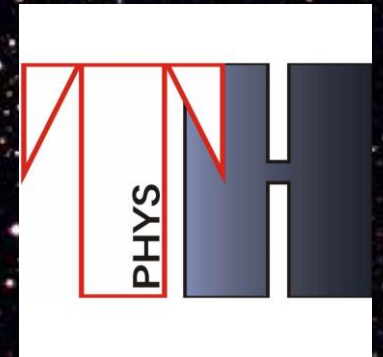


ULB

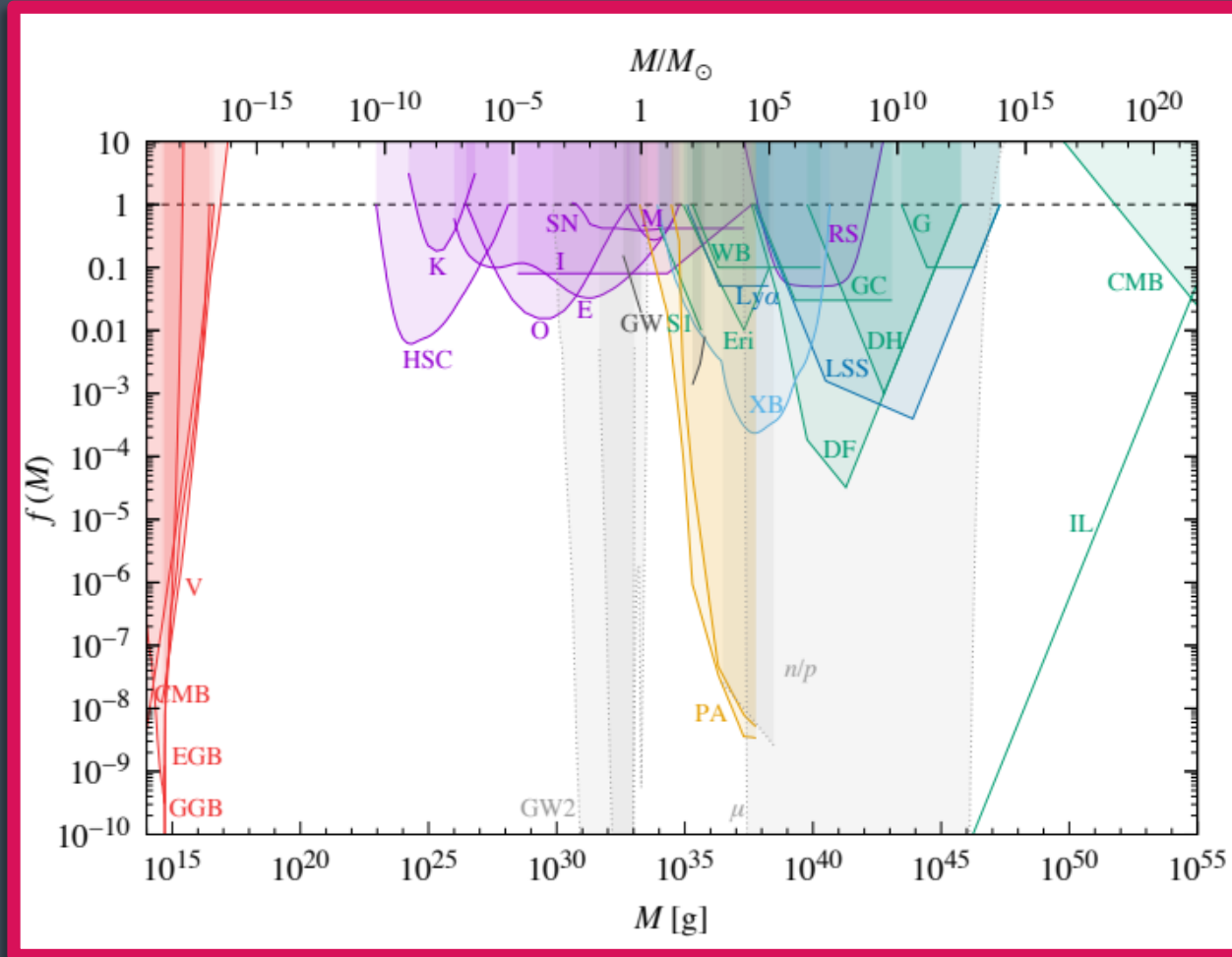
Invisibles 2025



Constraints on asteroid mass primordial black holes from stars

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

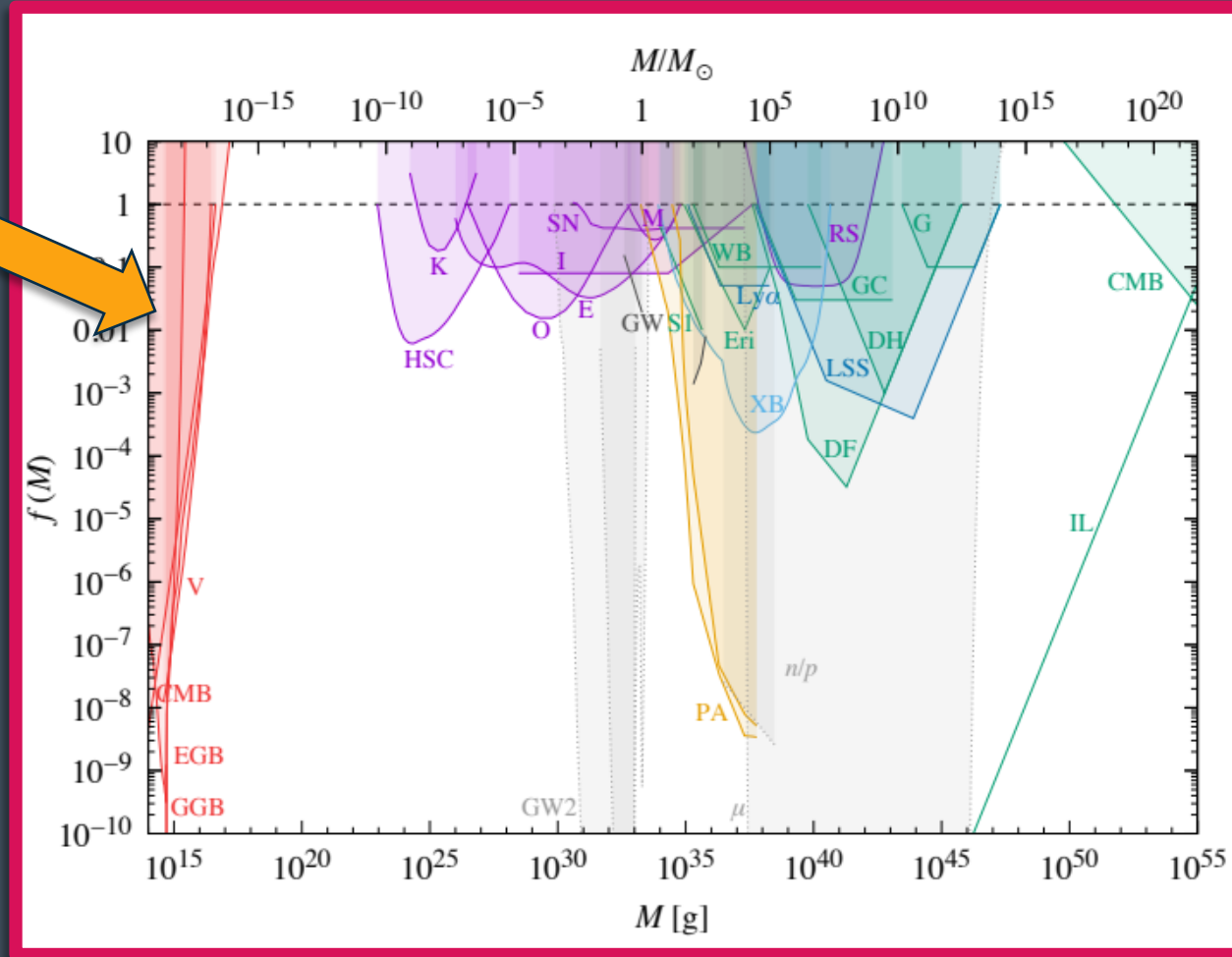
Current PBH constraints



Carr et al. (2021)

Current PBH constraints

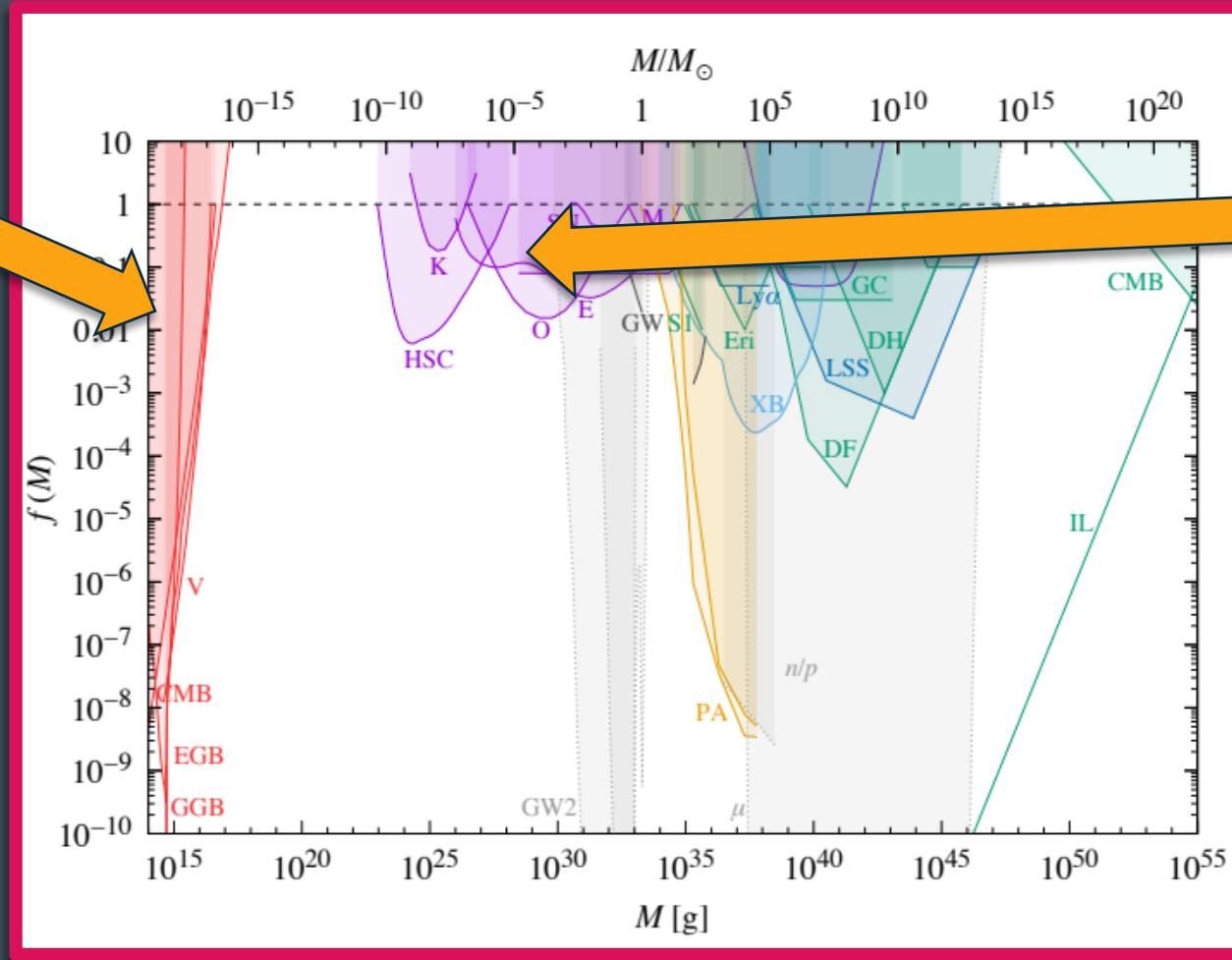
Evaporation



Carr et al. (2021)

Current PBH constraints

Evaporation

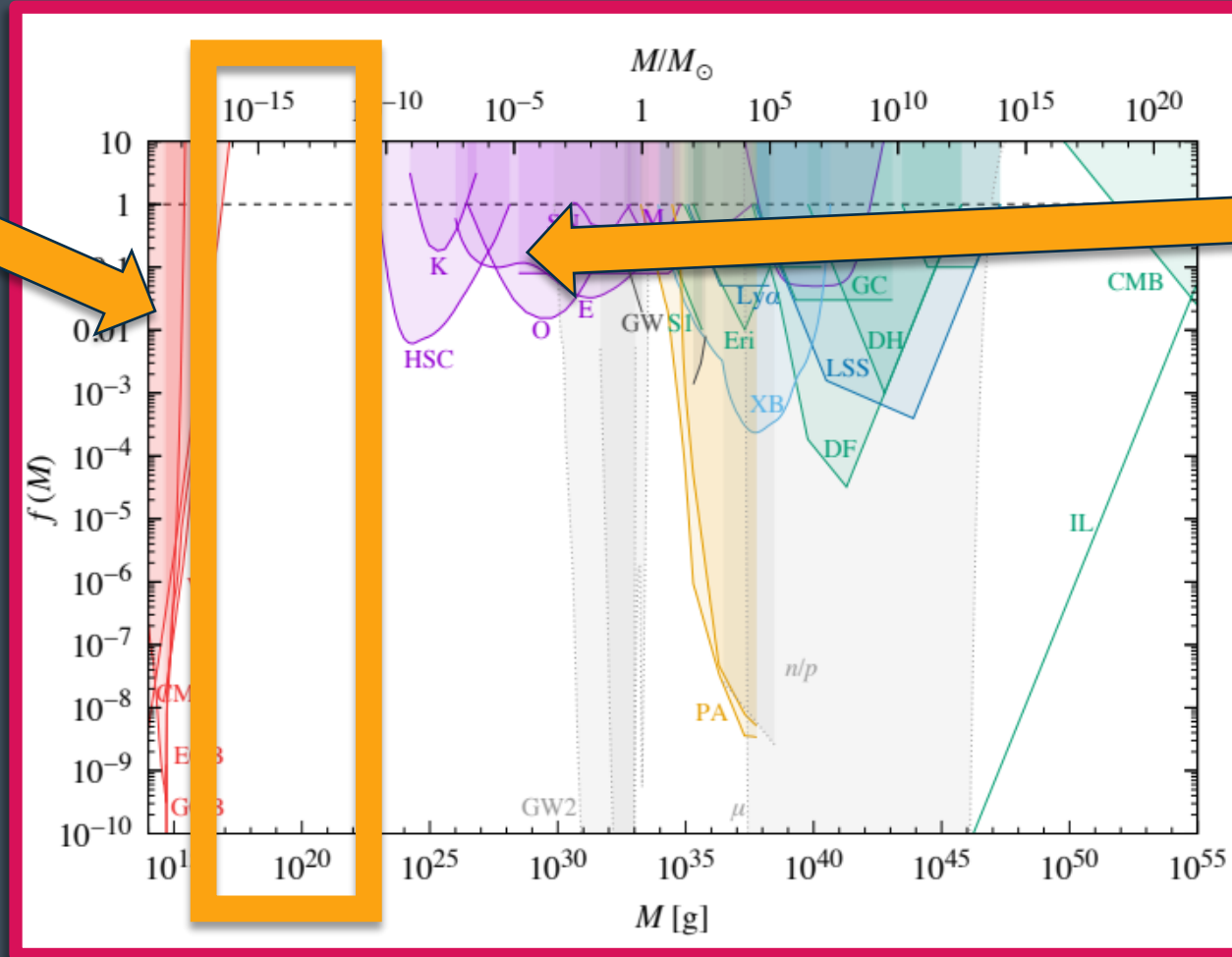


Lensing

Carr et al. (2021)

