Stellar Binary Systems and CTA

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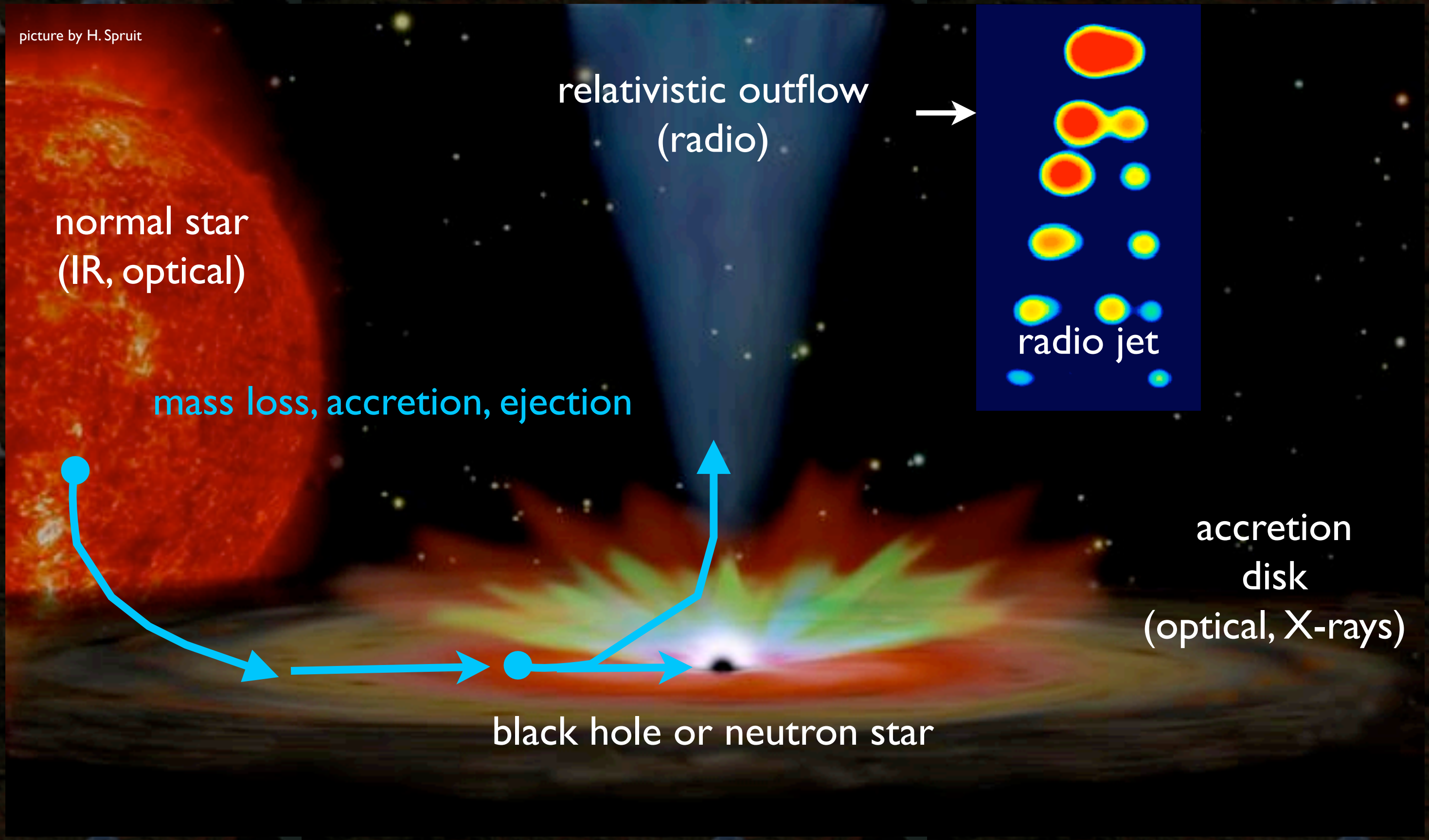
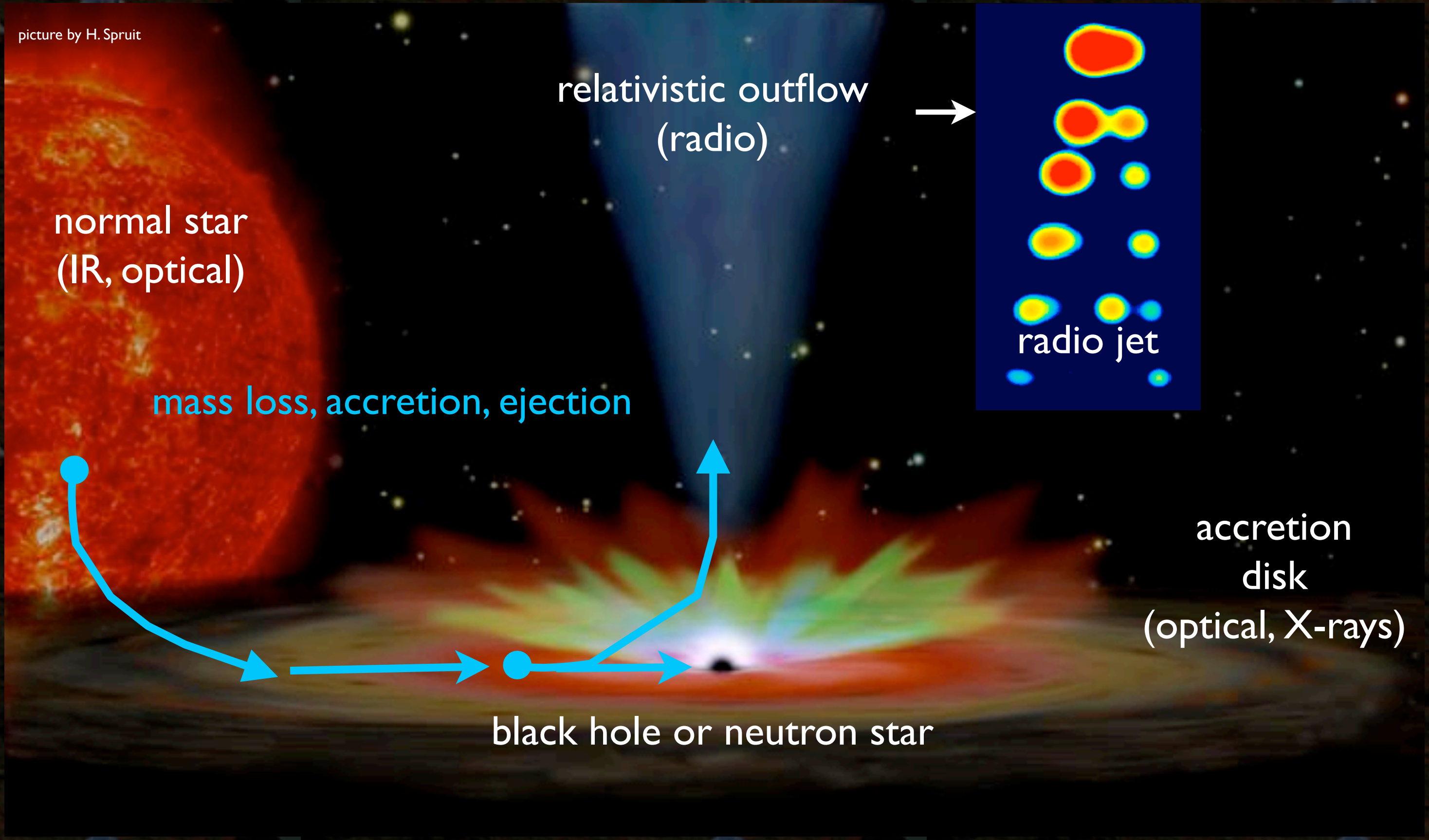
Barcelona Cherenkov Telescope Array Meeting, 24-25 January 2008

