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ScienceDirect

Advances in Space Research 62 (2018) 417–425

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

www.elsevier.com/locate/asr

A statistical study of CME-Preflare associated events

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Received 17 December 2017; received in revised form 24 March 2018; accepted 24 April 2018
Available online 4 May 2018

Abstract

We investigated the relationship of associated CME-Preflare during the solar period 1996–2010. We found 292 CME-Preflare associated events (∼2%). Those associated events have 0–1 h interval time, popular events occur within half an hour before flare starting time. Post-flares–CME associated events are wider than CME-Preflare associated events. CME-Preflare associated events are ejected from the northern hemisphere during the solar cycle 23rd, while the non-associated CMEs are ejected from the southern hemisphere. Polar CME-Preflare associated events are more energetic than the equatorial events. This means that post-flare–CME associated events are more decelerated than CME-Preflare associated events, CME-Flare associated simultaneously events and other CMEs. The CME-Preflare associated events are slower than the post-flare–CME associated events, and slightly faster than non-associated CME events. Post-flare–CME associated events are in average more massive than Preflare CME associated events and all other CMEs ejected from the Sun. CME-Preflare associated has a mean average speed which is equivalent to the mean average solar wind speed approximately.

Keywords: Sun; Solar flare; Preflare; Post-flare; Coronal mass ejection; CME; Space weather

1. Introduction

Coronal mass ejections (CMEs) are considered as magnetized plasma ejected from the Sun that is regarded as the main source of geomagnetic disturbances (Youssef et. al., 2013). CMEs are proved to play a role in the inflow and outflow of the Earth's mass, also they are considered as a source of some atmospheric phenomena (Mawad, 2017). CMEs involved large-scale eruptions of plasma and magnetic field are often accompanied by a more localized energy release in the form of flares, because of dissipative magnetic-field reconfiguration. Morphology and evolution of such flares reported also as dynamical flares which the eruptive magnetic flux rope and are often explained because of the reconnection of the arcade magnetic field, taking place below the erupting magnetic flux rope (Vršnak, 2016). Scientists are interested in studying CMEs to predict their arrival time and influence on the Earth (Rollett et al., 2016; Mawad et al., 2016; Korsós and Ruderman, 2016; Xie et al., 2009; Gopalswamy and Xie, 2008). Many researchers have studied the source of CMEs to understand the relationship between CMEs and solar flare (Mahrous et al., 2009; Fomin et al., 2005; Aarnio et al., 2011), filament and prominence (Mawad et al., 2015; Alissandrakis et al., 2013; Jing et al., 2003), Sunspots (Korsós and Ruderman, 2016) and coronal holes (Wood et al., 2012; Gopalswamy et al., 2009).

A solar flare is clearly an explosive energy release in the low corona observed as a sudden intensity enhancement in any part of the electromagnetic spectrum (X-rays, optical, micro, and radio waves). CME and flare relationship are the most important topic in order to improve the Space weather flares and CMEs forecasting as pointed out by Mahrous et al. (2009), Youssef et al. (2013), Harrison

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https://doi.org/10.1016/j.asr.2018.04.040
0273-1177/

(1995, 2006), Aurass, (1997), Hundhausen (1999) and Gopalswamy (2000). Lately, a high degree of synchronization between the acceleration of a CME and the impulsive phase of a flare (Zhang et al., 2001; Zhang and Dere, 2006) has been reported.

In order to investigate the CME-flare relationship, it is important to set spatial and temporal criteria (Vršnak et al., 2005; Mahrous et al., 2009; Youssef et al., 2013). These studies revealed a close temporal relationship between the physical processes of eruptive flares and CMEs.

Hundhausen (1999) examined the correlation between the flare strength and kinetic energy of CMEs.

Compagnino et al. (2017) found 19,811 CMEs associated with flares, among them, there are many CMEs associated with flares that occur before the flares peak and end time of the flares.

Kharayat et al. (2017) investigated the association of solar energetic particle (SEP) events, halo coronal mass ejections, and their associated solar flares during the solar cycle 23 and 24 (1997–2014). They found that halo CMEs are more influential in producing SEP events.

