

# Impact of feedback on haloes and large-scale structure

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Durham University

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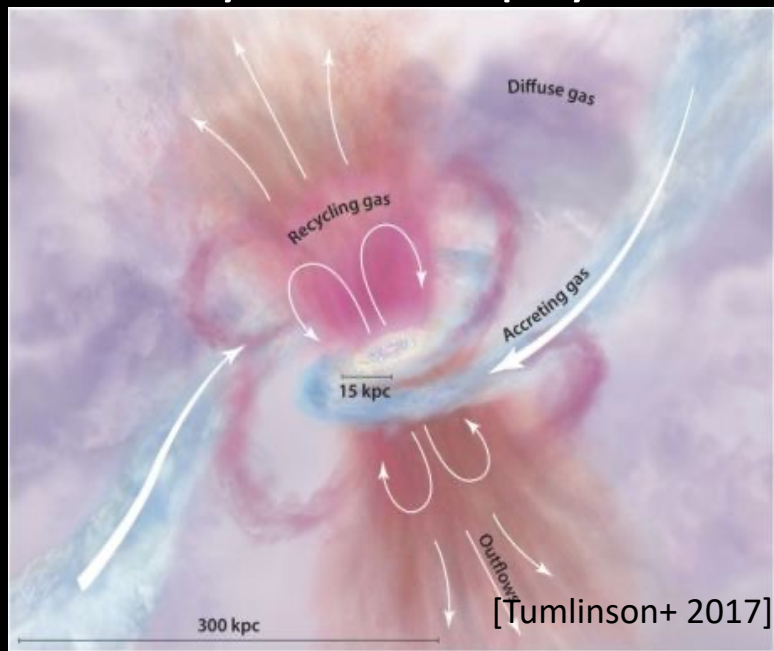


UK Research  
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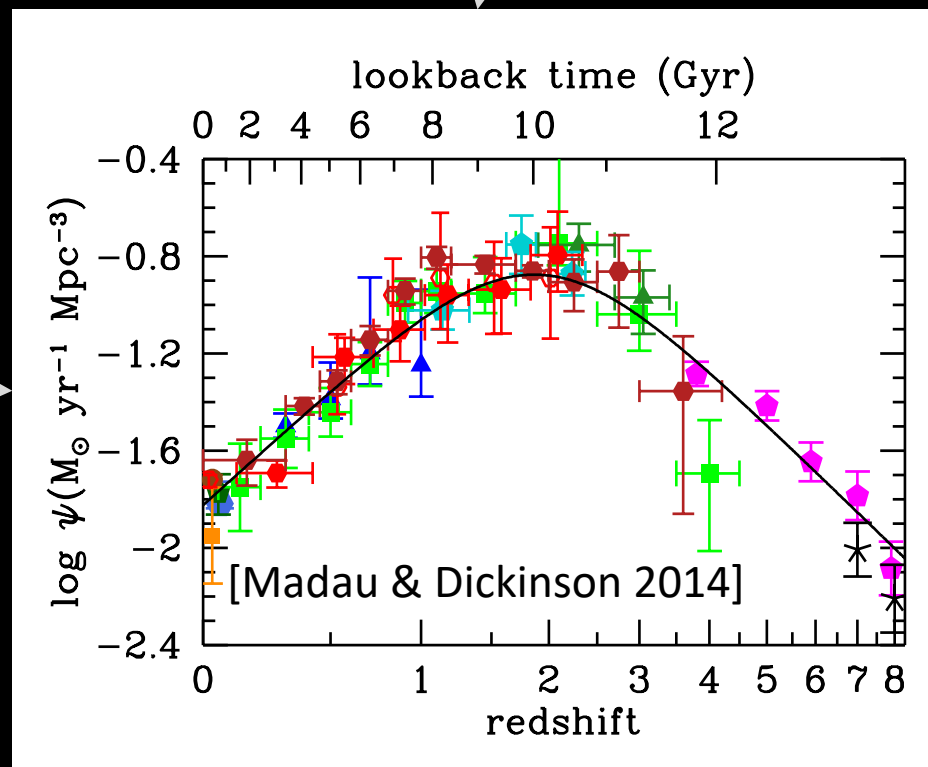
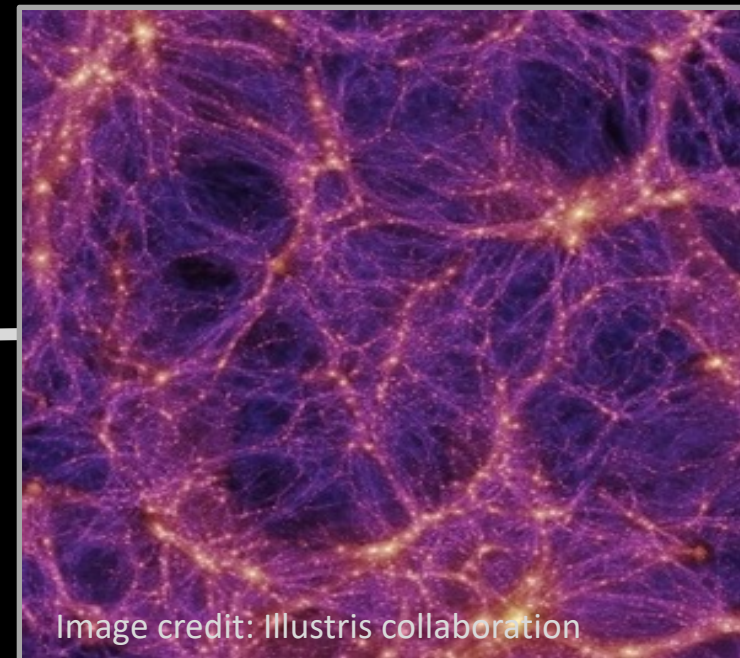
Simba Collaboration Workshop  
1<sup>st</sup> May 2023



# Baryonic astrophysics



# Background cosmology





## Structure of halos

- Density profiles  
[e.g. Schaller+ 2015, Pillepich+ 2018b; Macciò + 2020]
- Shape  
[e.g. Chua+ 2019, 2021; Cataldi+ 2021]
- Number of subhalos  
[e.g. Fattahi+ 2016; Sawala+ 2016; Despali & Vegetti 2017]

## Star formation history

[e.g. van de Voort+ 2011; Vogelsberger+ 2013; McCarthy+ 2017; Weinberger+ 2017; Choi+ 2017; 2018; Salcido+ 2018, 2020]

# Feedback

## Large-scale structure

- Cluster count cosmology  
[e.g. Debackere+ 2020, 2021]
- Void statistics  
[e.g. Pallas+ 2017]
- Matter power spectrum  
[e.g. Hellwing+ 2016; Barreira+ 2019; van Daalen+ 2020]
- Matter bispectrum [Foreman+ 2020]

## CGM/IGM

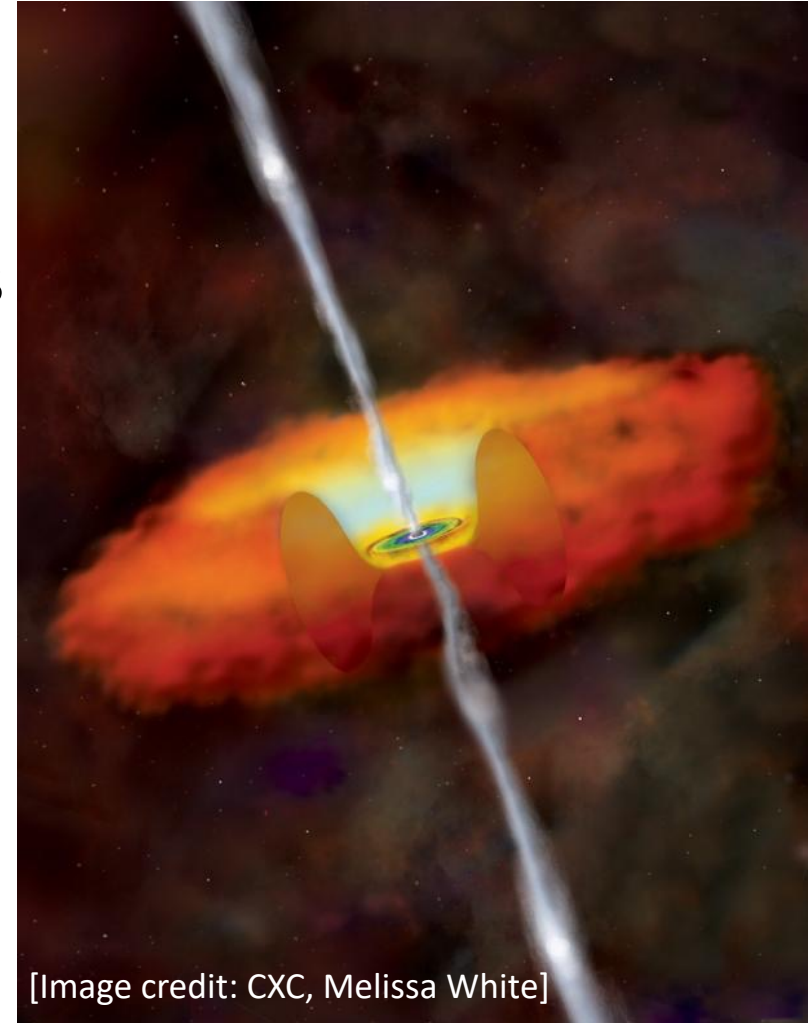
[e.g. Turner+ 2014, 2017; Nelson+ 2015, 2017; Suresh+ 2015; Keating+ 2016; Kauffmann+ 2017; Sorini+ 2018, 2020; Martin+2019, Fielding+ 2020]

# Effect of baryons on halos and LSS in the Simba simulation

## Stellar feedback

SN + stellar winds scaling relations  
based on FIRE zoom-in simulations

[Muratov+ 2015; Anglés-Alcázar+ 2017b]



[Image credit: CXC, Melissa White]

# Effect of baryons on halos and LSS in the Simba simulation

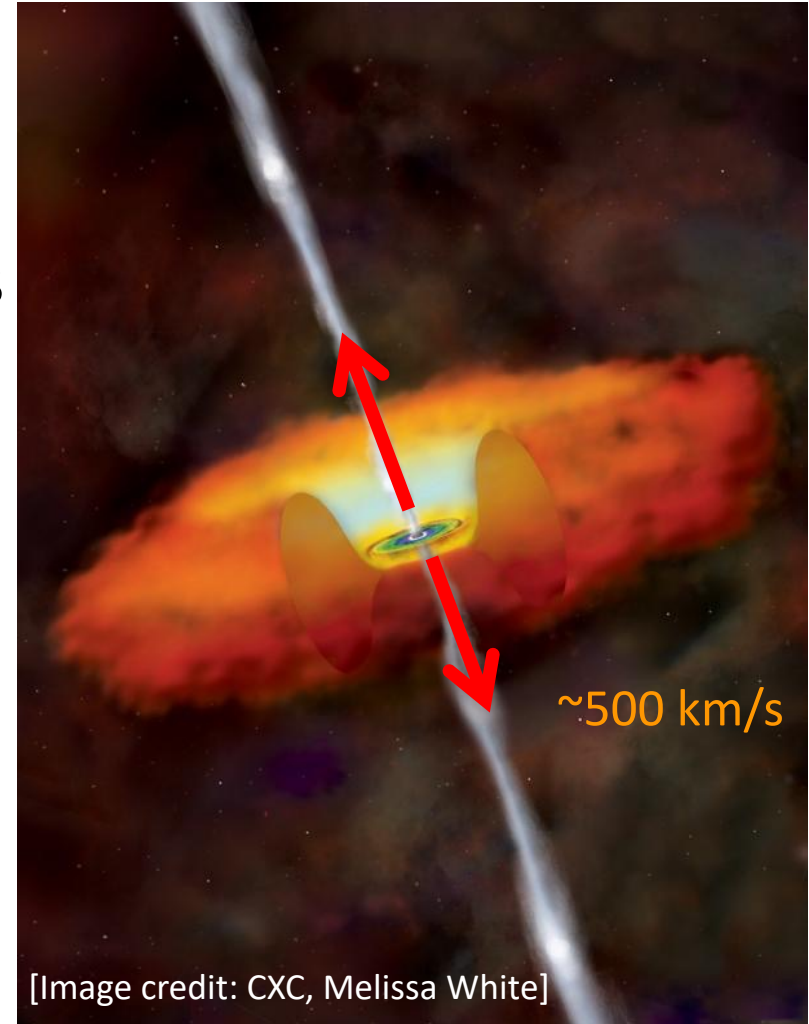
**Stellar feedback**

SN + stellar winds scaling relations  
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**AGN feedback**



**AGN WINDS**



[Image credit: CXC, Melissa White]

# Effect of baryons on halos and LSS in the Simba simulation

**Stellar feedback**

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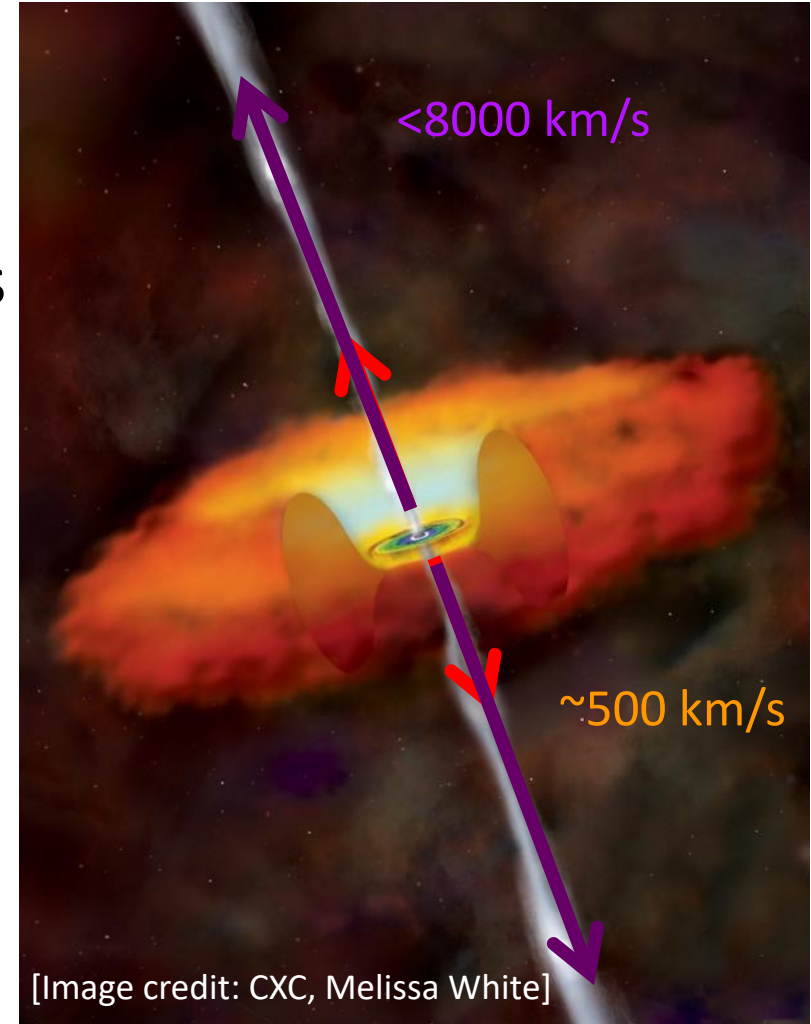
**AGN feedback**



