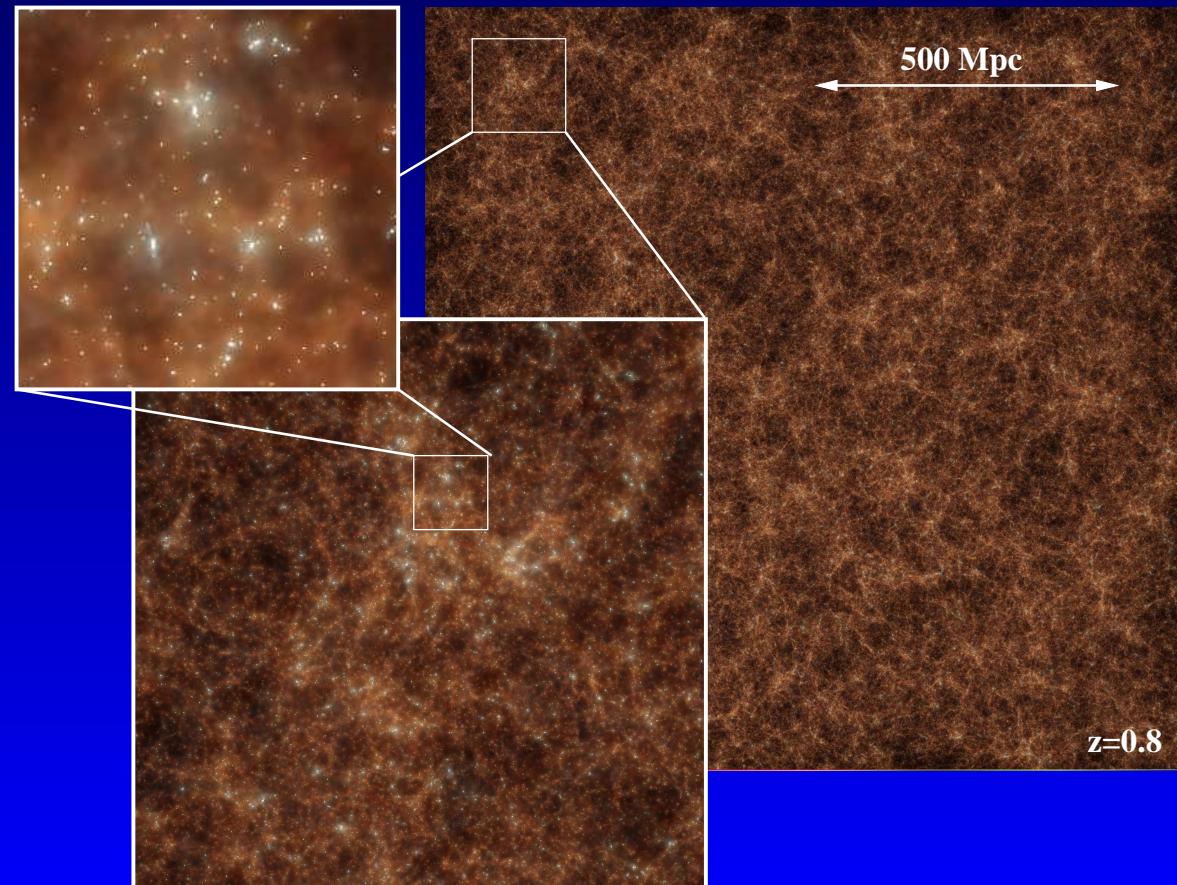


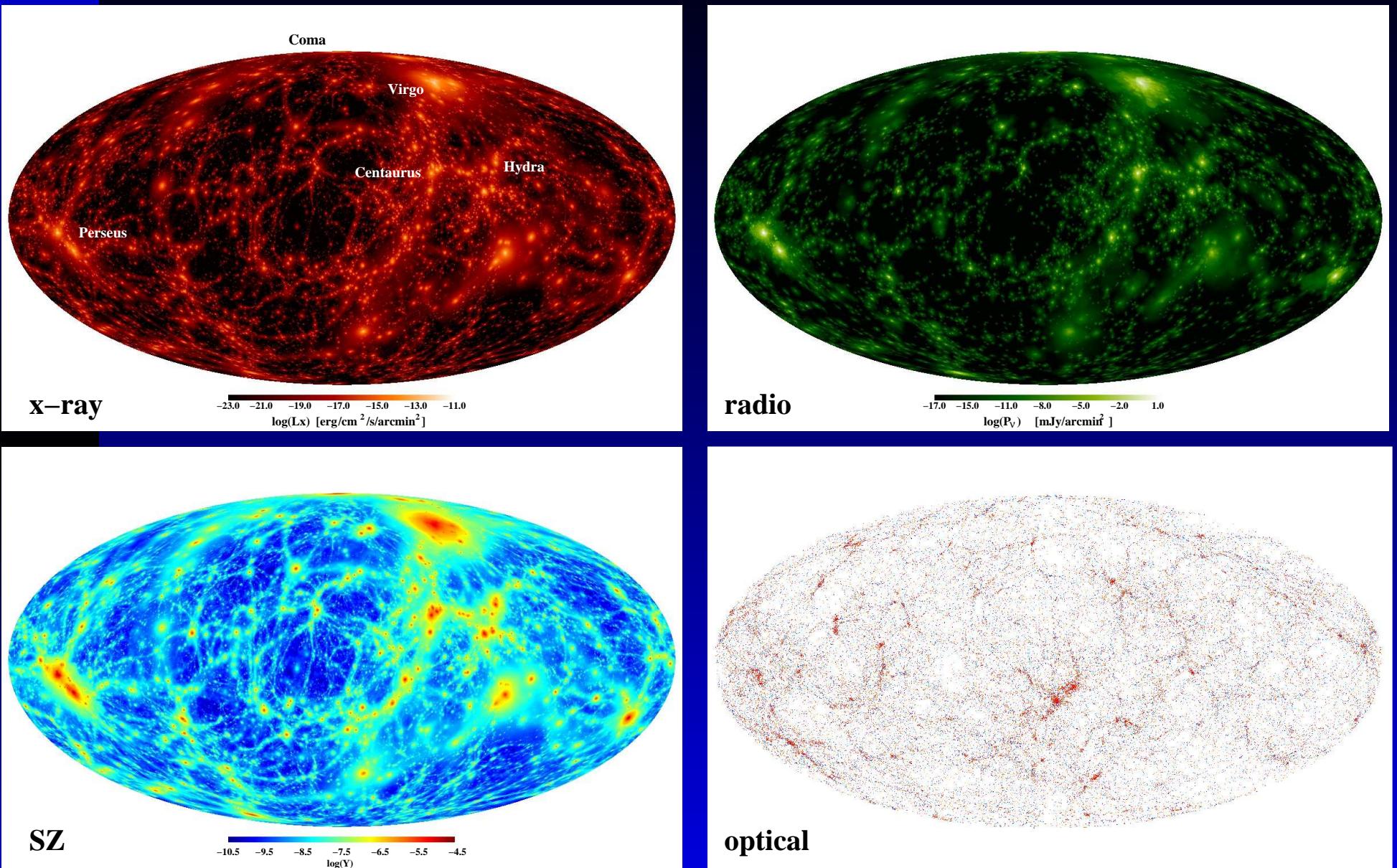
# Simulating the Formation and Evolution of LSS

Klaus Dolag

Universitäts-Sternwarte München, LMU

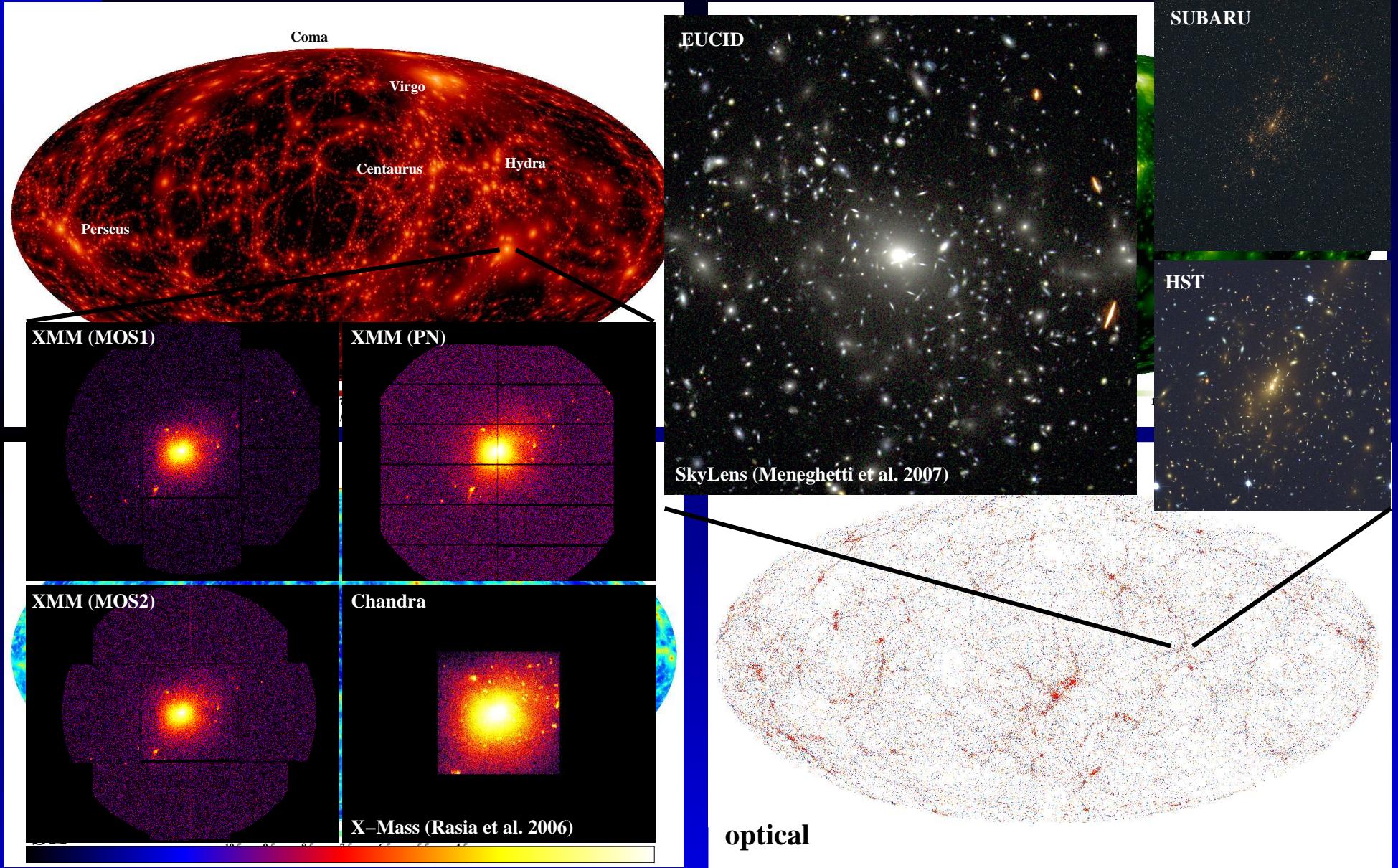


# The Aim



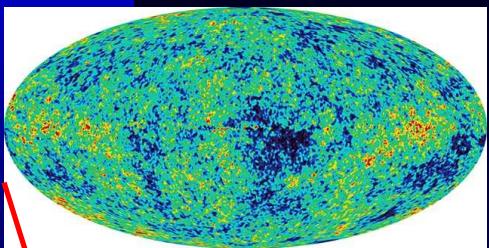
Cosmological, hydrodynamical simulations which at the same time allows predictions for ICM and stellar component for ongoing/future missions (Planck, SPT, LOFAR, eROSITA . . .)

# The Aim



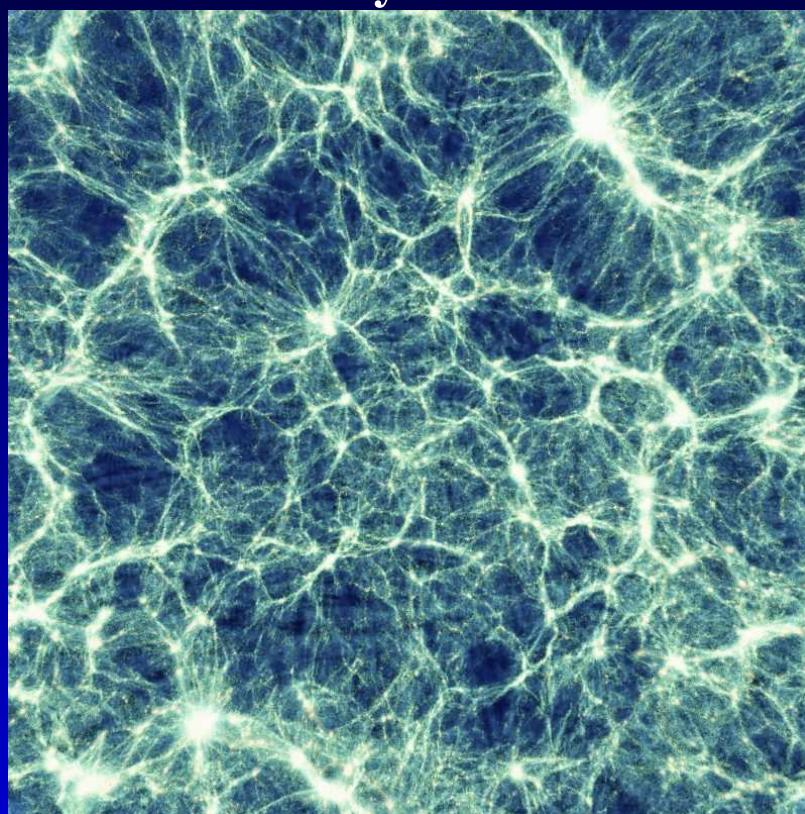
Mock optical/x-ray observations using SkyLens (Meneghetti 2010), X-Mass (Rasia 2007) and Phox (Biffi 2011).

# The Challenge



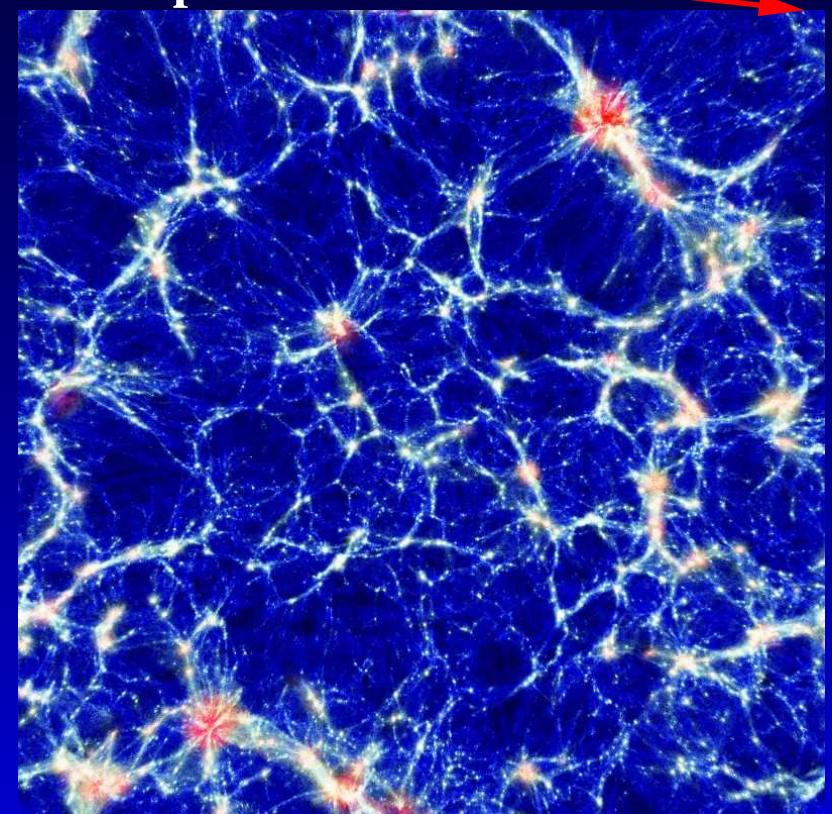
CMB ( $t = 0.38$  Myr)

Density



Cosmic structure today  
( $t = 13.7$  Gyr)

