FORMATION AND EVOLUTION OF GALAXIES: THEORETICAL AND COMPUTATIONAL ASPECTS

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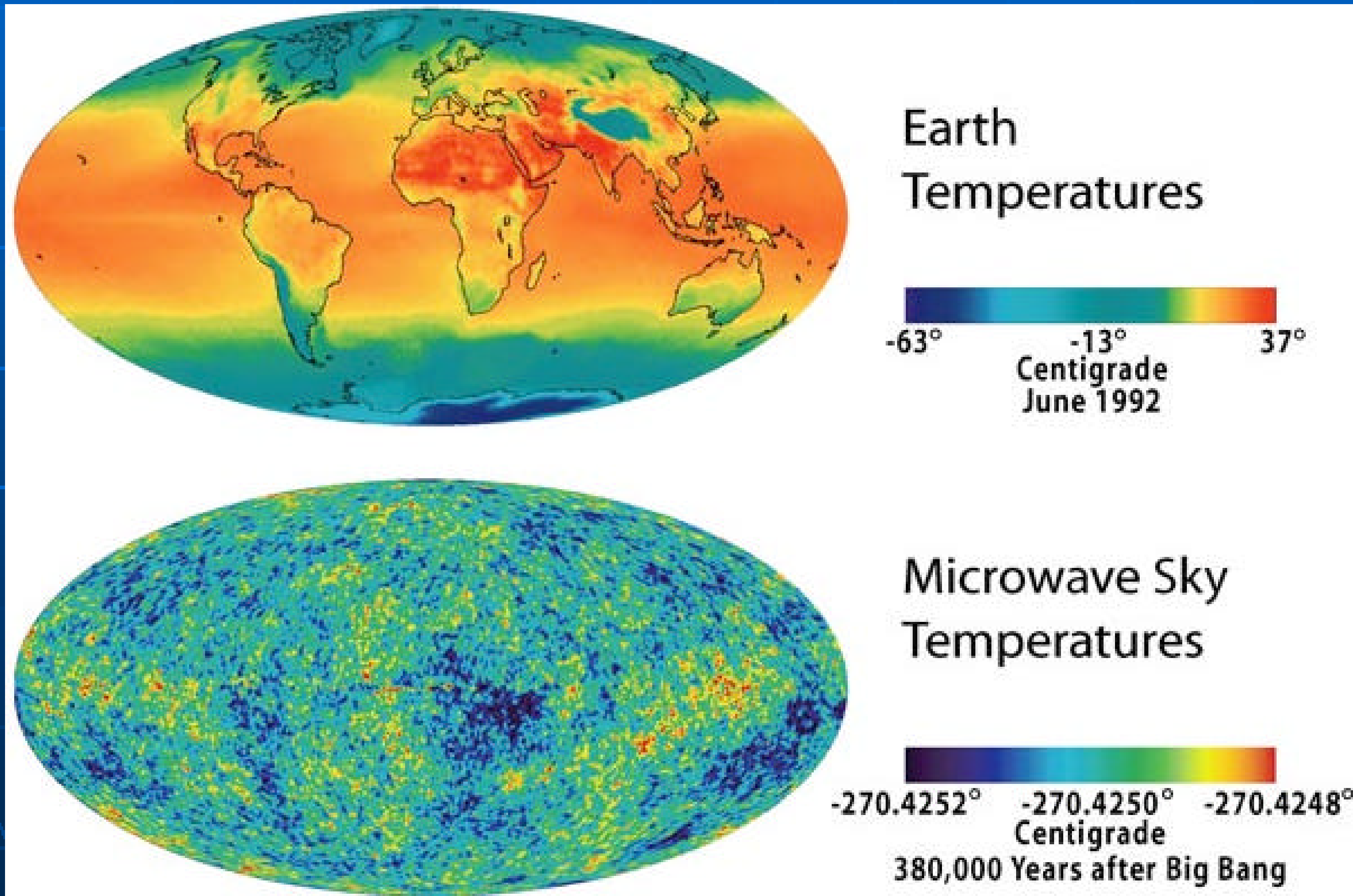
GALAXY FORMATION AND EVOLUTION vs
PRECISION COSMOLOGY & CMB ANISOTROPY

Do LSS & galaxies form from the primordial density inhomogeneities?



OBJECTIVE

Understanding the physical patterns involved into the assembly of galaxies in a cosmological context

