Massive black hole binaries in the era of gravitational wave detectors: Could we constrain cosmology with them?

David Izquierdo-Villalba

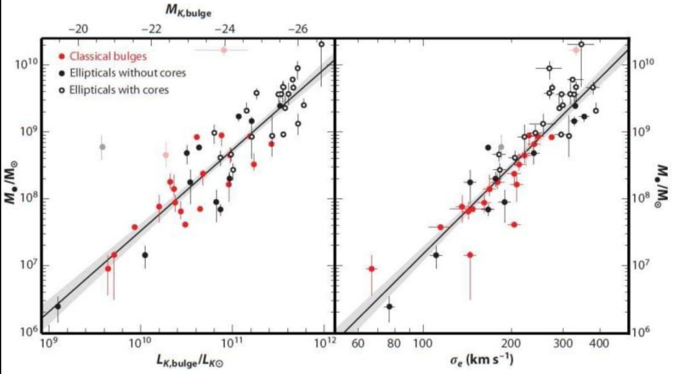
Collaborators: Alberto Sesana (Unimib)
Monica Colpi (Unimib),
Silvia Bonoli (DIPC),
Daniele Spinoso (Tsinghua University)
Marta Volonteri (IAP)

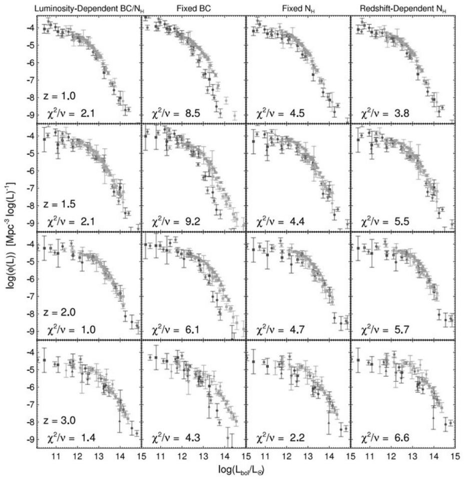
UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

Trieste – June 4nd – 9th 2023

erc B Massive

INTRODUCTION

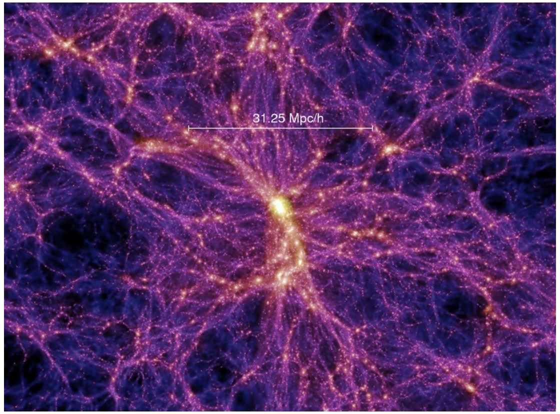




Most of the galaxies host a massive black hole $>10^6$ [M_o] in their centers

Galaxy mergers are one of the main drivers of galaxy evolution

Galaxies might host more than one massive black hole



INTRODUCTION

Distance

~ kpc — Galaxy nucleus → ~ pc — ~ 10^{-2} pc

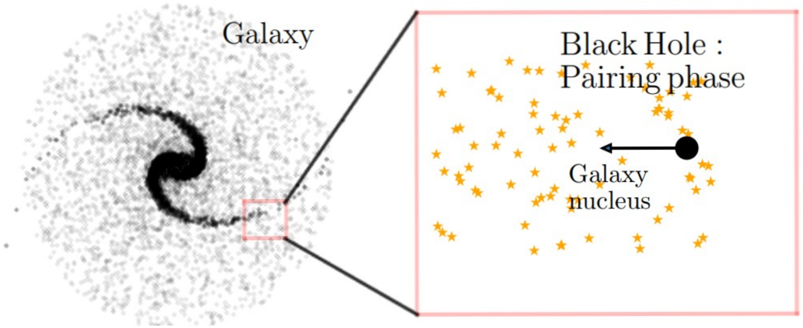
Galaxy merger → BH merger

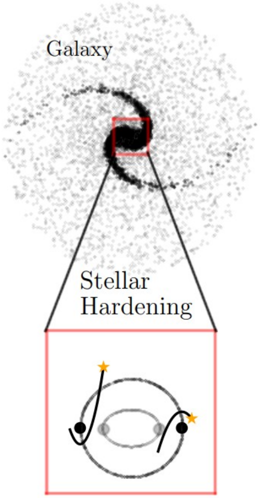
Shrinking mechanism

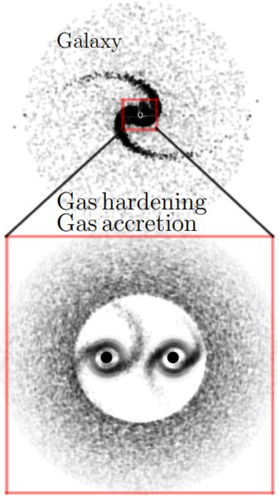
- Dynamical friction
- 1) Interaction with a massive gaseous circumbinary disc
  2) Three-body interactions with single stars
- Gravitational wave emssion

Phase

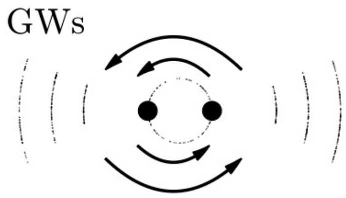
- PAIRING
- HARDENING
- GRAVITATIONAL WAVE INSPIRAL







EM EMISSION



INTRODUCTION

Distance — ~ kpc — Galaxy nucleus → — ~ pc — ~ 10^{-2} pc

Galaxy merger — BH merger

CURRENT EXPERIMENTS .... FUTURE EXPERIMENTS

LOUD GRAVITATIONAL WAVE SOURCES

Observed frequency:

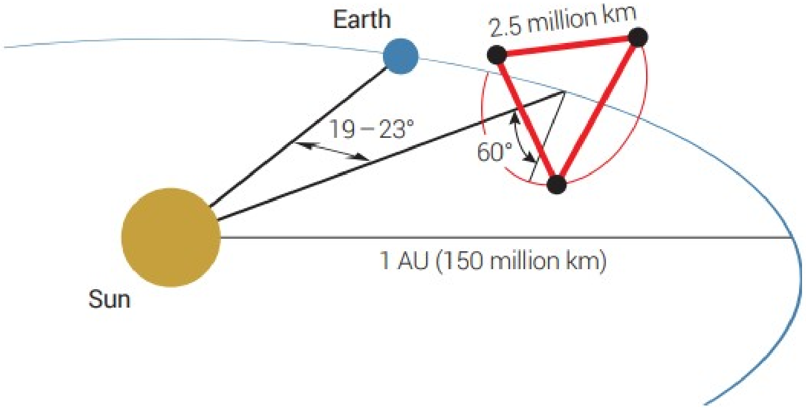
1) Chirp mass

$$\mathscr{M} = \frac{(M_{BH,1} M_{BH,2})^{3/5}}{(M_{BH,1} + M_{BH,2})^{1/5}}$$

2) Redshift

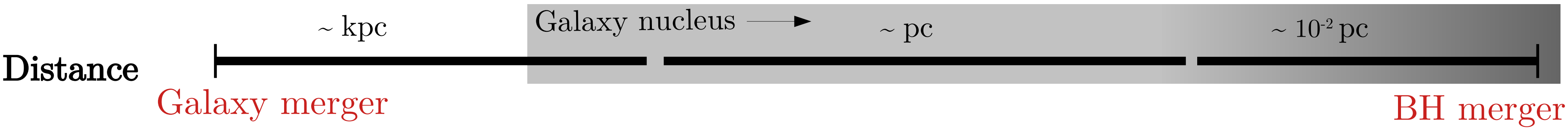
3) Binary separation

Pulsar Timming Arrays (PTA)



Laser Interferometer Space Antenna (LISA)

INTRODUCTION



LOUD GRAVITATIONAL WAVE SOURCES

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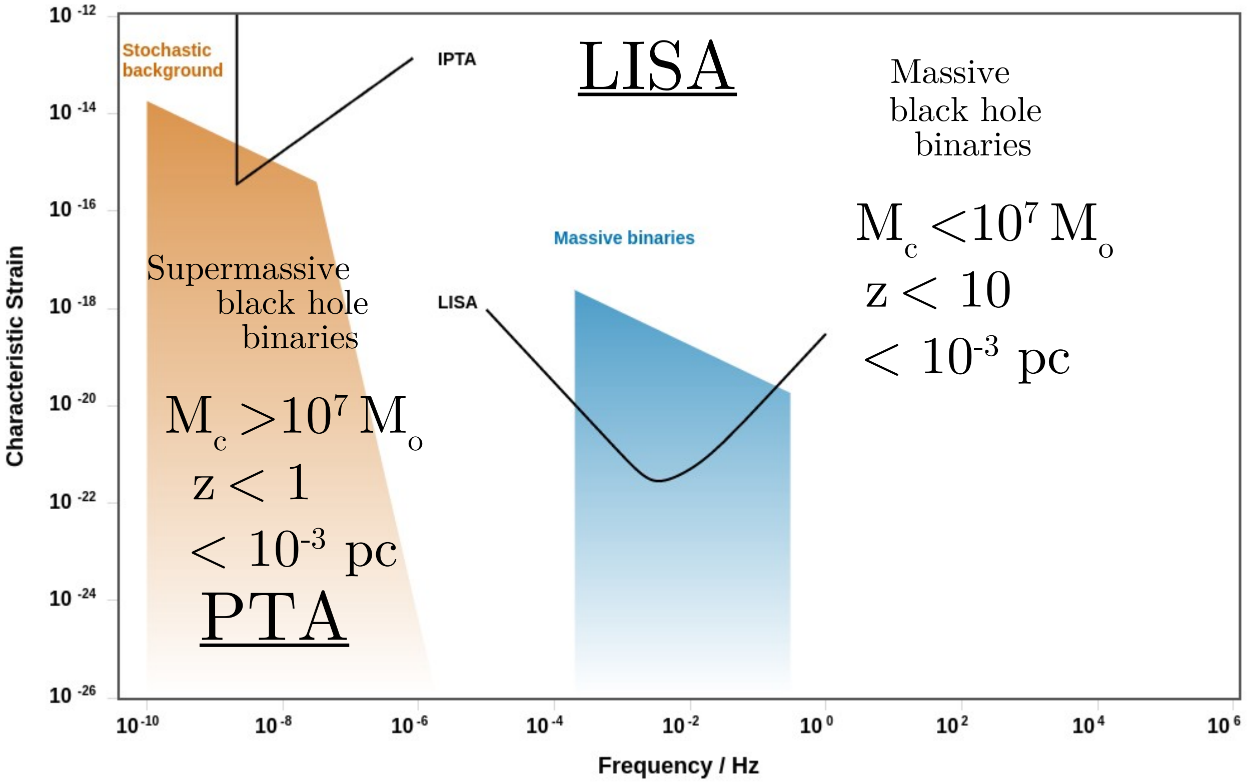
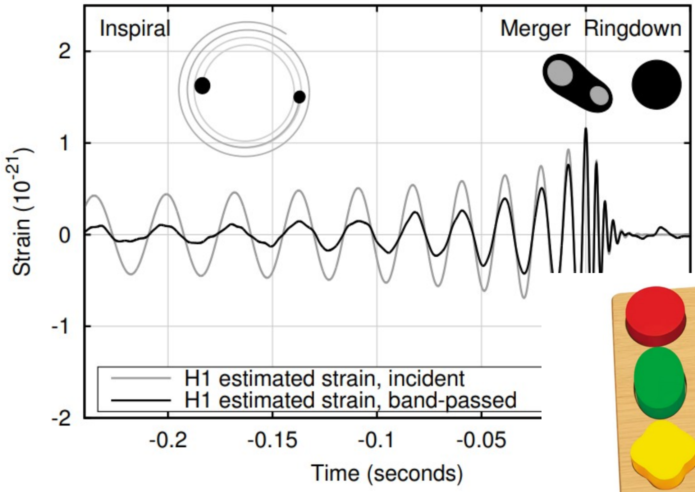


INTRODUCTION

GRAVITATIONAL WAVE DETECTION

WAVE FORM TEMPLATE MATCHING



Abbott et al. 2016

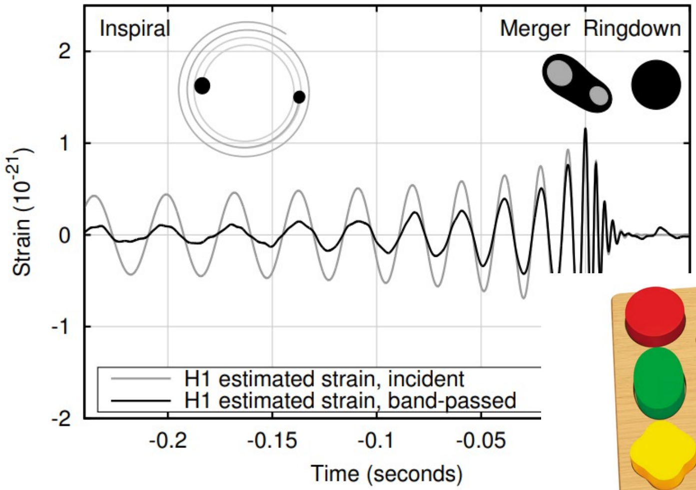
LUMINOSITY DISTANCE

INTRODUCTION

GRAVITATIONAL WAVE DETECTION

ELECTROMAGNETIC DETECTION

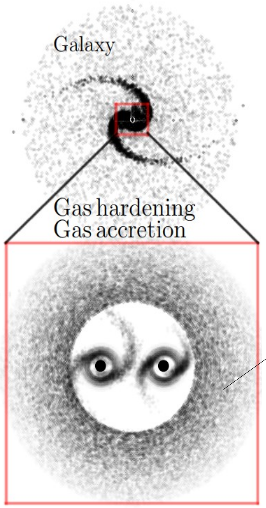
WAVE FORM TEMPLATE MATCHING



Abbott et al. 2016

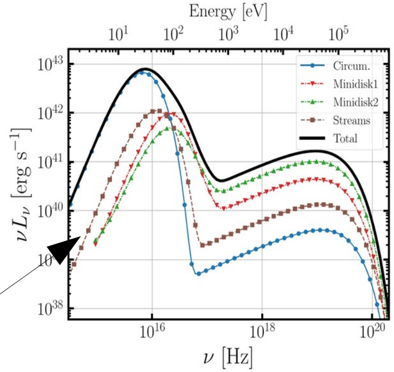
LUMINOSITY DISTANCE

DETECTION OF THE GALAXY/AGN



Accretion discs

Gutierrez et al. 2022



REDSHIFT

EUCLID, SKA
$\rightarrow z < 1$
$\rightarrow$ **PTA sources**

JWST, Athena
$\rightarrow z < 10$
$\rightarrow$ **LISA sources**

INTRODUCTION

GRAVITATIONAL WAVE DETECTION

WAVE FORM TEMPLATE MATCHING

ELECTROMAGNETIC DETECTION

DETECTION OF THE GALAXY/AGN

CONSTRAIN COSMOLOGICAL PARAMETERS

LUMINOSITY DISTANCE

REDSHIFT

INTRODUCTION

GRAVITATIONAL WAVE DETECTION

WAVE FORM TEMPLATE MATCHING

ELECTROMAGNETIC DETECTION

DETECTION OF THE GALAXY/AGN

NOT EASY...
(sky-localization)

CONSTRAIN COSMOLOGICAL PARAMETERS

LUMINOSITY DISTANCE

REDSHIFT

INTRODUCTION

PTA

$f_{\mathrm{Obs}} \sim 10^{-8}$ - 10^{-9} Hz
$M_{\mathrm{bin}} \sim 10^{8}\ M_{\mathrm{sun}}$

- Stochastic GWB ($A_{\mathrm{yr}^{-1}} \sim [1 - 3] \times 10^{-15}$)

- Sky localization

$$\Delta\Omega = 40\left(\frac{SNR}{10}\right) deg^2$$

$$\frac{\Delta d_L}{d_L} = No\ constraint$$

LISA

$f_{\mathrm{Obs}} \sim 10^{-4}$ - 0.1 Hz
$M_{\mathrm{bin}} \sim 10^{5}$ - $10^{6}\ M_{\mathrm{sun}}$

