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Study of Short term Asymmetric Cosmic Ray Intensity decreases with Coronal Mass Ejections and Solar Flare

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Abstract
We have analyzed asymmetric cosmic ray intensity decreases ≥4%, observed during the period of 1997 to 2013 with Coronal mass ejections and X-Ray solar flares. We have found total numbers of asymmetric cosmic ray intensity decreases (Fds) are 74. We have 67 CMEs events out of these 67 events 62 (92.54%) asymmetric cosmic ray intensity decreases (Fds) have been found to be associated with coronal mass ejections .The majority of associated CMEs are halo CMEs, the association rate of H Type and P types CMEs have been found 85.48% and 14.52 % respectively. Further we have observed that out of 74 asymmetric cosmic ray intensity decreases (Fds), 69 (93.24%) are associated with X ray solar flares of different categories and majority of the associated solar flares are M-Class solar flares. From the study of asymmetric cosmic ray intensity decreases (Fds) with speed of associated CMEs, we have determined positive correlation with correlation coefficient 0.46 between magnitudes of asymmetric cosmic ray intensity decreases (Fds) and speed of associated CMEs.

Keywords: *Coronal mass ejections, Solar flares, Asymmetric cosmic ray intensity.*

1. INTRODUCTION

The galactic cosmic-ray intensity recorded at Earth 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 (for recent reviews see 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. In the past years, much of the debate and research on cosmic-ray modulation has focused on the relative importance of drifts and diffusion/convection. 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. It is not clear what they envisage as the source of the gradual component, but Cane et al. (1999b) suggest that "there is no conceptual difference during most of a solar cycle between long-term changes and individual events or steps: in both casesmagnetic flux variations are carried outward with the solar wind." 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). In so far 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, to know relationship of short term cosmic ray decreases and these parameters and the physical processes mainly responsible to generate symmetric and asymmetric short term cosmic ray intensity decreases.

2. DATA ANALYSIS AND RESULTS

In this study we used monthly and hourly data of super neutron monitors for cosmic ray intensity variations. For the X-ray solar flares and coronal mass ejections we use monthly and hourly data also. Data of cosmic ray intensity decreases, CMEs and Solar flare are shown in table.

Table- Asymmetric Cosmic Ray Intensity decreases Associated CMEs and Solar Flares

		Asymmetric Cosmic Ray intensity decreases(Fds)					Coronal Mass Ejections			Solar Flares	
S. NO	date	Onset set time dd (hh)	max. dec. time dd (hh)	Recovery time dd (hh)	mag%	Type of decreases	Date time dd (hh)	Type H/P	Speed K/s	Date time dd(hh)	Class
1	10.04.97	10(18)	11(00)	15(16)	5	F	07(14)	H	905	na	na
2	01.05.98	01(20)	04(20)	08(06)	6	F	29(16)	H	1602	29(29)	M-68
3	04.07.98	04(16)	05(04)	06(16)	3	F	nd	nd	nd	03(00)	M-12
4	25.08.98	25(12)	26(08)	28(16)	8	F	nd	nd	nd	24(22)	X10
5	24.09.98	24(12)	26(00)	28(12)	10	F	nd	nd	nd	23(07)	M-71
6	08.11.98	08(04)	08(20)	13(16)	7	F	05(21)	H	1118	06(15)	M-17
7	22.01.99	22(20)	23(08)	27(20) _	7	F	nd	nd	nd	20(19)	M-52
8	12.12.99	12(16)	13(00)	19(18)	8	F	na	na	na	09(11)	C-16
9	11.01.00	11(12)	12(18)	20(12)	6	F	na	na	na	10(13)	M-33
10	07.04.00	07(00)	07(16)	11(16)	3	F	04(17)	H	1199	06(02)	M-18
11	08.06.00	08(08)	09(00)	17(00)	8	F	06(16)	H	1130	06(16)	X-23
12	15.07.00	15(12)	16(04)	18(16)	12	F	14(11)	H	1674	14(11)	X-57
13	14.09.00	14(20)	15(12)	16(20)	3	F	12(12)	H	1839	12(12)	M-10

