(X-ray) binaries in γ-rays

Guillaume Dubus

Understanding relativistic jets, Kraków 2011

Institut de Planétologie et d'Astrophysique de Grenoble

Variable galactic γ-ray sources

gamma-ray binaries

O/Be + compact object: PSR B1259, LS 5039, LS I+61 303, HESS J0632, 1FGL J1018

X-ray binaries / microquasars in gamma-rays

WR/O + compact object: Cyg X-3, (Cyg X-1)

symbiotic novae

M giant + white dwarf: V407 Cyg

colliding wind binaries

massive star binary: (Eta Carinae)

pulsars

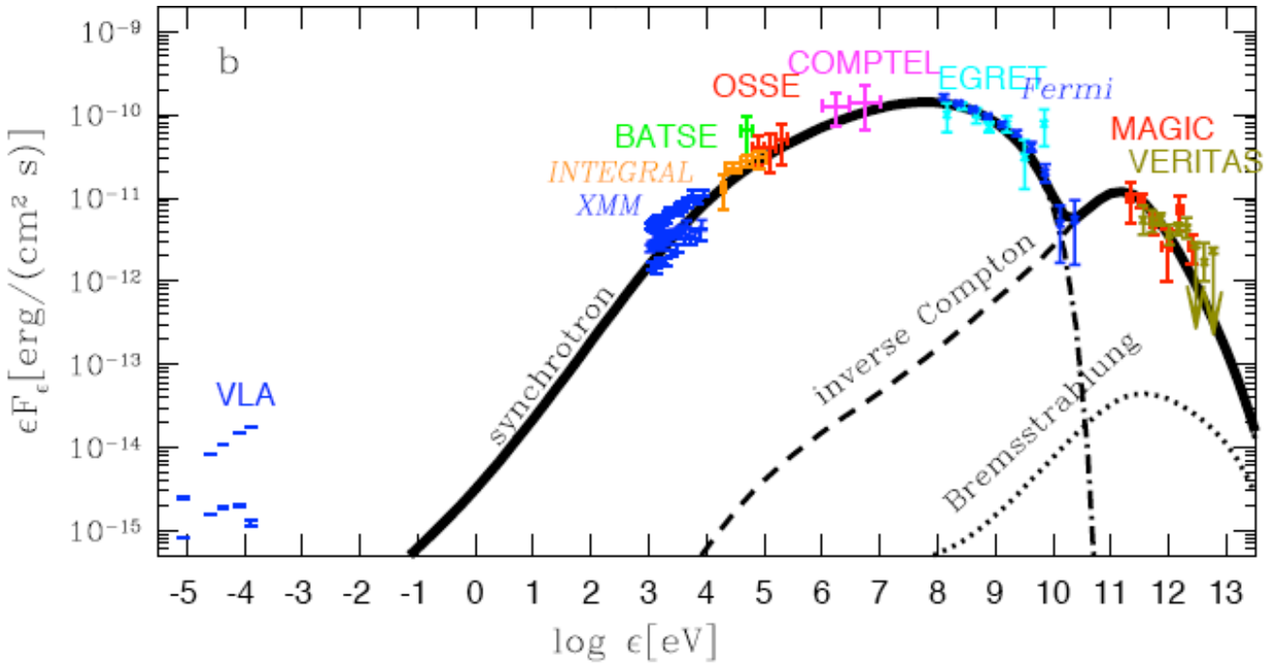
Crab flare, pulsars in binaries

unidentified transients in the Galactic Plane

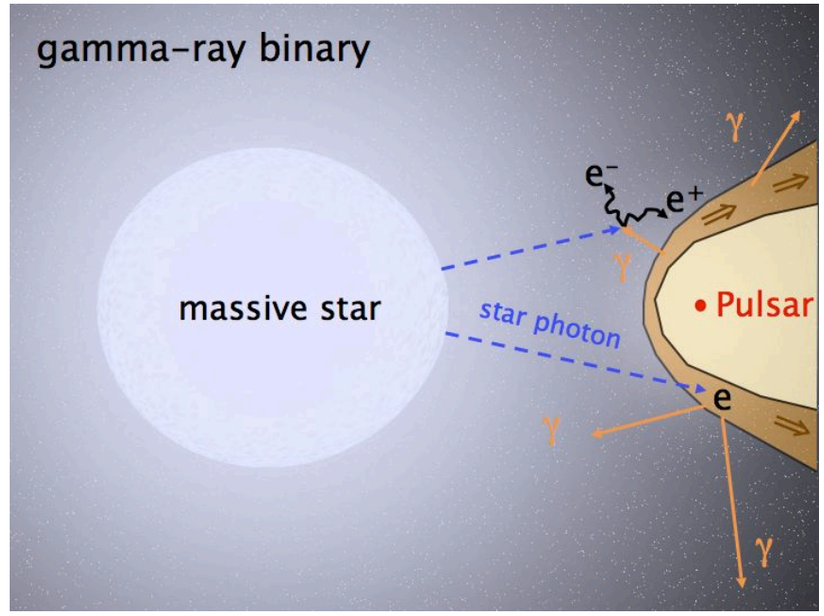
interacting black hole or neutron star + normal star

Gamma-ray binaries

- **O/Be + compact object** PSR B1259-63, LS 5039, LS I+61 303, HESS J0632, 1FGL J1018
- **dominant gamma-ray emission**
- **likely pulsar winds in binaries** PSR B1259-63



LS I +61 303 spectral energy distribution (Zdziarski et al. 2009)



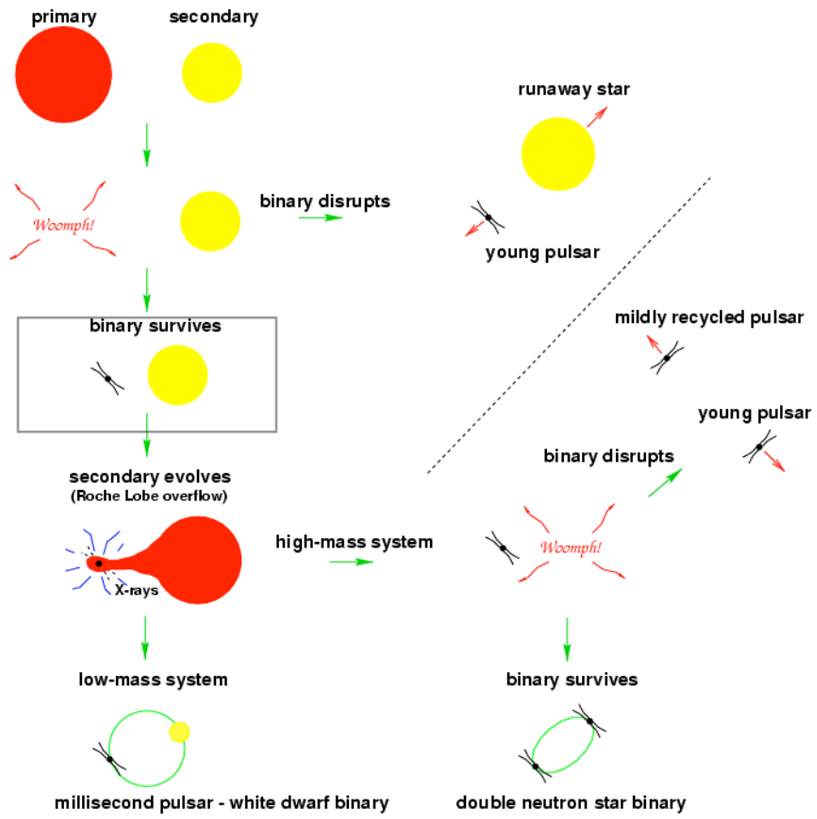
Gamma-ray binaries

- O/Be + compact object PSR B1259-63, LS 5039, LS I+61 303, HESS J0632, 1FGL J1018
- dominant gamma-ray emission
- likely pulsar winds in binaries PSR B1259-63
- known & expected

γ-rays

	pulse (ms)	P_{orb}	companion	dE/dt (erg/s)
PSR B1259-63	0.048	1237d	Be	$8\ 10^{35}$
PSR J1740-3052	0.570	231d	> 11 $M_\odot$	$5\ 10^{33}$
PSR J1638-4725	0.764	1941d	> 6 $M_\odot$	$4\ 10^{32}$
PSR J0045-7319	0.926	51d	> 4 $M_\odot$	$2\ 10^{32}$

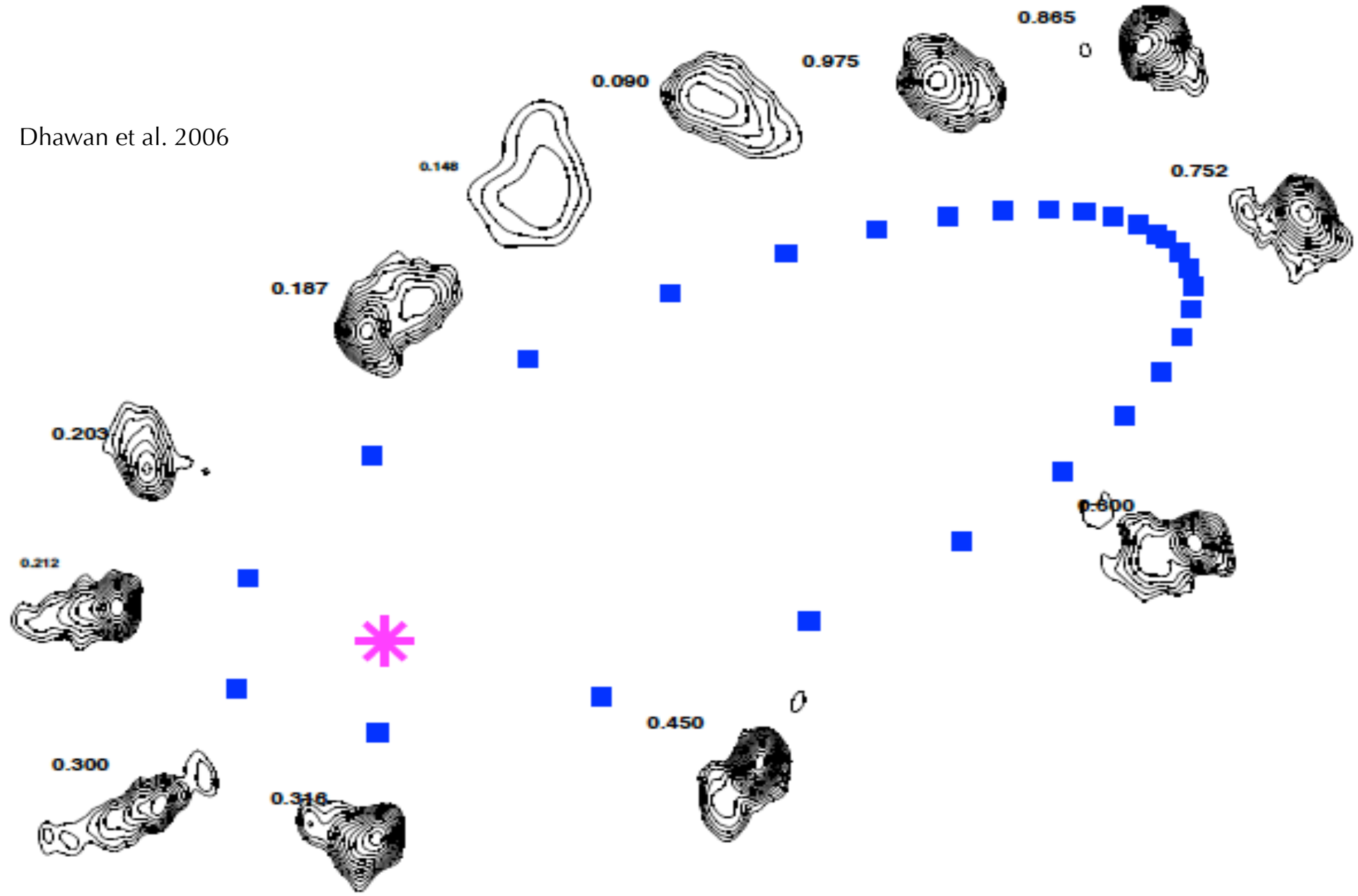
pulsar catalog



Lorimer 2008

Radio morphology

Dhawan et al. 2006



“comet tails” on m.a.s. scales in PSR B1259-63, LS I+61°303, LS5039

Gamma-ray binaries

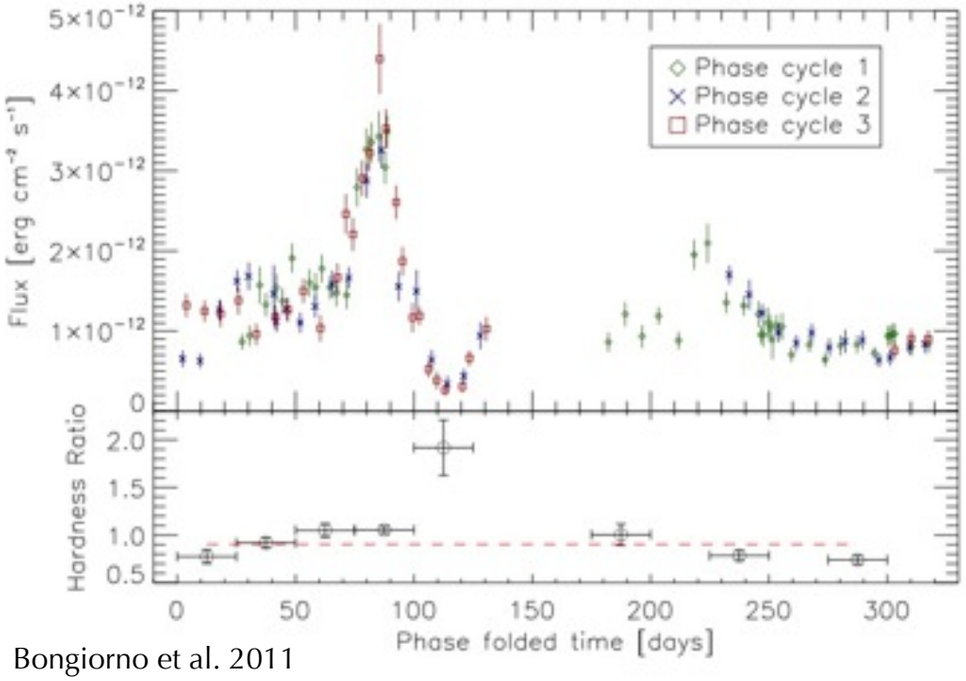
system			P_{orb}	radio	X-ray	GeV	TeV
PSR B1259-63	psr	Be	1237			NEW	
LS 5039	?	O	3.9				
LS I +61°303	?	Be	26.5				
HESS J0632+057	?	Be NEW	320				
NEW 1FGL J1018.6-5856	?	O	16.6				

detected

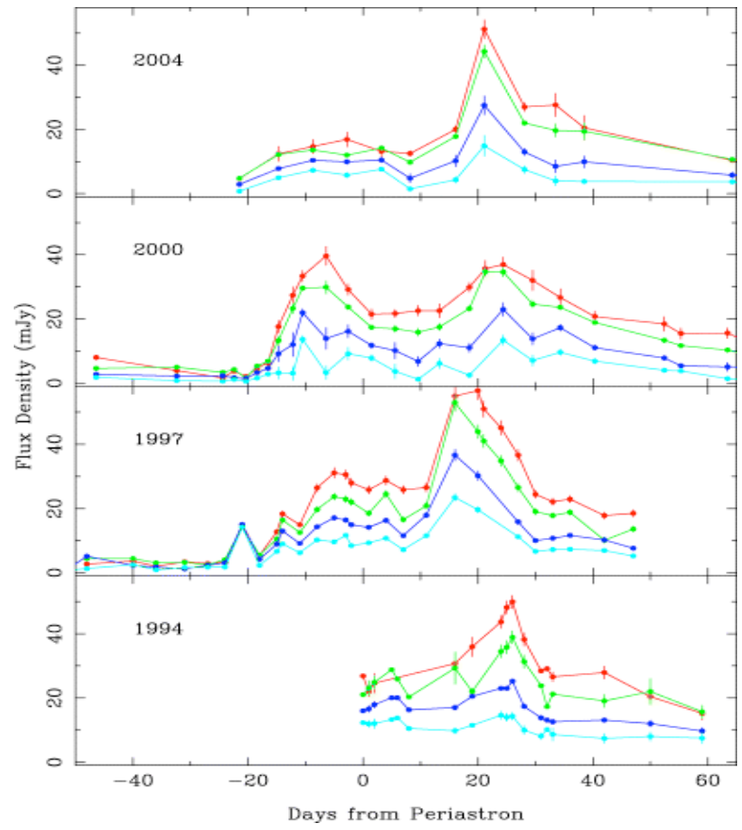
detected + orbital modulation

Orbital modulations

X-rays (HESS J0632) (Swift)

