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

Pei-Cheng Tung

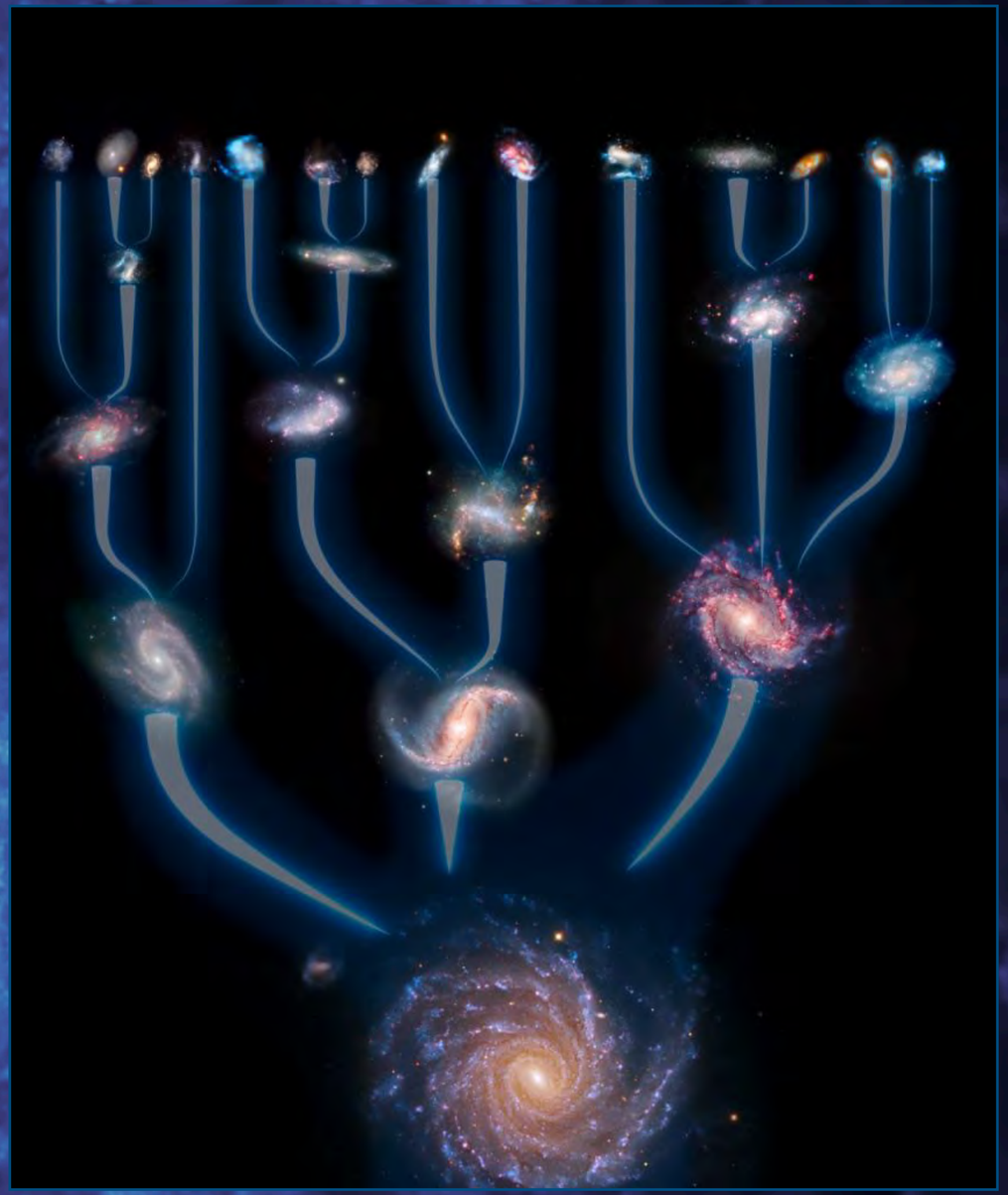
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Introduction

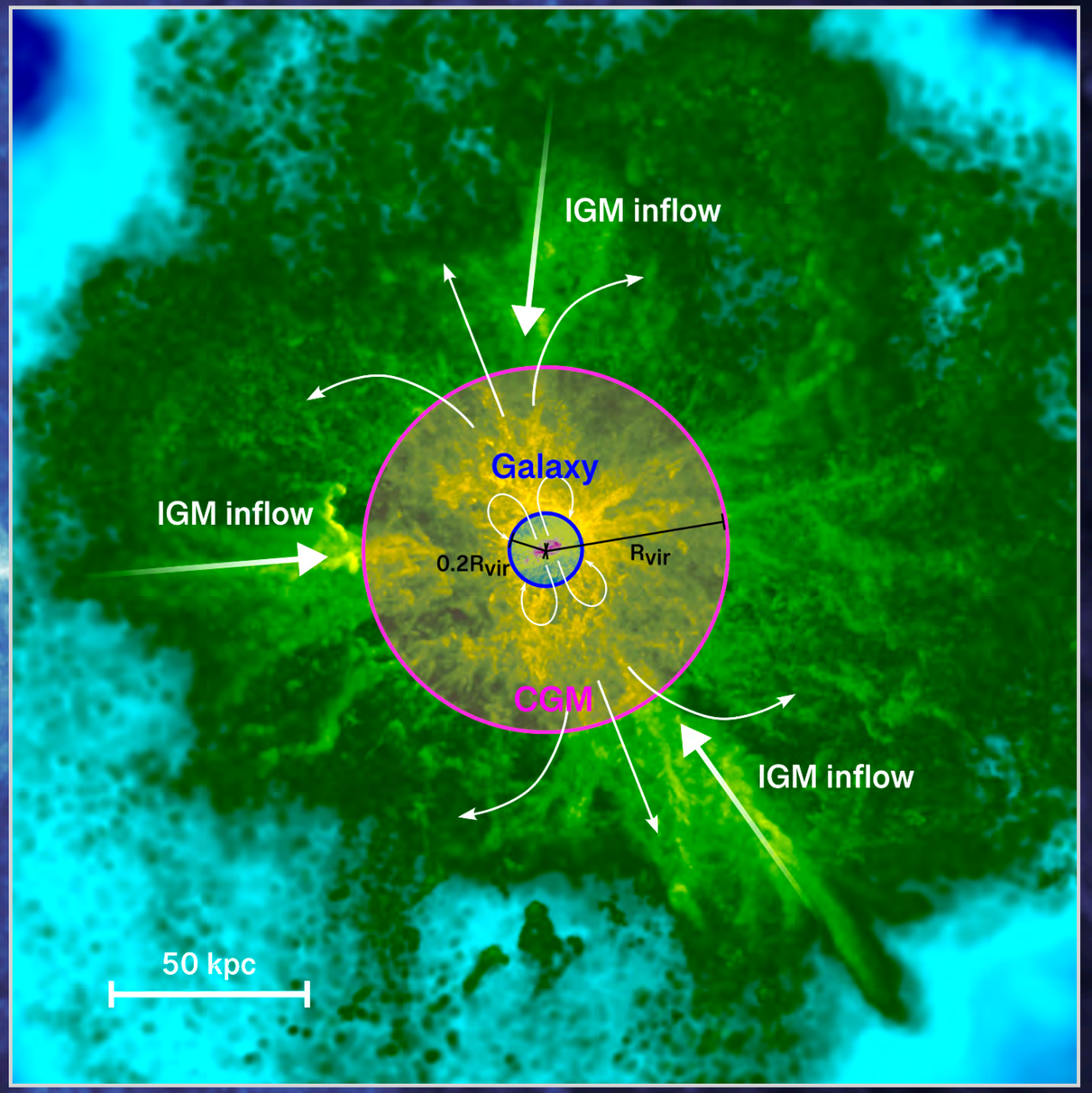
- Hierarchical galaxy formation
- Dwarf galaxy ($M_\star < 10^{10} M_\odot$)
  - Building blocks of the larger systems
  - Sensitive to feedback and environment



