Comet Exploration and Beyond

On December 22, 1983, the ISEE-3 spacecraft whipped by the moon and headed off on a new orbit designed to intercept the Giacobini-Zinner comet in late 1985 (see figure). After having completed this maneuver by passing just seventy miles above the moon's surface, the spacecraft was renamed ICE (for International Cometary Explorer) and its mission was switched from an exploration of the earth's magnetotail to an exploration of the local environment of a comet.

Comets are formed under conditions totally different from those that lead to the planets of our solar system. They appear to consist principally of ice mixed with dust, though cold chemistry within them has also produced more complex molecules such as methane, ammonia, and cyanogen.

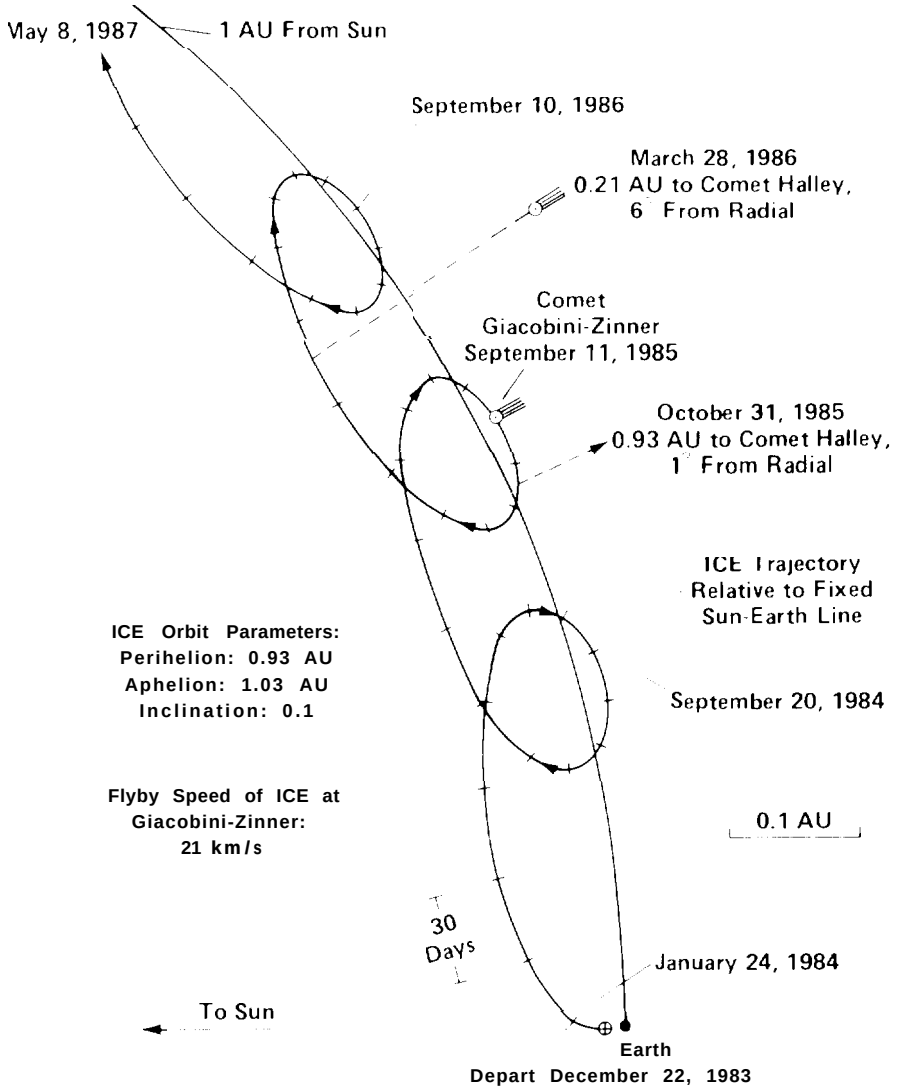
Giacobini-Zinner is an old, relatively small comet that passes by the earth approximately every thirteen years. The comet's glowing head of gases and dust blowing off its core reaches a visible size of 50,000 kilometers (intermediate in size between the earth and Jupiter) and then tapers into a tail that stretches out nearly 800,000 kilometers, Like other comets, Giacobini-Zinner is believed to have been formed in the vast reaches of space beyond Pluto and then pulled into our solar system by gravity. It has been observed since 1900, trapped in a circuit between the sun and the orbit of Jupiter.

