Galactic Binary Systems

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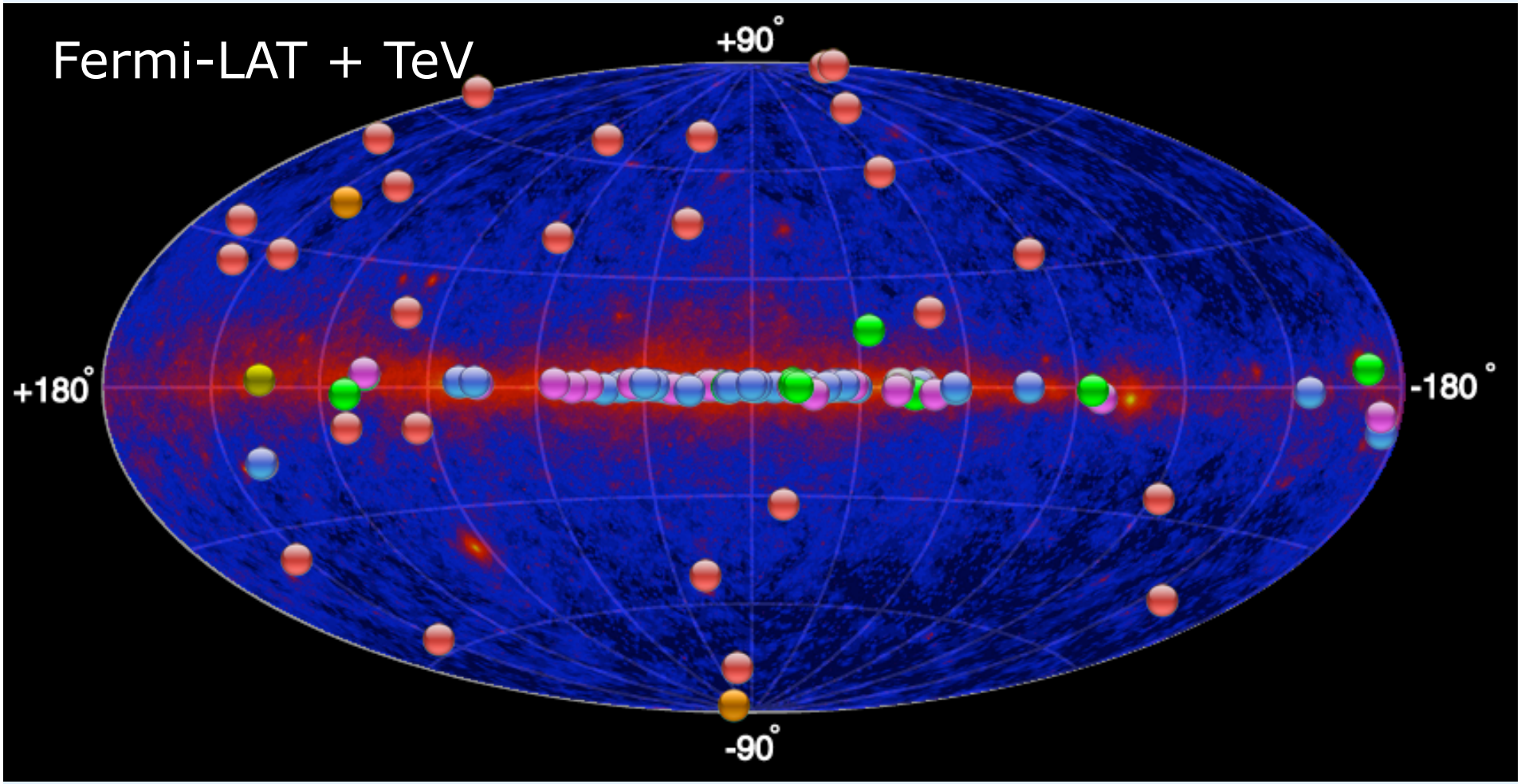
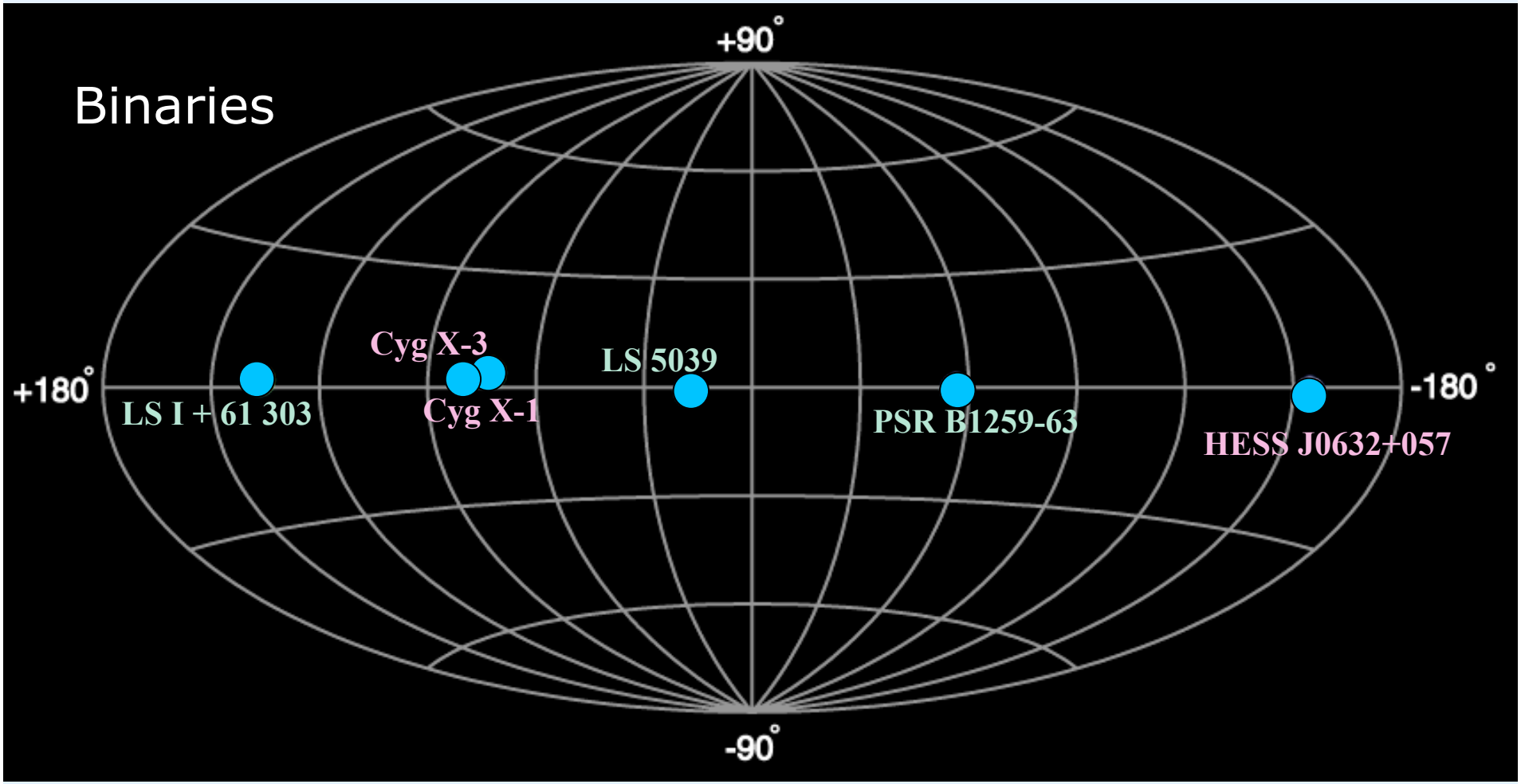
Overview

- Why are they interesting?
- Some history
- Observational status
- Interpretation
- Some questions we can answer soon

The Gamma-ray sky




Binaries
+90°
+180°
-180°
-90°
Cyg X-3
LS 5039
LS I + 61 303
Cyg X-1
PSR B1259-63
HESS J0632+057

