THE INTERNATIONAL COMETARY EXPLORER (ICE) MISSION TO COMET GIACOBINI-ZINNER (G/Z)

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ABSTRACT. The ICE spacecraft will pass through the tail of P/Giacobini-Zinner on September 11, 1985, to make <u>in situ</u> measurements of particles, fields, and waves that will contribute significantly to the knowledge of plasma tails and other aspects of the cometary/solar wind interaction. By obtaining data on the downstream side of G/Z, the ICE will complement the later upstream measurements obtained by the Comet Halley probes.

COMET GIACOBINI-ZINNER

This short period comet was discovered by M. Giacobini at Nice in 1900 and rediscovered in 1913 by E. Zinner at Bamberg. The discovery and recovery history of the comet is summarized in Table 1. The perihelion distance of 1.03 a.u. occurs near the ecliptic plane, making G/Z well suited to spacecraft encounters during its intervals of maximum nuclear and atmospheric activity. The orbital eccentricity and inclination are 0.71 and 31.9°, respectively. Typically, the plasma tail of G/Z is observed to develop beginning at a heliocentric distance of about 1.7 a.u. According to conventional photographic observations at previous apparitions, the plasma tail can attain a length exceeding 500,000 km. The coma, also observed photographically, reaches a typical diameter of about 50,000 km (see Figure 1).

G/Z is associated with the Draconid (Giacobinid) meteor showers. A recent analysis by D. K. Yeomans (private communication) indicates that there is a limited possibility that a Giacobinid shower will occur on October 8.5, 1985, although it is unlikely to rival the occasional great displays of this shower. Groundbased observers and interplanetary dust particle experimenters should attempt to observe this shower.

The dust generated by G/Z, besides producing meteor showers, represents a possible significant hazard to the ICE spacecraft. Of special concern is dust-impact degradation of the solar power

A. Carusi and G. B. Valsecchi (eds.), Dynamics of Comets: Their Origin and Evolution, 405–414.

Table 1

DISCOVERY AND RECOVERY OF PERIODIC COMET GIACOBINI-ZINNER

Apparition	Designation	First Observation	Observer/ Institution	Approximate Magnitude	Reference
1	1900III (1900c)	Dec. 20, 1900	Giacobini Observatoire de Nice	11	*A.N.* **154**, 161
2	1913V (1913e)	Oct. 23, 1913	Zinner Remeis-Sternwarte	9-10	*A.N.* **196**, 167 & 353
3	1926VI (1926e)	Oct. 16, 1926	Schwassmann Hamburger Sternwarte	14	*A.N.* **229**, 122
4	1933III (1933c)	Apr. 23, 1933	Schorr Hamburger Sternwarte	15	IAU Circ. 435
5	1940I (1939l)	Oct. 15, 1939	Van Biesbroeck Yerkes Observatory	15	IAU Circ. 797
6	1946V (1946c)	May 29, 1946	Jeffers Lick Observatory	17	IAU Circ. 1046
7	1959VIII (1959b)	May 8, 1959	Roemer U.S. Naval Observatory	20	IAU Circ. 1677
8	1966I (1965g)	Sept. 17, 1965	Roemer & Lloyd U.S. Naval Observatory	20	IAU Circ. 1923
9	1972VI (1972d)	Mar. 11, 1972	Roemer & McCallister University of Arizona	19	IAU Circ. 2390
10	1979III (1978h)	Apr. 30, 1978	Shao & Schwartz Harvard College Observatory	20-21	IAU Circ. 3216
11	1985_ (1984e)	Apr. 3, 1984	Djorgovski & Spinrad Univ. of California, Berkeley Will & Belton Kitt Peak National Observatory	23	IAU Circ. 3937

General References: (1) "Liste Générale Des Comètes De L'Origine A 1948," by M.F. Baldet, *Annuaire du Bureau des Longitudes (1950).*

(2) *Catalogue of Cometary Orbits,* 4th Ed., by B.G. Marsden, Smithsonian Astrophysical Observatory (1982).

arrays, which could reduce the power available to operate the spacecraft and payload during the cometary intercept. Studies of this hazard, based on a G/Z dust model prepared by N. Divine at NASA-Jet Propulsion Laboratory, are underway at NASA-GSFC so that operating procedures can be developed to deal with it.

