Understanding the Origin of the Critical Mass in Galaxy Evolution in HR5 Simulation

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What is critical mass?

Observations show that many properties of galaxies transition around logM*~10.5 or logMh~12

At this mass scale:

> Star Formation Rate declines, stellar mass-halo mass ratio peaks, mass-gas metallicity relation flattens

(Salim 2014, Wechsler+ 2020, Tremonti+24) [integrated properties]

> Change of shape in: size-mass relation, Faber-Jackson relation and inner galaxy rotation curve.

(Cappellari+ 2013, Choi, Park & Vogeley+ 2007, Yoon+ 2021) [resolved properties]

> Galaxy population becomes from being starforming to quenched & disk-dominated to spheroid dominated.

(Wetzel+ 2013, Kelvin+ 2014) [collective properties]

Seems like logM*~10.5 / logMh~12 is an important mass scale for galaxy evolution

Why this particular value? How it emerges?

Horizon Run 5 Cosmological Hydrodynamic Simulation (Lee et al 2021)

Large ~Gpc scale simulation

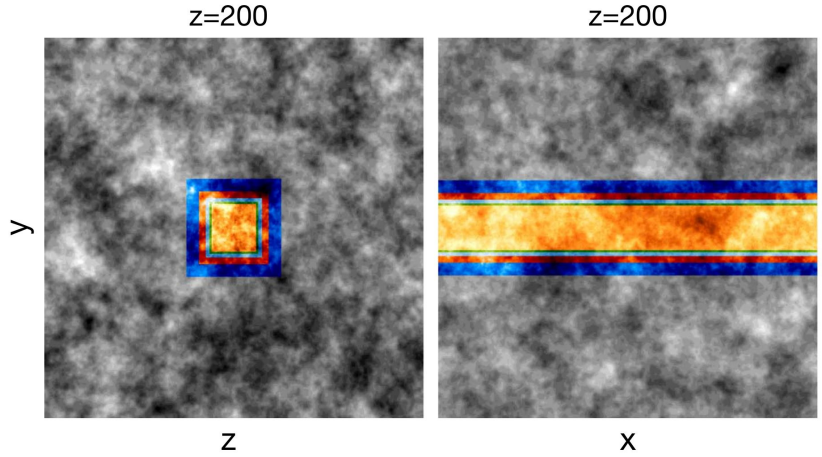
Simulation Box:

