The impact of baryons on halo density profiles

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Durham University

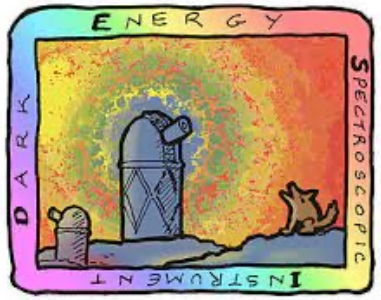
Cosmology 2023 in Miramare

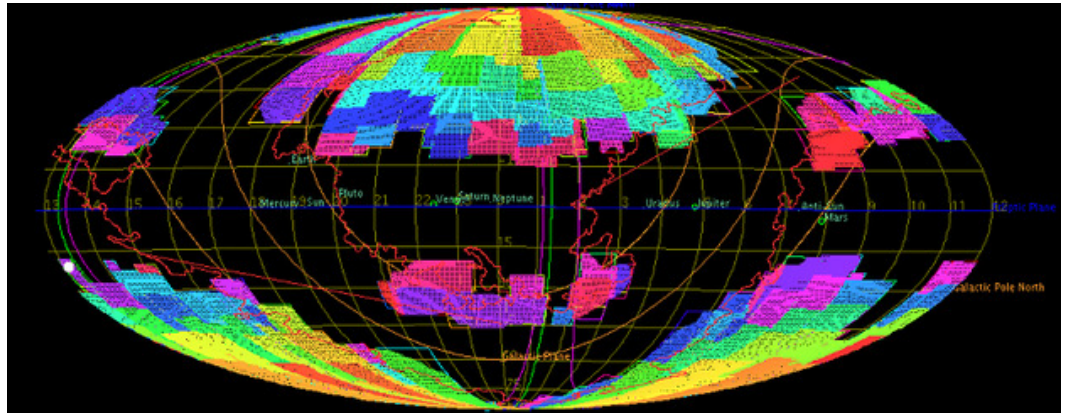
28th August 2023

UK Research and Innovation

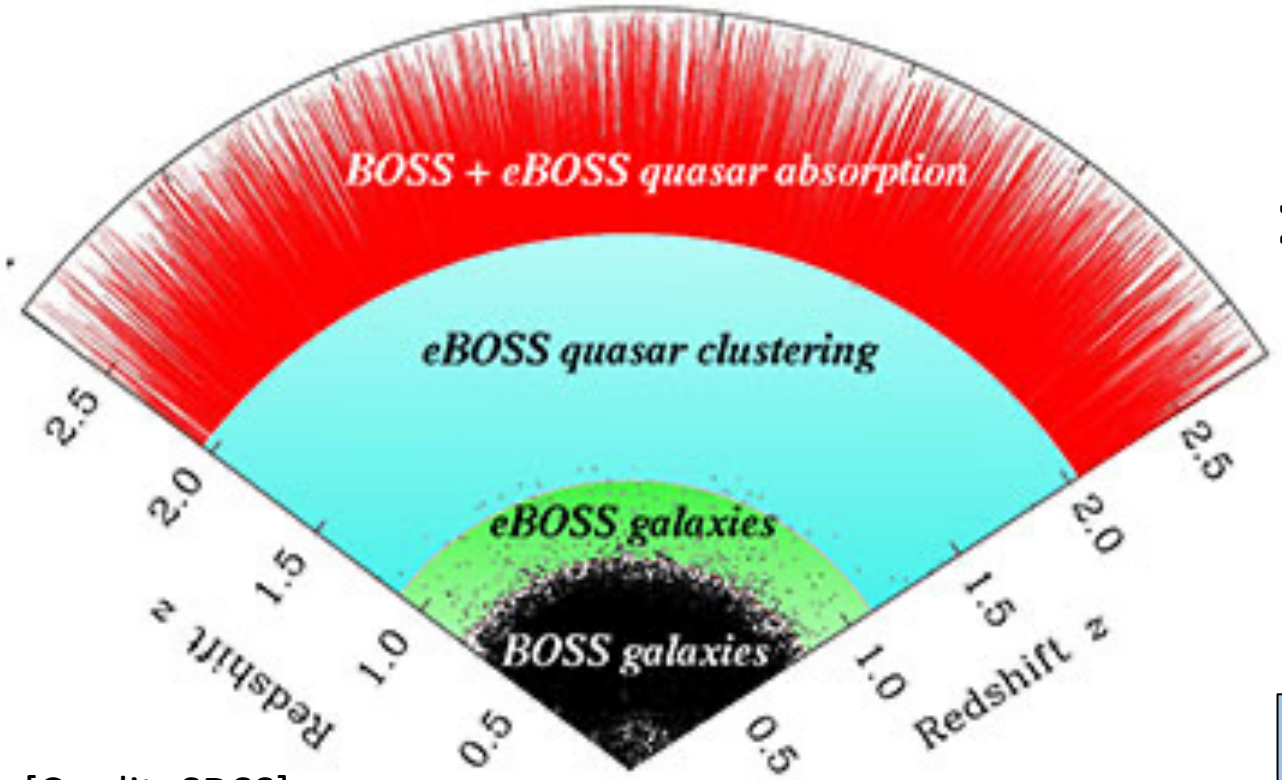
"Cosmology offers today one of the most important frontiers of physics. [...] On the observational side, there is an exponential growth of accurate and important data, which will help in establishing the new needed theories."

Cosmology 2023 in Miramare wesbite

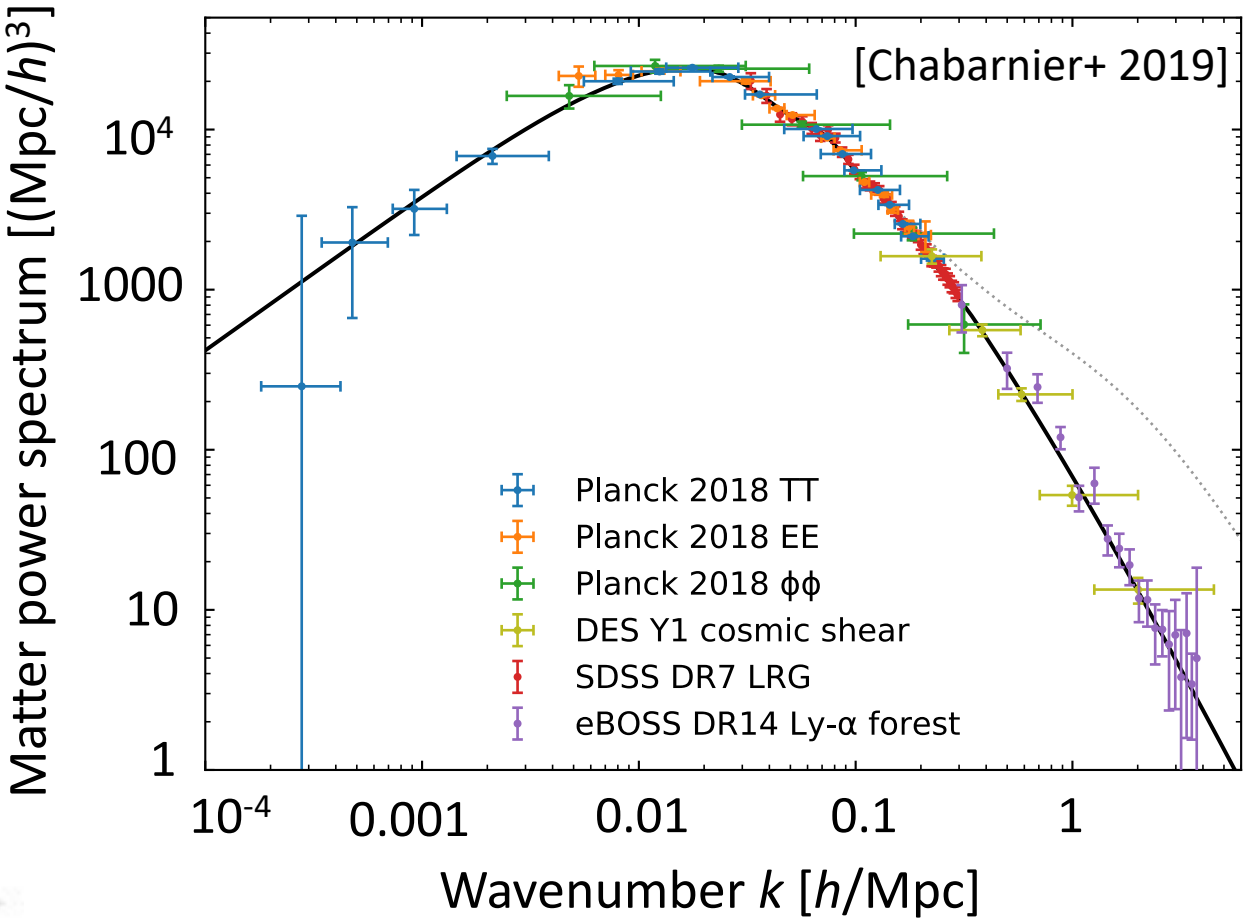




[Credit: Euclid collaboration]



[Credit: SDSS]

