ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 08, pp.35852-35857, August, 2016

INTERNATIONAL JOURNAL
OF CURRENT RESEARCH

RESEARCH ARTICLE

OBSERVATIONAL STUDY OF INTERPLANETARY CORONAL MASS EJECTIONS AND FLARE IN THE SOLAR CORONA

***Antony Dhivya Tharshini, S. and Shanthi, G.**

Department of Physics & Research Centre, Women's Christian College, Nagercoil, 629 001, India

ARTICLE INFO

Article History:
Received 16th May, 2016
Received in revised form
18th June, 2016
Accepted 09th July, 2016
Published online 20th August, 2016

Key words:

CMEs, Flare,
Linear speed,
Solar events,
Interplanetary medium.

ABSTRACT

Interplanetary Coronal Mass Ejections (ICMEs) are the region of light scattered due to the electron densities in solar corona. The main objective of the study is to determine the distributions of Coronal Mass Ejections (CMEs) and solar flare parameters for the purpose of establishing the relationship between CME/flare properties derived from remote solar observations at the Earth. The identified CMEs are measured and their basic attributes are catalogued in a data base known as the SOHO/LASCO CME catalog. We have investigated some properties of all the fast and slow CMEs events. Our results reflect some of relatively well-known relationships between remotely observed solar properties, namely the importance of CME linear speed, angular width and associated solar flare. We also utilized various types of CME associated with different times of the solar cycle to estimate the impact on Earth. This paper presents the possible interpretations of the global CMEs and solar flare parameters, the summary of results obtained using the extensive events of Solar Energetic Particles (SEP) and radio burst at low frequency range associated with the energetic CME are greatly discussed.

Citation: Antony Dhivya Tharshini, S. and Shanthi, G. 2016. "Observational study of interplanetary coronal mass ejections and flare in the solar corona", *International Journal of Current Research*, 8, (08), 35852-35857.

INTRODUCTION

CME ejected from the sun is one of the main solar phenomena. The Earth-directed CMEs are very important, since they can produce geomagnetic storms. Usually these CMEs are seen as Halo CMEs. Early measurements of the CMEs speed and their physical processes in the solar corona has derived the speed values of 500–1000 km/s, from their observations of metric type G bursts they concluded that these flare-associated bursts were produced by shock waves moving out through the interplanetary medium (Russell & Shinde., 2005; Andrei & Igor., 2007). When the ICMEs traverse interplanetary space (IP), are the primary source of severe space weather at Earth. They cause geomagnetic storms that can damage both military and civilian, space and ground assets. These hazardous storms are difficult to forecast and there are many false alarms (Liu *et al*., 2009). It has long been suspected that the interaction of a coronal mass ejection (CME) with nearby dense coronal structures like streamers or rays is important to solar type II radio bursts (Yurchyshyn *et al*., 2005). The mechanism of coronal mass ejections (CMEs) is a major puzzle in the physics of the solar corona. Theoretical investigations still cannot account for all the diverse manifestations of this energy release process in the solar atmosphere (Nivaor *et al*., 2011; Yaochen *et al*., 2014). According to the current paradigm, the coronal magnetic field plays a dominant role in the CME eruption process. Modern CME theories usually consider the CME initiation process as taking place locally, i.e., in a relatively small (of the order of the active region size) part of the solar corona with the bipolar field configuration. Even in the breakout model which requires multipolar magnetic field, the opening of field lines has a local character: only the middle flux system erupts. There is, however, increasing evidence that CMEs may involve structures on a larger spatial scale (Andrei & Igor 2007). Early measurements of the speeds of coronal mass ejections (CMEs) suggested that there are two distinct types of the speed profiles, slow CMEs which are associated with eruptive prominences and fast CMEs which originate in solar active regions. This classification was further supported by reports that the median speed of CMEs increases at the time nears a solar maximum and that flare associated CMEs have higher median speeds than those associated with eruptive filaments (Yurchyshyn *et al*., 2005) Several other CME detection methods have proposed the generation of a number of CME catalogs, which do not always agree in terms of measured speeds or of event identification. There are

---

****Corresponding author: Antony Dhivya Tharshini, S.***
Department of Physics & Research Centre, Women's Christian College, Nagercoil, 629 001, India.

