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## Cross references

Asteroid
Orbit

## VAN ALLEN, JAMES ALFRED (1914– )

A pioneer in space research, Van Allen was born in Mount Pleasant Iowa on 7 September 1914, the second of four children of Alfred Morris and Alma E. (Olney) Van Allen. His father was a lawyer as was his older brother George. The three younger sons all developed an interest in science; James and William received degrees in physics and Maurice became a neurosurgeon. James attended Iowa Wesleyan College in Mount Pleasant, graduating summa cum laude in 1935 with a BS in physics. The following year he received an MS from the State University of Iowa in Iowa City, Iowa (now called the University of Iowa). He graduated with his PhD in nuclear physics in 1939 from the same school and became a research fellow and later a physicist in nuclear physics at Carnegie Institution of Washington, DC. In 1941 he developed an interest in cosmic ray research and switched to the Department of Terrestrial Magnetism at the same institution.

In 1942 he became a physicist at the Applied Physics Laboratory (APL) of Johns Hopkins University and also lieutenant in the US Navy. During the war he worked on various military projects, including the proximity fuse. On 13 October 1945 he married Abigail Fithian Halsey, and subsequently had five children, three daughters and two sons. Leaving the Navy as a Lt Commander USNR, he return to research at APL where he was the supervisor of the high-altitude research group. This group was engaged in the measurement of cosmic rays, the Earth's magnetic field, atmospheric ozone and UV spectroscopy of the Sun at high altitudes using balloons. He pioneered the use of V-2 rockets for this work, and later supervised the development of the Aerobee rocket which replaced the V-2s in high-altitude research. He also led several scientific expeditions to measure cosmic rays at high altitudes using rockets launched from ships.

In January of 1951 Van Allen became Professor and Head of the Department of Physics and later (1959) Astronomy. In 1972 he was named the Carver Professor of Physics. He continued his high-altitude work at Iowa, developing small rockets that were launched from balloons.

Taking a leave of absence for the academic year 1953/4, he was a research associate at Princeton University working on Project Matterhorn, the early experimental work on controlled thermal-nuclear reactions. Feeling that there were years of work ahead in this area without much hope of success, he returned to Iowa and resumed his cosmic ray studies.

As part of the International Geophysical Year (IGY), his group at Iowa began preparing a cosmic ray instrument for the first US satellite. With the failure of the Vanguard launch vehicle, his group quickly modified the instrumentation for flight on the Jupiter-C rocket. This resulted in the first US satellite, Explorer 1. The next successful flight was Explorer 3, which included the same instrumentation along with a tape recorder. The data from these satellites were very puzzling. After several months of working with the data, Van Allen and his students came to the conclusion that they had detected energetic charged particles trapped in the Earth's magnetic field (The Van Allen belts). He and his former students have continued their research on the radiation belts of the Earth. He has had instrumentation on spacecraft that have made the first flybys past Venus, Mars, Jupiter and Saturn. The last two planets have very large natural radiation belts.

He officially retired in 1985 as the Head of the Physics and Astronomy Department, but has continued his research. His present research is concerned with the study of cosmic rays at great distances from the Sun using data from the Pioneer 10 and 11 spacecraft, the search for the boundary between the Sun and the interstellar medium, as well as the study of the natural radiation belts of the Earth, Jupiter and Saturn.

He is a member of numerous organizations, including the American Physical Society, American Geophysical Union and the National Academy of Sciences.

His numerous awards and medals include the National Medal of Science, the Nansen Medal and Prize and the Crafoord Prize.

Bruce Randall

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## Cross references

Earth: magnetic field and magnetosphere
Radiation belt

## VEGA MISSION

The name of the Vega mission comes from a contraction of the Russian words *Venera* (Venus) and *Gallei* (Halley). The unique opportunity to combine missions to these celestial bodies was realized in 1984, when twin spacecraft Vega 1 and Vega 2 were launched by Proton rockets from the Baikonur cosmodrome on 15 and 21 December respectively. The Vega project was an international one. Though the spacecraft were controlled by the Soviet Union, the scientific program and payload were coordinated by the International Science and Technical Committee (ISTC), representing scientific institutions from nine countries. ISTC designed the Vega mission to be complementary to the European Giotto and Japanese Suisei cometary missions (See also Giotto mission; Sakigate and Suisei missions).

