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THREE SPACECRAFT MEASUREMENTS OF AN UNUSUAL DISTURBANCE IN THE SOLAR WIND: FURTHER EVIDENCE FOR A COMETARY ENCOUNTER

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Abstract. On February 11, 1982 the Pioneer Venus orbiter detected an unusual disturbance of the interplanetary magnetic field and solar wind plasma. While this disturbance was being detected at Venus, Venera 13 and 14 were making measurements of the interplanetary magnetic field about 6 million km away. These spacecraft observed at most a very weak disturbance several hours after the peak of the event at Pioneer Venus. Had the event been a solar initiated disturbance it should have been seen almost unaltered by the Venera spacecraft. Thus the Venera 13 and 14 data provide further evidence for the cometary nature of this event.

Introduction

The Pioneer Venus spacecraft has been in a highly elliptical orbit about Venus since December 1978. During most of a Venus year, the spacecraft spends the majority of its orbit in the solar wind. During one of these periods, on February 11, 1982, it detected an unusual disturbance of the interplanetary magnetic field and solar wind plasma (Russell et al., 1983a). The magnetic field strength rose gradually and then ever more rapidly to a peak over 5-6 hours and then symmetrically declined in field strength. The properties of this disturbance led us to the conclusion that the event may have been due to the passage of an unsighted comet, or outgassing body. The earth was only 13° in longitude from the Venus-Sun line. ISEE-3, in front of the earth, saw no such disturbance. Later examination of high resolution measurements of plasma and magnetic field data revealed the apparent signature of a standing bow wave near the peak of the disturbance, another expected signature of a cometary disturbance (Russell et al., 1984a). Examination of all available Pioneer Venus, ISEE-3 and IMP-8 magnetometer records revealed more of these events but all smaller in magnitude and duration (Russell et al., 1984b; Arghavani et al., 1985). Intriligator (1985) has questioned this interpretation of the events on February 11. On the preceding day, February 10 there were variations in the helium content of the solar wind which were most probably solar in origin. This led her to infer that the variations in the interplanetary magnetic field on the next day were also of solar origin.

In February 1982 the Venera 13 and 14 spacecraft were well on their way to their March 1 and 5 encounters with Venus. These spacecraft carried magnetometers but no solar wind probes. On February 11, these spacecraft were being interrogated. It is the purpose of this paper to examine the magnetic field measurements of Venera 13 and 14 to determine whether or not these data provide further support for the initial hypothesis that Pioneer Venus encountered a comet.

Observations

Figure 1 shows the location of Venus, Venera 13 and Venera 14 in sun-oriented ecliptic coordinates. As is shown, Venera 13 was 5.85 x 10^6 km downstream from Venus, 0.56 x 10^6 km to the side of the Venus-Sun line in the direction opposite planetary motion and 4.01 x 10^6 km above the orbital plane of Venus. The corresponding distances for Venera 14 were 6.59 x 10^6, 0.58 x 10^6 and 4.50 x 10^6 km. As shown in Figure 2a, the magnetic disturbance seen by Pioneer Venus was large, rising to almost 165% above the pre-existing field levels. It lasted also nearly 12 hours. This event was not seen at the earth when the same element of solar wind plasma reached 1 AU even though the earth was only 12° away from the earth-Sun line (Russell et al., 1983). Figures 2b and 2c show the corresponding magnetic records from

Location of Venera Spacecraft Relative to Venus

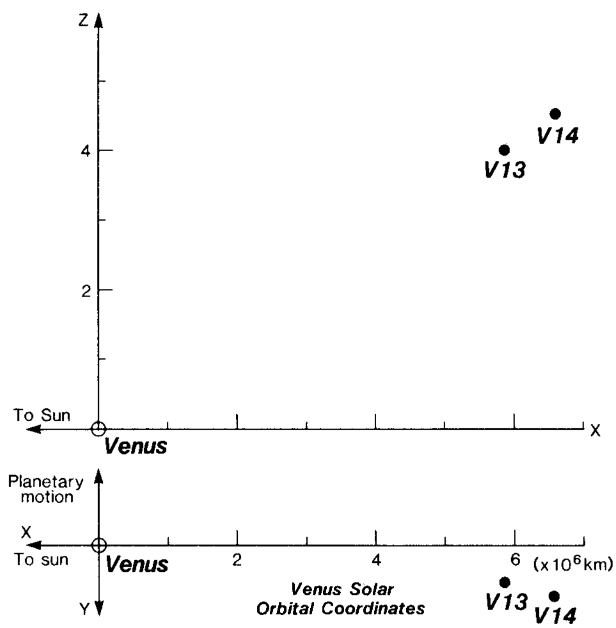

Fig. 1. Location of Venus, Venera 13 and Venera 14 in solar ecliptic coordinates at times they saw the maximum field enhancement on February 11, 1982.

