Modeling of spectra from $\gamma$-ray binaries with pulsars

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credit: NASA SVS
\[ \gamma \text{-ray binaries} \]

- compact object + massive star
- peak in \( \nu F_\nu \) above 1 MeV
- winds play crucial role
# γ-ray binaries

$HE \in (0.1-100) GeV$

$VHE > 100 GeV$

<table>
<thead>
<tr>
<th>PSR B1259-63</th>
<th>LS 5039</th>
<th>LS 1+61 303</th>
<th>HESS J0632+057</th>
<th>1FGL J1018.6-5856</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{\text{Be}} = 31 M_{\odot}$</td>
<td>$M_{\odot} = 23 M_{\odot}$</td>
<td>$M_{\text{Be}} = 12 M_{\odot}$</td>
<td>$M_{\text{Be}} = 16 M_{\odot}$</td>
<td>$M_{\odot} = 31 M_{\odot}$</td>
</tr>
<tr>
<td>$P = 1237 \text{ day}$</td>
<td>$P = 3.9 \text{ day}$</td>
<td>$P = 26.5 \text{ day}$</td>
<td>$P = 315 \text{ day}$</td>
<td>$P = 16.6 \text{ day}$</td>
</tr>
<tr>
<td>$e = 0.87$</td>
<td>$e = 0.35$</td>
<td>$e = 0.54$</td>
<td>$e = 0.84$</td>
<td></td>
</tr>
</tbody>
</table>

| HE + VHE           | HE + VHE | HE + VHE | VHE            | HE + VHE          |

credit: G.Dubus
γ-ray binaries

anti-correlation in fluxes from TeV and GeV ranges for LS 5039
Model
Pulsar

- electron energy distribution

\[ \frac{dN_e}{d\gamma d\Omega dx} = K_1 \gamma^{-\delta} \]

\[ \kappa_1 L_{sd} = 4\pi c \int \gamma mc^2 \frac{dN_e}{d\gamma d\Omega dx} d\gamma \]

- HE pulsar component

\[ \frac{dN_\gamma}{dE} = K_2 E^{-\Gamma} e^{E/E_{cutoff}} \]

\[ \kappa_2 L_{sd} = 4\pi \int E \frac{dN_\gamma}{dE} dE \]
• stellar photon emissivity

\[ \frac{dn_{ph}}{dE \, d\Omega} = \frac{2 \, E^2}{h^3 \, c^3 \left(e^{E/kT} - 1\right)^{-1}} \]
Termination shock

Ram pressures ratio: \[ \eta = \frac{P_{pw}}{P_{sw}} \]

\[ P_{pw} = \frac{L_{sd}}{4 \pi r^2 c} \]

\[ P_{sw} = \frac{\dot{M} V}{4 \pi r^2} \]

\[ \eta = 1 \]

\[ \eta = 0.05 \]

\[ \eta = 0.0011 \]
Cooling of electrons by ICS

\[
\frac{d\gamma}{dx} = -\frac{1}{mc^3} \int d\Omega \int dE \int dE_1 (E_1 - E) \frac{dn_{ph}}{dE d\Omega} \frac{dN}{dt dE_1}
\]

\[\eta = 0.0011 \quad \gamma_0 = 1 \cdot 10^3\]

\[\eta = 0.05 \quad \gamma_0 = 5 \cdot 10^3\]

\[\eta = 1\]

example for superior conjunction
Results for LS 5039

- pulsar spin down luminosity:
  \[ L_{sd} = 6 \cdot 10^{36} \text{ erg/s} \]
- in electrons with a Lorenz factor \( \gamma \in (10^3, 6 \cdot 10^3) \) with a \( \delta = 2 \):
  \( \kappa_1 = 0.2 \)
- in HE component of a spectrum with \( \Gamma = 2.22 \) and \( E_{\text{cutoff}} = 4.5 \text{ GeV} \):
  \( \kappa_2 = 0.14 \)
- star with a temperature \( T = 39000 \text{ K} \)
Results for LS 5039

\[ \eta = 0.05 \]

\[ \eta = 1 \]

\[ \eta = 0.0011 \]

almost the same for \( \eta = 1 \)

points - credit: D.Hadasch 2012
Results for LS 5039

\[ \eta = 0.0011 \]

\[ \eta = 0.05 \]

\[ \eta = 1 \]

Almost the same for \( \eta = 1 \)

PRELIMINARY

Points - credit: D.Hadasch 2012
Conclusions

- We match the results from Fermi
- Our results point to $\eta$ value in range $(0.0011 - 0.05)$
- The electrons' Lorenz factor no bigger than a few thousand