POSSIBLE SOURCES OF PLASMA DENSITY FLUCTUATIONS IN THE MAGNETOSHEATH

Z. Němeček[1], J. Šafránková[1], L. Přech[1], and G. Zastenker[2]

[1]*Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, 180 00 Prague 8, Czech Republic*

[2]*Space Research Institute, Moscow, Russia*

Abstract

Our study presents transient ion flux enhancements or depletions which are observed in the magnetosheath and which cannot be related to similar changes in the solar wind. The duration of the transient events varies from tens of seconds to a few minutes and their amplitude can exceed background levels by a factor 3. Spatial dimensions of the observed events estimated from simultaneous measurements of closely separated INTERBALL–1 and MAGION–4 satellites are of the order of units of R_E. We are testing possible sources which have been proposed for an explanation of magnetosheath density fluctuations – a scanning of the radial profile of the magnetosheath due to upstream pressure pulses, standing waves, and changes of the interplanetary magnetic field direction. Our study leads to the conclusion that none of them are able to account for all observed features and that a possible source of these events is the interaction of the rotational discontinuities generated in the foreshock region with the bow shock.

1. Introduction

Magnetosheath represents an interface between the solar wind and Earth's magnetosphere. Many researchers still rely upon the gasdynamic model for magnetosheath plasma and magnetic field parameters presented by [1]. This model predicts that velocities decrease from the bow shock to the magnetopause, whereas densities and temperatures increase in the vicinity of the stagnation streamline. Slightly sunward of the dusk/dawn meridian, the density and velocity decrease but the temperature increases along radial profiles from the bow shock to the magnetopause. Along the flanks of the near–Earth magnetotail, minimum velocities and maximum temperatures occur in the middle magnetosheath. The plasma flows radially away from the stagnation streamline. Under the frozen–in assumption, the strength and orientation of the magnetosheath magnetic field can be determined from the output of the gasdynamic model. However, this approach to the problem is not self–consistent because it contains an implicit assumption that the tensions and pressures associated with the magnetic field are insignificant.

The authors of [2] predicted that MHD effects will further depress densities just outside the magnetopause. They suggested that this plasma depletion layer would be more pronounced during periods of northward IMF orientation when merging and accelerated flows are absent. The authors of [3] reported statistical surveys of magnetosheath observations alone to show that the depletion layer is more common when the magnetosheath magnetic field points northward. By contrast, *Pudovkin et al.* in [4] argued that the depletion layer itself was a signature of magnetic merging, and would be more pronounced during periods of southward IMF. *Sibeck et al.* in [5] invoked boundary waves and the depletion layer to explain observations of a sequence of impulsive density depressions and magnetic field strength enhancements near the magnetopause.

MHD simulations provide another view of magnetosheath transient events. *Lin et al.* in [6] have shown that the interaction of rotational discontinuities with the bow shock can result in

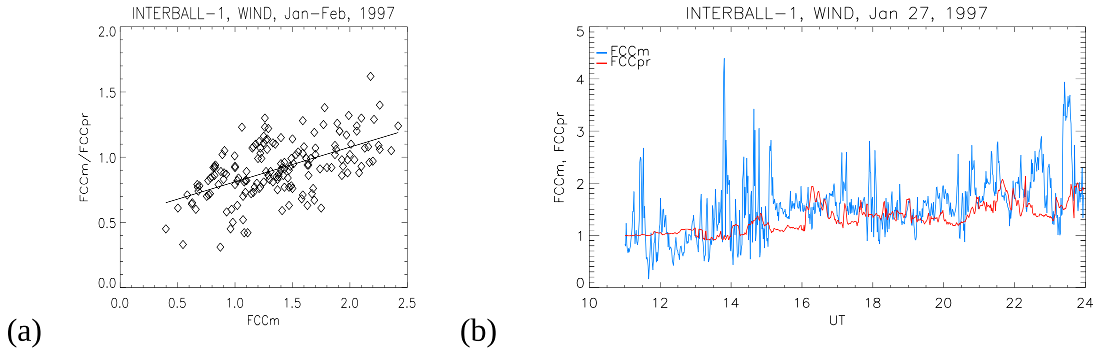

Figure 1. **(a)** Ratio of measured and predicted ion fluxes as a function of measured one (hourly averaged, Jan–Feb 1997). **(b)** A comparison of the measured and predicted ion fluxes.

transient pressure pulses in the magnetosheath. *Nemecek et al.* in [7] have reported the transient flux enhancements (TFEs) in the magnetosheath not correlated with the magnetic field changes and attributed them to this process.

As can be seen from the brief description of the present state, our knowledge on the magnetosheath is rather contraversional, in spite of the importance of this region for the investigation of solar-terrestrial relations. The paper deals with the systematic investigation of the magnetosheath ion flux on different time scales from hourly averaged data to the full available temporal resolution of measurements. The results of measurements are normalized to the solar wind conditions and compared with the model [1].

