

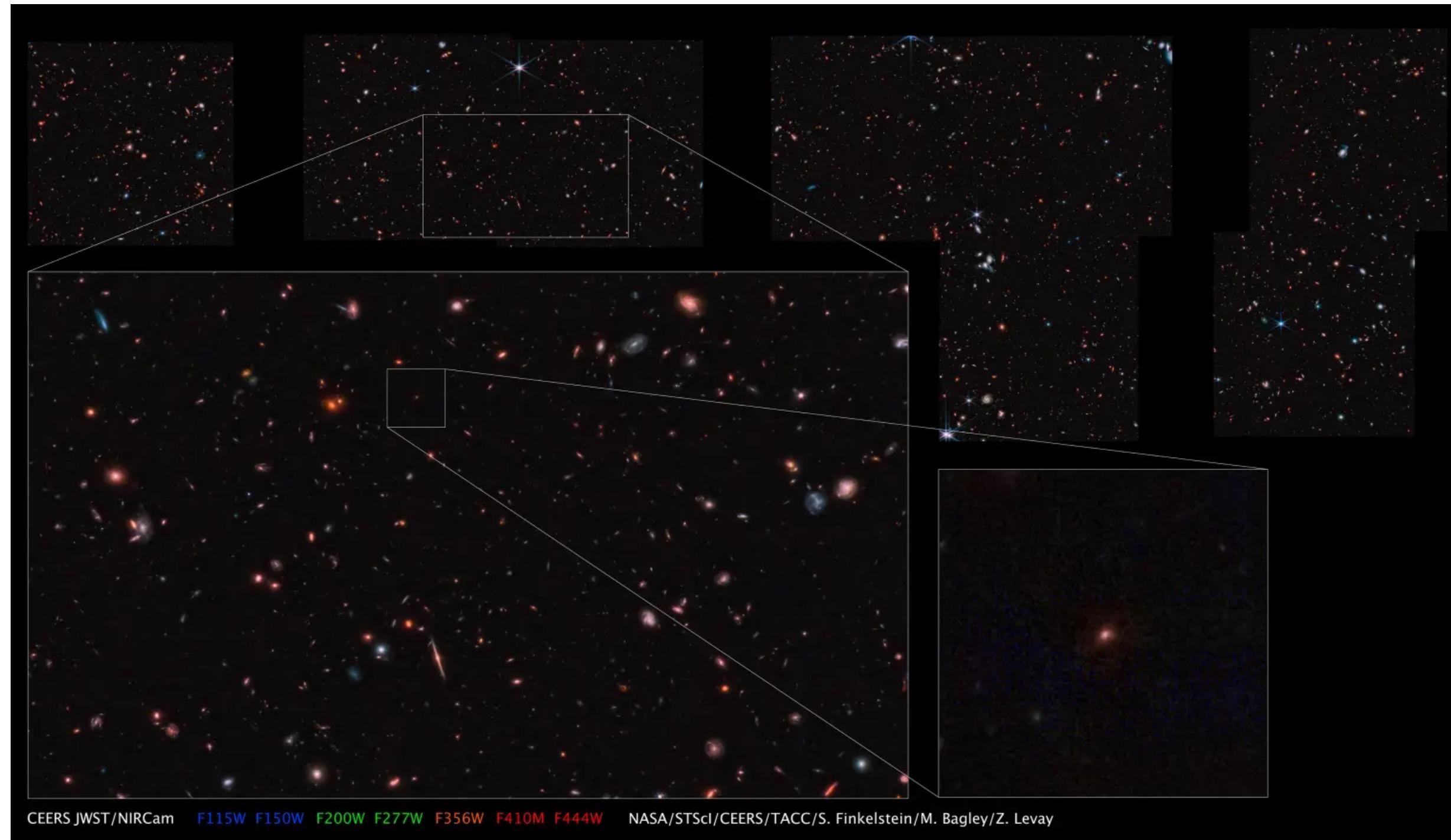
Evolution of Massive and Quenched Galaxies in Early Universe using Zoom-in Simulations

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 $z \gtrsim 7$.

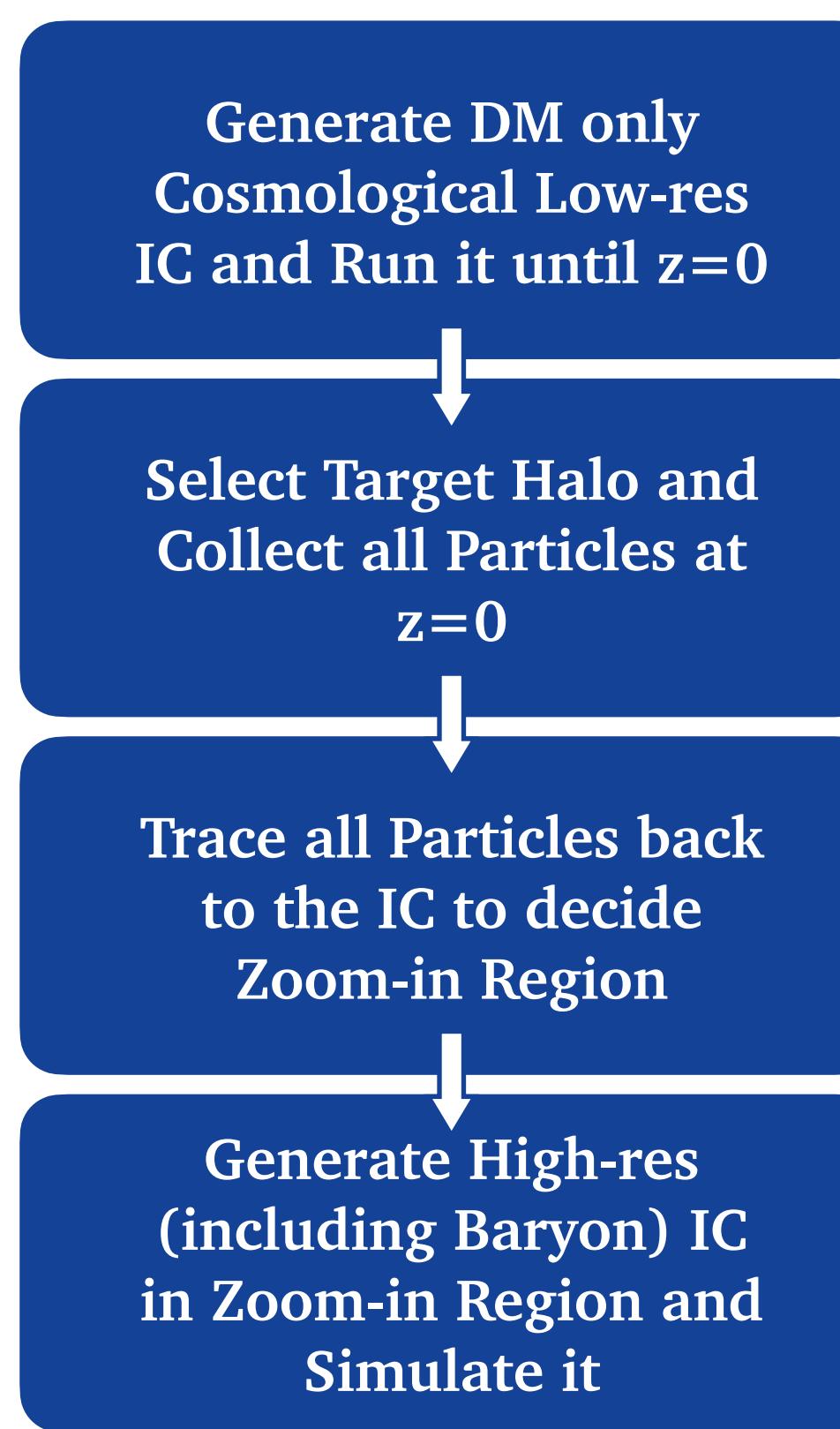
To simulate them, we need to begin from initial conditions with a larger box size and a higher starting redshift.

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.

