Correlative Study of Coronal Mass Ejections

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Abstract

We have investigated the some statistical properties such as occurrence rate, speed of halo, partial halo CMEs and all type of CMEs observed during the 1996-2010 by using solar heliospheric observatory (SOHO) and large angle spectrometric coronagraph (LASCO) data. We have investigated 14586 all CMEs which include halo plus partial halo CMEs. The 378 halo and 852 partial halo CMEs have been observed from 1996-2010. It is noticed that the occurrence rate per year of all CMEs, halo and partial halo CMEs have been found to be 972.4, 25.2 and 56.8 respectively during the year 1996-2010. The occurrence rate per day of all CMEs found to be~ 3 during the study period . It is also observed that the rate of occurrence of CMEs is good correlated with solar activity. The halo CMEs (wide) appear to faster and more energetic than non halo CMEs.

Keywords: Coronal Mass ejections (CMEs), Speed, Sunspot Number (SSNs), Halo CME, Partial halo (CME), Correlation Coefficient.

Introduction

Coronal mass ejections (CMEs) are an important sources of solar variability from the point of view of plasma and magnetic field. The CMEs remove billions of tons of magnetized plasma from the sun and dump them into sun and the earth connected space once every day during solar minimum and several times per day during solar maximum. The CMEs are most energetic solar events that eject huge amount of mass and magnetic fields in to helio sphere and are widely known as being for occurrence of storms in solar wind plasma parameter[1].The CMEs can also prove dramatic variable energy in to the magnetosphere, in addition to and some time in combination with the high speed solar wind streams that originates from coronal holes. The CMEs are the source of major disturbances in the interplanetary medium and can be directly observed up to 32 solar radii from the sun.

The first detection of a CME is made on 14 sep 1971 in Naval Research Laboratory using the seventh orbiting solar observatory(OSO7) by Tounsey[2]. Harrion (1995)[3] found that the longer duration flare events have greater change of CMEs associatio. Burkepile et al. (1994)[4] found that CMEs are associated with intensity flare where as Sheeley et al. (1983)[5] noticed that they are most commonly connected with long duration flare.The discovery of lower coronal signature has provided the opportunity to study other solar activity which is in same way linked to CMEs and obvious candidate is flaring .The active region which shows an association to a CMEs may flare both before, during and after CME launch.The CMEs are a topic of extensive study because they are interest for both technological and scientific reasons[6,7,8,9,10].For scientific point of view ,they are interest because they remove built up magnetic energy and plasma from the solar corona and technological they are of interest , they are responsible for the most extreme space weather effects at earth as well as they effects other planet s and space crafts through out the helio-sphere [11,12] .

Yashiro et al.(2003)[13] have studied the properties of CMEs observed with Large angle and spectrometric coronagraphs (LASCO) on board solar and heliospheric observatory (SOHO). Gopalswamy et al. (2003a)[10] have described the solar cycle variation of different properties of CMEs such as average, median speeds, daily occurrence rate and latitude of solar sources for the period 1996-2003. The measured properties of CMEs include their angular widths, speeds and acceleration masses and energies. Occurrence rate, locations relations to the solar disk have been also discussed by many researchers (Hundhausen, 1972[14] ;Kahler, 1992[15] ; St Cycer et al. 2000[16] ; Webb 2002[17]; Yashiro et al. 2004[18]).

The sunspots, their origin and formation with their cycle activity remain a mystery from the since of discover. In the similar way, the physics of the recently discovered the CMEs are to be understood. The solar cycle 23 and their activity phenomenon are some of the interesting physical process that is least understood.

Data Source and Selection Criteria

The data for CMEs have been taken from the catalog by the centre for solar physics and space weather(http://cdaw.gsfc.nasa.gov/C MElist)[19]. Sunspot number have been used from solar geophysical data reports and they are cross verified by Omni web data . CMEs properties observed from LASCO on board SOHO. We have taken in account all CMEs which include halo and partial halo CMEs during the study period. A CME is said to be halo if angular width is equal to 360^0 where as a partial halo CME have angular width greater than 120^0 and less than 360^0 .we have also count total number of CMEs containing angular width greater than $0^0$and less than 360^0 which are occurred during the study period 1996-2010.

