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Comet Halley

The View From Pioneer Venus

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Of Space, Not of Earth

Edmond Halley, scientist friend of Sir Isaac Newton, placed comets in their rightful place as celestial rather than terrestrial objects. Using observations of the bright comets of 1531, 1607, and 1682, he applied Newton's method of computing orbits of celestial bodies to calculate the paths of these comets. From the similarity of their elliptical orbits he concluded that these comets were one and the same comet which visits the inner Solar System every 75-76 years. Earlier beliefs that comets were atmospheric phenomena akin to meteors and aurora were finally totally dispelled when the comet again returned in 1758 and made a close approach to Earth as Halley had predicted.

Later, other astronomers searched ancient records and traced observations of the same comet back into the Middle Ages and ultimately to comets recorded in China and Babylon as long ago as 240 B.C. Sometimes its passage through the inner Solar System coincides with a favorable position of Earth from an observational point of view. At such times the comet becomes a splendid object in the sky. At other apparitions, such as the current one in 1986, the comet not only fails to pass near to Earth but also passes through perihelion, its closest approach to the Sun, on the far side of the Sun from Earth. The most active and spectacular period of the comet's passage, generated by solar radiation, is then hidden from Earth by the intervening brilliance of the Sun itself.

Comets are important to study because they are thought to preserve a record of the primordial nebula out of which the Solar System and its planets formed. Because comets spend most of their time in the cold outer reaches of the Solar System they are believed to preserve the record better than the planets do, since planets are subject to other modifying processes. Information on cometary ingredients can provide important clues about the early chemical and physical history of the Solar System.

Several spacecraft are headed for Halley's Comet on its current return, but they have all been targeted to intercept the comet when it is close to the plane of Earth's orbit, many weeks after perihelion.

Only one spacecraft is situated to observe Halley at its perihelion when it will be most active; Pioneer Venus orbiting the planet Venus. This spacecraft will be on the far side of the Sun at the time of Comet Halley's passage.

Another First for Pioneer

The Pioneer program has achieved many pioneering feats in the Solar System. The Pioneer 10 spacecraft was first to show that a spacecraft could pass safely through the asteroid belt. It became the first spacecraft to explore the giant planet Jupiter and its planet-sized moons. Pioneer 11 was first to explore the ringed planet Saturn. Pioneer 10 also became the first spacecraft to escape from the Solar System into the interstellar void carrying a message to possible extraterrestrials. Venus Pioneer probes penetrated the enormously dense atmosphere. The Pioneer Venus Orbiter charted the complex surface features, and observed for many years the particles and fields around the planet and their interaction with the solar wind.

The spacecraft that will observe Comet Halley is *Pioneer Venus Orbiter.* This highly reliable spacecraft is still gathering data about Venus and its interaction with the Sun to a high order of accuracy. It has already observed two other comets using an instrument that collects ultraviolet radiation from them: Comet Encke in April 1984 and Comet Giacobini-Zinner in September 1985. Giacobini-Zinner was observed just after the comet passed perihelion and when the comet was about 100 million miles (161 million km) from the spacecraft and just beyond Earth's orbit. Measurements were made simultaneously with the passage of the ICE spacecraft through the comet's tail.

The Pioneer Venus Orbiter discovered that Encke was losing water at a faster rate than expected. The observation suggests that water ice and dust are distributed unevenly in cometary nuclei. Also the observations showed that Giacobini-Zinner is much more active than Encke, but less active than is expected of Halley.

Pioneer Venus observations also detected Lyman alpha ultraviolet emissions from the hydrogen coma as far as three million miles (5 million km) on either side of the nucleus of Giacobini-Zinner.

