ISSN: 2455-1848
International Journal of Innovative Research & Growth
A Peer Reviewed & Referred International Journal
Volume-4 Issue-2 December-2016
Impact Factor-2.58
www.ijirg.com, editor@ijirg.com

Study Of Symmetric And Asymmetric Cosmic Ray Intensity Decrease (Fds) Association With Geomagnetic Storm And Interplanetary Shocks

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Abstract
In this article we have studied the association of Fds with geomagnetic storms and interplanetary shocks in the period of 1997-2013. We observed that the symmetric and asymmetric cosmic ray intensity decreases events are 47 and 74 respectively. Out of these events 29 and 62 events are found to be associated with geomagnetic storms respectively. Further we have observed that these symmetric and asymmetric cosmic ray intensity decreases are also associated with interplanetary shocks with the association rate 22 (46.81%), 60 (81.08%) respectively. The majority of interplanetary shocks following the onset of symmetric and asymmetric cosmic ray intensity decreases .We have 22 symmetric cosmic ray intensity decreases 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. We have 60 asymmetric cosmic ray intensity decreases out which arrival time of 37(61.66%) interplanetary shocks have been found after the onset time of asymmetric cosmic ray intensity decreases, The arrival time of 20(33.33%) interplanetary shocks have been found before the onset time of asymmetric cosmic ray intensity decreases and onset time of 03(5%) asymmetric cosmic ray decreases are common to arrival time of interplanetary shocks. Further we have found the positive correlation with correlation coefficient 0.09 and 0.60 between the magnitude of symmetric and asymmetric cosmic ray intensity decreases and geomagnetic storms respectively.
Keywords: *Cosmic ray intensity, geomagnetic storms, interplanetary shocks.*

1- INTRODUCTION

Decreases in the cosmic ray count rate which last typically for about a week, were first observed by Forbush (1937) and Hess and Demmelmair (1937) using ionisation chambers. It was the early 1950s work of Simpson using neutron monitors (Simpson, 1954) which showed that the origin of these decreases was in the interplanetary medium. There are two basic types. 'Non-recurrent decreases' are caused by transient interplanetary events which are related to mass ejections from the Sun. They have a sudden onset, reach maximum depression within about a day and have a more gradual recovery. 'Recurrent decreases' (Lockwood, 1971) have a more gradual onset, are more symmetric in profile, and are well associated with corotating high speed solar wind streams (*e.g.*, Iucci *et al.*, 1979a). Historically, all short term decreases have been called 'Forbush decreases'. However, some researchers use the name more selectively to apply to only those with a sudden onset and a gradual recovery, it i.e., the non-recurrent events associated with transient solar wind disturbances. In this paper, the term Forbush decrease (Fd) will be used in this way, and only this type of short-term cosmic ray decrease will be discussed.

When the MHD theory is taken into account, three possible speeds are present:

the sound, Alfv´en, and magnetoacoustic speeds (Landau; Lifshitz, 1960; Burlaga, 1971). Consequently there are six possible types of shocks: the fast, the slow, and four other types of intermediate shocks (Wu, 1990). However, based on the shock's evolutionary condition of ideal MHD, Taniuti (1962) and Kantrowitz and Petschek (1966) argued that the MHD intermediate shocks are not structurally stable and are physically unrealizable. However, theoretical study and numerical simulations showed that the MHD intermediate shocks are admissible and can be formed by the steepening of nonlinear MHD waves (Kennel et al. (1989) and Hau and Sonnerup (2001). The type of shock is dependent on the propagation speed of the surface in relation to the characteristic speeds of the medium (Parks (1991), Burlaga (1995) and references therein). In space, the most likely type is the fast one, characterized by an increase in the IMF strength, while the slow one is characterized by a decrease in the IMF strength. Both fast and slow shocks that move radially away from the Sun are socalled forward shocks, and the ones that move toward the Sun relatively to the solar wind are named reverse shocks. In the IP space, the forward shocks are normally formed as a consequence of the propagation of structures such as CMEs and identified by the sensors onboard satellites in orbit. In general, when a mass flux through the shock is observed and subsequently the solar wind parameters and the entropy of the system increase abruptly, a shock wave is identified.