AGN WINDS

JETS

$$M_{\text{BH}} > 10^{7.5} M_{\text{Sun}} \text{ \& } f_{\text{Edd}} < 0.2$$



# Effect of baryons on halos and LSS in the Simba simulation

## Stellar feedback

SN + stellar winds scaling relations  
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## AGN feedback

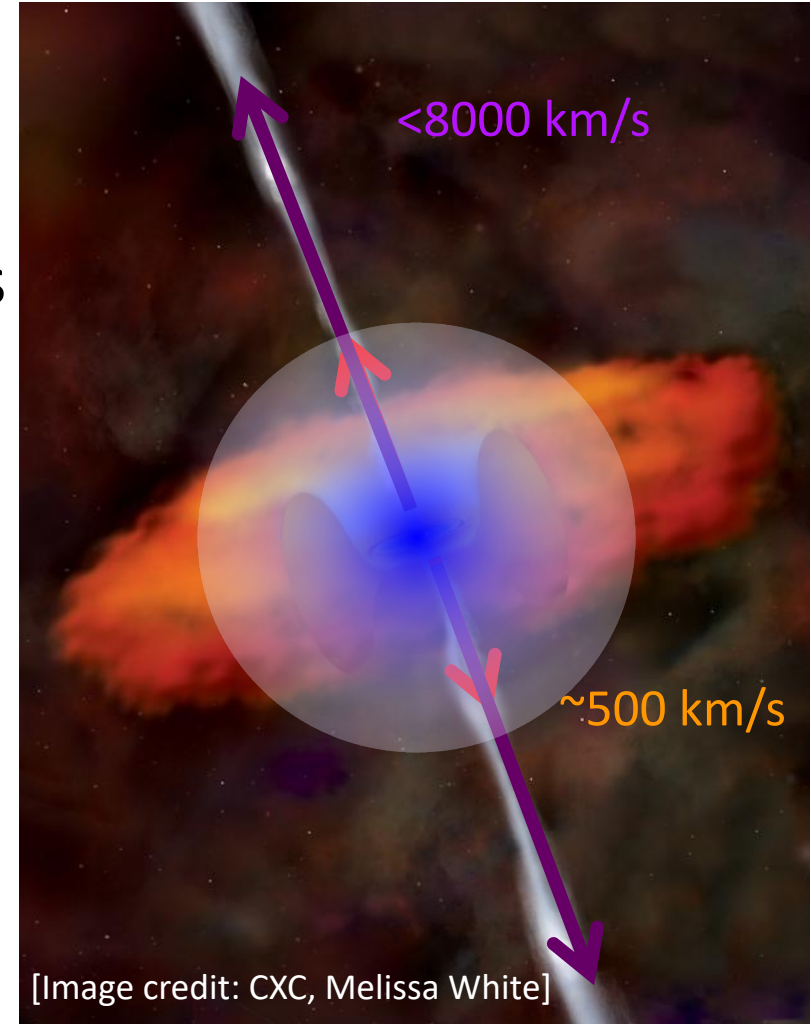
AGN WINDS

JETS

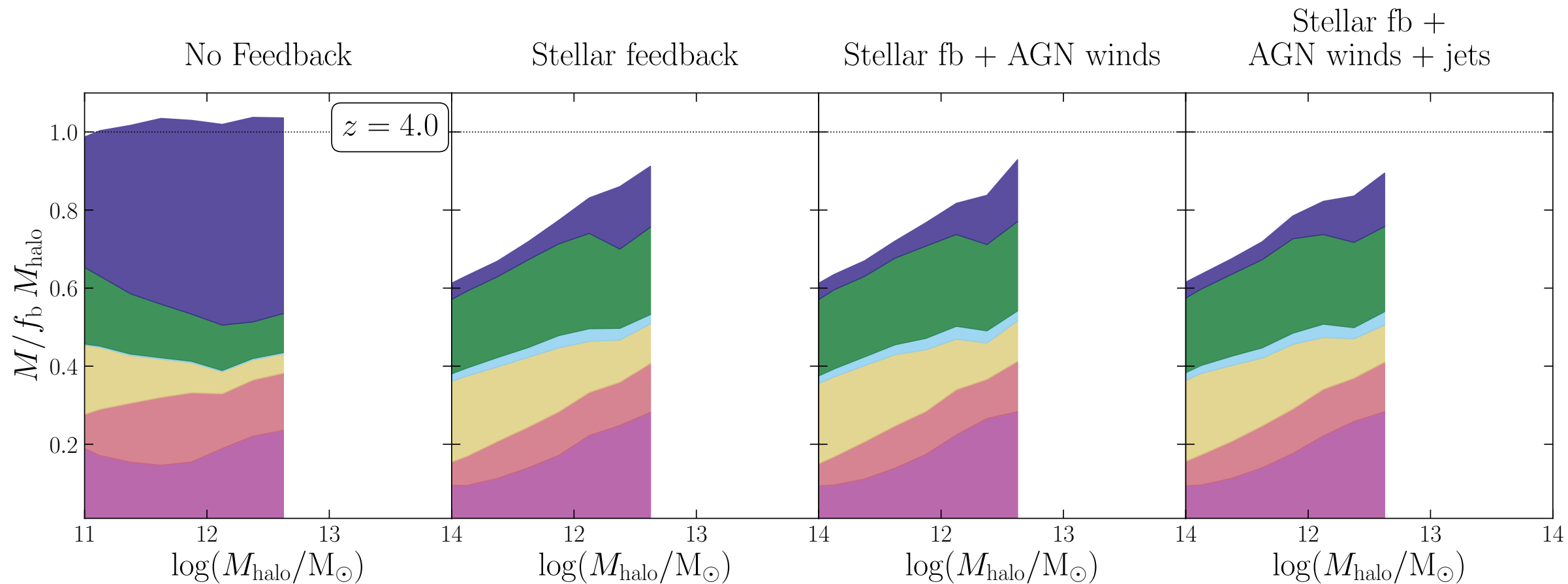
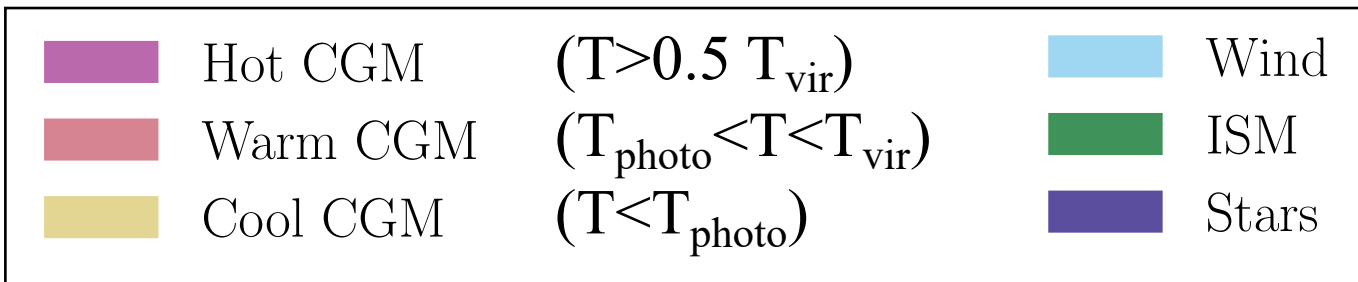
$M_{\text{BH}} > 10^{7.5} M_{\text{Sun}}$  &  $f_{\text{Edd}} < 0.2$

X-RAY HEATING

$M_{\text{BH}} > 10^{7.5} M_{\text{Sun}}$  &  $f_{\text{Edd}} < 0.2$  &  $f_{\text{gas}} < 0.2$

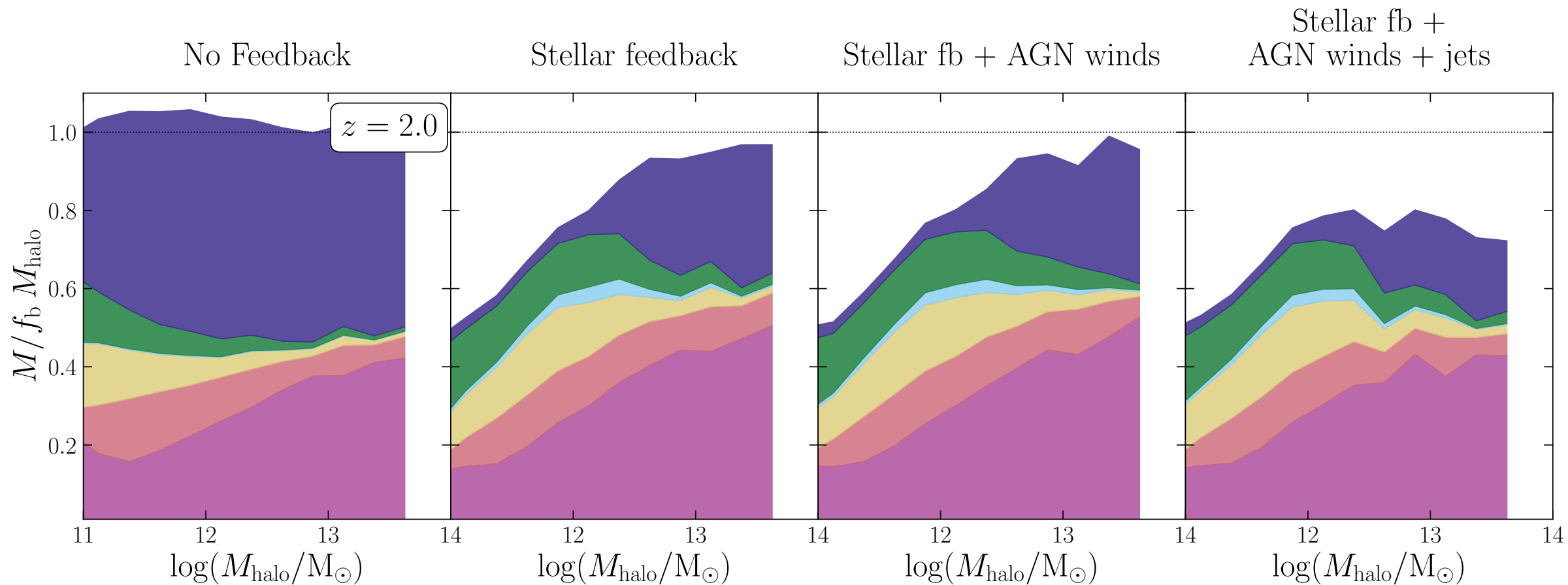
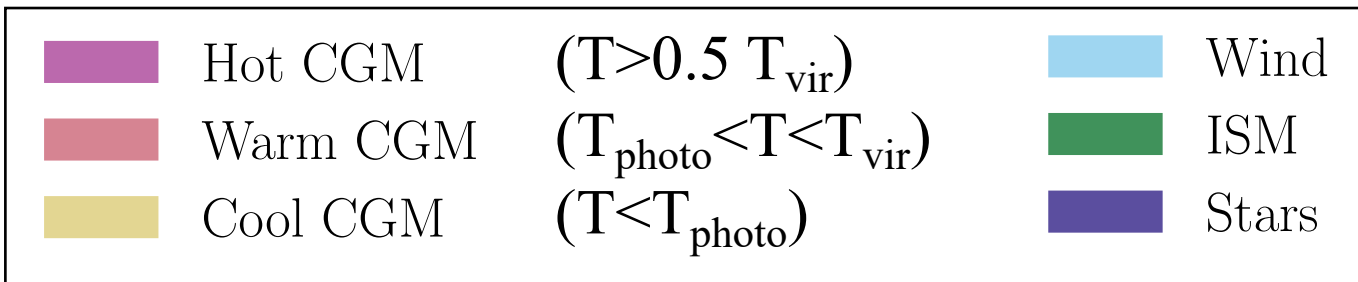


# Feedback decreases the baryon mass fraction

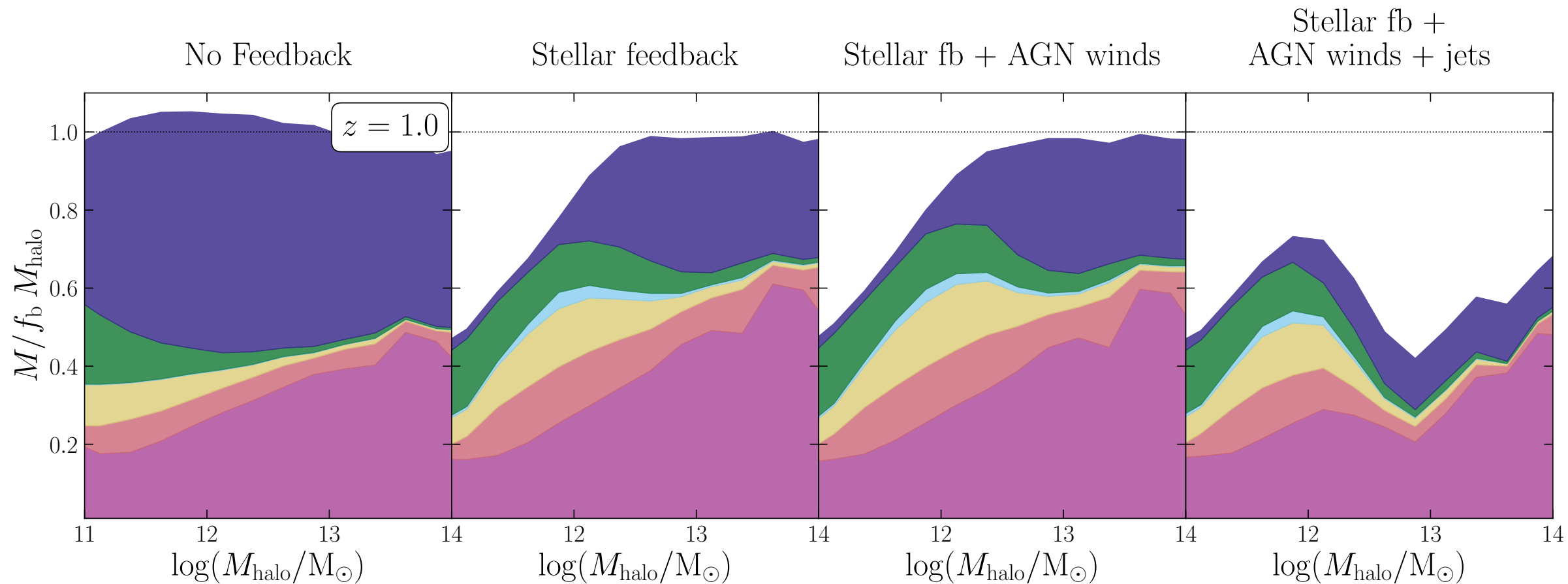
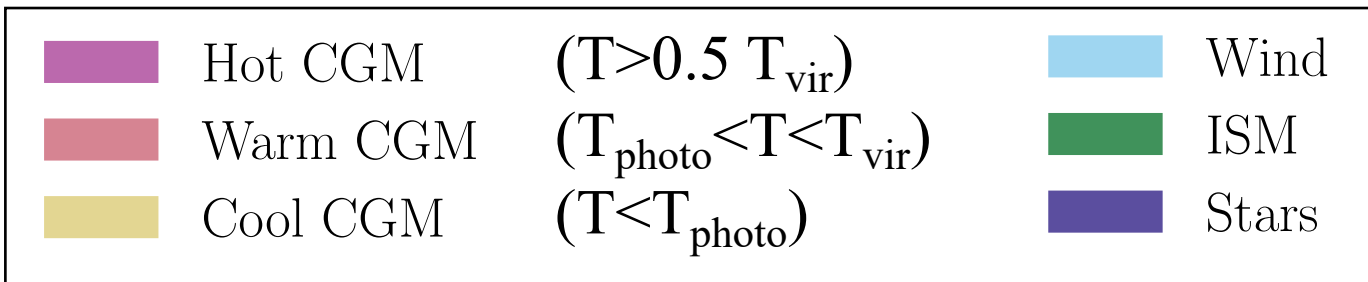