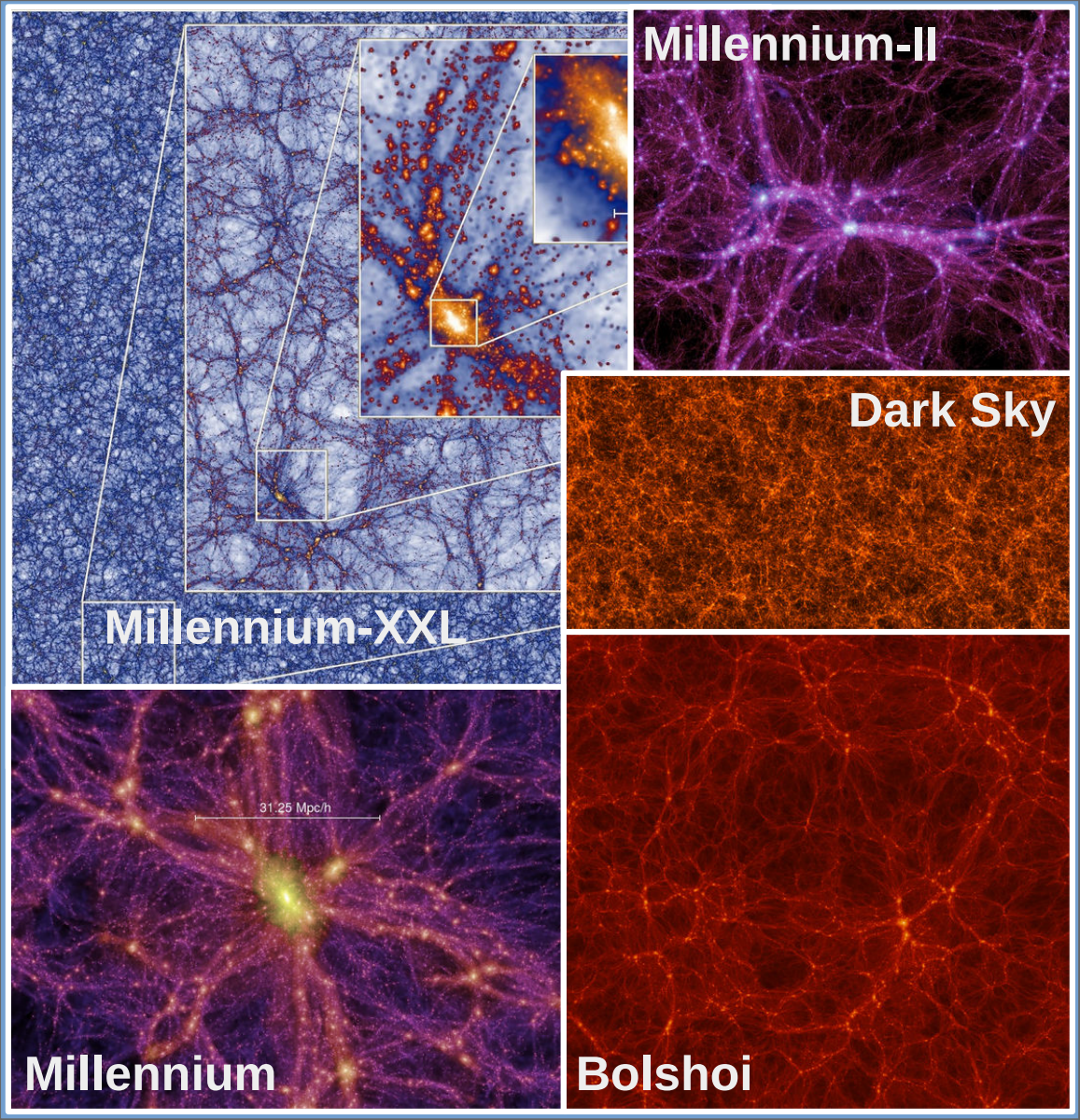


Wider and deeper surveys → Model large scales

Non-linear effects → Model small scales

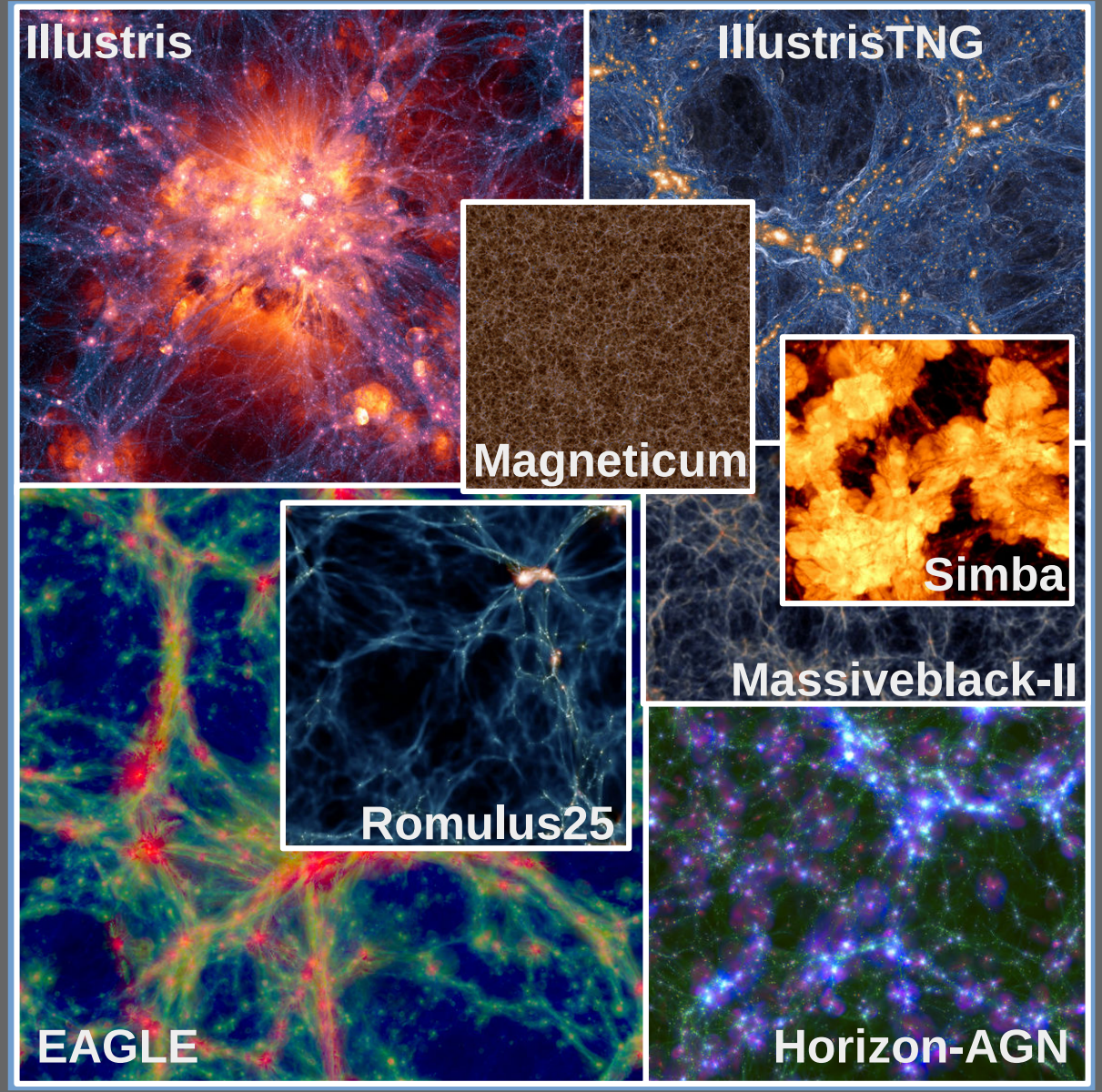
Dark matter only (N-body)

cheaper, less physics



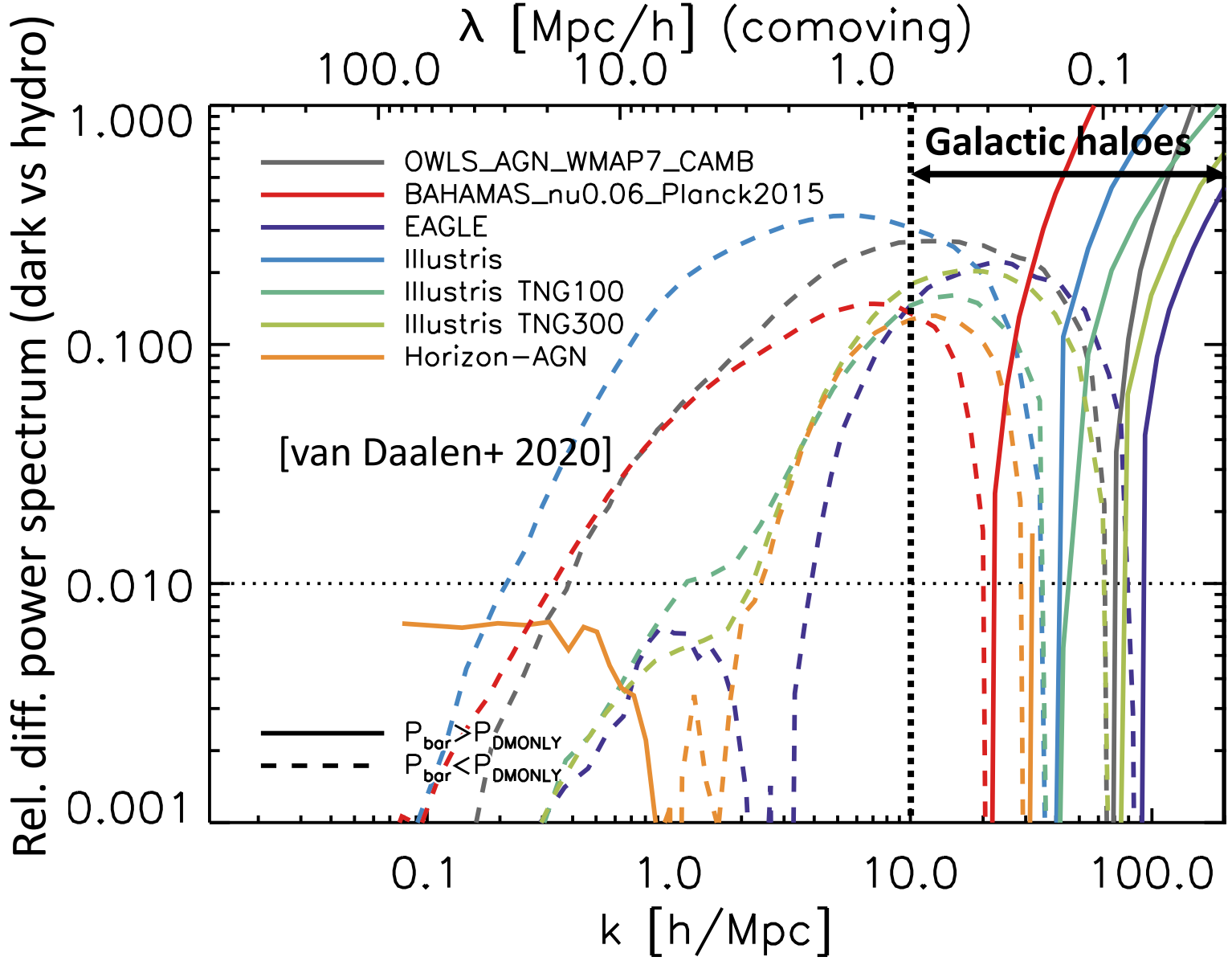
Dark matter + baryons (hydrodynamical)

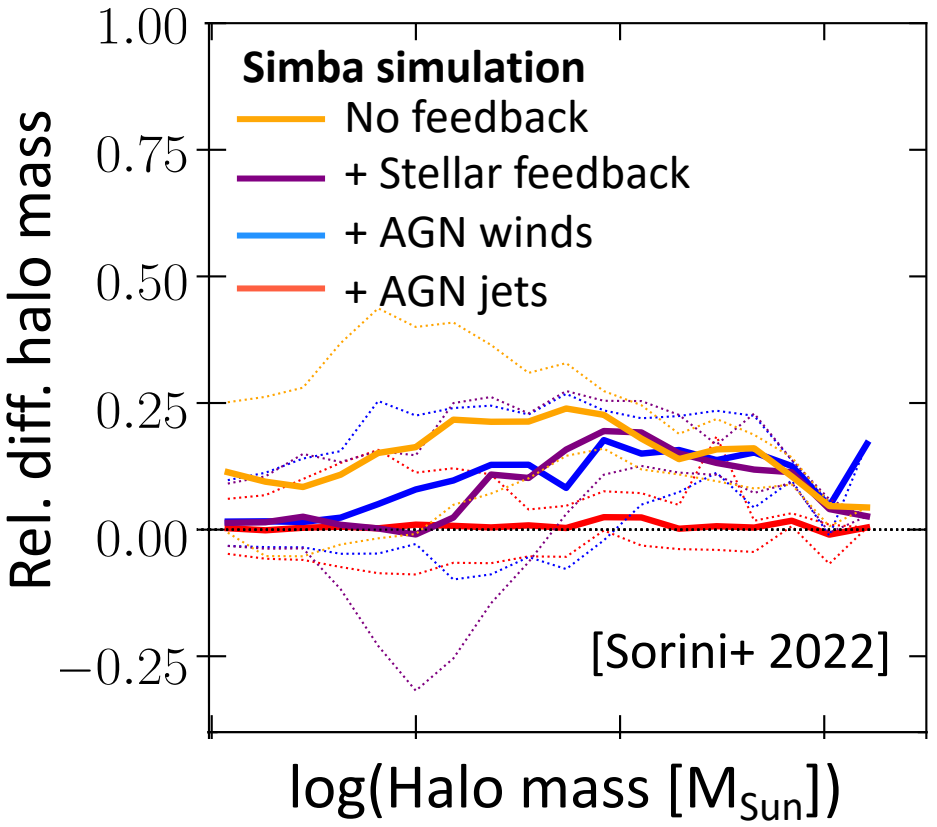
expensive, more physics



[Vogelsberger+ 2020]