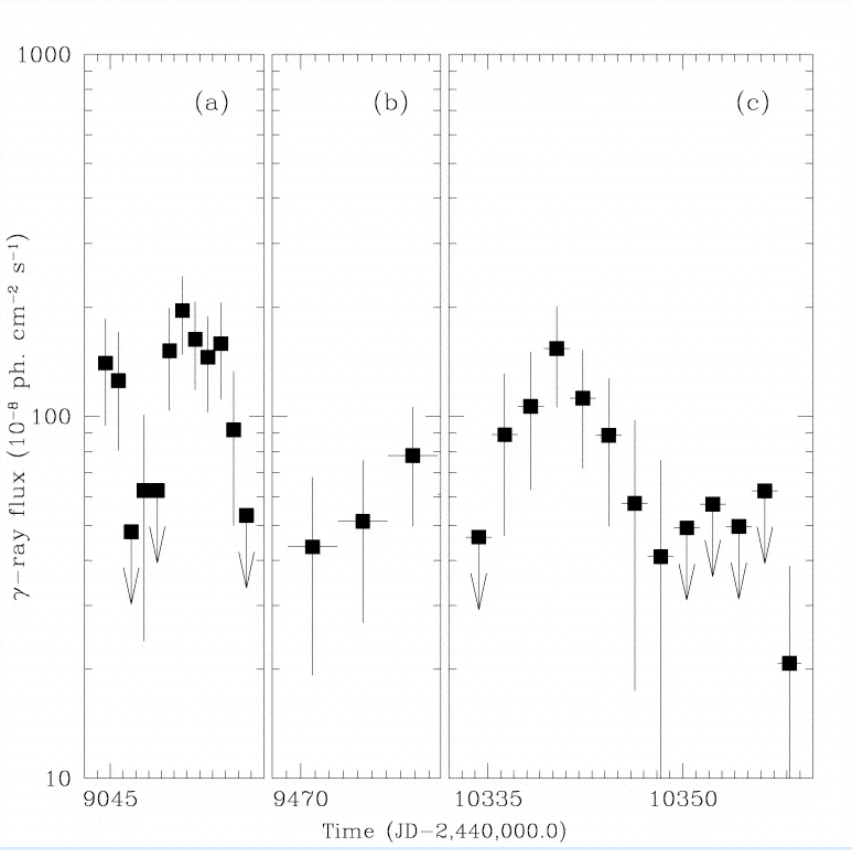
Why are these few so interesting?

- Binaries are the *only* variable galactic TeV sources
- They are natural particle accelerators operating under varying, but ***regularly repeating***, environmental conditions
- Provide a constraining laboratory for models of particle acceleration, and gamma-ray production, emission and absorption processes.
- May provide the keys to an understanding of astrophysical jets
- Each system is unique – and the population, as well as the data quality, is increasing

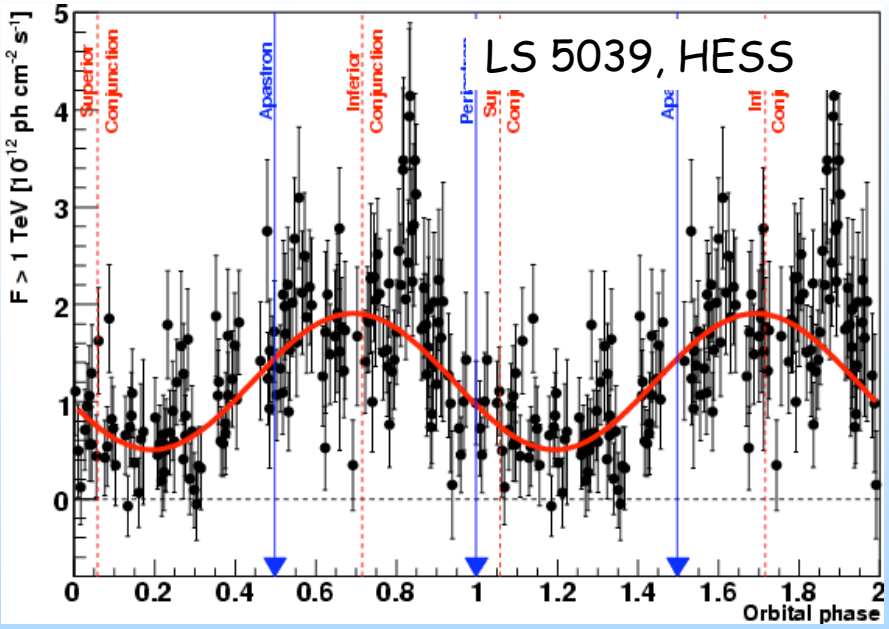
Brief history of High Energy binary results

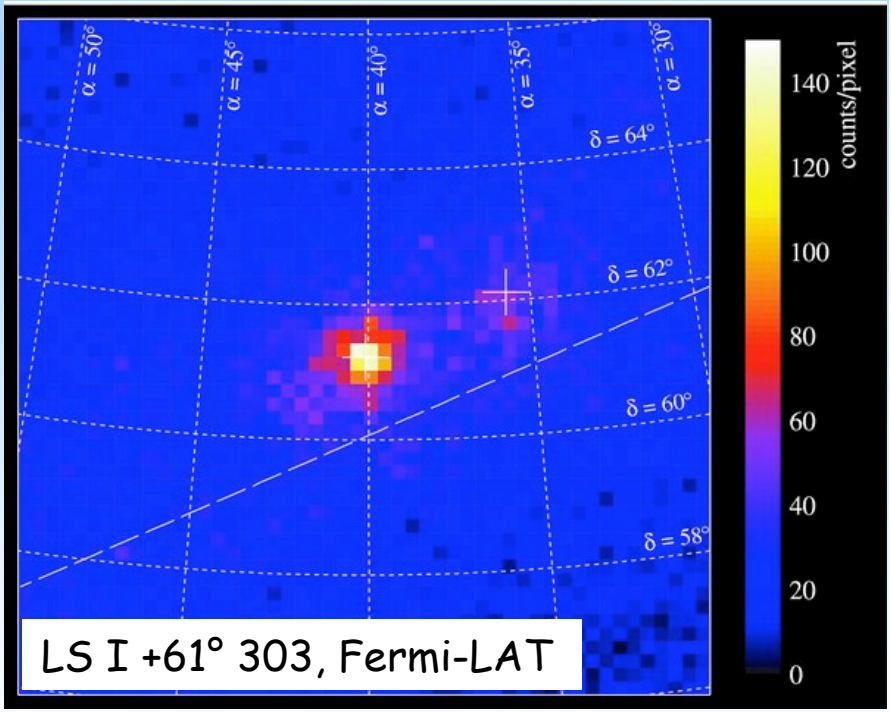
- Cygnus X-3 caused a lot of excitement in the 70's/ early 80's
- Among 13 gamma-ray sources, COS-B detected 2CG 135+01; the error box contained a periodic radio and X-ray source (LS I +61° 303).
- Various EGRET sources were associated with binaries
  - 3EG J0241+6103 (LS I +61° 303), Tavani et al., ApJ 1998
  - 3EG J1824-1514 (LS 5039), Paredes et al., Science, 2000
  - 2EG J2033+4112 (Cyg X-3) Mori et al., ApJ, 1997
- But weak or no variability, no periodicity, and limited positional accuracy