Correlative Properties of Coronal Mass Ejections

Occurrence rate of all CMEs, halo CMEs, partial halo CMEs with SSNs have been looked upon during the period 1996-2010. Fig 1 shows the annual variation of SSNs from 1996-2010. It is obvious from fig 1 that the year 2000 is the maximum activity year. The SSNs are increase from 1996-20000 which is the inclining phase and decreases from 2000 to 2006 which is the declining phase of solar cycle. The annual distribution of all CMEs from 1996 to 2010 have been depicted in fig 2. It is apparent from fig 1 and 2 that the occurrence frequency of all CMEs observed in white light almost tends to follow the sunspot cycle in both phases, amplitude which varies by an order of magnitude over the cycle. Some peculiarities have been also observed during the years 2002, 2005, 2007 and 2010, the SSNs decreases where as CMEs increases significantly. It is noticed that 0.57 CMEs occurs every day during the 23 solar cycle minimum (1996) and 4.5 per day at solar maximum (2000). This result is consistent with St Cyr et al.(2000)[16] and Gopalswamy et al. (2005,2006b)[20,21]result. SSNs are very good correlative to all CMEs and correlation coefficient found to be 0.644. Fig 3 shows the annual distribution of halo CMEs from 1996 to 2010. Two peculiar result have been observed during the year 2001, 2005, the SSNs decreases where as halo CMEs increase significantly. The SSNs halo CMEs are good correlative and correlation coefficient found to be 0.78, it is observable from fig 3 that peak in number of fast and wide CMEs at years 2001 and 2005. There are two peaks in the number of halo CMEs. Thus, we can conclude that the occurrence of halo or fast and wide CMEs is not excellent correlated solar cycle variations. We have noticed that number of halo CMEs are minimum (4) at the solar minimum (1996) and ,maximum (63) at second solar maximum (year 2001). Halo CMEs are only detected at a rate of 3% of all CMEs. It is also observed that 51% CMEs have occurred during the year maximum activity years from 1999 to 2002. The annual distribution of partial halo CMEs from 1996 to 2010 have been depicted in fig 4. It is evident from fig 4 that the more than 60% partial halo CMEs has occurred during maximum activity years from 1999 to 2002 of 23 sunspot cycle. Further, it is noticed that partial halo CMEs occur at the rate of ~9% that of all CMEs during the period 1996 to 2010. The SSNs are excellent correlated to partial halo CMEs during study period and coefficient correlation found to be 0.92.

The annual distribution of speed of halo and partial halo CMEs have been plotted histographically in fig 5,6 respectively. We have noticed that minimum average speed of halo CMEs is 143 km/s in year 2008 whereas maximum average speed is 1400 km/s in the year 2003. Furthermore, 260.5 km/s is the average speed of partial halo CMEs in year 2009 which is minimum whereas 774 km/s is the maximum average speed of partial halo CMEs during the year 2003. Thus, we can conclude that maximum average speed of full halo and partial halo CME have been occurred in same year 2003 which is not the year of maximum activity. Table 1 shows the correlation of various parameters of CMEs during the period 1996 to 2010. It is noticed the overall average speed of full halo and partial halo are 819 km/s and 531 km/s respectively during the year from 1996 to 2010. We have observed that CME rate continues to be correlated with the sunspot through its minimum and initial rise of cycle 24 with the CME rate minimum in late 2008 or early 2009. The occurrence frequency of halo and partial halo CMEs with their speed are very good correlated and correlation coefficient has been observed to be 0.754 and 0.753 respectively.