- Massive black hole binaries $z \sim 20$

- Sky localization

$$\Delta\Omega = 10^{-2} - 10^{3}\ deg^2$$

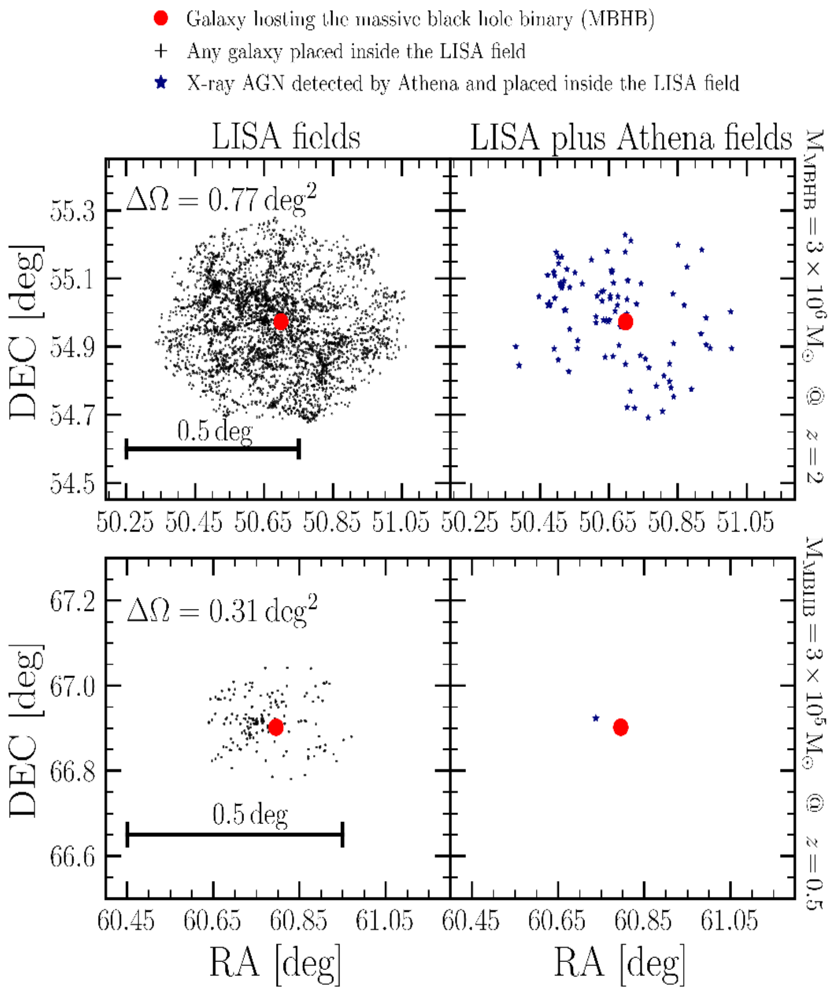
$$\frac{\Delta d_L}{d_L} = 10^{-3} - 1$$

→ *Depending on:*

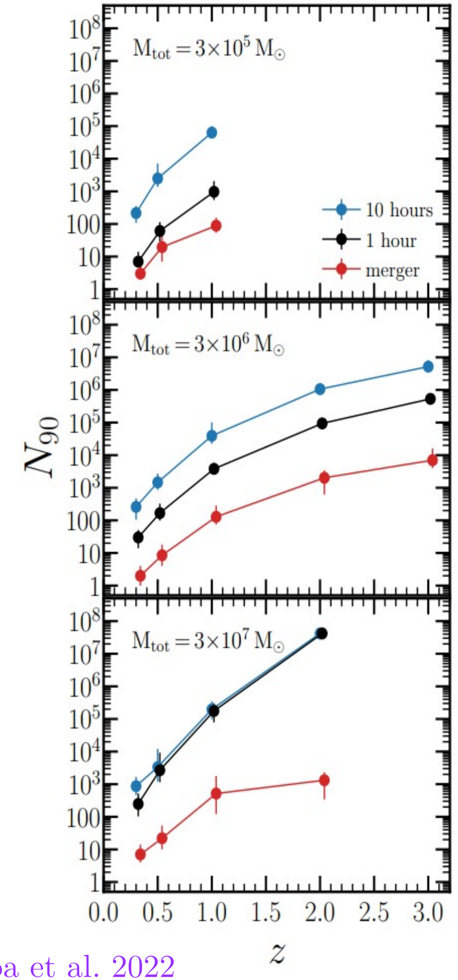
1) Binary mass
2) Redshift
3) Time before merger

Crowded of galaxies ↔

INTRODUCTION



Quantifying..



Lops & Izquierdo-Villalba et al. 2022

INTRODUCTION

PTA

$f_{Obs} \sim 10^{-8} - 10^{-9}$ Hz

- Sto

- Sky

$\frac{\Delta d_L}{d_L} = No\ constraint$

LISA

$f_{Obs} \sim 10^{-4} - 0.1$ Hz

M$_{sun}$

ies $z \sim 20$

...nding on:

...ary mass

2) Redshift

3) Time before merger

$\frac{\Delta d_L}{d_L} = 10^{-3} - 1$

Crowded of galaxies

In order to... **identify** the galaxy hosting the massive black hole binaries (MBHBs)**among all the galaxies in the sky localization area** we need

THEORETICAL WORKS which shed light on the properties of the galaxies or AGNs hosting MBHBs

INTRODUCTION

PTA

$f_{Obs} \sim 10^{-8} - 10^{-9}$ Hz

$M_{bin} \sim 10^{8} M_{sun}$

- Stochastic GWB ($A_{yr}^{-1} \sim [1 - 3] \times 10^{-15}$)

- Sky localization

$$\Delta\Omega = 40 \left(\frac{SNR}{10}\right) deg^2$$

$$\frac{\Delta d_L}{d_L} = No\ constraint$$

Massive black hole evolution models confronting the n-Hz amplitude of the stochastic gravitational wave background

David Izquierdo-Villalba,[1,2]★ Alberto Sesana,[1] Silvia Bonoli[3,4] and Monica Colpi[1,2]
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Unveiling the hosts of parsec-scale massive black hole binaries: morphology and electromagnetic signatures

David Izquierdo-Villalba,[1,2]★ Alberto Sesana,[1,2] and Monica Colpi[1,2]
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INTRODUCTION

Properties and merger signatures of galaxies hosting LISA coalescing massive black hole binaries

David Izquierdo-Villalba*[1,2], Monica Colpi[1,2], Marta Volonteri[3], Daniele Spinoso[4], Silvia Bonoli[5,6], and Alberto Sesana[1,2]

LISA

$f_{\rm Obs} \sim 10^{-4}$ - 0.1 Hz
$M_{\rm bin} \sim 10^5 - 10^6\ M_{\rm sun}$

- Massive black hole binaries $z \sim 20$
- Sky localization

$$\Delta\Omega = 10^{-2} - 10^3\, deg^2$$

$$\frac{\Delta d_L}{d_L} = 10^{-3} - 1$$

→

Depending on:

1) Binary mass
2) Redshift
3) Time before merger

METHODOLOGY

EXPLORE THE HOSTS OF PTA AND LISA MBHBs TO HELP IN THE IDENTIFICATIONS

↓ Ingredients ...

1) Reliable population of galaxies accros cosmic time

2) Reliable population of MBHs accros cosmic time

3) Reliable population of MBH binaries accros cosmic time

4) Simulated Universe with galaxies placed in RA-DEC-redshift plane

METHODOLOGY

SEMI-ANALYTICAL MODEL

L - GALAXIES

Guo et al. 2011, Henriques et al. 2015, Henriques 2020

L-Galaxies: the basics

- Subhaloes seeded with of hot gas at high redshift
- This gas can then cool, form stars, drive feedback, etc, via analytic prescriptions:

$$\Sigma_{\rm SFR} = \alpha_{\rm H_2}\Sigma_{\rm H_2}/t_{\rm dyn}$$

star formation

$$e_{\rm X}(t) = \int_{M_L}^{M_U} M_{\rm X}(M, Z_0)\ \psi(t - \tau_{\rm M})\ \phi(M)\ {\rm dM}$$

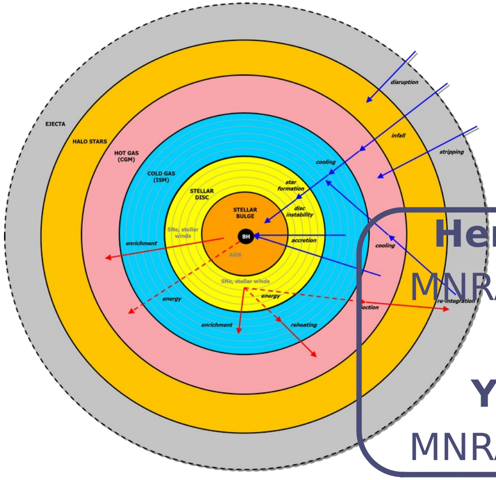
chemical enrichment

$$\Delta E_{\rm reheat} = \frac{1}{2}\,\epsilon_{\rm disc}\,\Delta M_{\rm ret,ISM}\,V_{\rm vir}^2$$

SN feedback reheating

Default prescriptions:

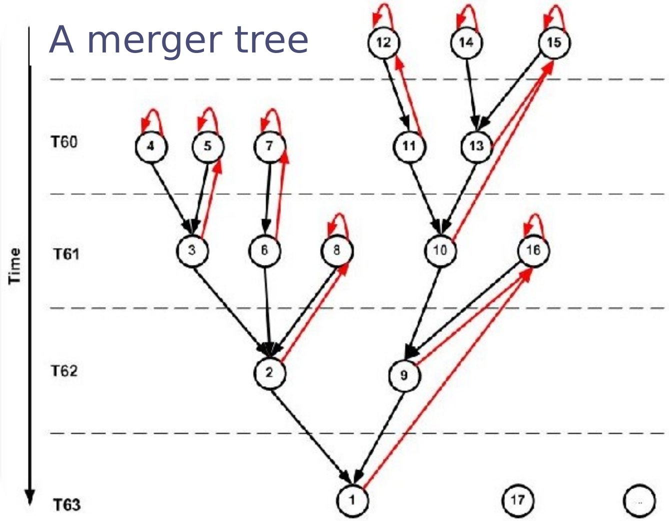
- Gas infall
- Gas cooling
- Star formation
- Disc instabilities
- SMBH growth
- Bulge formation
- Mergers
- Chemical enrichment
- SN feedback
- AGN feedback
- Gas reincorporation
- Gas stripping
- Satellite disruption
- ...



Henriques+20
MNRAS, 491, 5795

Yates+21a
MNRAS, 503, 4474

A merger tree



COURTESY AND CREDITS OF ROB YATES

MCMC parameter constraining

L - Galaxies

Henriques+20

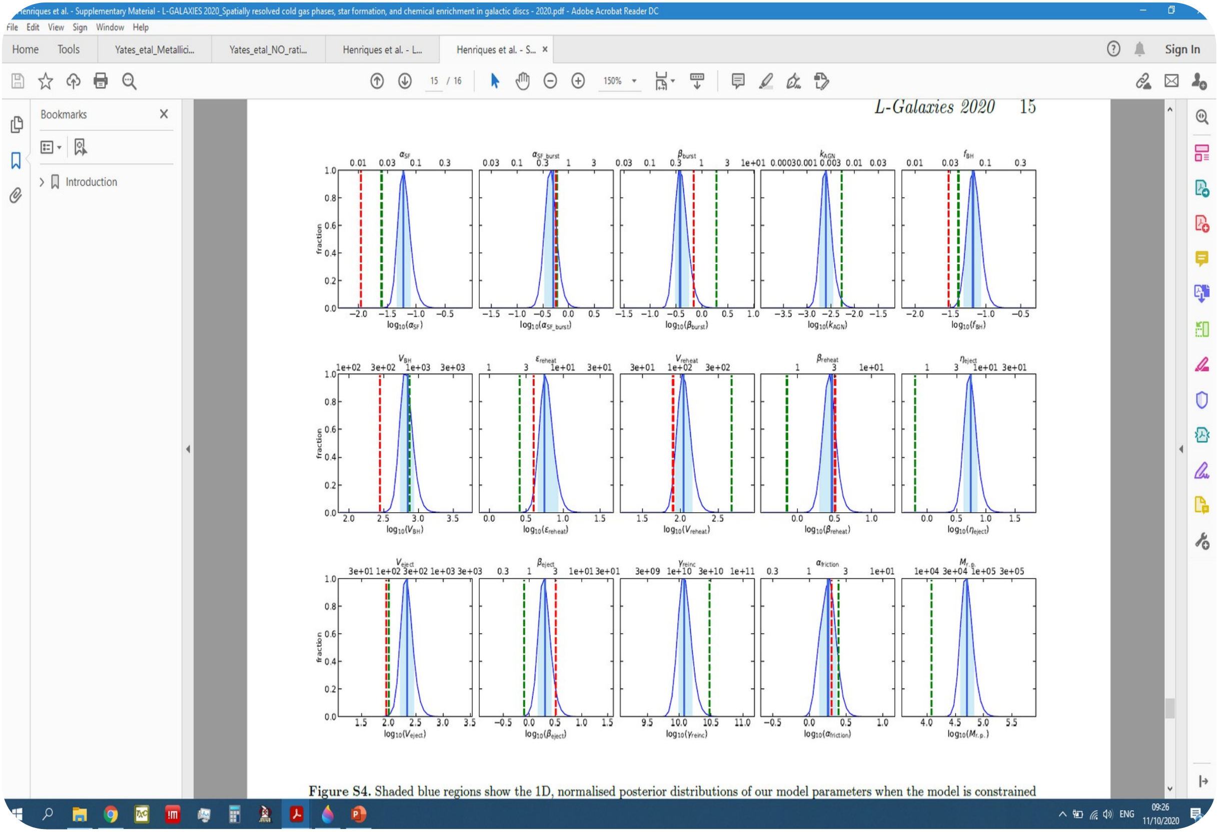


Figure S4. Shaded blue regions show the 1D, normalised posterior distributions of our model parameters when the model is constrained by observations of the abundance of galaxies as a function of stellar and HI mass at $z = 0$ and the passive fraction of galaxies as a function of stellar mass a $z = 0$ and 2. Straight lines represent values corresponding to our overall best-fitting model (solid blue lines) and to those of Henriques et al. (2015) (dashed green lines) and Guo et al. (2011) (dashed red lines).

Star-formation efficiency (α_{SF}), radio-mode SMBH accretion efficiency (κ_{AGN}), etc, are simultaneously fit

Units	α_{SF}	$\alpha_{SF,burst}$	$\beta_{SF,burst}$	k_{AGN} [$M_\odot\,yr^{-1}$]	f_{BH}	V_{BH} [$km\,s^{-1}$]	$M_{r.p.}$ [$10^{10}\,M_\odot$]	$\alpha_{dyn.fric.}$
Eq.	S16	S37	S37	S28	S27	S27	N/A	S36
Guo11	0.011	0.56	0.70	1.5×10^{-3}	0.03	280	N/A	2.0
Hen15	0.025	0.60	1.9	5.3×10^{-3}	0.041	750	1.2×10^4	2.5
This work	0.06	0.5	0.38	2.5×10^{-3}	0.066	700	5.1×10^4	1.8

Units	ϵ_{reheat}	V_{reheat} [$km\,s^{-1}$]	β_{reheat}	η_{eject}	V_{eject} [$km\,s^{-1}$]	β_{eject}	γ_{reinc} [yr^{-1}]
Eq.	S22	S22	S22	S20	S20	S20	S25
Guo11	4.0	80	3.2	0.18	90	3.2	N/A
Hen15	2.6	480	0.72	0.62	100	0.8	3.0×10^{10}
This work	5.6	110	2.9	5.5	220	2.0	1.2×10^{10}

Others are still tuned by hand

Units	v_{inflow} [$km\,s^{-1}\,kpc^{-1}$]	R_{merger}	$f_{z,hot,TypeII}$	$f_{z,hot,TypeIa}$
Eq.	S18	N/A	N/A	N/A
Guo11	N/A	0.3	N/A	N/A
Hen15	N/A	0.1	N/A	N/A
This work	1.0	0.1	0.3	0.3

COURTESY AND CREDITS OF ROB YATES

L-Galaxies 2020: Collaboration

L - Galaxies

Collaboration of many people

Raul Angulo, DIPC, Spain
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Matteo Bonetti, Uni-MiB, Italy
Camilla Eldridge, University Diego Portales, Chile
Brendan Griffen, MIT, USA
Andrew Griffin, NAO Beijing, China
Qi Guo, NAO Beijing, China
Jimi Harrold, University of Nottingham, UK
David Hendricks, University of Surrey, UK
Jessica May Hislop, University of Helsinki, Finland
Nils Hoyer, MPIA, Germany
Dyna Ibrahim, University of Hertfordshire, UK
Dimitrios Irodotou, University of Helsinki, Finland
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Rita Tojeiro, University of St. Andrews, UK
Julen Untzaga, ICE Barcelona, Spain
Marcel van Daalen, Leiden, Netherlands
Aswin Vijayan, DAWN, Denmark, UK
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Stephen Wilkins, University of Sussex, UK
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MAIN DEVELOPERS


Rob Yates


Peter Thomas


Reza Ayrmlou


Silvia Bonoli


Daniele Spinoso


David Izquierdo-Villalba

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- Environmental Effects (Reza Ayrmlou): **ayromlou -at- uni-heidelberg.de**
- Technical Development (Peter Thomas): **p.a.thomas -at- sussex.ac.uk**

- Seminar Series (Daniele Spinoso & David Izquierdo Villalba): **dspinoso -at- outlook.it** or **david.izquierdovillalba -at- unimib.it**

METHODOLOGY

SEMI-ANALYTICAL MODEL

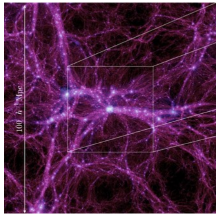
L - GALAxies

Guo et al. 2011, Henriques et al. 2015

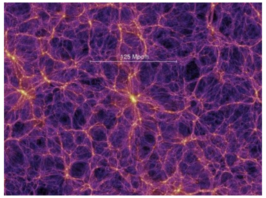
- Star formation
- Supernovae feedback
- AGN feedback
- Galaxy tidal disruption
- Gas stripping
- ...

