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The Geoeffective CMEs and Associated Interplanetary Parameters During Solar Cycle-24

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Abstract
In our investigation, we have taken the disk halo geoeffective CME events and their attributes: speed and associated solar flare. Furthermore, we have taken the following associated interplanetary parameters: interplanetary magnetic field (IMF), proton temperature, proton density, plasma flow speed and flow pressure during solar cycle-24. We have noticed the maximum value of the above mentioned interplanetary parameters on the day of storms. We have tried to study the geoeffective disk halo CMEs and related interplanetary parameters in association with geomagnetic storms. We found from our study that there is a low anti-correlation of CMEs speed with Dst index as well as with CMEs travel time (TT). Disk halo CMEs are majorly associated with M- class flares. IMF, proton density and plasma flow pressure majorly gain their maximum value 1hr-20hr, 1hr-22hr and 1hr -18hr before of the storms, respectively. Plasma speed and proton temperature reach their maximum before as well as after the storm for 49.12% and 45.6% events, respectively.

Keywords Coronal mass ejection, Interplanetary parameters, Geomagnetic storms

Introduction

Geoeffective CME and associated interplanetary parameters is the crucial subject regarding to geomagnetic disturbances. This geomagnetic disruption produces the storm of different intensity. CME is defined as a large eruption of plasma and magnetic field from the Sun. A typical CME comprises the mass of around 10^{11}-10^{12} kg and has a speed between 400 and 1000 km/s. The most common morphological characteristics of many CMEs is the three-part structure consisting of 1) a bright leading edge, 2) a dark void, 3) a bright core (Illing and Hundhausen 1985). CME which seems to be surrounding the occulting disk are defined as halo CME (Howard et al. 1982). Halo CME with their sources lies within $\pm 45^0$ of central meridian distance (CMD) are known as disk halo while those with CMD beyond $\pm 45^0$ but not beyond $\pm 90^0$ are known as limb halos. Interplanetary parameters include the IMF and solar wind characteristics. IMF is described as the magnetic field that exists in the space between planets in the solar system. Solar wind carries the IMF with it. The term GS is the disruption of Earth's magnetosphere that occurs when there is an exchange of energy from solar wind into Earth's magnetosphere. The duration of the main phase of storm determines the magnetic storm intensity

(Yokoyama 1997). The most frequent index used for the measurement of storm is disturbance storm time index (Dst). Dst index represents the deviation of horizontal H component of the geomagnetic field. More intense storm generally has a large negative Dst (Daglis et al. 1999). Based on the Dst index, GSs are classified as severe:<-200nT, intense -200nT≤ Dst <-100nT and moderate -100 nT≤ Dst < -50nT (Gonzalez et al.1999). Furthermore, Vennerstorm (2016), identified some key characteristics of extreme storms during 1868-2010. Geoeffective CMEs are those which can produce the storms. Prasad et al. (2013), found that halo CMEs are more geoeffective than non halo CMEs. Brithwal and Garia (2025), found during solar cycle-24 that geoeffective CME of speed ≥ 1000km/s and <1000km/s are mainly the disk event. According to Gopalswamy et al. (2007), the disk halo is followed by strong storms in comparison to limb halos and backside halos. Singh and Mishra (2015), studied the intense GSs and their link with different solar and interplanetary features. The term CME travel time (TT) is defined as the time taken by CME from its appearance time to Dst minimum time. In the last decade number of studies has been performed to investigate the association of CMEs and interplanetary parameters with the geomagnetic storms. Still, there is a need to explore the link of geoeffective CMEs and associated interplanetary parameters with geomagnetic activity. In our investigation we have taken the total 57 geoeffective disk halo CMEs out of 325 halo CMEs during solar cycle-24 and taken maximum value of the following associated interplanetary parameters on the day of storms: IMF, proton temperature, proton density, plasma speed and plasma flow pressure. We used the most commonly used geomagnetic activity index known as the Dst index. We have taken the minimum Dst value during a 4 day interval after the CME onset. We have tried to study the geoeffective disk halo CMEs and their interplanetary parameters in association with geomagnetic storm during solar cycle-24.