Baryonic physics impacts LSS and halo structure

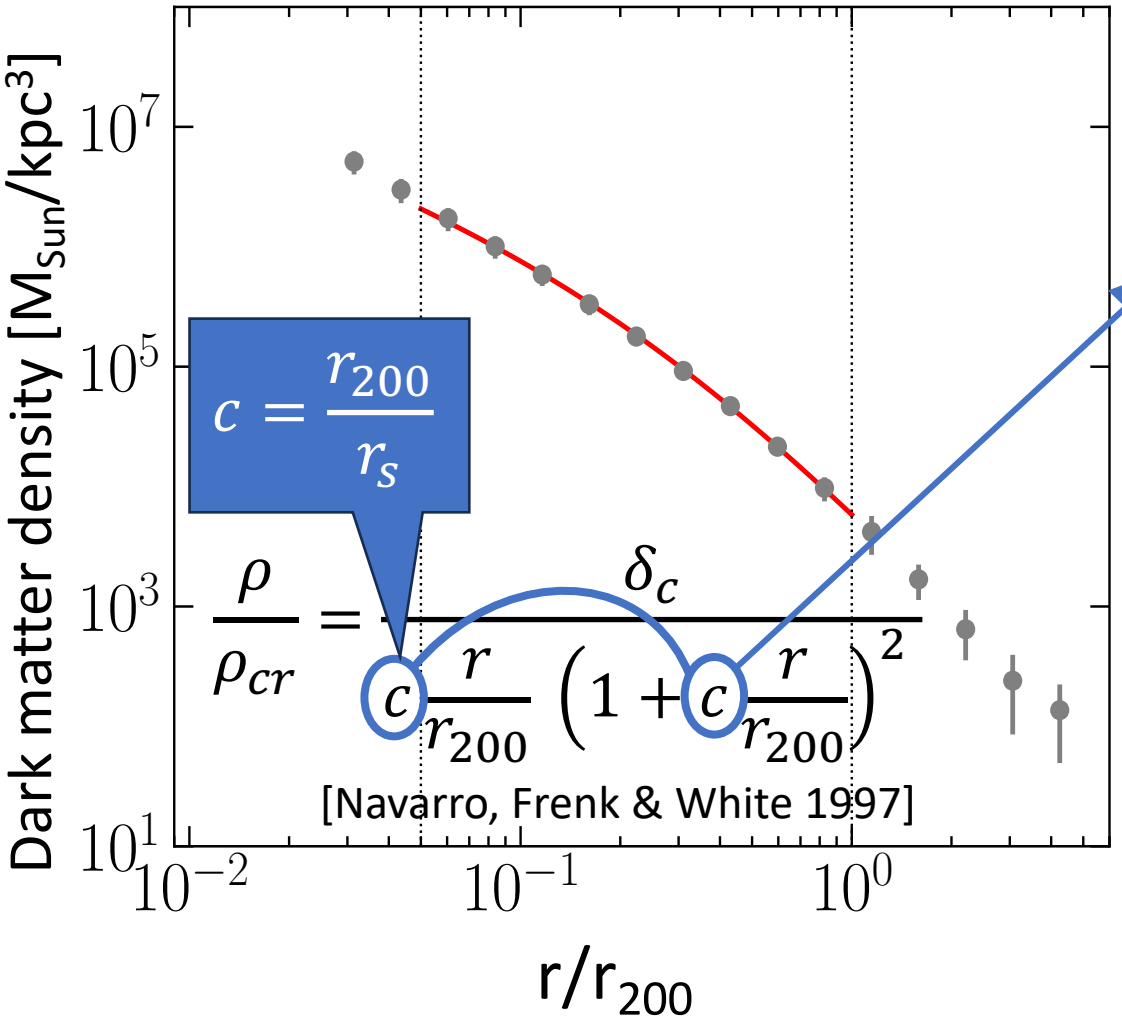


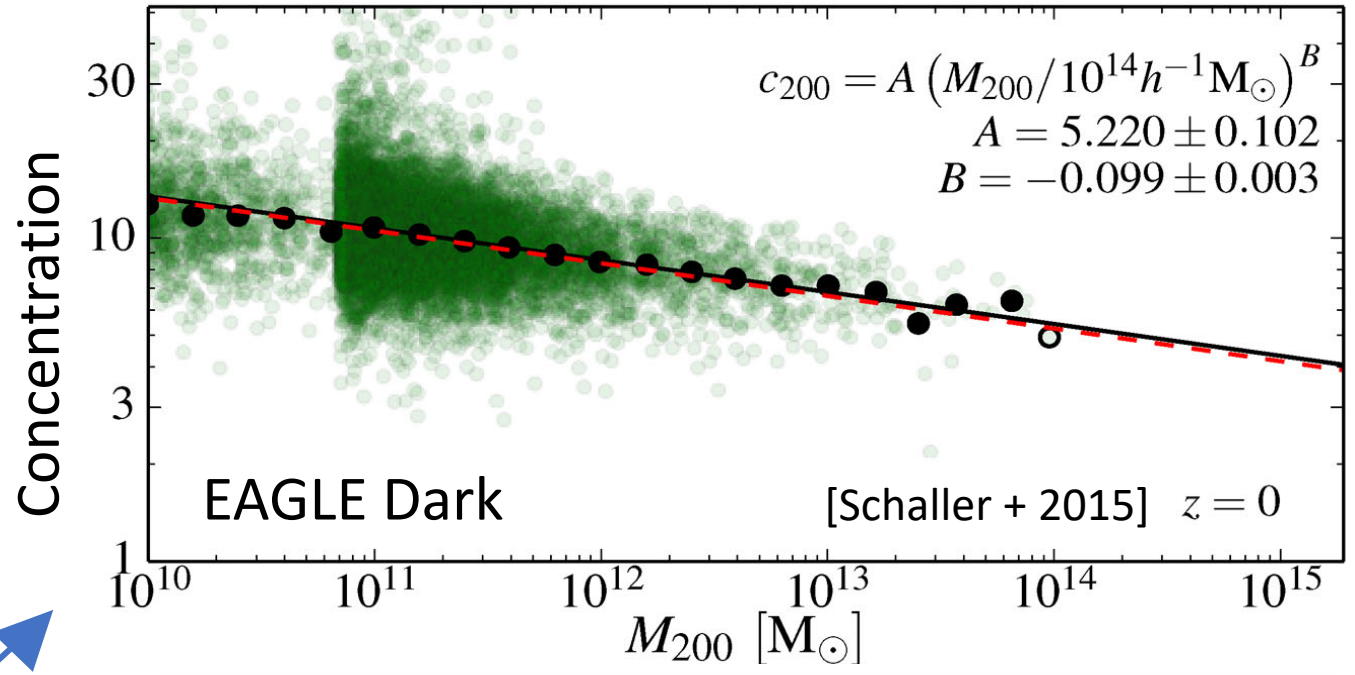


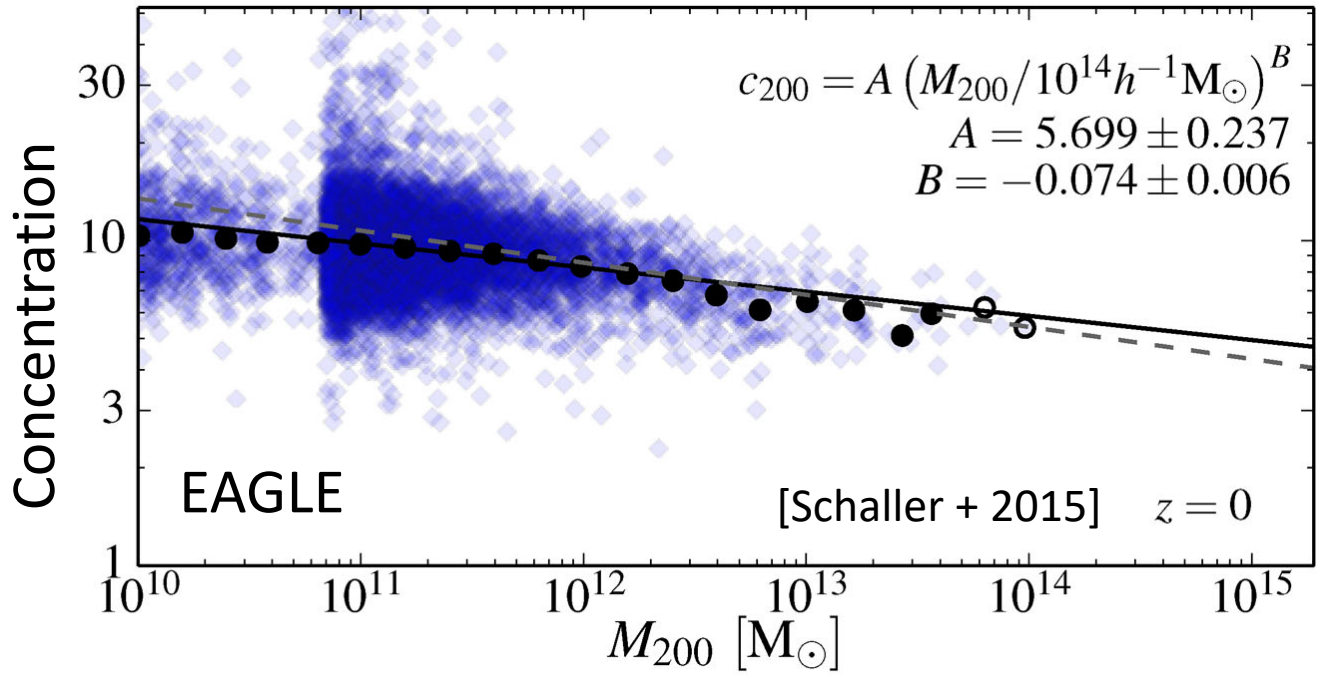
[see also Hellwing+ 2016; Barreira+ 2019; Schneider+ 2019; Salcido+ 2023]

[see also Fattahi+ 2016; Sawala+ 206; Despali+ 2017; Pillepich+ 2018b; Chua+ 2019, 2021; Cataldi+ 2021; Macciò + 2020]

