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Role of southward component of IMF and solar wind velocity in CR modulation

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The high amplitude wave train events (HAEs) of cosmic ray intensity observed during 1981-1994 were analyzed. We have studied the effect of southward component (Bz) of interplanetary magnetic field (IMF) and solar wind velocity on cosmic ray diurnal anisotropy. The neutron monitor data of Deep River station has been used in the present analysis. It has been observed that HAEs are weakly dependent on high-speed solar wind velocity. The occurrence of HAE is dominant for positive polarity of southward component (Bz) of IMF. The diurnal time of maximum significantly shifts towards earlier hours as compared to the azimuthal/corotational direction for majority of the HAEs during the period of investigation.

1. Introduction

The galactic cosmic rays are modulated in the heliosphere by four major mechanisms: inward diffusion and energy loss due to the scattering of cosmic rays of magnetic irregularities, outward convection due to radial flow of solar wind and the effect of gradient, curvature and neutral sheet drifts [1, 2]. This modulation leads to a small cosmic ray diurnal anisotropy with amplitude -0.5% in free space. Cosmic ray anisotropy only arises because particles of a particular rigidity suffer sufficient scattering in the interplanetary medium to remove the density gradient, which is otherwise set up to cancel the effect of the overall, conservative electric field [3, 4].

Using least square method Sabbah [5], found that the values of the upper cut off rigidity (Rc) show a magnetic cycle variation with the lowest values occur during years of solar activity minima of the positive state of solar cycle. Ahluwalia [6] correlated the values of Rc to the IMF magnitude (B) during the period 1966-1987. Sabbah [5] supported this conclusion by finding a good correlation between the later two parameters during the period 1968-1995. The cosmic ray intensity decreases as the interplanetary magnetic field (IMF) magnitude increases [7]. Cane et al. [8] obtained an inverse correlation between cosmic ray density and IMF magnitude. Sabbah and Duldig [9] have proved that the cosmic ray spectra are dependent on the magnetic state of the solar cycle. This is consistent with the predictions of the modulation drift model. Sabbah [10] found that the days characterized by high IMF magnitude are associated with higher diurnal variation amplitudes.

2. Data Analysis

Using the long-term plots of cosmic ray intensity data as well as the amplitude calculated from the cosmic ray pressure corrected hourly neutron monitor data using harmonic analysis; the High amplitude wave train events (HAE) have been selected. The high amplitude events for consecutive days have been selected when the diurnal amplitude found higher than 0.5% for each day of the event for at least five or more days. On the basis of these selection criteria we have selected 38 unusually high amplitude anisotropic wave train events (HAEs) during the period 1981-94. The pressure corrected hourly neutron monitor data after applying trend correction are harmonically analysed to have amplitude (%) and phase (Hr) of the diurnal anisotropy of cosmic ray intensity for HAE. The data related with interplanetary magnetic field and solar wind velocity have also been investigated.

3. Results and discussion

The variations observed near the Earth are an integral result of numerous solar and heliospheric phenomena, so it would be difficult to believe that any parameter alone can determine behaviour of CR. An existence of relation between SW magnetic field and long-term CR variations seems to be apparent. However, only when long data series of SW measurements had been accumulated, a strong correlation between the CR modulation and the IMF module was definitely established [8, 11]. A role of the solar wind velocity V for CR modulation was mentioned previously [12]. It seems necessary to account its influence, because the SW velocity determines two components of the CR modulation mechanism: the convection and adiabatic energy changes. Some evidences have appeared that changes of the solar wind velocity near the Earth may have not only local, but also the global character [13, 14]. Solar wind and IMF plays an important role in controlling the electrodynamics of the heliosphere [15]. Solar wind speed V and IMF parameters, such as vector **B**, spiral angle and tilt are important for the transport of energetic cosmic ray particles in the heliosphere, for the modulation of CR and creation of CR anisotropy in the interplanetary space. Kondoh et al. [16] found that the peak solar wind velocity have good anti-correlation with the high-energy galactic cosmic ray intensity. Recent enhancements of solar wind velocity are closely associated with the long-term decreases in the galactic cosmic ray intensity. The IMF magnitude and fluctuations are responsible for the depression of CR intensity during high-speed solar wind events [17].

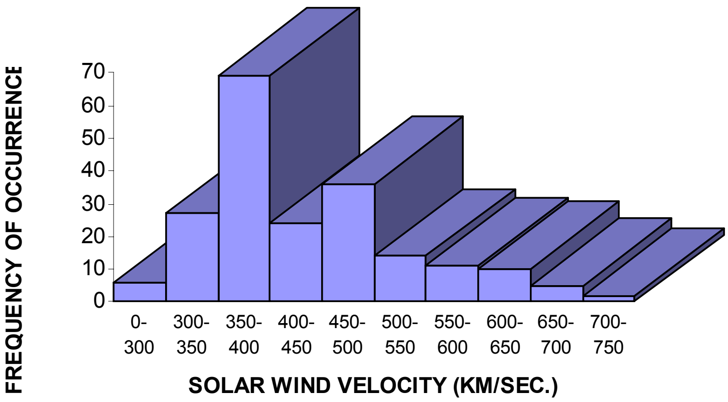

Figure 1: Frequency histogram of solar wind velocity for all the HAE events during 1981-1994
1994.

