MASSIVE GALAXIES IN GROUPS vs ISOLATED GALAXIES

FROM HYDRODYNAMICAL SIMULATIONS

Rosa Domínguez Tenreiro (1)
Paola Alpresa(1)
José Oñorbe (1)
Fran Martínez-Serrano (2)
Arturo Serna (2)

(1) Universidad Autónoma de Madrid, Spain
(2) **Universidad Miguel Hernández, Elche, Spain**

ORIGIN OF MASSIVE GALAXIES

- When were their stellar populations born? Where?
- When was their mass assembled?
- What makes the difference between I-Es and non-I-Es?

NATURE vs NURTURE or LAW vs CHANCE

VERY CONVENIENT:

study this problem in connection with the global cosmological model + hydro simulations

POSSIBLE SCENARIOS

A set of observations suggests that Es formed according with the monolithic collapse scenario

(Patridge&Peebles 1967; Tinsley 1972; Larson 1974)

However, another set of recent observations suggests that mergers at zs below 1.5 - 2 could have played an important role in E assembly (Toomre 1077; Kauffmann 1993)

PARADOXICAL and CHALLENGING!!

Halo Mass Assembly & Profiles

ASSEMBLY: Analytical models, as well as N-body simulations and the merger rate inferred from observations, **two different phases**

- first, **violent fast phase**: high mass aggregation rates
- Later on, **slower phase**: lower mass aggregation rates

(Wechsler et al. 2002; Zhao et al. 2003; Salvador-Solé, Manrique, & Solanes 2005; Conselice 2007).

PROFILES (spherically averaged): Depend on 2 parameters. Not on how the mass is assembled **(Manrique et al. 2003; Einasto 1974; NFW 1996)**

ABOUT LAW: SINGULARITY FORMATION AND DRESSING

DARK MATTER (Model Advanced Stages of NL Ins. + N-body)

- ZA (1970) → non-lasting singularities
- Adhesion model (Gurbatov et al. 84,89; Vergassola et al. 1994) →
  sticking matter **Based on Burger´s equation**

  Cell Structure

- Generalized AM (Gurbatov + 89; Domínguez 1994) →
  singularity regularized: in the neighborhood of a singularity, repulsive force appears >>> dispersion of velocity.

  Effective gravi. VISCOSITY changes ordered mass flow towards the singularity into velocity dispersion

  VIRIALIZATION

HYDRO SIMULATION NEEDED TO TEST **FLUID** BEHAVIOUR

METHOD

P-DEVA

(Mtnez.Serrano + 08)

. **OpenMP** **AP3M + SPH**

. Kennicutt-Schmidt SF algorithm

. Stellar Physics subresolution modelling

. Self-consistent element formation (Q_ij) & cooling (DDR)

. Conservation Laws >>

careful implementation of the nighbour searching algorithm in SPH

Newton´s reciprocity law

2 loops >> highly CPU time consuming !!

AP3M + SPH.2L + Q_ij +DDR

METAL ENRICHMENT

- Model (Lacey & Fall 83; Ferrini + 94; Tosi & Díaz 96)

  INCLUDES SNe TYPE I (old stars) and II (massive young stars) EXPLOSIONS
- Probabilistic SPH implementation >> statistical noise

- **Q_ij** matrix STELLAR EVOLUTION YIELDS >> **detailed, independent element enrichment**
- Full cooling dependence on detailed element composition <> but as fast as a simple table lookup **(DRR)**

OUTPUT

Z_i(r,t) i= H, He, C, N, O, Ne, Mg, Si, S, Ca, Fe

either for stars or gas

INPUT for DUST models (GRASIL, Silva + 98)

RUN DESCRIPTION

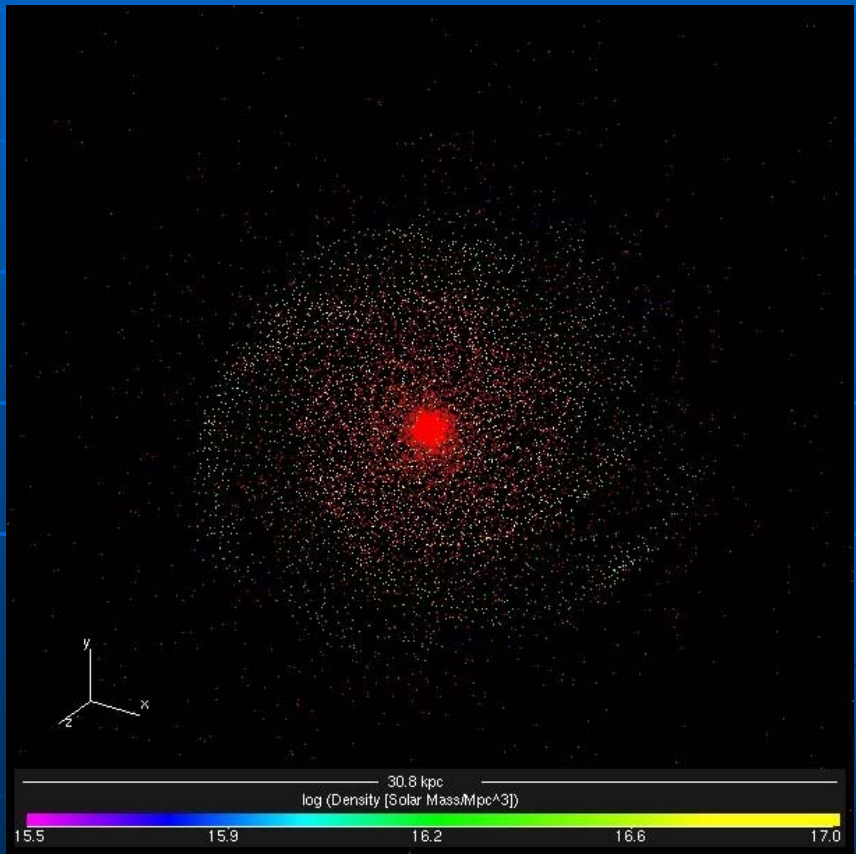
A DEISA Extreme Computing Initiative

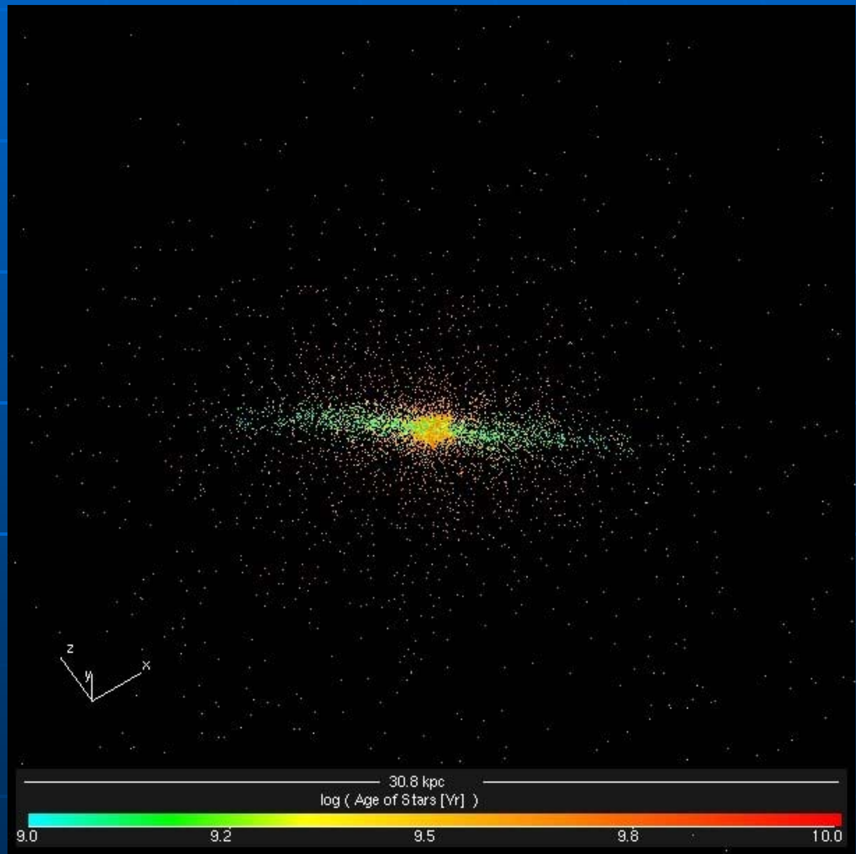
EQUILIBRIUM BOX SIZE / RESOLUTION

- 80 Mpc periodic box side >>

  cosmological convergence
- Initial Conditions : WMAP+BAO+SZ+SNEall+ SSDS, running
- 2 x 512^3 DM & baryon particles **(2.4 & 12.5 x 10^7 M_sun)**
- Space resolution: 2 kpc gravity; 1 kpc hydro
- Resampling possible (mass & space resolution increased)

