Origin and Evolution of Structure and Nucleosynthesis for Galaxies in the Local Group

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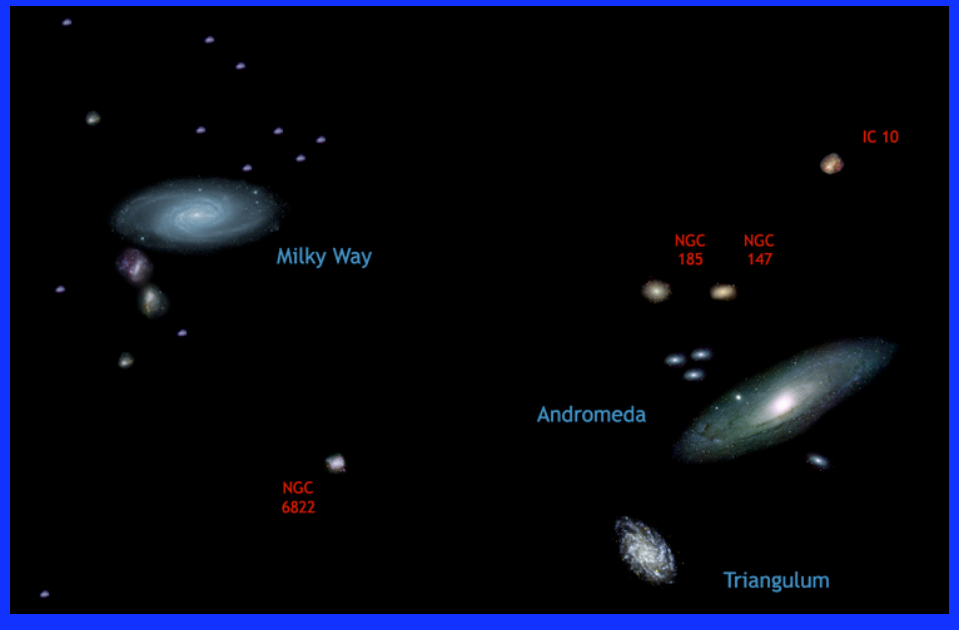


JINA GCE Workshop
"Building Virtual Galaxies"
April 29-May 1, 2010
East Lansing, MI

Swine Teaching & Research Center

Farm Manager:
Al Snedegar (517) 355-7485

Assistant Farm Manager:
Kevin Turner

Faculty Coordinators:
Dr. Ron Bates
Dr. Nathalie Trottier
(Metabolism Unit)

Location
3760 College Road (main swine farm)
3465 Forest Road (old swine farm)
East Lansing, MI 48824

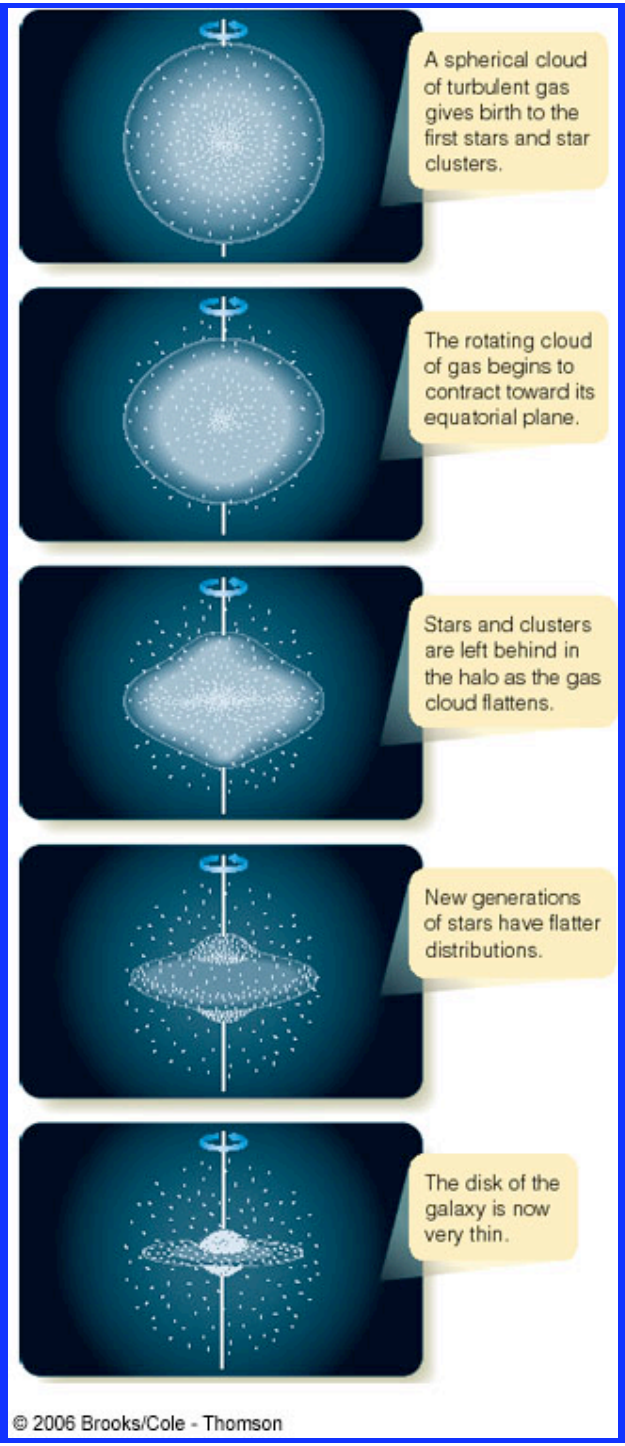
Goals of GCE Models

- Explain the distribution of stellar and ISM elemental abundances vs. kinematic properties, location, ages

- Use these to explain the properties of the Galaxy and external galaxies along with how they formed and evolved