Concentration-mass relationship

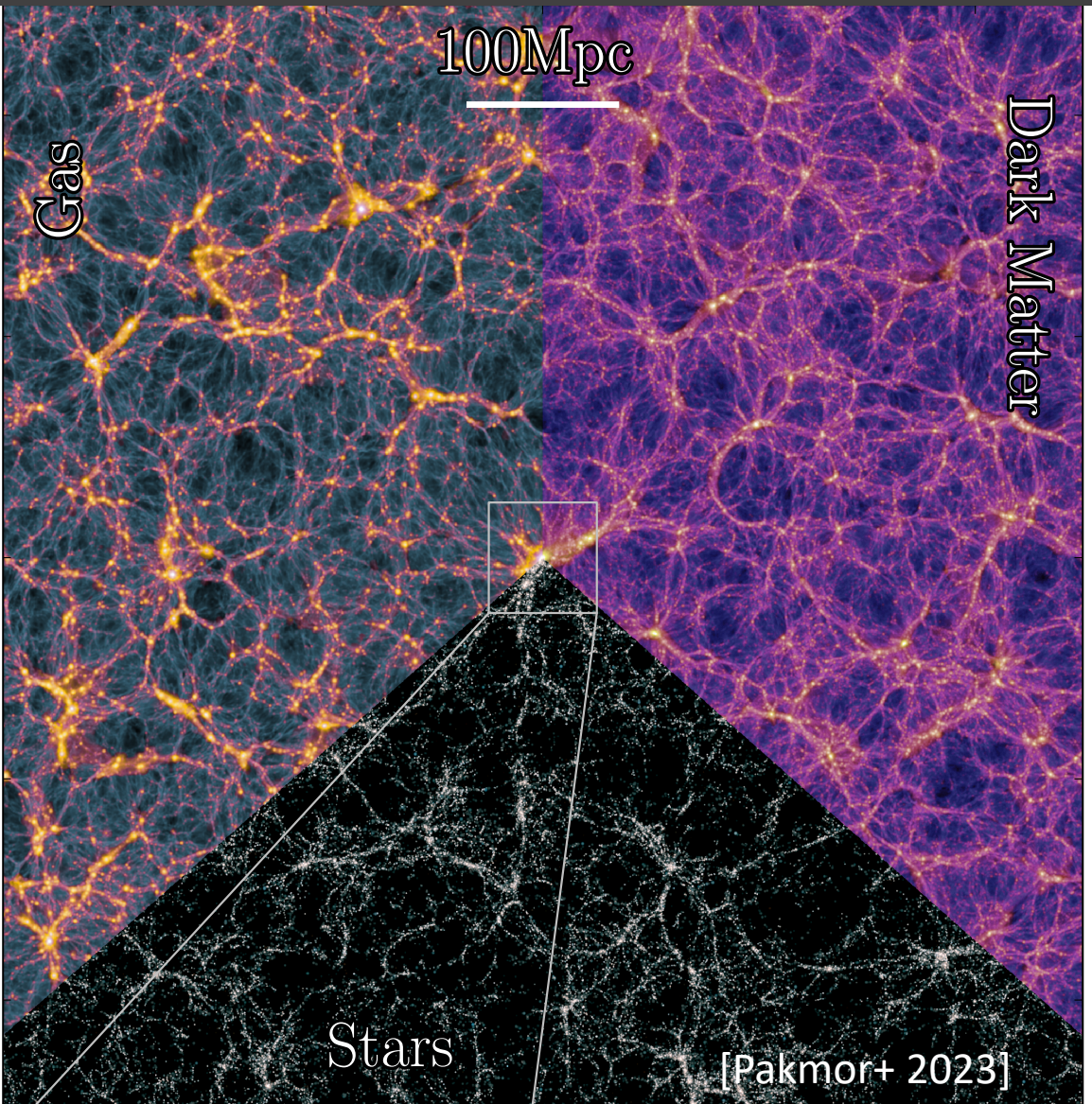






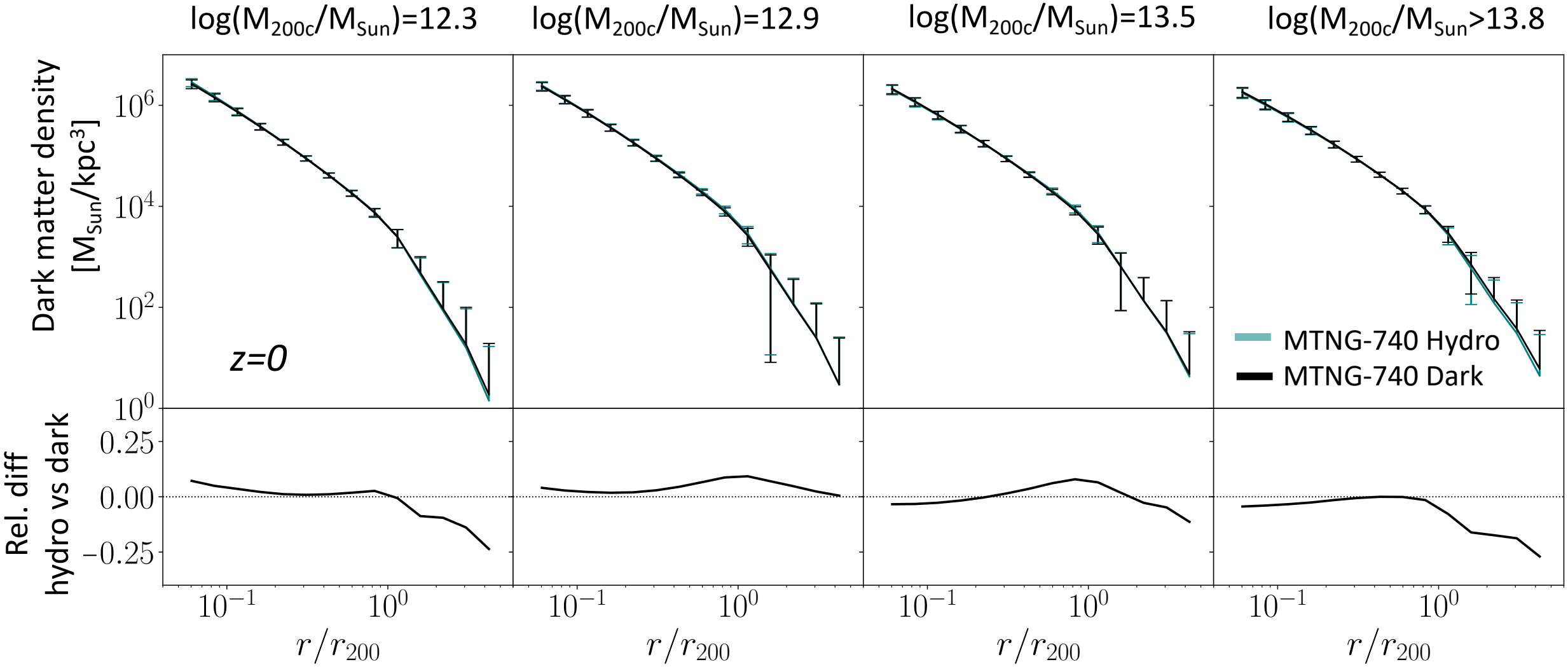
[see also Gnedin+ 2004; Bryan + 2013; Ragagnin+ 2019; Beltz-Mohrmann+ 2021; Anbajagane+ 2022a,b; Shao+ 2023]

MillenniumTNG simulation



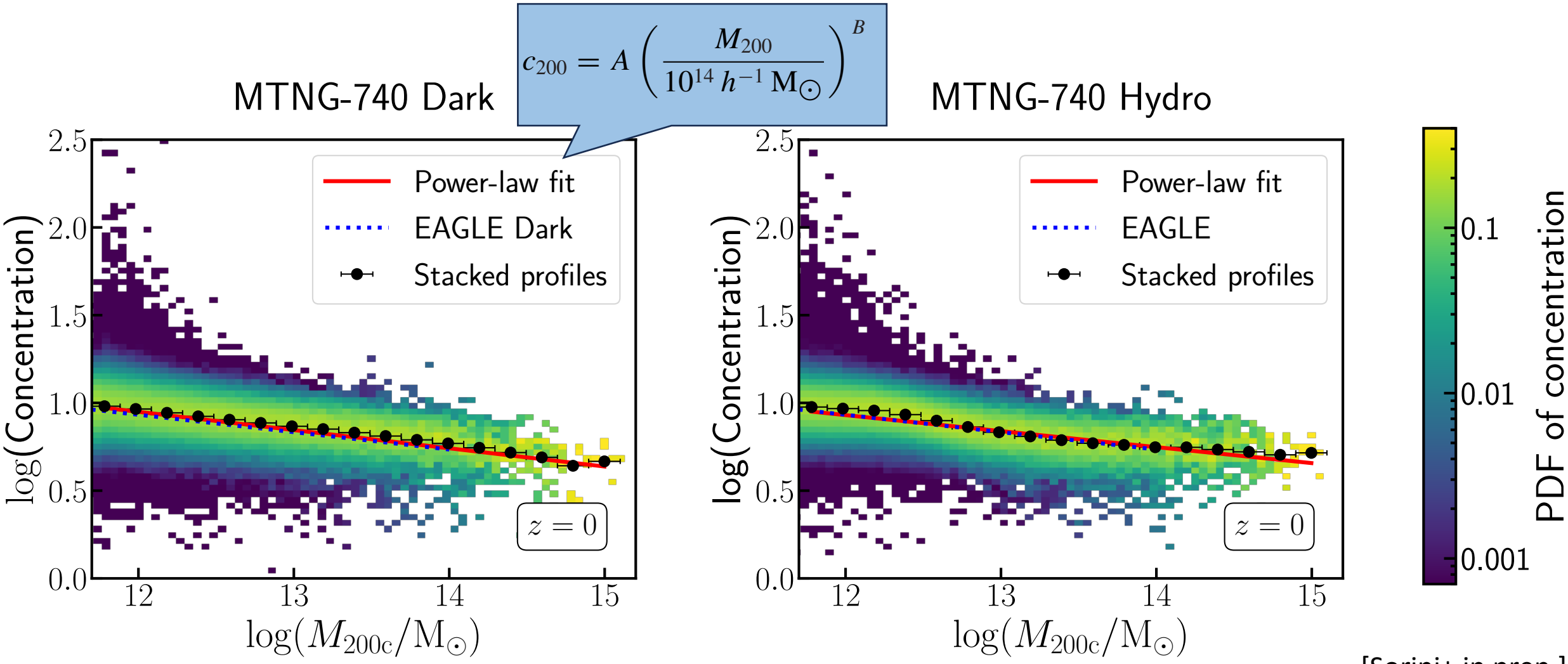
- Box size 740 cMpc
- Gas mass resolution 3.1 X 10^7 M_{Sun}
- Dark matter mass resolution 1.7 X 10^8 M_{Sun}
- Arepo moving mesh hydrodynamic code
  [Springel+2010; Pakmor+ 2016; Weinberger+ 2020]
- IllustrisTNG galaxy formation model
  [Weinberger+ 2017; Pillepich+ 2018a]
  with no magnetic fields

Dark matter density profiles in MillenniumTNG



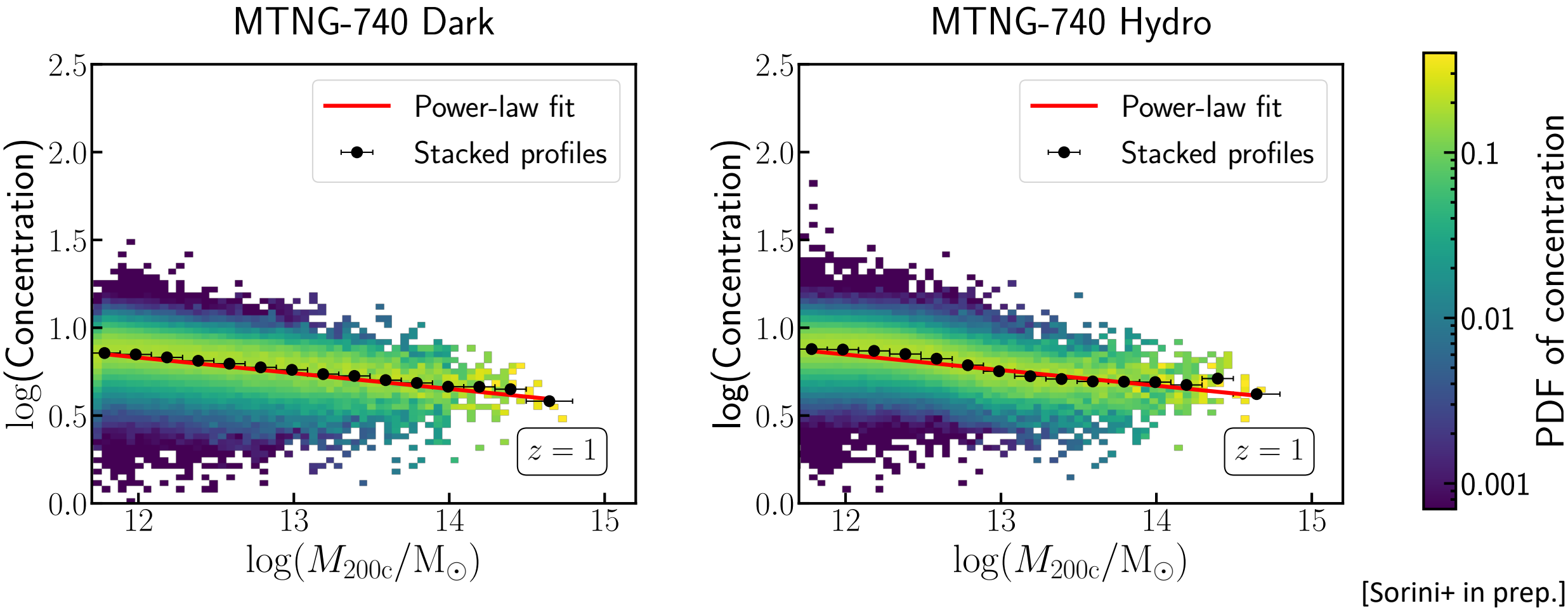
Concentration-mass relationship up to ~10^{15} M_{Sun}

$$c_{200} = A \left(\frac{M_{200}}{10^{14}\, h^{-1}\, \mathrm{M}_\odot} \right)^B$$



[Sorini+ in prep.]

