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Significance of two types of high-speed solar wind streams in modulating cosmic ray intensity

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Abstract - One of the most dynamical interplanetary phenomena of solar terrestrial physics is definitely the passage of solar wind streams near the Earth environment. In this work, we have identified the two types of high-speed solar wind streams using the spacecraft data during high amplitude days. The behaviour of high-speed solar wind streams during high amplitude anisotropic wave trains is investigated for the period 1981-1994. The two types of high-speed solar wind streams (corotating streams and flare-generated streams) produce significant deviations in cosmic ray intensity during high amplitude anisotropic wave trains. On the onset of both types of streams the cosmic ray intensity reaches its minimum during high amplitude events and then increases statistically. It has been observed that both types of solar wind streams (Corotating and Flare generated) produce significant deviations in cosmic ray intensity during high amplitude anisotropic wave train events.

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1. Introduction

The existence of high amplitude anisotropic wave train events (HAEs) and their association with solar wind plasma and interplanetary magnetic field parameters has been revealed through the long-term study of cosmic ray intensity. Periods of unusually large amplitude often occur in trains of several days. Number of high amplitude events has been observed with a significant shift in the diurnal time of maximum to later hours or earlier hours [1-3]. Such days are of particular significance when occur during undisturbed solar/interplanetary conditions, as the superposed universal time effects are expected to be negligible.

After a careful investigation of HAE events, Mishra [4] pointed out that the diurnal time of maximum consistently remains along the corotational direction for majority of the events or shift towards later/earlier hours and the occurrence of these events are weakly depend upon the high-speed solar wind streams (HSSWS).

Solar wind plays an important role in the heliospheric structure and dynamics and it is “the medium” through which all the solar perturbations are propagating towards the Earth. Numerous studies dealt with the presence of the two types of high-speed solar wind streams and their influence on cosmic ray intensity [5-9 and references therein].

The high-speed solar wind streams lasting for several days are observed by satellites and spacecrafts. These HSSWSs produce significant geomagnetic disturbances and variations in the level of cosmic ray intensity. The HSSWSs 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 [10-12].

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. [10] and Shukla et al. [13] have shown 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. [14] studied the effect of two types of HSSWSs 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.

The enhancement or subsidence of both high-speed solar wind streams 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 HSSWSs 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.

No doubt few work has already done in the past to study the modulation of cosmic ray intensity during high-speed solar wind streams. But this study doesn’t extend earlier to high amplitude anisotropic wave trains. This leads us to study the modulation of galactic cosmic ray intensity during the passage of high amplitude anisotropic wave train events by two different types of solar wind streams originating from two different sources.

2.Data and analysis

Using the long-term plots of the cosmic ray intensity data as well as the amplitude observed from the cosmic ray pressure corrected hourly neutron monitor data using harmonic analysis the High amplitude wave train events have been selected on the basis of following criteria:

High amplitude wave train events of continuous days have been selected when the amplitude of diurnal anisotropy remains higher than 0.4% 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 if the event is in recovery phase or declining phase are not considered.

On the basis of above selection criteria we have selected thirty-eight high amplitude wave train events during the period 1981-94. The hourly cosmic ray intensity data for Deep River neutron monitoring 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.

3.Results and Discussion

For the study concerning the stream occurrence, various definitions for a high-speed stream have been used. 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 viz. proton density, interplanetary magnetic field, proton temperature, bulk speed, north south component of interplanetary magnetic field, geocentric solar ecliptic latitude and longitude angle of average field vector [15-19] to study the role of these two types of streams in HAE. 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. [20]. 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 15 corotating streams and 2 flare-generated streams during 38 HAEs.

The occurrence of two types of HSSWSs during high amplitude days 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 HAE. Similar trends have also reported for low amplitude anisotropic wave trains [21]

