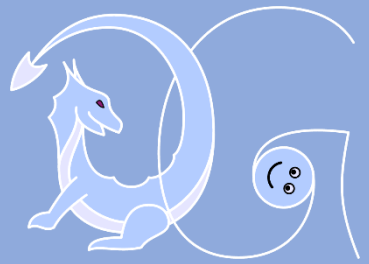
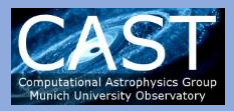


Neighborhood Issues

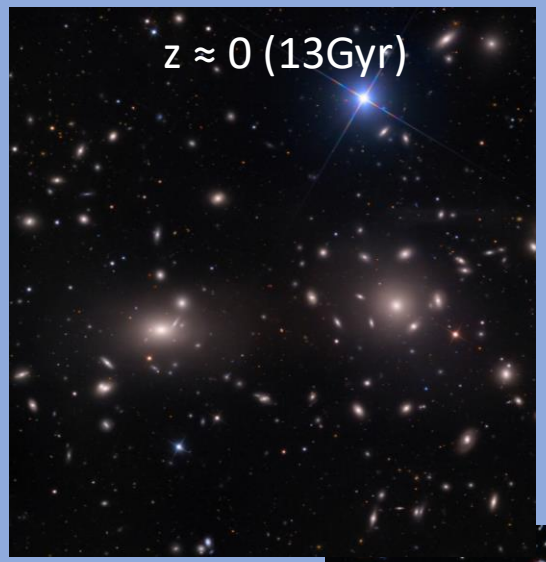
The Impact of Environment on Galaxy Properties at Cosmic Dawn

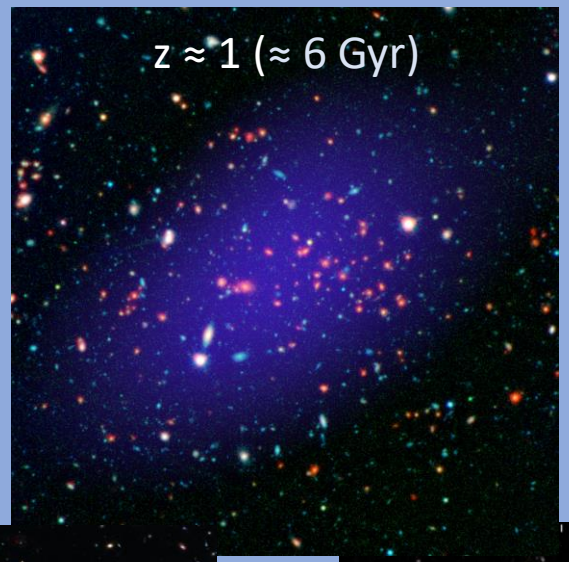
Rhea-Silvia Remus

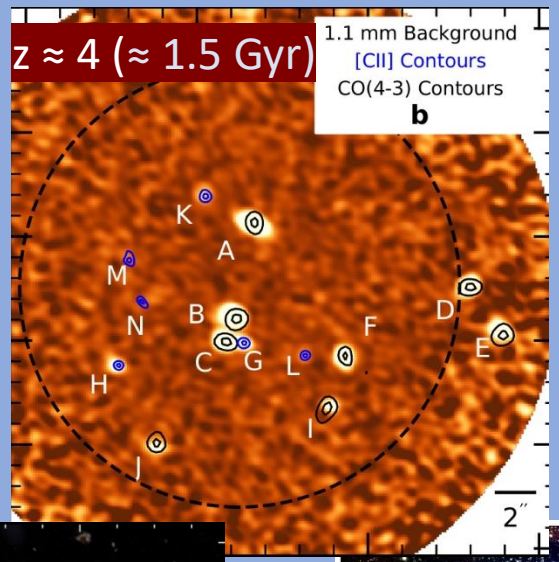
Ljubljana, 30.07.2024

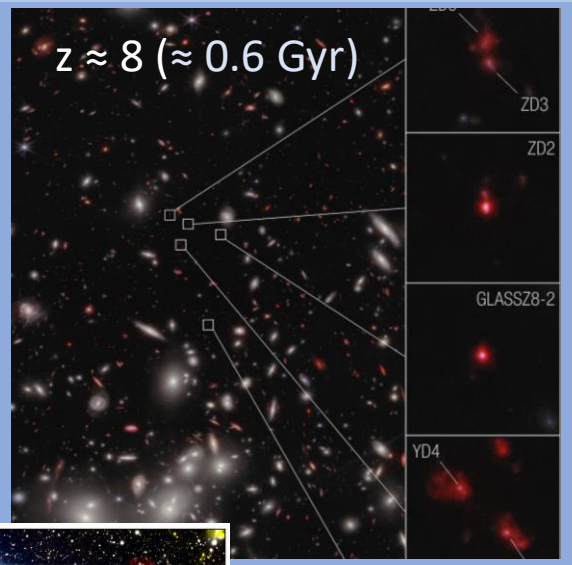


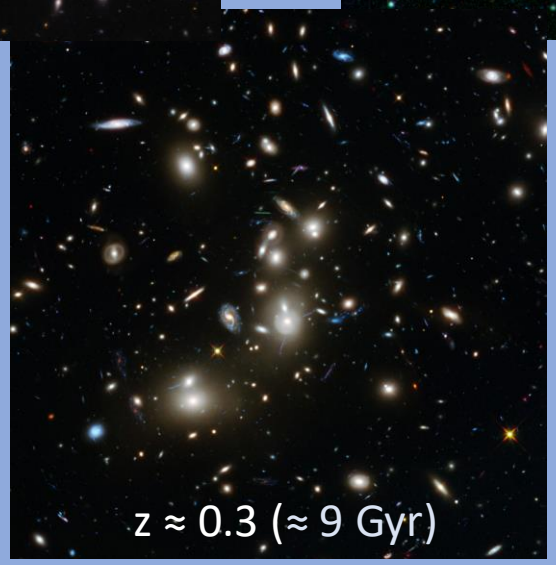
Observations of galaxies over cosmic time

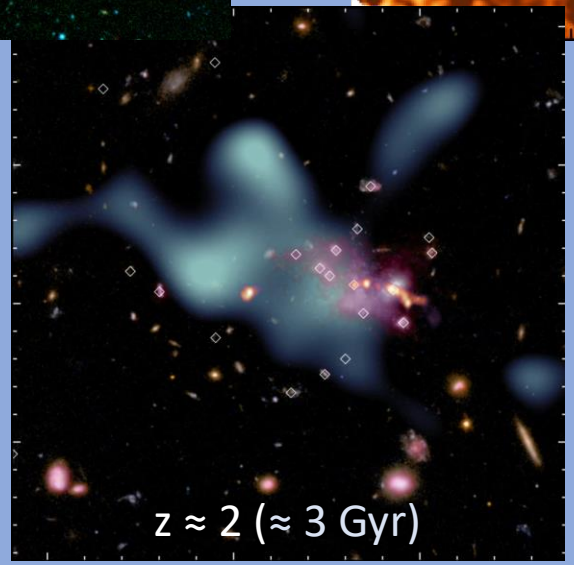


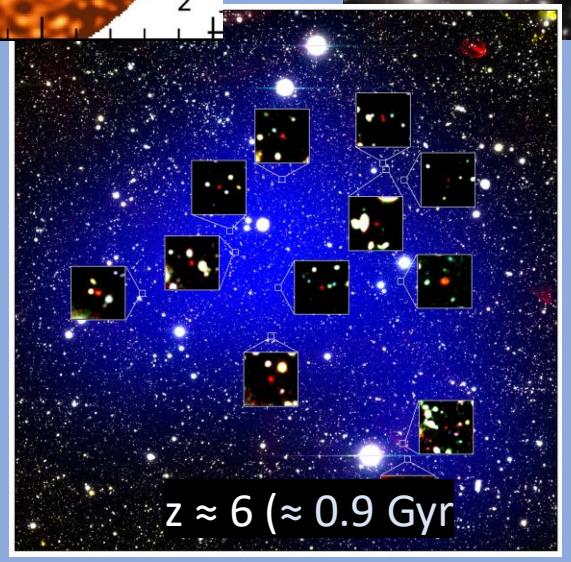




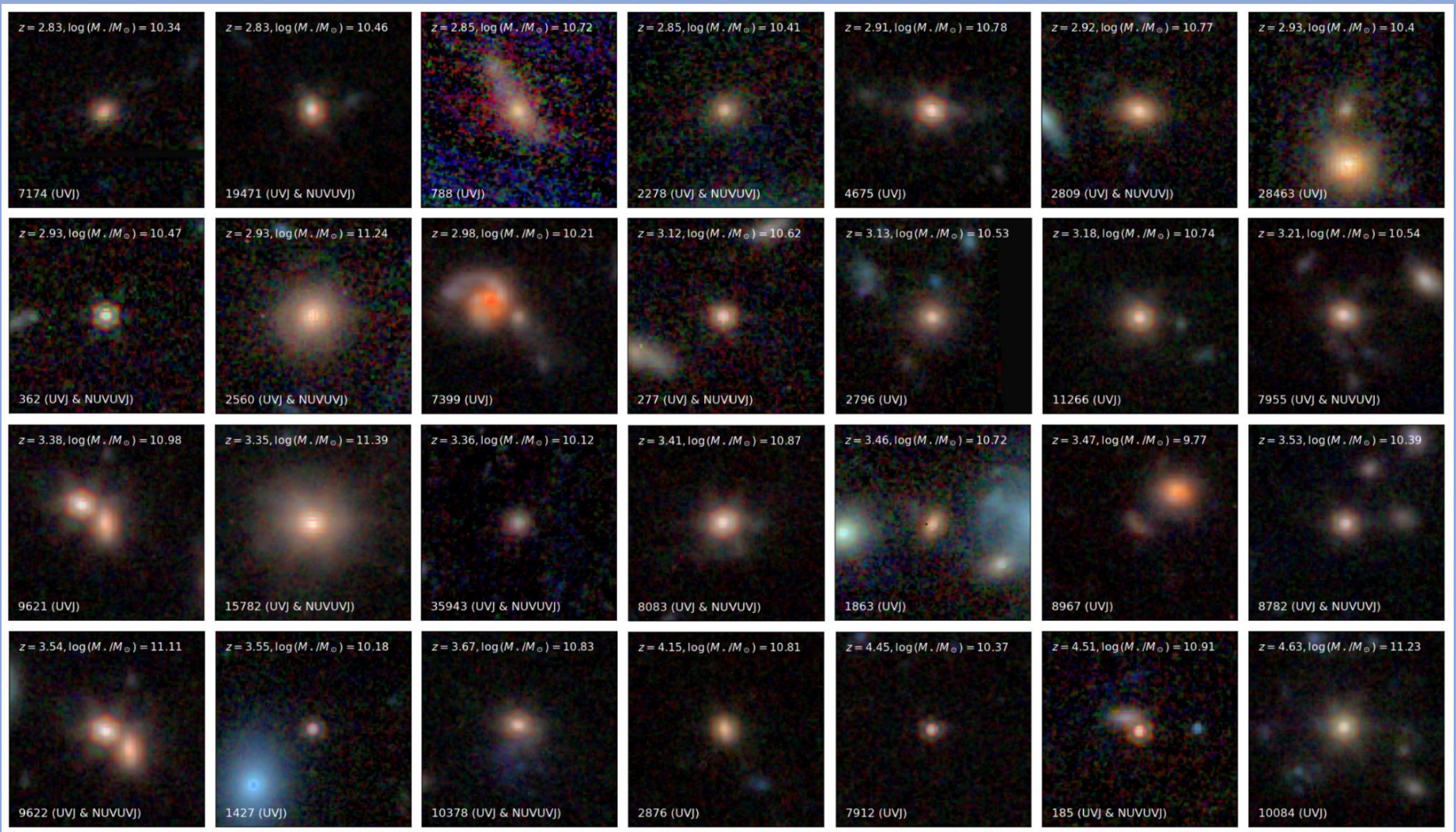




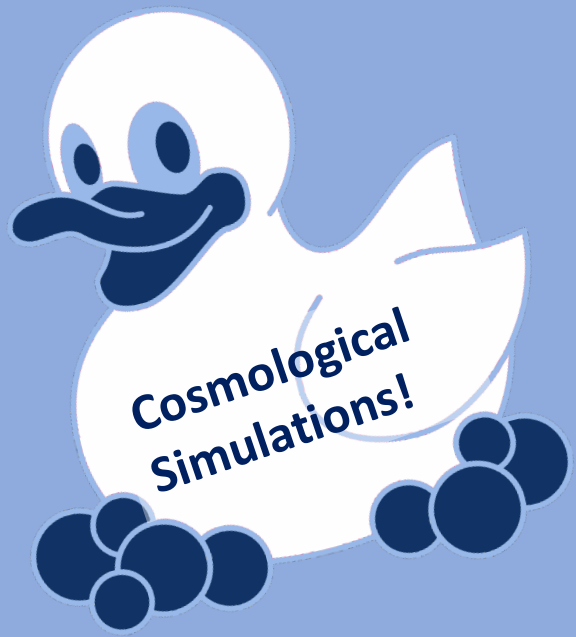




Quenched Galaxies

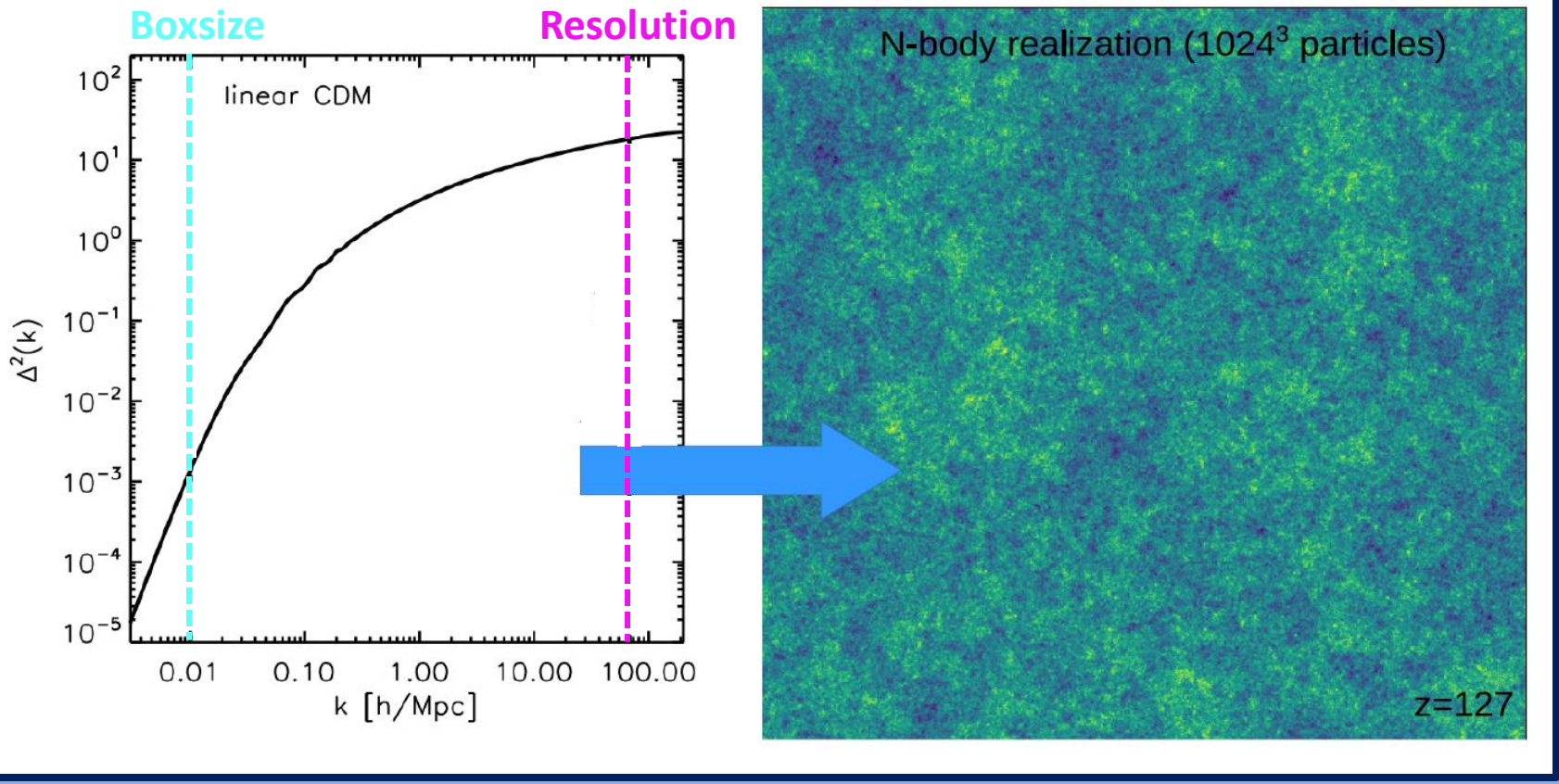


… when the Universe was only 1.5Gyr old ($z \approx 4$)