Method

For the present study, we have identified the disk halo CMEs and their attributes such as speed and solar flare from the Solar and Heliospheric Observatory (SOHO)/ Large Angle Spectroscopic Coronagraph (LASCO) catalog with the help of the website (http://cdaw.gsfc.nasa.gov/CME_list/halo). We have taken the maximum hourly value of interplanetary parameters on the day of the storm and Dst index value taken from the world data center in Kyoto by the website (http://wdc.kugi.kyotou.ac.jp/wdc/Sec3.html). We have used here the correlation method to investigate the link between disk halo CMEs and geomagnetic activity. Moreover, we have noticed the time of maximum value of interplanetary parameters on the day of GS from world data center in Kyoto.

Results and Discussion

From the observation we have taken the 57 geoeffective disk halo CMEs out of 325 halo CMEs during solar cycle-24.

We observed from the correlative study of CME speed and Dst index that there is a low anti-correlation (-0.23) between them. The scatter plot of CME speed and Dst index is shown in Figure 1. Furthermore, we noticed that the most intense storm (-234 nT) is linked with a CME of speed 719 km/s, while least intense storm (-56 nT) is linked with a CME of speed 812 km/s. Singh el al. 2014 found in their study that CMEs having higher speed (1000 > km/s) mainly generate the stronger storms.

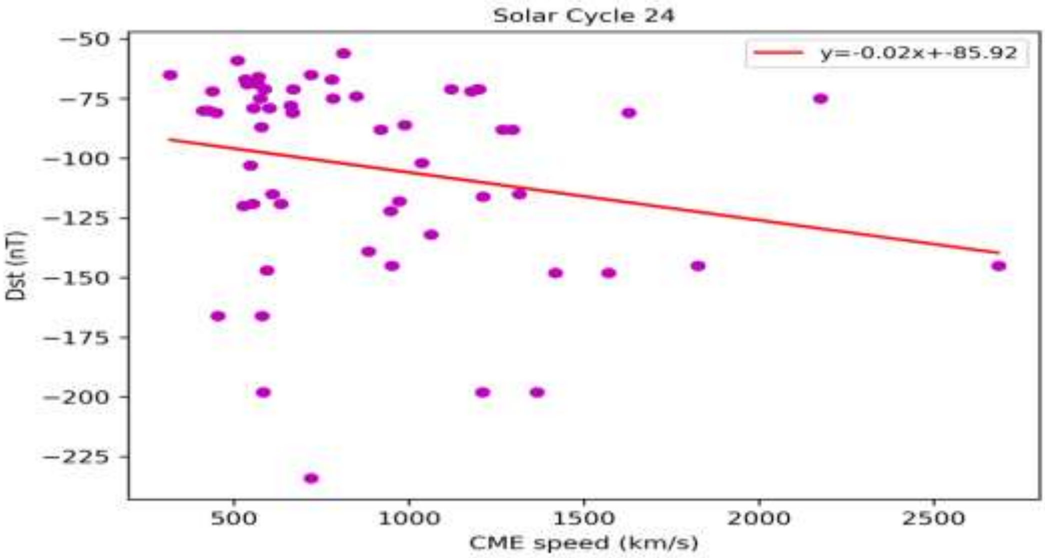

Figure1. Scatter plot of CME speed and Dst index

We also found from our investigation that CME speed shows a low anti-correlation with TT of CME (-0.27). The scatter plot between CME speed and TT is shown in Figure 2. We noticed that the highest speed CME showing the TT is 56.7 hr. Average travel time of disk halo CMEs is found to be 70.12 hr. The average TT was found 78 hr to reach the peak of GSs (Zhang et al. 2003).