First Principles

Theory
Simulations
Models

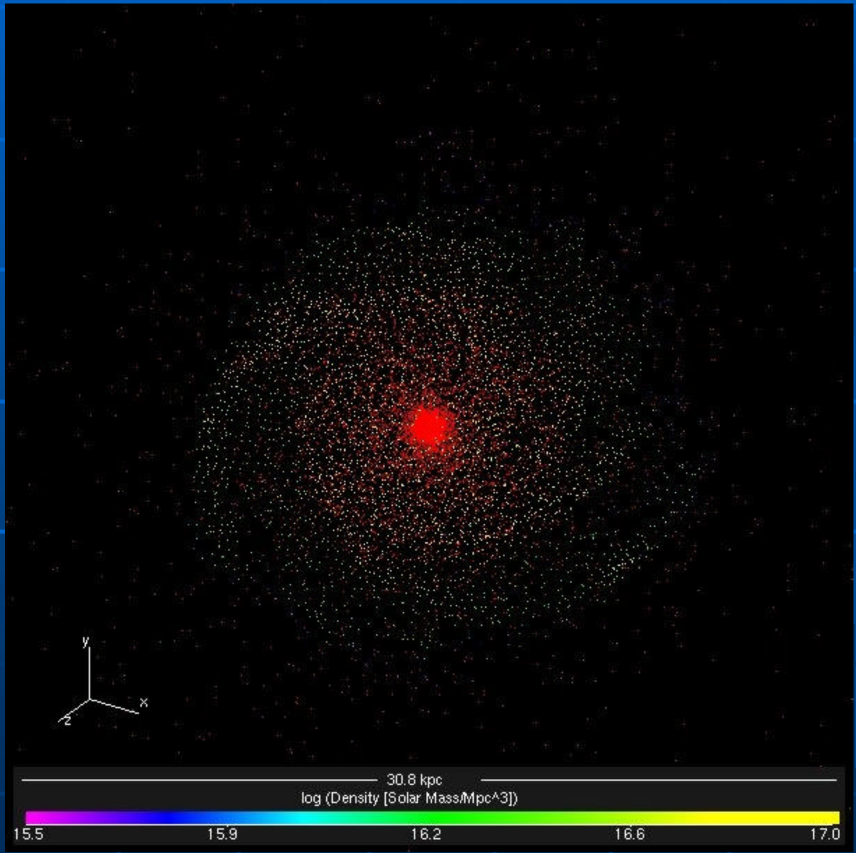
Virtual Objects:
Snapshots & Movies

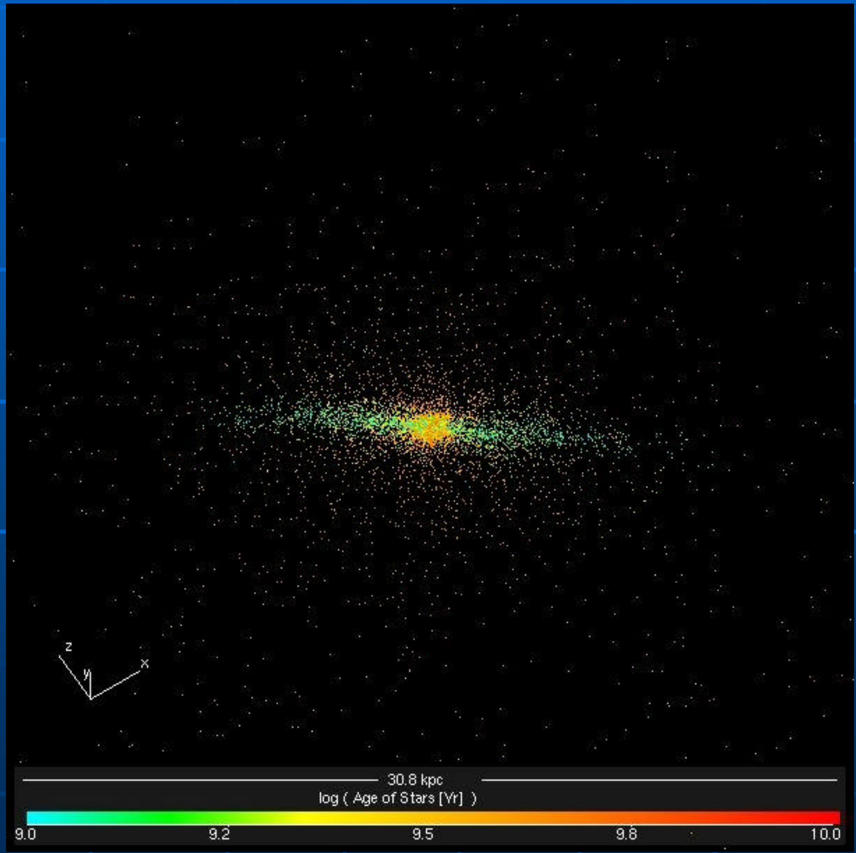
Scenario for Formation and Evolution

DATA: Snapshots

Observing Strategies

SPIRAL GALAXY (Martínez-Serrano et al.)





GALAXY FORMATION IN A COSMOLOGICAL CONTEXT: STEPS

1.- Cosmological Model; Adhesion Model

2.- Halo Formation & Statistics

3.- Gas Physics & Thermodynamics

4.- Gas Acumulation & Star Formation
(about 1 kpc)

5.- Short Scale Stellar Processes + BH

6.- Metal Enrichment + Diffusion

INTRINSIC OBJECT

7.- Observational Manifestation

1, 2, 3: Large Scale, from FP

5, 6, 7: Require Models

4 : KEY STEP: models, numerical

WHAT SIMULATIONS DO FOR YOU

- Follow mass density evolution under gravity and hydrodynamics
- Gas accretion onto proto-galaxies
- Gas cooling and heating
- Gas accumulation patterns at shorter scales

⇨

coupled evol. Of LSS, galaxies, gas accumulation

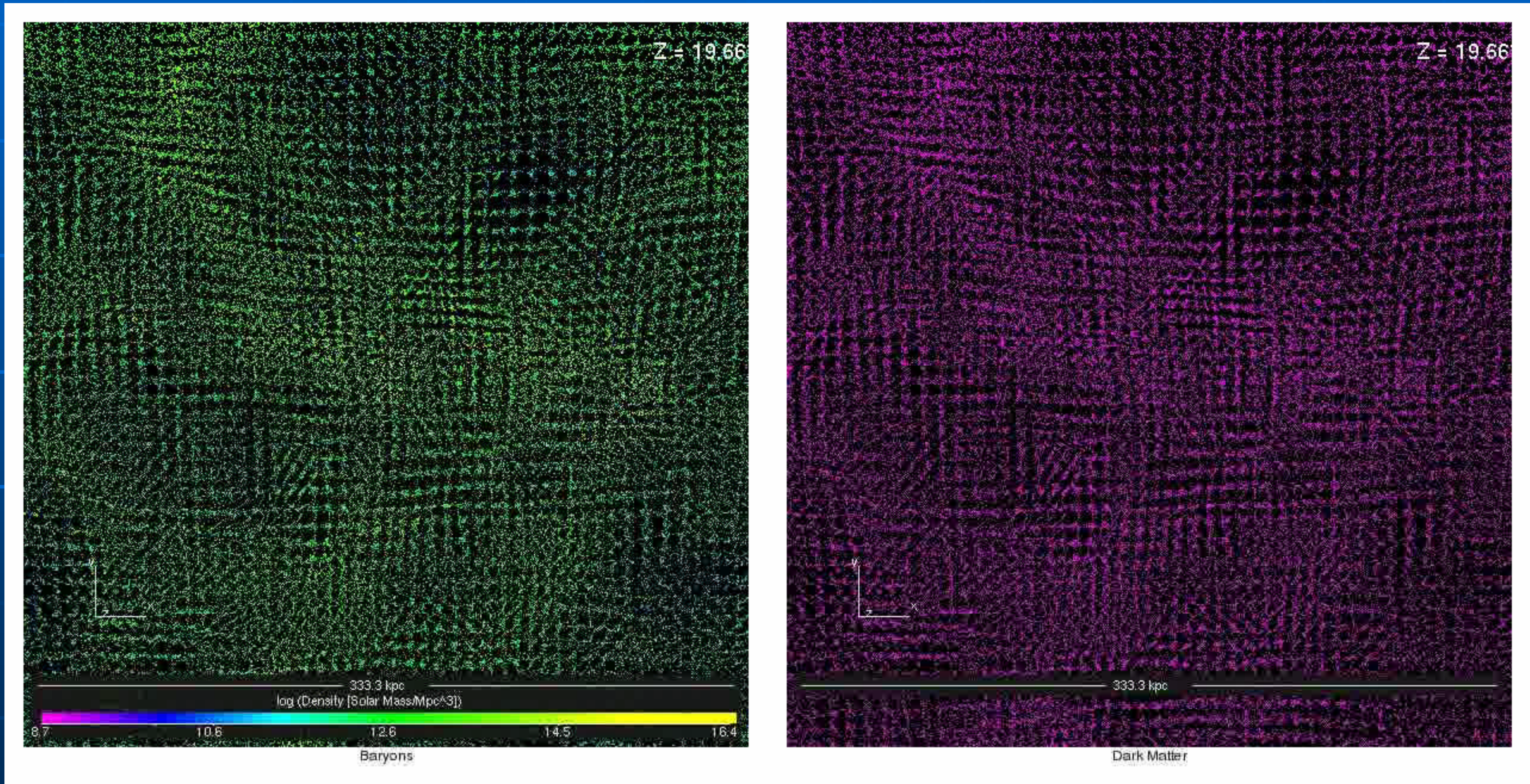
+ MODELS ⇨

Star Formation, BHs, Metal enrichment

At shorter scales (< 1 kpc), MHD

⇨ **ISM Structuration, turbulence, MFs; IMF**

FORMACIÓN de UNA ELÍPTICA



GAS y ESTRELLAS MATERIA OSCURA

OBSERVATIONAL CLUES (GALAXIES)

- Structure and Dynamics
- SFRH = age distribution for different populations
- Morphology
- Statistics: number counts, LFs, ...
- Metal Distribution

- Global SFRH
- Global Background Radiation

STILLL MISSING OBSERVATIONAL PIECES (GALAXIES)

- Resolve extragalactic background (Coppin et al. 06)
- Obscured SF at high z?
- Census: Spheroids; ULIRGs etc
- Compare low and high z ULIRGs (gas and dust distribution; phys. conditions; kinematics; Tacconi et al 06; Genzel 03)
- Dry/wet mergers census
- SB evolution: Moderate luminous population peaking at z = 1?
- The SB – AGN connection as a function of z, luminosity, environment
- Dust fraction as a function of z etc.
- Galaxy desert

SOME OPEN QUESTIONS

- The Hubble types
  - Massive SF at high z
  - Downsizing: how to stop SF in massive galaxies
  - Angular momentum
- Dwarfs as building blocks
- Do massive galaxies and their central BHs form through the same processes?
- Missing baryons and metals

SOME MISSING CLUES IN SF ENVIRONMENTS

CONFIRM:

- Multiphase character of the ISM
- Scaling Relations
- IMF
- Dust

Simple laws underlie complex processes?

