

The Coevolution of Dwarf Galaxies and Their Circumgalactic Medium Across Cosmic Time

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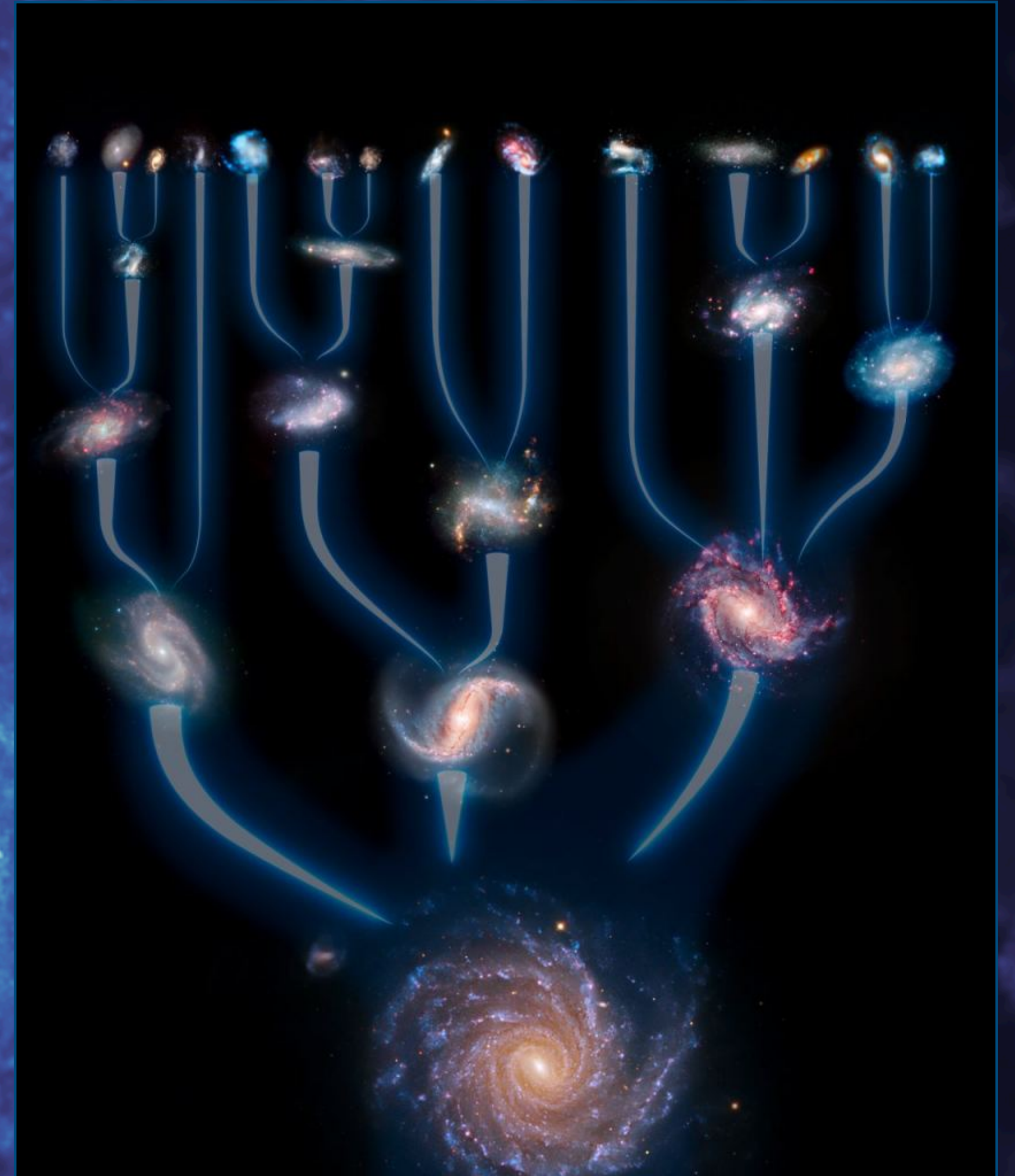
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10th East Asia Numerical Astrophysics Meeting · Jeju, South Korea



Introduction

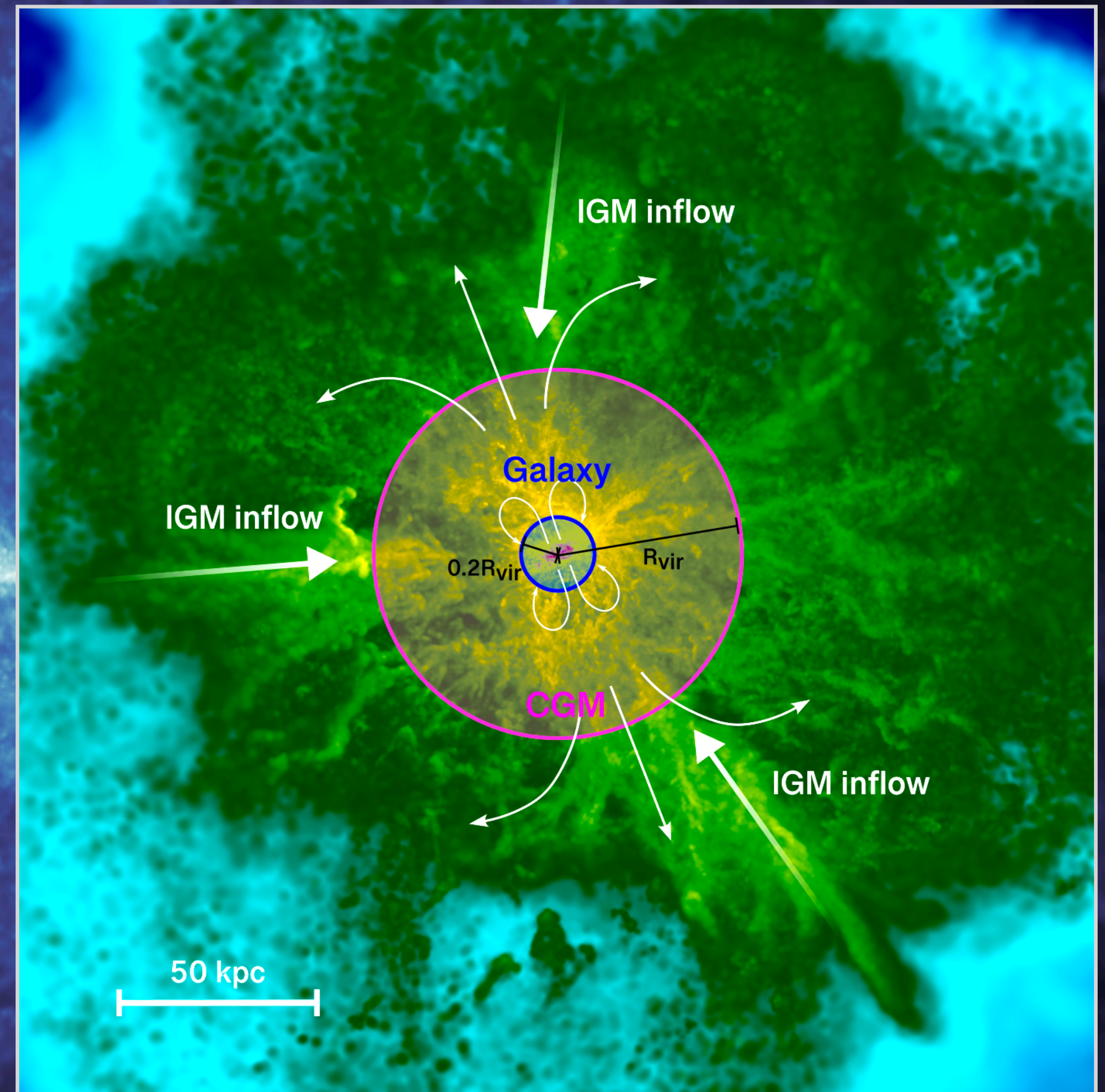
- Hierarchical galaxy formation
- **Dwarf galaxy** ($M_{\star} < 10^{10} M_{\odot}$)
 - **Building blocks** of the larger systems
 - **Sensitive** to feedback and environment



