Simulating the Formation and Evolution of LSS

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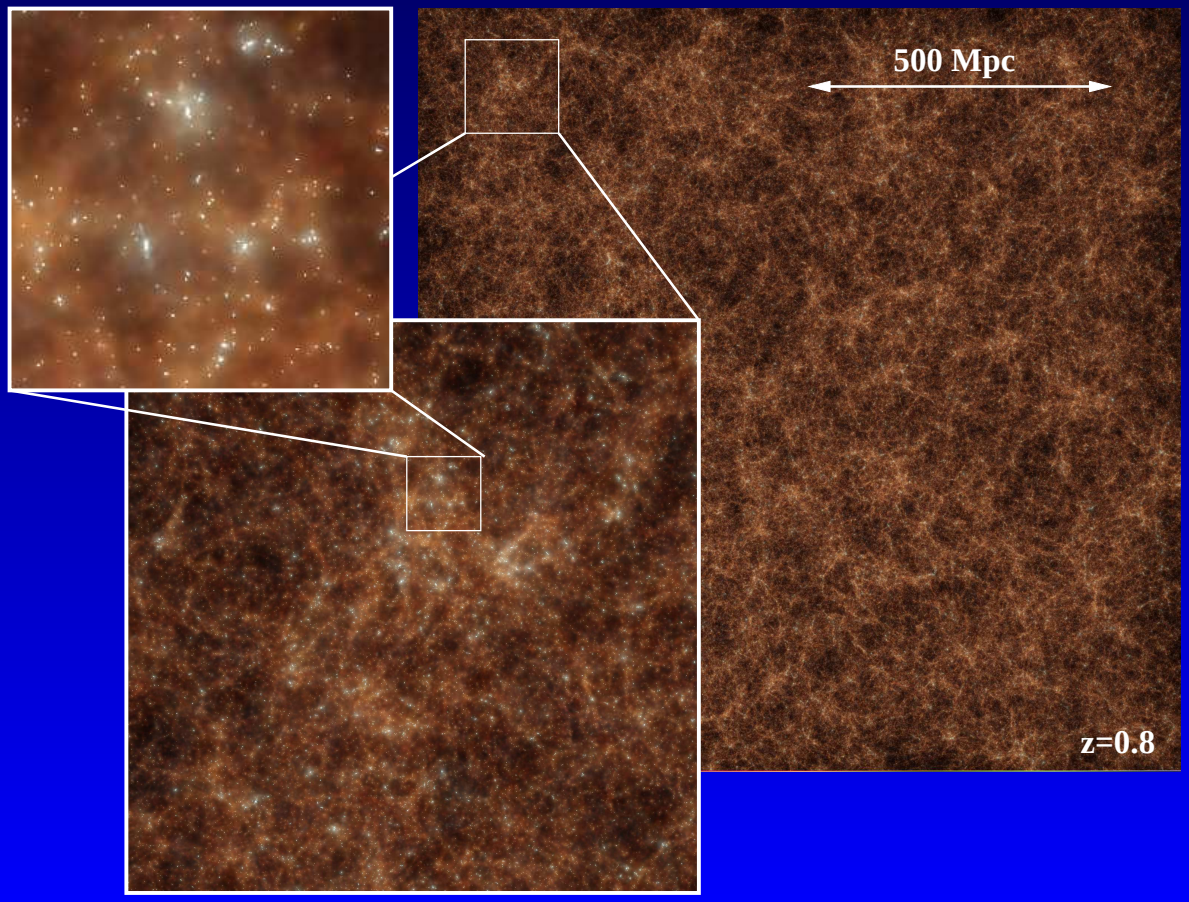
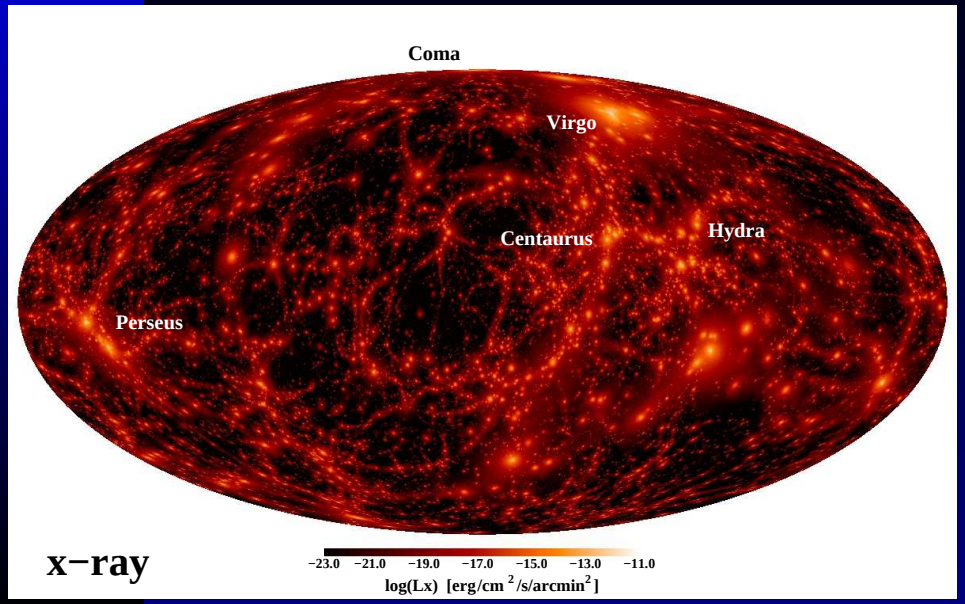
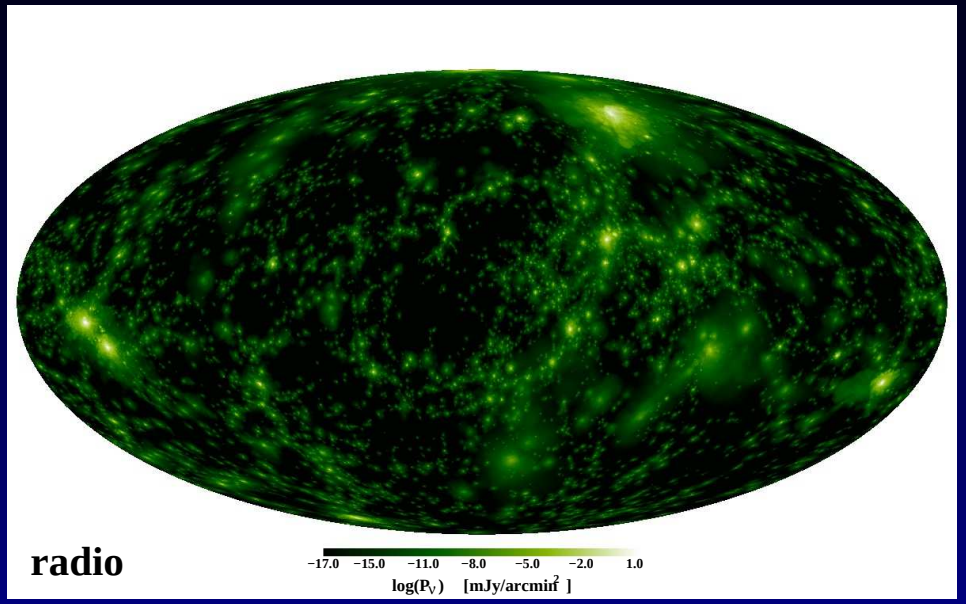
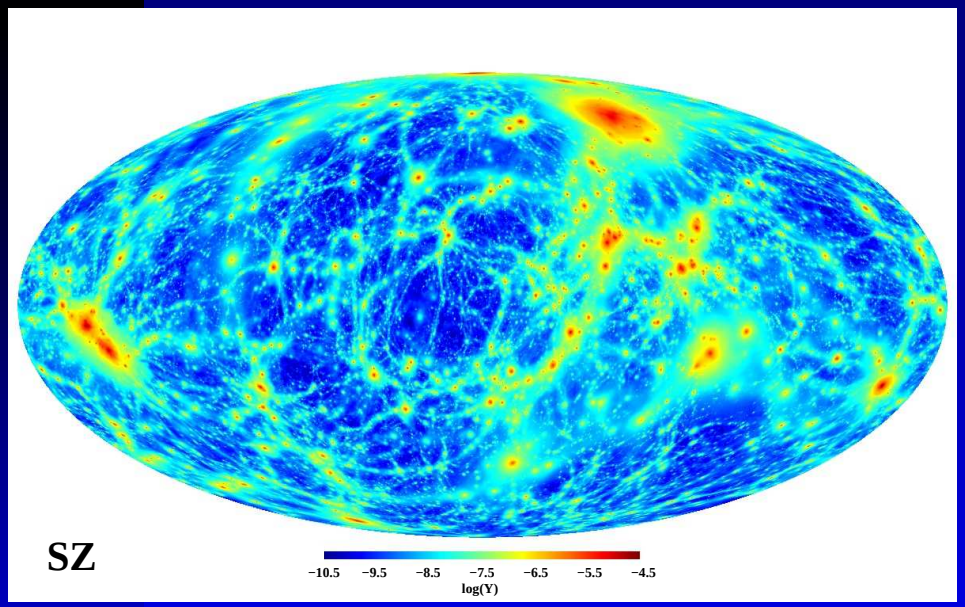
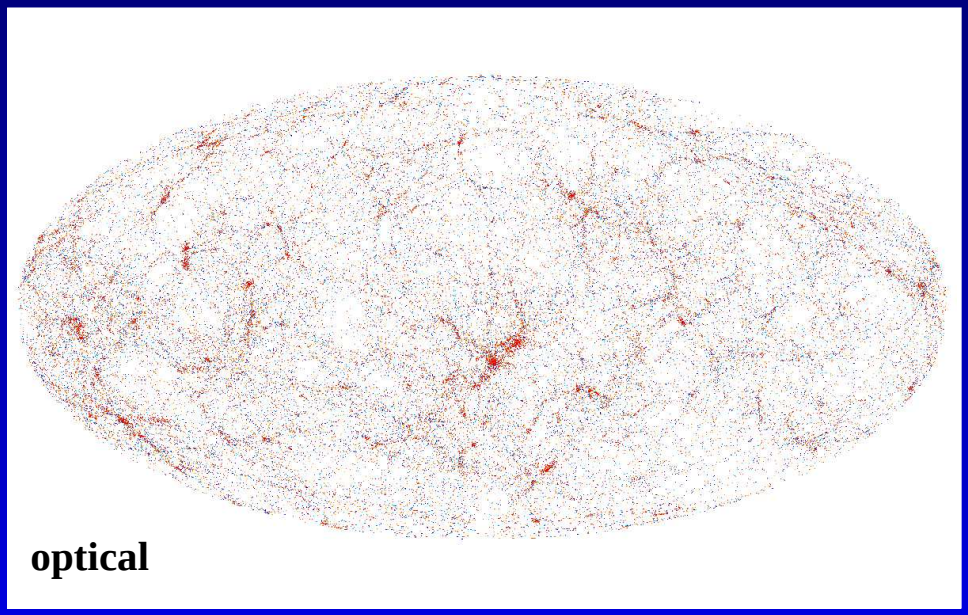


The Aim



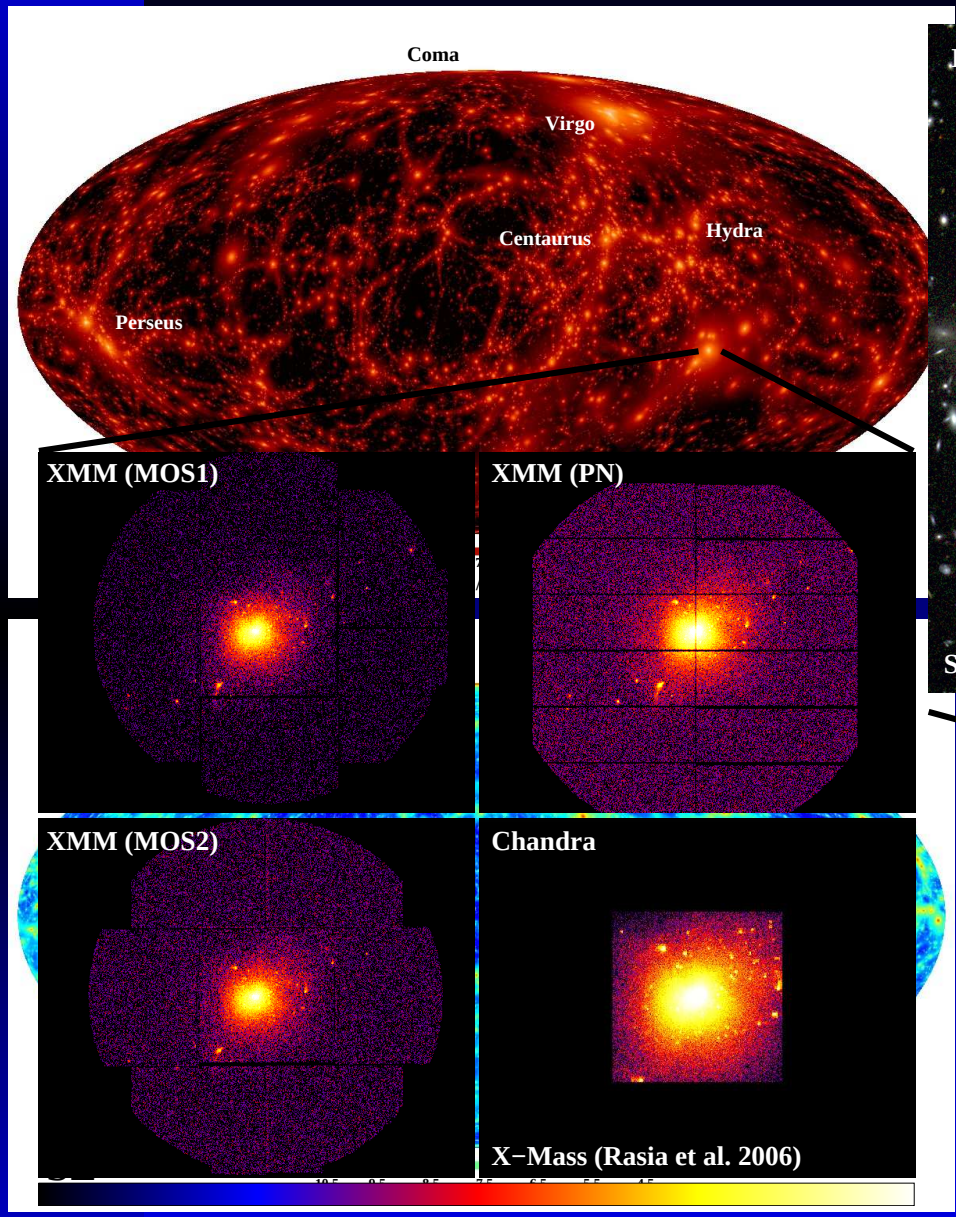


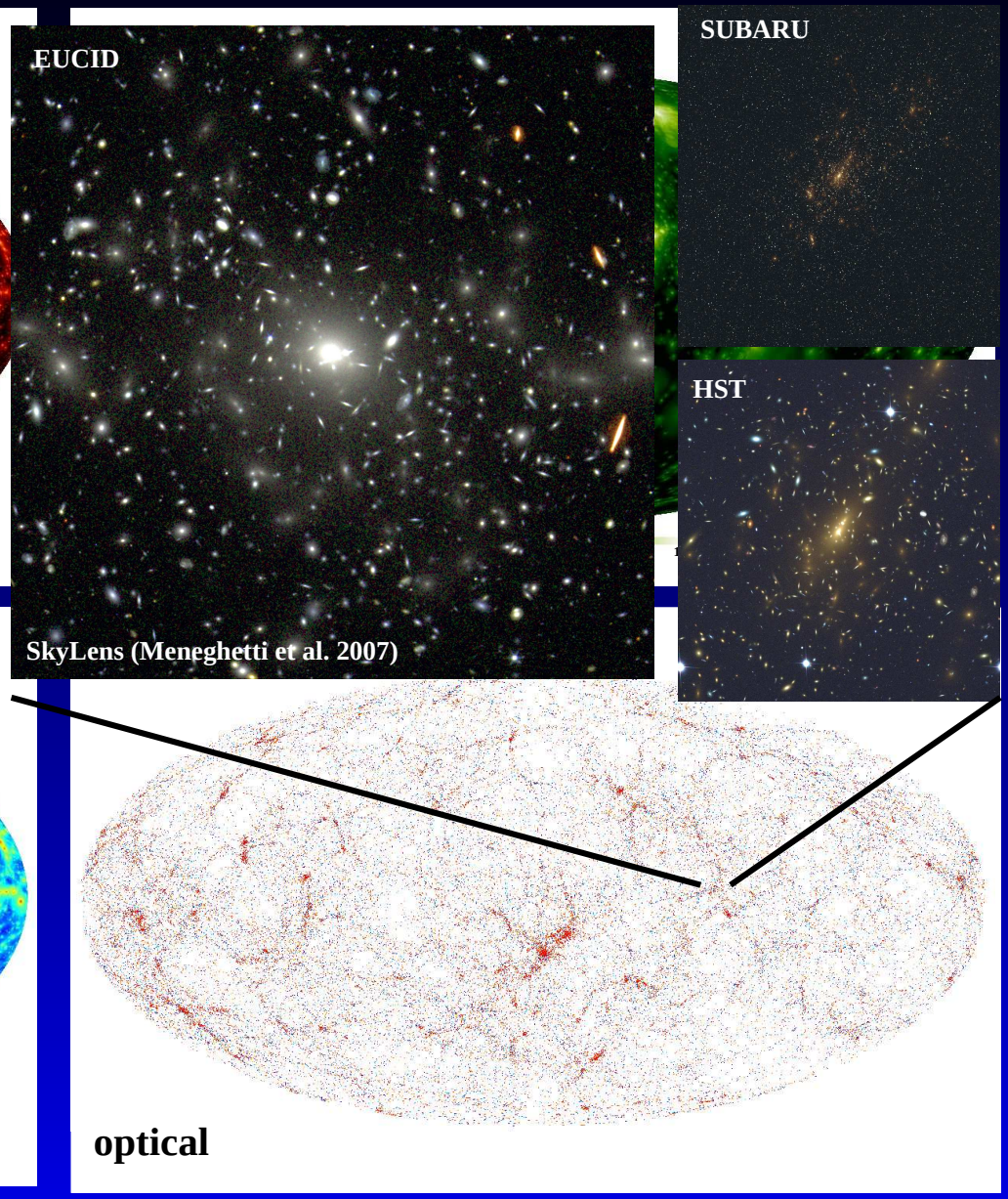




Cosmological, hydrodynamical simulations which at the same time allows predictions for ICM and stellar component for ongoing/future missions (Planck, SPT, LOFAR, eROSITA ...).