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).

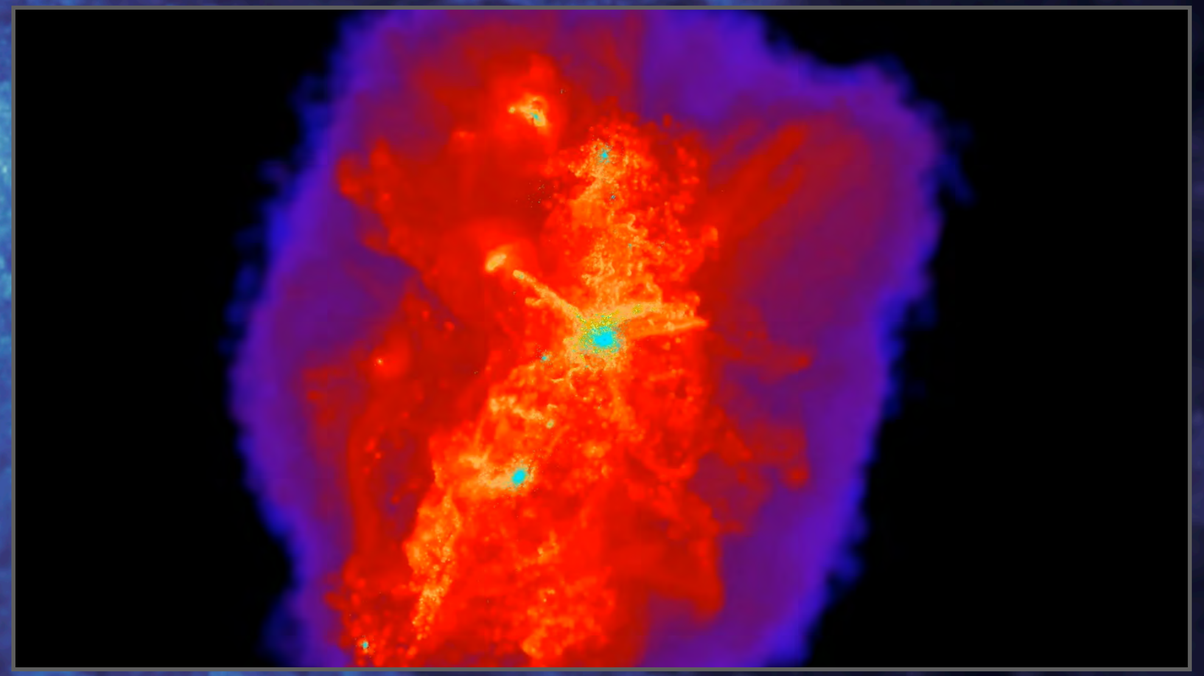
Quantitative measures

- Star formation contributed by CGM
- Gas redistribution

Methodology

A new zoom-in method!!

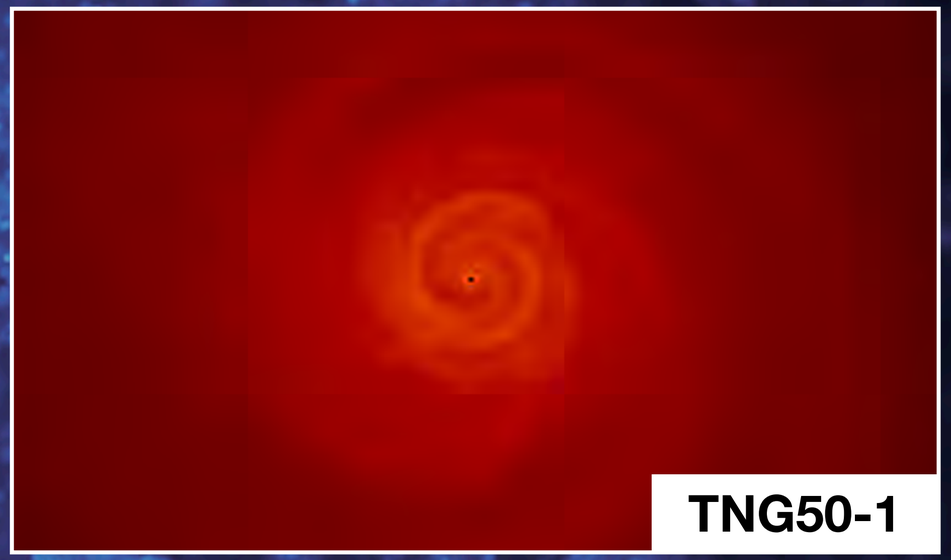
1. Dwarf galaxies of $M_{\rm vir} = 2 - 5 \times 10^{10} M_{\odot}$ from ***IllustrisTNG***
2. Choose 2 samples from z = 0, 1, 2
   - Gas-rich & star-forming
3. Include region $> 3R_{\rm vir}$
4. Evolve for 1.5 Gyr with ***GIZMO*** code



