29th International Cosmic Ray Conference Pune (2005) **00**, 101-104

Characteristics of high amplitude anisotropic wave train events in cosmic ray intensity

Santosh Kumar[a], Rajesh K. Mishra[b], Rekha Agarwal Mishra[c] and M.K. Richharia[c]
(a) Department of Post Graduate Studies & Research in Physics and Electronics,
Rani Durgawati University, Jabalpur 482001 India
(b) Computer and I.T. Section, Tropical Forest Research Institute, P.O.: RFRC, Mandla Road, Jabalpur (M.P.) 482 021
(c) Department of Physics, Govt. Model Science College (Autonomous), Jabalpur (M.P.) 482 001, India
Presenter: Santosh Kumar (rkm_30@yahoo.com), ind-kumar-S-abs1-sh32-oral

In this paper we continue to investigate the characteristic features in the connection between cosmic ray anisotropies (diurnal, semi-diurnal and tri-diurnal) and Interplanetary magnetic field as well as solar wind parameters. Using the ground based neutron monitor data of Deep River, the high amplitude anisotropic wave train events (HAE) in cosmic ray intensity have been investigated during the period 1991-94. It has been observed that the phase of diurnal anisotropy for majority of HAE cases remains in the same co-rotational direction whereas the phase of diurnal anisotropy has shifted to later hours for some of the HAE cases. Further, for majority of HAE cases the amplitude of semi-diurnal anisotropy remains statistically the same, whereas the phase of semi-diurnal anisotropy for all HAE cases has shifted to later hours. Furthermore, for tri-diurnal anisotropy the phase shifts towards later hours while amplitude remains statistically the same.

1. Introduction

A lot of research efforts, spent over the years, tried to analyse, characterize and interpret the changing shape of the cosmic ray (CR) modulation at the Earth's location. (Belov, 2000 and references therein). A large day-to-day variability is exhibited in the solar diurnal variation of cosmic ray (CR) intensity [1]. This variability is a reflection of the continually changing conditions in the interplanetary space [2]. The systematic and significant deviations in the amplitude/phase of the diurnal/semi-diurnal anisotropy from the average values are known to occur in association with strong geomagnetic activity [3]. Rao et al (1972) have shown that the enhanced diurnal variation of high amplitude events exhibits a maximum intensity in space around the anti-garden hose direction and a minimum intensity around the garden hose direction [4]. Number of high amplitude events has been observed with a significant shift in the diurnal time of maximum to later hours or earlier hours [5-7]. Such days are of particular significance when occur during undisturbed solar/interplanetary conditions, as the superposed universal time effects are expected to be negligible.

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 [8], 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 [9, 10]. The diurnal variation might be influenced by the polarity of the magnetic field [11], so that the largest diurnal variation is observed during the days when the daily average magnetic field is directed outward from the Sun.

The diurnal/semi-diurnal/tri-diurnal anisotropies during 1991-94 for HAE has been presented in this paper to investigate the basic reason causing the occurrence of these types of unusual events.

neutron monitoring stations and selected 16 unusually high amplitude anisotropic wave train events (HAEs) during the period 1991-94. The days having abnormally high amplitude for five or more consecutive number of days have been selected as HAE. The pressure corrected hourly neutron monitor data after applying trend correction are harmonically analysed to have amplitude (%) and phase (Hr) of the diurnal, semi-diurnal and tri-diurnal anisotropies of cosmic ray intensity for HAE. The data related with interplanetary magnetic field (IMF) and solar wind plasma (SWP) parameters have also been investigated.

2. Results and discussion

The amplitude and phase of the diurnal anisotropy has been plotted in Fig 1. It is quite apparent from Fig 1 that the phase of the diurnal anisotropy has shifted towards later hours for some of the HAEs. However, the phase of the diurnal anisotropy, as depicted in Fig 2, remains in the corotational direction for majority of the HAEs.

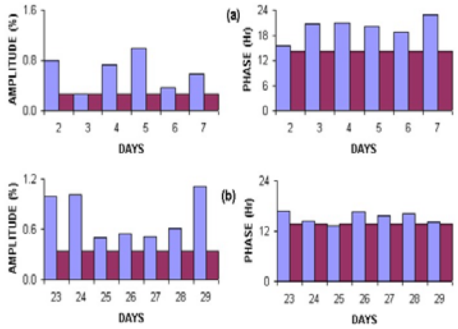

Fig 1: Amplitude and phase of the diurnal anisotropy for HAE of (a) 2-7 Oct., 1992 and (b) 23-29 Oct., 1994.