2- SOURCES OF DATA

In this study symmetric and asymmetric cosmic ray intensity decreases ≥4%, observed during the period of 1997 to 2013 at Oulu super neutron monitor. Geomagnetic storms data has been taken from Omni web data services (http;//omniweb.gsfc.nasa.gov/form/dxi.html). Data shown in the table-1 and table-2 below.

Table1- Asymmetric cosmic ray decrease associated geomagnetic storms and interplanetary shocks.

S. No.	Date	Asymmetric cosmic ray intensity decrease		Geomagnetic storms		Shocks
		Onset set timedd (hh)	Mag %	Onset set timedd (hh)	Magnitude in nT	
1.	10.04.97	10(18)	5	10(21)	-88	na
2.	01.05.98	01(20)	6	02(04)	-214	01(22)
3.	04.07.98	04(16)	3	05(16)	-30	na
4.	25.08.98	25(12)	8	26(09)	-171	26(07)
5.	24.09.98	24(12)	10	25(00)	-203	24(24)
6.	08.11.98	08(04)	7	08(20)	-126	08(05)
7.	22.01.99	22(20)	7	22(13)	-48	na
8.	12.12.99	12(16)	8	12(18)	-77	12(16)
9.	11.01.00	11(12)	6	11(15)	-77	11(14)
10.	07.04.00	07(00)	3	06(16)	-282	na
11.	08.06.00	08(08)	8	08(13)	-96	08(09)
12.	15.07.00	15(12)	12	15(15)	-308	15(15)
13.	14.09.00	14(20)	3	na	na	15(05)
14.	17.09.00	17(12)	8	17(20)	-197	na
15.	28.10.00	28(00)	7	28(21)	-126	28(10)
16.	06.11.00	06(16)	7	06(10)	-134	06(10)
17.	26.11.00	26(12)	8	26(22)	-127	26(08)

18.	03.03.01	3(18)	3	04(03)	-68	03(11)
19.	19.03.01	19(03)	4	19(11)	-150	19(11)
20.	26.03.01	26(06)	6	na	na	na
21.	04.04.01	04(16)	8	04(16)	-57	04(15)
22.	07.04.01	07(12)	6	08(12)	-63	08(11)
23.	11.04.01	11(16)	8.5	11(15)	-269	11(14)
24.	28.04.01	28(04)	6	28(13)	-48	28(05)
25.	27.05.01	27(12)	4	na	na	27(15)
26.	17.08.01	17(16)	7	17(17)	-102	17(11)
27.	27.08.01	27(18)	7	na	na	27(20)
28.	25.09.01	25(20)	8	25(22)	-102	25(20)
29.	11.10.01	11(16)	6	11(17)	-76	11(17)
30.	21.10.01	21(16)	5	21(16)	-178	21(17)
31.	06.11.01	06(00)	12	05(19)	-297	06(02)
32.	24.11.01	24(12)	10	24(06)	-223	24(06)
33.	15.12.01	15(00)	5	na	na	na
34.	30.12.01	30(16)	5.5	30(02)	-57	30(20)
35.	10.01.02	10(16)	4.5	10(10)	-71	na
36.	23.05.02	23(12)	5	23(17)	-89	23(11)
37.	10.11.02	10(02)	7	na	na	9(18)
38.	17.11.02	17(00)	8	17(12)	-43	na
39.	22.12.02	22(12)	4	22(22)	-62	22(13)
40.	01.02.03	01(16)	5	01(20)	-69	na
41.	29.05.03	29(16)	7	29(23)	-80	29(12)
42.	29.10.03	29(00)	25	29(06)	-384	29(06)
43.	07.01.04	07(00)	8	06(20)	-66	06(20)
44.	21.01.04	21(16)	8	22(05)	-144	22(01)
45.	26.07.04	26(16)	10	26(23)	-150	26(23)
46.	07.11.04	07(08)	12	09(10)	-150	07(03)
47	08.05.05	08(06)	6	07(20)	-126	07(19)
48.	15.05.05	15(00)	7	15(05)	-293	15(02)
49.	28.05.05	28(20)	10	28(15)	-48	28(04)
50.	23.08.05	23(20)	7	24(08)	-219	24(06)
51.	11.09.05	11(00)	12	11(02)	-127	11(01)
52.	14.12.06	14(18)	10	14(21)	-143	14(14)
53.	21.05.07	21(03)	3	22(01)	-41	21(23)
54.	08.03.08	8(000	3	na	na	08(11)
55.	05.04.10	05(12)	4	05(08)	-81	05(08)
56.	03.08.10	03(12)	5	03(20)	-61	03(17)
57.	18.02.11	18(00)	4.5	18(08)	-30	18(01)
58.	05.04.11	05(06)	4.5	18(08)	-30	na
59.	23.06.11	23(00)	4	na	na	23(02)
60.	10.07.11	10(12)	4	na	na	11(08)
61.	05.08.11	05(06)	5	5(20)	-107	05(17)
62.	25.09.11	25(12)	6	26(11)	-101	26(12)
63.	24.10.11	24(18)	6	24(21	-118	24(18)
64.	01.11.11	01(00)	3	31(06)	-53	na
65.	24.01.12	24(06)	5	24(17)	-80	24(15)