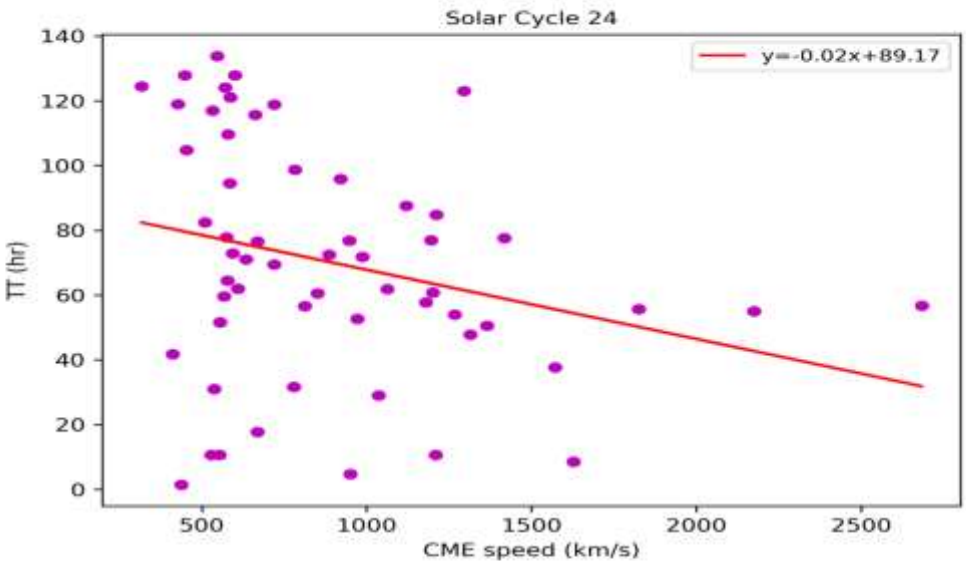

Figure 2. Scatter plot between CME speed and TT

In our investigation we found that disk halo CMEs are mainly linked with M class flares (49.12%). 10.5% events are associated with X class flares, 21.05% are linked with C class flares, and 7.01% are associated with B class flares. Solar flare data of 7 events are undefined in the source list. Bhatt and Chandra 2017 investigated that fast halo CMEs associated with X class flare originating from low latitudes are better potential candidates in producing the super intense storm than the slow halo CMEs associated with other class of flares. The distribution of different classes of flares is shown in Figure3.

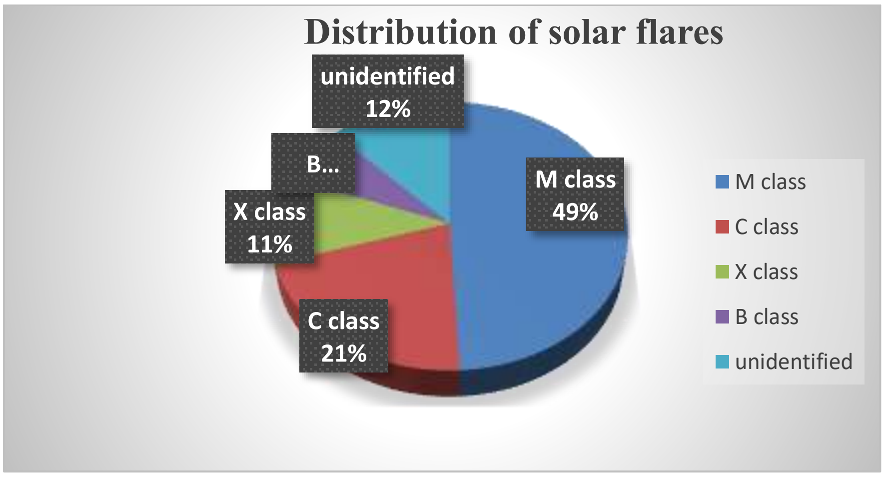

Figure 3. Solar flares distribution of different class

CME associated solar flare

Two typical examples of disk halo CMEs associated with solar flares are depicted in Figure 4 and 5. Figure 4 revealed that halo CME occurred on March 15, 2015 at 01:48 UT. It is linked to C9.1 class of flare. This CME having speed 719 km/s caused, the GS on March 17, 2015 at 23:00 UT having Dst index value -234 nT. Figure 5 indicated another halo CME occurred on October 28, 2013 at 15:36 UT is linked to M4.4 class of flare. This CME have speed 812 km/s, resulting the GS on October 30, 2013 at 24:00 UT, having Dst index value -56nT.