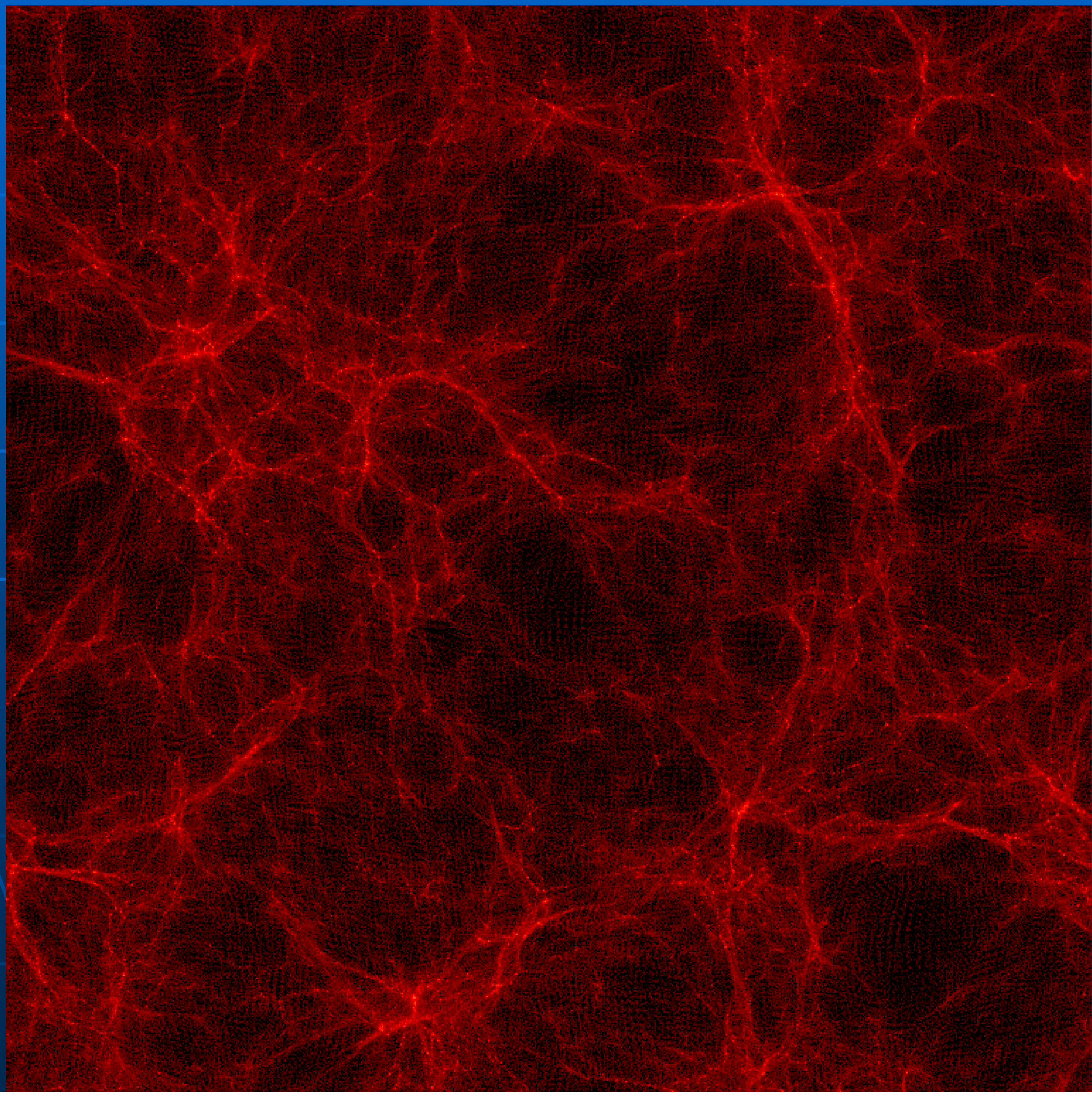
SPIRAL GALAXY (Martínez-Serrano et al.)





SPHEROID FORMATION

EARLIER ON (t = 1.78 Gyr, 13 % age now)
BARYON DENSITY: 40 x 40 x 8 Mpc^3



E FORMATION: CLUES FROM HYDRO SIMULATIONS

Es: assembled out of mass elements enclosed at high z by overdense regions R whose local coalescence length (Vergassola et al. 1994) grows much faster than average

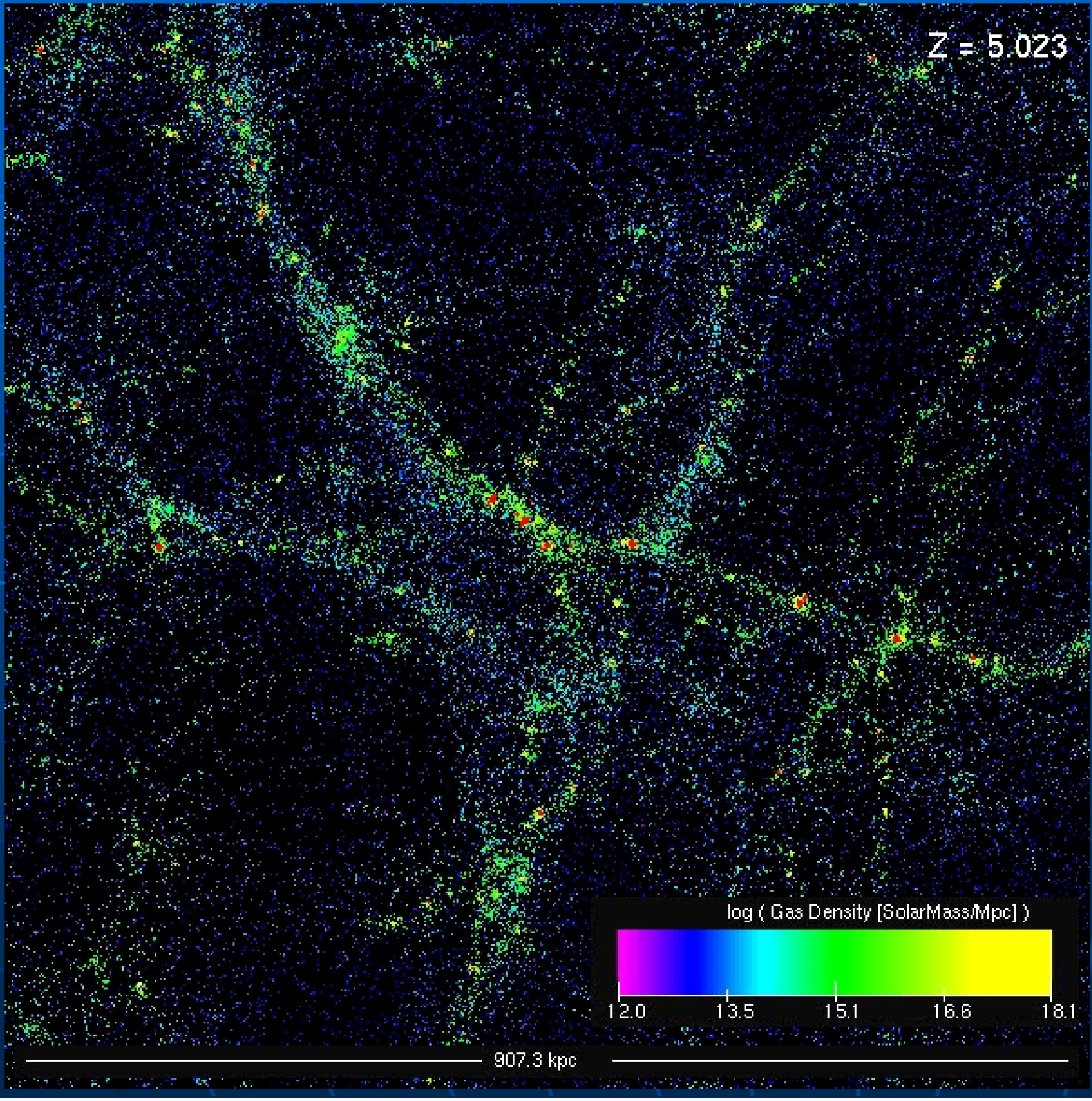
These overdense regions act as flow convergence regions (FCR) towards which cold mass elements flow

Flow singularities unavoidable (Mathematical Theory)

HYDRO adds cooling, heating to DM: more dramatic { Singularity Formation / Gravitational Heating }

GLOBAL COLLAPSE ON A CELL STRUCTURE with heating and dissipation

PROGENITOR OF AN MG AT z=5: cell structure



PROGENITOR OF AN ELO AT z = 5.
A projection of a 900 side box at z = 5.02. Red: stars. The other colors mean gas density according with the code in the bar. This region will transform later on into a virtual elliptical. At this high redshift we can appreciate the cellular structure, the denser regions already turned into stars, and dense (cold) gas flowing towards the node at the center of the FCR through filaments.