The early recovery of G/Z by ground-based observers was of special interest to the ICE mission flight dynamicists. In the event that the observed orbit had differed significantly from the expected orbit of G/Z, early detection of G/Z would have been crucial to carefully schedule operation of the on-board propulsion capability so as to successfully effect the flyby. Fortunately, the first recovery photographs (Figure 2), obtained on April 3, 1984, by S. Djorgovski, H. Spinrad, G. Will, and M. Belton with the 4-m Mayall telescope at Kitt Peak National Observatory, revealed that

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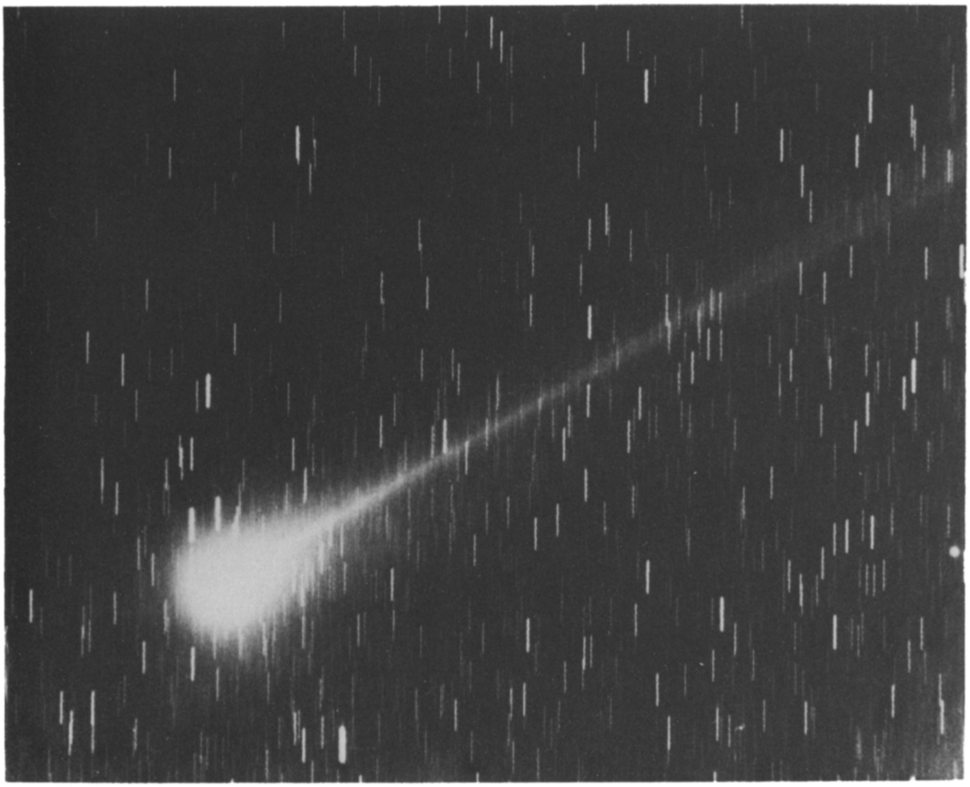

Figure 1. Photograph of Comet Giacobini-Zinner, obtained by E. Roemer on October 26, 1959. (Official U.S. Navy photograph).

G/Z was within 10,000 km of the anticipated position. Current projections (May 1984) indicate that if no further use were made of the propulsion system (last exercised for trajectory adjustment in November 1983), ICE would nevertheless pass through the nominal location of the G/Z tail at about 100,000 km from the nucleus. Ground commands will, however, target the tail intercept at a lesser distance from the nucleus, to be proposed by the ICE science team for approval by NASA. Should a scientific requirement exist, flight controllers could navigate ICE to within about 500 km of the nucleus, its approximate positional uncertainty near encounter. The intercept will occur with the spacecraft travelling from south to north in the rest frame of the comet.

The present, tentative ICE targeting strategy study utilized a baseline tail model (Figure 3) which assumes a gas production rate of 2.3 x 10^{28} molecules/sec at perihelion (derived by N. Divine from the measured brightness of G/Z at a previous apparition). The model suggests a plasma tail width of about 5000 km at 55,000 km from the nucleus, consistent with the measured size on a photograph of G/Z obtained by E. Roemer on October 26, 1959.

