



INTRINSIC TIME SCALE FOR RECONNECTION ON THE DAYSIDE MAGNETOPAUSE

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ABSTRACT

Recently much attention has been focused on the transient behavior of the magnetopause in response to pressure pulses and southward fluctuations of the interplanetary magnetic field. We examine the motion of the magnetopause behind the foreshock and conclude that this motion is affected by foreshock pressure variations but not by fluctuations in the direction of the magnetic field. Neither magnetopause erosion nor flux transfer event occurrence is controlled by the foreshock. On the contrary, flux transfer events occur at times of steady IMF and their quasi-periodic behavior is controlled by the magnetopause or the magnetosphere and is not driven by the external boundary conditions. Since flux transfer events are clearly due to reconnection, this observation implies that the IMF must be southward some time perhaps as long as 7 minutes before flux transfer begins.

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INTRODUCTION

Over the last several years the transient behavior of the magnetopause has drawn much attention because of the controversy between those who would drive flux transfer events (FTEs) [Russell and Elphic 1978; 1979] by pressure fluctuations [Sibeck, 1992] and those who felt this position untenable [Song et al., 1994]. It is clear from a variety of evidence that the flux transfer event is due to reconnection. The FTE consists of a core of twisted magnetic field containing a mixture of magnetosheath and magnetospheric plasma whether the FTE is in the magnetosphere or the magnetosheath [Le et al., 1996] and this core is surrounded by a draped magnetic field containing plasma of the type in which the FTE is embedded, i.e. magnetosheath plasma (only) for FTEs found on the magnetosheath side of the magnetopause and magnetospheric plasma (only) on the magnetospheric side. Over the dayside of the magnetopause the occurrence of FTEs is controlled by the southward component of the IMF and their east-west motion is controlled by the IMF, all as expected if FTEs are reconnected magnetic flux tubes.

These observations are not consistent with the conjecture that the foreshock causes FTEs through the production of pressure pulses. However, the foreshock also produces directional fluctuations in the magnetic field which could lead to reconnection [see e.g. Russell et al. 1987; Greenstadt and Russell, 1994]. Also it is important to establish what effect the foreshock pressure pulses do have on the magnetopause if they do not lead to FTEs. In this report we examine first the role of the foreshock in creating magnetopause transients and conclude that no reconnection phenomena are generated by these

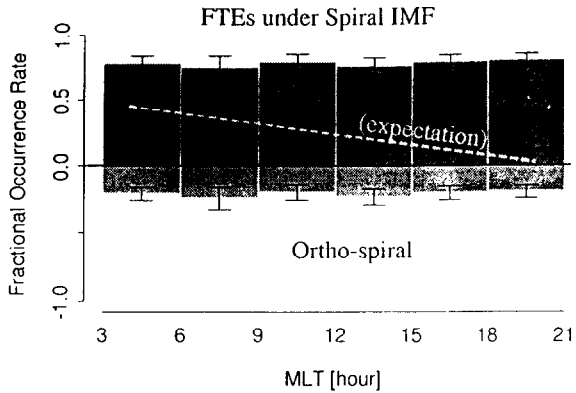


Fig. 1. The local time dependence of the relative number of FTEs produced under normal spiral IMF conditions and orthospiral IMF conditions. If the foreshock controlled FTE occurrence we would expect the relative rate of FTE occurrence to decrease with increasing local time in this diagram.

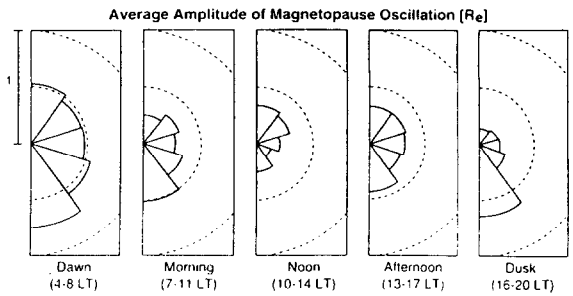


Fig. 2. The average amplitude of the magnetopause motion as a function of local time and the clock angle of the IMF in GSM coordinates. Clock angles have been folded into the righthand side of each pie chart and only normal spiral IMF conditions have been examined here. Pie slices have been overlapped by half, one either side in order to minimize aliasing of the distributions.

generally about 1 minute magnetic fluctuations. On the contrary FTEs appear to be generated when the IMF is constant. We conjecture that flux transferring reconnection does not occur unless the magnetic field at the magnetopause has been southward for the order of 7 minutes or more, and that this time scale is controlled by the magnetopause or the magnetosphere.

