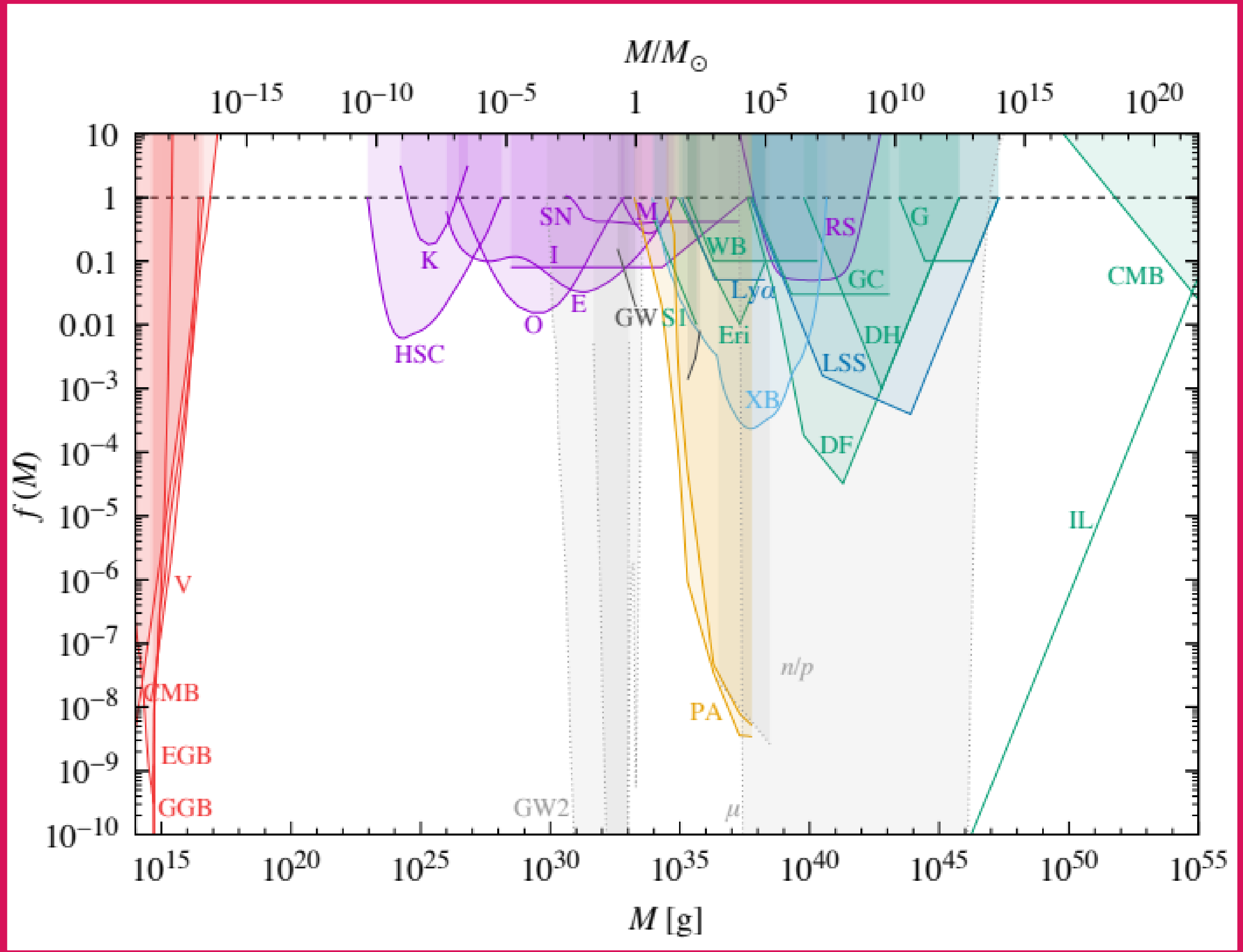
Invisibles 2025

Constraints on asteroid mass primordial black holes from stars

Nicolas Esser (with Peter Tinyakov, Sven De Rijcke & colleagues)

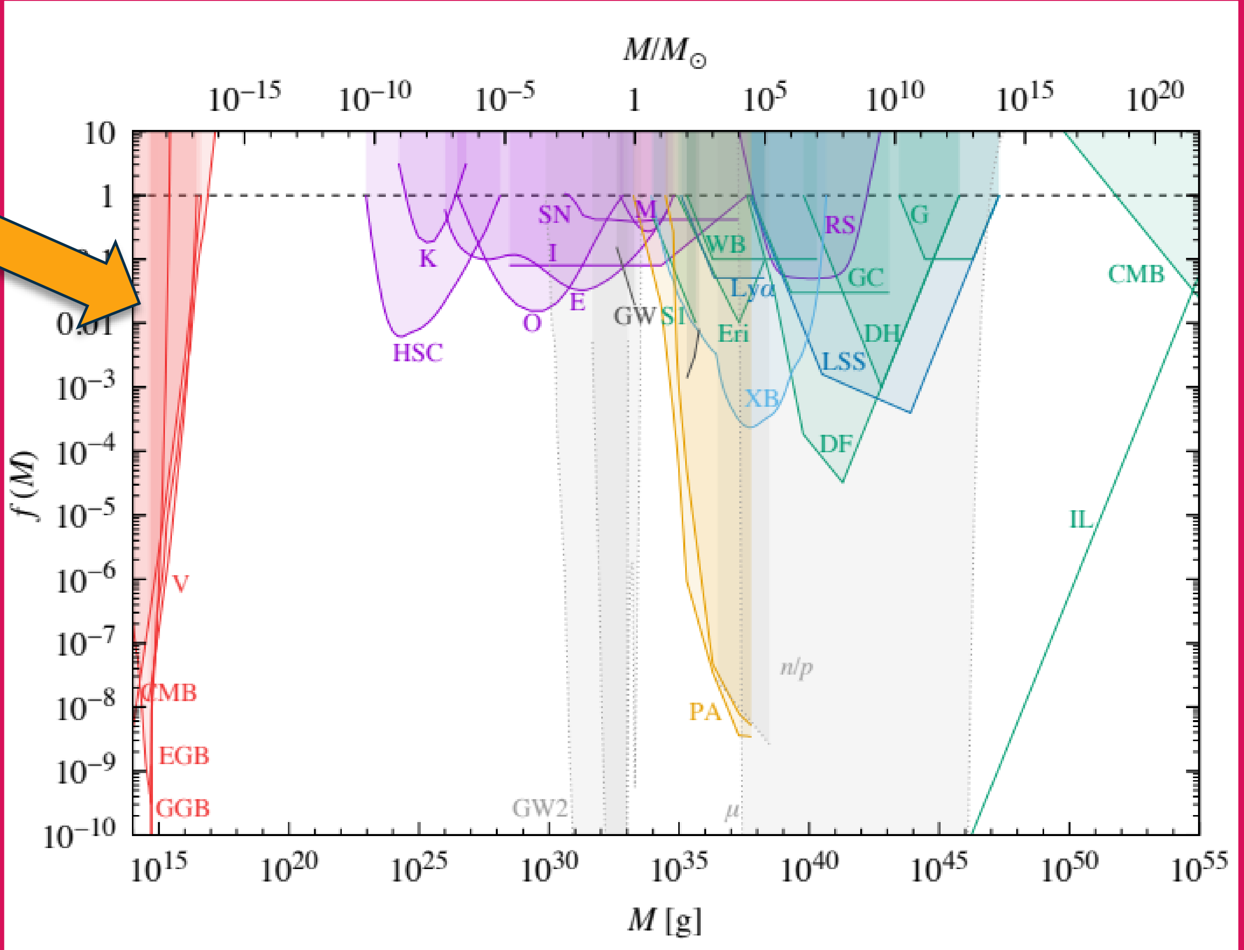
Current PBH constraints



Carr et al. (2021)

Current PBH constraints

Evaporation



Carr et al. (2021)

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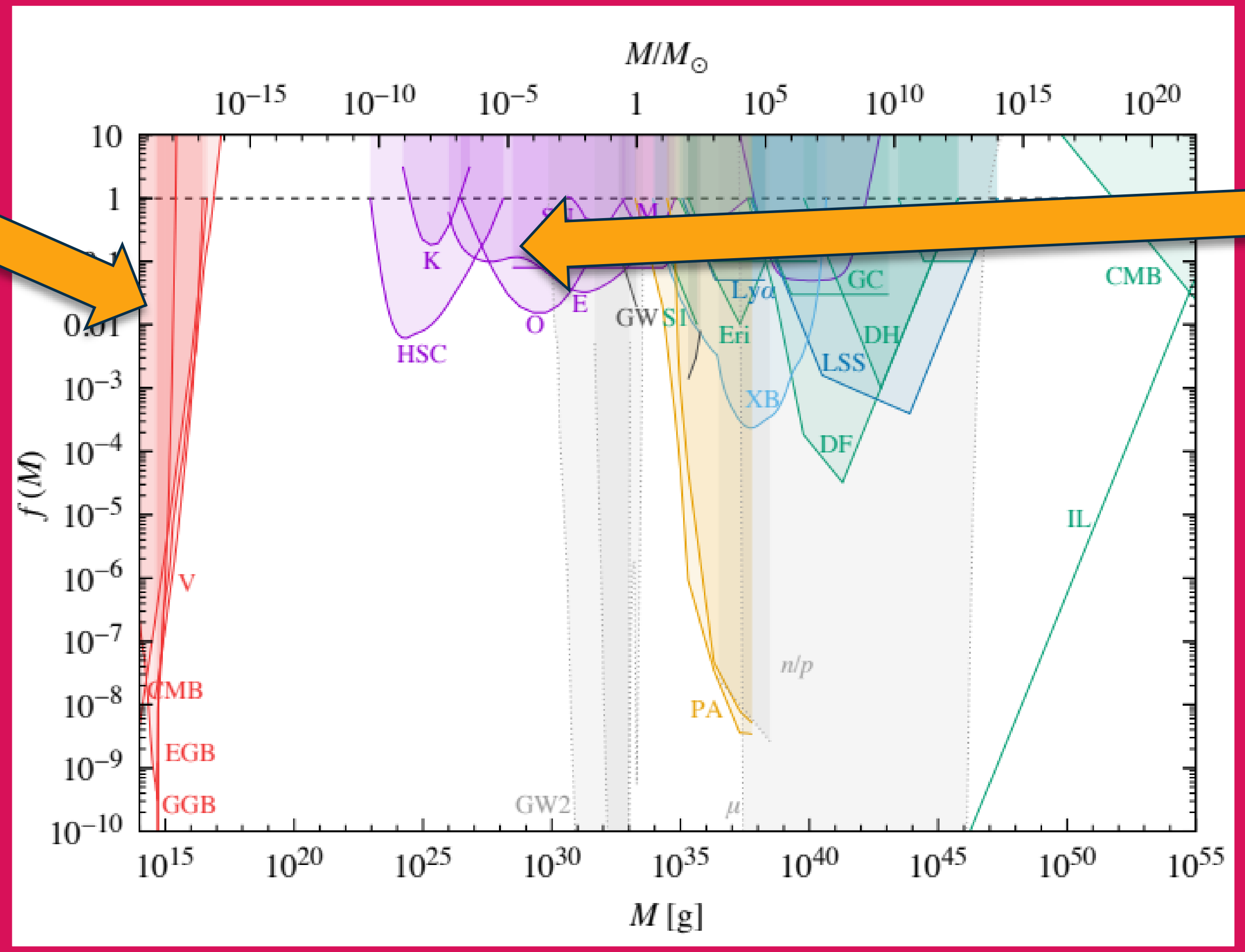
Current PBH constraints

Evaporation

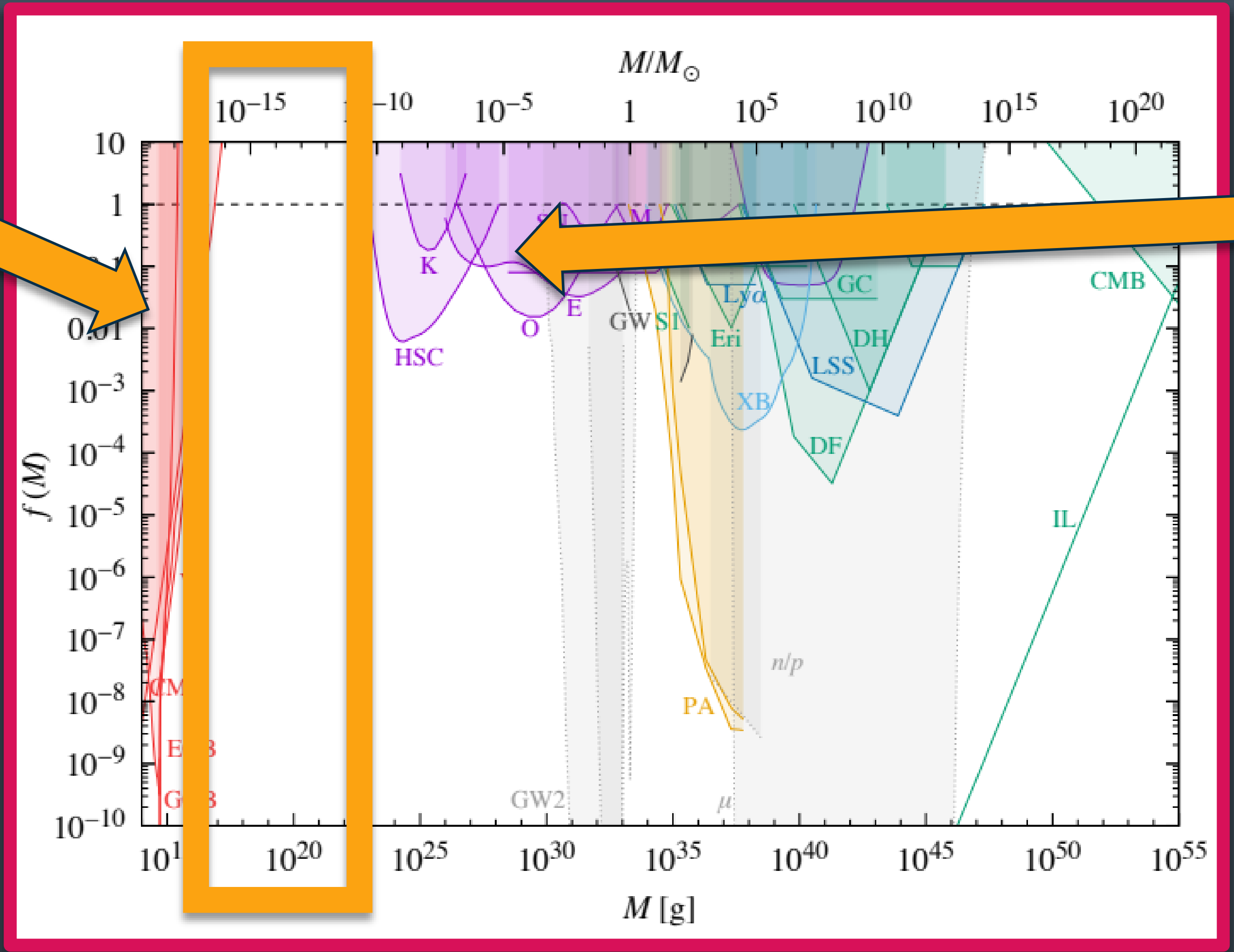


Lensing

Carr et al. (2021)