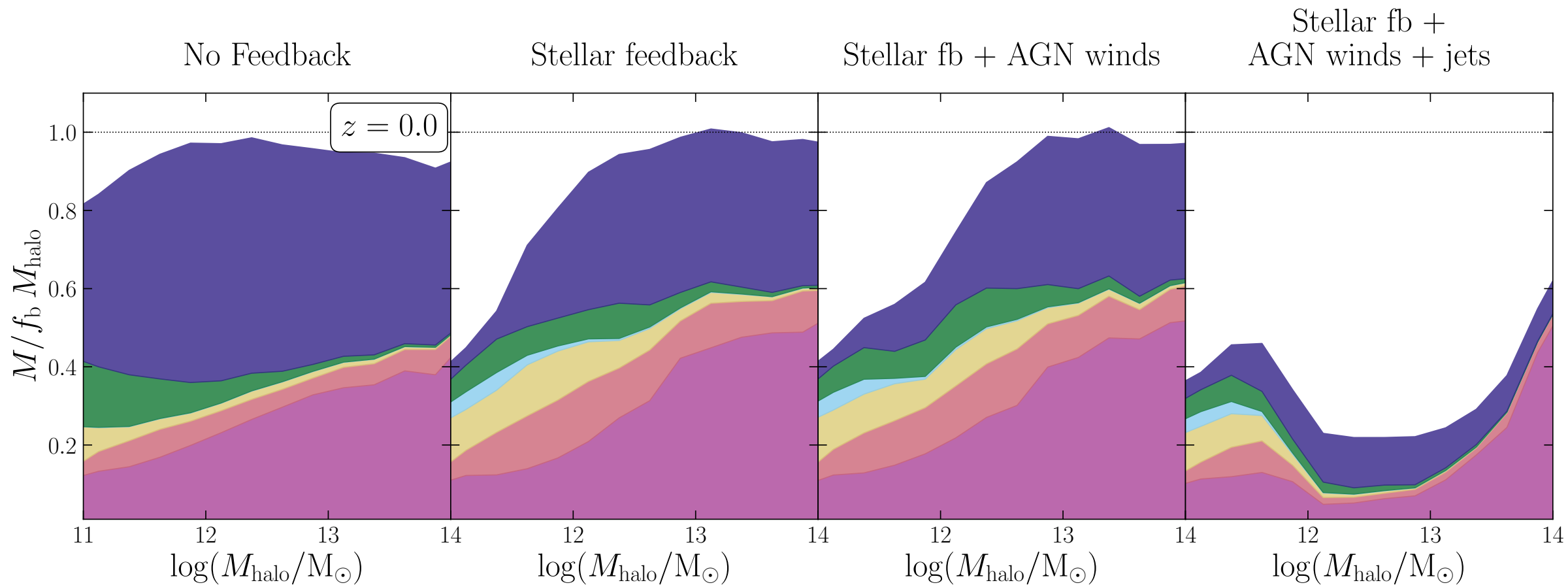
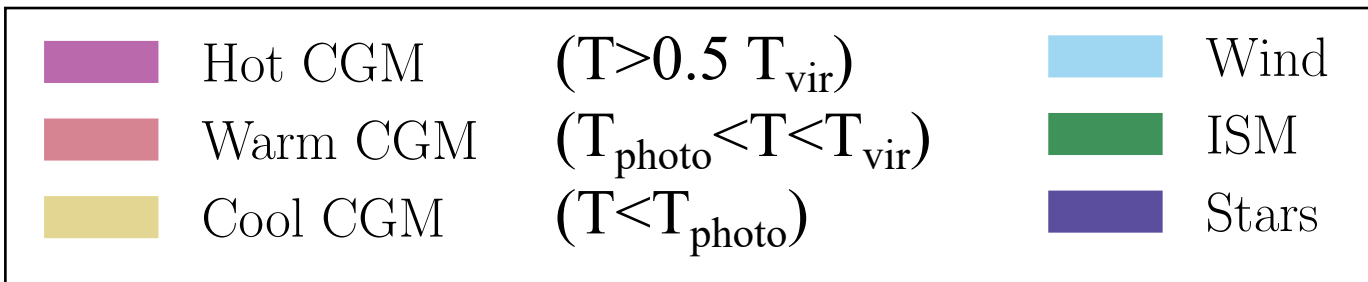
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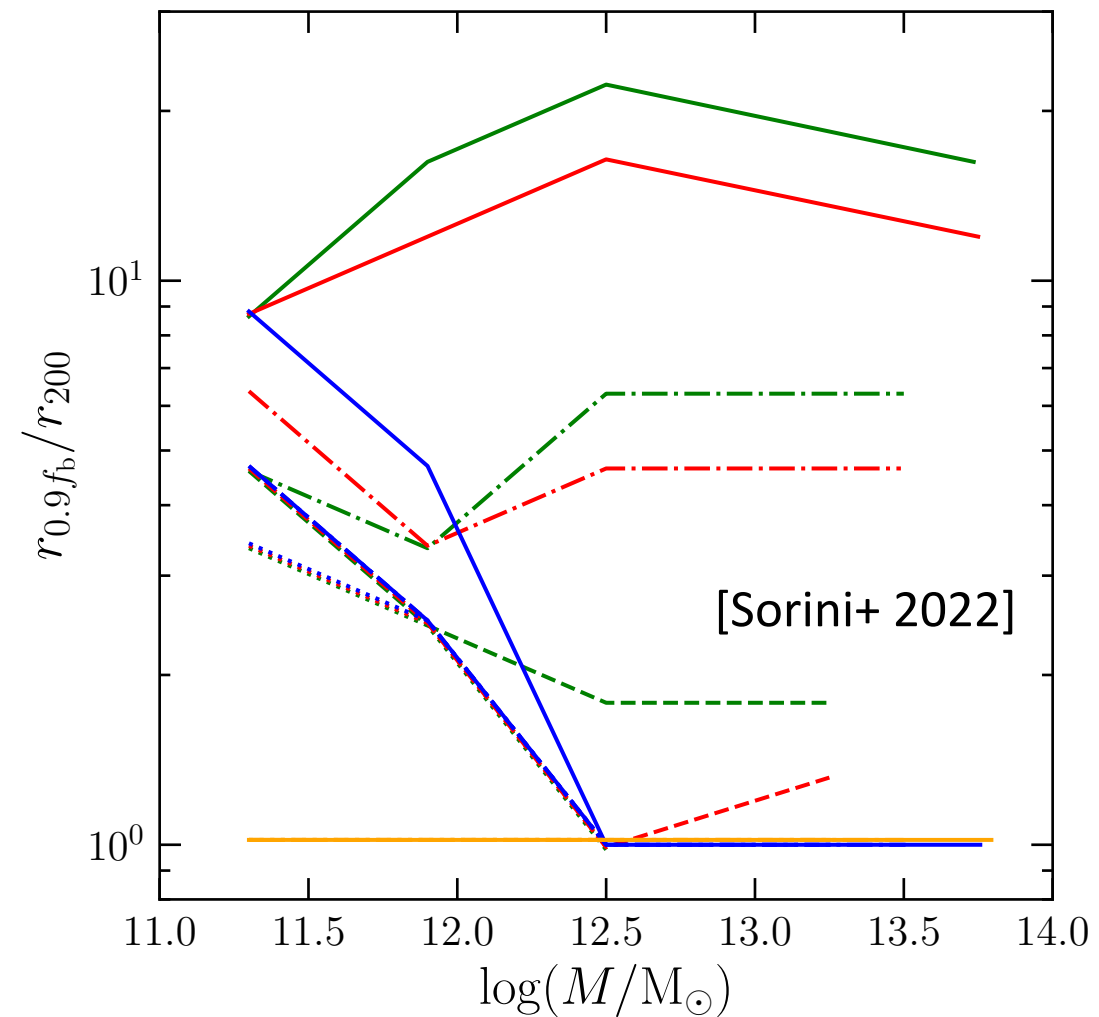
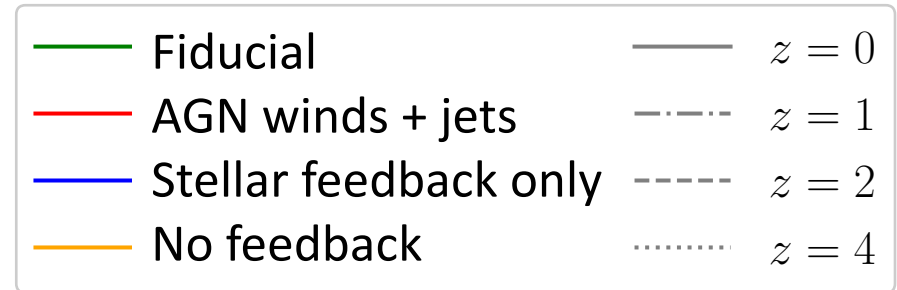
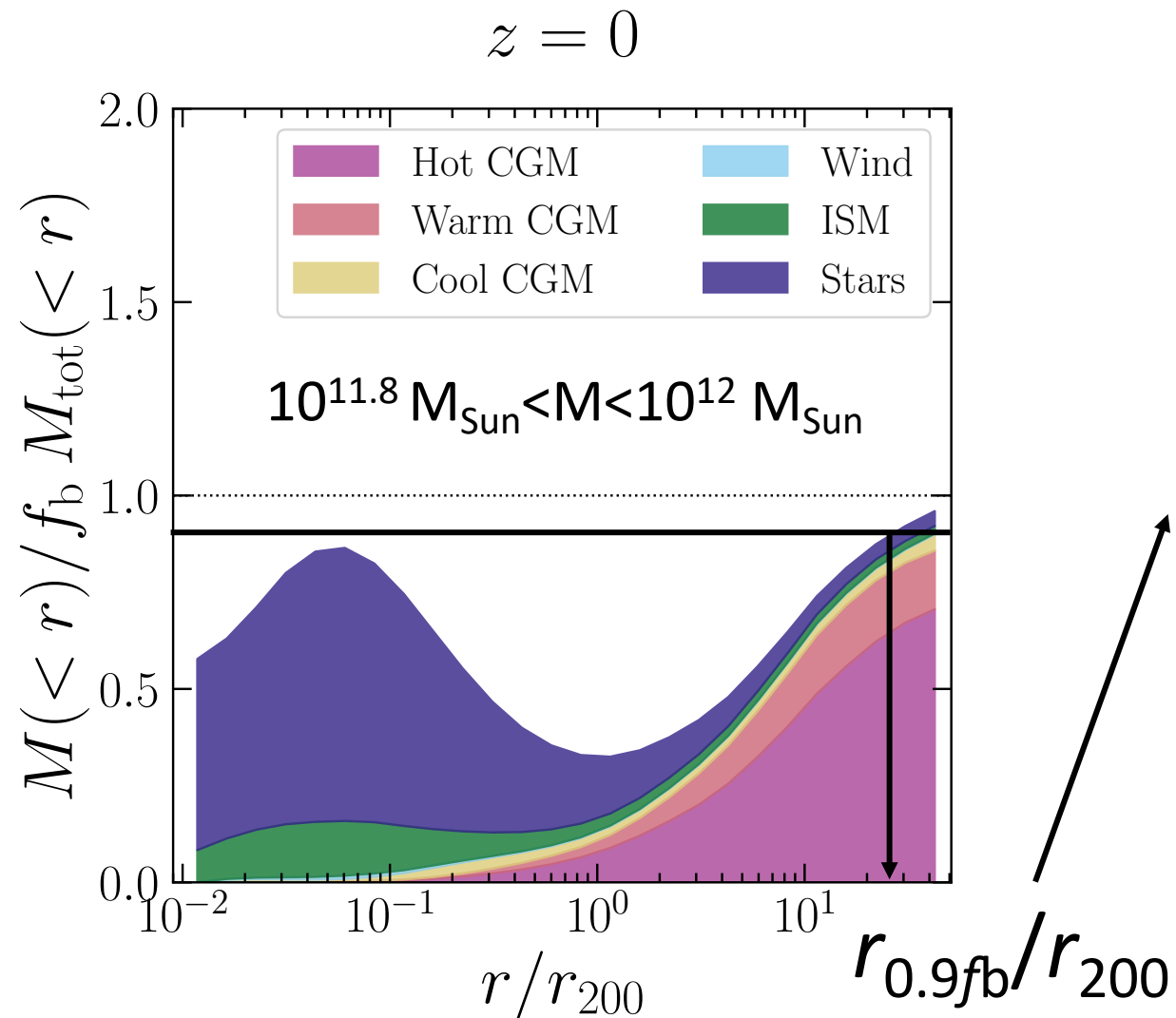
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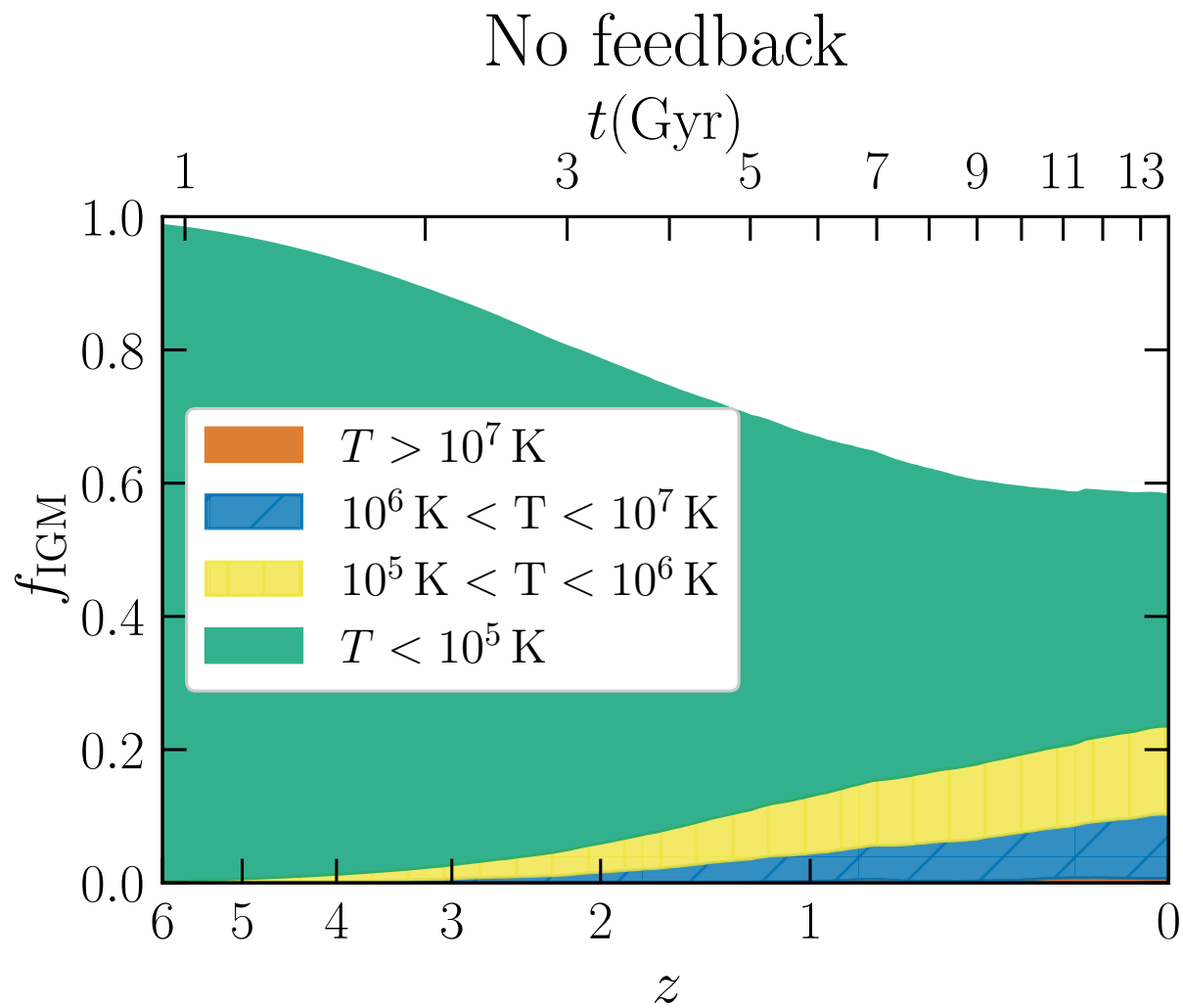


