1. The growth of MBHs via TDEs

2. What can we learn from JWST and PTA

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David Izquierdo-Villalba
Markos Polkas
Daniele Spinoso

Julen Untzaga – Nils Hoyer – Irene Valderrama

and:
Elisa Bortolas, Luca Broggi, Monica Colpi, Alberto Sesana
Nadine Neumayer, Lucio Mayer, Raffaella Schneider, Rosa Valiante, Volker Springel

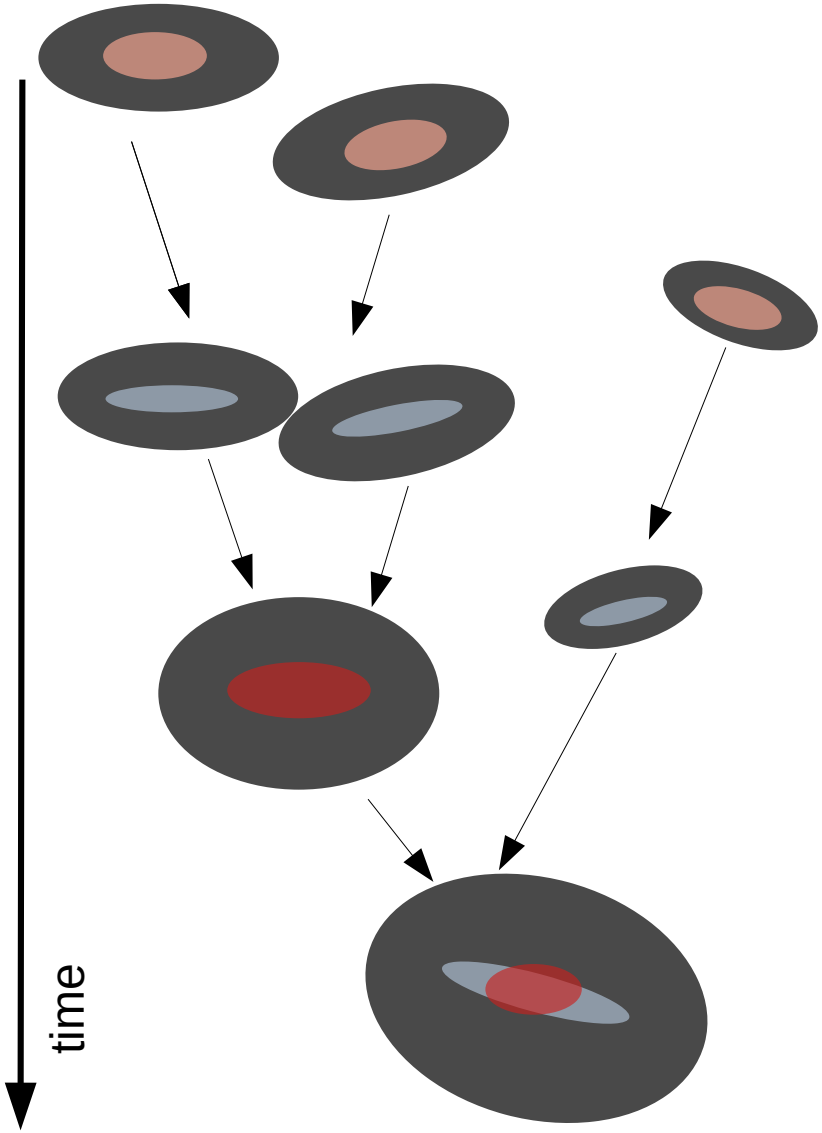
DIPC ikerbasque Basque Foundation for Science
GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

Donostia International Physics Center
(Donostia = San Sebastian in Basque)

Since 2018 a new astrophysics group … come visit!

L - GALAXIES

based on the seminal works of White 1989; White & Frenk 1991; Kauffmann et al. 1993,1999; Springel et al. 2001,2005



Max-Planck-Institut für Astrophysik

Analytical assumptions about the evolution of the baryonic component of the Universe

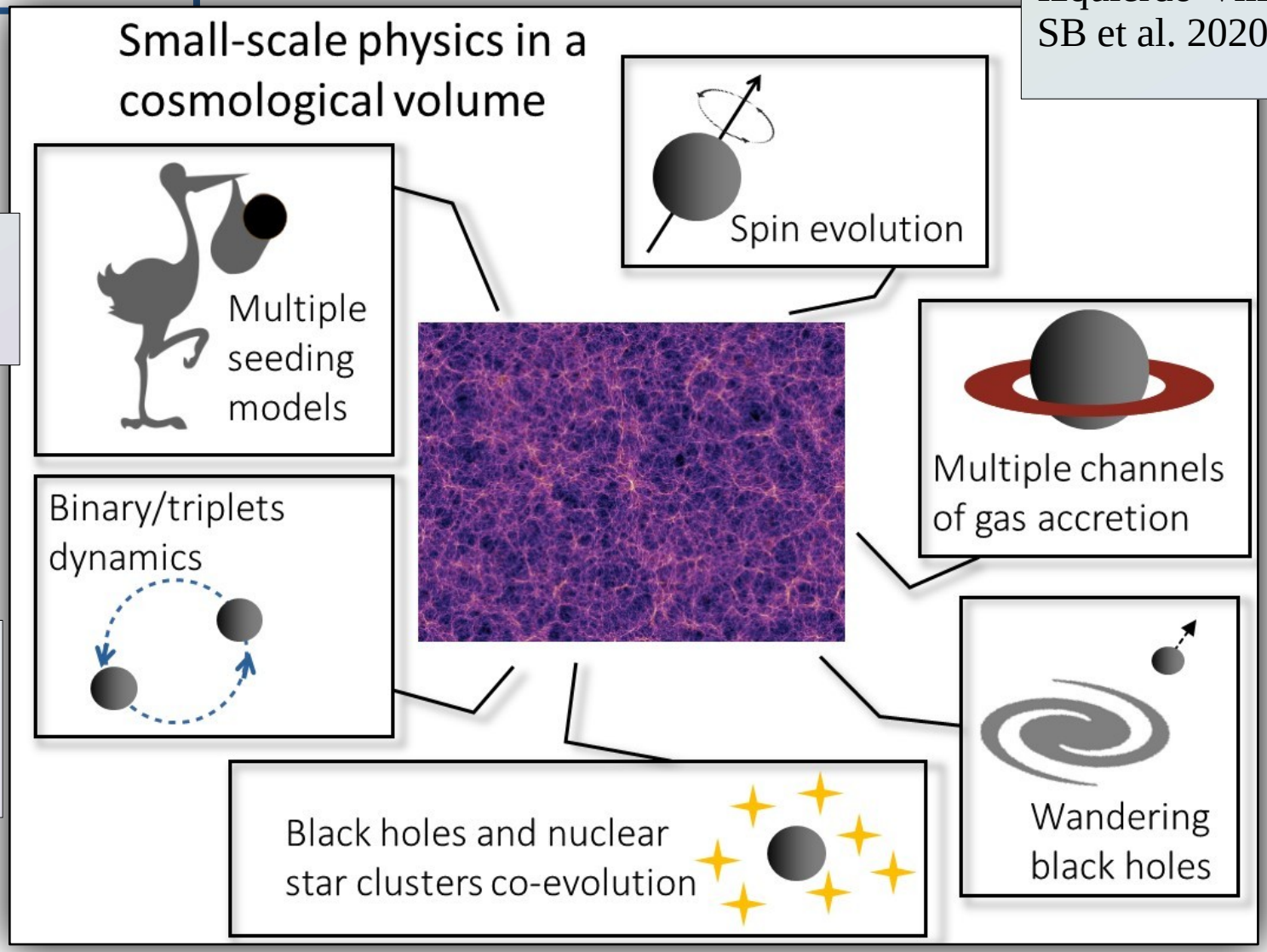
+

DM merger trees from N-body simulations

https://lgalaxiespublicrelease.github.io/

L-GalaxiesBH

An extension L-Galaxies, focused on the modeling of massive black holes



Izquierdo-Villalba, SB et al. 2020

SB et al. 2014
Spinoso, SB et al. 2023

Izquierdo-Villalba, SB et al. 2020

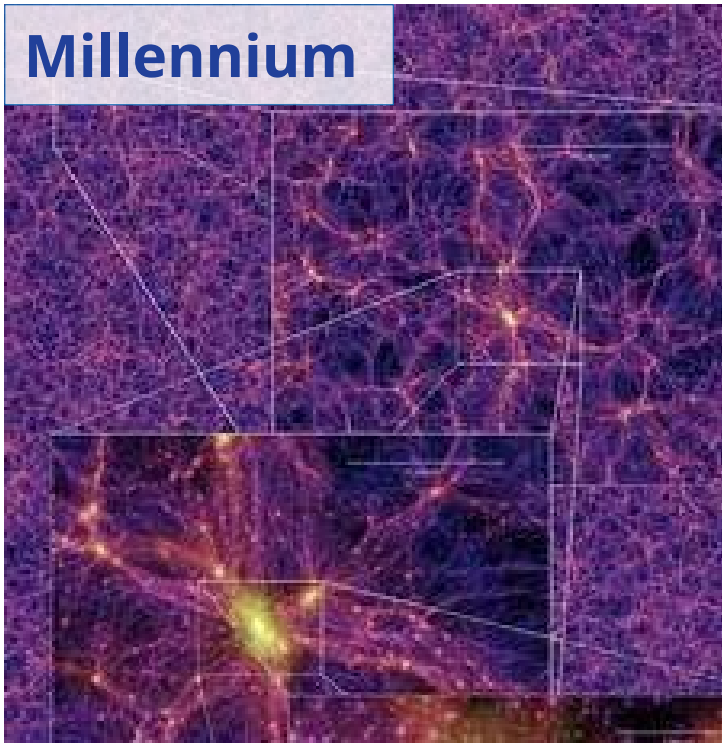
Izquierdo-Villalba et al. 2020,2022

Izquierdo-Villalba et al. 2020
Untzaga, SB et al. 2024

Polkas, SB et al. 2024
Hoyer, SB et al. in prep.