The frequency histogram of solar wind velocity for HAE has been plotted in Figure. 1. It is observable from the Figure that the majority of the HAE have occurred when the solar wind velocity lies in the interval 300-500 km/s i.e. being nearly average. A very few HAE occurred when solar wind velocity is 700 and above. Usually, the velocity of high-speed solar wind streams (HSSWSs) is 700 km/s [18]. Therefore it is quite apparent from Figure 1 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 high-speed solar wind streams. Duggal and Pomerantz [19] and Iucci et al. [20] pointed out that the effect of HSSWS on CR intensity is -0.5% per 100km/s in the case of high-speed wind emerging from the coronal holes. An analysis using groups of days with high and low solar wind speeds shows greater amplitude of both the tri-diurnal and semi-diurnal waves for the group of days with high wind speed [21, 22]. Agrawal et al. [22] suggested that the solar polar coronal holes could influence both semi/tri-diurnal variations.

The phases (Hr) of diurnal anisotropies for HAEs with the variations in the associated values of z-component of interplanetary magnetic field B, i.e. Bz have been plotted in Figure 2 during the period 1981-94.

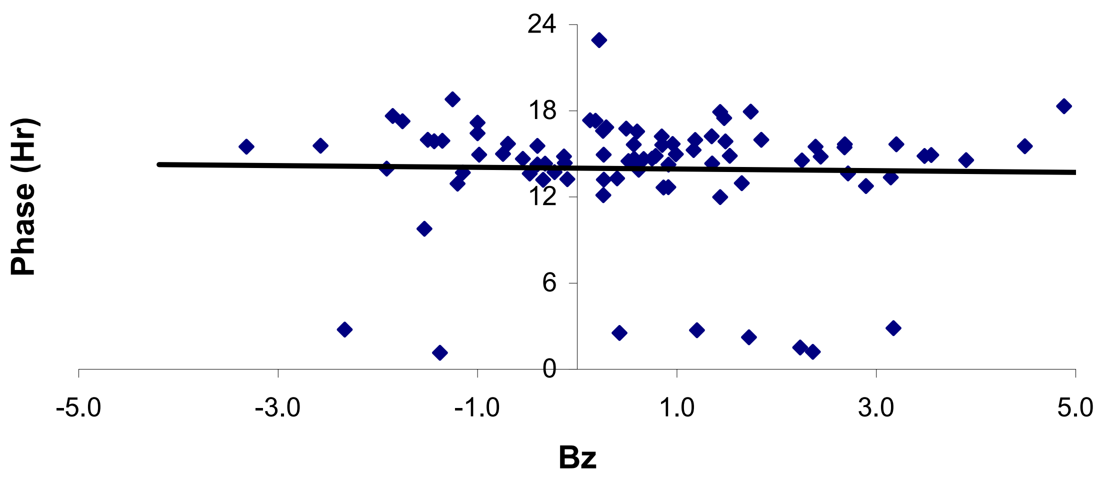

Figure 2: The phase of the diurnal anisotropy for all the HAE events with the variation in associated values of southward component of IMF (Bz) during 1981-1994.

It is observed form the Figure 2 that phase of diurnal anisotropy is evenly aligned for HAE. It is noteworthy that diurnal time of maximum significantly shifts towards earlier hours as compared to the co-rotational values for most of the HAE events for both positive and negative polarity of Bz; or, it remains in the corotational direction for rest of the events. The z component of IMF, Bz is found to remain positive i.e. away from the Sun for the majority of the days of HAE. However for some of the HAE it is observed to remain negative i.e. towards the Sun as it is quite apparent from Figure 2; which significantly confirm the earlier trends reported by Kananen et al. [23], where they 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. Thus the occurrence of HAE is found to be dominant during the positively directed Bz component of IMF polarity; which is in good agreement earlier findings [24-26]. On the basis of these anisotropic events it is deduced that for the positive polarity of IMF, Bz the phase shift towards earlier hours as compared to the corotational direction; whereas for nagative polarity of IMF, Bz the phase again shifts towards earlier hours as compared to the corotational value for HAE. An enhanced mean amplitude of diurnal anisotropy correlates with positively directed sectors while the amplitude of the diurnal anisotropy seems to decrease during sector boundaries [27]. Sabbah [28] also observed that the days characterized by high IMF magnitude are associated with higher diurnal variation amplitudes as well as higher solar plasma parameters.

4. Conclusion

1. On the basis of present investigations the following conclusions have emerged:
2. HSSWSs do not play any crucial role in causing the high amplitude anisotropic wave train events.
3. The phase of diurnal anisotropy shifts towards earlier hours for HAEs as compared to the corotational value.
4. The occurrence of HAE is dominant for the positive polarity of the z component of IMF i.e. Bz.
5. The time of maximum shifts towards earlier hours for both positive and negative polarity of IMF Bz in case of HAE.

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