WHAT WILL WE LEARN FROM HERSCHEL et al.

HERSCHEL

↓

G&S F SCENARIO

LARGE SCALES & TIMES

- Galaxy surveys: SEDs, z distribution, ...
- Galactic & Extragalactic broadband photometric surveys in the FIR-submm: E + bulge at t/tu < 1/3
- Characterizing the bolometric luminosity density of the Universe at high z
- Brightest cooling lines of the MIS: physical processes and energy production mechanisms in galaxies

SF ENVIRONMENTS (1 kpc)

- Stellar/ISM lifecycle (physics & chemistry)
- Mass and Luminosity Function for complete samples of thousands of cold condensations down to the proto-brown dwarf regime (first time)
- Large spatial dynamical range: dense cores and protoclusters within cloud complexes

→ Spatial hierarchy

- Dust properties with an unprecedent detail

→ **SF in different environments**

WHAT SIMULATIONS CAN DO FOR YOU

THEORY AND SIMULATIONS

↓

OBSERVATIONS

GALAXIES
Complementary information: 3D, dynamics, assembly

Intrinsic objects:

mass & velocity distributions
stellar age distributions
gas properties
metallicity
. . .

Movies:

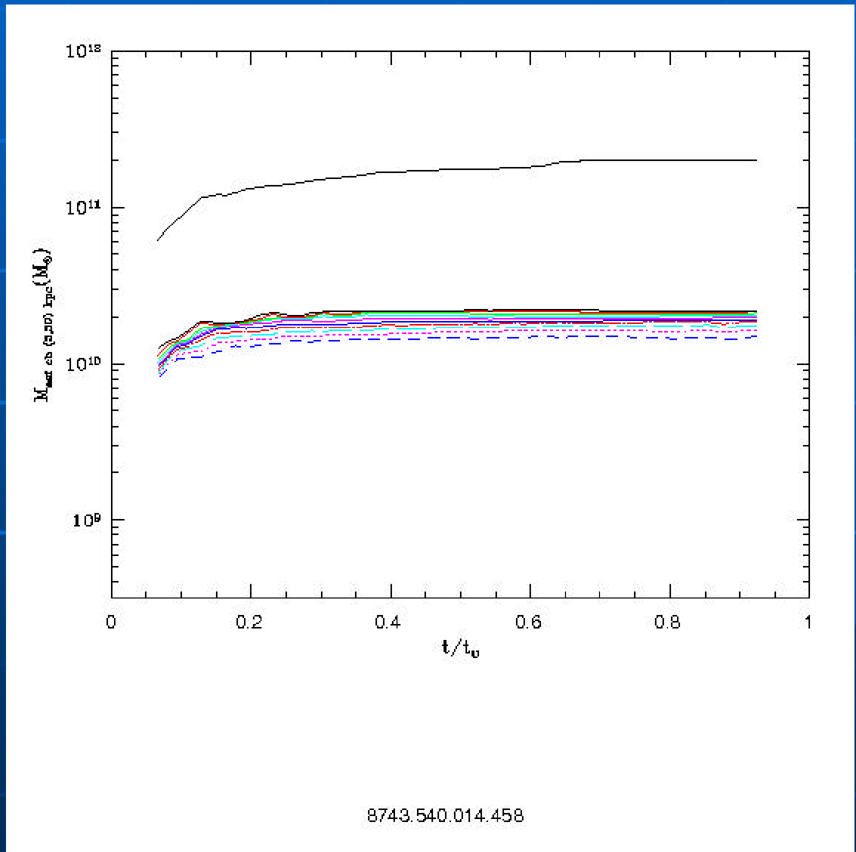
mass assembly
SF
. . .

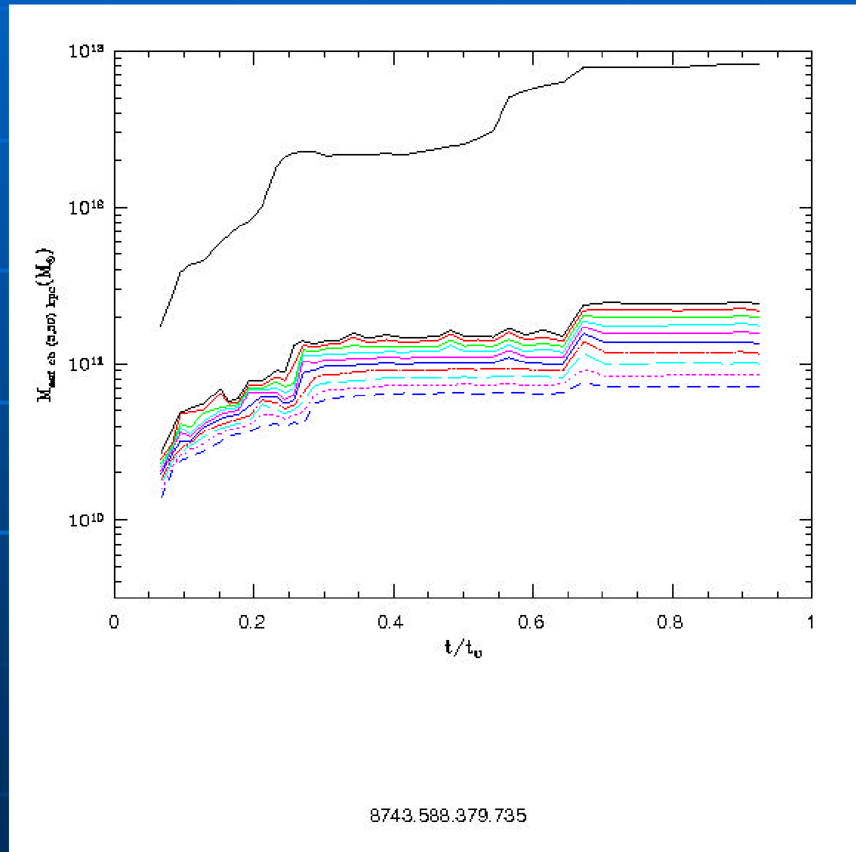
SOME ACHIEVMENTS

- Mass assembly: two dynamical phases (Salvador-Solé 04; Zhao et al. 03; Oñorbe et al. 06)
- Decoupling SF and Mass Assembly (Lucia et al 05; DT et al 06)
- Realistic Local Objects