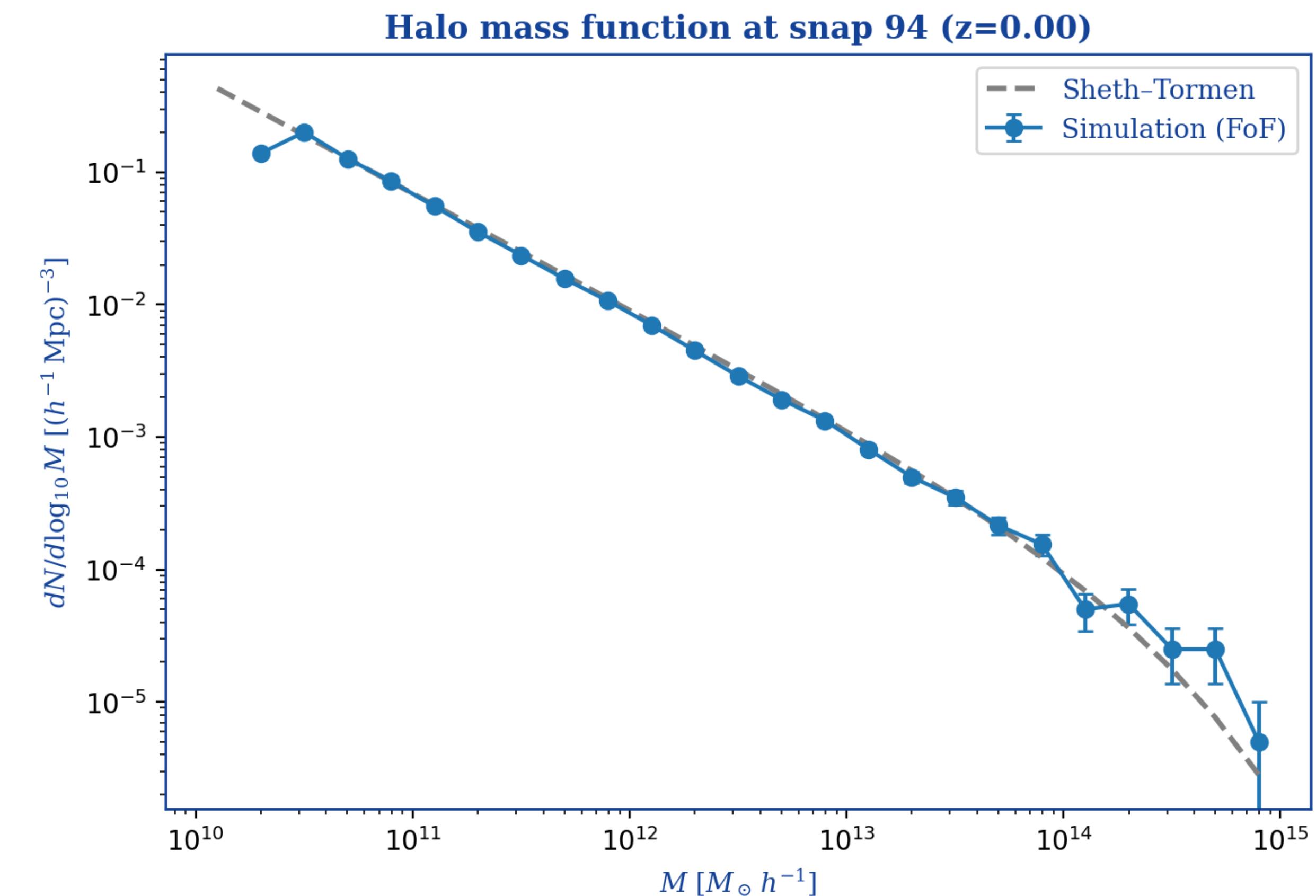
(Oser et al. 2010)

Generating Zoom-in ICs Using MUSIC

Simulation Details and Checking HMF

Simulation Properties	
Box Length	: $100 Mpc$
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

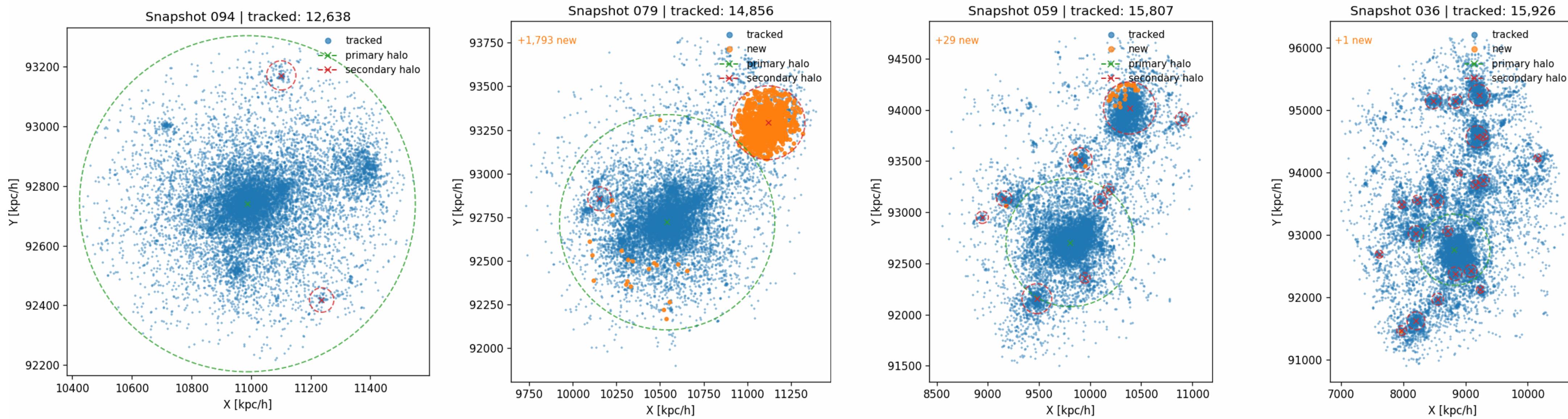


Generating Zoom-in ICs Using MUSIC

Target Selecting Process

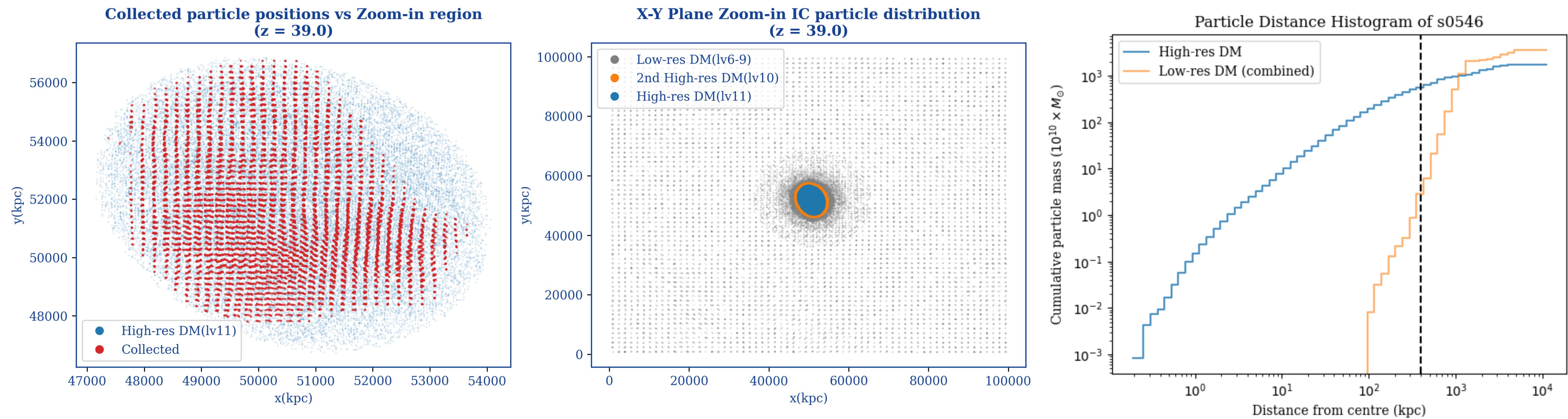
- Halos are selected between $10^{12}M_{\odot} < M_{target} < 10^{13}M_{\odot}$
- No halos with $M_{vir} > 10^{13}M_{\odot}$ within 7 Mpc.
- No halos with $M_{vir} \geq 0.5 \times M_{target}$ within 2.8 Mpc.