3EG J0241+6103, Tavani et al.,1998



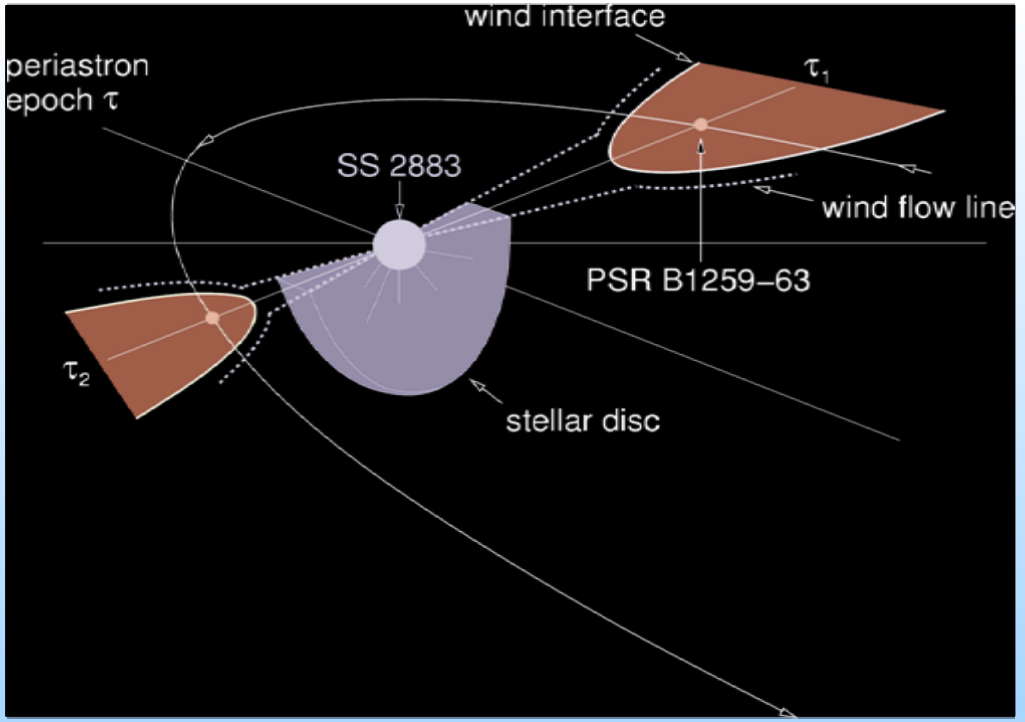
- 2004 – 2006: a few TeV sources strongly detected >100 GeV
  - PSR B1259-63 (HESS)
  - LS 5039 (HESS)
  - LS I +61° 303 (MAGIC)
- With good positions and clear, orbitally modulated variability, the associations are definitive.
- Fermi-LAT provides the next leap
  - Good sensitivity
  - Source localization
  - Near continuous monitoring
  - Firm ID of LS I +61° 303, LS 5039
- Stop press! AGILE detects transient emission from Cygnus X-3
- New LAT results at this conference

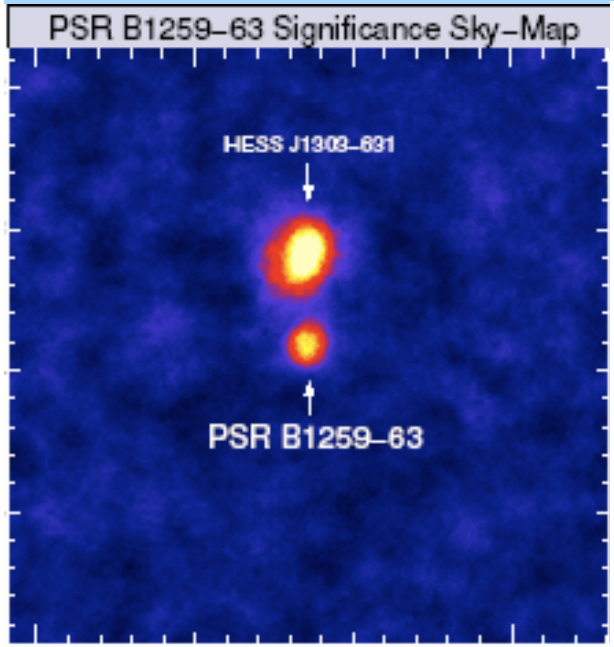


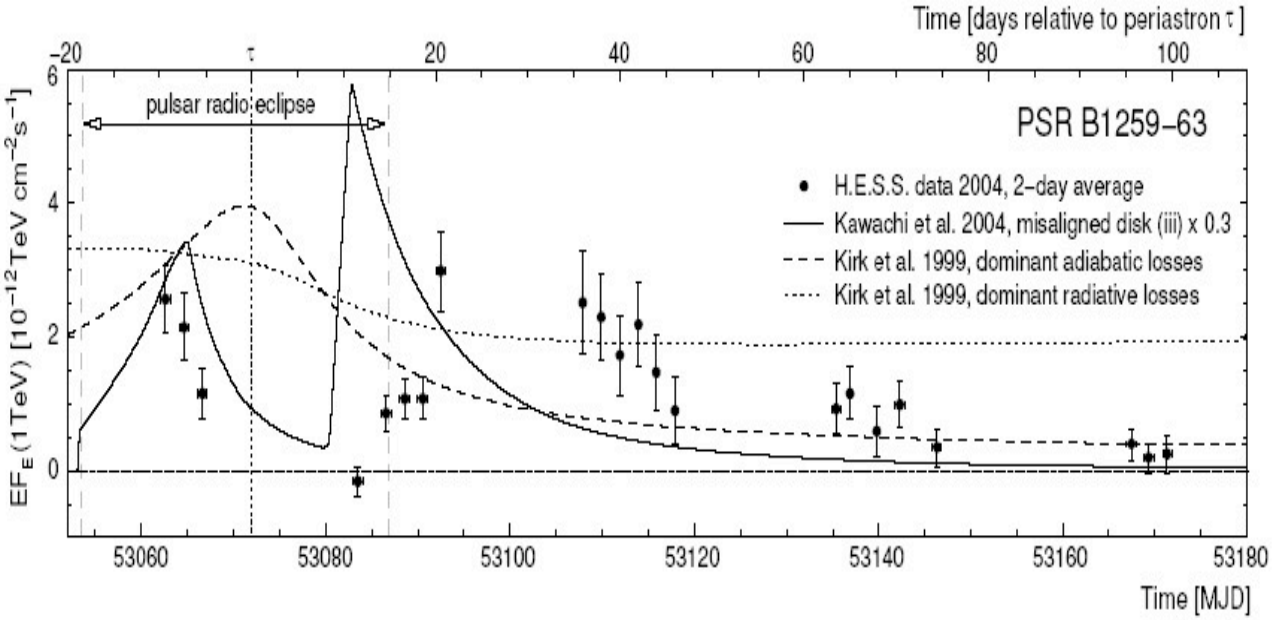


PSR B1259-63/ SS2883

- 48 ms pulsar orbiting a B2e companion with inclined disk
- 3.4 year, high eccentric orbit
- ~0.7 A.U separation at periastron (10 AU at apastron)
- Detected by HESS during 2004 periastron

