High energy gamma-rays from binaries

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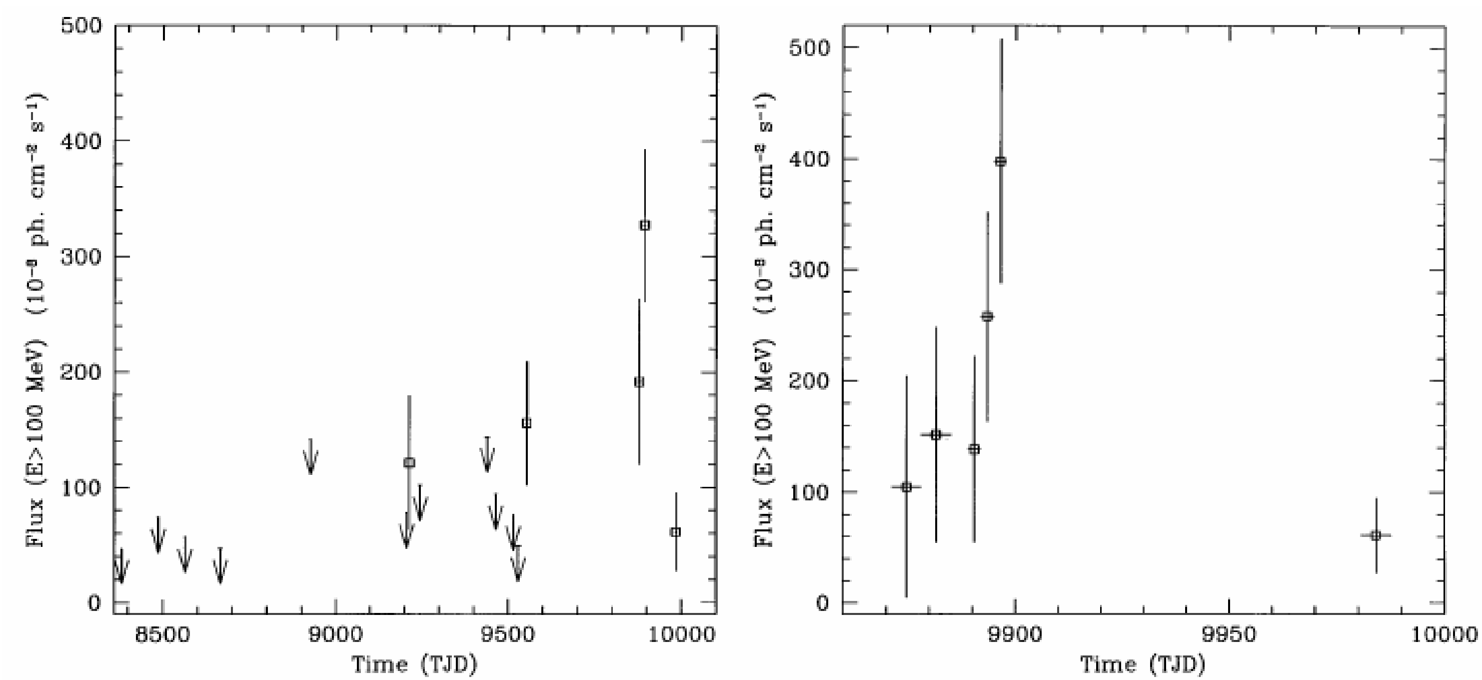
Binaries emitting high-energy γ-rays

- Radio pulsars in binaries, in particular ms radio pulsars (spun up by accretion), which are usually in binaries. Several ms radio pulsars have been detected by *Fermi*;
- PSR B1259–63, a young radio pulsar + Be star, emission from the pulsar wind colliding with the stellar wind;
- The persistent γ-ray sources LS I +61 303 and LS 5039; most likely of the same nature as PSR B1259–63;
- HESS J0632+057 – a new candidate γ-ray binary, similar to LS I +61 303;
- Collinding stellar winds of massive binaries, e.g., WR 20a, with two massive stars, have been predicted to emit γ-rays. But the emission found by HESS was *extended*, thus it was not clear if the binary itself is emitting γ-rays. **Now the case of Eta Carinae, *AGILE*.**
- The accreting black-hole binary Cyg X-1 – transient TeV emission observed once by MAGIC;
- The accreting X-ray pulsar Cen X-3 – GeV emission claimed by EGRET, not seen by *Fermi* as yet – *needs to be confirmed*.

