Effect of high-speed solar wind streams on cosmic ray nucleonic intensity during low amplitude days

REKHA AGARWAL MISHRA [1], RAJESH K. MISHRA [2], RAVI KATARE [1]
[1] *Department of Physics, Govt. Model Science College (Autonomous), Jabalpur (M.P.) 482 001, India*
[2] *Computer and IT Section, Tropical Forest Research Institute, P.O.: RFRC, Mandla Road, Jabalpur (M.P.) 482 021, India*
contact. rkm_30@yahoo.com

Abstract: There are two types of high-speed solar wind streams classified in two categories: coronal hole associated and flare generated streams. These two types of streams are classified in two categories base on magnetic field and solar wind plasma parameters. We studied the dependence of cosmic ray depressions due to high-speed solar wind streams during low amplitude days. Cosmic ray intensity data was subjected to superposed epoch analysis with respect to high-speed solar wind streams start time. The two types of solar wind streams (corotating streams and flare-generated streams) produce significant deviations in cosmic ray intensity during low amplitude anisotropic wave train events. On the onset of both types of streams the cosmic ray intensity reaches to its minimum during low amplitude events and then increases statistically.

Introduction

The enhancement or subsidence of both high-speed solar wind streams (HSSWS) and the galactic cosmic rays in the minimum or the maximum phase of the solar cycle are interpreted in a unified manner by the concept of geometrical evolution of the general magnetic field of corona-helio-magnetosphere system. The subsidence of HSSWS in the maximum phase is understood as a braking of the solar wind streams by the tightly closed and strong coronal field lines in the lower corona in the maximum phase.

The decrease of the galactic cosmic rays in the maximum phase (known as the Forbush's negative correlation between the galactic cosmic rays and solar activity or the Forbush solar cycle modulation of the galactic cosmic rays) is interpreted as a braking of galactic cosmic rays by the closed magnetic field lines at the heliopause.

The high-speed solar wind streams lasting for several days are observed by satellites and spacecrafts. These HSSWS produce significant geomagnetic disturbances and variations in the level of cosmic ray intensity. The HSSWS are thus a key link in the complex chain of events that link geomagnetic activity/cosmic ray intensity to the solar activity and are therefore, of great interest to the solar terrestrial physics community [1-4].

Two types of high-speed solar wind streams namely flare generated streams (FGS) and corotating streams (CS) are found equally effective in producing cosmic ray intensity decreases. Iucci et al. [1] and Shukla et al. [5] have shown that the close correspondence between the cosmic ray intensity decreases observed by high-speed streams produced by solar flares accompanied by Forbush decreases whose amplitudes are not directly correlated with the increase in solar wind speed. These latter decreases are usually large and are dependent on the location of the solar flares.

Yadav et al. [6] studied the effect of two types of HSSWS on cosmic ray intensity using the data of three neutron-monitoring stations. They reported that cosmic ray depressions associated with coronal hole streams are much smaller than the typically Forbush-like depressions and no spectral difference is found in the Forbush-like decreases

between the periods before and after the polarity changes. Jadhav et al. [7] have studied the behaviour of semi-diurnal anisotropy for low amplitude anisotropic wave train events (LAEs) by comparing the average semi-diurnal amplitude for each event with 27-day or annual average semi-diurnal amplitude. They found that there is no significant difference between the two wave trains. For these LAE cases the semi-diurnal amplitude is found to be normal, which shows that the diurnal and semi-diurnal anisotropies are not related with each other for these LAEs.

Number of low amplitude events has been studied and it was observed that the diurnal time of maximum consistently remains along the corotational direction for majority of the events or shifts towards later/earlier hours and the occurrence of these events do not found to depend upon the HSSWS [8-11]. The occurrence of LAE is dominant for the positively directed Bz component of IMF polarity [12].

Data and analysis

Using the long-term plots of the CR intensity data as well as the amplitude observed from the CR pressure corrected hourly NM data using harmonic analysis the Low amplitude wave train events have been selected on the basis of following criteria:

LAE events of continuous days have been selected when the amplitude of diurnal anisotropy remains lower than 0.3% on each day of the event for at least five or more days.

In the selection of these types of events, special care has been taken, i.e. if there occurred any pre-Forbush decreases or post-Forbush decrease before or after the event or the event is in recovery phase or declining phase are not considered.

On the basis of above selection criteria we have selected 29 LAE events during the period 1981-94. The hourly CR intensity data for Deep River NM station [Geog. Lat. 46.10 (Deg.), Geog. Long. 282.50 (Deg.), Vertical cut off rigidity 1.02 (GV)] has been investigated in the present study.

