Title: How non-thermal processes of the intracluster medium affect the Sunyaev-Zeldovich angular power spectrum

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Abstract: "There is considerable uncertainty in the theoretical predictions for the angular power spectrum from the Sunyaev-Zeldovich effect (SZe). The level of precision reached by ACT, SPT, and Planck for measurements of the normalization of the SZe power spectrum, sigma_8, will be limited by the uncertainty in the theoretical models for the angular power spectrum. The uncertainties in the predicted spectrum arise from the complicated physics of the ICM. We have explored these ICM complexities using hydrodynamical simulations in a cosmological setting with several different variants of simulated physics, including cooling and star formation, star formation feedback by galactic winds and supernovae as well as cosmic ray physics.

Our statistics were compiled from two independently stacked cluster samples consisting of cosmological box simulations and individual high-resolution cluster simulations. We show that a simple parametrized fit describes averaged ICM pressure profiles sufficiently well and compare this finding to previous hydrostatic models. We find that radiative cooling and the associated star formation is the dominant physical process that modifies our fit parameters for these profiles and the angular power spectrum.

"

How non-thermal processes of the intracluster medium affect the Sunyaev-Zeldovich angular power spectrum

Nick Battaglia

J. Richard Bond, Christoph Pfrommer, Jonathan Sievers;

+Debora Sijacki (on AGN feedback)

Contents

- Introduction (dick's talk)
- Motivation
- Method
- Simulations
- Results

Compiled large sample of clusters using hydrodynamical simulations with variants of physics and we show that a simple parameterized fit describes our averaged ICM pressure profiles sufficiently well

Motivation

- The level of precision reached by ACT, SPT, and Planck for measurements of the normalization of the SZe power spectrum, σ_8, will be limited by the uncertainty in the theoretical models for the angular power spectrum.
- Understanding of the current SZe power spectrum measurements (Jon's talk)

Angular power spectrum

$$C_l = g_\nu^2 \int_0^{z_{\max}} dz \frac{dV}{dz} \int dM \frac{dn(M,z)}{dM} \left| \widetilde{y}_l(M,z) \right|^2$$

- Halo formalism (Bond 88, Cole & Kaiser 88)
- Plus clustering of clusters

$$\widetilde{y}_l = \frac{4\pi r_s}{l_s^2} \int_0^\infty x^2 y_{3D}(x) \frac{\sin(lx/l_s)}{lx/l_s} dx$$

Pressure profiles

- The uncertainties in the predicted spectrum arise from the complicated physics of the ICM, non-thermal contributions the energy density: Cosmic rays, galactic winds, turbulence, AGN and magnetic fields.
- How can one attack this Problem?
- Observations
- Analytics
- Simulations

Simulations

SPH Gadget-2 & Gadget-3

Two types of simulations

High resolutions zoom simulations.

Cosmological box simulations.

Multiple sets of physics were simulated:

- Cooling and Star formation
- Galactic winds
- Cosmic rays (Christoph's talk)

We at look at the redshift evolution

Simulations

Current status with the computing capabilities at cita

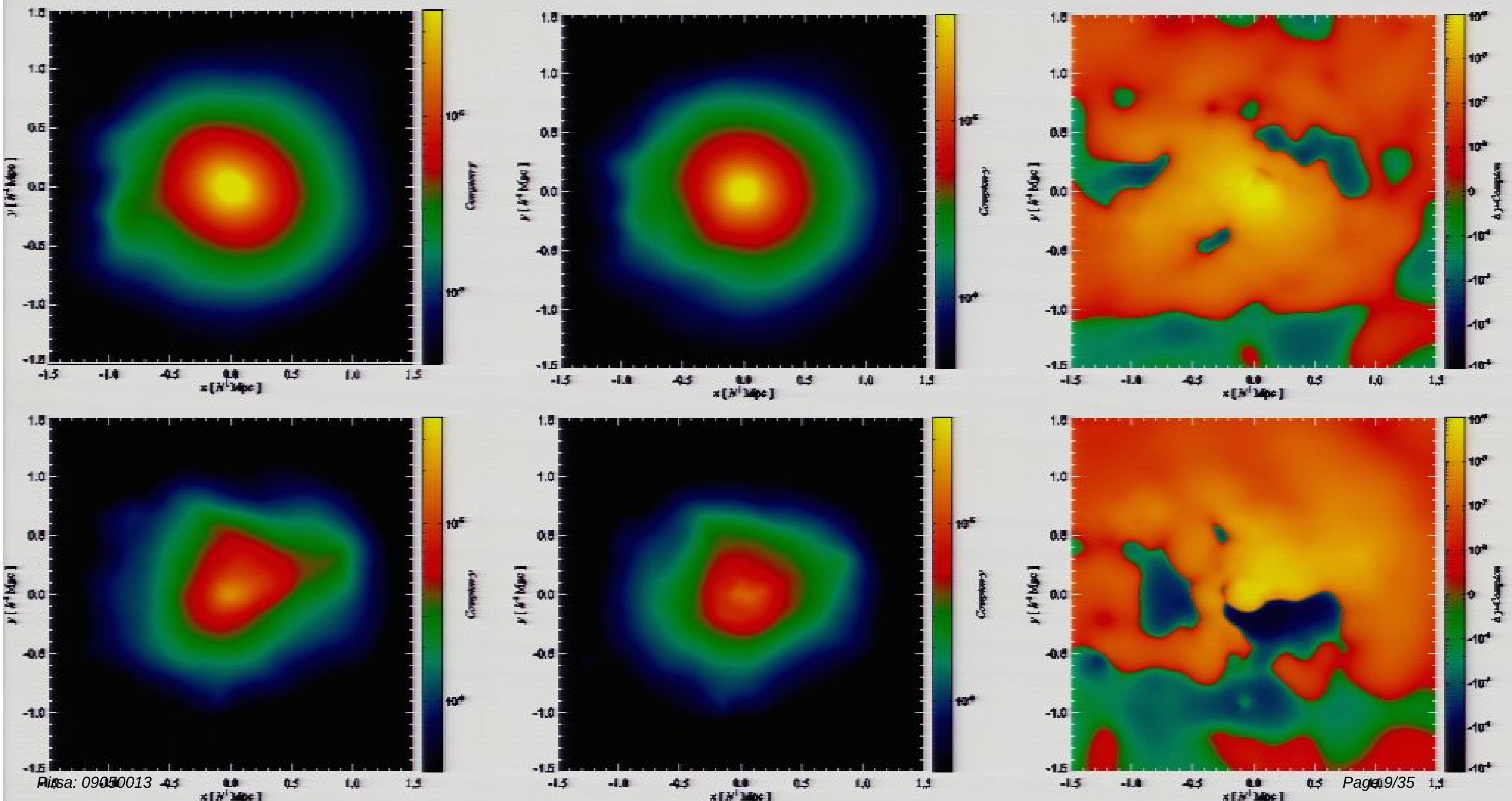
Physics	High Resolutions	256^3 Box Sims	512^3 Box Sims
Non-Rad	x	x	x
Non-Rad+CR	x	-	-
Rad+SF	x	x	Running
Rad+SF+W	-	x	Running
Rad+SF+CR	x	-	-
Rad+SF+CR+SNe	x	-	-
Rad+SF+w+CR+SNe	-	x	Running

All simulations have over-cooling problem

Ran 128^3 for (non) convergence test

Simulations

Projected electron pressure (Compton-y)

