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Coronal mass ejections in relation with radio burst related geomagnetic storms and sun spot

Preetam Singh Gour[1*], Nitin P Singh[2], Shiva Soni[3]
[1,2,3]Jaipur National University, Jaipur, Rajasthan, India
E-mail: singhpreetamsingh@gmail.com
* Corresponding Author

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Abstract
In this paper we have selected radio burst related geomagnetic storms of magnitude ≤-90nT from 1997-2012 (i.e. solar cycle 23&24). For this period we have found 42 geomagnetic storms and most of the geomagnetic storms are associated with halo and partial halo coronal mass ejections (CMEs) with association rate 67.57% and 32.43% respectively. Statistical analyses are performed to examine the relationship of magnitude of geomagnetic storms and speed of CME we observed weak correlation (0.28) between these two events. Further we have selected the average number of sunspot and find the statistical relation with average speed of radio burst related geomagnetic storms CMEs. We observed with statistical results of annual correlation between sun spot number (SSN) and halo and partial halo CMEs is 0.16 and 0.49 respectively and can be represented by a linear regression equation.

Keyword: - Coronal mass ejections, SSN, Geomagnetic storms.

1. Introduction

All solar radio bursts are set off by the interaction of nonthermal electrons with the plasma and magnetic field in the medium. Radio bursts not only provide the information on the disturbances that cause them, but also on the properties of the medium because the radio emission depends on the ambient density, magnetic field, and the level of turbulence. The mechanisms that accelerate electrons are also able to accelerate ions. Thus, radio bursts of various kinds are also useful indicators of solar energetic particle (SEP) events in the heliosphere that are important for space weather. Nonthermal electrons drive away from the Sun along open field lines produce type III radio bursts and storms over a wide range of wavelengths [1]. These electrons are generally lower energy (≤ 10 keV) electrons. Type IV radio bursts are produced by accelerated electrons at the flare site and trapped in moving and stationary magnetic structures. Type II radio bursts produce in shocks driven by coronal mass ejections (CMEs), and hence useful in obtaining information on shocks near the Sun and in the IP medium.

The plasma structured solar corona by magnetic fields. They emerge from the convective zone below the visible photosphere. Because of the motion of the ubiquitous plasma in this zone, magnetic fields continually emanate into the solar atmosphere and interact with already existing structures. The eruption of coronal magnetic structures into the interplanetary space – coronal mass ejections (CMEs) – and the release of charged particles with high relativistic energies are typical signatures. The solar energetic particles (SEPs) are accelerated from about 100 eV in the thermal corona to energies which may exceed 1GeV for protons. This may happen in electric fields induced during the explosive variation of the coronal magnetic field or at the shock wave driven by a fast CME [2].

Our interest to space weather is how the plasma and magnetic field characteristics of coronal mass ejections (CMEs) result in geomagnetic storm activity. We have consciousness to southward magnetic field and speed of CMEs at the Earth, because their cross product, the dawn-dusk electric field, controls the rate of the solar wind energy coupling to the terrestrial magnetosphere [3]. Still not clear how the ejecta speed and southward magnetic field work together to attain a sustained, enhanced dawn-dusk electric field and how they lead to the variability of geomagnetic storms.

The southward magnetic field is often found in interplanetary CMEs with a preceding shock when ejecta reaching to the earth. This leads to a classic geomagnetic storm sequence: a sudden commencement generated by the shock, a main decrease phase caused by southward magnetic field, and then a recovery phase [4]. In addition driver gas, the sheath region between the shock and ICME can also be geo-effective [5, 6] as both the sheath speed and southward magnetic field are amplified by shock compression. A recent study combining remote-sensing and in situ observations suggests a "perfect storm" scenario for the generation of an extreme space weather event [7].