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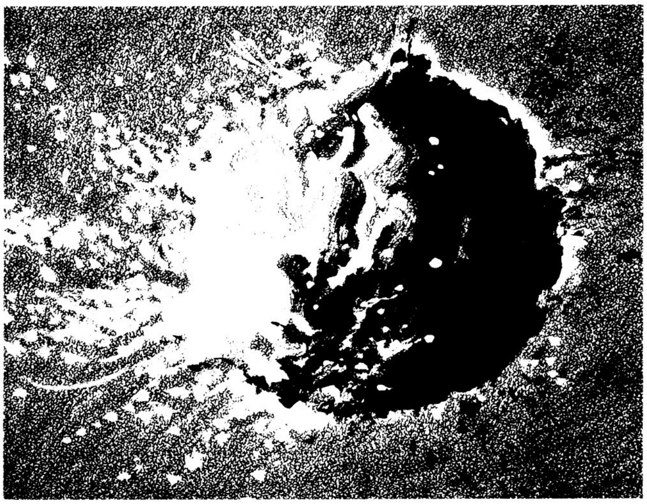
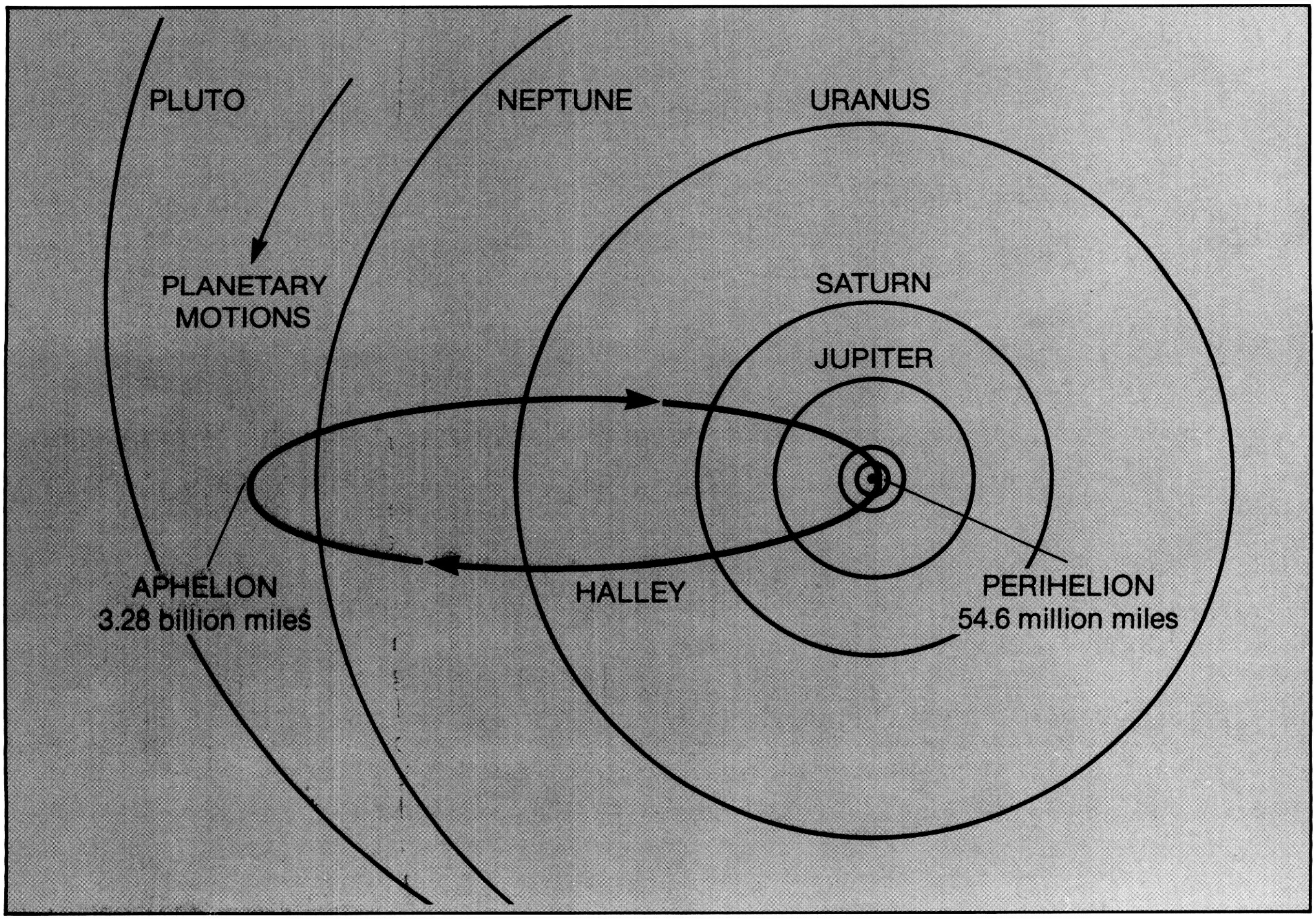
Perihelion Passage