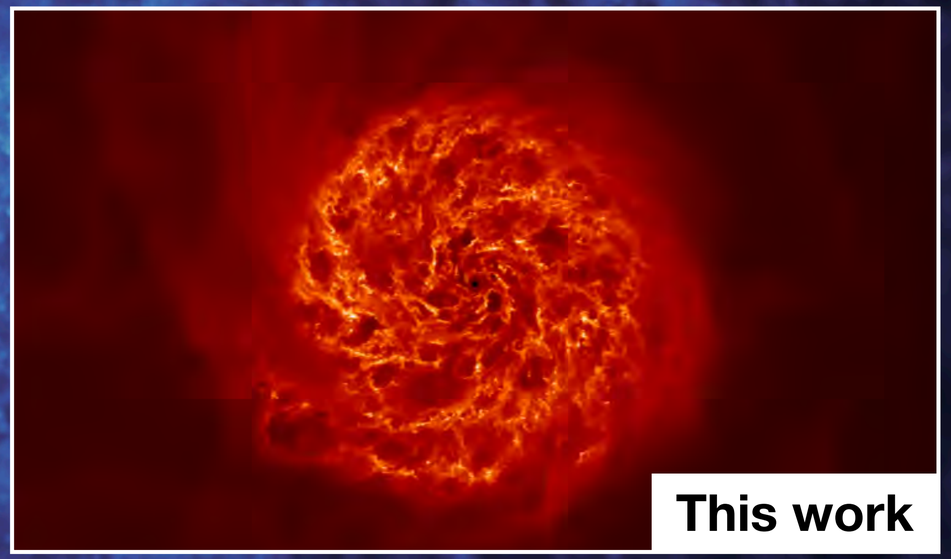
Methodology

Refinement

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



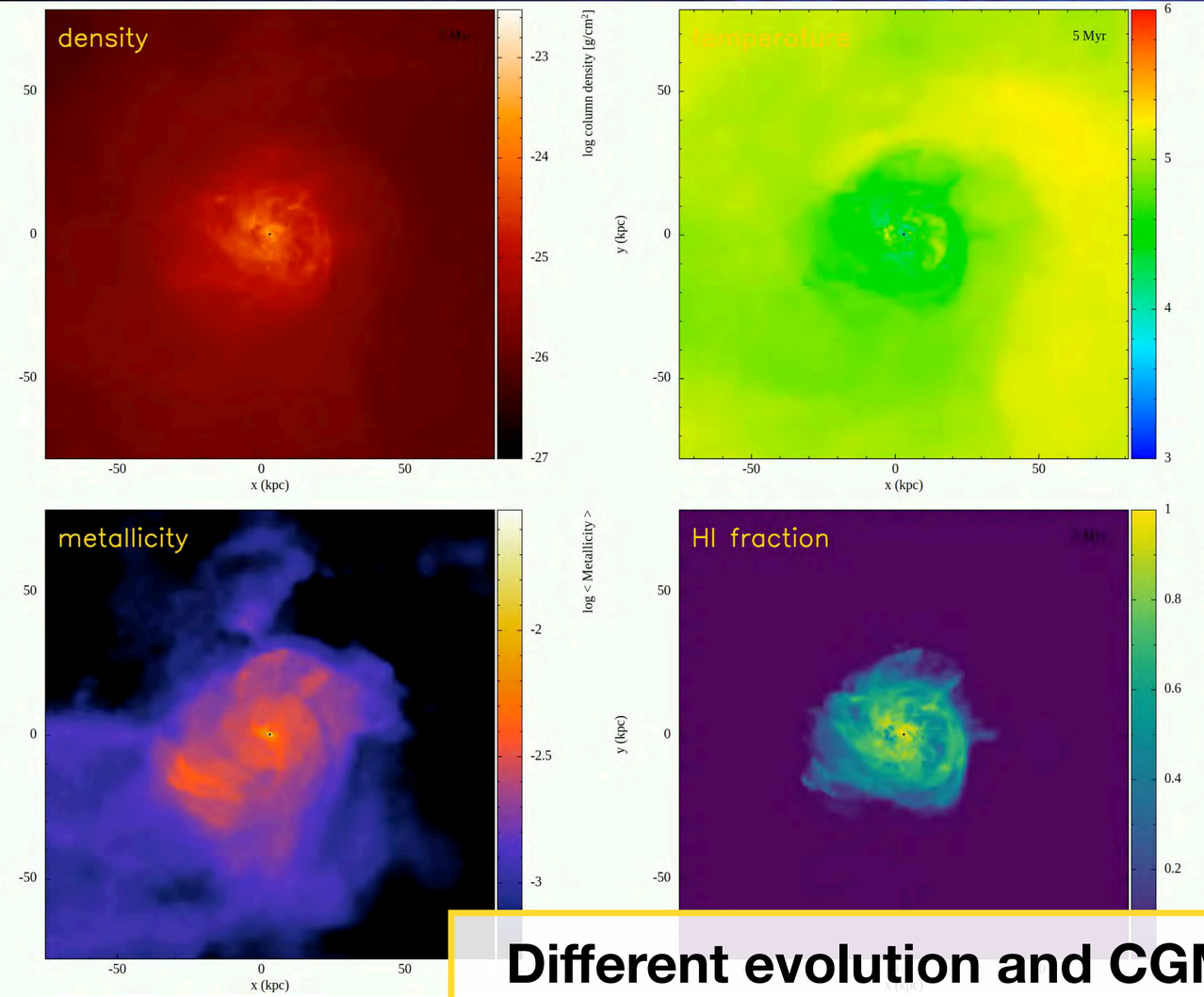
$\times 100$ resolution