Redshift evolution of the concentration-mass relationship



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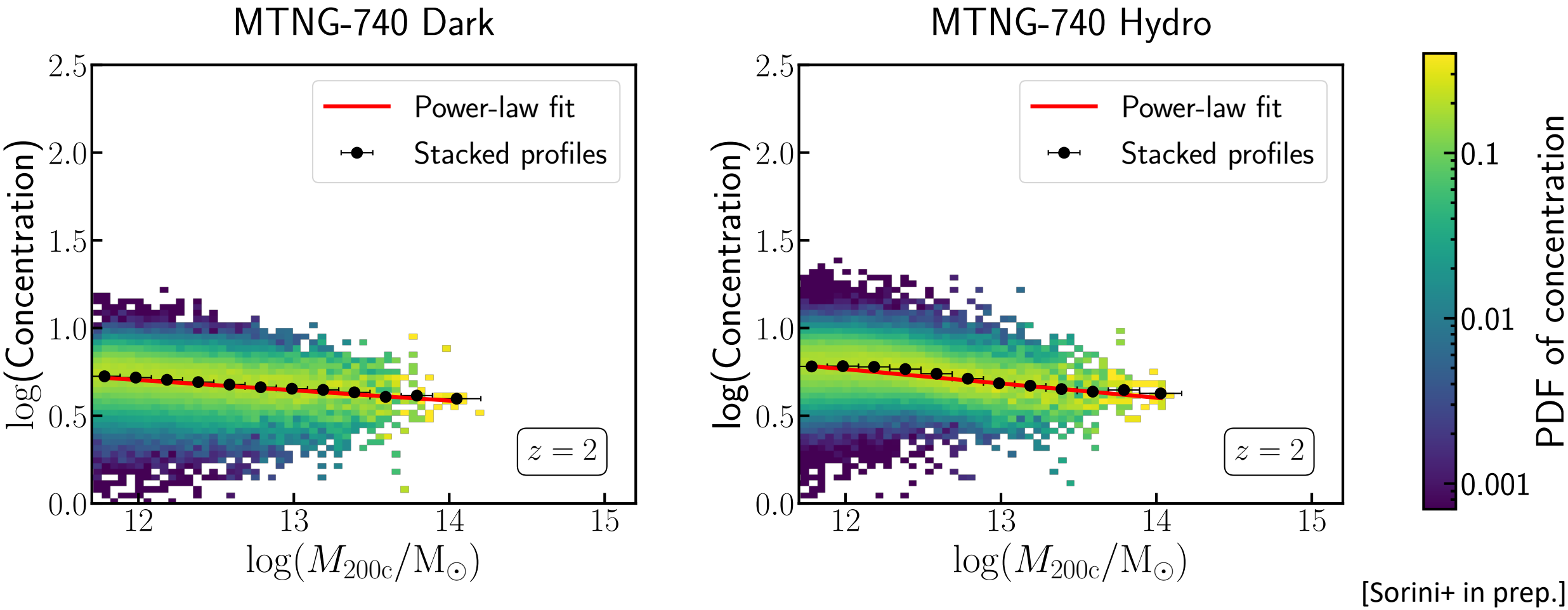

[Sorini+ in prep.]

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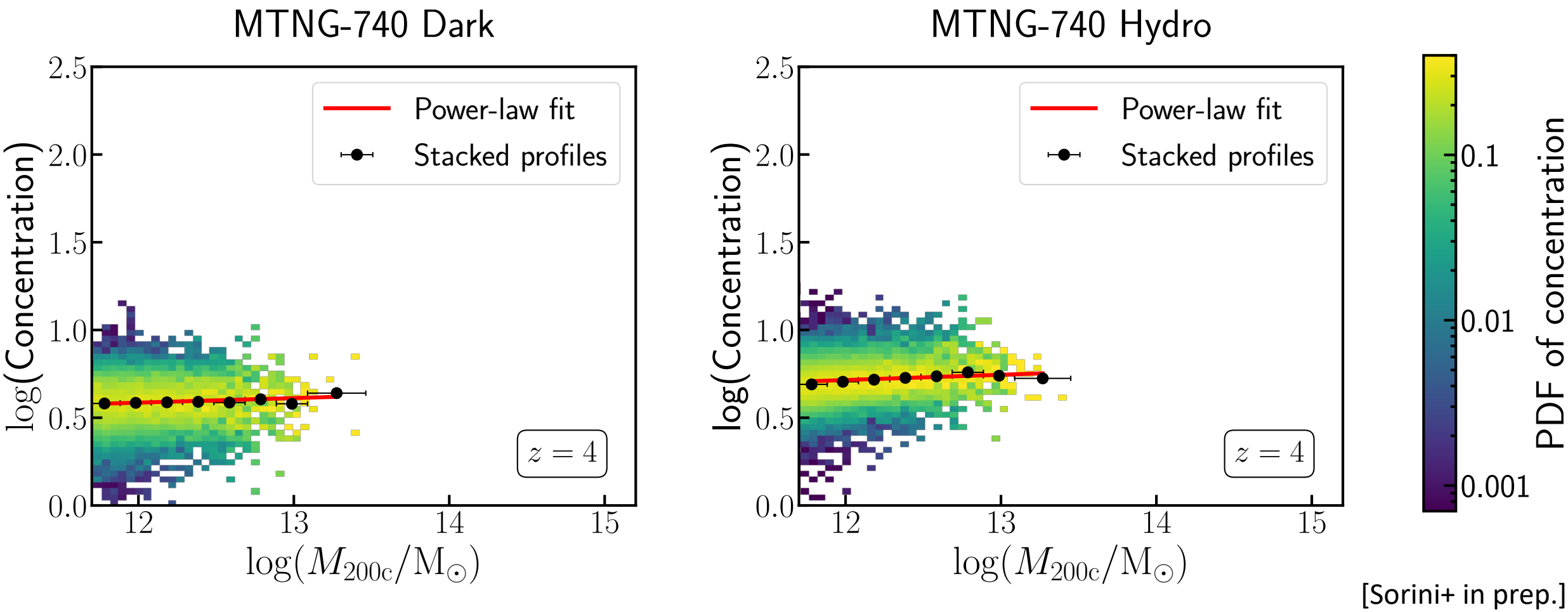

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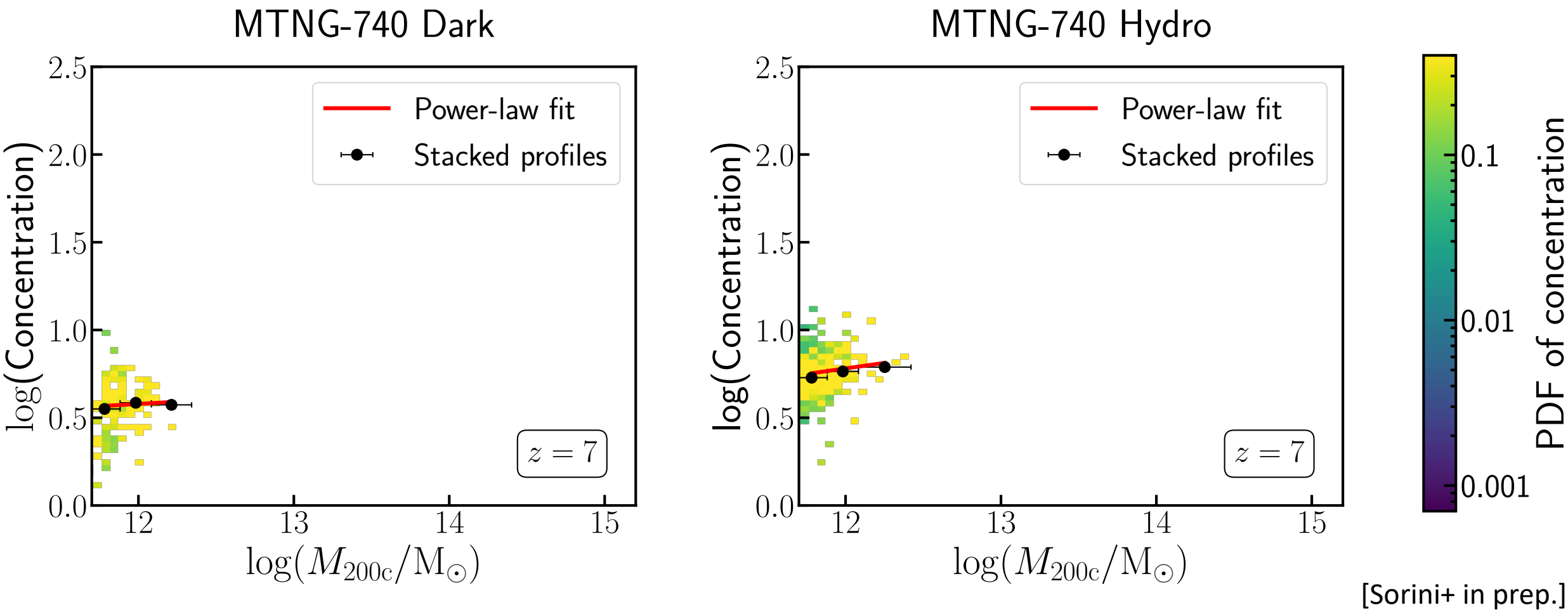
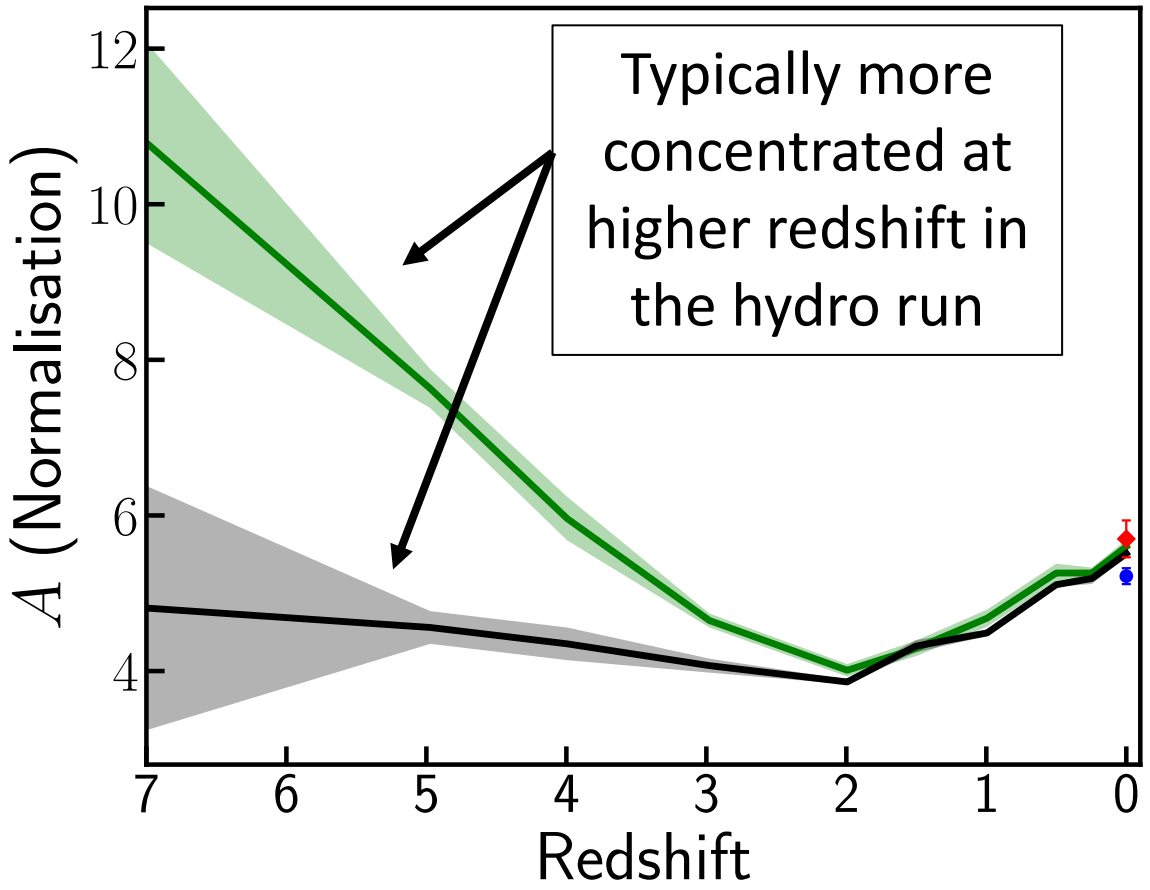
Redshift evolution of the concentration-mass relationship

