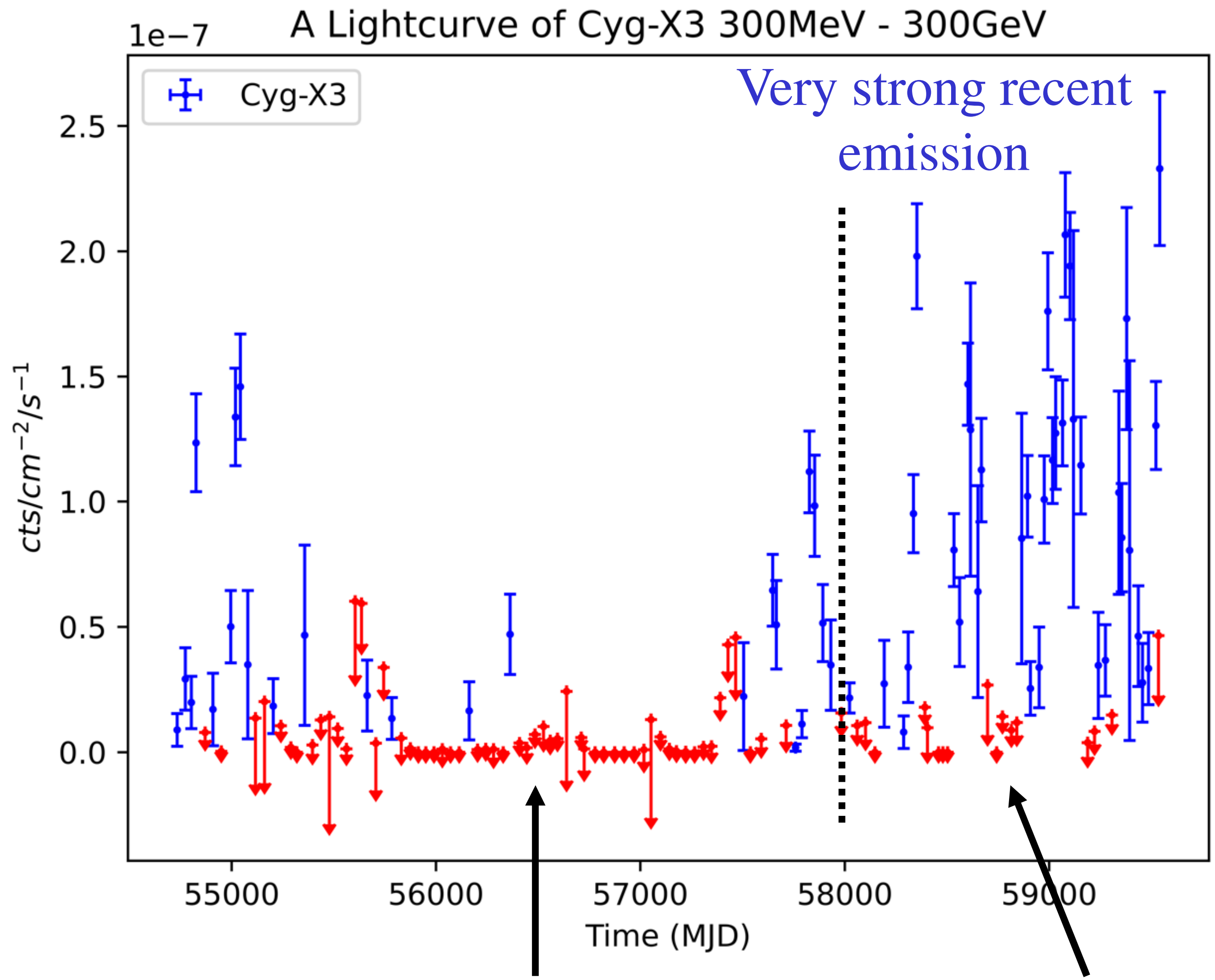
# Cyg X-3:
# Powerful $\gamma$-ray flares during 2017–21.
# Modelling and interpretation.