Comet Halley moves around the Sun opposite to the Earth's motion and on an elongated elliptical orbit which is inclined 18 degrees to that of the Earth. The comet's greatest distance from the Sun (aphelion) in 1948 was 3.28 billion miles (5.28 billion km), which is beyond the orbit of Neptune. The comet's closest approach to the Sun (perihelion) on February 9, 1986, will be 54.6 million miles (87.9 million km), which is inside the orbit of Venus.

The comet consists of a nucleus which is believed to be an irregularly shaped, roughly spherical body with a diameter of about five miles (eight km). From observations of the sunlight reflected from the nucleus, astronomers conclude that the nucleus of Comet Halley is rotating about once in 2 to 3 days. This nucleus is thought to consist of ices — predominantly water ice — mixed with rocky dust particles, a mixture that has been likened to a dirty snowball. This description was confirmed by the observations of Giacobini-Zinner.



A cloud of gas and dust is released from the comet's nucleus as it approaches the sun.



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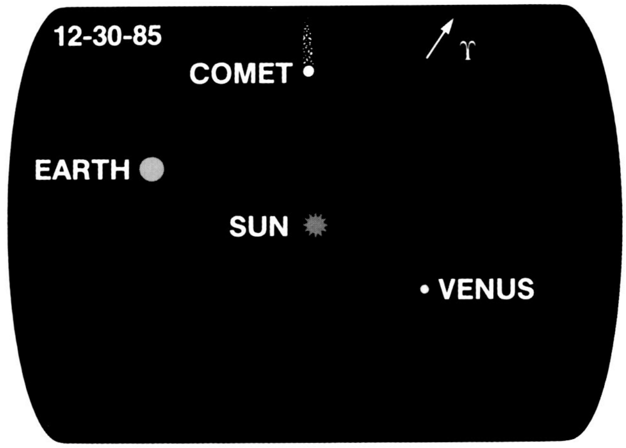
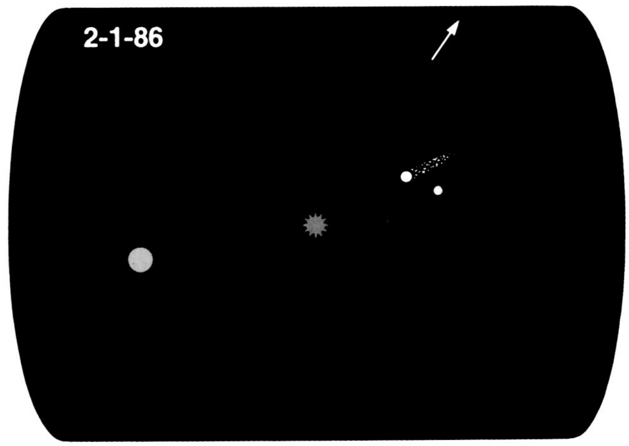
As the comet approaches the Sun, solar radiation heats the surface of the nucleus and changes the ices into gas, thereby releasing a cloud of gas and dust which spreads outward around the nucleus. This cloud is referred to as the coma. Sunlight reflected from the gas and dust of the coma produces the visible comet seen from Earth in the night sky. The nucleus is too small to be seen, but the coma can extend around the small nucleus for tens of thousands of miles. The coma reaches its greatest size when a comet is about twice Earth's distance from the Sun. The visible gas cloud is thought to consist mainly of carbon-bearing molecules with traces of other gases. The water vapor is not visible because of its transparency, but is inferred from ultraviolet observations.