Current PBH constraints

Evaporation



Lensing

Carr et al. (2021)

Current PBH constraints

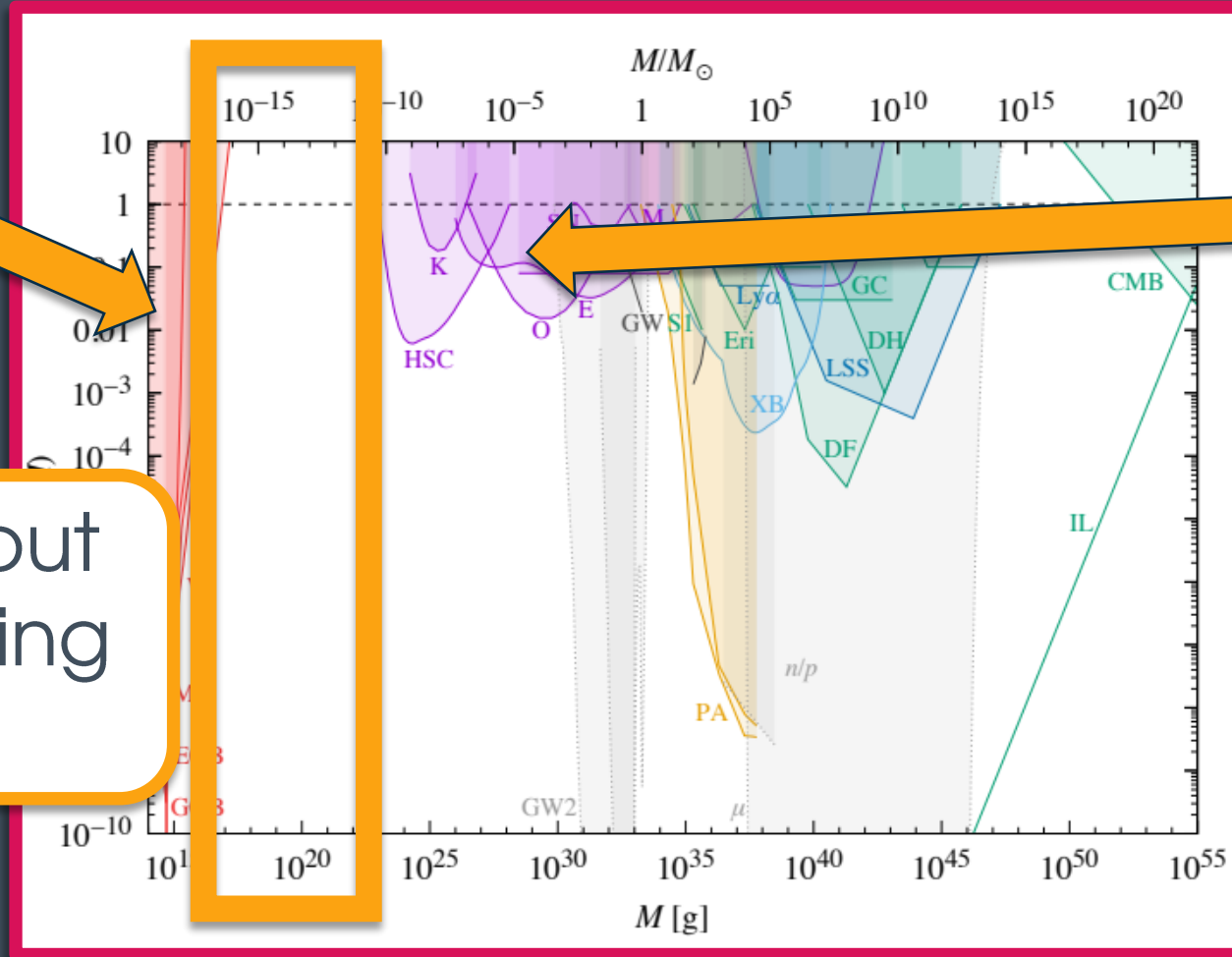
Evaporation



Lensing



Microscopic but
non-evaporating
PBHs



Carr et al. (2021)

Current PBH constraints

Evaporation

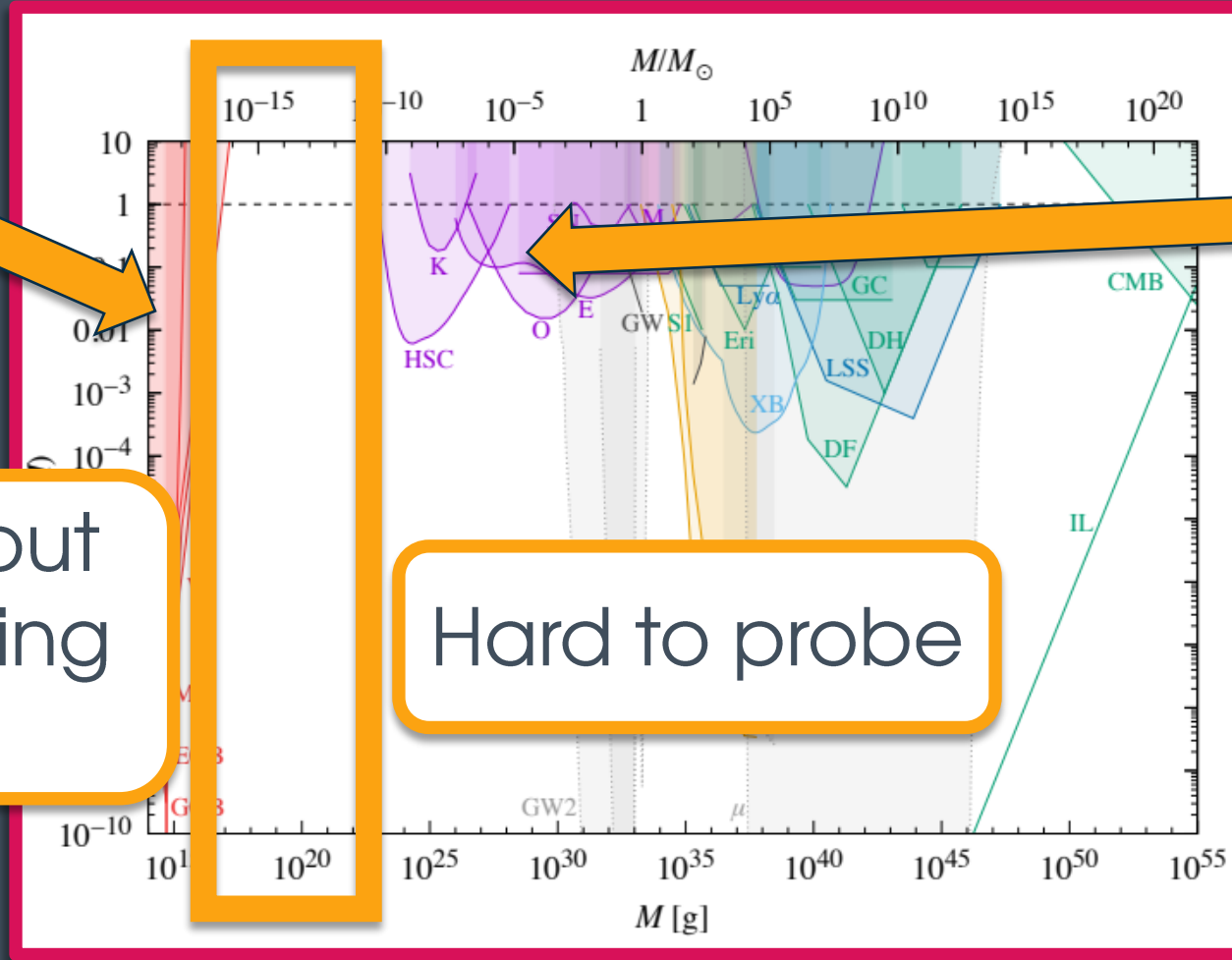


Lensing



Microscopic but
non-evaporating
PBHs

Hard to probe



Carr et al. (2021)

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:

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

Destruction probability

Adiabatic star formation + dynamical friction:

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

+ Bondi accretion

Destruction probability

Adiabatic star formation + dynamical friction:

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

+ Bondi accretion  stars that capture a PBH are destroyed:

Destruction probability

Adiabatic star formation + dynamical friction:

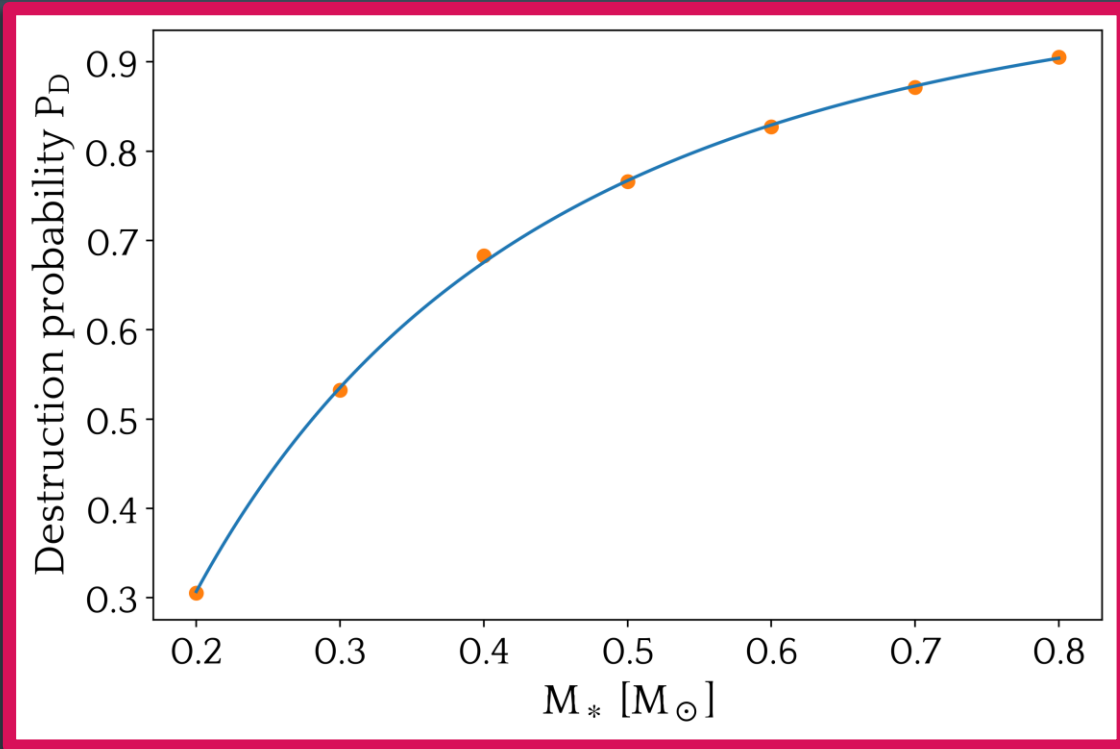
$$\bar{N}_{\text{cap}} = 12\sqrt{6\pi}G^2\ln(\Lambda) \times f_{\text{PBH}} \times \frac{\rho_{\text{DM}}}{\sigma^3} \times \tau_* \times M_*$$

+ Bondi accretion  stars that capture a PBH are destroyed:

Destruction probability:

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

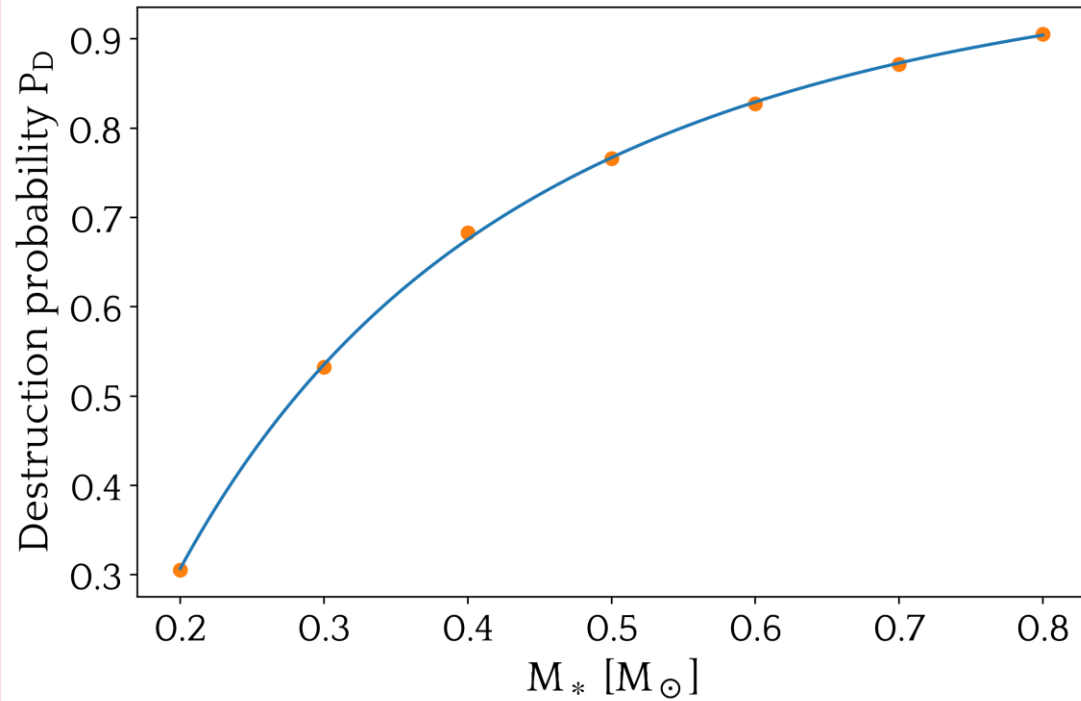
Destruction probability



Destruction probability:

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

Destruction probability



P_D  with the stellar mass!

