SOLAR-TERRESTRIAL CONNECTIONS: GEOMAGNETIC STORMS INDUCED BY CORONAL MASS EJECTIONS

OANA CHIRICUȚĂ [1, 2], IULIA CHIFU [3, 4], DIANA BEȘLIU-IONESCU1 [5], MARILENA MIERLA [1, 2, 6]

[1]*Institute of Geodynamics of the Romanian Academy*
Str. Jean-Louis Calderon 19-21, 020032 Bucharest, Romania
E-mail: oana@geodin.ro

[2]*Research Center for Atomic Physics and Astrophysics,*
Faculty of Physics, University of Bucharest,
Str. Atomiștilor 405, 077125 Bucharest-Măgurele, Romania

[3]*Max Planck Institute for Solar System Research*
Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany

[4]*Astronomical Institute of the Romanian Academy*
Str. Cuțitul de Argint 5, 040557 Bucharest, Romania

[5]*Centre for Stellar and Planetary Astrophysics, Monash University*
Victoria, Australia 3800

[6]*Royal Observatory of Belgium*
Avenue Circulaire 3, 1180 Brussels, Belgium

Abstract. Halo coronal mass ejections (HCMEs) associated with solar flares and directed towards the Earth are the main driver of major disturbances in the geomagnetic field. Ţo see what are the conditions for a HCME to produce a geomagnetic storm we analyzed the front-sided HCMEs between 1996 and 2008 that have produced major geomagnetic storms (*Dst* < –150 nT). We followed these HCMEs from the solar disk into the interplanetary space to the Earth. We analyzed the correlations between the parameters characterizing total and partial HCMEs, their signature into the interplanetary space and the related geomagnetic storms parameters. In this study we focused on the correlation between CME speeds and *Dst* indices.

Key words: coronal mass ejections– geomagnetic storms.

1. INTRODUCTION

It is well known that the coronal mass ejections (CMEs) that are interacting with

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the Earth magnetic field can produce strong geomagnetic storms (Gopalswamy et al. 2007), which in their turn can affect human lives. This is why it is important to know their characteristics from the moment they are expelled from the Sun until they reach the Earth. The goal of this paper is to find connections between solar signatures of CMEs (speeds), their effects on the interplanetary medium and on Earth.

2. DATA DESCRIPTION

We have analyzed all partial and full halo CMEs directed towards the Earth, in the period 1996–2008 that have produced major geomagnetic storms (geomagnetic index *Dst* smaller than –150 nT).

The CMEs observed into the interplanetary space are known as interplanetary coronal mass ejections (ICMEs). Amongst their signatures we mention: sudden increase of speed, increase of magnetic field intensity, decrease of proton temperature, small plasma beta, etc. (see Zurbuchen and Richardson 2006). All these parameters are recorded in-situ at the spacecraft (ACE or WIND).

Once arrived at the Earth, the ICME can produce a geomagnetic storm. The storms are usually described by the geomagnetic indices. The *Dst* index is defined as the average of the geomagnetic disturbance at several low-latitude stations weighted by a function of the station latitude (e.g., Pulkkinen et al. 2005).

An example from the data catalog we used is presented in Table 1 below (`http://www.geodin.ro/~diana.ionescu/research/TE.html`). We show here only the columns we used in this study.

Table 1

Example from the data catalog

	Solar signatures				ICME signatures				Geomagnetic signatures		
Date	Time	CME type	CME speed	Source location	Date	Bz	B	SW speed	Date	Time	Dst
09.04.2001	15:54	FH	1192	S21W08	11.04.2001	-5.5	24	721	11.04.2001	00:00	-271
10.04.2001	05:30	FH	2411	S22W20	11.04.2001	-5.5	24	721	11.04.2001	00:00	-271
28.09.2001	10:30	PH	665	S18W51	02.10.2001	-10.2	21.8	525	03.10.2001	15:00	-166
29.09.2001	11:54	PH	509	N14W01	02.10.2001	-10.2	21.8	525	03.10.2001	15:00	-166
01.10.2001	05:30	FH	1405	S18W75	02.10.2001	-10.2	21.8	525	03.10.2001	15:00	-166
19.10.2001	01:27	FH	558	S14W62	21.10.2001	-6.2	22.3	627	21.10.2001	22:00	-187
19.10.2001	16:50	FH	901	S14W62	21.10.2001	-6.2	22.3	627	21.10.2001	22:00	-187
24.10.2001	06:26	PH	597	S12E14	28.10.2001	-5.4	12.3	487	28.10.2001	12:00	-157
25.10.2001	15:26	FH	1092	S19W26	28.10.2001	-5.4	12.3	487	28.10.2001	12:00	-157
01.11.2001	22:30	FH	453	N11W24	06.11.2001	-36.6	60.5	99	06.11.2001	07:00	-292
03.11.2001	19:20	FH	457	N06W14	06.11.2001	-36.6	60.5	99	06.11.2001	07:00	-292
04.11.2001	16:35	FH	1810	N05W29	06.11.2001	-36.6	60.5	99	06.11.2001	07:00	-292

We analyzed 55 CMEs that arrived to the Earth and produced major geomagnetic storms. We built a catalog with all these events, which is structured in three data sets:

The first set is related to the solar signatures of CMEs. It comprises the date and time of the maximum registered of geomagnetic storm (columns 10–11), the type of the

HCME (full or partial – column 3), the projected speed of the CME on the plane of the sky (column 4), and the location of the source (X-ray flare or eruptive prominence) of the CME on the solar disk (latitude/longitude – column 5).