66.	07.03.12	07(06)	7	8(00)	-85	07(04)
67.	05.04.12	05(18)	4	04(21	-56	na
68.	16.06.12	16(06)	5	17(001)	-86	16(19)
69.	14.07.12	14(18)	7	15(02)	-133	14(17)
70.	03.09.12	03(12)	6	na	na	03(11)
71.	13.11.12	13(00)	3	13(17)	-109	12(22)
72.	14.03.13	14(00)	8	na	na	na
73.	13.04.13	13(18)	5.5	na	na	13(22)
74.	23.06.13	23(12)	4	23(08)	-59	23(04)

Table2- Symmetric cosmic ray decrease associated geomagnetic storms and interplanetary shocks.

S. No.	Date	Symmetric cosmic ray intensity decrease		Geomagnetic storms		Shocks
		Onset set timedd (hh)	Mag %	Onset set timedd (hh)	Magnitude in nT	
1.	06.10.97	06(08)	3	na	na	na
2.	17.11.97	17(12)	6	16(21)	-35	na
3.	09.12.97	9(12)	3	10(10)	-61	10(04)
4.	06.01.98	6(00)	3	6(15)	-83	6(14)
5.	05.06.98	05(18)	5	06(16)	-49	5(10)
6.	23.10.98	23(12)	4	na	na	na
7.	11.12.98	11(12)	4	na	na	na
8.	05.05.99	5(12)	4	na	na	5(16)
9.	22.05.99	22(18)	4	na	na	na
10.	12.09.99	12(02)	3	12(09)	-78	12(04)
11.	22.03.00	22(06)	3	na	na	na
12.	12.10.00	12(04)	4	13(00)	-73	12(22)
13.	23.01.01	23(06)	3	23(18)	-53	23(11)
14.	22.07.01	22(18)	3	na	na	na
15.	03.12.01	03(20)	3.5	03(18)	-30	na
16.	27.01.02	27(18)	4	na	na	na
17.	09.04.02	9(12)	4	na	na	na
18.	01.11.02	01(18)	4	na	na	na
19.	09.01.03	9(18)	3	na	na	na
20.	07.04.03	07(12)	4	na	na	08(01)
21.	02.04.04	2(18)	3	3(14)	-113	3(10)
22.	05.08.05	5(12)	3	6(110	-35	na
23.	09.07.06	9(18)	3	na	na	9(21)
24.	09.11.06	9(12)	3	9(21)	-53	9(17)
25.	17.05.07	17(12)	3	17(12)	-25	na
26.	05.01.08	5(00)	4	na	na	04(23)
27.	08.02.08	8(12)	3	na	na	na
28.	14.06.08	14(18)	4	14(20)	-31	14(12)
29.	06.11.08	6(21)	3	07(20)	-30	07(04)
30.	22.12.08	22(12)	3	na	na	na
31.	20.01.10	20(06)	3	20(16)	-38	na