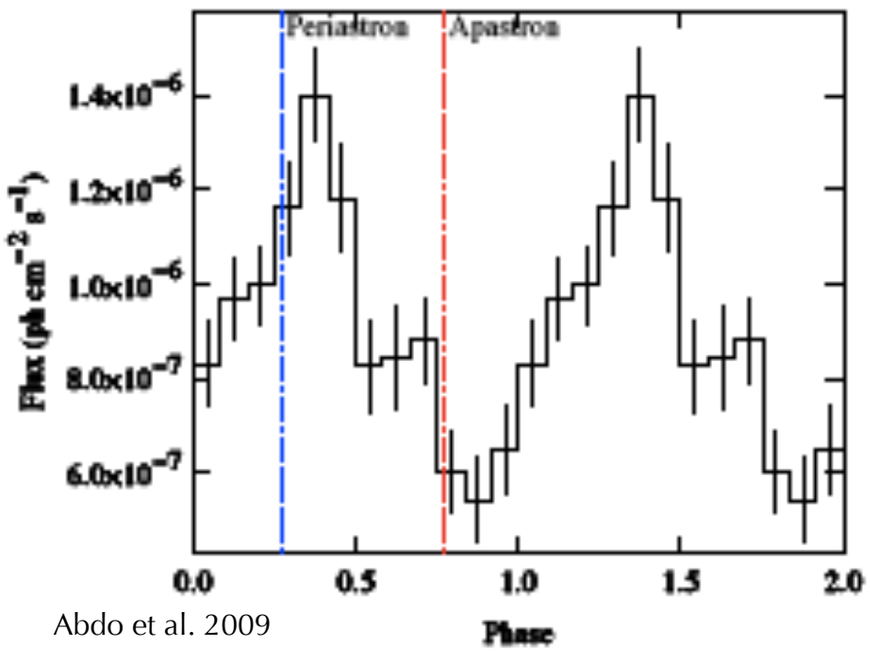


Bongiorno et al. 2011



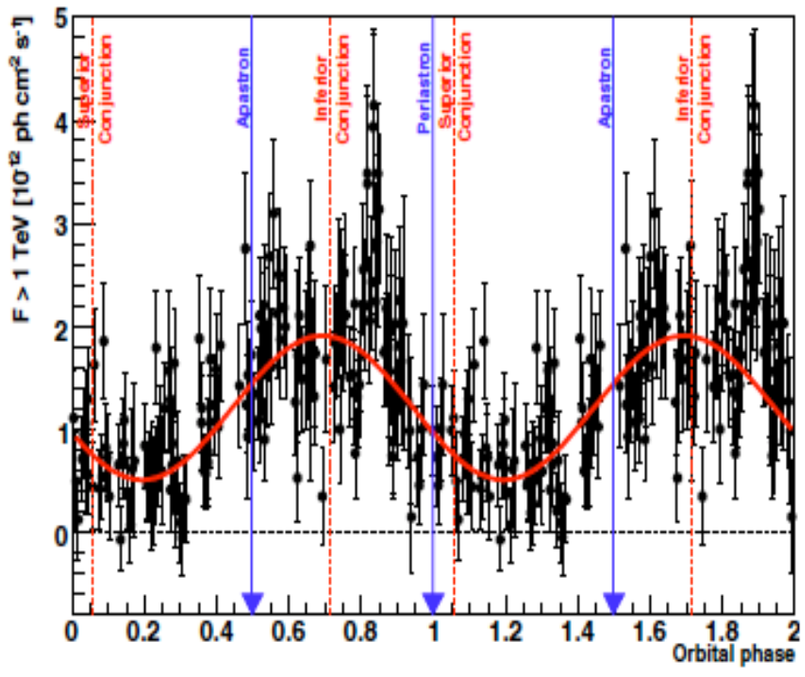
radio (PSR B1259-63) (Parkes)

Johnston et al. 2005



Abdo et al. 2009

GeV (LS I+61 303) (Fermi/LAT)

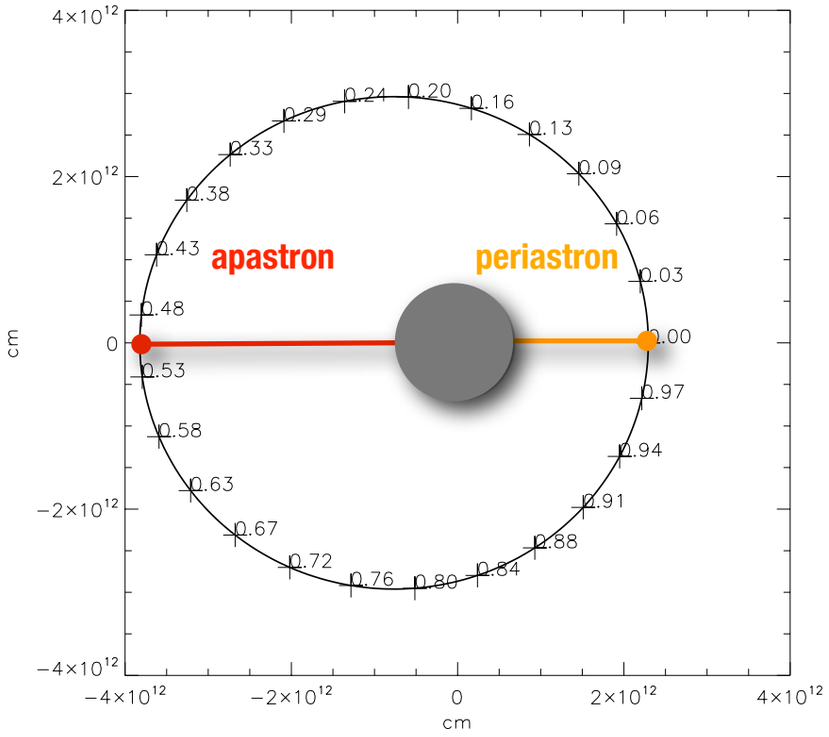


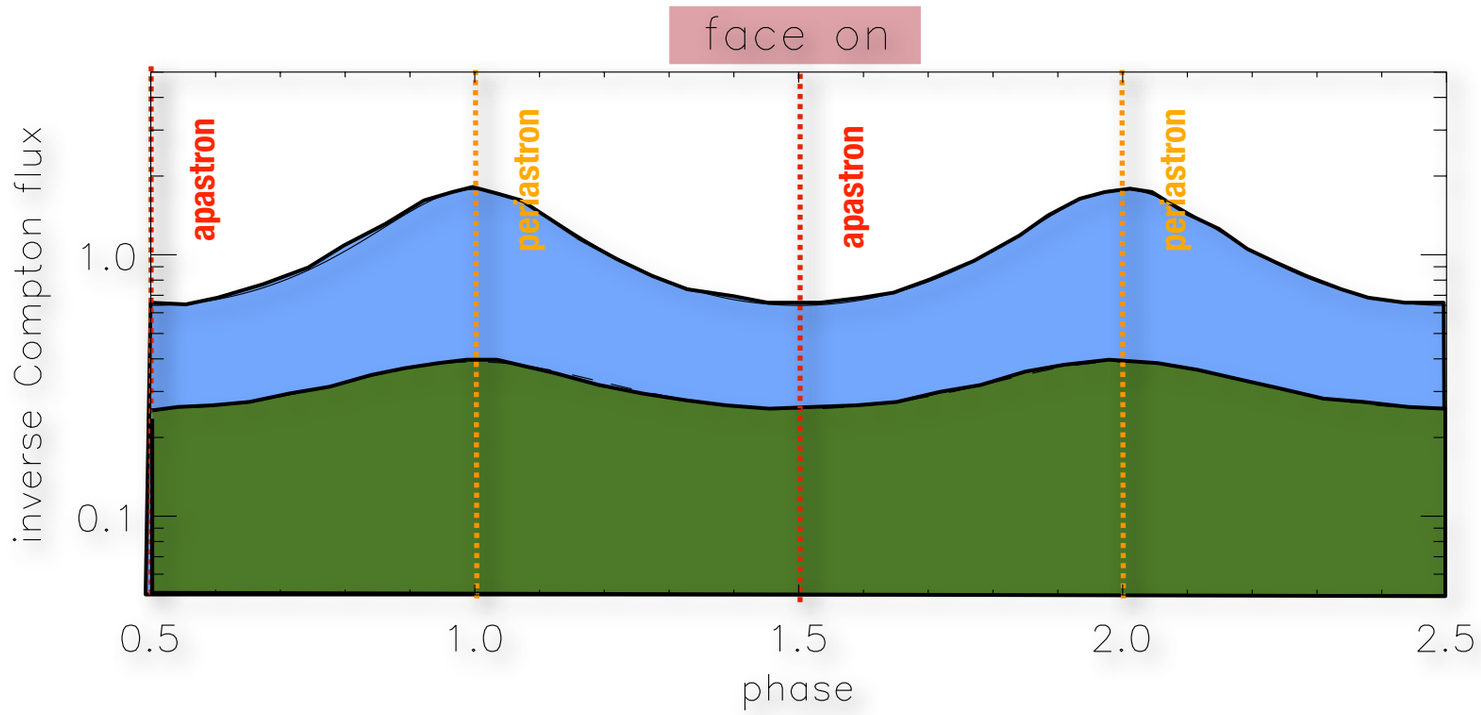
TeV (LS 5039) (HESS)

Aharonian et al. 2006

γ-ray modulation

- **inverse Compton on star photons**
- **pair production on star photons (opacity)**





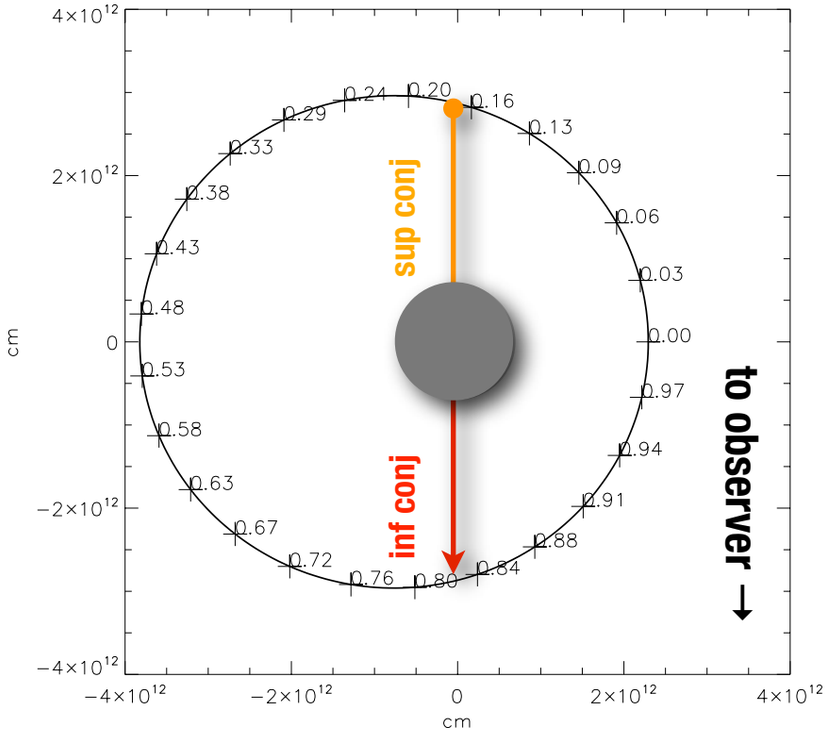
inverse Compton (GeV)

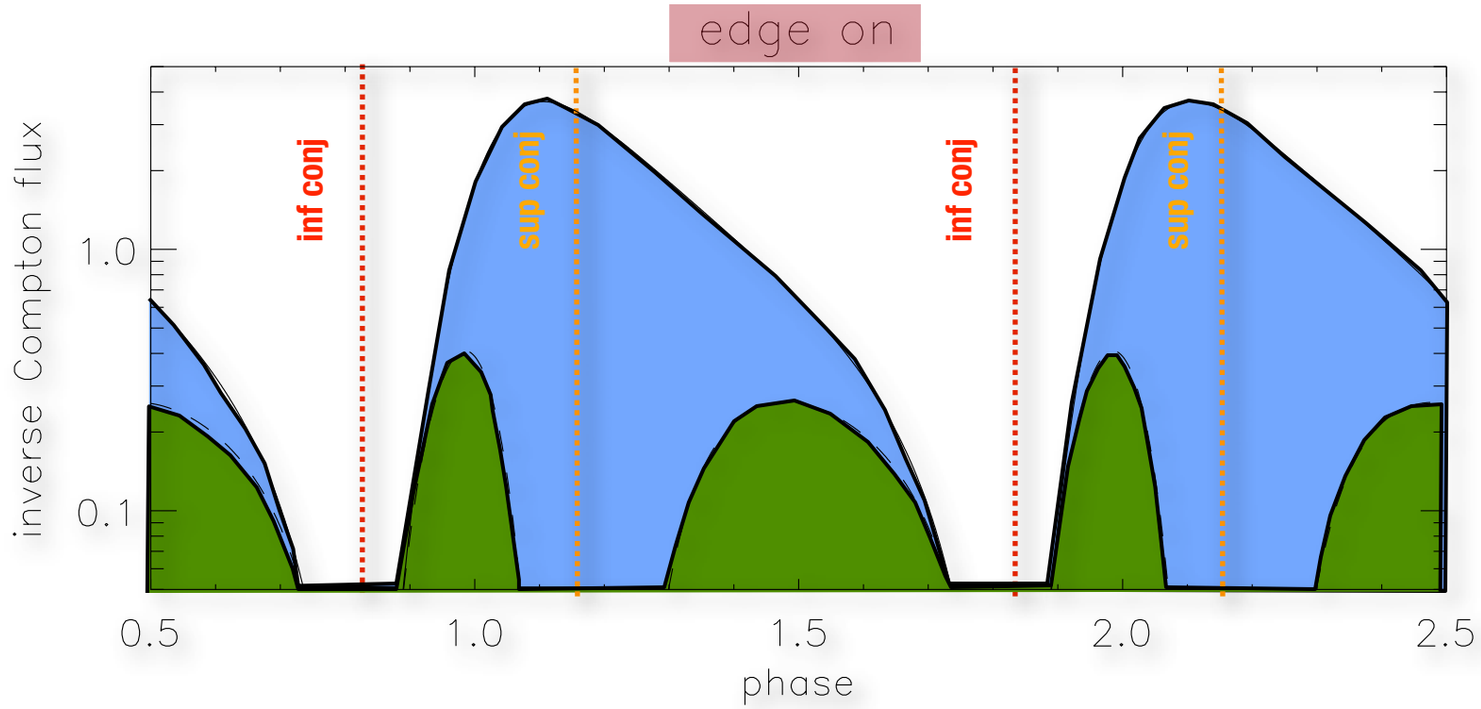
inverse Compton + pair production (TeV)

