The impact of feedback on haloes and large-scale structure

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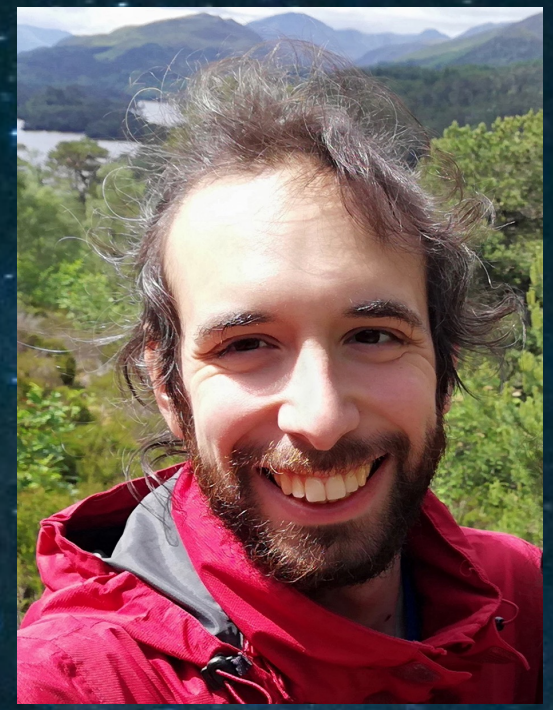

Main collaborators: Romeel Davé, Sownak Bose, Weiguang Cui, Sarah Appleby, John Peacock

Durham University

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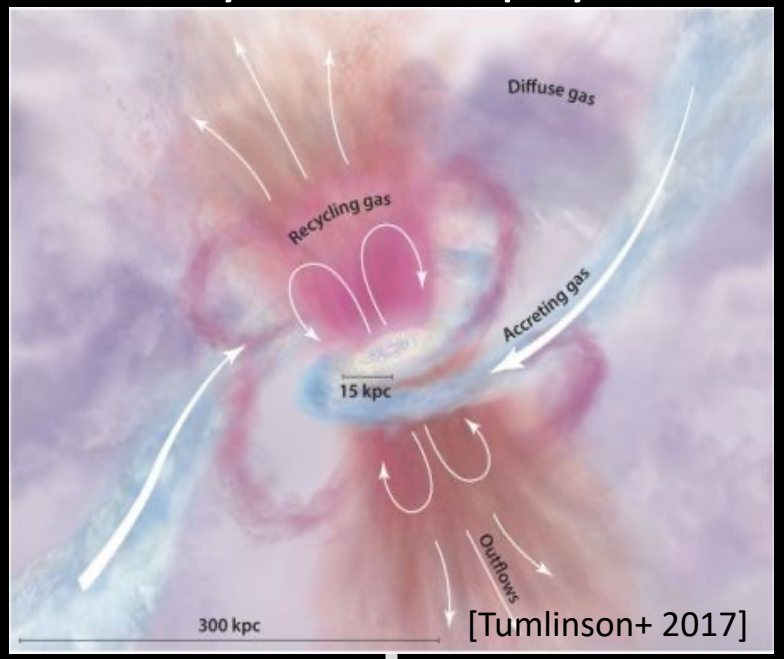
Cosmology from Home 2023

The University of Edinburgh

Baryonic astrophysics



[Tumlinson+ 2017]

Background cosmology

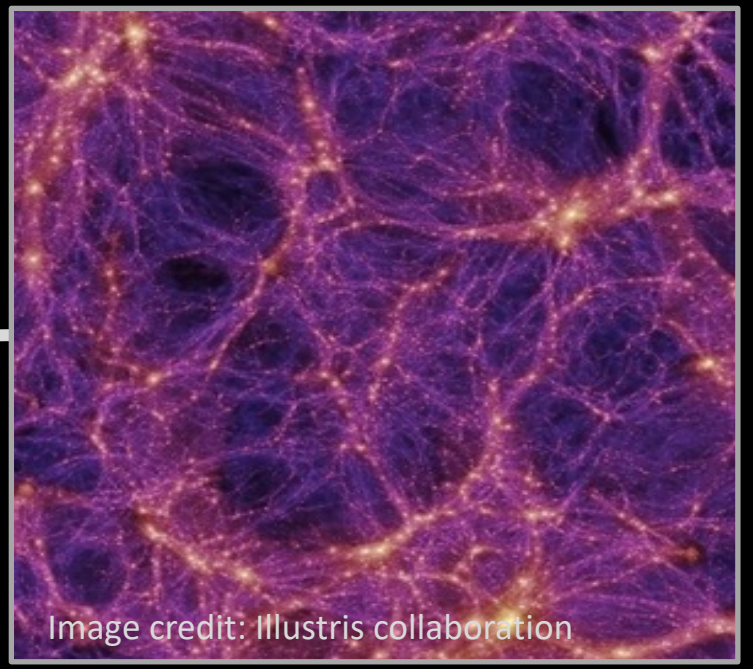
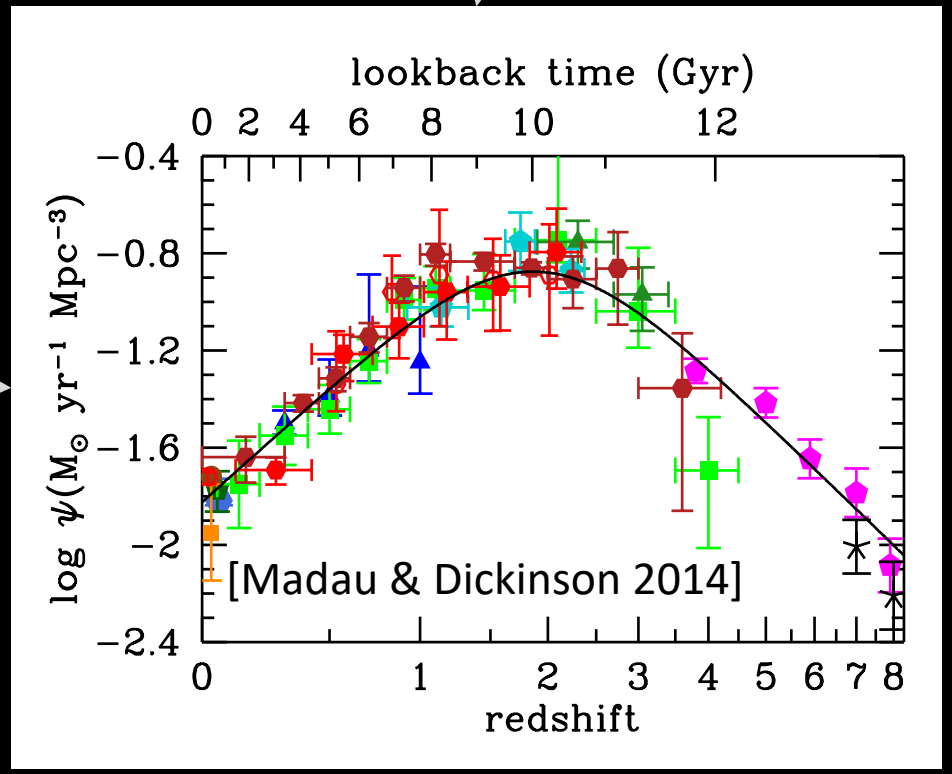