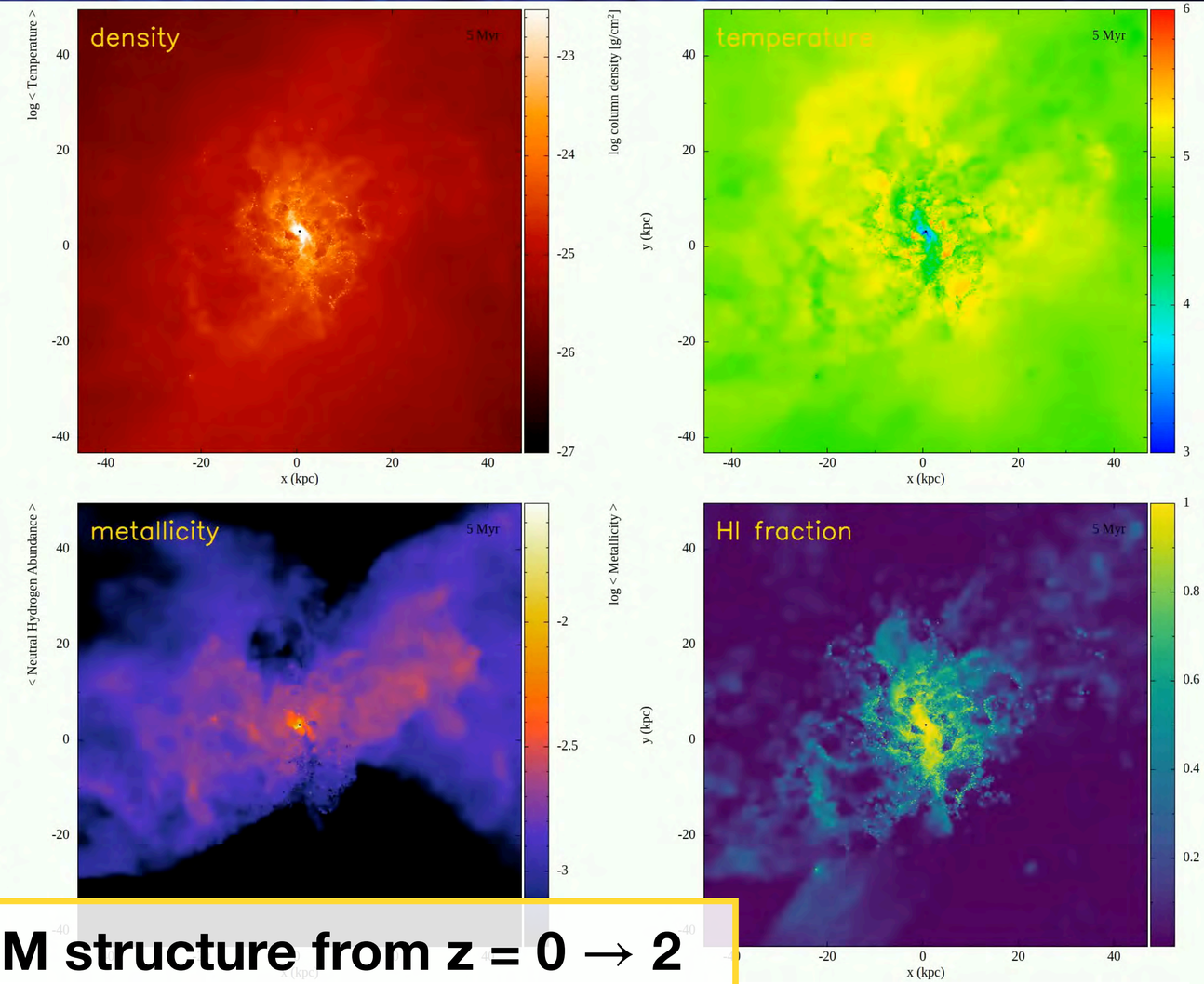
Galaxy Evolution (Halo scale)

Density	Temperature
Metallicity	HI fraction

Dwarf galaxy at z = 0 (z0b)



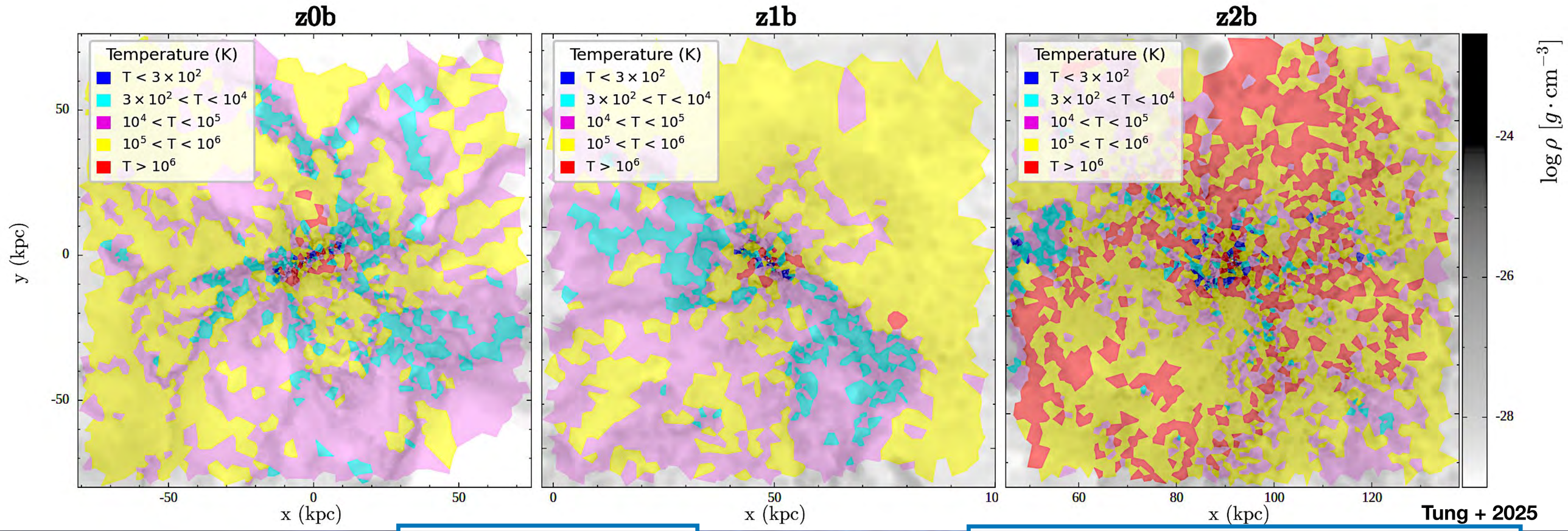
Dwarf galaxy at z = 2 (z2b)



