SH.2.2.08

A Tentative Method for Current Sheet Crossings Detection

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This work has been supported by the Comisión Interministerial de Ciencia y Tecnología (CICYT) of Spain, grant ESP95-0612.

Abstract

In this work we present an alternative method for identifying single Heliospheric Current Sheet (HCS) crossings. We have tested a simple local model of HCS, which provides specific solar wind features that can be used for identifying single HCS crossings. These solar wind signatures along with the traditional magnetic field and plasma traces already used, allow us to differentiate between an Interplanetary Magnetic Field (IMF) folding and an actual HCS crossing.

1 Introduction:

Since the publication of the work by Ness and Wilcox (Ness and Wilcox, 1964), it is known than the IMF presents a sector structure where the magnetic field is aligned toward the Sun in one sector and in the opposite direction in the other one. The region that separates sectors of opposite magnetic field polarity is called Current Sheet (CS). Many efforts have been made to determine both, the CS structure and the solar wind traces associated with this magnetic field reversal (Schultz, 1973; Hundhausend, 1977). Most of the scientific community assumes that: a magnetic field depression along a high density and low solar wind velocity are the specific traces of a current sheet crossing. Nevertheless, its internal structure is far from being established. Winterhalter et al. (Winterhalter et al., 1994) have found that the magnetic field reverses its direction in a very narrow layer which is embedded in a significantly thicker region characterized by an enhanced plasma density and depressed magnetic field strength; the Heliospheric Plasma Sheet (HPS).

As the HCS magnetic topology is very similar to that of the magnetotail current sheet, we have used the Harris field (Harris, K.K, et al, 1970.), which was firstly used by E.G. Harris in order to explain both, the magnetotail structure and the mean plasma characteristics which generated it. When the MHD equations are used to study this field, a current perpendicular to the field gradient arises. Following this result we have searched enhancement in the solar wind velocity with the aim of testing if these variations in the solar wind velocity could be used for a sharper identification of CS crossings.

We have used high-resolution data measured during 1996 by the Magnetic Field Instrument (MFI) and the Solar Wind Instrument (SWE) both on board of WIND spacecraft.

2 Data analysis

The criterium that we have used for identifying a CS cross is the following: first, the magnetic field strength must show a local minimum, second the magnetic field direction along to X-Y plane must suffer a rotation and finally the plasma density must increase. When these three conditions are satisfied, we proceed to rotate the plasma velocity components into the minimum variance coordinate system (Sonnerup and Cahill, 1967), where the i, j, and k unitary vectors, indicate the directions of maximum, intermediate, and minimum variance of the magnetic field, respectively. Following this model, the plasma velocity component in the maximum variance direction must show a local maximum or, in the worst case, it must show a very important variation according to the theoretical predictions.

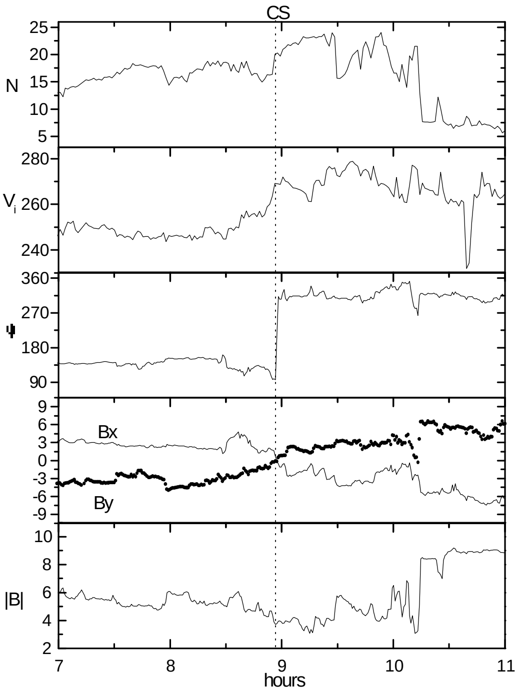

Figure 1: Current sheet crossing on September 4 1996. In this figure the proton density in particle/cm^3 (N) the velocity component in maximum variance direction in km/s (V_i) the magnetic field phi angle in degrees (ϕ), the Bx and By components in nT, and the magnetic field module in nT (B) have been plotted. The same treatment has been applied to the rest of the