Image credit: Illustris collaboration



[Madau & Dickinson 2014]

Star formation and feedback

Gas accretion and cooling

↓

Star formation

↓

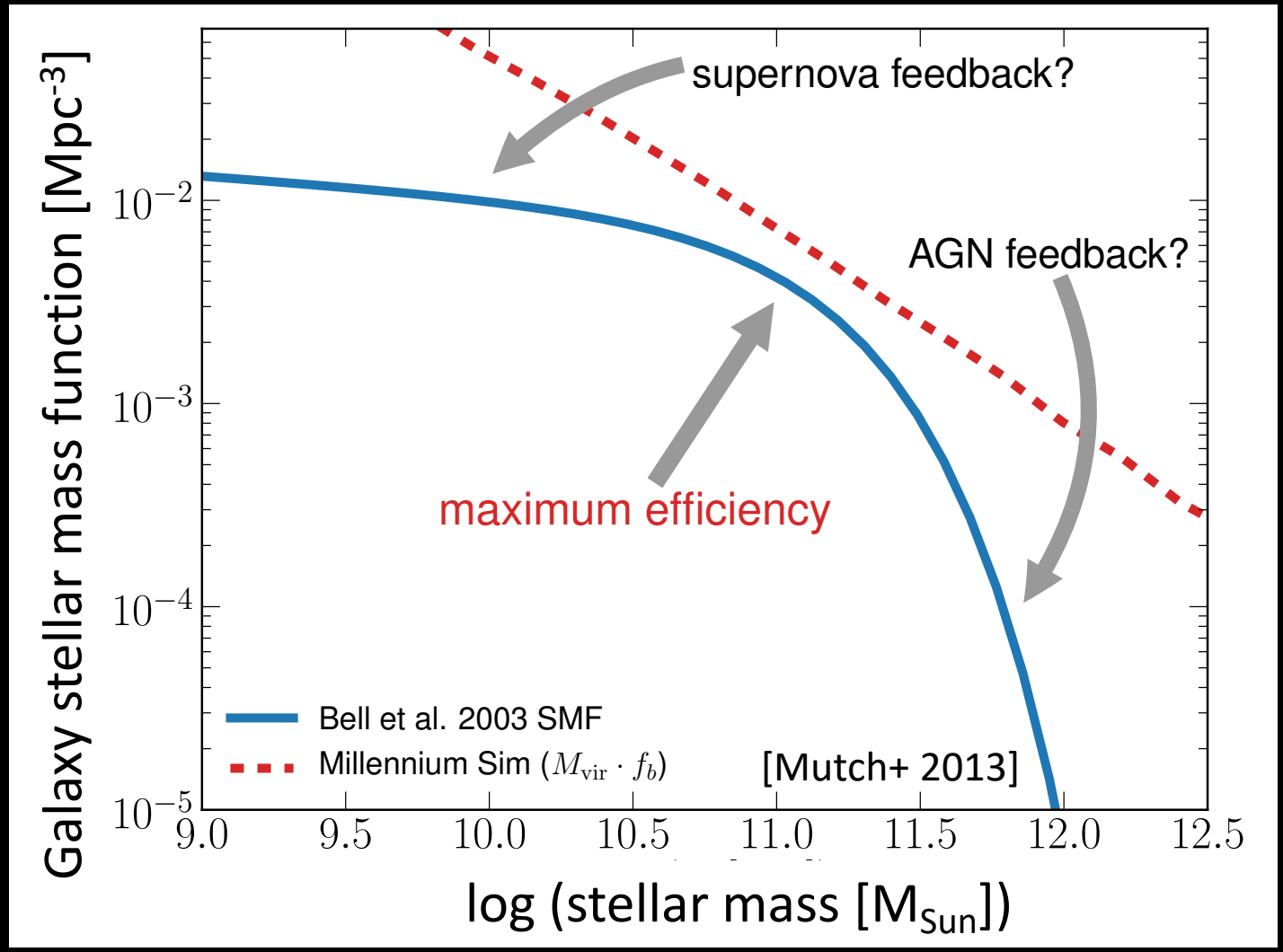
Stellar & AGN-driven outflows

↓

Gas heating & depletion

↓

Star formation is suppressed



Feedback

Structure of halos

- Density profiles
  [e.g. Schaller+ 2015, Pllepich+ 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; Salcido+ 2018, 2020]

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, Salcido+ 2023]
- Matter bispectrum [Foreman+ 2020]