Different evolution and CGM structure from z = 0 → 2

Multiphase CGM

Density & Temperature

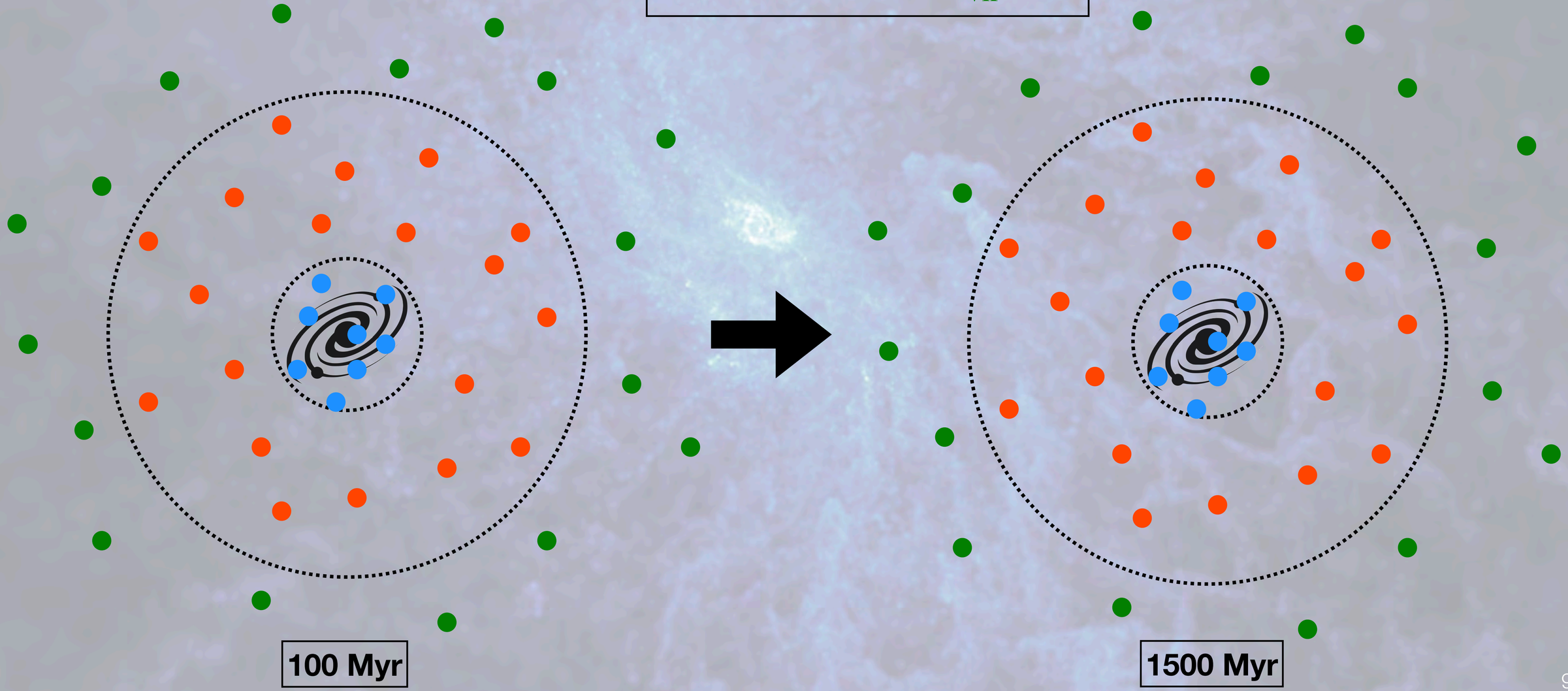


z = 0, 1: cold

z = 2: hotter and mixed phases

Gas Contribution

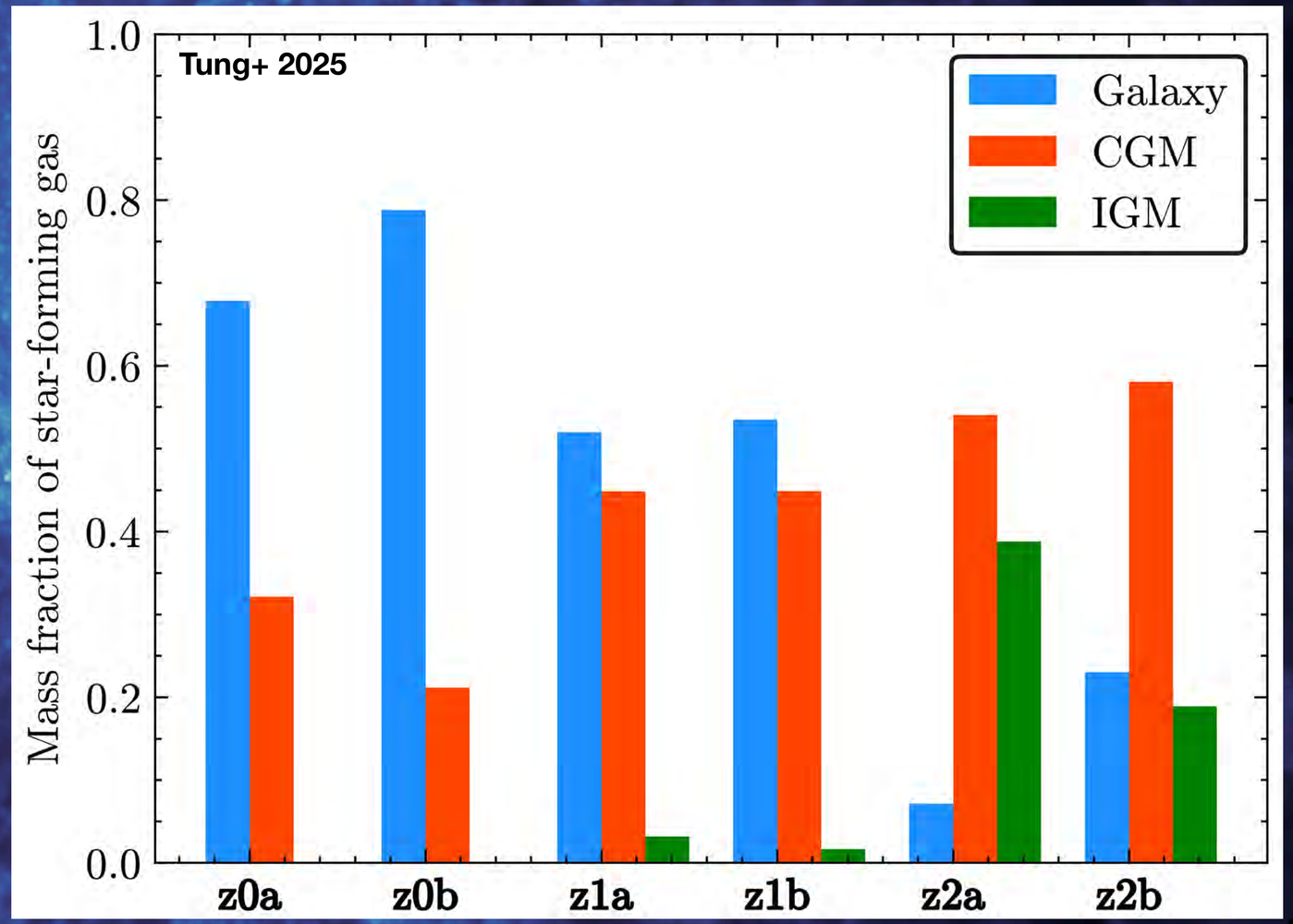
- Galaxy gas (<0.2 $R_{\rm vir}$)
- CGM gas (0.2~1 $R_{\rm vir}$)
- IGM gas (> 1 $R_{\rm vir}$)