Bednarek ;Kirk +, Khangulyan & Bosch-Ramon, Sierpowska-Bartosik & Torres, Takata & Taam, Yamaguchi & Takahara

γ-ray modulation

- **inverse Compton on star photons: anisotropic**
- **pair production on star photons (opacity): anisotropic**





inverse Compton (GeV)

inverse Compton + pair production (TeV)

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γ-ray modulation

- **inverse Compton on star photons: anisotropic**
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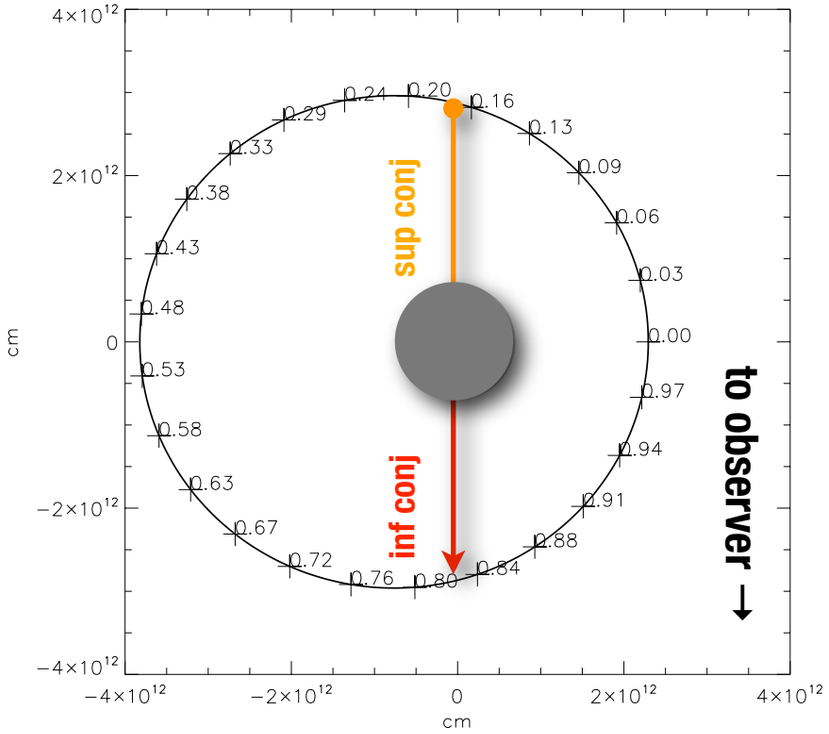
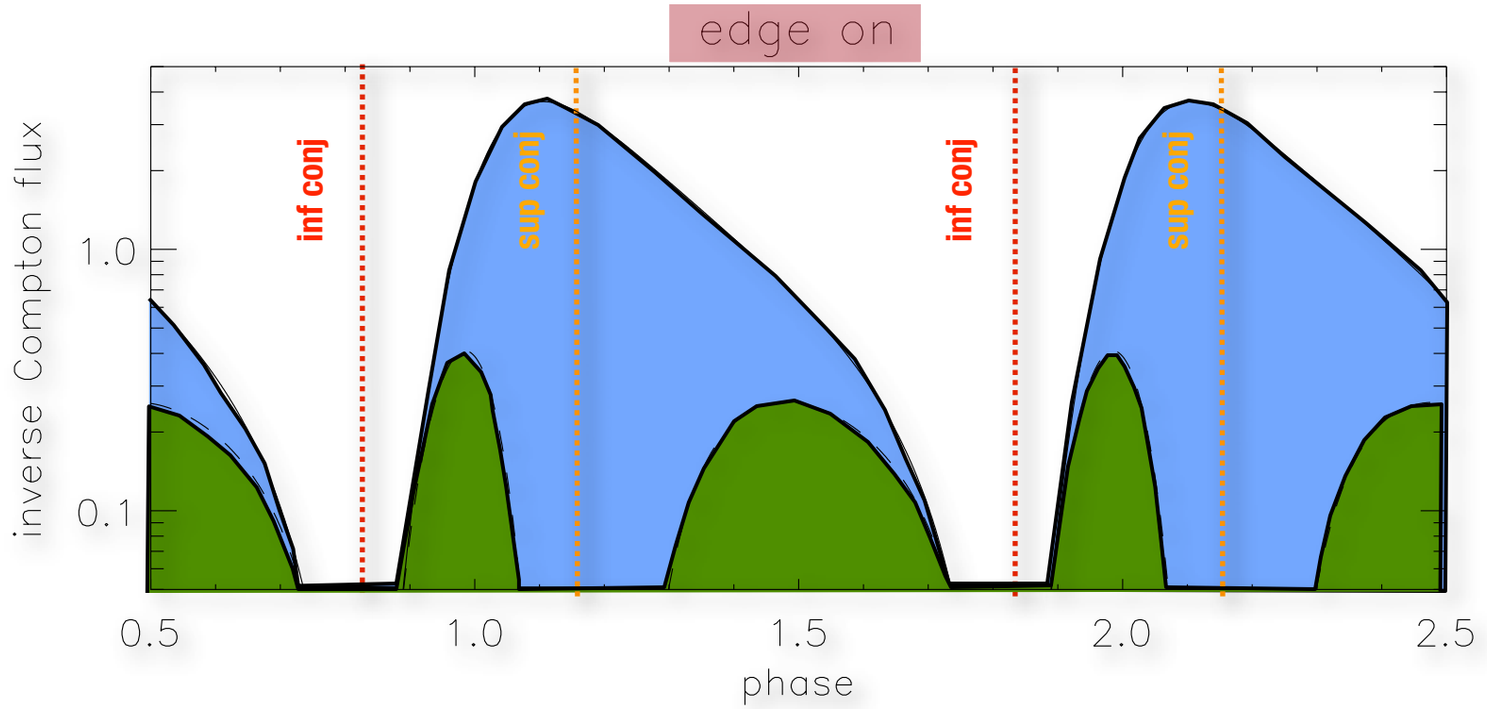




inverse Compton (GeV)

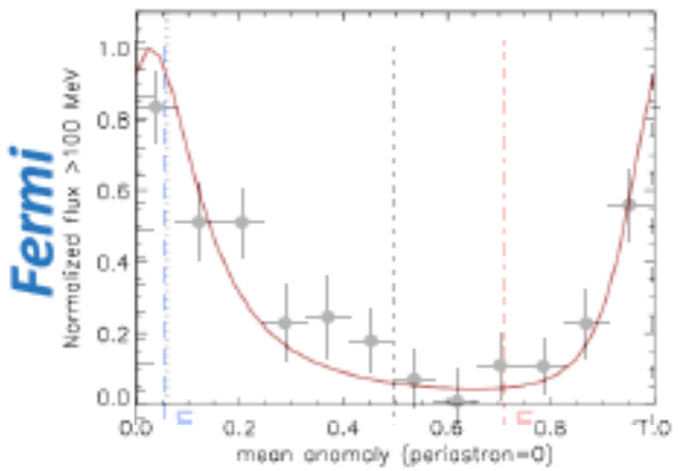
inverse Compton + pair production (TeV)

→ identify emission mechanism

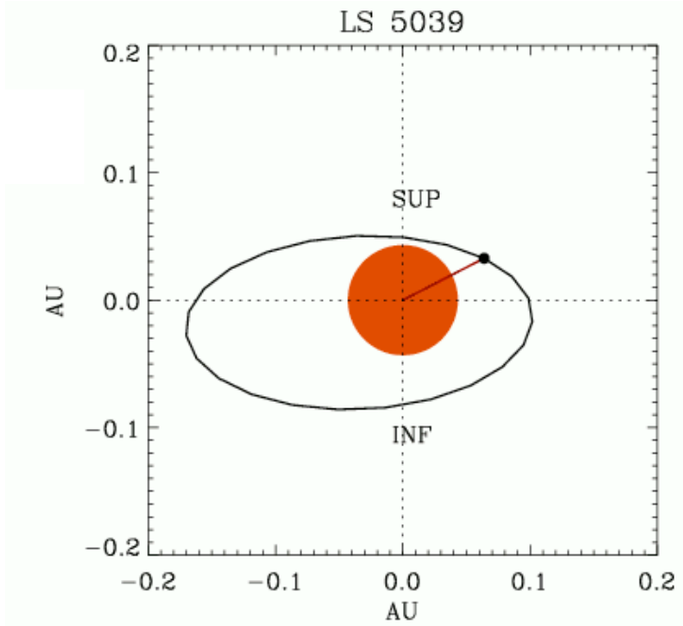
→ distinguish intrinsic variability from variability due to observer geometry

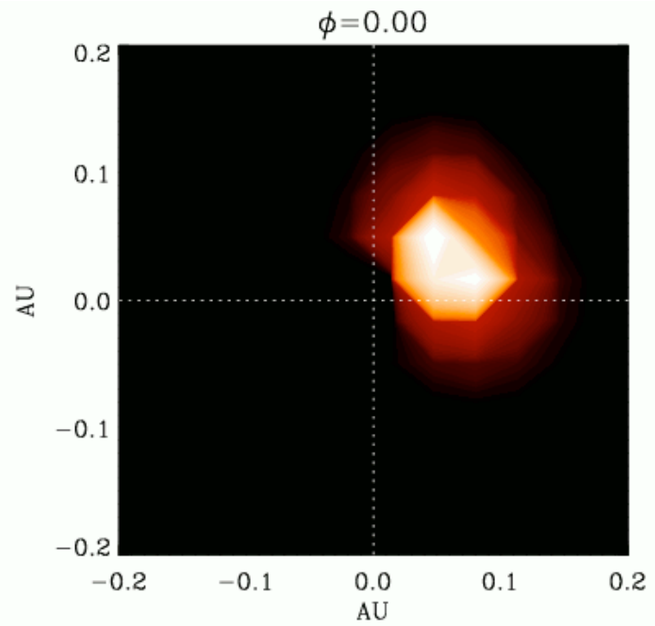
γ-ray modulation of LS 5039

Cerutti et al. 2010

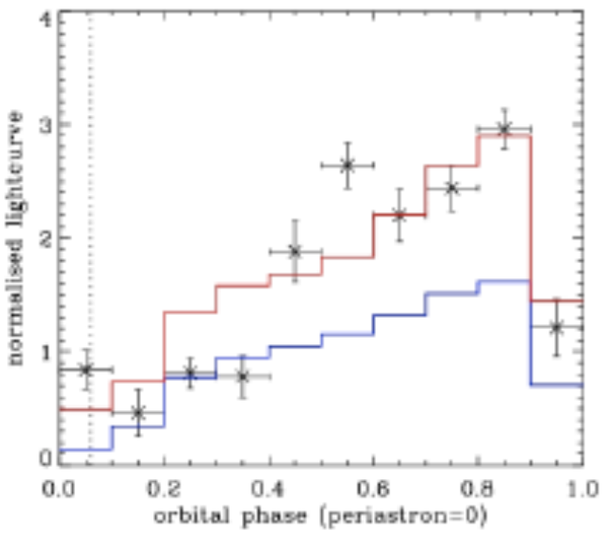


Fermi





HESS



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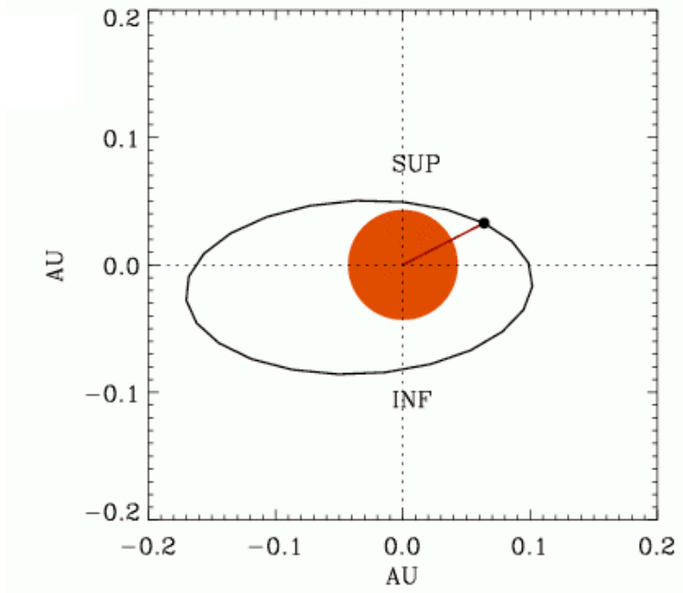
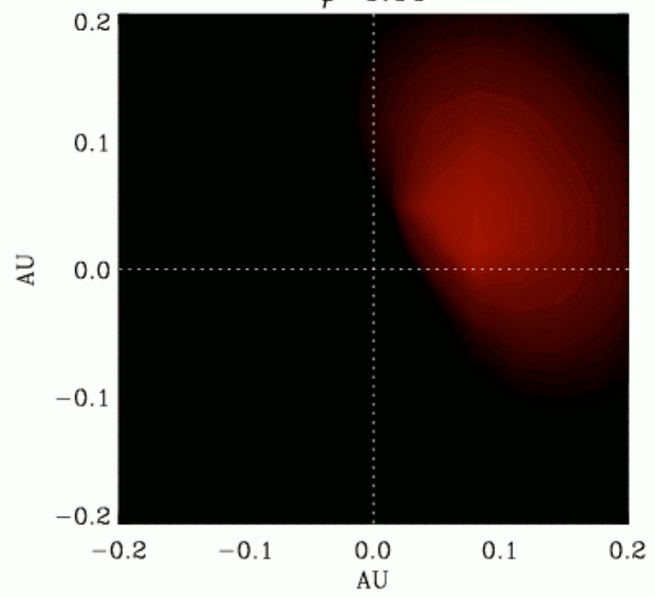