FORESHOCK CONTROL OF FTES

Flux transfer events are identified principally by their bipolar signature in the normal component of the magnetic field near the magnetopause. An automatic computer algorithm has been written to detect FTEs in the ISEE-1 magnetic field data [Kawano *et al.* 1996a]. A survey of all the ISEE-1 data shows that FTEs vary in occurrence rate at most slightly with local time or with the Parker spiral angle. If there is any bias it is toward greater occurrence in the afternoon sector. This lack of foreshock control is illustrated in Figure 1 that shows as a function of local time the fraction of FTEs created under Parker spiral and orthospiral conditions [Kawano and Russell, 1996b]. If the foreshock had any effect on the occurrence of FTEs, the relative occurrence rate would change as indicated on the plot by the line marked expectation. Thus the foreshock does not control FTEs.

FORESHOCK CONTROL OF MAGNETOPAUSE MOTION

Even if the foreshock does not control FTE production, it might cause motion of the magnetopause through the pressure pulses or possibly by reconnection caused by fluctuating magnetic fields. In order to test this we have examined the data base of Song *et al.* [1988] and used the radial difference between the closest magnetopause crossing and the most distant crossing on each pass. This distance is shown in 5 pie charts in Figure 2, one for each local time sector from dawn to dusk with the pie slices representing the clock angle of the IMF. The righthand pie charts cover local times where there is no foreshock effects because we have eliminated all data for which there were ortho-spiral conditions. When the IMF is southward oscillations in the magnetopause increase and this increase grows with local time. For

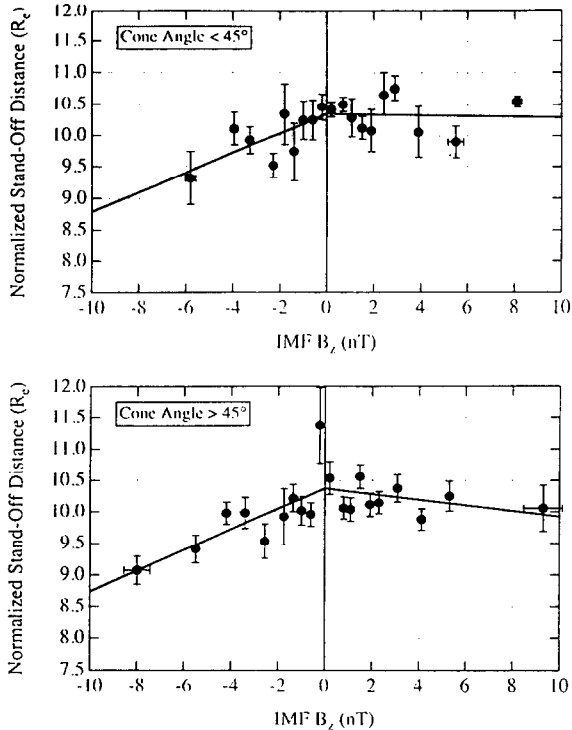


Fig. 3. Observed control of IMF B_z on the location of the nose of the magnetopause for two different cone angle ranges: less than 45° when the waves should impact the nose of the magnetopause and greater than 45° when they should not. The boundary positions have been normalized by the sixth root of the total solar wind pressure following the technique of Petrinec and Russell (1996).

northward IMF there is no increase with increasing local time. On the morning side, the southward IMF conditions do lead to increased oscillations but oscillations increase for northward IMF also. If the obvious effect of the foreshock on the morning side were due to reconnection we would have expected that the effect would be greatest in the equatorial regions and not at strongly northward and southward clock angles. Thus we must conclude that the principal role of the foreshock here is through the pressure fluctuations it creates and not the magnetic oscillations.

