

Rendezvous with a Comet



Courtesy: Pat Rawlings - Deep Impact -NASA & JPL

Introduction

- The history of comet watching dates back to 1000 BC from the Chinese records and Chaldea, a place in present Iraq.
- Comets have been regarded as omen, even as recently as 1986.
 - Battle of Hastings - 1066
- Today Astronomer study Comets from scientific perspectives, and our understanding of these fascinating objects have grown tremendously.

Dirty Snowballs

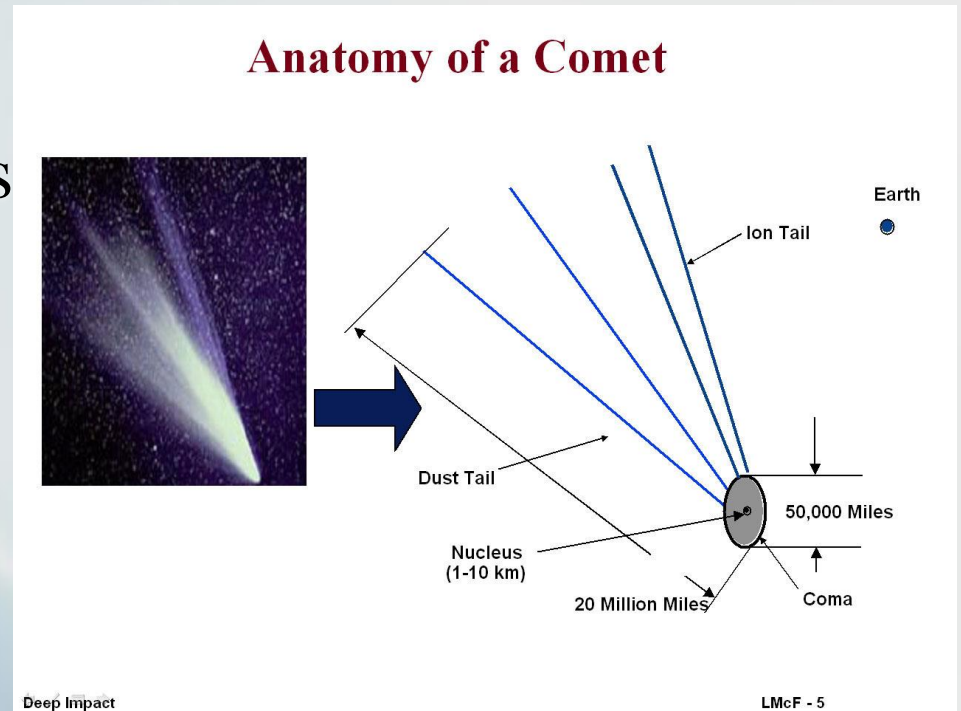
- Comets are dusty chunk of ice
- During each orbit around the sun they partially vaporize
- Have elliptical Orbits



