# The Magneticum Pathfinder Simulations

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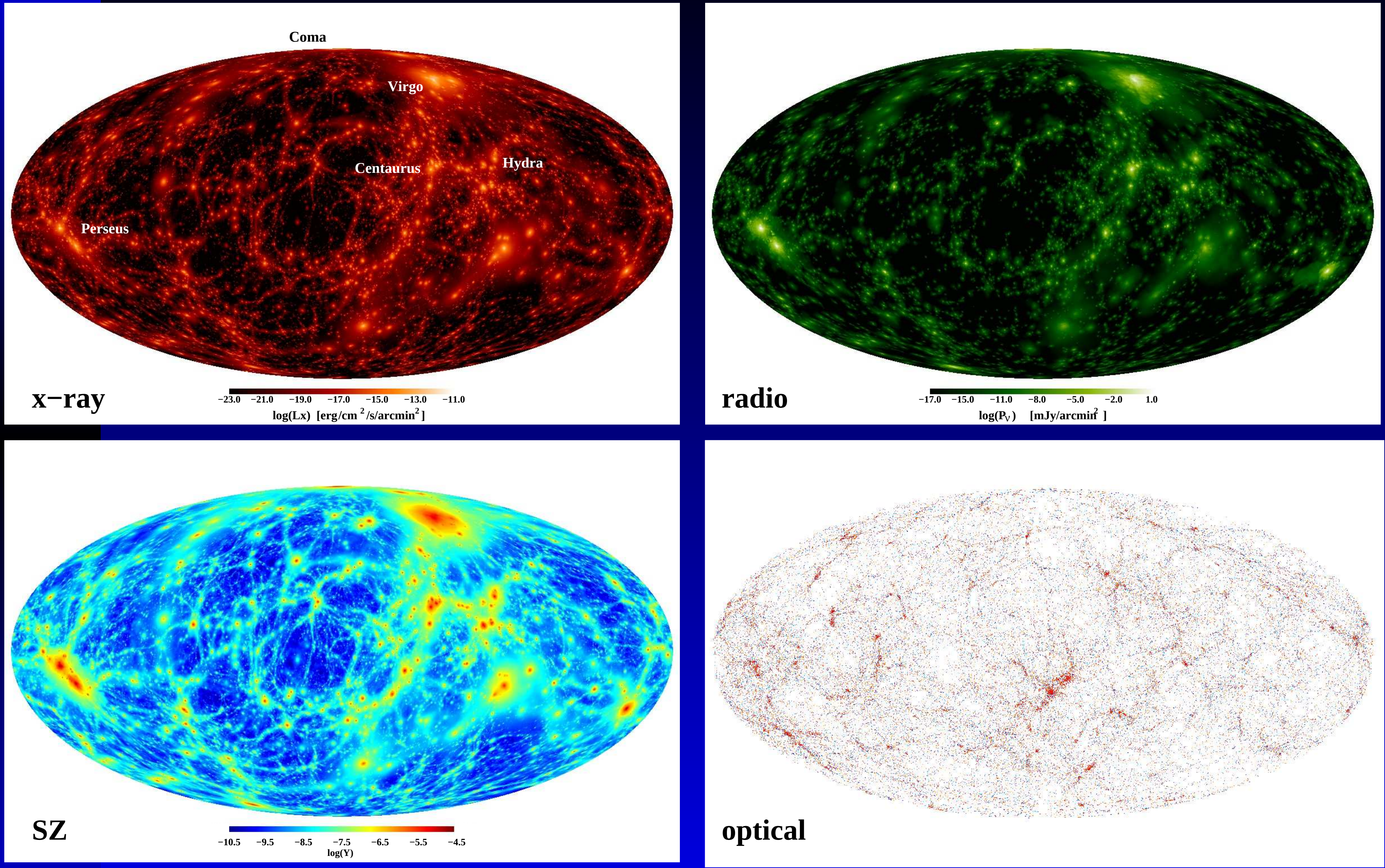
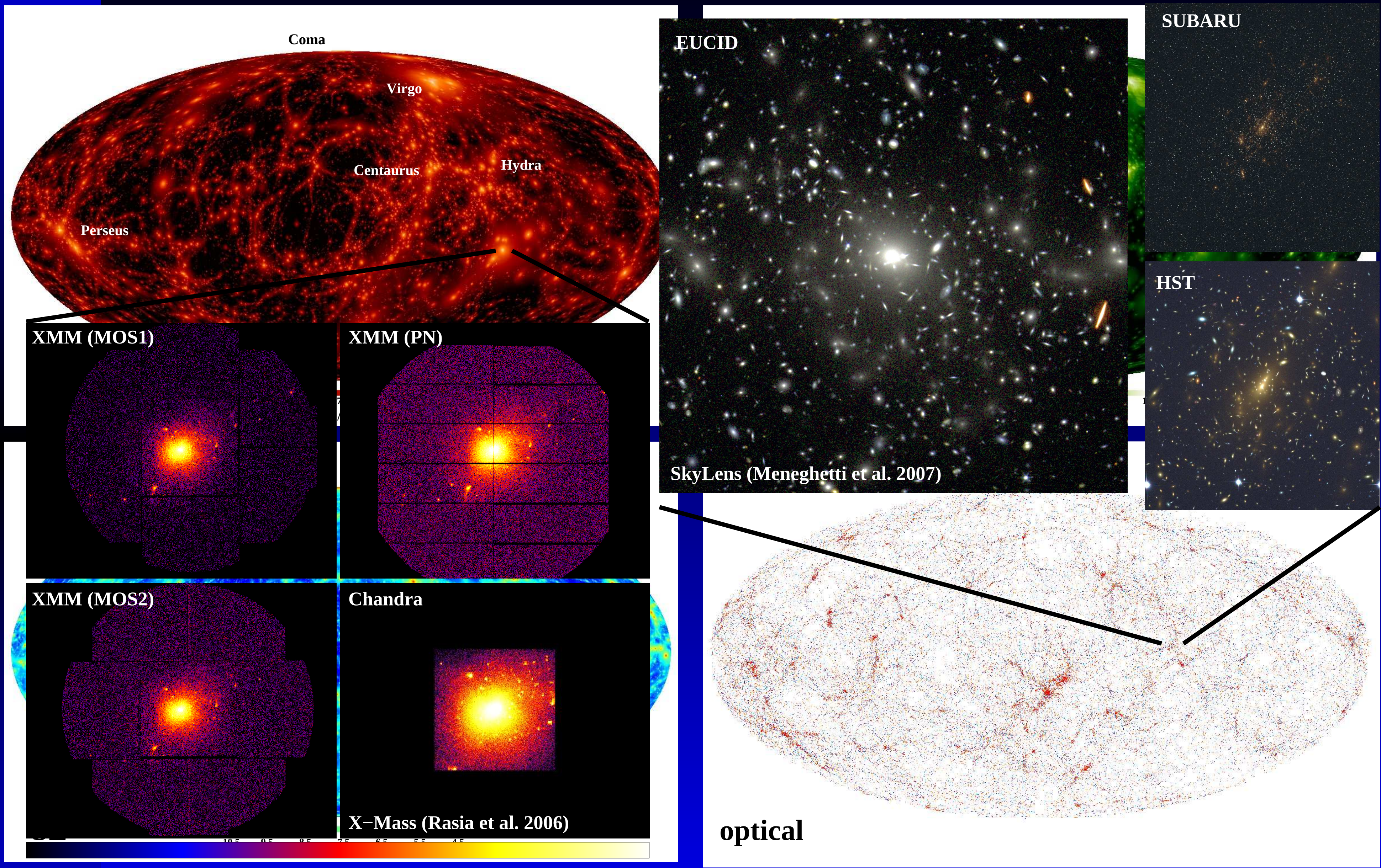
# The Aim




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

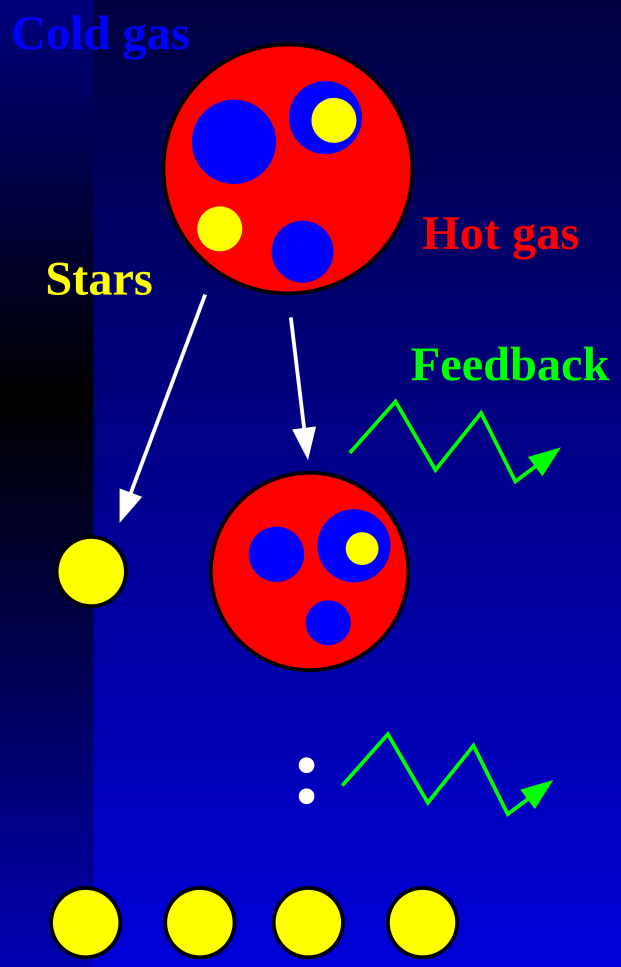



Mock optical/x-ray observations using SkyLens (Meneghetti 2010), X-Mass (Rasia 2007) and Phox (Biffi 2011).

# Simulating Subgrid Physics

## Multi phase model (sub−scale)

**Springel & Hernquist 2002**




**Star formation**

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

supernova mass fraction

star formation timescale

**Cloud evaporation**

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

cloud evaporation parameter

**Growth of clouds**

cooling function

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

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**

gas density

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

sound speed

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

**Feedback by BH**

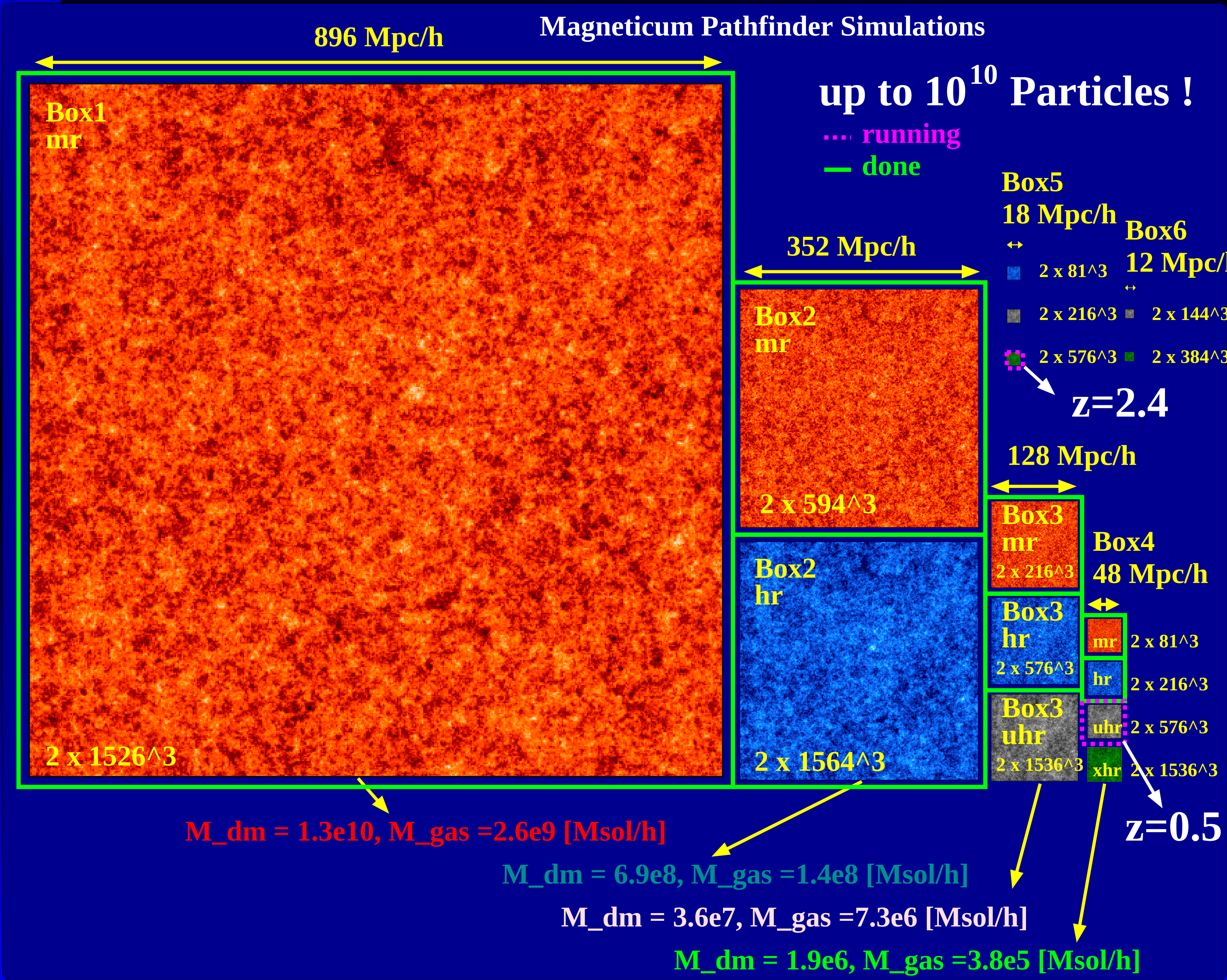
$$L_{bol} = 0.1 \times \dot{M}_\bullet c^2$$