ELO FORMATION FAST PHASE

- **Global collapse** involving **nodes connected by filaments**, that experience

fast head-on fusions

(i.e., multiclump collapse, see Thomas, Greggio & Bender 1999).

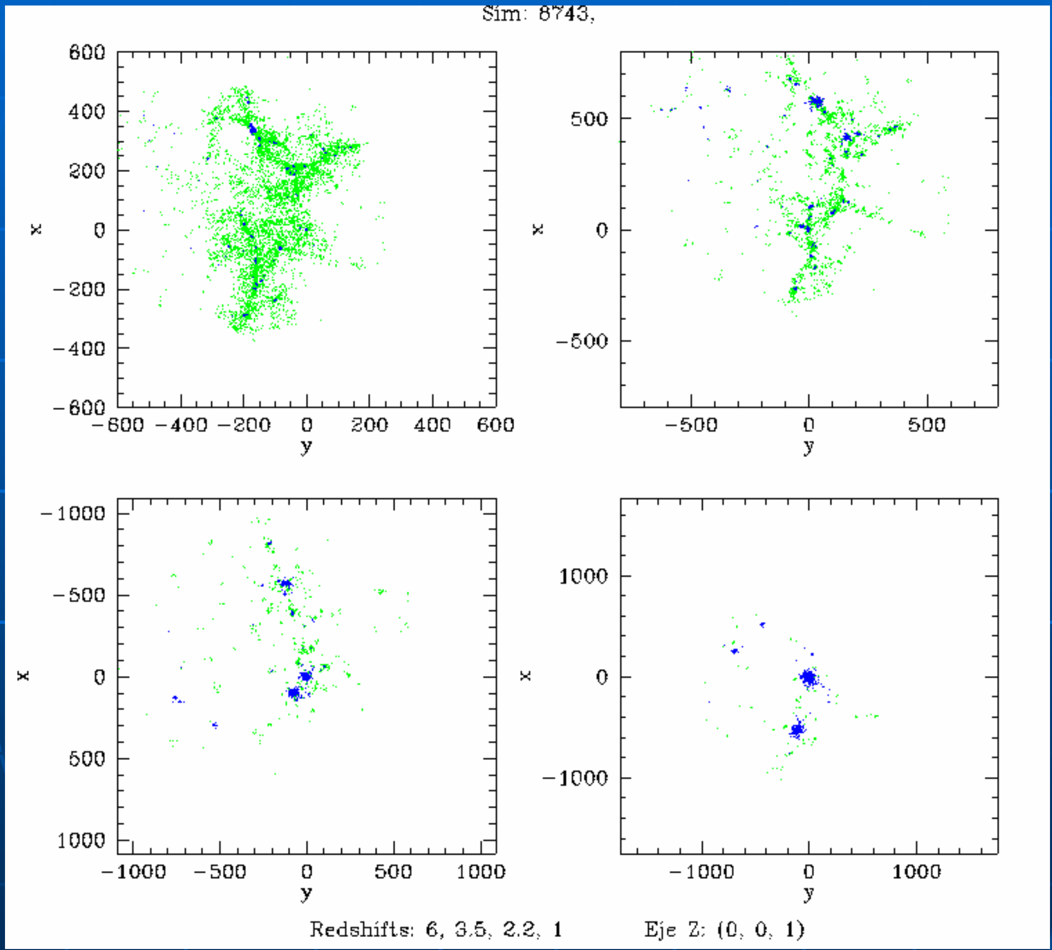
- ⇒ **strong shocks and high cooling rates DISSIPATION**
- ⇒ **strong and very fast SF bursts**

transform most of the available cold gas at the FCR into stars

- **COLD GAS Acquisition: through filaments, as in Keres et al. 2005** **(see Poster by Oñorbe et al.)**

- **Most of the dissipation involved in the mass assembly of a given ELO occurs in this violent early phase** at high z (6 – 2.5)

FLOW CONVERGENCE REGION DYNAMICS
(Collapse - induced CAUSTIC TREE)



Projections, at different redshifts, of the baryonic particles that at z = 0 form the STARS of a typical massive ELO. Green: cold gas particles. Blue: stellar particles. The redshift decreases from left to right and from top to bottom. Note the clumpy collapse of two different FCRs between z = 3.5 and z = 2.2 (fast phase) with ELO formation, and their merging between z = 2.2 and z = 1 to give massive ELOs (slow phase).

WALLS → **FILAMENTS** → **CLUMPS**

THE ROLE OF FAST PHASE

(Singularity Formation and Dressing)

CANNOT BE AVOIDED

- Mass assembly
- Star formation
- Set Fundamental Plane
- Metal and dust formation
- Metal diffusion
- Diffuse gas heating
- BHs?

THE SLOW PHASE

FOR A GIVEN GLO, DIFFERENT POSSIBILITIES

- Lower merger rates (no MMs possible)
- **Different kinds of mergers possible**
- No dissipative, lower SFR
  - Two- (or few-) body dry merging
- Relative orbital J, excep for the more massive ELOs

Mass Aggregation Tracks at Fixed Radii

Mass Assembly

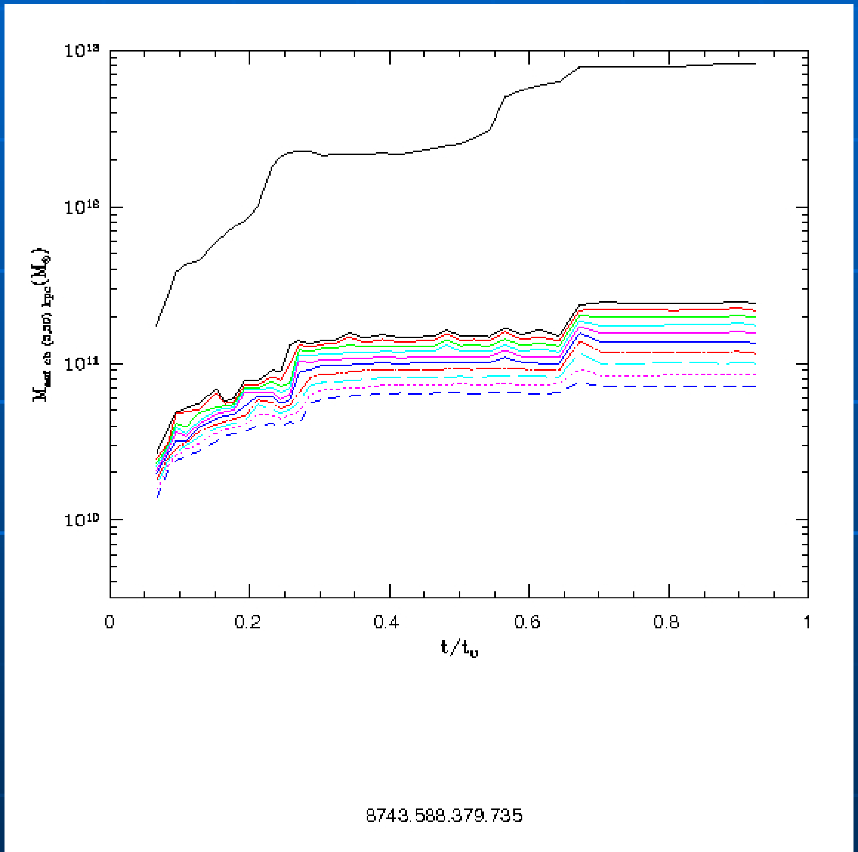
At the virial scale (black)

At the ELO scale (colors)

MMs **mMs** ...

3D Mass Distribution

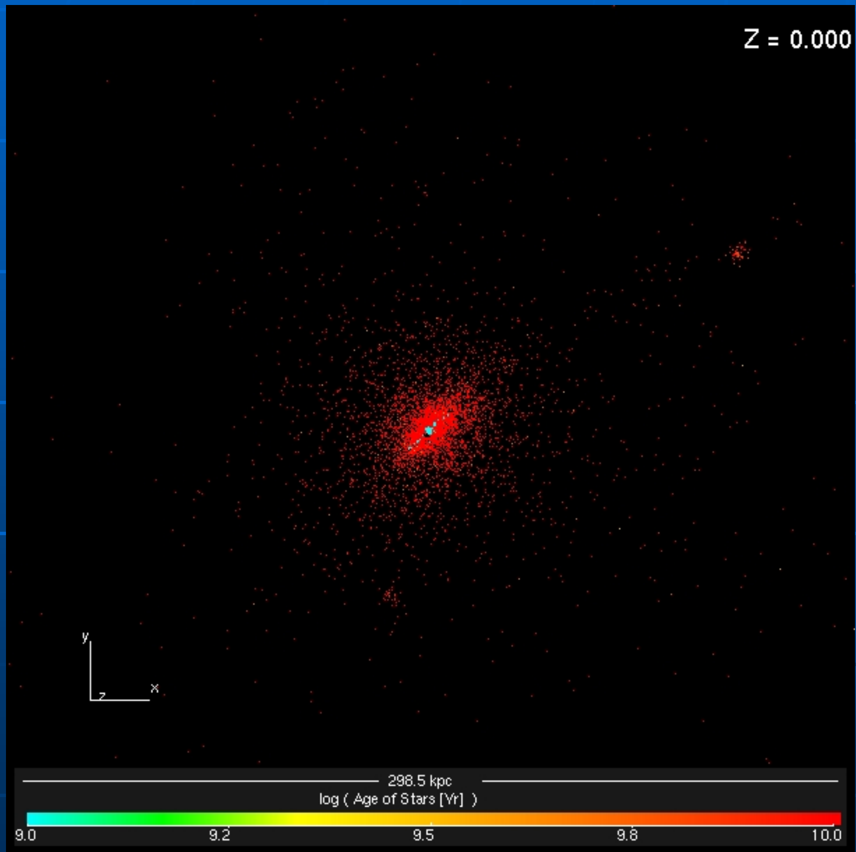
(Salvador-Solé et al., 2007)

