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# Preliminary measurements of the plasma near Venus with the Venera 9 satellite

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The thickness of the bow shock front at Venus is estimated from direct plasma measurements. Simultaneous data have been obtained for the first time for the electron and ion flux and temperature on both sides of the shock and for the electron flux and energy in the optical shadow of the planet.

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The Venera 9 satellite of Venus carries instruments for studying the electron and ion components of the interplanetary and circumplanetary plasma: an electron analyzer with a retarding potential and a modulation ion trap very similar to the instruments used on the Mars 2 and Mars 5 missions.[1] The ion trap was pointed toward the sun; the electron trap, in the antisolar direction.

The experiment with the Venera satellite differs from those on the Mars flights[1] in that the measurements have an improved time resolution. Although the duration of each spectrum measurement has been increased to 160 sec, the spectrum is measured continuously, with measurements taken every second for 10 sec in each energy interval.

Venera 9 has an orbit with pericenter in the optical shadow of the planet at a height of ~ 1500 km, apocenter at ~ 112,000 km, and an inclination of ~ 34°.

Disturbances of the solar wind near Venus (the circumplanetary bow shock wave) were first observed on Oct 18, 1967, with ion traps and magnetometers carried by the Venera 4 probe[2–4] and on Oct 19, 1967, with the Mariner 5 probe.[5] Subsequently, the shock wave around Venus was recorded on May 17, 1969, with the Venera 6 probe[6] and on Feb 5, 1974, with the Mariner 10 spacecraft.[7,8]

In some cases the crossing time of the shock front is subject to considerable uncertainty, for various reasons. With Mariner 10, for example, strong fluctuations in the magnetic field and plasma near the shock front resulted in the crossing time being established only to within 4-5 min, corresponding to an uncertainty of ~ 3000 km in the position of the shock front, a value comparable to the size of the obstruction producing the shock wave.[9] The characteristics of the plasma in the optical shadow of the planet were not measured on any of these missions.

The measurements with the Venera 9 satellite on Oct 26, 1975, have enabled the position of the circumplanetary shock front and its thickness to be determined with substantially higher resolution than in the previous experiments, and the plasma characteristics in the optical-shadow region have also been examined. In this letter we report only the first preliminary data obtained on Oct 26, 1975, on the part of the orbit near the planet.

In an $[X, (Y^2 + Z^2)^{1/2}]$ coordinate system (the X axis points toward the sun), Fig. 1 shows the trajectories of the Venera 4, Venera 6, and Mariner 5 probes (dashed curves at bottom), the Mariner 10 trajectory (above), and the portion of the Venera 9 orbit under consideration here. A solid curve indicates the position of the shock front derived by Ness et al.[8] in accord with the treatment by Spreiter et al.[10] and providing the best fit to the crossings

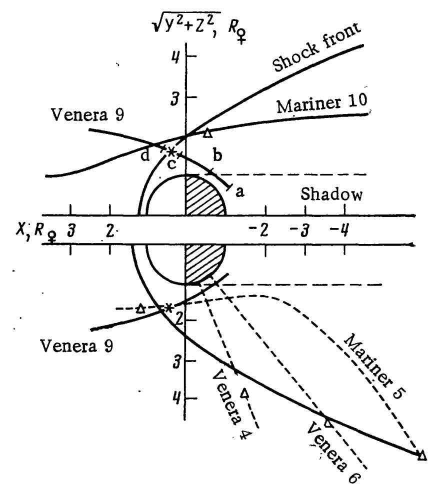


Fig. 1. Trajectories of space probes with which low-energy plasma has been measured in the neighborhood of Venus. Triangles, shock front recorded by the probes; asterisks, shock front encountered by the Venera 9 satellite on 1975 Oct 26.