Temperature

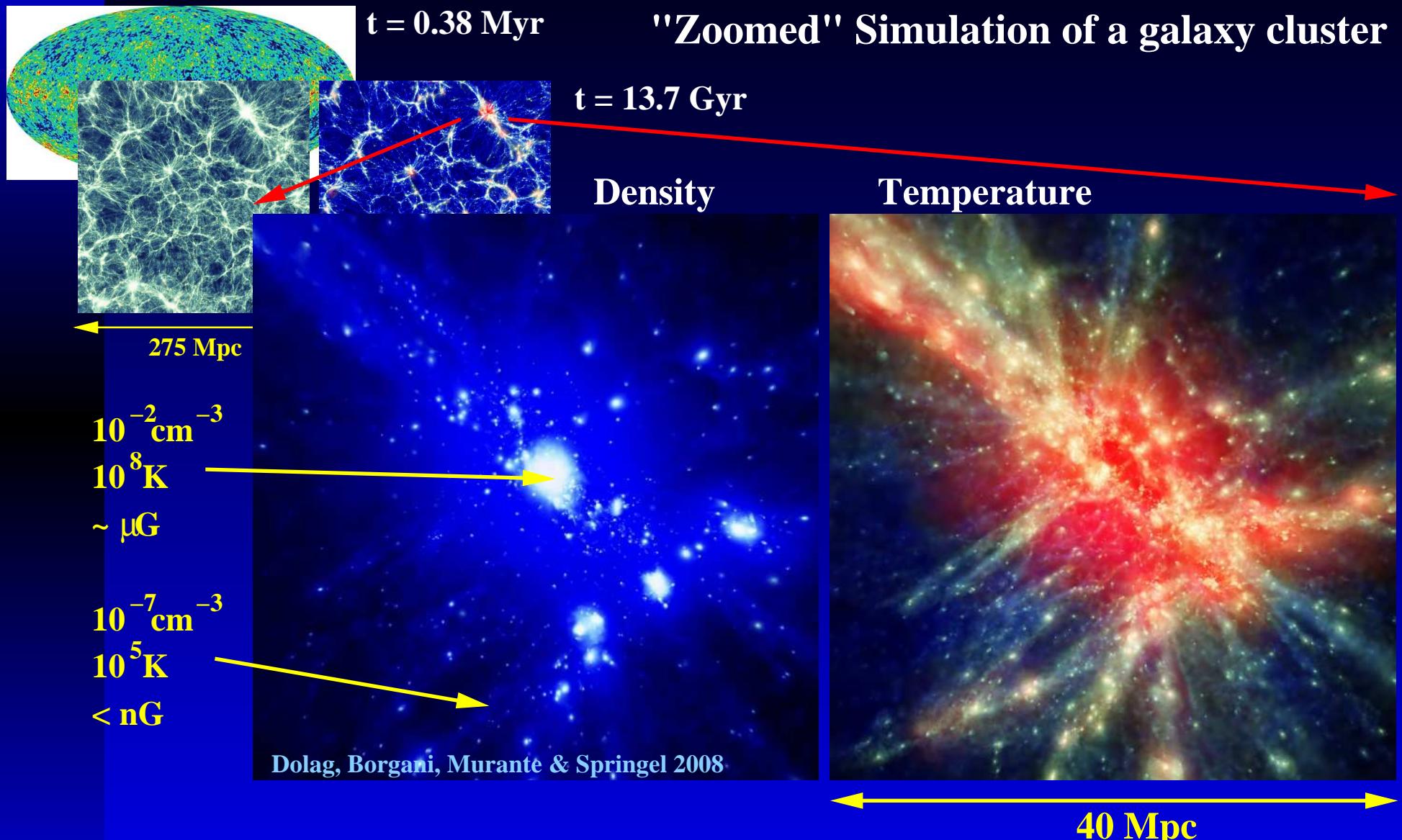


Borgani, Murante, Springel, Diaferio, Dolag et al. 2004

275 Mpc

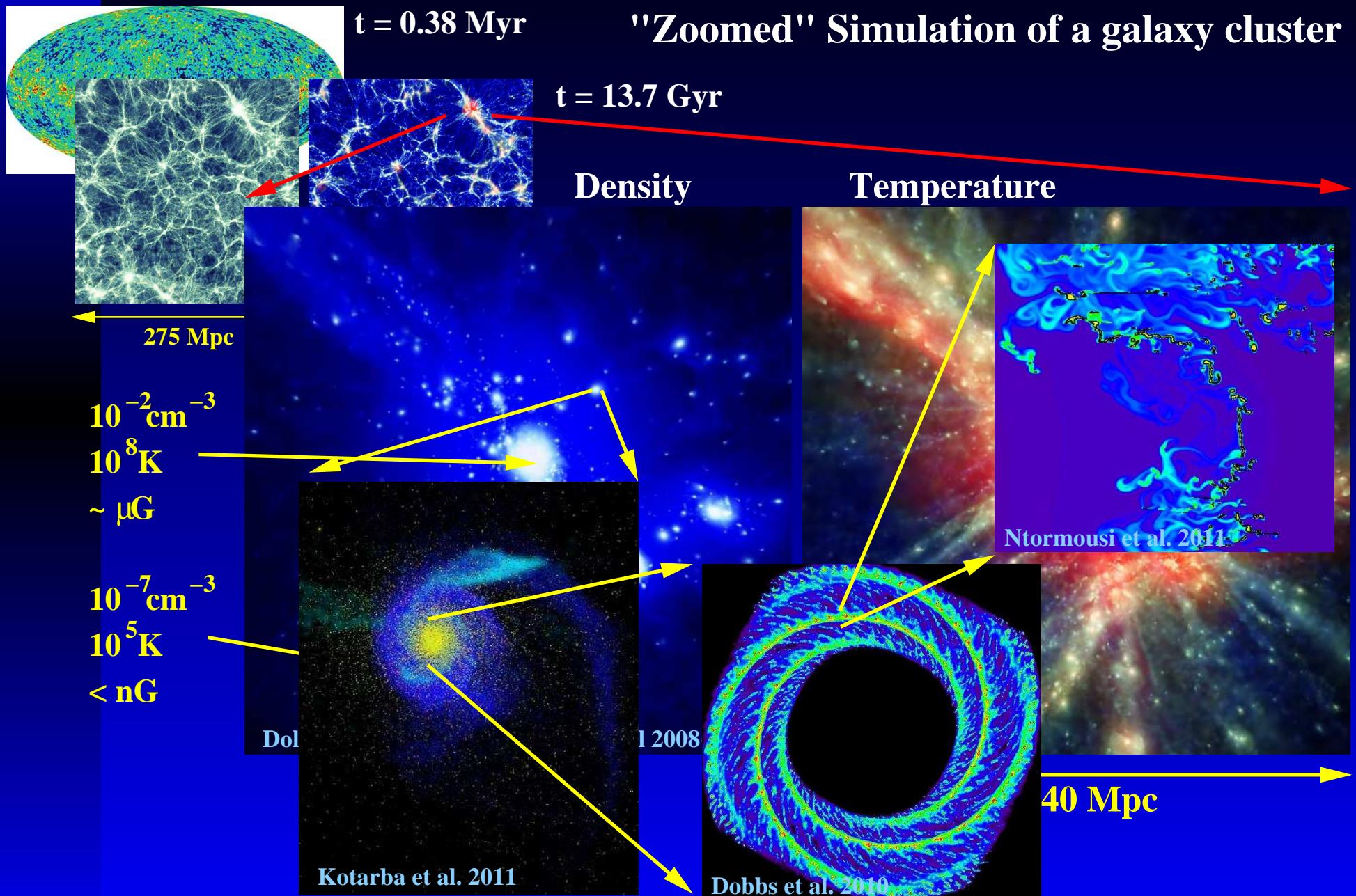
The cosmic web today ( $z = 0$ ) is mainly accessible through simulations (warm, thin). Simulations important to predict the non linear formation of cosmological structures.

# The Challenge



Clusters form at the nodes of the cosmic web and trace the high density environments. The gas falls into the potential, cools and form stars.

# The Challenge

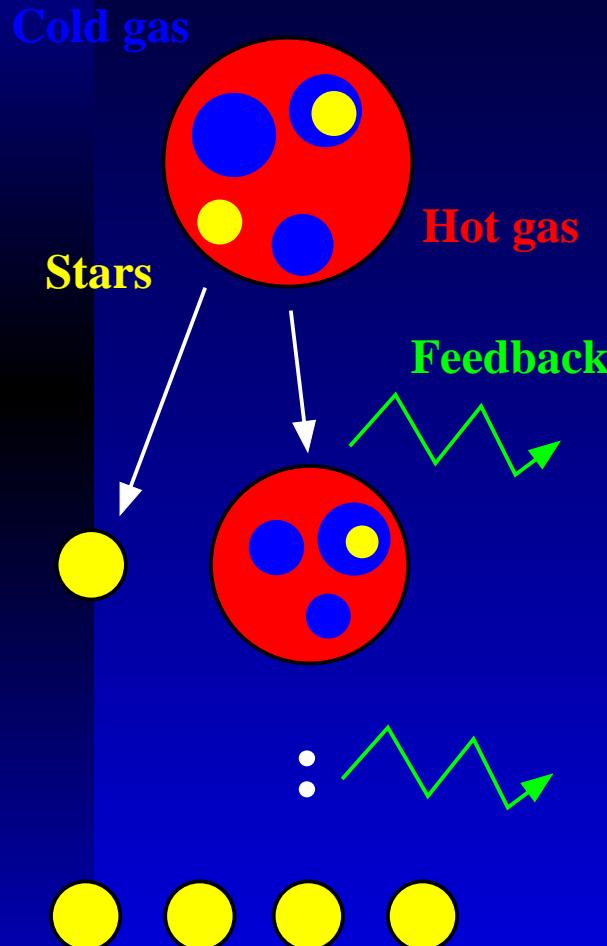


Need to capture processes happening far below the resolution !

# Simulating Subgrid Physics

## Multi phase model (sub-scale)

Springel & Hernquist 2002



Star formation

$$\frac{d\rho_*}{dt} = (1 - \beta) \frac{\rho_c}{t_*}$$

supernova mass fraction

star formation timescale

Cloud evaporation

$$\left. \frac{d\rho_h}{dt} \right|_{\text{evap}} = A\beta \frac{\rho_c}{t_*}$$

cloud evaporation parameter

Growth of clouds

$$\left. \frac{d\rho_c}{dt} \right|_{\text{TI}} = - \left. \frac{d\rho_h}{dt} \right|_{\text{TI}} = \frac{\Lambda_{\text{net}}(\rho_h, u_h)}{u_h - u_c}$$

cooling function

Sub-scale model for star-formation:  
gas particle ( $m = 10^9 M_o$ ) = star formation region  
start particle ( $m = 10^8 M_o$ ) = star cluster

# Simulating Subgrid Physics

## BH model (sub-scale)

Springel & Di Matteo 2006

### Seeding

Constant seeding  
Seeding on m-sigma

### Accretion on BH

$\alpha$ -Bondi (Springel & Di Matteo 06)  
 $\beta$ -Bondi (Booth & Schaye 09)

....

### Feedback

Thermal (Springel & Di Matteo 06)  
Bubbles (Sijacki et al. 07)

....

### Merging

Instant merging  
Based on velocity

....

### Growth of BH

$$\dot{M}_B = \alpha \times 4\pi R_B^2 \rho c_s \simeq \frac{4\pi \alpha G^2 M_\bullet^2 \rho}{(c_s^2 + v^2)^{3/2}}$$

$$\dot{M}_\bullet = \min(\dot{M}_B, \dot{M}_{Edd})$$

gas density

sound speed

### Feedback by BH

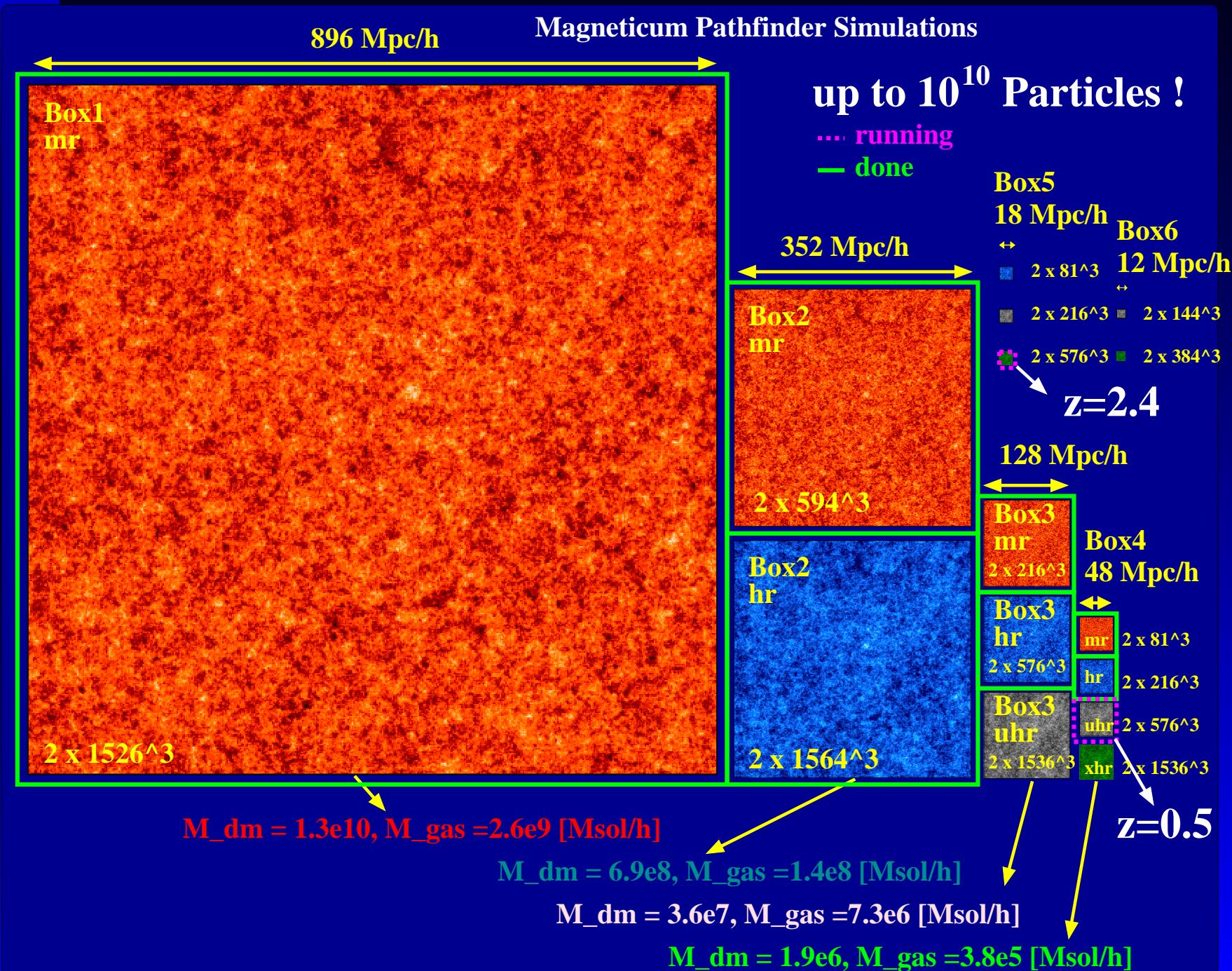
$$L_{bol} = 0.1 \times \dot{M}_\bullet c^2$$

$$\dot{E}_{feedback} = f \times L_{bol}$$

efficiency

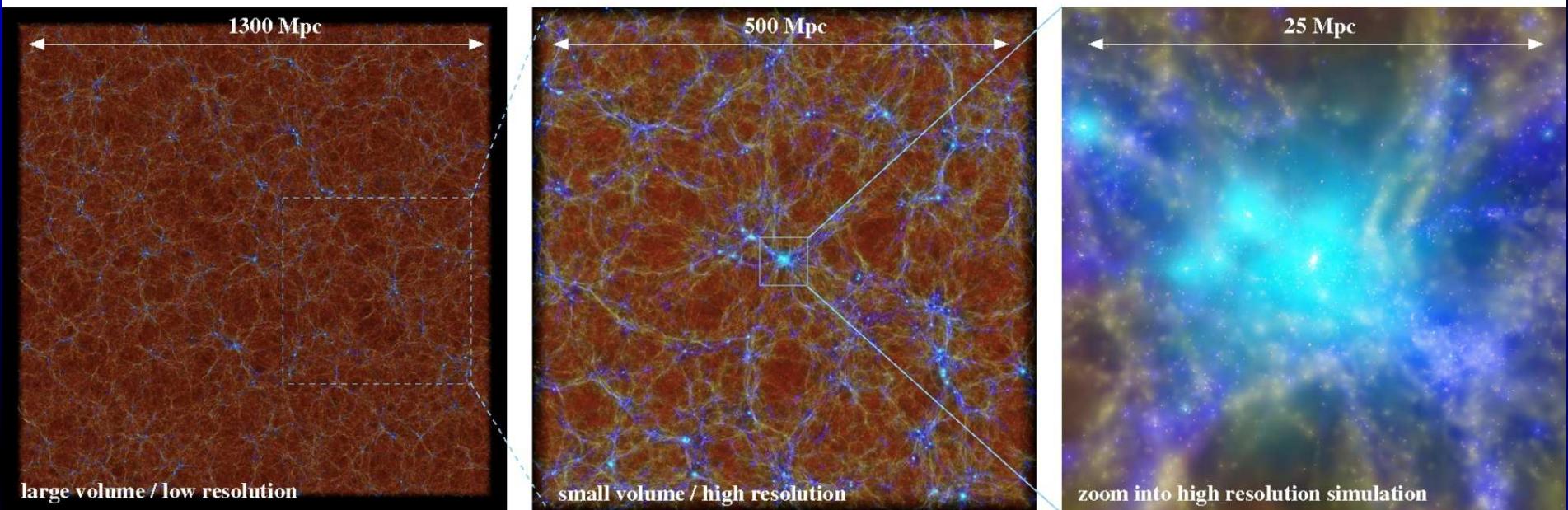
Sub-scale model for BH growth:  
Resolution dependence ?  
Various subtle extensions ...

# LSS Simulations



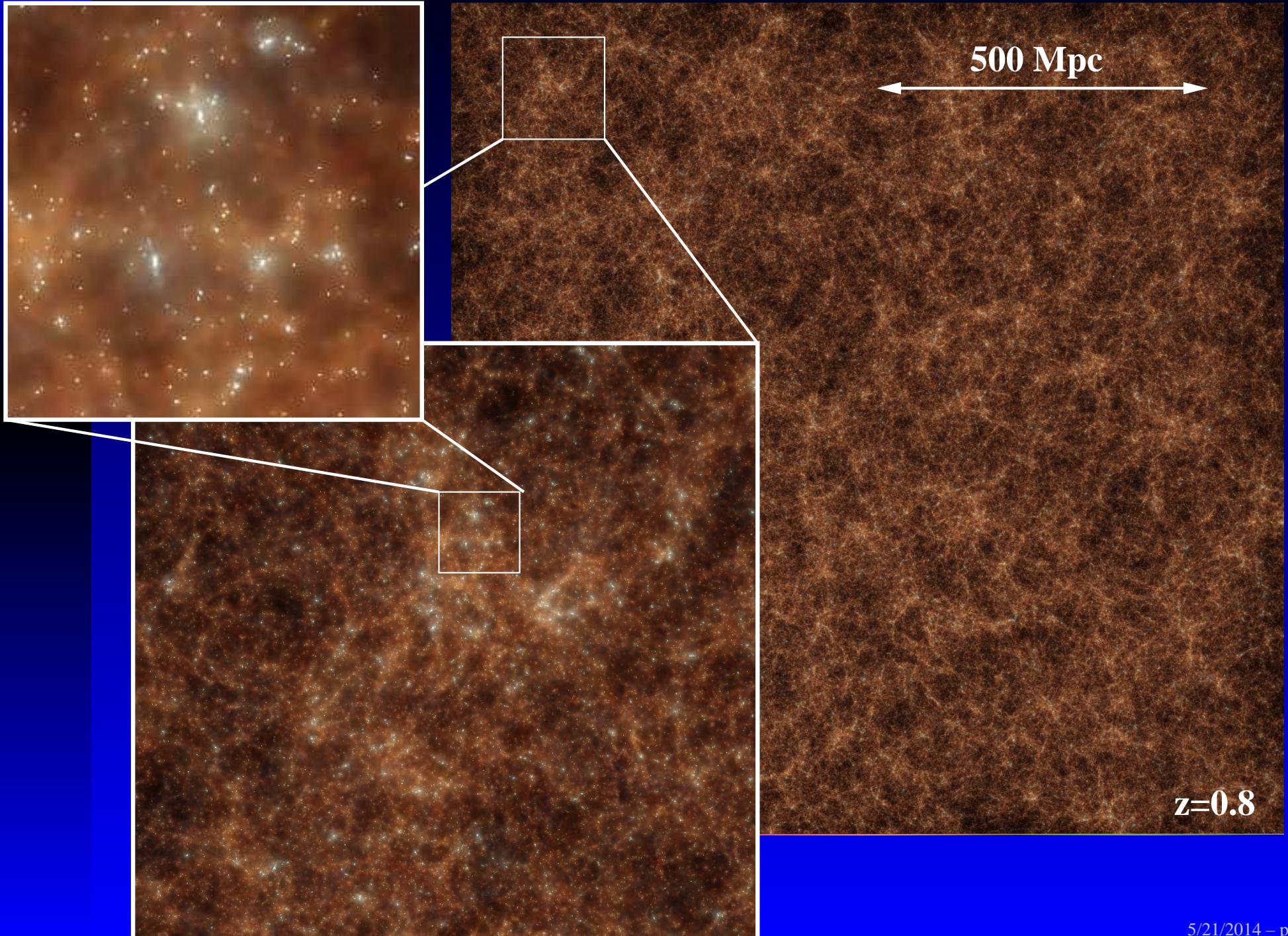
# LSS Simulations

## Magneticum Pathfinder Simulations

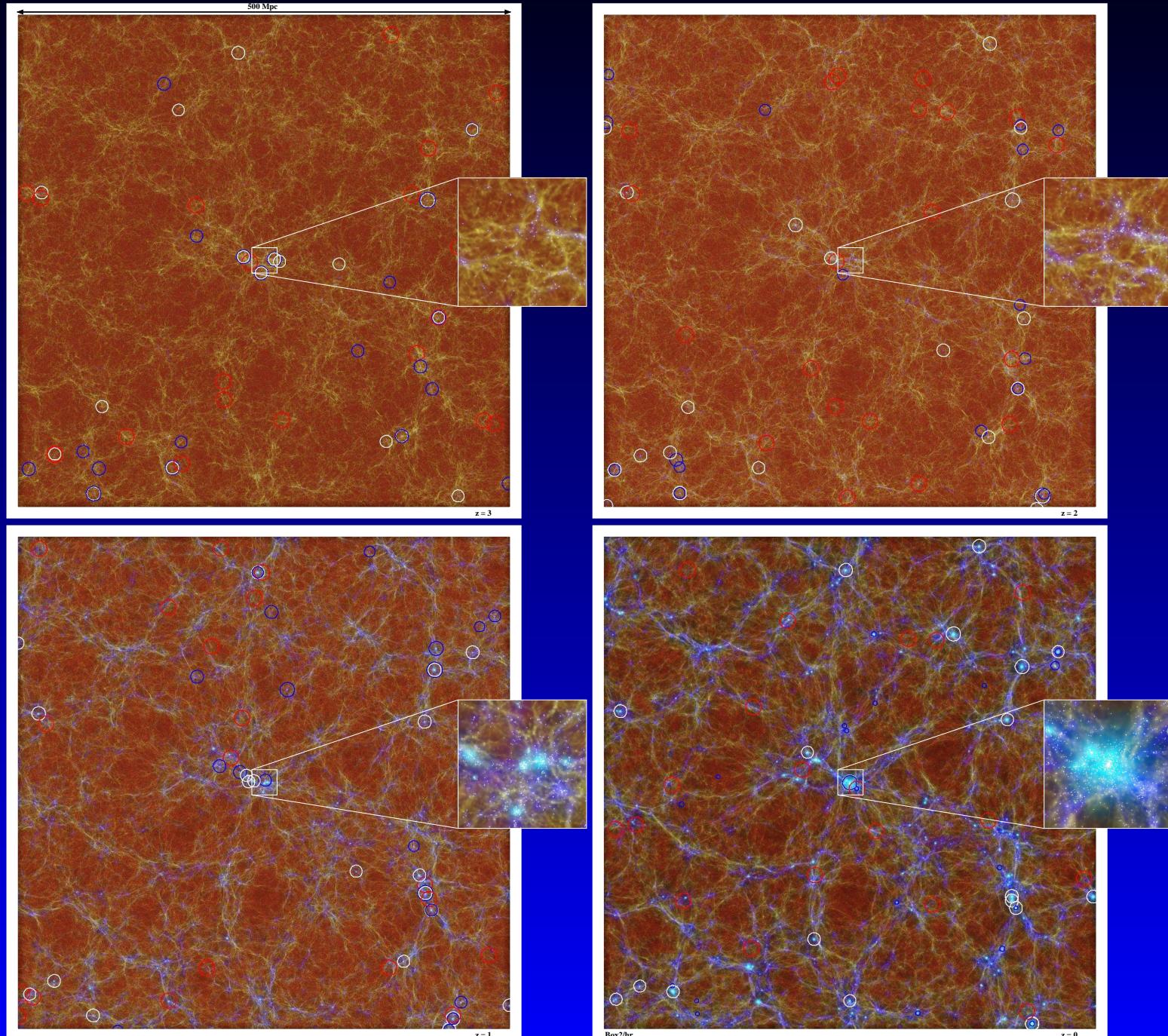


- cooling + star formation + winds Springel & Hernquist 2002/2003
- Metals, Stellar population and chemical enrichment, SN-Ia, SN-II, AGB Tornatore et al. 2003/2006 + new cooling tables Wiersma et al. 2009
- BH and AGN feedback Springel & Di Matteo 2006, Fabjan et al. 2010 + various modifications Hirschmann et al. 2013
- Low viscosity scheme to track turbulence Dolag et al. 2005
- Magnetic Fields (passive) Dolag & Stasyszyn 2009
- Thermal Conduction (1/20th Spitzer) Dolag et al. 2004
- High oder SPH Kernels Dehnen et al. 2012
- Galaxy properties (Opt/NIR: u,V,G,r,i,z,Y,J,H,K,L,M; sfr)