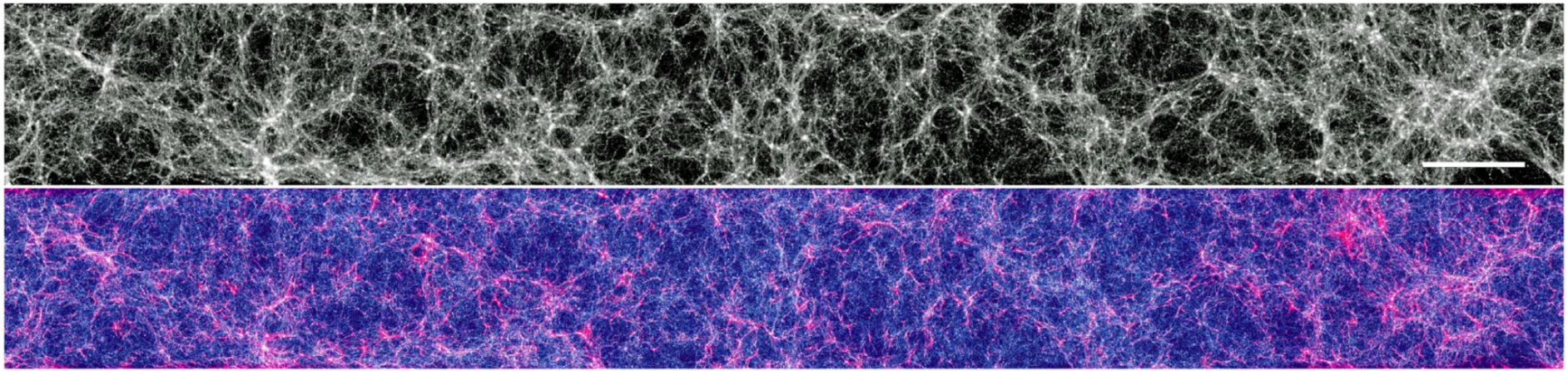
Volume = $(1049\ \mathrm{Mpc})^3$

Zoomed region = $1049 \times 119 \times 127\ \mathrm{Mpc}^3$

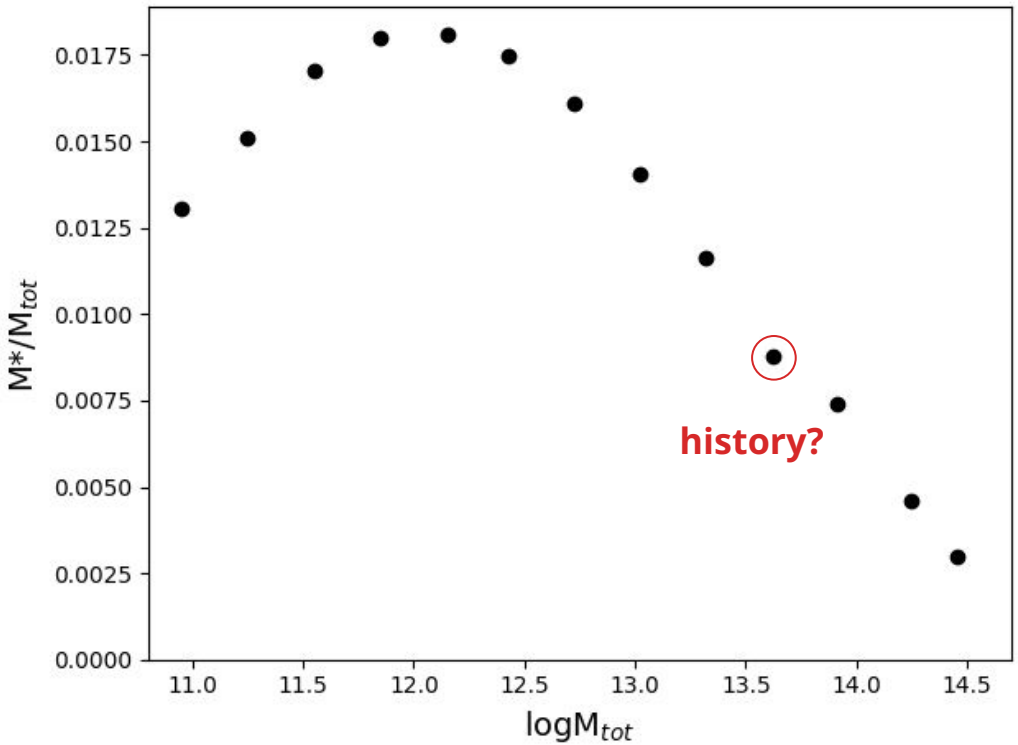
Spatial Resolution ~ 1 kpc

Final Snapshot at redshift $z = 0.625$



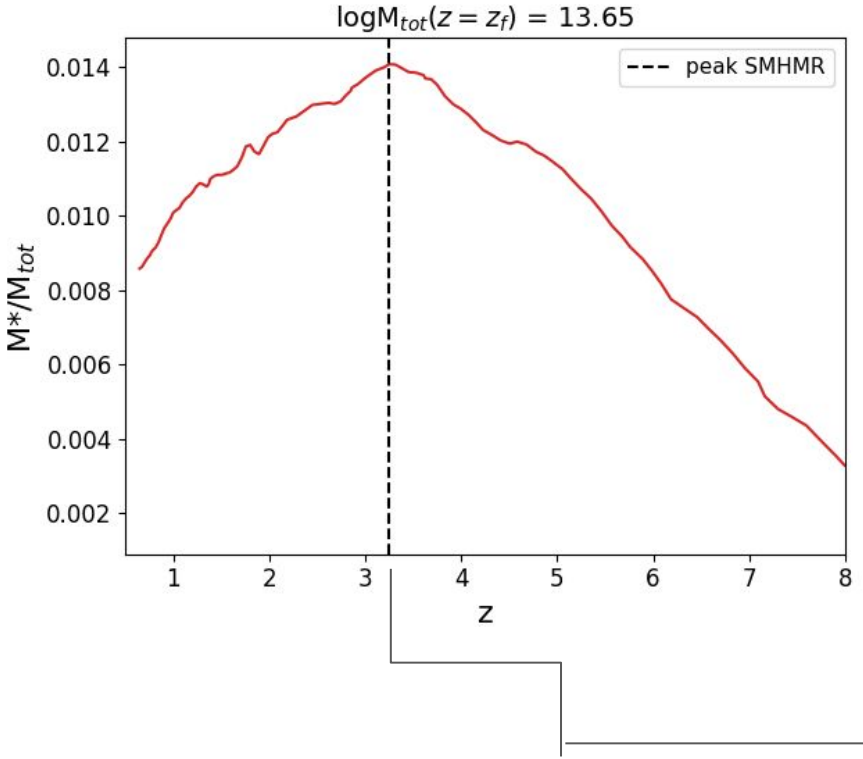


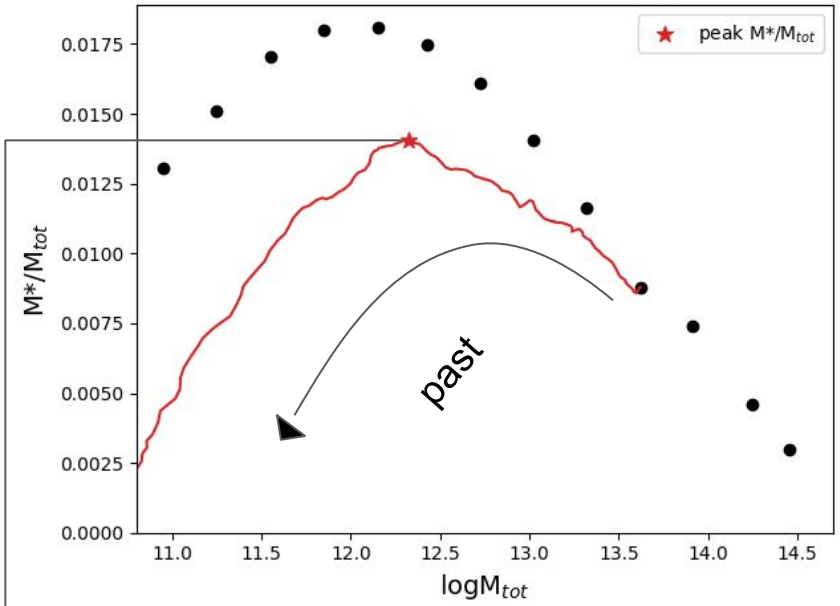