(Griffin et al. 2016)



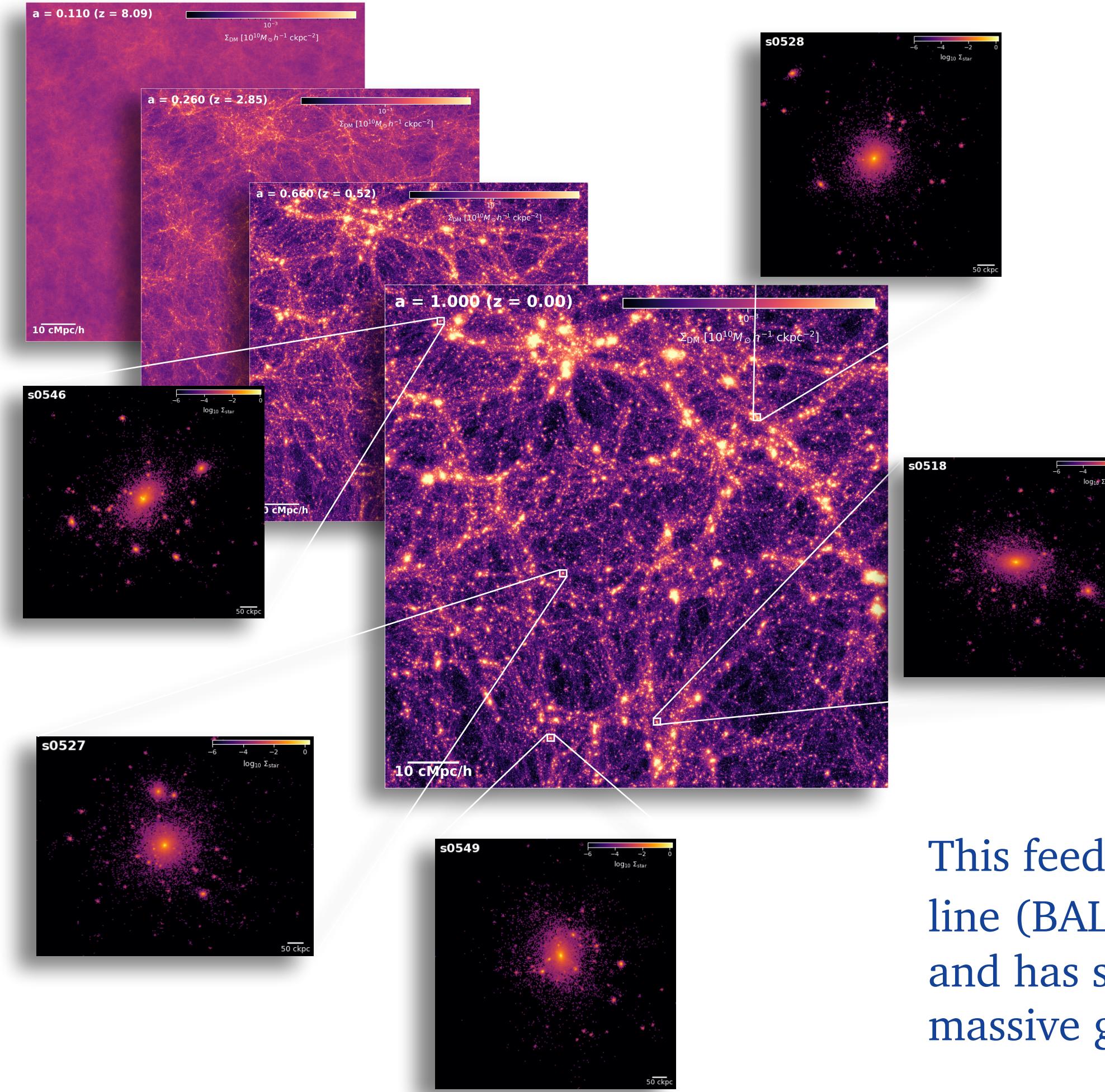
Generating Zoom-in ICs Using MUSIC

Generating Zoom-in IC Using MUSIC



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

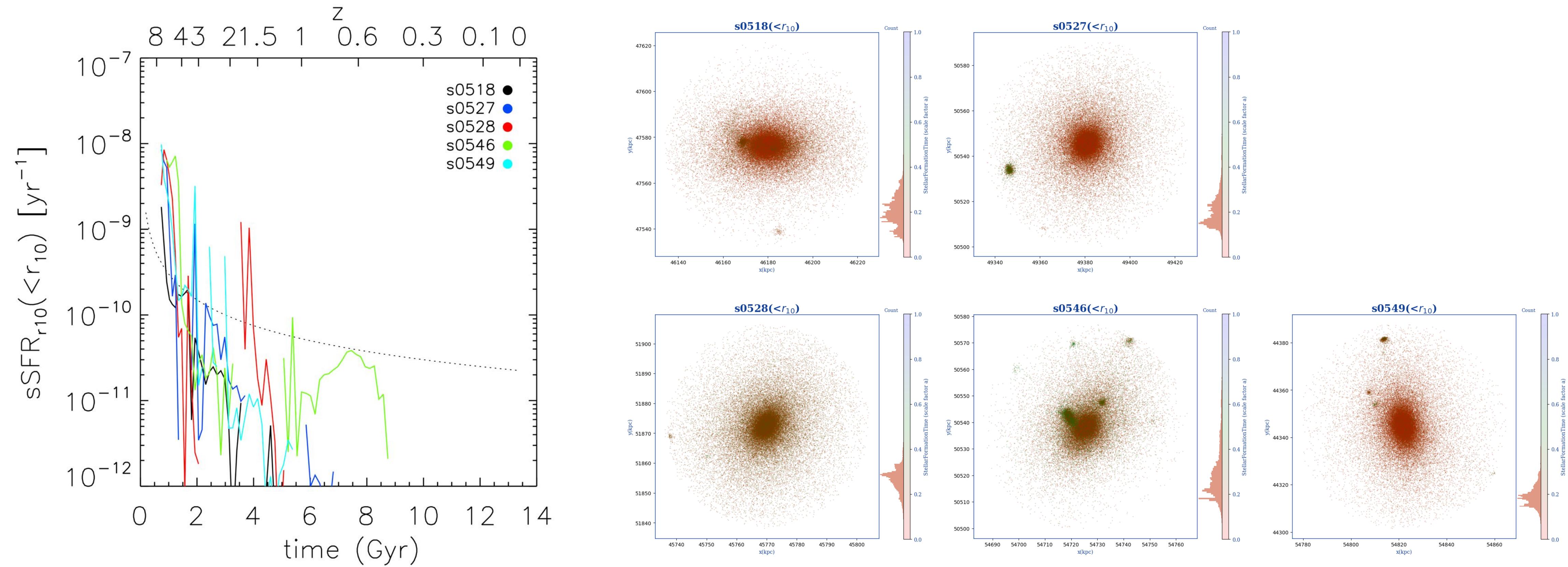
Zoom-in Simulation using SPHGal code (modified version of GADGET-3)



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



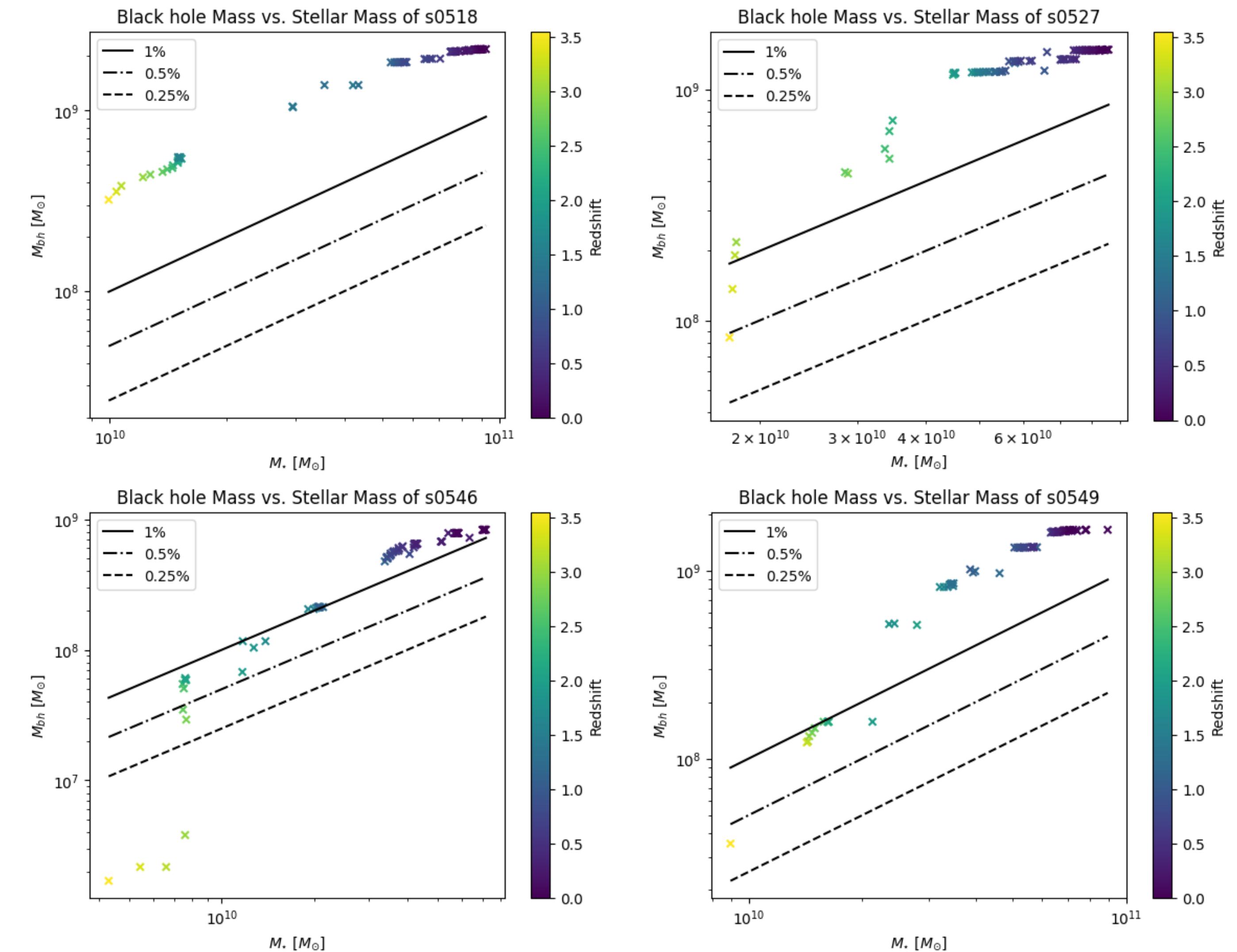
High-z Quenched Galaxy Formation with New Zoom-in ICs

Results

Blackhole Mass vs. Stellar Mass($< r_{10}$) plot.

