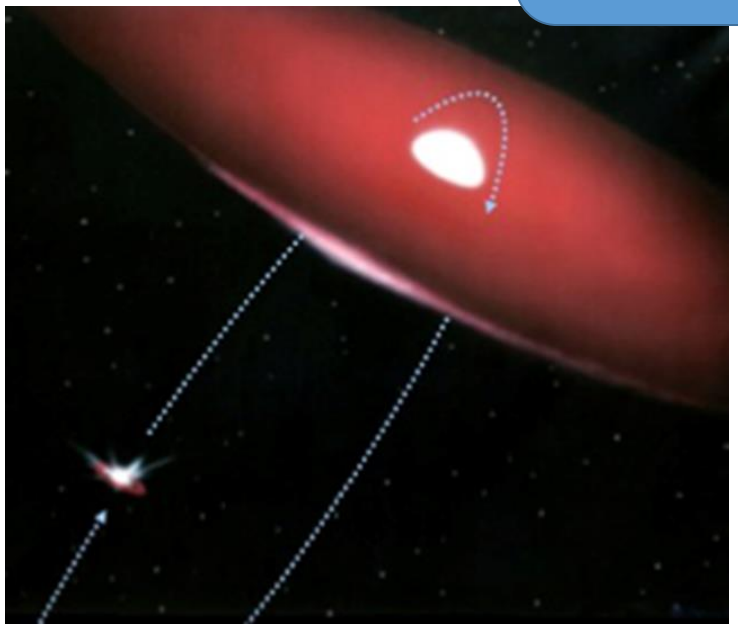
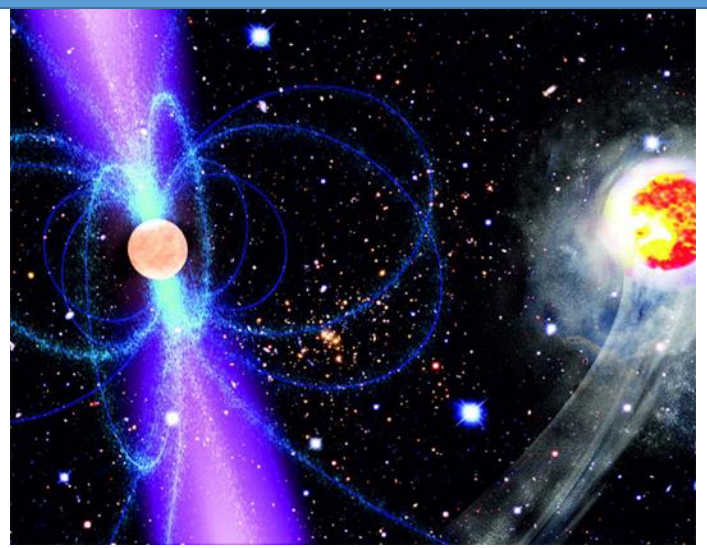
Gamma-Ray Emitting Binaries

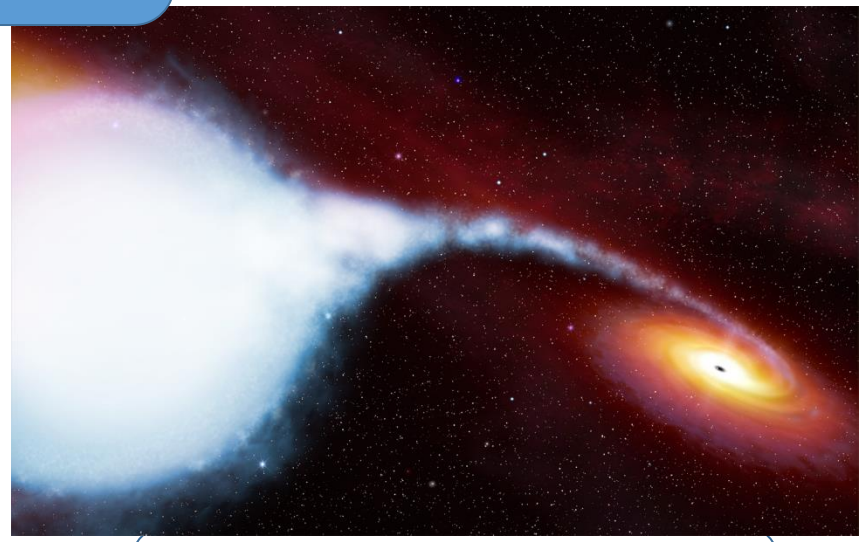
Zhongxiang Wang
(Shanghai Astronomical Observatory)
Nanjing Univ., 2020/01/10



Classical gamma-ray binaries:
Due to interaction of the winds of a pulsar and a high-mass star



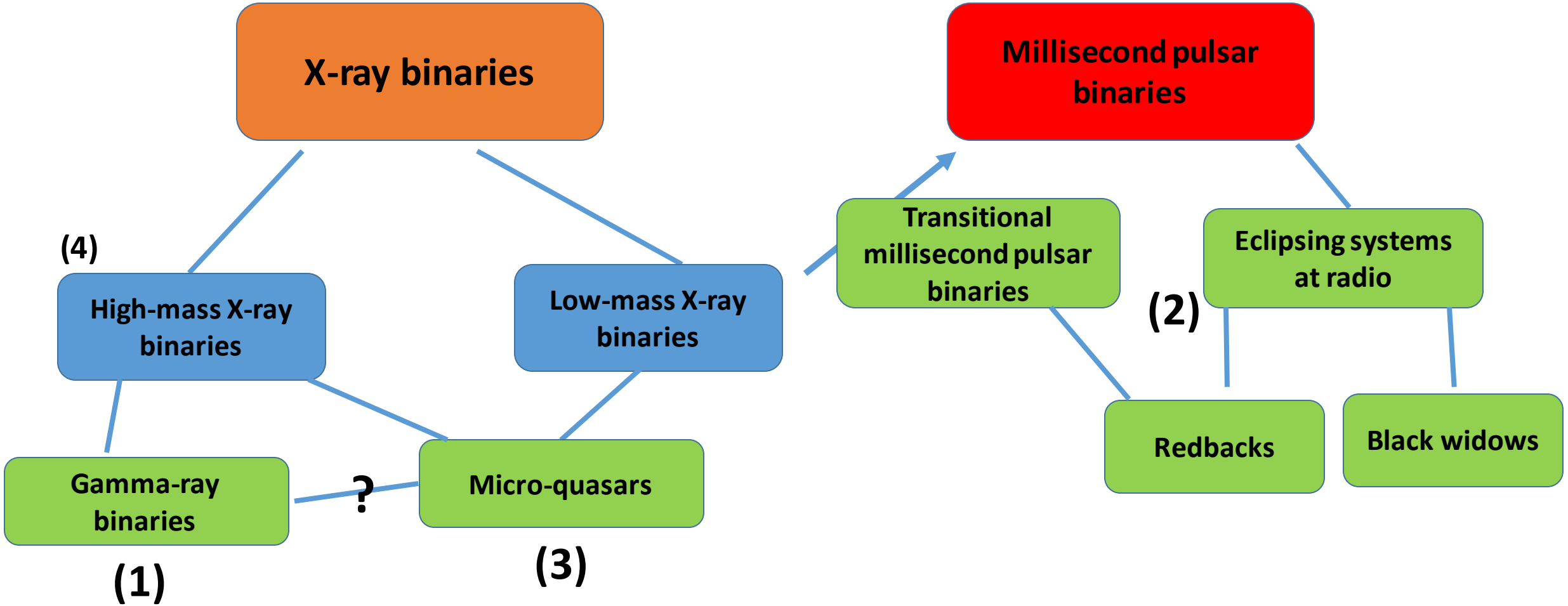
Eclipsing pulsar binaries:
Due to interaction of a pulsar wind with the outflow of a low-mass companion