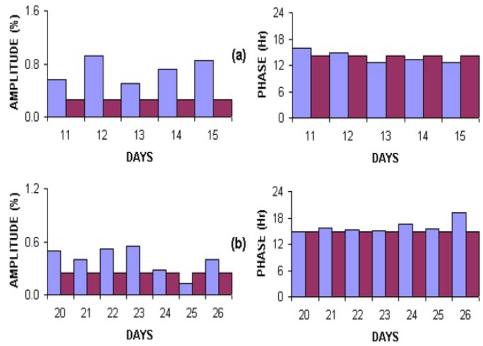

Fig 2: Amplitude and phase of the diurnal anisotropy for HAE of (a) 11-15 Apr., 1992 and (b) 20-26 May, 1993.

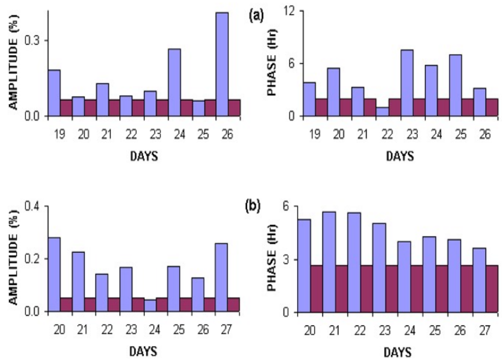

Fig 3: Amplitude and phase of the semi-diurnal anisotropy for HAE of (a) 19-26 Dec., 1991 and (b) 20-27 Mar., 1994.

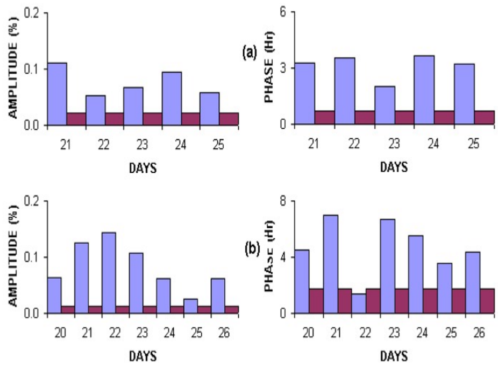

Fig 4: Amplitude and phase of the tri-diurnal anisotropy for HAE of (a) 21-25 Jul., 1992 and (b) 20-26 May, 1993.

Similarly, the amplitude and phase of the semi-diurnal anisotropy has been plotted in Fig 3. It is quite apparent from Fig 3 that the phase of the semi-diurnal anisotropy has a tendency to shift towards later hours. Further, the amplitude of the tri-diurnal anisotropy, as shown in Fig 4, remains statistically the same; whereas, the phase of the tri-diurnal anisotropy is found to shifts towards later hours for all HAEs.

The amplitude and phase of diurnal, semi-diurnal and tri-diurnal anisotropies for all HAEs along with the corresponding quiet-day annual average values have been plotted in Figs 5, 6 &7. It has been found that the amplitude of the diurnal anisotropy for all HAE attains significantly large values as compared to quiet day

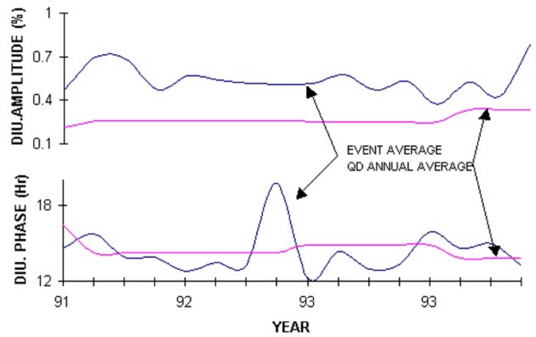

Fig 5: Amplitude and phase of the diurnal anisotropy for HAEs along with the quiet day annual average values during the period 1991-94.

annual average amplitude throughout the period, as shown in Fig 5 and the phase of the diurnal anisotropy remains in the corotational direction for most of the HAEs. The amplitude of the semi-diurnal anisotropy, as depicted in Fig 6, is significantly larger for some of the events as compared to the quiet day annual average values; whereas no definite trend has been found for phase of the semi-diurnal anisotropy, as shown in Fig 6. Further, the amplitude of the tri-diurnal anisotropy, as depicted in Fig 7, attains significantly larger values for all HAEs as compared to the quiet day annual average values throughout the period; whereas, the phase of the tri-diurnal anisotropy is found to shift towards later hours as compared to the quiet day annual average value for most of the events.