Current PBH constraints

Evaporation



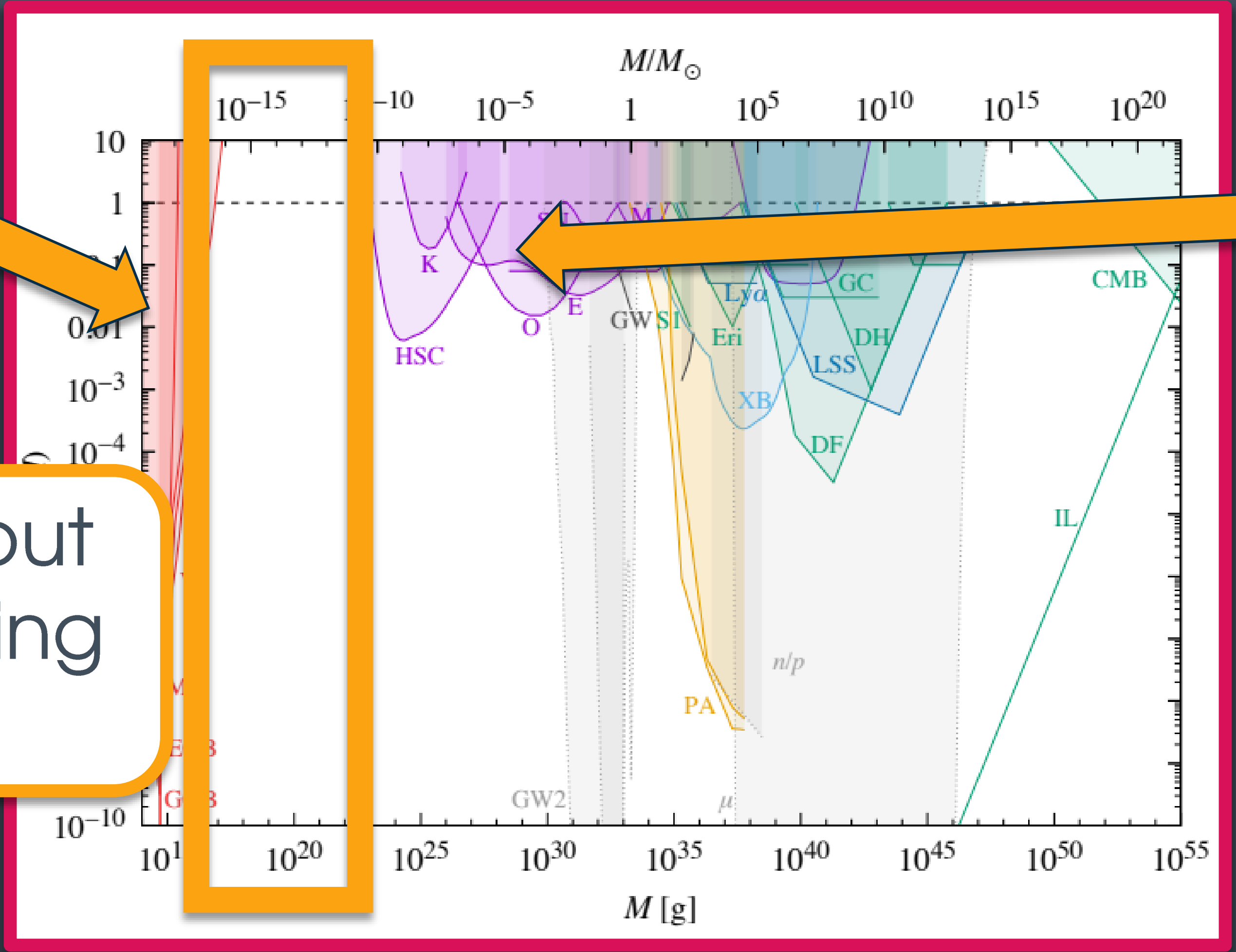
Lensing

Carr et al. (2021)

Current PBH constraints

Evaporation

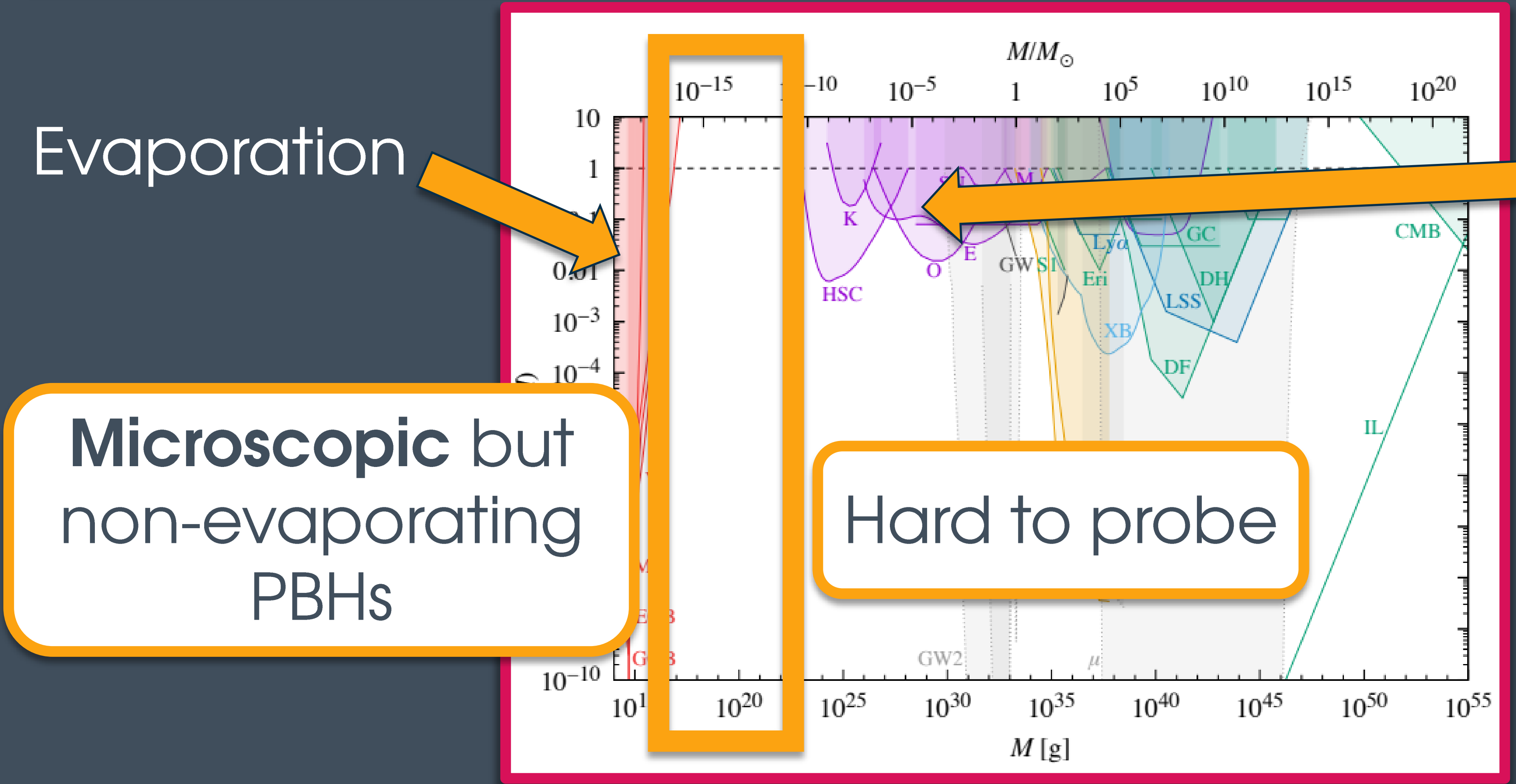
Lensing



Microscopic but non-evaporating PBHs

Carr et al. (2021)

Current PBH constraints



Carr et al. (2021)

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Current PBH constraints

Exotic mechanism required

Idea: stars capture PBHs which then destroy them from the inside

Destruction probability

Adiabatic star formation + dynamical friction:

Destruction probability

Adiabatic star formation + dynamical friction:

$$\bar{N}_{\mathrm{cap}} = 12\sqrt{6\pi}G^2 \ln(\Lambda) \times f_{\mathrm{PBH}} \times \frac{\rho_{\mathrm{DM}}}{\sigma^3} \times \tau_* \times M_*$$

Destruction probability

Adiabatic star formation + dynamical friction:

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+ Bondi accretion

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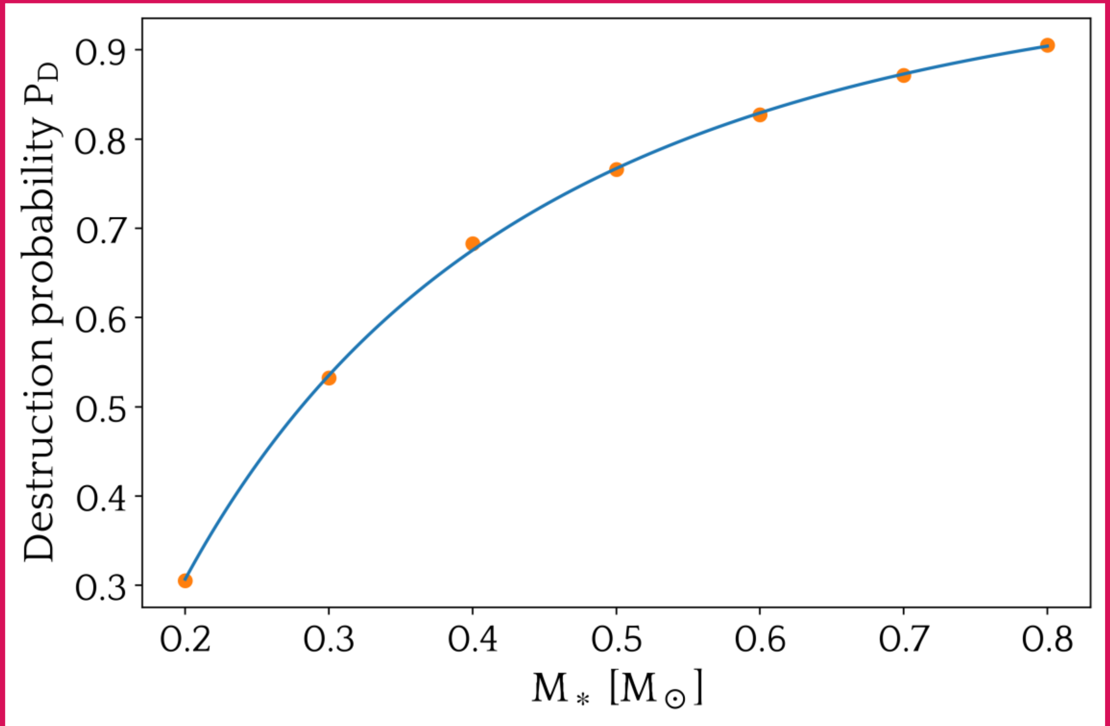
Destruction probability:

$$P_D = 1 - e^{-\bar{N}_{\rm cap}}$$

Destruction probability



Destruction probability:

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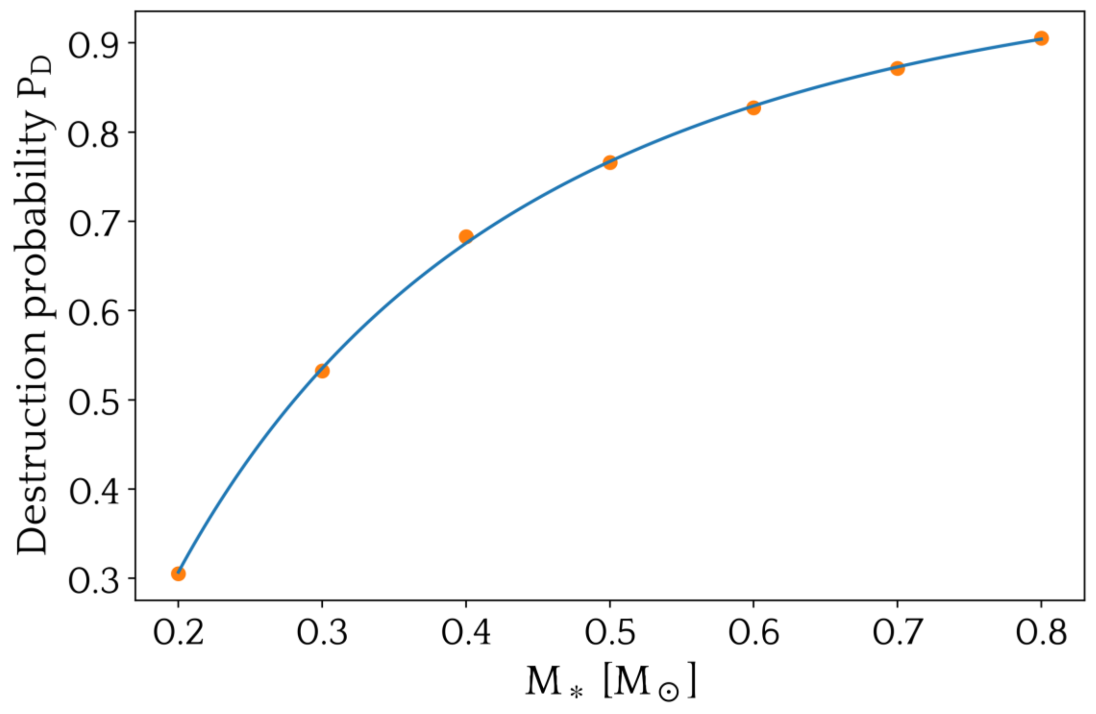
Destruction probability



P_D ↗ with the stellar mass!