→ Census spheroids, mergers, QSO Metallicity at high z

Mass Aggregation Trees at Fixed Radii: Two Phases





V: Old Object in a Young Universe

O: Cimatti et al. 2004; Mobasher et al. 2006

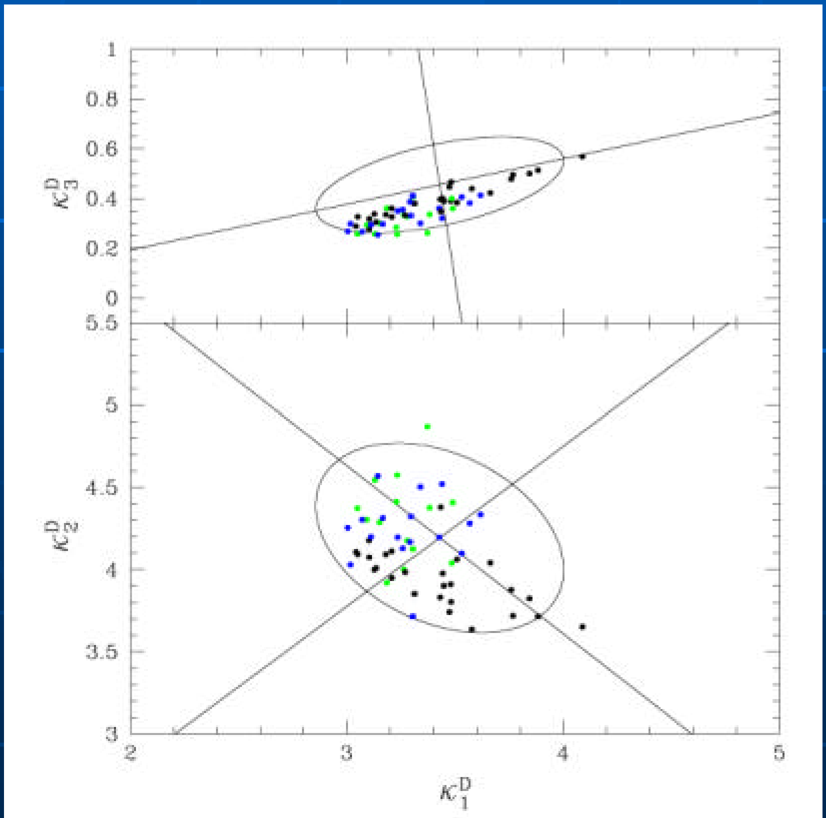
V: Dry Merger

O: Conselice et al. 2005

THE FP AND ITS LACK OF EVOLUTION (Oñorbe el al. 06, 07)

(Van Dokkum et al. 2001; Treu et al. 2005; di Serego-Alighieri et al. 2005)

ELO stellar masses, projected half- stellar mass radii, and stellar central l.o.s. velocity dispersions define a dynamical Fundamental Plane (FP), consistent with observations. The physical origin of the FP lies in the systematic decrease, with increasing ELO mass, of the relative amount dissipation experienced by the baryonic mass component along ELO mass assembly. This result hints to a possible way to understand the tilt of the observed FP in a cosmological context.



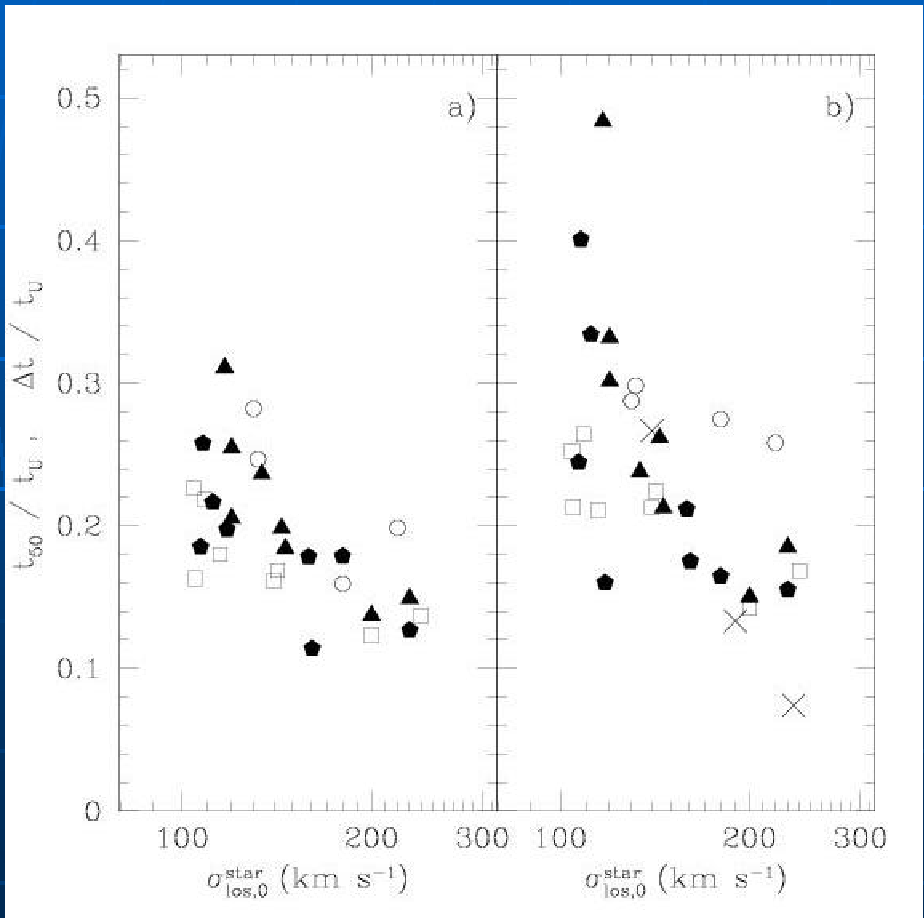
Edge-on projection (top panel) and nearly-face-on projection (bottom panel) of the dynamical FP of ELOs in the kappa^{D} variables (Bender et al. 1993). We also draw the respective concentration ellipses (with their major and minor axes) for the SDSS early-type galaxy sample from Bernardi et al. (2003) in the z-band.

BLACK: z=0
GREEN: z=1
BLUE: z=1.5

AGE EFFECTS IN ELLIPTICAL STELLAR POPs

More massive ELOs have older means and narrower spreads in their stellar age distributions than less massive ones, in consistency with observations.

These correlations hint, for the first time, at a possible way to reconcile age effects in ellipticals, and, particularly, the increase of a /<Fe> ratios with $s_{los,0}$, with the hierarchical clustering paradigm.



(a) Age of the universe in units of the actual universe age at which the 50 per cent of the total ELO stellar mass at z=0 was already formed, versus their corresponding stellar central l.o.s. velocity dispersion.
(b) Same as (a) for the width of the stellar population age distribution. Crosses are width estimations from elliptical data.