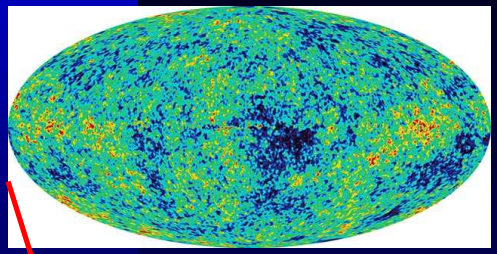
The Aim





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

The Challenge

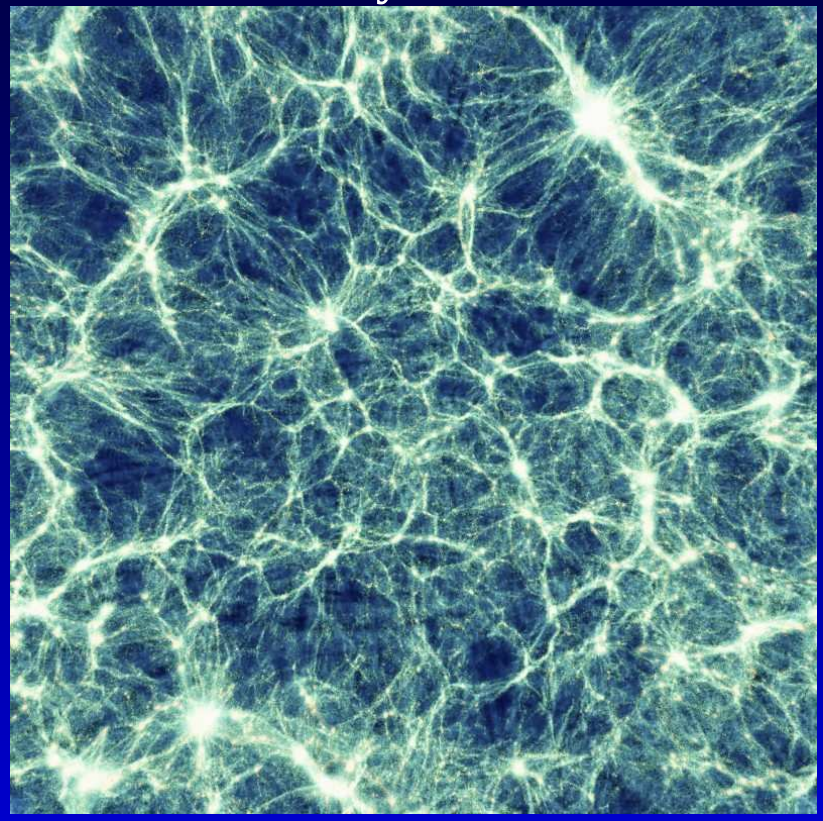


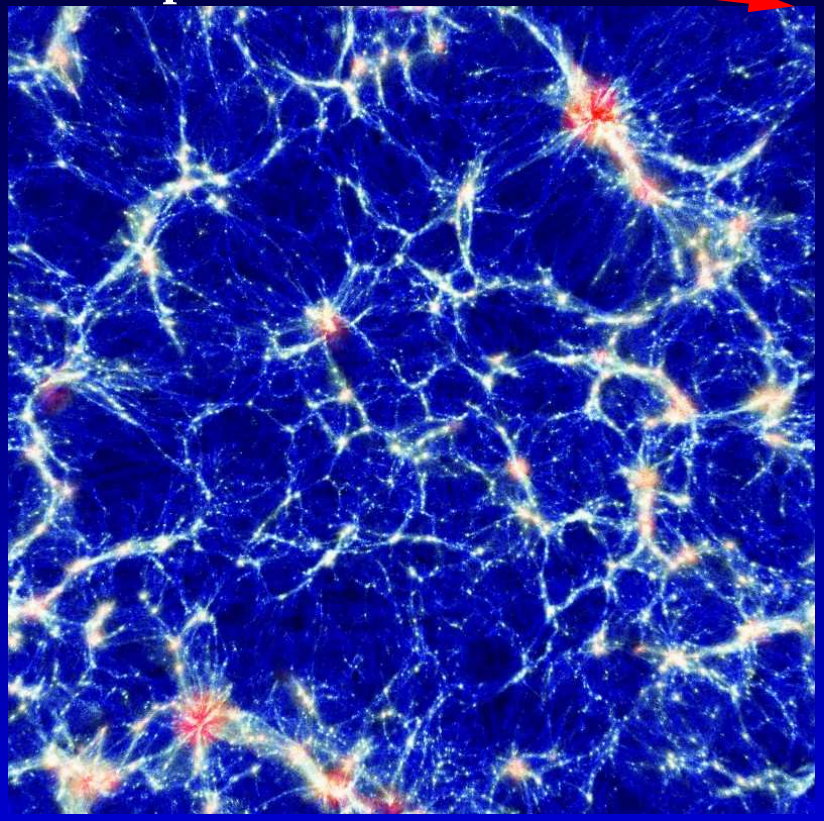
CMB (t = 0.38 Myr)

Cosmic structure today
(t = 13.7 Gyr)

Density

Temperature



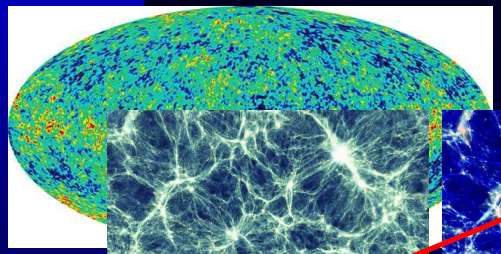


Borgani, Murante, Springel, Diaferio, Dolag et al. 2004

275 Mpc

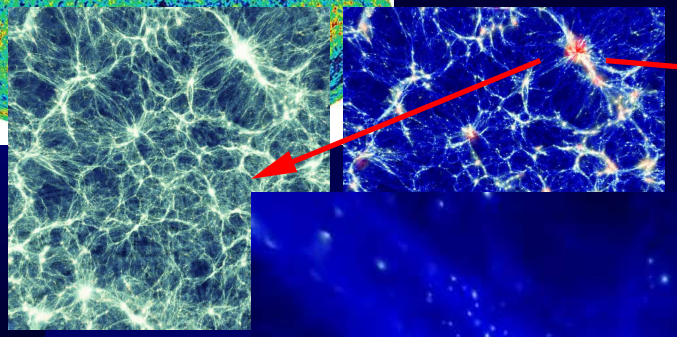
The cosmic web today ($z = 0$) is mainly accessible through simulations (warm, thin). Simulations important to predict the non linear formation of cosmological structures.

The Challenge



t = 0.38 Myr

"Zoomed" Simulation of a galaxy cluster



t = 13.7 Gyr

Density

Temperature

275 Mpc

10^{-2} cm^{-3}

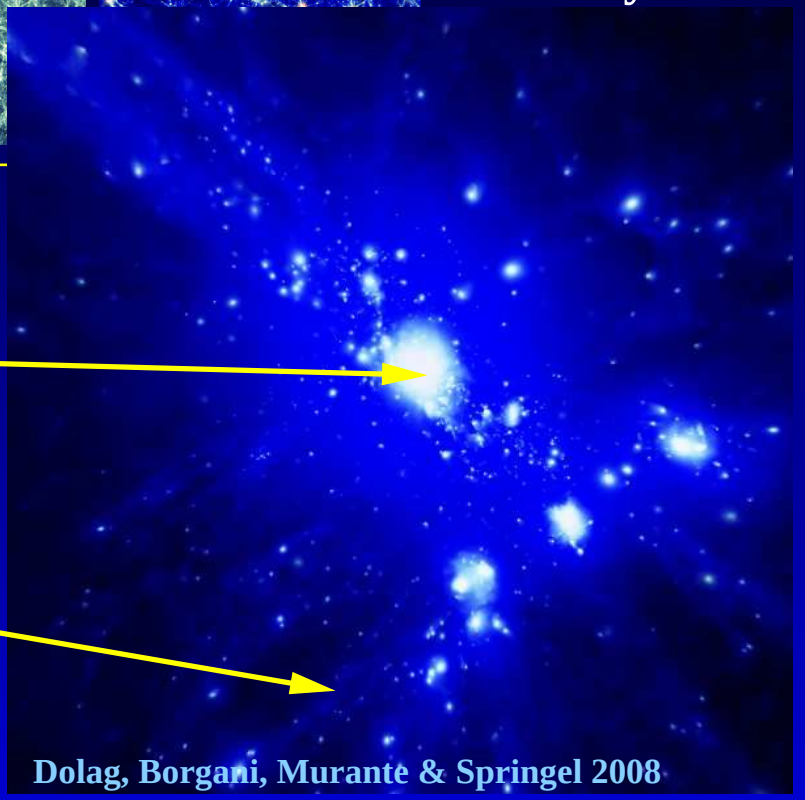
10^{8} K

~ μG

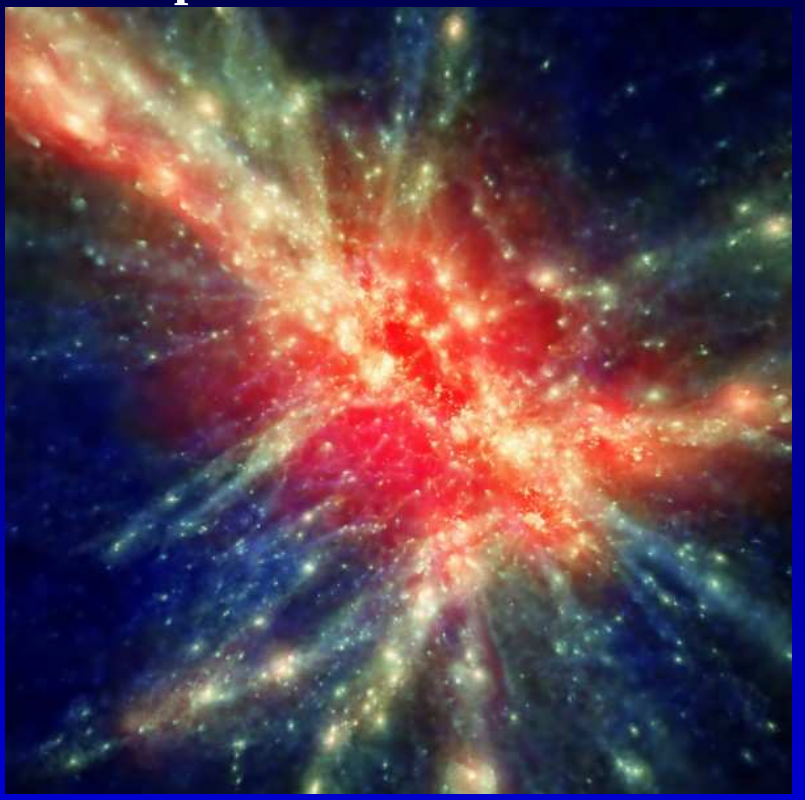
10^{-7} cm^{-3}

10^{5} K

< nG



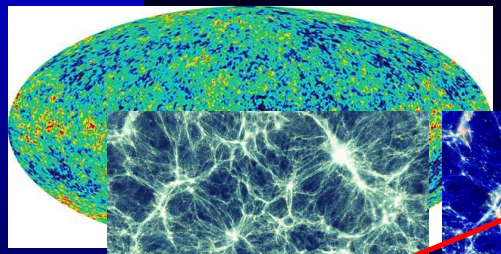
Dolag, Borgani, Murante & Springel 2008



40 Mpc

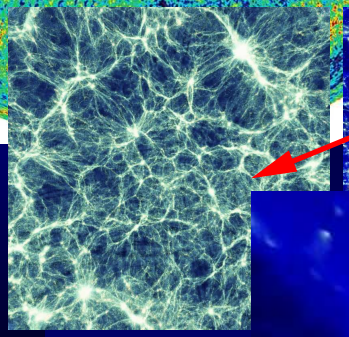
Clusters form at the nodes of the cosmic web and trace the high density environments. The gas falls into the potential, cools and form stars.

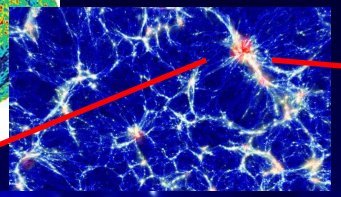
The Challenge



t = 0.38 Myr

"Zoomed" Simulation of a galaxy cluster





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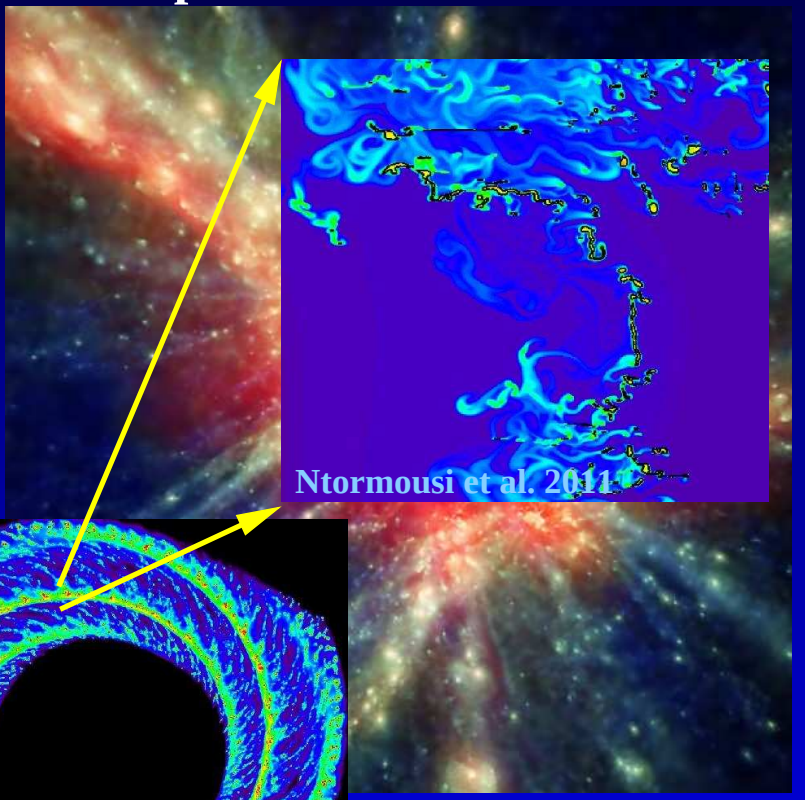
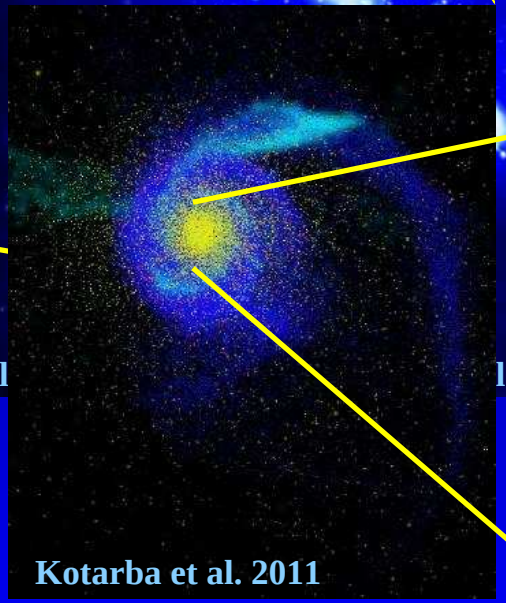
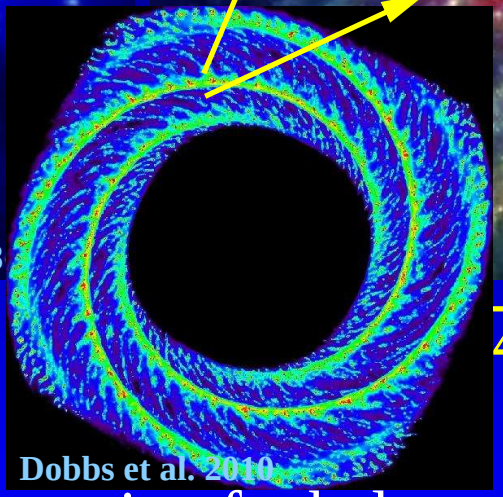


Ntormousi et al. 2011



Kotarba et al. 2011



Dobbs et al. 2010

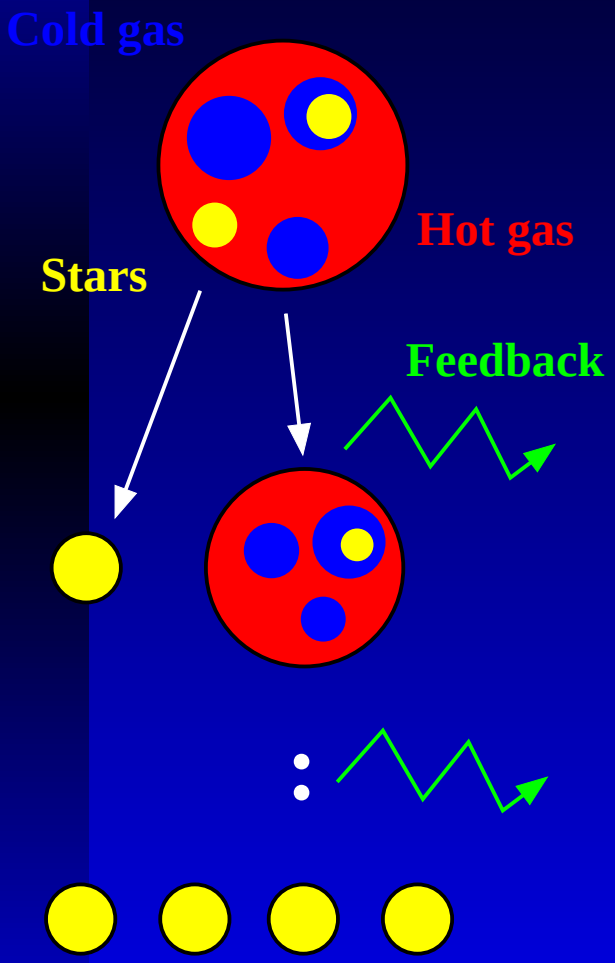
40 Mpc

Need to capture processes happening far below the resolution !

Simulating Subgrid Physics

Multi phase model (sub−scale)

Springel & Hernquist 2002



Star formation

supernova mass fraction

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

star formation timescale

Cloud evaporation

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

cloud evaporation parameter

Growth of clouds

cooling function

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

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

α −Bondi (Springl & Di Matteo 06)
β −Bondi (Booth & Schaye 09)
....

Feedback

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

Merging

Instant merging
Based on velocity
....

Growth of BH

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

gas density

sound speed

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

Feedback by BH

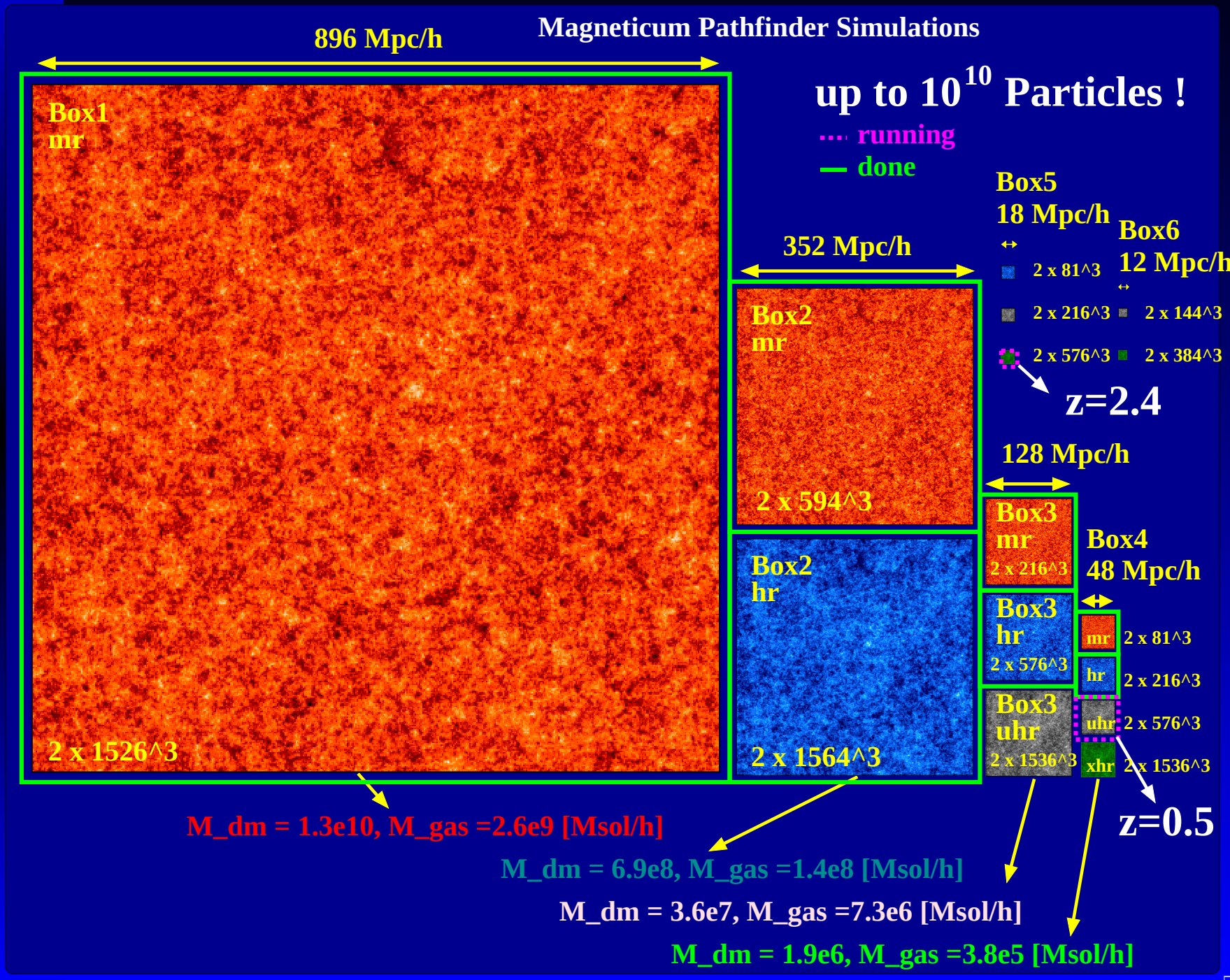
$$L_{\rm bol} = 0.1 \times \dot{M}_\bullet c^2$$