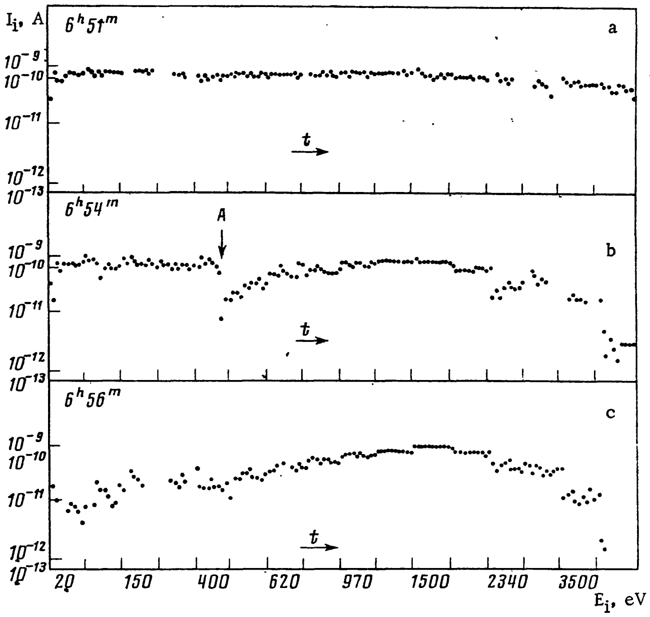


Fig. 2. The first recordings of three successive ion spectra, obtained on 1975 Oct 26. Spectrum a was recorded in the transition region; spectrum c, in the solar wind. At the instant marked by the letter A in spectrum b, Venera 9 crossed the shock front. Moscow Time is given.

of the front recorded experimentally (triangles in Fig. 1 for the flights prior to Venera 9).

Figure 2 displays three successive ion spectra recorded for the first time by Venera 9 as it passed from the transition region (spectrum a) into the undisturbed solar wind (spectrum c). The times indicated represent the approximate beginning of the measurements of each spectrum. In spectrum b the letter A designates the time when the satellite crosses the shock front.

In Fig. 3 we show the collector currents of the ion trap and the electron analyzer in a 30-sec time interval near point A of Fig. 2b, including the time when the shock front was crossed. The ion current has been measured at energies $E_i \sim 280$, 400, and 500 eV; the electron current, for retarding potentials of 40, 34, and 28 V. It is clear from Fig. 3 that the crossing of the front was recorded simultaneously by both detectors as a drop in the currents over a time interval of 1-2 sec. In this case, then the shock front was very sharp; taking the satellite velocity and assuming that the front remained stationary, we may estimate its thickness as 10-15 km.

The points where Venera 9 crosses the shock front are marked in Fig. 1 by asterisks on the part of the orbit in question. We notice from Fig. 1 that the position of the front according to the Venera 9 measurements is in good agreement with the results obtained earlier.

In a letter reporting the first results of the exploration of Venus with the Venera 9 and 10 spacecraft, Vaisberg et al.[11] give examples of the ion spectra and electron retardation curves obtained Oct 26 at various points of the Venera 9 orbit, together with the first preliminary estimates of the plasma parameters according to these spectra. The estimates have now been refined. At the points in space near Venus corresponding to these spectra (points a, b, c, d in Fig. 1), the plasma turns out to have the following values of the electron and ion temperatures $T_e$, $T_i$,

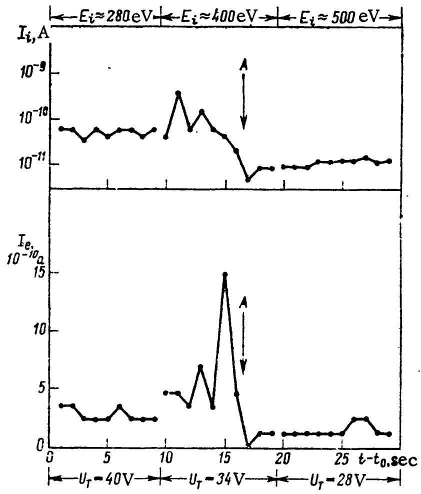


Fig. 3. Electron and ion currents recorded by particle traps as Venera 9 crossed the shock front (point A) on 1975 Oct 26.

directive ion velocity $V_i$, and number density n:

a) in the optical shadow of the planet, $T_e = 1.5 \cdot 10^5$°K, n = 2 cm$^{-3}$;

b) in the transition layer near the obstruction, $T_e = 2 \cdot 10^5$°K, $T_i = (3 \pm 1) \cdot 10^6$°K, $V_i = 300 \pm 50$ km/sec, $n = 7 \pm 2$ cm$^{-3}$;

c) in the transition layer near the shock front, $T_e = (3 \pm 1) \cdot 10^5$°K, $T_i = (1.4 \pm 0.2) \cdot 10^6$°K, $V_i = 490 \pm 20$ km/sec, $n = 60 \pm 20$ cm$^{-3}$;

d) in the solar wind, $T_e = 1.5 \cdot 10^5$°K, $T_i = 2 \cdot 10^5$°K, $V_i = 570$ km/sec, $n = 15 \pm 5$ cm$^{-3}$.

