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SEASONAL VARIATION OF THE TRIDIURNAL WAVE IN COSMIC RAY INTENSITY

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The existence of seasonal variation in the tridiurnal variation in cosmic ray intensity is investigated in the present study. The data used in the analysis are the hourly counting rates recorded at Deep River over a period of about one solar cycle from 1961—1971. The tridiurnal wave is found to be persisting during each season. The amplitude of the wave varies from one season to another. A comparison between the amplitude of that wave for the different seasons with their mean value over the investigated period indicates that the presence of the tridiurnal wave may be arising from the geometrical inclination of Earth's axis to the ecliptic plane in the presence of semidiurnal anisotropy.

1. Introduction

The existence of the tridiurnal variation (third harmonic component of the daily variation) in the recorded cosmic ray intensity was firstly reported by Mori et al.[1]. The worldwide nature of the tridiurnal wave is reconfirmed and significantly detected in several works (e. g. Kanno et al.[2]; Ahluwalia and Singh[3]; Asylbaeva et al.[4]; Murakami et al.[5]; Girgis et al.[6]). Moreover, Ahluwalia[7] showed the existence of that wave in data of detectors having response to rigidities in the range from few to one hundred gigavolts, which reveals its extraterrestrial origin.

The mechanism of the tridiurnal anisotropy, producing this variation, was explained by the *loss-conne* model, which arises from the pitch angle distribution hypothesis for the semidiurnal anisotropy. Fujii[8] discussed the cause of the loss cone in interplanetary space in terms of the scattering of cosmic rays in the interplanetary magnetic field together with the presence of heliolatidiudinal density gradient arising from the *virtual sink* idea originally proposed by Sarabhai et al.[9]. The model suggests that the tridiurnal component has a particular latitudinal distribution and a specific change in its amplitude from one year to another, while having the same rigidity dependence as that of the semidiurnal anisotropy. Moreover, the direction and the relative amplitude of this component are dependent on the angle of the loss cone.

On the other hand, several investigators (e. g. El Bedewi et al.[10]) studied the geometrical effect of the inclination of the Earth's axis on the observed semidiurnal variation for different cosmic ray stations in order to obtain accurate information about the outer space anisotropy. Their results revealed that the shape of the waveforms for the different seasons indicates the presence of higher harmonics superimposed on the semidiurnal wave. Hence, one may consider the effect of the inclination of the Earth's axis as a main cause for the presence of the tridiurnal wave in cosmic ray daily variation.

From the previous discussions, the possible mechanisms for the tridiurnal wave may be ascribed to either: (*a*) a real anisotropy which has its own dynamical process in interplanetary space: or (*b*) it may be considered as a result for the effect of the inclination of the Earth's axis. These two mechanisms represent the two extreme possible explanations for the nature of the tridiurnal wave. The first one (*a*) was investigated with other colleagues in Girgis et al.[6]. Here we are planning to study the second possibility (*b*). In order to check this hypothesis, the existence of seasonal variation in tridiurnal wave is investigated over a period of about one solar cycle (1961—1971).

2. *Selection of the appropriate cosmic ray station*

It is established that each cosmic ray station is characterized by an asymptotic cone of acceptance which controls the response of that station in observing the different components of the cosmic ray daily variation. McGracken et al.[11] had calculated the cosmic ray trajectories which form the asymptotic cone of acceptance of a particular cosmic ray station. Fig. 1 shows the cones of acceptance for Deep River, Alert, and Cairo. From this figure, it is clear that the cones of Deep River as well as of Cairo are mainly looking towards the ecliptic plane, which is not the case for the cone of Alert. Also, the cone of Deep River is characterized by a narrow longitudinal broadening while the cone for Cairo reveals a wide longitudinal broadening.

Assuming that the tridiurnal anisotropy is located in the ecliptic plane as a vector, then the longitudinal broadening of the asymptotic cone of acceptance would smooth the observed features of such a vector. In other words, the optimum condition for investigating the solar tridiurnal variation is to select the station which is looking towards the ecliptic plane and with the narrowest longitudinal broadening.

Accordingly, one may select Deep River station as the one which has a suitable asymptotic cone of acceptance for observing the tridiurnal wave.

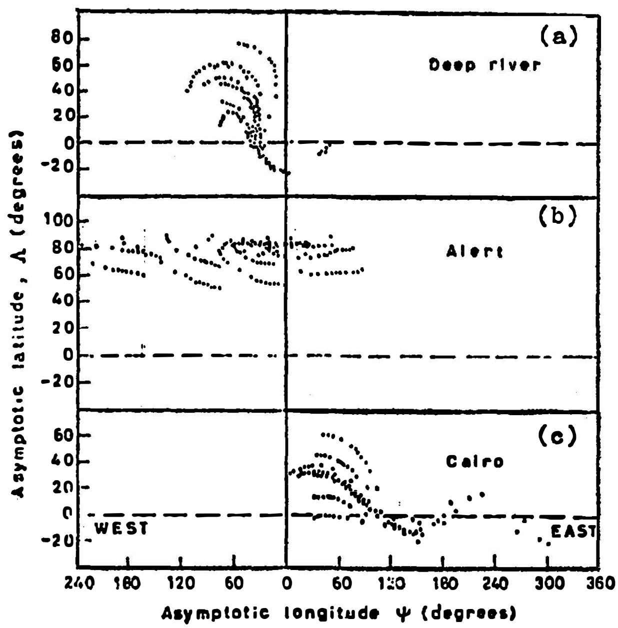

Fig. 1. Asymptotic cones of acceptance for (*a*) Deep River; (*b*) Alert; and (*c*) Cairo.

