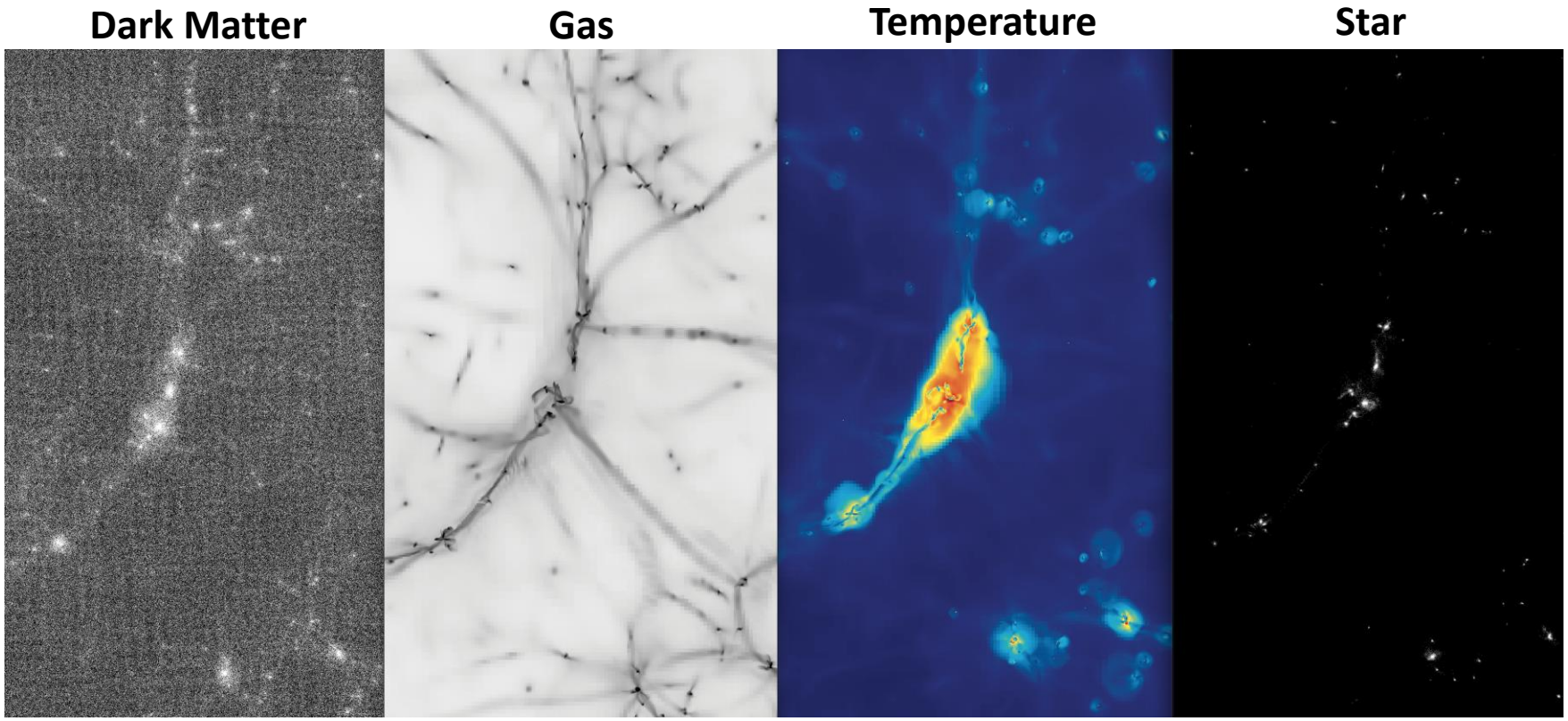

Horizon Run 5 – III. Evolution of Cosmic Structures

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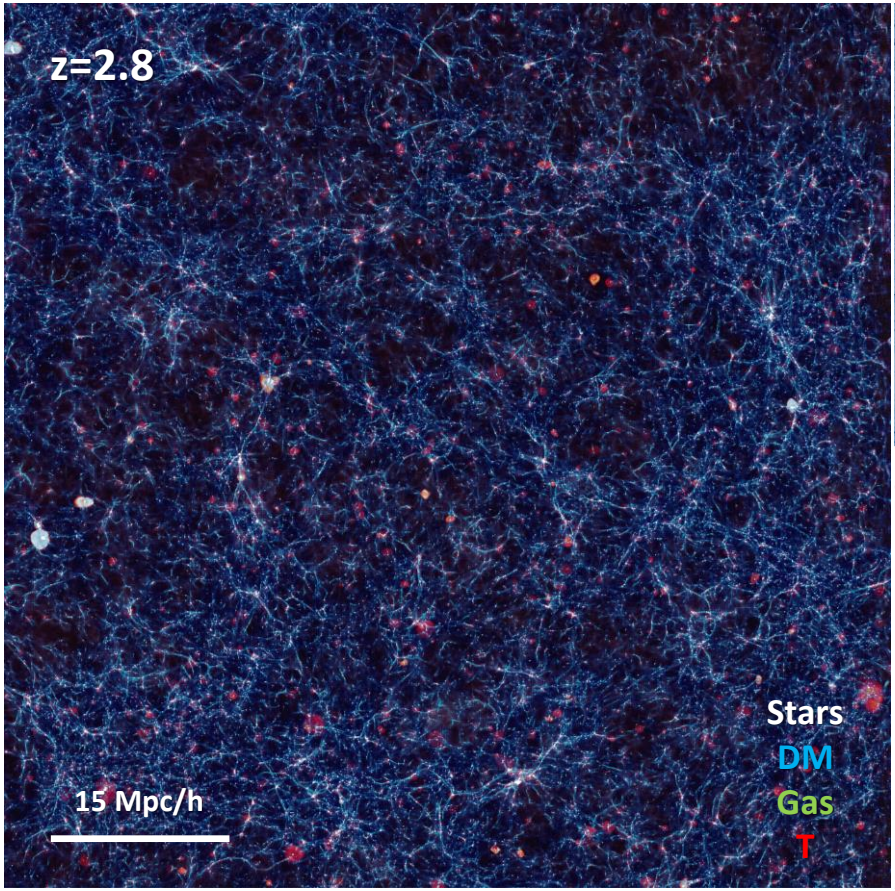
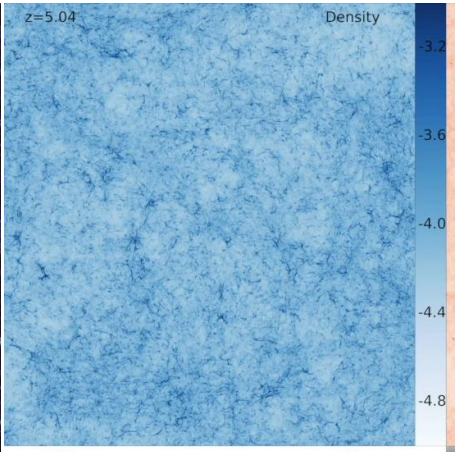
& Juhan Kim, Changbom Park, Owain Snaith, Jaehyun Lee (KIAS), Jihye Shin (KASI)

