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Features of low amplitude anisotropic wave train events in cosmic ray intensity

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The paper deals with the relation of short-term variations of cosmic ray anisotropies to the interplanetary magnetic field and solar wind parameters. The unusually low amplitude anisotropic wave train events (LAEs) in cosmic ray intensity using the ground based Deep River neutron monitor data has been studied during the period 1991-94. It has been observed that the phase of the diurnal anisotropy for majority of the LAE events remains in the corotational direction. However, for some of the LAE events the phase of the diurnal anisotropy shifts towards earlier hours. On the other hand, the amplitude of the semi-diurnal anisotropy remains statistically the same whereas, phase shift towards later hours; similar trend has also been found in case of tri-diurnal anisotropy. The interplanetary magnetic field (IMF) and solar wind plasma (SWP) parameters during these LAEs are also investigated.

1. Introduction

Cosmic Ray modulation is a complex phenomenon, which occurs all over the heliosphere and depends on many factors. The solar diurnal variation of cosmic ray (CR) intensity shows a large day-to-day variability [1]. This variability is a reflection of the continually changing conditions in the interplanetary space [2]. The average diurnal anisotropy of cosmic radiation is being explained in terms of azimuthal/corotation [3 and references therein]. The systematic and significant deviations of amplitude as well as phase for diurnal/semi-diurnal anisotropies from the average values are known to occur in association with strong geomagnetic activity [4]. The distinguishing features of these systematic deviations are the unusually low or high amplitude and usually, though not always, a shift in the phase towards earlier hours [5].

The average amplitude of diurnal and semi-diurnal anisotropy are found to be larger than normal during the initial phase of the stream while it is smaller as compared to the normal during the decreasing phase of the stream and phase is observed to remain almost constant [6], which infer that the diurnal as well as semi-diurnal variation of galactic cosmic ray intensity may be influenced by the solar polar coronal holes. The changes have also been observed in the amplitude and phase during the high speed solar wind streams (HSSWS) coming from coronal holes [7, 8]. The diurnal variation might be influenced by the polarity of the magnetic field [9], so that the largest diurnal variation is observed during the days when the daily average magnetic field is directed outward from the Sun.

Jadhav et al. [10] have studied the behaviour of semi-diurnal anisotropy for LAE 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. The study of diurnal/semi-diurnal/tri-diurnal anisotropies during 1991-94 for LAE has been presented in this paper to investigate the basic reason causing the occurrence of these types of unusual events.

2. Data Analysis

The anisotropic events are identified using the hourly plots of cosmic ray intensity recorded at ground based neutron monitoring stations and selected 13 unusually low amplitude anisotropic wave train events (LAEs) during the period 1991-94. The days having abnormally low amplitude for five or more consecutive number of days have been selected as LAE. The pressure corrected hourly neutron monitor data after applying trend correction is harmonically analysed to have amplitude (%) and phase (Hr) of the diurnal, semi-diurnal and tri-diurnal anisotropies of cosmic ray intensity for LAE. The data related with interplanetary magnetic field (IMF) and solar wind plasma (SWP) parameters have also been investigated.

3. Results and discussion

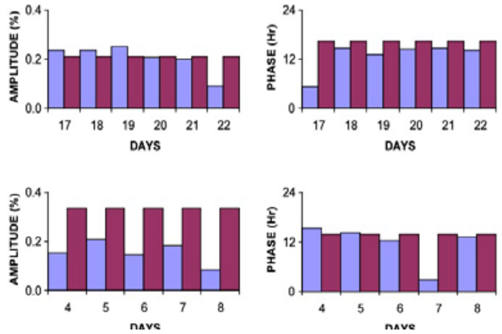

Fig 1: Amplitude and phase of the diurnal anisotropy for LAE of (a) 17-22 Sept. 1991 and (b) 4-8 Oct., 1994.

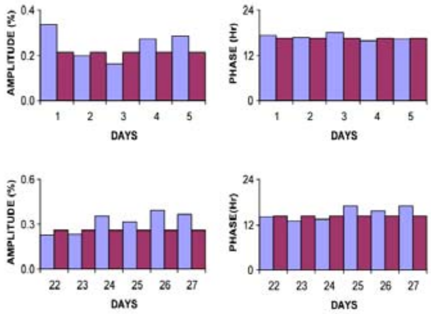

Fig 2: Amplitude and phase of the diurnal anisotropy for LAE of (a) 1-5 May 1991 and (b) 22-27 Mar., 1992.

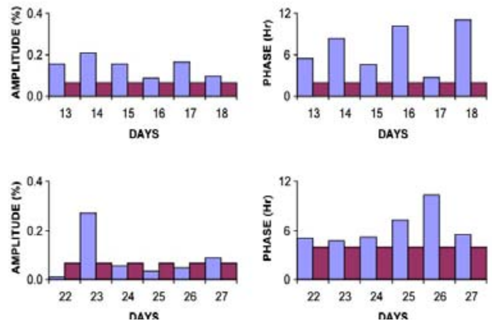

Fig 3: Amplitude and phase of the semi-diurnal Anisotropy for LAE of (a) 13-18 Jan.,1991 and (b) 22-27 Mar.. 1992.

