Coronal Mass Ejections and Disturbances in Solar Wind Plasma Parameters in Relation With Short Term Asymmetric Cosmic Ray Intensity Decreases

P.L. Verma\textsuperscript{1}, Shiva Soni\textsuperscript{2} Anil Kumar Pimpalker\textsuperscript{3}

\textsuperscript{1}Department of Physics, Govt. Vivekanand P.G. College Maihar Satna M.P. India.
\textsuperscript{2}Research Scholar Govt. P.G. College Satna M.P. India.
\textsuperscript{3}Research Scholar A.P.S. University Rewa M.P. India.

\textbf{Abstract.} Coronal mass ejections (CMEs) are a key aspect of coronal and interplanetary dynamics. They can eject large amounts of mass and magnetic field into the heliosphere, a key source of interplanetary shocks, disturbances in solar wind plasma parameters and asymmetric cosmic ray intensity decreases (Fds). We have studied asymmetric cosmic ray intensity decreases (Fds) (magnitude $> 3.0 \times 10^{-3}$) observed at Oulu super neutron monitor, during the period of 1986-2006 with coronal mass ejections, interplanetary shocks and disturbances in solar wind plasma parameters (solar wind temperature, velocity, density). We have found that 88.46\% are associated with halo and partial halo coronal mass ejections (CMEs). The association rate between halo and partial halo coronal mass ejections are found 89.13\% and 10.87\% respectively. Most of the asymmetric cosmic ray intensity decreases (Fds) are related to interplanetary shocks (76.00\%) and the related shocks are forward shocks. We have also found positive correlation with co-relation co-efficient .46 between magnitude of asymmetric cosmic ray intensity decreases (Fds) and speed of associated coronal mass ejections. From the further study it is concluded that asymmetric cosmic ray variations are strongly related to the disturbances in solar wind plasma parameters. Positive co-relation has been found between magnitudes of asymmetric cosmic ray intensity decreases (Fds) and magnitude of jump in temperature of associated JSWT events with co-relation co-efficient is .25 between these two events. Positive co-relation has also been found between magnitude of asymmetric cosmic ray intensity decreases (Fds) and maximum velocity associated JSWV events with co-relation co-efficient .37 between these two events.

1. Introduction
The galactic cosmic ray intensity remains constant in time and space outside the heliosphere, within the heliosphere, due to various dynamical processes occurring on the sun and extending into interplanetary space, the long term and short term variation in cosmic ray intensity takes place. There are mainly two specific types of cosmic ray intensity depressions, namely corotating...
and asymmetric short term (Fds) decreases [7, 10, 13.] Forbush decreases, characterized by a fast
decrease within ~1 day followed by a more gradual nearly exponential recovery over a few days,
have been observed continuously with neutron monitors since the 1950's. 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.
It has now been proved by the recent studies that short term cosmic ray variations are strongly
related to the coronal mass ejections. Cane H.V.[7] have studied cosmic ray intensity variations
with coronal mass ejections and concluded that CMEs are large-scale phenomena that change the
configuration of the interplanetary magnetic field (IMF) and clearly modulate the cosmic-ray
intensity on short-term (few day) timescales. Forbush decreases which falls under the category of
asymmetric short term cosmic ray variations are strongly associated with coronal mass ejections
and the interplanetary shocks, Badruddin [4] has reported that abrupt onset of decrease in
intensity starts upon the arrival of certain shocks and decreases continue till the passage of post
shock turbulent sheath. He has further determined that turbulent shocks are much more effective
in producing Asymmetric cosmic ray intensity decreases (Fds) than non-turbulent shocks. Cane et
al [5,6] have inferred that the short-term cosmic ray decreases are strongly associated with ejecta
and shocks. They have reported that 88% short term cosmic ray decreases are associated with
ejecta and 70% of these are associated with shocks. Robert F. Penna et al [11] have investigated
the relation between Forbush cosmic ray decrease recovery time and coronal mass ejection transit
time between the Sun and Earth. Fedeli S.O [9] has studied two-step asymmetric cosmic ray
intensity decreases (Fds) with coronal mass ejections magnetic clouds, interplanetary shocks and
interplanetary disturbances, interplanetary magnetic field (magnitude and direction). Interplanetary
coronal mass ejection (ICME) impacting on slow solar wind, there is a sheath upstream of the ICME led by a fast forward shock and the large IMF variations in this sheath, which sustained the Forbush decreases (Fds) in the cosmic ray intensity. P Subhrmanayam et al [12] have studied asymmetric short term cosmic ray intensity decreases (Fds) with coronal mass ejections and inferred that these decreases (Fds) are associated with front side coronal mass ejections.
E. A. Chuchkov et al [8] have analyzed the modulation structures of quasi-symmetric (“bays”)
short-term Forbush decreases. It is concluded that these Forbush decreases were recorded due to
the stations flying through coronal mass-ejection regions. The short term variation of cosmic ray
intensity recorded with ground based monitors have been studied by several scientists [1,2,3,9]
and have inferred that the measure cause of asymmetric cosmic ray decreases (Fds) are coronal
mass ejections and their interplanetary manifestations.