The second set describes the ICME signatures: the date when the ICME arrived to the spacecraft (column 6), the value of the *z* component of the magnetic field intensity (*Bz* – column 7), the value of the total magnetic field (*B* – column 8), the speed of the ICME recorded at the spacecraft (column 9). The arrival time was considered according to the ICME signatures (as seen by ACE) in a maximum interval of 5 days from the onset of the CME on the Sun.

The third set of the catalog represents the signature of geomagnetic storm: the date and time when maximum of geomagnetic storm was registered (columns 10–11), and the *Dst* value (column 12). The values of *Dst* characterize the maximum of the geomagnetic storm (in a time interval of approximate one hour after the ICMEs signatures).

Note that sometimes there are more than one CME producing the same geomagnetic storm (Chifu 2009). Those CMEs interact into the interplanetary space (the so called CME cannibalism: see `http://c2h2.ifa.hawaii.edu/ Pages/ research_cannibal.php`) and they arrive at the spacecraft as one complex event.

The data used in this study were taken from:

`http://cdaw.gsfc.nasa.gov/CME_list/` (solar signatures of CMEs);

`http://solarmonitor.org/` (source location);

`http://www.ssg.sr.unh.edu/mag/ace/ACElists/ICMEtable.html` (ICME signatures);

`http://omniweb.gsfc.nasa.gov/form/dx1.html` (both ICME and geomagnetic signatures)

3. DATA ANALYSIS

By analyzing a set of limb CMEs, Schwenn et al. (2005) have concluded to a relation between the radial speed and the expansion speed:

$$V_{rad} = 0.88\,V_{\exp} \tag{1}$$

where V_{rad} is the real speed of propagation of the CME and $V_{\exp}$ is the expansion speed, as measured in coronagraph images. Assuming that for all our halo events $V_{\exp} = V_{\mathrm{proj}}$, with V_{proj} the speed of the CME from the catalog, we can calculate the real speed of propagation. The assumption is justified since almost all of our CMEs are coming from the center of the Sun and they expand symmetrically in all directions.

In Fig. 1 (left panel) we plot V_{rad} as calculated with formula (1) versus V_{ICME} (the speed of the ICME recorded at ACE). We observe that all 55 events were decelerated while traveling into the interplanetary space. They interact with the ambient solar wind and their speeds tend towards the solar wind speed. In general, this applies to fast CMEs, while the slow CMEs usually accelerate while traveling into the interplanetary space. In the right panel of Fig. 1 we plot V_{rad} versus *Dst*. The correlation index between these parameters is 76%, showing that fast CME produce stronger geomagnetic storms.

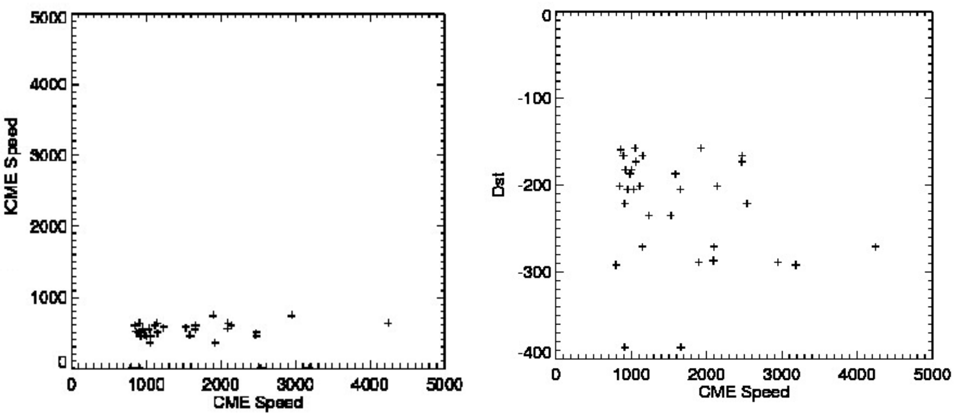

Fig. 1 – Left panel: ICME speed versus CME speed; Right panel: *Dst* versus CME speed.

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REFERENCES

Chifu, I.: 2009, M.Sc. Thesis, University of Bucharest.

Gopalswamy, N., Yashiro, S., Akiyama, S.: 2007, *J. Geophys. Res.*, **112**, A06112.

Pulkkinen, T. I., Ganushkina, N. Y., Donovan, E., Li, X., Reeves, G. D., Russel, C. T., Singer, H. J., Slavin, J. A.: 2005, in *The Inner Magnetosphere: Physics and Modeling*, Geophysical Monograph Series, Vol. **155**, AGU, Washington, DC, pp. 155–161.

Schwenn, R. et al.: 2005, *Ann. Geophys.*, 23, 1033-1059, 2005.

Zurbuchen, T. H., Richardson, I. G.: 2006, *Space Sci. Rev.*, **123**, 1.

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