ANNUAL VARIATIONS OF COSMIC RAYS AND THE CHANGE IN THE INTENSITY OF COSMIC RADIATION AS A FUNCTION OF THE EARTH’ S HELIOLATITUDE

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Abstract

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ANNUAL VARIATIONS OF COSMIC RAYS AND THE CHANGE IN THE INTENSITY OF COSMIC RADIATION AS A FUNCTION OF THE EARTH' S HELIOLATITUDE

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Numerous works have been devoted to seasonal variations of the secondary components of cosmic rays ($^{1-10}$), in which the variations are attributed mainly to their meteorological nature. The difference obtained between the observed variation and the theoretically calculated one—the annual wave—is ascribed to the inaccuracy of radiosonde data (^{1}) or to an underestimation of the contribution of temperature above the 50- or 100-mb level (^{4}). Vallarta and Godart (^{10}) proposed an explanation of the annual variation of cosmic rays associated with the annual change in the Earth' s heliolatitude, periodic changes in the distance between the Earth and the Sun, and the inclination of the Earth' s axis to the perpendicular to the plane of the ecliptic. However, the variation calculated on the basis of these assumptions did not agree with the experimental data (^{9}). E. S. Glokova (^{11}), using data from the worldwide network of stations for 1937-1946, found an annual course in the intensity of μ-mesons that correlated well with the annual course of the C-index of magnetic activity and was of a worldwide character. In (^{11}) the conclusion was drawn that the annual variations are of extra-atmospheric origin.

From the foregoing it is clear that there is no single point of view on the nature of annual changes in the intensity of cosmic rays. Obviously, an unambiguous answer to this question can be found only through a detailed study of data from the worldwide network of cosmic-ray stations and aerological sounding, with the inclusion of data on other geophysical phenomena.

In the present work such data for 1960 were used. Figure 1a, b shows curves of the seasonal course of monthly mean values of the intensity of the hard and neutron components of cosmic rays, corrected for the barometric effect and for the secular variation by the least-squares method (^{12}). Analysis of the curves shows that in the hard component there is a wave with a period of 12 months, whereas in the neutron component there is no such wave. The latter speaks in

Figure 1

Figure 1: Figure 1

favor of the fact that a large contribution to the seasonal variation of the hard component is made by the annual change in the temperature of the atmosphere.

Let us calculate the expected seasonal variation $\delta N(h_0)/N(h_0)$ of the hard component, using radiosonde data $\delta T(h)$ up to the 50-mb level by the integral method proposed in (^{13}):

$$\frac{\delta N(h_0)}{N(h_0)} = \int_0^{h_0} W(h)\, \delta T(h)\, dh,$$

where $W(h)$ is the density of the temperature coefficient, found theoretically in (^{13}). The results are shown in Fig. 1a by the dashed line. Subtracting the expected wave from the observed seasonal variation of the hard component, we obtain the residual annual variation, which is shown in Fig. 1b. As for the neutron component, the annual wave is traced—

is observed at all stations and has clearly expressed maxima near the equinox periods. The agreement of the annual behavior of the neutron component, which has almost no temperature effect, with the analogous behavior

Fig. 1. Seasonal behavior of the intensity of cosmic rays. **a**—hard component: solid line—the observed wave; dashed line—the expected wave; **b**—neutron component, corrected for noncyclicity; **c**—residual annual wave of the hard component, corrected for noncyclicity. **1**—Krasnaya Pakhra (shielded ionization chamber); **2**—Tbilisi (shielded ionization chamber); **3**—Hayes Island (counter telescope); **4**—Ottawa (counter telescope); **5**—Uppsala (counter telescope, neutron monitor); **6**—Sulphur (counter telescope, neutron monitor); **7**—Prague (counter telescope); **8**—Kampala (counter telescope); **9**—Hobart (counter telescope, neutron monitor); **10**—Washington (neutron monitor); **11**—Nederhorst (neutron monitor); **12**—Climax (neutron monitor); **13**—Tsumeb (neutron monitor); **14**—Jungfraujoch (neutron monitor); **15**—Pic du Midi (neutron monitor); **16**—Rome (neutron monitor); **17**—Norikura (neutron monitor); **18**—Huancayo (neutron monitor); **19**—mean for all neutron-component stations; **20**—mean for all hard-component stations; **21**—annual behavior of the K_p index. Designations: shielded ionization chamber; counter telescope; neutron monitor.

of the hard component of cosmic rays indicates the extra-atmospheric origin of this variation. It is clear that this variation cannot be attributed to inaccuracies in introducing corrections for the temperature effect [1].

Thus, the results obtained indicate the correctness of the theory of meteorological effects $^{(13)}$ and the presence of a characteristic extra-atmospheric annual

Figure 2

Figure 2: Figure 2

wave in the intensity of cosmic rays, with maxima during the equinoctial periods.

It is known (14,15) that the activity of magneto-ionospheric disturbances and auroras also exhibits pronounced maxima in the equinoctial periods. The annual course, constructed by us, of the monthly mean values of the geomagnetic-activity index K_p (Fig. 1b) for this same period shows a good positive correlation with the annual course of the cosmic-ray intensity corrected for meteorological effects.

Fig. 2. Dependence of the intensity of cosmic rays on the heliolatitude of the Earth.
a –neutron component;
b –hard component

It is evident that the noted behavior of the totality of geophysical phenomena during the year can be interpreted from the standpoint of the relative position of the plane of the Earth' s equator and the plane of the ecliptic. The point is that active regions on the Sun, which are sources of corpuscular streams, for the most part form within 25° north and south of the solar equator and shift toward the equator as solar activity declines. If, starting from the assumption of radial propagation of corpuscular streams, it is admitted that the region of propagation of these streams in a plane perpendicular to the plane of the ecliptic is limited, then the geophysical phenomena observed in the equinoctial periods receive a fully well-founded physical interpretation (14,15).

