Comets

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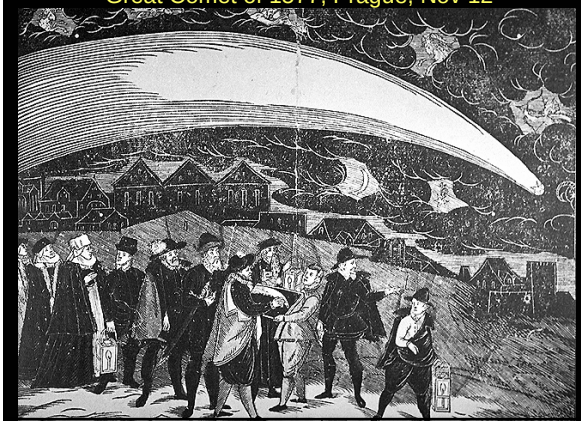
Ancient Ideas about comets

- *kometes* = `the hairy one" (hairy star)
- 550 BC Pythagoreans thought they were wandering planets.
- Aristotle (350 BC) thought that, like meteors, they were phenomenon of the upper atmosphere. This view dominates for 2000 years.
- 1577 AD, Tycho Brahe shows that a bright comet had no measurable parallax, hence must be at least 4x further away than the moon.

Aristotle

Tycho

Great Comet of 1577, Prague, Nov 12



Comets Orbit the Sun

- **1607 Sir William Lower accurately measures positions of what we now call "Halley's Comet". In 1610 suggests orbits are ellipses (?)**
- **1618 Cysat: First to observe structure of comet & evolution. Suggests orbit sun in parabola shape**
- **1665 Borelli is first to accurately describe comet orbit as an ellipse**

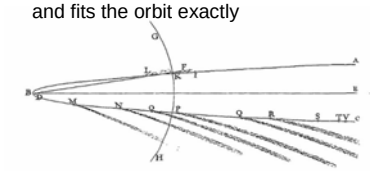
Cysat

Giovanni Borelli (1608-1679)

Great Comet of 1680

- First to be discovered by telescope (by Kirch)
- 1681 Doefel uses data to show orbit is nearly parabolic
- 1687 Newton shows his theory of gravity predicts ellipses/parabolas and fits the orbit exactly

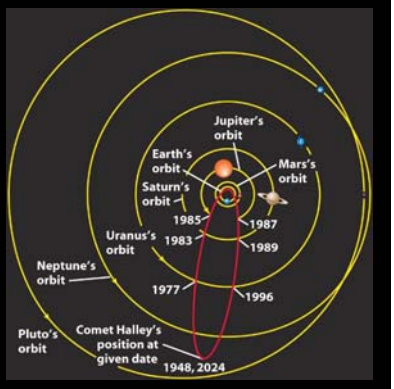
Kirch



Edmund Halley (1656-1742)

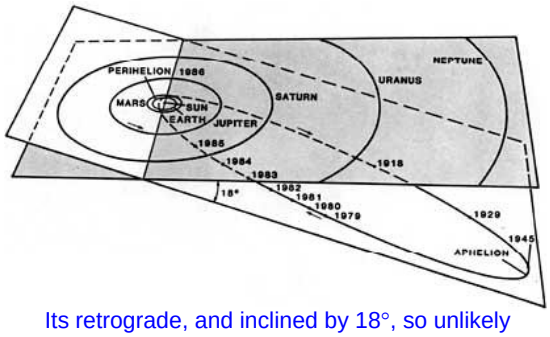
- 1705 proposes that the comets of 1431, 1531, 1607 and 1682 are the same comet, returning every 76 years
- Predicts return in 1758-9
- Comet indeed appears (16 years after his death). Now called "Halley's Comet"

Orbit of Halley's Comet



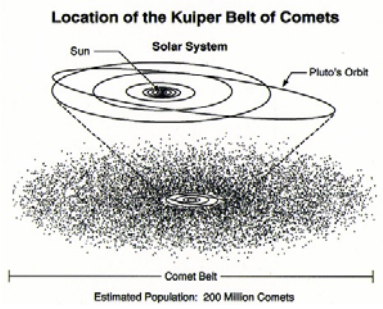
It goes outside the orbit of Neptune (probably originally captured by Neptune)

Orbit of Halley's Comet



Its retrograde, and inclined by 18°, so unlikely to hit the earth as it crosses our orbit