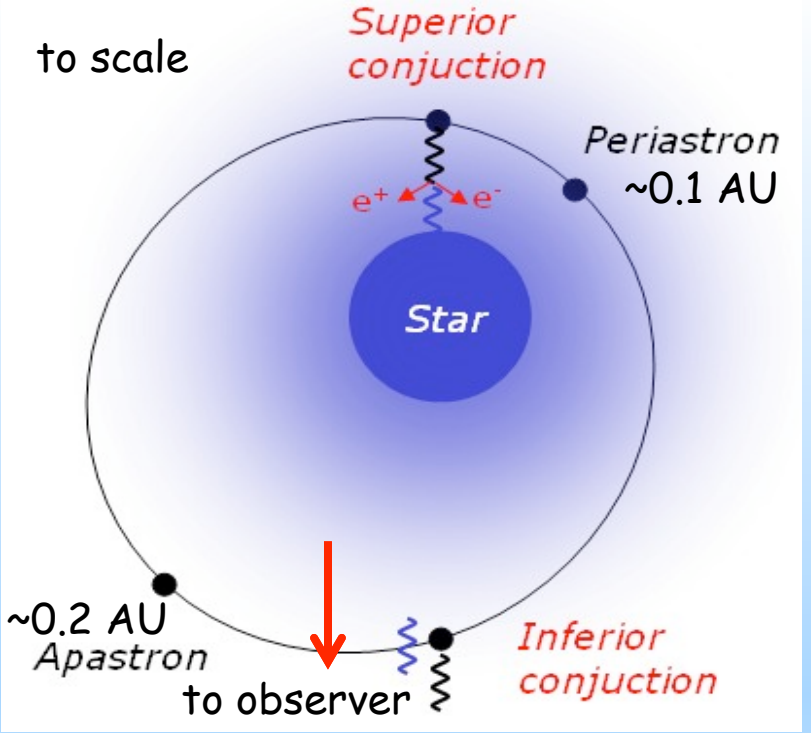


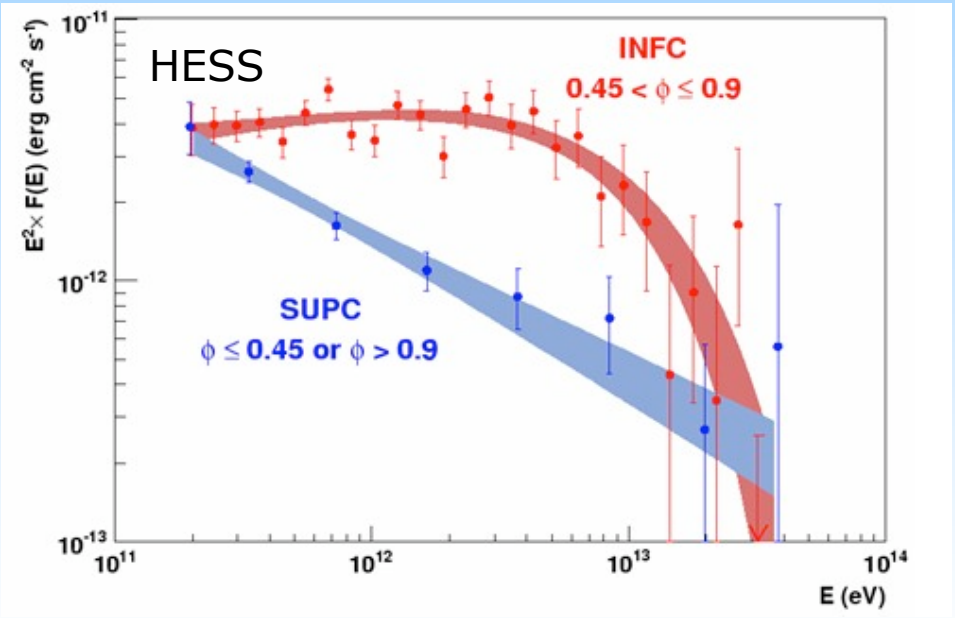


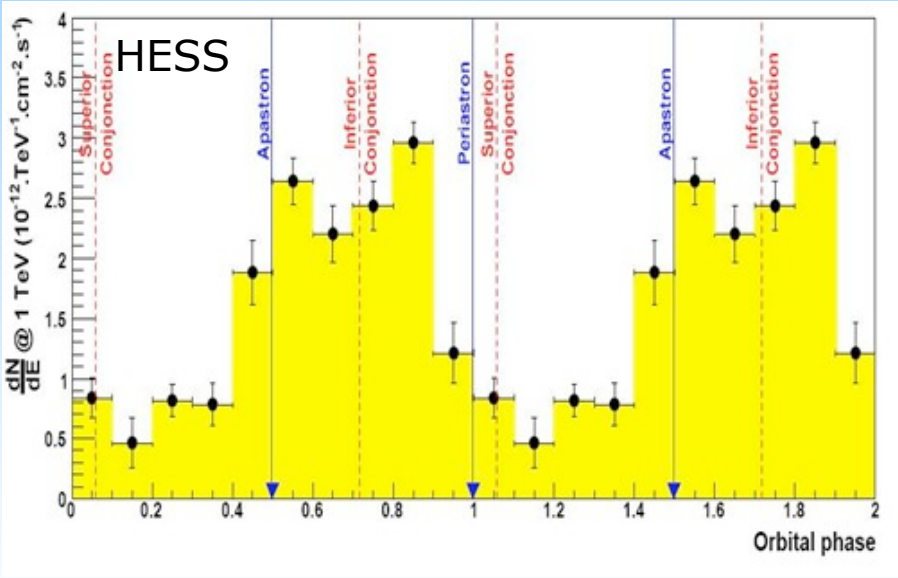


LS 5039

- Compact object orbiting an O6.5V companion ($23M_{\odot}$)
- 3.9 day, inclined orbit, e=0.35
- HESS measure clear periodicity >200GeV
- emission peaks at inferior conjuction
- spectrum varies





