

## Comets

The last type of minor solar system object is the one which has been most noticed since deep antiquity...

Comet Hale-Bopp in spring of 1997



## Reasons why comets were feared and considered omens prior to modern times

- They had a different appearance than other astronomical objects
- They appeared unexpectedly
- They (seemed to be) not periodic phenomena
- Their paths across the sky did not stick to the ecliptic (noted by Seneca in the first-century CE book *De Cometicis*)



## A prominent naked eye comet will appear about every 5 years



Comet West, 1975



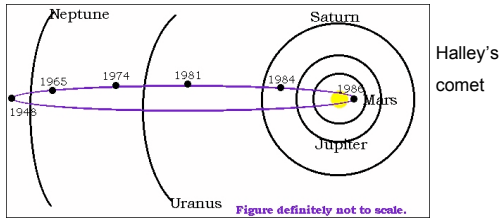
Comet Ikeya-Seki... spectacular in Iowa in fall of 1965

## Aspects of comets that we will discuss

- Orbits of comets
- Structure (or composition) of comets
- Where comets come from

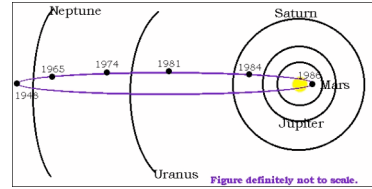


Orbits of comets... comets travel on highly eccentric elliptical orbits



There is a great difference between perihelion and aphelion. The aphelions are far out in space

The orbit of Halley's comet is not particularly eccentric by the standards of comets. Long period comets typically have eccentricities in excess of 0.990 and semimajor axes greater than 150 au



However, comet orbits are not hyperbolic (also a possibility according to laws of physics). They are highly eccentric ellipses. That means they are contained in the solar system

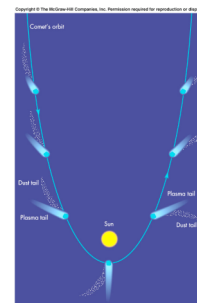
Example: Comet Hale-Bopp

- A (semimajor axis) = 187.00 au
- E (eccentricity) = 0.9951123
- Orbital period=2,557 years

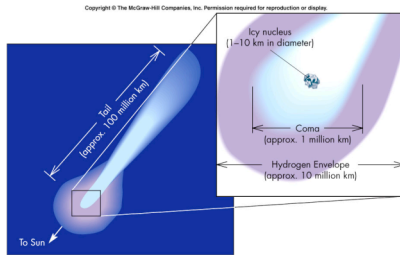


Observations show that comets only "light up" when they come within about 3 au from the Sun

The nature of their orbits, plus an application of Kepler's second law of planetary motion, means that comets are essentially invisible most of the time



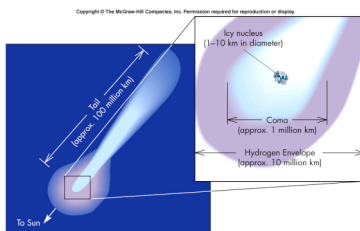
## The structure of comets



Structure deduced by Fred Whipple in 1940s. The real essence of a comet is a tiny nucleus buried inside the coma

The coma and the rest of the comet is formed from the nucleus by *sublimation* of the ices that make up the nucleus. Sublimation is a process by which a gas changes directly into a gas. A common example is the sublimation of solid carbon dioxide (dry ice) directly into carbon dioxide gas

The incredible fact about comets is that an astronomical object that sometimes can be seen to span an astronomical unit in size originates from a small object that can be only a few kilometers in diameter

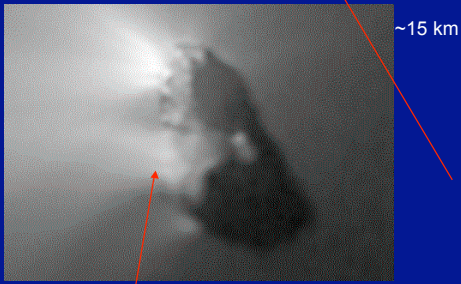


Whipple's model of a comet was a conjecture for many decades. From Earth, you see only the coma of a comet. The nucleus is too small, and too obscured by the coma to be seen.

This situation changed in 1986, when the *Giotto* spacecraft flew by the famous Halley's comet

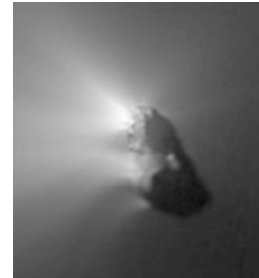


### The nucleus of Halley's comet



Jets of material forming the coma and rest of the comet

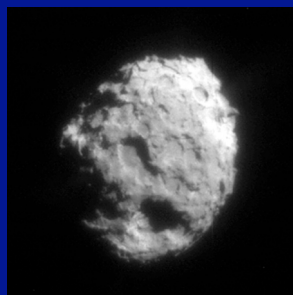
This object has been returning to the inner solar system every 76 years, and producing Halley's comet, since at least the time of the Roman Empire



### Since the 1980s, spacecraft have taken close up images of several other comet nuclei

This image taken by the *Stardust* spacecraft. *Stardust* returned to Earth with pieces of this comet

Cometary nuclei are covered with a dark, probably organic substance similar to that in carbonaceous chondrite meteorites

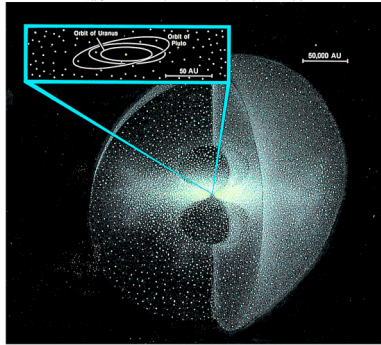


### The Oort Cloud (conclusions reached by Jan Oort in the 1920s)

- Comets are a common occurrence; one is in the inner solar system every few months
- The fraction of the time that a comet spends near the Sun is, by Kepler's 2nd Law, tiny
- We don't see comets at all unless they come within a few astronomical units of the Sun
- The orbits of most comets show that aphelion occurs hundreds to thousands of au from the Sun
- Conclusion: we are seeing only the tip of an iceberg of comets from deep space
- The "reservoir" of comets is called the "Oort Cloud"

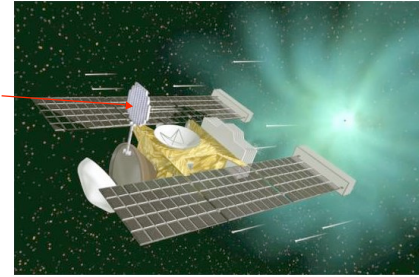
## The Oort Cloud

Estimates of content of Oort Cloud: > a trillion comets ( $10^{12}$ )



## The Stardust spacecraft and pieces of a comet

"paddles" for collecting pieces flaking off from the comet



## Characteristics of the "Stardust" mission

- Launch: February 1999
- Encounter with comet Wild 2: January 2004
- Sample return to Earth: January 2006
- Spacecraft used "paddles" of "aerogel" to slow down and snag cometary particles without shattering them

A sample piece of a comet from Stardust