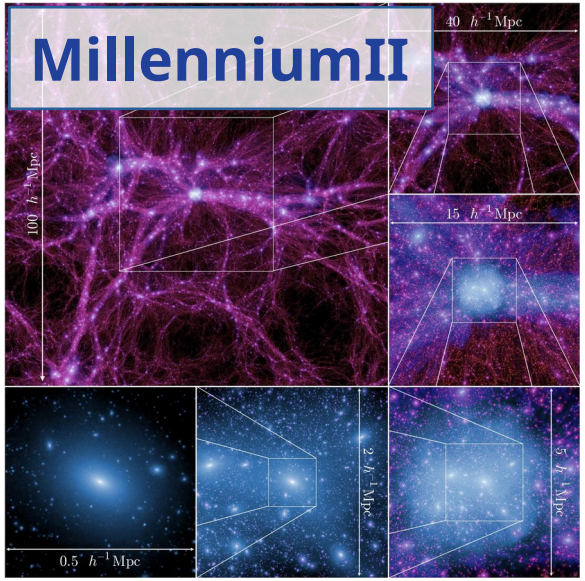
Backbones of the model:
DM simulations

"Grafting"



Springel et al. 2005

Min halo ~$10^{10}M_{sun}$



Boylan-Kolchin et al. 2009

Min halo ~$10^{8}M_{sun}$

Backbones of the model: DM simulations

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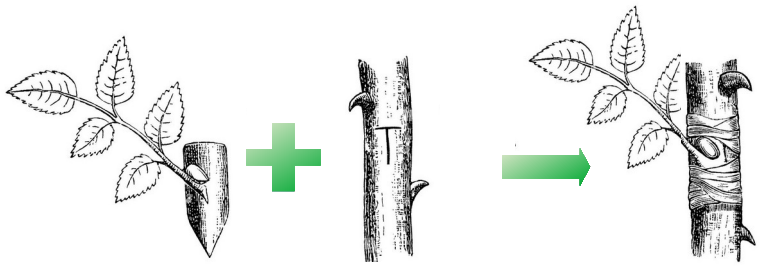
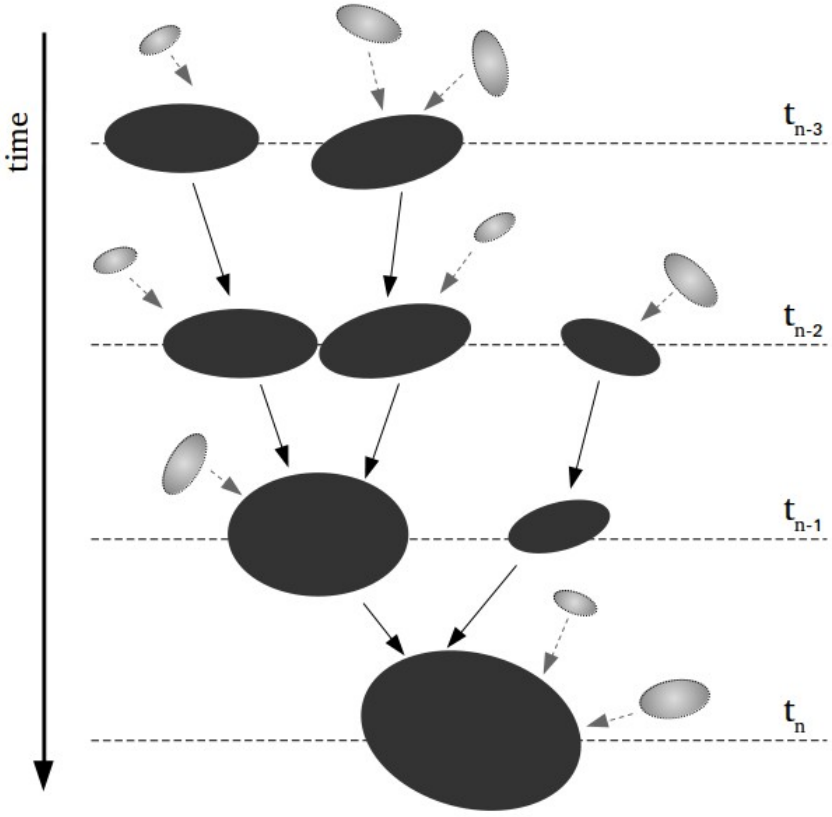
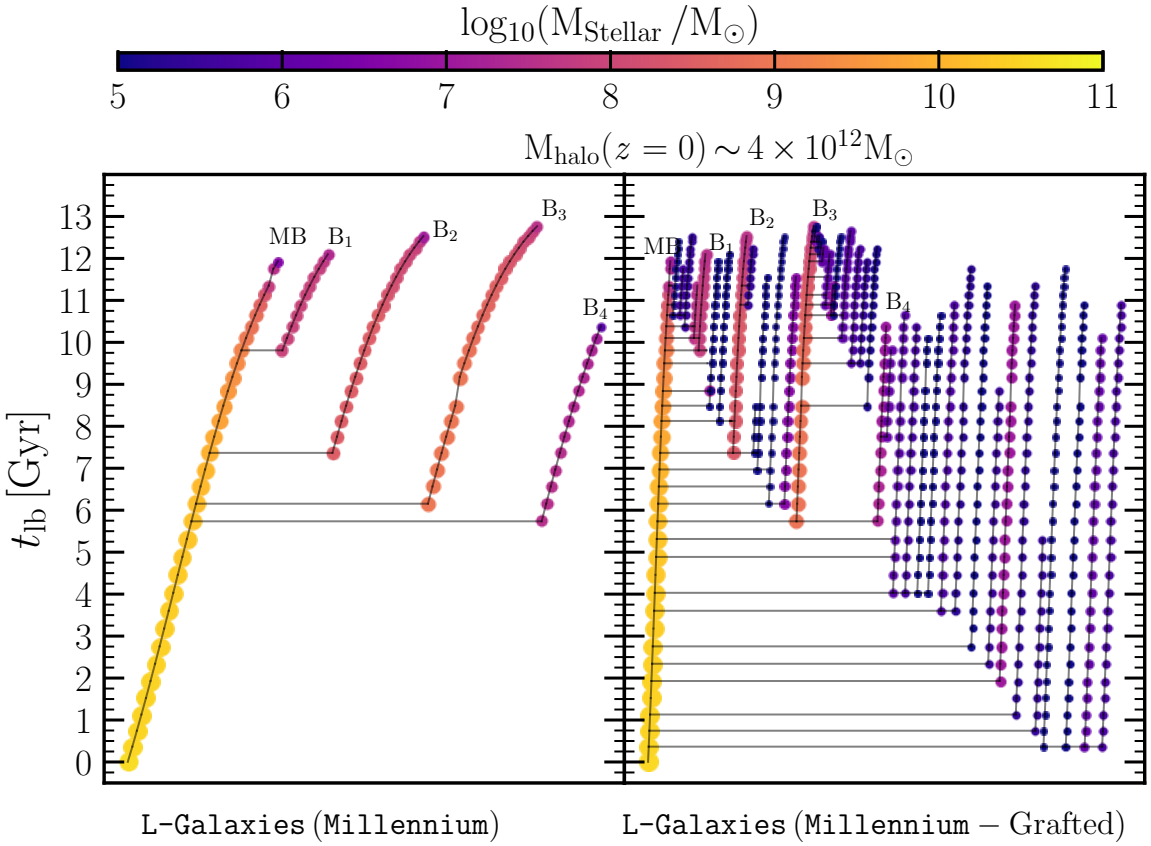
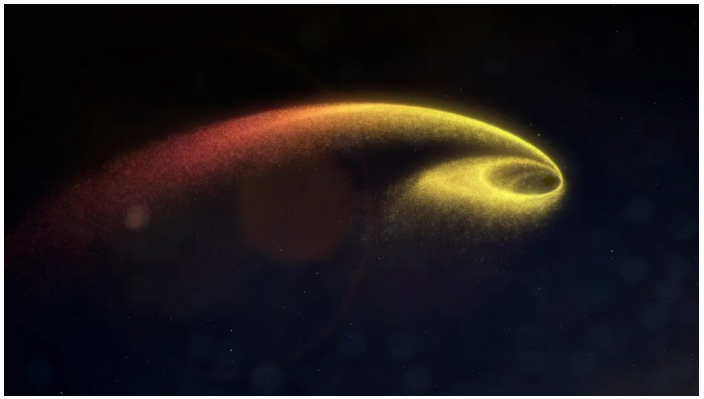






Growth of MBHs via TDEs: model



L-GalaxiesBH

Phaseflow

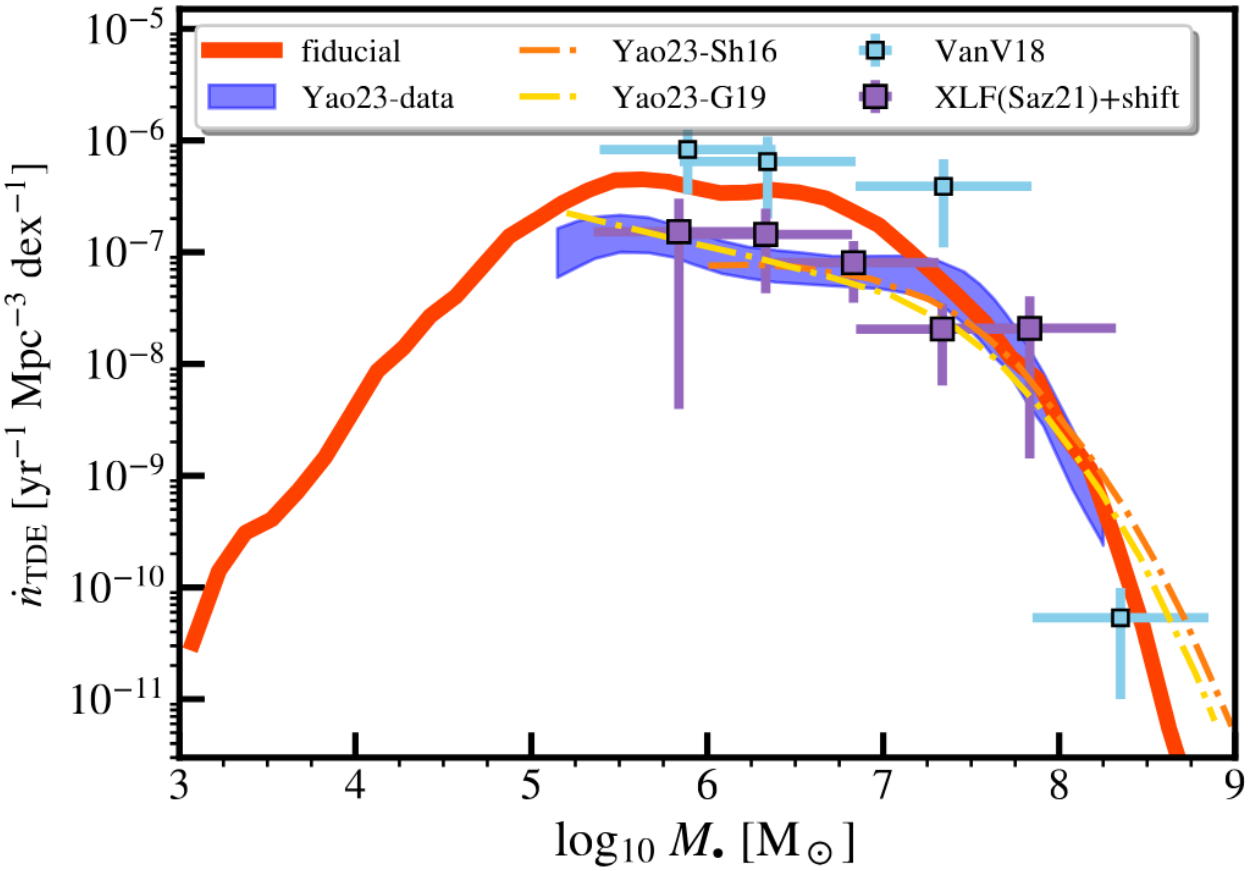
Provides galaxy and BH properties across time and environment