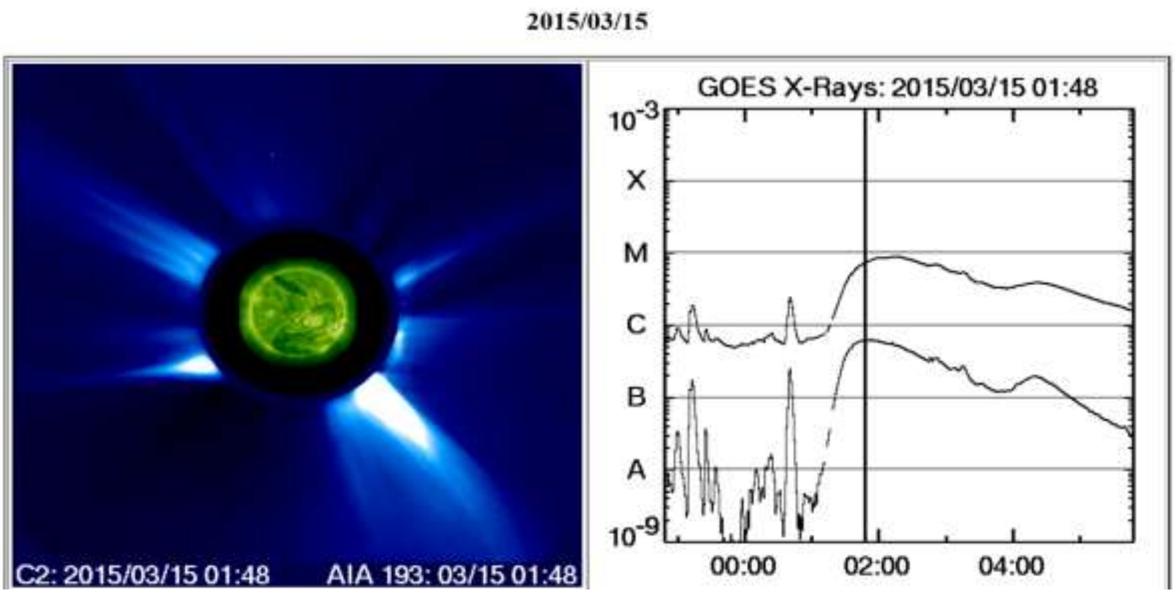

Figure4. Represent front halo CME observed on March 15, 2015 with respective occurrence time of CMEs flare.

