Chapter 9: Vagabonds of the Solar System

Comets

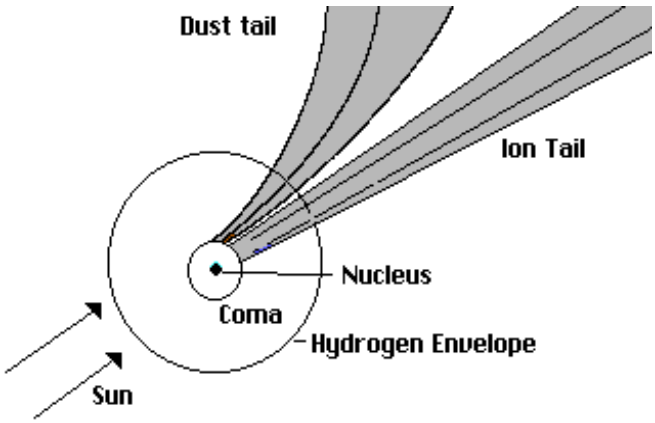
Structure:

1. Nucleus: ~ 10 km in diameter.

2. Coma: nebulous region surrounding the nucleus.

3. Dust Tail: smooth, with slight curvature. Points away from Sun.

4. Ion Tail: complex structure due to interaction of ionized gas with interplanetary magnetic field. Points away from Sun.



Model of Comets: Dirty Snowball Model. Ball of ice (volatile elements, such as; ammonia, methane, and water) mixed with dust and rocks.

> Support: observations of erratic motion caused by jets of gas escaping through the crust of dirt.

Orbits: elongated ellipses with random orientations relative to the ecliptic.

Oort Cloud: spherical distribution of comets between 50,000 AU to 100,000 AU containing about 100 billion comets with a total mass of about 100 times the mass of the Earth. Source of all long period comets.

Kuiper Belt: Source of short period (less than 200 years) comets. Confined close to ecliptic at a distance between 30 and 50 AU. Contains about one earth mass.

Spacecraft Observations:

Halley's Comet: observed by four spacecraft from Russia, Japan and a European consortium in 1986. Observations confirmed dirty snowball model with the exception that the nucleus was jet black.

Comet Borrelly: observed by Deep Space 1 in 2001.

Comet 81P/Wild 2: observed by the US spacecraft Stardust (Jan 2, 2004). Returned to Earth with samples Jan. 15, 2006.

Comet 9P?Tempe 1: visited by Deep Impact on July 4, 2005. Spacecraft released a washing machine sized copper impactor that blasted a crater in the comet in order to measure the composition of the material beneath the comet's crust.

Concept Test

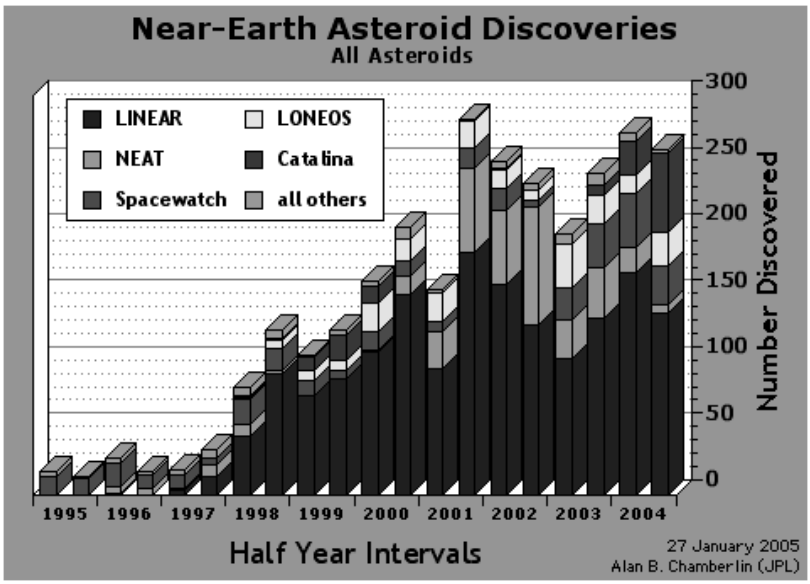
The tail of a comet ..

a) is gas and dust pulled off the comet by the Sun's gravity.
b) always points away from the Sun.
c) trails behind the comet, pointing away from the Sun as the comet approaches it, and toward the Sun as the comet moves out of the inner Solar System.
d) is gas and dust expelled from the comet's nucleus and blown outward by radiation pressure and the solar wind.
e) both (b) and (d).

