COSMIC GAMMA RADIATION IN THE 0.3 - 3.7 MeV RANGE

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Investigations with the satellite "Kosmos-135" [1] have established that measurements of γ radiation of medium and low energy with the aid of omnidirectional detectors, performed on low-flying satellites in a wide range of geomagnetic coordinates, makes it possible in principle to obtain accurate estimates of the flux of cosmic diffuse γ radiation and its contribution to the total γ-quantum flux measured near the earth.

We present below an analysis of the data obtained with the satellites "Kosmos-135" and "Kosmos-163." The measurements were made with a 64-channel γ spectrometer [2]. The γ-radiation detector was an NaI(Tl) crystal with diameter and height 40 mm, surrounded by a plastic scintillator to shield it against the charged particles.

The γ-quantum counting rate measured on the satellite orbit is the sum of two components

$$n = n_c + n_a. \tag{1}$$

In the vicinity of the earth, the most intense component is n_a, corresponding to the γ radiation generated in the earth's atmosphere when the latter is acted upon by primary cosmic ray particles. The component n_c of the primary cosmic γ radiation is much weaker. Modulation of the flux of cosmic rays by the geomagnetic field leads to a dependence of the total γ-radiation flux, and hence of the γ-quantum counting rate, on the rigidity R of the geomagnetic cutoff. Such a dependence can be represented in the range of R from 17.5 to 7 GV in the form of a function of R:

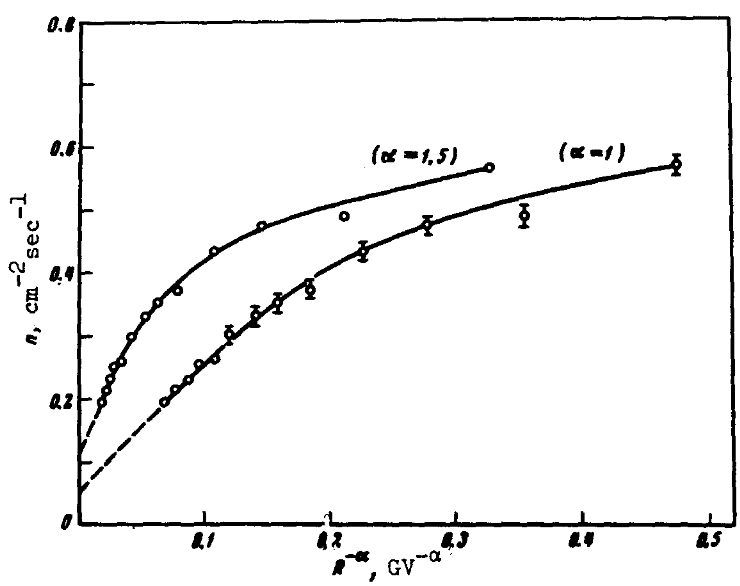

Fig. 1. Estimate of the counting rate n_c of the cosmic γ quanta in the energy range 0.4 - 2.5 MeV.

$$n = n_c + n^{\circ}_{\alpha} R^{-\alpha}. \quad (2)$$

The accuracy of the experimental data obtained in this range of variation of R is insufficient for a direct unambiguous determination of the constants and of the exponent α in (2). It can be indicated that α should range between 1.5 and 0.5, corresponding to the dependences of the charged-particle flux and the cosmic-ray energy flux on the threshold rigidity. For a number of possible values of α, extrapolation of (2) to $R \to \infty$ ($R^0 \to 0$) makes it possible to determine n_c. By way of an example, Fig. 1 shows the result of measurement on the satellite "Kosmos-135" in January 1967, plotted in terms of the coordinates n and $R^{-\alpha}$ for $\alpha = 1.5$ and 1. Extrapolation to $R \to \infty$ at $\alpha = 1.5$ yields the largest value of the cosmic γ-quantum counting rates, which in this case amounts to 55% of the value of the total counting rate n of the γ rays observed experimentally in the region of the geomagnetic equator. This value drops to 25% at $\alpha = 1$ and tends to zero at $\alpha = 0.7$.

We have obtained in addition data from which it follows that actually $\alpha \leq 1$. The γ radiation in the earth's atmosphere results primarily from the development of electron-photon showers in the atmosphere. Therefore, for radiation emerging from the atmosphere, the latitude dependences of the intensity of the 0.511-MeV line and of the intensity of the continuous spectrum should coincide. According to measurements with Ranger-3 [3], the 0.511-MeV line was not observed in interplanetary space. Consequently, in observations near the earth the component n_c can be present only in the continuous spectrum. An analysis of the data has shown that the dependences of the intensity of the atmospheric radiation in the 0.511-MeV line and in the continuous spectrum on the geomagnetic rigidity coincide closely under the conditions that n_c is equal to 25% of the total counting rate n in the equatorial region.