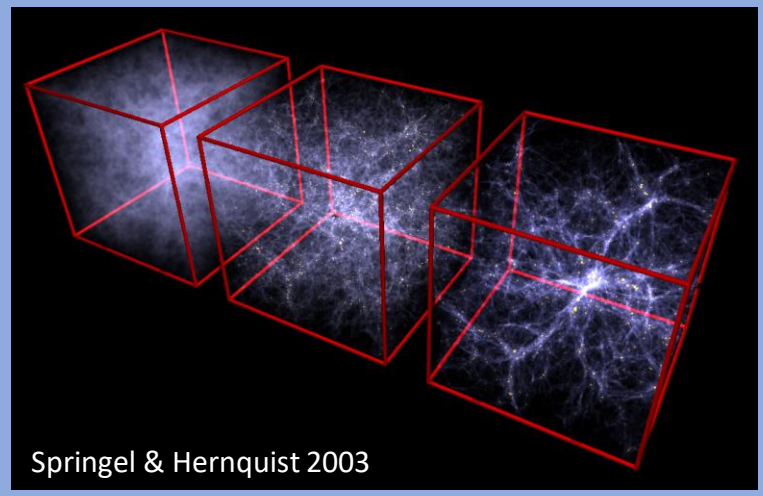


Ito et al. 2023

Cosmological Simulations

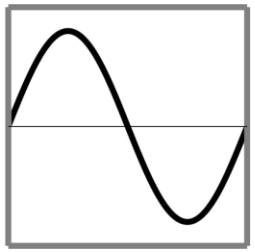


Zavala & Frenk 2019



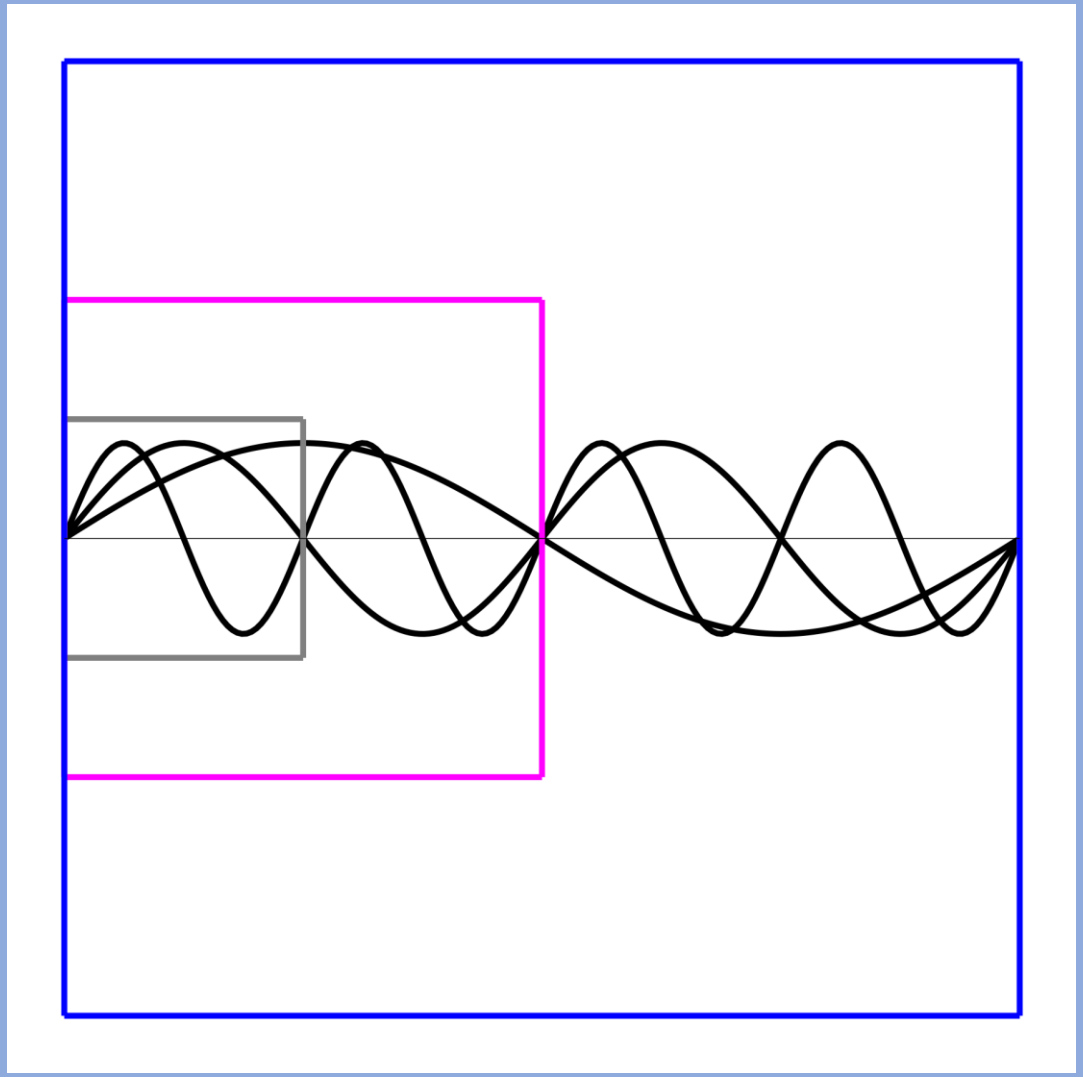
Modes in Cosmological Simulations

Boxsize



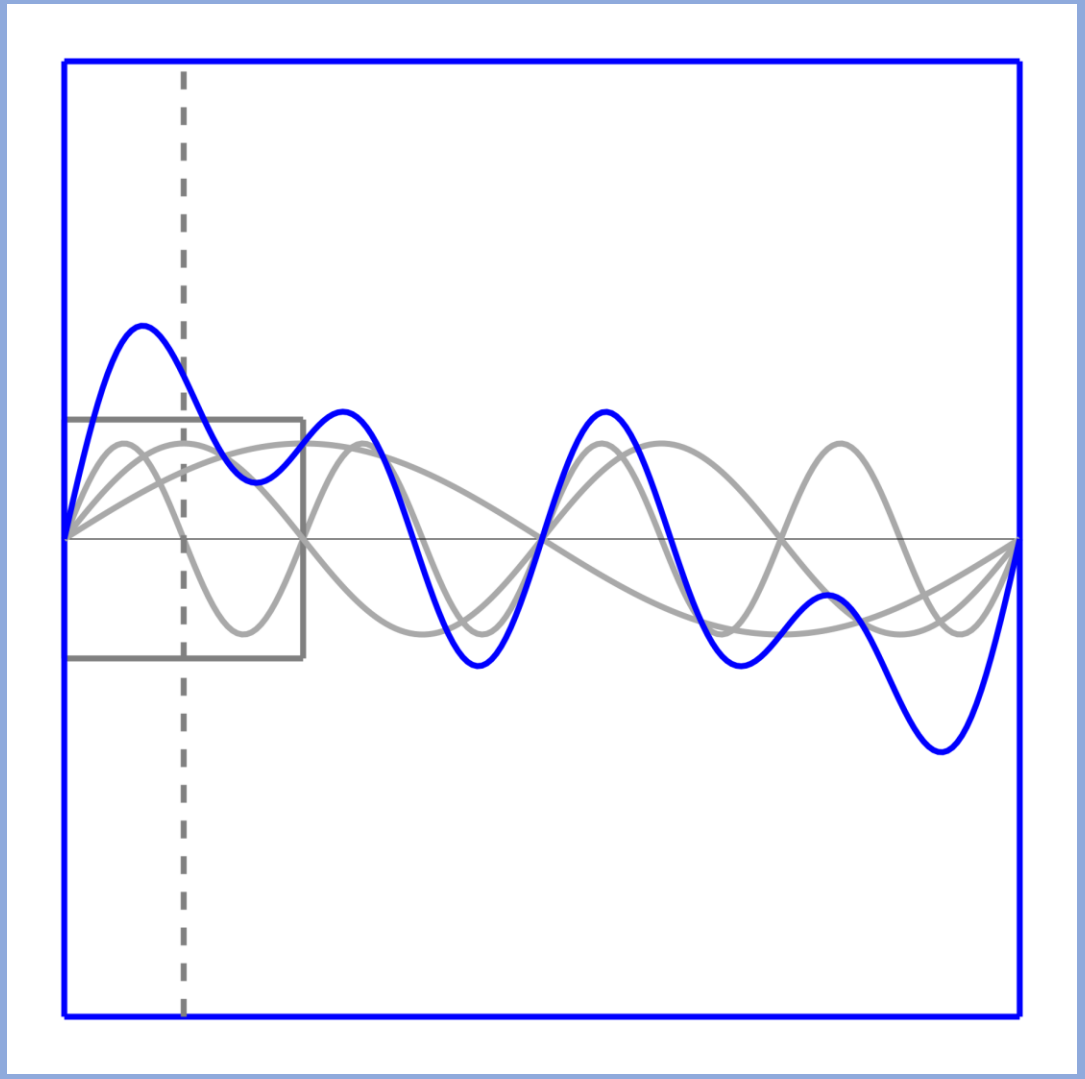
Modes in Cosmological Simulations

Boxsize



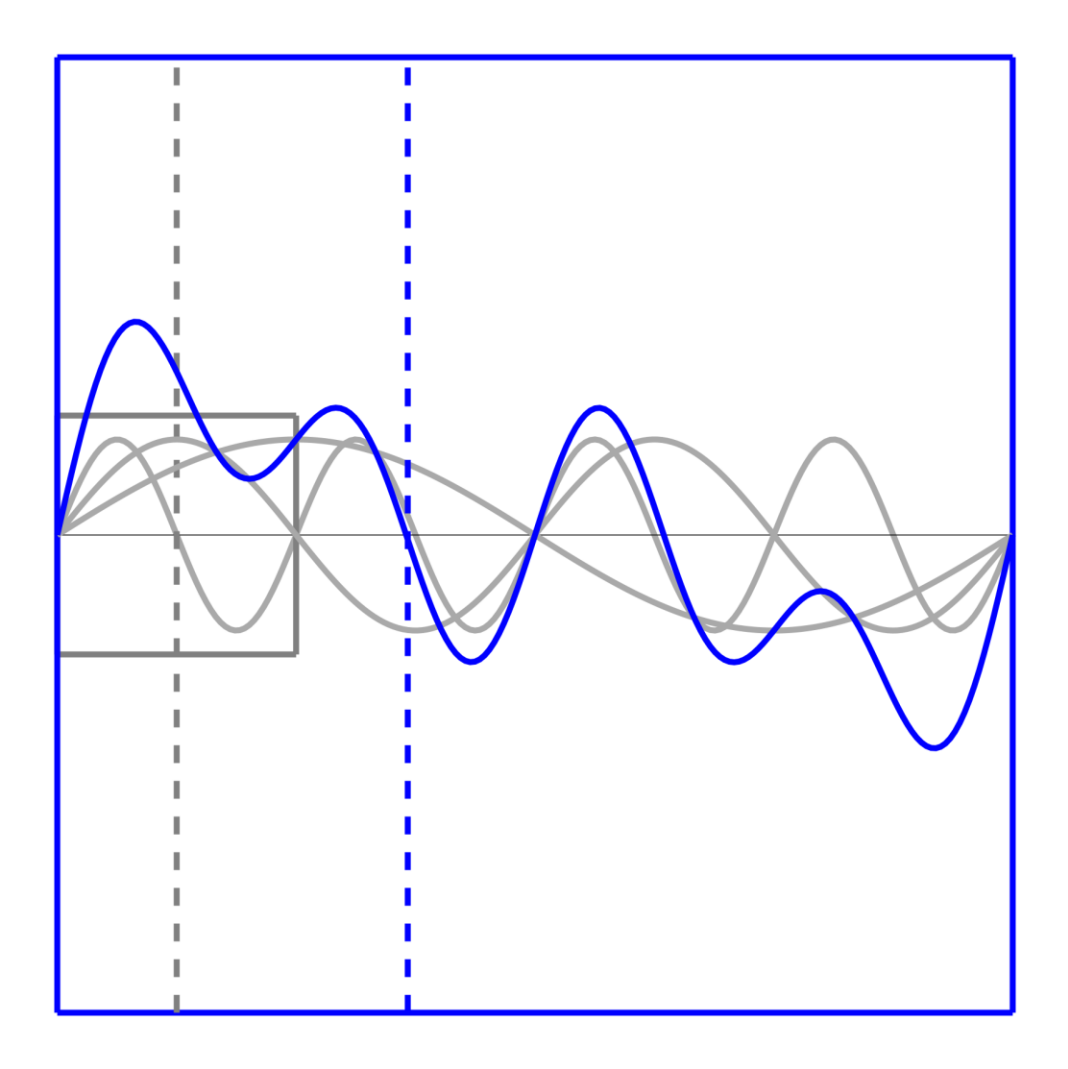
Modes in Cosmological Simulations

Boxsize

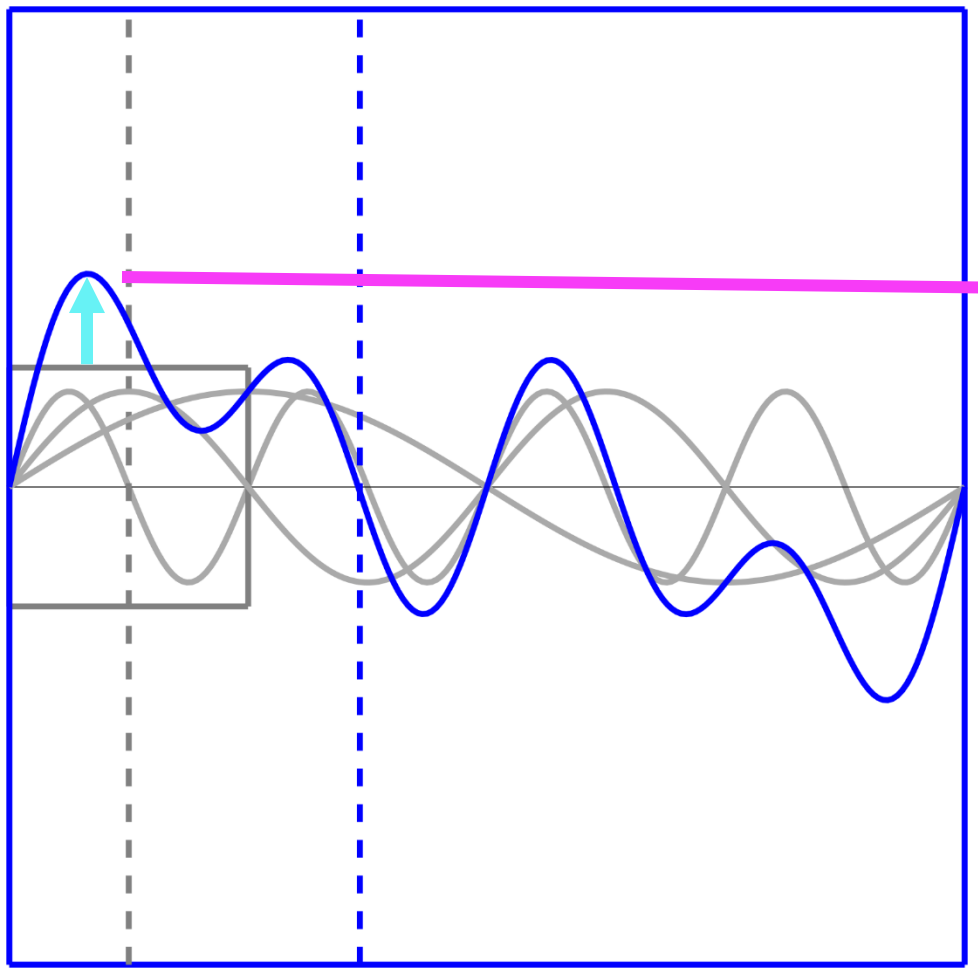


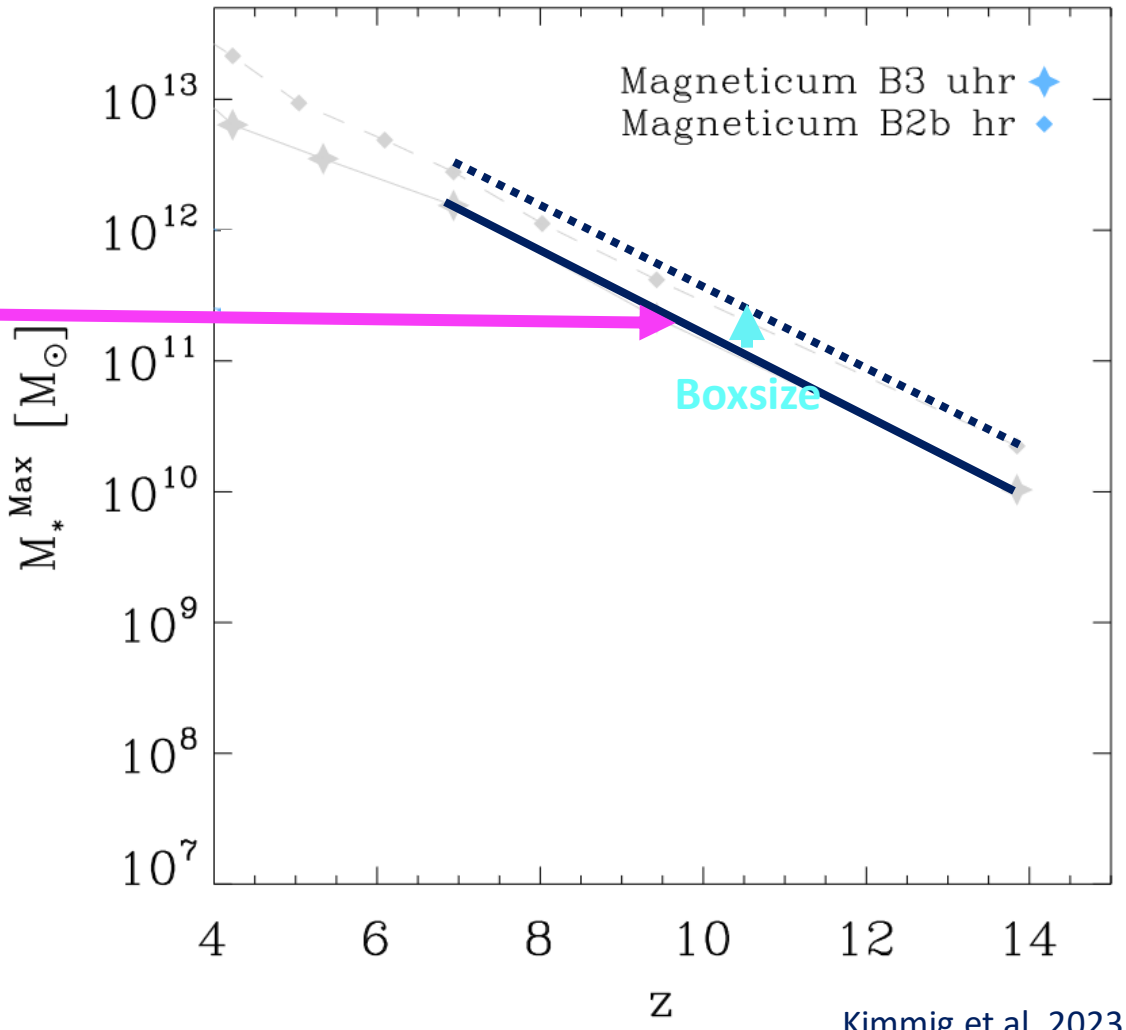
Modes in Cosmological Simulations

Boxsize



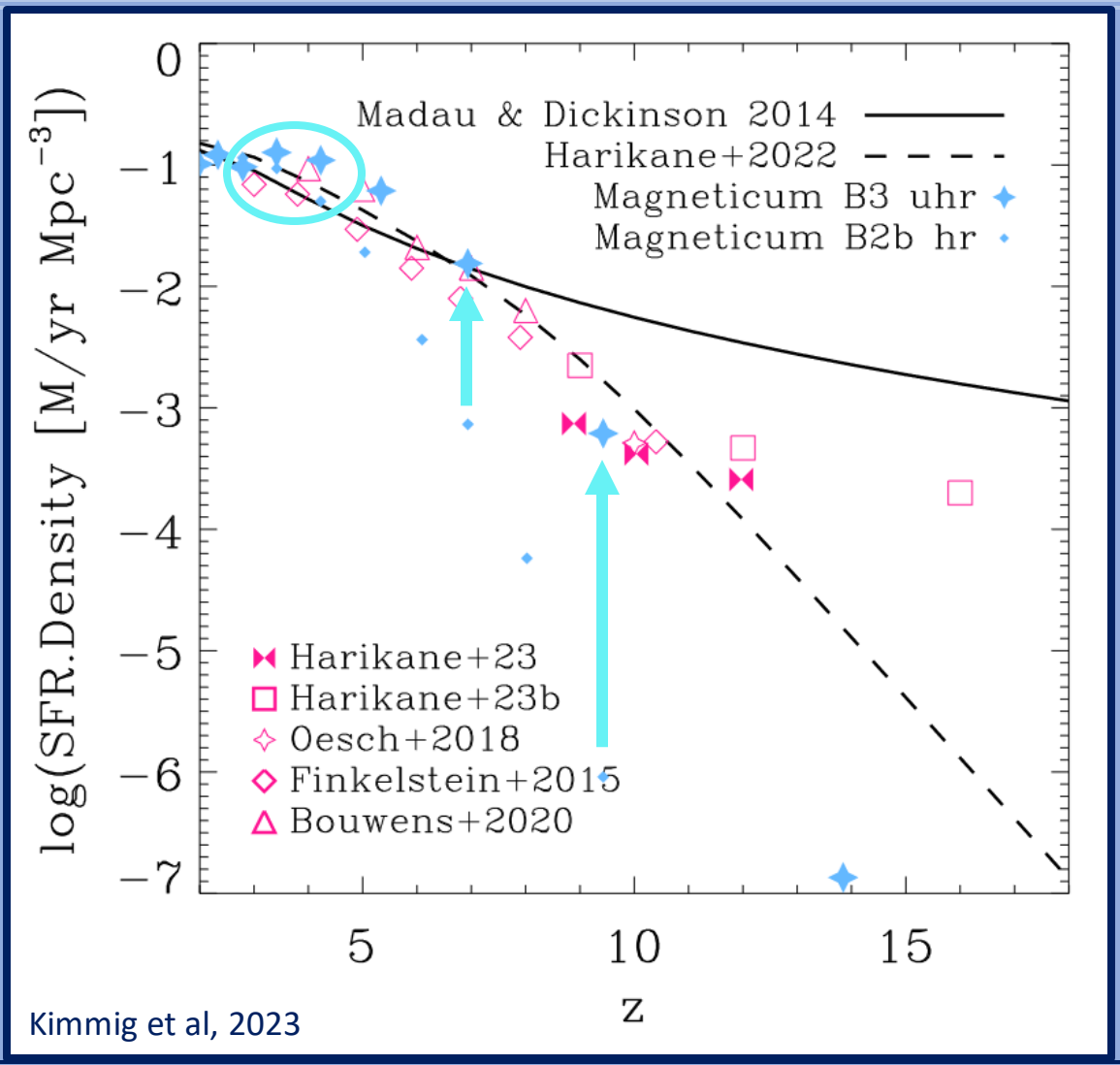
Modes in Cosmological Simulations





Kimmig et al, 2023

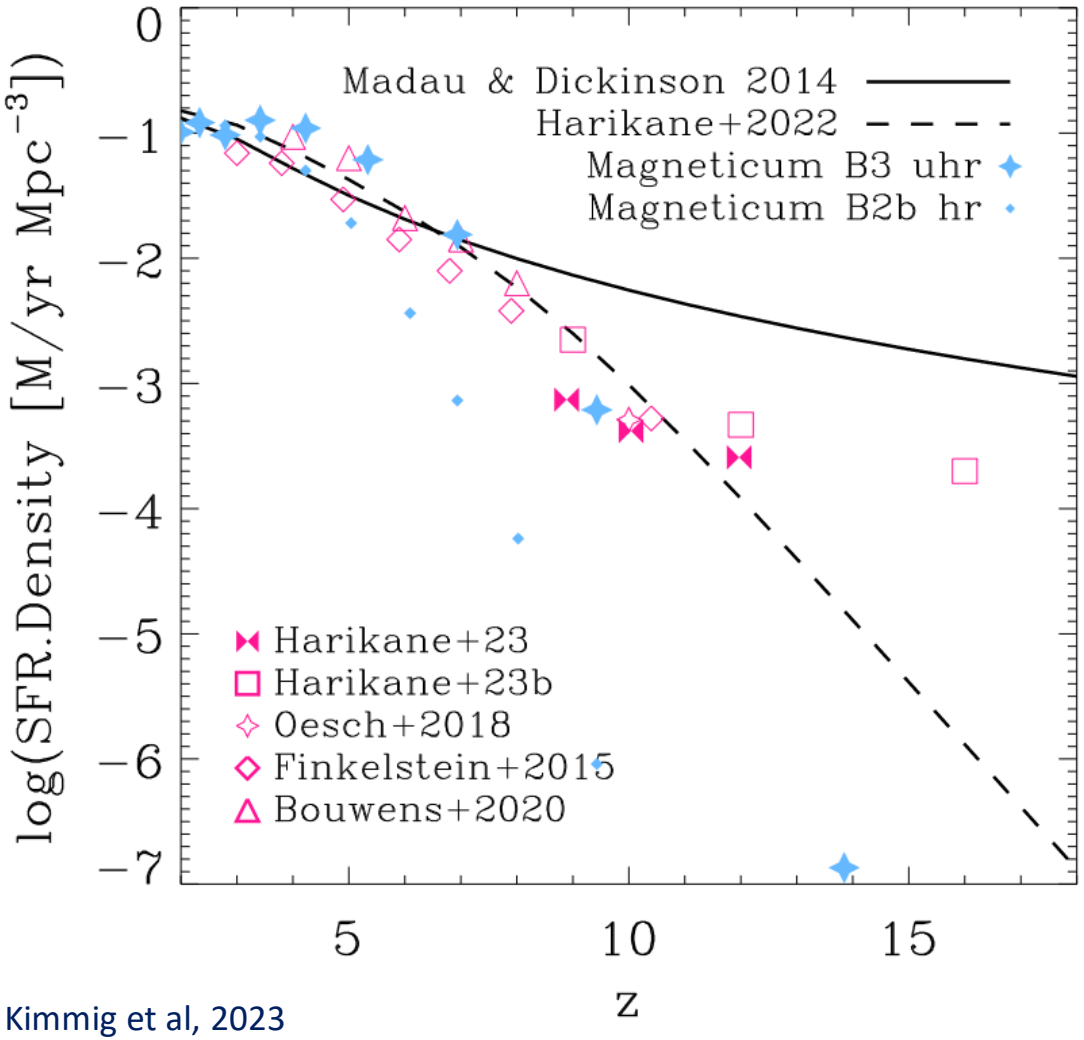
Simulations: Size vs Resolution

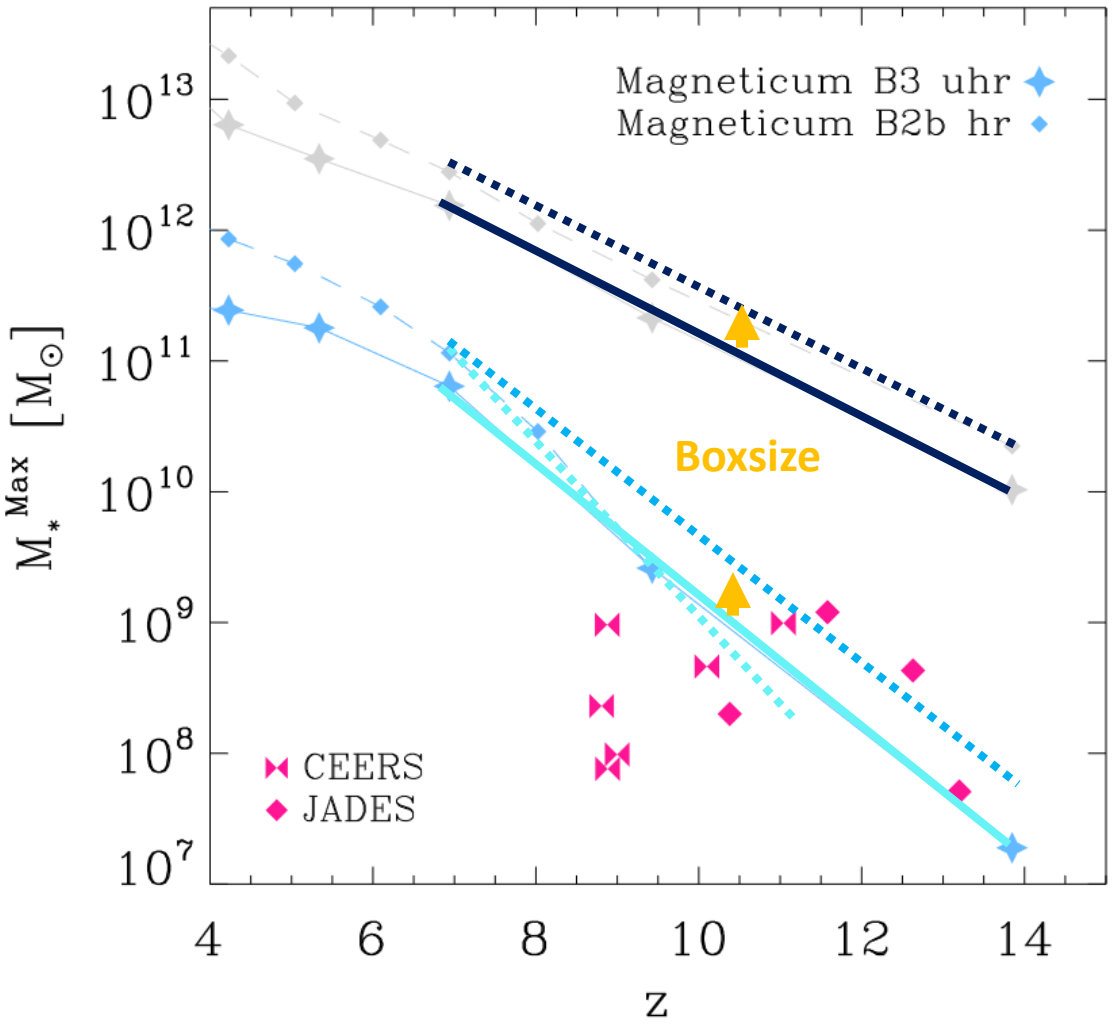


Kimmig et al, 2023

Star Formation depends on Resolution!