# AGN jets push baryons out to $\sim 20 r_{200}$ by $z=0$

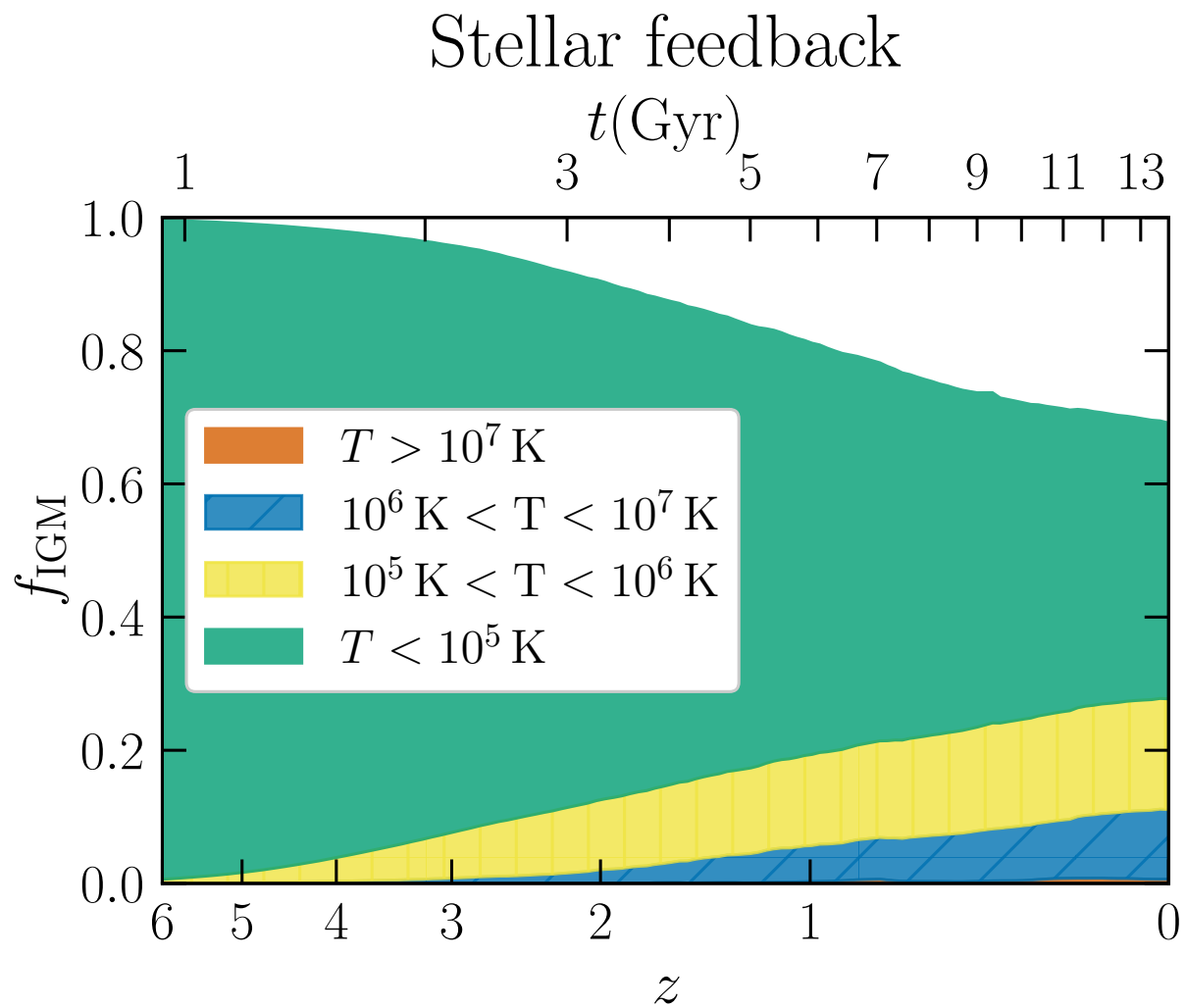




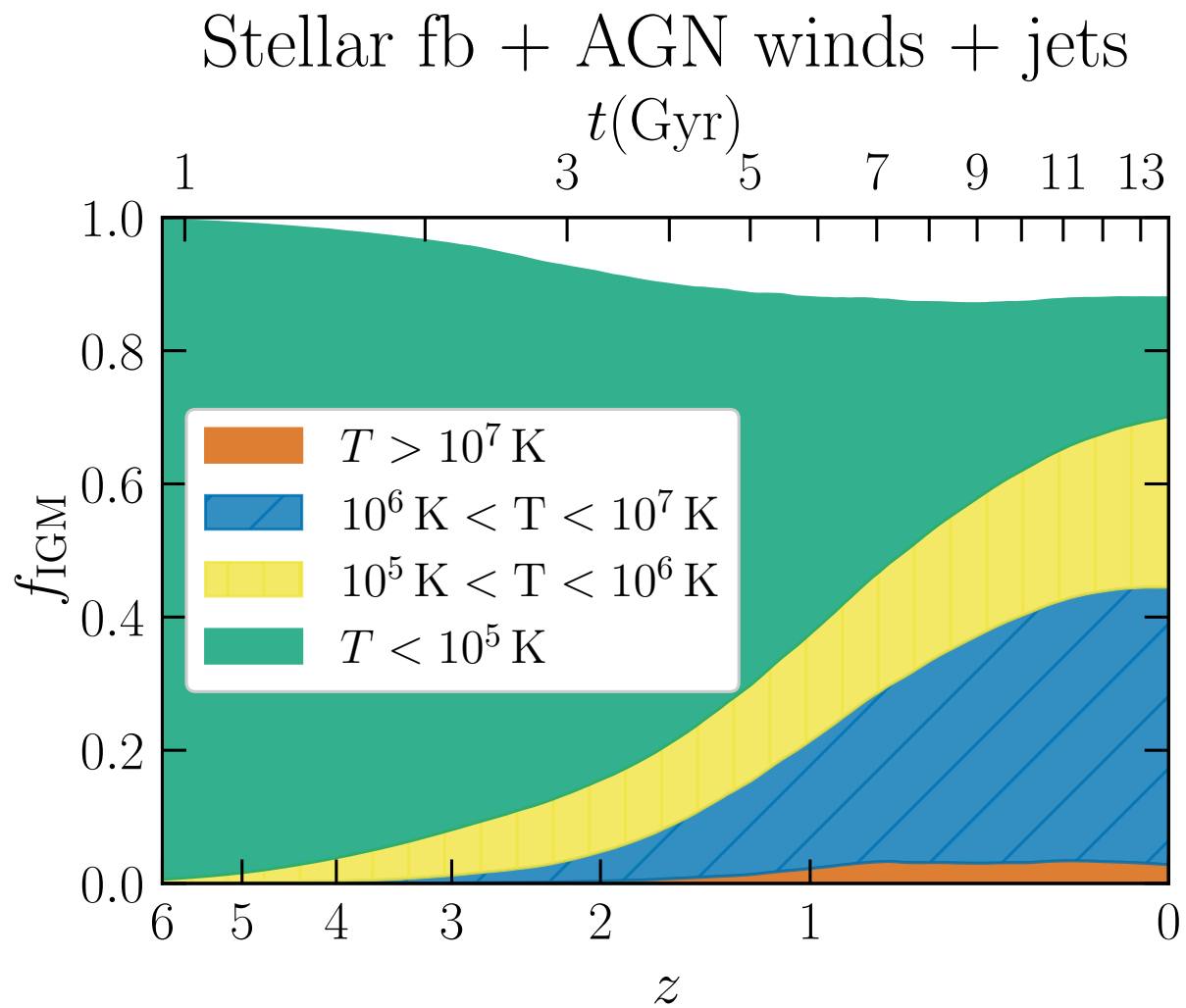
$z < 2$ : AGN jets transfer hot gas from halos to the IGM



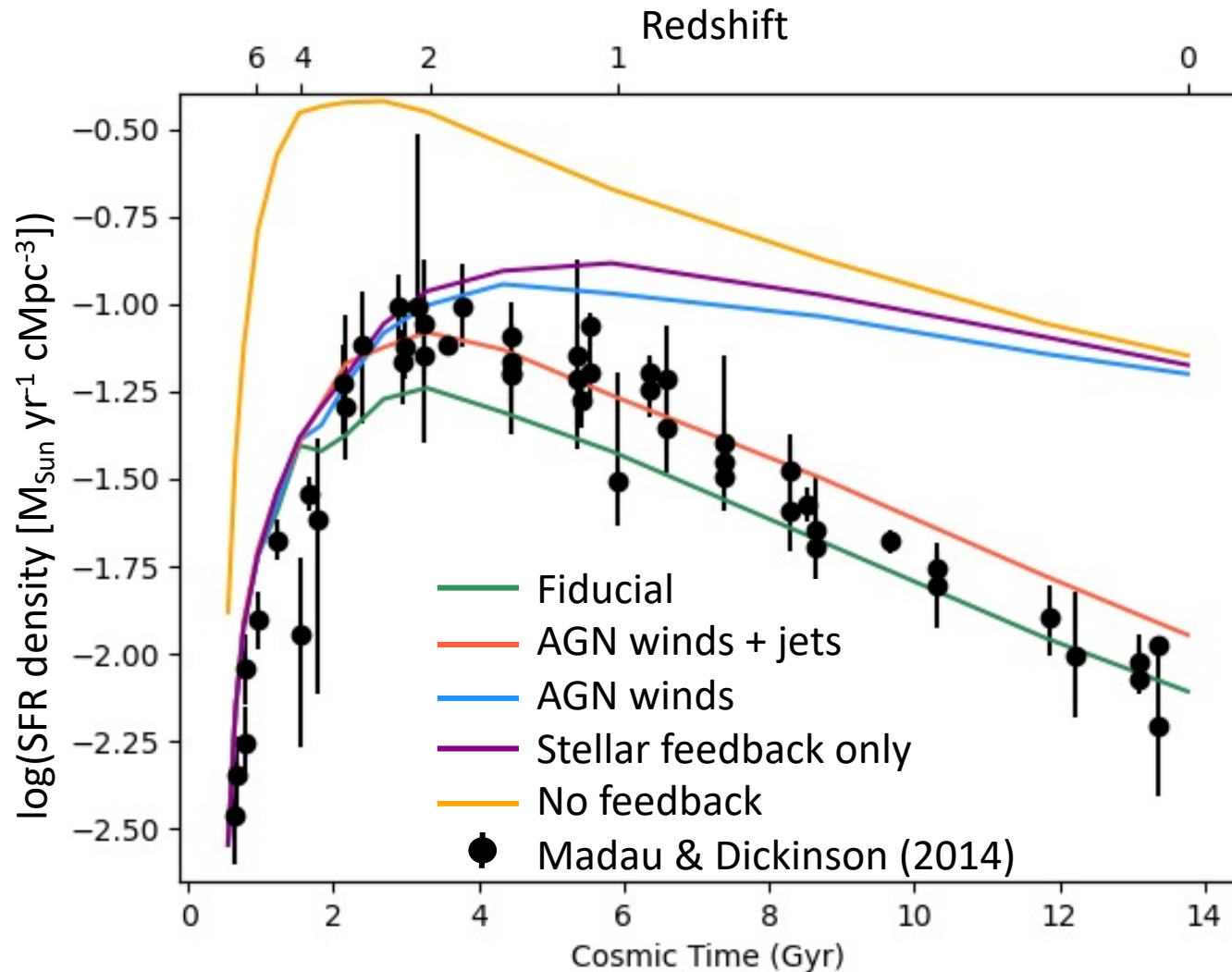
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# AGN jets suppress late-time star formation



