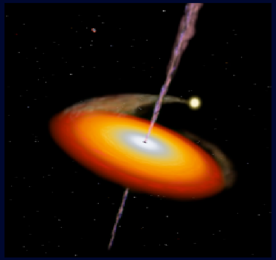
Binaries, microquasars and GLAST

Guillaume Dubus

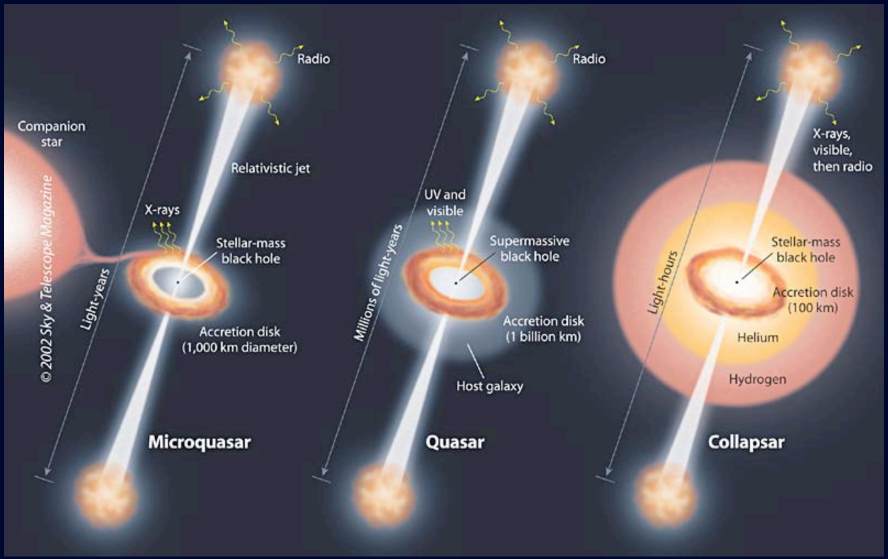
Laboratoire d'Astrophysique de Grenoble (France)

1st GLAST Symposium - Feb 6, 2007

(compact) binaries

- Prominent sources in the X-ray sky.
- Typically powered by accretion
  (more rarely: pulsar spindown).
- Some power emitted non-thermally.
- Many similarities with AGN: microquasars.

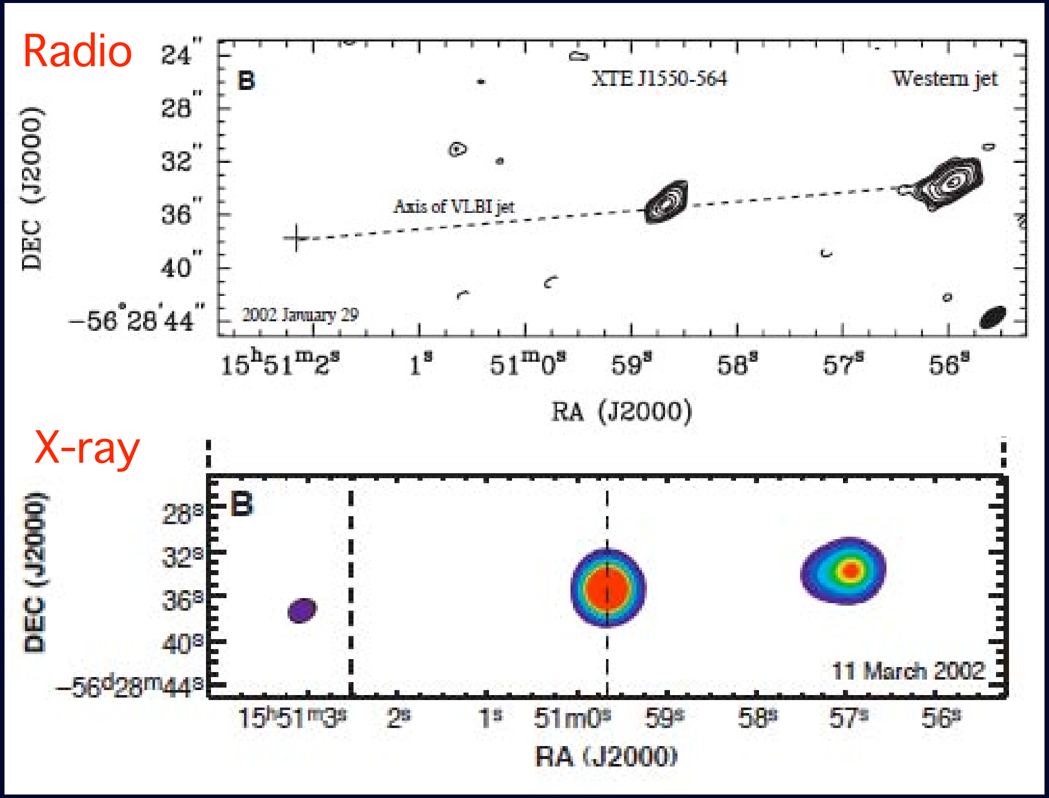
Do binaries emit
high energy γ-rays ?

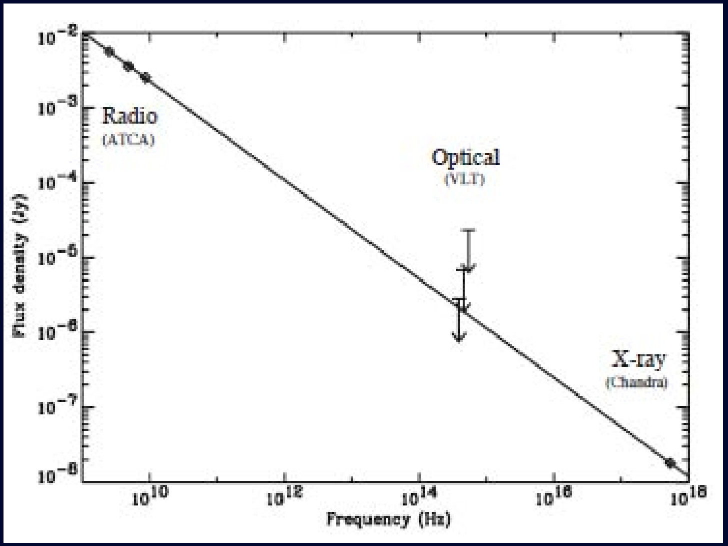


F. Mirabel

Radio and X-ray relativistic jets

Corbel et al. 2002





Radio to X-ray spectrum.

Radio and X-ray emission from jet at parsec distances.

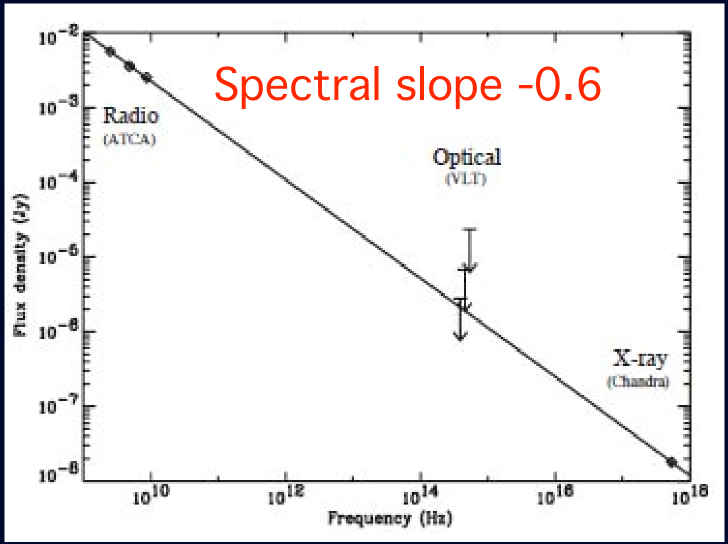
Evidence for non-thermal population of particles

Radio and X-ray relativistic jets

Gamma-ray emission ?

- Synchrotron could reach 100 MeV if acceleration very efficient but flux too low ($<10^{-12}$ erg/s/cm^2).

- Inverse Compton is also too low.



Synchrotron from e^-e^+

$B_{eq} \approx 0.3$ mG
CMB $\approx 4\ 10^{-13}$ erg/cm^3

$L_{ic}/L_{sync} = u_{ph}/u_B \approx 10^{-4}\ B_{eq}^{-2}$

same for SSC using X-ray flux $\nu F_\nu \approx 3\ 10^{-13}$ erg/cm^2/s and size

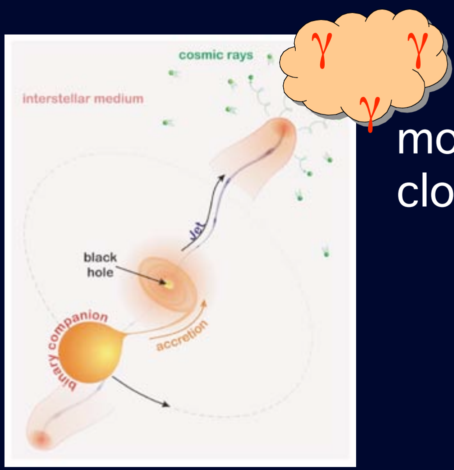
too faint for GLAST

Jet - ISM interaction

Jet-ISM interaction may lead to CR acceleration and γ-rays

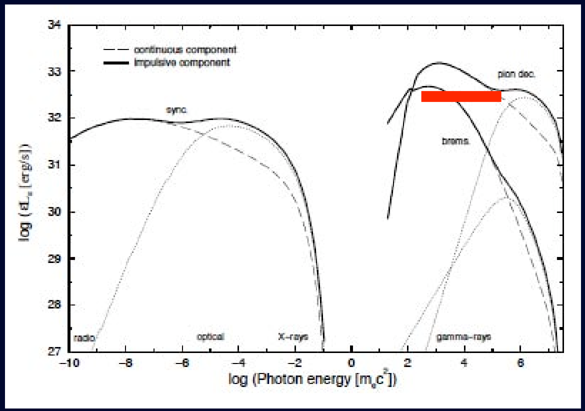
Jet may carry large(st) fraction of accretion power.

Heinz & Sunyaev 2003

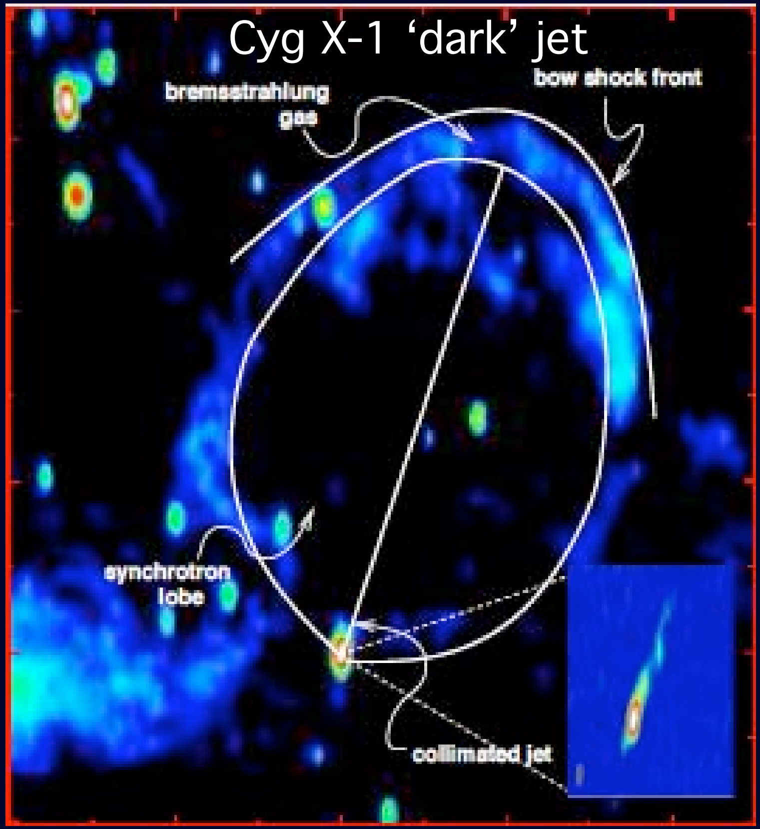


molecular cloud

Bosch-Ramon et al. 2005



GLAST
1 yr @ 1kpc

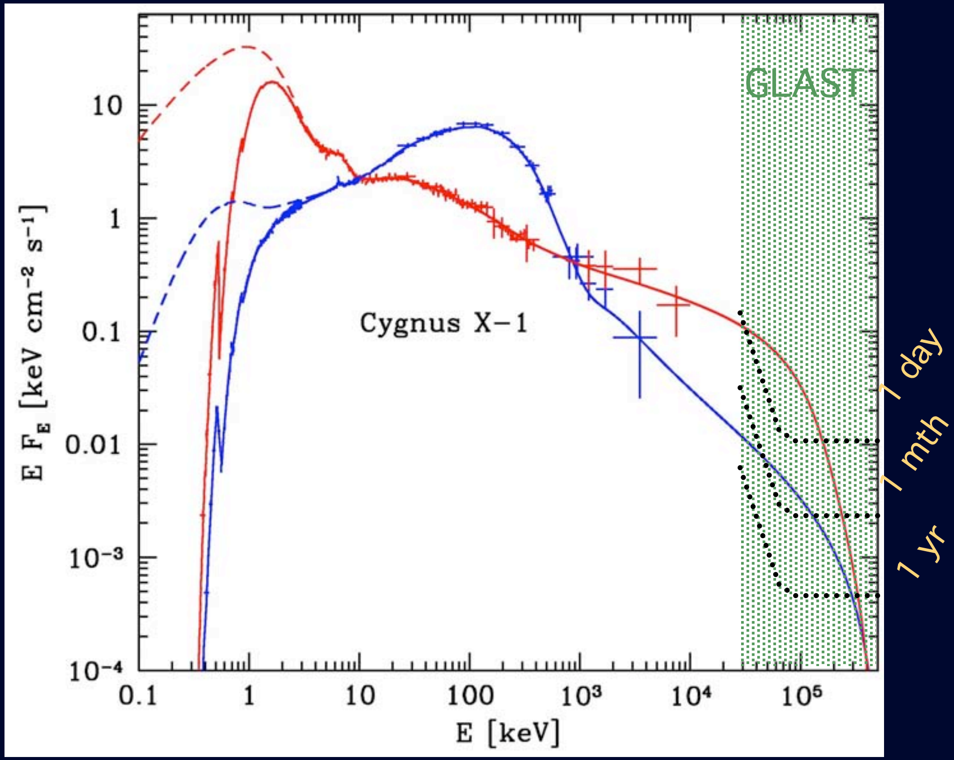


Gallo et al. 2005

γ-ray-ISM emission depends on jet composition, power, duty cycle, distance...