CGM/IGM

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

Effect of baryons on halos and LSS in the Simba simulation

BH accretion

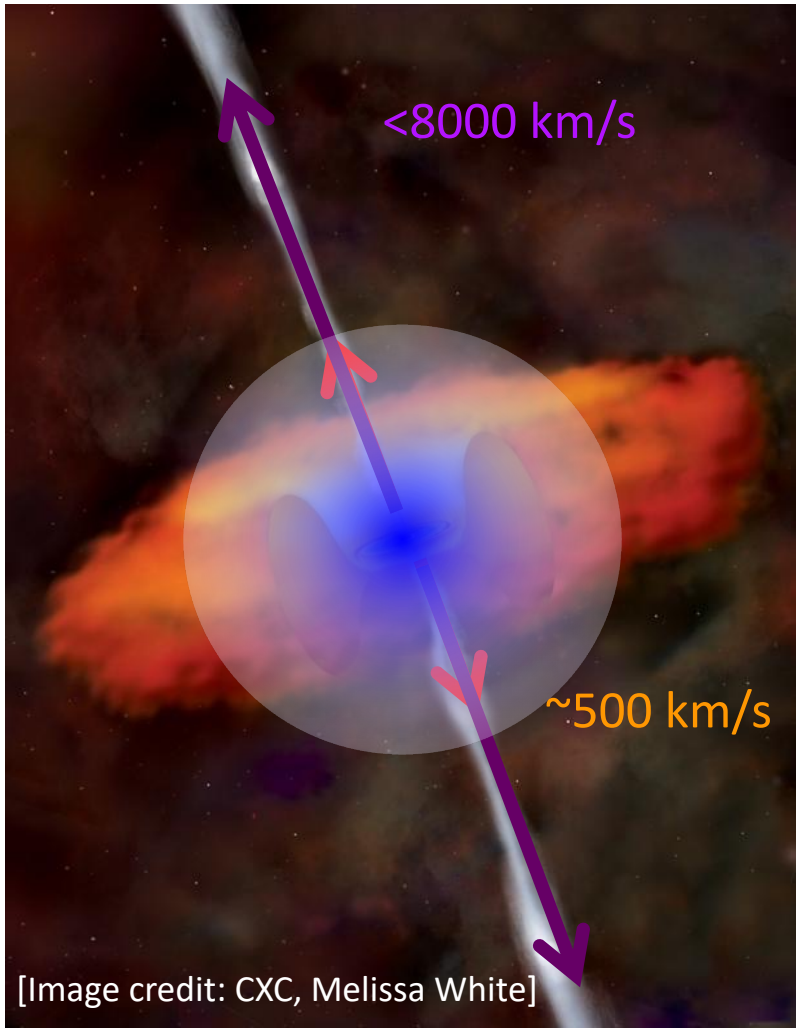
- HOT MODE [Bondi 1952]
- COLD MODE: torque-limited accretion [Hopkins & Quataert 2011; Anglés-Alcázar+ 2013, 2015, 2017a]

Stellar feedback

SN + stellar winds scaling relations based on FIRE zoom-in simulations [Muratov+ 2015; Anglés-Alcázar+ 2017b]

AGN feedback

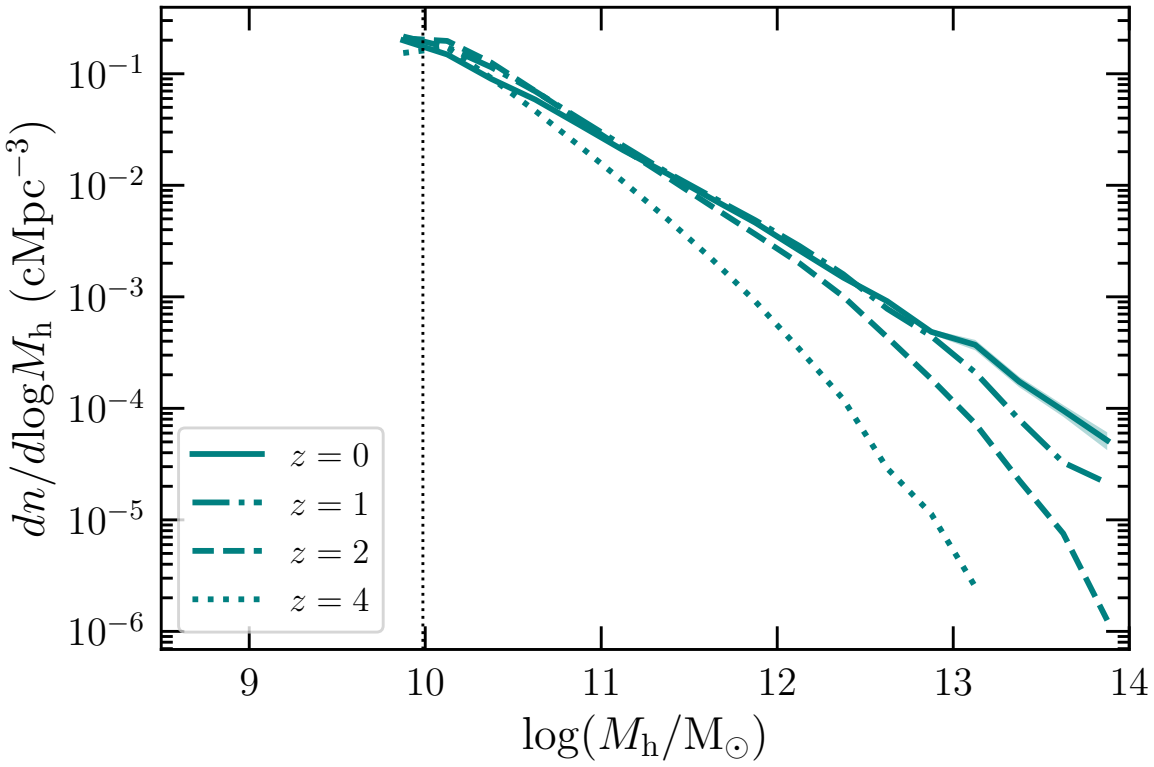
- AGN WINDS
- JETS $M_{BH}>10^{7.5}\ M_{Sun}$ & $f_{Edd}<0.2$
- X-RAY HEATING $M_{BH}>10^{7.5}\ M_{Sun}$ & $f_{Edd}<0.2$ & $f_{gas}<0.2$