automated CME detection methods until now no automatic CME detection method has the ability to determine the CME lateral expansion speed. The use of the halo CME lateral expansion speed, measured in Large Angle and Spectroscopic Coronograph (LASCO) C_3 images instead of a single direction projection speed to predict the CME travel time to Earth, obtaining very good results (Nivaor Rigozo *et al.,* 2011; Dumbovic *et al* 2014). Generally, an ICME corresponds to one CME from the Sun, but during solar maximum more than one CME can be launched from the sun in a short interval. These CMEs can interact in the interplanetary space and arrive at the spacecraft as one complex ICME (Oprea *et al*., 2013; Howard *et al*., 2006).It is our intent to concentrate on what can be derived from the solar parameters, the angular width, and linear speed. In contrast, there is a clear physical paradigm for the ejection and the subsequent behaviour of an ICME that has reached the level of quantification (Russell & Shinde 2005; Webb *et al*., 2009). In this paper we analyze the distribution of linear speed as a function of the CMEs and solar flare parameters by utilizing data from the catalog of SOHO LASCO CMEs. We compare the angular width against the observed speed distributions (Uwamahoro *et al*., 2012). It is important to know in this study we have used 180^0 & 270^0 as a threshold apparent angular width to define halo CMEs, where full halo CMEs (F-type) have an apparent sky plane of 360^0, while partial halos (P-type) are those with an apparent angular width in the range $90^0 \leq W \leq 360^0$. Since it gives us a hint of fast and slow CMEs are caused by two distinct physical mechanisms.

MATERIALS AND METHODS

Source of Data

The halo CMEs used in this study is collected from various sources in order to avoid possible bias in determination of the CMEs solar sources. We obtained archival measurements of flares and CMEs for the period of 1996- 2010. We used more than 14765 records of CMEs data (obtained from the CME catalogue) observed by SOHO/LASCO during this period. This CME data is available in the co-ordinate data analysis in CDA website, available online at http://cdaw.gsfc.nasa.gov/CME_list/. The selection criteria of halo CME are identified by its solar sources.

The LASCO Instruments

The Large Angle Spectrometric Coronagraph (LASCO) includes three coronagraphs C1, C2 and C3 with circular fields. C1 is a reflective, internally-occulted coronagraph while C2 and C3 are externally occulted coronagraphs. C1 handles the imaging from 1.1 to 3 solar radii, C2 images from 1.5 to 6 solar radii and C3 images from 3.7 to 30 solar radii (Brueckner *et al* 1995). The goals of the LASCO investigation were to study the diagnosis of the corona including regions as the polar holes and coronal streamers, the physics of coronal mass ejections (CME) and their geomagnetic effects, comets and dust in the solar system.

Properties of CMEs

Halo CMEs

Halo CMEs are so named because they appear to surround the occulting disk of the coronagraph (Howard *et al*., 1982). CMEs heading toward and away from the observer can appear as halos. Only those halo CMEs, which are directed towards the Earth, are geoeffective and can produce geostorms at Earth. The CMEs having width $>180^0$ are considered as halo CMEs. The Solar and Heliospheric Observatory/Large Angle Spectrometric coronagraph (SOHO/LASCO) (Brueckner *et al*., 1995; David Webb *et al*., 2012) has been detecting the occurrence of CMEs on the Sun for more than a decade. Halo CMEs are those appear to surround the occulting disk of the observing coronagraphs. It has been observed that halo CMEs originating from the visible solar disc and that are Earth directed have the highest probability to impact the Earth's magnetosphere (Webb *et al*., 2009), The number of halo CMEs is minimum at the solar minimum (1996) and maximum at solar maximum (2000) the situation is somewhat similar at the other solar minimum year (2008).The partial and full halo CMEs occur at a rate of about 10% that of all CMEs, but 360^0 halo CMEs are only detected at a rate of ~4% of all CMEs. It has been documented that halo CMEs appear to be faster and more energetic than non-halo CMEs (Landi and Miralles., 2014; Cyr *et al*., 2000). This, of course, does not imply that halo CMEs are somehow physically different, but rather it shows that even with LASCO some CMEs are not detected. LASCO does not observe faint CMEs near sun center.