Credit: ESA/NASA

Introduction

- Coevolution with ambient gas:
- Multiphase Circumgalactic medium (CGM)
- Cold accretion from intergalactic medium (IGM)
- **CGM effects amplified in dwarf galaxies!!**



Scientific Goal

- Current challenges
 - Limit resolution in cosmological runs
 - Constraints on redshift evolution of the CGM

A new high-resolution simulation model to study the coevolution of dwarf galaxies and their CGM ($z=0-2$).

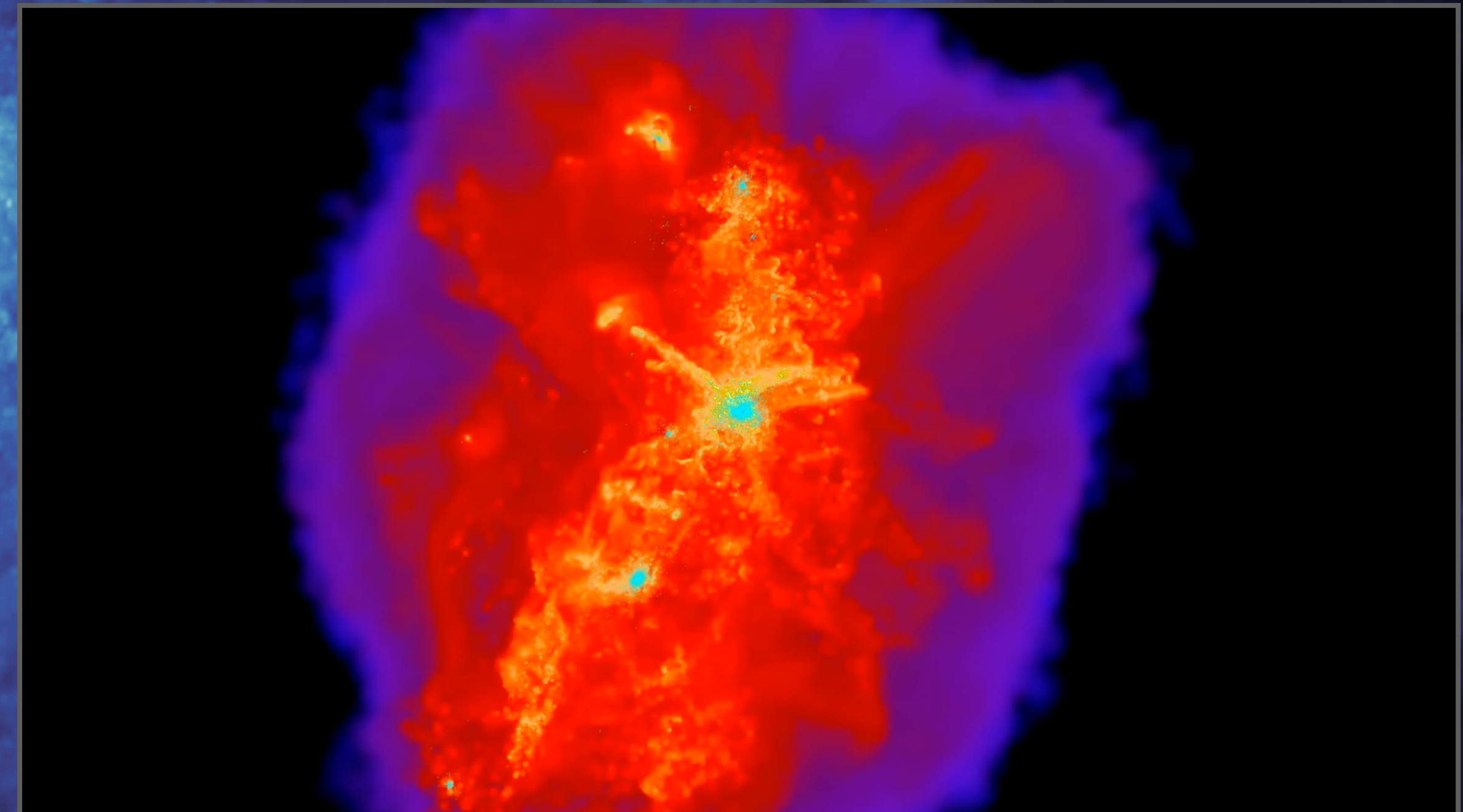
Quantitative measures

- Star formation contributed by CGM
- Gas redistribution

Methodology

A new zoom-in method!!

