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# Properties of HALO CME in relation to large geomagnetic storms

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Based on the observations from the Large Angle and Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory (SOHO) spacecraft we have studied the coronal mass ejections. Coronal mass ejections (CME) are dynamic large-scale event during which large amounts of plasma expel from the sun's outer atmosphere. When these ejections directed towards the earth (or conversely, directed away from the earth) it looks like roughly circular "HALO" surrounding the sun. The CME originates interplanetary shocks, which impinging the magnetosphere results the geomagnetic storms. In the presents paper we have analyzed 314 HALO CMEs, which have occurred during the current solar cycle 23. It is found that HALO CME is much faster and more energetic than the other CME. The occurrence of HALO CME increases during solar maximum. The maximum speed of HALO CME is found to be as large as 4000 km/sec., where as minimum speed of HALO CME is some time of the order of 100 km/sec. We have also found that HALO CME is the main cause to produce large geomagnetic storms.

## 1. Introduction

Although the concept of mass ejection from the sun has been known for a long time, the phenomenon of coronal mass ejection (CME) as we know them today, was first discovered in 1971, using the Seventh Orbiting Solar Observatory (OSO-7) coronagraph [1]. In fact, the concept of mass ejection existed as prominence eruption (active and eruptive) since the first scientific observation of Secchi and de la Rue in the late 1800's [2].

During coronal mass ejections large amount of matter expel out (about 1 to 10 billion tons of material) in the form of a large cloud of charged particles from the sun's outer atmosphere. Because the sun can eject matter in any direction, only some of the CMEs are actually directed towards earth. These earth directed CMEs are geo effective CMEs. The occurrence of CME depends on the phase of the solar cycle [3,4]. CME is the most dynamic large-scale event observed by Large Angle and Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory (SOHO) mission now provides the most effective means of identifying earthward directed CMEs, which are believed to be the primary cause of large non-recurrent geomagnetic storms [3,5].

Space weather is significantly controlled by coronal mass ejection, which can affect the earth in different ways. CMEs originating from regions close to the central meridian of the sun and directed towards the earth are of immediate concern because they are likely to be geoeffective. In coronagraphic observation, halo CMEs appear as enhancement surrounding the entire occulting disk, looks like a roughly circular "halo" surrounding the sun. The halo CMEs are more likely to impact the earth than those, which shot-out at right angle to the earth- sun line. [6]. In this paper, various properties of halo coronal mass ejection and their relation with large geomagnetic storms are presented.

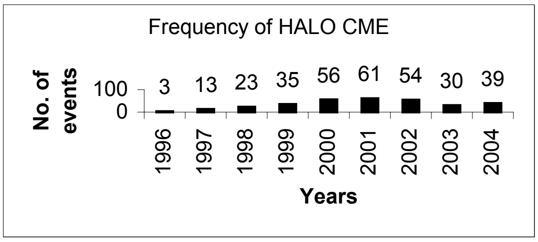
## 2. Selection criteria and data analysis

In the present study, we have analyzed in detail all halo CMEs occurred during current solar cycle 23. We have considered here two types of halo CMEs. First, the classical full halo CMEs that appears to surround the entire occulting disk very late, often in the field of view of the LASCO/$C_3$. Some times limb events appear as halo due to deflections of pre-existing coronal structures by the fast CME. Therefore, after very careful examination one can distinguish a real halo CME out of limb fast events deflecting coronal material. We have examined the various parameters for 314 halo CMEs from the data sample. Here, all CMEs with angular width only 360º have been considered as halo CME.

We have also analyzed large geomagnetic storms in relation to halo CMEs. All those large geomagnetic storms have been considered which are associated with Dst (Disturbance storm time index) decreases of more than -100 nT, observed during the period 1996-2004. The disturbance storm time index is the conventional measure of ring current intensity and energy observed at earth's surface over low and moderate latitudes. It is the best indicator of ring current intensity and a very sensitive index to measure the degree of solar disturbances. The value of geomagnetic index Dst obtained from Solar Geophysical Data Report (Part I and II) of U.S. Department of commerce, NOAA Monthly issues. The occurrence of halo CMEs is obtained from the website http://cdaw.gsfc.nasa.gov/cme_list.