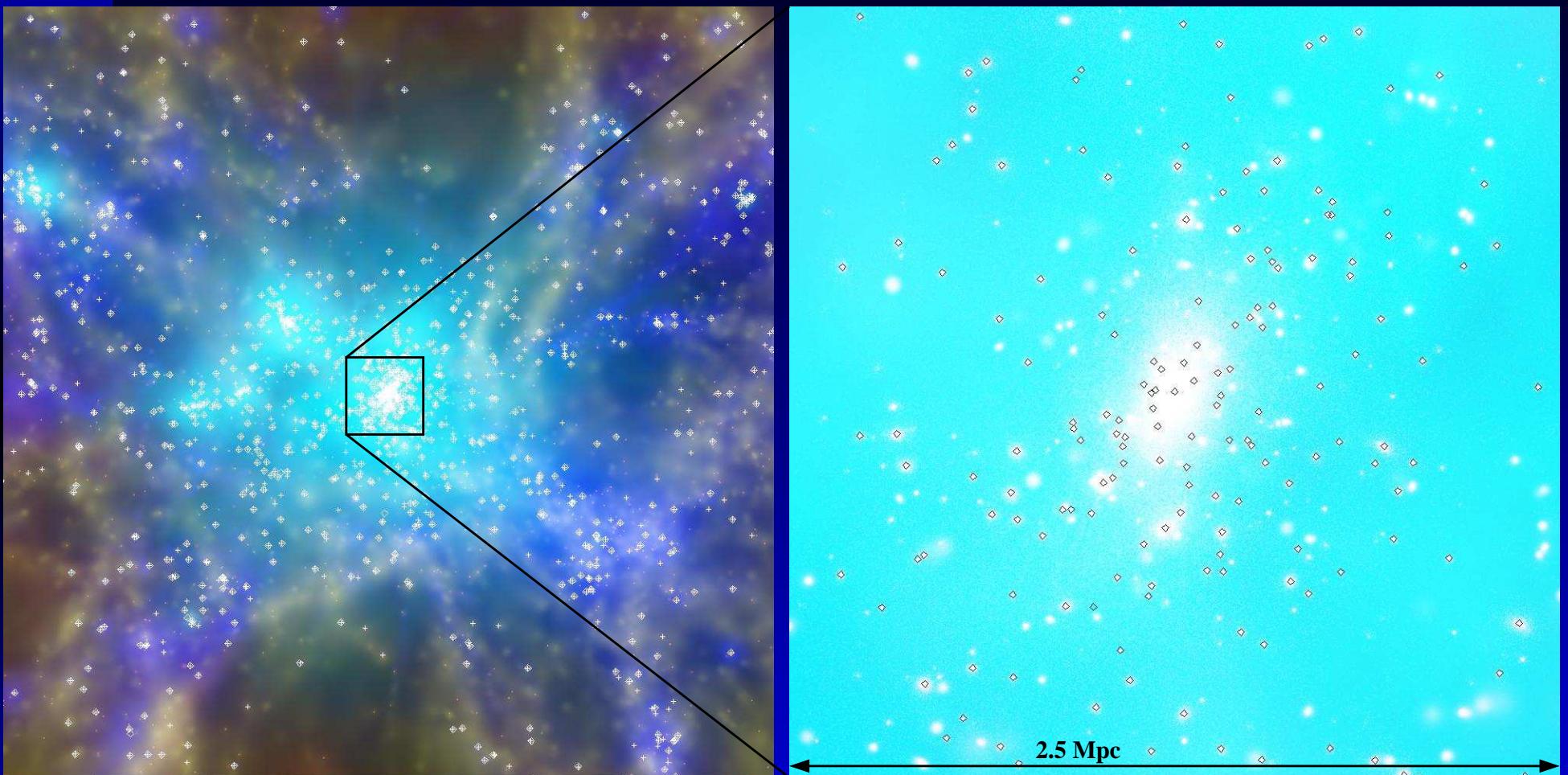
# LSS Simulations



# LSS Simulations

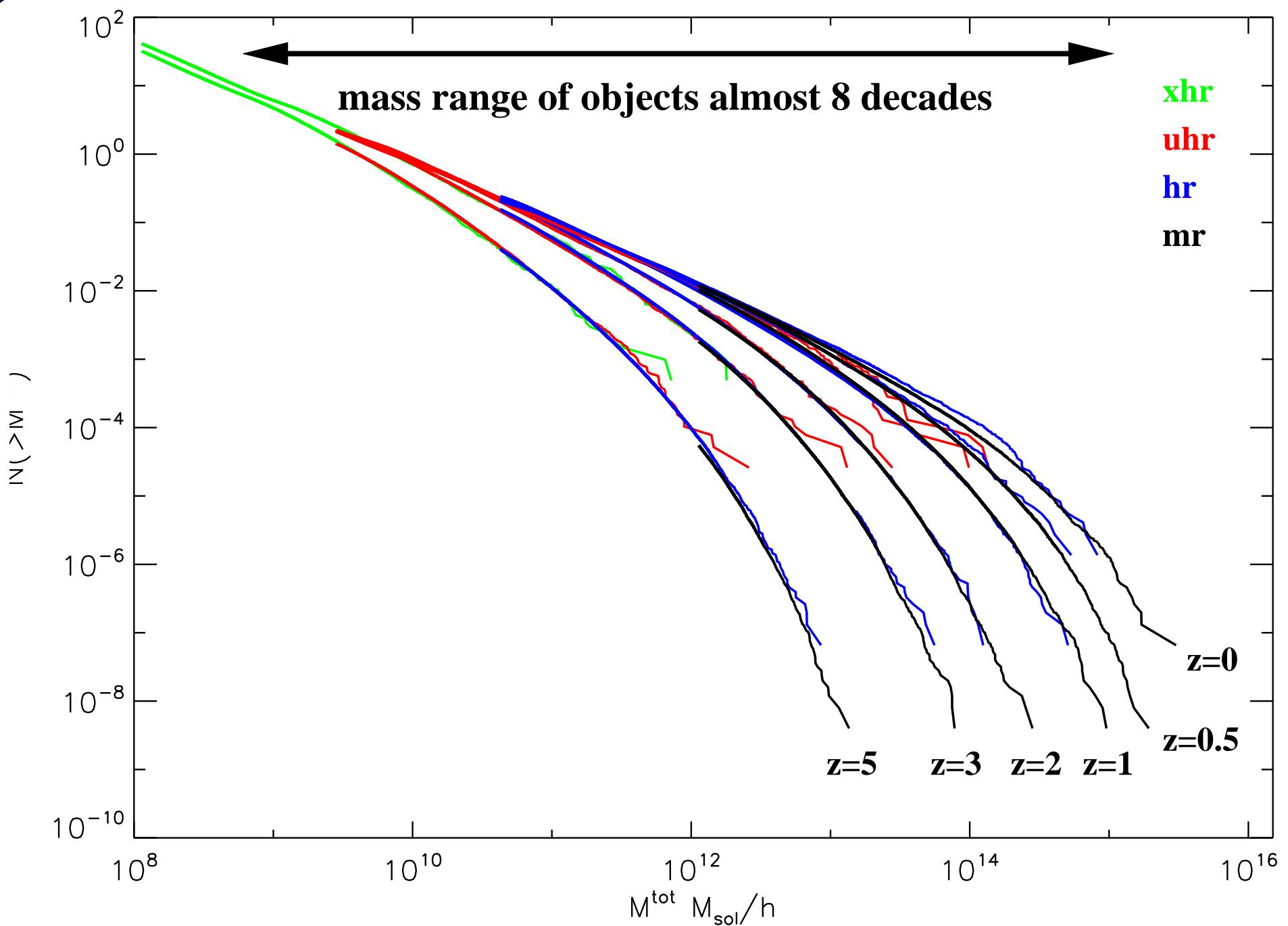


# LSS Simulations

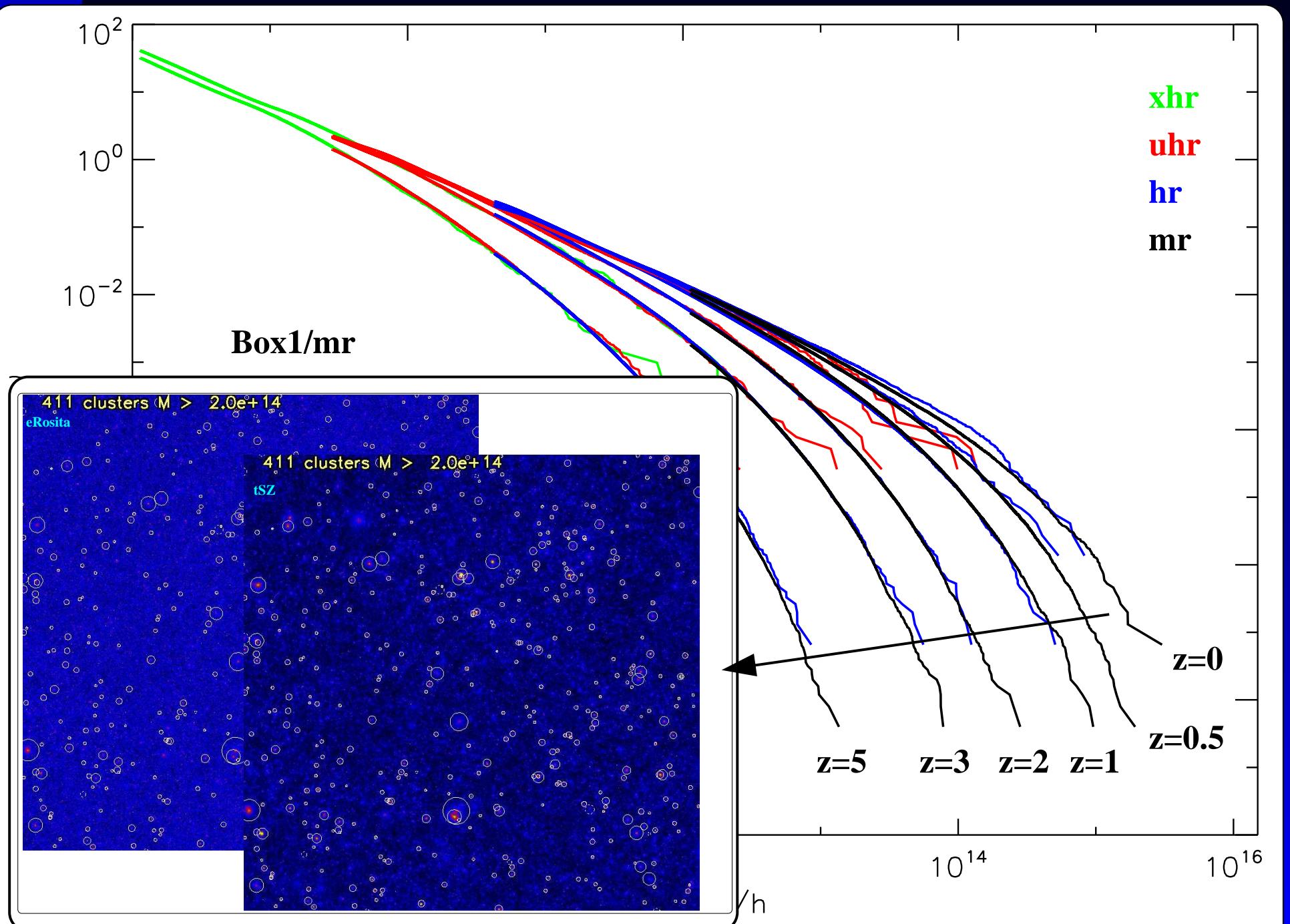


Zoom onto most massive cluster in Box2/hr. Transformation of galaxies inside the denser environment.