X-ray binaries



X-ray binaries

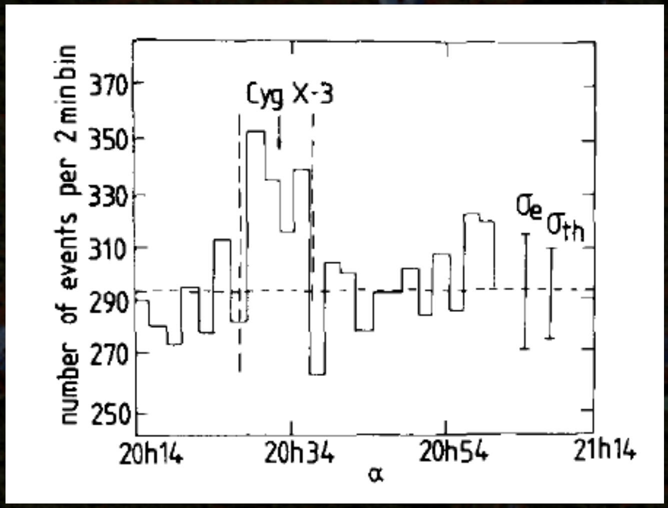


Open issues

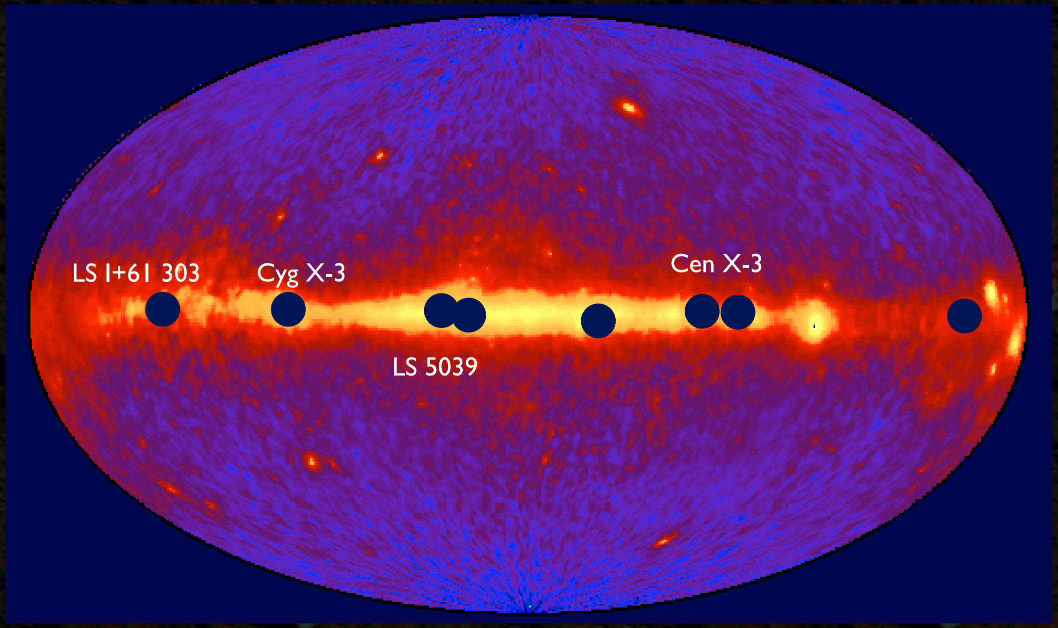
- How is gravitational/rotational energy released ?
- How are relativistic outflows launched ?
- What are the properties of these outflows ?

VHE emission from XRBs

- For a long time, VHE gamma-ray emission from binaries has been notorious for its episodic character.