Goal in this Work:

Obtain a realistic simulation of the formation of the Milky Way and other members of the Local Group



History of the Milky Way

The traditional theory:

Quasi-spherical gas cloud fragments into smaller pieces, forming the first, metal-poor stars (pop. II, III);

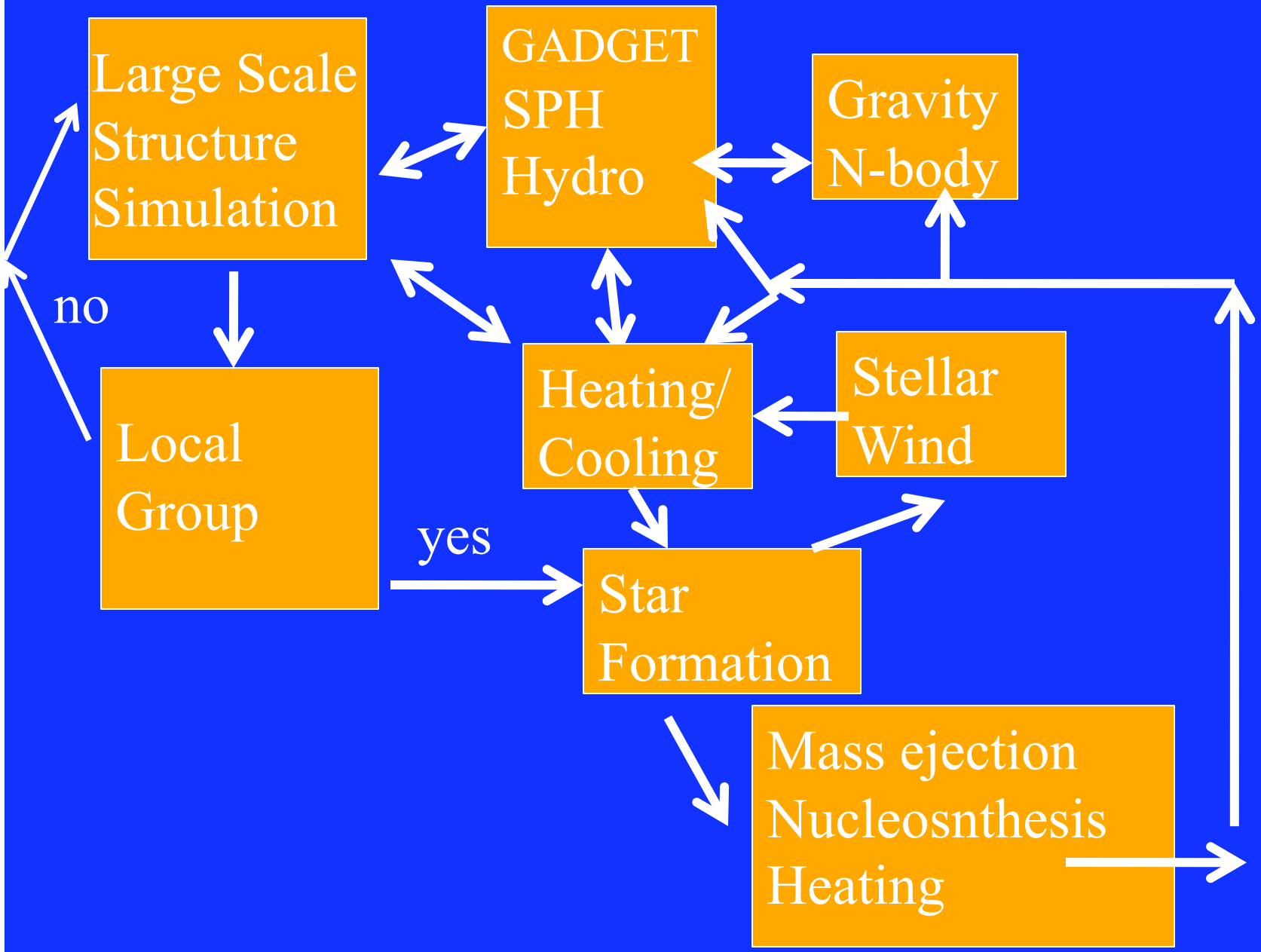
Rotating cloud collapses into a disk-like structure

Later populations of stars (pop. I) are restricted to the disk of the galaxy

Present View:

- The Galaxy did not form in isolation.
- It is the product of the development of much larger structure
- It was formed in concert with the entire Local Group and was affected by star formation and nucleosynthesis processes occurring throughout a large volume

Virtual Galaxies



Smoothed Particle Hydrodynamics

$$\frac{D\rho}{Dt} + \rho\nabla\cdot\mathbf{v} = 0$$
$$\frac{D\mathbf{v}}{Dt} = -\frac{1}{\rho}\nabla P - \nabla\Phi$$
$$\frac{Du}{Dt} = \frac{P}{\rho^2}\frac{D\rho}{Dt} + \frac{\nabla\cdot(\kappa\nabla T)}{\rho} + \frac{\Gamma-\Lambda}{\rho}$$
$$\nabla^2\Phi = 4\pi G\rho$$