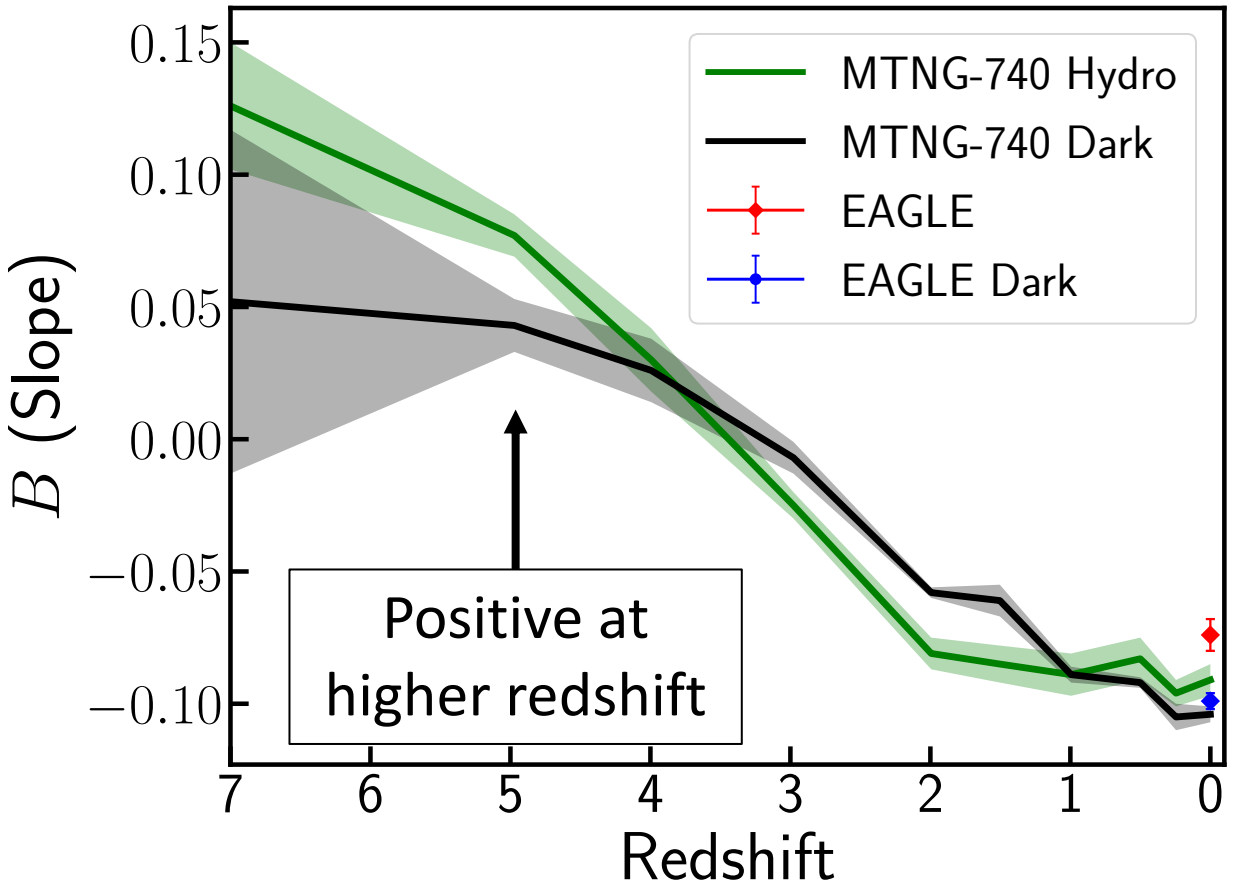


[Sorini+ in prep.]

Redshift evolution of fit parameters

$$c_{200} = A \left(\frac{M_{200}}{10^{14}\, h^{-1}\, \mathrm{M}_\odot} \right)^B$$



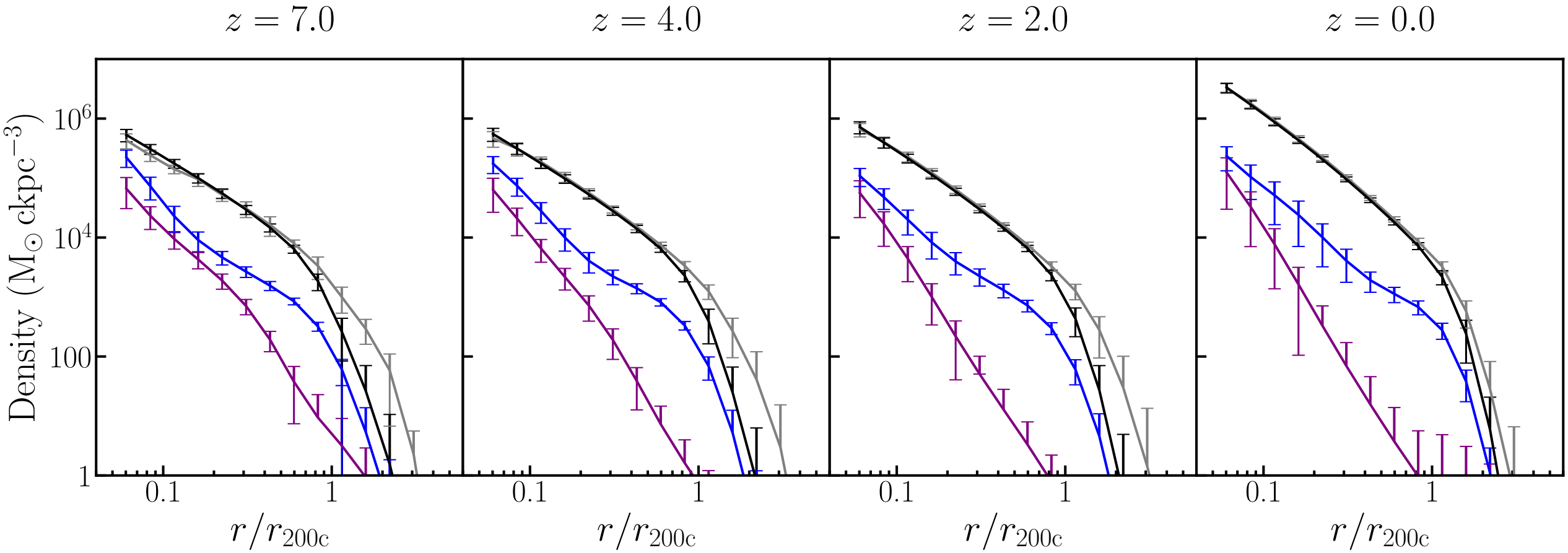


[Sorini+ in prep.]

Baryons drive the increase of concentration at high z

$M_{200c}=10^{11.6}\ M_{Sun}$

Gas
Stars
Dark matter in MTNG-740 Hydro
Dark matter in MTNG-740 Dark

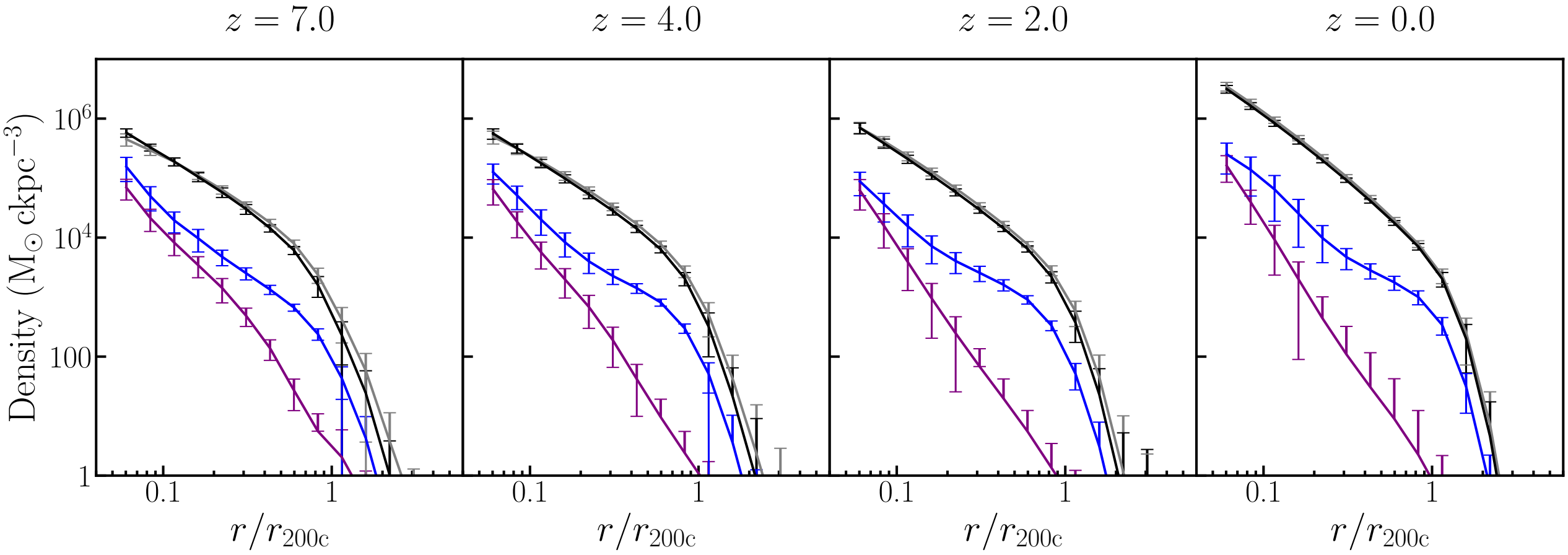


[Sorini+ in prep.]

