Pergamon

Adv. Space Res. Vol. 19, No. 12, pp. 1943–1946, 1997

Printed in Great Britain
0273-1177/97 $17.00 + 0.00

PII: S0273-1177(97)00106-3

DAYSIDE RECONNECTION DURING IMF NORTHWARD: A POSSIBLE FORESHOCK EFFECT

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ABSTRACT

The northward and southward orientation of the interplanetary magnetic field (IMF) is usually considered as providing the external boundary conditions in the solar wind interaction with the Earth's magnetopause but it is the magnetic field in the magnetosheath that interacts with the Earth's magnetic field. In this paper, we consider the possibility that the wave activity in the foreshock region may affect the magnetic field orientation in the magnetosheath with time scales that might be geomagnetically effective. If magnetosheath magnetic field becomes disturbed on plasma streamlines which are connected to the quasi-parallel bow shock and foreshock, the magnetic field orientation on the inner magnetosheath may differ significantly from the undisturbed IMF. We present a model of dayside reconnection which may occur when the IMF northward and illustrate its effects on the erosion of the magnetopause.

INTRODUCTION

Whether the interplanetary magnetic field is northward or southward is a significant boundary condition on most models of the magnetosphere. When the IMF turns southward, the reconnection of the IMF magnetic field and magnetospheric magnetic field occurs resulting in erosion of the magnetopause (Aubry *et al.*, 1970) and in the appearance of FTEs (Russell and Elphic, 1978). When the IMF turns northward, the solar wind interacts with magnetosphere principally via normal stresses and the magnetopause returns to its expected inviscid position (Petrinec and Russell, 1993). The functional form of the coupling of the IMF with the magnetopause is often taken or found to be a half wave rectifier of the clock angle about the solar wind flow direction (Petrinec and Russell, 1993; Arnoldy, 1971; Burton *et al.*, 1975).

In this paper, we examine the postulate that the wave activity in the foreshock region modifies the magnetic field orientation sufficiently to affect reconnection at the magnetopause. The magnetosheath magnetic field is disturbed on plasma streamlines which are connected to the quasi-parallel bow shock. This fluctuation is superposed on the shocked IMF. When the IMF B_Z is northward, the time average sheath B_Z would be northward but if the fluctuations are large could be southward from time to time. Thus a northward IMF does not exclude the possibility of reconnection on the low-latitude dayside magnetopause. We present a topological model of dayside reconnection which may occur in fluctuating sheath magnetic field when the IMF northward.

FLUCTUATIONS IN THE MAGNETOSHEATH FIELD

In this section, we examine two examples of ISEE magnetometer time series. We illustrate the presence of fluctations in the B_Z orientation both in foreshock region and in magnetosheath. To compare, we use IMP 8 observations to monitor the upstream IMF B_Z orientation.

November 1, 1981 case

Figure 1 shows the simultaneous measurements obtained by ISEE 1 and IMP 8 on Nov. 1, 1981 from 2300 to 2430 UT (adapted from Le and Russell, 1990). In this case, IMP 8 is in the undisturbed solar wind and ISEE 1 in the foreshock region. The magnetic field in the foreshock region is highly fluctuating. This fluctuation is superposed on the IMF. The IMF observed by IMP 8 is mainly in the ecliptic plane pointing slightly southward. Due to the wave activity in the foreshock region, the B_Z observation by ISEE 1 in the foreshock region could be either southward or northward. Near the magnetopause we would also expect to see such fluctuating fields and depending on the time scale for reconnection, the negative cycle of these fluctuations could lead to reconnection.

October 31, 1977 case.

This case has been well studied as the indication of the oscillating magnetopause. Here ISEE 1 is on the inbound leg with a large number of magnetopause crossings. Figure 2 shows the magnetic field measurements before the crossing.The first magnetopause crossing occurs at 2210 UT. All the crossings occured downstream of quasi-parallel shocks. The upstream IMF B_Z observed by IMP 8 is strong northward oriented through this time period. Although the magnetosheath B_Z remains mainly northward most of the time (if we make an average of the data with large time interval), the sheath field occasionally turns southward with a time period of 1-3 minutes due to foreshock oscillations. Such fluctuations could lead to the observed boundary motions.