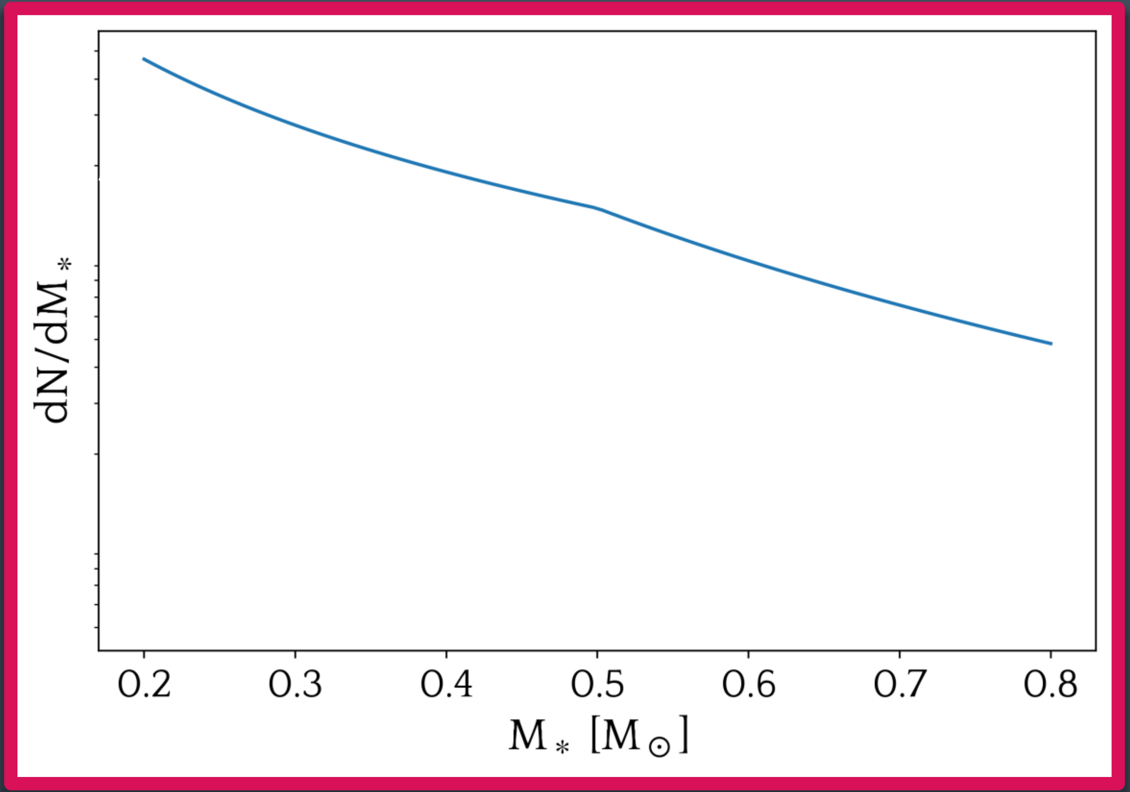
Destruction probability:

$$P_D = 1 - e^{-\bar{N}_{\mathrm{cap}}}$$

Heavier stars are more likely to be destroyed by PBHs

Impact on a stellar population

Stellar mass function



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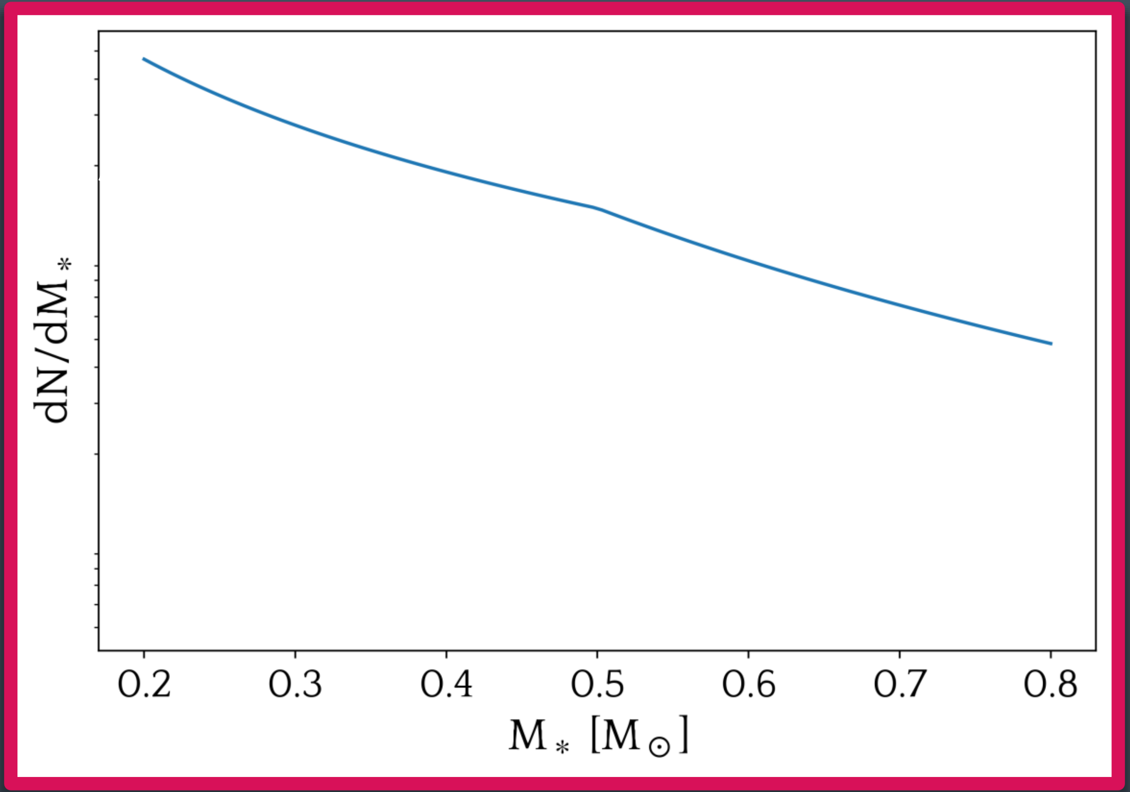
Impact on a stellar population

Stellar mass function



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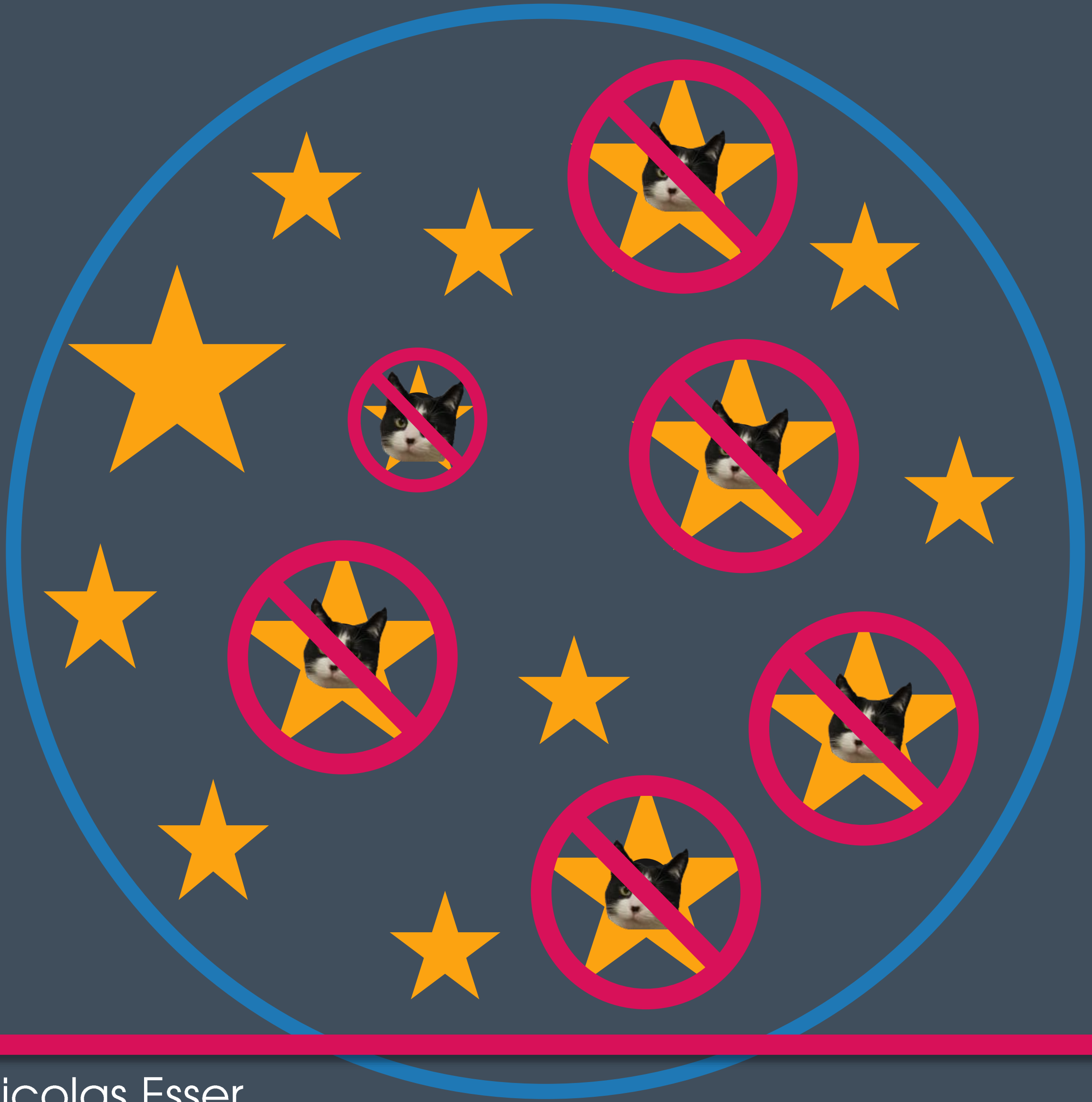
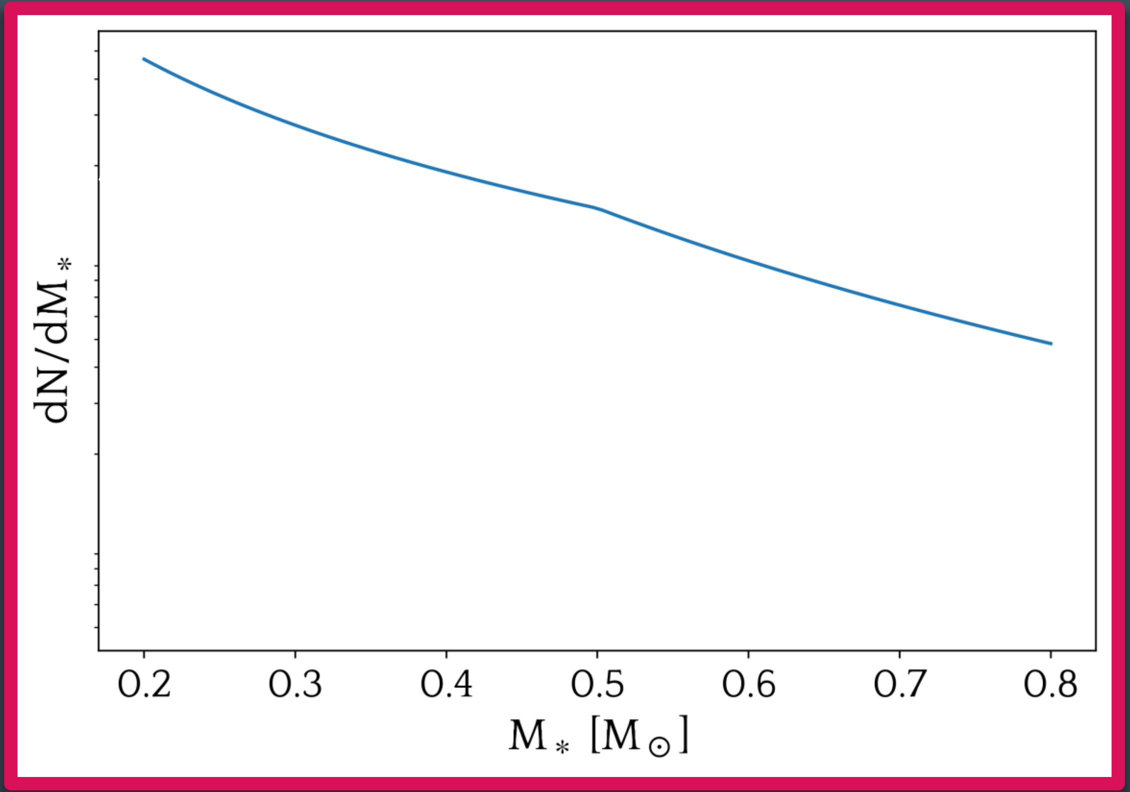
Impact on a stellar population



Stellar mass function



Impact on a stellar population

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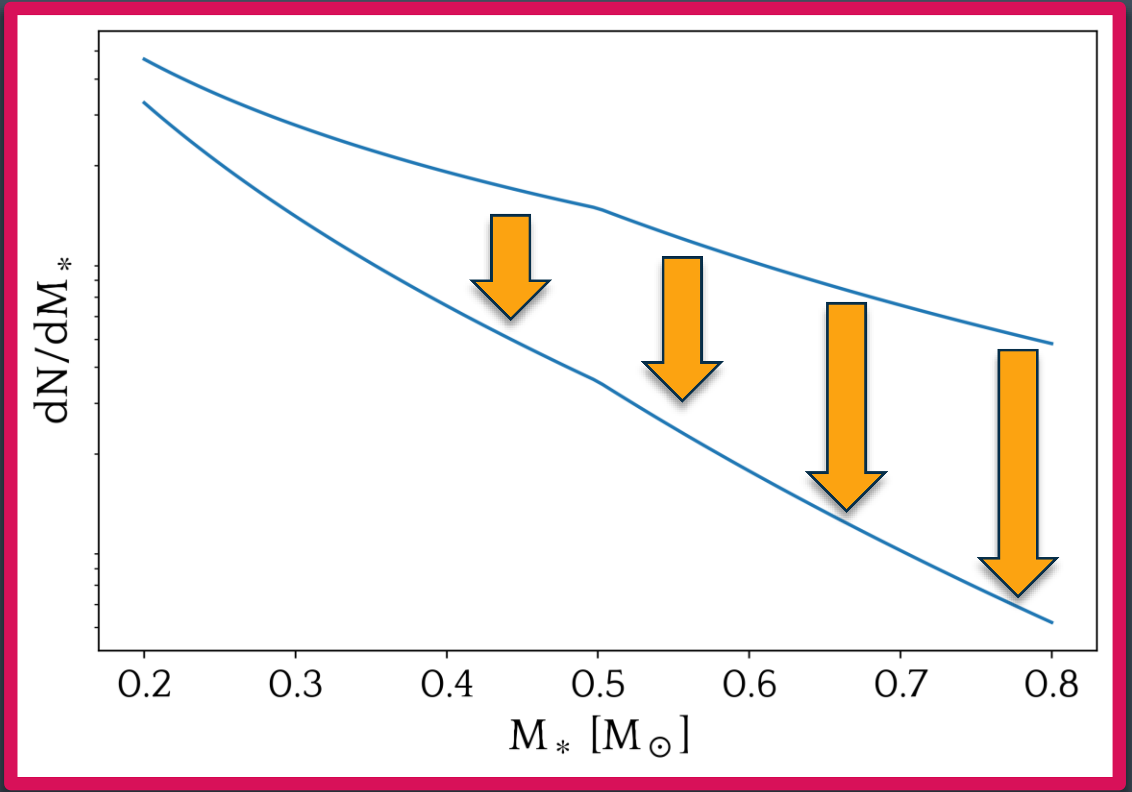