Destruction probability:

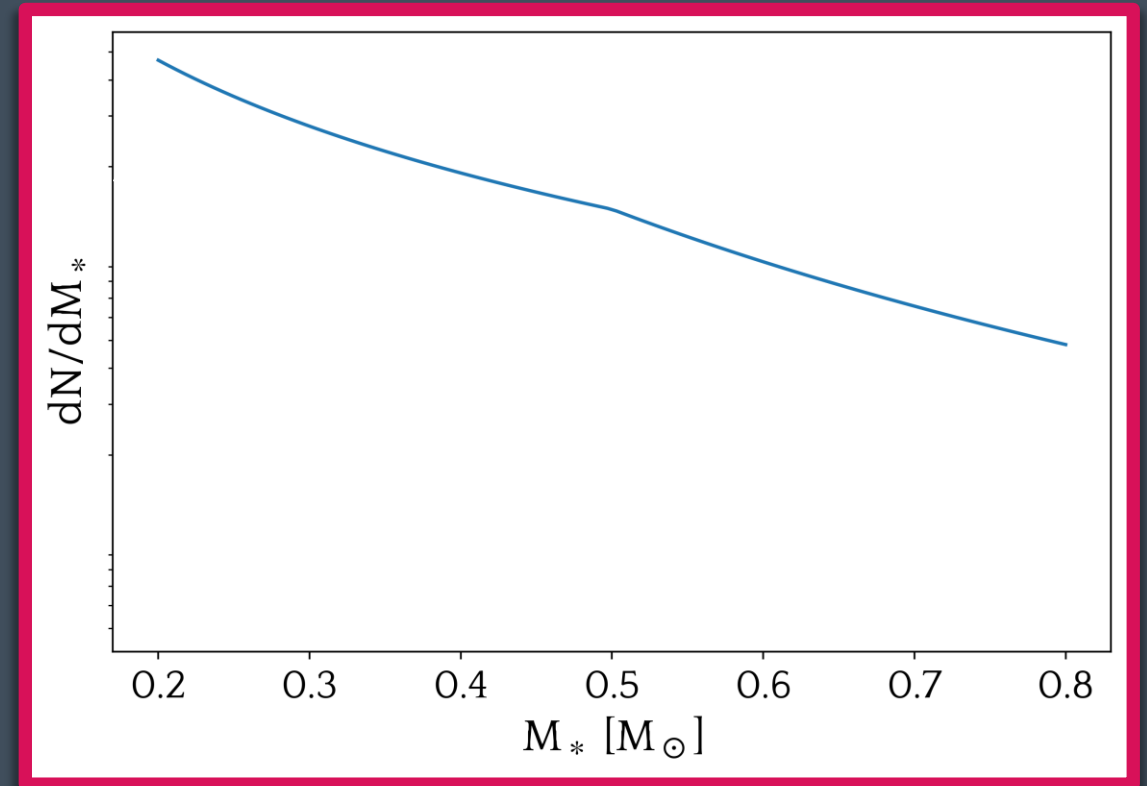
$$P_D = 1 - e^{-\bar{N}_{\text{cap}}}$$

Heavier stars are more
likely to be destroyed
by PBHs

Impact on a stellar population



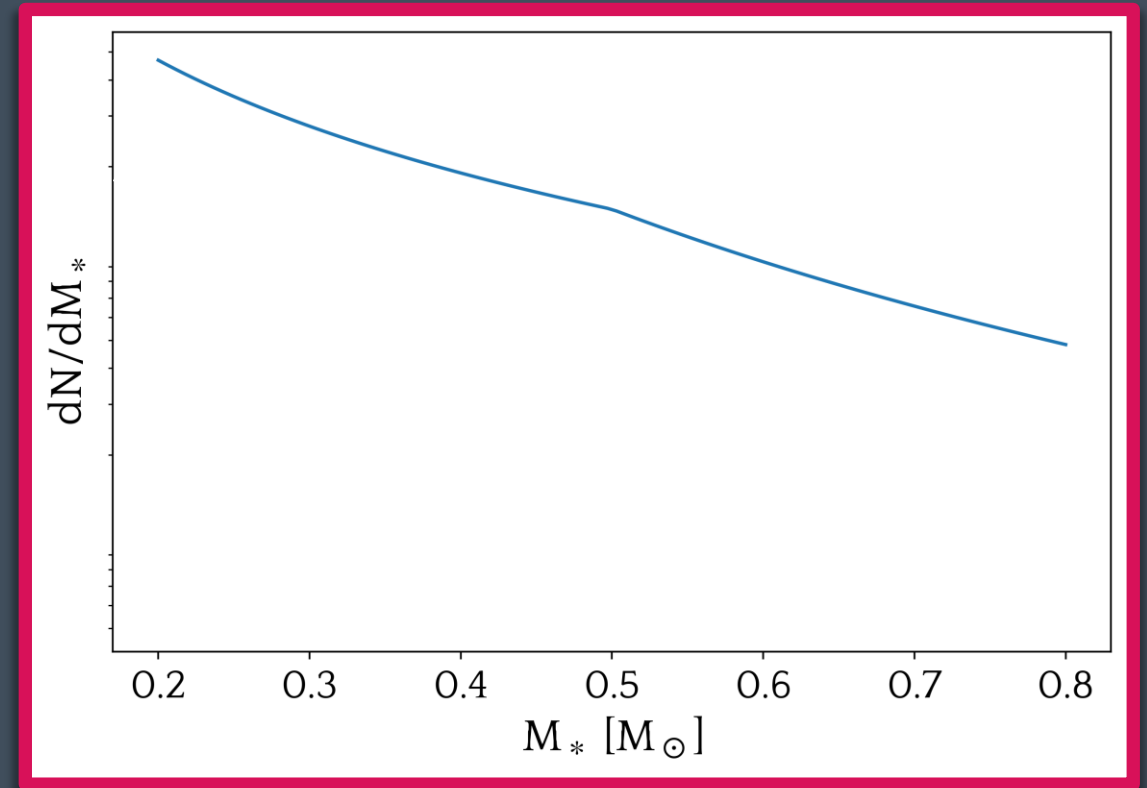
Stellar mass function



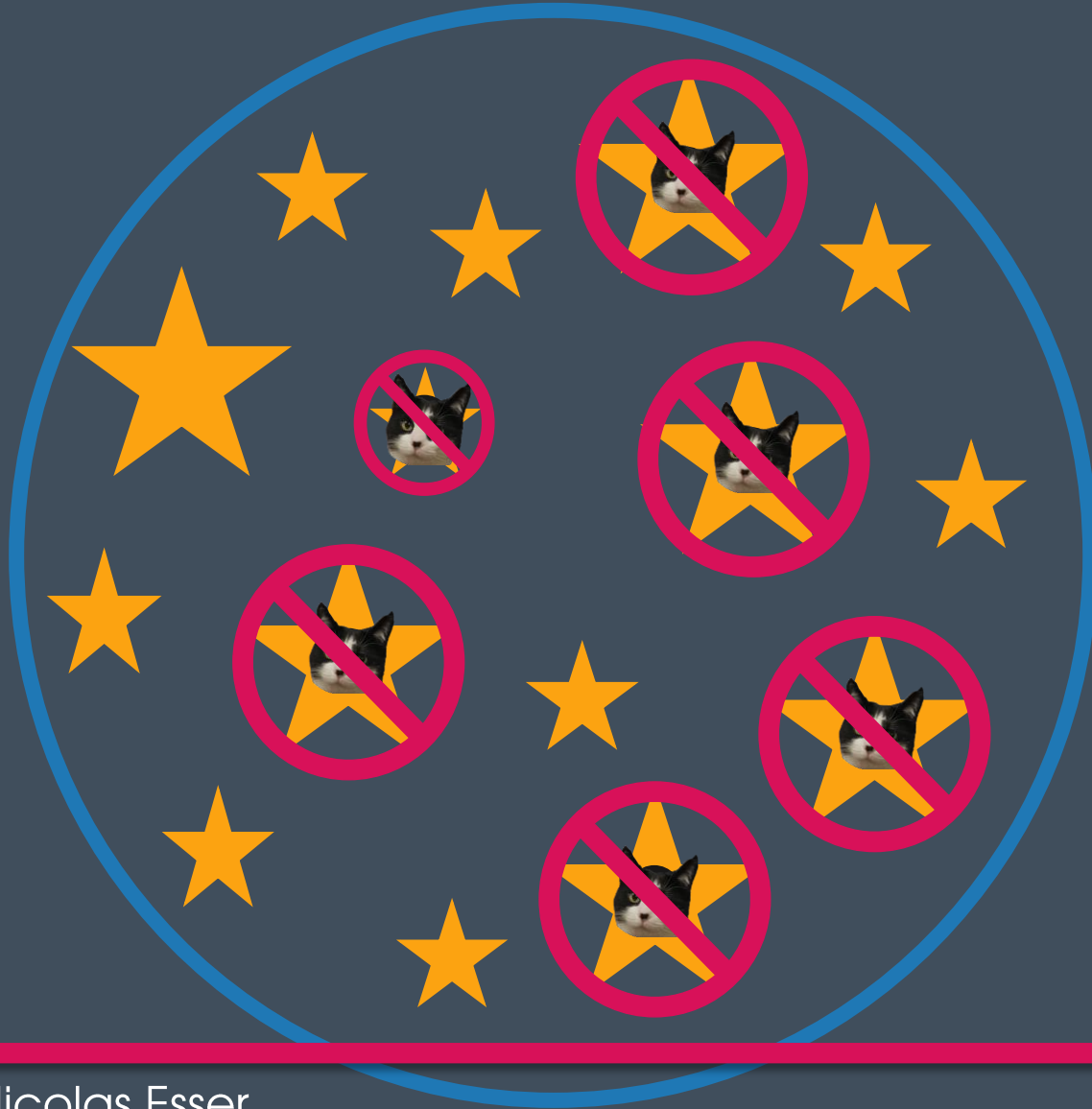
Impact on a stellar population



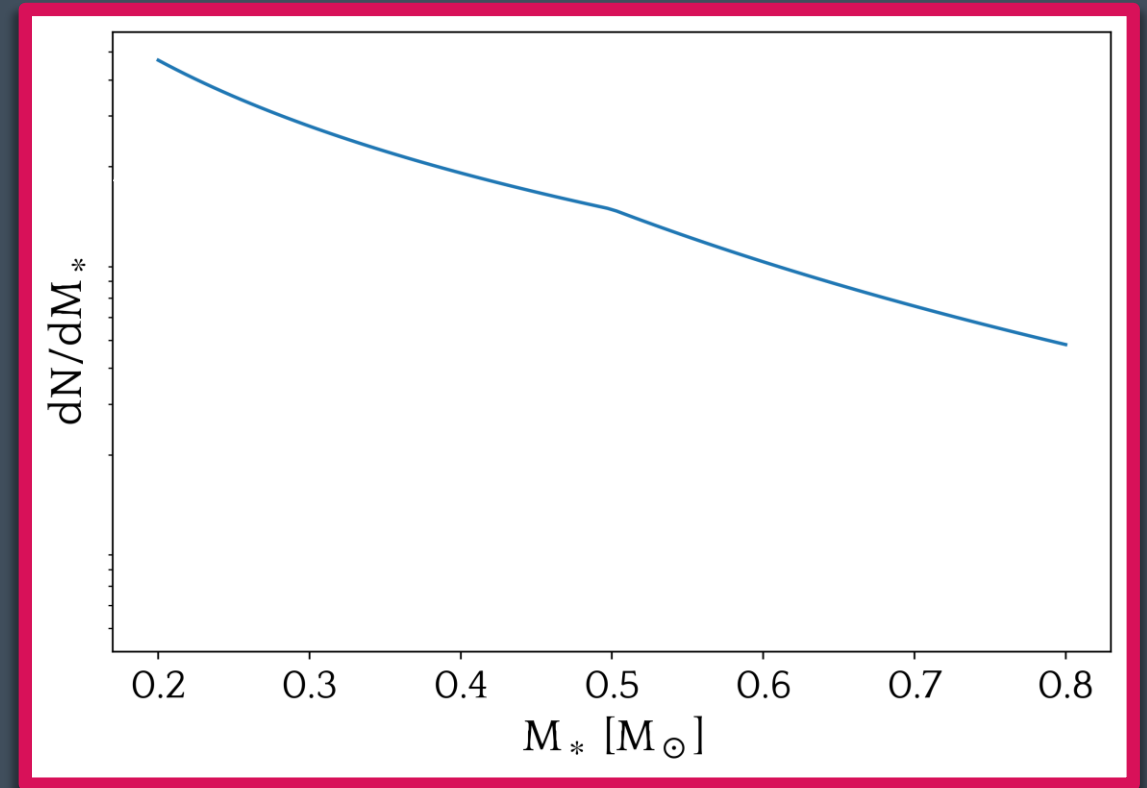
Stellar mass function



Impact on a stellar population



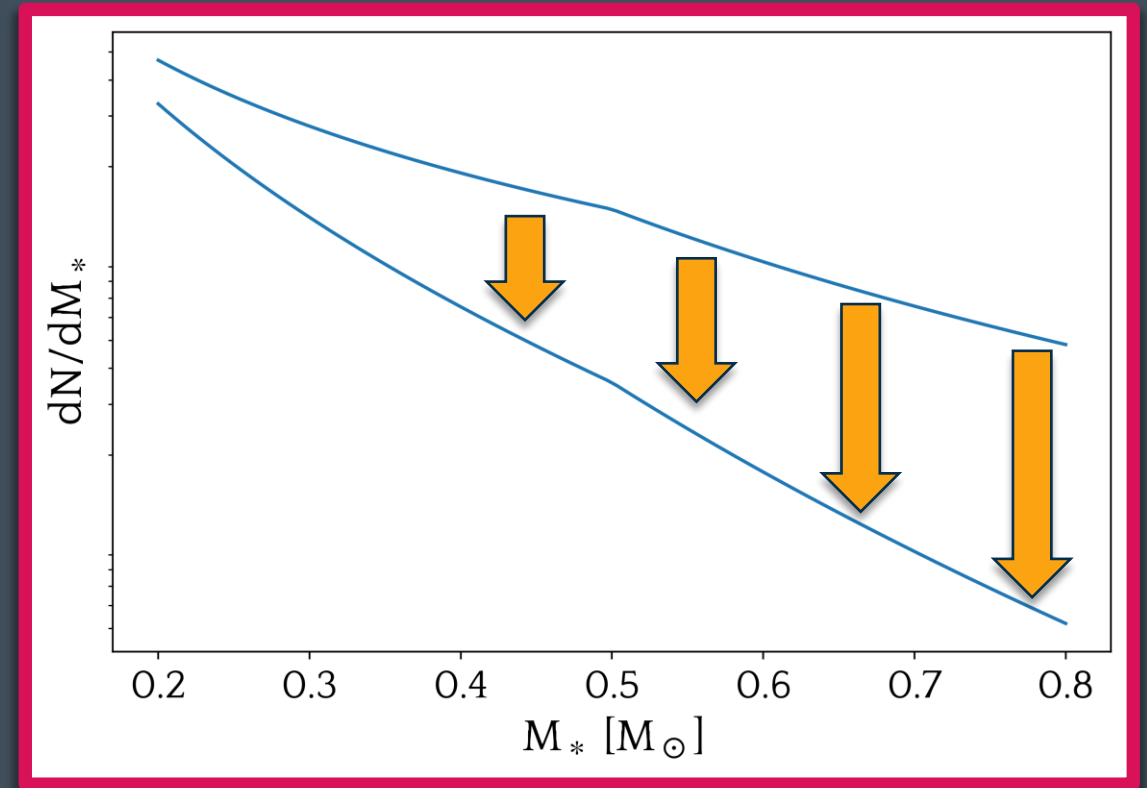
Stellar mass function



Impact on a stellar population



Stellar mass function



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

