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Association of symmetric cosmic ray intensity decreases with CMEs, solar flares and interplanetary shocks

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Abstract:

In this study we have studied the symmetric cosmic ray intensity decreases of magnitude ≥4%, during the period of 1997-2013. From this study we have found 47 symmetric cosmic ray intensity decreases, out of these we have no data of CMEs for 5 events. We have available data of CMEs only for 42 events; out of 42 events only 27 events are associated with coronal mass ejections (CMEs). The association rate of halo and partial halo types CMEs have been found 13(48.15%) and 14(51.85 %) respectively. Out of 47, 42 symmetric cosmic ray intensity decreases are found to be associated with different categories of X ray solar flares, 01(2.38%) symmetric cosmic ray intensity decreases are found to be associated with X class X-ray solar flares, 18(42.85%) symmetric cosmic ray intensity decreases are found to be associated with M class X-ray solar flares, 19(45.23%) symmetric cosmic rays intensity decreases are found to be associated with C class X-ray solar flares and 04(9.52%) are found to be associated with B class X-ray solar flares. Further 22 (46.81%) symmetric cosmic rays intensity decreases are associated with interplanetary shocks .The associated interplanetary shocks are forward shocks.

Key words: Coronal mass ejections, Interplanetary shocks, Solar flares.

INTRODUCTION

The galactic cosmic-ray intensity has an 11 year variation opposite to that of the sunspot number (Forbush 1954, 1958). The cosmic-ray intensity has its minimum at the maximum of the sunspot cycle. Generally, this variation is explained in terms of gradient and curvature particle drifts in the large-scale field of the heliosphere (Jokipii,Levy,and Hubbard1977) and diffusion/convection of cosmic rays (Morrison 1956;Burlaga et al 1984; Perko;&Burlaga 1992) in the solar wind (McDonald 1998;Potgieter 1998Burger 2000) Coronal mass ejections (CMEs), large-scale eruptions of magnetized plasma from the Sun (Hundhausen 1993,1999), are related to very strong, short-lived forbush decreases of cosmic-ray intensity at Earth and are considered to be the building blocks of global merged interaction regions (GMIRs) in the outer heliosphere (Burlaga, McDonald,& Ness 1993) which are associated with the extended Forbush-type decreases .There (Webber, Lockwood, & Jokipii 1986) Newkrik, Hundhausen, & Pizzo(1981) were among the first to suggest that CMEs might play a role in long-term modulation of cosmic rays. The consensus that has emerged is that drifts are more important at solar minimum, when the large-scale heliospheric field is relatively well ordered; and diffusion/convection modulation is dominant at solar maximum (Jokipii & Wibberenz 1998). At solar maximum, the CME rate, which tracks the sunspot number (Webb & Howard 1994), is high, and CMEs are observed at all latitudes, consistent with the closed shell of the GMIR picture (McDonald, Lal, & McGuire 1993), in which modulation proceeds as a series of steps. Cane, Wibberenz, and colleagues have prompted a rethinking of the causes of cosmic-ray modulation. In a series of papers (Cane et al. 1999b;Cane,Wibberenz, & Richardson 1999a; Wibberenz et al. 1999;Wibberenz & Cane 2000) these authors (1) demonstrated an anticorrelation between the cosmic-ray intensity and the strength of the interplanetary magnetic field (IMF) at 1 AU; (2) noted an apparent absence of CMEs at the onset of the 1974 "minicycle" of modulation (Cliver,Droge, & Muller-Mellin 1993a); (3) called attention to a peak in the CME rate in 1981, when the cosmic-ray intensity was recovering; and (4) pointed out an association between medium-term (∼1 yr) modulation events (steps) at 1 AU and enhancements in the solar open flux, calculated from photospheric magnetic field observations and a potential field model (Wang & Sheeley 1992;Wang 1995). The solar wind consists of high-speed streams from coronal holes, slow solar wind from as yet uncertain sources, and CMEs from closed-field regions (Richardson, Cliver, & Cane 2000). Insofar as no one has championed the slow solar wind (which has the lowest average field strength of the three solar wind components;(Richardson et al.2000) as a modulation driver, downplaying the role of CMEs implies that intermediate- and long-term modulation originates primarily in coronal holes, the source of the open magnetic flux. This inference is supported by the correspondence between open flux increases and intermediate-term cosmic-ray decreases reported by Cane et al.(1999a,1999b).The relative importance of CMEs, which originate in closed-field regions on the Sun and the open magnetic flux for modulation has been discussed by Hundhausen 1993,1999. In this investigation we have short term cosmic ray decreases with coronal mass ejections associated x-ray solar flares, interplanetary shocks and the physical processes mainly responsible to generate symmetric cosmic ray intensity decreases. For this study we considered symmetric cosmic ray decreases observed at oulu super neutron monitor for the period of 1997-2013.

SOURCES OF DATA

In this study the data of cosmic ray intensity decreases adopted from Oulu super neutron monitor. 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. The data of X-ray solar flares are taken from STP solar data (http://www.ngdc.noaa.gov/stp/solar/solardataservices.html).

The data of interplanetary shocks are taken from shocks arrival derived by WIND group from WIND observations.

