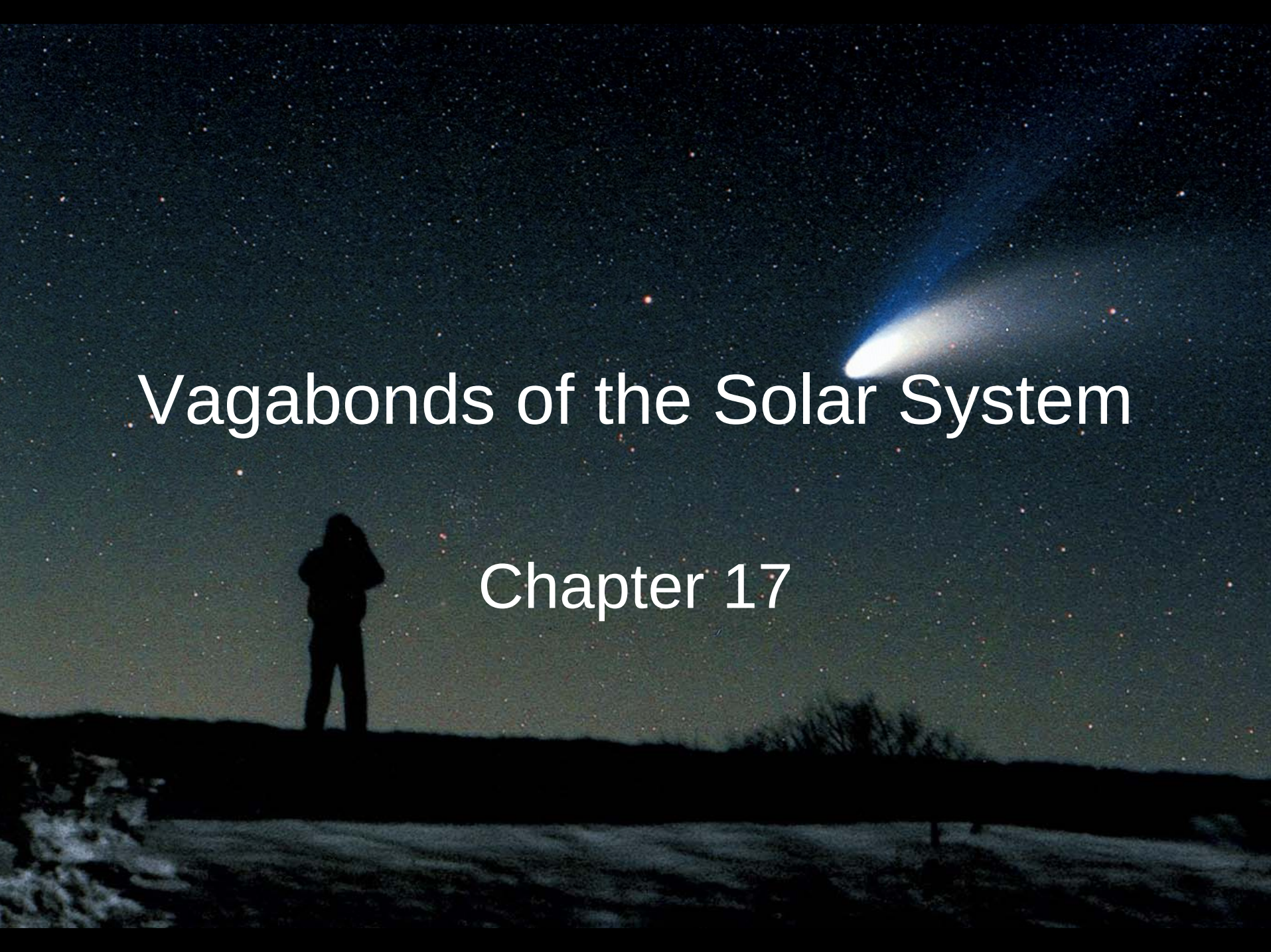


Vagabonds of the Solar System

Chapter 17

ASTR 111 – 003 Fall 2006
Lecture 13 Nov. 27, 2006

Introduction To Modern Astronomy I

Introducing Astronomy
(chap. 1-6)

Planets and Moons
(chap. 7-17)

Ch7: Comparative Planetology I
Ch8: Comparative Planetology II
Ch9: The Living Earth
Ch10: Our Barren Moon
Ch11: Sun-Scorched Mercury
Ch12: Cloud-covered Venus
Ch13: Red Planet Mars
Ch14: Jupiter and Saturn
Ch15: Satellites of Jup. & Saturn

Ch16: Outer World
Ch17: Vagabonds of Solar System

Guiding Questions

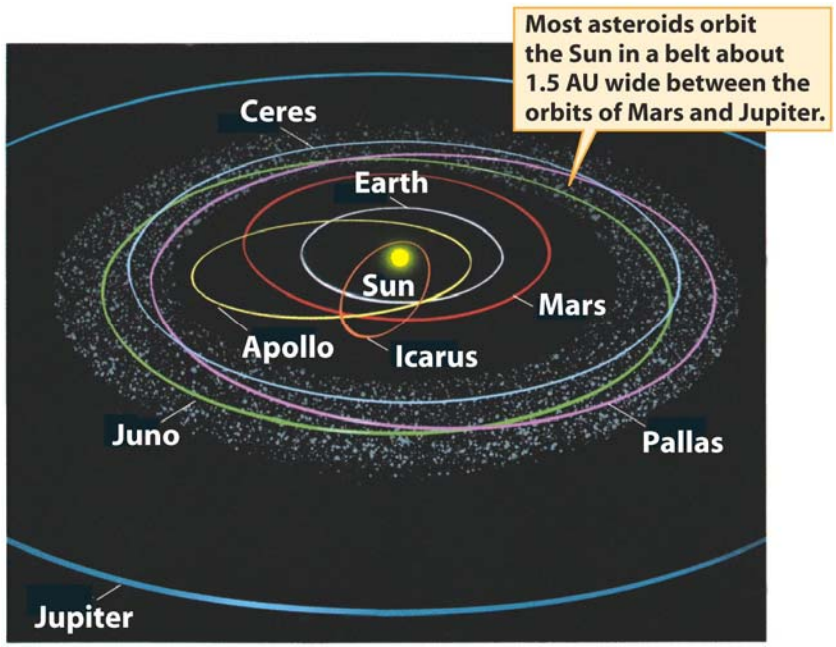
1. How and why were the asteroids first discovered?
2. Why didn’t the asteroids coalesce to form a single planet?
3. What do asteroids look like?
4. How might an asteroid have caused the extinction of the dinosaurs?
5. What are the differences among meteoroids, meteors, and meteorites?
6. What do meteorites tell us about the way in which the solar system formed?
7. Why do comets have tails?
8. Where do comets come from?
9. What is the connection between comets and meteor showers?