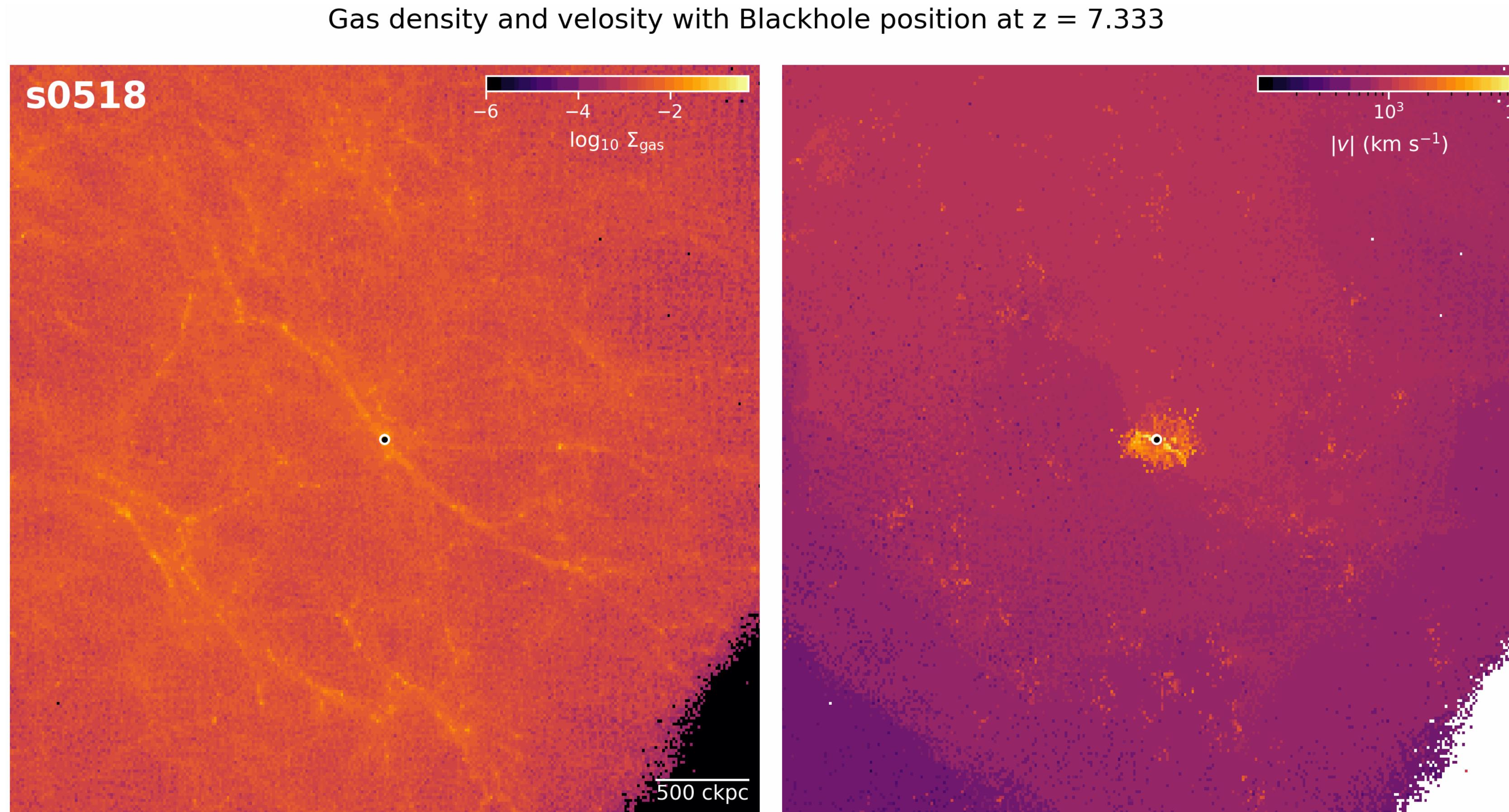
Generally central blackholes mass is bigger than 1% of stellar mass at $z=0$.

BHwind only model show overregulation of star formation.