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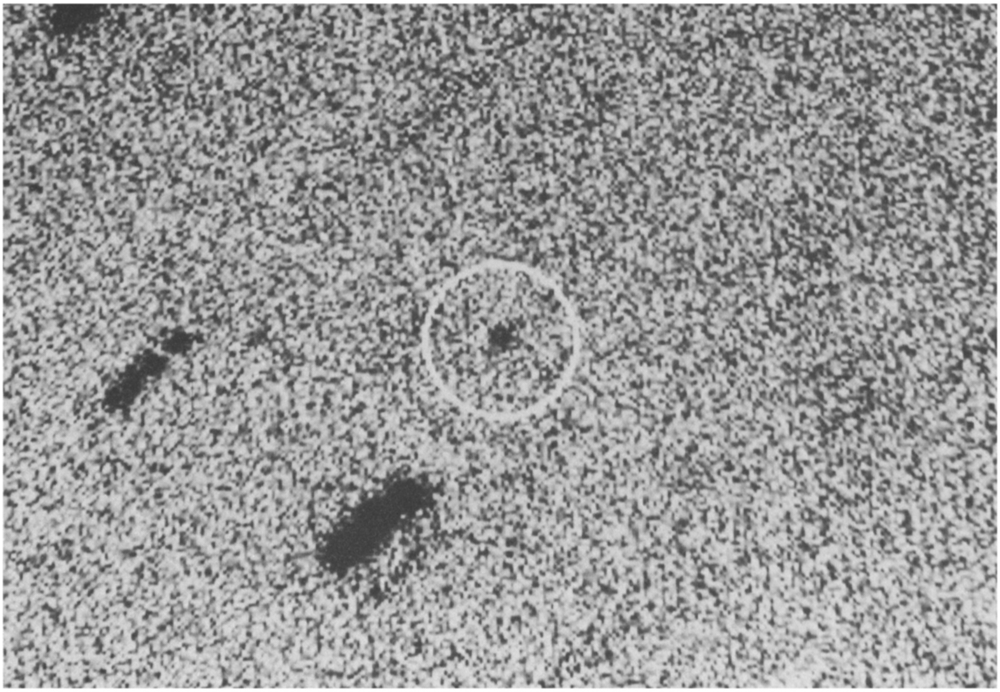

Figure 2. Recovery photograph of Comet Giacobini-Zinner, obtained by S. Djorgovski, H. Spinrad, G. Will, and M. Belton on April 3, 1984. (Kitt Peak National Observatory photograph).

SPACECRAFT AND PAYLOAD

The ICE mission objective is to provide in situ data on the interaction between the solar wind and a cometary atmosphere. This will be accomplished through the intercept of the tail of G/Z. Secondary objectives include the support of the various planned intercepts of Comet Halley through measuring solar wind phenomena upstream of P/Halley, following the G/Z tail intercept. ICE will pass 0.93 a.u. upstream of P/Halley on October 31, 1985 and 0.21 a.u. upstream of P/Halley on March 28, 1986.

The ISEE-3 spacecraft, launched August 12, 1978 on a Delta rocket, was renamed ICE by NASA, effective December 22, 1983, when the spacecraft made a close lunar swingby, passing only 120 km above the lunar surface to obtain the gravitational assist necessary to depart from the Earth-Moon system (Figure 4) and travel onward to intercept G/Z. Previously, ISEE-3 operated in a halo orbit about the sunward Lagrangian point of the Earth-Moon system. In 1983, ISEE-3 accomplished an extended mission to make the first extensive survey of the distant geotail. Its survey, conducted to distances as great as 237 earth radii in the tail, was accomplished through a series of lunar swingby maneuvers. The study of particle, field, and wave phenomena in the geotail, besides the scientific