Closer to black hole

McConnell et al. 2002



- Evidence for emission above an MeV in some binaries (soft tail with no cutoff).

Grove et al. 1998

- Thermal/non-thermal pair plasma cutoff constrains plasma compacity.

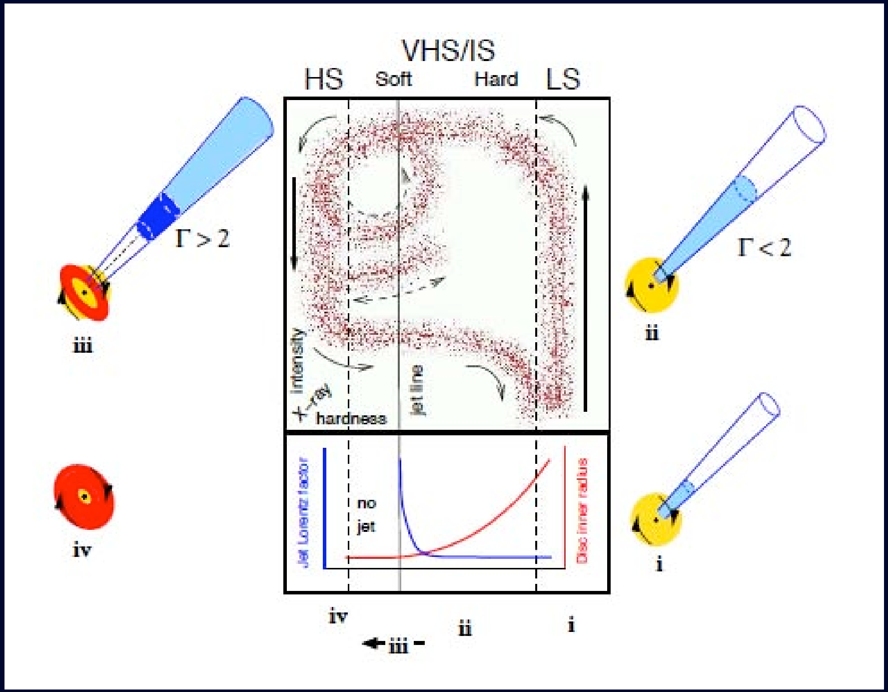
Zdziarski & Gierlinski 2004

GLAST should detect emission from Cyg X-1 in its high state and in its low-state.

State changes and ejection

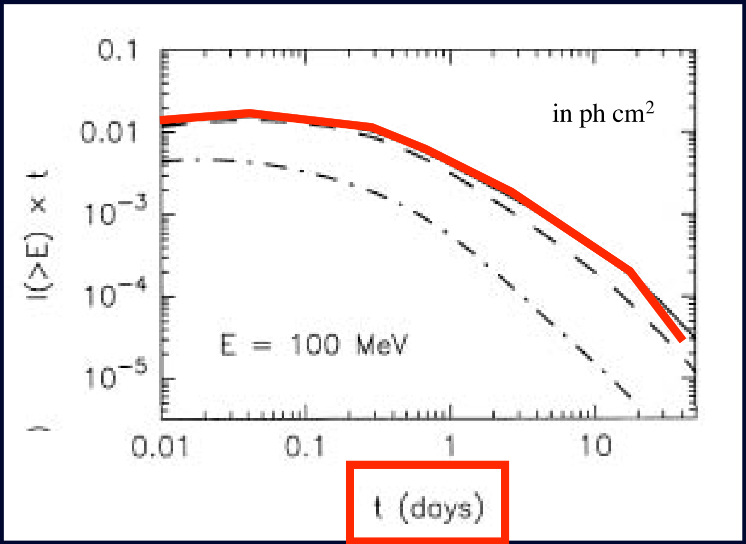
Conjecture: spectral state change are associated with major relativistic ejections (Fender & collaborators).

Fender et al. 2004



GLAST monitoring of HE γ-ray emission associated with radio ejections.

HE fluence during major radio ejection in GRS 1915



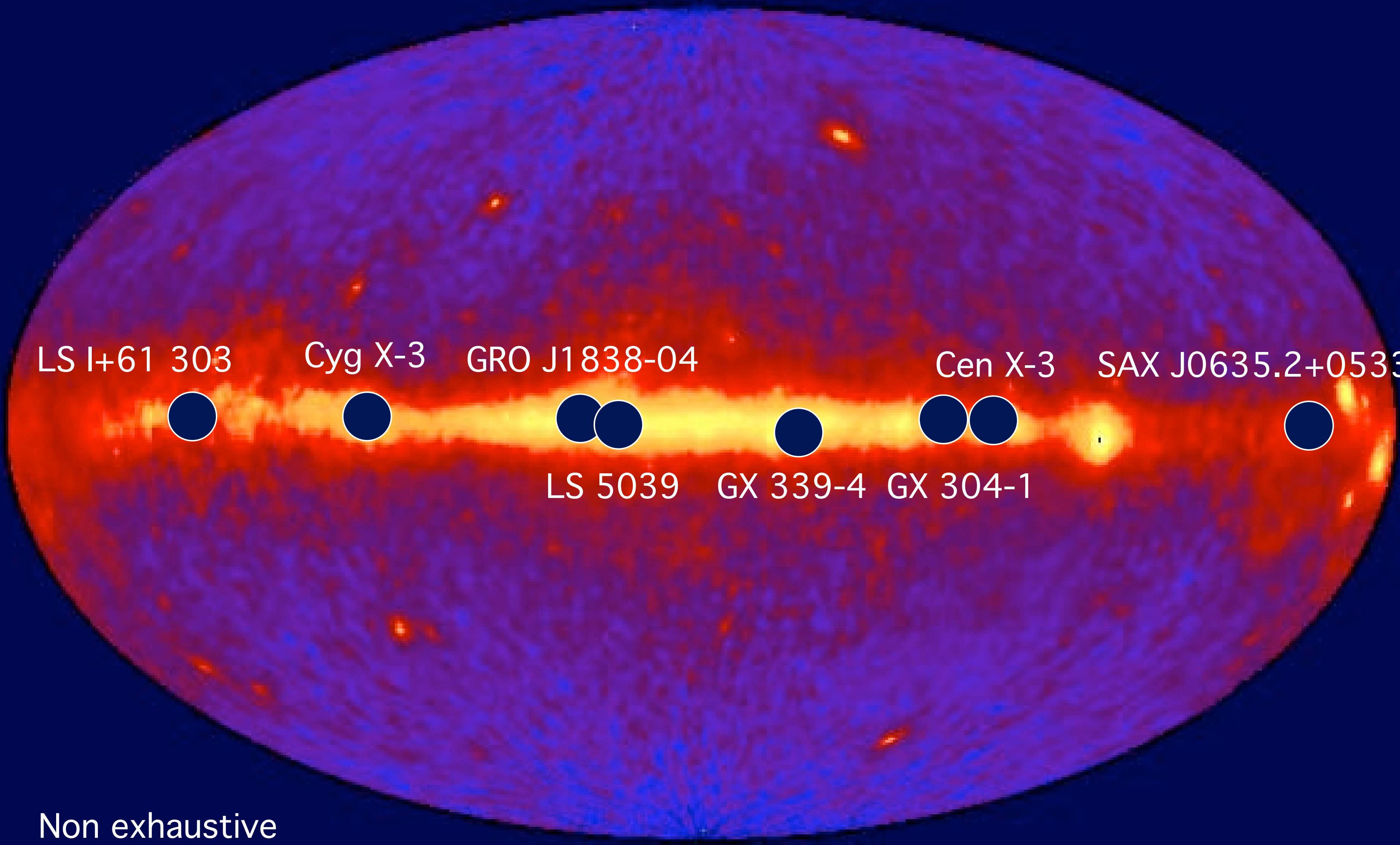
Aharonian & Atoyan 99

Note: if jet is e-/e+ there *has* to be γ-ray emission at some point (if only at a few MeV).

Good prospects, both observationally and theoretically motivated, for HE gamma-ray emission from compact, accreting binaries.

What’s the status ?

EGRET (> 100 MeV) binary *candidates*

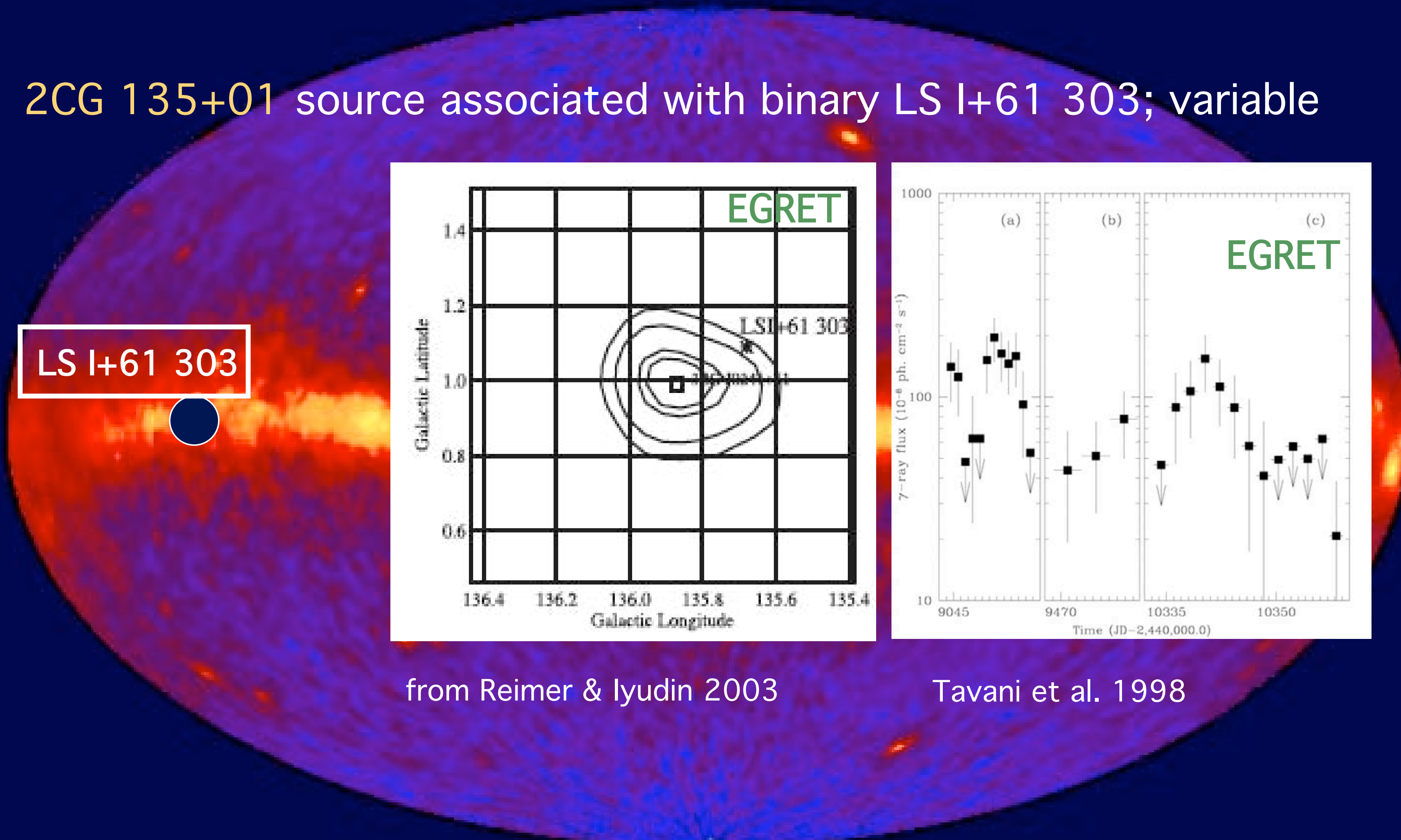


Non exhaustive

References: Gregory & Taylor 1978 Mori et al. 1997 Tavani et al. 1997, Nolan et al. 2003, Paredes et al. 2002, Reimer & Iyudin 2003, Vestrand 1997, Kaaret et al. 1999