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

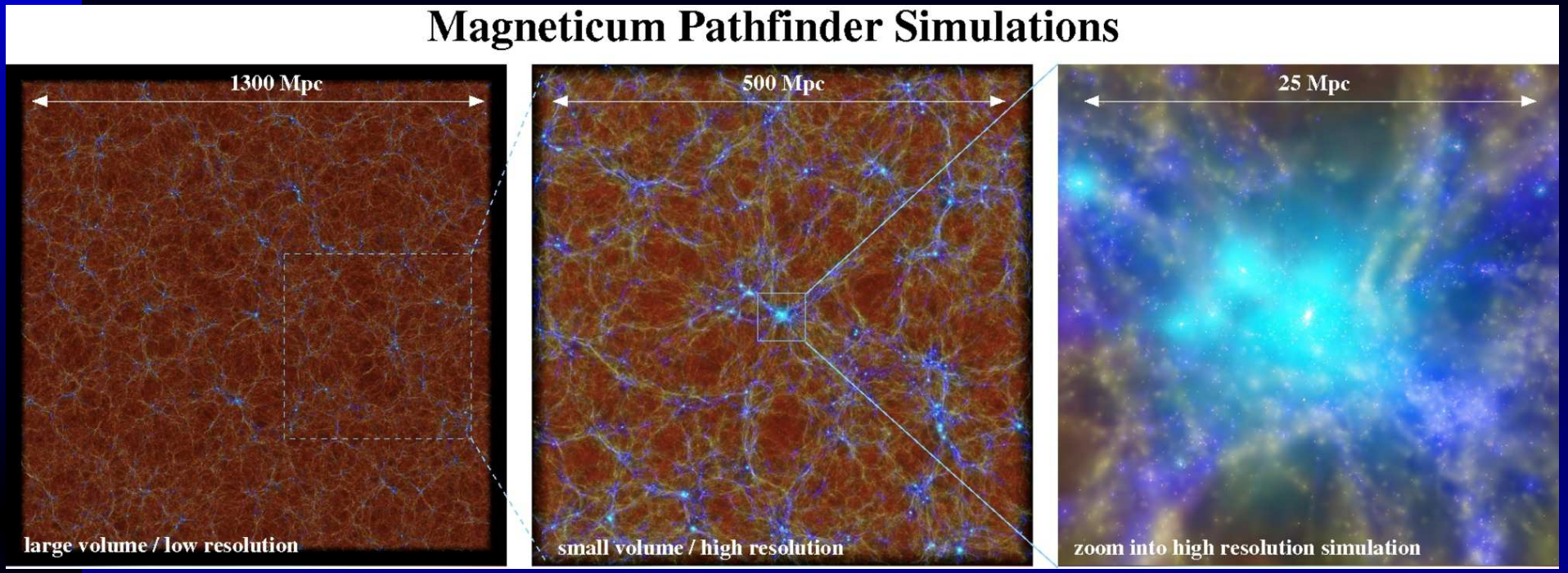
efficiency

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

LSS Simulations

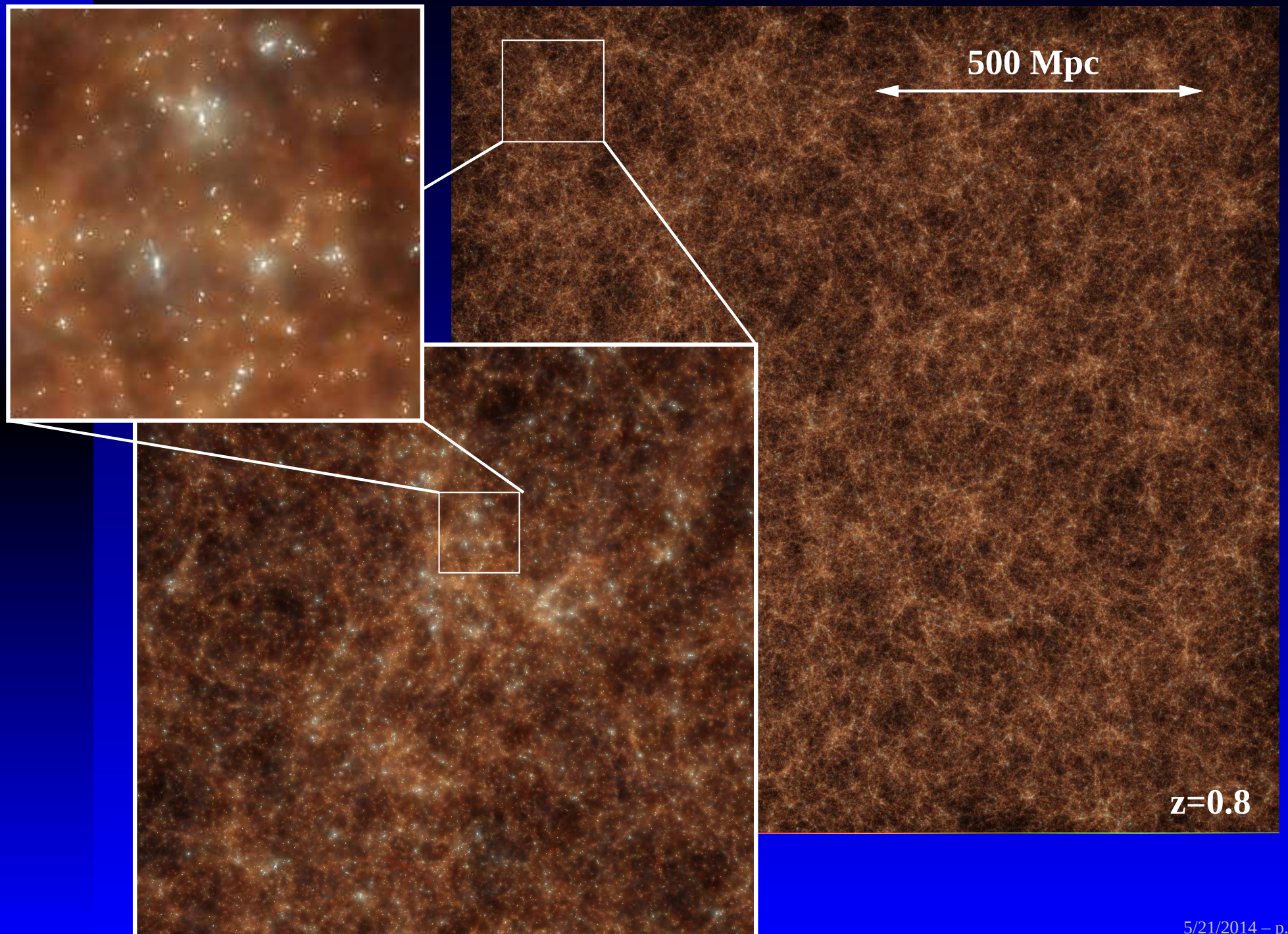


LSS Simulations



- 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



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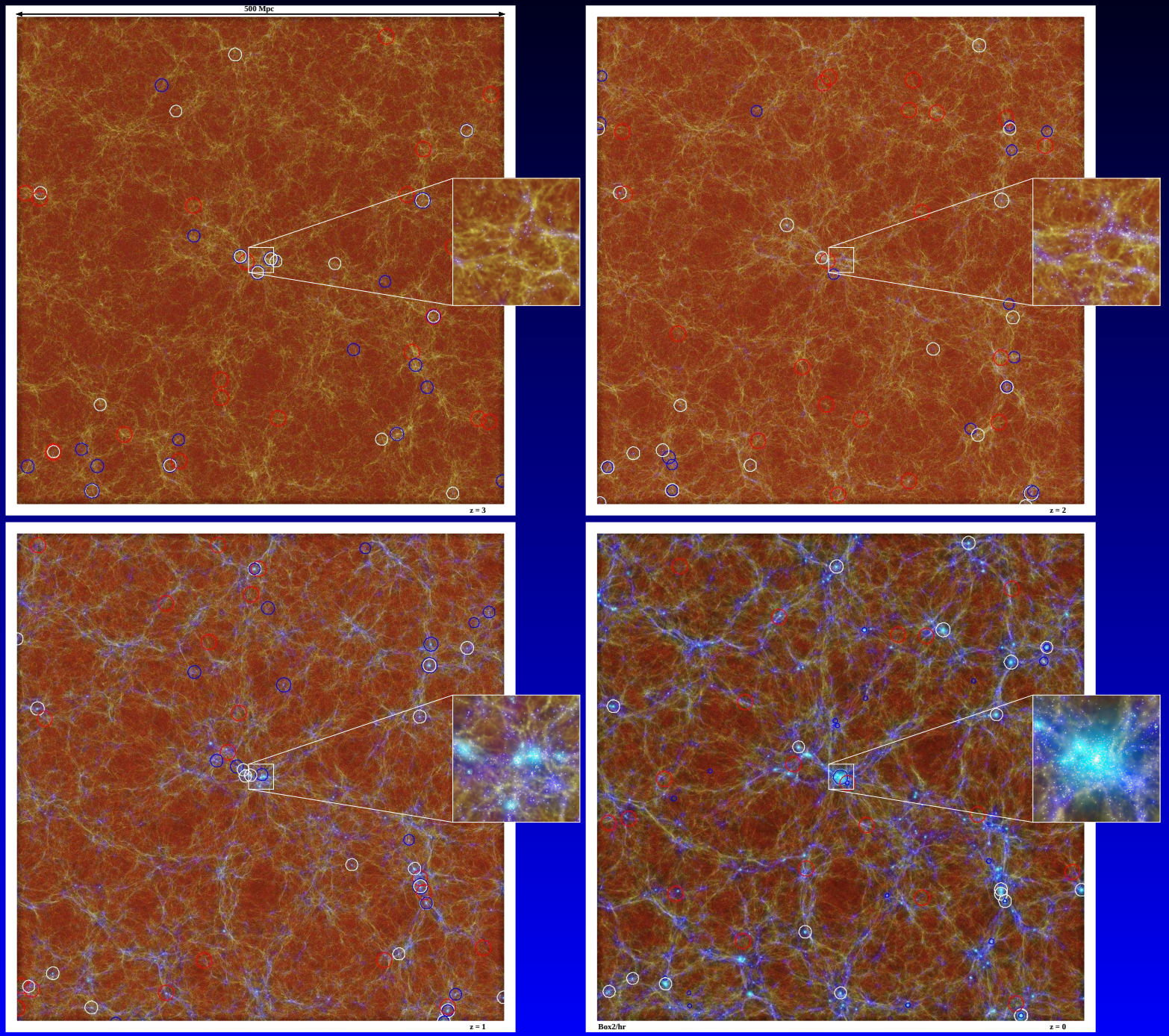

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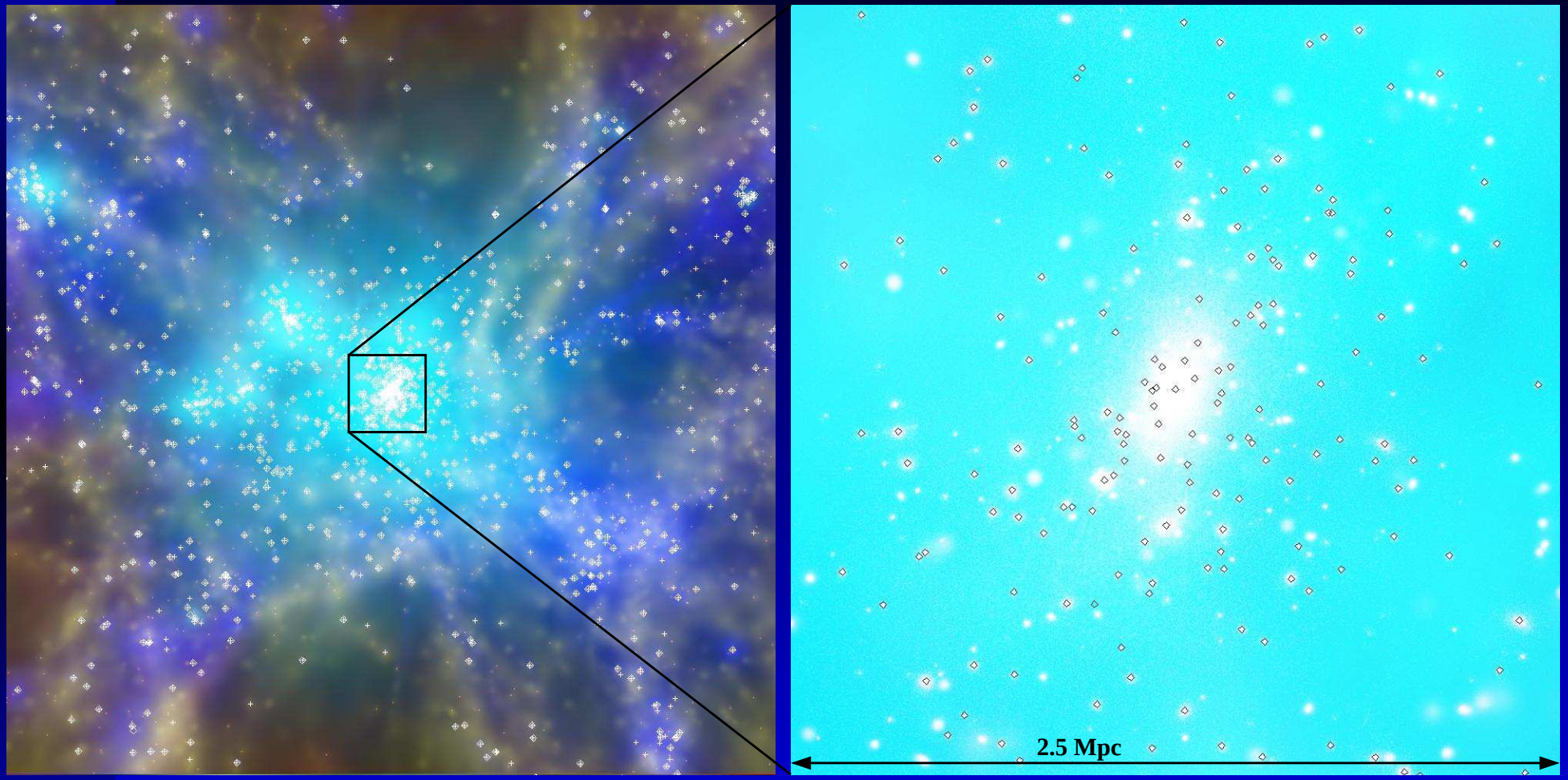
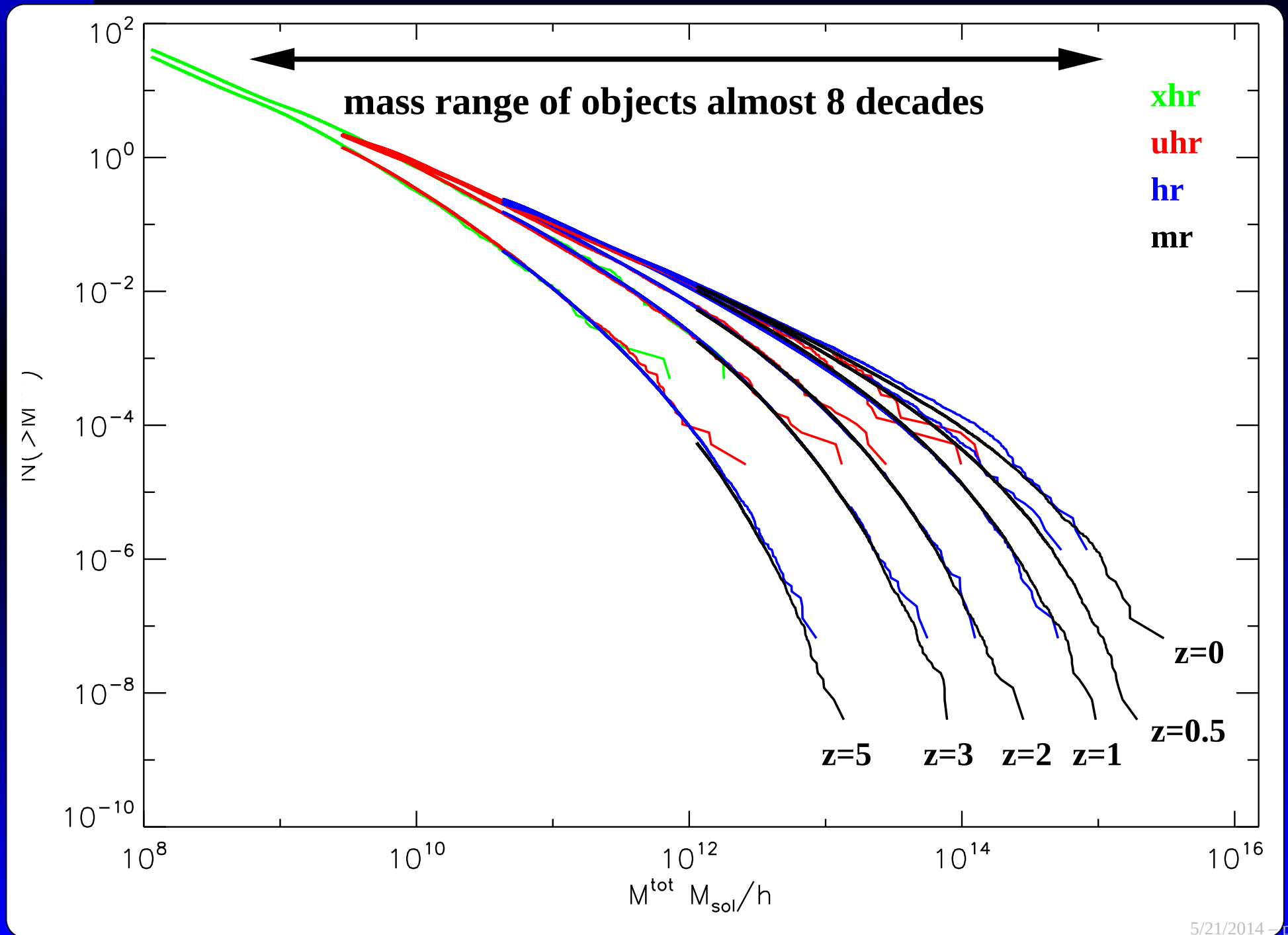


Zoom onto most massive cluster in Box2/hr. Transformation of galaxies inside the denser environment.

What we can expect



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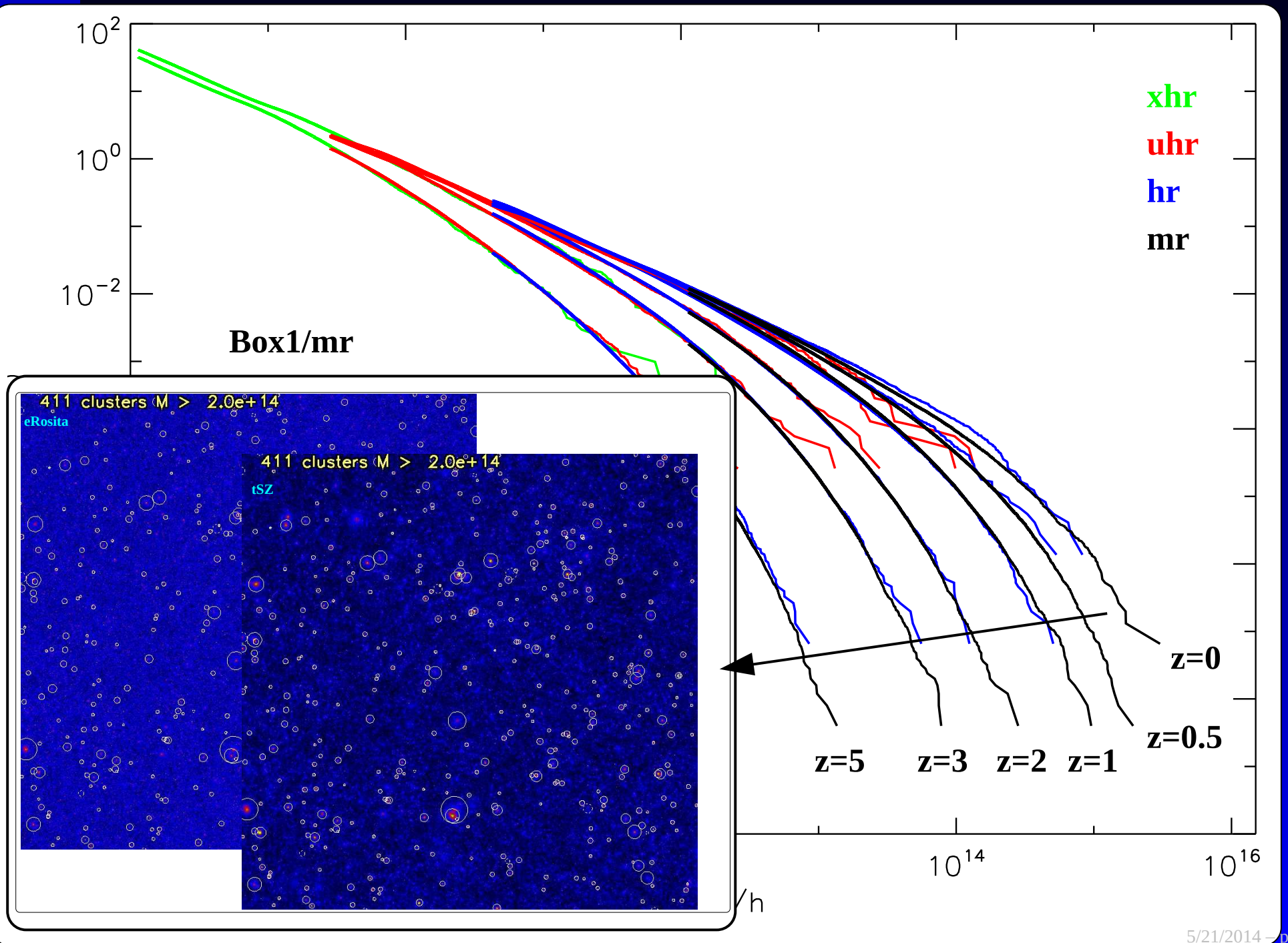
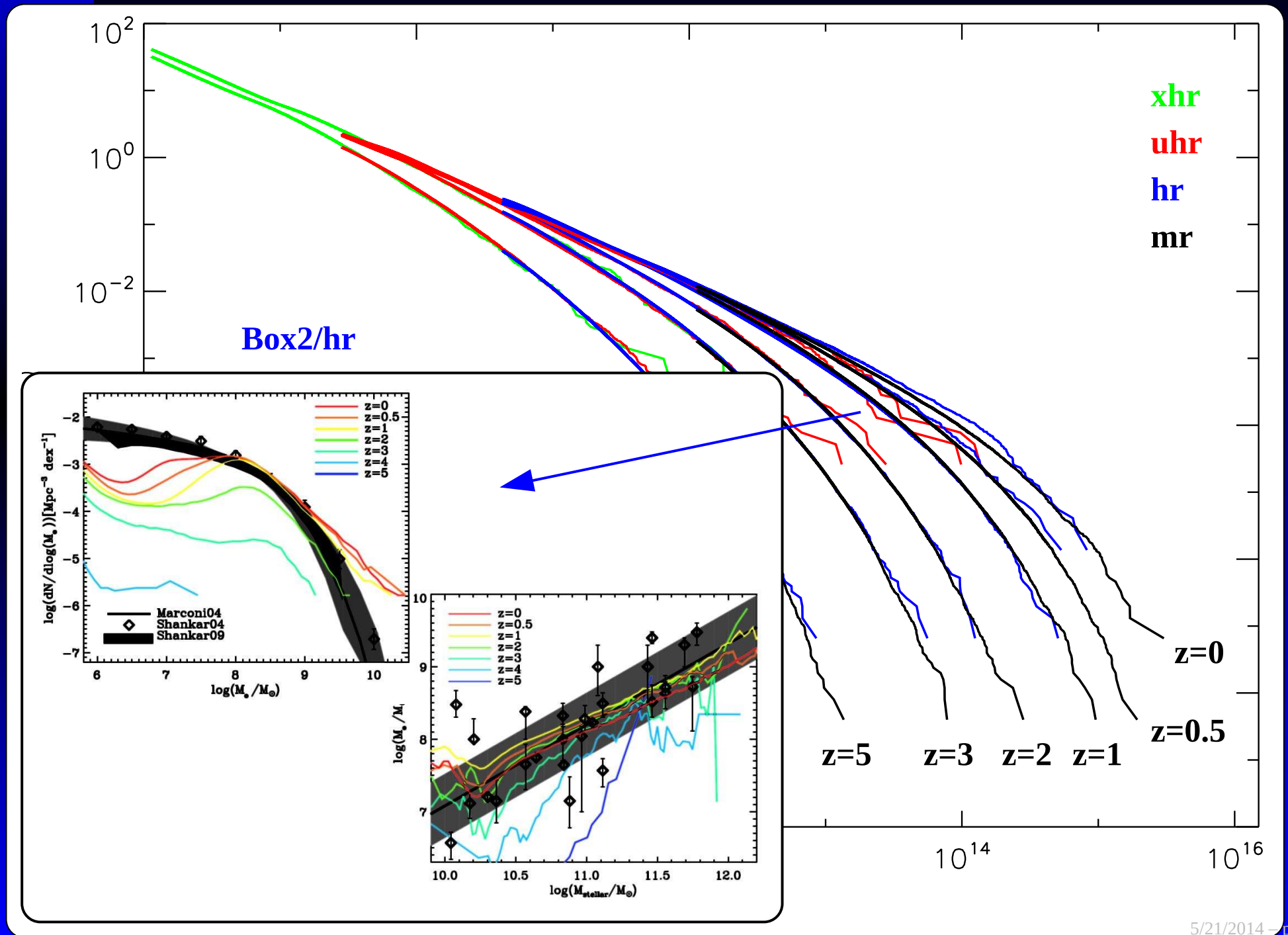