3. *Procedure of analysis*

In the present work, the tridiurnal wave is detected by the following procedure (Girgis et al.[12]):

(1) The hourly counting rates are arranged in trains each of length L days, and the average train, $T(1)$, $T(2)$,...... $T(24\,L)$ is obtained, where

$$T(t) = \frac{1}{M}\sum_{i=1}^{M} \Delta N(i, t)$$

where i is the train order, M is the number of trains and $\Delta N(i, t)$ is the percentage deviation from the mean counting rate of train i.

(2) The resultant train of data is then analyzed using the power spectrum technique with hanning window, following the formulae given by Blackman and Tukey[13].

The advantages of the above method are that (*a*) noise effect, due to statistical fluctuations, were reduced, and (*b*) showing the persistence as well as the contribution of the investigated frequency among the background and other existing frequencies.

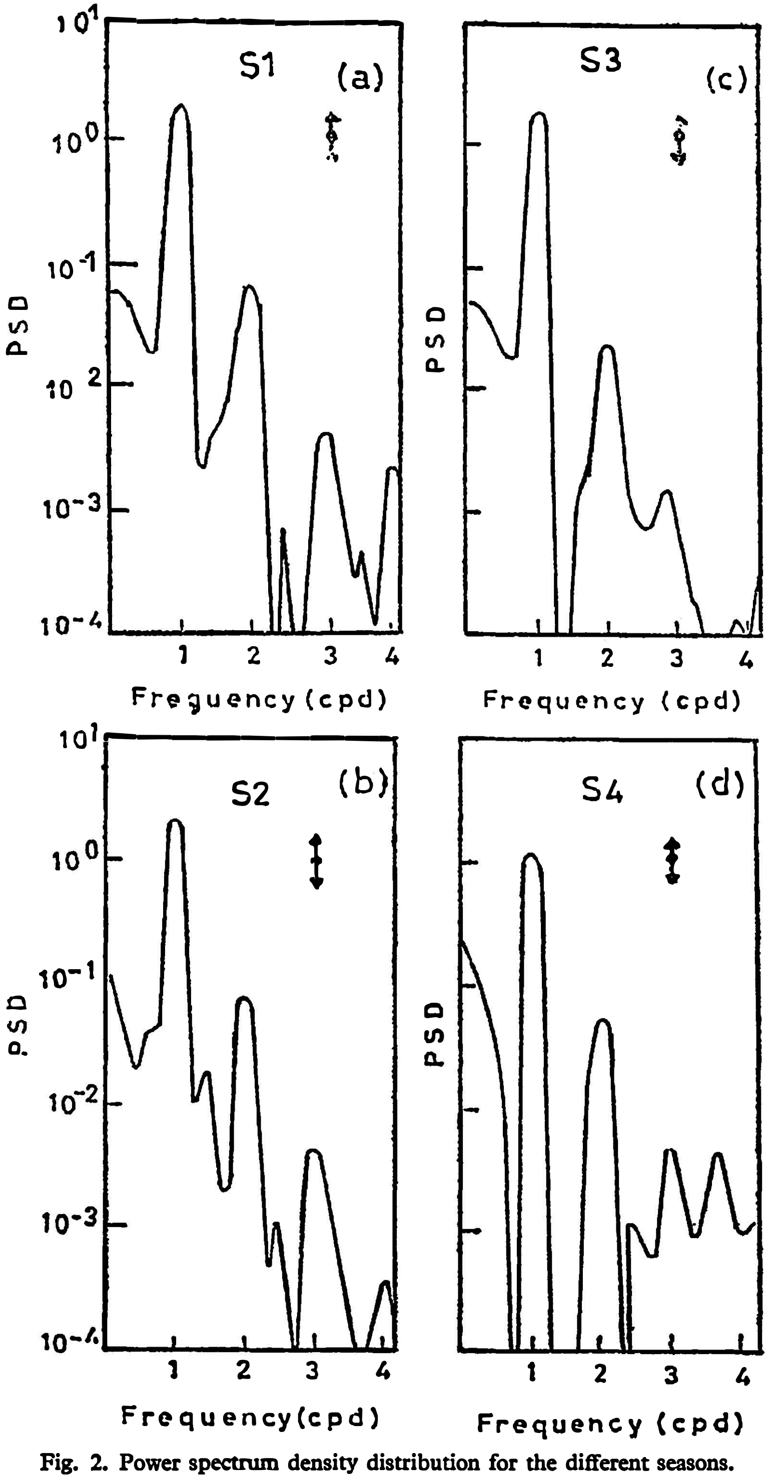

Fig. 2. Power spectrum density distribution for the different seasons.