Thus, an estimate of the flux of cosmic γ quanta in the continuous spectrum, obtained by extrapolation of the results of the measurement in the geomagnetic field to infinite rigidity for $\alpha = 1$, is the best-founded value of the upper limit.

Such estimates were carried out for a number of energy intervals. The results of the measurements of the intensity of the diffuse γ radiation I_c, corrected for the efficiency of registration of the radiation with a power-law spectrum and the screening by the earth, are gathered in the table. To increase the reliability of the estimates, we used mainly data obtained during the first day of flight of each satellite from the instant of its launching to the first passage through the zone of the South-Brazil anomaly. When corrections are

Experiment	Radiation energy E_γ, MeV	Primary cosmic γ-radiation energy I_γ, $cm^{-2}sec^{-1}MeV^{-1}sr^{-1}$
Kosmos-135	0,45 – 0,65	$\leqslant 4.0 \cdot 10^{-2}$
	0,65 – 2,50	$\leqslant 8.3 \cdot 10^{-3}$
	0,40 – 2,50	$\leqslant 9.7 \cdot 10^{-3}$
Kosmos 163	0,55 – 0,80	$\leqslant 1.5 \cdot 10^{-2}$
	0,80 – 3,70	$\leqslant 3.6 \cdot 10^{-3}$
	0,30 – 0,40	$\leqslant 6.5 \cdot 10^{-2}$
	0,40 – 0,60	$\leqslant 3.5 \cdot 10^{-2}$
	0,60 – 1,00	$\leqslant 8.8 \cdot 10^{-3}$
	1,00 – 2,00	$\leqslant 5.3 \cdot 10^{-3}$
	2,00 – 3,70	$\leqslant 1.5 \cdot 10^{-3}$
	0,40 – 2,50	$\leqslant 9.0 \cdot 10^{-3}$

introduced for the background of the radioactivity induced by the proton in the anomaly zone, such estimates are possible also for the succeeding days of the flight.

The results of our measurements of the intensity of the cosmic γ radiation together with the data obtained by others in the x-ray and γ bands are shown in Fig. 2.

The results of measurements outside the magnetosphere, performed with the ERS-18 satellite, were interpreted as observation of a new component in the diffuse cosmic γ radiation [4] and suggested the hypothesis that there exist specific mechanisms responsible for its occurrence [5, 6].

It follows from Fig. 2 that our data and the results of measurements of the x-radiation [7 - 9] and of the hard γ radiation [10, 11] can be satisfactorily represented by a common power-law spectrum proportional to E^{-n} with an exponent n = 2.3 - 2.5. Thus, our results do not confirm the data obtained in measurements with the ERS-18, and apparently contradict the hypothesis that the processes considered in [5, 6] predominate in the formation of the flux of diffuse cosmic γ radiation with energy 1 - 10 MeV.