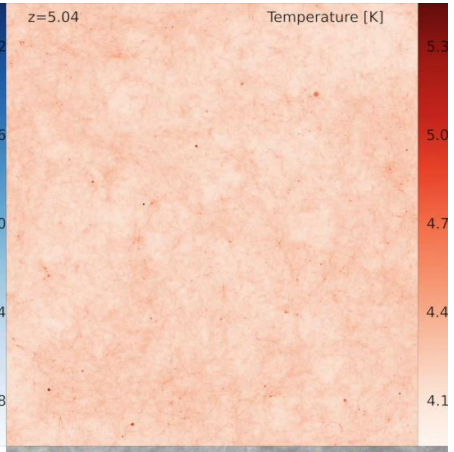
+ HR5 Collaboration

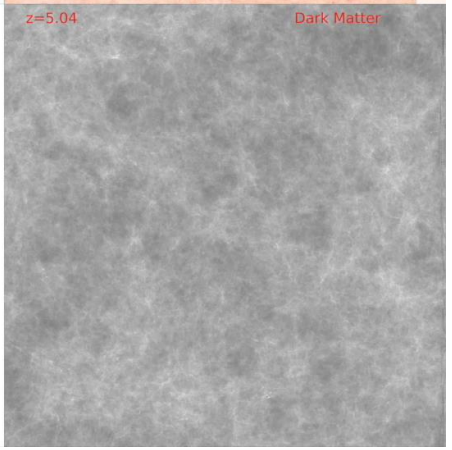
Running HR5

- Simulation time : from December 15, 2018 to March 15, 2019.
- HR5 has reached at z=2.7 and is expected to run until z=0.2.









