Modeling the high-energy radiation in gamma-ray binaries

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Some binaries in the gamma-ray sky

- LSI+61°303
- LS 5039
- PSR B1259-63
- HESS J0632+057

Distances:
- 2 kpc
- 2.5 kpc
- 1.5 kpc
- 1.5 kpc

Periods:
- 26.5 days
- 3.9 days
- 1240 days
- ?

Credit: NASA/DOE/Fermi LAT Collaboration
**GeV & TeV beacons: The orbital modulation**

- **TeV**
  - LS 5039
  - LSI +61°303
  - PSR B1259-63

- **GeV**
  - LS 5039
  - LSI +61°303

- **Orbital modulation** GeV and TeV
- **Stable modulation** ➔ **Orbital effect**

*Richard Dubois’ Talk!!*
The pulsar wind nebula scenario: The big picture!

[Maraschi & Treves 1981; Dubus 2006b]

High-energy processes:
- Inverse Compton
- Synchrotron radiation
- Pair production

Massive Star
Observer!

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Modeling the high-energy radiation in LS 5039

**Emission shocked wind**
- Pulsar spin-down power
  \( L_p = 10^{36} \text{ erg/s} \)
- Magnetic field at the shock
  \( B = 0.8 \pm 0.2 \text{ G} \)
- Injected electron index
  \( p = 2 \pm 0.3 \)

**Emission unshocked wind**
- Strong spectral signature!
- Low Lorentz factor or highly magnetized wind?
- Dominant contribution

[Cerutti et al. 2008]
[Hess et al. 2008]
[EGRET]
[Fermi]
[Dubus et al. 2008]
[Sierpowska-Bartosik & Torres 2008]
Theoretical GeV & TeV modulation in LS 5039...

- Cascades!

![Fermi flux variation](image1)

![HESS lightcurve](image2)

**Anti-correlation!**

- GeV-TeV anti-correlation due to pair production
  [Dubus 2006a]

- Computation of 3D pair cascade radiation with a Monte Carlo code, constraints:
  - Inclination: 40°
  - Max ambient magnetic field: 5 G
  - TeV emitter close to the pulsar

[Cerutti et al. In preparation]

[Abdo et al. 2009]
... as one would observe in the gamma-ray sky!

**Fermi**

**HESS**
New modeling challenges: LSI $+61^\circ 303$ seen by Fermi

- **GeV modulation**: Max/Min close to periastron/apastron

- **Spectrum**: Power-law + exponential cutoff at 6 GeV!
  - Incompatible with $\gamma\gamma$-absorption
  - Magnetospheric pulsar emission?
  - Signature unshocked pulsar wind?

**GeV-TeV link non trivial!!**
The pulsar wind nebula scenario: The big picture!

[Maraschi & Treves 1981; Dubus 2006b]
GeV excess: Signature of the unshocked pulsar wind?

- Pulsar spin-down power: $L_p > 10^{37}$ erg/s
- Electrons energy: $10^3 < \gamma < 5 \times 10^4$
- Injected electron index: $p=3.1$

[Abdo et al. 2009]

[EGRET, MAGIC, Fermi]

[Abdo et al. 2009]

Apastron
Periastron

Shift in phase!? + 0.25 ??

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Conclusions

- **Leptonic model** can explain the general features but complex interplay between high-energy processes for:
  - Shocked/unshocked wind components
  - Anisotropic effects
  - Cascades

- **Fermi** observations of LSI +61°303:
  - **Modulation** and cutoff spectrum challenge models
  - Are there **2 different components** at HE and VHE?
  - Signature from an **unshocked pulsar wind**?

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