INTEGRAL Deep Observation of LS I +61 303

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Stanford, First GLAST Science Symposium, 7 february 2007

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Netherlands Institute for Space Research

LS I +61 303:

- High-Mass X-ray binary at a distance of 2 kpc
- Optical companion is a B0 Ve star of 10.7 mag with a circumstellar disc
- High eccentricity of the orbit (0.7)
- Orbital modulation of the emission from radio to X-rays with period 26.5 days
- Secondary modulation of period 4 years attributed to changes in the wind flow
- Elongated radio structures resolved at different scales (100 AU) (Massi et al. 1993)
- VLBA data show cometry-shaped emission pointed away from massive companion (Dhawan et al. 2006/7)
- TeV source (Albert et al., 2006)

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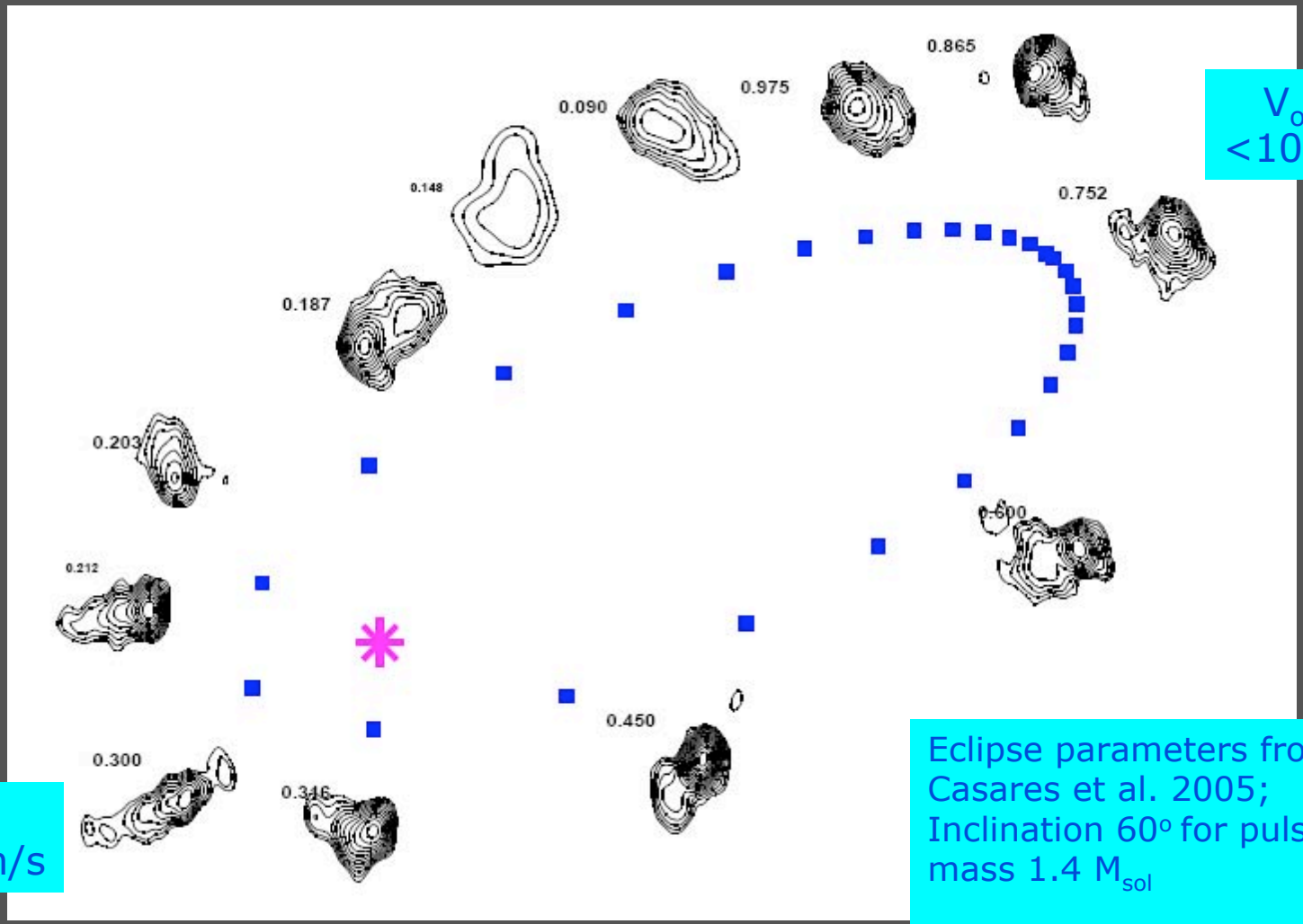
VLBA images LS I +61 303 at 3.6 cm

Dhawan, Mioduszewski, Rupen, PoS 2007



$V_{outflow}$ <1000 km/s

$V_{outflow}$ ~7500 km/s

Eclipse parameters from Casares et al. 2005; Inclination 60° for pulsar mass 1.4 M_{sol}

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Two main model scenario's:

- Non-accreting young pulsar in orbit around a mass-losing B star

  Maraschi & Treves 1981, Tavani 1995
  Dubus 2006, Chernyakova et al. 2006, Neronov & Chenyakova 2007, astro-ph

  PSR 1259-63 & LS I +61 303 (& LS 5039 ?)

- Super-Eddington accretion onto a compact object (NS or BH) embedded in mass outflow of the B-star
  e.g. Taylor et al. 1992

  Microquasar scenarios with acceleration in jet

  e.g. Bosch-Ramon & Parades 2004, Bosch-Ramon et al. 2006 (leptonic/hadronic emission),
  Gupta & Böttcher 2006, Bednarek 2006

  LS 5039 (?)

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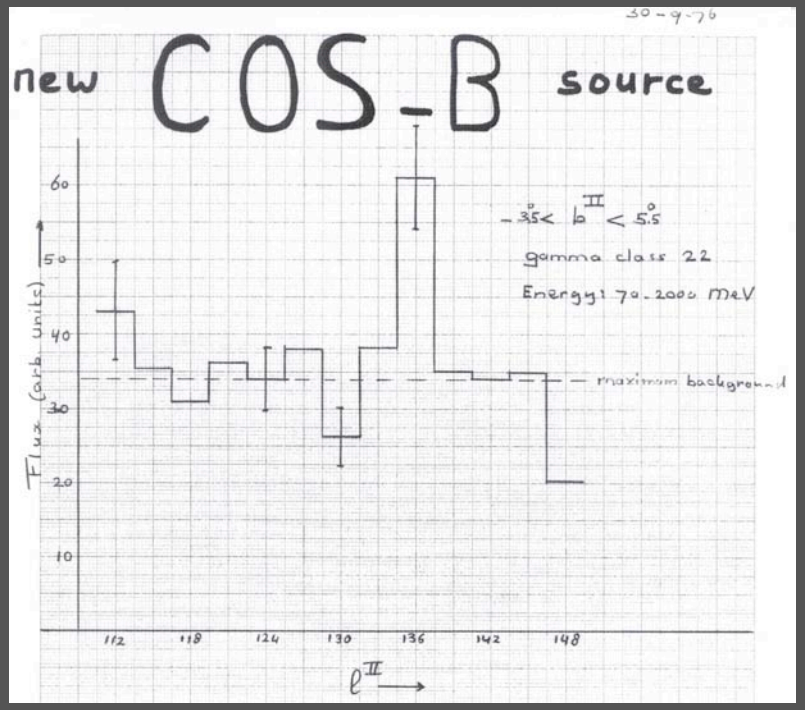

COS-B
1975-1982

First high-energy (> 100 MeV) COS-B gamma-ray source:
CG 135+01 = GT 0236+610 / LS I +61 303 (Gregory et al. 1979)
or QSO 0241+622 ?