2. Experimental data
In this work hourly data of oulu super neutron monitor are used to determine asymmetric cosmic
ray intensity decreases in cosmic ray intensity .The data of different types of coronal mass
ejections have been taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. The data of interplanetary
shocks are 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 has been used and these data has
also been taken from omni web data also.
| Asymmetric cosmic ray intensity decreases (Fds) | Temperature | Velocity | CMEs | Date time dd(hh) | Type H/ P | Speed dK/s |
|---|---|---|---|---|---|---|
| date | Onset set timedd (hh) | mag% | shocks | Start time dd(hh) | Magnitude of Jump in Deg k | Start time dd(hh) | Magnitude of Jump km/s |
| 06.02.86 | 06(12) | 12 | 06(13) | 06(03) | 138008 | 06(04) | 84 | nd | nd | nd |
| 04.11.86 | 04(00) | 5.5 | 03(24) | nd | nd | nd | nd | nd | nd | nd |
| 10.04.87 | 10(12) | 5 | na | nj | nj | nj | nj | nd | nd | nd |
| 25.08.88 | 25(06) | 6 | 25(10) | nd | nd | nj | nj | nd | nd | nd |
| 10.10.88 | 10(00) | 5 | 10(03) | 09(02) | 521861 | 09(01) | 58 | nd | nd | nd |
| 04.01.89 | 04(18) | 5 | 4(23) | 04(14) | 18666 | 04(11) | 32 | nd | nd | nd |
| 13.02.89 | 13(00) | 4 | na | nj | nj | nd | nd | nd | nd | nd |
| 16.02.89 | 16(08) | 3.5 | na | nd | nd | nd | nd | nd | nd | nd |
| 13.03.89 | 13(00) | 15 | 13(01) | nd | nd | nd | nd | nd | nd | nd |
| 27.03.89 | 27(00) | 6 | 27(14) | nd | nd | nd | nd | nd | nd | nd |
| 01.07.89 | 01(06) | 3 | 01(07) | nd | nd | nd | nd | nd | nd | nd |
| 08.11.89 | 08(13) | 6.5 | 08(11) | nd | nd | nj | nj | nd | nd | nd |
| 28.11.89 | 28(06) | 14 | 27(22) | 27(20) | 401301 | 27(19) | 195 | nd | nd | nd |
| 30.03.90 | 30(06) | 8 | 30(07) | 30(00) | 13004 | nj | nj | nd | nd | nd |
| 08.04.90 | 08(13) | 10.5 | 09(09) | nd | nd | nd | nd | nd | nd | nd |
| 27.09.90 | 27(10) | 5 | 28(01) | nd | nd | nd | nd | nd | nd | nd |
| 01.08.90 | 01(13) | 4.5 | 01(08) | 01(07) | 526211 | 01(06) | 169 | nd | nd | nd |
| 09.10.90 | 09(13) | 4 | 09(13) | 08(19) | 58997 | 08(21) | 114 | nd | nd | nd |
| 02.01.91 | 02(16) | 3 | na | nd | nd | nd | nd | dn | nd | nd |
| 24.01.91 | 24(12) | 4 | 23(21) | 23(09) | 31788 | nj | nj | nd | nd | nd |
| 24.03.91 | 24(02) | 16 | 24(02) | nd | nd | nd | nd | nd | nd | nd |
| 24.04.91 | 24(20) | 8.5 | 24(21) | 24(17) | 326958 | 24(17) | 158 | nd | nd | nd |
| 23.05.91 | 23(18) | 6 | 22(00) | 23(13) | 154262 | 23(06) | 116 | nd | nd | nd |
| 12.06.91 | 12(12) | 18 | 12(10) | 11(19) | 140534 | 11(12) | 32 | nd | nd | nd |
| 08.07.91 | 08(12) | 9 | 08(17) | 08(01) | 156329 | 07(15) | 37 | nd | nd | nd |
| 12.07.91 | 12(09) | 7 | 12(09) | 12(03) | 513598 | 12(02) | 112 | nd | nd | nd |
| 18.08.91 | 18(20) | 9.5 | 18(19) | 18(10) | 524912 | 18(11) | 204 | nd | nd | nd |
| 27.08.91 | 27(13) | 4.5 | 27(15) | 27(13) | 319599 | 27(13) | 129 | nd | nd | nd |
| 10.09.91 | 10(16) | 3.5 | na | 10(10) | 226419 | 10(11) | 85 | nd | nd | nd |
| 28.10.91 | 28(08) | 17 | 28(11) | 28(05) | 117686 | 10(06) | 347 | nd | nd | nd |
| 08.11.91 | 8(04) | 8 | 08(13) | nd | nd | nd | nd | nd | nd | nd |
| 03.02.92 | 03(02) | 3 | na | nd | nd | nd | nd | nd | nd | nd |
| 07.02.92 | 07(12) | 5.5 | na | 06(22) | 27029 | 07(00) | 38 | nd | nd | nd |
| 26.02.92 | 26(18) | 8 | 26(17) | nd | nd | nd | nd | nd | nd | nd |
| 01.03.92 | 01(06) | 4 | na | nd | nd | nd | nd | nd | nd | nd |
| 17.03.92 | 17(10) | 5 | 17(10) | nj | nj | 17(07) | 201 | nd | nd | nd |
| 09.05.92 | 09(13) | 8.5 | 09(20) | 08(19) | 264466 | nj | nj | nd | nd | nd |
| 10.06.92 | 10(06) | 4 | 10(04) | 09(11) | 171411 | 09(08) | 88 | nd | nd | nd |
| 20.08.92 | 20(10) | 8 | 19(22) | 19(12) | 21895 | nj | nj | nd | nd | nd |
| 08.09.92 | 08(10) | 7 | 09(02) | 08(22) | 67832 | 09(00) | 163 | nd | nd | nd |
| 08.10.92 | 08(06) | 5 | 08(19) | nd | nd | nd | nd | nd | nd | nd |
| 03.11.92 | 3(12) | 4 | na | 02(17) | 291417 | nj | nj | nd | nd | nd |
| 09.11.92 | 09(13) | 4 | na | 09(04) | 41619 | 09(04) | 38 | nd | nd | nd |
| 02.01.93 | 02(03) | 3.5 | na | nd | nd | nd | nd | nd | nd | nd |
3. Data Analysis and Results