MILLENNIUM SUIT OF SIMULATION

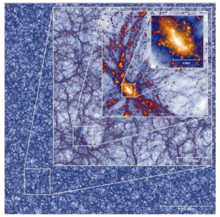
$L_{box} = 100$ Mpc / h
$M_{halo} \sim 10^8$ M_{sun}



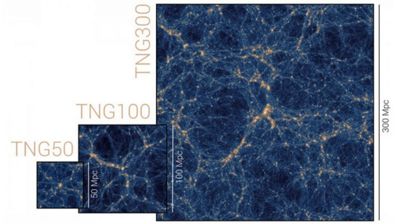
$L_{box} = 500$ Mpc / h
$M_{halo} \sim 10^{10}$ M_{sun}



$L_{box} = 3$ Gpc / h
$M_{halo} \sim 10^{11}$ M_{sun}



TNG SUIT OF SIMULATION



METHODOLOGY

SEMI-ANALYTICAL MODEL

L - GALAxies

Guo et al. 2011, Henriques et al. 2015

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MILLENNIUM SUIT OF SIMULATION

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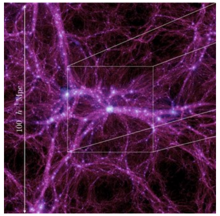
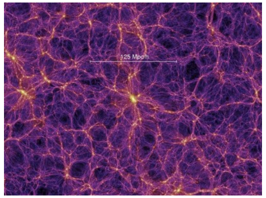
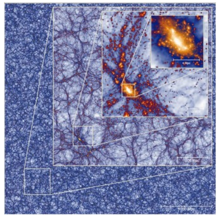


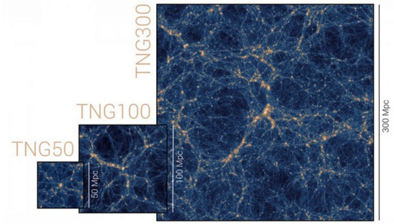
$L_{box} = 500$ Mpc / h
$M_{halo} \sim 10^{10}$ M_{sun}



$L_{box} = 3$ Gpc / h
$M_{halo} \sim 10^{11}$ M_{sun}



TNG SUIT OF SIMULATION



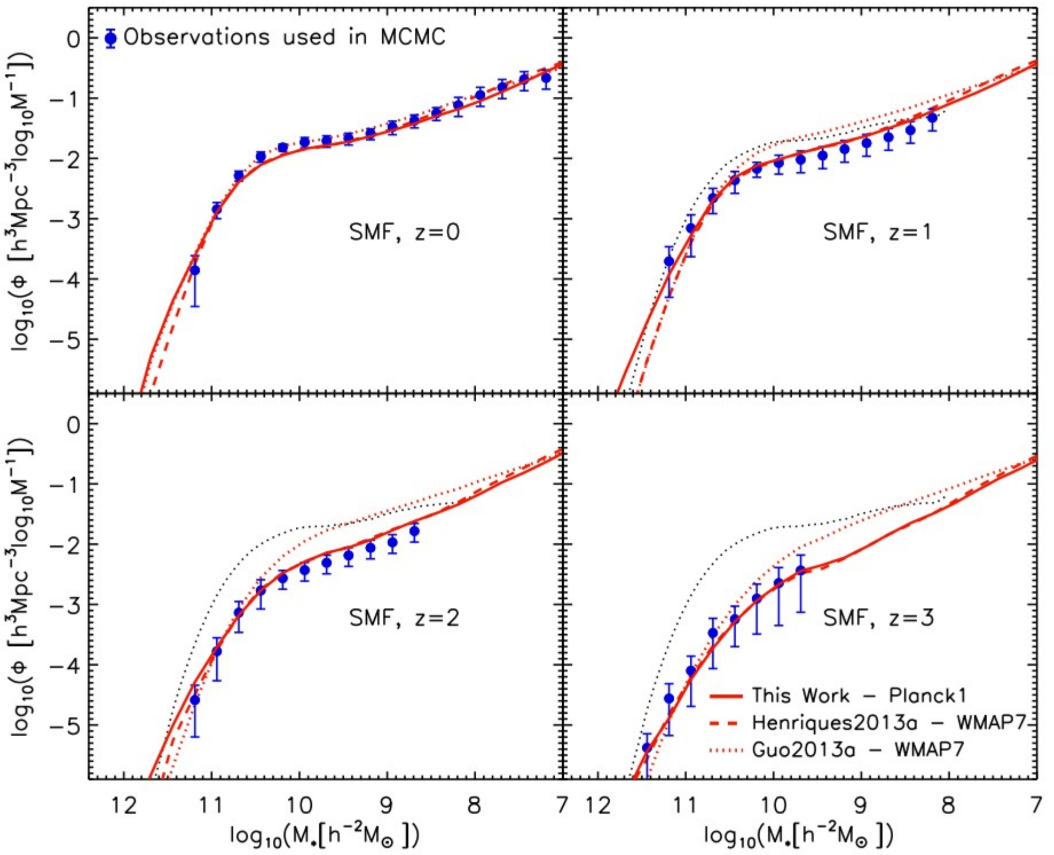
Generate a reliable population of galaxies accros cosmic time

METHODOLOGY

SEMI-ANAL

Guo et al. 2011, Henr

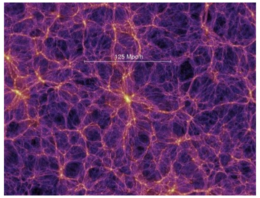
- Star formation
- Supernovae feed
- AGN feedback
- Galaxy tidal dis
- Gas stripping
- ...

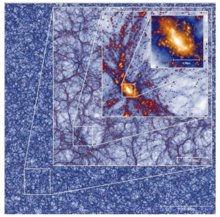


MILLENNIUM SUIT OF SIMULATION

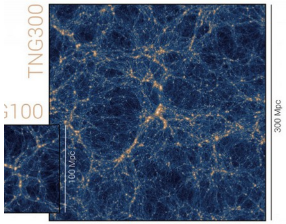
$_{ox} = 500$ Mpc / h $\quad$ $L_{box} = 3$ Gpc / h

$_{halo} \sim 10^{10}$ M_{sun} $\quad$ $M_{halo} \sim 10^{11}$ M_{sun}





SUIT OF SIMULATION



METHODOLOGY

SEMI-ANALYTICAL MODEL

L - GALAXIES

Guo et al. 2011, Henriques et al. 2015

MILLENNIUM SUIT OF SIMULATION

MILLENNIUM-II

$L_{box} = 100$ Mpc / h

$M_{halo} \sim 10^8$ M_{sun}

MILLENNIUM-I

$L_{box} = 500$ Mpc / h

$M_{halo} \sim 10^{10}$ M_{sun}

1) Reliable population of galaxies accros cosmic time

2) Reliable population of MBHs accros cosmic time → Izquierdo-Villalba et al. 2020, Spinoso et al. 2023

- Seeding of high-z MBHs
- Growth
- Spin evolution
- Recoil velocities
- Wandering black holes

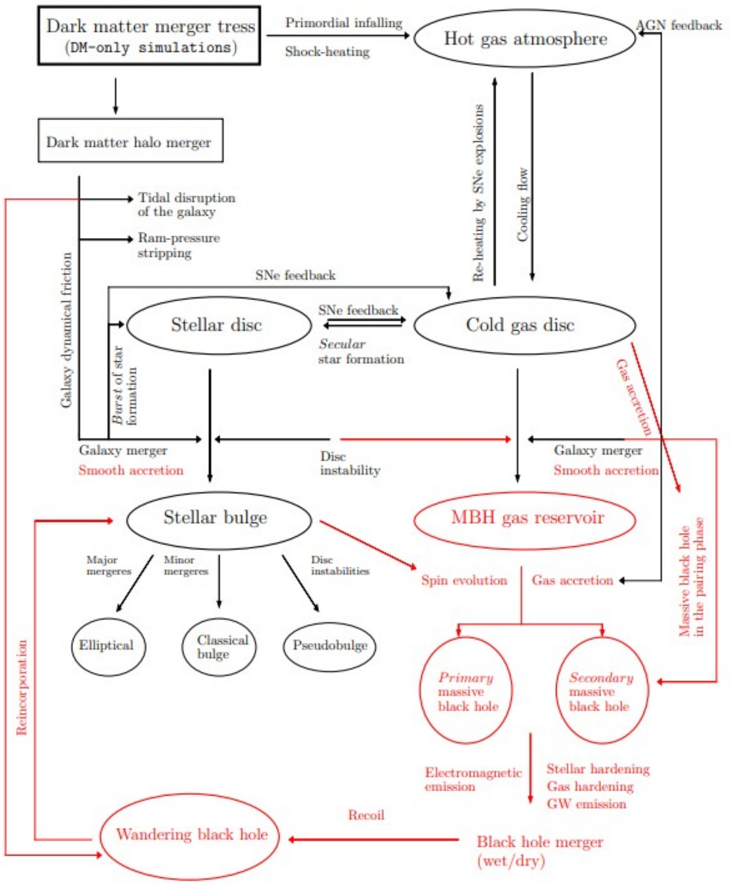
METHODOLOGY

New physics about MBHs

Standard model L-Galaxies

A lot of new physivs
in the MBH part

“L-GalaxiesBH”



L-Galaxies

METHODOLOGY

SEMI-ANALYTICAL MODEL

L - GALAXIES

Guo et al. 2011, Henriques et al. 2015

MILLENNIUM SUIT OF SIMULATION

MILLENNIUM-II

$L_{box} = 100$ Mpc / h
$M_{halo} \sim 10^8\ M_{sun}$

MILLENNIUM-I

$L_{box} = 500$ Mpc / h
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1) Reliable population of galaxies accros cosmic time ✓

2) Reliable population of MBHs accros cosmic time → Izquierdo-Villalba et al. 2020, Spinoso et al. 2023

- Seeding of high-z MBHs
- Growth
- Spin evolution
- Recoil velocities
- Wandering black holes

METHODOLOGY

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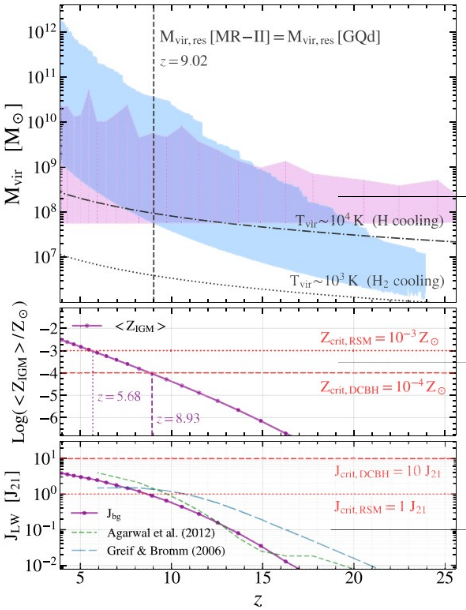
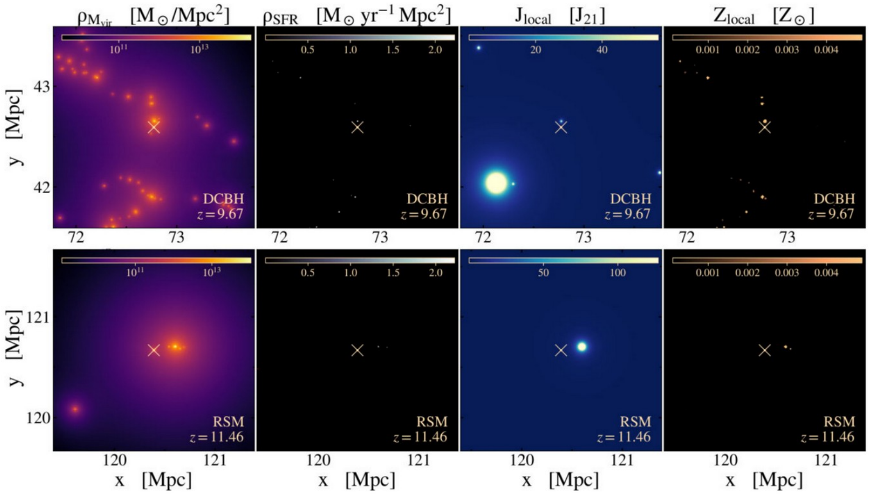


Halo resolution of MSII

Local and Global **Metallicity**

Local and Global **Lyman-Wernel background**



Multiflavour seeding

Birthplaces of

1) DCBH

2) PopIII remnants

3) RSM remnants

METHODOLOGY

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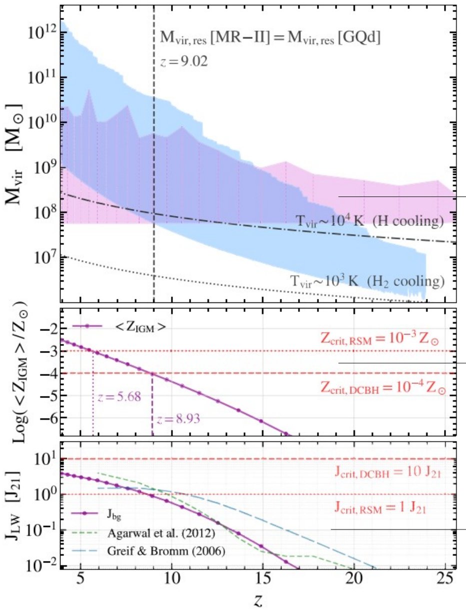

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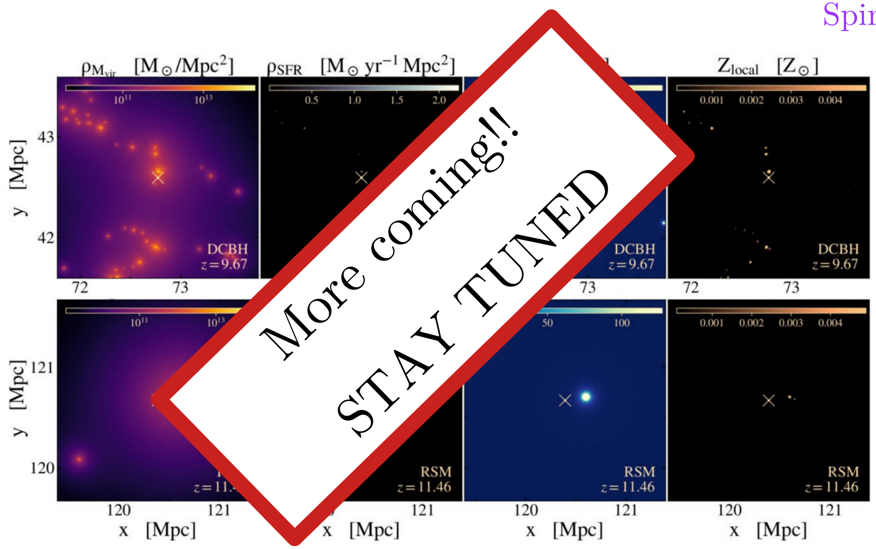

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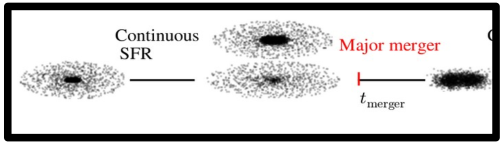
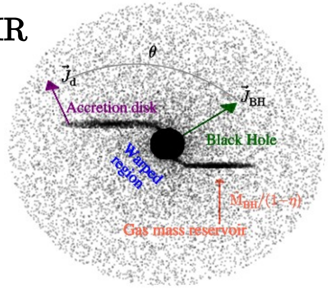
GROWTH

GALAXY MEGERS



GALAXY DISK INSTABILITIES

RESERVOIR



Eddington phase

$$\dot{M}_{BH} = \dot{M}_{Edd}$$

$$M_{Res}(t) < 0.3 M_{Res}(t=0)$$

Quiescent phase

$$\dot{M}_{BH} = \frac{\dot{M}_{Edd}}{\left[1 + (t/t_Q)^{1/2}\right]^{2/\beta}}$$