Simulations: Size vs Resolution





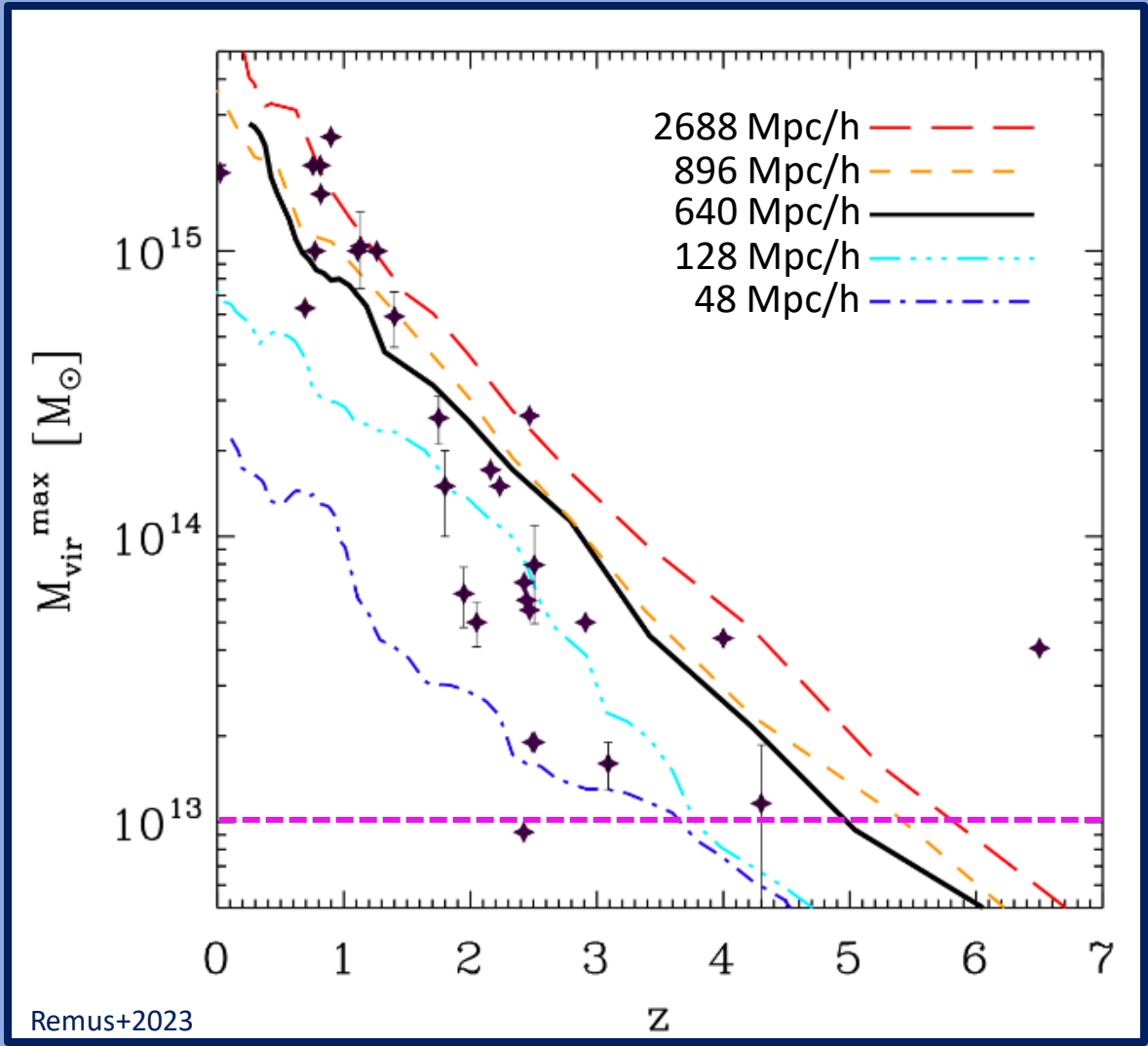
Kimmig et al, 2023

Cosmological Simulations: In a Nutshell

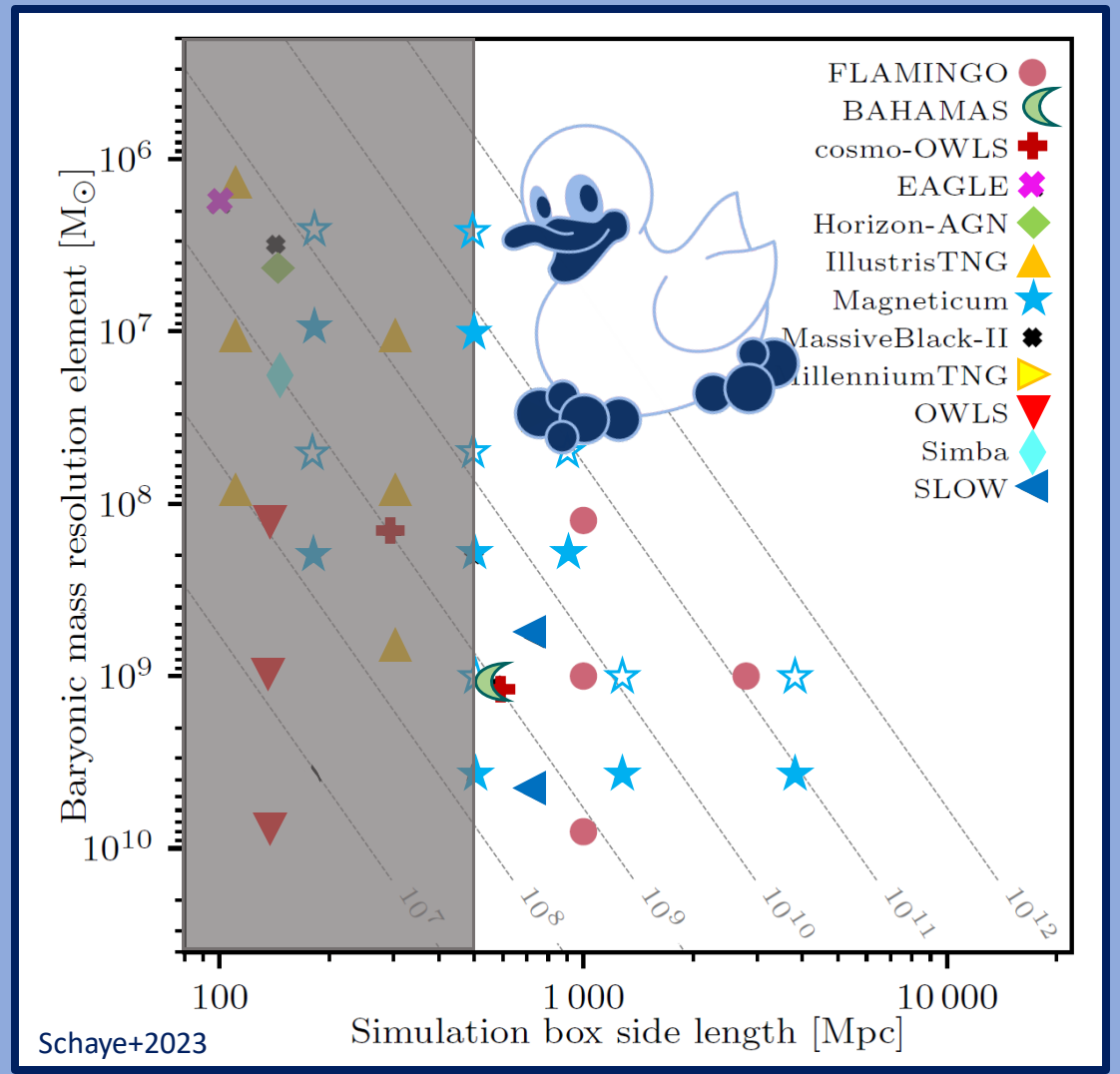
High Mass → Large Boxsize

Early SF → High Resolution

Simulations: Size vs Resolution

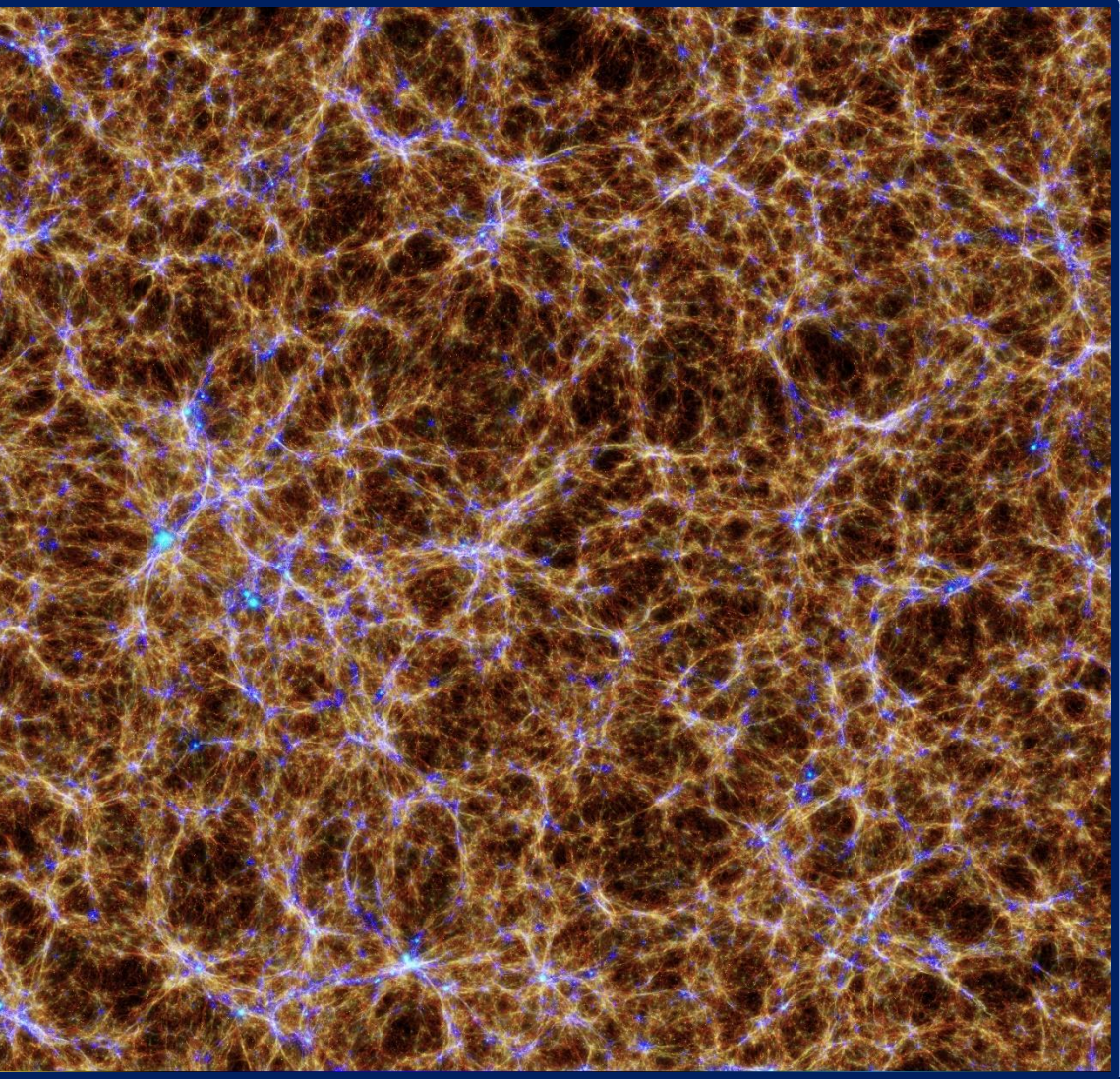


Remus+2023



Schaye+2023

Magneticum Simulations



www.magneticum.org

Box	Mpc/h	mr	hr	uhr
0	2688	y		
1	896	y		
2b	640	y	y	
3	128	y	y	(z=2)
4	48	y	y	y

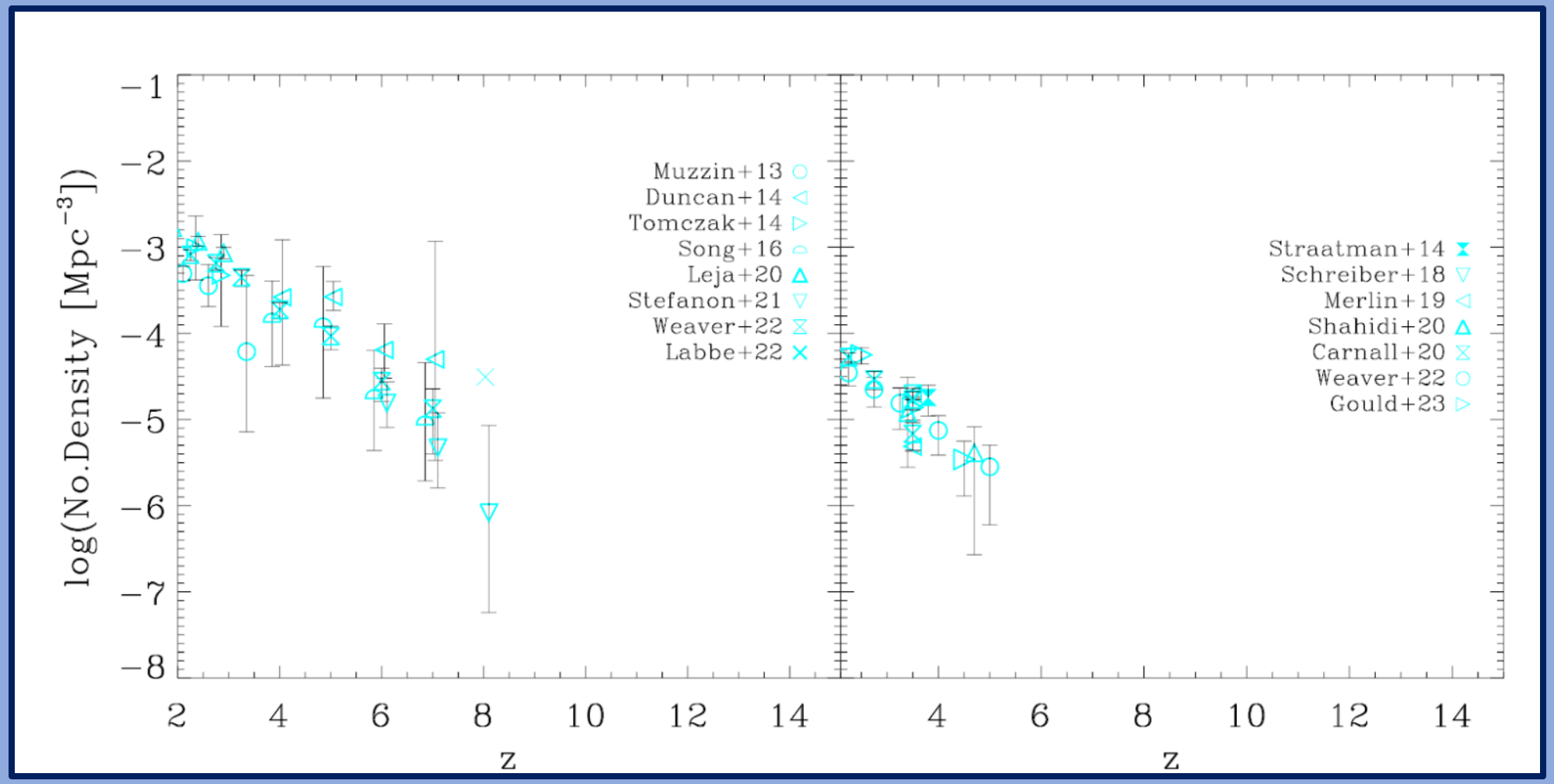
	mr	hr	uhr
m_{DM} $(M_\odot/h)$	$1.3 \cdot 10^{10}$	$6.9 \cdot 10^{8}$	$3.7 \cdot 10^{7}$
m_{Gas} $(M_\odot/h)$	$2.6 \cdot 10^{9}$	$1.4 \cdot 10^{7}$	$7.3 \cdot 10^{6}$

- Modified SPH version of GADGET-3 (incl. thermal conduction)
- Feedback from stellar winds
- Feedback from AGN
- Metal enrichment and star formation follow pattern of metal production from SNIa, SNII & AGB
- Gas cooling depends on local metallicity
- One gas particle can spawn up to 4 stellar particles.