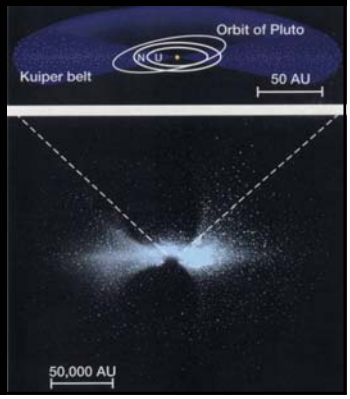
Short Period Comets

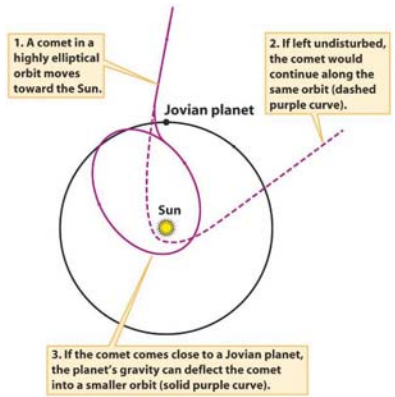


Comets with periods around 200 years or less probably come from Kuiper Belt (e.g. Halley's Comet)

Long Period Comets

Comets with periods around million years or less probably come from the Oort Cloud (500 to 50,000 AU) [e.g. Hale-Bopp]





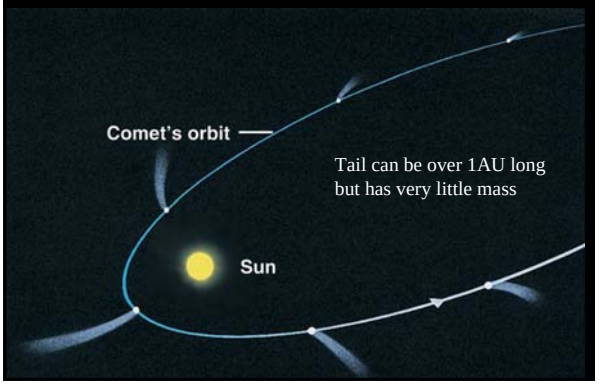
A long period comet can be changed into a short one if it passes near one of the planets

Most comets look like this …

Comet NEAT, showing dust Tail

Comet Bradfield, showing dust Tail

Comet's dust TAIL always points away from sun

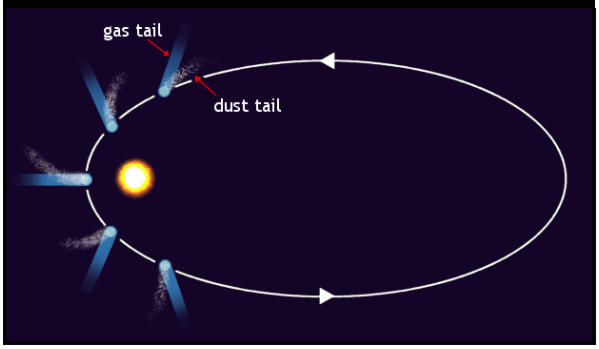


A tale of two tails

ION TAIL (top, blue): ionized gas pushed away from the Sun by the **solar wind.**

DUST TAIL (bottom, white): fine dust pushed away from the Sun by **radiation pressure.**

A tale of two tails

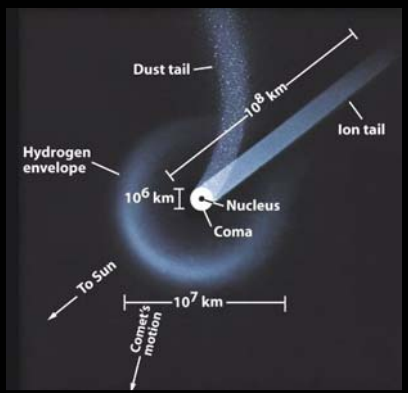


A comet is a dusty chunk of ice that partially vaporizes as it passes near the Sun

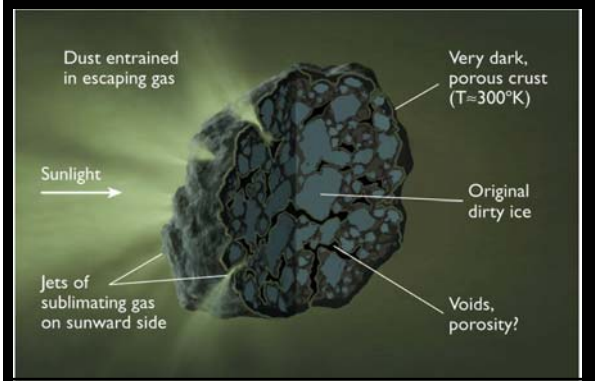
The parts of a comet: Nucleus, Coma, and Tail

Halley's Comet in 1986

As a comet approaches the Sun, its icy nucleus develops a luminous coma, surrounded by a vast hydrogen envelope



