

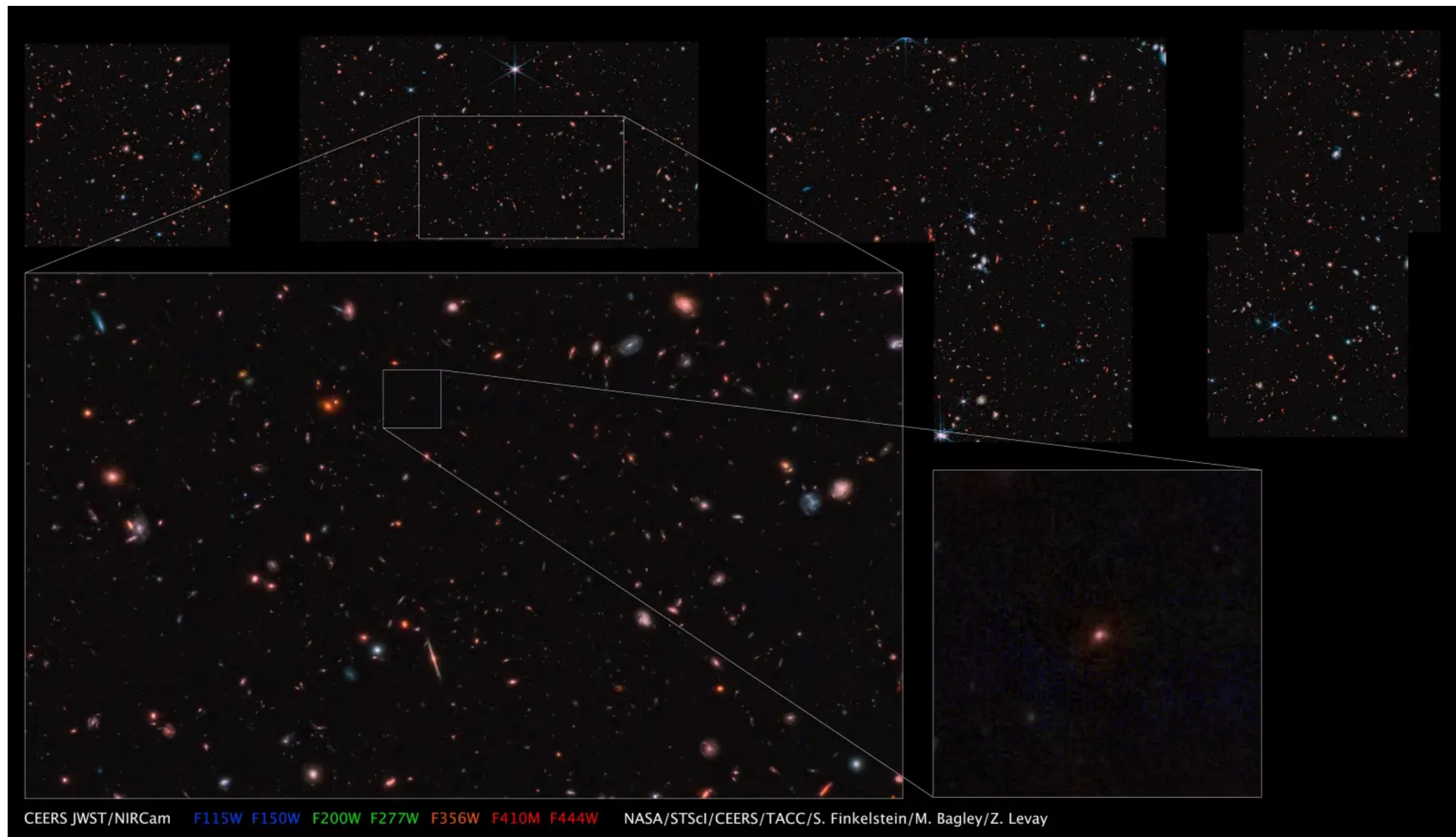
Evolution of Massive and Quenched Galaxies in Early Universe using Zoom-in Simulations

2025 NSRI Workshop

Sung Whee Cho, 15.01.2026

Generating Zoom-in ICs Using MUSIC

Motivation



Credit : NASA/STScI/CEERS/TACC/S. Finkelstein/M. Bagley/R. Larson/Z. Levay

JWST has found many massive quenched galaxies in the early universe at redshift $z \gtrsim 3$, and even beyond $z \gtrsim 7$.

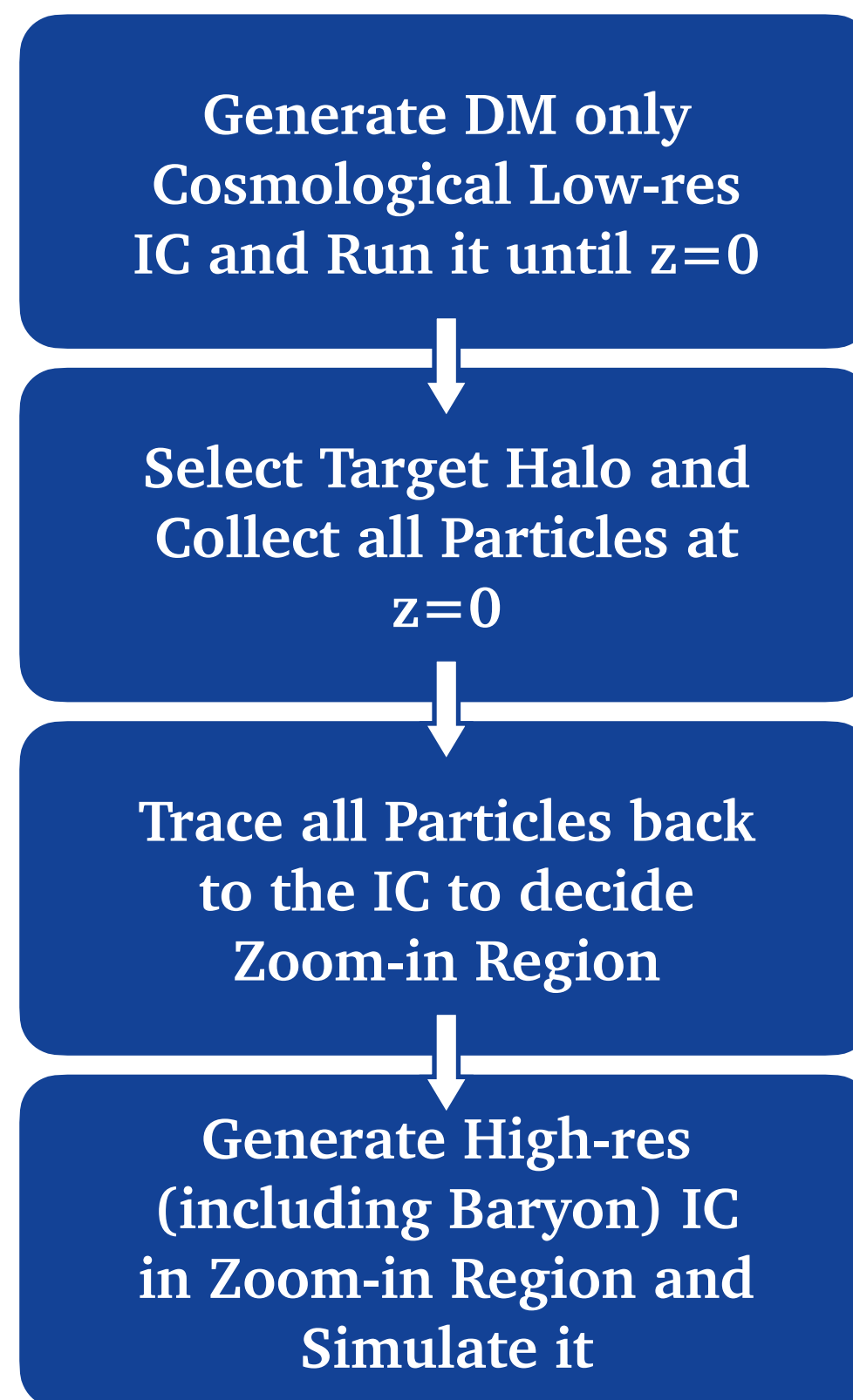
To simulate them, we need to begin from initial conditions with a larger box size and a higher starting redshift.

Explore more efficient quenching mechanisms by tuning AGN and SN feedback if necessary.

Generating Zoom-in ICs Using MUSIC

Zoom-in IC generating process

Zoom-in Simulation Work Flow



Checking points of each steps

- I) After running a large-volume simulation, verify its validity using the halo mass function.
- II) Select a target halo under appropriate conditions (e.g., mass threshold, isolation).
- III) Ensure that all particles approaching the progenitor of the target halo are properly traced.
- IV) Define the zoom-in region safely; otherwise, the simulation cannot be free from contamination.

(Oser et al. 2010)

Generating Zoom-in ICs Using MUSIC

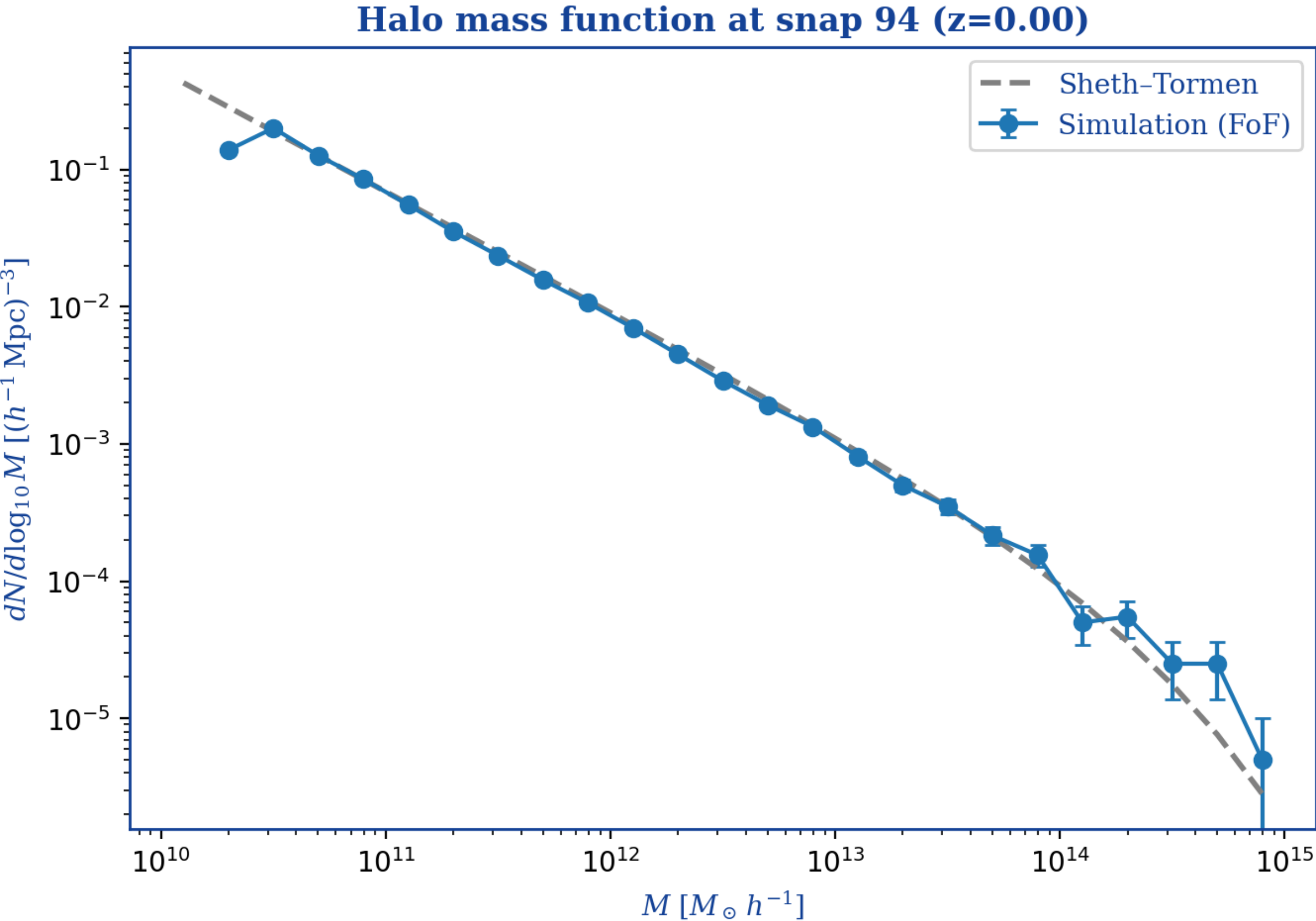
Simulation Details and Checking HMF

Simulation Properties

Box Length	: 100Mpc
Starting Redshift	: 39
Large Volume DM Mass	: $6.38087 \times 10^8 M_\odot$
Zoom-in High-res DM Mass	: $8.40966 \times 10^6 M_\odot$
Zoom-in 2nd High-res DM Mass	: $7.97609 \times 10^7 M_\odot$
Zoom-in Baryon Mass	: $1.56045 \times 10^6 M_\odot$

Cosmological Parameters (Planck 2013 Result)

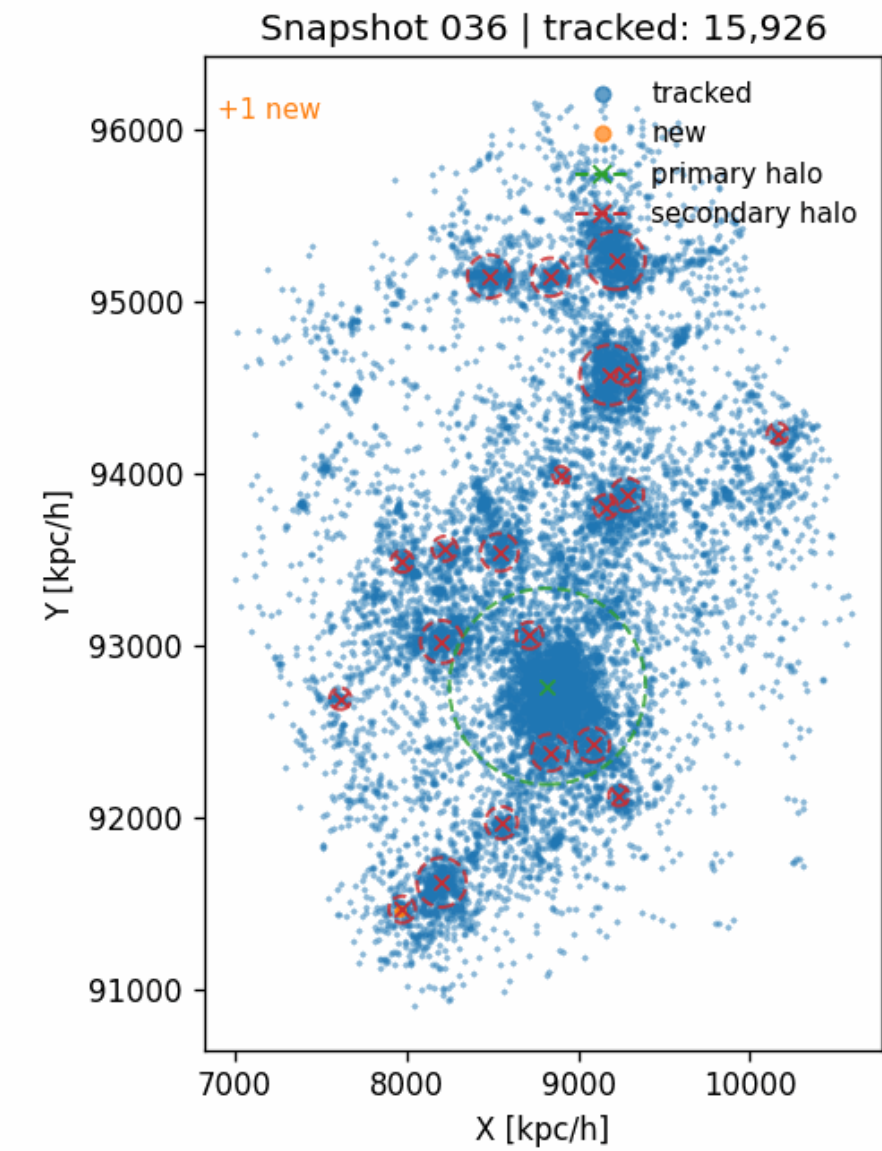
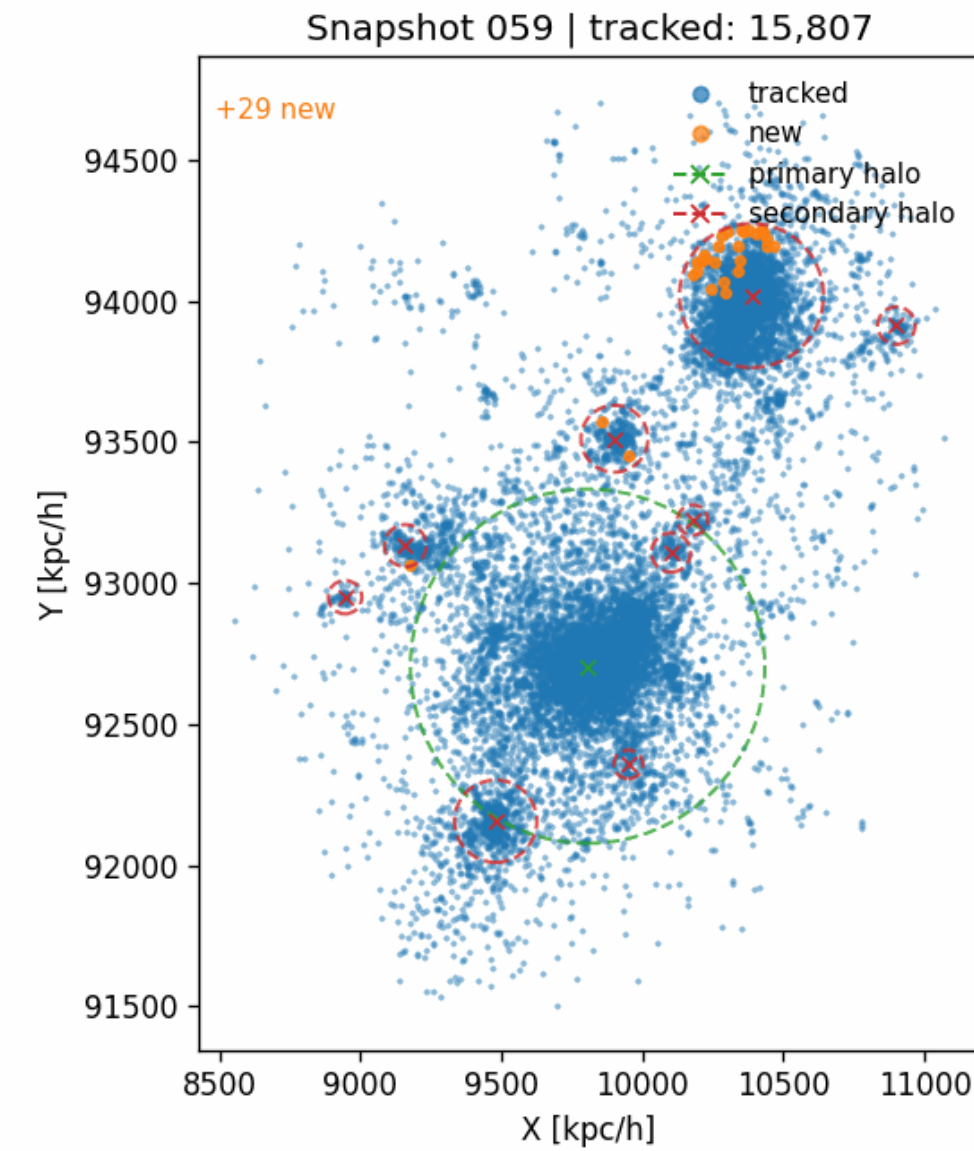
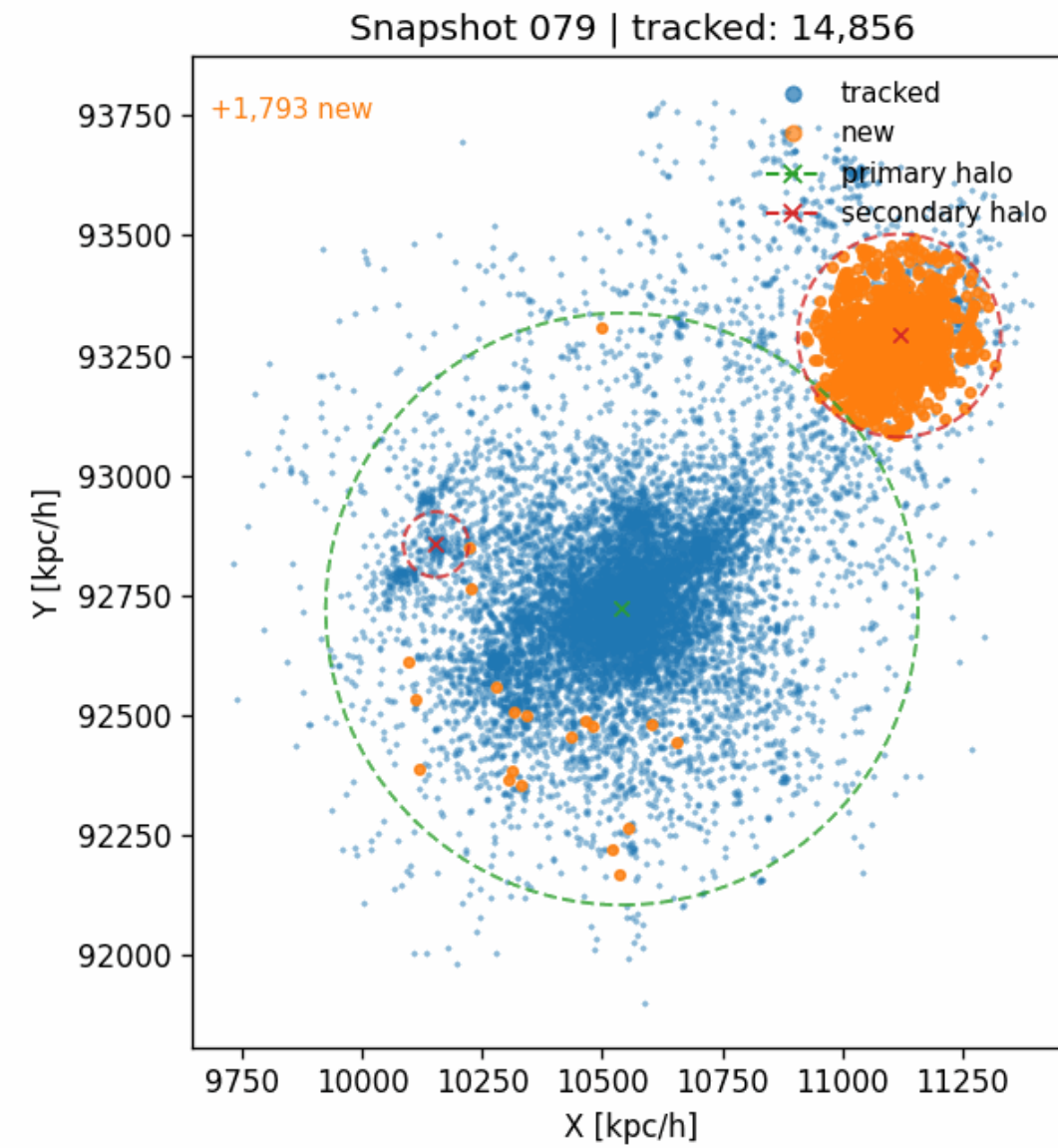
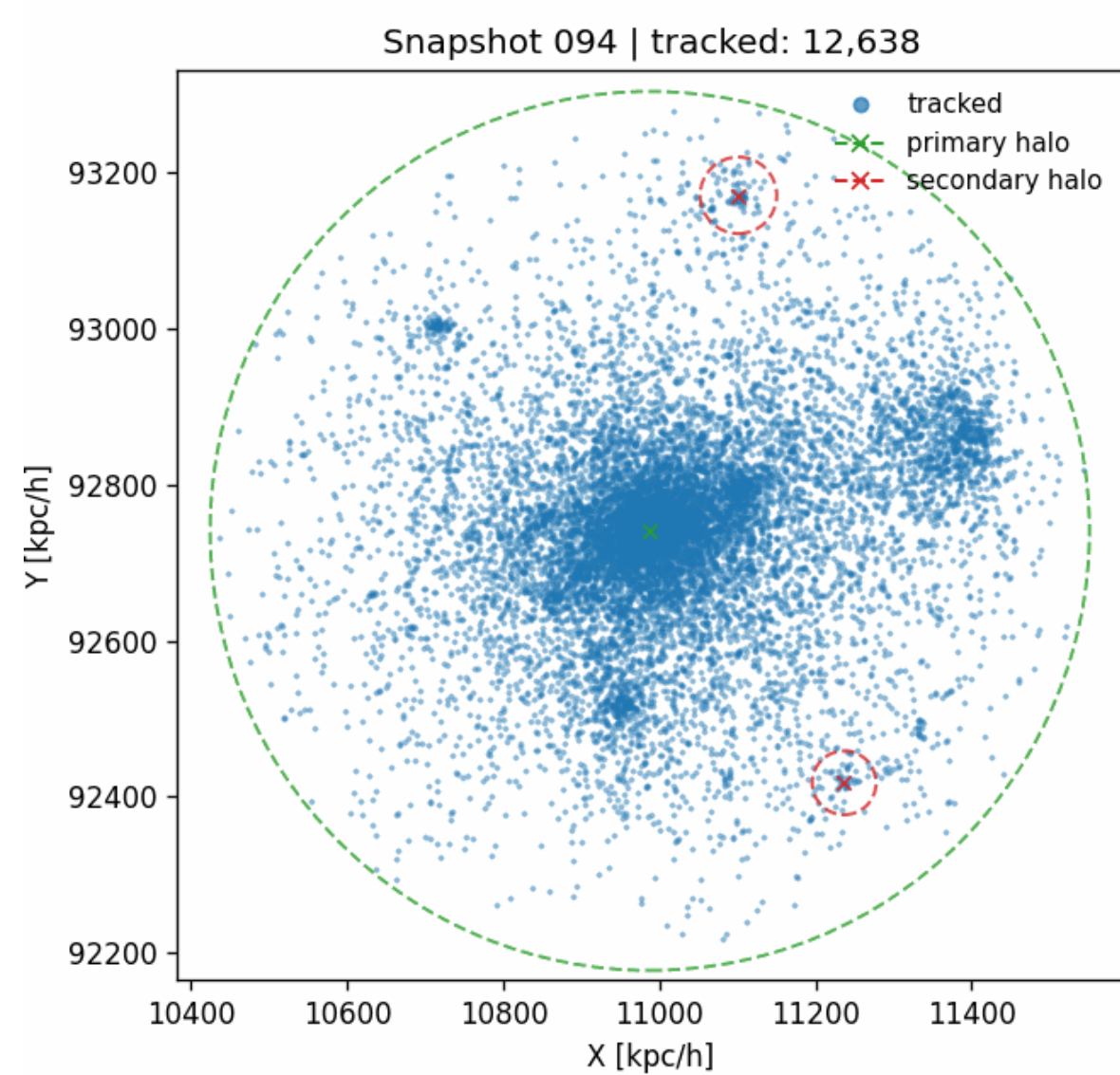
Ω_m : 0.3086	H_0 : 67.77
Ω_Λ : 0.6914	σ_8 : 0.8288
Ω_b : 0.0483	n_s : 0.9611