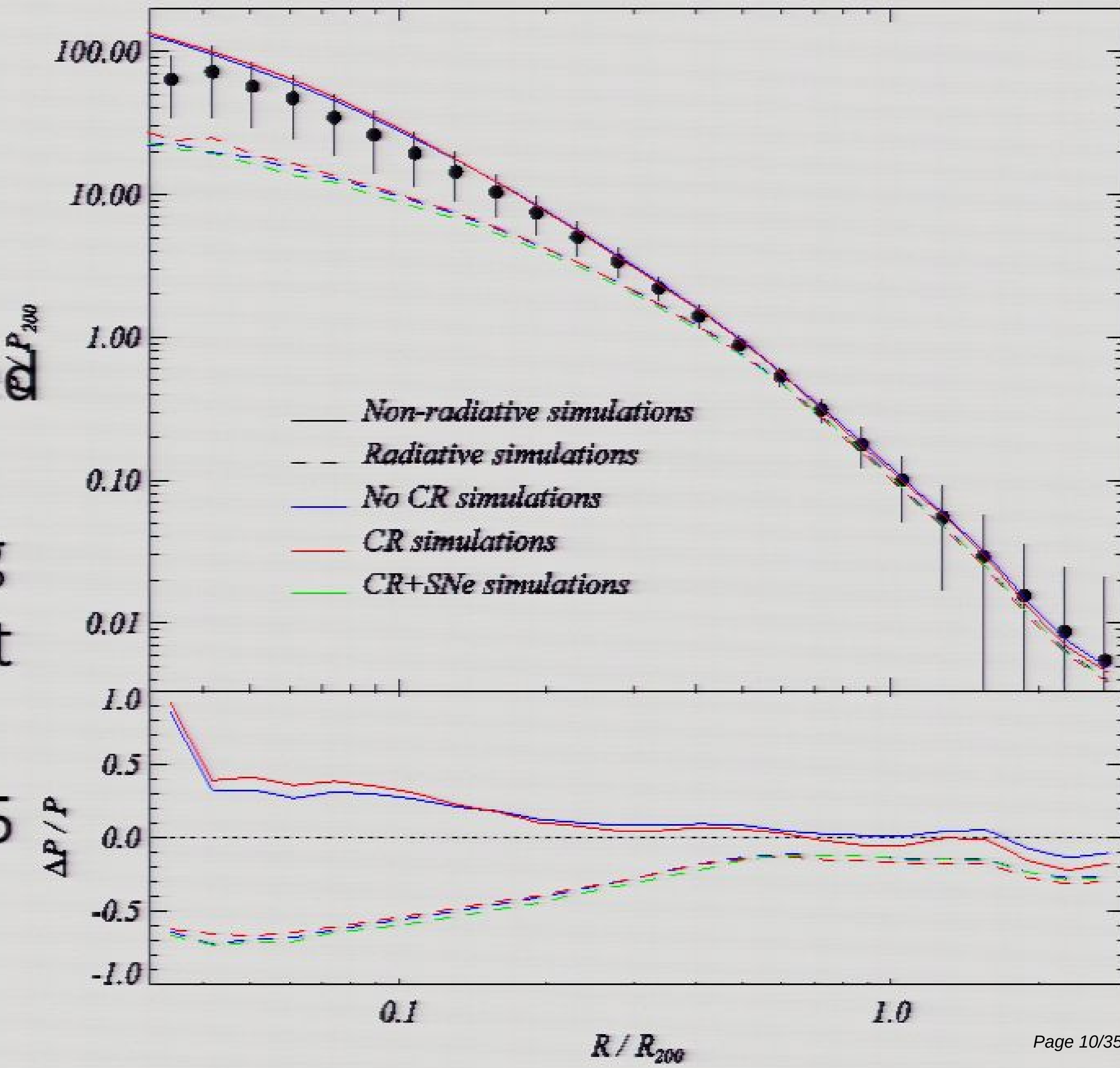


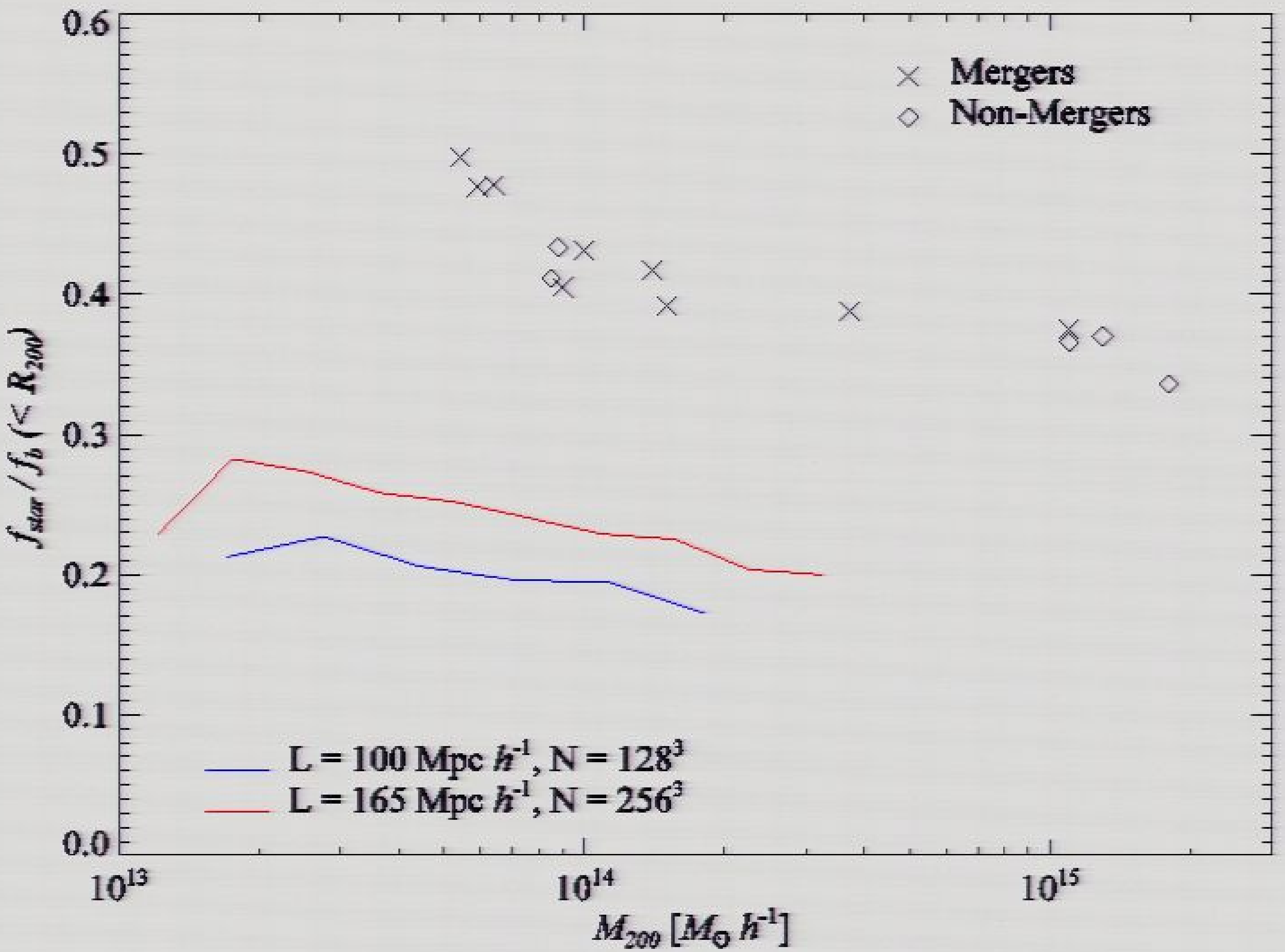
z = 0

14 stacked HR clusters

cf. 480 stacked box clusters

- Over cooling
→core cutout
- Δ HR & Box is ~20% at 0.5 r/R_{200}

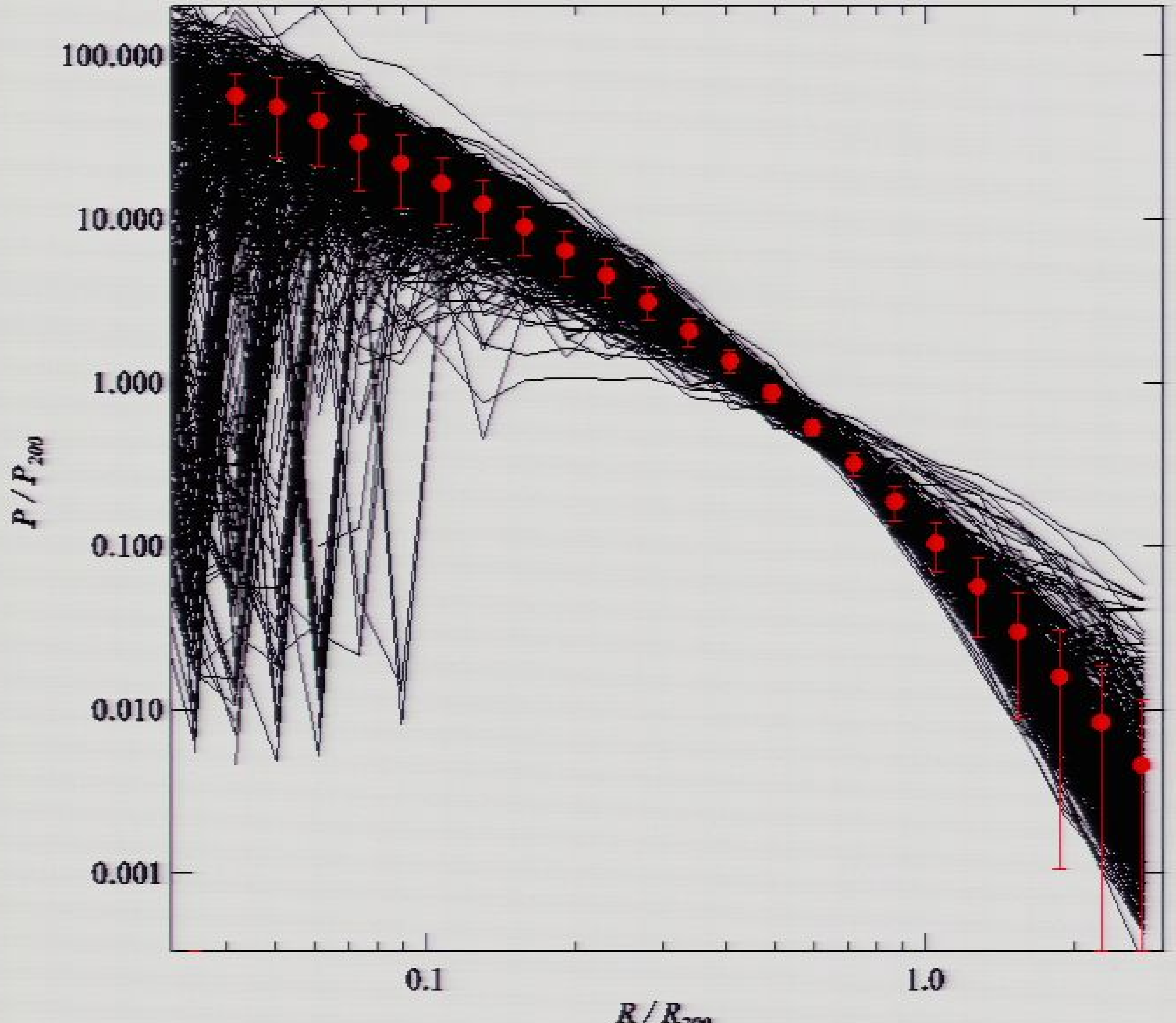




Difference ~20%

Half the stars are at the center

Lack of convergence in the cooling prescription