Discovery of Asteroids

- Astronomers first discovered the asteroids while searching for a “missing planet”
  - As a thumb of rule, from one planet to the next, the orbit size increases by a factor between 1.4 and 2
  - The Jupiter (5.2 AU) is more than 3 times farther from the Sun than Mars (1.52 AU).
  - A “missing planet between 2 and 3 AU
- Ceres was found in 1801
  - the largest asteroid, diameter of 918 km
  - Distance 2.77 AU from the Sun
  - Now has been newly classified as a “dwarf planet”

Asteroid Belt

- Asteroid belt: where most asteroids are.
  - At distance between 2 and 3.5 AU, between Mars and Jupiter
  - Three asteroids have diameter more than 300 km
  - About 200 asteroids are bigger than 100 km
  - Thousands of asteroids with diameters larger than 1 km
  - The vast majority are less than 1 km

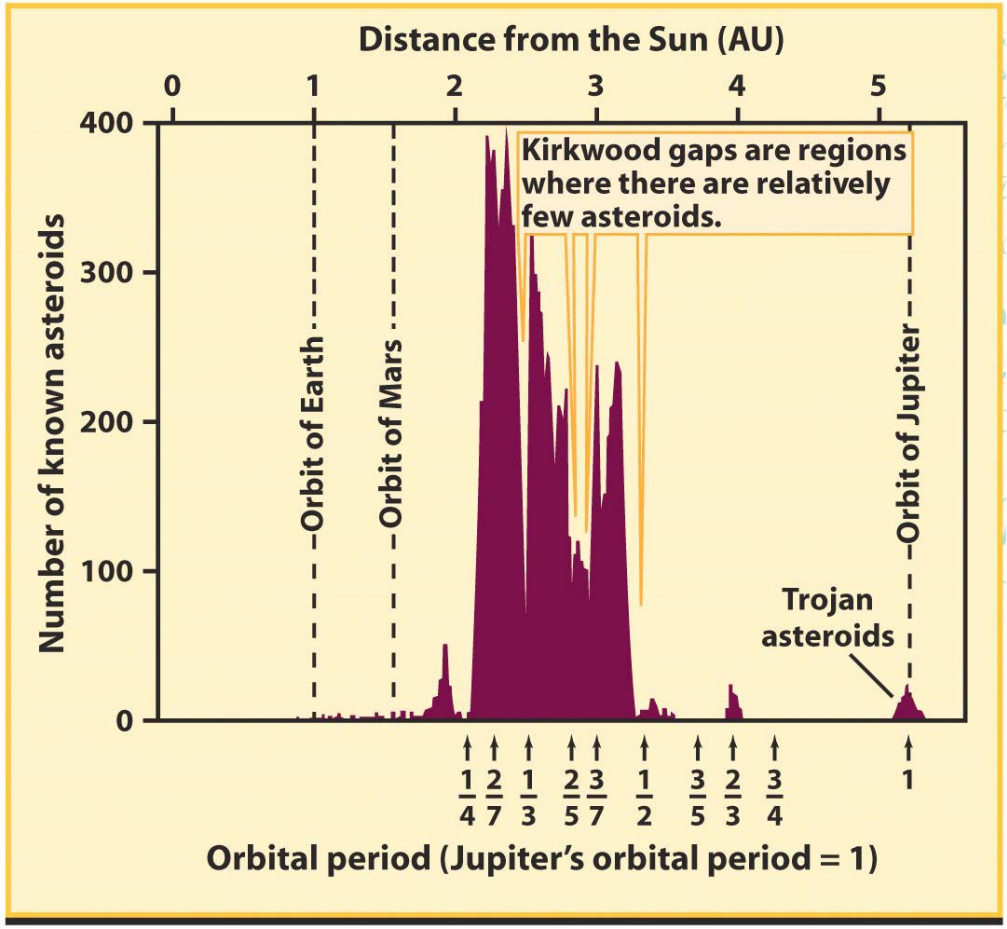


Asteroid: Formation

- Asteroids are relics of planetesimals that failed to accrete into a full-sized planet, thanks to the gravitational effects of Jupiter
- Without the effect of Jupiter, an Earth-sized planet may form in the asteroid belt
- Jupiter's gravitational pull "clears out" the asteroid belt by disrupting the orbits and ejecting most of planetesimals from the solar system altogether
- The few planetesimals remaining become the asteroids that we see today
- Combining all the asteroids would produce an object of 1500 km in diameter
- The average distance between asteroids is about 1 million kilometer; or mostly empty space

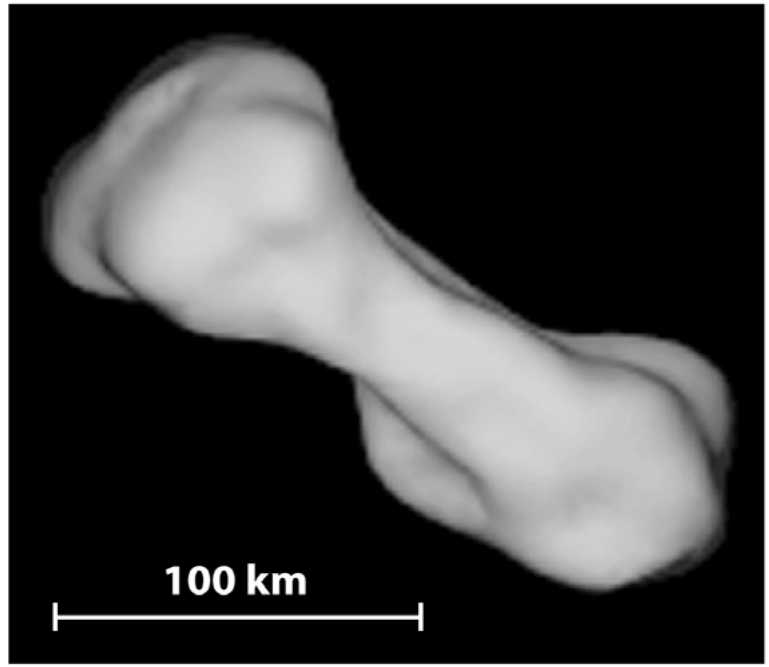
Asteroid: Formation

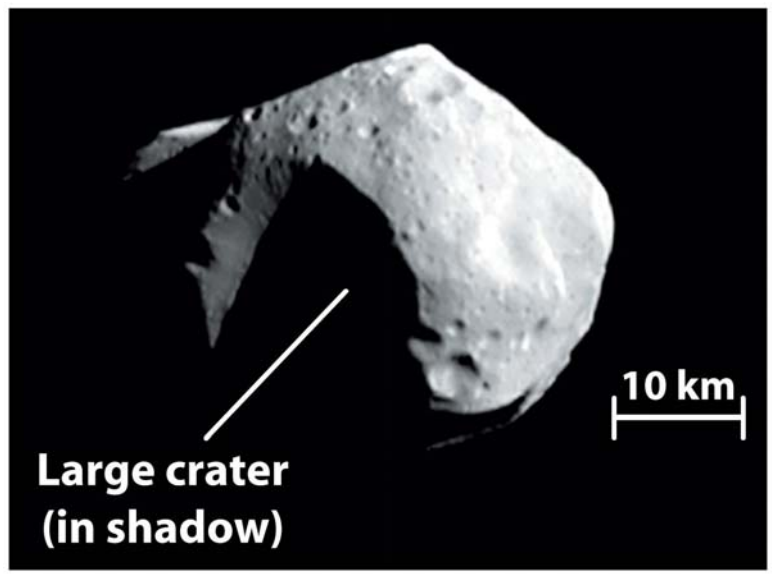
- Even today, gravitational perturbations by Jupiter deplete certain orbits within the asteroid belt
- The resulting gaps, called Kirkwood gaps, occur at simple fractions of Jupiter's orbital period
  - This is caused by **resonance** effect: the repeated alignment ultimately ejects an object from its orbit



