The Very Low Frequency Emission for Gamma-Ray Binaries

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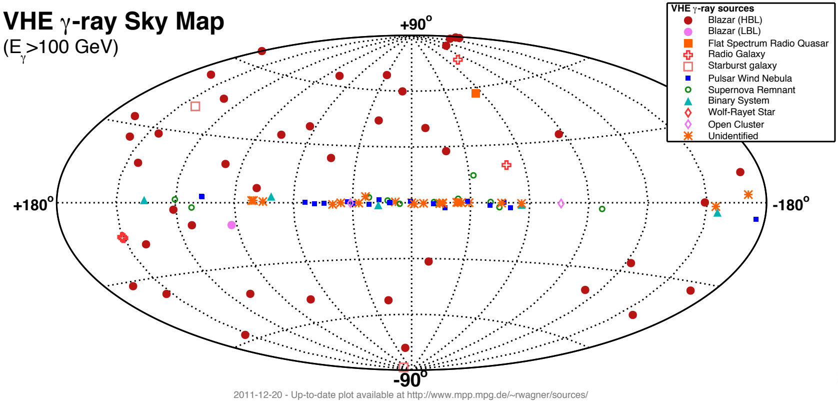
The Gamma-Ray Sky



- Very High Energy (> 100 GeV) sky seen by Cherenkov telescopes
- Only a few TeV source have been associated with binary systems

Gamma-Ray Binaries

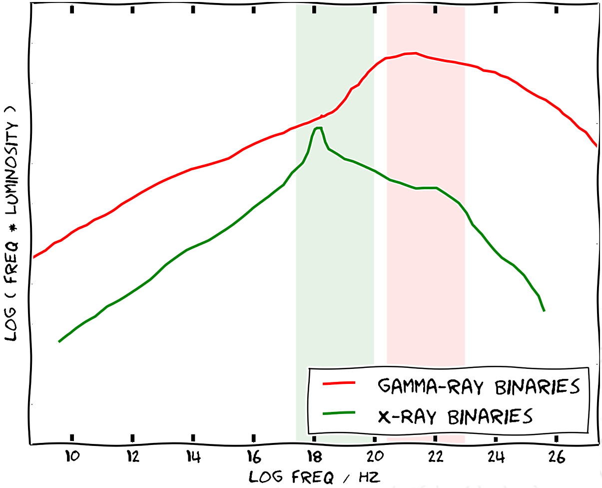
Only a few binary systems exhibiting gamma-ray emission have been detected up to now:

System	Primary star	Compact object	P / days
Cygnus X-3	WR	BH	0.2
Cygnus X-1 ??	09.7Ve	BH	5.6
HD 215227 ??	Be	BH	60.4
PSR B1259–63	09.5Ve	pulsar!	1236.7
HESS J0632+057	B0 Vpe	?	315.0
LS I +61 303	B0 Ve	?	26.5
1FGL J1018.6–5856	O6V	?	16.6
LS 5039	06.5V	?	3.9

The black ones are X-ray binaries exhibiting gamma-ray emission
The green ones are the only known gamma-ray binaries

Gamma-Ray Binaries

X-ray binaries VS gamma-ray binaries spectrum

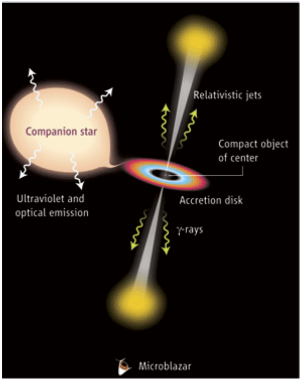


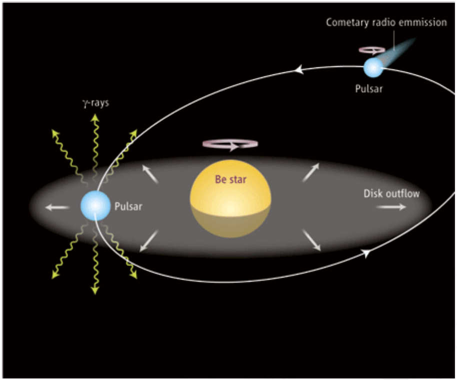
Gamma-Ray Binaries

Different scenarios seem to be required to describe the two kind of sources

Microquasar

Non-accreting pulsar wind





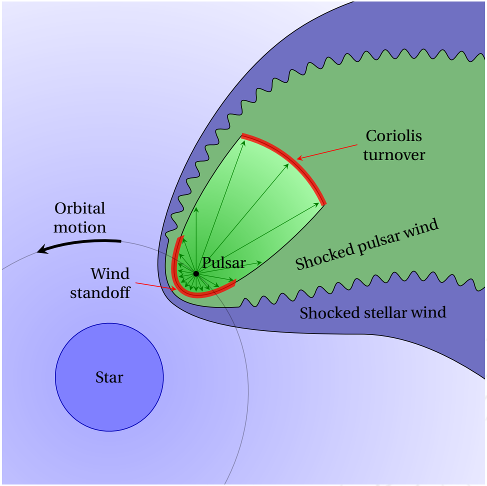
Mirabel (2006)