1977: CG catalogue of 13 sources (Hermsen et al. 1977)

1980: 2CG catalogue of 25 sources (Hermsen, 1980; Swanenburg et al. 1981)

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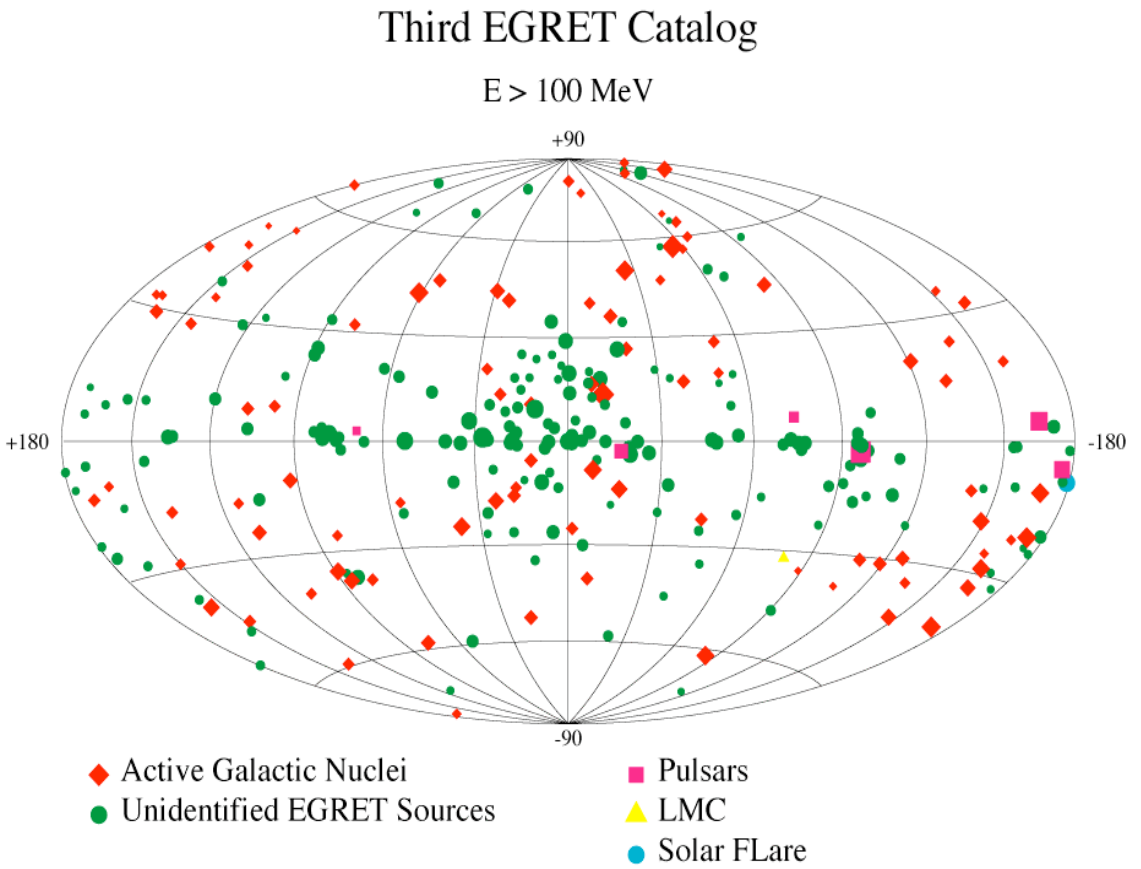
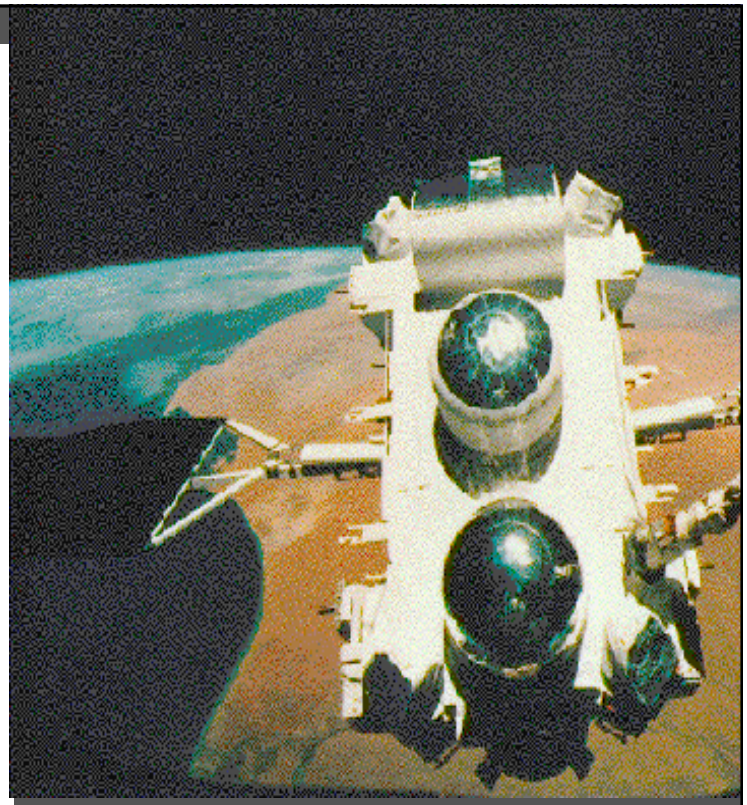


(Hartman et al. 1999)



CGRO
1991-2000

* 271 sources in total
* 170 sources unidentified
* 27 tentatively identified, including 2CG 135+01 / LS I +61 303

Now definitively 3 binaries are high-energy γ-ray/TeV sources:
PSR B1259-63, *LS 5039 and LS I +61 303*

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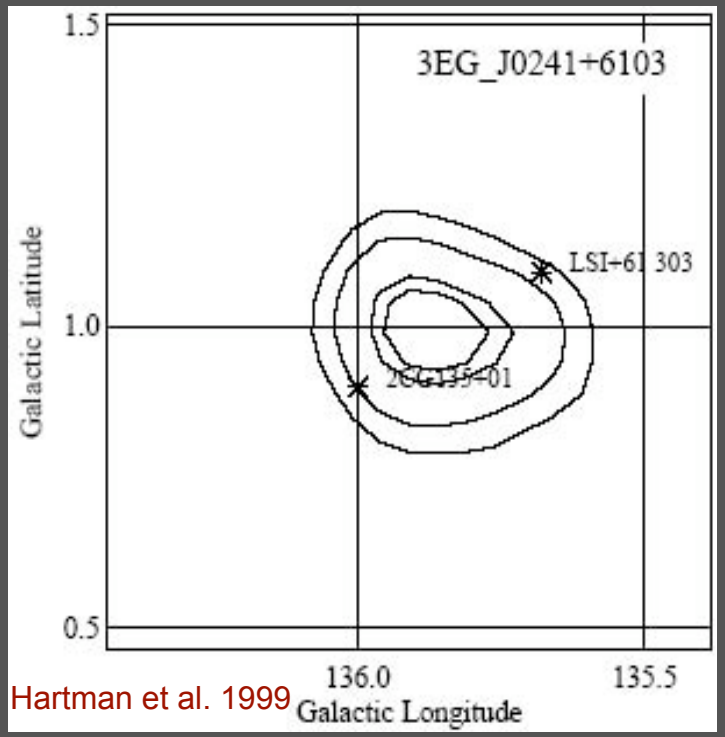
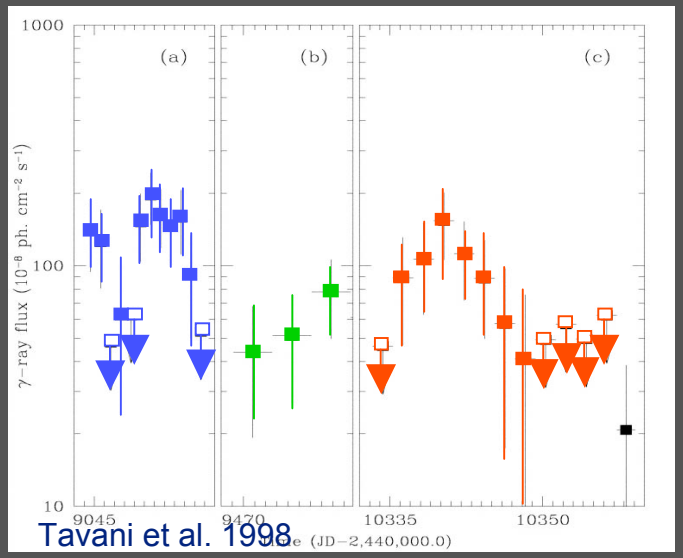
LS I +61 303 above 100 MeV (?)