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

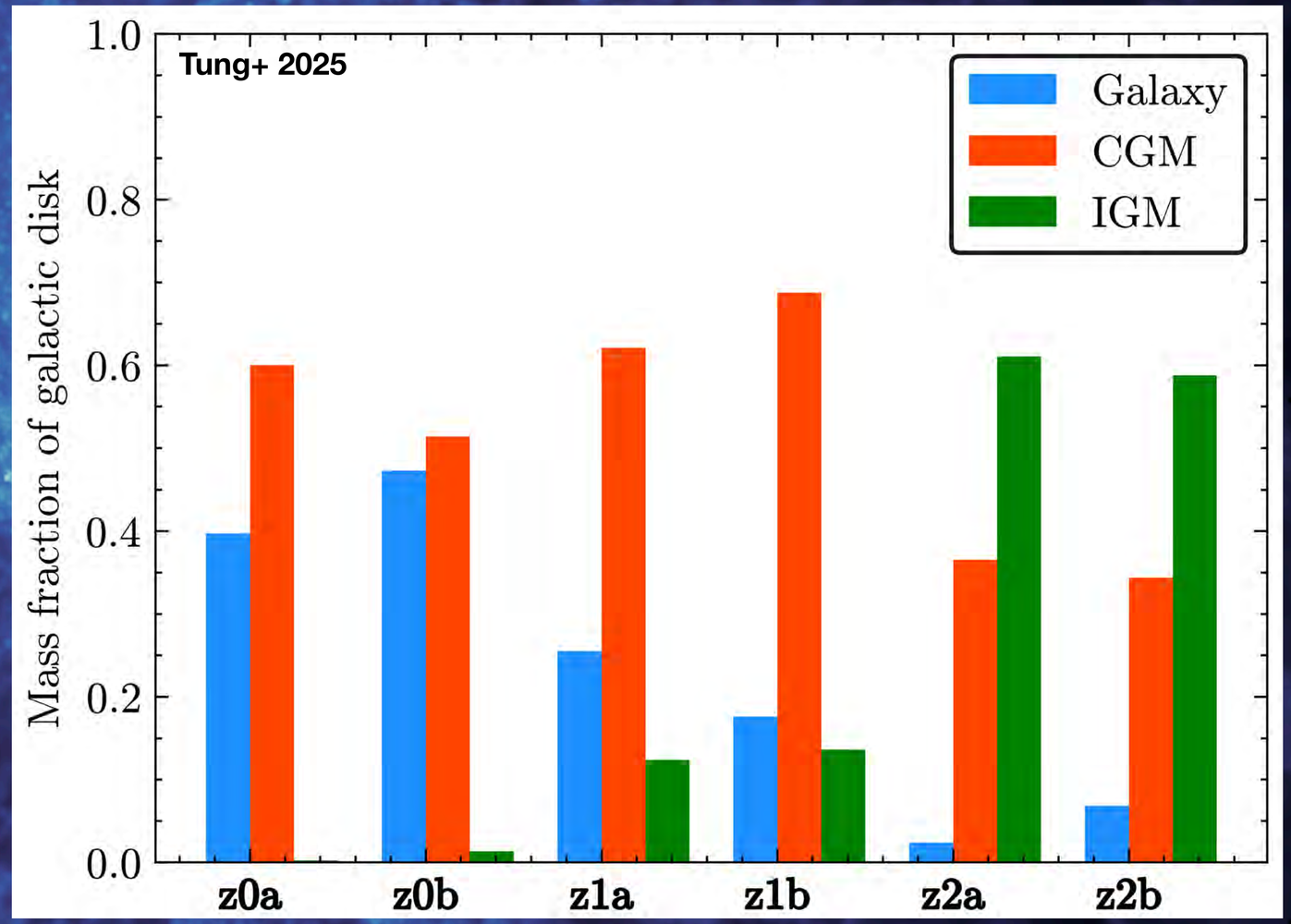
z = 0, 1:

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

z = 2:

- IGM dominates the gas mass: ~ 60 %

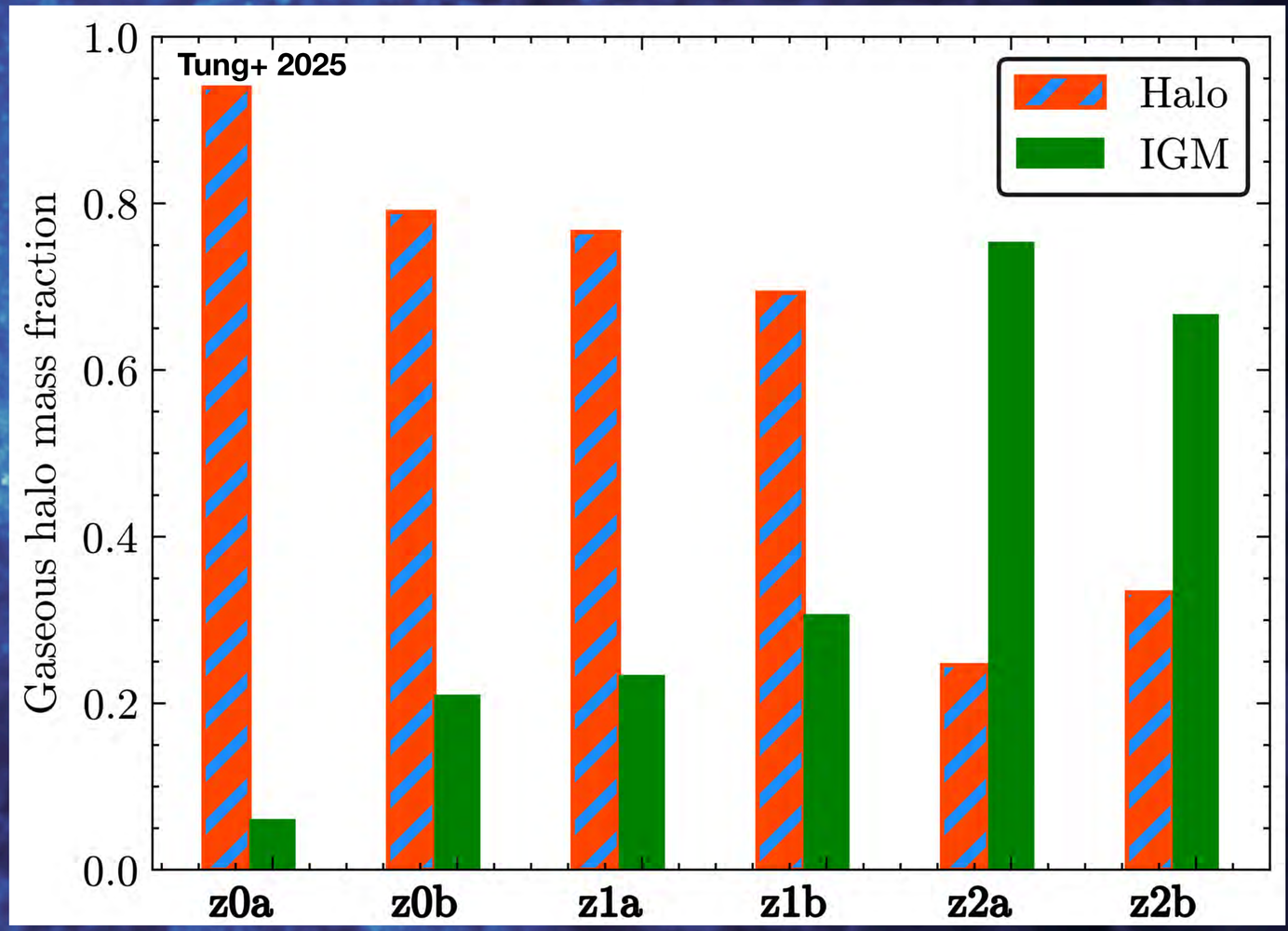
Most of the gas in the galaxy has been redistributed or replenished



Gas Contribution

Gas mass inside the halo

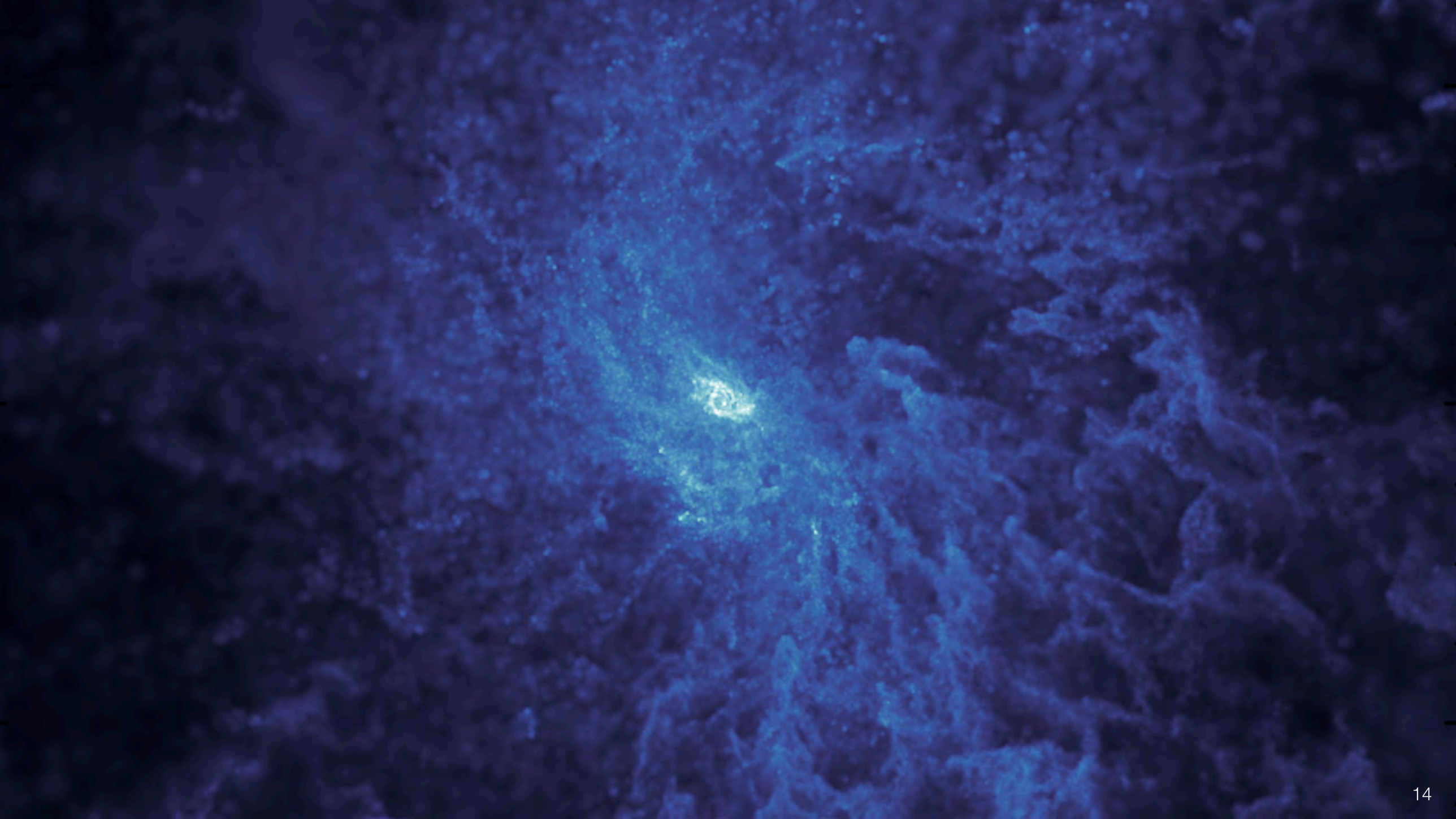
- Gas recycling dominates the halo at z = 0, 1
- Gas reservoir replenished by IGM at z = 2 (60% - 70%)