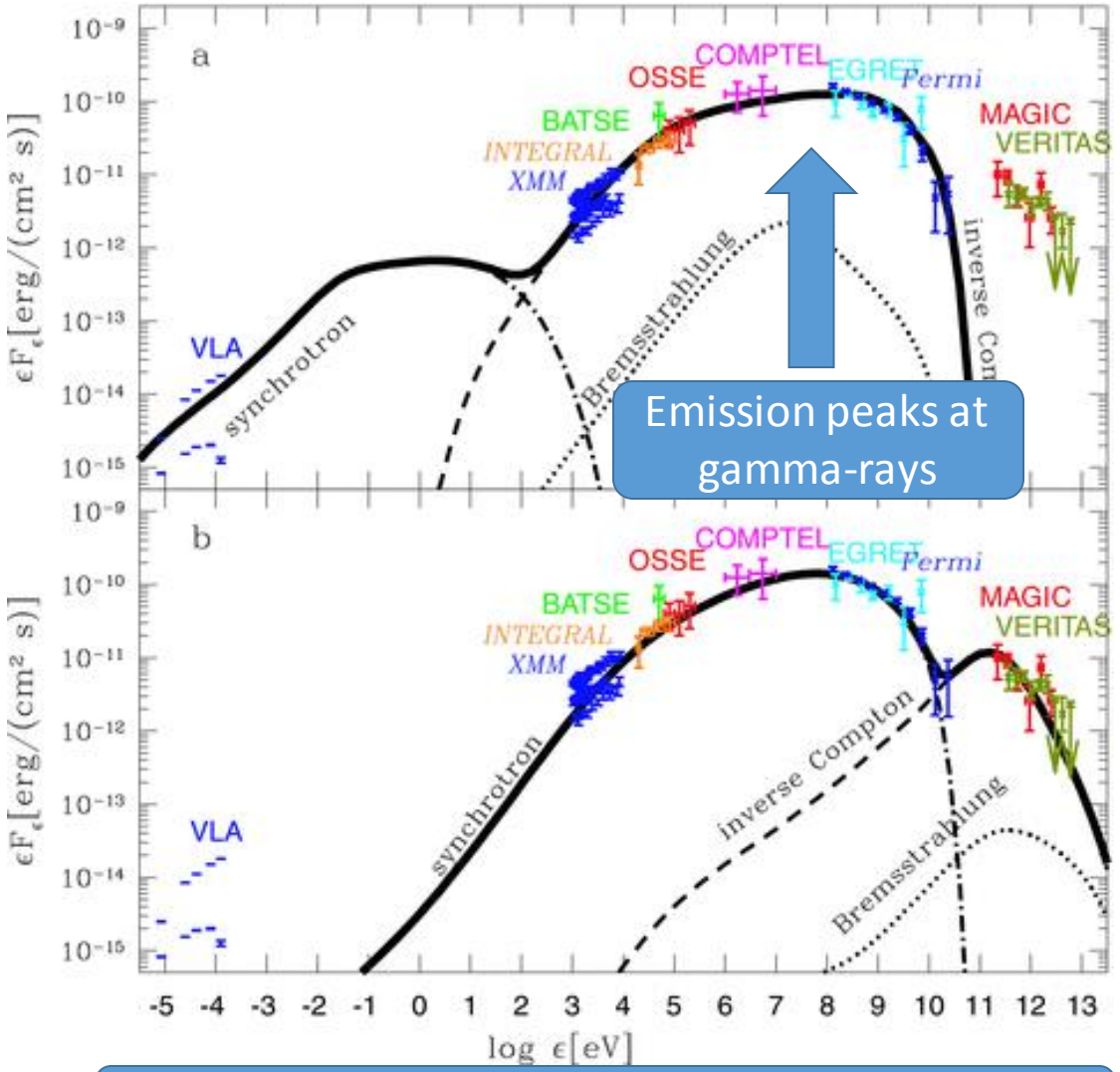
Micro-quasars:
Due to the presence of a jet

✓There are also
- Novae
- Colliding wind binaries

Different compact-star binary systems



(1) Gamma-ray binaries



Emission peaks at gamma-rays

SED of LSI +61d303 (Zdziarski et al. 2010)

Known GRBs	Orbital period (d)	Eccentricity	Companion type	Mass (Sun)	Distance (kpc)
PSR B1259-63	1236.7	0.87	O9.5Ve	31	2.3
LS 5039	3.9	0.35	O6.5V	23	2.9
LSI +61d303	26.5	0.54	BoVe	12	2.0
HESS J0632+057	315	0.83	BoVpe	16	1.6
1FGL J1018.6-5856	16.6		O6V	31	5.4
CXOU J053600.0-673507 (in LMC; candidate)	10.3		O5III		50
PSR J2032+4127 (candidate)	17670 (48 yrs)	0.989	Be	15	1.4-1.7
4FGL J1405.1-6119	13.7		O6 III (?)	~30	~7.7

(1) Gamma-ray binaries

Definition: X-ray binaries while with the emission peak at gamma-rays (>1 MeV)

Property summary:

- Contain an O/B massive companion
- Binary orbits highly eccentric
- Observable at multi-wavelengths, from radio to TeV
- Variable sources
- Showing different phenomena, which reflect underlying physical processes

