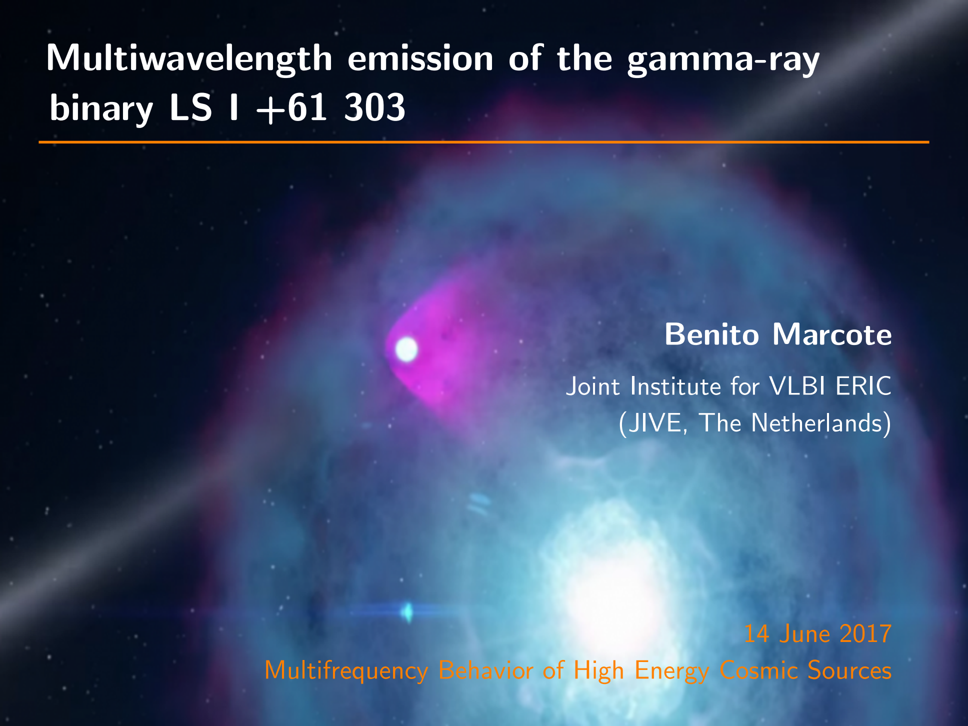
Multiwavelength emission of the gamma-ray binary LS I +61 303



Benito Marcote

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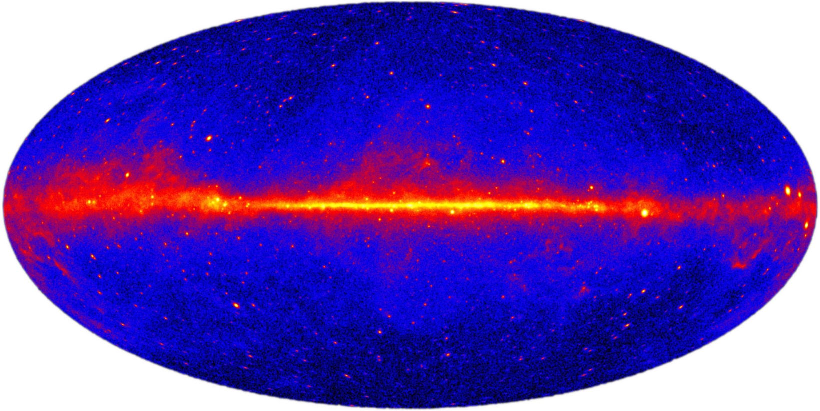
(JIVE, The Netherlands)