Ultra-faint dwarf galaxies

HST ACS Treasury Program GO-14734 (PI: N. Kallivayalil)

Photometric catalogs with star-like sources by Richstein +++

Ultra-faint dwarf galaxies

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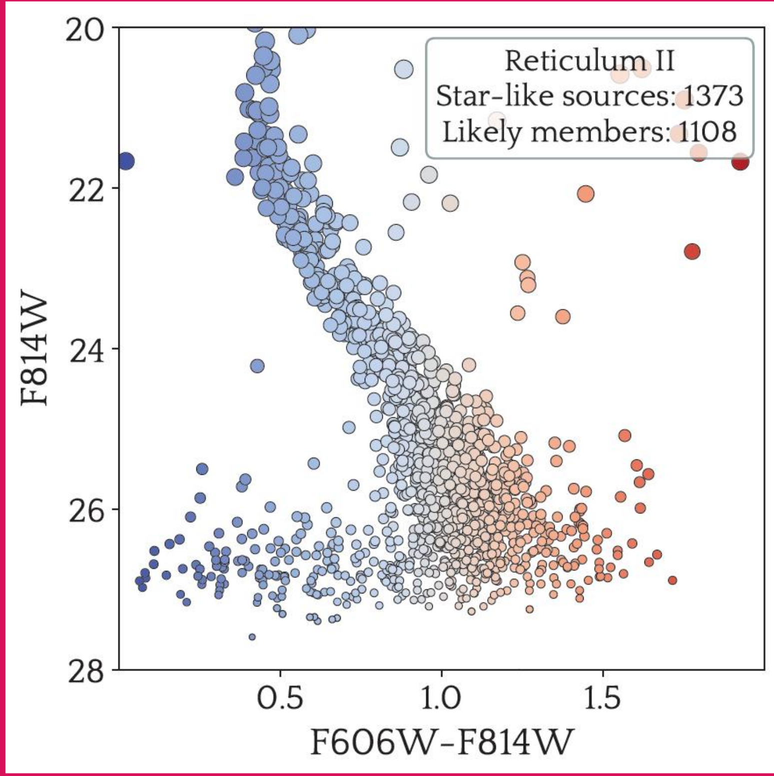
Photometric catalogs with star-like sources by Richstein +++

- Reticulum II, Segue 1, Triangulum II

Observation

Observation:



Observation

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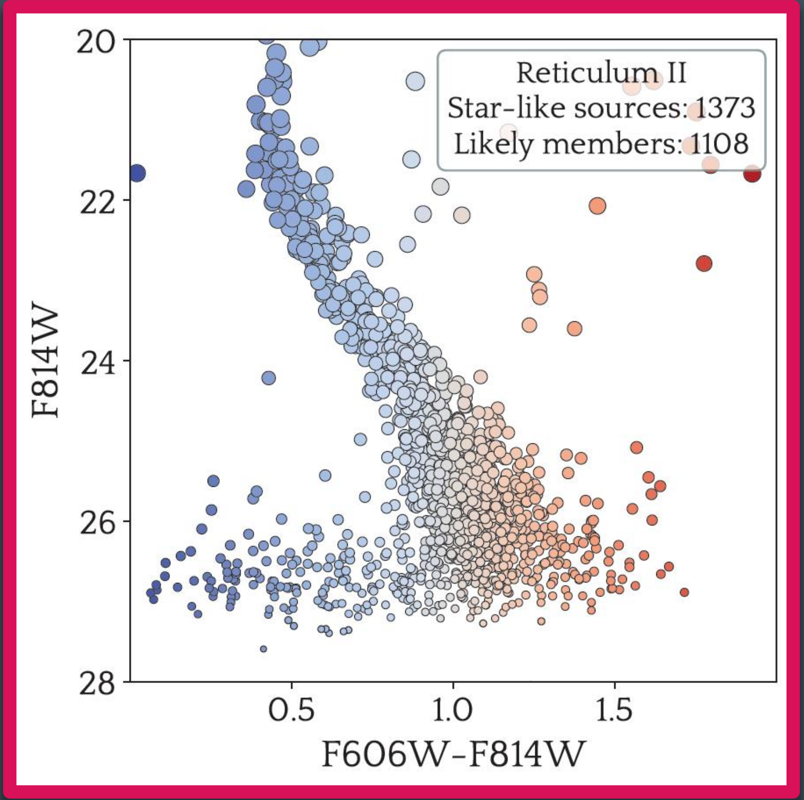

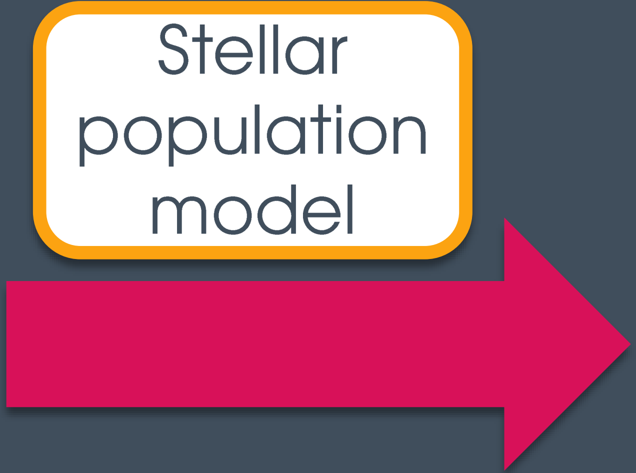

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Observation

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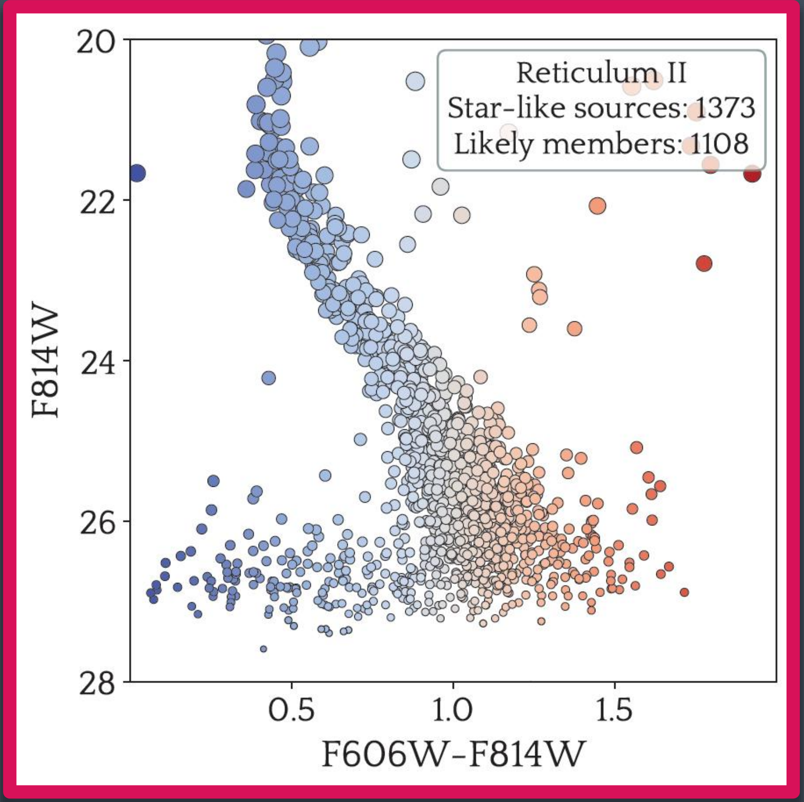

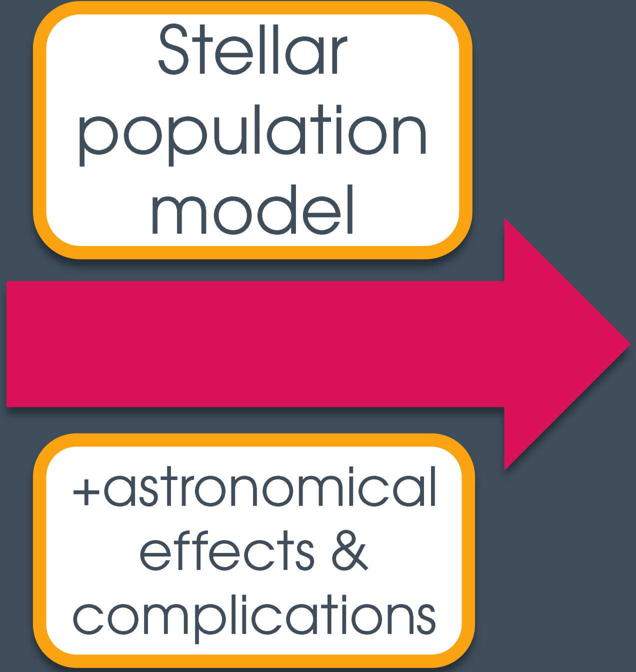

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Observation

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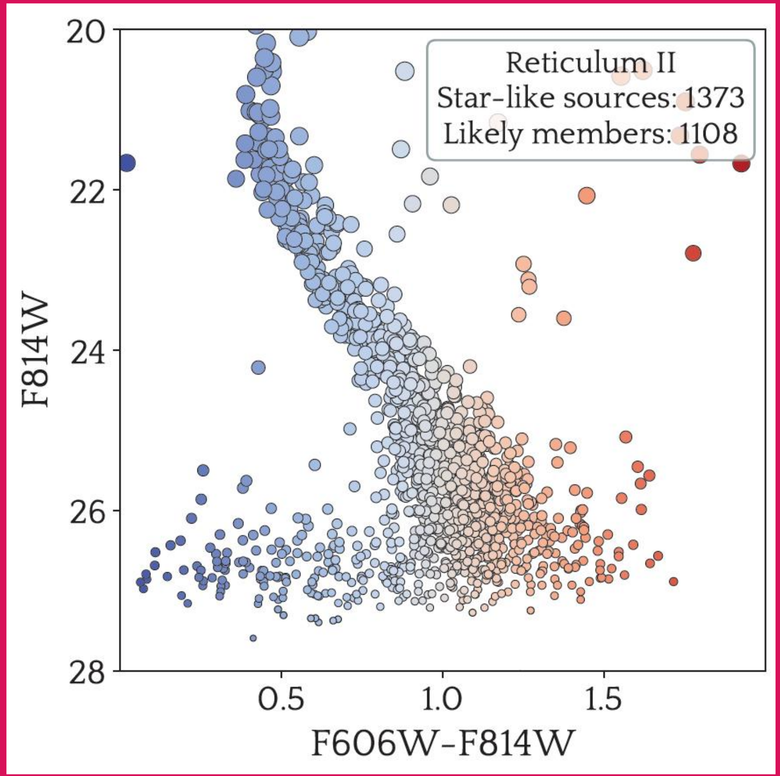
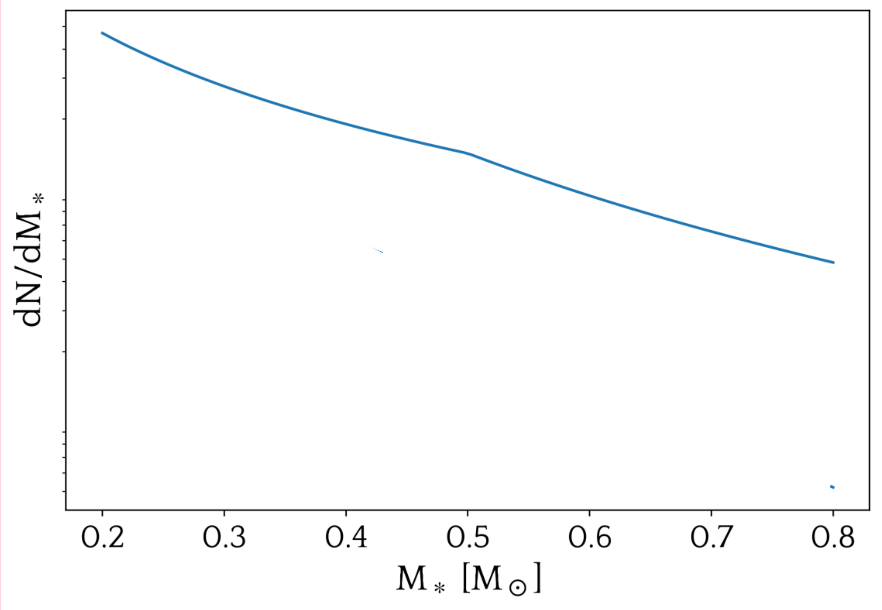


