Whispering in the dark: Faint X-ray emission from BH+OB star binaries

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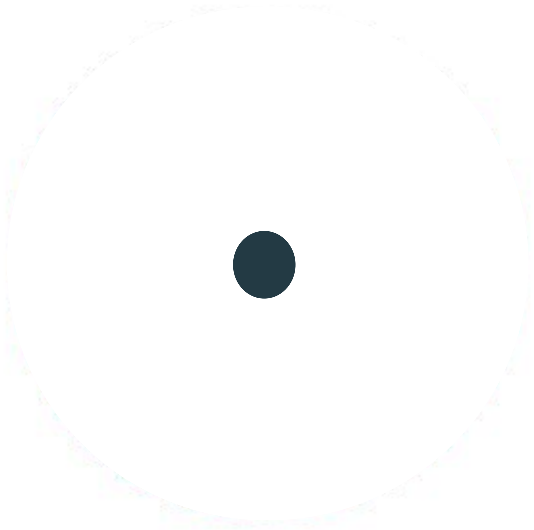
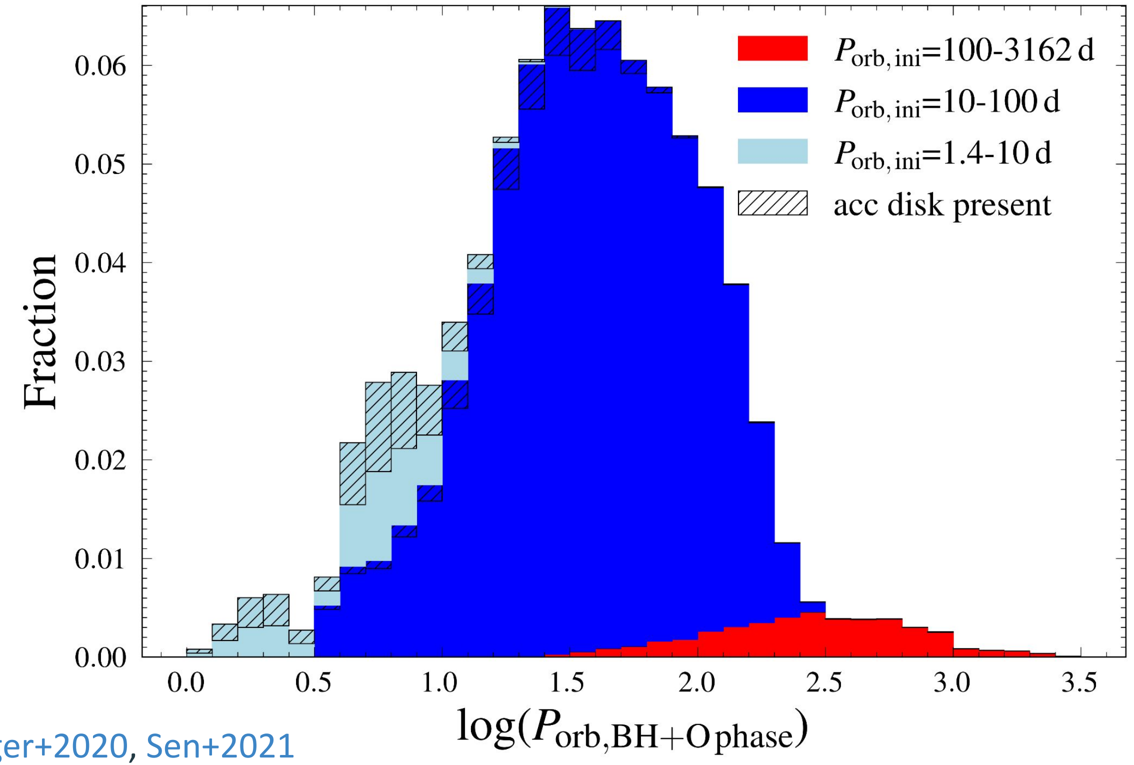
Massive binaries

