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ON THE COMPRESSIBILITY OF THE MAGNETIC TAILS OF MARS AND VENUS

K. I. Gringauz,* M. Verigin,* J. G. Luhmann,** C. T. Russell** and J. Mihalov***

** Space Research Institute, Russian Academy of Science, 117810 GSP 1, Profsoyuznaya UL. 84/32, Moscow, Russia*
*** Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024-1567, U.S.A.*
**** NASA Ames Research Center, Moffett Field, CA 94035, U.S.A.*

ABSTRACT

The compressibility of the Martian magnetic tail (the dependence of its diameter on the solar wind ram pressure) was first revealed by the Mars-5 spacecraft in 1975. Plasma and magnetic studies from the Phobos-2 spacecraft have provided the opportunity to investigate this dependence with good statistics. The observed dependence of the diameter on approximately the inverse one-sixth power of the solar wind dynamic pressure is similar to that expected for the location of a magnetopause of a planet with an intrinsic magnetic field. Until now, no one has examined the effect of solar wind dynamic pressure on the Venus tail with which to compare the Martian observations. In this paper we compare the compressibility of the Venus tail with that of Mars by using magnetic field signatures of the tail boundary as a proxy for high resolution plasma measurements.

INTRODUCTION

Recent results from analyses of the Phobos-2 TAUS experiment plasma data /1/ showed that the diameter of the Martian magnetotail responds to changes in solar wind pressure. The dependence of tail radius on the upstream dynamic pressure appears to be similar to the dependence that is expected for an intrinsic field magnetotail, even though the magnetic field polarities in the tail measured along the Phobos-2 orbit are consistent with an induced origin for the tail /2/. The Martian tail is also wider than the induced tail of Venus as was found in the earlier Mars-5 spacecraft measurements /3,4/. Both of these observations have been interpreted as evidence for an intrinsic field contribution to the Mars magnetotail.

In order to compare these results from Mars with a large sample of Venus tail data, we here use the Pioneer Venus Orbiter (PVO) observations to examine the dependence of the Venus tail diameter on solar wind pressure. The different orbit of the PVO, together with the different complement of instruments, make this comparison somewhat compromised. However, we consider that the results are worth presenting in view of the continuing debate over the nature of the Martian obstacle to the solar wind.

DESCRIPTION OF THE PHOBOS-2 RESULTS FROM MARS

Verigin et al. /1/ defined the location of the Martian tail boundary crossing along the Phobos-2 orbit as the location in the wake where the solar wind plasma was no longer detected. They used 2 min resolution TAUS plasma analyzer data like that shown in Figure 1. These data were obtained with an instrument aperture of roughly 40° width pointing in the sunward direction. As seen in this example, there is a relatively sudden disappearance of the proton flux which is often followed by the appearance of oxygen ions in the heavy ion detector. These tail crossings, when normalized by fitting to typical obstacle shapes, and plotted against the solar wind dynamic pressure that was measured just outside of the closest bow shock crossing, exhibited the significant dependence shown