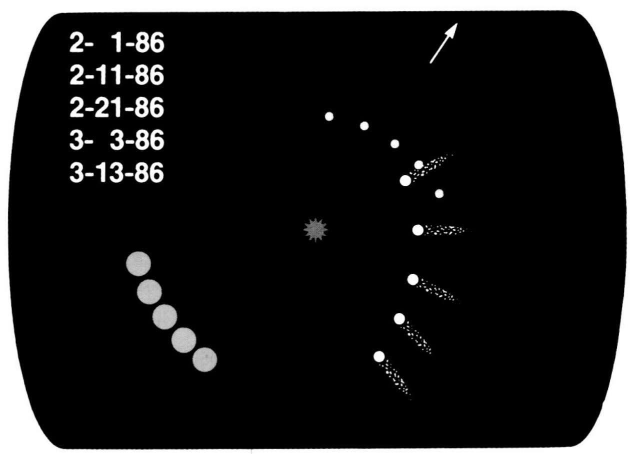
Material that forms the coma emerges from the nucleus irregularly, and as the material is pushed from the nucleus into the coma it acts as an array of weak rocket jets to affect the rotation rate and orbital motion of the comet. Jets from Comet Halley, confirmed in detail by new image-processing techniques applied to 1910 photographs, reveal dust particles spiraling outward into the coma. Jets from the nucleus, in addition to gravitational effects of the planets, change the comet's orbit. In the 30 recorded appearances of Halley's Comet it has sometimes taken just over 74 years to return to perihelion, while at others it has taken nearly 80 years.

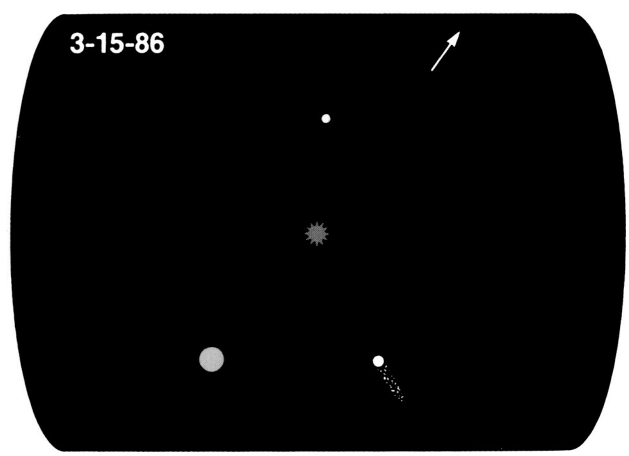
Surrounding the visible coma, and traveling with it, is an invisible hydrogen cloud extending for millions of miles around the nucleus of the comet. The presence of hydrogen, oxygen, and carbon atoms was speculated from theory, but direct observation required ultraviolet-sensitive instruments. The halo was confirmed by spacecraft observing ultraviolet light from comets.

Action of solar radiation on the coma produces two tails, a dust tail and a plasma or ion tail, both of which grow as the comet approaches the Sun. These tails point away from the Sun. Plasma tails are wispy in appearance; dust tails are smooth. The dust particles in the tail are accelerated by solar radiation pressure and move relatively slowly away from the comet. As a result the dust tail tends to curve away from the comet because the comet's speed changes along its elliptical