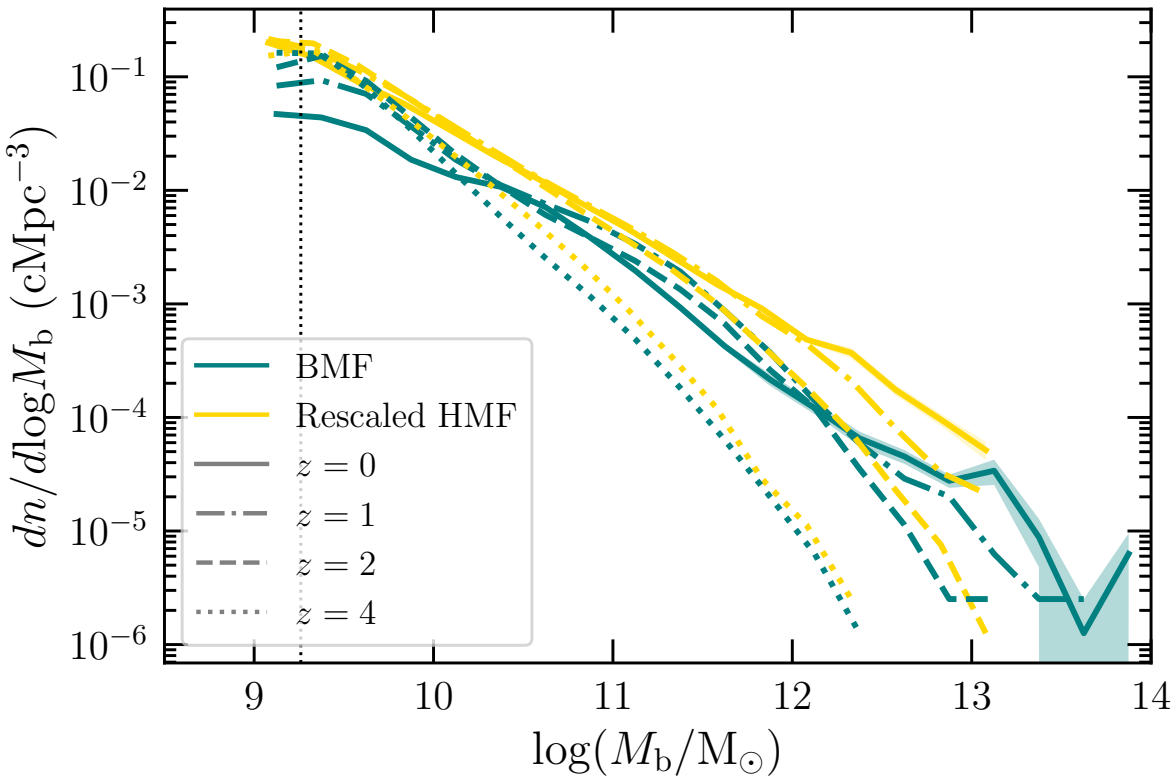
[Davé+ 19]