Generating Zoom-in ICs Using MUSIC

Target Selecting Process

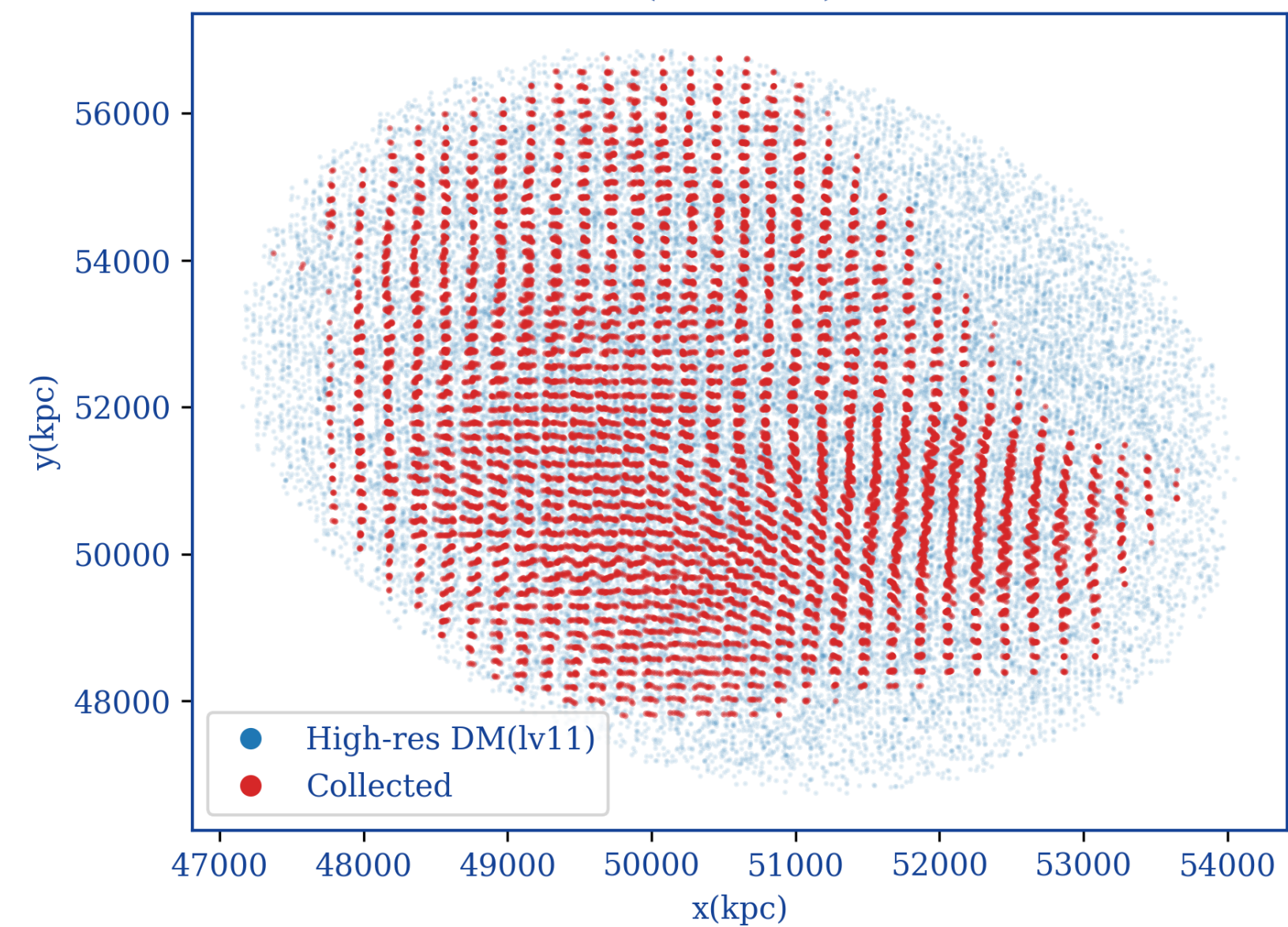
- Halos are selected between $10^{12}M_{\odot} < M_{target} < 10^{13}M_{\odot}$
 - No halos with $M_{vir} > 10^{13}M_{\odot}$ within 7 Mpc.
 - No halos with $M_{vir} \geq 0.5 \times M_{target}$ within 2.8 Mpc.
- (Griffin et al. 2016)



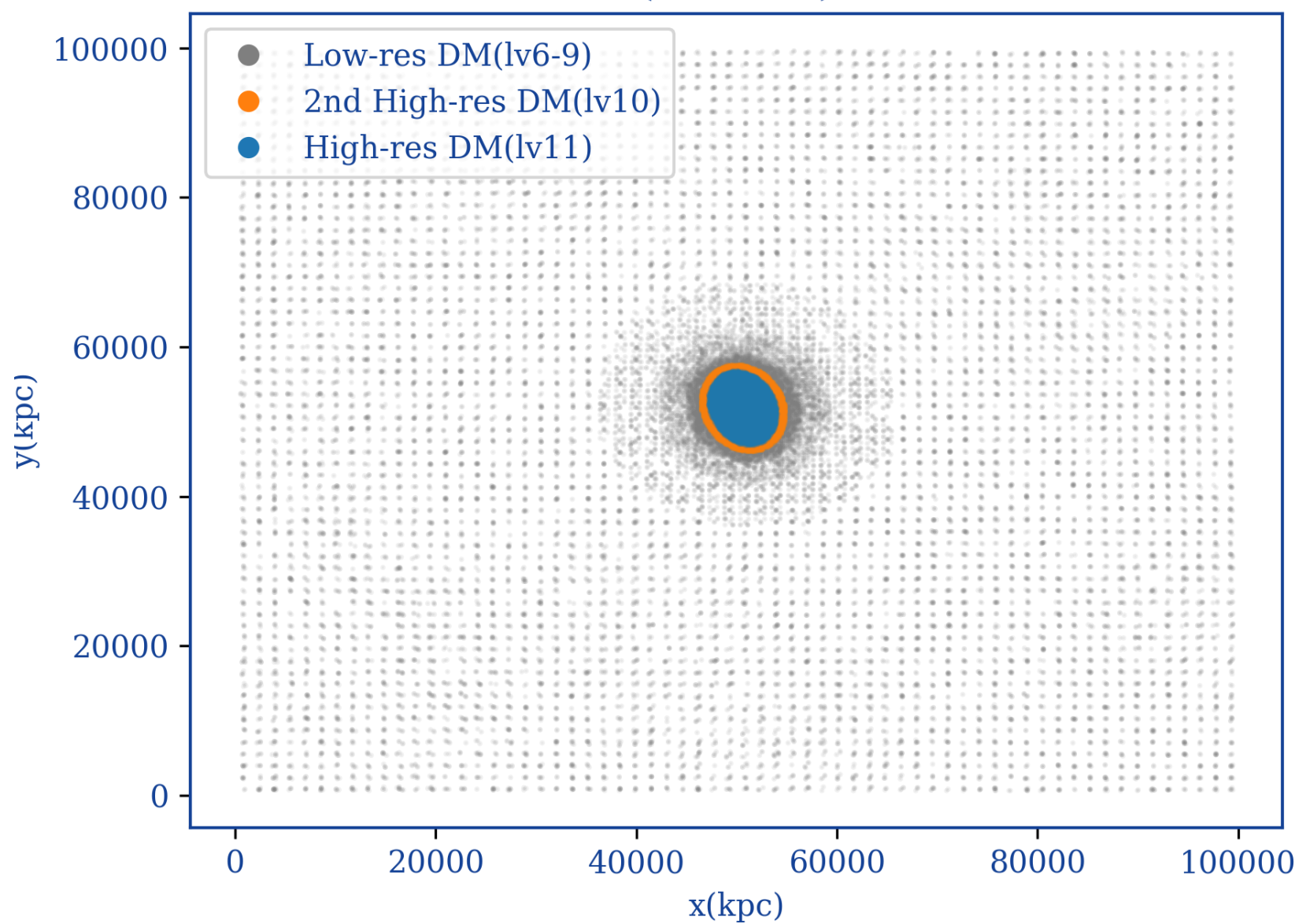
Generating Zoom-in ICs Using MUSIC

Generating Zoom-in IC Using MUSIC

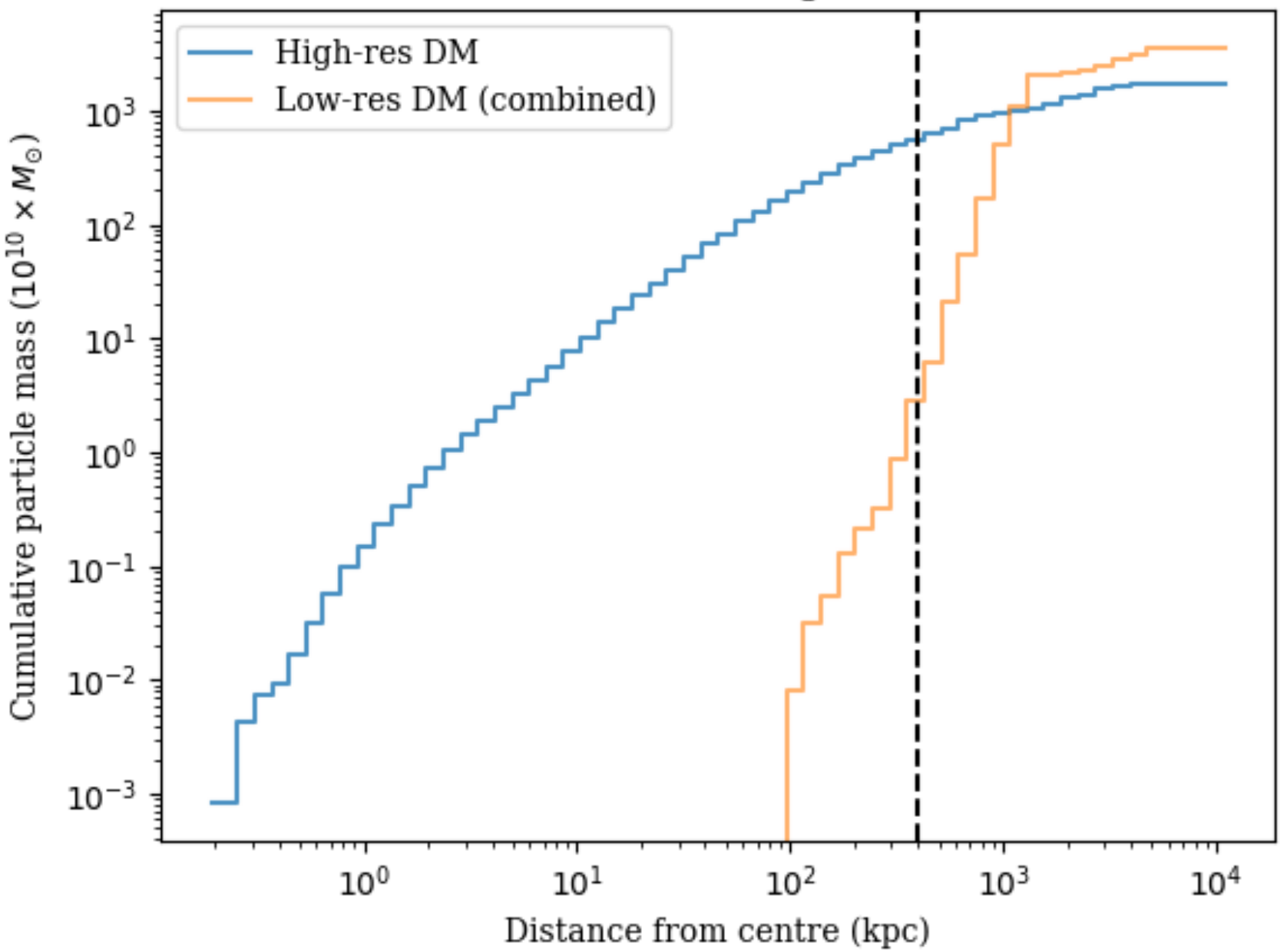
Collected particle positions vs Zoom-in region
($z = 39.0$)



X-Y Plane Zoom-in IC particle distribution
($z = 39.0$)

