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ON THE VENUS ION MAGNETOTAIL STRUCTURE

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ABSTRACT

The magnetic field data obtained by PVO in the low altitude Venusian magnetotail are reexamined for the study of peculiarities of its formation and its connection with the IMF. Although the general induced nature of the Venusian magnetotail lobes with their characteristic control by the IMF orientation is clear, some features are not in line with the simplest magnetic field draping model. Perpendicular or transverse magnetic field components reversed from the IMF direction often occur in the tail. These observations are discussed in terms of possible magnetotail field reconnection and twisting.

INTRODUCTION

The generally accepted model of the induced magnetotail of Venus is that of draped magnetosheath field lines that sink into the wake as shown in Figure 1. An implicit assumption of this model is that the cross-tail or transverse field is everywhere parallel to the prevailing transverse interplanetary magnetic field (IMF). In this paper we examine some low altitude magnetotail data obtained on the Pioneer Venus Orbiter (PVO) during a period when periapsis rose above the nightside ionosphere. We restrict ourselves to cases when a clear draped magnetosheath and tail lobe structure is present, indicating the presence of fairly steady solar wind and IMF conditions. Out aim is to determine how consistent these tail observations are with the standard induced tail picture.

OBSERVATIONS

Figure 2 shows the time series of the PVO magnetometer data that were selected for this study. In all cases the tail lobes have polarities in the x (Venus-sun) direction that are parallel to those in the adjacent magnetosheath in accord with the standard model. The orientation of the transverse field component throughout the tail and magnetosheath is most easily seen in vector projections of the magnetic field along the PVO orbit track. Figure 3 shows two orthogonal views of the field vector projection for each tail crossing. The x-z view is the noon-midnight projection, and the y-z view is the view through the planet from the sun. The second of these is most relevant here because it shows the transverse fields, while the first illustrates the degree to which the draped magnetosheath and induced tail fields are related. The y-z (transverse field) views in Figure 3 appear to exhibit two types of behavior. In two of the examples (orbits 2325 and 1643), the transverse fields in the upstream, magnetosheath, and tail regions are roughly parallel, consistent with Figure 1. However, in the remaining cases there is an apparent reversal in the transverse field component in the tail at about the halfway point.

POSSIBLE INTERPRETATIONS

One way of producing transverse field reversal in the induced tail is by reconnection of the lobe

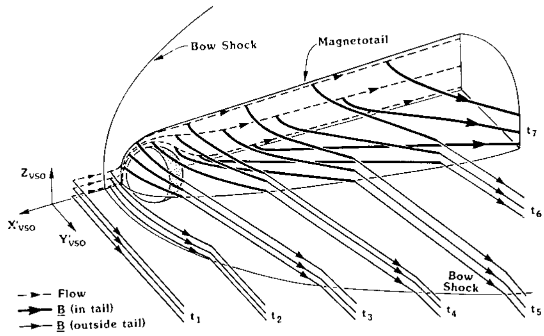

Fig. 1. Illustration of the configuration of the induced magnetotail of Venus (from /1/).

fields across the tail current sheet as illustrated in Figure 4. Yeroshenko et al. /1/ found reversed fields in the Venus wake in the Venera 9, 10 data and concluded that draped dayside fields closed in loops reaching to ~ 4 Venus radii downstream. Additional information on the frequency of occurrence of transverse field reversals found by Venera 9, 10 can be found in /2/. Saunders and Russell /3/ found a weak reversal in the transverse field in their statistical study of the near-apoapsis tail (at about 10 planetary radii downstream), and suggested that reconnection could be the cause. The formation of x-points in the Venus tail current sheet was also suggested by several other authors in a variety of contexts including nightside ionosphere hole formation /4/ and disappearing nightside ionospheres /5/. Particle observations on Venera 9, 10 /6/, which show an energetic component in the wake, can also be considered as possible reconnection signatures although other interpretations are possible /2/. Nevertheless, one problem that remains with this idea is the observation that usually only about half of the tail transverse field is reversed (see Figure 3).

An alternative interpretation to reconnection is illustrated in Figure 5. The reverse transverse fields in the tail lobes can occur as a result of twisting of the tail lobe fields, which in effect would add a cylindrical field component to the sunward and antisunward fields. To reverse the observed transverse field in one half of the tail, we estimate that a toroidal field of at least ~ 2 nT would usually be necessary. This is equivalent to an axial current of ~ 10^5 amp in the tail. The direction of that current appears to be down the tail in all cases, including the aforementioned orbits 2325 and 1643, where short periods of transverse field reversals are seen (Figure 3). It is noteworthy that if a (realistic) flux of ~ 10^{24} singly charged pickup ions per second move down the tail, the equivalent current is ~ 10^5 amp. This is consistent with the amount of O^+ ion scavenging estimated by McComas et al. /7/ from magnetotail field draping. However, scavenging associated with magnetotail draping would be expected to pick up both ion and electrons equally.