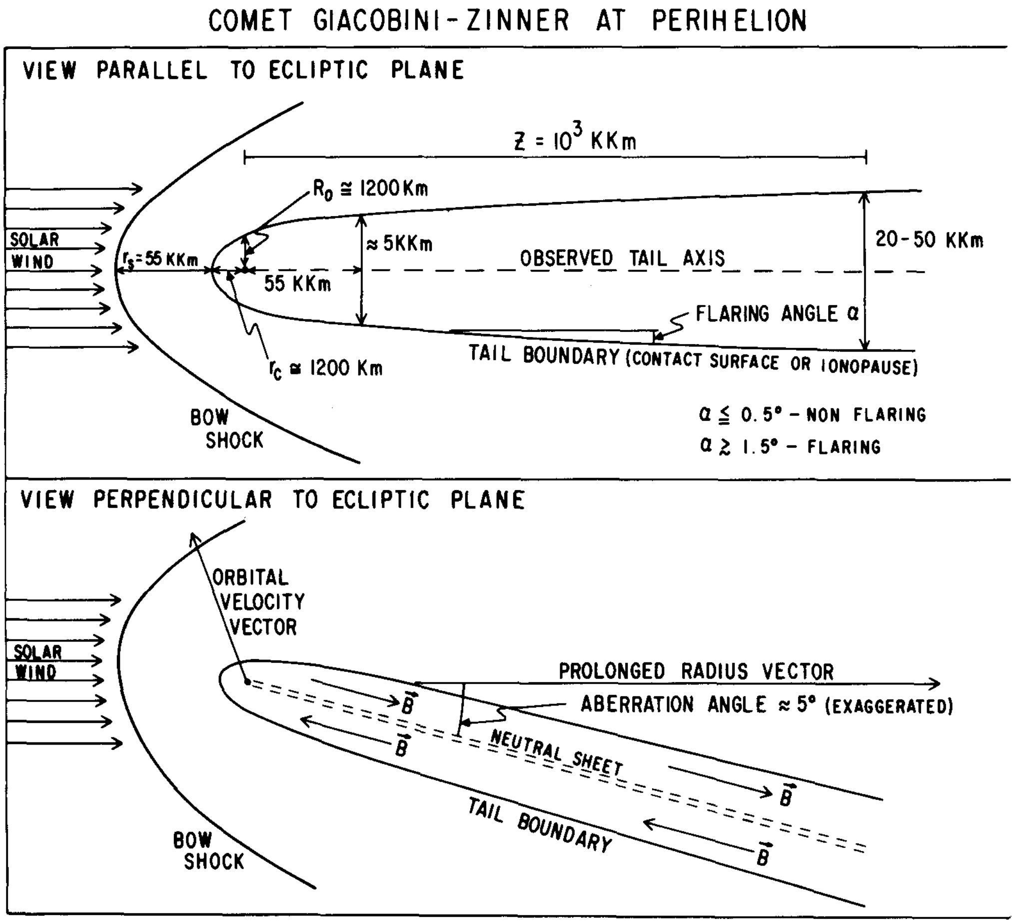

Figure 3. Schematic diagram of baseline ion tail model for Comet Giacobini-Zinner near perihelion.

significance of the results obtained, provided an excellent rehearsal and scientific baseline for experiment operations during the single brief comet tail encounter that will occur on September 11, 1985.

A schematic of the ICE spacecraft is given in Figure 5. From current knowledge, five of the ICE instruments are considered most suited to make major contributions to cometary science through measurements obtained in the G/Z intercept:

Vector Helium Magnetometer

Obtains three, high-accuracy, triaxial measurements per second in ranges extending from $\pm$ 4γ to +1.4 gauss.

Principal Investigator: E. Smith, Jet Propulsion Laboratory.

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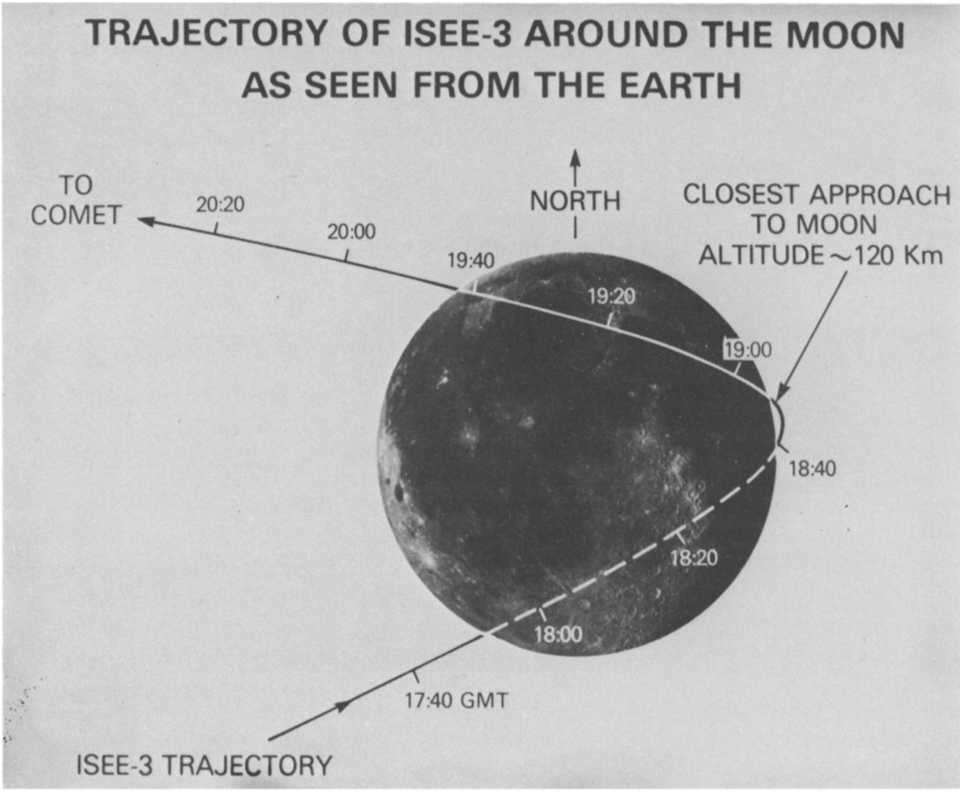