Fast CMEs

The fast CMEs produce shocks which accelerate high energy particles. Energetic particles are also produced low in the corona in association with solar flares. These particles then travel near the speed of light and can be detected near Earth, well ahead of the CME itself (Vasanth and Umapathy., 2013). The LASCO CCDs serve as rather unsophisticated energetic particle detectors. Cosmic rays continually impact the CCDs and are always evident in the LASCO movies as scattered twinkles in individual CCD pixels.

RESULTS AND DISCUSSION

CMEs identification and measurements

The CME parameter analyzed in this study is the first order linear speed derived from LASCO C2 and C3 images. Mass motion is the basic characteristic of CMEs which is quantified by their speeds. The mean speed during solar minimum is less than 300 km/s, while it is close to 600 km/s during maximum, thus varying over a factor of 2. It is not possible to measure the speed of ~11% of CMEs for various reasons, including the appearance of a CME in just a single frame. The CME relative speeds are presented in Table 1.

The events in our data sets associated with different speeds are categorized as CMEs with speeds less than 500 km/s as S-type, the speed ranges from 500 km/s to 999 km/s as C-type, range from 1000 km/s to 1999 km/s as O-type, range from 2000 km/s to 2999 km/s as R-type, and speeds above 3000 km/s are considered as ER-type. Linear speed relative to the center of sun measured by LASCO shows a dynamic spectral pattern for the solar maximum (2000) and minimum (2008). It permits us to visualize the CME events of various speed events as shown in the Figure (1&2).

Table 1. CMEs events and their relative speeds

Year	CME Speed (km s^{-1})	Active Region
1997	590	1059
1998	1038	1176
1999	1062	1429
2000	801	1508
2001	1117	1521
2002	1211	1577
2003	1279	1575
2004	1067	1944
2005	1295	1943
2006	853	2158
2007	1106	2432
2008	1106	2928