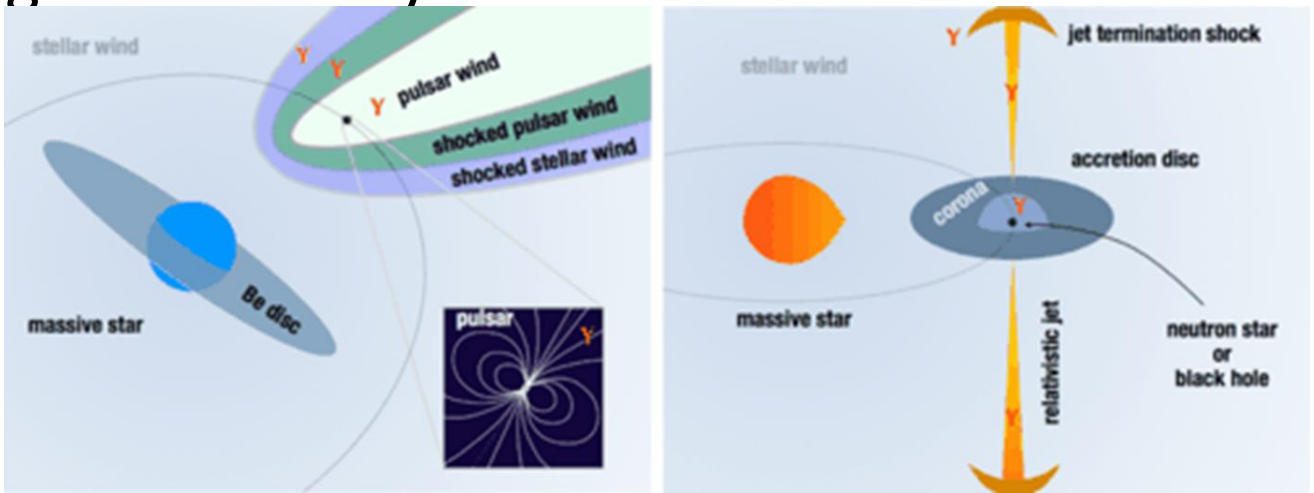
Known GRBs	Orbital period (d)	Eccentricity	Companion type	Mass (Sun)	Distance (kpc)
PSR B1259-63	1236.7	0.87	O9.5Ve	31	2.3
LS 5039	3.9	0.35	O6.5V	23	2.9
LSI +61d303	26.5	0.54	BoVe	12	2.0
HESS J0632+057	315	0.83	BoVpe	16	1.6
1FGL J1018.6-5856	16.6		O6V	31	5.4
CXOU J053600.0-673507 (in LMC; candidate)	10.3		O5III		50
PSR J2032+4127 (candidate)	17670 (48 yrs)	0.989	Be	15	1.4-1.7
4FGL J1405.1-6119	13.7		O6 III (?)	~30	~7.7

Questions

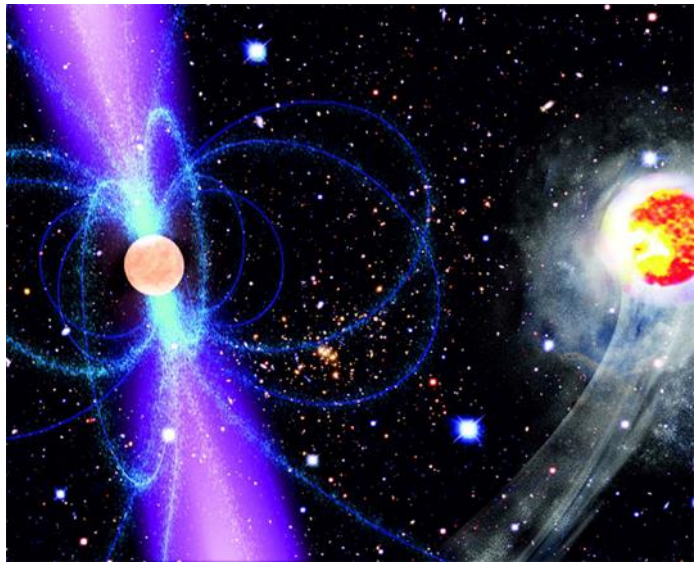
I. (1) phenomenological class or (2) evolutionary class?
   - If (1), either black hole or pulsar systems, powered by accretion or rotation respectively
   - If (2), all are pulsar systems, appearing in certain evolutionary phase (?)

II. Differences between them and high-mass X-ray binaries (or microquasars)
   - Physical differences leading to >MeV emission?

Dubus (2013)



(2) Millisecond pulsar systems



Consist of an MSP and a very low-mass companion

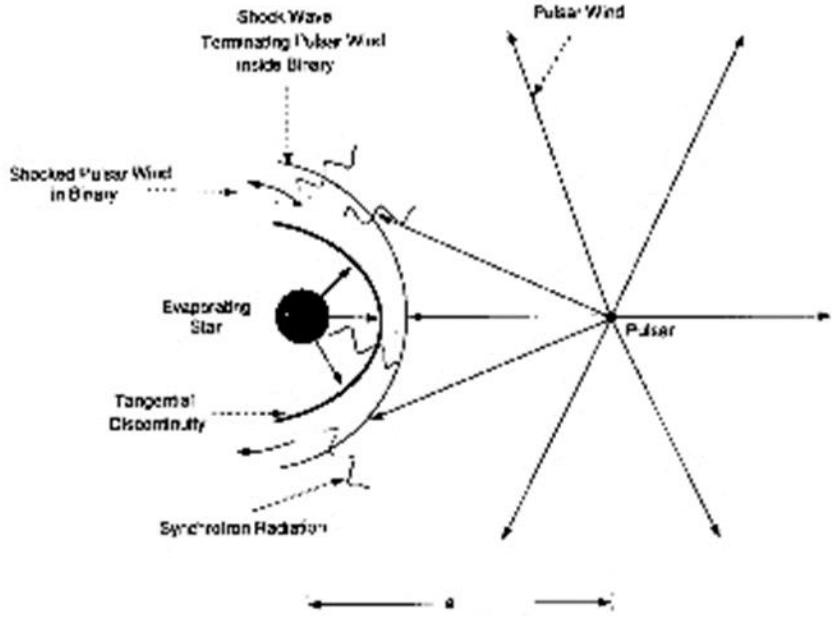
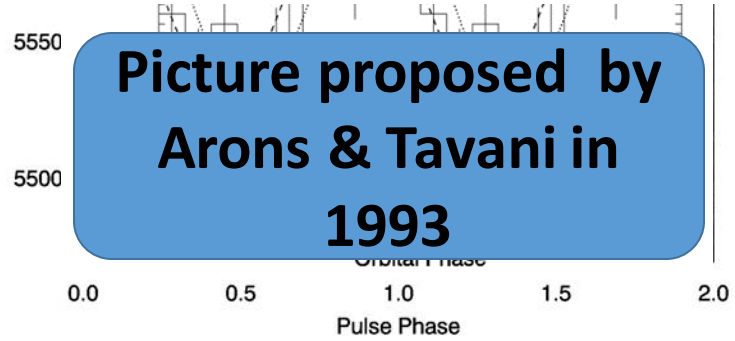