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

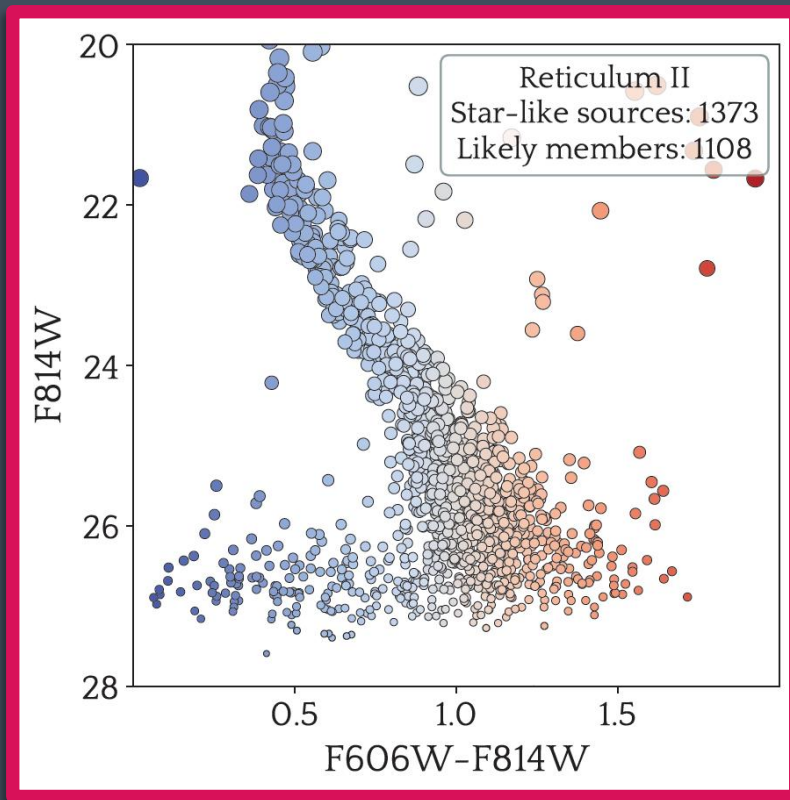
Photometric catalogs with star-like sources by Richstein +++



➤ Reticulum II, Segue 1, Triangulum II

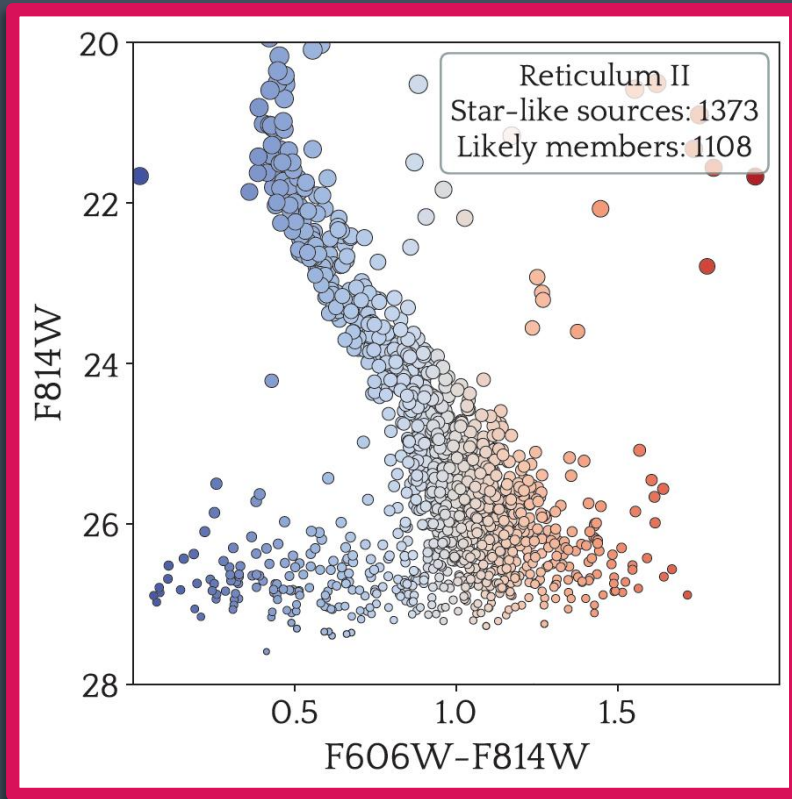
Observation

Observation:



Observation

Observation:

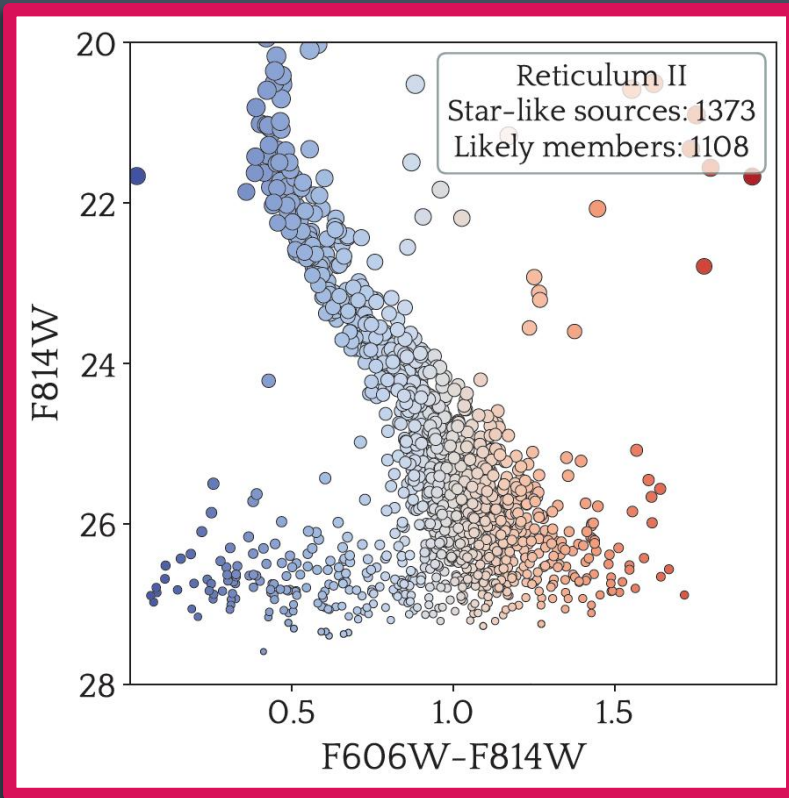


Stellar
population
model



Observation

Observation:



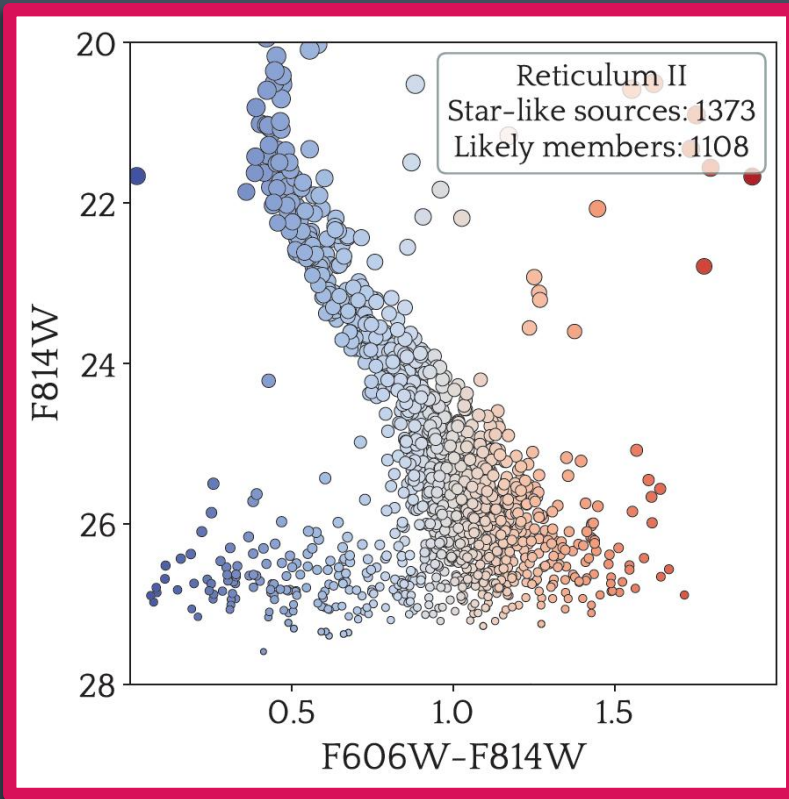
Stellar
population
model



+astronomical
effects &
complications

Observation

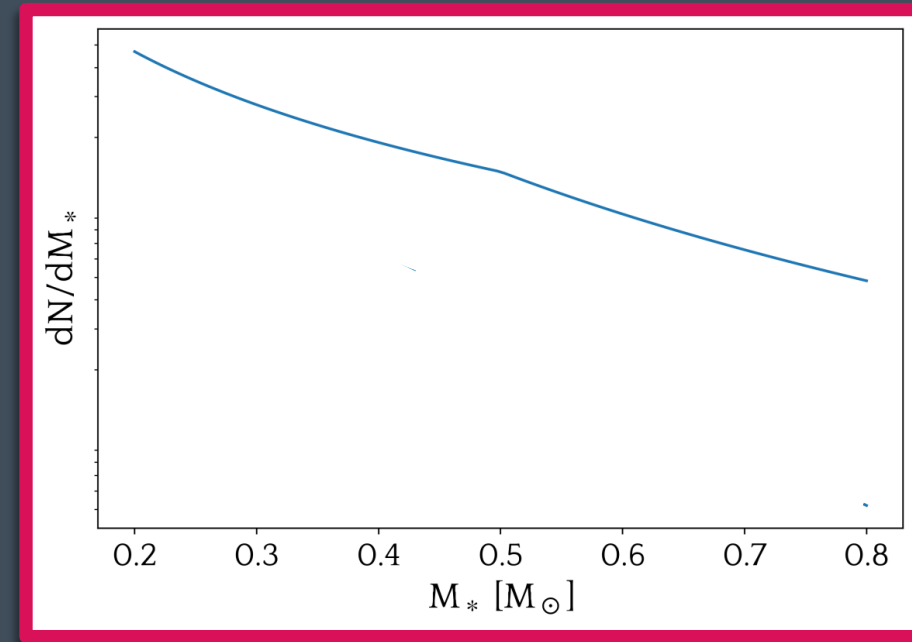
Observation:



Stellar
population
model

+astronomical
effects &
complications

Stellar mass function



Observation

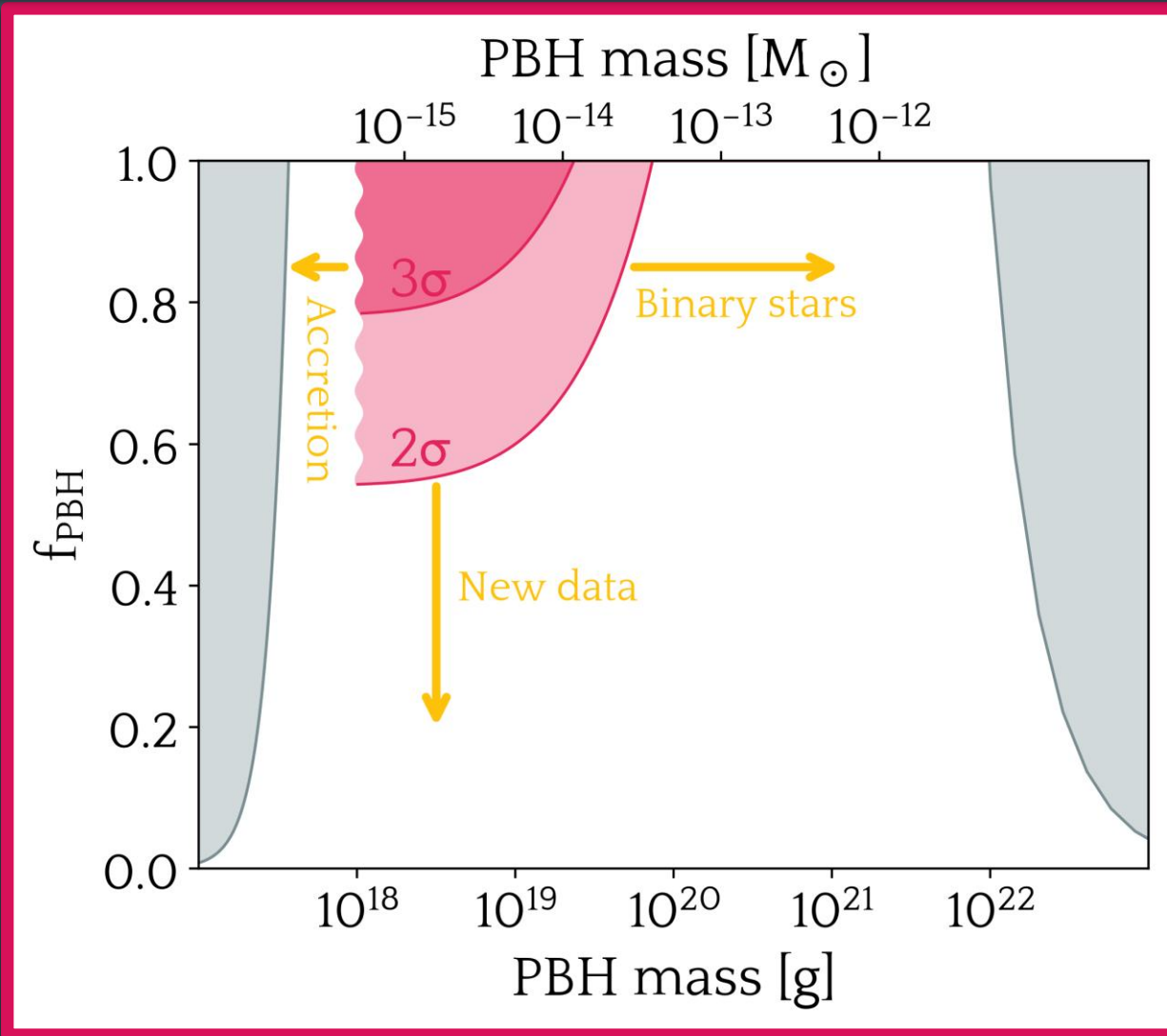
We do not observe the extra depletion of heavy stars due to PBHs

F814W



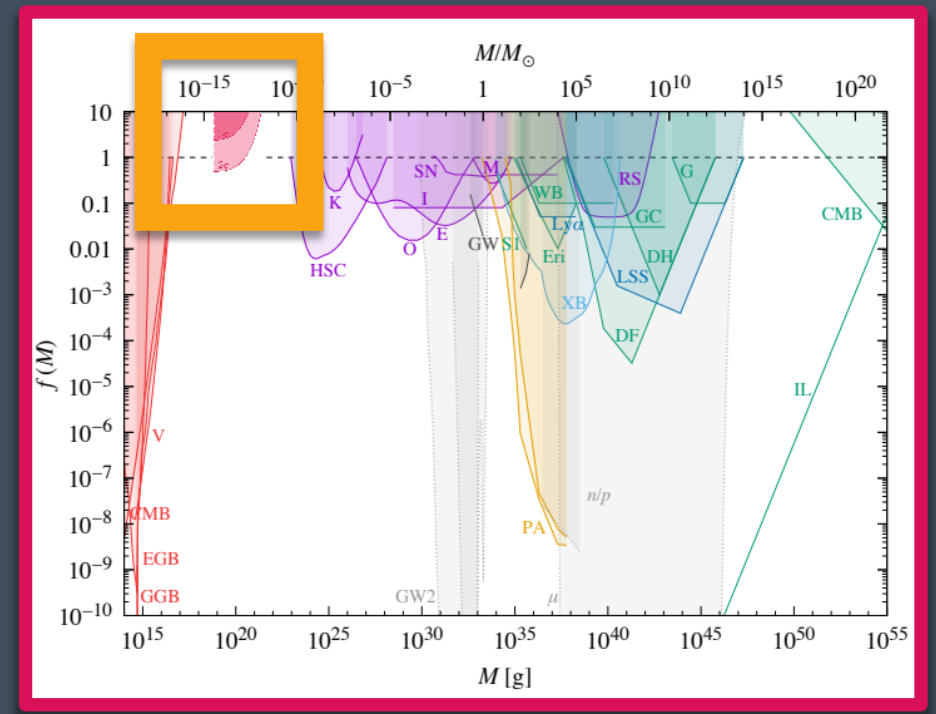
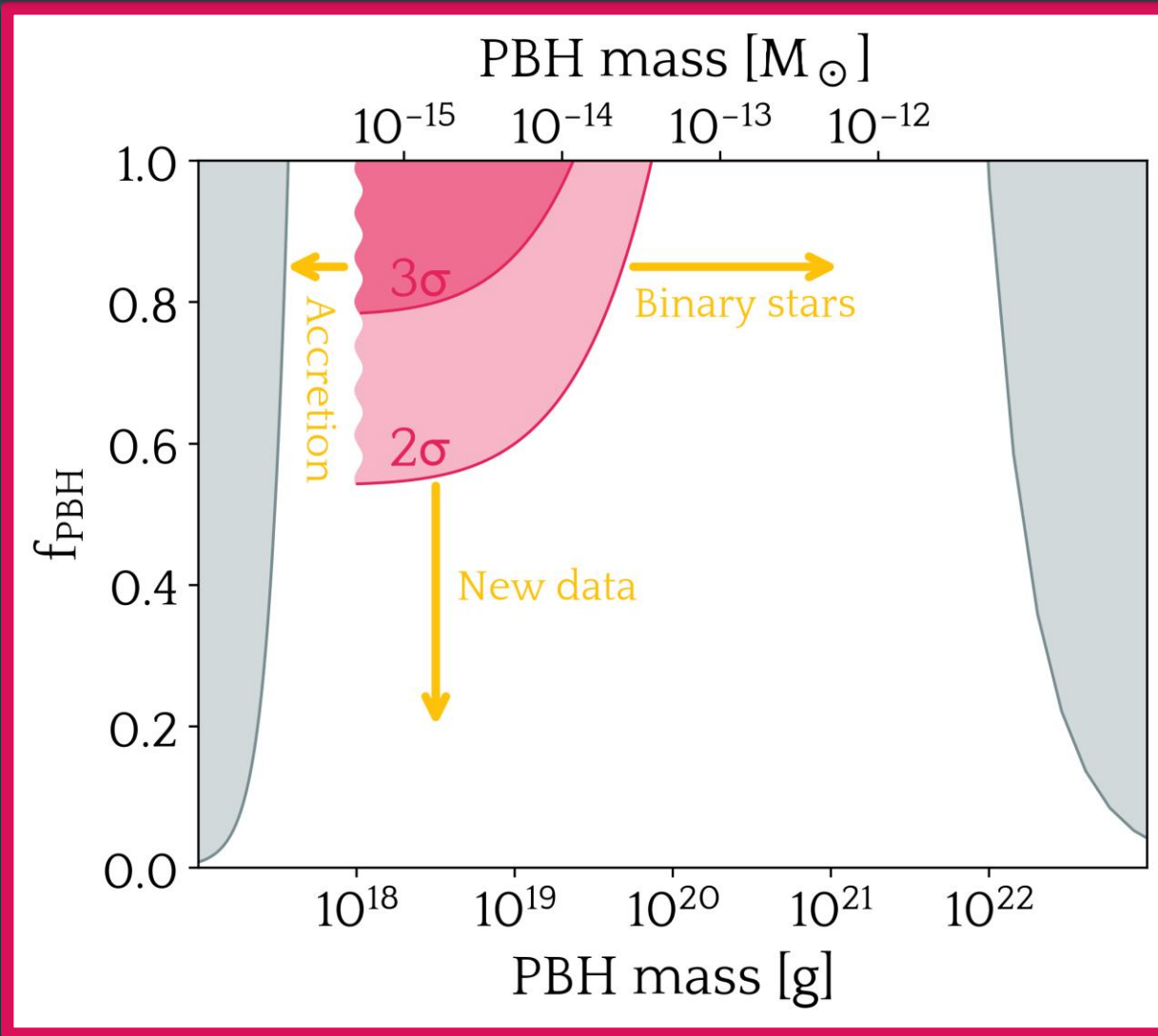
Brand new constraints

Esser et al. (2025)



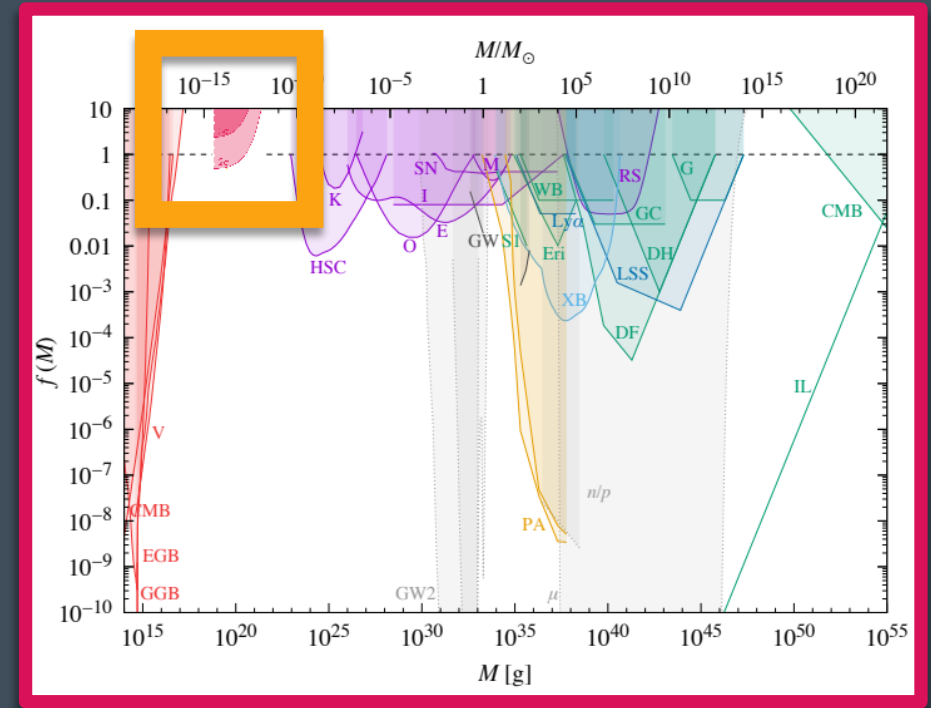
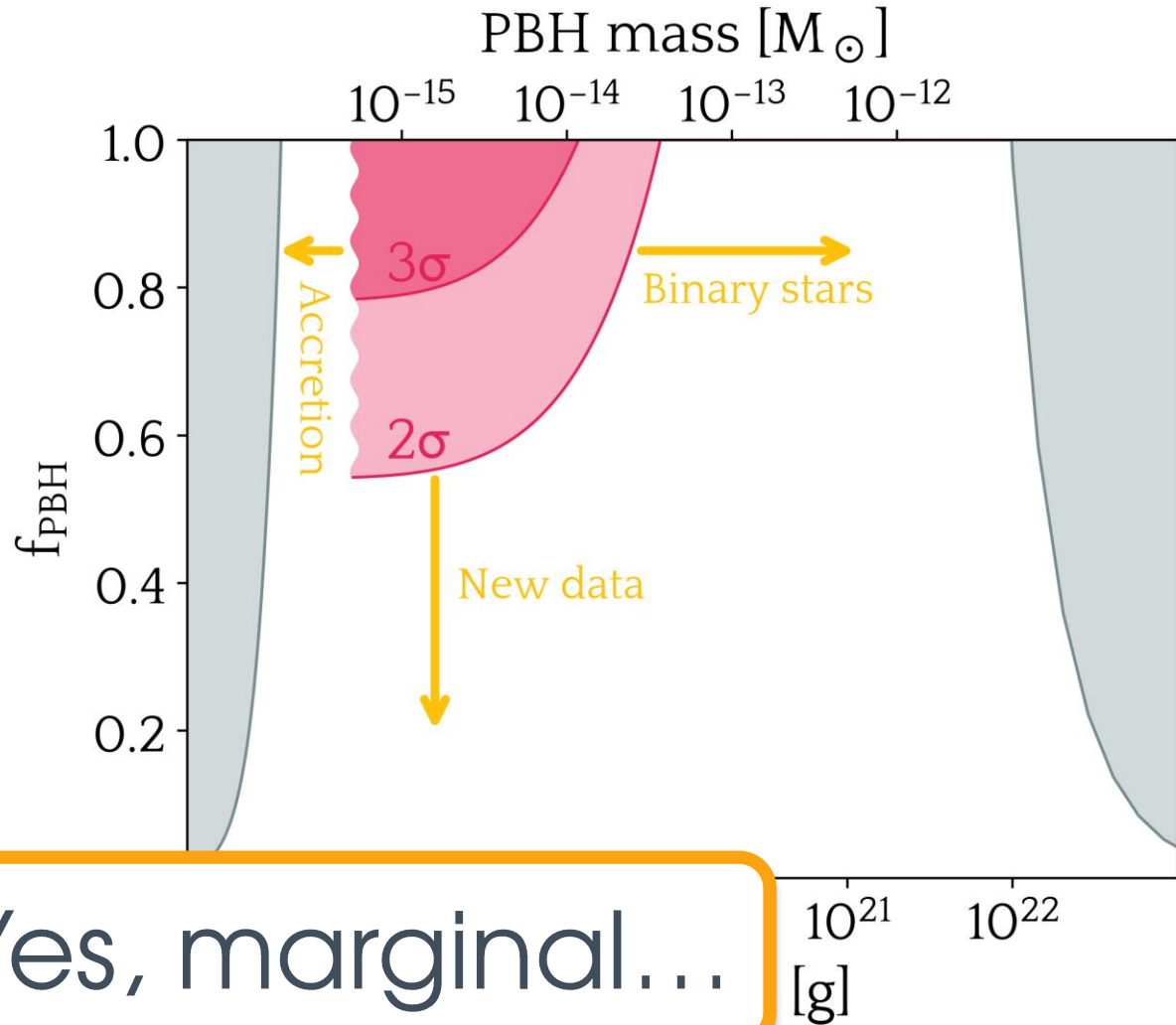
Brand new constraints