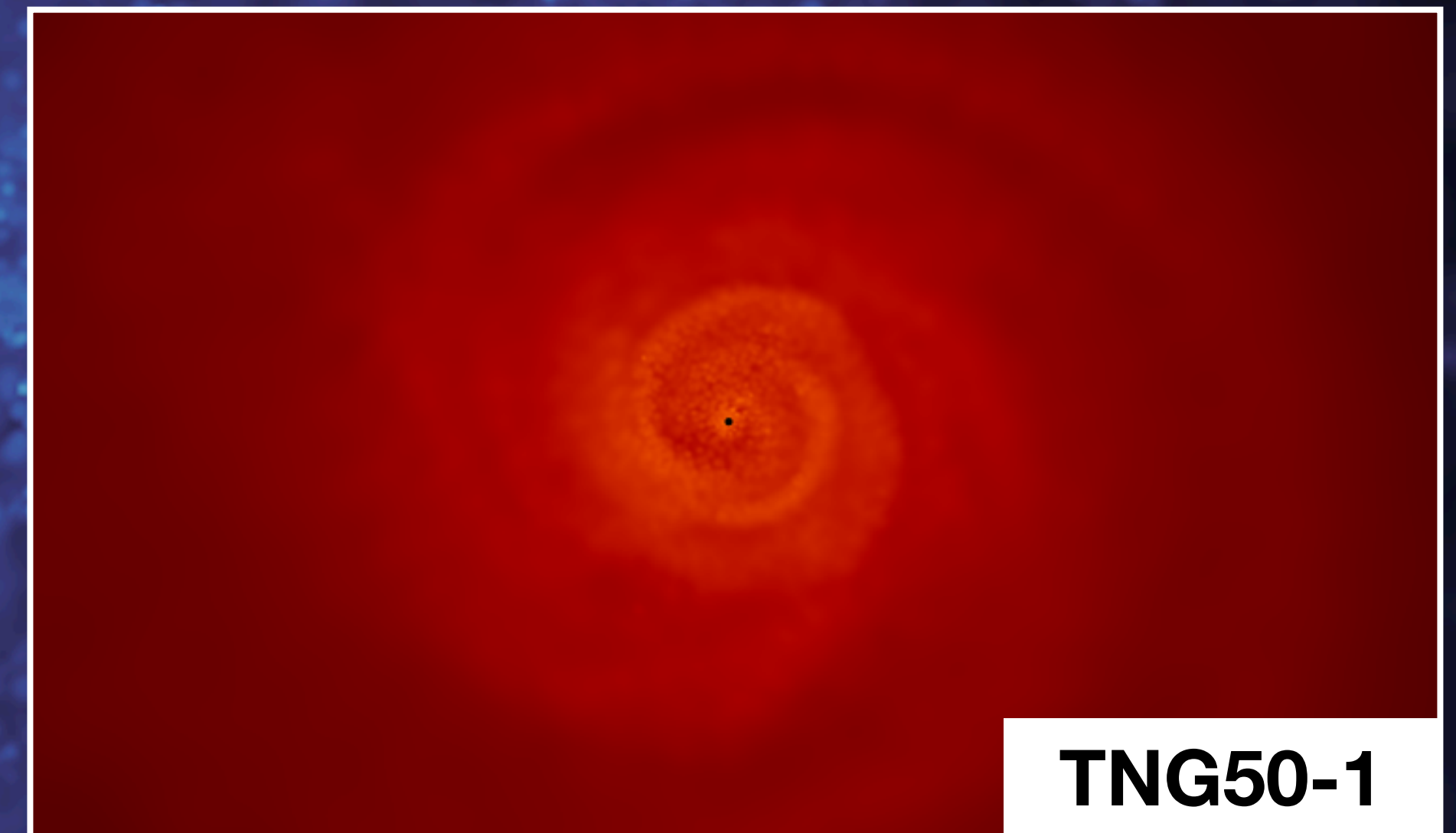
1. Dwarf galaxies of $M_{\text{vir}} = 2 - 5 \times 10^{10} M_{\odot}$
from *IllustrisTNG*
2. Choose 2 samples from $z = 0, 1, 2$
 - Gas-rich & star-forming
3. Include region $> 3R_{\text{vir}}$
4. Evolve for 1.5 Gyr with *GIZMO* code



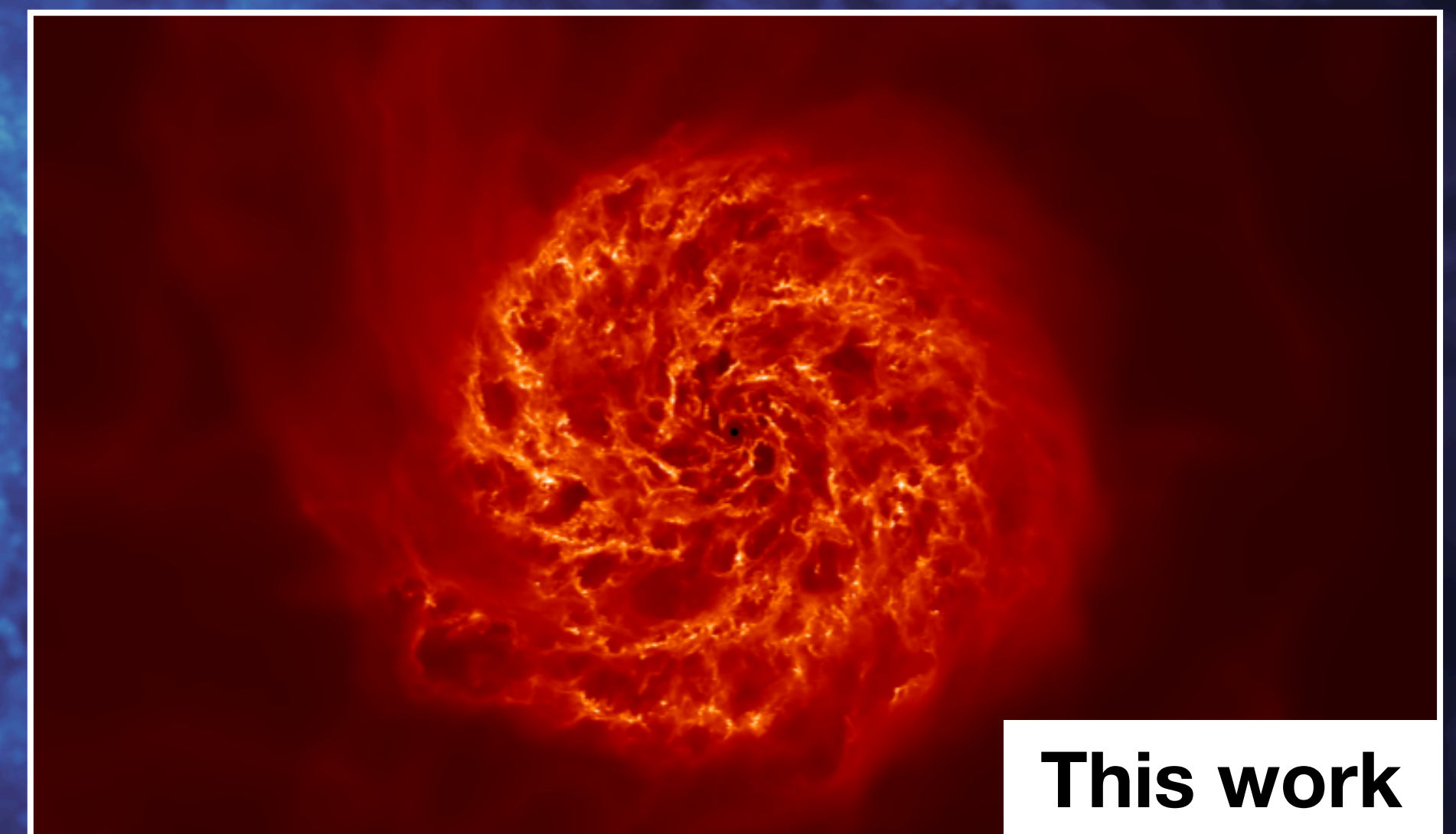
Methodology

Refinement

- **Super-Lagrangian** refinement (particle splitting)
- **Radial hierarchy** refinement
- Increase by $\times 2$ every 50 ckpc toward the center