4. *Data analysis and results*

The data used in the present study are the hourly counting rates recorded at Deep River over a period of about one solar cycle from 1961—1971. The data are corrected for atmospheric effects and are almost free from these effects (Mori et al.[1]).

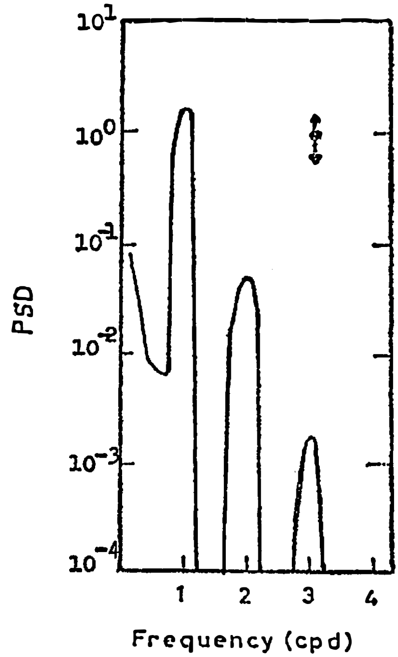

Fig. 3. Power spectrum density distribution for the whole period of study.

Following the above procedure of analysis, Figs. 2 and 3 have been drawn to represent the power spectrum density distribution (*PSDD*) for the 4-different seasons and for the whole period, respectively. In this analysis the maximum lag $\tau_0 = 30$ % from the total number of points in the average train, and the train length $L = 10$ days are used. Figures 2*a*, *b*, *c* and *d* represent the *PSDD* for seasons S_1 (Dec. 22), S_2 (Mar. 21), S_3 (June 22), and S_4 (Sep. 23), respectively. It is clear from these figures that the tridiurnal peak is significantly revealed for all seasons, in addition to the peaks correspoding to the well known diurnal and semi-diurnal waves. The error in the density of any peak is represented by the upward and downward arrows and is calculated such that the probability for the true density to be higher than upper arrow or less than the lower arrow is only 20 % (Martinic et al.[14]). The power spectral densities, which is proportional to the amplitudes square, of the tridiurnal peaks are 0.41, 0.45, 0.16 and 0.51×10^{-2} for S_1, S_2, S_3 and S_4, respectively. Fig. 3 shows a tridiurnal peak with density 0.22×10^{-2} for the whole investigated period. The amplitudes of the tridiurnal waves for the different seasons as well as for the whole period of study, obtained from our procedure are presented in Table 1. Also, the table shows the amplitude values calculated with the harmonic analysis method.

Table 1

Season	Power spectrum	Harmonic analysis
S_1	0.015 ± 0.003	0.016 ± 0.003
S_2	0.016 ± 0.002	0.015 ± 0.003
S_3	0.009 ± 0.003	0.009 ± 0.003
S_4	0.017 ± 0.003	0.016 ± 0.002
whole period	0.011 ± 0.003	0.013 ± 0.002

5. *Conclusions*

The observed tridiurnal wave in cosmic ray intensity may be arising from an anisotropy (first source) in the outer space and/or from the semidiurnal anisotropy due to the geometrical inclination of Earth's axis to the ecliptic plane (second source). Several investigators (e.g. Kanno et al.[2]; Girgis et al.[6]) investigated the possibility of the first source. Concerning the second source, the results of El-Bedewi et al.[10] revealed that the shape of the wave forms for the different seasons indicates the presence of higher harmonics superimposed on the semidiurnal wave. Moreover, it was found that the third harmonic, arising from the geometrical effect, has a seasonal variation in its phase and the phase shift from one season to another is 90°. From Table 1, the comparison between the amplitude of the tridiurnal peaks for the different seasons with their mean value verifies the presence of a tridiurnal wave arising from the semidiurnal anisotropy with the inclination of Earth's axis.

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SEZONSKA VARIJACIJA TRIDIURALNOG VALA U INTENZITETU KOZMIČKIH ZRAKA

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Istraživano je postojanje sezonske varijacije tridiuralne varijacije intenziteta kozmičkog zračenja. Analizirani su podaci iz Deep River-a skupljani preko perioda jednog solarnog ciklusa od 1961 do 1971. Tridiuralni val je perzistentan obzirom na sezonu. Amplituda vala mijenja se iz jedne sezone do druge. Usporedba amplituda za razne sezone indicira da postojanje tridiuralnog vala može nastati iz geometrijske inklinacije zemljine osi prema ekliptičkoj ravnini u prisutnosti semiduralne anizotropije.