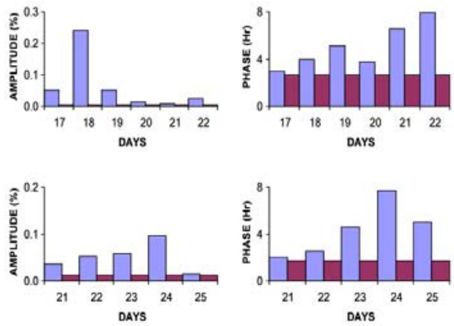

Fig 4: Amplitude and phase of the tri-diurnal anisotropy for LAE of (a) 17-22 Sep., 1991 and (b) 21-25 Dec., 1993.

The amplitude and phase of the diurnal anisotropy for the LAE events have been plotted in Figures 1 & 2. As depicted in Fig 1, it is quite apparent that the phase of the diurnal anisotropy has shifted towards earlier hours in some of the LAE events; whereas, in Fig 2, the phase of the diurnal anisotropy for majority of theLAE events remains in the corotational direction. Similarly, the amplitude and phase of the semi-diurnal anisotropy have been plotted in Fig 3. It is quite apparent from Fig 3 that the amplitude of the semi-diurnalanisotropy remains statistically the same for majority of the events; whereas, the phase has a tendency to shift towards later hours. Further, the amplitude and the phase of the tri-diurnal anisotropy has been plotted in Fig 4. It is quite clear from Fig 4 that the amplitude of tri-diurnal anisotropy remains statistically the same; whereas, the phase shifts towards later hours for most of the LAE events. The amplitude and phase of diurnal, semi-diurnal and tri-diurnal anisotropies for all LAEs along with the corresponding quiet-day annual average values have been plotted in Figs 5, 6 & 7.

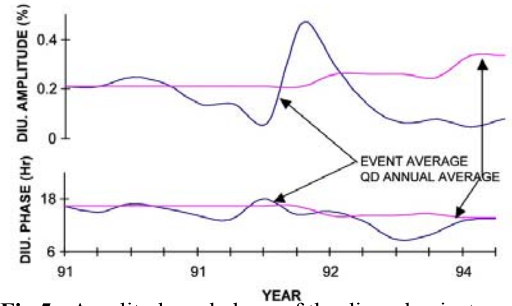

Fig 5: Amplitude and phase of the diurnal anisotropy for LAEs along with the quiet day annual average values during the period 1991-94.

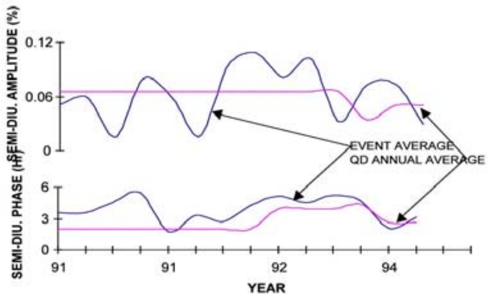

Fig 6: Amplitude and phase of the semi-diurnal anisotropy for LAEs along with the quiet day annual average values during the period 1991-94.

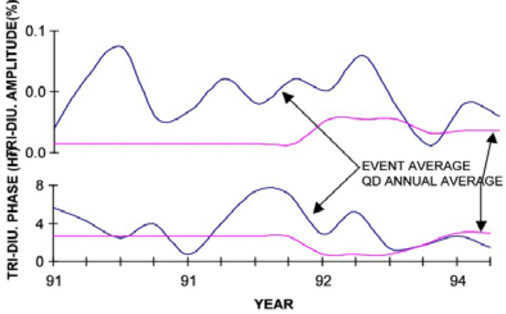

Fig 7: Amplitude and phase of the tri-diurnal anisotropy for LAEs along with the quiet day annual average values during the period 1991-94.

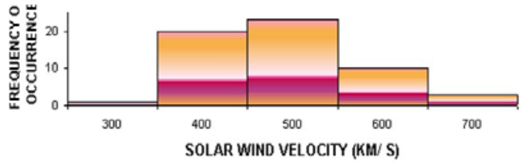

Fig 8: The frequency histogram of the solar wind velocity for all LAEs.