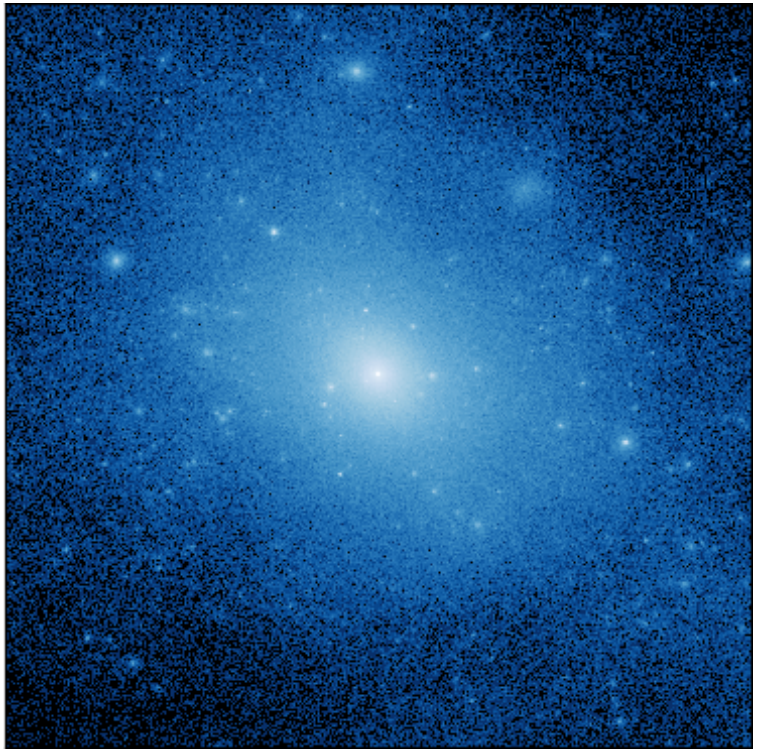
Significance

- Cosmological simulations for galaxy formation and evolution are reaching ever more mature levels of realism and physical complexity.
- The HR5 simulation suite is producing thousands of well-resolved galaxies.
- This simulation includes a broad range of galaxy-physics mechanisms and it hence captures a wide range of phenomena.
- With this self-consistent simulation, we can predict the distribution of the various matter components across orders of magnitudes of galaxy masses, spatial scales and times. → They are a uniquely suited to provide quantitative priors for cosmological quests.
- Gravity-only expectations on the phase-space properties of (C)DM can be modified (a lot) by gastrophysics.

➔ DM and DE searches/arguments/quantifications must consider a whole new fan of models.

Post Processing

- **Halo Finding** (AHF; Gill+04)
  - Adaptive mesh refinement of identify density peaks to identify halos and sub-halos
  - MPI enabled (important for HR5)
  - Builds merger trees to trace objects through time
- **SUNRIZE** (Jonsson 2002) or **SKIRT** (Camps 2014)
  - Radiative transfer code for mock observations
- **SUNSET** (RAMSES utils)
  - SUNRASE on-the-cheap but adequate for many applications at 1 kpc resolution
- Comparison with **SAM**s