Effect of baryons on mass function more important at lower *z*

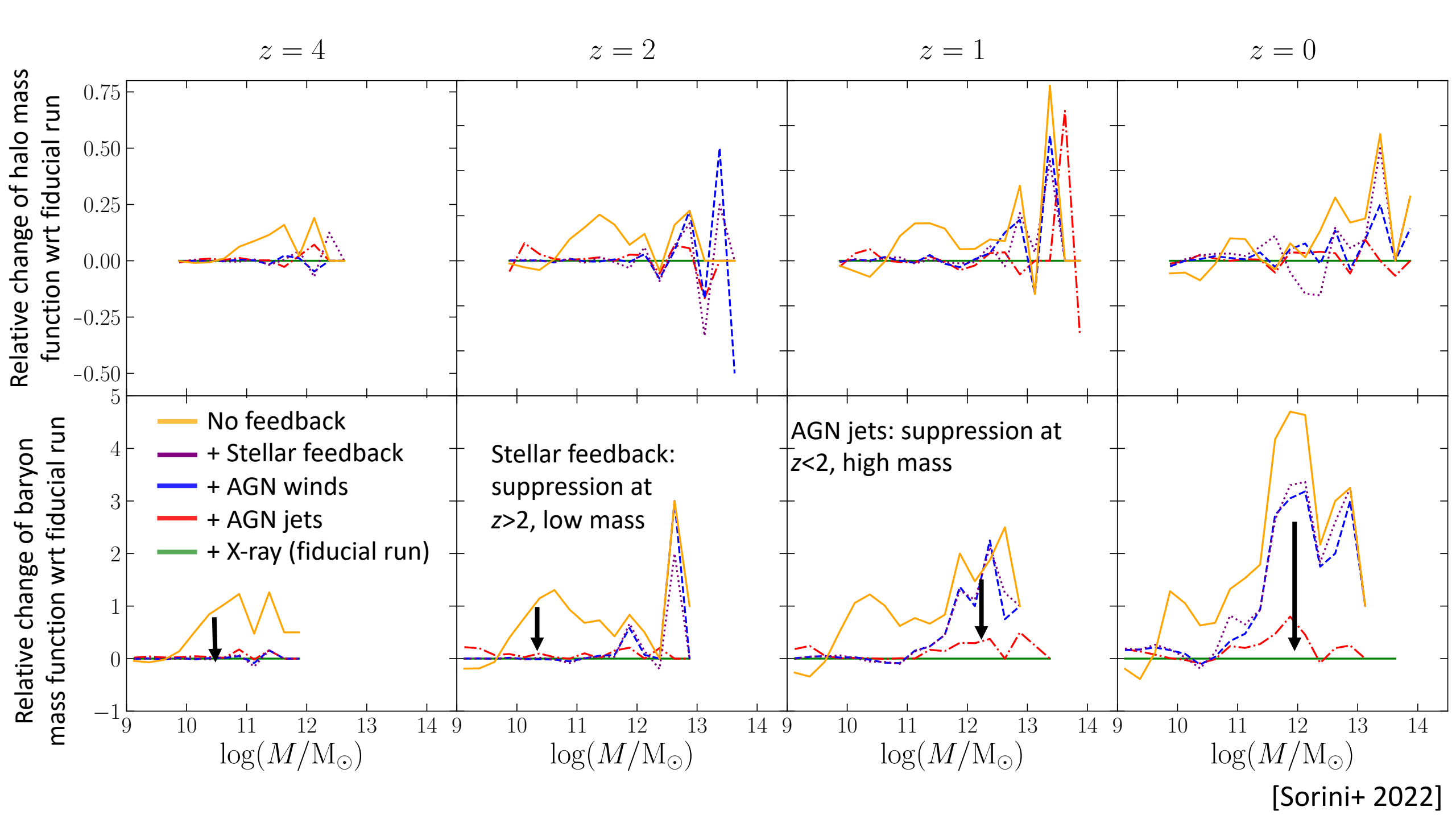
HALO MASS FUNCTION



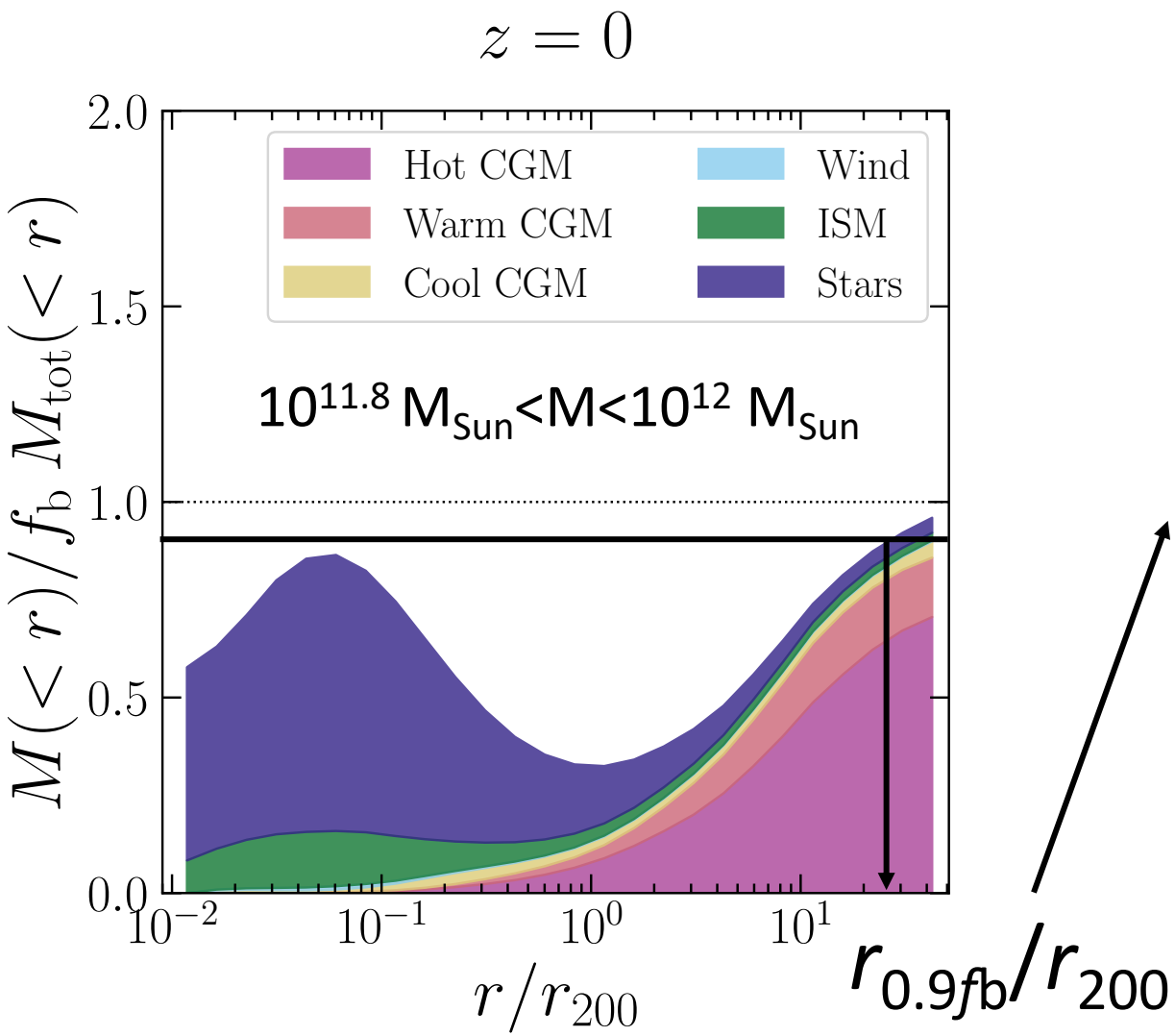
BARYONIC MASS FUNCTION

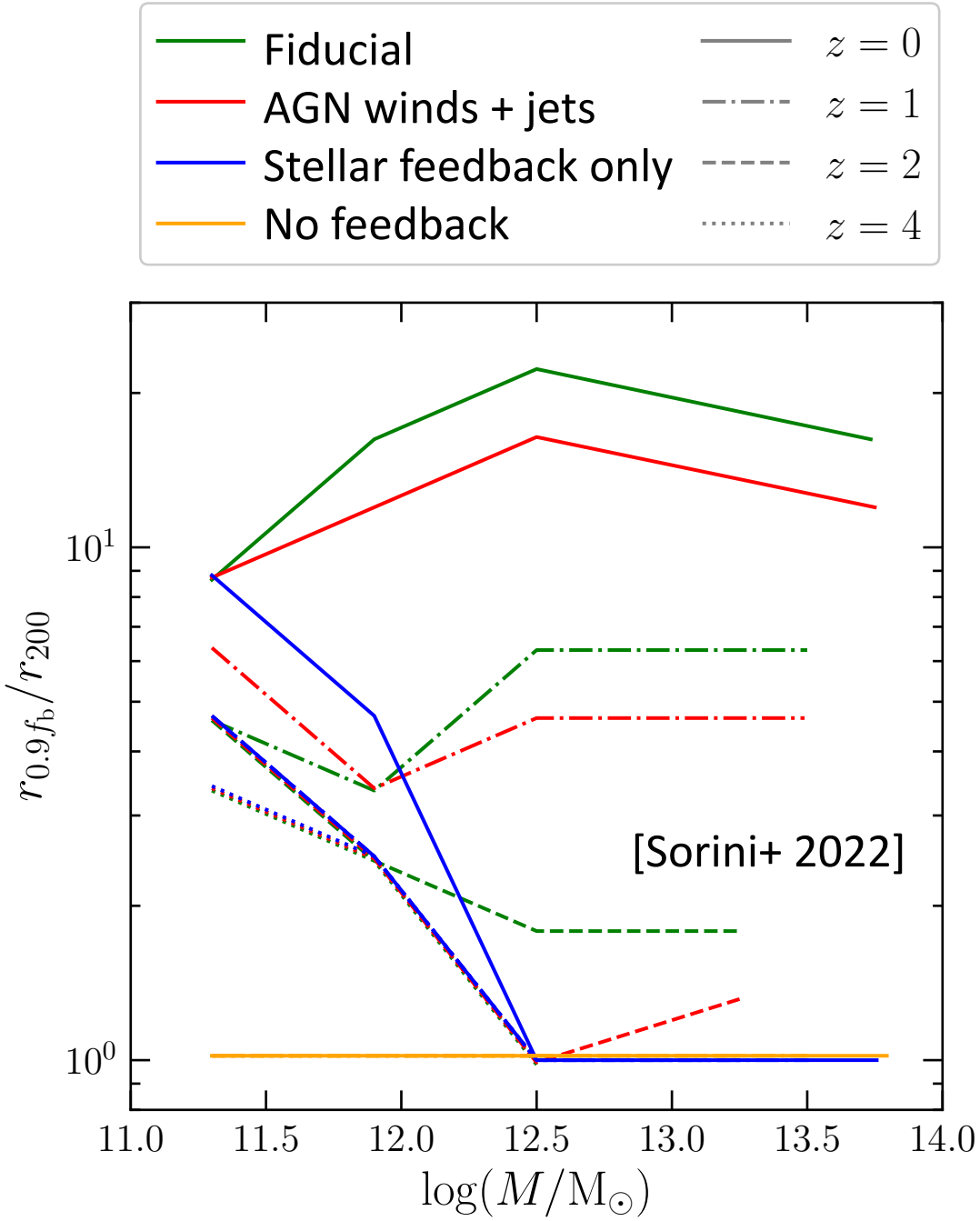


[Sorini+ 2022]


