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HALO CMES RELATED GEOMAGNETIC STORMS AND THEIR RELATION WITH X-RAY SOLAR FLARES, RADIO BURSTS AND INTERPLANETARY MAGNETIC FIELD

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ABSTRACT

Geomagnetic Storms (Dst ≤-75nT) associated with halo coronal mass ejections, observed during the period of 23rd solar cycle (1997-2007) have been studied with X-ray solar flares, radio bursts and interplanetary magnetic field. The observed halo coronal mass ejection associated geomagnetic storms have been divided in three categories , moderate geomagnetic storms, magnitude Dst ≤-75nT to ≥ -100nT, intense geomagnetic storms, magnitude Dst ≤-100nT to ≥-200nT and severe geomagnetic storms, Dst ≤-200nT .It is observed that most of the halo CME related geomagnetic storms are intense or severe geomagnetic storms .The association rates of moderate, intense and severe geomagnetic storms have been found, moderate 18.52%, intense 48.15% and severe 33.33% respectively. Further it is inferred that all the halo CME related geomagnetic storms are associated with X- ray solar flares of different categories. The association rates of geomagnetic storms with different types of flare are found 09(33.33%) X class flare, ,13(48.15%)M class flare, ,03(11.11)% C class flare and 02(7.41%) B class flare .Most of halo CME related geomagnetic storms are found to be related with type IV and type II radio burst 25(92.59. %) .The association rate of type IV and type II radio burst have been found 15(60) % and 10(40) % respectively. Majority of the halo CME related geomagnetic storms are found to be related with interplanetary shocks 26(96.30%) also .It is also determined that geomagnetic storms are closely related to interplanetary magnetic fields. Positive co-relation have been found between magnitude of geomagnetic storms and magnitude of jump in interplanetary magnetic field with correlation coefficient 0.72 between magnitude of geomagnetic storms and magnitude of interplanetary magnetic field, 0.85 between magnitude of geomagnetic storms and maximum value of southward component of interplanetary magnetic field.

Keywords –Coronal mass ejections, X-ray solar flares, radio bursts, solar wind plasma parameters and geomagnetic storms

INTRODUCTION

The geomagnetic field is influenced by several solar activity and interplanetary phenomena like sunspots, solar flares, coronal mass ejections (CMEs), magnetic clouds interplanetary shocks, disturbances in solar wind plasma. The major classes of solar activity tend to track the sunspot number during the cycle, including, radio burst, solar flares, filaments, and coronal mass ejections (CMEs) .This activity is transmitted to earth through the solar corona and its expansion into the heliosphere as the solar wind. The solar activity, solar flares and coronal mass ejections are most energetic solar events in the heliosphere and are widely recognized as being responsible for production of geomagnetic disturbances in geomagnetic field. It is generally believed that long intervals of enhanced southward interplanetary magnetic field (IMF) and the high solar wind speed are the primary causes of intense geomagnetic disturbances and that the solar sources of such geoeffective solar wind structures are usually CMEs [2,6,13,14]. Evidence has been presented that the properties of the earth-directed CMEs, such as the internal structure of the magnetic field may determine whether or not a geomagnetic storm subsequently occurs [1].This suggests that the magnetic field serves as a link between flares, CMEs and geomagnetic storms. Several scientists have studied interrelationship between solar flares coronal mass ejections and geomagnetic storms, [10, 12] and have concluded that flares, CMEs and geomagnetic storms are closely related magnetically. Gopalswamy et al. [3] have studied magnetic clouds ,coronal mass ejections and geomagnetic storms and they have found that 86% magnetic clouds are associated with full and partial halos coronal mass ejections .The remaining 14% of magnetic clouds are associated with non-halo CMEs originating from close to the disk center. They have concluded that magnetic clouds associated with partial halo and halo coronal mass ejections are most potential candidates for production of geomagnetic storms .They have further concluded that magnetic clouds associated with non halo CMEs may also cause geomagnetic storms. Gopalswamy et al. [4] analyzed 378 halo CMEs covering almost whole of solar cycle 23 and found that 71% of frontside halos are geoeffective. Michalek, G.et al [5] have concluded that halo coronal mass ejections (HCMEs) originating from regions close to the center of the sun are likely to be geoeffective. They have showed that only fast halo CMEs (with space velocities higher than ~1000 km/s) and originating from the western hemisphere close to the solar center could cause intense geomagnetic storms. The main cause of geomagnetic storms is believed to be the large IMF structure which has an intense and long duration southward magnetic field component, B_z [7,8].Verma P.L. et al [9] have studied geomagnetic storms Dst < - 50nT observed during the period of 1997-2006, with halo and partial halo coronal mass ejections associated with X-ray solar flares of different categories and concluded that halo and partial halo CMEs associated with X ray solar flares are most potential candidates for production of geomagnetic storms.Yurchyshyn [11] have analyzed data for major geomagnetic storms and found a relationship between hourly averaged magnitude of the Bz component of IMF and projected speed of CMEs launched from the central part of the solar disk. They have concluded that CMEs with V> 1000 Km/s are capable to generate geomagnetic storms. In this investigation, Halo CMEs related geomagnetic storms observed during the period of 1997to 2007 have been studied with with X-ray solar flares, radio bursts and interplanetary magnetic field to know the physical process responsible for geomagnetic storms.

