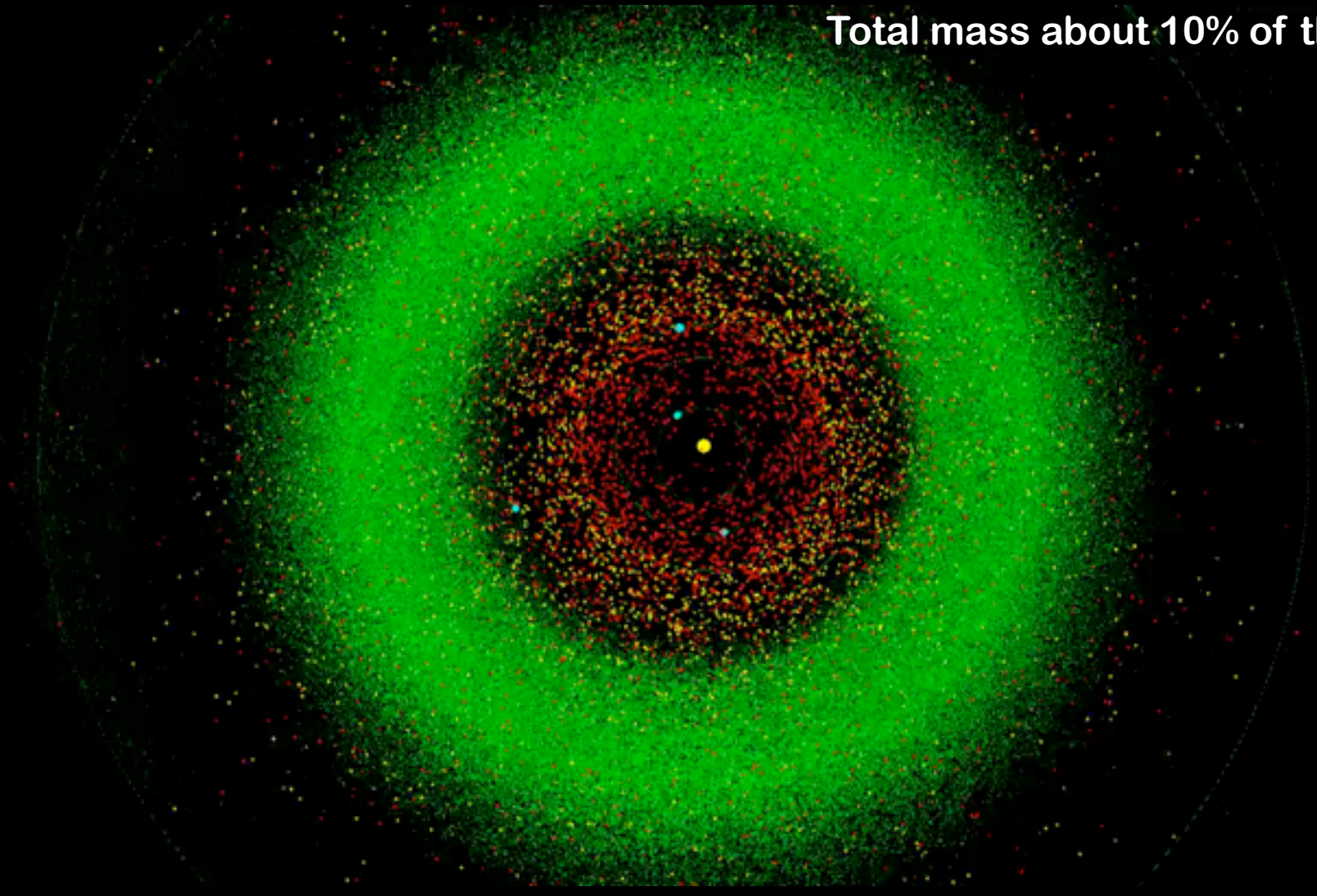


The Asteroid Belt

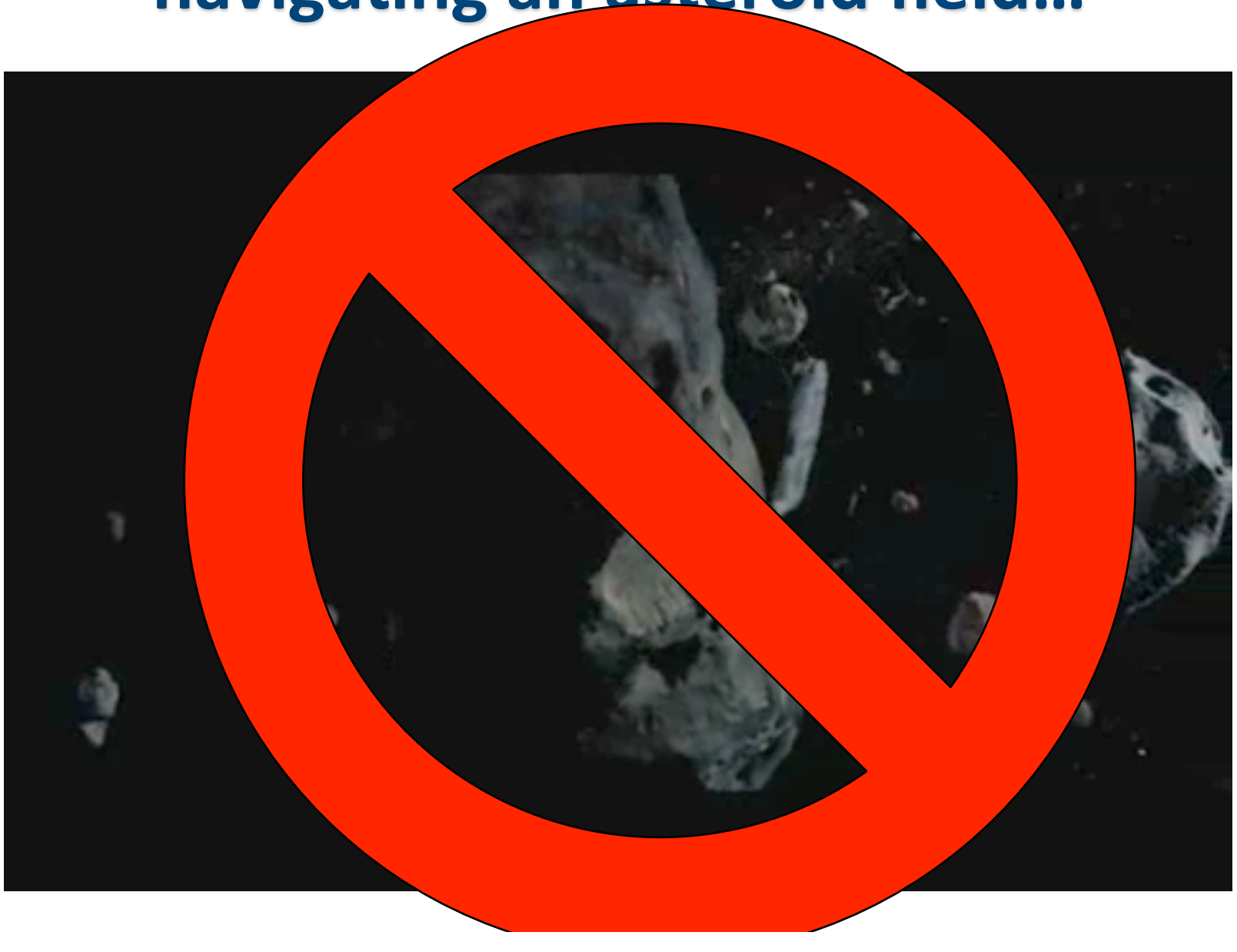
Total mass about 10% of the Moon



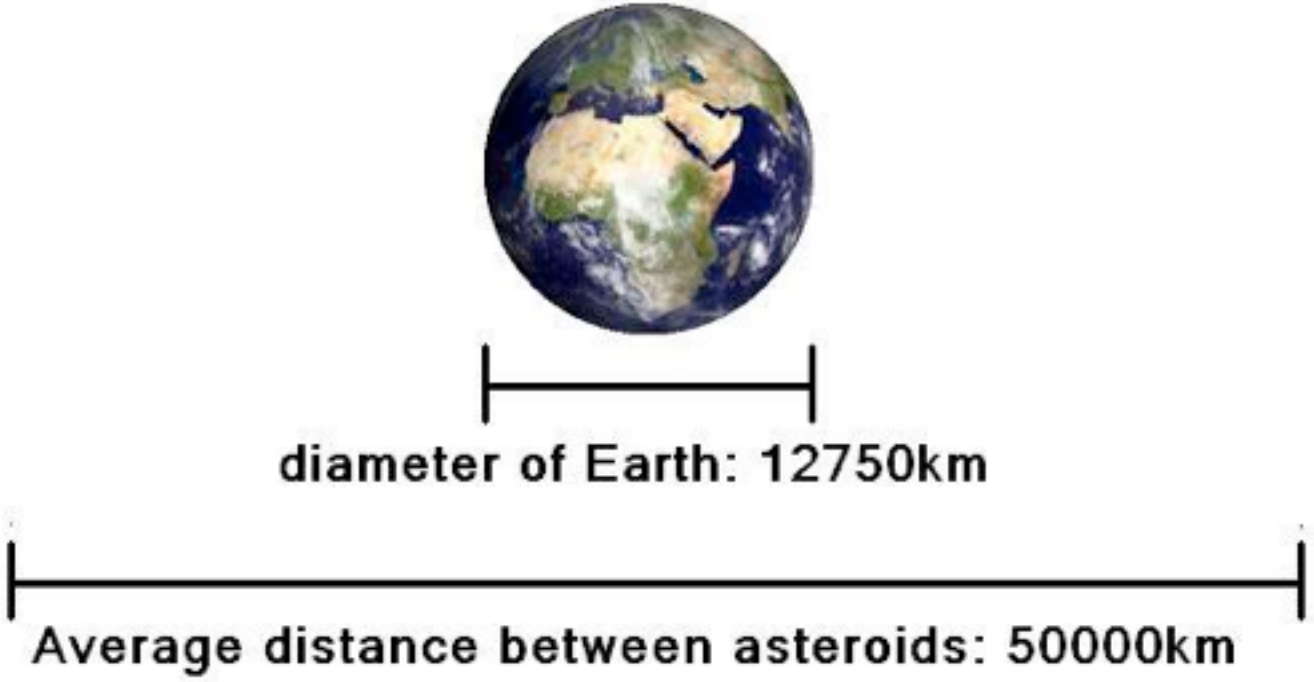
orbits from top and side:

http://www.youtube.com/watch?v=kSqYk6yD75I&feature=related

The possibility of successfully navigating an asteroid field…



Scientific View of the Asteroid Belt:
Mostly Empty Space!