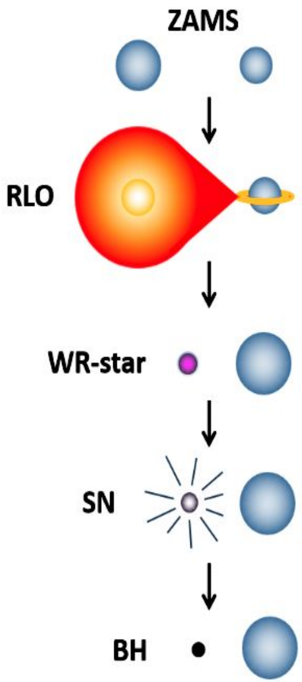


$M_1 = 30\ M_\odot$

$M_2 = 20\ M_\odot$

Black hole + OB star binaries





Langer+2020, Sen+2021

Searching techniques for BH+OB binaries

- strong X-ray emission (e.g. Walter et al. 2015; Motta et al. 2021).
- astrometric variations (e.g Breivik et al. 2017; Mashian & Loeb 2017; Yamaguchi et al. 2018; Andrews et al. 2019).
- photometric variability (Zucker et al. 2007; Masuda & Hotokezaka 2019).
- spectroscopic monitoring (e.g. Geisers et al. 2018, Thompson et al. 2019, Mahy et al. 2022, Shenar et al. 2022).

Accretion onto stellar mass BHs

figure not to scale

Matter is accreted from the stellar wind (v_{wind}) of the O star

$$v_{\rm wind} = 2.6\, v_{\rm esc}\, (1 - R_{\rm O}/a)$$

$$v_{\rm esc} = \sqrt{2GM_{\rm O}/R_{\rm O}}$$

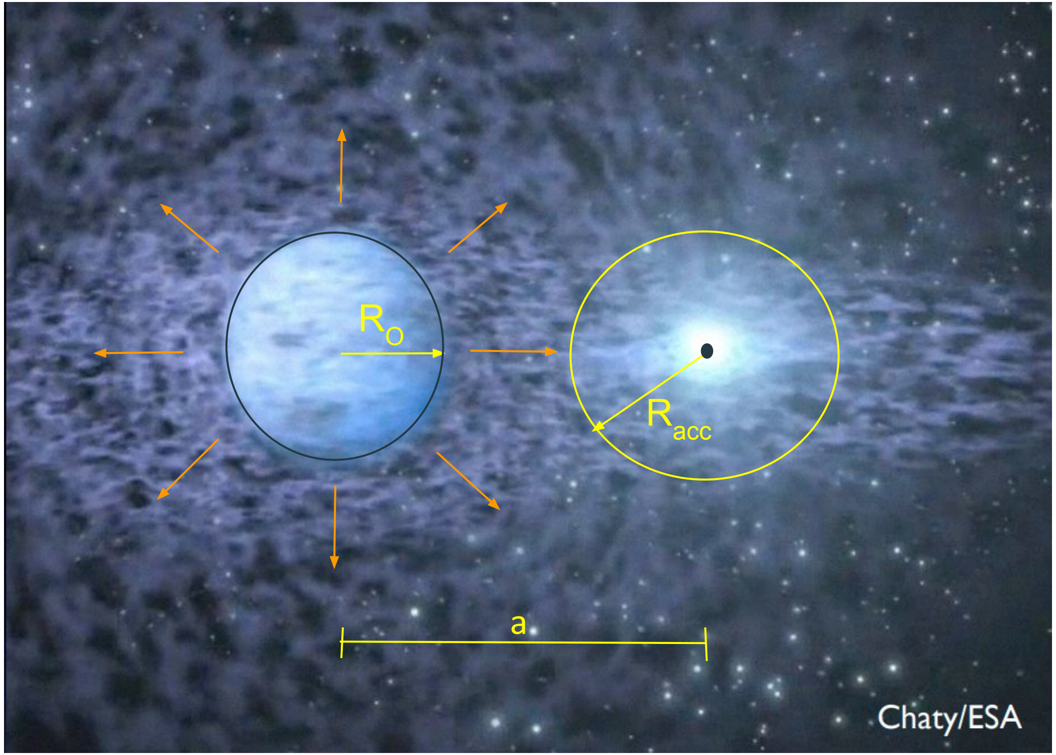
Accretion radius of the compact object (Davidson+1973)

$$R_{\rm acc} = \frac{2GM_{\rm BH}}{v_{\rm rel}^2}$$

$$v_{\rm rel} = \sqrt{v_{\rm wind}^2 + v_{\rm orb}^2}$$

Bondi-Hoyle mass accretion rate (Bondi+1944)

$$\frac{\dot{M}_{\rm acc}}{\dot{M}_{\rm w}} = \frac{\pi R_{\rm acc}^2}{4\pi a^2}\,\frac{v_{\rm rel}}{v_{\rm w}}$$