EGRET (> 100 MeV) binary *candidates*

2CG 135+01 source associated with binary LS I+61 303; variable

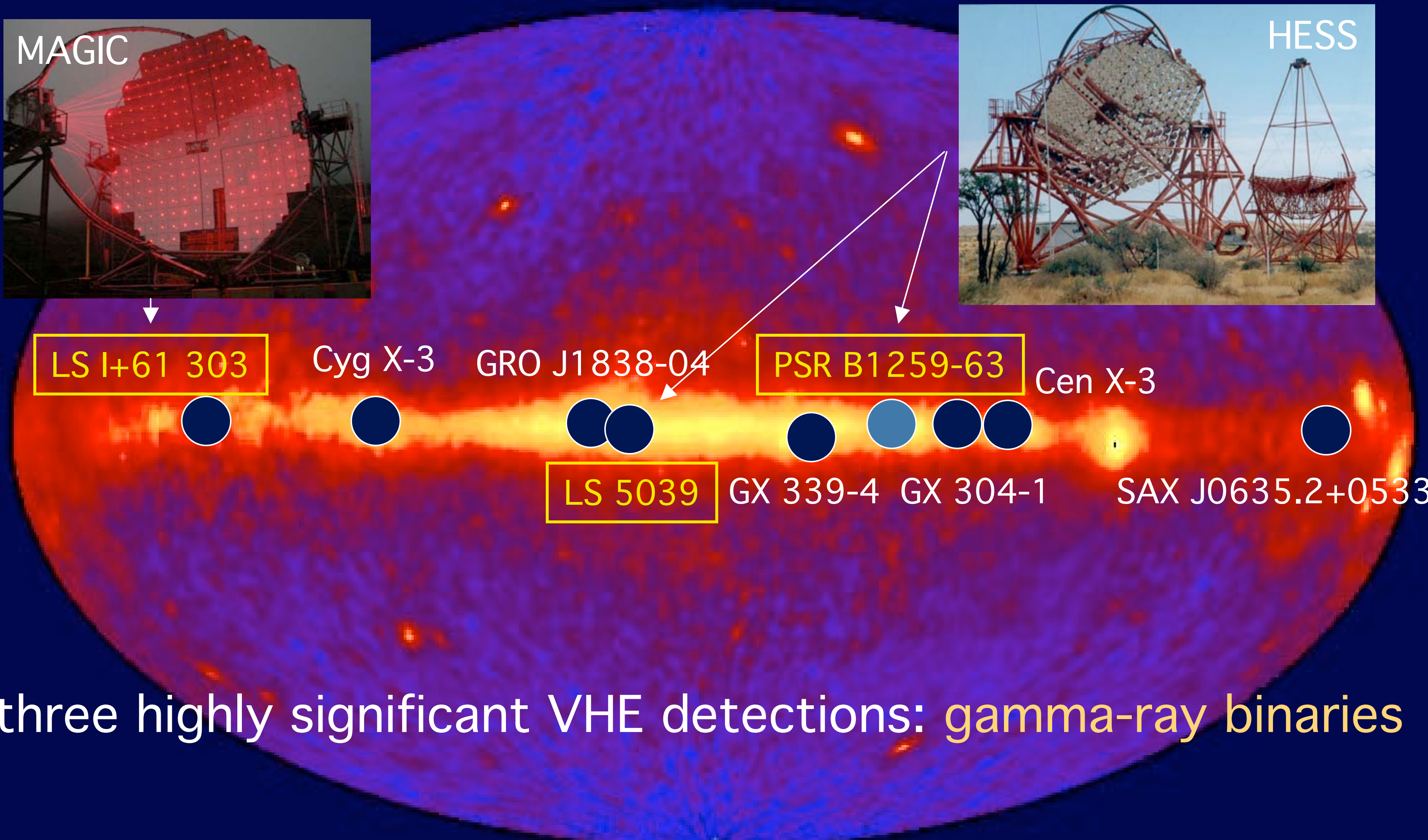


from Reimer & Iyudin 2003

Tavani et al. 1998

source confusion, no telltale variability: GLAST will help

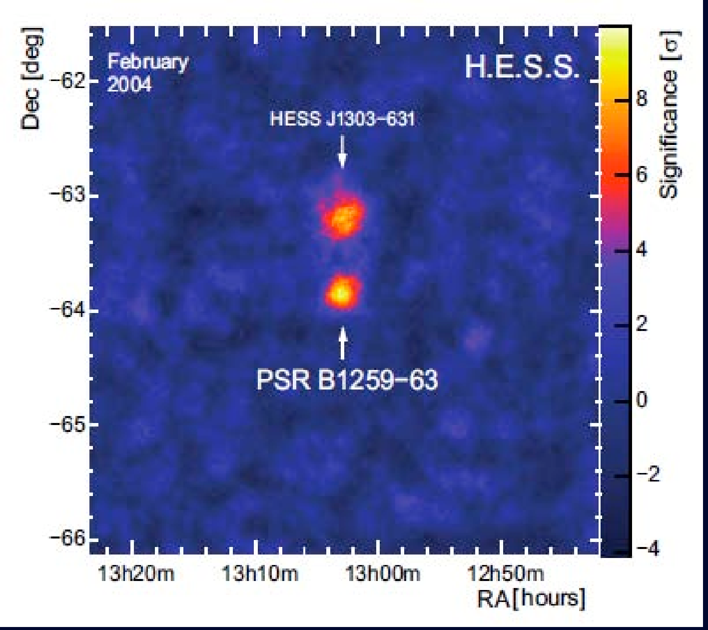
Ground-based Cherenkov arrays (>100 GeV)



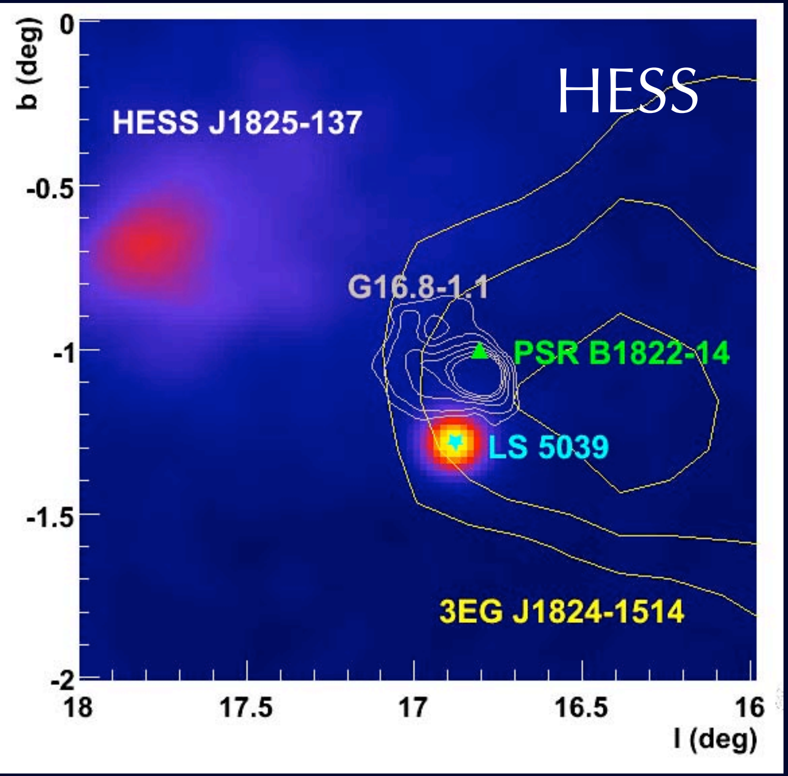
three highly significant VHE detections: gamma-ray binaries

+ a couple of superpositions of HESS GP sources with IGR sources, Aharonian et al. 2005 and WR20a (?) in Westerlund see O. Reimer talk)

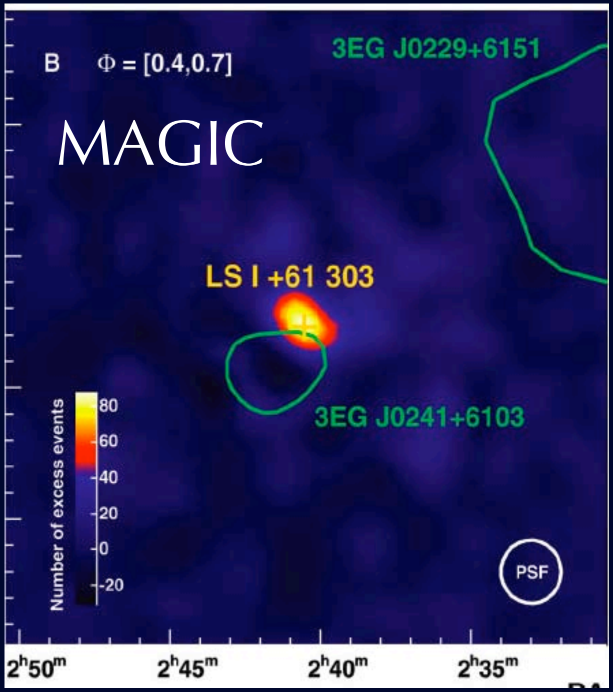
Sub-arcmin positions + orbital VHE variability = Binaries *are* sources of HE/VHE γ-rays