Variability with peaking at periastron passage (φ=0.2) and φ ~ 0.5-0.6

3EG J0214-6103 (2CG 135+01) consistent with LSI +61 303

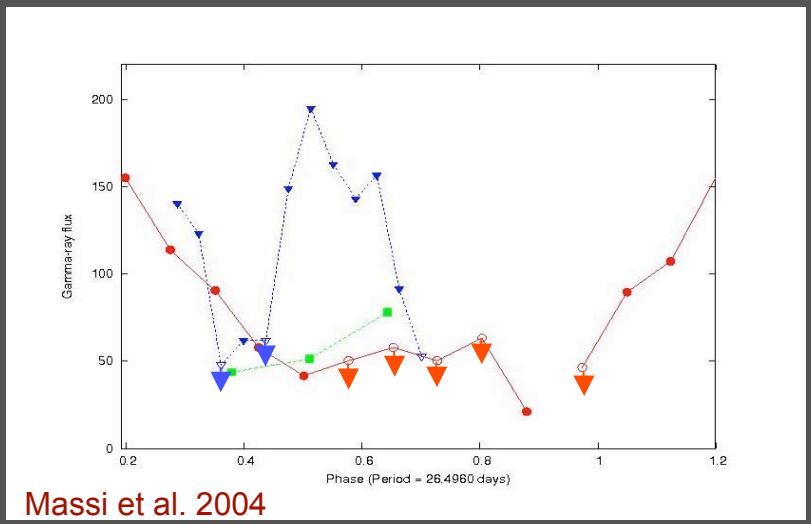


Hartman et al. 1999



Tavani et al. 1998

Kniffen et al. 1997



Massi et al. 2004

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INTEGRAL

Imager

IBIS-ISGRI

Energy range:	~20 keV - ~300 keV
Field of view:	9° x 9° (fully coded)
	19° x 19° (partially coded)
Angular resolution:	12’ (FWHM)
Point-source location accuracy:	30” – 3’

IBIS ISGRI Exposure of LS I +61 303: INTEGRAL Revs. 47-454

Orb. Phase	# ScW	Effective on-axis exposure (ks)
0.0 - 0.1	39	55.94
0.1 - 0.2	31	32.24
0.2 - 0.3	37	79.12
0.3 - 0.4	82	161.20
0.4 - 0.5	73	132.70
0.5 - 0.6	65	121.38
0.6 - 0.7	76	135.78
0.7 - 0.8	46	79.75
0.8 - 0.9	83	148.01
0.9 - 1.0	92	163.80
0.0 - 1.0	624	1109.93

March 2003 – July 2006

First reported INTEGRAL results (Chernyakova et al. 2006):

Orb. Phase	Exposure
0.4 – 0.6	50 ks
0.6 – 0.8	23
0.8 – 0.4	200
Total	273 ks

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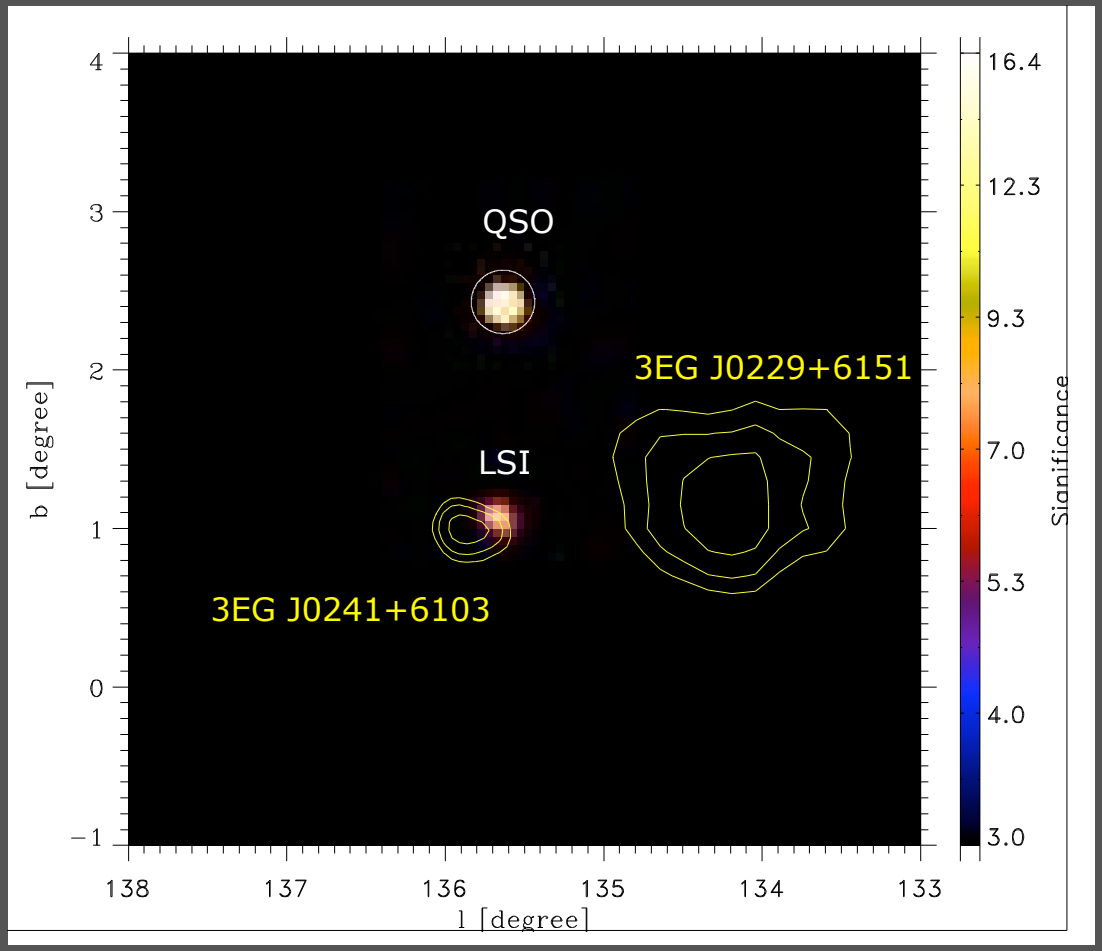
INTEGRAL / IBIS detection of LS I +61 303 and QSO 0241+622