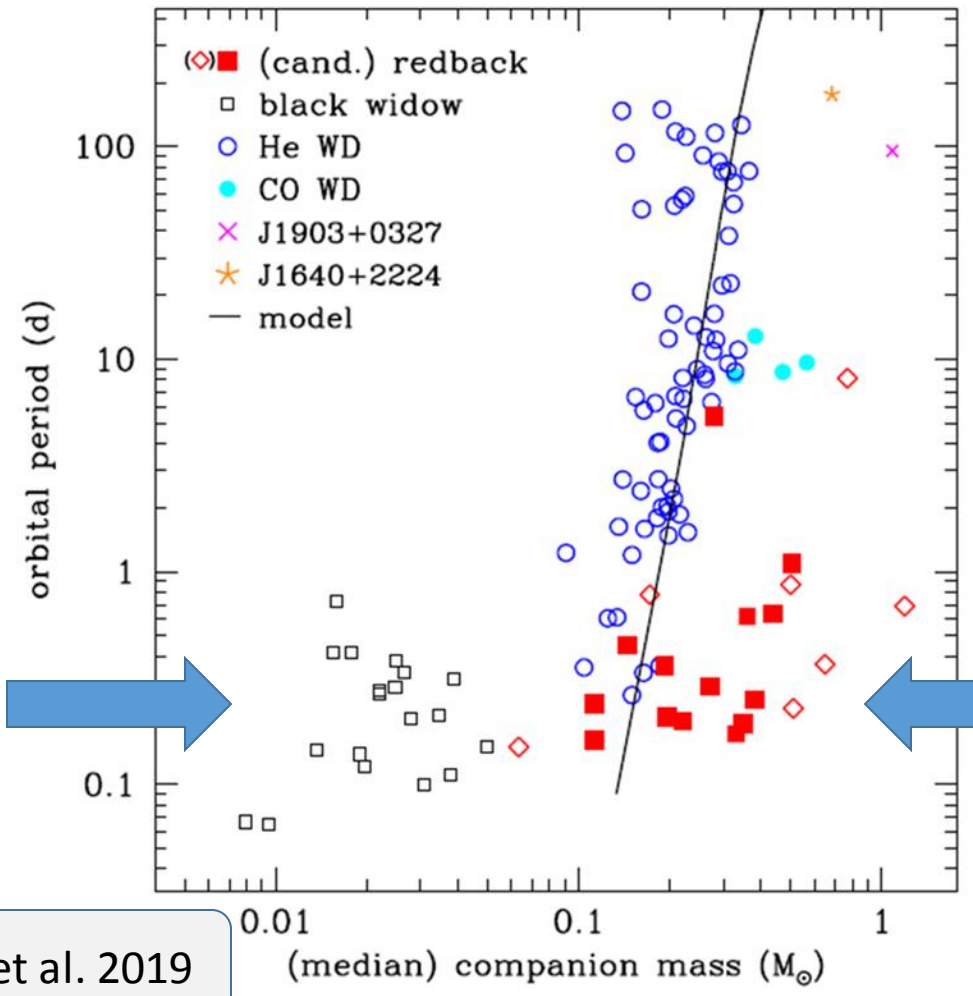
FIG. 2 Schematic representation of the shock geometry near the companion star.



Picture proposed by Arons & Tavani in 1993

- End product from evolution of low-mass X-ray binaries
- Long proposed to have intrabinary gamma-ray emission
- Firmly confirmed by Fermi observations
- Such emission is orbitally modulated

“Black widows” and “redbacks”



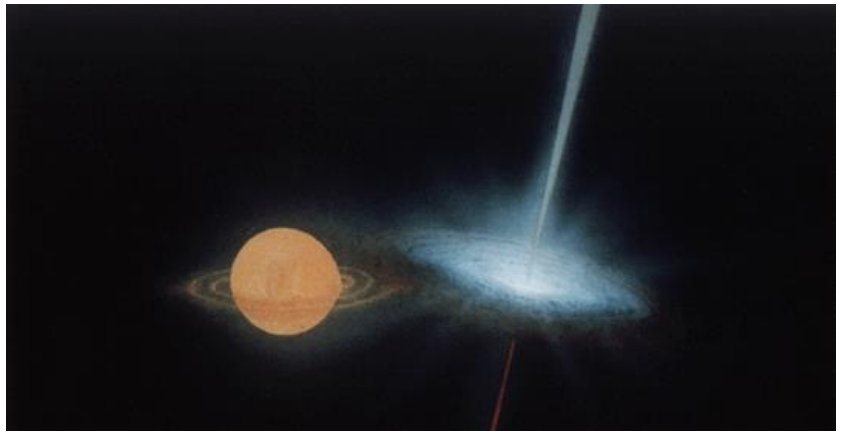
Black widow: <0.1 solar mass

Redback: >0.1 Solar mass

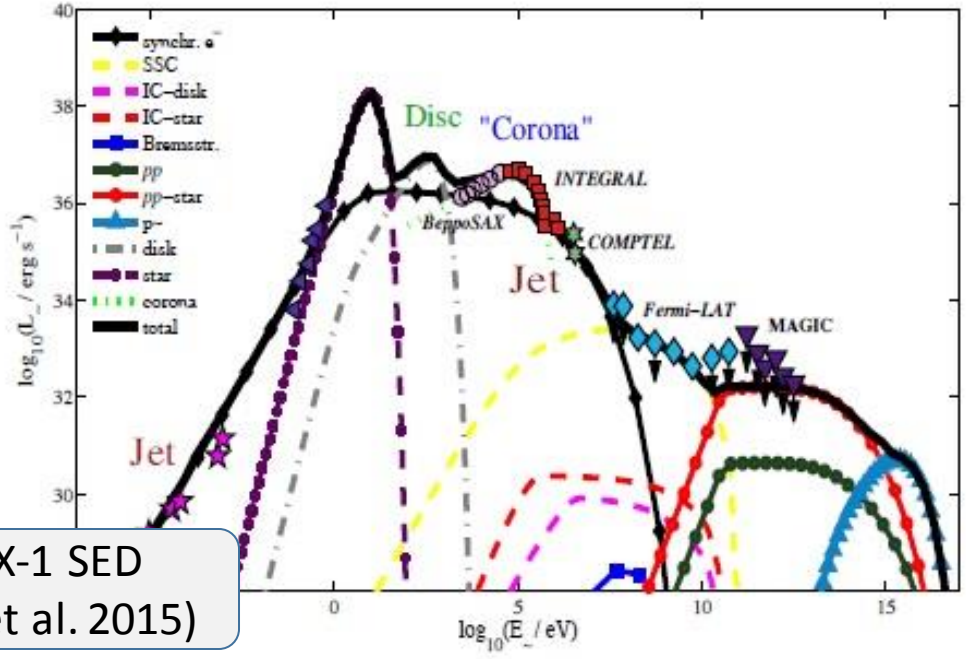
Strader et al. 2019

- Gamma-ray pulsars: having gamma-ray emission from the magnetosphere
- Extra gamma-ray emission due to intra-binary interaction: orbitally modulated
- Transitional systems: switching to have a temporary accretion disk (i.e. like an X-ray binary), but with enhanced gamma-ray emission

