**L. M. Ozernoĭ and V. V. Usov.** *The Origin of the High-Frequency (Optical, X-Ray, and Gamma-) Radiation of Pulsars.* For some time, the pulsar NP 0532 in the Crab Nebula was the only one from which high-frequency pulsating emission (infrared, optical, x-ray, and gamma) was registered in addition to the radio emission. Subsequently, gamma radiation from the pulsar PSR 0833-45 in Vela was also observed; a diligent search for optical radiation from it has also recently met with success.[1] The possibility of generation of high-frequency emission was linked to the youth of the pulsar, and the absence of optical and x-ray emission, not to mention $\gamma$-radiation, from middle-aged and "elderly" pulsars appeared quite natural. Thus the 1976 discovery[2] of pulsating $\gamma$-emission from two totally undistinguished radio pulsars, PSR 1747-46 and 1818-04, with the aid of the SAS-2 satellite came as even more of a surprise.*) The powers of their $\gamma$-radiation, which pulsates with the same period ($\sim 0.4$ sec) as that in the radio band, were in the tens of MeV and $10^5 - 10^6$ times greater than those of the radio emission. We are therefore justified in speaking not so much of the radiopulsar phenomenon as of a $\gamma$-pulsar, and it is difficulty to overvalue the significance of this fact for pulsar theory.

Before the discovery of $\gamma$-emission from old pulsars, the theory had encountered no particular difficulty in explaining the high-frequency emission of the Crab pulsar in terms of noncoherent mechanisms.**) In specific terms, if its radio emission is formed near the light cylinder (Smith-Zheleznyakov model), the infrared, optical, x-ray, and gamma emission with energies in the hundreds of MeV can be explained by synchrotron radiation from a source in spatial proximity to the radio source.[5-9] The most energetic (and at the same time variable) part of the $\gamma$-spectrum with energies of $10^{12} - 10^{13}$ eV is attributed to the inverse Compton effect.[10]

The synchrotron mechanism is obviously also capable of explaining the optical radiation of the Vela pulsar, since its power is consistent with the $L \sim P^{-10}$ dependence expected with this emission mechanism.[11] An attempt has also been made to interpet the $\gamma$-radiation of this pulsar by a synchrotron mechanism.[12]

However, when applied to old pulsars, the synchrotron mechanism of emission from a source localized near the light cylinder gives possible $\gamma$-radiation powers many orders of magnitude lower than the values derived from SAS-2 data. Other noncoherent mechanisms have also proven unworkable, except for emission of relativistic electrons governed by the curvature of magnetic force lines (curvature radiation[13]). In a strong curved magnetic field, when the transversal-field energy of relativistic electron motion is radiated out quickly, the subsequent emissive electron losses are governed by the bending of the magnetic force lines; we shall henceforth relate to this radiation as "bending radiation" for brevity.

Unlike synchrotron radiation, whose power is proportional to $E_e^2$ ($E_e$ is the energy of the relativistic electrons), the power of the bending radiation is proportional to $E_e^4$ and comes to predominate at large $E_e$. Its frequency is $\sim E_e^2$ for the synchrotron radiation. At comparatively low energies of the relativistic-electrons, we may expect them to emit synchrotron radiation in the optical and soft x-ray ranges, while gamma-range photons are naturally associated with the bending radiation.

A detailed analysis[14] showed that the $\gamma$-radiation of old pulsars, as well as that of 0833-45, can be explained by this mechanism. The bending radiation of particles pulled from the surface of the pulsar by the electric field and accelerated by it[13,15] must be treated with allowance for the production of electron-positron pairs by the $\gamma$-photon in the strong magnetic field of the pulsar; in turn, these pairs generate bending $\gamma$-radiation. According to calculations,[14] the escaping $\gamma$-radiation is formed basically at a distance of the order of several radii of the pulsar above the region of its polar cap (and at the surface itself in the region near the magnetic pole); here the characteristic energy of the $\gamma$-photons is $E_\gamma \sim 50-500$ MeV and their power $L_\gamma \sim 10^{32} - 10^{35}$ erg/sec, consistent with the observed parameters of $\gamma$-pulsars. The $\gamma$-radiation diagram of the pulsar is "pencil-shaped" with a solid angle $\sim 10^{-1} - 10^{-2}$ sr. If the radio emission originates near the light cylinder, the fraction of radio pulsars that exhibit $\gamma$-radiation should be of the order of a few percent, and we should generally expect the radio- and $\gamma$-pulses to be nonsynchronous. Gamma-pulsars without appreciable radio emission are possible, and many of them may occur in double-star systems.

Specific observational tests[14] are designed to verify the theory developed to account for the $\gamma$-emission of pulsars.

Massaro and Salvati[16] recently advanced similar arguments concerning the nature of $\gamma$-pulsars.

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*It was reported at a symposium on gamma astronomy (Frascati, May 1977) that three more pulsating gamma sources has been discovered, two of them identified with the radio pulsars PSR 1822-09 and 1742-30[3].

**Although the effective radiation temperature does not exceed $10^{11}$ °K in the optical band, certain authors have used coherent mechanisms for radiation from particle bunches to explain it[4].

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