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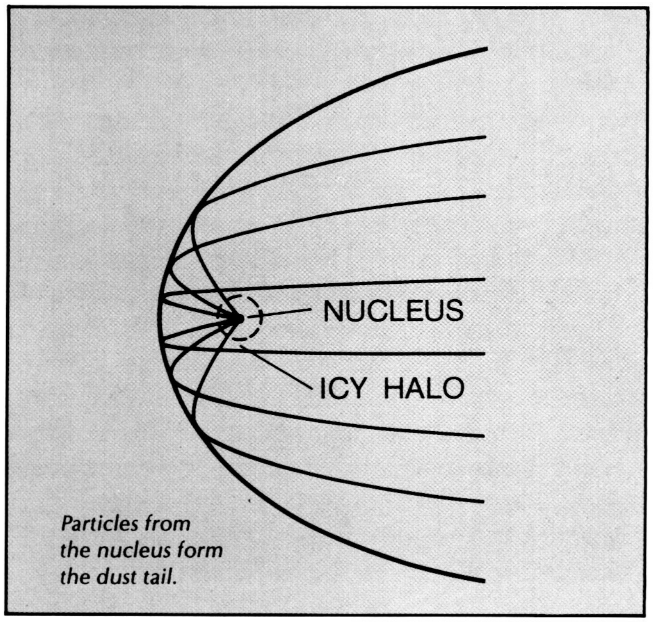
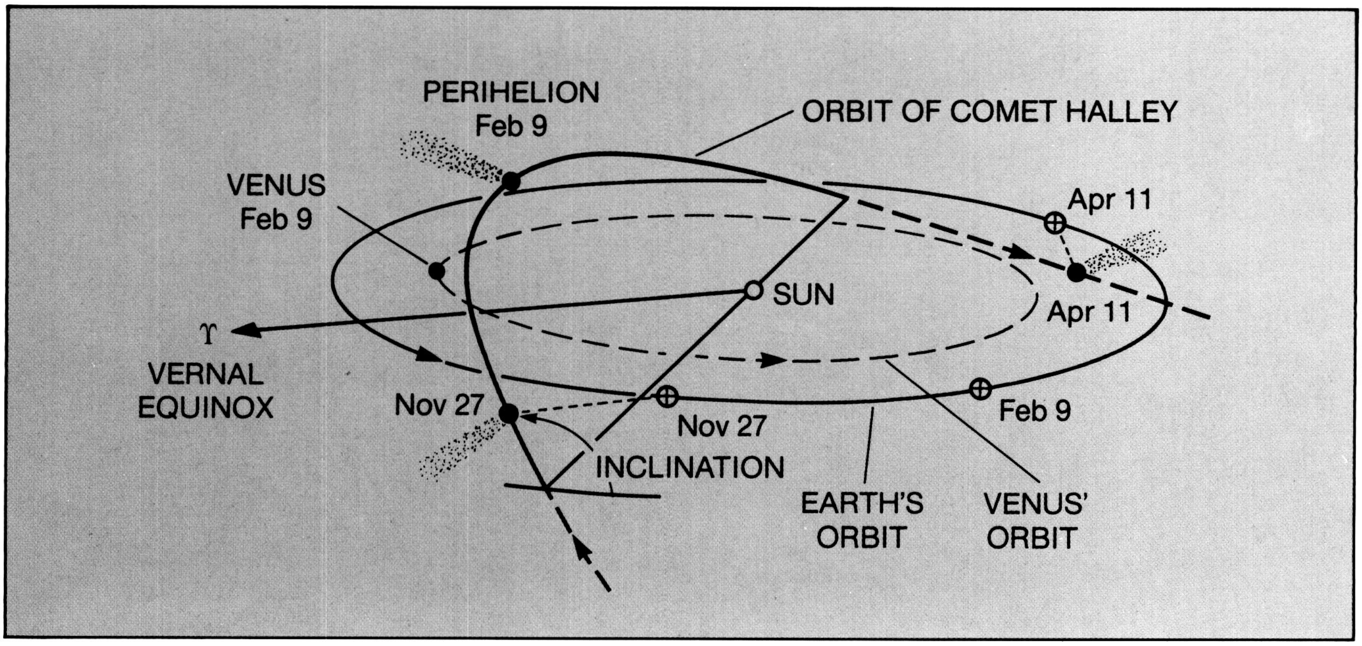
path. The dust tail can appear as a fan-shaped nebulosity when it is viewed broadside because dust particles of differing masses are accelerated to different velocities. The ion tail moves very much faster and is relatively straight. It results from solar radiation ionizing neutral molecules, and the resulting electrically charged ions being accelerated by the magnetic field of the solar wind at its enormous velocity of hundreds of miles per second. The ion tail stretches millions of miles from the comet in a direction away from the Sun. The dust tail is much shorter. Tails usually begin to develop when a comet is about one and a half times Earth's distance from the Sun (1.5 astronomical units or 140 million miles, 225 million km). Before its tail forms, a comet is a fairly inconspicuous, nebulous blob of light.