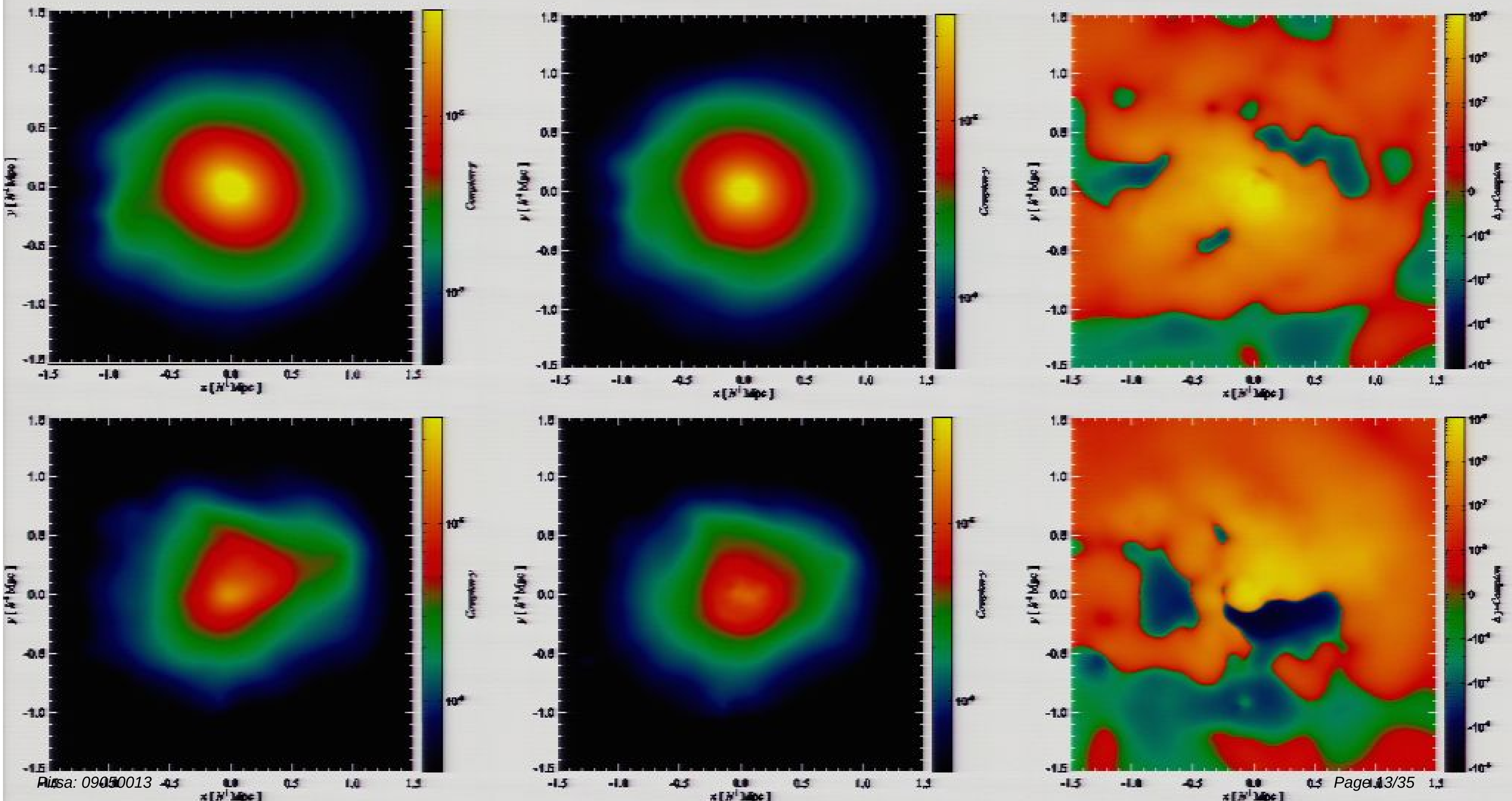
All clusters
Compared to
our average
and scatter
z = 0

Core cutout : Resolutions effects

Over-cooling........

Simulations

Projected electron pressure (Compton-y)



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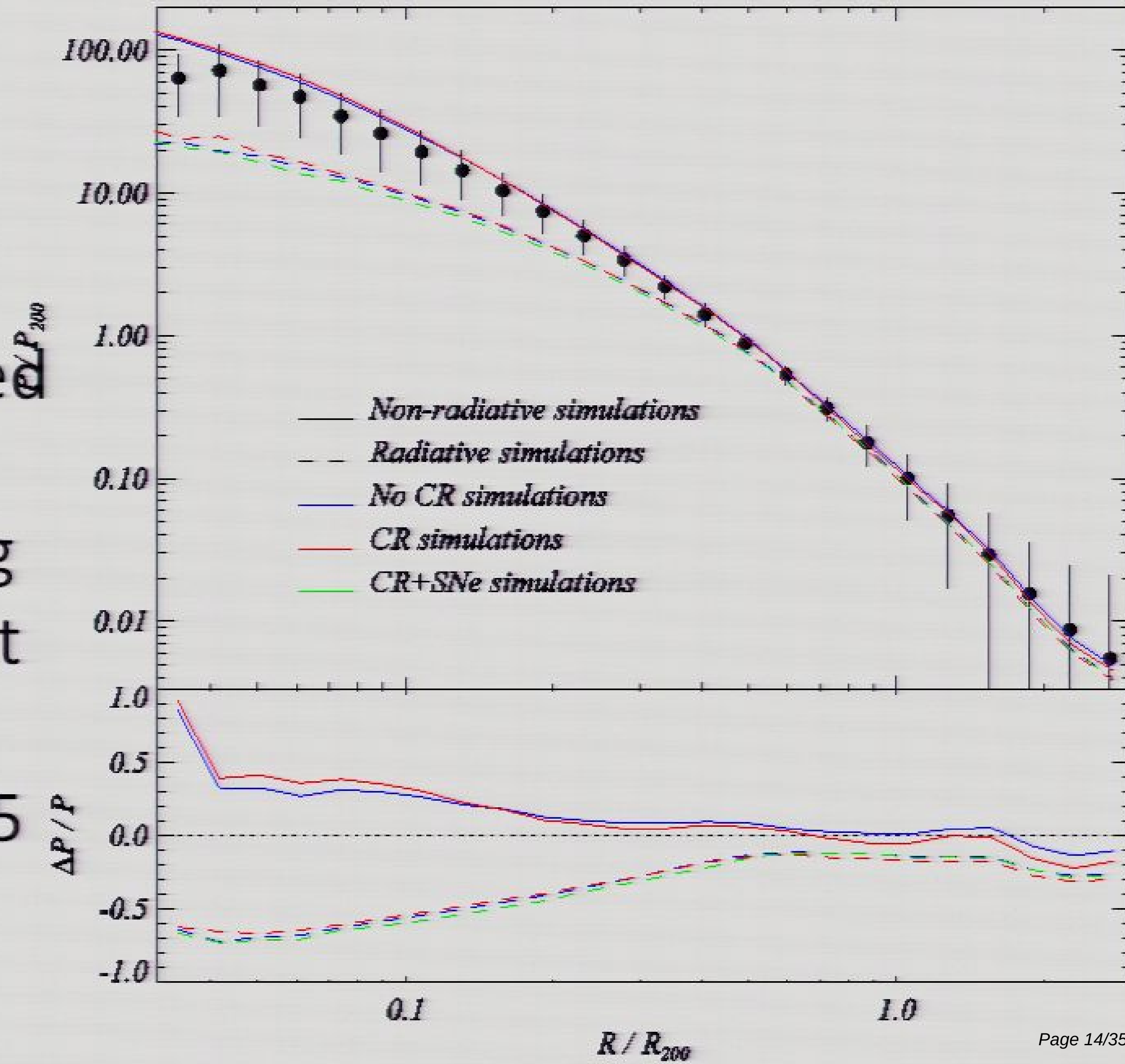
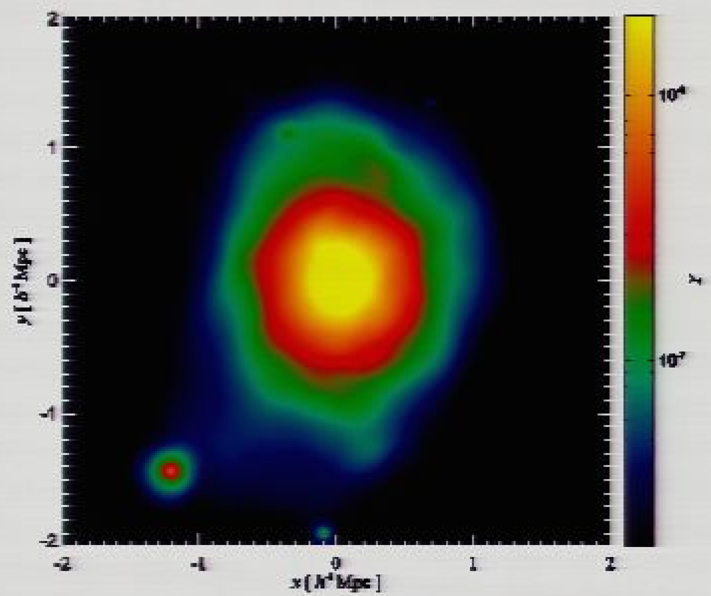
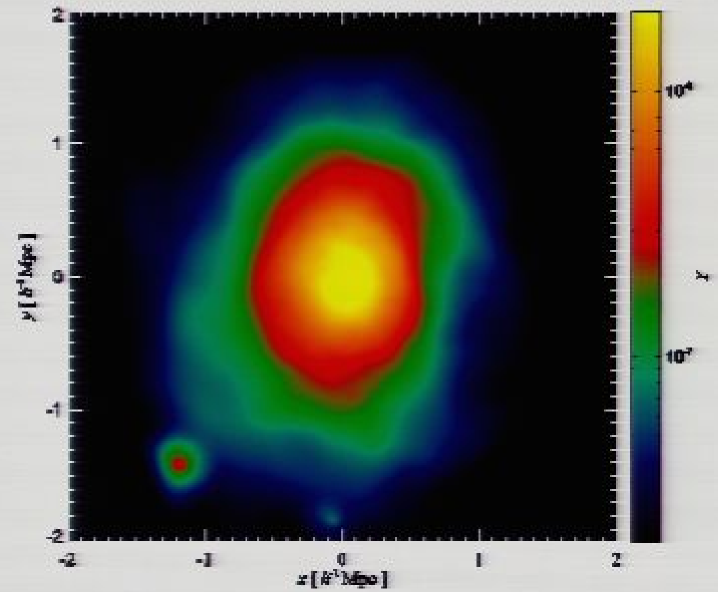