SPIN

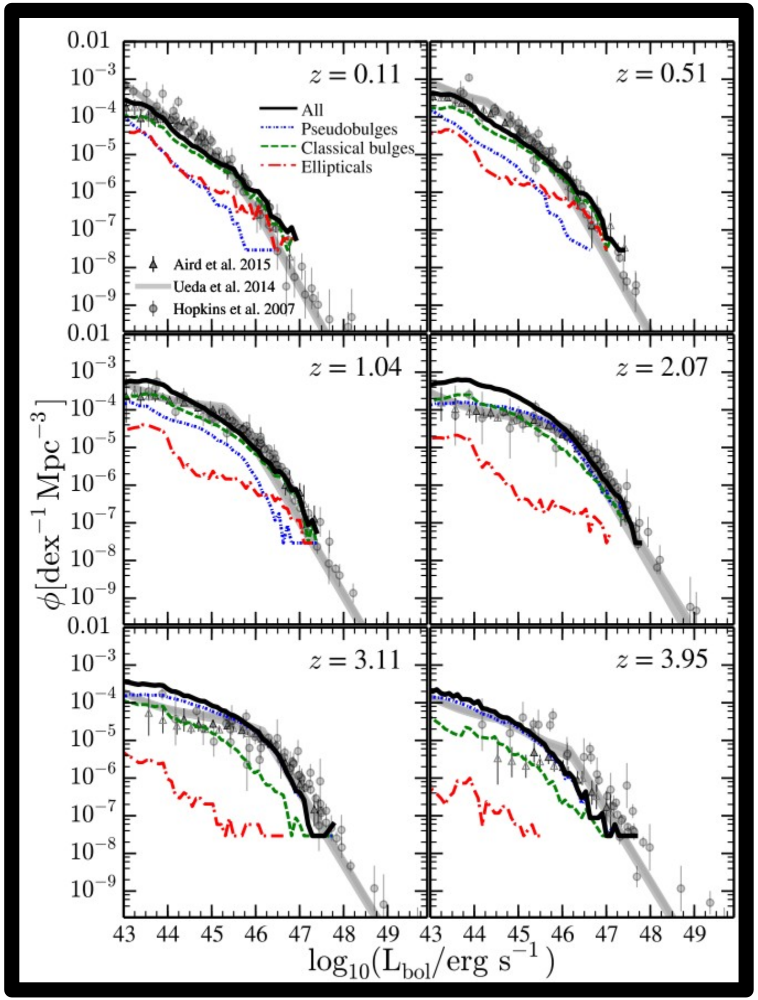
$$\cos\theta < -\frac{|\vec{J}_d|}{2\,|\vec{J}_{BH}|}$$

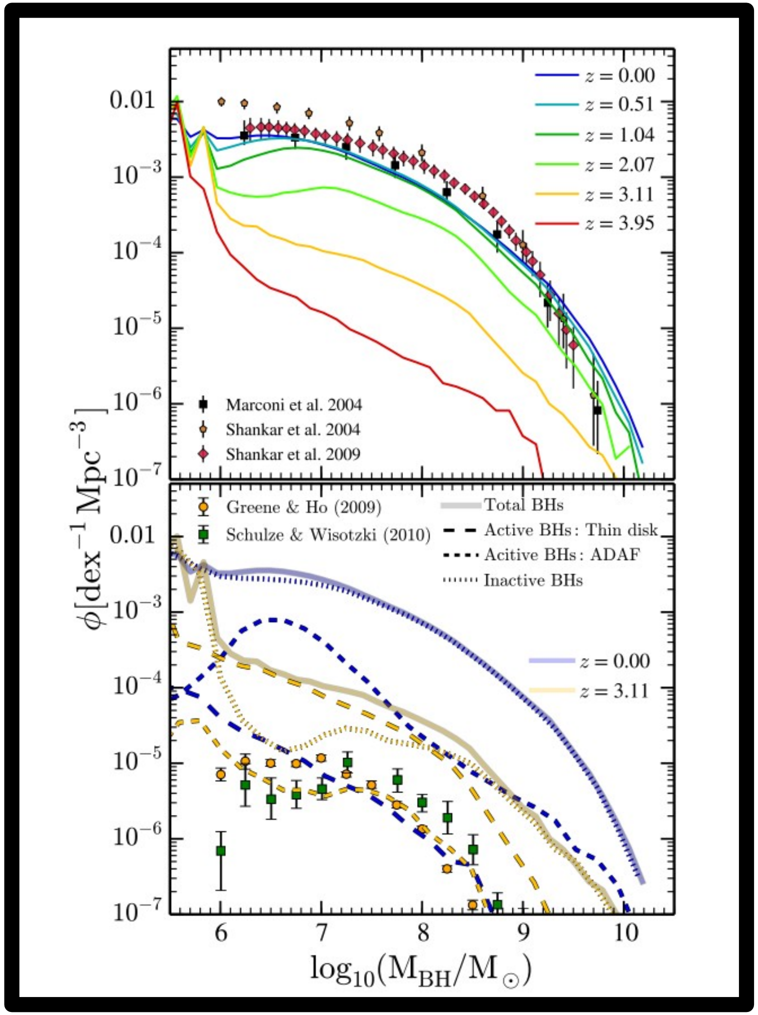
$$|\vec{J}_d| = \frac{8}{21}\frac{R_d^{7/4}(GM_{BH})^{1/2}}{A_\nu}M_{BH}$$

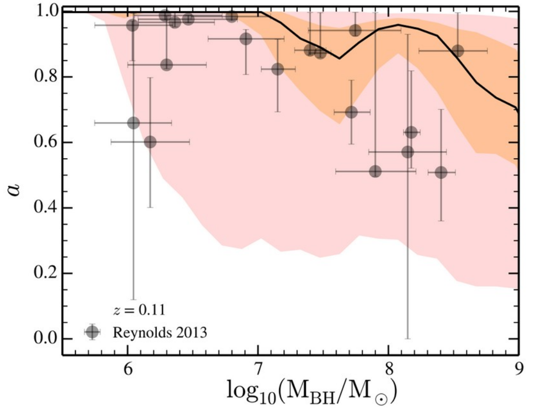
$$|\vec{J}_{BH}| = \frac{1}{\sqrt{2}}M_{BH}a\,(GM_{BH}R_{Sch})^{1/2}$$

$$n_{Pa} = F + \frac{|\vec{J}_d|}{2|\vec{J}_{BH}|}(1-F)$$

METHODOLOGY







Izquierdo-Villalba et al. 2020

METHODOLOGY

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2) Reliable population of MBHs accros cosmic time ✓

3) Reliable population of MBH binaries accros cosmic time

4) Simulated Universe with galaxies placed in RA-DEC-redshift plane

METHODOLOGY

Distance

Galaxy merger —— ~ kpc —— Galaxy nucleus → ~ pc —— ~ 10^{-2} pc —— BH merger

Phase

PAIRING

$$t^{\rm BH}_{\rm dyn} = 19\, f(\varepsilon) \left(\frac{r_0}{4\,{\rm kpc}}\right)^2 \left(\frac{\sigma}{200{\rm km/s}}\right) \left(\frac{10^8\,{\rm M_\odot}}{\rm M_{BH}}\right) \frac{1}{\Lambda}\ [{\rm Gyr}]$$

Izquierdo-Villalba et al. 2022

HARDENING

Gas poor

$$\frac{da_{\rm BH}}{dt} = \left(\frac{da_{\rm BH}}{dt}\right)_{\rm Hard} + \left(\frac{da_{\rm BH}}{dt}\right)_{\rm GW} = -\frac{GH\rho_{\rm inf}}{\sigma_{\rm inf}} a^2_{\rm BH} - \frac{64G^3({\rm M_{BH_1}} + {\rm M_{BH_2}})^3 F(e)}{5c^5(1+q)^2 a^3_{\rm BH}}$$

$$\frac{de}{dt} = a_{\rm BH}\frac{G\rho_{\rm inf} HK}{\sigma_{\rm inf}} - \frac{304}{15}\frac{G^3 q(M_{\rm BH_1} + M_{\rm BH_2})^3}{c^5(1+q)^2 a^4_{\rm BH}(1-e^2)^{5/2}}\left(e + \frac{121}{304}e^3\right)$$

Gass rich

$$\frac{da_{\rm BH}}{dt} = -\frac{2\dot{\rm M}}{\mu}\sqrt{\frac{\delta}{1-e^2}}\, a_{BH} - \frac{64G^3({\rm M_{BH_1}} + {\rm M_{BH_2}})^3 F(e)}{5c^5(1+q)^2 a^3_{\rm BH}}$$

Triplets

Bonetti et al. 2018

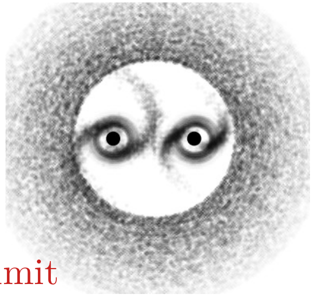
Gas accretion in binaries

$$\dot{M}_{\rm BH_1} = \dot{M}_{\rm BH_2}(0.1 + 0.9q)$$

Duffell et al. 2020

where M_{BH2} acccretes at Eddington limit

GRAVITATIONAL WAVE INSPIRAL



TRACK SELF-CONSISTENTLY VIA NUMERICAL INTEGRATION THE

- BINARY SEPARATION (a_{BH})
- BINARY ECCENTRICITY (e_{BH})

METHODOLOGY

SEMI-ANALYTICAL MODEL

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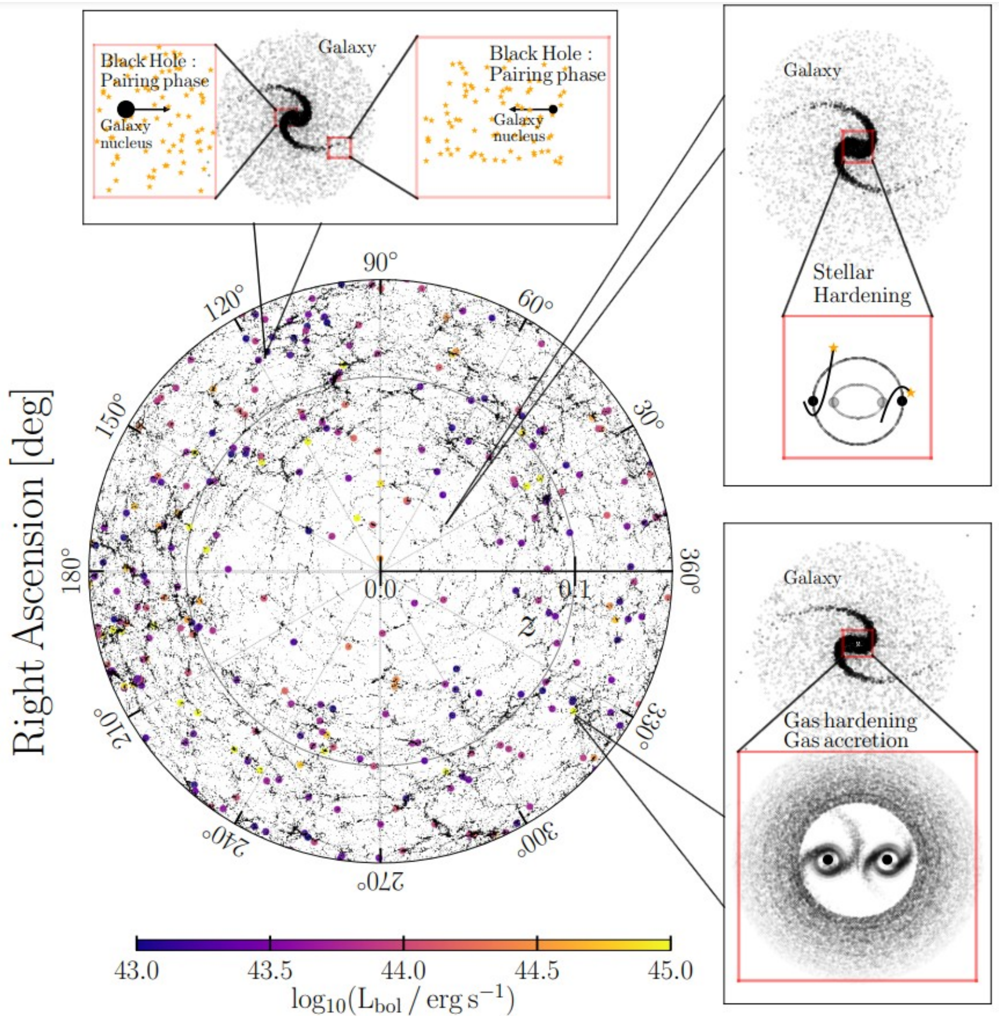
METHODOLOGY



RUN THE SEMI-ANALYTICAL MODEL

Output...

COMOVING BOXES OF SEMI-ANALYTICAL MODEL

Izquierdo-Villalba & Angulo et al. 2019

LIGHTCONE

- **Sky lightcone**
- Galaxies hosting single and binary black holes
- Galaxies in an active phase (AGNs)
- All the properties of the galaxies and binaries

METHODOLOGY

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I HAVE A POWERFUL TOOL READY!!

METHODOLOGY

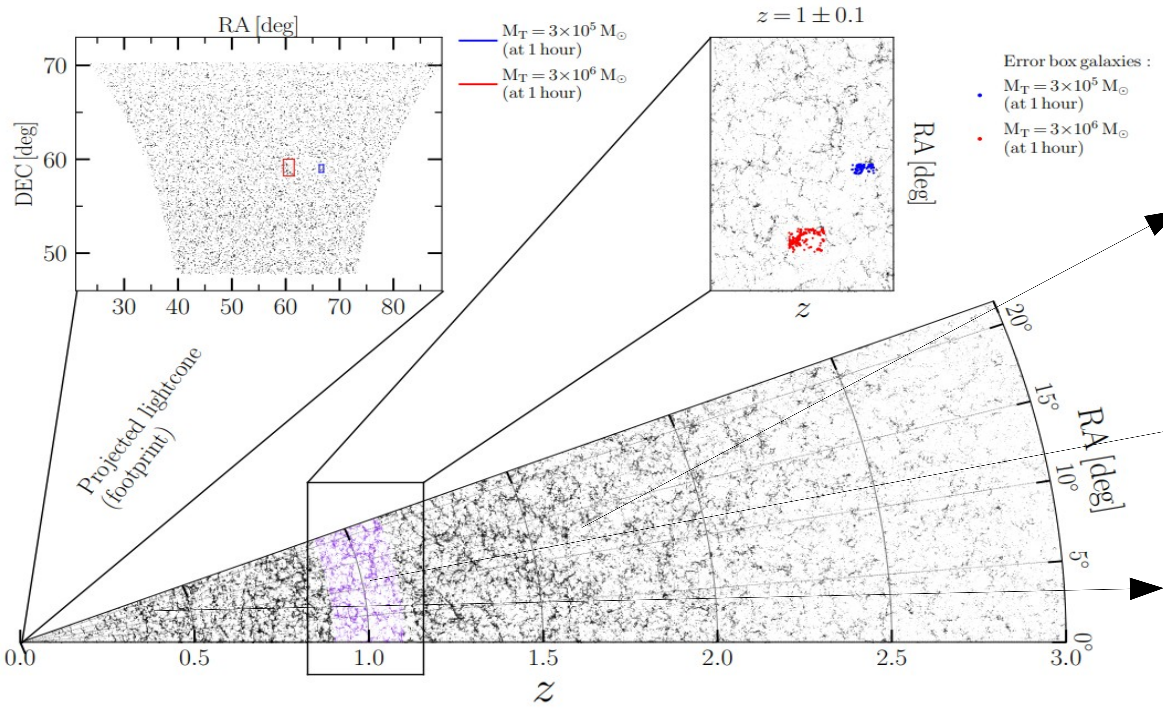
L - GALAXIES

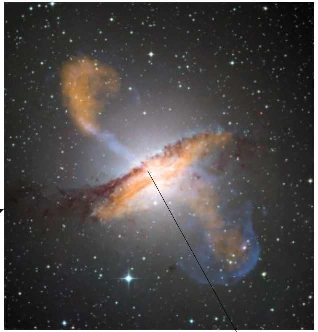
LISA sources

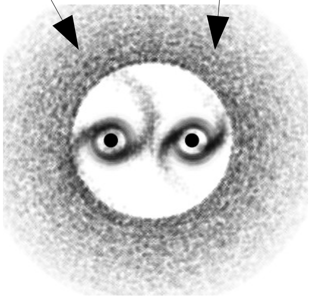
1 - The binaries with total mass 10^4-10^7 M_{sun}