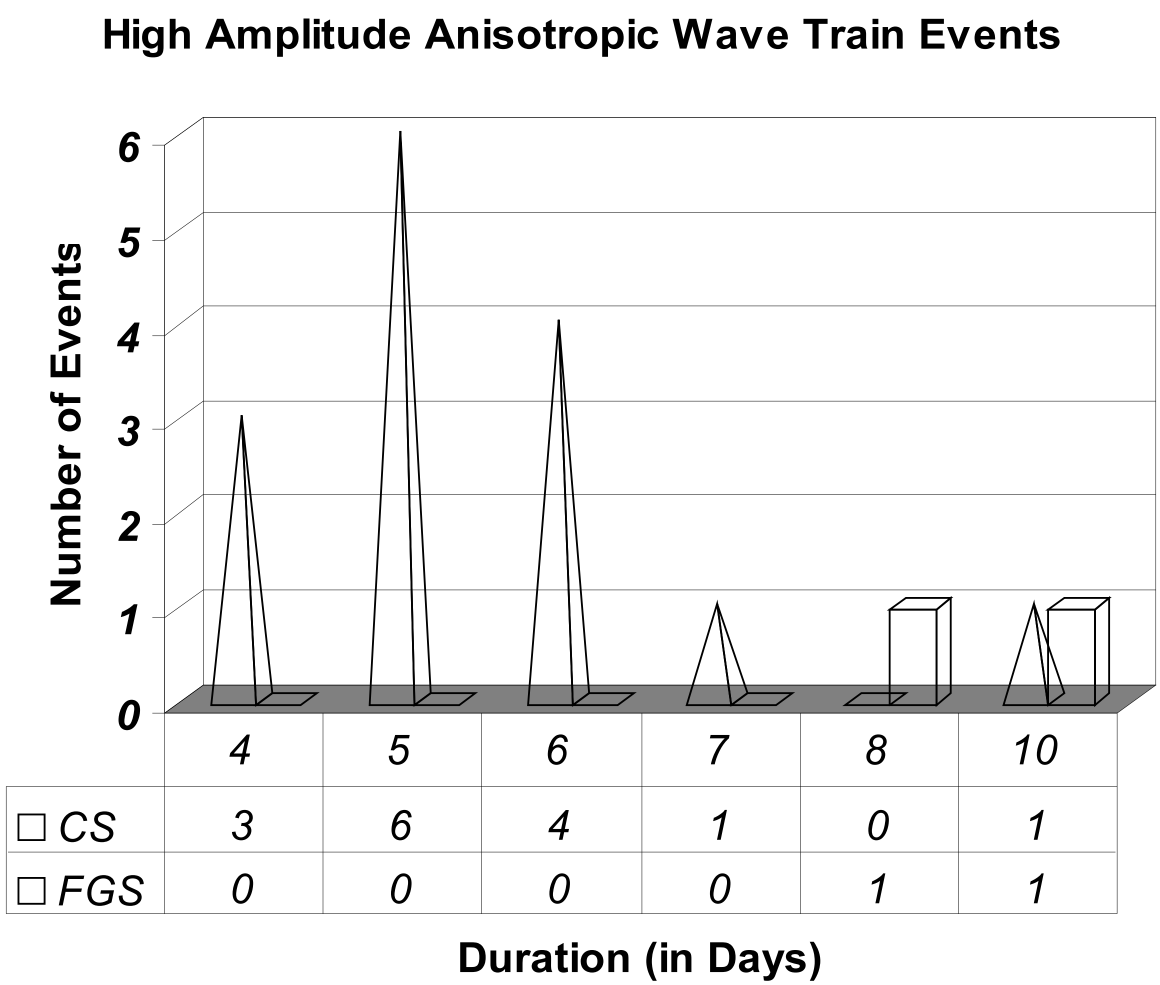

Fig 1: Frequency histogram of high-speed solar wind streams according to the duration of high-speed streams in days: Corotating and Flare-generated for HAE events during 1981-1994.

To study the effect of these streams on HAE, 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 along with statistical error bars (I)) for Deep River for the period 1981-94 during HAE. 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.