Calculation of time-dependent TDE rates with *Phaseflow*

(Vasiliev 2017, Bortolas et al. 2022)

Polkas, SB et al. 2024

Growth of MBHs via TDEs: volumetric rates

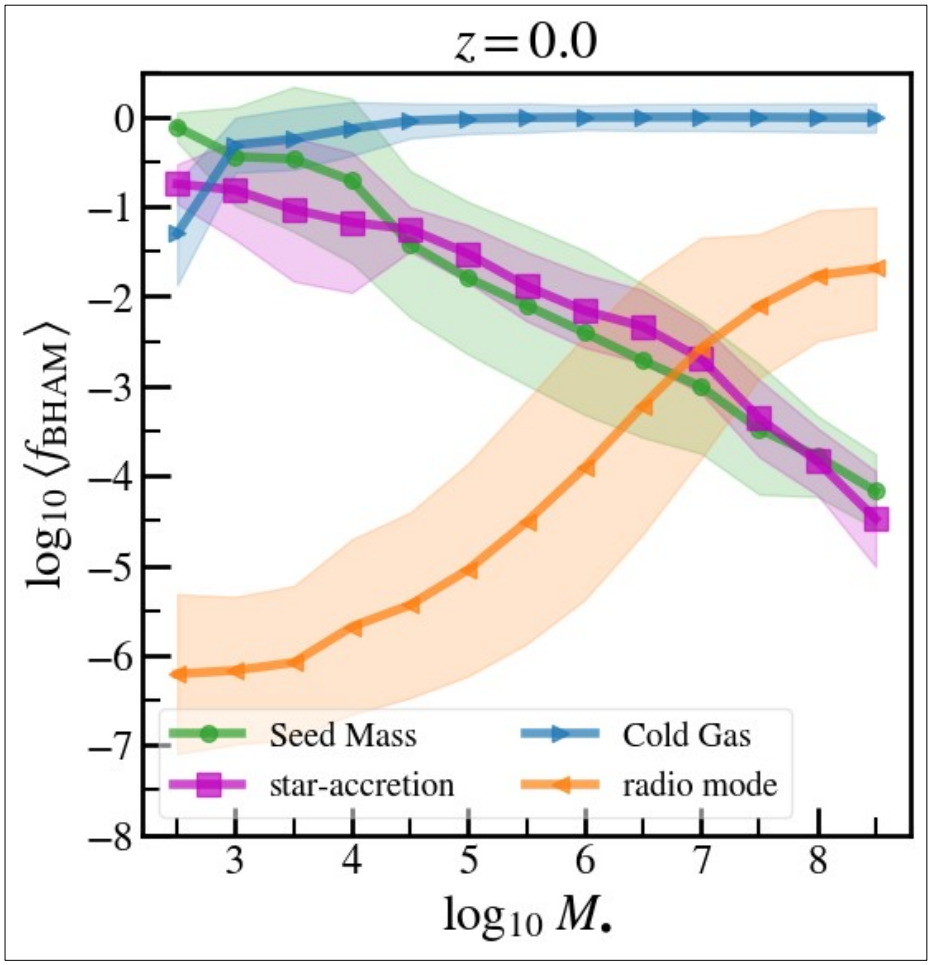


Van Velzen+ 2018 N=12
Sazonov+ 2021 XLF + shift N=13
ZTF Yao+2023 N=33

Polkas, SB et al. 2024

NSC are needed to explain the observed TDE rates

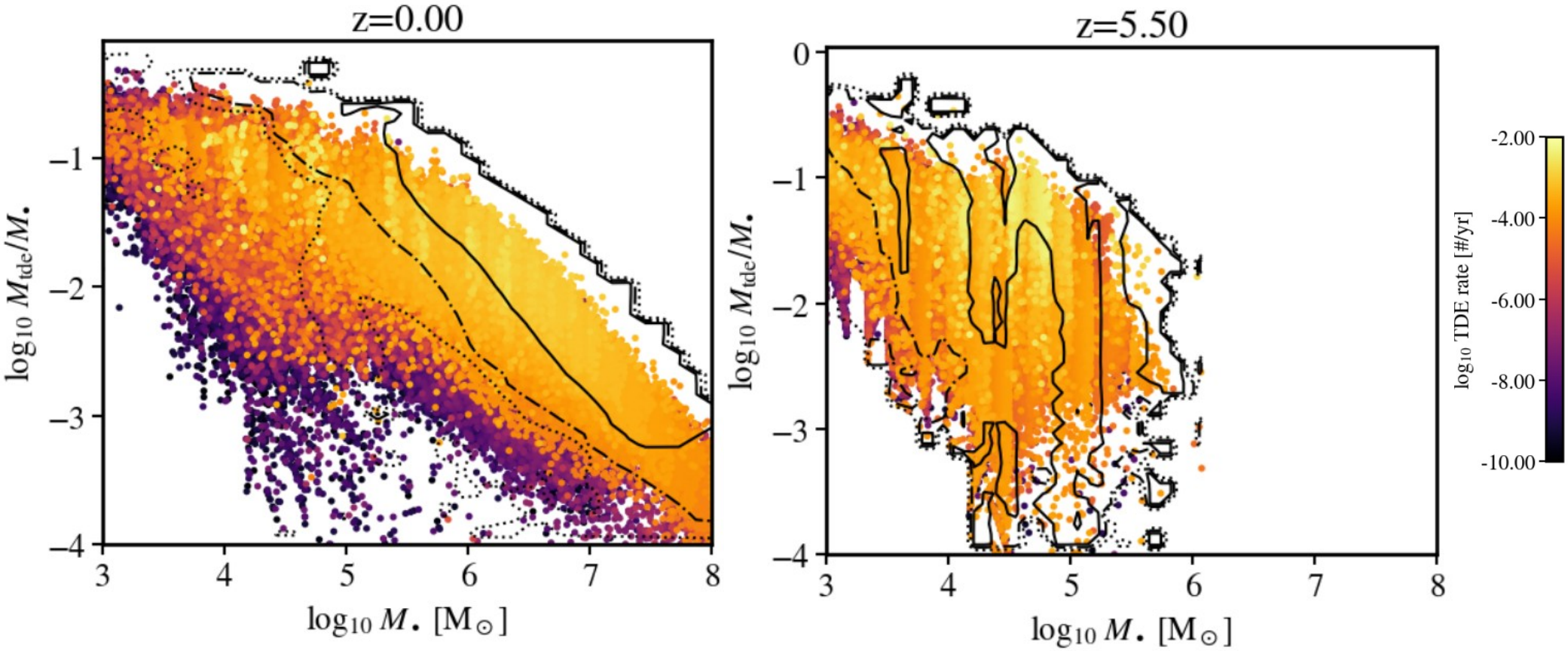
Growth of MBHs via TDEs



Only IMBHs can grow a non-negligible fraction of their mass via TDEs

Polkas, SB et al. 2024

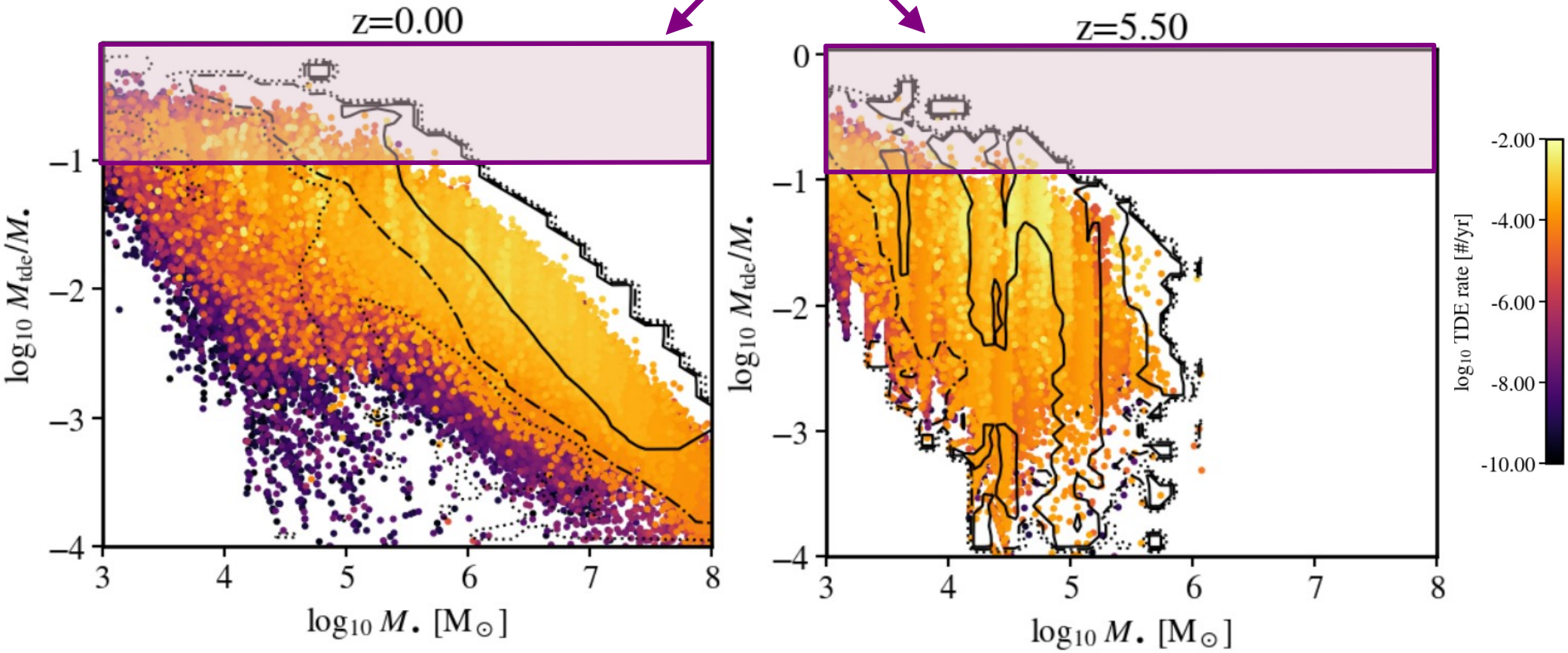
Growth of MBHs via TDEs



Polkas, SB et al. In prep

Growth of MBHs via TDEs

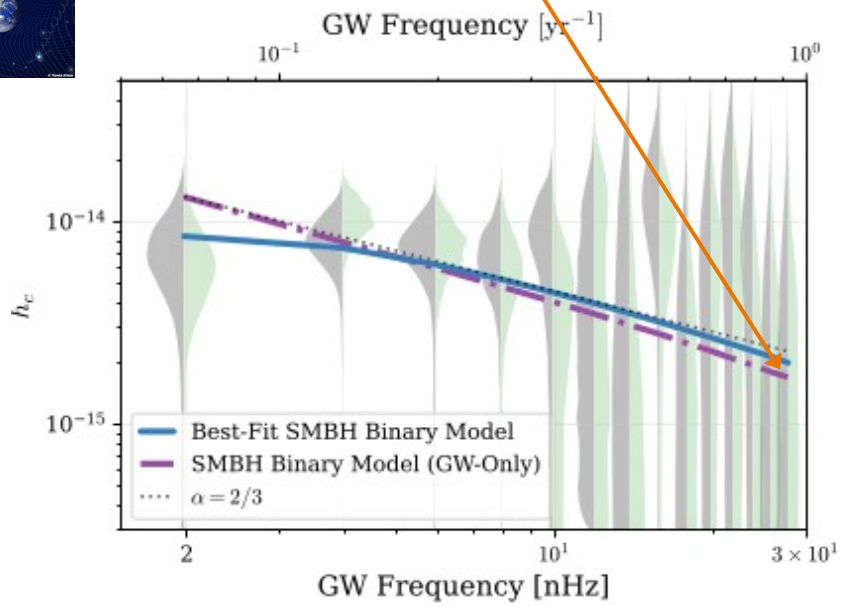
Significant growth via TDEs



