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CHANGES IN AMPLITUDE AND PHASE OF THE DIURNAL VARIATION OF COSMIC RAY INTENSITY

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Changes in both amplitude and phase of the 24-hour periodicity of the cosmic ray intensity measured by neutron supermonitors at Lomnický peak and Vostok are studied. The dispersion of both magnitude and direction of diurnal anisotropy is greater during the disturbances in the magnetic field near the Earth as well as during solar flares. This dispersion is connected with the changes of the regular magnetic field direction near the Earth.

ИЗМЕНЕНИЯ АМПЛИТУДЫ И ФАЗЫ СУТОЧНЫХ ВАРИАЦИЙ ИНТЕНСИВНОСТИ КОСМИЧЕСКИХ ЛУЧЕЙ

В работе приведены результаты исследований по изменению амплитуды и фазы суточных вариаций интенсивности нейтронной составляющей космических лучей, которая регистрировалась при помощи нейтронного супермонитора на станции „Ломницки штит" и станции „Восток". Выяснено, что дисперсия обеих величин и направления дневной анизотропии больше во время возмущений магнитного поля вблизи Земли и во время солнечных хромосферных вспышек. Эта дисперсия связана с изменениями регулярного межпланетного магнитного поля вблизи Земли.

I. INTRODUCTION

It is known that during the cosmic ray intensity fluctuations some periodical as well as quasiperiodical changes — variations and microvariations [1—2] can be observed. The latter are caused by solar activity (long-time variations), by changes of the atmosphere and of the Earth's magnetic field, or by changes in an interplanetary medium structure.

By observing cosmic ray intensity fluctuations with a neutron supermonitor on the Earth's surface with the asymptotic latitude $\lambda < 90°$ it can be found that the mentioned variations have been modulated by a frequency $f_0 = 1$ day^{-1}.

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Let us consider cosmic ray charged particles with energy from the sphere of the neutron supermonitors sensitivity (~ 10 GeV) flowing in the Earth't vicinity. Changes in the interplanetary magnetic field structure bring about consequent changes in the instantaneous direction of cosmic ray anisotropy and, in accordance with the solar activity variations as well as other parameters of the Earth's magnetic field, have an influence upon anisotropy variations. As a result of this there appear changes in the amplitude and phase of the so-called diurnal variation.

Duggal and Pomerantz [3] were observing the diurnal anisotropy vector changes during the high solar and magnetic activity in July 1961. The Fourier analysis revealed an evident turning of the diurnal anisotropy vector (counter clockwise) after the Forbush decrease on July 18th, 1961; see also [4—5].

Power spectrum variations in cosmic ray during geomagnetic disturbances connected with the power spectrum of the interplanetary magnetic field are referred to for instance, in [6—7]. The authors have found that in the course of "disturbances" the contribution of the particular frequencies was in the range from 10^{-6} to 10^{-3} Hz (i.e. 11 days — 1 min) and, conseeuently the amplitude of the particular frequencies as well.

II. POWER SPECTRUM OF COSMIC RAY INTENSITY

Let us assume that the magnetic field $\boldsymbol{B}$ in the interplanetary medium is homogeneous and the distribution of its random component $\boldsymbol{B}_1$ isotropic. Then therefore holds for the power spectrum of cosmic ray intensity $P(\omega)$ measured on the Earth's surface the relation [8—9]

$$P(\omega)=\left(\frac{\Lambda \nabla n}{R_L B_0}\right)^2 \left\{C_1 B(\omega)+\frac{\cos^2\lambda}{4} C_2 B(\omega-\omega_0)\right\}, \qquad (1)$$

in which $B(\omega)$ is the power spectrum of the magnetic field intensity fluctuations, B_0 is the regular component of the magnetic field, ∇n is the gradient of the cosmic ray density, Λ is the mean transport particle path and R_L is the Larmor radius in the field B_0. C_1 and C_2 are the constants ~ 1. The second member in (1) is non—zero only for $\cos^2\lambda > 0$, i.e. for non-polar stations only.

An ordinary shape of the power spectrum $B(\omega)$ is proportional to $(\omega^2+\omega_0^2)^{-\nu/2}$, while $2\pi/\omega_0=\tau_0$ is the mean time of the magnetic field correlation. It is obvious that for the frequency $\omega \gg \omega_0$ there is $B(\omega)\sim\omega^{-\nu}$. Most experimental values of the index ν are in the interval from 1.3 to 2.0 [10—11].

