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Symmetric Cosmic Ray Intensity Decreases in Relation with Coronal Mass Ejections and Disturbances In Solar Wind Plasma Parameters

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Abstract. We have studied symmetric cosmic ray intensity decreases (V Shape, and U Shape) magnitude ≥2.0%, observed at Oulu super neutron monitor, during the period of 1986-2006 with coronal mass ejections CMEs), interplanetary shocks and disturbances in solar wind plasma parameters (solar wind temperature, velocity, density). We have found that 76.92% V shape symmetric cosmic ray intensity decreases are associated with halo and partial halo coronal mass ejections (CMEs). The association rate between halo and partial halo coronal mass ejections are found 40.00%and 60.00% respectively. Most of the V Shape symmetric cosmic ray intensity decreases are related to interplanetary shocks (61.53%) and the related shocks are forward shocks. We have also found positive co-relation with co-relation co-efficient 0.54 between magnitude of V shape symmetric cosmic ray intensity decreases and speed of associated coronal mass ejections. From the further study it is concluded that V shape symmetric cosmic ray decreases are strongly related to the disturbances in solar wind plasma parameters. Negative co-relation has been found between magnitudes of V Shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma density of associated JSWD events with co-relation co-efficient -0.152 between these two events. Negative co-relation has also been found between magnitude of V Shape asymmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma velocity of the associated JSWV events with co-relation co-efficient -0.48 between these two events. From the study of U Shape symmetric cosmic ray intensity decreases and disturbances in solar wind plasma parameters, we found negative co-relation with correlation coefficient, -0.473 between magnitude of U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma temperature of associated JSWT events, -0.468 between magnitude of U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma density of associated JSWD events and -0.26 between U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma velocity of associated JSWV events.

1. Introduction

The solar modulation of Galactic cosmic-ray (GCR) intensity has been known since the work of Forbush (1954) and these variations have been classified according to the duration of variation, long term and short term variations. The short-term modulation in galactic cosmic ray intensity, are two types namely corotating and asymmetric short term (Fds) decreases [9,19,21,].Forbush decreases [FDs] are transient and rapid decreases in galactic cosmic ray intensity followed by a more gradual recovery phase typically lasting several days. These decreases are not only observed by ground based detector's but are also observed by space born detector's and so are present in interplanetary medium [22,23,]. These decreases are closely related to coronal mass ejections and interplanetary shocks that they generate. [7,8,20].Recurrent modulations of galactic cosmic rays, characterized by a slow decrease and a gradual recovery within a period of ~27 days, comparatively, are less impressive changes in cosmic ray intensity. Since their discovery through world-wide distribution of ion-chambers, these decreases have been extensively studied to search for their solar source [5,10,] interplanetary structure responsible [3,4,6,9,12,14,16] and the mechanism(s) playing major role in this phenomenon [1, 7,19,].The recurrent or corotating decreases in cosmic ray intensity have been analyzed by several scientists [13,19] it has been found that these decreases are closely related to coronal holes, corotating interaction regions. Some other scientists have also studied these variations with several interplanetary parameters [Richardson et al. [15,17,18 22] to identify potential sources and relative role of corotating interaction regions, high speed streams and heliospheric current sheet in corotating modulation. It is concluded polar coronal holes have been identified as potential solar source of co rotating decreases. Although solar polar coronal holes have been identified as potential solar source of corotating decreases, the relative role of corotating interaction regions, high speed streams and heliospheric current sheet in corotating modulation is yet to be decided.

2. Experimental Data

In this work monthly and hourly data of oulu super neutron monitor have been used to determine V shape and U shape symmetric cosmic ray decreases The data of coronal mass ejections (CMEs) will be taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. The data of interplanetary shocks have been taken from shocks arrival derived by WIND group from WIND observations, ACE list of transient and disturbances. To determine disturbances in solar wind plasma parameters, hourly data of solar wind plasma velocity density temperature average interplanetary magnetic field has been used these data has also been taken from omni web data.

3. Data Analysis and Results

The total number of V shape and U shape symmetric cosmic ray intensity decreases and associated coronal mass ejections ,interplanetary shocks ,disturbances in solar wind plasma parameters are listed in table no 1 and table no 2.