Cygnus X-1, Cygnus X-3

PSR B1259–63

Gamma-Ray Binaries

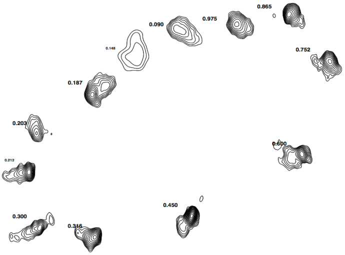
Young non-accreting pulsar wind scenario



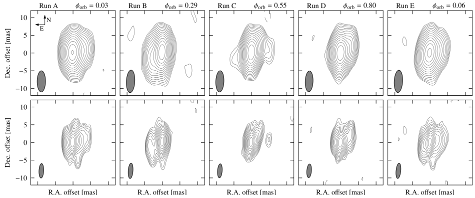
Model for LS 5039 from Zabalza et al. (2012)

Radio observations

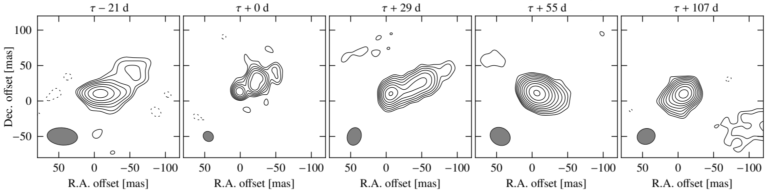
Published long baseline observations



LS I +61 303 (Dhawan et al. 2006)



LS 5039 (Moldón et al. 2012)



PSR B1259–63 (Moldón et al. 2012)

Radio observations

With long baseline interferometers:

- Periodic morphological changes are reported in several gamma-ray binaries
- The Position Angle rotates along the orbit
- Generally one-sided extended emission, but at specific orbital phases two-sided

At very low frequencies ($\ll$ 1 GHz) we expect...

- Absorption mechanisms arising from the spectrum
- A large extended structure ("*nebula*" or "*halo*")
- A more steady emission along the time
- *Almost unexplored up to now!*

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Objectives

Low frequency radio emission

- Determine the spectrum of the gamma-ray binaries
- Search for variability
- Search for absorption mechanisms
- Infer the geometry of the system and emission models

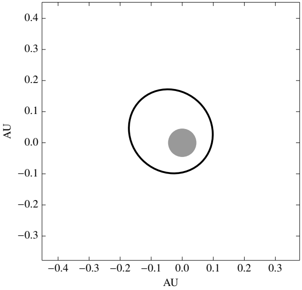
Extended emission

- Detect for first time the predicted extended emission around the binary system at low frequencies ($\sim$arcsec-arcmin)
- Determine the geometry of the system at larger timescales and farther away distances

Current research

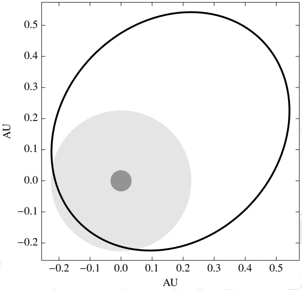
LS 5039

O6.5 V star ($23 \pm 3\ M_\odot$)
$P \approx 3.9$ d
$d = 2.5 \pm 0.5$ kpc
$e = 0.35 \pm 0.04$
Gamma-rays: single outburst
Radio: not periodic, small variability
Casares et al. (2005)



LS I +61 303

B0 Ve star ($12.5 \pm 2.5\ M_\odot$)
$P \approx 26.5$ d
$d = 1.9 \pm 0.1$ kpc
$e = 0.54 \pm 0.01$
Gamma-rays: doble outburst
Radio: double outburst
Aragona et al. (2009)

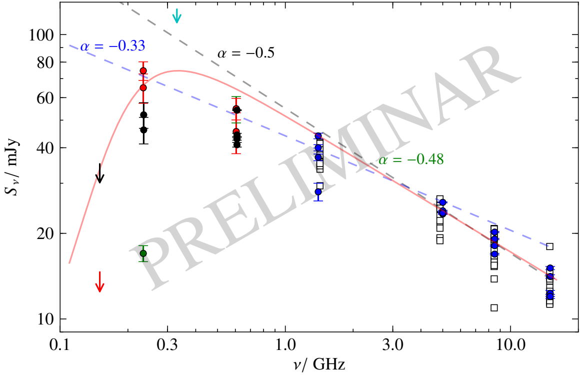


LS 5039

At ∼GHz frequencies, LS 5039 exhibits (Martí et al. 1998):

- Synchrotron emission (power-law with $\alpha = -0.46 \pm 0.01$)
- Emission persistent with a variability $\lesssim 30\%$

Analyzing archival (not simultaneous) VLA & GMRT:



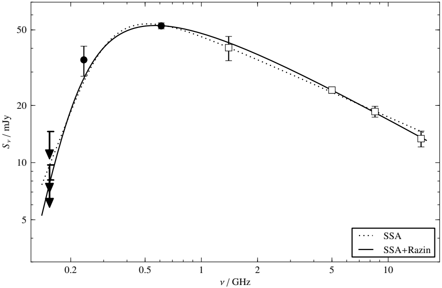
● Martí et al. (1998) ● Godambe et al. (2008) ● Pandey et al. (2007)