Figure 4. The orbit of ISEE-3 near the moon at the time of the close lunar swingby on December 22, 1983. The official name of the spacecraft became ICE as it departed from the vicinity of the moon.

Plasma Wave Experiment

Samples 16 channels in electric field in one second in the frequency range 20 Hz to 10^5 Hz.

Principal Investigator: F. Scarf, TRW.

Radio Wave Experiment

Samples the range 30 kHz to 1 MHz in 12 steps with Δf = 3 kHz.
Samples the range 40 kHz to 2 MHz in 12 steps with Δf = 10 kHz.
Each scan takes 56 seconds.

Principal Investigator: J.-L. Steinberg, Observatoire de Meudon.

Plasma Electron Experiment

Scans in 16 steps covering the energy range 5 eV to 1500 eV.
Sampling takes 24 seconds.

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Principal Investigator: S. Bame, Los Alamos National Laboratory.

Plasma Ion Experiment

Has velocity selector. Determines M/Q in 25 steps for the range 4 to 50 and velocity in 25 steps for the range 20 km/sec to 200 km/sec. Complete set of measurements takes 15 minutes.

Principal Investigator: K. Ogilvie, NASA-Goddard Space Flight Center.

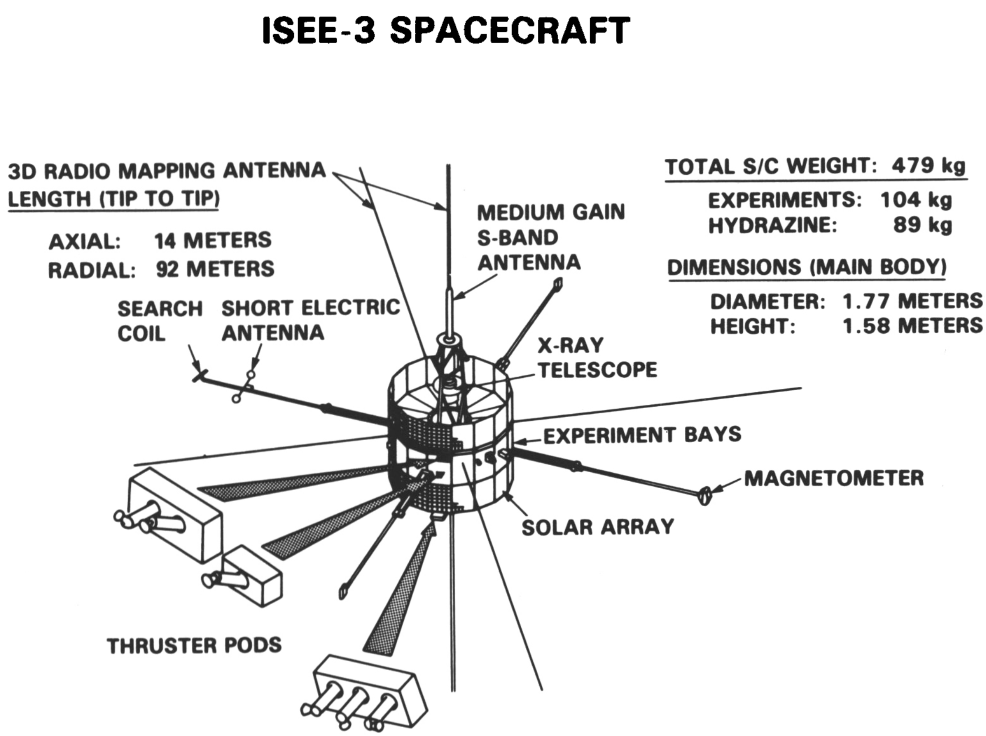

Figure 5. Schematic diagram of the International Cometary Explorer, as built under the name of ISEE-3.