The number of asymmetric cosmic ray intensity decreases (Fds), associated coronal mass ejections and disturbances in solar wind plasma parameters observed during the period of period of 22nd and 23rd solar cycle are listed in table. The total number of asymmetric cosmic ray intensity decreases (Fds are 112. From the data analysis of asymmetric cosmic ray intensity decreases (Fds) and coronal mass ejections it is observed that out of 112 asymmetric cosmic ray intensity decreases (Fds) we have no data of CMEs for 47 asymmetric cosmic ray intensity decreases (Fds) for association. We have CMEs data for 52 asymmetric cosmic ray intensity decreases (Fds) in which 46 (88.46%) are found to be associated with coronal mass ejection (CMEs). From the further analysis these CMEs associated asymmetric cosmic ray intensity decreases (Fds) 05 (10.87%) are found to be associated with partial halo CMEs and 41 (89.13%) are found to be associated with full halo coronal mass ejections. To know the relationship between magnitude of asymmetric cosmic ray intensity.

| Date       | Month | Day | CMEs (no.) | Asymmetric Cosmic Ray Intensity Decreases (Fds) |
|------------|-------|-----|------------|-----------------------------------------------|
| 10.11.02   | 10(02)|  7  | 9(18)      | 68657                                        |
| 17.11.02   | 17(00)|  8  | na         | 82834                                        |
| 22.12.02   | 22(12)|  4  | 22(13)     | 231230                                       |
| 01.02.03   | 01(16)|  5  | na         | 612954                                       |
| 29.05.03   | 29(16)|  7  | 29(12)     | 489103                                       |
| 29.10.03   | 29(00)|  25 | 29(06)     | 979536                                       |
| 07.01.04   | 07(00)|  8  | 06(20)     | 555367                                       |
| 21.01.04   | 21(16)|  8  | 22(01)     | 509255                                       |
| 26.07.04   | 26(16)| 10  | 26(23)     | 1532645                                      |
| 07.11.04   | 07(08)| 12  | 07(03)    | 786124                                       |
| 08.05.05   | 08(06)|  6  | 07(19)     | 866682                                       |
| 15.05.05   | 15(00)|  7  | 15(02)     | 117968                                       |
| 28.05.05   | 28(20)| 10  | 28(04)     | 187910                                       |
| 23.08.05   | 23(20)|  7  | 24(06)     | 2718176                                      |
| 11.09.05   | 11(00)| 12  | 11(01)     | 1876759                                      |
| 14.12.06   | 14(18)| 10  | 14(14)     | 240834                                       |