Summary

- A new zoom-in simulation scheme with super-Lagrangian refinement from TNG50-1
- Redshift depence 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

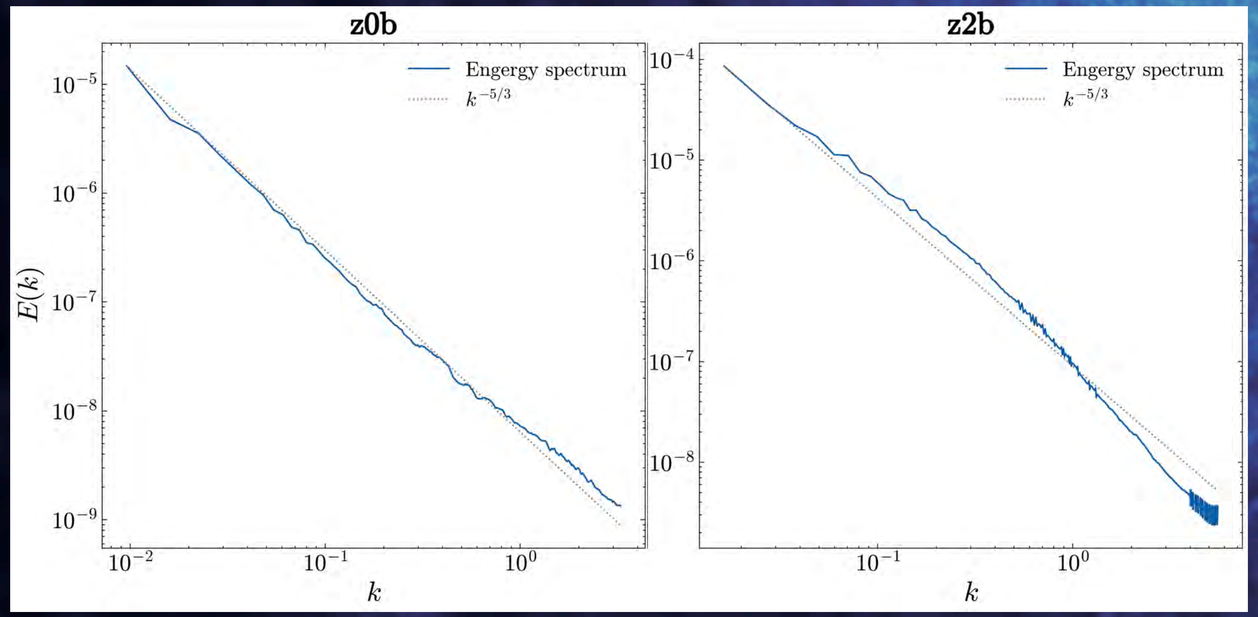
Tung+ 2025



Redshift Evolution of the CGM

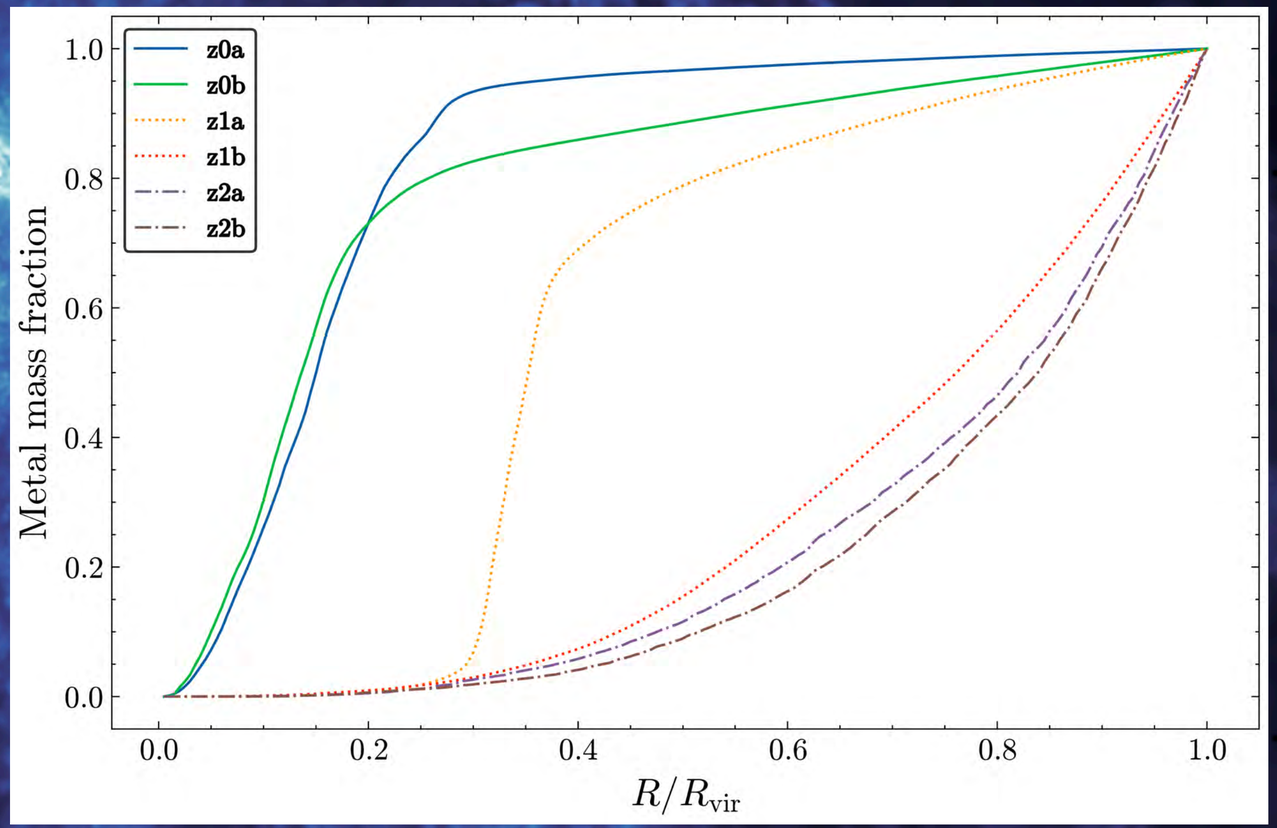
Turbulence & Metal distribution

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



Kolmogorov energy spectrum

- Transition of metal distribution at z = 1



Accumulated metal-mass fraction inside halos