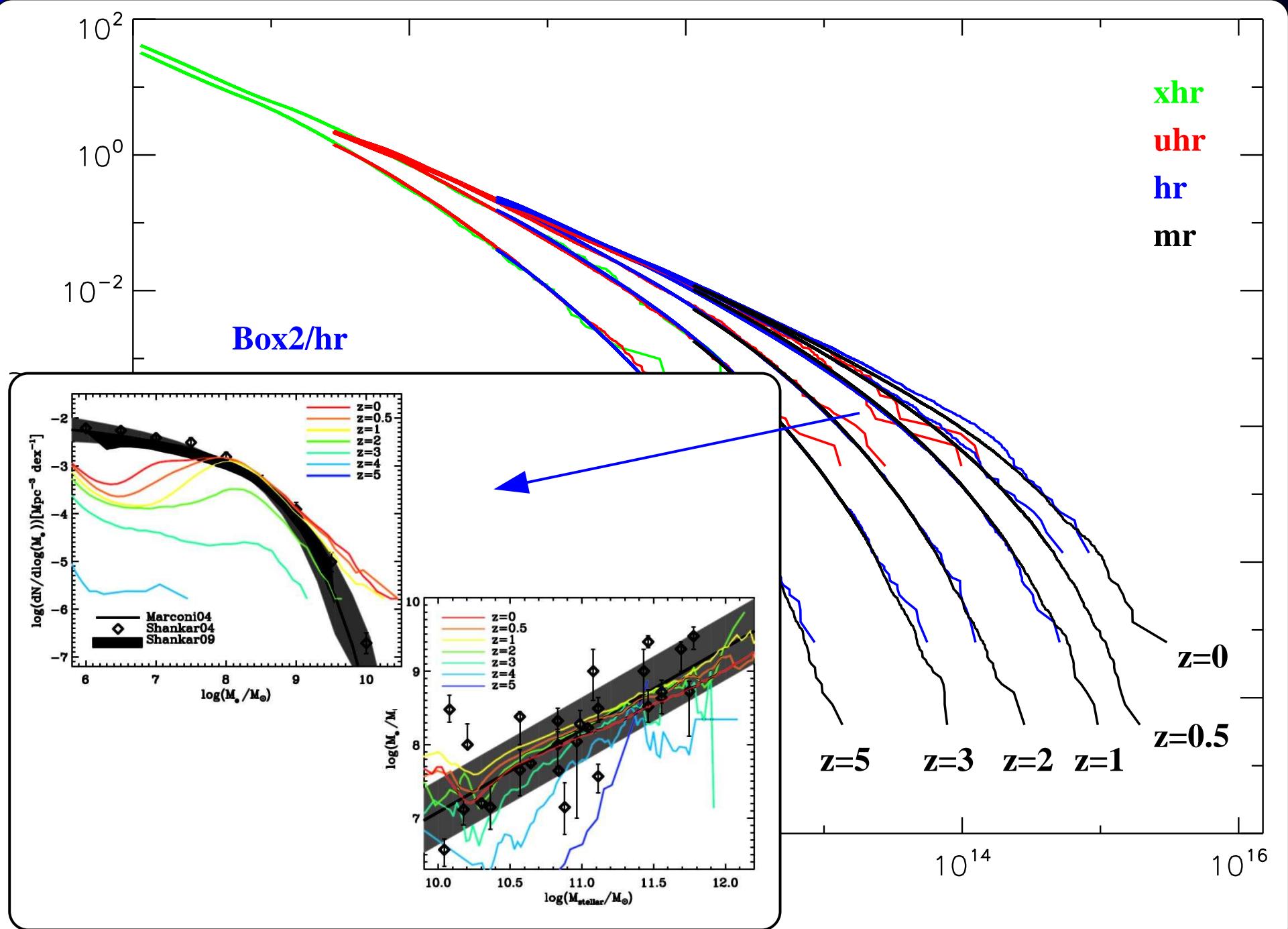
# What we can expect



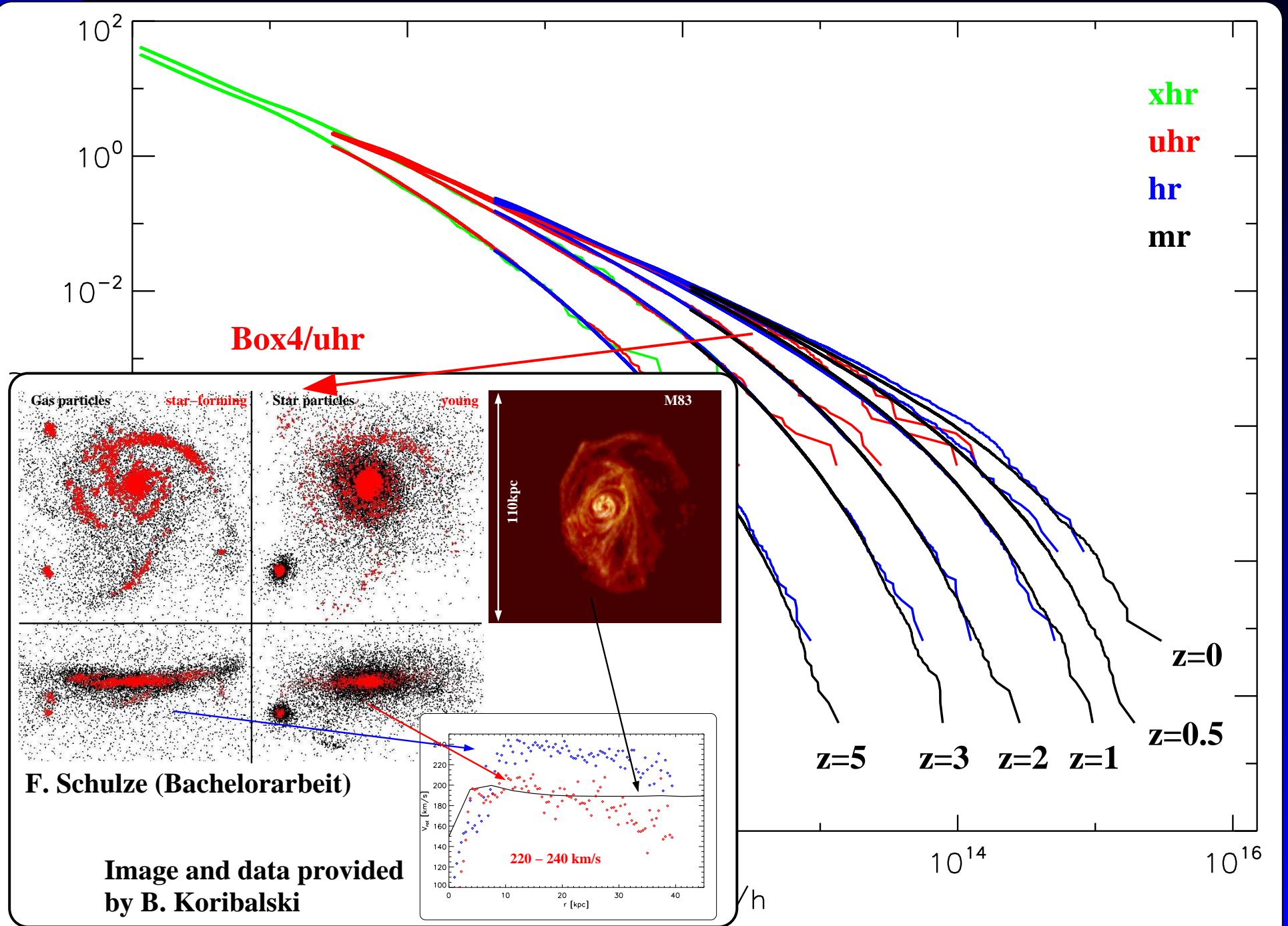
# What we can expect



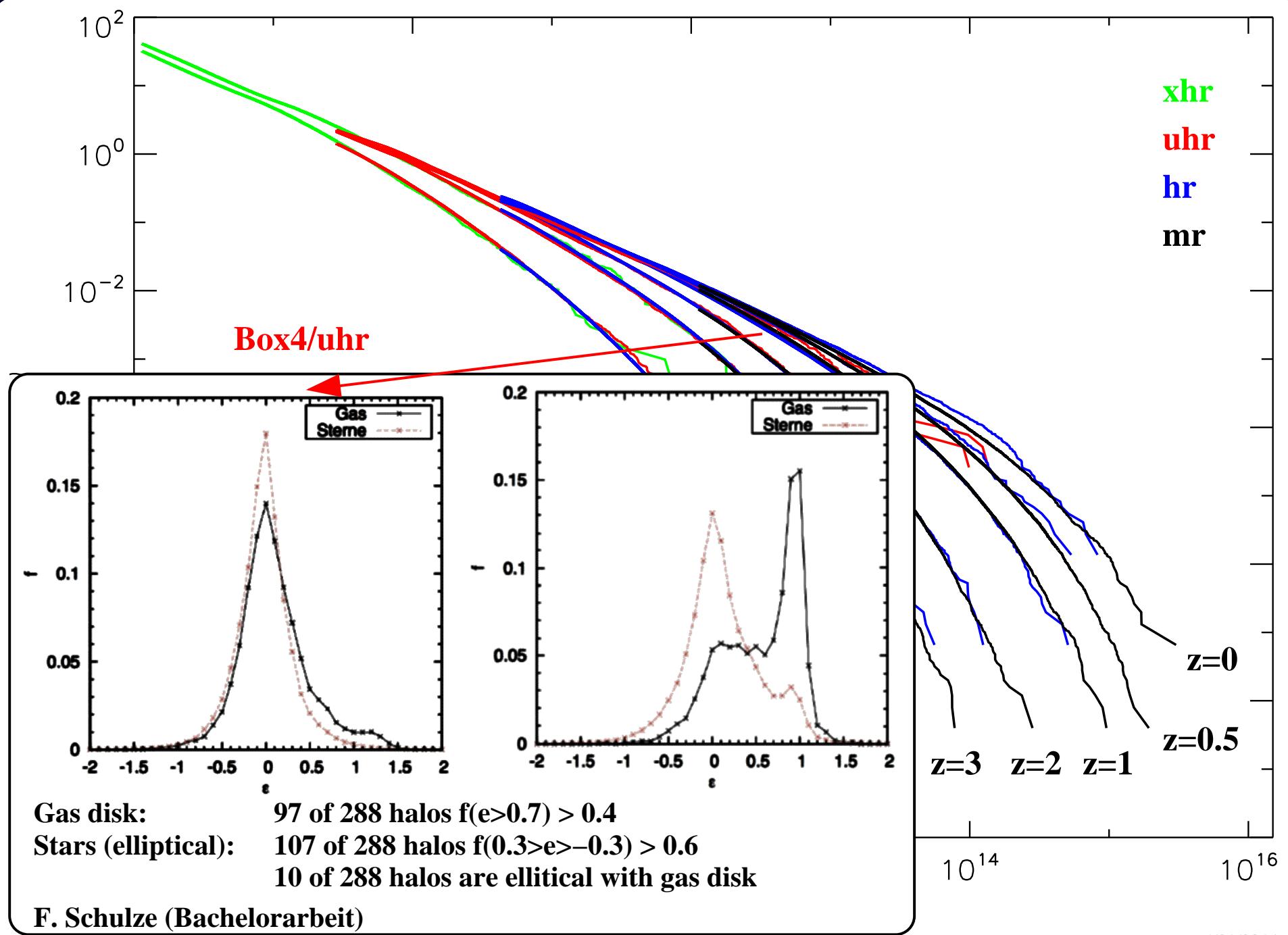
# What we can expect



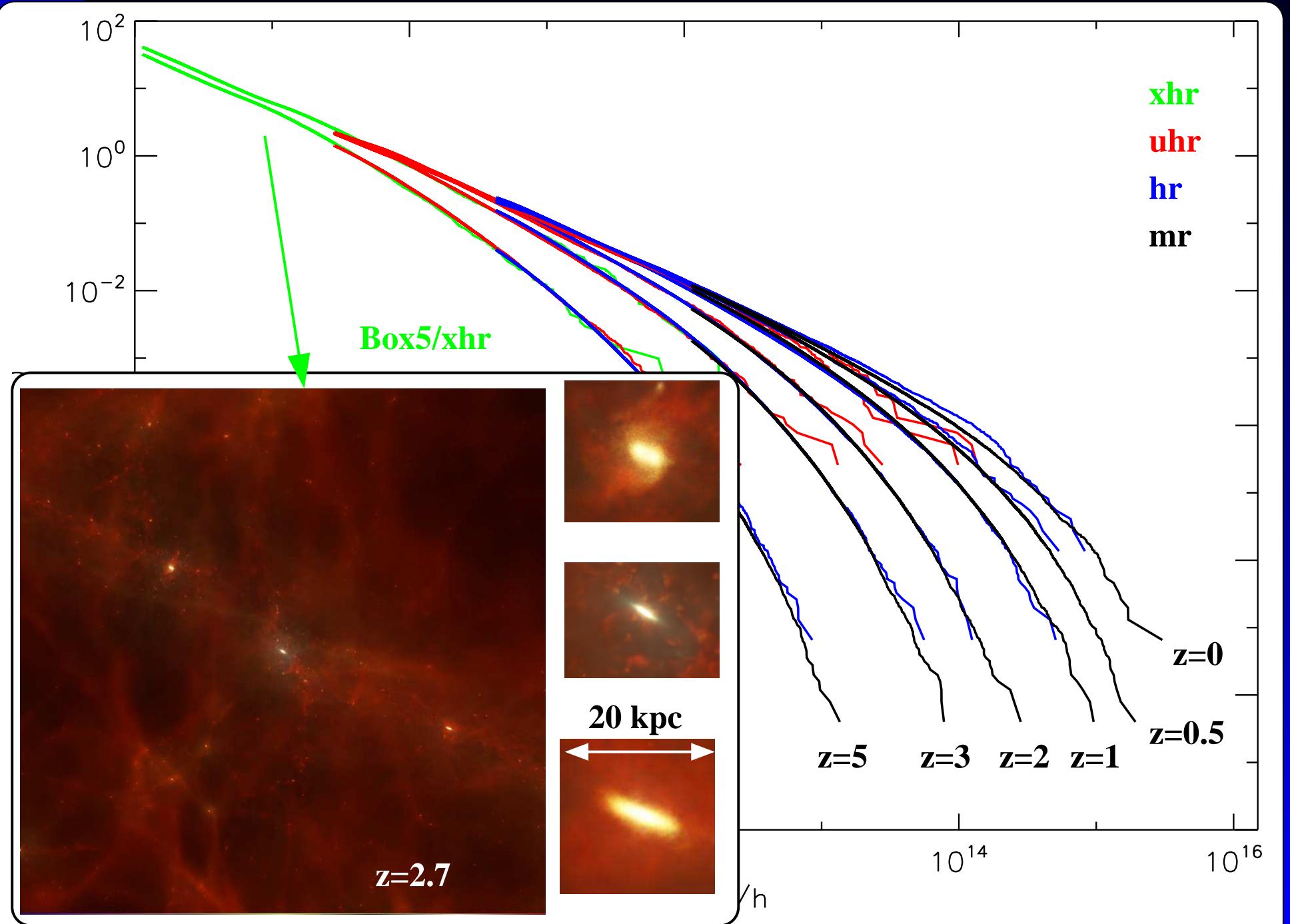
# What we can expect



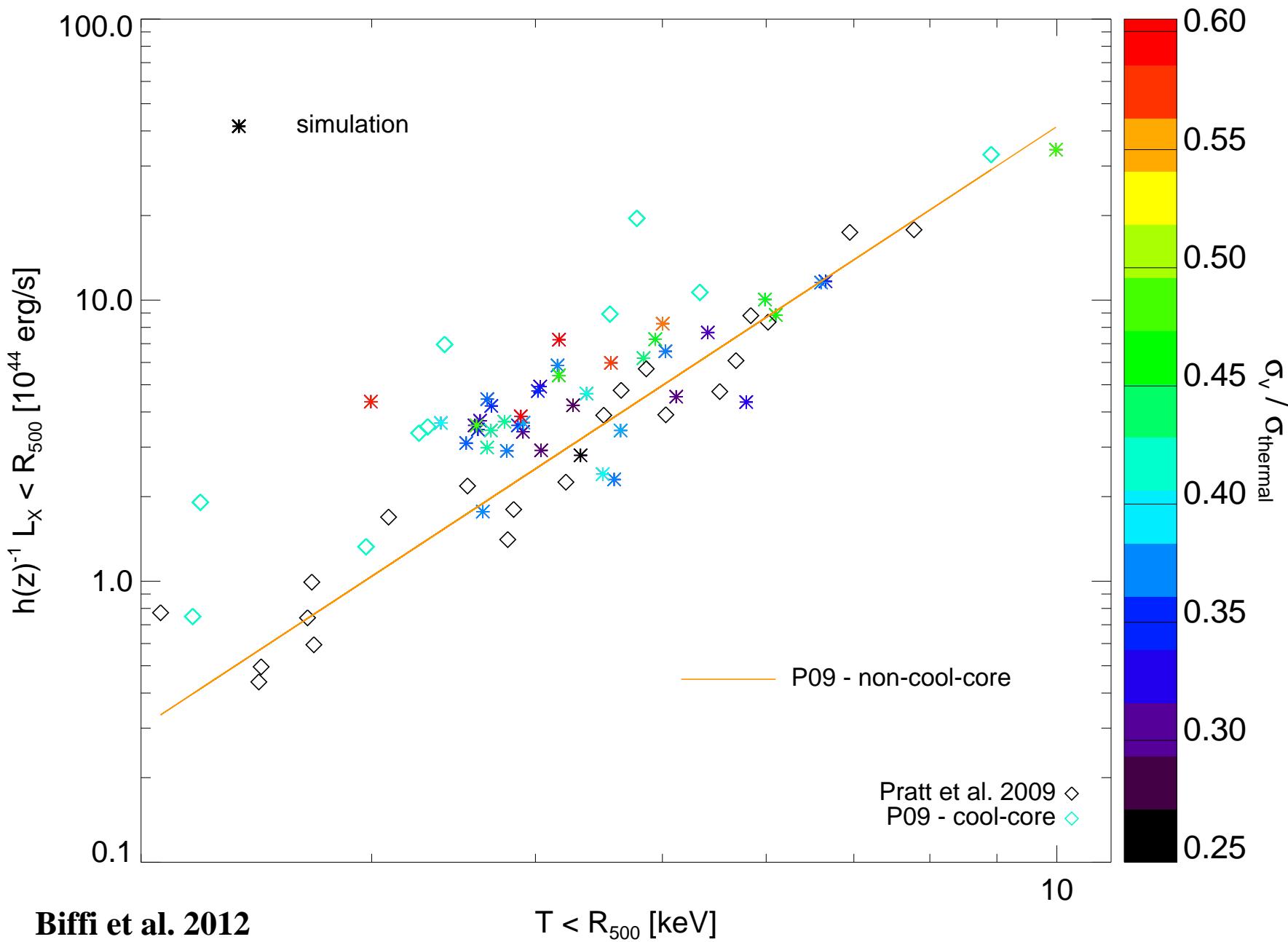
# What we can expect



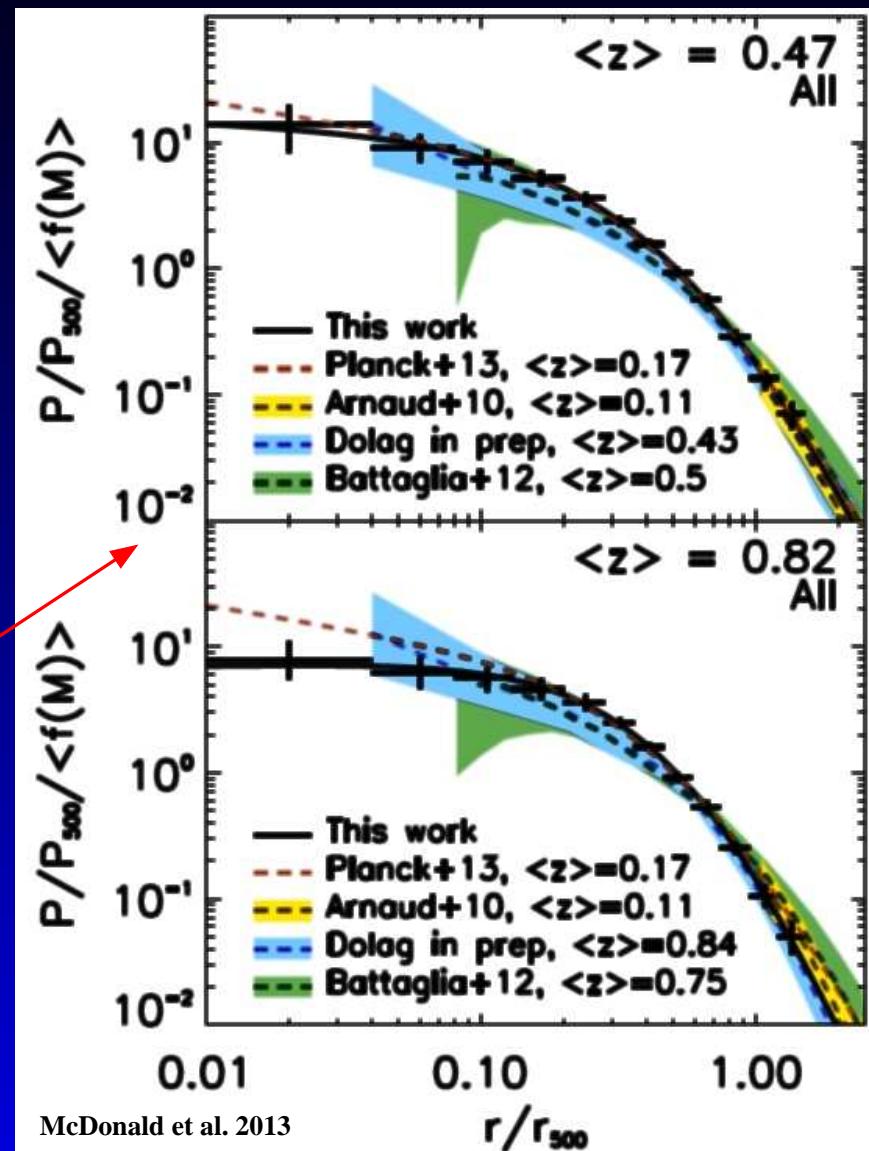
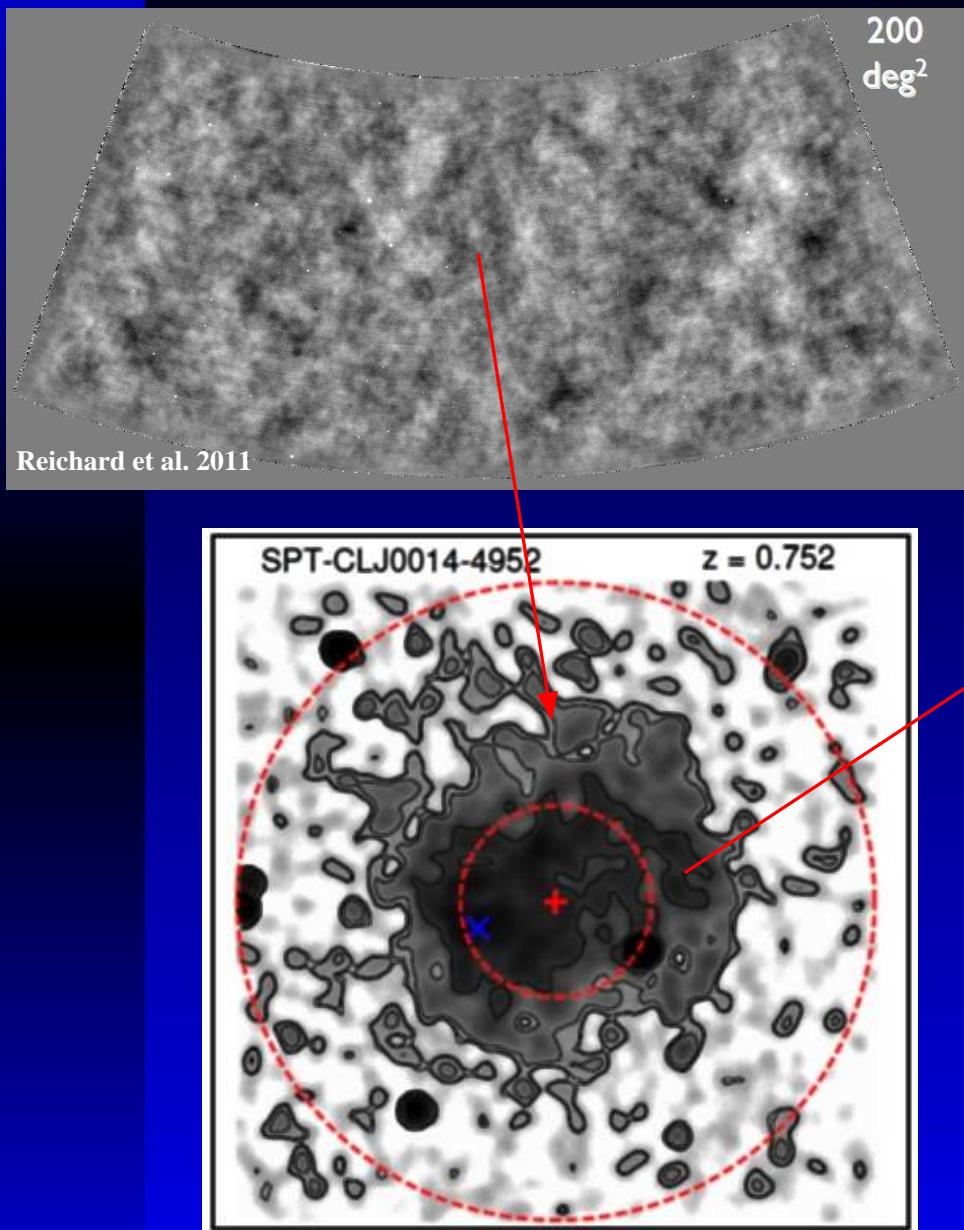
# What we can expect



