ON THE ORIGIN OF
X-RAY/VHE CORRELATION IN LS I +61 303

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4. Summary
- Night-to-night variability in VHE, X-ray.
- Kilosecond/hour scale variability in X-ray
- Long-term four year superorbital radio peak modulation (Paredes 1987) on top of orbital variability.
- SGR-like burst lasting $\sim 0.5$ s in hard X rays (de Pasquale et al. 2008, GCN 8209).
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SGR-like burst lasting $\sim 0.5$ s in hard X rays (de Pasquale et al. 2008, GCN 8209).

Orbital periodicity (26.5 d) in radio, X-ray, HE and VHE $\gamma$-ray.

Periodic outbursts in X-ray and VHE in $0.6 < \phi < 1.0$, while maximum in HE is around $0.0 < \phi < 0.4$. 
LS I +61 303

INTEGRAL Hard X-ray
(Hermsen et al. 2006)

Fermi HE $\gamma$-ray
(Abdo et al. 2009)

MAGIC VHE $\gamma$-ray
(Albert et al. 2009)
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But **NOT** stable! See talks by Diego, Tobias, Gernot.

- X-ray (*XMM-Newton* and *Swift*) and VHE (MAGIC) \(\sim 17\) observations.

- Significant correlation: 
  \[ r = 0.81^{+0.06}_{-0.21} \]  
  \[ (r = 0.97 \text{ for first outburst}) \]

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VHE/X-ray Multiwavelength observations

\[
F_X/[10^{-12} \text{ erg/cm}^2/\text{s}] = 12.2^{+0.9}_{-1.0} + (0.71^{+0.17}_{-0.14}) \times F_{\text{TeV}}/[10^{-12} \text{ ph/cm}^2/\text{s}]
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- OZM: Homogeneous physical properties throughout the emitter.
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Simultaneous modulation: dominant adiabatic losses

- Ultimately related to (magneto)hydrodynamical processes in the accelerator and emitter regions: naturally present in a variable pressure environment.

Khangulyan et al. (2007) and Takahashi et al. (2009) take the same approach for PSR B1259-63 and LS 5039.
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- Adiabatic losses inferred from X-ray flux above pedestal
  \[ F_X^{\text{ped}} = 11.5 \times 10^{-12} \text{ erg/cm}^2/\text{s} \]

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- Adiabatic losses inferred from X-ray flux above pedestal \( F^{\text{ped}}_X = 11.5 \times 10^{−12} \text{erg/cm}^2/\text{s} \)
- X-ray photon index \( \Gamma_X \simeq 1.5 \) matches a \( \alpha_e = 2 \) injection spectrum

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Model description: Derivation of $t_{ad}$

![Graph showing orbital phase and X-ray flux](image)

- **XMM-Newton**
- **Swift/XRT**

$F(0.3 - 10 \text{ keV}) \left[ 10^{-12} \text{ erg/cm}^2/\text{s} \right]$ vs. Orbital Phase
Model description: Derivation of $t_{ad}$
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Requirements for $t_{ad}$:
- $t_{ad} \propto F_X$
- $t_{ad} < \min(t_{IC}, t_{syn})$

Obtained $t_{ad}$: tens to hundreds of seconds
Constant injection spectrum: Power-law with high energy cutoff at balance of \( t_{acc} = \eta R_L/c \) and \( t_{cool} \):

\[
E_{e,\text{max}} \approx 9B_G t_{ad} \eta^{-1} \text{ TeV} \quad \text{ for adiabatic}
\]
\[
E_{e,\text{max}} \approx 60(B_G \eta)^{-1/2} \text{ TeV} \quad \text{ for synchrotron}
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To obtain 10 TeV electrons: \( \eta \lesssim \min(B_G t_{ad}, 40B_G^{-1}) \)
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Steady state electron energy distribution at each phase:

\[
n(\phi, \gamma_e) = \frac{1}{|\dot{\gamma}|} \int_{\gamma_e}^{\gamma_{e,\text{max}}} Q(\gamma') \, d\gamma'
\]

Orbital parameters from Aragona et al. (2009, ApJ, 698, 514) and $i = 45^\circ$
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Results: MW lightcurve

\[ F(0.3 - 10 \text{ keV}) \left[ 10^{-12} \text{ erg/cm}^2/\text{s} \right] \]

\[ N(E > 300 \text{ GeV}) \left[ 10^{-12} \text{ ph/cm}^2/\text{s} \right] \]

\[ B = 0.22 \text{ G} \quad \eta = 10 \quad L_{\text{inj}} \sim 10^{35} \text{ erg/s} \]
Results: SED during outburst (0.6 $< \phi < 0.7$)

- SED averaged over the phases of three observations during the first outburst.
- Best agreement:
  - $\alpha_e = 2.1$
  - $\eta = 7$–120
Fermi data in 10–100 GeV require a harder particle distribution below $E_e = 4 \times 10^{11}$ eV.

$$\alpha_e \begin{cases} \leq 1.8 & \text{if } E_e < E_{\text{break}} \\ = 2.1 & \text{if } E_e > E_{\text{break}} \end{cases}$$
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Simultaneous X-ray/VHE campaign provides great data to probe emitter

Adiabatically dominated OZM effective to isolate the emitter’s properties:

- \( B \approx 0.22 \text{ G} \)
- Adiabatic timescales from few tens to few hundreds of seconds.
- Efficient accelerator: \( \eta = 7 - 130 \)
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- Results are unable to clearly discern accreting/non-accreting, but poses constraint on future modeling.
- GeV component has different origin than the X-ray/VHE emission.
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For more information: arXiv:1011.4489
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