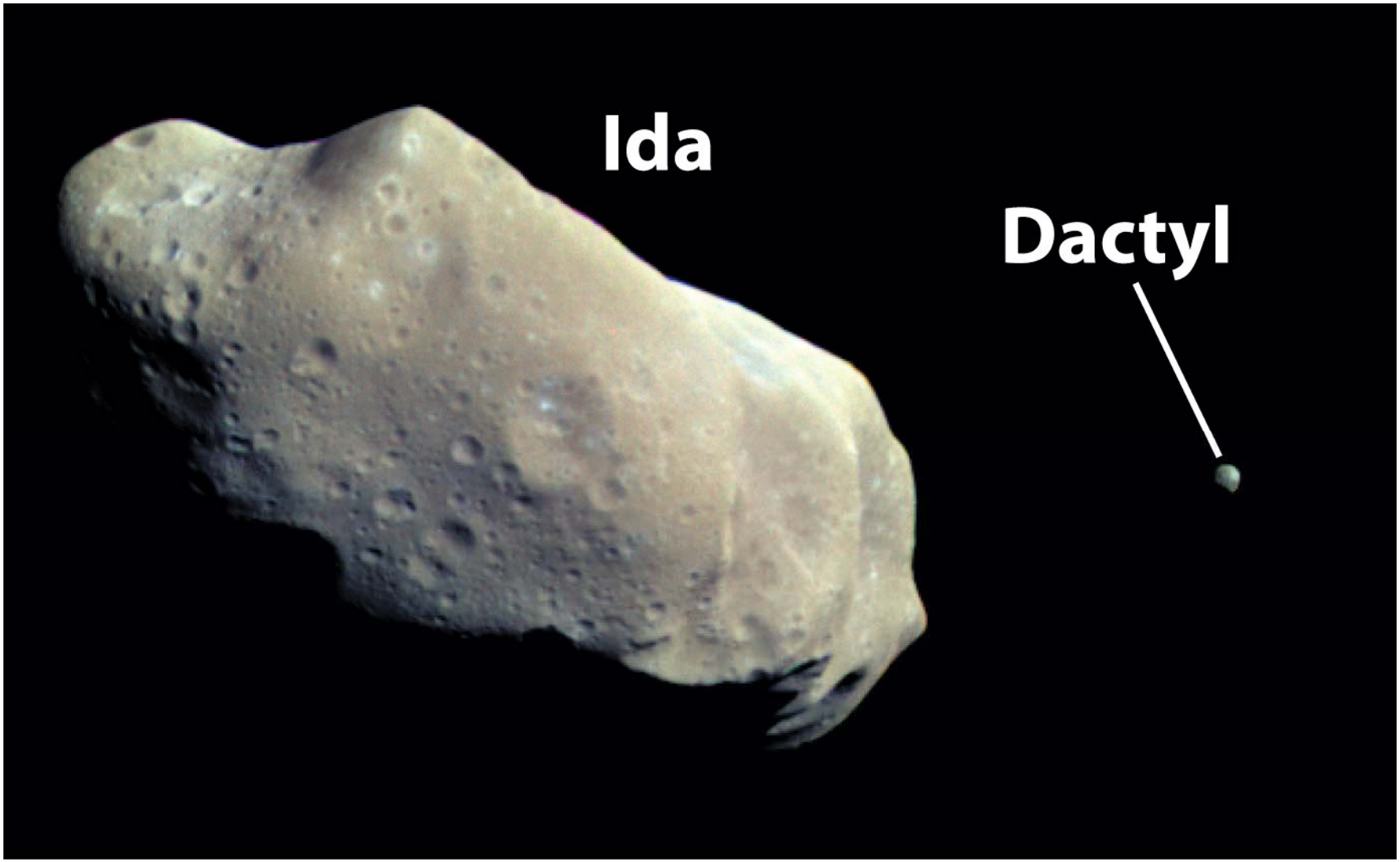
Asteroid: shape and composition

- Asteroids are rocky objects, often with irregular shape
- Most asteroids may not be entirely solid, but composed of several pieces
- An extreme case of Mathilde, which has a low density of 1300 kg/m3, may be a “rubble pile” of small fragments that fit together loosely
- A “rubble pile” can survive violent collisions that cause big craters



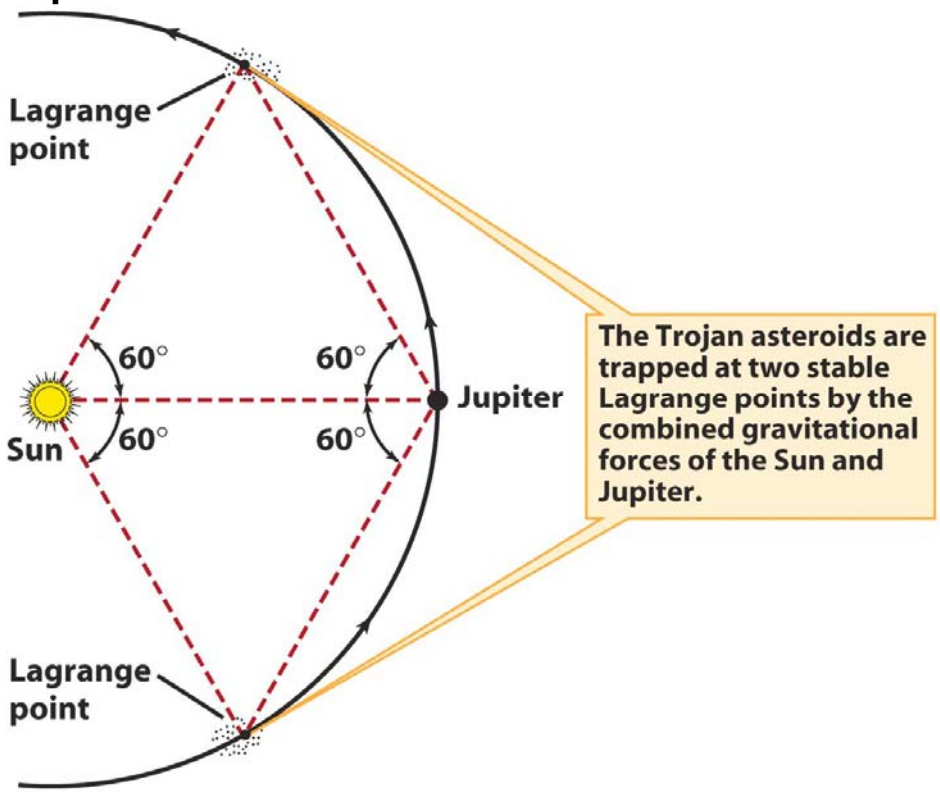


Asteroid: shape and composition



Asteroid: outside the belt

- **Trojan asteroids**
  - Over one thousand Trojan asteroids have been found at two locations along the Jupiter's orbit: the Lagrange points by the combined gravitational forces of the Sun and Jupiter