The comet will be met by ICE within 70.8 million kilometers of earth. Because its orbit is known to vary as much as half a million kilometers from one solar passage to the next, astronomers will be working to pin down its precise orbit. At the time of intersection (September 11, 1985), the spacecraft hopefully will pass through the comet's tail within about 3000 kilometers of its head.

The likelihood of encountering dust from the comet's core in this close approach may result in damage to the spacecraft instruments. However, the danger is expected to be minimal since the earth has moved across Giacobini-Zinner's debris path several times in the past and encountered spectacular meteor showers, but with relatively short path lengths indicating small particle size for the dust.

As ICE moves through the tail, its instruments will provide the first *in situ* measurements of a comet and its environment. We hope to measure the nature and rate of ionized-gas release and learn how the comet's head and tail are affected by the solar wind. Two questions of particular interest are whether a bow shock forms upstream in the solar wind and whether the solar wind interaction accounts for the mysteriously high rate at which ionized material spews from a comet. The loss rate is known to be ten times higher than can be explained by evaporation due to solar radiation. It will also be interesting to search for magnetic reconnection in the tail.

The passage of Giacobini-Zinner in September 1985 will be followed only a few months later by Halley's comet. Observations of both comets will offer an un-



Trajectory of the ICE spacecraft after its lunar boost (bottom) on December 22, 1983. Here the line from earth to sun has been fixed in space, and we see that the relative motion of the spacecraft takes it around the sun with a radius of about one astronomical unit (AU), but in a manner that causes it to spiral ever further from earth. ICE will cross through the tail of the Giacobini-Zinner comet on September 11, 1985 and will make observations of Halley's comet from upstream positions in the solar wind around October 31, 1985 and March 28, 1986.

paralleled opportunity to compare two quite different visitors from interstellar space. Halley's comet is younger, larger, and moving faster than Giacobini-Zinner. As it passes the earth every seventy-six years, the size of its head becomes nearly as large as Jupiter, and its tail stretches 100 million kilometers. Significant differences between the two comets are expected in composition, structure, and their interaction with the solar wind.

To study Halley's comet, Russia, the European Space Agency, and Japan will launch a fleet of probes ahead of its path. Five spacecraft will make visible and ultraviolet images of the comet's sunlit core, measure the dust it throws off, and detect any bow shock the comet may create in ramming its way through the solar wind.

ICE will also make measurements near Halley's comet by moving to two positions upstream of the comet after leaving Giacobini-Zinner (see figure). The first position (October 31, 1985) will place the spacecraft 138.4 million kilometers from the comet and 76 million kilometers from the earth; the second (March 28, 1986) will place it 35 million kilometers from the comet and 96.5 million kilometers from the earth. From both upstream positions ICE will collect data on the solar wind a day or so before the plasma reaches the comet. The effect of this measured solar wind on the comet will then be observed both by the international probes close to the comet and by telescopes on the earth.

This spacecraft's exploration of the magnetotail and two comets will conclude in 1987, almost a year after its final observation of Halley's comet. Though it will continue measuring the interplanetary solar wind, the spacecraft by this time will be 121 million kilometers from earth. At this point radio signals from its low-gain antennas, originally designed for use only to a distance of 1.6 million kilometers, will be growing too weak to be detected. ICE will return to near-earth orbit in 2015 as gravity pulls it around the sun-earth system. ■