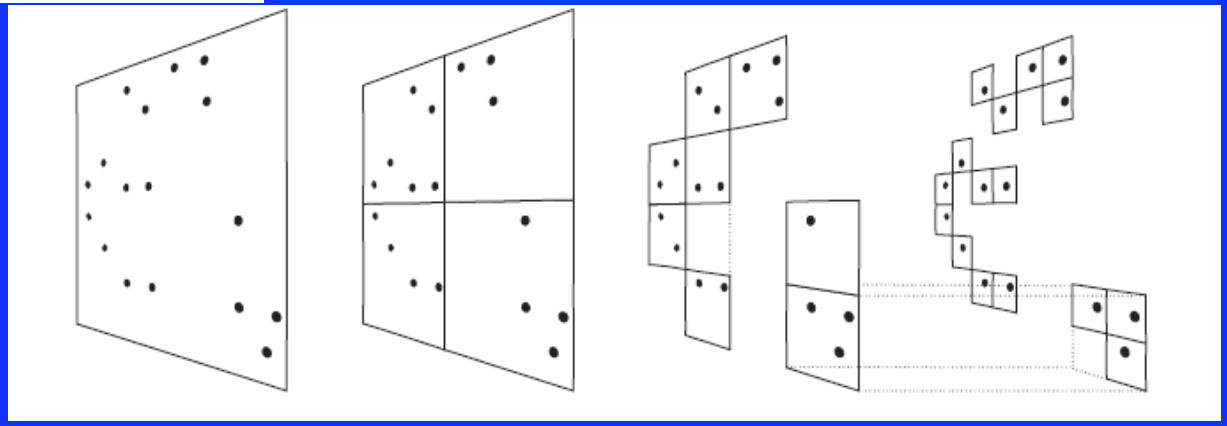
SPH method

$$\rho_i = \sum m_j W(\mathbf{r}_i - \mathbf{r}_j; h)$$
$$\frac{D\mathbf{v}_i}{Dt} = -\sum m_j\left(f_i\frac{P_i}{\rho_i^2}\nabla_i W_{ij}(h_i) + f_j\frac{P_j}{\rho_j^2}\nabla_i W_{ij}(h_j)\right) - \sum m_j\Pi_{ij}\nabla_i\overline{W}_{ij}$$
$$\frac{DA_i}{Dt} = \frac{1}{2}\frac{\gamma-1}{\rho_i^{\gamma-1}}\sum m_j\Pi_{ij}\mathbf{v}_{ij}\cdot\nabla_i\overline{W}_{ij} + \frac{\gamma-1}{\rho_i^{\gamma}}(\Gamma-\Lambda)$$

GADGET:

Springel, Yoshida, White (2000)

Gravity Tree Algorithm



Key Issues

1. What are the conditions for star for
function of metallicity, environmen
momentum, magnetic fields, densit

$$\text{(i)} \quad (\nabla \cdot v)_i < 0,$$

$$\text{(ii)} \quad t_{\text{cool}} < t_{\text{dyn}},$$

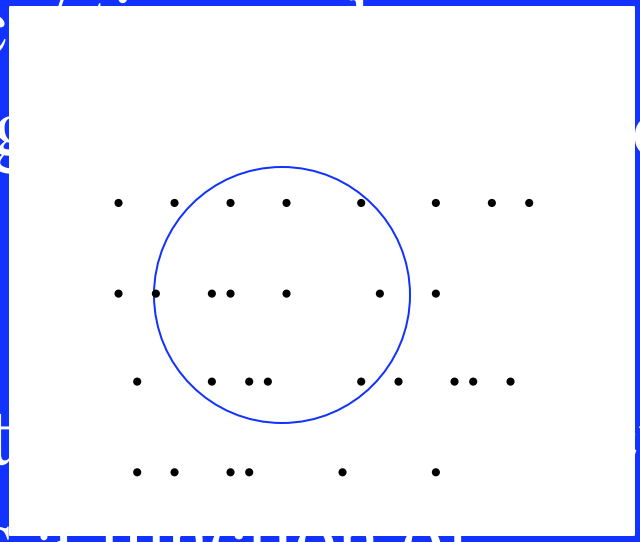
$$\text{(iii)} \quad t_{\text{dyn}} < t_{\text{sound}},$$

2. How universal is the stellar initial mass function: Function of cloud metallicity and environment, ..?

3. **What are the nucleosynthesis yields as a function of progenitor mass, chemical composition, rotation, Mag. Field, …?**

4. **What are the stellar lifetimes, remnant masses, ejected mass, ejected energy in stellar winds, AGB, SNI, SNII, VMOs, …..?**

5. What are the dynamic
efficiencies for mixing
interstellar medium?



6. Cooling of the ISM t
star forming clouds as a function of
environment
7. .
8. .

Projects JINA Should Undertake

1. Definitive models for star formation and the IMF as a function of metallicity, environment (molecular cloud cooling, angular momentum, magnetic fields, density, etc.)

2. Form a universal updated data base of nucleosynthesis yields, stellar lifetimes, remnant masses, ejected mass, ejected energy in stellar winds, PNe, SNI, SNII, VMOs, based upon various stellar evolution models as a function of progenitor mass, composition, rotation, mag. field, …?

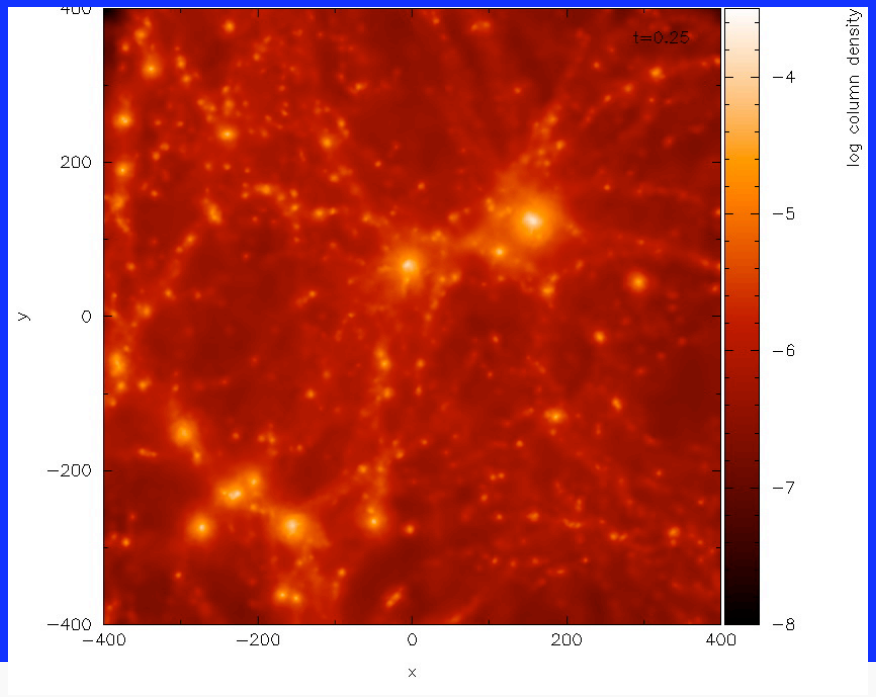
3. Form and maintain a universal easily accessible data base of observed stars, their metallicity, location, proper motion, velocity dispersion, etc.