With Denys Malyshev, Masha Chernyakova and Dave Green

# Cyg X-3 – a puzzling microquasar

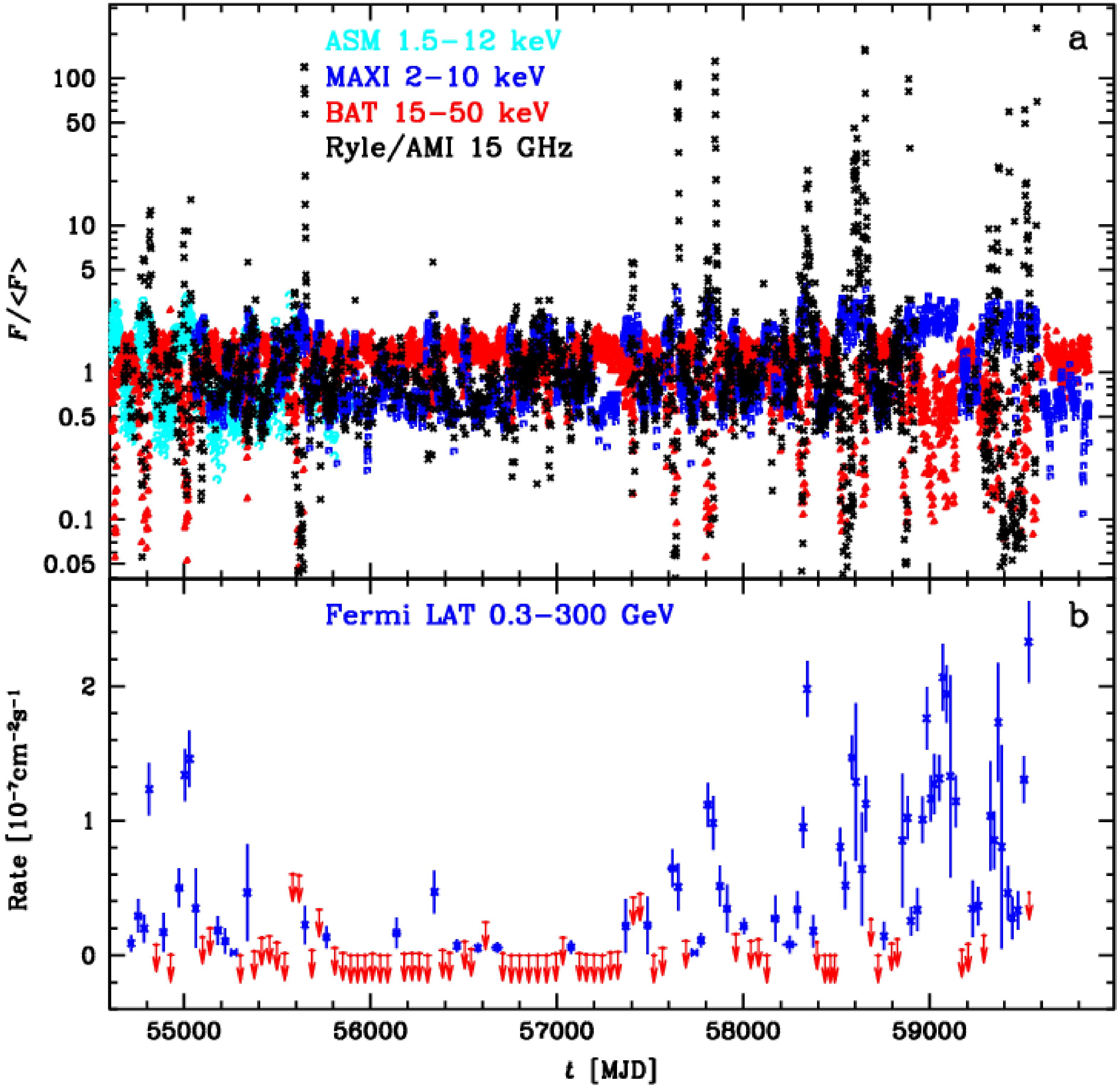
- A very luminous radio and X-ray source, Wolf-Rayet + either a low-mass BH (most likely) or NS; a very short (for HMXBs) $P = 4.8$h, $L/L_{\rm Edd}$ up to ~1.
- A likely BH–BH or BH-NS progenitor and merger candidate (Belczyński+13).
- A hard state with a radio/X-ray correlation similar to BH binaries.
- Major radio flares ($\lesssim$20 Jy) and strong γ-ray emission in the *soft, disc dominated state*, unlike the jet quenching in BH LMXBs, but similar to luminous blazars.