Solar cycle is a key parameter in the helioshperic phenomena which takes approximately 11 years on average. With this time, the sunspot number (SSN) starts from a minimum value and increases which marks the start of the solar cycle. Then, the SSN tends to reach a maximum value, then decreases to a minimum value again which marks the end of a solar cycle. The reason for this phenomenon is due to the continuous fluctuation of the solar magnetic field, and this belief is strongly supported by the observed fact that a sunspot maintains a strong magnetic field compared to that of the sun's surface [8]. Sunspots are the most perceptible feature on the disturbed surface of the photosphere above the solar atmosphere and appear to play a key role in major solar and terrestrial disturbances [9]. Some of the researchers study the occurrence of CMEs in relation to sunspot number and found that sometimes the correlation is quite weak during the solar cycle maxima [10-11].

2. Data Sources and Method

In this manuscript we have selected those CMEs which are associated with radio Burts related GMS and extract the CMEs data form SOHO LASCO CME catalog during 1997 to 2012. The CME catalog is generated and maintained at CDAW data centre by NASA [12]. The SSN (American) data was extracted from NOAA National Geophysical Data Center [13]. The data of geomagnetic storms has been taken from the NSSDC Omni web data system [14] which been created in late 1994 for enhanced access to the near earth solar wind, magnetic field and plasma data of Omni data set , which consists of one hour resolution for different parameters and solar activity indices.

3. Data Analysis and Discussion

In this paper we have find out the relationship of geomagnetic storms with coronal mass ejections and radio bursts related coronal mass ejections to the sun spot number. We extracted geomagnetic storms data from NSSDC Omni web data system [14] associated with halo and partial halo CMEs in the period 1997 to 2012. Further we have find out the relationship of average value of SSN with storms related average speed of CMEs.

The correlation coefficient is a degree of association, denoted by r. It is sometimes called Pearson's correlation coefficient after its originator and is a measure of linear association between two parameters. The correlation coefficient is measured on a scale that varies from + 1 to – 1. Complete correlation between two parameters is expressed by either + 1 or -1. Complete absence of correlation is represented by 0.

The calculation of the correlation coefficient with x representing the values of the independent variable and y representing the values of the dependent variable. The formula to be used is:

$$r = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{\sqrt{[\Sigma(x-\bar{x})^2(y-\bar{y})^2]}}$$

3.1 Geomagnetic storms and coronal mass ejections

We have selected radio burst related geomagnetic storms of magnitude ≤-90nT from 1997-2012. In this duration 42 geomagnetic storms are extracted out of 42 geomagnetic storms 37(88.09%) are found to be associated with CMEs. Further we obtain that majority of the storms associated with halo coronal mass ejections (CMEs) with association rate 67.57% (25) and rest are associated with partial halo CMEs 32.43% (12), see in figure-1. No CME events observed for radio bursts related geomagnetic storms in the year 2001 and 2007-2011.

To show the possible statistical behavior between radio bursts related geomagnetic storms and speed of associated CMEs, a scatter plot has been plotted between magnitude of radio bursts related geomagnetic storms and speed of associated CMEs and resulting plot is shown in figure-2.

By the statistical analysis correlation between magnitude of radio bursts related geomagnetic storms and speed of associated CMEs, weak positive correlation with correlation coefficient 0.28 have been found.