The Nucleus of a Comet

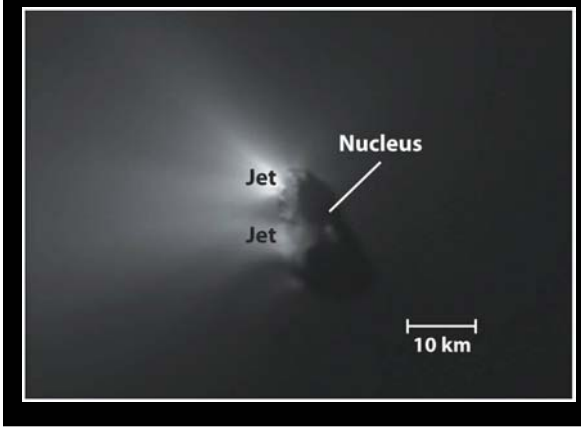


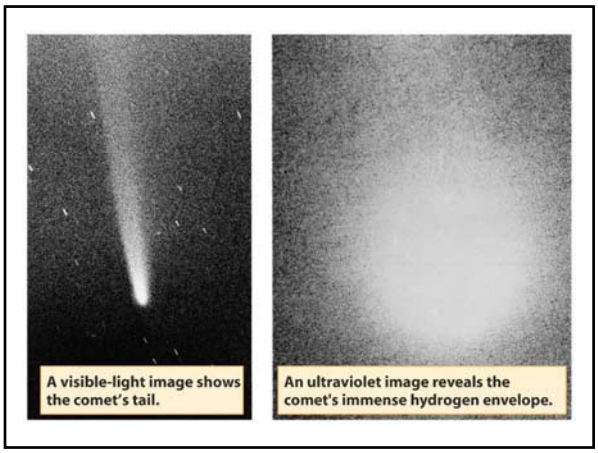
What the nucleus is made of

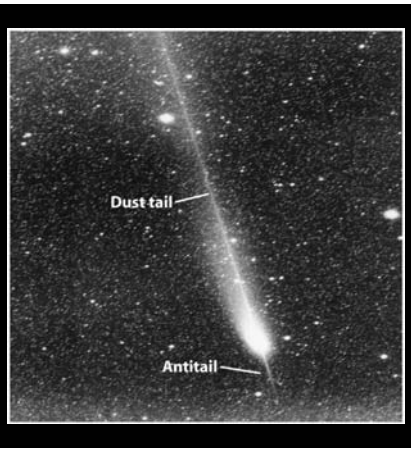
- Ices
  - H_2O, Carbon Monoxide (CO), Methanol (CH_3OH), and other frozen materials
- Minerals
  - Silicate minerals
- Complex organic molecules and dust particles
  - C = carbon
  - H = hydrogen
  - O = oxygen
  - N = nitrogen
- This is the "dirty snowball" concept

The Coma

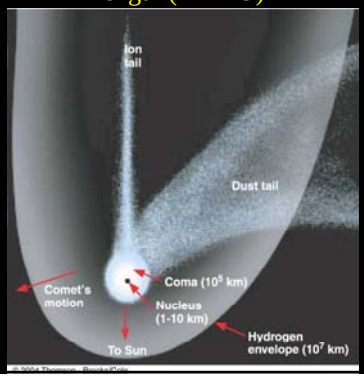
- The ***coma*** is the cloud of gas and dust that <u>evaporates</u> from the nucleus when the comet is close to the Sun and warms up.







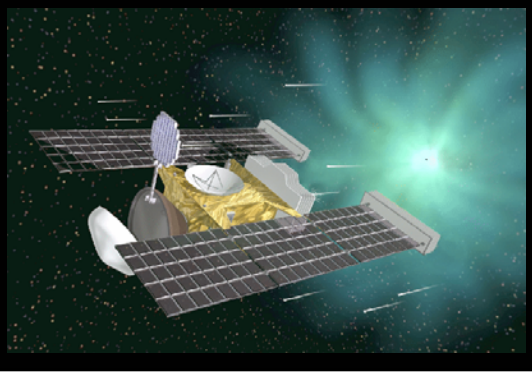
Comet tails can be as much as 100 million miles in length (~ 1 AU)



Three Adventures with Comets

- Comet Shoemaker-Levy 9 collides with Jupiter (July 16-22, 1994)
- NASA's Stardust mission collects comet dust from Comet Wild-2 (January 2, 2004)
- NASA's Deep Impact mission collides with Comet Tempel 1 (July 4, 2005)