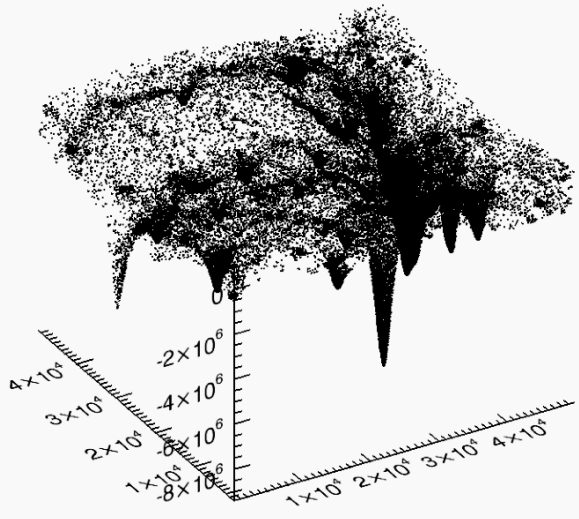
4. Develop statistical measures of the relevant observables for easy comparison with code results.

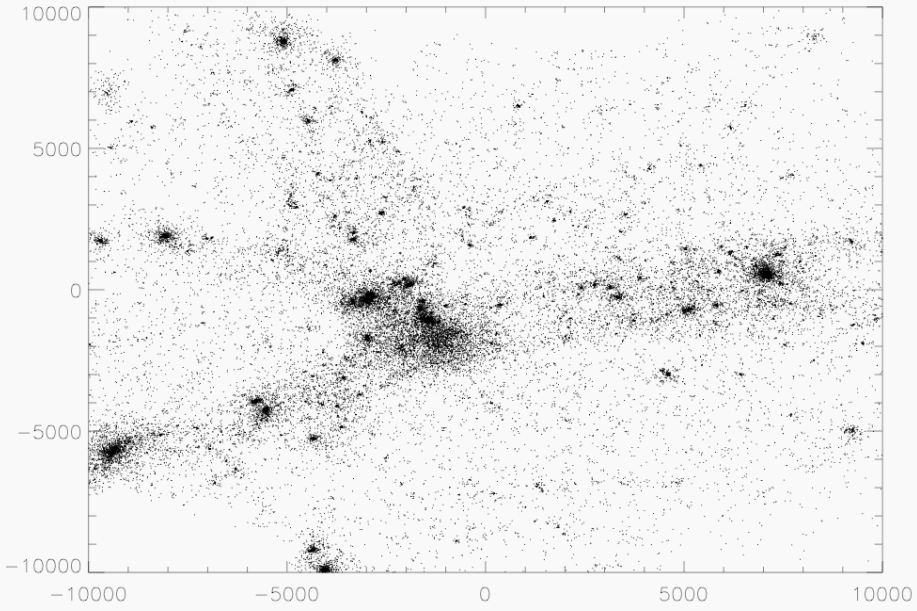
5. Develop a state-of-the aret data base of cooling functions as a function of metallicity, etc.