The View from Pioneer Venus

On February 9, 1986, Comet Halley will hurtle at over one hundred thousand miles per hour within 54.6 million miles (87.9 million km) of the Sun before starting its outward journey again. At the perihelion passage solar radiation will have maximum impact upon the nucleus. The blizzard of charged particles and associated magnetic fields of the solar wind will tear at the hydrogen halo and the coma. At this time the comet will have passed by Venus; its closest approach to Venus being February 4, 1986, five days before perihelion. At the time of closest approach to Venus, the comet will be above the plane of Venus' orbit and some 25 million miles (40 million km) from the planet, between the planet and the Sun.

Preparing for the unique opportunity to observe Comet Halley at close range during its perihelion passage, the Pioneer Missions Operations Team will send commands to the spacecraft to change the tilt of its spin axis. Pioneer Venus Orbiter spins on this axis five times a minute as it travels around Venus. Thrusters on the spacecraft will fire at a predetermined time in each spin so as to tilt the spacecraft to the desired

Lick Observatory photograph

position for its ultraviolet instrument to scan the comet instead of Venus. A similar maneuver was successfully made in 1984 to inspect Comet Encke and in 1985 to inspect Comet Giacobini-Zinner. The thrusters will fire about 100 half-second pulses to move the spin axis.

Because the ultraviolet spectrometer carried by Pioneer was designed with a small field of view to map variations in Venus' atmosphere, a general picture of the comet can be gathered as a series of strips, one each spin, with the comet moving slightly between each spin to expose a sequence of strips along its length. The ability to scan at high resolution across the comet's coma, tail, and hydrogen halo, allows the distribution of particles and gases to be determined. The ultraviolet data recorded by this instrument will be studied by scientists at the University of Colorado, Boulder. There, a team of researchers, headed by Dr. A. Ian F. Stewart, the principal investigator for the ultraviolet spectrometer instrument on the Pioneer Venus Orbiter, will use the new data to learn more about the makeup, evolution, and activities of the comet.

This spectrometer, one of many scientific instruments carried by the Venus Orbiter, detects light in the ultraviolet region of the spectrum. Most atoms emit ultraviolet light when exposed to sunlight. By measuring the wavelength and intensity of the emitted ultraviolet light, researchers can determine which elements are in the comet and in what relative quantities. Thus, data from this experiment will inform us of the comet's gas composition, its water vaporization rate, and the ratio of gas to dust in the coma and in the nucleus.

Comets are thought to be frozen remnants of the material that formed the Sun and the planets, so information on cometary ingredients can provide important clues about the early chemical and physical history of the Solar System.

Objectives of the ultraviolet experiment are to determine the composition of the gaseous coma and to measure the total gas production rate of the comet continuously during its passage through perihelion and, in particular, the rate at which water sublimates from the nucleus. This can be established by measuring the ultraviolet emission from hydrogen, oxygen, and the hydroxyl radical in the coma and thereby determine the relative amounts of these gases. Nitrogen, carbon, sulfur, carbon monoxide, and carbon dioxide will also be searched for.

