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Association between M-class solar flares and Coronal Mass Ejections during the solar cycle 23rd

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Abstract

Solar flares and Coronal Mass Ejections (CMEs) are the most interesting and widely studied phenomena on the Sun. In this paper we are trying to investigate the association of M-class flares with CMEs. Data is chosen from 1996 to 2007 i.e. a solar cycle 23rd. Over this period we have identified total 1444 M-class flares. Applying the temporal condition we found that only 583 M-class flares are associated with CMEs. A spatial condition is applied to examine the flare position with respect to CME span on these 583 events. Our analysis indicates that during 1996 to 2007 only 141 M-class flares lie under the CME span whereas 442 M-class flares widely spread outside the CME span. Under the CME span the maximum number of M- class flares lie at the center. 10 to 20˚ latitudinal belts are more effective in producing M-class flares which lie under the CME span. In 10 to 20˚ latitudinal belts the northern region is found to be more effective. We also found that time window play a key role for flares distribution under the CME span.

Key words Sun: Solar Flare, Coronal Mass Ejection.

1. Introduction

Solar flares are among the most interesting and widely studied phenomena on the Sun. Flares occur suddenly, releasing enormous amount of energy (of the order of 10^{23} to 10^{32} ergs) in a very short time (few second to minutes). They emit energy over a wide range of wavelength extending from Radio, Visible, EUV, X-rays and γ-rays together with particle emission (Prasad et al. 2008). CME is another type of energetic, dynamically evolving and huge phenomena occurred on the sun. The association between solar flare and CME is studied by several authors (Gosling et al. 1976; MacQueen & Fisher, 1983; St. Cyr et al. 1999; Sheeley et al., 1999; Andrews & Howard, 2001; Moon et al., 2002). The most widely accepted flare-CME model is 2D

magnetic reconnection model that evolved from the concepts of Carmichael (1964), Sturrock (1966), Hirayama (1974), Kopp & Pneuman (1976), called the CSHKP model. The CSHKP flare-CME model required that the flare occurs near the centre of the CME span (yashiro et al., 2007). Harrison in 1986 analyzed the data of 48 flare-CME events and found that many flares occurred near one leg of the associated CMEs. His results do not follow the CSHKP flare-CME model. Similarly in 1989 Kahler et al. examined 35 events and concluded that maximum number of flare positions did not at the center or near one leg of the CME span. The results also do not follow the CSHKP flare-CME model. Yashiro et al. (2007) examined 498 events from 1996 to 2005 and found that the most frequent site of solar flare is at the center of the CME span. They analyzed 303 events of M-class flares and found that almost 74% M-class flare lie under the CME span for the main CME body and they also analyzed 271 events of M-class flares for whole CME body and found that almost 89% M-class flare lie under the CME span. In 2008 Yashiro et al. added two year 2006 and 2007 to and again found that most of the flares are lie under the center of CME span.

For this study we have examined the association between M-class flare and CME, using the temporal and spatial conditions for the period 1996 to 2007.

2. Data Analysis and Identification Method

For this study we are taken a data from 1996 to 2007 i.e. a solar cycle 23rd. Over this period we have identified total 23337 Solar flares. Out of 23337 Solar flares only 1444 are M-class flares. Solar flares data is provided by the website ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FLARES/XRAY_FLARES. The list of CMEs is available in the SOHO/LASCO catalogue provided by website http://cdaw.gsfc.nasa.gov/CME_list. In this study we are tried to associate those flares with CMEs in between the maximum temporal window $\Delta t = \pm 2h$, where $\Delta t = T_F - T_{CME}$, T_{CME} is the time of first occurrence of the CMEs and T_F is the lift-off time of associated M-class flares. Appling these condition to our selected 1444 M-class flares we found that only 583 solar flares are associated with CMEs under this temporal window. Almost 40% M-class flares are associated with CMEs under this temporal window. We are executing flare associated halo CME and those M-class flares whose position angle is not given. After that we investigate the flare position with respect to the CME span using the following formula