Each Vega spacecraft weighed about 4, 500 kg at launch including the 2,000 kg Venus descent module. Half a year after the launch, on 11 and 15 June respectively, the spacecraft delivered the first balloons into the Venusian atmosphere (each carrying four scientific experiments) as well as delivering landers with nine experiments to the surface of the planet. The results of this part of the mission and more details on the complete project can be found in the papers of the scientific leadership of the mission (Sagdeev *et al.*, 1986a,b), and in papers describing preliminary results of separate scientific instruments.

After a gravitational maneuver near Venus the flyby modules were targeted to intercept Halley's comet (astronomical name P/Halley 1986 III). The interplanetary orbit of Vega 1 from Venus to Halley flyby is shown in Figure V1. The flight operation center was located in Evpatoria (Crimea), equipped with a 70-m main antenna, but most investigators were in Moscow at the Space Research Institute of the Russian Academy of Sciences (acronym IKI), where they were able to receive telemetry from deep space antennas in both Evpatoria and Medvezy Ozera (near Moscow, with a 64-m dish).

Vega 1 first encountered comet Halley on 6 March 1986 at 7 : 20 : 06 UT with a relative velocity of 79.2 km $s^{-1}$. Vega 2 passed near the comet nucleus 3 days later on 9 March 1986 at 7 : 20 : 00 UT with a velocity of 76.8 km $s^{-1}$. Their closest approaches to the nucleus were 8 890 km and 8 030 km respectively. The encounter trajectories of Vega 1 and 2 as well as those of Giotto and Suisei are presented in Figure V2.

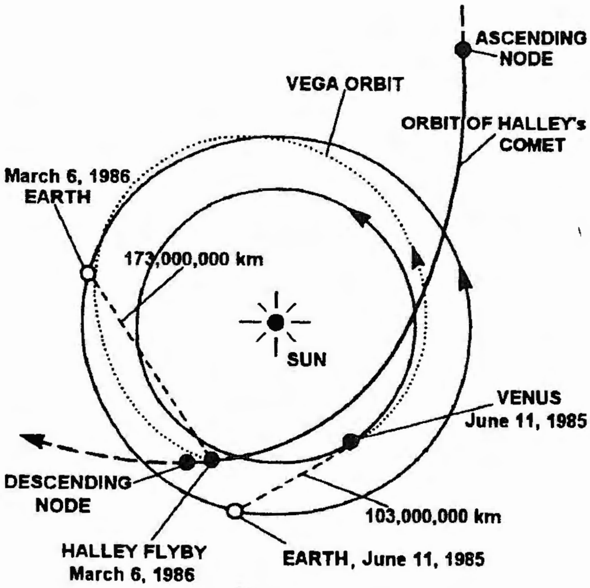

**Figure V1** The path of Vega 1 probe from Venus to Halley. The projection of the inner portion of Halley's comet on the plane of the ecliptic is also shown.

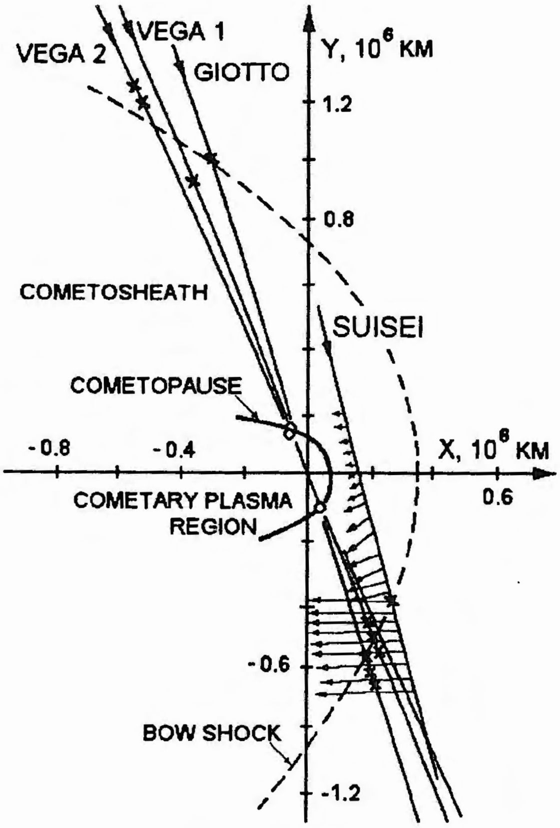

**Figure V2** General overview of the spacecraft flyby trajectories and locations of the bow shock (crosses), cometopause (circles), cometosheath and cometary plasma region as identified from *in situ* plasma observations. Arrows on the Suisei trajectory show the direction of the plasma flow; their lengths are proportional to the plasma velocity.