32.	14.09.10	14(18)	3	14(15)	-28	na
33.	12.12.10	12(18)	5	13(21)	-22	na
34.	11.04.11	11(6)	3	12(09)	-55	na
35.	10.06.11	10(06)	3	11(02)	-24	10(08)
36.	16.06.11	16(12)	5	na	na	17(02)
37.	23.06.11	23(00)	4	23(04)	-28	23(02)
38.	05.08.11	5(06)	6	05(20)	-111	05(17)
39.	16.09.11	16(12)	3	17(09)	-65	17(03)
40.	21.11.11	21(00)	3	22(01)	-27	na
41.	22.01.12	22(18)	4	22(11)	-71	22(05)
42.	13.02.12	13(12)	4	13(14)	-62	na
43.	18.01.13	18(00)	4	17(15)	-53	na
44.	16.02.13	16(18)	3	17(07)	-35	16(11)
45.	24.04.13	24(18)	3	24(10)	-74	na
46.	24.05.13	24(06)	3	24(18)	-55	24(18)
47	25.06.13	25(00)	3	na	na	na

3- ANALYSIS OF DATA AND RESULTS

The data of symmetric cosmic ray intensity decreases and associated geomagnetic storms are listed in table2. From the data analysis we have found 47 total number of symmetric cosmic ray intensity decreases. Out of these 47 events 29 (61.7%) symmetric cosmic rays intensity decreases have been found to be associated with geomagnetic storms.

To know the possible correlation between magnitude of symmetric cosmic ray intensity decreases and magnitude of associated geomagnetic storms .A scatter plot has been plotted between magnitude of symmetric cosmic ray intensity decreases and magnitude of associated geomagnetic storms. The scatter plot obtained between these two parameters is shown in Figure-1. The trend line of the scatter plot shows positive correlation with correlation coefficient 0.09 between magnitude of symmetric cosmic ray intensity decreases and magnitude of associated geomagnetic storms.

