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on

MULTIDISCIPLINARY RESEARCH ETHICS

Certificate

This is to certify that ~~Prof./~~Dr/~~Mr/Mrs/Ms~~ R.P.TEBIN has ~~participated~~ / presented a research paper entitled A Statistical Distribution of SEP with the parameters of CME and Solar flares during the minimum period of Solar cycle 25, in the National Conference on "Multidisciplinary Research Ethics" organised by MAC Research Forum, Muslim Arts College, Thiruvithancode, held on September 4 & 5, 2025.

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A STATISTICAL DISTRIBUTION OF SEP WITH THE PARAMETERS OF CME AND SOLAR FLARES DURING THE MINIMUM PERIOD OF SOLAR CYCLE 25

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Abstract

In this paper we analysed the statistical distribution of solar energetic particles with the parameters of Coronal Mass Ejections (CMEs) and Solar Flares during the minimum period of solar cycle 25. During solar minimum, solar flare activity diminishes, and often does not occur for days at a time. For this statistical study, we considered all 3150 CMEs and 1709 flares that occurred between 2020 January and 2022 December. The CMEs and flare properties shows that there is significant features in all physical properties such as kinetic energy, speed and acceleration. The flare consist of four classes: C,B,M,X.

Keywords: Coronal Mass Ejections, Solar Flares

1.Introduction

Coronal mass ejections (CMEs) and Solar flares are the two important phenomena of solar activity. A coronal mass ejection is a significant ejection of magnetic field and the accompanying plasma from the sun's corona into the heliosphere. CMEs are often associated with solar flares and other forms of solar activity. A solar flare is an intense localized eruption of electromagnetic radiation in the sun's atmosphere. Flares occur in active regions and are often, but not always, accompanied by coronal mass ejections, solar particle events and other solar phenomena. Solar flares are rarely seen in the white light at photospheric region but easily visible in the chromospheric region at different wavelength bands. The phenomena of flare-associated CMEs have been observed during a solar prominence eruption (Munro et al. 1979).

Compagnino et al. (2017) have studied the correlations between flares and CME properties based on a statistical analysis in the interval from 1997 to March 2014 over the solar cycles 23 and 24. Bidhu et al. (2017) examined the relation between the CMEs and flare properties in the maximum phases of 23 and 24 solar cycles. They detected larger number of CMEs in cycle 24 than the solar cycle 23, although the solar cycle 24 was very weak, focusing on study of their speeds in the two cycles. Recently, Ibrahim et al. (2018) studied the CMEs and flare properties, considering the CME data from the Coordinated Data Analysis Workshops catalog and X-ray flares data from the Hinode /XRT satellite.

2.Data Analysis

In the following procedure, the CME and flare data are analysed. CME data for the period of 2020 to 2022 over the cycle 25 was observed with the Large Angle Spectrometric Coronograph and Heliospheric Observatory (SOHO/LASCO). Based in the CME data set, there are 3150 CMEs recorded in the period time 2020 to 2022. While the solar flare data sets are taken from the Hinode/XRT Satellite in the same period. There are 1709 flare events recorded during this period. LASCO gives information about acceleration, CPA and the linear speed of CME from which only the linear speed is considered for this study.

Year	0-500	500-1000	1000-2000	2000-3000	>3000
2020	595	49	2	1	-
2021	840	114	10	-	-
2022	1091	385	62	1	-

Table 1. The linear speed of CME of solar cycle 25 (2020-2022).

Table 1 indicates the linear speed of CME which is categorized in the range of 0-500 in which 2,526 CMEs are observed, 500-1000 in which 548 CMEs are observed, 1000-2000 in which 74 CMEs are observed, 2000-3000 in which 2 CMEs are observed for the time period of 2020-2022 of solar cycle 24.

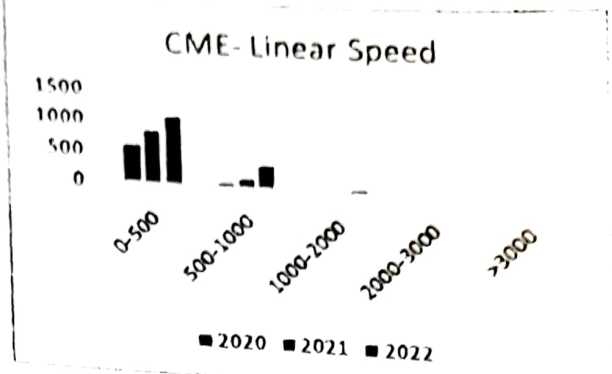
Year	C	B	M	X
2020	32	161	1	-
2021	155	499	13	1
2022	620	142	76	2

Table 2. The classification of flare of solar cycle 25 (2020-2022)

Table 2 shows the classification of flare events. Solar flare is classified into four classes C,B,M,X. The number of C class flares are 807, B class flares are 802, M class flares are 90 and X class flares are 3 of solar cycle 25 (2020-2022).

3.Result and Discussion

A statistical analysis of the CME linear speed is carried out. In this paper, the statistical trends found in a large number of events observed at SOHO/LASCO is presented. Moreover we analysed solar cycle 24 events, whereas similar statistical studies dealt with solar cycle 23 events (e.g.,.Kahler 2005, 2013; Pan et al. 2011).