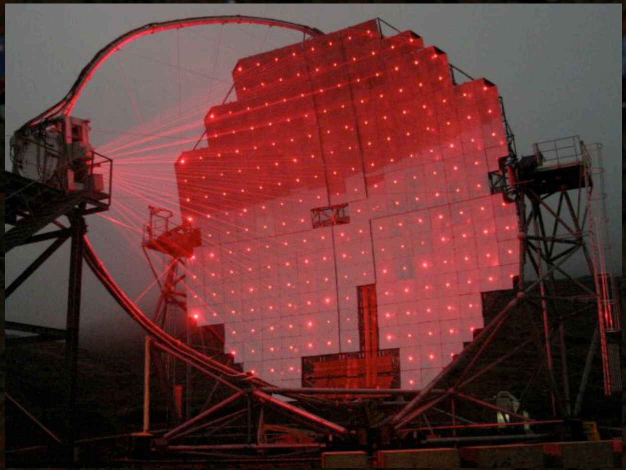


- Tentative identifications in HE gamma-rays but poor localization and no telltale variability.



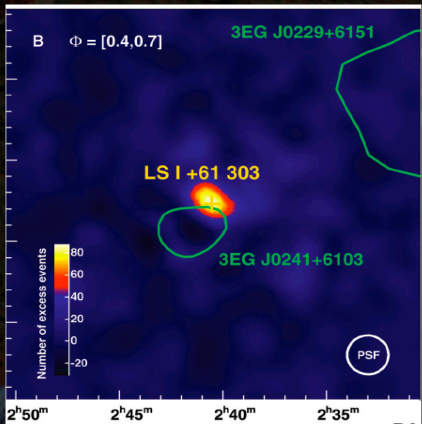
Breakthrough

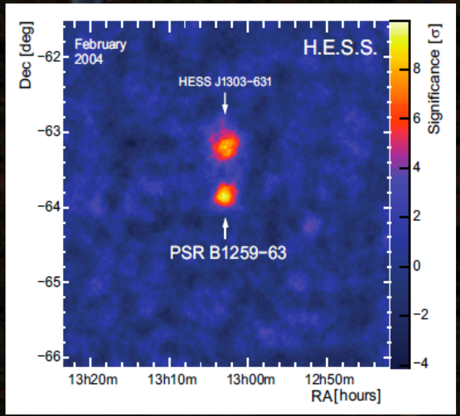
Current Cherenkov arrays *have* established that some X-ray binaries emit VHE gamma-rays.

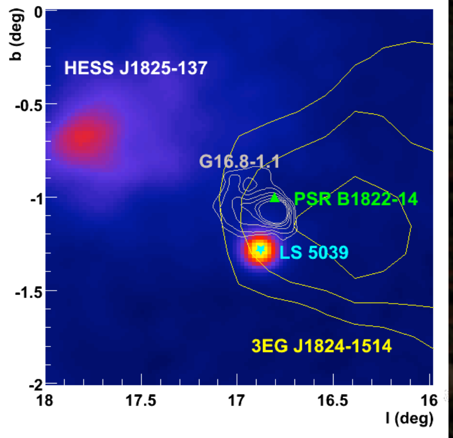


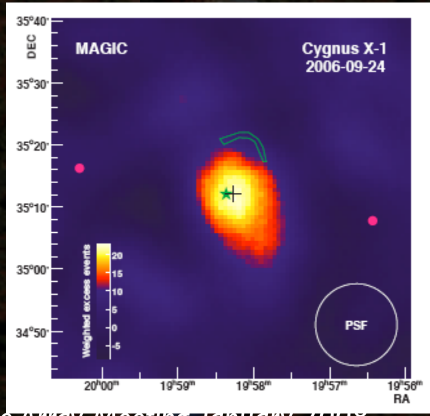
Key factors: <0.1° *spatial resolution* and *sensitivity to variability* on day timescale for ~0.1 Crab sources.

Spatial resolution





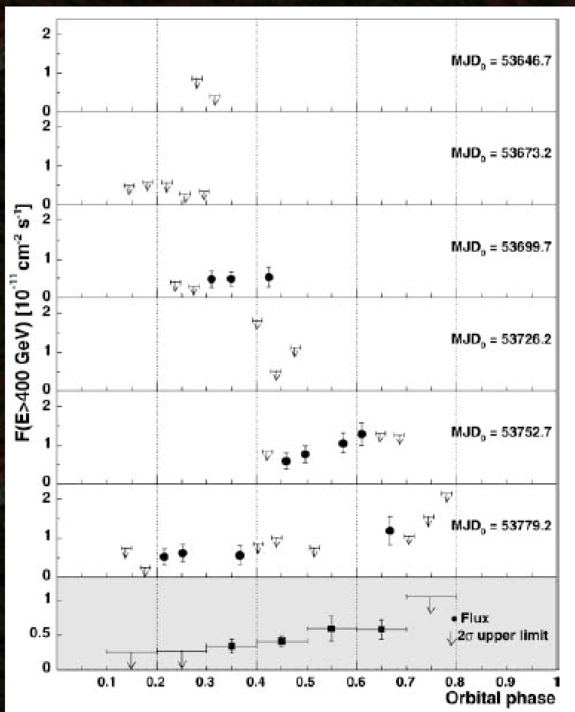




- Localize gamma-ray emission consistently (LSI+61 303)
- Distinguish from nearby VHE sources (PSR B1259-63)
- Exclude other possible MWL counterparts (LS 5039)
- Exclude VHE emission from jet termination shock (Cyg X-1)