# ICM Properties

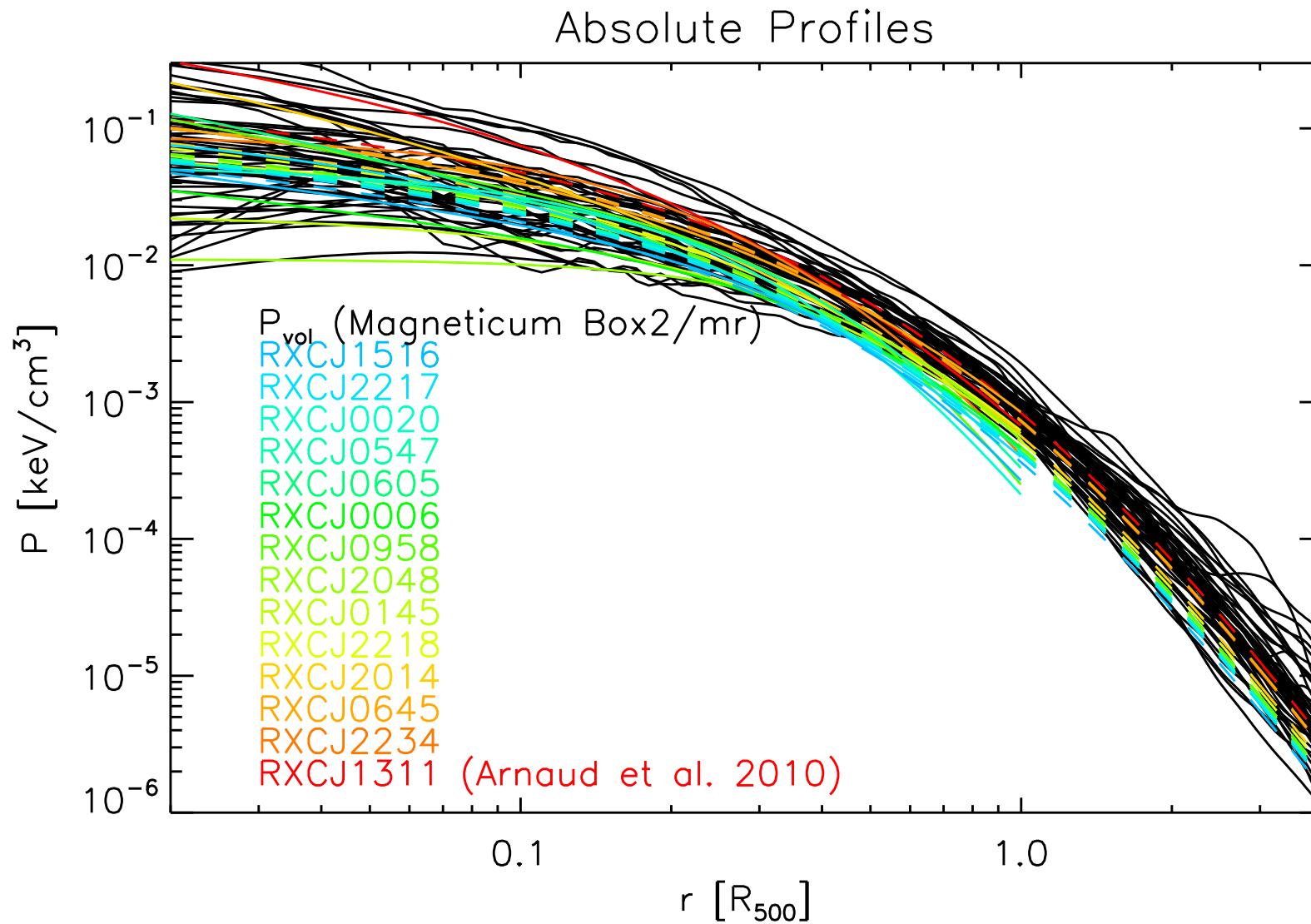


# ICM Properties



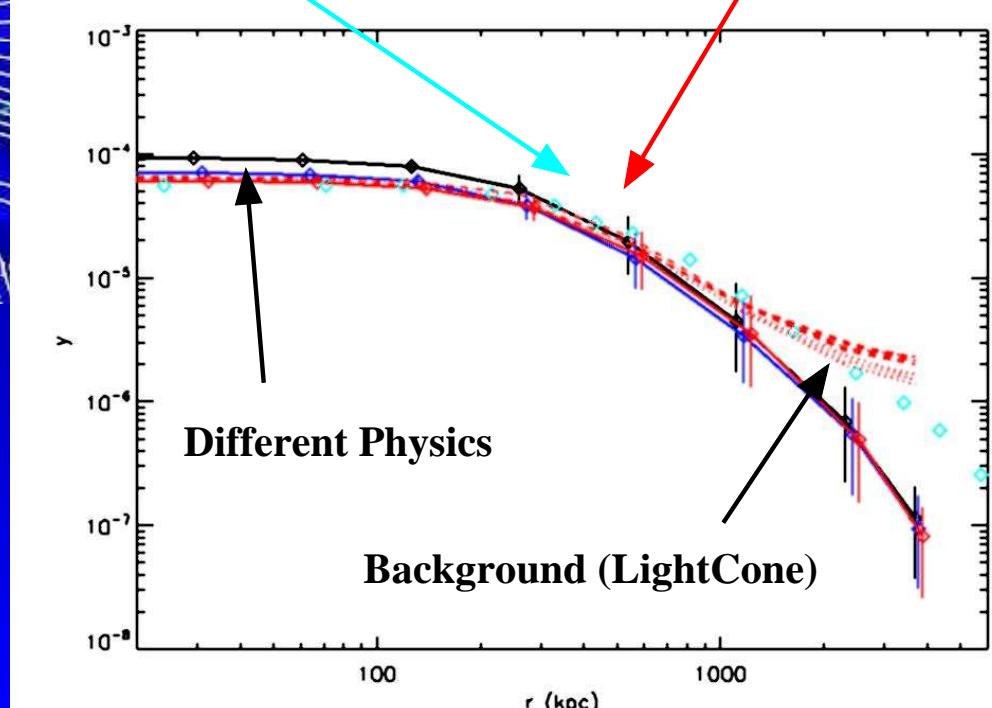
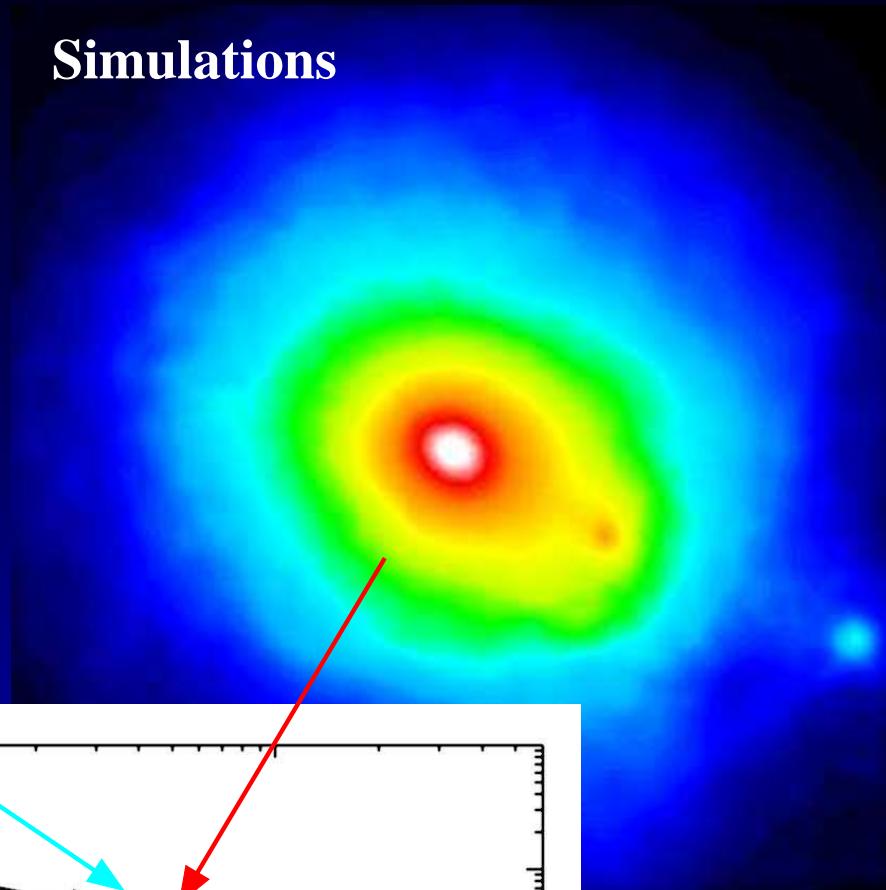
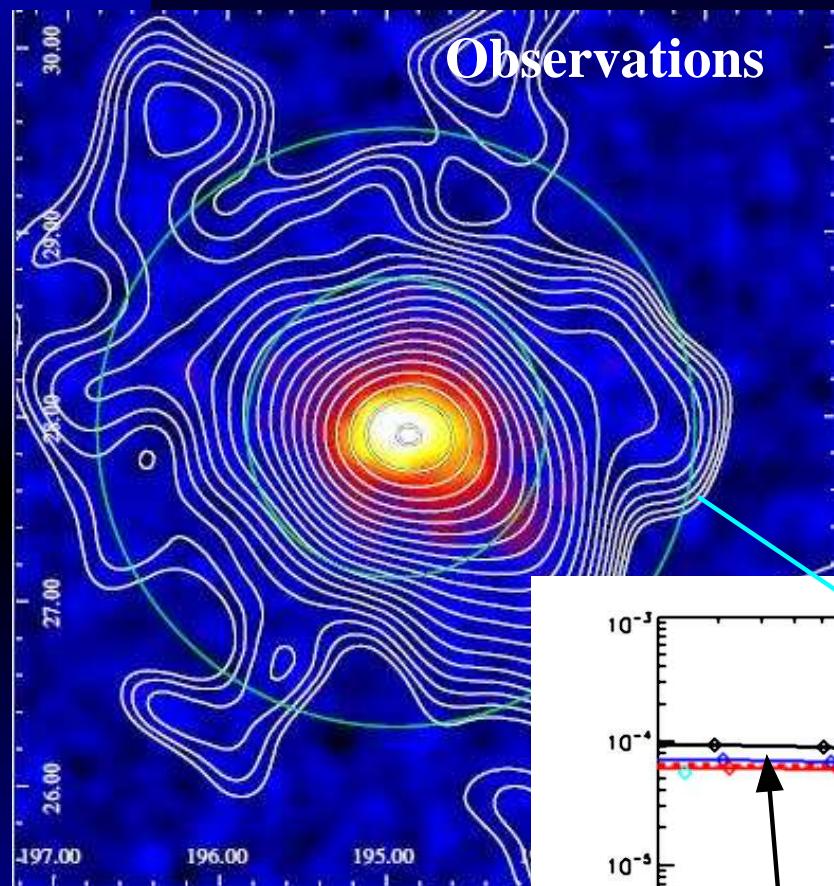
Mean ICM pressure profiles from CMB foreground (SPT).

# ICM Properties

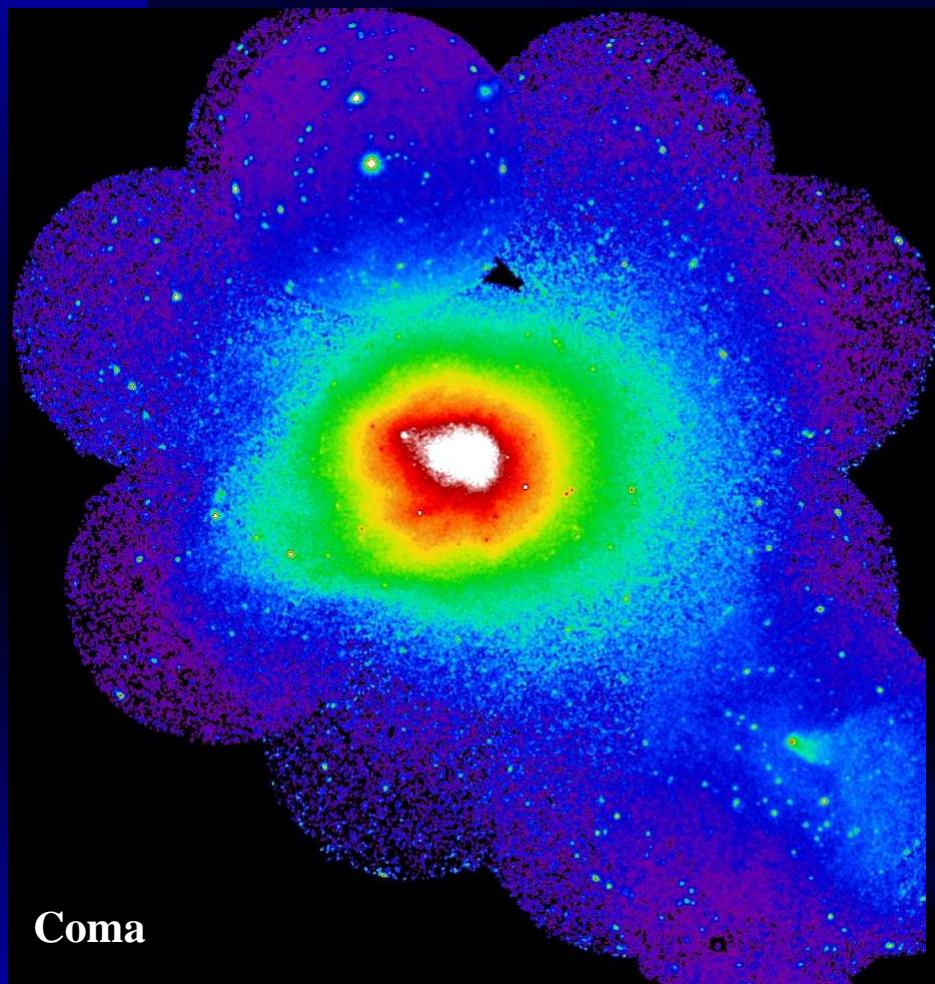


Comparison of simulated ICM pressure profiles with x-ray observations (matching shape and scatter !).