Aharonian et al. 2005, A&A, 442, 1

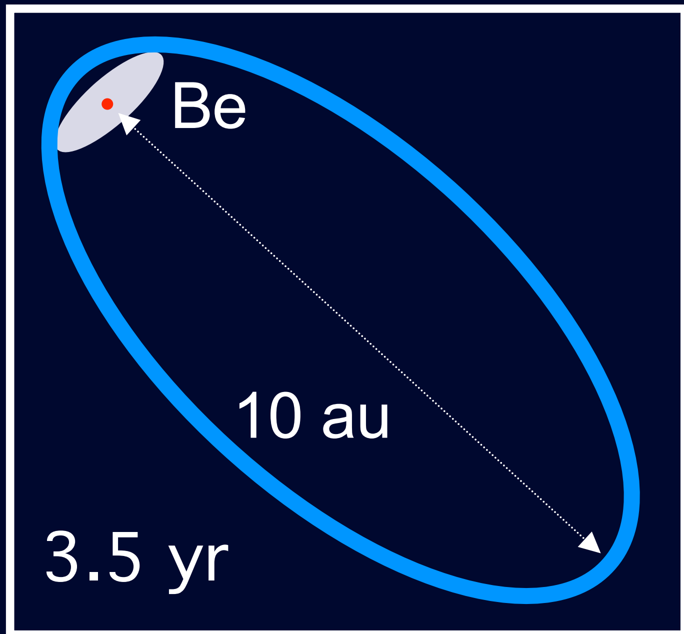


Aharonian et al., 2005, Science, 309, 746

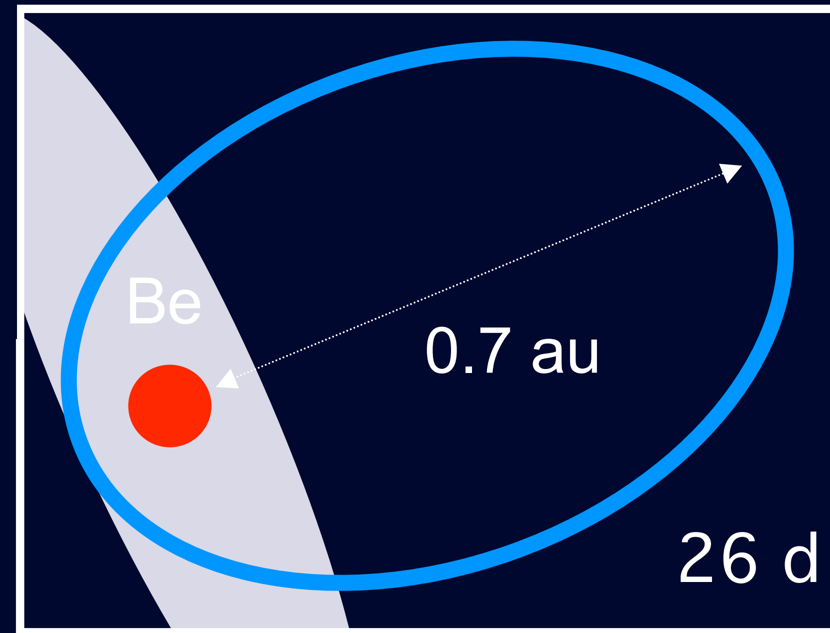


Albert et al., 2006, Science

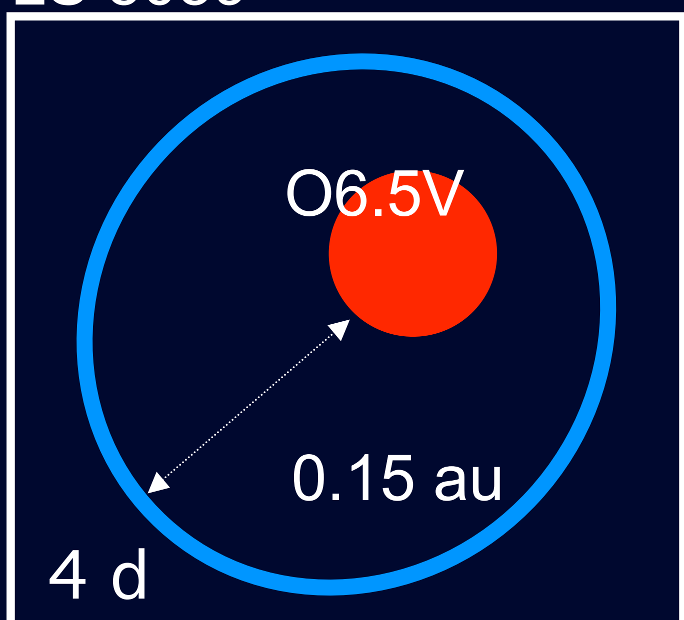
PSR B1259-63



LS I +61 303



LS 5039

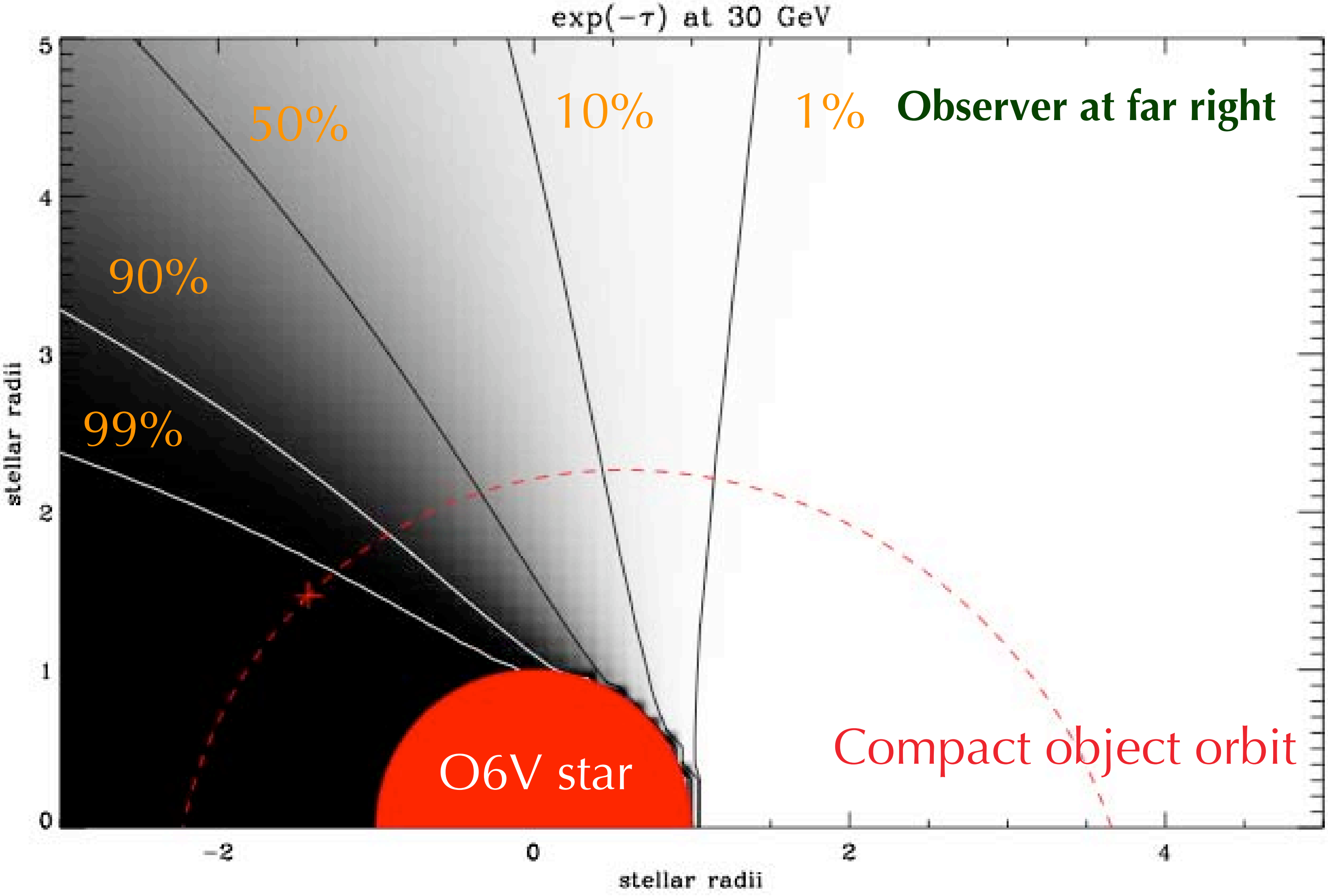


Massive star: instrumental to γ-ray emission?

Large stellar photon density in UV: VHE pair production

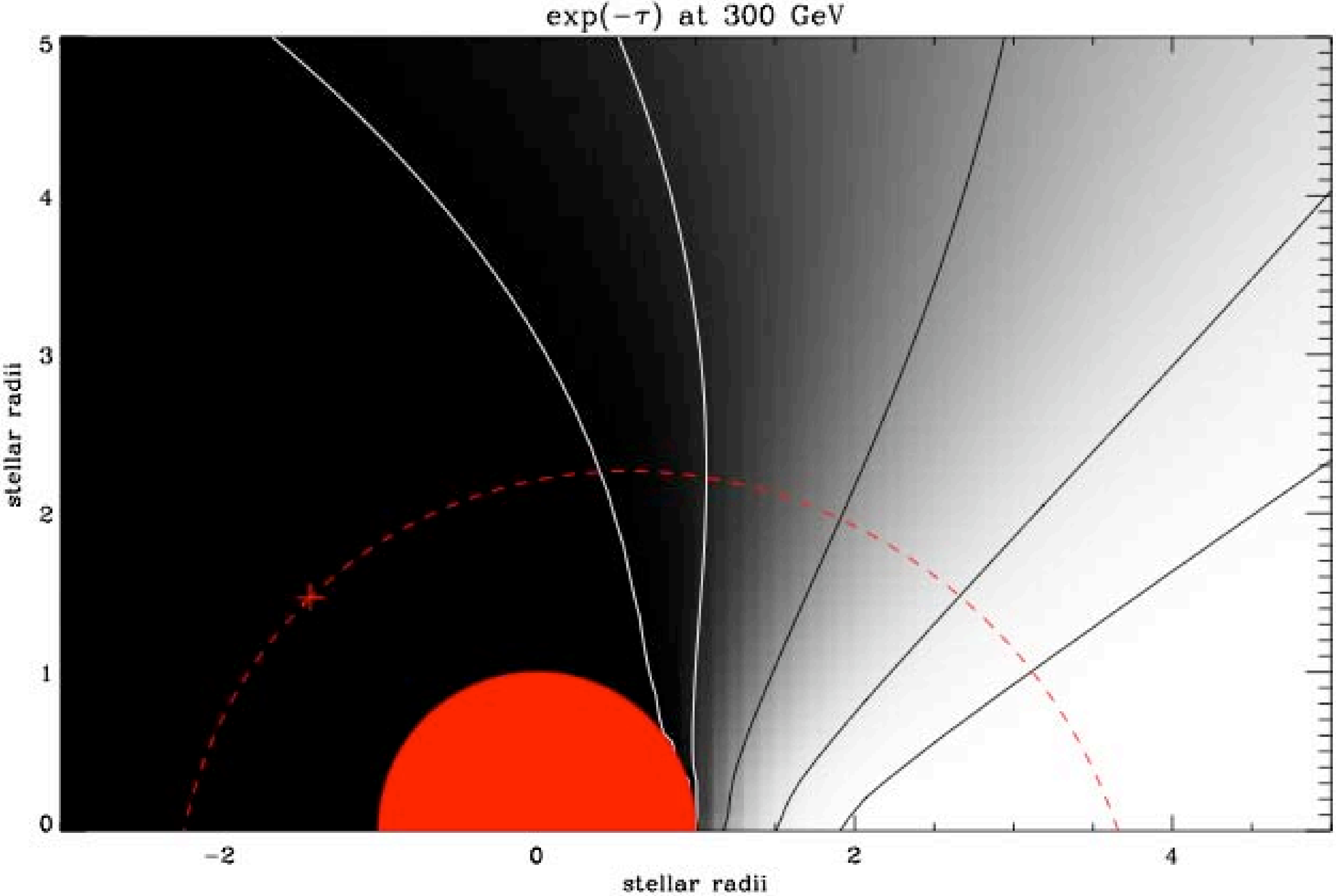
Bottcher & Dermer 2005, GD 2006, Bednarek 2006

Fraction of absorbed 30 GeV flux



GD 2006

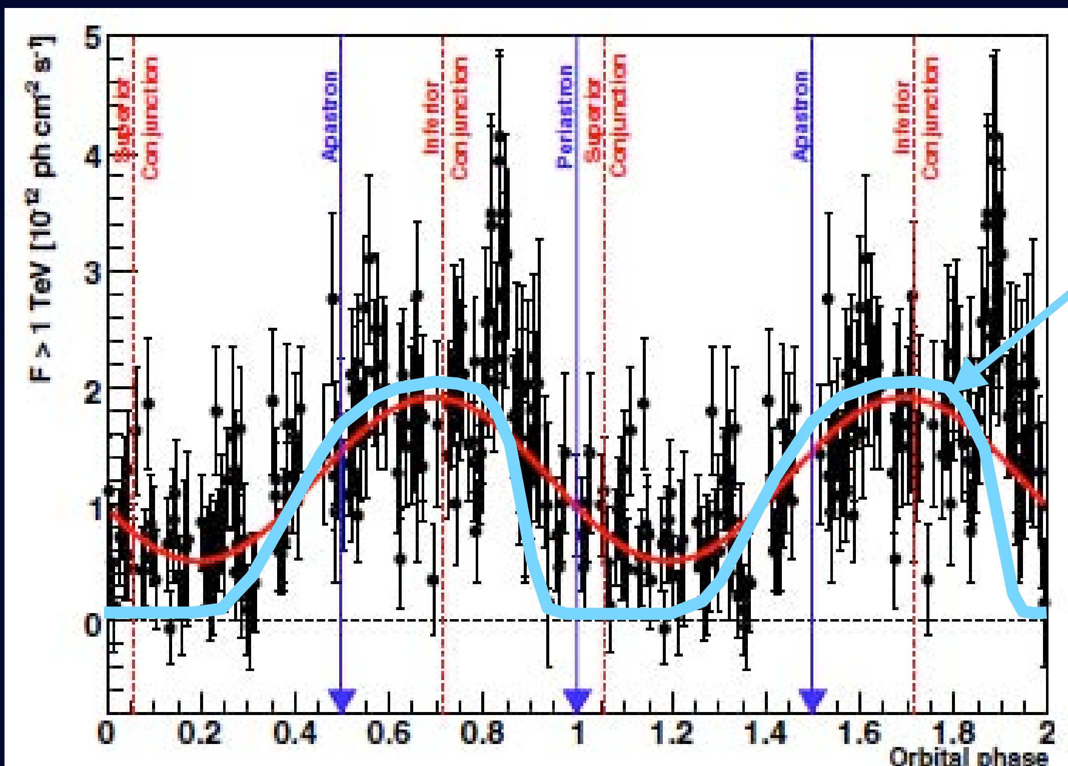
Fraction of absorbed 300 GeV flux



GD 2006

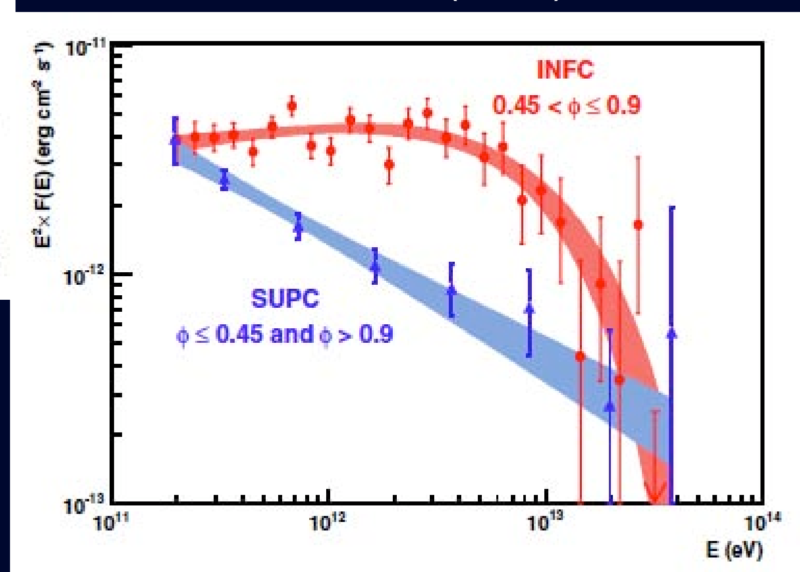
Orbital modulation of VHE flux in LS 5039

Exludes emission >1 AU from companion



Pure absorption due to pair production.