Other experiments are intended to measure Energetic Protons, X Rays, Low Energy to High Energy Cosmic Rays, Cosmic Ray Electrons, and Gamma Ray Bursts. These experiments do not seem as likely to produce cometary data as those described above, other than upper limits. However, our detailed knowledge of cometary physics and structures is sufficiently insecure that these instruments should be

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operated in a serendipitous mode during the cometary intercept, provided that sufficient operating power is available. ICE has no imaging nor dust experiments.

The ICE spacecraft measurements will be supplemented with ground-based measurements of G/Z obtained by arrangement with the International Halley Watch and concentrated in September, 1985. Astrometric and orbital work is being carried out in collaboration with Dr. Yeomans.

MISSION TARGETING

It is thought that a cometary plasma tail is formed from interplanetary magnetic field lines that are captured and frozen into the cometary ionosphere and which entrain plasma that is accelerated in the antisunward direction. In the simplest model, the tail is organized into two magnetic lobes of opposite field direction, separated by a current sheet (Figure 6). Directly in the

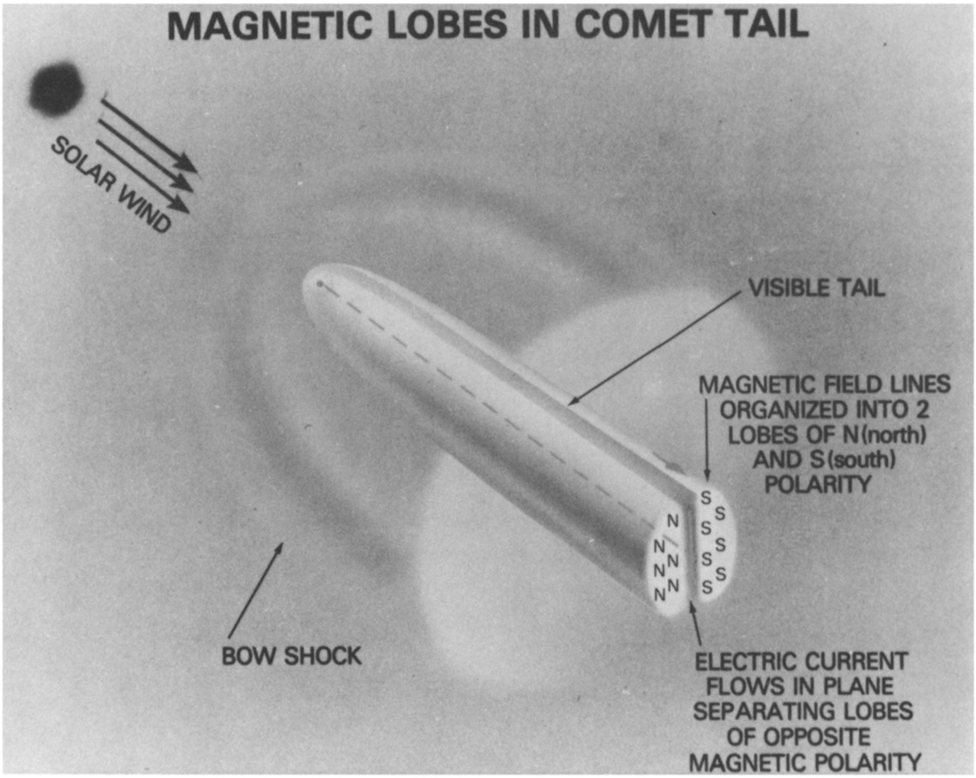

Figure 6. Schematic diagram of simple ion tail model with two magnetic lobes.