Asteroid: outside the belt

- **NEO: near-Earth objects**
  - Asteroids that cross Mars's orbit due to high eccentricity, or whose orbits lie completely within that of Mars
- More than 2500 near-Earth objects have been detected
- If such an asteroid strikes the Earth, its effect depends on both the mass and the speed of the asteroid

Asteroid: impact

- **NEO: near-Earth objects**

Mini-impact by meteorite
: New York, Oct. 9, 1992

Tunguska Event: 1908
•Seared and felled the trees in an area of 50 kilometer in diameter
•By 80-m diameter asteroid

Asteroid: impact

- The Barringer Crater: 1.2-km wide. Arizona
- An impact about 50,000 year ago
- By a 50-m diameter iron-rich meteroid

Asteroid: impact

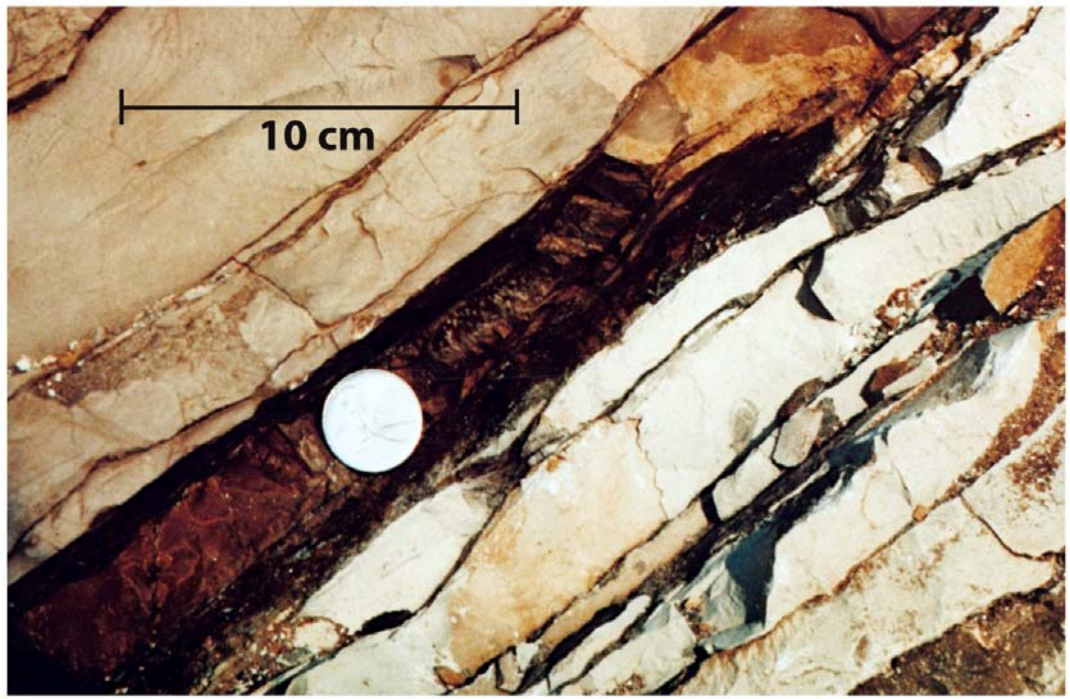
•An asteroid impact may cause the extinction of the dinosaurs and many other species 65 million year ago

•An iridium-rich layer within limestone strata was discovered (1979)

- •Found at numerous site around the world
- •Geological dating reveals deposition 65 million years ago

•By a 10-km diameter asteroid

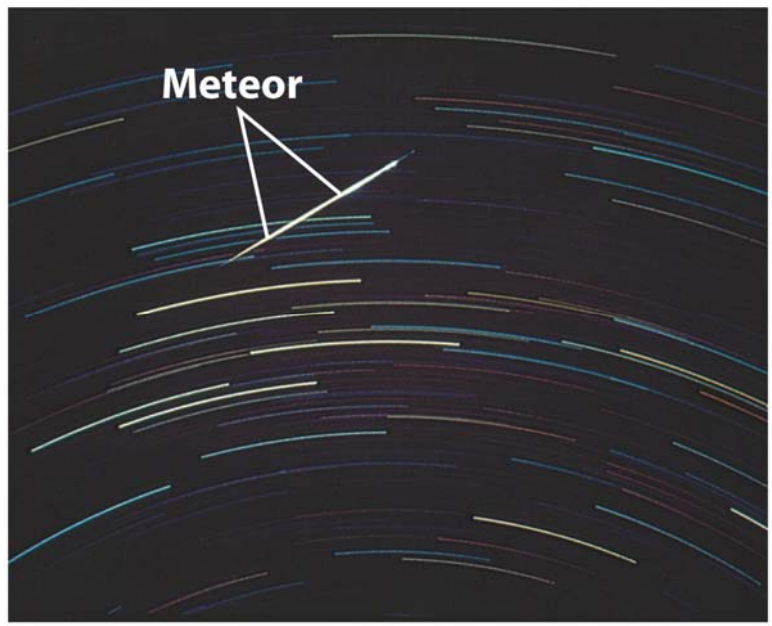
•The site is possibly the 180-km-diameter Chicxulub crater on the Yucatan Peninsula, Mexico (1992).



Meteoroid, Meteor, Meteorite

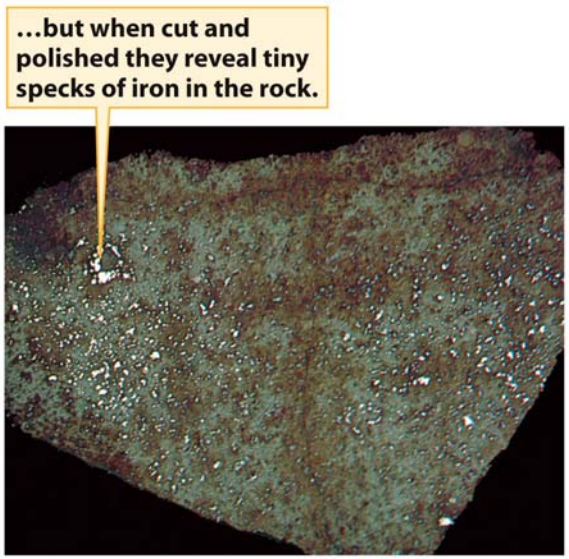
- **Meteoroid**: small chuck of rock in space
  - Like an asteroid but smaller
  - Asteroid generally larger than one hundred meters across
- **Meteor**: the brief flash of light caused by a meteoroid when it enters the Earth's atmosphere, and produces a fiery trail across the night sky
  - The glowing is the result of intense heat caused by atmospheric friction

