The solar origin of the October 21st-22nd (1999) very intense geomagnetic storm

A. Dal Lago, L. E. A. Vieira, E. Echer, F. L. Guarnieri, M. R. da Silva, A. de Lucas, W. D. Gonzalez, A. L. Clua de Gonzalez

Instituto Nacional de Pesquisas Espaciais, INPE, São José dos Campos, SP, Brazil.

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Abstract

In this work we address the solar origin of the October 21st -22nd (1999) very intense geomagnetic storm, which was caused by the interaction between an interplanetary ejecta (ICME) and a high speed stream. We believe that a high speed stream compressed the interplanetary ejecta and intensified its internal magnetic field, thus increasing the intensity of the geomagnetic storms. This kind of event is very difficult to predict based on remote observations of the solar corona, such as those from the Large Angle and Spectroscopic Coronagraph – LASCO, abord the Solar and Heliospheric Observatory – SOHO, because they are normaly related to relatively slow CMEs. Using combined data from different instruments, we present evidences on the solar disk of a coronal hole just beside (to the east) the active region from which the coronal mass ejection was liftted off. In the last solar cycle at least 1 out of 14 very intense geomangetic storms, i.e. peak Dst < -200 nT, was caused by such a mechanism.

Introduction

High speed streams, originated in coronal holes, are often observed following interplanetary coronal mass ejection – ICMEs, at 1 AU (Klein and Burlaga, 1982). One of the most important effects of the interaction between these two structures is the intensification of the magnetic cloud field in the latter part, due to compression, thus leading to a stronger geomagnetic perturbation if the cloud's intensified magnetic field is pointing southward (Burlaga et al., 1987; Bothmer and Schwenn, 1995; Badruddin, 1998; Fenrich and Luhmann, 1998; Dal Lago et al., 2001, 2002).

One of the aims of space weather studies is to forecast earth disturbances using solar observation in order to have enough time to prevent damages in satellites and other man made equipment. It is well known that coronal mass ejections – CMEs, observed by coronographs at the sun are one of the most important causes of geomagnetic disturbances (e. g. Gosling, 1993).

In this paper we present the solar origin of the October 21st-22nd (1999) very intense geomagnetic storm, which was caused by the interaction between an interplanetary ejecta (ICME) and a high speed stream. Specifically, we addres the solar causes of this event, using combined data from different instruments, both space and ground based.

Method

Since 1996, the Large Angle and Spectroscopic Coronagraph – LASCO (Brueckner et al., 1995), and the Extreme ultraviolet Imaging Telescope – EIT, both abord the Solar and Heliospheric Observatory – SOHO provide continous measurements of CMEs and their disk counterparts, like EIT eruptions. LASCO is a white light coronagraph and it is able to reveal eruptions of coronal mass ejections. One of the EIT filters is able to image the solar disk in 19.5 nm with enough time resolution to identify EIT eruptions related to CMEs. The National Solar Observatory – NSO, at Kitt Peak, provides coronal hole maps, obtained by groud based instrumentation, which detect the 1083 He I absoption line (Harvey et al., 1975). To complete this set of solar observations, we have in situ mangetic field and plasma data from the Advanced Composition Explorer – ACE satellite, siting in the Lagrangean point L1, and Kyoto Dst index, which show the arrival at earth of a complex interplanetary structure and a very intense geomagnetic storm, respectively.

Solar origin of the October 21-22 (1999) disturbance

On the October 18th, 1999, at 00:06 UT, LASCO C2 observed a coronal mass ejection, which evolved to a halo in LASCO C3 instrument with an expansion speed of 546.1 km/s, as shown in Figure 1. Associated with this CME, an EIT eruption was observed toward the east side of the solar disk, during the last hour of day 17. Its evolution can be seen in Figure 2.

NSO/KP maps from October 17th to October 18th, as well as YOHKOH Soft X-ray telescope on October 19th, clearly reveal a positive coronal hole close to the site of the EIT eruption observed in the EIT images of day 17, as shown in Figure 3.