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

efficiency

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

# Magneticum Pathfinder



# Magneticum Pathfinder

Physics to be included:

- 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

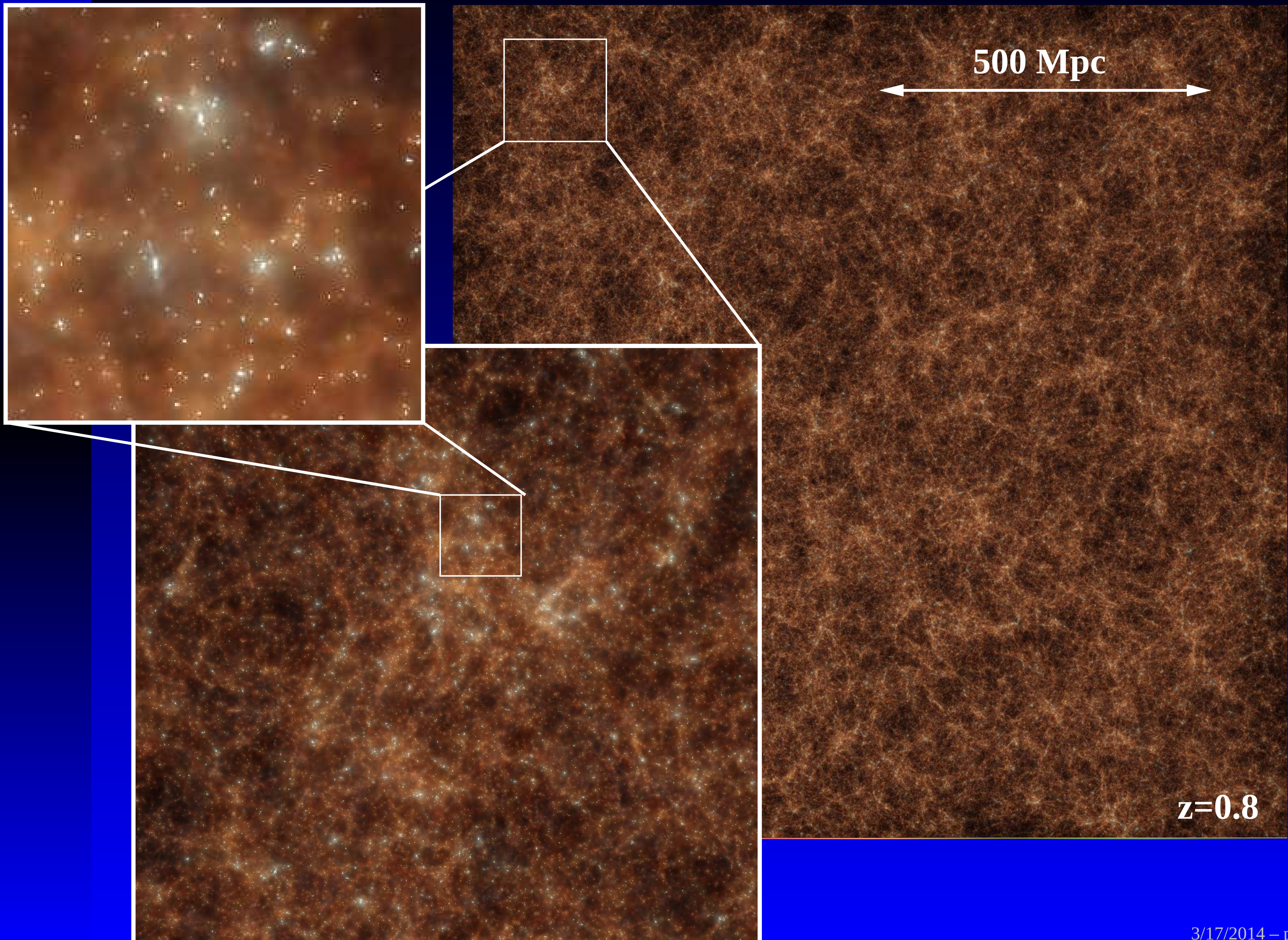
Requirements:

- 10GB main memory, ca. 1TB per snap, 40TB per sim.
- thousands (Intel) / ten thousands (BluGene) of cores.

Add ons:

- On the fly Sub-Find Springel et al. 2001/2010, Dolag et al. 2009
- Photometric code to assign optical/near-IR luminosities to galaxies (u,V,G,r,i,z,Y,J,H,K,L,M) Saro et al. 2006, Nuzza et al. 2010
- On the fly Cluster/Groups properties

# Magneticum Pathfinder



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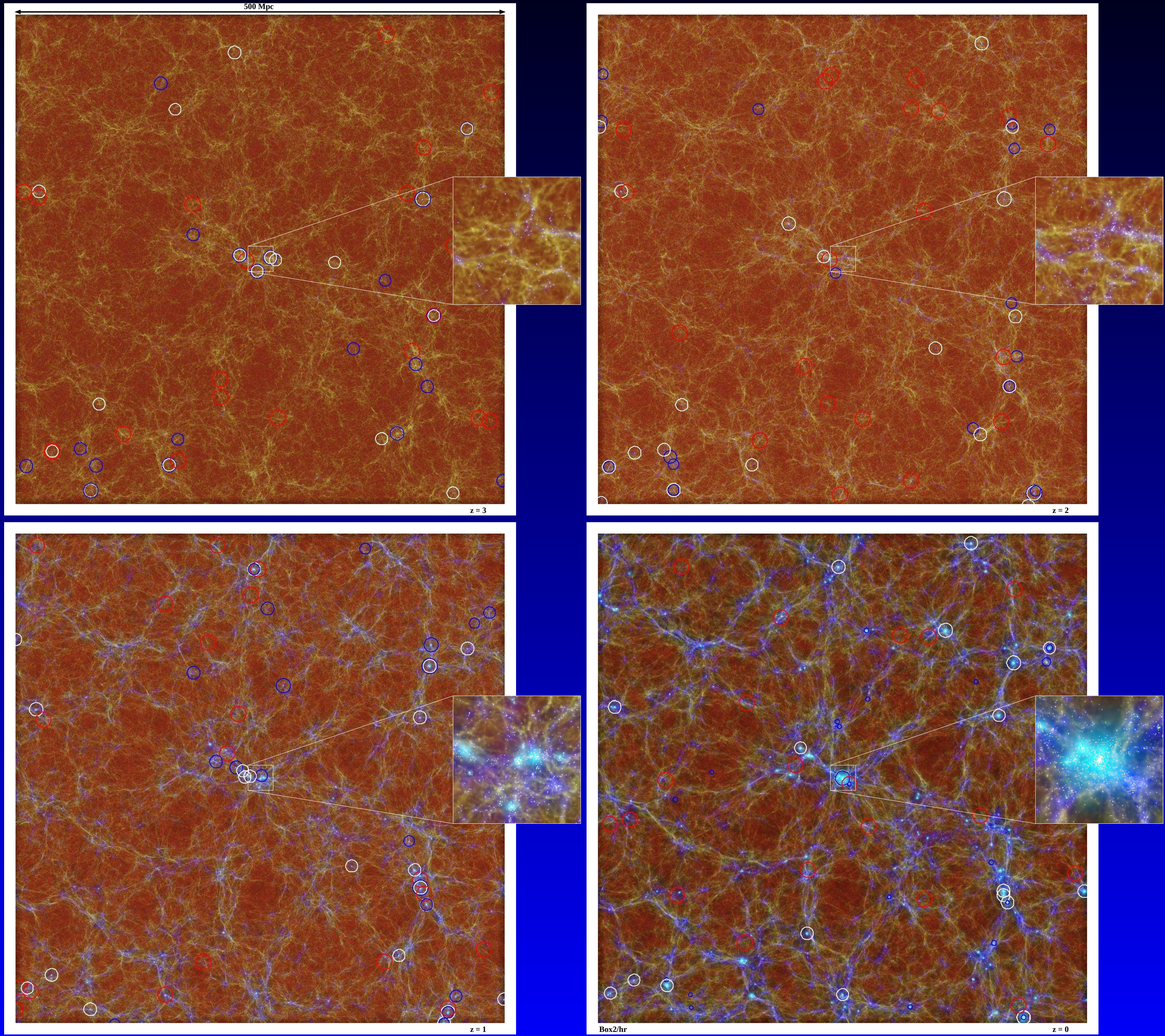

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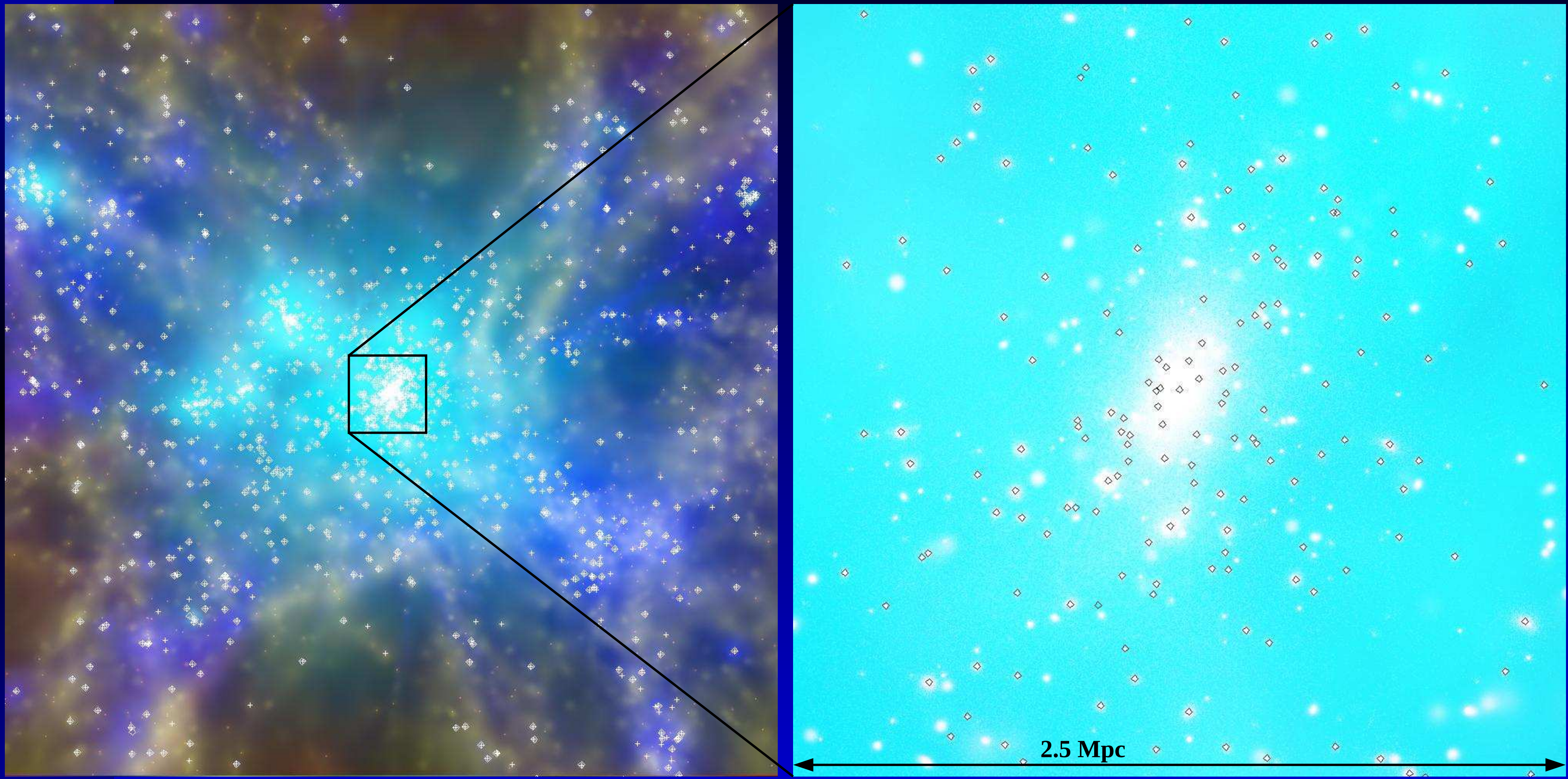
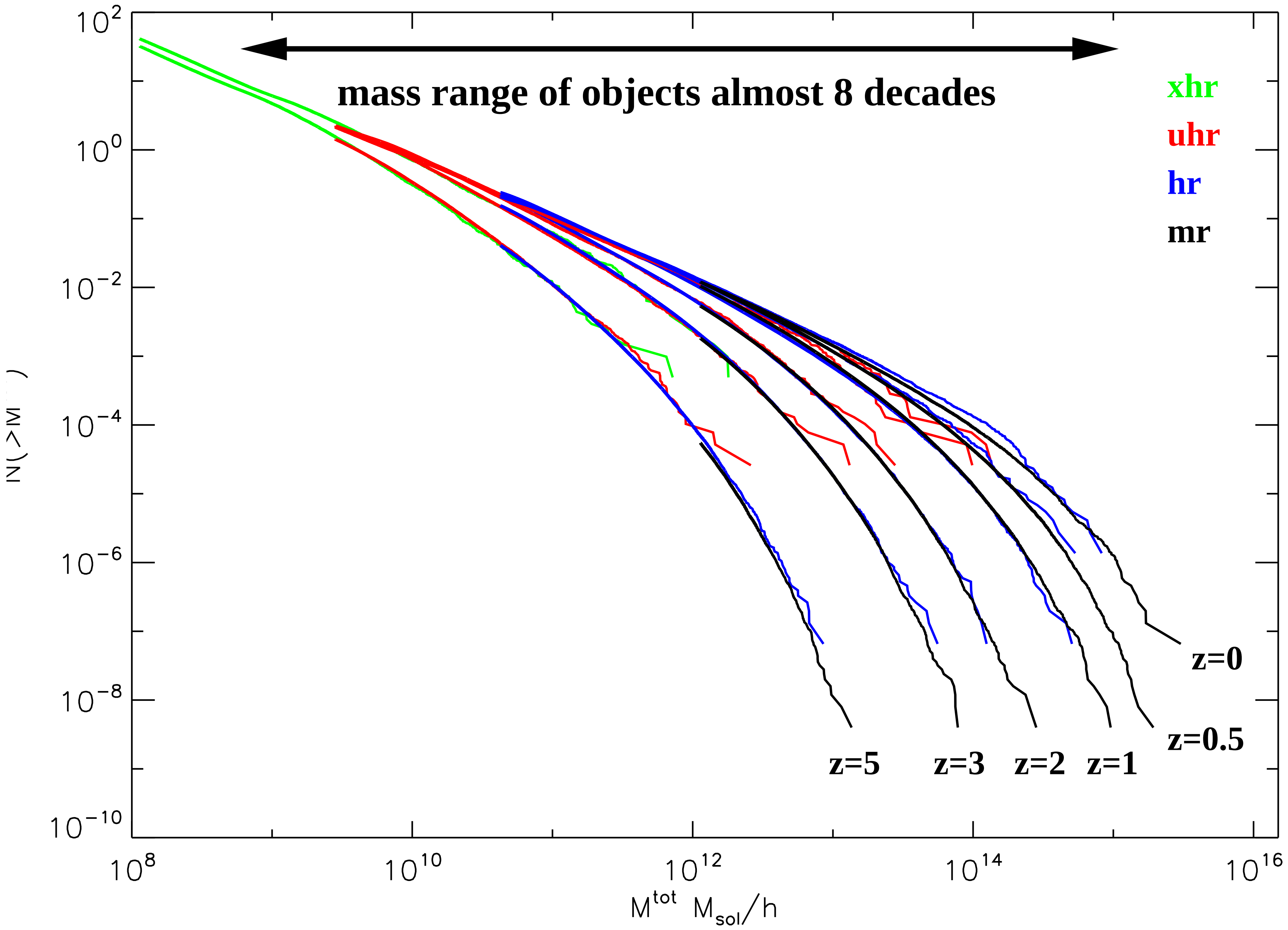