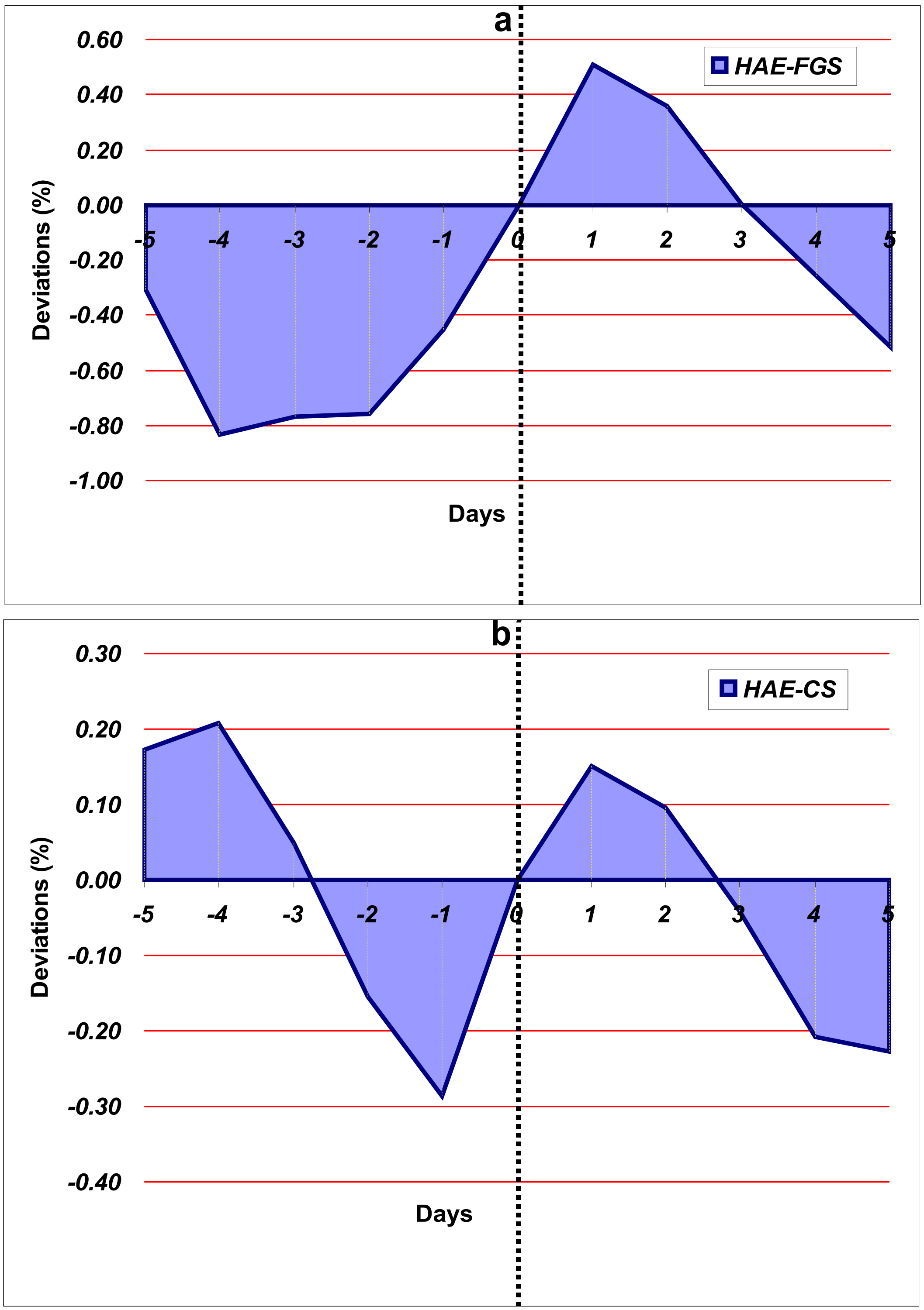

Fig 2: Chree analysis of superposed epoch from –5 to 5 days with respect to zero epoch days for HAE events during (a) Corotating and (b) Flare-generated streams during 1981-94.

As depicted in Fig 2a during corotating streams the decrease in cosmic ray intensity starts from –4 day and reaches to minimum on –1 day i.e. before one day of the onset of HSSWS. It starts increasing from –1 day to +1 day and then decreases upto +5 day. However during flare-generated streams (Fig 2b) the intensity significantly increases from –4 day and reaches it's maximum on +1 day i.e. after one day of the onset of stream and then decreases up to +5 day. Thus, we observed that significant deviations are seen in cosmic ray intensity during HAE events for both types of solar wind streams. Agarwal and Mishra [21] observed that both types of these streams produce significant deviation in cosmic ray intensity as well as solar/interplanetary/geomagnetic parameters during the passage of low amplitude anisotropic wave trains. Shrivastava and Shukla [22] indicates that the solar flare generated high speed solar wind streams are more effective in producing cosmic ray decreases than are the coronal hole generated streams. Shrivastava and Jaiswal [23] and Shrivastava [24] reported almost equal influence of flare generated and coronal hole associated solar wind streams on cosmic ray transient decreases.

Badruddin [25] studied the two classes, coronal hole and solar flare associated streams along with 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 [26] 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 HSSWSs 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 interplanetary magnetic field magnitude and fluctuation are responsible for the depression of cosmic-ray intensity during HSSWSs 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.

4.Conclusions

From the present investigations following conclusions may be drawn:

- On the onset of both types (Corotating and Flare generated) of streams the cosmic ray intensity reaches to its minimum during high 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 high amplitude anisotropic wave train events.
- Conclusively we can say that observed variations in cosmic ray intensity during the passage of both types of high-speed solar wind streams may be attributed to the intrinsic differences in the solar wind-plasma and interplanetary magnetic field parameters.
- In the future, the study of cosmic ray modulation by high speed solar wind streams as a function of Bartels rotation days using the dominant polarity of interplanetary magnetic field associated with the referred fast streams will be very useful to determine the modulation pattern of cosmic ray intensity.

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