Experimental Data

In this investigation hourly Dst indices of geomagnetic field have been used over the period 1997 through 2007 to determine onset time, maximum depression time, magnitude of geomagnetic storms. This data has been taken from the NSSDC omni web data system 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 near earth, solar wind magnetic field and plasma data, energetic proton fluxes and geomagnetic and solar activity indices. The data of coronal mass ejections (CMEs) have been taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. To determine disturbances in interplanetary magnetic, hourly data of average interplanetary magnetic field has been used, these data has also been taken from omni web data(http;//omniweb.gsfc.nasa.gov/form/dxi.html)). The data of X ray solar flares radio bursts, and other solar data, solar geophysical data report U.S. Department of commerce, NOAA monthly issue and solar STP data (http://www.ngdc.noaa.gov/stp/solar/solardataservices.html.) have been used. . Interplanetary shocks data are taken from the list of the shocks derived by PM group.

Table-1-Association of Halo Coronal Mass Ejection Associated Geomagnetic Storms with X -Ray Solar Flares, Radio Bursts for the period of 1997-2007

Geomagnetic storms				CMES		Solar Flares		Radio bursts	
S. NO.	Date	Onset time in dd(hh)	Magnitude in nT	Start time in dd(hh)	types H/P	Start time in dd(hh)	Class	Start time in dd(hh)	Type
1	02.05.98	02(09)	-203	29(16.58)	H	29(17)	M-68	29(16.30)	II
2	08.11.98	08(20)	-126	05(20.24)	H	05(19)	M-84	05(20.15)	IV
3	11.02.00	11(07)	-132	08(09.30)	H	08(09)	M-13	08(08.58)	II
4	06.04.00	06(16)	-282	04(16.32)	H	04(15)	C-97	04(15.30)	II
5	08.06.00	08(15)	-89	06(15.54)	H	06(15)	X-23	06(14.49)	IV
6	15.07.00	15(15)	-308	14(10.54)	H	14(10)	X-57	14(12.57)	II
7	17.09.00	17(20)	-197	16(05.18)	H	16(04)	M-59	16(04.33)	IV
8	26.11.00	26(22)	-127	24(15.30)	H	24(15)	X-23	24(15.12)	II
9	11.04.01	11(15)	-269	09(15.54)	H	09(15)	M-79	09(15.58)	IV
10	17.08.01	17(17)	-102	15(23.54)	H	16(03)	B-76	15(23.31)	II
11	28.10.01	28(01)	-142	25(15.26)	H	25(15)	X-13	25(15.05)	IV
12	05.11.01	05(19)	-297	04(16.35)	H	04(16)	X-10	04(16.12)	IV
13	24.11.01	24(06)	-223	22(20.30)	H	22(20)	M-38	22(20.25)	II
14	23.05.02	23(12)	-89	22(03.50)	H	22(03)	C-50	na	na
15	18.08.02	18(22)	-110	16(12.30)	H	16(12)	M-52	16(12.44)	II
16	02.06.03	02(02)	-85	31(02.30)	H	31(02)	M-93	31(02.18)	IV
17	04.11.03	04(08)	-90	02(09.30)	H	02(12)	M-18	02(17.15)	II
18	20.11.03	20(02)	-461	18(08.05)	H	18(09)	M-45	18(08.11)	IV
19	16.01.05	16(20)	-117	15(06.30)	H	15(06)	M-86	15(22.33)	IV
20	21.01.05	21(19)	-103	19(08.29)	H	19(08)	X-13	19(08.12)	IV
21	07.05.05	07(20)	-126	05(20.30)	H	05(20)	C-78	05(20.18)	II
22	15.05.05	15(05)	-293	13(17.12)	H	13(16)	M-80	13(17.03)	IV
23	17.07.05	17(06)	-77	14(10.54)	H	14(10)	X-12	14(10.23)	IV