CME – Speed [km s^{-1}]

Fig 1. Distribution of CME speed (in km s^{-1}) for all 3150 CMEs in our sample from 2020-2022. The colour Blue represents year 2020, orange 2021 and grey for year 2022.

The CME speed is taken in the range of 0-500km s^{-1}, 500-1000 km s^{-1}, 1000-2000 km s^{-1} and 2000-3000 km s^{-1}. The CME speed is higher in 2022 for 0-500 km s^{-1}, 2022 for 500-1000 km s^{-1} and so on. There were no CMEs greater than 3000 km s^{-1}. The average speed of CME is ~430 km s^{-1}. Extremely fast CMEs of >1500 km s^{-1} are rare, occupying ~0.5% of all CMEs (Wang and Zhang, 2007). The fastest CME was 2776 km s^{-1} on September 5,2022.

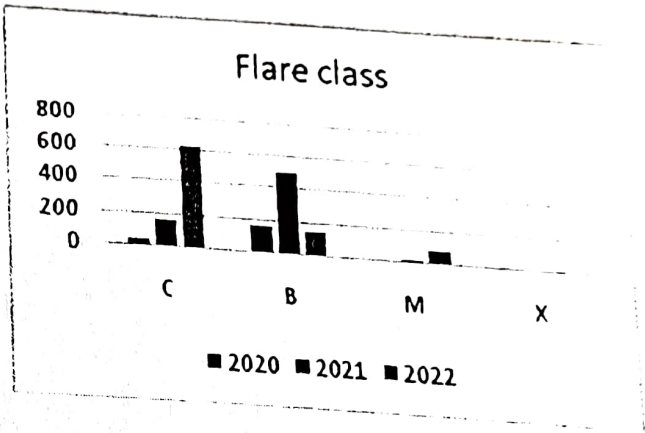
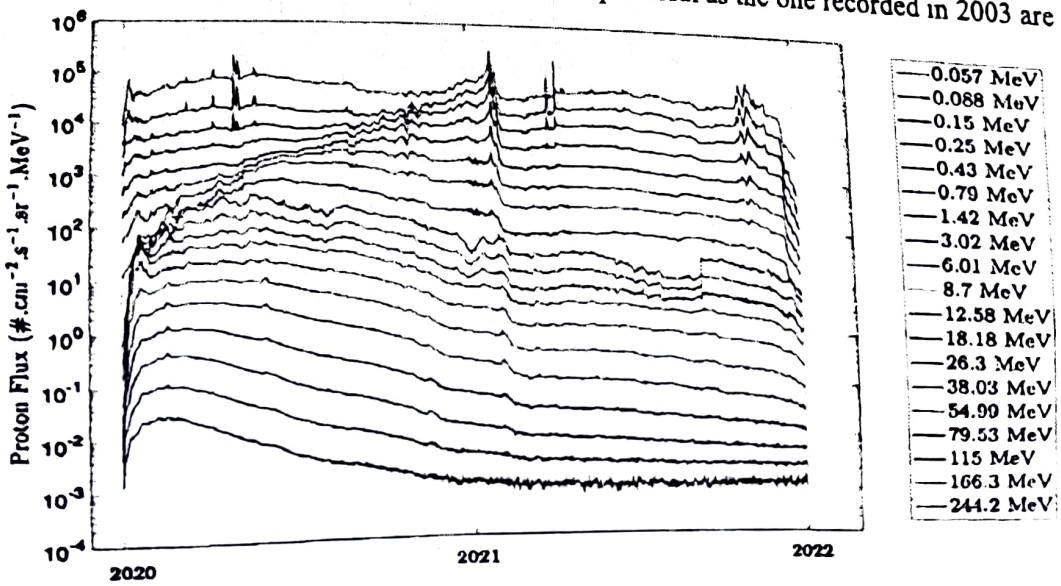


Fig 2. Distibution of flare classes C,B,M,X of all 1709 flares in our sample from 2020-2022.

The flare classes in our sample (1709) events are B,C,M,X. The number of each flare class is given in Table 2 and shown in Fig 2. The majority of the sample is in B- class (161) for the year 2020, in B- class (499)for the year 2021 and in C- class (620) for the year 2022. C- class has the least number of flares. X-class flares occur on average about 10 times per year, and flares as powerful as the one recorded in 2003 are even less likely.

Lower energy ion data are available from the Electron, Proton and Alpha Monitor (EPAM) instrument on board NASA's



Advanced Composition Explorer (ACE). This figure shows that while the powerful shock of the CME launched from the Sun's western limb generates peaking values of high-energy particles after ~6hr, the lower energy particles peak 2 days later when the limb of the expanded CME and shock pass the Earth. Data from the figure were used to derive integral fluxes for energies from >1 to >260 MeV. By adding the integral particle fluxes from GOES for energies above the higher-energy bin limits of these channels the fluxes can be compared to integral fluxes derived from ACE/EPAM and GOES/Energetic Particle Sensor Measurements shown in the figure.

4.Conclusion

We have analysedthe coronal mass ejection (CME) and the solar flare during solar cycle 24 from January 2020 to December 2022. It is shown that the CME for our sample is 3150 events and the flare for our sample is 1709 events. The fastest CME was 2776 km s^{-1} on September 5,2022. We have analysed the four classes of flare: C,B,M,X in which the majority of the sample is in B-class for 2020, B-class for 2021, and C-class for 2022. Integral fluxes of energies from >1 to >260 MeV is derived.

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