Stellar population model

+astronomical effects & complications

Stellar mass function



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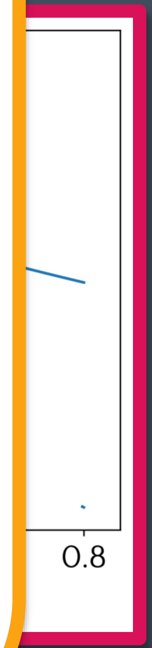
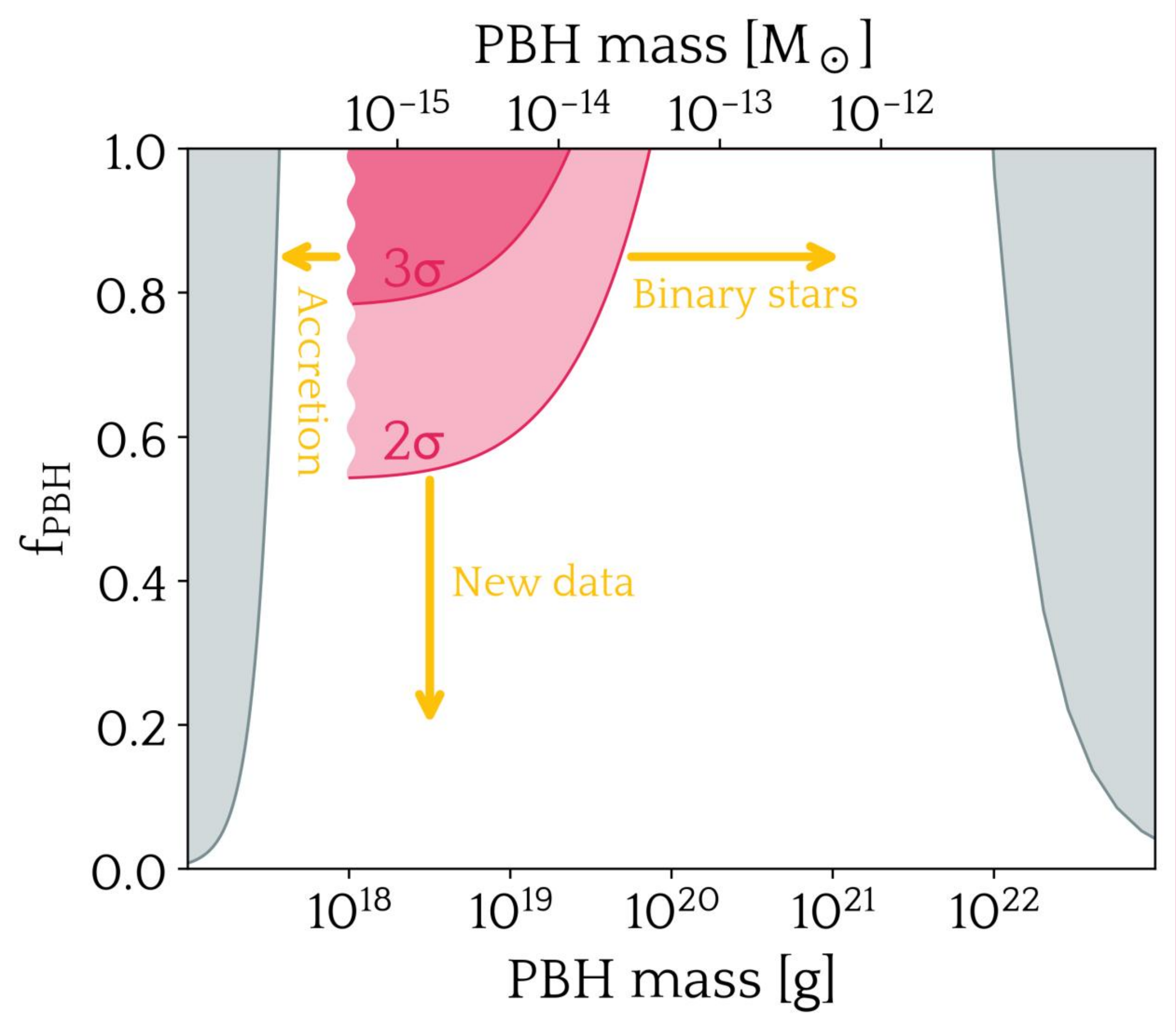
Observation

We **do not** observe the extra depletion of heavy stars due to PBHs



Brand new constraints



Esser et al. (2025)

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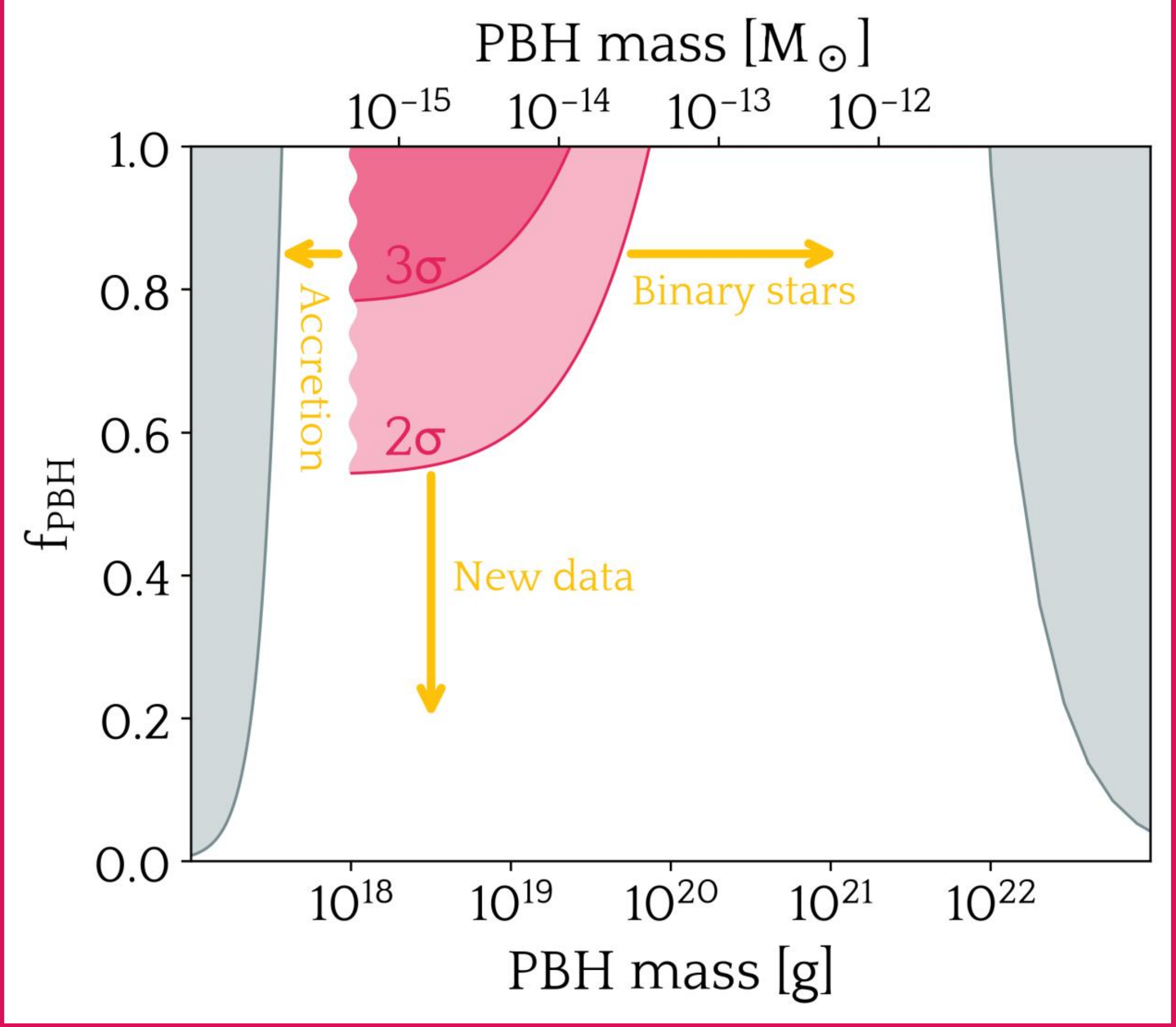
Brand new constraints



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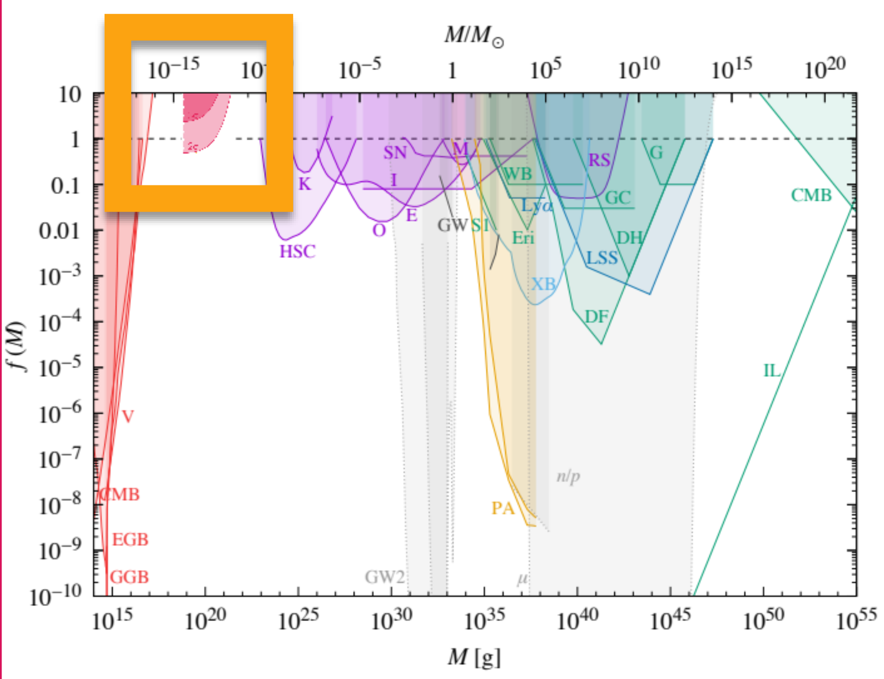

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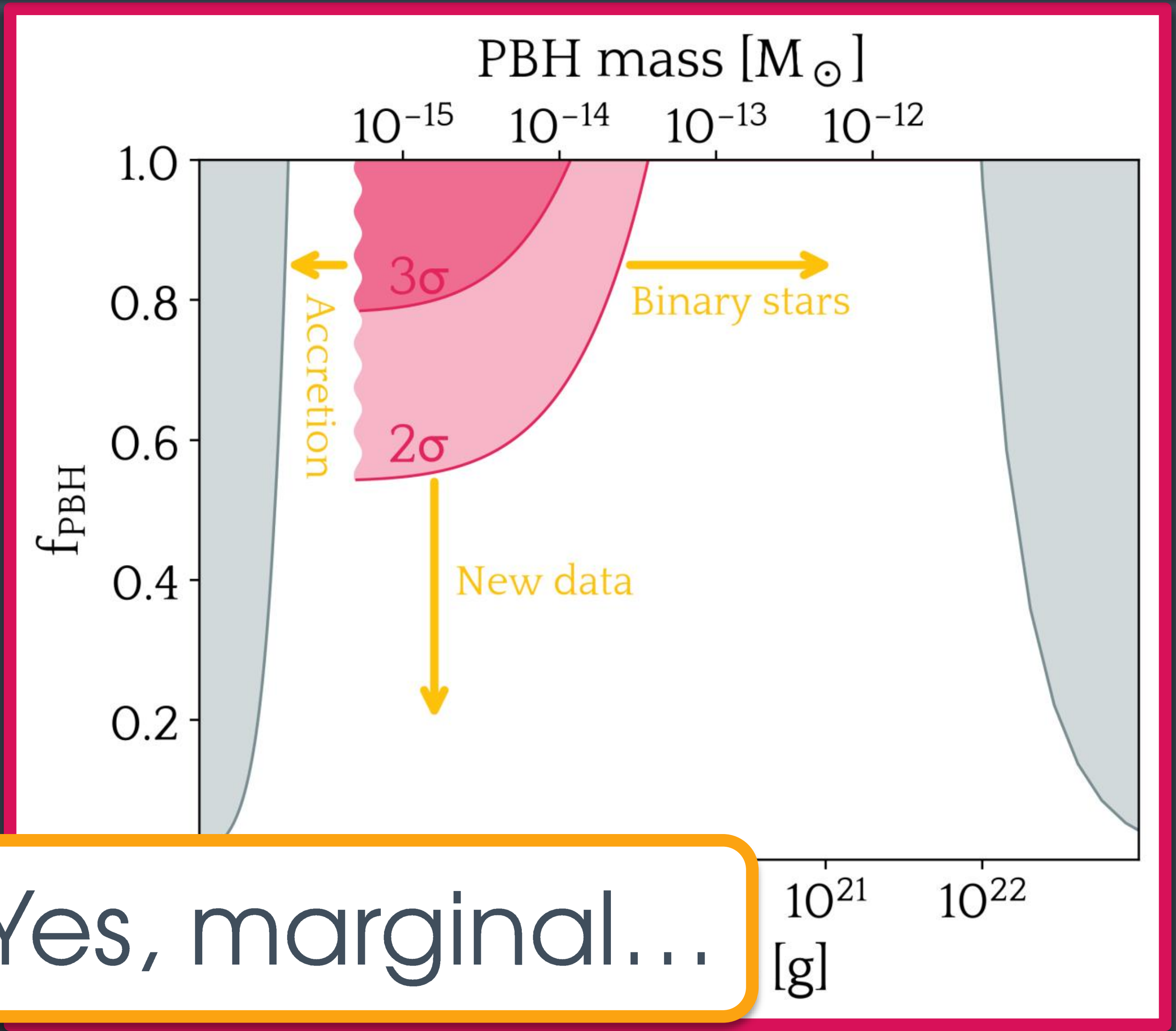
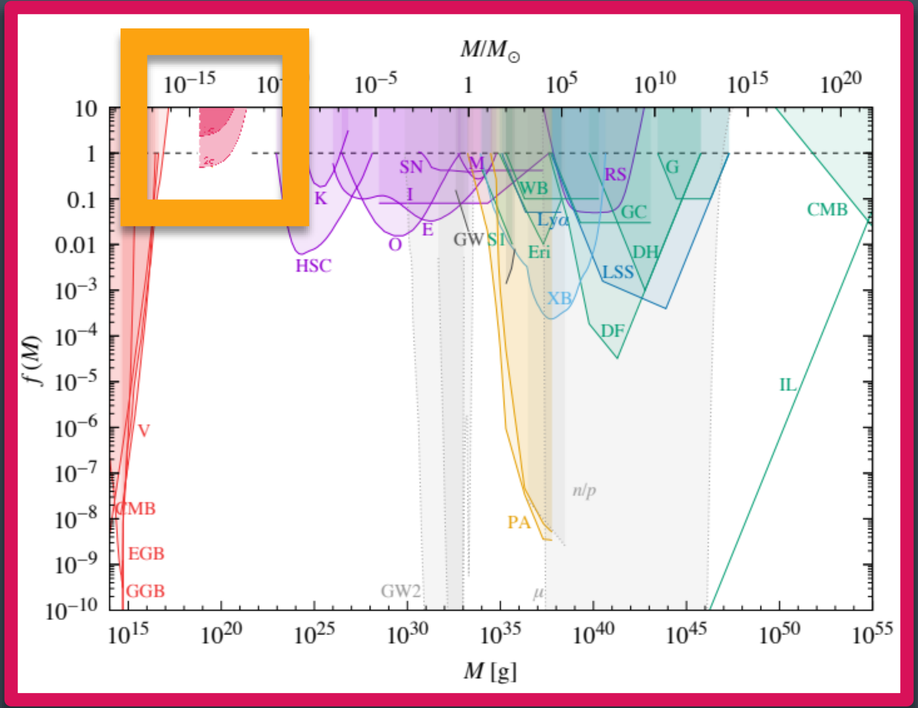


Yes, marginal...