Each Vega spacecraft, with a 'wingspan' of ~ 10 m, was three-axis stabilized and carried 14 experiments (Table V1). The three optical experiments. (TVS television system, IKS infrared spectrometer and TKS three-channel spectrometer) required a steerable platform (ASP-G), which could be automatically pointed at the cometary nucleus with an accuracy of 2.5 arc min. It could scan an angular sector of 110° in the ecliptic plane and 60° in a plane perpendicular to the ecliptic.

The twin Vega spacecraft reached the comet a few days before the Giotto spacecraft. Optical observations of the cometary nucleus by Vega 1 and 2 TVS cameras, combined with a very accurate determination of trajectories using very long baseline interferometry, permitted the successful completion of the cooperative project 'Pathfinder.' As a result the uncertainty of Giotto's flyby distance was reduced from ± 1500 km to about ± 40 km, thus enabling the successful completion of its scientific program (Münch Sagdeev and Jordan, 1986).

Of the three missions to comet Halley, the scientific package of Vega 1 and 2 (Table V1) could support the most composite studies. The payload of Giotto, though capable of more detailed plasma and neutral gas measurements, did not include optic and plasma wave experiments, while Suisei payload consisted of only two scientific instruments.

During the journey of Vega 1 to comet Halley, the data returned from the scientific instruments were displayed in IKI in real time. It was first time that it was possible to observe a cometary nucleus. The existence of the solid, single nucleus, as predicted by F.L. Whipple, was demonstrated. Here the most obvious quantum jump in our knowledge was achieved. The nucleus turned out to be an irregular peanut-shaped body of about 14 × 7.5 × 7.5 km in size. Its rotation period of 53 ± 3 h was obtained from a comparison of TVS images obtained from Vega 1 and Vega 2. First estimates based on measured brightness gave a geometrical albedo of $0.04\,^{+0.02}_{-0.01}$, which places Halley's nucleus among the darkest objects in the solar system.

The temperature of the nucleus (300–400 K as measured by the IKS spectrometer onboard Vega 1 at 0.8 AU) was much higher than the equilibrium temperature of subliming water ice of about 200 K. It was therefore reasonably assumed that what we were observing was not a bare icy nucleus but rather a nucleus covered by a layer of dark, warm dust.

The total gas production rate of Halley's nucleus was $Q \approx 1.3 \times 10^{30}$ molecules $s^{-1} \approx 40$ metric ton $s^{-1}$ (if the gas is $H_2O$). This was determined by a PLASMAG radial profile of the overall neutral gas density $n_n(r)$ of the cometary coma. Those data shown in Figure V3 were presented to the scientific community meeting in IKI on the day after the Vega 1 flyby. The evaluations of $Q$ and ionization scale length ($\lambda$, $2 \times 10^6$ km) resulted from fitting observational data using a curve of the form.

$$n_n(r) = Q/(4\pi r^2 v_g)\exp(-r/\lambda)$$

where $v_g \approx 1$ km $s^{-1}$ is the expansion velocity of the spherically expanding neutral gas with a specific ionization lifetime of $\lambda/v_g$.

In the internal part of the coma (< 500 km from the nucleus), the most abundant molecules ($H_2O$ and $CO_2$) were identified by their infrared spectra as measured by the IKS and TKS experiments. Many secondary neutral species, such as OH, $C_2$, CH, CN and NH, were revealed by numerous spectra obtained by TKS. These provide information concerning the detailed chemistry of the inner coma.