AGN feedback



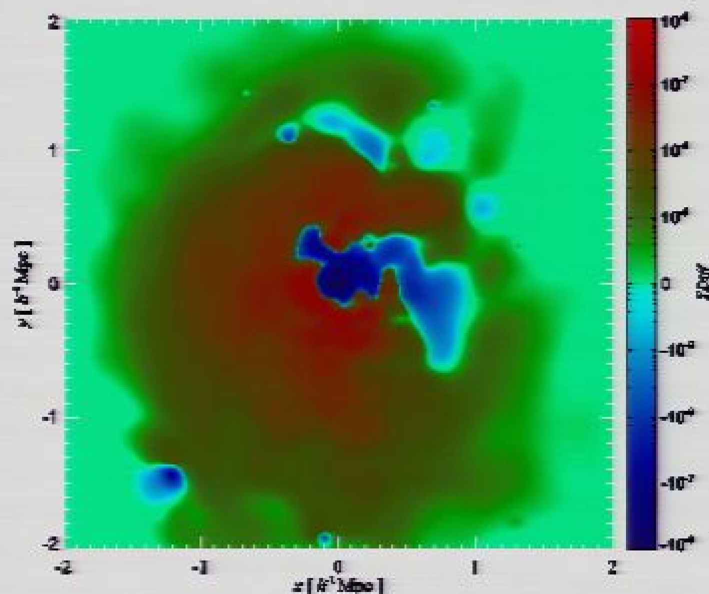


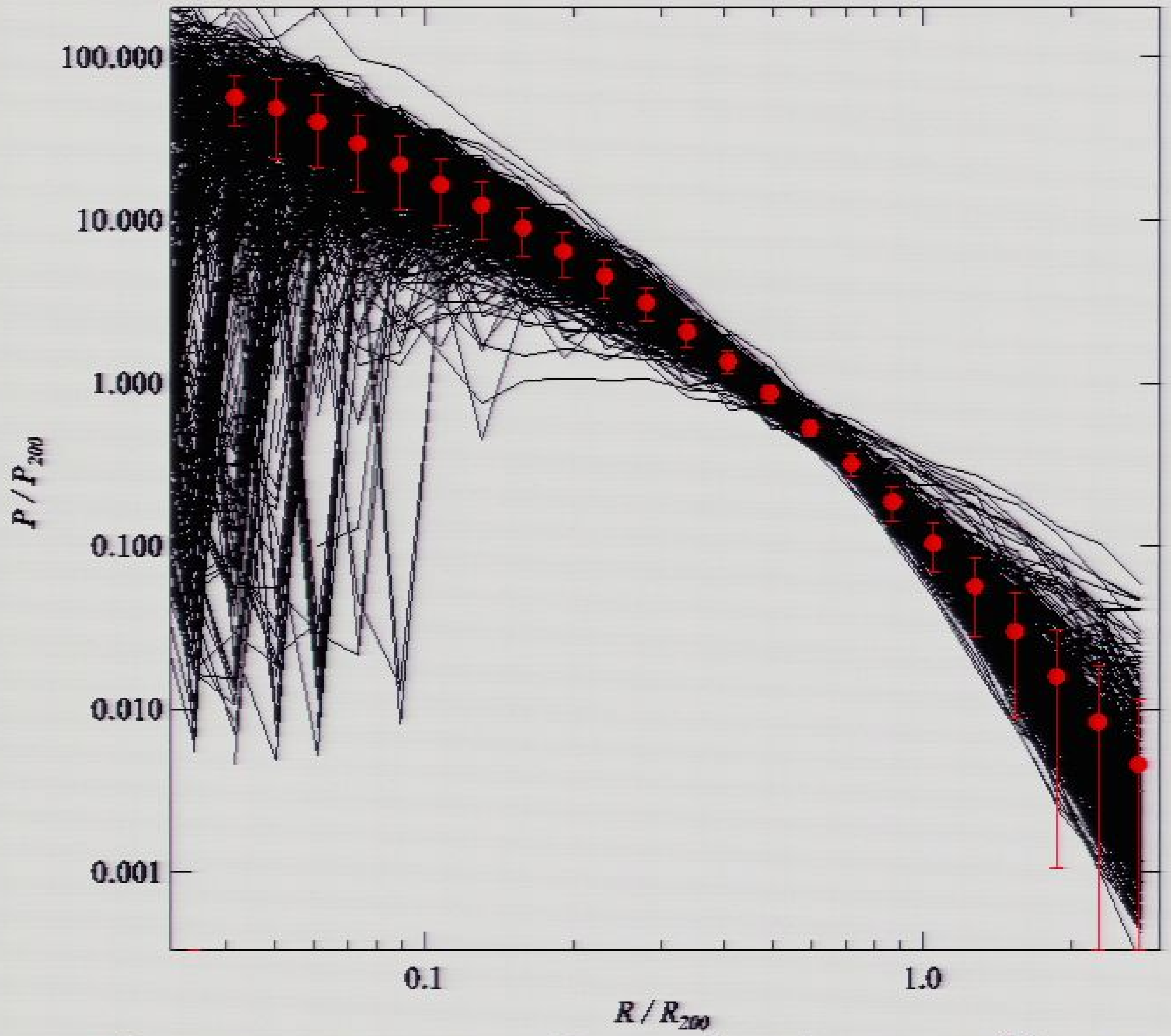
Seed halos with black holes, Bondi-Hoyle acc.