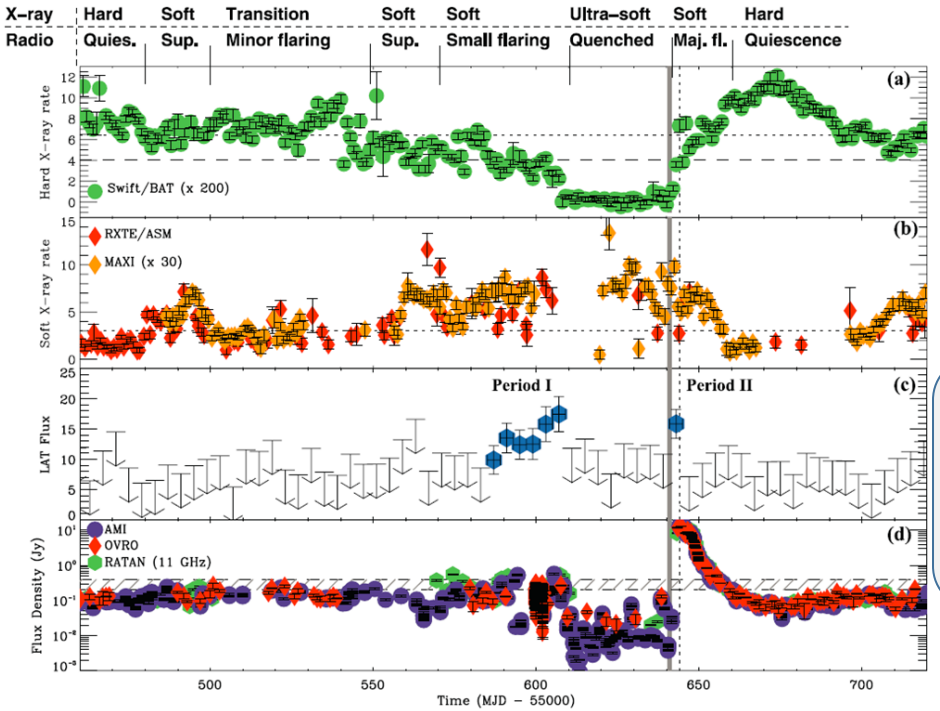
(3) Microquasars



- Consist of a black hole with jets (so a micro-quasar)
- Showing variable emission at multi-wavelengths
- Gamma-ray flares are seen
- High-energy and very-high-energy emission associated with jets' activity

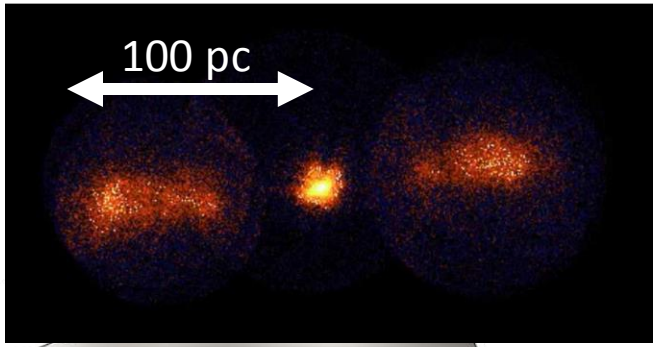


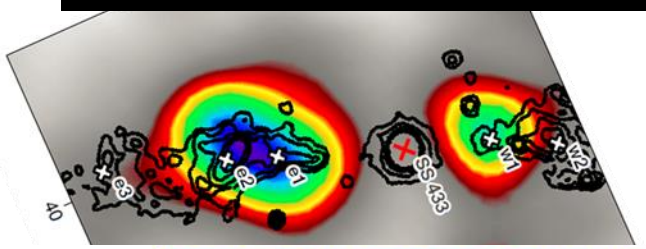
Cyg X-1 SED
(Pepe et al. 2015)