Courtesy: Calvin J. Hamilton

Structure of a Comet

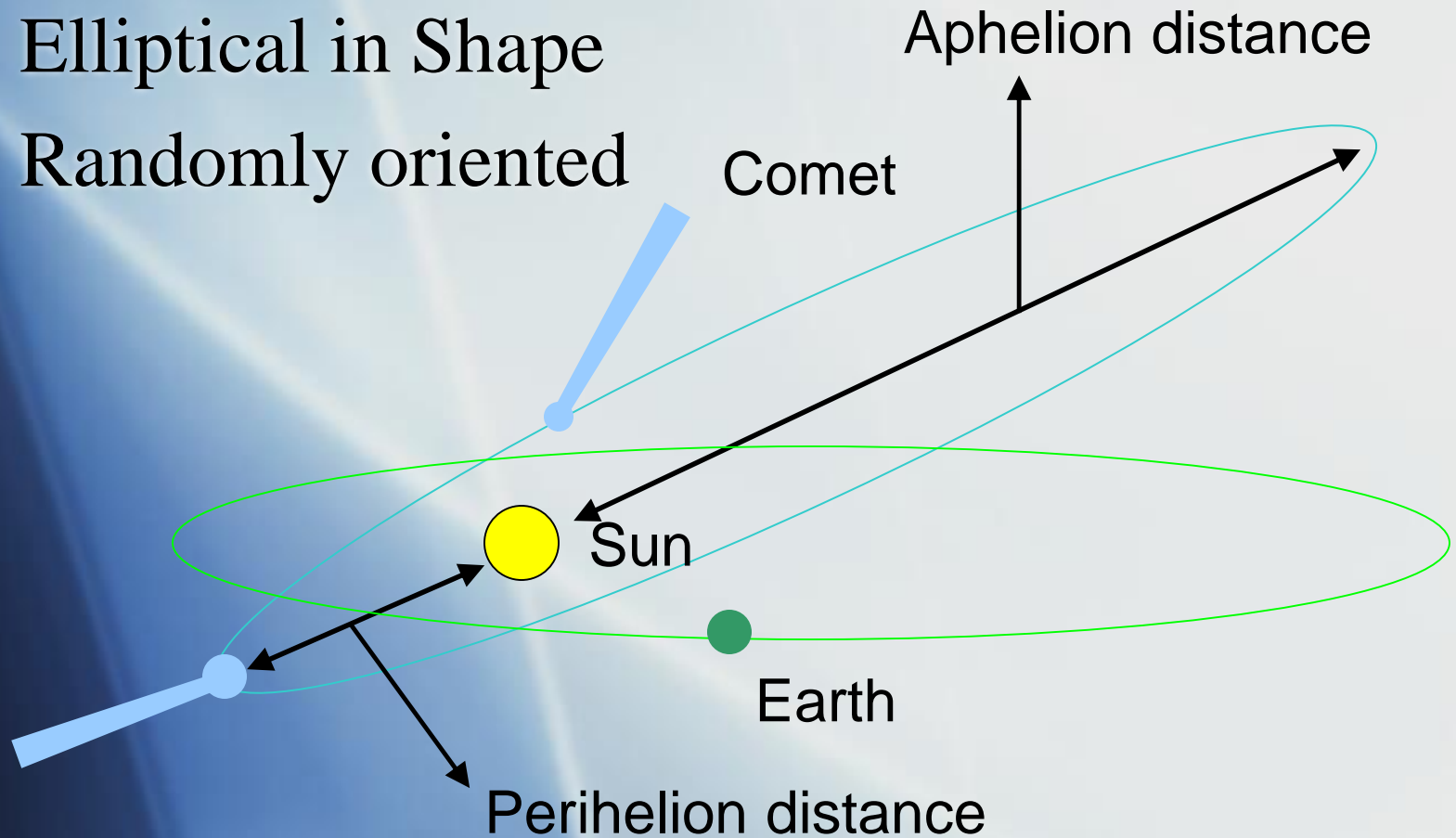
- Solar heat vaporizes the nucleus to produce
 - Coma - Hydrogen gas Envelope
 - Dust tail
 - Ion tail