What we can expect



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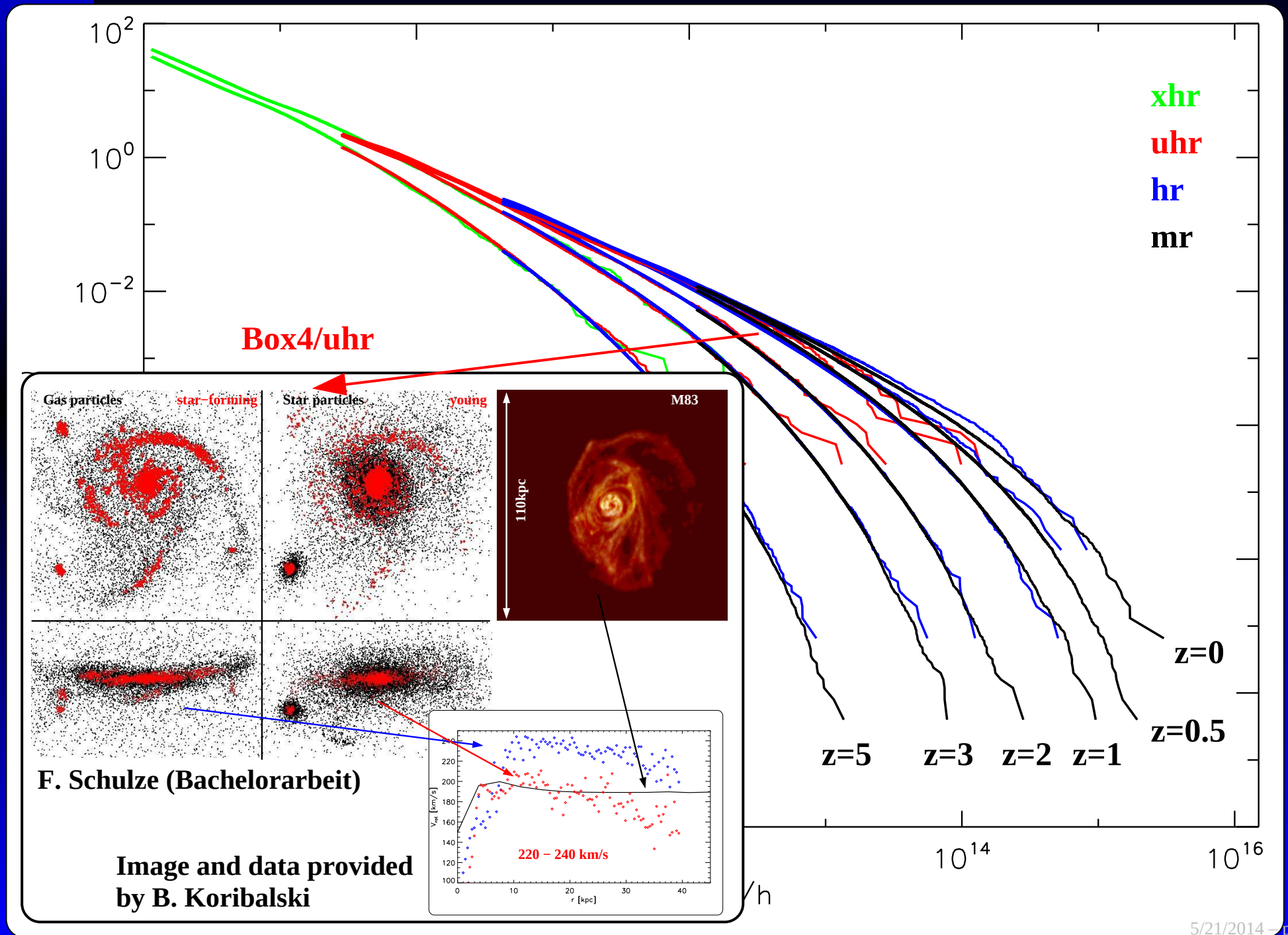

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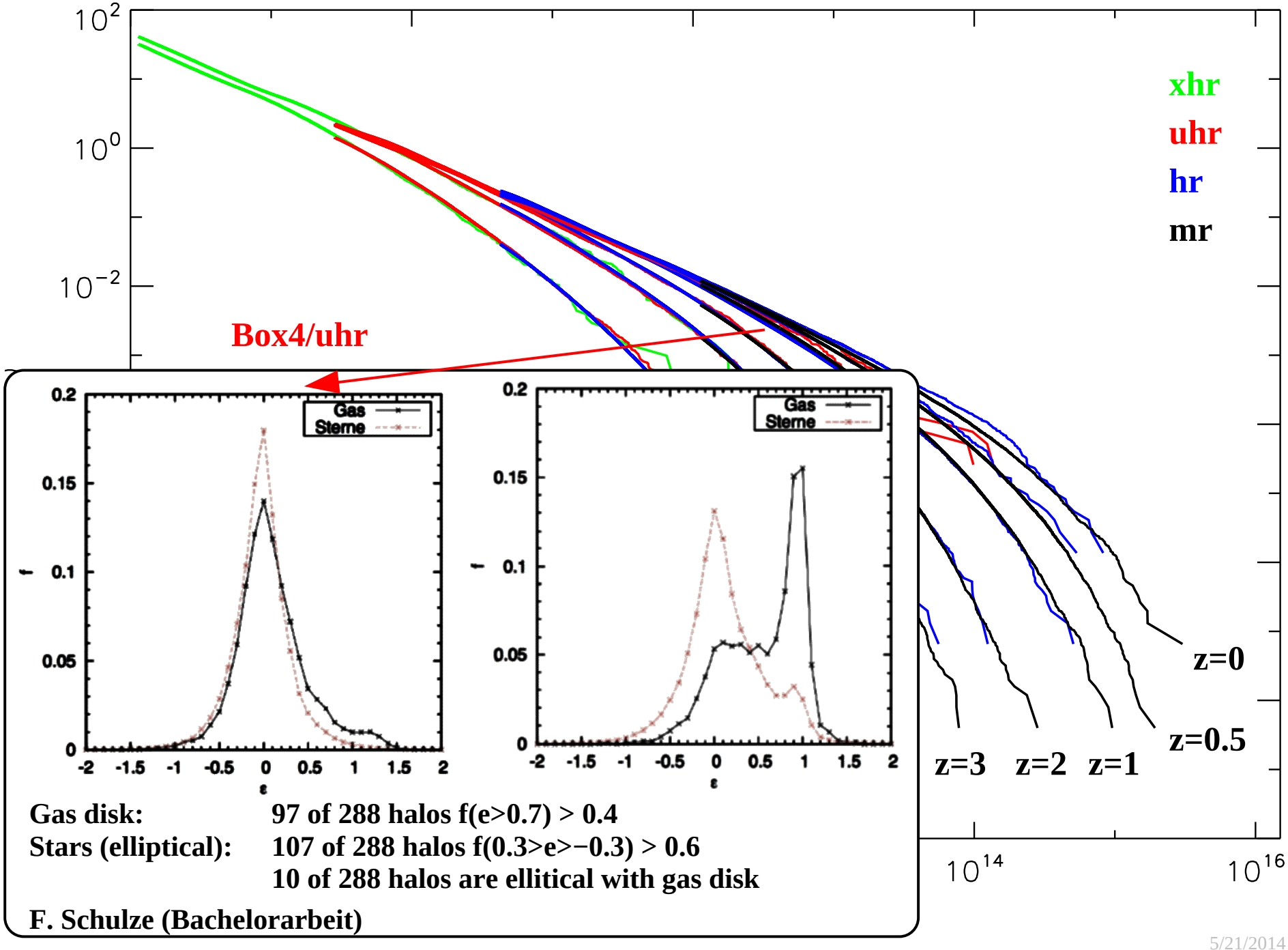


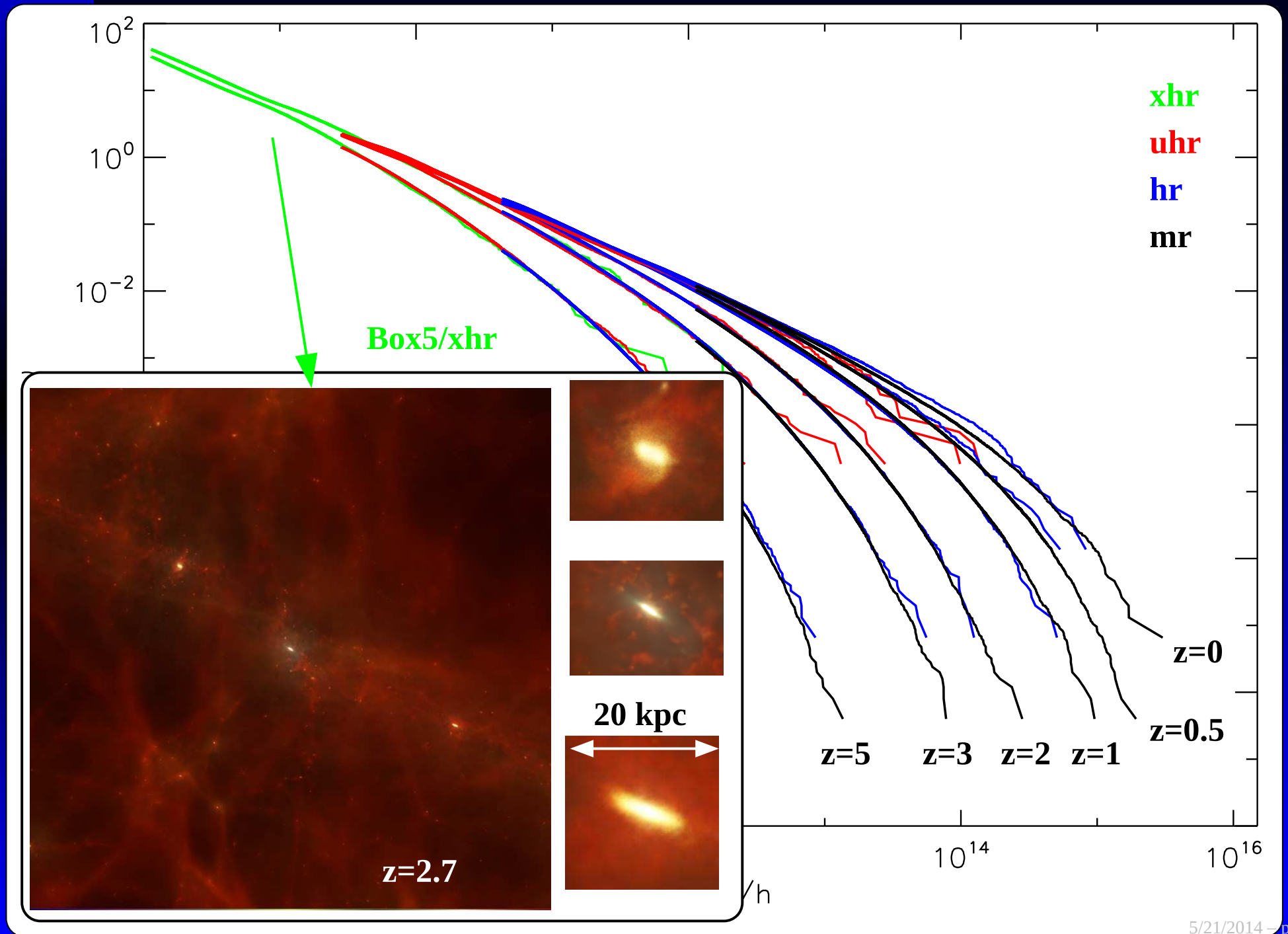
Gas disk: 97 of 288 halos f(e>0.7) > 0.4

Stars (elliptical): 107 of 288 halos f(0.3>e>−0.3) > 0.6

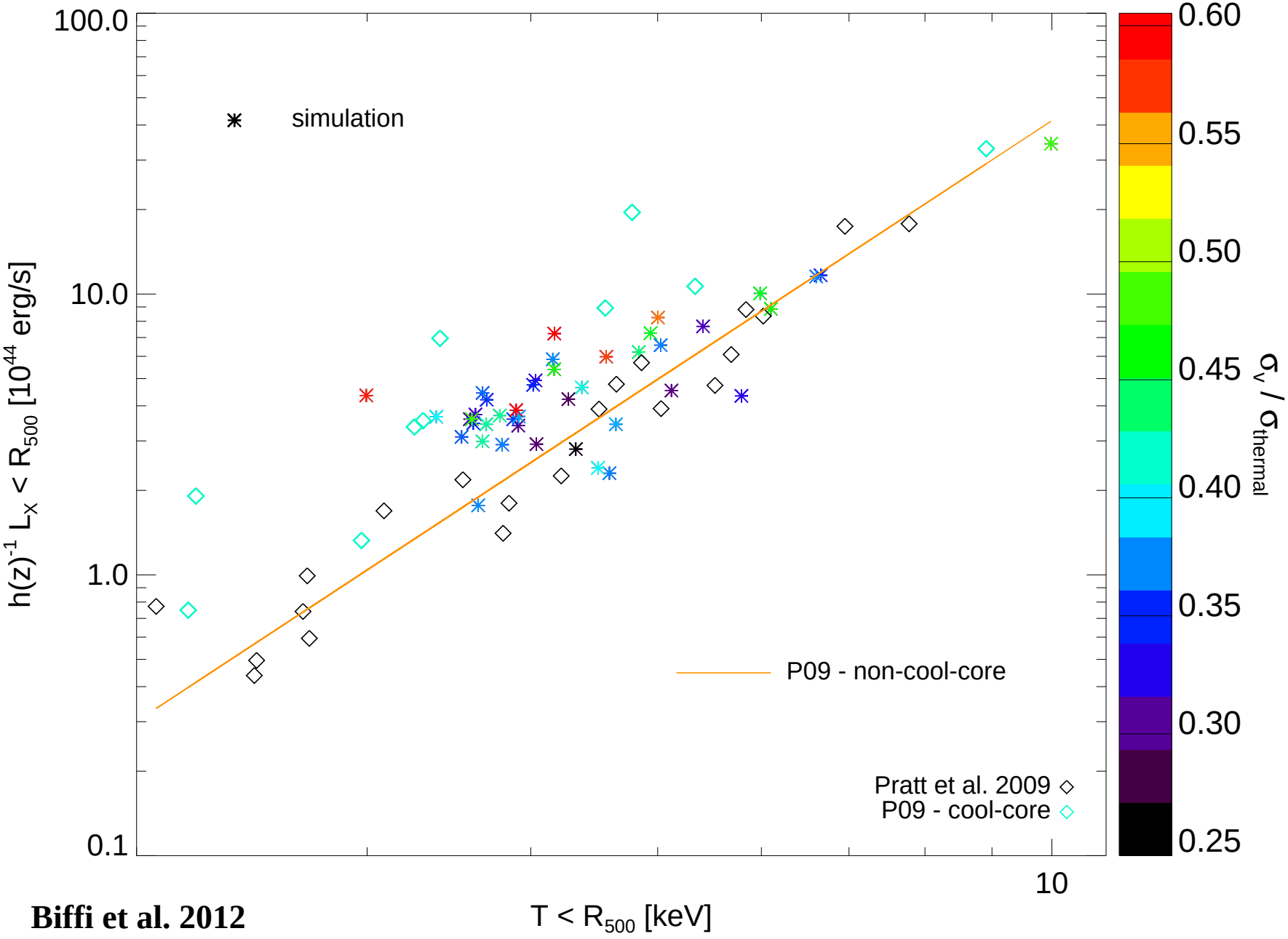
10 of 288 halos are ellitical with gas disk