Test Case: Stellar Mass-Halo Mass relation



Stellar Mass-Halo Mass (median) relation for central galaxies in HR5 **at z = 0.625**

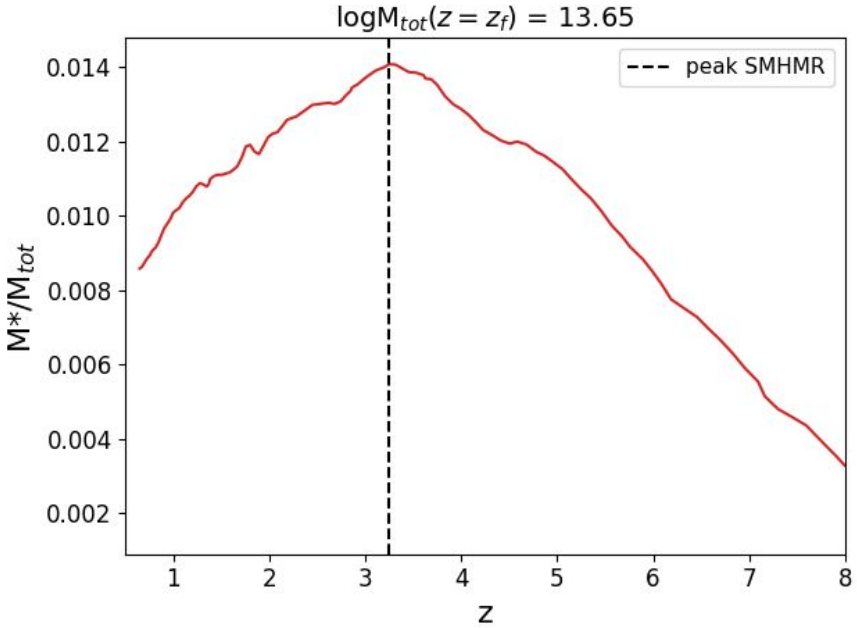
Results





What is happening at this epoch / mass that makes SMHMR turnover?

Results



M*/M$_{tot}$ =

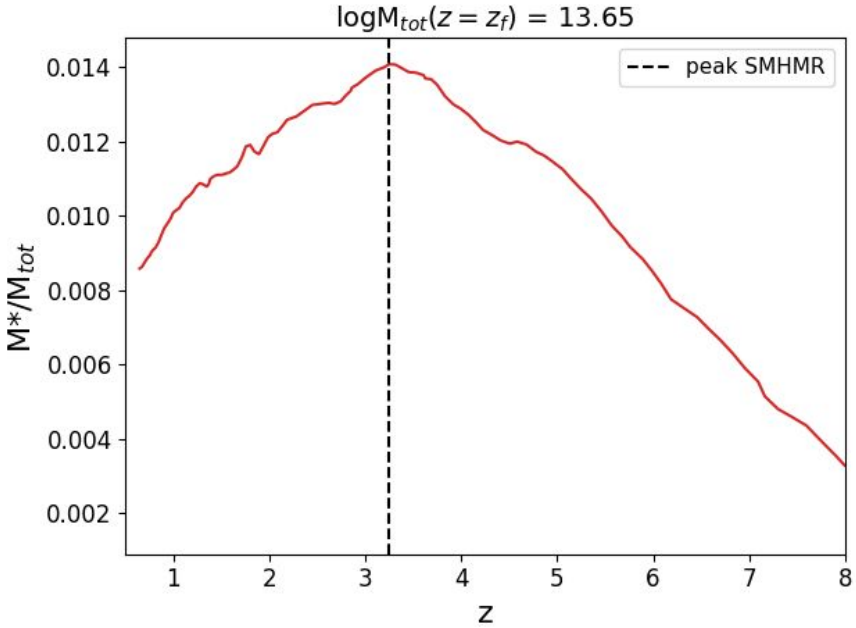
SMHMR

X

M*/M$_{bar}$ Star Formation Efficiency (SFE)