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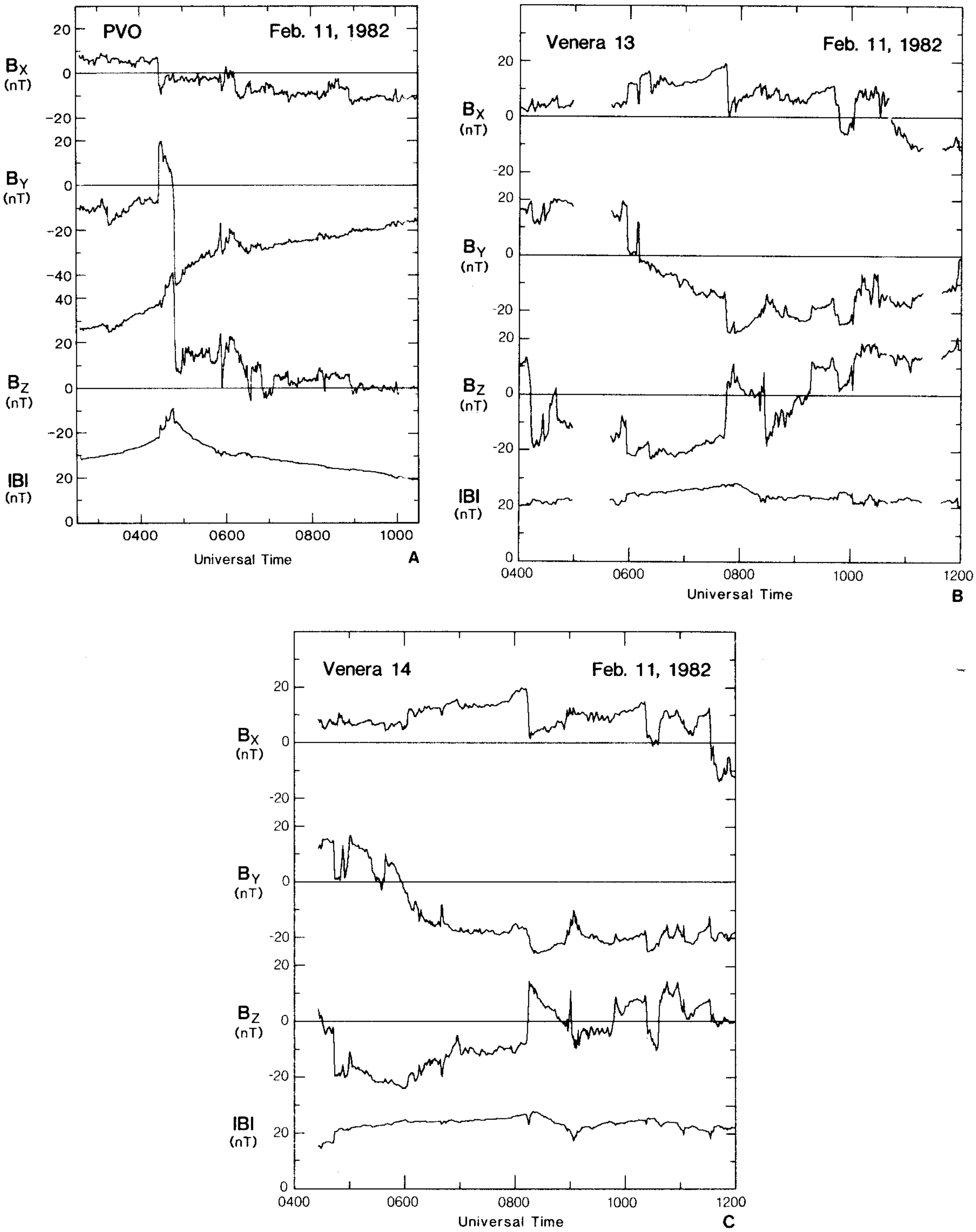

Fig. 2. One-min. averages of the magnetic field as observed by the vector magnetometers on three spacecraft. a) Pioneer Venus measurements in solar ecliptic coordinates. b) Venera 13 measurements in solar-pointing coordinates. c) Venera 14 measurements in solar-pointing coordinates. The azimuthal orientations of the Venera 13 and 14 coordinate systems about the solar (X) direction are unknown.

