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DETERMINATION OF CIR RELATED SHOCK PARAMETERS

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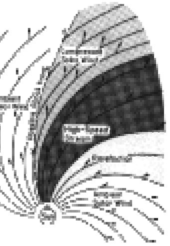
ABSTRACT

the descending and minimum solar cycle phase, polar coronal holes extend from the polar regions down to the solar equator. The high-speed streams emitted by coronal holes can interact with the ambient, vind streams and form corotating interaction regions (CIR). These CIRs are usually well developed only beyond 1.5 astronomical units, when a pair of reverse and fast forward shocks can form and delim interface. The stream interface is the region when the ambient solar wind is compressed by the high speed stream and as a result both magnetic field strength and density are enhanced. At the Earth's or omical unit, one does not usually observe CIR related fast forward shocks, but reverse shocks are estimated to be present in 20% of the cases. In this work, we study the CIRs events of solar cycle 23 maximun ding phases (2001-2004) to identify which is the percentage of CIRs with interplanetary shocks at Earth's orbit. For the CIRs events with shocks, the interplanetary shock parameters (Mach number, magnetic nsity compression rations and shock speed) are computed. A few examples are shown that illustrate the presence of the CIR-reverse shock and also the possible presence of a pair of fast and reverse shocks.



. - Schematic illustration of a fast stream g with a slow stream [Hundhausen, 1972].

COTORATING INTERACTION REGIONS:

The fast streams from coronal holes interact with the slow solar wind (as seen in Figure 1 on the left) compressing the magnetic field and plasma ahead and sometimes, though not always, creating a shock front. The compressed plasma is heated and a rarefaction follows. Within the stream the magnetic field maintains the same polarity and is the same as in the corresponding coronal hole. The fast streams from coronal holes co-rotate with the Sun and can persist for several rotations.

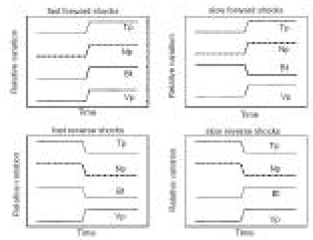


Figure 2 – Sketch of solar wind plasma and magnetic field parameter variations across the interplanetary shocks. Four type of interplanetary shocks are shown: fast forward, slow forward, fast reverse and slow reverse shocks. [Echer et al., 2003]

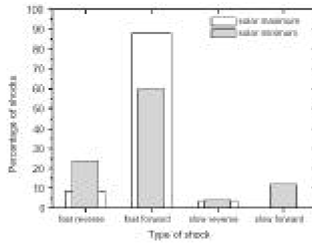
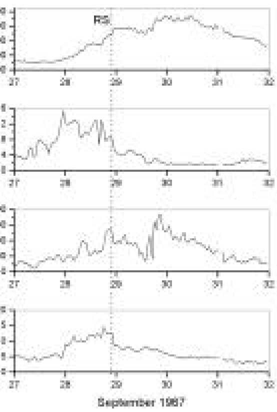


Figure 3 - Distribution of interplanetary shock typ observed during solar minimum (1995-1996) ar solar maximum (2000) [Echer et al., 2003].



- First reverse interplanetary shock identified in solar a during September 1967 [Burlaga, 1970].

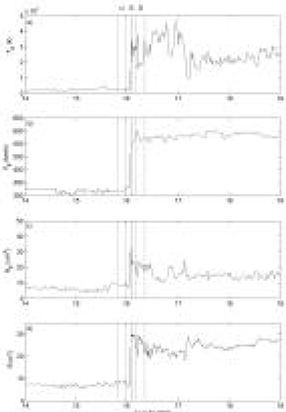


Figure 06: Definition of three time windows to calculate shock parameters. Shock observed near Earth on April, 6, 2000, at ~16UT. Dotted lines define the upstream (U), shock (S) and downstream (D) regions.

