Astronomy 301 - Wed. Oct. 6

Guest lectures, Monday and today:

Prof. Harriet Dinerstein

Monday: The outer planets & their moons

Today: asteroids, comets, & the Kuiper Belt; formation of the Solar System

Discovery of the Asteroid Belt

Ceres - Jan. 1, 1801

Pallas - 1802

Juno - 1804

Vesta - 1807

Are these new planets? Controversy over this was reminiscent of what happened 200 years later with the discovery of the “10th planet” Eris.

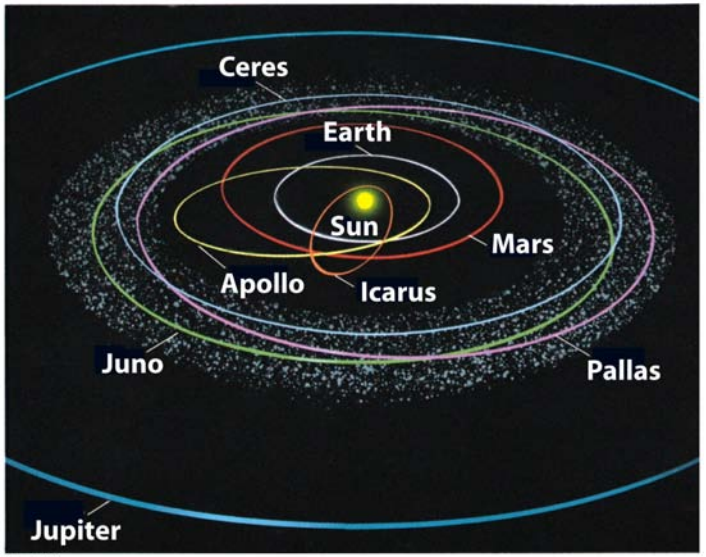


Figure 15-3
Universe, Eighth Edition

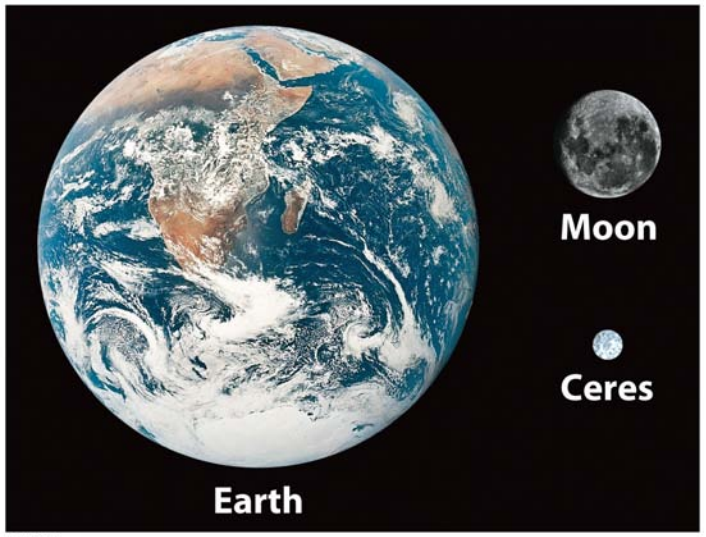
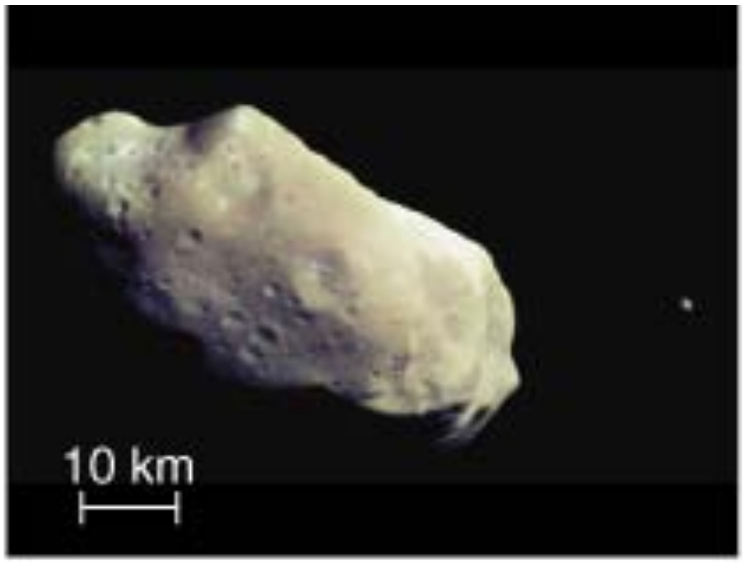


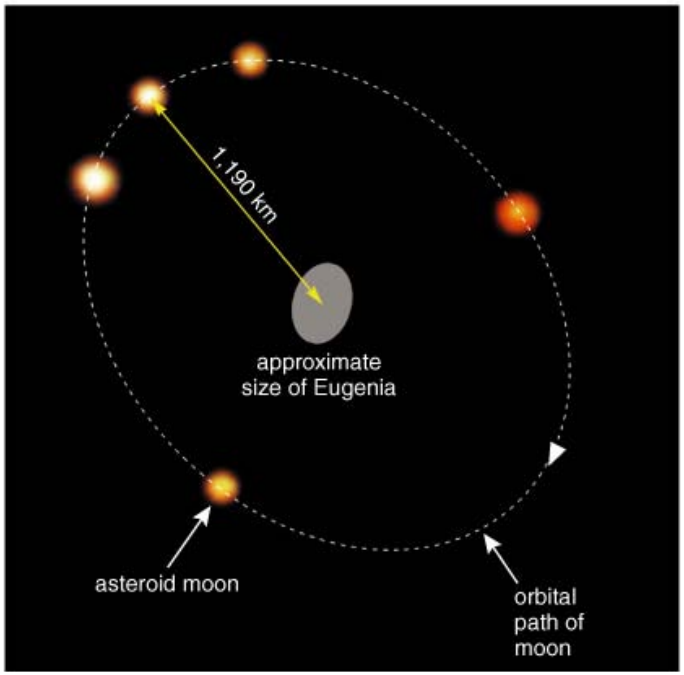
Figure 15-1
Universe, Eighth Edition

Asteroids with Moons

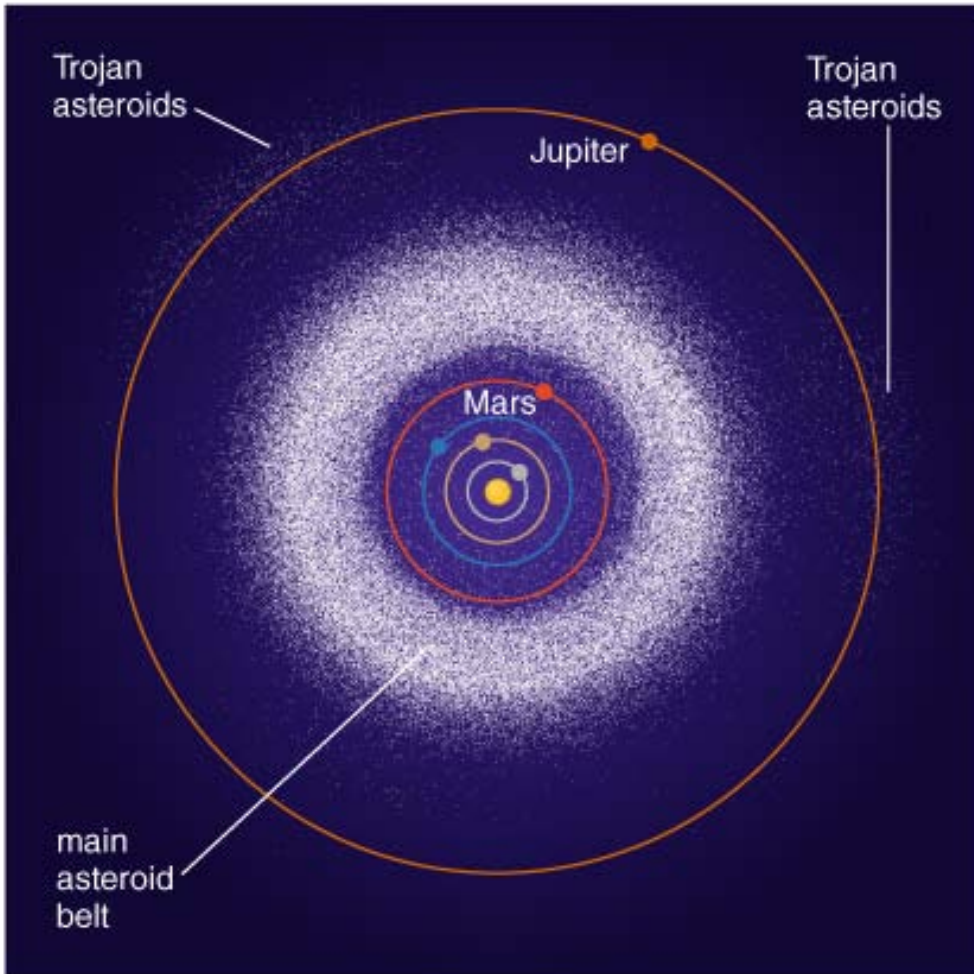


- Some large asteroids have their own moon, e.g. Ida and Dactyl (left)
- Why might this be useful to us?

- Measuring orbit of asteroid's moon tells us asteroid's mass
- Mass and size give us density
- Some asteroids are solid rock; others just piles of rubble



Asteroid Families



- Most asteroids orbit in a belt between Mars and Jupiter
- The *Trojan asteroids* follow Jupiter's orbit
- Orbits of some *near-Earth asteroids* cross Earth's orbit, they include the Apollos and Atens