Though the first dust particles were detected as far as ~ $3 \times 10^5$ km from the nucleus, the sharp increase in the number densities of small dust particles of $10^{-15}$–$10^{-16}$ g took place at a distance of ~ $1.5 \times 10^5$ km. This was interpreted as the inbound crossing of the dust paraboloid produced by the light pressure effect with an apex of ~ $4.53 \times 10^4$ km. For larger masses of $10^{-12}$–$10^{-14}$ g, the boundary of the dust coma moves closer to the comet as a result of enhancement of the light pressure for such particles due to Mie resonances. Total dust production rate was estimated as 5–10 metric ton $s^{-1}$ in the mass range $10^{-6}$–$10^{-16}$ g. The chemical composition of dust particles has been analyzed by the dust mass spectrometer PUMA. More than 1000 spectra have been classified into three broad classes: (1) composed mainly of low-*z* elements (C, H, O, N), (2) reminiscent of C1 carbonaceous chondrites but enriched in C, and (3) similar to class 2 . . . second but more enriched in hydrogen.

The outermost signatures of comet Halley were detected by the energetic particle telescope TÜNDE-M as far as 10 million km from the nucleus. How can this observation be linked with the presence of a comet? The charged particles originating from ionization of the cometary neutral gas have energies of only a few eV, which should

**Table V1** Scientific experiments aboard Vega spacecraft

| Acronym | Experiment | Goal and instrument parameters |
|---|---|---|
| TVS | Television system | Inner coma and nucleus imaging. Two CCD cameras, fields of view 0.43° × 0.57° and 3.5° × 3.5° |
| IKS | Infrared spectrometer | Detection of infrared emissions of coma and thermal radiation of nucleus with $2.5 < \lambda < 12$ m |
| TKS | Three-channel spectrometer | Spectral mapping of coma emission in the range $0.12 < \lambda < 1.9$ m |
| PUMA | Dust mass spectrometer | Dust particle and elemental composition |
| SP-1 | Dust particle counter | Dust particle flux and mass spectrum for $m > 10^{-16}$ g |
| SP-2 | Dust particle counter | Dust particle flux and mass spectrum for $m > 10^{-16}$ g |
| DUCMA | Dust particle detector | Dust particle flux and mass spectrum for $m > 1.5 \times 10^{-13}$ g |
| FOTON | Shield penetration detector | Large dust particle detection (under anti-dust shield) |
| PLASMA G | Plasma energy spectrometer | Integral fluxes and energy spectra of cometary (15–3500 eV) and solar wind (0.05–25 keV) ions, electron spectra (3–10000 eV), neutral gas density $\geq 1$ cm$^{-3}$ |
| TÜNDE-M | Energetic particle telescope | Energy and flux of accelerated cometary ions, 0.04–13 MeV |
| ING | Neutral gas experiment | Neutral gas composition |
| MISHA | Magnetometer | Magnetic field ± 100 nT |
| APV-N | Wave and plasma analyzer | Plasma waves, 0.01–1000 Hz, plasma ion flux fluctuations |
| APV-V | Wave and plasma analyzer | Plasma waves, 0–30 kHz, plasma density and temperature |

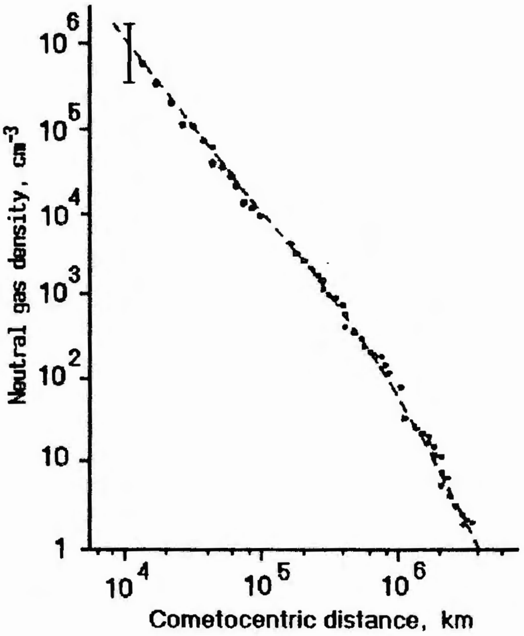

**Figure V3** Comparison of the neutral gas density profile determined from the Ram Faraday Cup sensor of the PLASMAG experiment with that one predicted by theory (dashed line).