2 – MBHBs at $z<3$

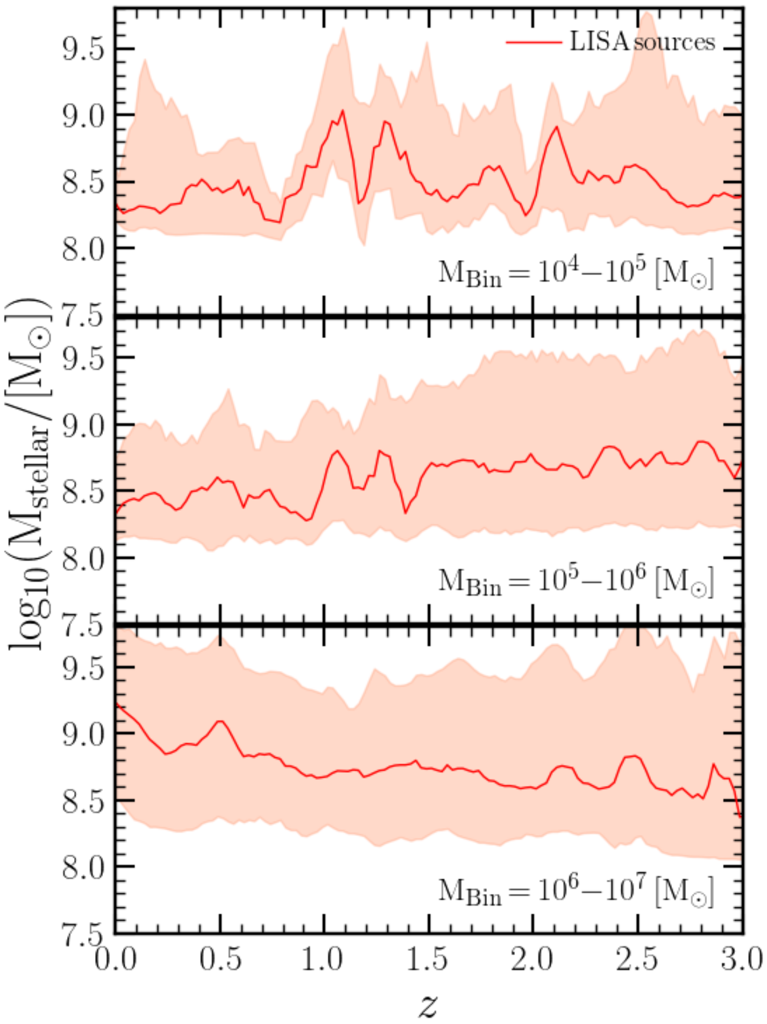
3 – The coalescing time is < 1 Myr





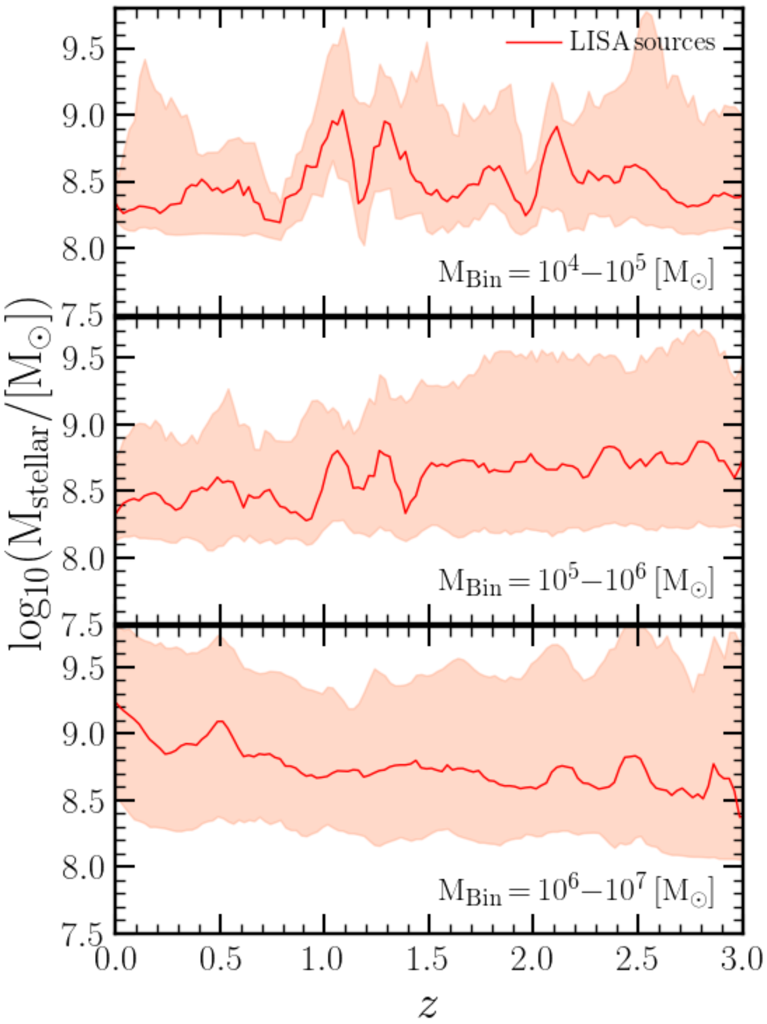


RESULTS



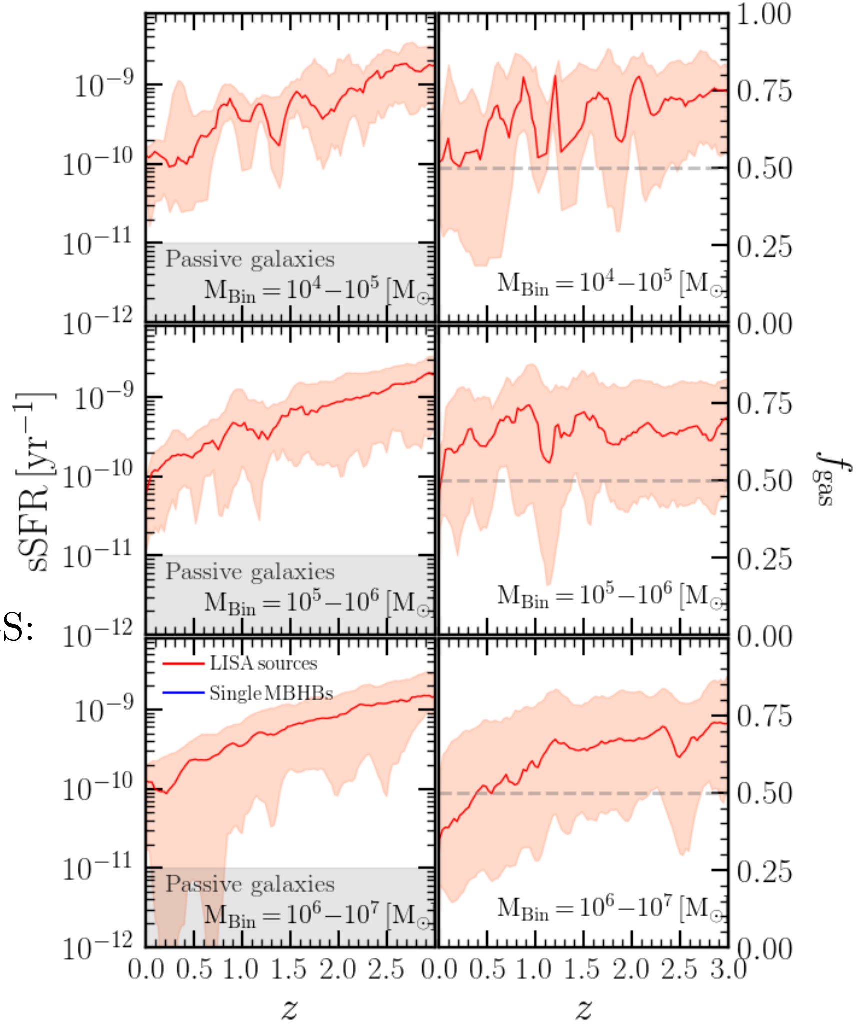
LISA MBHBs are hosted in **DWARF GALAXIES**

RESULTS



LISA MBHBs are hosted in **DWARF GALAXIES**

DWARF GALAXIES:
- **Star forming**
- **Gas rich**



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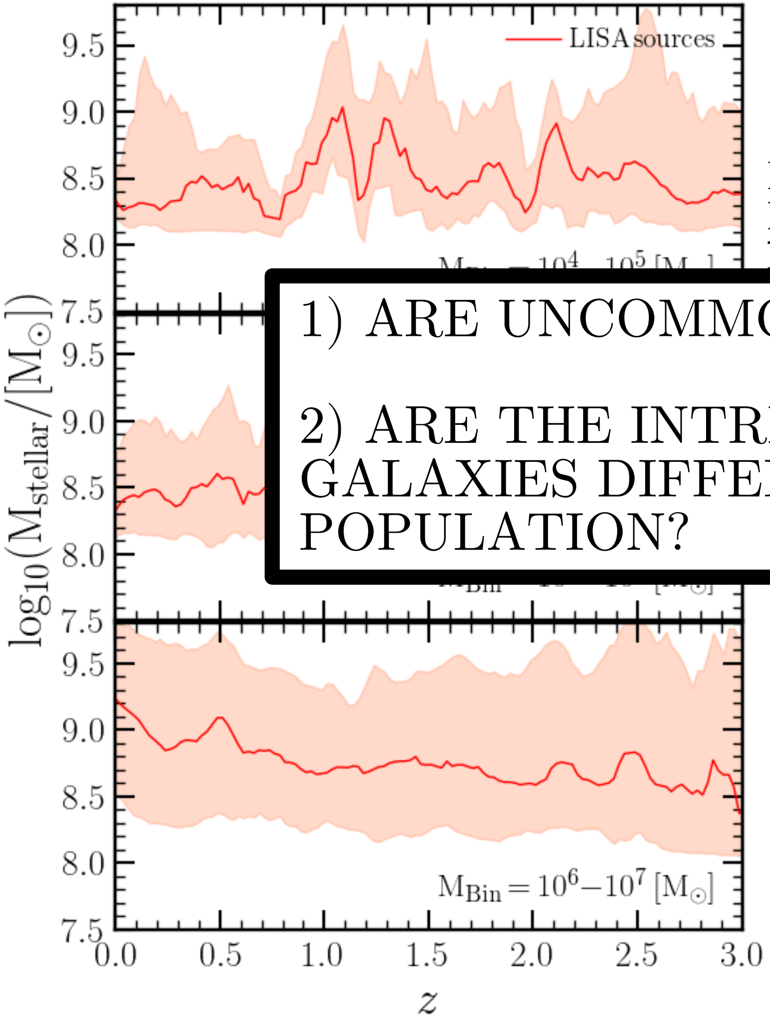


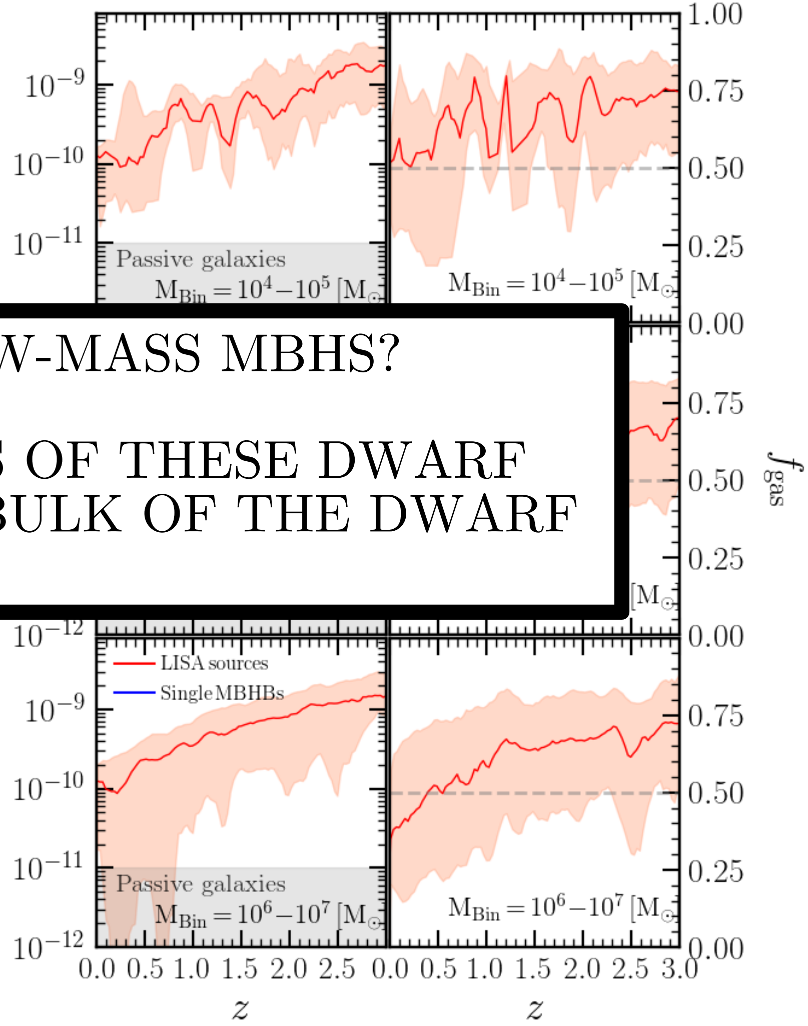
LISA MBHBs are hosted in **DWARF GALAXIES**

1) ARE UNCOMMON HOSTS FOR LOW-MASS MBHS?

2) ARE THE INTRINSIC PROPERTIES OF THESE DWARF GALAXIES DIFFERENT FROM THE BULK OF THE DWARF POPULATION?

DWARF GALAXIES:

- **Star forming**
- **Gas rich**



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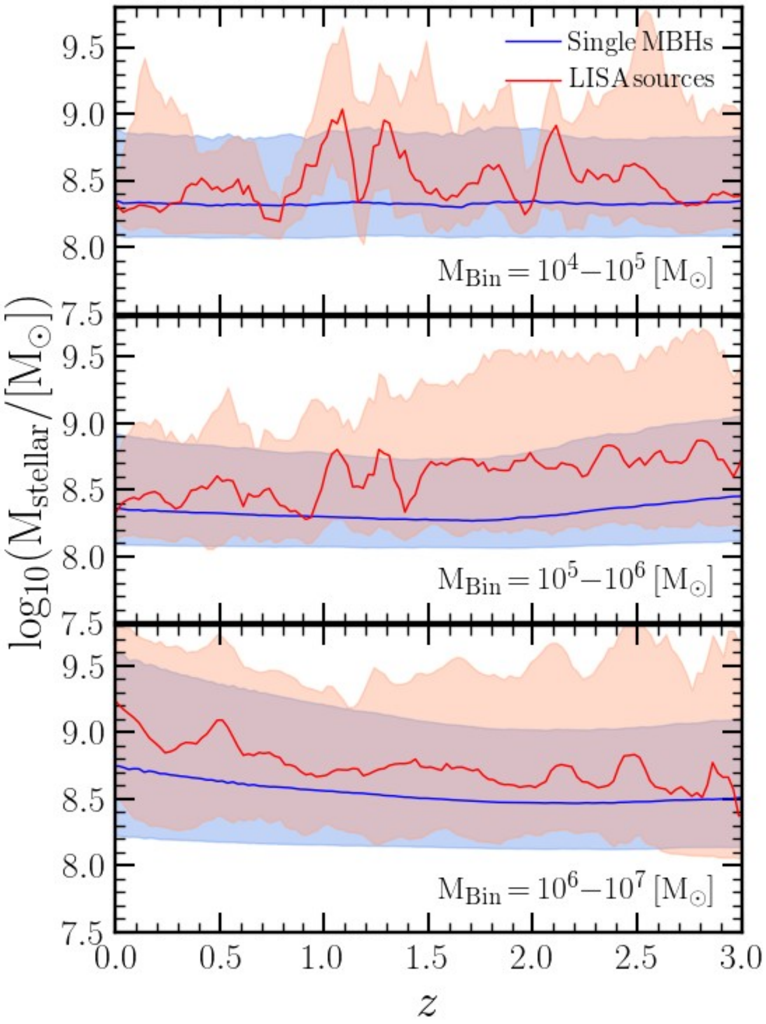

LISA MBHBs are hosted in **DWARF GALAXIES**

... but single low-mass MBHs as well

DWARF GALAXIES:
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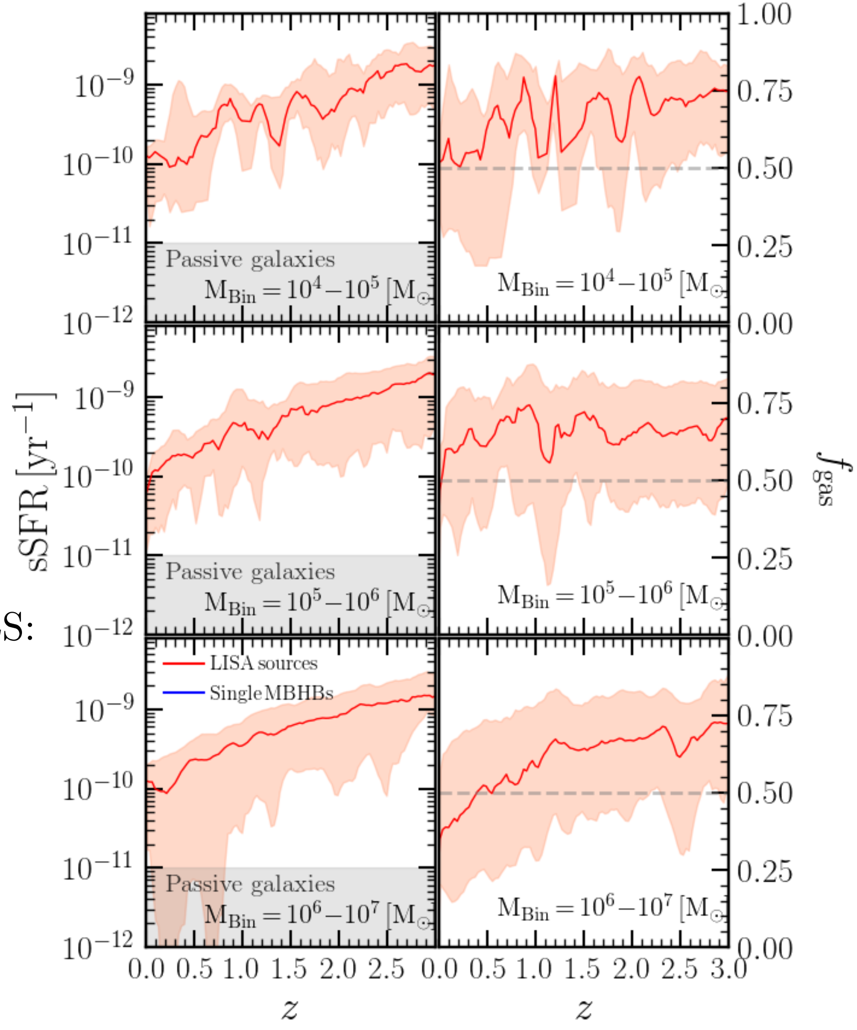