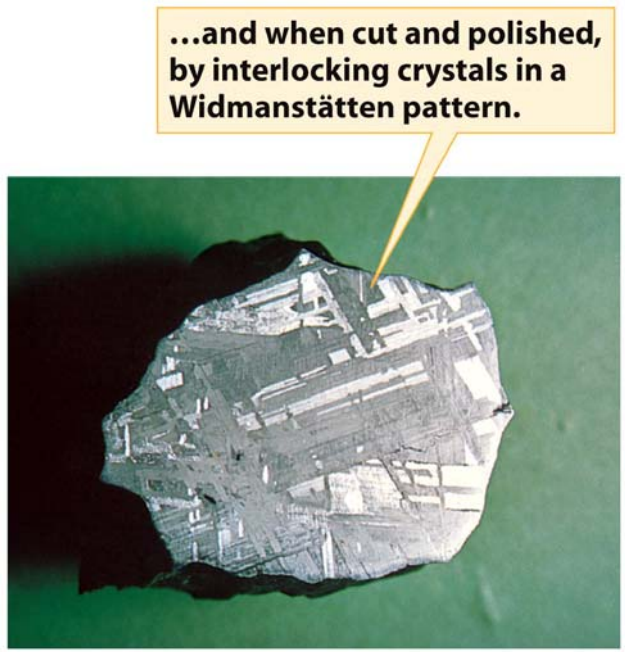
•**Meteorite**: If part of the object survives the fall, the fragment that reaches the Earth's surface is called a meteorite



Meteorite

•Meteorites are classified as stones, stony irons, or irons, depending on their composition
•Stony meteorites account for about 95% of all meteoritic material that falls to the Earth
•About 300 tons of extraterrestrial matter falls on the Earth each day, mostly in the form of dust.





Meteorite: the Trace

- Radioactive age-dating indicates that some meteorite is 4.56 billion years old, indicating the age of the solar system
- Rare stony meteorites called carbonaceous chondrites may be relatively unmodified material from the solar nebula
- These meteorites often contain organic material and may have played a role in the origin of life on Earth

Allende Meteorite

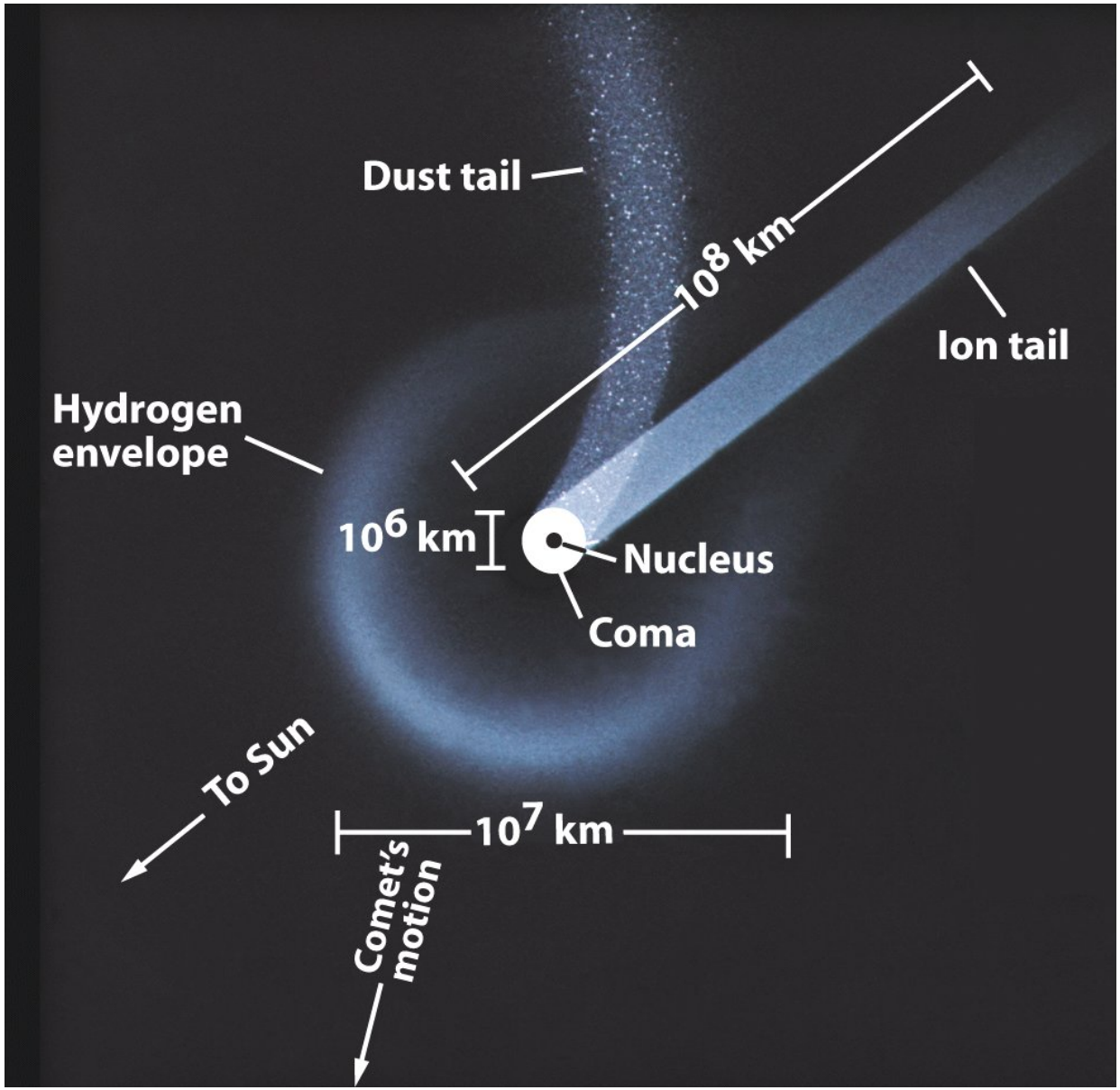
(Mexico, Feb. 8 1969)

Comet

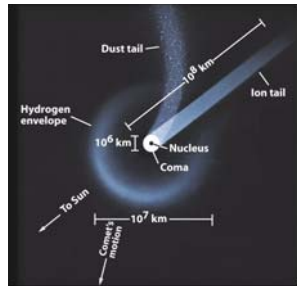
- A comet is a chunk of mixture of ice and rock fragments that partially vaporizes as it passes near the Sun
- Unlike asteroids, a comet generally moves in a highly elliptical orbit about the Sun