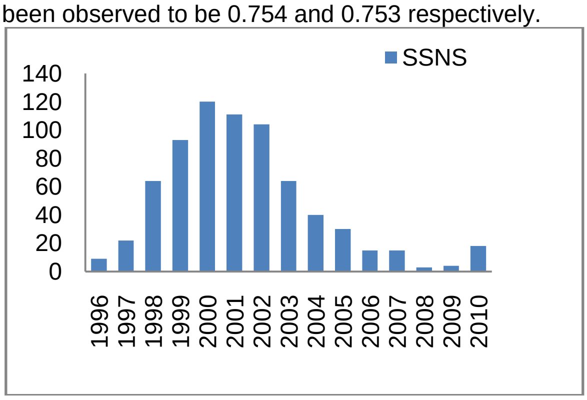

Figure 1: Shows the Variation of Annual Occurrence Sun Spot Numbers from 1996 to 2010.

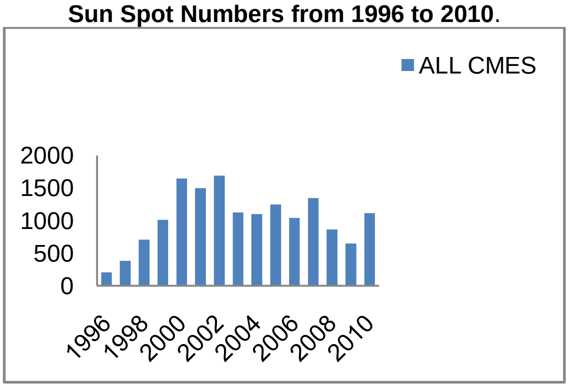

Figure 2: Shows the Annual Distribution of All CMEs from 1996 to 2010.

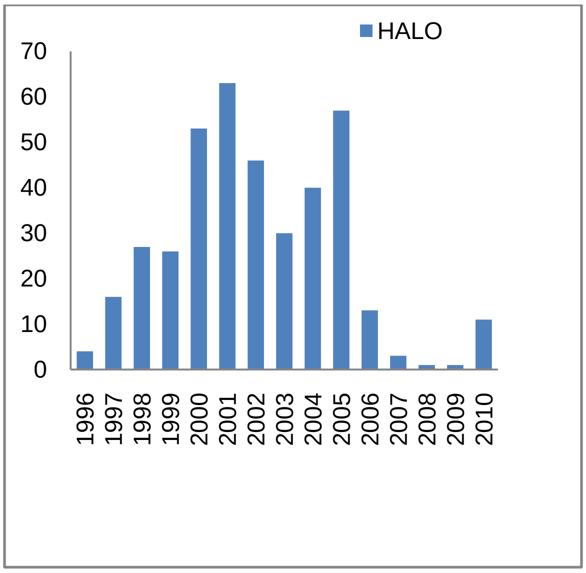

Figure 3: Shows the Annual Distribution of Halo CMEs from 1996 to 2010.

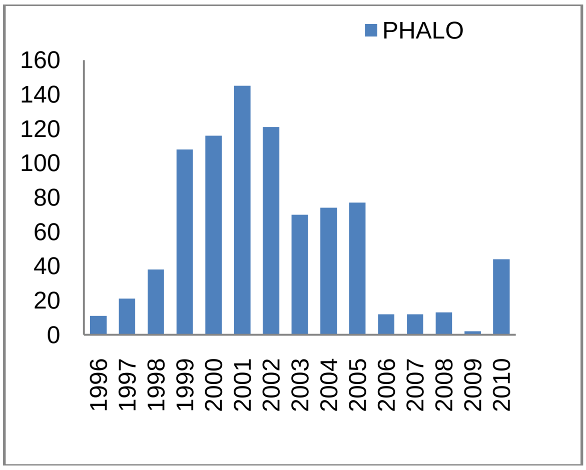

Figure 4: Shows the Annual Distribution of Partial Halo CMEs from 1996 to 2010.