Esser et al. (2025)



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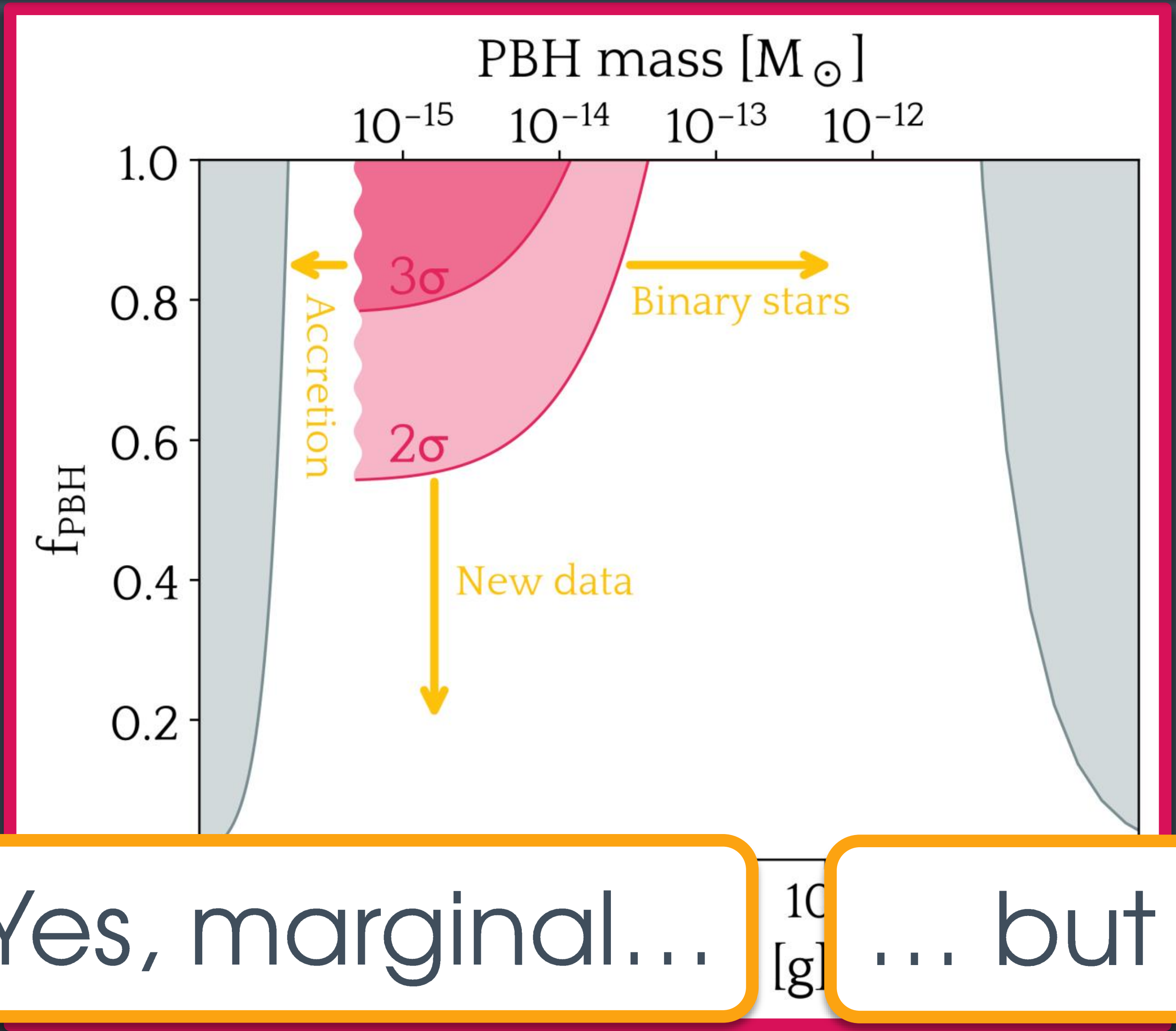

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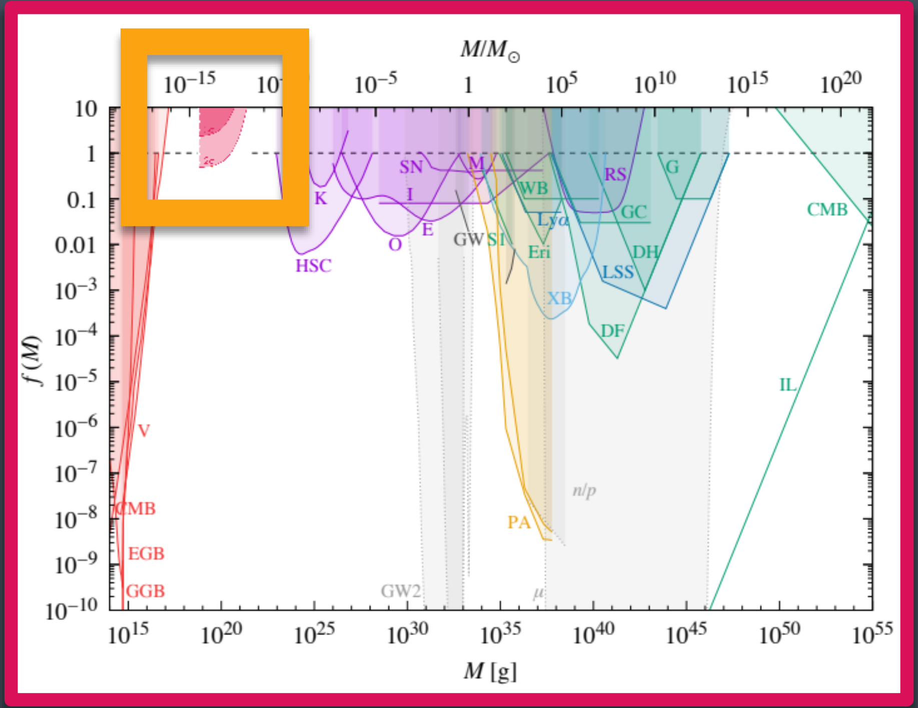

Yes, marginal...

... but likely to improve!

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Thank you!

Come talk to me if you are interested in the astro part ☺

arXiv:2503.03352 (A&A)
arXiv:2311.12658 (MNRAS)
arXiv:2207.07412 (PRD)

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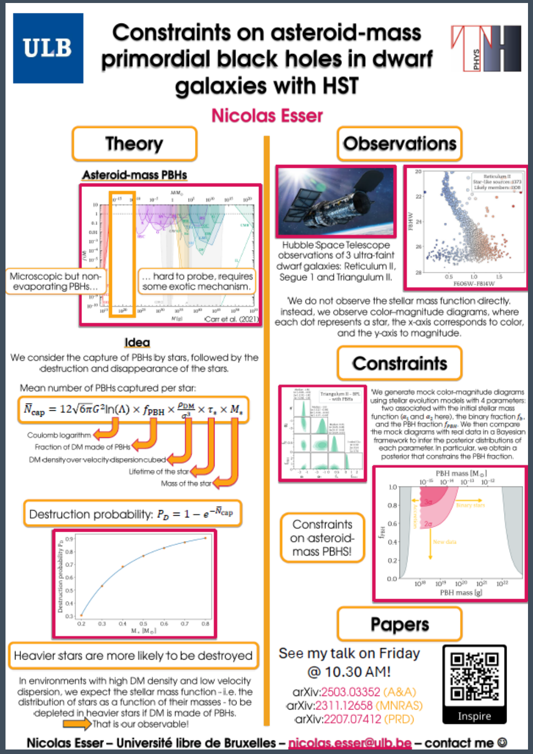


Backup slides

Adiabatic star formation + dynamical friction:

$$\bar{N}_{\text{cap}} = 12\sqrt{6\pi}G^2\ln(\Lambda) \times f_{\text{PBH}} \times \frac{\rho_{\text{DM}}}{\sigma^3} \times \tau_* \times M_*$$

- f_{PBH} is the fraction of DM in the form of PBHs
- $\propto \frac{\rho_{\text{DM}}}{\sigma^3}$ ⇒ DM-dominated environments with low velocities
- $\propto \tau_*$ ⇒ Stars with long lifetimes ⇒ $M_* < 1M_\odot$
- $\propto M_*$ ⇒ Heavier stars capture more PBHs

Backup slides

Generate M_* (2 parameters)

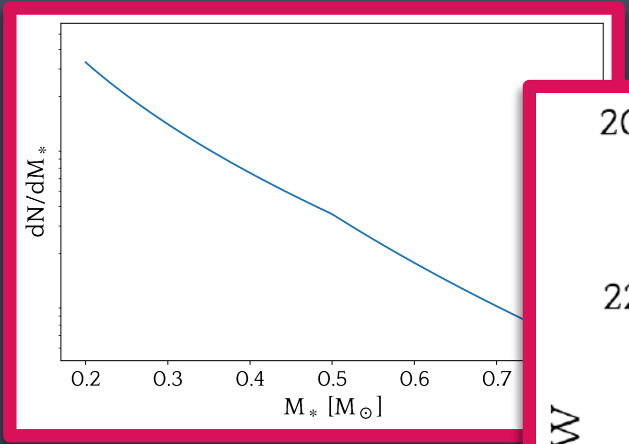
Generate [Fe/H]

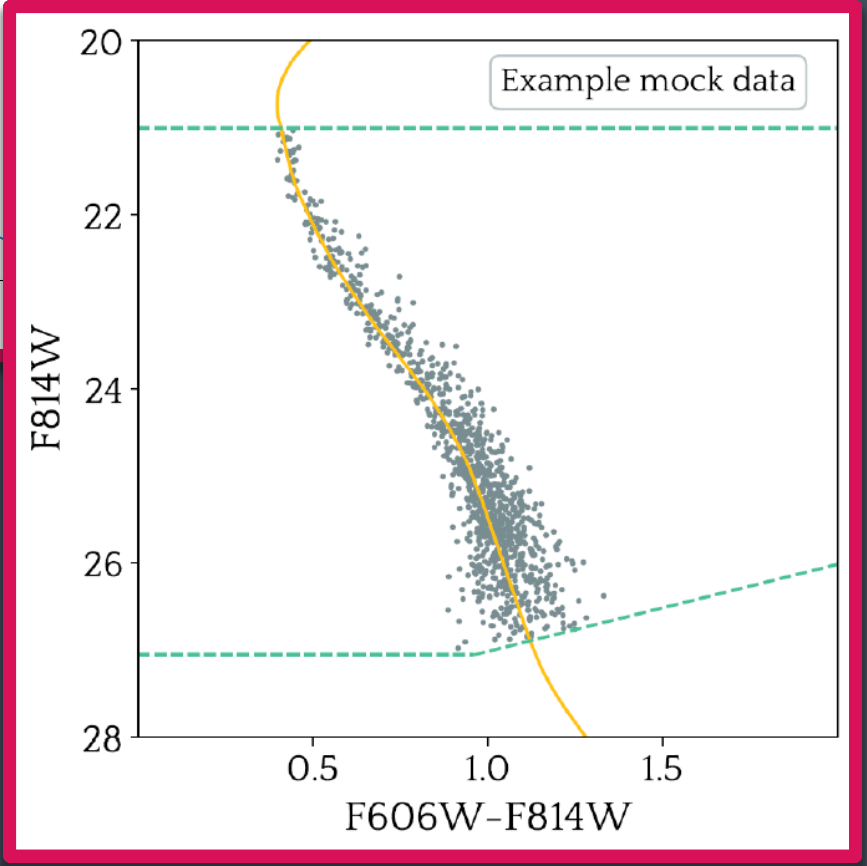
Create binaries (1 parameter)

PBH effect (1 parameter)

Dartmouth stellar isochrone models

F606W and F814W mag + Fancy astronomy effects





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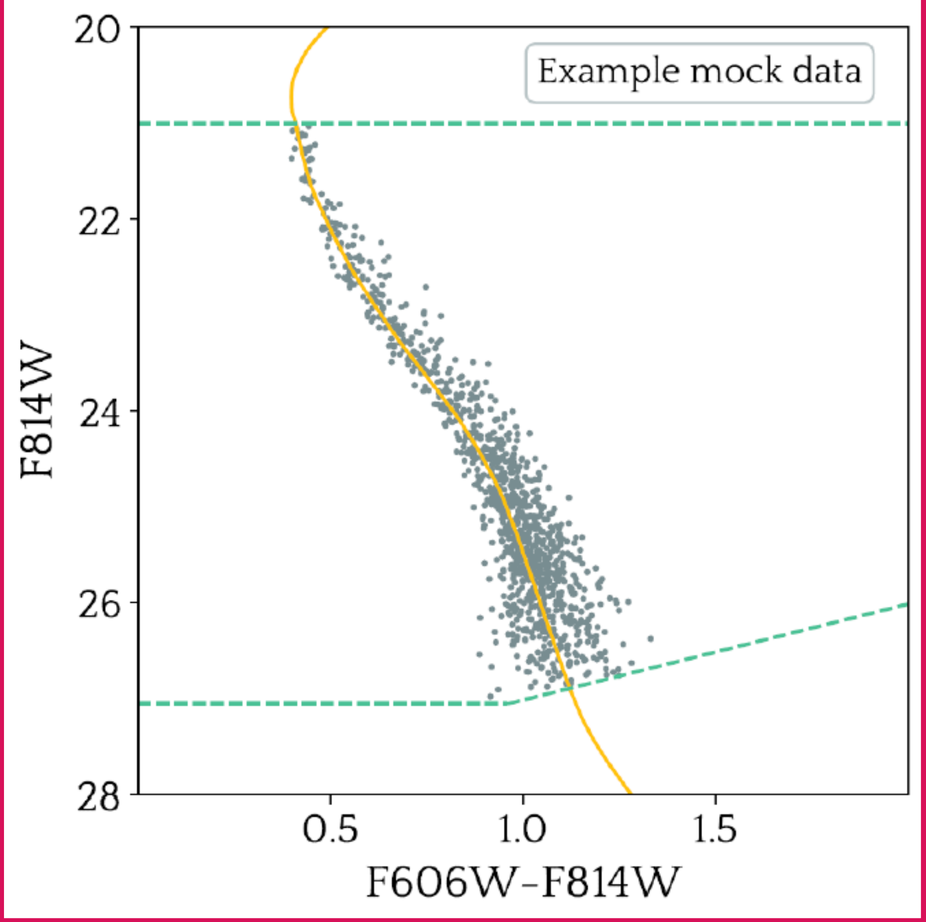
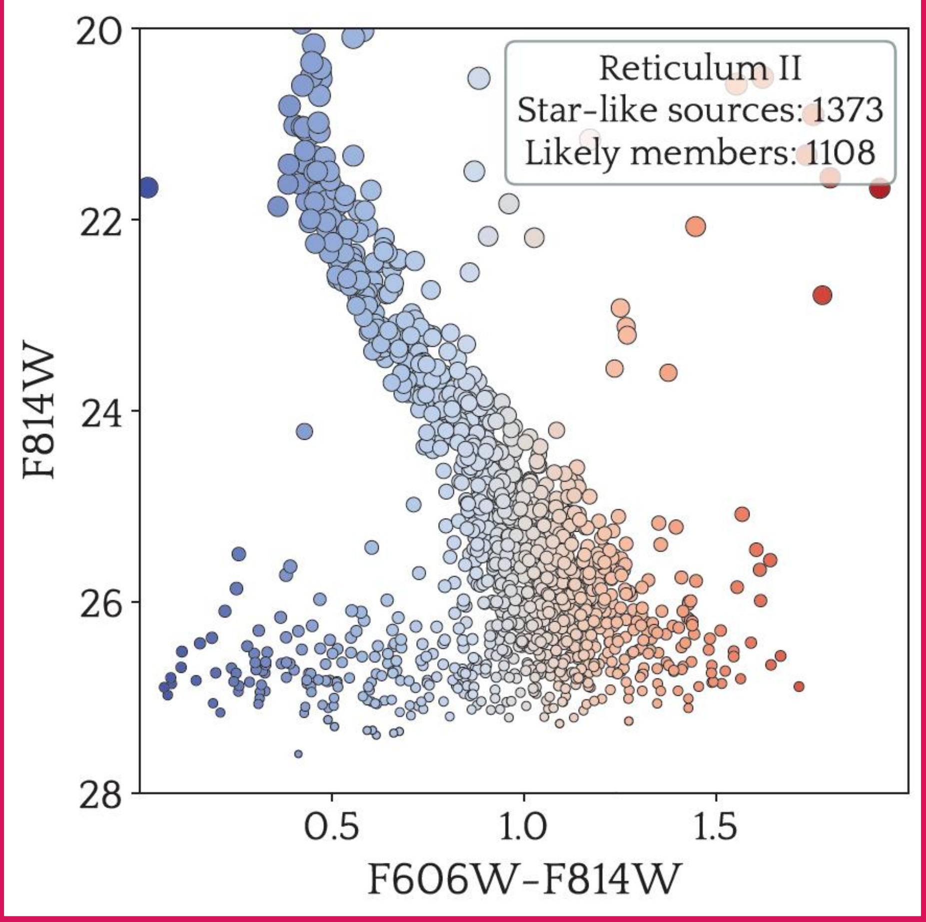