Zoom onto most massive cluster in Box2/hr. Transformation of galaxies inside the denser environment.

# What we can expect



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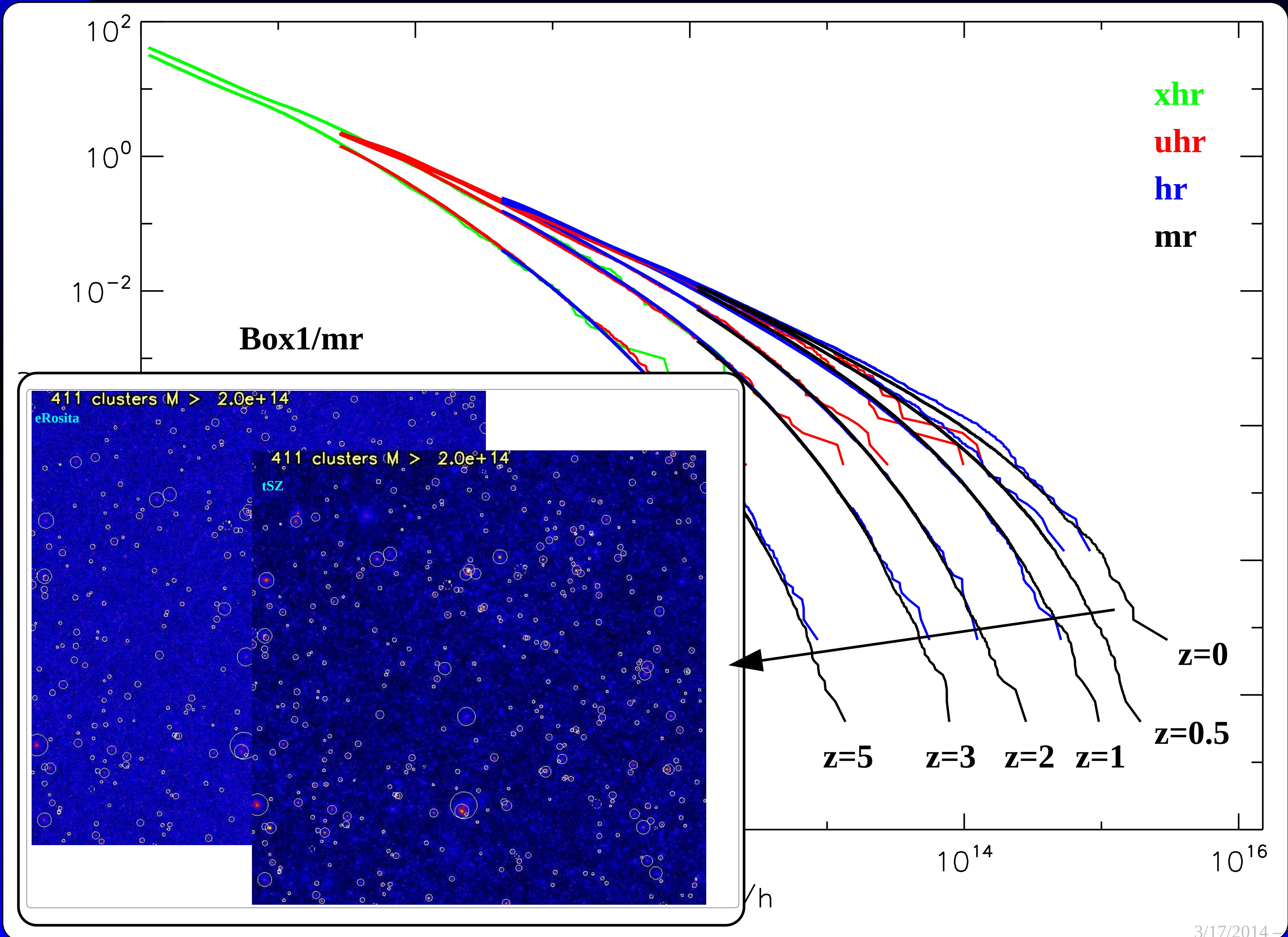

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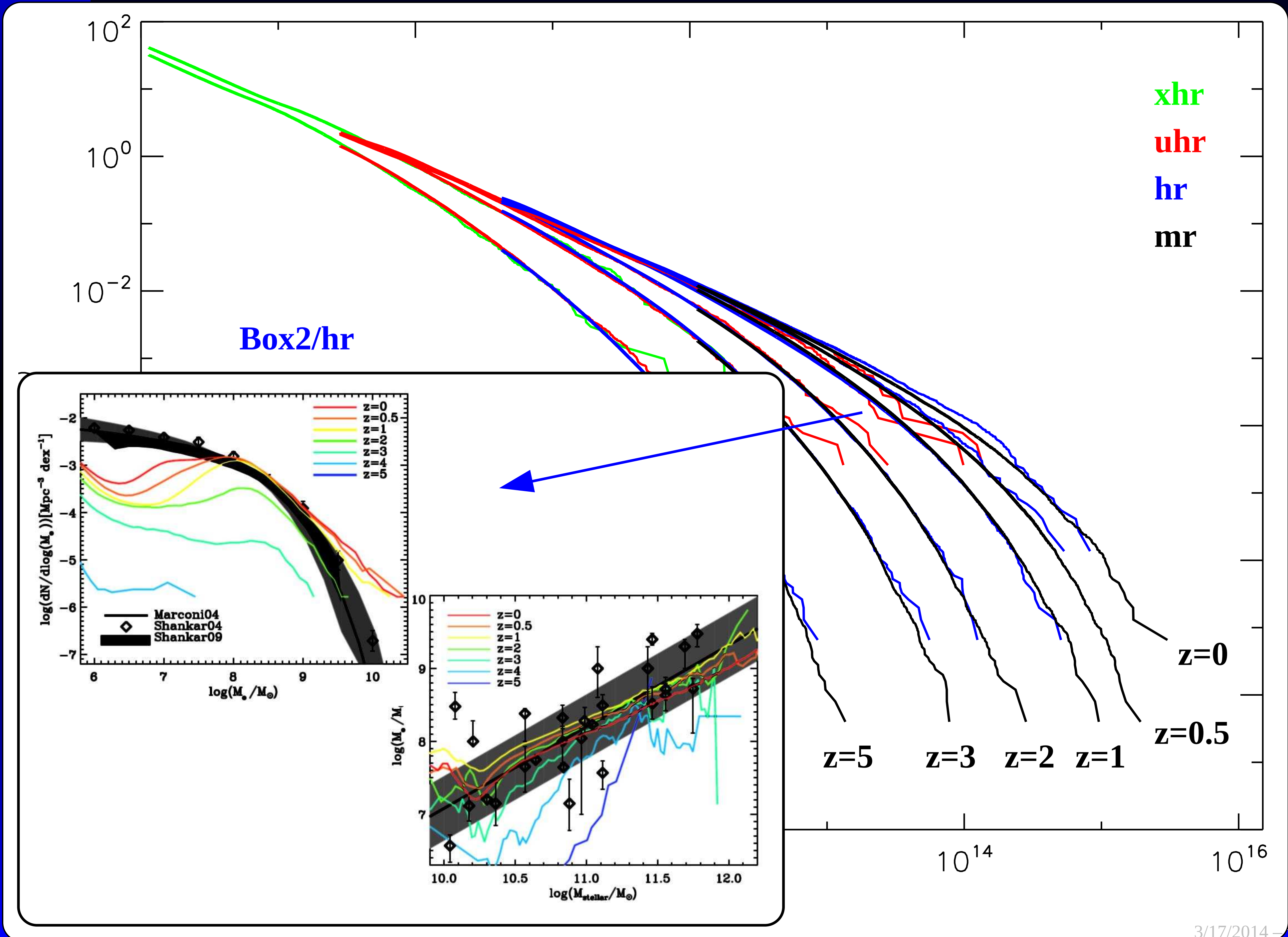

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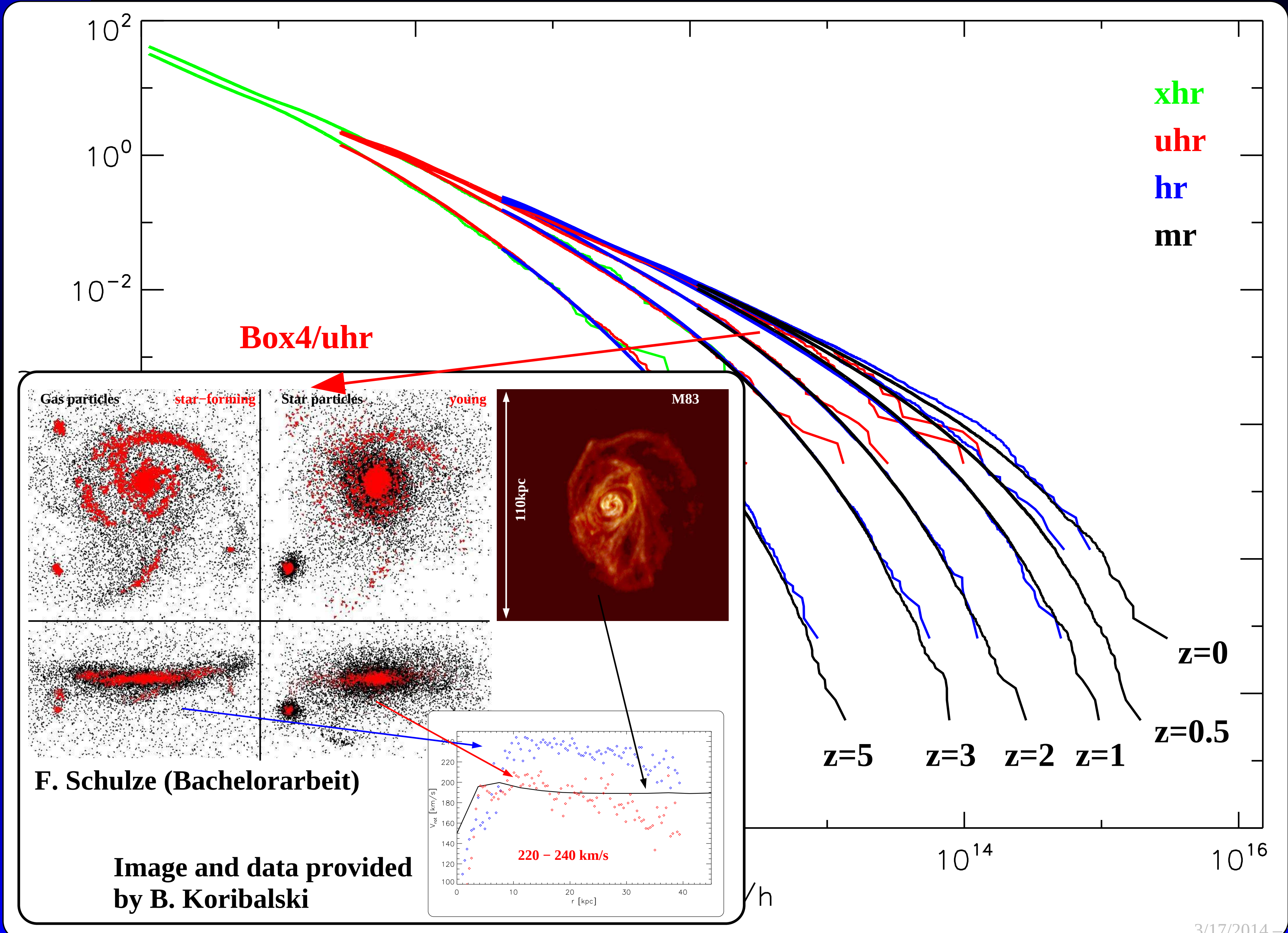