20 – 95 keV

EGRET contours



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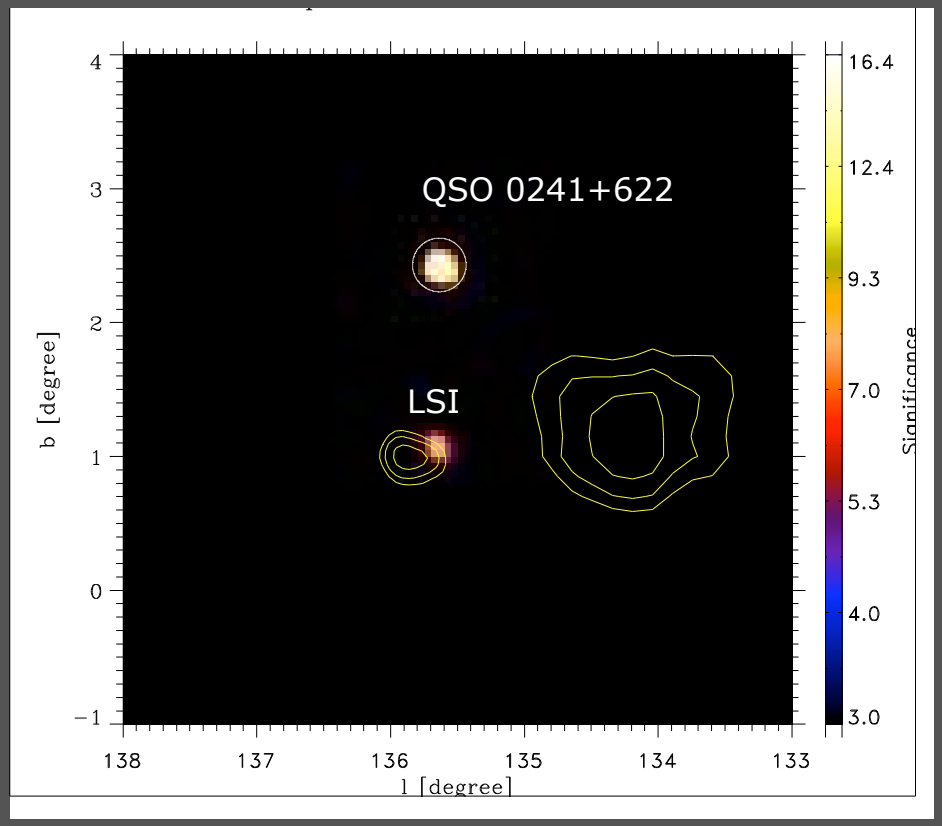
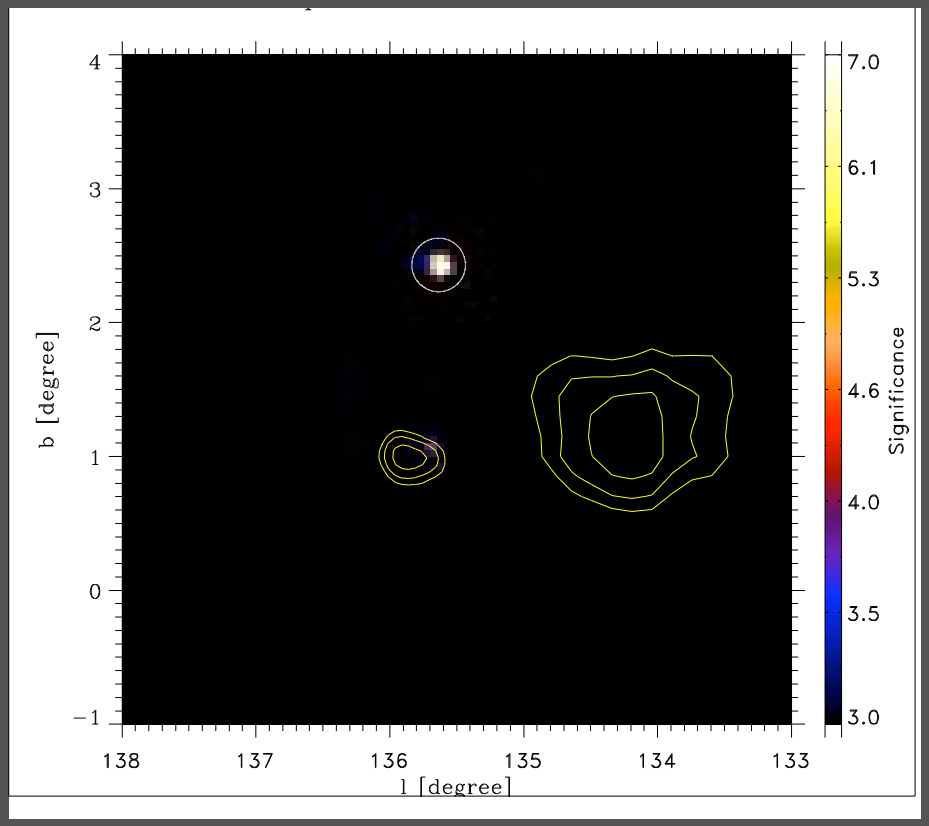
INTEGRAL / IBIS-ISGRI