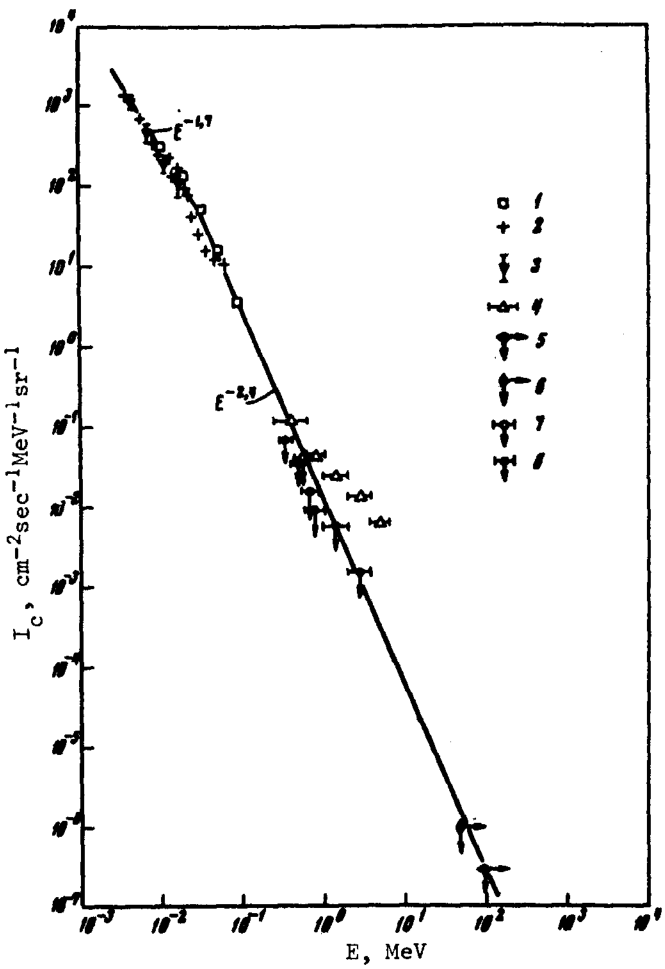

Fig. 2. Intensity of cosmic x-radiation and γ radiation: 1 - [7], 2 - [8], 3 - [9], 4 - [4], 5 - [10], 6 - [11], 7 - "Kosmos-135," 8 - "Kosmos-163."

The possible cause of the indicated discrepancies in the results of the measurements of the intensity of the primary γ radiation with energy 1 - 6 MeV near the earth and outside the magnetosphere is the difference in the background level, connected with the induced radioactivity of the detectors. This radioactivity is produced by nuclear reactions caused by particles of the primary cosmic rays. The energy of excitation of most radioactive nuclei lies precisely in the 1 - 6 MeV range. The decay of such a nucleus in the detector is not discriminated by the protective anticoincidence circuit and is registered by the instrument as a γ quantum. In measurements of the γ-radiation flux near the earth in the region of the geomagnetic equator, the intensity of the primary cosmic rays drops in comparison with the interplanetary space by more than one order of magnitude, and the indicated component of the background becomes of no significance.

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OBSERVATION OF SMALL POLARONS IN β-FeSi WITH THE AID OF THE MOSSBAUER EFFECT

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The semiconducting nature of the low-temperature modification of the higher silicide of iron (β-$FeSi_2$) has been investigated in a number of papers [1 - 5]. The widths of the forbidden band in its energy spectrum is ~0.9 eV. The impurity conductivity and the optical absorption of β-$FeSi_2$ doped with cobalt (n-type) have been interpreted in the small-polaron model [2, 5].

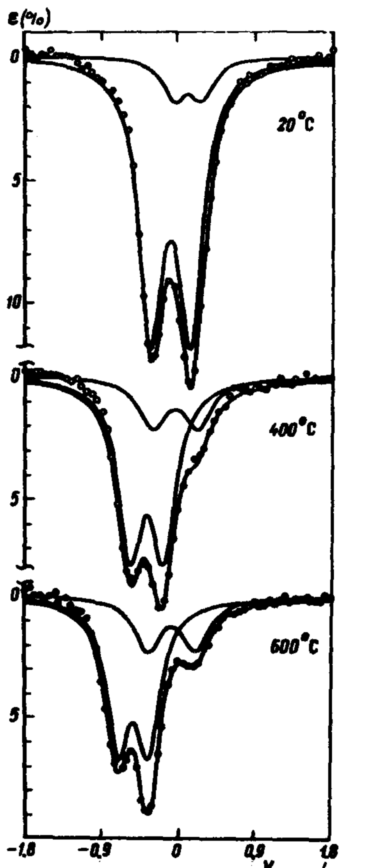

Fig. 1. Mossbauer spectra of Fe^{57} in β-$FeSi_2$ at different temperatures.

The crystal structure of β-$FeSi_2$ was determined in [6], viz., Cmca, rhombic lattice, a = 9.763 Å, b = 7.797 Å, c = 7.833 Å, the Fe atoms occupy the positions 8d and 8f, and the Si the positions 16g with two sets of structure parameters. Different data, however, are given in [7] concerning the space group of the silicide in question.

The Mossbauer spectrum of Fe^{57} in β-$FeSi_2$ [8] was investigated earlier at the nitrogen boiling temperature and at room temperature.

To obtain new information on the electronic structure of β-$FeSi_2$, we investigated the Mossbauer effect in the temperature region from -196 to 600°C. The samples were prepared by direct fusion of high-purity components in a hermetically sealed high-frequency furnace. The obtained alloy was annealed at 950°C for 100 hours. Metallographic and x-ray structure analyses have confirmed the single-phase character of the compound.

The Mossbauer absorber was prepared by deposition of β-$FeSi_2$ powder from an alcohol suspension onto a beryllium disk. The thickness of the absorber was 15 mg/cm^2. The radiation source was Co^{57} introduced into Pd. The spectra were processed with a "Mir" computer assuming a Lorentz line shape.

Figure 1 shows the Mossbauer spectra of β-$FeSi_2$ at three temperatures. At room temperature the absorption line is an almost symmetrical doublet. With increasing temperature, the spectrum