$$r_3 = \frac{\emptyset_F - \emptyset_3}{0.5\omega_3}$$

Where $r_3$is flare position under the CME span, $\emptyset_F$ is position angle of flare, $\emptyset_3$ is central position angle (CPA) of CME and ω_3 is angular span of CME. If $r_3=\pm1$ it indicates that solar flare is located at either leg of CME frontal structure and $r_3=0$ indicates that the flare is located at the center of the CME span (Yashiro et al. 2008). Using this formula to our 583 events we found total 141 events under the CME span and 442 out of CME span. To determine the position angle of flares we used the following formula

$$\emptyset_F = \tan^{-1}(\frac{sin\beta}{tan\gamma})$$

Where β is flares heliographic longitude and γ is heliographic latitude.

3. Results and Discussion

In this study we are trying to know the association between M-class flares and CMEs. Using the temporal and spatial condition we found total 583 M-class flares associated with CMEs during the period 1996 to 2007. Figure 1 shows the distribution of M-class flares under the CME span. At the centre of the CME span the number of flares is 25, whereas other M-class flares are spread throughout the CME span.

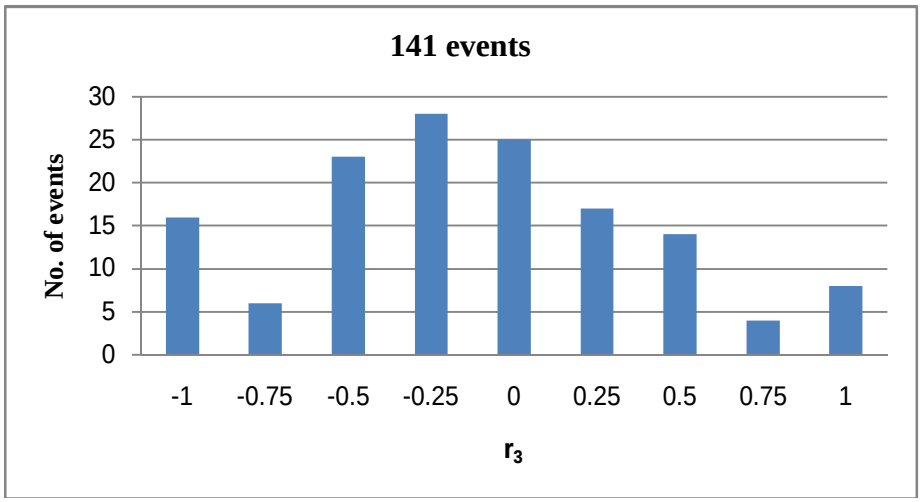

Figure 1. Distribution of M-class solar flares under the CME span.

In figure 1, the points -0.25 means the flare position range from -0.1 to -0.25 under the CME span, similarly for other points. We can see that -0.1 to -.025 ranges i.e. point -0.25 is more effective for flare occurrence, under the CME span. We also found that distribution of M-class flares under the CME span is maximum in negative sides of the span. Our results are disagreeing with Yashiro et al (2007). They analyzed 271 events of M-class flares and found that almost 89% events lie under the CME span but we analyzed that almost 24% M-class flares lie under the CME span. We found that almost 75.8% M-class flares are outside the CME span i.e. our result does not follow the CSHKP flare-CME model. They checked the consistency of the associations by viewing both flare and CME movies in the catalog. They played the movies obtained by the Extreme-ultraviolet Imaging Telescope (EIT) on SOHO and the Soft X-Ray Telescope (SXT) on Yohkoh to look for any eruptive surface activities e.g., filament eruptions, dimmings, and arcade formations and take a maximum time window Δt= ±3h, whereas we used Δt= ±2h. So the result of disagreement with Yashiro et al. (2007) is due to the difference in taking the flare CME pair. Therefore our result is based on temporal condition. We only agree with Yashiro et al. (2007) at a point that under the CME span the maximum flare side is at the centre. Figure 2

shows the yearly distribution of 141 M-class flares. We found that year 1999 is more effective for producing the flares under the CME span than the other year. During the year 2000, 2001 and 2003 occurrence of number of M-class flares under the CME span is equal.