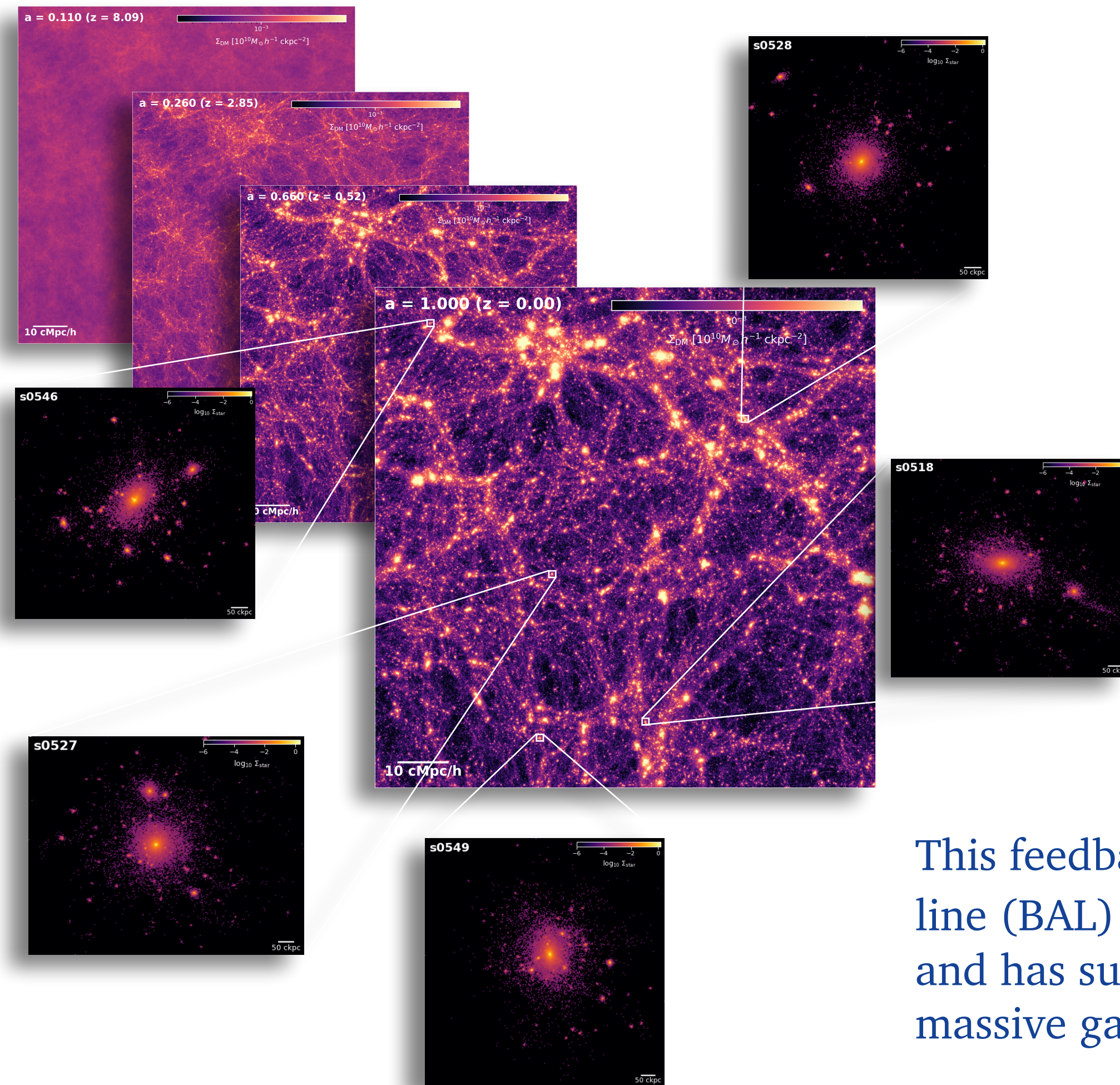


Particle Distance Histogram of s0546



High-z Quenched Galaxy Formation with New Zoom-in ICs

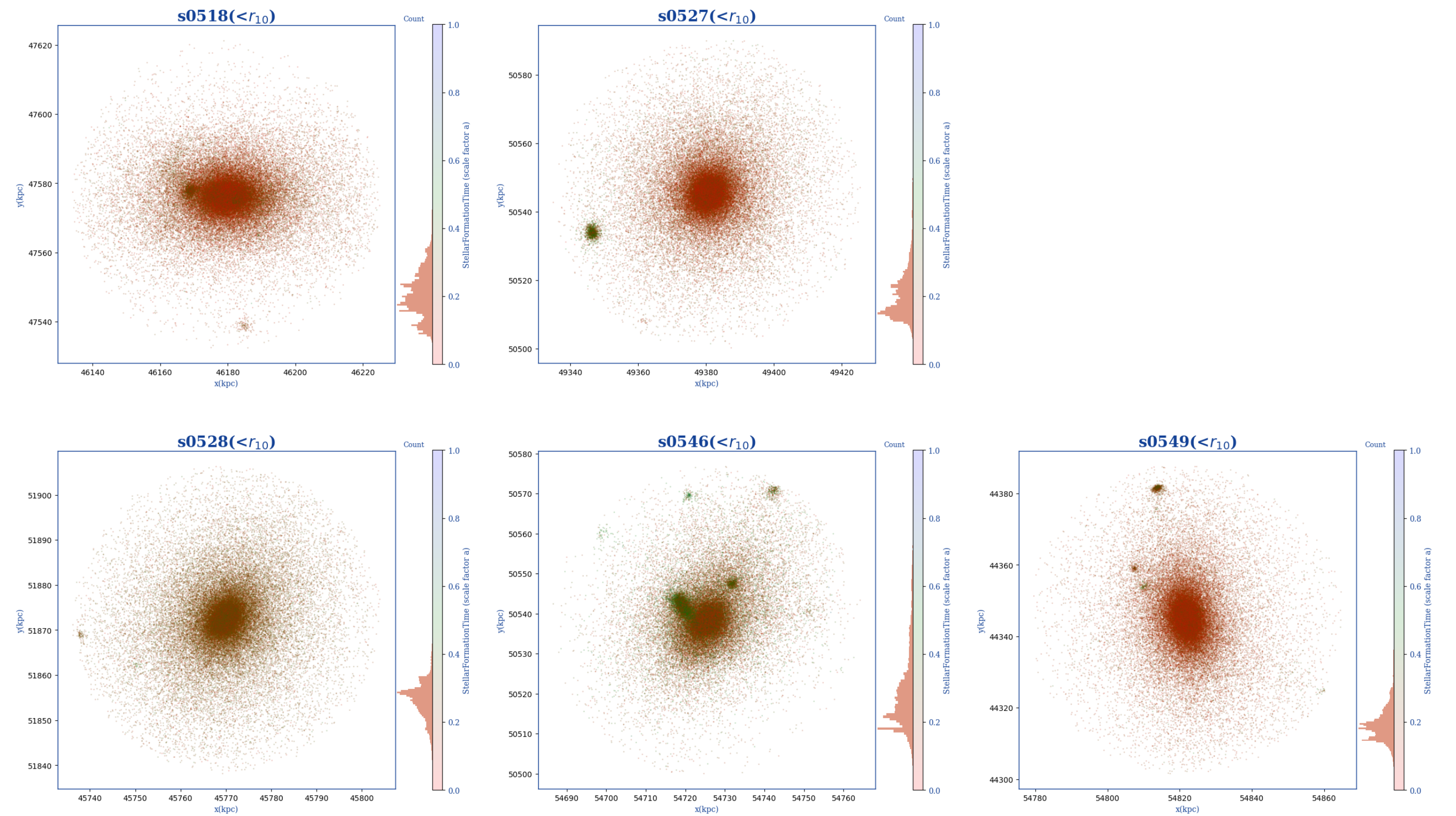
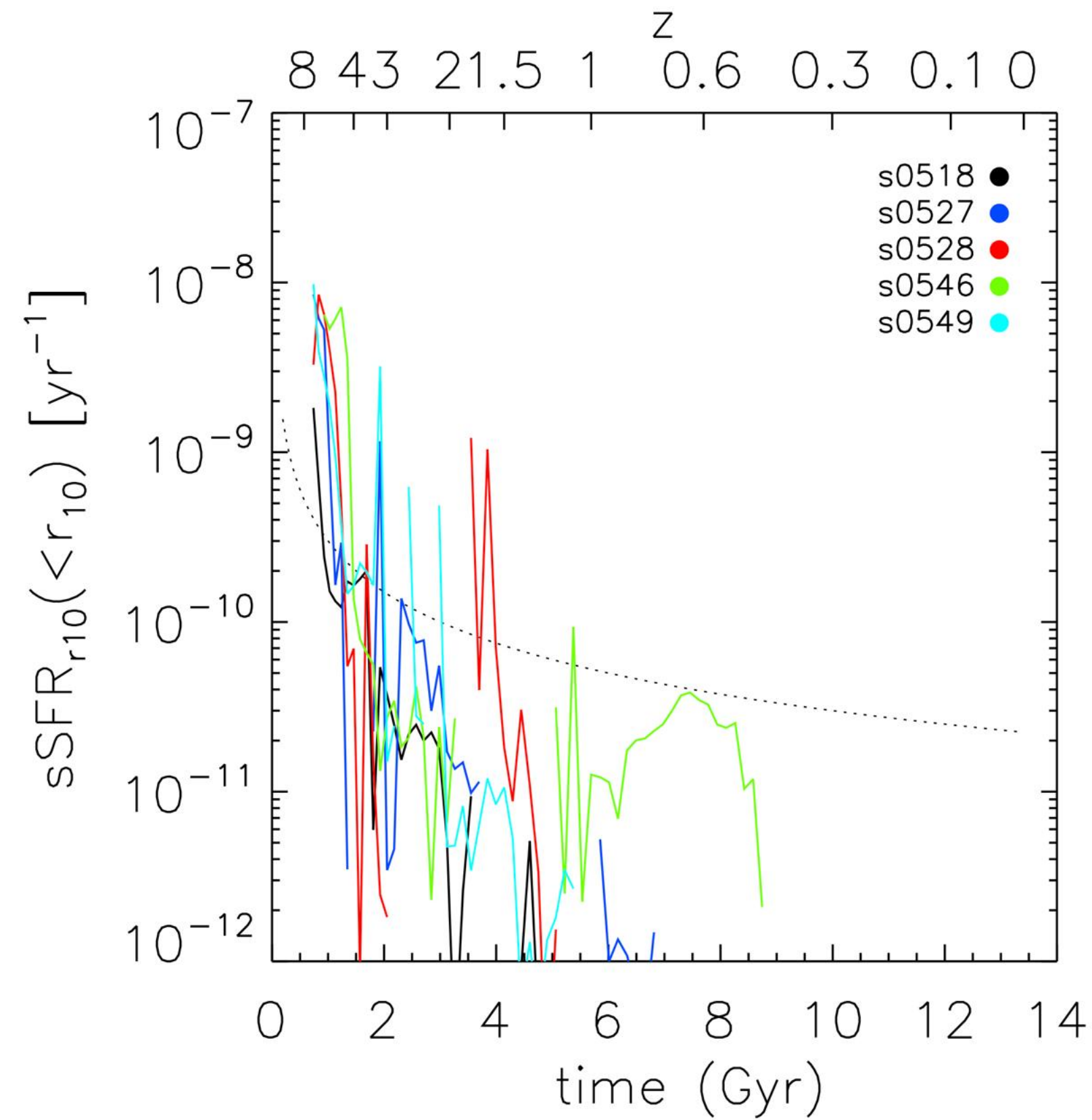
Zoom-in Simulation using SPHGal code (modified version of GADGET-3)



This feedback model launches broad absorption line (BAL) winds with velocities of $\sim 10^4$ km/s and has successfully reproduced quenched massive galaxies at low redshift.

High-z Quenched Galaxy Formation with New Zoom-in ICs

Results



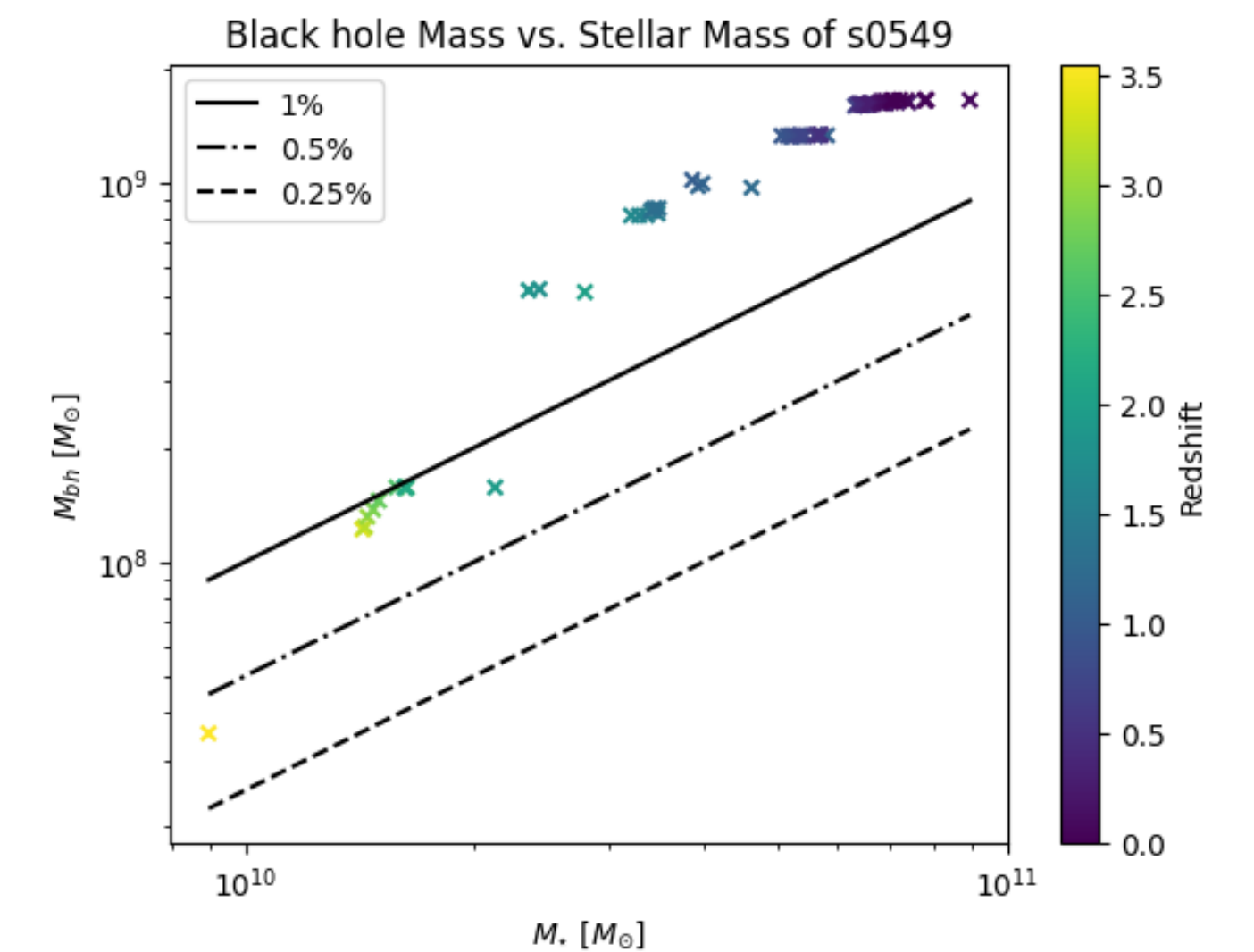
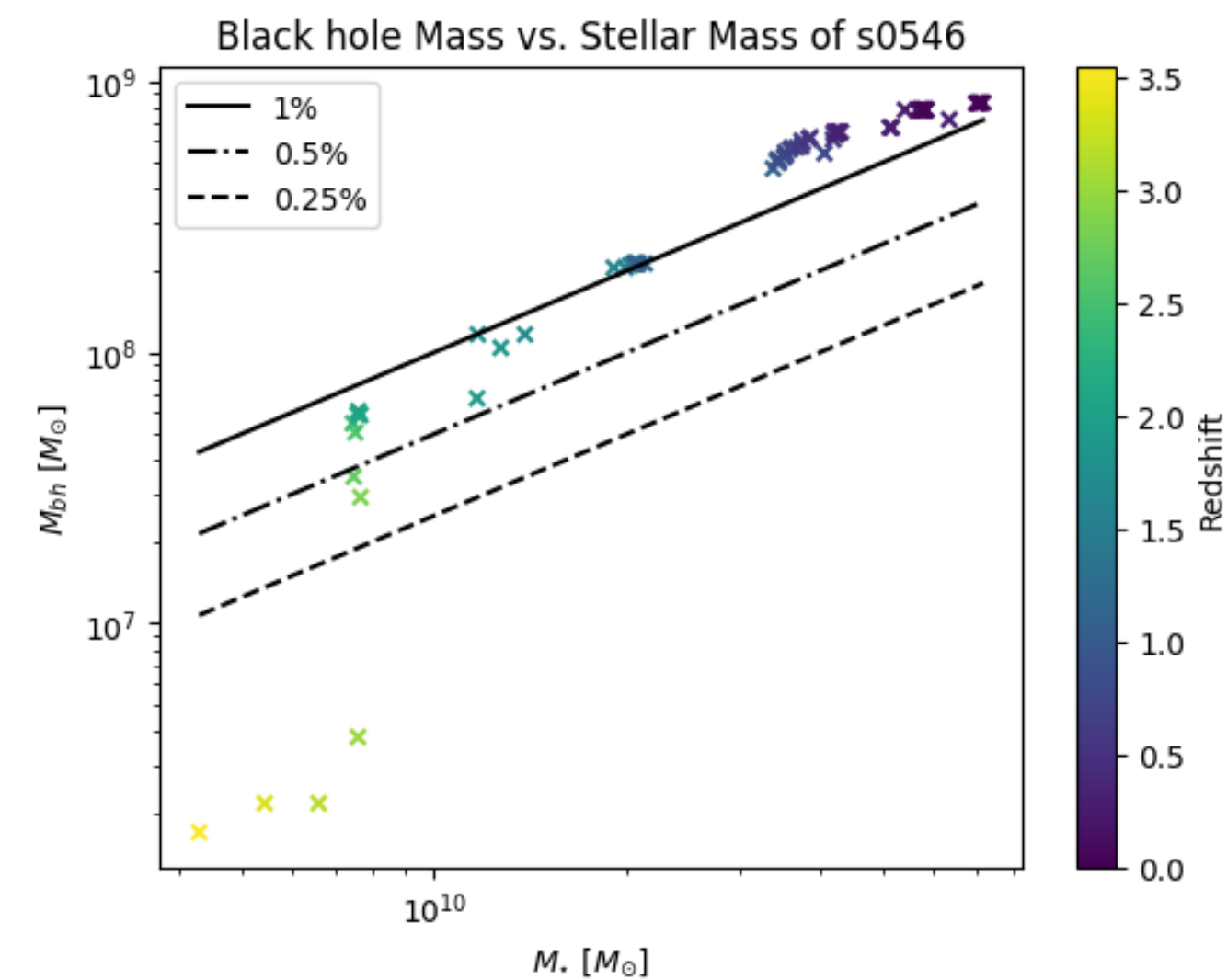
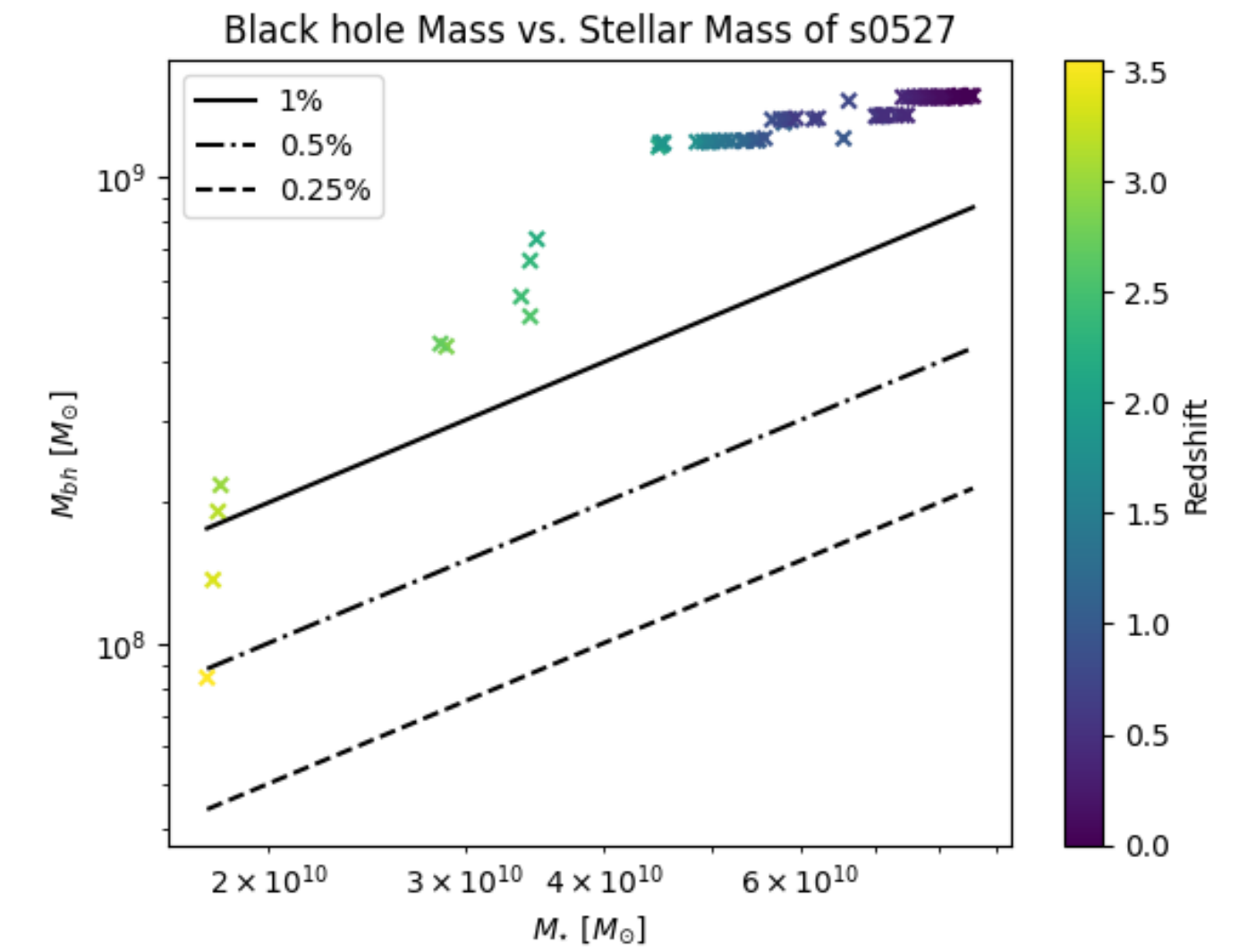
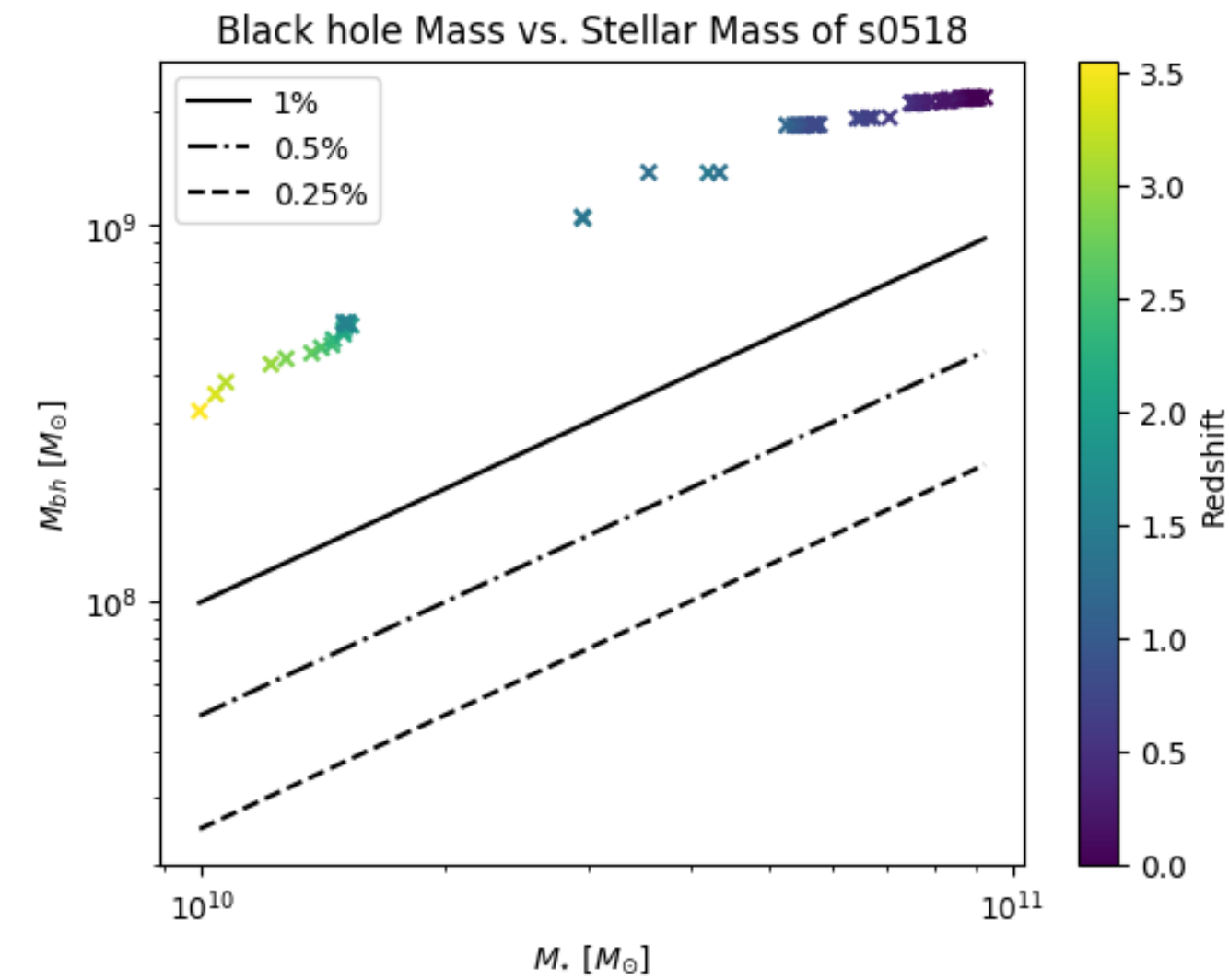
High-z Quenched Galaxy Formation with New Zoom-in ICs

Results

Blackhole Mass vs. Stellar Mass(<r10) plot.