Asteroids

Asteroids (Minor Planets): small in size and irregularly shaped. Most located between orbits of Mars and Jupiter with nearly circular orbits. Over 250,000 known asteroids. ESO (European Space Agency) study (2002) estimates between 1.1 and 1.9 million objects larger than 1 km may exist.

Near Earth Objects (NEOs): > 32,000 objects that cross the Earth's orbit with 669 (as of Jan. 2005) rated as potentially hazardous (large).



Trojan Asteroids: groups of asteroids located on Jupiter's orbit 60 degrees ahead and behind Jupiter (Lagrangian Points)

Kirkwood Gaps: regions in asteroid belt that contain few asteroids due to perturbations from Jupiter. Asteroids with orbital periods that are simple ratios of Jupiter's period experience cumulative perturbing forces that eject them into other orbits.

Hirayama Family: asteroids that share the same orbit. Probably were parts of larger asteroids that were broken into smaller pieces due to collisions.

Interplanetary Dust

Zodiacal Light: produced by reflected sunlight from interplanetary dust concentrated along the ecliptic that has been deposited by fragmented asteroids and comets. It is seen about 90 minutes before sunrise and about 90 minutes after sunset near the Sun.

Gegenschein: sunlight reflected off dust in the direction opposite to the Sun.

Very dark skies are needed to see these phenomena.

Concept Test

The asteroids that cross the Earth's orbit are called

a) Trojans.
b) Main belt objects.
c) NEOs.
d) Hirayama Families.

Meteors, Meteor Showers, and Meteorites

Meteoroids: interplanetary debris (sand grain sized) in orbit about the Sun.

Meteors: debris that burns up in the Earth's atmosphere.

Meteorites: larger pieces of debris that strike the ground.

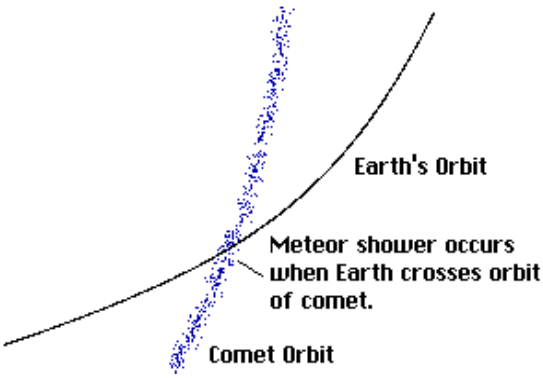
Micrometeorites: dust grains that are able to radiate heat away and float to the Earth's surface.

Meteorite Craters: produced by larger objects. Craters are a result of the explosive release of the kinetic energy that the object had.

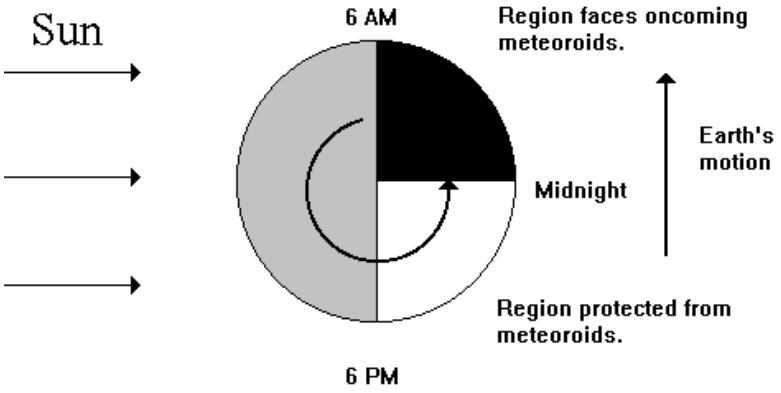
Fireball: meteors that can be seen during the day.

Bolide: fireball that has a booming sound associated with it due to the meteor exploding in the atmosphere.