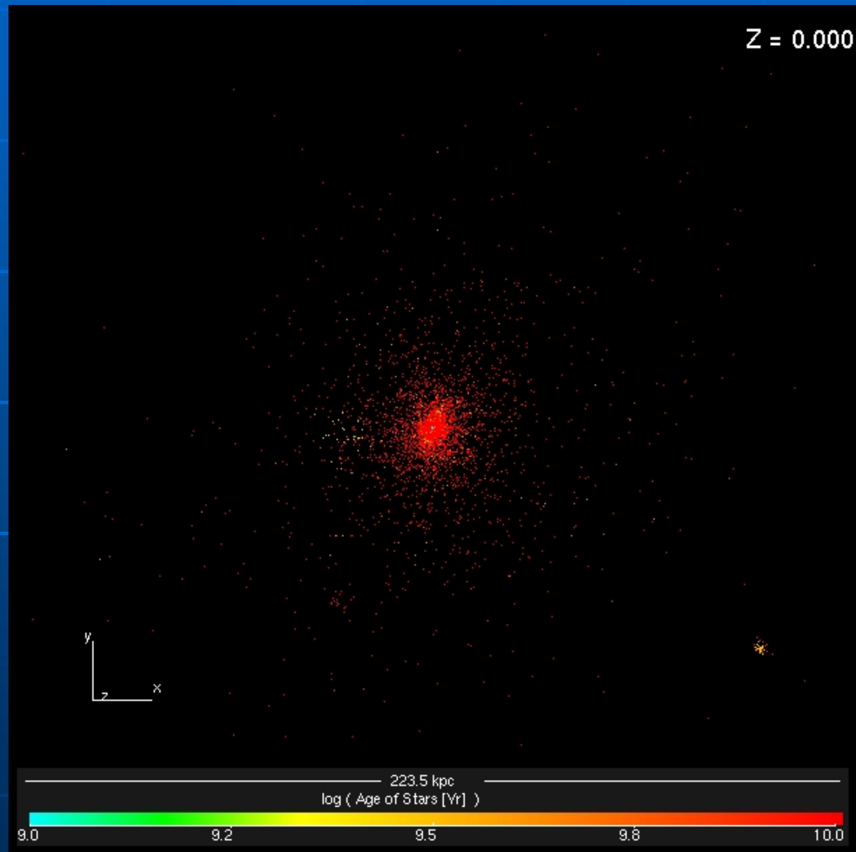


FAST

SLOW

GALAXIAS ELIPTICAS





O: van Dokkum 2003; Menanteau et al. 2004

REALISTIC MASSIVE OBJECTS AT Z=0

- 3D mass distribution
- Fundamental Plane
- Stellar age distribution
- Rotation & shape
- Mass – metallicity relation

(Oñorbe et al. 2005; 2006; González-García + 09; Martínez_Serrano +)

SOME GENERIC CONSEQUENCES

Large-scale, diffuse, hot gas component (regular mass el.)

BH formation at high z at centers of flow convergence

Relaxed, massive, old objects in a young Universe

SFR history and the AGN z-distribution correlated and they peak at high z (Shaver et al. 1999; Ferrarese 2002)

QSO-morphology correlation changes with z (Aretxaga et al. 1998; Schramm et al. 2007)

High-z galaxies generally have messy morphologies

Bimodality

Shape and kinematical evolution determined by dry merging

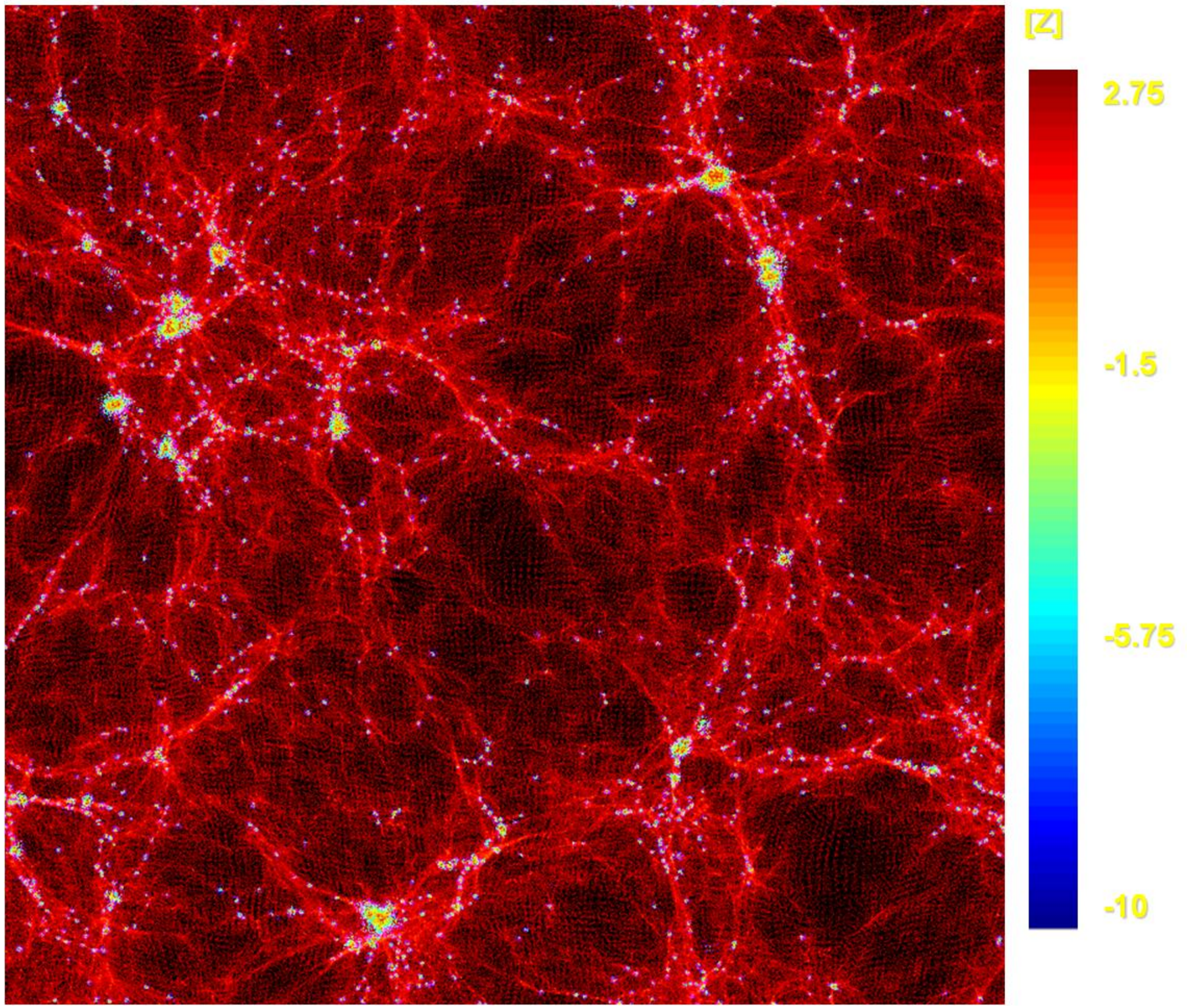
NATURE

FROM BIRTH

By law

ELEMENT CONTENT

Where and when are the heavy elements produced?
To what extent do galaxies exchange material with their environment?