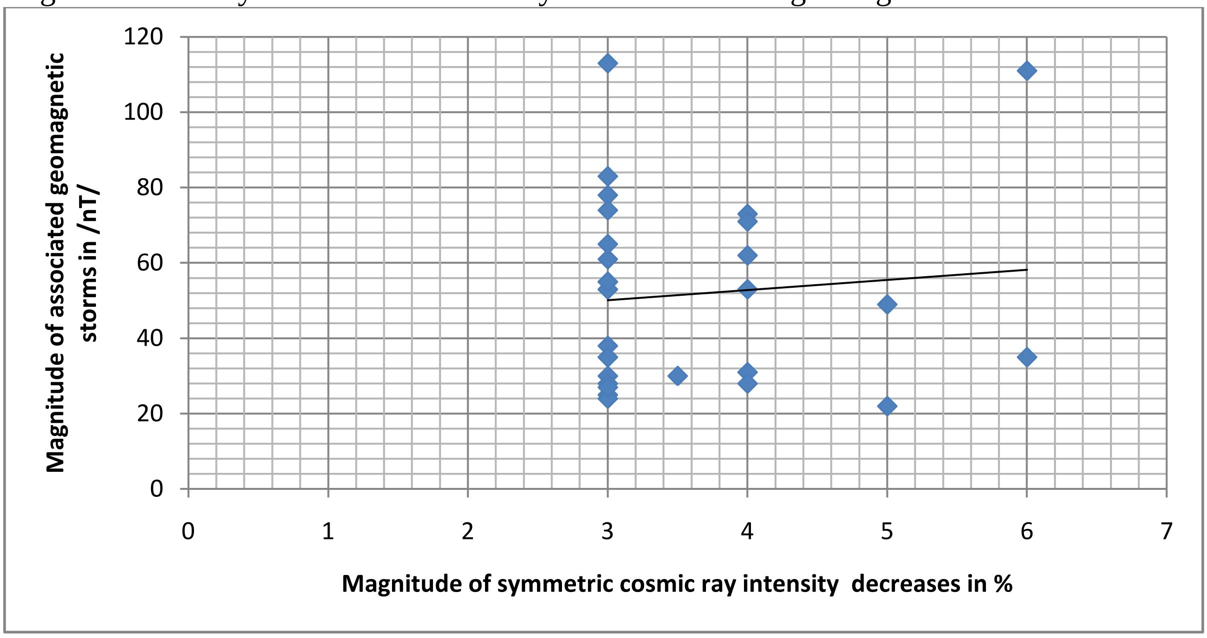

Figure 1- Shows magnitude symmetric cosmic ray intensity decreases and magnitude of associated geomagnetic storms for the period of 1997-2013 showing positive correlation with correlation coefficient 0.09.

From the data analysis given in table-1, we have found 74 total number of asymmetric cosmic ray intensity decreases.Out of these 74 asymmetric cosmic ray intensity decreases 62 (83.87 %) asymmetric cosmic rays intensity decreases have been found to be associated with geomagnetic storms.

We have plotted a scatter diagram between magnitude of asymmetric cosmic ray intensity decreases and magnitude of associated geomagnetic storms. The scatter plots obtained between these two parameters are shown in Figure-2. The trend line of the figure shows positive correlation with correlation coefficient 0.60 between magnitude of asymmetric cosmic ray decreases and magnitude of geomagnetic storms.