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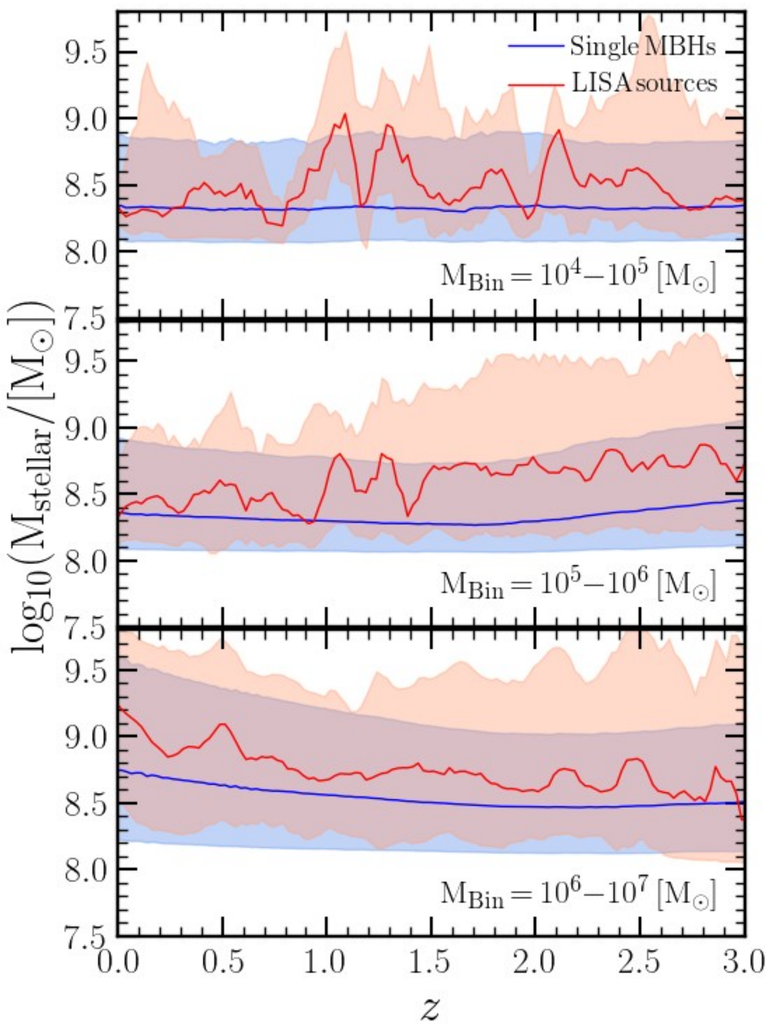

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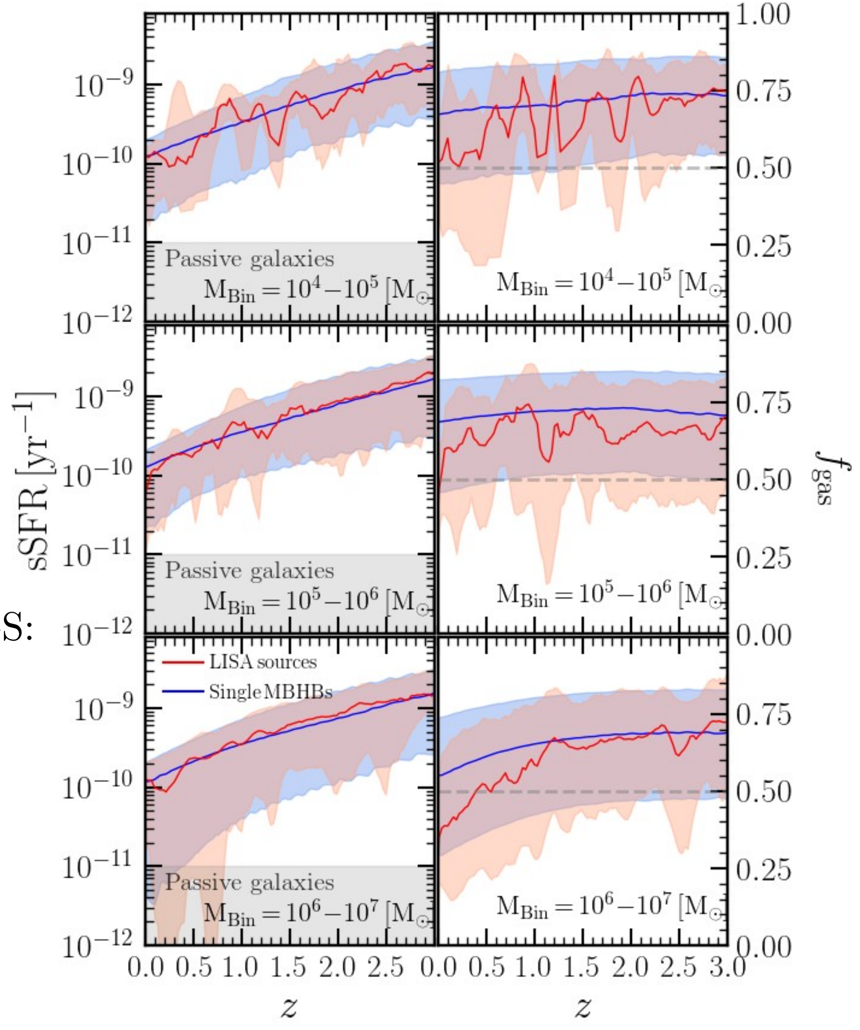

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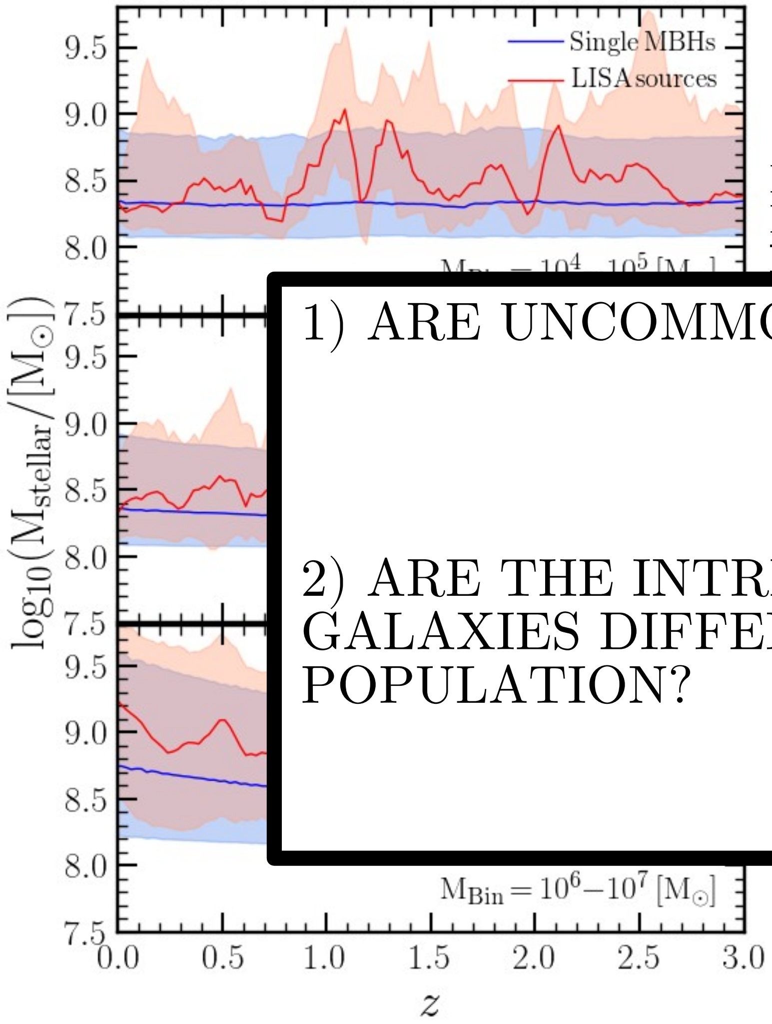

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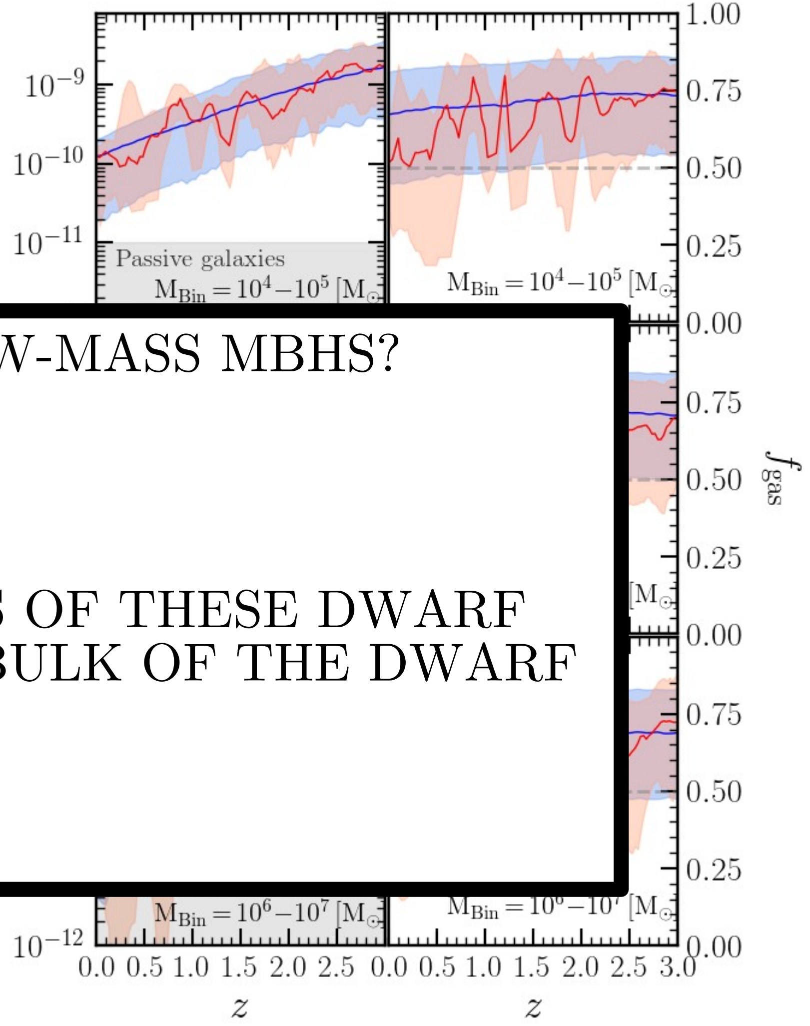


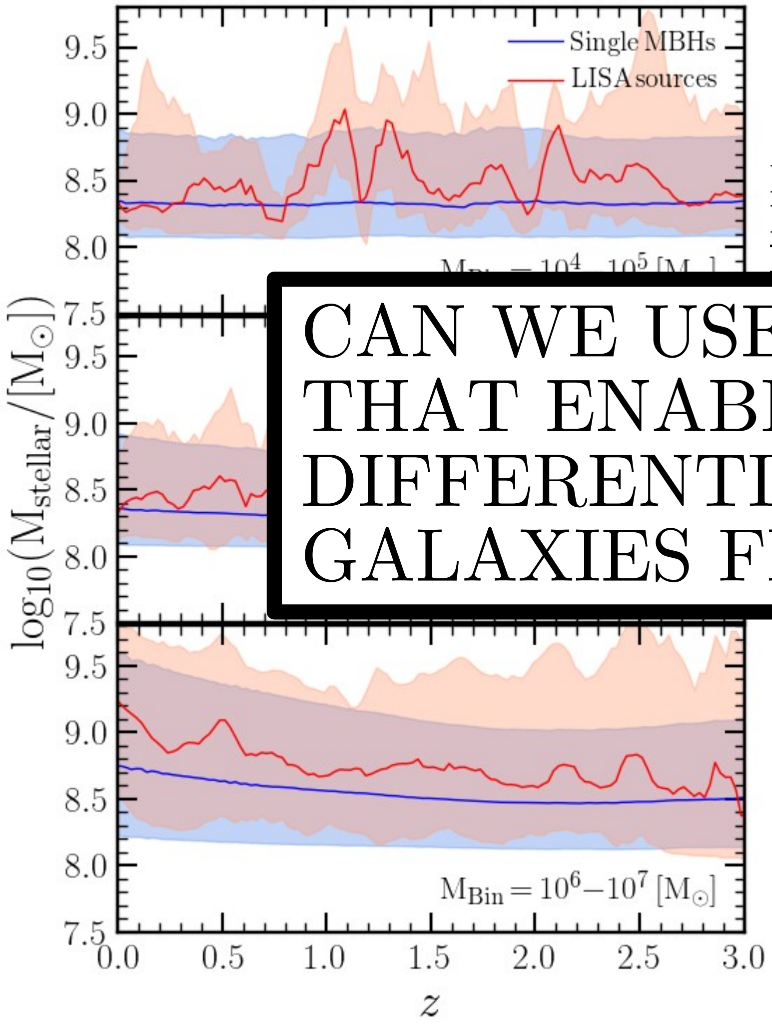
1) ARE UNCOMMON HOSTS FOR LOW-MASS MBHS?

NO

2) ARE THE INTRINSIC PROPERTIES OF THESE DWARF GALAXIES DIFFERENT FROM THE BULK OF THE DWARF POPULATION?

NO

RESULTS

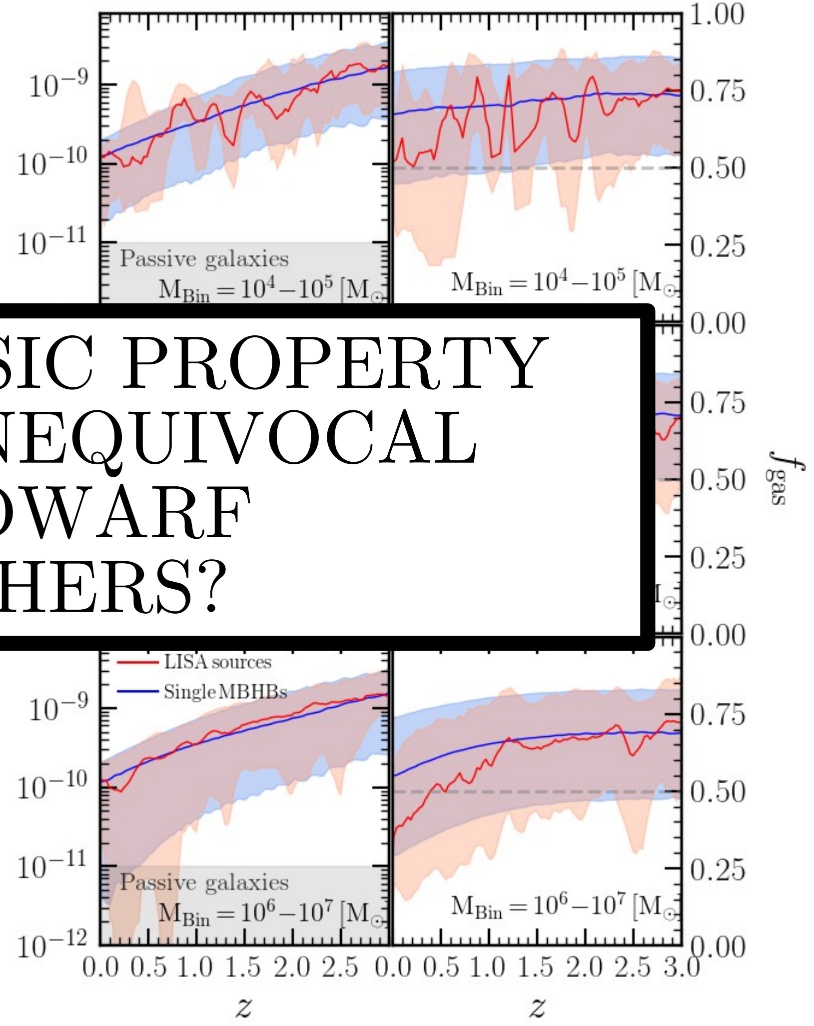


LISA MBHBs are hosted in **DWARF GALAXIES**

CAN WE USE AN EXTRINSIC PROPERTY THAT ENABLES US TO UNEQUIVOCAL DIFFERENTIATE THESE DWARF GALAXIES FROM THE OTHERS?