Generally central blackholes mass is bigger than 1% of stellar mass at $z=0$.

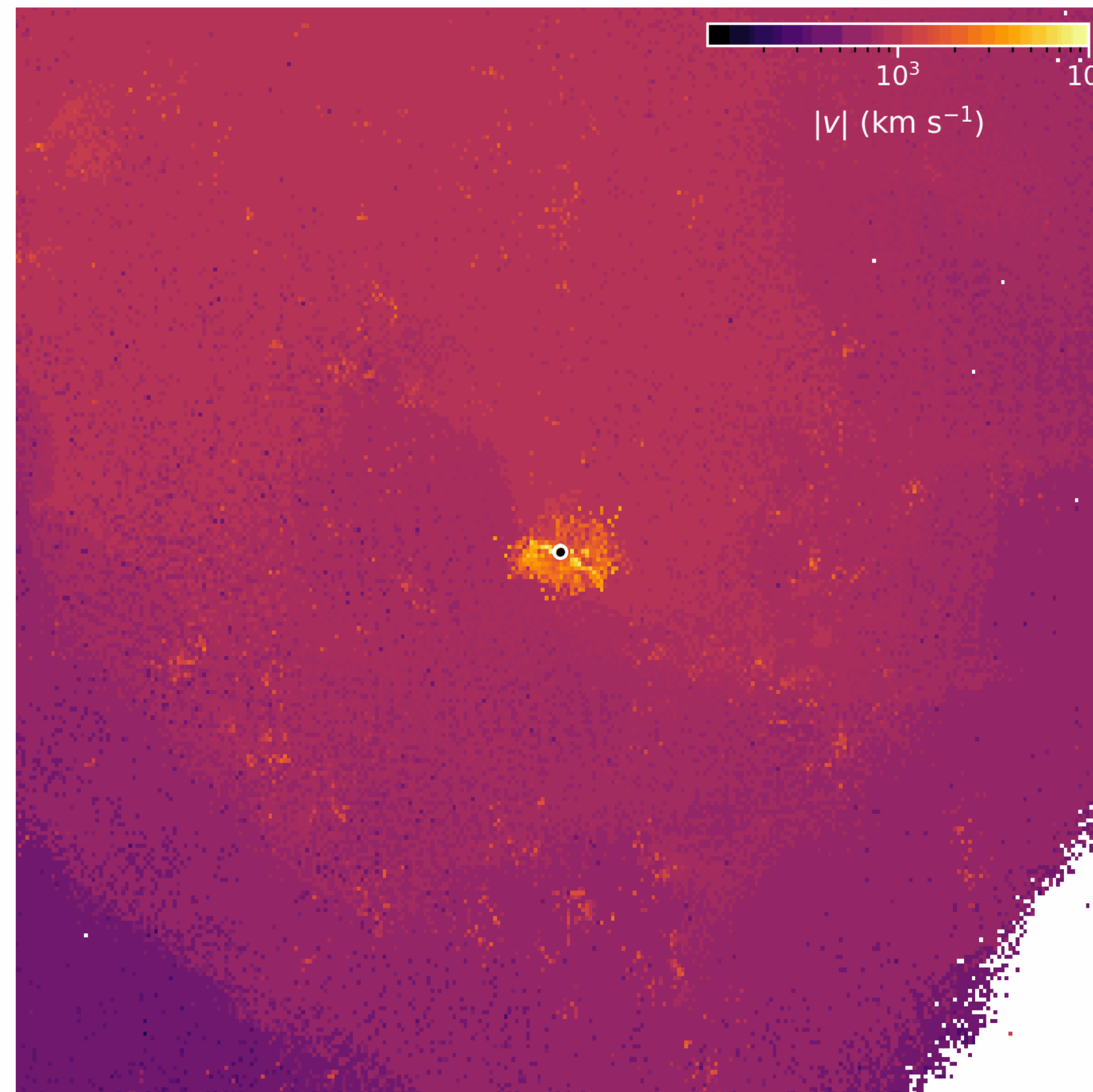
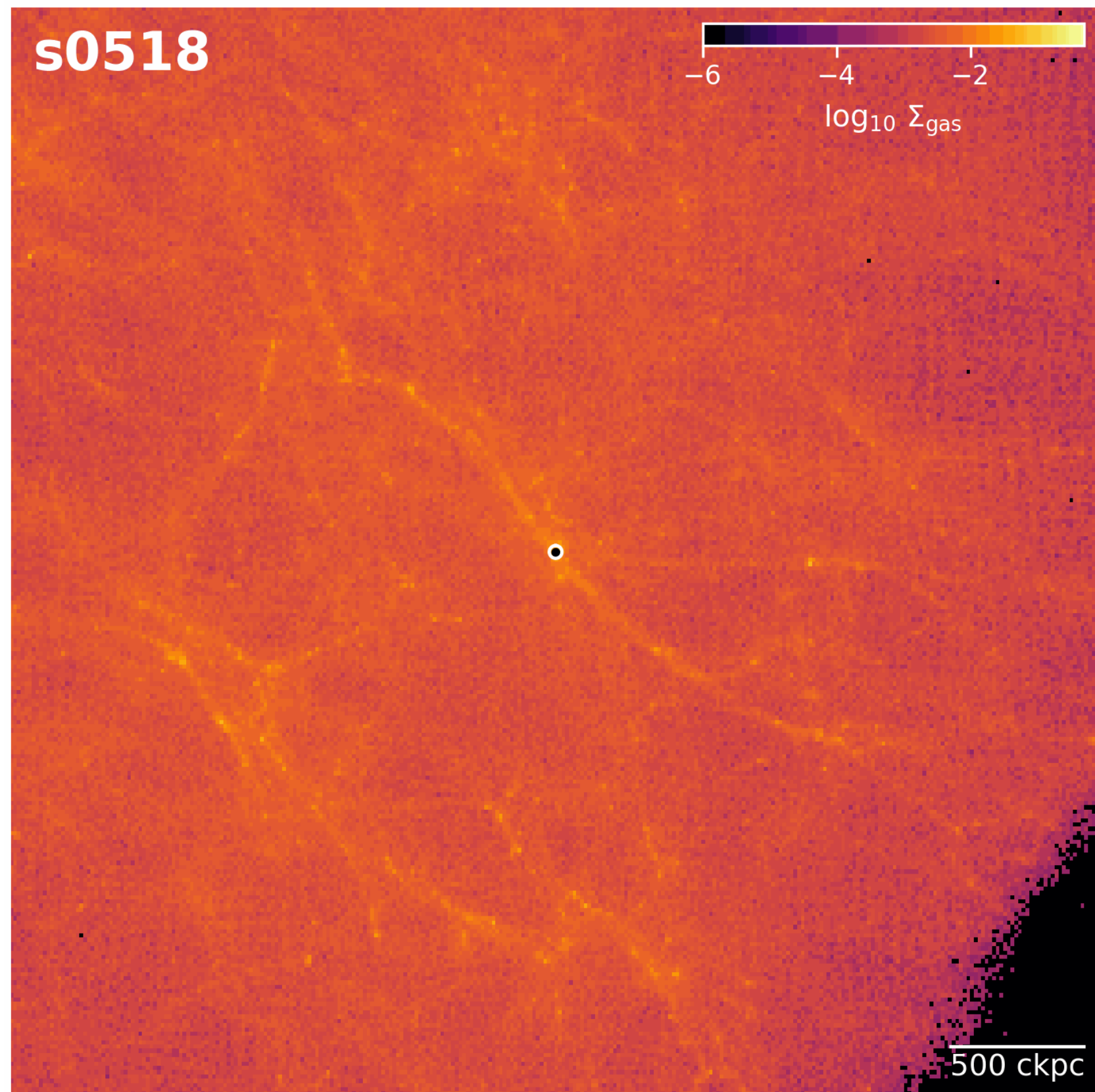
BHwind only model show overregulation of star formation.



High-z Quenched Galaxy Formation with New Zoom-in ICs

Results

Gas density and velocity with Blackhole position at $z = 7.333$

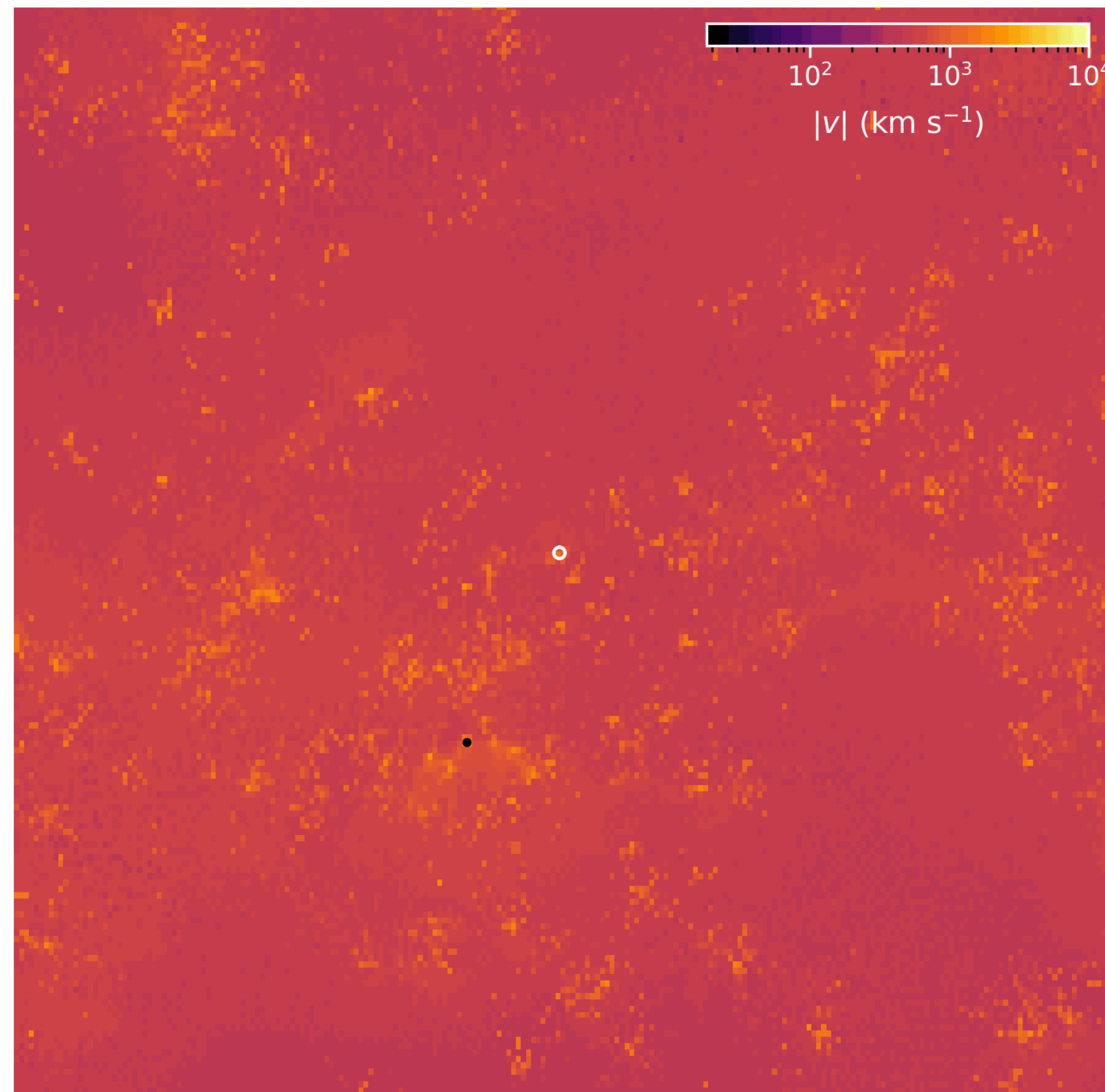
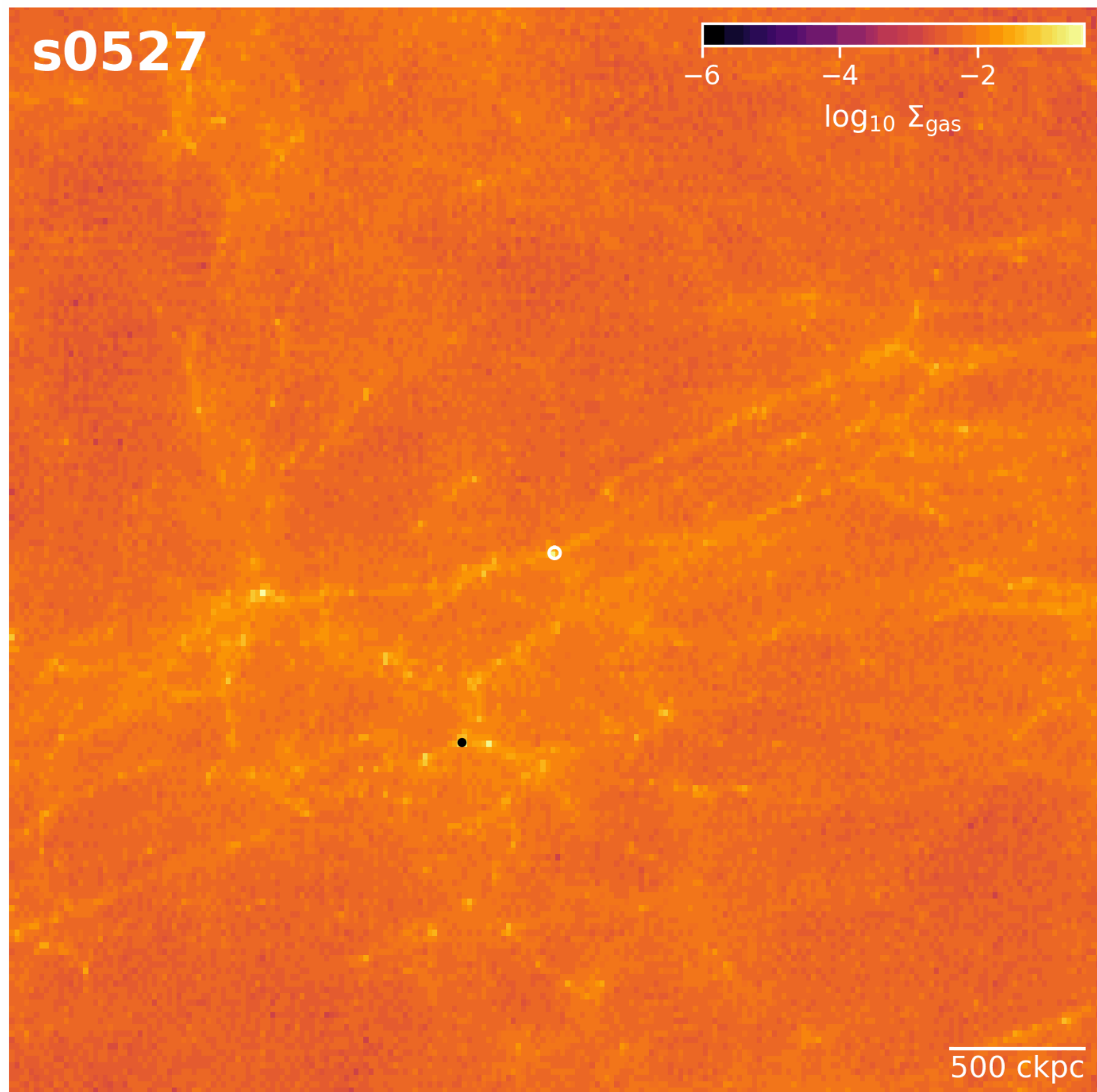


Projected gas density and velocity with blackhole position. Outflow of the gas by blackhole wind can be seen clearly.

