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SUMMARY

The intensity variations of cosmic rays are measured by the counters of Zond-3 and Venus-2; these probes moving in different directions allow to account for their temporal variations and to determine their radial gradient.

To explain the radial gradient of protons with energy 1 ÷5 Mev, detected by the probes' apparatus, and of which the temporal character is ruled out, various mechanisms are proposed, which concern both the galactic and solar origin of these protons.

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Two interplanetary probes were simultaneously in flight at the end of 1965 and at the beginning of 1966. These are VENUS-2 and ZOND-3. While the latter drifted away from the Sun during its motion, the former was drawing nearer it. The trajectory projections on the ecliptic plane are shown in Fig.1. The simultaneous measurement of intensity variations of cosmic rays on probes moving in different directions allows us to account in the best manner for their temporal variations and to find the dependence of this quantity on the distance from the Sun, that is, to determine their radial gradient. The estimates of the latter were published earlier in references [1-3].

In Fig.2 we brought out the results of measurements of cosmic ray intensity by the gas discharge counters STS-5 installed aboard Venus-2 and Zond-3 for the period from 14 November 1965 to 21 January 1966. On Venus-2 the averaging of data was done for 4-hour interval, except for the portion 19-26 December 1965, for which the average available covers the entire interval. The data available from Zond-3 for that time are only in the form of average values for large time intervals (5 to 7 days and more). Plotted in Fig.4 are also the 4-hour values of the counting rate of the neutron monitor at Deep River. It may

*VARIATSII KOSMICHESKIKH LUCHEY PO DANNYM STANTSIY ZOND-3 I VENERA-2 be seen from Fig.2 that the variations of intensity in different regions of interplanetary space have not only a different amplitude, but are noncontemporary, which is particularly clearly seen by the time of occurrence of characteristic intensity variations.

This is why two flight portions were chosen for the determination of the radial gradient of cosmic ray intensity, at the beginning and at the end of the joint flight of Venus-2 and Zond-3, characterized by a relative quiescent state of intensity of cosmic rays. The portion t_1 from 15 to 20 Nov. was chosen at the beginning of the flight, and t_2 from 4 to 11 January 1966 at the end. The mean values of intensities for these time intervals are known with great precision, up to 0.02 percent.

However, since the variations of intensities in the regions of Venus-2 and Zond-3 are different, the dispersions of the 4-hour values of intensities were determined by the counter readings of Venus-2, and they were taken for the measurement error.

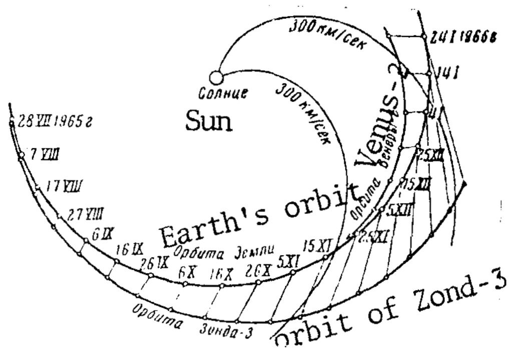

Fig.1. Trajectory projections of Venus-2 and Zond-3 on the ecliptic plane. The lines from the Sun indicate the shape of the corpuscular stream for radial velocity of 300 km/sec