20 – 45 keV



45 – 95 keV



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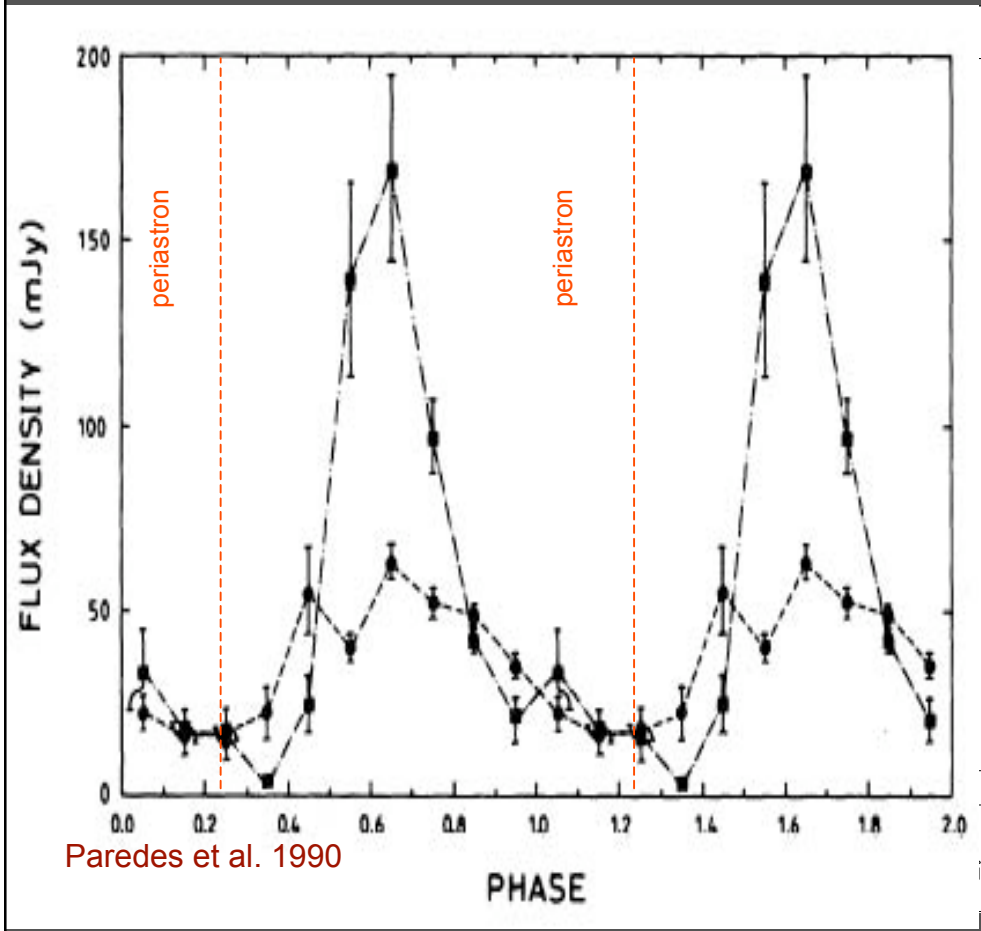
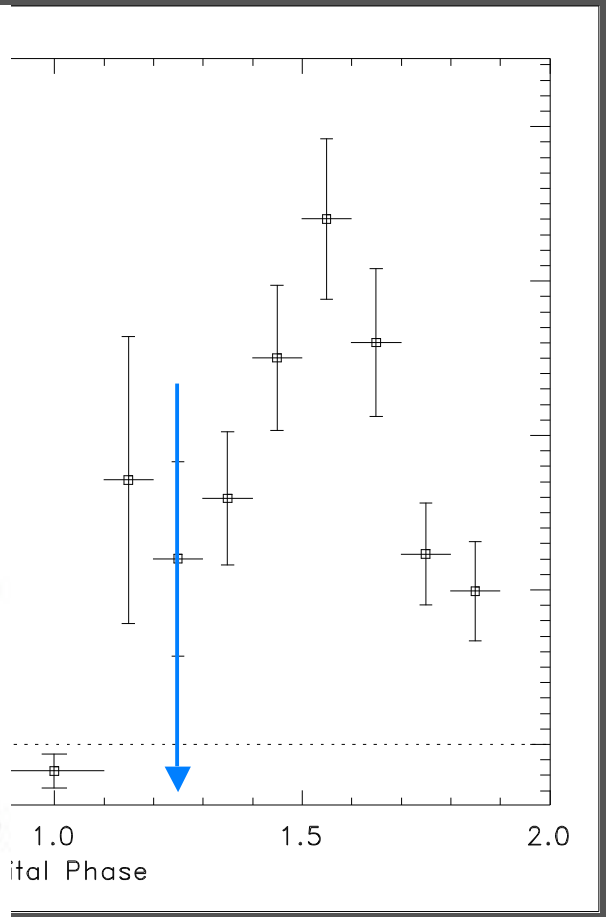
INTEGRAL / IBIS: LS I +61 303 flux vs orbital phase

March 2003 – July 2006

20 – 60 keV



Paredes et al. 1990



Radio outbursts at phases 0.5-0.8;

Periastron Passage at ~0.23

4-year modulation in intensity and peak position

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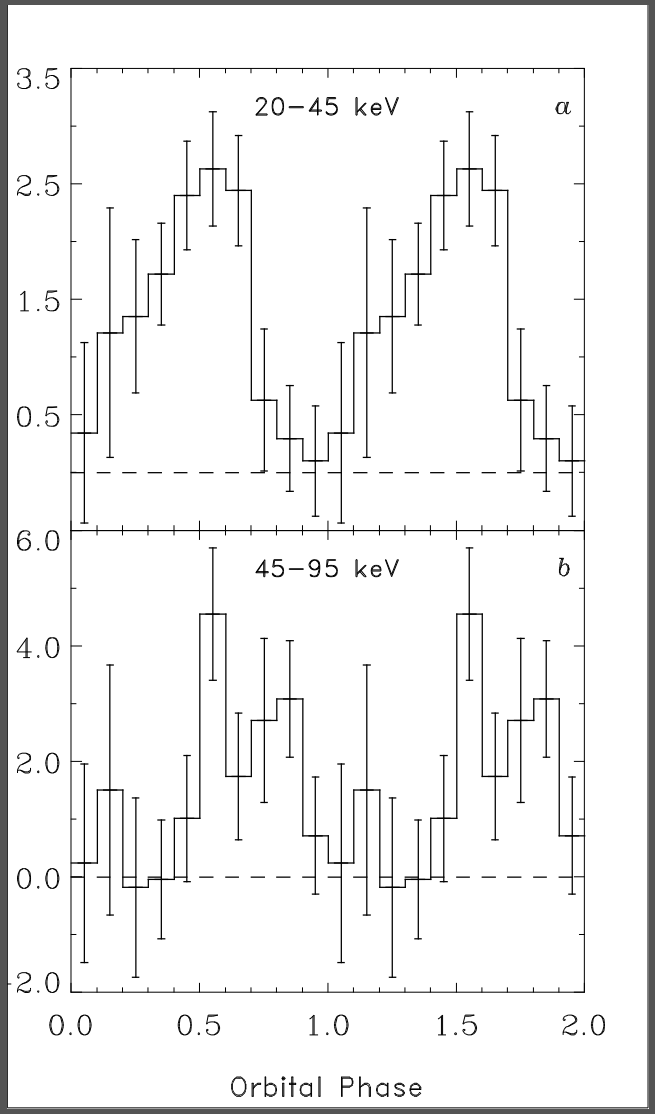
INTEGRAL / IBIS: LS I +61 303 flux vs orbital phase

March 2003 – July 2006

20 – 45 keV

45 – 95 keV



Suggestion for spectral hardening over phases 0.3–0.9

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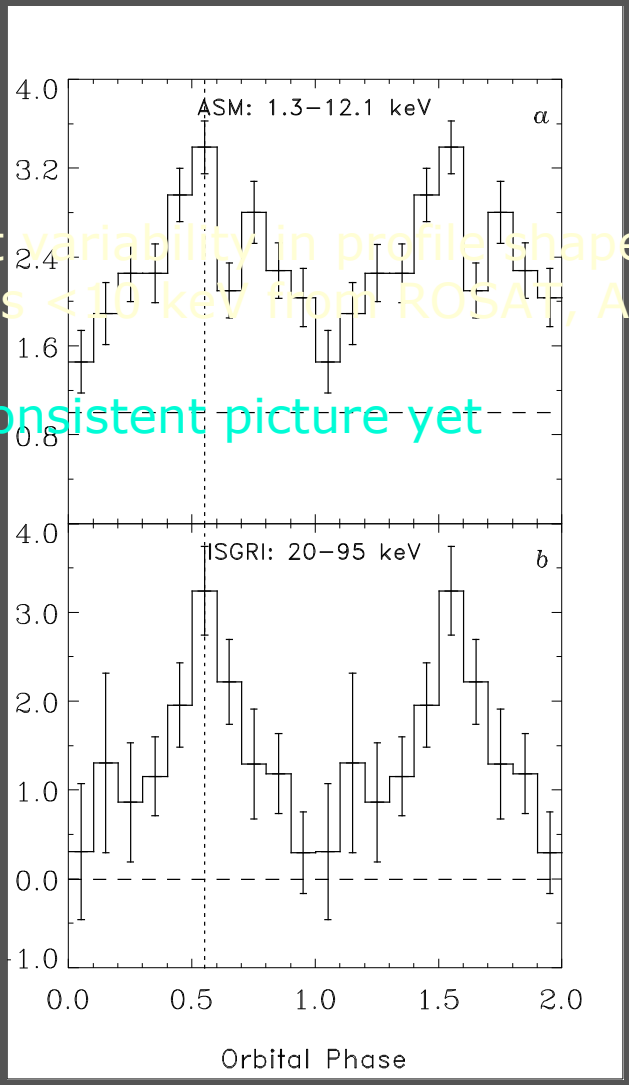
Orbital profiles hard X-rays vs soft X-rays