14 June 2017
Multifrequency Behavior of High Energy Cosmic Sources

High-energy binary systems

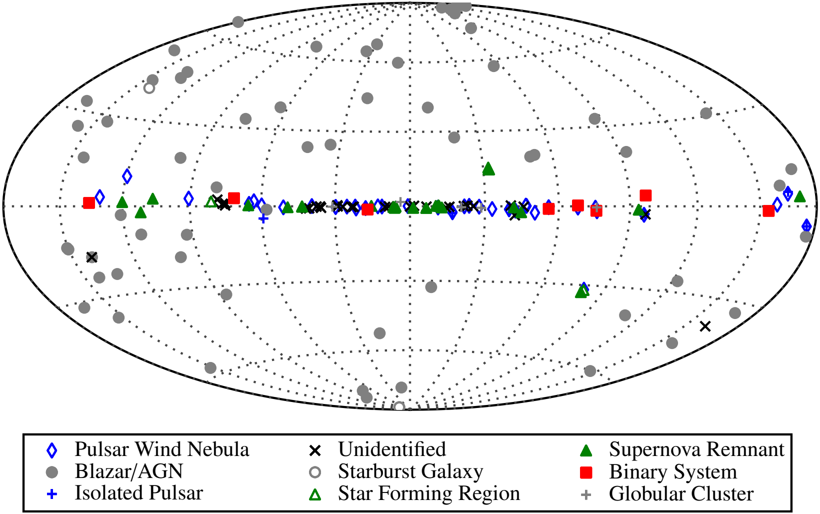


High-Energy (above 1 GeV) sky from *Fermi*/LAT

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

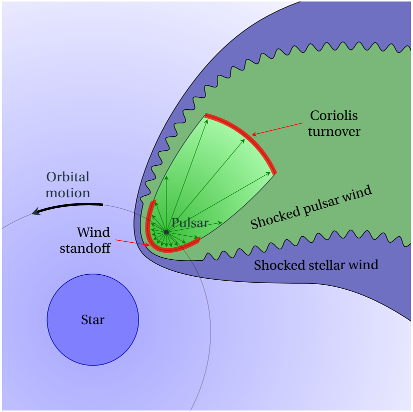
Massive star and compact object

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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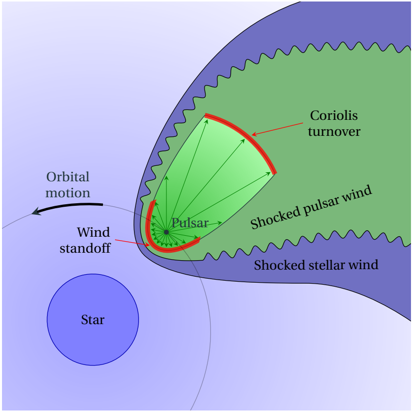


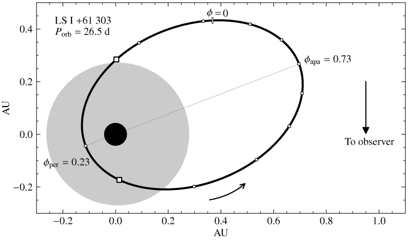
Zabalza et al. (2012)

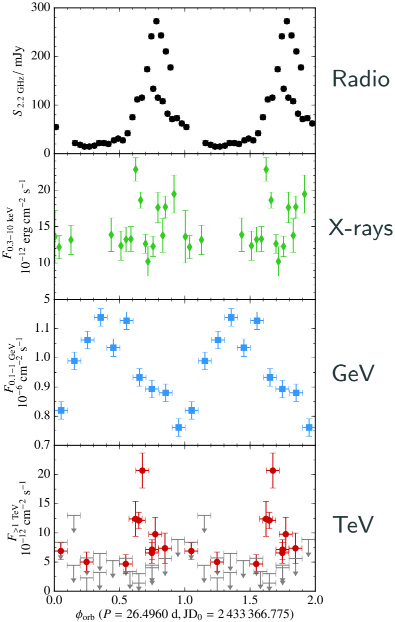
The Gamma-Ray Binary LS I +61 303

B0 Ve star ($12.5 \pm 2.5\ \mathrm{M}_\odot$)
$d = 2.0 \pm 0.2$ kpc
$e = 0.72 \pm 0.15$