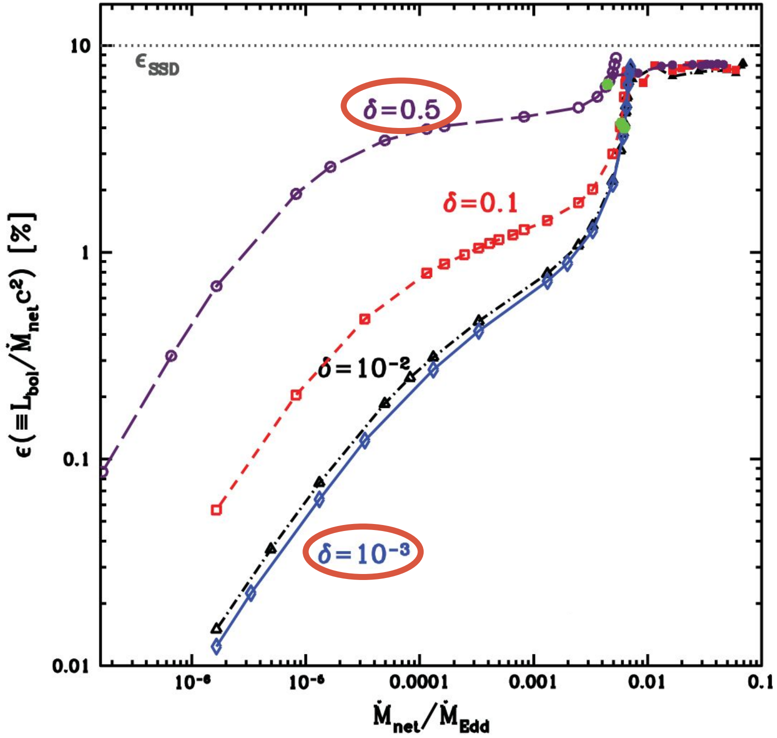
Radiative efficiency of accreting BHs

$$L_X = \epsilon \dot{M}_{net} c^2$$

ϵ = radiative efficiency

$\epsilon = \epsilon(\dot{M}_{net}, \delta)$

δ = electron heating parameter



Xie & Yuan (2012)