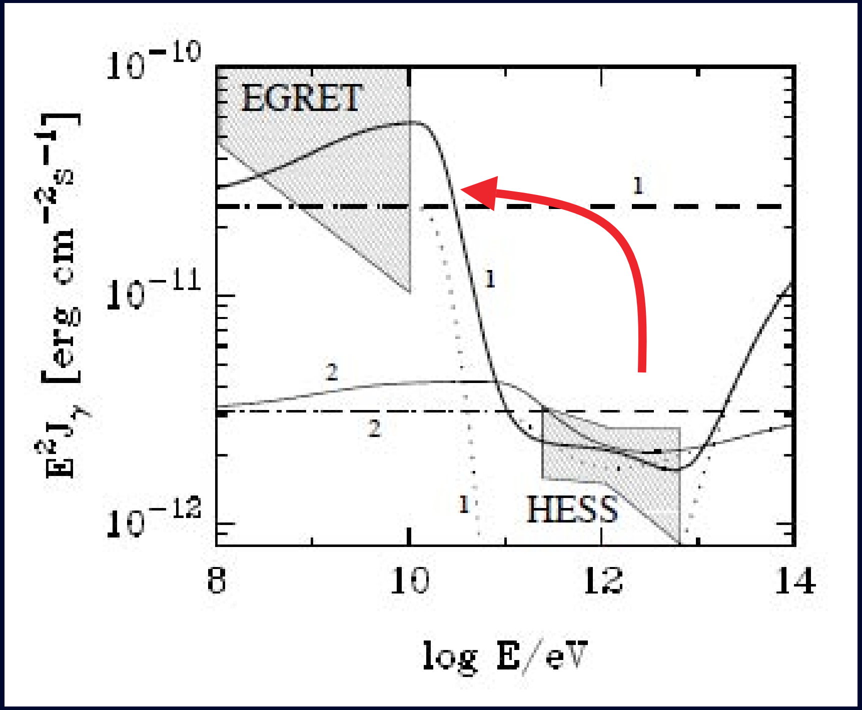
Aharonian et al. (HESS) 2006



spectrum and detection at all phases: *other effects ?*

Pair cascade can redistribute the VHE energy in the GLAST range (if magnetic field < 10 G)

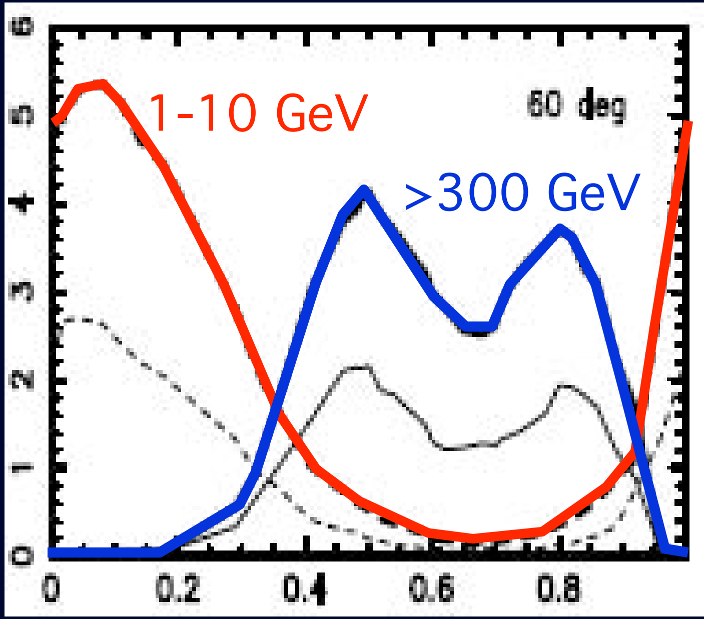
Aharonian et al. 2006



LS 5039 spectrum

Expect an anti-correlation of HE and VHE modulations

[need 1 yr of data, R. Dubois (Como MQ workshop)]



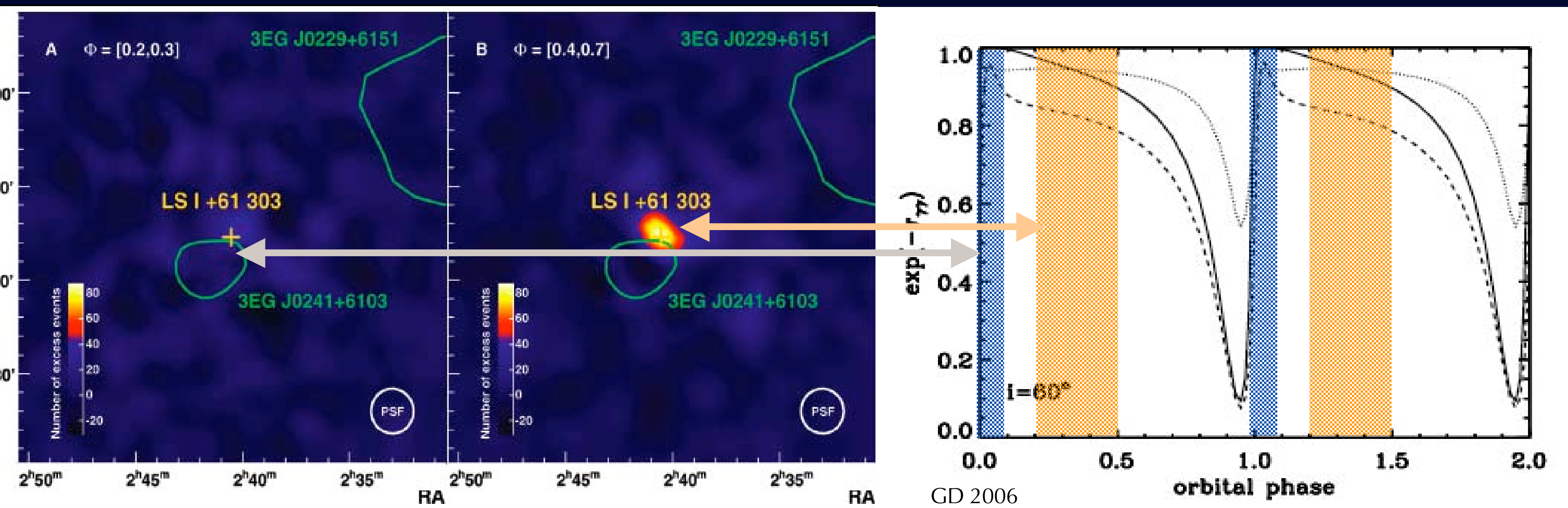
LS 5039 lightcurve with cascades

Bednarek 2006

TeV variation in LS I+61°303

Albert et al. (MAGIC) 2006

Expected modulation due to absorption



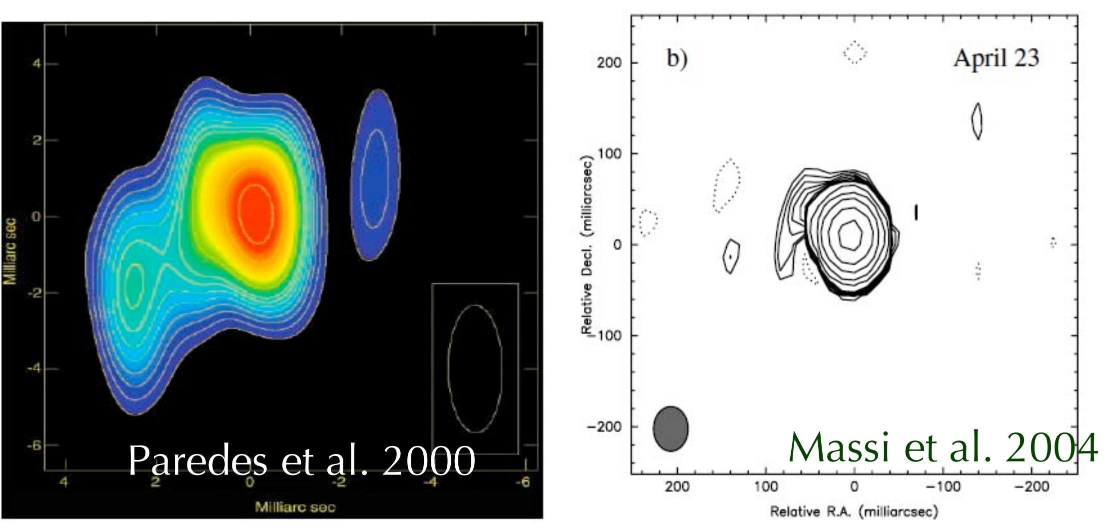
[Note: 100% modulation in GLAST band would be seen in 60 days (R. Dubois)]

Max/min do not match + wide orbit so absorption moderate

intrinsic TeV flux variation ?

What powers these gamma-ray binaries ?

Resolved radio emission



Resolved radio emission in LS 5039 and LS I +61 303 interpreted as microquasar jet.

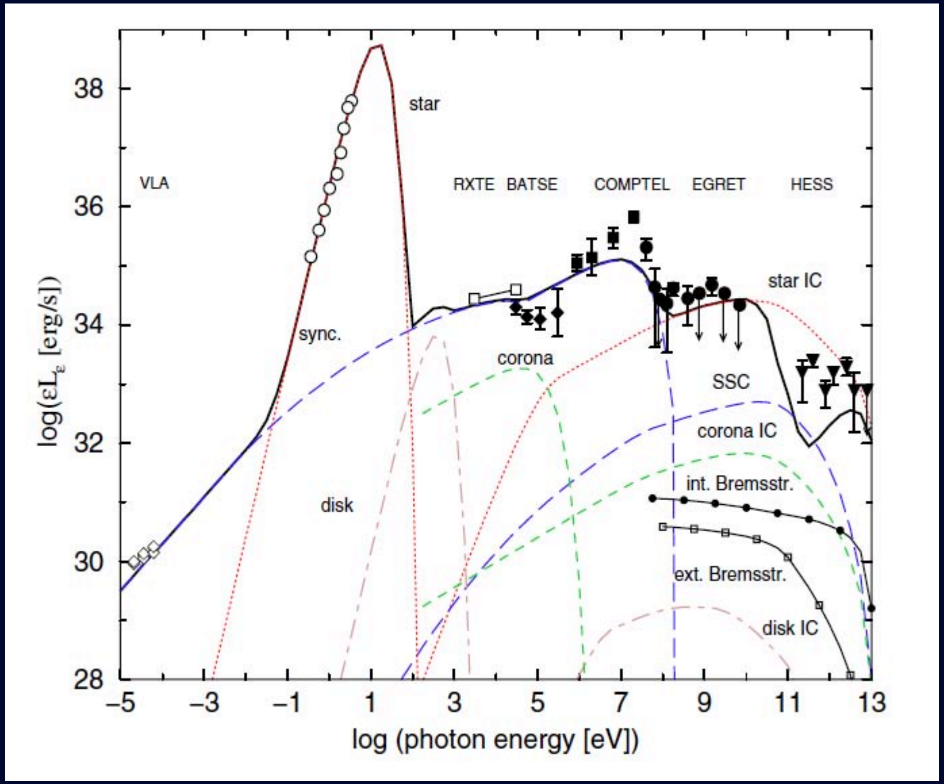
Confirmation of the long-held suspicion that small-scale analogues of AGN should also display VHE emission ?!