INTEGRAL / IBIS 20 – 95 keV vs **RXTE / ASM** 1.3 – 12.1 keV



Apparent variability in profiles shapes and intensities for X-rays < 10 keV from ROSAT, ASCA, RXTE, XMM

=> No consistent picture yet

Time-averaged profiles from March 2003 for both instruments

Alignement soft and hard X-rays

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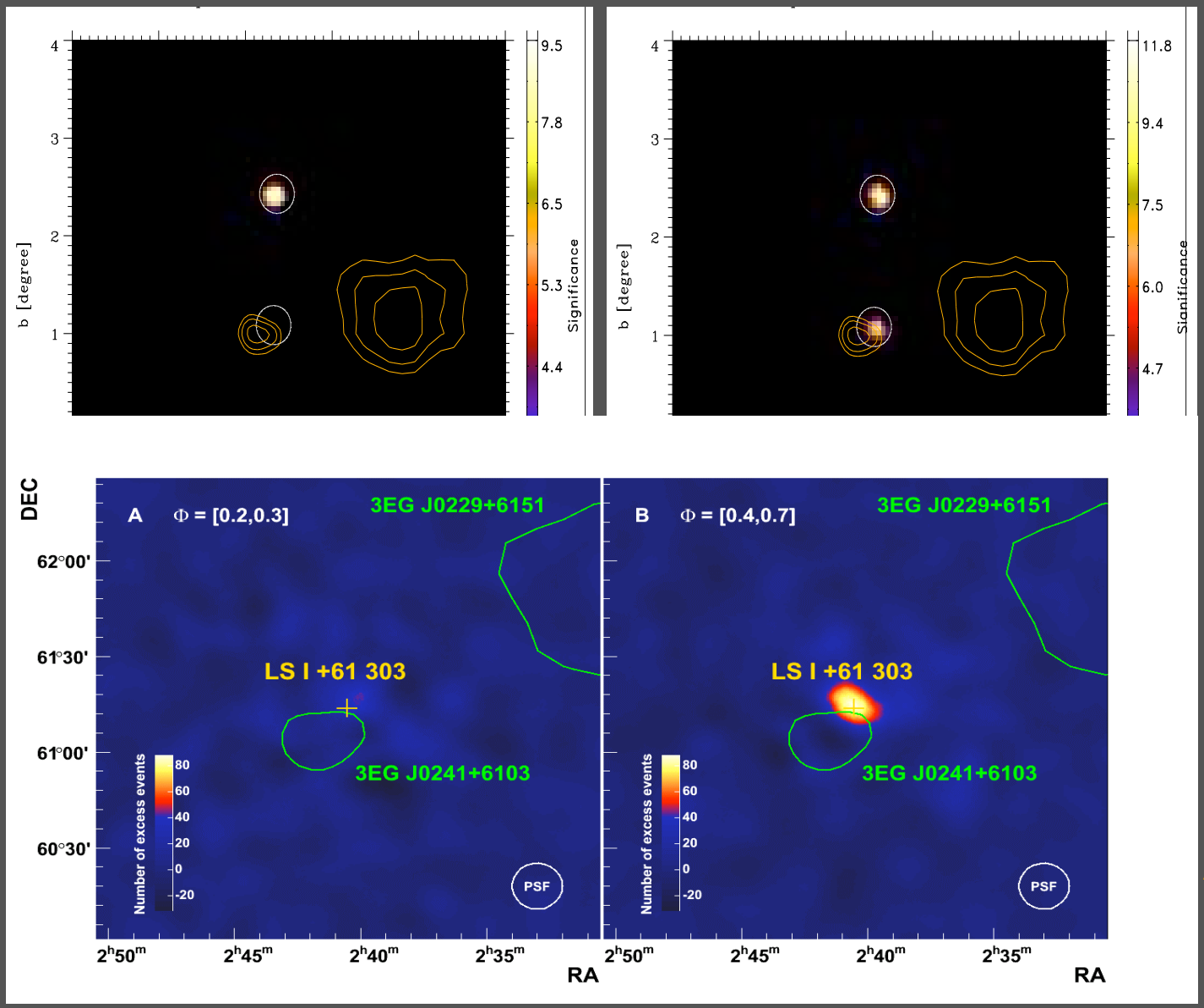
LSI +61 303, 20 – 95 keV:

"OFF" (phase 0.8 – 1.3) "ON" (phase 0.3 – 0.8)