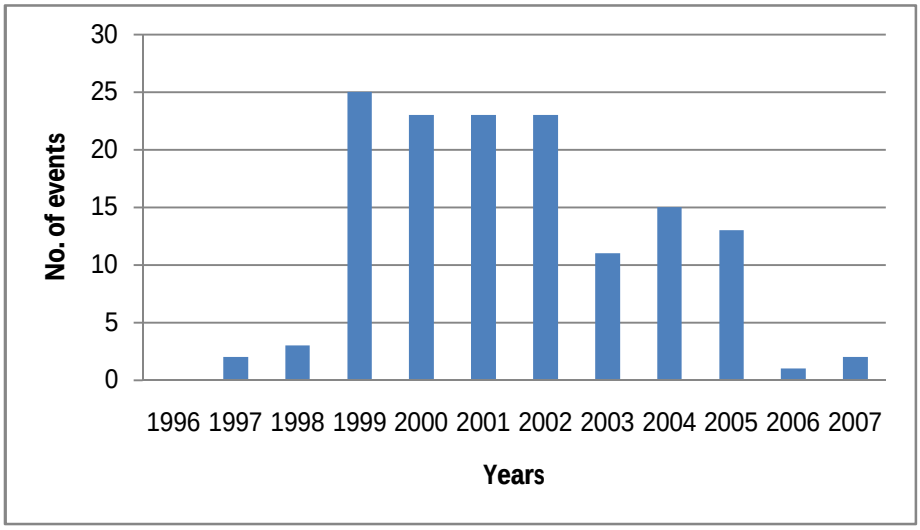

Figure 2. Year wise distribution of M-class solar flares under the CME span.

Similarly figure 3 represents the latitudinal distribution of 141 events. We found that 10 to 20˚ latitudinal belts is more effective in producing M-class flares (under the CME span) than the other latitudes. We also found that in 10 to 20˚ latitudinal belts dominance of events exits towords the northern side. We analysed that lower latitude is effective for flare-CME association.

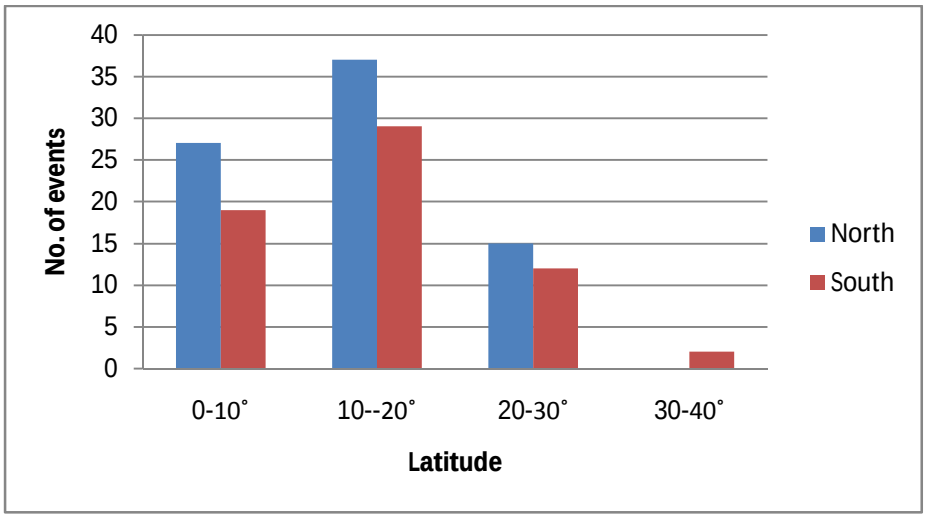

Figure 3. Latitudinal distribution of M-class flares under the CME span.

4. Conclusion

From the above studies we concluded the following points.

(1) M-class flares are widely distributed outside the CME span.
(2) Only 24% M-class flares lie under the CME span.
(3) Out of 583 M-class flares only 141 lies under the CME span during the period 1996 to 2007.
(4) 10 to 20˚ latitudinal belts are more effective in producing M-class flares which lie under the CME span.
(5) In 10 to 20˚ latitudinal belts the northern region is more effective.
(6) Under the CME span the maximum flare side is at the centre.

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