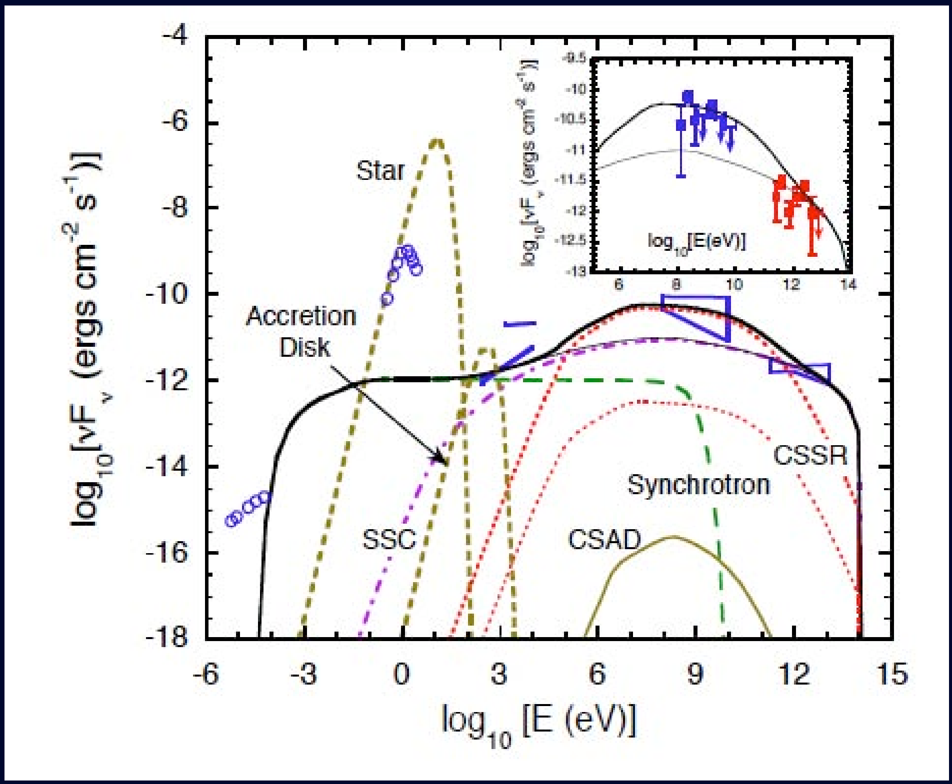
Jet models

LS 5039

Paredes et al. 2006

Dermer & Bottcher 2006



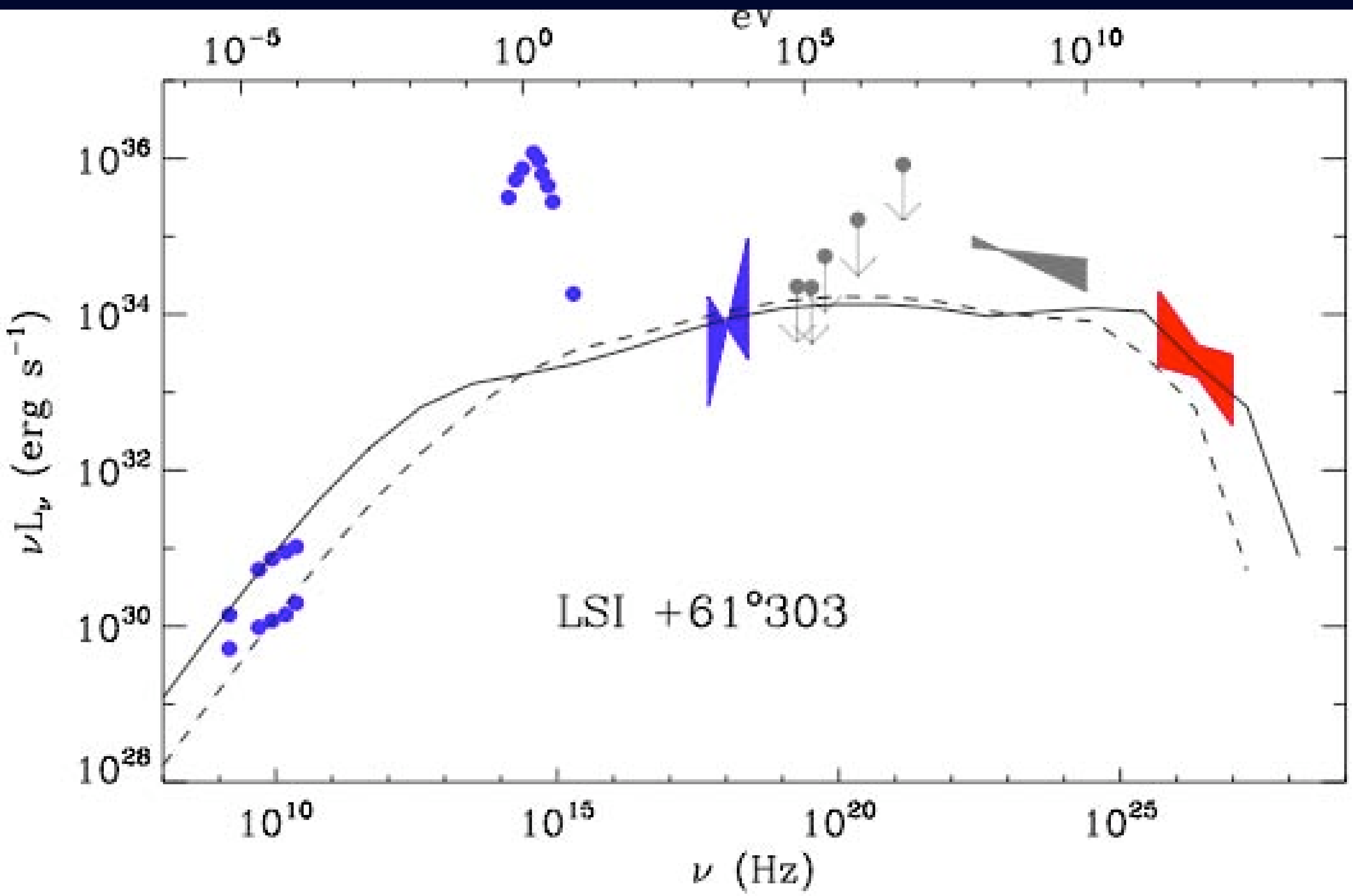


Similarities suggest a new class of source ?

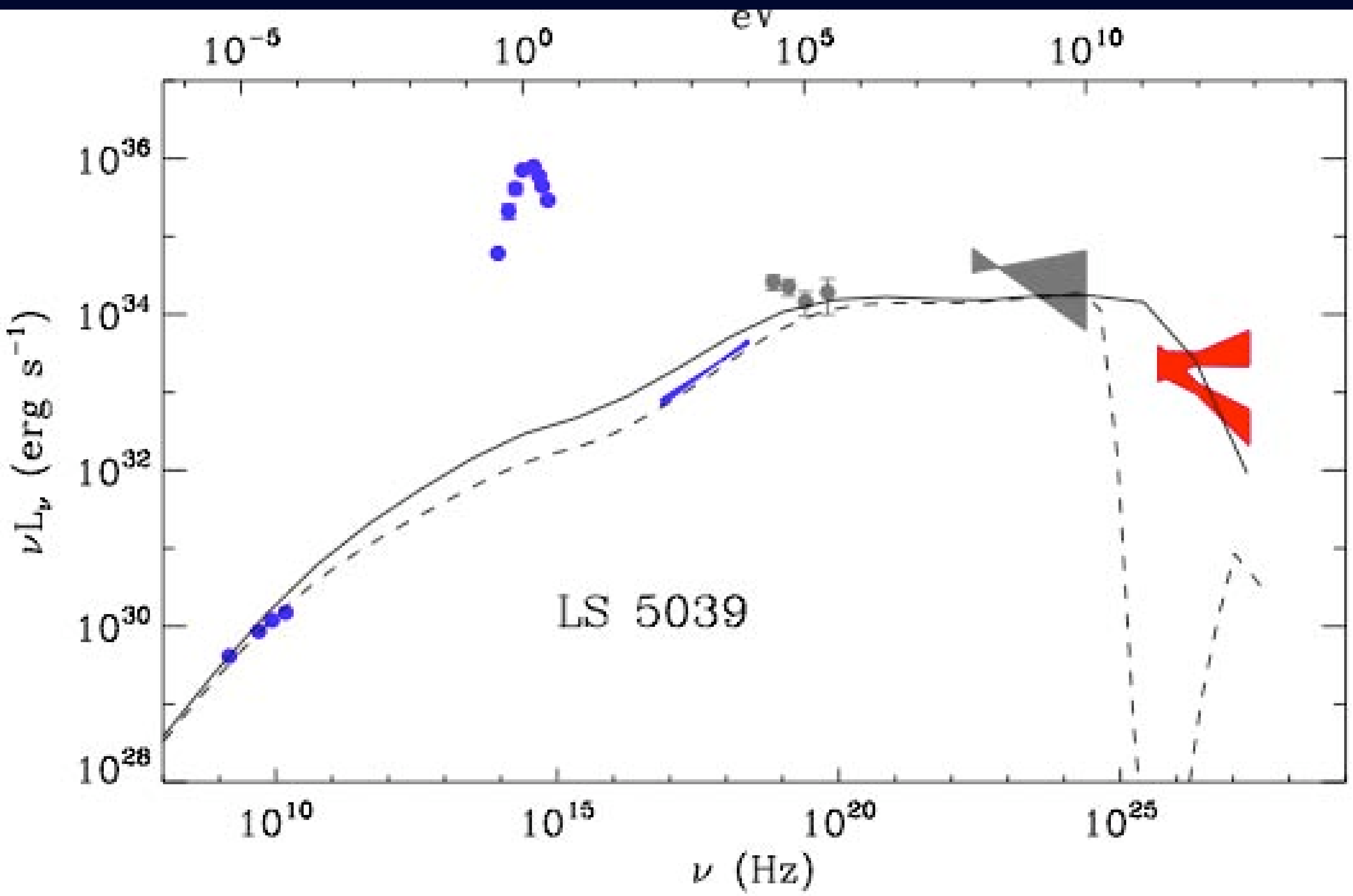
- massive star (O, Be) eccentric orbit
- Variable TeV emission ~ $10^{33\text{-}34}$ erg/s
- Low, ~ stable *radio* and X-ray emission

  (periodic radio outbursts in LS I+61 303 and PSR B1259-63)
- Spectral energy distributions

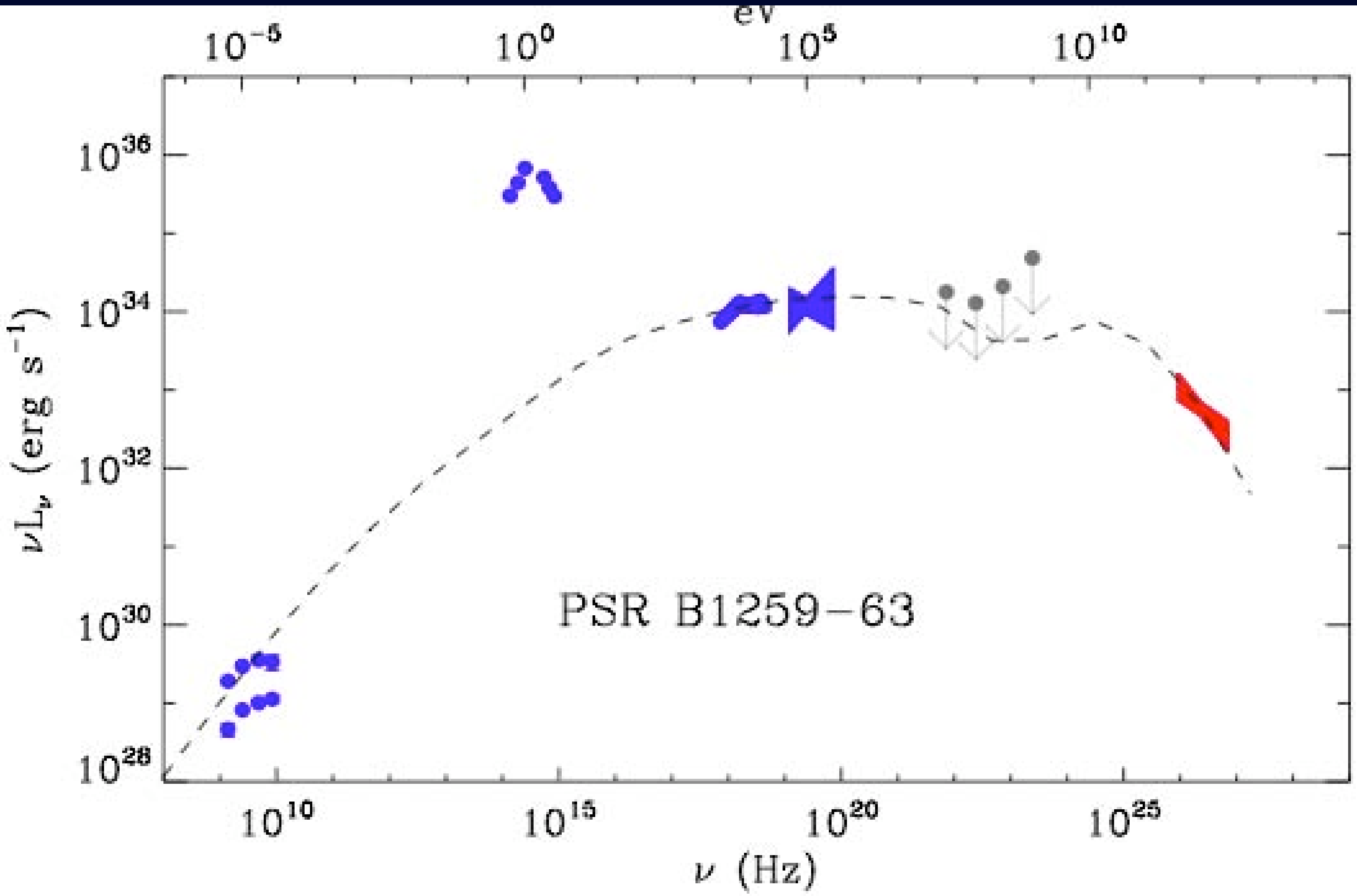
Similarity of spectra energy distributions