Courtesy: Deep Impact - NASA & JPL

Orbits of Comets

- Elliptical in Shape
- Randomly oriented



Comet Hunters

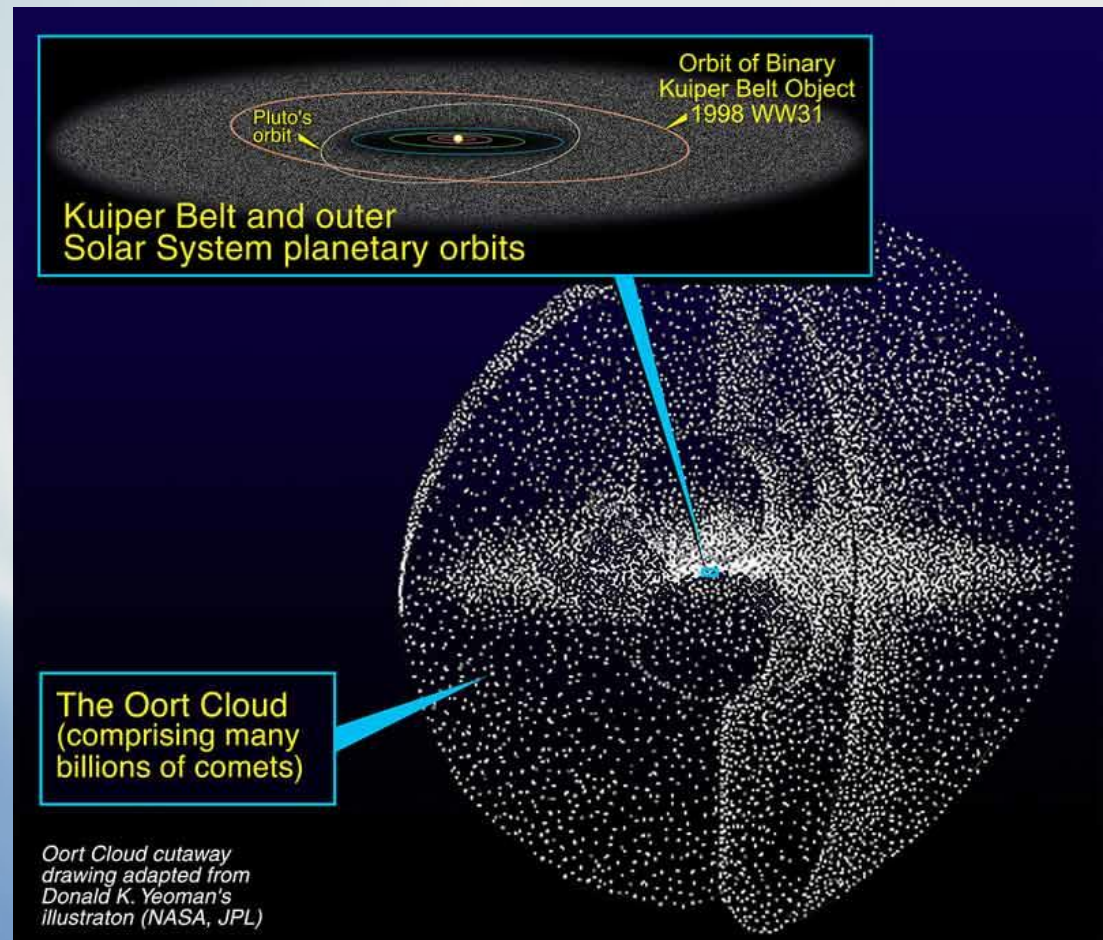
- Comet are named by International Astronomical Union (IAU) after the person who first discovers them.
- Many comets are discovered by amateur astronomers.
- Charles Messier, E. E. Bernard, Shoemaker and Levy, Hale and Bopp, Ikeya, Seki and Hayakutake are popular comet hunters.

Origins of Comets

- Comets are thought to be the left over debris from during the time of formation of the solar system.
- The elliptical orbits of comets suggest that they underwent gravitational pull from the giant planets.
- This all lead us to infer two possible locations where comets could start their journey towards the sun.

Possible Homes for Comets

- Kuiper Belt
- Oort Cloud



Kuiper Belt

- Discovered by Gerard Kuiper in 1951
- The belt is 30 to 500 AU from the Sun
- The plane of the belt is close to the ecliptic
- Probably contains more than 100,000 objects
- Some of these objects are 100 km or larger in diameter

Oort Cloud

- Hypothesized by a Dutch Astronomer Jan Oort in 1950.
- Shape is spherical distribution around the Sun.
- 50,000 AU from the Sun.
- May contain 5 trillion objects.
- Probably created 4.6 billion years ago.