Quasar mode

Mechanical mode (20%)

Sijacki et al. (2007)





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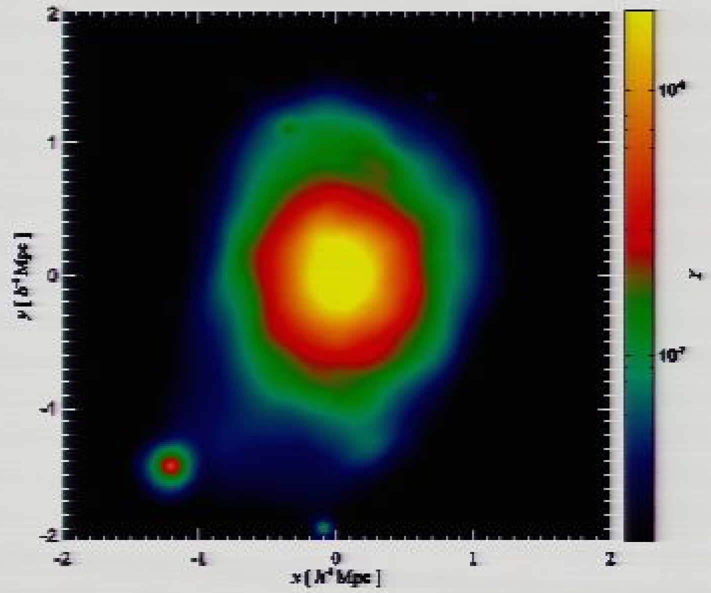

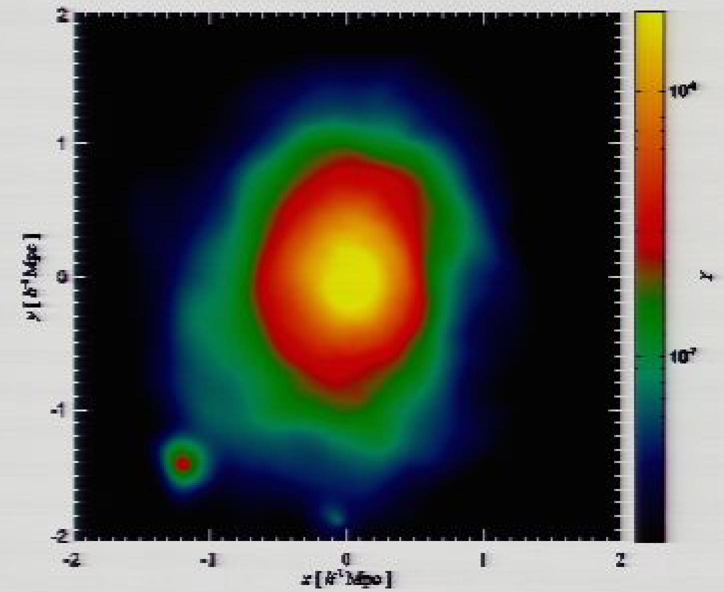

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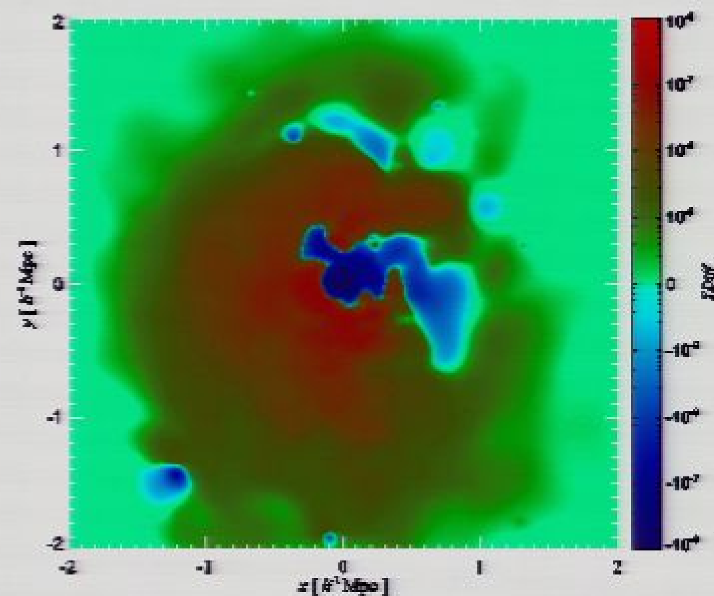

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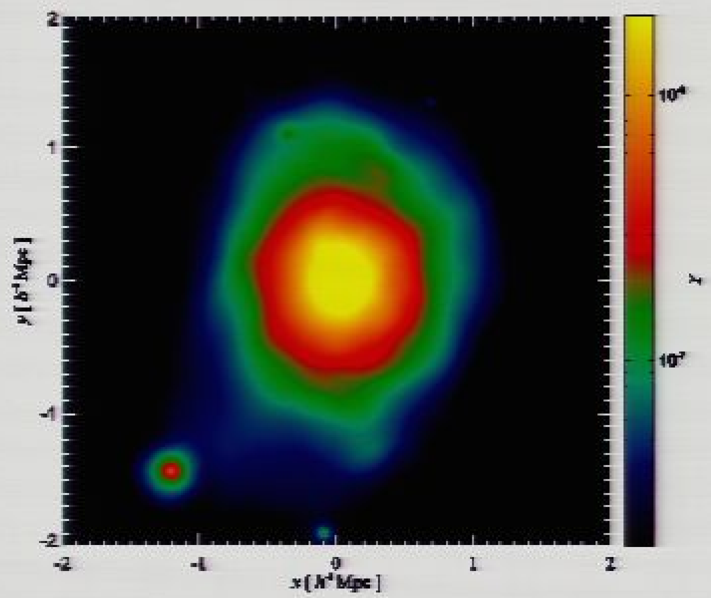
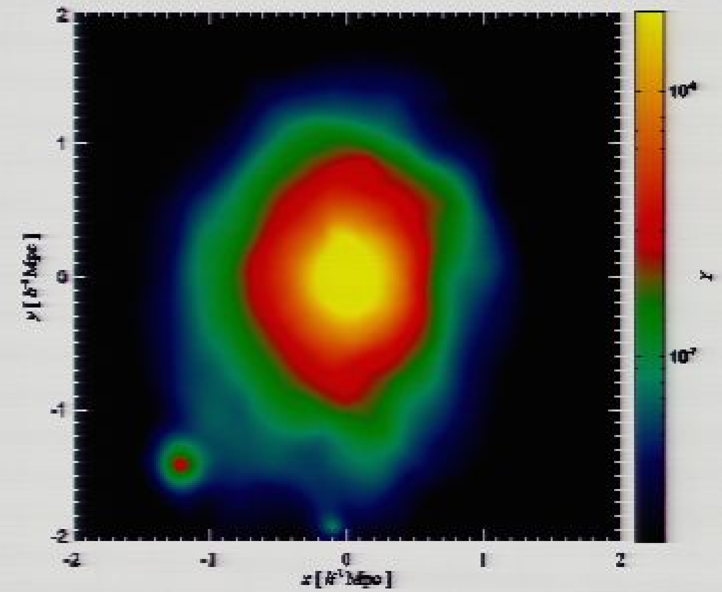
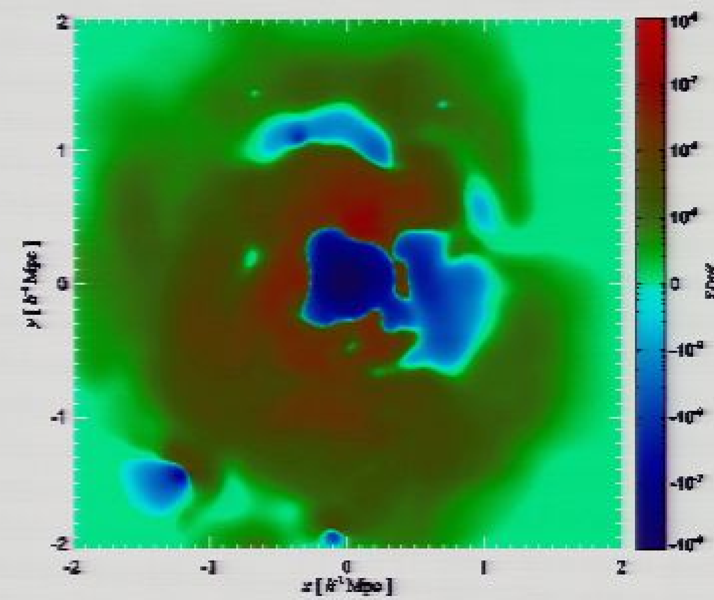




Cosmic ray filled bubbles
(Sijacki et al. 2008)
Small cluster 9×10^{13}



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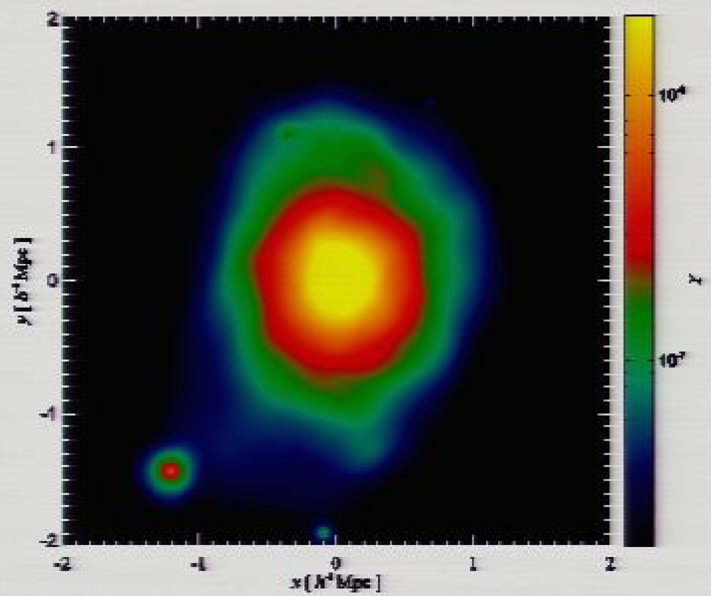

