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Comment on "Interplanetary conditions leading to superintense geomagnetic storms (Dst ≤ -250 nT) during solar cycle 23" by E. Echer et al.

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[1] *Echer et al.* [2008] studied the interplanetary causes of superintense (Dst ≤ -250 nT) geomagnetic storms that occurred during solar cycle 23. From a sample of 11 events (listed in Table 1 of *Echer et al.* [2008], hereinafter referred to as Echer Table), they found that 1/3 of the superstorms are caused by MC (magnetic cloud) fields, 1/3 by a combination of SH (sheath) + MC fields and 1/3 by SH fields. From these results, joint to a study by *Tsurutani et al.* [1992] for the five greatest storms in the period 1971–1986, they concluded that "only MC and sheath fields seems to be important causes for the development of superstorms''. Thus, corotating interaction regions (CIRs) or heliospheric current sheet (HCS) fields are not causes of superstorms. Moreover, *Echer et al.* [2008] concluded that "there is a higher probability of single structures causing the events''.

[2] Nevertheless, several papers reported complex interplanetary structures as drivers of severe geomagnetic activity. *Wang et al.* [2003a] found out that two of three Multi-MCs (multiple magnetic cloud, which is formed by the overtaking of successive CMEs), are associated with the great geomagnetic storms (Dst ≤ -200 nT). Analyzing long-lived geomagnetic storms *Xie et al.* [2006] concluded that the intensity of large geomagnetic storms is well-related to the degree of interaction (the number of interplanetary coronal mass ejections –ICMEs– interacting with a high speed stream –HSS– event or with themselves).

[3] *Huttunen et al.* [2002] studied the event of April 7, 2000 (event 1 of Echer Table) and they concluded that the fluctuating but strongly southward field accompanied by the high pressure allowed for the exceptionally strong driving magnetospheric activity. A high speed stream from a coronal hole interacting with the 'magnetic cloud like' was reported by *Xie et al.* [2006] for this event, resulting the enhanced pressure inside the ICME which causes great geomagnetic activity.

[4] The paper of *Wang et al.* [2003a] shows a detailed analysis of the event of March 31, 2001 (event 3 of Echer Table). *Wang et al.* [2003a, Figure 2] shows clearly two MCs with an interacting region between them, and another small ejecta as the interplanetary cause of this geomagnetic storm. For this event, *Xie et al.* [2006] described the interplanetary driver causing southward as 'magnetic cloud like' and added as a comment that four CMEs were involved in the interaction. *Zhang et al.* [2007a, 2007b] also reported multiple structures of type SH + MC cloud involved in this geomagnetic storm, as well as in the event of April, 12, 2001 (event 4 of Echer Table). *Wang et al.* [2003a] also analyzed this last event and found that several interacting MCs are indeed the interplanetary driver of the geomagnetic activity. *Wang et al.* [2003a, Figure 3] show Ace observations from 11 April to 14 April 2001, which are carefully described in Section 4 of the paper.

[5] *Xie et al.* [2006] identified the interplanetary driver of the geomagnetic storm of November 6, 2001 (event 5 of Echer Table) with a SH + compressed ICME + HSS. They also stated that 3 halo CMEs were participating in the event. *Zhang et al.* [2007a, 2007b] identified the interplanetary sources of this event as MC + PMC-SH (a shock propagating through a preceding magnetic cloud) + ICME, although they commented that there were optional choices of solar sources and an EIT data gap. Figure 1 shows ACE spacecraft data from November 5 to November 7, 2001. Two solid lines have been drawn in order to show the main phase of this geomagnetic storm. There is no doubt that the interplanetary event associated is a complex structure and, although a solar wind data gap appears, two interplanetary shocks (S1 and S2 in Figure 1) and some regions with smooth and elevated magnetic field can be identified. A sharp decrease in proton temperature and density is also evident at November 5 19:35 UT, indicating the boundary of an ICME, which magnetic signatures guided *Wang et al.* [2003b] to consider the first shadowed region as a MC. Although solar wind data are missing, an ejecta can be also guessed in the second shadowed area, driving the shock S2 which overtakes the first magnetic cloud. *Wang et al.* [2003b] pointed out that the compression between the overtaking shock and the preceding MC increased the geoeffectiveness of this event.