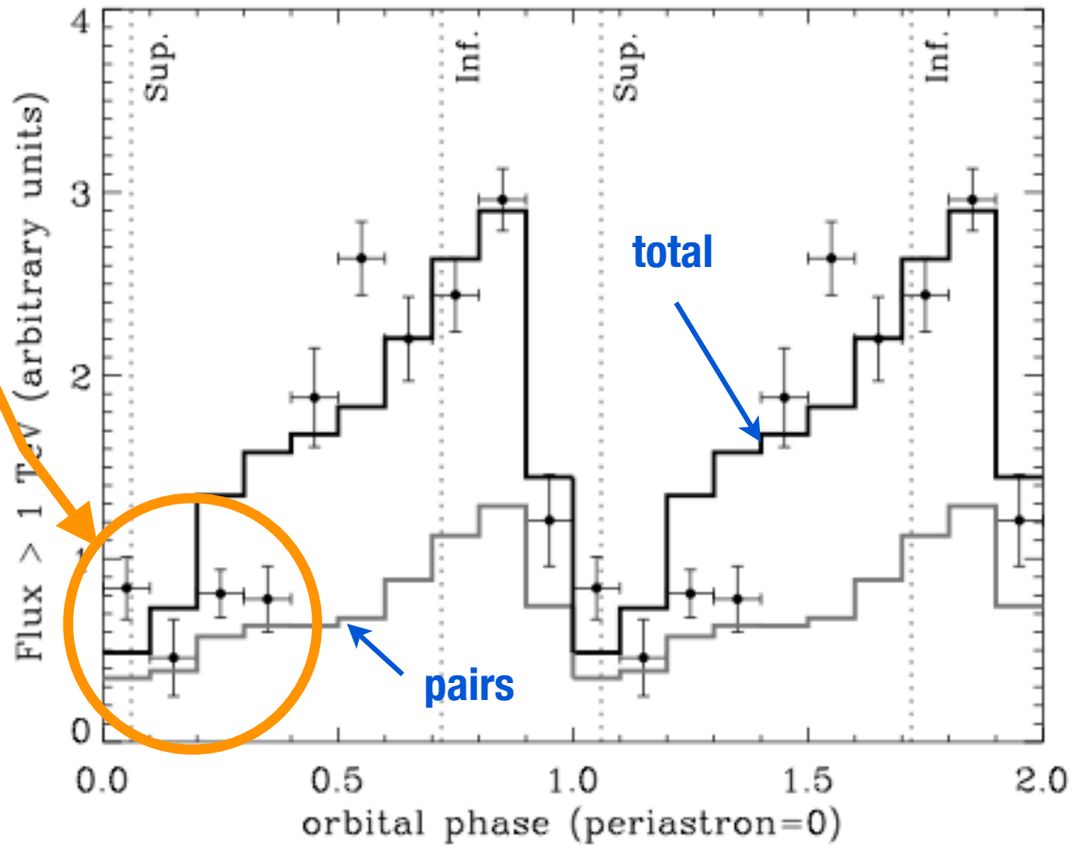


Massive star + orbit fixes emission → value of B

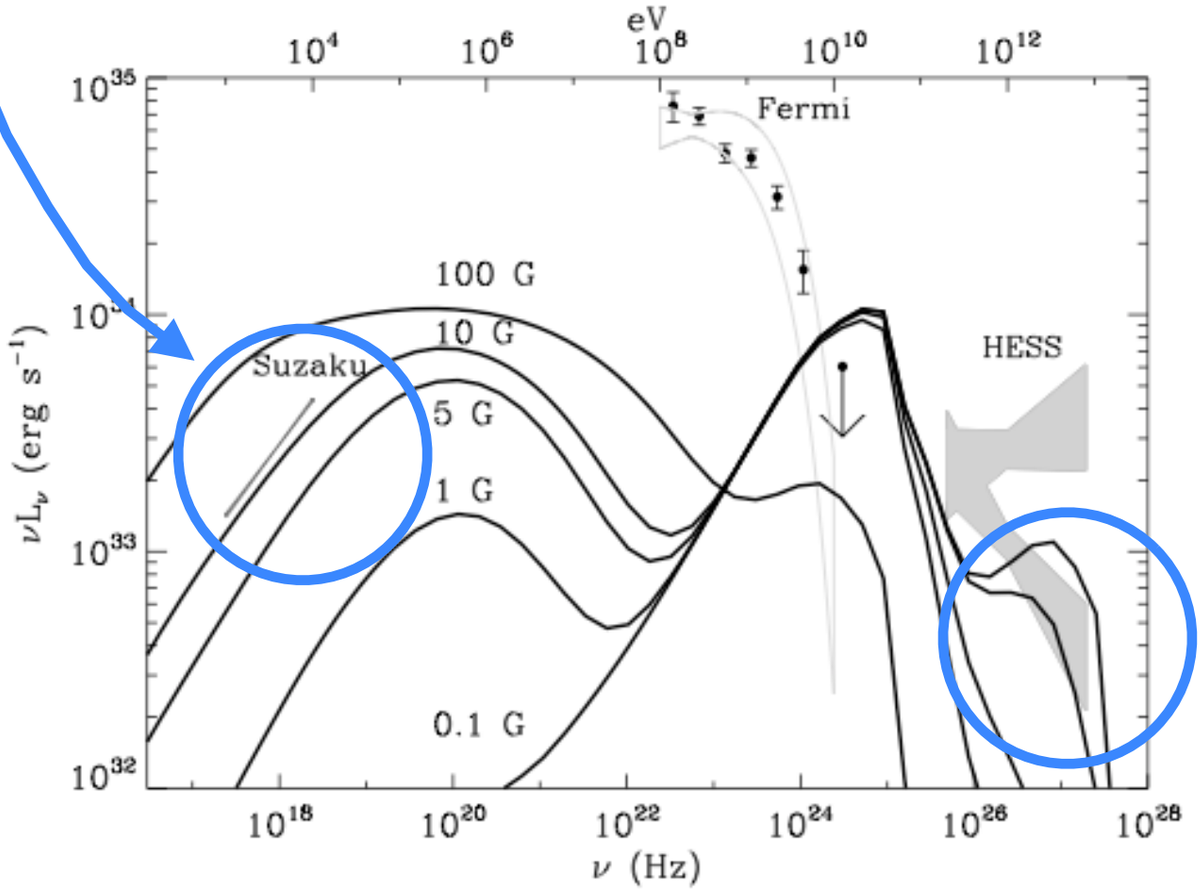
Pair cascade LS 5039

- **Significant pair cascade emission at sup conj.**
- **Limits magnetic field <B>~a few G, compatible with pulsar.**

VHE lightcurve & model



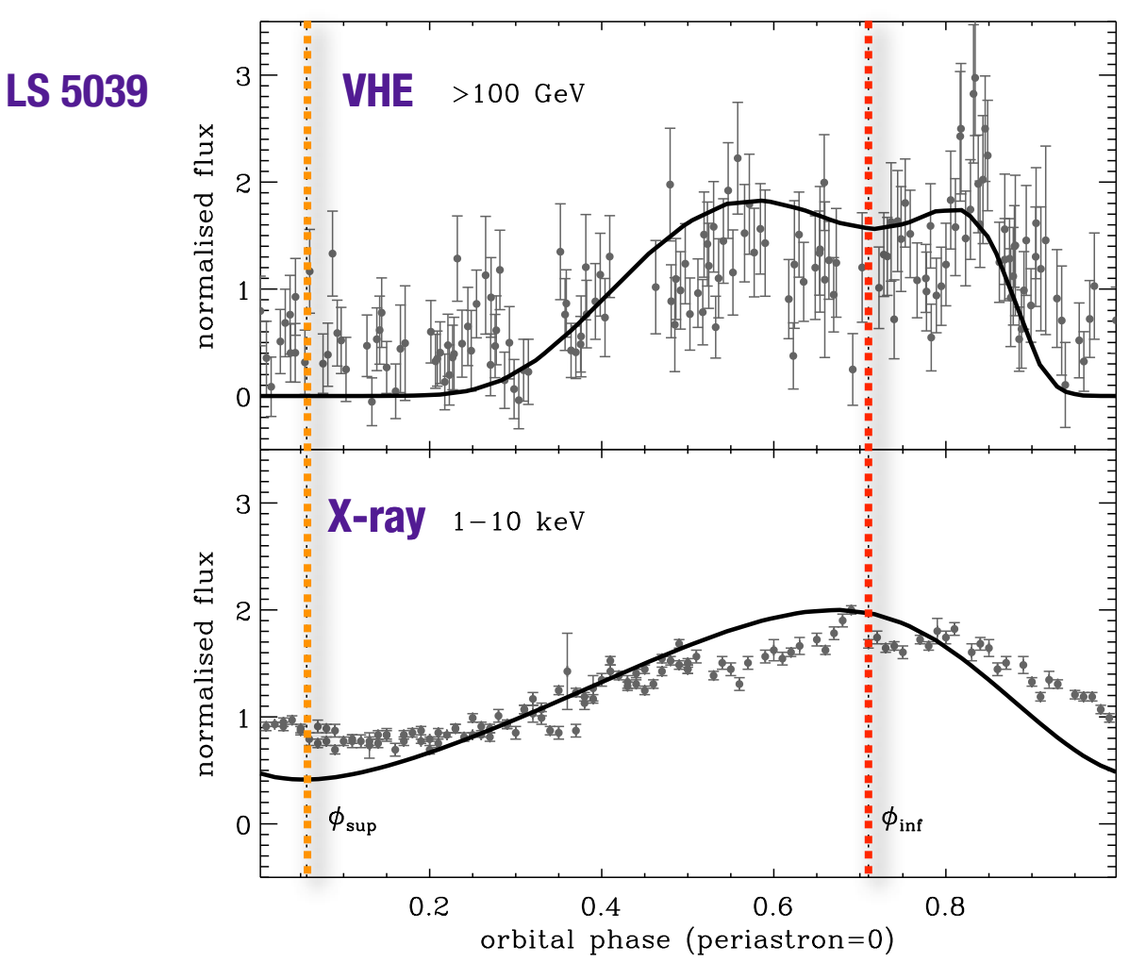
cascade emission (only) @ sup. conjunction



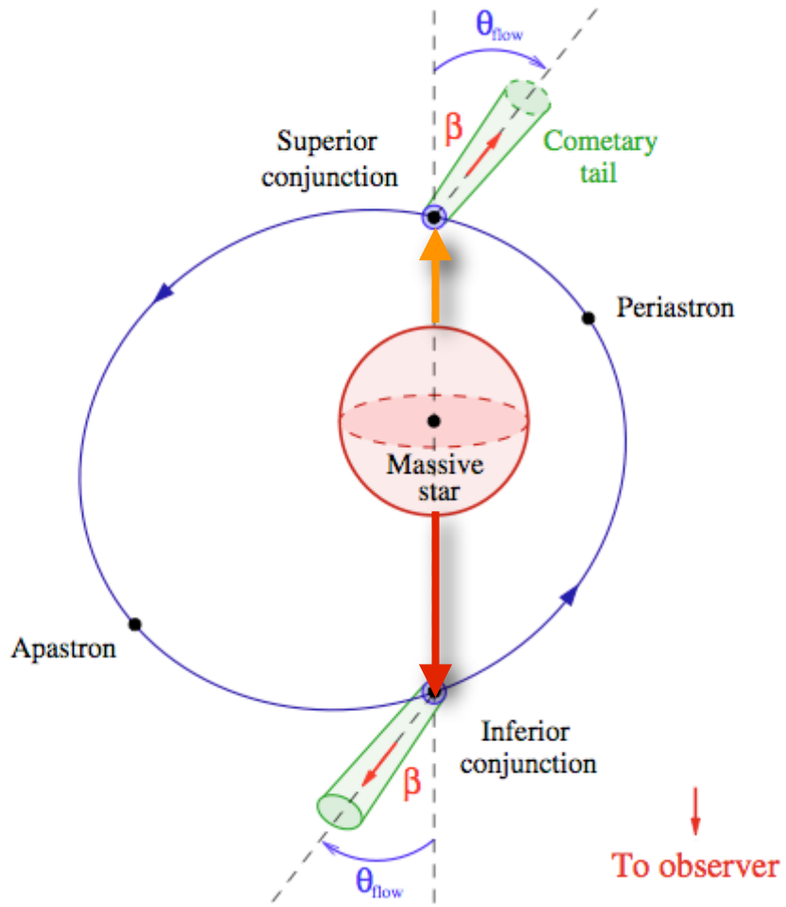
Cerutti et al. 2010

Modulated Doppler boost

- **Puzzling X-ray modulation in LS 5039** Takahashi et al. 2009
- **Shocked wind ~ relativistic, orientation changes along orbit**
- **Doppler boost changes synchrotron and IC lightcurve**



GD et al. 2010

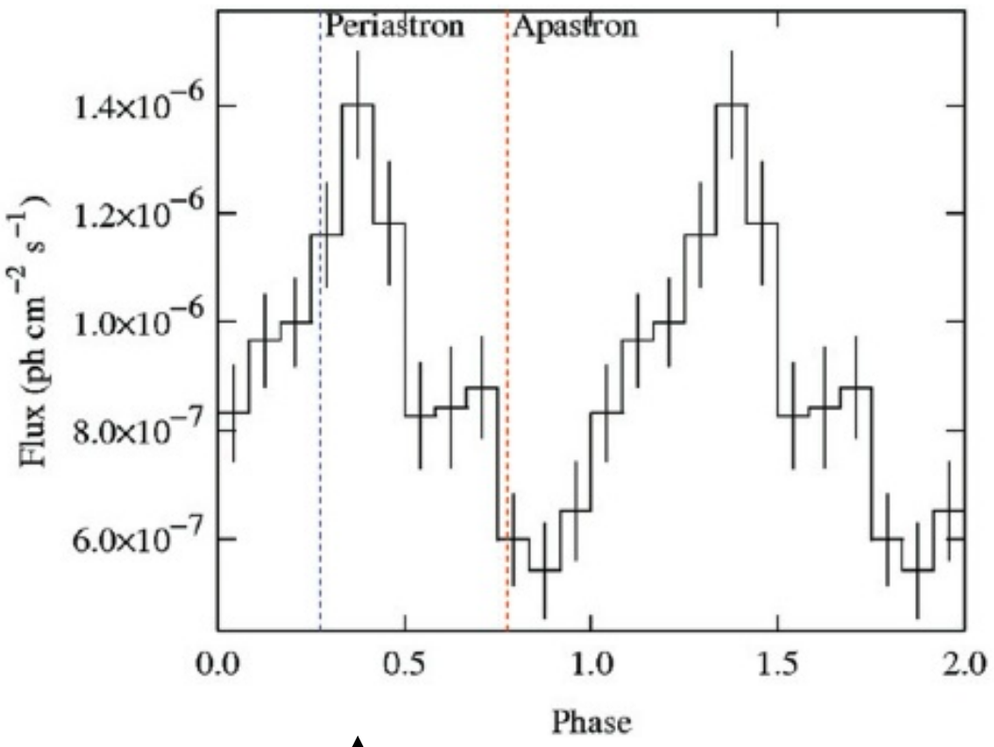


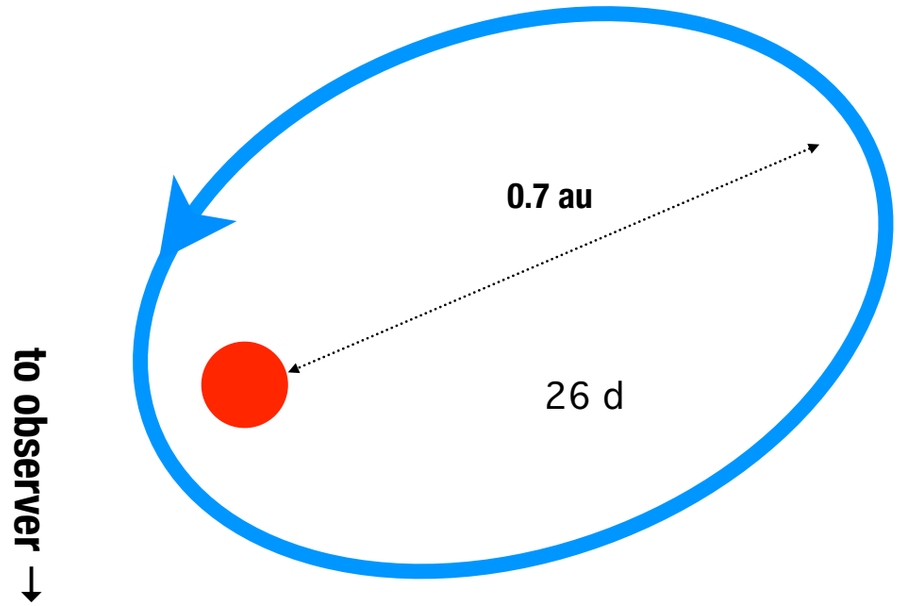
caveat: X-ray emission region likely large Szostek+ 2011