Esser et al. (2025)



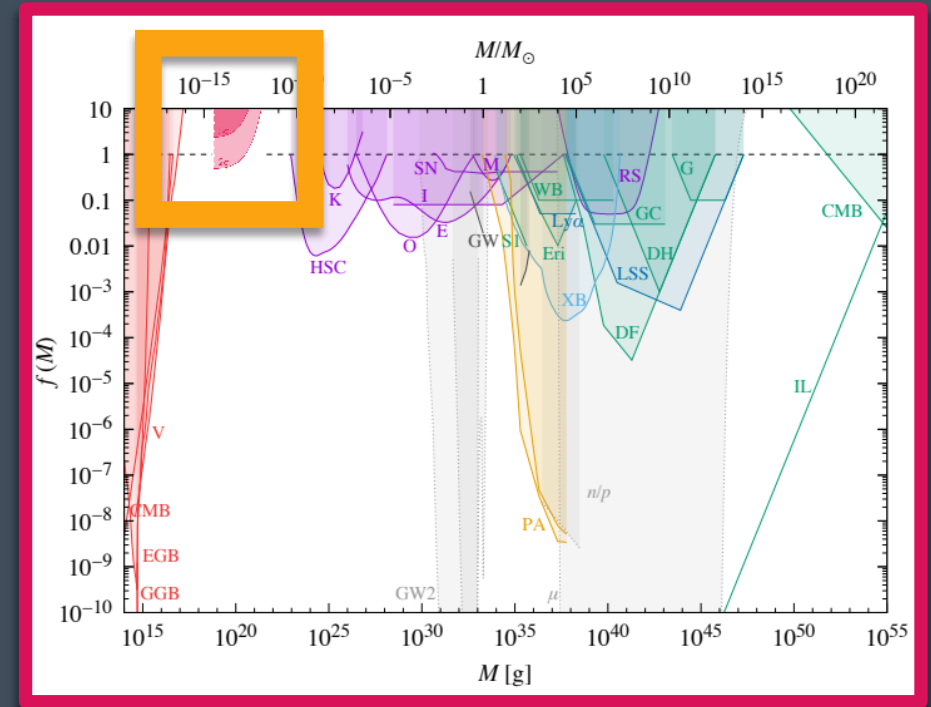
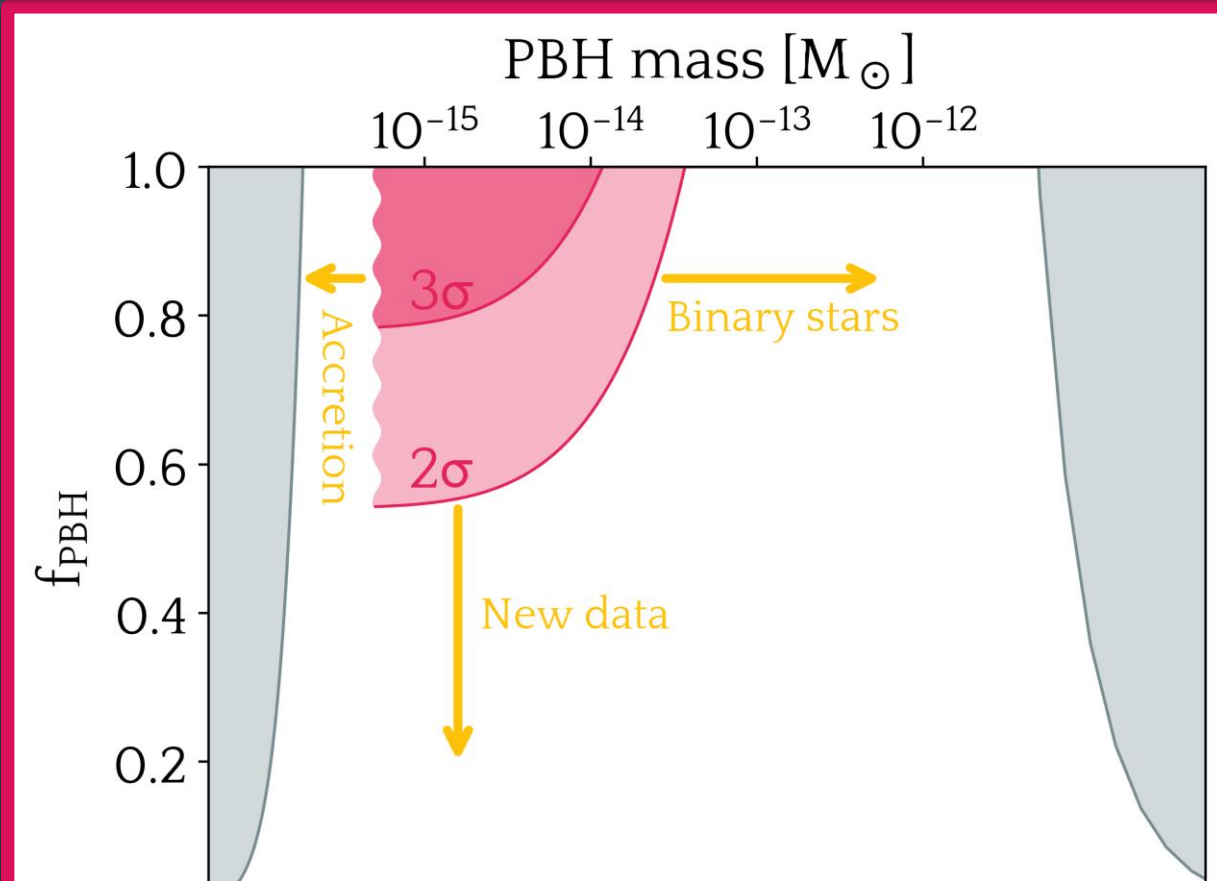
Brand new constraints

Esser et al. (2025)



Brand new constraints

Esser et al. (2025)



Yes, marginal...

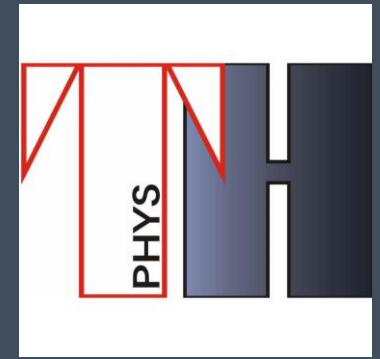
10¹⁵
[g]

... but likely to improve!

ULB


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)

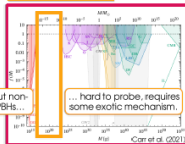
Nicolas Esser

ULB **Constraints on asteroid-mass primordial black holes in dwarf galaxies with HST** 

Nicolas Esser

Theory

Asteroid-mass PBHs



Microscopic but non-evaporating PBHs. ... hard to probe, requires some exotic mechanism.

Idea

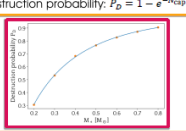
We consider the capture of PBHs by stars, followed by the destruction and disappearance of the stars.

Mean number of PBHs captured per star:

$$\bar{N}_{\text{cap}} = 12\sqrt{6}\pi^2 \ln(\Lambda) \times f_{\text{PBH}} \times \tau_{\text{DM}} \times \tau_{\text{DM}} \times M_{\text{star}}$$

Coulomb logarithm $\ln(\Lambda)$
Fraction of DM made of PBHs f_{PBH}
DM density over velocity dispersion cubed τ_{DM}
Lifetime of the star τ_{DM}
Mass of the star M_{star}


Destruction probability: $P_D = 1 - e^{-R_{\text{cap}}}$



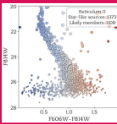
Heavier stars are more likely to be destroyed

In environments with high DM density and low velocity dispersion, we expect the stellar mass function - i.e. the distribution of stars as a function of their masses - to be depleted in heavier stars if DM is made of PBHs. → that is our observable!

Observations



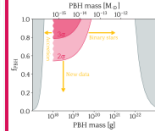
Hubble Space Telescope observations of 3 ultra-faint dwarf galaxies: Reticulum II, Segue 1 and Triangulum II.



We do not observe the stellar mass function directly, instead, we observe color-magnitude diagrams, where each dot represents a star. The x-axis corresponds to color, and the y-axis to magnitude.

Constraints

We generate mock color-magnitude diagrams using stellar evolution models with 4 parameters: two associated with the initial stellar mass function (α and β), the binary fraction f_b , and the PBH fraction f_{PBH} . We then compare the mock diagrams with real data in a Bayesian framework to infer the posterior distributions of each parameter. In particular, we obtain a posterior that constrains the PBH fraction.




Constraints on asteroid-mass PBHs!

Papers

See my talk on Friday @ 10.30 AM!

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



Inspire

Nicolas Esser - Université libre de Bruxelles - nicolas.esser@ulb.be - contact me ☺

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
- $\propto \frac{\rho_{\text{DM}}}{\sigma^3}$ \longrightarrow DM-dominated environments with low velocities
- $\propto \tau_*$ \longrightarrow Stars with long lifetimes $\longrightarrow M_* < 1M_{\odot}$
- $\propto M_*$ \longrightarrow Heavier stars capture more PBHs

Backup slides

Generate M_* (2 parameters)

Generate $[\text{Fe}/\text{H}]$

Create binaries (1 parameter)

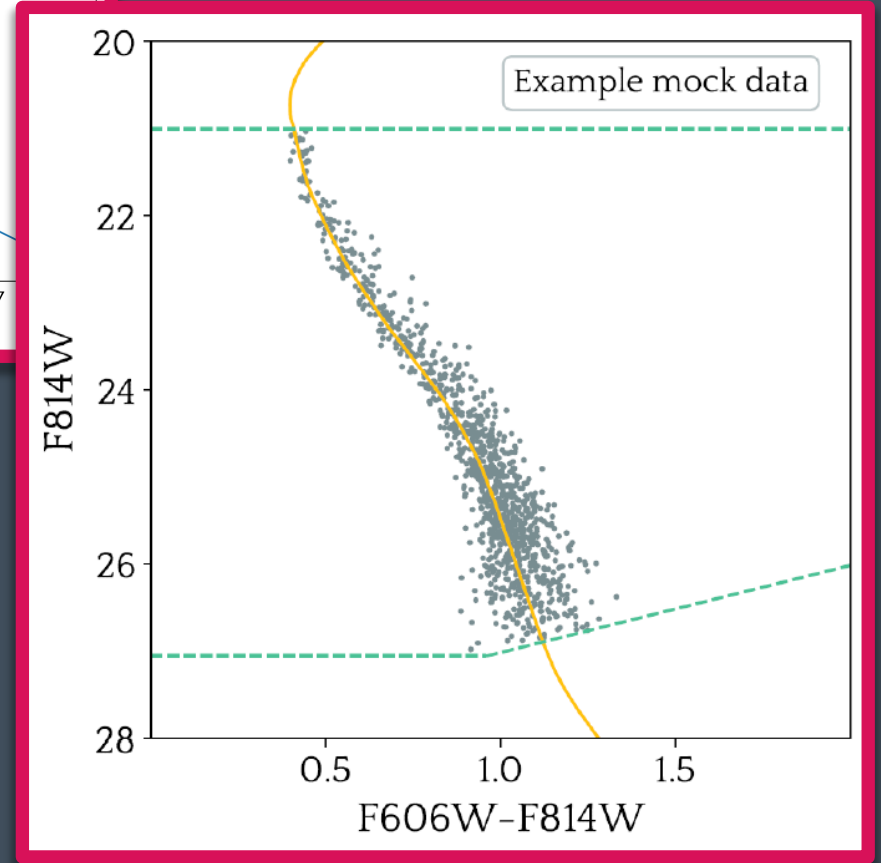
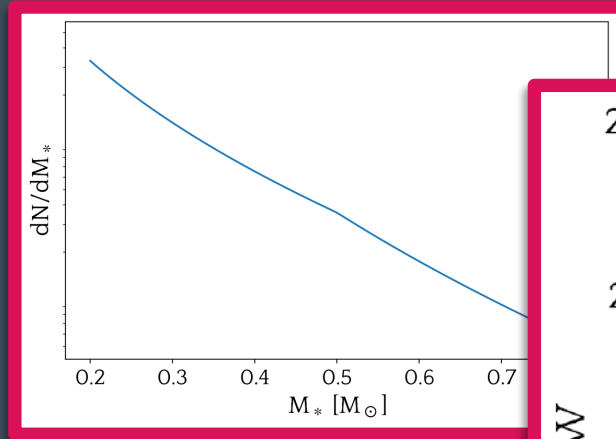
PBH effect (1 parameter)