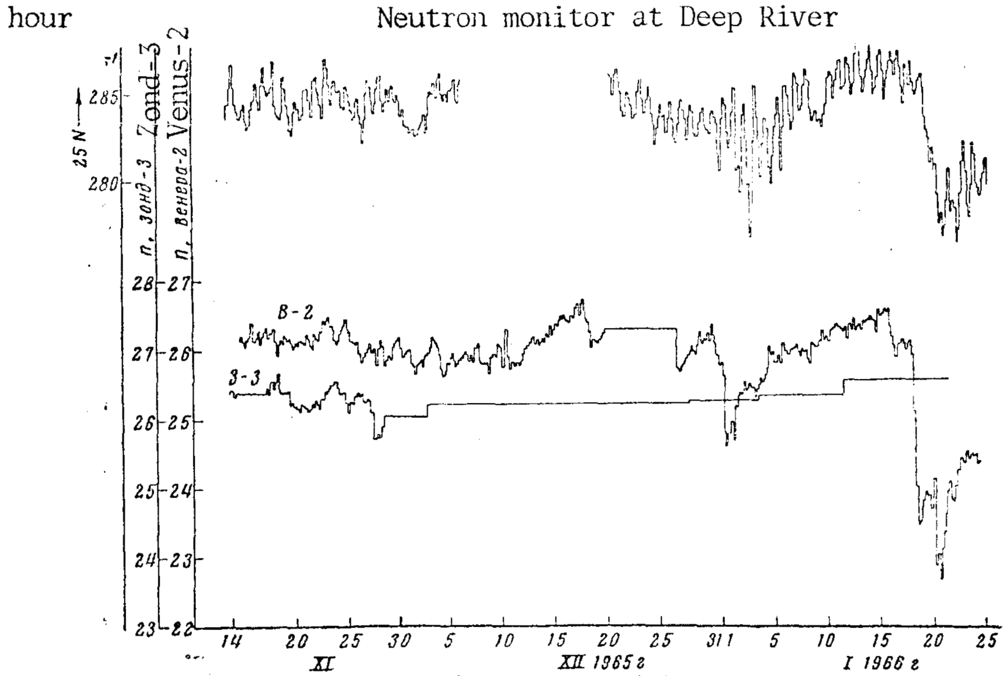

Fig.2. Cosmic ray intensity registered on Venus-2 and Zond-3, and by ground neutron monitor at Deep River

As a result of this, all the following values of mean counting rate of Zond-3 and Venus-2 counters have been obtained for these time intervals, the probes being then at average distances R from the Sun as follows:

$$N_{Zond-3}(t_1, R_1) = 26.38 \pm 0.015;$$
$$N_{Zond-3}(t_2, R_2) = 26.31 \pm 0.03$$
$$N_{Venus-2}(t_1, R_3) = 26.17 \pm 0.015;$$
$$N_{Venus-2}(t_2, R_4) = 25.95 \pm 0.03;$$

where

$$R_1 = 182 \cdot 10^6 \text{ km},$$
$$R_2 = 192 \cdot 10^6 \text{ km},$$
$$R_3 = 148 \cdot 10^6 \text{ km},$$
$$R_4 = 134 \cdot 10^6 \text{ km}.$$

The value of the radial gradient, found from these data was $\delta = (3.1 \pm 0.4)$ % on 1 a.u.

The shift in time of the characteristic peculiarities of cosmic ray intensity behavior for the various regions of the solar system may be conditioned by the displacement in space of magnetic inhomogeneities, either facilitating or hindering the hitting at the given point by particles of primary cosmic radiation. It is natural to assume that the displacement velocity of these inhomogeneities is near that of the solar wind, i. e., it constitutes some 300 km/sec. During the time of the joint flight of Venus-2 and Zond-3 the difference of the distances from the points of stations to the Sun varied from 30 to $65 \cdot 10^6$ km. This means that the characteristic variations of intensity must have been observed on Zond-3 one to two days earlier than the corresponding variations on Venus-2.

In order to compare the counter readings on the probes Venus-2 and Zond-3 we plotted in Fig.3 the mean values of intensities registered on the two probes at identical and coinciding time intervals (see Fig. 3a), and also at those shifted in time by $\Delta t = \Delta l / V$, where Δl is the difference between the distances from the Sun for the positions of Zond-3 and Venus-2 at the given moment of time, V being the solar wind velocity, equal to 300 km/sec. If we consider that such a shift leads to more correct accounting of temporal variations, and if we compute the gradient of cosmic rays on the basis of the values of intensities obtained after the shift and of length variation of averaging intervals, we shall find for the gradient a value $\delta = 5\%$ on 1 a.u. As may be seen from Fig. 3b, there is an irregularity of the radial gradient, which may be linked with the variation of the character and of the magnitude of the Forbush effects at various distances from the Sun. This is why it is possible that the obtained radial gradient is determined by Forbush effects.