Grid of binary evolution models

$M_{donor,i}$ = 10 - 90 M_{sun}

$q_i = M_{accretor,i}/M_{donor,i}$ = 0.25 - 0.95

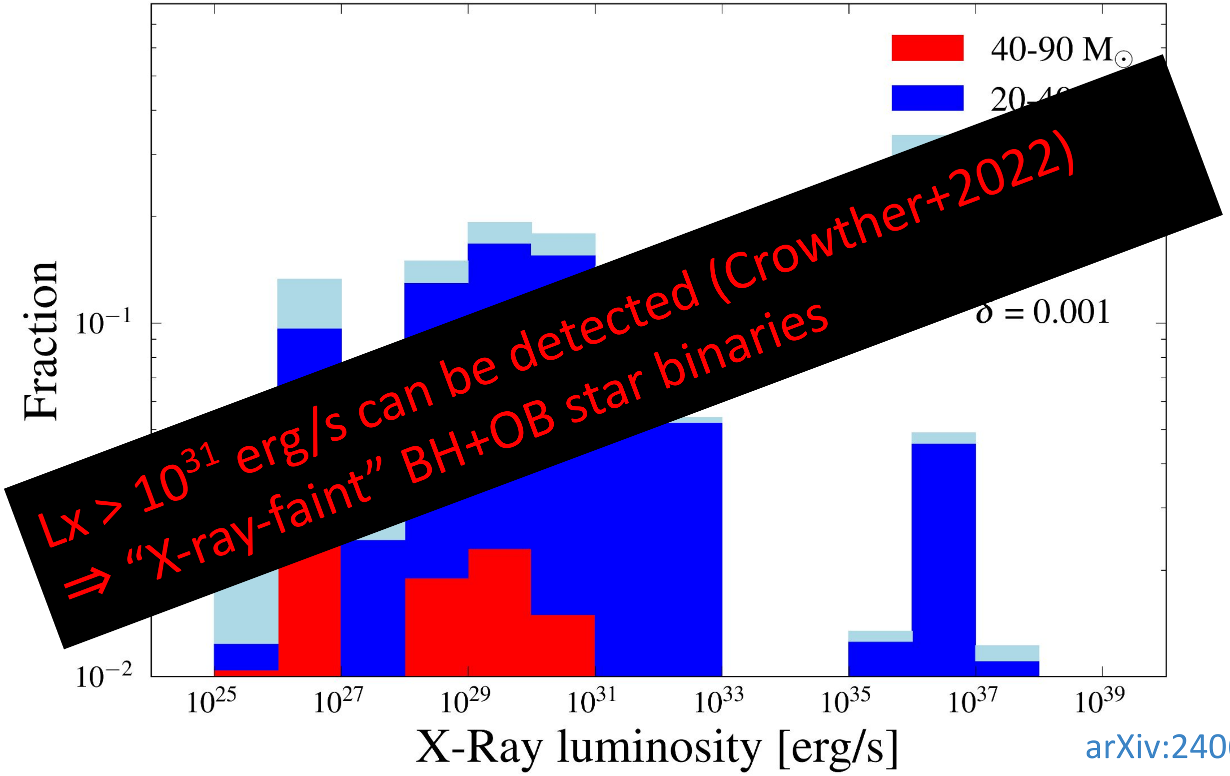
$P_{orb,i}$ ~ 1 - 3162 days

Population syn* of BH+OB binaries

*weighted by the Salpeter IMF, initial binary distribution functions, and the time spent in the BH+OB phase