High-z Quenched Galaxy Formation with New Zoom-in ICs

Results

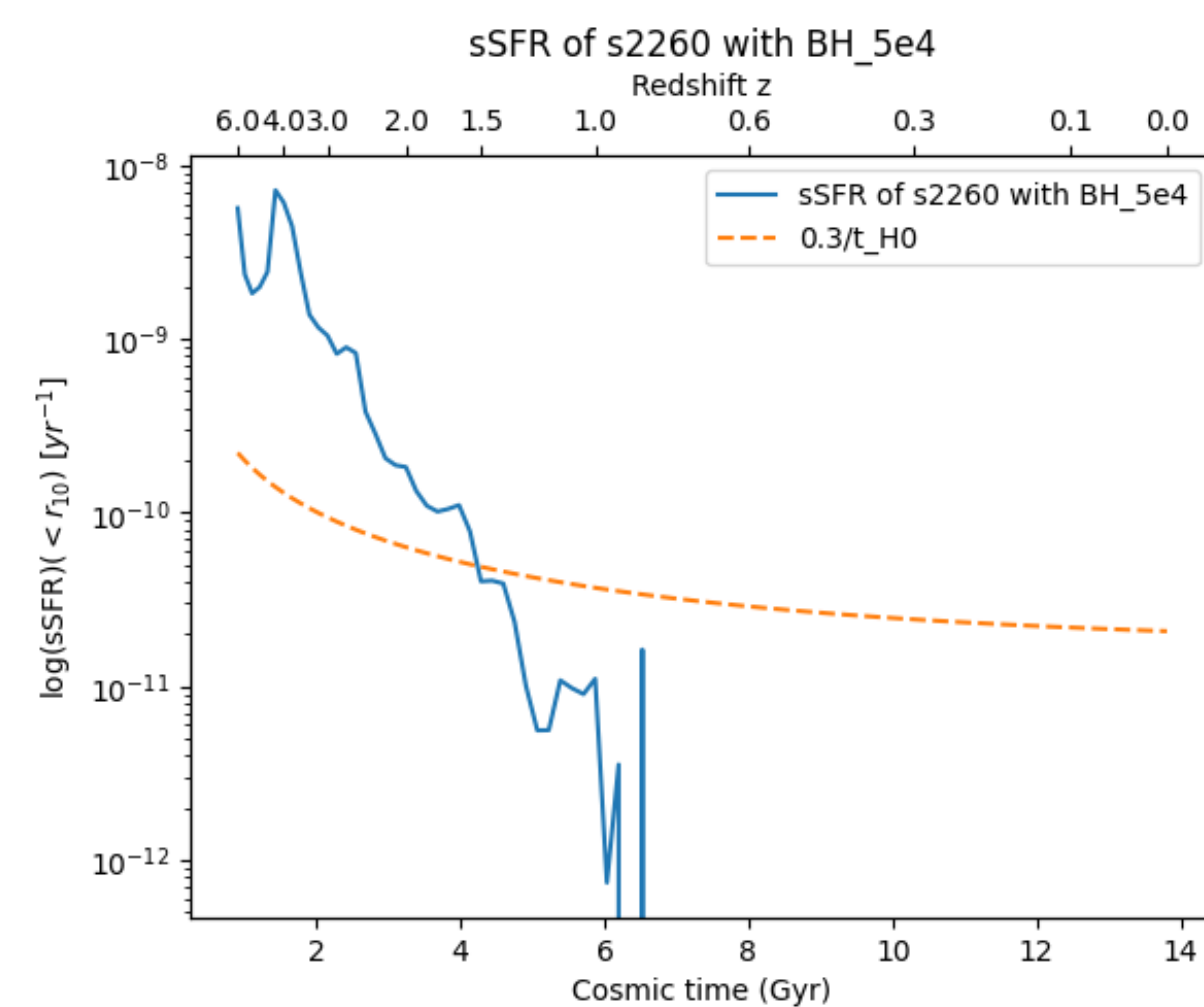
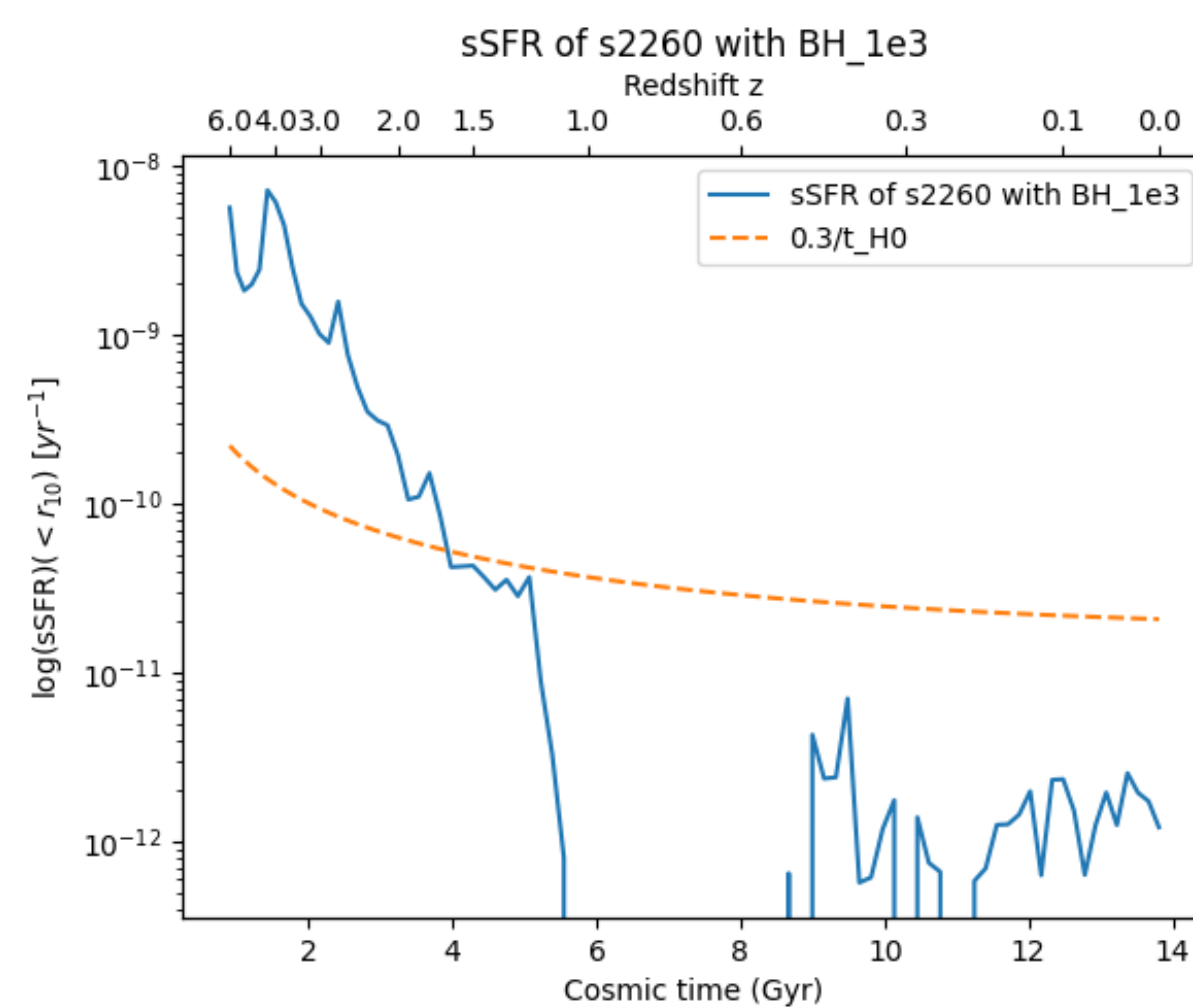
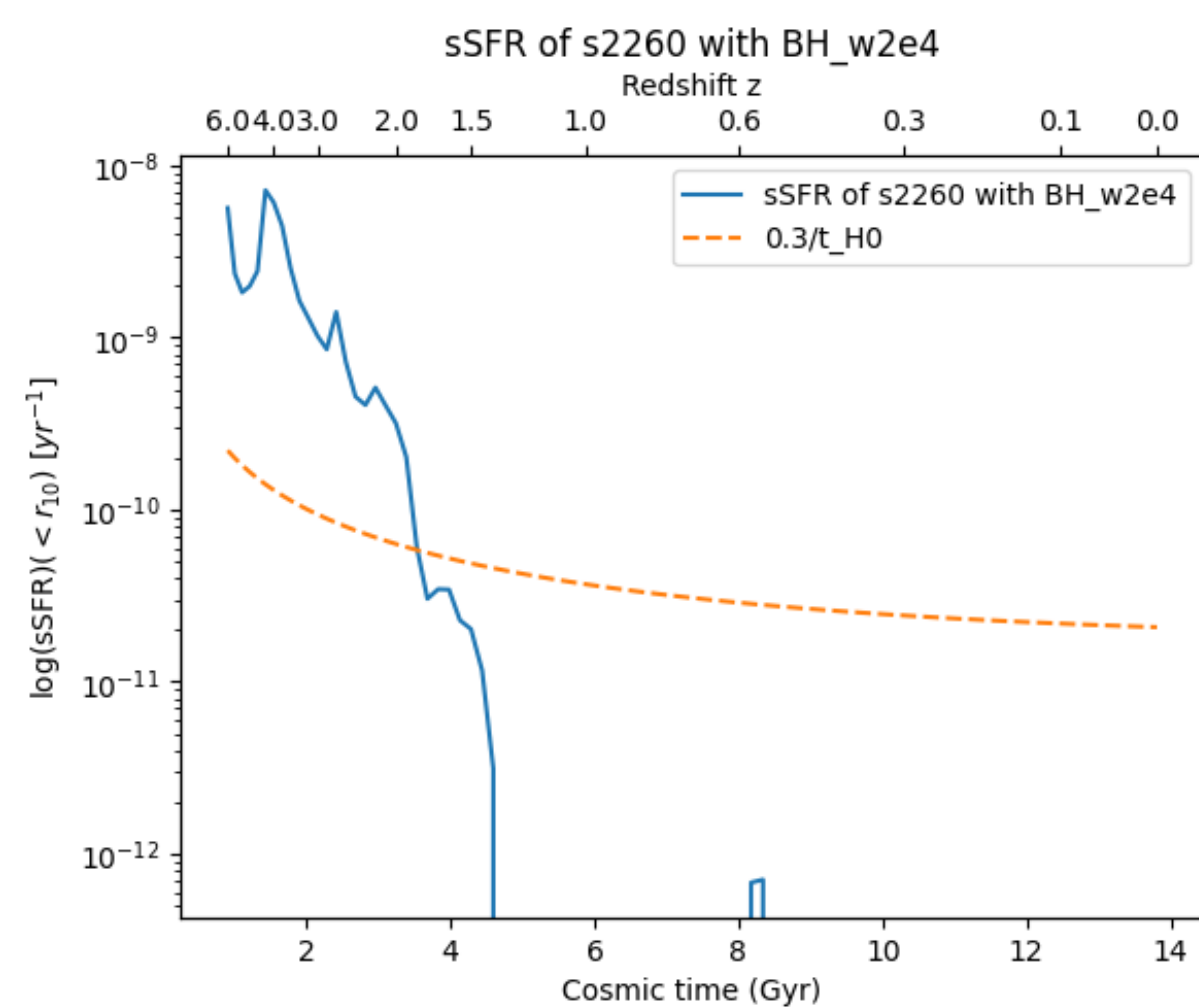
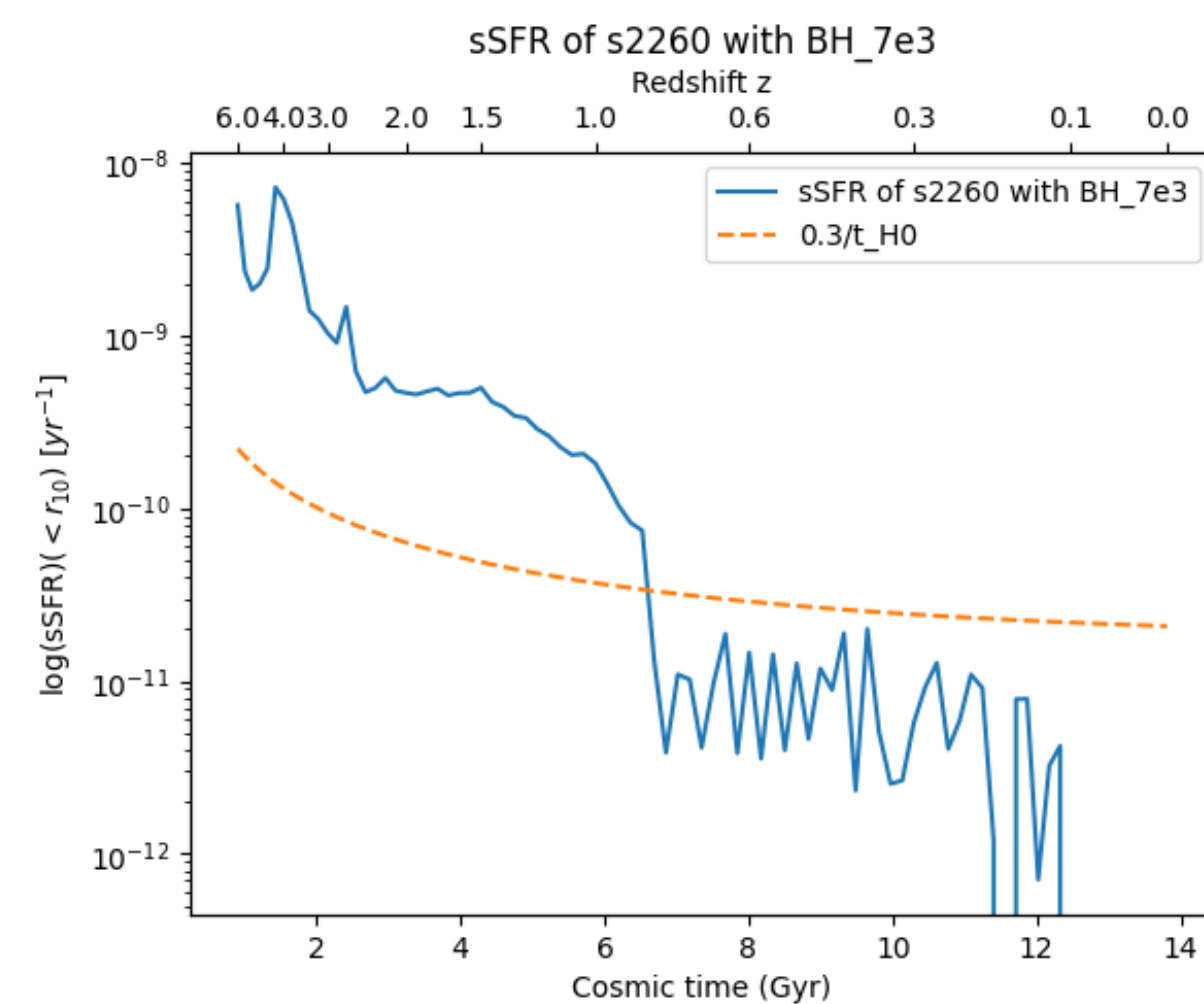
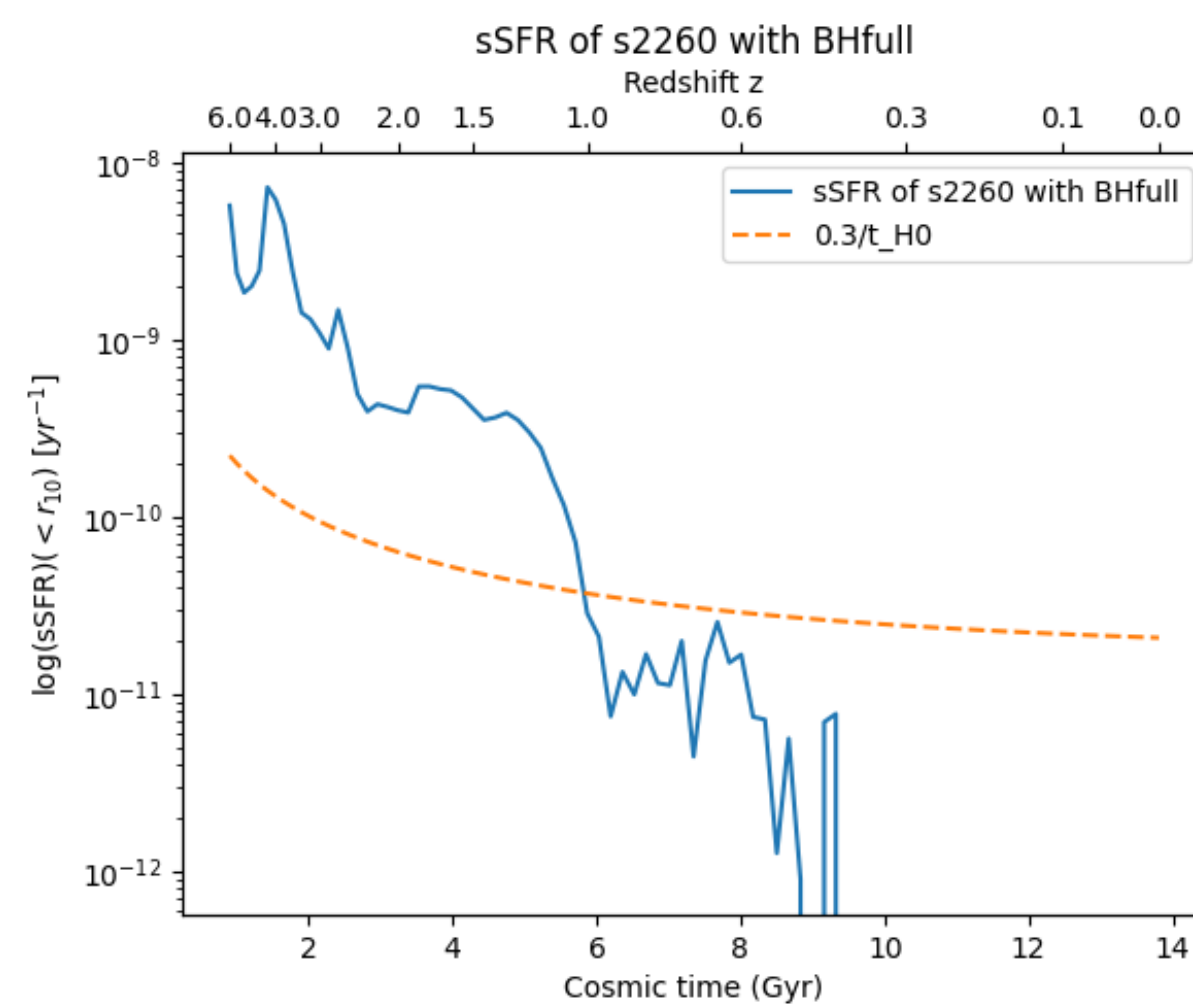
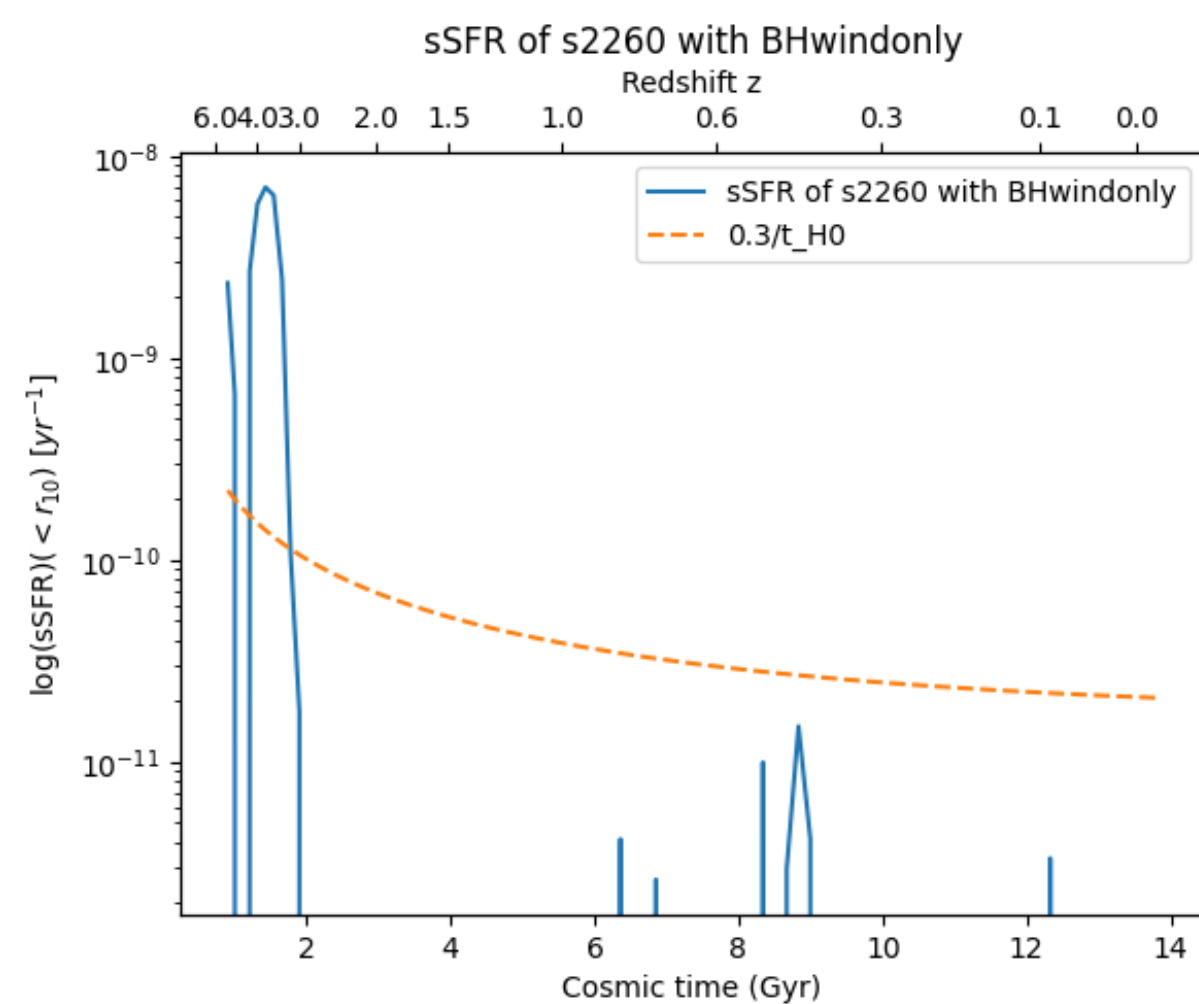
Gas density and velocity with Blackhole position at $z = 6.143$



Projected gas density and velocity with blackhole position. Outflow of the gas by blackhole wind can be seen clearly.

High-z Quenched Galaxy Formation with New Zoom-in ICs

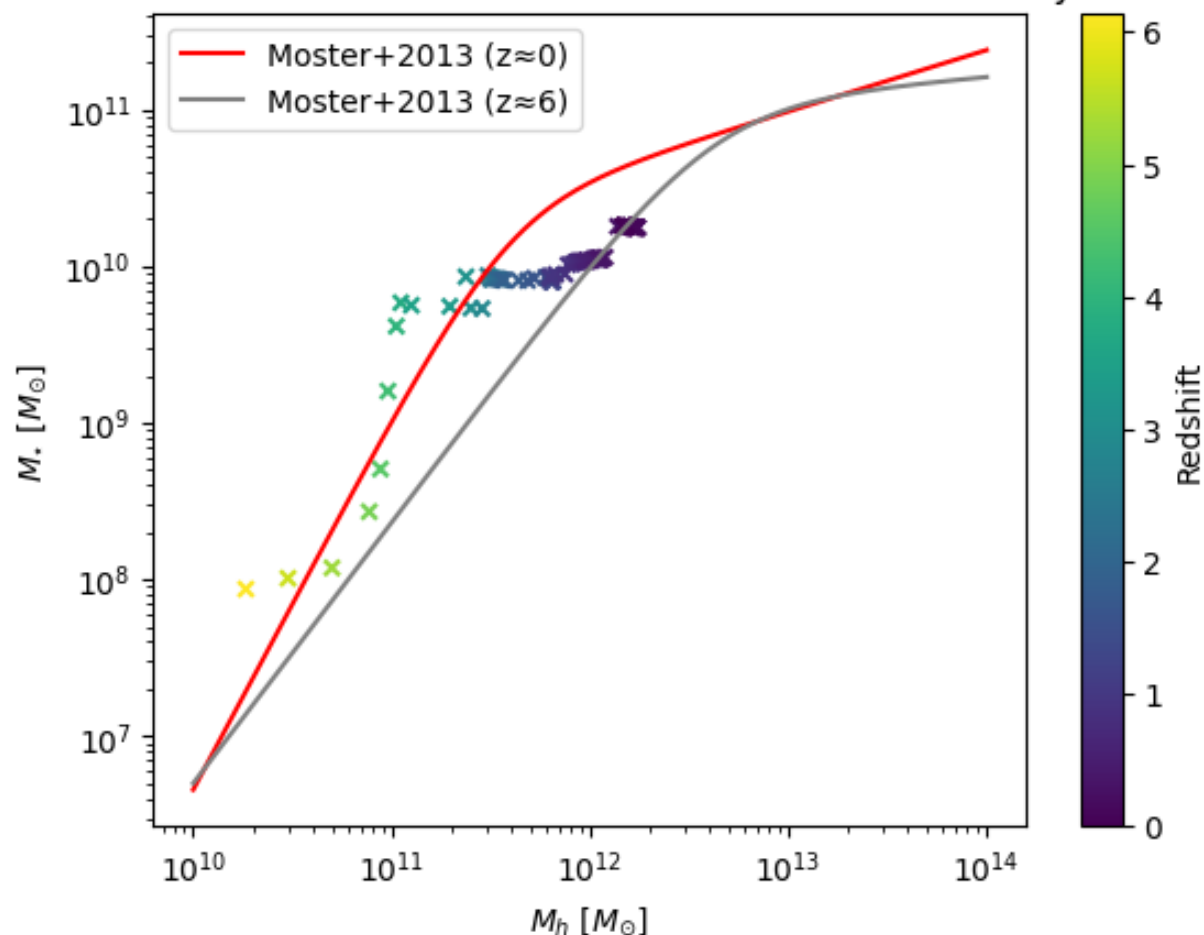
s2260 with Different BH Models



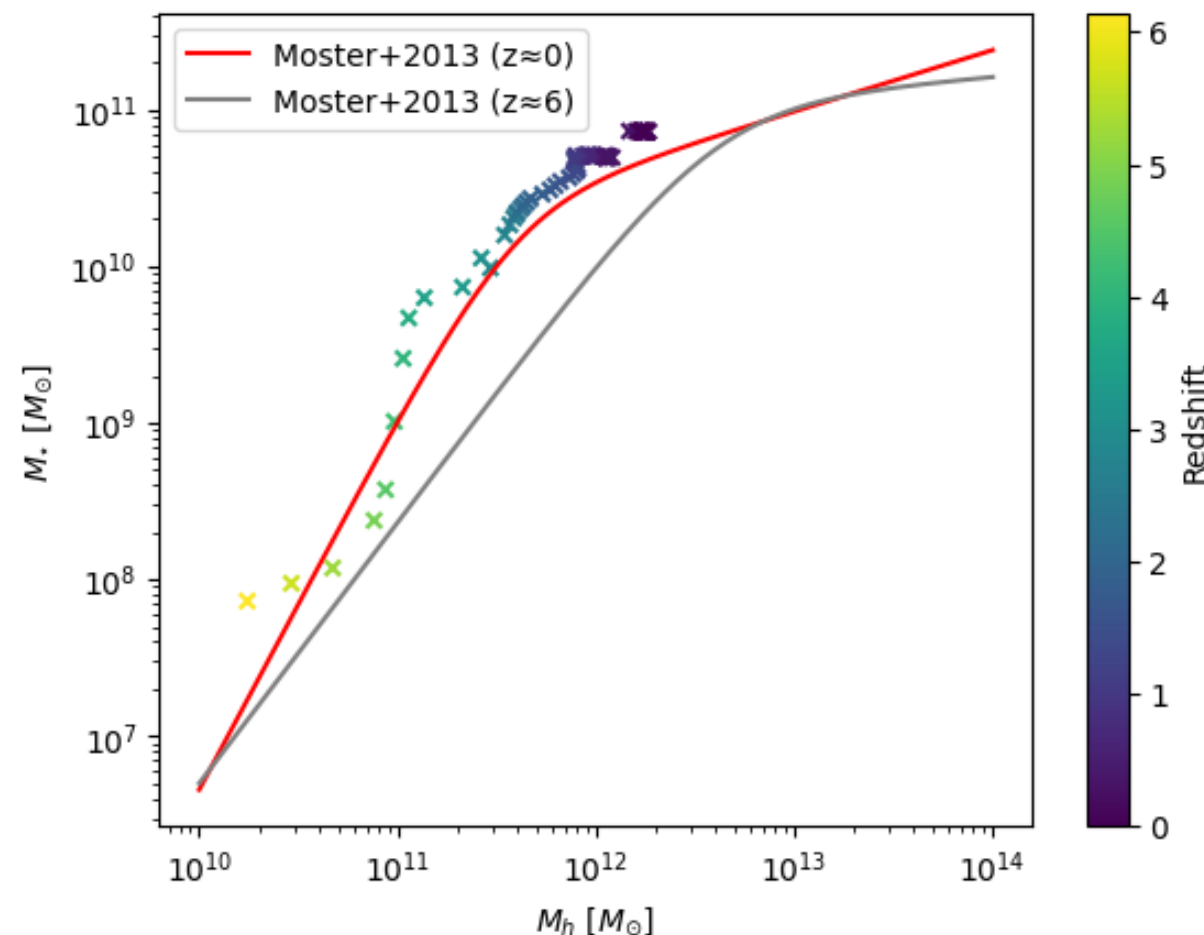
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models