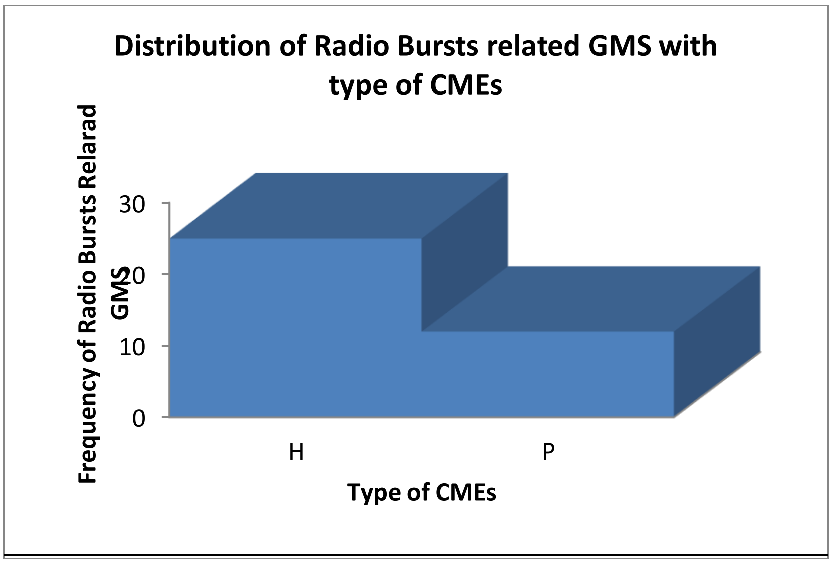

Figure-1 Distribution of radio bursts related geomagnetic storms with coronal mass ejections.

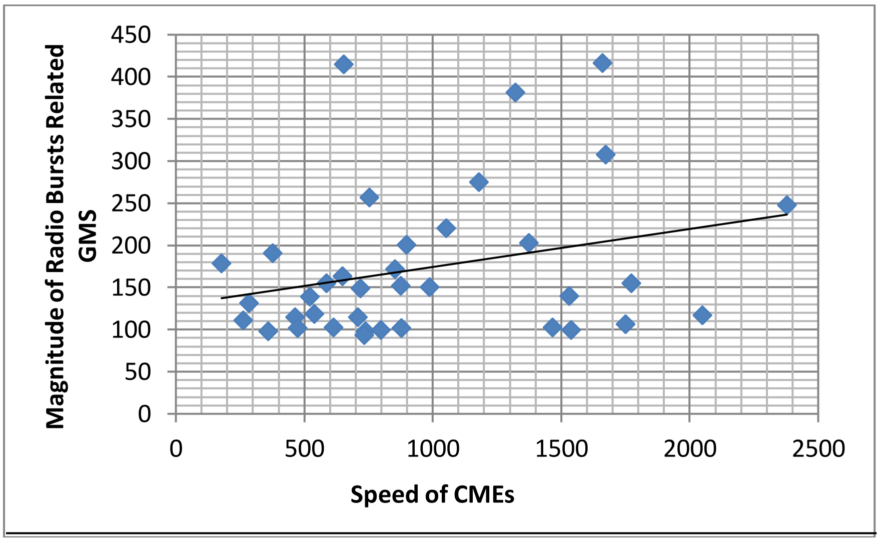

Figure-2 Scatter plot between speed of CMEs and magnitude of radio bursts related geomagnetic storms.

3.2. Sunspot number (SSN) and CMEs with radio bursts related geomagnetic storms

For this analysis we have selected the average number of american sunspot [13] and the average sunspot numbers are shown in table-1 below. The statistical analysis was conducted to derive the correlation between SSN and CMEs for the annual time during the period from 1997-2012 to investigate the behaviors of these parameters.

Table-1: Yearly average of American SSN.

S. No.	Year	Yearly mean SSN
1	1997	20.3
2	1998	62.38
3	1999	96.1
4	2000	123.3
5	2001	123.3
6	2002	109.4
7	2003	65.7
8	2004	43.3
9	2005	30.2
10	2006	15.4
11	2007	7.9

12	2008	2.4
13	2009	2.8
14	2010	15.6
15	2011	50.1
16	2012	52.8

In this paper, we find the linear regression equation for halo and partial halo CMEs with SSN by using least square method. The regression equation for halo and partial halo CMEs are y = 0.011x + 44.52 and y = 0.050x + 35.71. We also determine the correlation between halo and partial halo CMEs with SSN with the correlation coefficient 0.16 and 0.49 respectively. There is no correlation is observed between the occurrence rate of halo coronal mass ejections and sunspot number, as shown in the correlation chart of figure-3. A very good relationship rate is observed between the occurrence rate of partial halo CMEs and SSN, as shown in the correlation chart of figure-4.