A Tale of Comet Tails

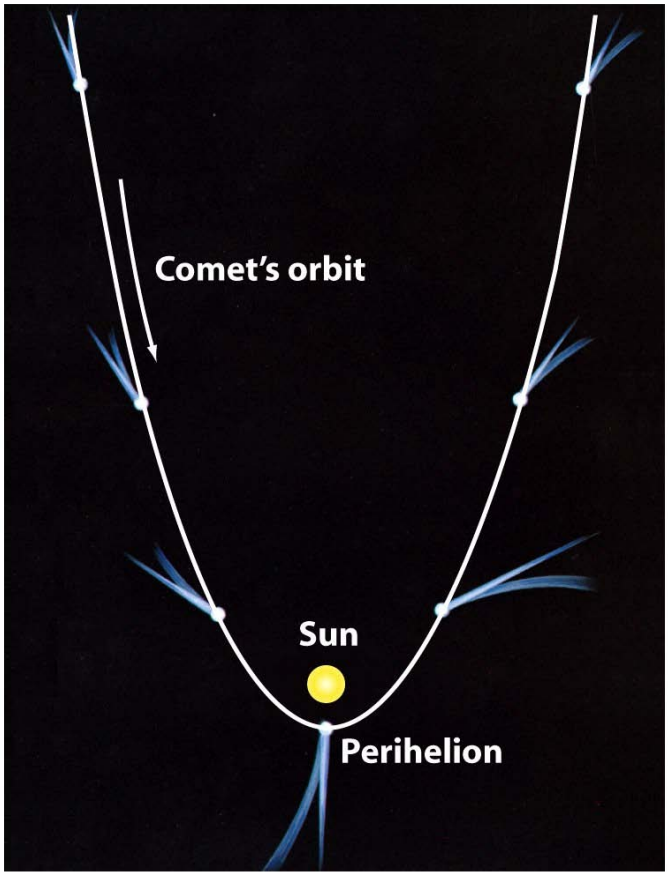


Figure 15-23
Universe, Eighth Edition

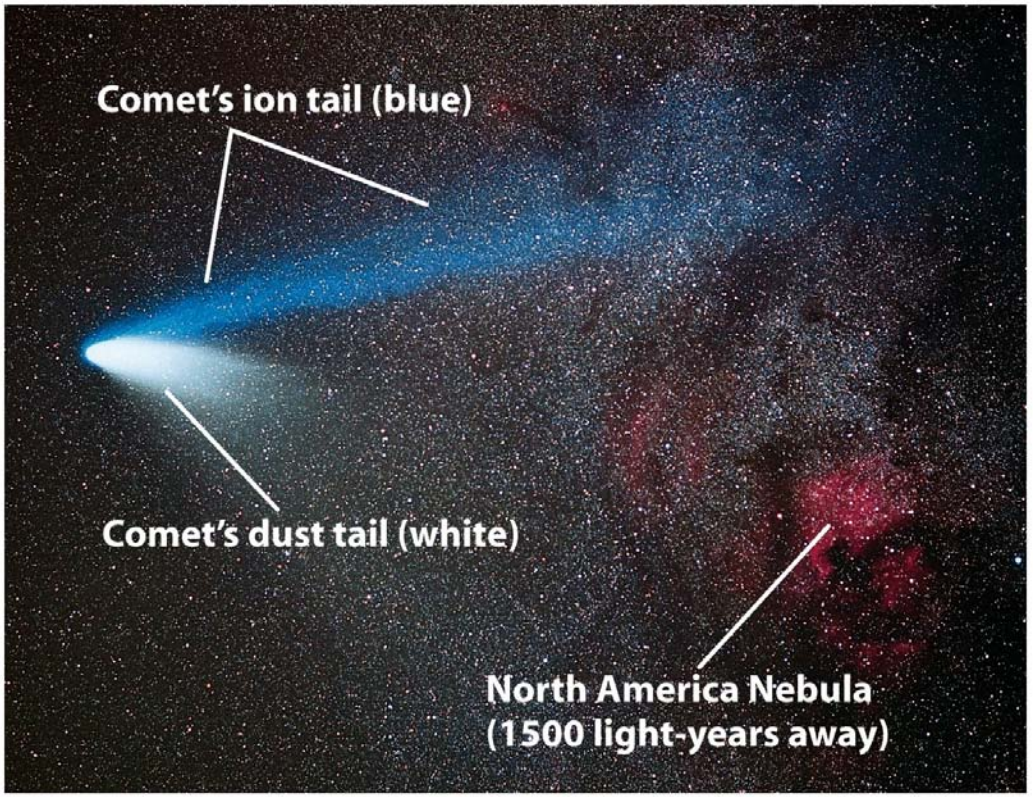
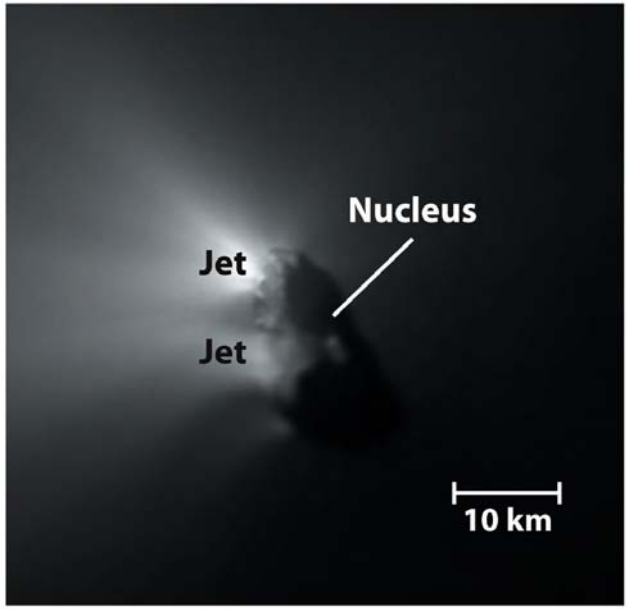


Figure 15-24
Universe, Eighth Edition

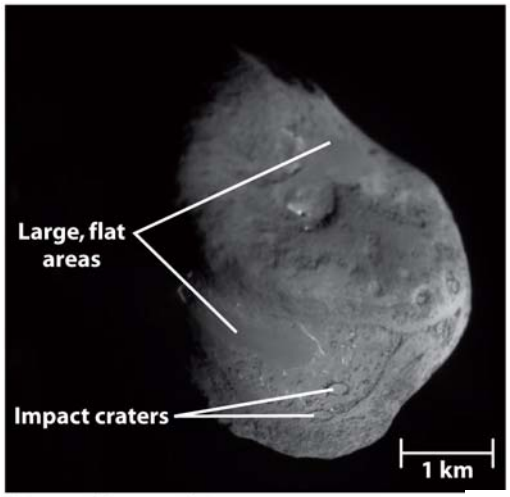
Close Encounters of the Comet Kind

Giotto meets Halley,1986



Comet Halley

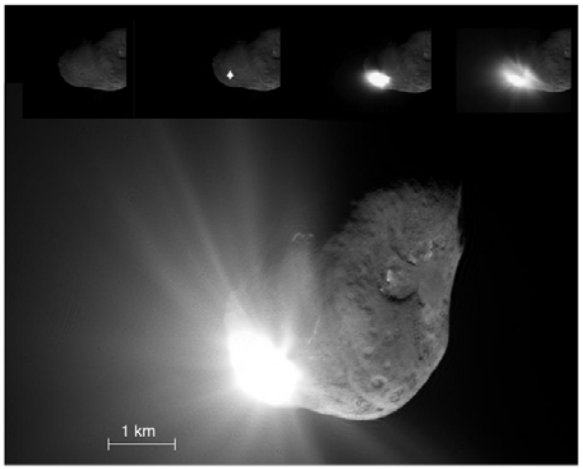
Figure 15-21a
Universe, Eighth Edition
© 2008 W. H. Freeman and Company



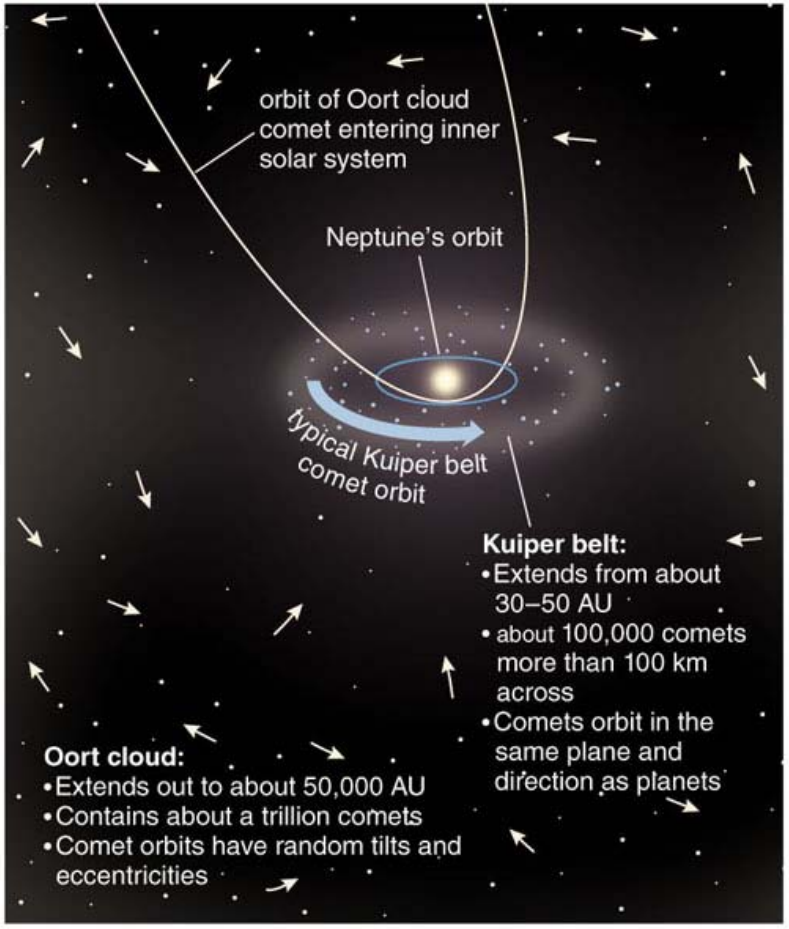
Comet Tempel 1

Figure 15-21b
Universe, Eighth Edition
© 2008 W. H. Freeman and Company

Deep Impact slams Comet Tempel, 2005



Where do Comets Come From?



Long-Period Comets: an iceball in the Oort Cloud experiences a jolt or perturbation, and starts falling in towards the Sun. The Oort Cloud is a spherical, low-density swarm of small, icy bodies.