$z = 4$
$z = 2$
$z = 1$
$z = 0$
Relative change of halo mass function wrt fiducial run
Relative change of baryon mass function wrt fiducial run
No feedback
+ Stellar feedback
+ AGN winds
+ AGN jets
+ X-ray (fiducial run)
Stellar feedback: suppression at z>2, low mass
AGN jets: suppression at z<2, high mass
$\log(M/\mathrm{M}_\odot)$
[Sorini+ 2022]

AGN jets push baryons out to ~20 r_{200} by z=0

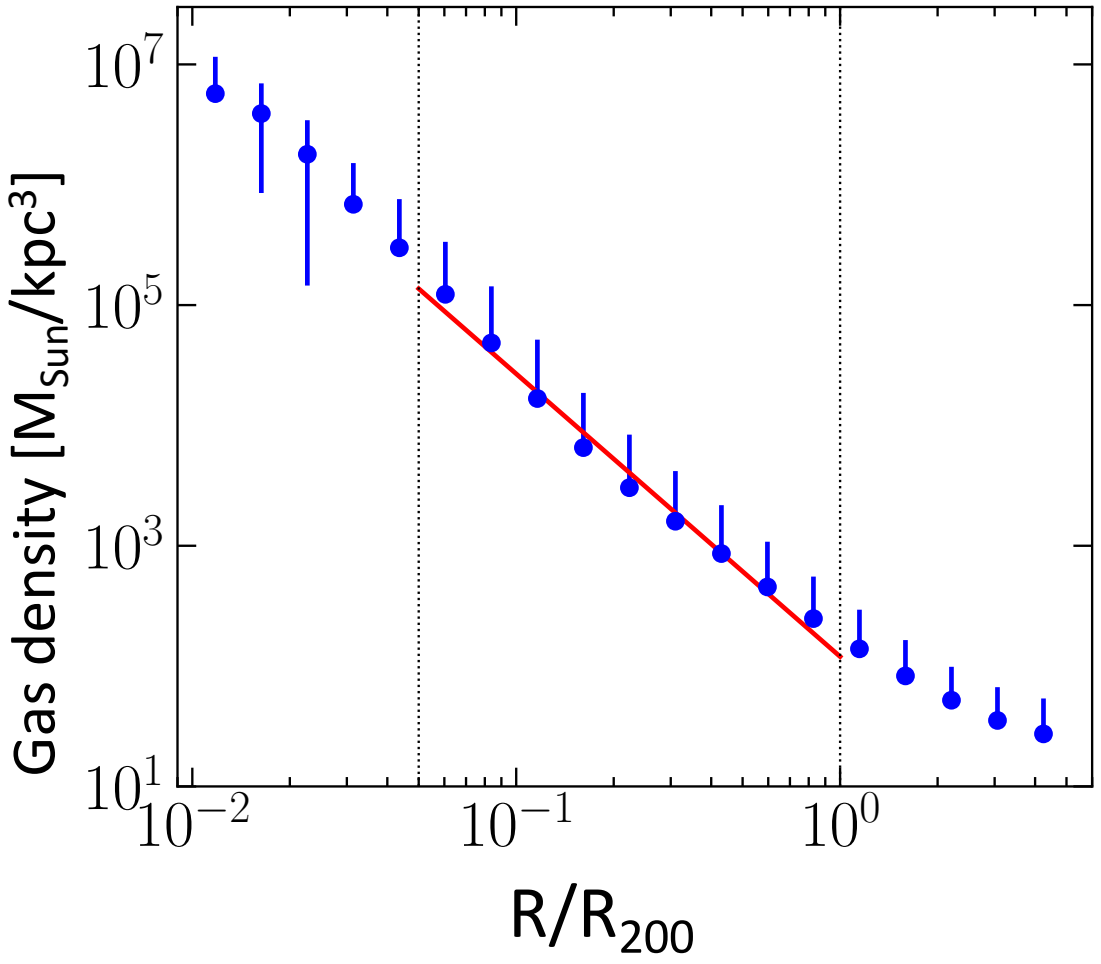




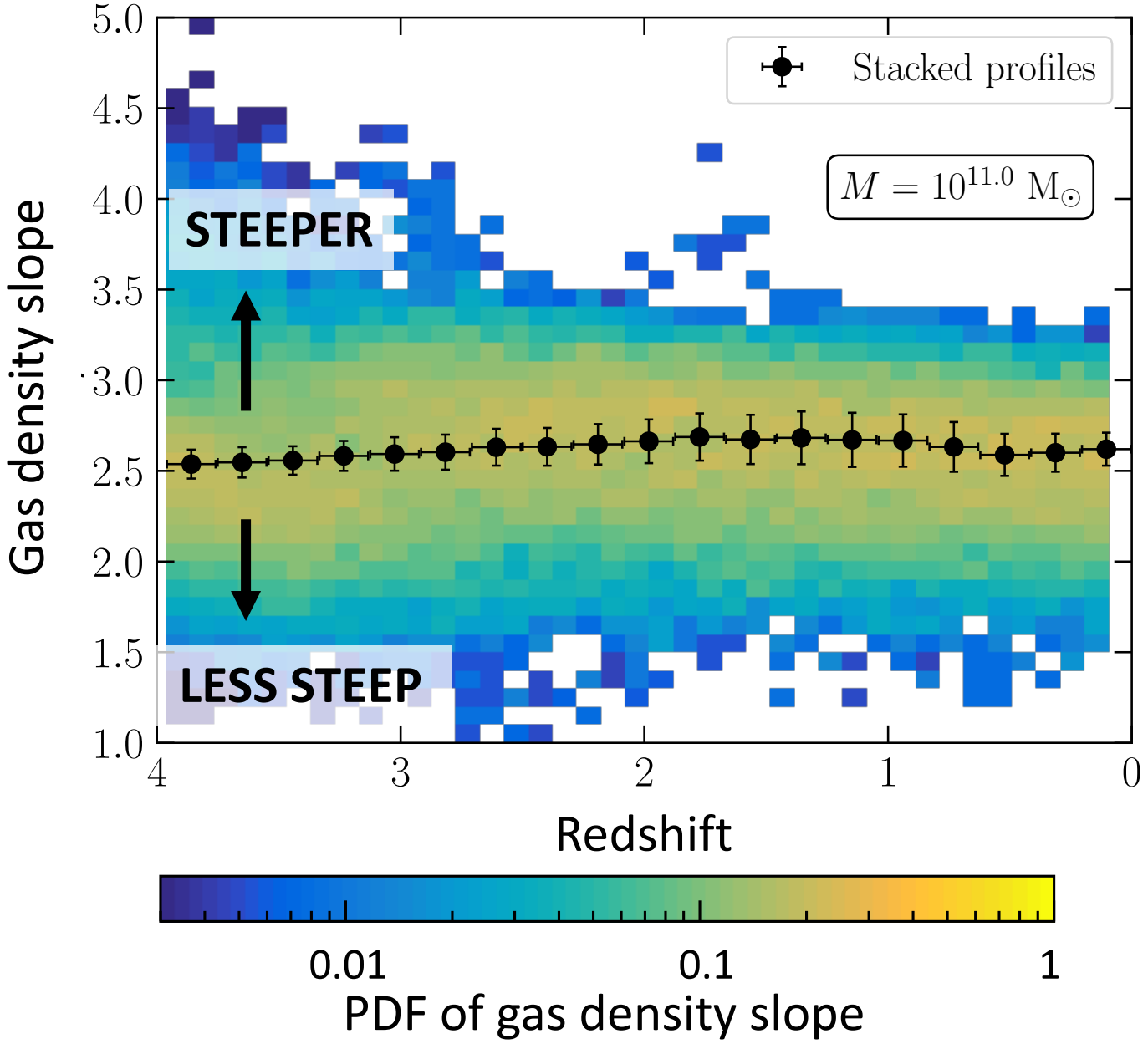
[see also Angelinelli+ 2022, 2023; Ayromlou+ 2023]

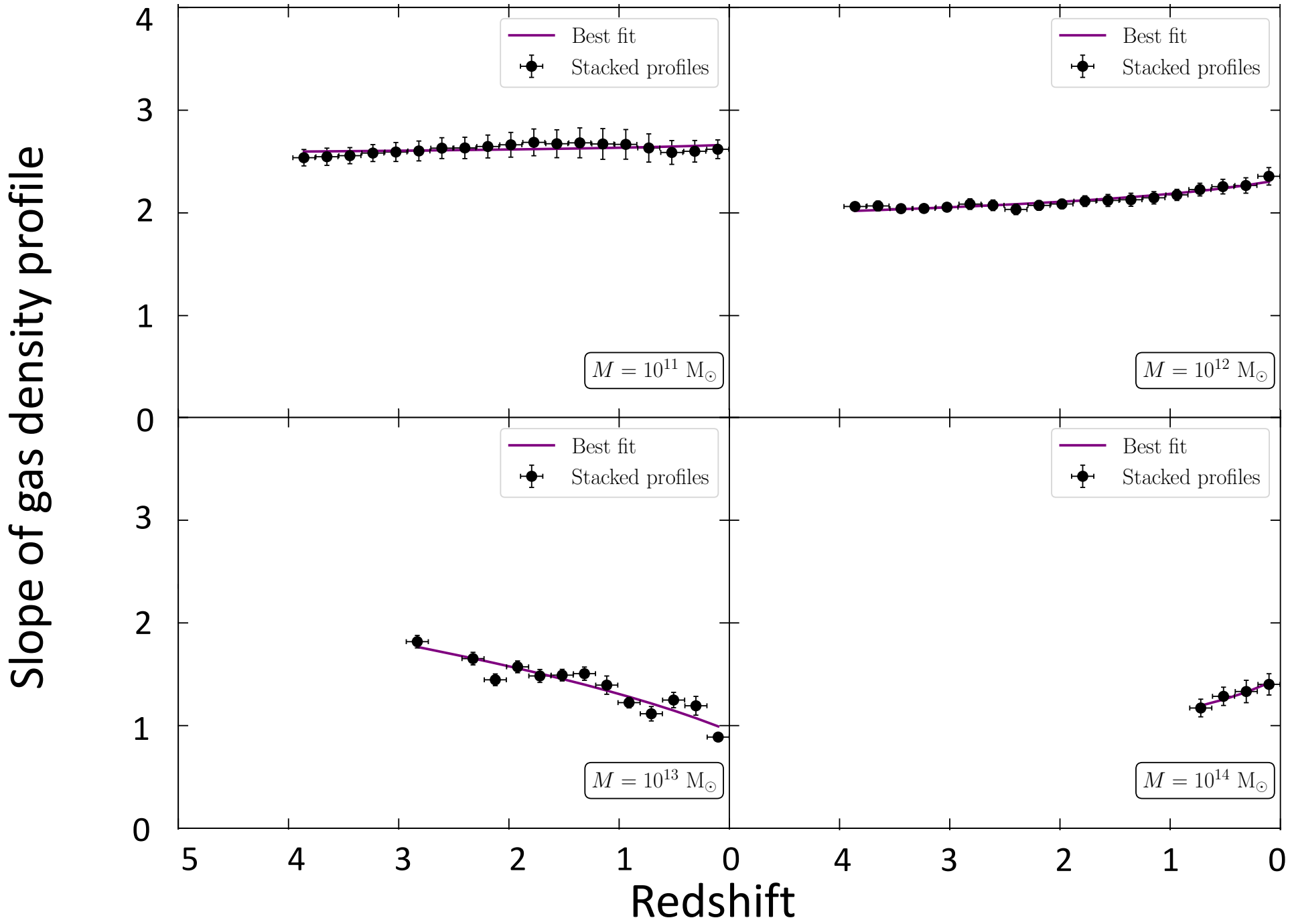
Fit gas density profiles

PRELIMINARY



[Sorini+ in prep.]