F. Schulze (Bachelorarbeit)

What we can expect

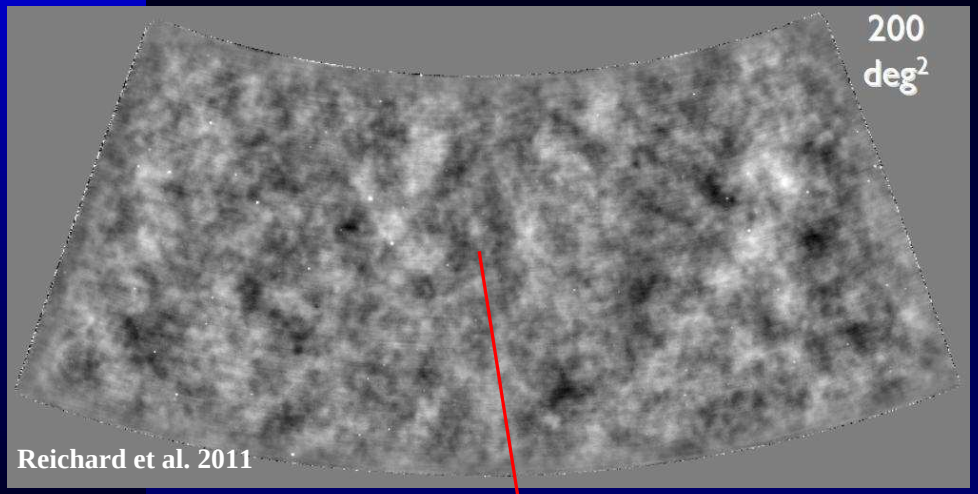


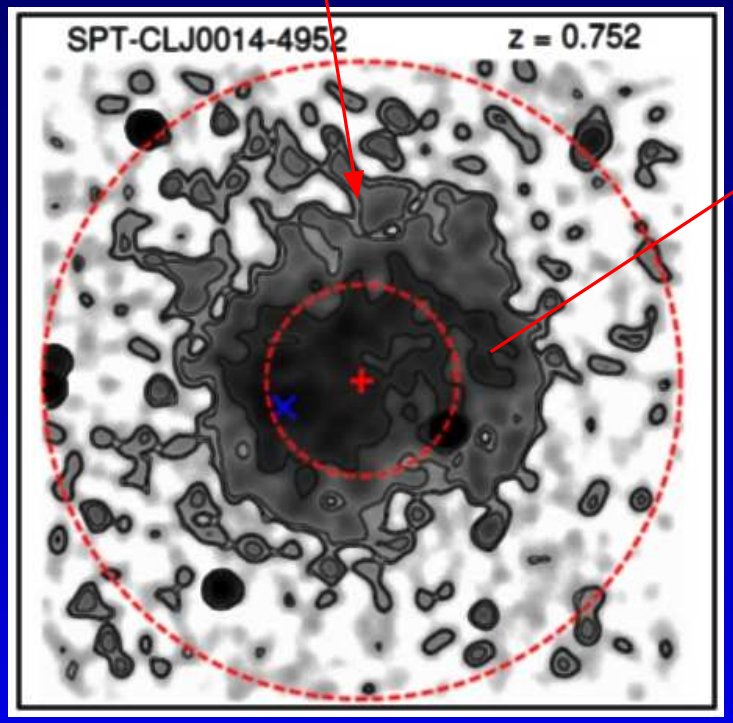
ICM Properties

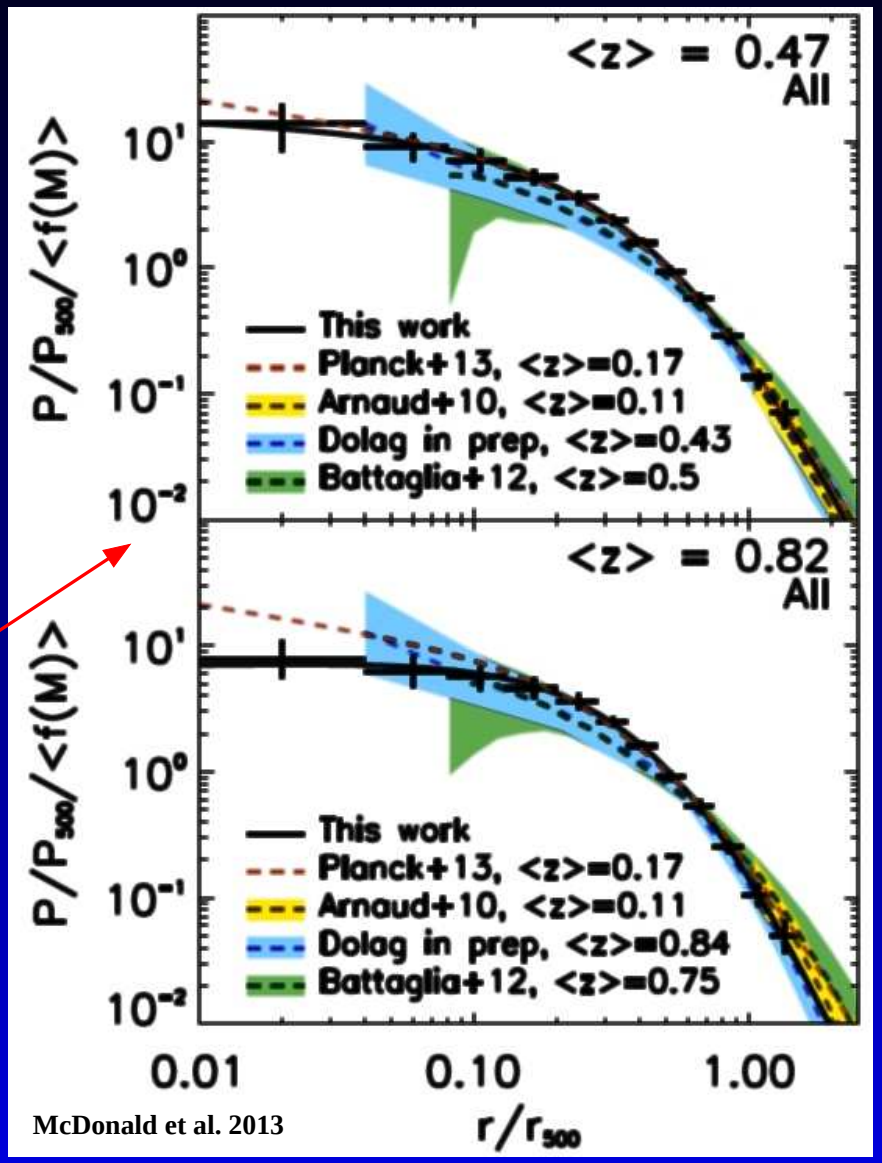


Biffi et al. 2012

ICM Properties

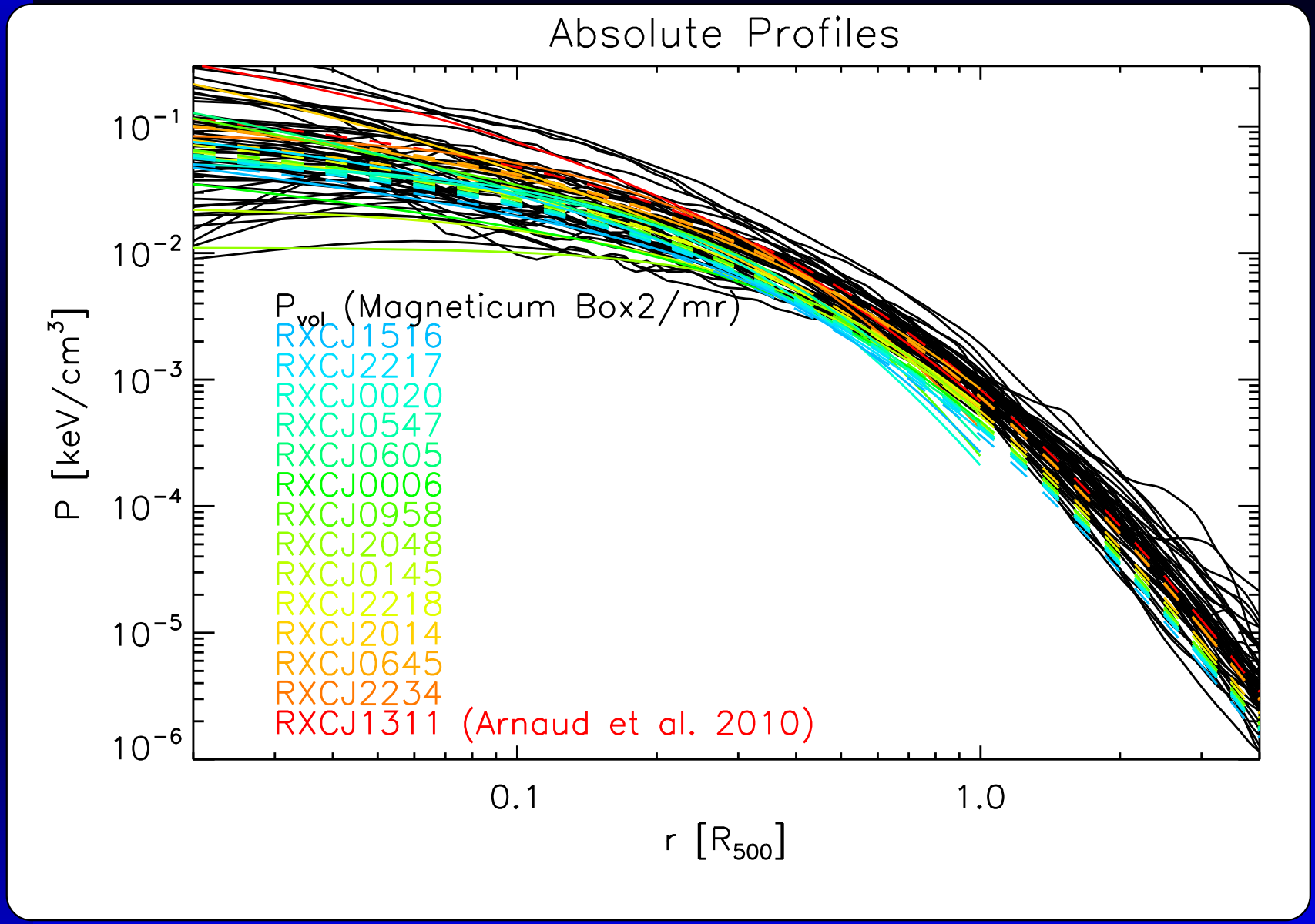






Mean ICM pressure profieles from CMB foreground (SPT).

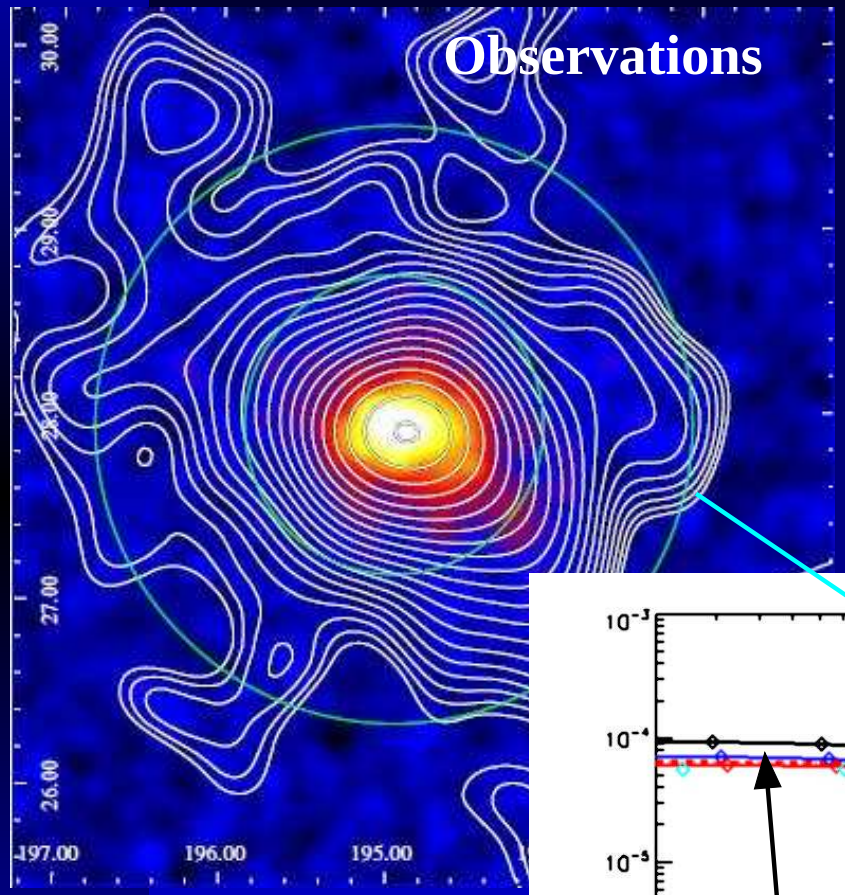
ICM Properties



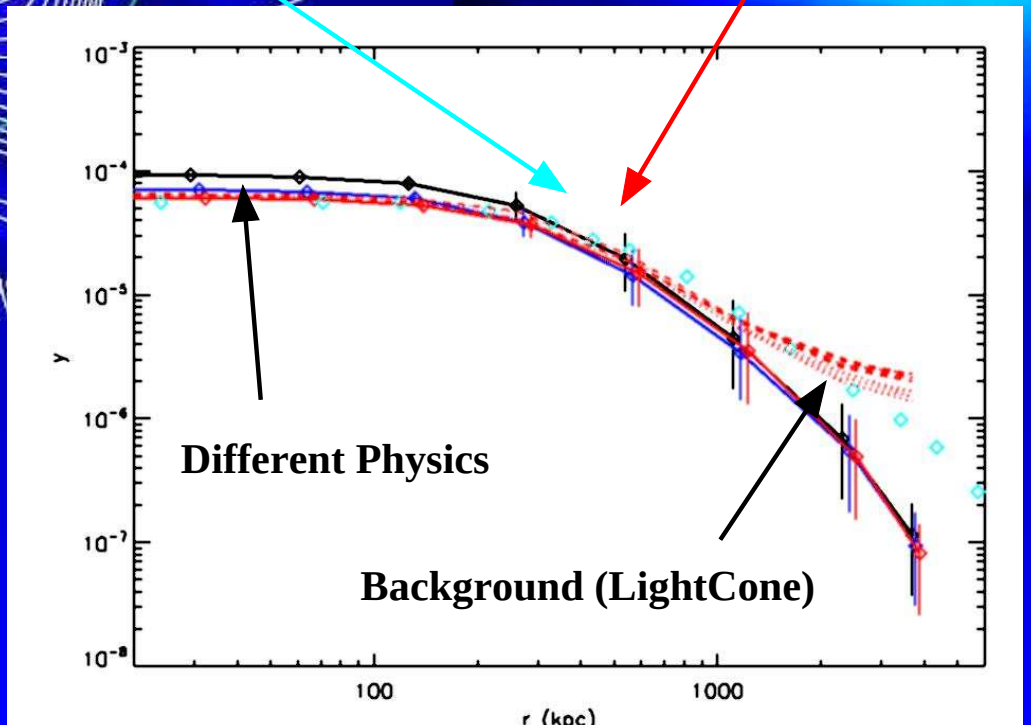
Comparison of simulated ICM pressure profiles with x-ray observations (matching shape and scatter !).