The Simulations

http://www.nd.edu/~xzhao/

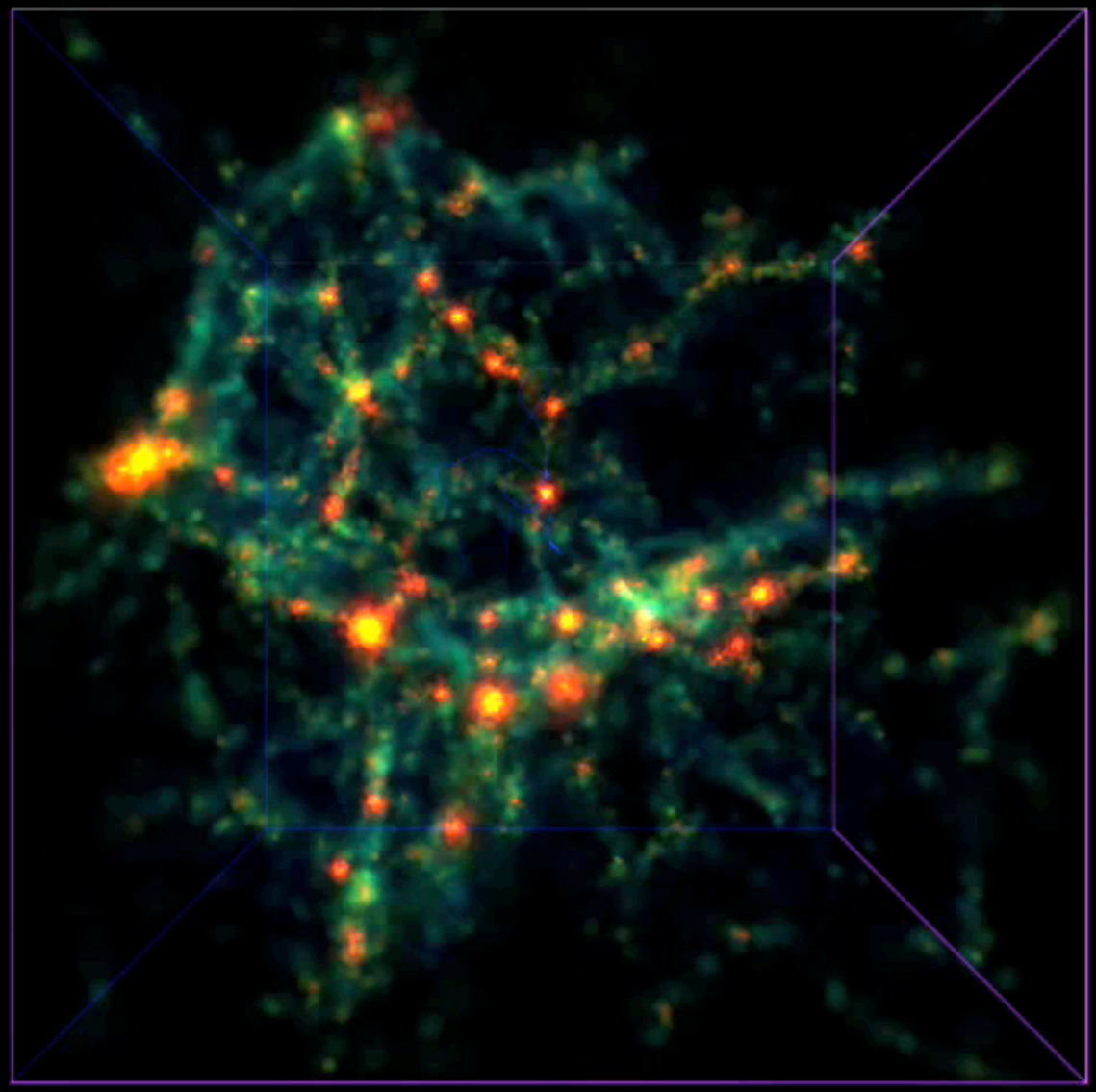






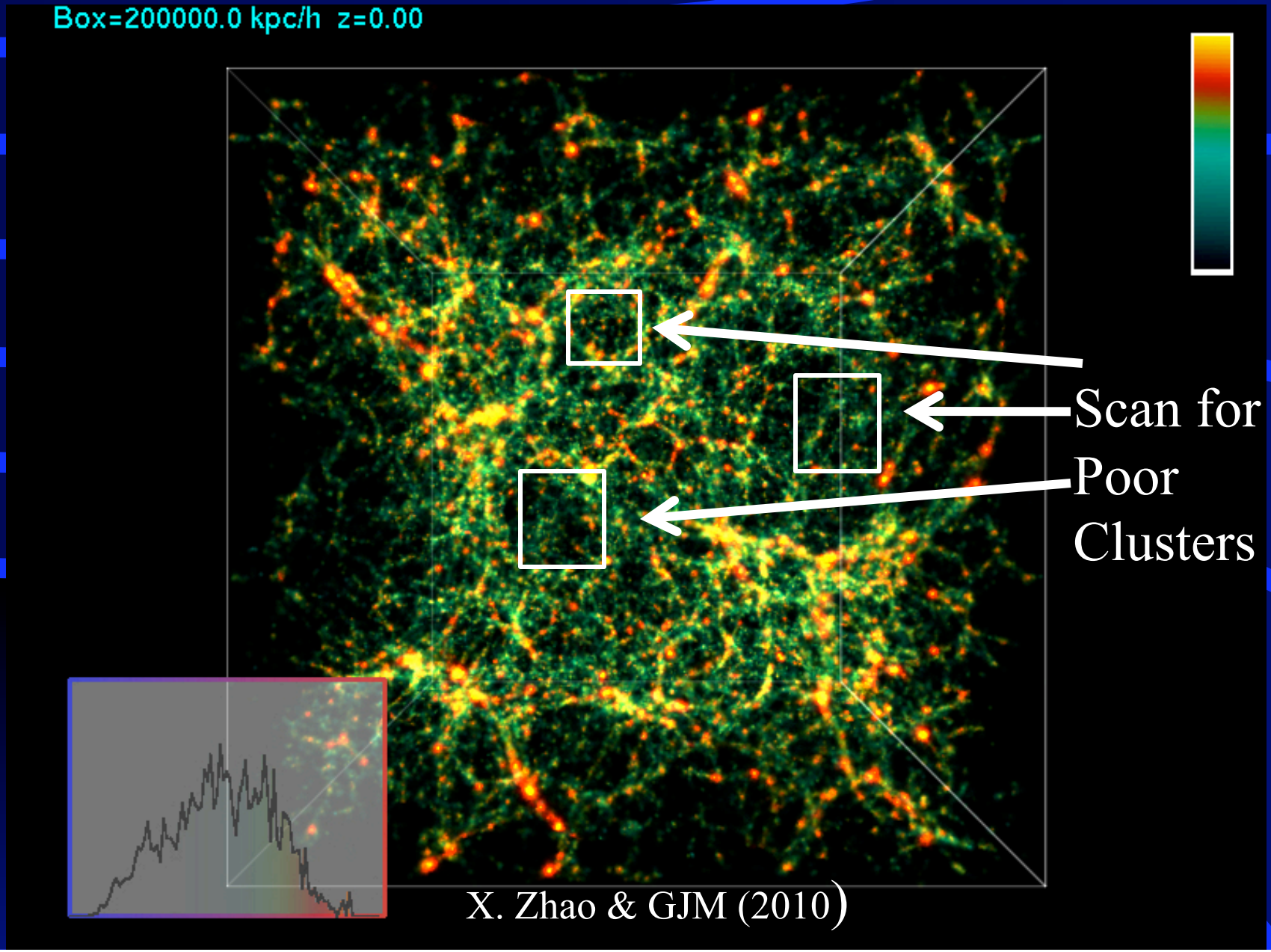
X. Zhao & GJM (2010)