t/t_u=0.13

Suprasolar at
densest subvolumes

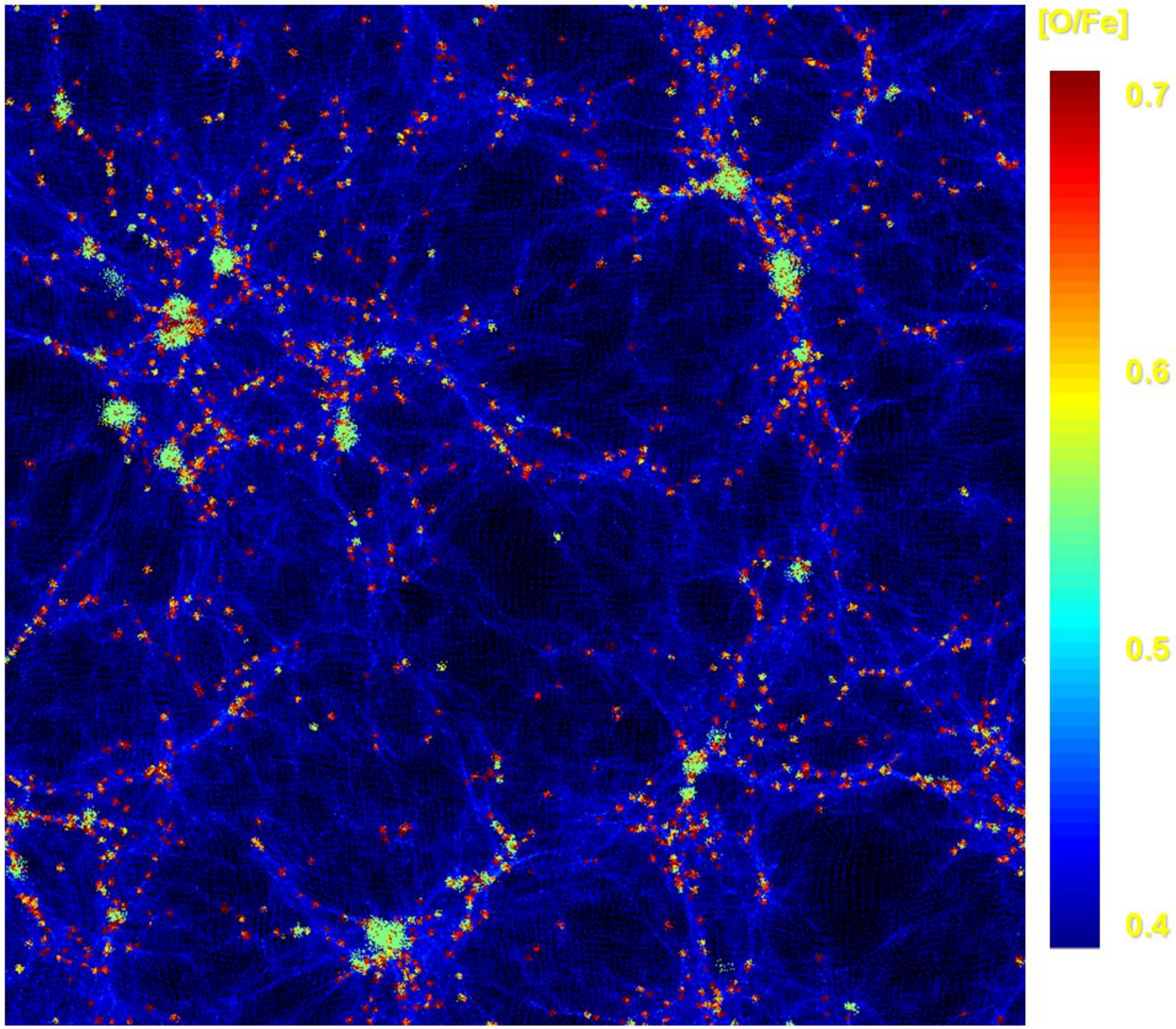
Diffusion

[Z]=log(Z /Z_sun)

[α/Fe] ELEMENT RATIO

How many parameters to describe element abundances?

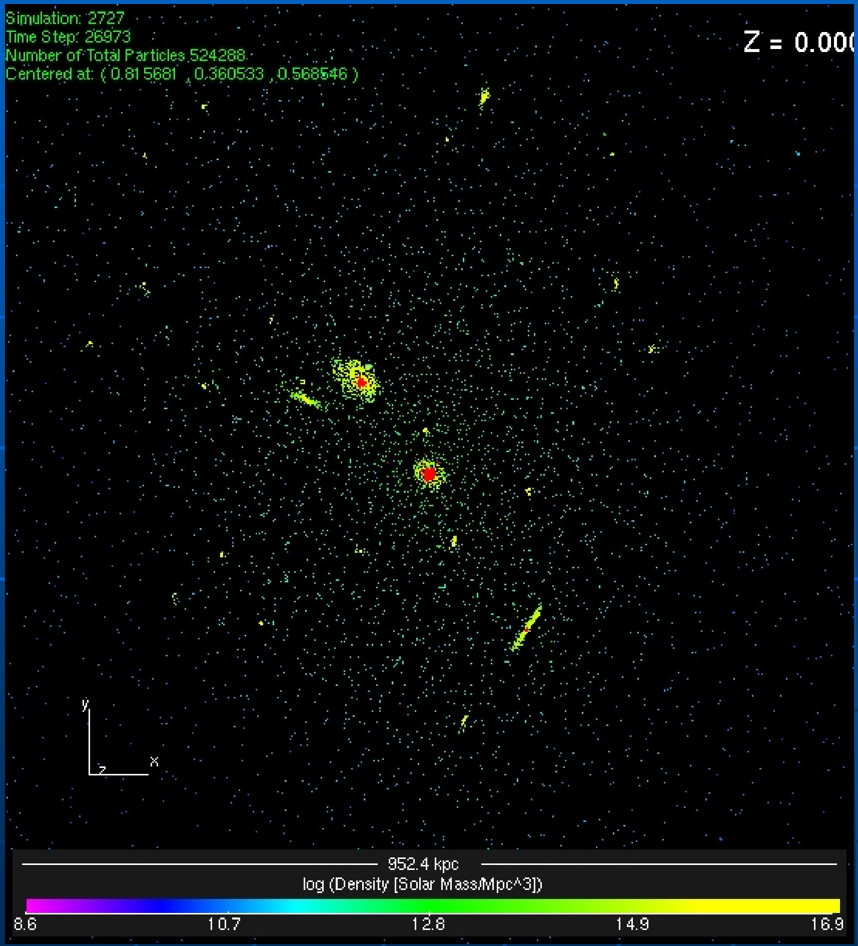
Do different elements have different formation timescales?