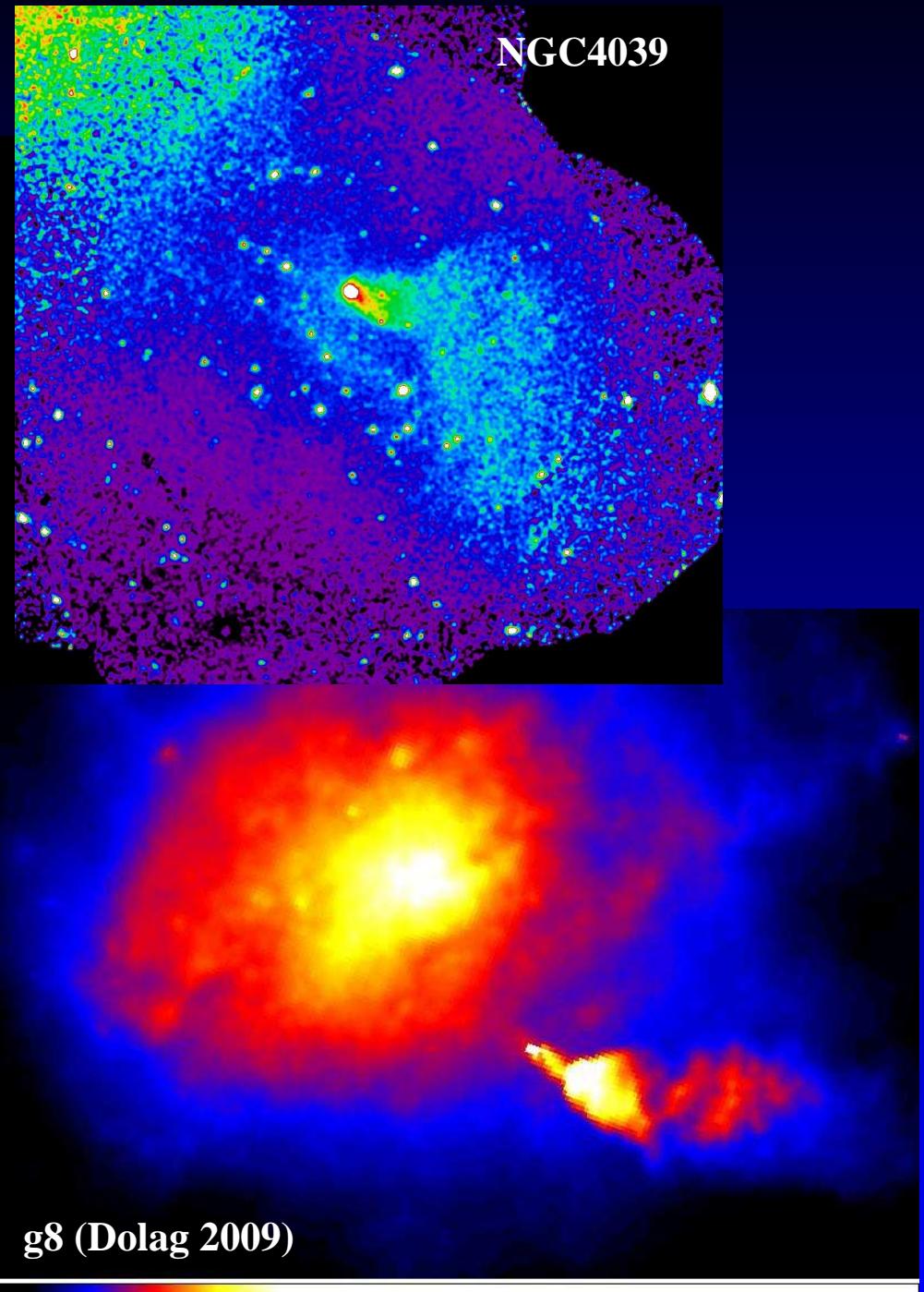
# ICM Properties



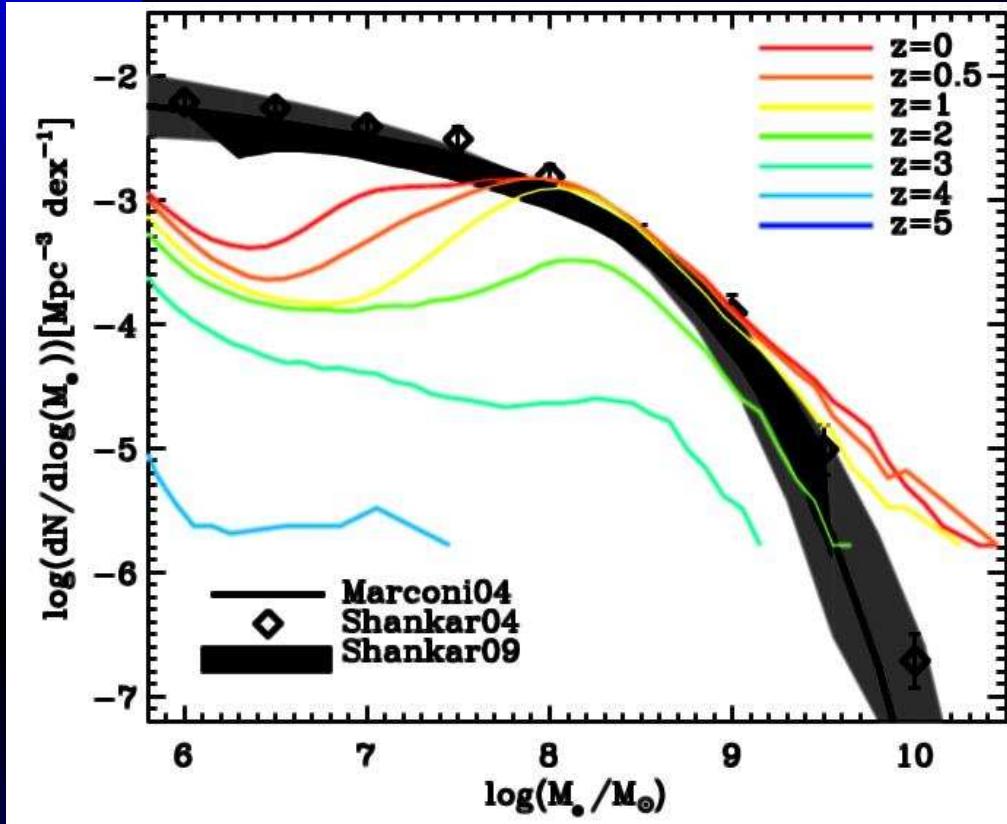
# ICM Properties



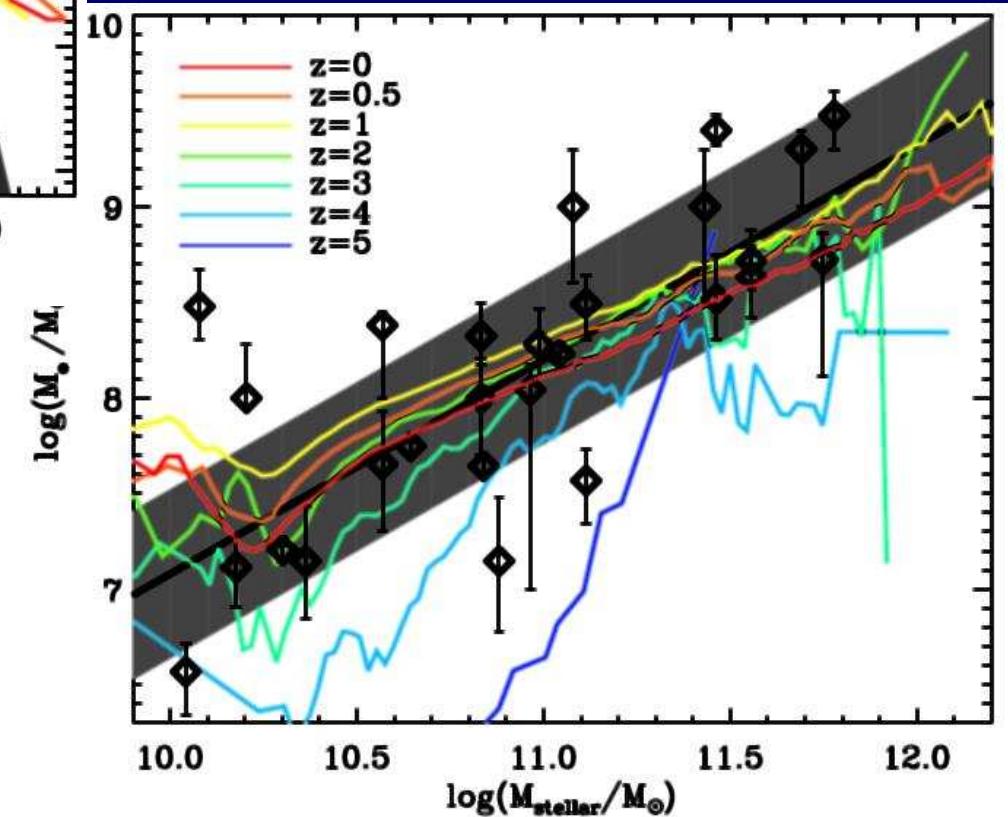
Provided by N. Lyskova & E. Churazov



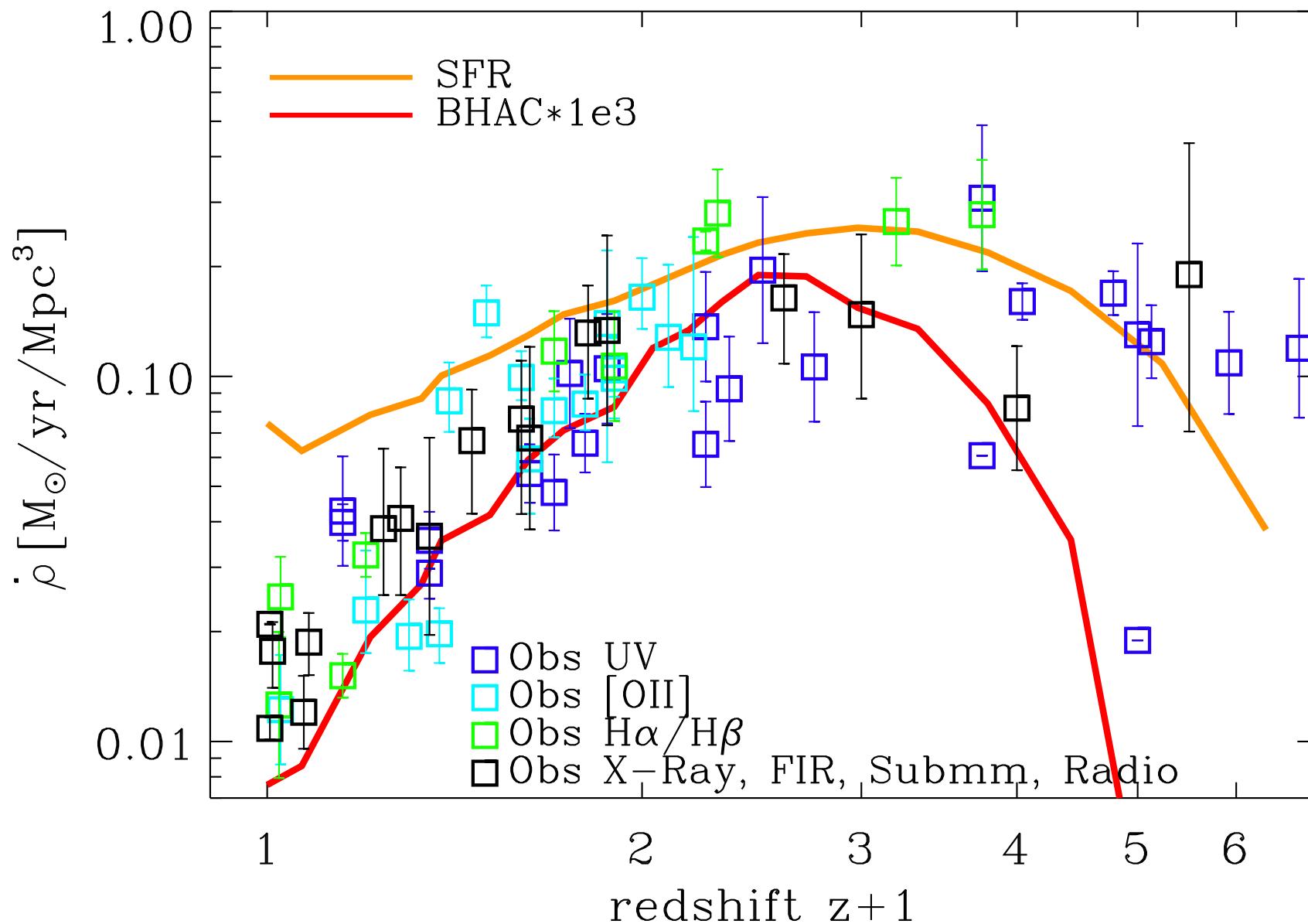
# AGN feedback model



Hirschmann et al. 2013

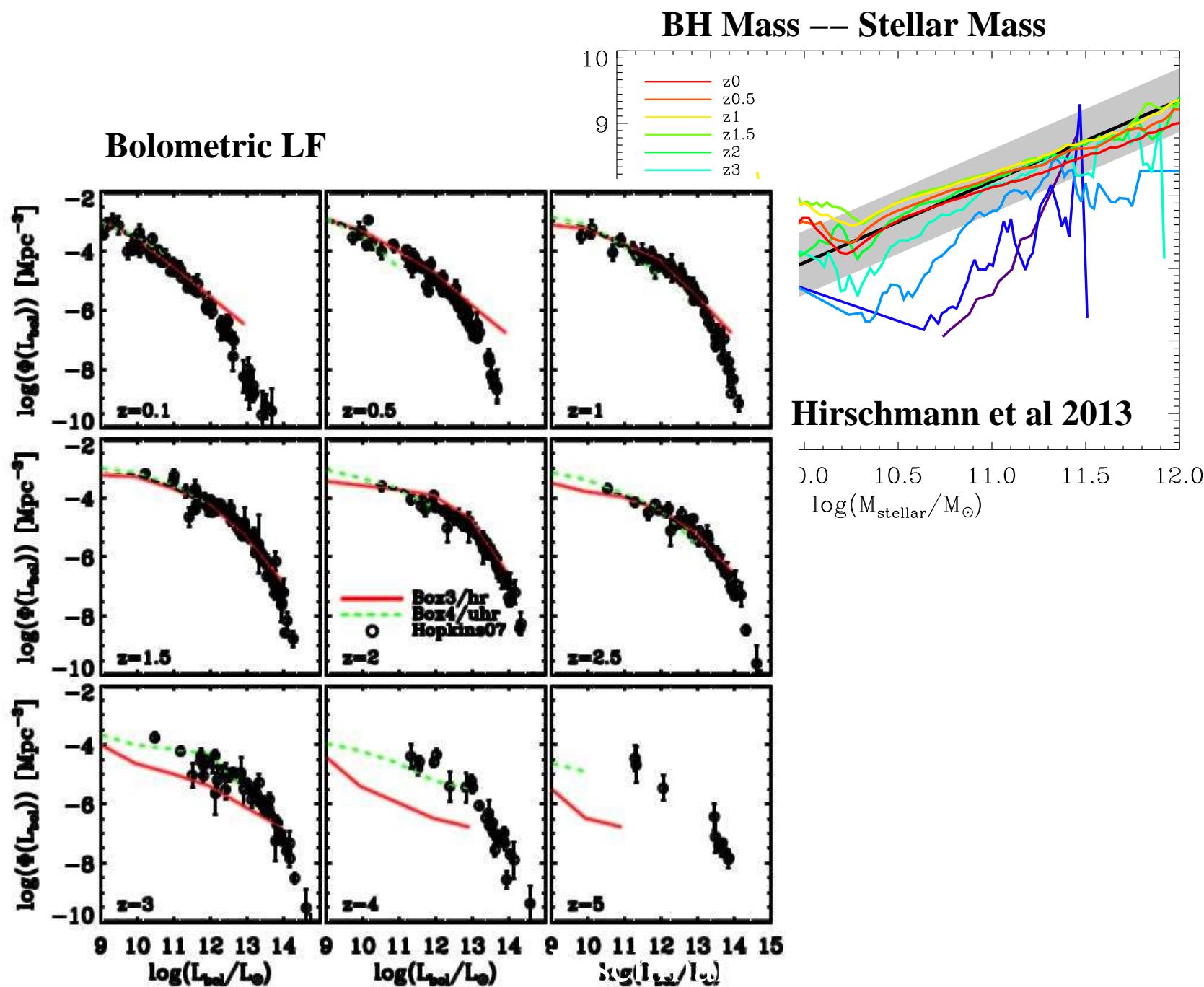


# AGN feedback model

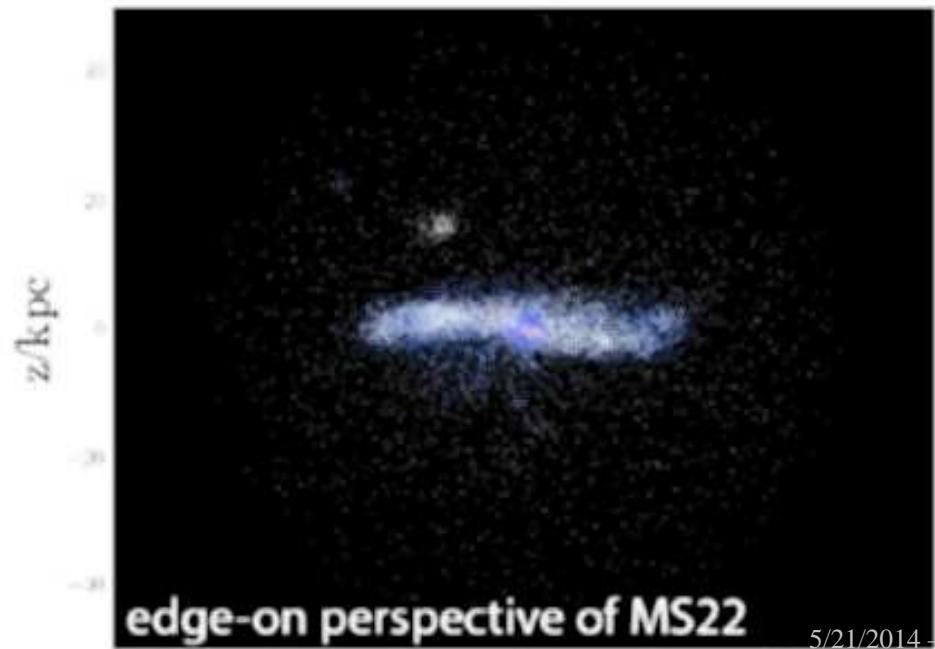
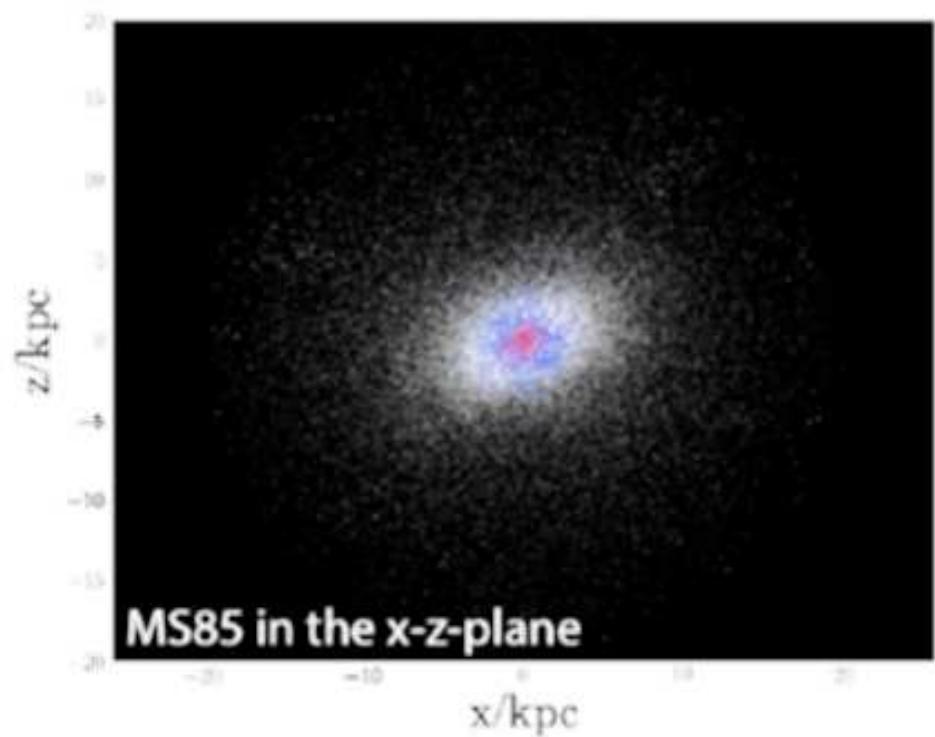
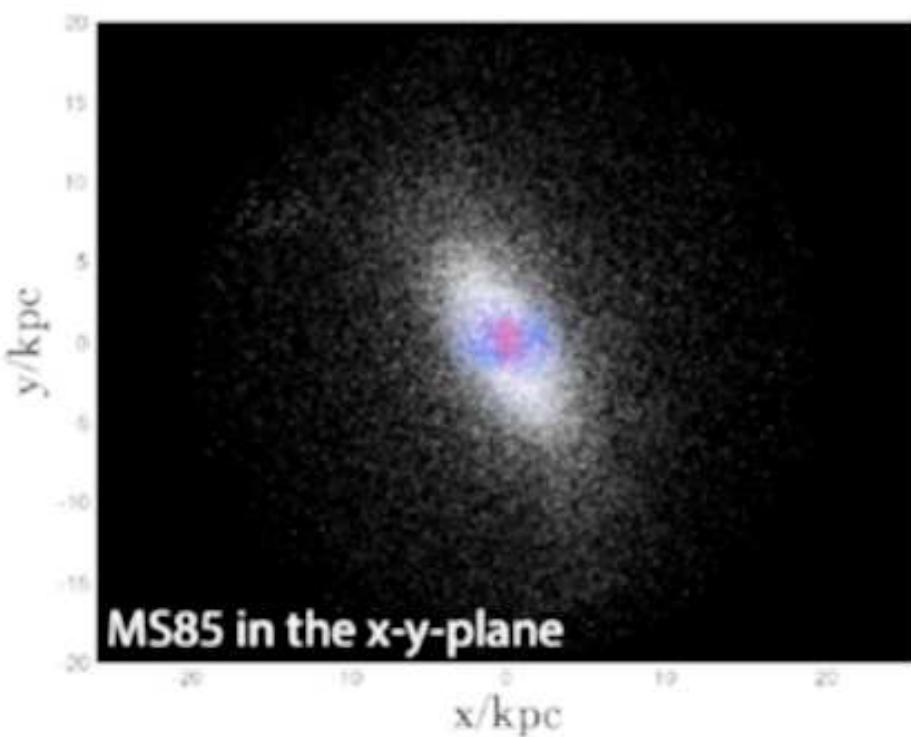


BH growth linked to star-formation

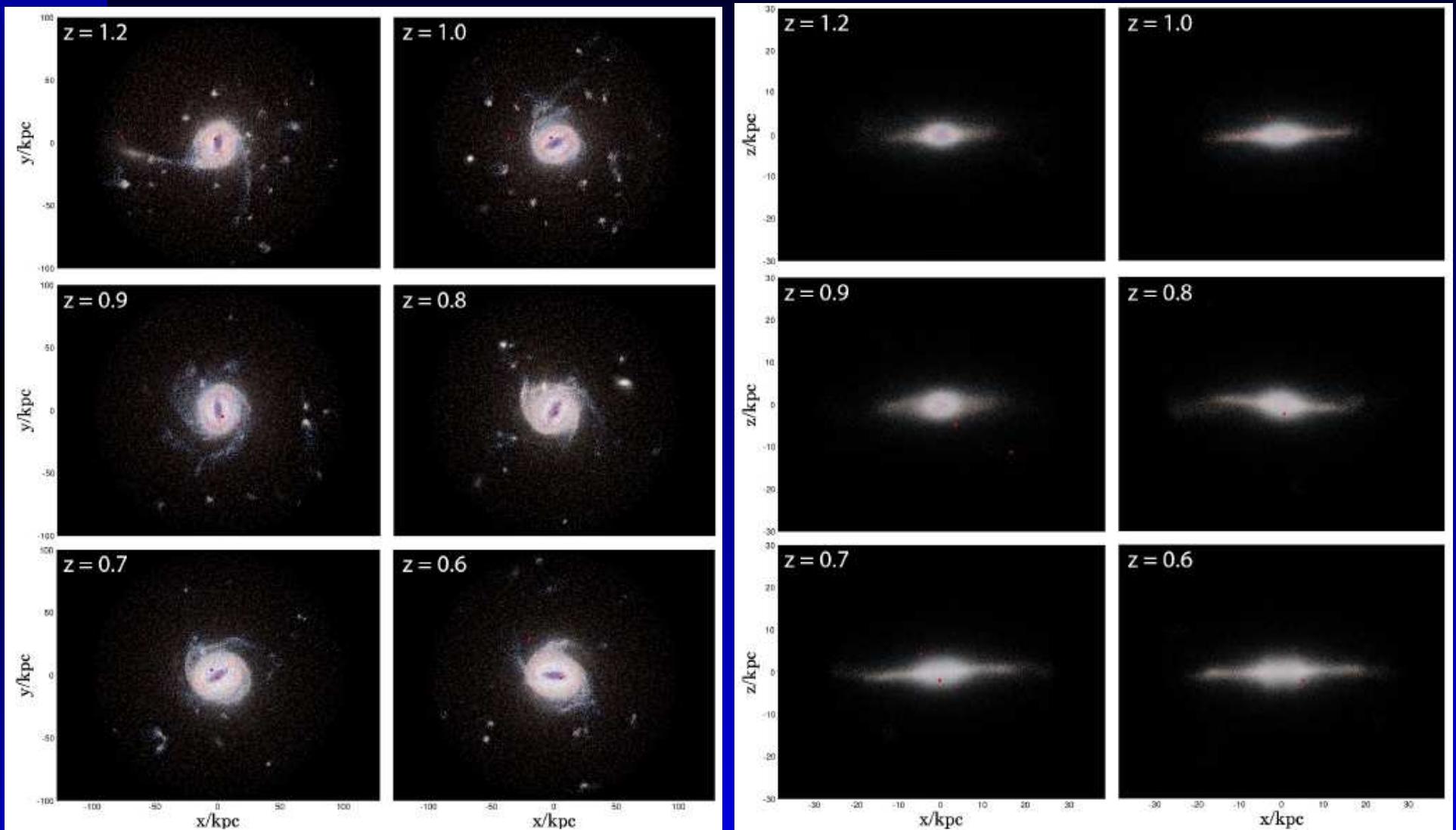
# AGN feedback model



# Galaxy properties



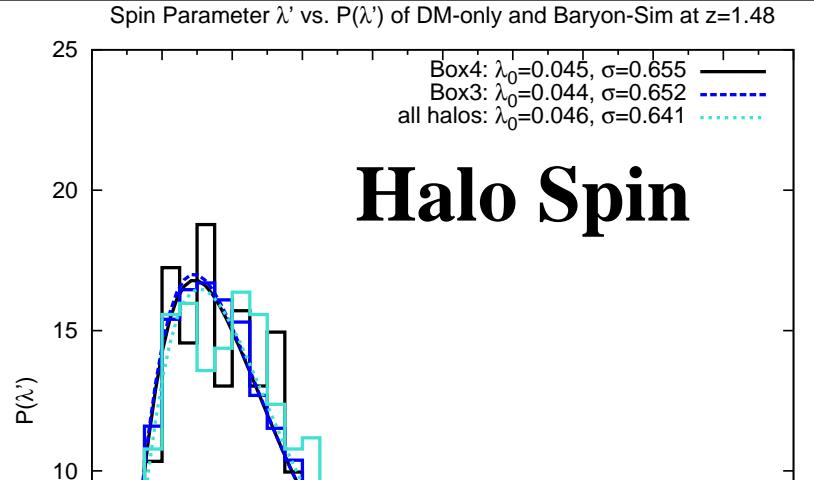
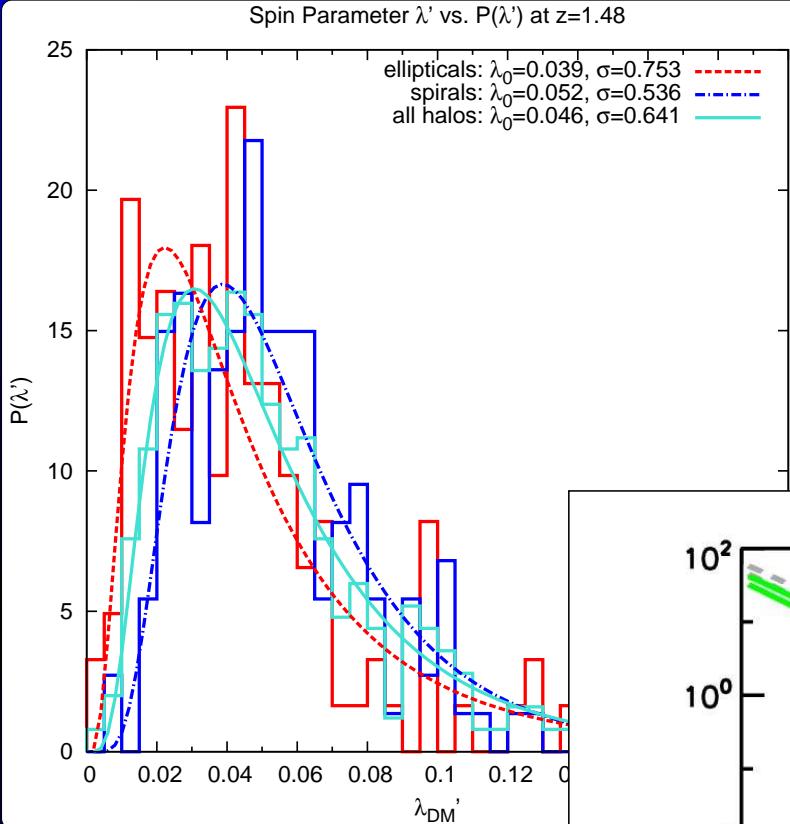
# Galaxy properties



