Observational relationship between gamma – ray and X-ray emissions from pulsars

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Introduction

To determine the statistical relationship between the spectral properties of X-rays and the spectral properties of gamma-rays from rotational powered pulsars. we analyzed the data from pulsars exhibiting both X-ray and gamma ray emissions as available in archival datasets.

Motivation

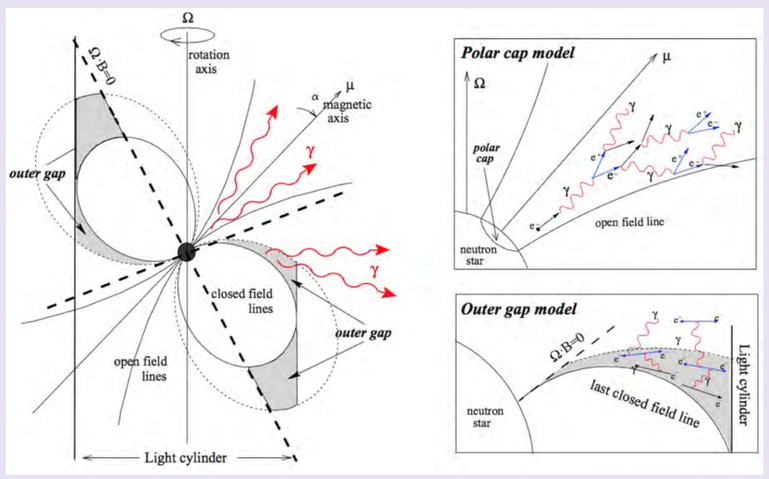


Figure 1
Pulsar Magnetosphere. Right panel shows the particle acceleration mechanism.

Credits: Yating Chai et al, J. Astron. Space Sci. 33(2), 75-92 (2016)

- In Outer-gap model, the electrons accelerated produces gamma rays which interacts with Thermal X-rays from neutron star surface producing electron-positron pair resulting in a cascade process.
- In Polar cap model, the accelerating pairs looses energy through Inverse Compton scattering with thermal x-rays.
- So, We expect to see co-relation between Gamma ray spectral parameters and x-ray spectral parameters.

Data Selection

- Fermi 3PC is used for the gamma ray data.
- Sample includes only Rotational powered Pulsars.
- X-ray data in the 0.5 – 8 KeV range.
- 44 Pulsars with X-ray and Gamma ray emission
- 22 pulsars with Power law(PL) fitting (Non- thermal emission)
- 22 Pulsars with PL + Blackbody(BB) fitting (Thermal emission).

Spectrum Model

Gamma Ray spectral model

$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{-\Gamma+\frac{d}{b}} \exp\left[\frac{d}{b^2}\left(1-\left(\frac{E}{E_0}\right)^{b}\right)\right]$$

Γ - Photon index at reference energy (E_0)
d – SED curvature at E_0
b – asymmetry parameter

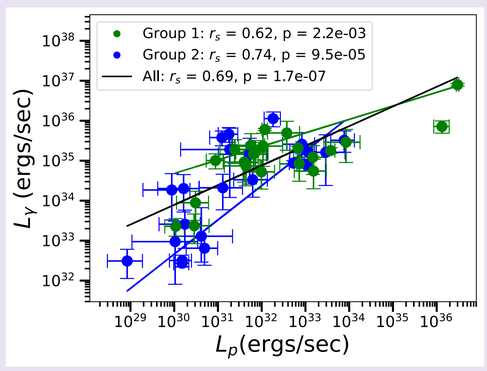
Γ_{100} – photon index at 100MeV

$$\Gamma_{100} = \Gamma - 1.26\,d$$

d_p - SED curvaturve at peak energy (E_P) (inversely proportional to SED width)

$$d_p = d + b\,(2 - \Gamma)$$

Results



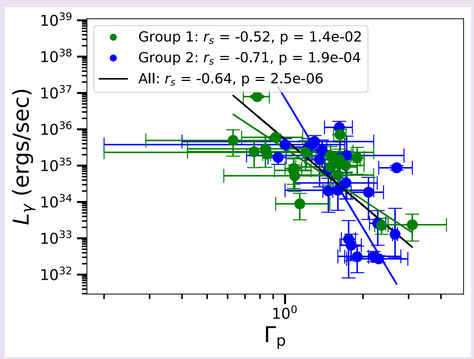
Group 1 – Pulsars without thermal emission
Group 2 - Pulsars with thermal emission

$L_\gamma \propto L_p^{(0.49\pm0.05)}$ $(\chi_\nu^2 = 23.1)$

$L_\gamma \propto L_p^{(0.34\pm0.04)}$ $(\chi_\nu^2 = 17.4)$ (Group 1)

$L_\gamma \propto L_p^{(0.86\pm0.14)}$ $(\chi_\nu^2 = 9.8)$ (Group 2)

Figure 2: Gamma Ray Luminosity (L_γ) vs non-thermal X-ray Luminosity (L_p)



$\log L_\gamma = (-1.94 \pm 0.28)\Gamma_p + (37.53 \pm 0.35)$ $(\chi_\nu^2 = 5.2)$