Table: - Symmetric cosmic ray intensity decreases associated with CMEs, Solar flares and interplanetary shocks.

S. No.	Date	Symmetric cosmic ray intensity decreases		Coronal Mass Ejections (CMEs)		Solar Flares		Interplanetary Shocks	
		Onset set time dd (hh)	Magnitude %	Date time dd (hh)	Type H/P	Date time dd (hh)	Class	Shock	Tsy-Tsh
1	06.10.97	06(08)	3	na	na	na	na	na	na
2	17.11.97	17(12)	6	14(13.36)	P	15(21)	M-10	na	na
3	09.12.97	9(12)	3	06(10.27)	P	06(20)	C-15	10(04)	-16
4	06.01.98	6(00)	3	02(23.28)	H	03(17)	M-27	6(14)	-14
5	05.06.98	05(18)	5	04(02.04)	H	na	na	5(10)	8
6	23.10.98	23(12)	4	na	na	20(20)	C-74	na	na
7	11.12.98	11(12)	4	na	na	08(14)	C-57	na	na
8	05.05.99	5(12)	4	03(06.06)	H	03(06)	M-44	5(16)	-4
9	22.05.99	22(18)	4	21(17.50)	P	18(11)	C-39	na	na
10	12.09.99	12(02)	3	10(17.30)	P	09(16)	C-33	12(04)	-2
11	22.03.00	22(06)	3	18(23.54)	P	20(17)	M-24	na	na
12	12.10.00	12(04)	4	09(23.50)	H	09(23)	C-67	12(22)	-18
13	23.01.01	23(06)	3	20(21.30)	H	20(21)	M-77	23(11)	-5
14	22.07.01	22(18)	3	19(10.30)	P	19(10)	M-18	na	na
15	03.12.01	03(20)	3.5	01(16.54)	P	01(18)	M-18	na	na
16	27.01.02	27(18)	4	na	na	26(19)	M-13	na	na
17	09.04.02	9(12)	4	na	na	07(02)	C-96	na	na
18	01.11.02	01(18)	4	na	na	31(16)	X-12	na	na
19	09.01.03	9(18)	3	07(08.30)	P	07(07)	M-10	na	na
20	07.04.03	07(12)	4	04(21.50)	P	04(19)	M-19	08(01)	-13
21	02.04.04	2(18)	3	29(00.40)	P	31(20)	C-74	3(10)	-16
22	05.08.05	5(12)	3	na	na	03(05)	M-34	na	na
23	09.07.06	9(18)	3	06(08.54)	H	06(08)	M-25	9(21)	-3
24	09.11.06	9(12)	3	06(17.54)	H	06(18)	C-88	9(17)	-5
25	17.05.07	17(12)	3	15(19)	P	15(18)	B-32	na	na
26	05.01.08	5(00)	4	02(10)	P	02(06)	C-12	04(23)	1
27	08.02.08	8(12)	3	na	na	na	na	na	na
28	14.06.08	14(18)	4	na	na	na	na	14(12)	4
29	06.11.08	6(21)	3	na	na	03(11)	C-16	07(04)	-7

30	22.12.08	22(12)	3	na	na	na	na	na	na
31	20.01.10	20(06)	3	na	na	18(19)	C-49	na	na
32	14.09.10	14(18)	3	na	na	11(08)	B-50	na	na
33	12.12.10	12(18)	5	na	na	09(03)	B-13	na	na
34	11.04.11	11(6)	3	07(14)	P	07(16)	C-15	na	na
35	10.06.11	10(06)	3	na	na	07(06)	M-25	10(08)	-2
36	16.06.11	16(12)	5	13(04)	H	13(00)	C-12	17(02)	-14
37	23.06.11	23(00)	4	21(03)	H	21(00)	C-77	23(02)	-2
38	05.08.11	5(06)	6	03(14)	H	04(04)	M-93	05(17)	-11
39	16.09.11	16(12)	3	14(10)	P	14(11)	C-22	17(03)	-15
40	21.11.11	21(00)	3	17(20)	H	17(15)	C-20	na	na
41	22.01.12	22(18)	4	19(14)	H	19(14)	M-32	22(05)	13
42	13.02.12	13(12)	4	09(21)	H	09(22)	B-75	na	na
43	18.01.13	18(00)	4	0	0	15(22)	C-18	na	na
44	16.02.13	16(18)	3	0	0	14(04)	C-10	16(11)	7
45	24.04.13	24(18)	3	0	0	22(10)	M-10	na	na
46	24.05.13	24(06)	3	0	0	22(13)	M-50	24(18)	-12
47	25.06.13	25(00)	3	0	0	23(20)	M-29	na	na

DATA ANALYSIS AND RESULTS

From the data analysis given in table, we have found 47 total number of symmetric cosmic ray intensity decreases. Out of these 47, we have available data of CMEs are 42 events and out of these 42 events 27 (64.28%) symmetric cosmic ray intensity decreases have been found to be associated with coronal mass ejections. The association rate of H Type and P types CMEs have been found 13 and 14 respectively (figure-1).