Comet: structure

- Nucleus
- Coma
- Hydrogen envelope
- Dust tail
- Ion Tail



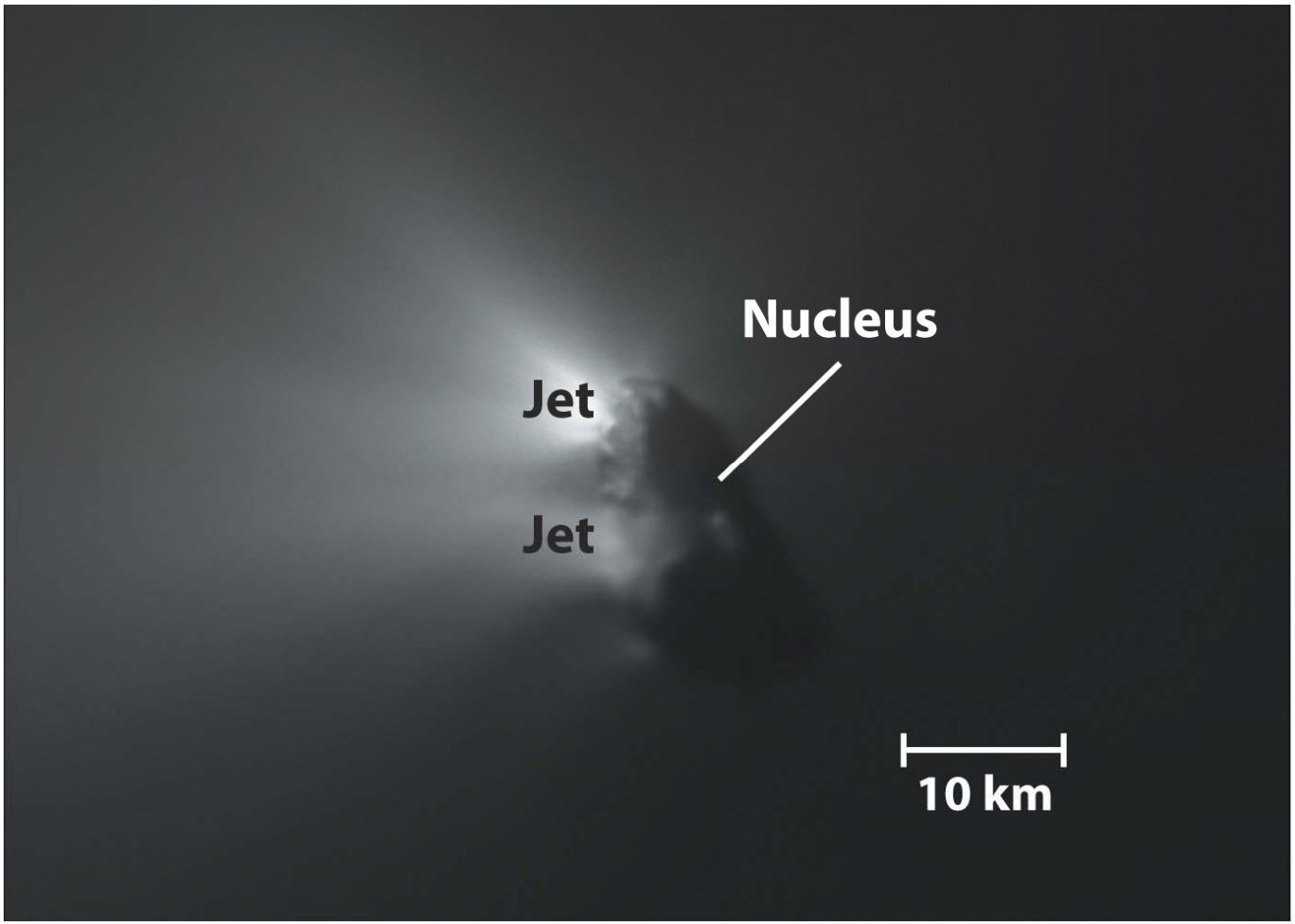
Comet: structure



- **Nucleus**
  - Solid part of comet from which coma and tails emanate
  - Mixture of ice and dust
  - Typically a few kilometer across
- **Coma**
  - the fuzzy, luminous gas ball produced by the liberated gas as the comet near the Sun
  - Typically 1 million km in diameter
- **Tails**
  - Caused by the luminous gas streaming outward
  - About 100 million km in length