From the data analysis of V shape symmetric cosmic ray intensity decreases and associated coronal mass ejections it is observed that the number of V shape symmetric cosmic ray intensity decreases during the period of 1986 to 2006 have been found 26.We have no data of CMEs for 13 V-shape symmetric short term cosmic ray decreases for association. The CMEs data available for association is for 13 V shape symmetric cosmic ray intensity decreases, in which 10 (76.92%) V shape symmetric cosmic ray intensity decreases are found to be associated with coronal mass ejections .Out of theses associated CMEs 06 (60%) V-shape symmetric short term cosmic ray decreases are found to be associated with partial halo CMEs where as 04 (40%) V-shape symmetric short term cosmic ray decreases are found to be associated with full halo coronal mass ejections. We have also found positive co-relation with co-relation co-efficient 0.54 between magnitude of V shape symmetric cosmic ray intensity decreases and speed of associated coronal mass ejectionsFrom the data analysis of V shape cosmic ray intensity decreases and interplanetary shocks,16 out of 26 (61.54) V shape symmetric cosmic ray decreases found to be associated with interplanetary shocks. The onset time of 12.5 % V shape symmetric cosmic ray decreases are found after the arrival time of interplanetary shocks where as the onset time of 87.5% V shape symmetric cosmic ray decreases are found before the arrival time of interplanetary shocks. The onset time of half of the V shape symmetric cosmic ray decreases are found at ± 10 hours time lag between onset time of V shape symmetric cosmic ray decreases and arrival time of interplanetary shocks We have obtained 16 V shape symmetric cosmic ray decreases, which are associated with interplanetary shocks out of which 08(50%) are found at ± 10 hours time lag between onset time of V symmetric cosmic ray decreases and arrival time of interplanetary shocks.From the data analysis of V shape symmetric cosmic ray decreases and JSWD events. We have obtained that the maximum V-shape Symmetric short term cosmic ray decreases events are associated with JSWD events. We have 26 V-shape Symmetric short term cosmic ray decreases in which available data for association with JSWD events are 23, out of which 19 V-shape Symmetric short term cosmic ray decreases (82.61%) are found to be associated with JSWD events. To see how the magnitude of V-shape Symmetric short term cosmic ray decreases is correlated with magnitude of JSWD events. We have plotted a scatter diagram between the magnitude of V-shape Symmetric short term cosmic ray decreases and magnitude JSWD events and resulting figure is shown in fig1. From the fig it is clear that, most of the V-shape Symmetric short term cosmic ray decreases which have large magnitude are associated with such JSWD events which have relatively small magnitude.Negative co-relation has been found between magnitudes of V Shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma density of associated JSWD events with co-relation co-efficient -0.152 between these two events.

Table No 1 Association of Symmetric V shape Cosmic Ray Intensity with Coronal Mass Ejections and Disturbances in Solar Wind Plasma Parameter

Date	Onset set timedd (hh)	mag%	Type of decreases	SSC	Start time dd(hh)	Magnitude of Jump n/cc	Start time dd(hh)	Magnitude of Jump km/s	Date time dd(hh)	TypeH /P	S eed K/s
05.03.86	05(16)	3.5	V	06(11)	04(17)	17.2	04(18)	145	nd	nd	nd
07.10.87	07(00)	3	V	na	06(21)	2.3	nj	nj	nd	nd	nd
09.12.87	09(12)	4	V	9(20)	08(23)	4.2	nj	nj	nd	nd	nd
09.02.88	09(12)	6	V	na	08(22)	17.2	09(05)	47	nd	nd	nd
05.05.88	05(08)	4	V	6(04)	05(02)	4.2	05(05)	210	nd	nd	nd
23.06.88	23(12)	3	V	24(00)	nj	nj	22(19)	77	nd	nd	nd
11.01.89	11(13)	4.5	V	11(12)	nd	nd	nd	nd	nd	nd	nd
15.01.89	15(10)	4	V	na	14(12)	7.7	14(11)	67	nd	nd	nd
27.12.89	27(20)	6	V	na	nd	nd	nd	nd	nd	nd	nd
12.03.90	12(10)	6	V	12(15)	nd	nd	nd	nd	nd	nd	nd
27.04.91	27(14)	3	V	na	27(18)	4.1	nj	nj	nd	nd	nd
01.01.92	01(10)	4.5	V	01(17)	31(11)	6.1	nj	nj	nd	nd	nd
26.11.94	26(04)	3	V	26(07)	25(13)	37.4	25(13)	58	nd	nd	nd
06.10.97	06(08)	3	V	na	10(05)	4.8	nj	nj	na	na	na
17.11.97	17(12)	6	V	na	16(04)	8	16(11)	46	14(13.36)	P	967
09.12.97	9(12)	3	V	10(04)	nj	nj	nj	nj	06(10.27)	P	567
06.01.98	6(00)	3	V	6(14)	06(13)	19.1	06(12)	114	02(23.28)	H	548
05.06.98	05(18)	5	V	5(10)	04(22)	13.4	05(12)	41	04(02.04)	H	1821
23.10.98	23(12)	4	V	na	23(01)	7.5	23(04)	107	na	na	na
12.09.99	12(02)	3	V	12(04)	12(03)	31.4	12(02)	204	10(17.30)	P	723
12.10.00	12(04)	4	V	12(22)	11(05)	1.7	11(08)	40	09(23.50)	H	881
09.01.03	9(18)	3	V	na	09(12)	13.1	09(08)	135	07(08.30)	P	513
07.04.03	07(12)	4	V	08(01)	07(04)	33.2	nj	nj	04(21.50)	P	257
02.04.04	2(18)	3	V	3(10)	nj	nj	nj	nj	29(00.40)	P	489

