γ-RAY EMISSION FROM SLOW PULSARS

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Among the COS-B Galactic γ-ray sources two have been identified with the young pulsars PSR0531+21 and PSR0833-45, while for most of the others there are no convincing counterparts (1). An obvious explanation is that at least part of them are also pulsars. Because of the rarity of pulsar formation, an important issue for testing this possibility is to discuss whether relatively old pulsars ($\sim 10^5$y) may be sources of γ-rays of the luminosity observed by COS-B (φ (100 MeV) 10^{-6}cm^{-2}s^{-1}). On this line it is of great interest the claim of observation of γ-rays with SAS II from PSR1747-46 (2) and with COS-B from PSR0740-28 and PSR1822-09, communicated at other conferences, but yet not confirmed (3). The three slow pulsars mentioned above were reported to have γ-ray luminosities of 10^{33}erg s^{-1}, close to their intrinsic energy loss $L_T = I\omega\dot{\omega}$. Their periods are about 0.1-1s and their distance $\sim$1 Kpc.

The scope of this communication is to calculate the expected γ-ray flux from such objects, neglecting the problem of the reliability of the observations. Our key hypothesis is that since the γ-ray luminosity is a substantial fraction of L_T it should be produced in the vicinity of the speed of light radius. This comes from the well known argument of simultaneous conservation of energy and angular momentum (4-5).

We refer to a model where a large fraction k of the total energy released $L_T = 2B_o^2 R^6 \omega^4/3c^3$ is in the form of a relativistic electron beam. Let k' be the fraction of the active polar cap ($R_c = R(\frac{\omega R}{c})^{\frac{1}{2}}$) occupied by the beam. Let r_o be the distance out of which the pitch angle of relativistic particles departs from zero. At $r > r_o$ the electron distribution is taken isotropic within a cone of semiaperture Ψ. As typical values we take k=0,5; r_o=0.1 c/ω, k'=10^{-2}-10^{-3}, Ψ =1-10^{-1}rad, and a monochromatic electron spectrum with $\gamma_o = 10^3$. These parameters are suggested by several pulsar models (6-7-8). One can verify that in these conditions synchrotron radiation does not contribute to the γ-ray luminosity. The contribution from Compton scattering derives predominantly from the scattering of the electrons with the synchrotron photons (Synchro-Compton), which move in the direction of the generating electrons. The calculation of the resulting spectrum is rather complicated, since the electron energy

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B_o=5x10^{12} G	Small angle Compton Scattering		Isotropic Compton scattering	
R = 10^6 cm	1822-09	1822-09	1822-09	0740-28
γ_o	1000	5000	3200	8000
k	0.5	0.5	0.5	0.1
k'	0.005	0.02	0.002	0.024
$r_o(c/\omega)$	0.12	0.19	0.09	0.36
Ψ (rad)	1.4	0.14	0.02	0.002
$m_V(A_V$=2mag/kpc)	20.4	23.6	18.7	26.1
L_V (erg s^{-1})	2.1x10^{31}	1.3x10^{29}	1.7x10^{30}	2.7x10^{28}
ϕ (50-150MeV)($cm^{-2}s^{-1}$)	5.0x10^{-18}	2.2x10^{-22}	2.5x10^{-6}	3.5x10^{-8}
ϕ (150-500MeV)($cm^{-2}s^{-1}$)	1.1x10^{-19}	1.6x10^{-24}	1.9x10^{-6}	1.4x10^{-7}
L_γ(50-500MeV)(erg s^{-1})	3.4x10^{22}	1.7x10^{17}	8.8x10^{32}	5.4x10^{31}

varies because of radiative losses, the photon density depends on the synchrotron radiation, and varies with the radial distance. Moreover the scattering cross section depends strongly on the angle between electrons and photons (9), which in turn, is a function of the distance. The results are summarized in the Table. It is apparent that while the γ-ray fluxes are orders of magnitude below those of the three slow pulsars referred above, the luminosity in the visible is well above the limit of detectability, and nevertheless no optical counterpart was found thus far.

An important parameter in the calculations is the choice of the angle Ψ, which describes the anisotropy of electron and photon distributions. In the previous scheme the average electron-photon angle depends on Ψ. For small Ψ the synchro-Compton γ-ray flux diminish dramatically. As a limiting case one can consider small pitch angles, postulating that the electron-photon cross section is still that of isotropic distributions. The results are reported in the Table. This shows that, in order to account for $L_\gamma \simeq 10^{33}$erg/s by synchro-Compton scattering at the speed of light radius, one should consider a situation which appears unrealistic, and still one finds an optical flux which is too large, requiring different beamings for optical and γ-ray photons.

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