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Abstract

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PHYSICS

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27-DAY VARIATIONS IN THE INTENSITY OF COSMIC RAYS IN THE STRATOSPHERE

Experiments carried out at sea level and at mountain altitudes have established the existence of 27-day variations of cosmic rays ([1], [2]), associated with the rotation of the Sun about its axis. In papers ([3]), based on materials from the Carnegie Institution, it was shown that the 27-day variation in the intensity of cosmic rays is clearly expressed in years of maximum solar activity and weakly expressed in years of minimum solar activity.

The study of variations with 27-day periodicity from measurement data at low altitudes is a complex problem. In this case the variations are, to a considerable extent, masked by various meteorological effects. Inaccurate allowance for corrections associated with changes in the temperature and pressure of the atmosphere leads to errors comparable with variations of cosmic rays of extra-atmospheric origin. More direct data on variations of primary cosmic rays can be obtained in experiments at high altitudes, where these variations are mainly of extra-atmospheric origin.

We have carried out a large series of measurements of cosmic-ray intensity in the stratosphere with the aid of balloon-borne sondes. These measurements, which form part of the IGY program, were begun regularly on July 1, 1957, at two geomagnetic latitudes: 1) near Moscow ($\lambda = 51^\circ$, Dolgoprudnaya station, Scientific Station of the Physics Institute of the Academy of Sciences of the USSR) and 2) in the Murmansk region ($\lambda = 64^\circ$, Loparskaya station, Northern Scientific Station of the Academy of Sciences of the USSR). At both latitudes the instruments were launched, as a rule, at one and the same time of day (mainly at 9 or 10 a.m. Moscow time).

In the present article some results will be given for measurements at latitude 51° from July 1, 1957, to February 1, 1958, and at latitude 64° from July 1, 1957, to October 1, 1957, using the RK-1 radiosonde.

In the RK-1 radiosonde sent into the stratosphere there was placed a thin-walled self-quenching charged-particle counter of the STS-6 type, the pulses from

Fig. 1

Figure 1: Fig. 1

which were shaped in a definite way and then fed to a radio transmitter. Each discharge in the counter, transmitted by the radio transmitter, was registered on the ground with the aid of apparatus consisting of a radio receiver connected to a scaling circuit and a mechanical counter. The readings of the mechanical counter were recorded every minute.

Altitude was measured with the aid of a barograph. At the moments when the barograph pointer passed over the contacts, brief pauses occurred in the transmission of signals. By recording these interruptions in the transmission of signals, data were obtained on the altitude of the instrument. The flight weight of the RK-1 radiosonde, including the power supply, designed for 6–8 hours of operation, is 2.2 kg.

Calibration of the counters was carried out by measuring the number of pulses produced by a radioactive source. The measurements were carried out with

with a statistical accuracy of 0.4%. On the basis of this calibration, corrections were introduced into the final results of the measurements in the stratosphere, taking into account differences in the efficiency of the counters.

The STS-6 counters used in the work, at the maximum of the cosmic-ray intensity, registered on average about 2000 pulses/min, which gives a statistical accuracy of the measurements for 1 min of 2%. Obviously, the greatest accuracy in determining cosmic-ray variations in the stratosphere can be obtained from data referring to the maximum of the intensity curve, since in this case there are no high requirements on the accuracy of altitude determination, and the results can be averaged over a relatively long observation time. In our measurements this time was equal to 10–12 min. Consequently, the statistical accuracy of the measurements of cosmic-ray intensity at the maximum for each flight was ~0.8%.

Fig. 1

The results relating to the maximum of the intensity curve in the pressure interval 50-90 g/cm^2 are presented below. The results obtained are shown in Fig. 1, where curve *I* refers to measurements at latitude 51°, and curve *II* to measurements at latitude 64°. Along the ordinate is plotted the deviation, expressed in percent relative to the mean. Curve *III* in Fig. 1, for sea level (Moscow, Krasnaya Pakhra), shows the results of measurements of the ionizing component by means of a spherical ionization chamber of NIIZMIR ([4]). The columns in the figure mark the days of magnetic storms. Their width corresponds to the duration of the storm in days, and their height to the intensity of the magnetic storm: the greatest column height corresponds to a very large magnetic storm, medium height to a large one, and small height to a moderate magnetic storm.

Fig. 2

Figure 2: Fig. 2

The data shown in Fig. 1 indicate periodicity in the variation of cosmic-ray intensity in the stratosphere at both latitudes. Fig. 1 also shows the presence of a correlation of the wave phase in the stratosphere and at sea level. However, the wave amplitude in the stratosphere is 8–10 times greater than the wave amplitude at sea level. The latter means that the variations studied by us are caused to a greater degree by primary cosmic particles of low energies. From the data on magnetic storms it follows that not in every case is there a connection between variations in the intensity of cosmic radiation and the occurrence of magnetic storms.

It is of great interest to find the recurrence period of the variations of cosmic radiation that we are studying. As can be seen from Fig. 1, during the measurements, with a total duration of 212 days (at latitude 51°), 15 half-periods can be noted. If it is assumed that, because of the uncertainty in the beginning of the cycles, the number of half-periods was determined by us with an accuracy of one half-period, then the duration of one half-period is found to be $215 : 15 = 14.3 \pm 1$ days. A more exact value of the period can be found in the following way.

Fig. 2

The set of points on curve I of Fig. 1 was divided into cycles with a period of T days. For each time interval T, the deviation data were written down successively by days in rows. Then these deviations were added arithmetically by rows and by columns over all cycles separately, for the first and second half-periods $T/2$. In this way the difference of the mean deviations between the two half-periods, $\sigma(T)$, was found. At the same time, by shifting the starting point of the cycle (within $T/2$ days), the values of $\sigma(T)$ were chosen so that in each case they had the maximum value $\sigma_{\max}$.

Obviously, in the case of periodic phenomena the dependence of σ on T will give a curve with a maximum that will lie near the true period. The dependence of $\sigma_{\max}$ on T obtained from our data is shown in Fig. 2, where it is seen that the maximum is obtained when $29 > T > 28$ days.

The data characterizing the wave that gives the maximum deviation (on the curve of Fig. 2, $T = 28.5$ days) are shown in Fig. 3 (curve I). The smooth curve II (Fig. 3) represents the form of the same wave obtained after averaging the points over three days (with allowance for the statistical weight determined by the number of measurements on the given day). The errors shown are the root-mean-square deviations from the mean value obtained over three days. We note that the waves obtained for other values of T are less distinct. This can be seen, in particular, on curve III of Fig. 3, obtained for $T = 27$ days.

Fig. 3

Figure 3: Fig. 3

Fig. 3

In the period from July 11 to October 29, 1957, measurements in the stratosphere were carried out by M. A. Pomerants and others. The authors report that the data of their preliminary analysis indicate the existence of 27-day variations of cosmic-ray intensity in the stratosphere ([5]). It appears that, by improving the methods of processing and obtaining new measurement data, it will be possible to trace changes in the period of the investigated variations of cosmic radiation in the stratosphere and to find new connections of these variations with phenomena on the Sun.

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Note: Figure translations are in progress. See original paper for figures.