## 3. Characteristic features of Halo CME

Here we have analyzed 314 halo CMEs occurred during period 1996-2004. The histograms of annual distribution of the frequency of halo CME is shown in figure1. We have found that the occurrence frequency of halo CME generally follows the phase of solar cycle. During the solar maximum Year 2001 the maximum number of halo CMEs have occurred. In the year 1996,only 3 halo CMEs have occurred. The actual number of observed halo CMEs might differ substantially if there are data gap. The discrepancies in results are sometime seen due to major data gap.



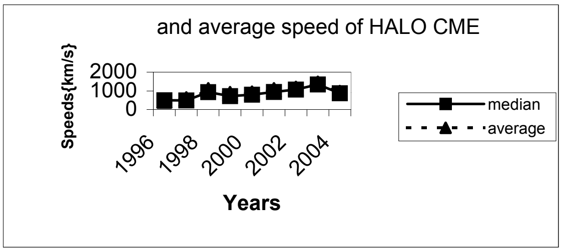




**Figure 1,** Histogram of annual distribution of the frequency of halo CME (Left panel) and **Figure 2,** Variability of the median and average speeds of halo CMEs (annual average) (Right panel).

The variability of the median and average speeds of halo CMEs (annual average) is depicted in fig.2. The CME speed (annual average) is found to be maximum in the year 2003. Fig.2 shows the clear increase in the mean speed from the minimum to maximum (from 450 km/s to 1400 km./s). In figure 3, the histogram of speed distribution of halo CME is depicted. In the year 1996, which is the period of minimum solar activity, speed of halo CME is not more than 1000 km/s. During the solar maximum the speed of halo CME is much higher as greater as 4000 km/s, where as during the period of solar minimum the speed of halo CME is much slower, sometimes of the order of 100 km/s. It is found that halo CME is much faster and more energetic than other CMEs [7]. Table 1 shows the association of severe geomagnetic storms with coronal mass ejection and solar flare. Twelve severe geomagnetic storms (Dst>-200nT) are observed during current solar cycle. The largest storm was observed on 20 Nov. 2003. This event can be put in the category of super storm. The Dst magnitude during this event is observed to be -472 nT. This event is associated with halo coronal mass ejection from solar active region. The speed of CMEs is found to be about 1660km/s.