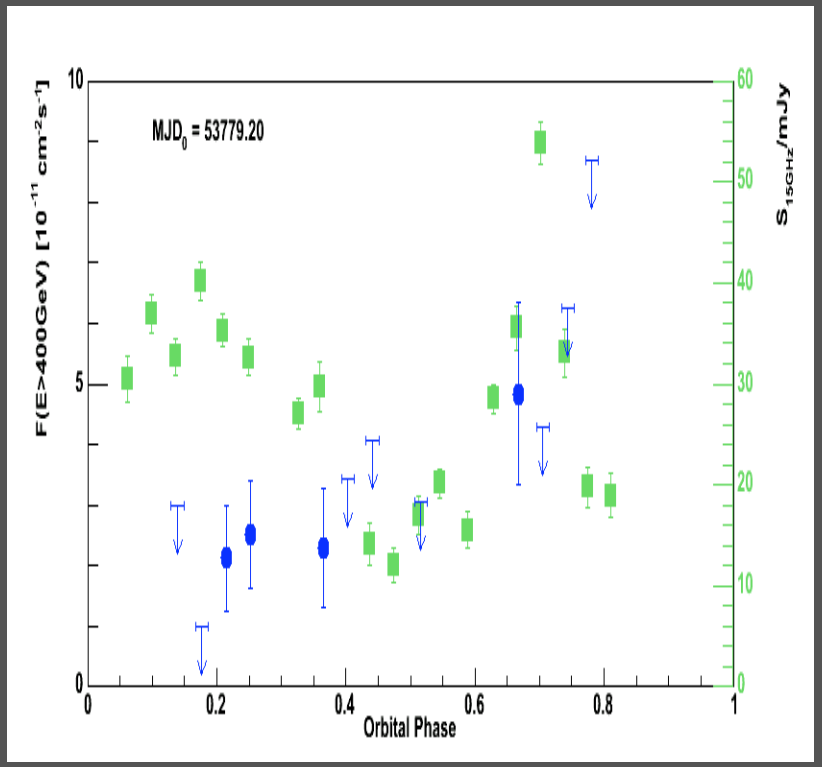


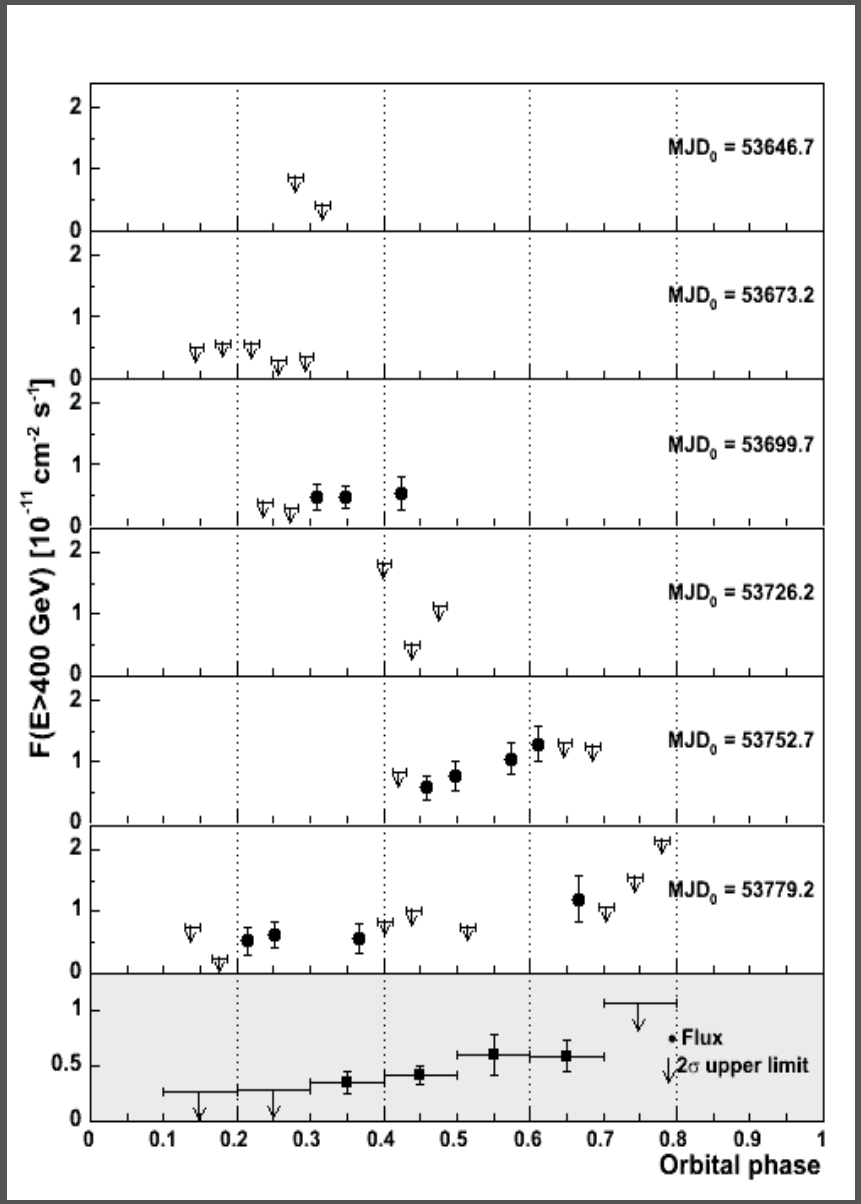
MAGIC
Albert et al. 2006

Periastron passage

MAGIC: TeV flux variability

Albert et al. 2006,
presentation Cortina





contemporaneous radio (Ryle, 15GHz)
v.s. TeV γ-rays (MAGIC)

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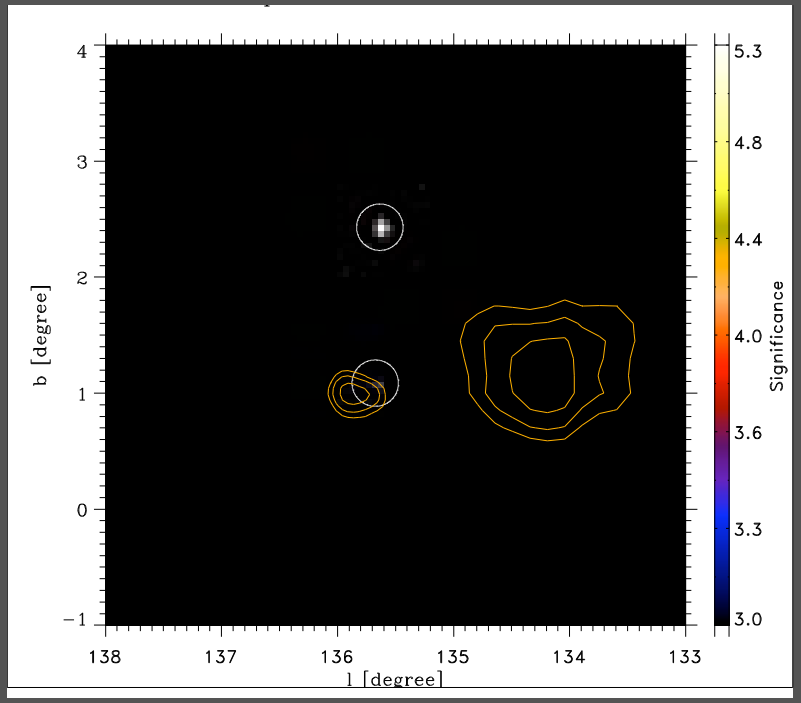
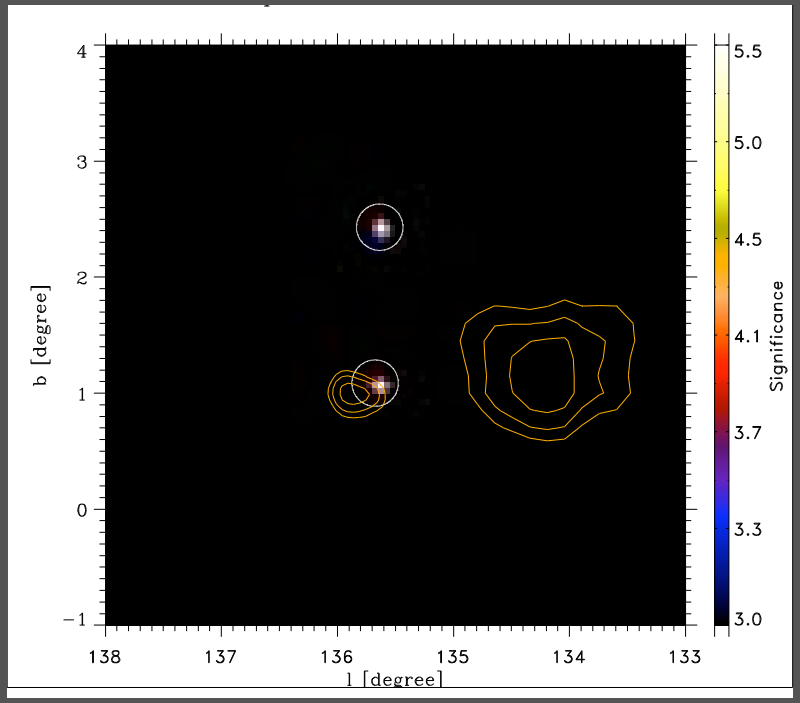
LSI +61 303, "ON" (phase 0.3 – 0.8)