ICM Properties

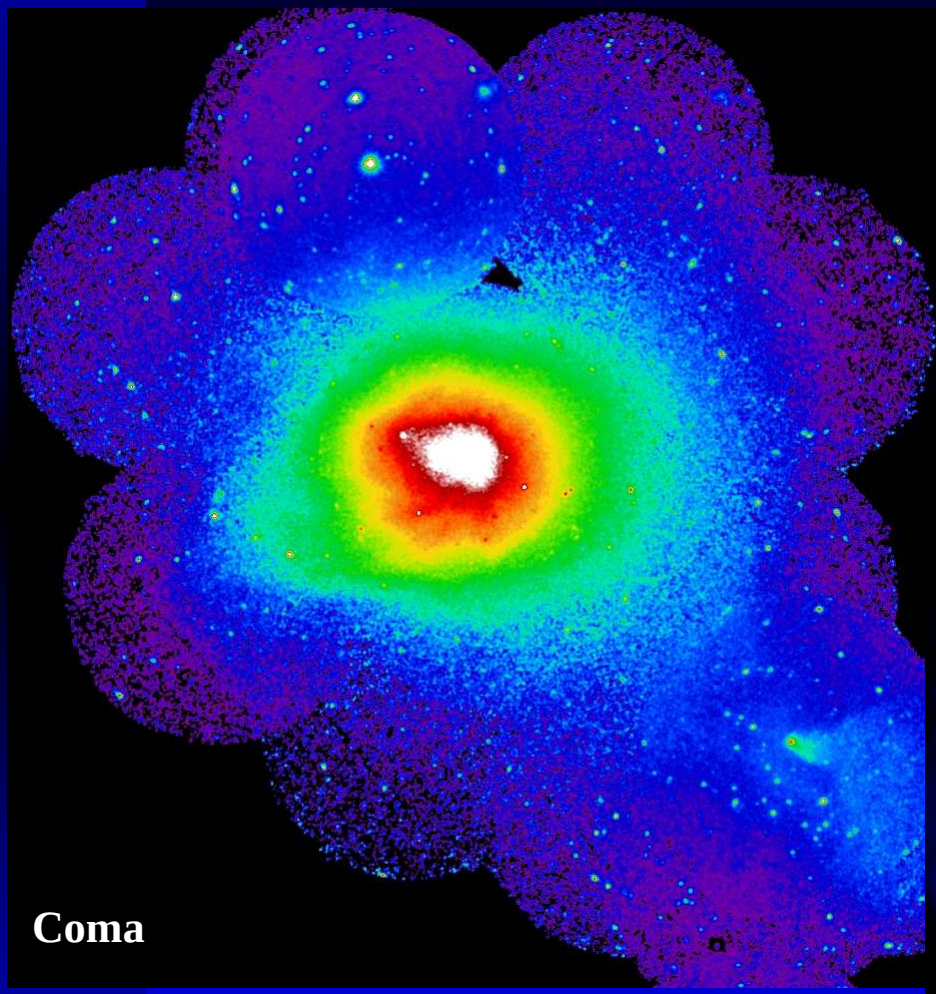
Simulations

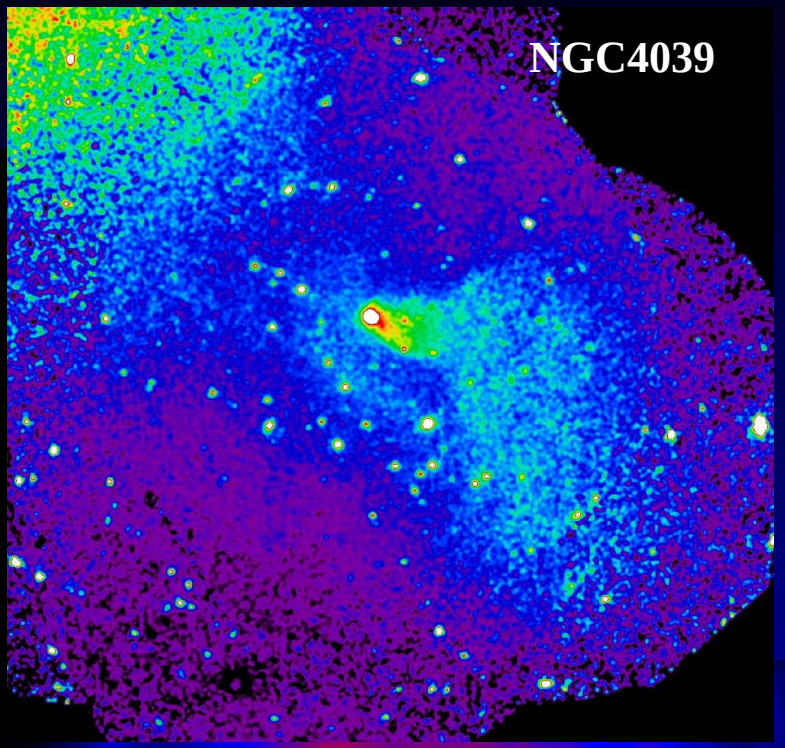


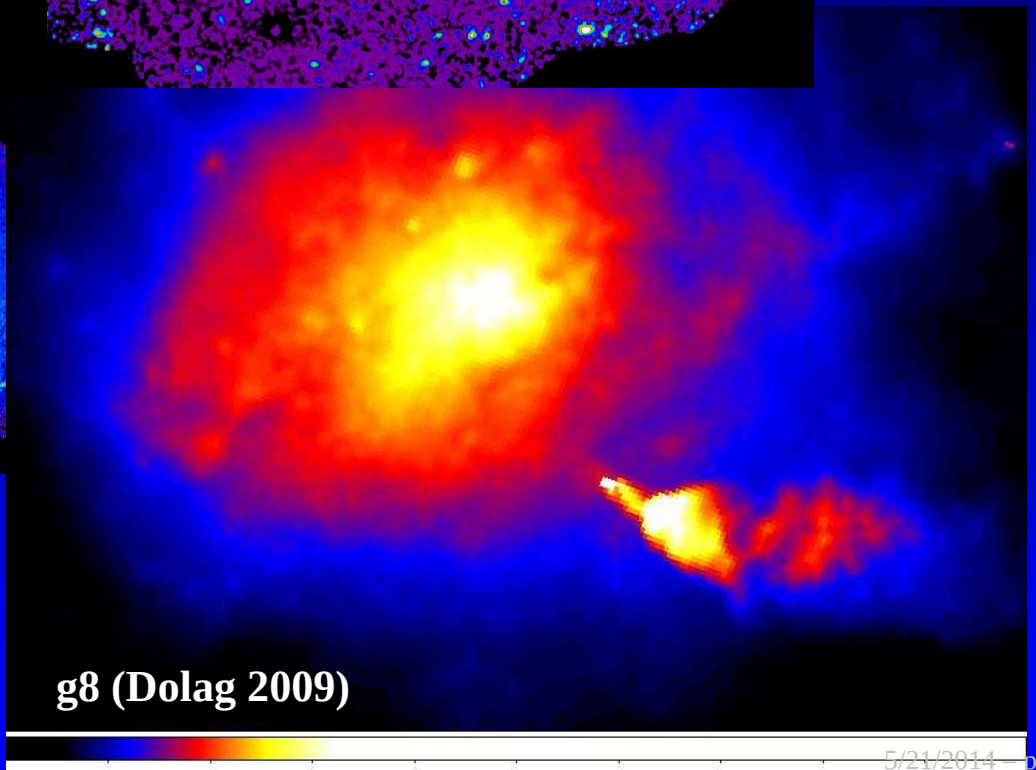
PLANCK 2013



ICM Properties

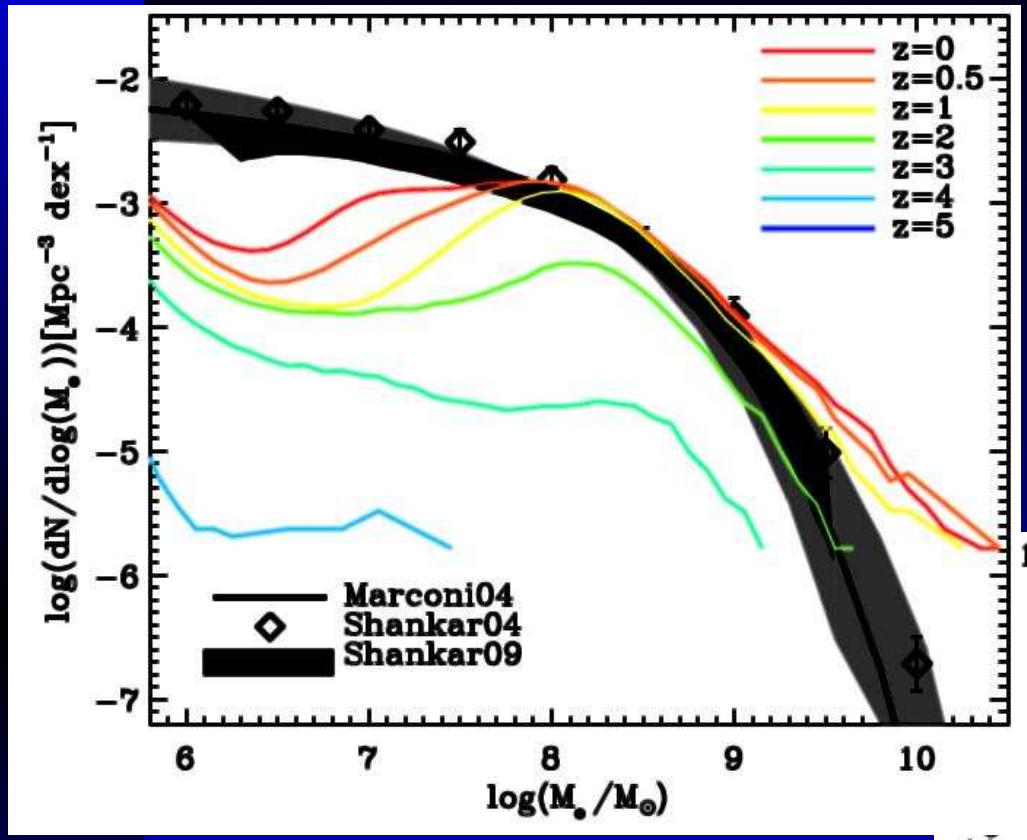




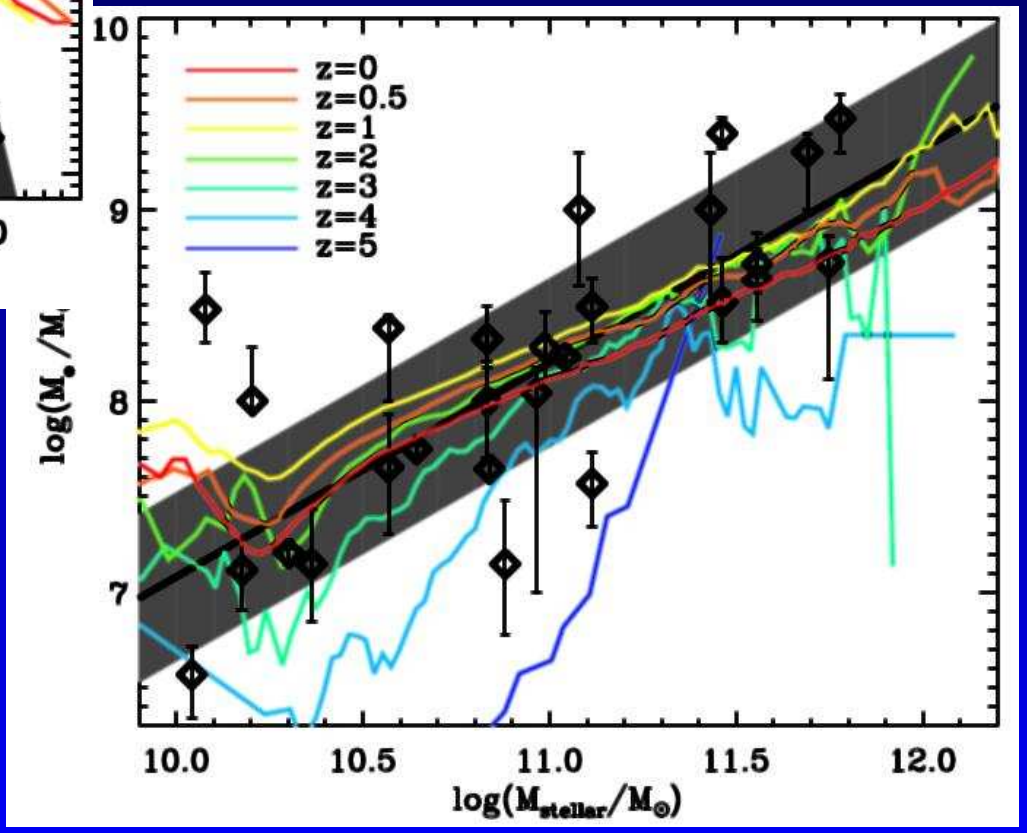


Provided by N. Lyskova & E. Churazov

AGN feedback model



Hirschnmann et al. 2013



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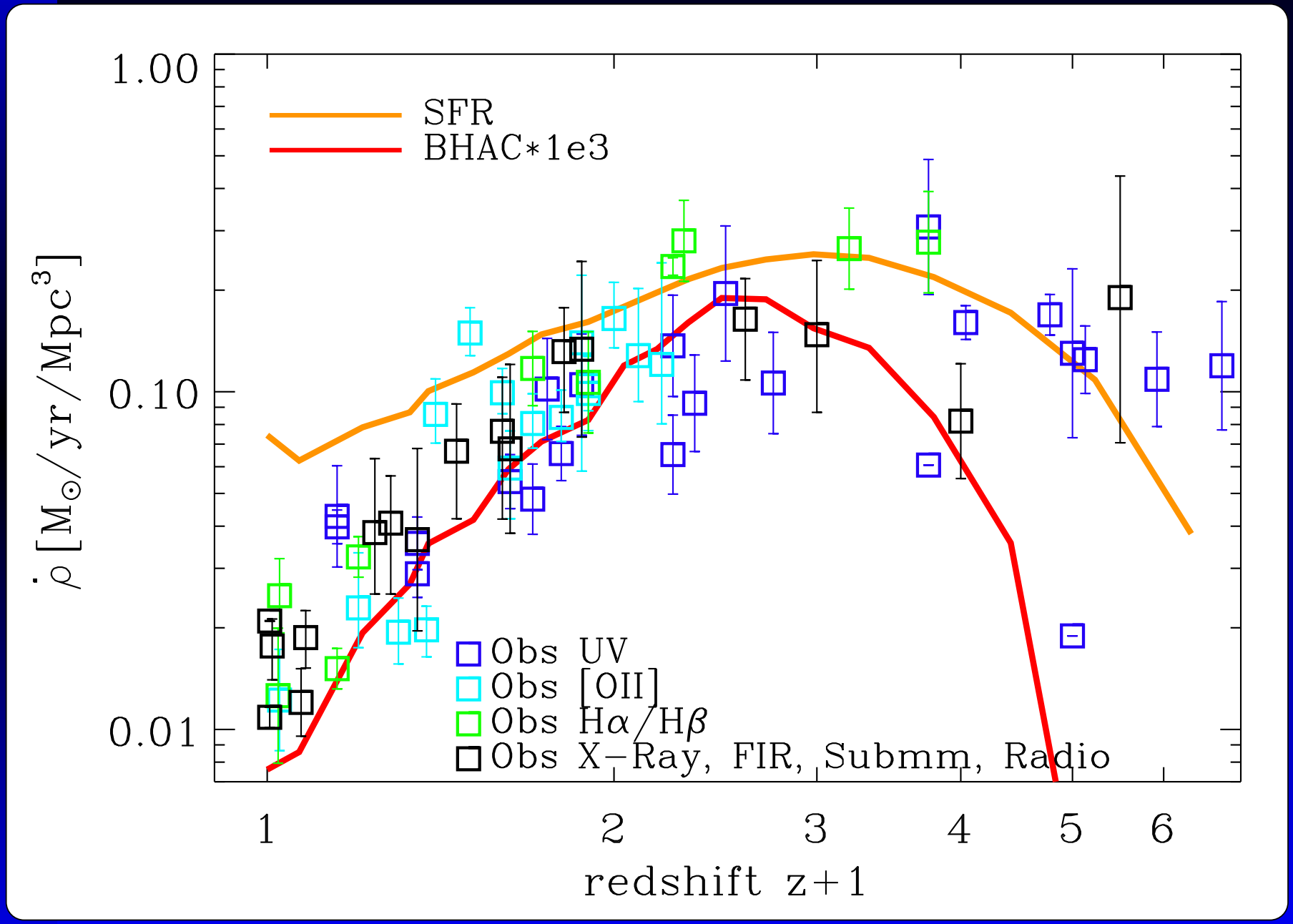
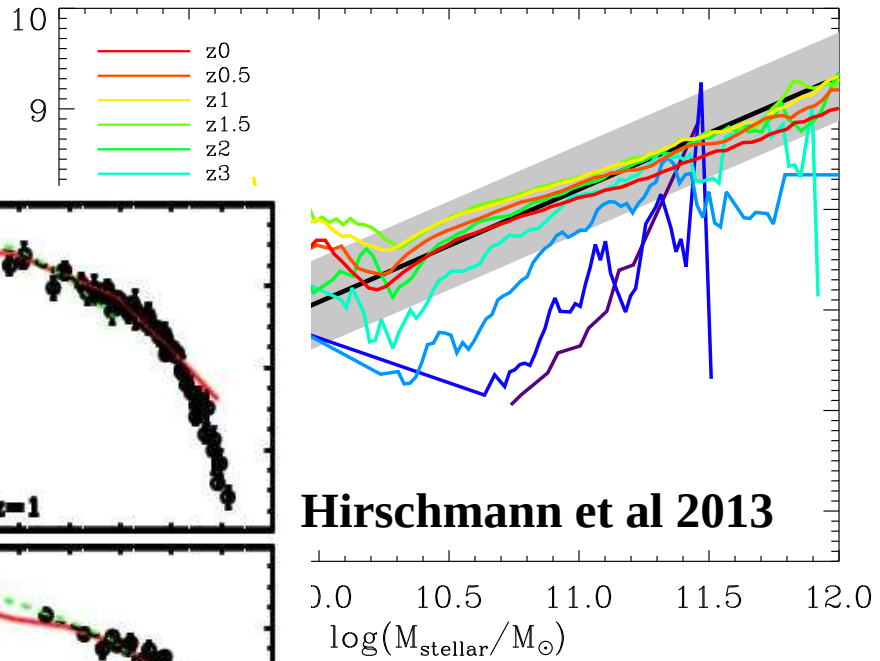