Figure 1 Shows scatter plot between magnitude of asymmetric cosmic ray intensity decreases and speed of associated CMEs showing positive correlation with correlation coefficient 0.46
Figure 2 Shows Scatter plot between magnitude of geomagnetic storms and magnitude of Jump in solar wind plasma temperature (JSWT) showing positive correlation with correlation coefficient 0.25

Figure 3 Shows Scatter plot between magnitudes of geomagnetic storms and magnitude of Jump in solar wind plasma velocity (JSWV) showing positive correlation with correlation coefficient 0.37

decreases and speed of associated CMEs we have plotted scatter diagram between magnitude of asymmetric cosmic ray intensity decreases and speed of associated CMEs .The resulting diagram is shown in fig 1 and figure shows positive correlation between these two events .Statistically calculated co-relation co-efficient .46 have bee found between magnitude of asymmetric cosmic ray intensity decreases (Fds) and speed of associated coronal mass ejections.
From the data analysis of asymmetric short term cosmic ray decreases (Fds)and jump in solar wind plasma temperature we have found that the most majority of Asymmetric (Fds) short term cosmic ray decreases are found to be associated with JSWT events. We have 112 Asymmetric (Fds) short term cosmic ray decreases data for which is available for association with JSWT events are 85 .Out of these 85 events, 78 asymmetric (Fds) short term cosmic ray decreases are (91.76%) found to be associated with jump in solar wind plasma temperature.
To sees how the magnitude of asymmetric cosmic ray intensity decreases (Fds) is correlated with JSWT events. We have plotted a scatter diagram between the magnitude of asymmetric cosmic ray intensity decreases (Fds) and magnitude JSWT events in fig.2 It is clear from the fig that most of the asymmetric cosmic ray intensity decreases (Fds) which have large magnitude are associated with such JSWT events which have large magnitude, but the magnitude of these two events do not have any fixed proportion, we have found some asymmetric cosmic ray intensity decreases (Fds) which have
large magnitude but they are associated with such JSWT events which have small magnitude. Positive co-relation has been found between magnitudes of asymmetric cosmic ray intensity decreases (Fds) and magnitude of jump in temperature of associated JSWT events. Statistically calculated co-relation co-efficient is .25 between these two events.

The asymmetric cosmic ray intensity decreases are also associated with jump in Solar wind plasma velocity (JSWV). From the analysis we have112 asymmetric cosmic ray intensity decrease (Fds) but data of JSWV events for association are available for 86 asymmetric cosmic ray intensity decrease (Fds). From the data analysis we have obtained that asymmetric cosmic ray intensity decrease (Fds) are closely associated with JSWV events. Out of these, 86, 69 (80.23%) asymmetric cosmic ray intensity decrease (Fds) are associated with JSWV events.

To see how the magnitude of asymmetric cosmic ray intensity decreases (Fds) are correlated with the magnitude of JSWV events, we have plotted a scatter diagram between the magnitude of asymmetric cosmic ray intensity decreases (Fds) and JSWV events in fig.3 From the figure it is clear that maximum asymmetric cosmic ray intensity decreases (Fds) which have large magnitude are associated with such JSWV events which have relatively large magnitude but magnitude of these two events do not have any quantitative relation their amplitude do not have any fixed proportion. We have found some asymmetric cosmic ray intensity decreases (Fds) which have large magnitude but they are associated with such JSWV events which have small magnitude. Positive co-relation has been found between magnitude of asymmetric cosmic ray intensity decreases (Fds) and magnitude of associated JSWV events. Statistically calculated co-relation co-efficient is .37 between these two events.

4. Conclusion
From our study 46 out of 52 asymmetric cosmic ray intensity decreases (Fds) (88.46%) are found to be associated with coronal mass ejection (CMEs). The association rates of halo and partial halo coronal mass ejections have been found 89.13% and 10.87 % respectively. Positive co-relation with co-relation co-efficient .46 have bee found between magnitude of asymmetric cosmic ray intensity decreases (Fds) and speed of associated coronal mass ejections. Most of the asymmetric cosmic ray intensity decreases have been found associated with interplanetary shocks. Positive correlation have also been found between magnitude of asymmetric cosmic ray intensity decreases and associated jump in solar wind temperature and solar wind velocity. From these results it is concluded that majority of the asymmetric cosmic ray intensity decreases(Fds) are caused by halo coronal mass ejections and interplanetary shocks, disturbances in solar wind plasma parameters that they generate.

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