Stardust mission to collect comet dust

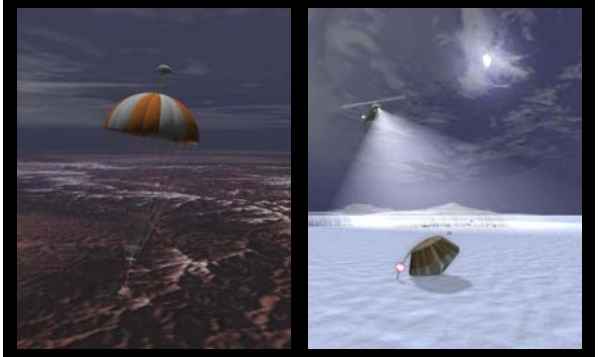


Stardust mission to collect comet dust

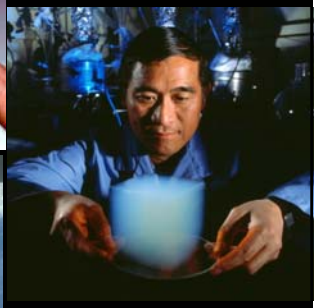
- Comet Wild-2 is an ordinary, short-period comet
- The spacecraft approached the comet and collected dust from the coma
- The capsule containing the dust was returned back to Earth
- It landed in the Utah desert in January, 2005, to be picked up for analysis of the dust grains

The Nucleus of Comet Wild-2

The capsule landed in Utah in January, 2005



The dust was captured in Aerogel in January, 2004



The dust was captured in Aerogel in January, 2004

What are we learning from Stardust?

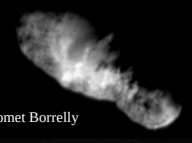
-The comet's nucleus has a surprising amount of minerals that formed in a high temperature environment (but comets are COLD in the outer solar system!). Material formed closer to our Sun or around another star altogether.

-The 4.5 billion-year-old comet sulfides (sulfides are key to life).

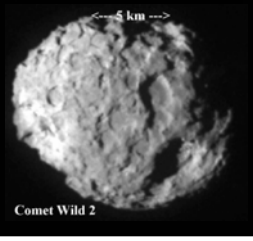
-The comet also contains iron, sulfides, glassy materials, and olivine.

-Carbon bearing compounds are present as well.

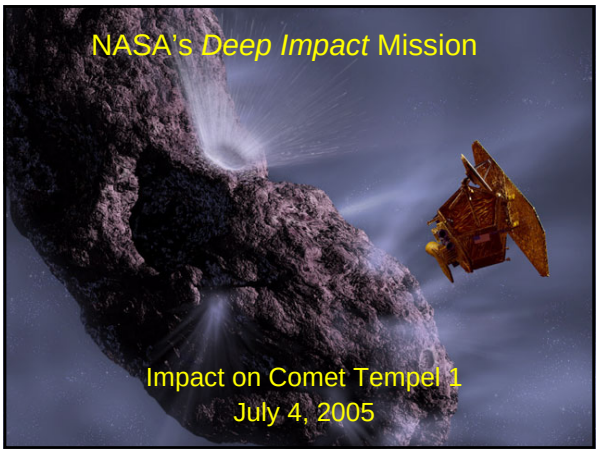
Comparison of comets we have seen up close



Comet Tempel 1



NASA's *Deep Impact* Mission

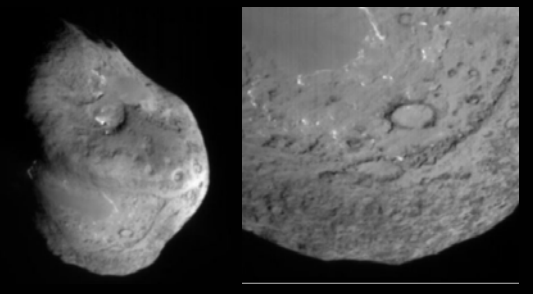


Impact on Comet Tempel 1
July 4, 2005

- ***Deep Impact*** mission was launched in January, 2005
- Impactor (820 pounds) hit the comet at velocity 10 km/sec (~6 miles/sec)
- The energy of the collision vaporized the Impactor
- Impactor took images up to 3 sec before the collision
- The fly-by spacecraft took images before, during, and after the impact
- The fly-by spacecraft was the re-targeted to another comet

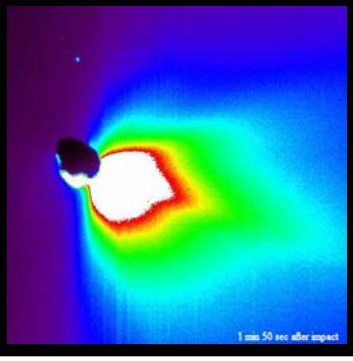
View of Comet Tempel 1 a few moments before impact