Such observations through the perihelion passage are very important to ascertaining the effects of solar radiation and the solar wind upon the comet. Rapid and large changes of the angle at the comet between the Sun and the spacecraft during about two months of observations will allow scientists to investigate the way light is scattered by the dust at different phase angles to help estimate the density and distribution of sizes of dust particles.

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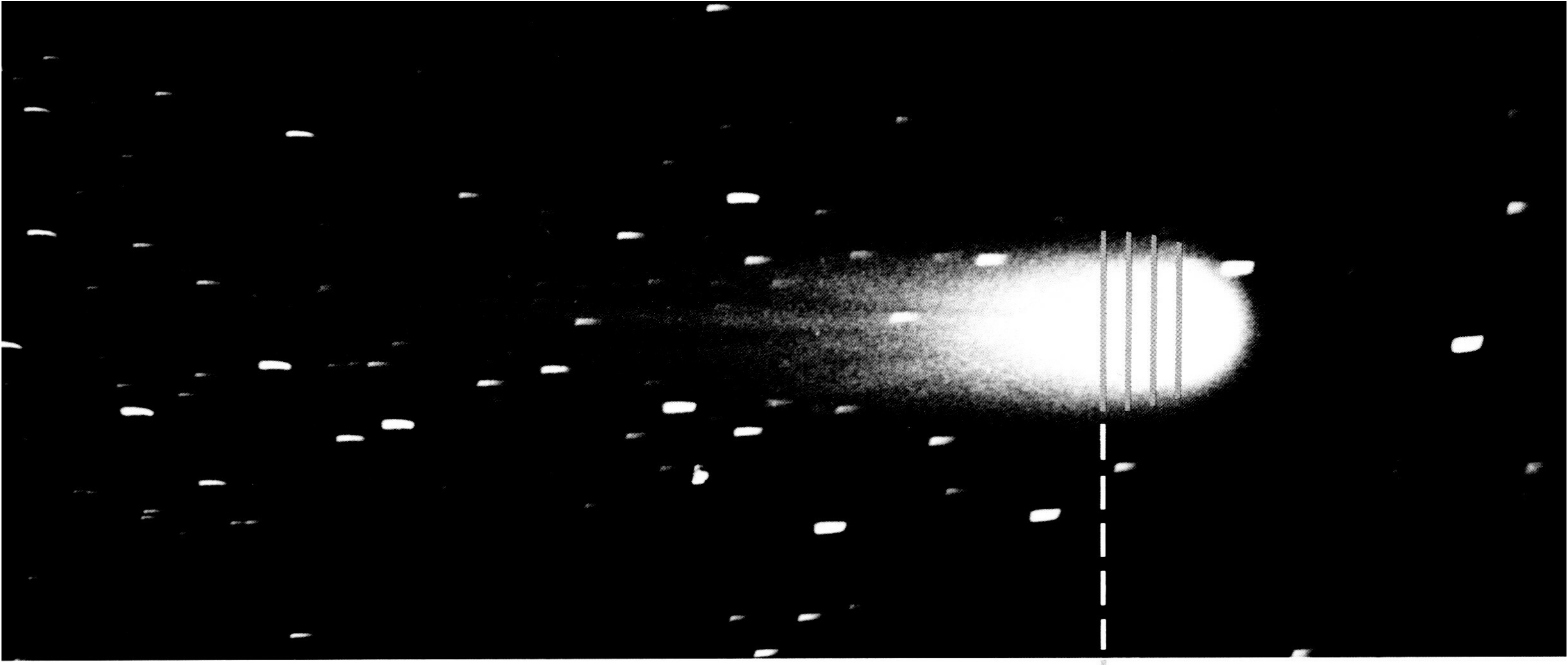
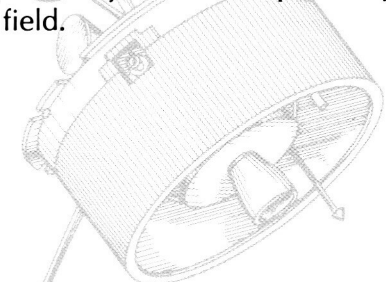