BH growth linked to star-formation

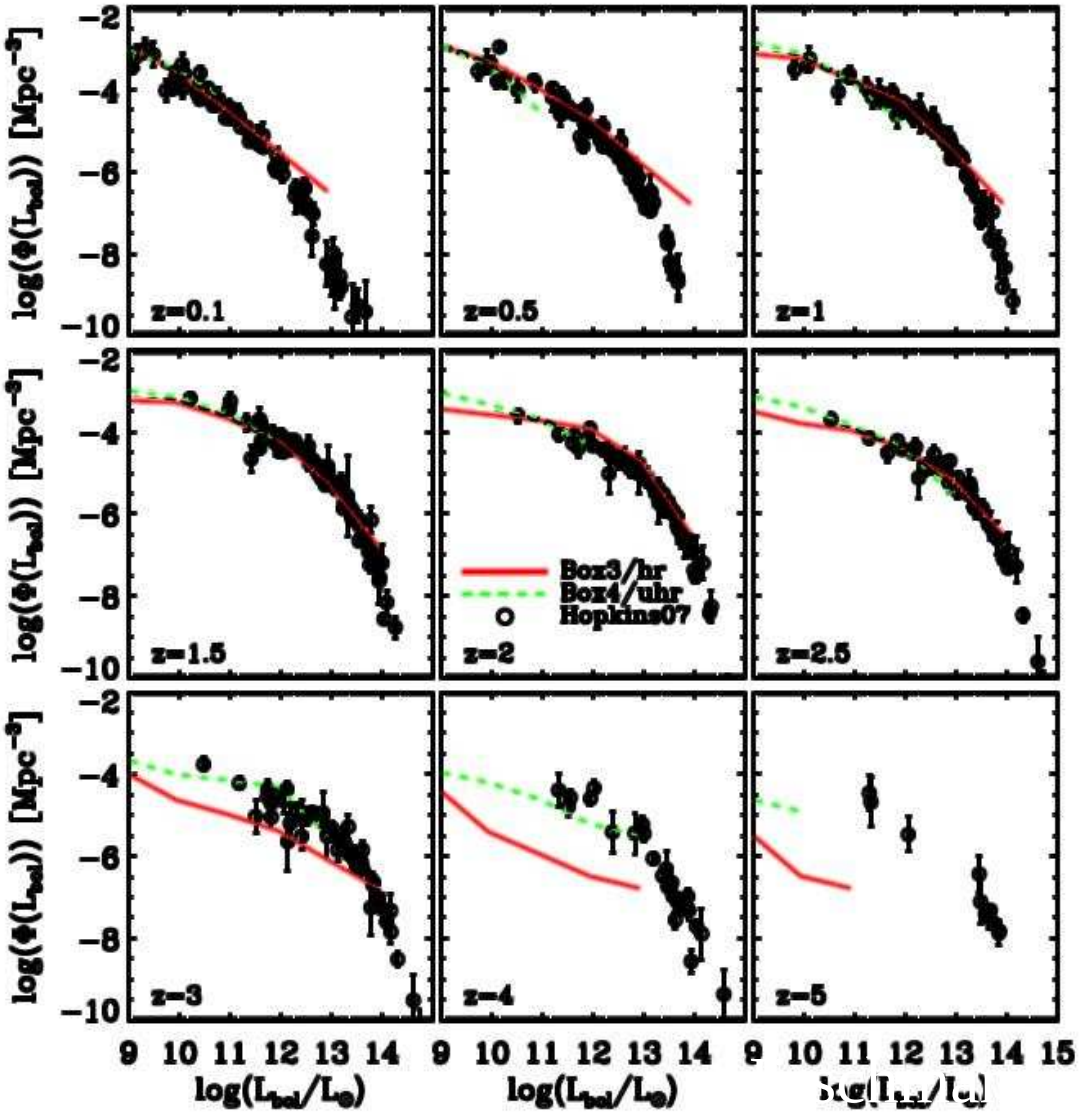
AGN feedback model

BH Mass −− Stellar Mass

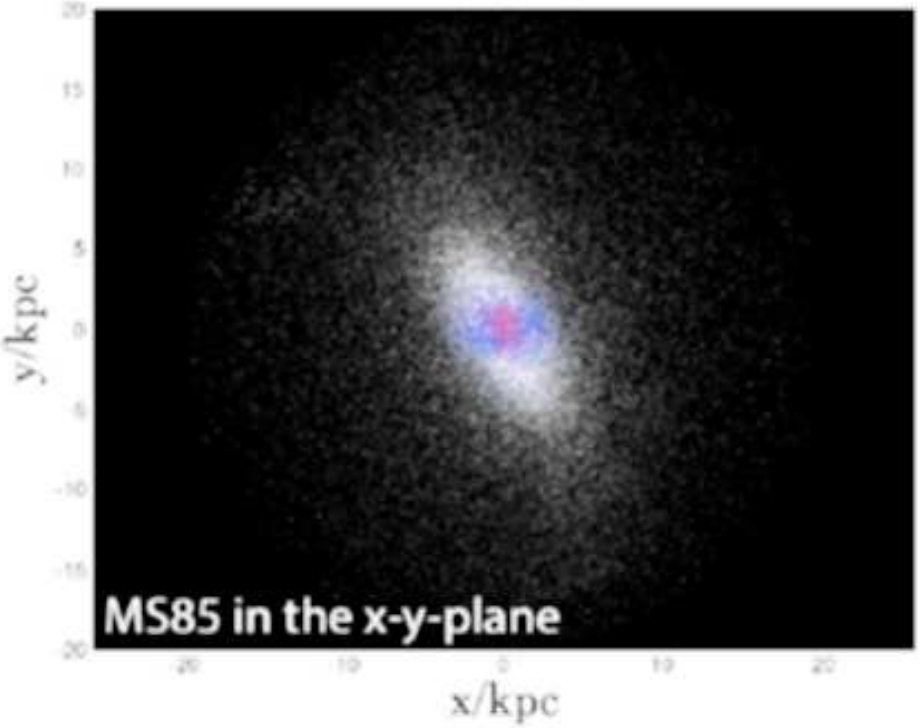


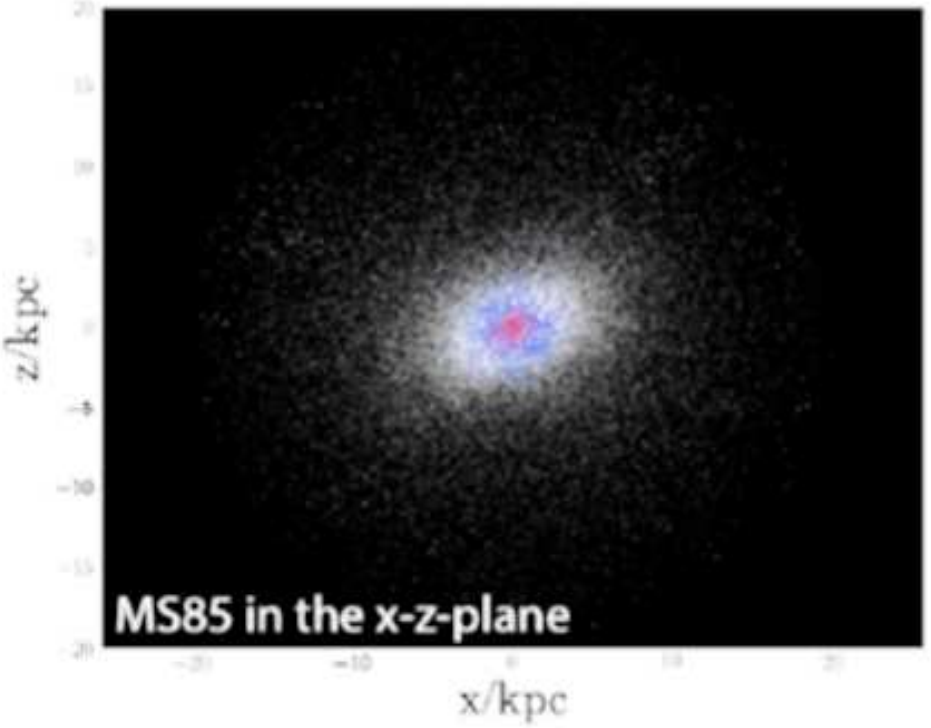
Hirschmann et al 2013

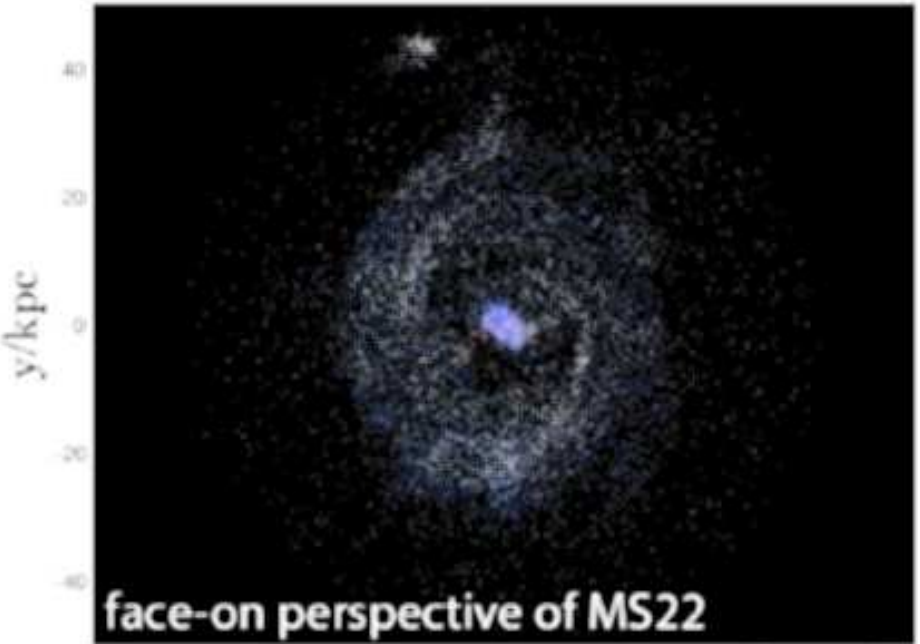
Bolometric LF



Galaxy properties







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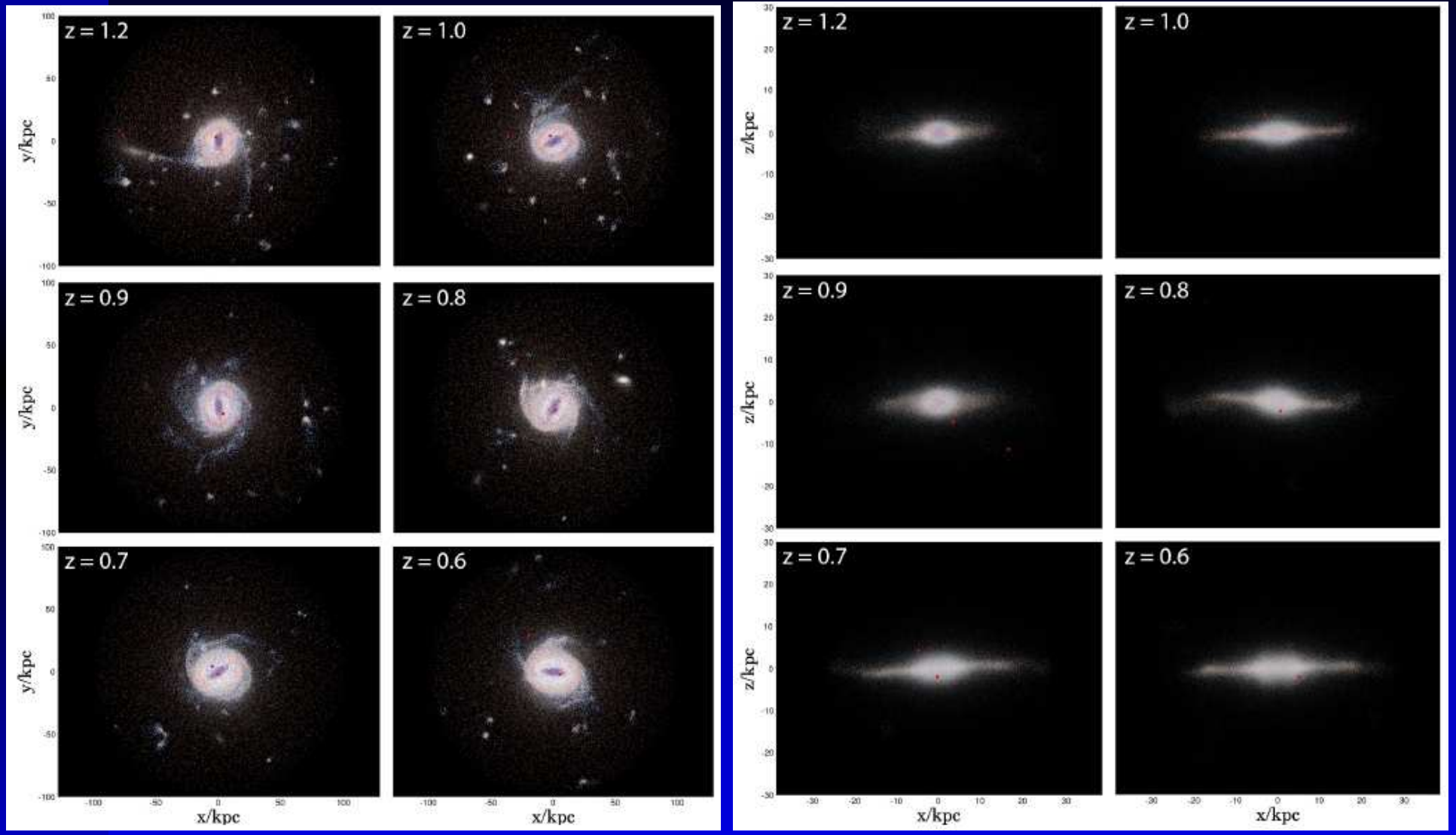
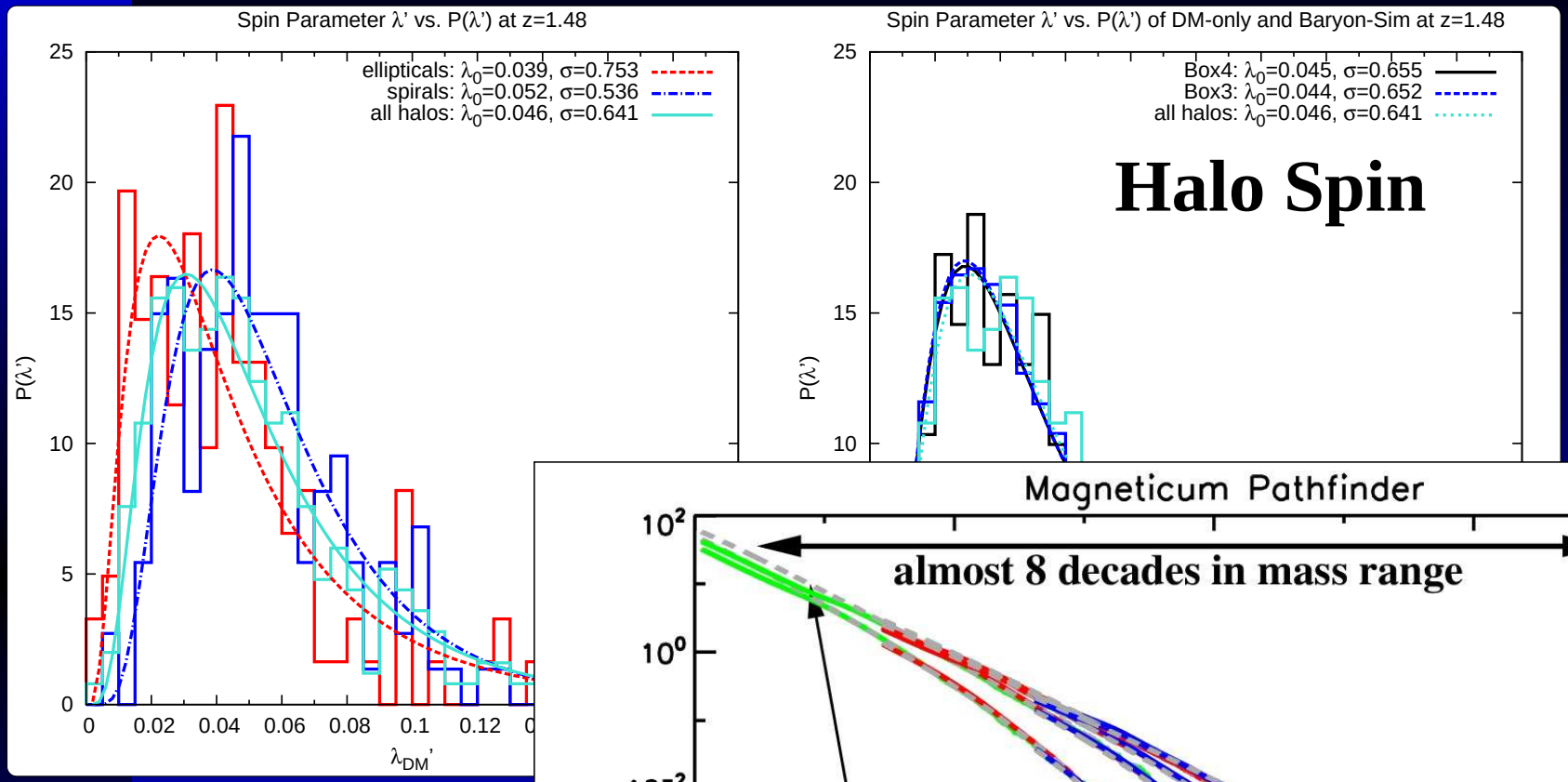


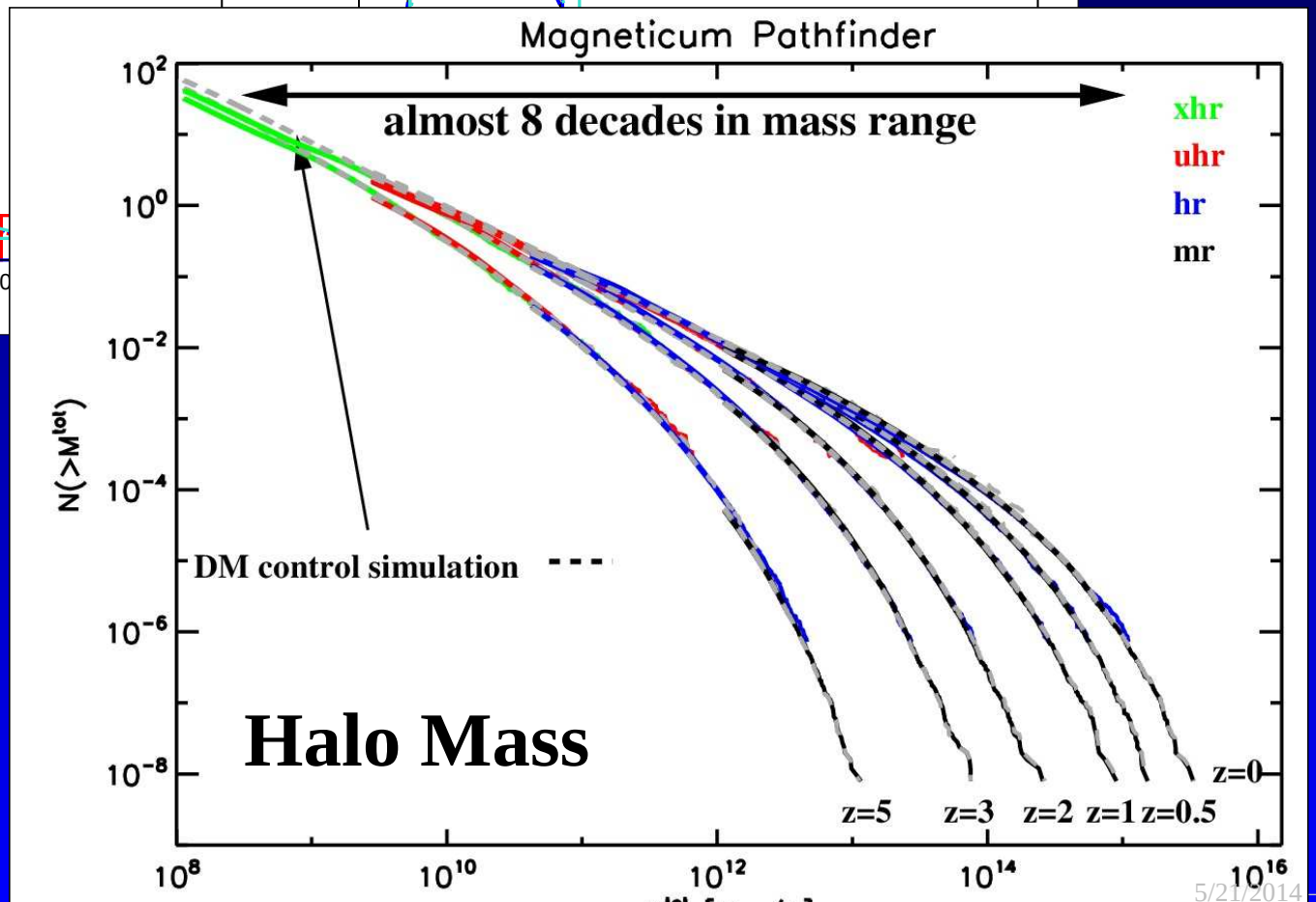
MA Lisa Bachmann

⇒ Implication for halo properties !