LS I+61°303

- **modulation: inverse Compton on star photons ?**

Abdo et al. 2009



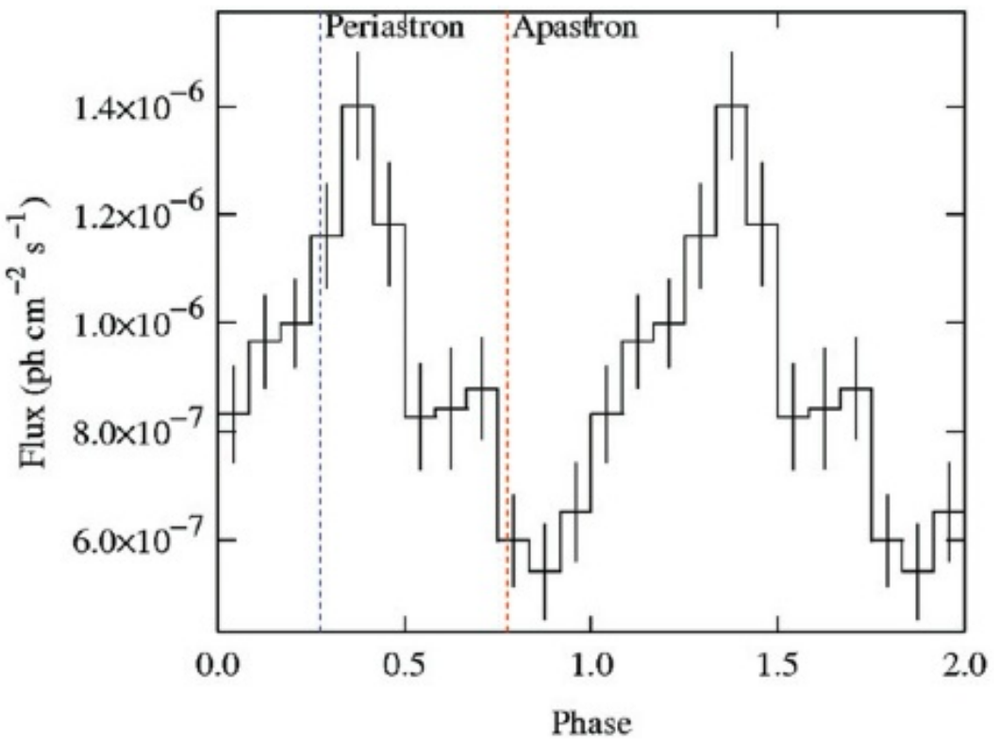


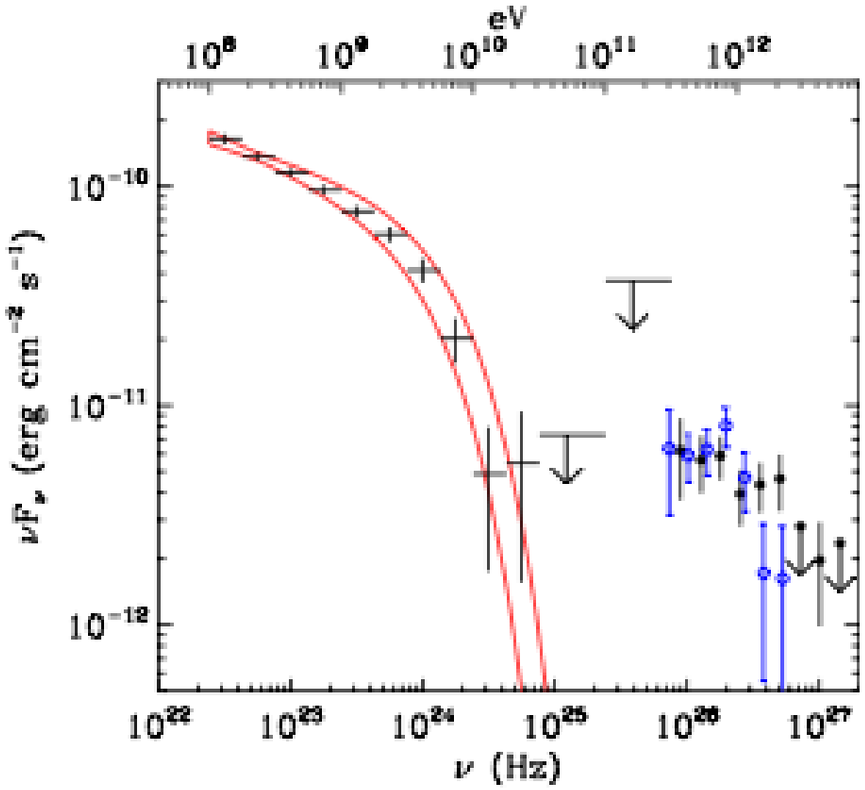
HE peak offset from IC expectations
HE modulation absent recently
VHE peak phase varies

LS I+61º303

- **modulation: inverse Compton on star photons ?**
- **spectrum: two populations of HE particles ?** **(also LS 5039)**

Abdo et al. 2009





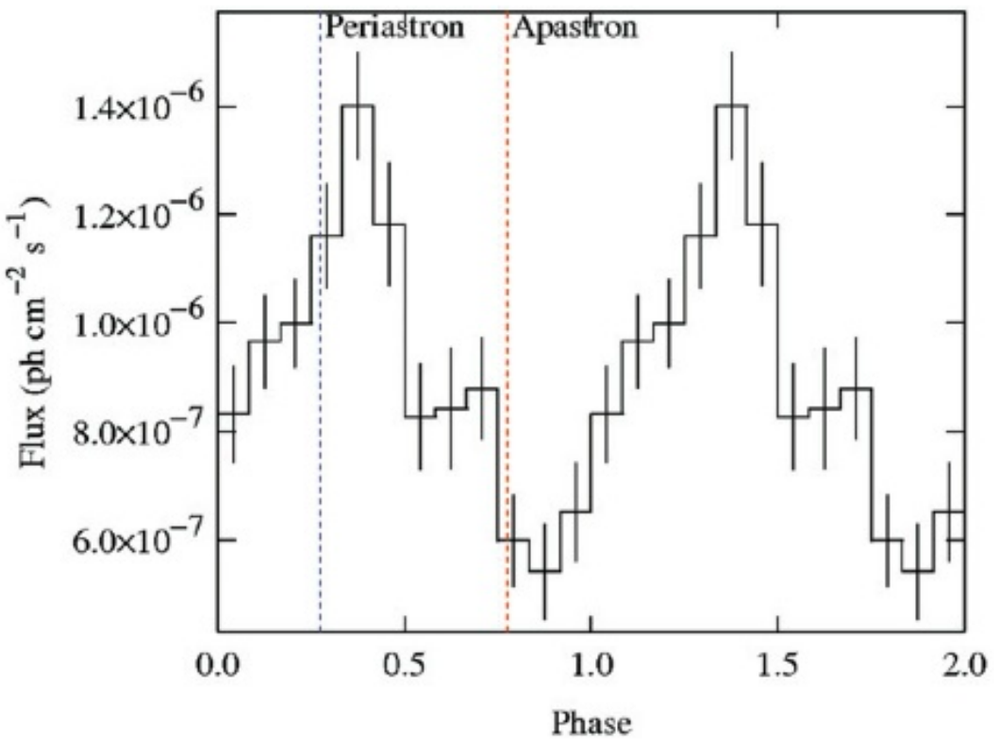
pulsar magnetospheric emission **pulsar wind nebula**

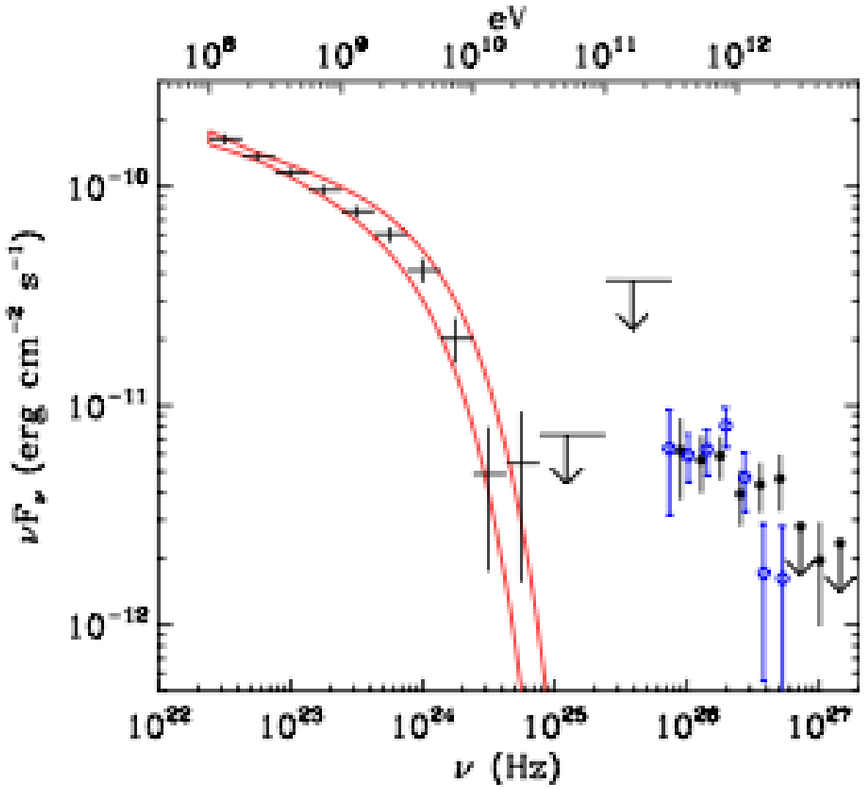
(but modulation, variability ??)

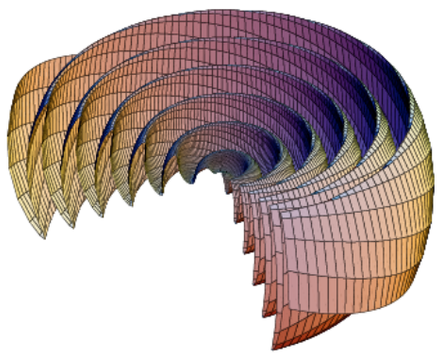
LS I+61º303

- **modulation: inverse Compton on star photons ?**
- **spectrum: two populations of HE particles ?** (also LS 5039)

Abdo et al. 2009







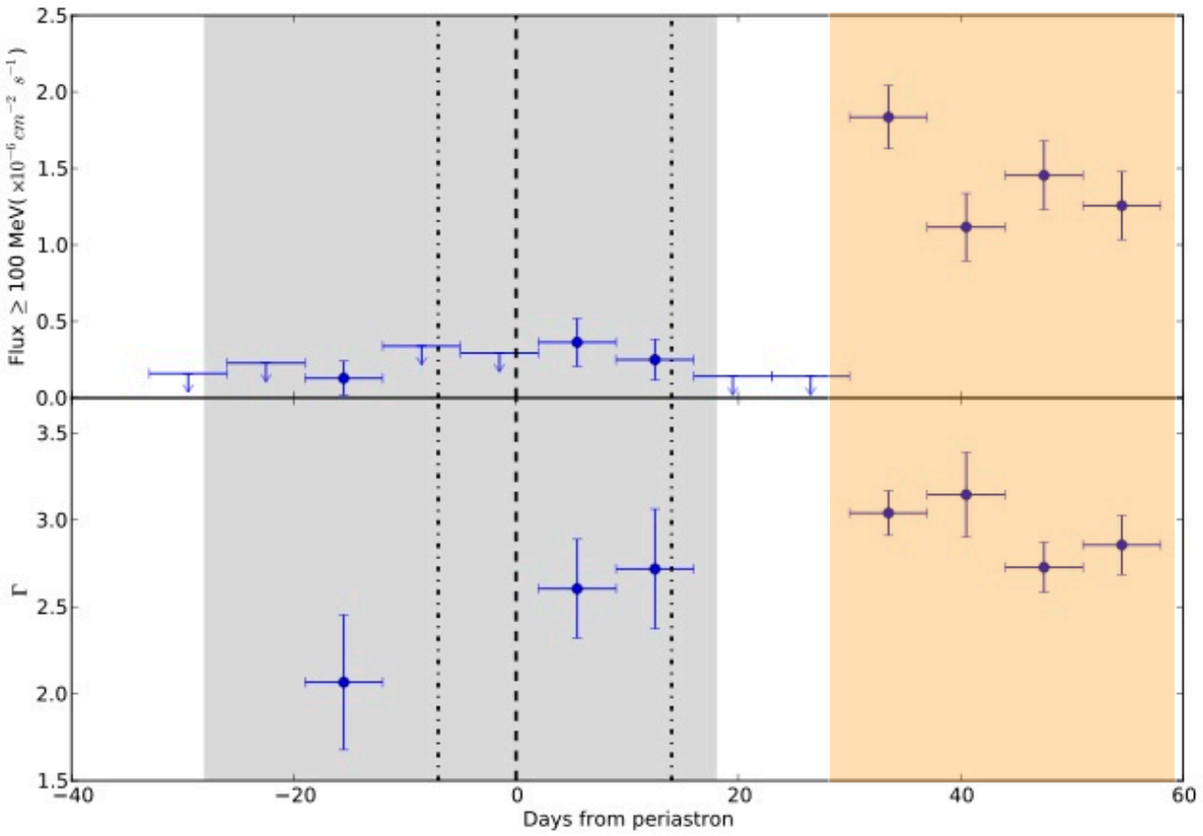
striped pulsar wind emission ?

(Pétri & GD 2011)

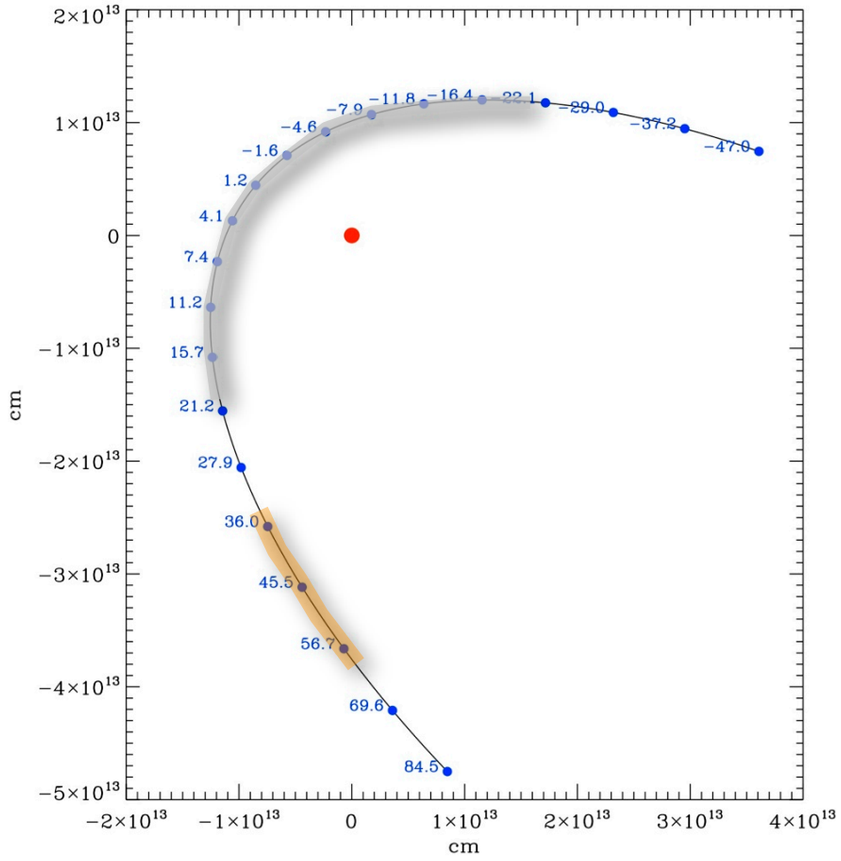
pulsar wind nebula

PSR B1259-63

Fermi/LAT lightcurve (Abdo et al. 2011)