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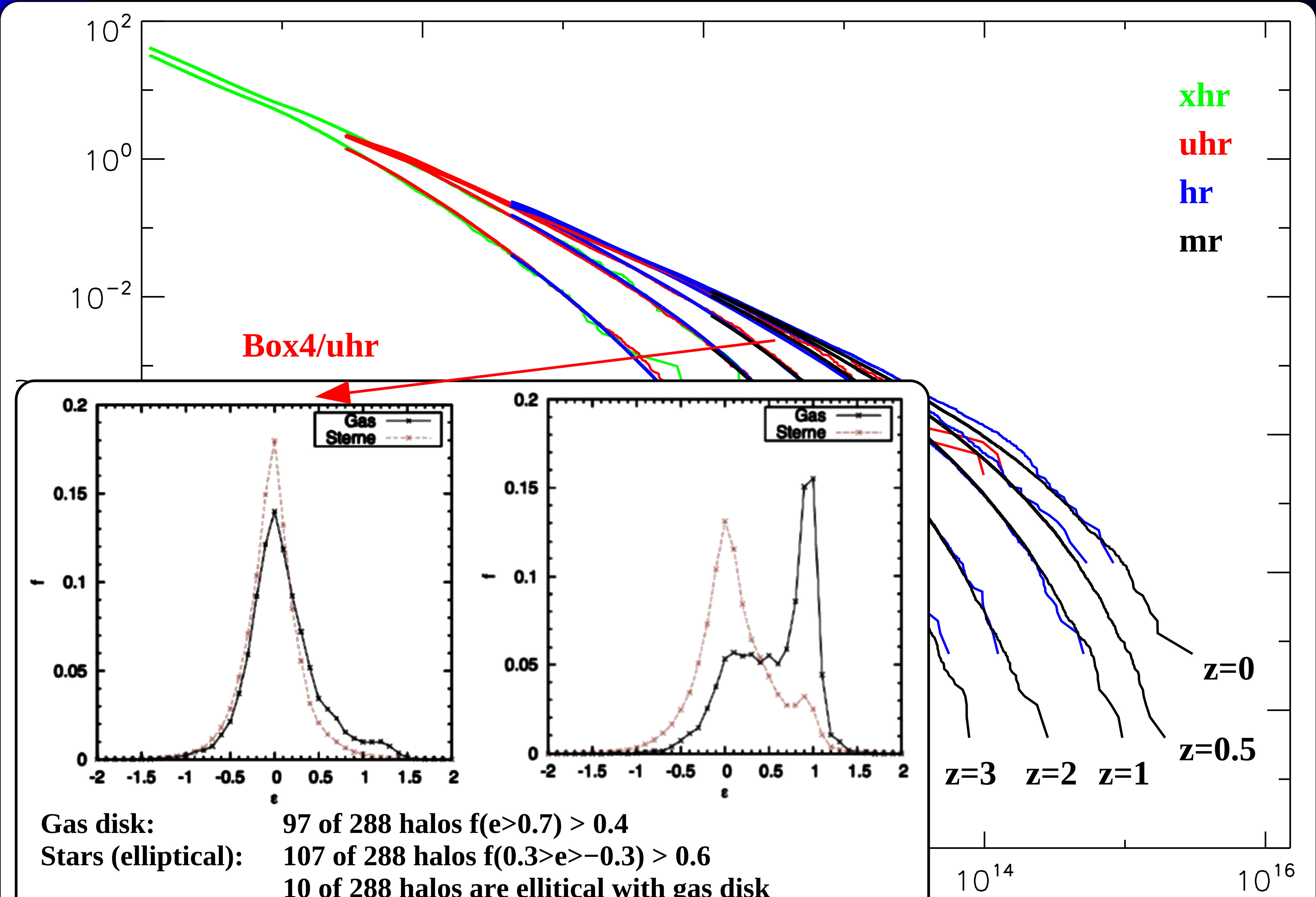


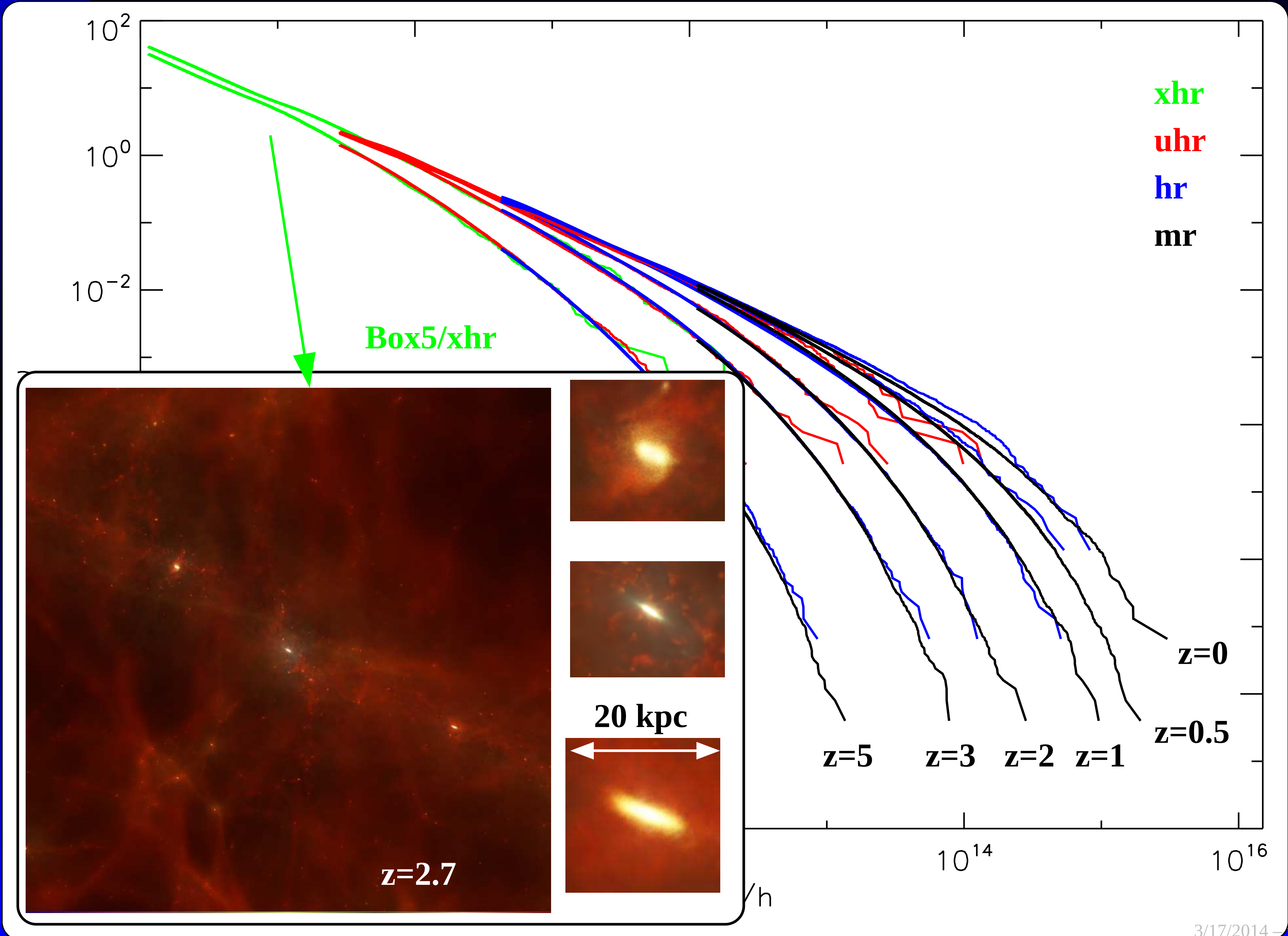

Gas disk: 97 of 288 halos f(e>0.7) > 0.4

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

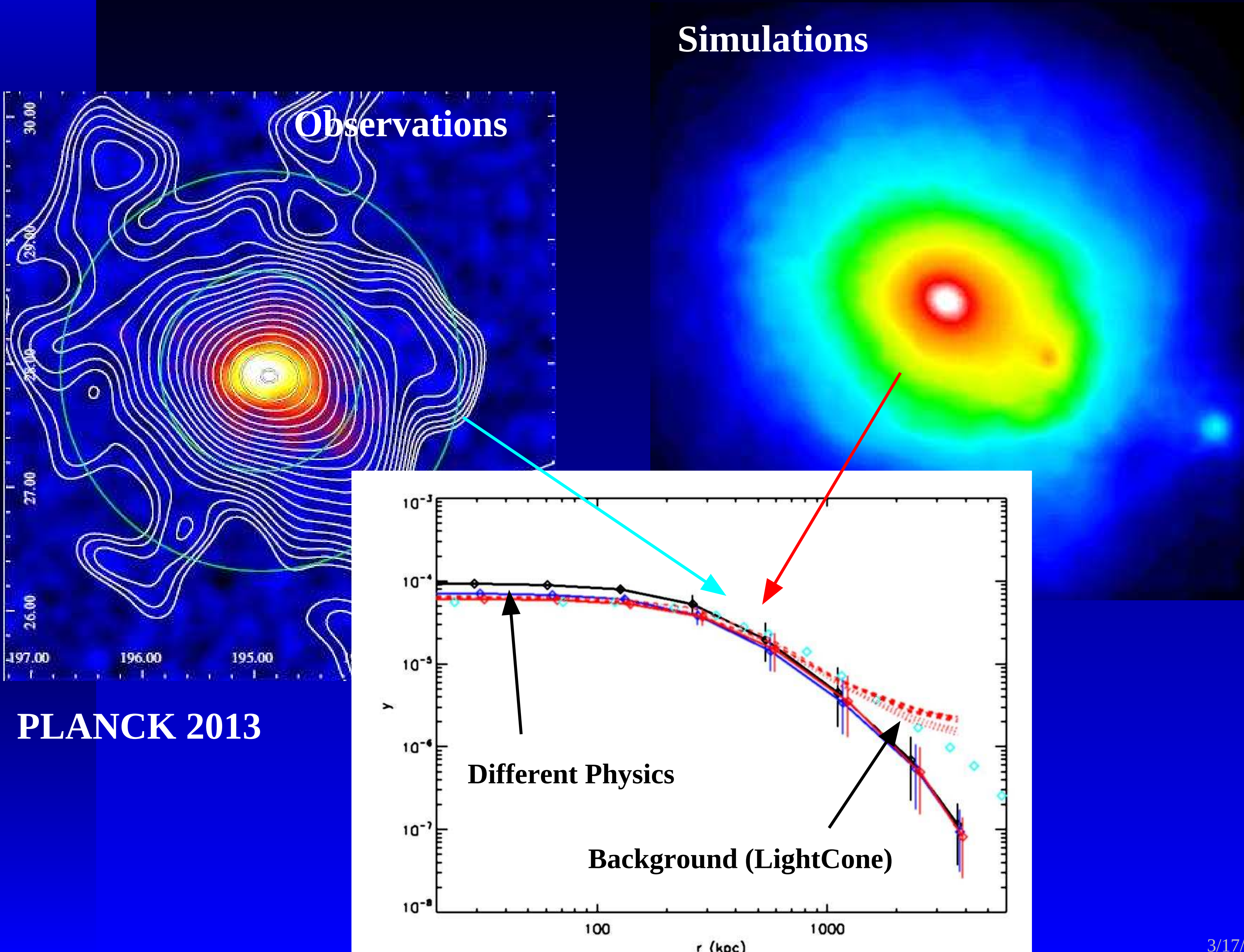
10 of 288 halos are ellitical with gas disk