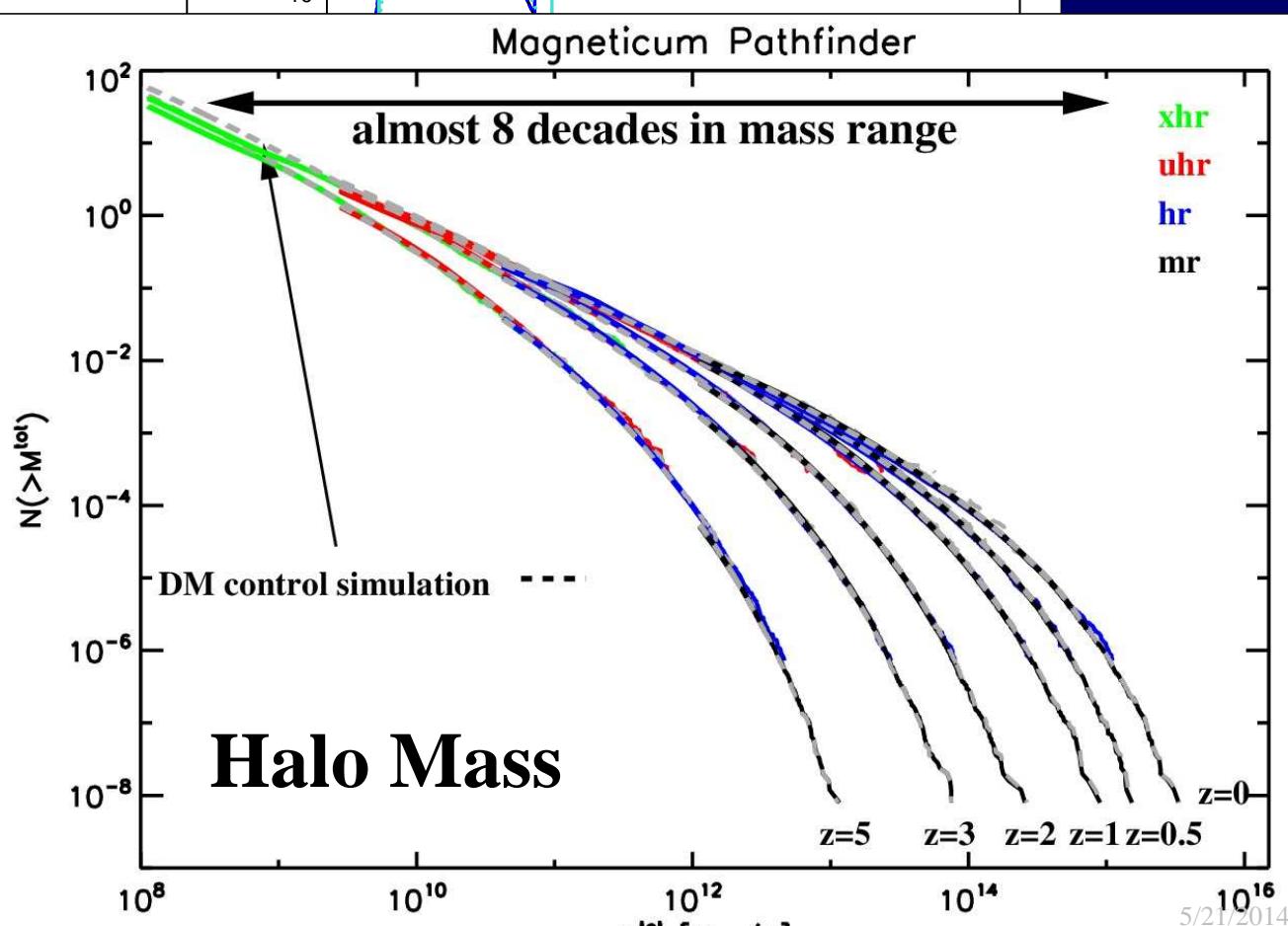
MA Lisa Bachmann

$\Rightarrow$  Implication for halo properties !

# Galaxy properties

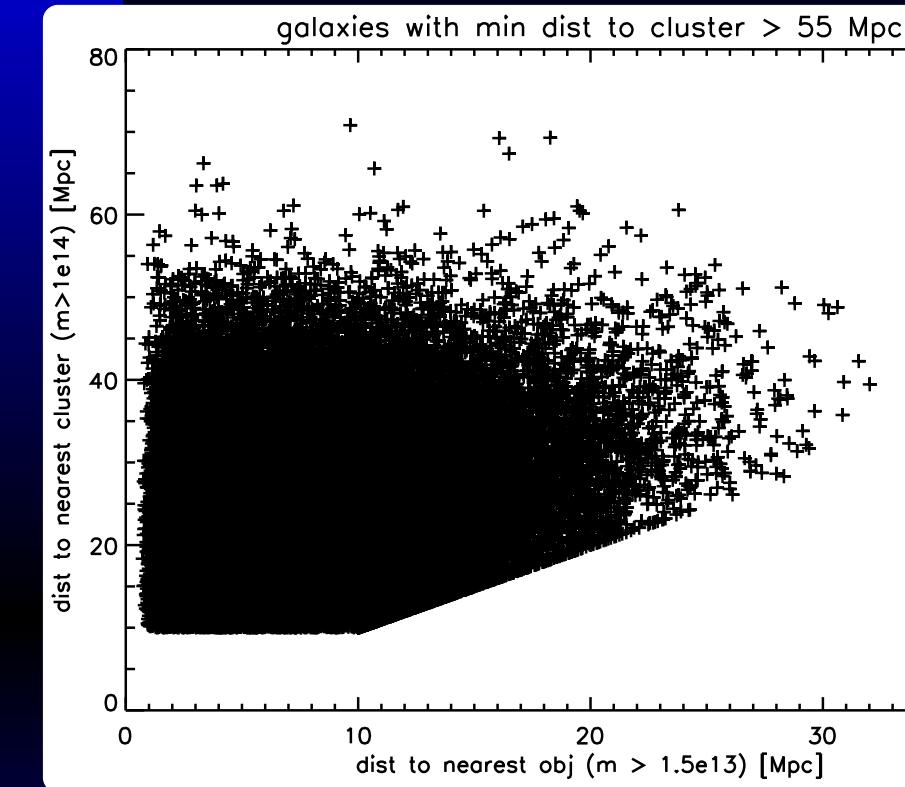


A. Teklu

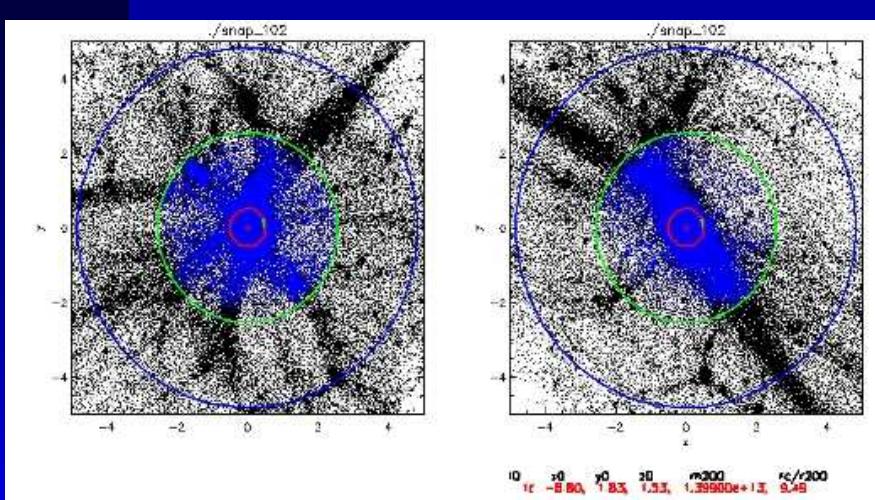
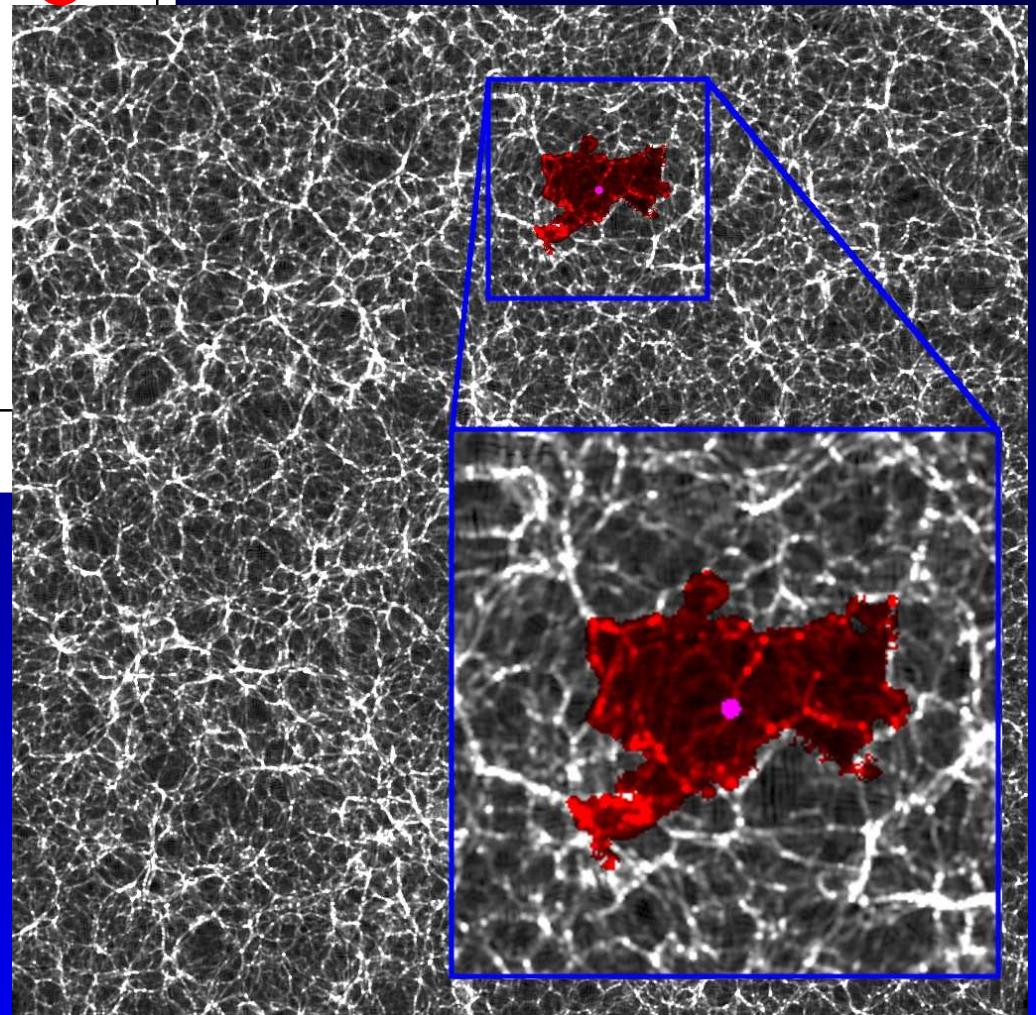


S. Bocquet

# Massive galaxies in voids

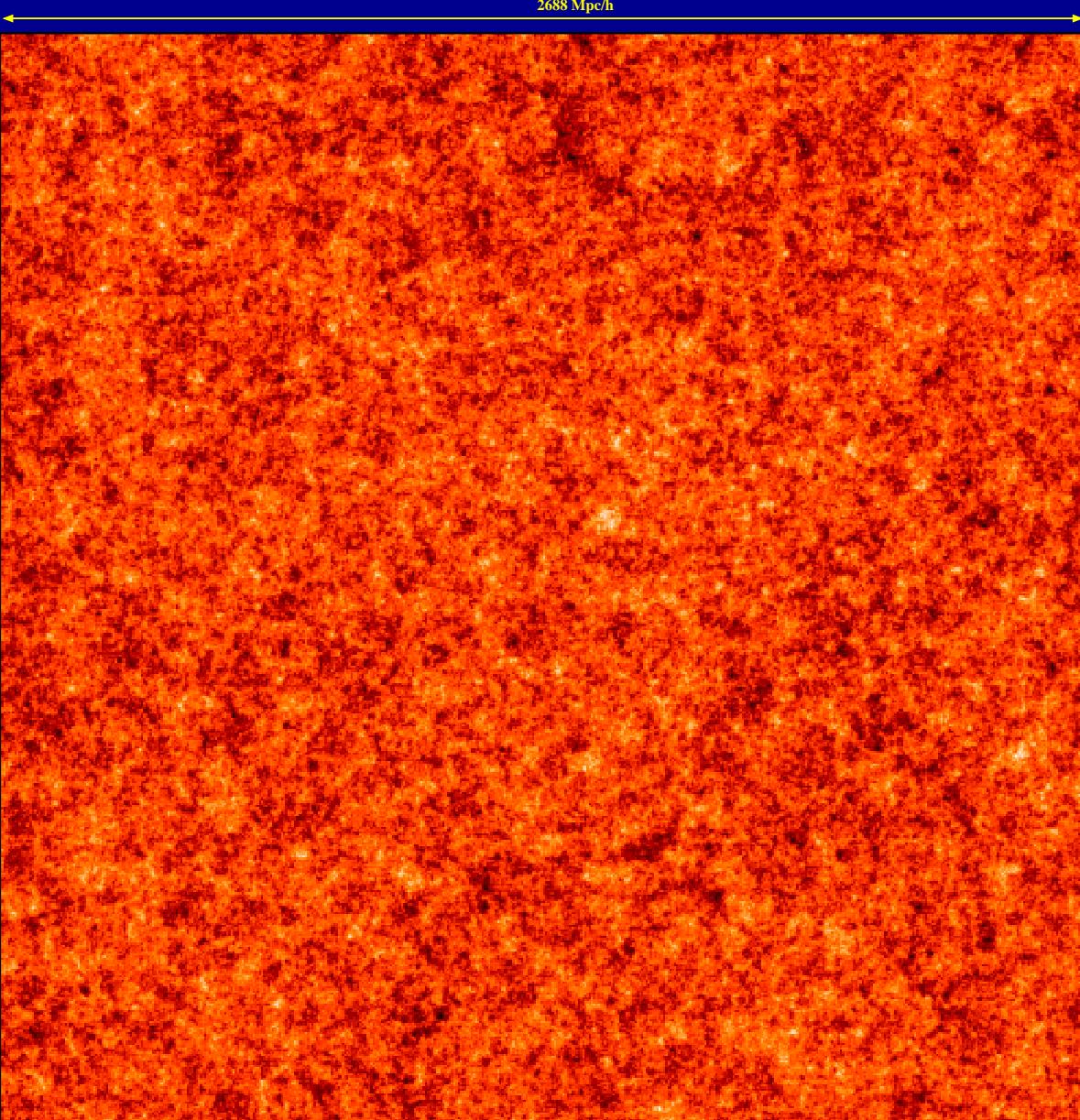


Selecting massive void galaxies



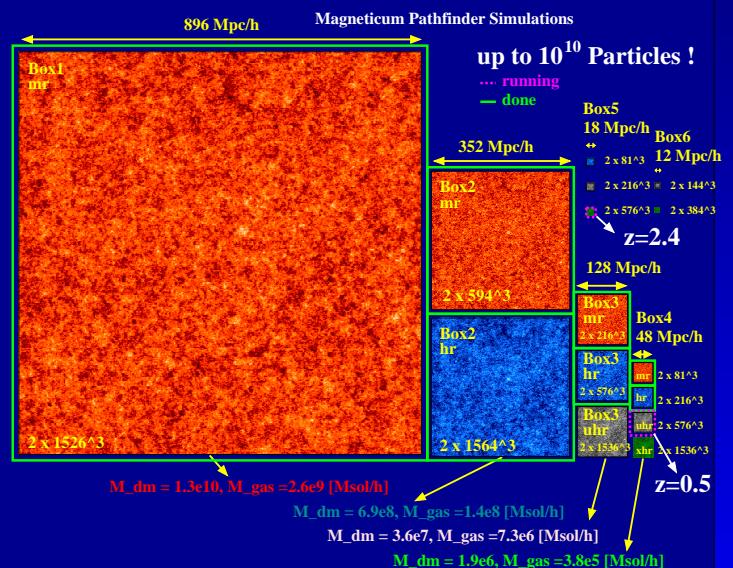
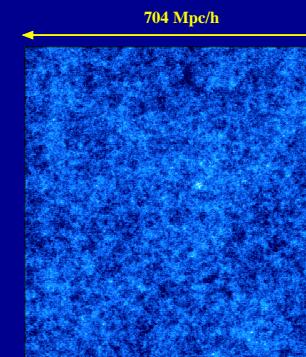
# Massive galaxies in voids

# Future Prospects



## Magneticum Simulations

up to  $10^{11}$  Particles !



Next generation of Simulations are under way !

# Future Prospects

Smac - Input - Mozilla Firefox X

File Edit View History Bookmarks Tools Help

http://www.g-vo.org/JobRunner/Smac.do?action=input

Most Visited Computing Privat Planck Wetter Kino OS/2

Smac - Input + Remember Never for This Site Not Now X

Do you want Firefox to remember the password for "astrosim" on g-vo.org?

## Job Runner@GAVO

### Smac - Input :

Go to: [Main](#) - [Previous Page](#) - [Job Queue](#) - [History](#)

This page allows you to visualise hydrodynamical simulations using Smac. Please see [here](#) for further information about the simulations. Please see [here](#) for documentation about the Smac visualisation code.