Gas density profile

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

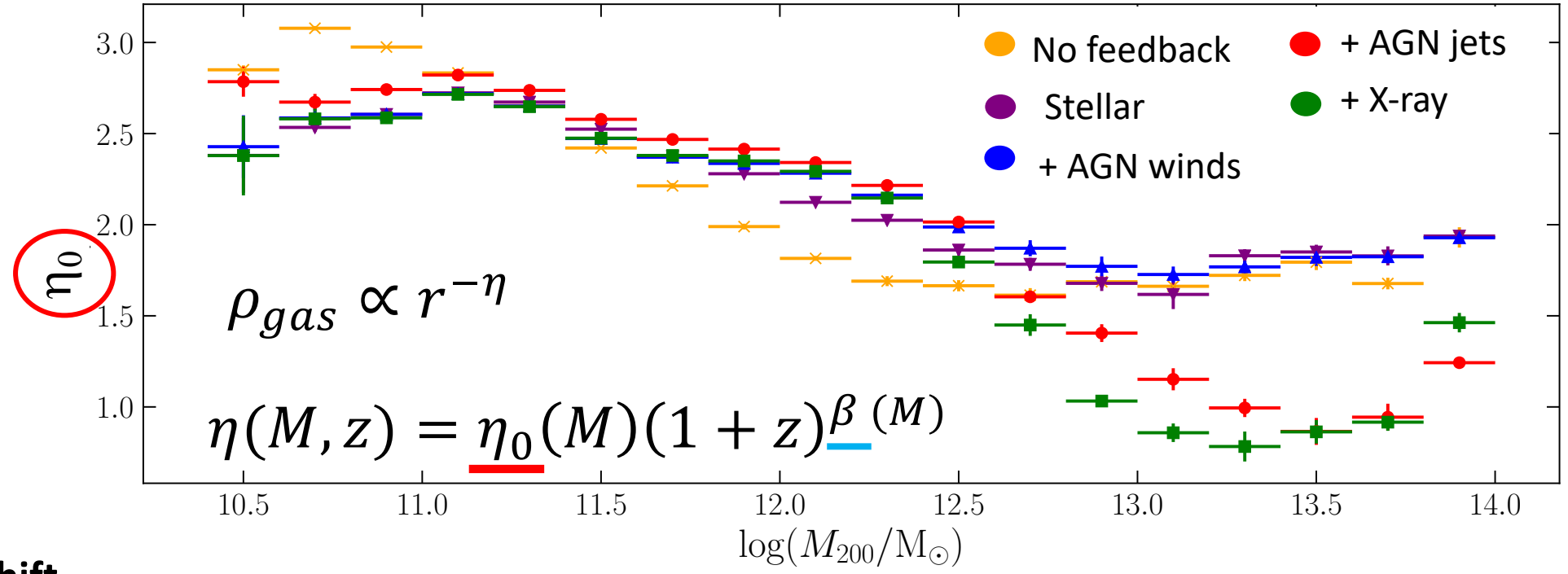
At fixed mass:

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

[Sorini+ in prep.]

STEEPER

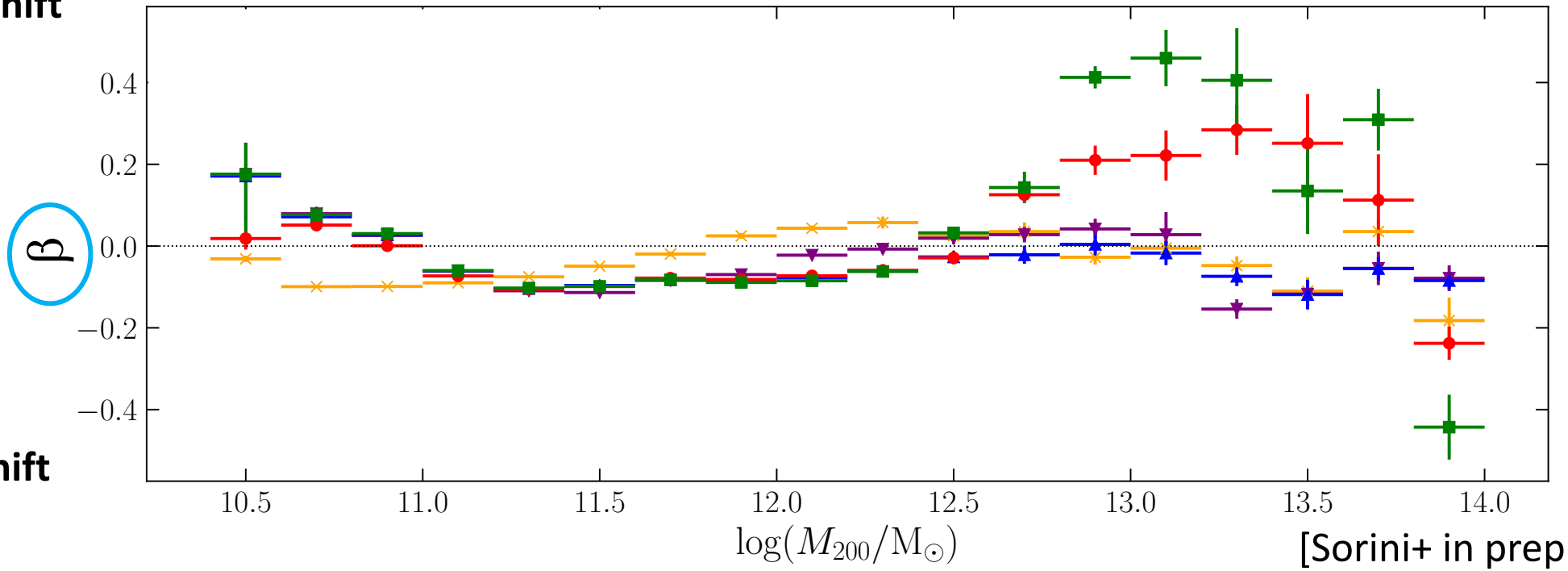
LESS STEEP



Steeper @ higher redshift

Constant with redshift

Steeper @ lower redshift



[Sorini+ in prep.]

arXiv:2111.13708

Conclusions

- Main mechanisms shaping the distribution of baryons in haloes:
  - Stellar feedback in lower mass halos at z>2
  - AGN jets in higher mass halos at z<2
- Impact of feedback on halo mass function: <~25-75%
- Feedback strongly impacts the halocentric radius enclosing a baryon mass fraction equal to the cosmic value
- *Preliminary*: AGN-driven jets are associated with less steep gas density profiles in group-size haloes