↓ $\times 100$ resolution

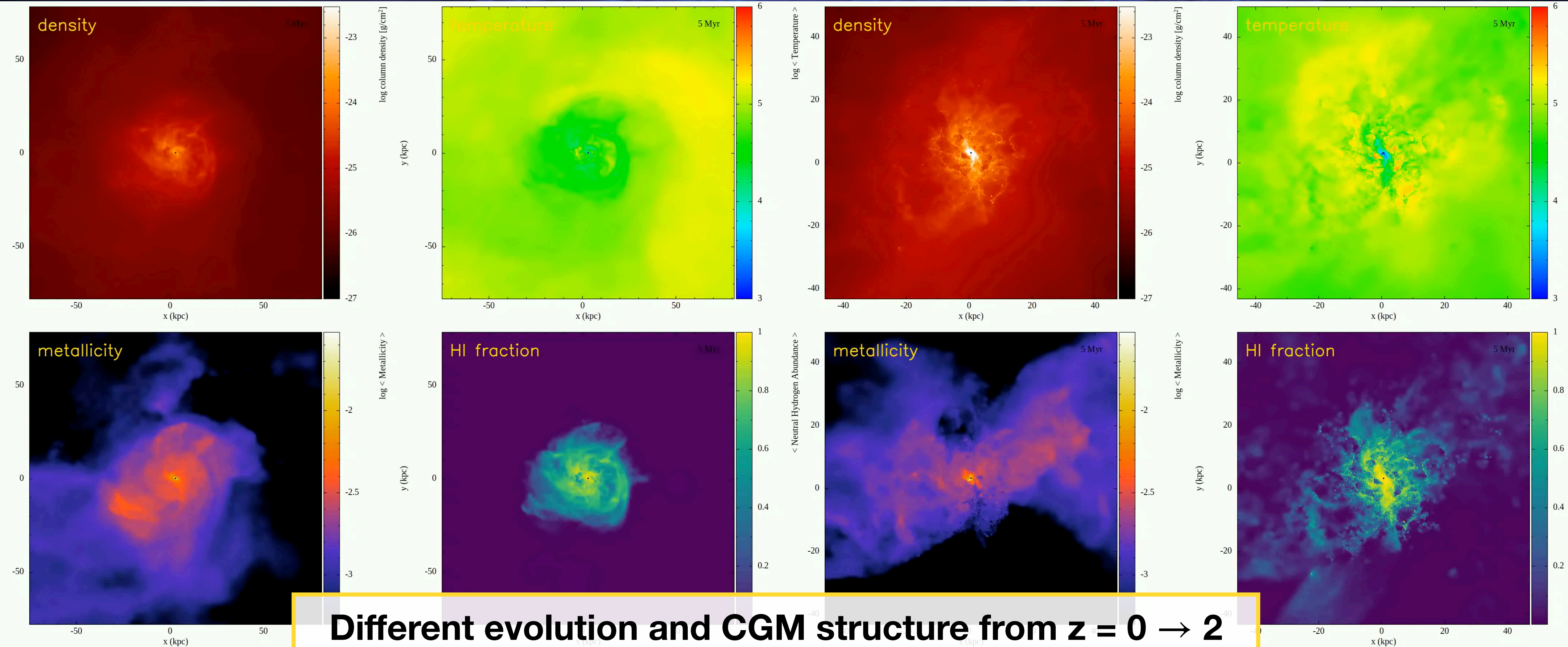


Galaxy Evolution (Halo scale)

Density	Temperature
Metallicity	HI fraction

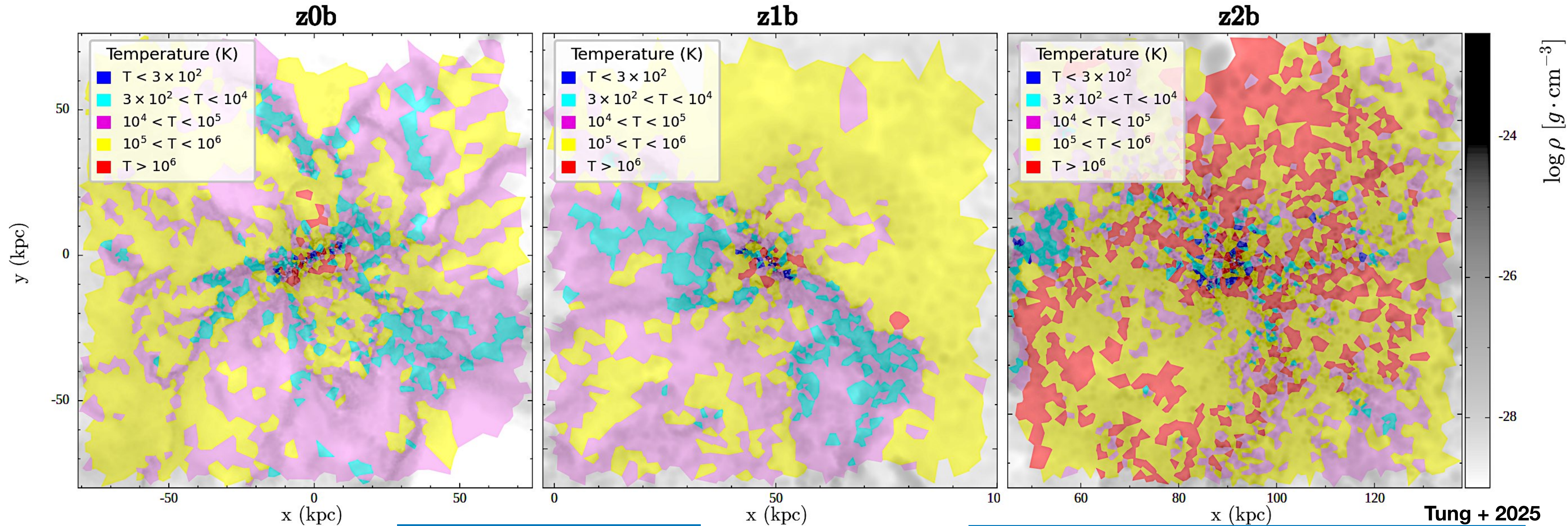
Dwarf galaxy at $z = 0$ (z0b)

Dwarf galaxy at $z = 2$ (z2b)