MORE SPECIFICALLY

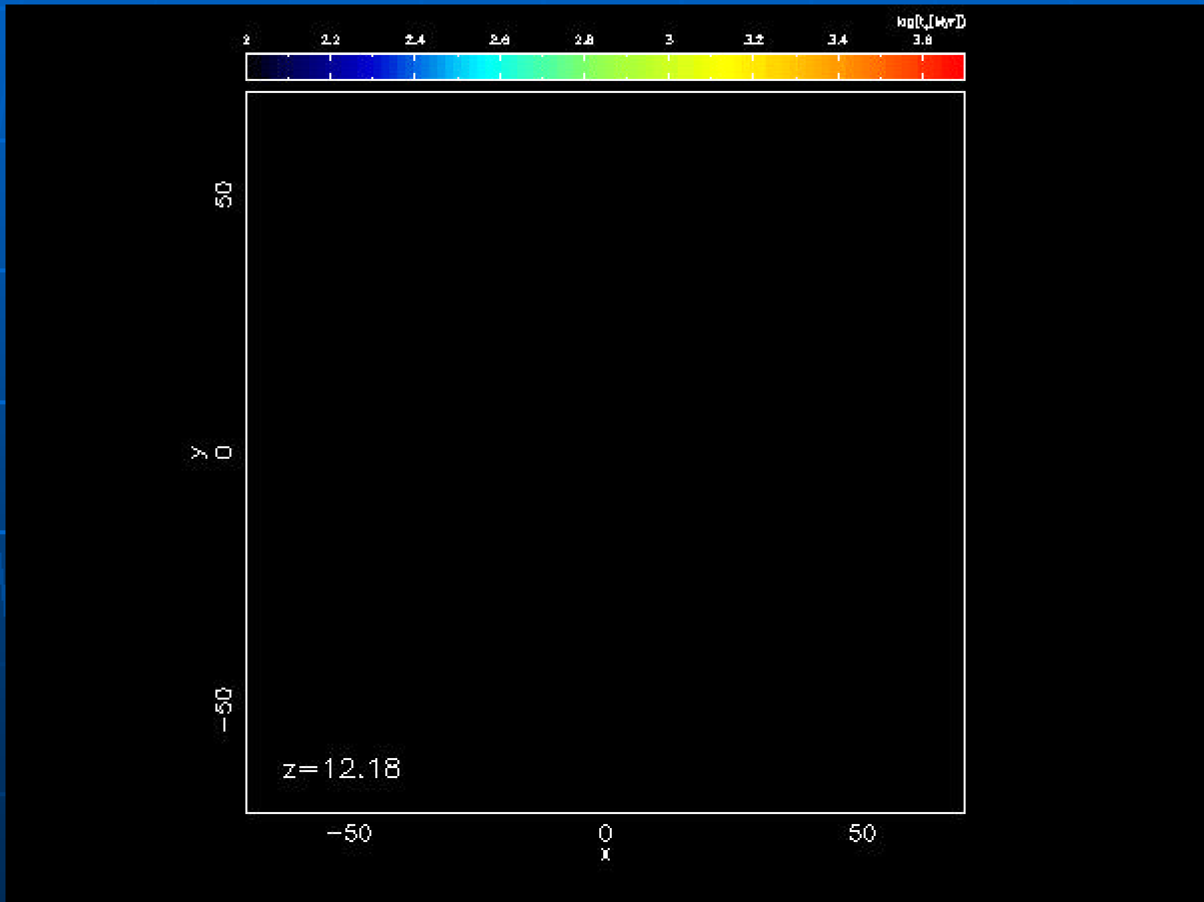
FORMATION AND EVOLUTION

ANCESTORS & DESCENDENTS

- Ellipticals
- QSOs
- Moderate L Population at $z \sim 1$

MASSIVE E FORMATION: THE STELLAR COMPONENT

Color code: steller age



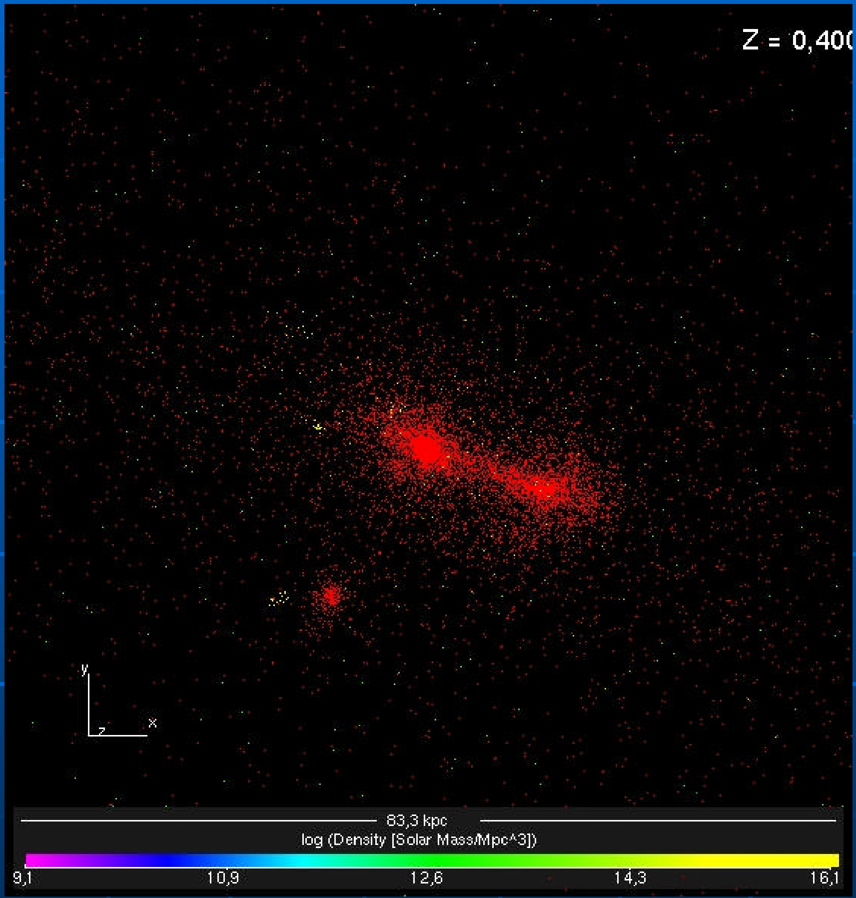
ULIRGs

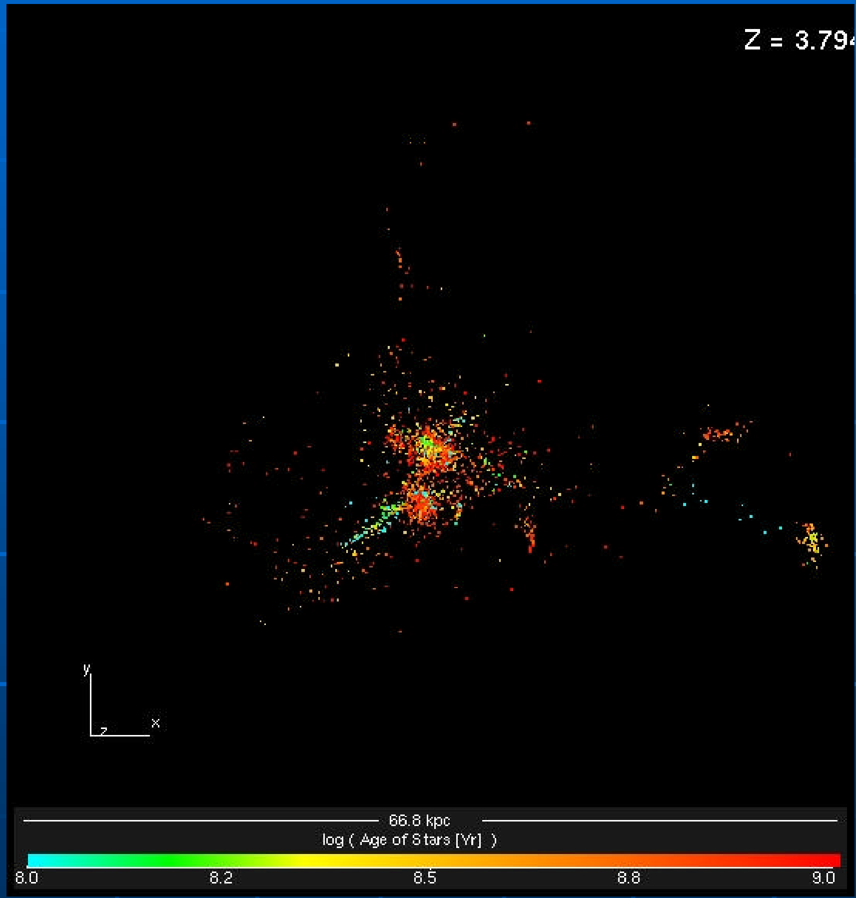
- Collapse versus Merger Events
- Detailed Analysis of Mergers (z, environment, mass)
- Merger Statistics
- Dry vs Wet Mergers: Observational Characterization

ARE LOCAL ULIRGs = HIGH z ONES?