2013/10/28

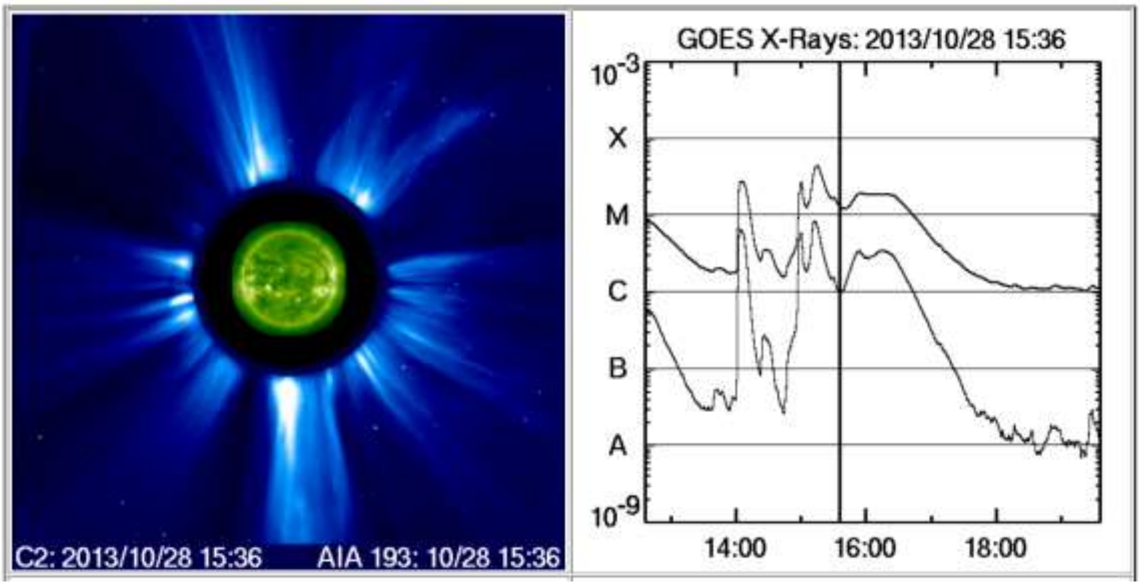

Figure 5. Indicates the typical halo CME observed on October 28, 2013 with occurrence time of solar flare.

We observed the maximum value of interplanetary parameters on the day of Dst minimum and found the following.

IMF achieves its maximum value 1 hr to 20 hr before of Dst minimum for 40 events, while IMF reaches its maximum 1hr to 13 hr after the minimum value of Dst index for 16 events and observed the maximum value on the same hour of Dst minimum for 1 event.

Proton temperature reaches its maximum value 2hr to 22 hr before of the Dst minimum value for 28 events, while it reaches its maximum 1hr to 18hr after the Dst minimum for 26 events, and it gains the maximum value at the same hour when Dst goes to minimum for 3 events.

Proton density reaches its maximum 1 hr to 22 hr before of the minimum value of Dst for 39 events, while proton density reaches to its maximum 1 hr to 21 hr after of the minimum value of Dst for 17 events. For 1 event, proton density gains to its maximum at the same hour when Dst goes to its minimum. Gupta and Badurddin (2009), presented the density of solar wind is a potential parameter to advance warning of major storm, 10-24 hr prior.

Plasma speed increases to its maximum 1 hr to 22 hr before the Dst minimum for 28 events, while plasma speed increases to maximum 1 hr to 19 hr after the Dst minimum for 26 events. In addition to this, plasma speed reaches to maximum at the same hour when Dst reaches to minimum for 3 events. Kharayat and Prasad 2017 studied the interplanetary solar wind parameters and GS on day to day basis and found a time lag of 1 day between plasma flow pressure and plasma density with GSs. No time lag found between GS and peak value of solar wind speed. Rathore et al. 2014, found that GSs strength is strongly dependent on total magnetic field but found no significant role of density and temperature behind the storms.

Plasma flow pressure gains its maximum value 1 hr to 18 hr before the Dst minimum for 40 events while it gets maximum value 1 hr to 21 hr after the Dst minimum for 16 events. For 1 event, flow pressure reaches to maximum at that hour when Dst goes to minimum.

In our investigation we have observed the hourly variation of taken interplanetary parameters on the day of storm and noticed the maximum value of interplaneteray parameteres.
One typical example of such variation is discussed below.

GS occurred on 17/03/2015

We have taken the severe storm event having Dst index value -234nT occurred on 17/03/2015, then we observed the hourly variation of the following interplanetary parameters; IMF, solar wind proton temperature, plasma speed, proton density, flow pressure with Dst index on the day of severe storm, which is shown in Figure 6. We noticed that Dst reaches to minimum value (-234 nT) on 17/03/2015, at 23:00UT. IMF gains its maximum value 8 hr before of the Dst minimum, solar wind proton temperature and plasma speed reaches to maximum value 11 hr before of Dst minimum. Proton density achieves to maximum value 17 hr before of Dst minimum, while flow pressure achieves to maximum 7hr before of Dst minimum.