arXiv:2406.08596

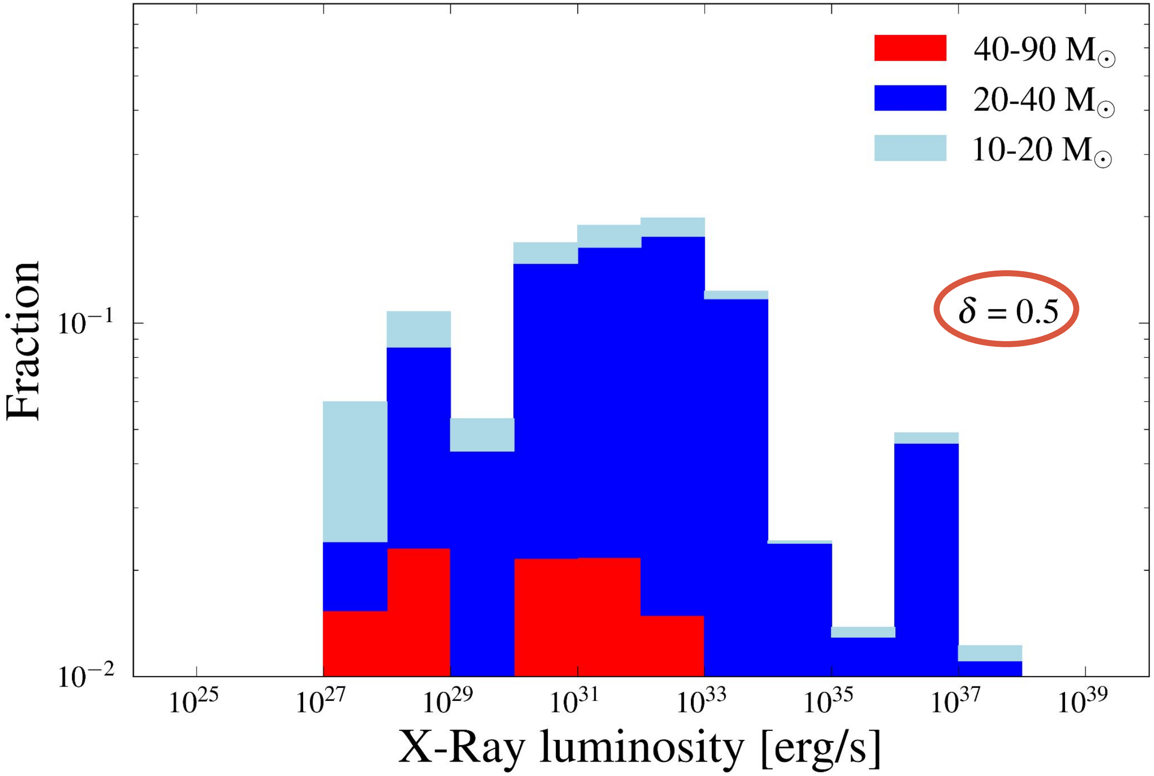
X-ray luminosity of BH+OB star binaries



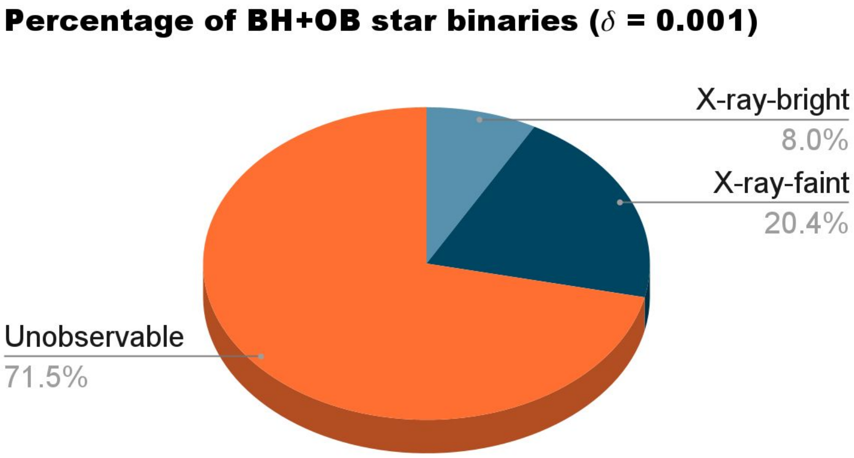
arXiv:2406.08596

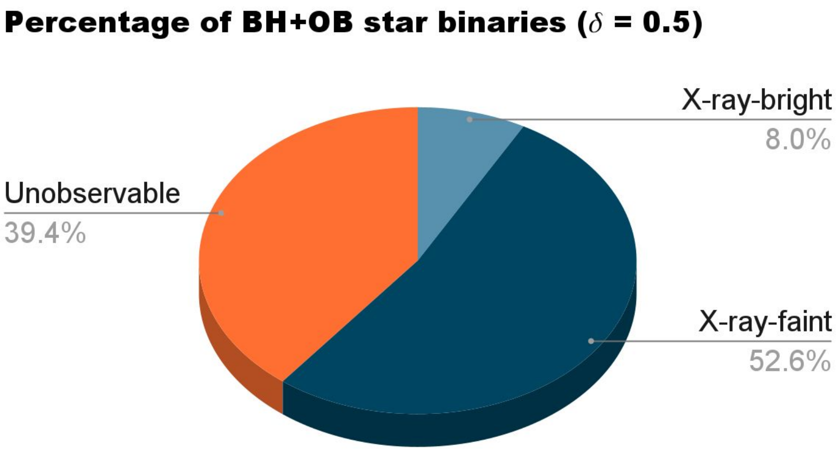
X-ray luminosity of BH+OB star binaries

Sen, el Mellah, Langer et al. (2024, arXiv:2406.08596)