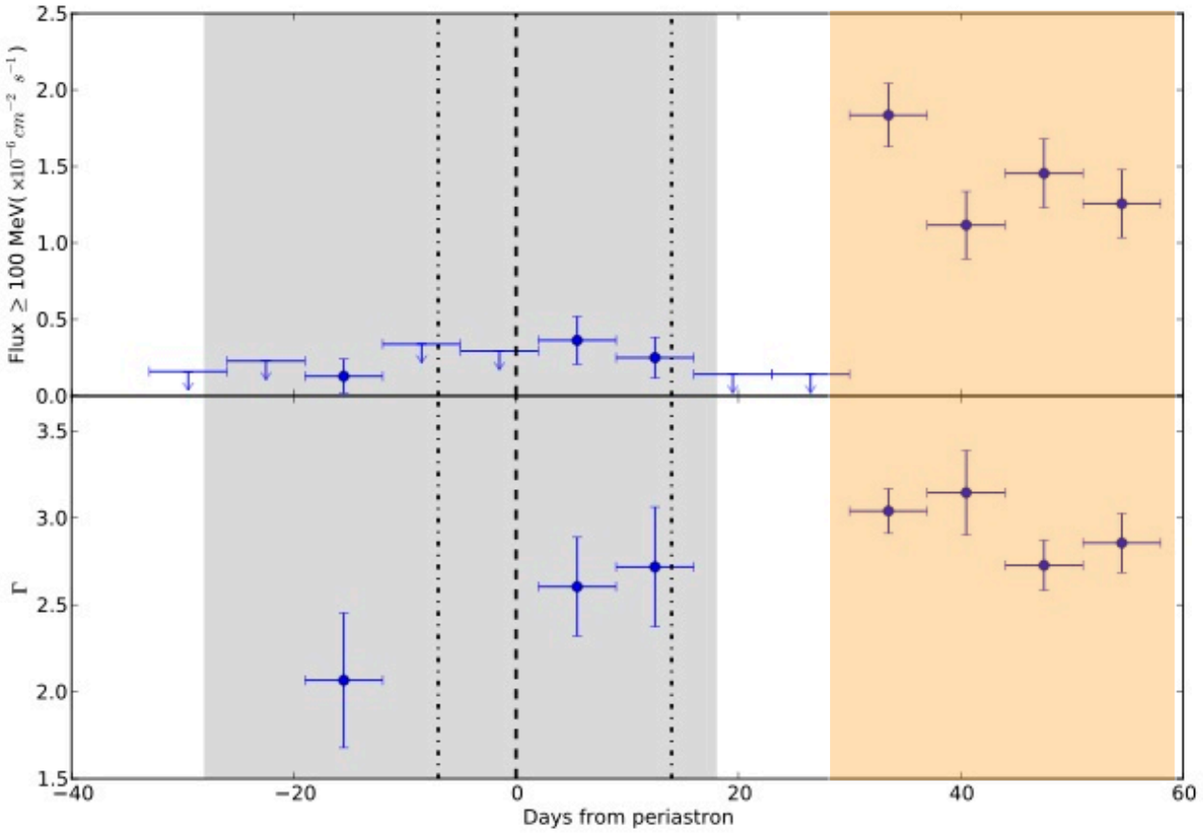
orbit close to periastron



- **10^{36} erg/s spindown pulsar in 3.5 year orbit around Be star**
- **Fermi/LAT detection at periastron mid-December 2010**
- **brighter in February (near inf. conjunction)**

PSR B1259-63

Fermi/LAT lightcurve (Abdo et al. 2011)



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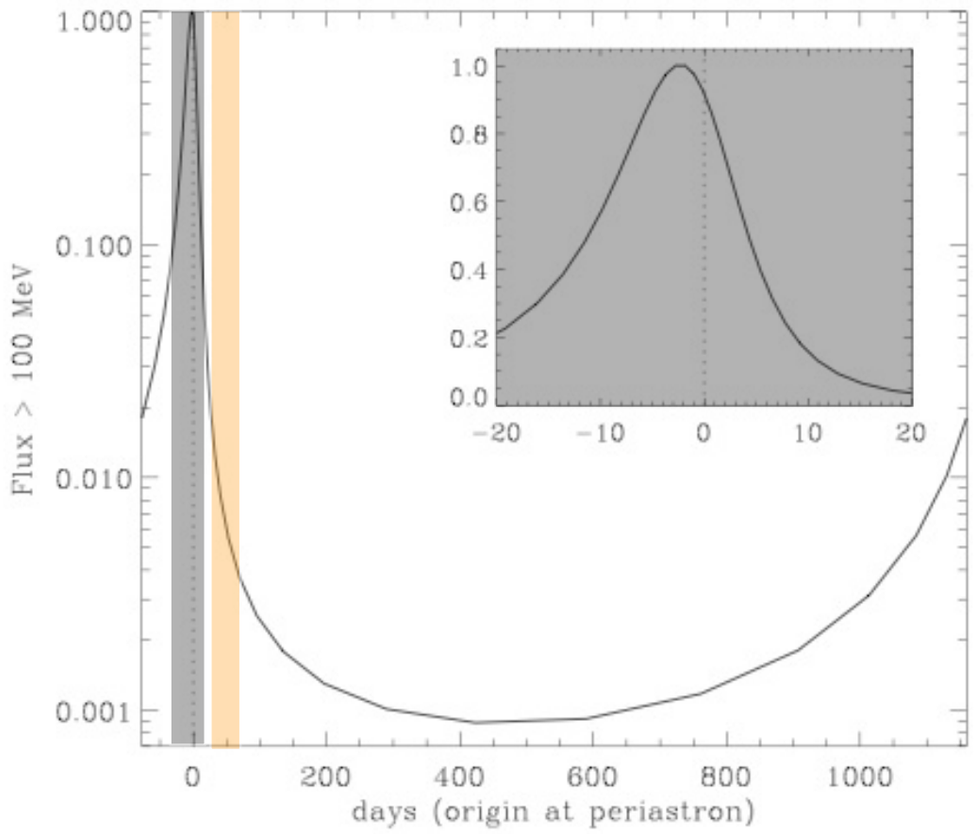


- **More complex than inv. Compton on star photons**
  - **Be disk (π_0, free-free...) ? HE sync ? Doppler boost ? IC on other fields ?...**
- **Nearly all spindown power radiated away at peak**

X-ray binaries / microquasars

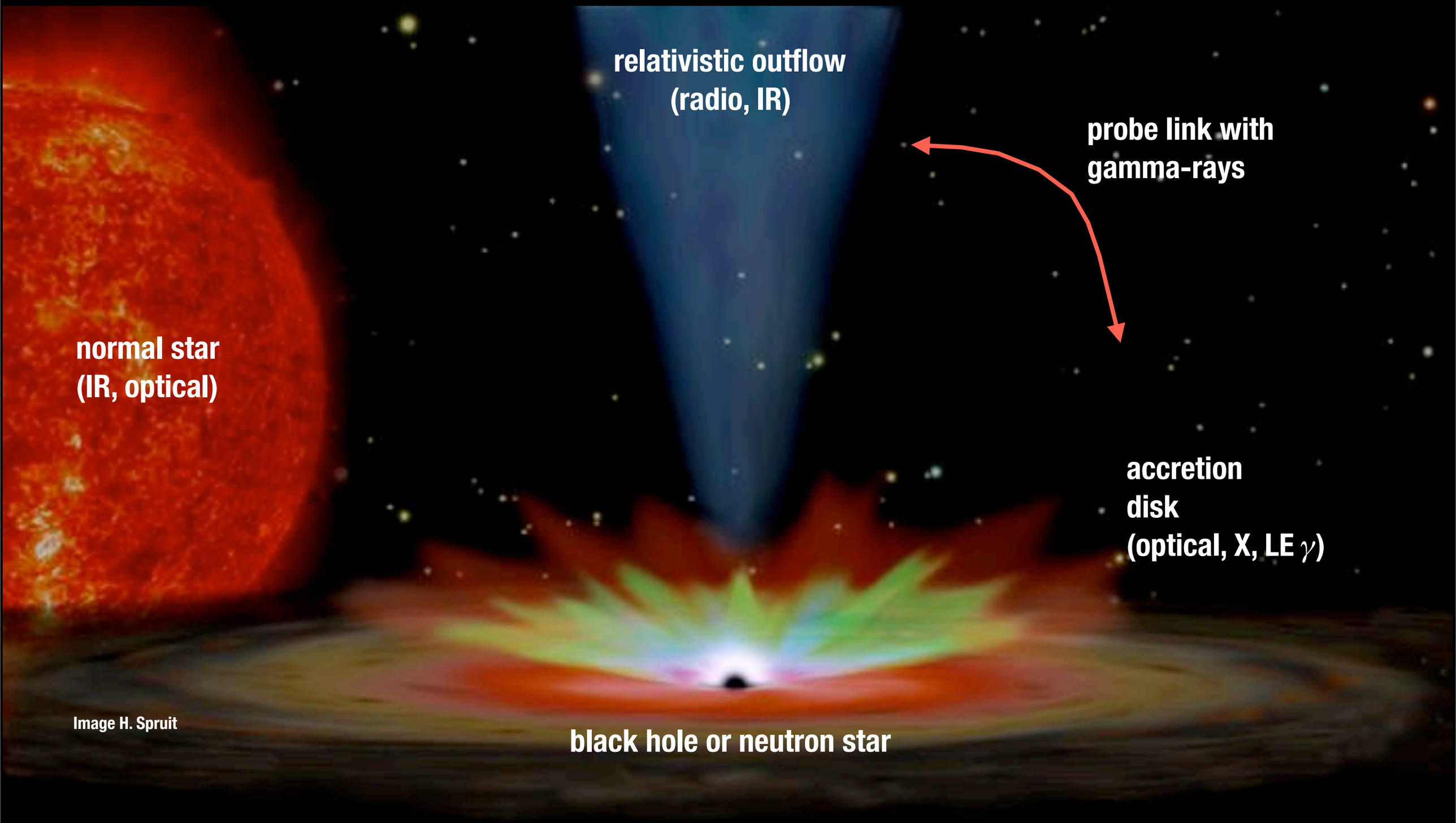


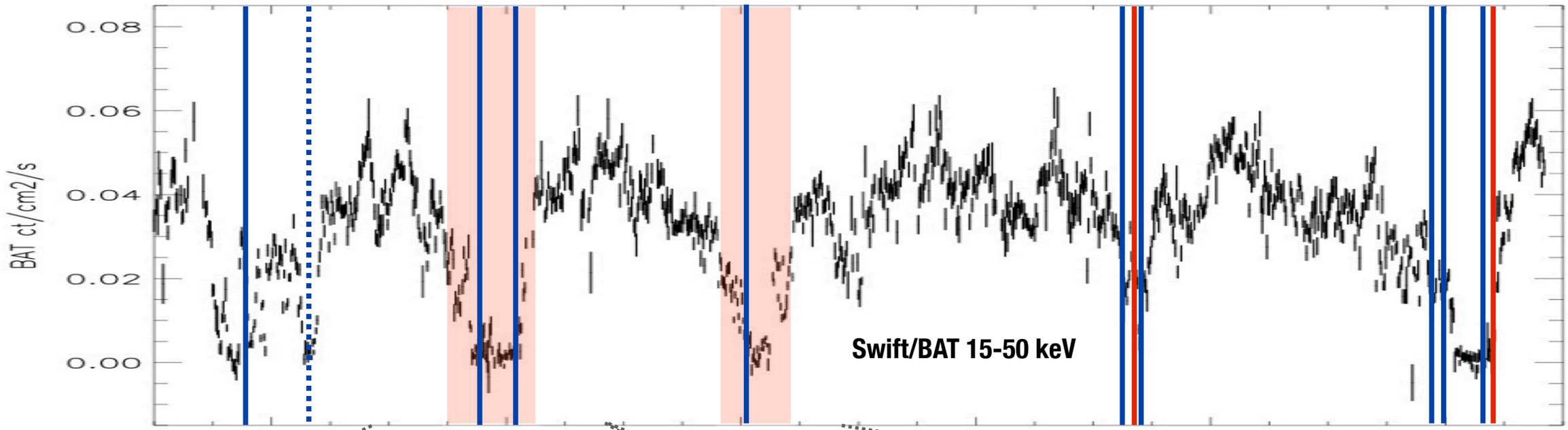
Image H. Spruit

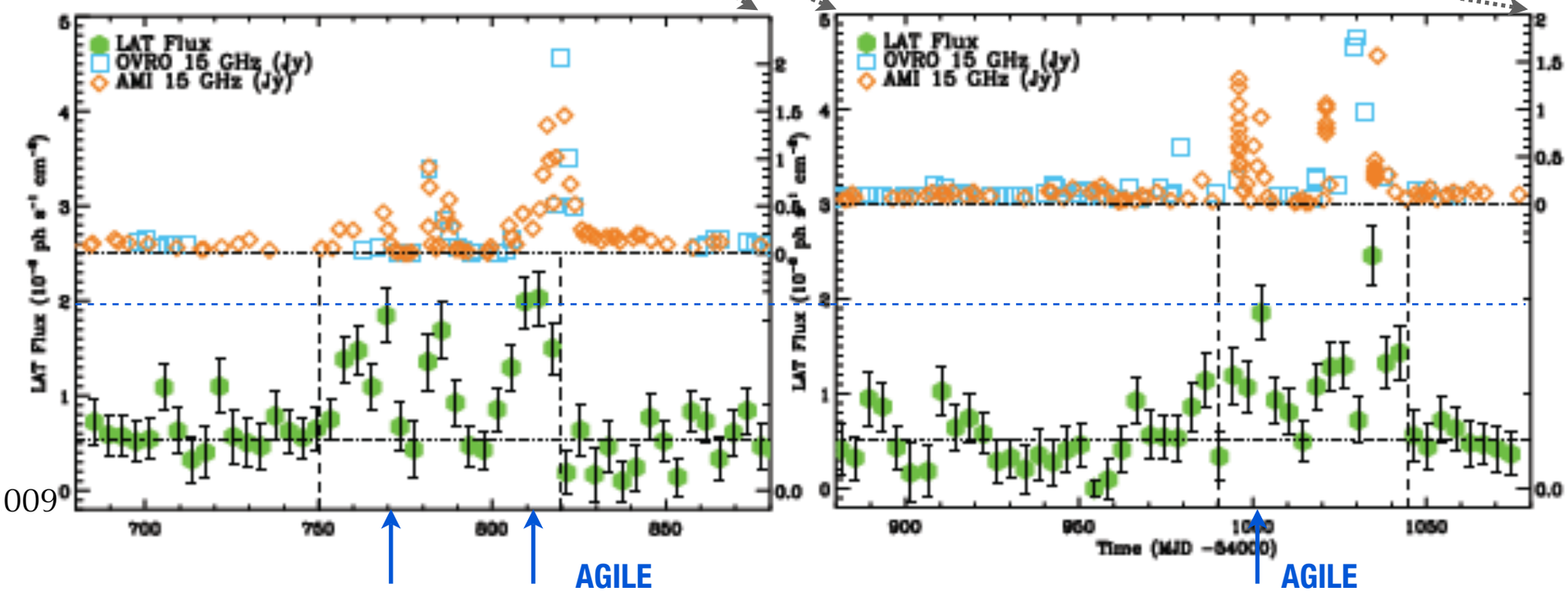
Accreting binaries in gamma-rays: Cygnus X-3