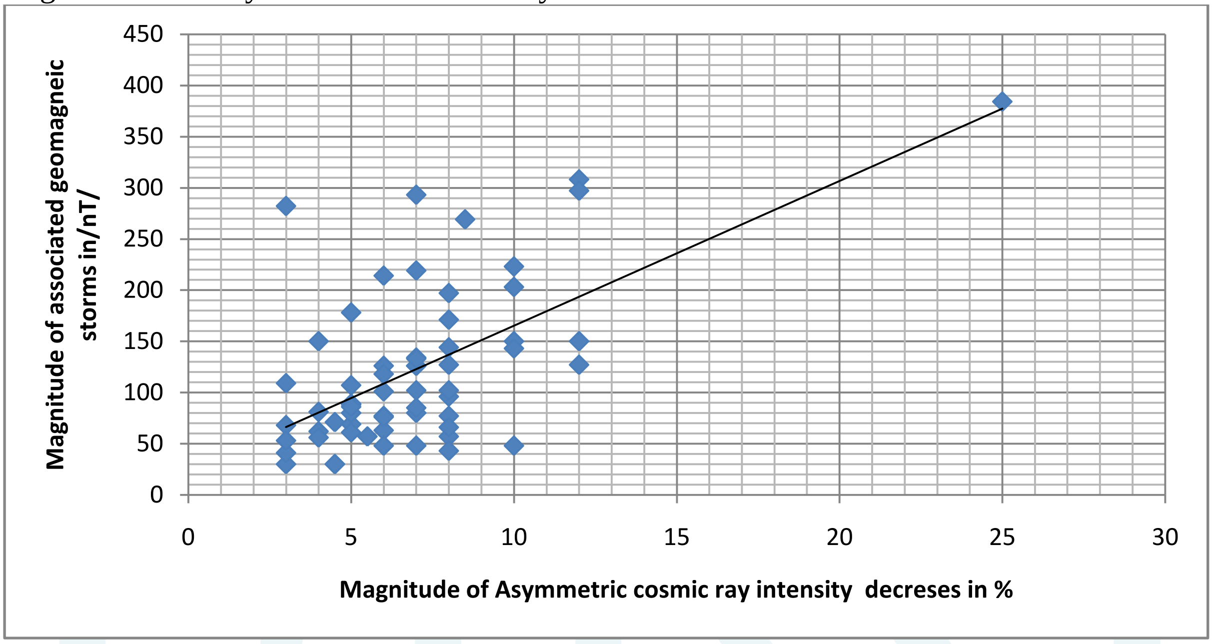

Figure 2 -Shows scatter plot between magnitude asymmetric cosmic ray intensity decreases (Fds) and magnitude of associated geomagnetic storms for the period of 1997-2013 showing positive correlation with correlation coefficient 0.60.

We have found total numbers of symmetric cosmic ray intensity decreases are 47. Out of 47 symmetric cosmic ray intensity decreases 22 (46.81%) symmetric cosmic rays intensity decreases have been found to be associated interplanetary shocks .The associated interplanetary shocks are forward shocks. 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 .

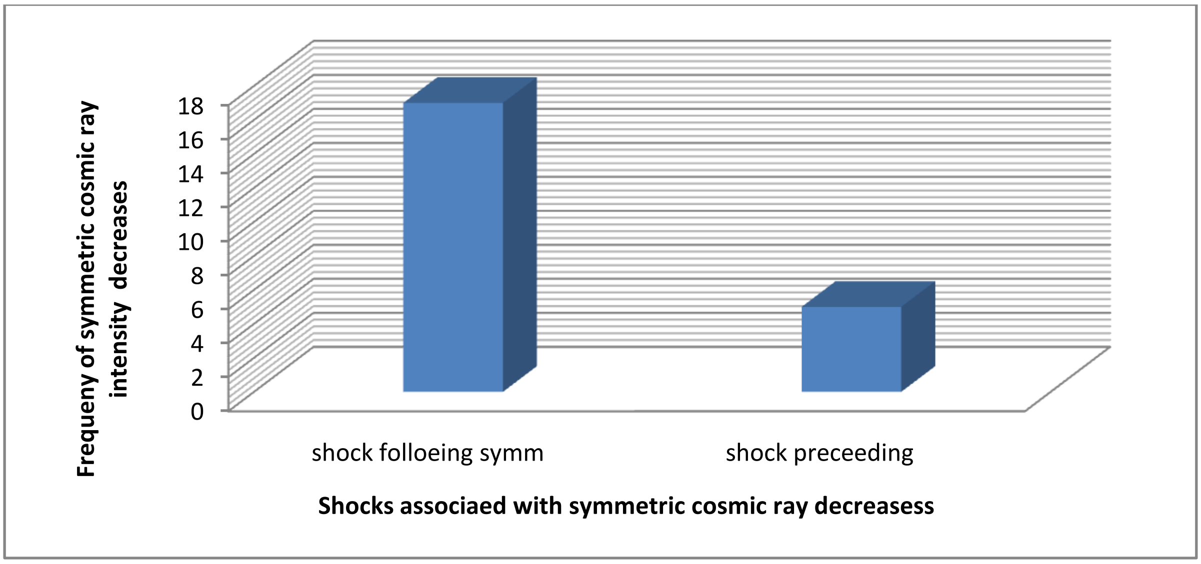

Figure 3- Shows Frequency of symmetric cosmic ray intensity decreases (Fds) associated with common onset, preceding and following the onset time of symmetric cosmic ray intensity deceases.