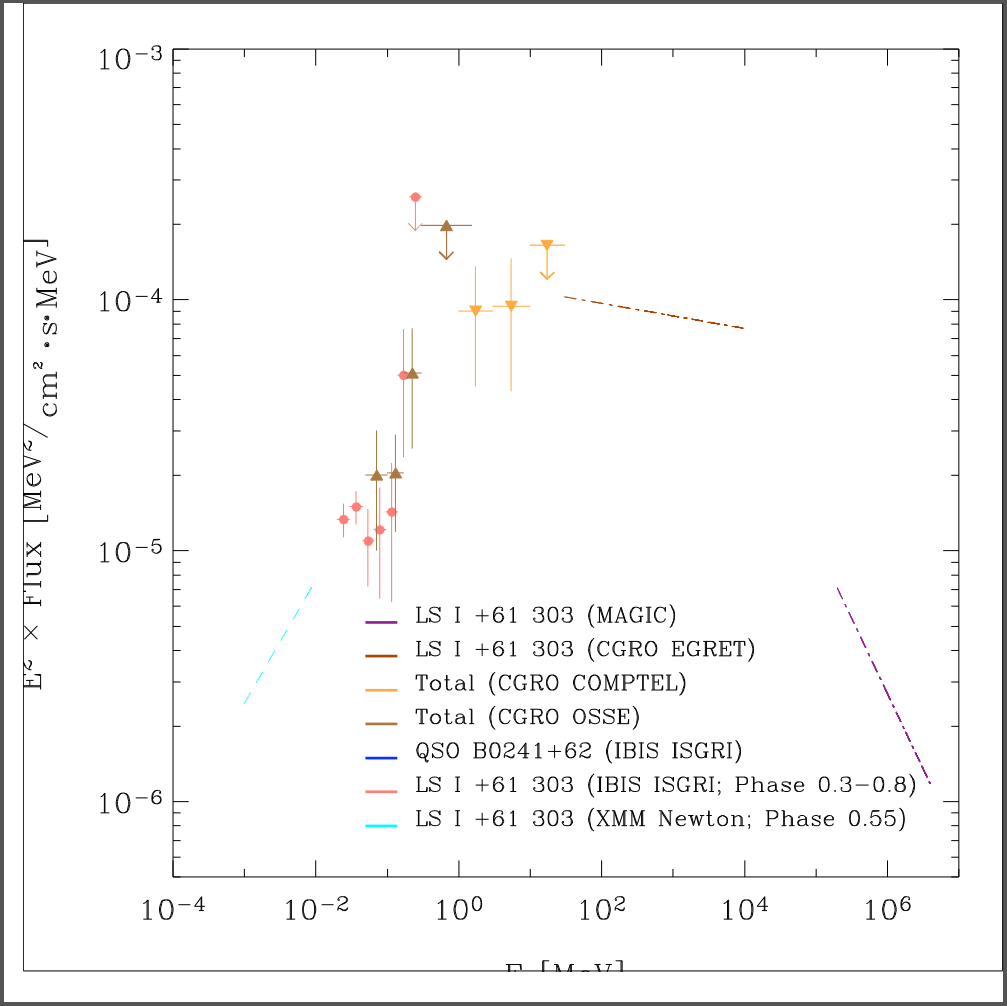
45 – 95 keV



45 – 205 keV



LS I +61 303 High-Energy SED



IBIS power-law spectral index Γ
for orbital phase 0.3 – 0.8, "ON"

LSI +61 303 Γ = -1.70 ± 0.20

Chernyakova et al. 2006: **No** cut-off or spectral break for 10–60 keV
=> No accretion disk

Spectral feature around 50 keV?

Note:
XMM-Newton, IBIS and MAGIC fluxes for "ON" phases

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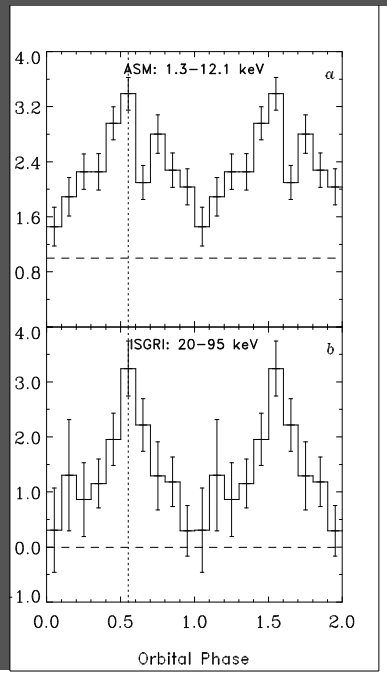
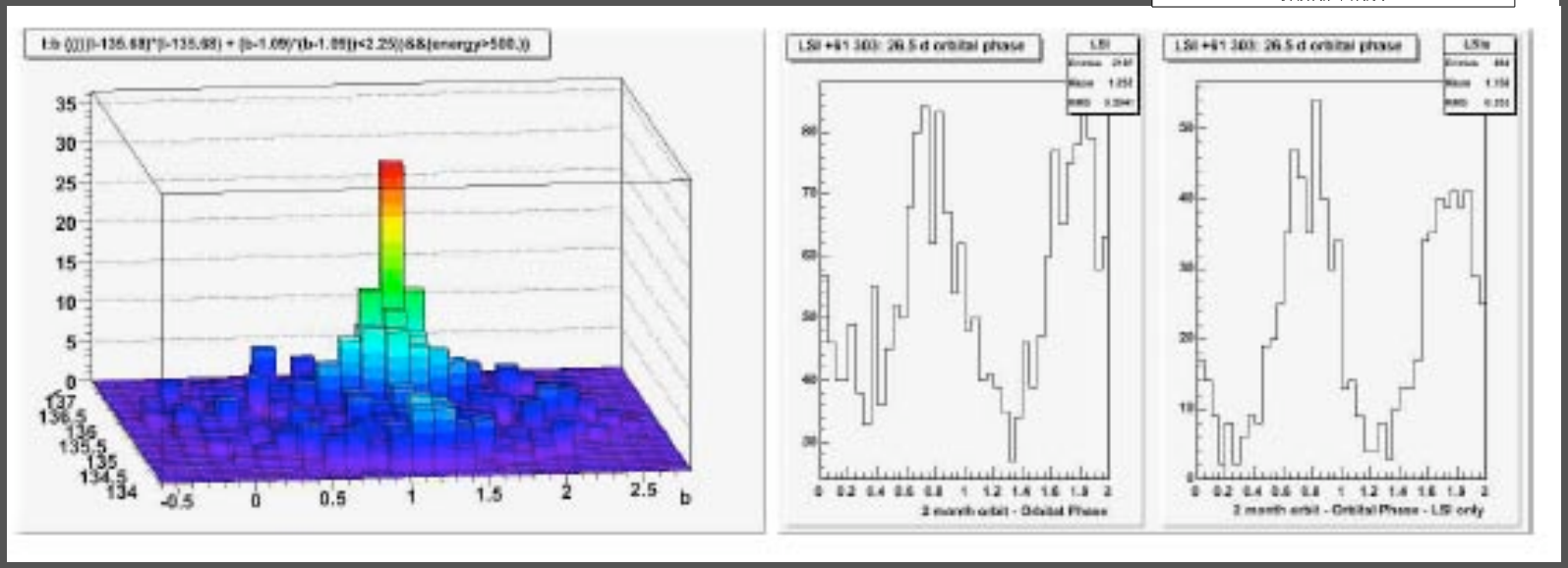
GLAST simulation for LS I 61 303:
55 days observation (DC2)

Multiwavelengths campaign !



ASM/RXTE
X-rays:
1.5–12.1 keV

INTEGRAL
hard X-rays:
20-95 keV



GLAST
γ-rays:
E > 100 MeV

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Summary

- **INTEGRAL / IBIS** detected LS I + 61 303 up to energies ~100 keV (total) and ~200 keV (pulse)
- Orbital modulation with maximum at phase ~0.55, consistent with one possible EGRET pulse, but not at periastron passage
- ASM soft X-ray profile aligned with INTEGRAL hard X-ray profile
- INTEGRAL maximum seems to precede that at TeV and radio
- Power-law spectrum with index 1.7 ± 0.2
- **Multiwavelengths campaign** required to further constrain the scenario with a relativistic wind from a young pulsar interacting with the wind from its companion.

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