Comets and their periods

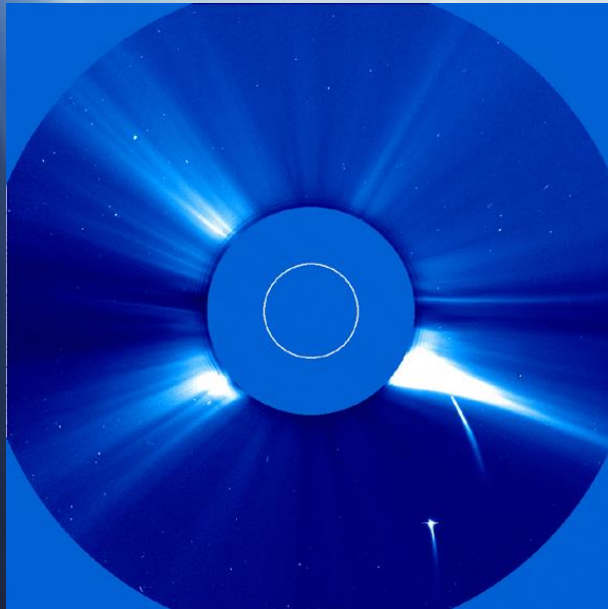
- Jupiter-family: Kuiper belt
 - 20 years.
 - Gravitational perturbations by Neptune
 - Elliptical orbits close to the Sun
 - Or Captured by Saturn as outer satellites

Comets and their periods

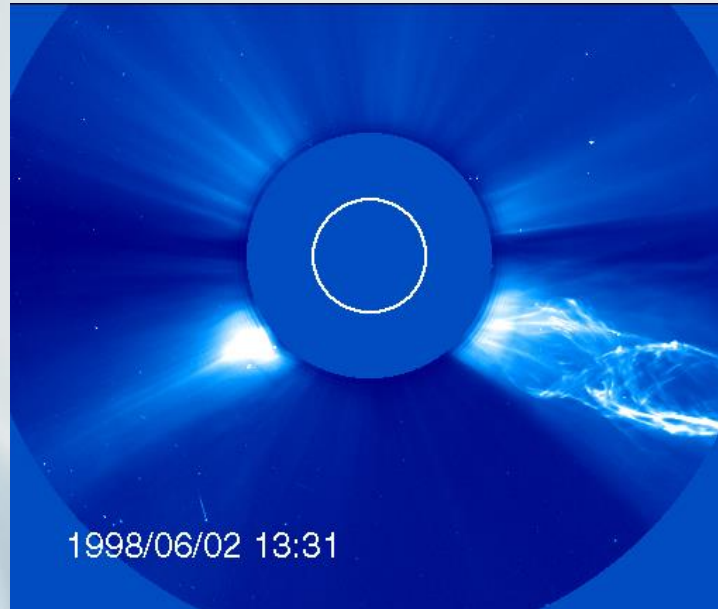
- Oort Cloud Comets
 - Intermediate-periods: period 20 - 200 years
 - Long-periods: period 1-3 million years
 - Orbits steeply inclined to the plane of ecliptic
 - Spend most of their time 10,000 to 100000 AU from Sun
 - About 1 long-period comet is discovered every month
 - It is thought that many of these comets were icy planetesimals that orbited the Sun and were near the Jovian planets when the solar system was formed. Gravity from the Jovian planets catapulted these objects into outer space.

Sun Grazing Comets

- These Comets come very close to the Sun and can also fall into the Sun.



Twin Comets



Eruptive performance

Hydrogen Envelope of Comet

- When the Comet approaches the Sun, its nucleus begins to vaporize creating a hydrogen gas envelope around it. This envelope is not visible to the naked eye.
- The hydrogen in the envelope comes from water molecules breaking up when they absorb the ultraviolet photons from the Sun.
- The hydrogen atoms also absorb ultraviolet photons and can only be detected by space based telescopes (Earth's atmosphere absorbs UV radiation) when they emit back ultraviolet radiation.

Comets Tails

- Ludwig Biermann propose the idea of solar wind to explain comet tails. Mariner 2 spacecraft captured the one such event in 1962.