To know the dependence of magnitude of symmetric cosmic ray intensity decreases on speed of associated CMEs a scatter diagram has plotted between them (figure-2). From the observation of the trend line of the Figure-2 it is inferred that the magnitude of symmetric cosmic rays intensity decreases and speed of associated CMEs are positively correlated with correlation coefficient 0.19.

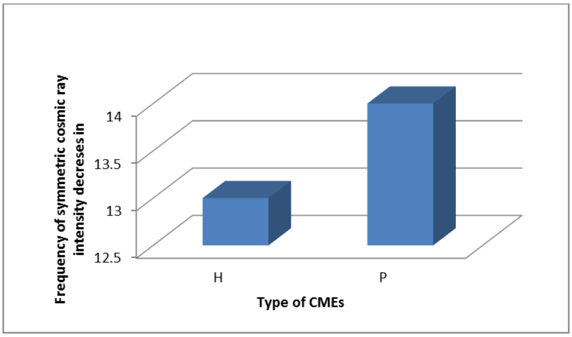

Figure 1-Shows bar diagram of symmetric cosmic ray decreases in cosmic ray intensity and types of associated CMEs for the period of 1997-2013.

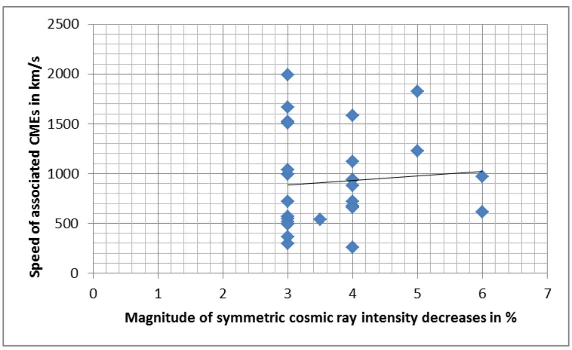

Figure 2-Shows Scatter plot between magnitude of symmetric cosmic ray intensity decreases and speed of associated CMEs for the period of 1997-2013, showing positive correlation with correlation coefficient 0.19.

From the analysis it is concluded that symmetric cosmic rays intensity decreases are also closely related with solar flares of different categories. The bar diagram between different categories of solar flares and frequency of associated symmetric cosmic ray intensity decreases is shown in Figure-3. From the analysis we found that majority of the symmetric cosmic ray intensity decreases are associated with X-ray solar flares and most of the symmetric cosmic ray decreases in cosmic ray intensity are associated with M class and C class solar flares.

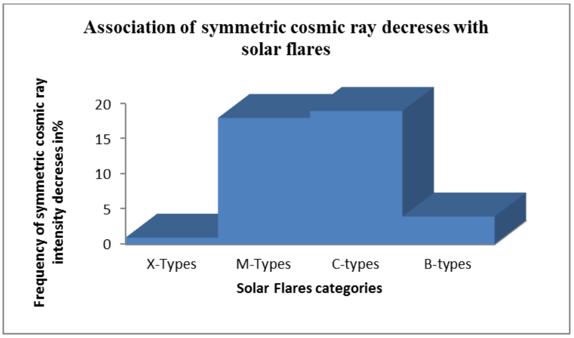

Figure 3-Shows bar diagram between different types of solar flares and frequency of associated symmetric cosmic ray intensity decreases for the period of 1997-2013.

From the further analysis it is observed that majority of interplanetary shocks following the onset of symmetric cosmic ray intensity decreases .We have 22 symmetric cosmic ray intensity decreases which are associated with interplanetary shocks out which arrival time of 17(77.27%) interplanetary shocks have been found after the onset time of symmetric cosmic ray intensity decreases, The arrival time of 05(22.72%) interplanetary shocks have been found before the onset time of symmetric cosmic ray intensity decreases (figure-4).

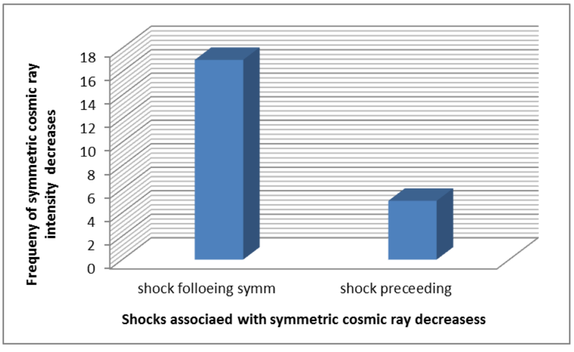

Figure 4- Shows Frequency of symmetric cosmic ray intensity decreases (Fds) associated with common onset, preceding and following the onset time of symmetric cosmic ray intensity deceases.

CONCLUSION

From our study we have found that 47 symmetric cosmic ray intensity decreases which are related to Coronal mass ejections and solar flares and interplanetary shocks. Out of these 42 events are associated with CMEs, the majority of associated CMEs are partial halo CMEs. Further we concluded that these 42 events are also associated with X-ray solar flares. The majority of the associated solar flares are M and C-class X-ray solar flare. The interplanetary shocks related CMEs are 22. It is concluded that symmetric cosmic ray intensity decreases are closely related with X-ray solar flares.

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