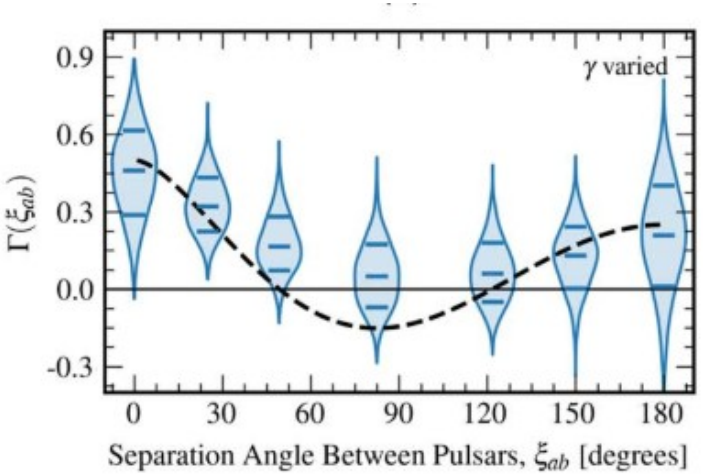
Polkas, SB et al. In prep

Constraints on MBH growth from PTA and JWST

Amplitude @ yr^{-1}
[1.7-3.1] x 10^{-15}



Antoniadis et al. 2024



Agazie et al. 2023

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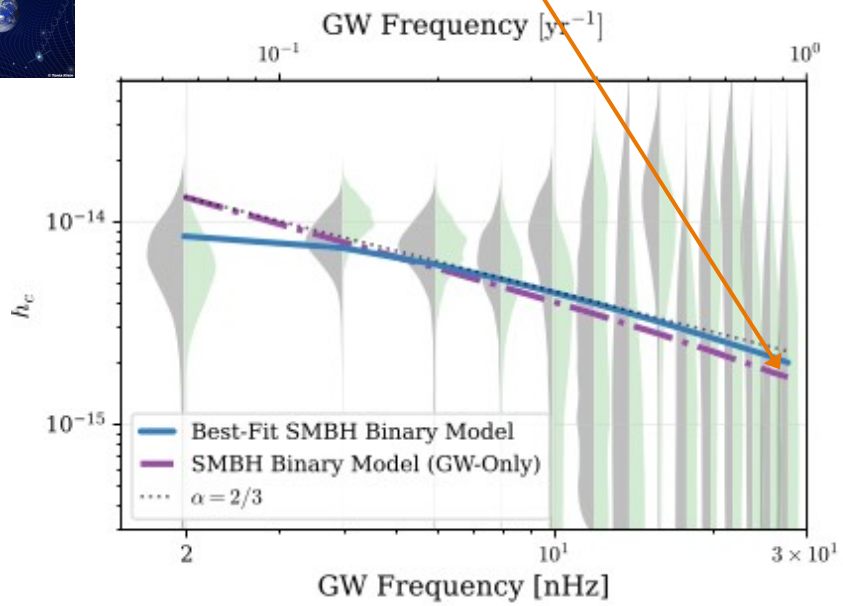
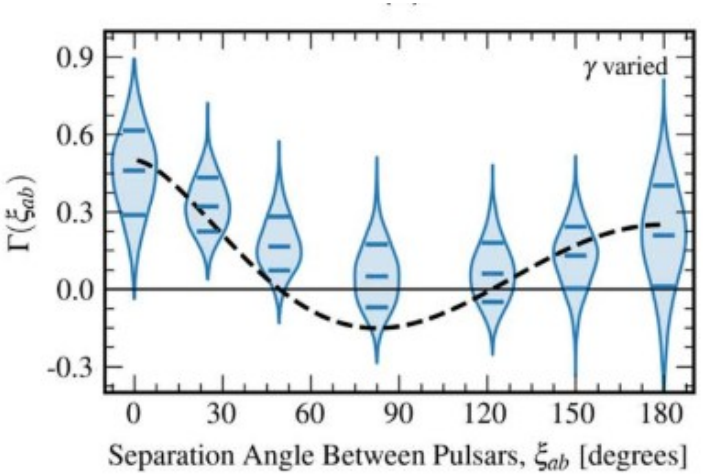
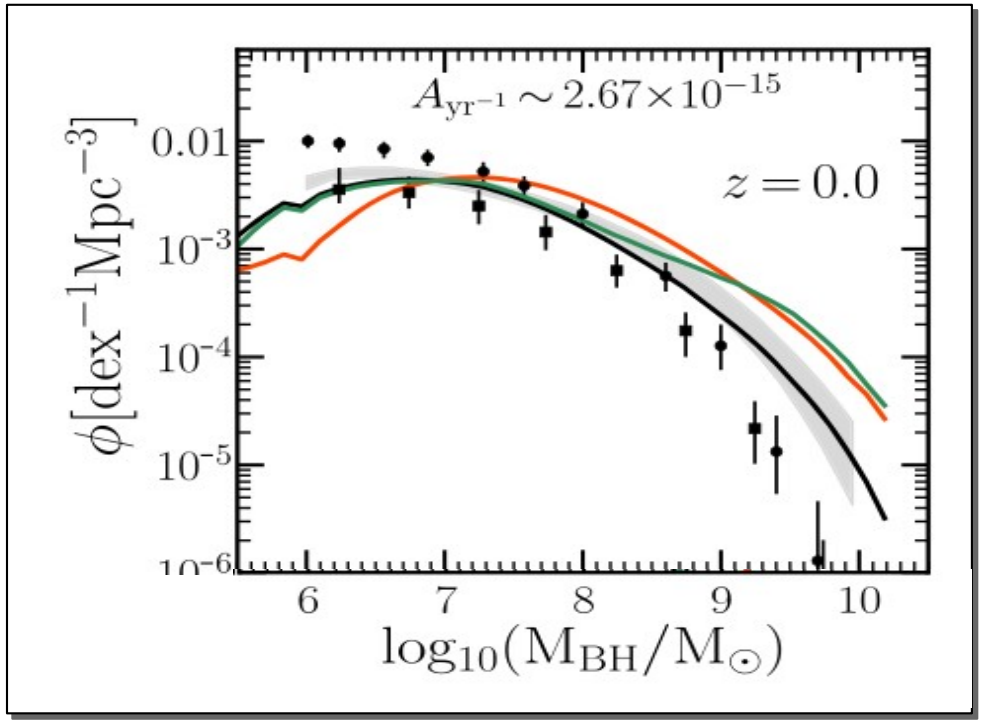


Antoniadis et al. 2024



Agazie et al. 2023

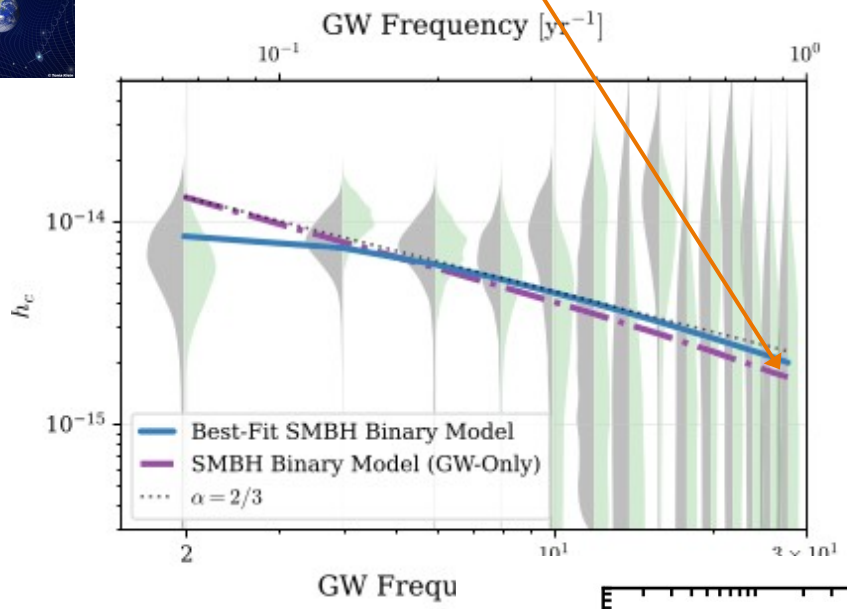


To reach higher amplitudes, **boosted growth** is needed
→ The number density of massive black holes in the local universe needs to be higher than currently estimated
Izquierdo-Villalba, Sesana, SB & Colpi 2022