Fig. 1 shows the power spectrum of the cosmic ray intensity computed from the values measured in 1 hour intervals from March 1st, 1979 to December 31st, 1979 by means of the neutron supermonitor on Lomnický peak (full line). The threshold rigidity $R_0=3.9$ GV. For the power spectrum computation the algorithm TUKEY [12] was used with a maximum lag $M=199$ hours. The dashed line corresponds to

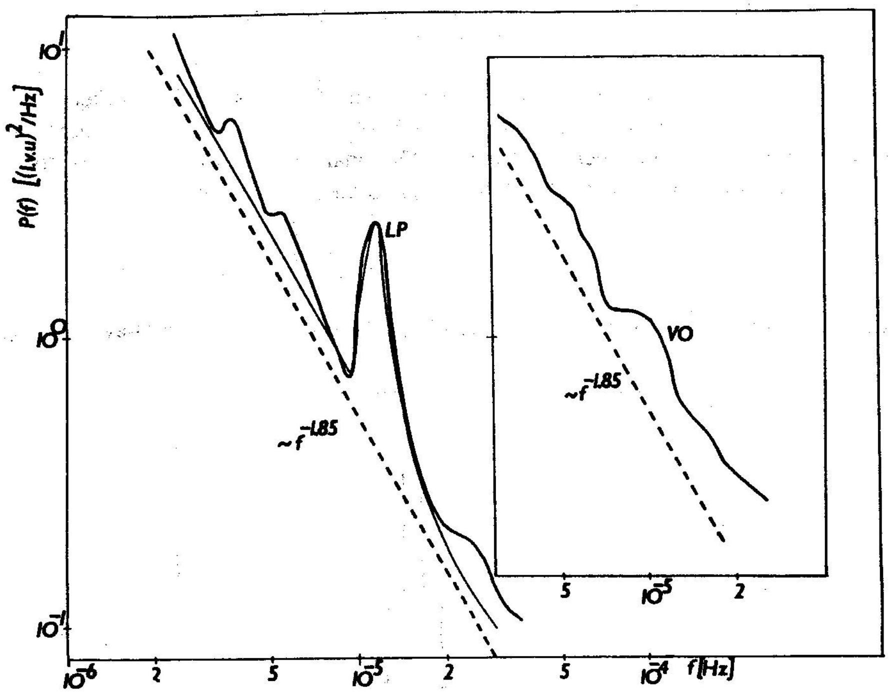

Fig. 1. Power spectra of Lomnicky peak pressure-corrected neutron hourly data (LP) and of Vostok pressure-corrected neutron hourly data (VO), see test.

the dependence $f^{-1.85}$. The thin line corresponds to a theoretically supposed form of the power spectrum according to 1, provided $\nu=1.85$. For comparison there is in this figure also the power spectrum found from the hour values of the Vostok station whose threshold rigidity approaches zero. The peaks in the power spectrum have been shown to be insignificant.

Since the phase and the amplitude of the anisotropy vary, the peak should not approach the delta function, regardless of the frequency resolution. Instead, there should be a increase of the power by about $f=1$ day^{-1}, connected with the phase and amplitude variations. Note that the integral of the power spectrum under the main lobe peak at $f=1$ day^{-1} corresponds to a root mean square anisotropy [13].

The non-zero width of the peak corresponding to the daily variations is due to our assumption during computations of a random component $\boldsymbol{B}_1$ isotropically distributed on the background of the regular field $\boldsymbol{B}_0=\boldsymbol{B}-\boldsymbol{B}_1$. (Direction $\boldsymbol{B}$ varies according to its value $\boldsymbol{B}_0$, the vector $\boldsymbol{B}_0$ being included at an angle $\Psi \doteq 45°$ between the Sun — the Earth).

In the following we shall study the problem of the changes of both the amplitude and the phase of diurnal variations in the period mentioned above.

III. THE AMPLITUDE AND THE PHASE OF THE DIURNAL VARIATION

The Lomnicky peak neutron hourly data from March 1st, 1979 to December 31st, 1979 were divided into 3 parts, each of 102 days. For every part the calculations given below were performed. The final result is the average of these three parts. For every i day the amplitude A_i and the phase φ_i were computed:

$$A_i = \sqrt{a_i^2 + b_i^2}, \qquad \mathrm{tg}\ \varphi_i = b_i / a_i ,$$

where $a_i = (1/12) \sum_{j=0}^{23} I_j \cos \omega_{24} J$, $b_i = (1/12) \sum_{j=0}^{23} I_j \sin \omega_{24j}$, $\omega_{24} = 2\pi/24$ and I_j is the

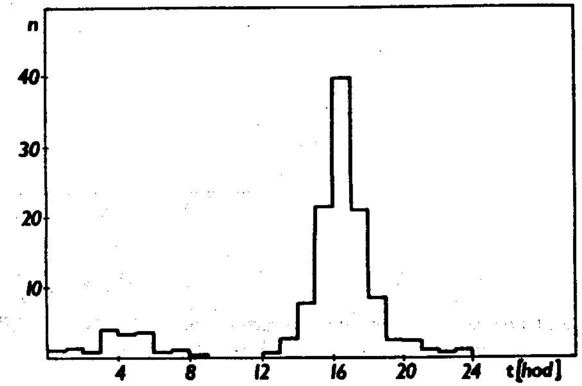

Fig. 2. Distribution of diurnal anisotropy phase.