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

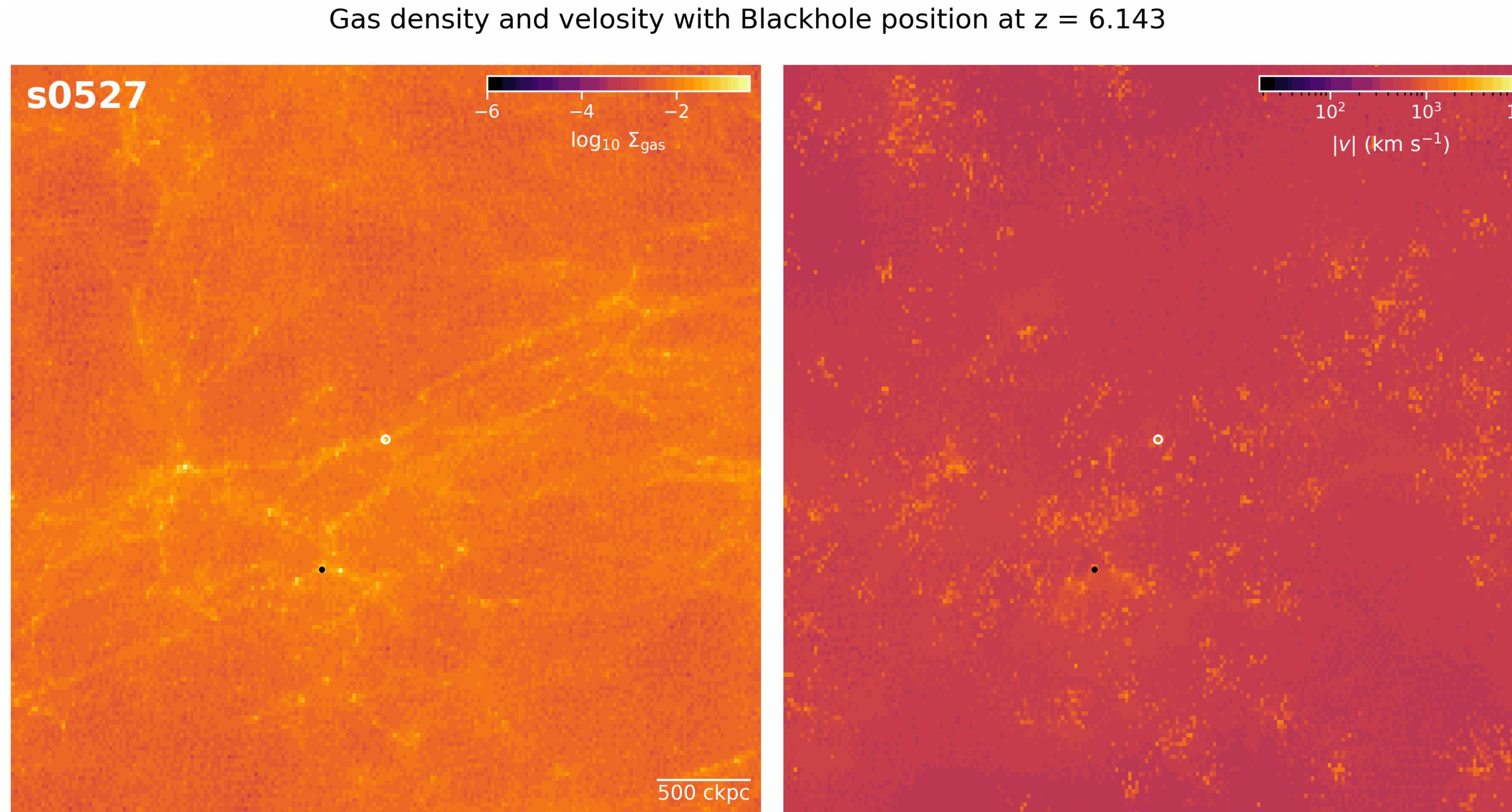
Results



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

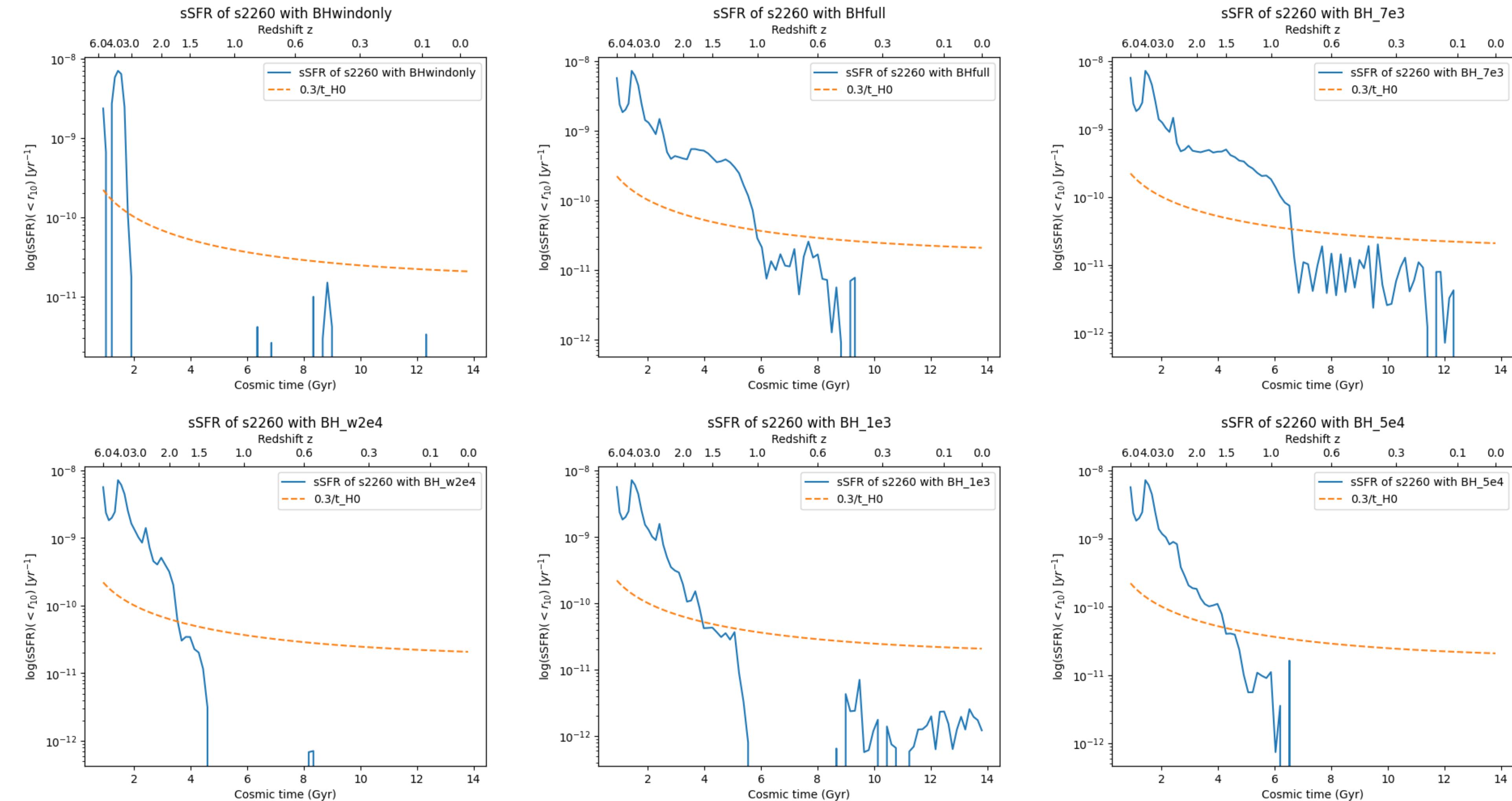
Results



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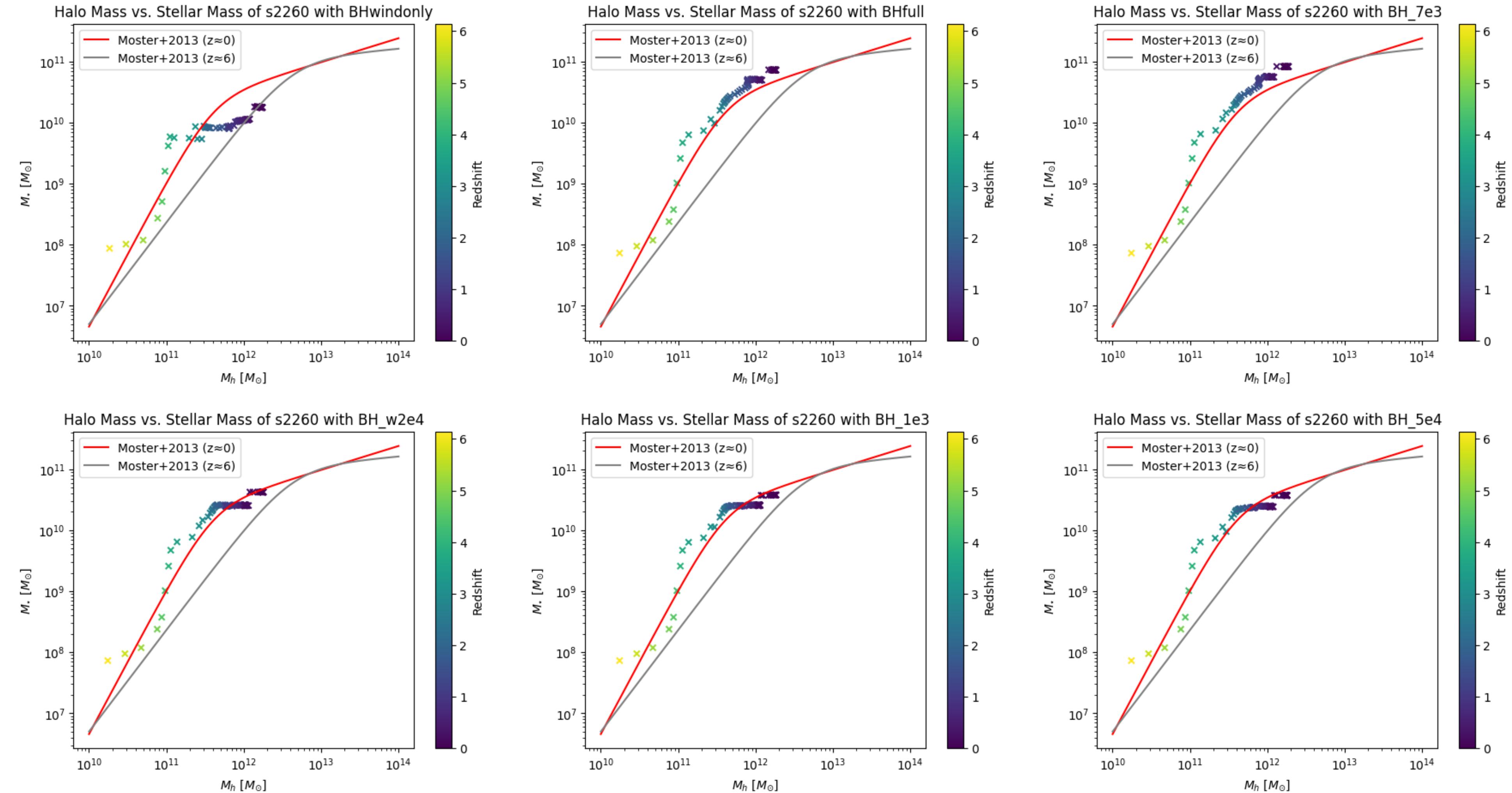
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models