Web-Portal: c2papcosmosim.srv.lrz.de

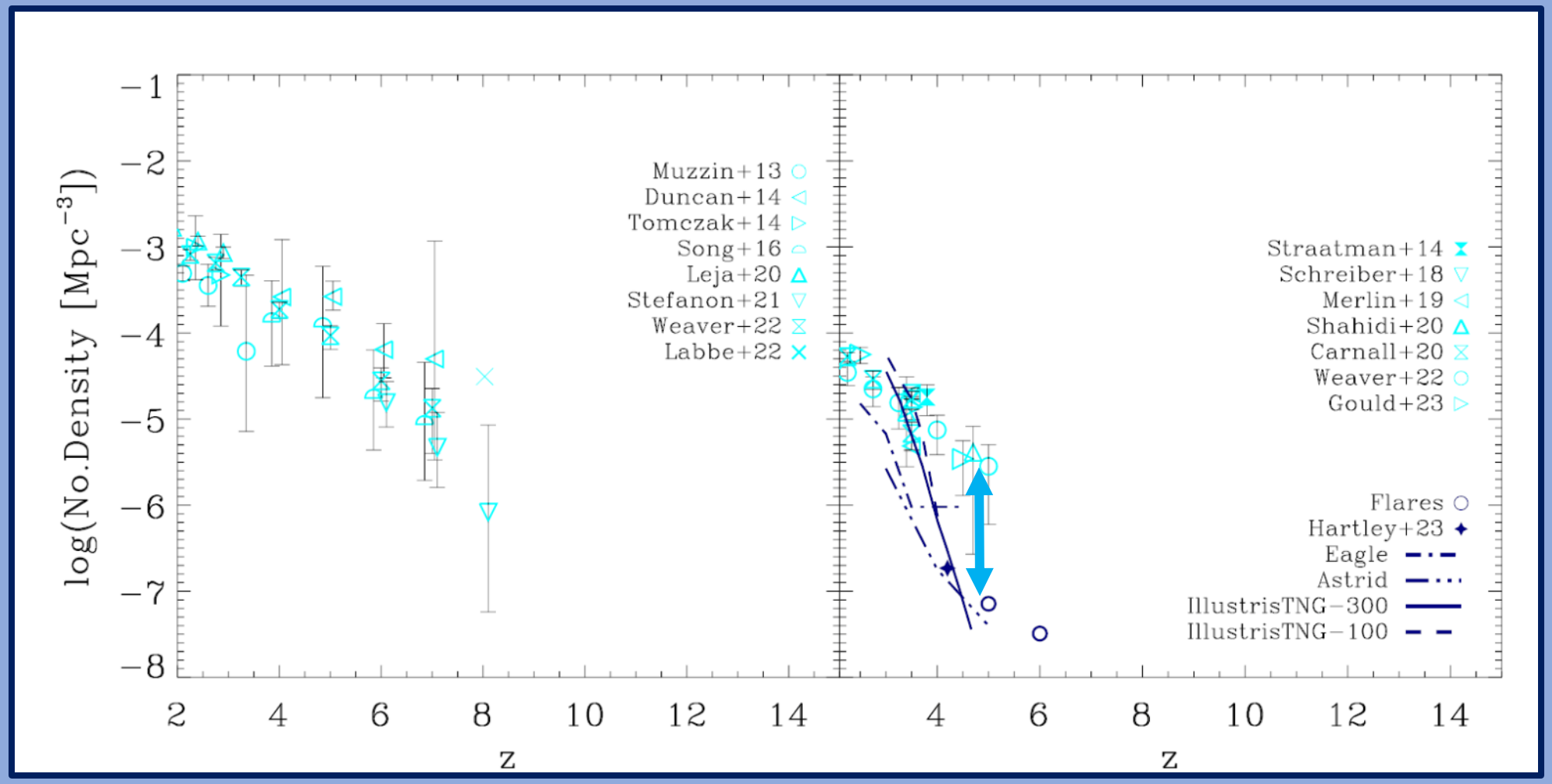
Ragagnin et al., 2017

Quenched Galaxies



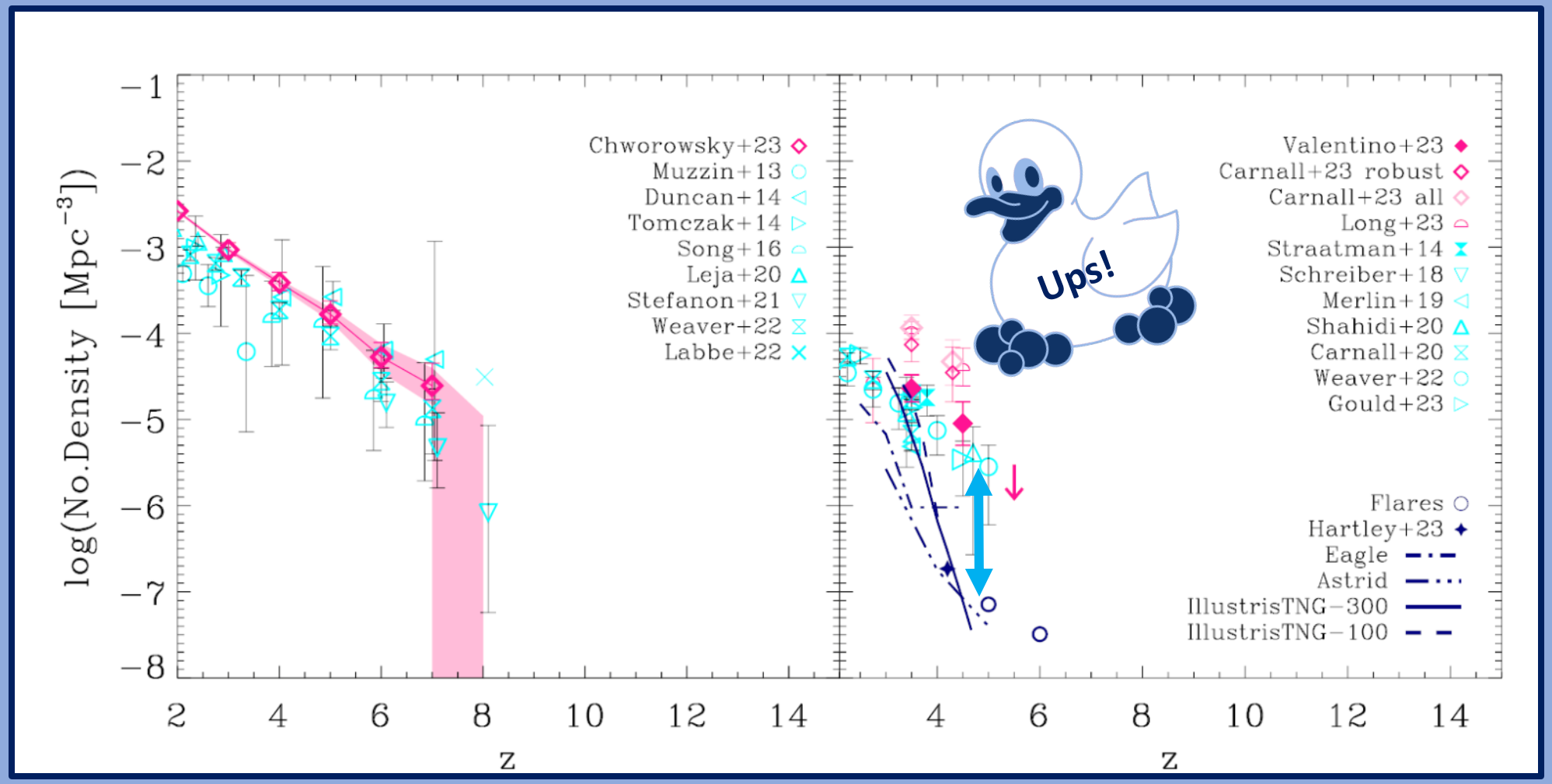
Kimmig et al. 2023

Quenched Galaxies



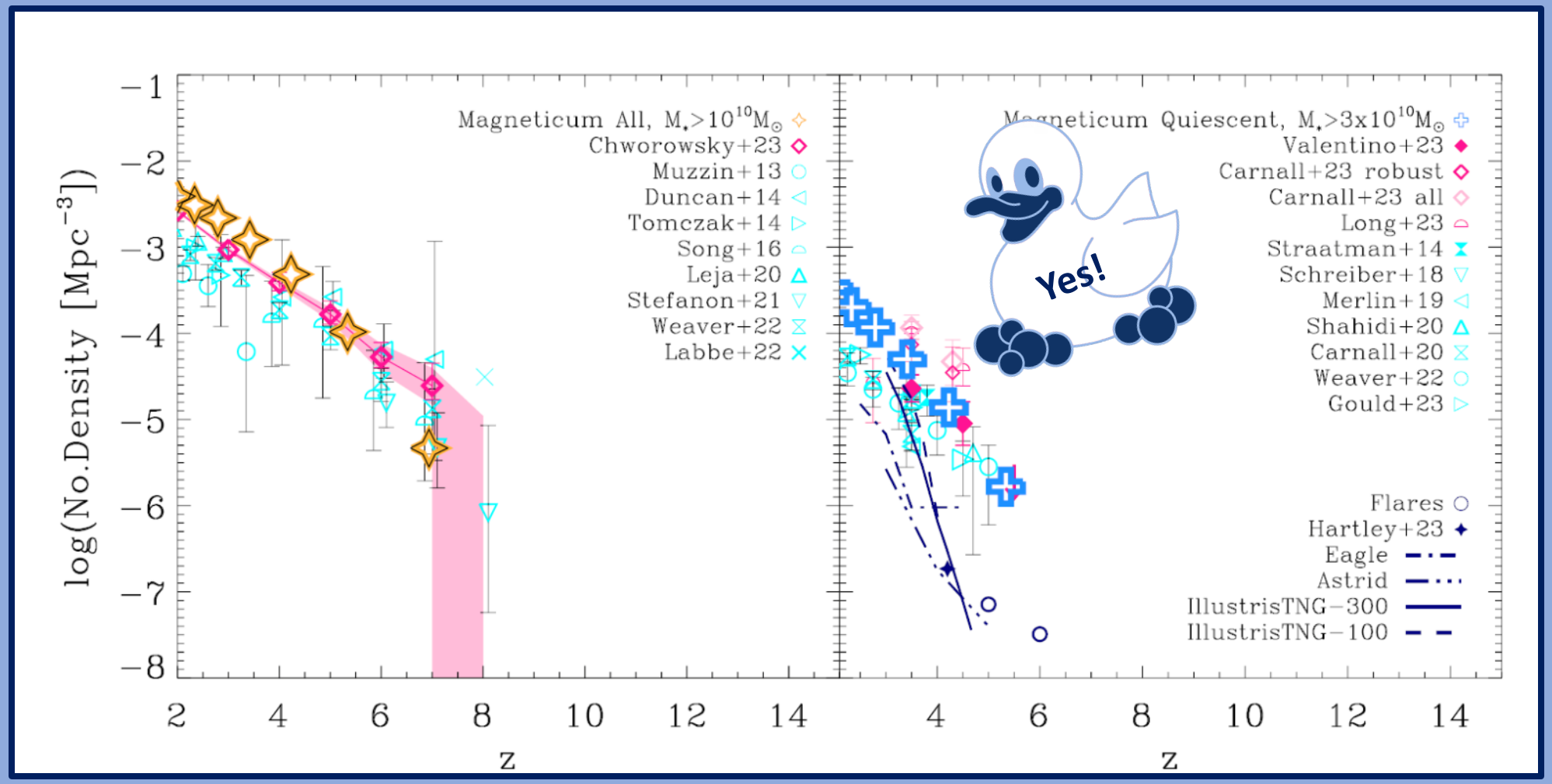
Kimmig et al. 2023

Quenched Galaxies



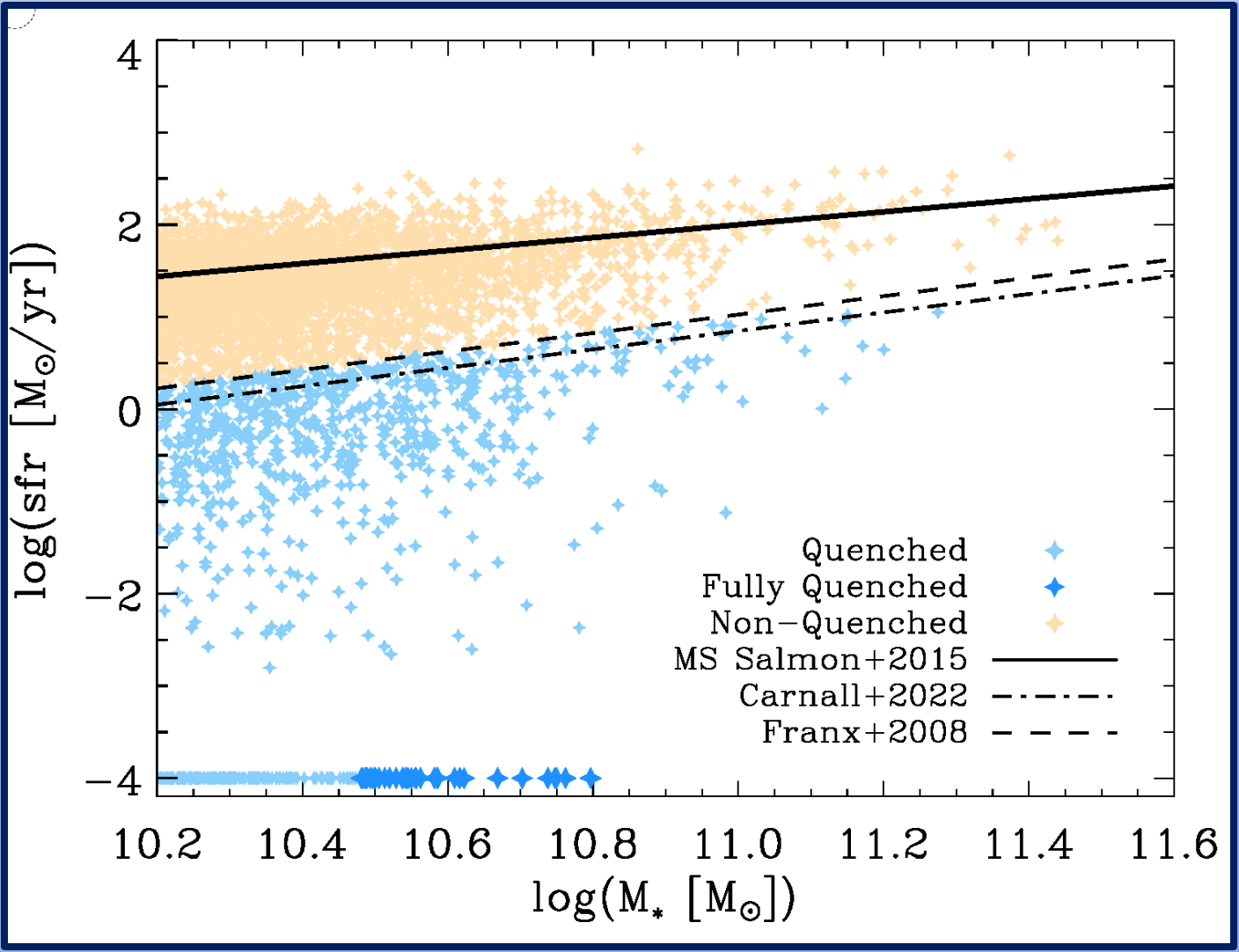
Kimmig et al. 2023

Quenched Galaxies



Kimmig et al. 2023

Quenched Galaxies



Galaxies with $M_* > 3e10$

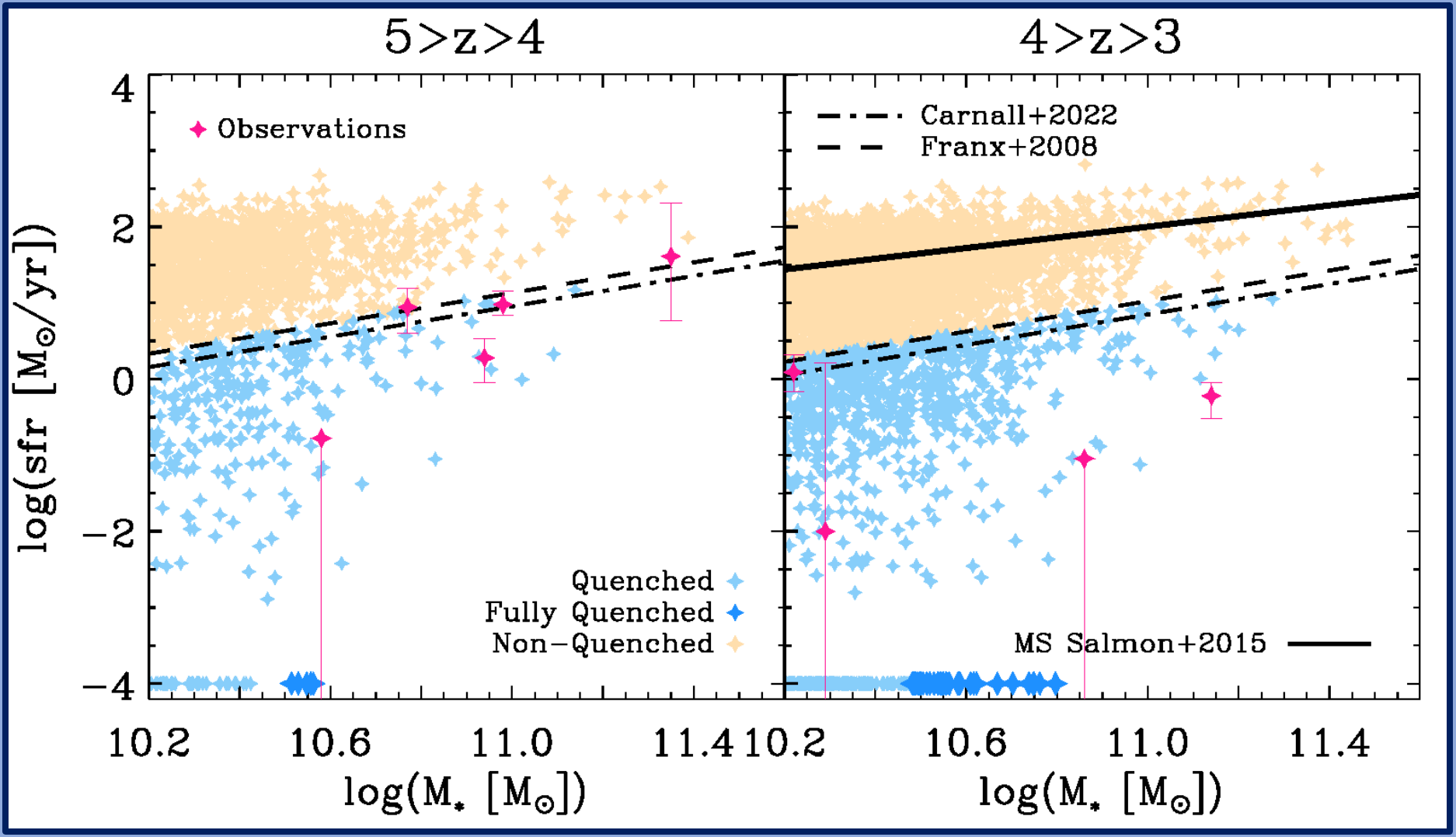
- 1309 Total
- 36 Quenched

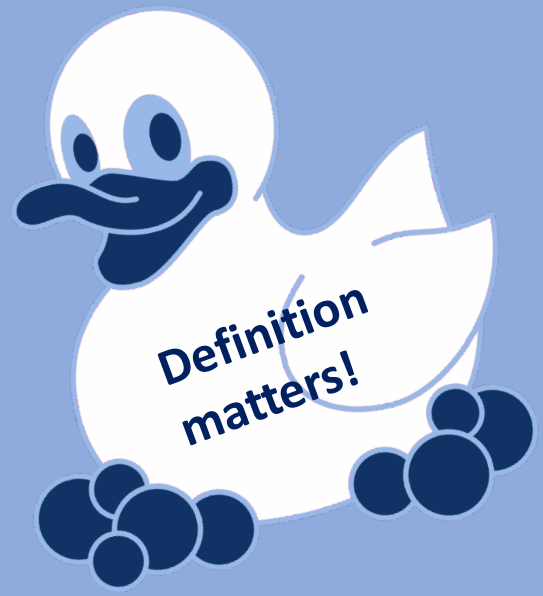
Carnall+20 criterion:

~300, 10 with $M_* > 1e11$

Remus & Kimmig 2023

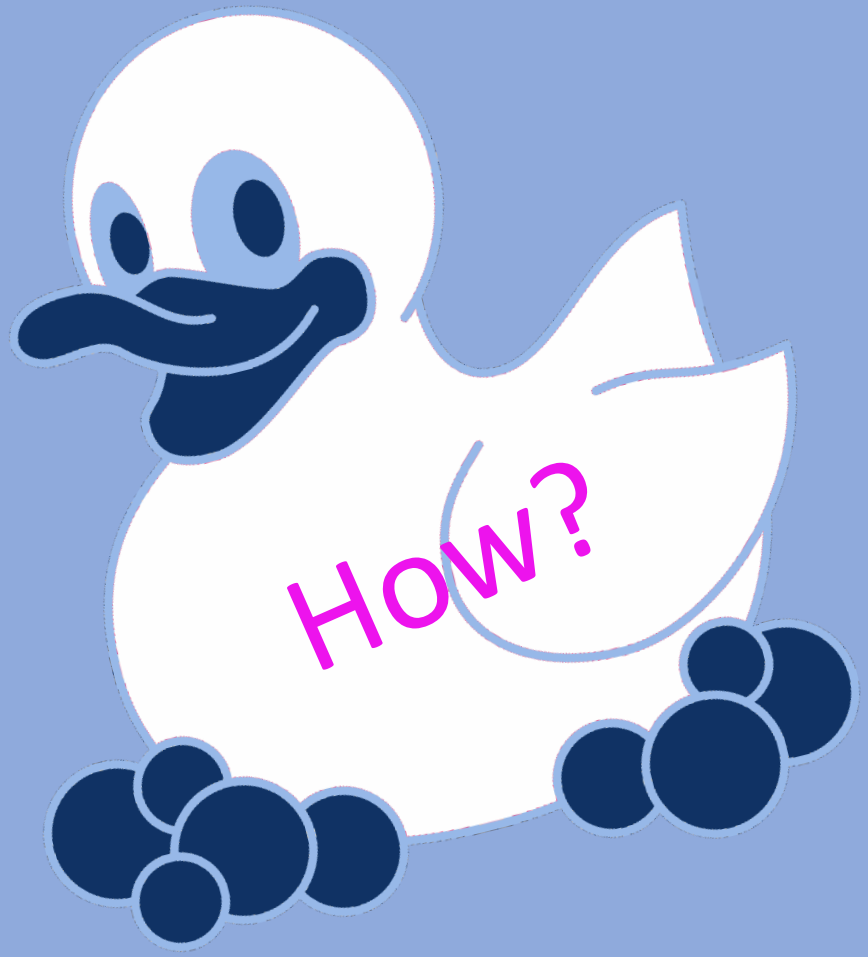
Quenched Galaxies





Remus & Kimmig 2023

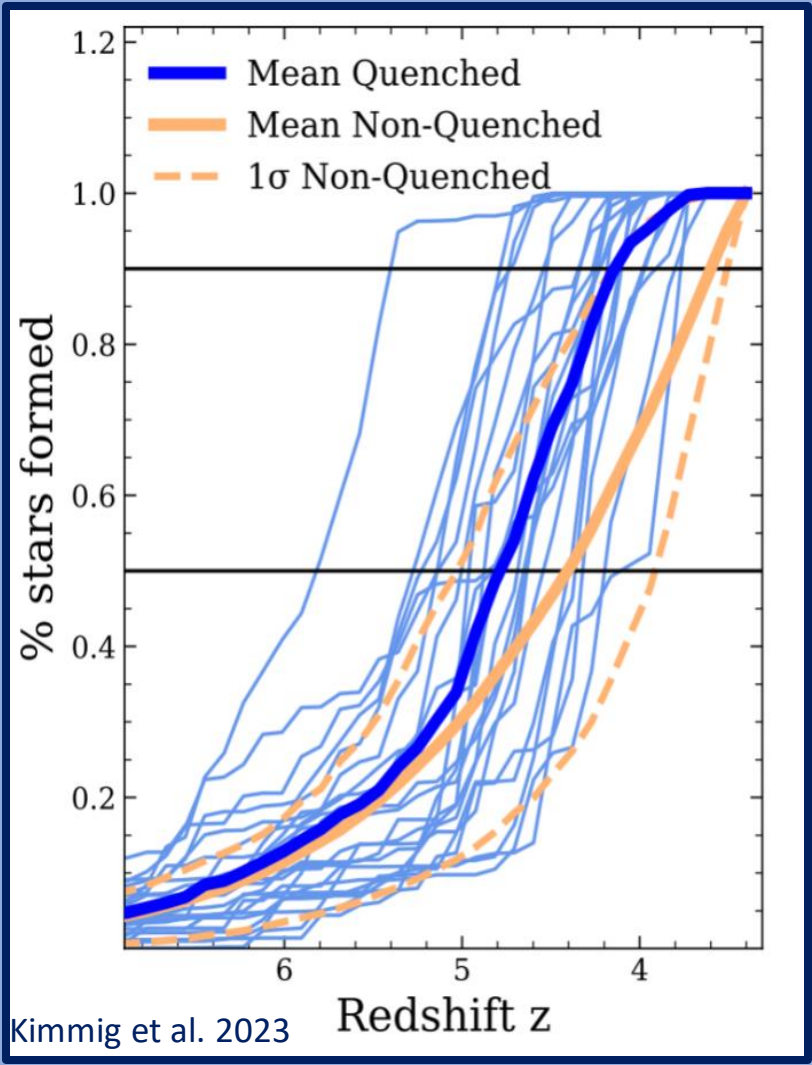
Quenching at High-z



Rhea-Silvia Remus

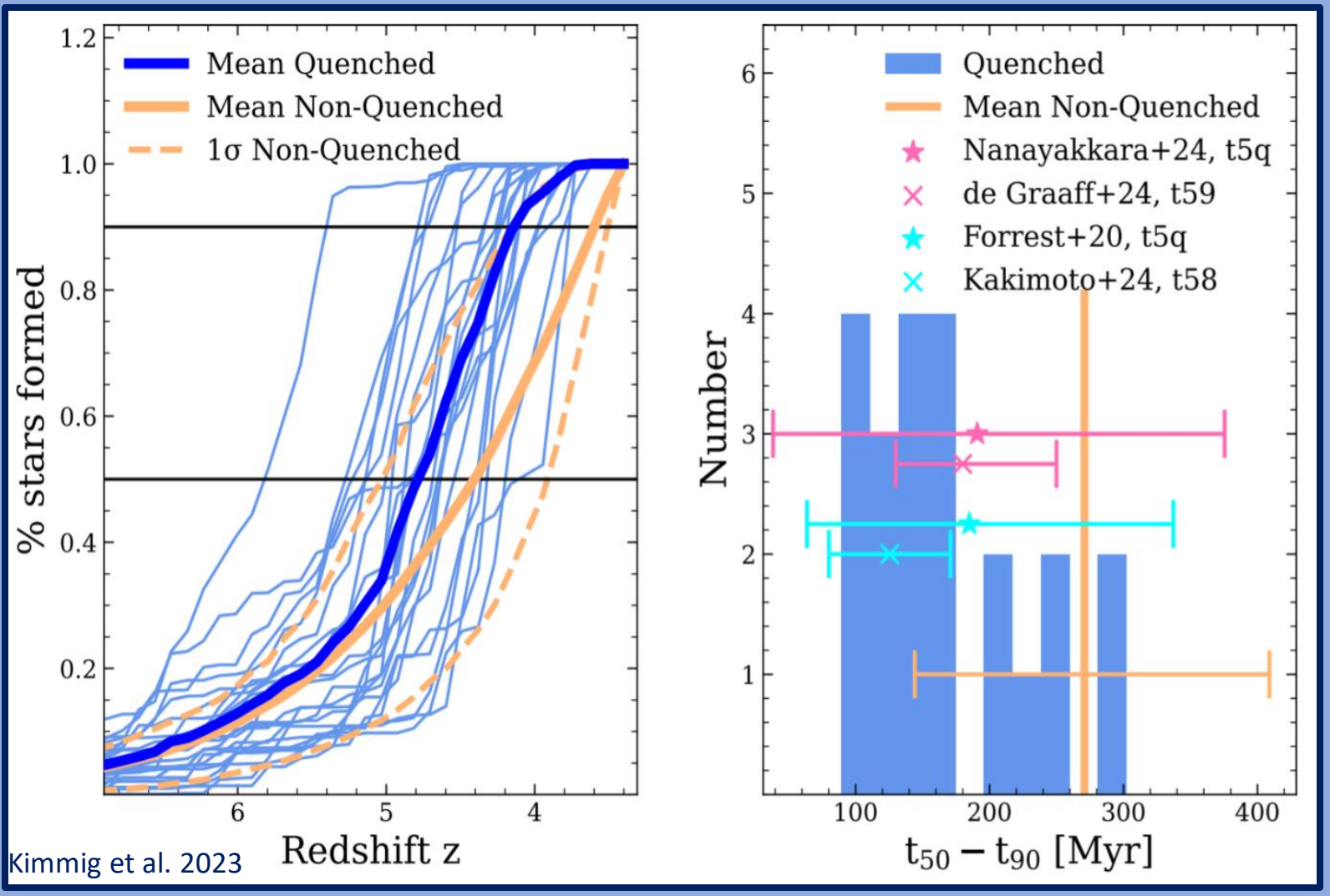
Ljubljana, 30.07.2024

Quenching at High-z



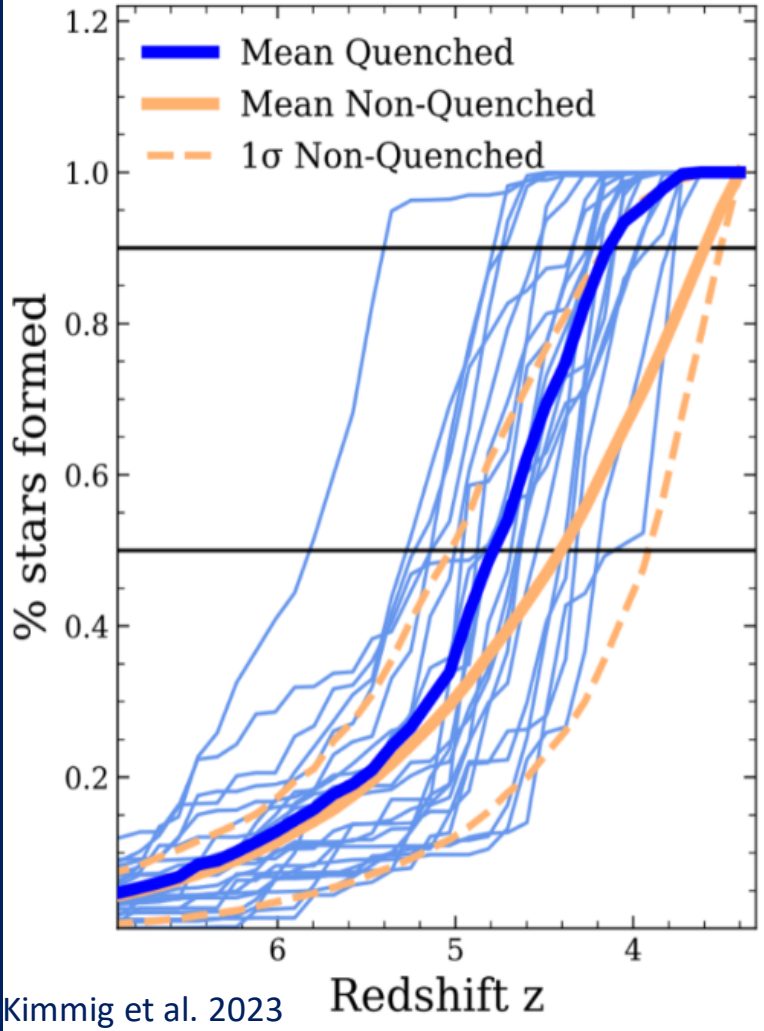
Kimmig et al. 2023

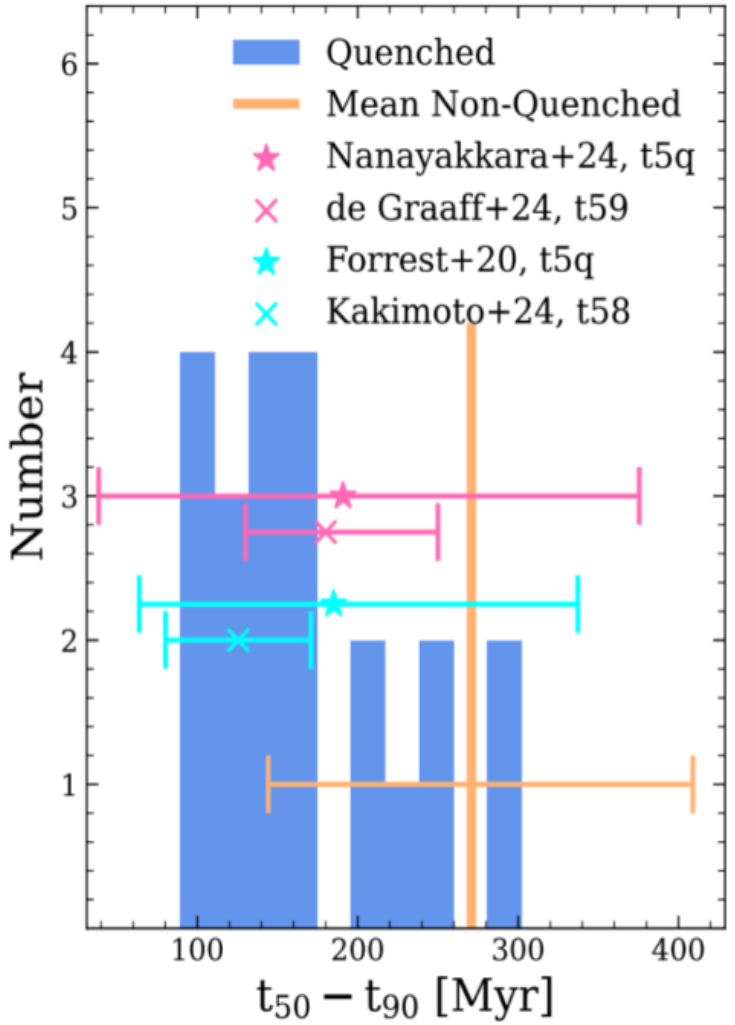
Quenching at High-z

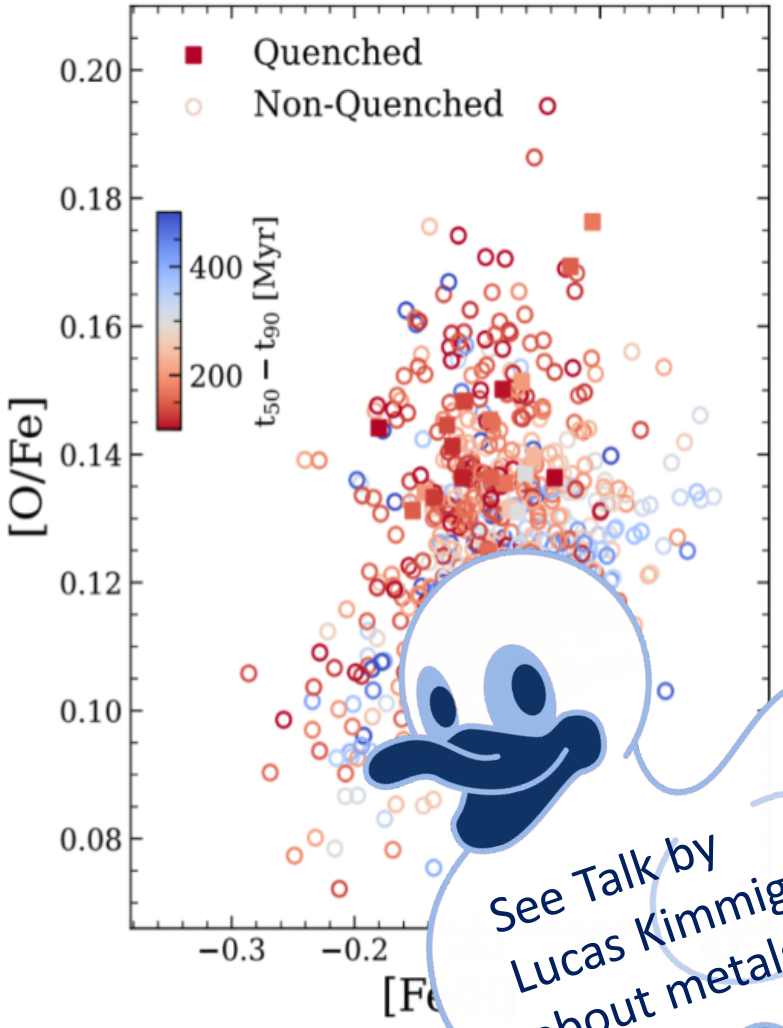


Kimmig et al. 2023

Quenching at High-z







Kimmig et al. 2023

See Talk by Lucas Kimmig about metals

Quenching at High-z

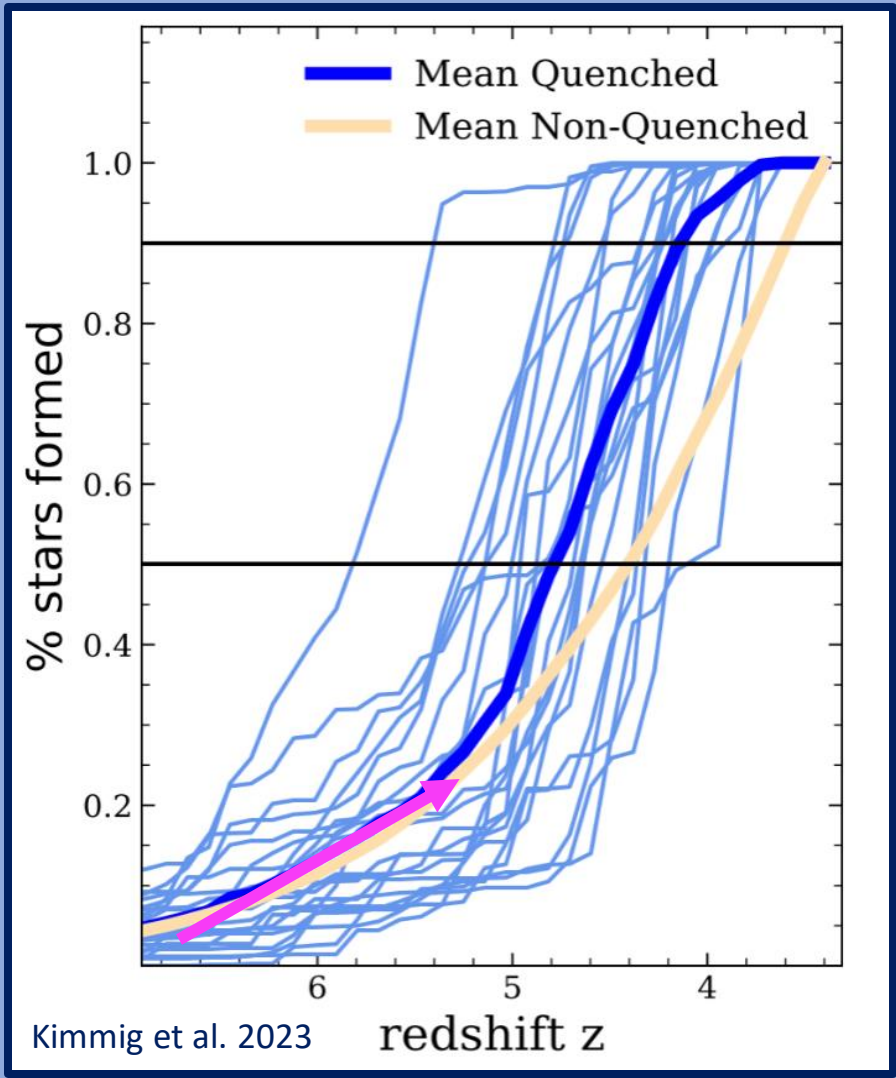
Massive Quiescents Quench Quickly

Rhea-Silvia Remus

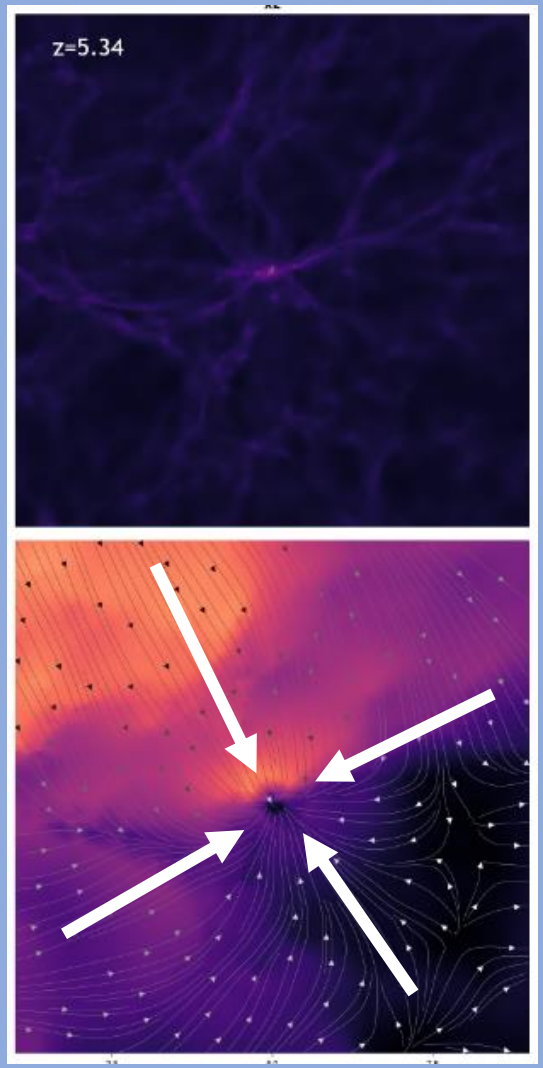
Ljubljana, 30.07.2024

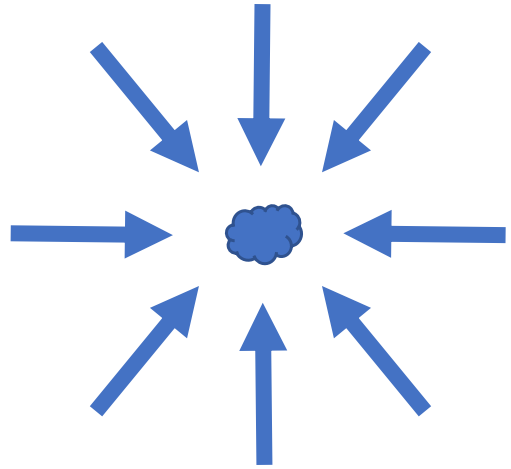
Quenching at High-z

Quenching at High-z



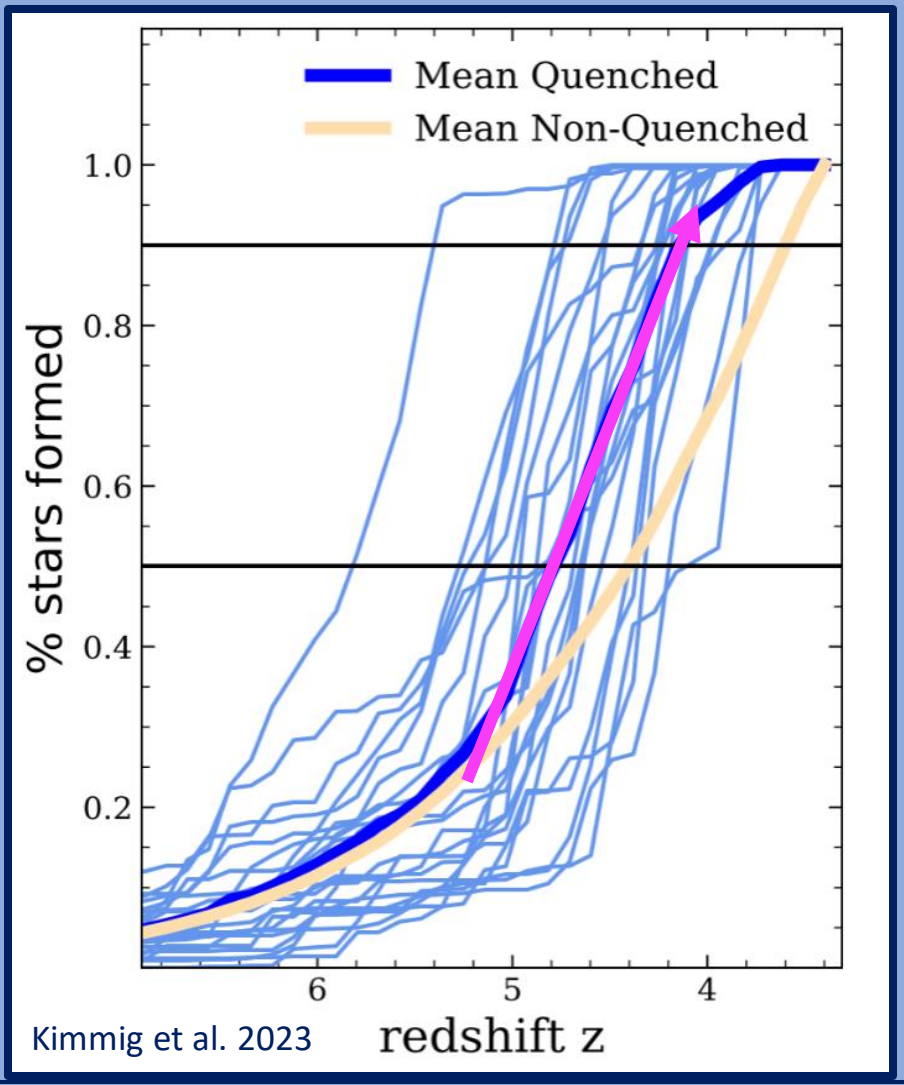
Kimmig et al. 2023



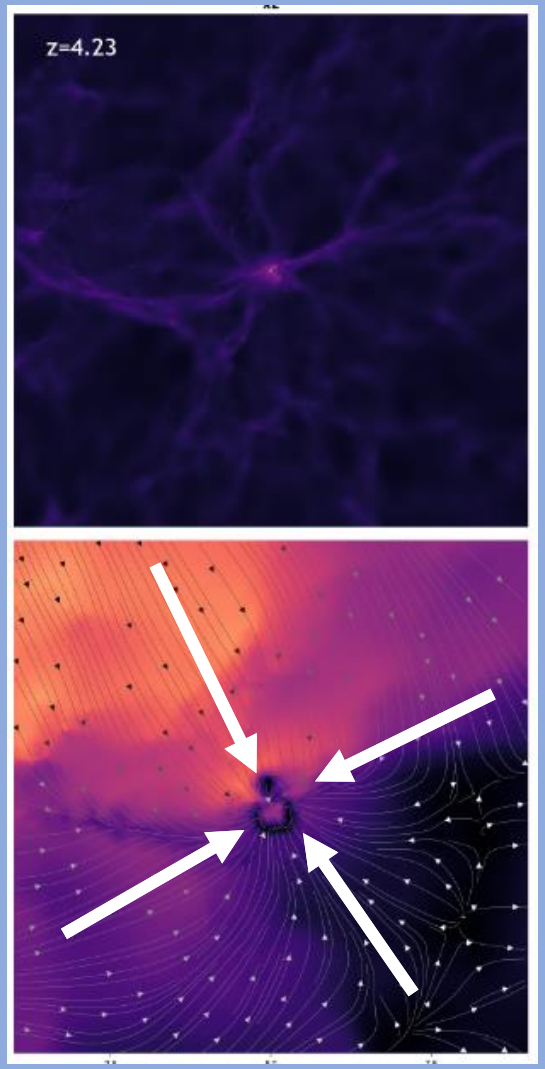


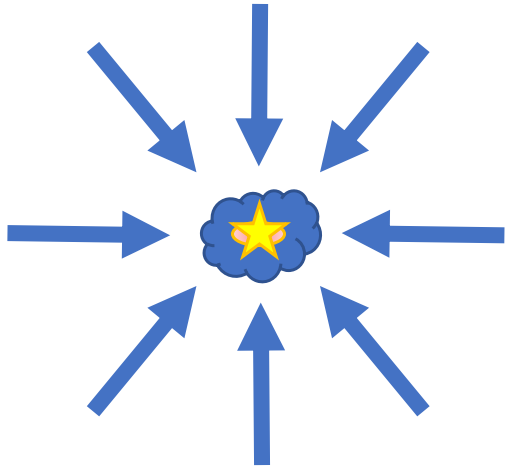
Isotropic Gas Accretion

Quenching at High-z



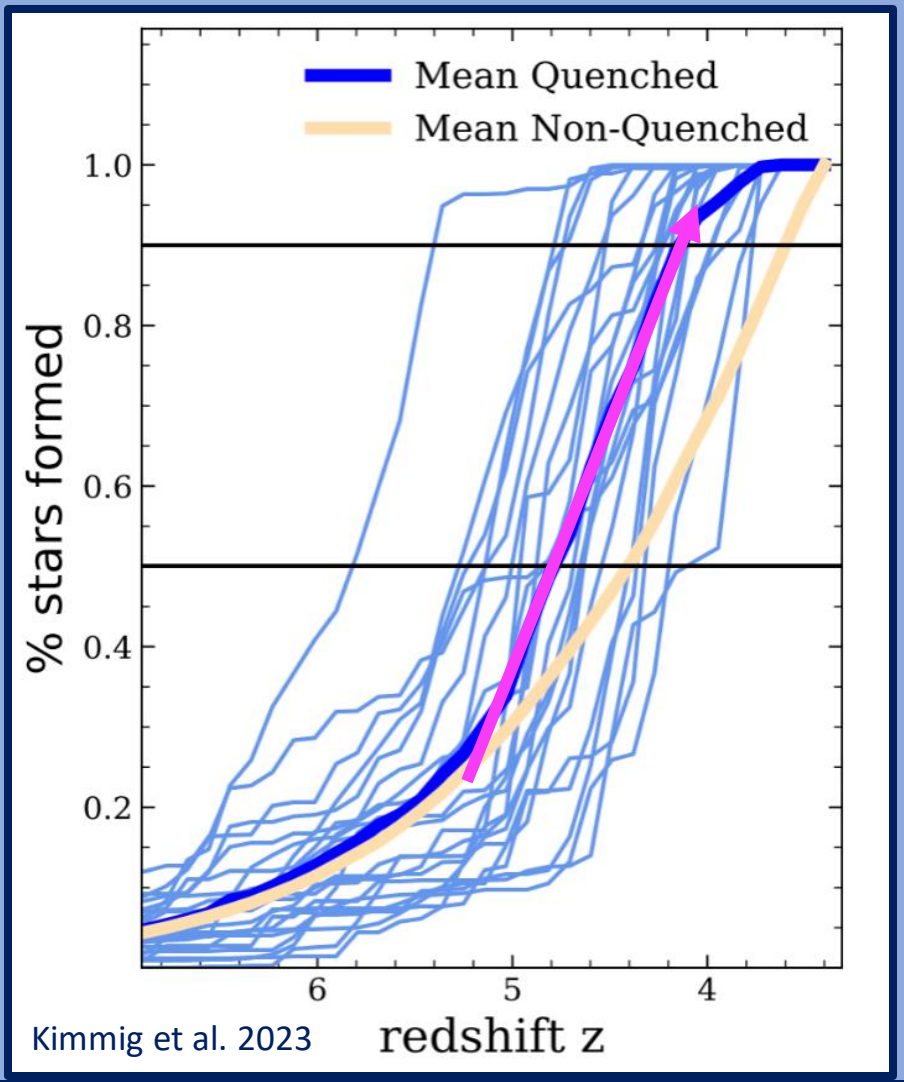
Kimmig et al. 2023



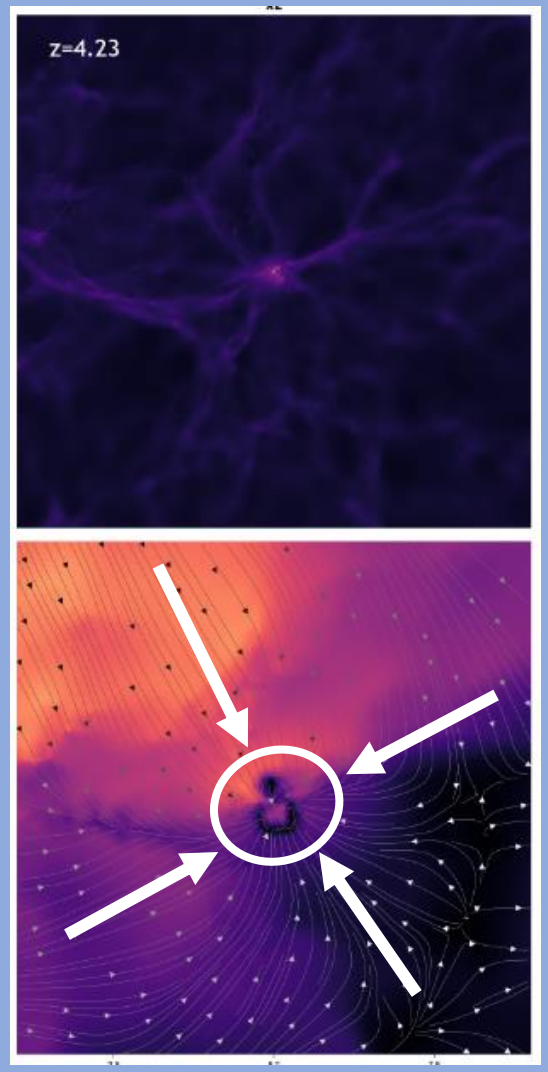


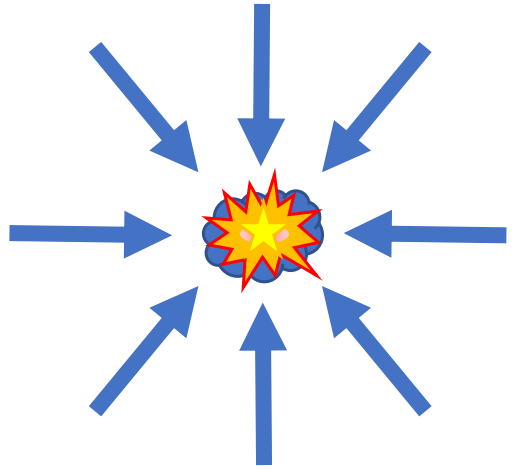
Many Stars Form Quickly: Starburst

Quenching at High-z



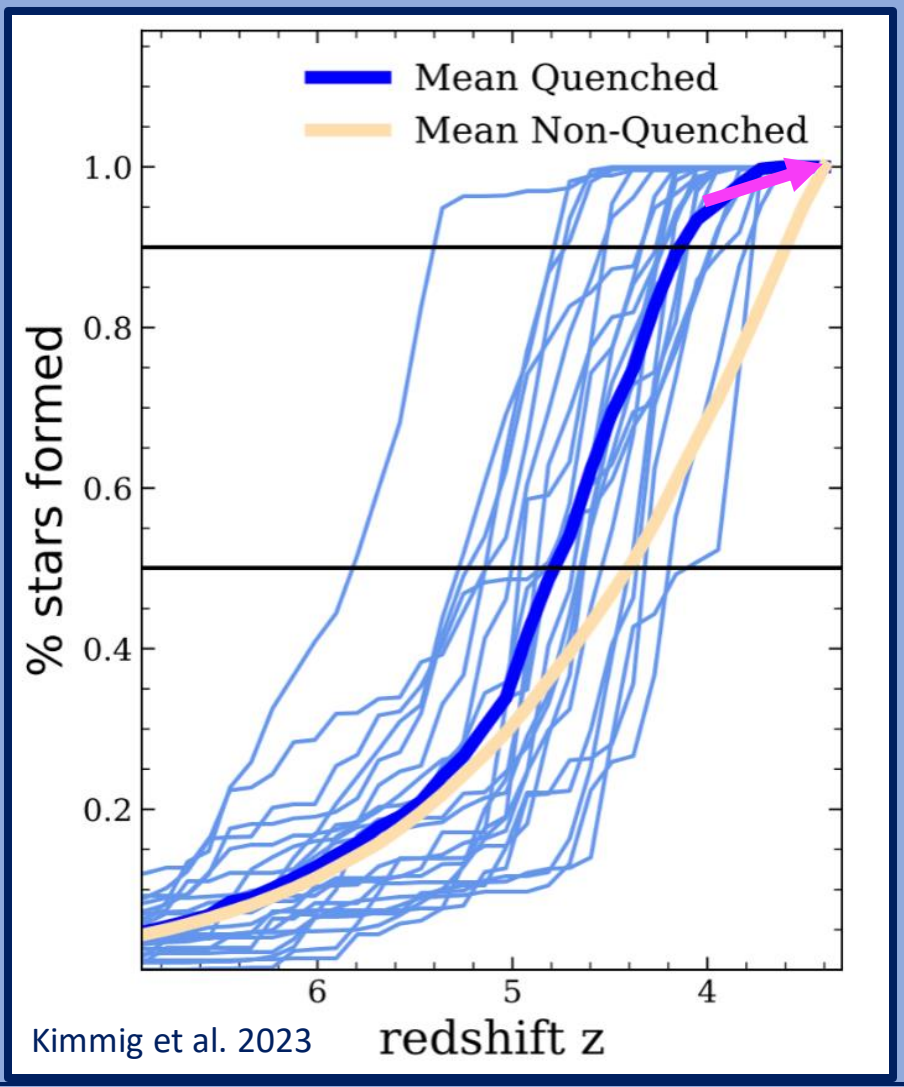
Kimmig et al. 2023



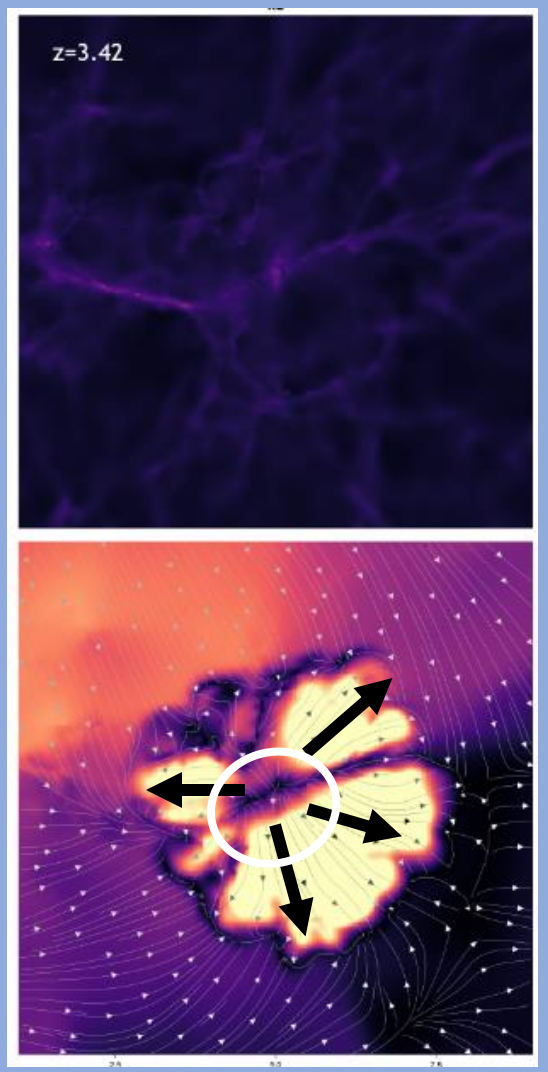


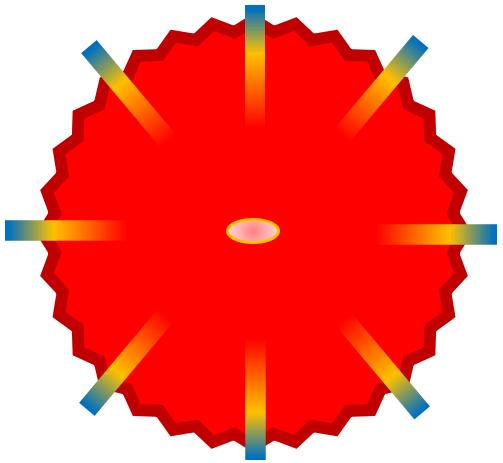
Starburst -> Stellar Feedback

Quenching at High-z



Kimmig et al. 2023





AGN Feedback -> Removes Cold Gas

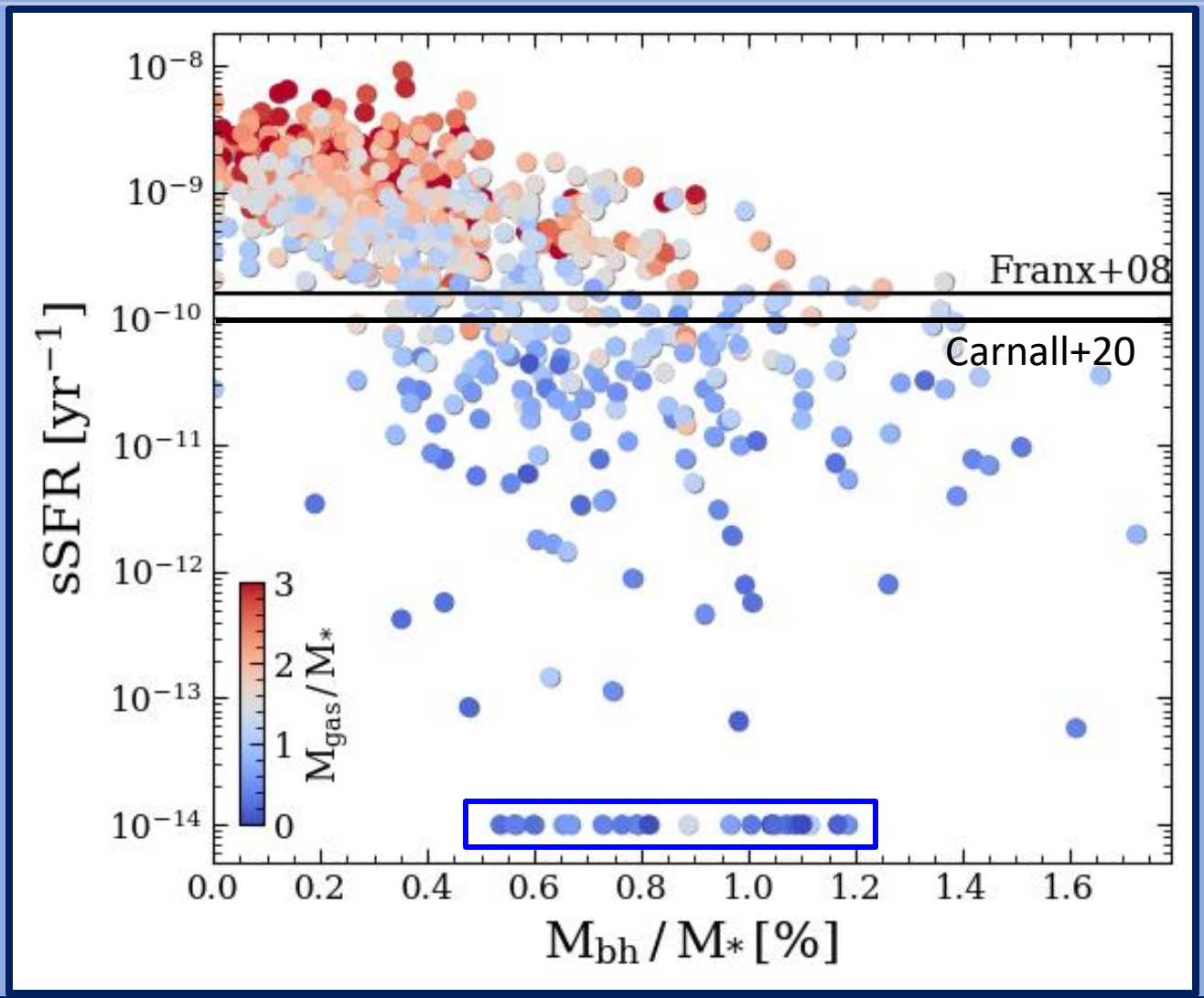
Quenching at High-z

So it is the AGN?

Quenching at High-z

No, not only AGN!

So what else?

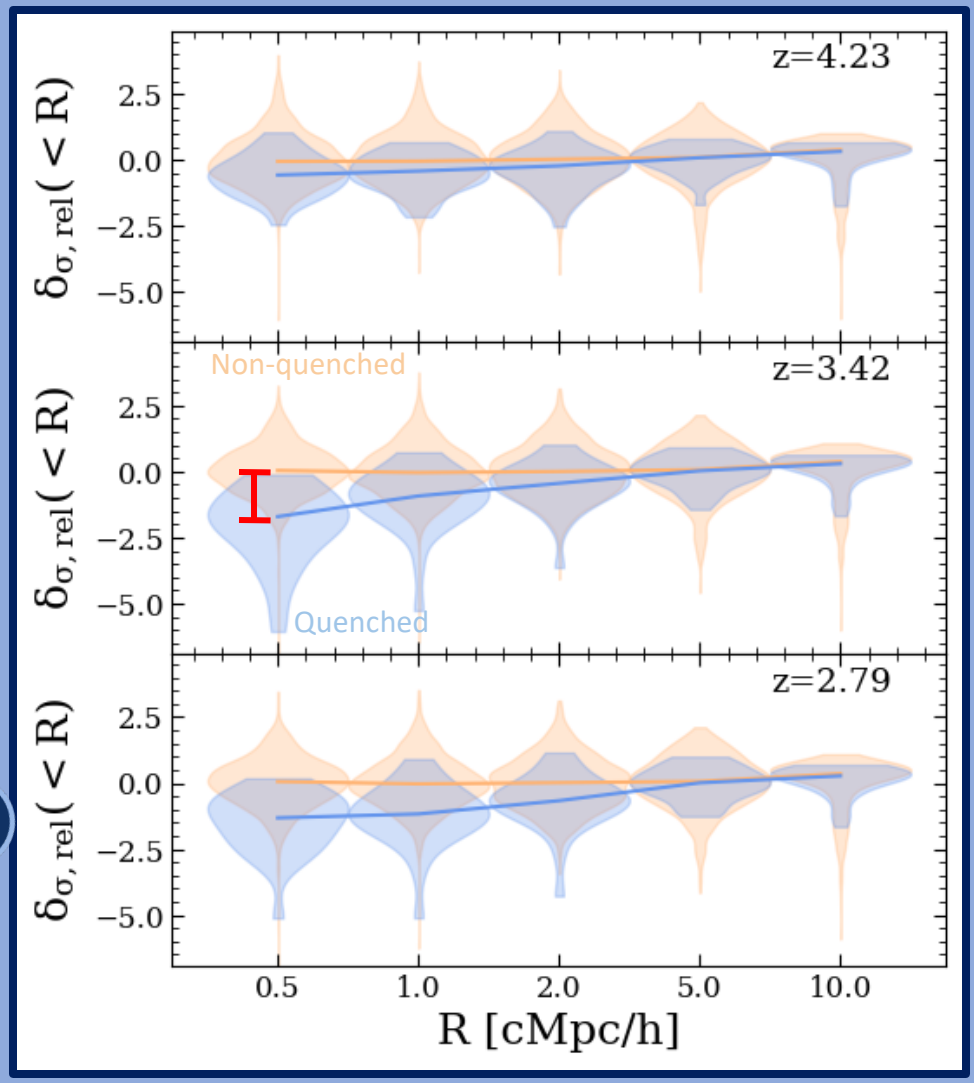


Kimmig et al. 2023

Environment!

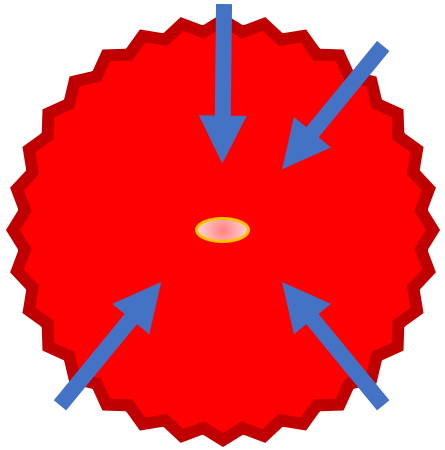
$$\delta_{\sigma,\mathrm{rel}}(<R) = \frac{\delta(<R) - \bar{\delta}(<R)}{\sigma_{\delta,R}}$$

$$\delta(<R) = \frac{\rho(<R) - \bar{\rho}}{\bar{\rho}}$$

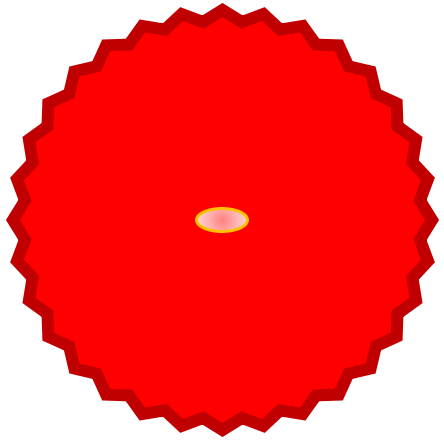


Kimmig et al. 2023

Environment!