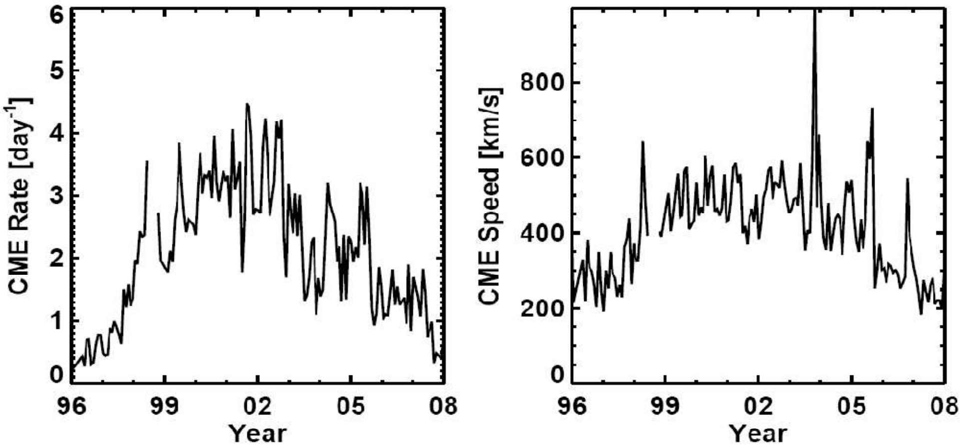

Figure 1. CME occurrence rate for the year 1996-2008

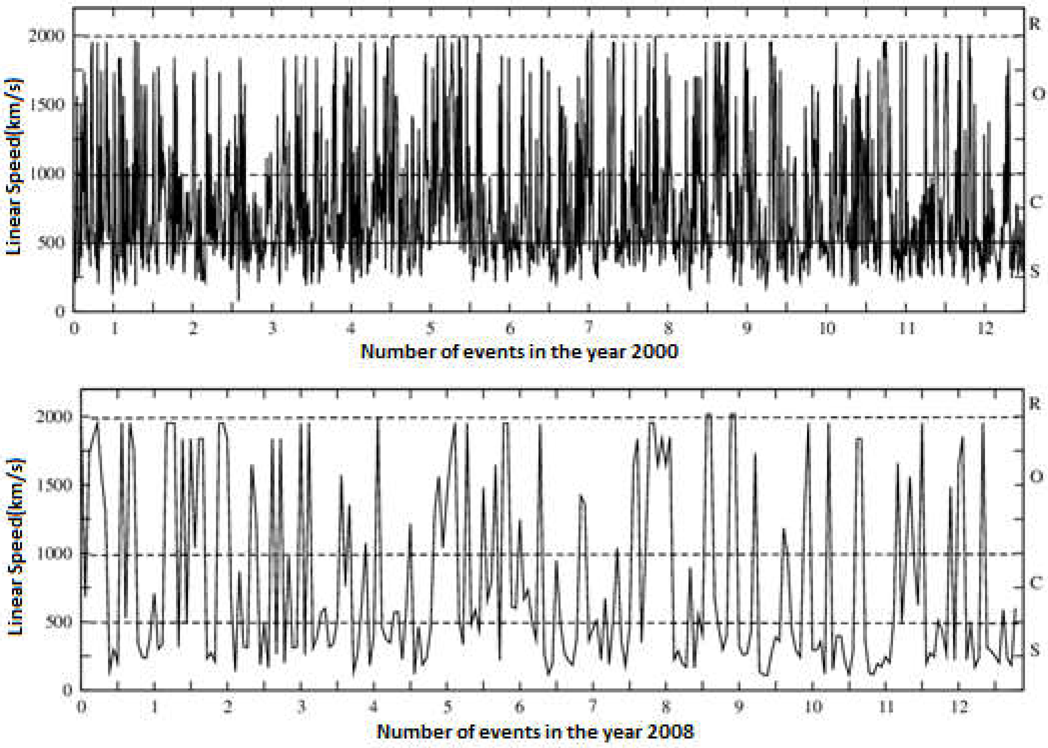

Figure 2. Linear speed versus number of events in the ascending phase of solar cycle (2000) and descending phase of solar cycle (2008)

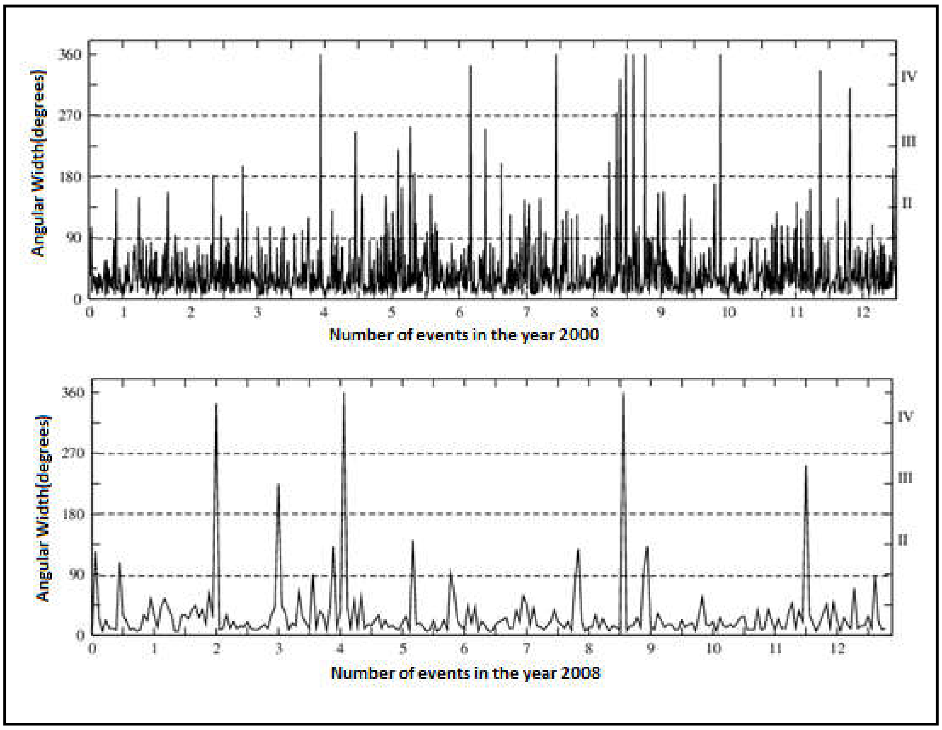

Figure 3. Angular Width versus number of events in the ascending phase of solar cycle (2000) and descending phase of solar cycle (2008)