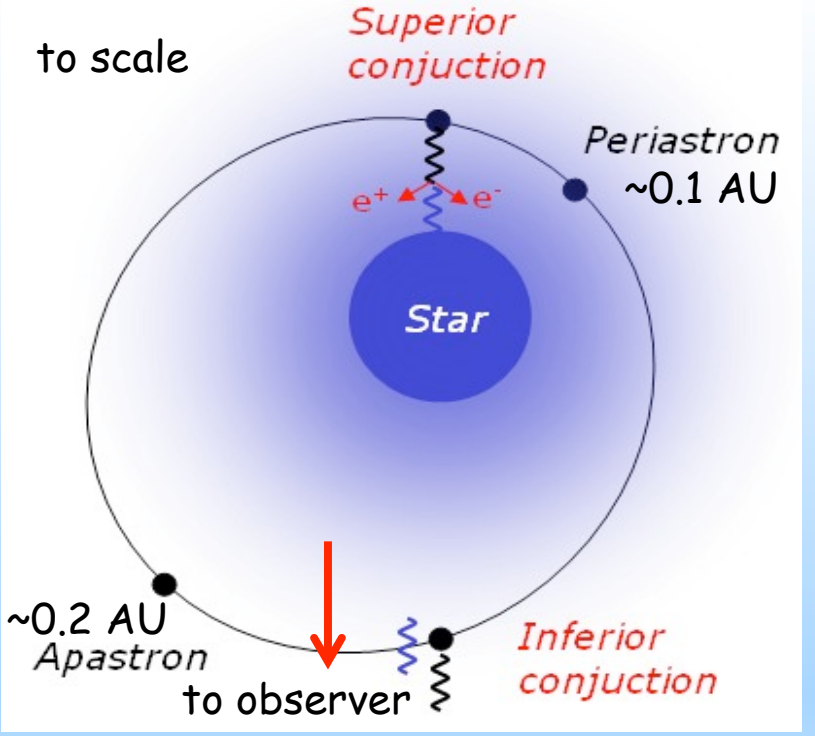


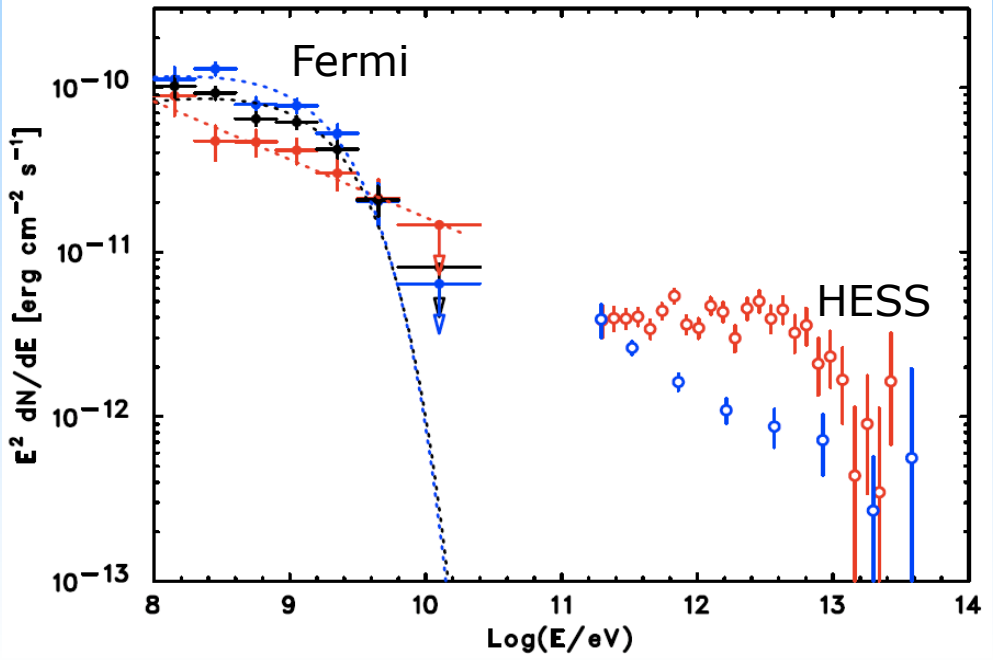
LS 5039

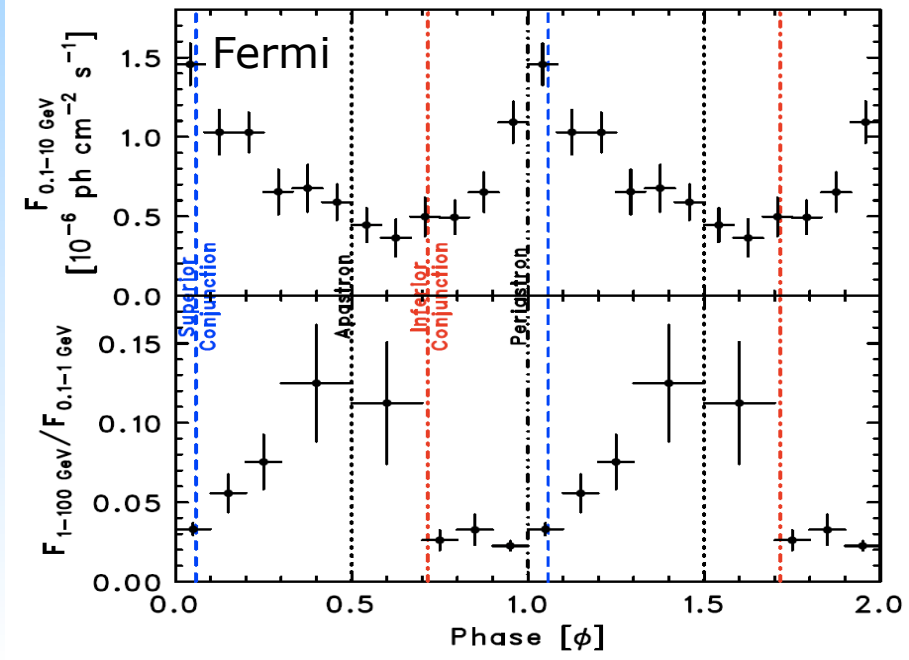
- Detected by Fermi-LAT (BSL)
- Orbital modulation now measured
- See Dubois, this Symposium

(and arXiv:0910.5520, ApJL 706, L56)

- Flux variability *anti-correlated* with HESS
- Spectral variability, and ~2 GeV cut-off observed

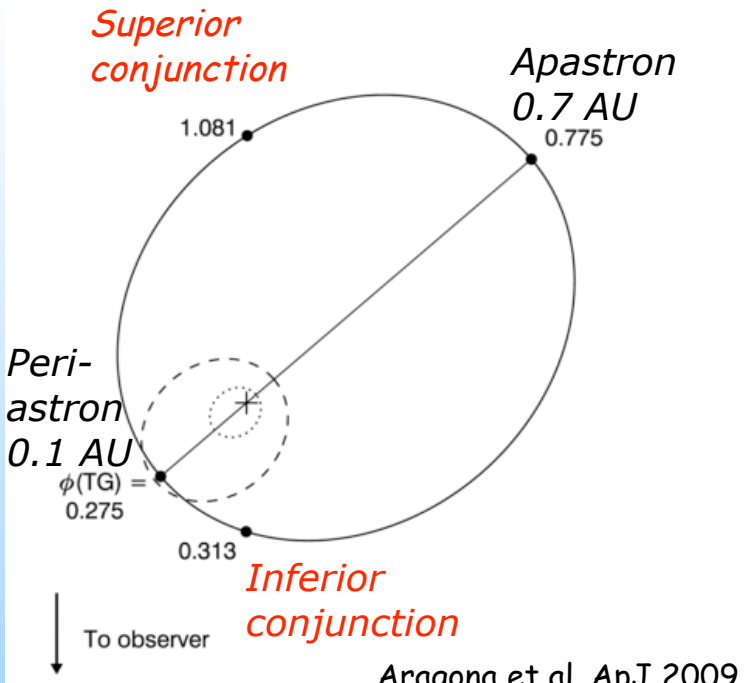




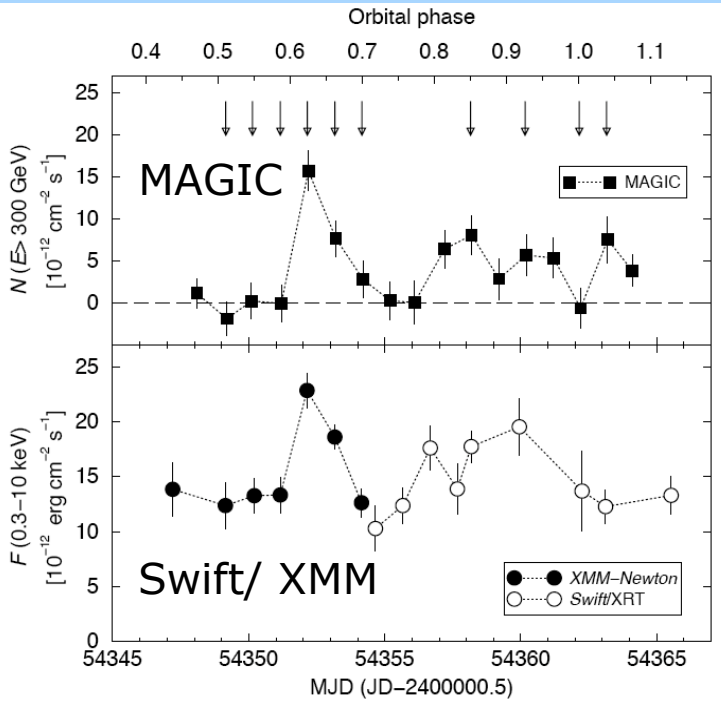


LS I +61° 303

- Compact object orbiting an B0Ve companion (12.5$M_\odot$).
- 26.5 day, inclined orbit, e=0.54
- extended radio structures; microquasar?
- Detected by MAGIC, then VERITAS
- Strong emission only detected near apastron (ϕ=0.5-0.8)
- MAGIC measure periodicity, and X-ray correlation in 60% of one orbit (arxiv: 0910.4381)
- X-ray emission is periodic, but shows more than just orbital variability, and some evidence for bright flares (e.g. Smith et al, 2009)