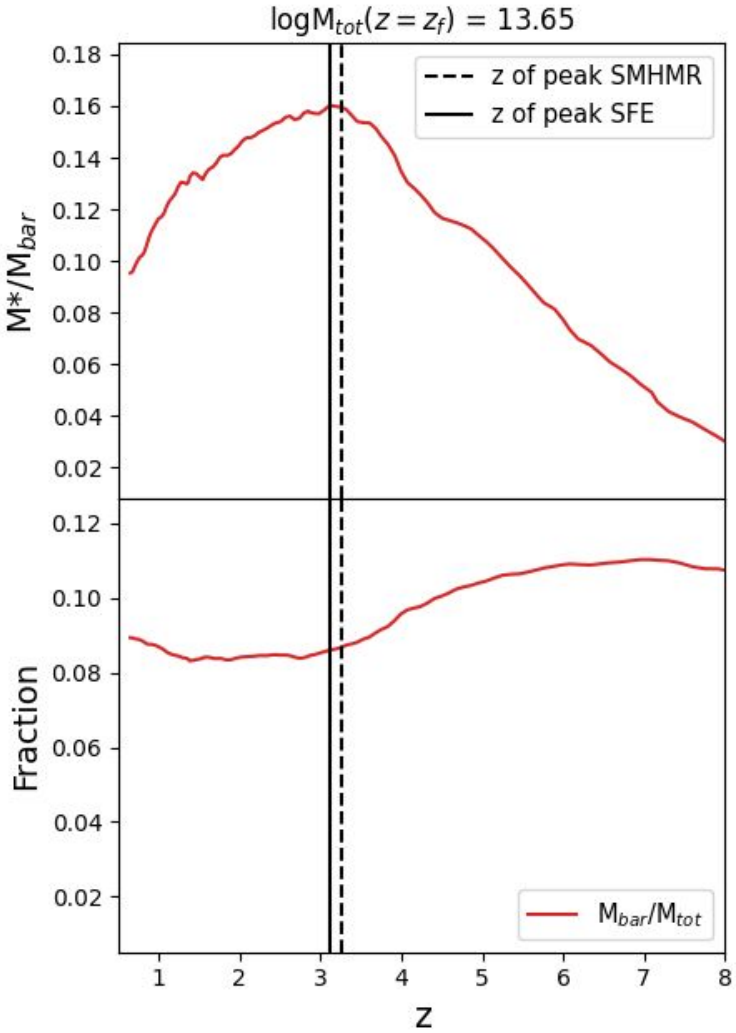
M$_{bar}$/M$_{tot}$ Baryon retention fraction