Gas accumulation prior to energy production triggering

VIRTUAL MERGERS (DT et al. 07)





DRY: Local SB: High z

O: Bell et al. 2005; Conselice et al. 2005

INTRINSIC SFRs

- Vs z
- Vs environment
- Metallicity dependence
- Vs morphology

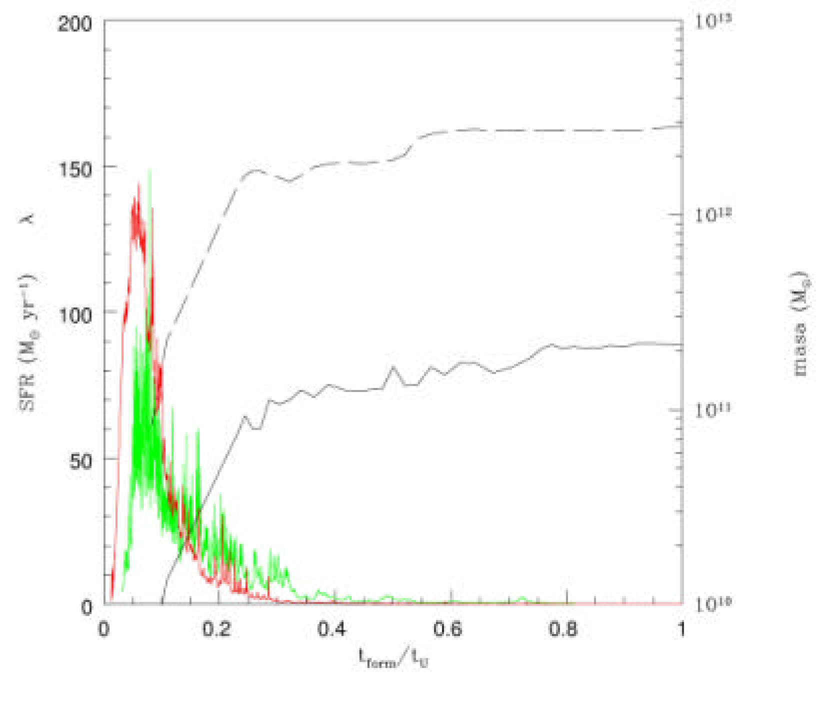
- Global SFRs

- **GAS acquisition**
- **SF inhibition in rich environments: downsizing**

VIRTUAL SFRH & DISIPATION RATE HISTORY (DT et al. 06)

Most dissipation involved in ELO assembly takes place at an early violent phase (z>1.5 - 2) and results in the FP formation and the transformation of most of the available gas into stars.
In the subsequent quiescent phase, ELO stellar mass growth preferentially occurs through non-dissipative processes, so that the FP is preserved and the SFR considerably decreases.

A possible way of explaining, in the context of cosmological simulations, different recent apparently paradoxical observational result on ellipticals, i.e., **DOWNSIZING**



GREEN: SFRH of a massive ELO as a function of universe age

RED: Cooling RH

BLACK: Merger Aggreg. Tree

O: Bell et al. 2004; Bundy, Ellis 205; Faber et al. 2006

BUILDING BLOCKS

- Mass Assembly
- Dissipation

Merging Scenario:

ARE TODAY DWARFS THE BUILDING BLOCKS OF ADULT GALAXIES?

AND AT 1 kpc SCALES

SOME ACHIEVMENTS AND FUTURE

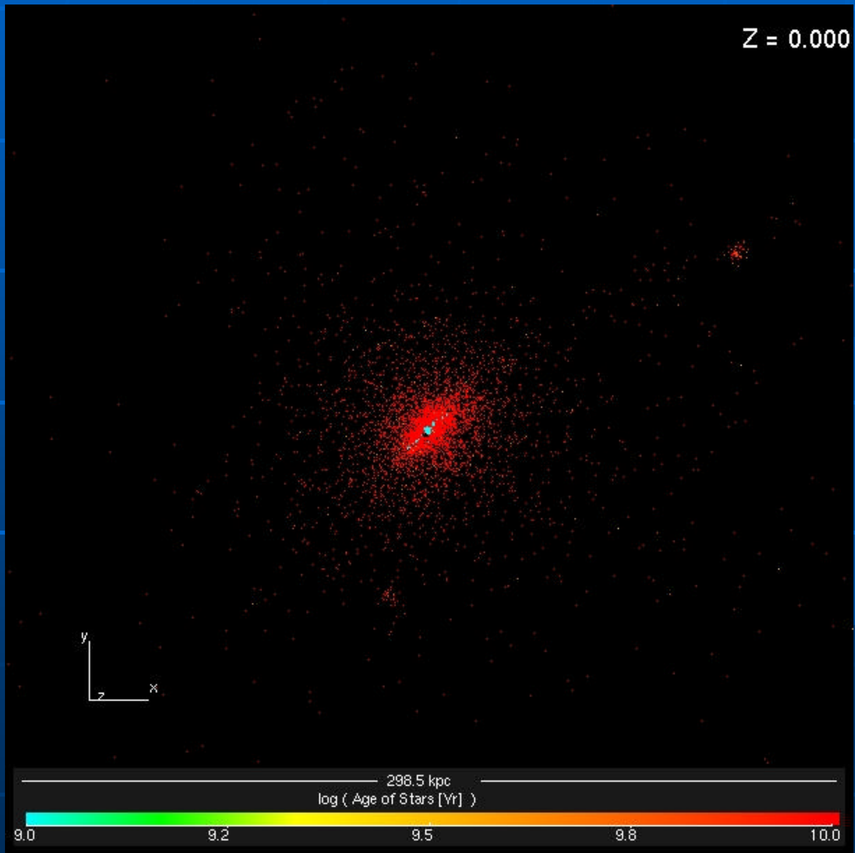
- The Structuration of the ISM
- Some hints on the role of turbulence

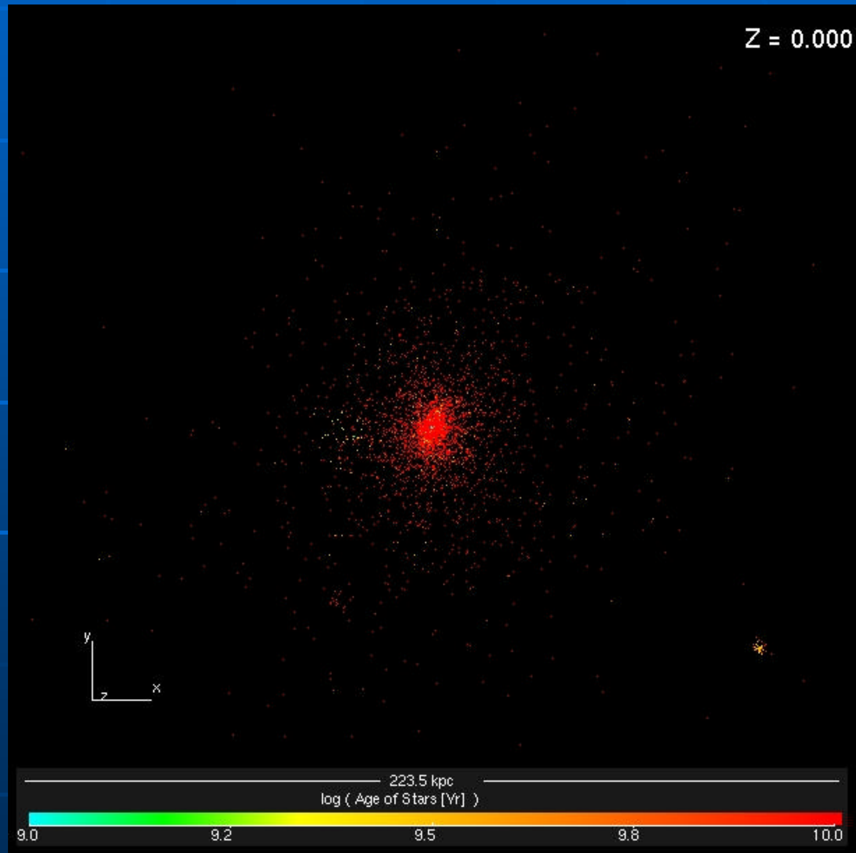
→ Scaling Laws?
Universality?