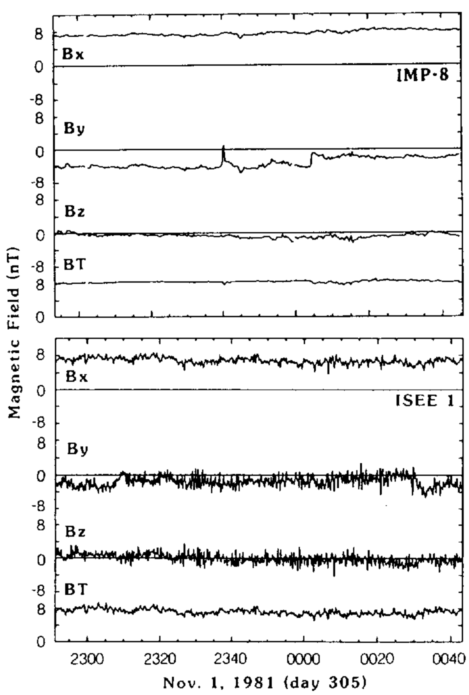

Fig.1, The magnetic field time series on Nov. 1, 1981 from ISEE 1 and IMP 8. Characteristics include the appearance of the magnetic fluctuation enhancement in the foreshock region. The B_Z in the foreshock is not simply a compressed version of the IMF B_Z.

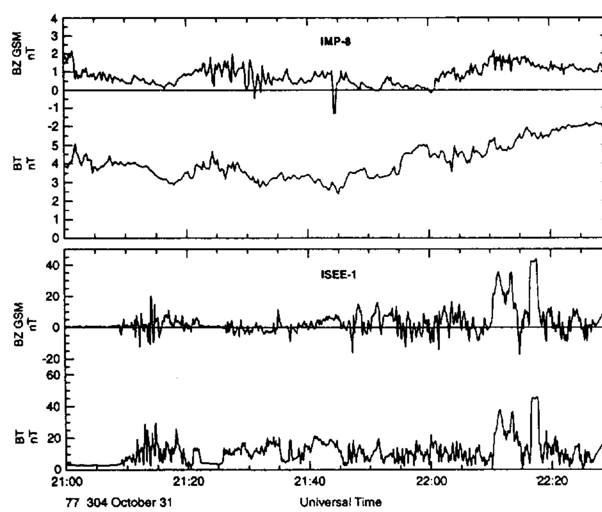

Fig. 2, Example of the magnetic field observed in the magnetosheath by ISEE 1 (bottom panel) when the IMF strongly northward as recorded by IMP 8 (top panel). The variation of the B_Z generally occurs with periods less than 1 minute.

The magnetosphere will be affected by magnetosheath fluctuations only if the fluctuations reach the magnetopause. This will occur when the stagnation point streamline originates in a region of quasi-parallel shock. Figure 3 shows the configuration of the magnetic field in the plane defined by the solar wind flow and the IMF for typical Parker spiral conditions at 1 AU. The dividing line between the quasi-parallel and quasi-perpendicular shock occurs very close to the stagnation streamline that "coats" the magnetopause. If the Parker spiral angle is greater than 45^0 the magnetopause should be free of fluctuations. If the Parker spiral angle is less than 45^0 it should be covered with fluctuating fields.

A TOPOLOGY OF THE DAYSIDE RECONNECTION DURING NORTHWARD IMF

Dungey's (1961) reconnection picture is a singular case since the IMF can have arbitrary orientation in general (Russell, 1972). Various models have been proposed since. In most models of dayside reconnection the reconnection line passes through the subsolar stagnation point. For a purely northward IMF, the reconnection can also occur on the polar cusp boundary. In principle it is therefore feasible that reconnection can occur for any IMF orientation. However, the earlier models have ignored the possible effects of the fluctuations of the sheath magnetic field.

