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A View on Cosmic Ray Intensity with Solar Flares and Coronal Mass Ejections

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Abstract

The galactic cosmic-ray intensity recorded at Earth has an 11 year variation opposite to that of the sunspot number (SSN). The cosmic-ray intensity has its minimum at the maximum of the sunspot cycle. In this study we have considered cosmic ray intensity decreases of asymmetric type which have magnitude $\geq 4.0\%$ *during the period of 1997 to 2008 at Oulu super neutron monitor with coronal mass ejections (CMEs) and solar flares (SF). In this duration the maximum count of SSN was 180.3. During decreasing phase of the cycle (2003-2008) the cosmic ray intensity decreases are high. For this period we have observed 54 cosmic ray intensity decreases (Fds) out of which 50 (92.59%) cosmic ray intensity decreases (Fds) have been identified as being associated with CMEs and SF. The association rate of Halo and Partial Halo CMEs have been found (90.00%) and (10.00%) respectively. The association rate of solar flares of different categories and majority of the associated solar flares are M-Class flares (56%). The association rate of X, C and B class solar flares are found to be 28%, 14% and 2% respectively. With statistical observation found that the magnitude of cosmic ray intensity decreases and associated speed of CMEs are correlated with correlation coefficient 0.45.*

Keywords: Cosmic ray intensity decreases, SSN, CMEs, Solar Flares.

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 ionization 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. Historically, all short term decreases have been called 'Forbush decreases'.

The intensity of galactic cosmic rays measured on Earth is related to the Sun's cycle of activity, which is well known by astronomers. The solar magnetic field flips every 11 years and the number of sunspots and coronal mass ejections rises and falls twice in each complete 22-year cycle. The cosmic ray intensity on Earth also peaks twice every 22 years in time with the solar cycle. Cliver and Ling (2001) have discovered a quirk in this pattern - and they believe that coronal mass ejections could be responsible for it. The interaction of cosmic rays with the strong magnetic fields of CMEs affects the intensity of cosmic rays on Earth.

Cane et al. (1996) have studied and reported the combined effect of solar flares and CMEs for producing short term decreases in cosmic ray intensity.

Soni & Gour (2017) reported that CRI of symmetric type associated with the CMEs and flares but most of the CRI related with P type CMEs and C class flares. CMEs and CRI decreases were weakly correlated. Cosmic ray intensity (CRI) varies with numerous causes including the solar wind parameters and sunspots numbers. Mishra et al. (2008) argued that solar wind velocity has a strong positive correlation with CRI during solar cycle 21.

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.

Belov et al. (2014) investigated FDs making use of the CME database from SOHO and GCR intensity from the worldwide neutron monitor network. They found good correlations of the FD magnitude with the CME initial speed, the ICME transit speed, and the maximum solar wind speed. The cosmic-ray intensity remains exceptionally high after reaching the highest levels in the space age during the extended solar minimum (Gopalswamy et al. 2015).

In this work an attempt has been done to study the asymmetric type forbush decreases with major solar flares and CMEs for solar cycle 23.

2. DATA SELECTION AND METHOD

The data used in this study were obtained from different sources between 1997 and 2008. 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 cosmic ray intensity decreases adopted from the Cosmic Ray Station of the University of Oulu/Sodankyla Geophysical Observatory (http://cosmicrays.oulu.fi/).

To achieve the objective of the study we use the statistical analysis by using the Carl Person correlation coefficient. The correlation coefficient is a degree of association, denoted by r. It is sometimes called Pearson's correlation coefficient after its originator and is a measure of linear association between two parameters. The correlation coefficient is measured on a scale that varies from + 1 to – 1.

3. RESULT AND DISCUSSION

In this manuscript we have indentified asymmetric cosmic ray intensity decreases (Fds) from 1997-2008 having magnitude ≥ 4.0% at Oulu neutron monitor. We find out the association of these Fds with CMEs and SF by collecting the data from various catalogues.