What powers the turbulent cascade?

GALERÍA OBJETOS VIRTUALES

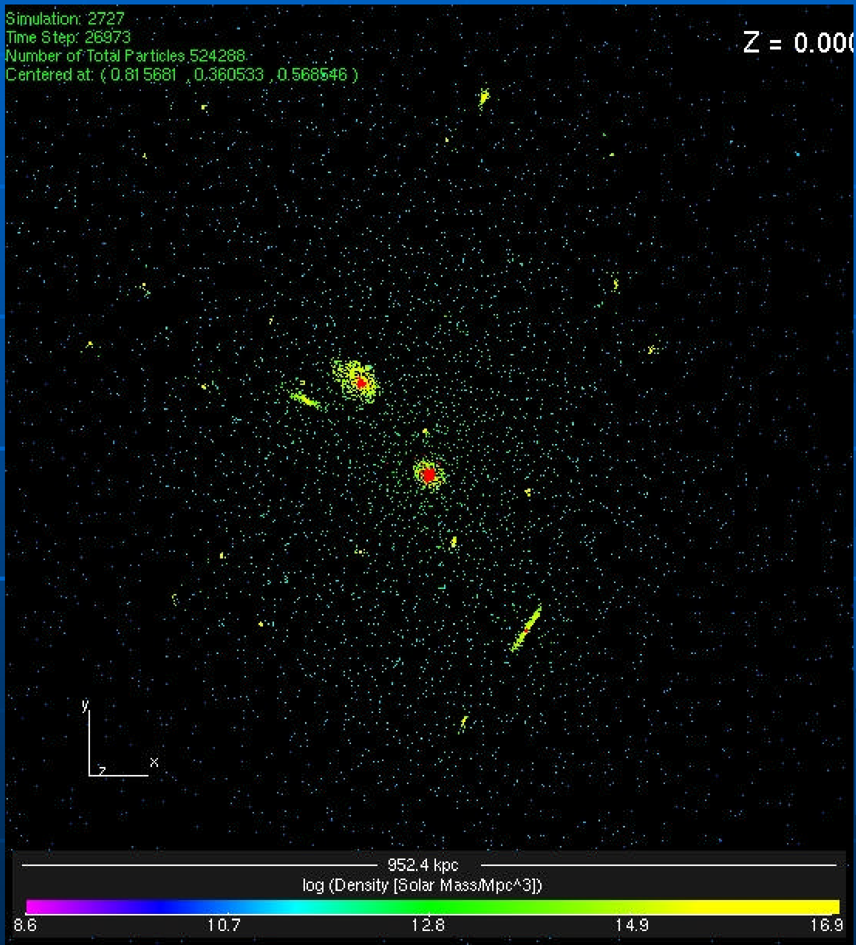
GALAXIAS ELIPTICAS

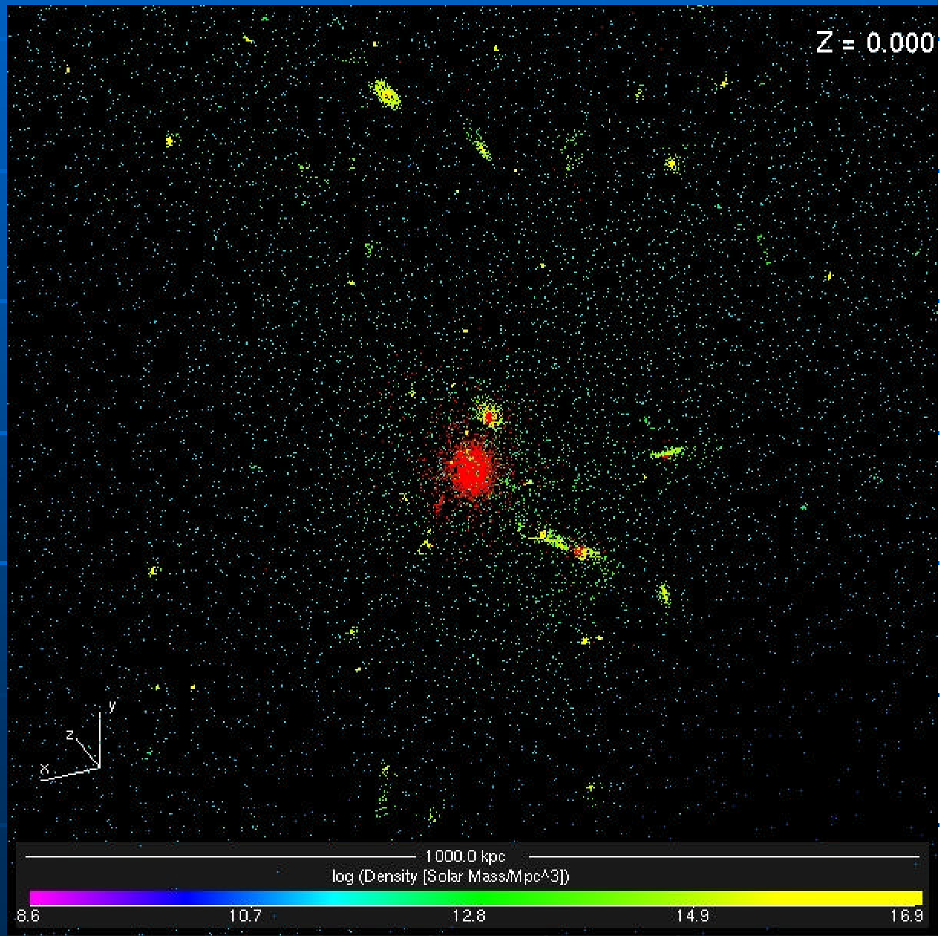




O: van Dokkum 2003; Menanteau et al. 2004

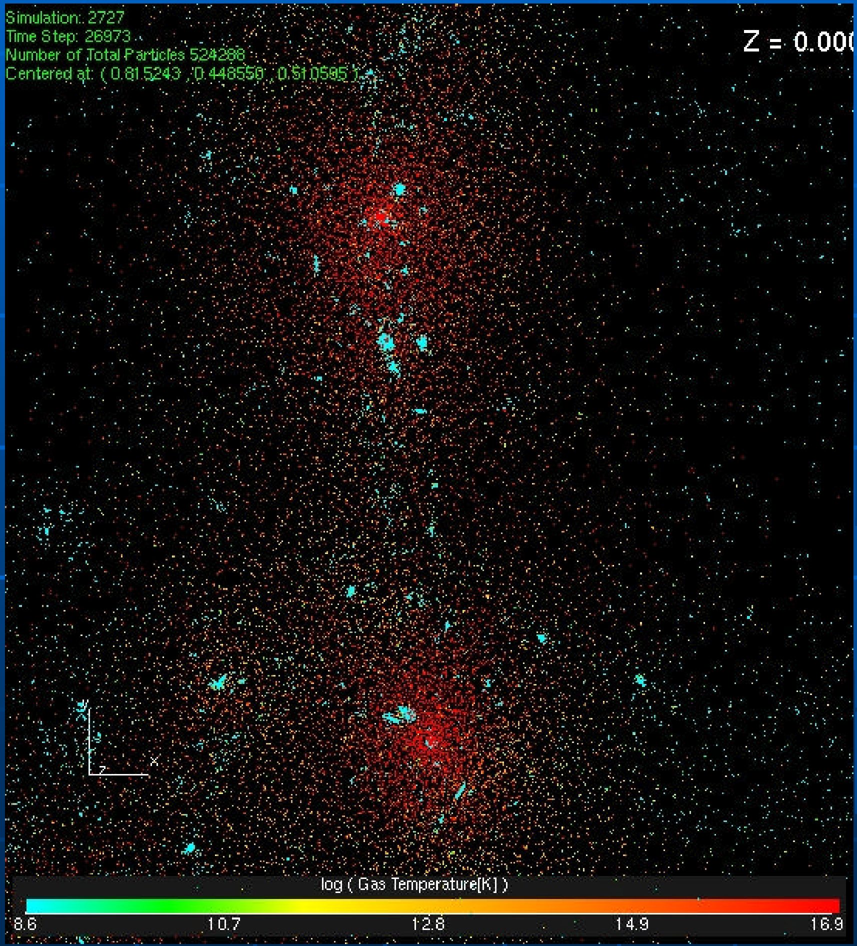
GRUPOS DE GALAXIAS

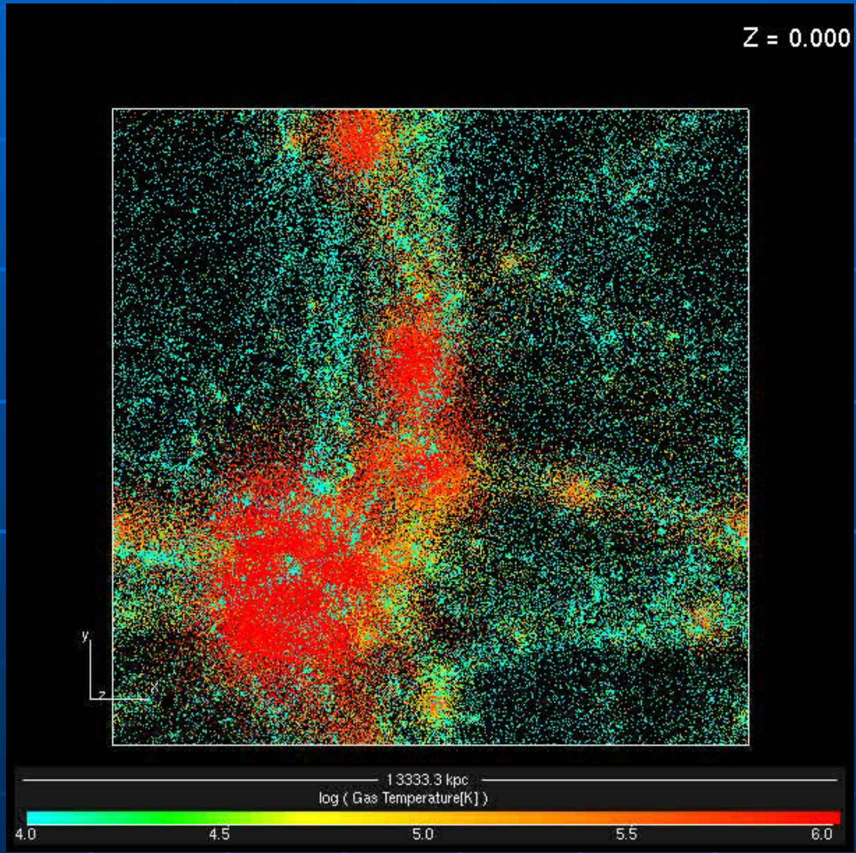




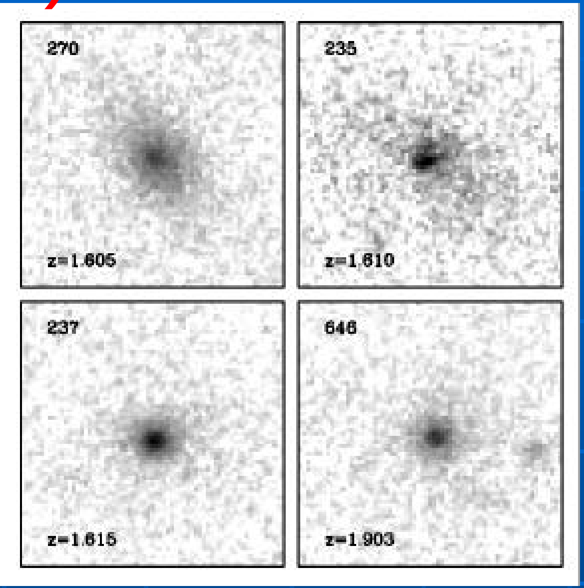
Galaxias, enanas, gas difuso, DM

GAS DIFUSO EN GRUPOS

