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Luminosity of synchrotron radiation from outer magnetosphere of pulsars

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Abstract.
We calculate the luminosity of the synchrotron radiation from the vicinity of the light cylinder. We find that even if the thermal emission from the entire surface is included as the seed photon, the γ-ray to X-ray flux ratio for young pulsars is significantly higher than the observations. For these pulsars, most of γ-ray photons may be absorbed in the magnetosphere.

Keywords. stars: neutron, (stars:) pulsars: general, acceleration of particles, radiation mechanisms: nonthermal

1. Introduction

Observed γ-ray pulsed emission comes from the outer magnetosphere. Recent particle simulations also show that the particle acceleration takes place in the current sheet close behind the light cylinder (e.g., Cerutti & Beloborodov 2017). A fraction of the γ-ray photons converts to electrons and positrons which emit synchrotron radiation in X-ray and optical bands (e.g., Romani 1996). Therefore, the X-ray and optical emission provides useful tool to prove the particle acceleration and creation in the magnetosphere.

In the calculation of the synchrotron luminosity by Kisaka & Tanaka (2017), we did not consider the thermal emission from the entire neutron star surface as the seed photon for the pair creation. This may increase the synchrotron luminosity, and may decrease the curvature to synchrotron flux ratio. In this proceeding, we calculate the luminosity of synchrotron radiation including the effect of the thermal emission from the entire surface.

2. Model and results

We adopt the synchrotron radiation model for the two-photon collision scenario described in Kisaka & Tanaka (2017). The luminosity of the synchrotron radiation $L_{\rm syn}$ is approximately described as

$$L_{\rm syn} \sim \eta\tau_{\gamma\gamma}(\gamma_{\rm s,syn}\alpha/\gamma_{\rm s,pair})L_{\rm sd}, \tag{2.1}$$

where η is the energy conversion efficiency from the spin-down luminosity $L_{\rm sd}$ to curvature radiation, $\tau_{\gamma\gamma}$ is the optical depth for curvature photon with energy $E_{\rm cur}$, $\gamma_{\rm s,pair}$ and $\gamma_{\rm s,syn}$ are the Lorentz factor of the created particles from photon with $E_{\rm cur}$, and of the synchrotron emitting particles with the characteristic frequency $\nu_{\rm obs}$, respectively, and α is the pitch angle.

For the optical depth $\tau_{\gamma\gamma}$, we consider the thermal emission from the entire surface in addition to that from the heated polar cap. For the luminosity and the temperature, we

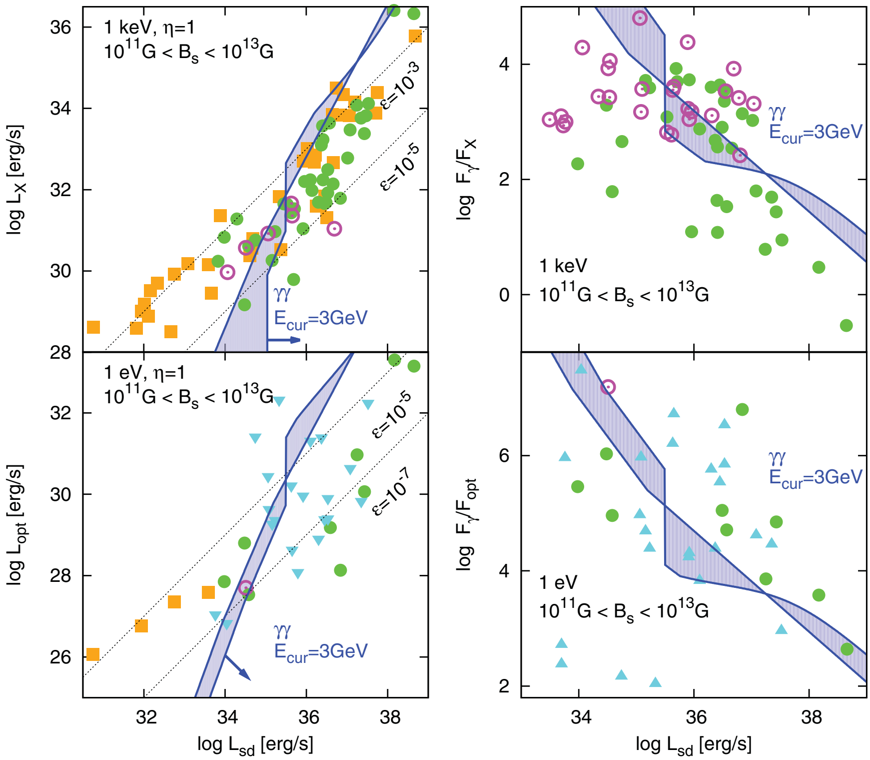

Figure 1. Left: Luminosities of synchrotron radiation in 1 keV (upper) and 1 eV (lower) as a function of spin-down luminosity L_{sd}. Right: Flux ratios F_γ/F_X (upper) and F_γ/F_{opt} (lower) as a function of L_{sd}. Filled and open circles are radio-loud and radio-quiet γ-ray pulsars, respectively. Squares denote the non-γ-ray pulsars. Upper and lower limits on the optical luminosity L_{opt} and the flux ratio F_γ/F_{opt}, respectively, are also plotted as triangles.

adopt the cooling curve for the minimum cooling scenario with light element composition envelope given by Page *et al.* (2004).

Figure 1 shows the results of the synchrotron luminosity and the flux ratio to the curvature luminosity in X-ray and optical bands. The synchrotron luminosity is enhanced at the range 10^{35} erg s^{-1} $\lesssim L_{sd} \lesssim 10^{37}$ erg s^{-1} by the effect of the thermal emission from the entire surface. At the range $L_{sd} \lesssim 10^{35}$ erg s^{-1}, the age becomes $\gtrsim 10^5$ yr, so that the temperature of the neutron star surface is too low to create the pairs with photon with energy $E_{cur} = 3$ GeV. However, the effect is not enough to decrease the flux ratio to the observed values as seen in the upper right panel of Figure 1. Therefore, the γ-ray emission from young pulsars may have strong anisotropy and most of them are not seen, or may be strongly absorbed as expected in the Crab pulsar (Aleksić *et al.* 2011).

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