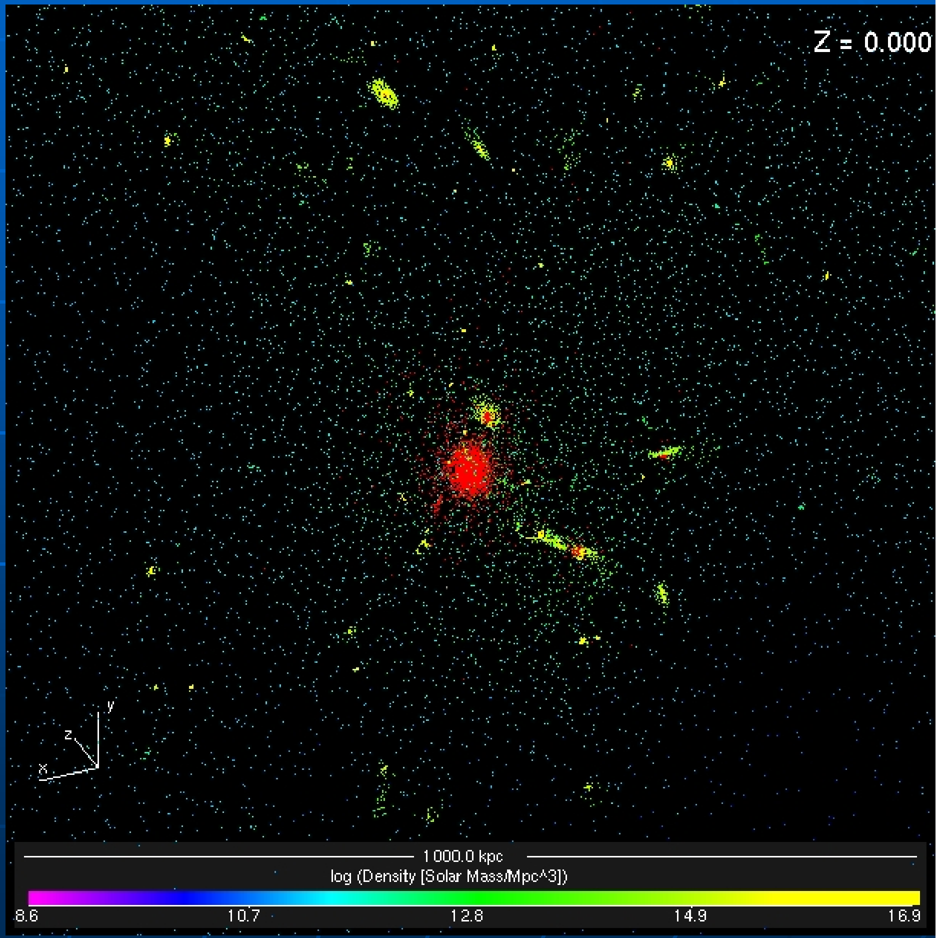


t/t_u=0.13

NO SOLAR RATIO

GALAXY GROUPS



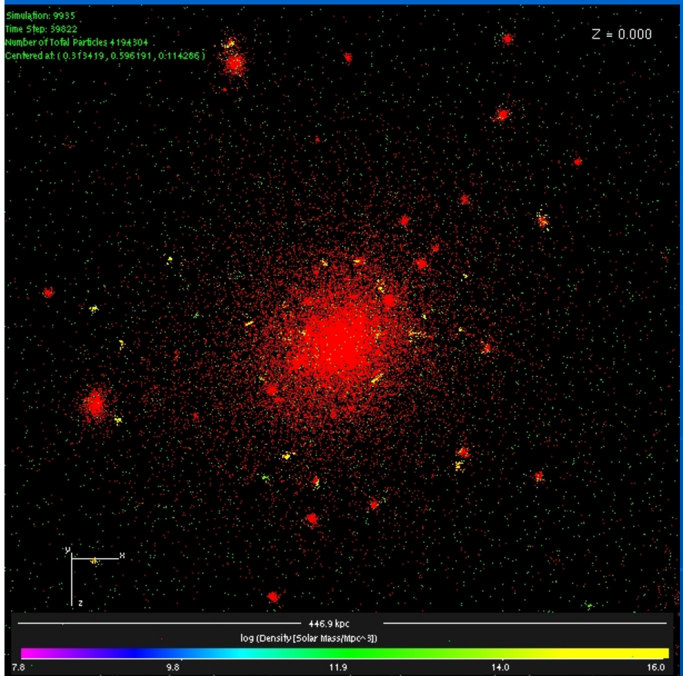


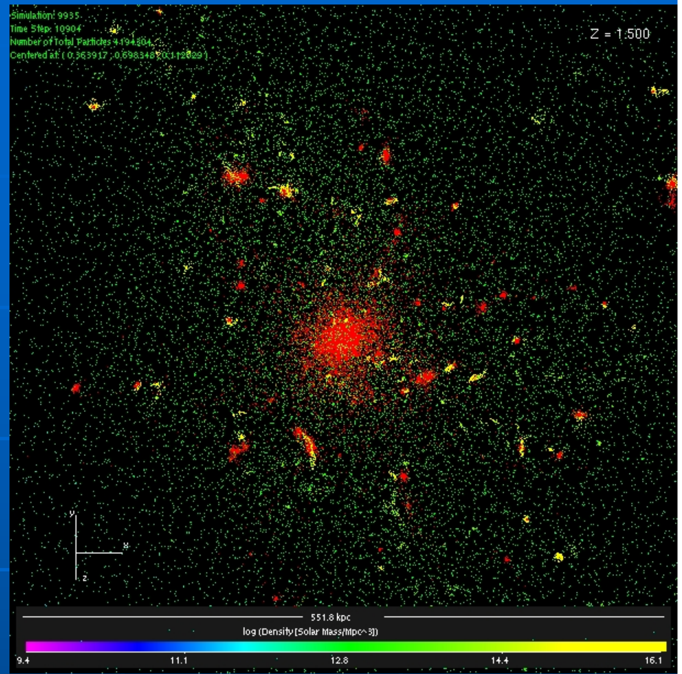
Galaxies, dwarfs, diffuse hot gas, DM

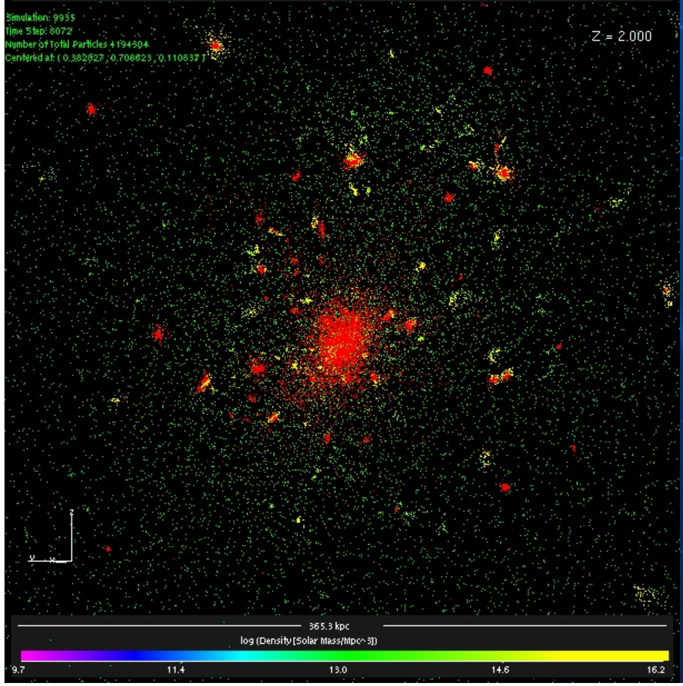
CORRELATIONS

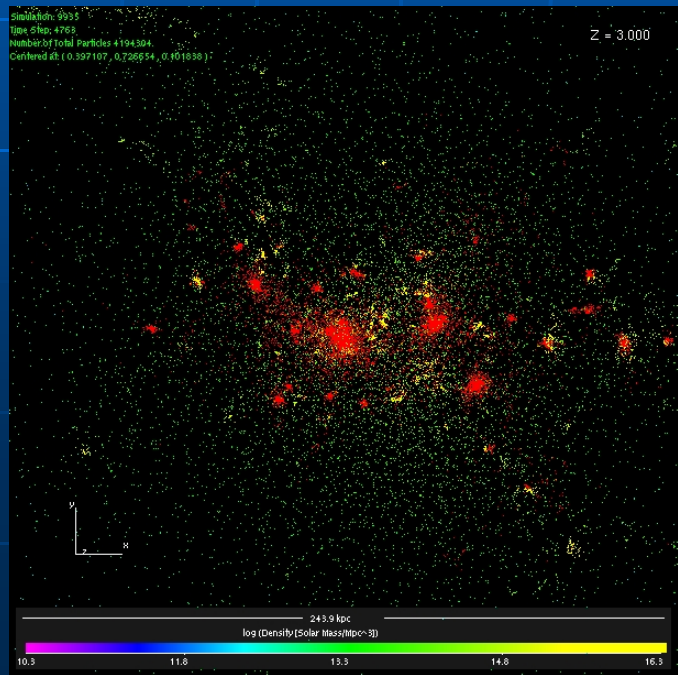
- Neighbour # vs av. density
- Neighbour # vs mass
- Mass vs av. density (Alpresa et al. Poster)

AT ANY Z ...


Simulation: 9935
Time Step: 39822
Number of Total Particles 4194304
Centered at: (0.313419 , 0.596191 , 0.114286)
Z = 0.000
446.9 kpc
log (Density [Solar Mass/Mpc^3])
7.8
9.8
11.9
14.0
16.0

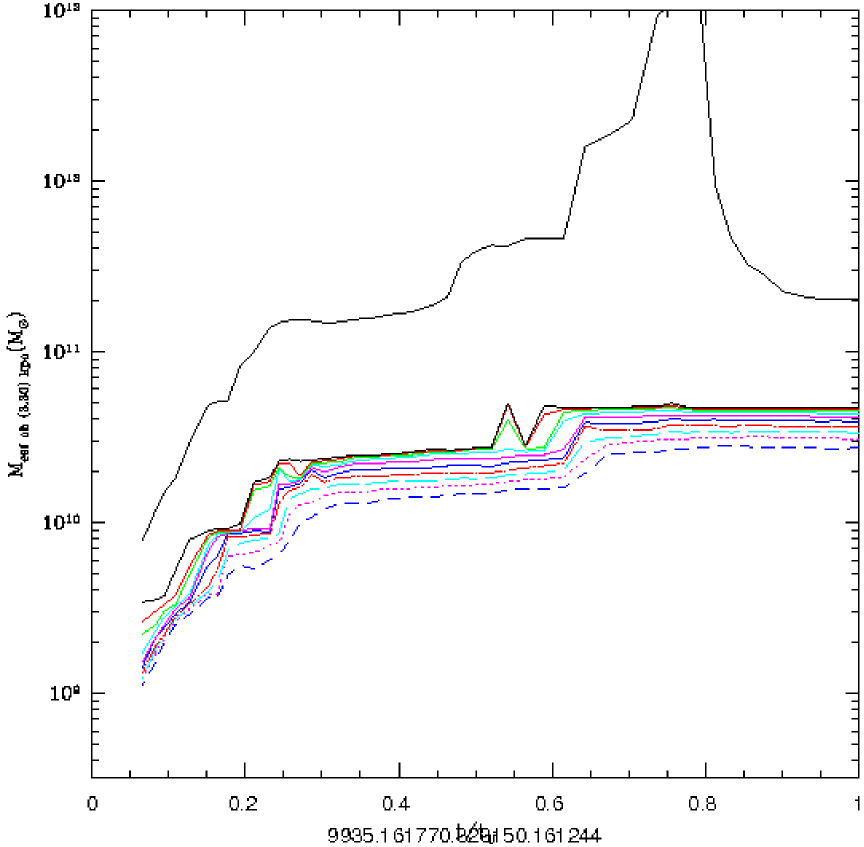

Simulation: 9935
Time Step: 10904
Number of Total Particles 4194304
Centered at: (0.363917 , 0.698348 , 0.112029)
Z = 1.500
551.8 kpc
log (Density [Solar Mass/Mpc^3])
9.4
11.1
12.8
14.4
16.1