$P_{\mathrm{orb}} = 26.496 \pm 0.003$ d
$P_{\mathrm{super}} = 1667 \pm 8$ d

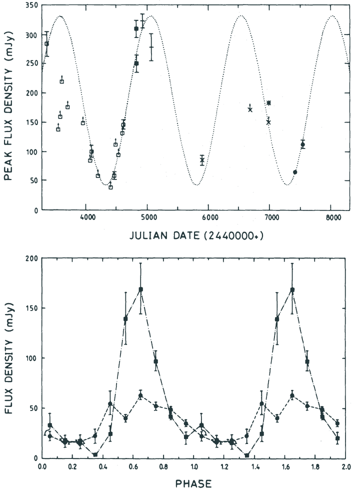
Frail & Hjellming (1991), Casares et al. (2005), Gregory (2002)



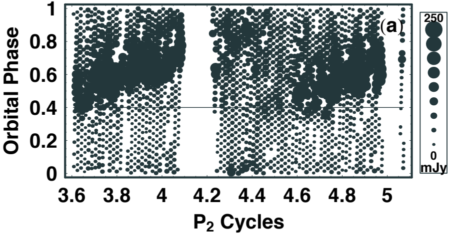


Superorbital modulation

Superorbital modulation of the amplitude & phases of these outbursts with $P_{\mathrm{so}} \approx 1\,667$ d (≈ 4.4 yr)



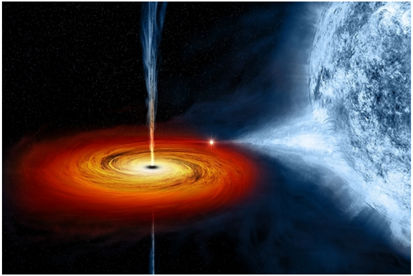
Paredes et al. (1990)

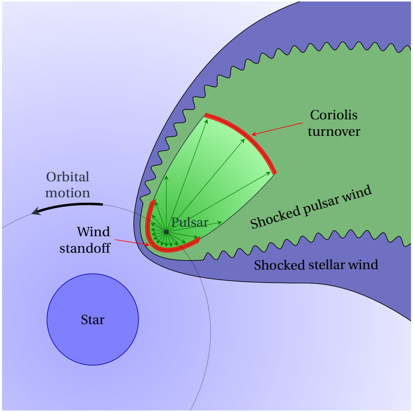


Gregory (2002)

Observed from radio to TeV

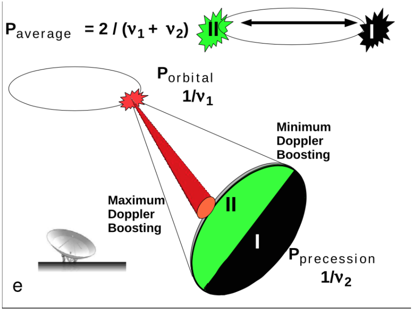
Microquasar or non-accreting pulsar wind?





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

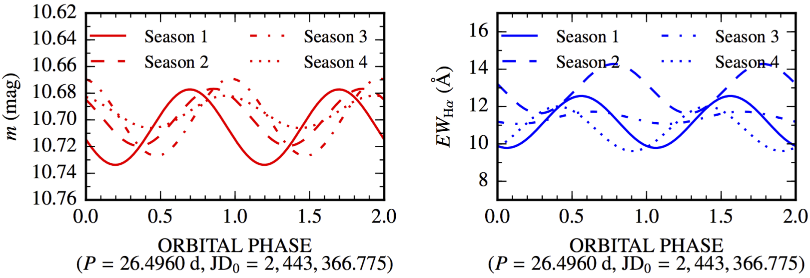
Non-accreting pulsar evidences?

- 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:
  $1.3\ \mathrm{M}_\odot < M < 2.0\ \mathrm{M}_\odot$, 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