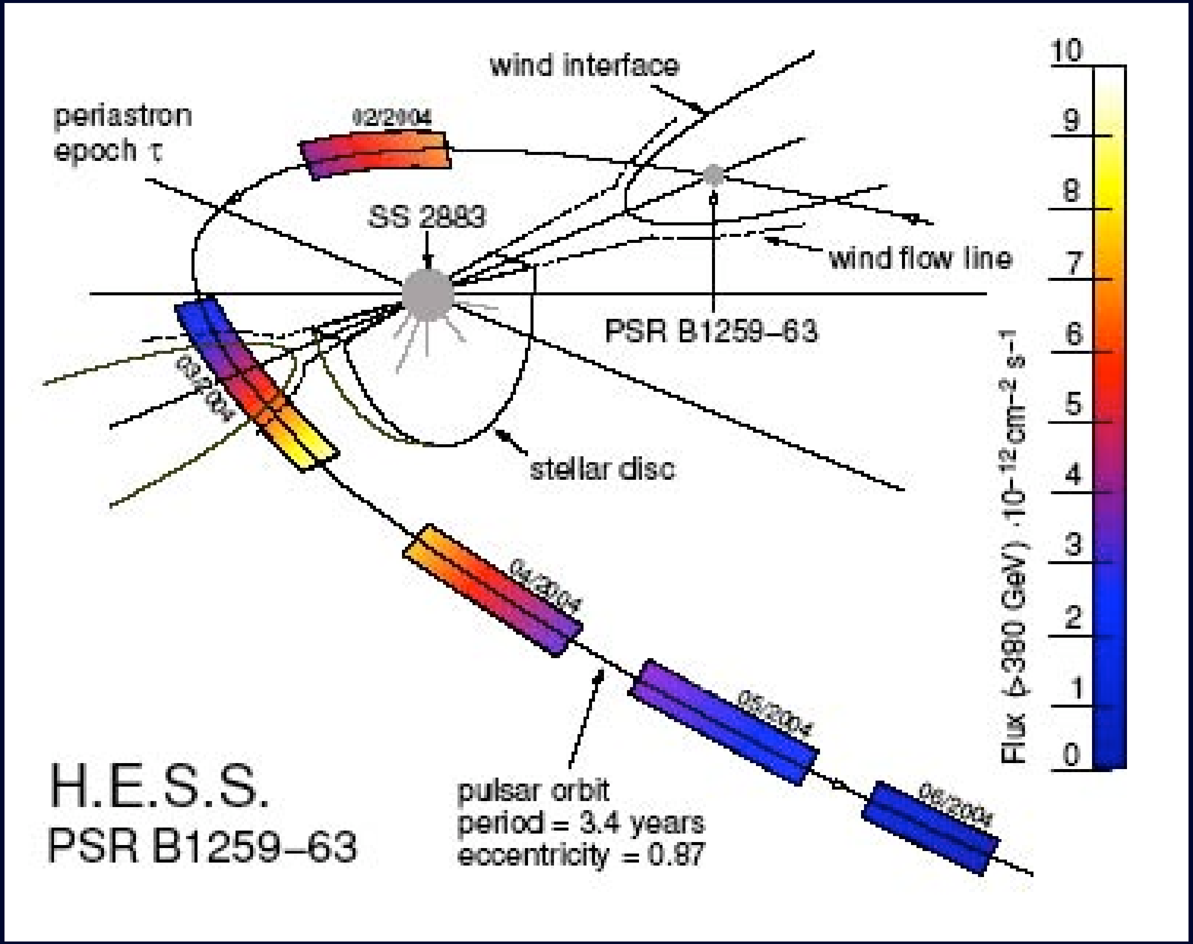
Similarity of spectra energy distributions



Similarity of spectra energy distributions



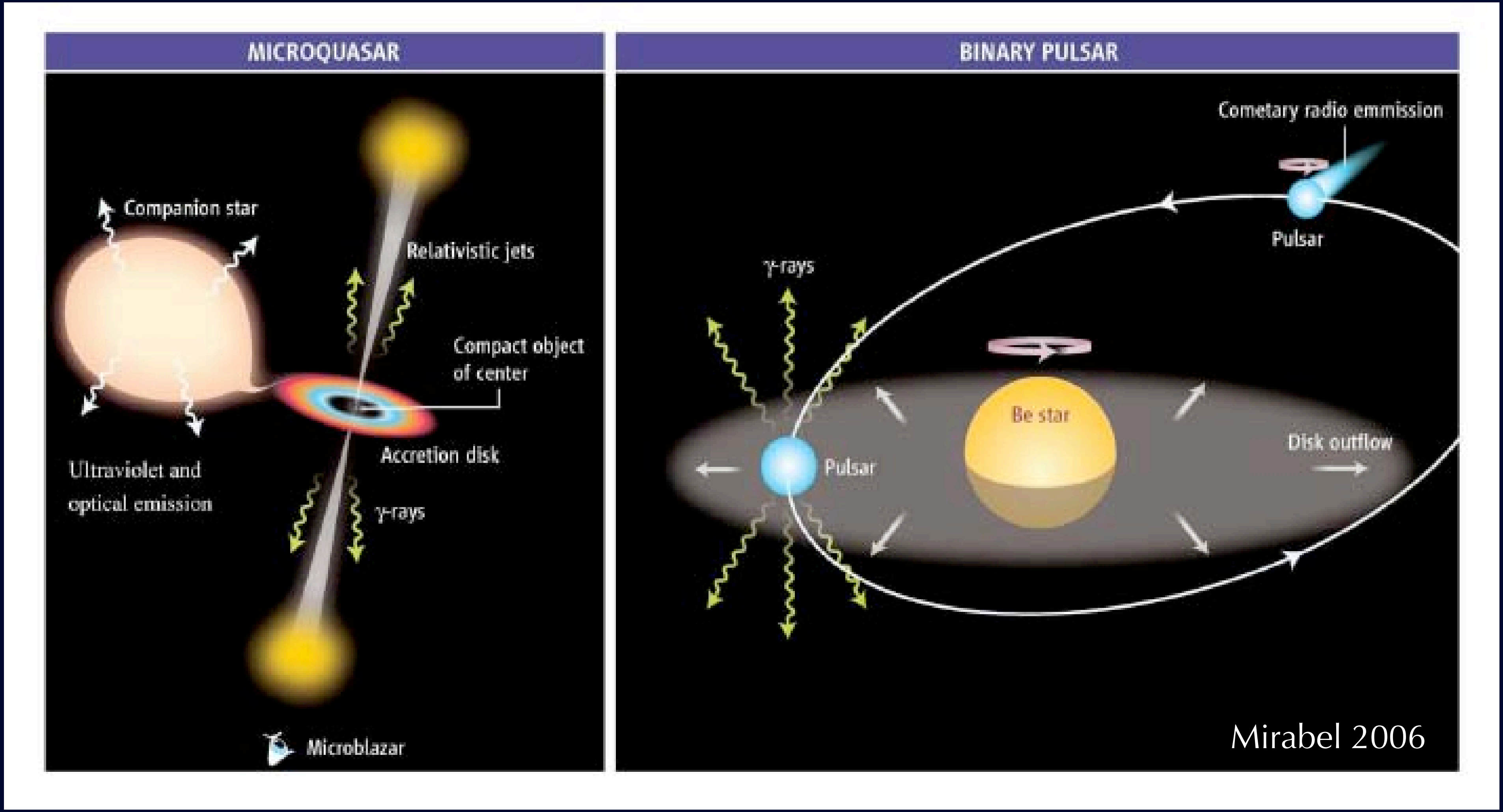
In PSR B1259-63, VHE emission due to particle acceleration at PW termination shock



48 ms pulsar with spindown power 10^{36} erg/s, no accretion

See Tavani & Arons 97; proposed for LS I+61 303 by Maraschi & Treves 81

Controversy: microquasar or pulsar ?