[6] The Dst profile (Figure 1 (bottom)) shows a complex development, where at least two intense dips can be noticed, departing from a classical "main-recovery'' phase development. The number of peaks in Dst is not necessarily directly related to the number of interplanetary transients that are involved in generating the storm [*Richardson and Zhang*, 2008]. However, in this case, after the initial phase of the storm, related to the shock (S1) and sheath, the main phase

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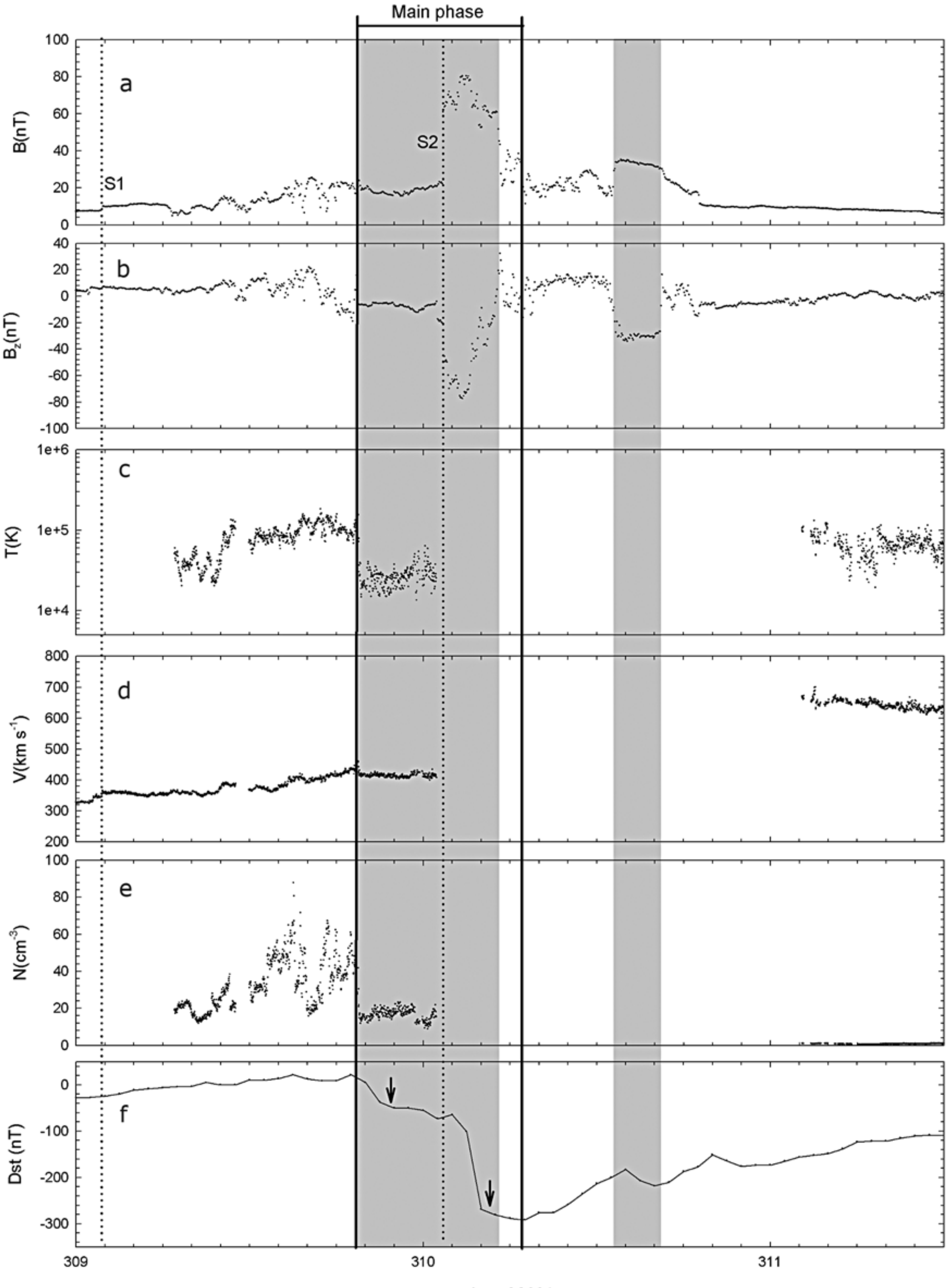