Variability

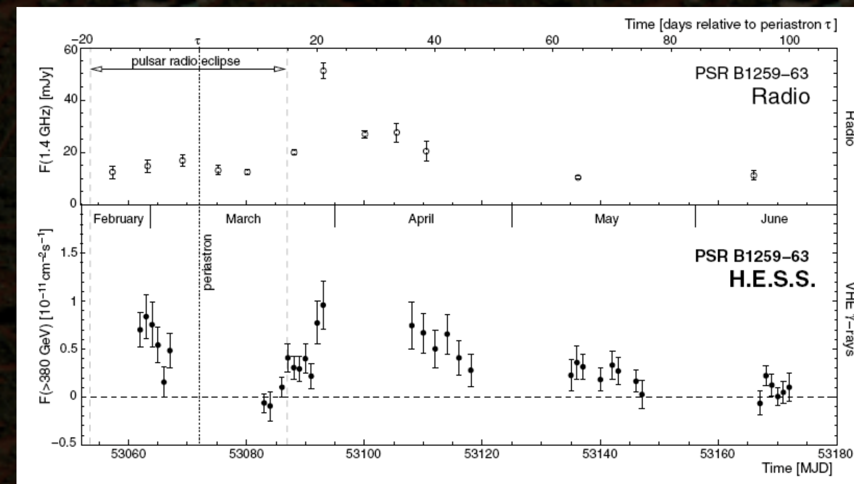
very likely orbital modulation



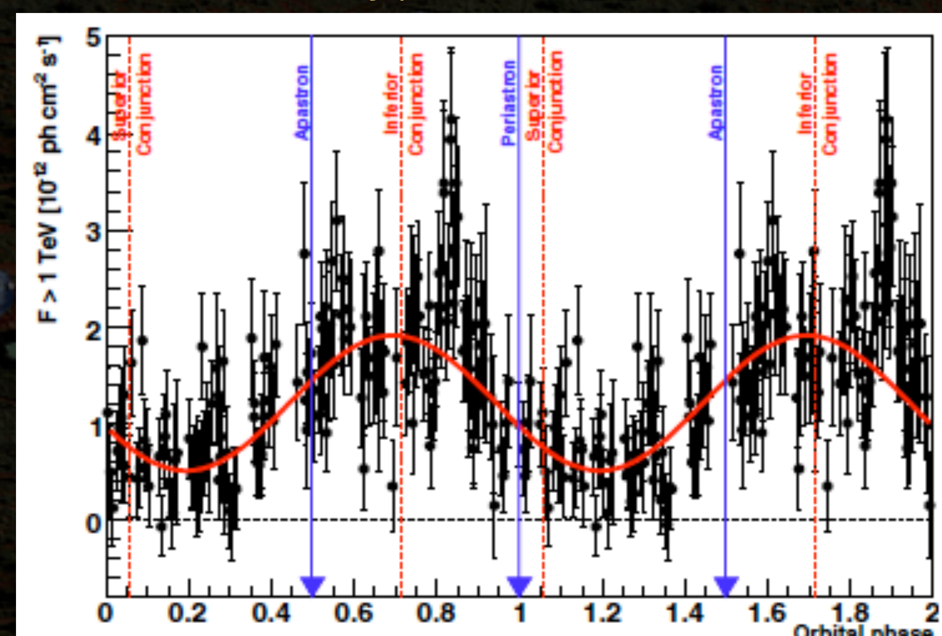
LS I +61 303

very likely orbital modulation

PSR B1259-63

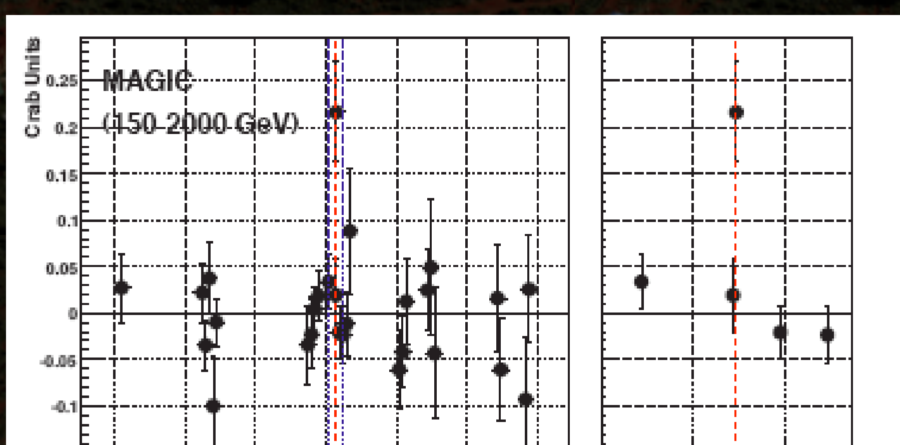


LS 5039: (formally proven) orbital modulation



VHE flare associated with X-ray flare

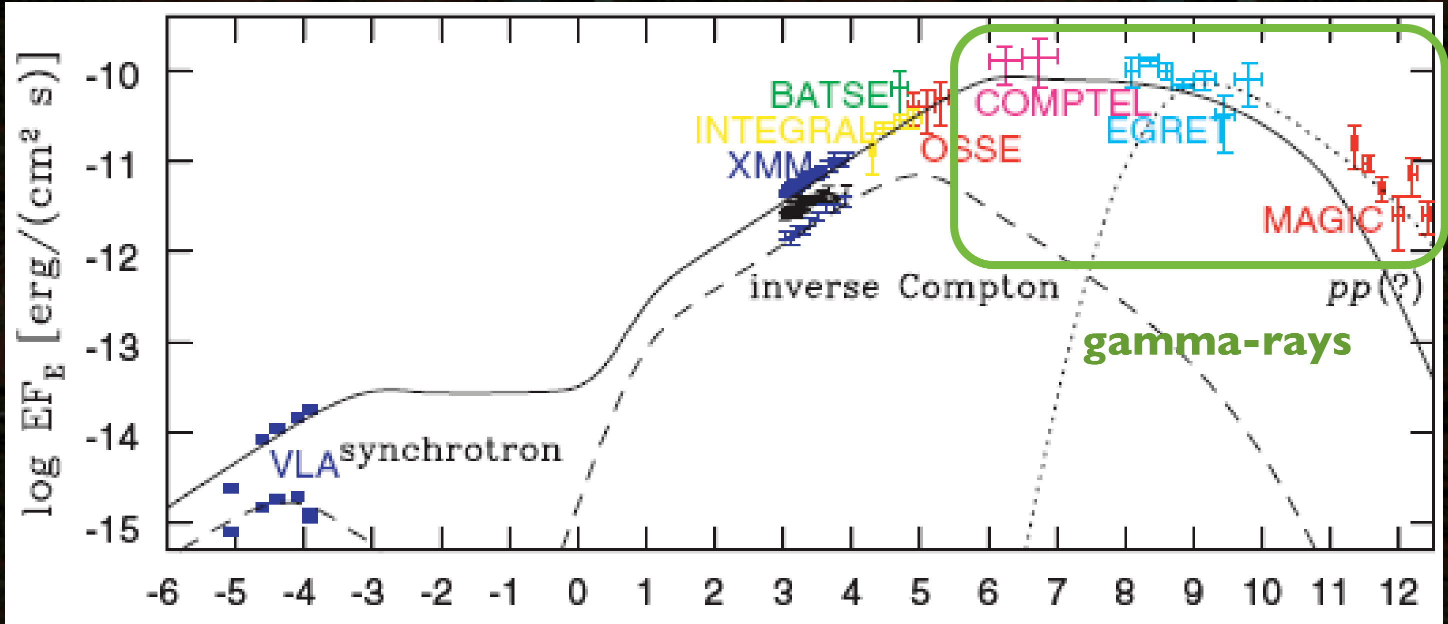
Cyg X-1



What have we learned by discovering VHE emission from binaries?

What have we learned?