Results

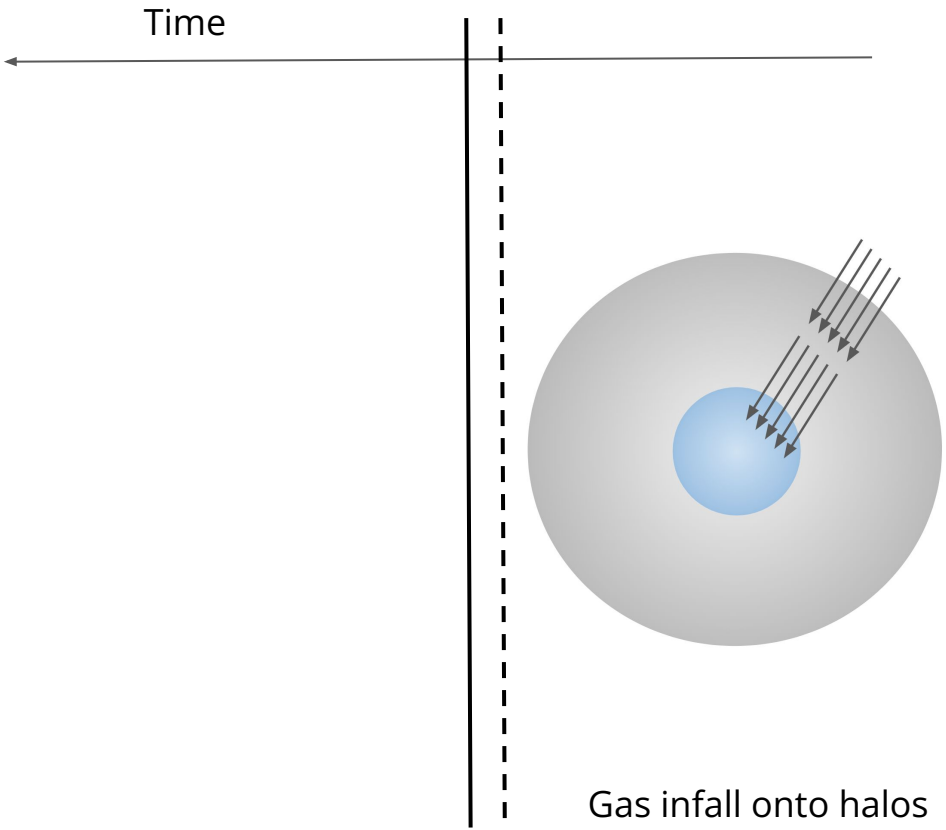


SFE & SMHMR transition at similar times

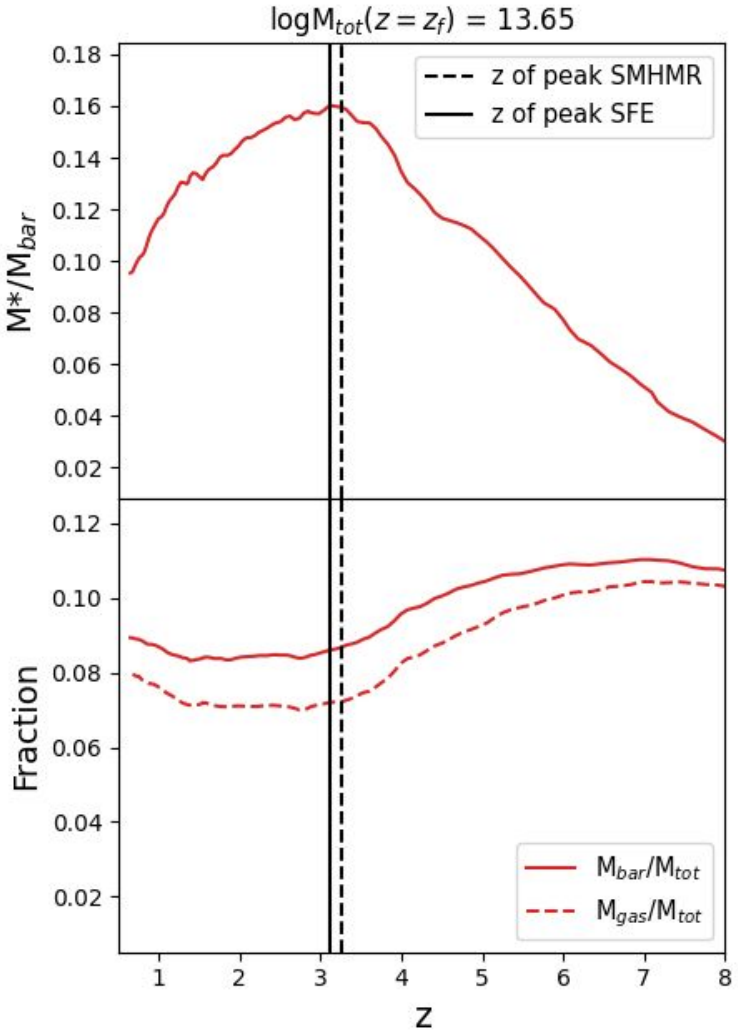
SFE –>



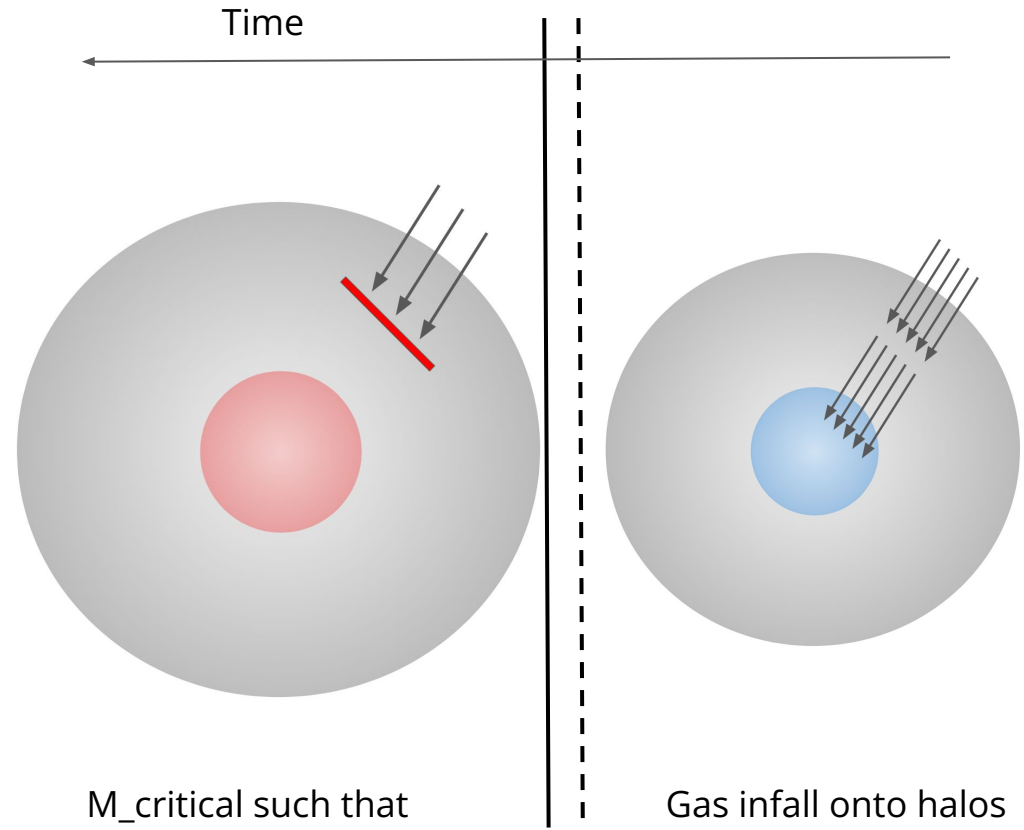
Results