Cygnus X-3 flares

AGILE & Fermi/LAT detections

Tavani et al. 2009, Abdo et al. 2009, Williams et al. 2011, + ATels





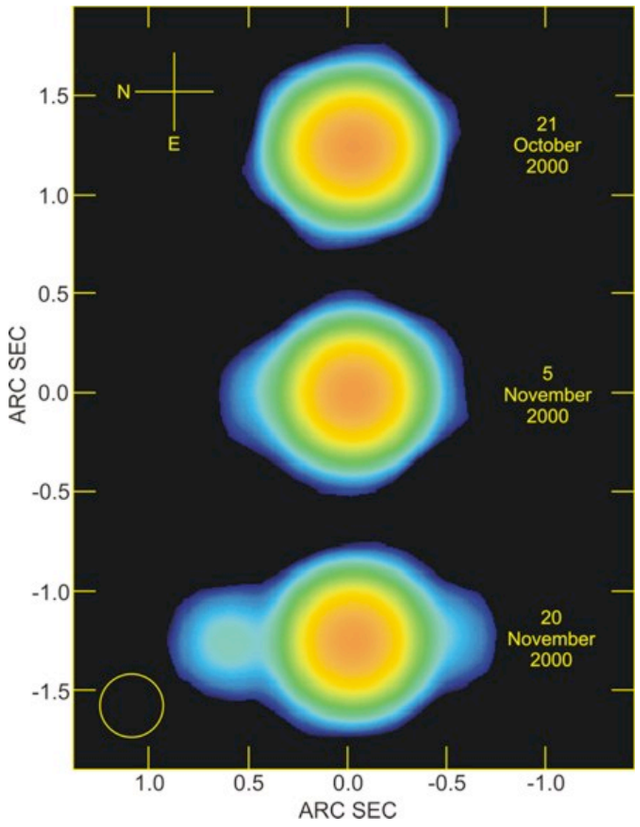
Fermi

Abdo et al. 2009

HE γ-rays from a microquasar

- Relations between X-rays, radio, γ-ray
- Link between non-thermal processes and jet formation ?
- Only confirmed detection from a microquasar

Radio jet Cyg X-3 (Martí et al. 2001)



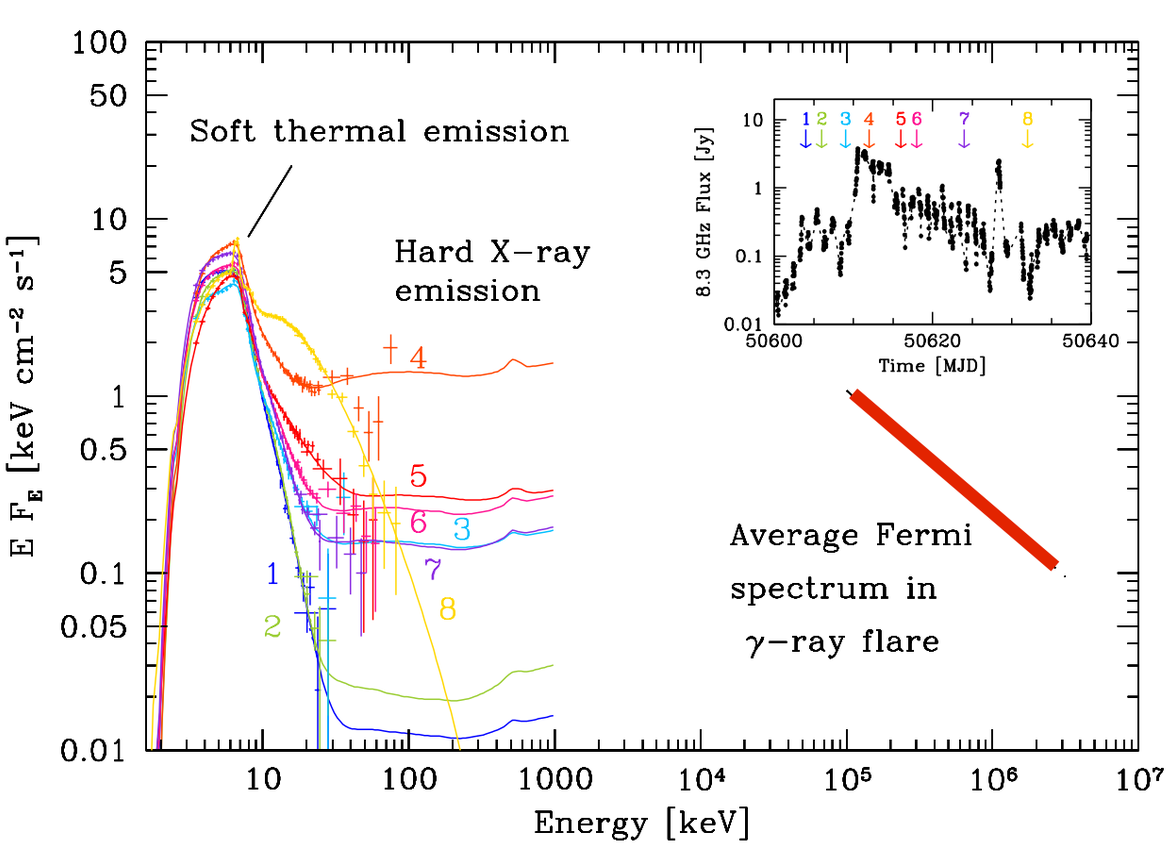
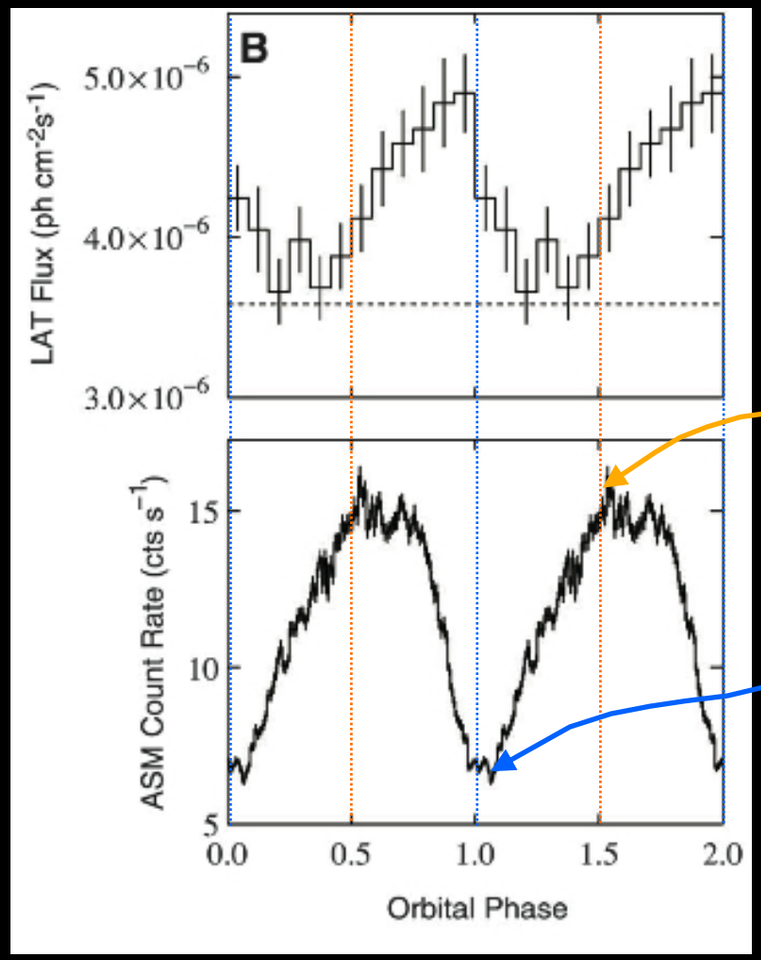


Figure: A. Szostek

γ-rays <10% X-rays

γ-ray and X-ray modulation

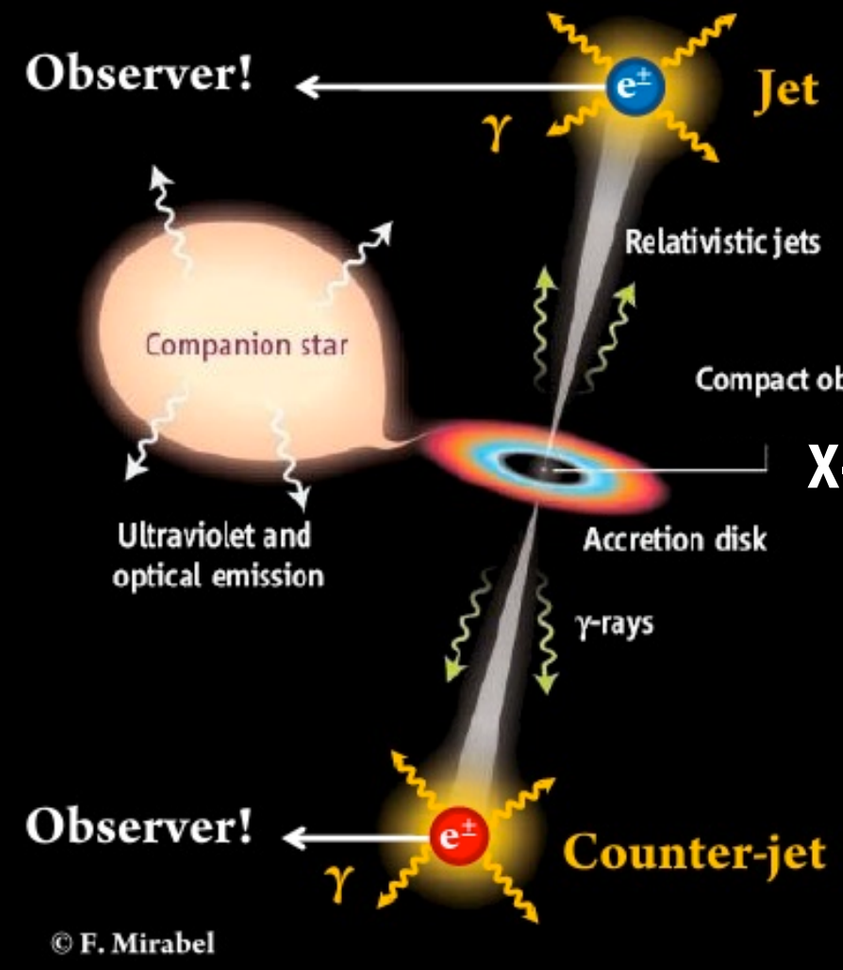
- X-ray modulation from Thomson scattering in Wolf-Rayet wind



Abdo et al. 2009

X-ray max inf. conj.

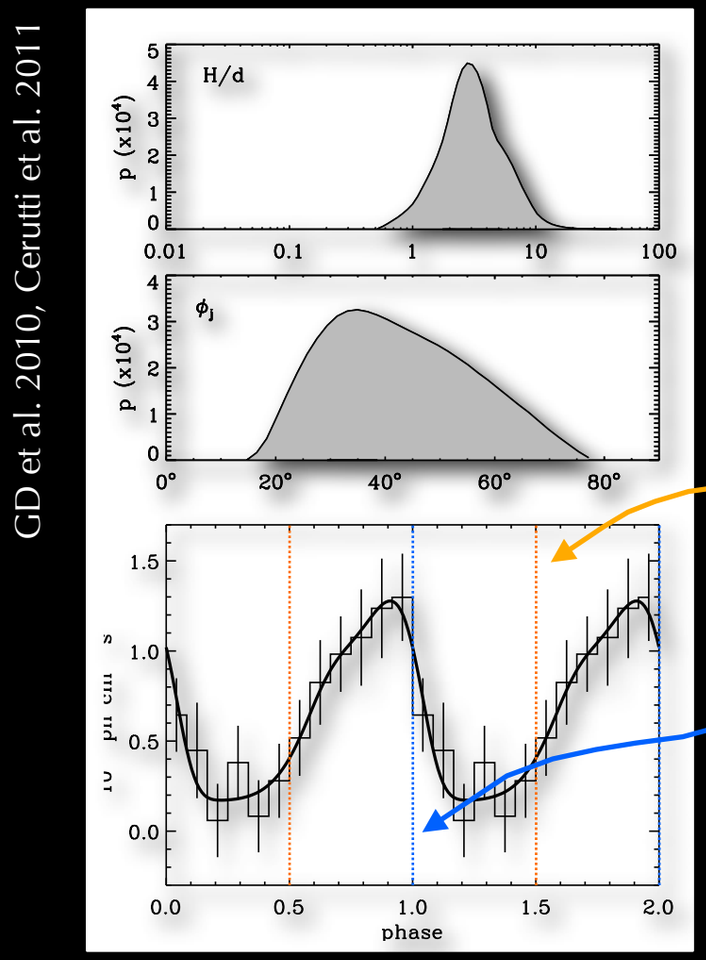
X-ray min sup. conj.



- γ-ray modulation due to inv. Compton on Wolf-Rayet photons ?

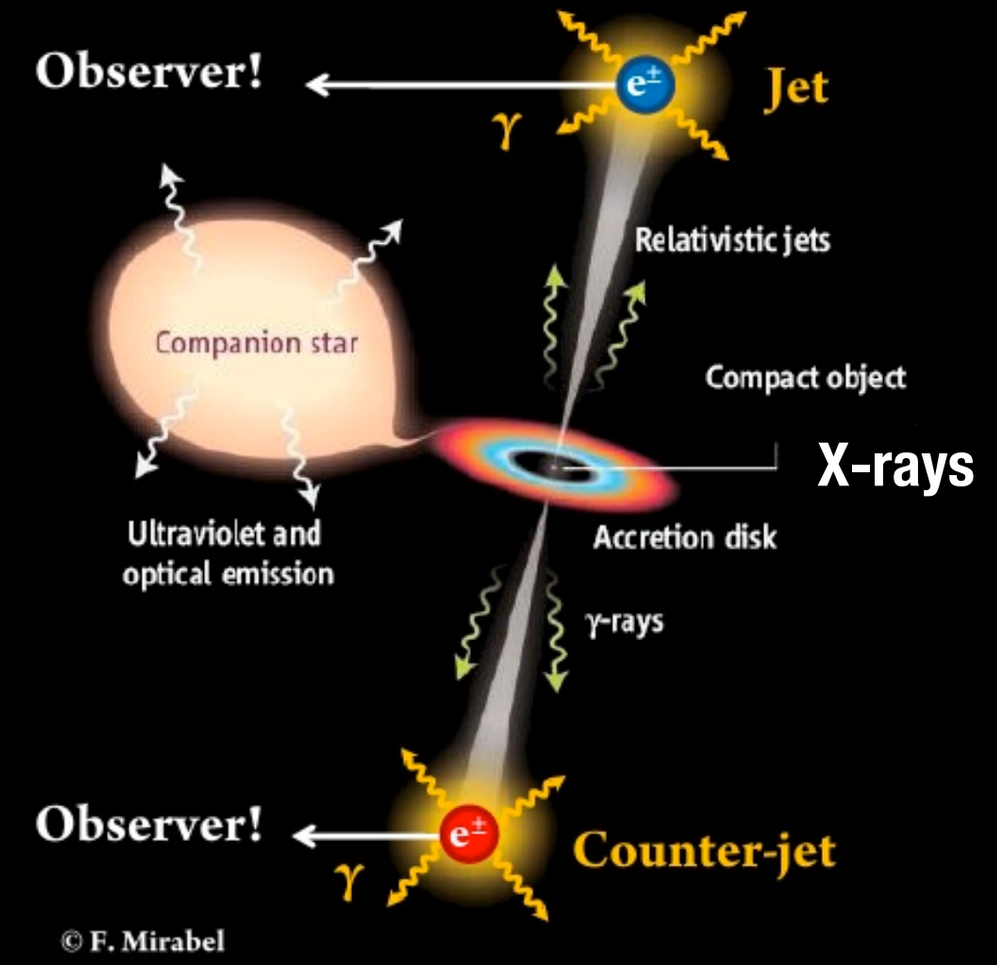
γ-ray and X-ray modulation

- γ-ray modulation due to inv. Compton on Wolf-Rayet photons



X-ray max
inf. conj.
~γ-ray min

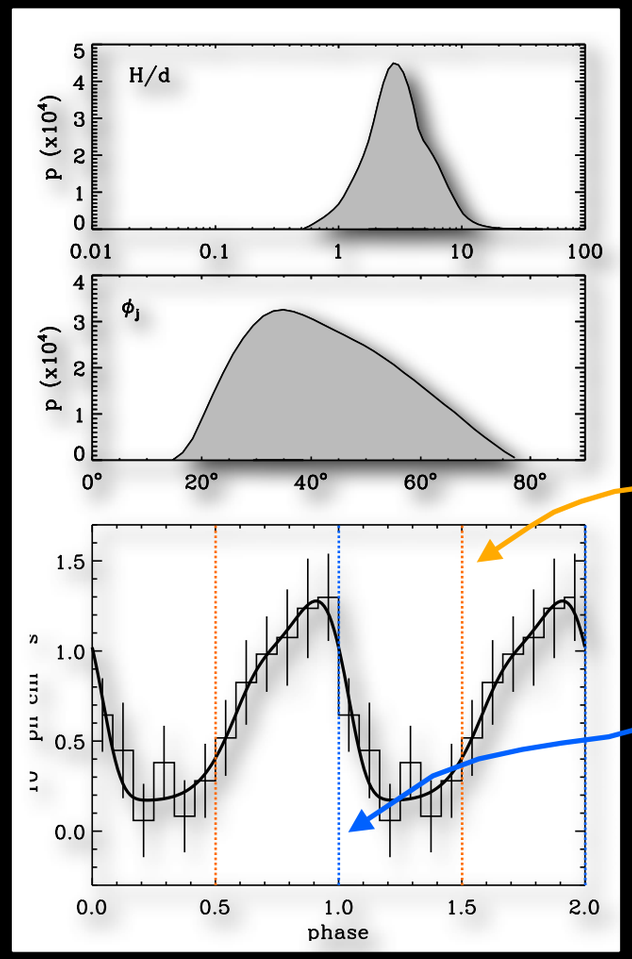
X-ray min
sup. conj.
~γ-ray max



- location: not too close/far, recollimation shock ? precession ?