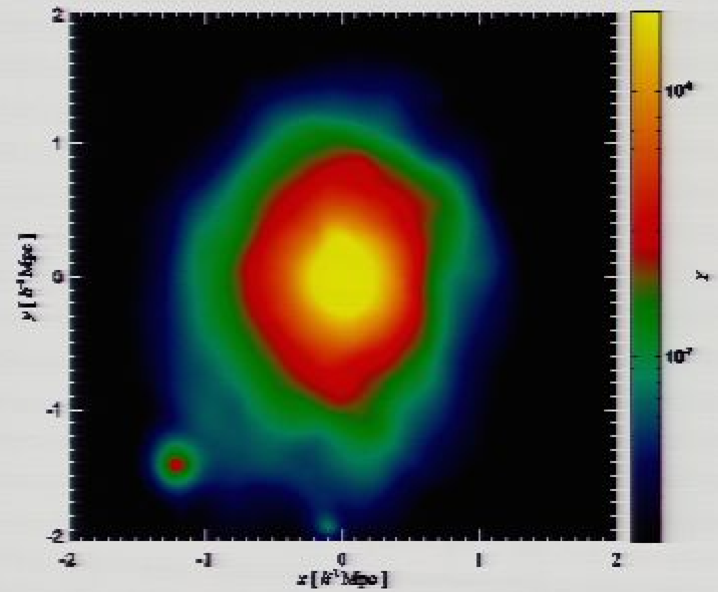

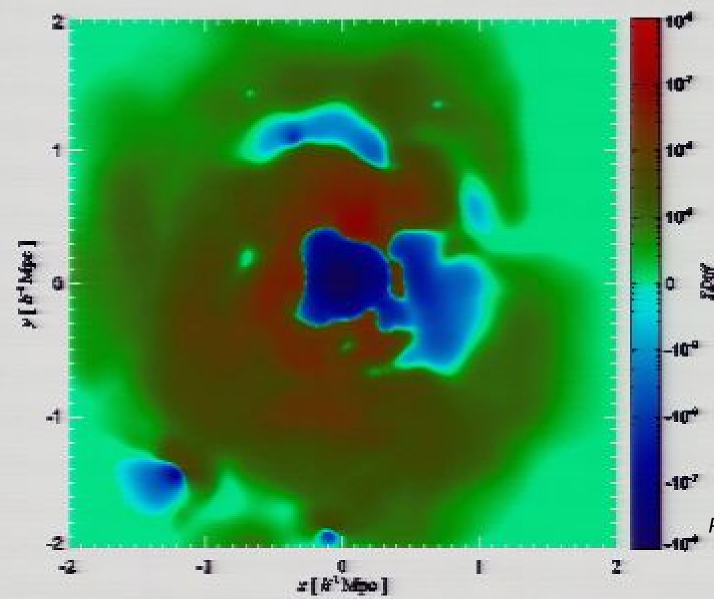

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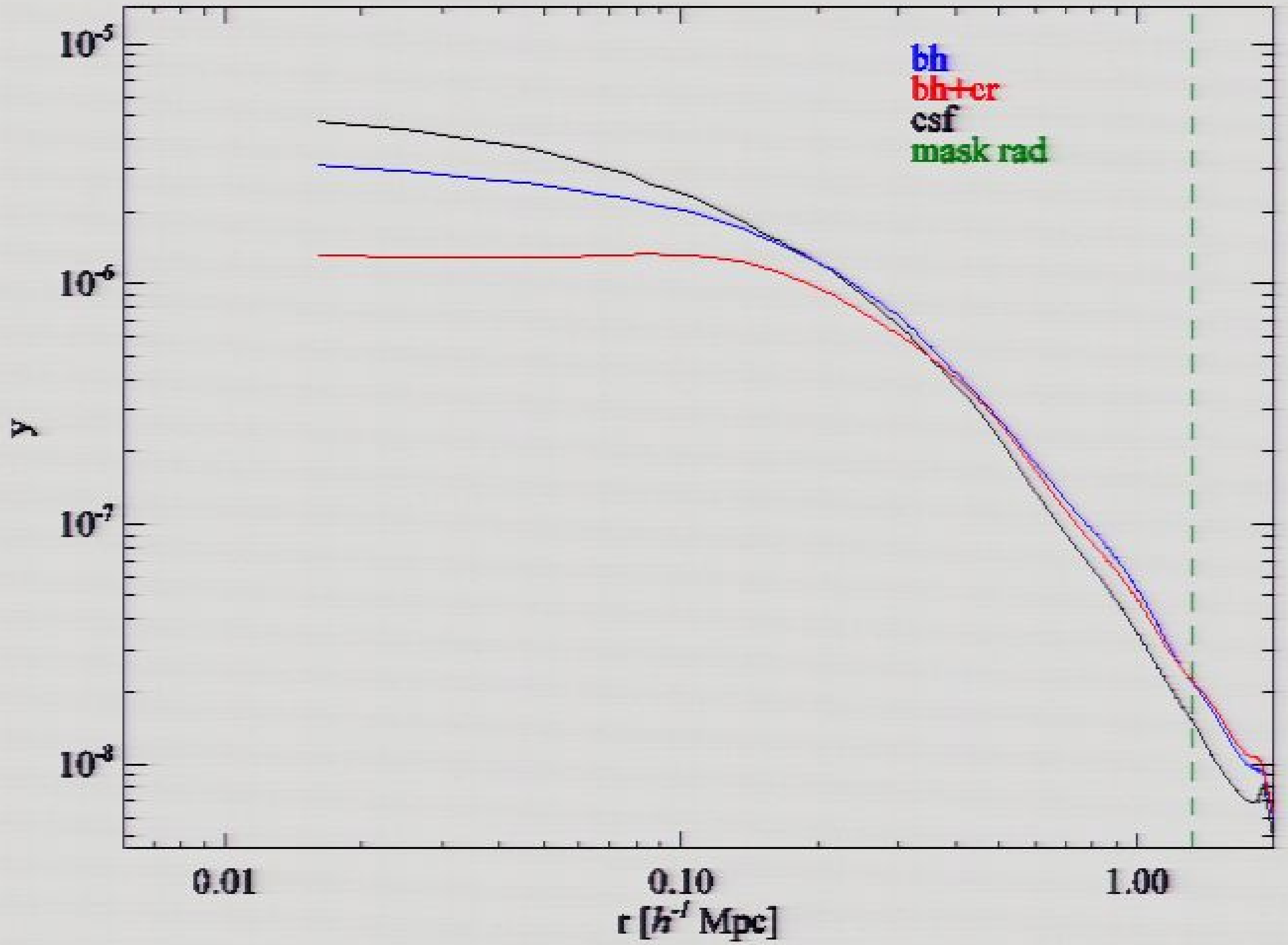
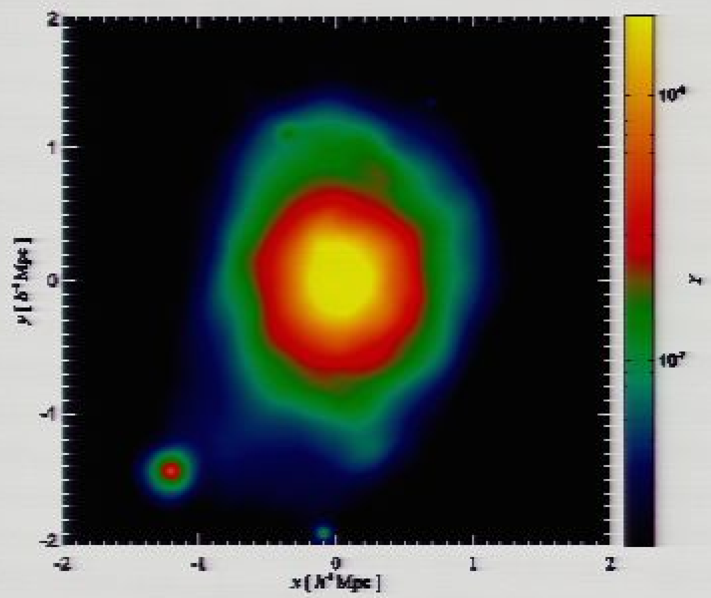
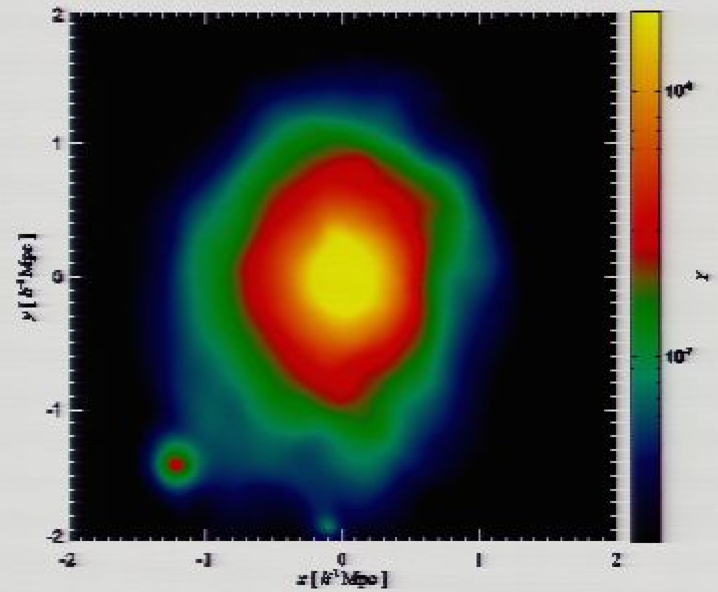