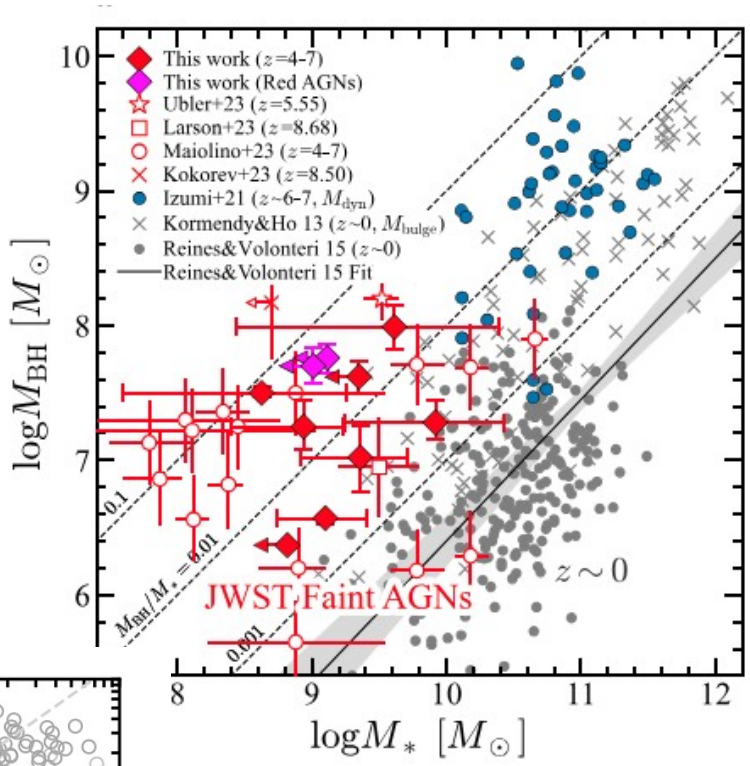
(See also Sato-Polito et al. 2023)

Constraints on MBH growth from PTA and JWST

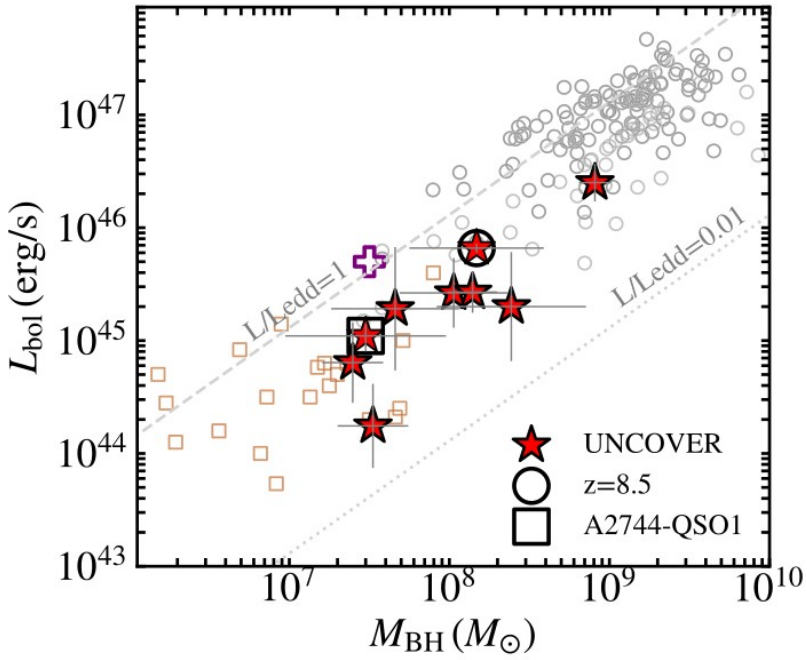
Amplitude @ yr^{-1}
[1.7-3.1] x 10^{-15}



Antoniadis et al. 2024

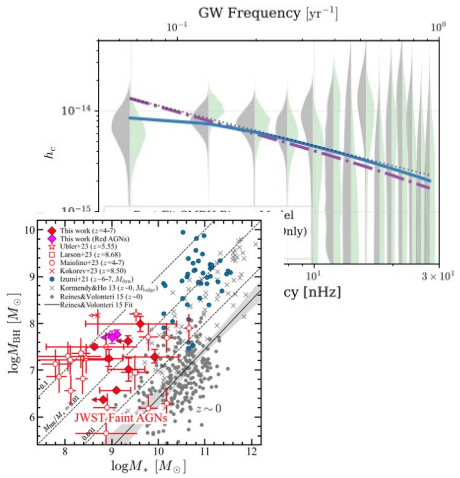


Harikane et al. 2023



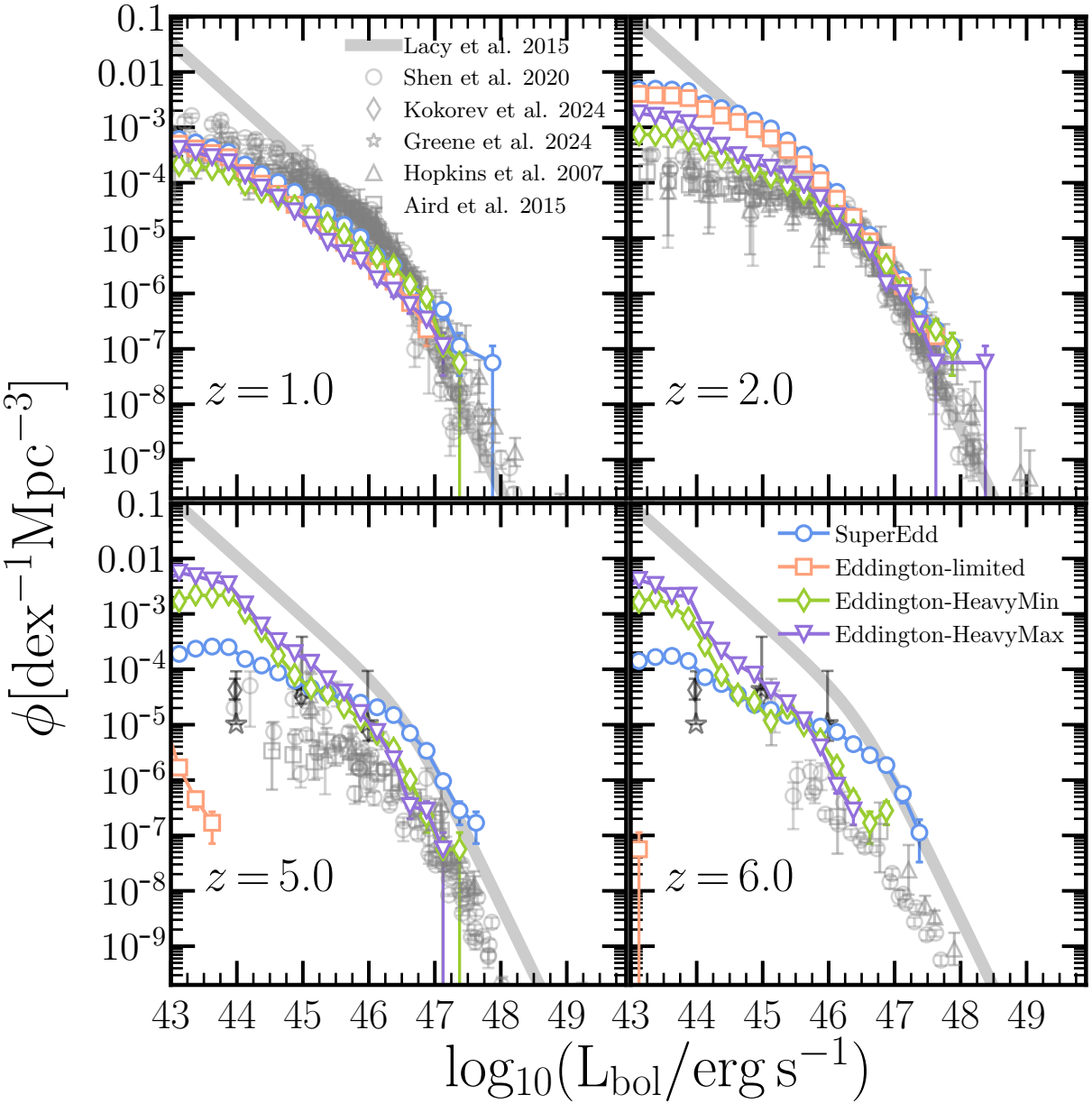
Greene et al. 2024

Constraints on MBH growth from PTA and JWST



- **Eddington Limited (Light+Heavy)**
- **SuperEddington (Light+Heavy)**
- **Eddington (Only Heavy – low occupation)**
- **Eddington-HeavyMax (Only Heavy – high occupation)**

SB, Izquierdo-Villalba et al. In prep



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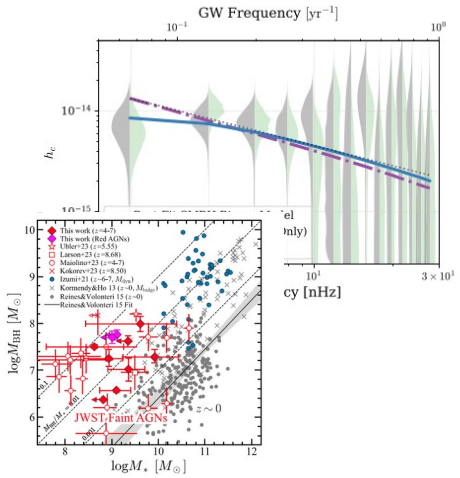