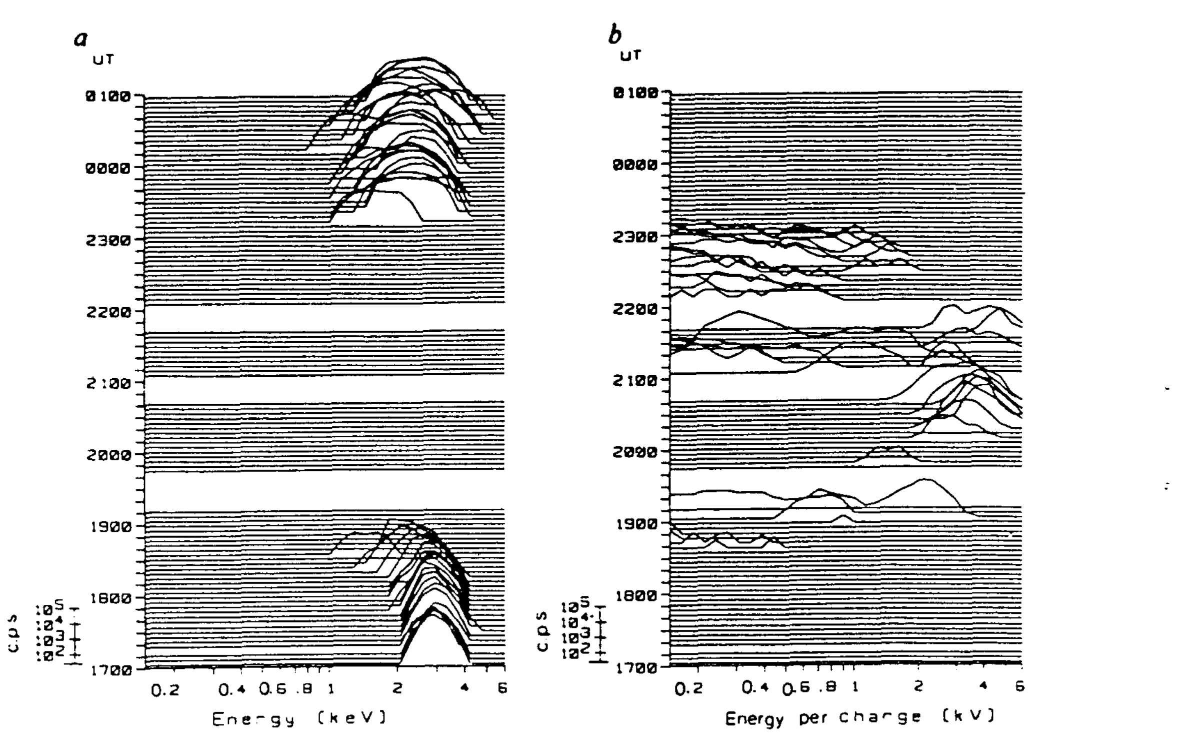

Fig. 1. Example of energy per charge spectra obtained once every two minutes by the Phobos-2 TAUS spectrometer as Phobos-2 passed behind Mars. The locations of the dropouts of the solar protons (a) were use by Verigin et al. (1992) to define the tail boundary crossings. Inside of this boundary, heavy ions (O^+) were detected (b). (Figure from /5/)

in Figure 2. Verigin et al. /1/ pointed out that the apparent functional dependence of the Martian tail radius on the solar wind dynamic pressure resembled that expected for the magnetotail of an intrinsic magnetosphere.

AVAILABLE PVO OBSERVATIONS FROM VENUS

The Pioneer Venus Orbiter did not have a comparable plasma analyzer in terms of temporal resolution and so we could not routinely determine the Venus tail boundary in the same way. Moreover, the bulk of the tail crossings used in the Verigin et al. /1/ analysis at Mars came from the circular orbits of Phobos-2 and were thus located at a distance of about 2 Mars radii downstream. The PVO orbit did not pass through the tail boundary in the corresponding region behind Venus. Although some of the tail crossings near PVO apoapsis were near 10 planetary radii like the few Mars tail crossings from the 4 Phobos-2 elliptical transfer orbits, these latter data were not sufficiently numerous to make a statistical study. Moreover, motion of the distant tail can add "noise" to such a study. Nevertheless, for a period in 1985-7, when the PVO orbit had evolved to the extent that periapsis, at ~ 2300 km (about 1.3 Venus radii) was above the nightside ionosphere, magnetic field data were obtained which could be used provided that a magnetic signature of the solar wind plasma boundary could be identified.

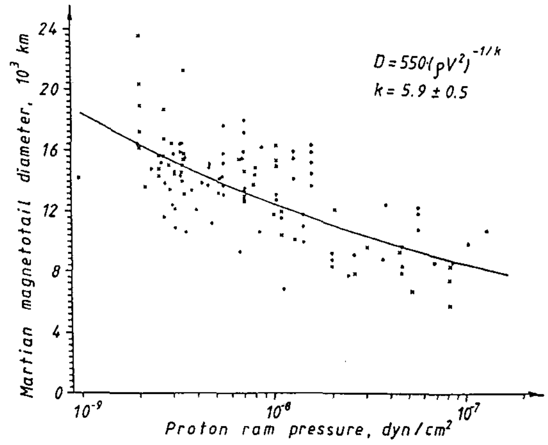

Fig. 2. Dependence of Martian tail crossings, defined by solar wind plasma dropouts, on upstream solar wind dynamic pressure. (Figure from /1/)

An example of the PVO magnetic field data obtained during one of these low altitude Venus tail crossings is shown in Figure 3. One distinctive feature of these time series is the dip in the field magnitude (designated in Figure 3 by the arrows) that seems to occur on each side of periapsis between the bow shock crossing and the tail lobe field maxima near the center. These dips coincide with the place where the field also becomes more x-directed (x is along the Venus-sun line). Thus these features are good candidates for the tail boundary. Indeed, they were used for such a definition in an earlier study by Luhmann et al. /6/. However, it remains to be demonstrated that they coincide with solar wind plasma dropouts.