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05.08.05	5(12)	3	V	na	nj	nj	nj	nj	na	na	na
09.07.06	9(18)	3	V	9(21)	09(15)	13.8	09(16)	99	06(08.54)	H	995

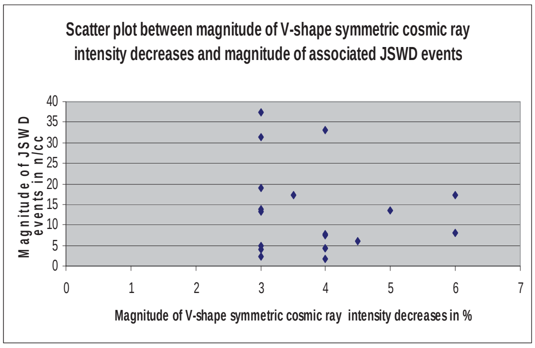

Figure 1 shows Scatter plot between magnitude of V shape symmetric cosmic ray decreases and magnitude of JSWD events showing negative correlation with correlation coefficient -0.152

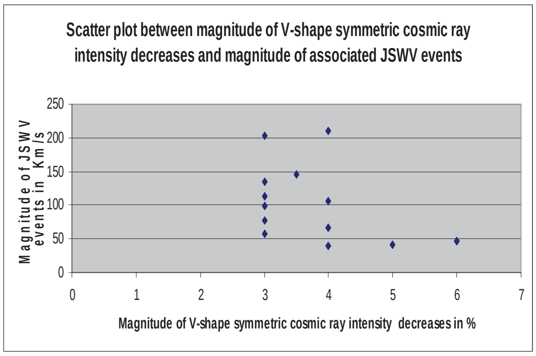

Figure 2 shows Scatter plot between magnitude of V shape symmetric cosmic ray decreases and magnitude of JSWV events showing negative correlation with correlation coefficient -0.48

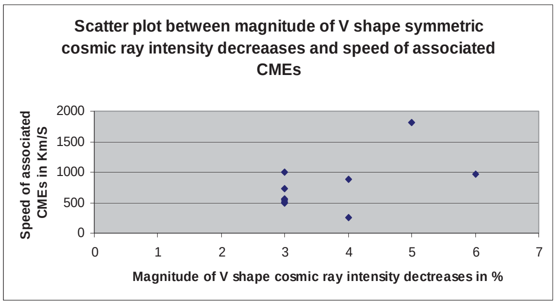

Figure 3 shows Scatter plot between magnitude of V shape symmetric cosmic ray decreases and speed of associated CMEs with correlation coefficient 0.54

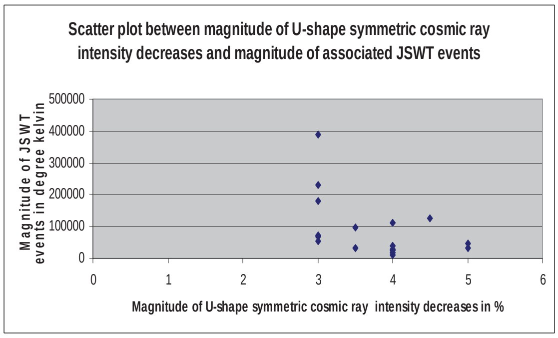

Figure 4 Shows Scatter plot between magnitude of U shape symmetric cosmic ray decreases and magnitude of JSWT events showing -0.473