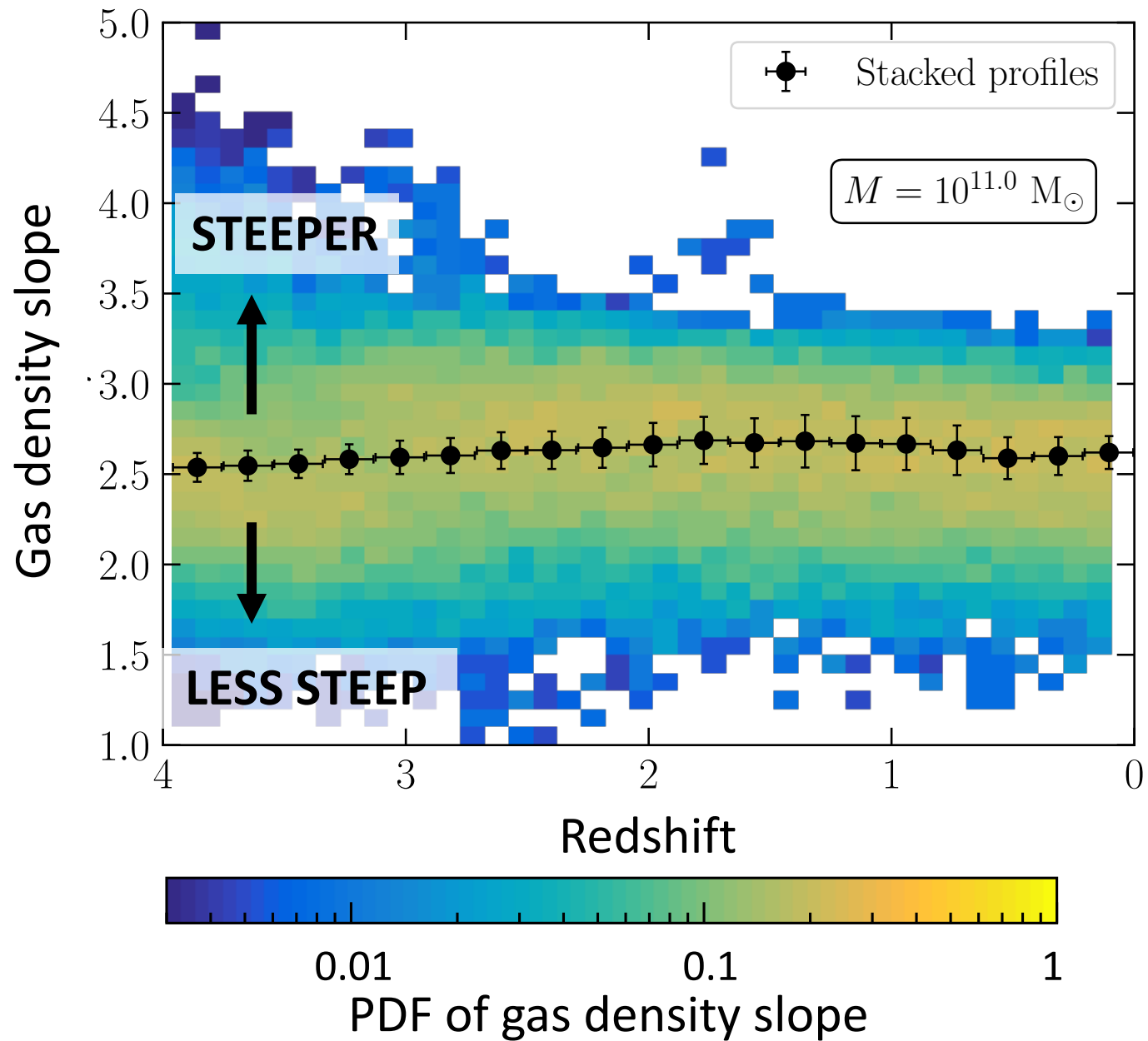
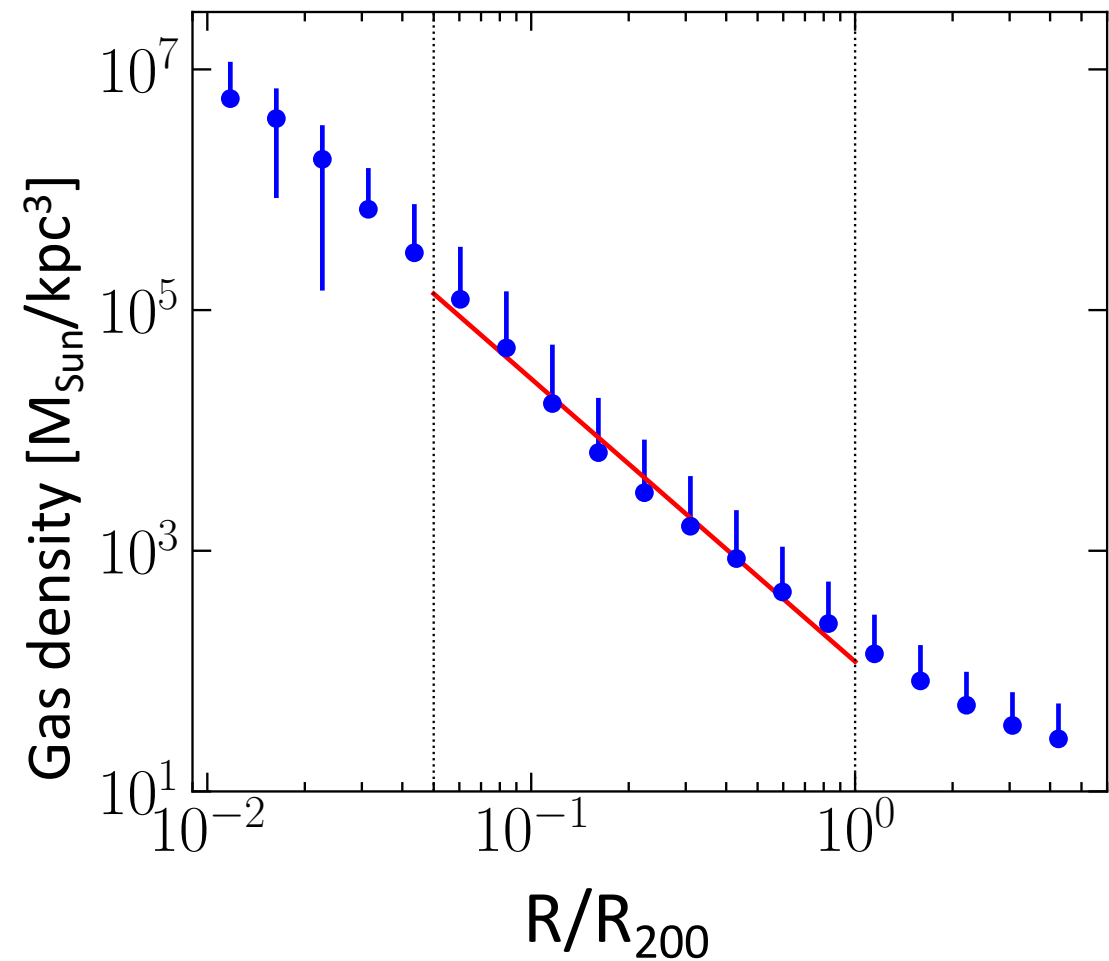
Lucie Scharré



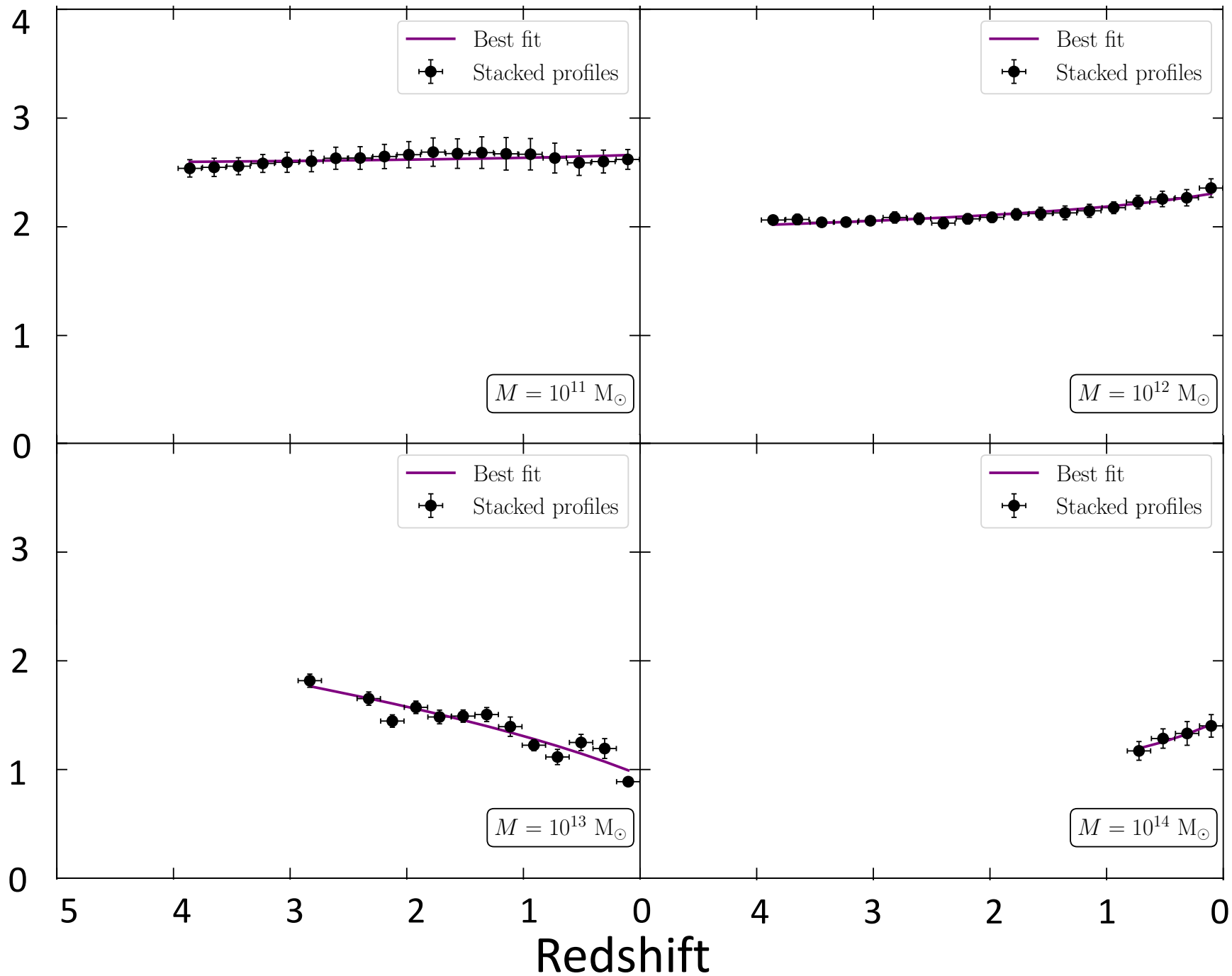
Main mechanisms shaping the distribution of baryons in the universe, the thermal state of the IGM and star formation history:

- Stellar feedback in lower mass halos at  $z > 2$
- AGN jets in higher mass halos at  $z < 2$