VS



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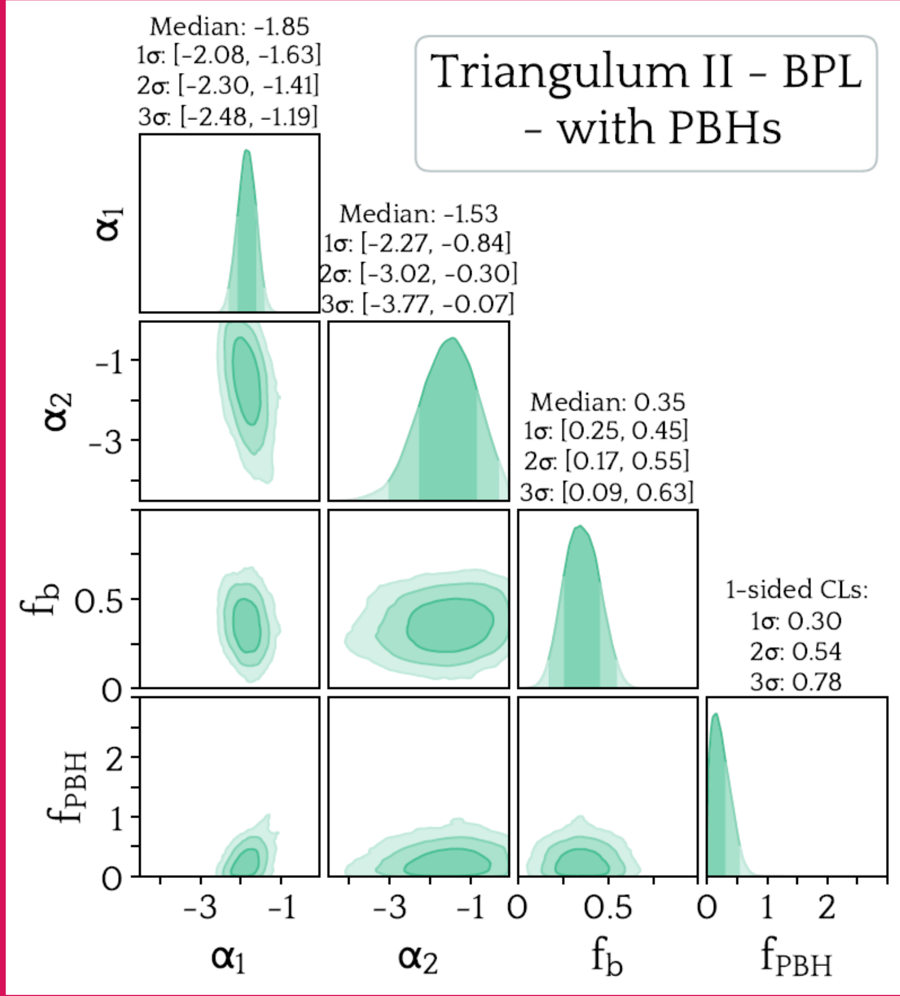
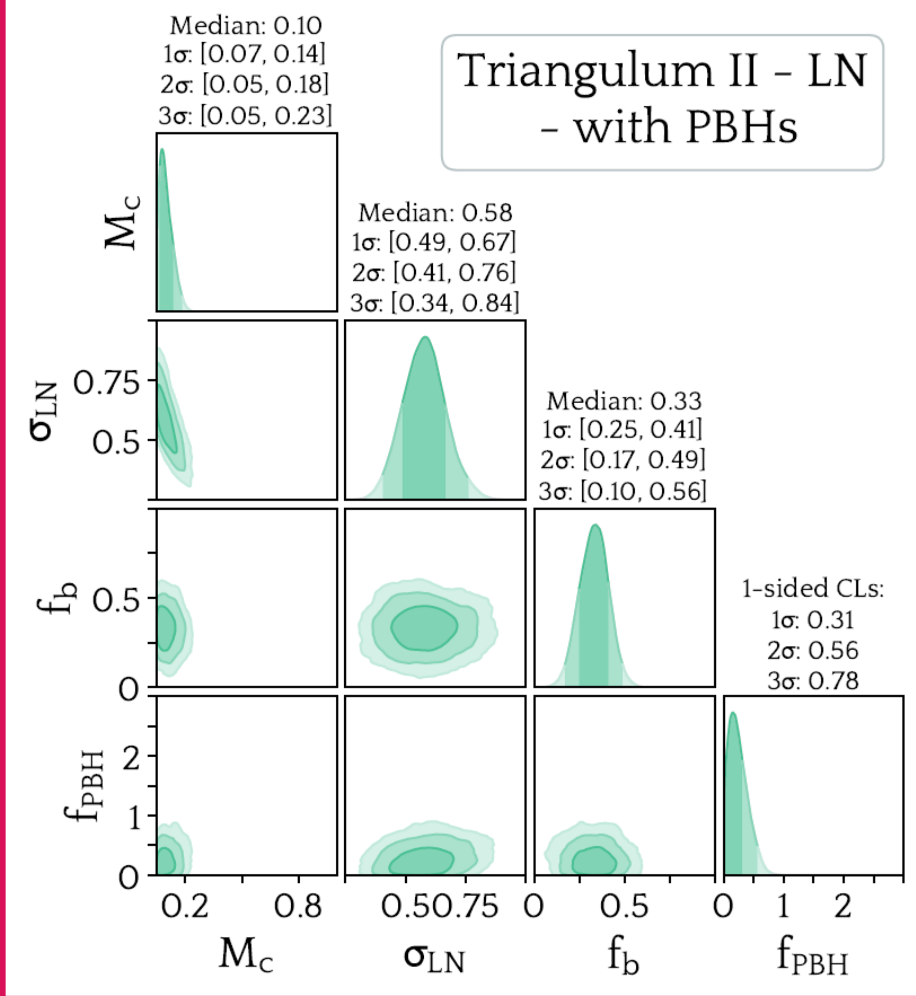


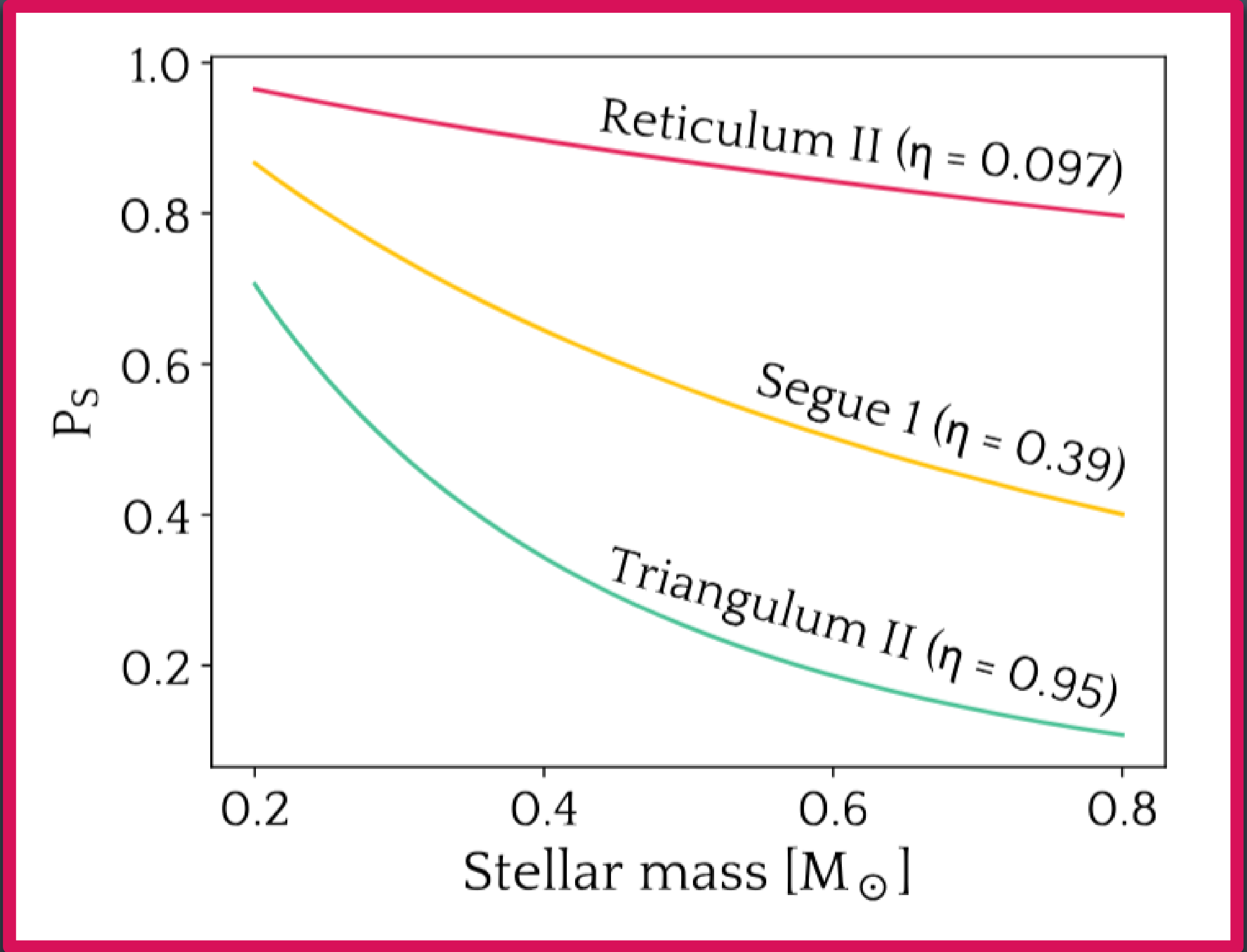


Backup slides

Two main caveats:

- We assume Bondi accretion → neglect effects that may stall accretion → important for PBHs $\lesssim 10^{19}$g.
- We compare dwarf galaxies → assume universal IMF among these galaxies (but they share // properties !). Without this assumption: $\sim 2\sigma$ exclusion in Triangulum (but even less motivated prior).

Backup slides



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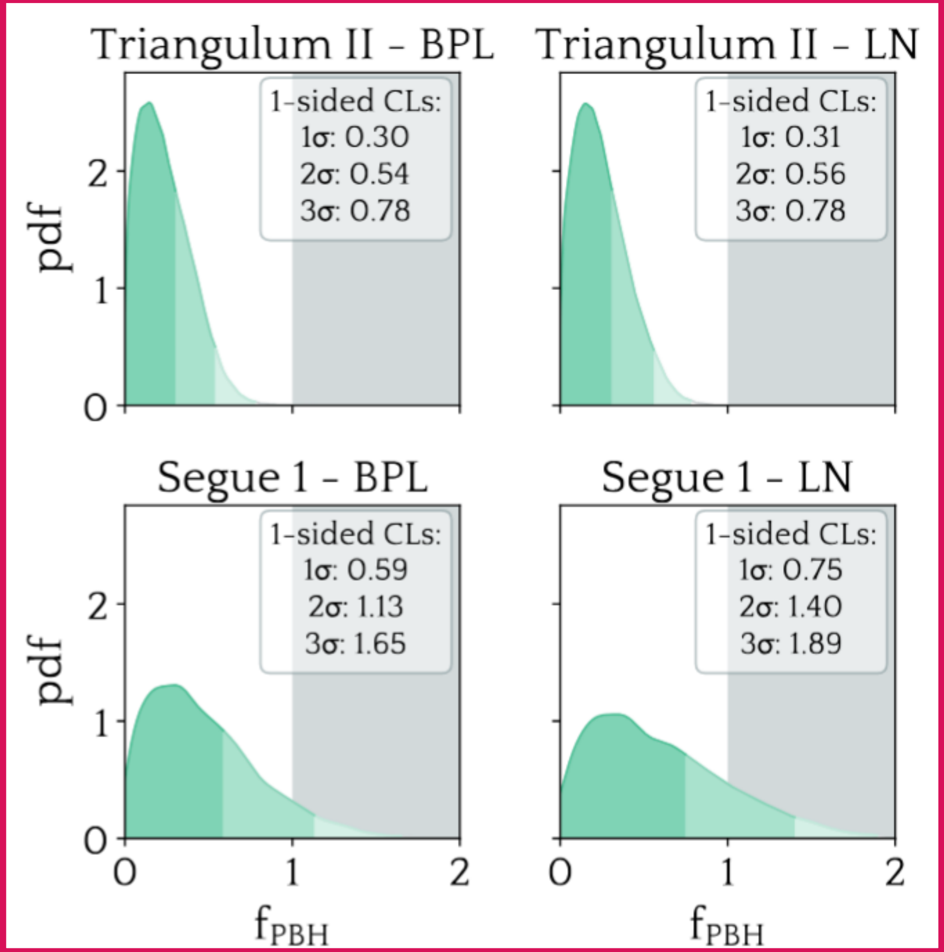