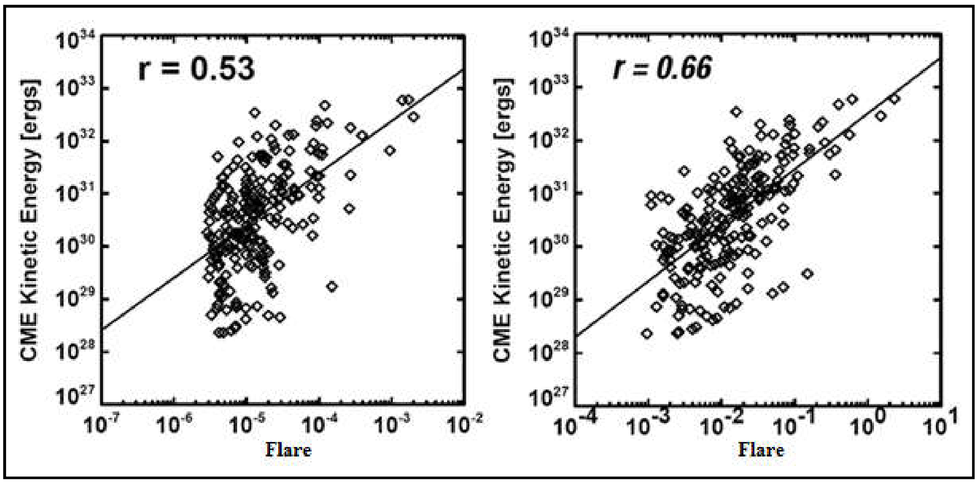

Figure 4. Variation of CME Kinetic energy associated with the solar flare for the ascending and descending phase of solar cycle

Table 2. CME/flare occurrence time with CME start time, speed, kinetic energy and angular width are taken from the CME catalog along with GOES soft X-ray flare

CME start time	CME Speed(km/s)	CME E_{kin}(erg)	CME AW(deg)	Flare
2000 Jul 14, 10:54	1674	1.9x10^{32}	360	X5.7
2001 Aug 15,23:54	1575	1.3x10^{32}	360	M4.2
2002 Jul 16,16:02	1636	1.0x10^{31}	360	M3.1
2003 Nov2,17:30	2598	1.6x10^{32}	360	X8.3
2004 Oct 29,20:54	2029	2.2x10^{32}	360	X1.3
2005 Jan 15,23:06	2861	3.4x10^{32}	360	X2.6
2006 Nov 6,17:54	1994	6.2x10^{30}	360	X2.1
2007 Jan 25,06:54	1367	8.3x10^{28}	360	M7.2
2008 Oct 17,07:31	948	8.7x10^{27}	360	None