Aragona et al. ApJ 2009

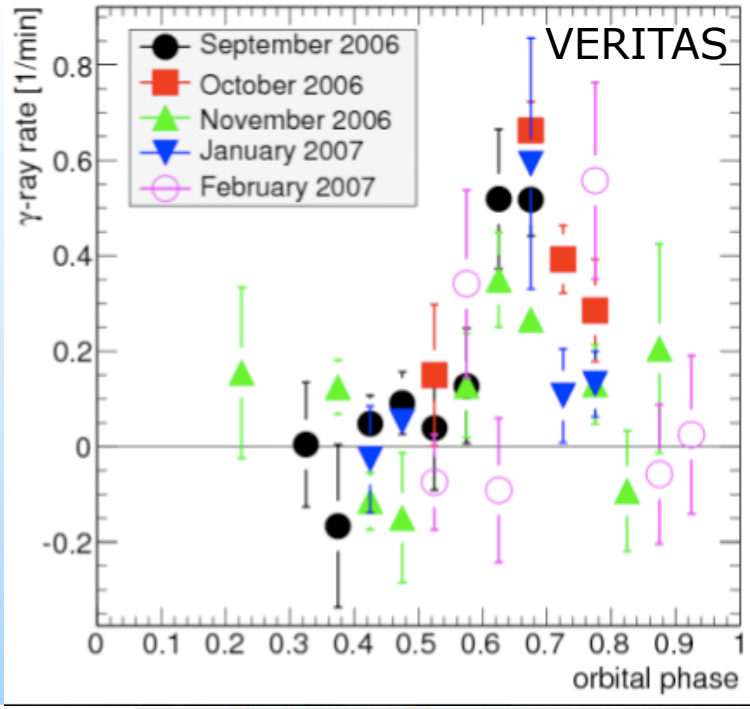


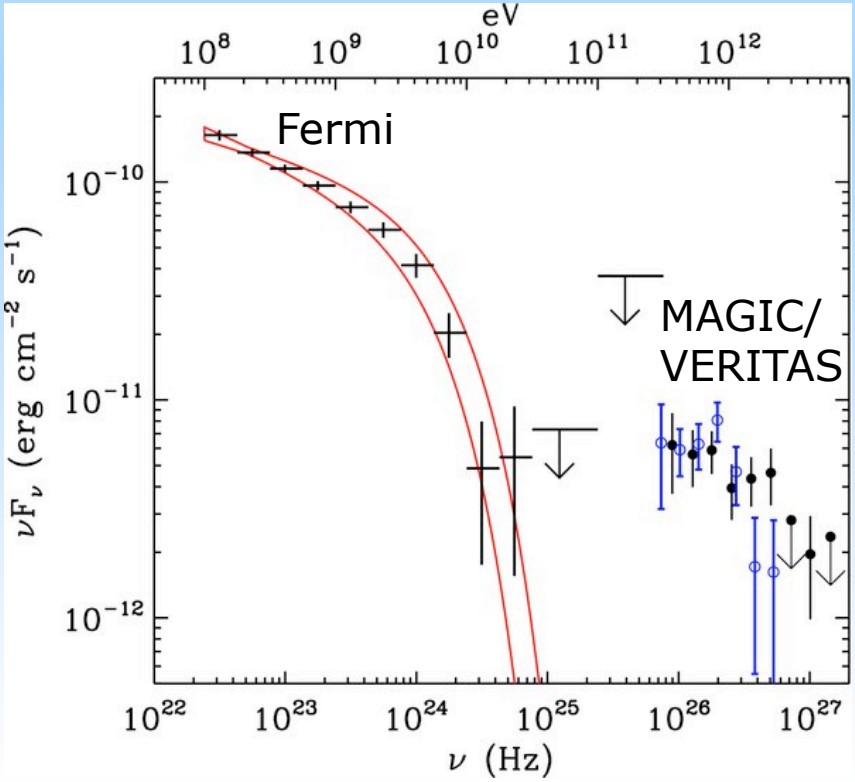
LS I +61° 303

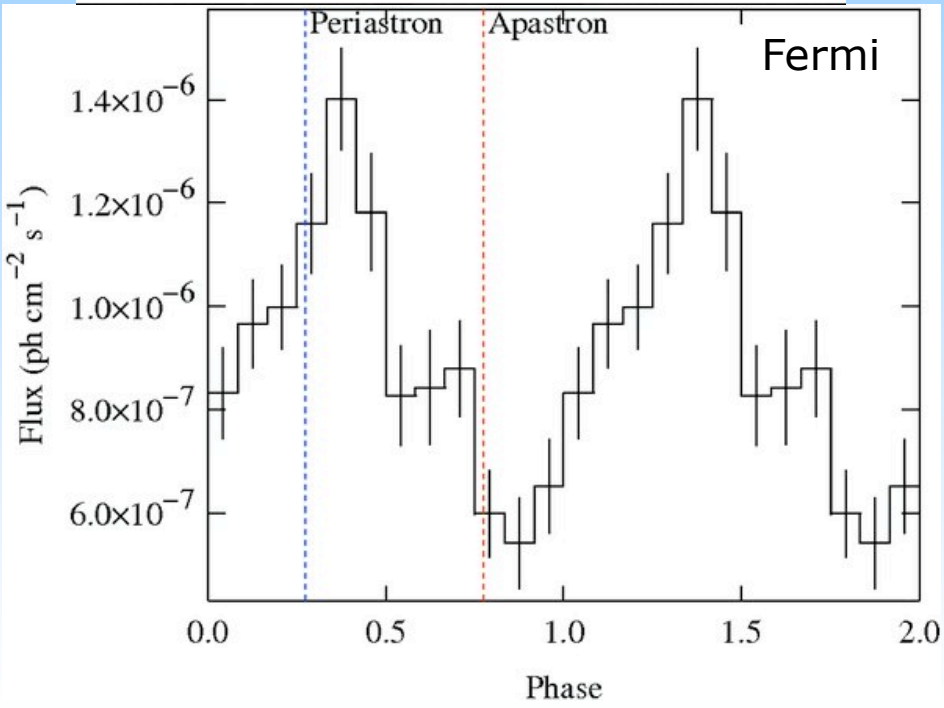
- Detected by Fermi-LAT (BSL)
- Orbital modulation well measured
- See Dubois, this Symposium

(and Abdo, ApJ, 2009)

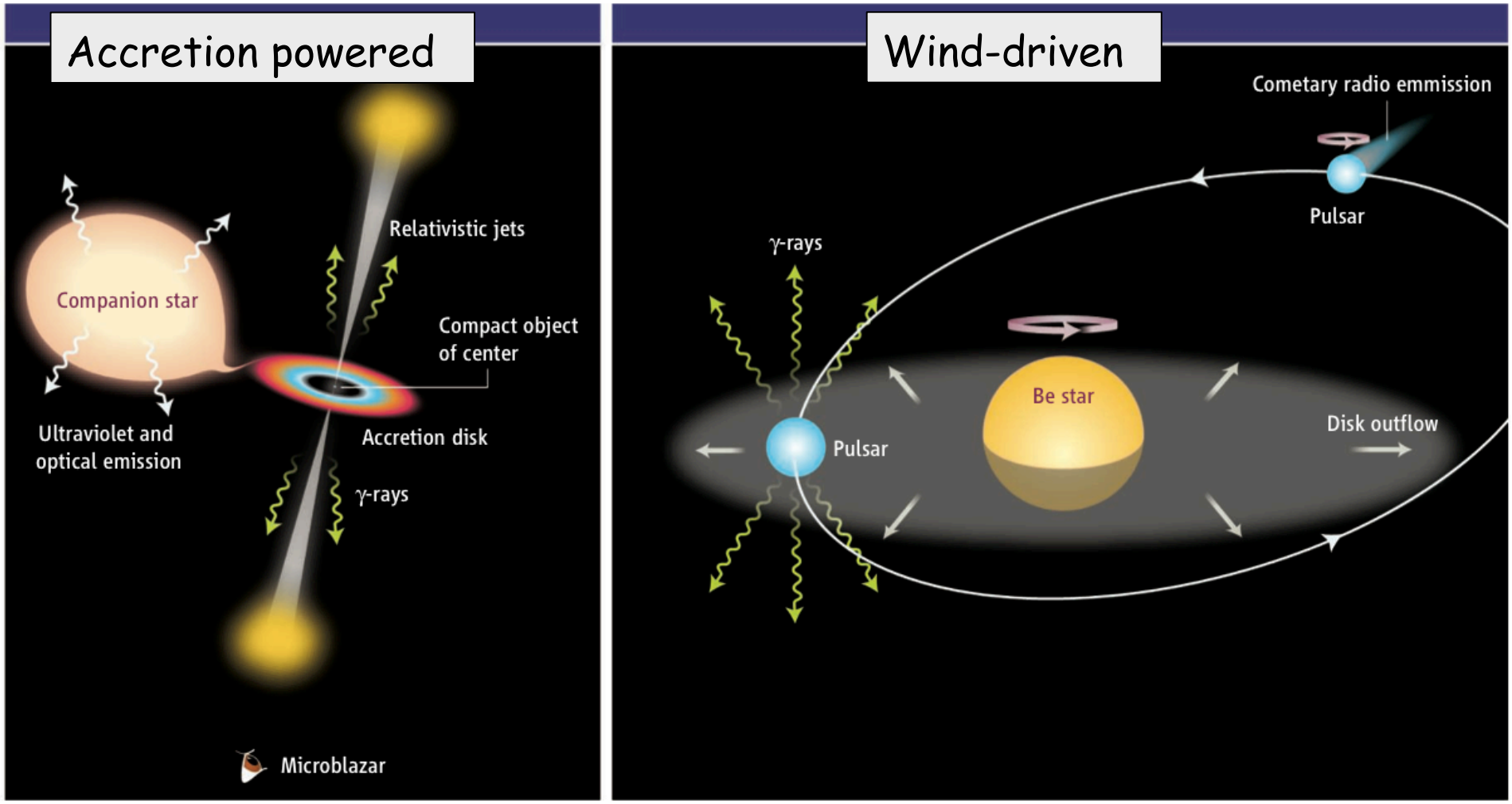
- Emission peaks near *periastron*
- ~6 GeV cut-off observed







What's going on?