AGN feedback has a significant affect on the profile

We need sub-grid model for this effect

AGN feedback





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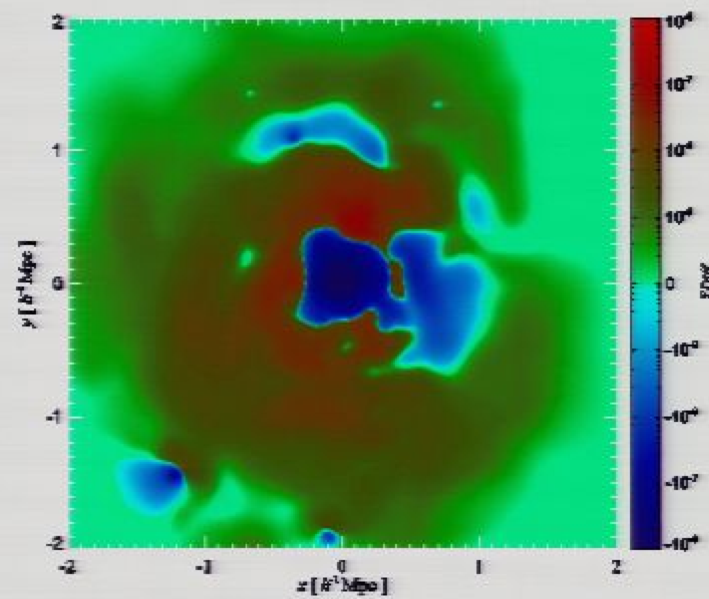

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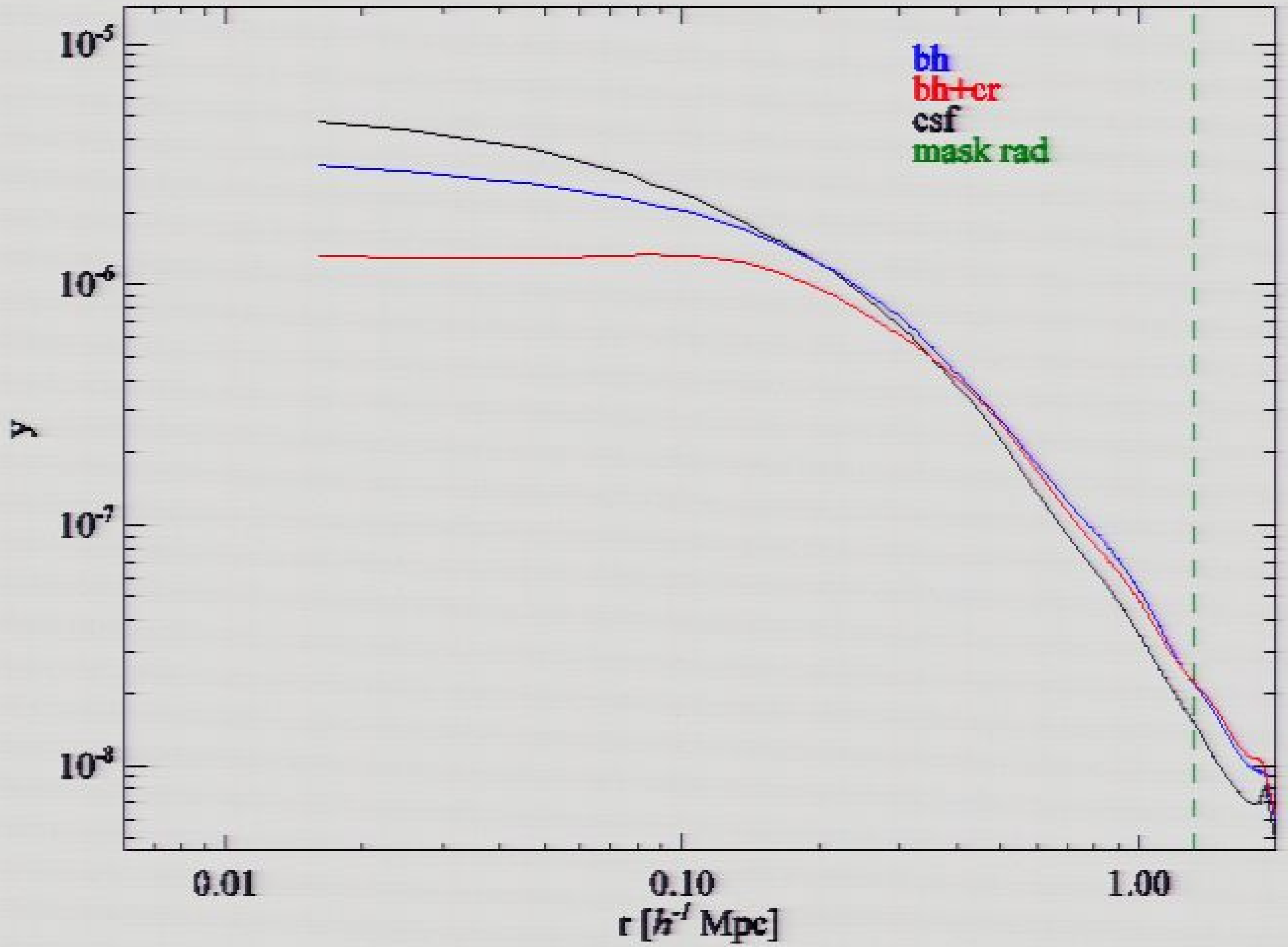

AGN feedback has a significant affect on the profile

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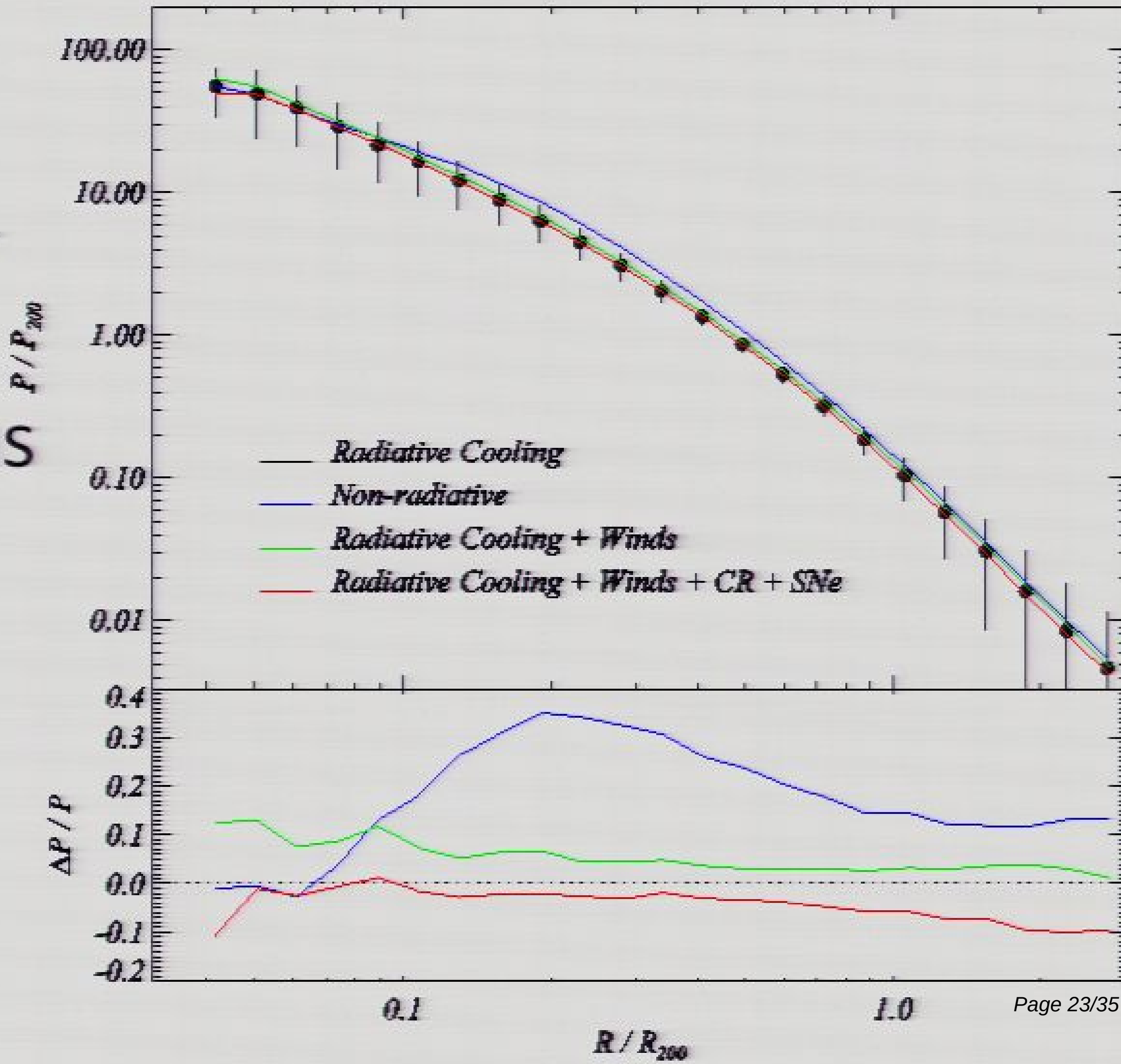
Physics comparison