2. Observations

The study is based on the observations of the INTERBALL–1, MAGION–4, and WIND satellites. We suppose that the magnetosheath ion flux would be proportional to the solar wind one. To account for the changes of solar wind parameters, we compute the flux compression coefficient (FCC) as a ratio of the magnetosheath and solar wind ion fluxes. This measured FCC was compared with the value predicted by the model [1]. The solar wind ion flux is taken from the WIND data. Fig. 1a shows that there can be a slight systematic deviation of the predicted FCC from the measured one. The statistics is done for the dusk flank where the FCC increases toward the bow shock. It seems that the real radial magnetosheath profile is steeper than the predicted one. It can be connected with the presence of plasma depletion layer which decreases the magnetosheath density in the vicinity of the magnetopause.

The values of FCC in the region adjacent to the magnetopause is shown in Fig. 1b. The predicted value changes in the range 0.8-1.8 but the measured value fluctuates from 0.2 to 4.4. All available information on this day is shown in Fig. 2. Conditions in the solar wind were quiet and until $1400\,UT$, the IMF was directed nearly sunward. It means that the subsolar bow shock was quasiparallel in the subsolar region which serves as a source of the plasma in the magnetosheath.

The magnetosheath flux exhibits sharp fluctuations at the beginning of the depicted time interval. These fluctuations stop at $\sim$ 15 UT but during the whole day one can find a few intervals with similar fluctuations. These fluctuations are not correlated with the changes of the solar wind ion flux. The temporal resolution of the WIND measurements is about $90\ s$ only, but some of the spikes observed in the magnetosheath are longer, up to 5 min, and thus they should be recorded in the solar wind if they exist.

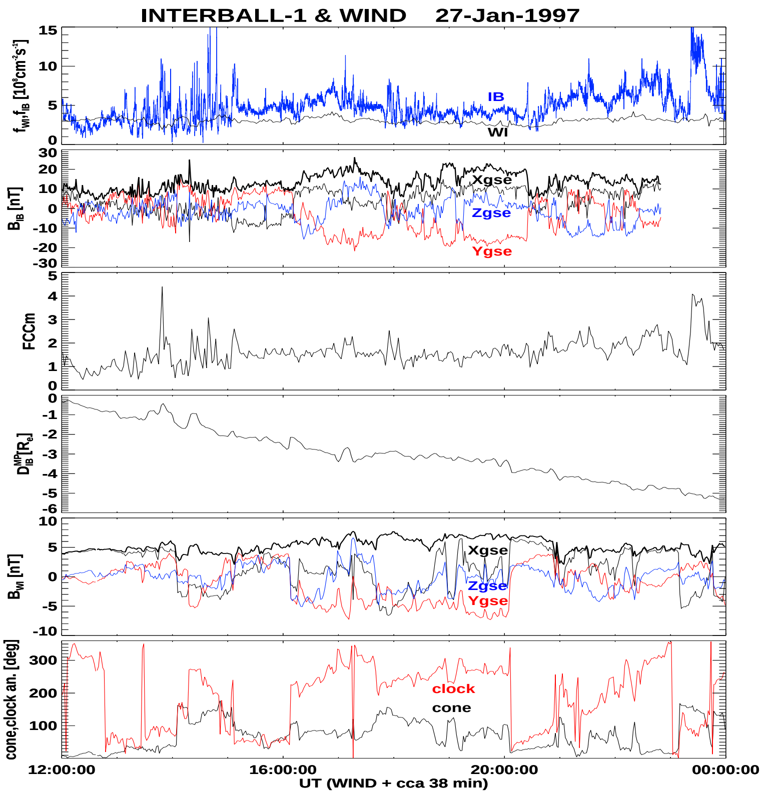

Figure 2. Solar wind and magnetosheath parameters on January 27, 1997.