Figure 4(a) and 4(b) show our proposed reconnection topology where the IMF is northward with a B_Y component and viewed from the Sun. As we have discussed in the last section, a southward magnetic field may exist in the magnetosheath due to the activity of the quasi-parallel shock wave. For easy illustration, we show only one southward magnetic kink on the magnetosheath field which points northward in interplanetary space. Figure 4(a) shows that there may occur a region of reversed field in the subsolar point even the IMF points northward. Figure 4(b) shows the directions that magnetic tension will tend to pull these field lines. The plasma is going to be accelerated away from the subsolar point as the field lines straighten up.

In contrast, we show in Figure 4(c) an illustration of traditional reconnection model where the IMF is southward. We can see that Figure 4(b) and 4(c) are similar. That is, both IMF northward and southward produce similar reconnection topology with magnetic tension to accelerate the plasma away from the subsolar point. The only difference lies in the size of the angle between the connected Earth's field and IMF field (here we name it the alpha angle). When the end of the IMF points southward, alpha is less than 90^0. When the end of the IMF points northward, this alpha is greater than 90^0. The smaller the alpha angle, the stronger the is plasma accelerated away from the subsolar point.

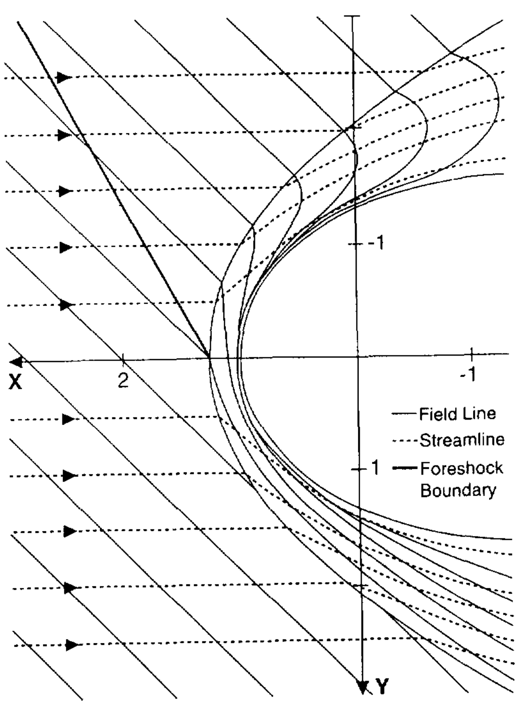

Fig. 3, Illustration of the global appearance of the magnetosheath magnetic field in the X-Z plane. The foreshock in front of the bow shock generates waves that are carried from the foreshock into the magnetosheath.

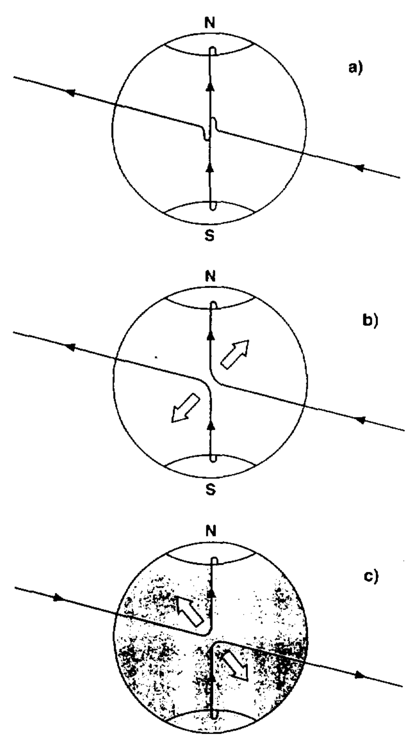

Fig. 4, Dayside reconnection model for IMF northward (4a and 4b). 4c shows the traditional reconnection model where the IMF is southward.