Two Forbush-drops of cosmic ray intensity took place during the flight of Venus-2 (see Fig.2). Besides the above-noted absence of contemporaneity of this effect, a different character of its development is clearly perceptible. On Venus-2 the Forbush effect sets in very rapidly, the sharp intensity decrease takes place in a time less than 4 hours for 31 December 1965 and near 8 hours for 18 Jan. 1966. During both Forbush effects the neutron monitor on the ground shows a considerably slower drop, constituting some 2 - 3 days, i.e., 10 times slower than for Venus-2. The gradual commencement of the Forbush-effect on the ground may be either explained by the influence of the Earth's magnetosphere or by the fact that particles with greater impulses are measured on the ground by comparison with those on the probe Venus-2.

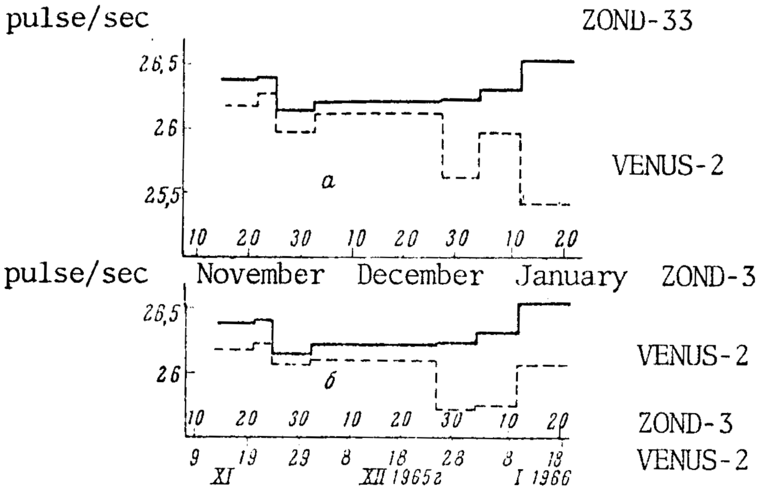

Fig. 3. Values of the counting rate for the probes Venus-2 and Zond-3 averaged for several days during the time of their joint flight; a) averaging by identical contemporary time intervals; b) averaging for Venus-2 by time interval shifted relative to Zond-3

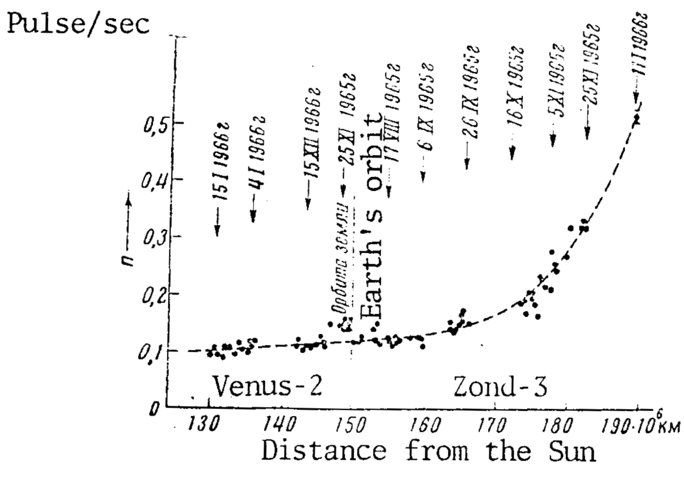

Fig.4. Dependence of proton intensity of 1 ÷ 5 Mev on the distance from the Sun. The dots correspond to average daily intensity for quiet days those with observed proton flares 1 ÷ 5 Mev being excluded

Radial Gradient of Protons with Energy 1 ÷ 5 Mev. Besides the sharp increase of the counting rate the n - p-detectors installed on the probes Zond-3, Venus-2 and Venus-3, and sensitive to protons with energy 1 ÷ 5 Mev, revealed a very steady and rather constant in time background, exceeding by about a factor of 10 the possible background of high-energy particles.