Multiphase CGM

Density & Temperature

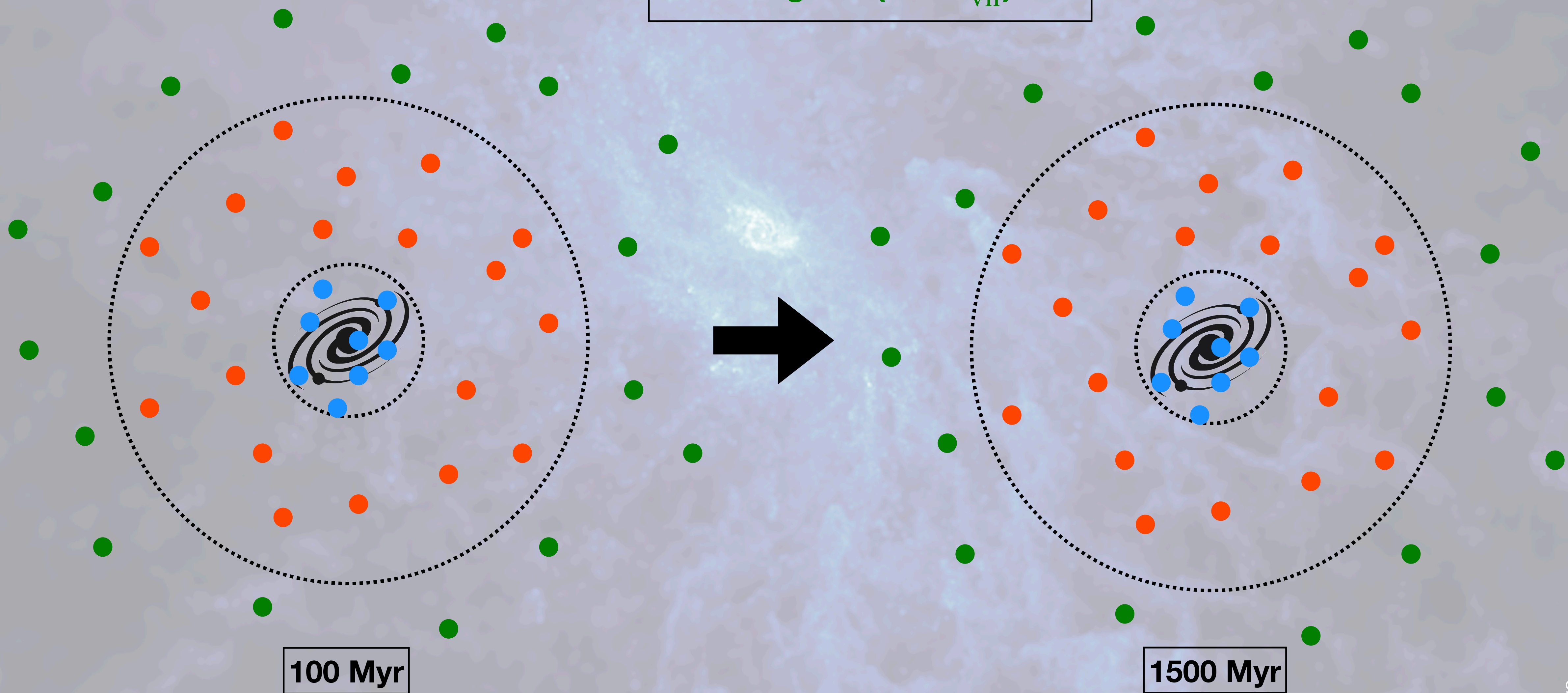


z = 0, 1: cold

z = 2: hotter and mixed phases

Gas Contribution

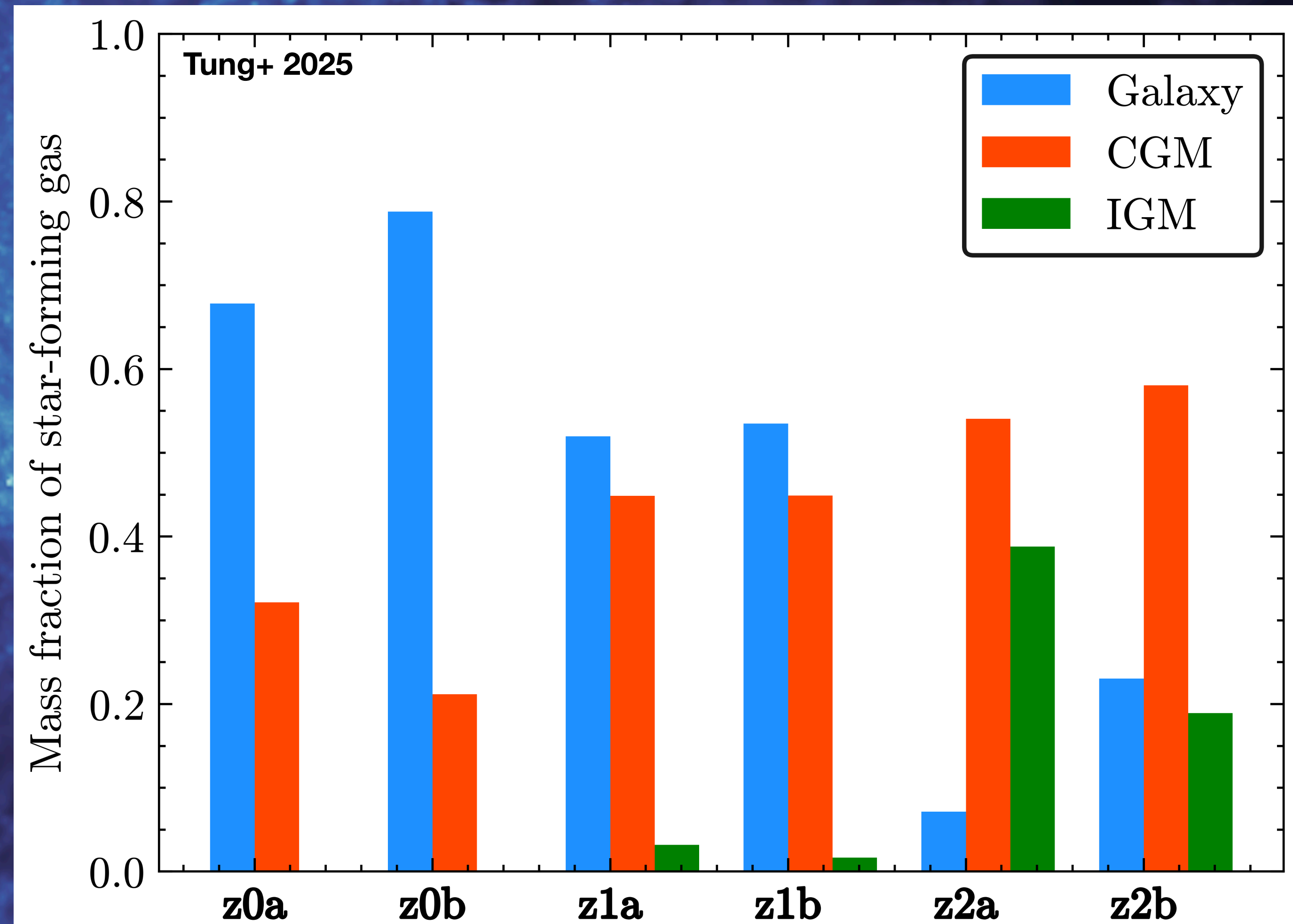
- Galaxy gas ($< 0.2 R_{\text{vir}}$)
- CGM gas ($0.2 \sim 1 R_{\text{vir}}$)
- IGM gas ($> 1 R_{\text{vir}}$)