Group 1
$\log L_\gamma = (-2.03 \pm 0.49)\Gamma_p + (37.5 \pm 0.5)$ $(\chi_\nu^2 = 7.5)$

Group 2
$\log L_\gamma = (-2.65 \pm 0.57)\Gamma_p + (38.72 \pm 0.85)$ $(\chi_\nu^2 = 2.6)$

Figure 3: Gamma Ray Luminosity (L_γ) vs X-ray photon index

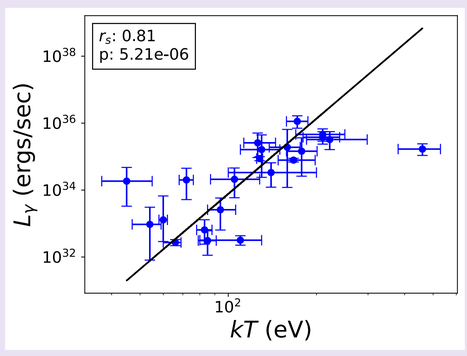


Figure 4: Gamma Ray Luminosity (L_γ) vs Blackbody Temperature (kT)

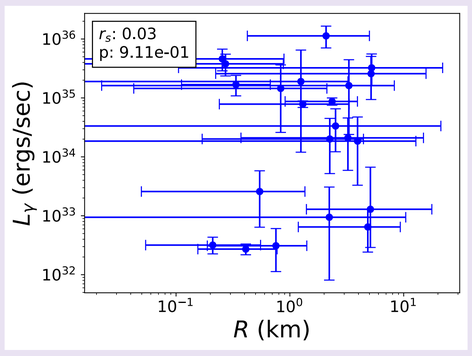
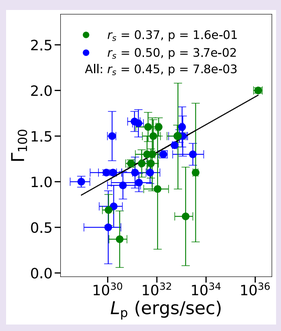
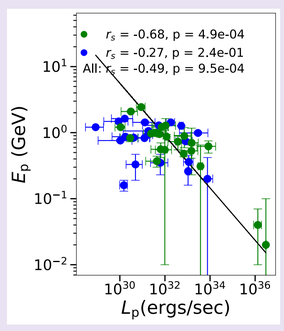
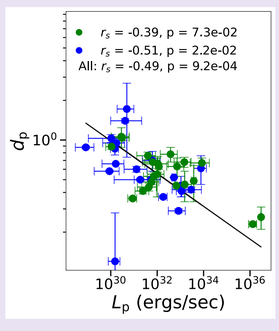
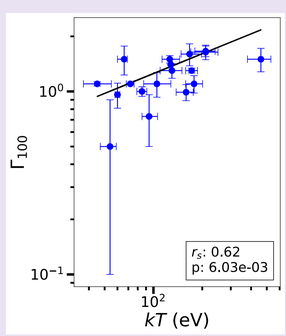


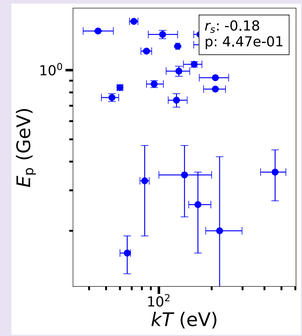
Figure 5: Gamma Ray Luminosity (L_γ) vs Blackbody Radius (R)











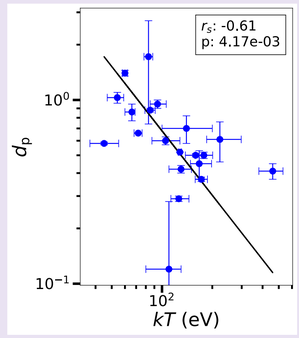
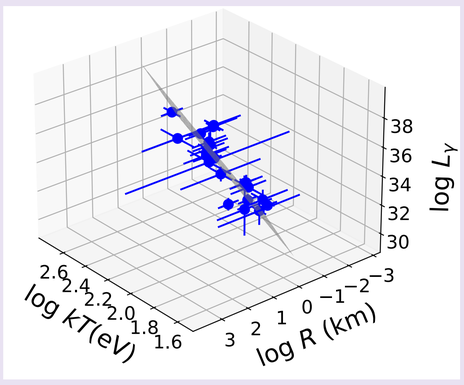


Figure 6:Gamma-ray spectral parameters vs thermal spectral parameters



$L_\gamma \propto kT^{(4.79\pm0.90)}\ R^{(2.55\pm0.58)}$
$(\chi_\nu^2 = 0.54)$

Figure 7: Fundamental Plane of Gamma-ray Luminosity

- Gamma-ray luminosity shows a correlation with non-thermal X-ray luminosity, but the form of this relationship varies between the two groups
- Gamma ray luminosity is positively correlated with blackbody temperature.
- Gamma-ray Luminosity forms a fundamental plane in the space of Blackbody temperature and Radius.