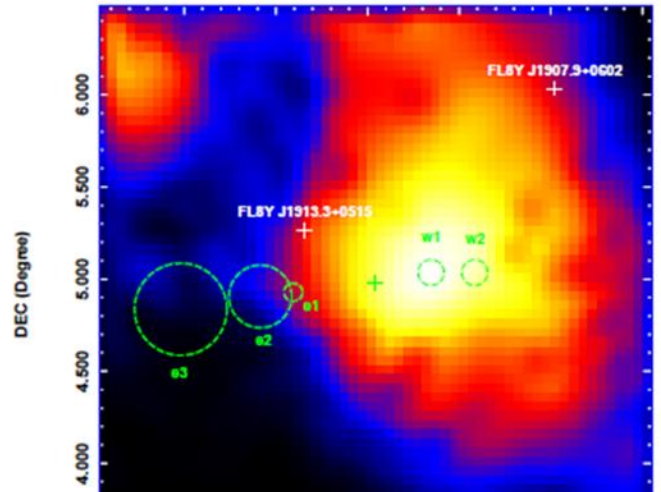


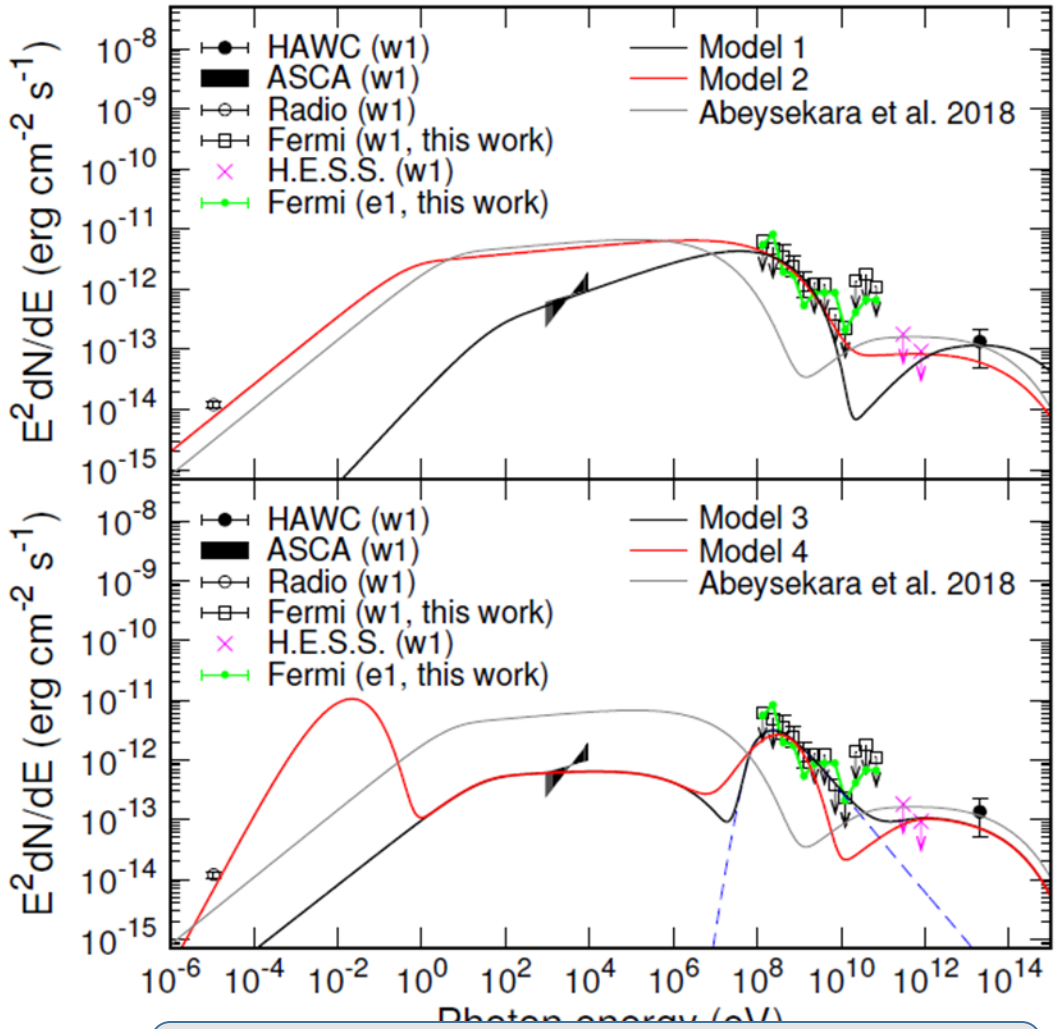
Multi-wavelength monitoring of Cyg X-3 (Corbel et al. 2012)

Microquasar SS 433





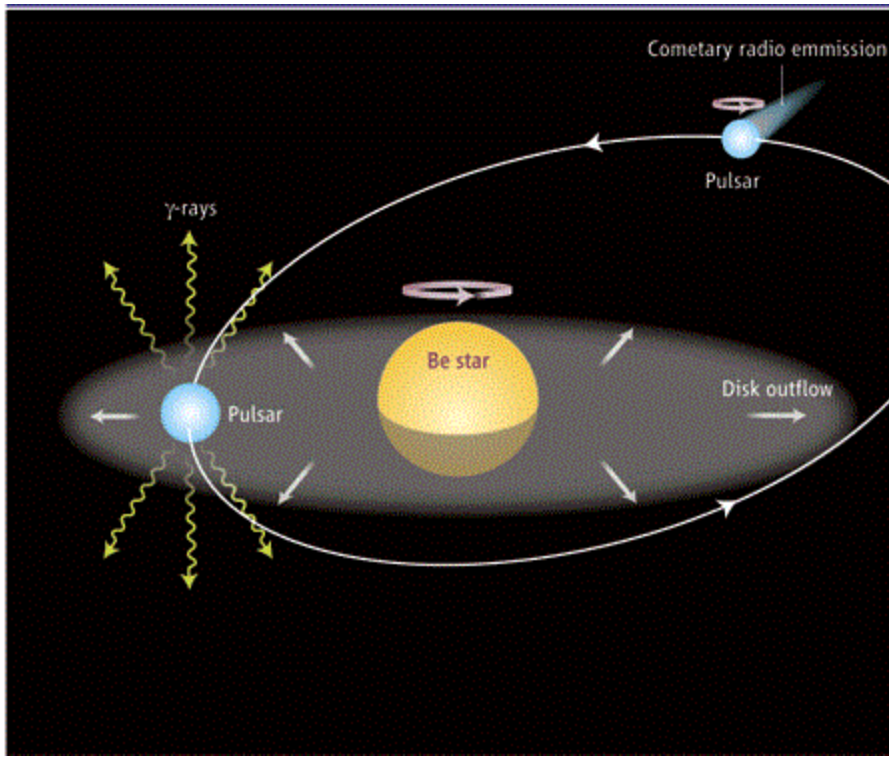




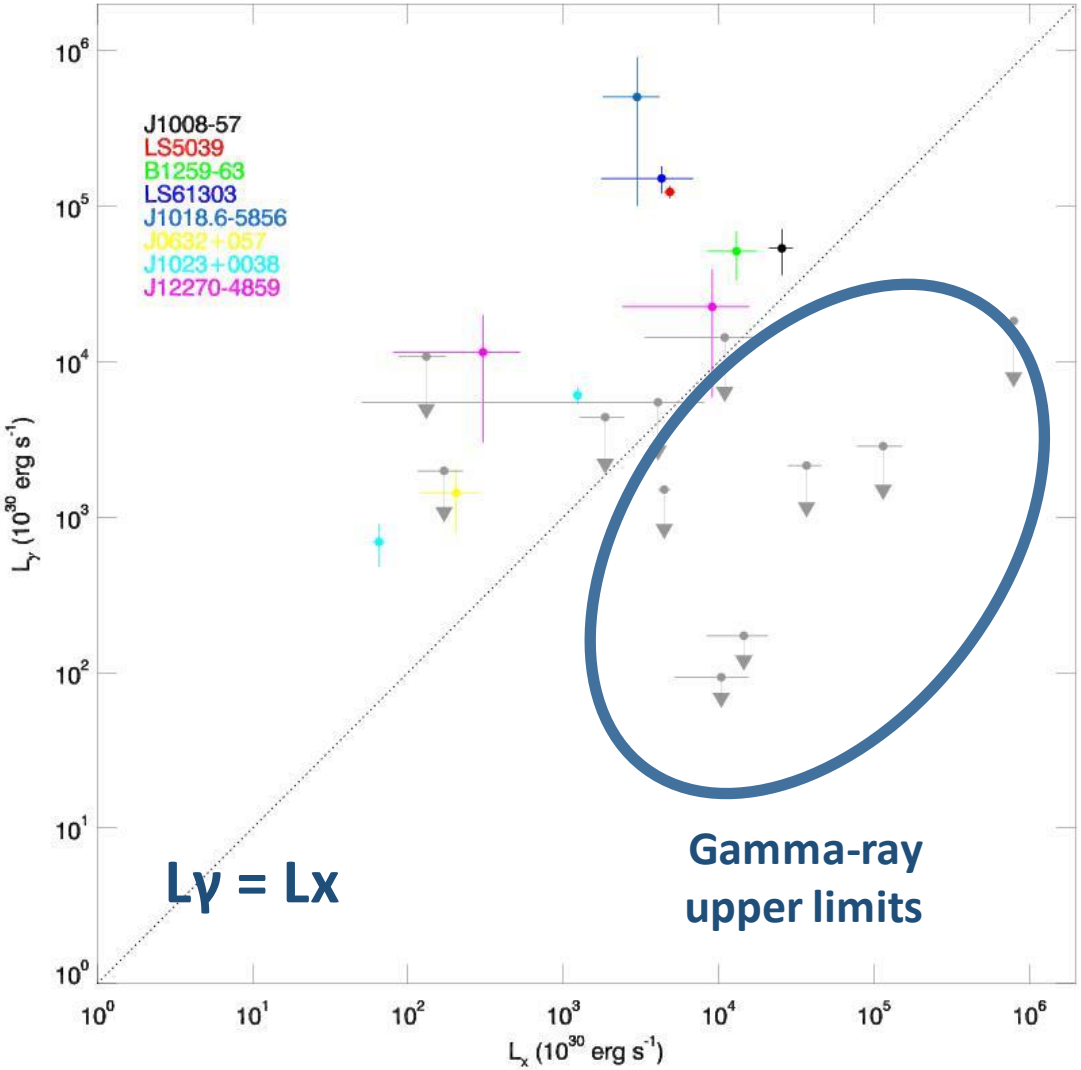
Xing, Wang, Zhang, Chen (2019, ApJ)