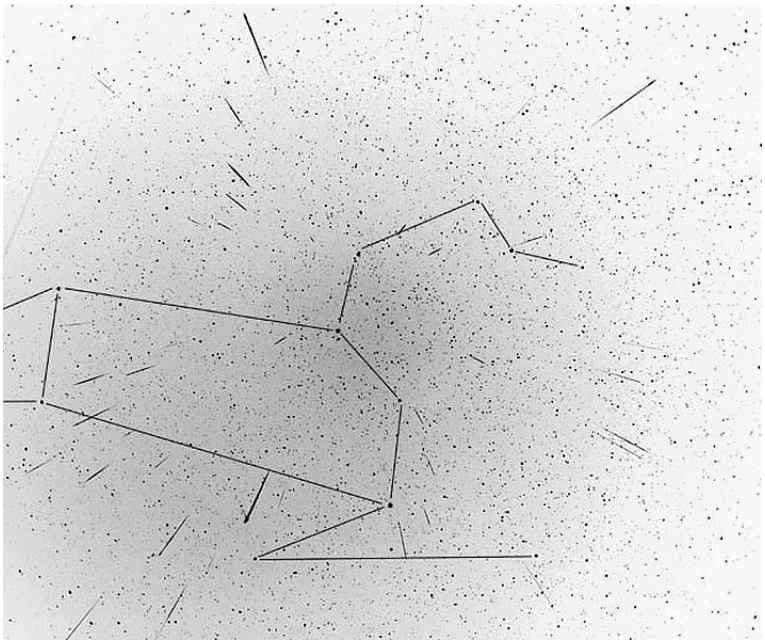
Meteor Showers: occur when the Earth crosses the orbit of a comet and sweeps up dust particles that have been shed from the comet.



Showers are best seen after midnight when the observer is facing into the direction of the Earth's orbital motion.



Radiant: point in the sky where the meteors appear to originate. It is an optical allusion. Meteors are moving along parallel paths, but appear to be coming from a point just like parallel railroad tracks appear to meet in the distance.



Leonids Radiant

Concept Test

On a given day one is likely to see the most meteors ("shooting stars")

a) after midnight.
b) before midnight.
c) during the afternoon.
d) at sunset.
e) it doesn't depend on the time of day.

Meteorite Composition

Definitions:

Fall: meteorite that has been seen passing through the atmosphere and then recovered.

Find: meteorite that has been found but was not seen passing through the atmosphere.

Types of Meteorites

1. **Irons:** composed entirely of iron and nickel.

2. **Stones:** look very much like terrestrial rocks. Some have small flakes of iron in them.

    a. Carbonaceous Chondrites: rare type of stone that contains a large fraction of hydrocarbons and water.

3. **Stony-Irons:** contain a mixture of iron and rock.

Over 90% of falls are stones, while over 2/3 of finds are irons. Stones are difficult to distinguish from terrestrial rocks, while irons stick out.

Chemical composition of meteorites is very similar to the Earth, which leads to the conclusion that the asteroid belt once contained larger bodies that were large enough to experience separation of the elements (differentiation). These bodies were then broken up by collisions to form some meteoroids made mostly of iron and some made primarily of stone.

- Irons – material from the core.
- Stony-irons- material from the region between the core and the outer crust.
- Stones – material from the crust.

Internal Structure:

Stones: contain chondrules (spherical inclusions). Chondrules can have widely different chemical compositions.

Irons: contain large crystal patterns (**Widmanstätten patterns**) that indicate a very long period of cooling.

Radioactive Dating: Ages of meteorites have been found to be about 4.5 billion years.

Half-life: time required for 1/2 of the original radioactive sample to decay.

The ratio of decay product to original material gives a measure of the age of the meteorite.

Allende Meteorite: enriched with ^{26}Mg, which is the product of ^{26}Al decay. Most likely source for ^{26}Al is a supernova. This may provide evidence that a supernova triggered the formation of our solar system.

Concept Test

Why are some meteorite made of lower density rock while others are made of higher density iron and nickel?

a) The two types were formed in different parts of the Solar System.
b) They are the result of larger parent bodies being broken up. The lighter material coming from the crust and the denser material from the core.
c) a and b.