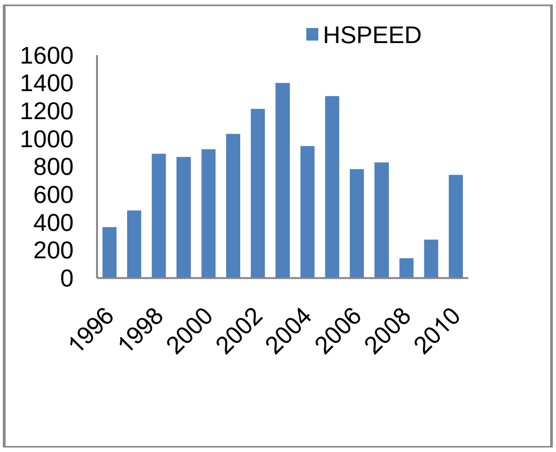

Figure 5: Shows the Annual Distribution of Speed of Halo CMEs from 1996 to 2010.

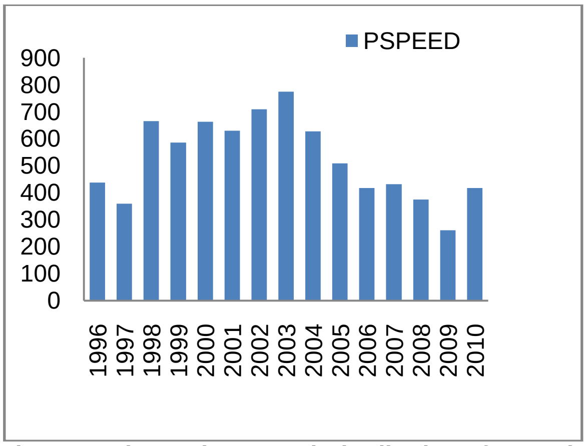

Figure 6: Shows the Annual Distribution of Speed of Partial Halo CMEs from 1996 to 2010.

Table 1: Shows the Correlation of Various Parameters of CMEs During the Period 1996 to 2010.

S.No.	Correlationbetween theParameters	Correlation coefficient
1	SSNs between Total CMEs	0.644
2	SSNs between Halo CMEs	0.780
3	SSNs between Partial Halo	0.918
4	SSNs between Halo CMEs speed	0.604
5	SSNs between Partial Halo CMEs speed	0.804
6	Occurrence frequency of Halo CMEs between Halo CME speed	0.754
7	Occurrence frequency of partial Halo CMEs between Partial CMEs speed	0.753

Conclusions

From the above analysis, the following conclusions have been drawn:

1. It is noticed that halo CMEs appear to be faster than non halo CMEs.
2. More than 60% partial halo CMEs have occurred in maximum activity years from 1999 to 2002.
3. It is observed that the 0.57CMEs per day occurs during 23 solar minimum and 4.5 per day at solar maximum.
4. The occurrence of halo CME is minimum (4) at the solar minimum (1996) and maximum (63) at second solar maximum year (2001). Halo and partial halo CMEs are detected at the rateof 3% and 6% of all CMEs.
5. The more than 50% CMEs have occurred during the maximum activity year from 1999-2002.
6. The minimum and maximum average speed of halo CME have been observed to be 143 km/s and 1400 km/s during the year 2008 and 2003 respectively where as the minimum and maximum average speed of partial halo CMEs found to be 260.5 km/s and 774 km/s during the year 2009 and 2003 respectively.
7. The maximum average sped of halo and partial halo CMEs have been observed to be ~1400 km/s and ~774 km/s during the same year 2003.
8. Occurrence rate,speed of halo , partial halo, all CMEs are well correlated to SSNs.

9. The overall speed of halo and partial halo CMEs have been observed 819 km/s and 531 km/s respectively for the period 1996-2010.

Acknowledgement

We are thankful to various experimental groups for providing the data. In particular data from SOHO mission. We are also thankful to N Gopalswamy and S Yashiro for helping us with their groups latest LASCO CME results.

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