We have found 74 asymmetric cosmic ray intensity decreases (Fds). Out of 74 asymmetric cosmic ray intensity decreases (Fds) ,60 (81.08%) asymmetric cosmic rays intensity decreases (Fds) have been found to be associated interplanetary shocks .The associated interplanetary shocks are forward shocks. From the further analysis it is observed that majority of interplanetary shocks following the onset of asymmetric cosmic ray intensity decreases(Fds) .We have 60 asymmetric cosmic ray intensity decreases which are associated with interplanetary shocks out which arrival time of 37(61.66%) interplanetary shocks have been found after the onset time of asymmetric cosmic ray intensity decreases (Fds), The arrival time of 20(33.33%) interplanetary shocks have been found before the onset time of asymmetric cosmic ray intensity decreases (Fds) and onset time of 03(5%) asymmetric cosmic ray decreases are common to arrival time of interplanetary shocks .

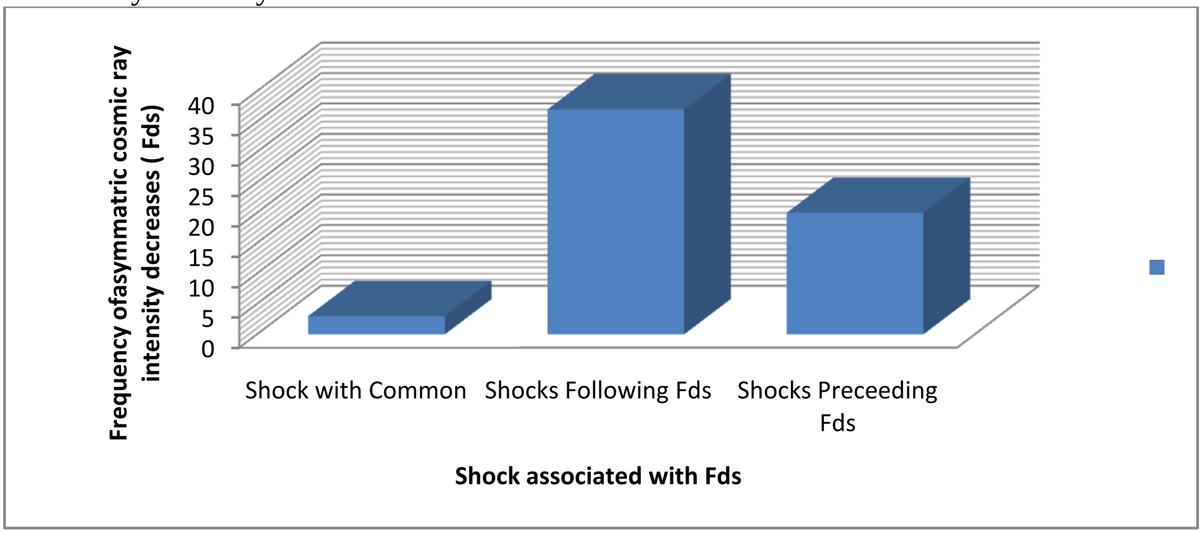

Figure 4- Shows Frequency of asymmetric cosmic ray intensity decreases (Fds) associated with common onset, preceding and following the onset time of asymmetric cosmic ray intensity deceases (Fds).

4- DISCUSSION AND CONCLUSION

From this study we have observed that most of the cosmic ray intensity decreases are found to be associated with geomagnetic storms and interplanetary shocks. The majority of interplanetary shocks following the onset of symmetric and asymmetric cosmic ray intensity decreases .We have 22 symmetric cosmic ray intensity decreases out which arrival time of 77.27% interplanetary shocks have been found after the onset time of symmetric cosmic ray intensity decreases, The arrival time of 22.72% interplanetary shocks have been found before the onset time of symmetric cosmic ray intensity decreases. We have 60 asymmetric cosmic ray intensity decreases out which arrival time of 61.66% interplanetary shocks have been found after the onset time of asymmetric cosmic ray intensity decreases, The arrival time of 33.33% interplanetary shocks have been found before the onset time of asymmetric cosmic ray intensity decreases and onset time of 5% asymmetric cosmic ray decreases are common to arrival time of interplanetary shocks.

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