Begin with LSS

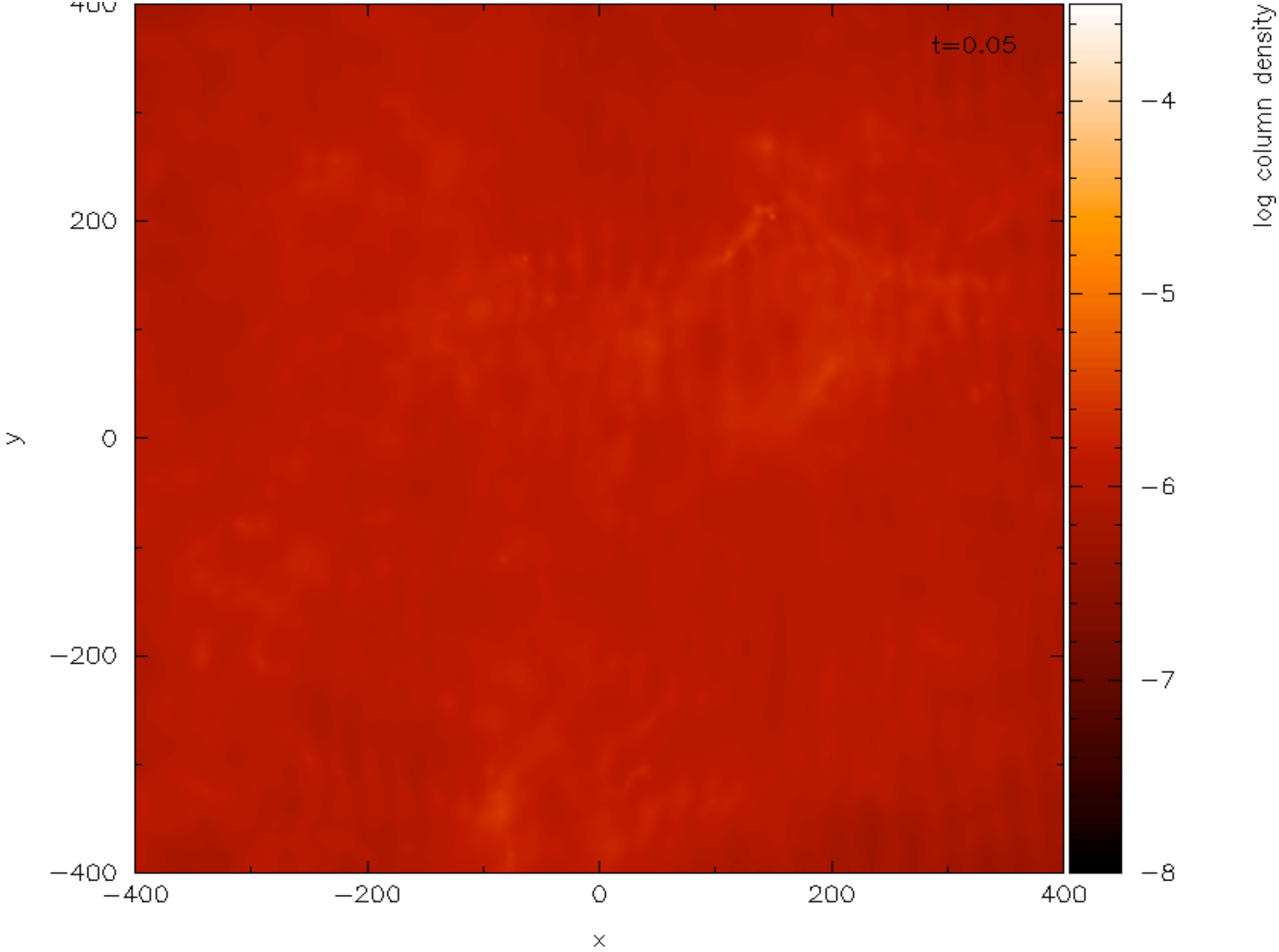


X. Zhao & GJM (2010)

Large Scale Structure Simulations



X. Zhao & GJM (2010)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−7
−8
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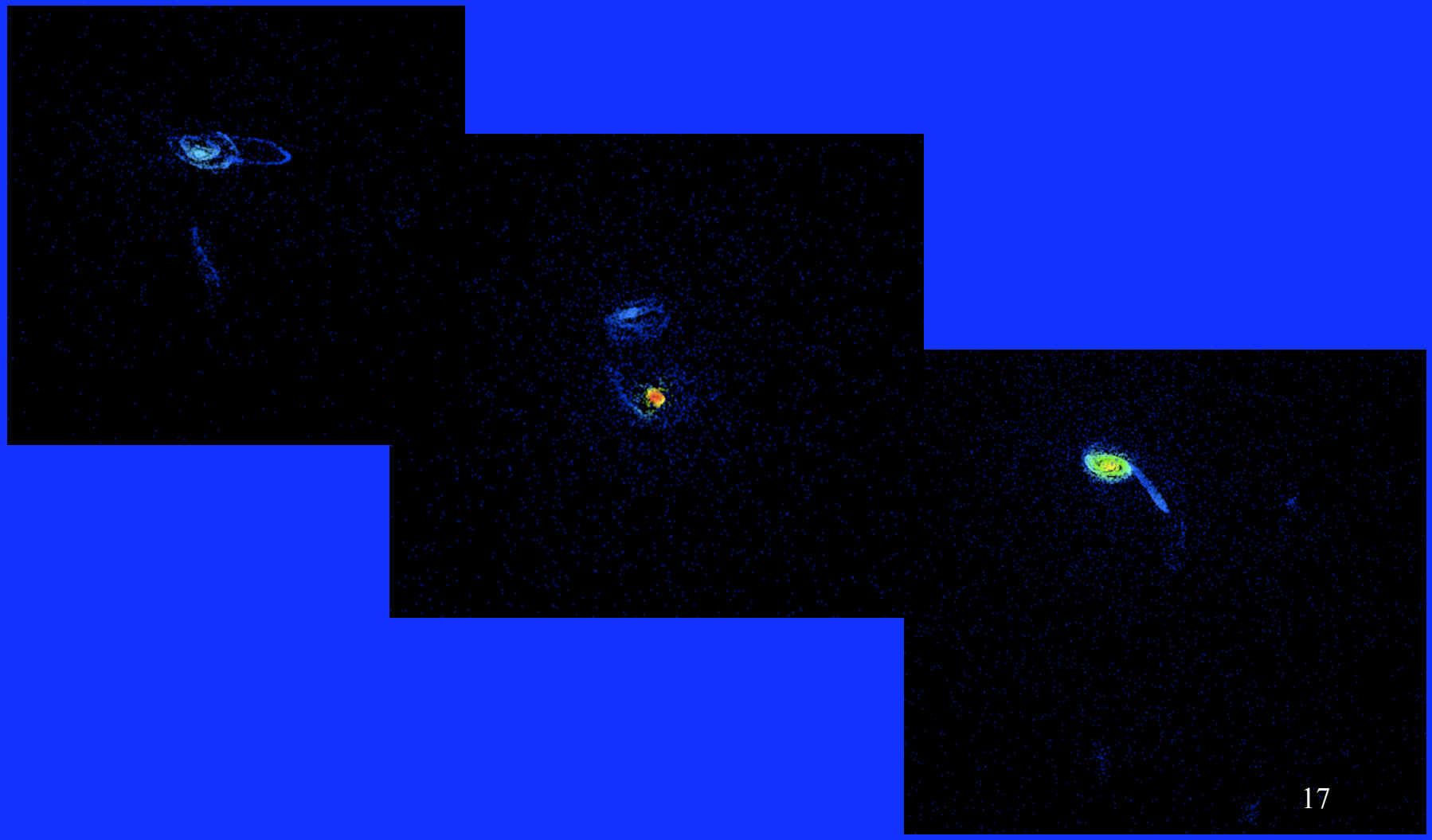