# High-energy γ-rays from Cyg X-3




AAZ+2018: a study of *Fermi* γ-ray and radio emission up to MJD 58000

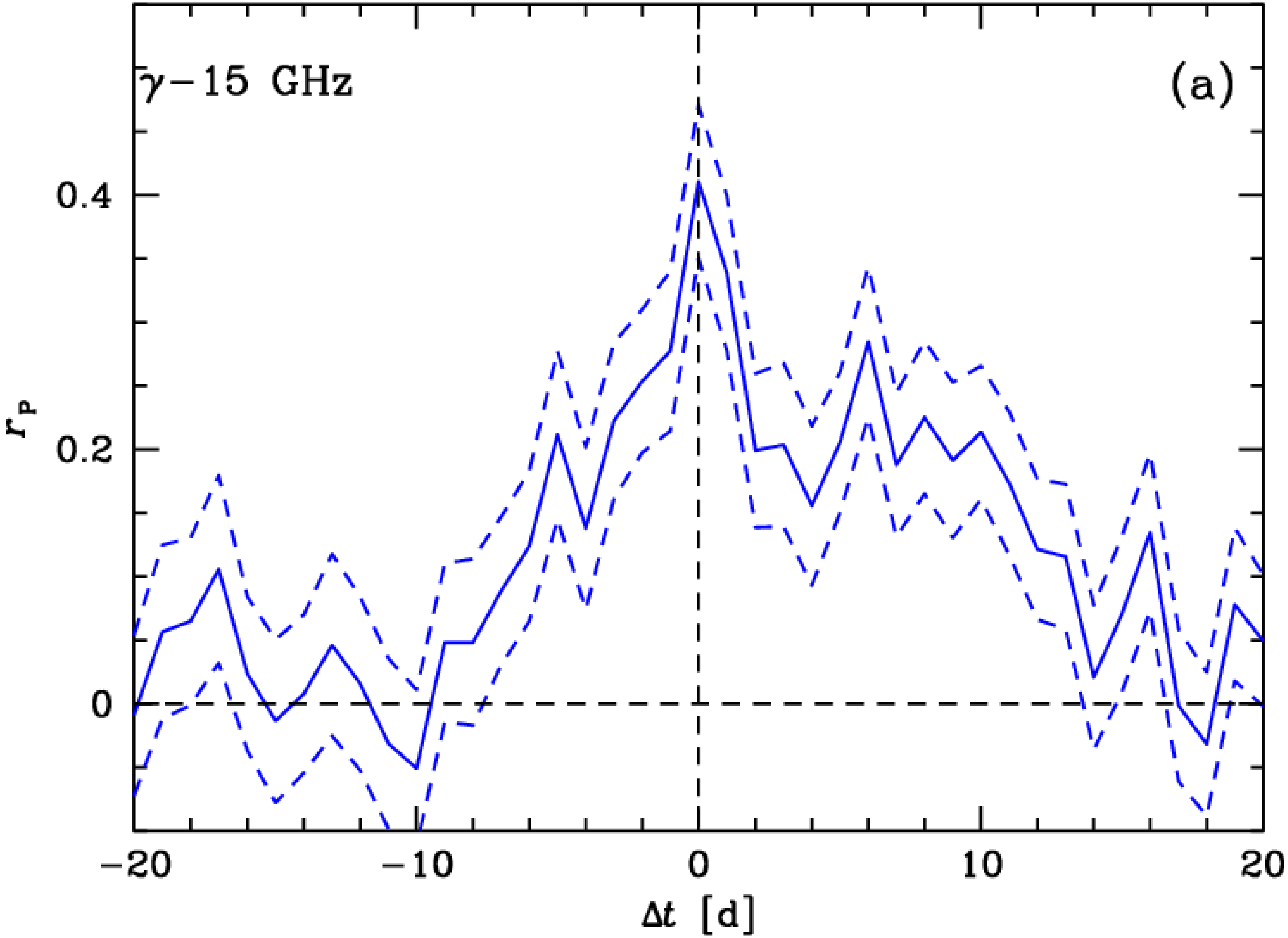
New results



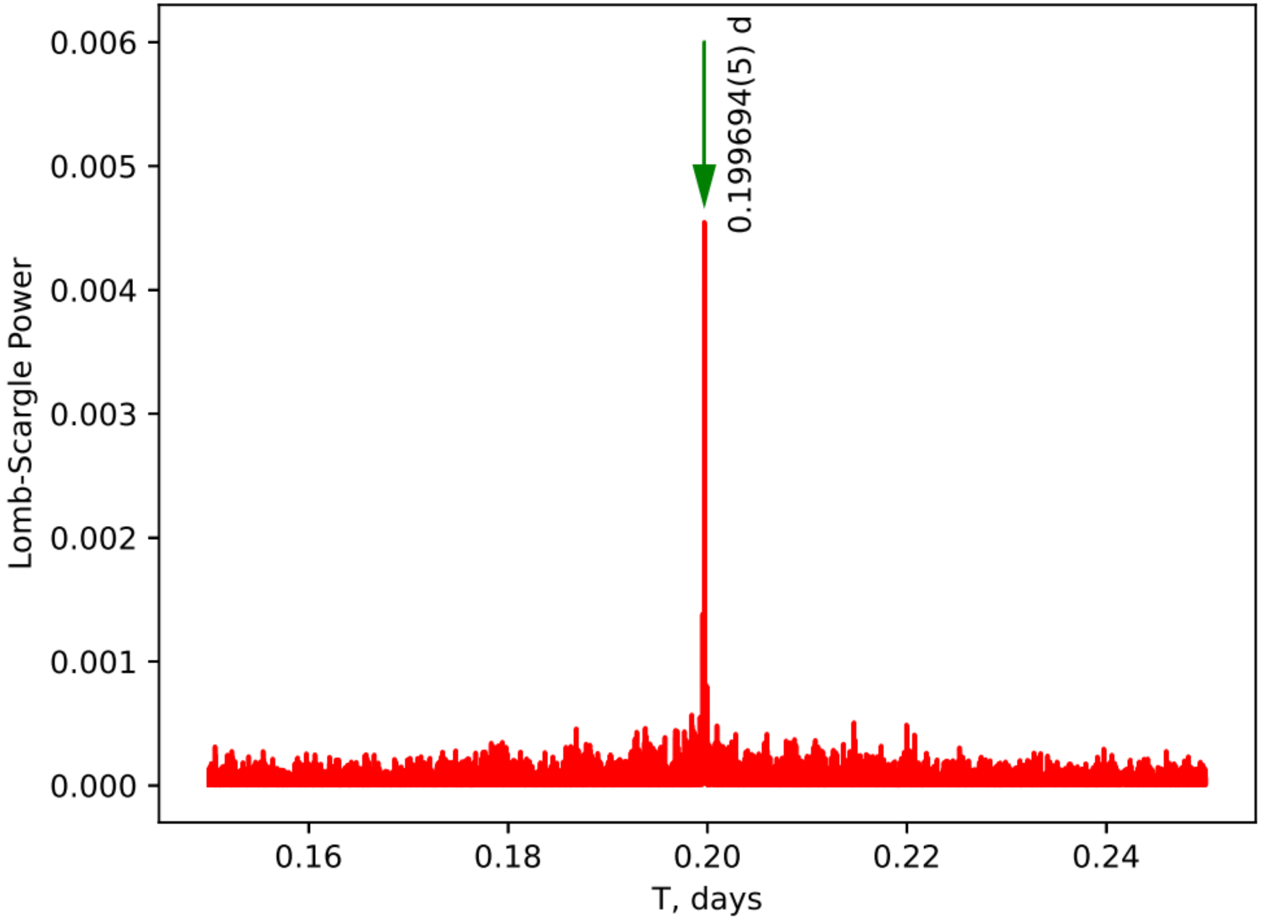
ASM 1.5–12 keV
MAXI 2–10 keV
BAT 15–50 keV
Ryle/AMI 15 GHz
a
F/<F>
100
50
10
5
1
0.5
0.1
0.05
Fermi LAT 0.3–300 GeV
b
Rate [10⁻⁷cm⁻²s⁻¹]
2
1
0
55000
56000
57000
58000
59000
t [MJD]

# Radio vs. γ-ray correlation

- A strong positive correlation at zero lag between GeV γ-rays and radio, using all -ray detections with S/N>2:



# γ-ray modulation at the orbital period

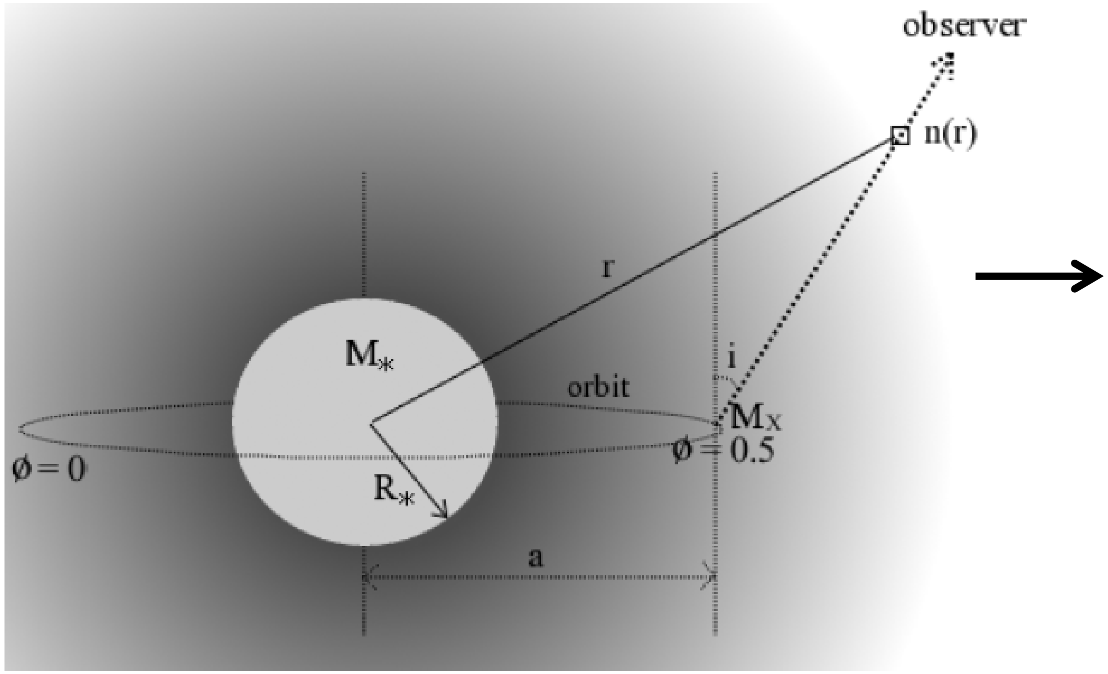



The Lomb-Scargle analysis taking into account the observed increase of the orbital period. The obtained period agrees with that from X-rays.

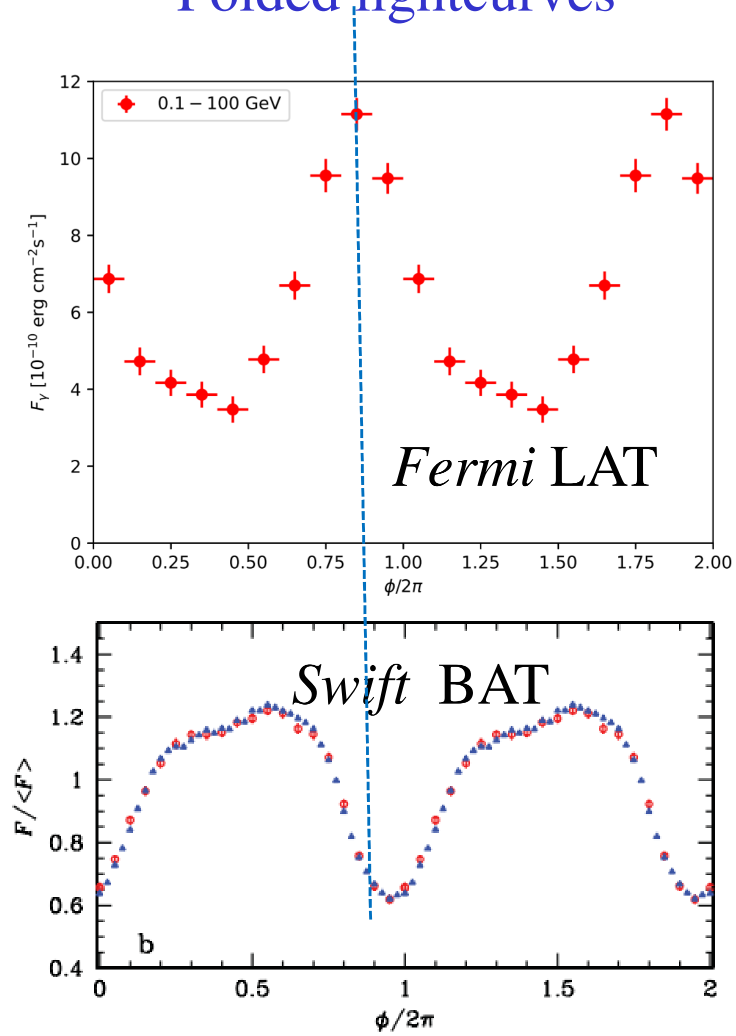
# γ-ray modulation at the orbital period

Orbital modulation of γ-rays during the flaring periods.
The γ-rays have the ***maximum*** close to the superior conjunction.

X-rays undergo wind absorption, thus their ***minimum*** *F* is at the superior conjunction (black hole behind the donor).