Average spacing between sizable asteroids is bigger than Earth's diameter!

NASA has sent many spacecraft safely through the asteroid belt with no problems!

Their average spacing is several million kilometers. Collisions are thus extremely rare; an average 1-kilometer asteroid suffers one collision every few billion years, or maybe one or two collisions over the lifetime of the solar system.
Spacecraft pass through the asteroid belt with virtually no chance of a collision, and in fact considerable effort is required for a close flyby of even one asteroid, such as the Galileo spacecraft flyby of Ida in 1993. The spacing is also so large that seen from one asteroid, even the nearest 1-kilometer asteroid would likely be too faint to be visible without a telescope.

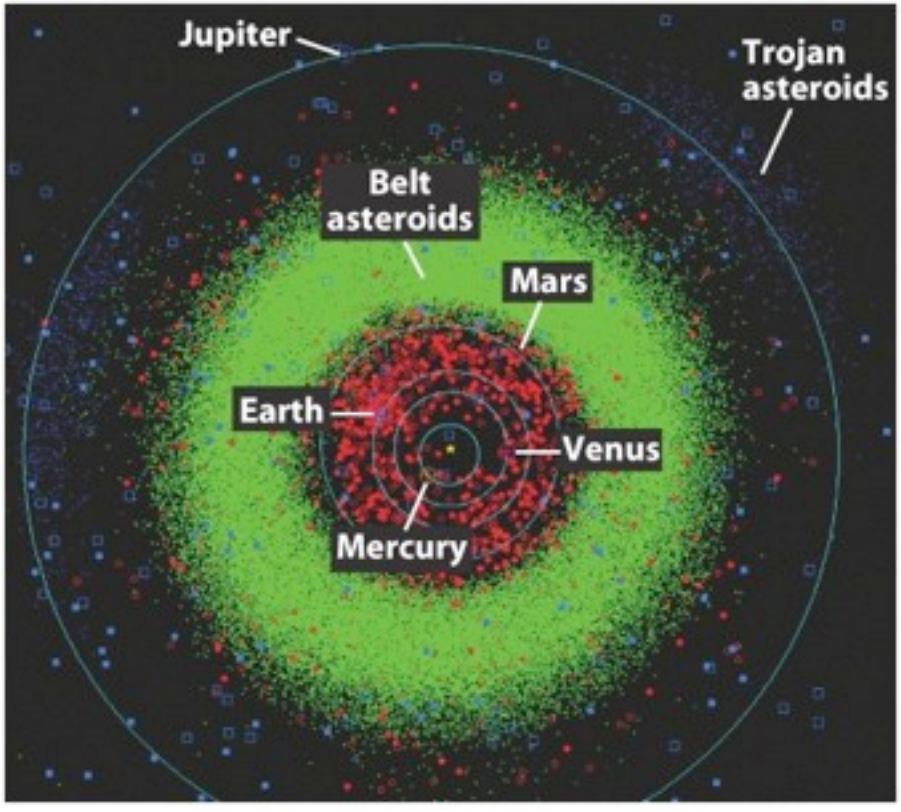
Apollos

Some asteroids are on orbits that cross Earth's orbit

Called Apollo asteroids

At least 3000 are known

In 1972, one skipped off the Earth's atmosphere



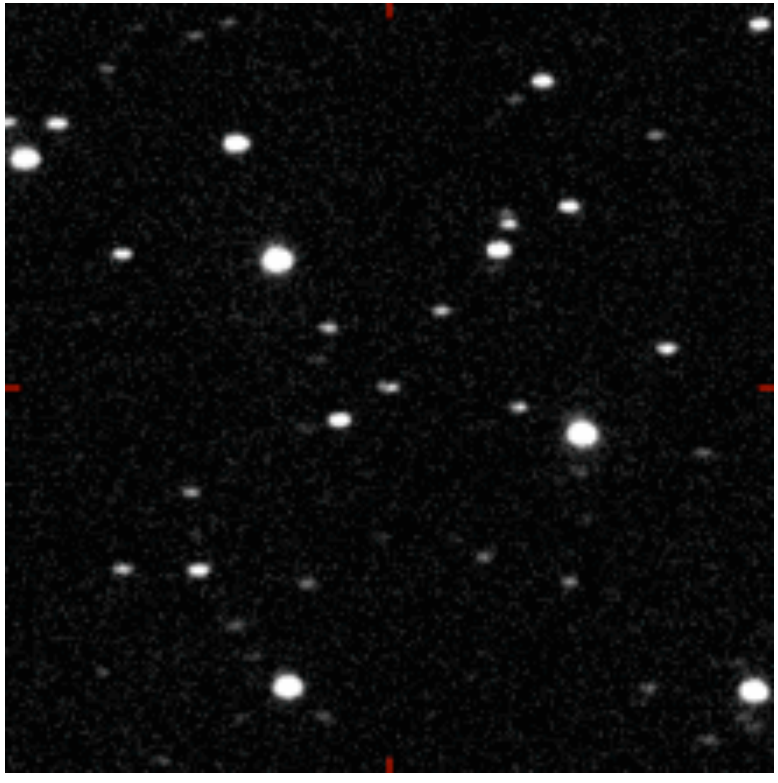
i>clicker question

Asteroids:

A. Are rocky and small–typically the size of a grain of rice or a marble
B. Are rocky, with a wide range of sizes, up to hundreds of miles in diameter
C. Are made mostly of metals
D. Are mostly found inside the orbit of Mars
E. Have more mass than all the planets combined

Near Earth Asteroids

- Short-lived (few million years)
  - Orbital decay and Sun accretion
  - Collision with inner planets
  - Ejected from system by interactions
- Must be replenished
- Gravity interactions with asteroids and Jupiter can send them to Earth



2004 FH (30 meter) passing 10% the Earth-Moon distance

THE MIDDLE SOLAR SYSTEM

This animation shows the motion of the middle part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth Mars and Jupiter are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

The individual frames were generated on an OpenVMS system, using the PGPLOT graphics library. The animation was put together on a RISC OS 4.03 system using !InterGif.

http://www.cfa.harvard.edu/iau/Animations/Animations.html

THE INNER SOLAR SYSTEM

This animation shows the motion of the inner part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth and Mars are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

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A Ride With The Earth

An animation centered on Earth showing the known objects that have approached to within 20 million km between July 2007 and June 2008. See the Animations Page on the MPC website for a description of the symbols used in this animation.

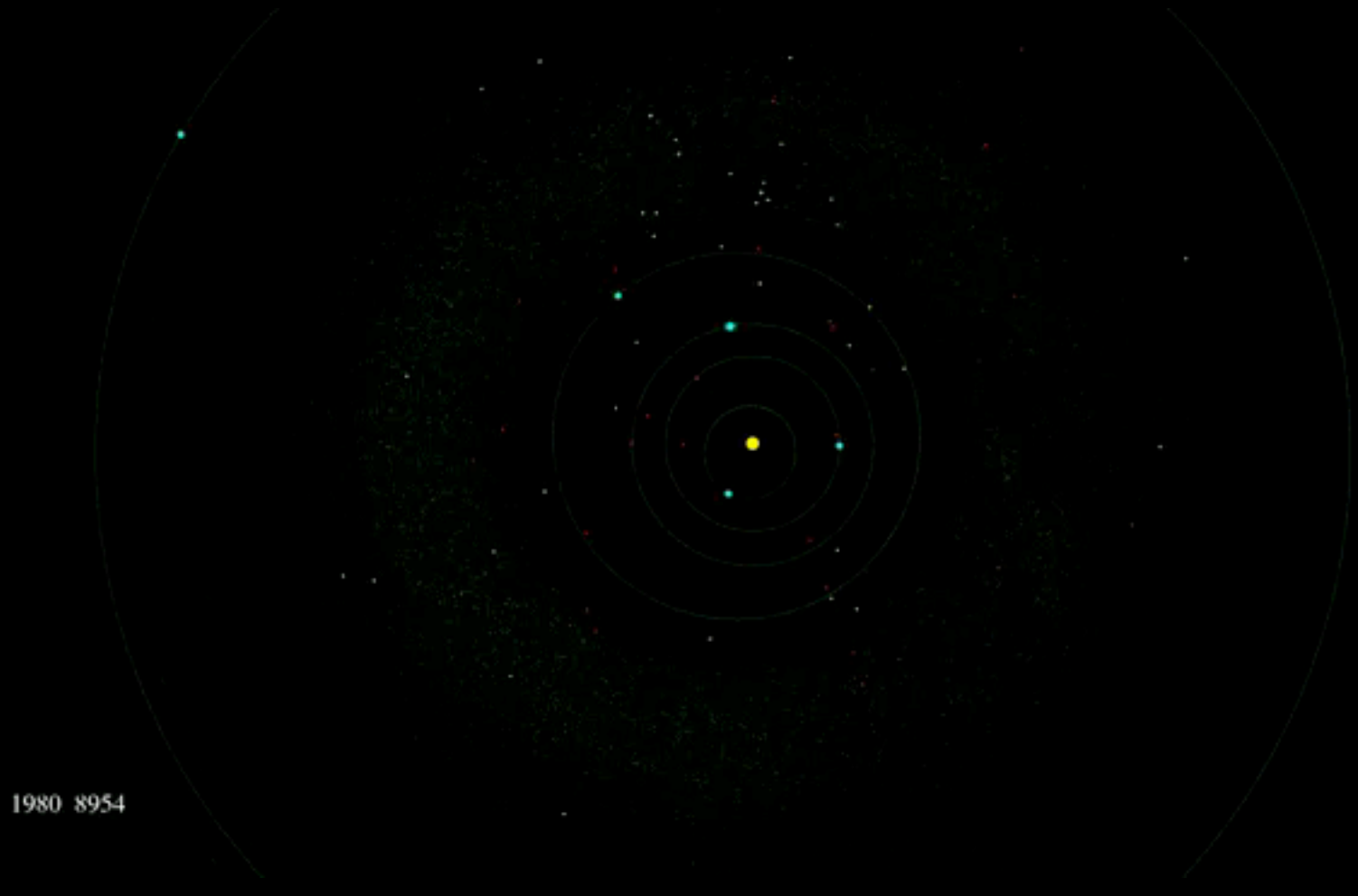
Right now, over 3000 Earth-crossing asteroids are known.
And over 1000 potential dangerous ones.

Near Earth Asteroids

And we're still finding them!