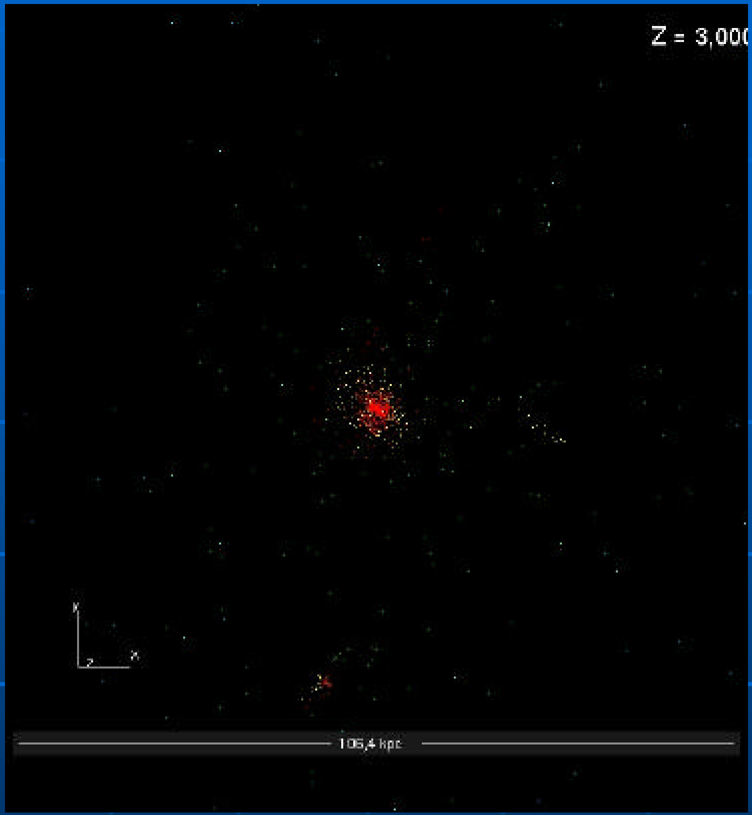




Objetos galácticos Extremadamente Rojos (EROs)



t/tU = 0.28, 0.24



GALAXIAS VIEJAS EN UN UNIVERSO JOVEN (Cimatti y col., 2004; Mobasher et al. 2006)

Masas ~ Masa elípticas cercanas o actuales

Sus estrellas se formaron cuando la edad del Universo era un décimo de la edad actual

FORMAS: esferoides relajados

Menos abundantes que las elípticas actuales

VIRTUAL

t/tu =0.15