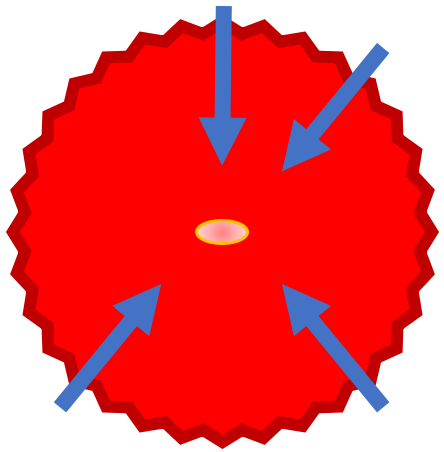


Dense Environment

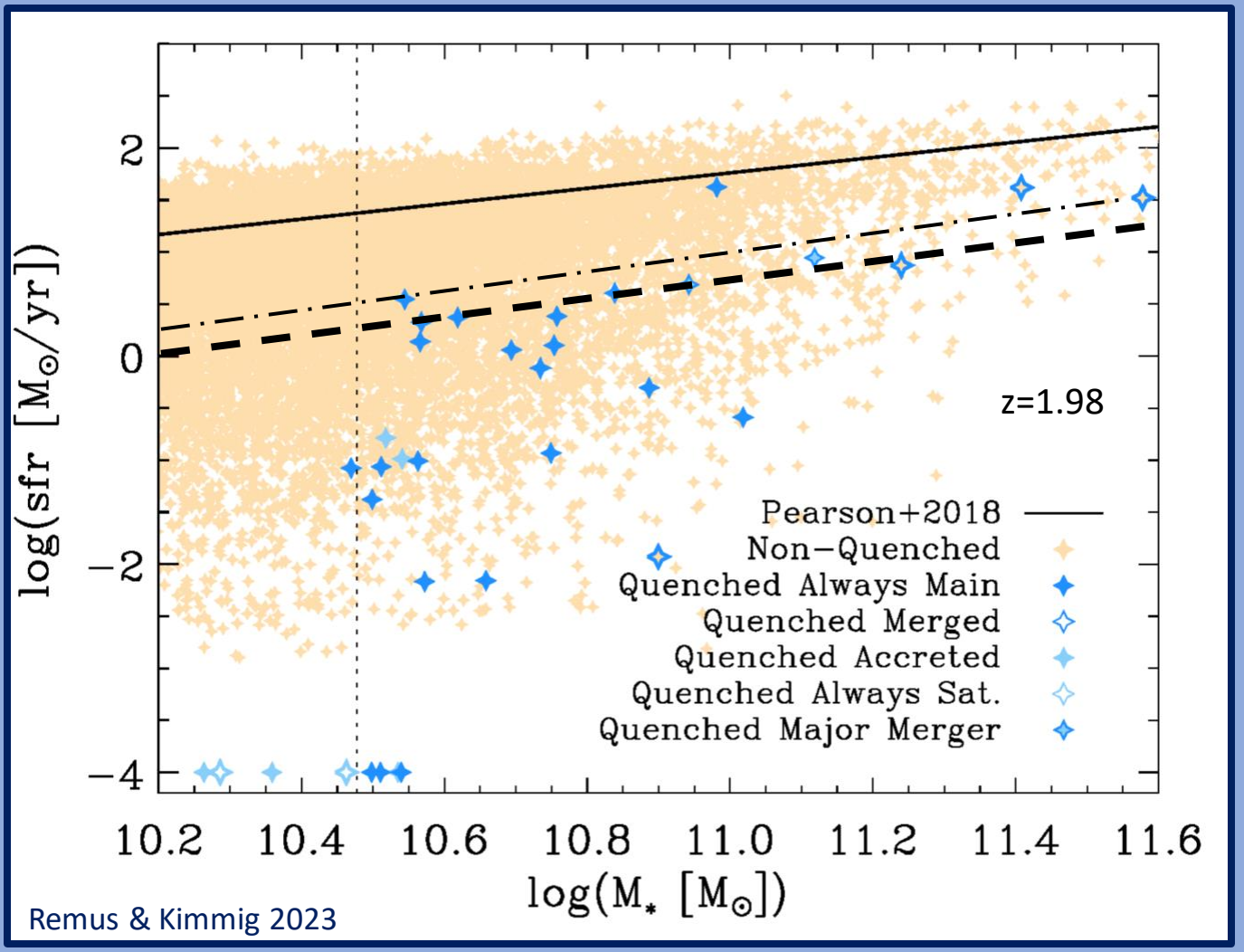


Underdense Environment

Rejuvenation

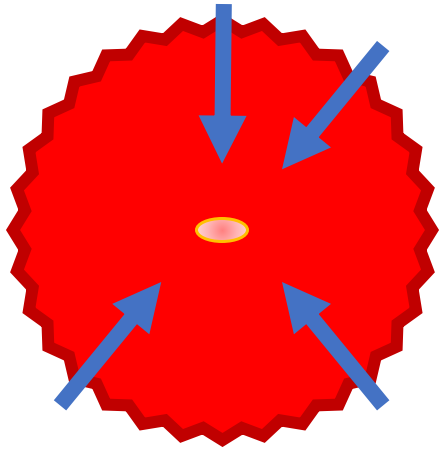


Dense Environment

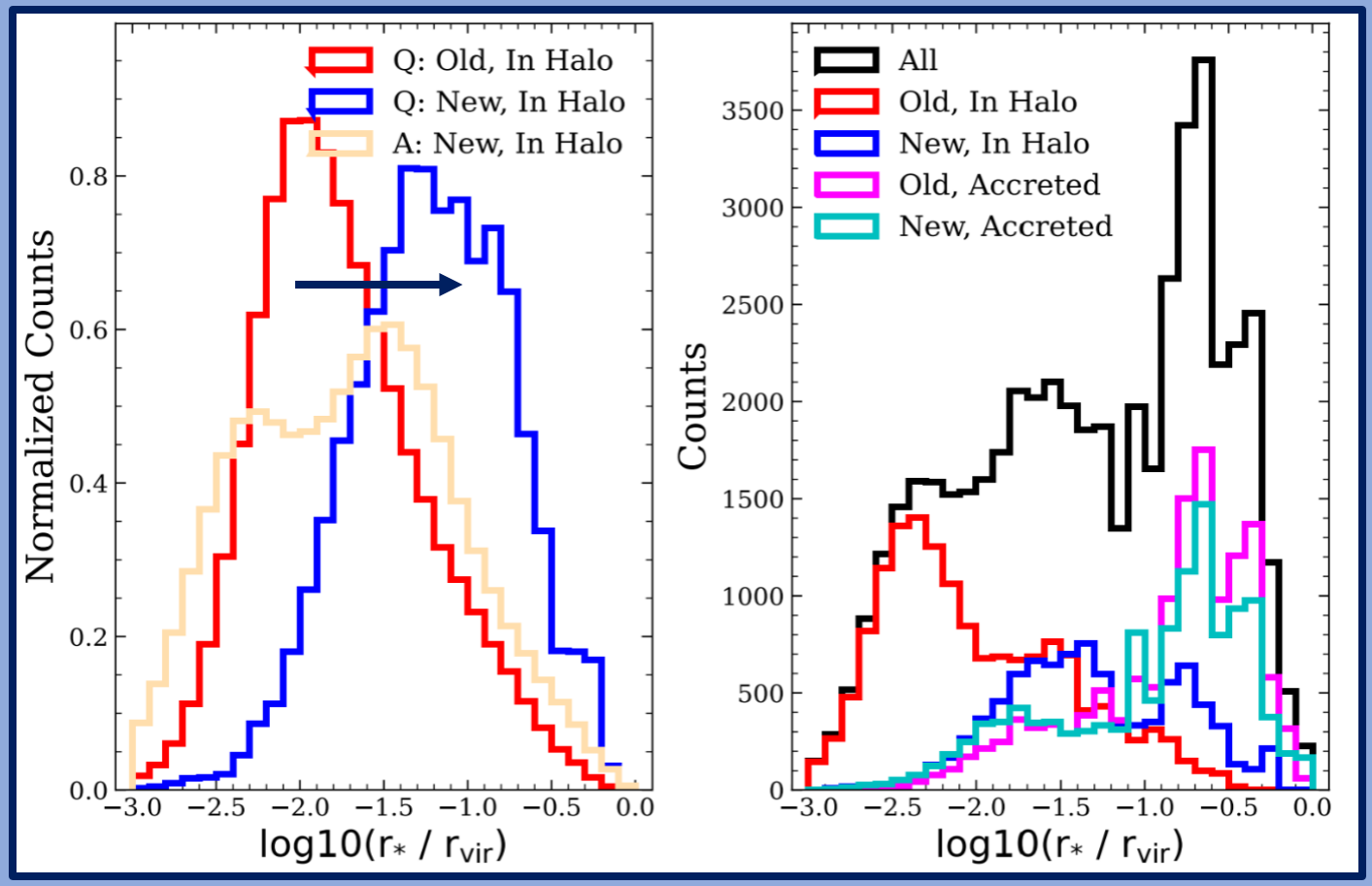


Remus & Kimmig 2023

Rejuvenation

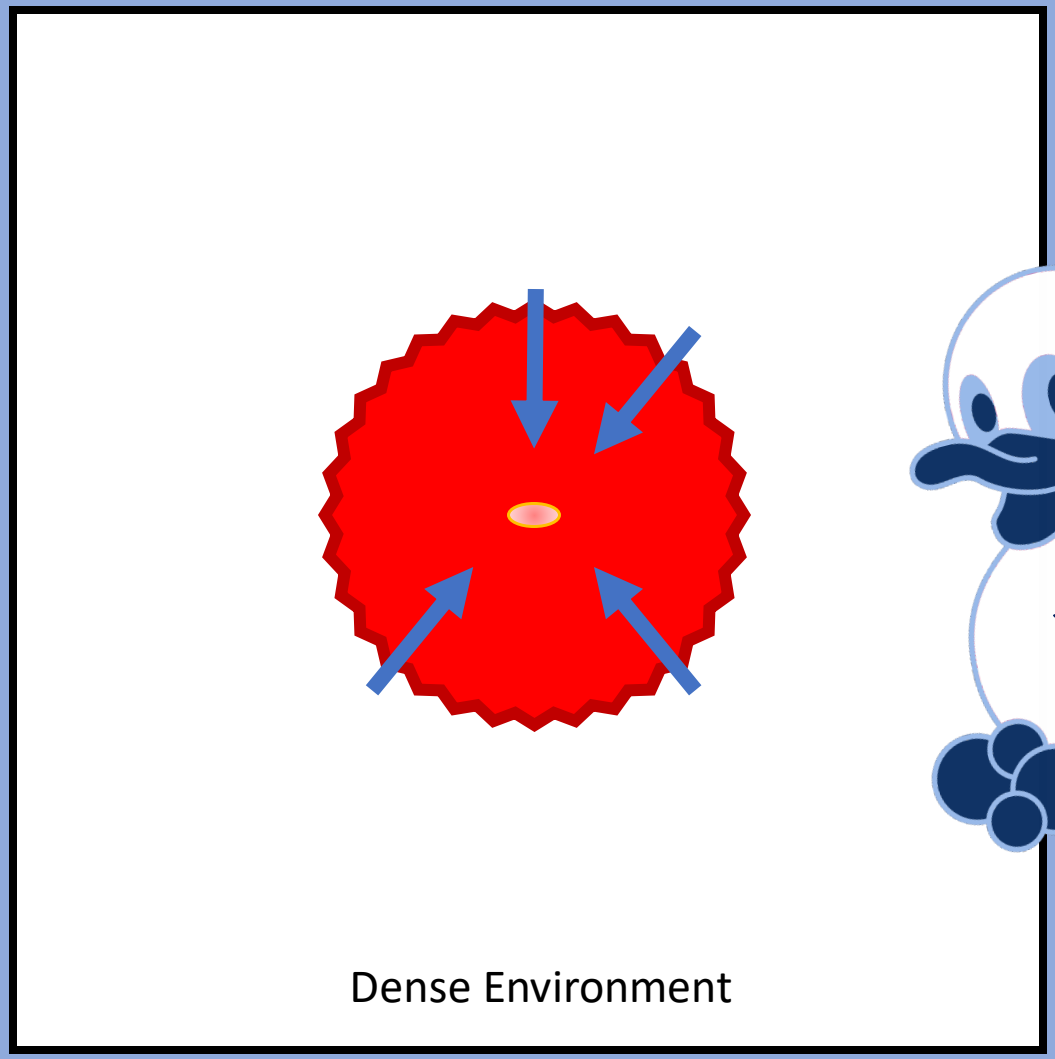


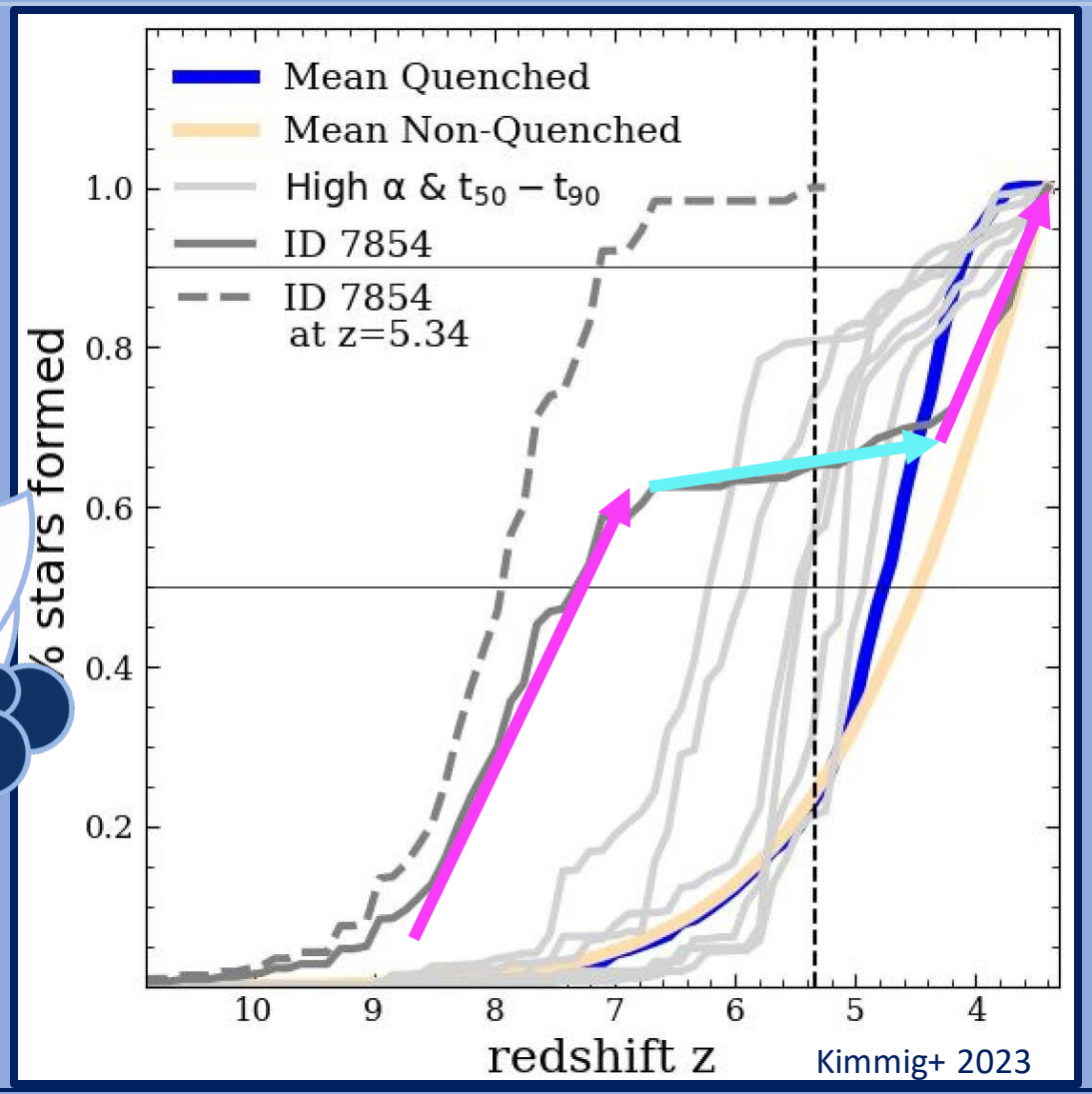
Dense Environment



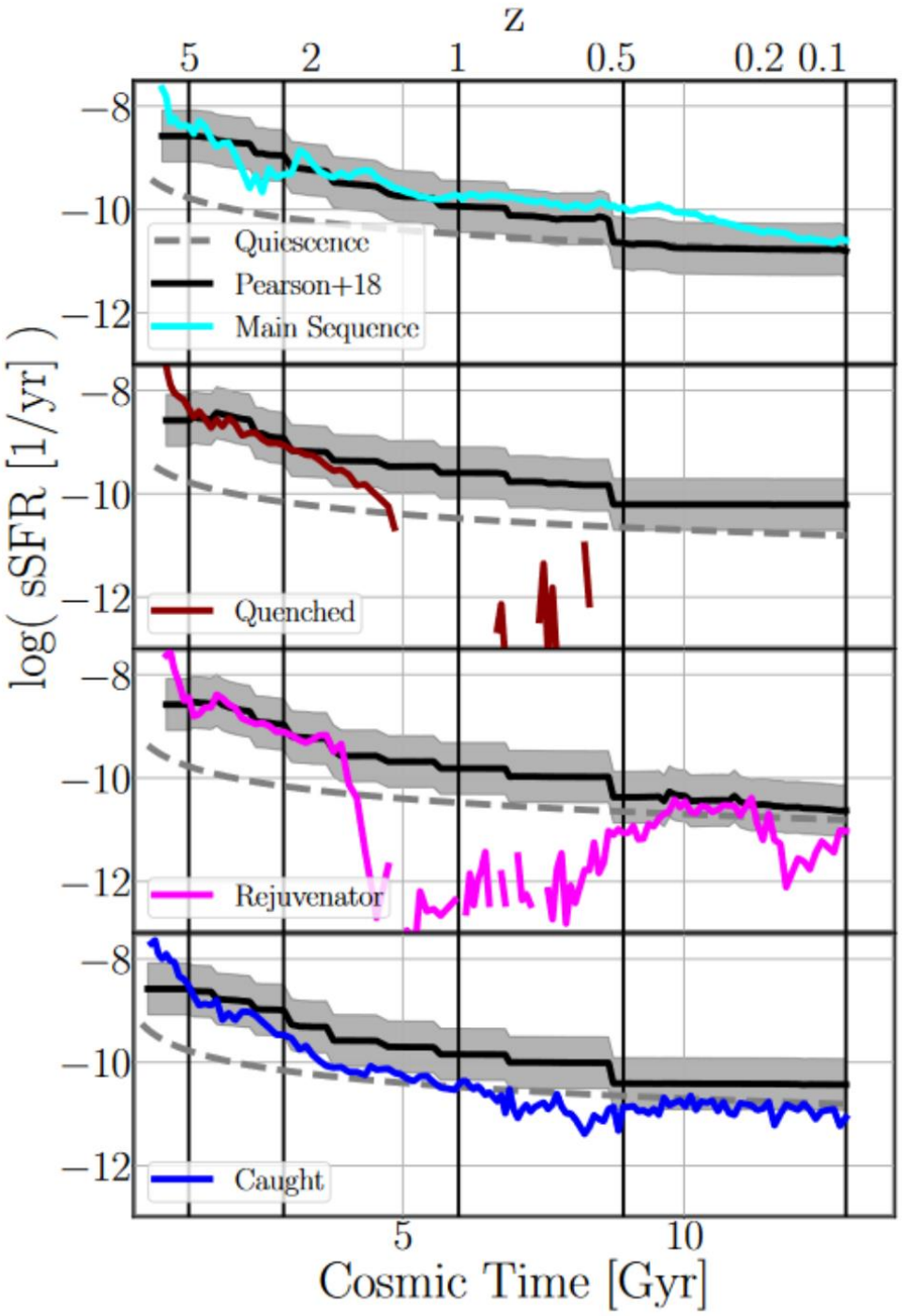
Remus & Kimmig 2023

Rejuvenation also earlier!

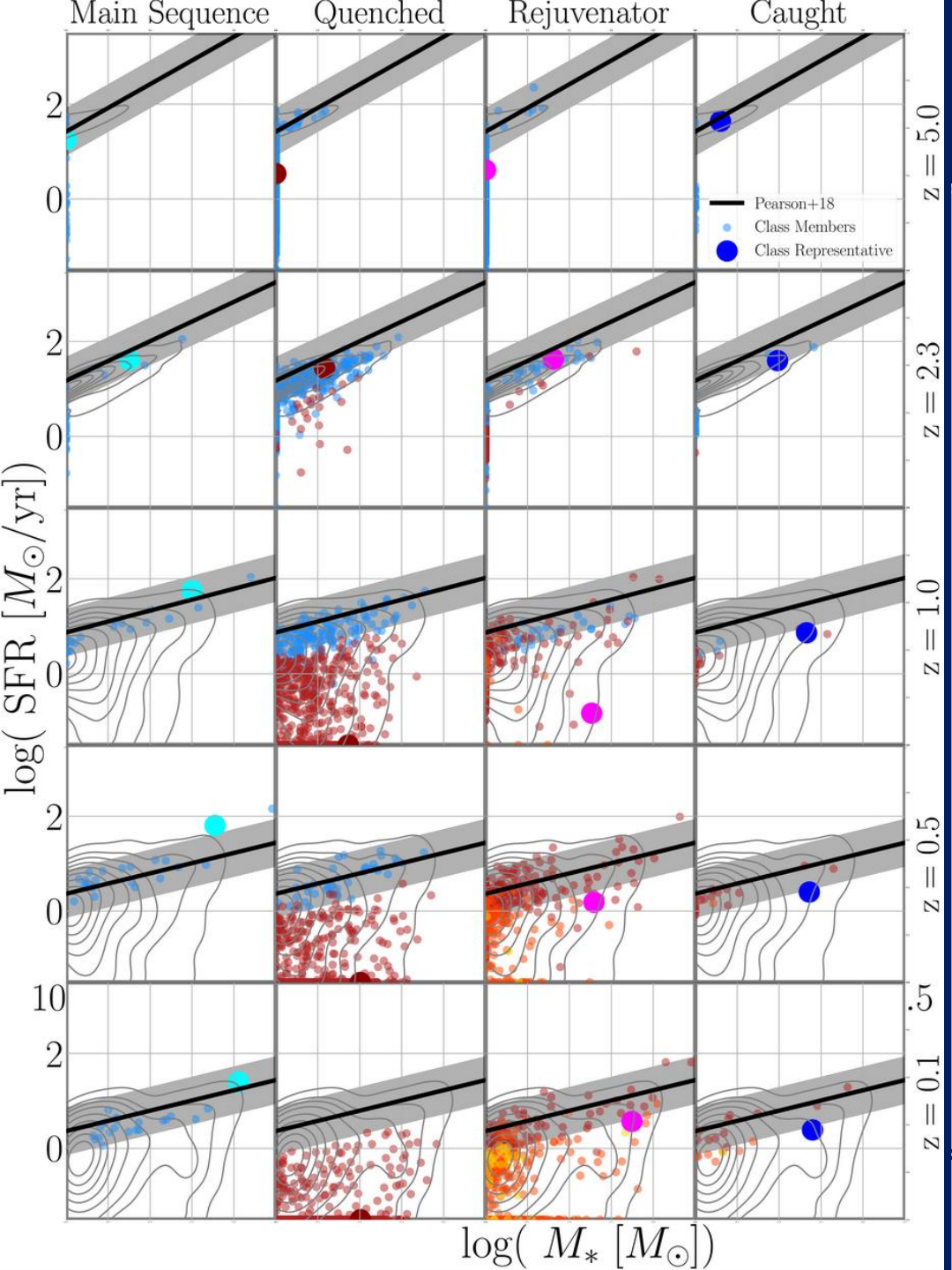




Rejuvenation over cosmic time



Fortuné+ to be submitted



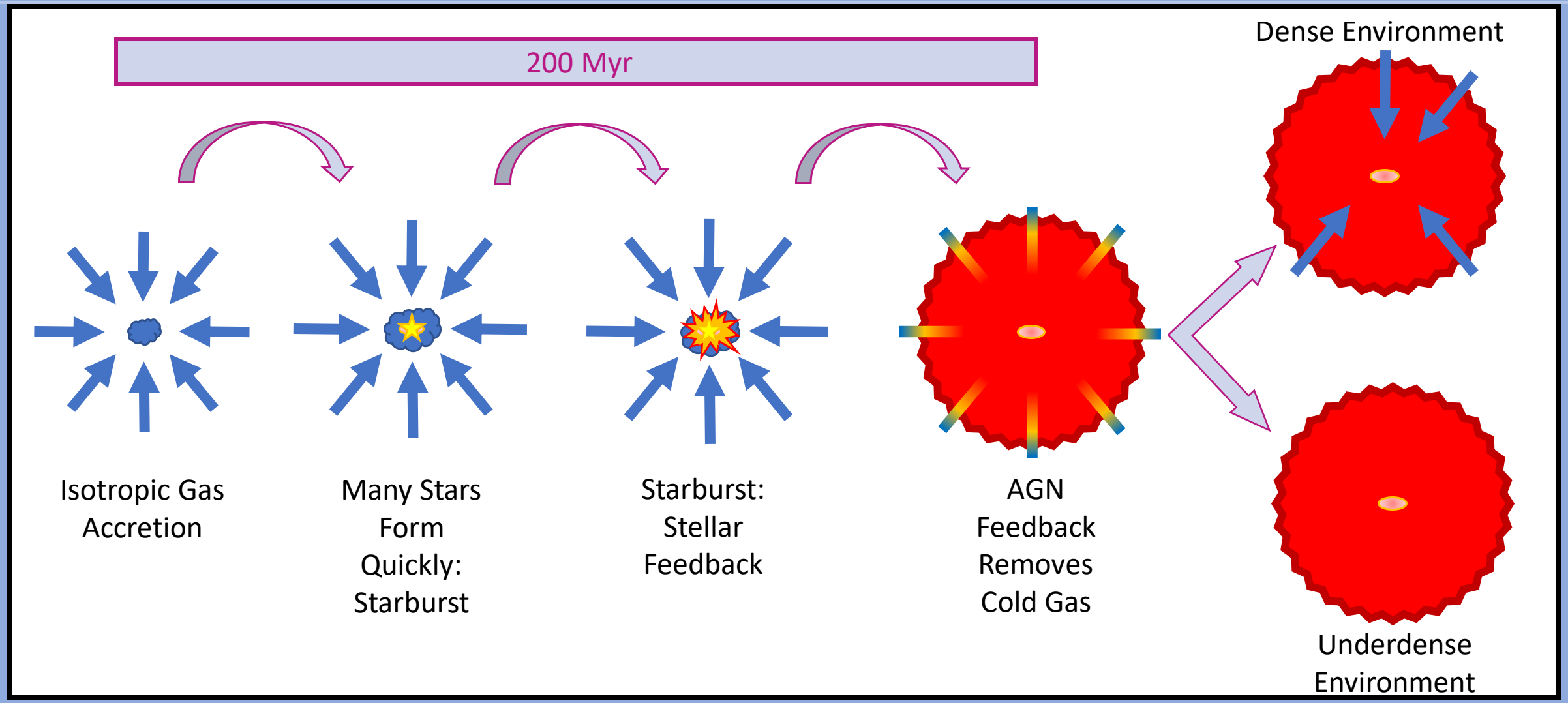
Rejuvenation over cosmic time

Staying on the Main Sequence for a lifetime is rare! Most galaxies switch on-and-off