- **Star forming**
- **Gas rich**

... but single low-mass MBHs as well

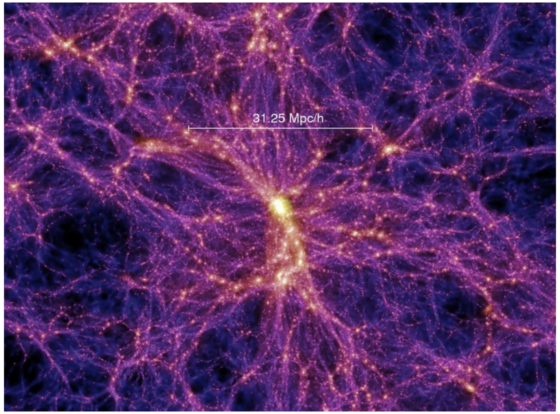


RESULTS

LISA MBHBS HOSTS
WILL BE **POST-MERGER GALAXIES**

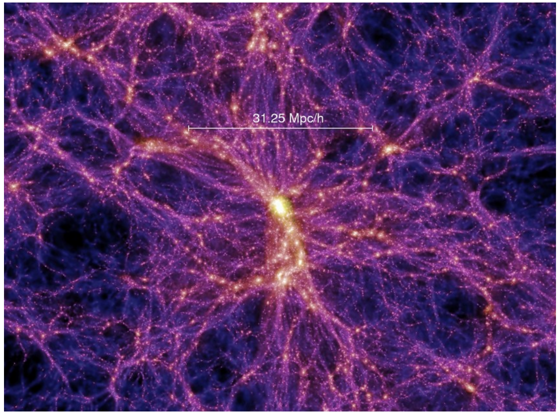
↓

THEY WILL DISPLAY
MERGER FEATURES



RESULTS

STREAMS
(visible time-scale 3 - 4 Gy)



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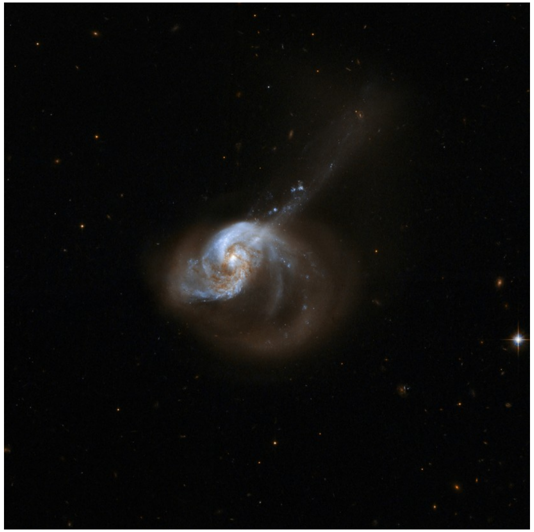
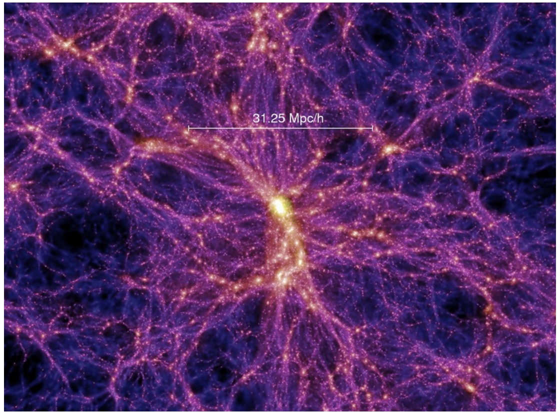


SHELLS
(visible time-scale 1.5 - 3 Gy)



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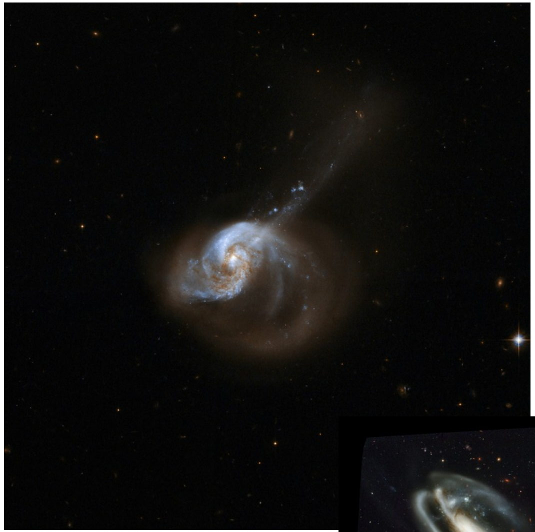
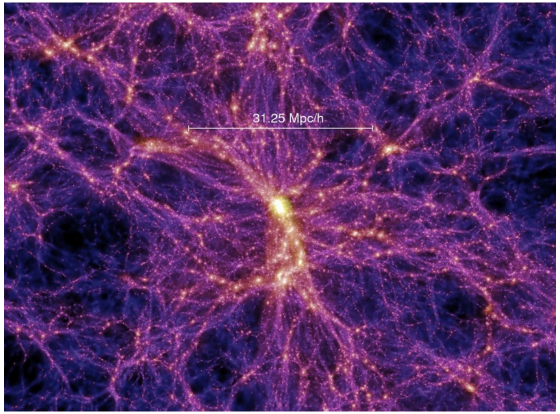


SHELLS
(visible time-scale 1.5 - 3 Gy)

TIDAL FEATURES
(visible time-scale 0.7 - 1 Gy)



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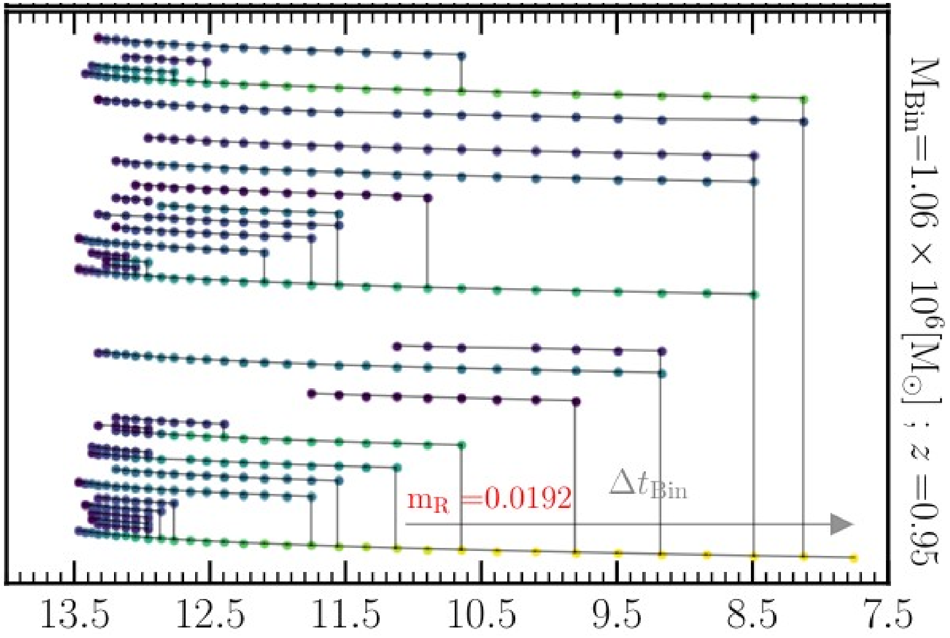
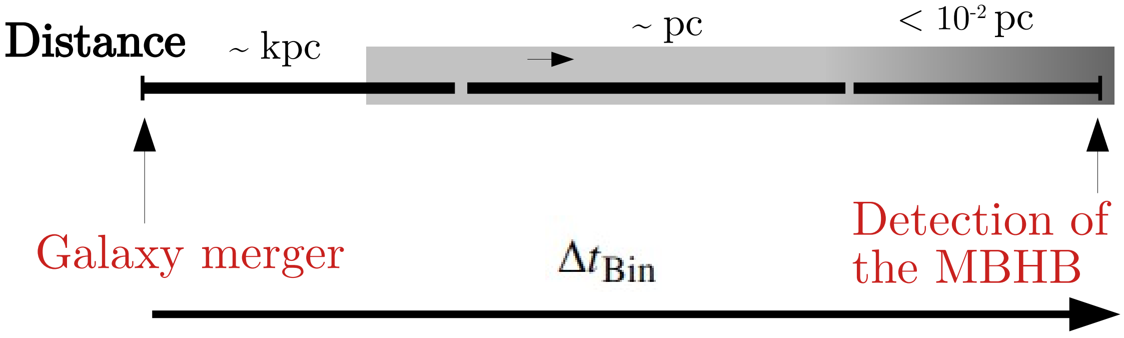


Studying the merger trees of LISA MBHB hosts



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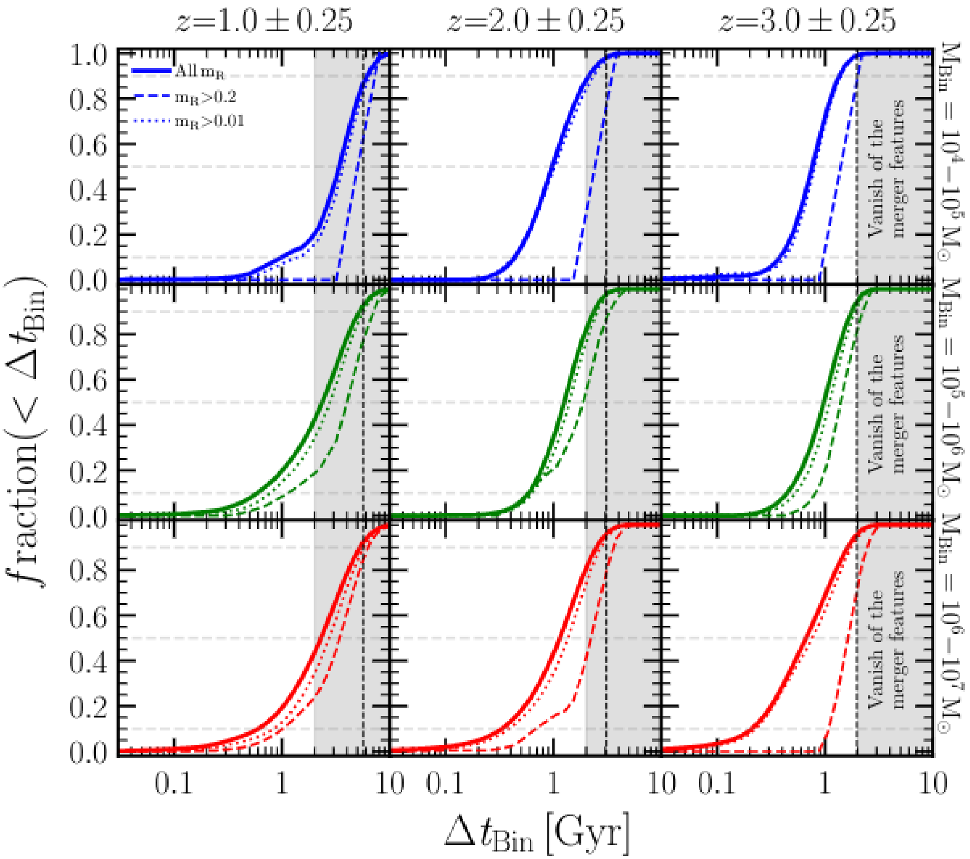

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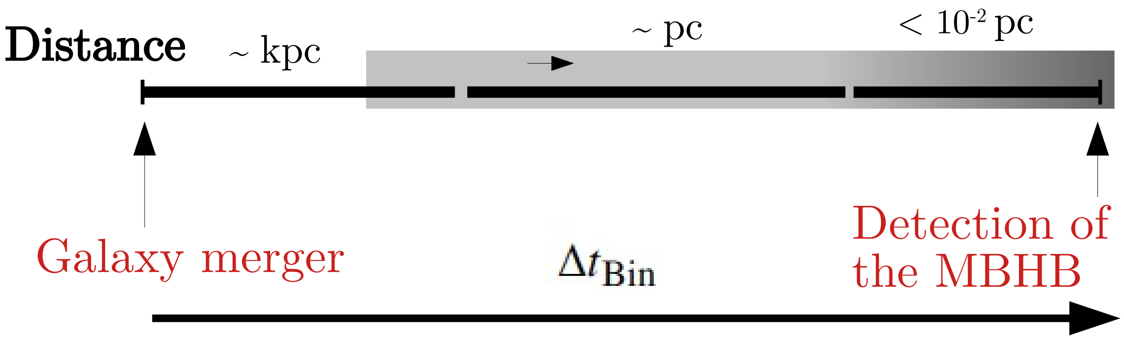
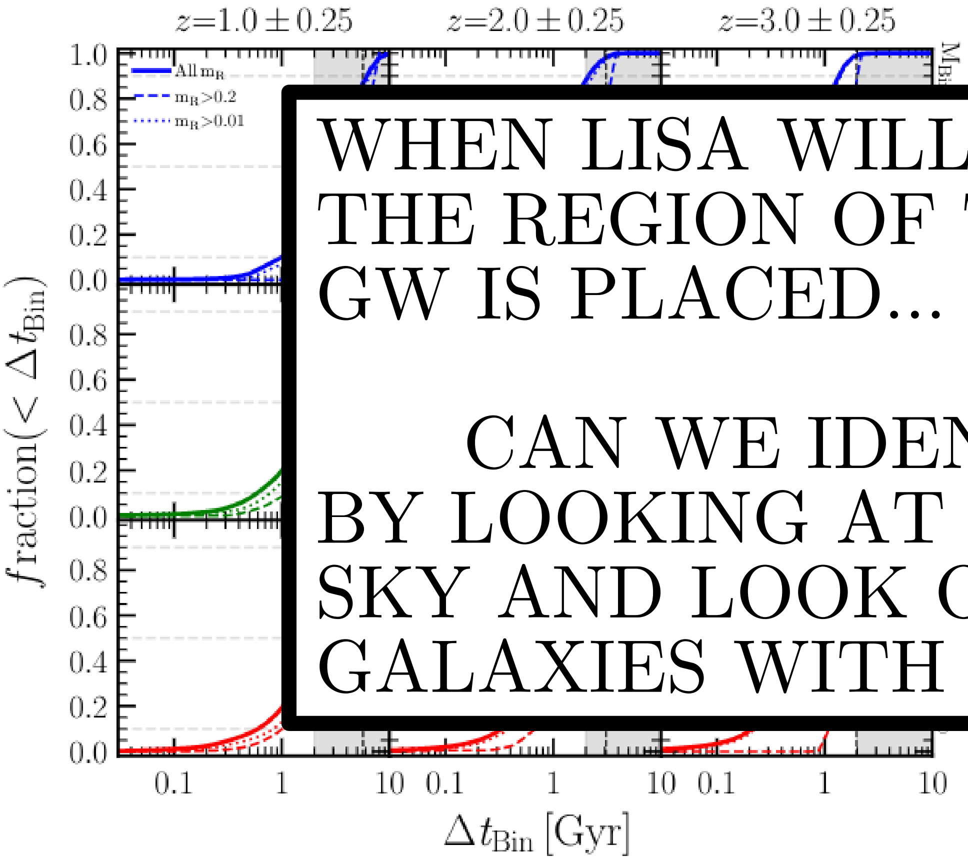


1) 90% of high-z hosts will display merger features

2) 10% of low-z hosts will display merger features

RESULTS



Studying the merger trees of LISA MBHB hosts

pc

tion of
BHB

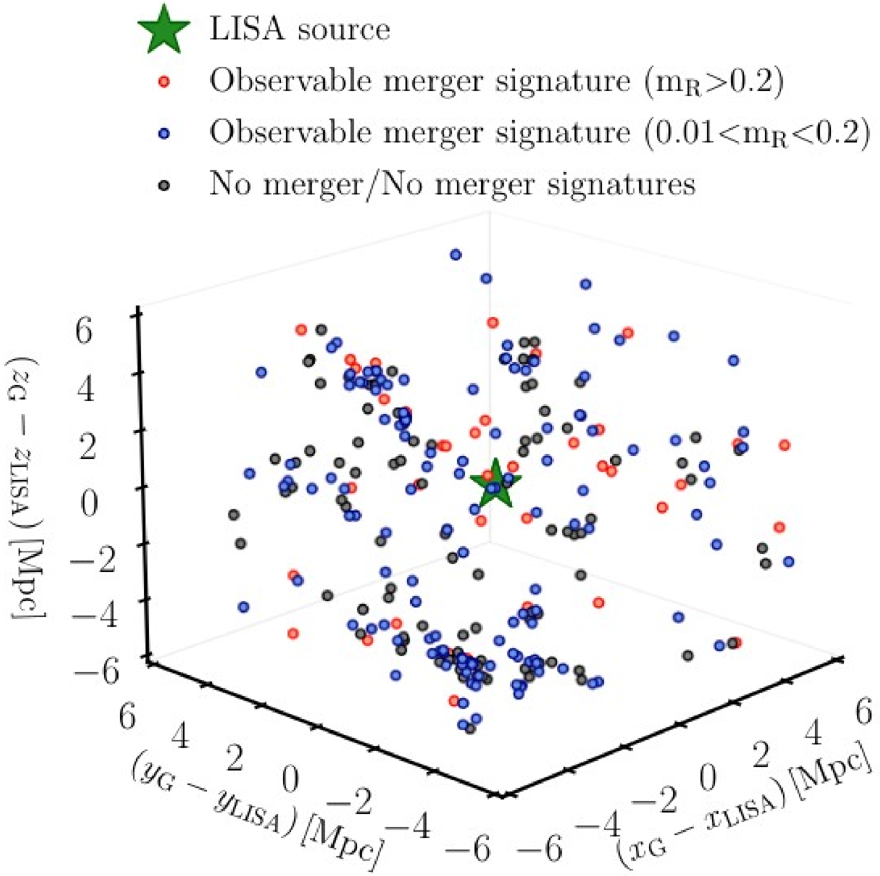
atures

2) 10% of low-z hosts will display merger features

WHEN LISA WILL DETECT/CONSTRAIN THE REGION OF THE SKY WHERE THE GW IS PLACED...