Venera 13 and 14 which are both nearly aligned with the Sun-Venus line. Both Venera spacecraft are rotating slowly about the spacecraft-Sun line and have an unknown orientation about this line. Thus, the X-axes of all three spacecraft point in similar directions but the Y and Z-axes do not. The Venera spacecraft see at most a magnetic enhancement and a thin current sheet near the center of the disturbance at times lagging the Pioneer Venus peak disturbance of 3.2 and 3.6 hours. These are similar in some respects to the disturbance seen by Pioneer Venus but much much weaker. The enhancements at Venera 13 and 14 are only 20% above the preexisting field. At Venera 14, the enhancement is followed by a clear depression in the field. Furthermore the enhancements last only about two hours. If we assume that the disturbance observed by Pioneer Venus was propagating in the solar wind away from the Sun or convected by it, the over 600 km/sec solar wind velocity at this time implies the disturbance would be 21,000,000 km long. Interplanetary shocks and stream-stream interactions have azimuthal dimensions equal to or greater than their radial dimension. Magnetic clouds are expected to have roughly equal radial and azimuthal dimensions. We know of no solar-initiated disturbance that has the pencil-like shape necessary to be observed so strongly and so long at Venus yet be so weak and rapid at Venera 13 and 14. Furthermore, if we assume that the disturbance was propagating radially at or above the solar wind speed, the delay between the peak disturbance at Venus and the peak at Venera 13 and 14 would be much shorter than observed. The apparent radial speed between Venus and Venera 13 and 14 is 490 km/sec compared with the 610 km/sec measured at Pioneer Venus. The apparent radial speed between Venera 13 and Venera 14 was 440 km/sec. If this difference were due to a velocity shear in the solar wind, the 2° difference in latitude of the Venera and Pioneer Venus would imply a 60 km/sec/deg gradient which is high for usual solar wind conditions.

Discussion

There is a model that can explain the apparently strong spatial gradients in the magnetic field and the long time delays. That model is the one originally proposed, i.e., that the three spacecraft have encountered a disturbance in the magnetic field which surrounds a slowly moving outgassing body or comet. In this model the disturbance is large at Pioneer Venus because this spacecraft passed near the nucleus. The disturbance is weak at Venera 13 and 14 because they are far downstream from the nucleus and 4×10^6 km from the Sun-nucleus line. The long duration (∿10 hours) at Pioneer Venus is associated with the slow motion (∿30 km/sec) of a disturbed region of the order of 10^6 km across the spacecraft. The shorter duration at Venera 13 and 14 suggests that either the disturbed region is thinner far behind the nucleus, or that the wake is perhaps flapping in the solar wind. In this model the lack of tail-like fields at either Pioneer Venus or at Venera 13 and 14 is due to the fact that Pioneer Venus is near to the coma and Venera 13 and 14 are far from the tail axis. There is some change in the sunward-antisunward field component, B_x, at all three spacecraft which suggests that they all passed through the plane of the cometary current sheet which we would expect to be perpendicular to the ambient interplanetary magnetic field and containing the solar wind-nucleus vector.

We could calculate the velocity of the current sheet if we knew its shape, i.e., planar, the two intersatellite time delays, the separation vector and one other constraint (cf. Russell et al., 1983b). We attempted to perform such calculations using the times of occurrence of similar features in the records of the three spacecraft, assuming that these features all lay in the same plane and that the solar wind velocity vector also lay in this plane. As can be seen in Figure 1, the three spacecraft lie almost along a straight line. This geometry is not ideal for determining the normal to the plane of the disturbance and its speed along the normal. The solution, in fact, was found to be extremely sensitive to the timing of features and the direction of the solar wind. Thus, we could not determine a reliable estimate of the orientation of the normal to the disturbance or the velocity along this normal.

Conclusion

Venera 13 and 14 observed at most a weak disturbance 3.2 and 3.6 hours after the strong enhancement in field strength seen at Venus on February 11, 1982. The weakness of the event at the two nearby Venera spacecraft, 6×10^6 km away, rules out a solar disturbance as the cause of the Pioneer Venus disturbance. Our original hypothesis, that the disturbance was due to the passage of a comet, is consistent with the weakness of the events at Venera 13 and 14.

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