−400
−400
−200
0
200
400
x

Disk Galaxies



Galaxy Formation

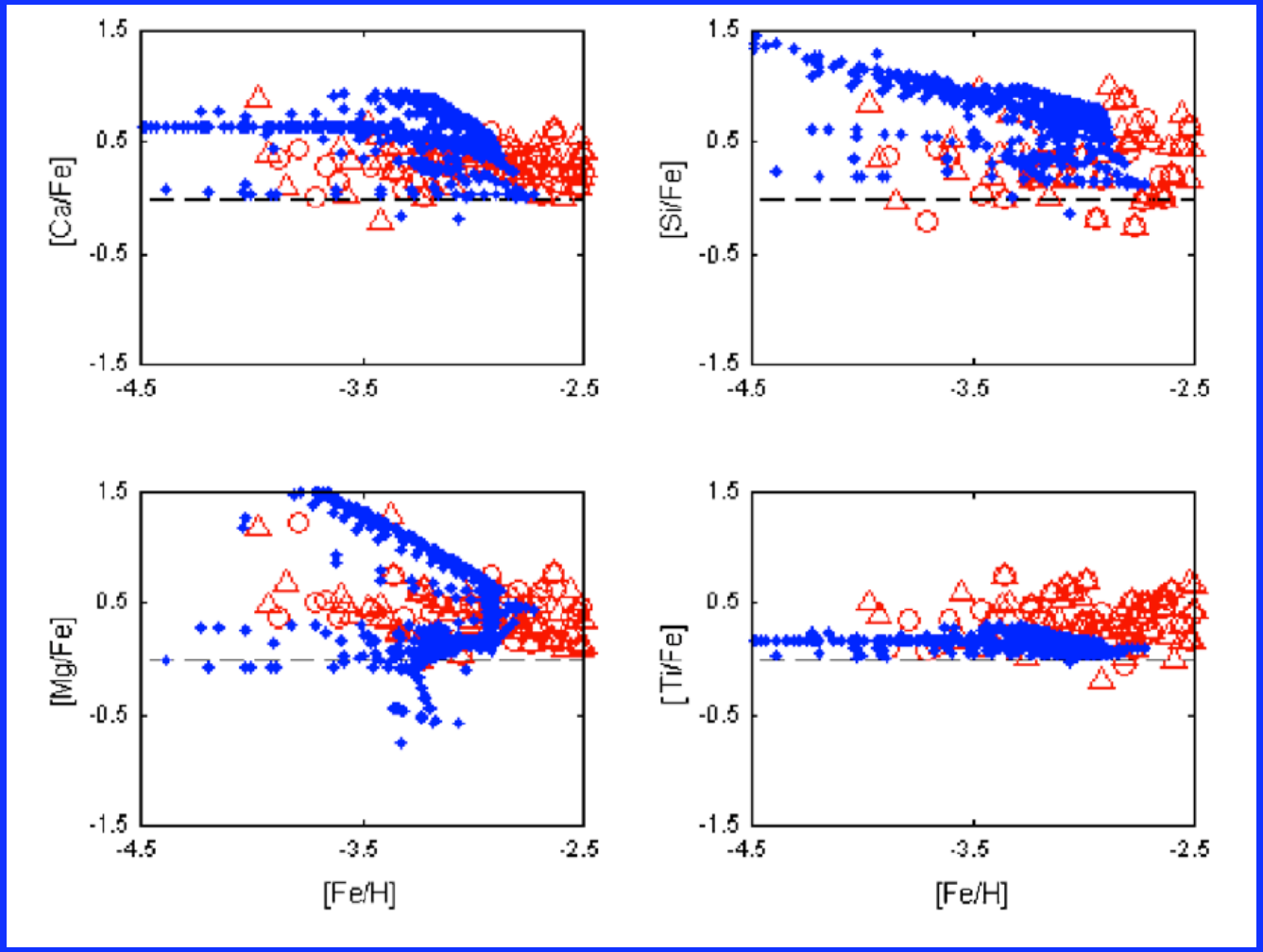
•Galaxies are not isolated objects but are the culmination of halo formation, mergers, star formation and nucleosynthesis in an extended connected environment.