- Gamma-ray emission above 10 MeV can dominate the output in some X-ray binaries: gamma-ray binaries.



Chernyakova et al. 2006

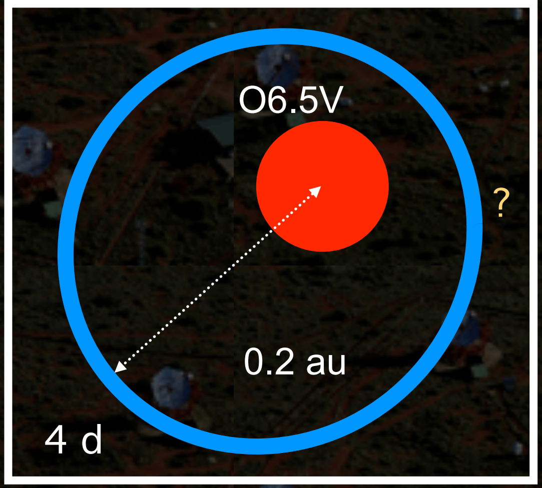
LS 5039,
PSR B1259-63,
LSI+61303
$L_{vhe} \sim L_x$

but in Cyg X-1
$L_{vhe} \sim 10^{-4} L_x$

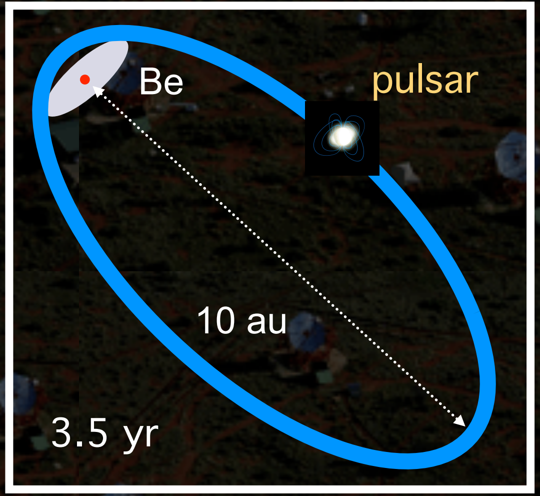
What have we learned?

- Gamma-ray emission above 10 MeV can dominate the output in some X-ray binaries: gamma-ray binaries.
- All have massive, early-type companions: the large luminosity and strong stellar wind likely to play a role.