Comets Tails

- The solar wind produces three Comet tails that point away from the motion of the Comet.
 - The blue ion tails is ionized atoms of CN and C₂.
 - The dust tail is produced when the photons from the Sun strike the dust particles and produce radiation pressure on them. This causes the dust particles to drift away from the come.
 - The effect of solar wind on dust particles is less compared to that on ions, this gives the dust tails a curved shape.
 - The third tail is made up of Sodium and is usually invisible to the unaided eyes.

Basic Physics of Comets

- Comets obey Kepler laws of planetary motion, Newton law's of motion and Newton's law of gravity.
- Nucleus Density = Mass /Volume $\approx 1000 \text{ kg/m}^3$
- From Kepler's 3rd Law the aphelion distance can be determined
 - $(\text{Period in years})^2 = (\text{aphelion distance in AU})^3$

Basic Physics of Comets

- The tidal force on the Comet can be estimated from:
 - $\text{Force} = (\text{Solar Mass})(\text{Comet Radius}) / (\text{distance})^3$
- The brightness of a Comet can be determined from:
 - $\text{Brightness} \propto (\text{distance from Sun})^{-n} (\text{distance from earth})^{-2}$
 - Near the sun $n \approx 4$

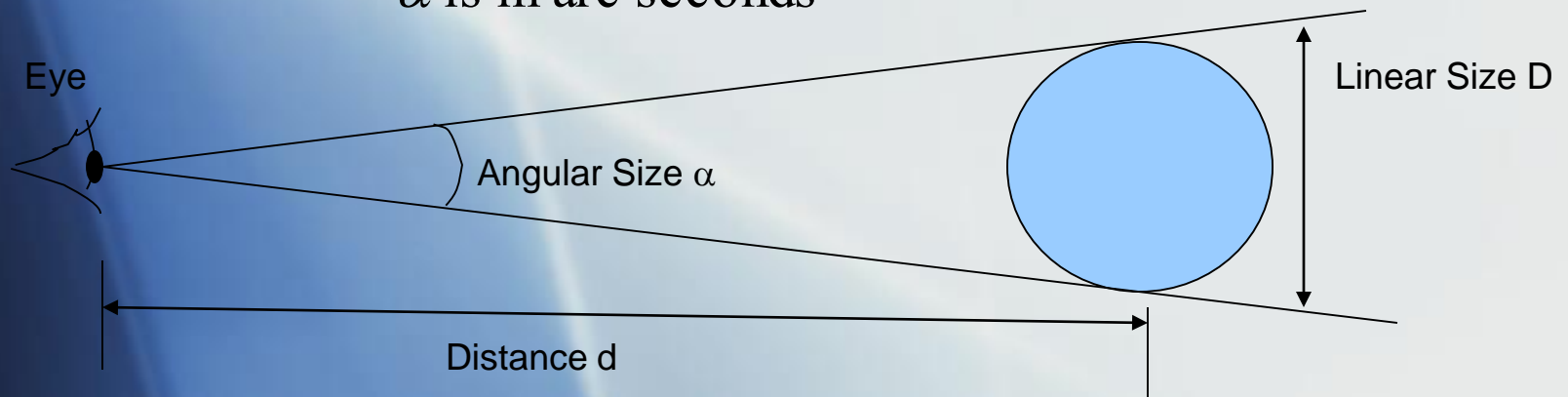
Basic Physics of Comets

- The linear size of any object in the sky can be determined by the small angle formula:

$$D = \frac{\alpha d}{206,265}$$

$$\frac{360^\circ \times 60 \times 60}{2\pi} = 206,265$$

α is in arc seconds



Comets and their Spectra

- Spectroscopy is a technique in which light is broken into its component colors. Each chemical element show their fingerprint in the spectrum of the object.
- We can thus find the composition of Comets by identifying the fingerprints.
- Most of the information on Comets come from Infrared radiation, because Comets are cold objects they radiate strongly at Infrared radiation.