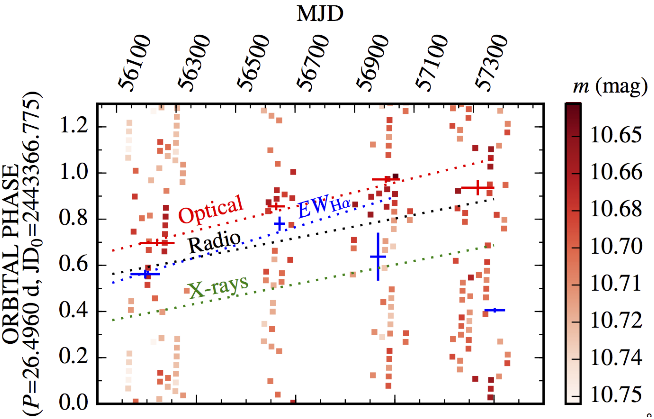
Optical observations

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

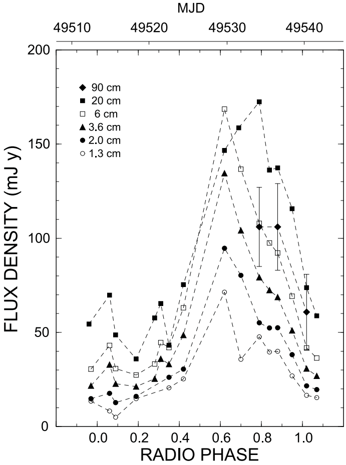
Periodic changes in the circumstellar disk

(Paredes-Fortuny et al. 2015; 2017 in prep)

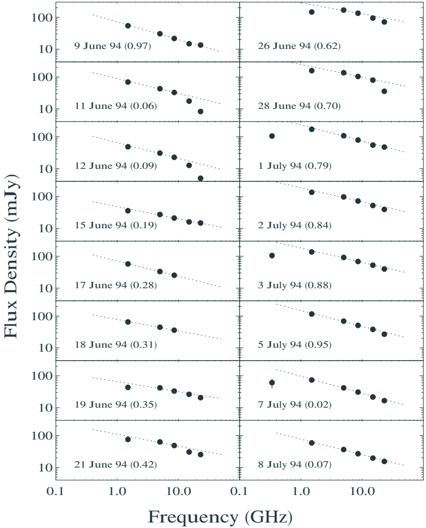
Similar evidences observed at TeV (Ackermann et al. 2013)

Profile of a single radio outburst

Focusing on a single outburst (Strickman et al. 1998):

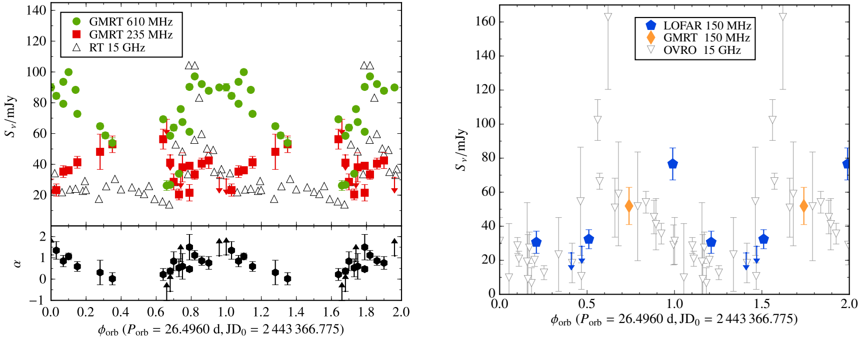


1.5–23 GHz



Low-frequency radio emission of LS I +61 303

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!

Low-frequency radio emission of LS I +61 303

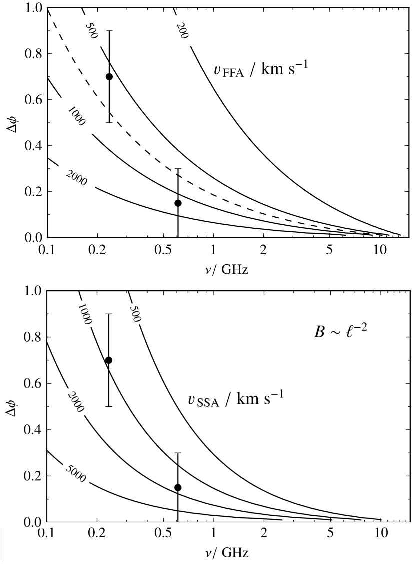
Absorption process?

- Free-free abs:
  $v_{\mathrm{FFA}} = 700 \pm 200$ km s^{-1}

- Synchrotron self-absorption:
  $v_{\mathrm{SSA}} = 1\,000 \pm 140$ km s^{-1}

Wind velocity $1\,500 \pm 500$ 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!