Fortuné+ to be submitted

Ljubljana, 30.07.2024

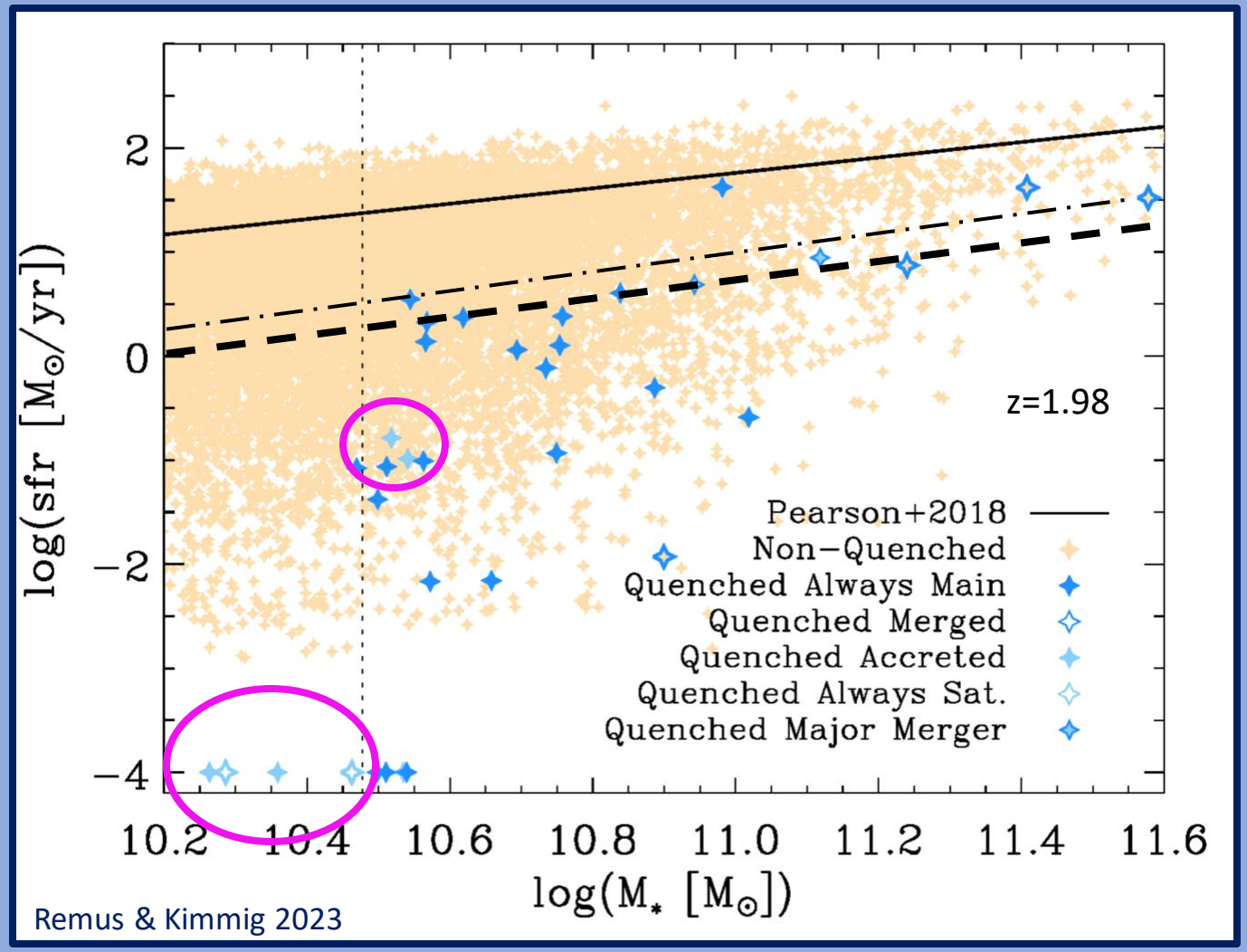
High-z Quenching in a Nutshell



But what about (proto)cluster environment?

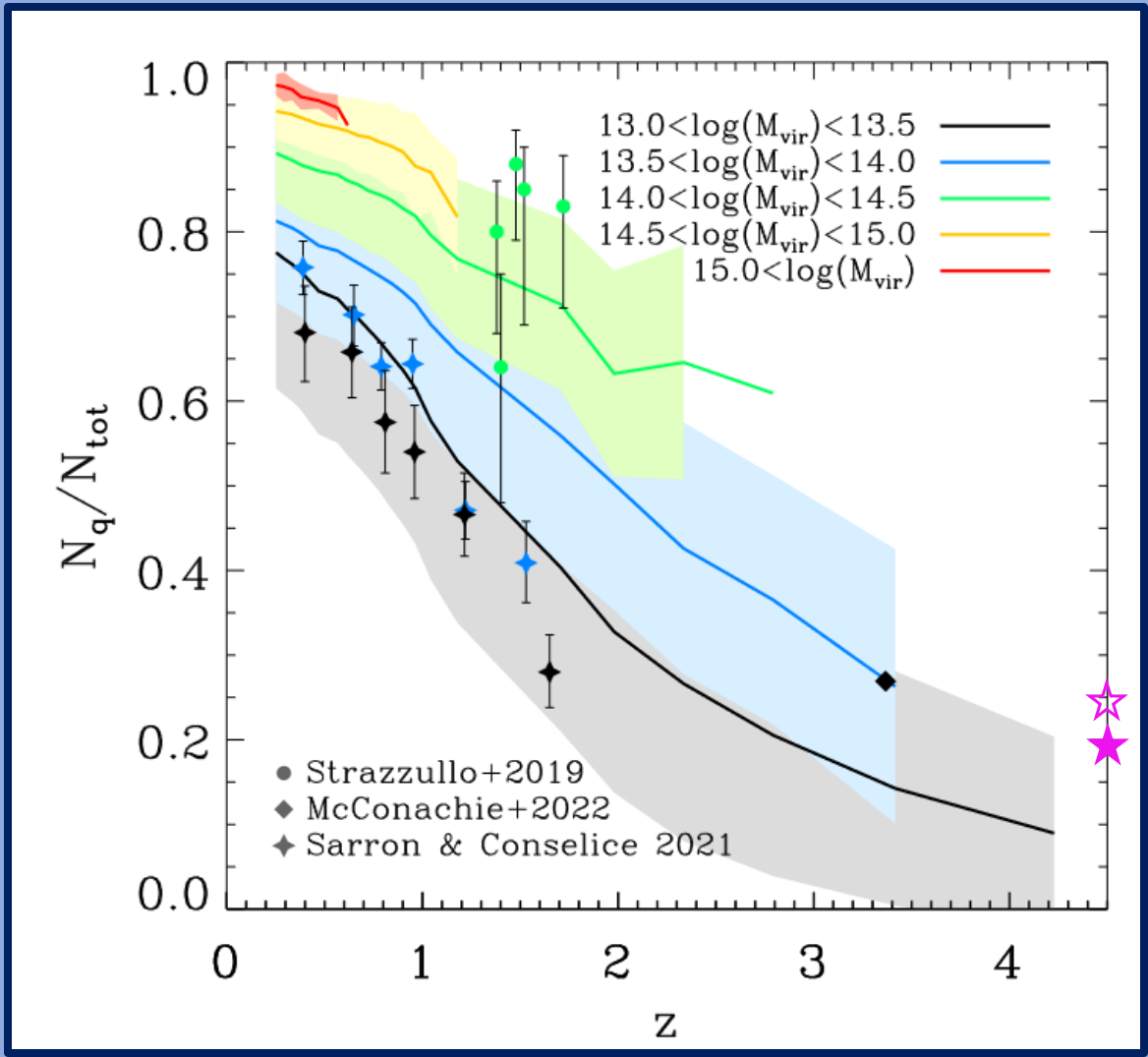
But what about (proto)cluster environment?

Quenched galaxies in protoclusters cannot rejuvenate



Remus & Kimmig 2023

Protocluster Quenched Fractions



Quenched Galaxy in a Group at z=4.5 (Kakimoto+2023): 1 out of 5 (4) galaxies quenched, expected group mass about $M_{group} = 10^{13} M_{\odot}$

Remus et al., 2023

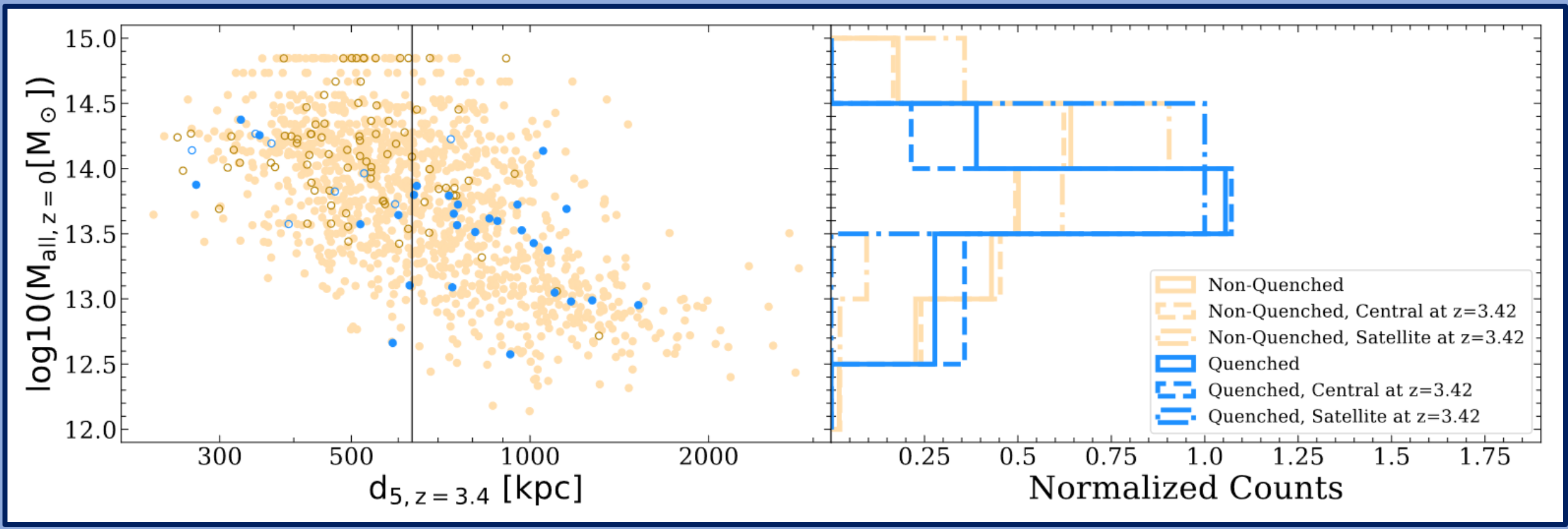
Protocluster environments shields from rejuvenation

Rhea-Silvia Remus

Ljubljana, 30.07.2024

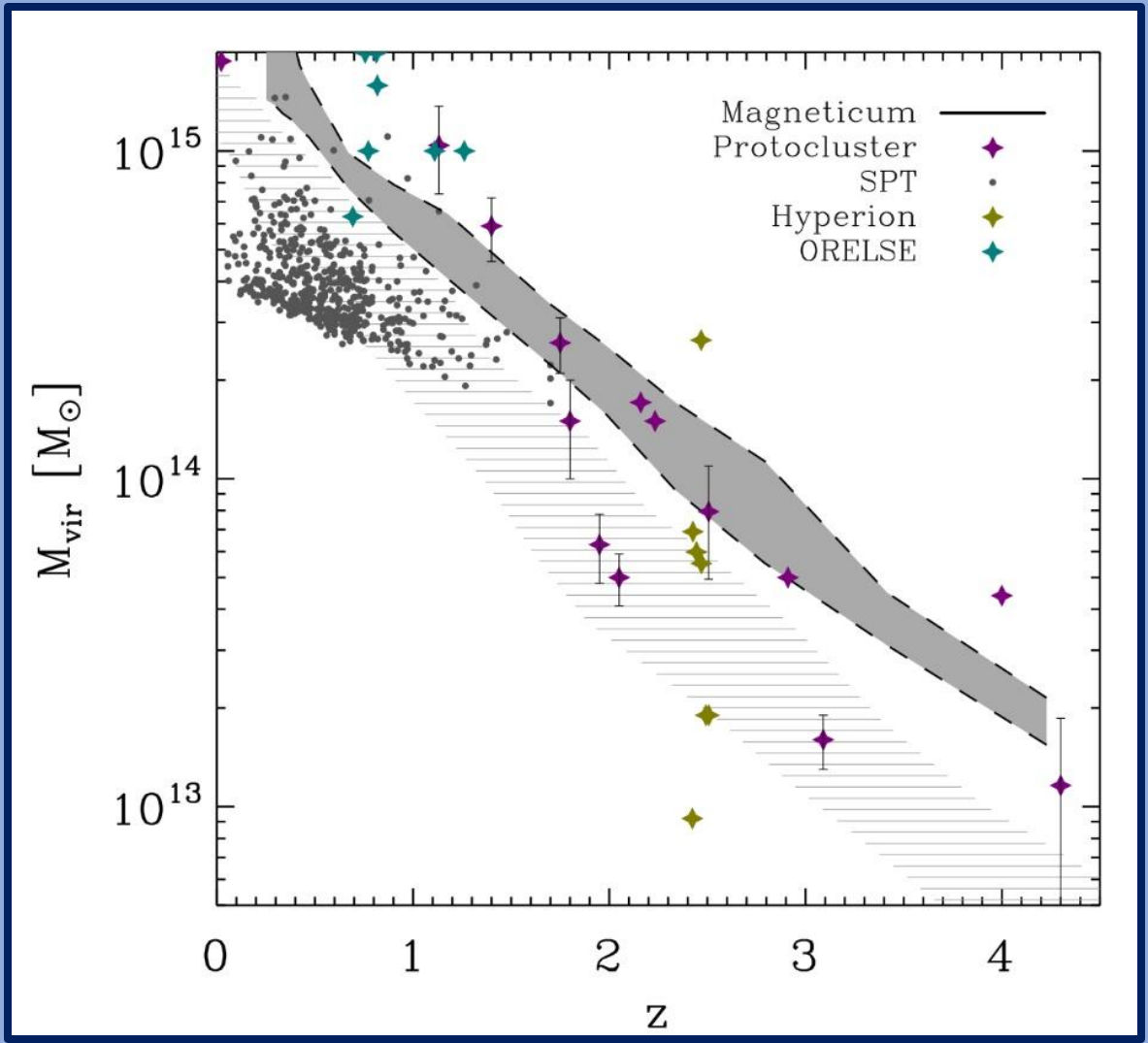
So are all galaxies and protocluster structures we see at high redshift future massive clusters?

Massive Galaxy Evolution



Remus & Kimmig 2023

Protocluster Evolution

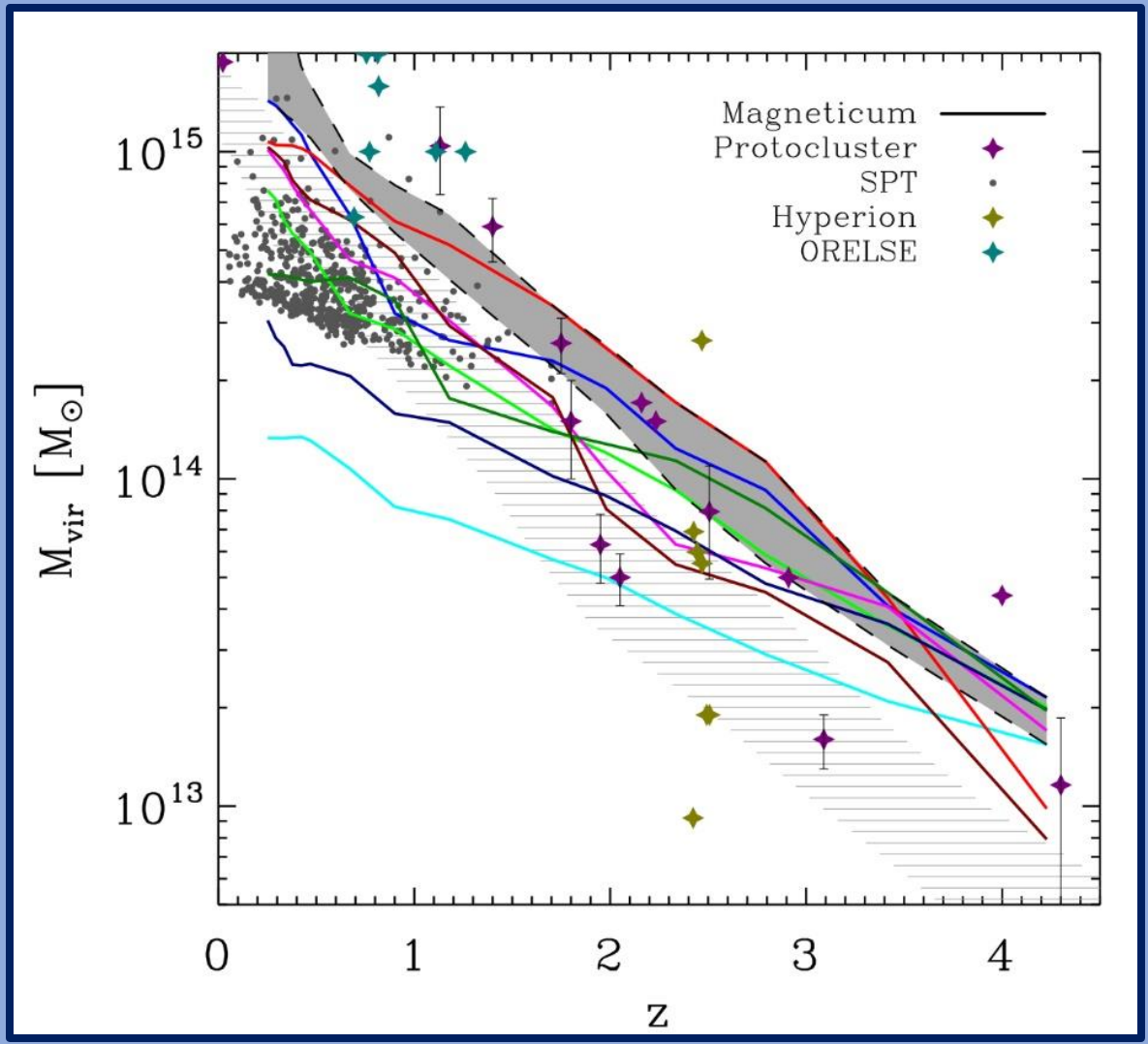


Shade: Magneticum Most Massive at each redshift, Remus+2023

Striped: Millenium prediction, Chiang+2013

Remus et al., 2023

Protocluster Evolution



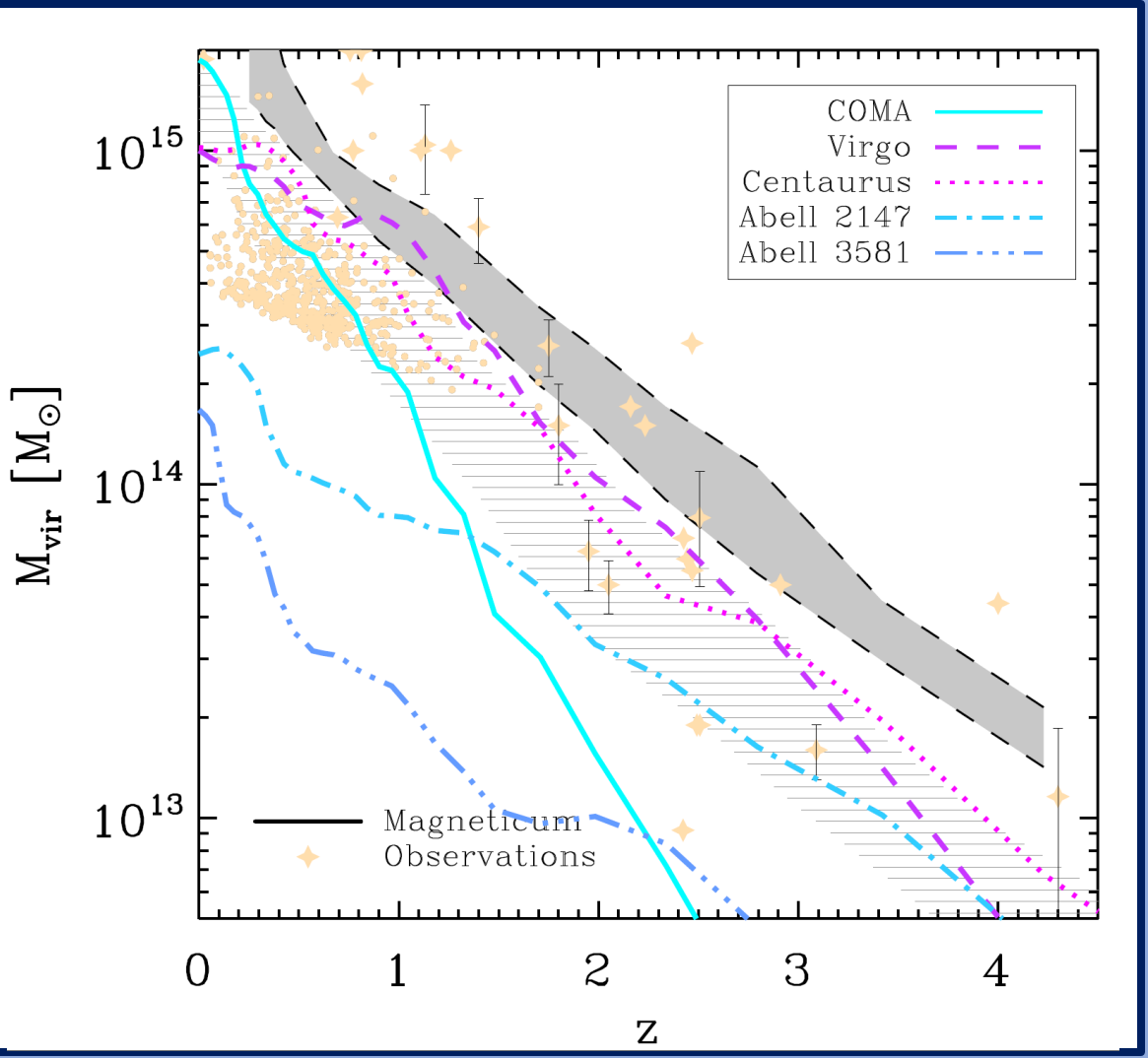
Remus et al., 2023

Colored lines: Tracked Protoclusters

Shade: Magneticum Most Massive at each redshift, Remus+2023
Striped: Millenium prediction, Chiang+2013

Not All Protoclusters become actual clusters at z=0!

Protocluster: Going Local

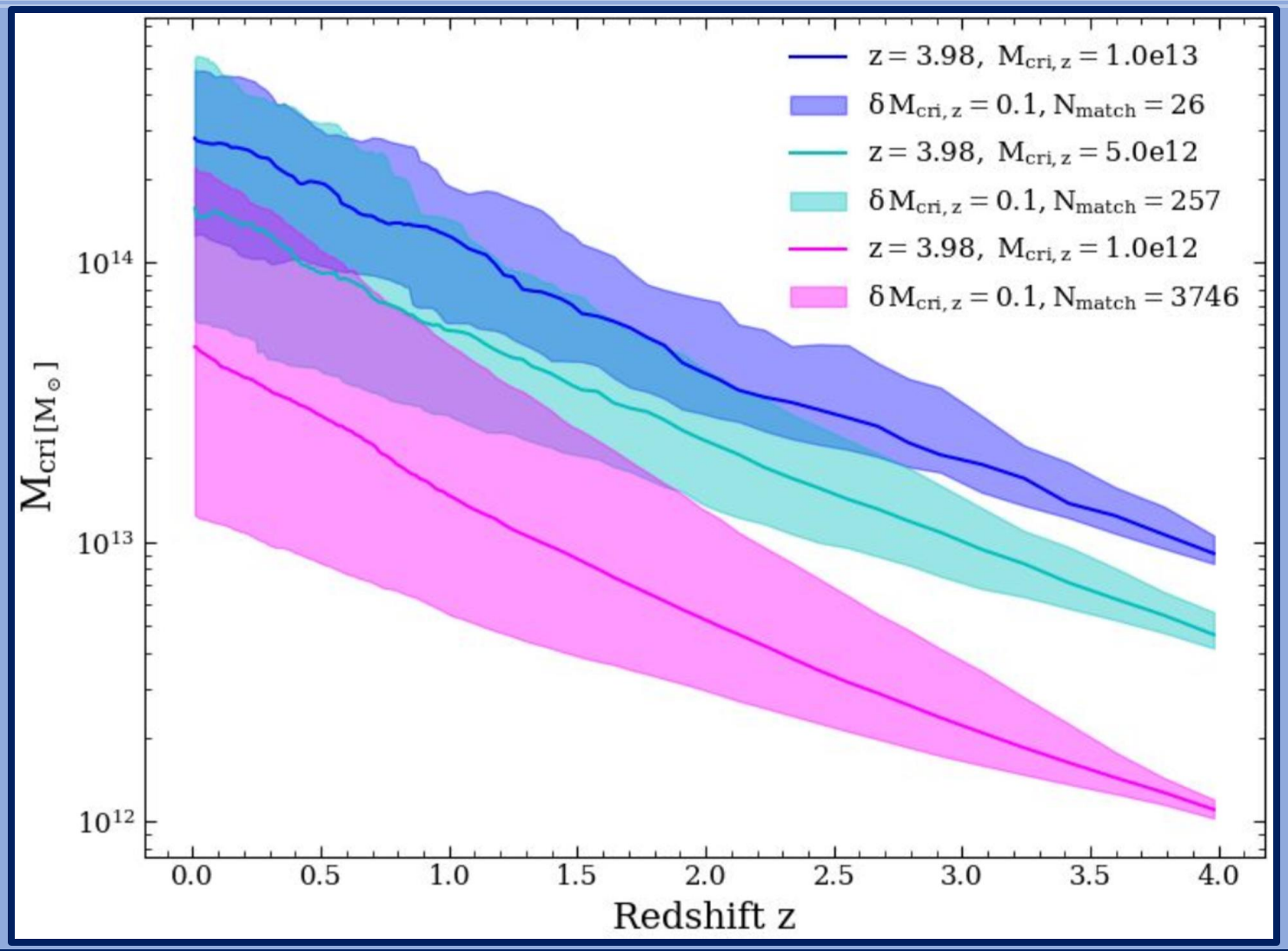


Dolag et al., 2023: The SLOW simulations.