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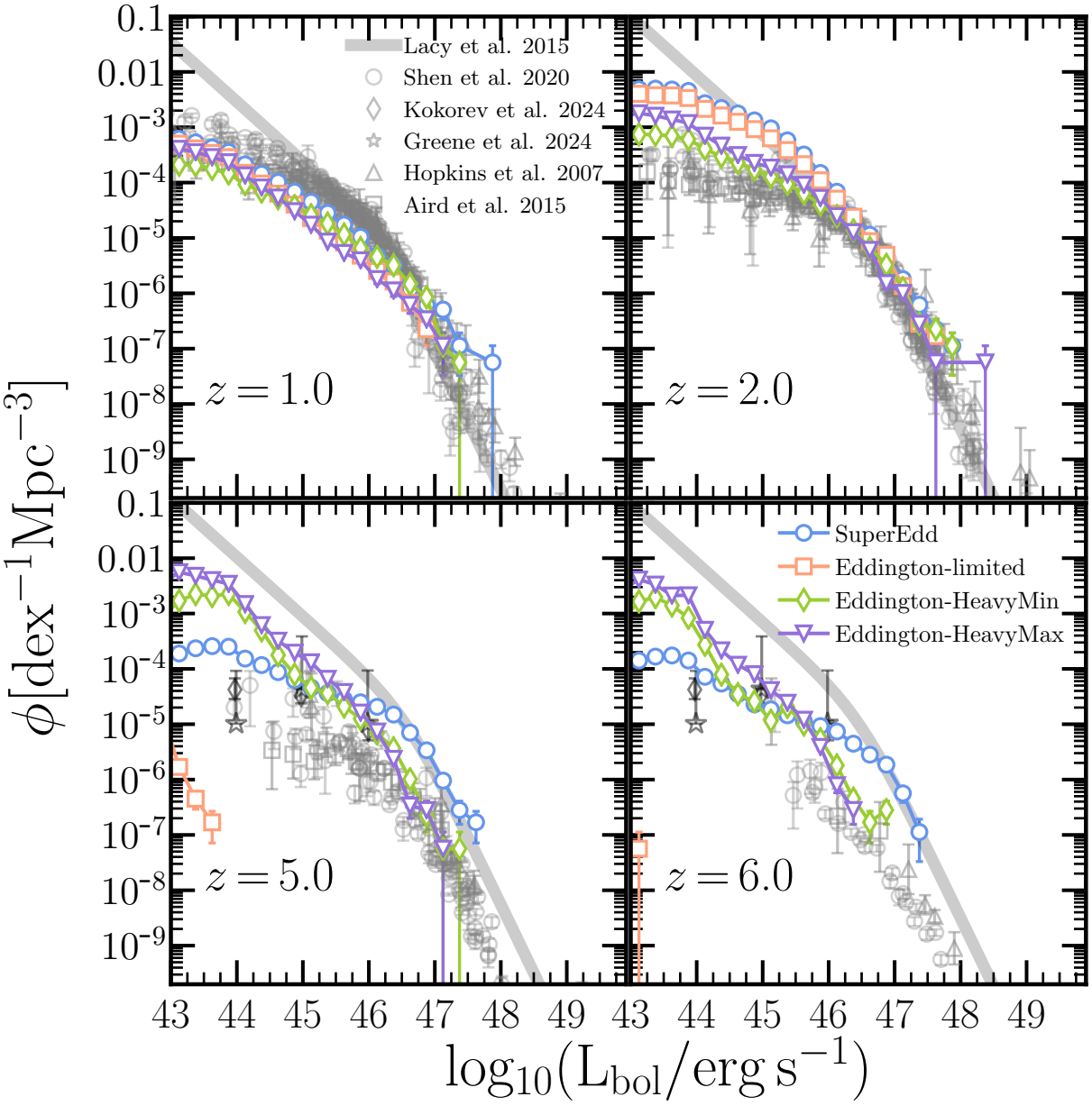
SB, Izquierdo-Villalba et al. In prep



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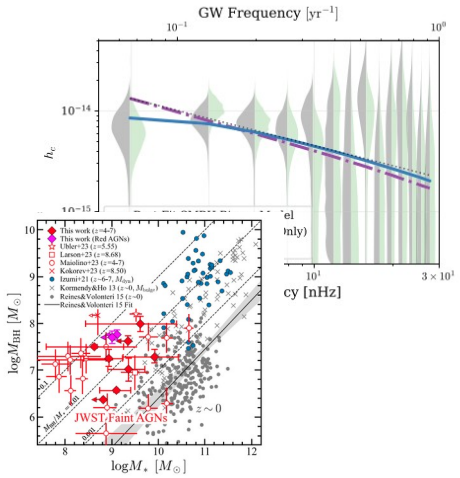

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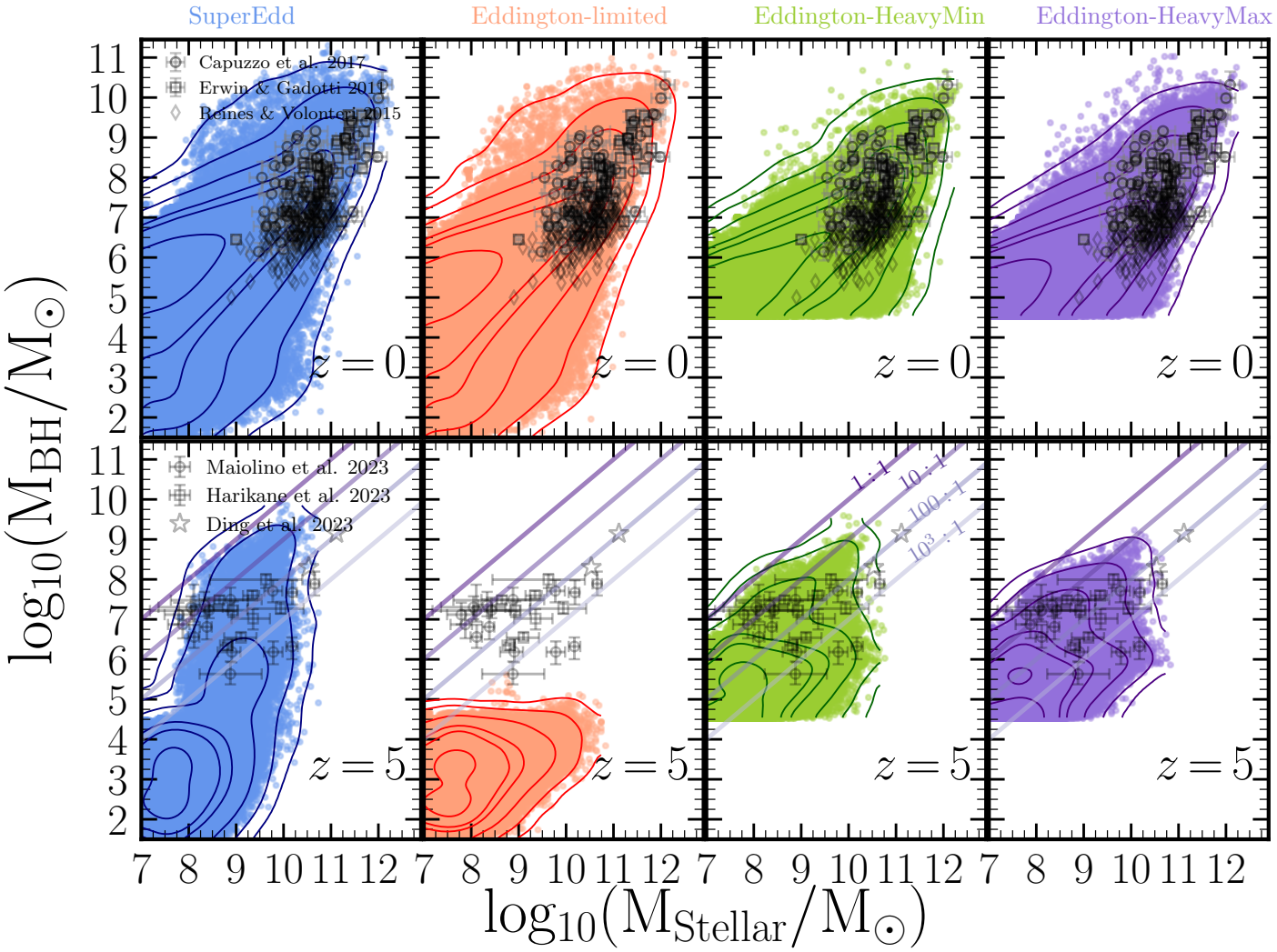

SB, Izquierdo-Villalba et al. In prep

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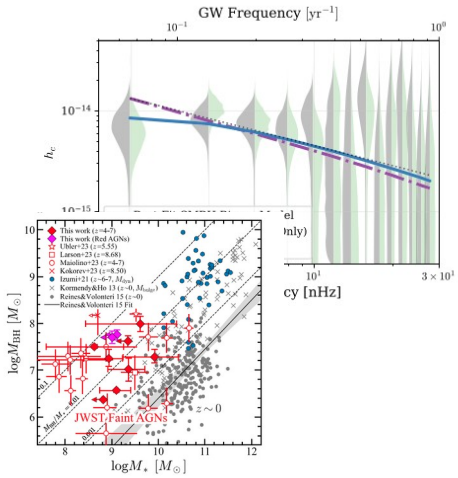