24	24.08.05	24(08)	-219	22(01.31)	H	22(01)	M-26	22(01.00)	IV
25	31.08.05	31(12)	-138	29(10.54)	H	29(18)	B-56	na	na
26	11.09.05	11(02)	-127	09(19.48)	H	09(19)	X-62	09(19.48)	IV
27	14.12.06	14(21)	-143	13(02.54)	H	13(02)	X-34	13(02.47)	IV

Data Sources, 1-Geomagnetic storms Data Source, http://omniweb.gsfc.nasa.gov. 2- Solar Data Source http://www.ngdc.noaa.gov/stp/solar/solardataservices.html.

Table-2-Association of Halo Geomagnetic Storms with Interplanetary Shocks and Magnetic Field for the period of 1997-2007

Geomagnetic storms				**Shocks**	**IMF**		**IMFBz**	
S. NO.	Date	Onset time in dd(hh)	Magnitude in nT	Start time in dd(hh)	Start time in dd(hh)	Magnitude of IMF in nT	Start time in dd(hh)	Magnitude of maximum IMFBz in nT
1	02.05.98	02(09)	-203	01(21)	01(21)	14.2	02(03)	-11.6
2	08.11.98	08(20)	-126	08(05)	07(20)	26.9	07(20)	-11.6
3	11.02.00	11(07)	-132	11(02)	11(23)	14.3	12(07)	-16.4
4	06.04.00	06(16)	-282	06(16)	06(10)	26.5	06(16)	-27.3
5	08.06.00	08(15)	-89	08(09)	08(05)	19.1	08(13)	-6.9
6	15.07.00	15(15)	-308	15(14)	15(08)	45.2	15(17)	-49.4
7	17.09.00	17(20)	-197	17(17)	17(14)	34.1	17(15)	-23
8	26.11.00	26(22)	-127	26(11)	26(08)	24.2	26(21)	-10.8
9	11.04.01	11(15)	-269	11(14)	11(09)	30.1	11(18)	-20.5
10	17.08.01	17(17)	-102	17(12)	17(07)	28	17(14)	-18.1
11	28.10.01	28(01)	-142	28(03)	27(22)	12.8	27(22)	-14.5
12	05.11.01	05(19)	-297	06(02)	05(12)	51.2	06(18)	-64
13	24.11.01	24(06)	-223	24(05)	24(04)	51.2	24(10)	-27.8
14	23.05.02	23(12)	-89	23(10)	22(23)	33.4	23(11)	-14.1
15	18.08.02	18(22)	-110	18(19)	18(18)	9.1	18(21)	-3.7
16	02.06.03	02(02)	-85	na	01(22)	3.7	02(04)	-8.9
17	04.11.03	04(08)	-90	04(06)	04(01)	13.4	04(08)	-11.9
18	20.11.03	20(02)	-461	20(07)	20(05)	48.1	20(11)	-50.9
19	16.01.05	16(20)	-117	17(07)	17(07)	31.1	16(08)	-5.1
20	21.01.05	21(19)	-103	21(17)	21(15)	24.8	22(18)	-2.6
21	07.05.05	07(20)	-126	07(19)	07(12)	10.7	07(18)	-12.5
22	15.05.05	15(05)	-293	15(02)	15(01)	48.4	15(05)	-38
23	17.07.05	17(06)	-77	17(01)	17(12)	6.8	17(21)	-8.7

