Multiwavelength emission of the gamma-ray binary LS I +61 303

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Multifrequency Behavior of High Energy Cosmic Sources
High-energy binary systems

High-Energy (above 1 GeV) sky from Fermi/LAT

Binary systems:
High-Mass X-ray binaries, Colliding Wind Binaries, Gamma-Ray Binaries
High-energy binary systems

Very High-Energy (≈TeV) sky from Cherenkov Telescopes

High-Mass X-ray binaries, Colliding Wind Binaries, Gamma-Ray Binaries
Gamma-ray binaries

Massive star and compact object

Non-thermal SED dominated by γ-rays

Only six systems are known to date:

| System         | Main star | P/ days |
|----------------|-----------|---------|
| LS 5039        | O6.5 V    | 3.9     |
| LMC P3         | O5 III    | 10.3    |
| 1FGL J1018.6–5856 | O6 V   | 16.6    |
| LS I +61 303   | B0 Ve     | 26.5    |
| HESS J0632+057 | B0 Vpe    | 315.0   |
| PSR B1259–63   | O9.5 Ve   | 1236.7  |

Only in PSR B1259–63 we know the nature of the compact object: NS

Zabalza et al. (2012)
Gamma-ray binaries

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The Gamma-Ray Binary LS I +61 303

B0 Ve star \((12.5 \pm 2.5 \, M_\odot)\)
\(d = 2.0 \pm 0.2 \, \text{kpc}\)
\(e = 0.72 \pm 0.15\)

\(P_{\text{orb}} = 26.496 \pm 0.003 \, \text{d}\)
\(P_{\text{super}} = 1667 \pm 8 \, \text{d}\)

Frail & Hjellming (1991), Casares et al. (2005), Gregory (2002)
Superorbital modulation

Superorbital modulation of the amplitude & phases of these outbursts with $P_{SO} \approx 1667$ d (≈ 4.4 yr)

Paredes et al. (1990)

Gregory (2002)

Observed from radio to TeV
Microquasar or non-accreting pulsar wind?

A sketch of the system, as described in the previous section, can contribute significantly to the non-thermal emission of the system i.e., those not marked in red in Fig. 1. The intermediate regions of the pulsar wind shock, quasi-parallel shocks: the wind standoff and Coriolis turnover shape of the pulsar wind zone gives rise to two distinct regions...
Presence of a precessing jet?

- The two observed periods can be explained as a beat frequency due to a precessing jet and the orbital motion. 
  Massi & Jaron (2013); Massi & Torricelli-Ciamponi (2016)

- Anti-correlation between X-ray luminosity and photon-index consistent with BH X-ray Binaries (Massi et al. 2017)

- Jet velocities of $\beta \sim 0.006–0.5$ (Jaron et al. 2017)

Requires the presence of a black-hole
Non-accreting pulsar evidences?

- X-ray spectrum and spectral variability consistent with a rotation-powered pulsar (Chernyakova et al. 2006)

- Estimation of the mass of the compact object to be: $1.3 \, M_\odot < M < 2.0 \, M_\odot$, likely a Neutron Star (Zamanov et al. 2017)

- Absorption profile derived at X-rays as a function of orbital and superorbital phases.
  Circumstellar disk disrupted at $\Phi \approx 0.6$ and slowly regenerated (Chernyakova et al. 2017)
Optical and radio campaigns
Optical observations

Observations with the robotic Telescope Fabra-ROA Montsec (TFRM):

Orbital and superorbital modulation also observed in the optical band
Paredes-Fortuny et al. (2015; 2017 in prep)
Optical observations

Coupling between the thermal and non-thermal superorbital variability
Periodic changes in the circumstellar disk
(Paredes-Fortuny et al. 2015; 2017 in prep)
Similar evidences observed at TeV (Ackermann et al. 2013)
Focusing on a single outburst (Strickman et al. 1998):
GMRT and LOFAR observations contemporaneous with 15-GHz RT and OVRO ones

Marcote et al. (2016)

Both campaigns at different superorbital phase. Cannot be compared!
Absorption process?

- Free-free abs:
  \[ v_{\text{FFA}} = 700 \pm 200 \text{ km s}^{-1} \]

- Synchrotron self-absorption:
  \[ v_{\text{SSA}} = 1000 \pm 140 \text{ km s}^{-1} \]

Wind velocity \( 1500 \pm 500 \text{ km s}^{-1} \)

Marcote et al. (2016)
Conclusions

• LS I +61 303 remains as a challenging gamma-ray binary

• Many clues suggest the presence of a neutron star

• The optical and non-thermal correlation suggest a common origin

• Superorbital modulation dominated by perturbations of the circumstellar disk?

• The low-frequency turnover constrains the conditions on the region

• A more detailed low-frequency radio campaign is ongoing (spectrum, variability along the orbit)
Thank you!