See also Sorce+2017, 2019 for more details on the Virgo-Cluster CLONE

Remus et al., in prep

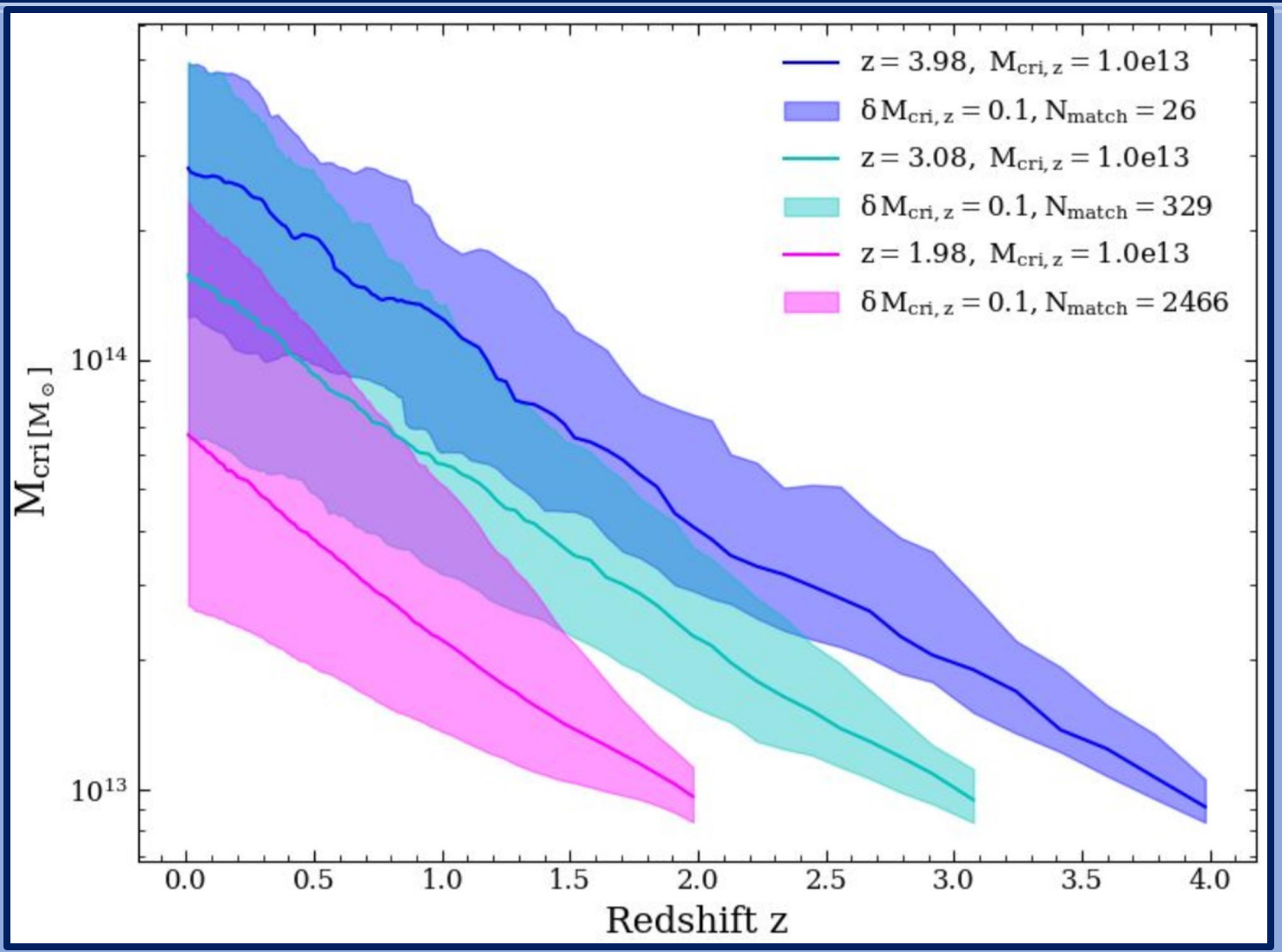
Do I end in a Cluster?



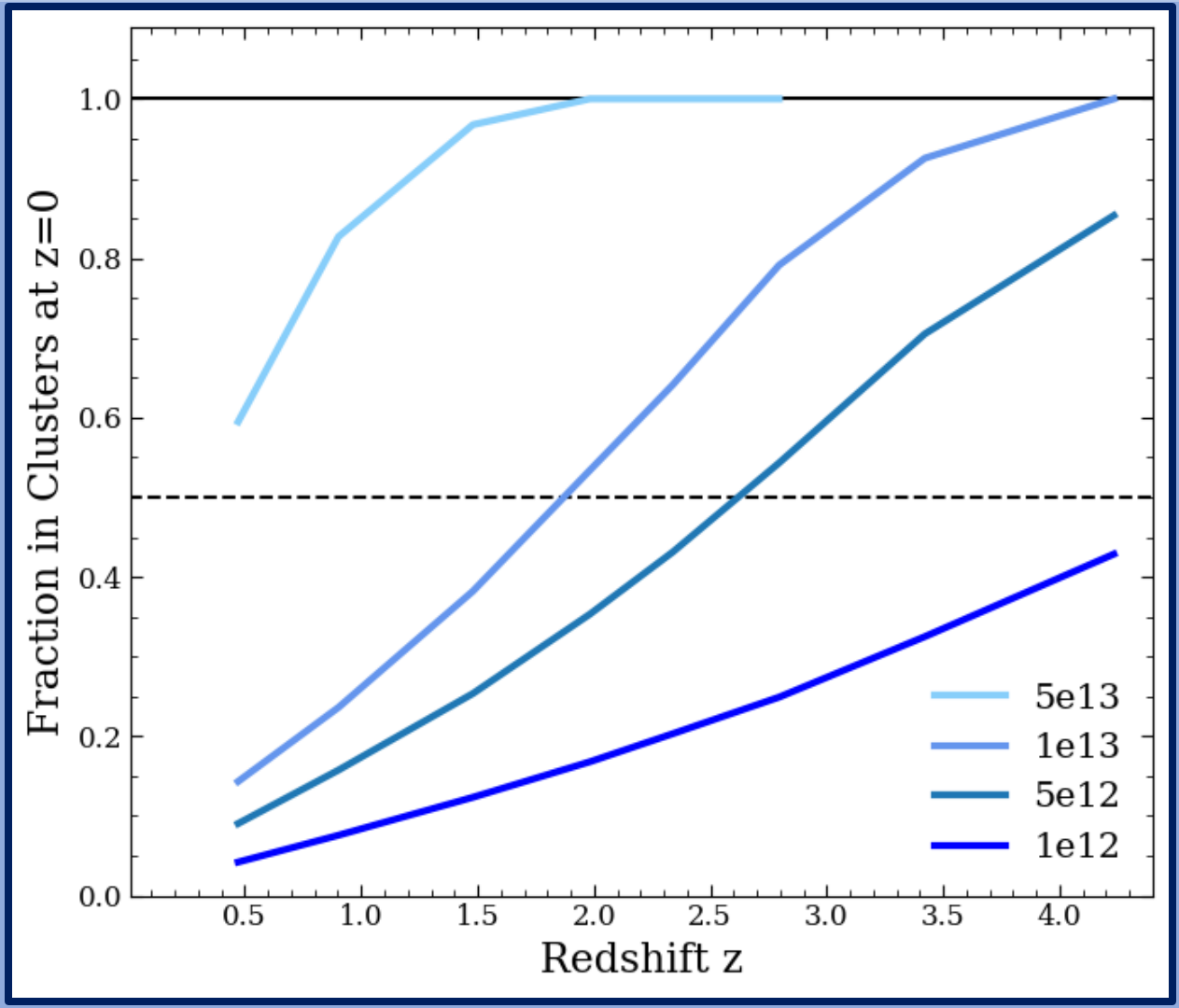
Kimmig et al., in prep

Do I end in a Cluster?

Kimmig et al., in prep

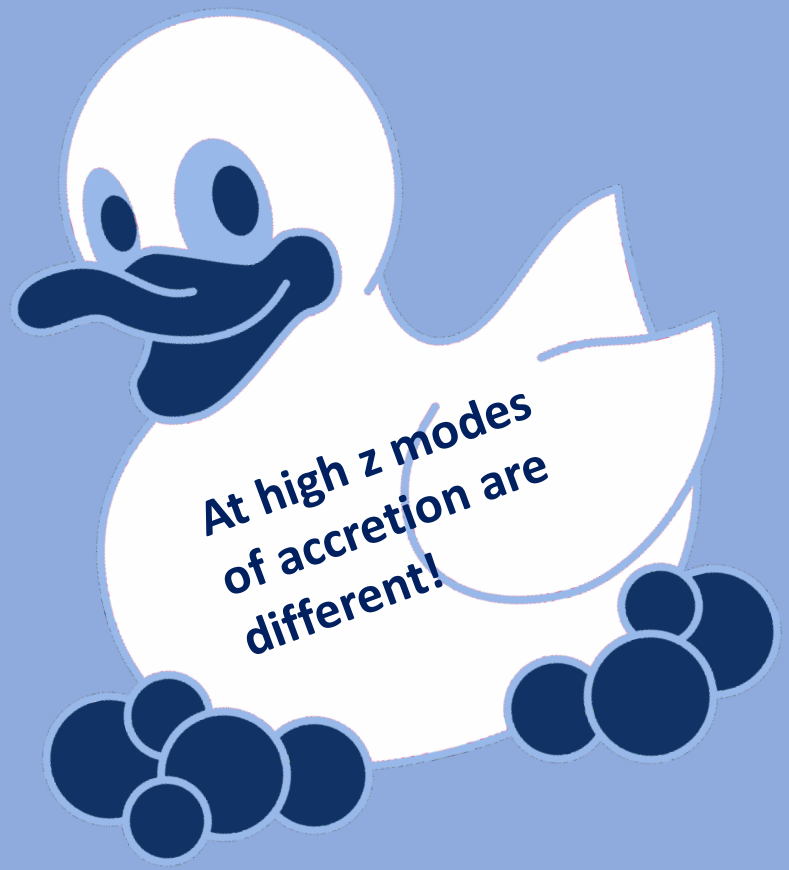


Do I end in a Cluster?

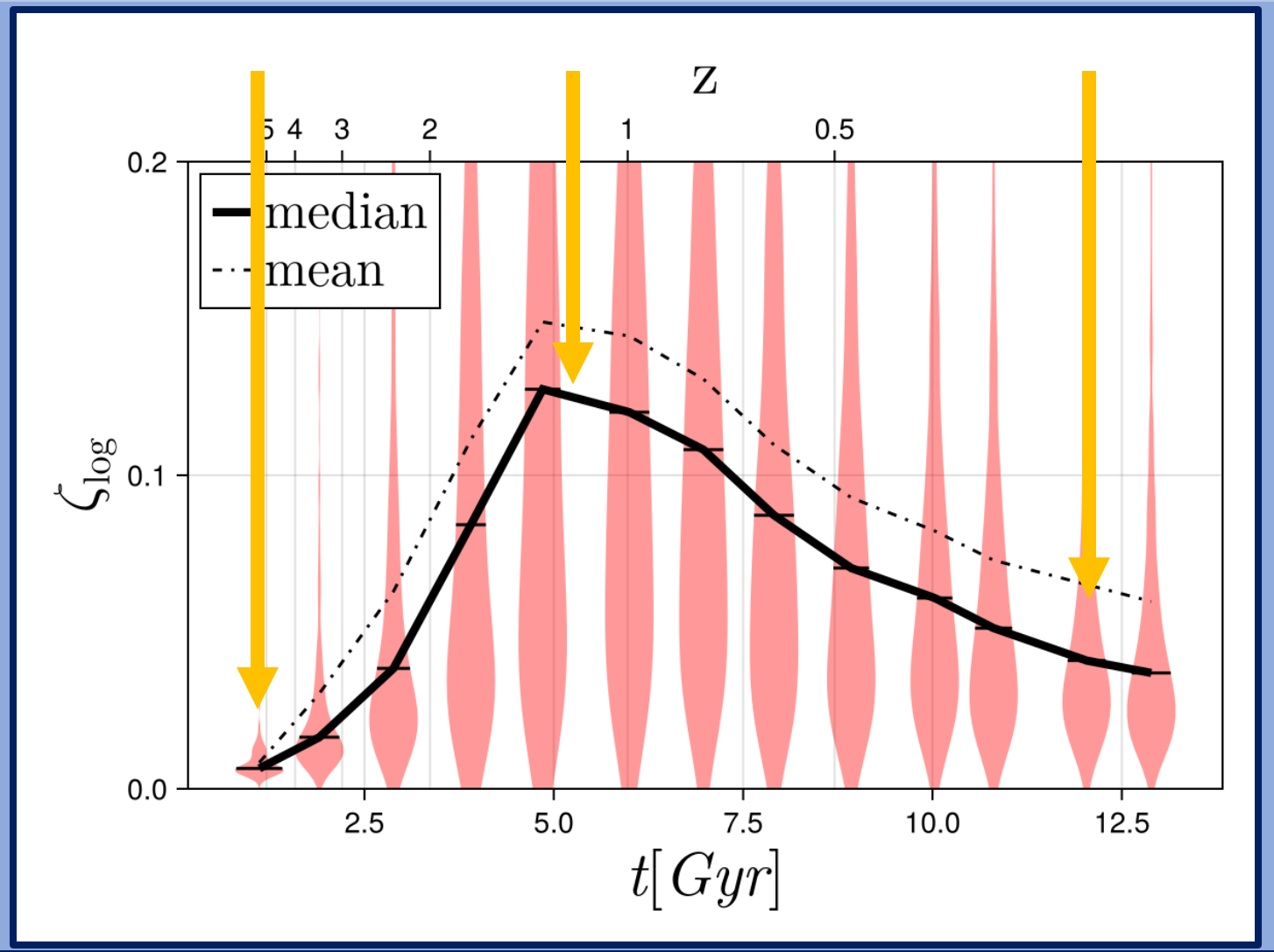


Kimmig et al., in prep

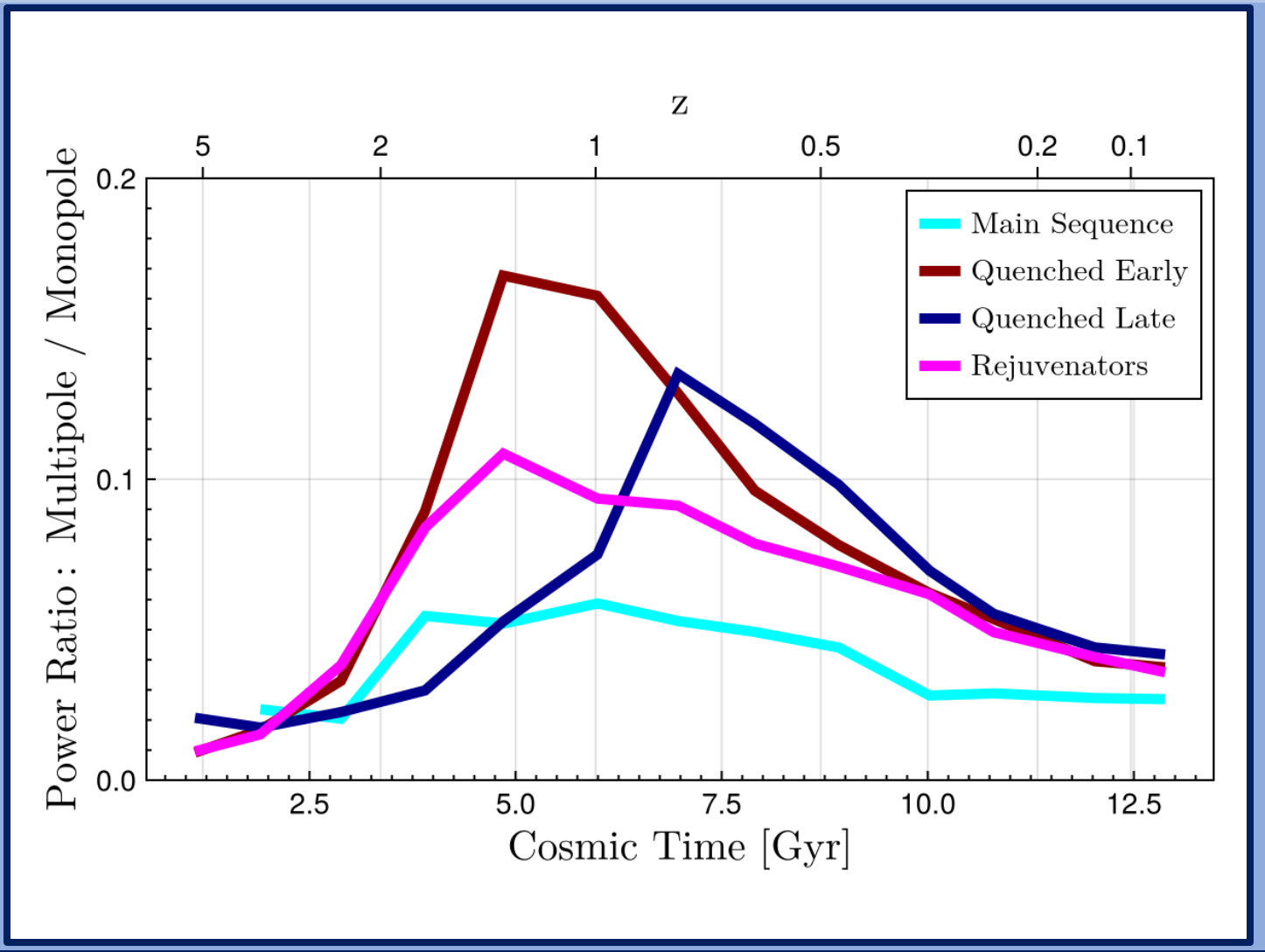
Outlook



Seidel et al., in prep

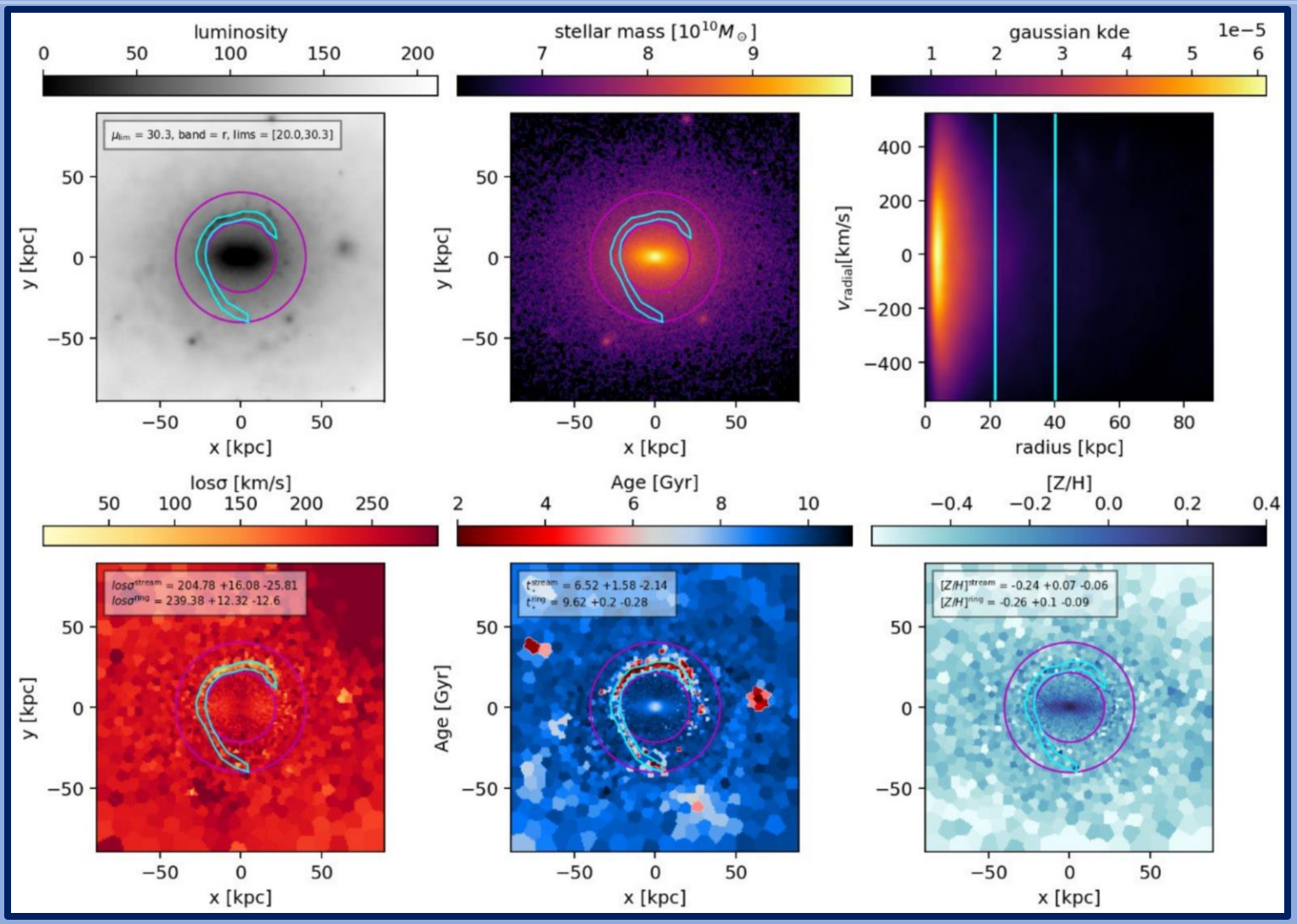


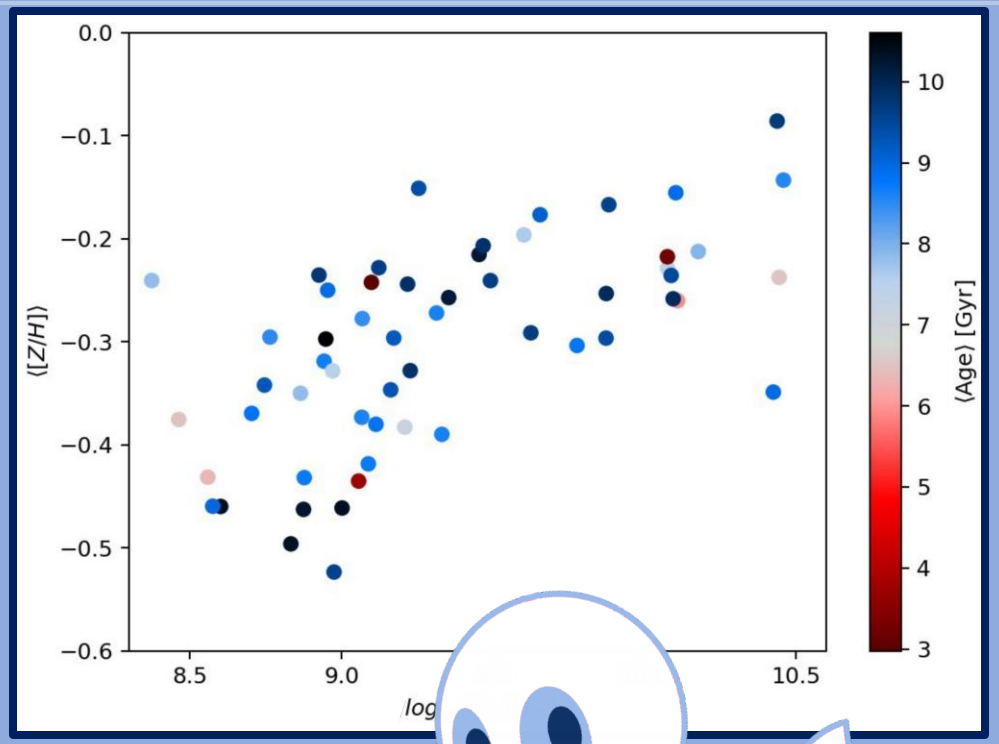
Outlook



Fortuné et al., in prep

Outlook

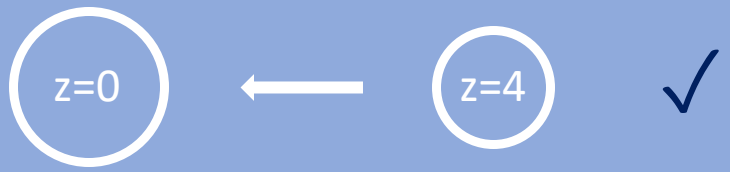




Stoiber et al. (a & b), in prep

See Talk by Johannes Stoiber

Summary



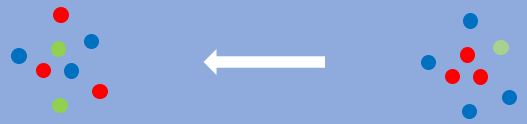
✓

Massive at high redshift ≠ Massive now

At High-z

✓

Quenching: Massive Quiescents Quench Quickly, not only AGN but Environment (and SF)

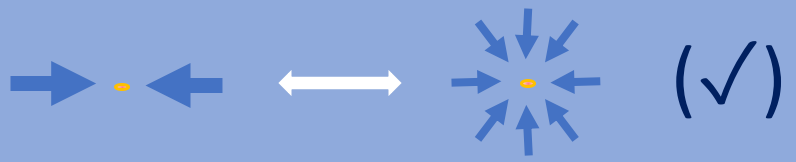


✓

Rejuvenation: Galaxies go through on-off cycles of starformation, rejuvenating after quenching

✓

Environment: Protocluster environments prevent rejuvenation. Underdense environments support lasting quenching.



(✓)

Feeding Mode: Isotropic versus Filamentary