Investigations of diffuse cosmic γ radiation in the range 28 keV–4.1 MeV

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We consider the results of measurements of the spectrum of the diffuse cosmic x rays and γ rays in the range 28 keV–4.1 MeV, performed on the "Kosmos-461" satellite.

The need for refining the experimental data on the spectrum of the diffuse background radiation is dictated by the possibility of extracting very important astrophysical information from these data. One of the tasks of the experiments performed on the "Kosmos-461" satellite, launched December 2, 1971 on a circular orbit of 500 km altitude, was the study of the diffuse background of x rays and γ rays in the range 28 keV–4.1 MeV. A multichannel scintillation γ spectrometer was in operation on board the satellite. An omnidirectional γ-ray detector (geometric factor 57.5 cm^2), consisting of an NaI(Tl) crystal and a photomultiplier, was located on the end of a long rod.

The investigations in this energy range are greatly

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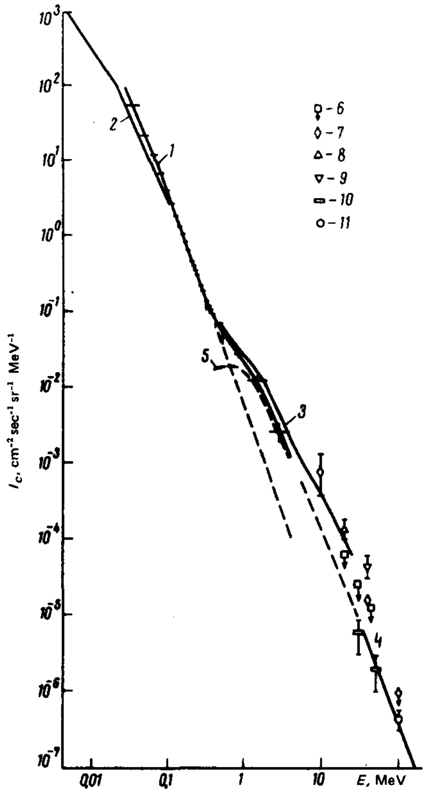

Diffuse cosmic background in accordance with the data of various experiments: 1—present paper; 2—[8]; 3—"Apollo 15"[5]; 4—SAS-2[6]; 5—excess-radiation intensity; 6—[9]; 7—[10]; 8—[11]; 9—[12]; 10—[13]; 11—[14].

hindered by the x rays and γ rays of the earth's atmosphere, as well as by the radioactivity background induced by cosmic rays in the detector matter and in the surrounding materials. In view of these difficulties, the results obtained in a number of experiments are subject to discrepancies and contradictions.[1] One of the means of overcoming these difficulties is the procedure developed for the satellites "Kosmos" 135 and 163[2,3] and employed with certain improvements in the present study. The main features of the measurement consist in the following: The measurements are carried out on an orbit close to the earth with a large inclination, passing lower than the zone of captured radiation. The flux of the primary cosmic rays causing activation of matter is greatly attenuated inside the magnetosphere by the geomagnetic field in comparison with interplanetary space. To exclude the effect of proton bombardment of the satellite in the dropping zone of the radiation belt, we reduced only the measurement data obtained in the first hours of the flight, up to the first series of passages of the satellite through the region of the South-Atlantic anomaly. Under these conditions, the influence of the induced-activity background on the results of the measurements is small and can be disregarded. No measures were taken in the experiment to discriminate against the γ rays from the atmosphere. Their contribution to the measured counting rate was determined during the data reduction.

In the space near the earth, the intensity of γ radiation of energy E is the sum of two components, cosmic and atmospheric, $I(E) = I_c(E) + I_a(E)$. The corresponding component I_c of the counting rate $n_c(E)$ does not vary when the satellite moves on a circular orbit. The counting-rate component $n_a(E)$, due to atmospheric γ radiation, depends on the coordinates of the measurement point. The γ radiation in the continuous spectrum and in the 0.511 MeV line is generated in the atmosphere when the latter interacts with the cosmic-ray flux. Owing to the modulation of the intensity of the cosmic rays by the geomagnetic field, the coordinate dependence of the intensity of the atmospheric γ radiation can be generalized in the form of a dependence on the threshold geomagnetic rigidity R, calculated for the corresponding points of the satellite route on the earth's surface.[3] Thus, $n_a(E) = a(E)f(R)$, and the measurement of the results of the total counting rate can be written in the form of geomagnetic relations $n(E) = n_c(E) + a(E)f(R)$.

The exact form of the $f(R)$ dependence was determined from the "Kosmos-461" data for the atmospheric radiation intensity in the 0.511-MeV line. Data reduction by least squares yielded an analytic representation of this dependence in the range 3—17.5 GeV in the form of the expression $f(R) = (0.046 \pm 0.017) + \exp(R/8.5)$.

The experimental points of the geomagnetic curves plotted for each energy channel of the spectrometer in $[n(E), f(R)]$ coordinates lie on straight lines, with a very small scatter. The reduction of these data by least squares yields the values of $n(E)$, $a(E)$, and their errors, i.e., makes it possible to obtain the spectra of the energy loss in the detector for the cosmic and atmospheric components of the radiation. The energy-loss spectra were then converted into the γ-quantum energy spectra. The spectrum of the diffuse γ radiation is represented by curve 1 in the figure, which shows also for comparison the results of a number of investigations in the range 10 keV—100 MeV, obtained mainly in recent years.

The data obtained by us lead to several conclusions.

In the investigated energy range, the spectrum of the diffuse background cannot be represented by a single law. At an energy below 400 keV, we have a power-law spectrum $I_c = (5.6 \pm 0.5) \times 10^{-3} E^{-(2.8 \pm 0.05)}$ cm^{-2} sec^{-1} sr^{-1} $\times$ MeV^{-1}. This spectrum is much steeper than was previously assumed on the basis of the energy-loss spectrum measured in interplanetary space with the "Ranger-3."[4] Starting with 400 keV, the power-law dependence no longer holds, and the spectrum has a clearly pronounced step, which is observed also in the data of "Apollo-15."[5] Quantitatively, however, the values of the flux obtained on "Kosmos-461" are lower. It follows from the figure that the discrepancies between curves 1 and 3 increase and become significant with increasing energy. Extrapolation of spectrum 1 to energies 30—40 MeV leads to an agreement with the spectrum obtained with the SAS-2.[6] This circumstance can serve as an indication that the measurements on the "Apollo-15" and high-altitude balloons overestimate the γ-ray flux in the 10—30 MeV range.

Extrapolation of the power-law relation $I_c \propto E^{-2.8}$ into the region of higher energies shows that the γ-ray component causing the change in the form of the spectrum is quite intense and determines the diffuse background in the 1—100 MeV range almost completely. The intensity of the excess radiation is maximal in the region 700—800 keV and amounts to $\sim 1.8 \times 10^{-2}\ cm^{-2}\ sec^{-1}\ sr^{-1}\ MeV^{-1}$. The form of the spectrum of the high-energy component of the diffuse background, obtained in accordance with the data of "Kosmos-461" and SAS-2 (curve 5), agrees with the assumptions that the radiation is of cosmological origin.[7]

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