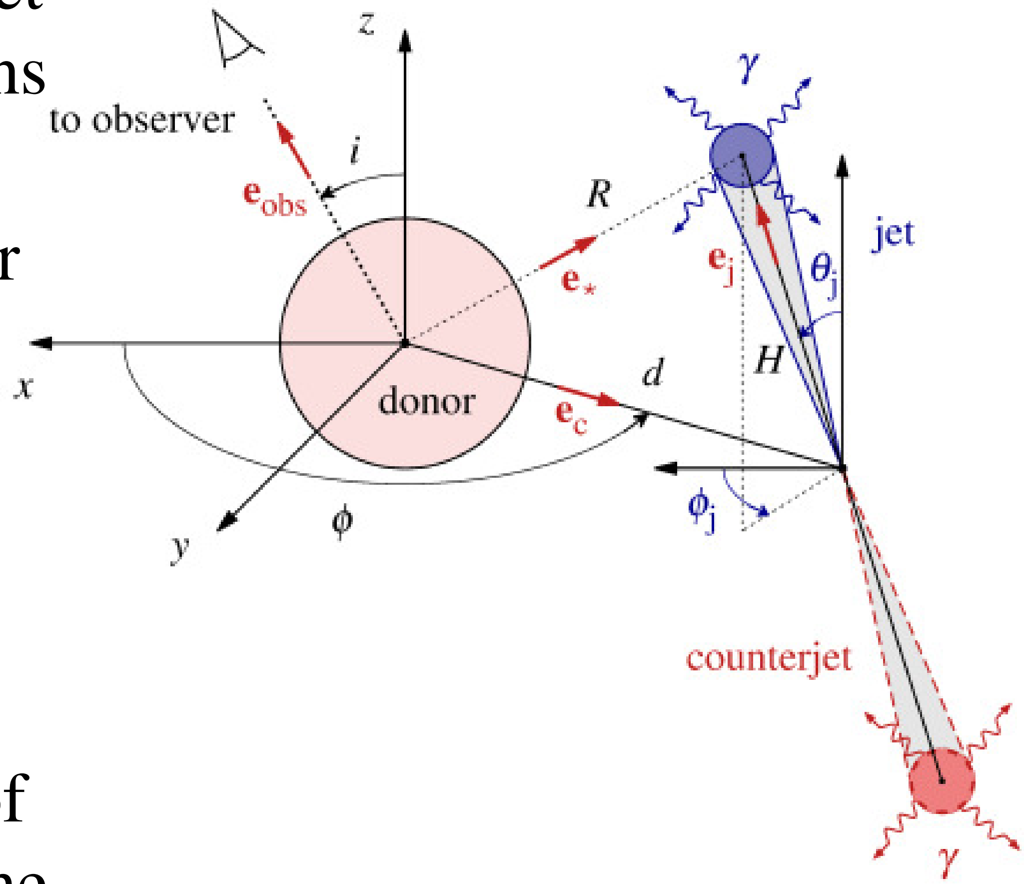

Folded lightcurves



# A model for the GeV modulation

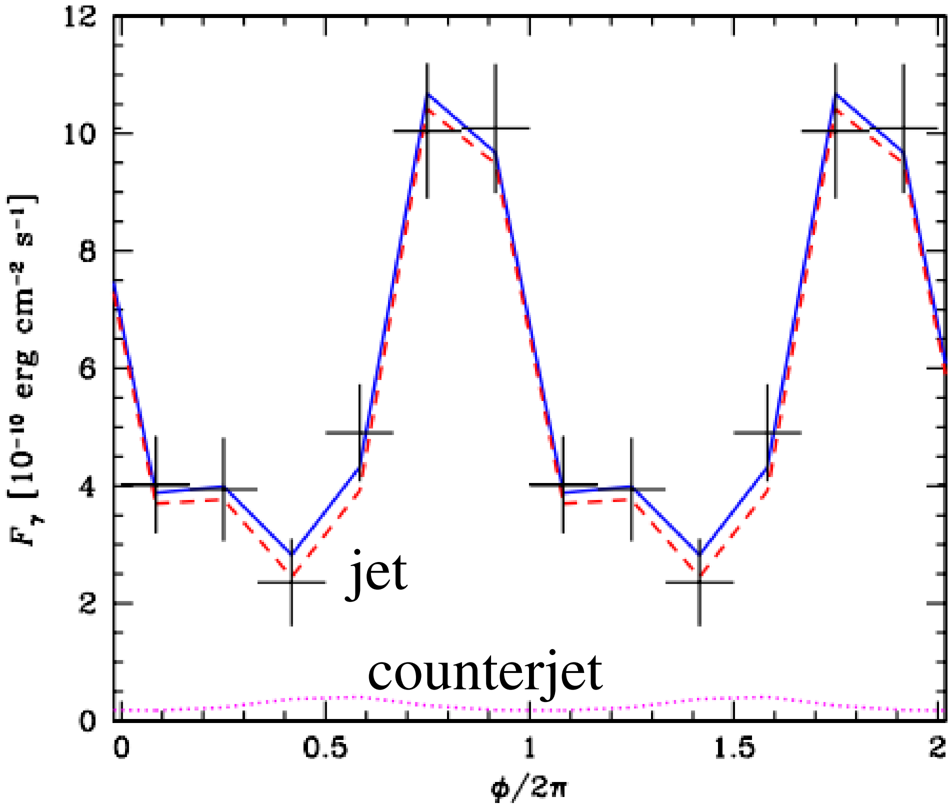
## Compton scattering in the jet

- The relativistic electrons in the jet Compton upscatter stellar photons to GeV energies.
- Highest scattering probability for electrons moving towards the stellar photons.
- Relativistic electrons emit along their direction of motion.
- Thus, most of the all emission is toward the star. The maximum of the observed emission is when the jet is behind the star.