LS 5039

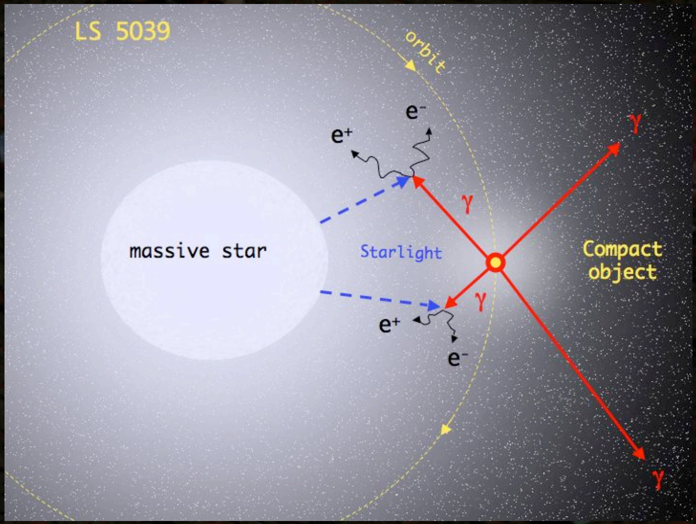


PSR B1259-63



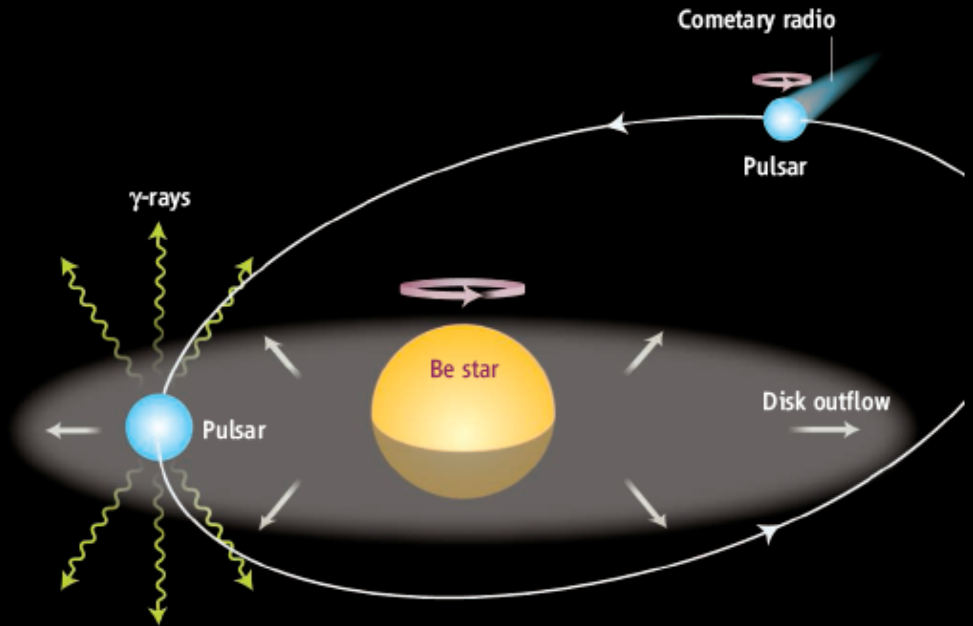
What have we learned?

- Gamma-ray emission above 10 MeV can dominate the output in some X-ray binaries: gamma-ray binaries.
- All have massive, early-type companions: the large luminosity and strong stellar wind likely to play a role.
- VHE modulation: orbital dependence of the accele-ration and/or of the radiative processes (e.g. pair production).