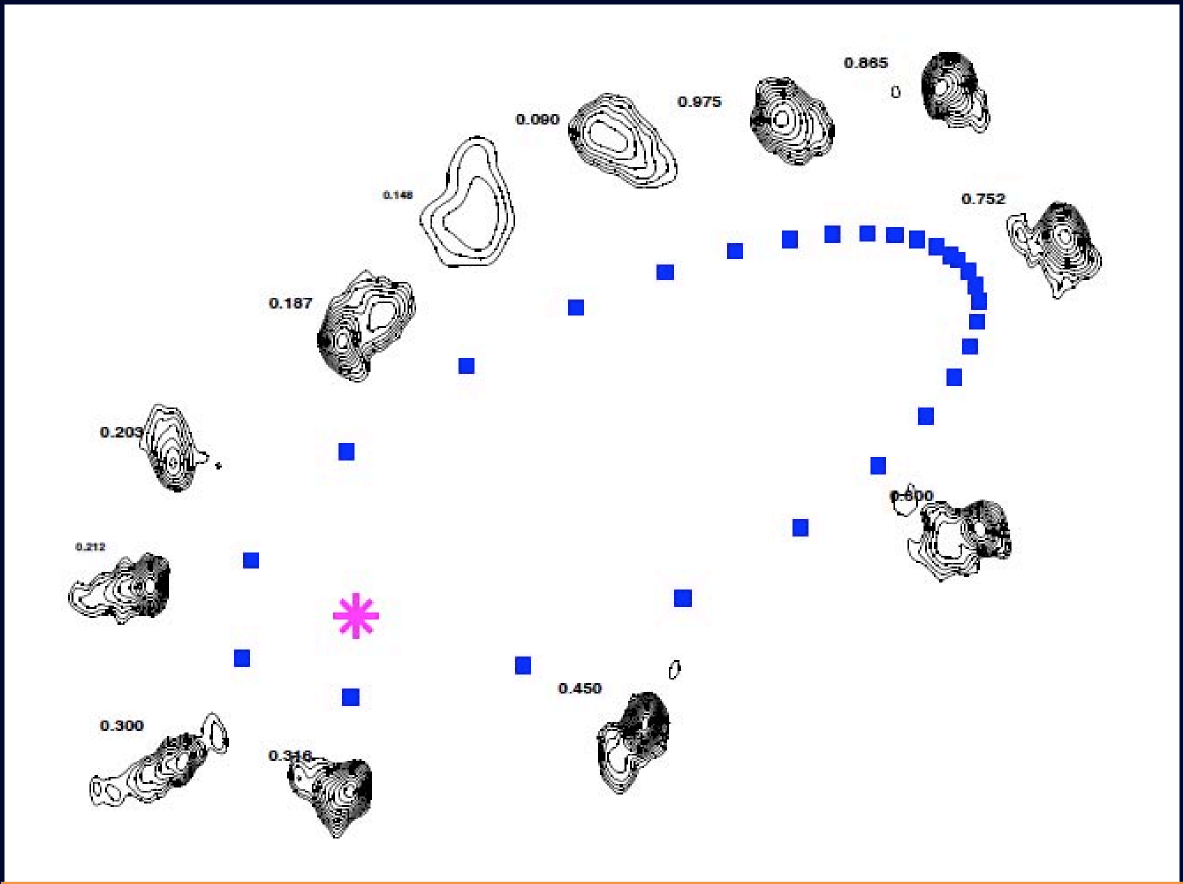


Accretion power

Rotation power

LS I+61 303 is a pulsar not a microquasar

Radio VLBI observations by Dhawan et al. Como Workshop, PoS



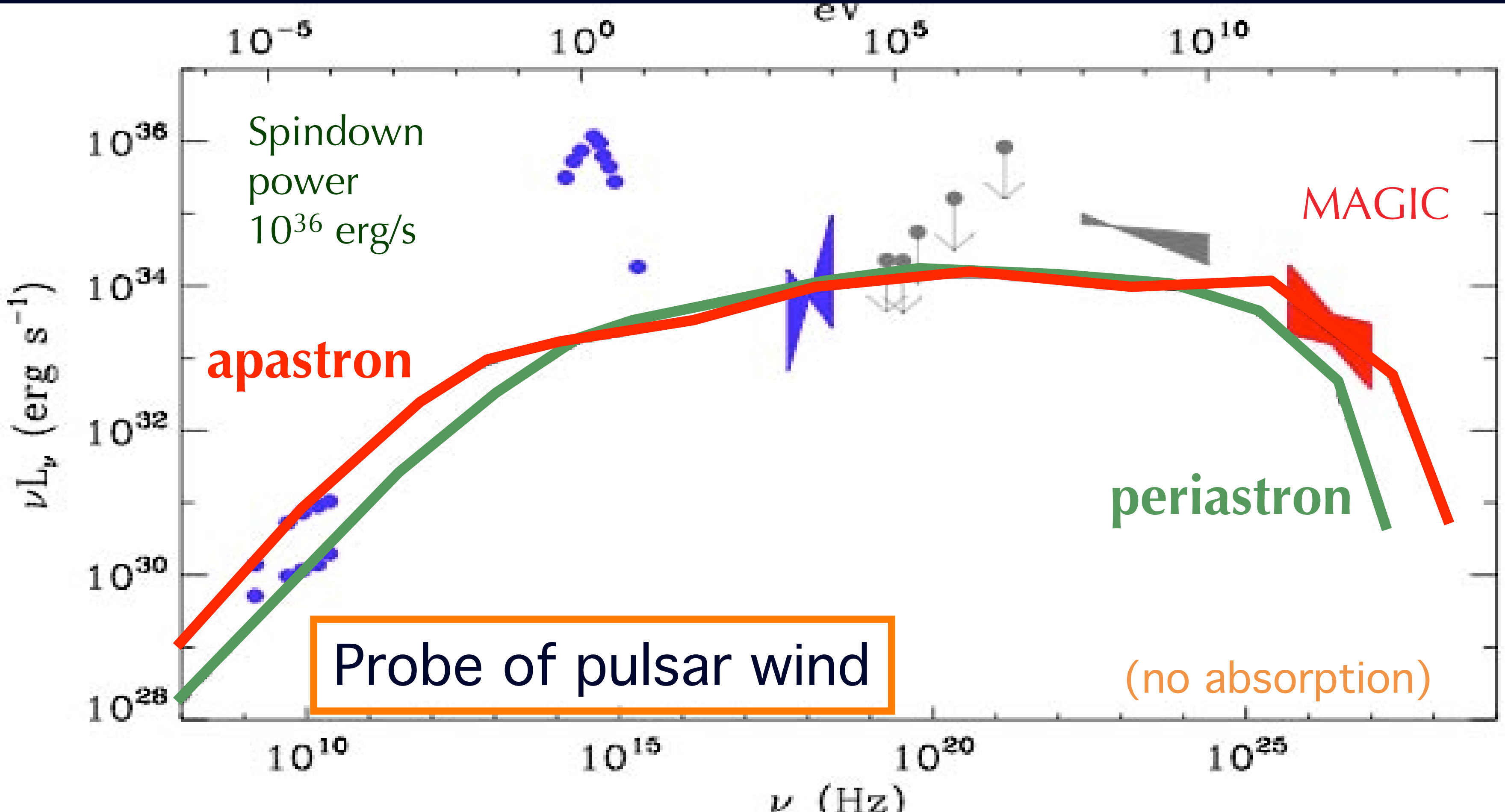
- No bulk relativistic motion
- Opacity gradient with highest frequencies toward head
- Resolved, tail points away from star.
- Morphology varies along orbit

We conclude that the pulsar model is strongly supported, i.e., the radio synchrotron emission arises not in a jet, but from particles shock-accelerated in the interaction of the pulsar wind with the dense equatorial wind from the Be star.

LS I+61°303 TeV modulation: passage through dense Be wind ?

Apastron: diffuse polar wind, large shock distance, low B = VHE

Periastron: dense equatorial wind, small shock distance, high B = *no* VHE

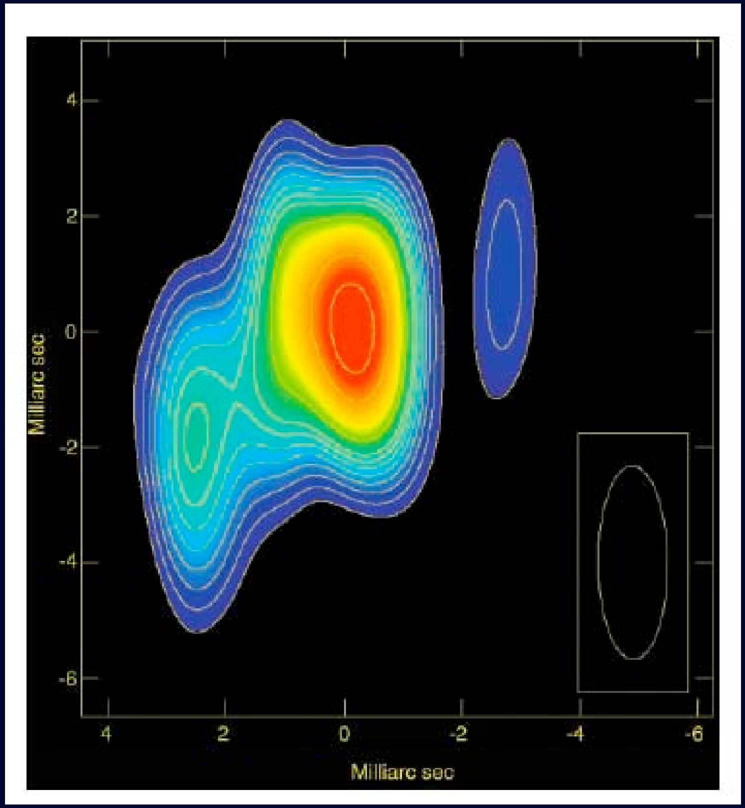


GD 2006

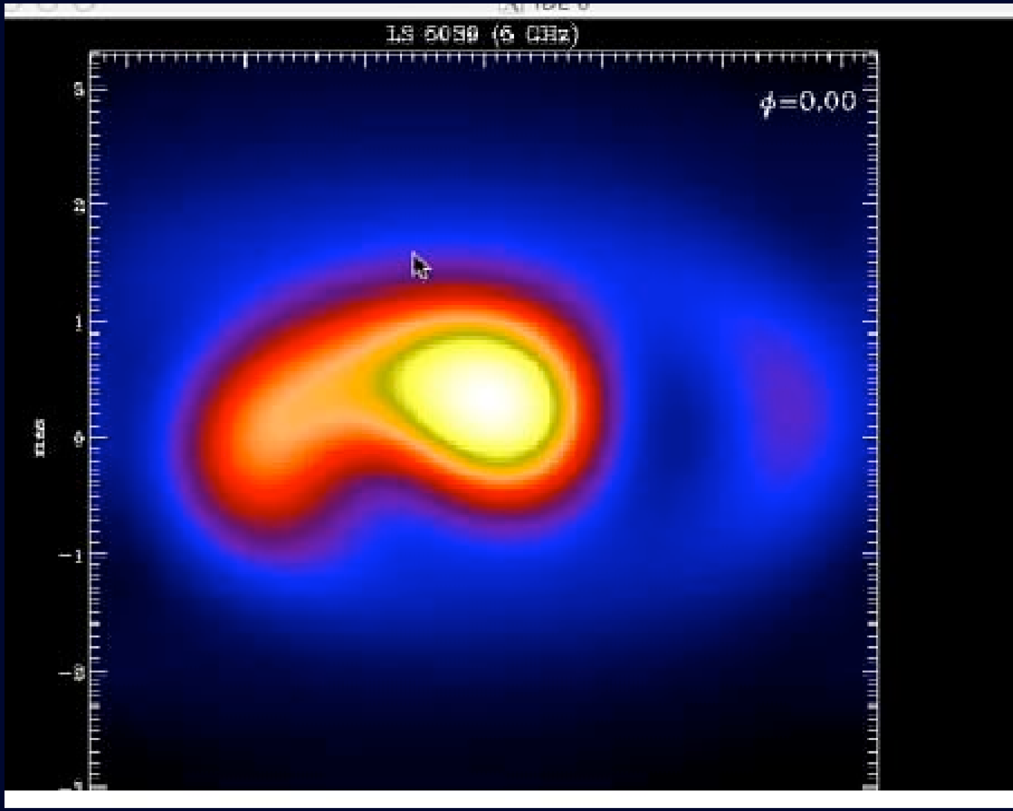
Radio emission from comet tail in LS 5039

VLBI observation

Paredes et al. 2000



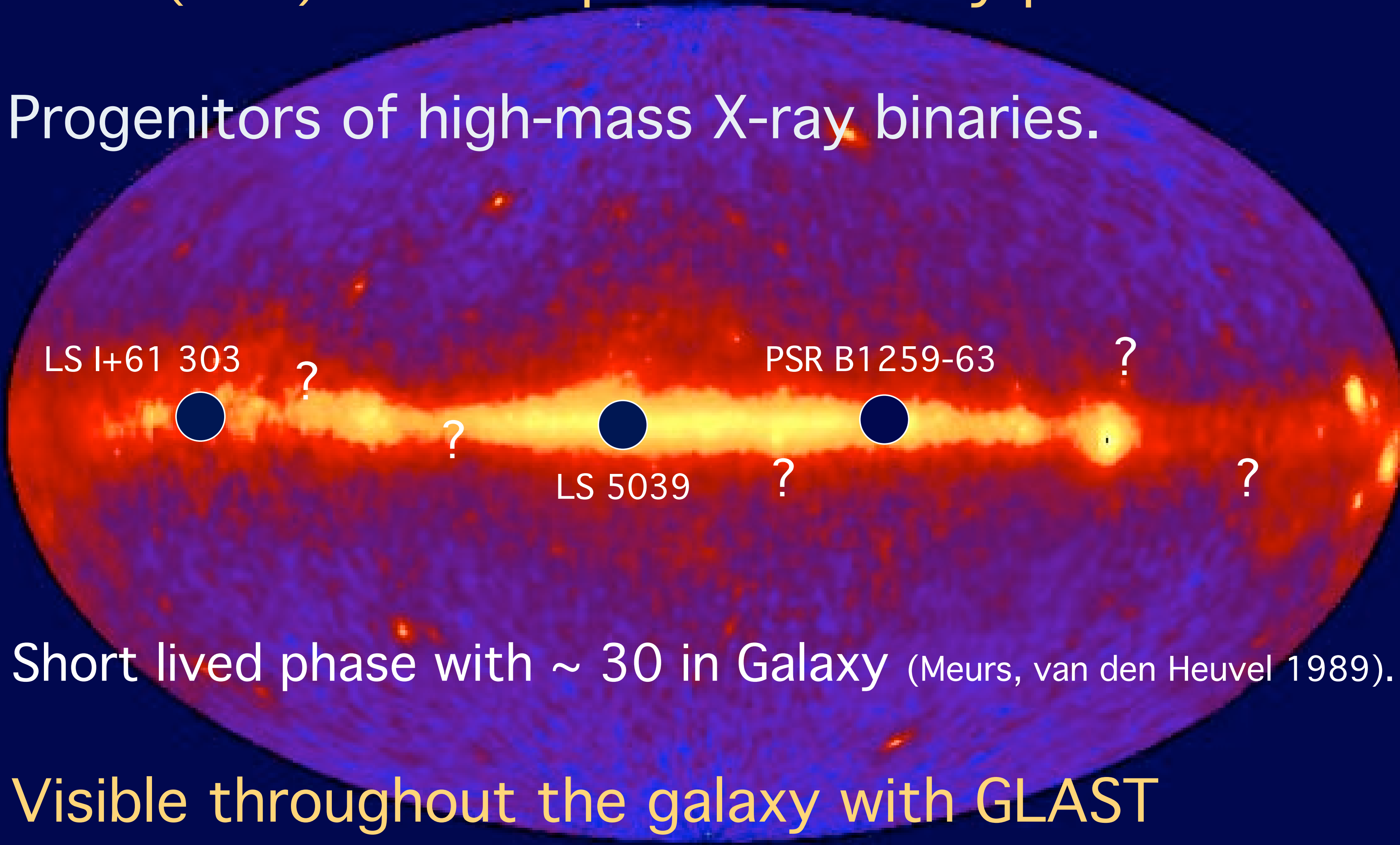
Model 5 GHz emission



GD 2006

All three binaries detected in HE γ-rays could be (rare) rotation-powered binary plerions.

Progenitors of high-mass X-ray binaries.



Short lived phase with ~ 30 in Galaxy (Meurs, van den Heuvel 1989).

Visible throughout the galaxy with GLAST

with $L_{>100\ \mathrm{MeV}} \sim 10^{35}$ erg/s and no background (!)

Binaries and GLAST: conclusions

- Ground-based Cherenkov arrays have confirmed that binaries are sources of HE/VHE gamma-rays.
- High mass companions; orbital VHE modulation.
- Binary plerions, new window for pulsar wind physics.
- Emission from *accretion-powered* binaries expected. GLAST sensitivity & sky coverage should enable their detection.