24	24.08.05	24(08)	-219	24(06)	24(04)	43.1	24(05)	-38.3
25	31.08.05	31(12)	-138	30(19)	31(03)	10.8	31(04)	-16.9
26	11.09.05	11(02)	-127	11(01)	10(21)	13	11(00)	-6.4
27	14.12.06	14(21)	-143	14(14)	14(11)	13.9	14(22)	-14.7

Data Sources, 1-Geomagnetic storms and IMF, http://omniweb.gsfc.nasa.gov. 2-Shocks- list of the shocks derived by PM group, http://umtof.umd.edu/pm/FIGS.HTML

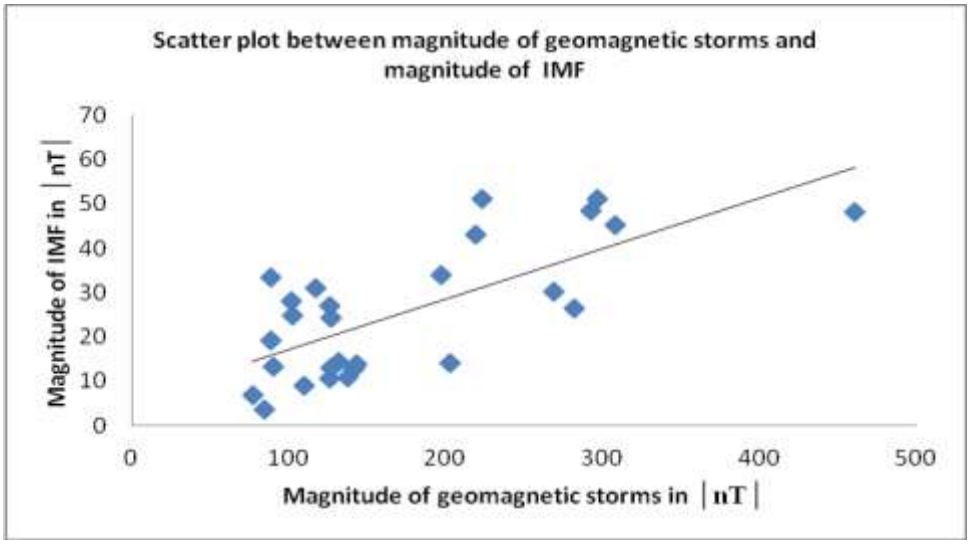

Figure-1 Shows scatter plot between magnitude of geomagnetic storms and magnitude of IMF showing positive correlation with correlation coefficient 0.72

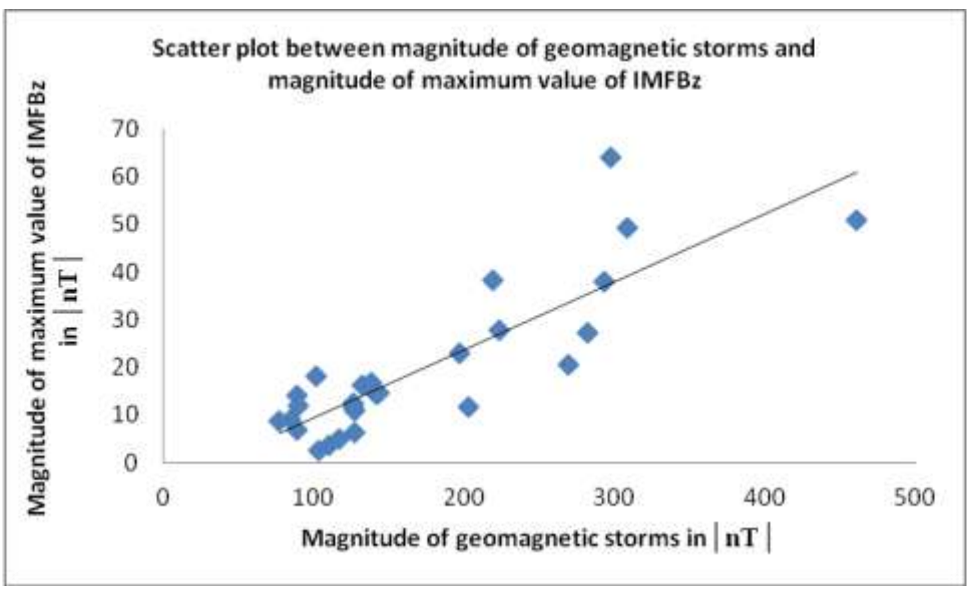

Figure-2 Shows scatter plot between magnitude of geomagnetic storms and magnitude of maximum value of IMFBz showing positive correlation with correlation coefficient 0.85

