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Study of cosmic ray anisotropy along with solar activity

Rekha Agarwal Mishra[a] and Rajesh K. Mishra[b]
(a) Department of Physics, Govt. Model Science College (Autonomous), Jabalpur (M.P.) 482 001, India
(b) Computer and I.T. Section, Tropical Forest Research Institute, P.O.: RFRC, Mandla Road, Jabalpur (M.P.) 482 021, India
Presenter: Rekha Agarwal Mishra (rkm_30@yahoo.com), ind-mishra-RA-abs1-sh32-poster

The study of cosmic ray (CR) diurnal anisotropy using the Deep River neutron monitor data has been made with solar activity (sunspot numbers) during quiet days (QD) for the period 1964-1995. The amplitude of the diurnal anisotropy during QD found to remain low during solar activity minimum. However it is found to remain high during the declining phase of solar activity cycle (SAC) 20, 21. The direction of the anisotropy shifts gradually towards earlier hours till 1976 (solar activity minimum) and to later hours till 1991 (solar activity minimum) and then again towards earlier hours. The time of maximum shows a ~22-year periodicity in cosmic ray diurnal anisotropy. The anisotropy seems to be completely dominated by the two components one in the 1600 hr and the other in the 1200 hr direction.

1. Introduction

The solar diurnal anisotropy of CR intensity gives a very important information about fast changes of electromagnetic conditions in a limited region of space around the Earth, the knowledge of which is of great theoretical and practical importance. Therefore, it is evident that a lot of study deals with the study of the variations of that type. Many workers [1-4] noticed that the amplitude and time of maximum of solar diurnal anisotropy experience strong changes with the cycle and phase of solar activity.

The purpose of this work to investigate the solar cycle dependence of the diurnal anisotropy vectors over the period 1964-1995 and tried to interpret the behaviour of the diurnal anisotropy during quiet days in terms of the distribution and characteristics of the diurnal vectors.

2. Experimental data and analysis

Pressure corrected data of Deep River neutron-monitoring (NM) station (cutoff rigidity 1.02 GV; latitude 46.1º N; longitude 282.5º E; altitude 145 M) has been Fourier analyzed after applying trend corrections to obtain the first harmonic at ground for the period 1964-95. According to solar geophysical data five quietest days are selected in a month; thus 60 quietest days in a year. These are called International Quiet Quiet days or QQ days. The study of diurnal variation has been performed on 60 QQ for the period 1964-95. The days with extraordinarily large amplitude, if any, have not been taken into consideration. Also all those days are discarded having more than three continuous hourly data missing. The daily values of sunspot numbers (Rz) and solar wind velocity (km/sec.) for each corresponding quiet days have been used in the present analysis.

3. Result and Discussion

The values of amplitude (%) and phase (Hr) of the diurnal anisotropy of CR intensity obtained on a day-to-day basis for 60 QD in a year has been plotted for three solar cycles 20, 21 and 22 along with the corresponding sunspot numbers (Rz) on quiet days and shown in Fig 1. It is observed that the diurnal amplitude found to decrease during 1964-65, 1976-77, 1986-87 and 1995 as compared to the preceding years.