DICUSSION AND CONCLUSIONS

Our hypothesis was very straightforward. Reconnection is known to take place for southward IMF. The foreshock and quasi-parallel shock clearly lead to southward field orientations in the magnetosheath. The fluctuations are of significant amplitude and are found right up to the magnetopause. Thus, we would expect reconnection behind the foreshock. Nevertheless, it is possible that the fluctuations caused by the foreshock are too rapid for reconnection to be initiated. Thus, we have to test our conjecture. The erosion of the magnetopause first discussed by (Aubry *et al.*, 1970) and later quantified by (Petrinec and Russell, 1993) may provide such a test. As the most recent study of the orientation of the IMF on the magnetopause position shows (Petrinec and Russell, 1996) nose of the magnetopause lies at a constant distance from the Earth for all northward IMF components when normalized for the solar wind dynamic, thermal and magnetic pressure. When the IMF is southward, the nose moves inward linearly proportional to the southward component of the IMF. We have used these same data to test our conjecture about the role of the fluctuating magnetic field in the sheath due to the foreshock. We separated the same data by cone angle into two groups: 1. the cone angle of the IMF is less than 45° so that fluctuating fields should be seen in the magnetosheath in the subsolar region; 2. the cone angle of the IMF is greater than 45° and the subsolar region should be free of oscillations (Russell *et al.*, 1983; Luhmann *et al.*, 1986). We find that the nose of the magnetopause is at 10.35 ± 0.11 R_E when there are fluctuations at the nose and 10.37 ± 0.12 R_E when there are not. To the level of accuracy of these data, we have seen no effect of the fluctuations on reconnection. Given all the evidence for the effectiveness of southward field for reconnection we can only conclude that the time scale of the fluctuations behind the shock are too short for reconnection to occur. Thus while the foreshock may be an important source of pressure oscillation and wave 'noise' in the magnetosphere, it does not appear to be responsible for enhanced magnetic flux transfer.

ACKNOWLEDGEMENT

The work at UCLA was supported by the National Aeronautics and Space Administration under research grant NAGW 3948; by the National Science Foundation under research grant ATM 94-13081 and by a grant from the IGPP branch of the Los Alamos National Laboratory.

REFERENCES

Arnoldy, R. L., Signature in the interplanetary medium for substorm, *J. Geophys. Res., 76*, 5189 (1971).

Aubry, M. P., C. T. Russell, and M. G. Kivelson, Inward motion of the magnetopause before a substorm, *J. Geophys. Res., 75*, 7018 (1970).

Burton, R. K., R. L. McPherron, and C. T. Russell, An empirical relationship between interplanetary conditions and Dst, *J. Geophys. Res., 80*, 4204 (1975).

Dungey, J. W., Interplanetary magnetic field and the auroral zone, *Phys.Rev. Lett., 6*, 47-48 (1961).

Le, G., C. T. Russell, Observations of the magnetic fluctuation enhancement in the Earth's foreshock region, *Geophys. Res. Lett.*, 905-908 (1990).

Luhmann, J. G., R. J. Warniers, C. T. Russell, J. R. Spreiter, and S. S. Stahara, A gas dynamic magnetosheath field model for unsteady interplanetary fields: Application to the solar wind interaction with Venus, *J. Geophys. Res., 91*, 3001 (1986).

Russell, C. T.,The configuration of the magnetosphere, in *Critical Problems of Magnetospheric Physics, the Proceedings of the Joint COSPAR/IAGA/URSI Symposium*: Madrid May 11-13, 1972, Edited by E. R. Dryer 1-16 IUCSTP, Secretariat Washington DC. (1972).

Russell, C. T., and R. C. Elphic, Initial ISEE magnetometer results: Magnetopause observations, *Space Sci. Res., 22*, 681 (1978).

Russell, C. T., J. G. Luhmann, T. J. Odera, and W. F. Stuart, The rate of occurrence of dayside Pc 3, 4 pulsations: The L-value dependence of the IMF cone angle effect, *Geophys. Res. Lett, 10*, 663-666 (1983).

Petrinec, S. M., and C. T. Russell, External and internal influences on the size of the dayside terrestrial magnetosphere, *Geophys. Res. Lett., 20*, 339-342 (1993).

Petrinec, S. M., and C. T. Russell, Influencing factors on the shape and size of the dayside magnetopause, *Adv. Space Sci., 18*, 207-211 (1996).