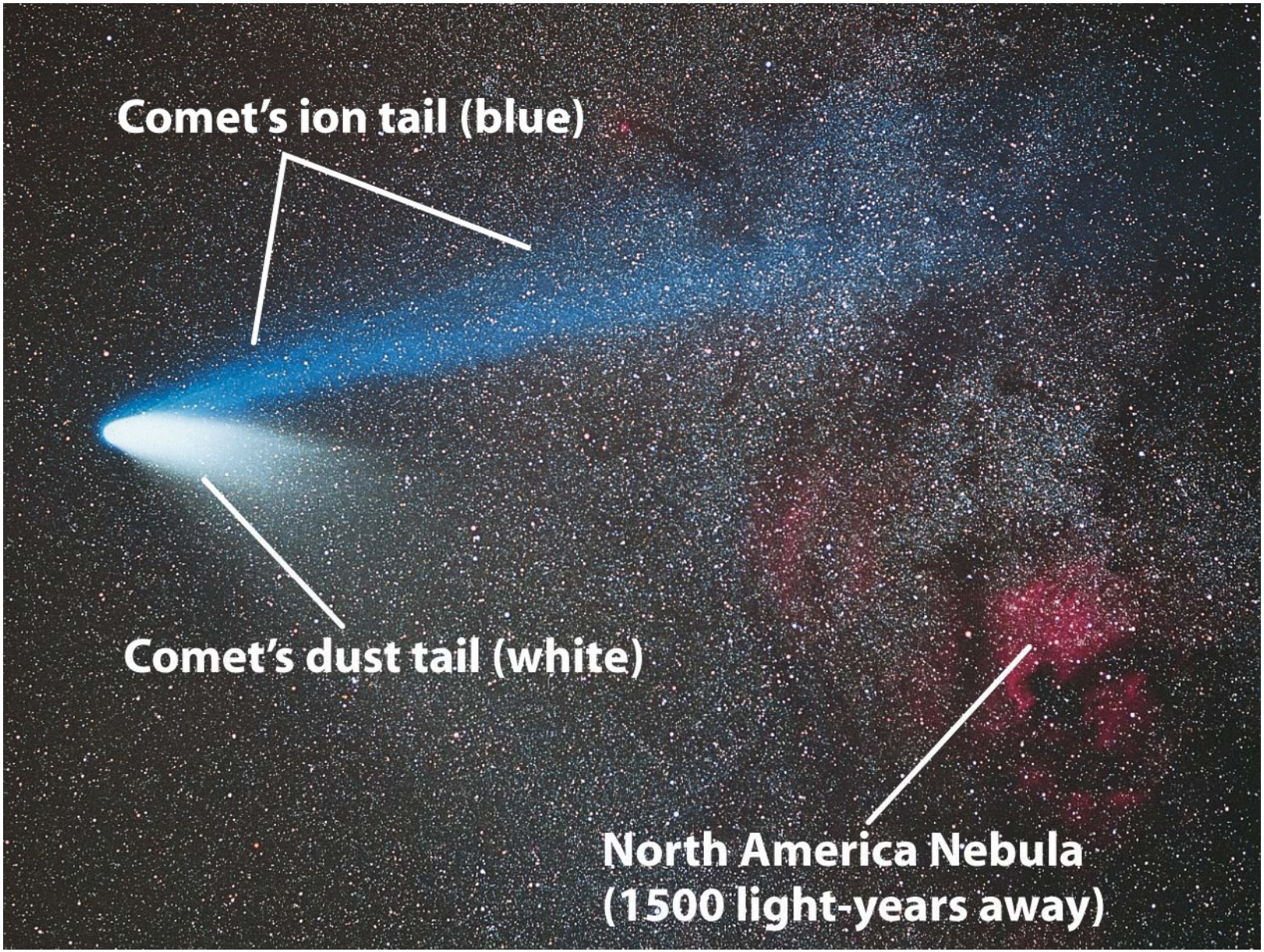
Comet: structure

- **Nucleus**



Comet Halley. 1986 by Giotto spacecraft

Comet: structure

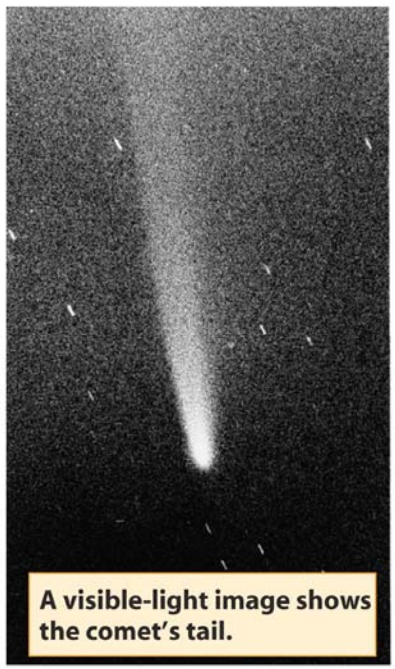


Comet: structure

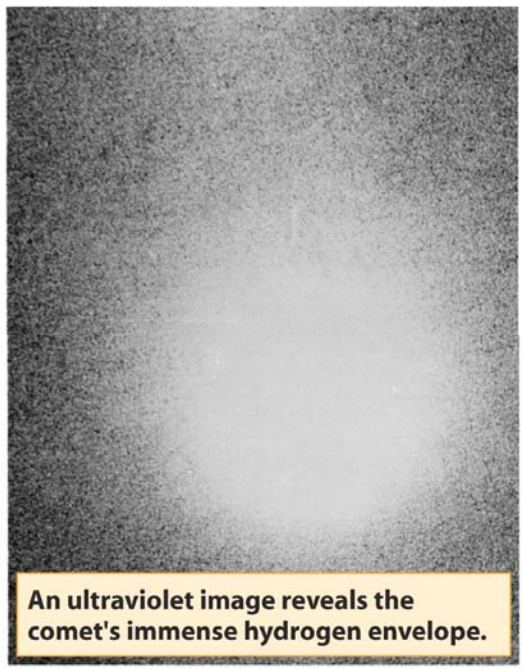
- **Dust tail**
  - formed by the **radiation pressure** on the fine-grained dust particles in the coma
  - **Radiation pressure: photons exerts a pressure on any object that absorbs or reflects it.**
  - Dust particles slowly drift away forming a curved tail
- **Ion tail**
  - Ionized atoms and molecules are swept directly away by the solar wind to form the relatively straight ion tail
  - The distinct blue color is caused by emission from carbon-bearing molecules such as CN and C_2.

Comet: structure

- **Hydrogen envelope**
  - A huge sphere of tenuous hydrogen gas
  - Invisible in visible light, but visible in ultraviolet light
  - typically about 10 million km in diameter
  - Hydrogen comes from water molecules that break apart when they absorb ultraviolet photons from the Sun



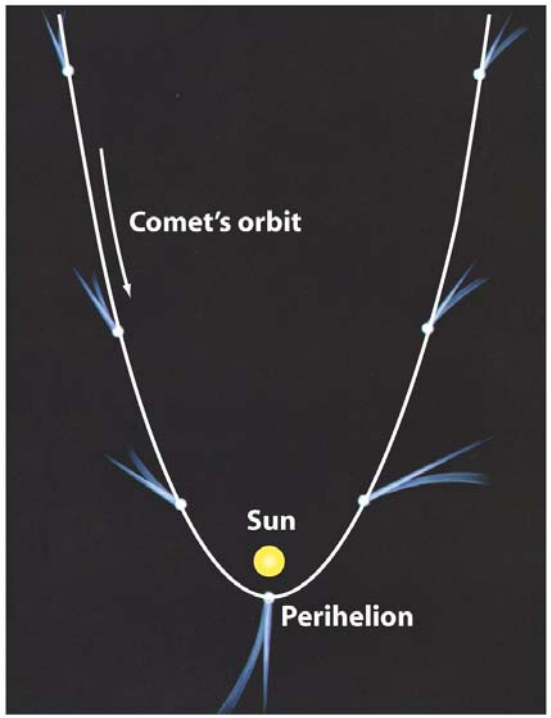
A visible-light image shows the comet's tail.

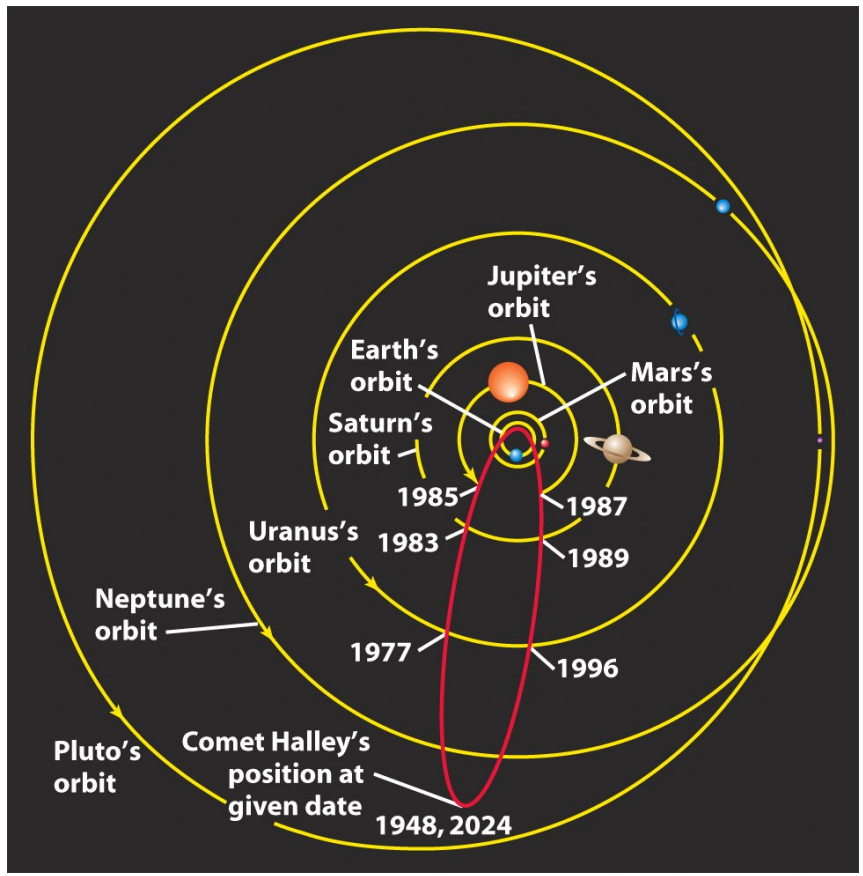


An ultraviolet image reveals the comet's immense hydrogen envelope.