Dartmouth stellar isochrone models

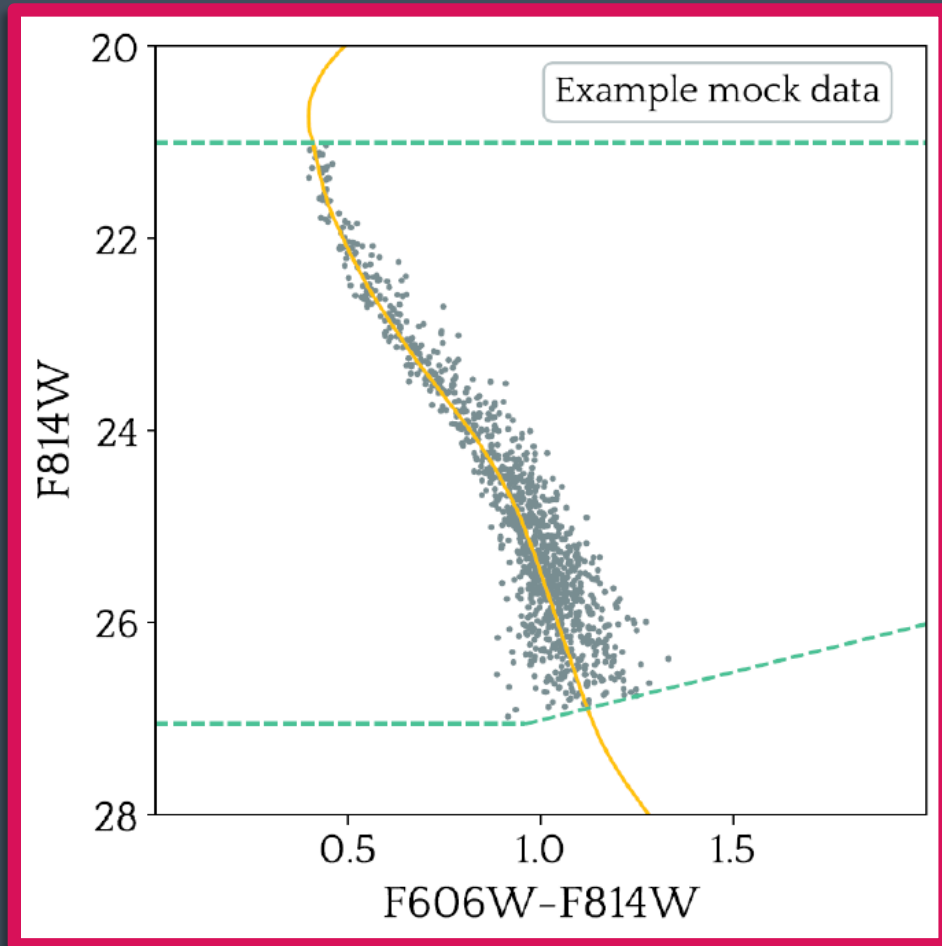
F606W and F814W mag

+

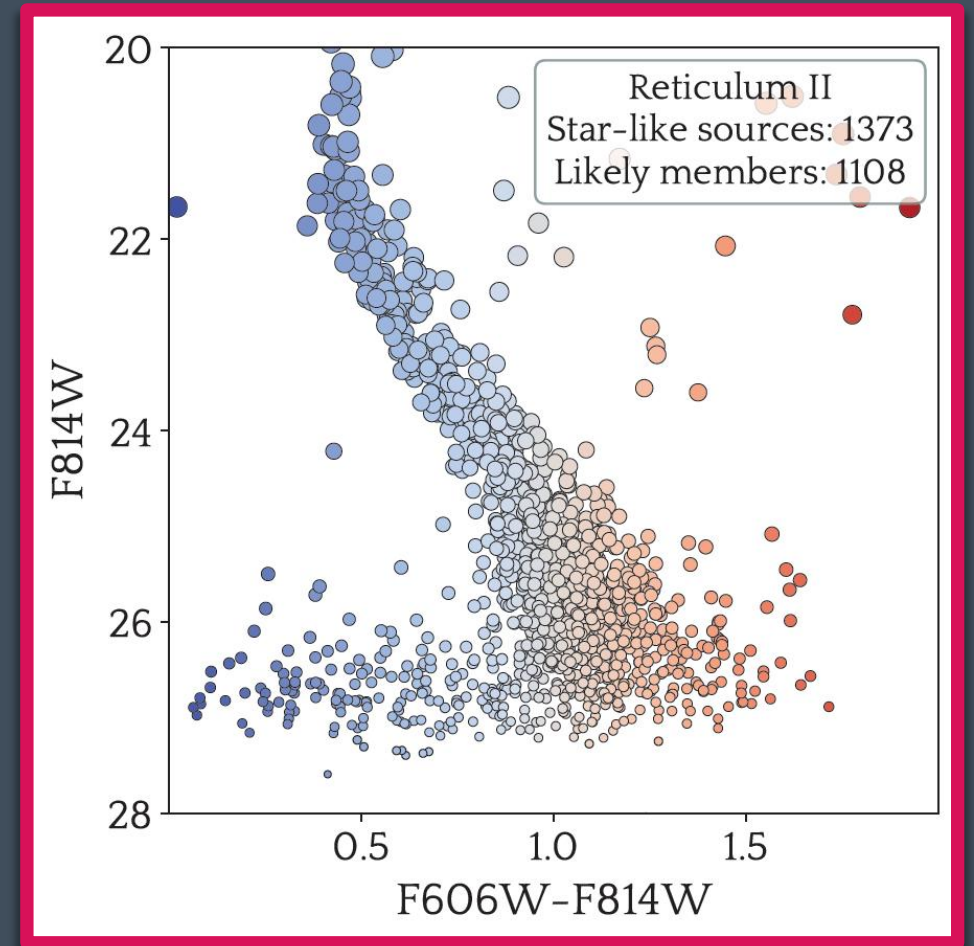
Fancy astronomy effects



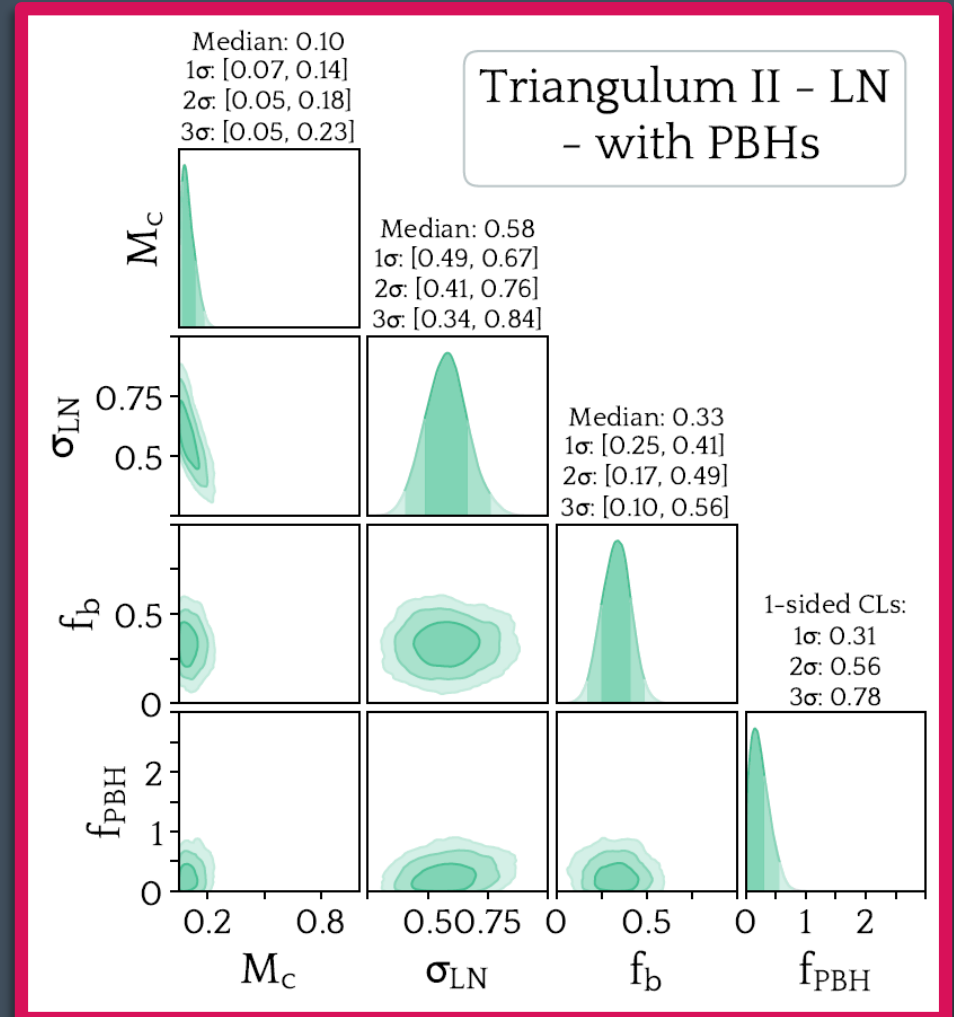
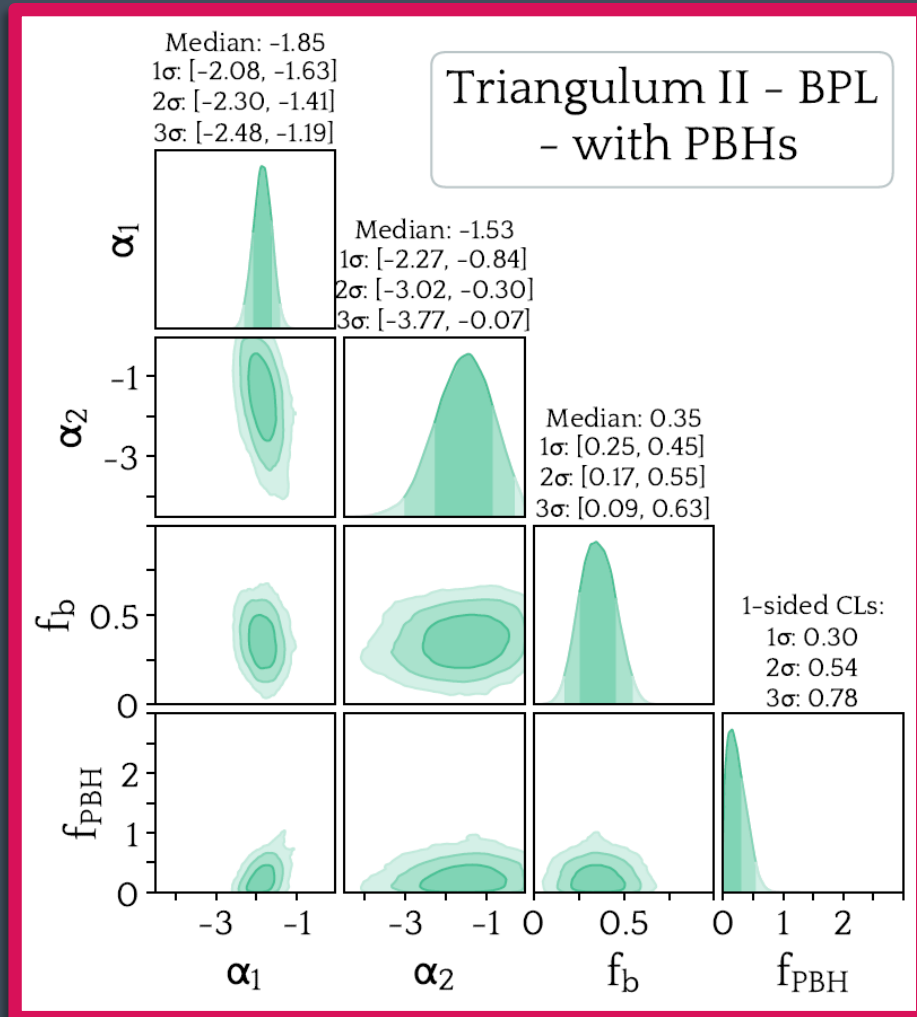
Backup slides