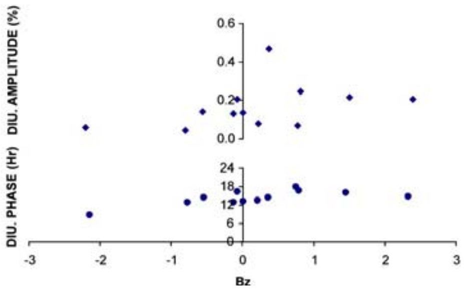

Fig 9: Amplitude and phase of the diurnal anisotropy for each LAE with the variation in associated values of Bz during 1991-94

It has been found that the amplitude of the diurnal anisotropy for majority of the LAE events attains significantly lower values as compared to the quiet day annual average amplitude throughout the period as depicted in Fig 5 and the phase of the diurnal anisotropy has a tendency to shift towards earlier hours as compared to the quiet day annual average value for majority of the LAEs. It is depicted from Fig 6 there is no definite trend for amplitude of the semi-diurnal anisotropy; whereas, the phase of the semi-diurnal anisotropy has a tendency to shift towards later hours as compared to the quiet day annual average values for majority of the events. Further, it is quite apparent from Fig 7 that the amplitude of the tri-diurnal anisotropy attains significantly higher values for majority of the LAE events as compared to the quiet day annual average amplitude throughout the period; whereas, the phase of the tri-diurnal anisotropy has a tendency to shift towards later hours as compared to the quiet day annual average values for majority of the LAE events.

During the period of each LAE event, the interplanetary magnetic field (IMF) and solar wind plasma (SWP) parameters have also been investigated. It is quite apparent from the frequency histogram of solar wind velocity for all LAEs, as depicted in Fig 8 that majority of the LAE events have occurred when the solar wind velocity lies in the interval 400-500 km/s i.e., being nearly average. Usually, the velocity of high-speed solar wind streams (HSSWSs) is 700 km/s[7]. Therefore, it is quite apparent from Fig 8 that LAE events are not caused either by the HSSWS or by the sources on the Sun responsible for producing the HSSWS such as polor coronal holes (PCH) etc. Thus, it is inferred that HSSWS do not serve a significant role in causing the LAE events. The amplitudes (%) and phases (Hr) of diurnal, semi-diurnal and tri-diurnal anisotropies for all the

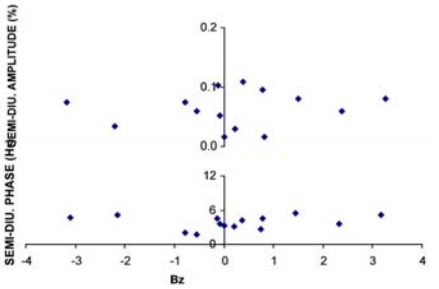

Fig 10: Amplitude and phase of the semi-diurnal anisotropy for each LAE with the variation in associated values of Bz during 1991-94.

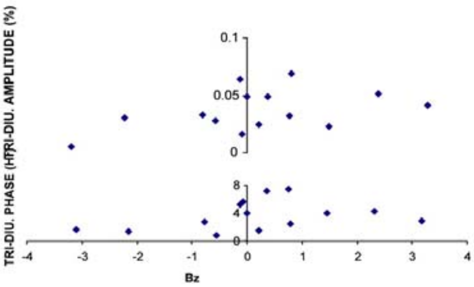

Fig 11: Amplitude and phase of the tri-diurnal anisotropy for each LAE with the variation in associated values of Bz during 1991-94.

LAE events with the variations in the associated values of z-component of interplanetary magnetic field B, i.e. Bz have been plotted in Figs 9, 10 & 11 during the period 1991-94. It is observable from the Fig 9 that the amplitude of the diurnal anisotropy positively directed IMF (+Bz) attains higher values for some of the LAE events; whereas, the amplitude remains low for negatively directed IMF (-Bz) for most of the LAE events. The phase of the diurnal anisotropy, as shown in Fig 9, for both positive and negative polarity of Bz has a tendency to shift towards earlier hours as compared to corotational value for all the LAE events. For semi-diurnal anisotropy, as shown in Fig 10, the Bz is found to remain +ve i.e. away from the Sun for majority of the days of LAE events. However, for some of the days of LAE events Bz is found to remain -ve i.e. towards the Sun. Further, in case of tri-diurnal anisotropy, as depicted in Fig 11 the Bz is found to remain +ve for majority of the days of LAE events; whereas, for some of the events it is also found to remain -ve, which indicates that the occurrence of LAE is dominant when the IMF polarity is positively directed. Kananen et al. [11] have found that for positive polarity of IMF the amplitude is high and phase shifts to early hours; whereas, for negative polarity of IMF the amplitude is lower and phase shifts to early hours as compared to corotational values.

4. Conclusions

On the basis of the present investigation the following conclusions have emerged:

1. The phase of the diurnal anisotropy has shifted towards earlier hours for some of the LAEs; whereas, it remains in the co-rotational direction for most of the LAEs.
2. The amplitude remains statistically the same; whereas, the phase has a tendency to shifts towards later hours for both semi-diurnal and tri-diurnal anisotropies for most of the LAE events.
3. The high-speed solar wind streams do not play a significant role in causing the LAE events.
4. The occurrence of LAE is dominant for the positively directed Bz component of IMF polarity.

5. Acknowledgements

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