Halley: An “Intermediate-Period” Comet

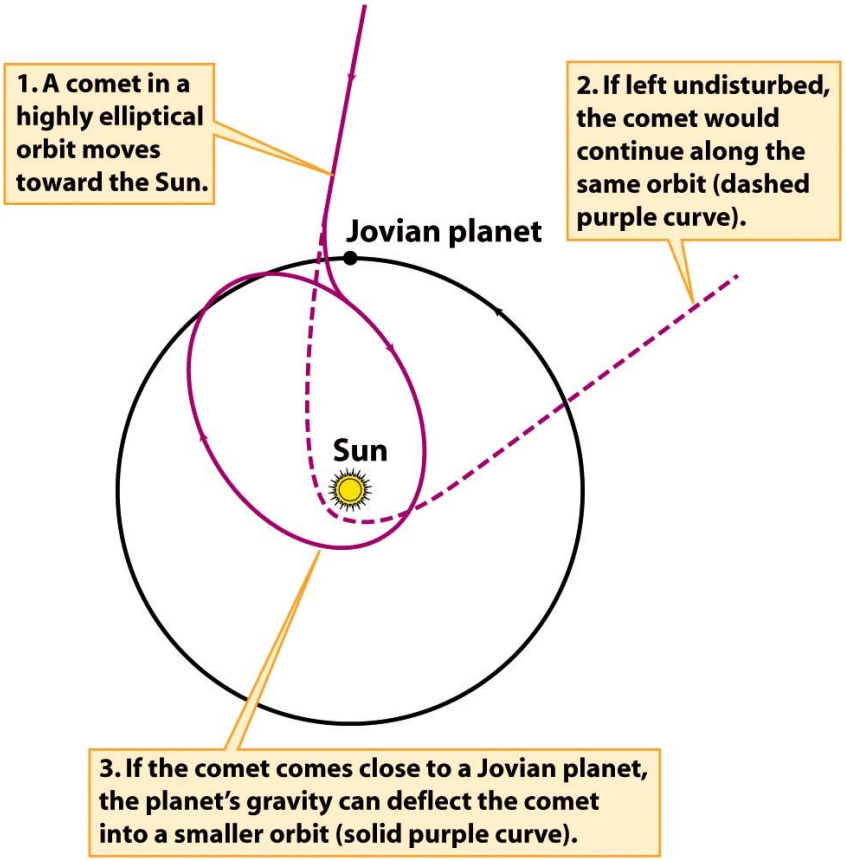


Figure 15-28
Universe, Eighth Edition

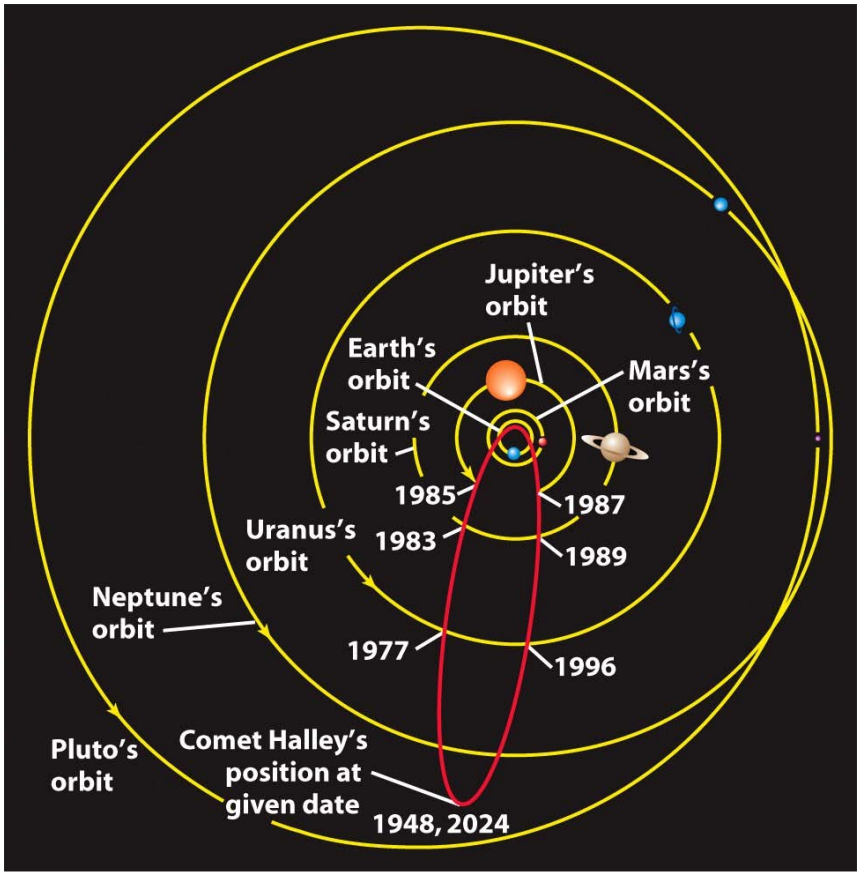


Figure 15-26
Universe, Eighth Edition

Meteor, meteorite: what's the difference?

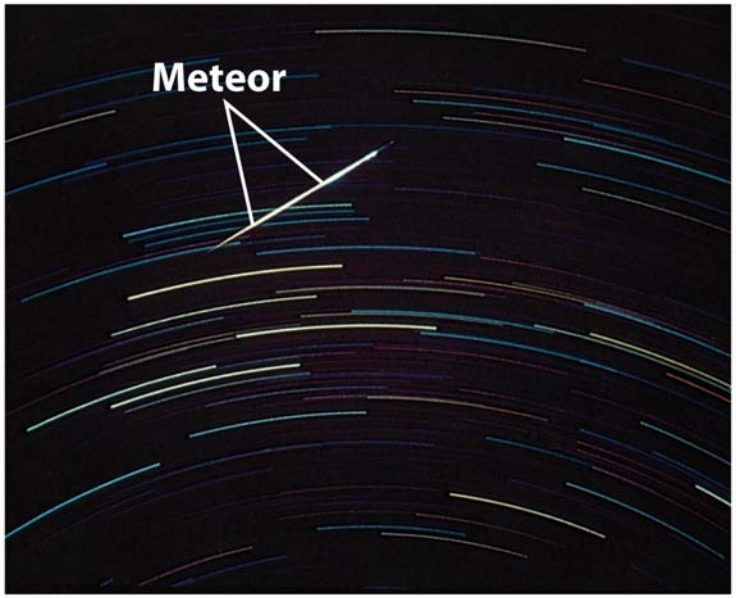


Figure 15-13
Universe, Eighth Edition

Meteor: flash of light as a small rocky object burns up in the Earth's atmosphere.

Bright ones: fireballs, "bolides"

Meteorite: the rocky fragment that (sometimes) survives the trip and reaches the ground.

Figure 15-15a
Universe, Eighth Edition

Meteor Showers: “Grins” of Extinct Comets

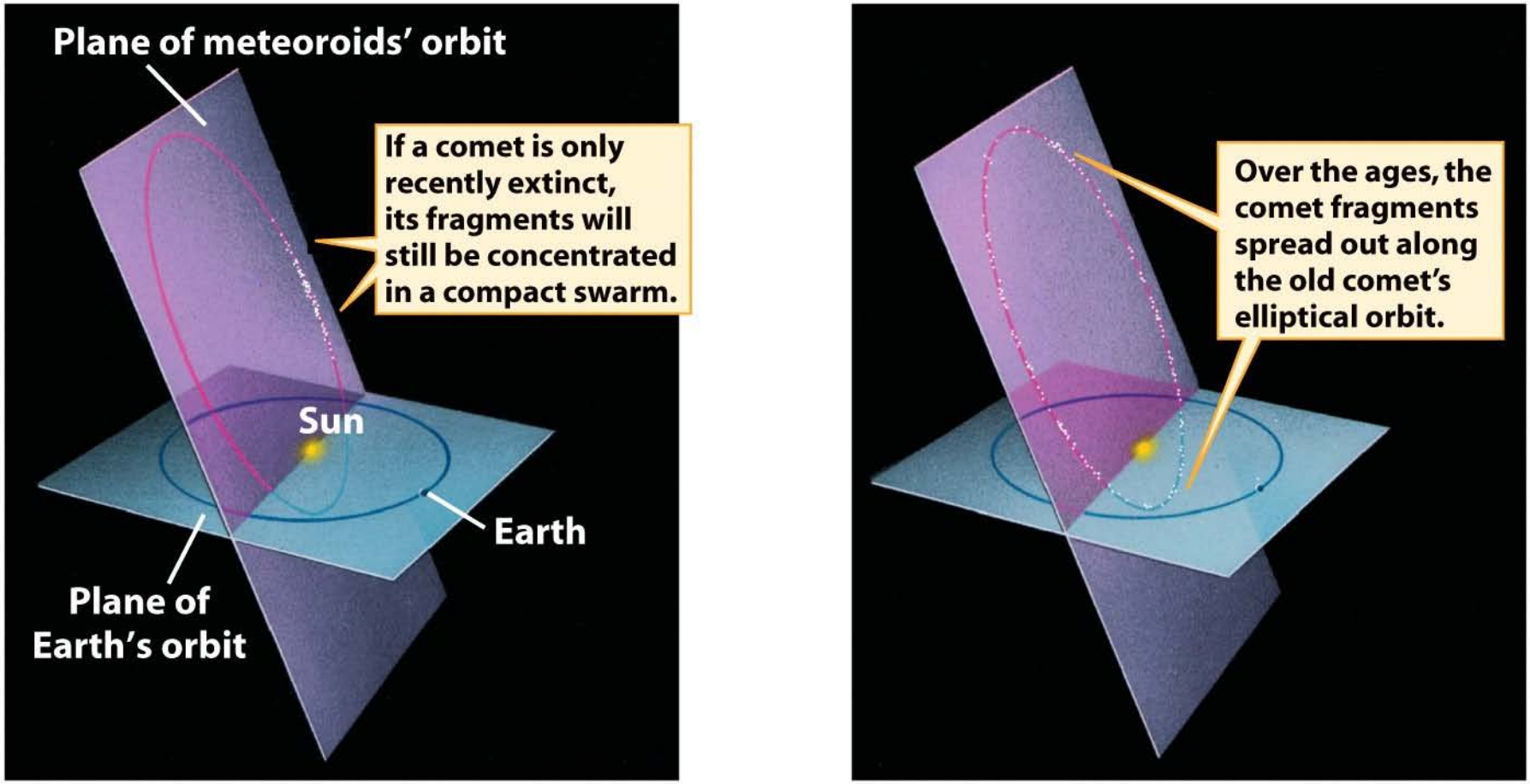
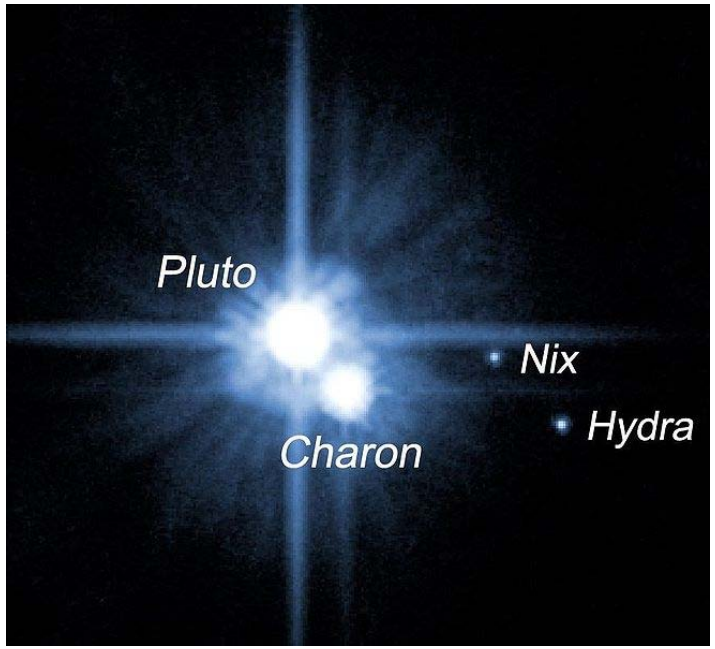


Figure 15-30
Universe, Eighth Edition

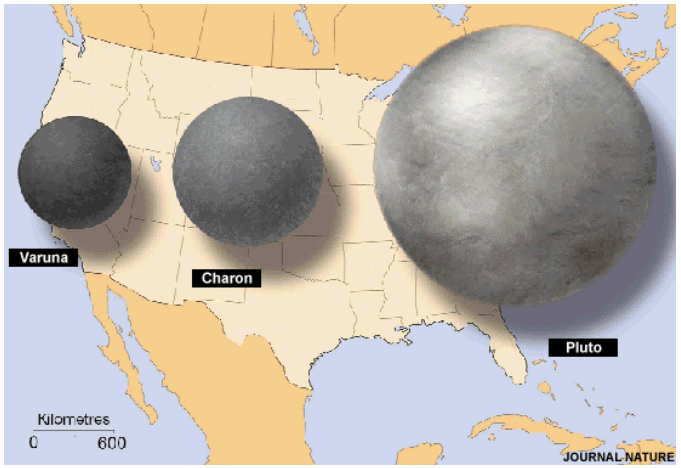
Pluto: To be or not to be … a Planet

- Orbit: large semi-major axis (40 AU), with a relatively large eccentricity (e = 0.25) and tilt (17°).
- Physical properties: cold (40K). Surface at least partly coated with frozen methane (CH_4).
- Its moon Charon is very large relative to Pluto itself.