F. Schulze (Bachelorarbeit)

# What we can expect



# ICM Properties



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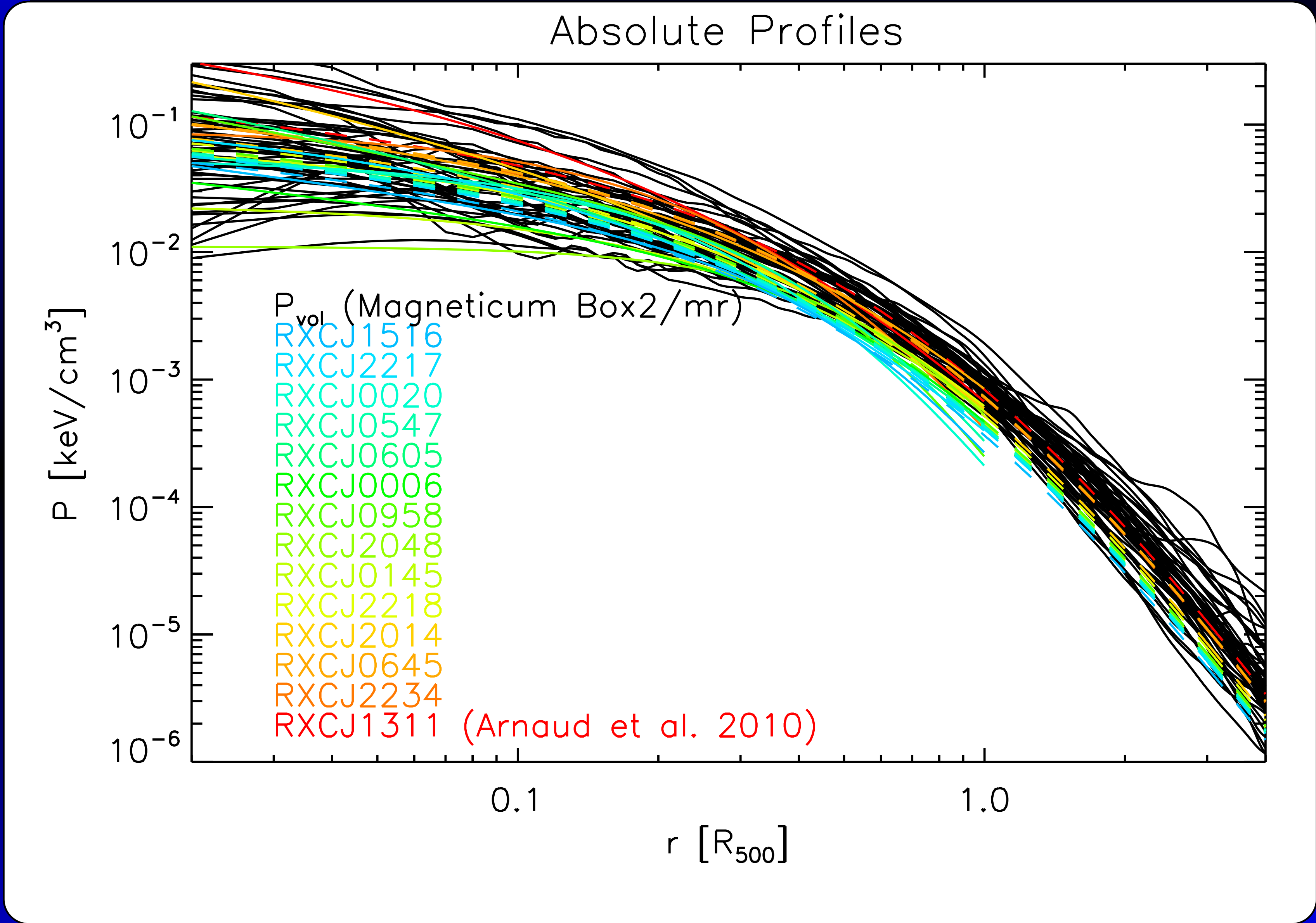
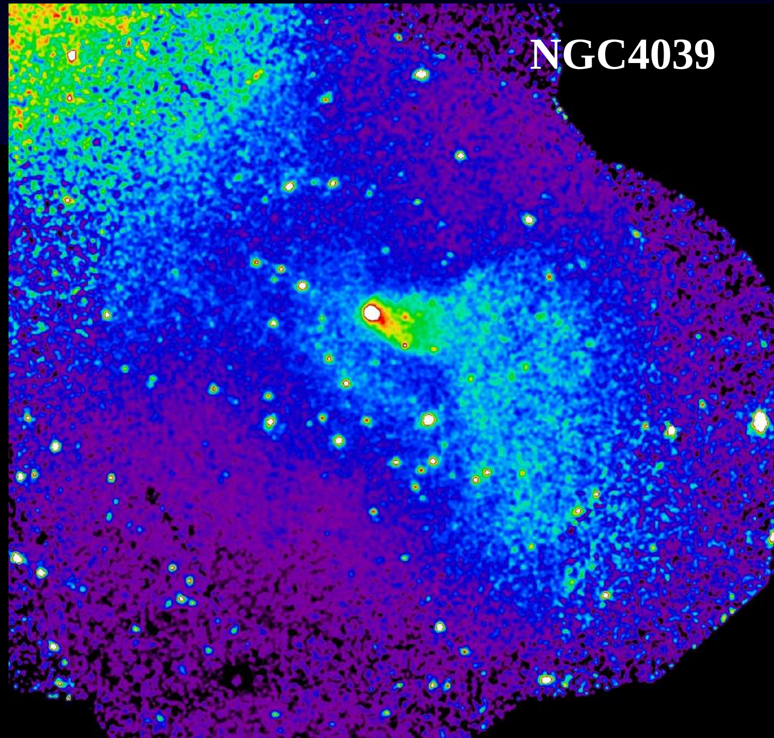
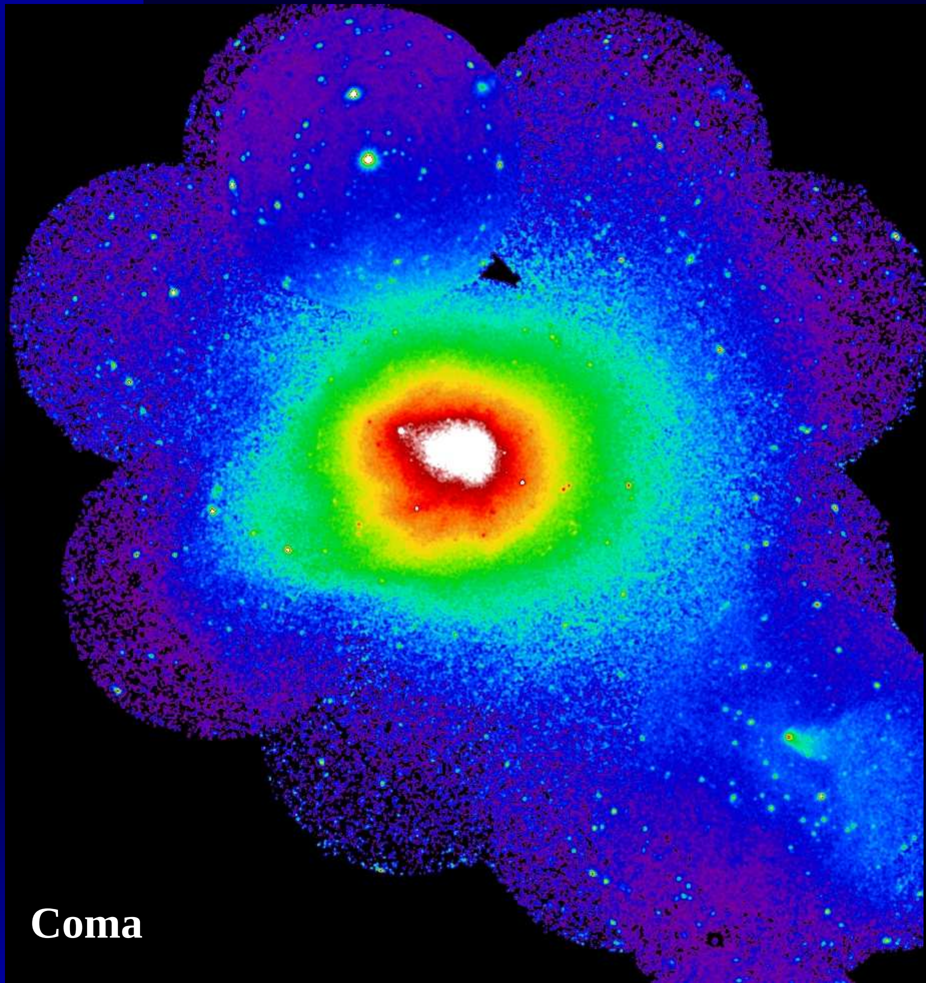
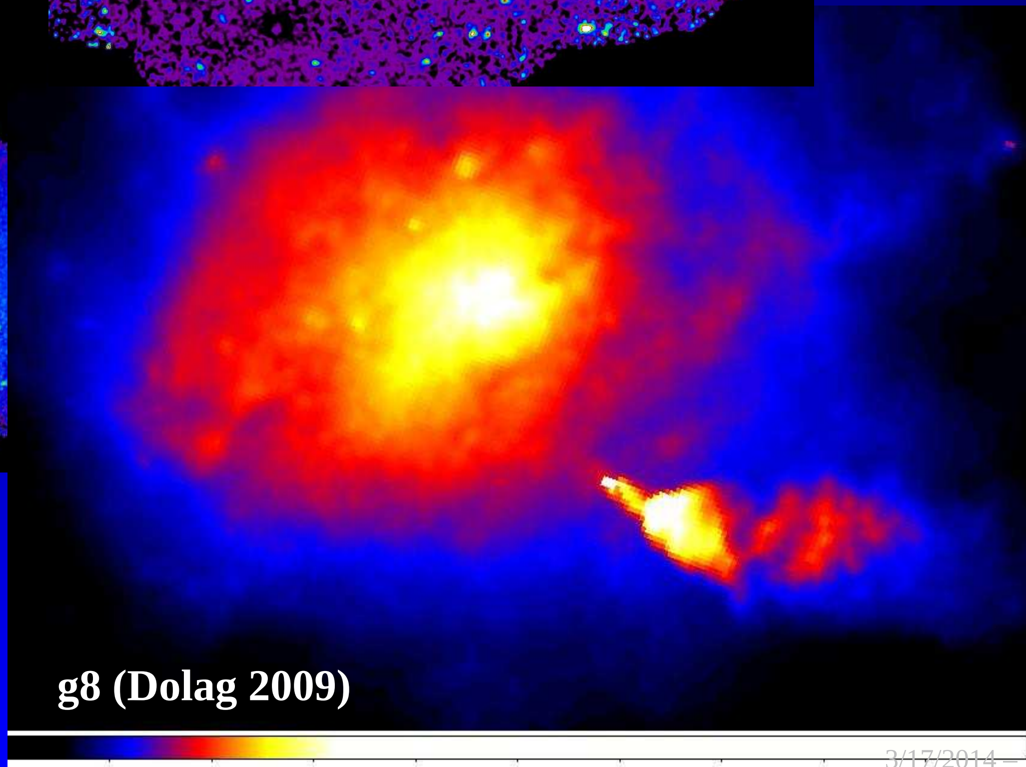



Comparison of simulated pressure profiles with observations (shape and scatter !).