An example of the magnetic field data from the Phobos-2 tail crossings in the circular orbit phase is shown in Figure 4. In this example, which resembles the Venus field data, the location of the solar wind plasma dropouts can be seen in the corresponding TAUS data. In general, the solar wind plasma disappears in coincidence with the increase of the field between the dips and the central tail lobe field maxima. Thus we will use these gradients, just inside of the field dips in the inner magnetosheath, as a "proxy" for the solar wind plasma boundary in the PVO data. The available Venera plasma data appear to support this assumption /8/.

RESULTS

Figure 5 shows the relative locations of the Venus tail boundaries, defined as described above, compared to the Mars tail boundaries of Verigin et al. /1/. A difference in behavior is clearly apparent even in these positions alone. When we now plot the cylindrical distance of the tail crossings versus the solar wind dynamic pressure measured outside the nearest bow shock crossings we obtain the result seen in Figure 6. This result gives further information about the comparison as well as raising new questions.

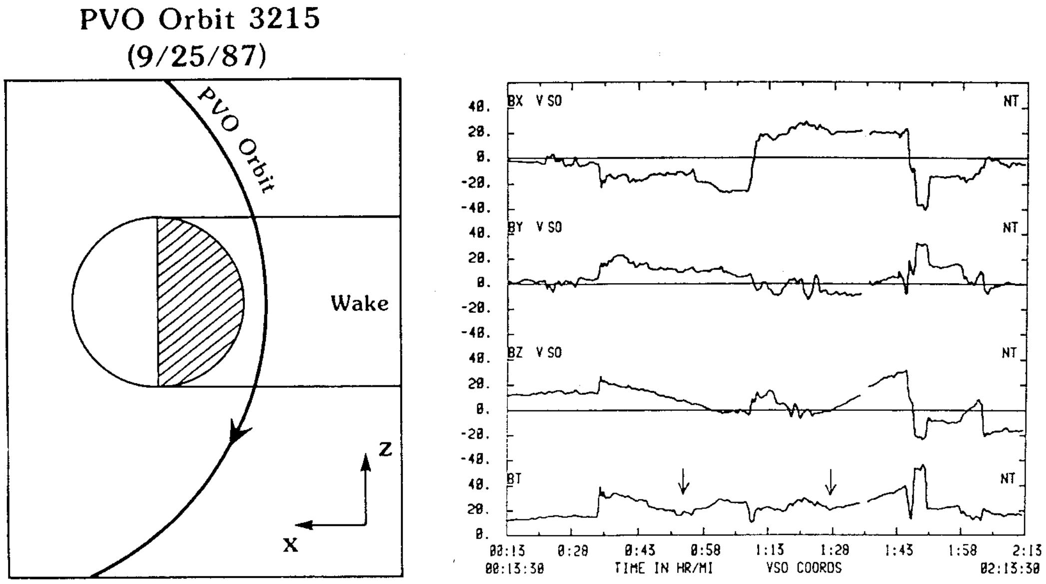

Fig. 3. Example of PVO magnetometer data obtained during one of the low altitude tail crossings in the extended mission phase (right). The orbit trajectory is also shown.