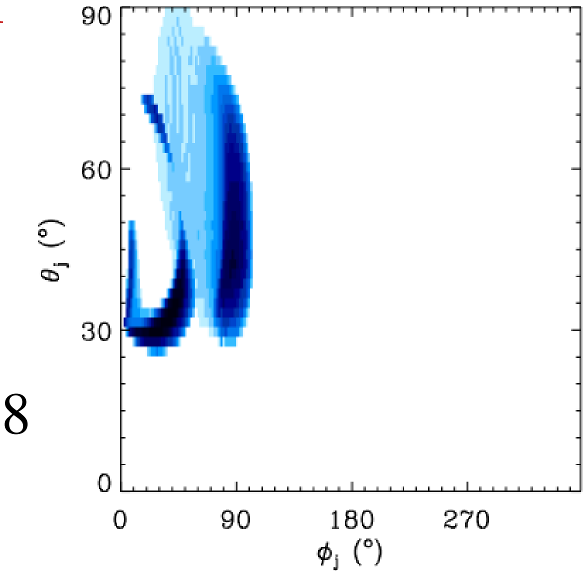


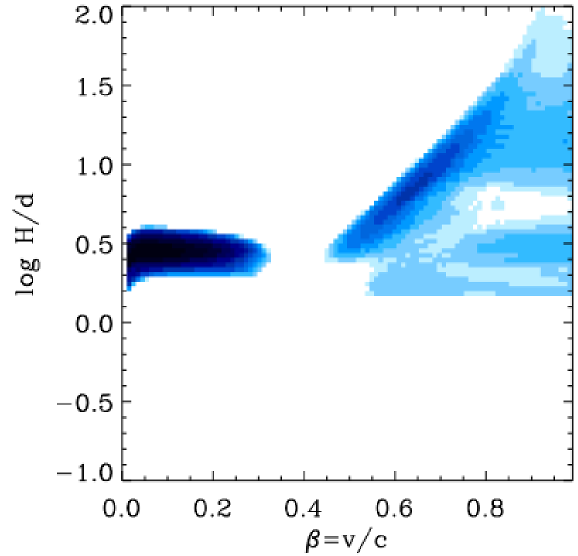

Dubus+10, AAZ+12, 18

# Fit of this model to the folded γ-ray light curve from our 2018 paper




AAZ+18



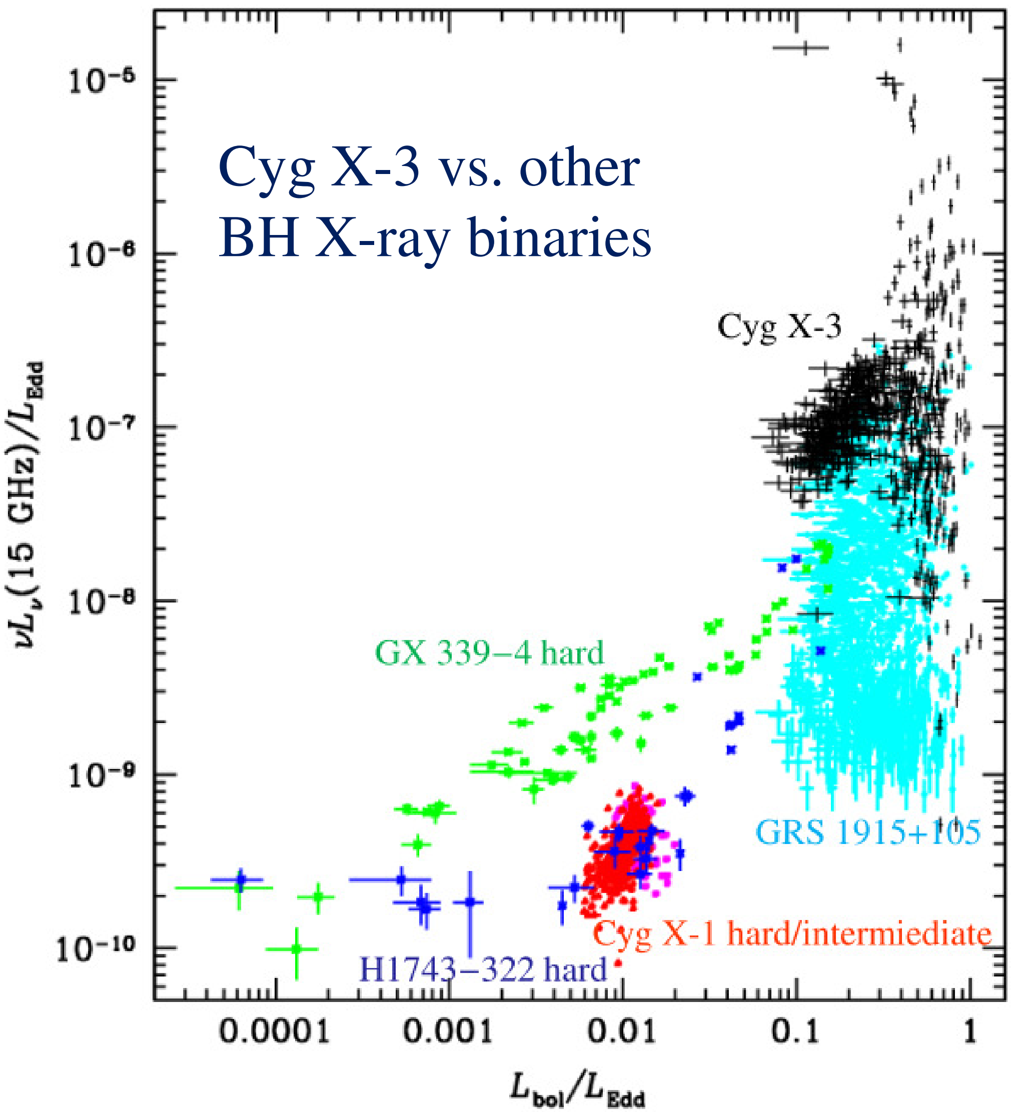




γ-ray emission region at ~(2–3)× stellar separation ~$10^{12}$ cm~$10^6$ $R_g$. *The jet is misaglined w/r the binary axis*, $\theta \gtrsim 30°$, and relatively slow.