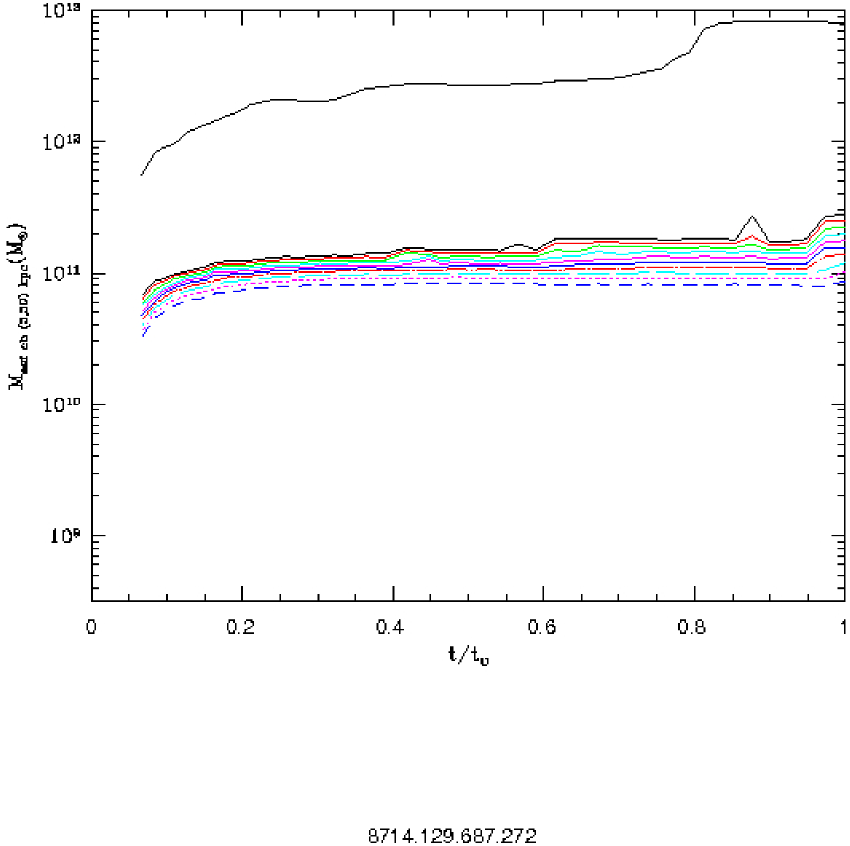

Simulation: 9935
Time Step: 8072
Number of Total Particles 4194304
Centered at: (0.382827 , 0.708623 , 0.110837)
Z = 2.000
365.3 kpc
log (Density [Solar Mass/Mpc^3])
9.7
11.4
13.0
14.6
16.2


Simulation: 9935
Time Step: 4763
Number of Total Particles 4194304
Centered at: (0.397107 , 0.726654 , 0.101838)
Z = 3.000
243.9 kpc
log (Density [Solar Mass/Mpc^3])
10.3
11.8
13.3
14.8
16.3

HALO SHIELDING

Spheroids are stable systems along the slow phase





ISOLATED ELLIPTICALS

How do they fit into this formation scenario?

WHAT MAKES THE DIFFERENCE ?

- **ISOLATION at z = 0** >> **¨FLAT LIVES¨**

  either in the last Gyrs or along all the slow phase

  both in the dark and in the baryon component

Most often, formation within a poor environment, where baryon mass supply is unlikely

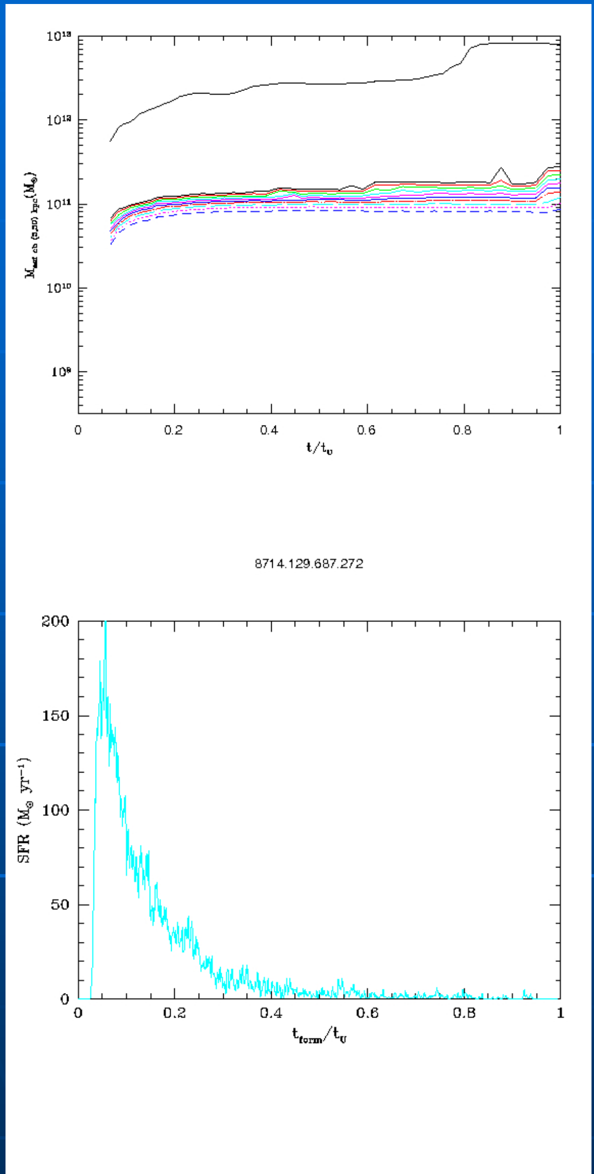
See poster by P. Alpresa et al.

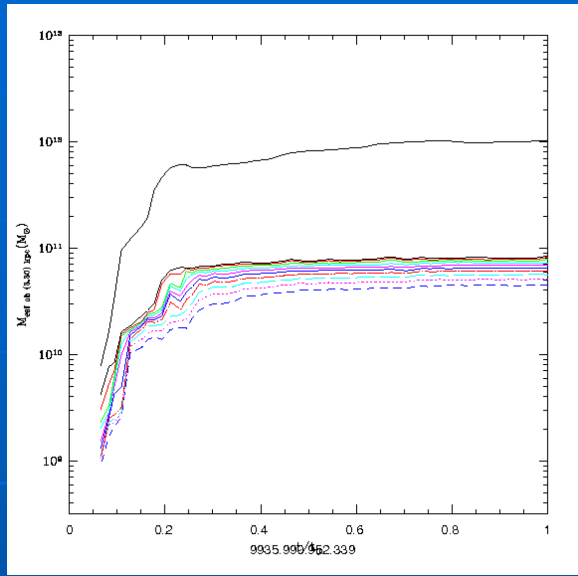
- **GROUPS at z = 0** >> ¨CAPTURE¨

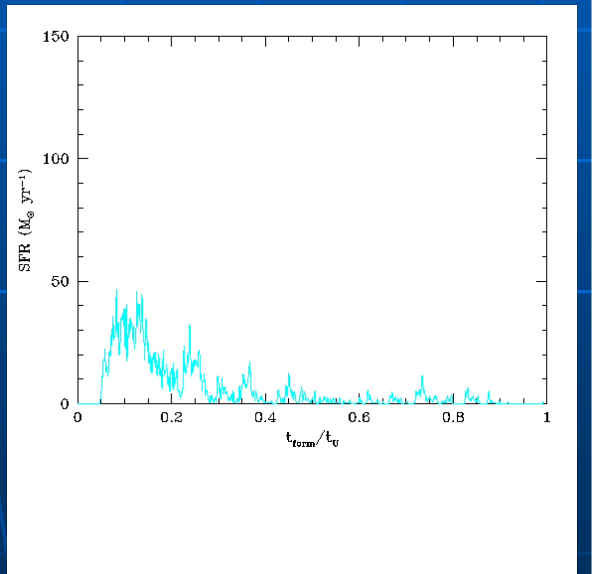
  either in the last Gyrs or long-lasting