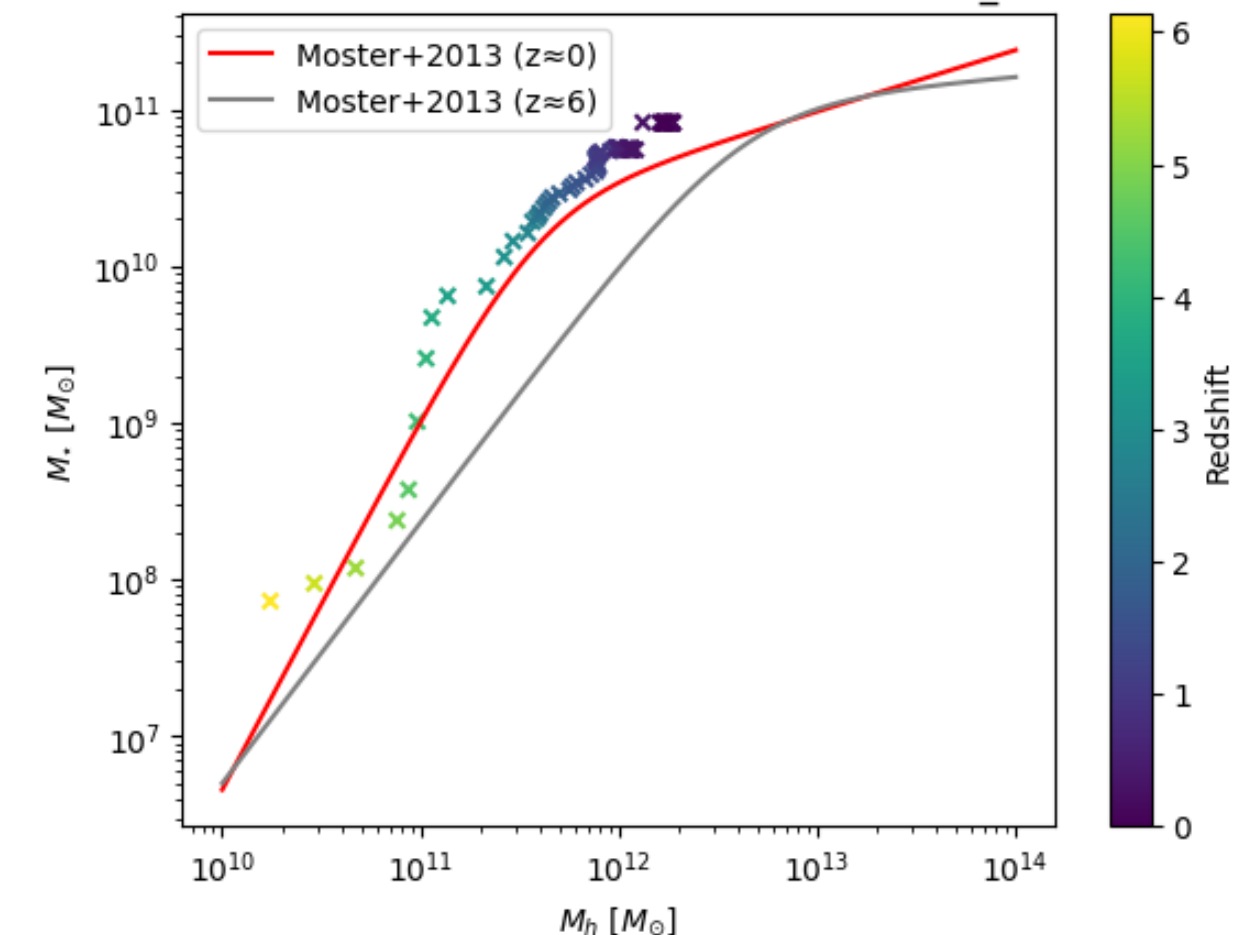
Halo Mass vs. Stellar Mass of s2260 with BHwindonly



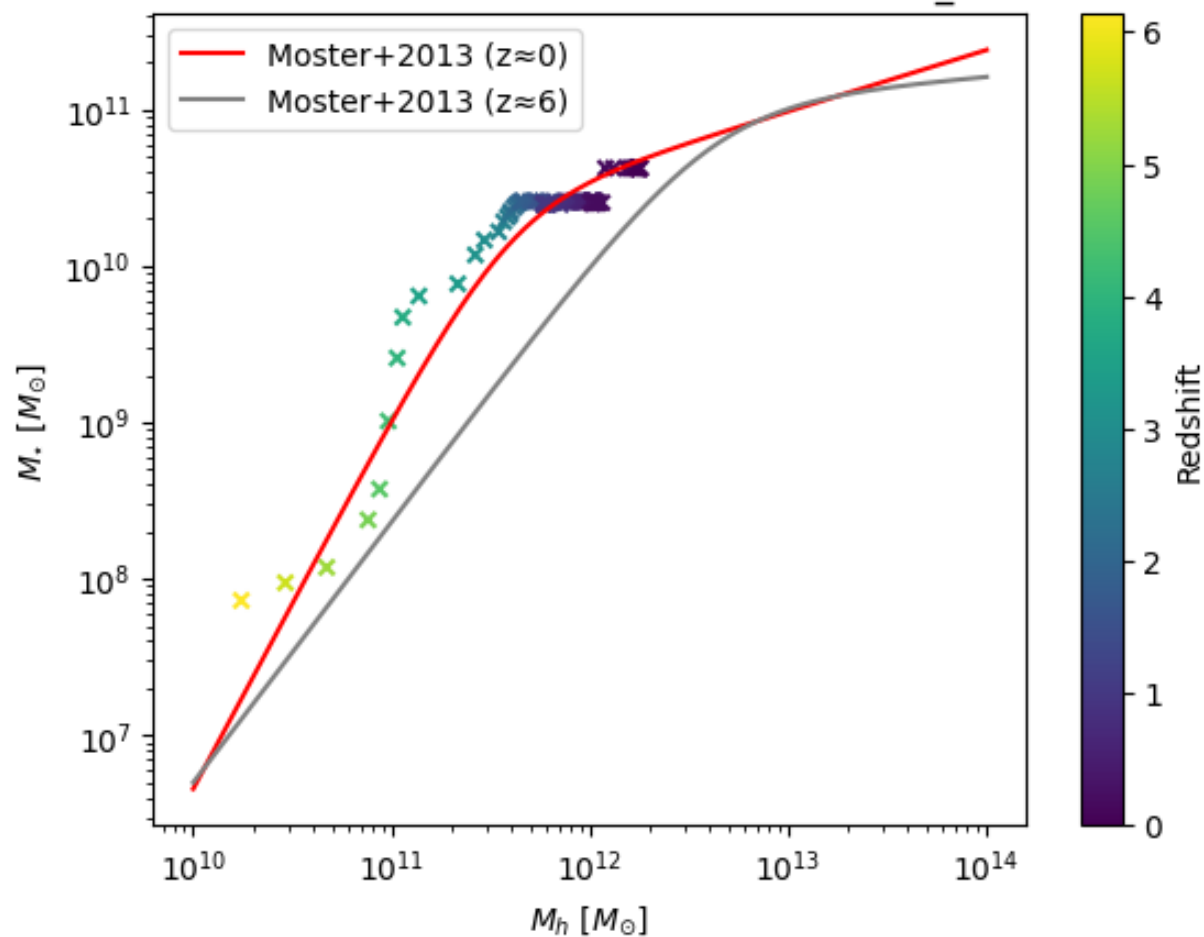
Halo Mass vs. Stellar Mass of s2260 with BHfull



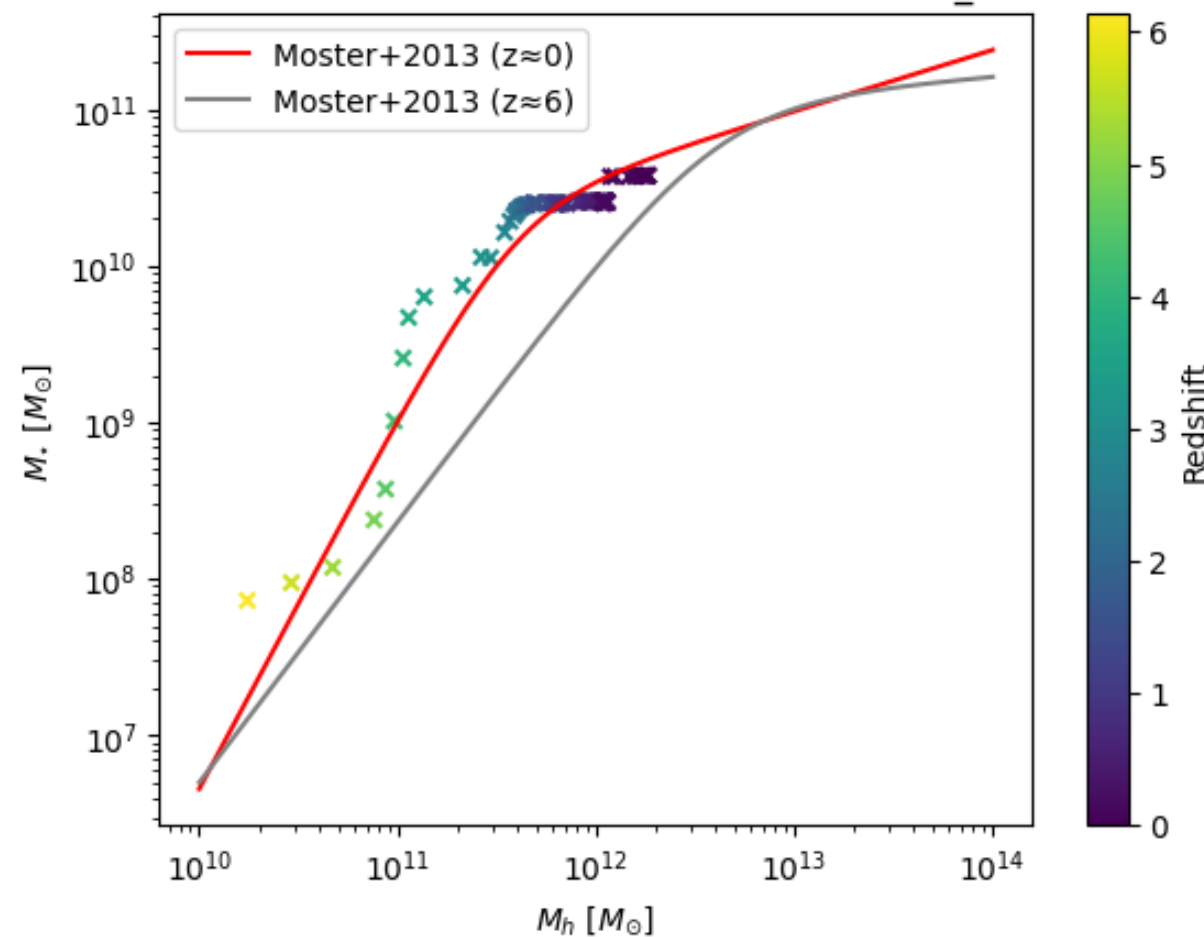
Halo Mass vs. Stellar Mass of s2260 with BH_7e3



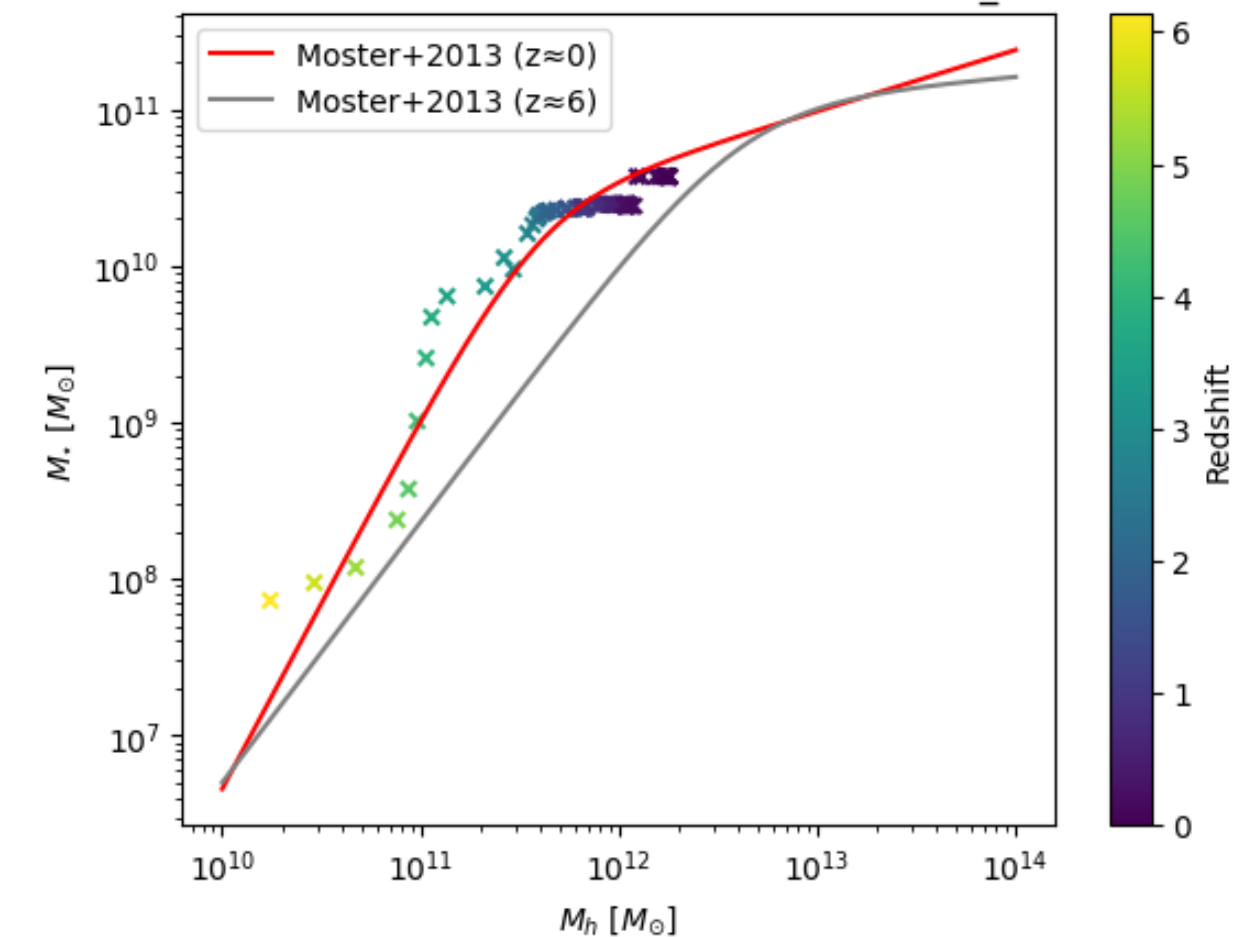
Halo Mass vs. Stellar Mass of s2260 with BH_w2e4



Halo Mass vs. Stellar Mass of s2260 with BH_1e3



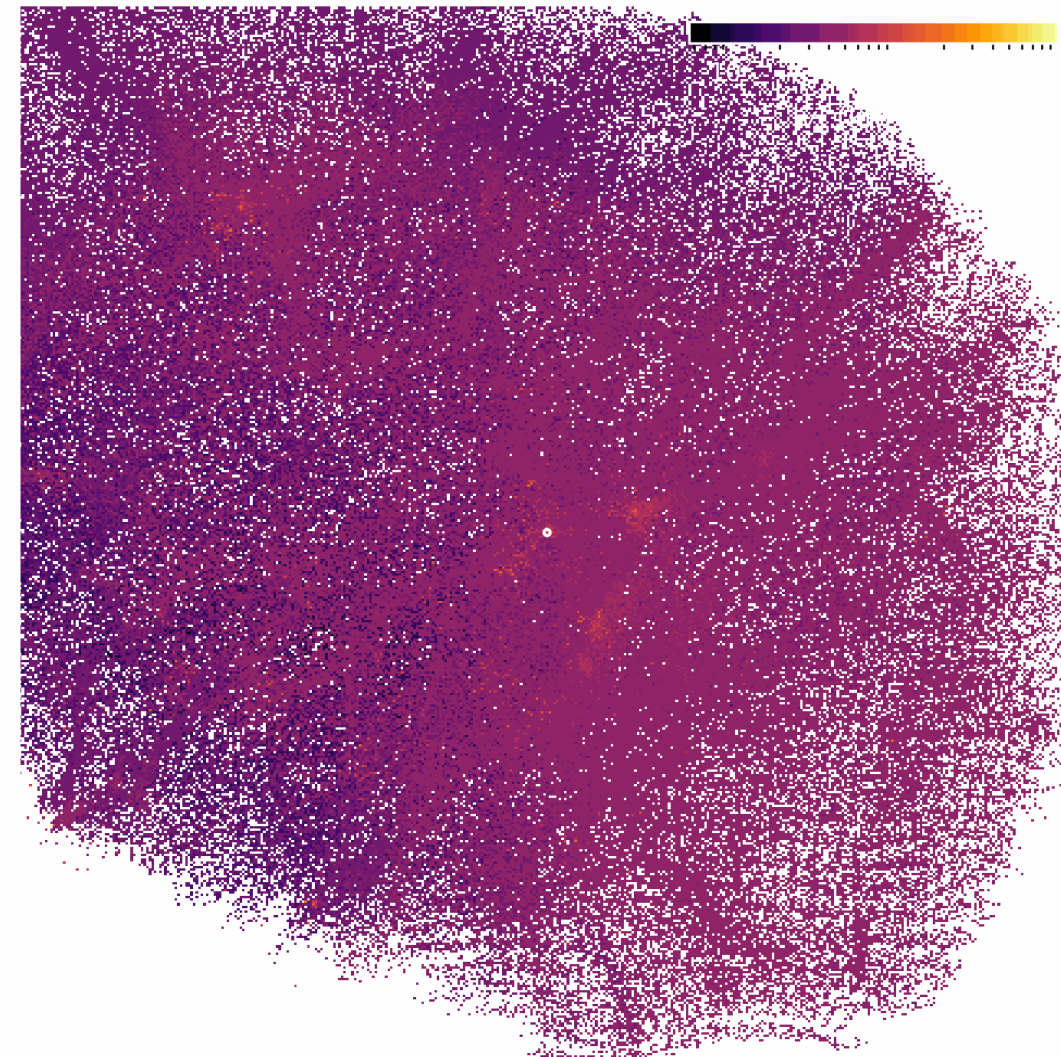
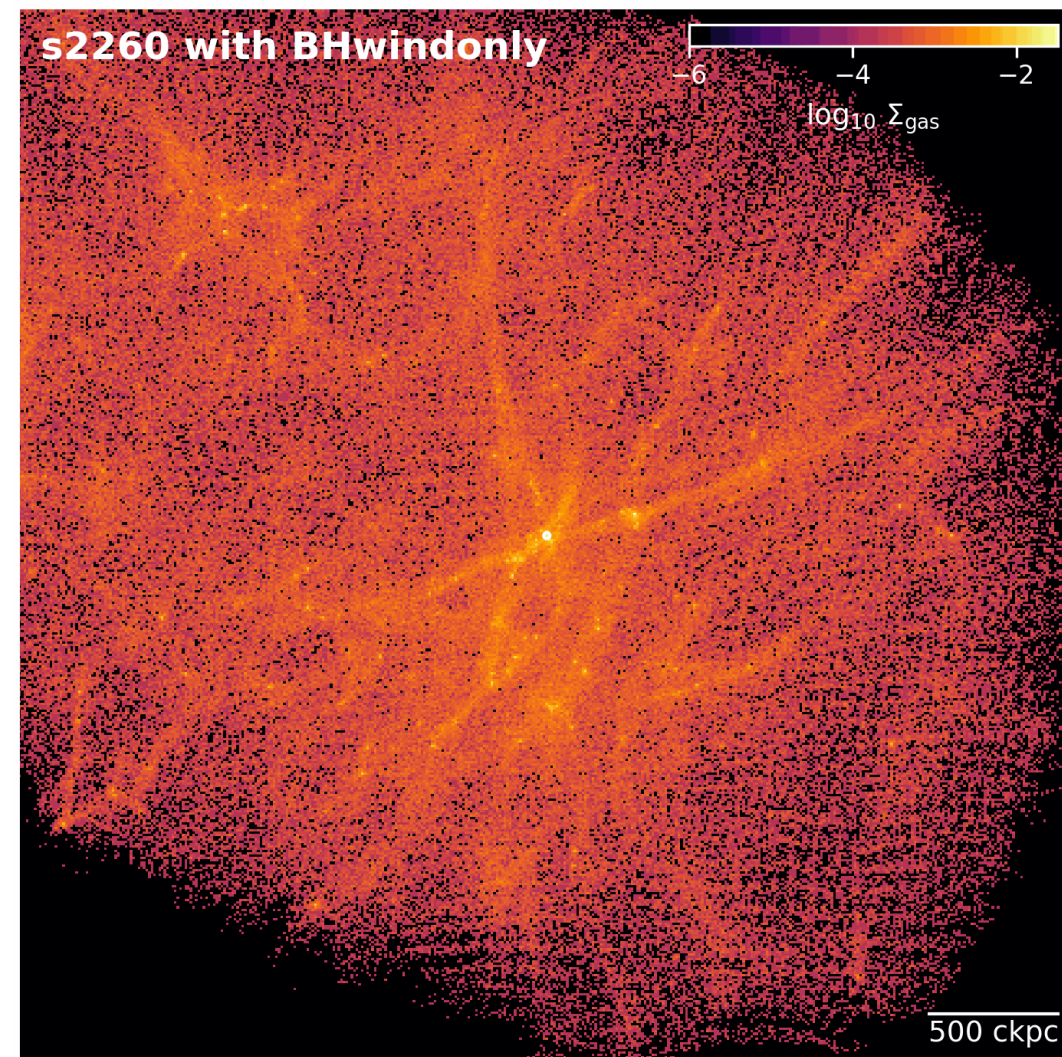
Halo Mass vs. Stellar Mass of s2260 with BH_5e4