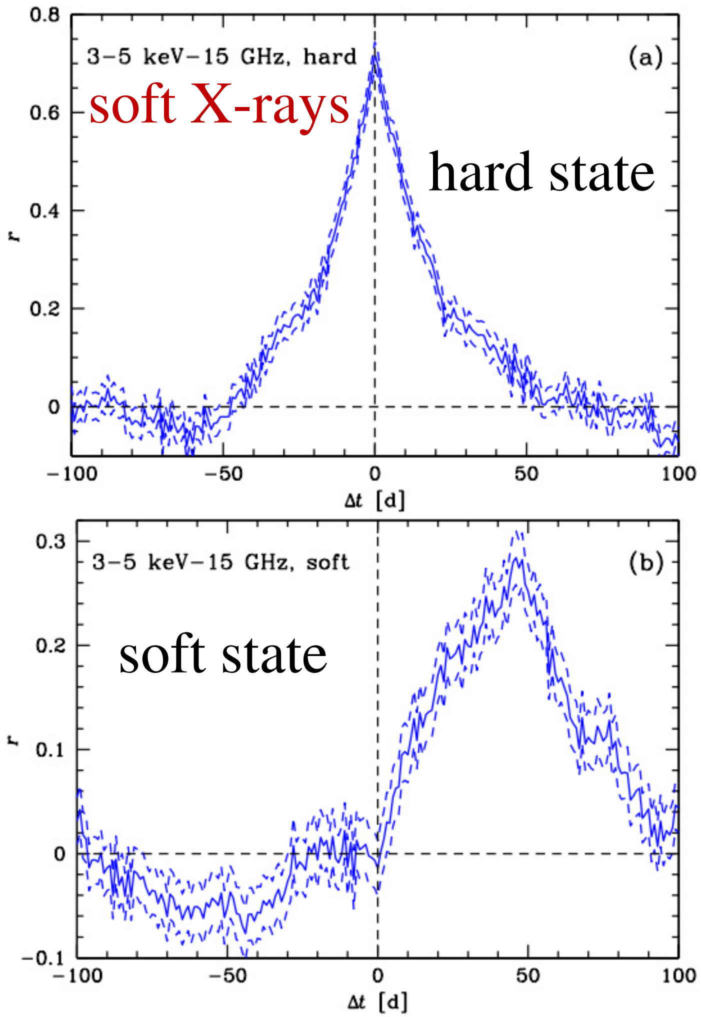
This analysis will be updated using the present, much better, data.

# Radio/X-ray correlations and time lags

- 15 GHz radio: no lag w/r to soft X-rays in the hard spectral state, but a highly significant ~50 d lag in the soft state.

