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<th><strong>Title</strong></th>
<th>Soft Gamma-ray Pulsars</th>
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Abstract: We propose a model to explain the X-ray and soft gamma-ray spectra and light curves of a class of young pulsars: PSR B1509-58, PSR J1846-0258, PSR J1811-1925, PSR J1617-5055 and PSR J1930+1852.

Introduction:
The five young spin-down powered pulsars, PSR B1509-58, PSR J1846-0258, PSR J1811-1925, PSR J1617-5055 and PSR J1930+1852, have similar shapes of pulse profiles and spectra of non-thermal X-rays, which can be described by power law with photon index around 1.5. None of them has multi-GeV photon detected. We explain the non-thermal X-rays and soft gamma-rays of them based on the model in Wang et al., (2013).

The outer gap model predicts that most pairs created inside the gap are around the null charge surface, and the electric field separates the opposite charges to move in opposite directions (Cheng, Ho & Ruderman, 1986). Consequently, the region from the null charge surface to the light cylinder is dominated by the outflow of particles and that from the null charge surface to the star is dominated by the inflow of particles. Since the electric field decreases rapidly from the light cylinder to the null charge surface, the incoming radiation flux is weaker than that of the outgoing flux. These particles emit curvature photons, and the incoming curvature photons are converted by the strong magnetic field of the neutron star to pairs. We suggest that the outgoing curvature photons of the five pulsars are missed by the lines of sight, and the X-rays and soft gamma-rays of them are the synchrotron radiation of the pairs generated by the magnetic field.

Simulation Method:
1. Trace the field lines and calculate the direction of the curvature radiation, \( \psi_{cur} \), at each step \( r \).
2. Trace \( \psi_{rad} \) of the incoming curvature radiation to find the place, \( r \), where the pair creation happens.
3. Calculate the pulse phases and viewing angles, \( \psi_{view} \), along the hollow cone at \( r \).
4. Calculate the spectrum of the radiation that satisfies \( |\psi_{rad} - \psi_{view}| < \theta \), where \( \theta \) is the viewing angle.
5. Trace the direction of synchrotron radiation to calculate the attenuation of the radiation caused by the pair creation, and remove the photons that covered by the star.
6. Integrate the phase resolved spectra to obtain the energy dependent light curves.

Simulation Result:

Pulse Phase of the Synchrotron Radiation:
The pulse phase and viewing angle of the synchrotron radiation may be much different with the original curvature radiation.

Where are the GeV curvature photons?
The outgoing GeV curvature photons are missed by the viewing angle. If the viewing angle or inclination angle increases, the GeV curvature photons can be seen.

Why is the cut-off energy of the spectrum so low?
This is because of the attenuation of the synchrotron photons caused by the magnetic pair creation.

How to constrain the inclination and viewing angles?
1. The “ring” in the SNR
2. The energy of the peak of the spectrum
3. The shape of the light curve
4. The phase lag of the peak of the X-ray radiation to the radio radiation

References:

Kuiper, L., Hermsen, W., 2013, in preparation

Conclusion:
The lines of sight of these five pulsars are in the directions of incoming beams instead of outgoing beams, otherwise a characteristic power law with exponential cut-off spectrum with cut-off energy around a few GeV should be observed. The observed spectrum is the synchrotron radiation emitted by the pairs produced by the magnetic field that converts the major part of the incoming curvature photons.

The details of the simulation can be found in:


References:

Kuiper, L., Hermsen, W., 2013, in preparation