In this case, the positive correlation of the annual course of the K_p-index of magnetic activity and the intensity of cosmic rays could be explained in light of ideas about the influence of the deformed magnetosphere of the Earth on the intensity of cosmic rays (16,17). However, the estimate we made, according to formulas (18), from changes in the horizontal component of the Earth' s magnetic field $\bar{H}$ at the equatorial station Huancayo (6.2°S), of the expected changes in the intensity of the neutron component shows that the expected effect is no more than 0.2%. This effect is much smaller than the observed one, and it practically does not affect the annual course obtained for the intensity of cosmic rays.

The study of 11-year variations in the intensity of cosmic rays (18,19) and measurements in cosmic space carried out on the "Pioneer-V" rocket (20) speak in favor of the existence of a radial gradient of the density of cosmic rays in interplanetary space ($\lesssim 1\%/0.1$ AU). It is evident that if the propagation conditions and the frequency of emission of corpuscular streams change with a change in angle with respect to the plane of the solar equator, then the position of the Earth, as a probe registering cosmic rays, relative to the center of symmetry of these streams may provide important information on the transverse gradient of cosmic-ray density. In particular, a change in the position of the Earth relative to the plane of the solar equator, in the presence of a transverse gradient of intensity, should lead to a distinctive change in the intensity of cosmic rays on the Earth over time.

Figure 2 shows the dependence of the intensity of the neutron and hard components of cosmic rays on the Earth' s heliolatitude during 1960*. The figure shows that there is indeed a small transverse gradient of cosmic-ray density in interplanetary space. An estimate of this gradient (in the direction perpendicular to the plane of the ecliptic) from the experimental data analyzed gives a value of $\sim 1.3\%/0.1$ AU for the neutron component and $\sim 1.0\%/0.1$ AU for the hard component. This value is an order of magnitude smaller than the gradient assumed in (21) to explain the solar diurnal variation of cosmic rays**.

The peculiarity of the distribution of intensity on Earth as a function of heliolatitude indicates the existence in interplanetary space of a region with a minimum value of the cosmic-ray intensity. It lies near the plane of the helioequator. The hysteresis phenomena observed on these same curves may be a consequence of a certain asymmetry in the distribution of active regions on the Sun during the year, and may also be connected with a lag in changes of the cosmic-ray intensity relative to changes in solar activity.

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CITED LITERATURE

1. Yu. G. Shafer, V. D. Sokolov, *Tr. Yakutskogo filiala AN SSSR*, ser. fiz., vol. 1, Izd. AN SSSR, 1955, p. 5.
2. Yu. G. Shafer, V. D. Sokolov et al., *Geomagnetic and Heliophysical Effects in Cosmic Rays and Polar Auroras*, "Nauka," 1964, p. 29.
3. L. I. Dorman, A. I. Kuzmin et al., *ZhETF*, 26, no. 5, 537 (1954).
4. L. A. Fruk, B. F. Shvartsman, *Trudy Yakutskogo filiala AN SSSR*, ser. fiz., vol. 2, Izd. AN SSSR, 1958, p. 118.
5. R. J. Hynds, *J. Atmosph. and Terr. Phys.*, 24, 257 (1962).

6. N. S. Kaminer, S. F. Ilgach, T. S. Khadakhanova, *Geomagnetism and Aeronomy*, 4, no. 5 (1964).
7. A. I. Kuzmin, G. F. Krymskii et al., in: *Cosmic Rays*, no. 7, "Nauka," 1965, p. 30.
8. A. I. Kuzmin, *Variations of Cosmic Rays of High Energies*, "Nauka," 1964.
9. S. E. Forbush, *Phys. Rev.*, 54, 975 (1938); *Rev. Mod. Phys.*, 11, 168 (1939).
10. M. S. Vallarta, O. Godart, *Rev. Mod. Phys.*, 11, 180 (1939).
11. E. S. Glyukova, *Izv. AN SSSR*, ser. fiz., 20, 47 (1956).
12. B. S. Yastremskii, *Some Questions of Mathematical Statistics*, 1961.
13. L. I. Dorman, *Variations of Cosmic Rays*, 1957.
14. N. P. Benkova, A. N. Sukhodolskaya, in: *Cosmic Rays and Problems of Cosmophysics*, Novosibirsk, 1965, p. 224.
15. B. M. Yanovskii, *Terrestrial Magnetism*, part 1, L., 1964.
16. L. G. Asaulenko, L. I. Dorman et al., *Geomagnetism and Aeronomy*, 5, no. 5, 809 (1965).
17. L. I. Dorman, A. M. Chkhetia, in: *Cosmic Rays*, no. 7, "Nauka," 1965, p. 140.
18. L. I. Dorman, *Variations of Cosmic Rays and Space Research*, Izd. AN SSSR, 1963.
19. I. V. Dorman, L. I. Dorman, in: *Cosmic Rays*, no. 7, "Nauka," 1965, p. 5.
20. C. Y. Fan, P. Meyer, J. A. Simpson, *Phys. Rev. Letters*, 5, no. 6, 272 (1960).
21. G. F. Krymskii, A. I. Kuzmin, G. V. Skripin, in: *Cosmic Rays*, no. 7, "Nauka," 1965, p. 18.

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* The averaging was carried out taking into account the statistical weights for each station. The list of stations is given in the caption to Fig. 1.

** This shows that the mechanism considered in (21) is insufficient to explain the solar diurnal variation.

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