# ICM Properties

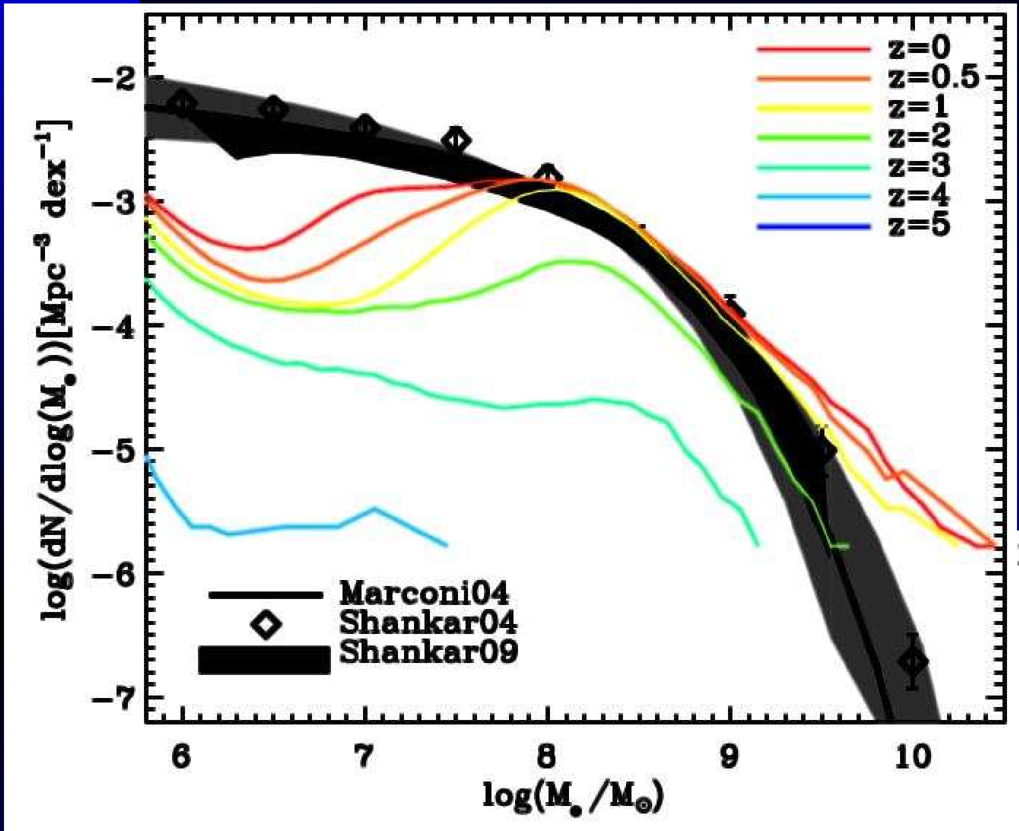


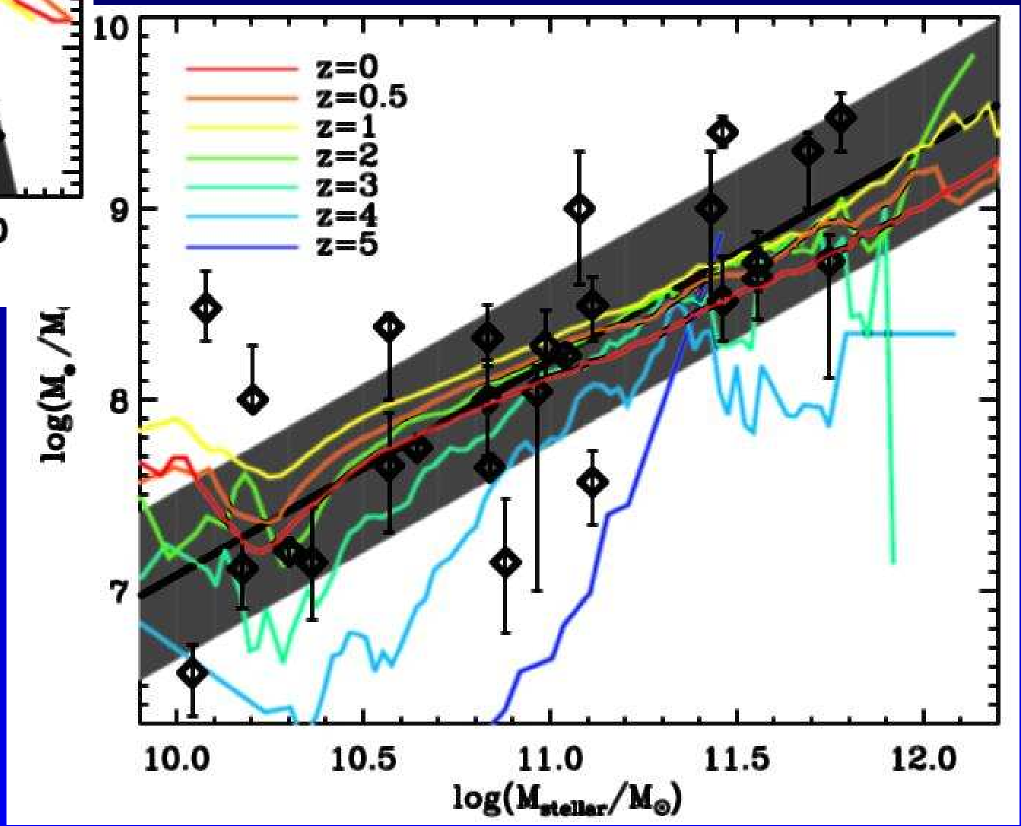




**Provided by N. Lyskova & E. Churazov**

# AGN feedback model




Hirschnmann et al. 2013



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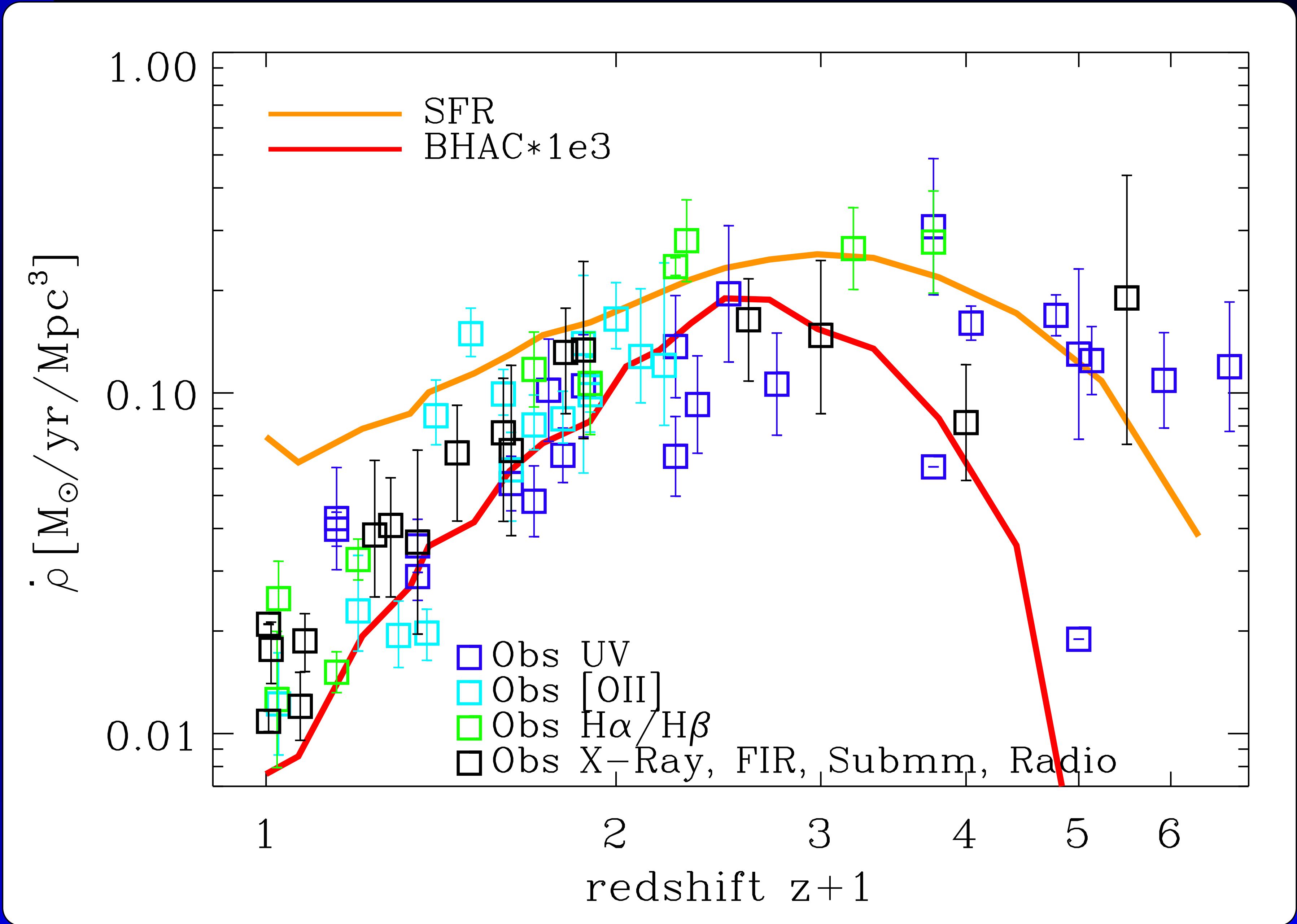
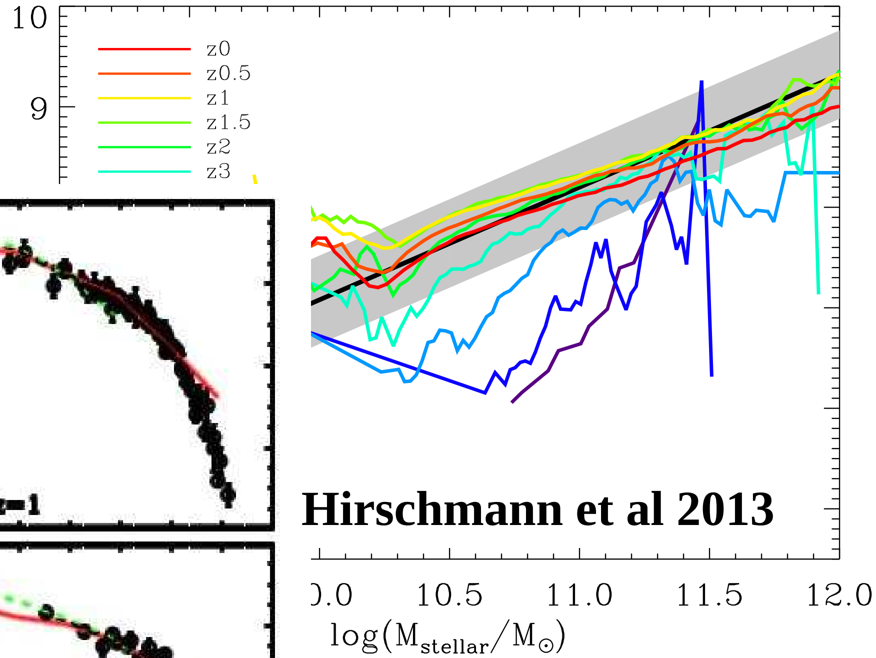