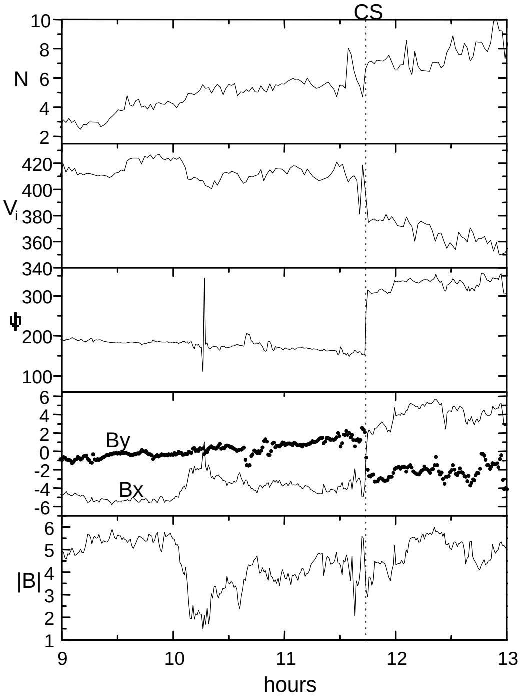

Figure 2: Current sheet crossing on April 13 1966. The variables plotted in this figure are the same than those of figure 1.

We have chosen three different current sheet crossings detected by WIND spacecraft dated on February 15th, 1996, on April 13rd, 1996 and on September 4th, 1996. Using the WIND spacecraft data mentioned in the introduction, we have plotted the magnetic field and plasma parameters of these particular CS crossings (figures 1, 2 and 3).

The crossing of the HCS is indicated by the point in which, simultaneously, the Bx and By components vanished and the variation in the phi angle is greater than 135 degrees. The dotted lines in figures 1, 2 and 3 indicate the time of the CS crossing suggested by the point mentioned above. As it can be seen, while the proton density enhances, the magnetic field B magnitude suffers a depression through the region that surrounds the current sheet. This later decrease extends over a much broader region than the region which present the main B direction change.

Once the current sheet has been identified, we can observe the particular response of the solar wind V_i component through the current sheet crossing. Despite the fact that our model predicts that the solar wind velocity along the maximum variation direction must show a maximum during the current sheet crossing, this maximum value only happens in one of the three periods under consideration, the crossing on September 4th, 1996. In the other hand, we have to point out that in the other two periods the solar wind component present a remarkable variation during the CS crossing. Our opinion is that this result does not suggest that our model is simply wrong, but that the CS internal structure could be more complex than the one that we have assumed.

Table I: Step conditions of current sheet crossing

Date	$\bar{e}_i$	Phi angle in GSE (º)	Angle on the ecliptic plane (º)	MFI inversion duration (hours)	ΔV_i (km/s)
February 15, 1996	(-0.92,0.31,0.20)	- 18.6	- 0.2	- 0.8	- 33
April 13, 1996	(-0.90,0.41,0.03)	- 24.5	- 1.7	- 0.2	-40
September 4, 1996	(-0.71,0.67,0.18)	- 43.3	- 10.44	- 2.3	- 21