3.1 Cosmic ray intensity decreases with CMEs

From the data analysis we have found total numbers of asymmetric cosmic ray intensity decreases (Fds) are 54. Out of 54, we have no data of CMEs for 4 events. The available data of CMEs for association are 50 events (92.59%). The majority of associated CMEs are halo CMEs, the association rate of H Type and P types CMEs have been found 45(90.00%) and 5(10.00 %) respectively see in figure-1.

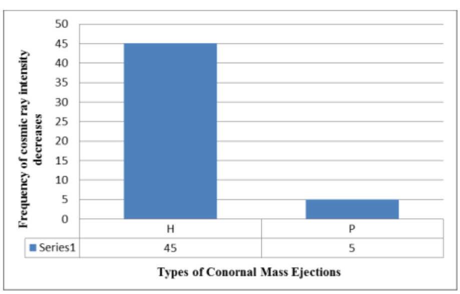

Figure1-Shows bar diagram of asymmetric cosmic ray intensity decreases (Fds) and types of associated CMEs.

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. Figure-2 shows positive correlation between magnitude of asymmetric cosmic ray intensity decreases (Fds) and speed of associated CMEs with correlation coefficient 0.45.

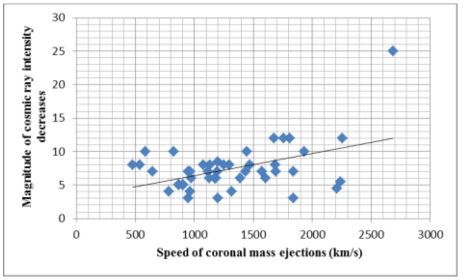

Figure2-Shows Scatter plot between magnitude of asymmetric cosmic ray intensity decreases (Fds) and speed of associated CMEs showing positive correlation with correlation coefficient 0.45.

3.2 Cosmic ray intensity decreases with solar flares

We have analyzed asymmetric cosmic ray intensity decreases (Fds) with X ray solar flares of different categories. From the data analysis it is observed 54 asymmetric cosmic ray intensity decreases (Fds) out of which 50 (92.59%) asymmetric cosmic ray intensity decreases (Fds) have been identified as being associated with X ray solar flares of different categories and majority of the associated solar flares are M-Class solar flares 28(56.00%). Gour et al. 2022 argued that for cycle 23 & 24 Fds associated mostly with M class flares. Figure-3 shows X-ray solar flares and frequency of associated asymmetric cosmic ray intensity decreases (Fds).

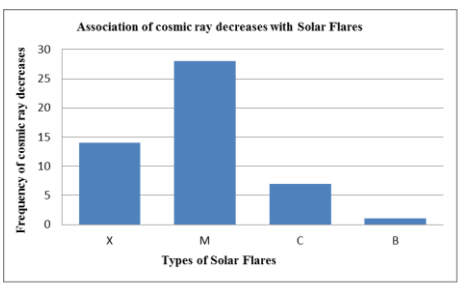

Figure3- Shows types of solar flares and frequency of associated asymmetric cosmic ray intensity decreases (Fds).

With the help of statistical analysis we have found that M and X class flares have positive correlation with cosmic ray intensity decreases having coefficient 0.33 and 0.77 respectively but B and C class flares have no correlation. From these results it is concluded that asymmetric cosmic ray intensity decreases (Fds) are closely related to X- ray solar flares, particularly M and X class flares. From these analysis we have conclude that both CMEs and flares are responsible for the cosmic ray intensity variation (Cane et al.1996) but here X class flares have more that 70% association with decreases that means it is responsible for the depressions in the cosmic ray intensity.

4. CONCLUSIONS

In this investigation we have studied asymmetric cosmic ray intensity decreases (Fds) of magnitude ≥4% during the solar activity cycle 23 (1997-2008) with different solar parameters. We have seen that asymmetric cosmic ray intensity decreases are closely related with X-ray solar flares particularly M and X class solar flares with positive correlation 0.33 and 0.77 respectively. Asymmetric cosmic ray intensity decreases (Fds) are also well related with CMEs, particulary with Halo type CMEs. Further this study may continue with coronal holes eruptions which may also responsible for cosmic ray intensity depressions.

Acknowledgement
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