Note the craters, ridges, and the entirely unexpected smooth regions (maybe flows of ice)

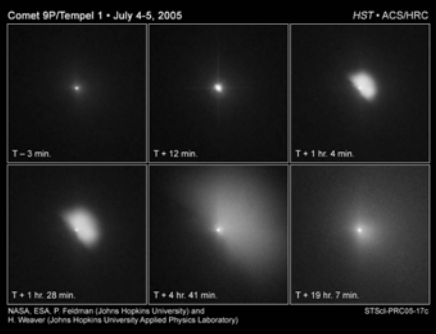


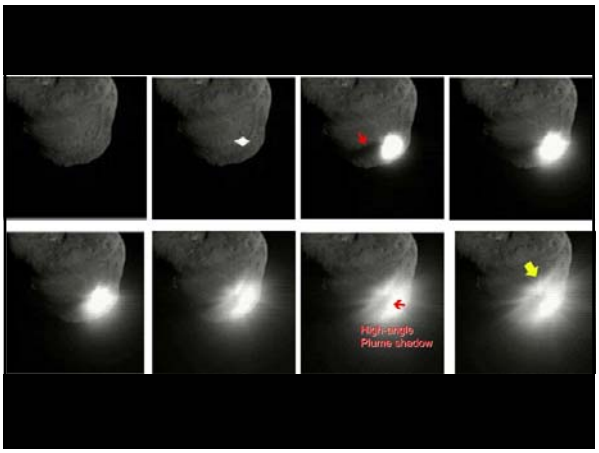
A few moments afte impact

The comet and the spray of debris released by the impact



Pictures of the comet before and after the impact by the spacecraft.





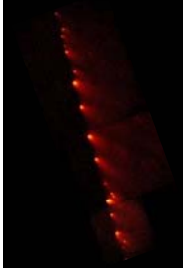
What is being learned?

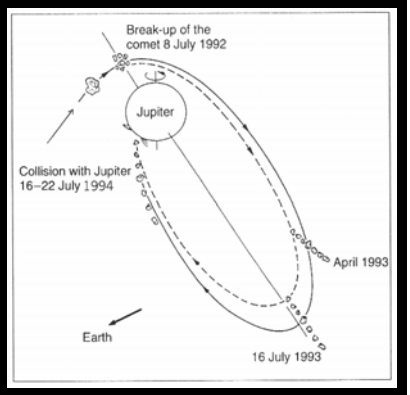
- The comet is not a rigid solid body
- The impact occurred in a “powdery” layer
- A crater about 200 yards across was formed
- The ejected material made the comet brighter, but it dissipated after about two days
- We’re waiting to hear about the composition of the comet’s surface and the material ejected by the impact
- This comet has an appearance quite different from the other three comets we have examined up close
- The impact-induced activity subsided after about 4 days

Comet Shoemaker-Levy 9 collides with Jupiter (July 16-22, 1994)

- In 1993, a cluster of comets was discovered on a collision course with Jupiter
- The cluster had originally been a single comet, but an earlier close pass by Jupiter broke it up into

Here’s what happened …



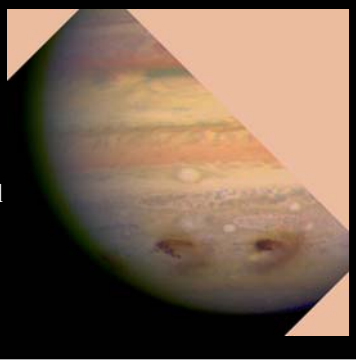


The comet swarm heads for impact on Jupiter

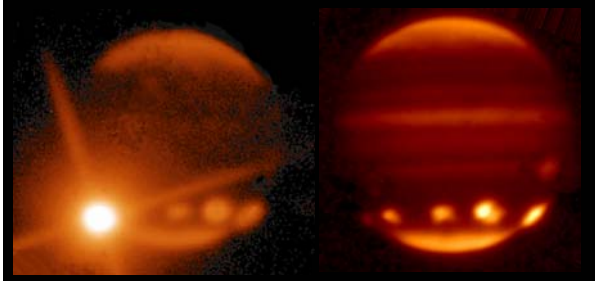
July 1994

Scars in Jupiter’s Atmosphere

The irregular dark smudges are the sites in Jupiter’s atmosphere where two fragments of the comet impacted



The heat from Jupiter
Hot spots from the impact of comet fragments



July 1994

The impact events were predicted a year in advance.

They were observed by astronomers world-wide.

For the first time ever, we had the opportunity to observe collisions between Solar System bodies. 20 of them !!!