Gas Contribution

Star-forming gas

- **CGM** is always an important source: 20% - 50%
- At $z = 2$, gas from **Galaxy** is subdominant due to strong accretion and outflow
- Gas from **IGM**: 20% - 40%



Gas Contribution

Gas mass inside the galaxy

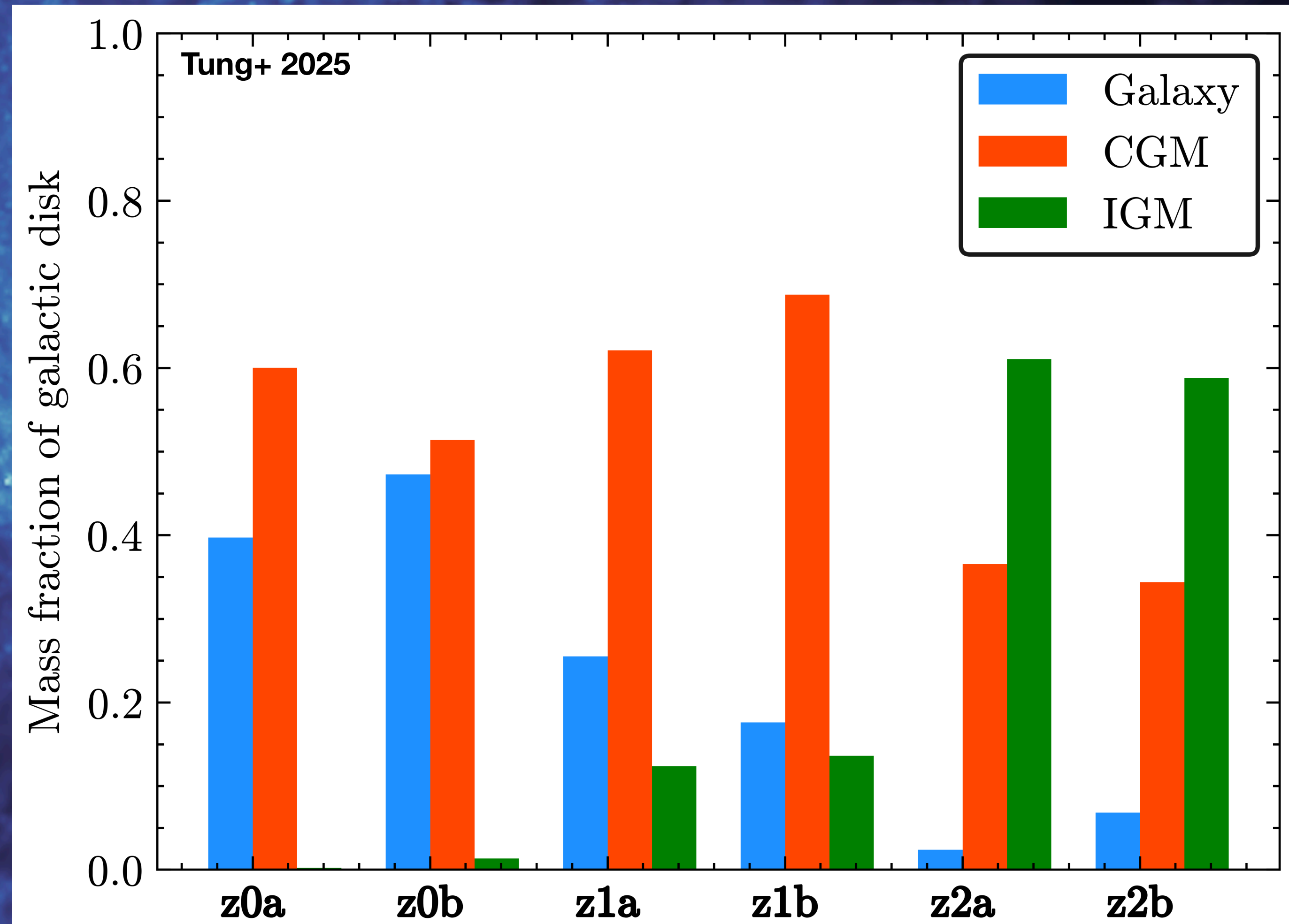
$z = 0, 1$:

- **CGM** dominates the gas mass: 40% - 70 %

$z = 2$:

- **IGM** dominates the gas mass: ~ 60 %

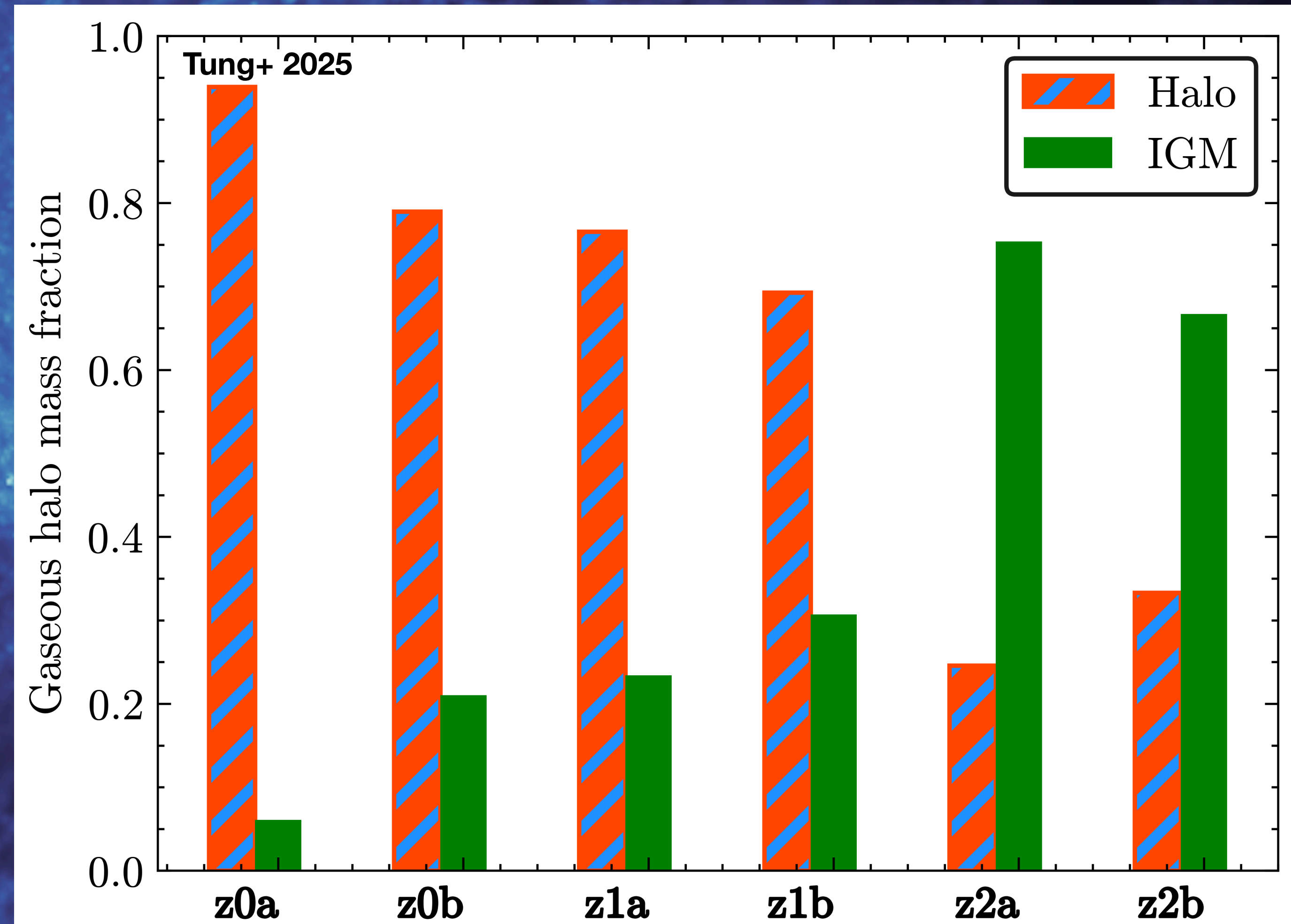
Most of the gas in the galaxy has been replenished or redistributed