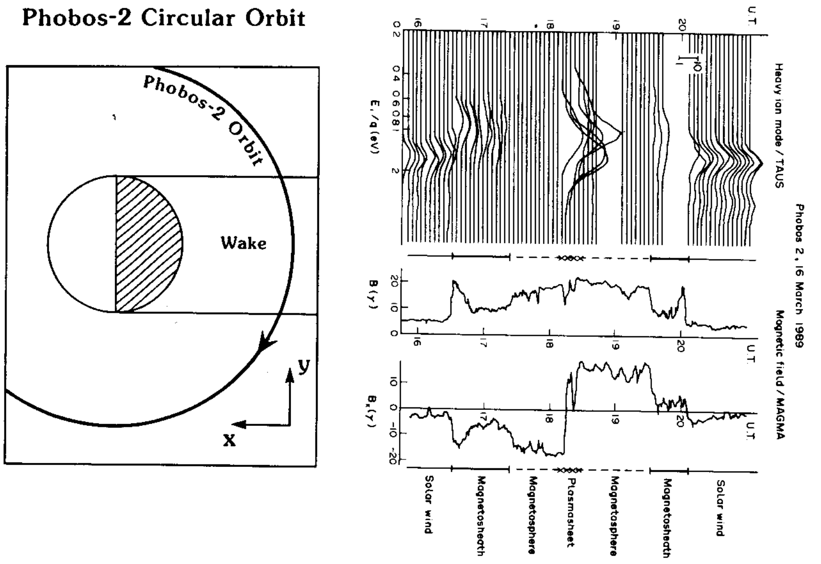

Fig. 4. Example of magnetic field and TAUS plasma data from a circular orbit tail crossing by Phobos-2. In this example of plasma data, the heavy ions and protons have been combined. The peaks in the center of the tail are heavy ions. (Data from /7/) The location of the circular orbit as it passes through the Martian wake is also shown.

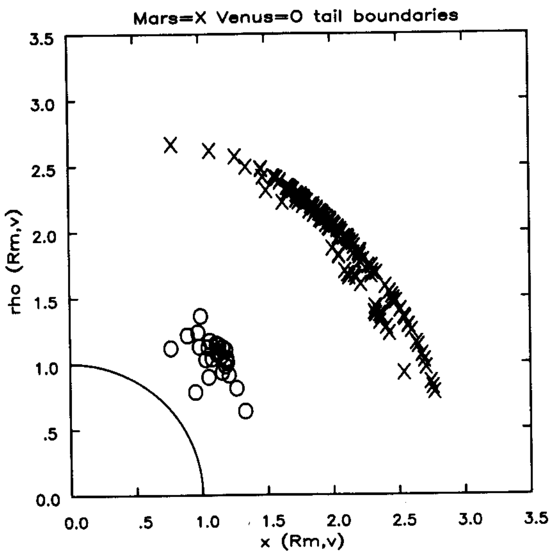

Fig. 5. Relative locations of the Phobos-2 tail crossings from Verigin et al. /1/ and the Venus tail crossings identified in this study.

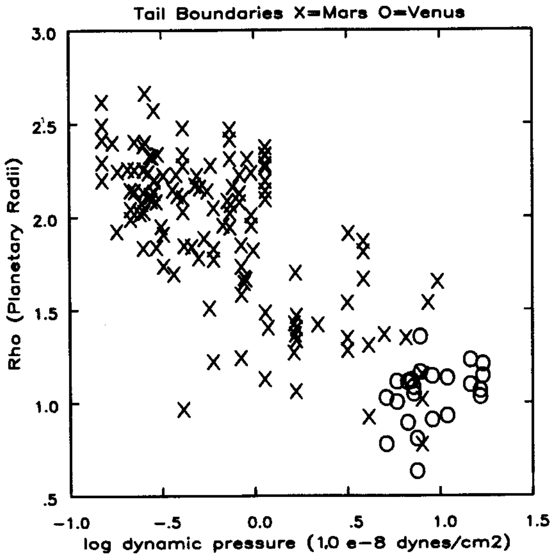

Fig. 6. Cylindrical positions of Mars and Venus tail crossings (with respect to the planet-sun axis) versus the upstream solar wind dynamic pressure.

First, from Figure 6 it is apparent that the range of solar wind dynamic pressures during the period of the Phobos-2 observations near solar maximum was much greater than the range of pressures during the PVO observations, which were obtained near solar minimum. Second, we know that at solar minimum the Venus ionosphere is probably too weak to stand-off the solar wind as it did during the primary low altitude mission of PVO (e.g. /9/). Is the different Venus tail behavior a result of the fact that these data were obtained at solar minimum instead of solar maximum? How would similar Venus results look for solar maximum conditions? Does the Mars tail boundary at solar minimum behave as it did during Phobos-2 observations? Gringauz et al. /10,11/ studied Mars-5 data from a period of low solar activity and suggested, on the basis of fewer observations, that the Mars tail was still compressible. Perhaps data from Mars-94, which will revisit Mars while solar activity is low, will finally resolve the questions raised by the comparison described here.

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