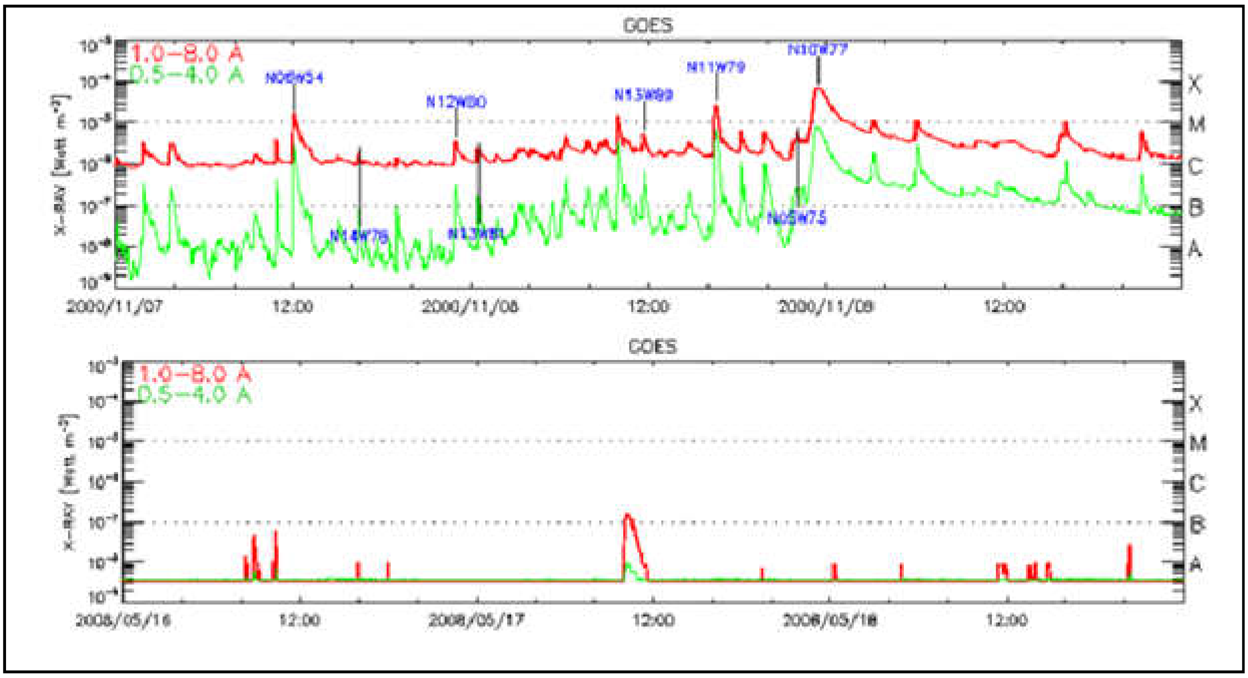

Figure 5. GOES X-ray light curves in two wavelength bands is shown for both solar maximum and minimum

The average width from the 14-year data for non-halo CMEs is 45^0 and the median width is 38^0. Halo CMEs are those CMEs with width > 120^0 but they are excluded because it is difficult to measure the actual width of such halo-CMEs due to projection effect. The events in our data sets are categorized into the angular width in degrees > 90^0 as type II, > 180^0 as type III, > 270^0 as type IV. The average width for all CMEs is smallest during solar minimum. The peak in width occurs around the year 1999 and declines slowly to minimum. The top panel presents the angular width which is more precise in range 90^0 to 360^0 and the bottom panel manifests the linear speed.

Flares evolution

There is no one- to- one relationship between CMEs and flares. Many CMEs are associated with solar flares but many are not, just as most flares are not associated with mass ejection. When CMEs and flares occur together, the CME onsets seem to precede the flares in many cases and CMEs contain far more total energy than that radiated by the flare itself. Several aspects of CME/flare source position were analyzed. First the events were investigated whether there is a symmetry regarding the source position of flare. In figure 3, the CME/flare is been plotted with the GOES satellite. The GOES XRS measurements have been made since 1970s.

On each GOES satellite there are two X-ray sensors (XRS) which provide solar X-ray fluxes for the wavelength bands of 0.5 to 4 A^0(short channel) and 1 to 8 A^0(long channel). It is very clear that during the solar maximum most of the CMEs are associated with the flares and during solar minimum no such events were originated. During solar maximum very intense flare has occurred, the flare X5.7 on 14 July 2000 and flare M7.4 on 8 November 2000 as tabulated below in Table 2.

Conclusion

The results of ICME and flare parameters show a relatively well-known relationship between the observed solar properties namely the CME linear speed, apparent width, and associated solar flare. The best significance is the linear speed variation which is consistent during the ascending phase of the solar cycle. The CMEs with higher linear speed shows intense events. The average angular width distribution is observed with more number of spikes below 90^0. The maximum and minimum phase variations of linear speed are possible during every single trigger of the angular width with respect to the CMEs events. The CME width increases as the flux of its associated solar flare increases.

- At some stage in the solar maximum most of the CME events are associated with the solar flares.
- There is a positive linear relation between the CME linear speed and associated flare. The CME mass increases as the flux of its associated solar flare increases.

This study also shows the general idea with the distribution of CME speeds observed by the LASCO instrument. We found that the linear speed determined for all observed events and separately for all the events in the solar sources which affects the Earth. The fact that the two groups of accelerating and decelerating CMEs can be modelled by a single distribution may suggest that the same driving mechanism is acting in both slow and fast dynamical types of CMEs. These results are in accordance with *SOHO* LASCO CME catalog with a correlation coefficient of 0.92 between radial speeds.

REFERENCES

Andrei. N. Zhuekov and Igor. S. Veselovsky, 2007. "Global Coronal Mass Ejections ", *The Astrophysical Journal*, 664: L131 – L134.