Current understanding

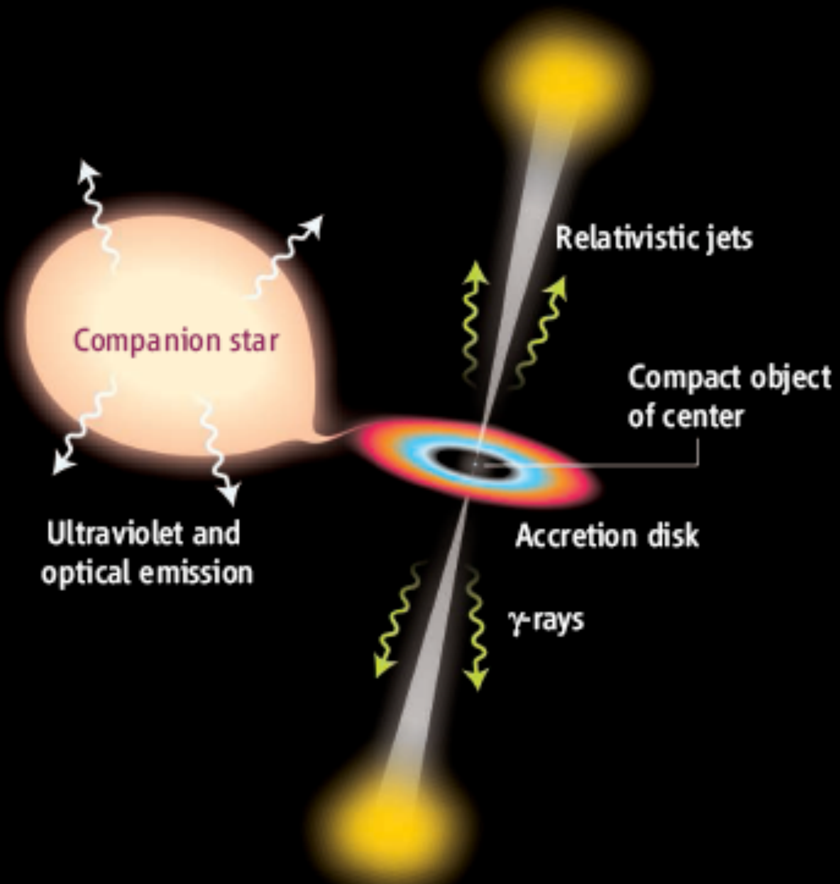
Binary pulsar wind nebula



Felix Mirabel, *Science News & Views*

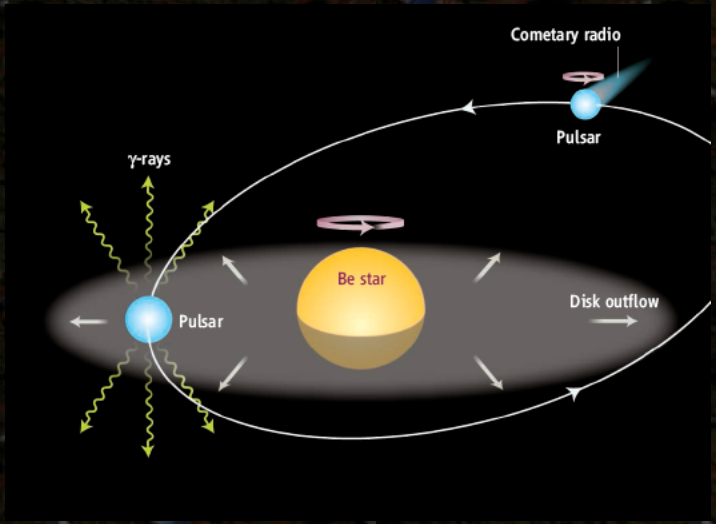
gamma-ray binaries

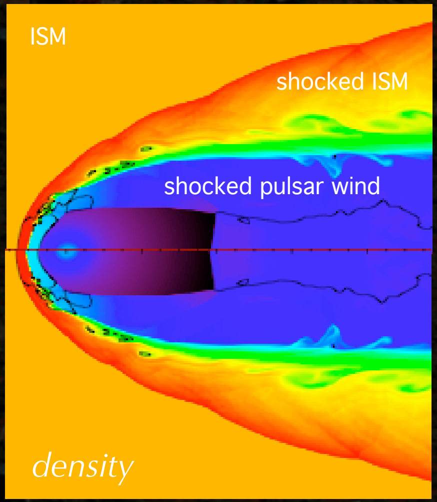
Microquasar jet



Cyg X-1

Pulsar wind physics in binaries





Bucciantini et al. 2005

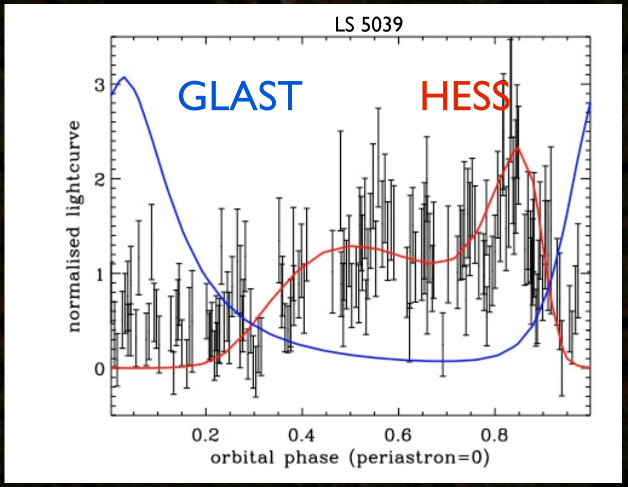
- Rotational energy of a young pulsar powers a relativistic wind, as in the Crab, which is contained by the stellar wind. Probe of pulsar winds on very small scales.
- Containment changes along the orbit: repeated sampling of various conditions for *same* pulsar.
- Great lab to study the formation of relativistic outflows from highly magnetized rotating objects.

Pulsar wind physics in binaries

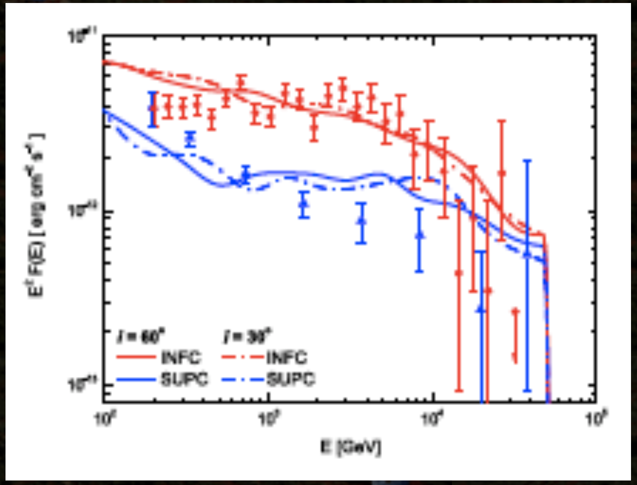
Wish List

- **Phase-resolved spectra,** especially in low-state
  - ➡ CTA: high quality in few hrs (0.01 phase for LS 5039).
- **Census:** about ~ 100 in Galaxy predicted. Constrains binary evolution.
  - ➡ CTA: spatial resolution better suited than GLAST.
  - ➡ CTA: see current systems halfway across the Galaxy: several dozens to expect.
  - ➡ CTA: Galactic plane survey with multiple visits.