Baryons drive the increase of concentration at high z

$M_{200c}=10^{12}\ M_{Sun}$

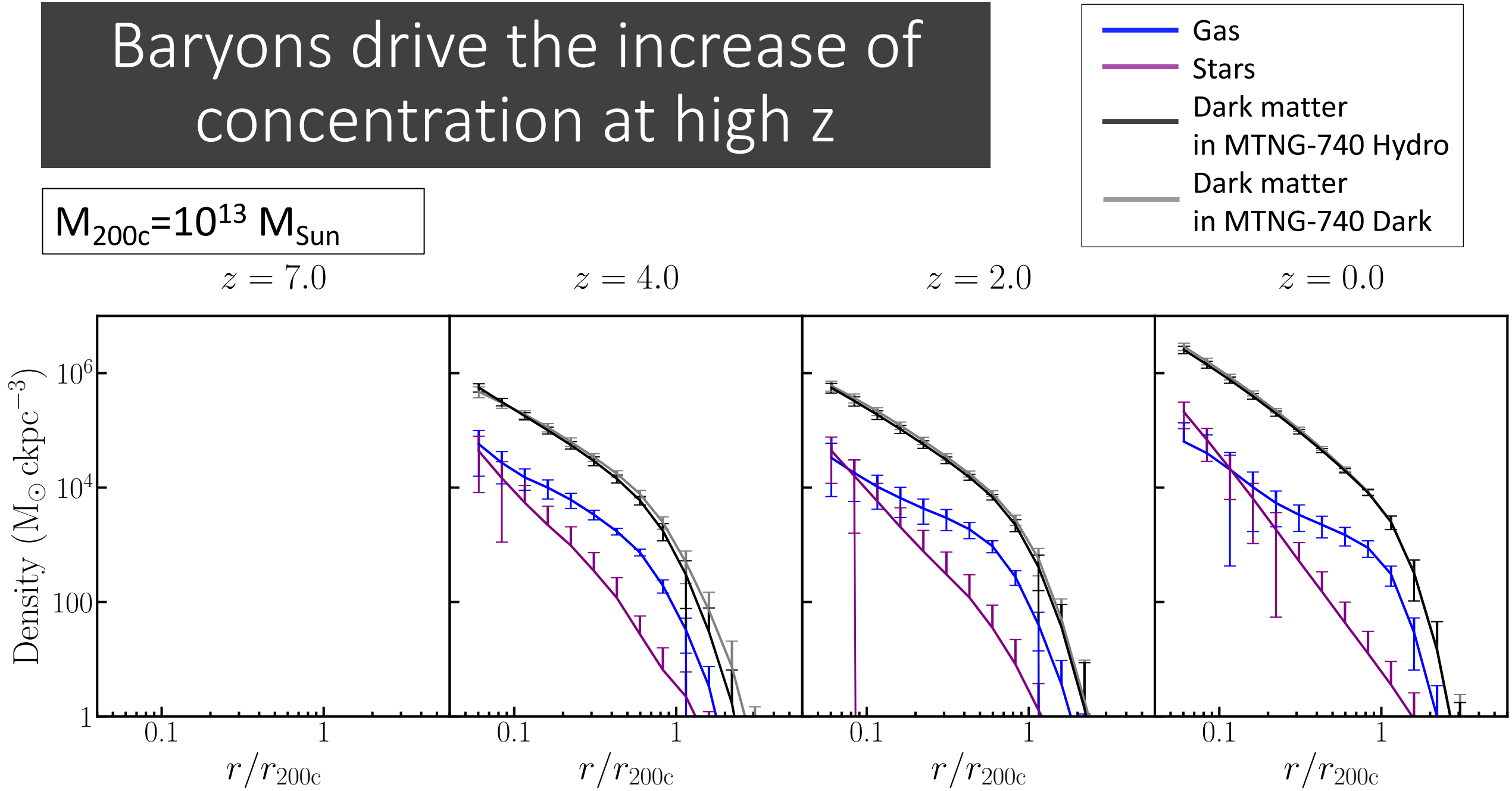
Gas
Stars
Dark matter in MTNG-740 Hydro
Dark matter in MTNG-740 Dark



[Sorini+ in prep.]

Baryons drive the increase of concentration at high z

$M_{200c}=10^{13}\ M_{Sun}$

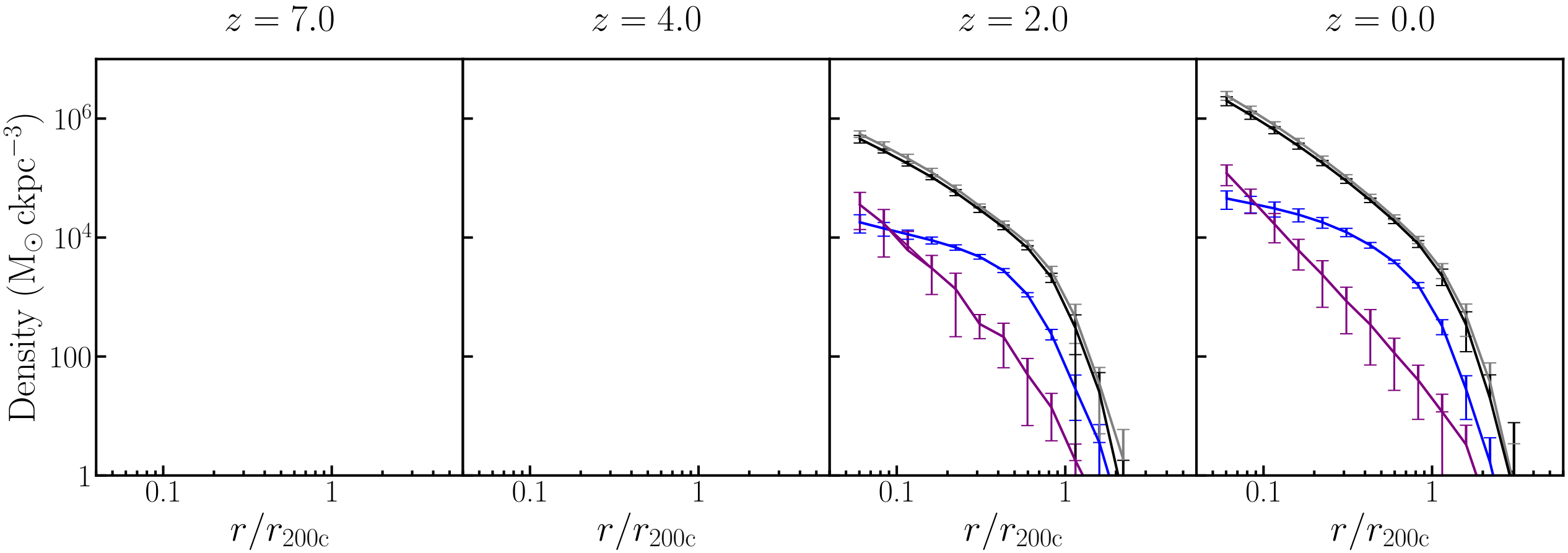


[Sorini+ in prep.]

Baryons drive the increase of concentration at high z

$M_{200c}=10^{14}\ M_{Sun}$

Gas
Stars
Dark matter in MTNG-740 Hydro
Dark matter in MTNG-740 Dark



[Sorini+ in prep.]

Effect of baryons on gas profiles in the Simba simulation

BH accretion

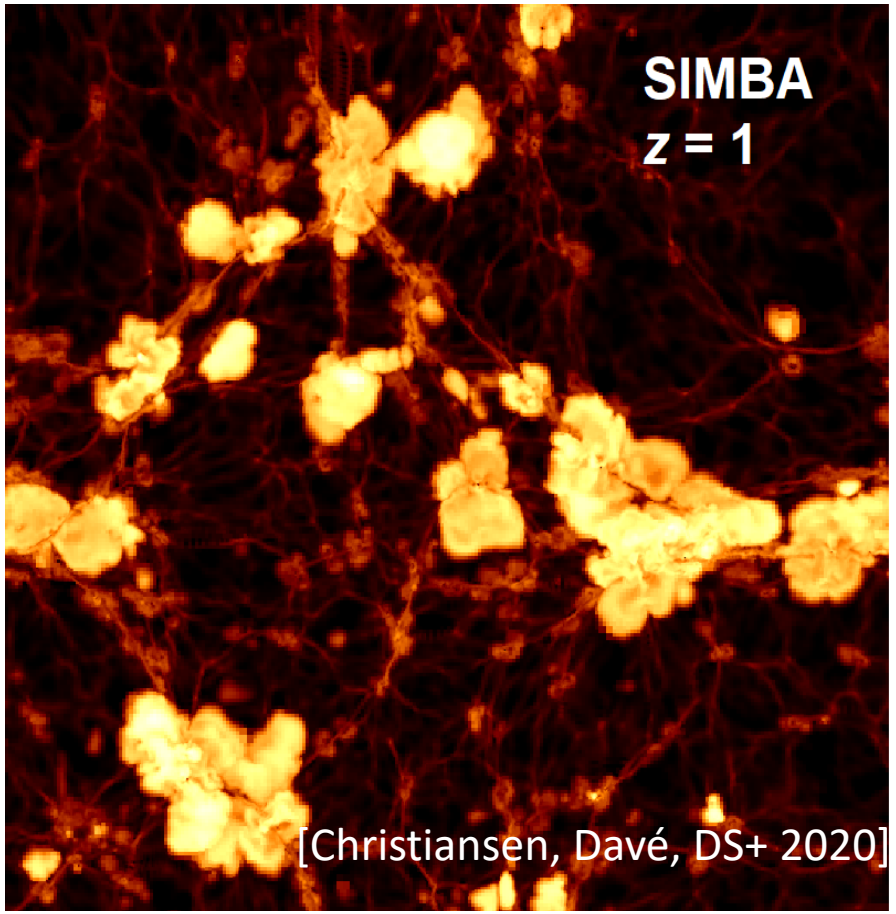
- HOT MODE [Bondi 1952]
- COLD MODE: torque-limited accretion [Hopkins & Quataert 2011; Anglés-Alcázar+ 2013, 2015, 2017a]

Stellar feedback

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

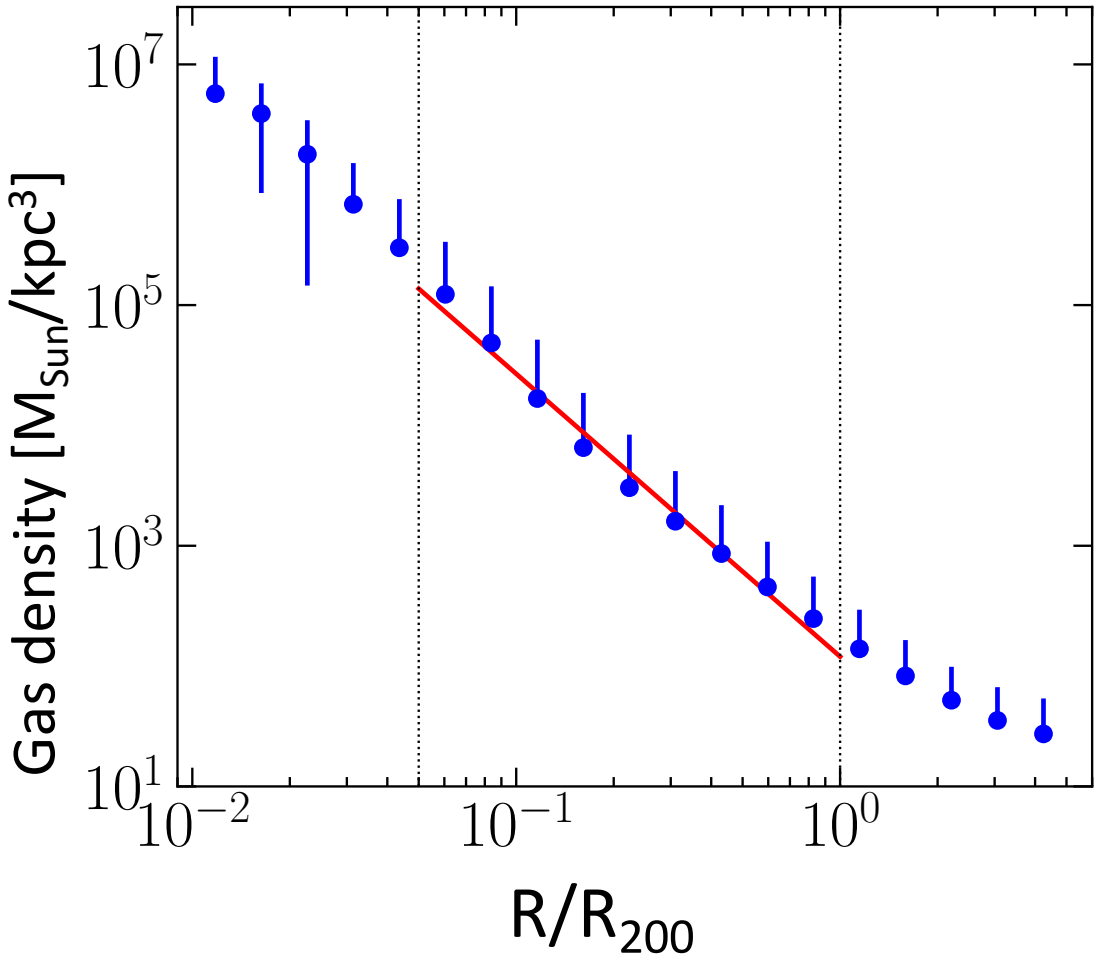
AGN feedback

- 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+ 2019]