---

CLUSTER_ID	<input type="text" value="g676"/>	The cluster that was re-simulated.
PHYSICS	<input type="text" value="csf"/>	The physics included in the simulation.
HALO_ID	<input type="text" value="a"/>	ID of few most massive halos to center the images on for CENTER='read by a file'
SNAPNUM	<input type="text" value="85 - 0.06963"/>	Start snapshot
SNAP_END	<input type="text" value="-1 - ***"/>	Ending snapshot to loop to from SNAPNUM. '-1 - ***' indicates no loop
OUTPUT_MAP	<input type="text" value="6 - X-ray surface brightness"/>	Flag of the type of output map
OUTPUT_SUB	<input type="text" value="0 - simple sqrt(T)"/>	Flavor of OUTPUT_MAP ...
PROJECT	<input type="text" value="1 - along z, xy plane"/>	Last direction to project along
CENTER	<input type="text" value="2 - read by a file"/>	Flag of the definition of the center
CENTER_X	<input type="text" value="0"/>	X-coordinate of center position/Cluster data for CENTER='selected by user'
CENTER_Y	<input type="text" value="0"/>	Y-coordinate of center position/Cluster data for CENTER='selected by user'
CENTER_Z	<input type="text" value="0"/>	Z-coordinate of center position/Cluster data for CENTER='selected by user'
IMAGE_Z	<input type="text" value="0"/>	image redshift (set IMAGE_Z=0. to obtain it from the input data)
PART_DISTR	<input type="text" value="1 - SPH (flat 2D-map)"/>	Flag of particle distribution scheme on the image.
IMG_XY_UNITS	<input type="text" value="2 - kpc"/>	Flag of the units of the side of image
IMG_XY_SIZE	<input type="text" value="2000"/>	The size of the image (in units given by IMG_XY_UNITS) (default value assumes kpc as units!)
IMG_Z_UNITS	<input type="text" value="2 - kpc"/>	side of the third dimension (default assumes kpc as units).
IMG_Z_SIZE	<input type="text" value="2000"/>	Number of image side pixels, if ==-1, given by smoothing
IMG_SIZE	<input type="text" value="256"/>	
NSIDE	<input type="text" value="***"/>	HEALPix variable. This variable must be a power of 2 and <= 8192.
MIN_DIST	<input type="text" value="2000"/>	min radius of sphere around x0,y0,z0 to be used [kpc]

Find:  Previous Next Highlight all Match case

Done

# Future Prospects

File Edit View History Bookmarks Tools Help

MPI Phox The PHOX Virtual X-ray Observatory +

galformod.mpa-garching.mpg.de/phoxybrowser/ Ask.com Search

EMPIRE STRUSSBACH

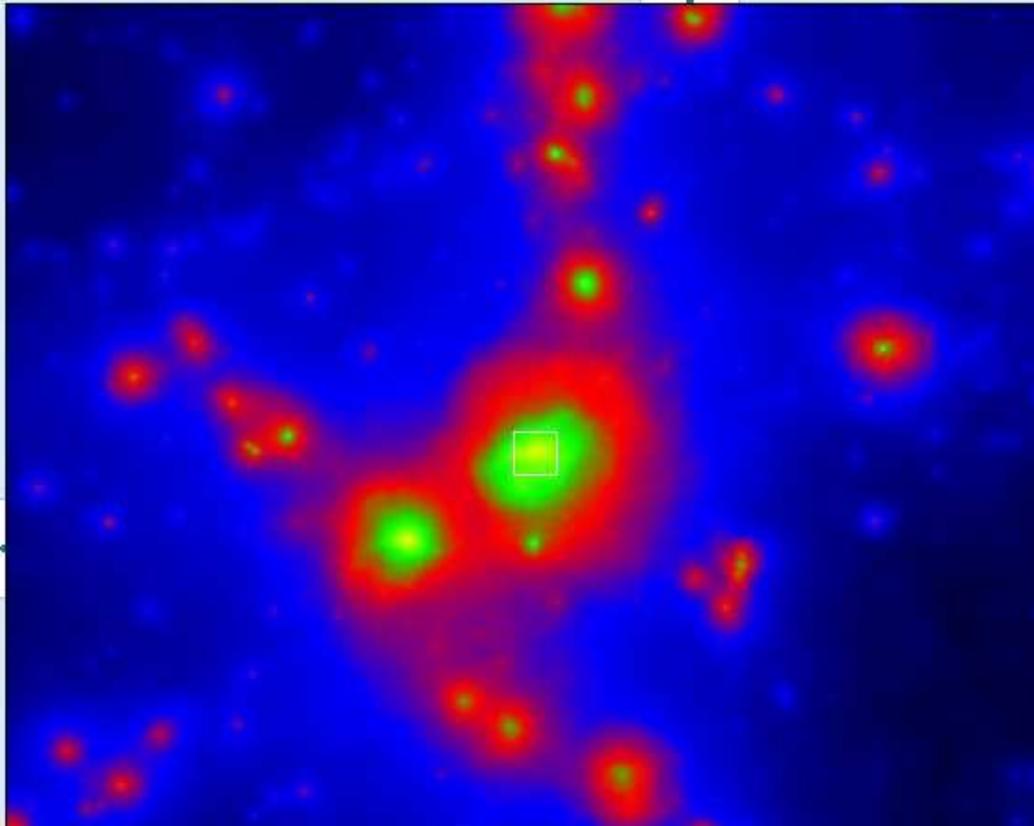
Hi koolag | logout | legal notice | portal

The PHOX Virtual X-ray Observatory  
- Interactive PHOX Browser -

Filament X-Y

Images:  
[tSZ](#)  
[kSZ](#)  
[ne](#)  
[M](#)  
[LX](#)

Highlights:



Run PHOX code

xc: 77028  
yc: 74407  
zc: 47

Instrument: XMM (MOS)

T\_obs: 50000

Submit

Rank	Haloid	X	Y	Z	Mass
1	1	77119	74184	125805	443420309000000

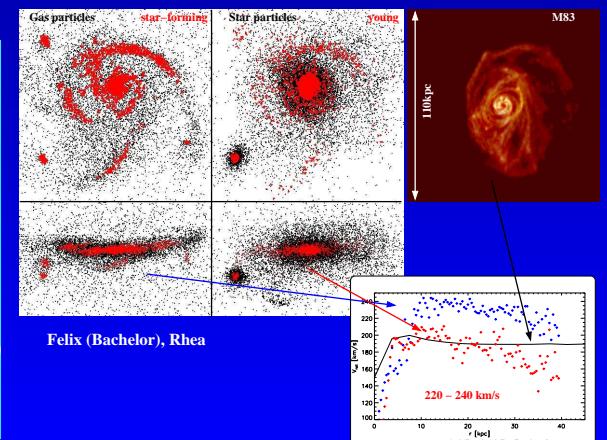
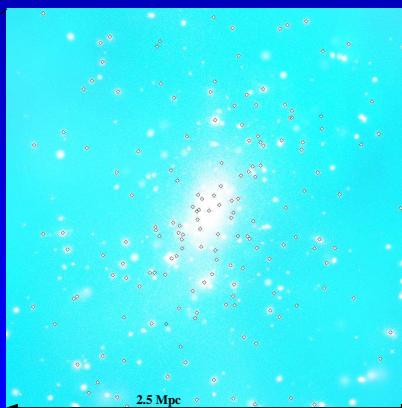
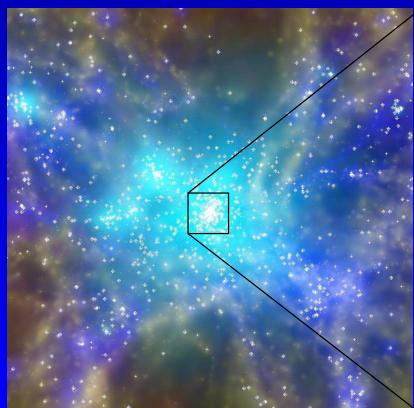
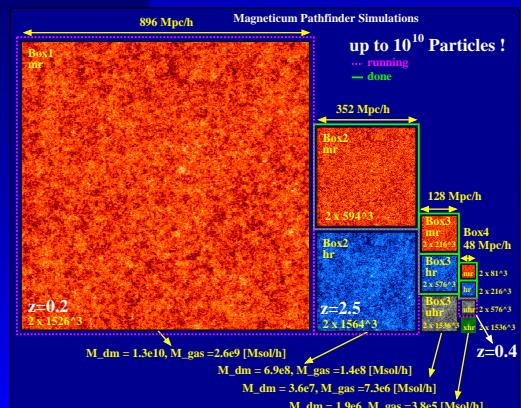
Showing 1 to 1 of 1 entries

First Previous 1 Next Last

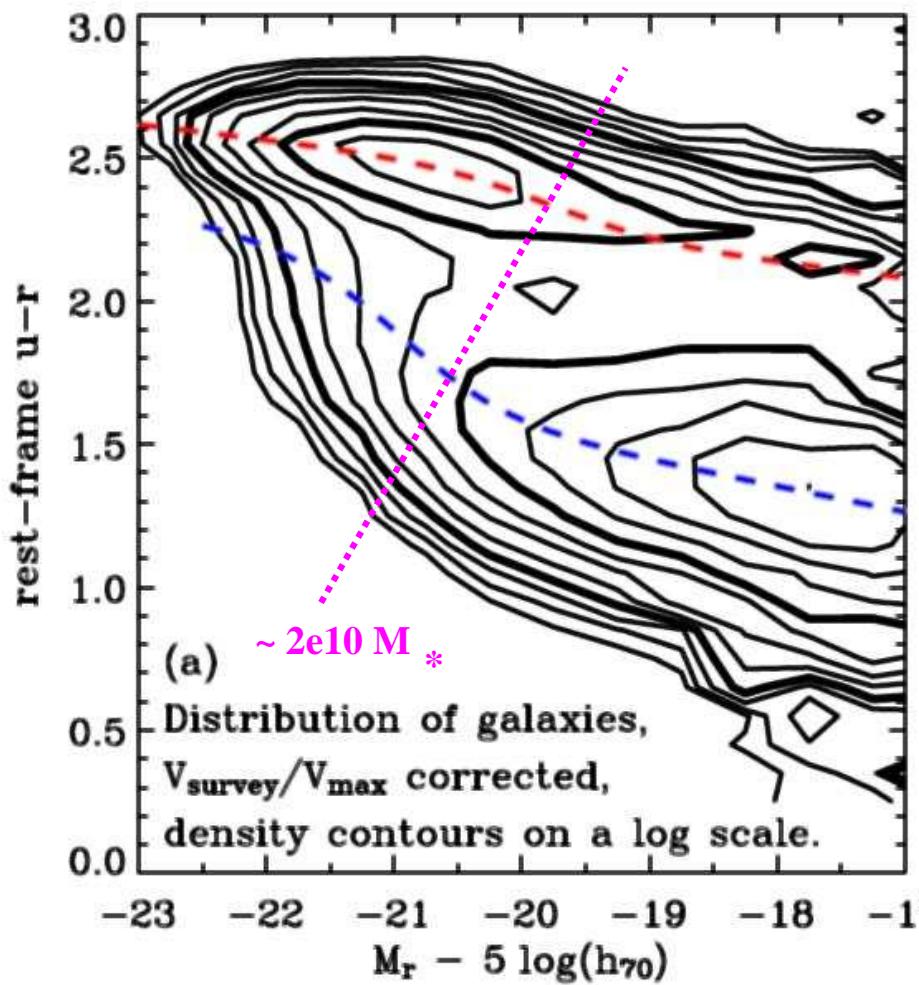
# Conclusions

Cosmological, hydrodynamical simulations which at the same time allows predictions for ICM and stellar and AGN component for ongoing/future missions.

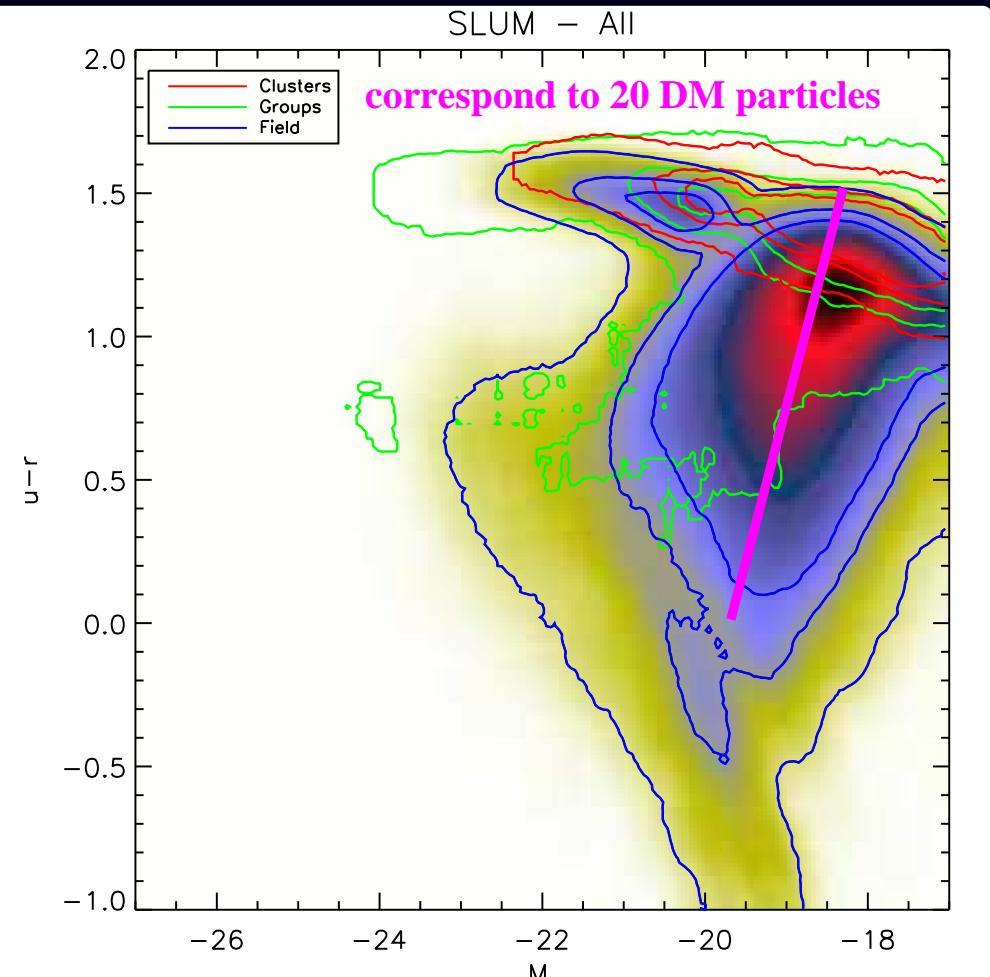
- Simulated stellar properties (reasonable)  
luminosity function, colors, specific star-formation rates
- ICM properties (very good)  
pressure profiles, x-ray scaling relations
- AGN properties (very good)  
accretion histories, luminosity functions
- Dynamics of galaxies  
Spirals vs. Ellipticals, Spin, Warps, Bars, ...
- High resolution Zoom simulations available  
Evolution, transformation and environment effects for galaxies



# Galaxy properties



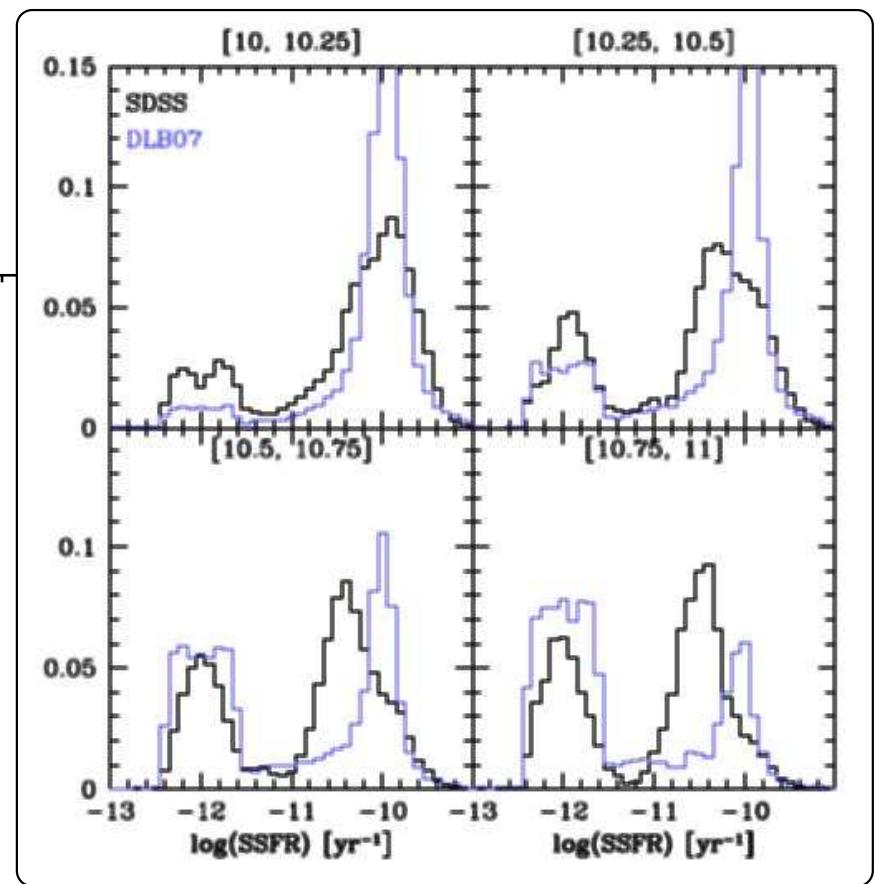
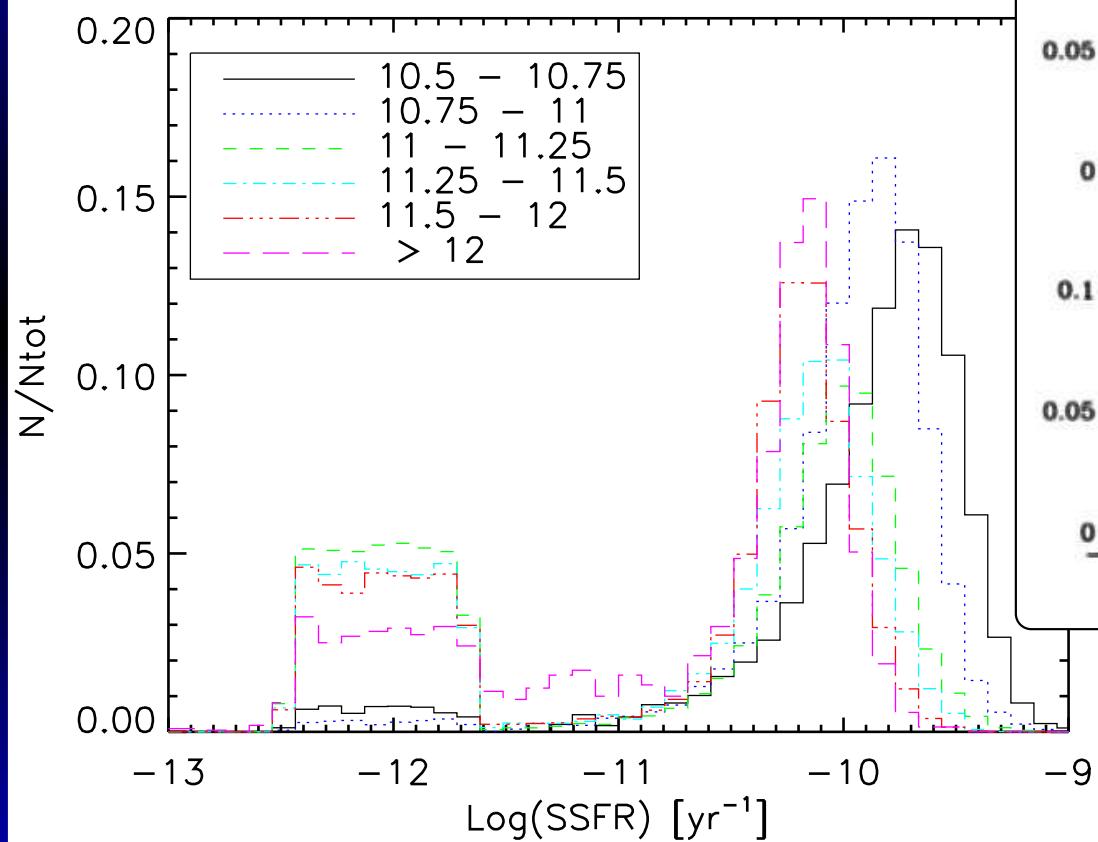
Baldry et al. 2004



Color-Magnitude relation as function of environment.

A. Saro, work in progress

# Galaxy properties



Weinmann et al. 2010

SSFR (compared to SAM and SDSS, Weinmann 2010)