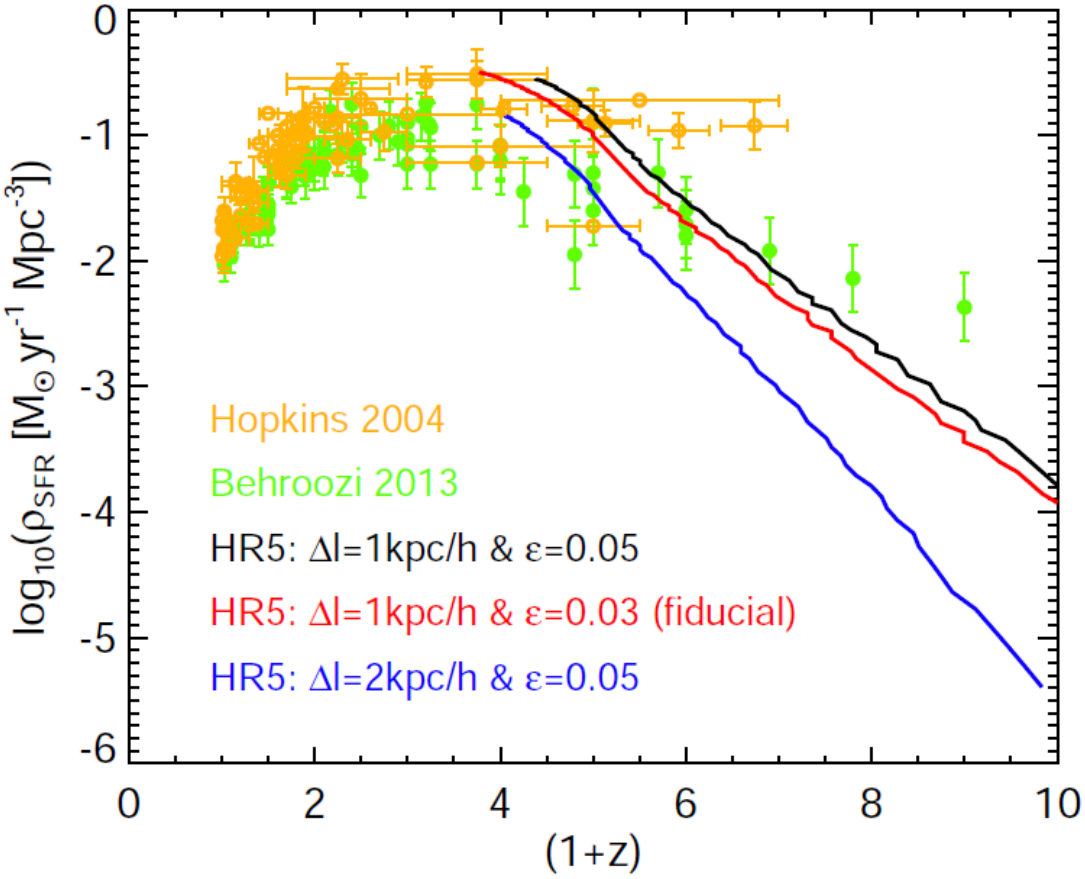


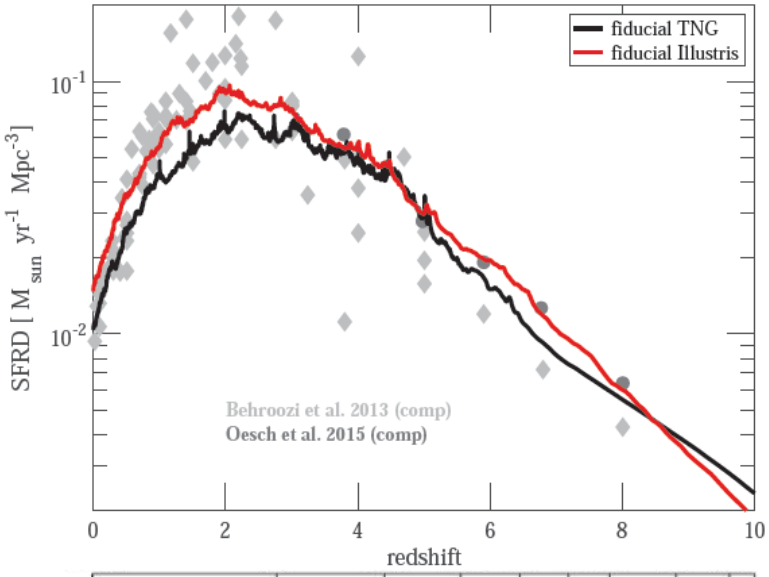
Credit Illustris Team

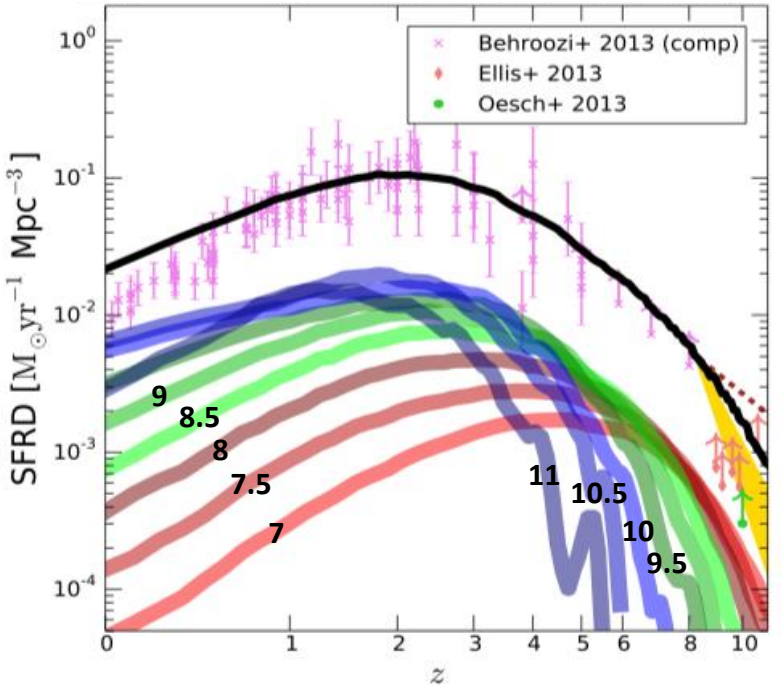
z=0 observables of reference

- Galaxy stellar mass function