Comet: Origin

- Comets have highly elliptical orbits, indicating they come from the outer part of the solar system
- Comets often have highly inclined orbits (not on the ecliptic plane), indicating a different origin from planets and asteroids





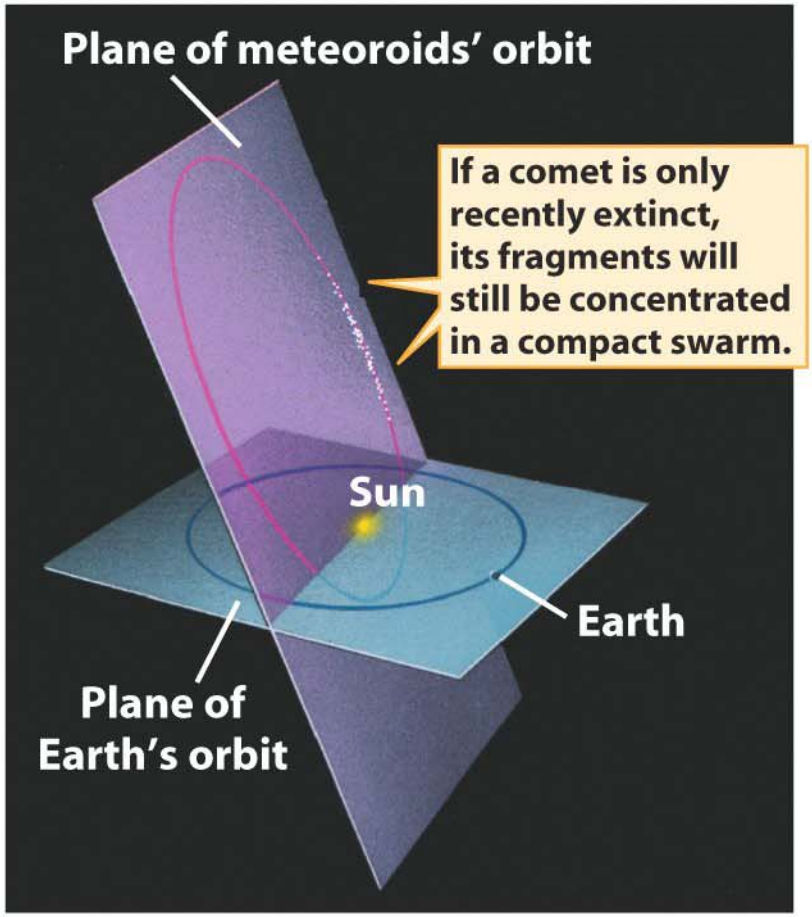
Comet: Origin

- From two large reservoirs: **Kuiper Belt and Oort Cloud**
- **Kuiper belt**
  - lies in the plane of the ecliptic at distances between 30 (Neptune's orbit) and 500 AU from the Sun
  - contain many tens of thousands of comet nuclei
  - Produce **Jupiter-family comets**, which orbits the Sun in fewer than 20 years and return at predictable interval
- **Oort cloud**
  - A sphere extending from the Kuiper Belt to some 50,000 AU from the Sun
  - contains billions of comet nuclei
  - **Intermediate period** (20 to 200 years) and **long-period comets** (1 to 30 million years) are thought to originate in the Oort cloud

Comet: Meteor Shower

- **Meteoritic swarm:** as a comet's nucleus evaporates, residual dust and rock fragments form a loose collection of debris that continues to circle the Sun along the comet's orbit
- **Meteor shower**: it happens when the Earth's orbit happens to pass through a meteoritic swarm

Comet: Meteor Shower



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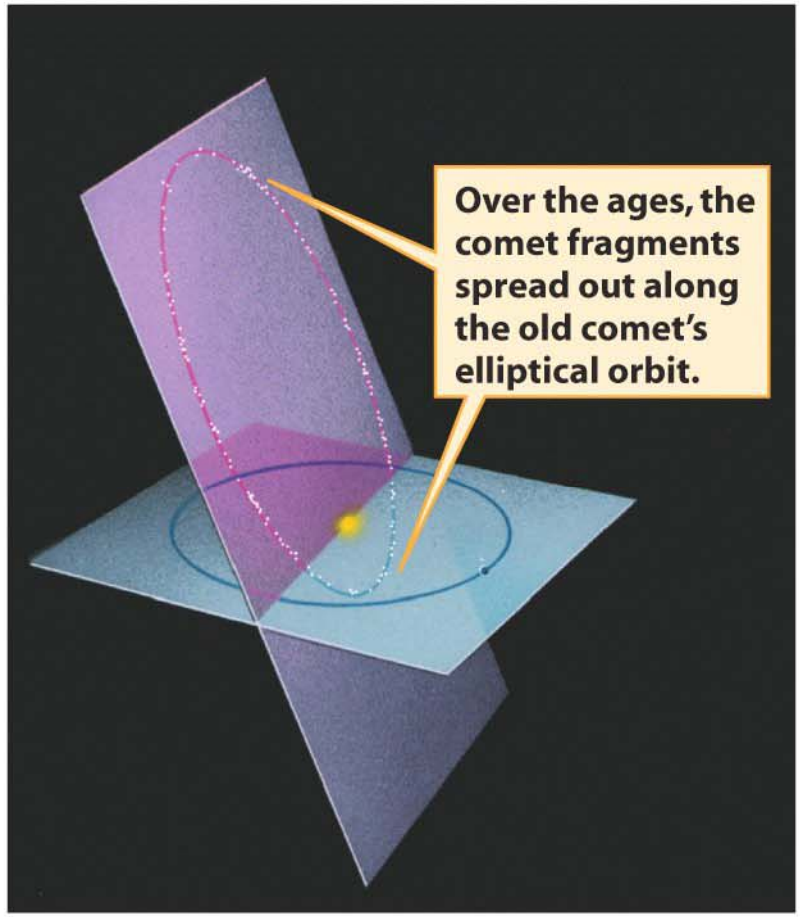

(b)

Comet: Meteor Shower

table 17-1 Prominent Yearly Meteor Showers

Shower name	Date of maximum intensity*	Typical hourly rate	Average speed (km/s)	Radiant constellation
Quadrantids	January 3	40	40	Boötes
Lyrids	April 22	15	50	Lyra
Eta Aquarids	May 4	20	64	Aquarius
Delta Aquarids	July 30	20	40	Aquarius
Perseids	August 12	50	60	Perseus
Orionids	October 21	20	66	Orion
Taurids	November 4	15	30	Taurus
Leonids	November 16	15	70	Leo
Geminids	December 13	50	35	Gemini
Ursids	December 22	15	35	Ursa Minor

**The date of maximum intensity is the best time to observe a particular shower, although good displays can often be seen a day or two before or after the maximum. The typical hourly rate is given for an observer under optimum viewing conditions. The average speed refers to how fast the meteoroids are moving when they strike the atmosphere.*

Final Notes on Chap. 17

- There are 9 sections in total.
- All sections are covered