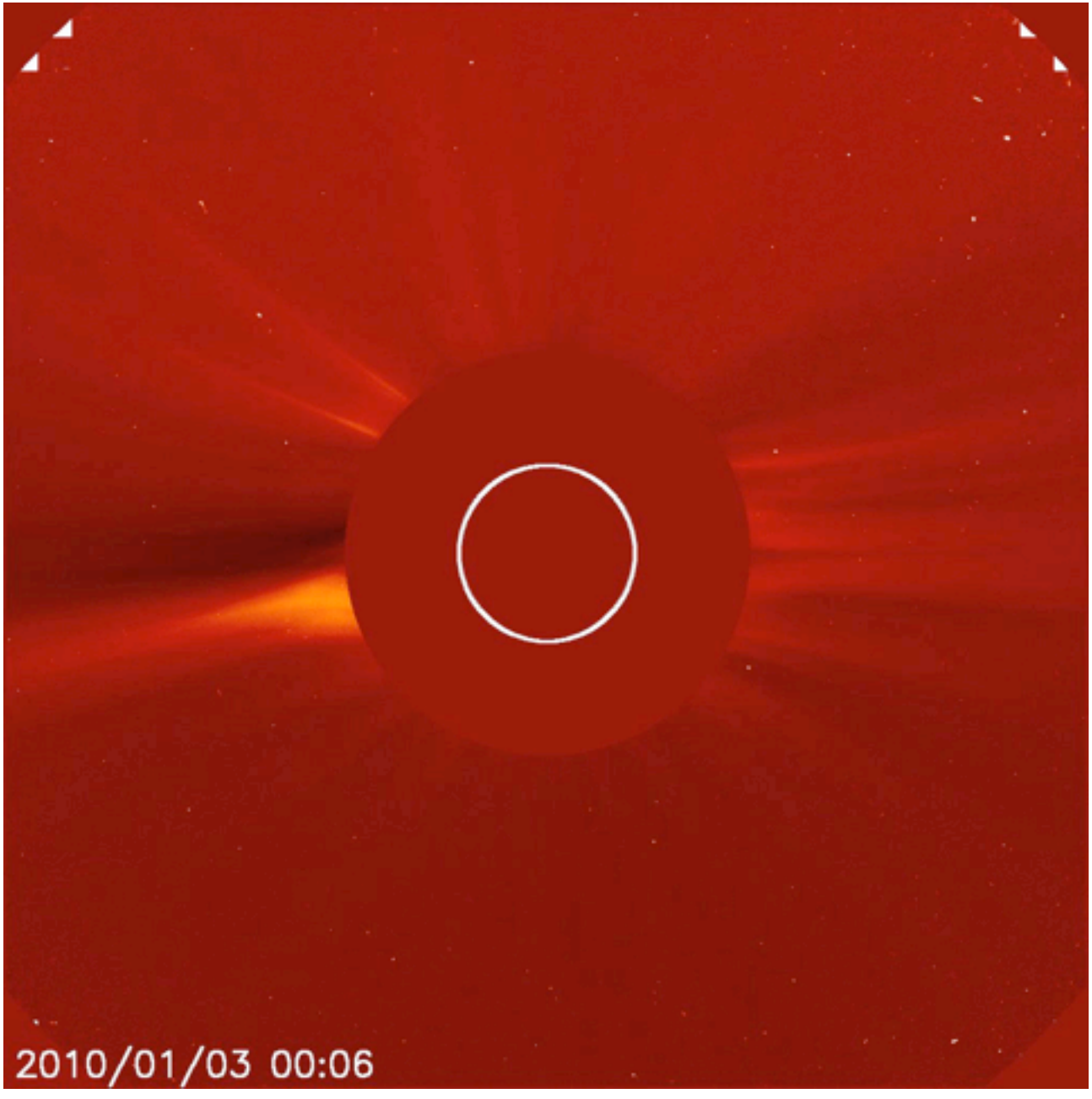
And since they are replenished, it is a never ending job!!!

Near Earth Asteroids



http://www.youtube.com/watch?v=S_d-gs0WoUw

Comets



Comets have always fascinated mankind

- "Unusual" behavior
  - Appear unexpectedly
  - Persist briefly
  - Gradually disappear
- Often considered "bad omens"
  - Deaths of kings
  - Coming catastrophes
  - Attacks by the gods

Halley's Comet

In 1705, Edmund Halley used Newton's Law of Gravity to determine that comets observed in 1531, 1607, & 1682 were the same object

Successfully predicted its return in 1758

Last appearance, 1986

Next appearance, 2061

Halley's Comet in 1986

Halley himself did not live to see the comet's return as he died in 1742.
Appearances of Halley's Comet exist in recorded history back to 240 BC!

Halley's Comet: Harbinger of Death?

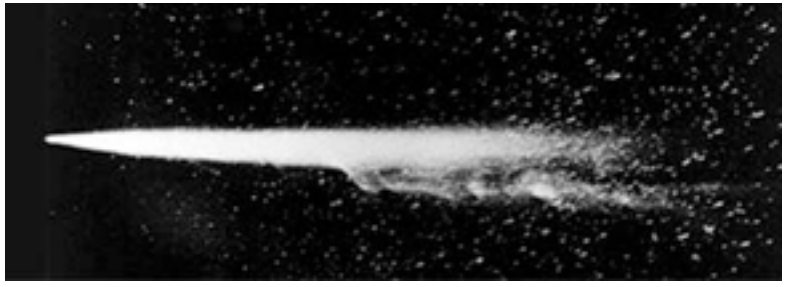
- In 1066, Halley's Comet was observed
- In England, thought to be a bad omen
- Later that year, Harold II of England died at the Battle of Hastings during the Norman invasion

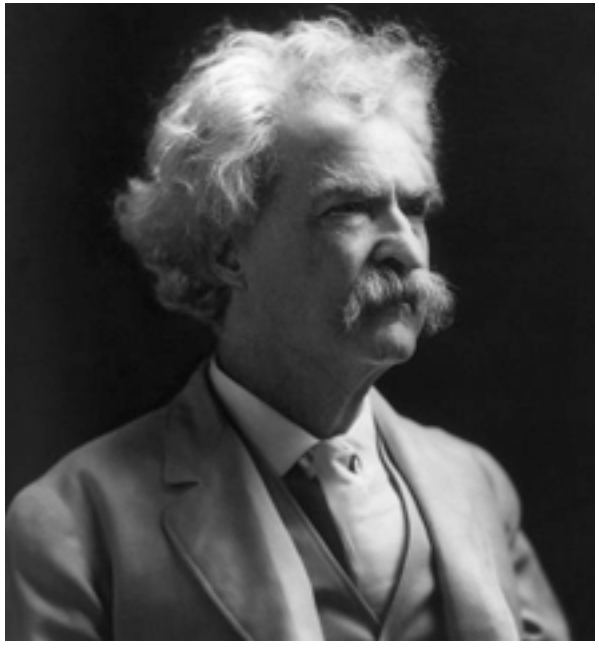
Halley's Comet shown in the Bayeux Tapestry

In 1066, the comet was seen in England and thought to be an omen: later that year Harold II of England died at the Battle of Hastings; it was a bad omen for Harold, but a good omen for the man who defeated him, William the Conqueror.

I shit you not!

- Mark Twain was born on 30 Nov 1835
- Exactly two weeks after Halley's Comet's closest approach to the Sun
- Twain died on 21 April 1910, the day following the comet's subsequent closest approach to the Sun!



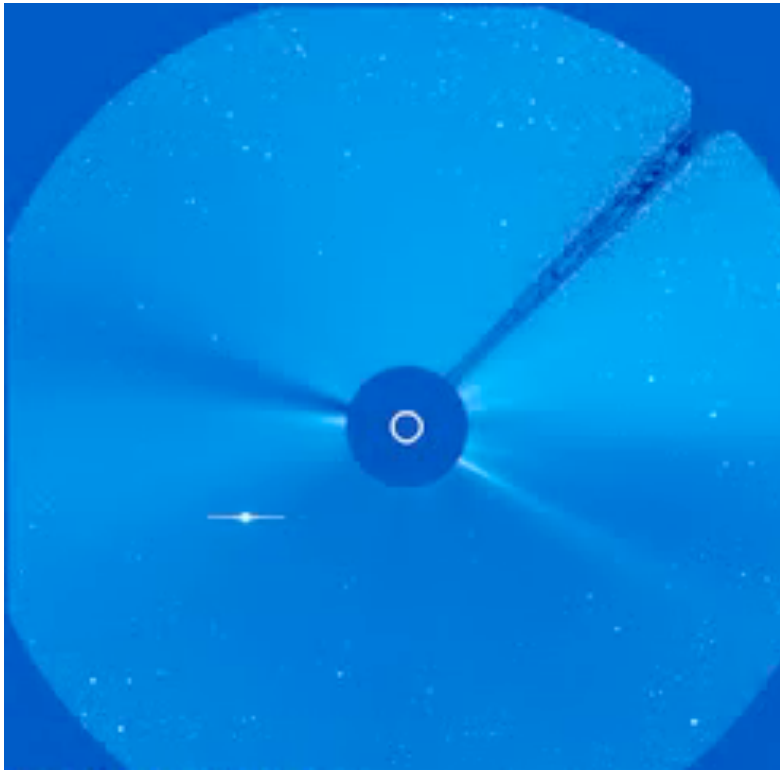


"I came in with Halley's Comet in 1835. It is coming again next year, and I expect to go out with it. It will be the greatest disappointment of my life if I don't go out with Halley's Comet. The Almighty has said, no doubt: 'Now here are these two unaccountable freaks; they came in together, they must go out together.'" – Mark Twain

Comets: Basic Facts

Comets have very eccentric, elongated orbits

- Most time spent far from Sun: small & difficult to see
- When near Sun, grow long tails which shrink and disappear as they go far away again