Zhang et al. (2016) studied the pre-flare coronal dimming relationship; they explained it by the density depletion as a result of the gradual expansion of the coronal loop system surrounding the magnetic flux rope (MFR) during its slow rise.

Mahrous et al. (2009) studied the simultaneous associations of solar flares and CMEs during solar cycle 23rd they show that the time interval between the triggering time of the X-ray flare and the lifting-off time of CME associated events occur within a range of $0.4\text{ h} \leq \Delta t \leq 1\text{ h}$. They listed 41 CME–flare associated events which show a good correlation between the CME energy and the X-ray flare flux with a correlation coefficient of 0.76.

Youssef et al. (2013) listed 291 post-flare–CME associated events (PFA-CMEs). Linking the flare flux with CME speed of these paired events they found that there is a reasonable positive linear relationship between the CME linear speed and associated flare flux. The results also showed that the CME width increased as the flux of its associated solar flare increased, this was also noted by Compagnino et al. (2017). Matching the flare fluxes with CME masses of these paired events, we found that the CME mass increased as the flux of its associated solar flare increased. The PFA-CME events are in general more decelerated than the other CMEs.

In the current study, we have investigated and examined the relationship of the CME-preflare association events during the solar cycle 23 (from 1996 to 2010).

2. Data sources

The dataset used in this analysis was acquired from the observations of X-ray flares and CMEs recorded by Geostationary Operational Environmental Satellite (GOES), Large Angle and Spectrometric Coronagraph on board the Solar and Heliospheric Observatory SOHO/LASCO catalog obtained from CDA respectively.

From the selected dataset in the period January 1996 to 2010, we have 15,875 CME events and 25,112 solar X-ray flare events.

3. Selecting the CME-Preflare associated events

For selecting the CME-Preflare associated events, we applied both a spatial and temporal criteria, by requiring that both flare and CME occur within a specific time window and angular separation.

3.1. Temporal condition

We initially set the time window to select CMEs which occur within 1–2 h before flare's start time as shown in Fig. 1.

A clear peak is seen within 0–1 h, so we adopt this time window as the temporal condition. Also, we notice that most of CME events happened in half an hour before X-ray flare start time.

3.2. Spatial condition

In order to apply the spatial condition, we need to convert the spherical coordinate (heliographic coordinate) in longitude and latitude, of the flare positions on the solar disk, to 2-dimensional plane coordinate (projective-circular coordinates) in position angle. We convert the flare's longitude and latitude to position angle, by the following equation:

$$\Psi_{\mathbf{Flare}} = \arctan[\mathbf{Sin}\,\lambda/\mathbf{Tan}\,\beta] \quad (1)$$

where β is the solar flare latitude, λ is the flare longitude.

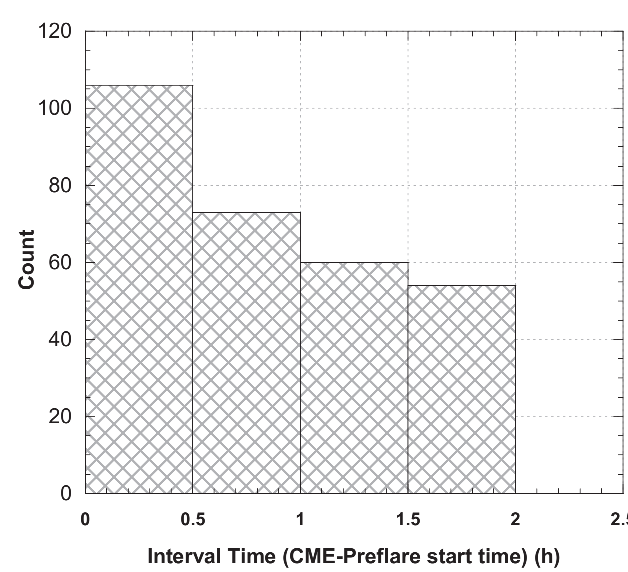

Fig. 1. Time interval between a solar preflare and its associated CME.