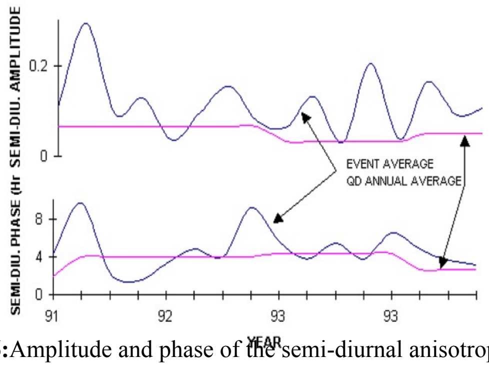

Fig 6: Amplitude and phase of the semi-diurnal anisotropy for HAEs along with the quiet day annual average values during the period 1991-94.

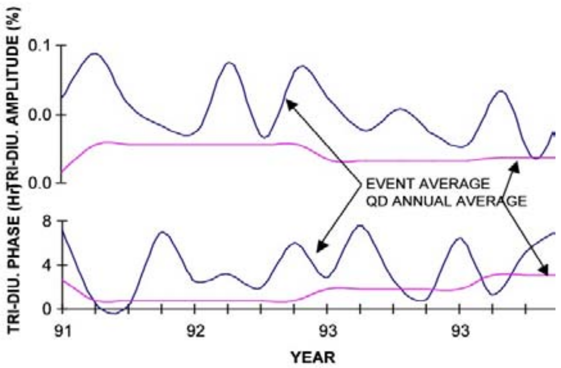

Fig 7: Amplitude and phase of the tri-diurnal anisotropy for HAEs along with the quiet day annual average values during the period 1991-94.

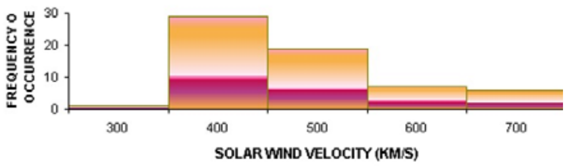

Fig 8: The frequency histogram of the solar wind velocity for all HAEs.

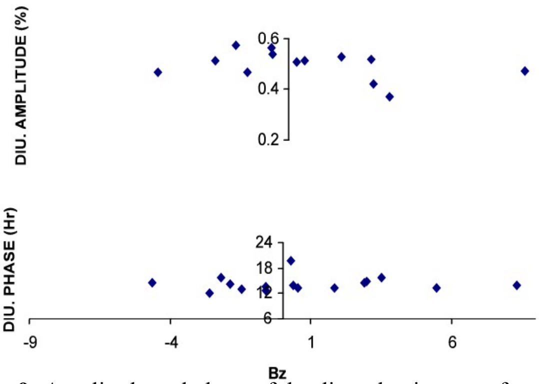

Fig 9: Amplitude and phase of the diurnal anisotropy for each HAE with the variation in associated values of Bz during 1991-94.

The IMF and SWP parameters have also been studied during the period of all HAEs. The frequency histogram of solar wind velocity for all HAEs has been plotted in Fig 8. It is observable from Fig 8 that the majority of the HAE 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[9]. Therefore, it may be deduced from Fig 8 that HAE events are not caused either by the HSSWS or by the sources on the Sun responsible for producing the HSSWS such as polar coronal holes (PCH) etc. Thus, we may infer that HAEs are weakly dependent on solar wind velocity.