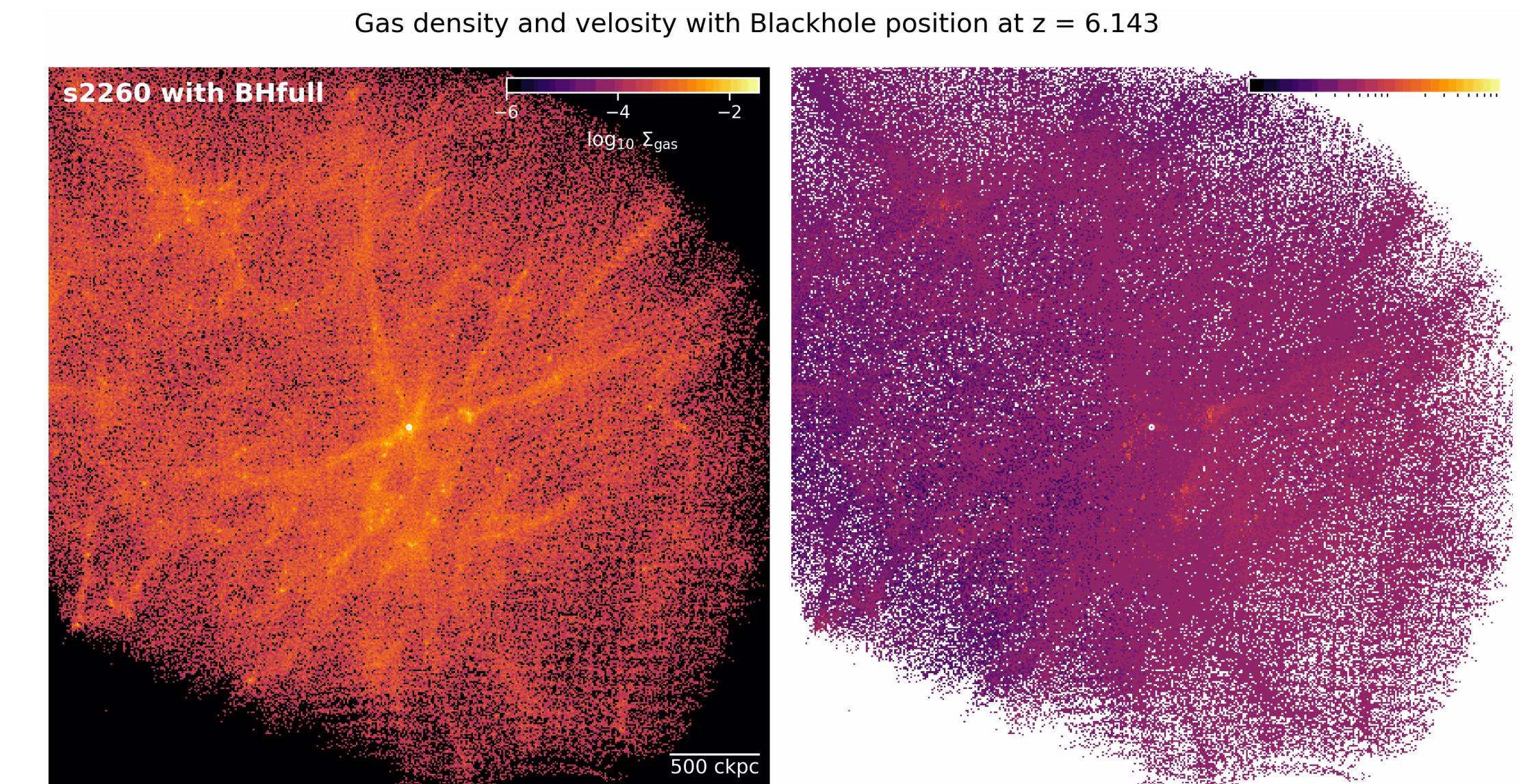
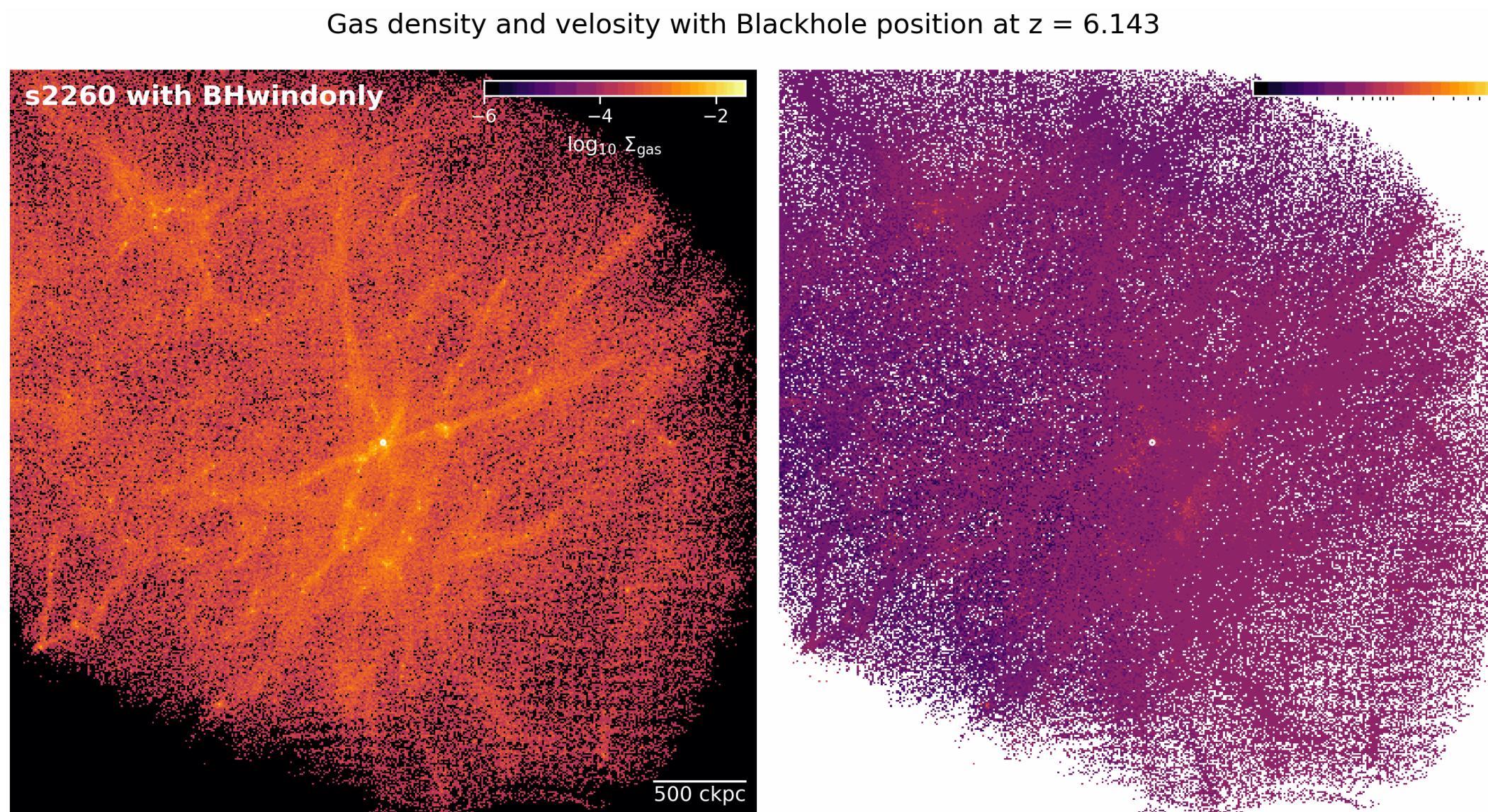
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models