Comets: Basic Facts

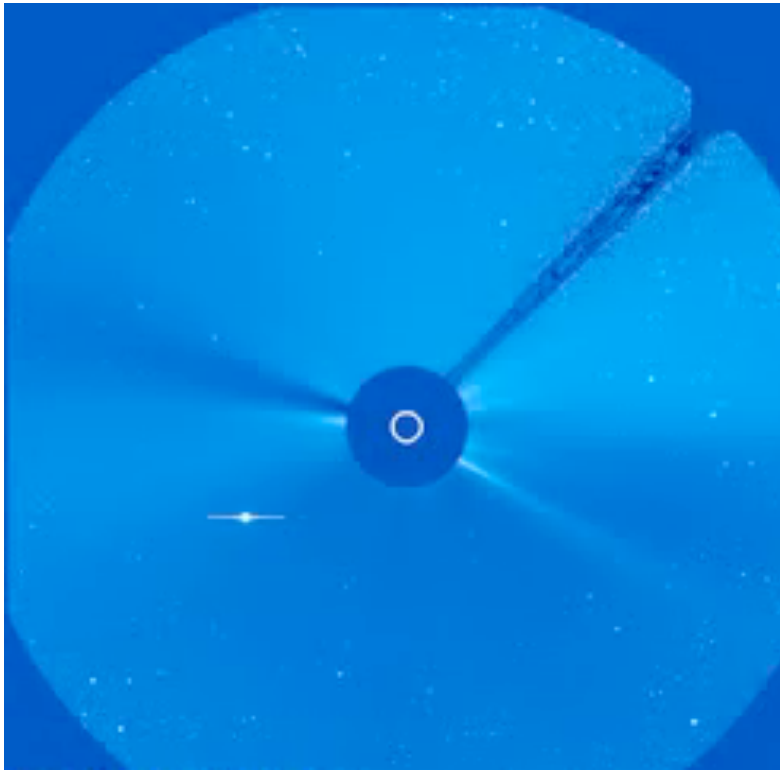
Two main groups of comets

Short period comets

- Periods $P < 200$ years
- Orbits near the same plane as the planets

Long period comets

- Periods $P =$ thousands to millions of years
- Orbits on random orientations



iClicker Poll: Comet Orbits and Locations

Short-Period Comets: $P_{\rm short} < 200$ years

Long-Period Comets: $P_{\rm long} = 10^5$ to 10^6 years

What does this tell us about where these groups of comets live?

A. Short-period comets are farther away, long-period comets are closer.

B. Short-period comets are closer, long-period comets are farther away.

C. Trick question! Orbit period unrelated to distance.

Answer B. Simple use of Kepler's 3rd law. The farther away then the mush longer period.

Where do comets come from? Do the math!

Kepler's mighty 3rd law:

$$(a_{\text{in AU}})^3 = (P_{\text{in yr}})^2$$

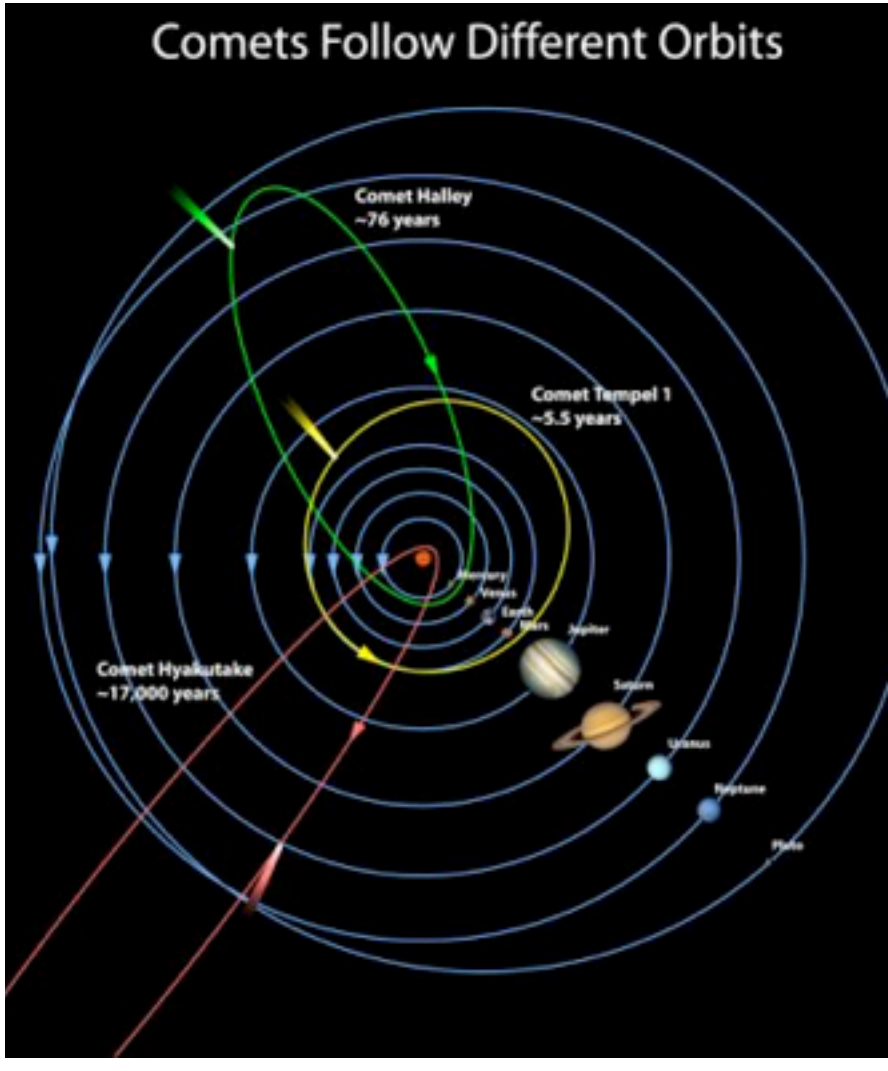
$$a = P^{2/3}$$

Short period comets

- ***P = 200 years***
- $a_{\text{short}} < 200^{2/3} = 34 \text{ AU}$
- **just beyond Neptune**

Long period comets

- **for *P* = 1 million years = 10^6 yr**
- $a_{\text{long}} = (10^6)^{2/3} = 10,000 \text{ AU}$
- **way beyond all planets!**
- **most distant objects in Solar System!**



Short Period Comets: Kuiper Belt

Distances from Sun

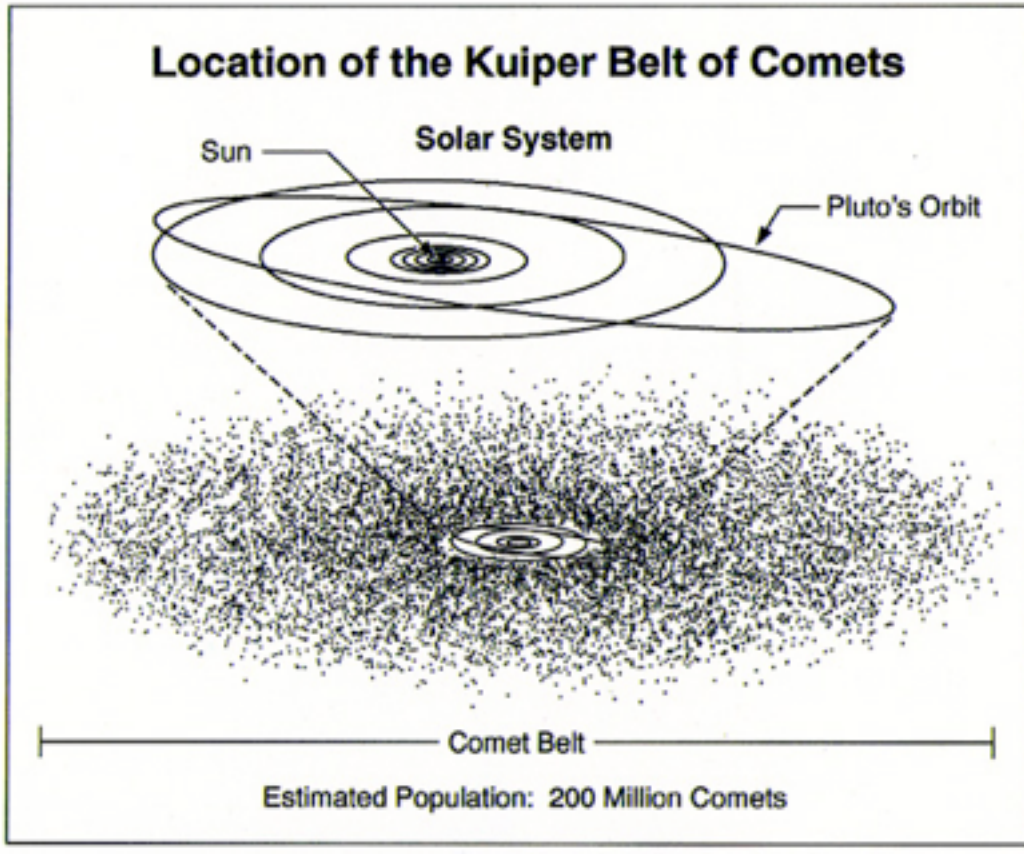
- 30-100 AU: Neptune's orbit and beyond

Orbit orientations:

- orbits concentrated near same plane as Earth-Sun orbit (Ecliptic) but can be "tilted" significantly
- A 'thick disk' of short-period comets beyond the orbits of the planets

How many?

- Estimated: 100s of millions of short-period comets



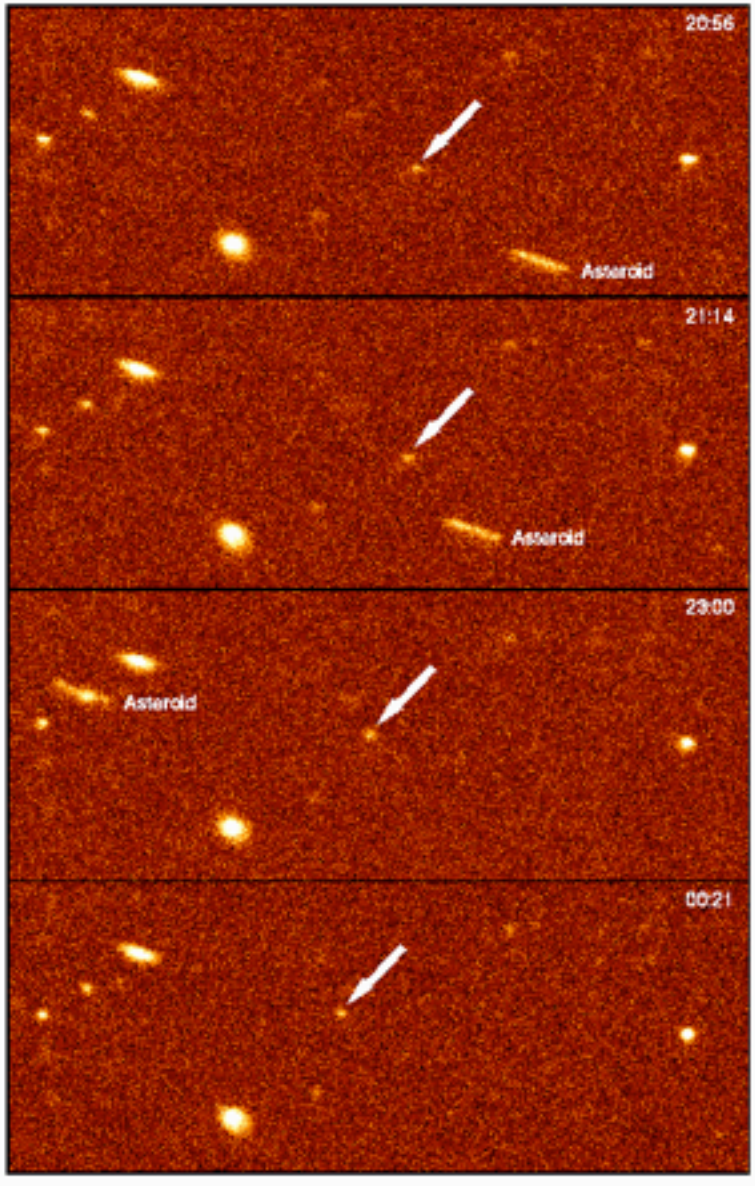
PR95-26 • ST ScI OPO • June 14, 1995 • A. Cochran (U.TX), NASA

Using the observed characteristics of the short period comet orbits, the Dutch-American astronomer Gerard Kuiper proposed the existence of a disk of 100's of millions of comets from 30 to 100 or more A.U. from the Sun orbiting roughly along the ecliptic. This belt of comets, called the Kuiper Belt, was first observed in 1992.