- Stellar-to-halo mass relation
- Gas fraction within R_{500}
- BH mass vs. Galaxy mass relation
- Stellar sized vs. Galaxy mass relation
- ……

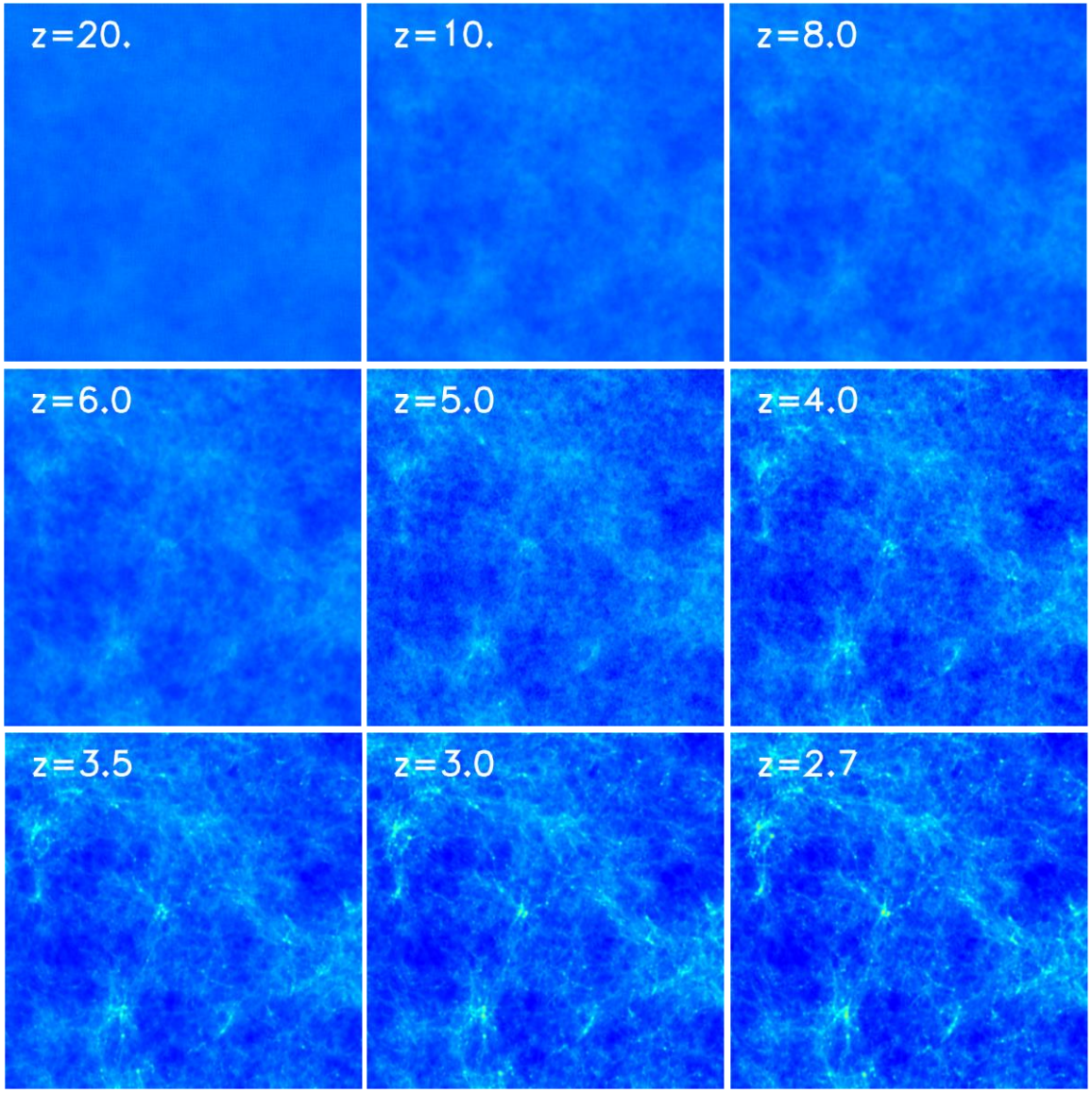
Preliminary Result : Star Formation History