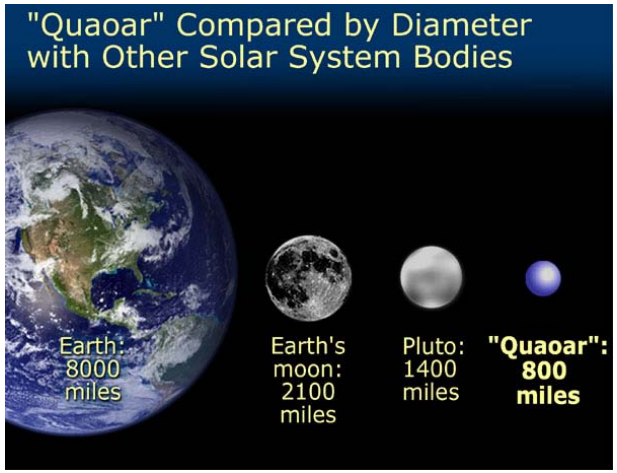


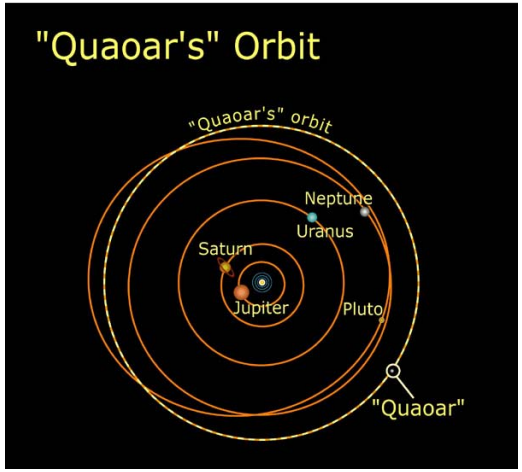
New Kuiper Belt Objects

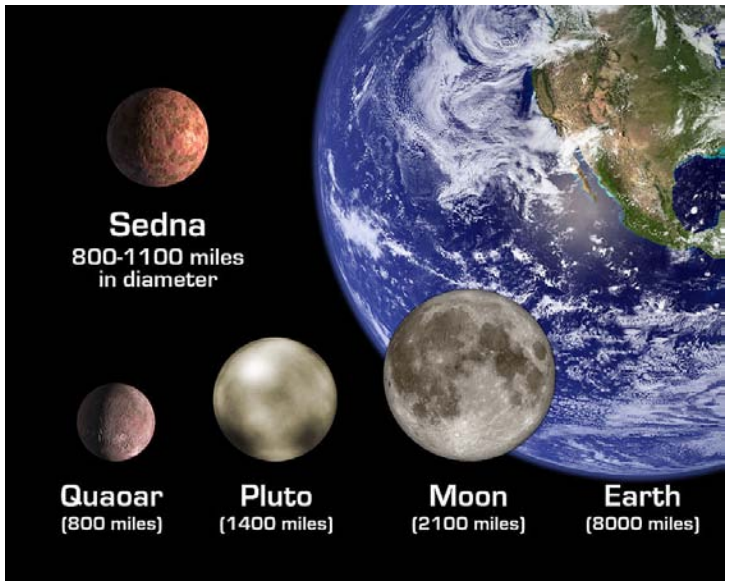
Varuna, 2000



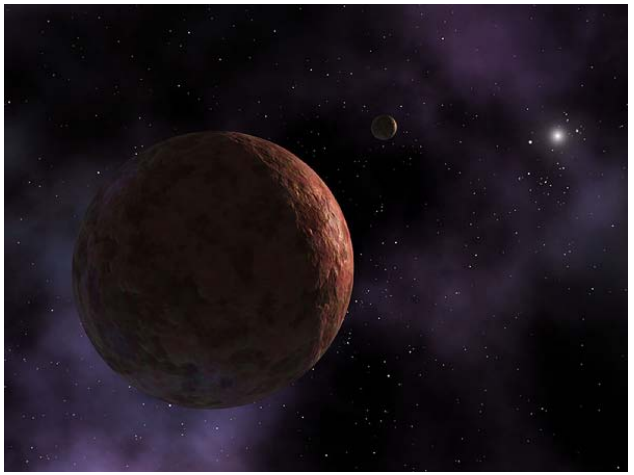
Quaoar, 2002





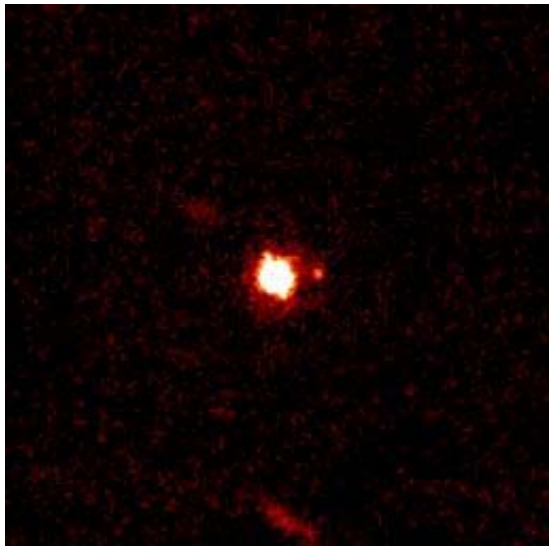


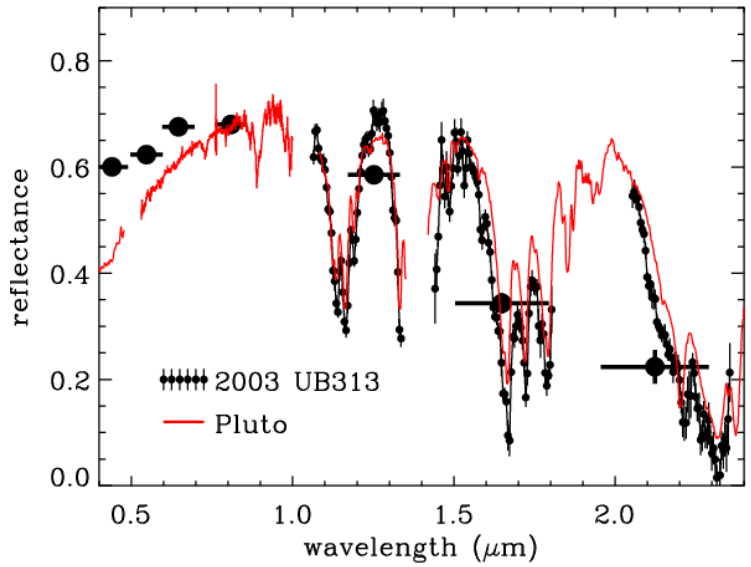
Sedna, 2003



Eris: The Tenth Planet?

- Size: larger than Pluto!
- Orbit: semi-major axis almost twice Pluto's (68 AU), with an even larger eccentricity (e = 0.44) and tilt (44°).
- Also has a moon that is large for the planet's size.
- Its spectrum also shows the presence of methane ice on the surface, like Pluto.





Trans-Neptunian Objects: A New Class

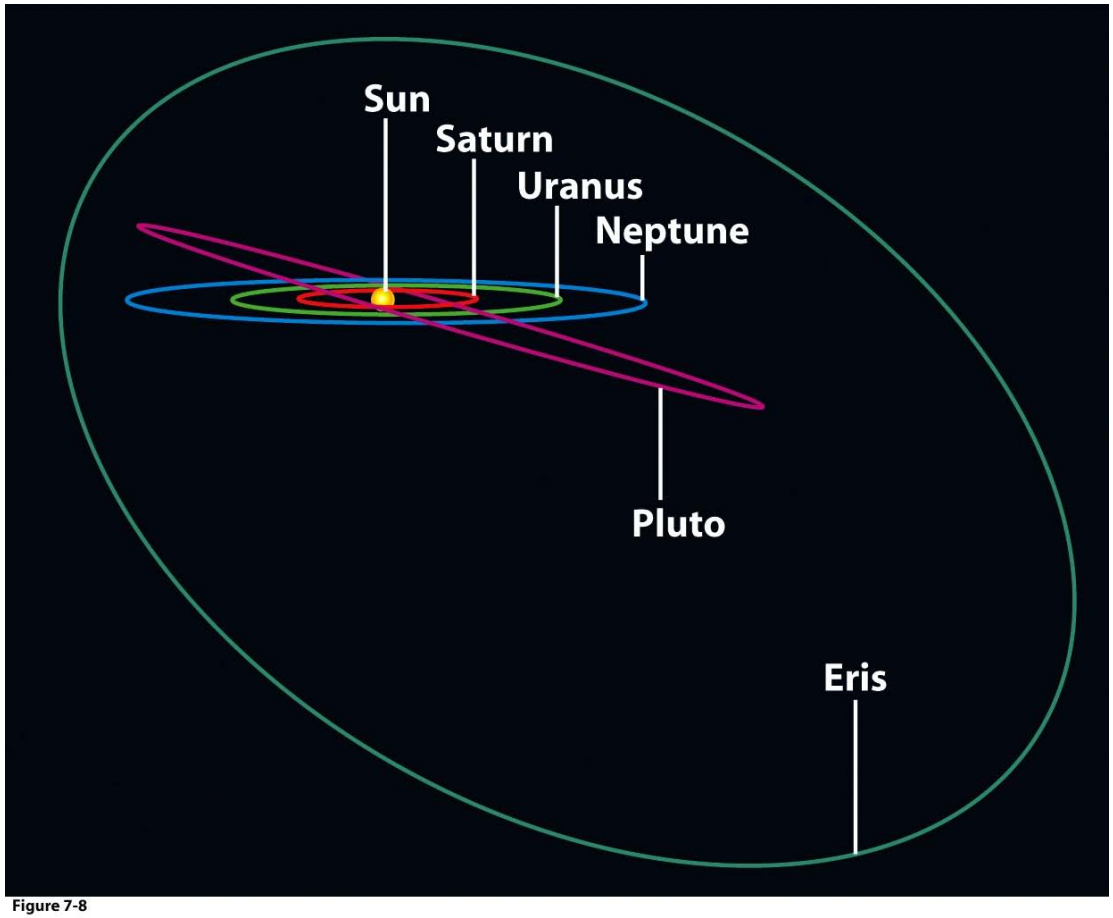
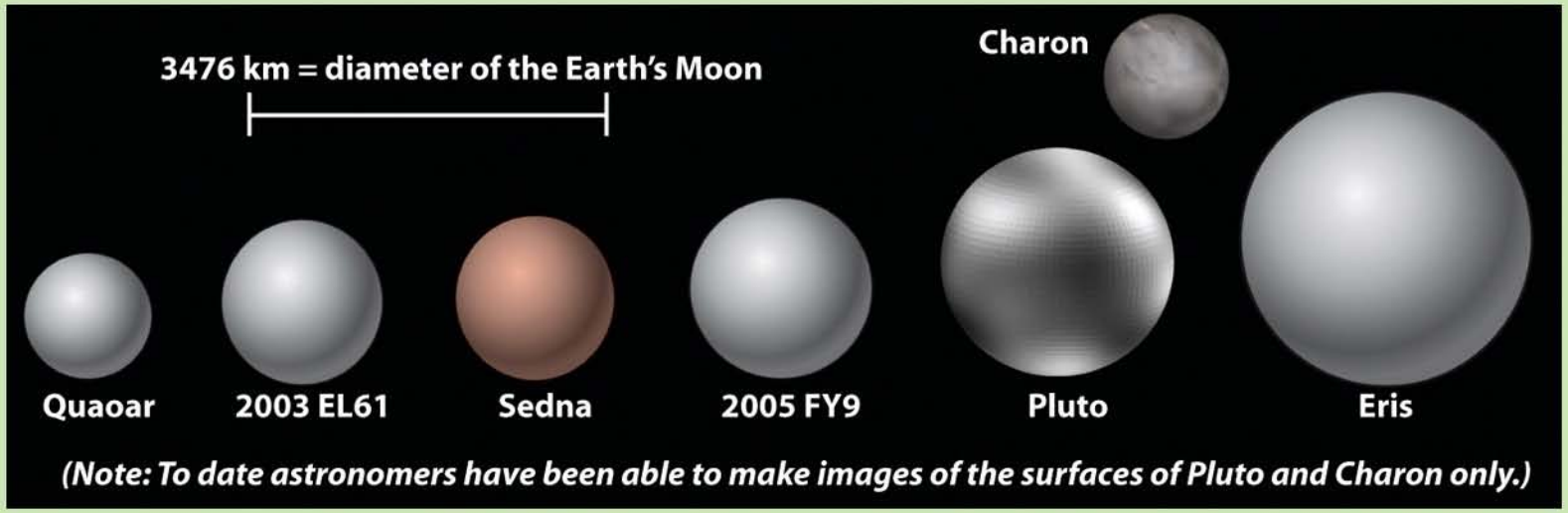