Kuiper Belt Discovery

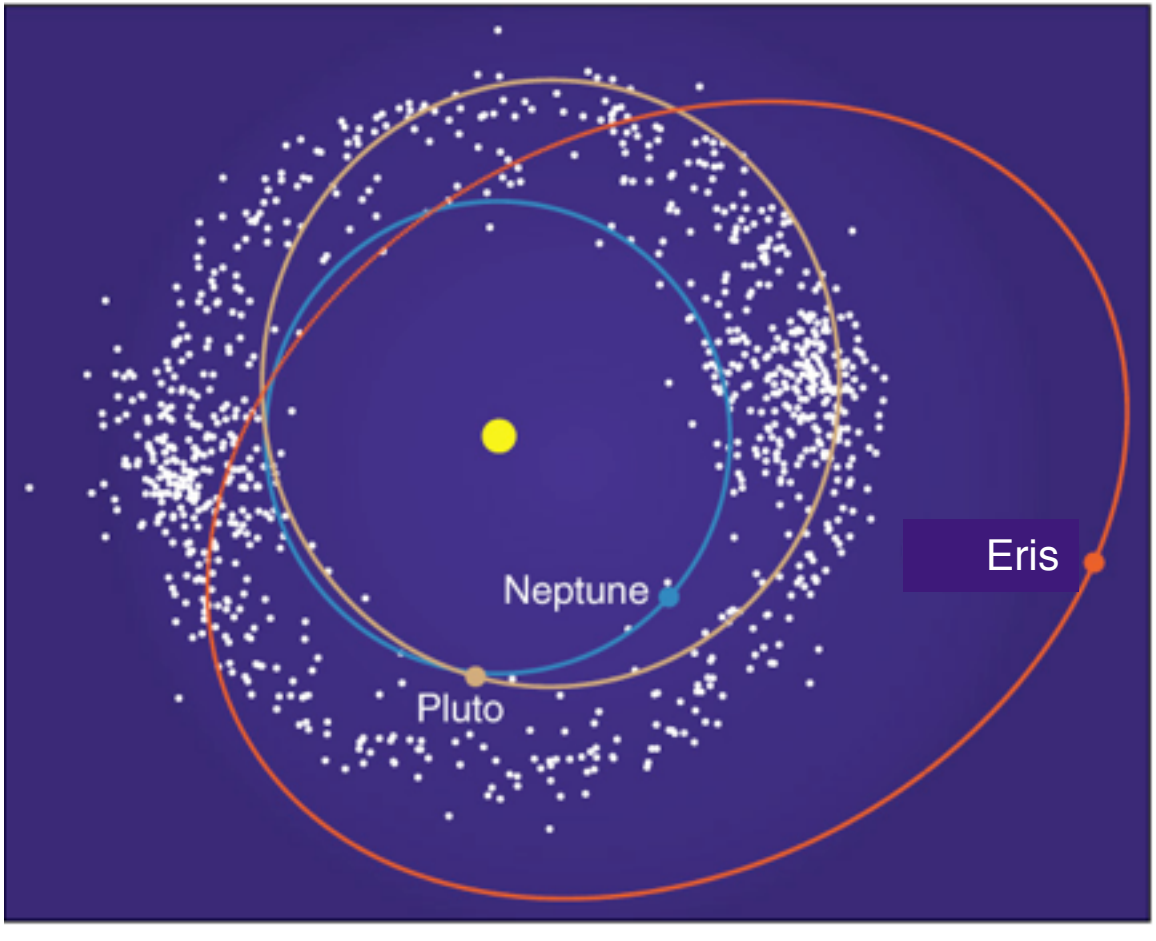
first object detected in orbit at location of Kuiper belt in 1992, beyond Neptune

- KB objects also called Trans-Neptunian objects
- today, tally of KB objects is hundreds
- typically small iceballs, <10% size of Pluto
- estimates: 70,000 KBO's total mass ~ $0.1M_{Earth}$

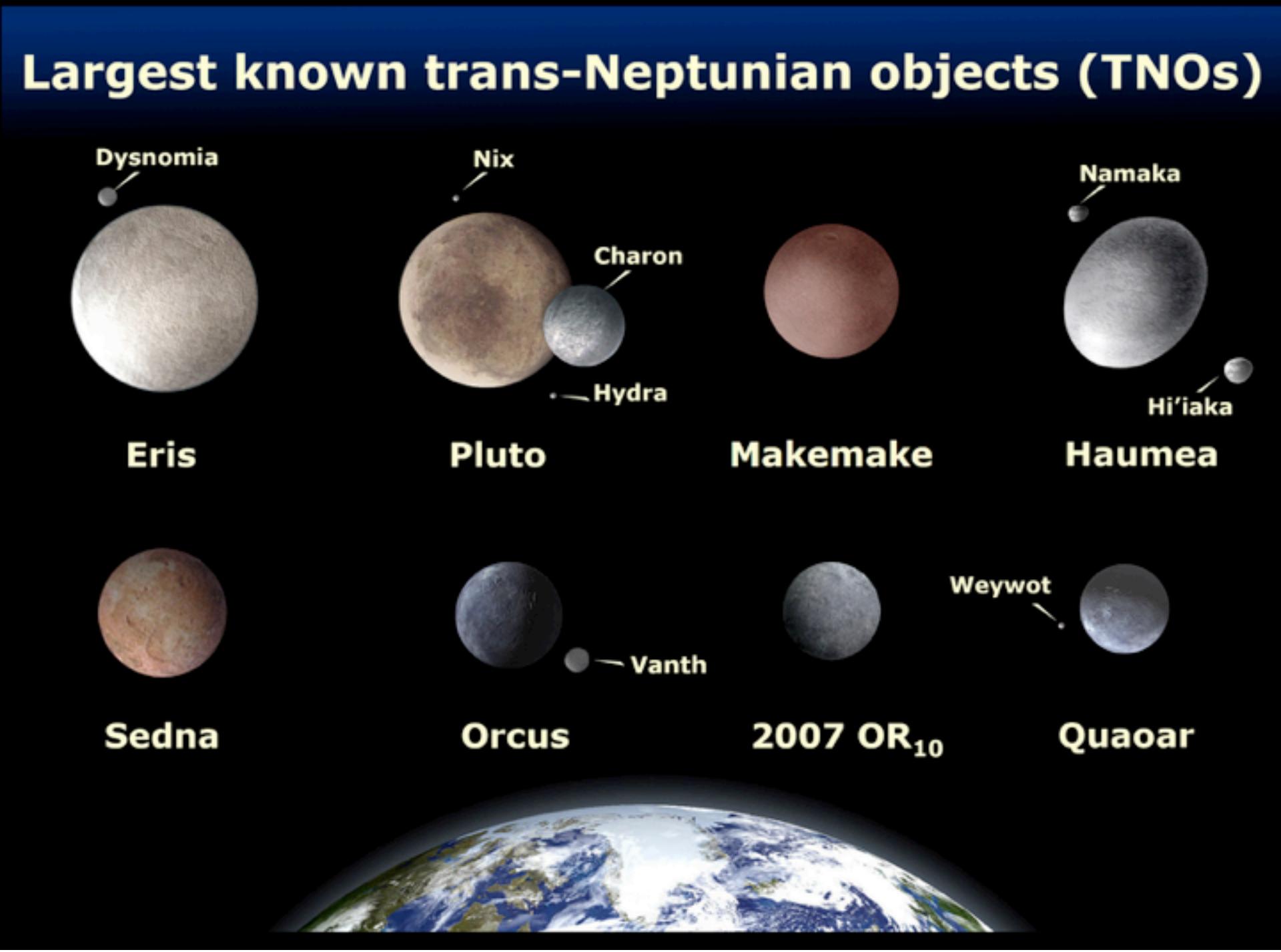


Discovery Image http://www2.ess.ucla.edu/~jewitt/images/qb1.gif

Pluto's orbit lies in the Kuiper Belt!



Pluto is (one of) the largest members of the Kuiper Belt



Pluto is comparable in size to the largest Kuiper Belt Objects, in fact, its not the largest
Sedna might be an Oort Cloud object on an elliptical orbit.

Pluto: History and Status

Clyde Tombaugh -- born in Streator IL!

- 1930: Pluto discovered in sky scan
- totally unlike its neighbors: Uranus, Neptune

1930's-1950's: Kuiper belt idea proposed

1990's: Kuiper belt objects discovered

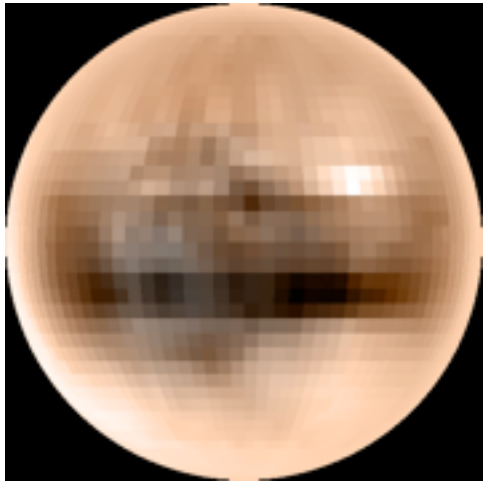
2002–present: more large outer solar system objects

- Quaoar ("Kwawar") ≈ 60% Pluto size
- Sedna ≈ 70% Pluto size
- "Xena" → Eris: more massive, and maybe larger than Pluto!!