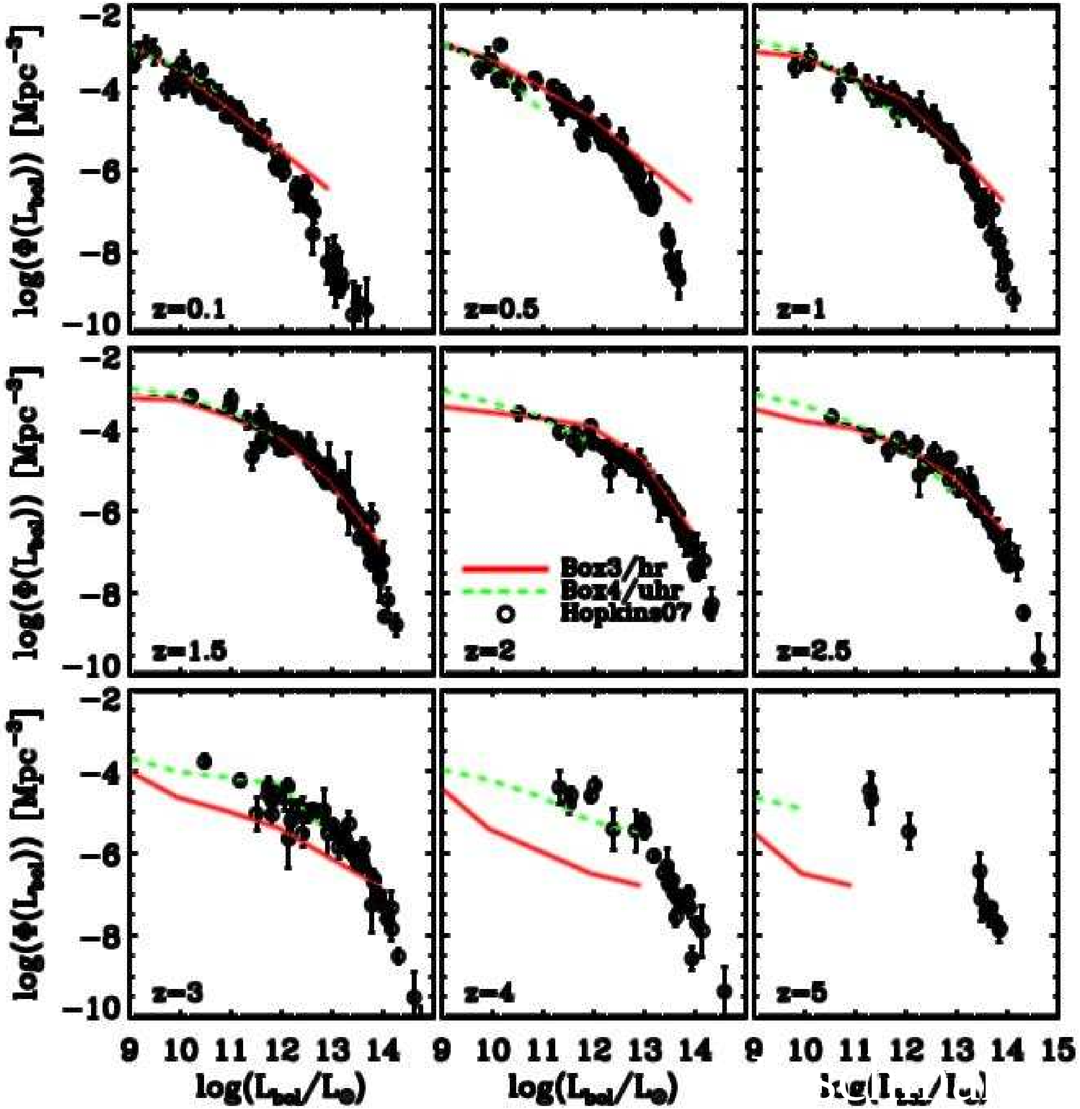

BH growth linked to star-formation

# AGN feedback model

BH Mass -- Stellar Mass

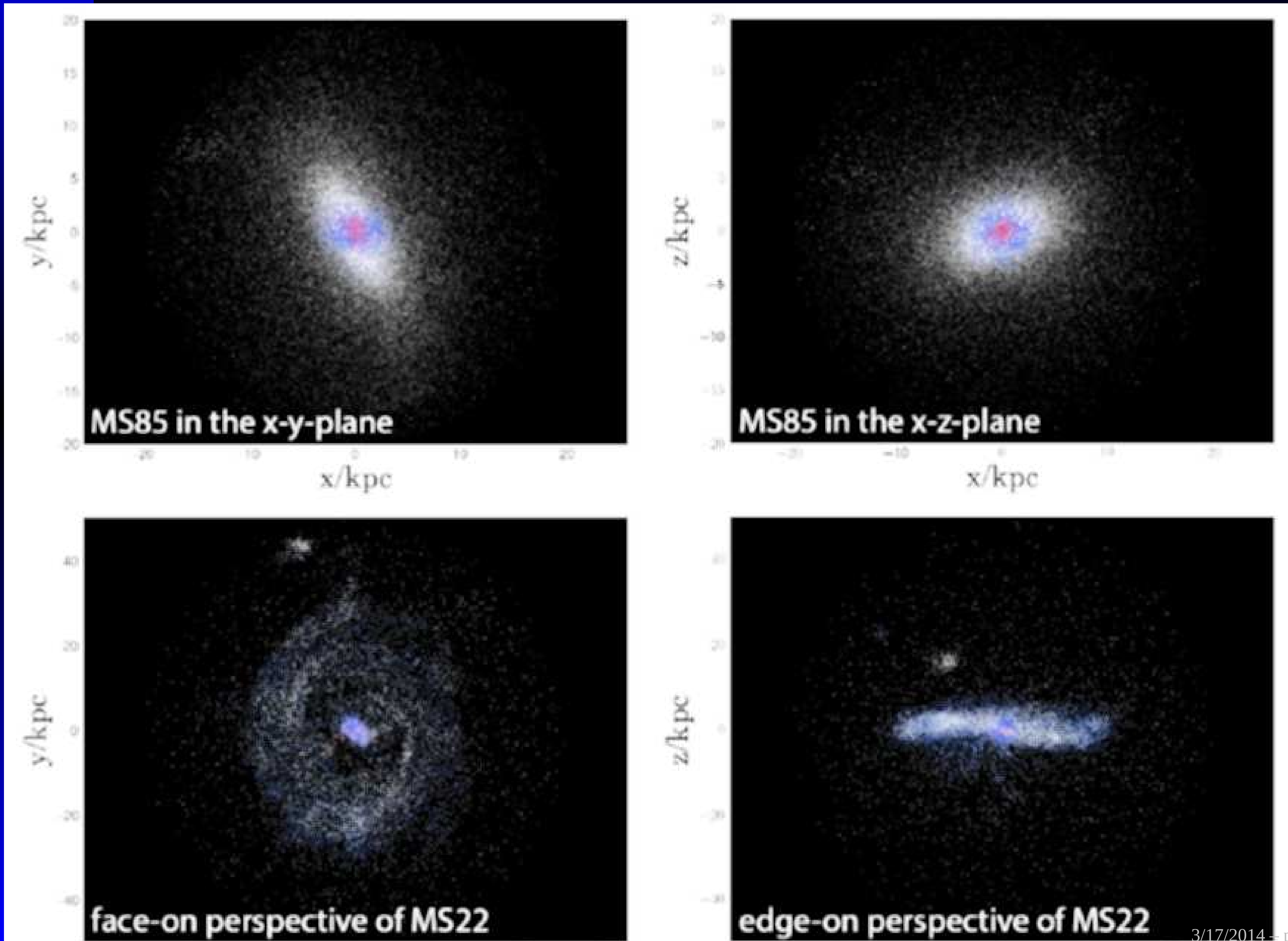



Bolometric LF




Hirschmann et al 2013

# Galaxy properties



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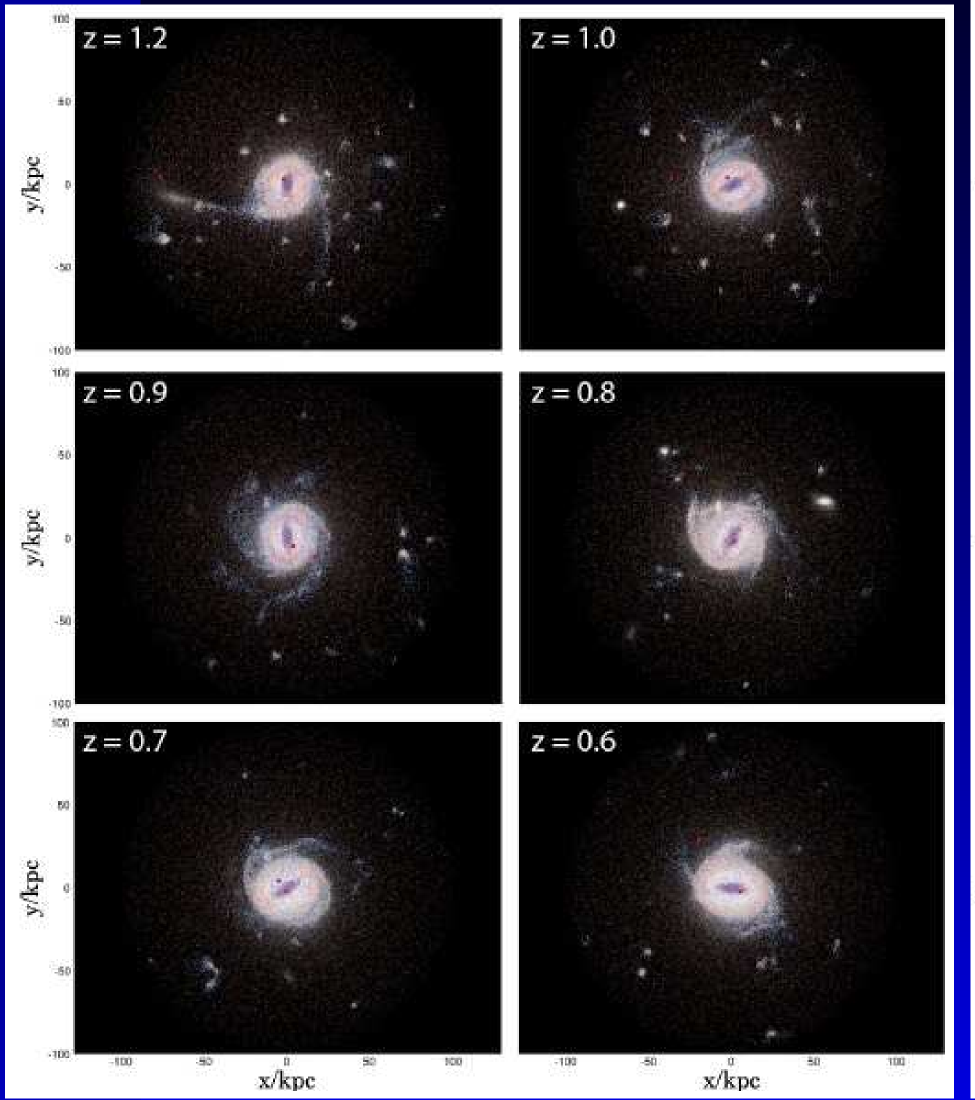
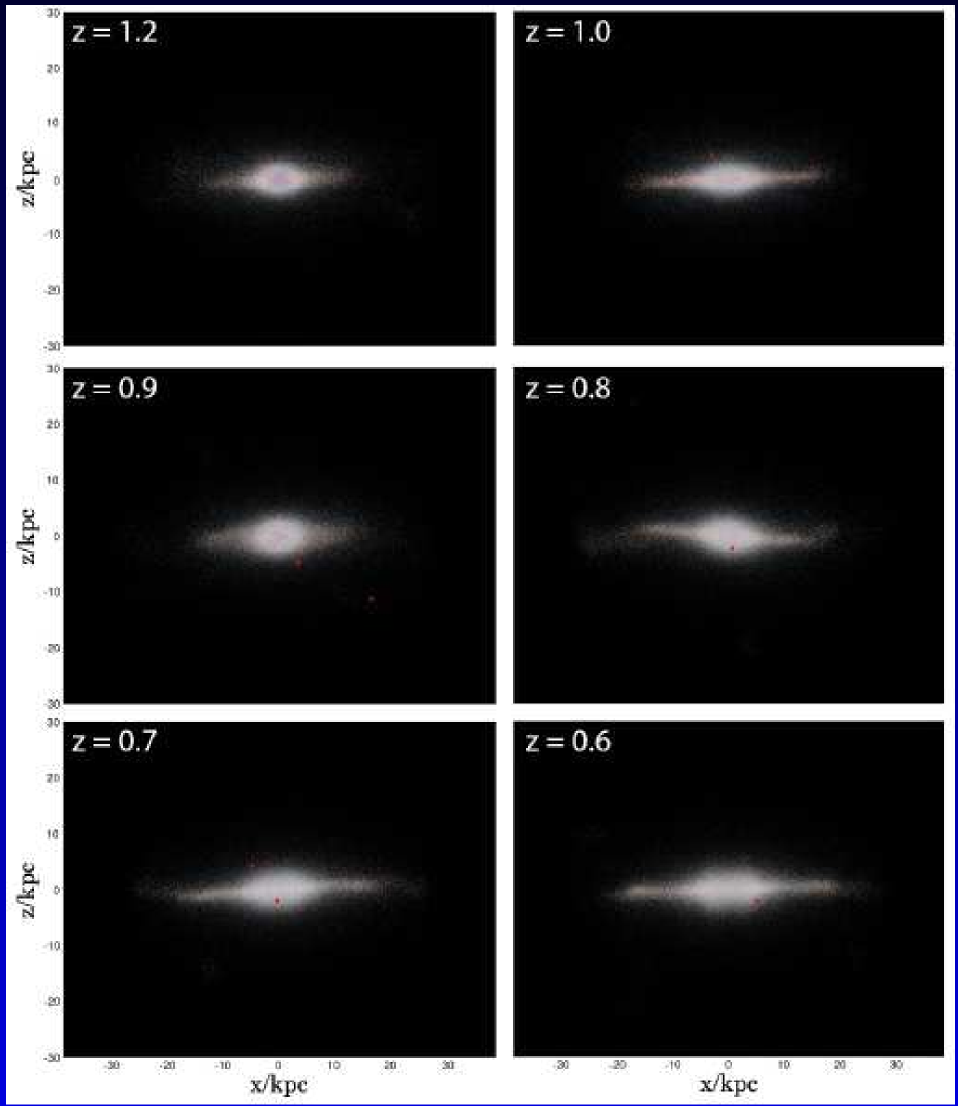
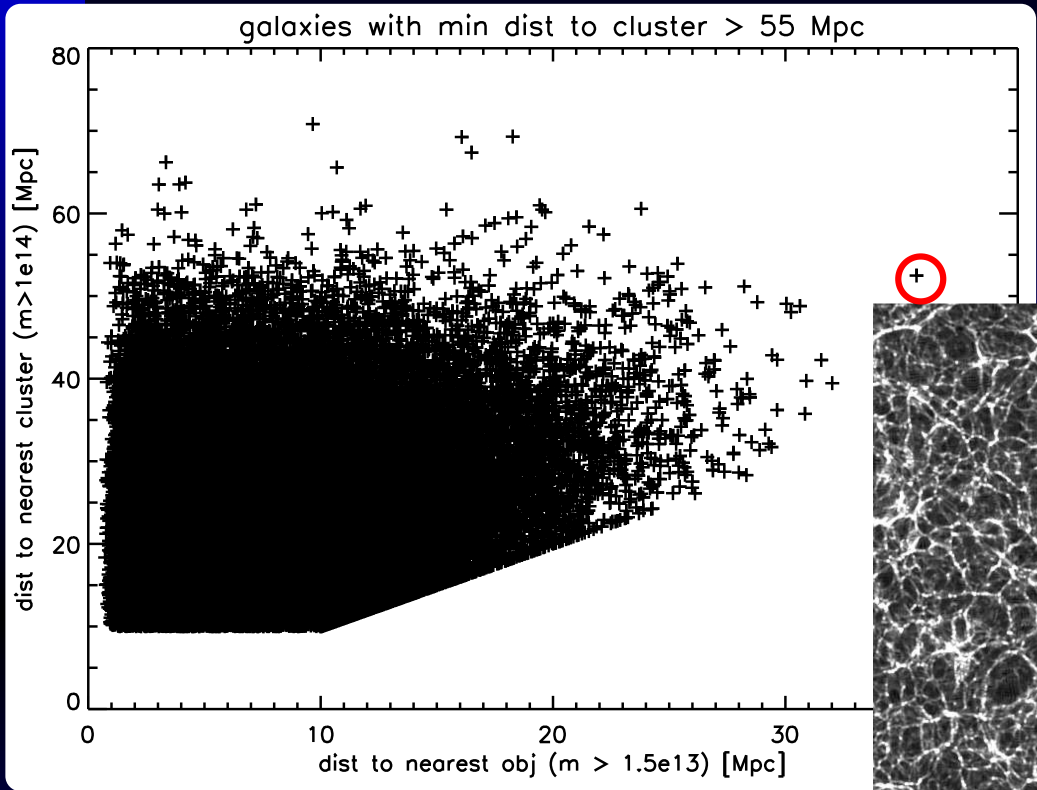