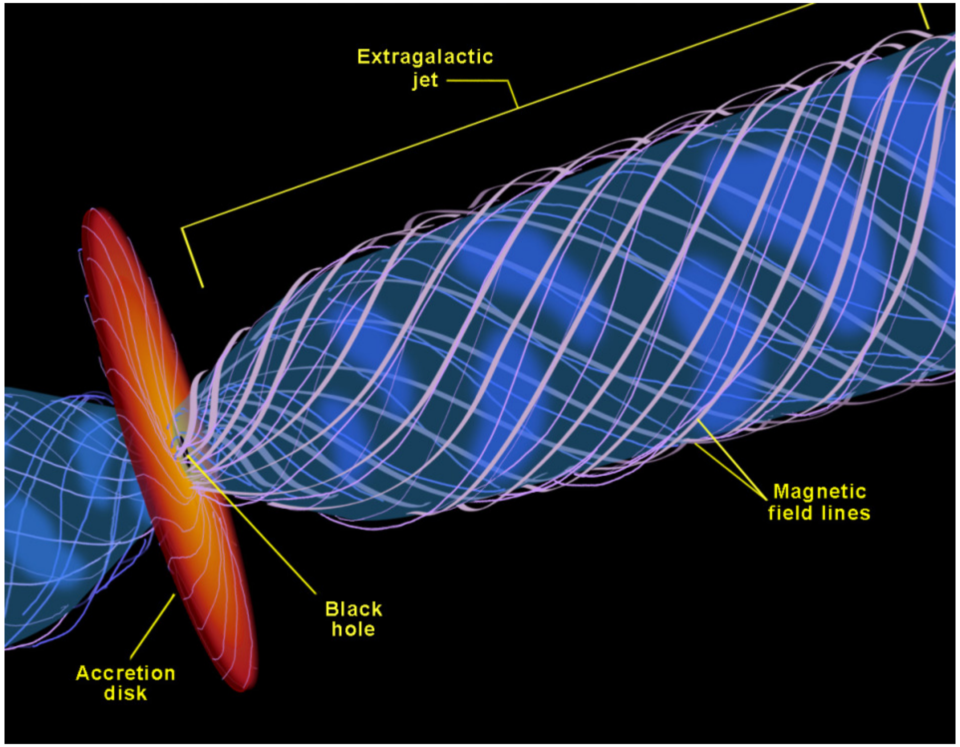


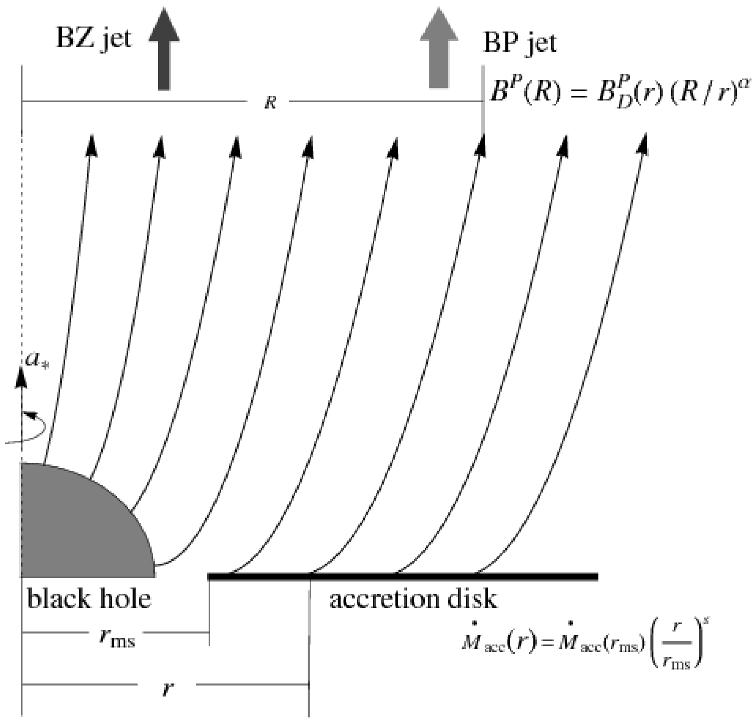

AAZ+2018



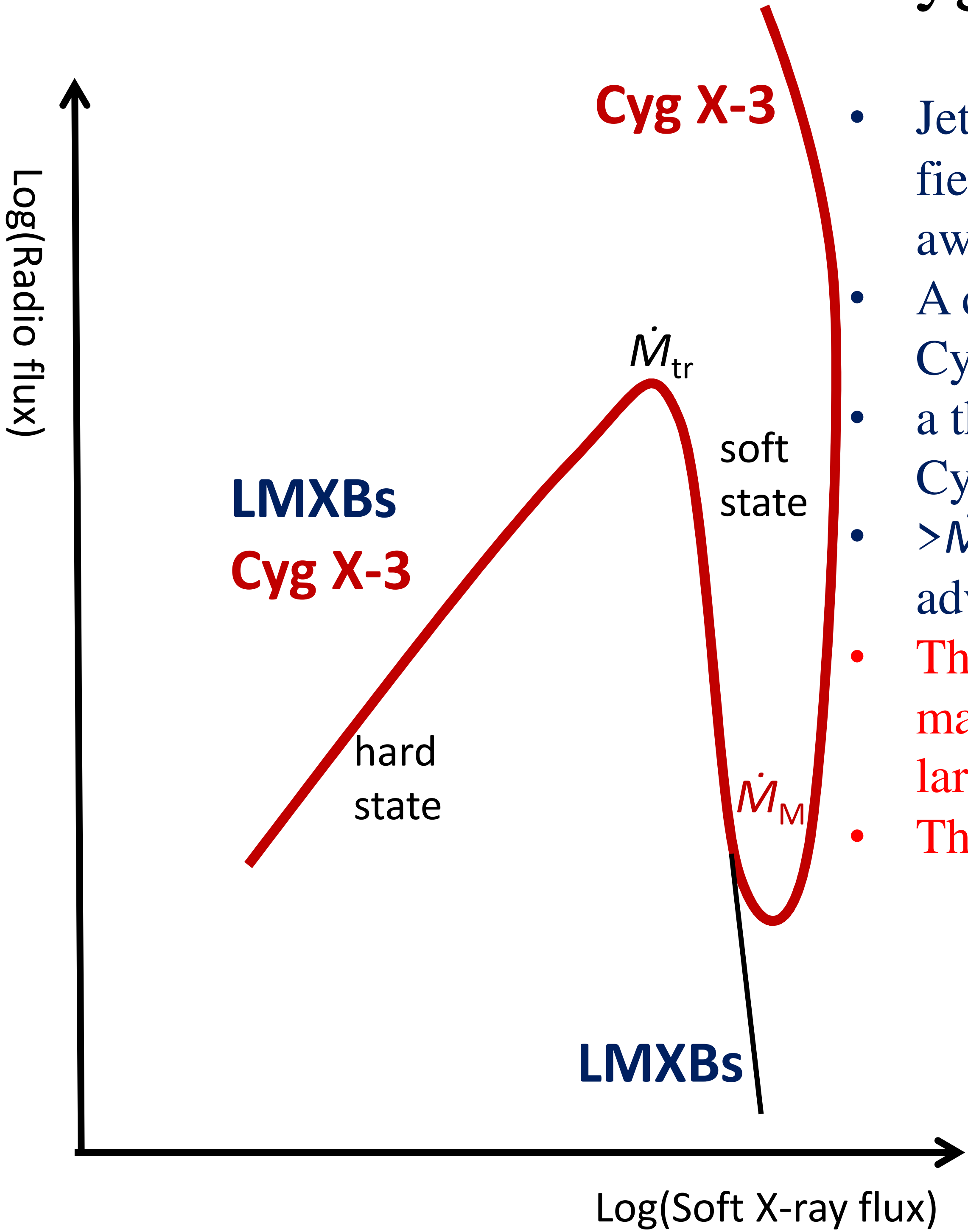
# Jet launching mechanisms

- Extraction of spin energy of a rotating BH (Blandford & Znajek 77; Tchekhovskoy+11; McKinney+12). $P_{\mathrm{jet}} = \kappa a_*^2 B_{\parallel}^2 R_g^2 c$.
- Collimation and acceleration by disc poloidal magnetic field (Blandford & Payne 1982). A much lower jet power.
- *Both mechanisms require the presence of a vertical/poloidal field.*



# BH LMXBs vs. Cyg X-3




- Jet quenching at $\dot{M}_{tr}$: poloidal field of the hard state diffusing away in the formed thin disc.
- A delayed jet in the soft state of Cyg X-3 →
- a threshold condition satisfied in Cyg X-3 but not in LMXBs:
- $>\dot{M}_{M}$: a large magnetic flux advected from the donor.
- The threshold condition: onset of magnetic outflows requiring a large enough $\dot{M}$.
- The lag time scale: viscous.

Cao & AAZ 20

# Conclusions

- Very strong activity in γ-rays and radio during 2017–21.
- No measurable lag between radio and γ-rays ($\ll$ 1 day).
- Modulation by a factor of ~4 of γ-rays at the orbital period.
- Modelled by the jet with electrons acceleration only at $z \sim 10^6 R_g$, where they anisotropically upscatter the stellar radiation.
- The jet is misaligned by $\theta \gtrsim 30°$ with respect to the binary axis.
- A ~50 d lag of radio emission vs. soft X-rays, modelled as delayed advection of magnetic flux from the donor above a threshold $\dot{M}$ due to an onset of disk magnetic outflows.
- BH LMXBs do not reach that threshold $\dot{M}$.
- The lag time scale: viscous time scale at the disc outer edge.

- Planned IXPE observations: 2022-10-13, 2022-10-31.