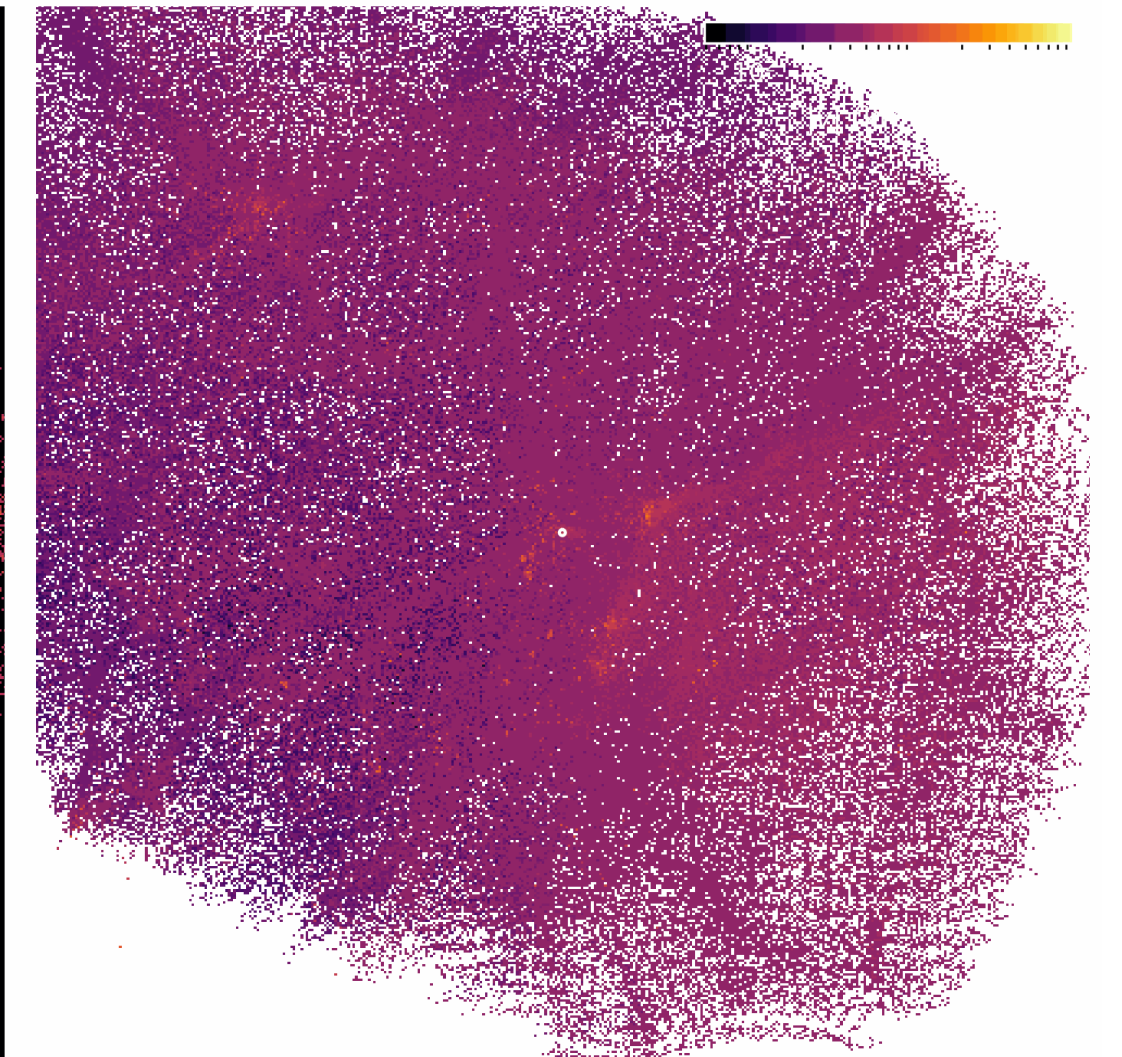
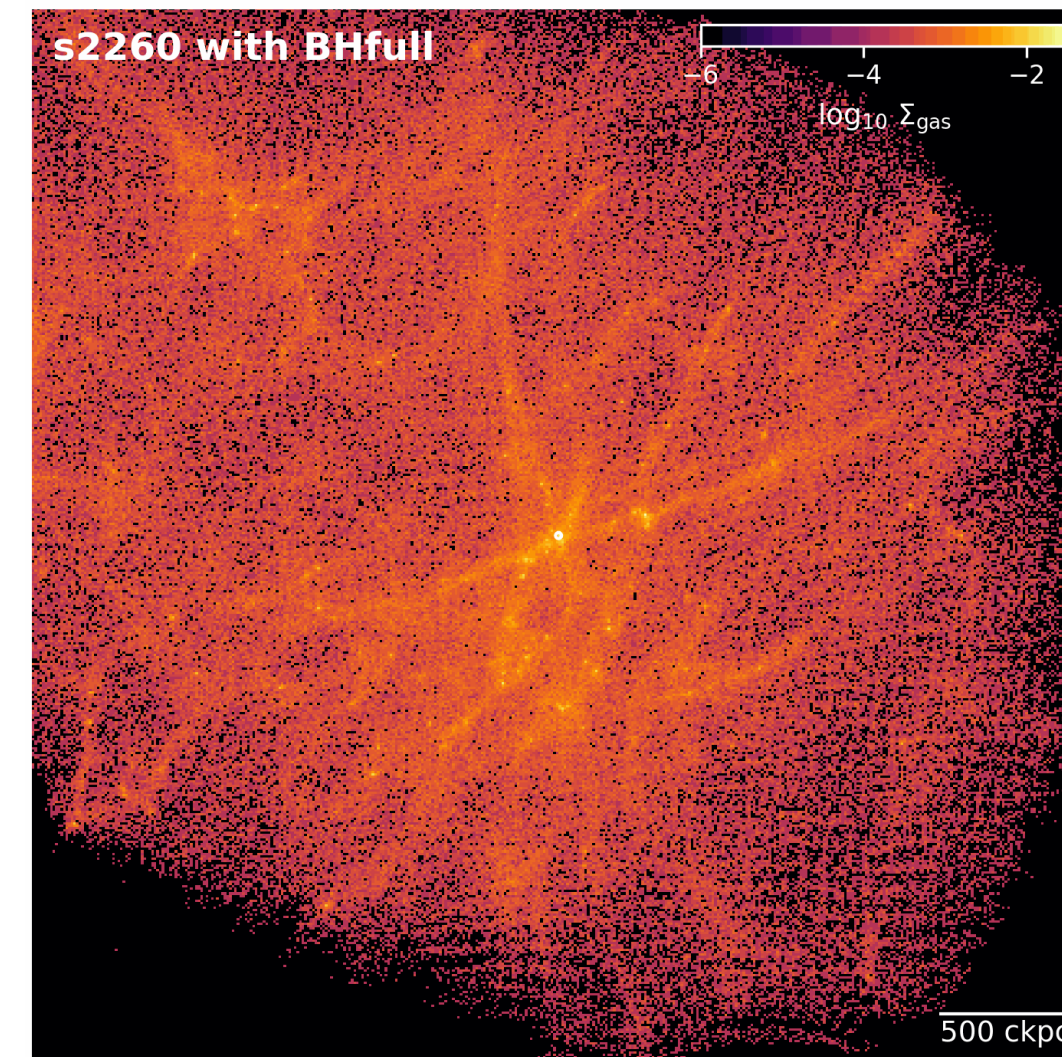
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models

Gas density and velocity with Blackhole position at $z = 6.143$



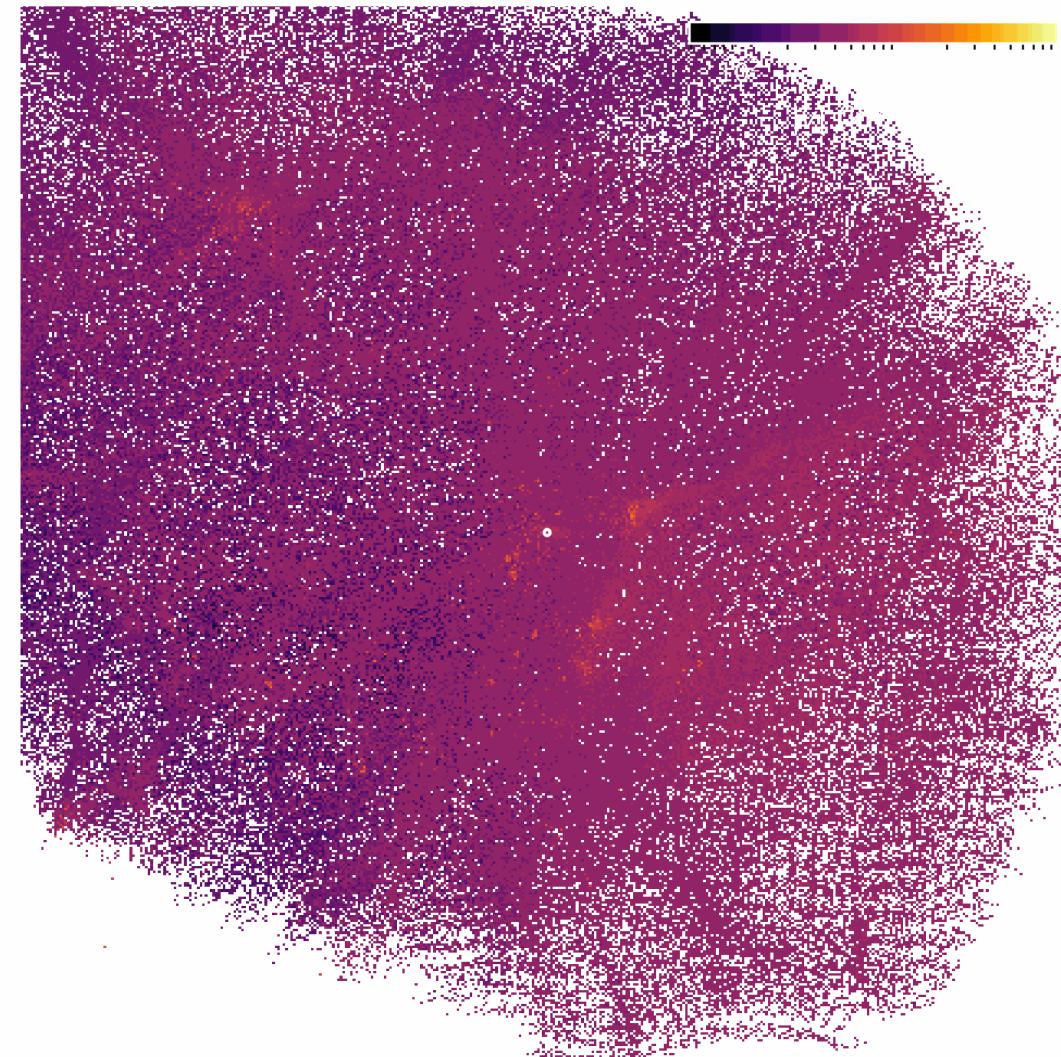
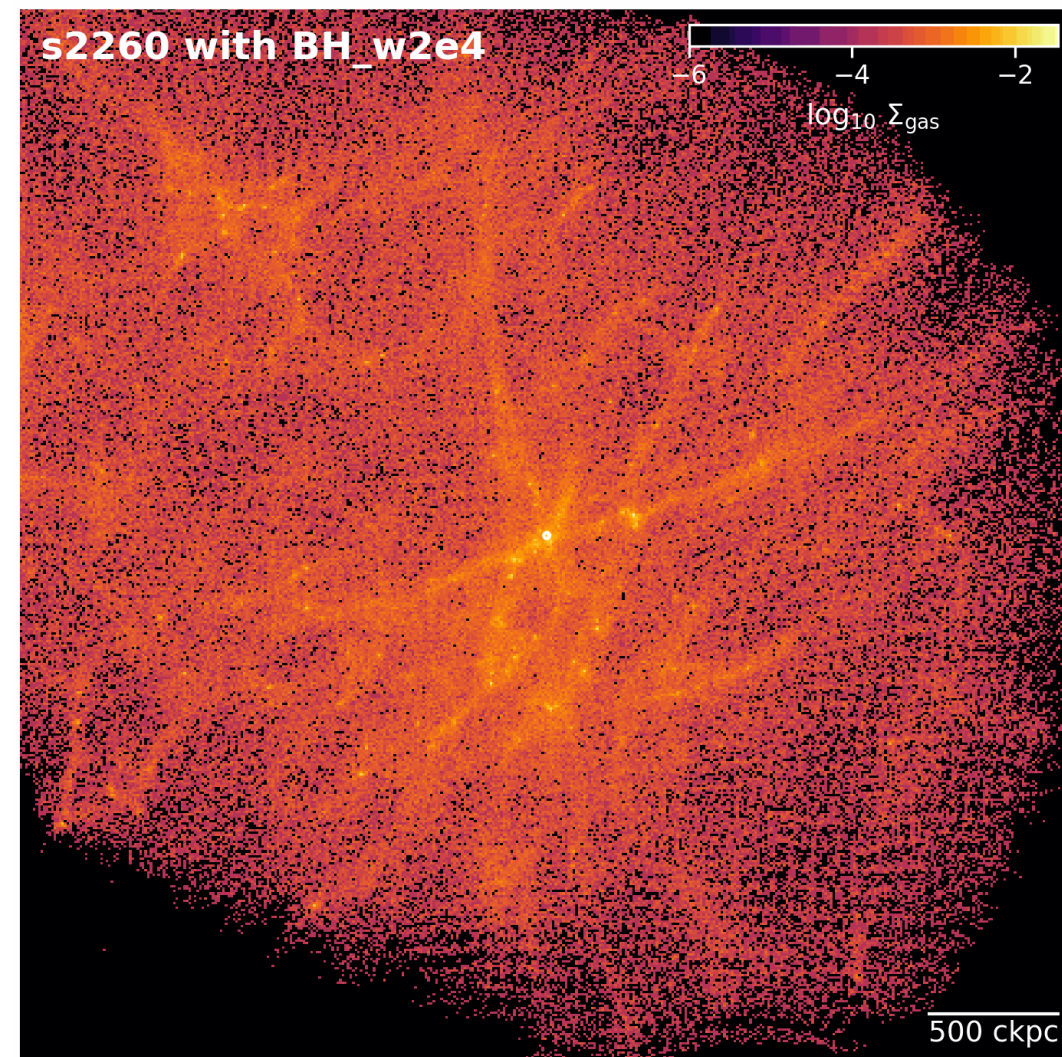
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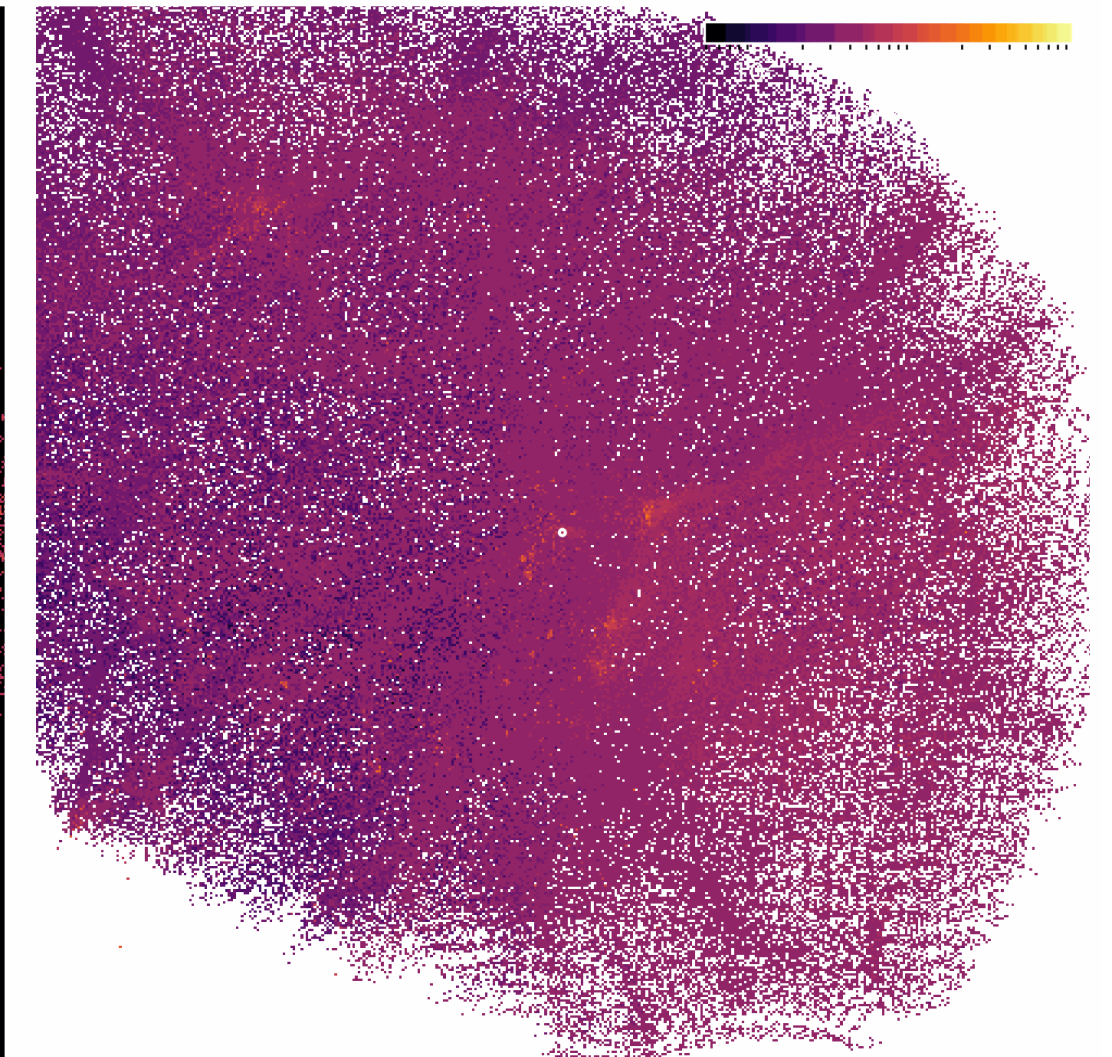
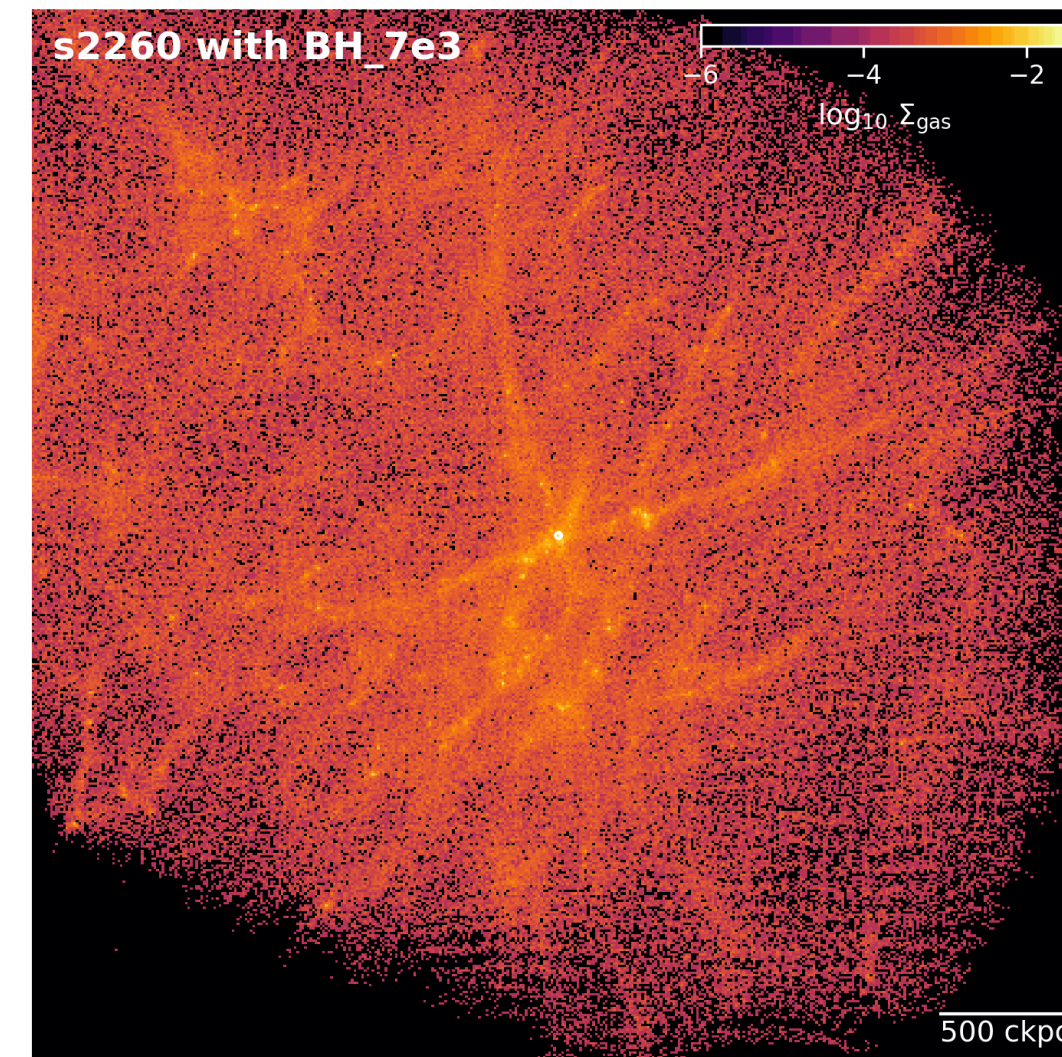
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models