Gas infall onto halos affected by feedback



Results

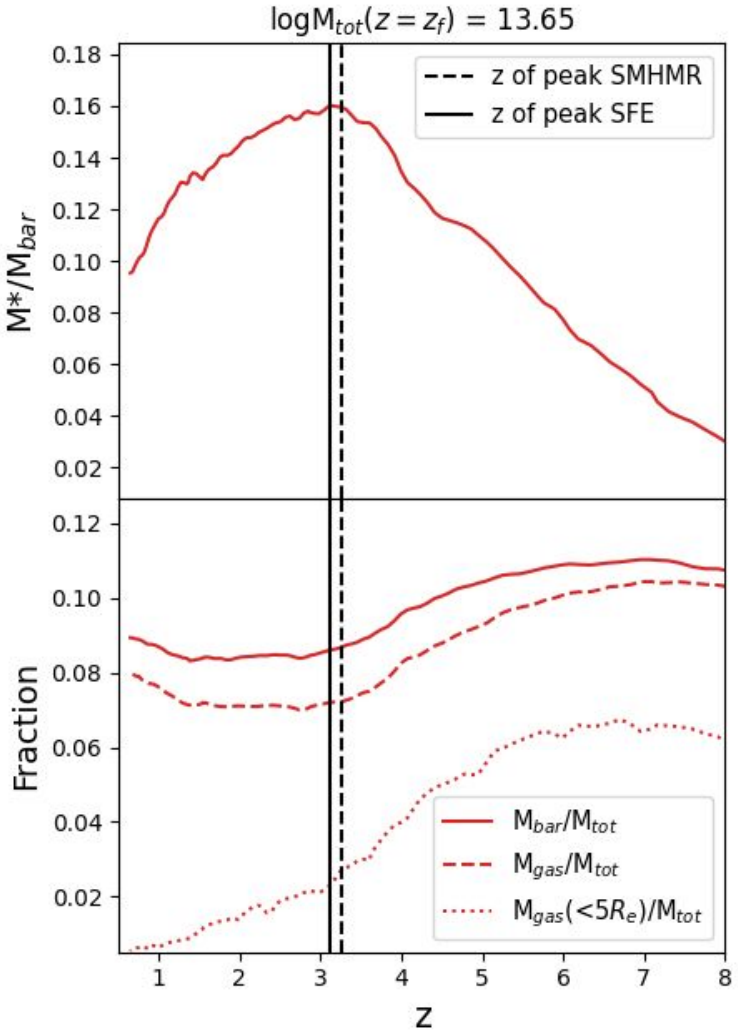


M_critical such that

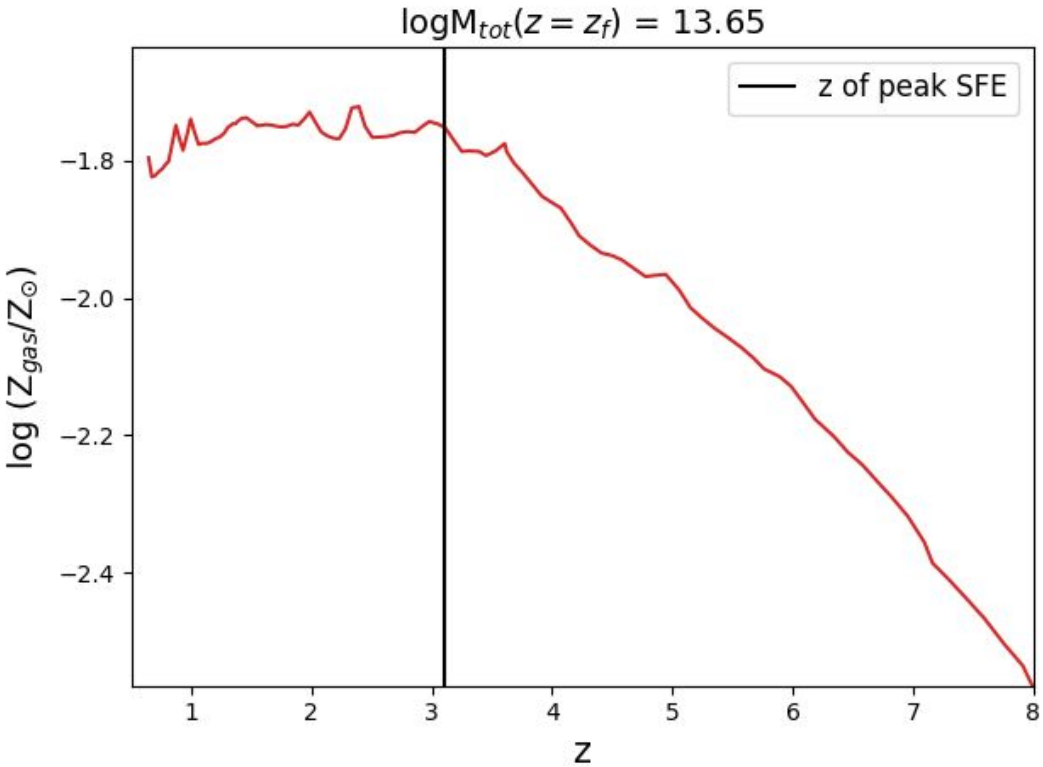
Gas cooling time > free fall time