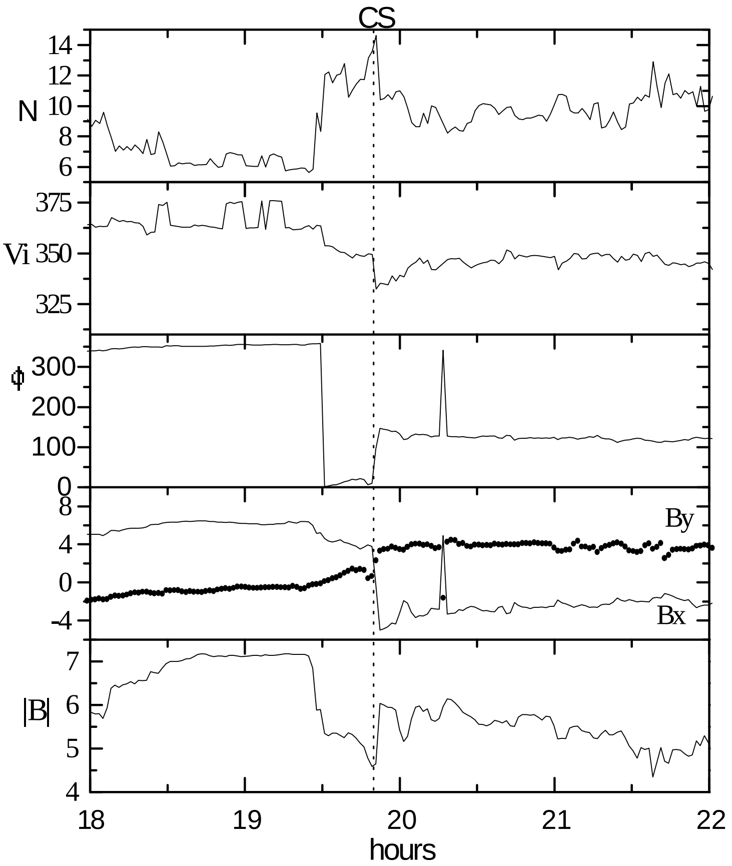

Figure 3: Current sheet crossing on February 15, 1996 The variables plotted in this figure are the same than those of figure 1.

This abrupt variation happens when the Bx and By components vanish. We think that this V_i behavior could be used as an additional current sheet crossing tracer, allowing to discriminate between a real CS crossing and an IMF folding.

In Table I, we show the CS crossing date, the components of the maximum variance direction vector $\bar{e}_i$, longitude angle in GSE system, latitude angle with the ecliptic plane, duration of the interplanetary magnetic field inversion and finally, variation of the solar wind velocity along the maximum direction during the three heliospheric current sheet crossings that we have studied. The maximum variance direction $\bar{e}_i$ is perpendicular to the current sheet crossing. Its latitude and the angle with the ecliptic plane determine the inclination of the current sheet respect to the ecliptic plane. The duration of the magnetic field duration of magnetic field rotation has been determined by measuring the time elapsed between the point in which one of the magnetic components begins to change and the point in which this component recovers its “stable” value.

Moreover, from Table I, we can observe that the change in the solar wind velocity magnitude is anticorrelated with the current sheet crossing duration. Besides, the results suggest that if the magnetic field rotation is smoother, the velocity jump is smoother too. In our opinion, these results indicate that this variation is strongly related with the plasma conditions on each side of the current sheet, and therefore emphasizing the current sheet border behavior. However, the relative current sheet inclination to the ecliptic plane does not seem to play a significant role in the solar wind velocity variation.

3 Conclusions

Three current sheet crossings have been studied using the rotation of the velocity coordinates into the maximum magnetic field variance system. Our results suggest that the response of the solar wind velocity component in the maximum variance direction, V_i, to the current sheet crossing is characterized by a sudden variation that occasionally induces a maximum value.

The change in the solar wind velocity magnitude seems to be anticorrelated with the current sheet crossing duration. Besides, if the magnetic field rotation is smoother, the velocity jump is smoother too.

This dramatic change in V_i could be used for distinguishing between a true current sheet cross and interplanetary magnetic field folding.

These results must be considered as preliminary and we hope that our model will be improved in future works.

Acknowledgments. The authors acknowledge the use of the WIND/MFI-SWE data in this communication. R. Gómez Herrero is indebted to the Universidad de Alcala for a pre-doctoral grant.

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