A. M. Gal'per, V. G. Kirillov-Ugryumov and B. I. Luchkov. *Discrete Sources of Cosmic Gamma Radiation.* Several discrete sources of cosmic γ radiation have been discovered in recent years.[1-3] Substantial progress of research in this new high-energy band of the electromagnetic spectrum ($E_\gamma \gtrsim 1$ MeV) has been aided by substantial increases in observing times (the specialized satellites SAS-2 and COS-B, repeated balloon observations) and by recognition of the fact that the radiation varies and the taking of appropriate measures to register it. This last circumstance, to which we made reference several years ago,[4] has in some cases been the decisive factor in discovery of discrete sources. On the whole, γ astronomy has become an inseparable part of extra-atmospheric astronomy and has made its own significant contribution to our understanding of the general physics of the Universe.

One of the first reliably established discrete γ-radiation sources is the Crab Nebula with its pulsar NP 0532. The total flux of γ radiation with energies $\geqslant 35$ MeV from the Crab Nebula is $2 \cdot 10^{-5}$ kV/cm^2-sec, which corresponds to a luminosity of $2 \cdot 10^{36}$ erg/sec. Detailed observations from satellites[1,5,6] have shown that a considerable fraction of the γ-radiation flux is of periodic nature (Fig. 1a). Since the period of the γ radiation coincides with that of the radio pulsations of NP 0532 (~ 33 msec), the observed periodic γ-quantum flux originates from the pulsar. The pulsating emission of NP 0532 can be traced from the radio band to super high-energy (~ 10^{12} eV) γ quanta.[7] The radiation of the pulsar in the Crab Nebula is of synchrotron nature, as is indicated, among other things, by its single power-law energy spectrum.

Another discrete γ-radiation source is the supernova residue Vela X with its pulsar PSR 0833, whose total γ flux and luminosity at energies $\gtrsim 35$ MeV are $1.5 \cdot 10^{-5}$ kV/cm^2-sec and 10^{35} erg/sec. Recent COS-B measurements have shown that no less than 85% of the radiation is of pulsating nature with a period of 89.2 msec (Fig. 1b).[2,6] Therefore its source is the radiopulsar PSR 0833, which has exactly the same period. We should note the absence of optical and x-ray emission from this pulsar (in contrast to the Crab pulsar) and the surprising similarity of their γ radiations: in both cases, there are two peaks with the identical 0.4-period distance between them (see Fig. 1). This similarity, with the sharp difference in other bands of the radiation and the high luminosity of the γ radiation, which exceeds the radio luminosity by several orders, points to the conclusion that the γ radiation is a principal manifestation of at least young pulsars. The γ-emission energy spectrum of PSR 0833 is no different from the spectrum of

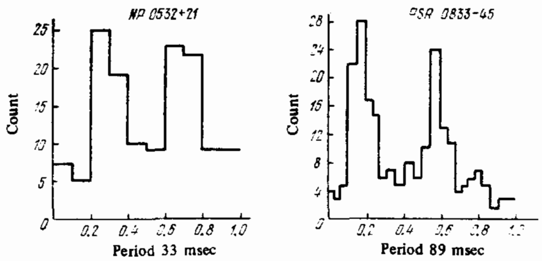

FIG. 1. Distribution in the phases of gamma radiation of energy >35 MeV.

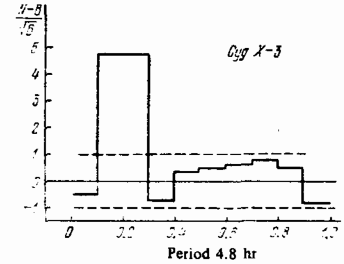

FIG. 2. Distribution in the phases of gamma radiation of energy >40 MeV.

diffuse Galactic emission and is consistent with the hypothesis that the basic process generating the γ quanta is the decay of neutral pions formed on interactions of cosmic rays with the gas. In this case, the pulsar can be regarded as one of the sources of cosmic rays, confirming that the latter are of Galactic origin.[8] Recent observations[6] have shown that the flux of γ quanta from PSR 0833 has doubled over the data of[2]. Such sporadic increases in the flux, which have also been observed in NP 0532 in various γ-radiation ranges,[9-11] are related to jumps in the object's period of rotation that occur when it undergoes internal restructuring.

The hypothesis that young pulsars are sources of γ radiation was verified by the SAS-2 group, who observed γ radiation from two more comparatively young ($<10^8$ years) pulsars (among 75 candidates).[5] However, the intensity of their gamma radiation was almost an order lower than that of the pulsars in the Crab and Vela X.

It appears that the object Cygnus X-3, from which γ radiation has also been observed, is a different type of source. The fluxes of γ quanta from this source were registered by the KrAO [Crimean Astrophysical Observatory] (in the range $10^{12}-10^{14}$ eV)[12] and MIFI [Moscow Engineering Physics Institute] groups (in the range $4\cdot10^7-10^9$ eV)[13] soon after the powerful radio flareup of Cygnus X-3 in September 1972. Subsequent observations of the source[14-18] reliably established the periodic nature of the γ radiation, with a period of 4.8 hr—the same as that of the x-radiation. Figure 2 shows the phase distribution of the period for $E_\gamma \geq 4\cdot10^7$ eV. By far the greater part of the flux is concentrated in the narrow (<1 hr) pulse. The variable γ-radiation flux is $7\cdot10^{-5}$ kV/cm^2-sec, and the luminosity of the source, which is ~10 kiloparsecs distant from us, is ~10^{38} erg/sec. This is the strongest of the known γ-radiation sources (the luminosity in the range $E_\gamma \geq 10^{12}$ eV is 10^{36} erg/sec). A review of SAS-2 observational data also showed periodic γ radiation from Cygnus X-3.[5] As in the case of the young pulsars, we observe marked sporadic variations of the γ-quantum flux and coupling of the intensities in the gamma- and radio bands. (We note that the single registration of solar γ radiation in the 0.5, 2.2 and 4.4 MeV lines was also associated with a strong sporadic flareup on the sun.)[17]

In several cases, observed discrete γ-radiation sources have coincided with "possible" sources that had been observed earlier on balloons but were not as statistically certain. This obliges us to view seriously "balloon" sources that have been observed by two or more groups. In this case, the number of discrete γ-radiation sources would become much larger. Almost all of them are situated near the plane of the Galaxy and concentrated in regions rich in gas and young stars (OB associations), but at the same time they show no evident correlation with the distribution of the Galactic x-ray sources.[18]

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