Gas infall onto halos

affected by feedback



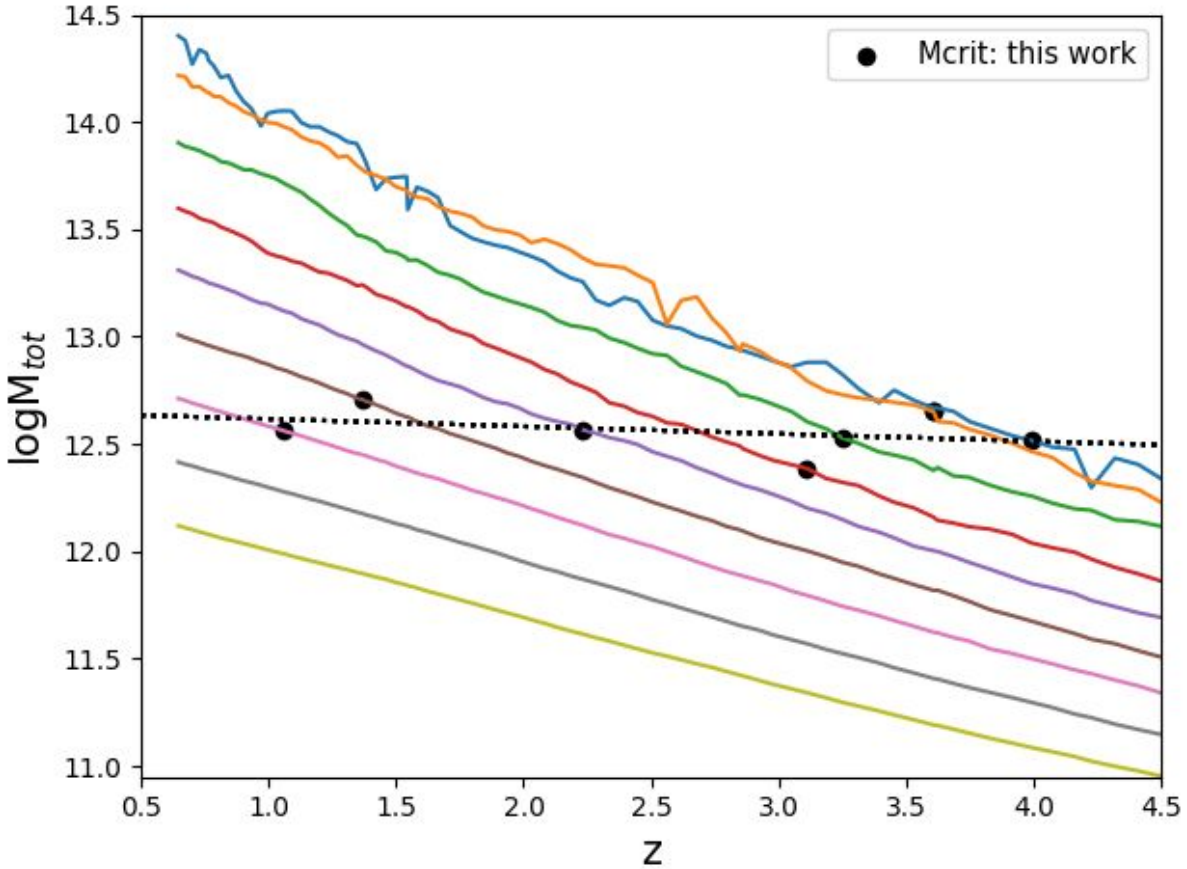
Results



There is a single **Mcrit** where: SMHMR goes down, Star formation efficiency declines, metallicity saturates.