Brueckner. G. E., Howard, R.A., Koomen.M. J., Korendyke. C.M., Michels. D.J., Moses.J.D., Socker. D.G., Dere.K.P., Lamy. P.L., Llebaria. A., Bout M. V., Schwenn.R., Simnet, G.M., Bedford. D.K and Eyles. C.J. 1995. "The Large Angle Spectroscopic Coronograph (LASCO)" solar physics, Volume 162, issue 1, pp 357-402.

Cyr. O.C., St., Howard, R.A., Sheeley.N.R., Jr., Plunkett.S.P., Michels.D.J., Paswaters.S.E., Koomen.M.J., Simnett.G.M., Thompson.B.J., Gurman.J.B., Schwenn.R., Webb.D.F., Hildner.E., and Lamy.P.L. 2000. "Properties of Coronal Mass Ejections : SOHO LASCO Observations" from January 1996 to June 1998.

David.F.Webb and Timothy.A.Howard 2012. "Coronal Mass Ejections : Observations", *Living Rev. Solar Physics*., 9,3 .

Dumbovic. M. Devos.A., Vrsnak. B., Sundar.D. Rodriguez.L. Ruzdjak. D., Leer.K. Vennerstrom.S. Veronig.A 2014. "Geoeffectiveness of Coronal Mass Ejections in the SOHO era" Solar Physics DOI 10. 1007/S11207-014-0613-8.

Howard. R.A. Michels. D.J., Sheeley. N.R., Jr., Koomen. M.J. (1982),"The Observation of a Coronal transient directed at Earth, Astrophysics. 263, L101 – L104.

Howard. R.A., Webb.D.F., Tappin.S.J., Mizuno.D.R and Johnston. J.C 2006. "Tracking halo coronal mass ejections from 0-1 AU and Space weather forecasting using the solar mass ejection imager (SMEI)," *Journal of Geophysical Research*, Vol-111A04105.

Landi. E and Miralles. M.P. 2014. "Density diagnostics of coronal mass ejection cores with the solar dynamics observatory/Atmospheric imaging assembly", *The Astrophysical Journal Letters*, 780 : L7.

Liu. Y. Luhmann. J.G., Bale. S.D and Lin. R.P. 2009. "Relationship between a coronal mass ejection – Driven shock and a coronal metric Type II burst," *The Astrophysical Journal*, 691: L151 – L155.

Nivaor.R.Rigozo., Alisson Dal Lago and Nordeman, D.J.R. 2011. "Coronal Mass Ejection dynamics regarding radial and expansion speeds", *The Astrophysical Journal*, 738:107.

Oprea.C., Mierla.M., Besliu – Ionescu.D., Stere.O and Maris Muntean. G. 2013. "A study of solar and interplanetary parameters of CMEs causing major geomagnetic storms during SC 23", *Ann.Geophysics*., 31, 1285 – 1295.

Russell. C.T and Shinde. A.A. 2005. "On defining interplanetary coronal mass ejections from fluid parameters", *Solar Physics*, 229:323 – 344.

Uwamahoro. J. Mckinnell. L.A. and Habarulema. J.B. 2012. "Estimating the geoeffectiveness of halo CMEs from associated solar and IP parameters using neural networks," *Ann.Geophysics*., 30, 963 – 972.

Vasanth.V and Umapathy.S. 2013."A Statistical study on DH CMEs and its Geoeffectiveness" *ISRN Astronomy and Astrophysics,* vol 2013, Article ID 129426, 13.

Webb. D.F., Howard. T.A., Fry. C.D., Kuchar. T.A., Mizuno. D.R., Johnston. J.C., and Jackson. B.V. 2009. "Studying geoeffective interplanetary coronal mass ejections between the sun and earth : space weather implications of solar mass ejection imager observations", space weather, Vol 7, S05002.

Yaochen., Guohui Du., Li Feng., Shiwei Feng., Xiangliang Kong., Fan Guo., Bing Wang and Gang Li. 2014. "A Solar type II radio burst from coronal mass ejection – coronal ray interaction : simultaneous radio and extreme ultraviolet imaging", *The Astrophysical Journal*, 787 : 59.

Yurchyshyn.V. Yashiro.S., Abramenko.V. Wang.H and Gopalswamy.N. 2005."Statistical distributions of speeds of coronal mass ejections", *The Astrophysical Journal*, 619: 599-603.

****