Gas Contribution

Gas mass inside the halo

- Gas recycling dominates the halo at $z = 0, 1$
- Gas reservoir replenished by IGM at $z = 2$ (60% - 70%)

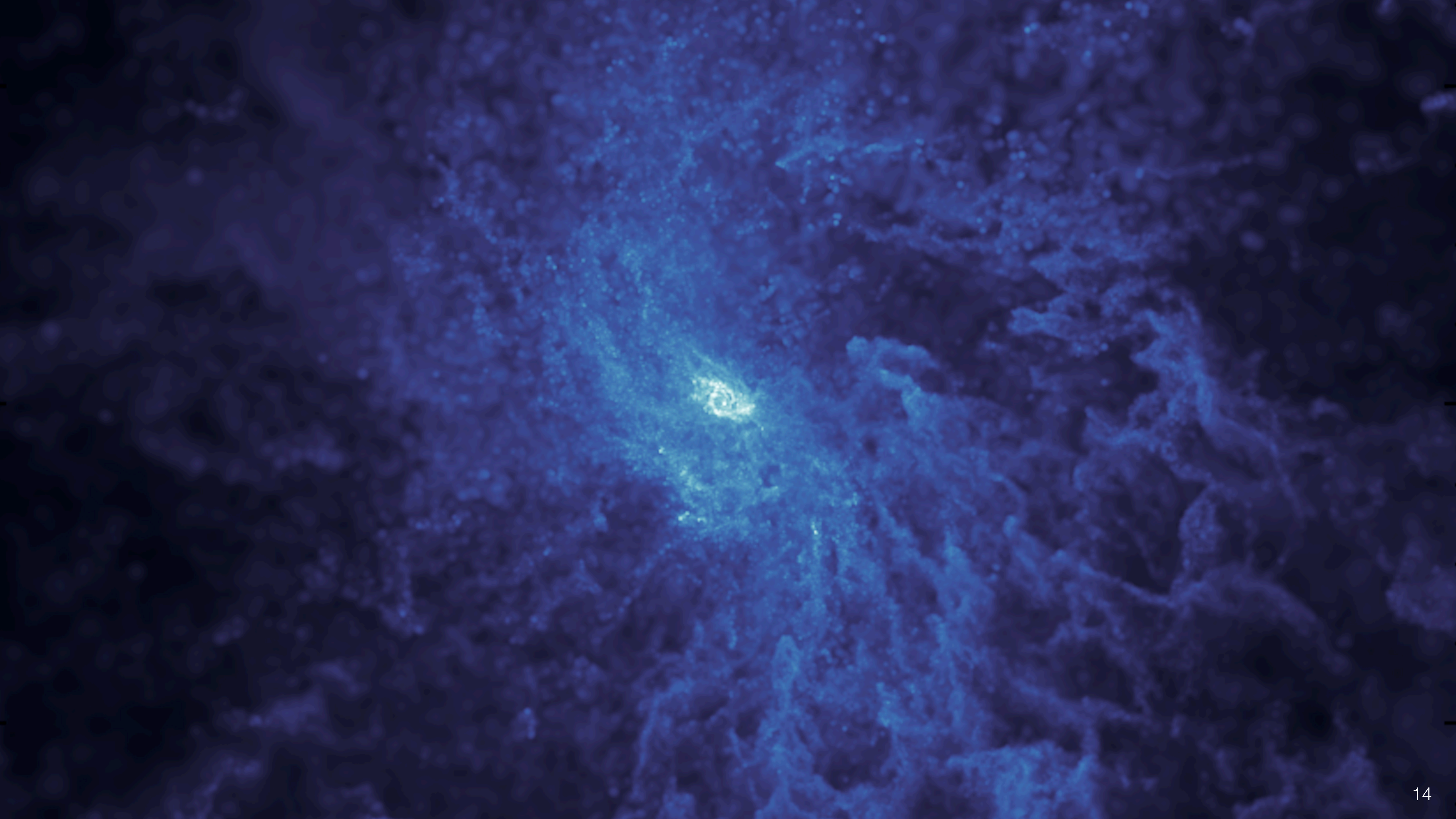


Summary

- A new zoom-in simulation scheme with super-Lagrangian refinement from TNG50-1
- Redshift dependence of the multiphase CGM and metal distribution
- **CGM** is an important source for both star formation (**20% - 50%**) and the gas disk (**40% - 70%**) across different redshift.
- Gas from the **IGM** is more sensitive to redshift. The effect is significant at $z = 2$ with **20% - 40%** of the total star formation and **60% - 70%** of the gas disk