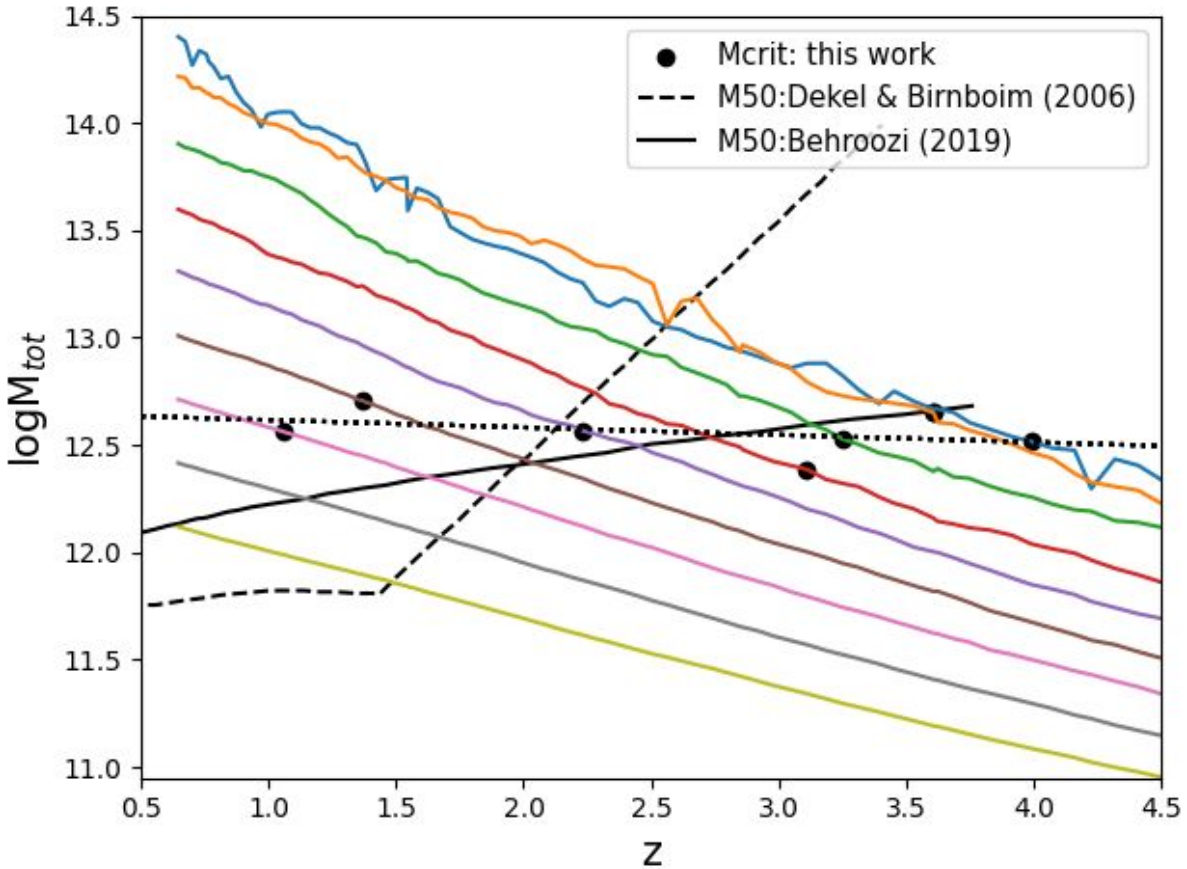
We find that the story presented for one mass bin is also similar for other mass bins.

Results



Mcrit: SMHMR goes down, Star formation efficiency declines, metallicity saturates.

Results



Mcrit: SMHMR goes down, Star formation efficiency declines, metallicity saturates.

M50 is the mass above which 50% of galaxies are quenched.

Summary

- Observation points to the existence of a mass scale where many galaxy scaling relation show transition.
- Using HR5 simulation we find this mass scale to be around logMh ~12.5
- At this mass: Stellar-to-halo mass ratio shows turnover, star formation efficiency declines, gas metallicity saturates.
- The critical mass seems to be a constant of redshift.
- The mass scale is set up by interplay of baryon accretion (BA) onto halos and baryon-to-star conversion efficiency (SFE).

Currently assessing the relative role of feedback processes vs dynamical heating of gas due to halo mass on Mcrit

Perhaps also useful to compare predictions of Fiducial HR5 run with HR5 low-QSO and maybe with others sims.