Output Variable : (a) Dark Matter

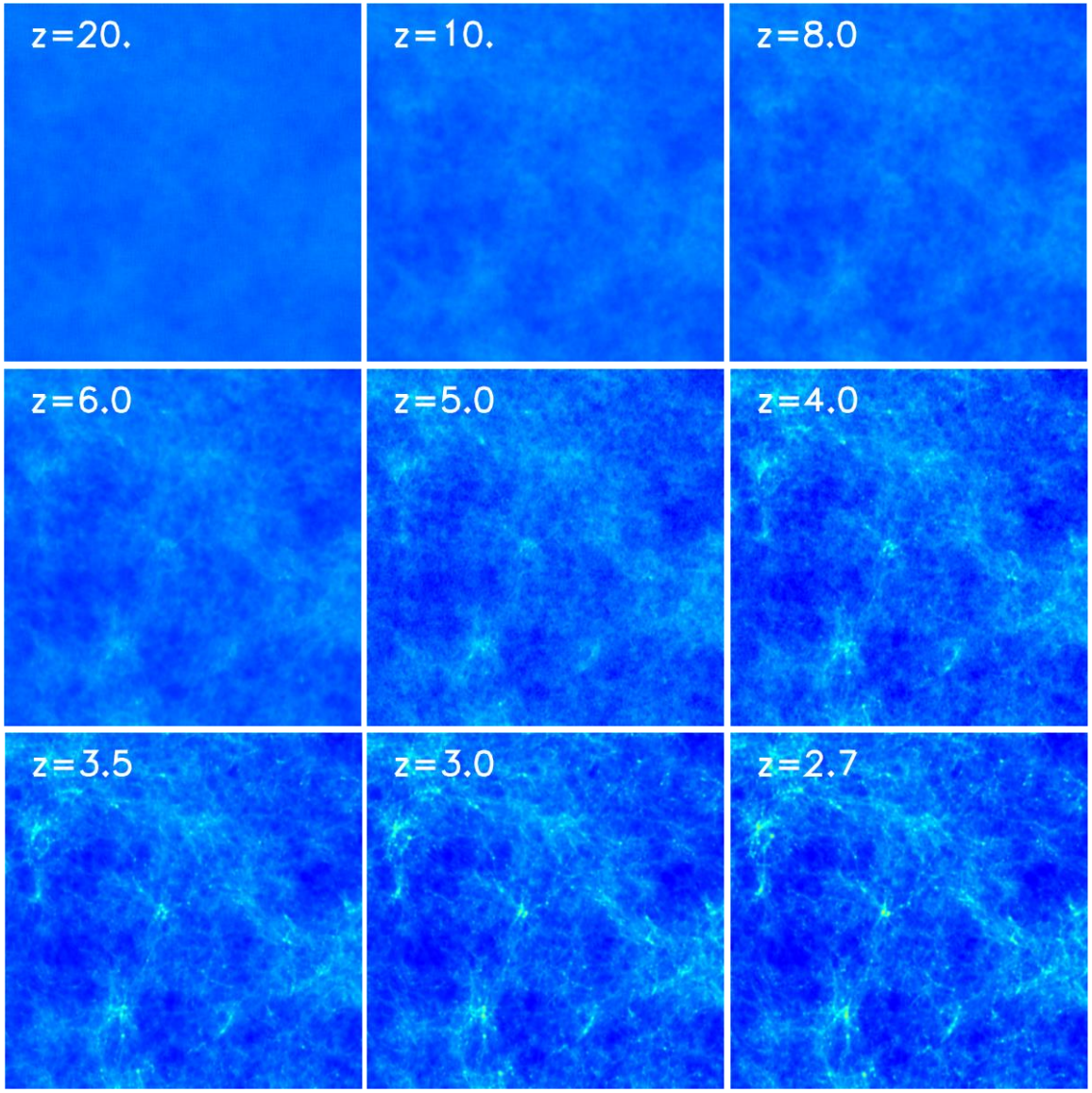


CDM Problems

- Small-scale CDM problems
  - Missing satellites
  - Core/cusp problem
  - Too-big-to-fail problem
  - Diversity problem
  - Plane of satellites problem
- Fundamental problems
  - Generic WIMP/axions not detected so far

5 Mpc/h

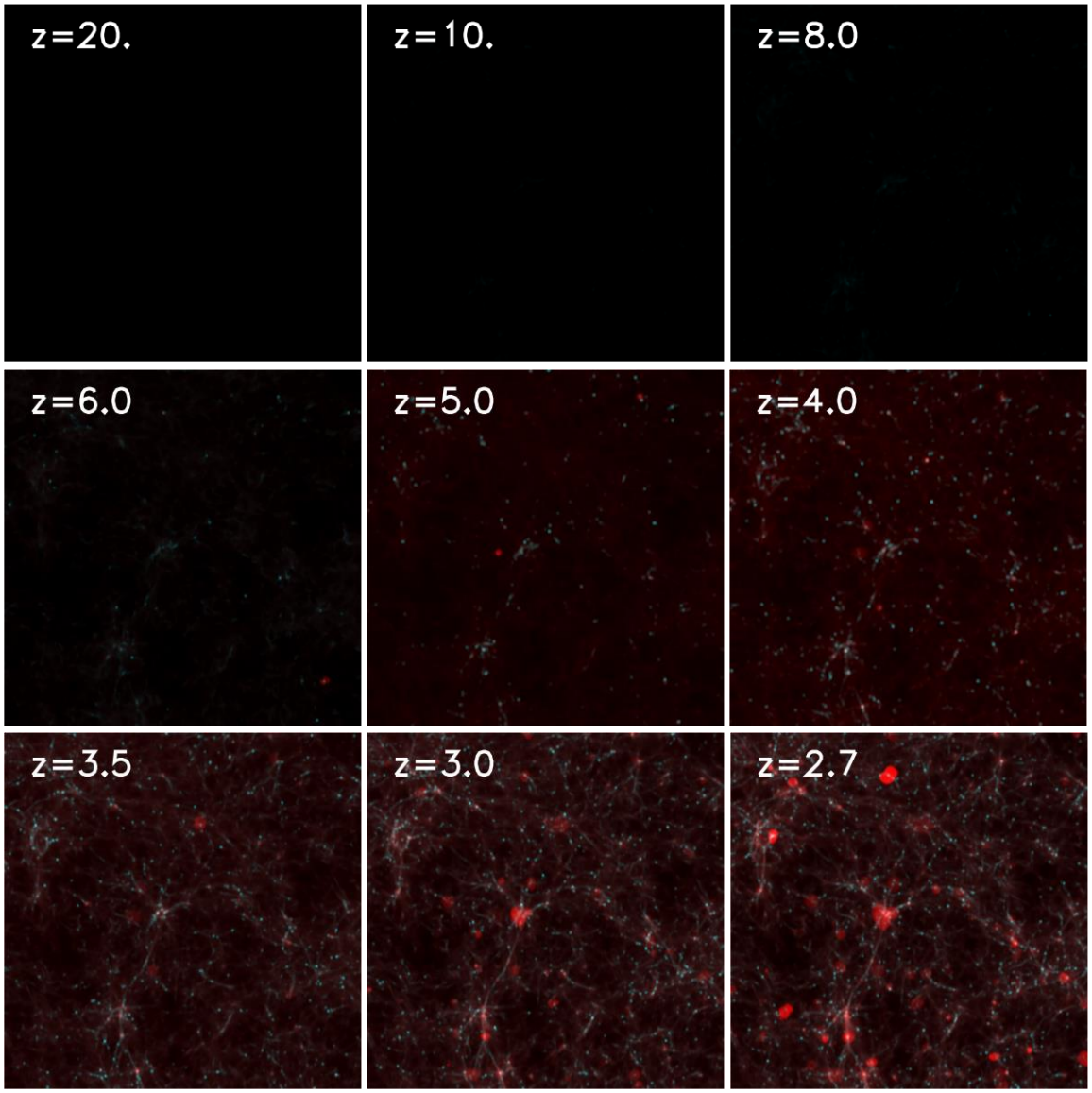
Output Variable : (a) Dark Matter



Solutions

- Baryon physics (most small-scale problems) have been identified in DM only simulations
- Systematic uncertainties in observations
- DM is no exactly CDM
  - WDM
  - Self-interacting DM
  - BECDM