FORESHOCK CONTROL OF MAGNETOPAUSE EROSION

Another means of checking the efficacy of the magnetic fluctuations of the foreshock region on inducing reconnection at the magnetopause is to examine the standoff position of the magnetopause when those oscillations are illuminating the subsolar region and when they are not. Figure 3 shows the standoff distance of the magnetopause normalized by the total pressure of the incoming solar wind for varying IMF for two situations, when the foreshock is producing magnetosheath oscillations at the subsolar point (top) and when it is not (bottom) [Zhang et al., 1996]. The intercept of the two best fit lines is 10.35 ± 0.11

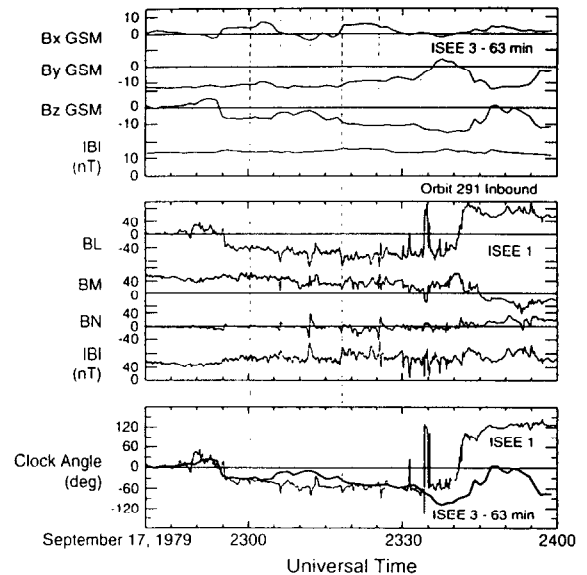


Fig. 4. Flux transfer events detected by ISEE-1 in the magnetosheath under conditions of approximately steady IMF conditions. The top four traces show the IMF at ISEE-3 measured in GSM coordinates. The middle four traces show the magnetic field at ISEE-1 measured in boundary normal coordinates and the bottom panel shows the clock angle measured by ISEE-1 and 3 that was used to determine the relative time delay of the two observations.

Re in the top panel and 10.37 ± 0.12 Re in the bottom. Clearly foreshock induced waves have no effect on the erosion of the magnetopause.

FTES UNDER STEADY SOLAR WIND CONDITIONS

The studies examined above show that the pressure fluctuations produced by the foreshock can induce movement of the magnetopause but that the fluctuating field directions associated with the foreshock seem not to produce any reconnection associated phenomena (FTEs or erosion) at the magnetopause. Thus individual FTEs do not appear to be directly driven by external conditions. The only alternative is that the time scale of FTEs is set by the magnetosphere or the magnetopause and not by the IMF. This observation is also consistent with the lack of dependence of the rate of occurrence of FTEs on solar wind parameters such as beta, dynamic pressure, and Mach number [Kuo *et al.*, 1995].

Figure 4 shows an example of FTE occurrence seen by ISEE-1 while ISEE-3 detects a nearly constant southward IMF. The first FTE is seen 5 min after the southward turning is detected at ISEE-1 and FTEs are seen every 6 to 7 minutes later [Le *et al.*, 1993]. There is no apparent solar wind or interplanetary driver for the observed periodicity or the initial delay of the first FTE.

DISCUSSION AND CONCLUSIONS

The above studies provide four lines of evidence that reconnection is not immediately responsive to a southward IMF. First, extra FTEs are not produced behind the foreshock when there are fluctuations with a period of about one minute. Second, increased erosion of the magnetopause does not occur behind the foreshock. Third, FTE production does not begin immediately after a southward turning, and four, FTEs occur in a quasi-periodic manner under steady solar wind conditions, rather than reconnection taking place in a quasi-continuous manner.

The reason for this time scale is not obvious. One 3-D MHD simulation of FTE production has draped magnetic field lines in the magnetopause holding back the escape of reconnected flux tube [A. Otto, personal communication, 1996]. On the other hand in global MHD models the rate of reconnection is controlled by ionospheric conductivity [Fedder *et al.*, 1995] and thus the time for communication to the ionosphere should be involved. Finally, studies of the time delay between southward turnings and ionospheric response as measured by coherent radars, also find a similarly delayed response [Etemadi *et al.* 1988; Greenwald *et al.*, 1990]. Discovering the reason for this apparent time scale for reconnection at the magnetopause is important and may provide clues as to why at times the magnetopause reconnects in a quasi-steady manner and at other times reconnects in a quasi-periodic manner.

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