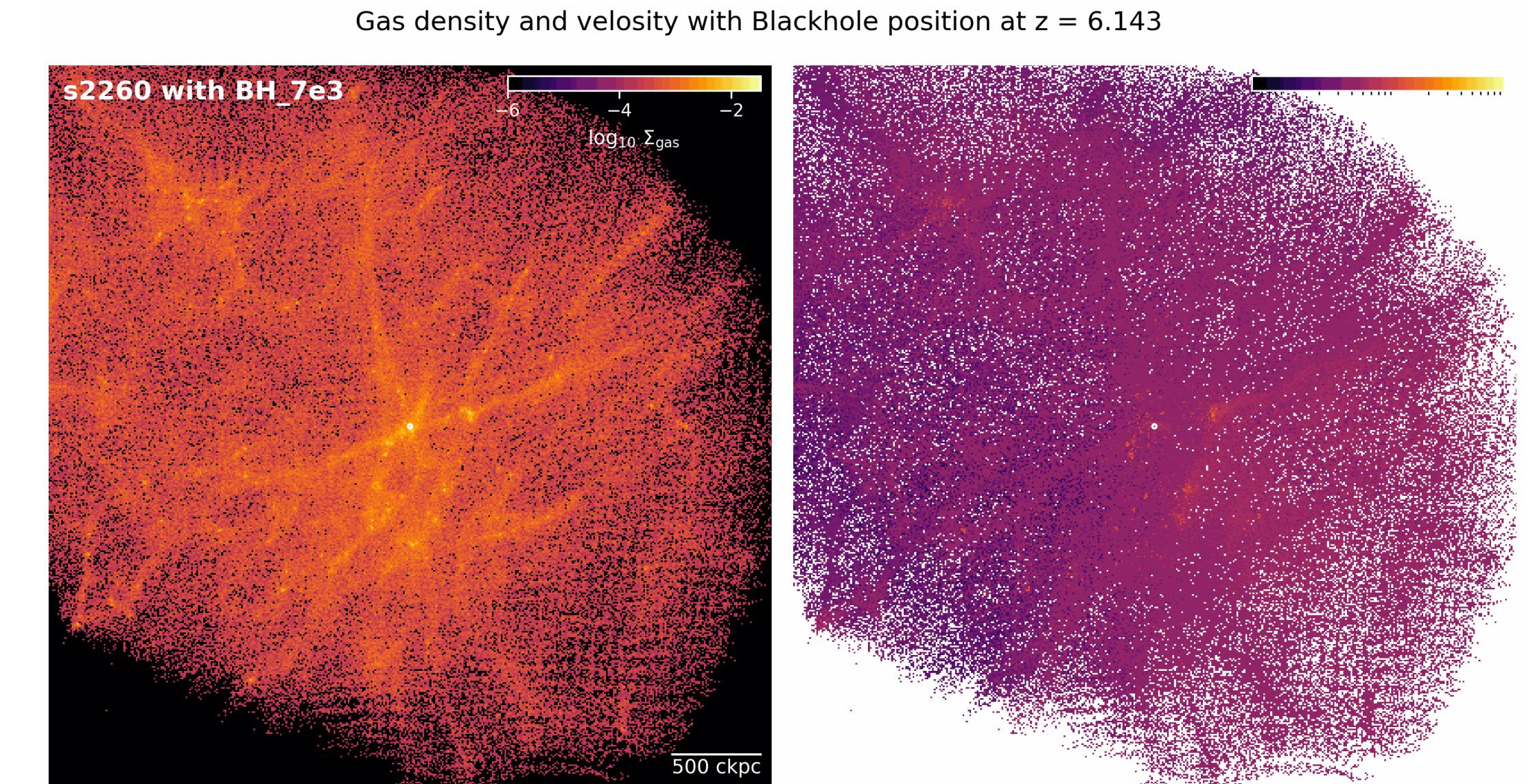
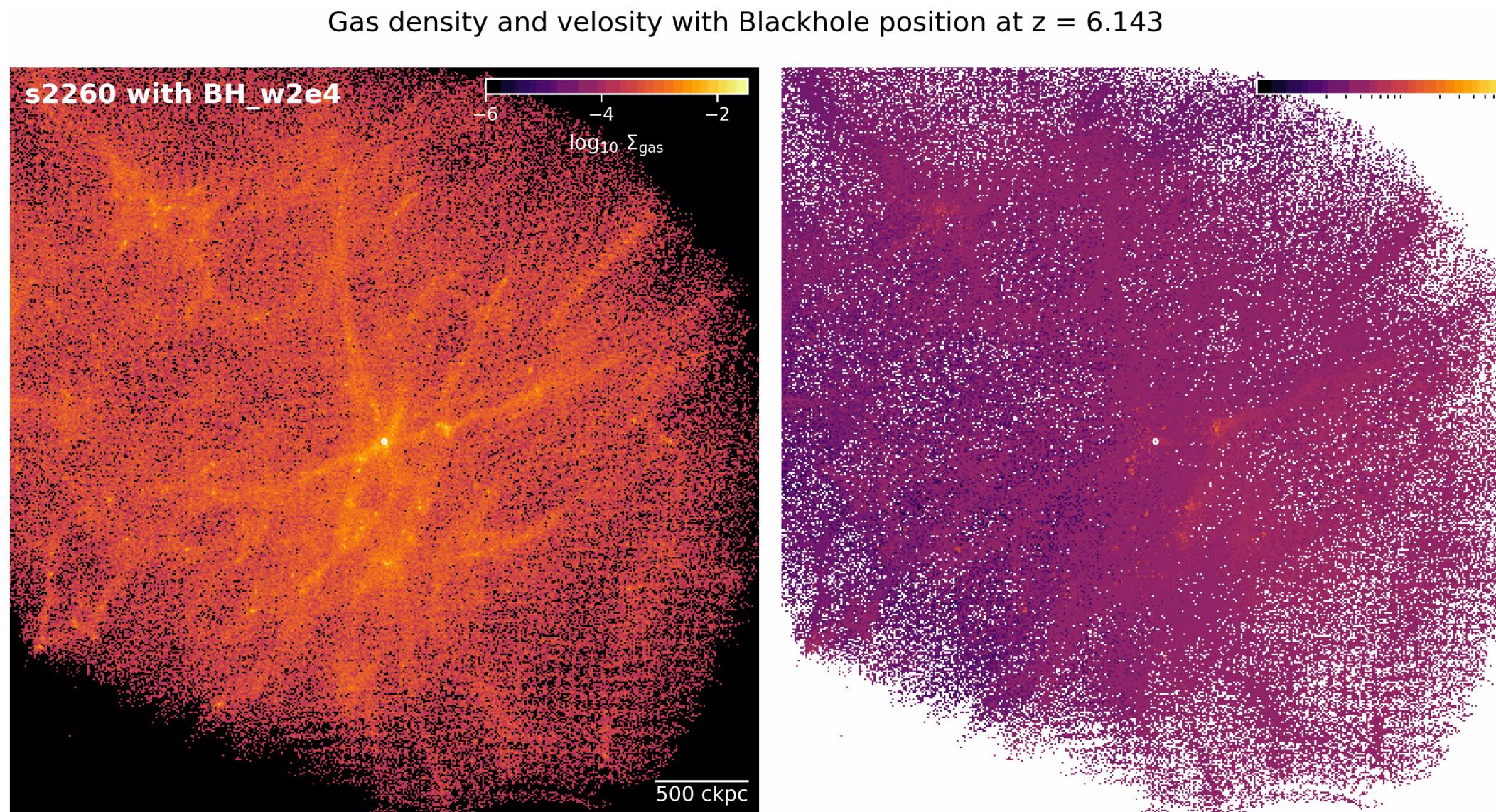
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models