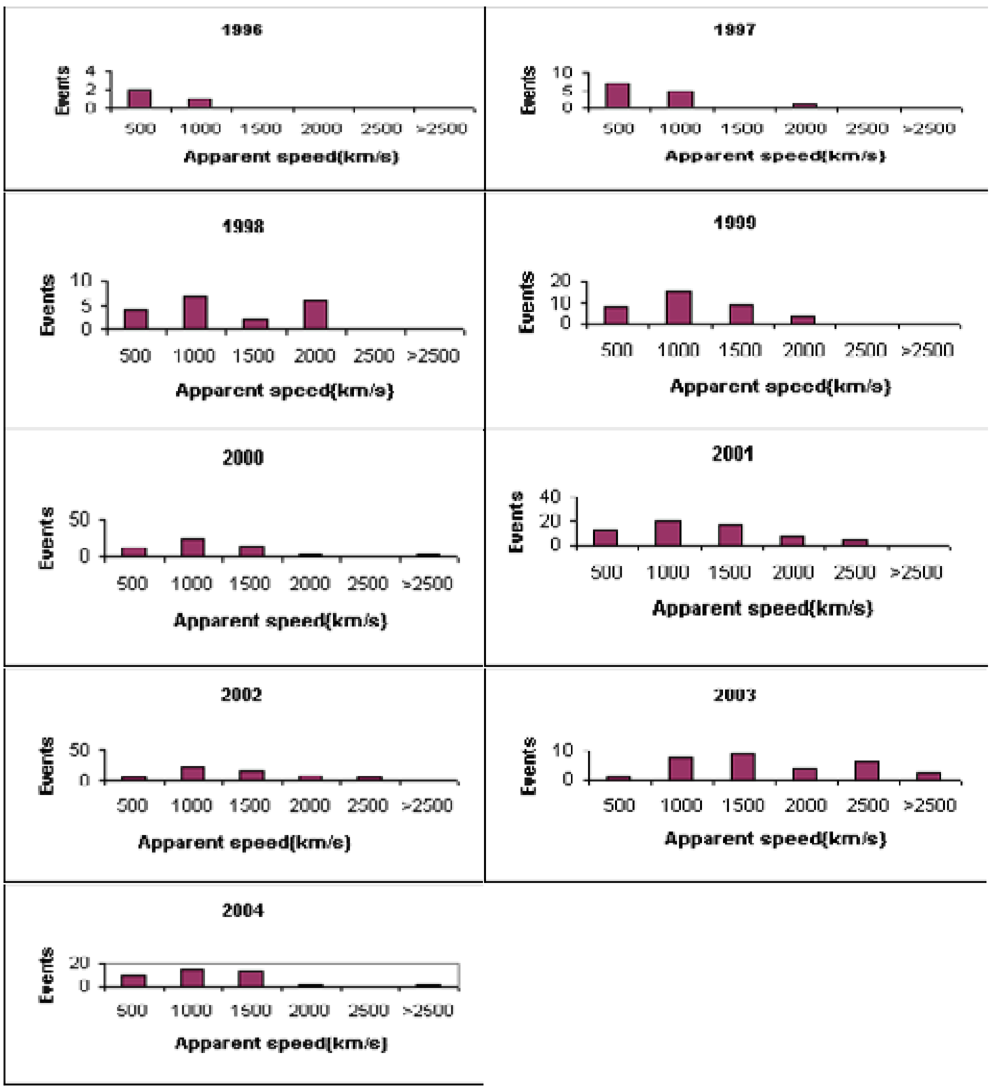



**Figure 3**, Histogram of speed distribution of halo CME.

**Table 1.** Severe Geomagnetic Storm observed during solar cycle 23

| Sr. | Date | Max. mag. Of event (nT) | CME/Flare association | type of CME/Flare |
|---|---|---|---|---|
| 1. | 04 May 1998 | -216 | CME (871Km/s) | Halo CME |
| 2. | 25 Sept 1998 | -233 | data gap | |
| 3. | 22 Oct.1999 | -231 | CME(739Km/s) | B Flare |
| 4. | 15 July 2000 | -300 | CME (1147Km/s) | Halo CME |
| 5. | 07 April 2000 | -312 | CME (890 Km/s) | B flare |
| 6. | 12 Aug 2000 | -237 | CME (999Km/s) | Halo CME |
| 7. | 31 Mar 2001 | -358 | CME (1147Km/s) | Halo CME |
| 8. | 11 Apr 2001 | -256 | CME (2975Km/s) | Halo CME |
| 9. | 06 Nov 2001 | -277 | CME (1691Km/s) | Halo CME |
| 10. | 24 Nov2001 | -212 | CME (1409Km/s) | Halo CME |
| 11. | 30 Oct2003 | -401 | CME (1519Km/s) | Halo CME |
| 12. | 20 Nov2003 | -472 | CME (1656Km/s) | Halo CME |

## 4. Conclusion

On the basis of investigation of 314 halo CMEs and 57 large geomagnetic storms (Dst>-100nT) ,it is concluded that population of halo CMEs and their average speed increases during solar maximum and their occurrence generally follow the phase of solar cycle. The minimum speed of halo CME is found to be ≥ 450Km/s with maximum speed ≈ 4000km/s. Halo CME is found to responsible to produce large geomagnetic storms. Out of selected 57 large geomagnetic storms occurred during current solar cycle23, 44 large geomagnetic storms are associated with coronal mass ejections in which 25 coronal mass ejection are halo CMEs. Out of 12 severe geomagnetic storms, 9 severe geomagnetic storms are associated with particular halo coronal mass ejections and remaining two severe storms are associated with flare. We could not find the association of 1 severe geomagnetic storms due to major data gap. Hence results discussed as above clearly indicate that the halo CMEs is the major cause to produce large geomagnetic storms.

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