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wake of the nucleus, however, conditions may be chaotic and it is thought that the tail may not be organized as just described closer than a few thousand km to the nucleus. This sets a lower bound to the distance from the nucleus at which the ICE science team would prefer that the intercept occur. At very large distances from the nucleus, the observed tendency of a plasma tail to wag back and forth in response to solar wind velocity variations would lower the probability of a successful tail intercept. Therefore an intercept distance in the range of about 5000 km to 15,000 km may be desirable. The plasma tail at that location may be obscured by the coma on photographs taken from the ground, so that a measurement of the tail width by ICE would be especially interesting. From such a measurement, an independent (but model-dependent) derivation of the gas production rate can be made. (Specifically, an accurate determination of the width of the contact surface at the flank should be possible without model-dependent assumptions). The dust hazard will also be considered in making the final targeting decision. In any case, ICE will surely probe the bow shock and contact discontinuity regions predicted by current theory of the cometary/solar wind interaction, if they exist on roughly the anticipated scales. A precise intercept of the tail could allow investigation of the current sheet that divides the two magnetic lobes in the simple plasma tail model, assuming the model is applicable. Even if precise targeting is not possible, the existence of the current sheet should be inferred from the detection of waves generated there (Figure 7).

As already mentioned, the targeting accuracy for ICE is potentially about 500 km. Tracking data will allow very precise calculation of the spacecraft location, so that the dominant term in the targeting accuracy actually attained will be the uncertainty in the location of the comet. G/Z is an active comet with irregular brightness variations. Non-gravitational forces on G/Z increased during 1900 to 1965. Therefore, an accurate dynamical model may be necessary to achieve the targeting accuracy goal. The development of such a model may allow the identification of one or more quantities that can be measured by the instruments on ICE. We invite the attention of dynamicists and modellers to the possibility of expanding their methodology for studying nongravitational phenomena in comets using astrometric observations via the incorporation of in situ measurements.

CONCLUSION

In situ measurements of a comet's tail region and other features associated with the comet's interaction with the solar wind should be of interest to all comet scientists. In particular, the ICE tailward measurements are complementary to the sunward measurements to be made by the missions to Halley's Comet.

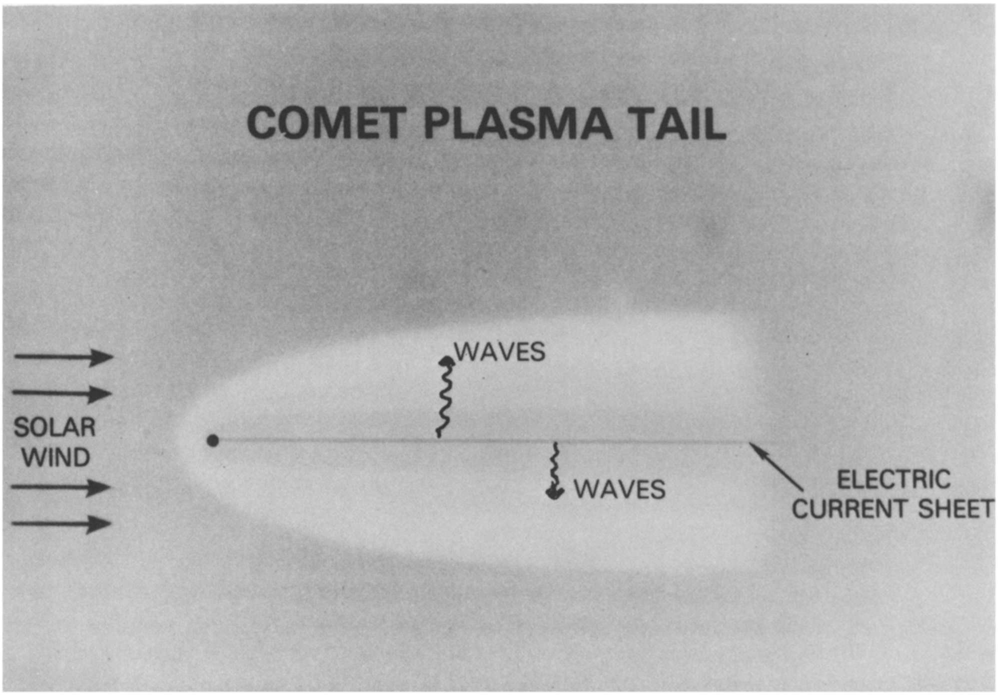

Figure 7. Schematic diagram indicates presence of waves that are thought to be generated in the ion tail of a comet and which may be detectable as ICE passes through the tail of Comet Giacobini-Zinner.

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