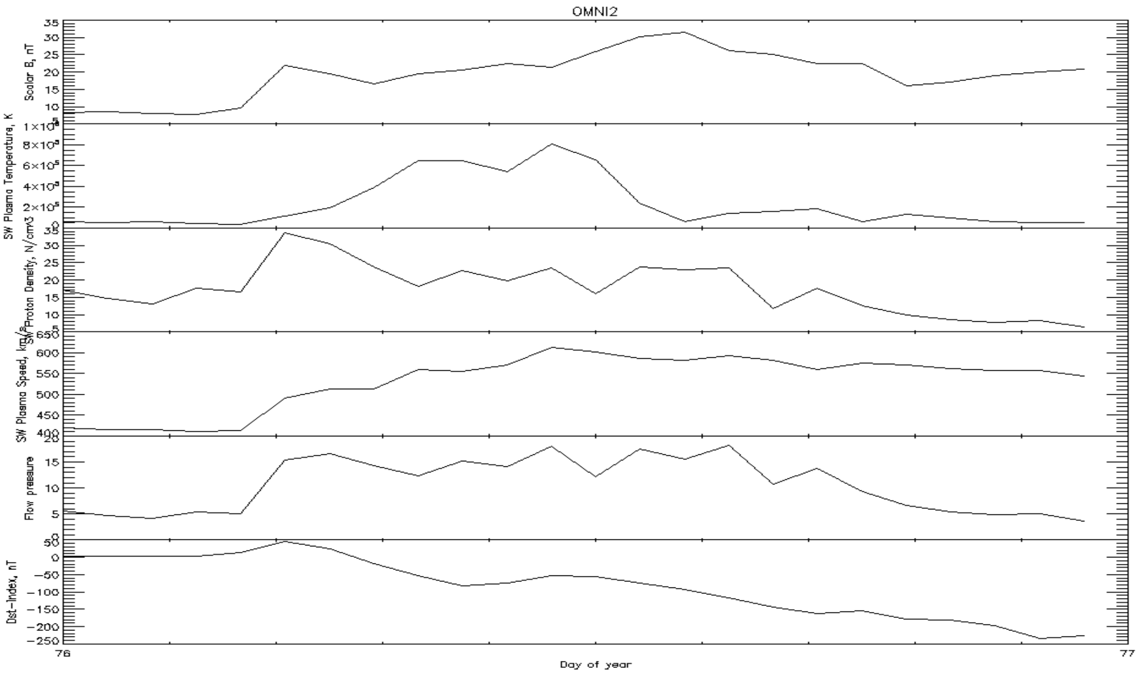

Figure 6. Variation of interplanetary parameters with Dst index.

Conclusions

We found the low anti-correlation between CME speed and Dst index (-0.22).The result suggests that severity of the storm does not depend only on the speed of CME. Furthermore, there was also found a low anti-correlation between CME speed and TT (-0.28), which indicates that mere high speed is not a factor for CME to obtain a minimum TT. In our investigation, we discovered the average TT of disk halo CMEs is 70.12 hr. We investigated that disk halo CMEs are although associated with M class, C class, X class and B class flares respectively but majorly associated with M class flares. IMF (1 hr to 20 hr before), proton density (1hr to 22 hr before) and flow pressure (1 hr 1to 18 hr before) mainly reach their maximum before the Dst minimum. Proton temperature and plasma speed reaches to its maximum value before the Dst minimum for 49.12% of events and after the Dst minimum for 45.6% of events. We concluded from our results that IMF, proton density, and flow pressure are precursor factors before the

GS, while the maximum value of proton temperature and plasma speed are not definite at the time of GS.

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