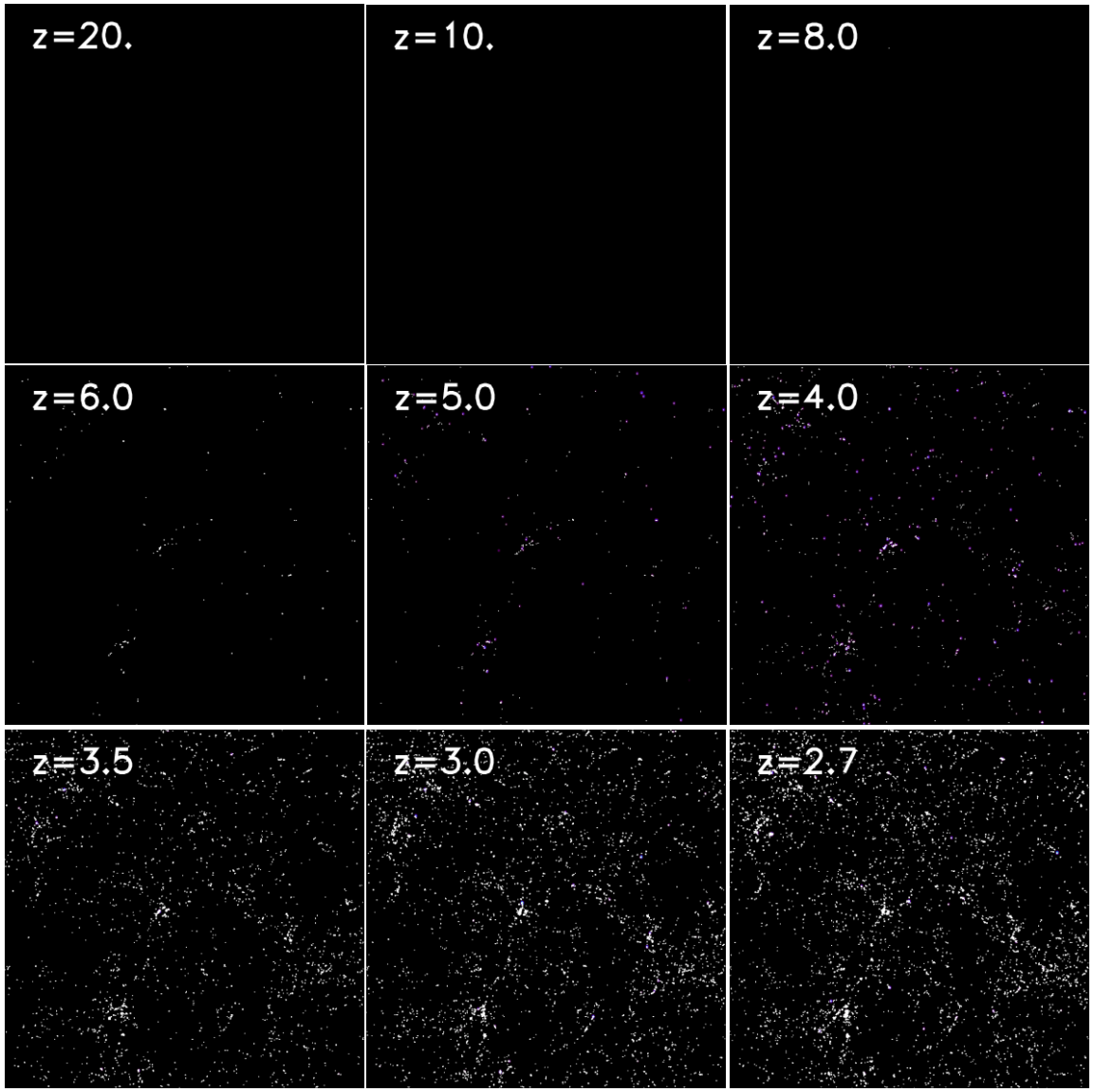
Output Variable : (b) Baryons Physics – Gas + Temperature



- Cooling & Heating
  - Collisional excitation
  - Collisional ionization
  - Recombination
  - Free-free emission
  - UV background
  - Metal line cooling

5 Mpc/h

Output Variable : (c) Baryonic Physics – Stars + Metallicity



- SN Ia, SN II, AGBs
- Feedbacks from stars, SMBHs and AGN

➔ Galactic outflows & SF regulation

➔ Chemical enrichment & metal diffusion

Output Variable : (d) Baryonic Physics – Chemistry and others

- 5 chemical elements

  : H, He, O, Fe, and metal

[Important]