Tung+ 2025

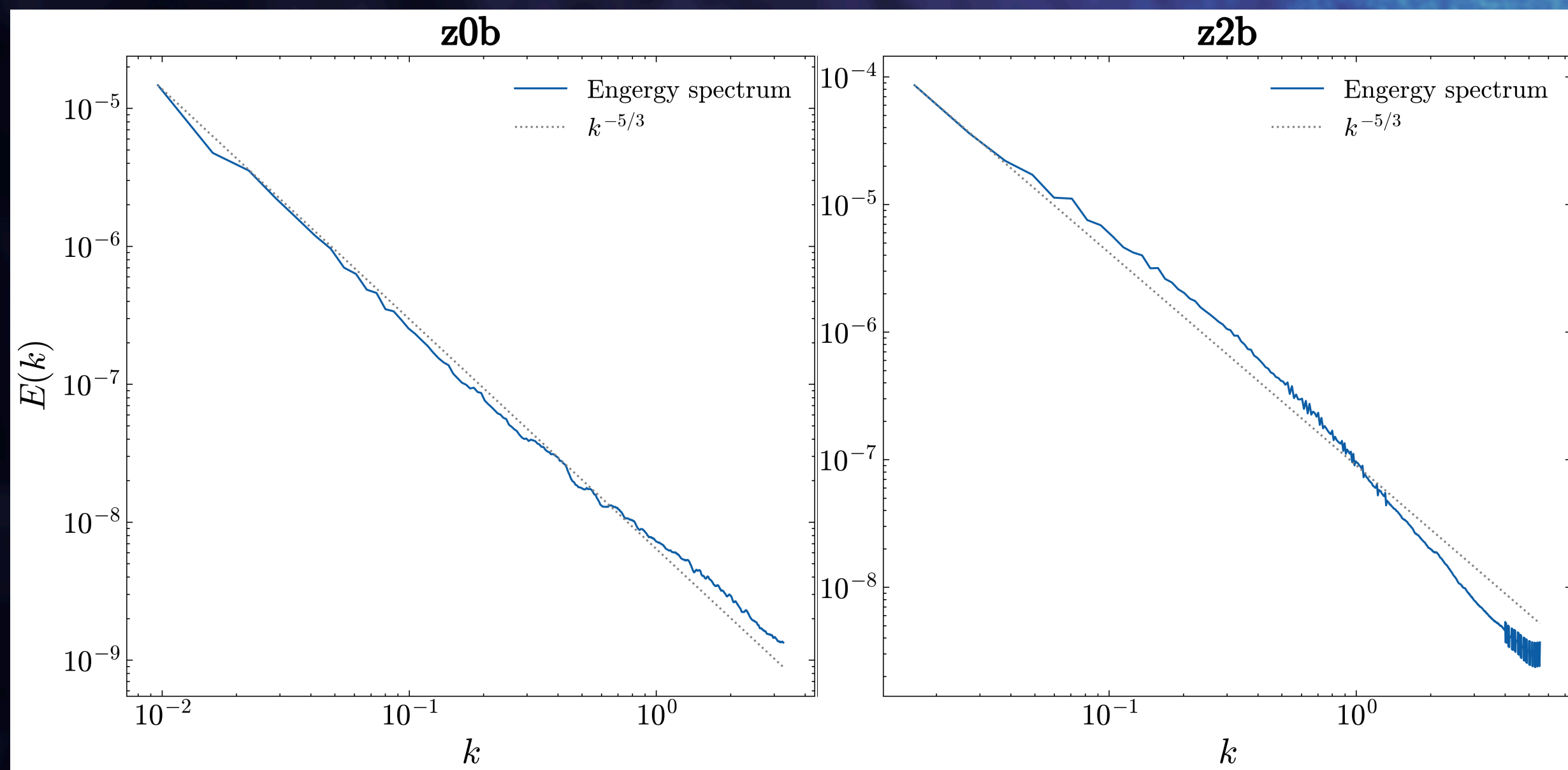


Redshift Evolution of the CGM

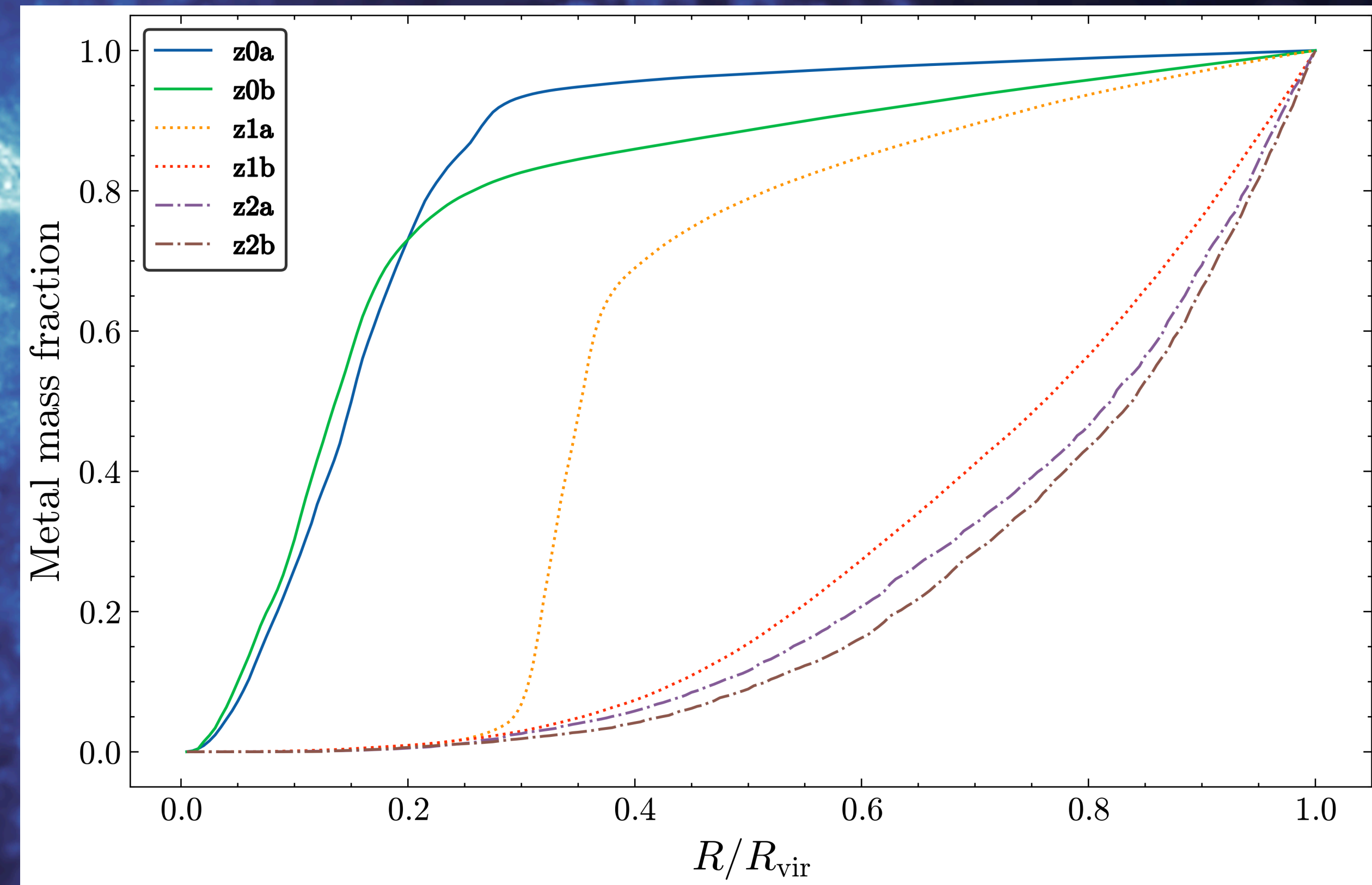
Turbulence & Metal distribution

- Turbulent CGM
 - Subsonic turbulence: $k \propto -5/3$
- Well-mixed CGM at $z = 0$

- Transition of metal distribution at $z = 1$



Kolmogorov energy spectrum



Accumulated metal-mass fraction inside halos