DATA ANALYSIS AND RESULTS

In this study I have observed 27 geomagnetic storms associated with halo coronal mass ejections (CMEs), occurred during the period 1997 to 2007.I have divided observed geomagnetic storms in three categories, geomagnetic storms Dst ≤-75nT >100 nT as moderate, Dst≤-100 nT >200nT as intense and Dst≤-200 nT as severe .It is found that most of halo CMEs related geomagnetic storms (81.48 %) are intense or severe geomagnetic storms .I have 27 halo CMEs related geomagnetic storms in list out of which 22 halo CMEs related geomagnetic storms have been found intense or severe geomagnetic storms .The association rates of moderate, intense and severe geomagnetic storms have been found 18.51%,48.15% and 33.33% respectively. From the data analysis of observed halo CMEs related geomagnetic storms and radio bursts, most of the halo CMEs related geomagnetic storms (92.59)% have been found to be related with type II and type IV radio bursts and majority of them are associated with type IV radio bursts . The association rates of type IV and type II radio bursts have been found 15 (60.00%) and 10 (40%) respectively. From the further analysis it is observed that, halo CMEs related geomagnetic storms are also related with X-ray solar flares of different categories and majority of them are related with M class solar flares. The association rates of halo CMEs related geomagnetic with different X-ray solar flares are found 09 (33.33)% X class flare, 13 (48.15%) M class flare ,03 (11.11)% C class flare and 02(7.41)% B class flare respectively .The data analysis of observed halo CMEs associated geomagnetic storms and interplanetary shocks, majority of the halo CMEs related geomagnetic storms are found to be related with interplanetary shocks 26 (9630%) .From the data analysis of halo CMEs related geomagnetic and interplanetary magnetic field, I have found that halo CMEs related geomagnetic storms are closely related to disturbances in interplanetary magnetic fields and southward component of interplanetary magnetic field. Further to see how the magnitude of halo CMEs related geomagnetic storms are correlated with the magnitude of jump in interplanetary magnetic fields , a scatter diagram has been plotted between the magnitude of halo CMEs related geomagnetic storms and magnitude associated disturbances in interplanetary magnetic fields in Fig.1.From the Fig it is clear that maximum halo CMEs related geomagnetic storms which have large magnitude are associated with such JIMF events which have relatively large magnitudes value. I have determined positive co-relation between magnitude of halo CMEs related geomagnetic storms and magnitude of JIMF with correlation coefficient 0.72 .Further to see how the magnitude of halo CMEs related geomagnetic storms are correlated with magnitude of JIMFBz events, a scatter diagram have been plotted between the magnitude of halo CMEs related geomagnetic storms and magnitude of value of JIMFBz events in Fig.2. From the Fig it is clear that maximum halo CMEs related geomagnetic storms which have large magnitude are associated with such JIMFBz events which have relatively large magnitudes values .Positive correlation with correlation coefficient 0.85 have also been found between magnitude of halo CMEs related geomagnetic and magnitude of southward component (IMF Bz) .

CONCLUSION

From our study, most of the halo CMEs related geomagnetic storms have been identified as intense or severe geomagnetic storms and associated with different types of X ray solar flares and type IV and type II radio bursts. Majority of the halo CMEs related geomagnetic storms are associated with interplanetary shocks. Large positive co-relation have been determined between magnitude of halo CMEs related geomagnetic storms and magnitude of IMF with correlation coefficient 0.72 and magnitude of halo CMEs related geomagnetic storms and magnitude of southward component of IMFBz with correlation coefficient 0.85.These results shows that halo coronal mass ejections associated with X-ray solar flares and radio bursts are very much effective in producing moderate, intense and severe geomagnetic storms .Further it is concluded that interplanetary shocks and disturbances in interplanetary magnetic fields are closely related to moderate ,intense and severe geomagnetic storms.

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