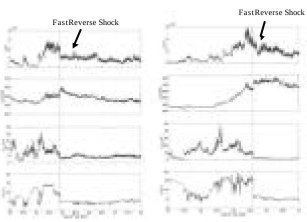


Figure 07: Example of fast reverse shocks observed near Earth on March, 5, 2001 and February, 24, 2000.

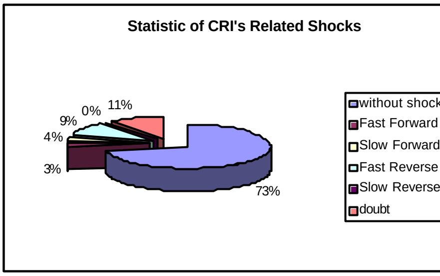


Figure 08: Percentage of CIR's related shock in the period 1998-2002

Table 01: Calculated shock parameters.

Example of the calculated parameters			
CIR's with	Fast Reverse Shock		Slow Reverse Shock
TIME	02/06/2002 02:03 UT	03/31/2002 15:25 UT	03/03/2002 22:00 UT
Nu (/cm³)	8.6	4.6	41.7
Nd (/cm³)	5.5	1.9	20.1
? N	-3.1	-2.7	-21.6
Tu (K)	310522	282246	35985.1
Td (K)	248.342	254956	26248.3
? T	-62.180	-27290	-9.737
Vu (Km/s)	624.8	645.8	353.1
Vd (km/s)	650.9	700.7	367.9
? V	26.1	54.9	14.8
Bu (nT)	14.5	12	10
Bd (nT)	8.8	7.3	15.1
? B	-5.7	-4.7	5.1
Us (Km/s)	578.5	607.2	115.8
r b	0.61	0.61	1.51
r n	0.64	0.41	0.48
Vectors in GSE coordinates			
Vu (Km/s)	[-615.9; 95.1; -32.5]	[-642.5; 36.2; 50.4]	[-346.9; -56.5; -33.1]
Vd (km/s)	[-648.1; 55.5; 1.9]	[-699.3; 42.1; -2.1]	[-364.2; -45.2; -25.2]
Bu (nT)	[-9.9; 9.2; 3.7]	[-7.5; 8.9; 1.7]	[6.4; -4.1; 6.2]
Bd (nT)	[-60.4; 50.9; -0.9]	[-7.2; -10.5; -10.5]	[-7.9; 12.5; -1.6]

CLUSION

arch the CIRs occured in the period 1998-2002 for identify the associated shocks. We have found 17 fast reverse shocks, 6 fast rd shocks, 7 slow forward/reverse shocks. There are in additon another ~20 candidate events that need to be confirmed as shocks.

re works we will study the occurrence of CIR's related shocks in the period 1998-2003. We will also confirm the identification of ndidate shocks that need confirmation and calculate other parameters –Mach number, shock orientation.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the ACE work teams for providing the data used in this work. The authors would also like to acknowledge the PIBIC program from CNPq supporting agency (Brazil).

REFERENCE:

Burlaga, L. F., A reverse hydromagnetic shock in the solar wind, Cosmic Electrodynamics, 1, 233-238, 1970.

Echer, E., W. D. Gonzalez, L. E. A. Vieira, A. Dal Lago, F. L Guarnieri, A. Prestes, A. L. C. Gonzalez and N. J. Schuch, Interplanetary shock parameters during solar activity maximum (2000) and minimum (1995-1996), Brazilian Journal of Physics, 33, 115-122, 2003b.

Echer, E., M. V. Alves and W. D. Gonzalez, Geoeffectiveness of interplanetary shocks during solar minimum (1995-1996) and solar maximum (2000), Solar Physics, 221, 361-380, 2004.

Parks, G. K, Physics of Space Plasmas, An introduction, Addison-Wesley Publishing Company, 538p., 1991.

Tsurutani, B. T., Gonzalez, W. D., Tang, F., Akasofu, S. I. and Smith, E., Origin of interplanetary southward magnetic fields responsible for major magnetic storms near solar maximum (1978-1979), Journal of Geophysical Research, 93, 8519-8531, 1988.