14	17.09.00	17(12)	18(00)	22(00)	8	F	15(22)	H	537	16(04)	M-59
15	28.10.00	28(00)	29(00)	31(16)	7	F	25(08)	H	948	25(09)	C-40
16	06.11.00	06(16)	07(04)	10(00)	7	F	03(18)	H	643	03(20)	C-53
17	26.11.00	26(12)	27(08)	02(08)	8	F	24(05)	H	1298	24(05)	X-20
18	03.03.01	3(18)	4(00)	8(00)	3	F	01(18)	P	947	na	na
19	19.03.01	19(03)	19(18)	23(06)	4	F	18(02)	H	785	16(10)	C-54
20	26.03.01	26(06)	28(00)	31(08)	6	F	24(21)	H	1185	24(19)	M-17
21	04.04.01	04(16)	05(00)	06(12)	8	F	01(11)	H	1683	01(11)	M-55
22	07.04.01	07(12)	08(20)	11(16)	6	F	05(17)	H	1390	05(17)	M-51
23	11.04.01	11(16)	12(04)	17(20)	8.5	F	09(16)	H	1198	09(16)	M-79
24	28.04.01	28(04)	29(04)	03(16)	6	F	26(12)	H	1171	26(12)	M-78
25	27.05.01	27(12)	28(04)	28(16)	4	F	25(17)	P	962	24(24)	C-40
26	17.08.01	17(16)	18(00)	20(08)	7	F	15(24)	H	1575	14(10)	C-97
27	27.08.01	27(18)	28(08)	03(20)	7	F	25(17)	H	1433	25(16)	X-53
28	25.09.01	25(20)	26(04)	29(08)	8	F	23(20)	H	478	23(11)	M-11
29	11.10.01	11(16)	12(16)	19(16)	6	F	09(11)	H	973	09(11)	M-14
30	21.10.01	21(16)	22(04)	25(04)	5	F	19(170	H	901	19(16)	X-16
31	06.11.01	06(00)	06(16)	08(20)	12	F	04(17)	H	1810	04(16)	X-10
32	24.11.01	24(12)	25(00)	26(20)	10	F	22(20)	H	1443	22(20)	M-38
33	15.12.01	15(00)	17(12)	19(16)	5	F	13(15)	H	864	13(14)	X-62
34	30.12.01	30(16)	03(04)	08(20)	5.5	F	28(20)	H	2239	28(20)	X-34
35	10.01.02	10(16)	11(08)	18(08)	4.5	F	08(18)	H	2210	07(14)	C-38
36	23.05.02	23(12)	23(16)	24(20)	5	F	21(22)	P	900	21(21)	M-15
37	10.11.02	10(02)	12(00)	16(20)	7	F	09(13)	H	1838	09(13)	M-46
38	17.11.02	17(00)	18(00)	23(16)	8	F	16(07)	H	1250	15(01)	M-24
39	22.12.02	22(12)	23(00)	28(00)	4	F	19(22)	H	1318	19(20)	M-27
40	01.02.03	01(16)	02(04)	05(20)	5	F	30(10)	P	869	na	na
41	29.05.03	29(16)	31(04)	04(20)	7	F	27(24)	H	964	27(23)	X-13
42	29.10.03	29(00)	29(16)	04(20)	25	F	28(11)	H	2686	28(10)	X-172
43	07.01.04	07(00)	09(00)	13(16)	8	F	06(06)	P	1469	06(06)	M-58
44	21.01.04	21(16)	22(12)	27(12)	8	F	20(00)	H	1074	20(07)	M-61
45	26.07.04	26(16)	27(08)	31(00) _	10	F	23(16)	H	824	23(17)	M-22
46	07.11.04	07(08)	10(00)	18(00)	12	F	07(17)	H	1759	07(16)	X-20
47	08.05.05	08(06)	09(12)	14(20)	6	F	06(17)	H	1128	06(11)	M-13
48	15.05.05	15(00)	15(08)	20(08)	7	F	13(17)	H	1689	13(16)	M-80
49	28.05.05	28(20)	29(20)	31(16)	10	F	26(15)	H	586	27(12)	M-11
50	23.08.05	23(20)	25(04)	29(00)	7	F	22(01)	H	1194	22(01)	M-26
51	11.09.05	11(00)	11(12)	21(05)	12	F	09(20)	H	2257	09(19)	X-62
52	14.12.06	14(18)	15(000	19(18)	10	F	13(02)	H	1931	13(02)	X-34
53	21.05.07	21(03)	21(22)	24(180	3	F	na	na	na	19(12)	B-95
54	08.03.08	8(000	9(12)	15(00)	3	F	na	na	na	na	na
55	05.04.10	05(12)	05(18)	08(12)	4	F	03(11)	H	668	03(09)	B-74
56	03.08.10	03(12)	04(18)	08(18)	5	F	01(13)	H	1309	01(08)	C-32
57	18.02.11	18(00)	18(18)	23(12)	4.5	F	14(18)	H	449	14(17)	M-22