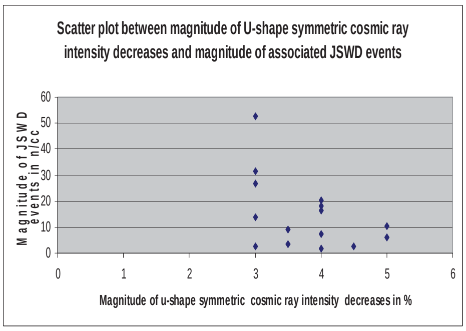

Figure 5 shows Scatter plot between magnitude of U shape symmetric cosmic ray decreases and magnitude of JSWD events showing negative correlation with correlation coefficient 0.468

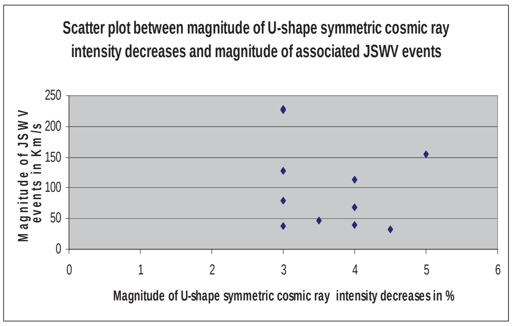

Figure 6 shows Scatter plot between magnitude of U shape symmetric cosmic ray decreases and magnitude of JSWV events showing negative correlation with correlation coefficient -0.26

From the data analysis of V-shape Symmetric short term cosmic ray decreases and JSWV events it is concluded that V shape symmetric cosmic ray decreases are closely associated with JSWV events. We have found 14 out of 23 V shape symmetric cosmic ray decreases are associated with JSWV events (60.87%).

To see how the magnitude of V-shape Symmetric short term cosmic ray decrease are correlated with the magnitude of JSWV events, we have plotted a scatter diagram between the magnitude of V-shape Symmetric short term cosmic ray decrease and JSWV events and the resulting figure is shown in figure 2 .From the it is clear that maximum V-shape Symmetric short term cosmic ray decrease which have large magnitude are associated with such JSWV events which have relatively small magnitude but magnitude of these two events do not have any quantitative relation their amplitude do not have any fixed proportion. These results indicate that although these events have not any quantitative relation but the V-shape Symmetric short term cosmic ray decrease of higher magnitude are generally associated with such JSWV events, which have relatively low magnitude. Negative co-relation has also been found between magnitude of V Shape asymmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma velocity of the associated JSWV events with co-relation co-efficient -0.48 between these two events.

From the data analysis of U shape symmetric short term cosmic ray intensity decreases and jump in solar wind plasma temperature ,density and velocity we have found 86.96% of U shape Symmetric short term cosmic ray decrease events are found to be associated with JSWT events. To sees how the magnitude of U-shape Symmetric short term cosmic ray decrease is correlated with JSWT events. We have plotted a scatter diagram between the magnitude of U-shape Symmetric short term cosmic ray decrease events and magnitude JSWT events in figure 4 .From the it is clear that, most of the U-shape Symmetric short term cosmic ray decrease which have large magnitude are associated with such JSWT events which have small magnitude. We found negative co-relation with correlation coefficient, -0.473 between magnitude of U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma temperature of associated JSWT events. From the analysis of U-shape Symmetric short term cosmic ray decrease with jump in solar wind plasma density (JSWD), 83.33%U-shape cosmic ray intensity decreases are found to be associated with JSWD events. To sees how the magnitude of U-shape Symmetric short term cosmic ray decrease is correlated with magnitude of JSWD events. We have plotted a scatter diagram between the magnitude of U-shape Symmetric short term cosmic ray decrease and magnitude JSWD events and the resulting figure is shown in figure 5. From the fig. it is clear that, most of the U-shape Symmetric short term cosmic ray decrease which have large magnitude are associated with such JSWD events which have small magnitude. We found negative co-relation with correlation coefficient, -0.468 between magnitude of U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma density of associated JSWD events. From the analysis of U-shape Symmetric short term cosmic ray decrease with that of jump in solar wind plasma velocity JSWV 61.11% U-shape Symmetric short term cosmic ray decrease is associated with JSWV events. We found negative co-relation with correlation coefficient and -0.26 between U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma velocity of associated JSWV events.

