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Short-term variation of cosmic ray anisotropy and solar activity

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A correlative analysis has been made between cosmic ray intensity and solar activity (sunspot numbers) during high amplitude days for the period 1991-1994. The high amplitude days with the time of maximum in the corotational/azimuthal direction do not indicate any significant correlation with solar activity. The diurnal amplitude significantly remains constant and high (0.5%) during the entire period. Our observations suggest that the direction of the anisotropy of HAE events contribute significantly to the short-term behaviour of the cosmic ray diurnal anisotropy. The correlation coefficient found to remain positive during solar activity maximum for all the HAE.

1. Introduction

It is noticed from a long time that the intensity as well as the energy spectrum of galactic cosmic rays is modulated by solar activity. The general negative correlation between cosmic rays and solar activity is well pronounced. However, the details of the temporal behaviour of this correlation have not been studied so far. The solar activity presents many significant characteristics features from cycle to cycle and has been studied in detail by several workers. Legrand and Simon [1] have pointed out that there are series of cycles with very high activity level (cycle 18, 19) as well as low activity (cycles 5, 6, 12 and 14). Xanthakis et. al. [2] showed that the amplitude of solar modulation in the 20^{th} solar cycle was smaller than the corresponding one of the 19^{th} solar cycle.

The neutron monitor observations indicate that the anisotropy vector exhibits a significant variability in amplitude and time of maximum, when considered on a long-term basis. The studies of the long-term behaviour of diurnal anisotropy [3-5] have indicated that the anisotropy consists of two components, one related to the 22-year solar cycle and the other related to the 11-year solar activity (sunspot) cycle. Further Agrawal and Bercovitch [3] have also shown that the direction of the 22-year component is perpendicular to the diurnal anisotropy vector and is along the line 162° east of the Sun-Earth line; they have attributed the 11-year component to the variation of cut-off rigidity.

Many authors have used the sunspot number or/and the flare activity in order to simulate the cosmic-ray intensity from the solar activity [6, 7]. An attempt was made to find out the most suitable index of the solar activity in order to reproduce to a certain degree the modulation of the cosmic ray intensity [8]. The contribution of more than one solar, interplanetary or geophysical parameter to the cosmic ray modulation process as solar flares, sunspot number, proton events, geomagnetic index etc. have also been reported [9]. Thus to examine the pattern of cosmic ray modulation with respect to the most suitable solar, interplanetary and geophysical parameters we can investigate the characteristic phenomena of the solar activity during a solar cycle.

The purpose of this work to investigate the solar cycle dependence of the diurnal anisotropy vectors over the period 1991-1994 and tried to interpret the behaviour of the diurnal anisotropy of the HAE events in terms of the distribution and characteristics of the diurnal vectors.

2. Data and Analysis

The pressure corrected data of Deep River Neutron monitor NM (cut off rigidity=1.02 GV, Latitude=46.1°N, Longitude=282.5°E, Altitude=145M) has been subjected to Fourier Analysis for the period 1991-94 after applying the trend correction to have the amplitude (%) and phase (hr) of the diurnal and semi-diurnal anisotropies of cosmic ray intensity for unusually low amplitude events. The amplitude of the diurnal anisotropy on an annual average basis is found to be 0.4%, which has been taken as reference line in order to select low amplitude events.

The days having abnormally high amplitude for a successive number of five or more days have been selected as high amplitude anisotropic wave train events. The anisotropic wave train events are identified using the hourly plots of cosmic ray intensity recorded at ground based neutron monitoring station and selected sixteen unusually high amplitude wave train events during the period 1991-94. The average values of sunspot numbers (Rz) for each corresponding HAE event have been used in the present analysis.