58	05.04.11	05(06)	06(12)	07(12)	4.5	F	03(10)	H	668	03(05)	C-12
59	23.06.11	23(00)	24(00)	27(12)	4	F	21(03)	H	719	21(00)	C-77
60	10.07.11	10(12)	11(00)	18(00)	4	F	09(07)	P	546	09(09)	B-42
61	05.08.11	05(06)	06(00)	09(12)	5	F	04(04)	H	1315	04(04)	M-93
62	25.09.11	25(12)	26(18)	5(12)	6	F	22(10)	H	1905	22(10)	X-14
63	24.10.11	24(18)	25(060	29(18)	6	F	22(01)	H	739	22(10)	M-13
64	01.11.11	01(00)	01(18)	02(18)	3	F	na	na	na	31(14)	M-11
65	24.01.12	24(06)	25(00)	02(06)	5	F	23(04)	H	2283	23(04)	M-87
66	07.03.12	07(06)	10(00)	18(18)	7	F	04(11)	H	1473	04(10)	M-20
67	05.04.12	05(18)	06(00)	07(18)	4	F	02(02)	P	350	02(02)	B-79
68	16.06.12	16(06)	17(00)	21(12)	5	F	02(04)	P	1227	02(04)	C-14
69	14.07.12	14(18)	15(12)	18(18)	7	F	12(16)	H	1092	12(16)	X-14
70	03.09.12	03(12)	5(12)	8(18)	6	F	02(04)	H	538	02(02)	C-29
71	13.11.12	13(00)	14(00)	15(12)	3	F	11(01)	P	1039	na	na
72	14.03.13	14(00)	18(12)	25(12)	8	F	nd	nd	nd	12(22)	C-36
73	13.04.13	13(18)	14(22)	21(18)	5.5	F	nd	nd	nd	11(06)	M-65
74	23.06.13	23(12)	24(00)	25(18)	4	F	nd	nd	nd	21(02)	M-29

From the data analysis we have found total numbers of asymmetric cosmic ray intensity decreases (Fds) are 74. The available data of CMEs for association are 67 events and out of these 67 events 62 (92.54%) asymmetric cosmic ray intensity decreases (Fds) have been found to be associated with coronal mass ejections .The majority of associated CMEs are halo CMEs The association rate of H Type and P types CMEs have been found 85.48% and 14.52 % respectively.

To see how the magnitude of asymmetric cosmic ray intensity decreases (Fds) are dependent on associated CMEs a scatter plot has been plotted between magnitude of asymmetric cosmic ray decreases and speed of associated CMEs, shown in fig.-2. The trend line of the figure shows positive correlation between magnitude of asymmetric cosmic ray intensity decreases (Fds) and speed of associated CMEs. We have found positive co-relation with correlation coefficient 0.46 has been between magnitudes of asymmetric cosmic ray intensity decreases (Fds) and speed of associated CMEs.

