Observation of periodic gamma radiation from the discrete source Cygnus X-3

A. M. Gal'per, V. G. Kirillov-Ugryumov, A. V. Kurochkin, N. G. Leikov, B. I. Luchkov, and Yu. T. Yurkin

Moscow Engineering Physics Institute

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A spark-chamber telescope mounted on high-altitude balloons was used in 1972, 1974, and 1976 to measure fluxes of γ rays of energy exceeding 40 MeV from the discrete source Cygnus X-3. The radiation was found to be variable, with a period 0.199686 of a day coinciding with the x ray period. The registered γ radiation is concentrated in a narrow pulse of duration less than 1 hour, which arises near the minimum of the x ray flux. The γ ray luminosity of the Cygnus X-3 source is $\sim 10^{38}$ erg/sec.

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The cosmic object known as the Cygnus X-3 source has attracted attention in September 1972, when two powerful radio-emission flares from the source were registered,[1,2] lasting several days, during which the flux increased by a factor 10^3-10^4. Several other flares were registered later on.[3-5] Subsequent observations, carried out in various bands of the electromagnetic spectrum, have revealed a number of interesting singularities of the object.

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TABLE I.

Number of flights	Date	Start of measurement, *UT*	Number of registered γ photons	Number of expected γ photons
1	12.10.1972	$12^h\ 42^m$	36	18.8
2	10.7.1974	$22^h\ 30^m$	29	28.3
3	5.7.1976	$23^h\ 15^m$	27	27.6

Besides the sporadic bursts of radio and infrared[6] radiation, regular oscillations of the fluxes in the infrared[6] and x-ray[7,8] bands were observed, with a period ~4.8 hr. The observed period is more readily the period of the orbital motion of the components of a tight binary system. Because of the discovered periodicity, the Cygnus X-3 source was identified with an infrared object located on the periphery of the galactic disk at a distance ~10 kpc from the sun.

Of great interest in determining the character of Cygnus X-3 is an investigation of its γ radiation. Immediately after the September, 1972 flares from the region of Cygnus X-3, streams of γ rays were observed in two energy intervals: $\gtrsim 10^8$ eV[9] and $\gtrsim 10^{12}$ eV.[10] A subsequent analysis [11–13] has revealed the periodicity of the radiation in the two intervals, with a period 4.8 hr. This has made it possible to identify reliably the γ-radiation source with Cygnus X-3. A review of the data obtained with the American satellite SAS-2 has also disclosed a periodic flux of γ rays with the same period.[14]

The present communication is devoted to the results of a series of measurements of γ radiation from Cygnus X-3, performed with high-altitude balloons on 12 October, 1972, 10 July 1974, and 5 July 1976. The balloon launchings were made at the geographical latitude 52°N. The height of the balloon drifts corresponded to 6—10 g/cm^2 of residual atmosphere.

A large-aperture γ telescope with spark chambers[15] registered γ photons with energy higher than 40 MeV. The telescope area was 250 cm^2 and the subtended angle was ~80°, so that whenever the telescope was aimed at the zenith it was possible to observe the source for not less than 5 hours, i.e., to note the change of the flux over one period. The angle of resolution of the instrument, averaged over the spectrum of the registered γ photons, was ~3°. In accordance with the angle of resolution, we determined the number of γ photons incident on a circle of radius 3.5° around the direction to Cygnus X-3. In addition, from the data of each flight we calculated the expected number of γ photons of the atmospheric background.[16] The results are given in Table I. Only in the first flight we obtained during the entire time of observation a statistically significant excess—the fluctuation probability did not exceed 5×10^{-5}. In the two other flights no excesses of γ photons registered during the entire time of observation were found. They were observed, however, in individual hours of observation, as seen from the time distribution of the registered γ photons shown in Fig. 1. The abscissas represent the phase of the variable x radiation, which according to the latest data[17] has a period P_x