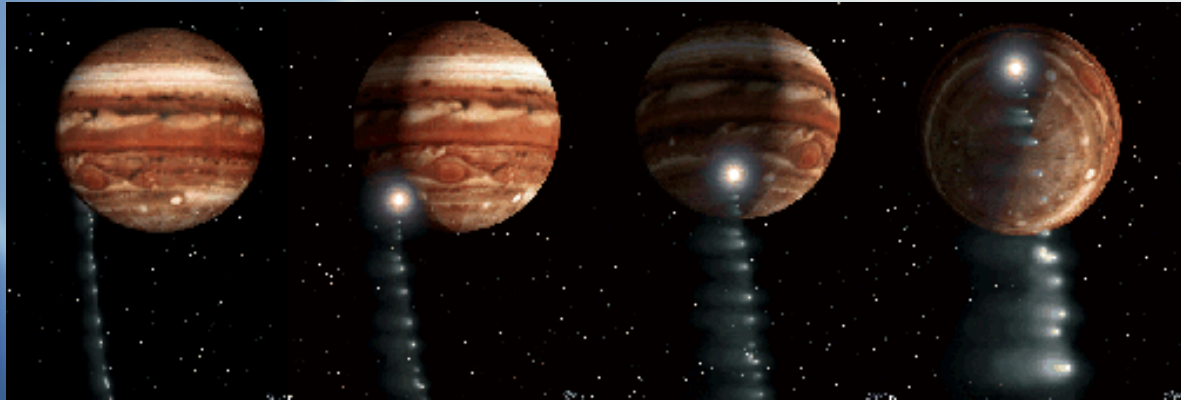
Observed Composition

- Coma
 - H, C, C₂, C₃, CH, CN, HCN, CH₃, NH, NH₂, O, OH, H₂O, Na, K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu plus dust particles with silicates
- Tail
 - CH⁺, CO⁺, CO₂⁺, N₂⁺, OH⁺, H₂O⁺, Ca⁺, plus dust particles with silicates

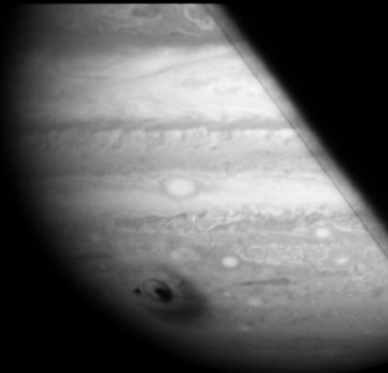
Comet Collisions

- Comet collision with Earth can bring devastation to life on Earth.
- Jupiter in our solar system is the largest planet and thus exerts greater gravitational pull on incoming Comets.
- Study of Shoemaker-Levey collision with Jupiter gave us important facts about Comet collisions.

Comet Collisions

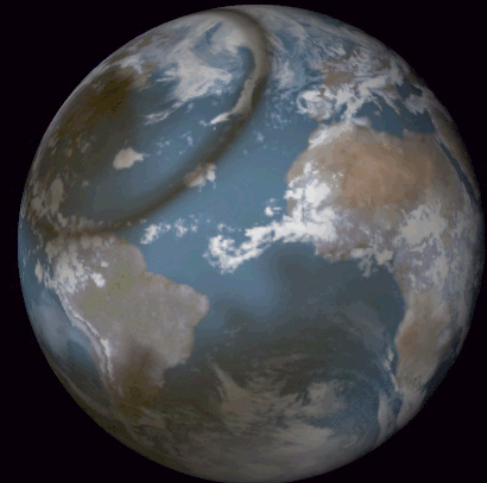


Jupiter
18 July 1994



Hubble Space Telescope
Planetary Camera

Earth 100 minutes after a G-Sized impact



G impact scar reprojected onto Earth, to scale

*From the upcoming book "The Great Comet Crash", edited
by J. Spencer and J. Milton, Cambridge University Press*