In this simulation, we do not consider

(a) Complex molecules

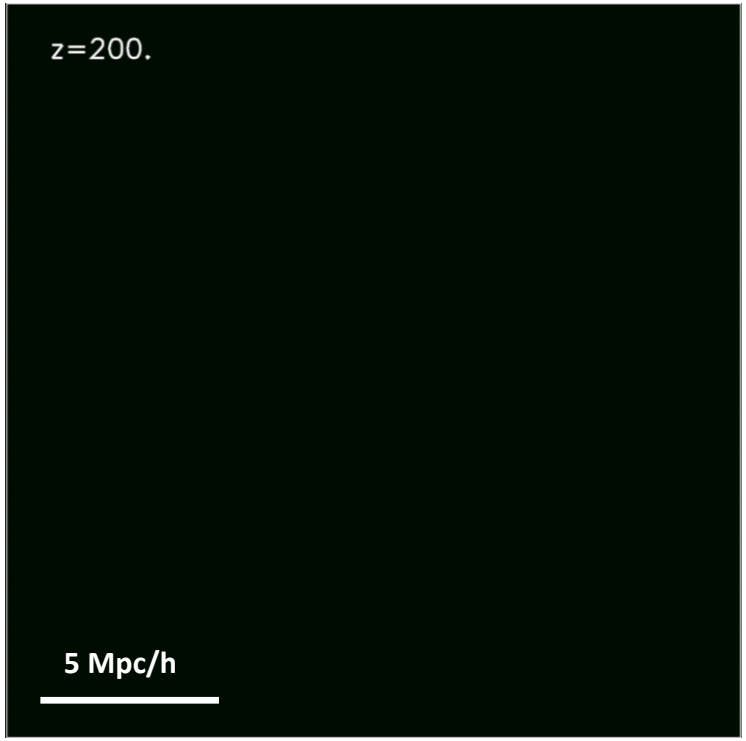
(b) Dust formation/disruption

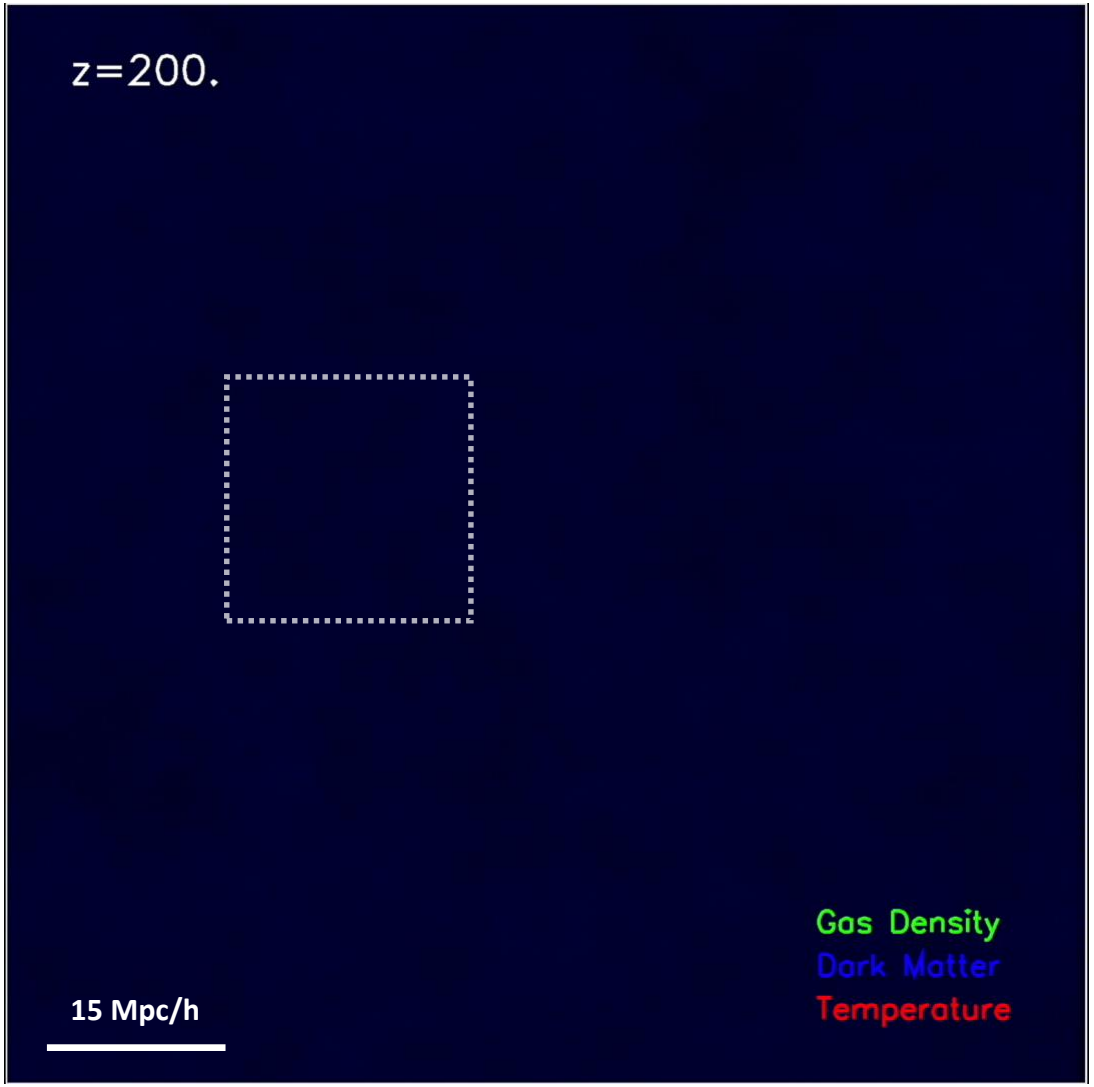
(c) Effects of radiation pressure (in most)

(d) Radiative transfer (just use simple assumptions)

and do not distinguish between HI and H_2.

Public Outreach : Movies





Thank you