3. Results and Discussion

The short term variation of the amplitude (%) and time of maximum (Hr) of the

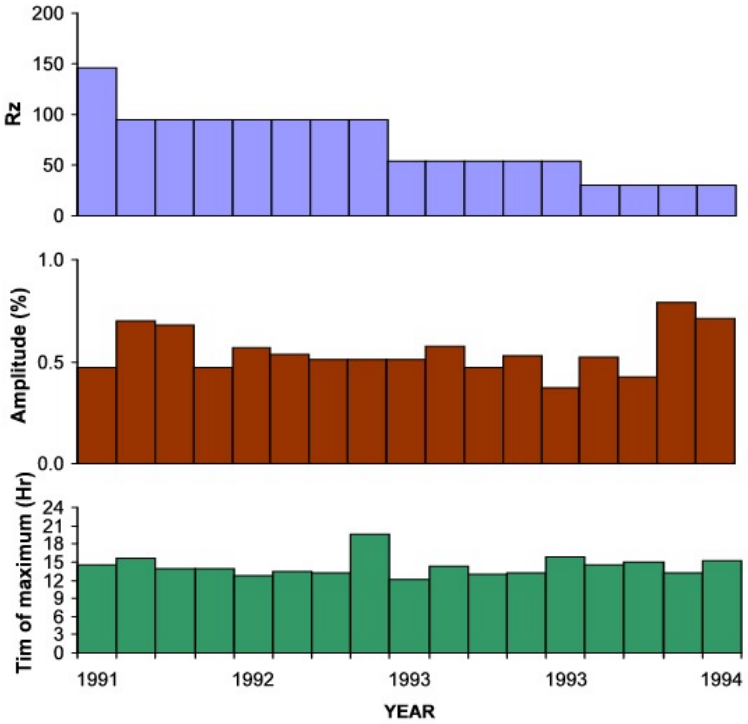

Figure 1: The short-term variation of cosmic-ray diurnal anisotropy amplitude (%) and the time of maximum (hr) for each HAE event is shown as a function of solar cycle represented by sunspot number (Rz) for the period 1991-1994.

Short-term variation of cosmic ray diurnal anisotropy for each HAE event is plotted for 1991-1994 and shown in Figure 1, along with the corresponding sunspot number (Rz). It can be clearly seen from the figure that the amplitude of the diurnal anisotropy consistently remains constant (0.5%) during the entire period. However it does not indicate a one-to-one correlation with the sunspot numbers. It is also evident from the figure that the amplitude distribution shows peaks during the year 1992 and 1994. Further we find from the figure that the diurnal time of maximum does not show any correlation with the sunspot numbers but indicates a shift towards earlier hours from the normal corotational/azimuthal direction during the entire period of event. These observations are found to be consistent with that of Kumar et al. [10] and Ananth et al. [11] and suggest that the amplitude of the diurnal anisotropy is correlated with the solar cycle but the direction of the anisotropy is not correlated with the solar cycle and shows a systematic shift to earlier hours.

It is clearly seen from the figure that frequency of days with diurnal phase in the 1500 hr direction significantly remains constant and the frequency of days with diurnal phase in the 2000 hr direction show an increase during 1992. This clearly indicates that during 1991-1994, the change in the direction of the diurnal anisotropy vector has been caused by two kinds of flow of cosmic ray particles; one having a maximum in the 1500 hr direction and another in the 2000 hr direction. During 1992 the phase shift of diurnal anisotropy has been caused by the streaming of particles in the 20 hr direction and during the rest of the period, in addition to the 15 hr component, the presence of excess streaming in the 15 hr direction caused a shifting of the diurnal phase to earlier hours. Thus the anisotropy seems to be completely dominated by the two components in the 1500 hr and 2000 hr direction.

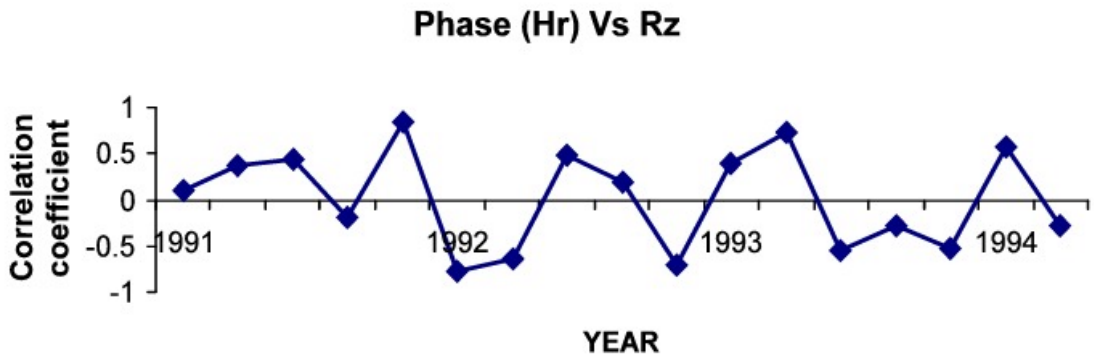

Figure 2: Correlation coefficient between sunspot numbers (Rz) and cosmic ray diurnal amplitude (%) during all the HAE for the period 1991-1994

Using the daily values of sunspot number (Rz) and the amplitude (%) of cosmic ray diurnal anisotropy, the correlation coefficients have been derived for each HAE during the period of investigation. The coefficient of correlation as shown in Figure 2 is found to remain positive as well as negative during the entire period. However, it changes positive to negative and vice versa quiet frequently. It is also noteworthy that the correlation coefficient is significantly remains positive during solar activity maximum year (1991).

4. Conclusions

From the above analysis and observations we may conclude the following:

- The amplitude of the diurnal anisotropy is correlated with the solar cycle but the direction of the anisotropy is not correlated with the solar cycle and shows a systematic shift towards earlier hours as compared to the 18-Hr direction.

- The short-term behaviour of the time of maximum of the diurnal anisotropy vectors could be explained in terms of 2000 Hr component and 1500 Hr component.
- The correlation between sunspot numbers and diurnal amplitude is found positive as well as negative. However, it significantly remains positive during solar activity maximum.

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