# Fit gas density profiles



Slope of gas density profile



**Gas density profile**

$$\rho_{gas} \propto r^{-\eta}$$

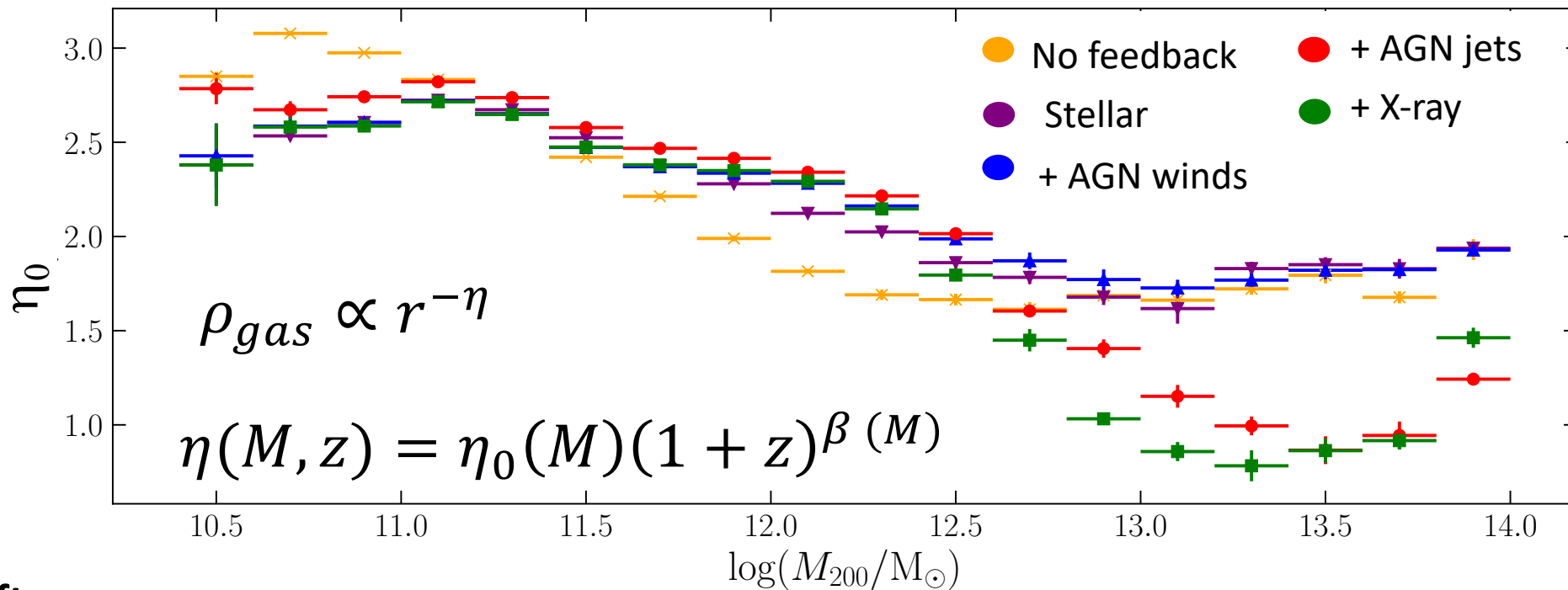
**At fixed mass:**

$$\eta = \eta_0 (1 + z)^{\beta}$$

**STEEPER**



**LESS STEEP**



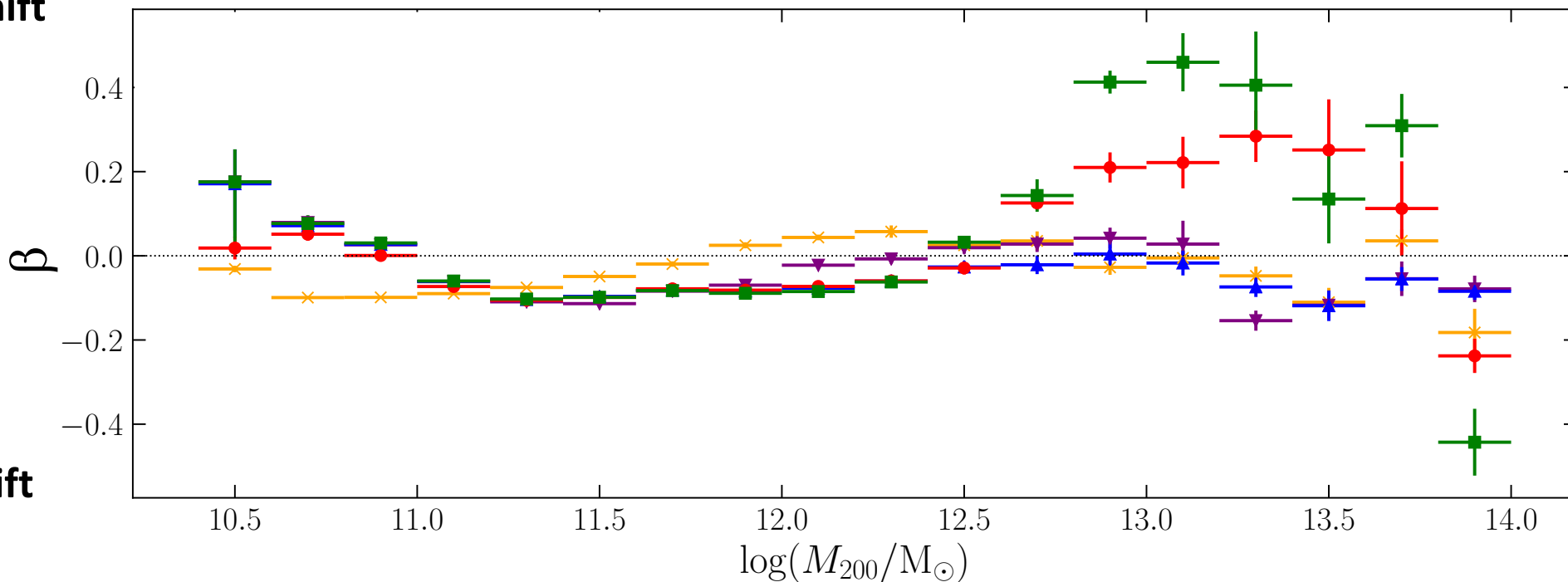
**Steeper @ higher redshift**



**Constant with redshift**

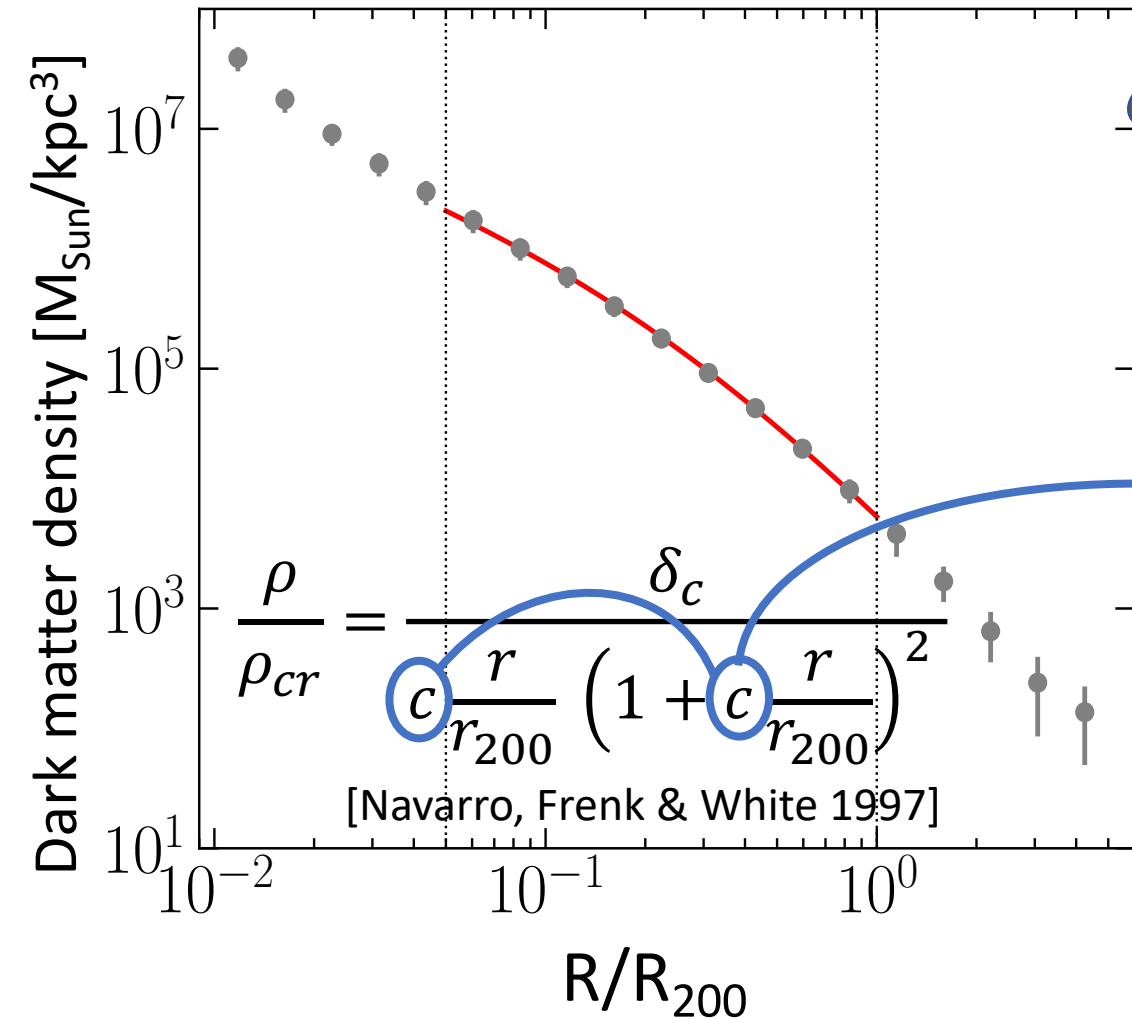


**Steeper @ lower redshift**

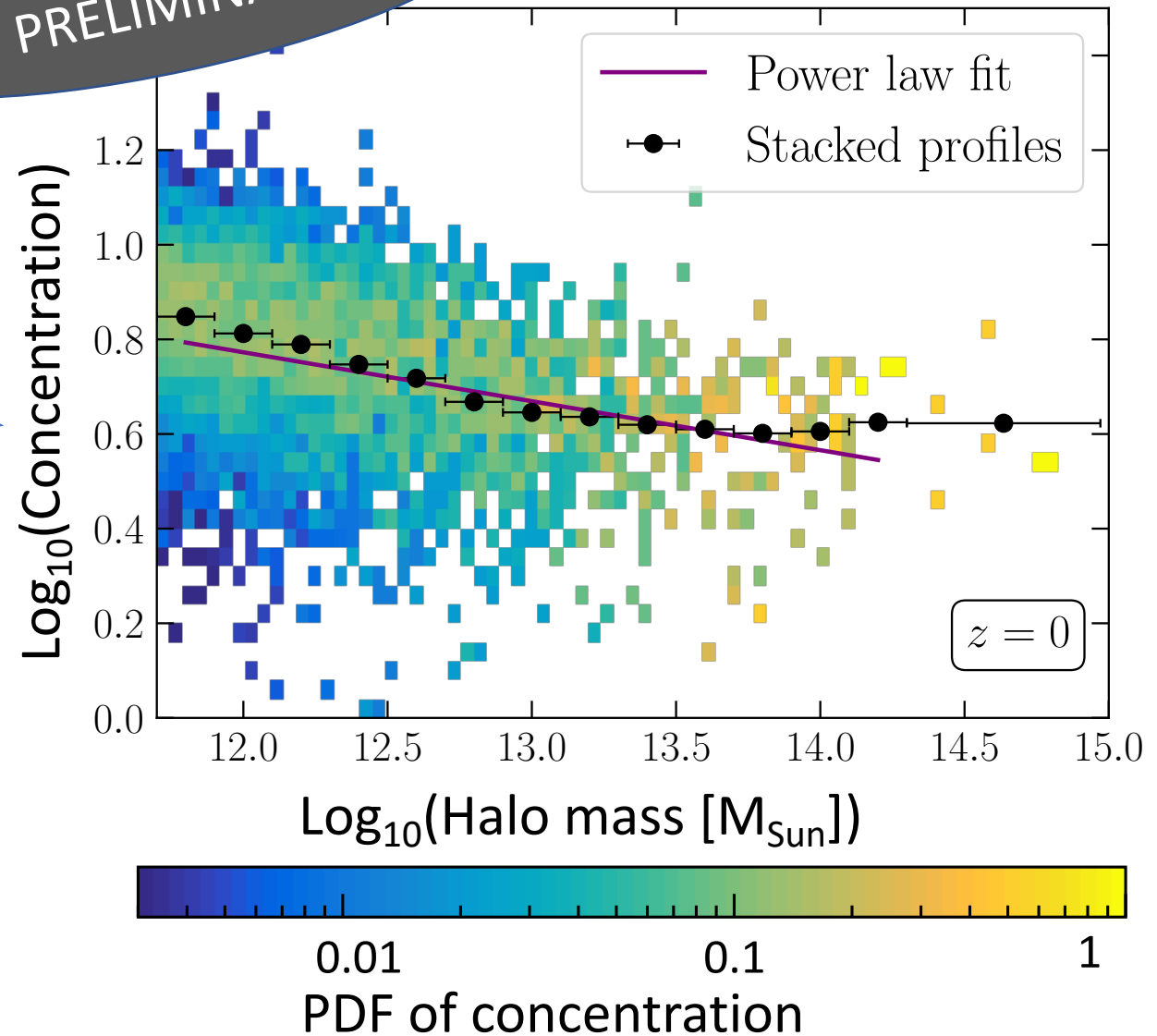




# Concentration-mass relationship



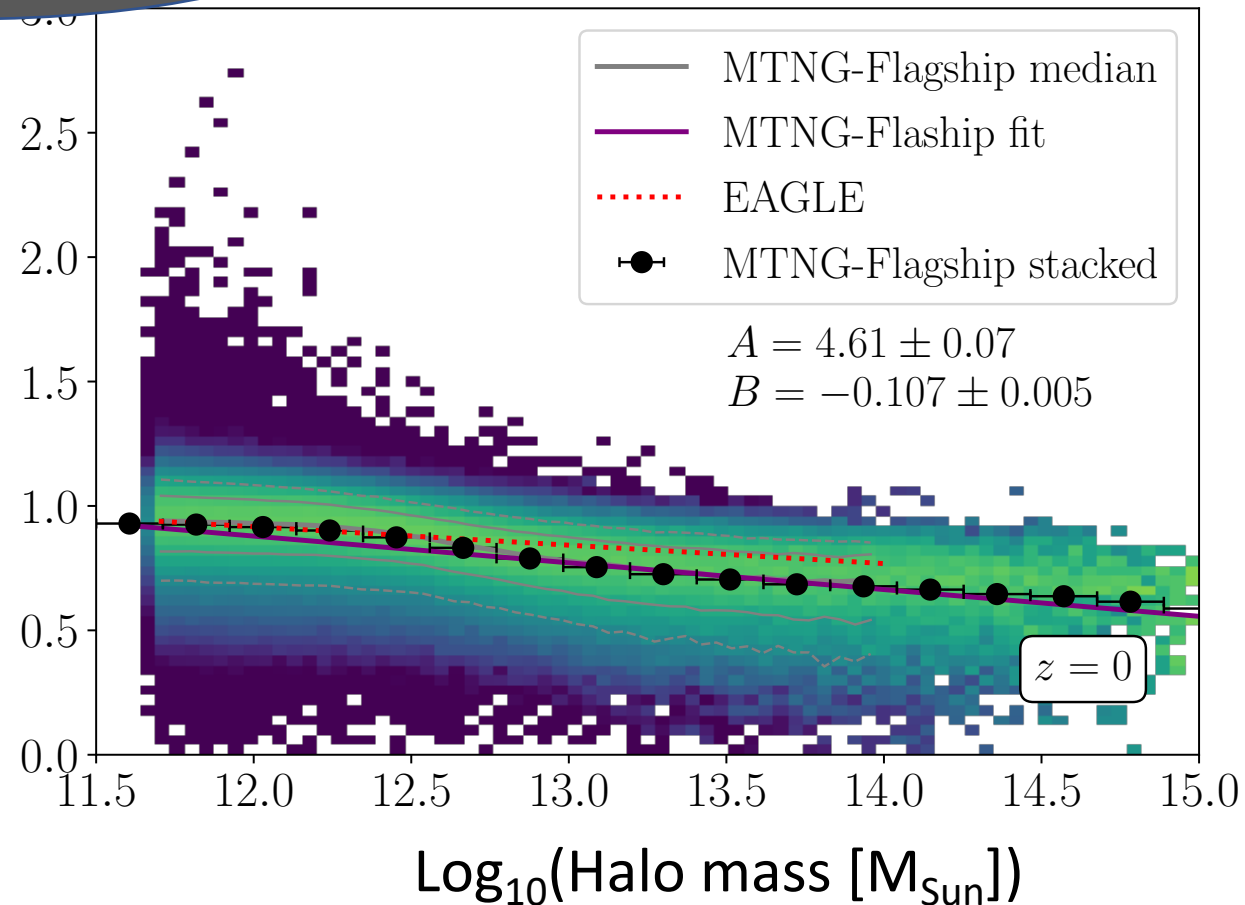
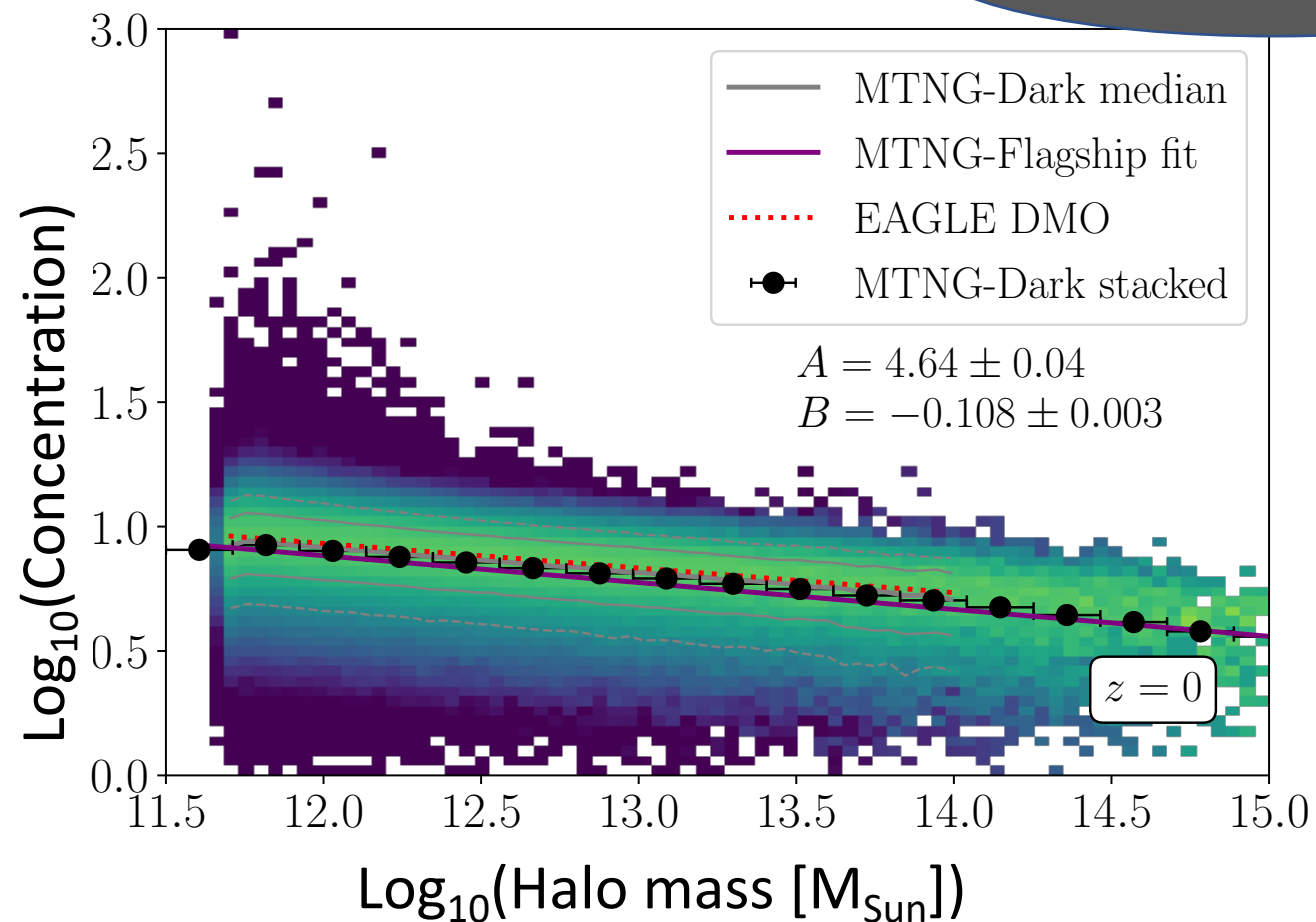
PRELIMINARY