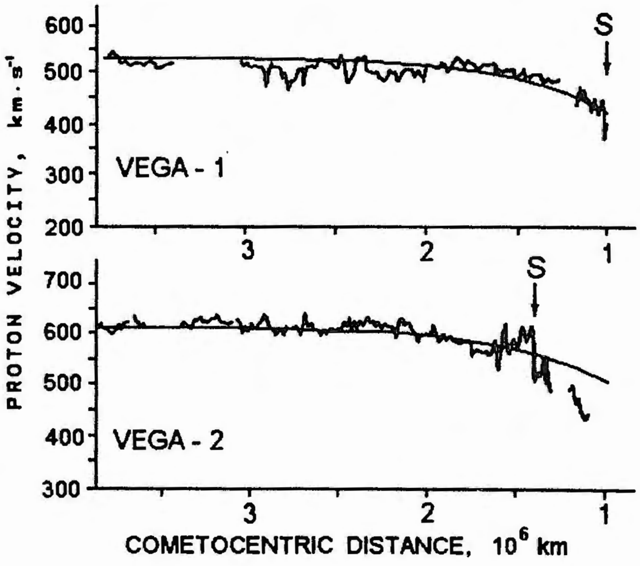

**Figure V4** Radial dependence of the solar wind bulk velocity, as observed by the PLASMAG experiment at Vega 1 and 2 inbound trajectories upstream of the bow shock S of comet Halley. Solid line is the theoretical expectatation for the cometary neutral gas production rate $Q$ ($1.3 \times 10^{30}$ molecules s$^{-1}$). (From Gringauz and Verigin, 1990.)

be insufficient to register on this instrument. The explanation comes from the fact that the cometary nucleus moves not in an empty space but in the highly supersonic stream of solar plasma – 'solar wind'. The self-consistent electric and magnetic fields of the solar wind accelerate fresh cometary ions up to velocities less than twice that of the solar wind (~ 1000 km s$^{-1}$) for about one cyclotron period. This mechanism alone is still insufficient to explain TÜNDE-M observations, so it was concluded that the second-order Fermi process of turbulent acceleration must be effective even at great distances from the nucleus, and that this process is responsible for the acceleration of charged particles up to energies > 100 keV.

The general increase of the energetic particle fluxes was accompanied by deep and striking quasi-periodic variations. This effect was linked with the variation of the neutral gas production rate by the rotating cometary nucleus. The existence of periodic structures in the outer coma was not known from earlier distant Lyman alpha measurements.

Other effects of the increasing loading of the supersonic solar wind by fresh charged particles are the deceleration of the plasma flow on approach to the nucleus (Figure V4) and the formation of the cometary bow shock at ~ $10^6$ km (Figure V2). Both effects were revealed by Vega's *in situ* measurements. The formation of the cometary bow shock is not caused by solar wind compression and heating due to interaction of the supersonic plasma flow with a sufficiently rigid obstacle (as in the case of the solar wind flow around the near-Earth magnetic obstacle or around the non-magnetized ionosphere plasma confined by the strong gravitational field of Venus). In this case the bow shock forms due to 'overloading' of the solar plasma by picked-up ions of cometary origin (Galeev, 1987). In addition to the plasma flow heating and deceleration, crossing of the cometary bow shock was accompanied by a rapid increase of the magnetic field (MISCHA magnetometer) and of plasma waves intensity with frequencies less than lower hybrid resonance (APV-N experiment).

It was proposed by the Vega plasma team that the plasma region downstream of the cometary bow shock should be called 'cometo-

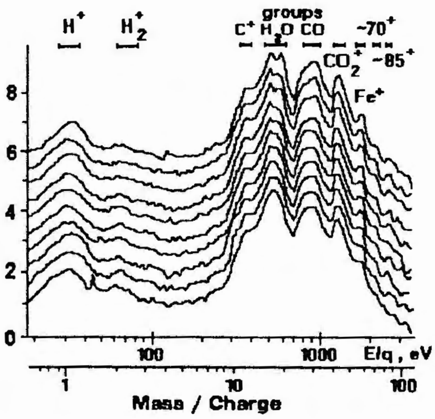

**Figure V5** The sequence of ion energy/charge (mass/charge) spectra, as observed on board Vega 2 in the stagnating part of the cometary plasma region at cometocentric distance of (1.4–1.7) × $10^4$ km.

sheath' (Gringauz *et al.*, 1986) since the energy distribution of ions in this region is unique compared with similar regions near solar system planets, for example, the magnetosheath near Earth or the ionosheath near Venus. One of the differences is that the three different branches of ions are present in the ion energy distribution; the ratio of intensities of these branches changes with cometocentric distance. This feature of the cometosheath is associated with the above-noted principal difference in the bow shock formation process near planets and comets. Another characteristic feature of the cometosheath revealed by Vega measurements is cooling of the electron plasma component on approach to the comet. The decrease of electron temperature was explained by inelastic collisions between thermal electrons and cometary neutral gas (Gringauz and Verigin, 1990).