Figure 7-8
Universe, Eighth Edition

In retrospect, Pluto was not the ninth planet, but the first Trans-Neptunian/Kuiper Belt Object to be discovered

Table 7-4 Seven Large Trans-Neptunian Objects

	Quaoar	2003 EL61	Sedna	2005 FY9	Pluto	Charon (satellite of Pluto)	Eris
Average distance from Sun (AU)	43.54	43.34	489	45.71	39.54	39.54	67.67
Orbital period (years)	287	285	10,800	309	248.6	248.6	557
Orbital eccentricity	0.035	0.189	0.844	0.155	0.250	0.250	0.442
Inclination of orbit to the ecliptic	8.0°	28.2°	11.9°	29.0°	17.15°	17.15°	44.2°
Approximate diameter (km)	1250	1500	1600	1800	2274	1190	2900

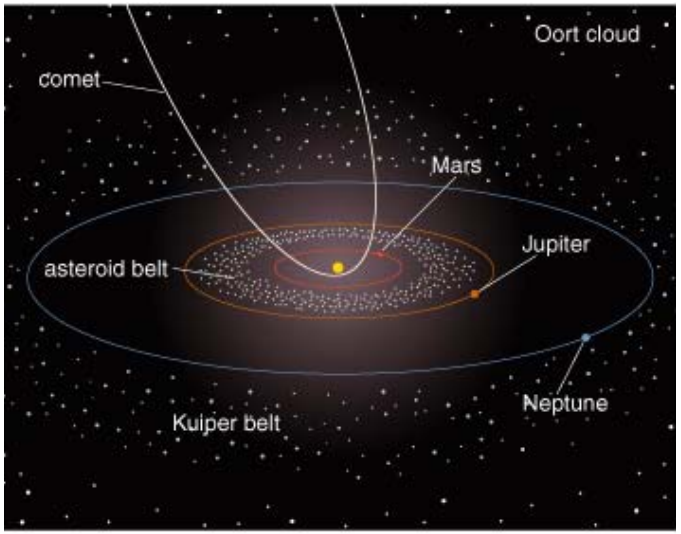


R I V U X G

(Images of Pluto and Charon: Alan Stern, Southwest Research Institute; Marc Buie, Lowell Observatory; NASA; and ESA)

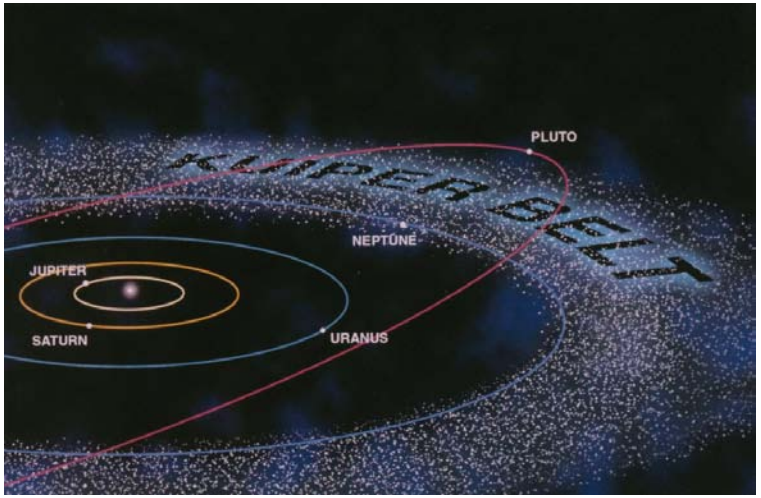
Table 7-4
Universe, Eighth Edition

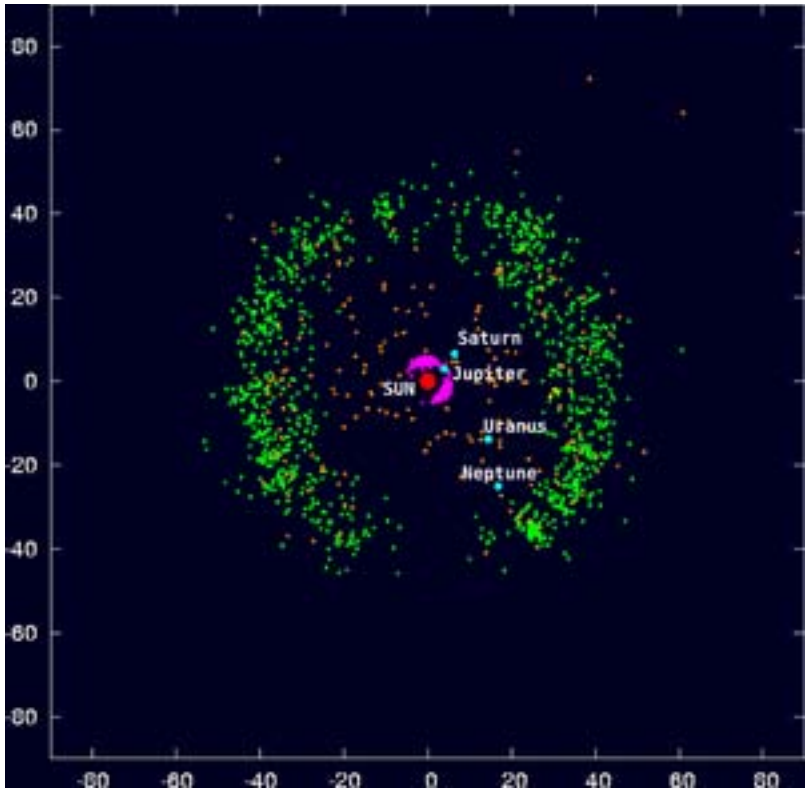
The Kuiper Belt: Remnant of the Solar System's protoplanetary disk



← View from the side

View from above ↓





Any Successful Theory of Formation of the Solar System must explain why….

1. The major planets all orbit in the same direction and roughly the same plane
2. There are two classes of planets, terrestrial and Jovian, with different sets of properties
3. There are many small bodies in addition, mainly in the asteroid and Kuiper Belts, and Oort Cloud
4. There is evidence of violent events in the past: the Earth's moon, odd tilts and inclinations, etc.

The Nebular Theory of the Formation of the Solar System

- Our solar system formed by gravitational collapse of an interstellar cloud - called the *solar nebula*

  (Nebula is the Latin word for cloud)
- Kant and Laplace proposed this idea two centuries ago
- A large amount of evidence now supports this idea
- It implies that the planets formed *together with the Sun,* which suggests that the formation of a planetary system (star plus accompanying system) must be common

Nebular Theory, Part I

Step 1: A cool interstellar cloud starts to contract due to its own gravity. At first it is nearly spherical.

Step 2: Its initially slow rotation is amplified by contraction, so it rotates faster, and flattens into a ***protostellar disk***.