A bright transient GRO J1838–04 detected by EGRET near the Galactic Plane



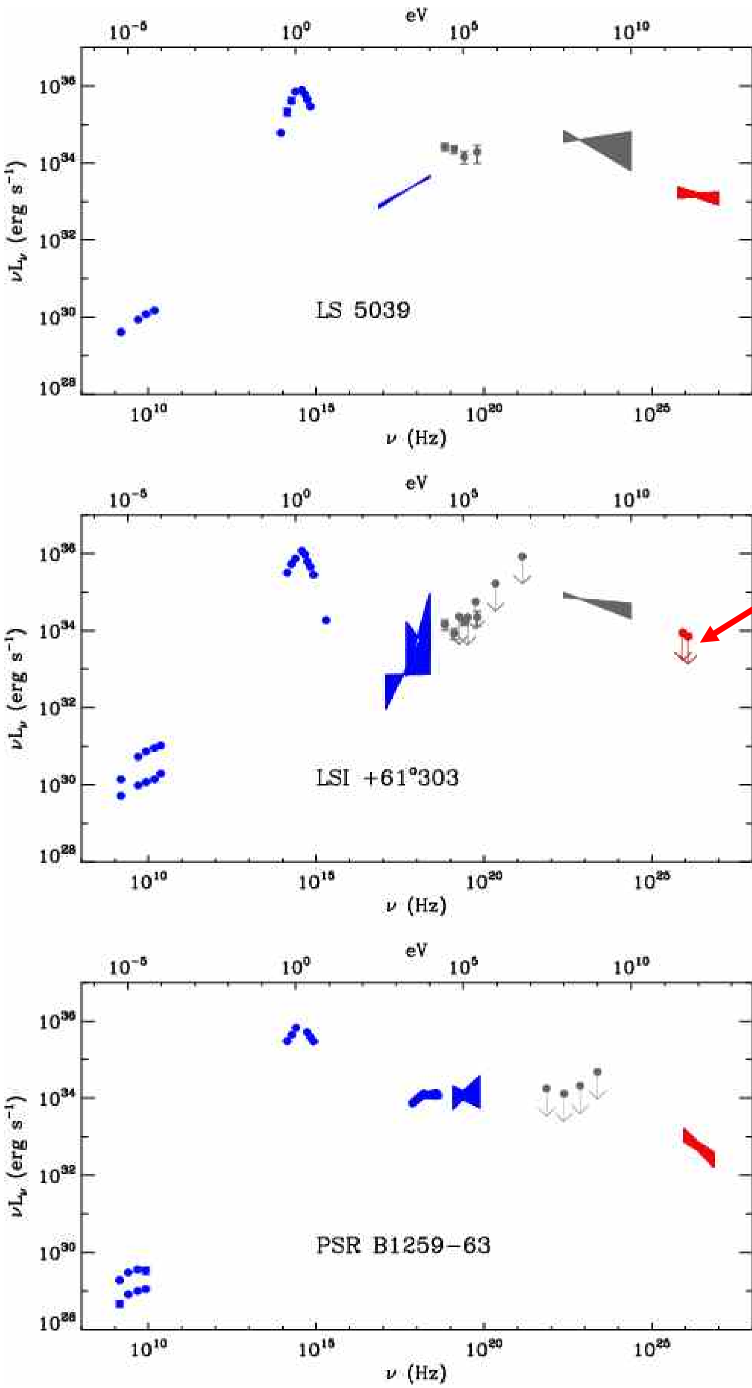
One of the most intense γ-ray transients ever detected, the 2nd brightest EGRET source in the sky at the time of the detection. No identification, in particular no blazar counterpart. Possibly a binary.

A Supergiant Fast X-ray Transient???

Tavani et al. 1997

Three known persistent TeV-emitting binary systems:

- All three are high-mass, eccentric, Be/O binaries.
- One of them, PSR B1259–63, is a radio pulsar which wind interacts with the Be wind, which gives rise to the γ-ray emission.
- The other two systems, LS I +61 303 and LS 5039, have properties similar to PSR B1259–63, and likely also contain young pulsars (e.g., Dubus 2006; Z., Neronov, Chernyakova 2009).



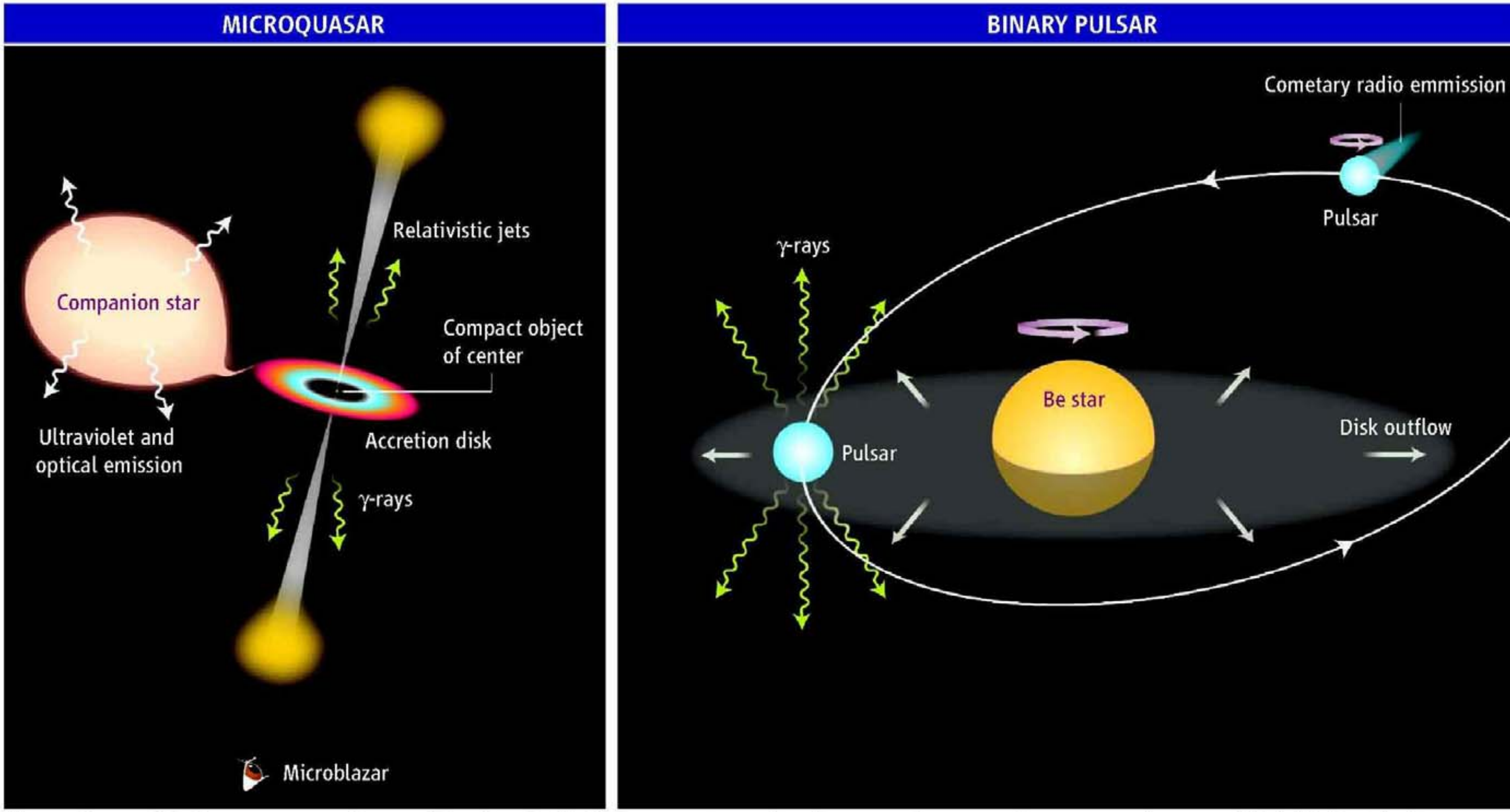
The three persistent TeV-emitting binaries:

now detections by MAGIC and VERITAS

Dubus 2006, A&A, 456, 801:
„Gamma-ray binaries: pulsars in disguise"

They all look very similar to each other, but PSR B1259–63 is a well-known 48-ms radio pulsar with a Be companion (3.4 yr orbit), in which the wind of the pulsar interacts with the wind of the Be star, giving rise to the broad-band emission.

The microquasar/pulsar wind controversy



Alternative models for very energetic γ-ray binaries. **(Left)** Microquasars are powered by compact objects (neutron stars or stellar-mass black holes) via mass accretion from a companion star. This produces collimated jets that, if aligned with our line of sight, appear as microblazars. The jets boost the energy of stellar photons to the range of very energetic γ-rays. **(Right)** Pulsar winds are powered by the rotation of neutron stars; the wind flows away to large distances in a comet-shaped tail. Interaction of this wind with the companion-star outflow may produce very energetic γ-rays.

Mirabel 2006

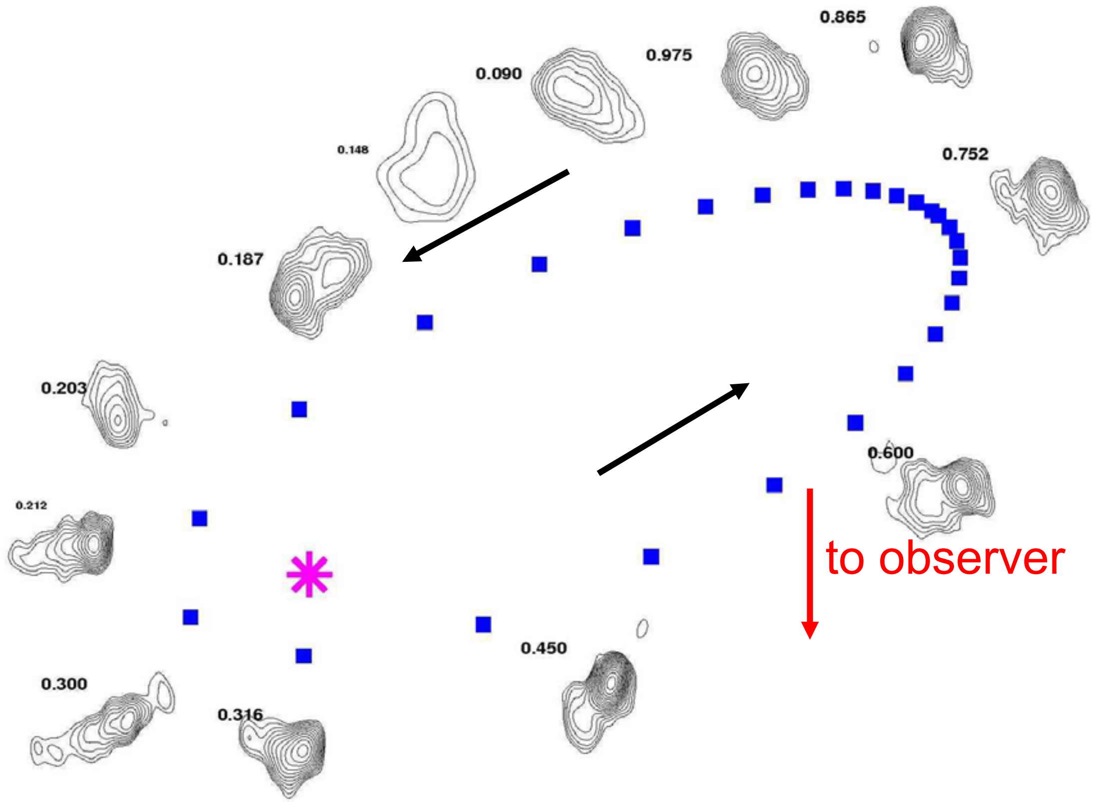
The main problem with the accretion model:

- The spectrum does not look like that of any accreting binary, e.g., the spectrum shows no high-energy cutoff up to >10 GeV.