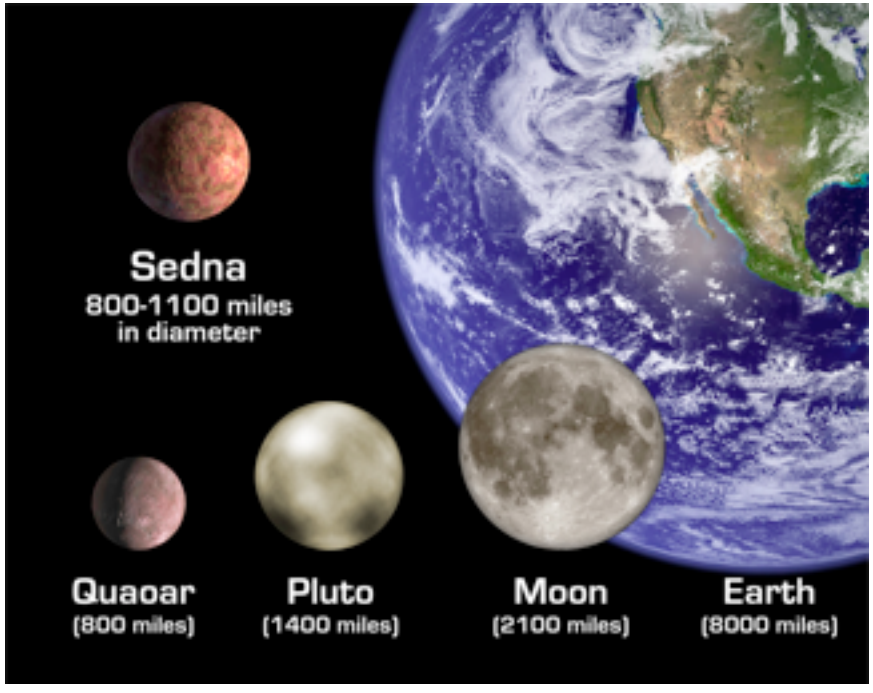
All these are spherical rocky iceballs

Largest of huge population of objects beyond Neptune

- Orbits more elliptical than planets, but still near ecliptic
- "Transneptunian objects" or Kuiper belt objects (KBOs)



Pluto: mapped by Hubble



iClicker Poll:
Pluto: Planet or Plan-not?

2006: International Astronomical Union redefines "planet"

Pluto demoted to "dwarf planet"

along with Ceres (asteroid belt),

and KBO's Eris + 2 others

Vote your conscience!

Is Pluto a full-fledged planet?

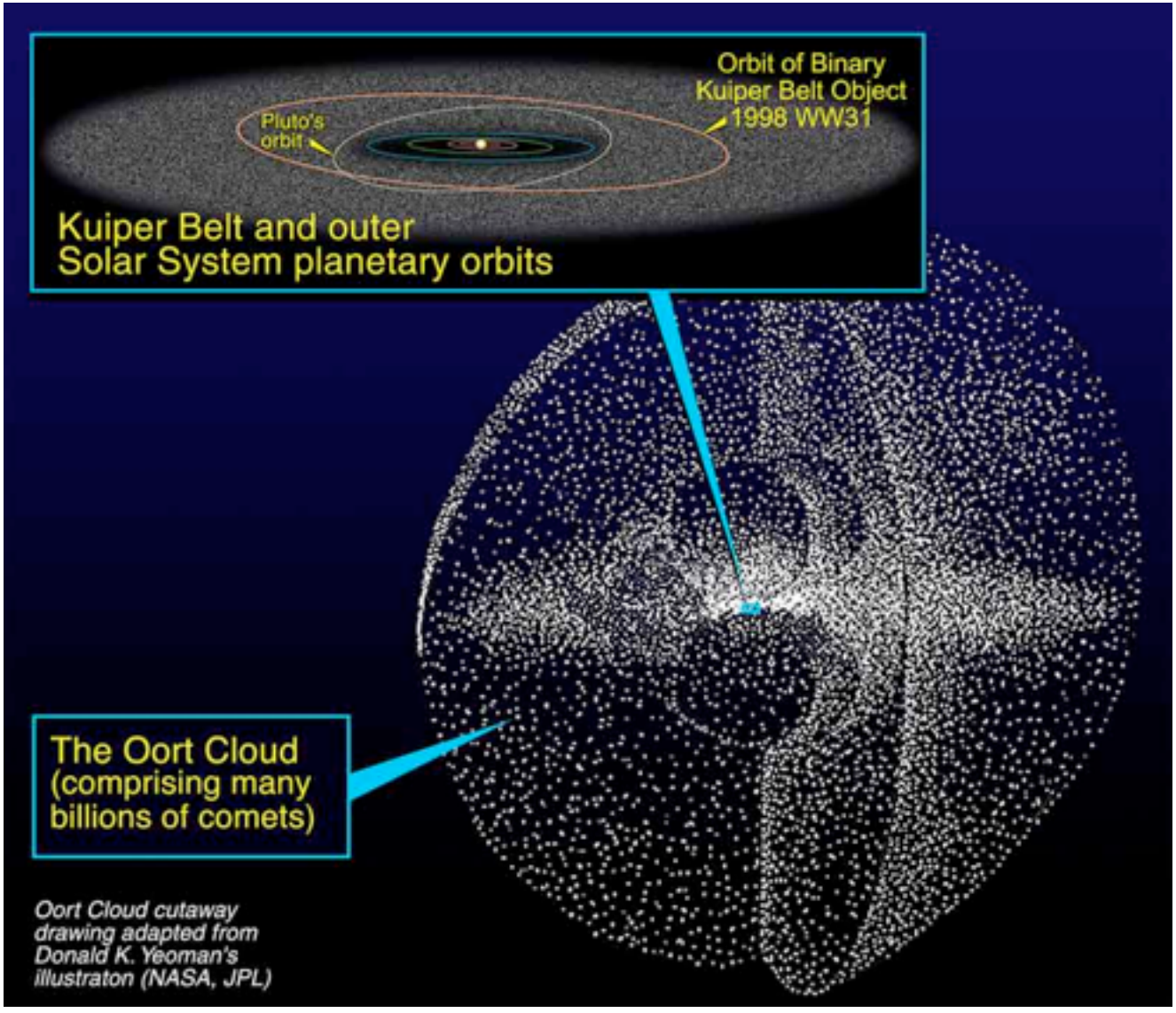
A. No way! Good riddance! And I've got my eye on you, Neptune!

B. Umm, probably not?

C. Umm, probably so?

D. Yes way! Pluto was robbed! Long live Pluto!

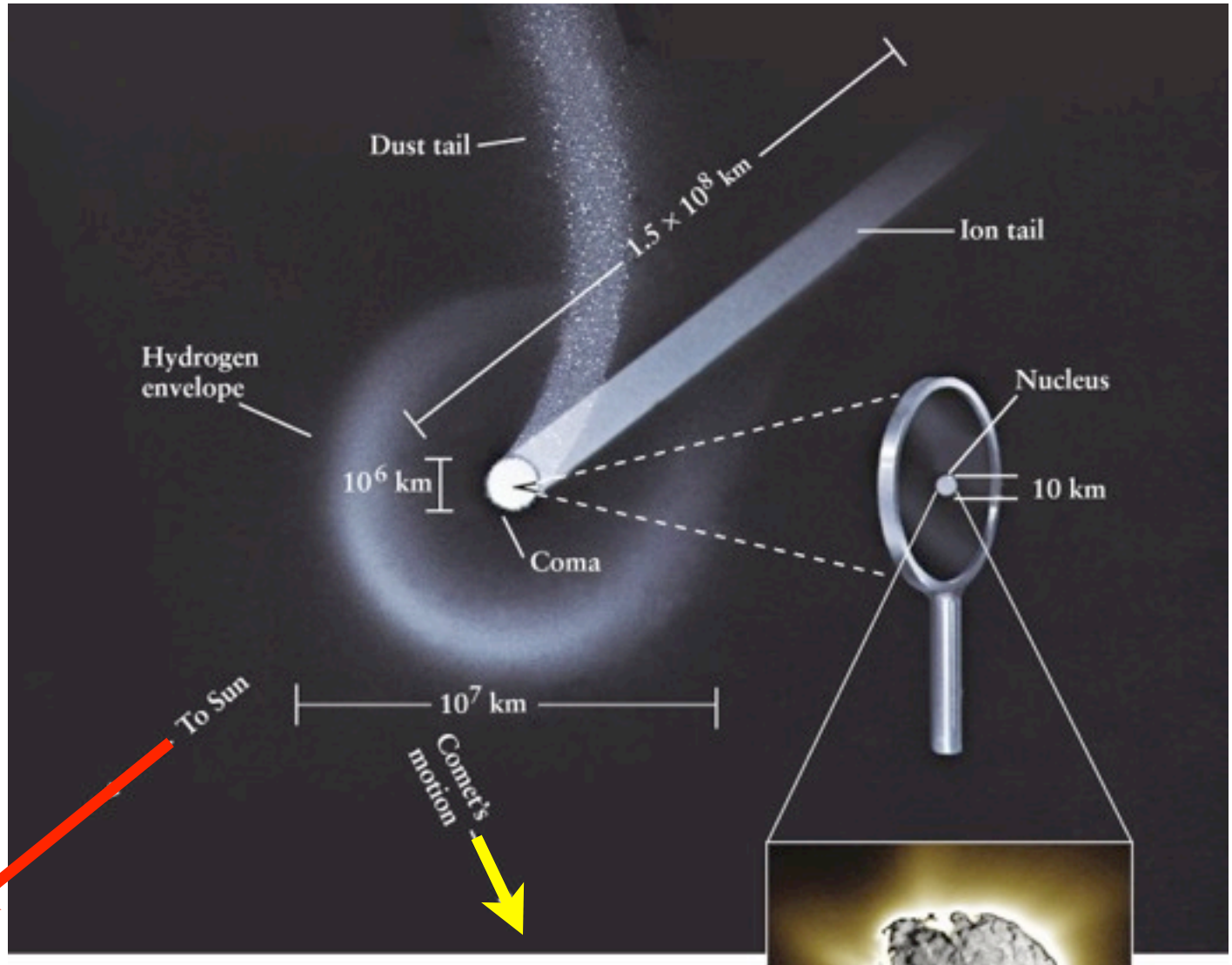
Long Period Comets:
Oort Cloud



The Oort Cloud is a large spherical cloud with a radius from 50,000 to 100,000 A.U. surrounding the Sun filled with billions to trillions of comets. It has not been directly observed.