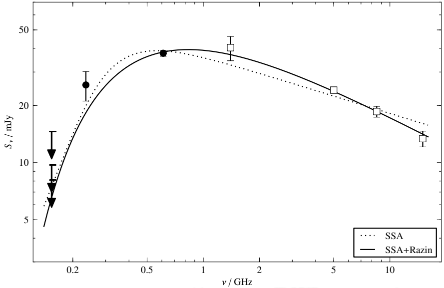
□ VLA ● GMRT ↓ VLA 330 MHz ↓ GMRT ↓ LOFAR (commissioning)

Benito 2012 Master Thesis

LS 5039

We conducted simultaneous observations with GMRT and WSRT from July 18 to 22, 2013: 150, 235/610 MHz, 1.4, 2.3, 5.0 GHz





Data from WSRT with problems (Mean values from Martí et al. 1998 showed here)

- The WSRT are necessary to completely described the spectrum
- Synchrotron Self-Absorption can explain the left spectrum
- Free-Free Absorption does not change appreciably the spectra
- Razin effect seems to be needed for the right spectrum

LS 5039

Results

From the previous spectra we infer:

- $B \sim 2{\cdot}10^{-5}$ T $\quad (\sim 1{\cdot}10^{-6}$ T$)$
- $R \sim 8 \cdot 10^{11}$ m

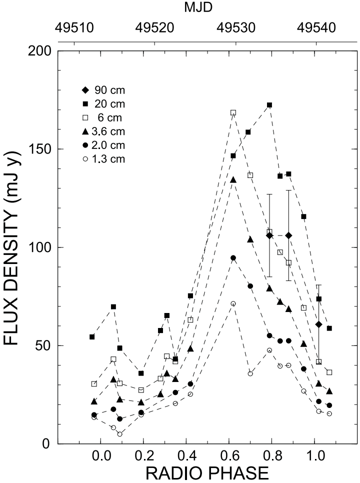
- $B \sim 2{\cdot}10^{-4}$ T $\quad (\sim 8{\cdot}10^{-7}$ T$)$
- $R \sim 2 \cdot 10^{12}$ m

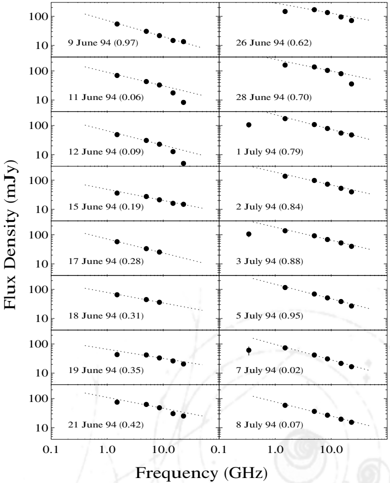
Razin effect

- The emission from relativistic charges surrounded by a cool, collisionless plasma is exponentially suppressed at low frequencies.
- Widely reported in Colliding Wind Binaries, but not in microquasars

LS I +61 303

Contrary to LS 5039, this system shows a large variability in radio

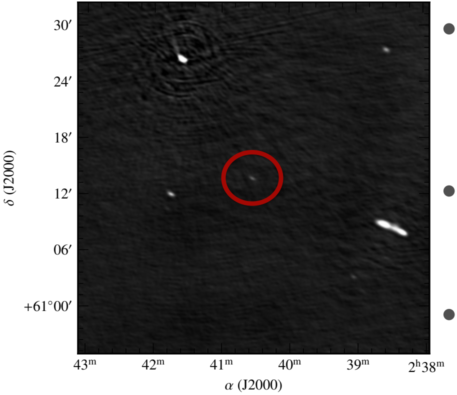




Strickman et al. (1998)

LS I +61 303

- $\sim$ 30 unpublished archival GMRT observations at 235/610 MHz in 2005–2006 and one observation at 150 MHz in 2008
- We performed with the TKP 6 LOFAR observations in Cycle 0 at $\sim$150 MHz



- GMRT detection at 150 MHz
  $S_\nu > 30$ mJy
  $\phi = 0.5$
  (point-like source)
- LOFAR not detected anything
  $rms \sim$ 6–10 mJy
  $\phi = 0.4,\ 0.0$
- On-going work to determine the spectrum with the 235/610 MHz archival GMRT data

Conclusions

For LS 5039...

- We have reported a turnover in the spectrum at frequencies below 1 GHz
- The shape of the spectrum changes with the time
- A strong suppression appears at very low frequencies
  No detections at 150 MHz up to now
- Similarities with CWBs could support the pulsar scenario

For LS I +61 303...

- Still on-going work
- A full covering of an orbit is required to compare the emission with the observed at GHz frequencies
  The peak of the emission is reached at the same time, or after?
- Extended emission could remain during the weak point-like emission

Thank You!