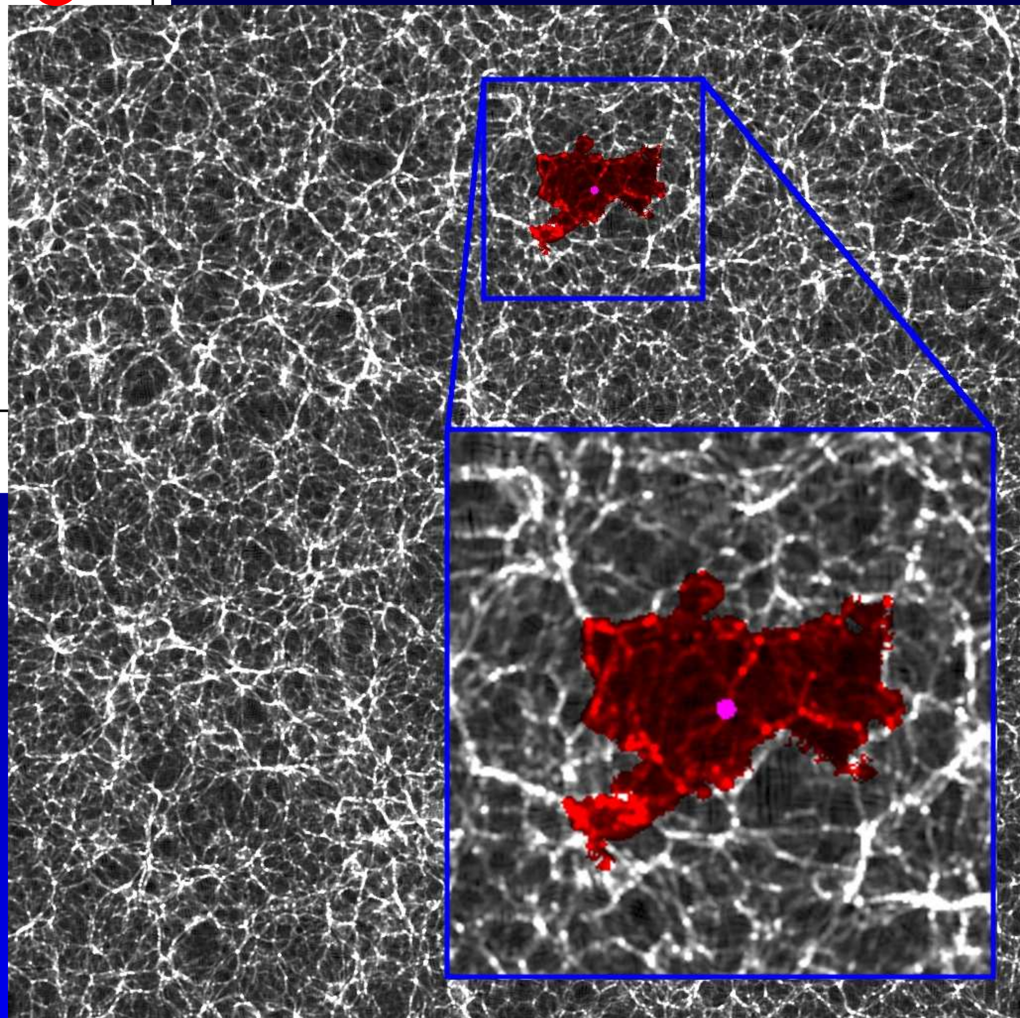

MA Lisa Bachmann

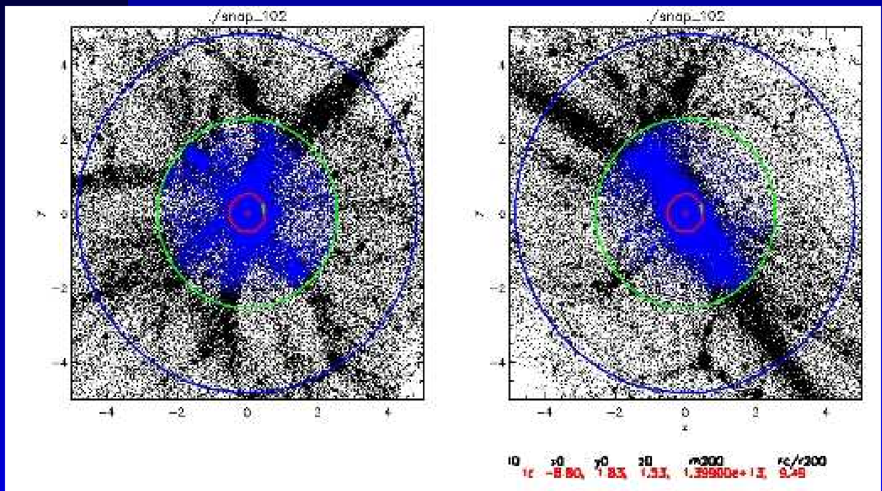
Implication for halo properties, see next talk by R. Remus.

# Massive galaxies in voids




Selecting massive void galaxies





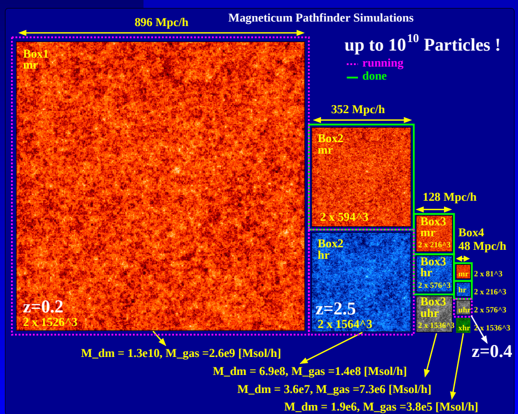

MA David Schachtberger

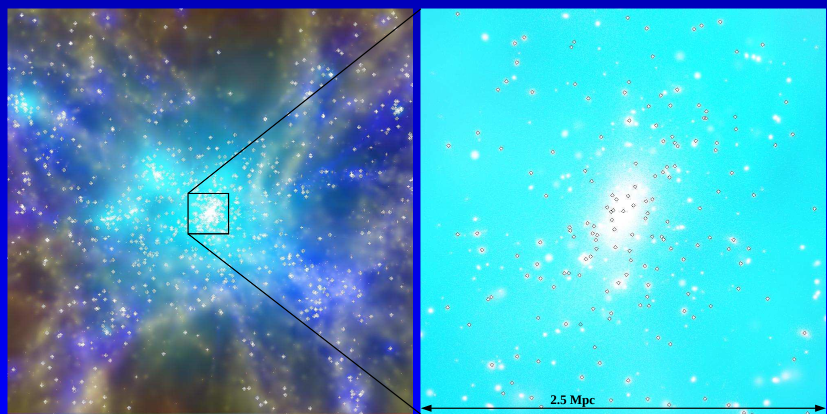
# Massive galaxies in voids

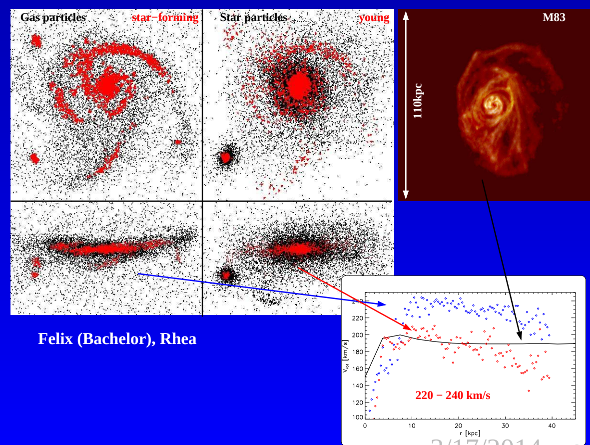
# Conclusions

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

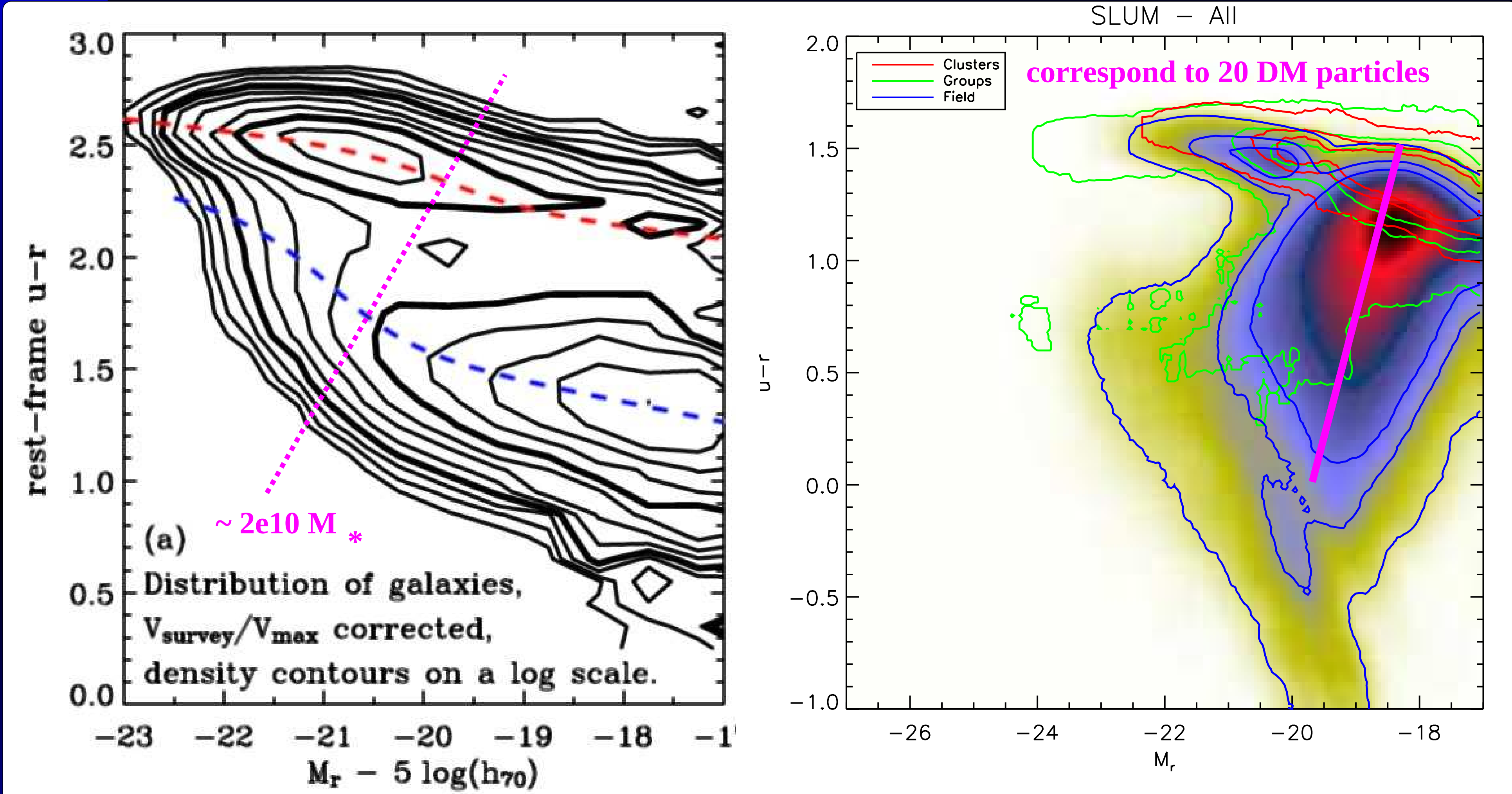
- Simulated stellar properties (reasonable)
  luminosity function, colors, specific star-formation rates
- ICM properties (very good)
  pressure profiles, x-ray scaling relations
- AGN properties (very good)
  accretion histories, luminosity functions
- Dynamics of galaxies
  Spirals vs. Ellipticals,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



# Galaxy properties

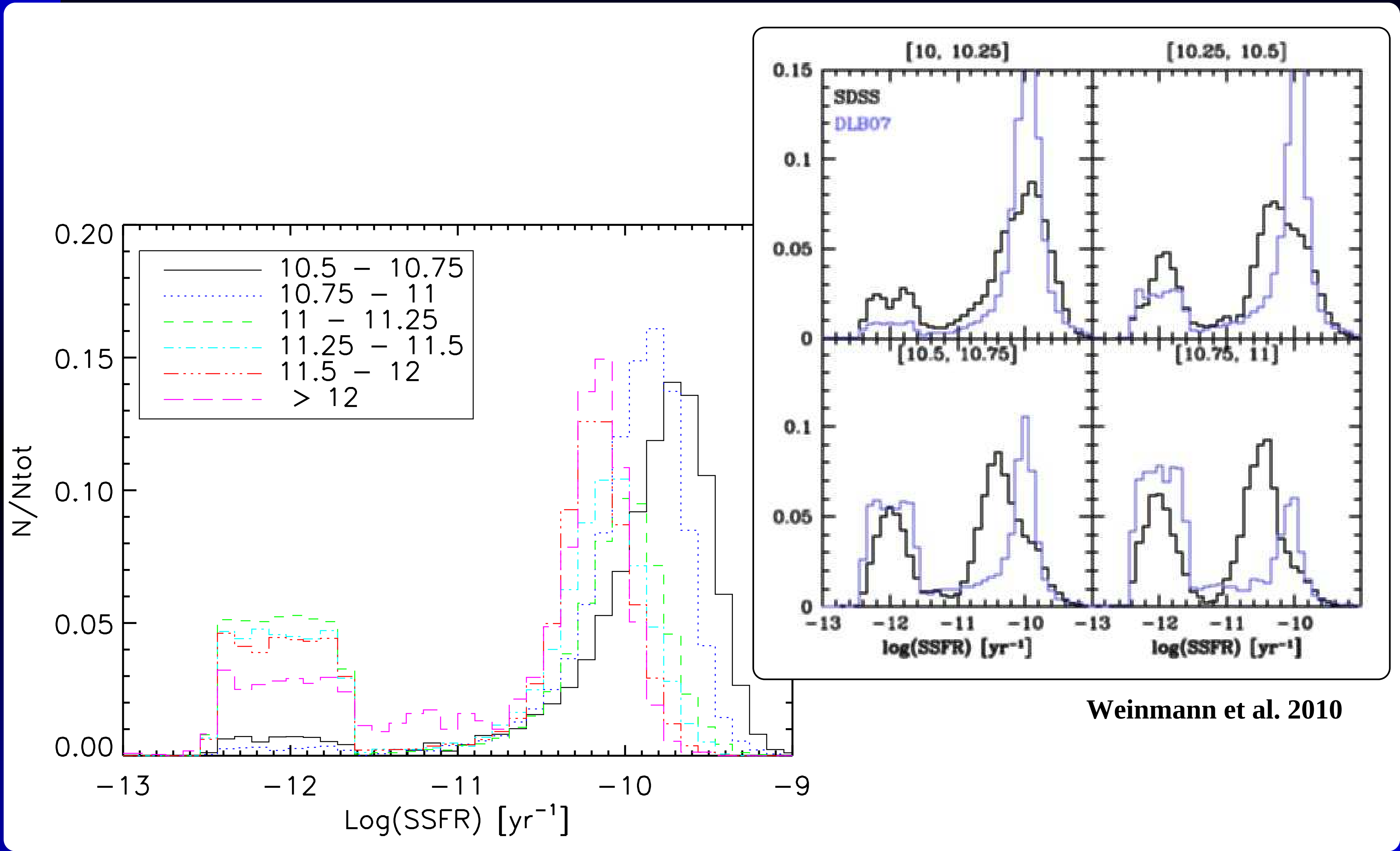



Baldry et al. 2004

Color-Magnitude relation as function of environment.

A. Saro, work in progress

# Galaxy properties




SSFR (compared to SAM and SDSS, Weinmann 2010)