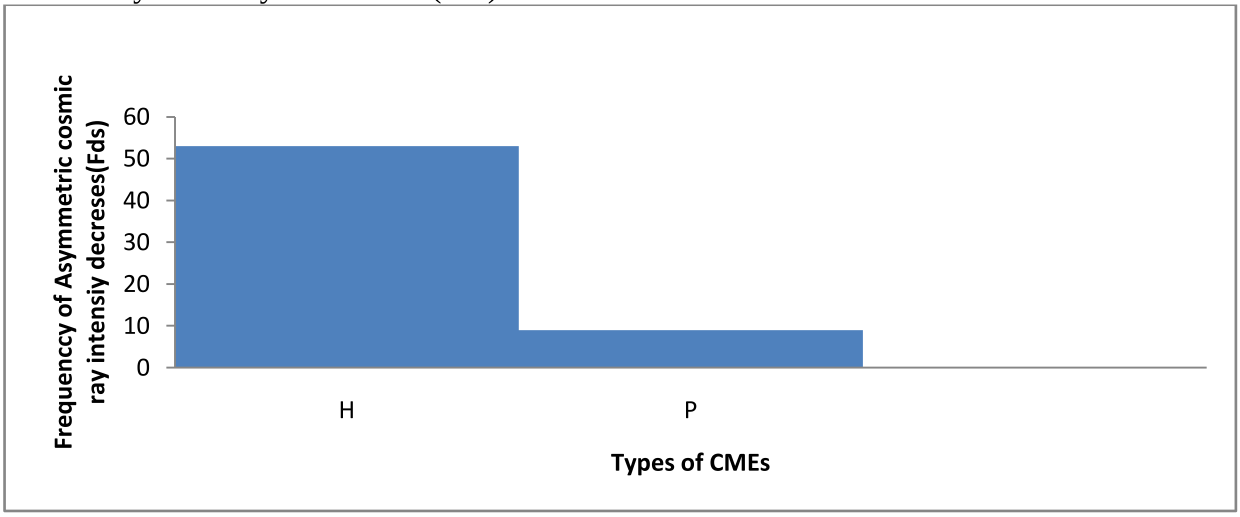

Figure.1-shows bar diagram of asymmetric cosmic ray intensity decreases (Fds) and types of associated CMEs for the period of 1997-2013.

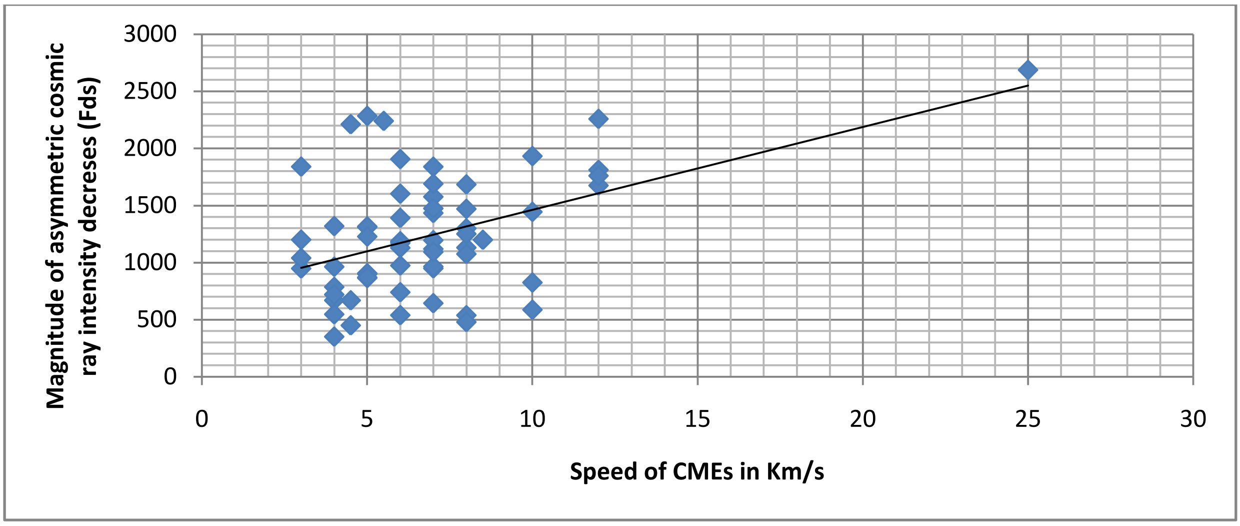

Figure.2- Scatter plot between magnitudes of asymmetric cosmic ray intensity decreases (Fds) and speed of associated CMEs.