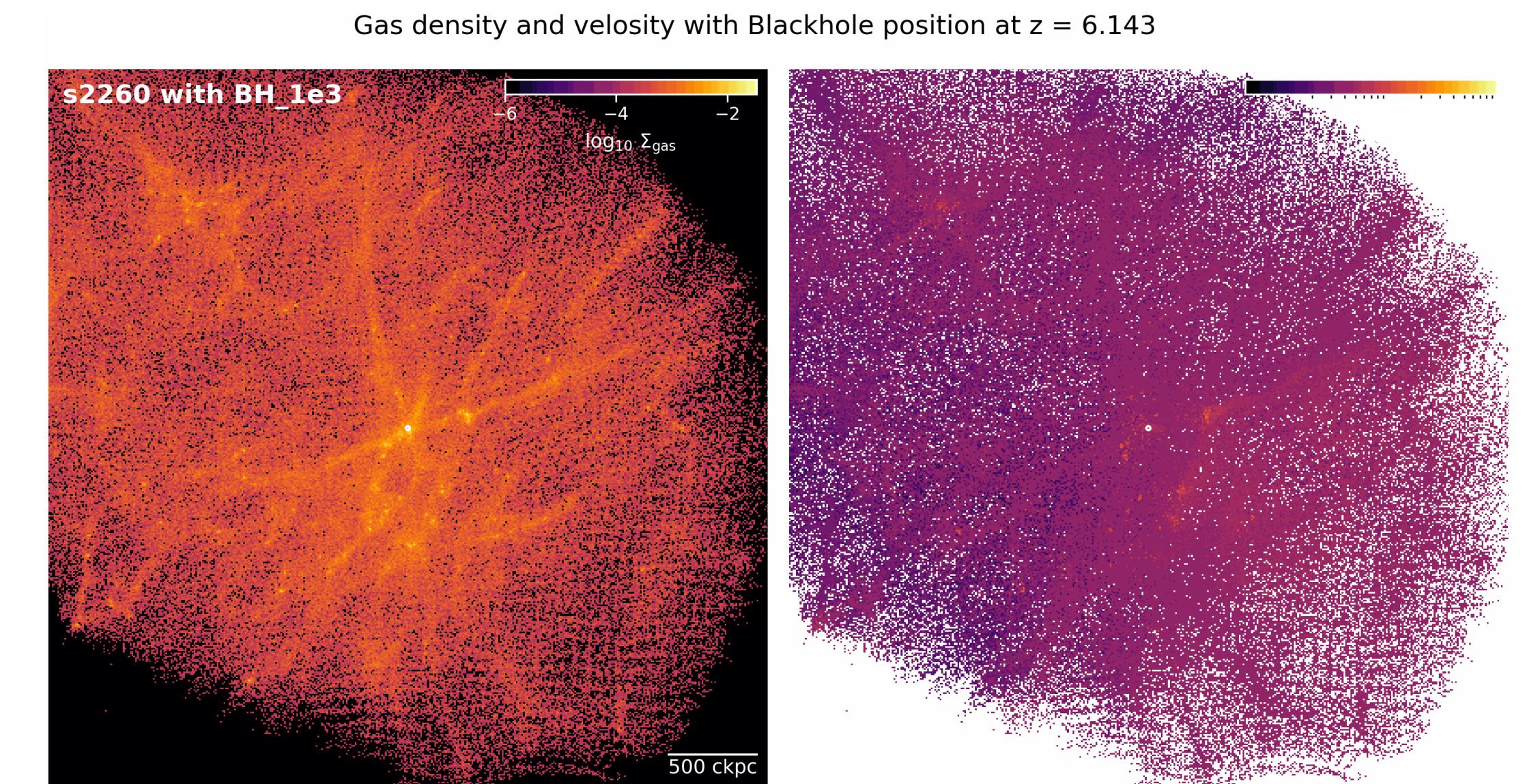
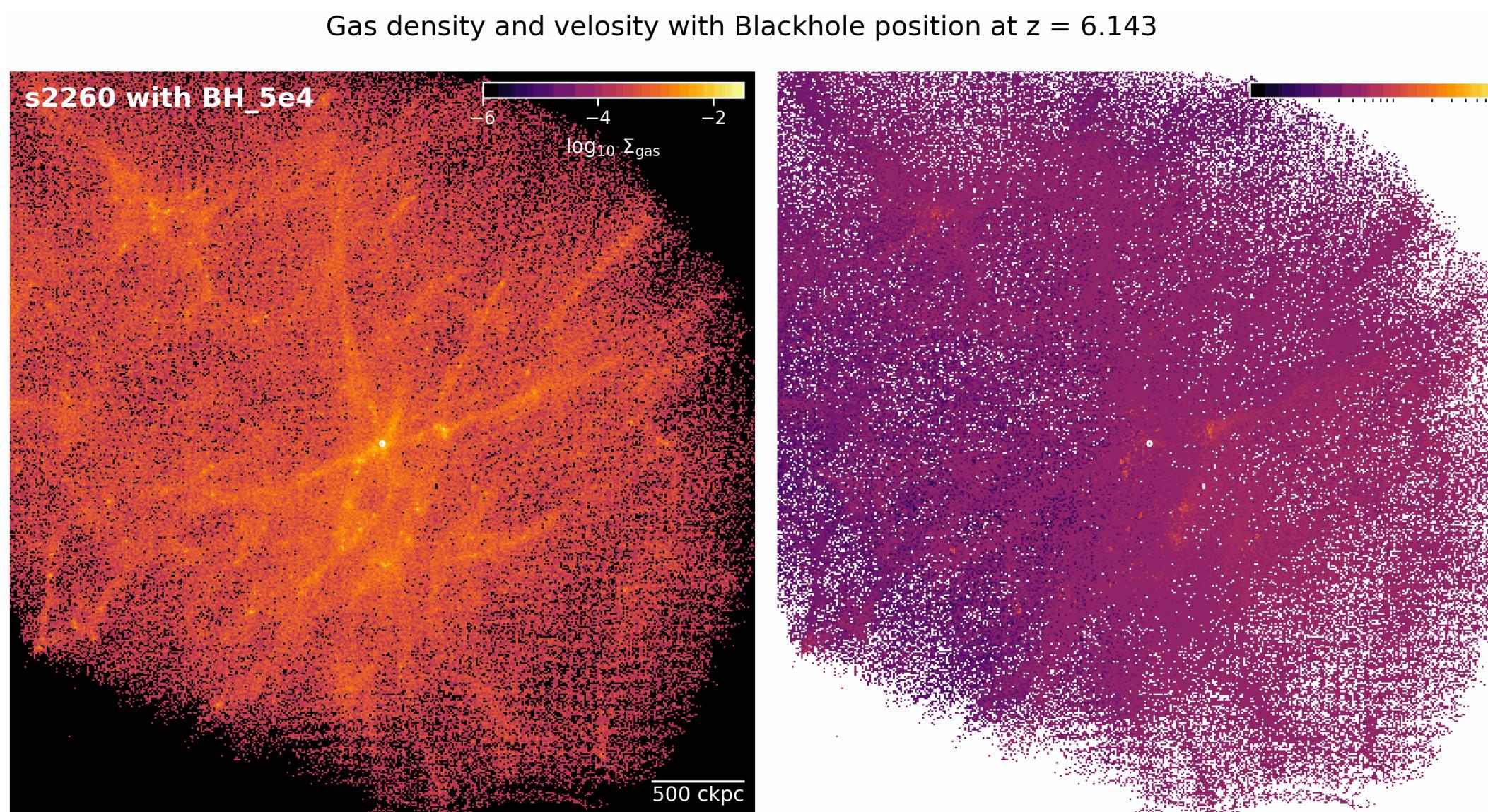
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models



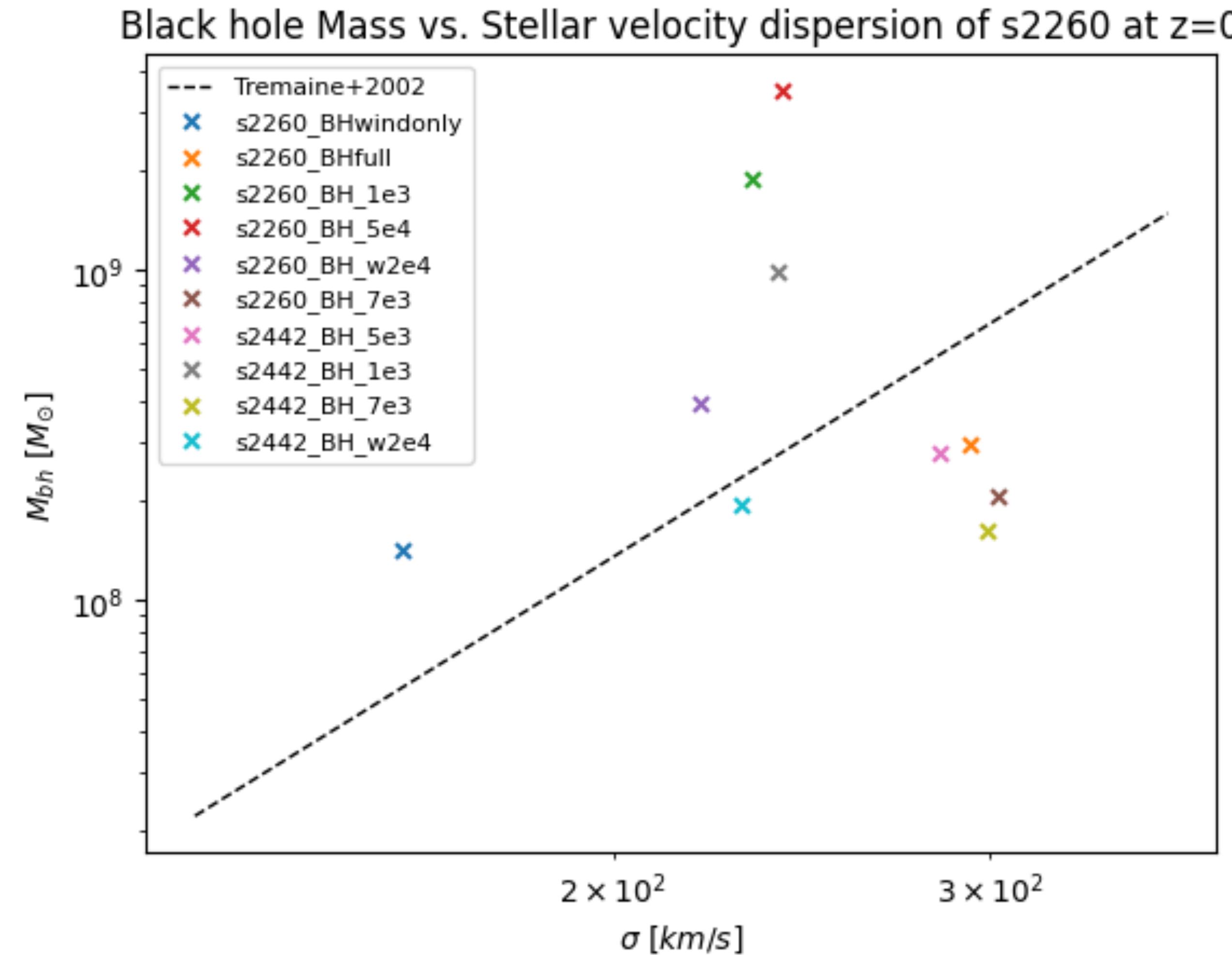
High-z Quenched Galaxy Formation with New Zoom-in ICs

s2260 with Different BH Models



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

s2260 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.