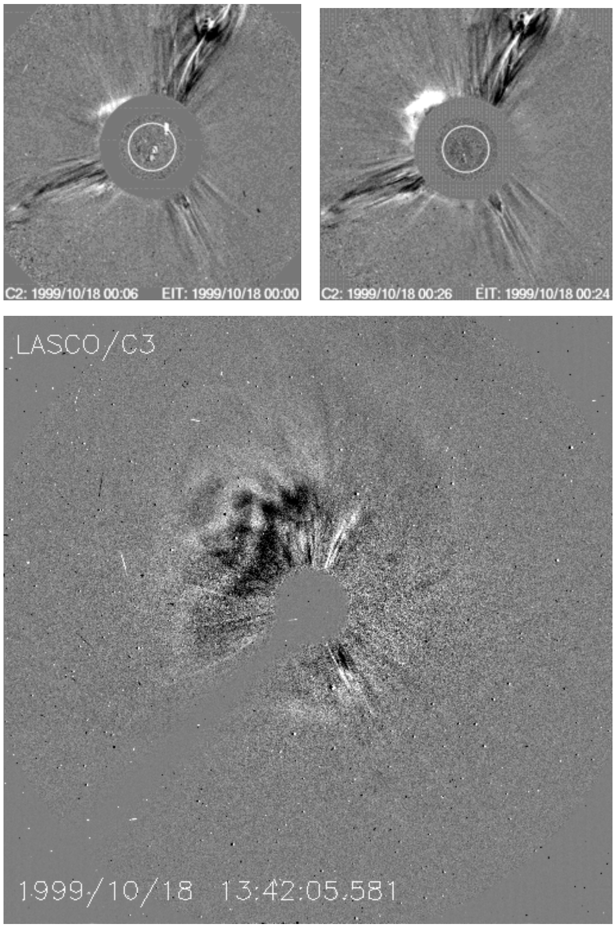

Fig. 1 – LASCO C2 (top images) and LASCO C3 (bottom) observations of the October 18th (1999) CME.

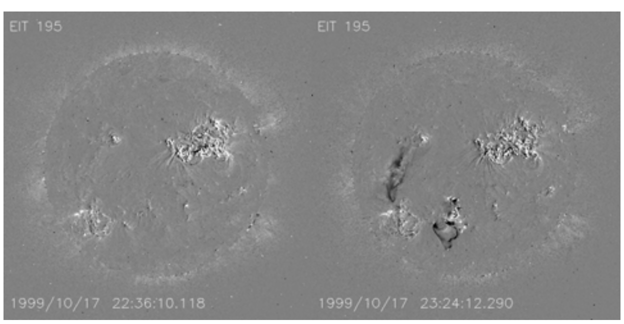

Fig. 2 – EIT running difference images of the eruption during the last hour of day 17, in October, 1999. Another eruption in the southern solar hemisphere is also visible in the image, but this one was not related with our event.

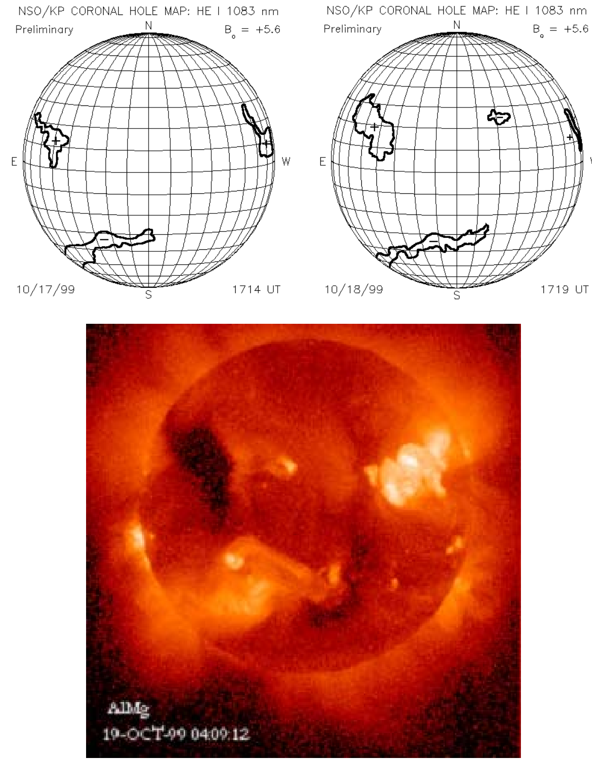

Fig. 3 – NSO/KP coronal hole maps (top images) from Oct. 17th and Oct. 18th, 1999. Yohkoh SXT image from Oct. 19th. In all images, a clear (positive) coronal hole can be identified.