Further from the data analysis it is observed that out of 74 asymmetric cosmic ray intensity decreases (Fds) 69 (93.24%) are associated with X ray solar flares of different categories and majority of the associated solar flares are M-Class solar flares. Out of 69 asymmetric cosmic ray intensity decreases (Fds), 16 (23.19%) asymmetric cosmic ray intensity decreases (Fds) are found to be associated with X class X-ray solar flares, 36(52.17%) asymmetric cosmic ray intensity decreases (Fds) are found to be associated with M class X-ray solar flares,(18.84%) asymmetric cosmic rays intensity decreases (Fds) are found to be associated with C class X-ray solar flares and 04(5.7%) are found to be associated with B class X-ray solar flares. The bar diagram between types of X-ray solar flares and frequency of associated asymmetric cosmic ray intensity decreases (Fds) are shown in figure-3.

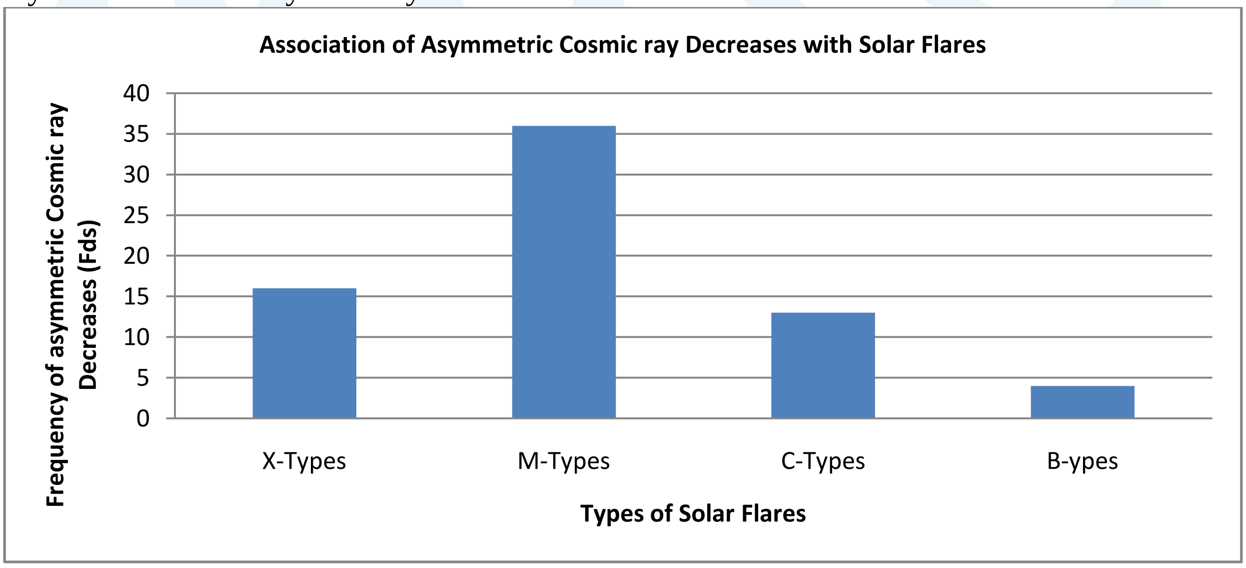

Figure.3- Shows bar diagram between different types of solar flares and frequency of associated asymmetric cosmic ray intensity decreases (Fds).

3. CONCLUSION

From our study we have found that 74 asymmetric cosmic ray intensity decreases which are related to Coronal mass ejections and solar flares. Out of these 62 CMEs are associated with asymmetric cosmic ray intensity decreases, the majority of associated CMEs are halo CMEs. We have found that out of these 74, 69 events are associated with X-ray solar flares, the majority of the associated solar flares are M-Class solar flares. From the study of asymmetric cosmic ray intensity decreases (Fds) with speed of associated CMEs, we have determined positive correlation with correlation coefficient 0.46 between magnitudes of asymmetric cosmic ray intensity decreases (Fds) and speed of associated CMEs. From these results it is concluded that asymmetric cosmic ray intensity decreases (Fds) are closely related with X-ray solar flares.

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