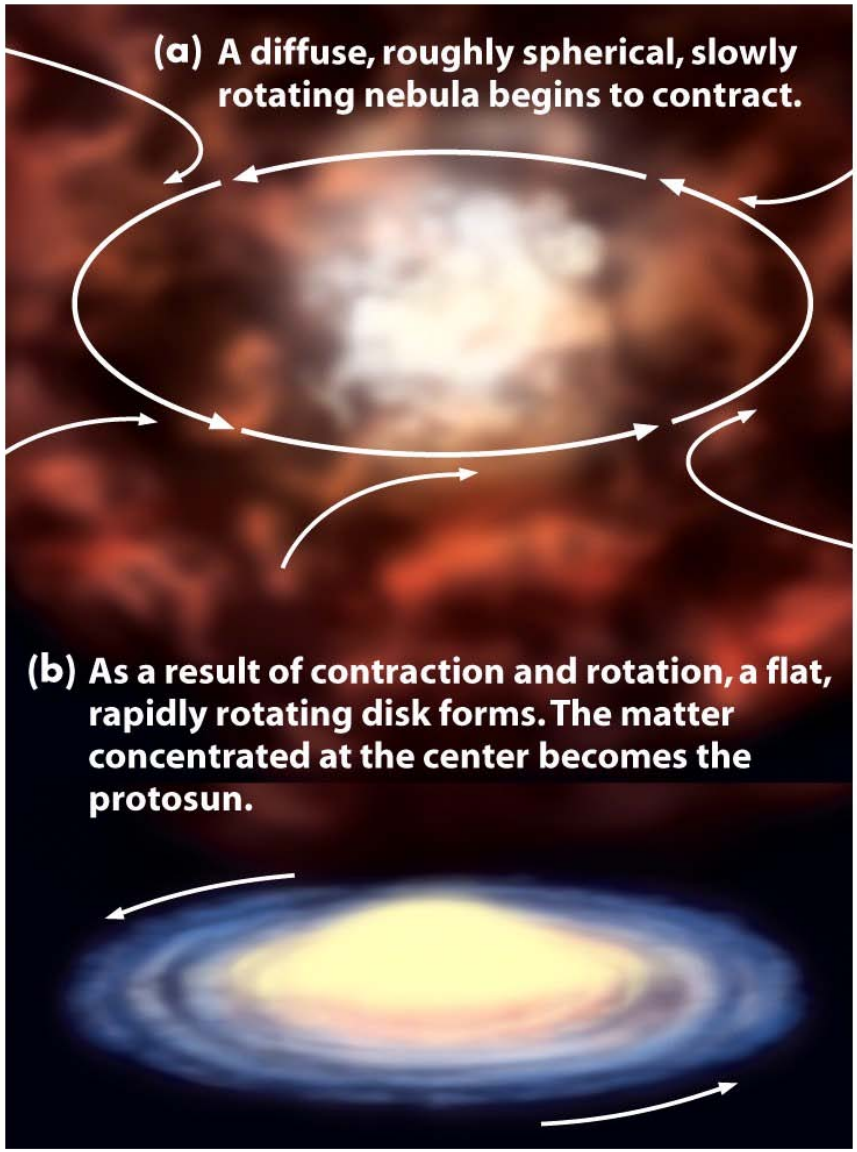


Figure 8-6
Universe, Eighth Edition

Nebular Theory, Part 2

Step 3: Clumps of matter form in the disk and grow by ***accretion***, the sticking together of solid particles. Small bodies form, called ***planetesimals***; they eventually build up into planet-sized objects

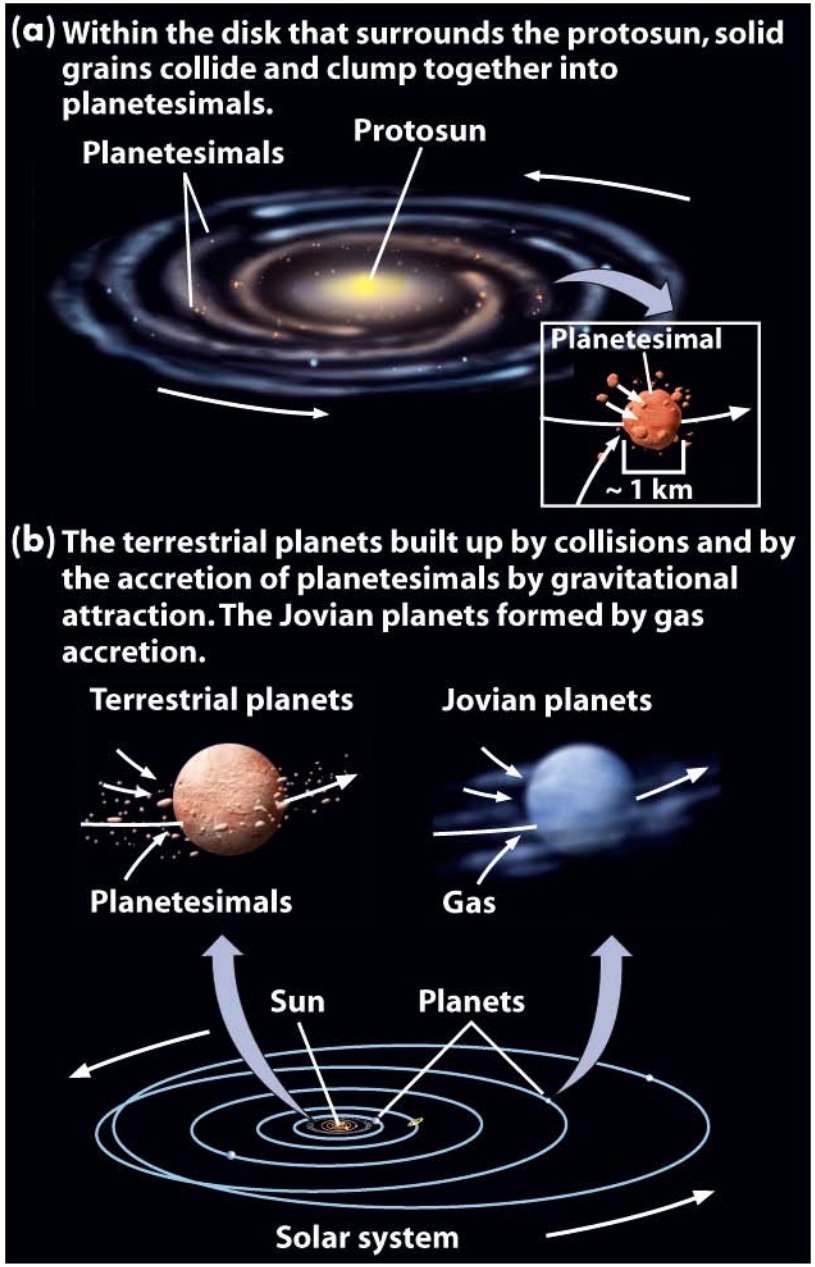
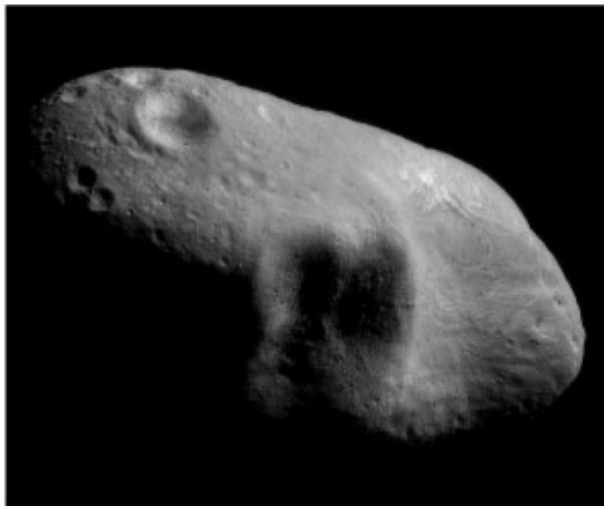


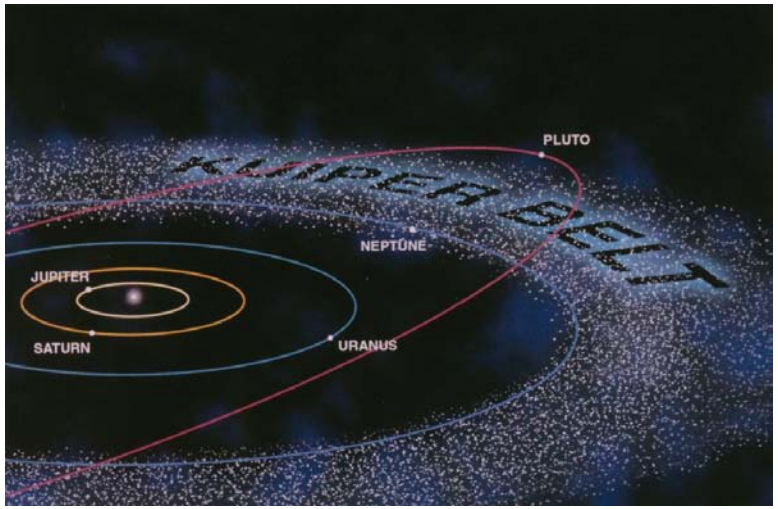
Figure 8-13
Universe, Eighth Edition

Asteroids, comets, and Kuiper Belt Objects are the “leftovers,” or debris



Comets & KBOs: icy planetesimals found in the outer Solar System

Asteroids: rocky planetesimals, found in the inner Solar System

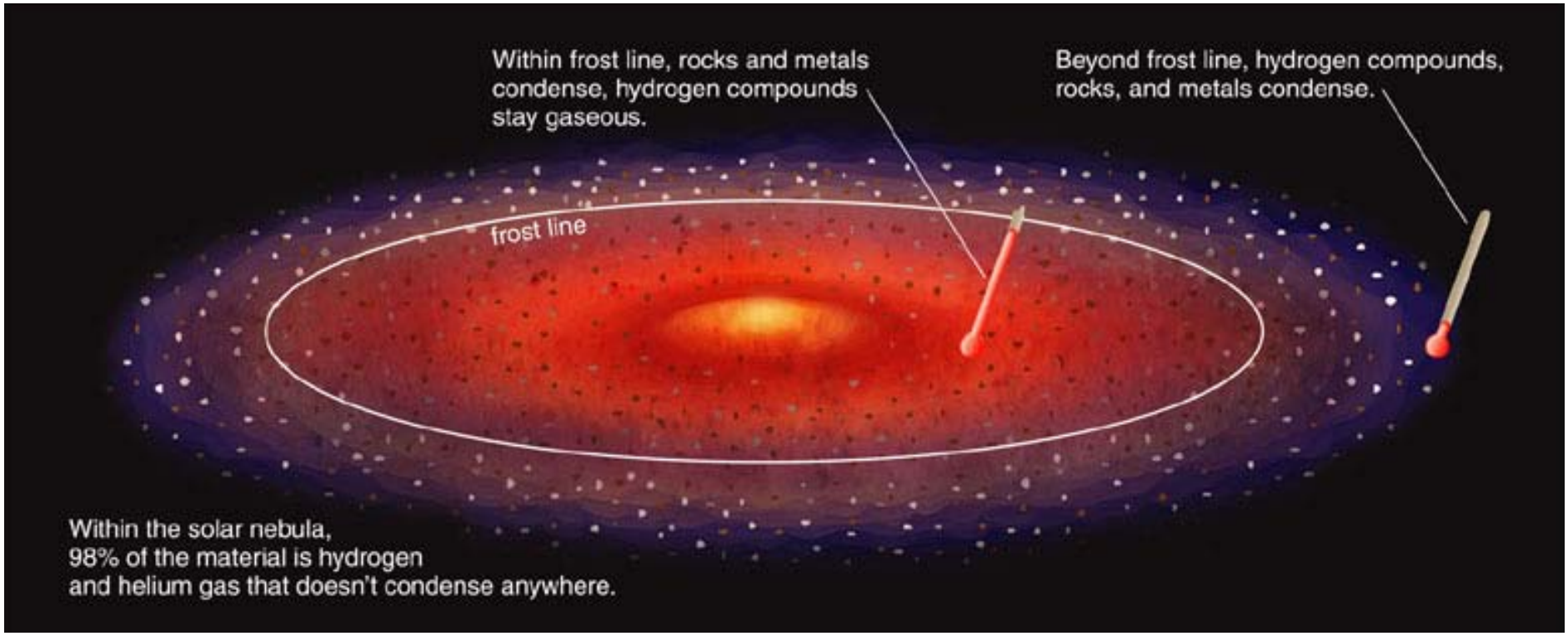


Why Two Types of Planets?