The radio-pulsar model of LS I +61 303:

- A radio pulsar (rotation-powered) model for was proposed by Maraschi & Treves (1981). Accretion is inhibited by the pressure of the pulsar wind. Emission from interaction of the stellar and pulsar winds.

The controversy appears to have been resolved by radio observations:



A cometary tail pointing (mostly) away from the Be star, and rapid changes at periastron.

Dhawan et al. 2006 „LS I +61 303 is a Be-pulsar binary, not a microquasar"

HESS J0632+057

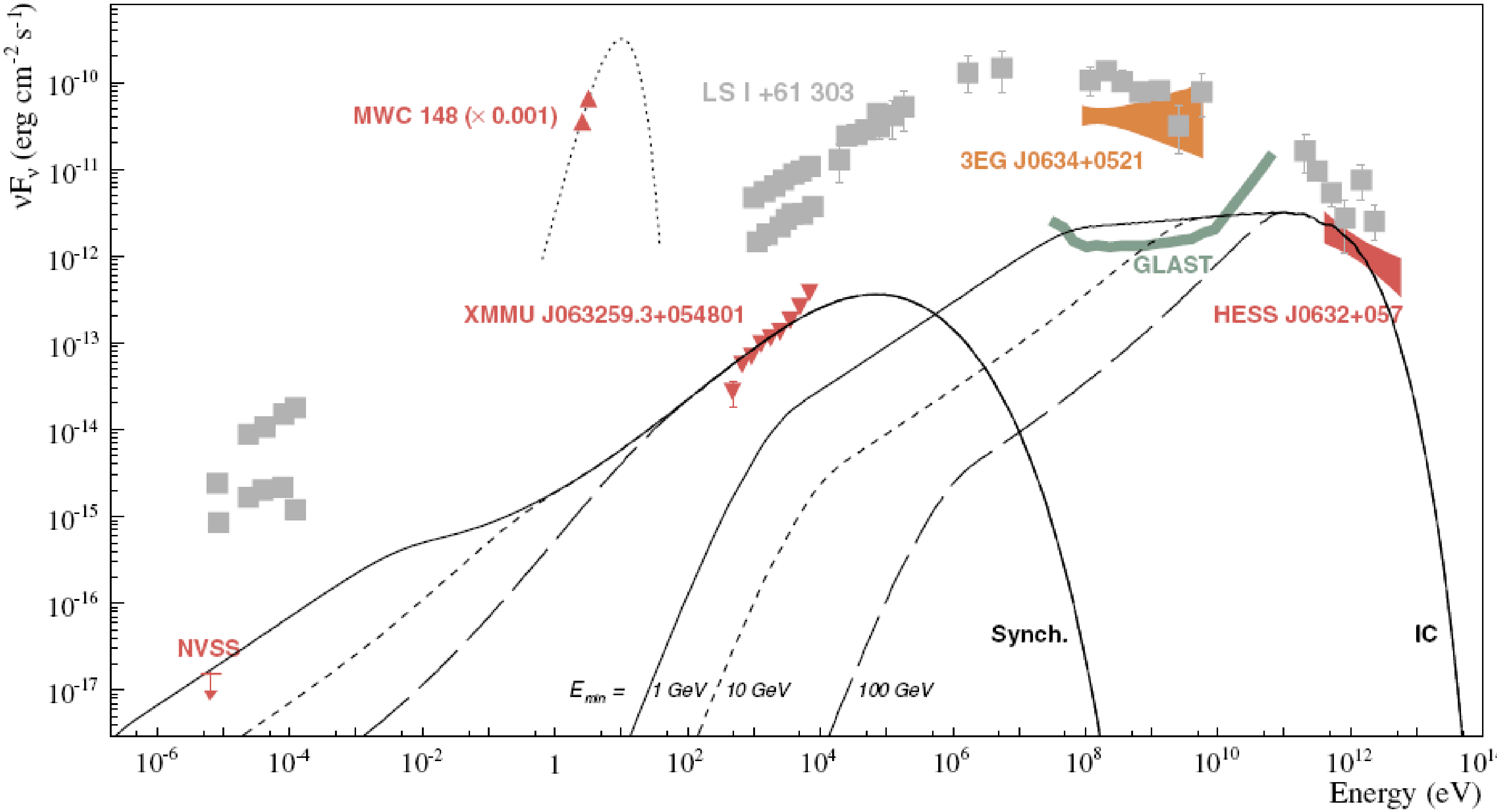
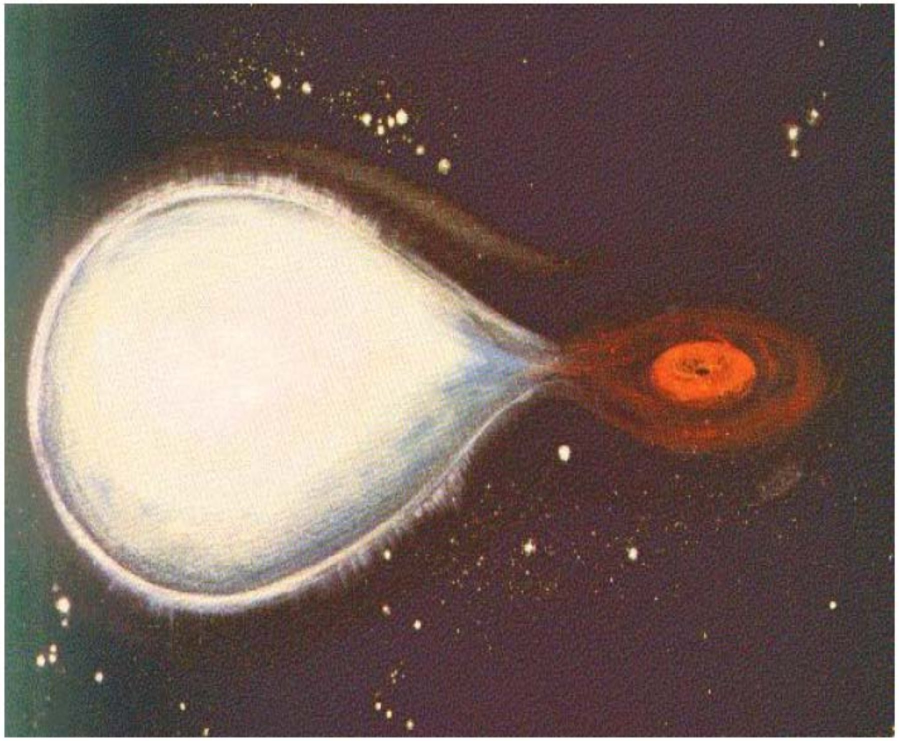