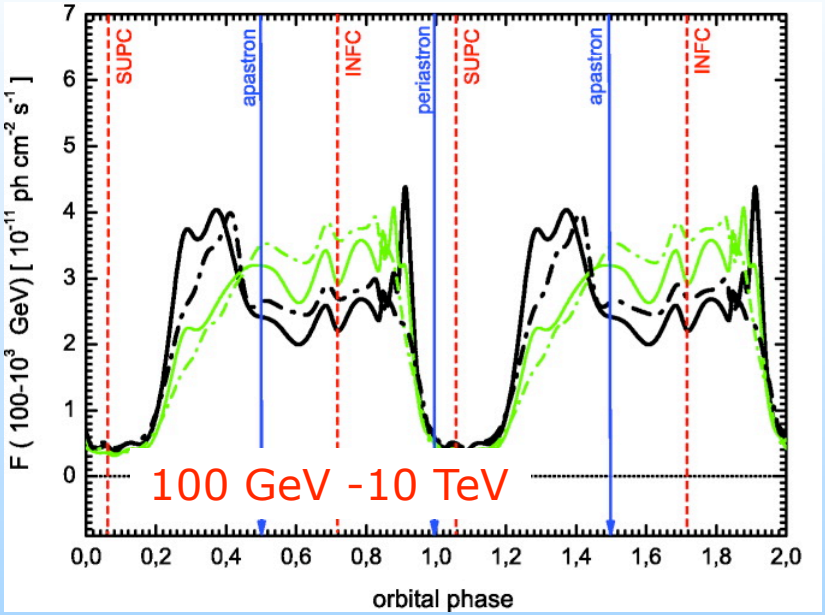
Mirabel (Science 309, 714, 2006)

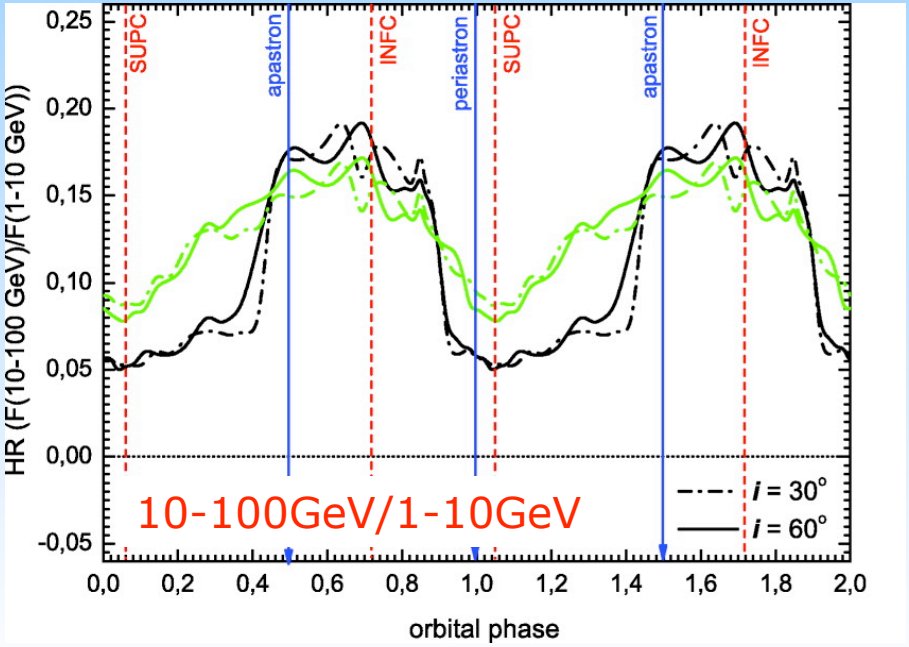
A few things to think about (not exhaustive)...

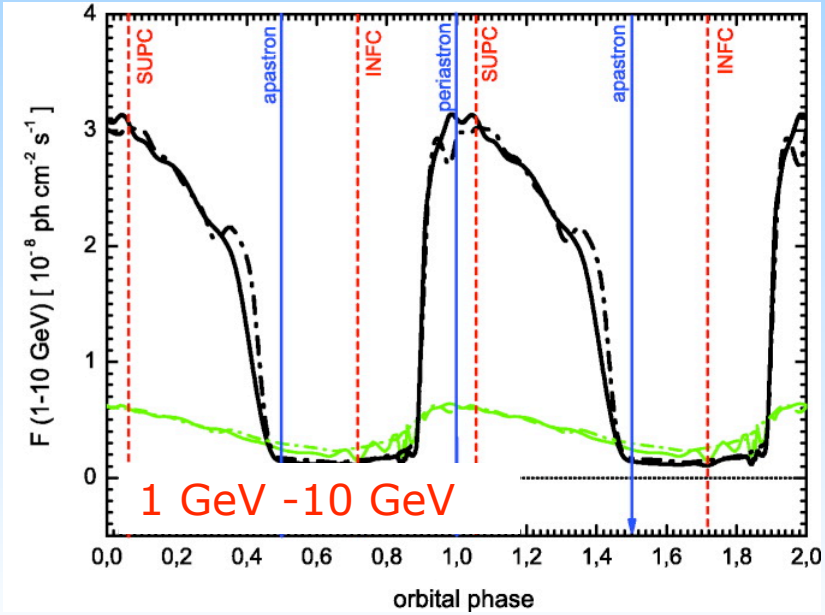
What is the power source?	Accretion-powered jet	Pulsar wind		
What is the particle acceleration mechanism?	Jet shocks	Magnetic reconnection	Wind shocks	
What are the dominant particles?	Hadronic	Leptonic		
How are the γ-rays produced?	Pion decay	Inverse Compton	Curvature Radiation	
Where are the γ-rays produced?	Near the jet	Wind collision region	Pulsar wind zone	
	Circumstellar environment	Pulsar magnetosphere		
What modulates the flux?	Geometry	Photon fields	Matter density	B-fields
Other effects?	Wind clumping	Pair cascades	Unknown geometries	

Many of these are not mutually exclusive...

- Difficult, but detailed predictions can be made, and are beginning to be strongly tested
- (e.g. Sierpowska-Bartosik & Torres, LS 5039)