It is difficult to distinguish between these two possible explanations of the anomalous transverse fields in the Venus tail with the available data. We also cannot completely rule out the possibility that they are associated with the remaining lobes from a previous IMF orientation, but if this is the case, it is not clear why they seem to be restricted to only half of the tail and why the sense of the implied axial current is always directed away from the planet. As for the twisting or reconnection interpretations, it is not unreasonable that both effects may be operating.

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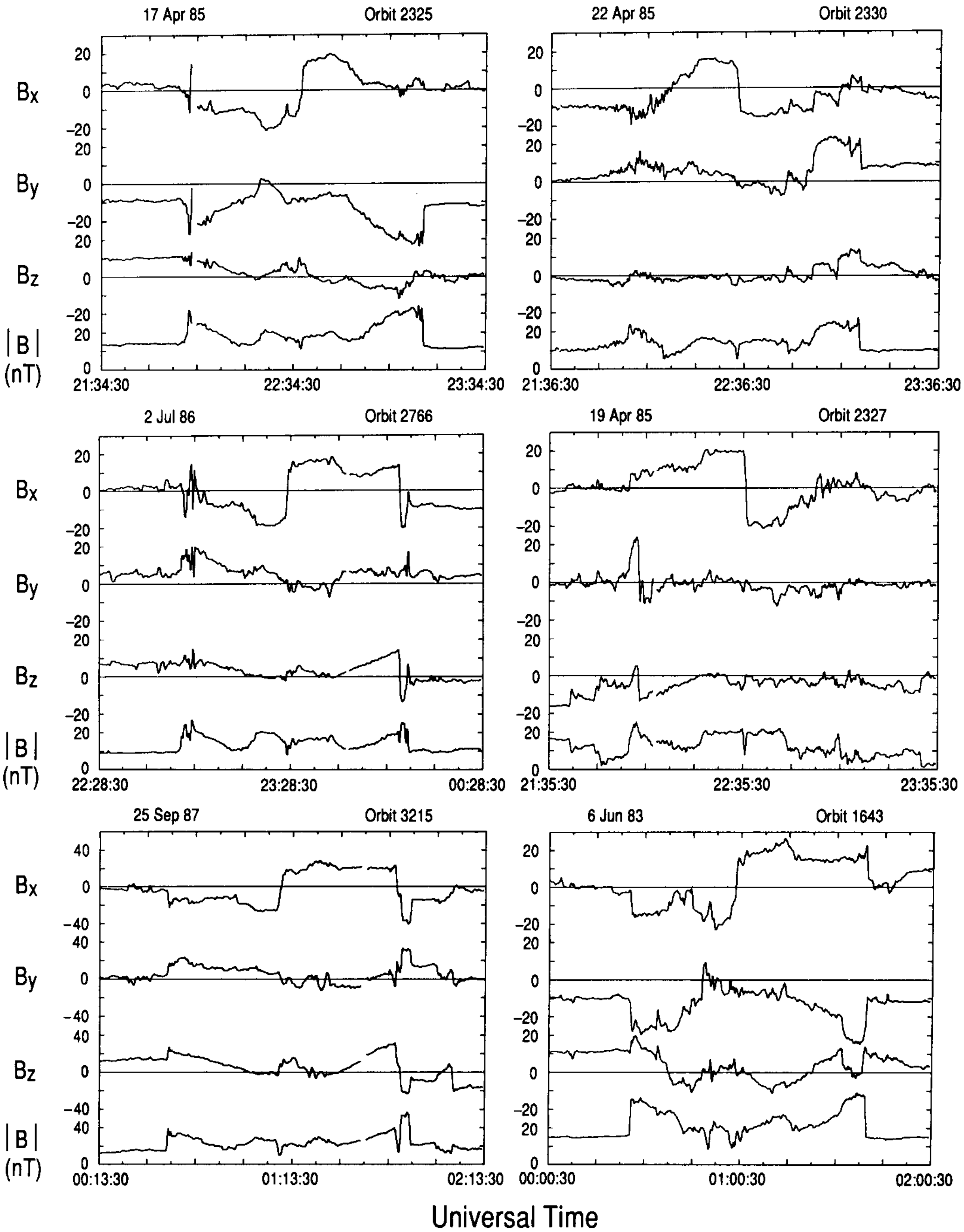

Fig. 2. Time series of PVO magnetometer data (10s aves) used in this study. The B_x components show clear double tail lobes which have directions or "polarities" consistent with those of the draped field in the adjacent magnetosheath. The minimum (periapsis) altitudes of these tail passes lie in the range 1000-2300 km.