Figure 4. SED of HESS J0632+057/XMMU J063259.3+054801 (red symbols/regions) compared with that of the γ-ray binary system LSI+61303 (gray symbols/regions; see Chernyakova et al. 2006 and references therein) and the estimated 1 year *GLAST* sensitivity for this region (thick solid line). The solid, short-dash, and long-dash curves show the synchrotron and IC components of a simple time-dependent one-zone model with $E_{\rm min}$ set to 1 GeV, 10 GeV, and 100 GeV, respectively—see text for details.

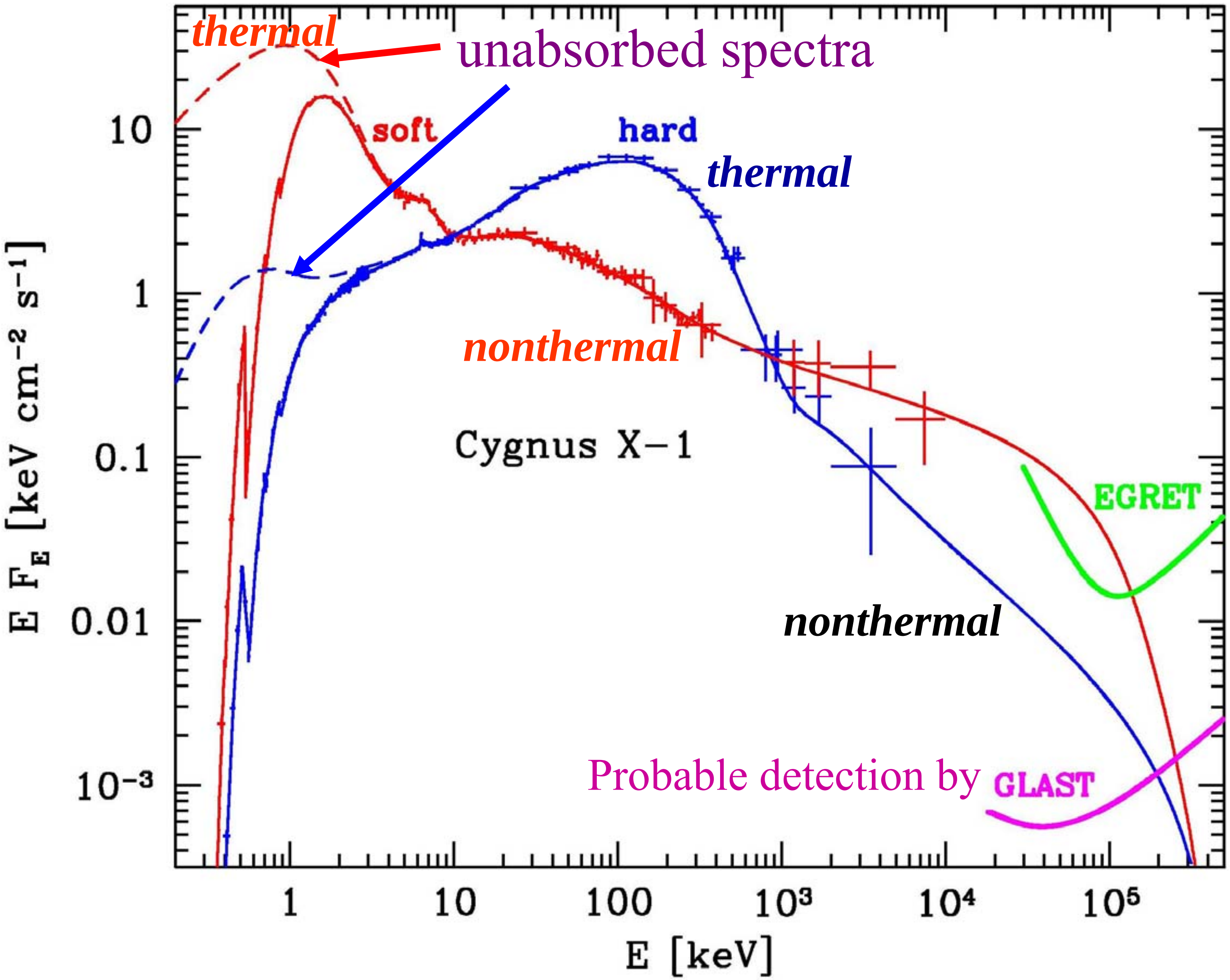
A high-mass X-ray binary similar to LS I 61+303