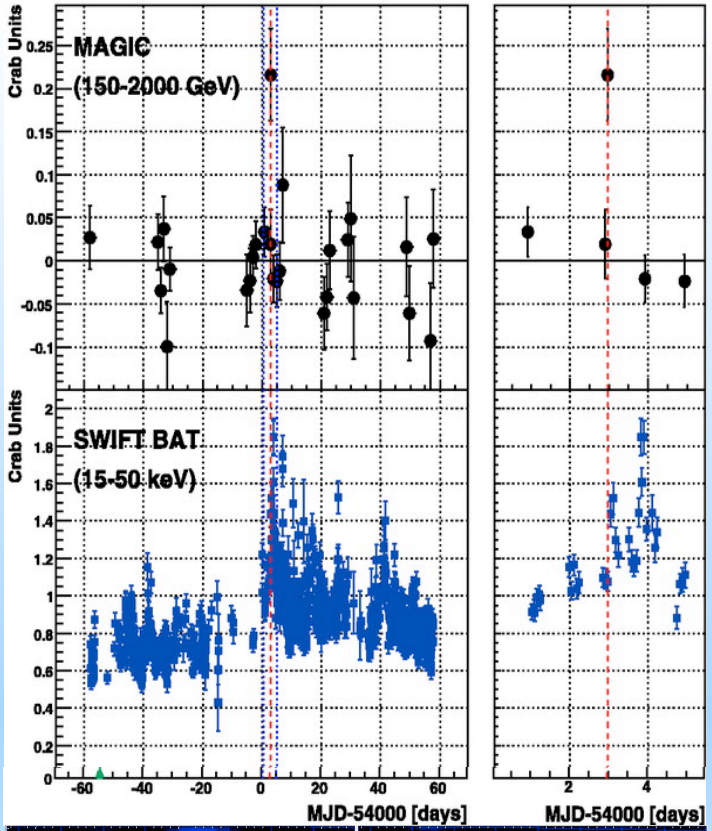


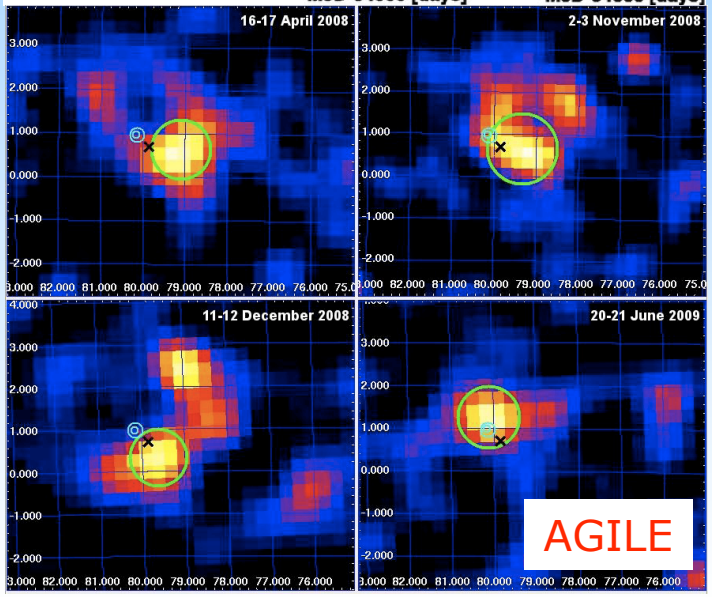


The microquasars

- Cygnus X-1 21±8 $M_\odot$ compact object, 40±10 $M_\odot$ O9.7Iab companion.
- 5.6 day circular orbit
- Accretion powered
- MAGIC observed 40 hours: no emission
- See one episode at ~4σ, close to an X-ray flare

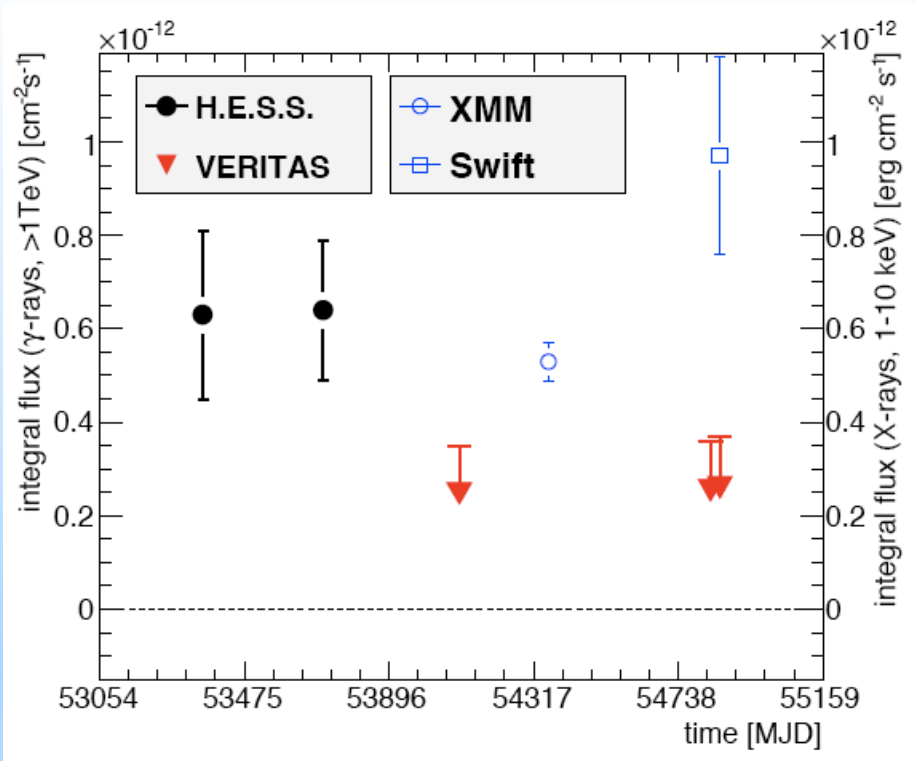
- Cygnus X-3 10-20 $M_\odot$ compact object, Wolf-Rayet companion.
- 4.8 hour orbit
- Accretion powered
- AGILE detect 4 episodes of GeV emission during soft X-ray states
- New Fermi-LAT results presented yesterday (Stephane Corbel)
- Orbital modulation gives firm identification



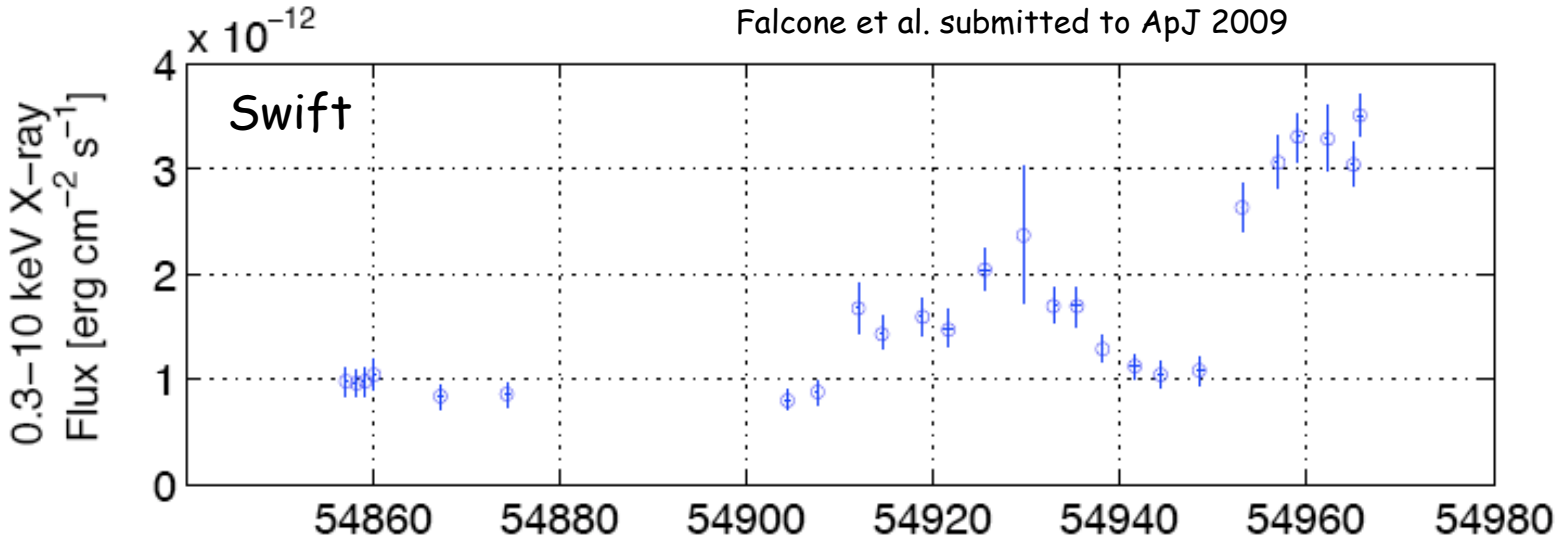


A mystery…

- HESS J0632+057
- Unidentified TeV source in the Galactic plane
- A rare unresolved source
- VERITAS non-detection implies gamma-ray variability
- X-ray & radio sources coincident with a Be star (MWC148)
- Swift measures long term variability



Falcone et al. submitted to ApJ 2009



Summary

- Gamma-ray binaries constitute a small, but uniquely valuable, population of high energy sources.
- The field is extremely active: some key observational questions which may be resolved shortly
  - What is the cause of the Fermi-LAT GeV cutoffs?
  - What other binaries does the LAT see?
  - What will HESS & Fermi see from PSR B1259-63 in 2010/2011?
  - Does Cygnus X-3 produce TeV emission? When?
  - What is HESS J0632+057?
- Ongoing multiwavelength campaigns on LS I +61° 303 and HESSJ0632+057. See VERITAS home page and gammamw list for details.