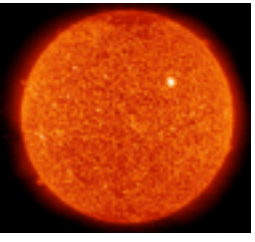
they have orbital periods of 100,000's to millions of years. However, their orbits are so elliptical that they spend only 2 to 4 years in the inner part of the solar system where the planets are and most of their time at 50,000 to 100,000 A.U. With such long orbital periods their presence in the inner solar system is, for all practical purposes, a one-time event. Yet we discover several long period comets every year. This implies the existence of a large reservoir of comets.

Basic parts of a comet



Sun direction

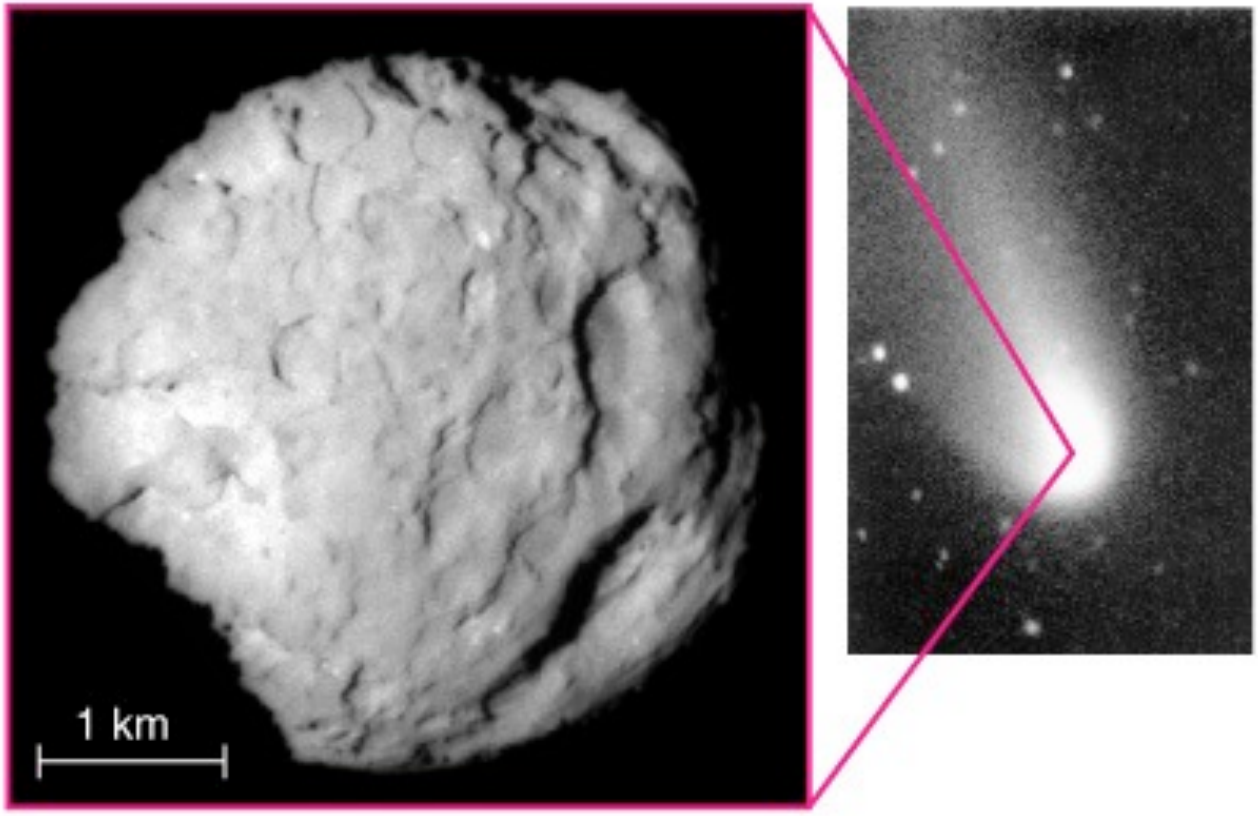
Sun size and distance not to scale!



Direction of comet motion

Nucleus: Dirty snowballs, <1–100 km across.
Coma: Cloud of gas & dust around nucleus
Tails: Gas/ion tail, Dust tail, Point away from the Sun!

Nucleus of Comet: "dirty snowball"



"crunchy center" ingredients

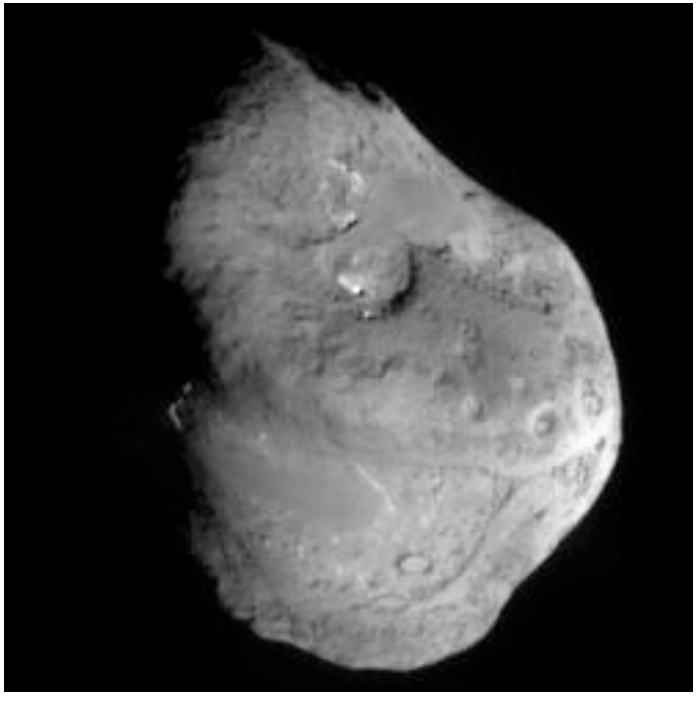
- ices of water, CO_2, methane, and ammonia,
- plus dirty dust: small rocky particles

Comet nuclei are 0.5 to 20 kilometers in size and are potato-shaped conglomerate of dust (silicates and carbonaceous) embedded in ice (frozen water, carbon dioxide, carbon monoxide, methane, and ammonia).
The density is about that of a loosely-compacted snowball and it is quite fragile---you could break a piece of the nucleus in two with your bare hands!

i>clicker question

Which is darker?

A) A lump of coal



B) A comet nucleus

Answer B!
Nucleus reflects only 4% of the sunlight (coal reflects about 6%).

Near the Sun, comet ices evaporated into gases

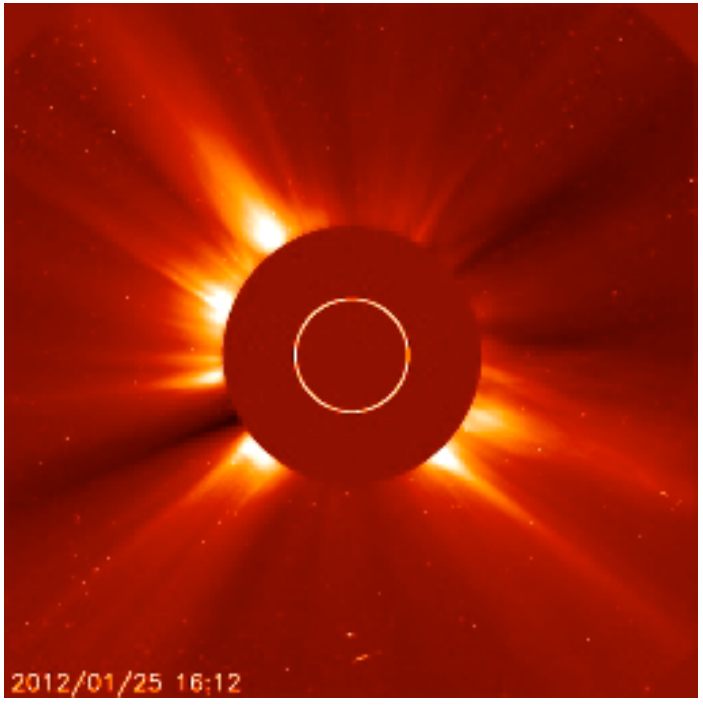
Important solar system fact:

- hotter when closer to Sun!

When a comet nears the Sun, its ices start to vaporize = "sublimate"

- Jets of dust and hot gas erupt from its surface
- Produce a comet's coma
- stream of hot, magnetized gas from Sun = solar wind, and sunlight too both push hot gas (ions) and dust away from Sun: forms tail