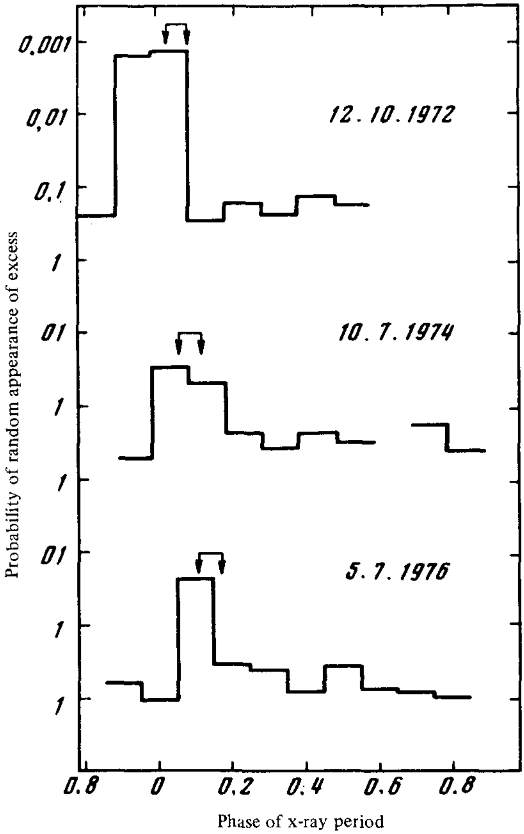

FIG. 1. Temporal distributions of the registered γ photons.

$= 0.1996814 \pm 5 \times 10^{-7}$ of a day and an initial phase $\phi_0 = 2440949.9176 \pm 0.0024$ JD. The ordinates show the probability of a random appearance of an excess. In all the measurements statistically significant excesses were observed in the phase interval from 0.9 to 0.2, and the probability of random appearance of the excesses amounted to 1.3×10^{-5}, 3×10^{-3}, and 1×10^{-2} for the first, second, and third flights, respectively. The period determined from the observed excesses turned out to be $P_{\gamma 1} = 0.199686 \pm 5 \times 10^{-6}$ of a day. The arrows show the positions of the pulses of the ultrahard γ photons ($E \geq 10^{12}$ eV), whose periods, according to observations made at the Crimean Astronomical Observatory, amounts to $P_{\gamma 2} = 0.199684 \pm 2 \times 10^{-6}$ of a day.[18] All three periods agree within the limits of the measurements errors. The presented picture demonstrates convincingly the periodicity of the γ radiation of the Cygnus X-3 source.

As seen from Fig. 1, the entire radiation is concentrated in a narrow pulse of duration less than an hour near the minimum of the x radiation. Small phase shifts of the pulses are observed and lead to a broadening of the phase distribution summed over all three flights (Fig. 2). Although the waveform of the summary pulse agrees qualitatively with the distribution obtained in[14] by a

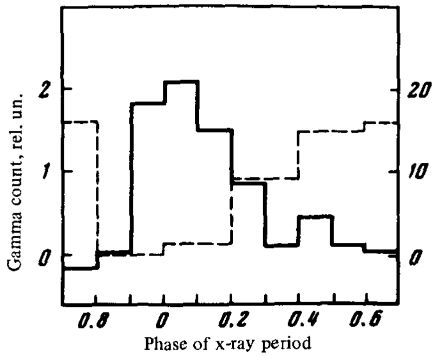

FIG. 2. Shape of summary pulse; dashed—from[14]

superposition of 50 periods, a phase shift of ~ 0.4 period does exist between them. In addition, the flux obtained in[14] is several times smaller than the flux as determined from the results of our observations: $(11\pm 3)\times 10^{-5}$, $(6\pm 3)\times 10^{-5}$, and $(8\pm 6)\times 10^{-5}$ $(\text{cm}^2\,\text{sec})^{-1}$ for the three flights, respectively. The reason for these differences is not clear at present. It is possible that the Cygnus X-3 source has a more complicated character, and in particular its radiation may be subject to a strong amplitude modulation. This is evidenced by investigations[19–21] in which no pulsating radiation was found.

The γ-ray luminosity of the source, if its radiation is assumed to be isotropic, is $L_\gamma(\geq 40\ \text{MeV}) \approx 10^{38}$ erg/sec, which agrees with its x-ray luminosity and exceeds by several orders of magnitude the luminosity of other discrete γ-ray sources.

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