[see also Schaller+ 2015, Macciò+ 2020, Wang+ 2020]

# Increase statistics at high-mass end with Millennium-TNG

PRELIMINARY

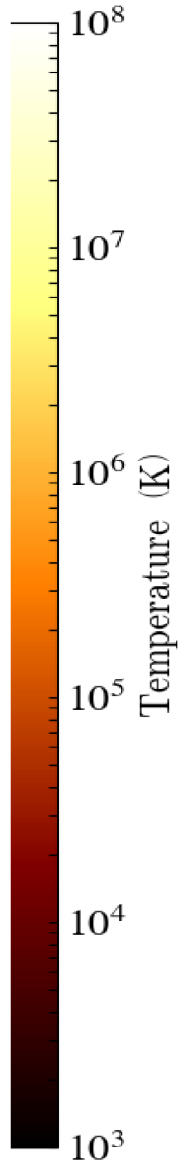
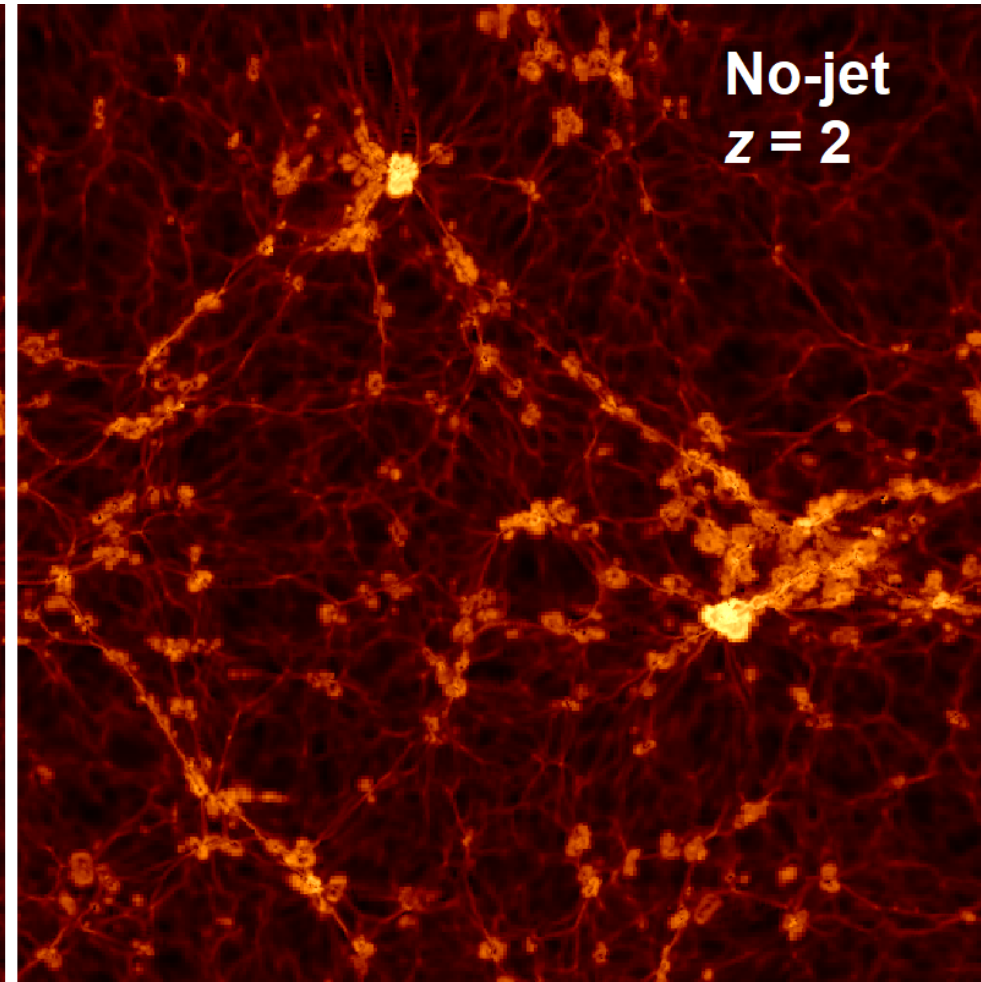
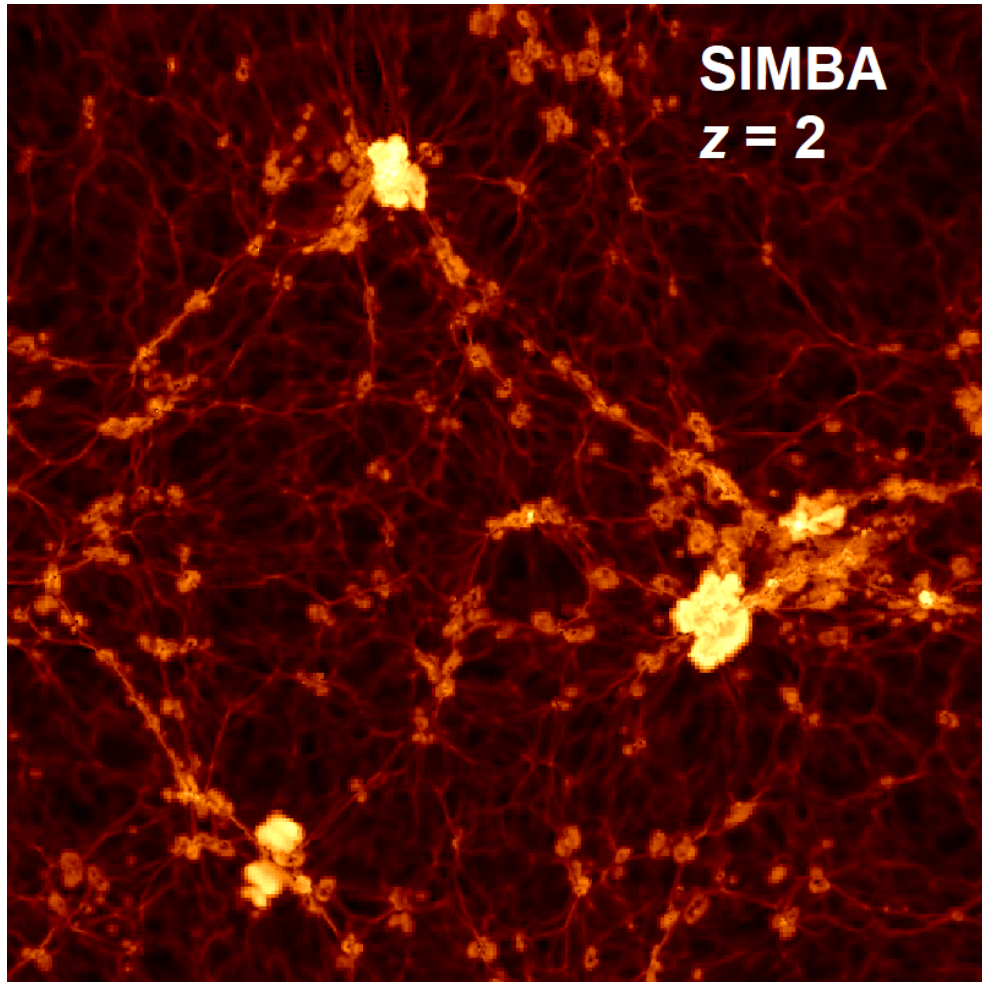


Preliminary

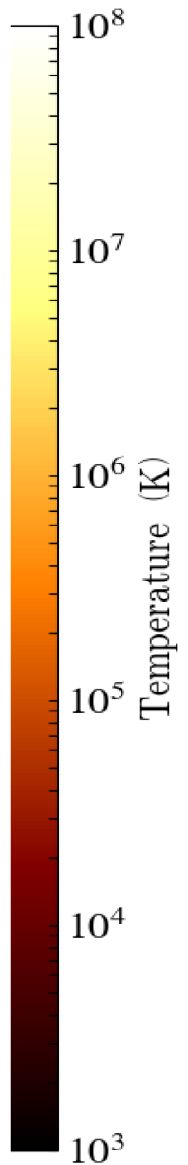
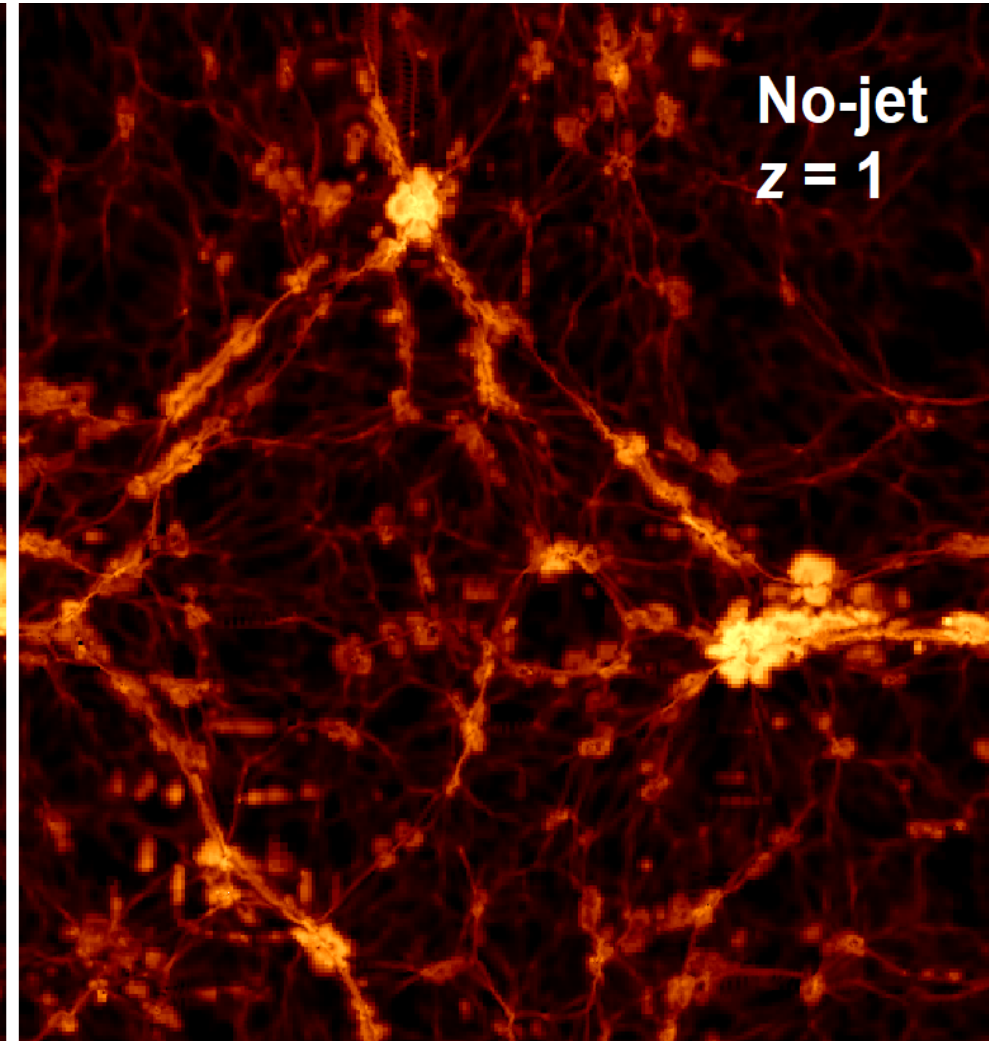
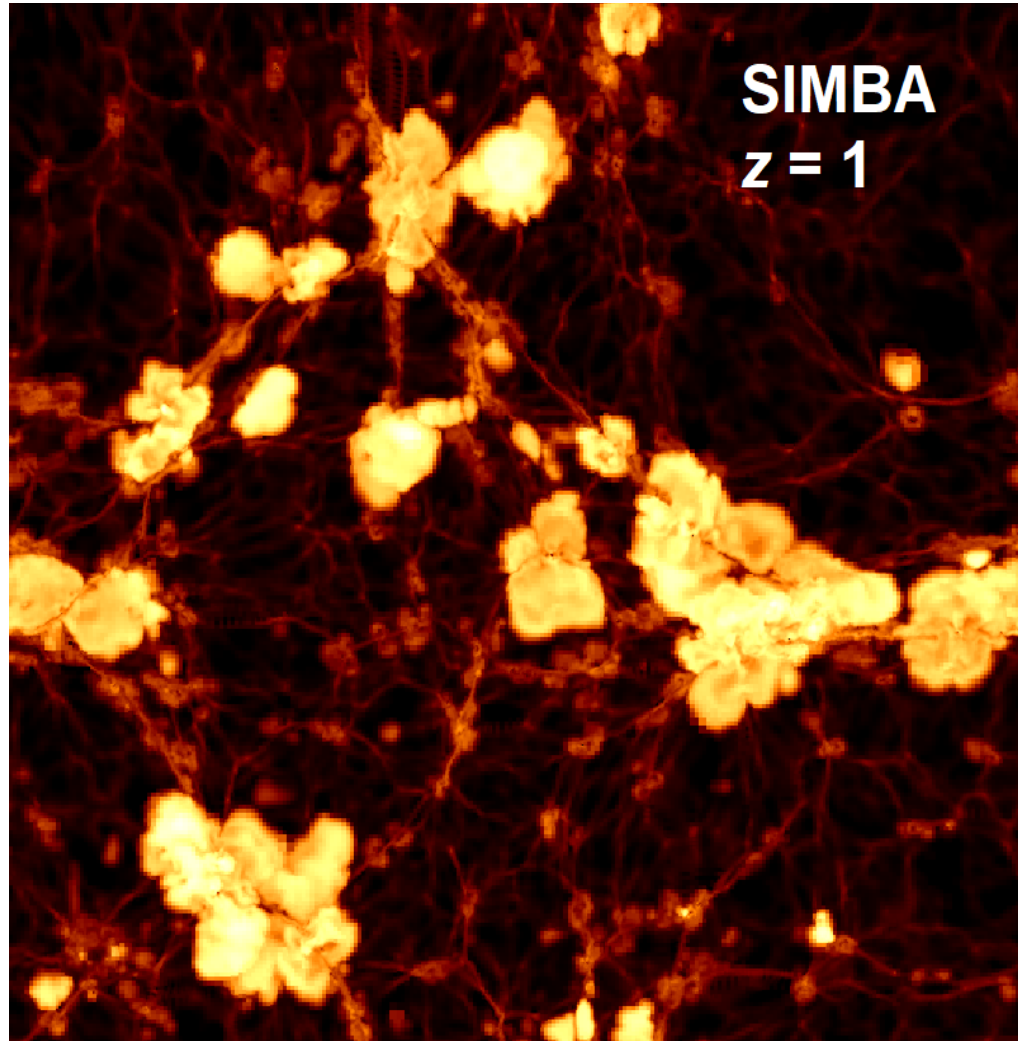
Conclusions