Number predictions for the LMC





≅ 28 X-ray-faint systems in the LMC

≅ 72 X-ray-faint systems in the LMC

arXiv:2406.08596

A smoking gun: HD 96670

M_{BH} = 6.2 Msun, M_{OB} = 22.7 Msun

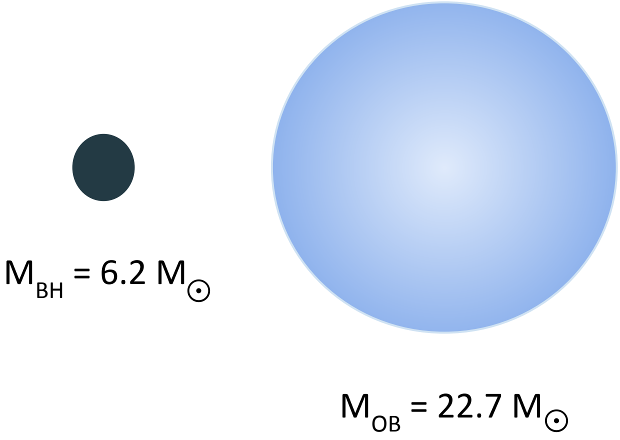
P_{orb} = 5.28 d, R_{OB} = 17.1 Rsun

Teff = 38000 K (Hohle+2010)

Observed Lx = 2.2e32 erg/s (NuSTAR, Gomez+2021) to 2.4e34 erg/s (XMM-Newton, Saxton+2008)

Predicted Lx = 8e33 erg/s

*stellar parameters not well-constrained (Gomez+2021, Wang+2022)
=> excellent target for follow-up spectroscopy and a Chandra proposal



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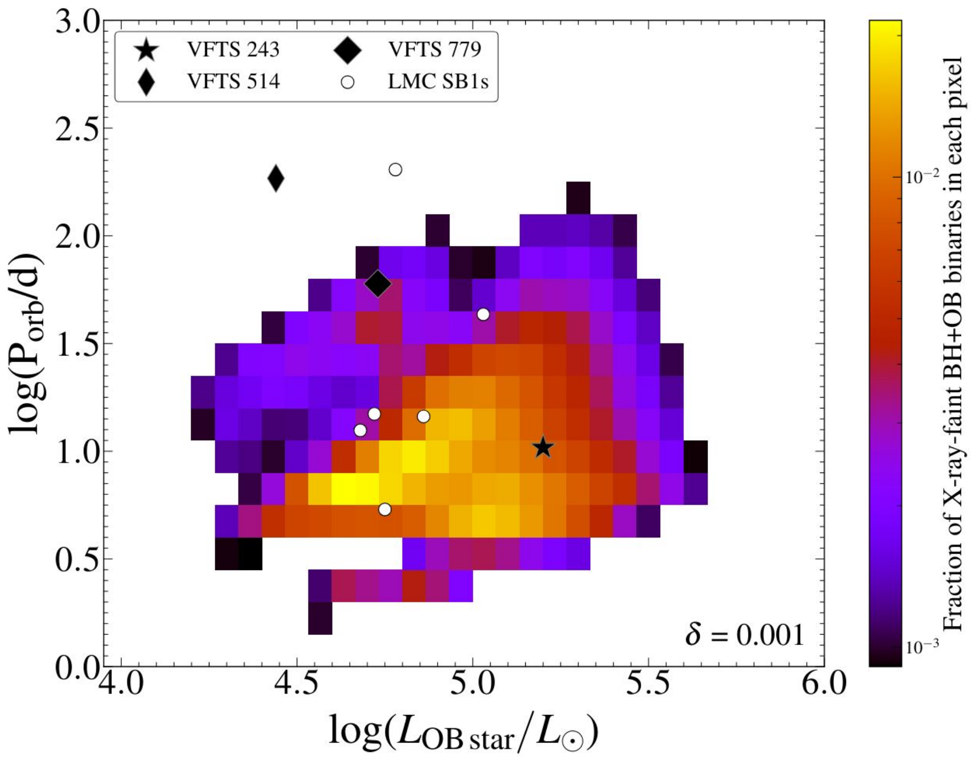
Observable properties of X-ray-faint systems



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Summary

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is a smok ay.