•Significant starformation and nucleosynthesis occurs far from the galaxy in protogalactic structures.

•Protogalactic halos that arrive in a stochastic stream flowing along dark-matter filaments.

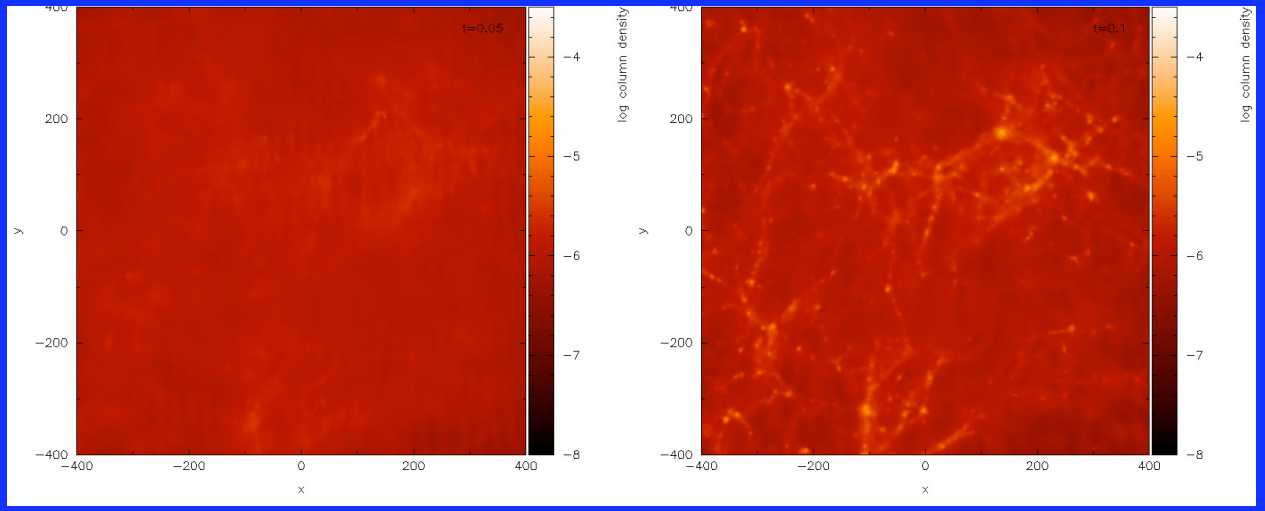
•There should be a distribution of kinematic and metallicity distributions in the halo

Next Step: Reconstruct Abundance vs Metallicity Relations for different stellar populations



Saleh, Beers, Mathews (2006)

Snapshots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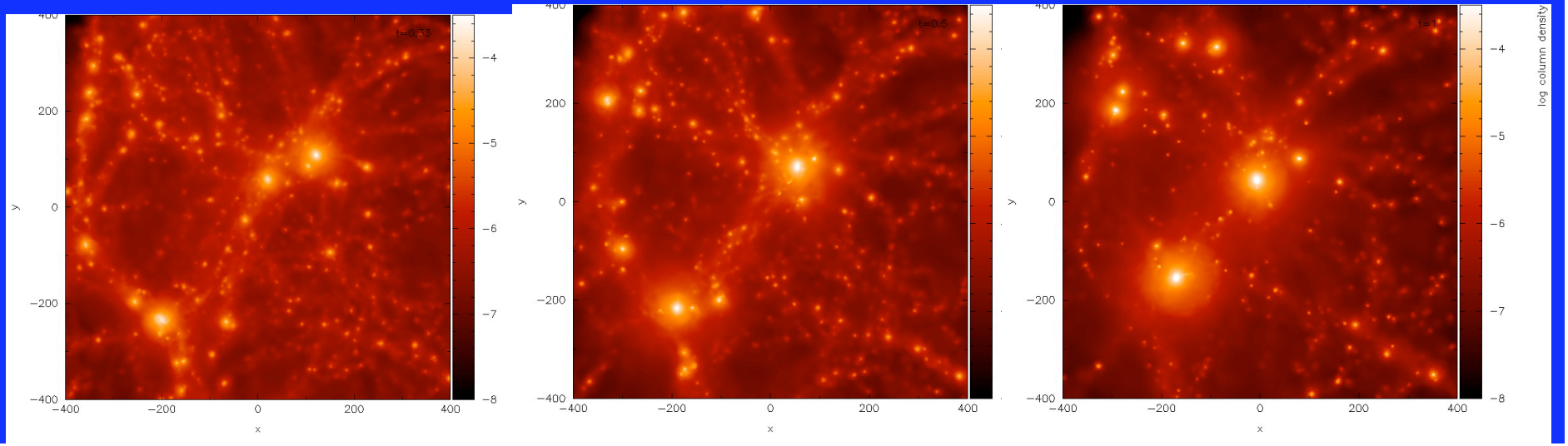
log column density
x
y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t=1
log column density
x
y