These plasma parameters have been calculated with allowance for the instrumental characteristics and for a Maxwellian particle velocity distribution. In the transition region, where the particle flux is subject to strong fluctuations, the temperature and density estimates are uncertain by as much as ~ 30–40%.

The comparatively good agreement in the positions of the circumplanetary shock front determined from measurements in different years with a variety of space probes would appear to suggest that an obstacle of nonmagnetic (ionospheric) nature is responsible for generating the shock wave. Near the earth[12,13] and Mars[14,15] the positions of the circumplanetary shock waves are considerably more variable.


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# Preliminary magnetic-field measurements near pericenter of the Venera 9 orbit

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**The measurements of Venus' magnetic field during pericenter passage of the Venera 9 satellite on October 28, 1975, are consistent with the upper limit previously set on the magnetic moment of Venus (1/4000 that of the earth).**

PACS numbers: 96.40.Fg

In order to measure the magnetic field in the neighborhood of Venus, the Venera 9 and Venera 10 satellites carry three-component ferroprobe magnetometers with a measurement range of $\pm 60\gamma$ in each component. We present below the results obtained with the Venera 9 satellite on October 28, 1975, near pericenter of the orbit, a point located on the night side at a height of ~ 1500 km. At this time the magnetometers were interrogated at 1-Hz frequency. As the absolute values of the components have not yet been established accurately, we shall consider only the relative variations in the field.

The magnetograms reproduced in Fig. 1 exhibit field-strength variations typical of regions of space near Venus having different physical properties. The boundaries of these regions are designated by numerals 1, 2, 3 (compare the orbit illustrated in Fig. 2). The field variations are observed to be quiet to within $5\gamma$ from the start of the measurements to the point 1, where the field becomes strongly fluctuating in all components. The fluctuations reach a maximum amplitude of $25\gamma$ at the point 2. At the 0.7 level the maximum is ~ 600 km wide. As the satellite continues along its orbit the amplitude of the fluctuations steadily declines. The oscillations in the field disappear first in two of the components and then in the third.

These boundaries for the regions are readily identified as the following: 1) the crossing by the satellite of the boundary of the plasma shadow on the night side of the planet; 2) the crossing of the shock front; 3) the emergence into the undisturbed solar wind. We can compare the boundaries with theoretical models for the flow of solar wind around Venus and with the actual crossing of the shock front by the Mariner 10 probe. In Fig. 2 the solid curve passing through the point 2 represents the shock wave for a model in which the height of the obstruction to the solar wind is determined by the height of the ionosphere on the day side (450 km). The accompanying dashed curve shows the shock wave calculated for an obstruction with a height (150 km) set by currents induced in the vicinity of maximum conductivity of the ionosphere – the induced-magnetosphere model. These curves have been derived by Ness et al.[1]

Notice that the Venera 9 and Mariner 10 spacecraft

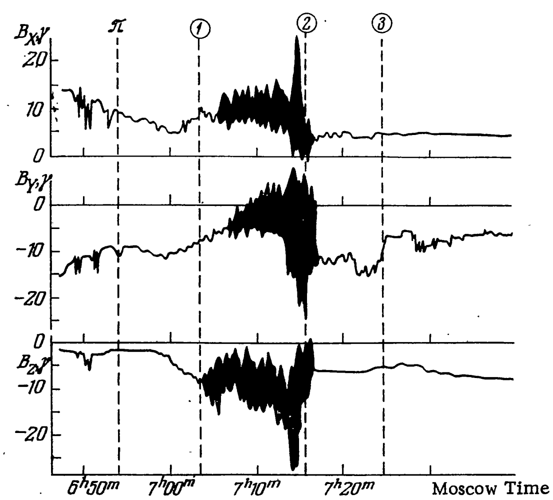


Fig. 1. Magnetic-field components measured with the Venera 9 satellite on October 28, 1975. The component $B_X$ lies in the ecliptic plane and is directed toward the sun, $B_Z$ is normal to the ecliptic plane, and $B_Y$ completes a right-handed coordinate system.