X-ray-quiet

X-ray-faint

X-ray-bright

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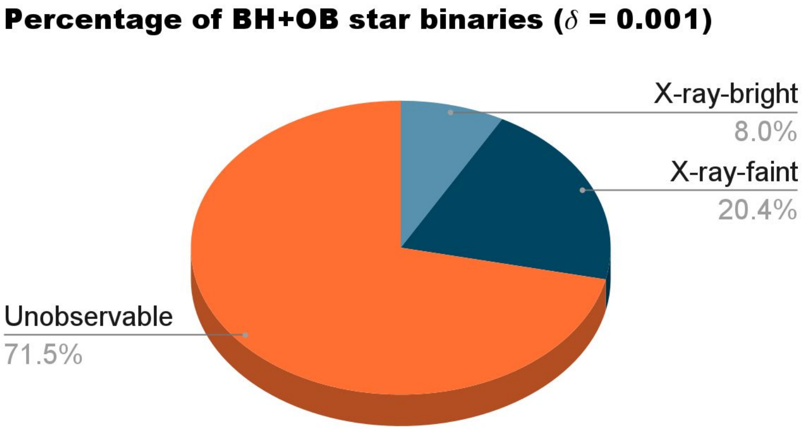
Number predictions for the LMC

- 120 BH+OB star binaries in 10-40 Msun range (Langer+2020).
- 136 BH+OB star binaries in 10-90 Msun range (this work).
- 10 BH+OB are X-ray-bright.
- For δ = 0.001, 28 are X-ray-faint.
- For δ = 0.1, 44 are X-ray-faint.
- For δ = 0.5, 72 are X-ray-faint.



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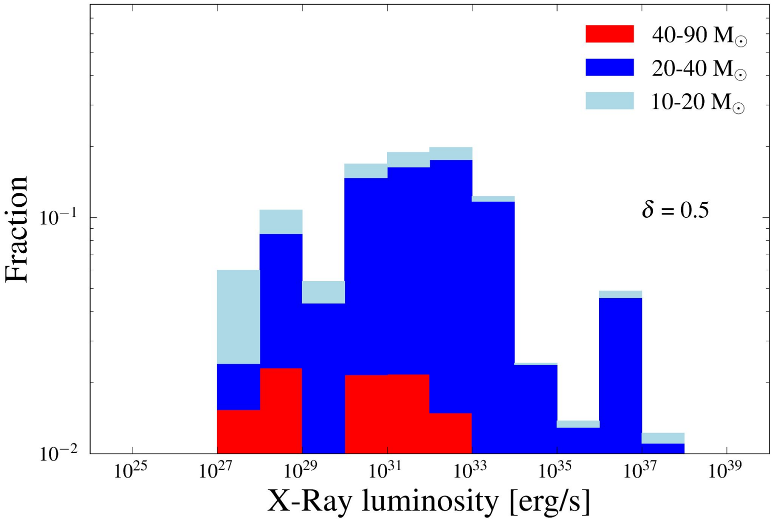

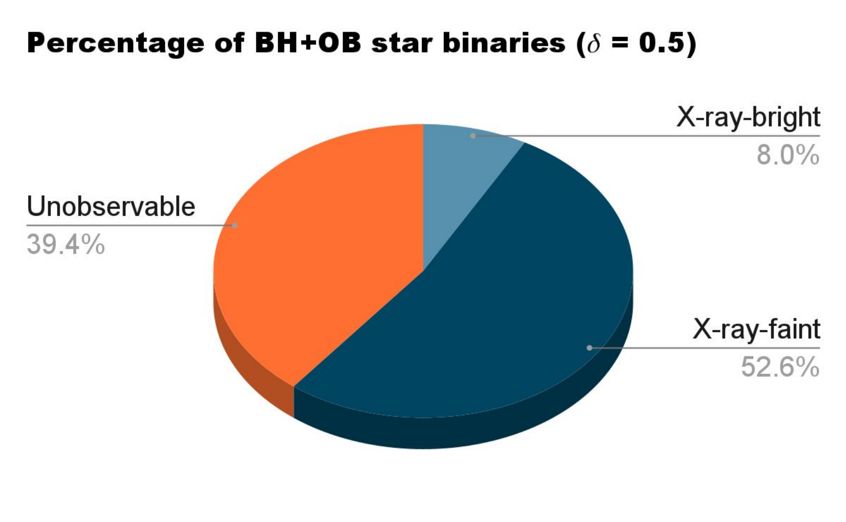

Lx > 10^{31} erg/s can be detected (Crowther+2022)

⇒ “X-ray-faint” BH+OB star binaries