- An edge-on micro-quasar
- Interaction region of a jet with ambient medium can produce persistent gamma-rays
- (But see Rasul et al. 2019 and Sun et al. 2019 for other possibilities)

High-mass X-ray binaries

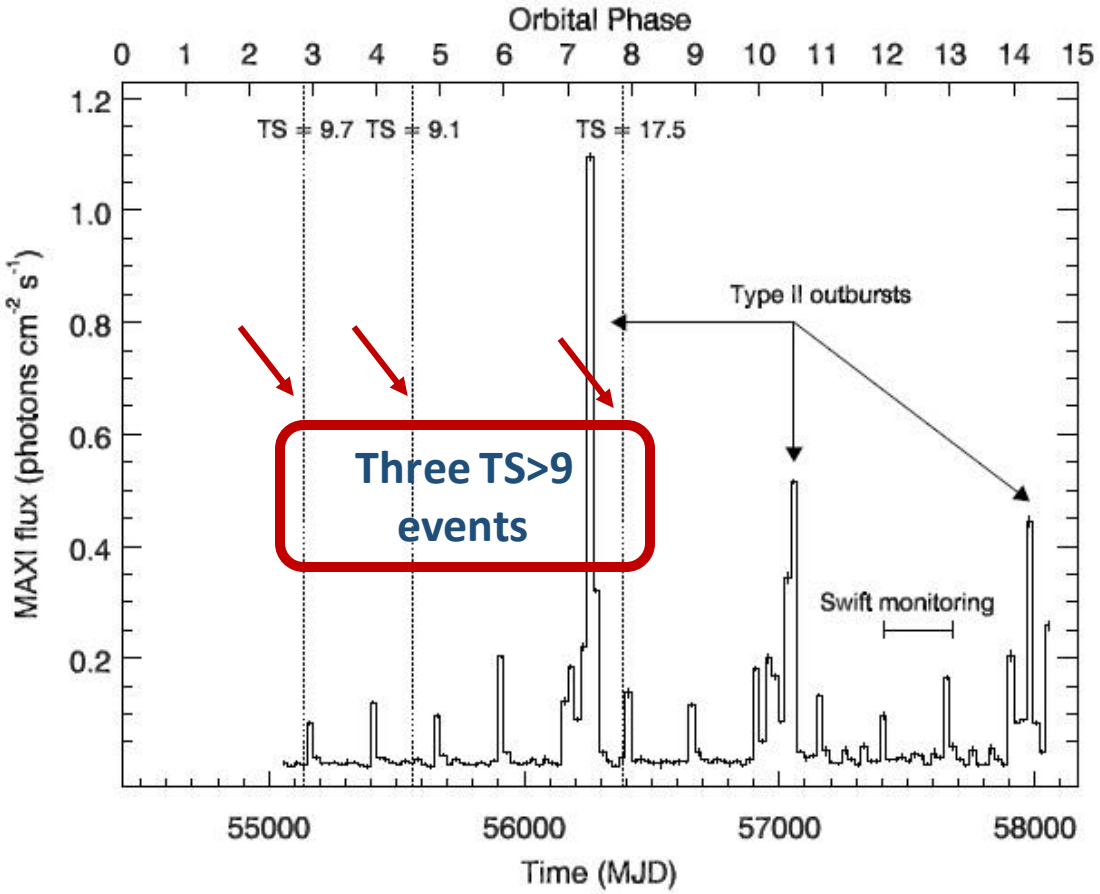


Typical Be HMXBs
(F. Mirabel)



- Be HMXBs are very similar to some of gamma-ray binaries
- But pulsars are older, accreting
- Should have gamma-rays or not?
- We have searched in ~20 Be HMXBs, obtaining deep upper limits