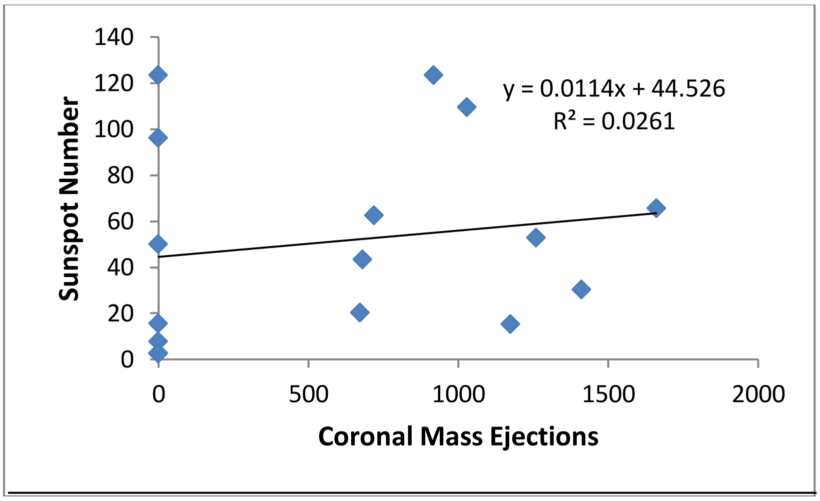

Figure-3 Correlation between Halo CMEs and SSN with correlation coefficient 0.16.

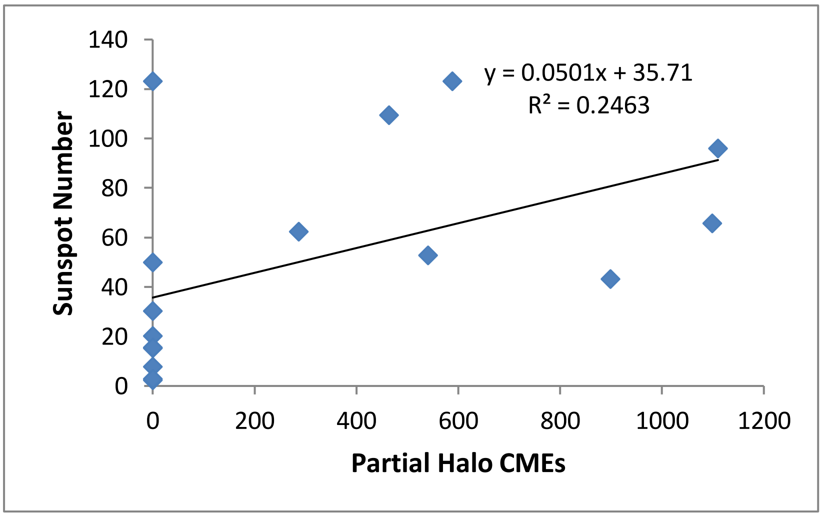

Figure-4 Correlation between Partial Halo CMEs and SSN with correlation coefficient 0.49.

4. Conclusion

In this investigation, the statistical analysis was conducted to investigate the behaviors of CMEs with radio bursts related geomagnetic storms and SSN and derive the mutual correlation between these parameters for the annual time during the period from 1997 to 2012. The solar cycle 24 initially have activity less than cycle 23. Emissions of CMEs can occur at any time during a solar activity but increase with solar activity and solar energy [15]. Statistical analyses are performed to examine the relationship of magnitude of geomagnetic storms and speed of CME and we observed weak positive correlation with correlation coefficient 0.28 between these two events i.e. these two parameters are not related to each other strongly that is they are may be independent. Again we perform statistical analysis for SSN and storms related CMEs to examine the relationship between these parameters and as a result we have to conclude that SSN has moderate relationship with storms related partial halo CMEs with correlation coefficient 0.49 but don’t have any relation with storms related halo CMEs. The present results for CMEs and radio bursts related geomagnetic storms is not as per expectation, only partial halo CMEs is weakly related to SSN.

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