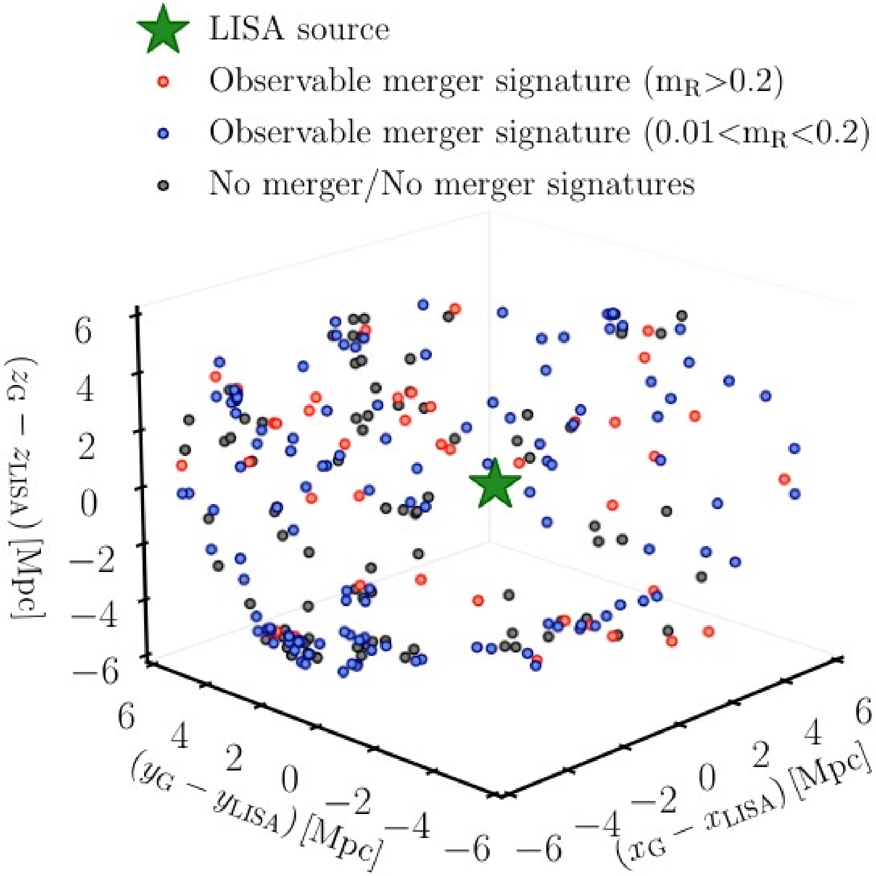
CAN WE IDENTIFY THE LISA HOSTS BY LOOKING AT THAT PART OF THE SKY AND LOOK ONLY FOR DWARF GALAXIES WITH MERGER FEATURES?

RESULTS



$M_{Bin}=3.91 \times 10^5 [M_\odot]$

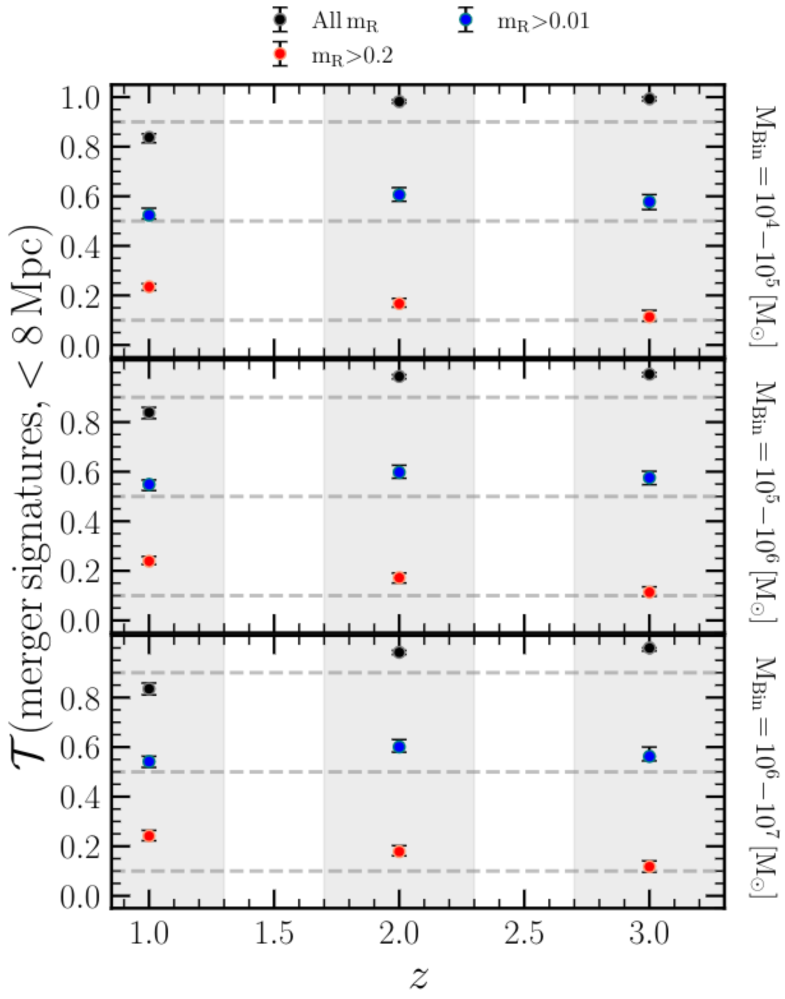
$z \sim 2.13$



$M_{Bin}=7.78 \times 10^6 [M_\odot]$

$z \sim 2.08$

RESULTS



All m_R
m_R>0.01
m_R>0.2
$\mathcal{T}$(merger signatures, < 8 Mpc)
1.0
0.8
0.6
0.4
0.2
0.0
$M_{Bin} = 10^4 - 10^5\,[M_\odot]$
$M_{Bin} = 10^5 - 10^6\,[M_\odot]$
$M_{Bin} = 10^6 - 10^7\,[M_\odot]$
1.0
1.5
2.0
2.5
3.0
z

CONCLUSIONS

1) LISA MBHBS will be placed in dwarf galaxies , being starforming and gas rich

2) LISA MBHBS will be placed in “standard galaxies”

3) LISA MBHBs will display merger features

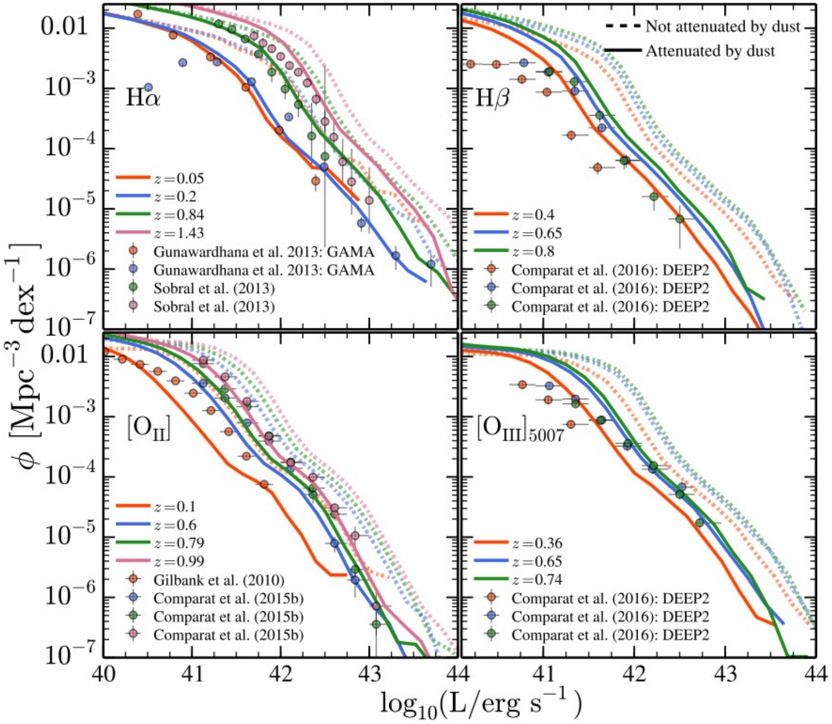
4) LISA MBHBs will display merger features but other normal dawrf galaxies as well

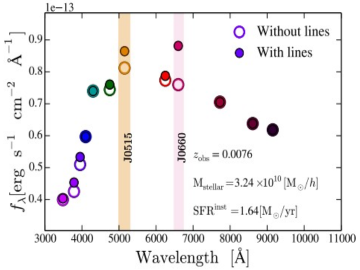
5) The unequivocal identification of LISA MBHBs trough galaxy properties or merger features will be CHALLENGING

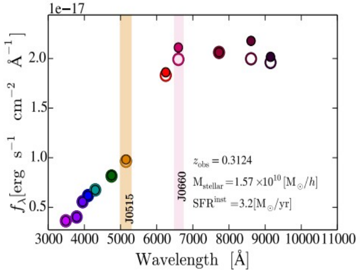
WHAT ABOUT GAEA?

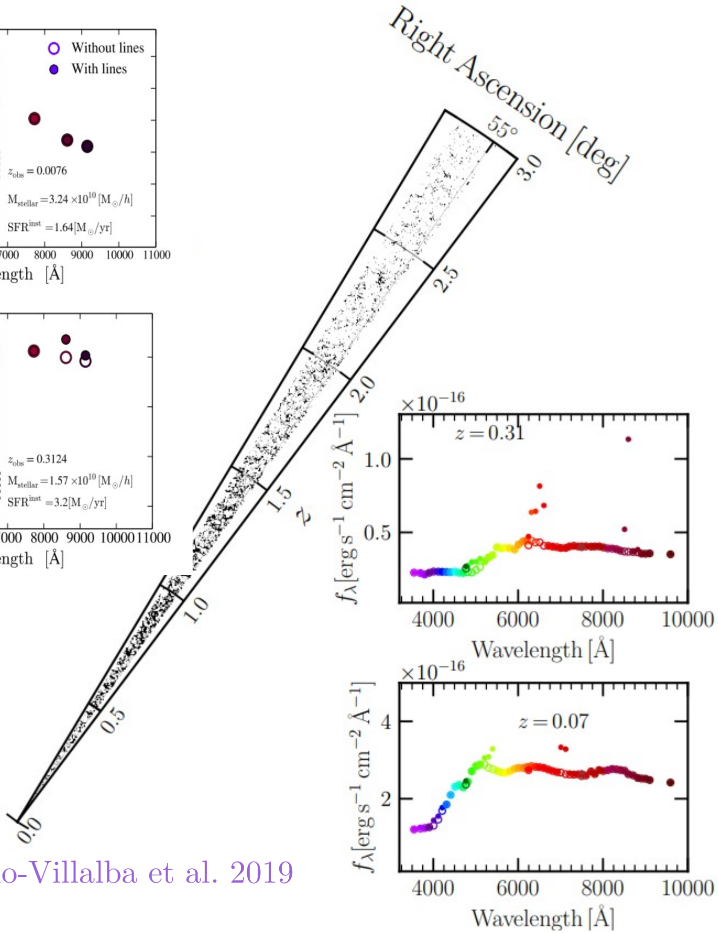
1) LIGHTCONES WITH EMISSION LINES

Izquierdo-Villalba & Angulo & Orsi & Bonoli & JPLUS collaboration 2019







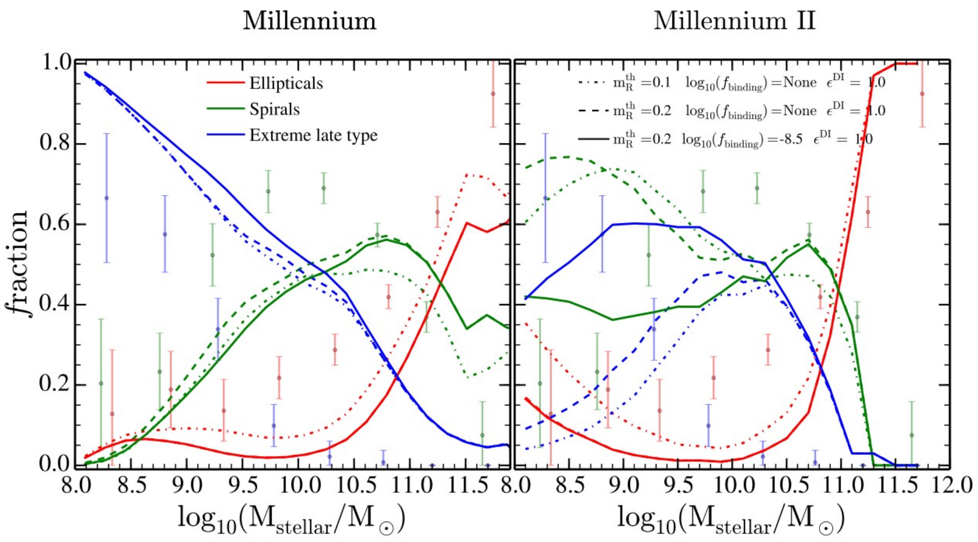


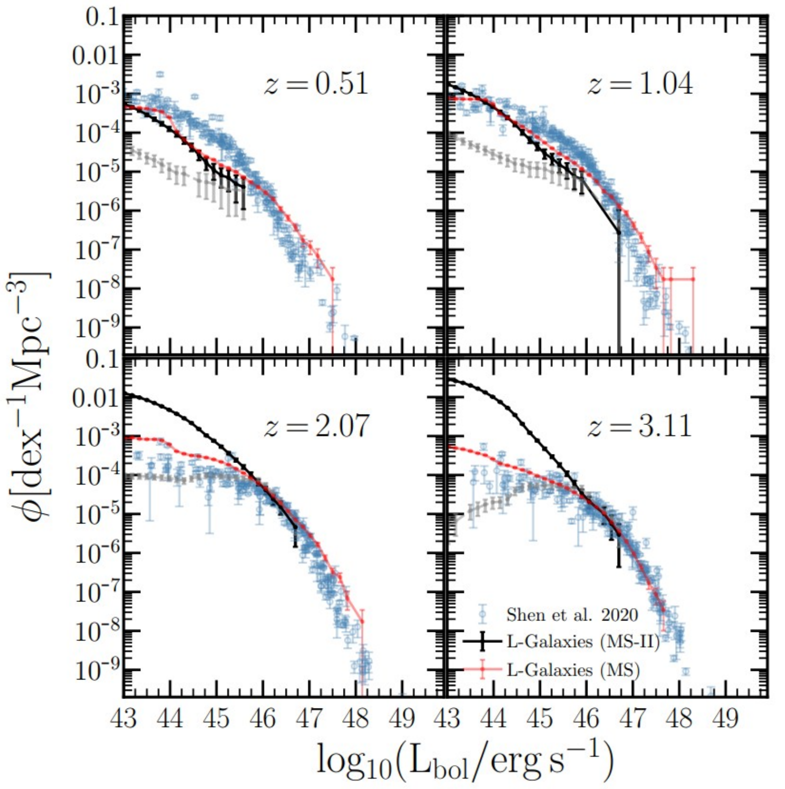
Izquierdo-Villalba et al. 2019

WHAT ABOUT GAEA?

2) CONVERGENCE ISSUES IN L-GALAXIES...

Izquierdo-Villalba et al. 2019





THANKS