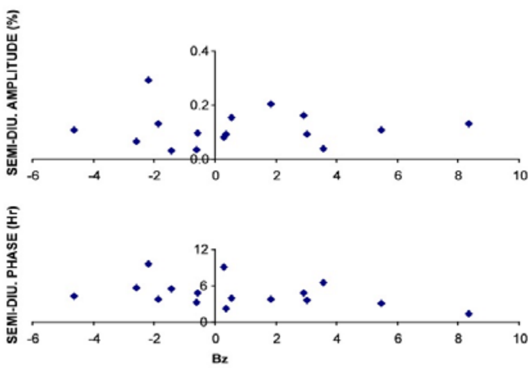

Fig 10: Amplitude and phase of the semi-diurnal anisotropy for each HAE with the variation in associated values of Bz during 1991-94.

The amplitudes (%) and phases (Hr) of diurnal, semi-diurnal and tri-diurnal anisotropies for HAEs with the variations in the associated values of z-component of interplanetary magnetic field B, i.e. Bz has been plotted in Figs 9, 10 & 11 during the period 1991-94. It is quite apparent from Fig 9 that the amplitude of diurnal anisotropy is evenly aligned for both positive and negative polarity of IMF for all HAEs. The amplitude of diurnal anisotropy for both the polarity is higher and phase shifts towards earlier hours as compared to the corotational values for most of the HAEs. For semi-diurnal anisotropy as depicted in Fig 10; HAEs may occur independent of nature of Bz component of IMF. Further, for tri-diurnal anisotropy, as shown in Fig 11, the amplitude is evenly aligned for most of the HAEs. Kananen et al.[12] 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 value.

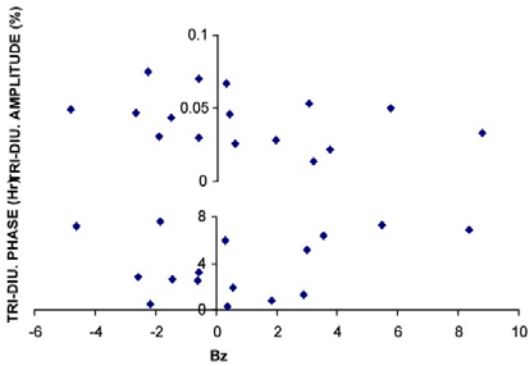

Fig 11: Amplitude and phase of the tri-diurnal anisotropy for each HAE with the variation in associated values of Bz during 1991-94.

3. Conclusions

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

1. The phase of the diurnal anisotropy has shifted towards later hours for some of the HAEs; whereas it remains in the co-rotational direction for most of the HAEs.
2. The amplitude remains statistically the same; whereas, the phase has a tendency to shift towards later hours for both semi-diurnal and tri-diurnal anisotropies for most of the HAE events.
3. The high-speed solar wind streams do not play a significant role in causing the HAE events.

4. 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] A. Belov, Space Sci. Rev., 93, 79 (2000).
[2] A.G. Ananth, S.P. Agrawal and U.R. Rao, *Pramana,* 3, 74 (1974).
[3] E.O. Fluckiger, 22nd Int. Cosmic Ray Conf., Dublin, 5, 273 (1991).
[4] S. Kumar, Rekha Agarwal, Rajesh Mishra and S.K. Dubey, Int. J. Mod. Phys.-D, 11, 1243 (2002).
[5] U.R. Rao, A.G. Ananth and S.P. Agrawal, Planet. Space Sci., 20, 1799 (1972).
[6] S. Kumar, and M.L. Chauhan, Ind. J. Radio & Space Phys., 25, 106 (1996a).
[7] S. Kumar and M.L. Chauhan, *Ind. J. Radio & Space Phys*., 25, 232 (1996b).
[8] S. Kumar, M.L. Chauhan and S.K. Dubey, Solar Phys., 176, 403 (1997).
[9] S.P. Agrawal, J. Geophys. Res., 86, 10115 (1981).
[10] Y. Munakata et al., 20th Int. Cosmic Ray Conf., Moscow, 4, 39 (1987).
[11] N. Iucci, M.Parissi, M. Storini, and G. Villoressi, 17th Int. Cosmic Ray Conf., Paris, 10, 238 (1981).
[12] E.N. Parker, 22nd Int. Cosmic Ray Conf., Ireland, 5, 35 (1991).
[13] H. Kananen, H. Komori, P. Tanskanen and J. Oksman, 17th Int. Cosmic Ray Conf., Paris, 10, 190 (1981).