Cyg X-1

A black-hole and
an OB supergiant

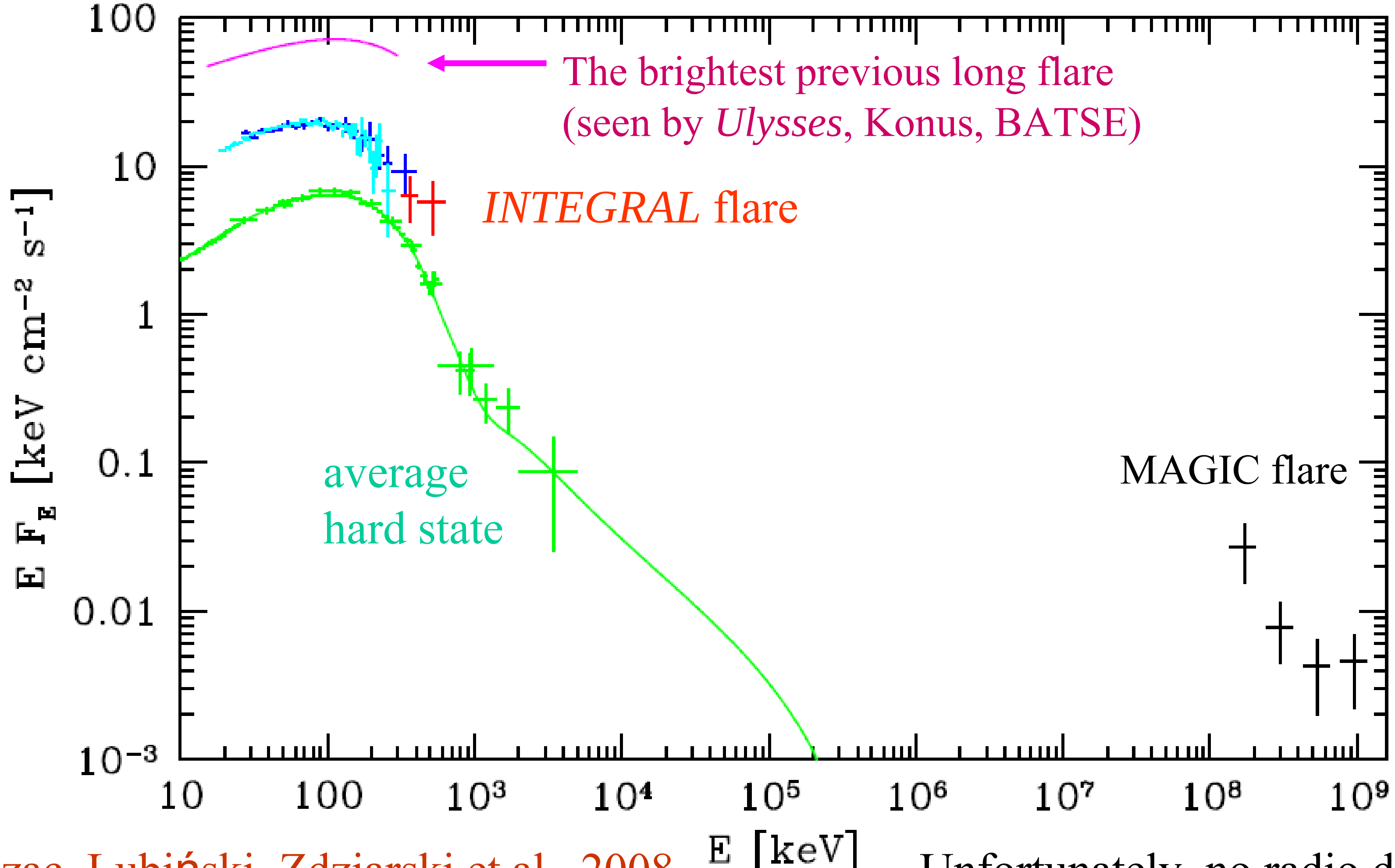


The spectral states and possible detection:



Z. & Gierliński (2004)

Cyg X-1 TeV flare detected by MAGIC during an X-ray flare seen by *INTEGRAL*



Malzac, Lubiński, Zdziarski et al., 2008

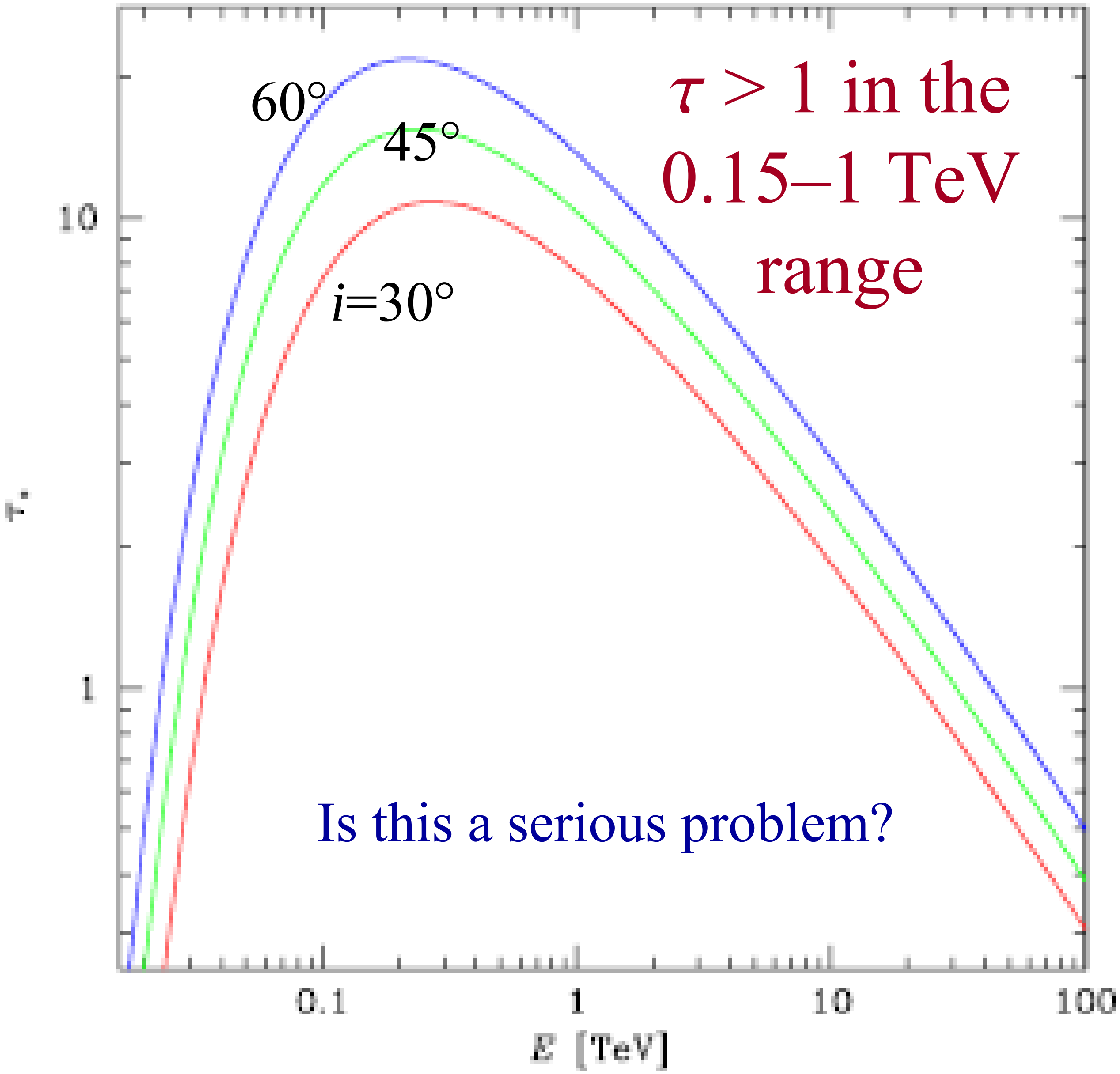
Unfortunately, no radio data.

Could the flare originate near the X-ray source?

- Can electrons be accelerated to sufficiently high energies? Yes.
- Can photons escape the X-ray radiation field? Yes.
- Can then they escape the stellar photon field? Yes, via a spatially extended pair cascade.

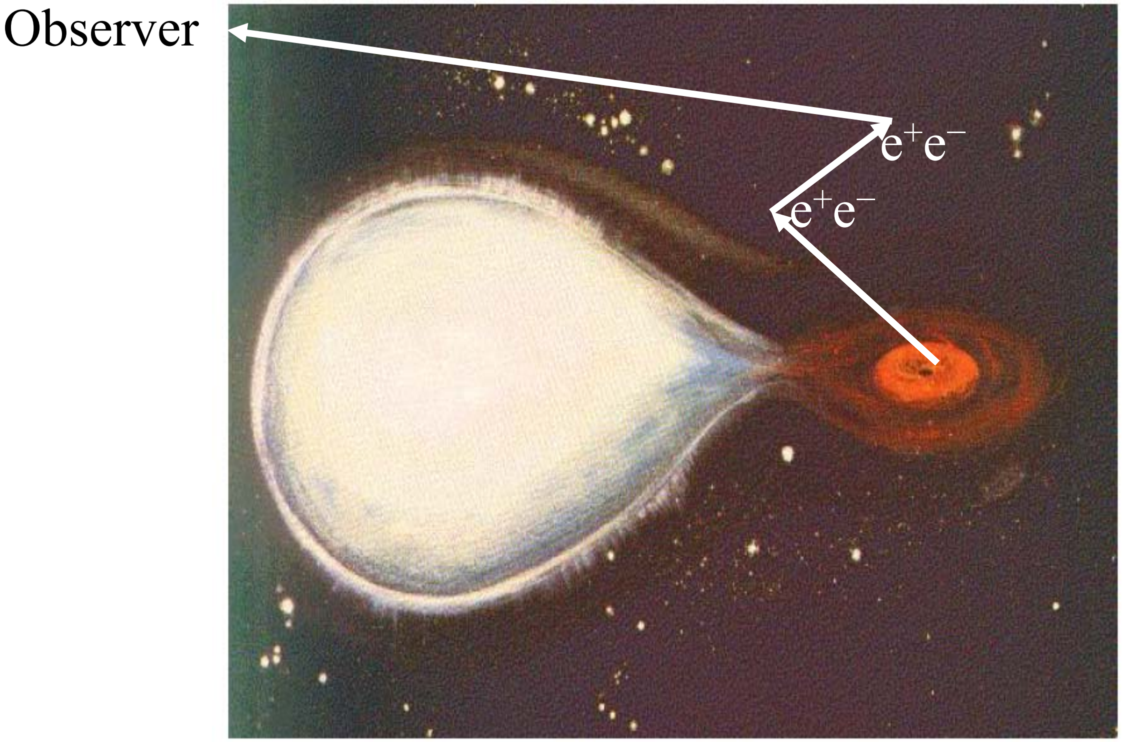
Zdziarski, Malzac & Bednarek 2009

Pair opacity of the stellar field:



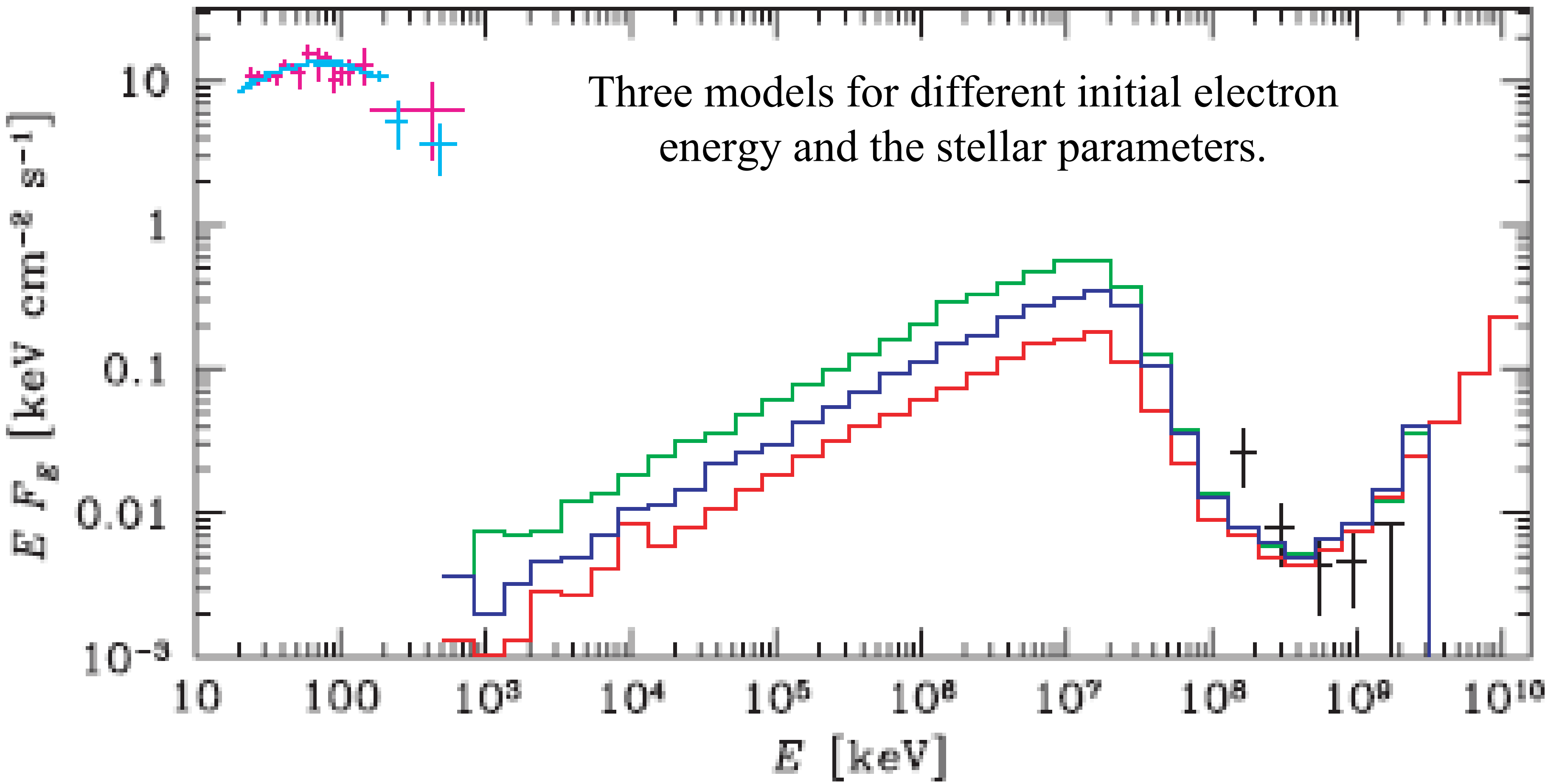
Spatially extended pair cascades:

Monte Carlo calculations: the initial high-energy electrons at an energy of several TeV are accelerated at a distance from the black hole ≪ the separation between the stars ($a = 3\times10^{12}$ cm). The acceleration site can be a shock between the stellar wind and the hot flow, or the jet.



The e^+e^- pairs produced in photon-photon collisions isotropize locally due to magnetic fields.

Spatially extended pair cascades:



Extended pair cascades initiated by γ-rays produced at ~3–10 TeV are able to approximately reproduce the observed spectrum, provided the magnetic field between the stars is weak, B<10 G or so.

Conclusions

- Colliding pulsar and stellar winds can explain most of the high energy γ-ray emision from massive binaries.
- If accretion operates in some of those systems, it has to have a mode completely different from all known types of accretion.
- Cyg X-1 is the only accreting binary with high energy γ-ray emision observed (so far only once). A theoretical model developed. The GeV/TeV emission marginal in the energy output.