Results and Discussion

In the present study we have identified the two types of high-speed solar wind streams using the plots of hourly values of interplanetary parameters [13-17] to study the role of these two types of streams in LAE.

These two types of high-speed solar wind streams namely corotating or coronal hole associated streams (CS) and the flare-generated streams (FGS) are identified following the criteria suggested by Mavromichalaki et al. [18]. The large Forbush decreases in cosmic ray intensity if any have been excluded to avoid their influence. On the basis of above selection criteria we have identified 7 corotating streams and 1 flare-generated stream during 29 LAEs.

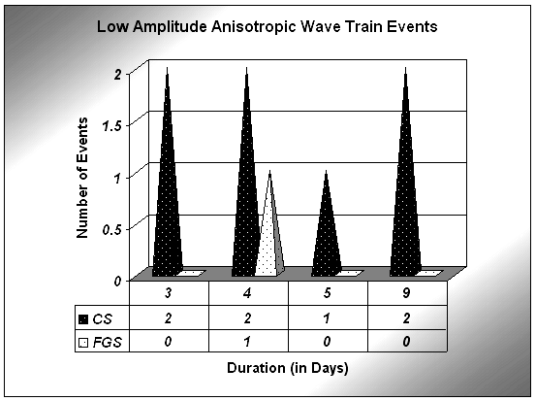

Fig 1: Frequency histogram of high-speed solar wind streams according to the duration of high-speed streams in days: Corotating and Flare-generated for LAE events during 1981-1994.

We have adopted the chree analysis of superposed epoch to study the effect of high- speed solar wind streams on cosmic ray intensity using the daily average cosmic ray intensity of Deep River neutron monitor during LAE. The occurrence of two types of HSSWS during LAE for the period 1981-94 has been plotted in Fig 1. It is clearly seen from the Fig that number of corotating streams is greater than the number of flare-generated streams and also indicates the tendency for larger duration in corotating streams for LAE.

To study the effect of these streams on LAE, we have adopted the Chree analysis of superposed epoch for days –5 to +5 and plotted in Fig 2 (a, b) as a percent deviation of cosmic ray intensity data alongwith statistical error bars (I) for Deep River for the period 1981-94 during LAE. Deviation for each event is obtained from the overall average of 11 days. Epoch day (zero day) correspond to the starting days of high-speed solar wind streams. As depicted in Fig 2a the decrease in cosmic ray intensity starts from –4 day and reaches to its minimum on zero epoch day i.e. on the onset of flare-generated stream and then start increasing upto +2 day. On the other hand as seen from Fig

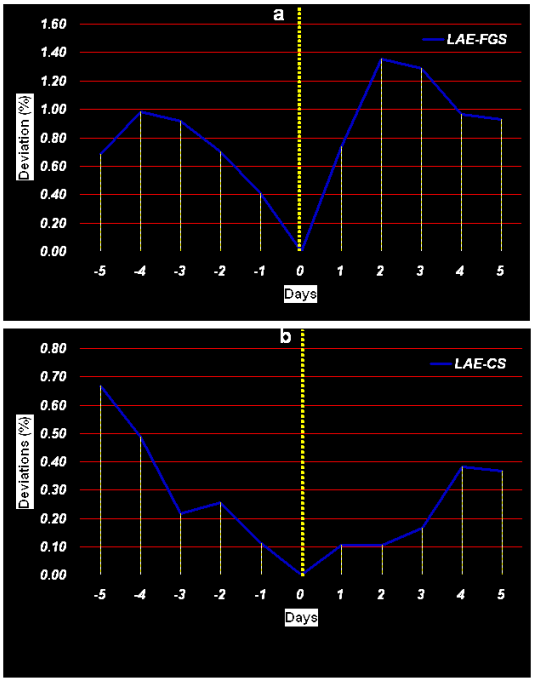

Fig 2: The results of chree analysis of superposed epoch from –5 to +5 days with respect to zero epoch days for LAE events alongwith statistical error bars (I) during (a) Corotating and (b) Flare-generated streams during 1981-94.

2b the significant decrease in cosmic ray intensity starts from –5 day during corotating stream and reaches to its minimum on the onset of stream i.e. epoch day and then increases statistically up to +5 day.

Thus we observed that on the onset of both types of streams the cosmic ray intensity reaches to its minimum during LAE events and then increases statistically. It is also evident that both types of streams produce significant deviation in cosmic ray intensity during LAE. Thus we may conclude that both types of solar wind streams produce significant deviations in cosmic ray intensity during LAE. Shrivastava and Jaiswal [19] and Shrivastava [20] reported almost equal influence of FGS and CS solar wind streams on cosmic ray transient decreases.