AGN jets associated with less steep gas density profiles in  
group-size haloes

# Jets turn on at $z < 2$

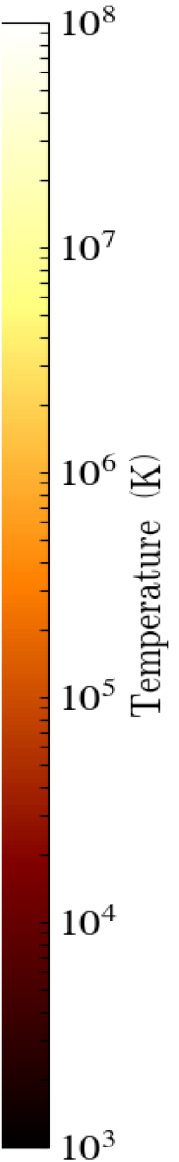
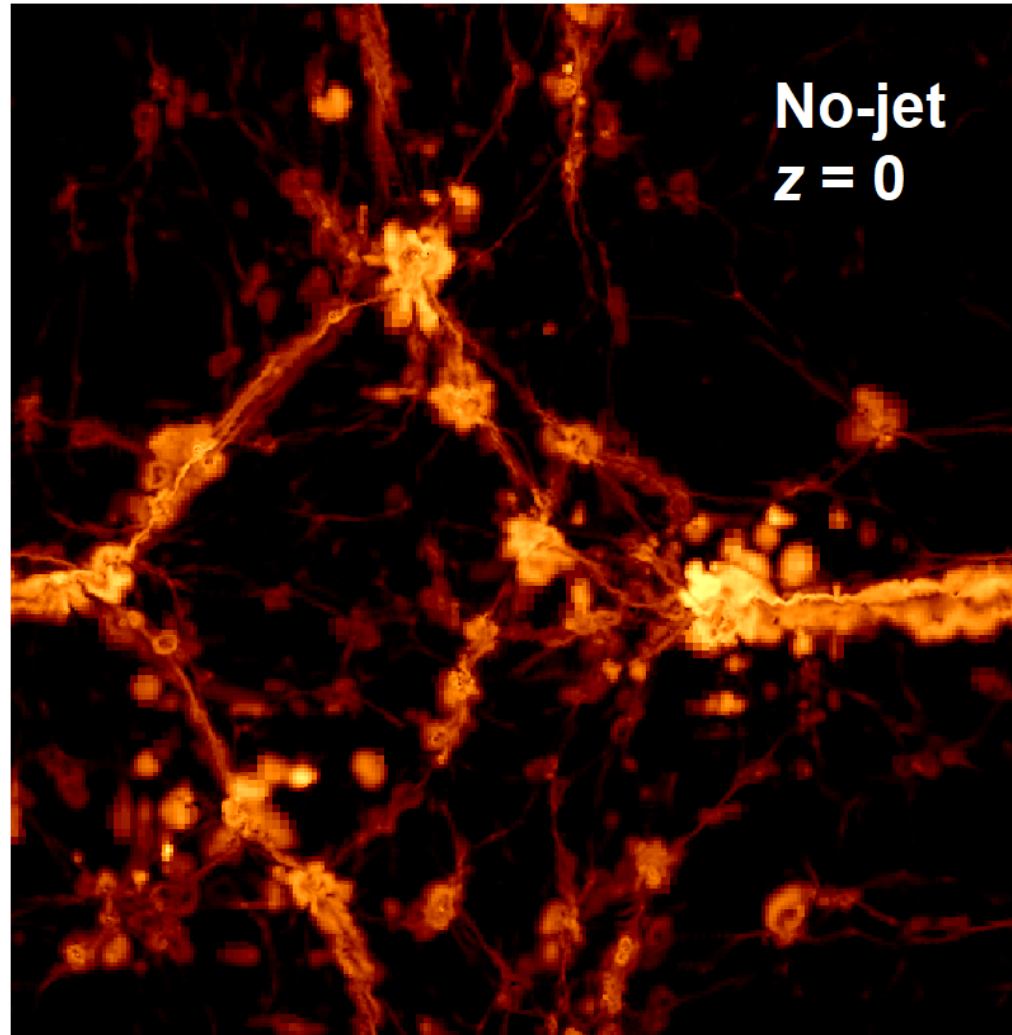
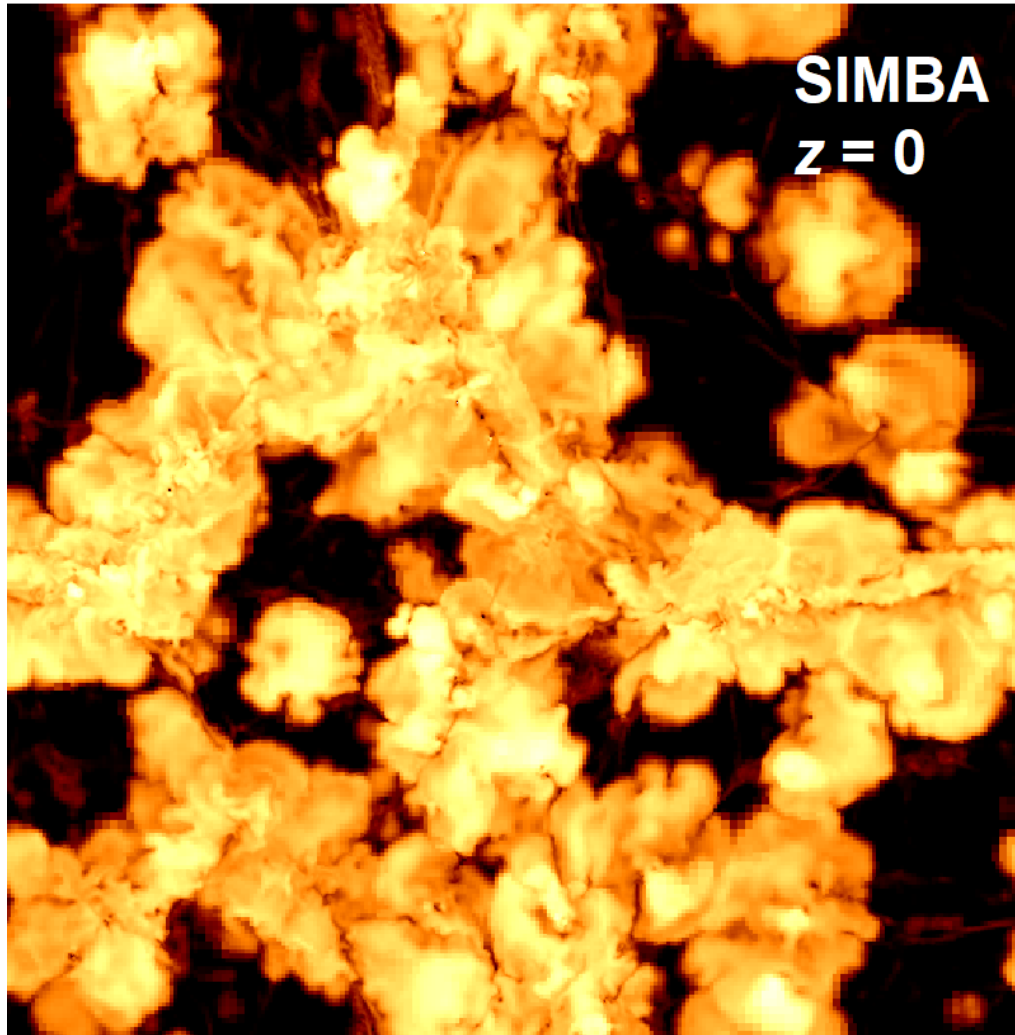


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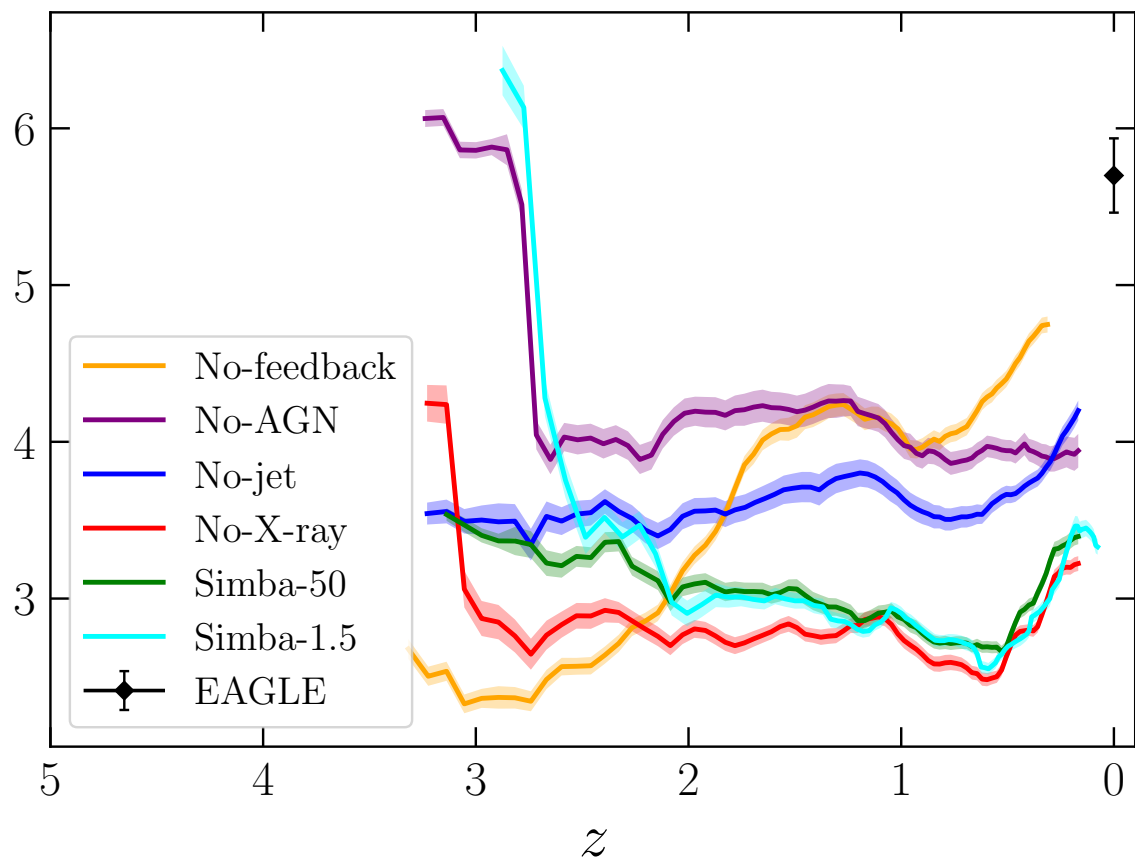


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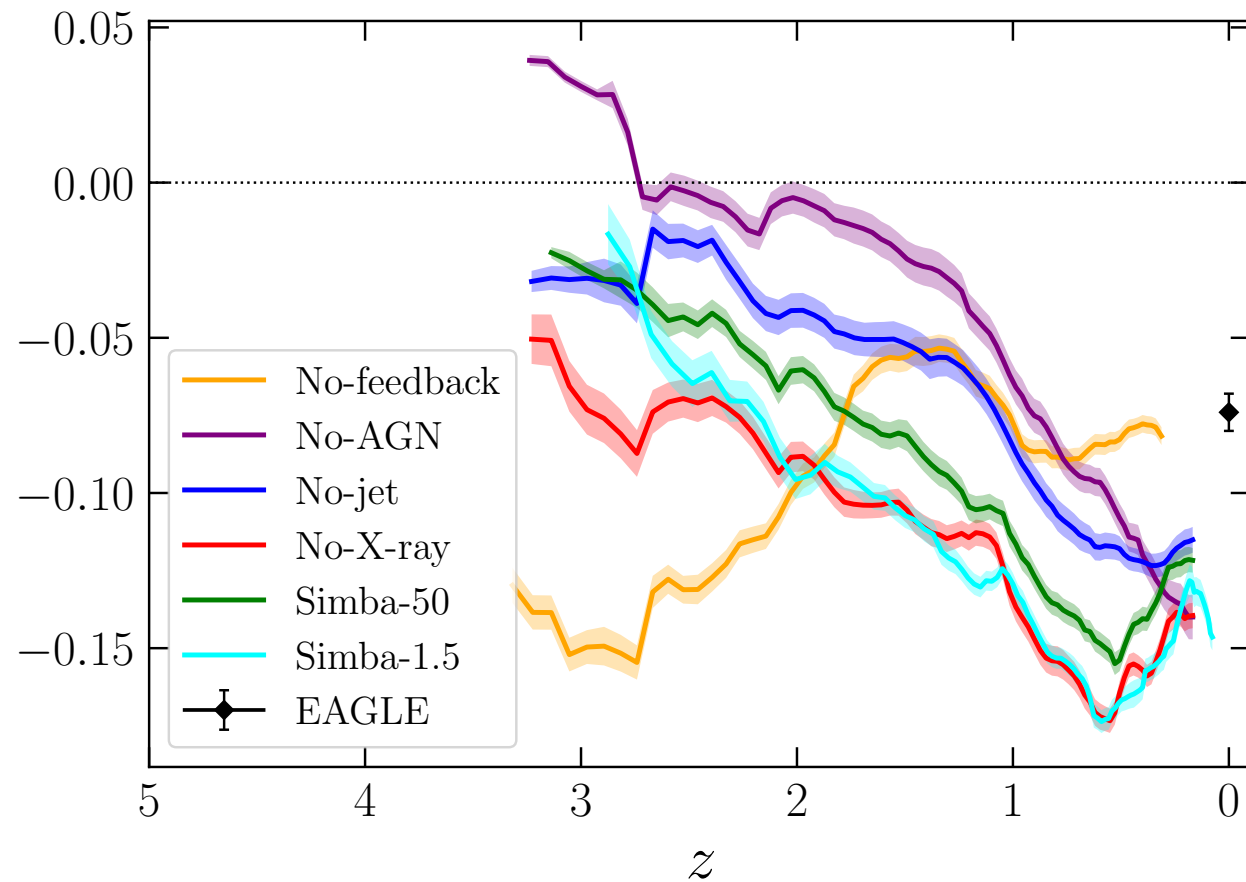


# Redshift evolution of the concentration-mass relationship

## Normalisation



## Slope



[Sorini+ in prep.]