The Vega 2 spacecraft recorded a sharp (~ $10^4$ km along the trajectory) change of the proton distribution function at a distance of ~ 1.6 × $10^5$ km from the nucleus. This boundary, called the 'cometopause' (Gringauz, *et al.*, 1986), was not predicted theoretically; it separates the cometosheath itself from the inner cometary plasma region (Figure V2). In the vicinity of the cometopause the dominance of solar wind protons changes to the dominance of heavy ions of cometary origin. The analysis of the physical processes at the cometopause based on PLASMAG, MISCHA, APV-V and APV-N data led to a conclusion that it is not one of the MHD discontinuities, and that it is the firehose instability that initiates the rapid change of the proton distribution function (Galeev *et al.*, 1988).

Well inside the cometary plasma region Vega 2 encountered a region where both thermal and bulk velocities of cometary ions become small compared to the spacecraft relative velocity of 76.8 km s. Under these conditions energy per charge (*E*/*q*) spectra measured by the ram analyzer of the PLASMAG experiment can easily be interpreted as the mass spectra (Figure V5). These were the first *in situ* measurements of the mass composition of the cometary plasma. At $r \sim 1.5 \times 10^4$ km the relative abundance of water-group ions was 70–80%, with about 15–20% CO group ions and about 2–5% ions with *m*/*q* 44 ($CO_2^+$). A somewhat unexpected result was the observation of a well-defined peak at *m*/*q* 56 ($Fe^+$?). No ions of iron were identified earlier in optical spectra of Halley's comet; in optical spectra of other comets the metallic ions (usually light metals) have been identified at much smaller heliocentric distances compared with those where Vega 2 intercepted Halley's comet.

M.I. Verigin

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Comet: observation
Giotto mission
Halley, Edmond, and Halley's comet
Sakigake and Suisei missions

## VENERA MISSIONS

### Venera 9 And 10 first satellites of Venus

Venera 9 and 10 were the first artificial satellites to orbit Venus. Their objectives included the study of the surface and atmosphere of Venus and its environment. Landers that separated from the mother spacecraft 2 days before orbit insertion provided the first panoramas of the rocky Venusian surface. Plasma and magnetic field packages on the two orbiters provided the first detailed study of solar wind–Venus interaction.

### Orbit

The interplanetary probe Venera 9 was launched from the Baikonur Cosmodrome on 8 June 1975, and Venera 10 was launched on 14 June 1975. After the landers separated from the spacecraft (two days before insertion), final corrections of the trajectories were made to ensure the passage of the spacecraft through the planned pericenter regions. After braking maneuvers near Venus, on 22 and 25 October 1975 respectively, they entered Venus orbit. Initial parameters of the satellites' orbits are given in Table V2 (Abramovich *et al.*, 1976).

### Spacecraft

The Venera spacecraft is shown in Figure V6. It consists of an orbital module and lander. The orbiter is a combination of a cylinder that provides the main structure of the spacecraft and support subsystems of the spacecraft, and a pressurized torus for the electronics boxes of spacecraft systems and of scientific instrumentation.

A three-axis stabilization mode of the spacecraft allowed the high-gain antenna to be directed to the Earth, and the solar panels were oriented nearly perpendicular to the Sun direction. As Venus moved around the Sun the angle between the solar panels' normal and the

**Table V2** Orbital parameters of Venera spacecraft

| | Venera 9 | Venera 10 |
|---|---|---|
| Apocenter height (km) | 118 190 | 119 930 |
| Pericenter height (km) | 1545 | 1665 |
| Inclination | 34°10′ | 29°30′ |
| Period of revolution | 48h 18min | 49h 23min |
| Longitude of ascending node | 76°25′ | 107°05′ |
| Time of pericenter passage (UT) | 03h 01min 17s | 03h 02min 19s |