Badruddin [21] studied the two classes, coronal hole and solar flare associated streams alongwith the observed heliospheric plasma and field parameters of these streams such as speed, field strength and its variance in a systematic manner in order to see their effects in cosmic ray modulation. He found that flare associated streams are much more effective in modulation than streams from coronal holes. However, the possibility that solar wind structures during two types of streams might be different, the field variance appears to be the most critical parameter responsible for this difference in their effectiveness in modulation.

Sabbah [22] studied the behavior of cosmic rays observed by three stations during a time of high-speed solar-wind events. These stations cover the median rigidity range 16-164 GV. The influence of the interplanetary magnetic field associated with HSSW has also been studied. They reported that both the cosmic-ray intensity and geomagnetic activity are enhanced by coronal-mass-ejection events. They argued that IMF magnitude and fluctuation are responsible for the depression of cosmic-ray intensity during HSSW events and this depression is rigidity dependent. Low-energy cosmic rays suffer more intensity depression. The rigidity spectrum of the cosmic-ray intensity decreases is dependent upon the phase of the solar cycle.

Conclusions

From the present study following conclusions may be drawn:

- On the onset of both types of streams the cosmic ray intensity reaches to its minimum during low amplitude events and then increases statistically.

- The two types of solar wind streams (Corotating and Flare generated) produce significant deviations in cosmic ray intensity during low amplitude anisotropic wave train events.

Acknowledgements

The authors are indebted to various experimental groups, in particular, Prof. Margret D. Wilson, Prof. K. Nagashima, Miss. Aoi Inoue and Prof. J. H. King for providing the data.

References

[1] N. Iucci, M. Parisi, M. Storini and G. Villoresi, Nuovo Cimento, 2C, 421, 1979.

[2] D. Venkatesan, A. K. Shukla, and S. P. Agrawal, Solar Phys., 81, 375, 1982.

[3] H. Mavromichalaki, A. Vassilaki, E. Martmatsouri, Solar Phys., 115, 345, 1988.

[4] B. A. Lindblad, H. Lundstedt, B. Larsson, 120, 145, 1989.

[5] J.P. Shukla, A.K., Shukla, R.L. Singh, and S.P. Agrawal, Ind. J. Rad. And Space Phys., 8, 230, 1979.

[6] R. S. Yadav, N. K. Sharma, and Badruddin, Solar Phys., 151, 393, 1994.

[7] D. K. Jadhav, M. Shrivastava, A. K. Tiwari, and P. K. Shrivastava, 18th Int. Cosmic Ray Conf., Bangalore, 3, 337, 1983.

[8] S. Kumar, and M. L. Chauhan, Ind. J. Radio & Space Phys., 25, 106, 1996a.

[9] S. Kumar, and M. L. Chauhan, Ind. J. Radio & Space Phys., 25, 232, 1996b.

[10] S. Kumar, M. L. Chauhan, and S. K. Dubey, Solar Phys., 176, 403, 1997.

[11] Rajesh K Mishra, Ph.D. thesis, Rani Durgawati University, Jabalpur, INDIA, 2006.

[12] S. Kumar, Rajesh K. Mishra, Rekha Agarwal Mishra, and S. K. Dubey, 29th Int. Cosmic Ray Conf., Pune, 2, 69, 2005.

[13] J. King, Interplanetary Medium Data Book-Supplement 2, NSSD/WDC-A, Goddard Space Flight Centre, Greenbelt, Maryland, 1983

[14] J. King, Interplanetary Medium Data Book-Supplement 3, NSSD/WDC-A, Goddard Space Flight Centre, Greenbelt, Maryland, 1986a.

[15] J. King, Interplanetary Medium Data Book-Supplement 3A, NSSD/WDC-A, Goddard Space Flight Centre, Greenbelt, Maryland, 1986b.

[16] J. King, Interplanetary Medium Data Book-Supplement 4, NSSD/WDC-A, Goddard Space Flight Centre, Greenbelt, Maryland, 1989.

[17] J. King, and N. E. Papitashvili, Interplanetary Medium Data Book, NSSCD/WDC-A-R@S94-08, Goddard Space Flight Centre, Greenbelt, Maryland, 1994.

[18] H. Mavromichalaki, A. Vassilaki, and E. Marmatsouri, Solar Phys., 115, 345, 1988.

[19] P. K. Shrivastava, and K. L. Jaiswal, Solar Phys., 214, 195, 2003.

[20] P. K. Shrivastava, 28th Int. Cosmic Ray Conf., Tsukaba, 3, 3731, 2003.

[21] Badruddin, Astrophys. and Space Sci., 246, 2, 171, 1996.

[22] Sabbah, Can. J. Phys./Rev. can. phys., 78, 4, 293, 2000.