- The inner parts of the contracting solar nebula get hotter than the outer parts.
- Since rock condenses at higher T than ice, rocky bodies form in the inner disk, icy ones further out.
- Since they are composed of the heavy elements *and there isn't much matter in them,* the inner planets have relatively small masses.

	Examples	*Typical Condensation Temperature*	*Relative Abundance (by mass)*
Hydrogen and Helium Gas 	hydrogen, helium	do not condense in nebula	 98%
Hydrogen Compounds 	water (H_2O) methane (CH_4) ammonia (NH_3)	<150 K	■ 1.4%
Rock 	various minerals	500–1,300 K	▪ 0.4%
Metals 	iron, nickel, aluminum	1,000–1,600 K	▪ 0.2%

Why Two Types of Planets?

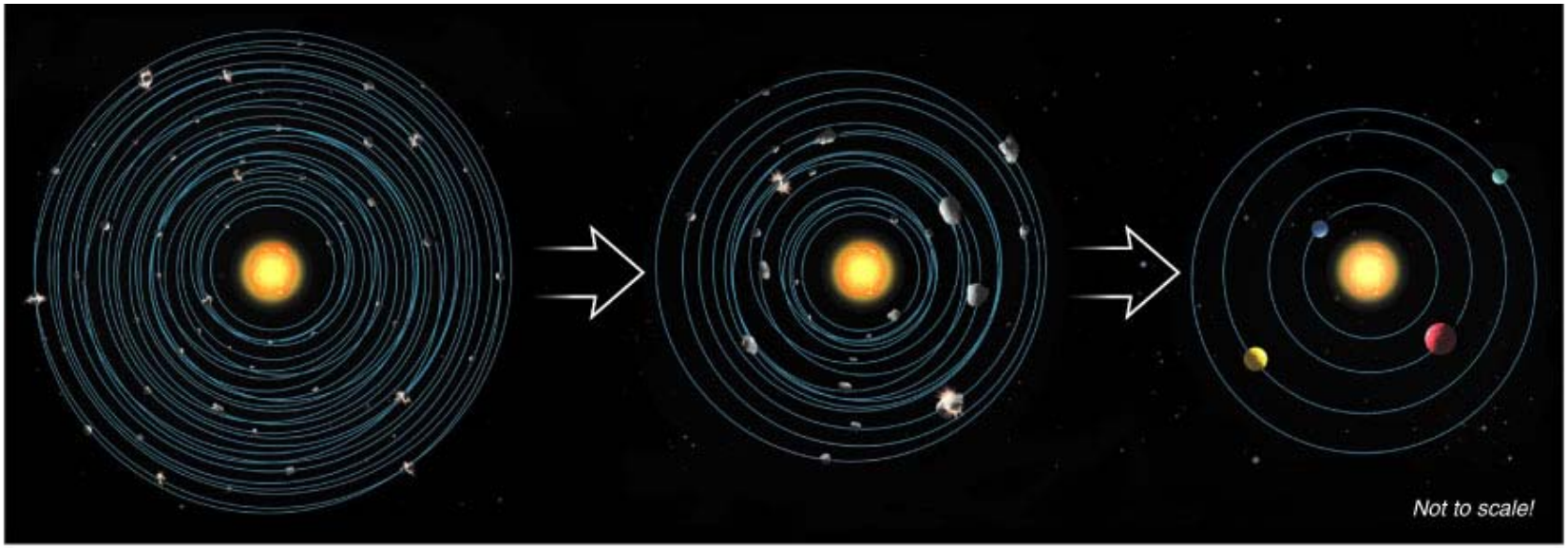


Inside the ***frost line***: Too hot for hydrogen compounds to form ices.

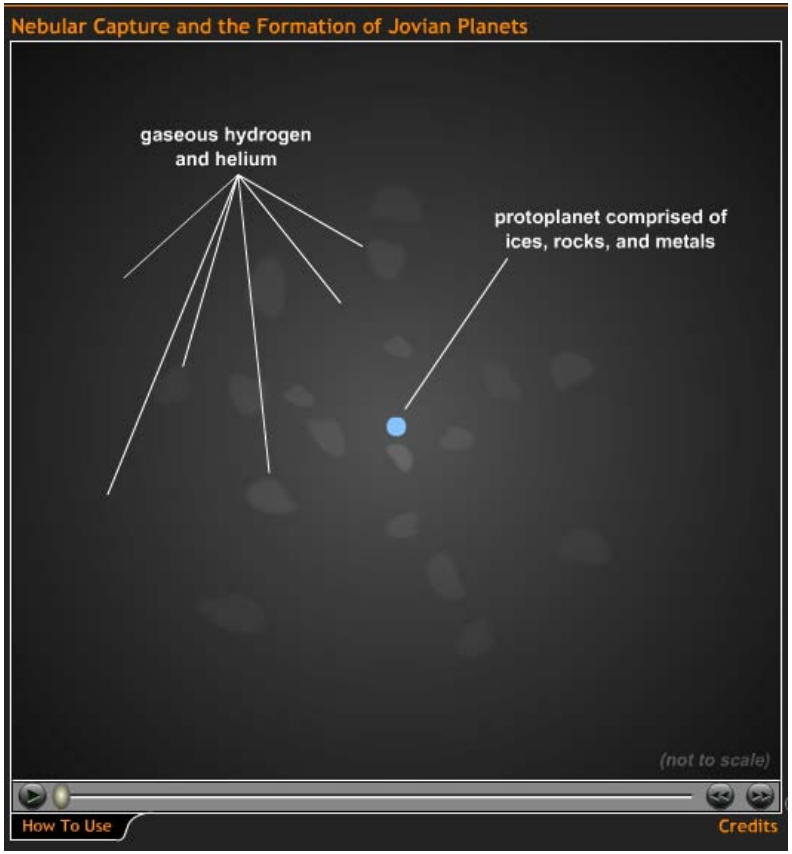
Outside the ***frost line***: Cold enough for ices to form. This means there is a larger reservoir of matter to make the outer planets.

Formation of the Terrestrial Planets

- Inside the “frost line,” particles of rock and metal collided and stuck together, building ***planetesimals.***
- Gravity drew the planetesimals together until they assembled into the terrestrial planets***.***
- The larger bodies “mopped up” the remaining small planetesimals and debris



Formation of the Jovian Planets



Two Current Theories:

1. ***Core accretion:*** Solid cores form first, then their gravity draws in gases

2. ***Gravitational Instability:*** clumps of gas form within a protoplanetary disk, they have strong enough gravity to collapse rapidly

An Epoch of Epic Collisions

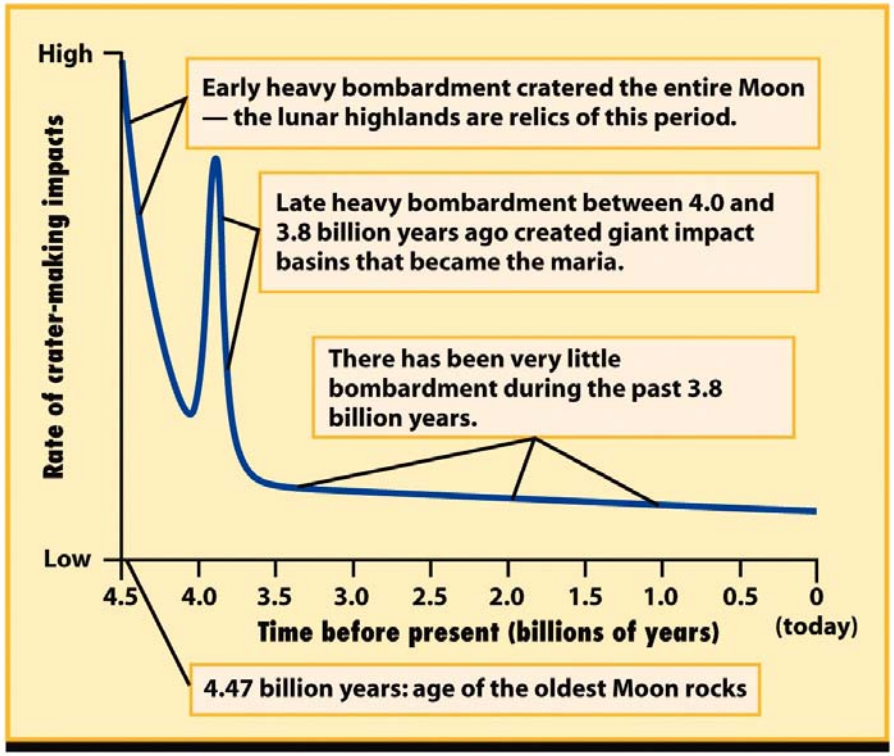
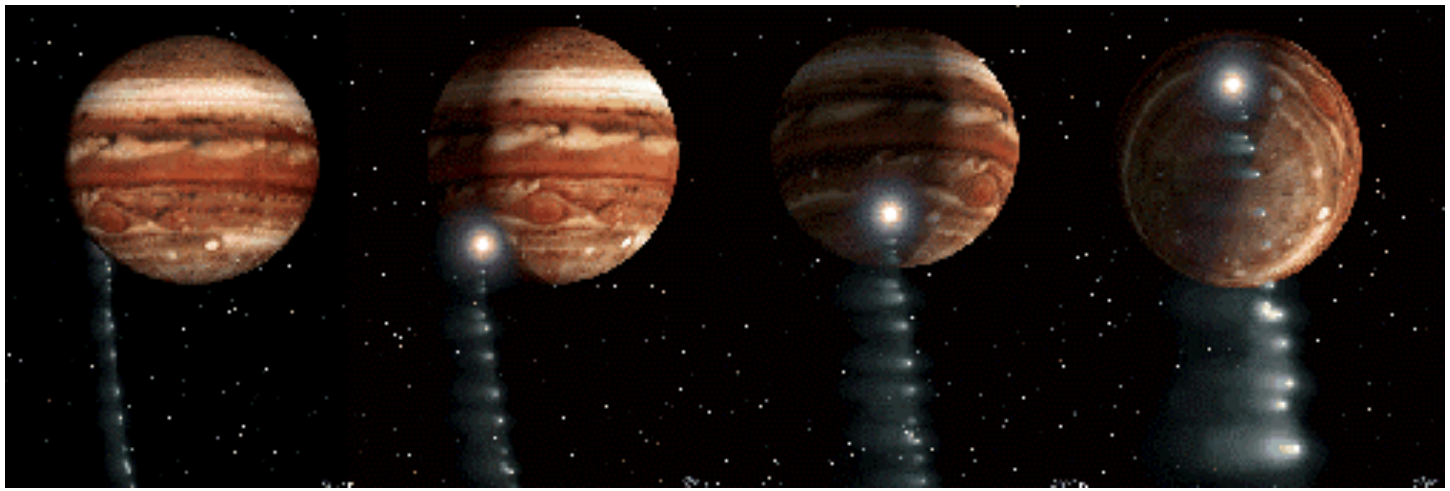