γ-ray and X-ray modulation

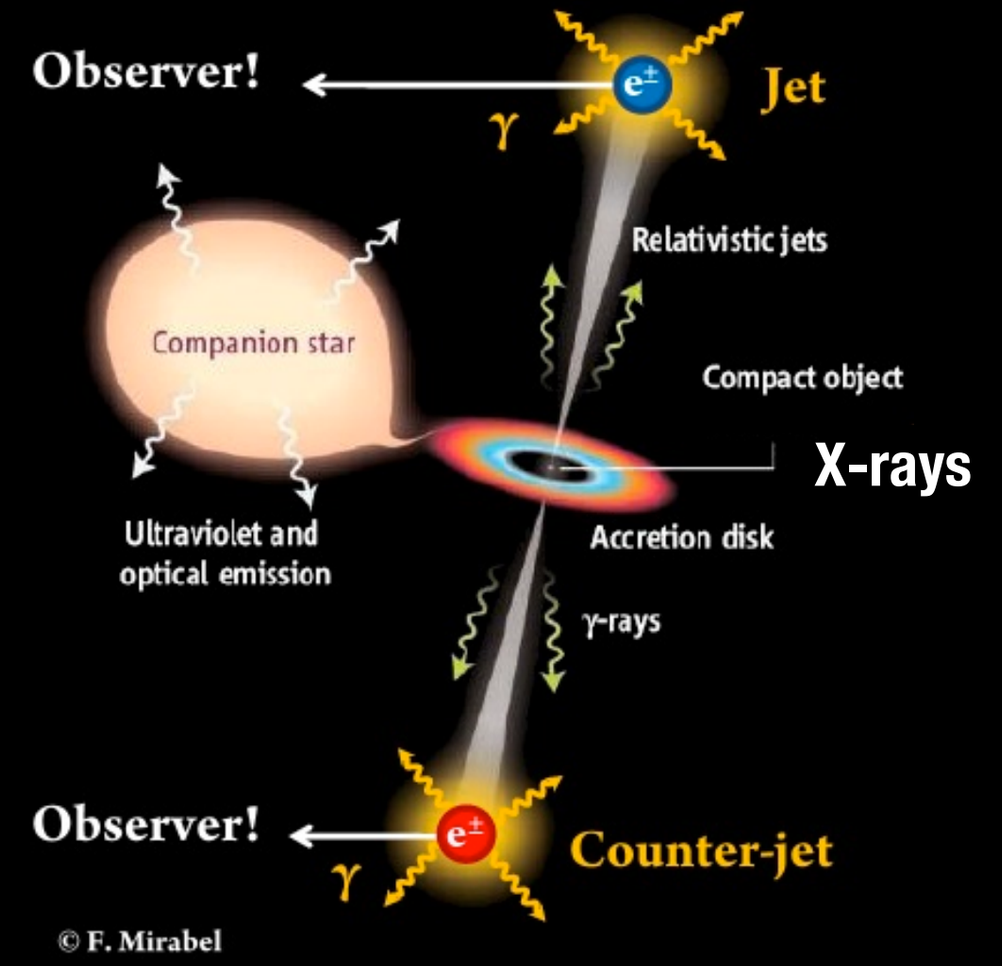
- γ-ray modulation due to inv. Compton on Wolf-Rayet photons



GD et al. 2010, Cerutti et al. 2011

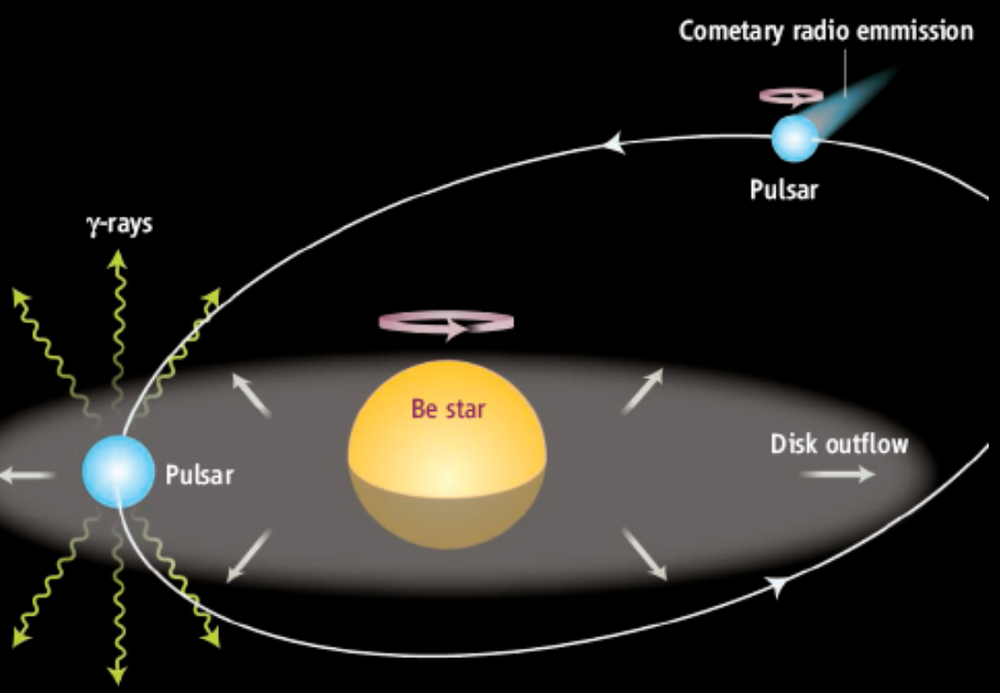
X-ray max
inf. conj.
~γ-ray min

X-ray min
sup. conj.
~γ-ray max

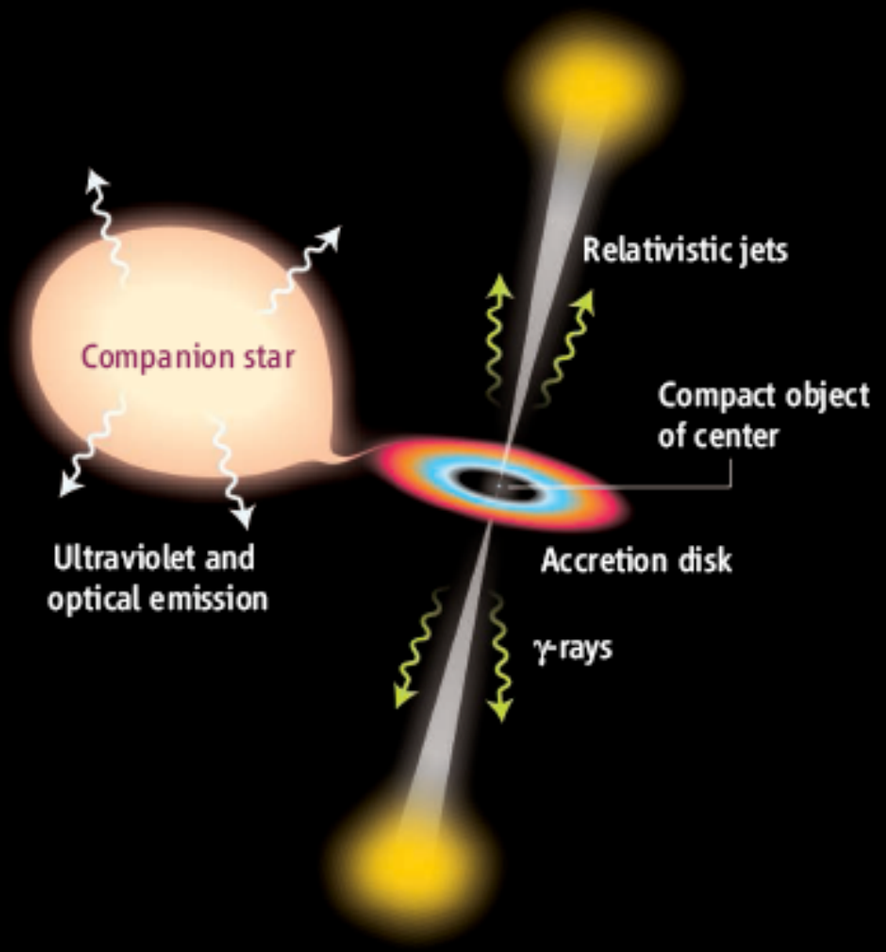


- location: not too close/far, recollimation shock ? precession ?
- matter, radiation field density : is Cyg X-3 unique ?

Summary γ-ray emission from NS/BH binaries



F. Mirabel 2006

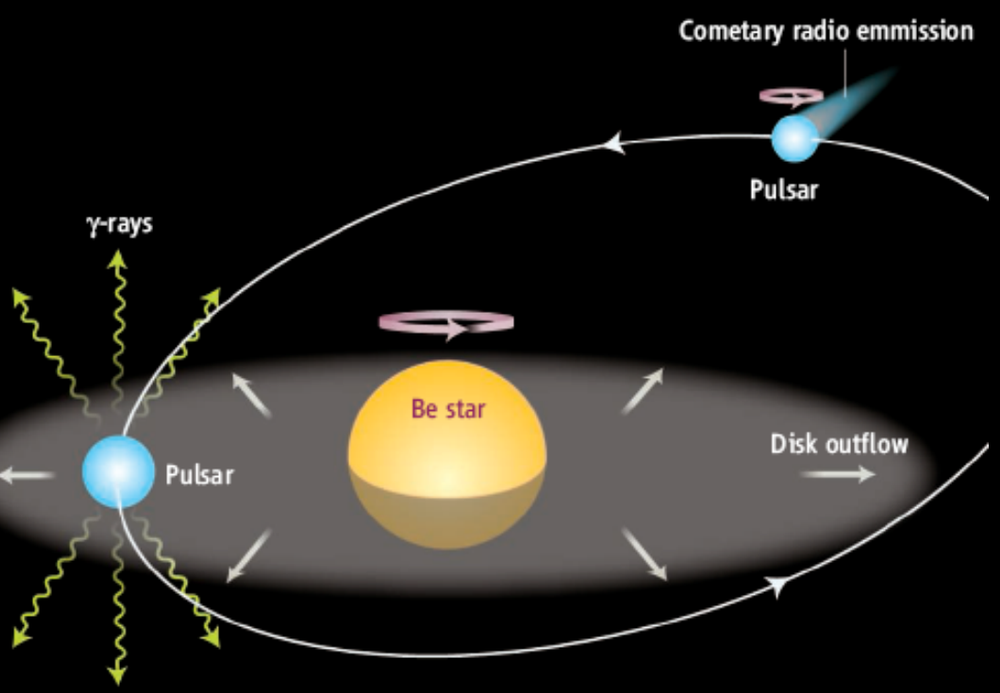


gamma-ray binaries (rotation)

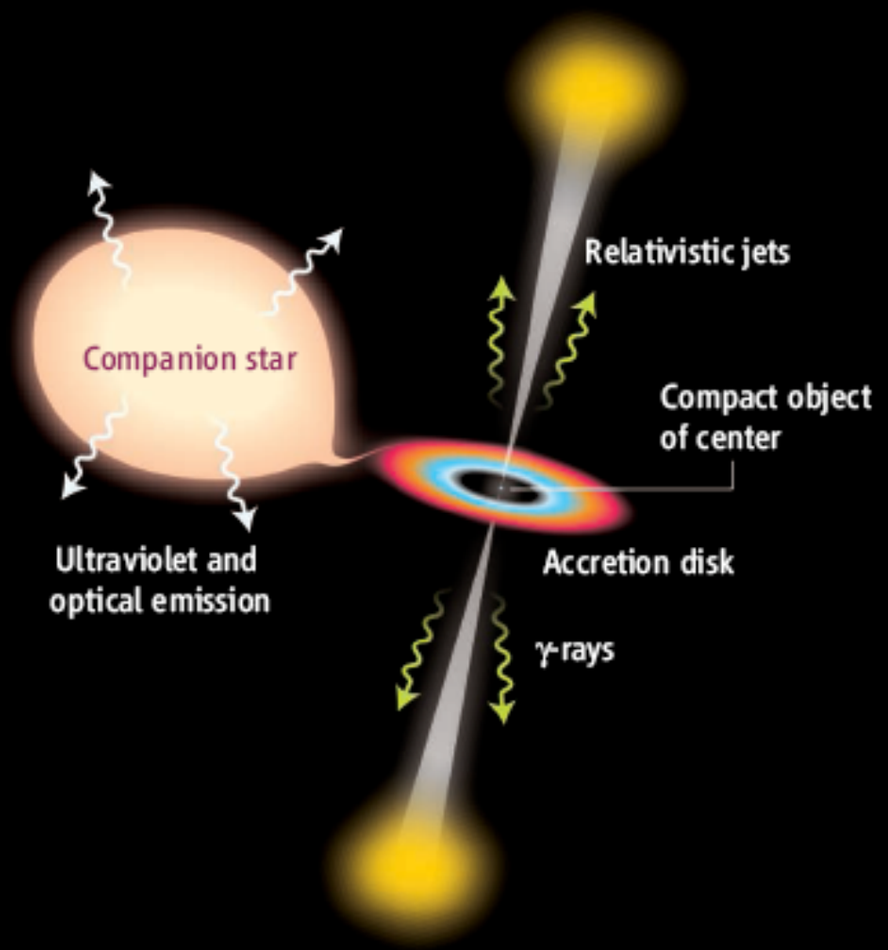
X-ray binaries / μquasar (accretion)

Orbital modulations are a powerful tool to understand these systems

Summary γ-ray emission from NS/BH binaries



F. Mirabel 2006



gamma-ray binaries (rotation)

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Pulsars, Pulsar Wind Nebulae
(Colliding Wind Binaries)

X-ray binaries / μquasar (accretion)

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Active Galactic Nuclei
Gamma-Ray Bursts