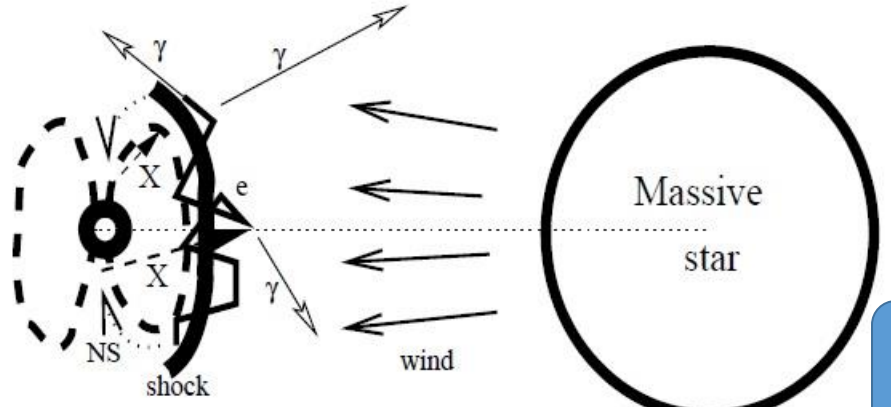
Gamma-ray emission from GRO J1008-57



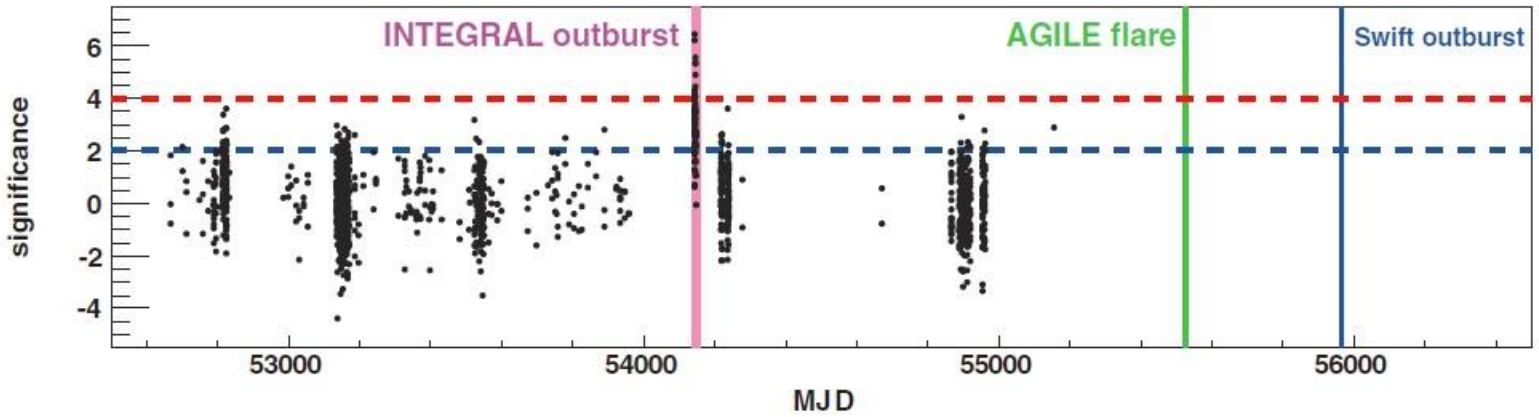
Detection events for GRO 1008-57 (Xing & Wang 2019)

- Pspin=93.5 s pulsar
- Orbital period 249.5 days, eccentricity 0.68
- Highest known magnetic field among HMXBs, B~8x10^12 G, confirmed by Chinese HXMT
- Regular type I outbursts, and occasional giant type II outbursts
- Gamma-ray emission is due to occasional gamma-ray emitting events
- Lγ ~ 10^34 erg/s, hard to be explained by current models

How to produce gamma-ray emission from GRO J1008-57



Bednarek 2009



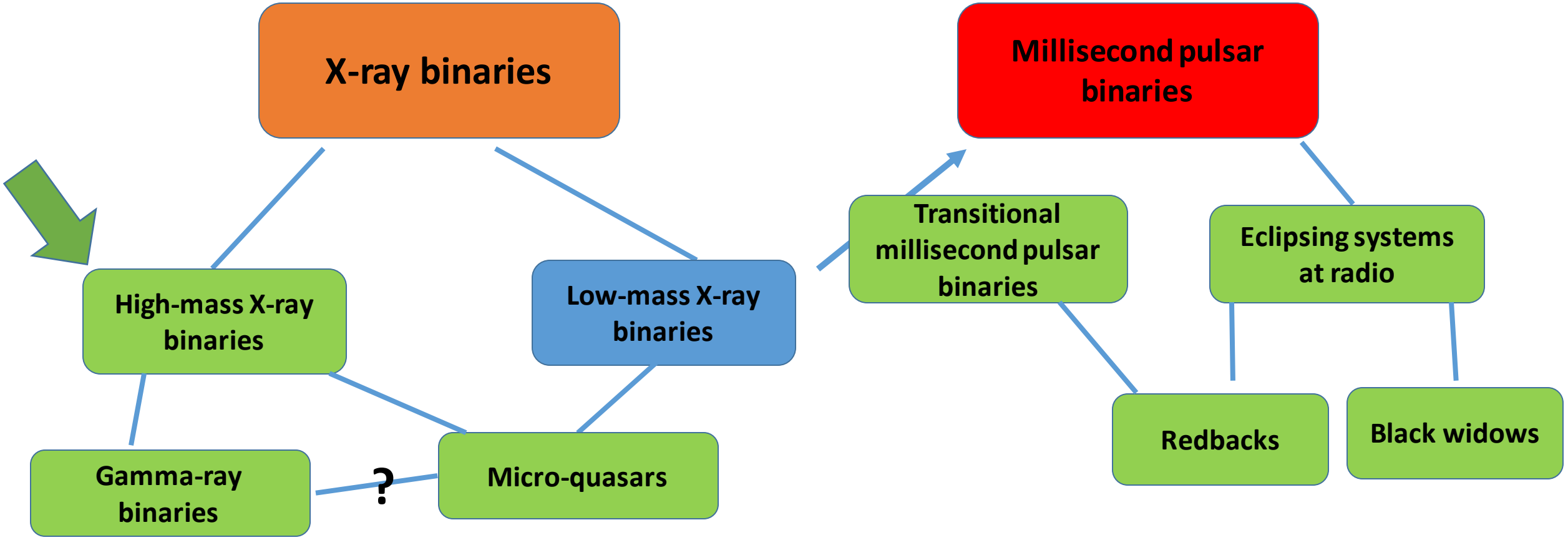
Outburst activity of HMXB 4U 1036-56 (Pspin=855 s; Li et al. 2012)

Accreting neutron star:

- In HMXBs, there could be a turbulent region near the neutron star
- Particles might be accelerated in this region, giving rise to gamma-rays
- Li et al. (2012) used this model to explain an gamma-ray outburst event seen in HMXB 4U 1036-56
- However the predicted gamma-ray luminosity can only roughly match the observed ones of GRO J1008-57 and 4U 1036-56

?

Conclusion


X-ray binaries
High-mass X-ray binaries
Low-mass X-ray binaries
Gamma-ray binaries
?
Micro-quasars
Millisecond pulsar binaries
Transitional millisecond pulsar binaries
Eclipsing systems at radio
Redbacks
Black widows

Summary

Mainly from *Fermi*, different compact star binaries can have gamma-ray emission due to different mechanisms:

1. Gamma-ray binaries can be powered by a young pulsar; it is a question whether some of them are powered by accretion or jets?
2. Millisecond pulsar binaries are due to intrabinary processes
3. Micro-quasars are because of their jets
4. Two Be HMXBs are known to have occasional gamma-ray emission events; how they occur remain to be understood

Thank You!