Figure 1. Observations by ACE spacecraft from 00:00 UT November 5 (doy 309) to 12:00 UT November 7 (doy 311), 2001. From top to bottom are plotted: (a) magnetic field strength, (b) z-GSM magnetic field component, (c) radial component of the proton temperature, (d) bulk speed and (e) proton number density. The bottom panel (f) presents the geomagnetic index Dst from Kyoto database. The main phase of the geomagnetic storm appears between the solid lines. Dotted lines indicate two shocks detected at Ace (S1 and S2). Shadowed areas correspond to a MC and a ejecta previously identified by *Wang et al.* [2003b]. This storm, associated with a shock running into the trailing edge of a preceding magnetic cloud, has two distinct dips (indicated by arrows) in Dst index.

starts with the arrival of the magnetic cloud. Then, the second dip in Dst index (more strong than the former) corresponds to the arrival of the overtaking shock S2. Moreover, the fluctuating magnetic field at the end of the main phase suggests that also a second sheath could contribute to the overall geoeffectiveness of this storm.

[7] The type of interplanetary solar wind structure associated to events 9 and 10 of Echer Table (November 8, 2004 and November 10, 2004) was identified by *Zhang et al.* [2007a, 2007b] as multiple SH + multiple MCs and PICME-SH (a shock propagating through a preceding ICME) + MC, respectively. In conclusion, up to our knowledge five out of eleven superintense geomagnetic storm events studied by *Echer et al.* [2008] are associated with multiple ICMEs, and two of the eleven events have high speed streams involved.

[8] Thus, although *Echer et al.* [2008] claimed that in their method of analysis 'only interplanetary structures that contributed to a storm main phase development are noted', we would like to point out that these structures alone cannot drive so major storms and, if they do, it is so because of the overtaking of successive structures in their travel far from the solar surface. Therefore, an analysis of the whole scenario of the solar-interplanetary event, and all structures involved in it, is needed in order to study the interplanetary conditions leading to superintense geomagnetic storms.

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References

Echer, E., W. D. Gonzalez, and B. T. Tsurutani (2008), Interplanetary conditions leading to superintense geomagnetic storms (Dst ≤ -250 nT) during solar cycle 23, *Geophys. Res. Lett.*, *35*, L06S03, doi:10.1029/2007GL031755.

Huttunen, K. E. J., H. E. J. Koskinen, T. I. Pulkkinen, A. Pulkkinen, M. Palmroth, E. G. D. Reeves, and H. J. Singer (2002), April 2000 magnetic storm: Solar wind driver and magnetospheric response, *J. Geophys. Res.*, *107*(A12), 1440, doi:10.1029/2001JA009154.

Richardson, I. G., and J. Zhang (2008), Multiple-step geomagnetic storms and their interplanetary drivers, *Geophys. Res. Lett.*, *35*, L06S07, doi:10.1029/2007GL032025.

Tsurutani, B. T., W. D. Gonzalez, F. Tang, and Y. T. Lee (1992), Great magnetic storms, *Geophys. Res. Lett.*, *19*, 73–76.

Wang, Y. M., P. Z. Ye, and S. Wang (2003a), Multiple magnetic clouds: Several examples during March–April 2001, *J. Geophys. Res.*, *108*(A10), 1370, doi:10.1029/2003JA009850.

Wang, Y. M., P. Z. Ye, S. Wang, and X. H. Xue (2003b), An interplanetary cause of large geomagnetic storms: Fast forward shock overtaking preceding magnetic cloud, *Geophys. Res. Lett.*, *30*(13), 1700, doi:10.1029/2002GL016861.

Xie, H., N. Gopalswamy, P. K. Manoharan, A. Lara, S. Yashiro, and S. Lepri (2006), Long-lived geomagnetic storms and coronal mass ejections, *J. Geophys. Res.*, *111*, A01103, doi:10.1029/2005JA011287.

Zhang, J., et al. (2007a), Solar and interplanetary sources of major geomagnetic storms (Dst ≤ -100 nT) during 1996–2005, *J. Geophys. Res.*, *112*, A10102, doi:10.1029/2007JA012321.

Zhang, J., et al. (2007b), Correction to "Solar and interplanetary sources of major geomagnetic storms (Dst ≤ -100 nT) during 1996–2005", *J. Geophys. Res.*, *112*, A12103, doi:10.1029/2007JA012891.

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