Gas density and velocity with Blackhole position at $z = 6.143$



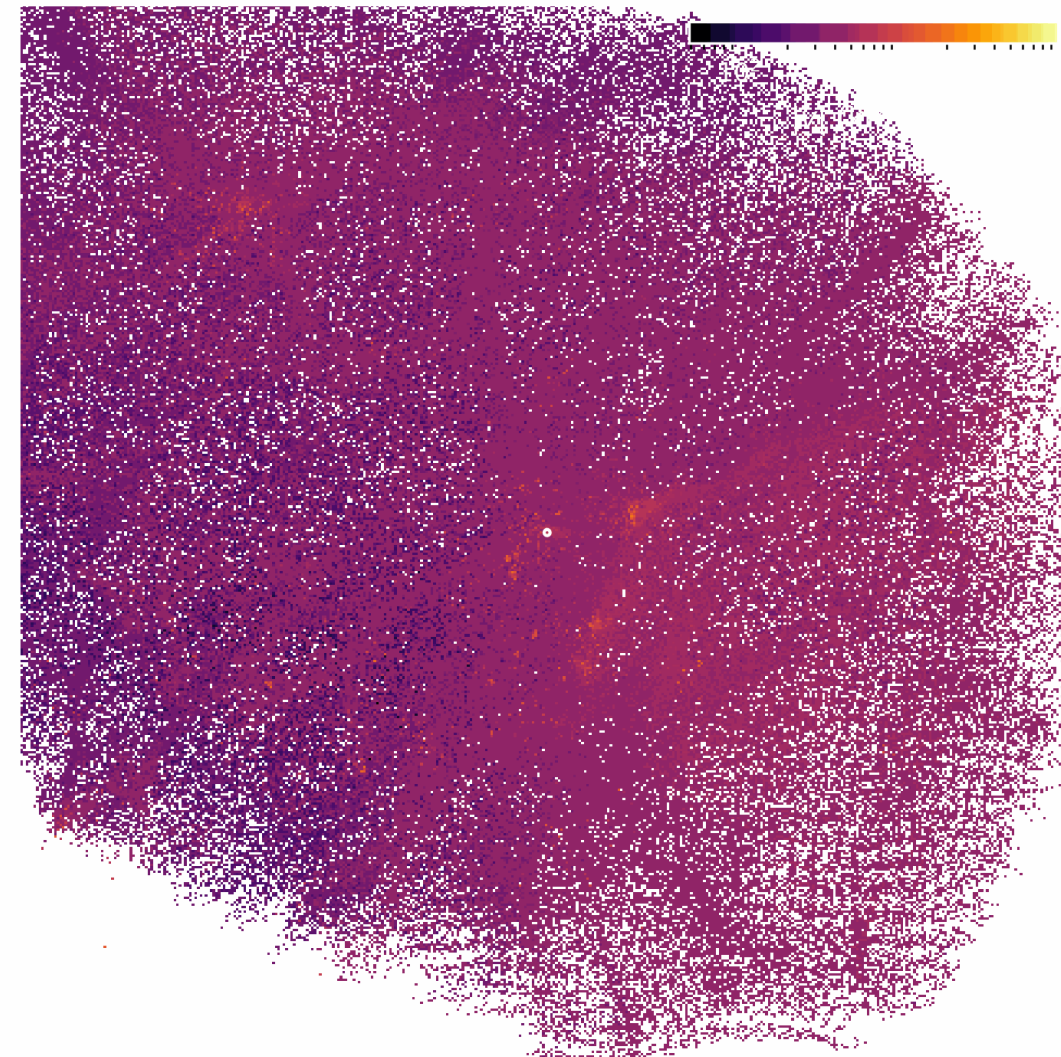
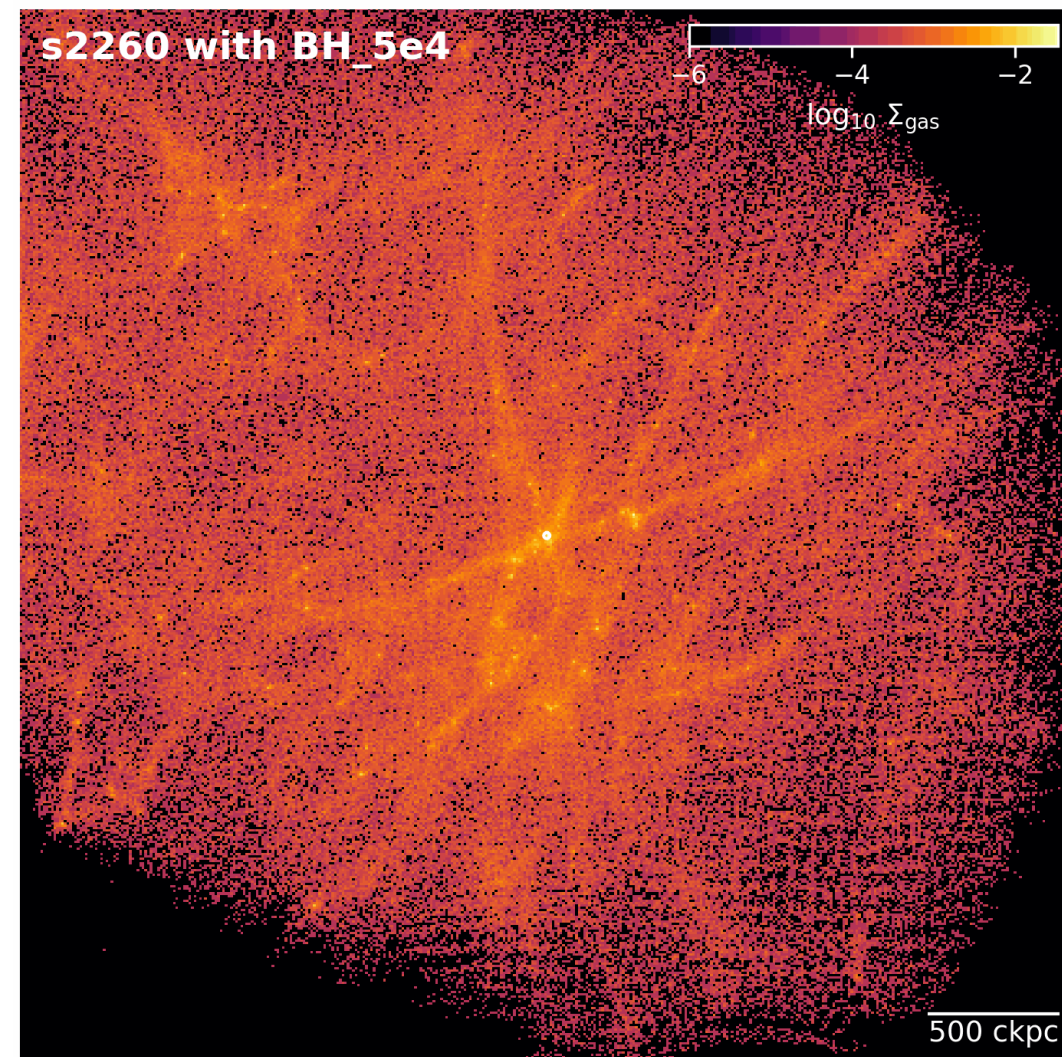
Gas density and velocity with Blackhole position at $z = 6.143$



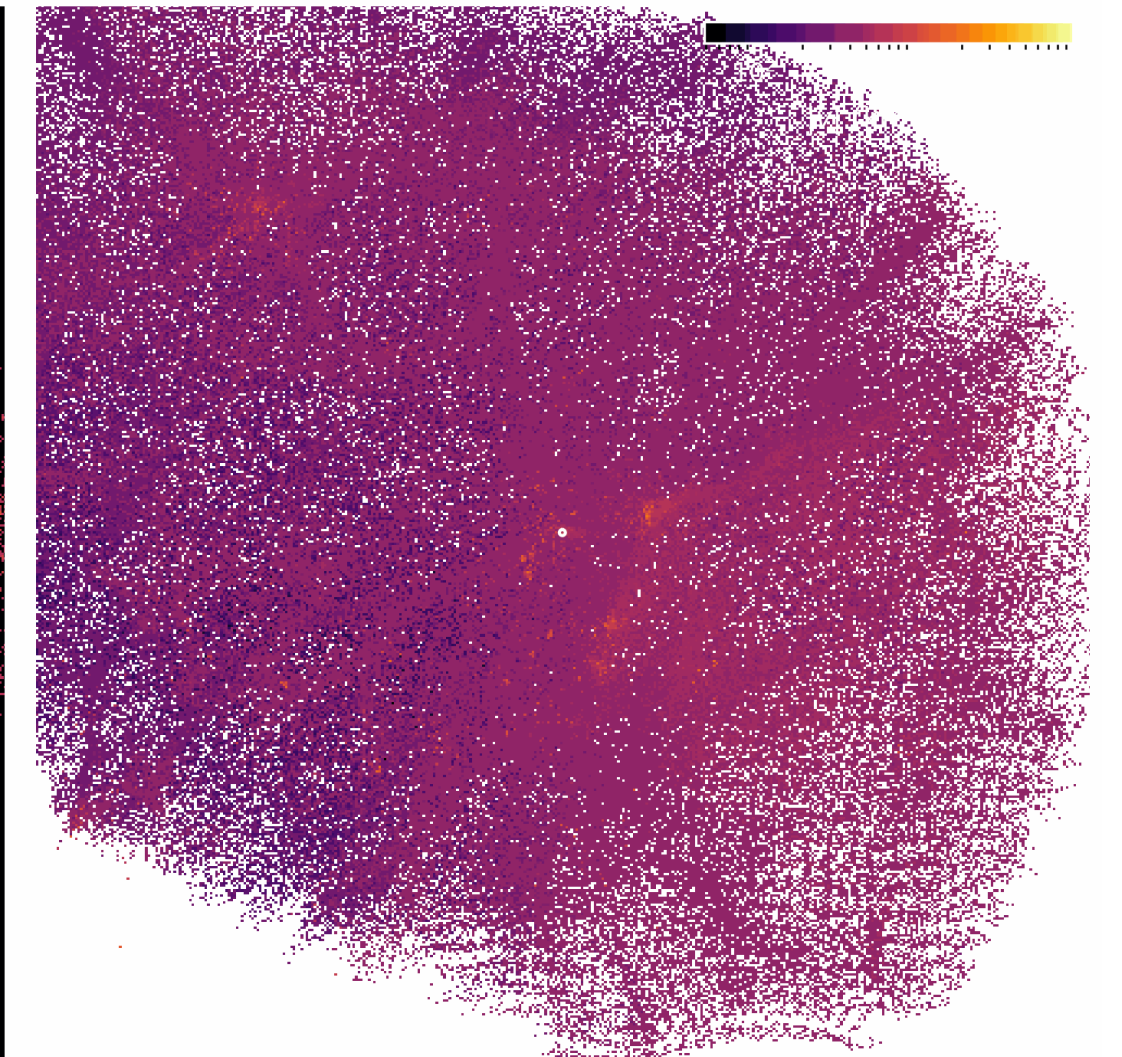
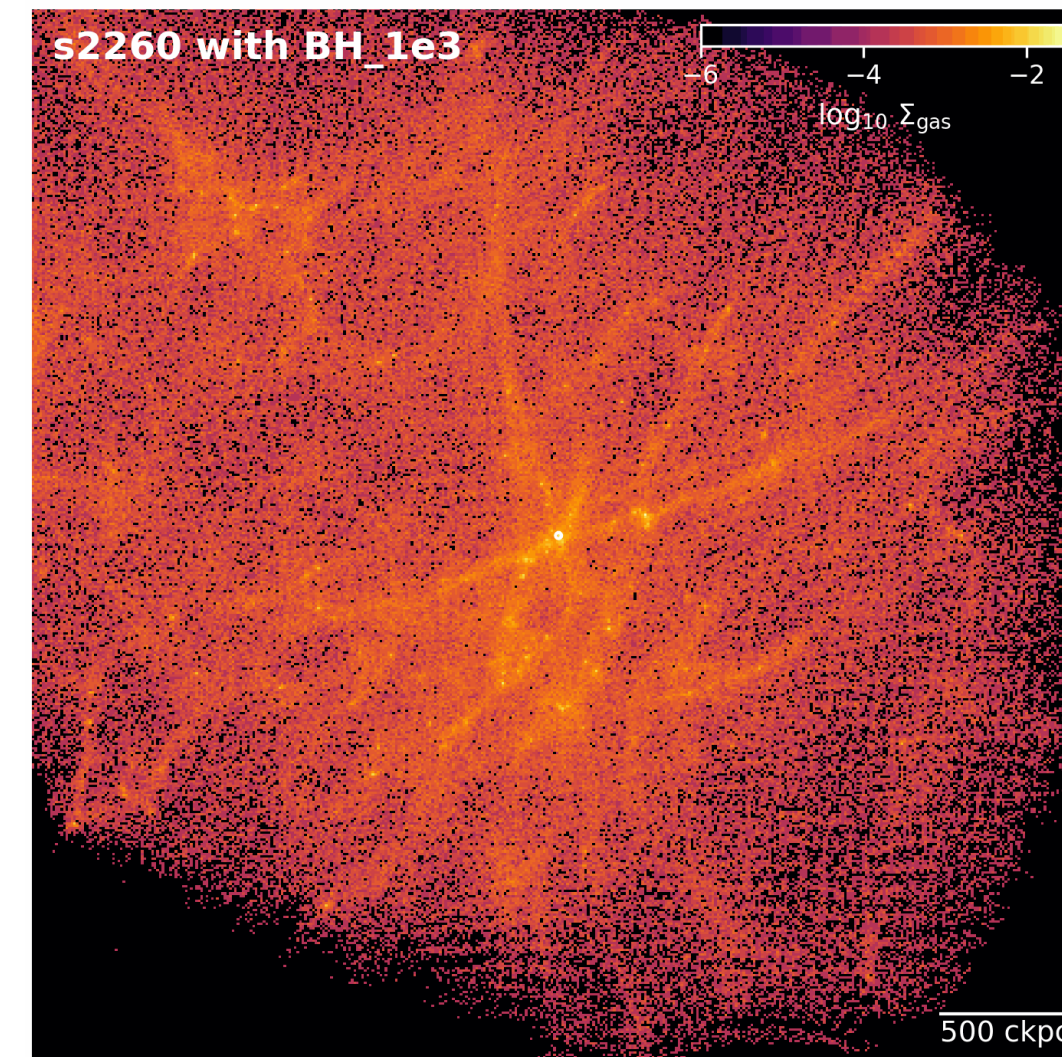
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models

Gas density and velocity with Blackhole position at $z = 6.143$

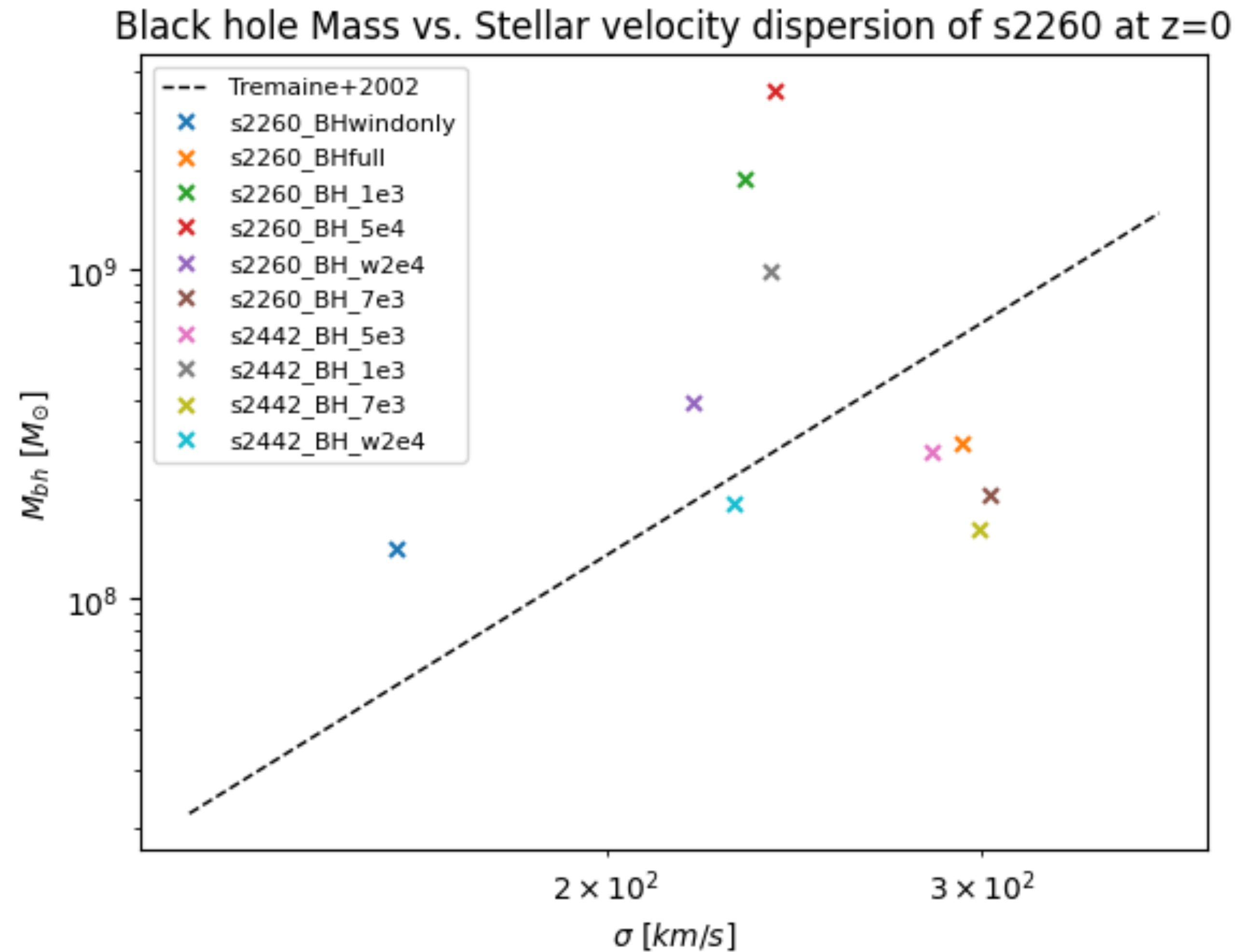


Gas density and velocity with Blackhole position at $z = 6.143$



High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 and s2442 with Different BH Models



Future Tasks

- I) Generate more reliable initial conditions (ICs) at higher resolution, and perform various tests based on them.
- II) Explore different mass cuts and environmental conditions in order to simulate not only quenched but also massive galaxies at high redshift.
- III) Investigate the subsequent evolution of these massive quenched galaxies, including the possibility of rejuvenation.