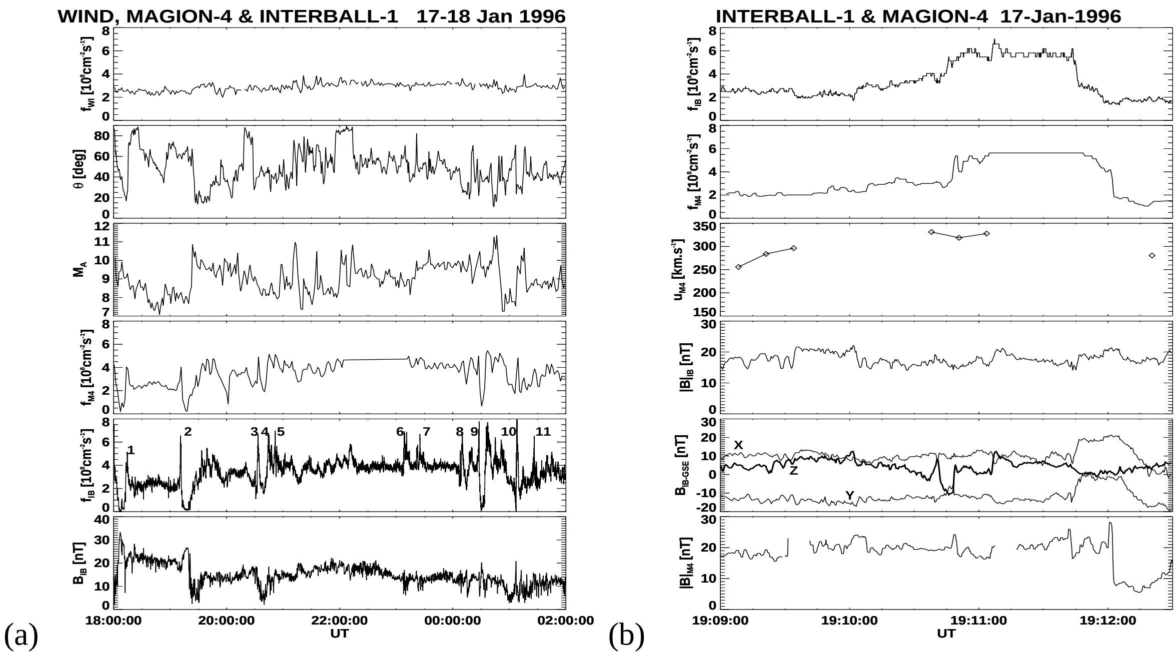

Figure 3. **(a)** An example of TFEs in the magnetosheath (from top to bottom: the solar wind ion flux, θ_{BN} of the subsolar bow shock, Mach number (M_A), the ion flux observed by MAGION–4 and INTERBALL–1, the magnetosheath magnetic field). **(b)** Detail of the TFE No.2 (u_{M4} stands for the magnetosheath speed, other abbreviations are the same as in part (a).

For the case study of TFEs, we chose the time interval from 1800 UT to 0200 UT starting on January 17, 1996. This period was chosen because the separation between INTERBALL–1 and MAGION–4 (ΔX= 1700 km, ΔY= 1900 km, ΔZ= 160 km); sufficed to determine the velocity of the flux structures. The INTERBALL satellites moved from $X, Y, Z_{GSE} = (-8.9, 16.0, 12.7)R_E$ to $(-11.2, 19.1, 12.8)$ R_E during this time interval. The top panel in Figure 3a shows that the solar wind flux (f_{WI}) was quiet with $N_{SW} \sim 6$ cm^{-3} and $v_{SW} \sim 490$ km/s. The IMF underwent a few rapid changes of the direction and magnitude which are demonstrated by the cone angle, θ, and Alfvénic Mach number computed from the WIND key parameter data. The magnetosheath ion flux measured by both INTERBALL satellites exhibited a strong modulation by transient enhancements which are numbered in Fig. 3a.

To consider the detailed structure of the TFEs, we plot TFE No. 2 at higher time resolution in Figure 3b, where the fluxes from both satellites are shown. Note the similarity of the ion flux profile observed by both satellites but the different time delays for the leading and trailing edges of the spike to reach the two satellites. This indicates either significant evolution on a time scale of tens of seconds or some spatial structure. Assuming that the TFE moves with the magnetosheath speed (∼300 km/s), the TFE thickness is $\sim 3\ R_E$. We suggest that the observed features are due to the 3–D spatial profile of the density because careful examination of the ion bulk velocity inside and outside the TFEs, computed from the MPS/SPS spectrometer onboard MAGION–4, has shown only small changes in speed. The comparison of the ion flux and magnetic field profiles in Fig. 3b shows that there is no correlation of these two quantities.

3. Conclusion

We present the statistical study of the solar wind - magnetosheath ion flux ratio for the dusk flank of the magnetosheath. From this study it follows that, except a small underestimation of the steepness of the magnetosheath profile, the model [1] gives a good description of the magnetosheath plasma compression. On the other hand, the better time resolution shows substantial declinations of the measured parameters from the model.

A part of the observed declinations from the model is connected with TFEs which definitely have any cause in the solar wind plasma. Their origin can be attributed to the interaction of foreshock instabilities with the bow shock [7]. In this case, the prediction of such events is very difficult because they occur when the subsolar bow shock is quasiparallel. It means that the IMF B_X component should be principal. Most of the IMF discontinuities are tangential and, if the B_X component is dominant, these discontinuities are nearly parallel to the solar wind velocity. When such discontinuity is monitored out of the subsolar region the estimation of the arrival time to the Earth is nearly impossible.

Acknowledgements

The present work was supported by the University Grant Agency under Contract 23/97, and by the Czech Grant Agency under Contracts 202/97/1122 and 205/96/1575.

References

[1] Spreiter, J.R., et al.: Planet. Space Sci., **14**, 223, 1966.
[2] Zwan, B.J. and R.A. Wolf: J. Geophys. Res., **81**, 1636, 1976.
[3] Phan, T.-D., et al.: J. Geophys. Res., **99**, 121, 1994.
[4] Pudovkin, M.I., et al.: Ann. Geophys., **13**, 828, 1995.
[5] Sibeck, D.G.: J. Geophys. Res., **95**, 3755, 1990.
[6] Lin Y., et al.: J. Geophys. Res., **101**, 479, 1996a.
[7] Němeček, Z., et al.: Geophys. Res. Lett., **25**, No.8, 1273, 1998.