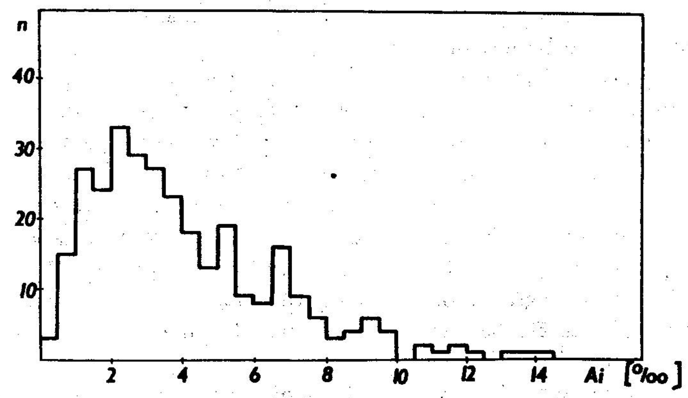

Fig. 3. Distribution of diurnal anisotropy amplitudes.

intensity at the j-hour. The phase φ was computed from φ_i with a weight of A_i/σ_i^2, where σ_i^2 is the variance for 24 hours.

If we take into consideration the geographic longitude of Lomnicky peak (20.22°E) and define $\varphi = 0$ in the direction of the cosmic ray intensity anisotropy, we can obtain the distribution of $\bar{\varphi}_i$ given in Fig. 2. The value $\bar{\varphi}_i$ is equal to φ_i times the corresponding weight. The mean phase is $\varphi = (16.6 \pm 2.6)$ hour, i.e. the mean deviation of the anisotropy vector according to its mean direction is $\Delta\vartheta \doteq 40°$.

The mean amplitude of the diurnal variation is 0.29 %. Its distribution is shown in Fig. 3. Both the drab maximum and the relatively long "tail" of this distribution are connected with the fact that the considered period is charakcterized by frequent disturbances in both the interplanetary medium and the Earth's magnetic field [1].

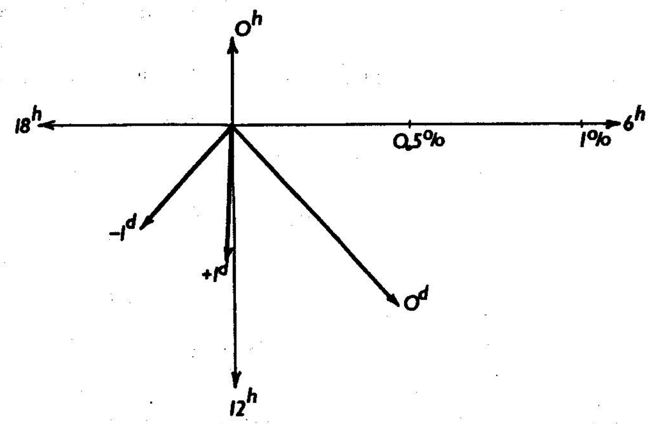

Fig. 4. Changes of the diurnal anisotropy vector during the days in which the K_p-index was increased, see test.

IV. CHANGES OF THE DIURNAL ANISOTROPY PHASE

In order to find the diurnal variation phase dependence upon the Earth's magnetic field changes we selected the days with the increased planetar K_p-index ($\Delta_{min} = +2$) from the period from March 1st, 1979 to December 31st, 1979, altogether 33 cases. In every case we denoted the day in which the K_p-index increased as the zeroth one all and we computed both the amplitude and the phase in three days: -1, 0, $+1$. In Fig. 4 there is the vector diagram of the obtained mean values at the local time. One can clearly see the shift of the phase to early hours on the 0-th day and the opposite shift in the -1st day due to the mean value of the anisotropy direction. Numerically (U.T.):

-1st day — 18.9 hour, 0th day — 13.8 hour, $+1$st day — 16.6 hour.

V. CONCLUSION

The increase of the diurnal anisotropy amplitude of the cosmic ray intensity depends on the state of both the heliosphere and the Earth's magnetosphere. It follows from Figs. 3 and 4 an increase of the amplitude for the disturbed days. The anisotropy direction (phase) changes near the value 16.6 hour (U.T.). Simultaneously the conforming character of the change in this direction can be observed for the days with an increased K_p-index: The phase is delayed the day before the disturbance and laggs behind the mean phase during the disturbed days.

The diurnal anisotropy vector turns counter clockwise and the full revolution (2π) lasts approximatedly 8 days [4]. Unlike this, the diurnal anisotropy vector returns into the mean direction during 2 days in the case of short-time geomagnetic disturbances, when the increase of the K_p-index has lasted a few hours.

A study which is in progress, will report upon the observed diurnal anisotropy as well as its relationship to the power spectrum of the interplanetary magnetic field.

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