Pioneer Orbiter will observe Comet Halley in detail for about five weeks in February and March 1986. During that time the comet will travel at high speed away from Venus. It will be about 25 million miles (40.2 million km) from the spacecraft at the time of perihelion passage on February 9, and some 125 million miles (200 million km) away when the observations end about March 6. The Orbiter will also make long-range, less-detailed observations of the comet in December 1985. Through the month of January 1986, comet observations will be curtailed by solar interference with communications as Venus passes on the far side of the Sun from Earth.

In addition, the spacecraft will continue monitoring the solar wind with particle and fields sensors to provide important data on the state of the wind affecting the comet for correlation with observations by other spacecraft and ground-based observers. Pioneer Orbiter has a special relationship to the study of comets' interactions with the solar radiation and plasma wind, because it has been used since late 1978 to study *in situ* just such interactions of the wind with the planet Venus. Like comets, Venus is unprotected from the solar plasma by an intrinsic planetary magnetic field.



Expected Results

Ultraviolet spectra at much closer range than possible from Earth will be obtained during the perihelion passage and the post-perihelion period. These will be correlated with observations by Earth-orbiting astronomical observatories where possible. Materials present in the coma and tail will be identified, and the rate these materials are evaporated from the nucleus and within the coma will be established. Changes in evaporation rate and gaseous components will help us understand the uneven composition of the nucleus. Substances not previously identified in comets may be discovered, thereby providing a more detailed description of the composition of the nucleus, and hence of primordial material of the Solar System. From these data, scientists expect to obtain a better understanding of the chemical processes taking place in the inner coma and how the coma reacts with the solar wind.

Coupled with ground-based observations and observations from other spacecraft on inbound and outbound legs of the comet's path, Pioneer Venus Orbiter will help provide another important piece of the jigsaw puzzle of how solar systems are formed and how planets develop to the point at which they can support biological systems with the ability to question their own origin and purpose.

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Halley's Comet

Orbital inclination	162 degrees 18 degrees retrograde
Orbital period	75 years
Longitude of ascending node	58 degrees
Argument of perihelion	112 degrees
Semi-major axis	17.9185 A.U.
Perihelion passage distance	9 February 1986 0.5871 A.U. 54.6 million miles 87.9 million km
Aphelion passage distance	1948 35.25 A.U. 3.28 billion miles 5.28 billion km
Earth close approaches	27 November 1985 0.62 A.U. 57.6 million miles 92.7 million km
	11 April 1986 0.42 A.U. 39.0 million miles 62.8 million km
Venus close approach	4 February 1986 0.27 A.U. 25.1 million miles 40.4 million km

(Note: one A.U. is 92,900,000 miles (149,500,000 km), the mean distance of Earth from the Sun.)

Pioneer Venus Orbiter

Launched	20 May, 1978
Arrived at Venus	4 December, 1978
Weight	824 lb 374 kg

The Pioneer Orbiter is controlled and managed from NASA Ames Research Center, Moffett Field, California.
Project Manager, Richard O. Fimmel
Science Chief, Roger A. Craig
Space Operations Office Chief, John W. Dyer
Flight Director, Robert W. Jackson
Assistant Flight Director, David W. Lozier
Trajectory Analyst, James A. Phillips
Power Systems and Hardware, Martha A. Smith
Ground Data System Manager, Manfred N. Wirth

Ultraviolet Spectrometer

Principal Investigator	A. Ian F. Stewart
Optics type	Cassegrain telescope
aperture	5 cm
f/number	5
Monochromator type	Ebert-Fastie
focal length	12.5 cm
f/number	5
diffraction grating	3600 grooves/mm
Spectral resolution	13 A
Grating steps	4.4 A
Wavelength ranges	1100-1900 A 1800-3400 A