Galaxy properties

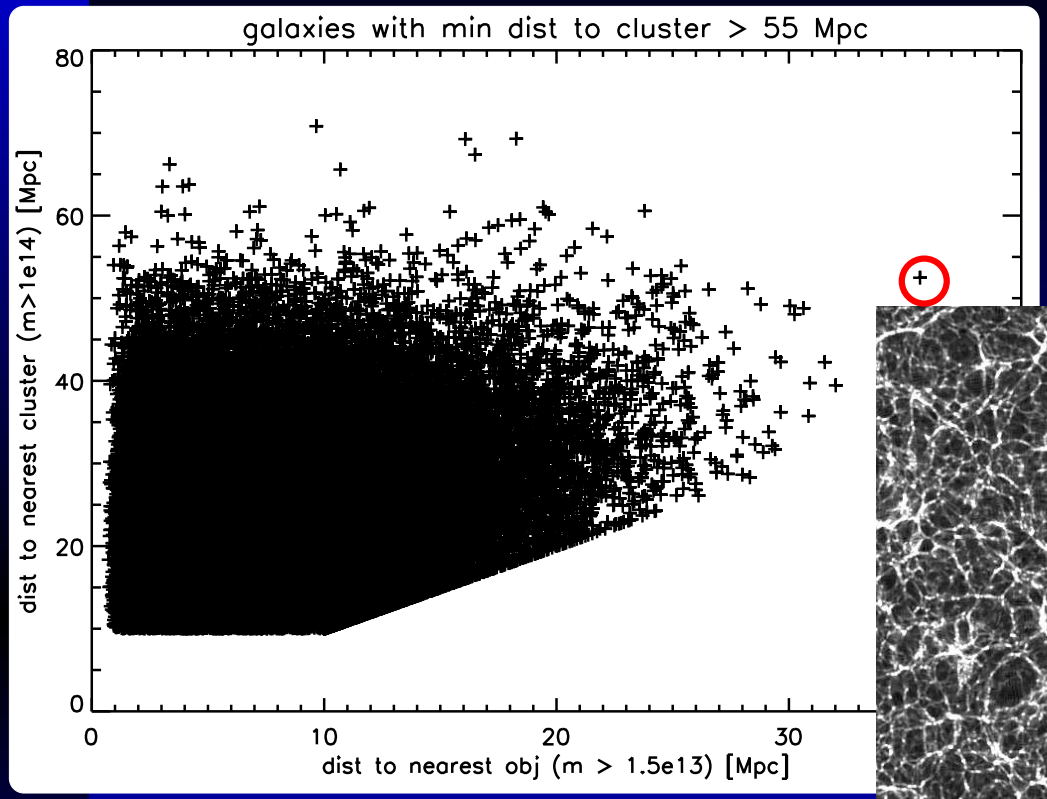


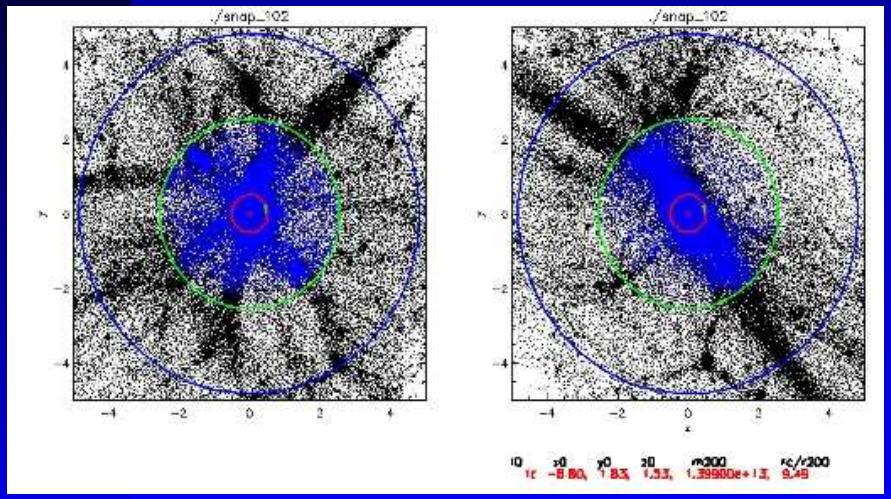
A. Teklu



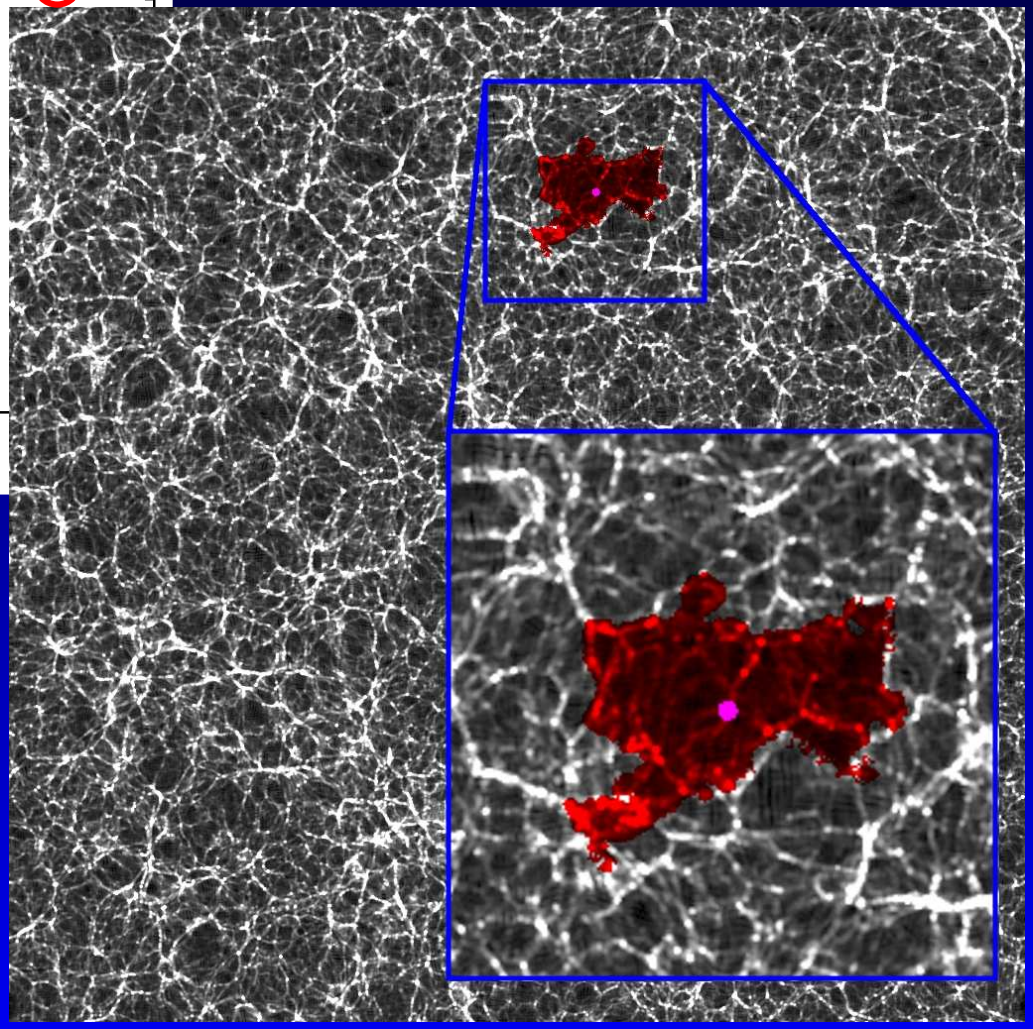
S. Bocquet

Massive galaxies in voids





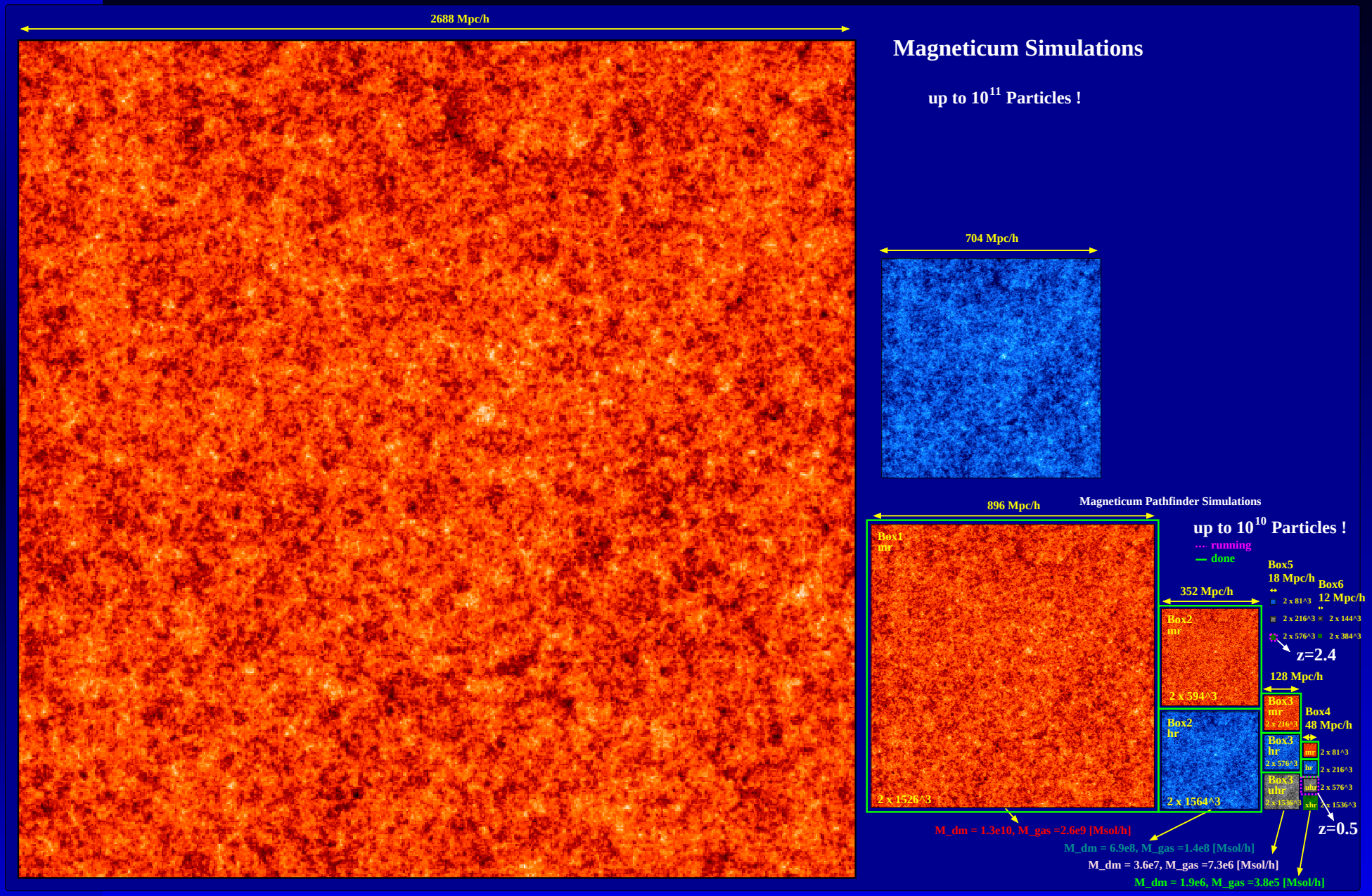
Selecting massive void galaxies



MA David Schachtberger

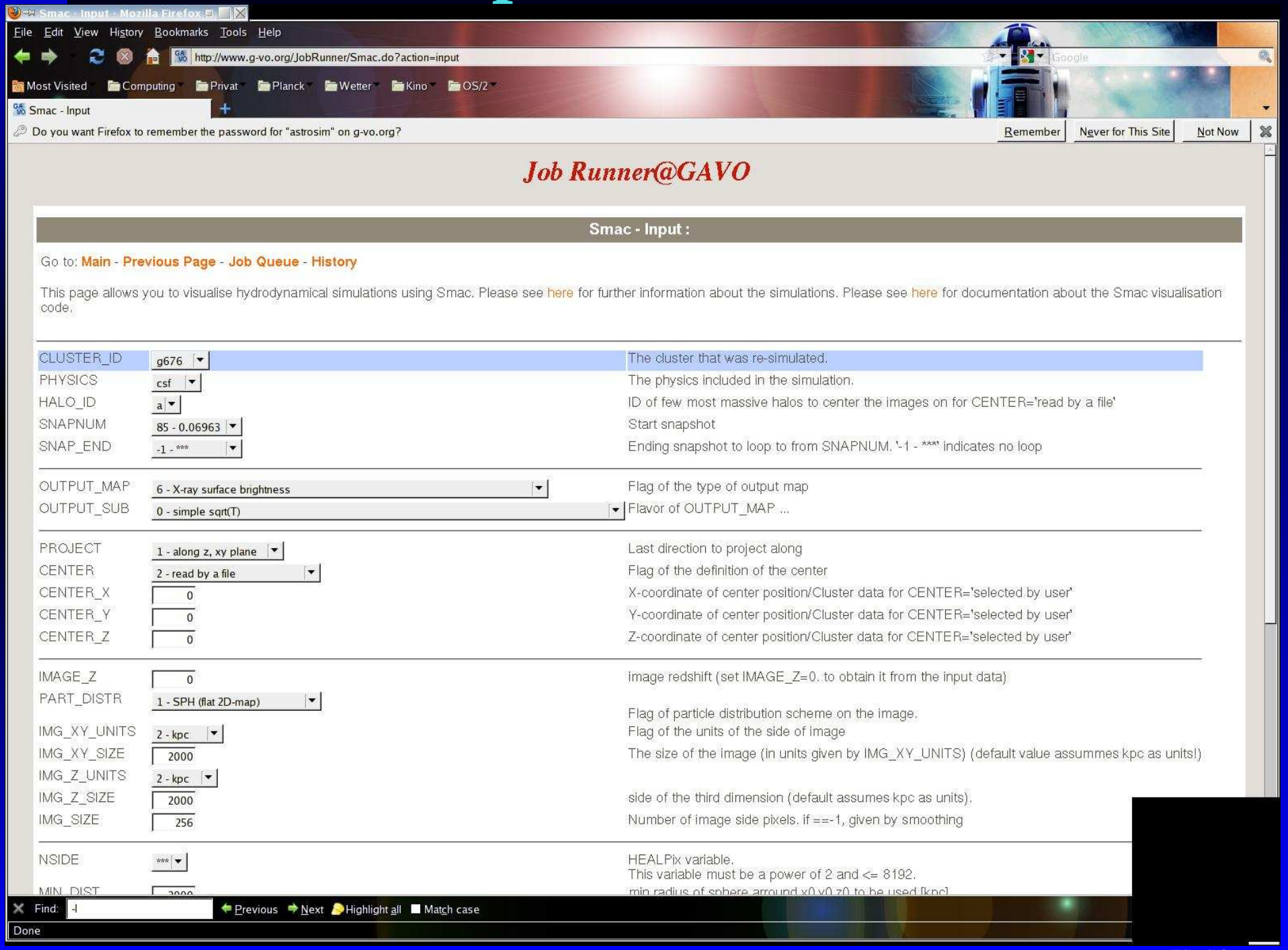
Massive galaxies in voids

Future Prospects

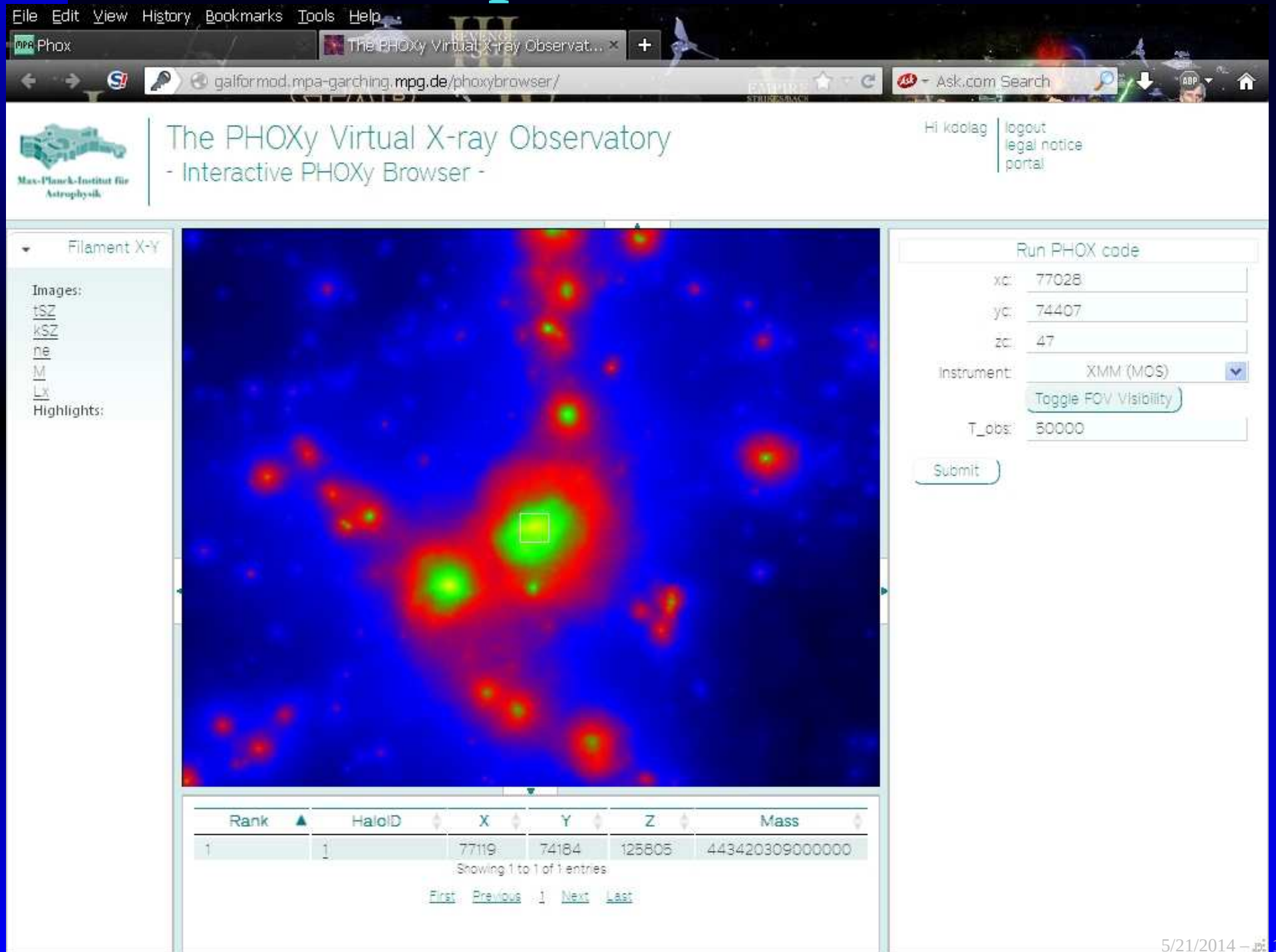


Next generation of Simulations are under way !

Future Prospects



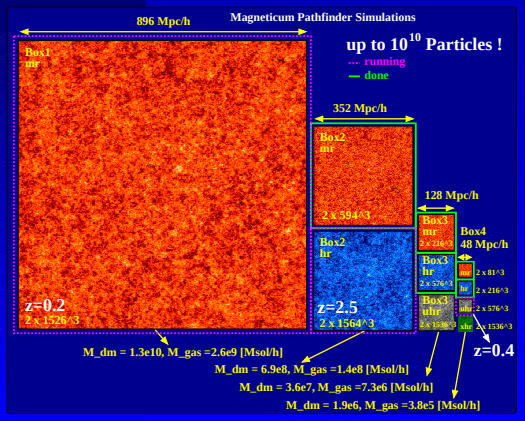
Future Prospects

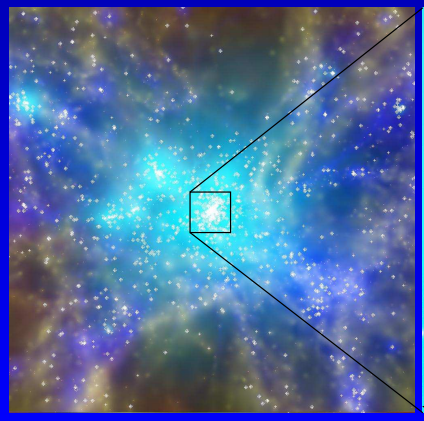


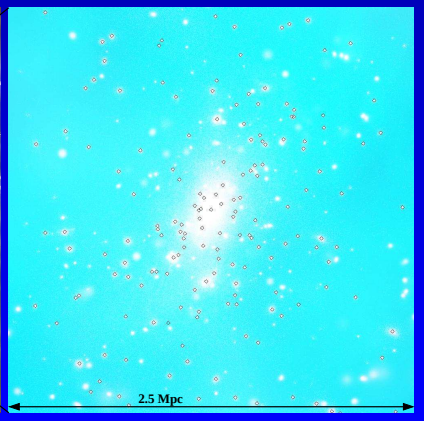
Conclusions

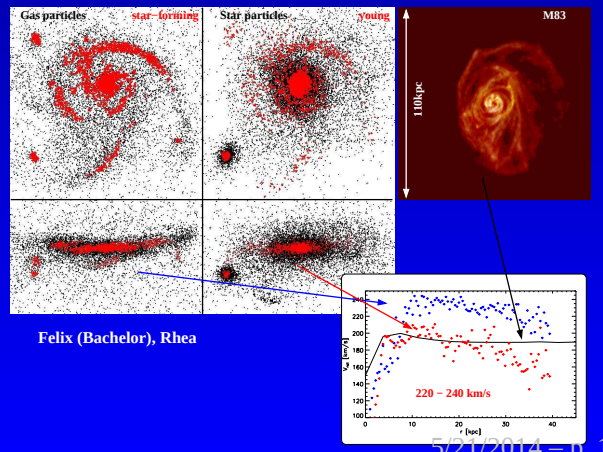
Cosmological, hydrodynamical simulations which at the same time allows predictions for ICM and stellar and AGN component for ongoing/future missions.

- 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

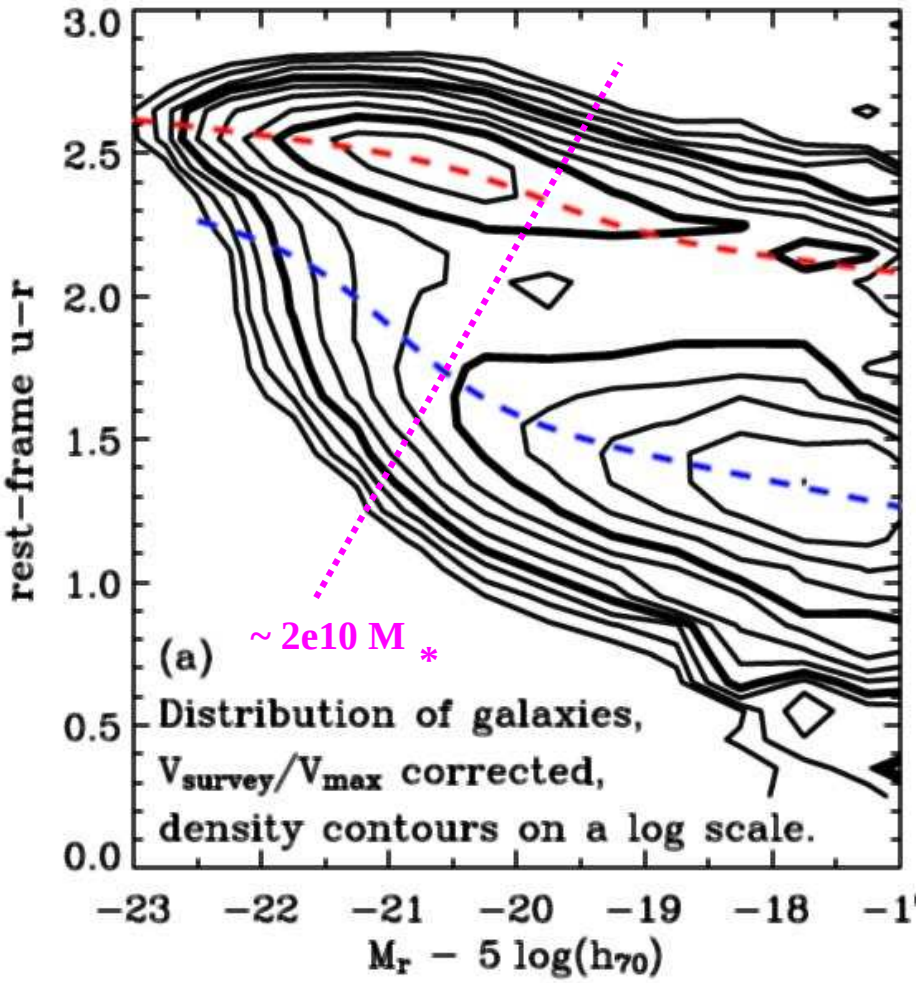




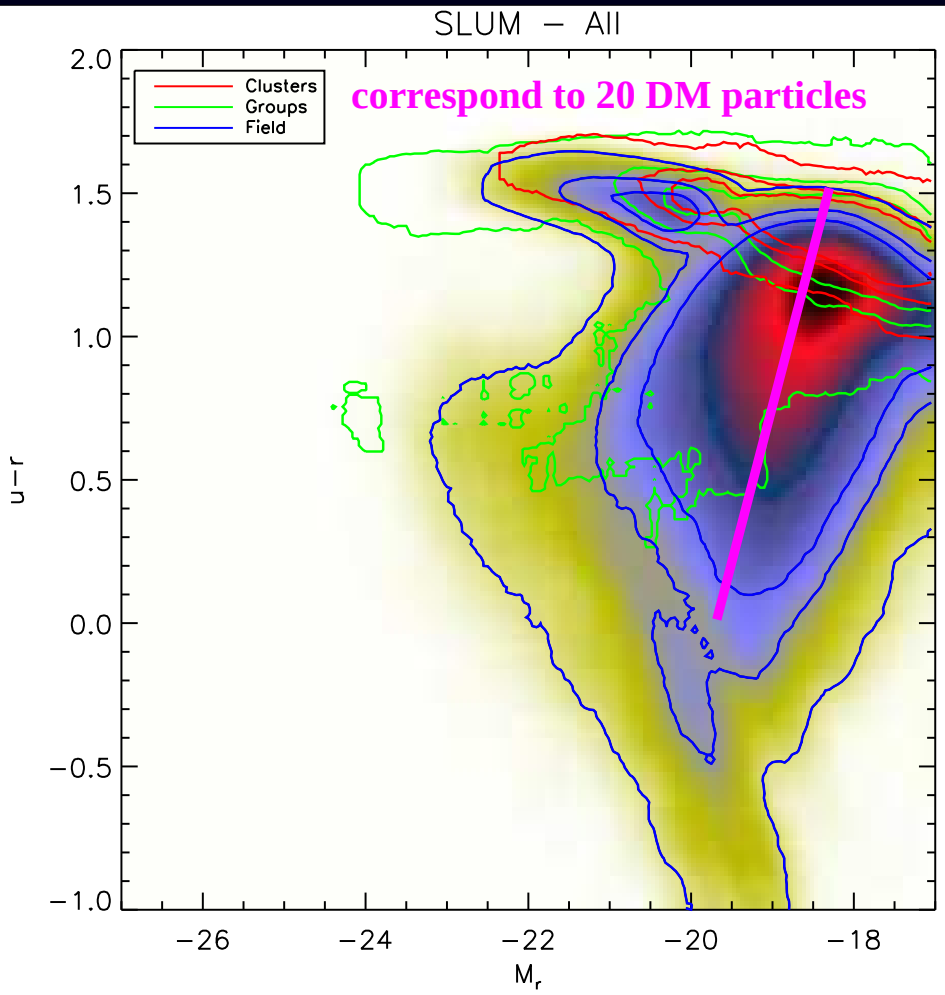




Galaxy properties



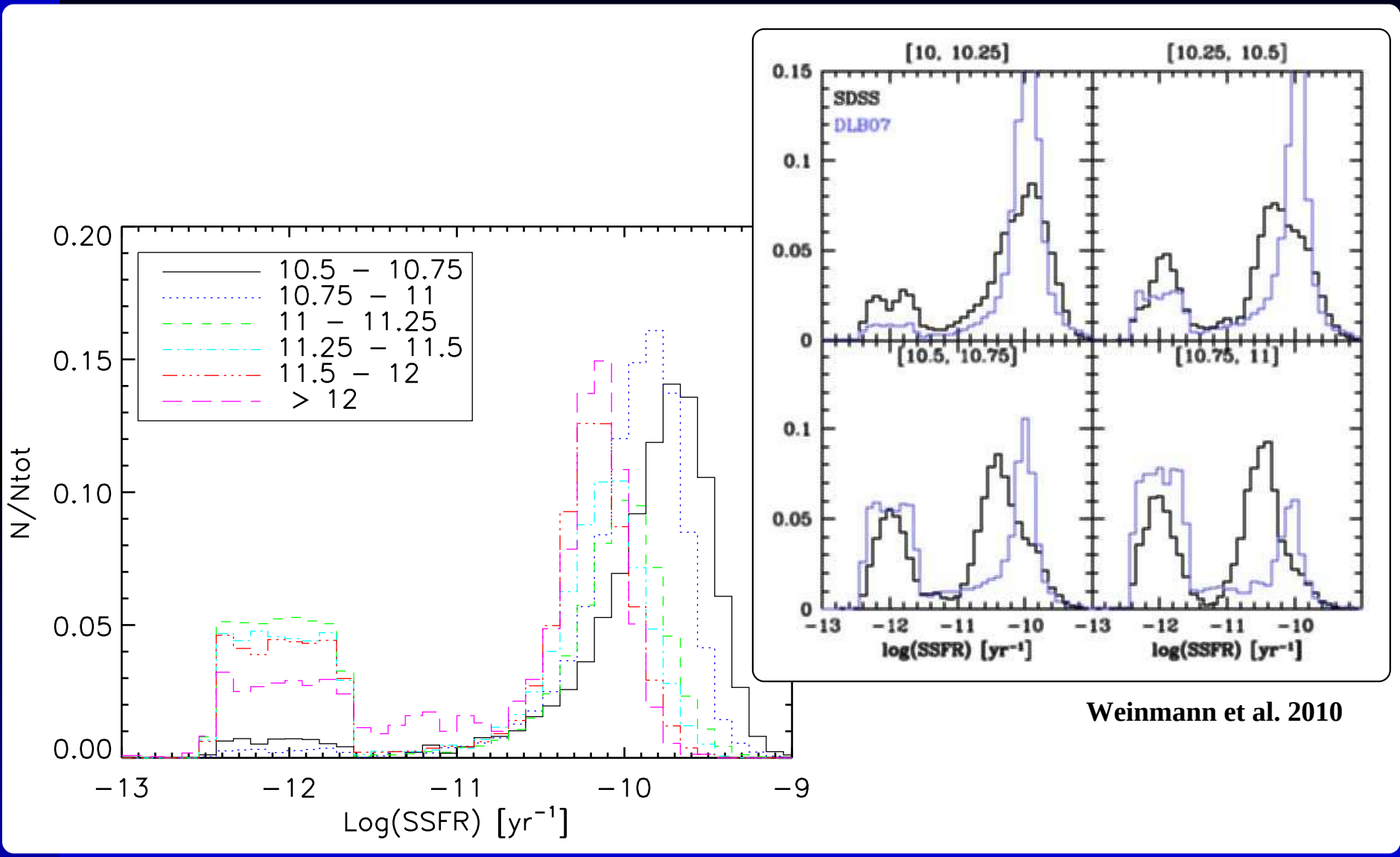
Baldry et al. 2004



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)