Combining the observation from EIT in Figure 2 from Oct. 17th, at 23:24UT with the NOS/KP coronal hole map of Oct. 17th, one can easyly see that the coronal hole was sitting beside the EIT eruption site, more precisely to the east, as shown in Figure 4.

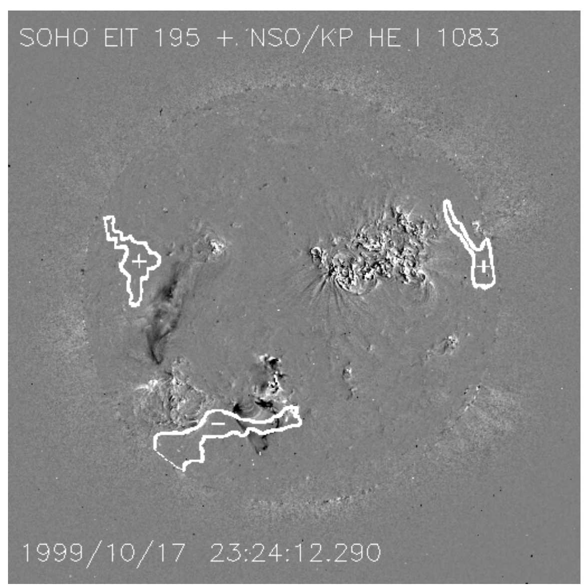

Fig. 4 – Combined observations from SOHO/EIT 195 and NOS/KP coronal hole map, from Oct. 17th, 1999.

Close to the earth, at L1, a insterplanetary shock was detected by the ACE magnetic field and plasma instruments, 73.5 hours after the first apearence of the related CME in the LASCO C2 field-of-view, on October 21st (1999), at 01:34 UT, as shown in Figure 5.

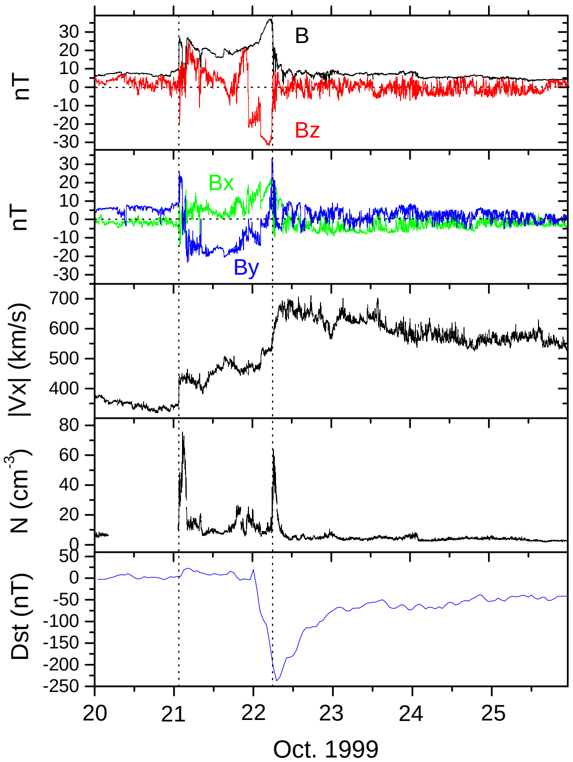

Fig. 5 – From top to bottom: Magnetic field intensity B and its Bz component, By and Bx components, solar wind velocity and density, and the Dst index.

Imediately after the ICME structure (second vertical dotted line), a high speed stream can be seen, with a speed close to 700 km/s. The interaction between this high speed stream and the ICME probably caused compression and intensification of the magnetic field inside the ICME, as can be observed in the top pannel of Figure 5. The very intense negative Bz field in the rear portion of the ICME structure lead to the very intense geomagnetic storm.

Summary and Conclusions

We have presented the solar origin of the October 21st-22nd (1999) very intense geomagnetic storm, which was caused by the interaction between an interplanetary ejecta (ICME) and a high speed stream. Combined observations from SOHO/EIT 195 and NSO/KP maps revealed a proximity of an eastward positive coronal hole and an EIT eruption, both observed on the Oct. 17th. Following that, on the Oct. 18th SOHO/LASCO observed a CME, closely related in time with the EIT eruption. The combination of these solar structures was probably the solar origin of the ICME-high speed stream structure observed by ACE instruments near earth, on the Oct. 21st-22nd, and hence the cause of the very intense geomagnetic storm.

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