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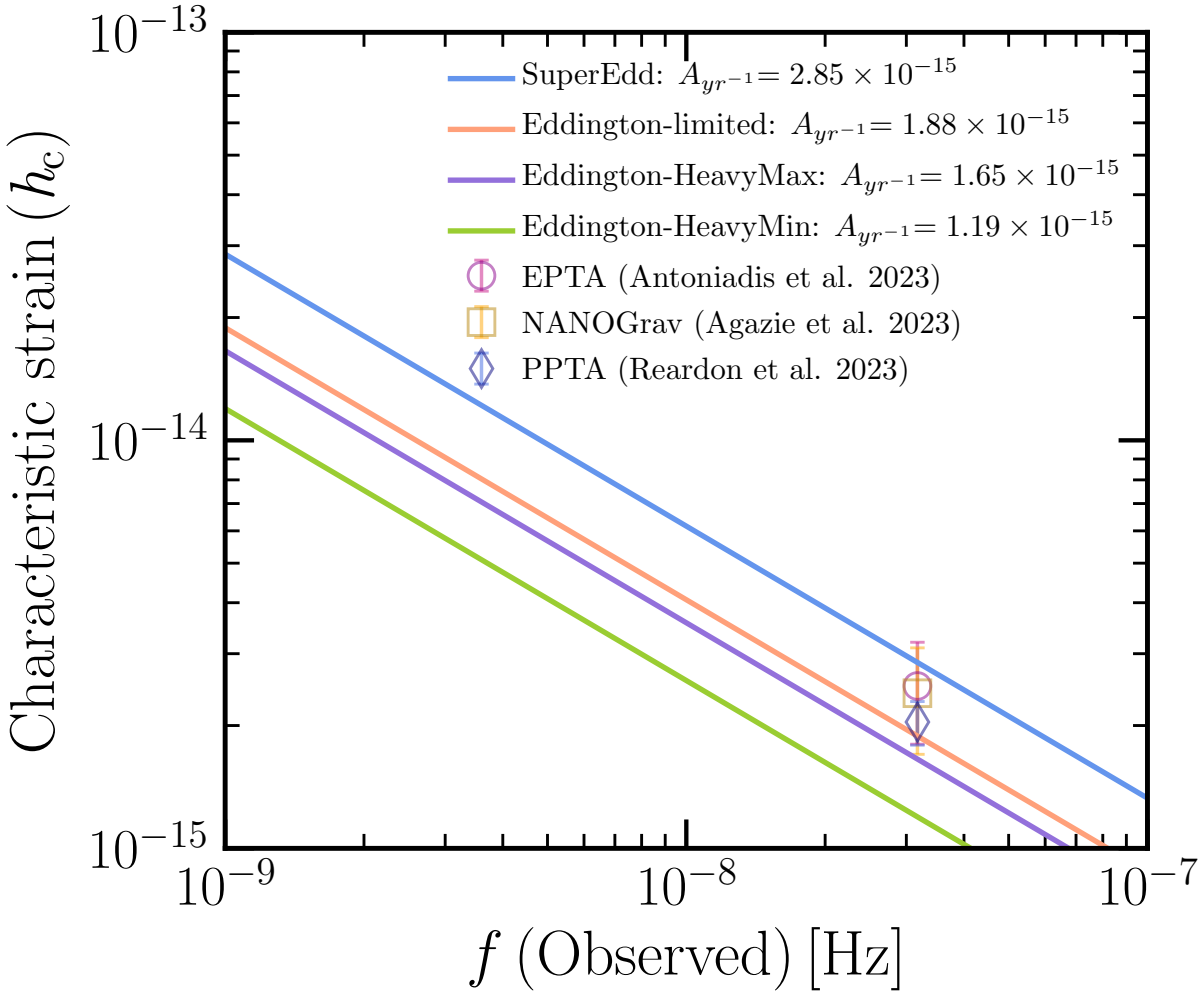

SB, Izquierdo-Villalba et al. In prep

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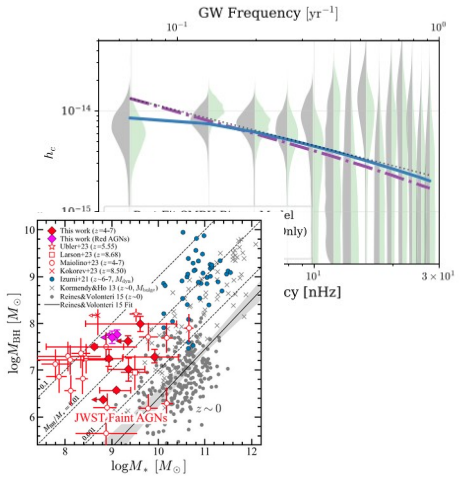

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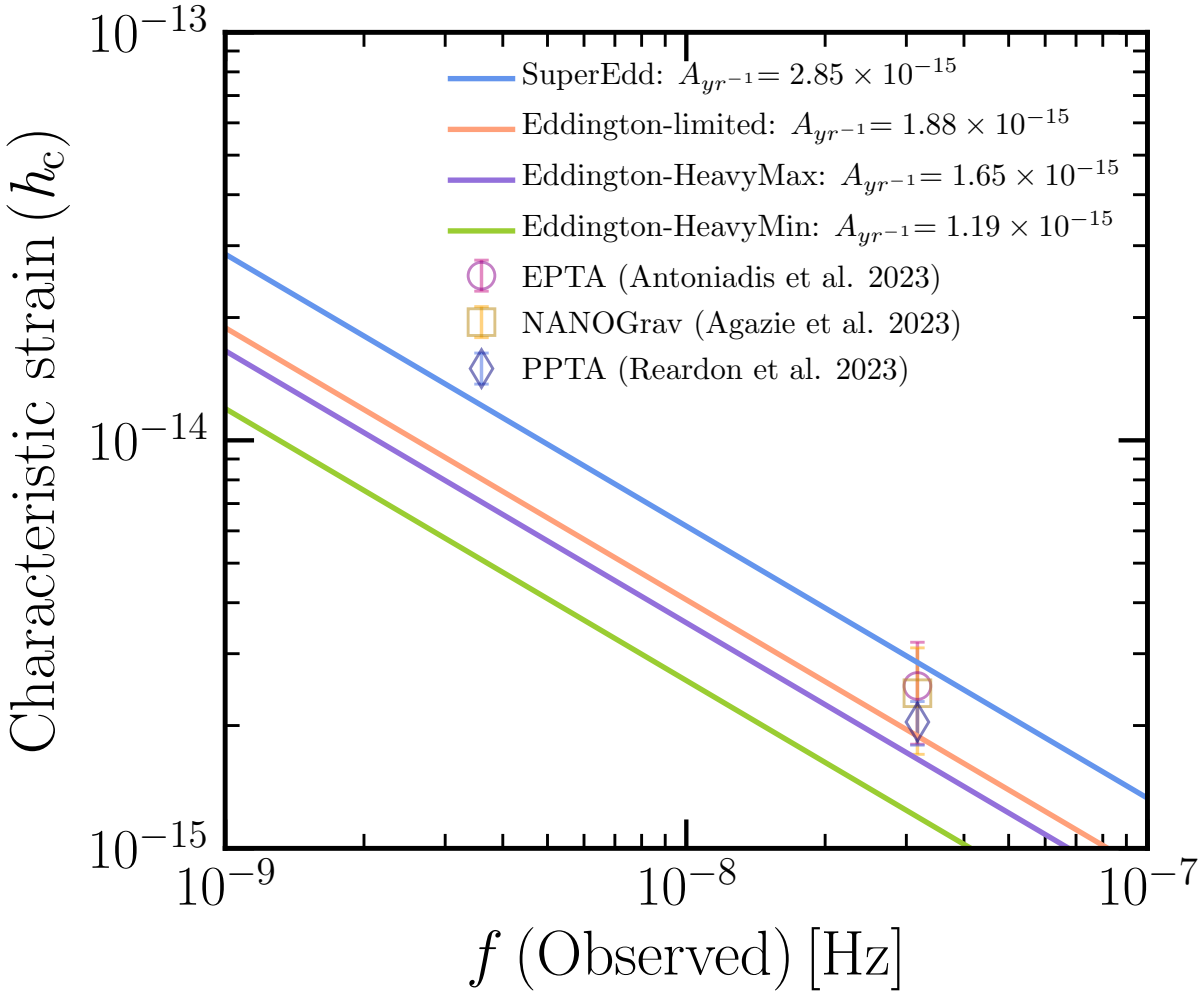
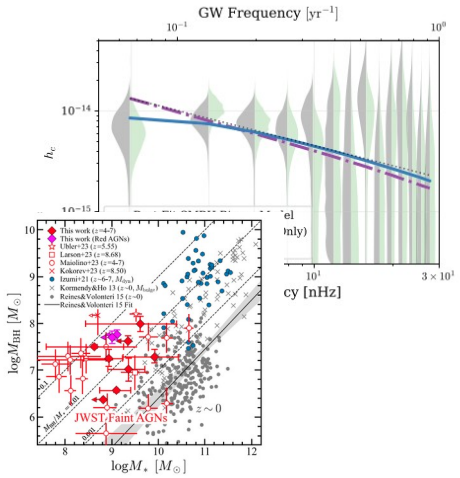