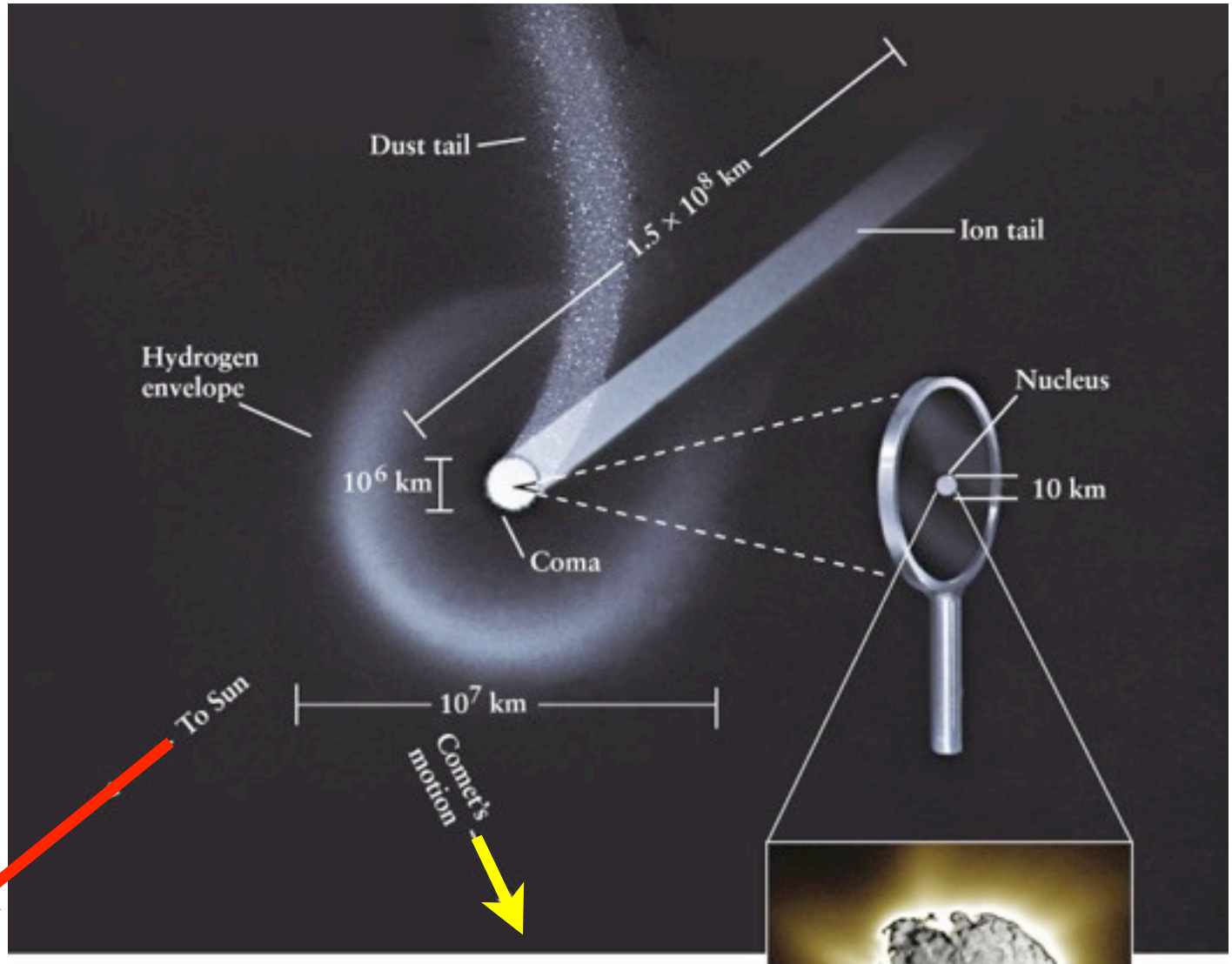
The nucleus of Halley's Comet, imaged by the Giotto probe in 1986.



The Sun today: NASA SOHO

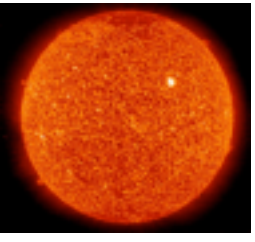
Nucleus reflects only 4% of the sunlight (coal reflects about 6%).
When a comet nears the Sun, its ices start to vaporize, releasing gas and dust
Gas and dust forms comet's coma
The dark coloration of the nucleus can be observed, as well as the jets of dust and gas erupting from its surface.

Basic parts of a comet



Sun direction

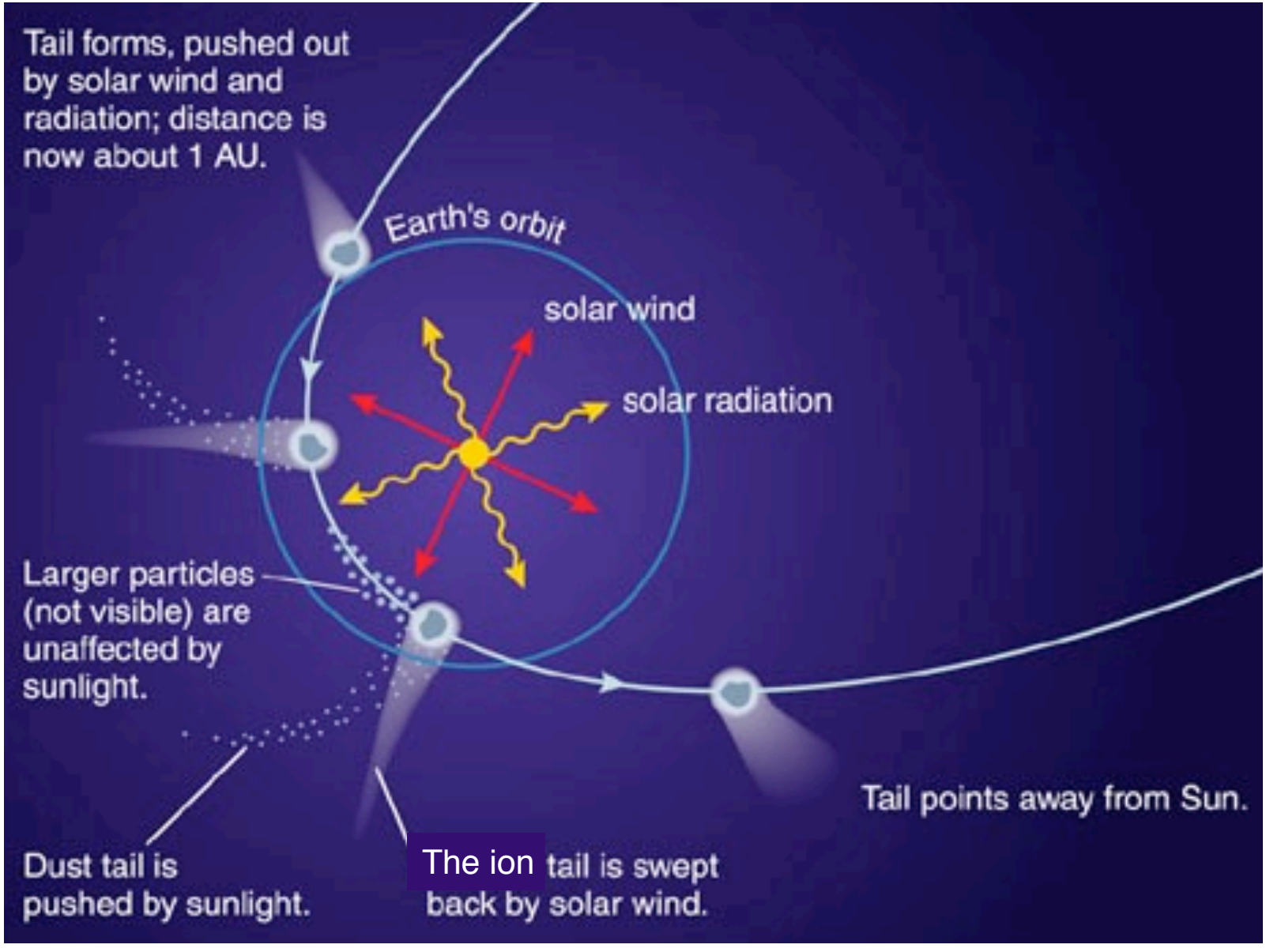
Sun size and distance not to scale!



Direction of comet motion

Nucleus: Dirty snowballs, <1–100 km across.
Coma: Cloud of gas & dust around nucleus
Tails: Gas/ion tail, Dust tail, Point away from the Sun!

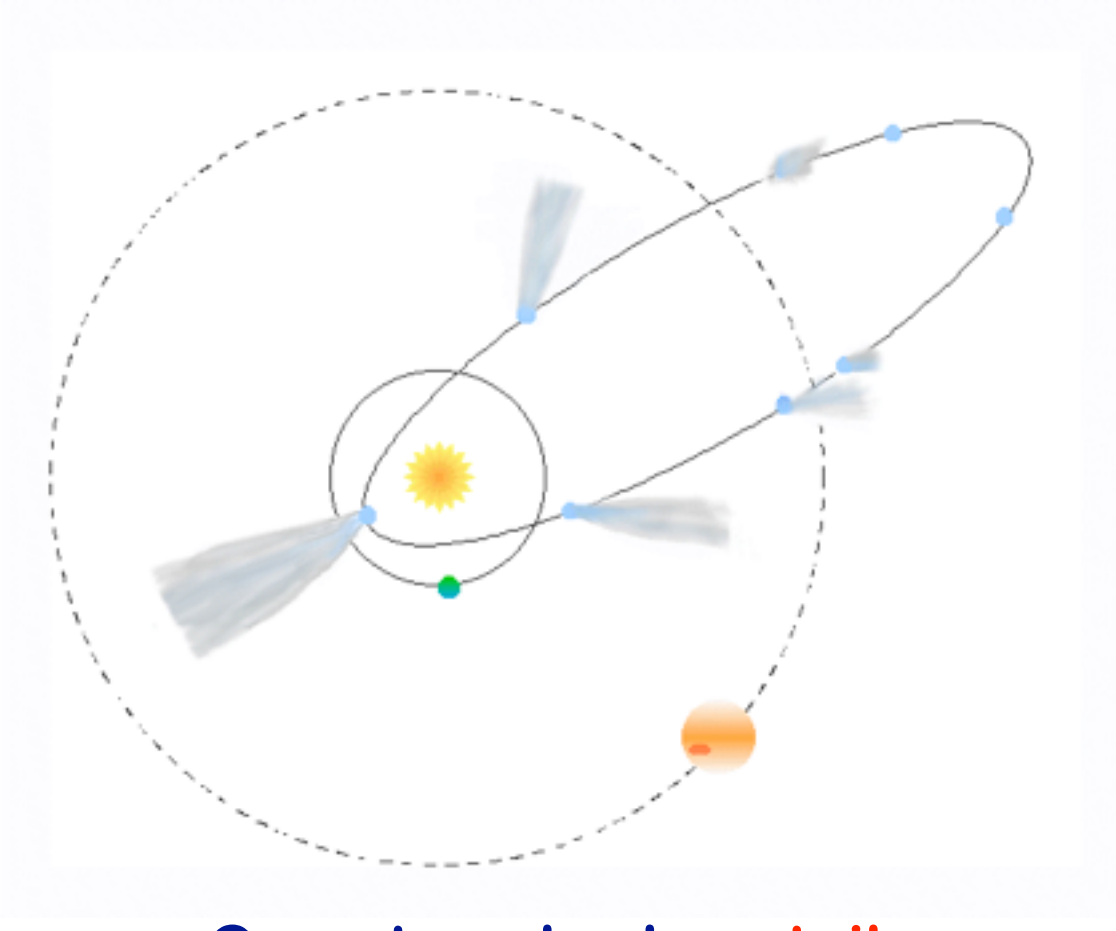
Why do comets have tails?



Sunlight and solar wind push small dust particles and gas, respectively, into tails

Comets that pass close to the Sun have elongated orbits

- Very eccentric / elongated long orbits
- Most spend the majority of their orbit far from the Sun: too cold to burn away gas and dust
- So comets only have a tail during a relatively brief period



Comets only show tails when close to the Sun