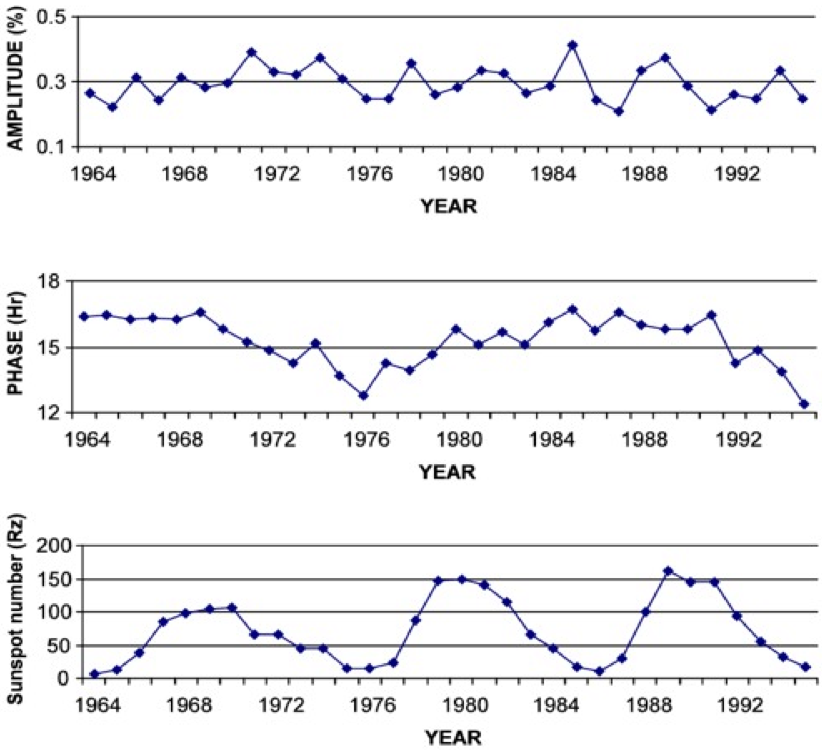

Figure 1: The long-term variation of cosmic-ray diurnal anisotropy amplitude (%) and the time of maximum (hr) during quiet days is shown as a function of solar cycle represented by sunspot number (Rz) for the period 1964-1995.

These are the periods of solar activity minimum. Ahluwalia et al. [5] noticed large values of diurnal amplitude during high solar activity and low values during solar activity minimum. Pransky et. al. [6] using ionization chamber data for the period 1954-89 obtained similar results, observing a decrease in amplitude during 1964, 76 and 86, i.e. the years of minimum solar activity. It is also evident from the Fig that the amplitude distribution shows peaks during the years 1971, 1974, 1978, 1985 and 1989. The amplitude of diurnal anisotropy is observed to be high during declining phase of solar activity cycle (SAC) 20, 21. However it does not indicate a one to one correlation with the sunspot numbers. Ahluwlalia and Riker [7] observed large values of diurnal amplitude during 1973-75; whereas, Ahluwalia et. al. [5] observed similar large values of diurnal amplitude for the period 1984-85 at Deep River neutron monitor. Fikani et al. [8] using the Deep River NM data for 1966-88 observed a broad enhancement in the amplitude for the year 1973 through 1976.

Further, it is observable from the plot that the time of maximum of diurnal anisotropy consistently remains constant during 1964-70, and then it starts to shift towards earlier hours until 1976. The shift to earlier hours is significantly high during the year 1973 and 1995, which are the periods close to minimum solar activity, confirming a ~22-year periodicity in the diurnal time of maximum. The diurnal time of maximum recovered gradually to 18-Hr/azimuthal/corotational directions from 1976 to around 1991, which is in agreement with the findings of Fujii and Ueno [9]. It is also noticed that the phase of diurnal anisotropy has the tendency to shift towards the corotational direction when the sunspot number (Rz) is high and when it lowers down the phase shifts towards earlier hours. Tiwari et al. (2004) found significant positive correlation for the diurnal amplitude and phase with the sunspot number. A correlative analysis has been done by Tiwari et al. (2004) between cosmic ray intensity and sunspot numbers for the solar cycle 19 to ascending phase of recent solar cycle 23. They noticed that the correlation between sunspot number and cosmic ray is negative and high. The variation trend is similar for odd solar cycles (21 and 23) and even solar cycles (20 and 22) thus confirming the odd-even hypothesis in correlative study.

It is clearly seen from the figure that frequency of days with diurnal phase in the 1600 hr direction significantly remains constant and the frequency of days with diurnal phase in the 1200 hr direction shows a decrease during 1976 and 1995. This clearly indicates that during 1964-1995, 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 1600 hr direction and another in the 1200 hr direction. During 1978 and 1995 the phase shift of diurnal anisotropy has been caused by the streaming of particles in the 12 hr direction and during the rest of the period, in addition to the 16 hr component, the presence of excess streaming in the 16 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 1600 hr and 1200 hr direction.

4. Conclusions

From the above analysis and observations we may conclude the following:
The amplitude of diurnal anisotropy found to remain low during solar activity minimum or close to it.
The time of maximum of diurnal anisotropy significantly found to shift towards earlier hours during solar activity minimum and thus once again confirming the periodic nature of the diurnal anisotropy.
The long-term behaviour of the time of maximum of the diurnal anisotropy vectors could be explained in terms of 1600 Hr component and 1200 Hr component.

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