Fit gas density profiles



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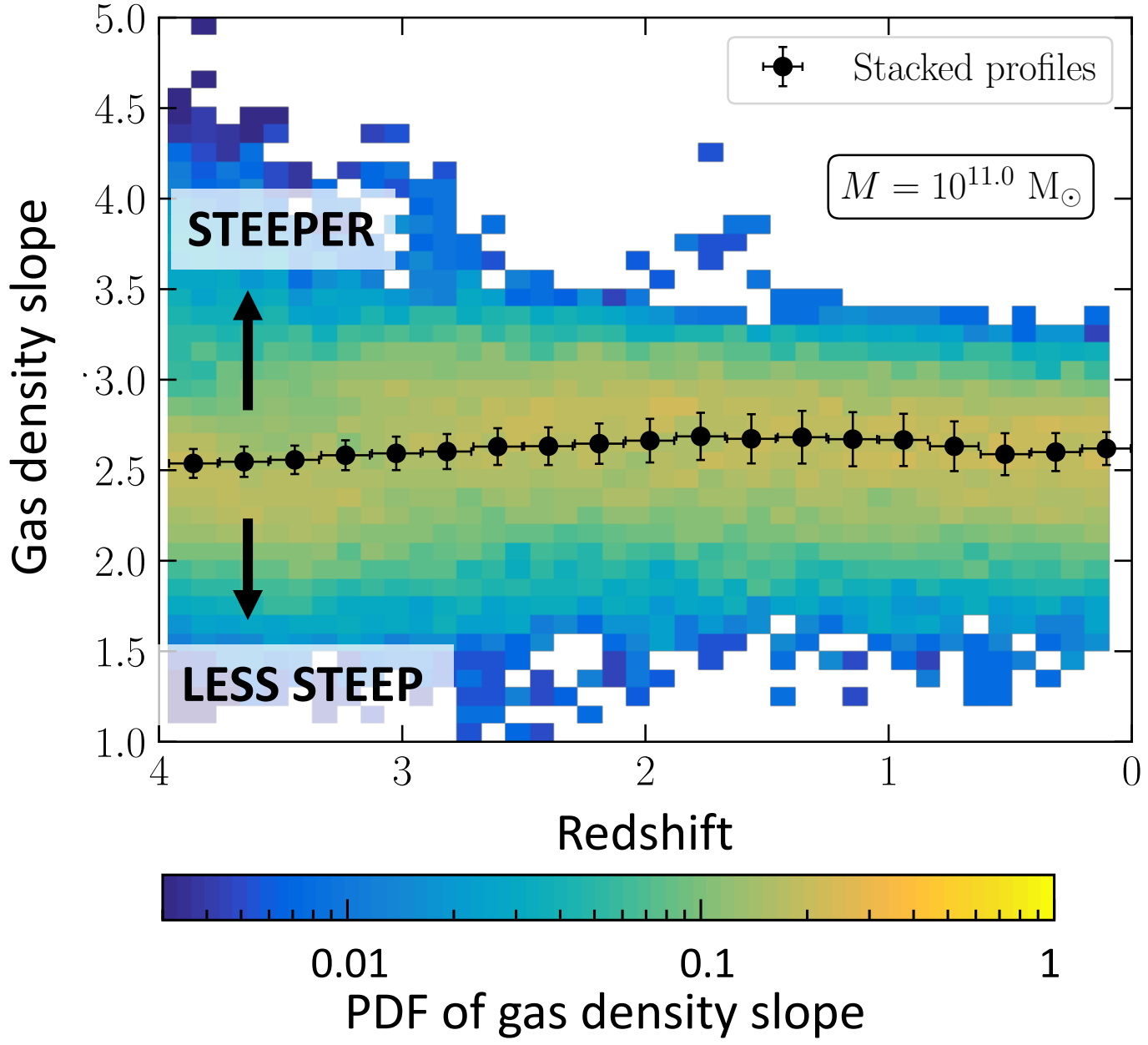
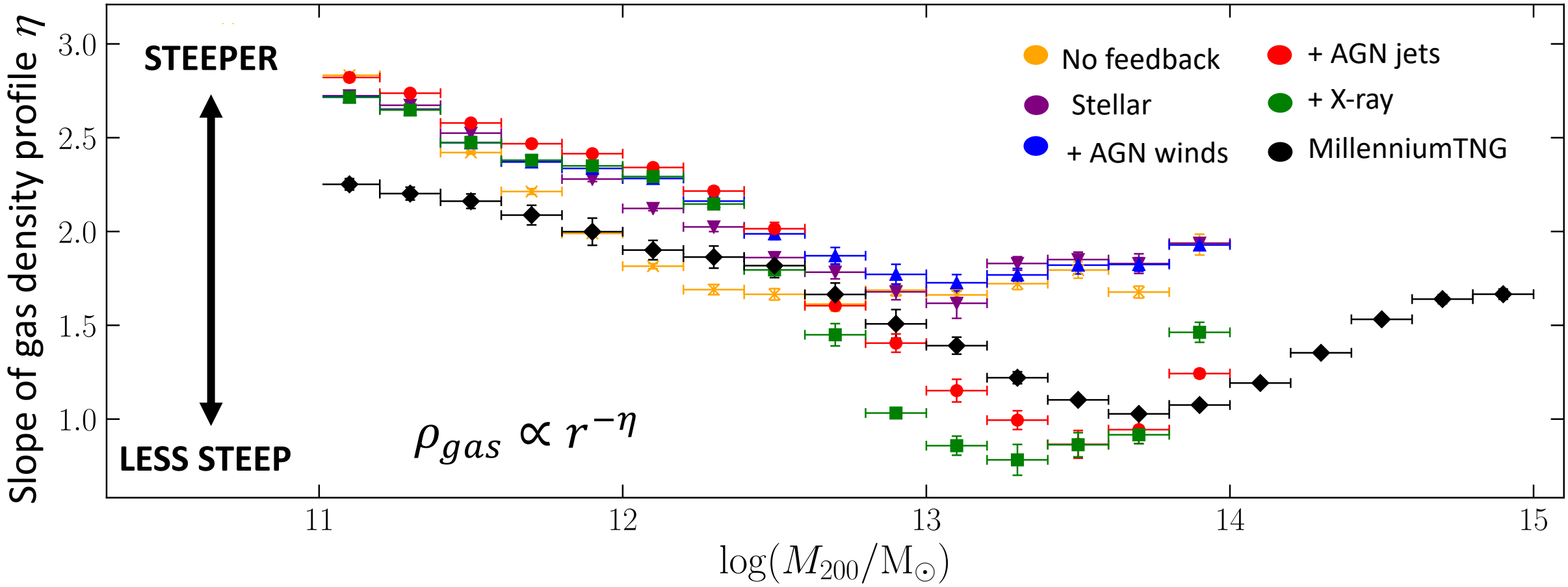


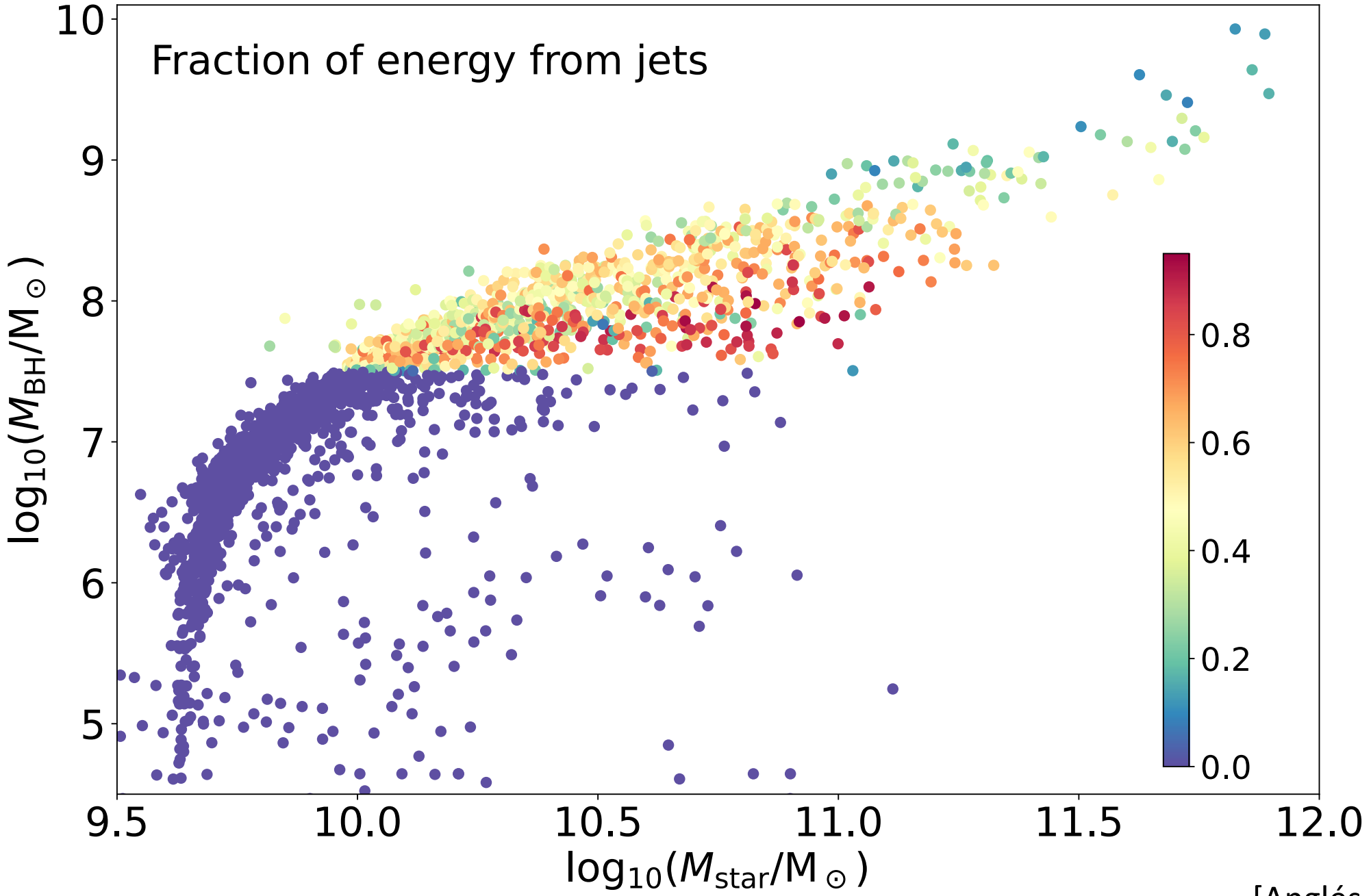
AGN jets decrease slope of gas density profile in massive haloes



[Sorini+ in prep.]

Conclusions

- *MTNG*: Baryons increase both normalisation and slope of concentration-mass relationship at high redshift
- *MTNG*: At lower redshift, the concentration-mass relationship in the hydrodynamical simulation is consistent with the dark-matter-only run
- *Simba*: AGN-driven jets are associated with less steep gas density profiles in group-size haloes



[Anglés-Alcázar in prep.]