The average daily readings of the proton detectors of Venus-2 and Zond-3 are plotted in Fig.4. The time periods corresponding to sharp intensity increase (flares) are excluded. It may be seen from the graph that the intensity of protons rises sharply with the distance from the Sun. As the latter varied from $130 \cdot 10^6$ to $190 \cdot 10^6$km, the intensity of this, apparently isotropic radiation of protons with energy 1 ÷ 5 Mev increased fivefold. The segment of contemporary variation on Zond-3 and Venus-2 at different distances of the Sun rules out the temporal character of this phenomenon. As follows from Fig.4, the particularly rapid rise begins from distances of $160 \cdot 10^6$km.

It is natural to assume that these protons have a solar origin. But then it is rather difficult to conceive the rise of their intensity as the distance from the Sun increases. It is nonetheless possible to propose certain mechanisms explaining qualitatively the rise in intensity with the distance from the source, provided we take into account that here reference is made to intensity ouside the channels, along which the ejection of particles from the Sun takes place.

The sharp increase of intensity at a distance $\geqslant 1.4$ a.u. is evidence that the accumulation of protons, egressing along magnetic channels beyond the Earth's orbit, takes place at a comparatively small distance from the Sun, say, 1.5 ÷ 2 a.u., i. e., we must assume that at these distances the field of magnetic tubes loses its orderliness, and the motion of protons acquires a chaotic and possible diffusive character. Part of particles of this proton belt leaves the solar system, and another part diffuses toward the center.

In order to explain the gradient we might take advantage of the Parker theory forecasting the gradient of galactic cosmic rays, but with the source not at infinity, but in the form of a ring, disposed in the 1965 period in the region of Mars' orbit. The value of the gradient of proton intensity (1 ÷ 5 Mev) between the orbits of Venus and of the Earth constitutes 100 percent on 1 a.u., that is, 30 times more than the possible gradient of galactic cosmic rays. This difference is apparently justifiable by the difference in particle energy. Incidently, it is possible that the application of the Parker diffusion theory for the explanation of gradient in the region of the terrestrial orbit, where the magnetic field has a quasiregular character, is unlawful.

However, particle extrusion in the presence of a regular radial field is possible when these particles originate from without, at the expense of propagation from the Sun of magnetic disturbances and shock waves. But it may be admitted that the motion of protons in the region of the Earth's orbit takes place in a very orderly fashion, with the preservation of the magnetic moment. It is difficult to expect in this case a gradient of galactic cosmic rays. But for protons of solar origin, the following mechanism is possible.

Protons of 1 ÷ 5 Mev energy, which are often accelerated on the Sun (see [4]), along the lines of force, are carried at great distances from the Sun, where the magnetic field is strongly attenuated and loses its regular character. This is why the pitch-angle of particles may vary there in connection with the nonpreservation of the magnetic moment. When the pitch angle becomes > 90°, the return motion of particles begins toward central regions of the solar system. If we assume that the pitch-angle varies basically by small angles, for the returning particles the maximum because of that must take place for a pitch-angle equal to 90°. Further, the particles may perform oscillations, for at great distances from the Sun they must change their pitch-angle only by a small quantity. Contrary to that particles with a small pitch-angle will either depart beyond the limits of the solar system, or return to its central parts with a pitch-angle close to 90°.

The considered mechanism must lead to the presence of a large radial gradient of protons with energy 1 ÷ 5 Mev.

***** T H E E N D *****

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