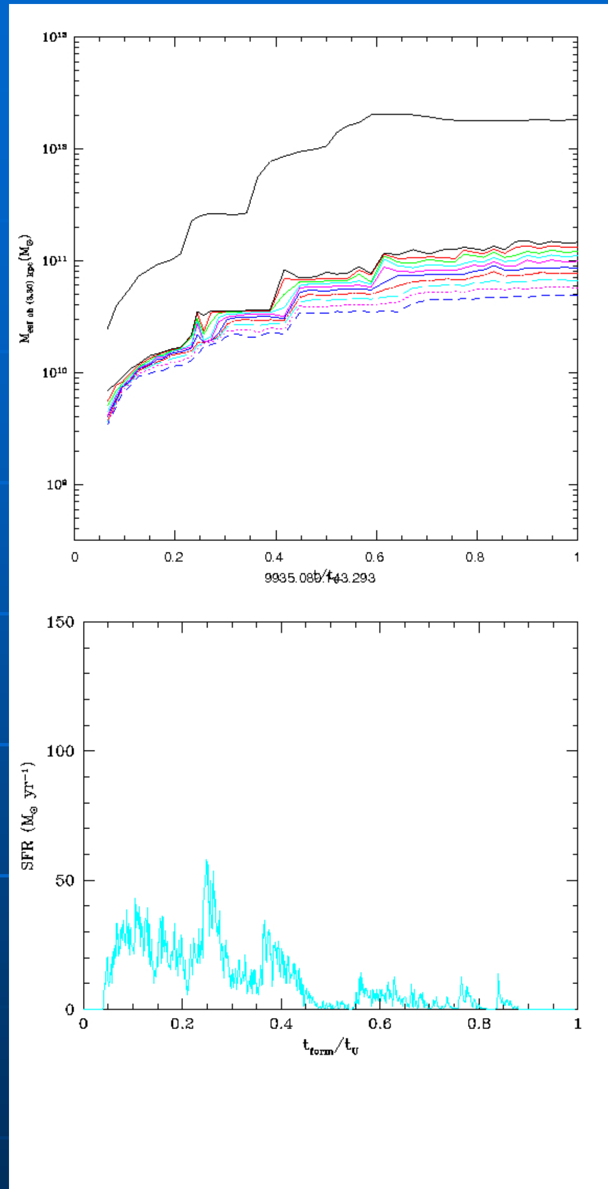
  both in the dark and in the baryon component

  Most often, formation within a rich environment, where continuous baryon mass supply is very likely









Dynamical History versus Star Formation Rate History

ISOLATED

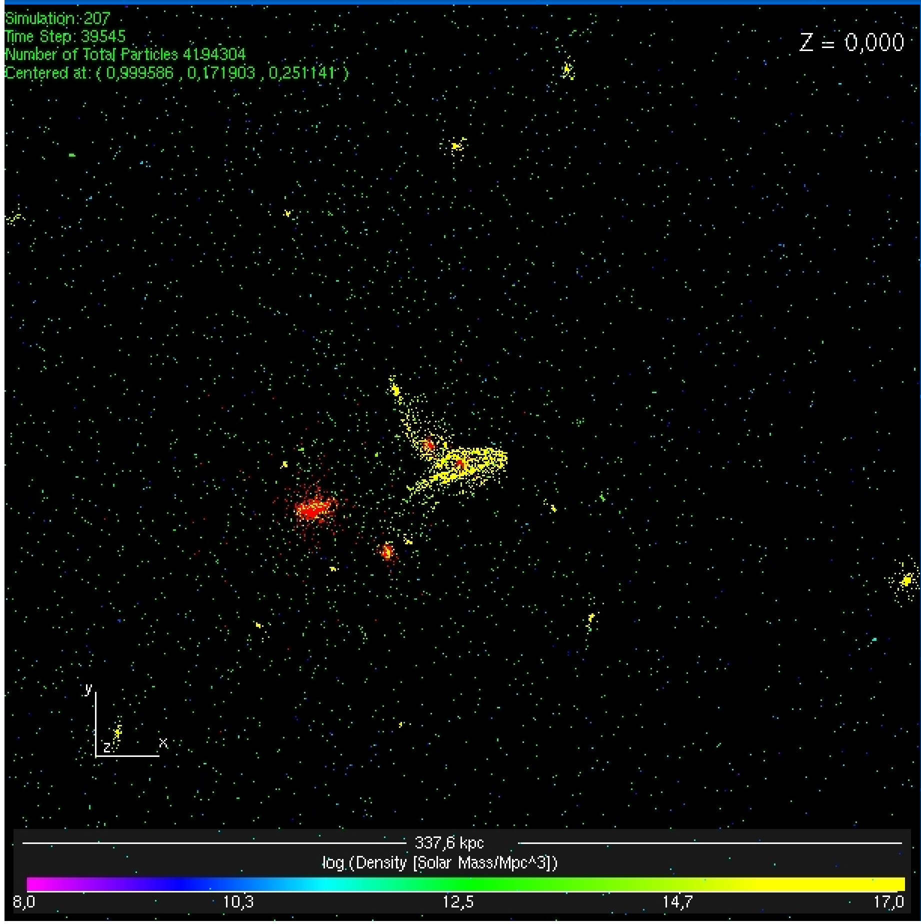
NURTURE

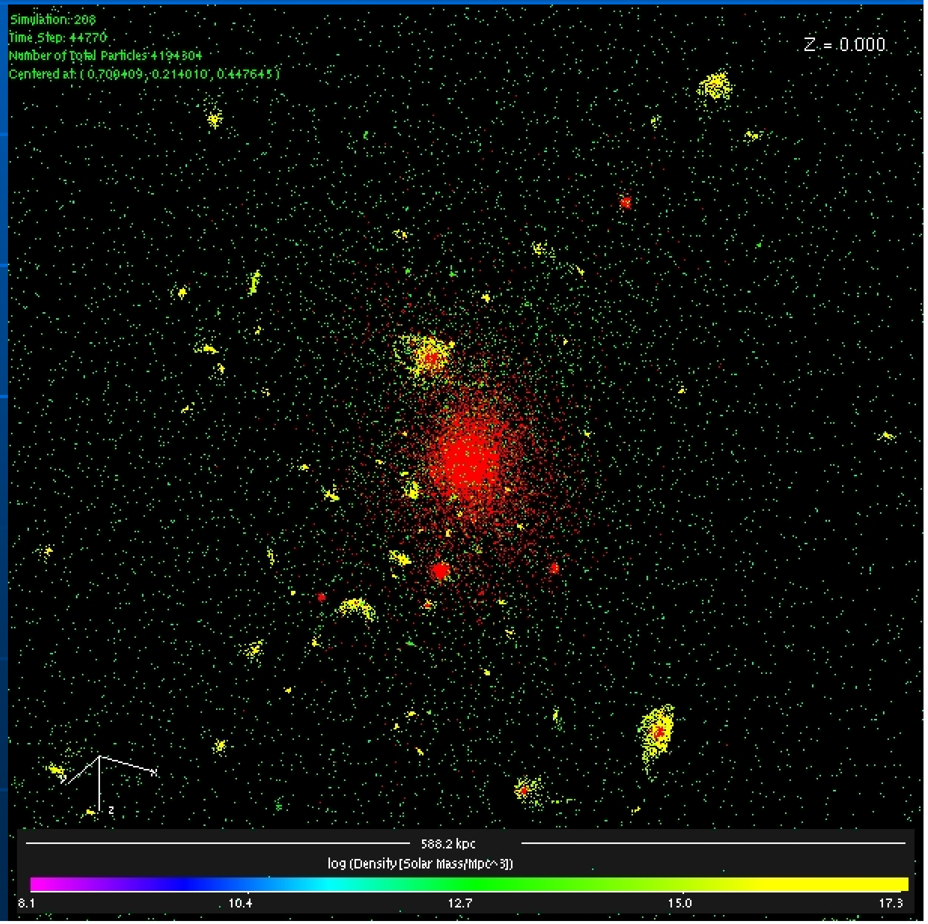
ALONG THE LIFETIME

by chance

DISKS ARE UNSTABLE SYSTEMS

DISTURBED BY INTERACTIONS





MASSIVE GALAXIES:
ROTATIONAL SUPPORT & SHAPE

- Depend critically on the characteristics of the last merger

event they have suffered

ang. momentum content, multiplicity,
MM or mM, dissipation
(see poster by González – García et al.)

>>> Environment dependent

SUMMING UP

Hydro Cosmological Simulations

A SCENARIO FOR E FORMATION

- TWO PHASES: **FAST & SLOW**
- Way out for apparently paradoxical observations

Within this scenario we can understand

ISOLATED MASSIVE GALAXY FORMATION

ENVIRONMENT unlike GAS SUPPLY

MOST MASS ASSEMBLED IN FAST PHASE

NATURE vs NURTURE in massive galaxies

- Fast phase >> role of law
- Slow phase >> role of chance