VS



Backup slides

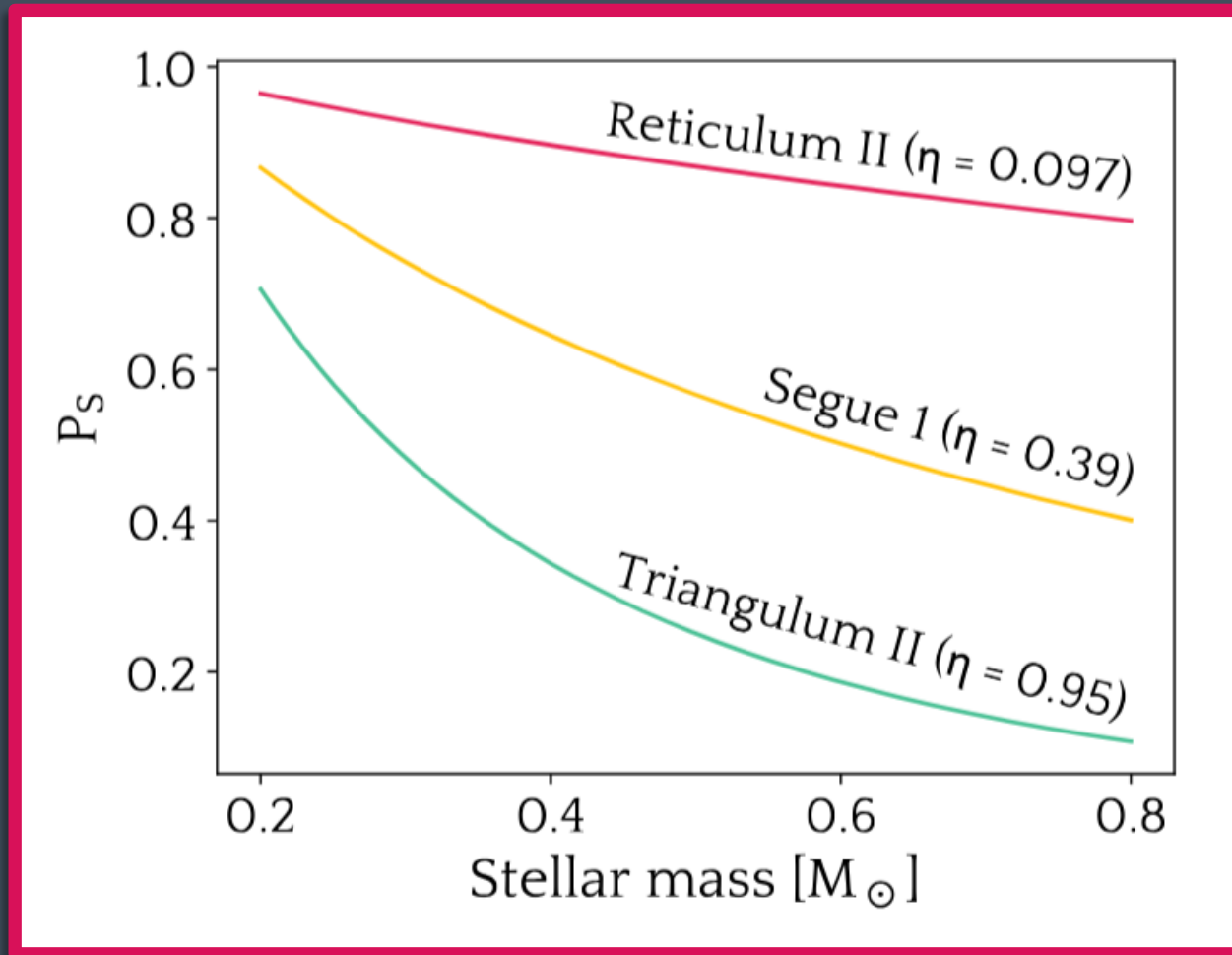


Backup slides

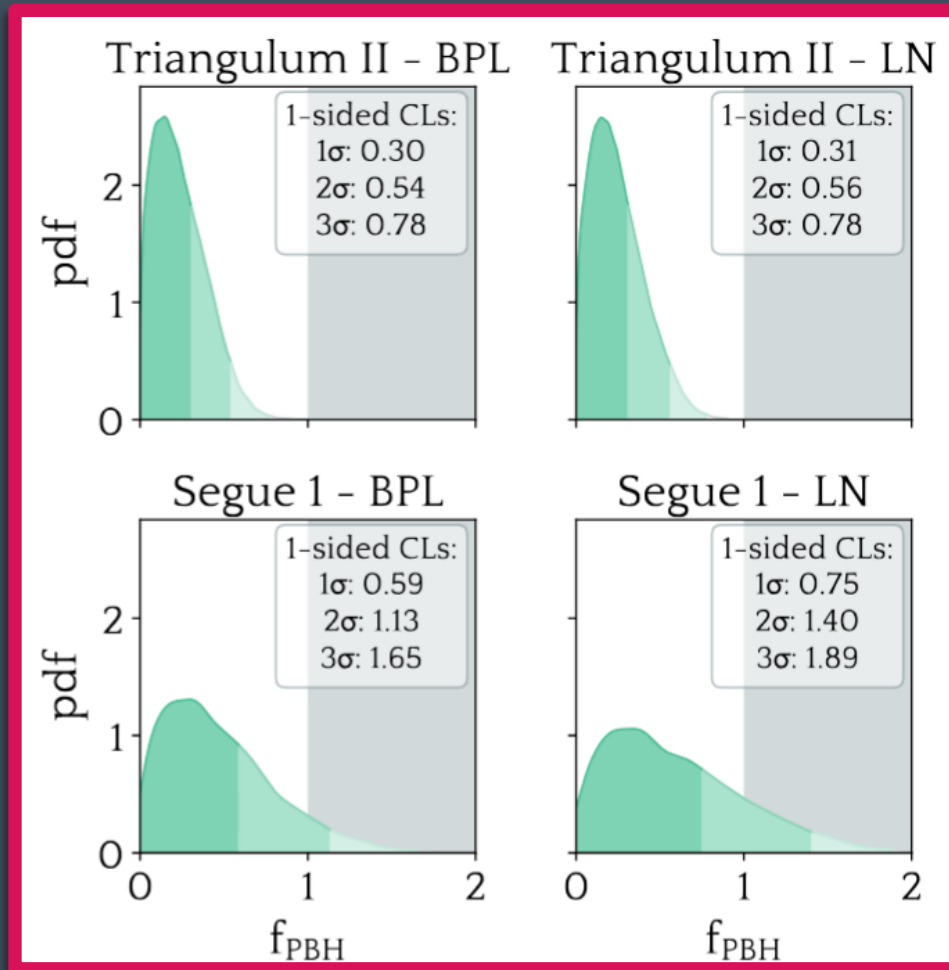
Two main caveats:

- 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).

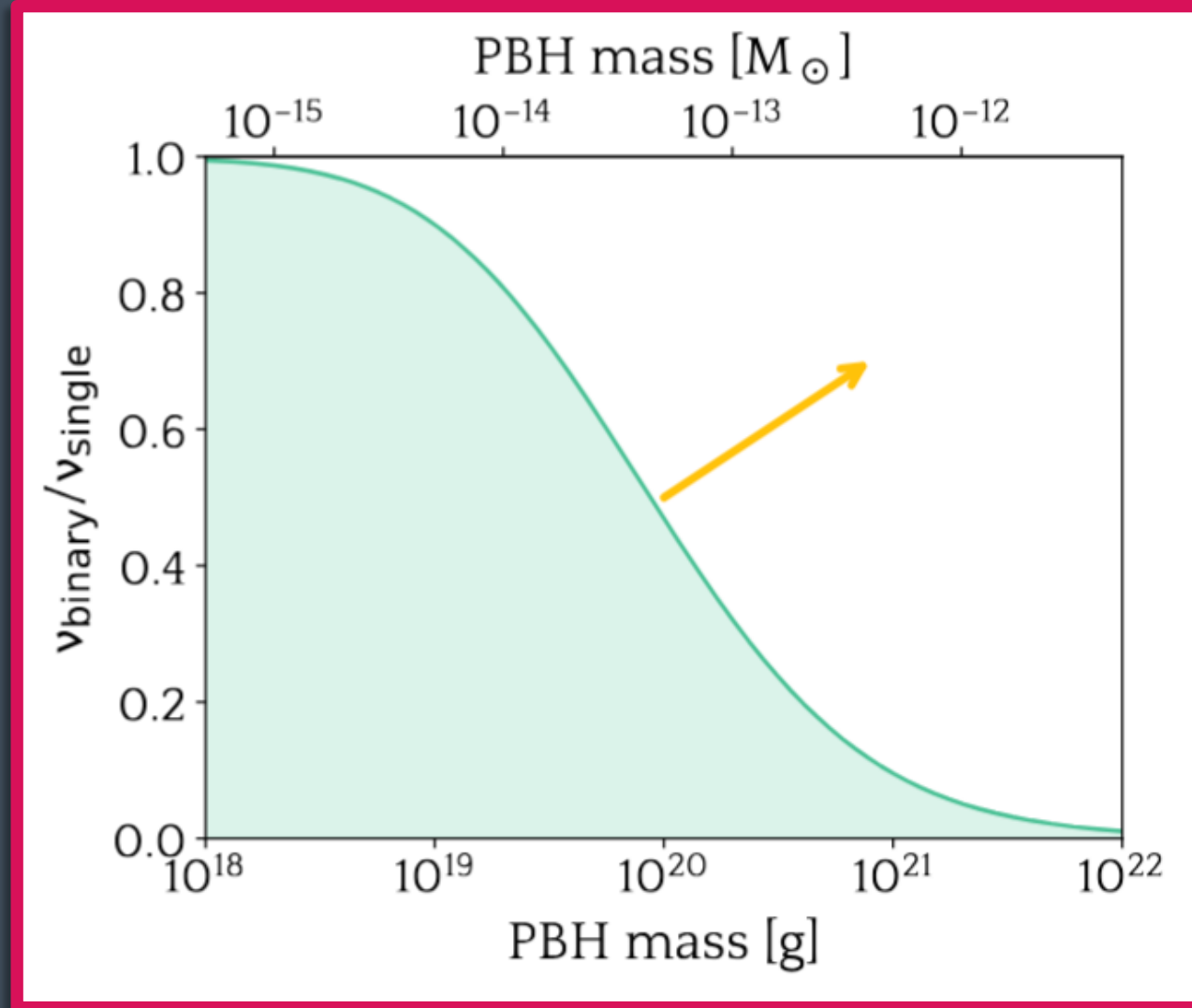
Backup slides



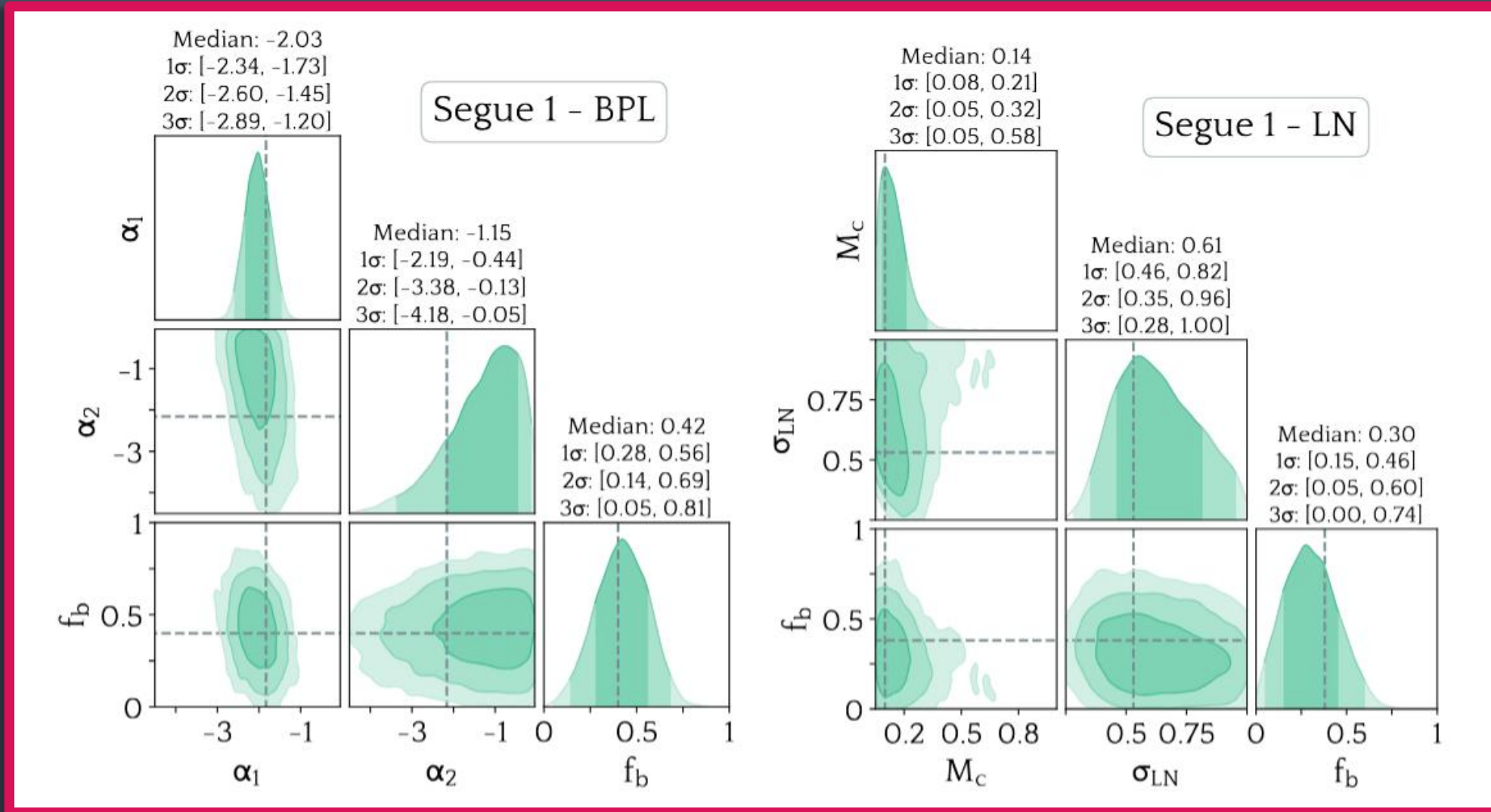
Backup slides



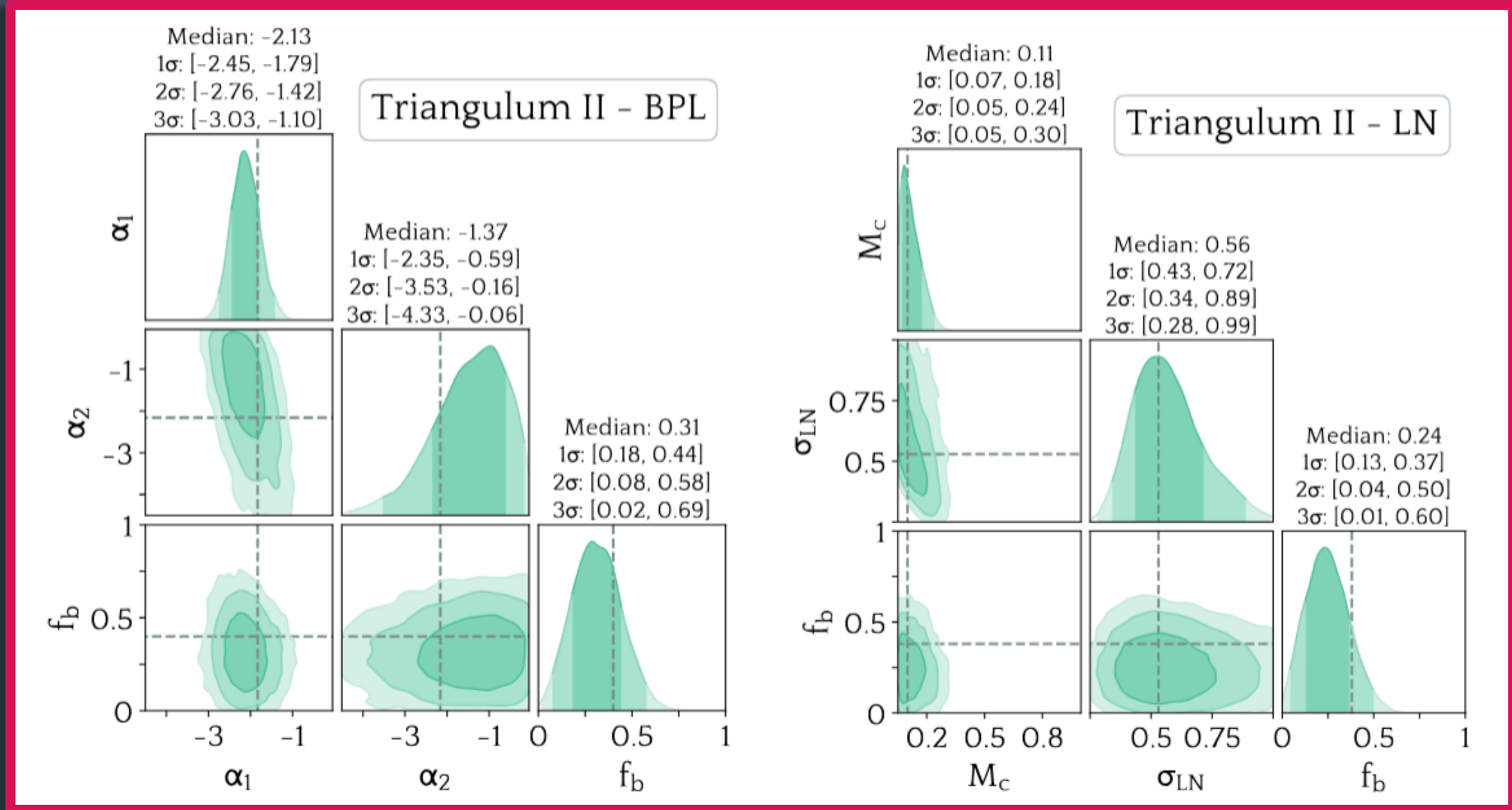
Backup slides



Backup slides



Backup slides



Backup slides