Table No 2 Association of Symmetric U shape Cosmic Ray Intensity with Coronal Mass Ejections and Disturbances in Solar Wind Plasma Parameters

	Symmetric U Shape cosmic ray intensity decreases				Tempara ture		Density		Velosity	
Date	Onset set timedd (hh)	mag %	Type of decre ases	Shocks	Start time dd(hh)	Magnitu de of Jump in Deg k	Start time dd(hh)	Magnitu de of Jumpn/c c	Start time dd(hh)	Magnitu de of Jumpm/ s
18.09.88	18(12)	4	U	17(19)	nd	nd	nd	nd	nd	nd
23.02.89	23(09)	4.5	U	na	22(13)	126963	22(22)	2.5	22(16)	33
05.05.89	5(00)	5	U	04(24)	04(22)	31385	04(22)	10.3	04(20)	155
12.06.90	12(06)	6	U	12(08)	nd	nd	nd	nd	nd	nd
20.12.90	20(04)	3	U	na	19(21)	72941	nj	nj	nj	nj
20.02.91	20(12)	4	U	na	20(02)	11653	20(01)	1.9	nj	nj
11.07.92	11(13)	3.5	U	na	10(15)	31654	11(08)	8.9	nj	nj
04.08.92	4(18)	5	U	4(14)	04(05)	45467	04(02)	5.9	nj	nj
03.06.93	03(06)	3	U	na	02(18)	54712	03(03)	26.6	03(02)	127
23.06.93	23(06)	3	U	na	nd	nd	nd	nd	nd	nd
11.12.98	11(12)	4	U	na	10(14)	24850	10(15)	18.1	10(14)	39
05.05.99	5(12)	4	U	5(16)	05(11)	109721	15(02)	16.6	15(14)	113
22.05.99	22(18)	4	U	na	22(09)	29329	nj	nj	nj	nj
22.03.00	22(06)	3	U	na	21(23)	69823	22(01)	52.8	22(01)	227
23.01.01	23(06)	3	U	23(11)	23(02)	230408	23(05)	13.8	22(07)	80
22.07.01	22(18)	3	U	na	22(04)	178323	21(23)	2.5	22(12)	37
03.12.01	03(20)	3.5	U	na	03(06)	96635	03(05)	3.4	03(05)	46
27.01.02	27(18)	4	U	na	nj	nj	nj	nj	nj	nj
09.04.02	9(12)	4	U	na	08(23)	18921	09(08)	20.1	nj	nj
01.11.02	01(18)	4	U	na	01(14)	39058	01(09)	7.3	01(10)	68
09.11.06	9(12)	3	U	9(17)	09(11)	389111	09(07)	31.3	09(11)	229

4. Conclusion

From our study we have found that 76.92% V shape symmetric cosmic ray intensity decreases are associated with halo and partial halo coronal mass ejections (CMEs). The association rate between halo and partial halo coronal mass ejections are found 40.00%and 60.00% respectively. Most of the V Shape symmetric cosmic ray intensity decreases are related to interplanetary shocks (61.53%) and the related shocks are forward shocks. We have also found positive co-relation with co-relation co-efficient 0.54 between magnitude of V shape symmetric cosmic ray intensity decreases and speed of associated coronal mass ejections. Negative co-relation has been found between magnitudes of V Shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma density of associated JSWD events with co-relation co-efficient -0.152 between these two events. Negative co-relation has also been found between magnitude of V Shape asymmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma velocity of the associated JSWV events with co-relation co-efficient -0.48 between these two events. From the study of U Shape symmetric cosmic ray intensity decreases and disturbances in solar wind plasma parameters, we found negative co-relation with correlation coefficient, -0.473 between magnitude of U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma temperature of associated JSWT events, -0.468 between magnitude of U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma density of associated JSWD events and -0.26 between U shape symmetric cosmic ray intensity decreases and magnitude of jump in solar wind plasma velocity of associated JSWV events. These results shows that coronal mass ejections and disturbances in solar wind plasma parameters are the solar and interplanetary phenomena, characteristics of which are closely related to the characteristics of symmetric cosmic ray intensity decreases and these parameters will help in better understanding for theses decreases.

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