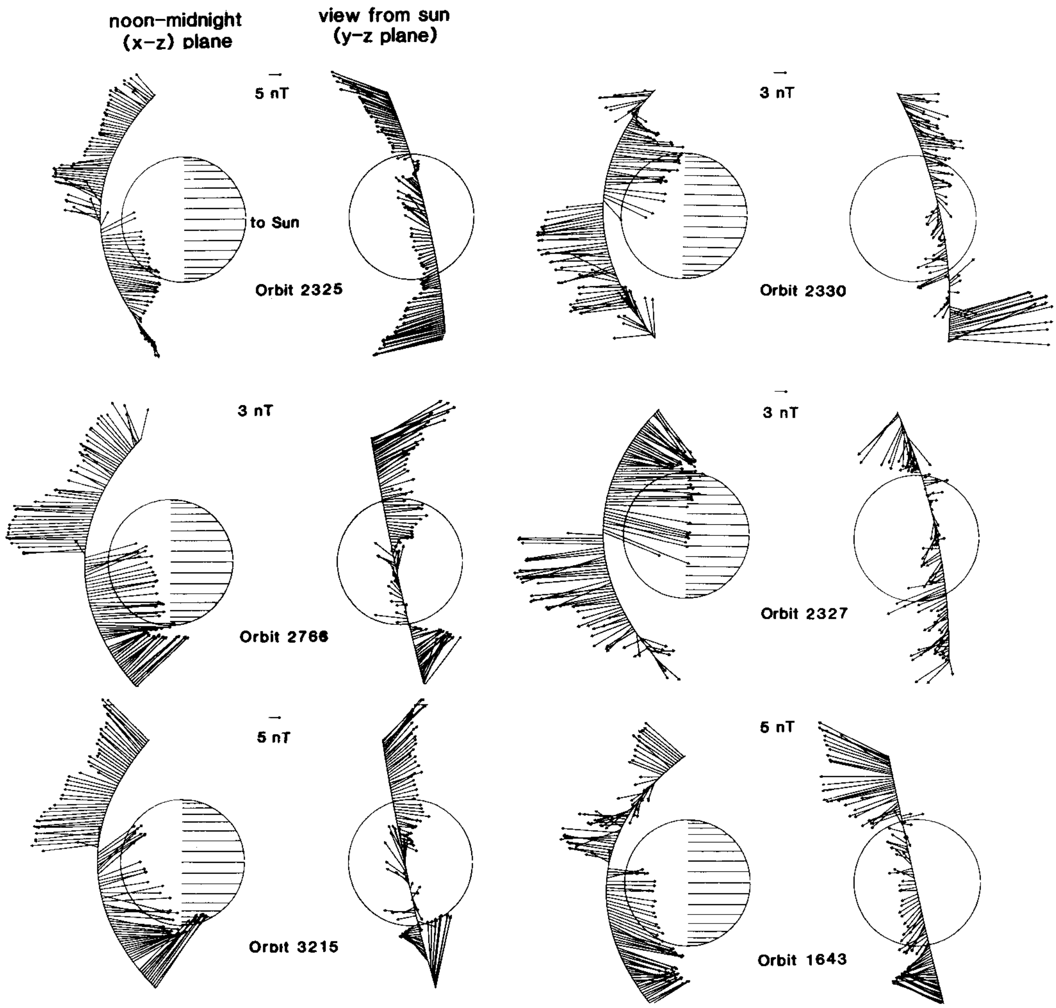

Fig. 3. Vector projections along the orbit for the data in Figure 2. The coordinate system is such that the x-z view is the noon-midnight plane projection (dayside is shaded), and the y-z view is through the planet as seen from the sun.

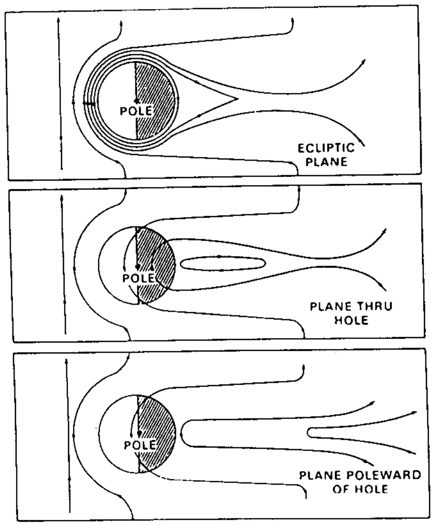

Fig. 4. Illustration of the possible effect of reconnection on the induced magnetotail of Venus (from /2/).

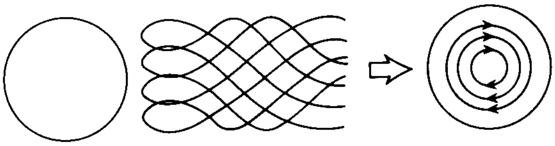

Fig. 5. Illustration of an alternate interpretation of the y-z views of the tail lobe magnetic vectors in Figure 3 that show a reversal with respect to the transverse IMF.

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