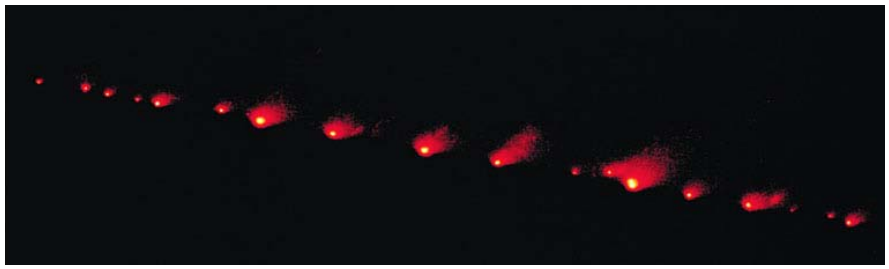
Figure 10-16
Universe, Eighth Edition

There seems to have been an era when the remaining planetesimals bombarded the newly formed objects, leaving impact craters and tilting the rotational axes of several of the planets

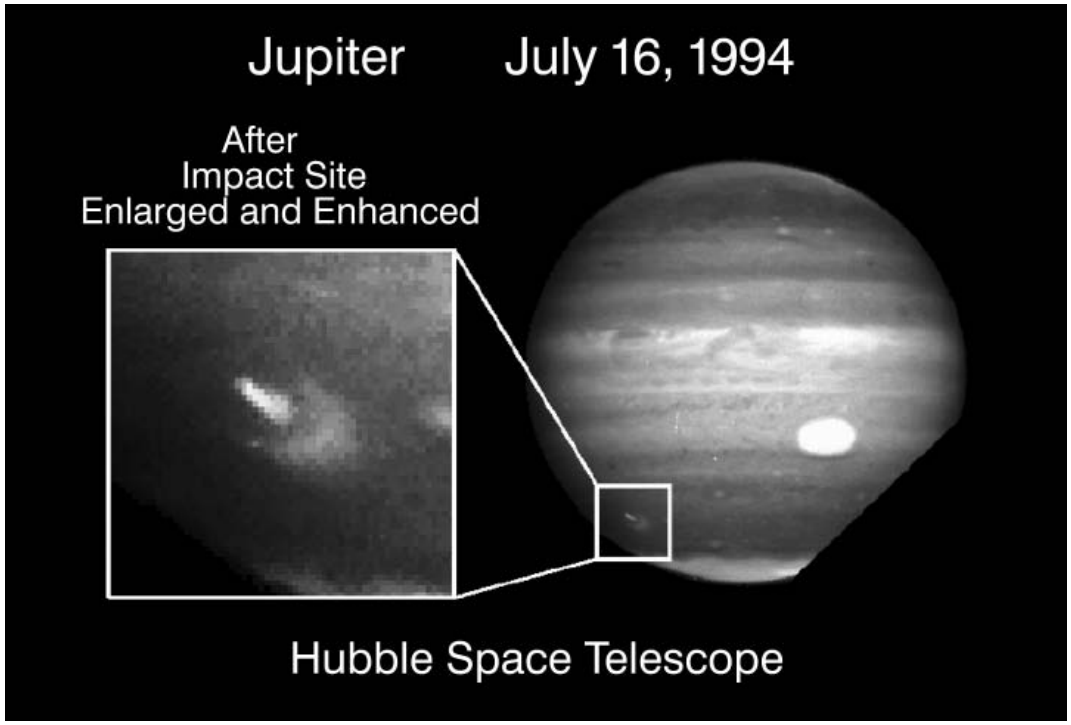
Some Bombardment continues today

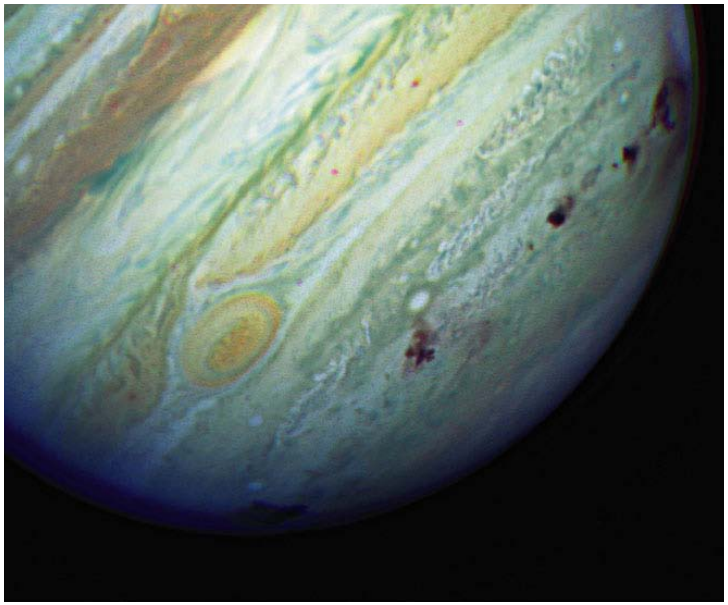


Comet Shoemaker-Levy 9 collided with Jupiter in 1994, after getting caught in Jupiter's gravity and torn apart by tidal forces into over a dozen pieces



Comet Shoemaker-Levy at Jupiter

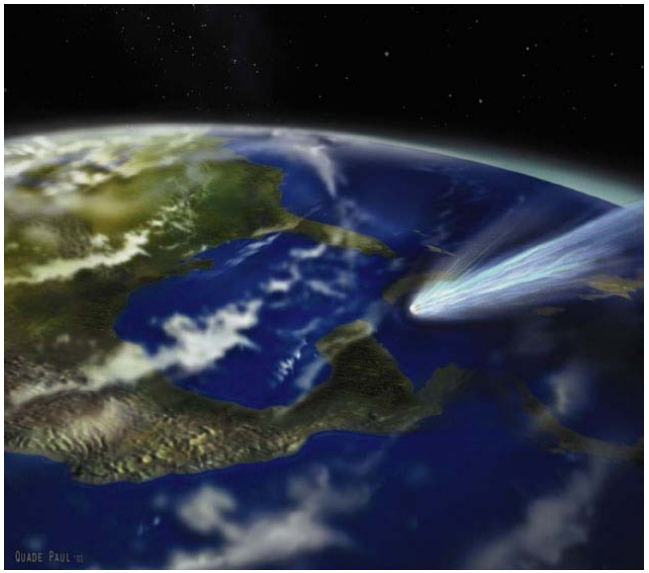




The falling fragments left marks that were seen for several days; a similar event occurred in July 2009


DO YOU EVER WORRY ABOUT WHAT WOULD HAPPEN IF THE ASTEROID WAS HIT BY A PLANET?

Could an Asteroid Hit the Earth?



It's happened in the past; some left craters we see today. Some events were drastic enough to wipe out a number of species (mass extinctions). There are some "Earth-crossing" asteroids, or NEO's (Near Earth Objects).

Could an Asteroid Hit the Earth?

Asteroid 99942 “Apophis” will pass close to the Earth in 2029, and was at one time projected to have a 1 in 5,000 chance of hitting the Earth in 2036, but this has now been revised to a 1:45,000 chance.

Astronaut Edward Lu NASA-JSC proposed that we send a small space probe to hover next to this asteroid, providing a gravitational tug strong enough to pull it into a different orbit and avoid a collision. This concept is called a “gravitational tractor.”

Formation of Earth's Moon

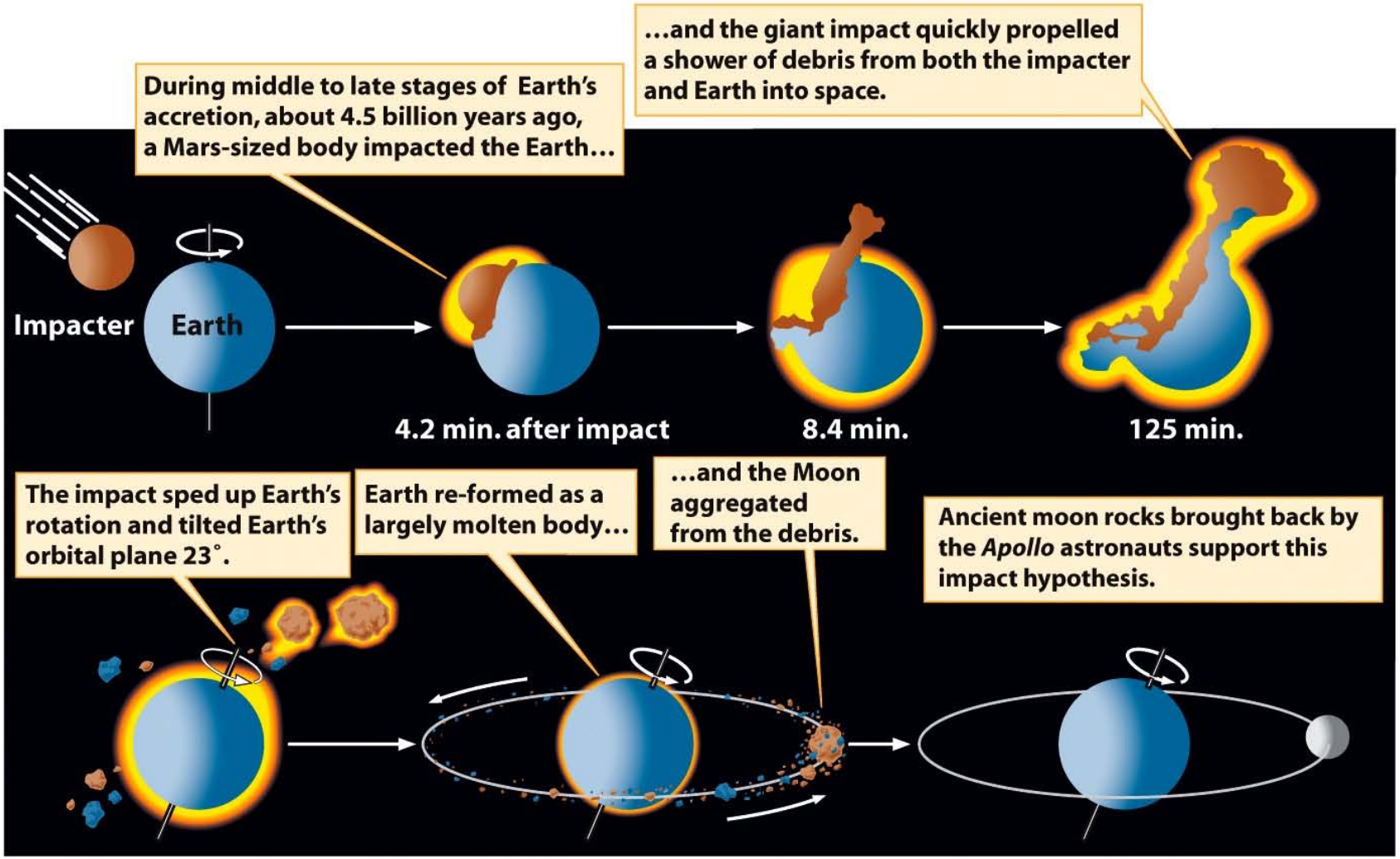


Figure 10-18
Universe, Eighth Edition