High-Energy Emission of PSR B1937+21

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Abstract:
PSR B1937+21 is the first millisecond pulsar (MSP) detected and it is representative of an emerging class of MSPs that shows aligned pulse profiles in different energy bands (Guillemot et al. 2012). We report on a study of the high-energy emission of the pulsar using archival Chandra, XMM-Newton, and Fermi LAT observations. Our results indicate that the pulsar X-ray emission is ~100% pulsed and has a purely non-thermal spectrum with a hard photon index of 0.9±0.1. Using 5.5 yr of Fermi survey data, we obtained much improved constraints on the pulsar’s gamma-ray timing and spectral properties. The pulsed spectrum is adequately fitted by a simple power-law with a photon index of 2.3±0.07, and an exponential cutoff power-law model is not significantly better. Both the gamma-ray and X-ray pulse profiles exhibit similar two-peak structure and generally align with the radio peaks.

A comparison with other MSPs suggest that the aligned profiles and the hard spectrum in X-rays could be common properties among MSPs with high magnetic fields at the light cylinder. We discuss a simple model in which the non-thermal X-rays are contributed by IC scattering between radio waves and primary particles in the outer magnetosphere and by synchrotron radiation from secondary particles. As shown in the SED below, this toy model is capable to qualitatively reproduce the observed spectral energy distribution in X-rays and gamma-rays.

Observations:

<table>
<thead>
<tr>
<th>Telescope / Instrument</th>
<th>Date</th>
<th>Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chandra / ACIS-S</td>
<td>2005 Jun 28</td>
<td>49.5ks</td>
</tr>
<tr>
<td>XMM-Newton/ MOS1, MOS2, PN</td>
<td>2010 Mar 29</td>
<td>40.4ks, 47.5ks, 40.4ks</td>
</tr>
<tr>
<td>Fermi / LAT</td>
<td>2008 Aug – 2014 Jan</td>
<td>5.5yr</td>
</tr>
</tbody>
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X-ray images of the field of PSR B1937+21

Gamma-ray spectrum

Best-fit PL X-ray spectrum

High-\(E\), high-\(B_\gamma\), MSPs:
- Aligned radio, X-ray, and gamma-ray profiles
- Large pulsed fraction
- Hard power-law spectrum in X-rays
- Giantron pulses

Aligned profiles => same emission zone
- Gamma-rays: curvature radiation from primary particles
- X-rays: inverse-Compton between primary particles and radio waves? + Synchrotron
- Radio: coherent emission from plasma instability?

Fit the X-ray to gamma-ray spectrum:
assuming a broken power-law radio spectrum with turnover at 10MHz:

\[ F_{\nu}(\nu) = \begin{cases} A \left( \frac{\nu}{\nu_0} \right)^{-\alpha_1} & \text{for } \nu \geq 10\text{MHz} \\ A \left( \frac{\nu}{\nu_0} \right)^{-\alpha_2} & \text{for } \nu < 10\text{MHz} \end{cases} \]

\(\beta_f\) from observed flux density between 400MHz and 1.4GHz, \(\beta_f\) taken to be 0.5.

Future radio observations LOFAR and hard X-ray observations with NuSTAR or Astro-H would be useful

Reference:

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