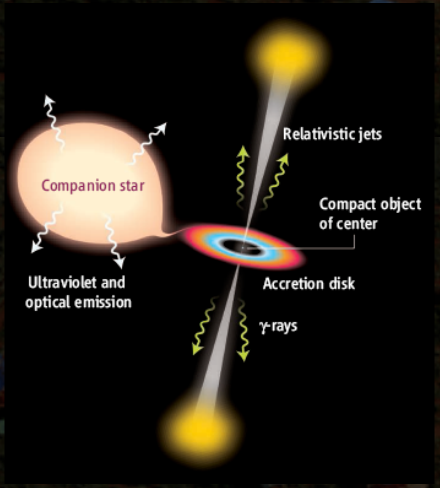
Dubus et al. 2007: B=0.8±0.2 G

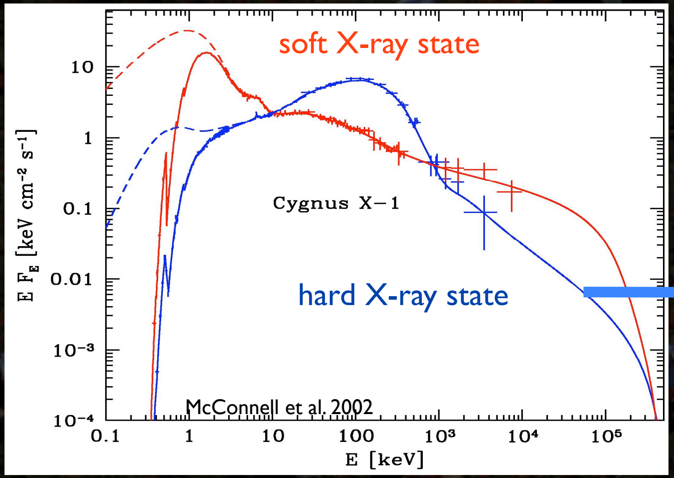


Sierpowska-Bartosik & Torres 2007

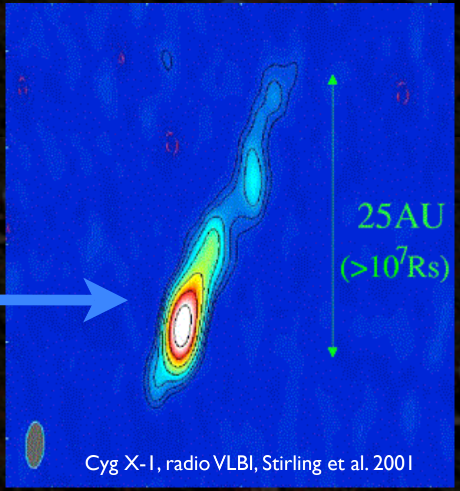


Microquasar jet





steady jet in hard X-ray state

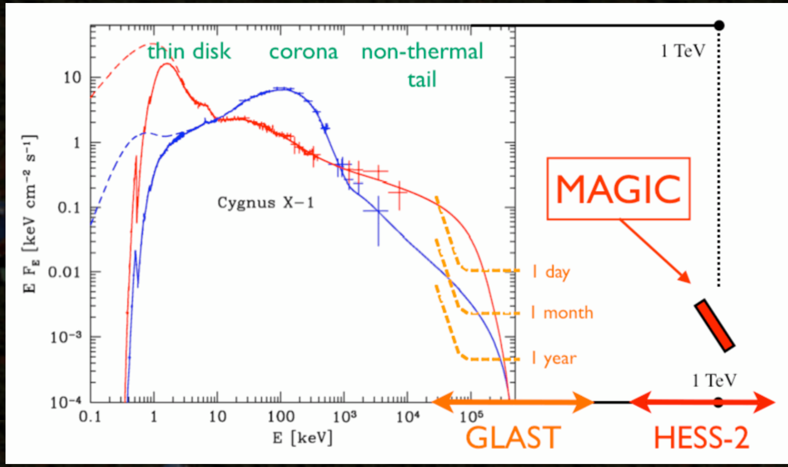


- Accretion-powered but some energy used for ejection: this process likely related to non-thermal emission.
- Microquasars have X-ray states, related to switches between types of accretion flows. Steady or flaring relativistic jet outflow depends on X-ray state. The how and why are unclear.
- Great lab to study accretion ejection around compact objects (better than GRBs or AGNs).

Microquasar jet

Wish List

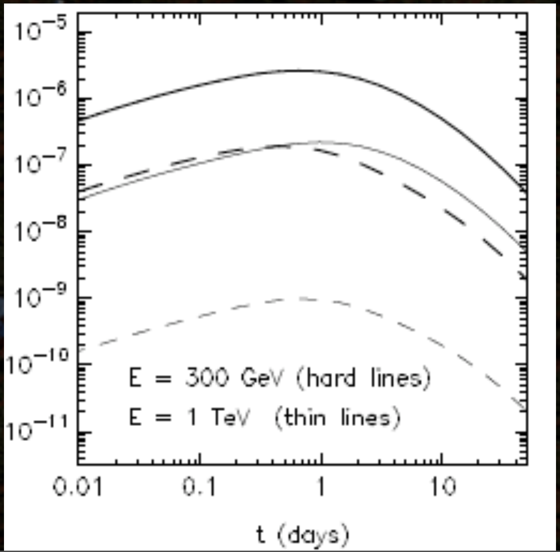
What's happening here?



- Quantify how much non-thermal energy emitted in VHE.
  - ➡ CTA: <100 GeV sensitivity useful.

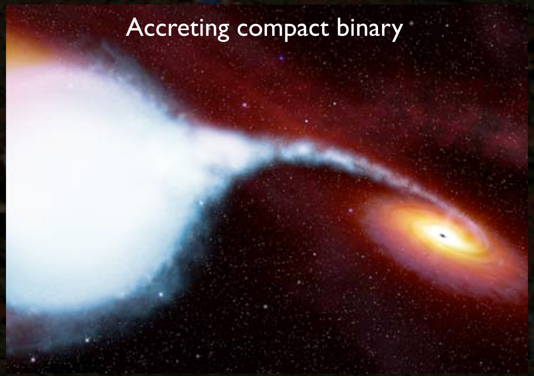
  Flaring on timescales of hours is likely:
  - ➡ CTA detects 0.01 Crab flare in few hours, ie 10^{-5} L_{edd} for a black hole close to Galactic Center.

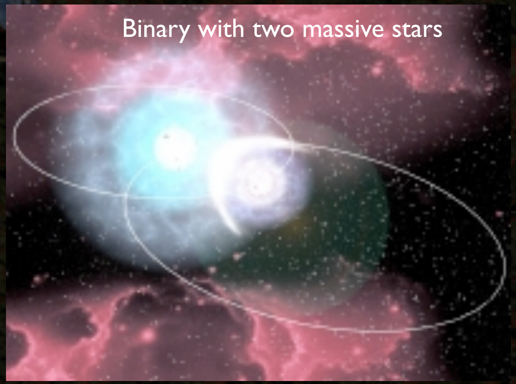
Model GRS 1915+105 flare.
Atoyan & Aharonian 99



- Relate VHE emission to hard X-ray emission from jet/corona.
  - ➡ CTA: split in sub-arrays for efficient monitoring.
  - ➡ CTA: flexibility to ToOs with ~ day turnaround.
  - ➡ CTA: desirable GLAST, LOFAR, SKA overlap.

Summary





- Binaries are emitters of VHE radiation.
  - Breakthrough has come from the ability to localize point sources to arcmin scales and to study their variability on day timescales.
  - *Binary PWN* (γ-ray binaries) *microquasars* (Cyg X-1).
- Science objectives for CTA:
  - Obtain phase-resolved spectra of gamma-ray binaries and use this to *study relativistic outflows from highly magnetized rotating objects.*
  - Quantify how much VHE radiation is emitted in microquasars, relate it to spectral states and use this to *study accretion ejection around compact objects.*
- Future breakthroughs should come from a *deep survey of the Galaxy*, and the *ability to monitor* sources for sub-hour flaring.