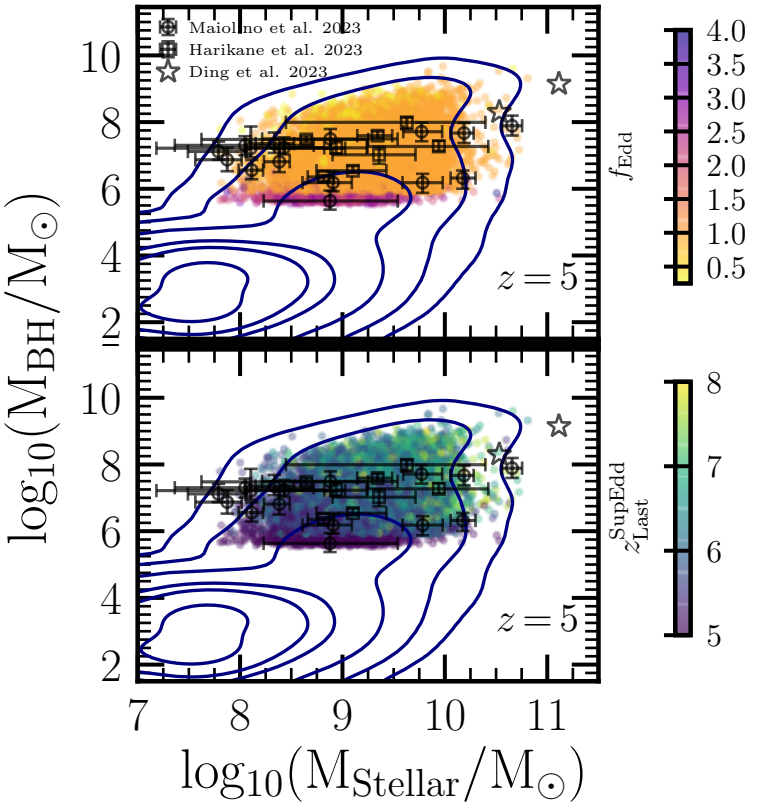
SB, Izquierdo-Villalba et al. In prep

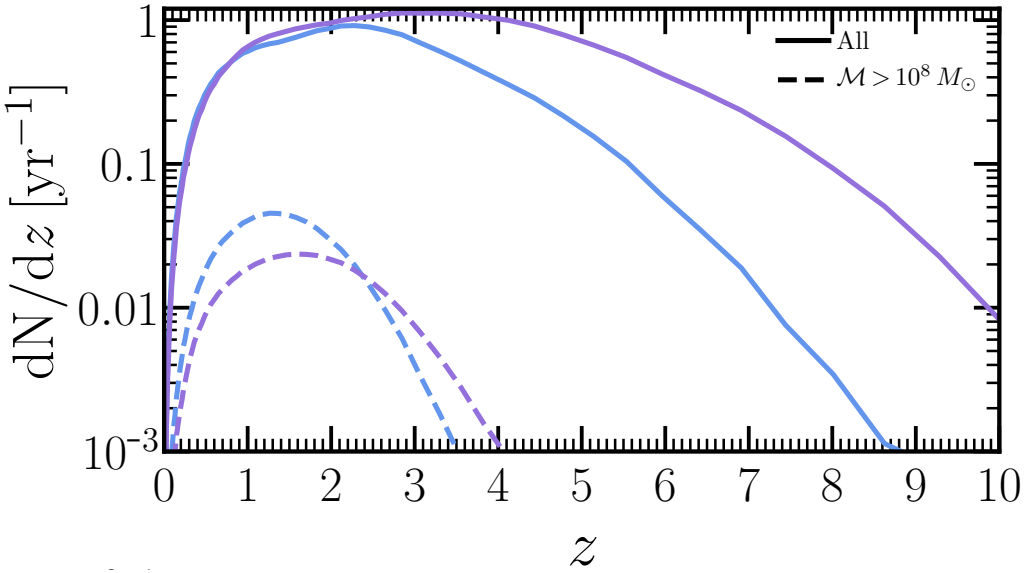
Constraints on MBH growth from PTA and JWST



Eddington rate for JWST AGN

SuperEddington (Light+Heavy)





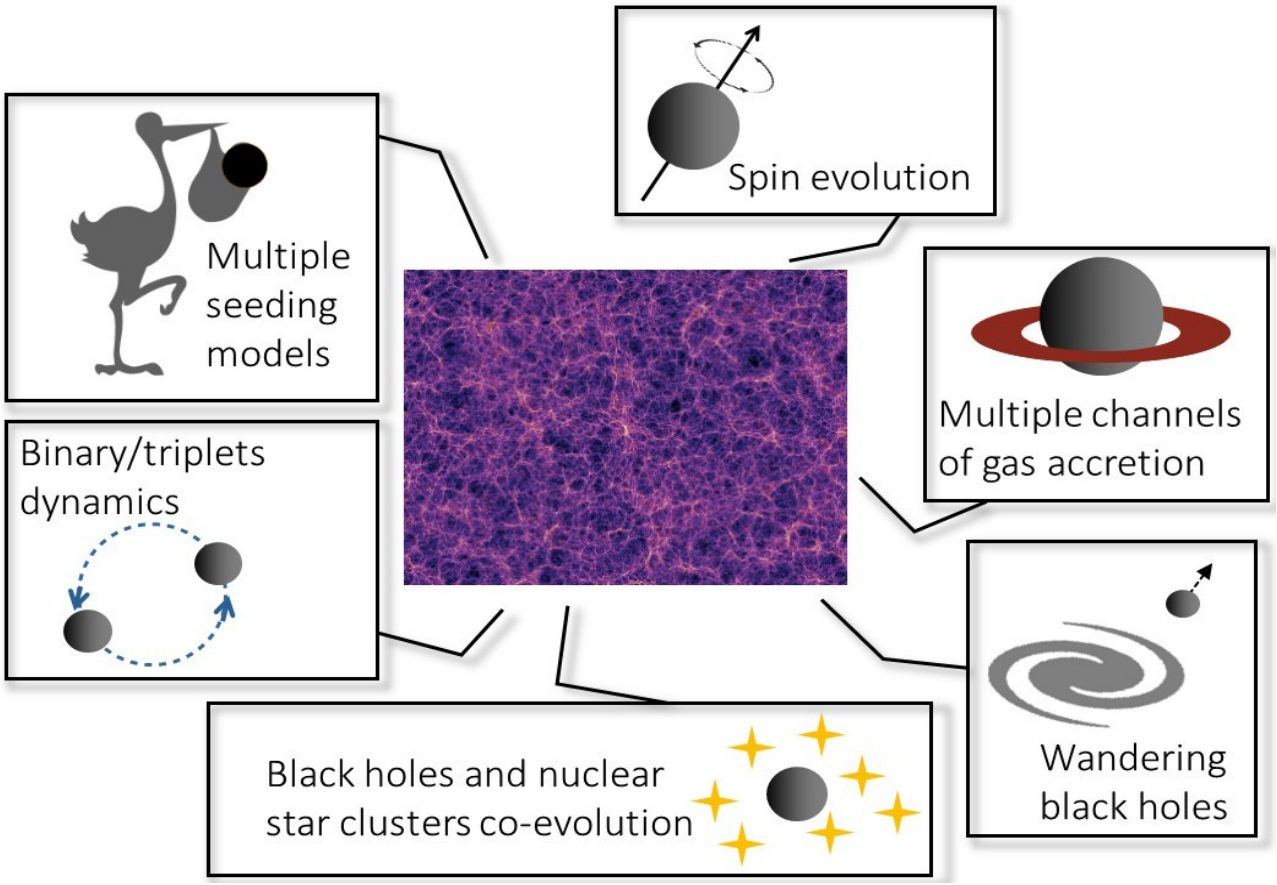
Expected merger rates

SuperEddington (Light+Heavy)
Eddington-HeavyMax (Only Heavy – high occupation)

SB, Izquierdo-Villalba et al. In prep

L-GalaxiesBH

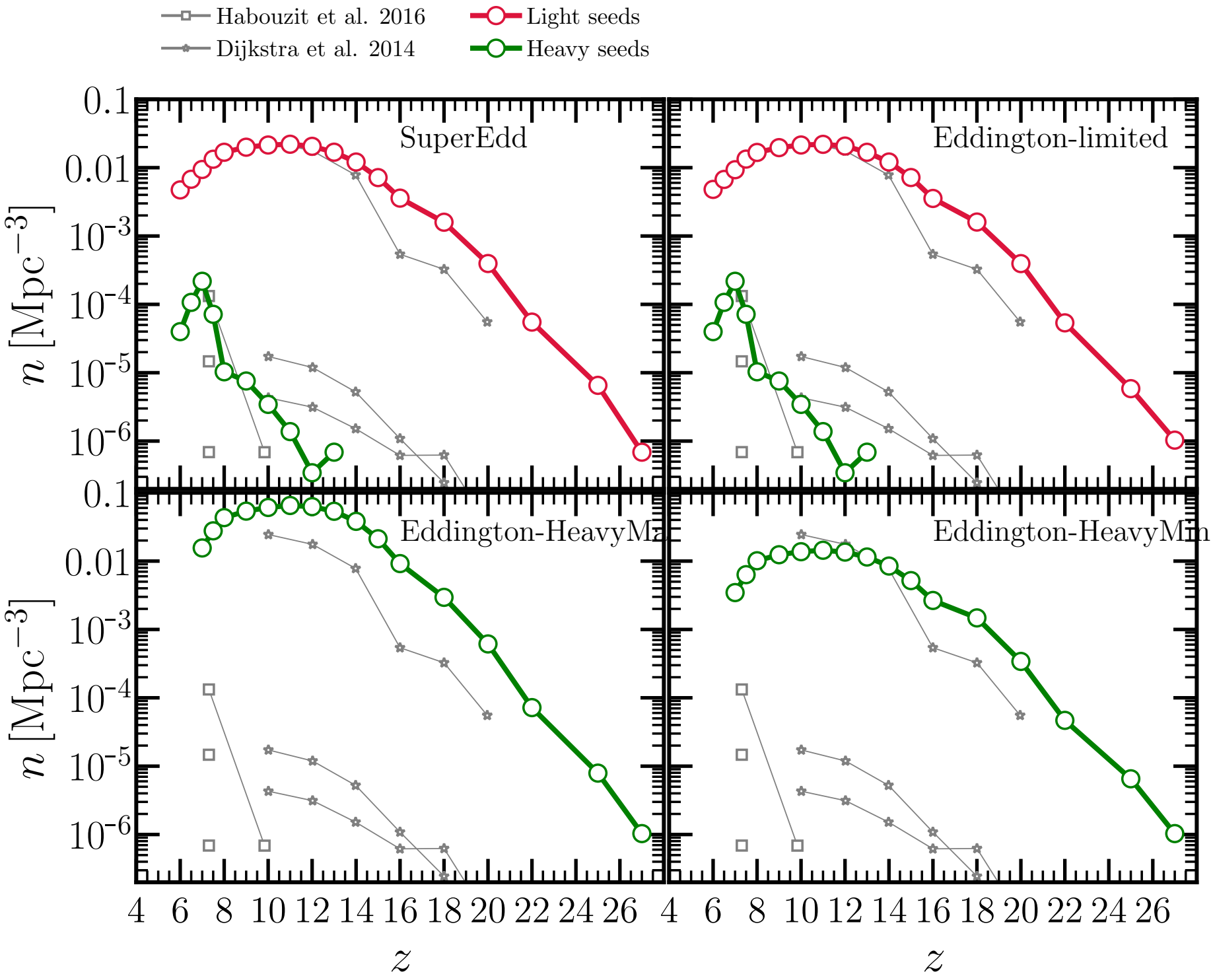
An extension of the semi-analytical model L-Galaxies, focused on the modeling of massive black holes



- **A fraction of IMBH do grow via TDEs**
- **PTA+JWST can help constrain the first phases of MBH growth**

  Degeneracies breakable as more multi-messenger data are flowing in

L-Galaxies (Millennium − Grafted)
L-Galaxies (Millennium)
0.5 [Mpc]
log10(MStellar /M⊙)
5
6
7
8
9
10
11
12


Habouzit et al. 2016
Dijkstra et al. 2014
Light seeds
Heavy seeds
SuperEdd
Eddington-limited
Eddington-HeavyMa
Eddington-HeavyMin
n [Mpc^{-3}]
z
0.1
0.01
10^{-3}
10^{-4}
10^{-5}
10^{-6}
4 6 8 10 12 14 16 18 20 22 24 26