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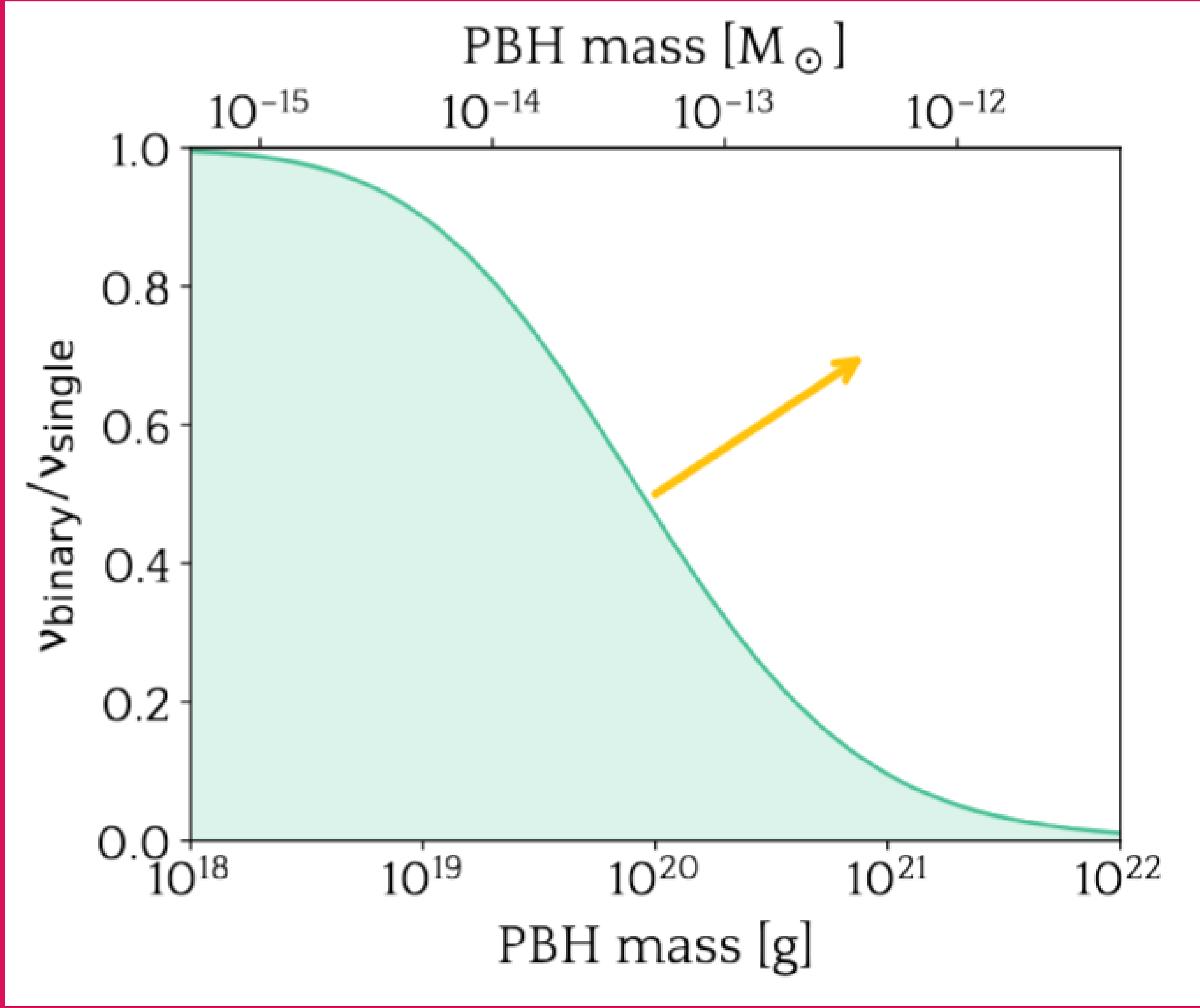

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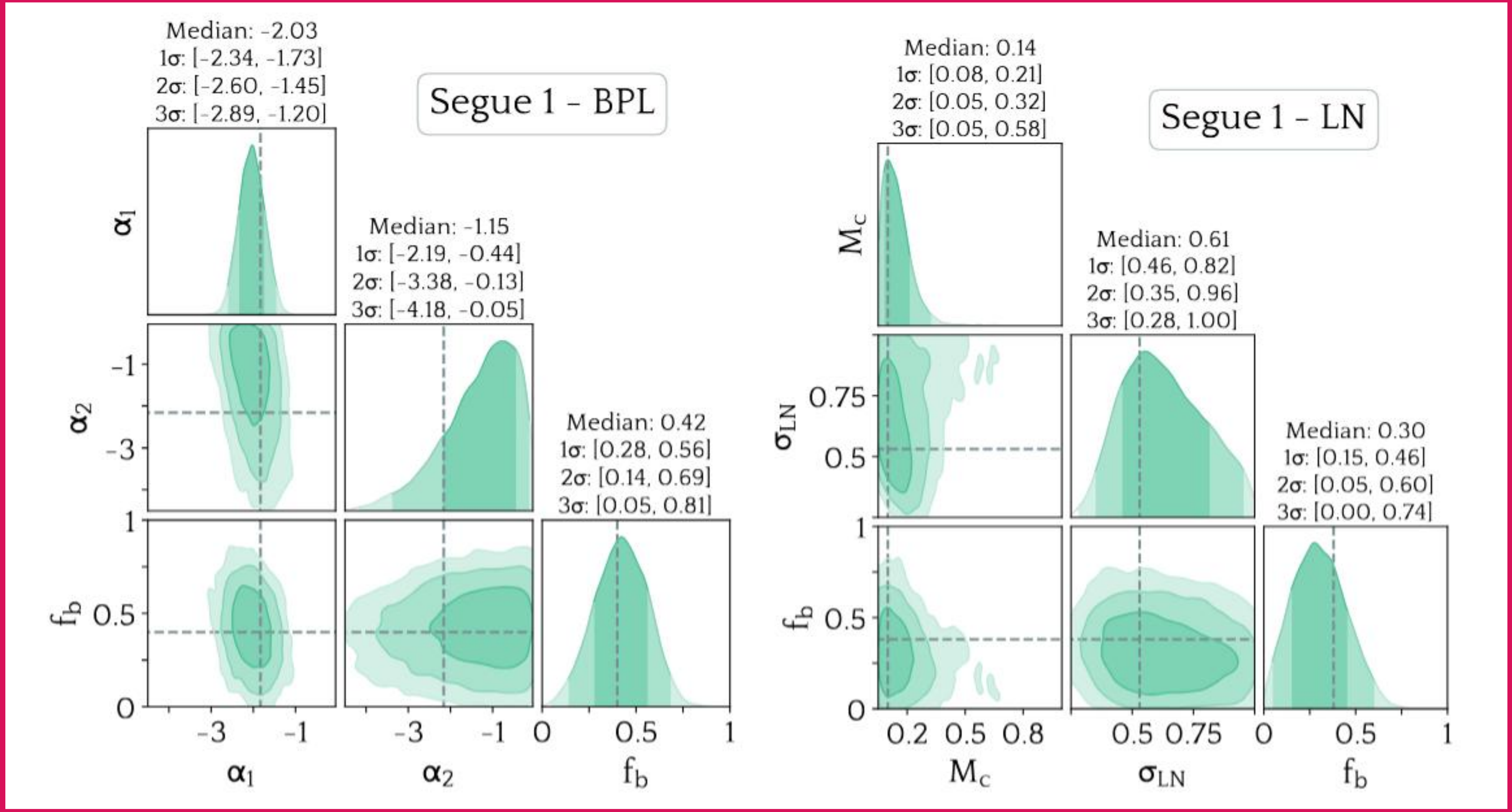

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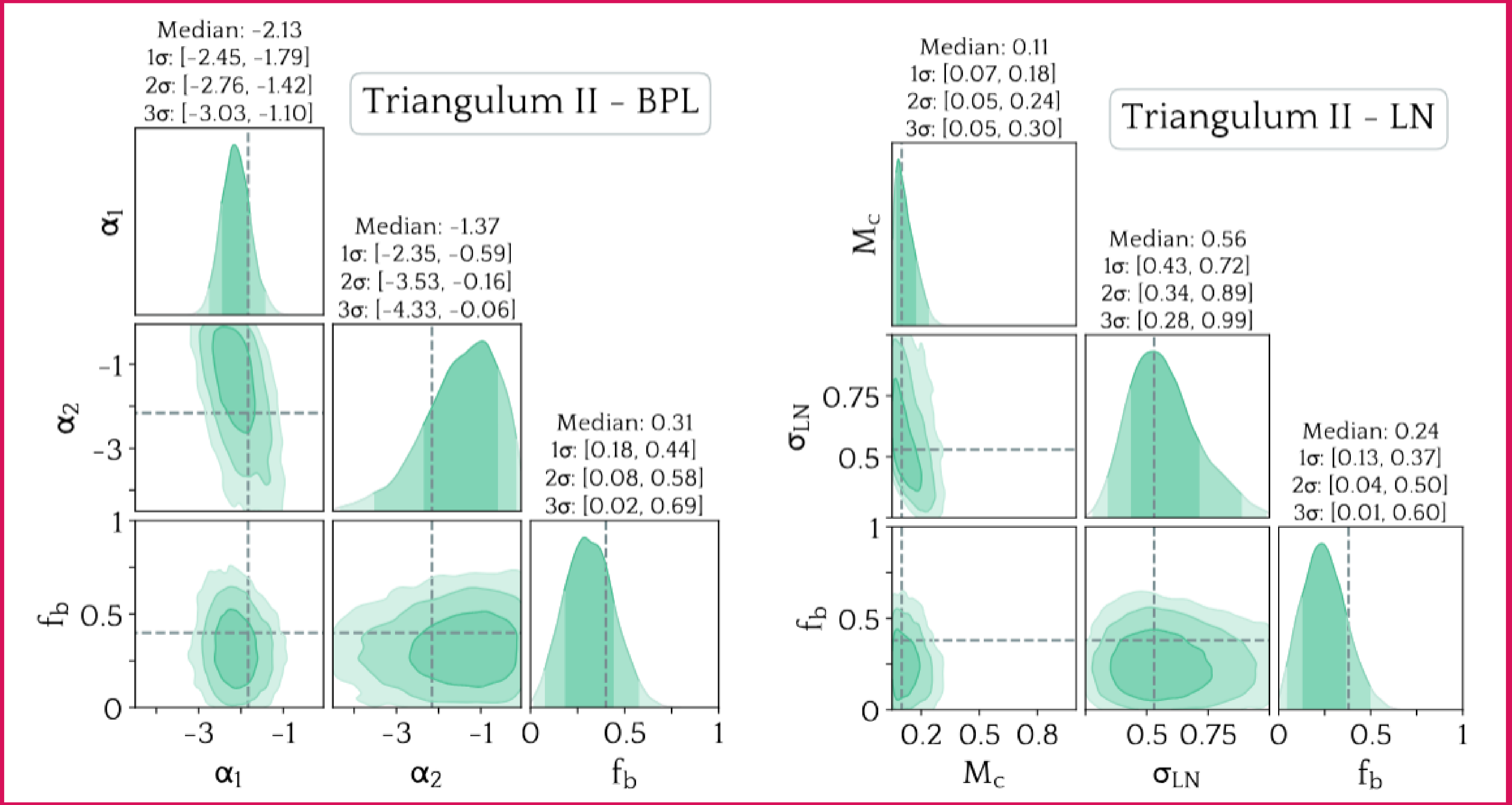

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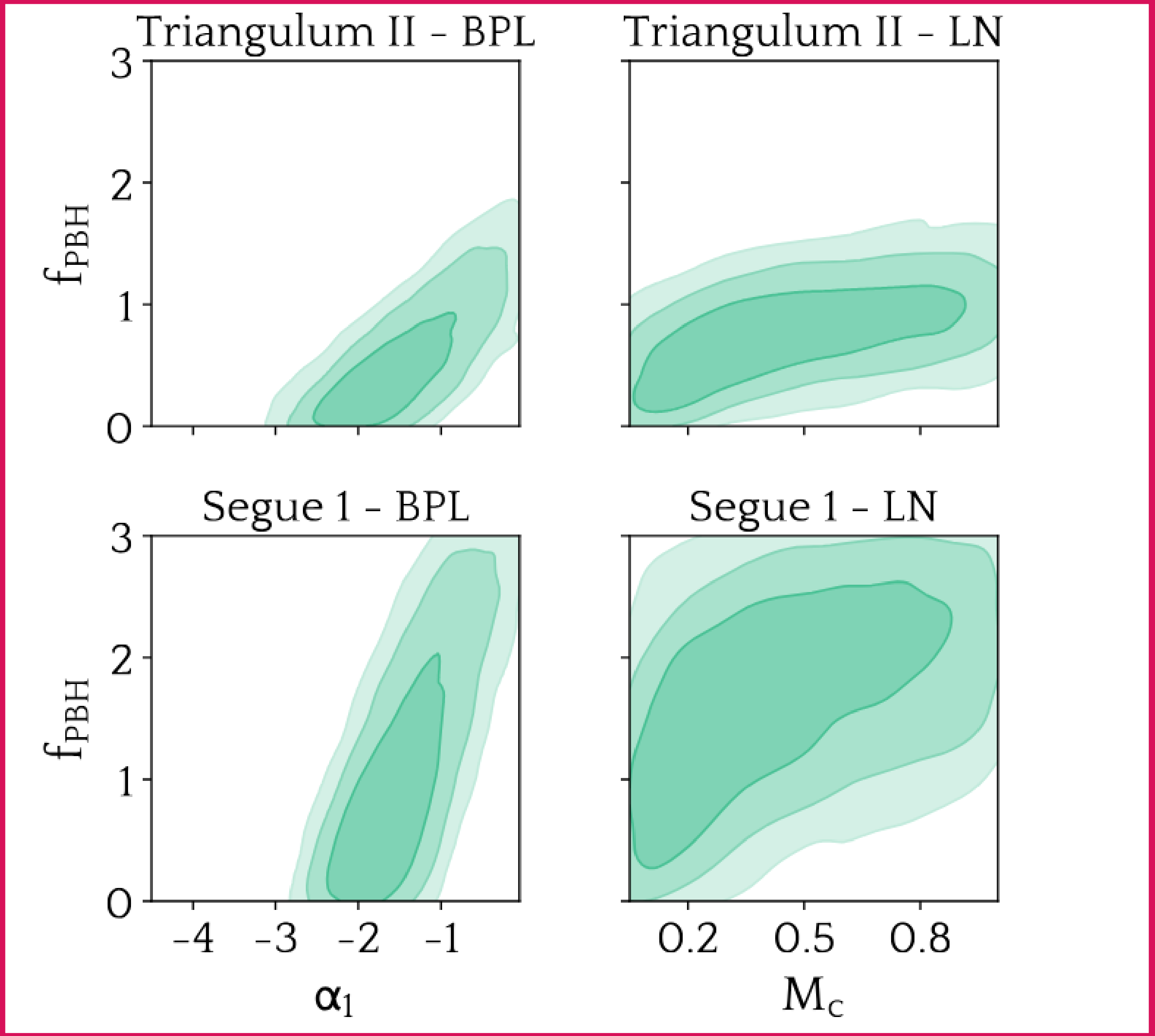

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