- Large differences again between non-radiative and radiative simulations
- Cosmic rays and winds have little affect



Phenomenological fits

Modified beta model

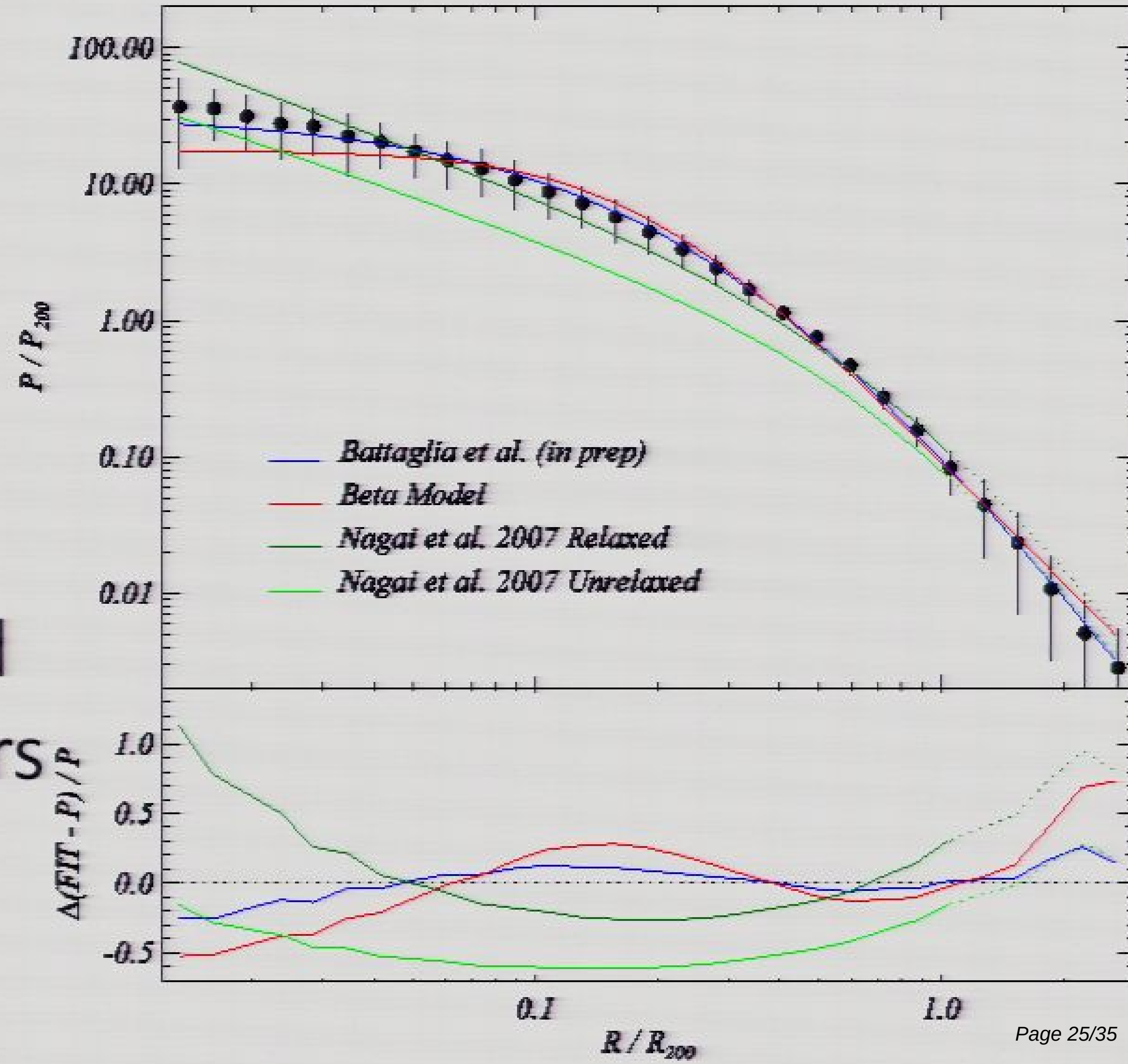
$$P = \frac{P_0}{(1 + r / r_c)^{3\beta}}$$

Beta model

$$P = \frac{P_0}{(1 + [r / r_c]^2)^{3\beta/2}}$$

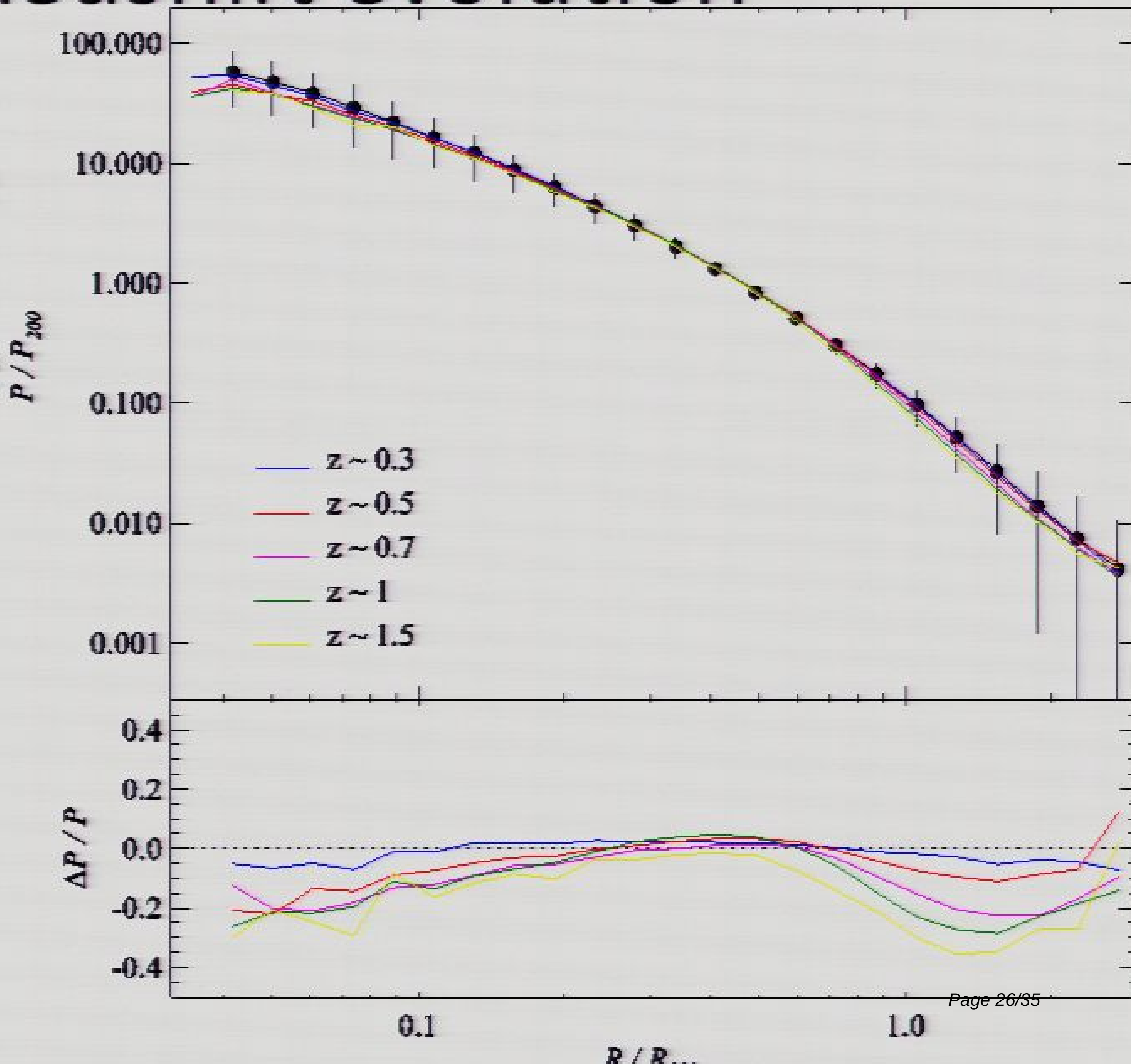
Compare fits

- High resoultion simulations
- Modified beta fits better than the beta model
- Both relaxed and un-relaxed clusters are included

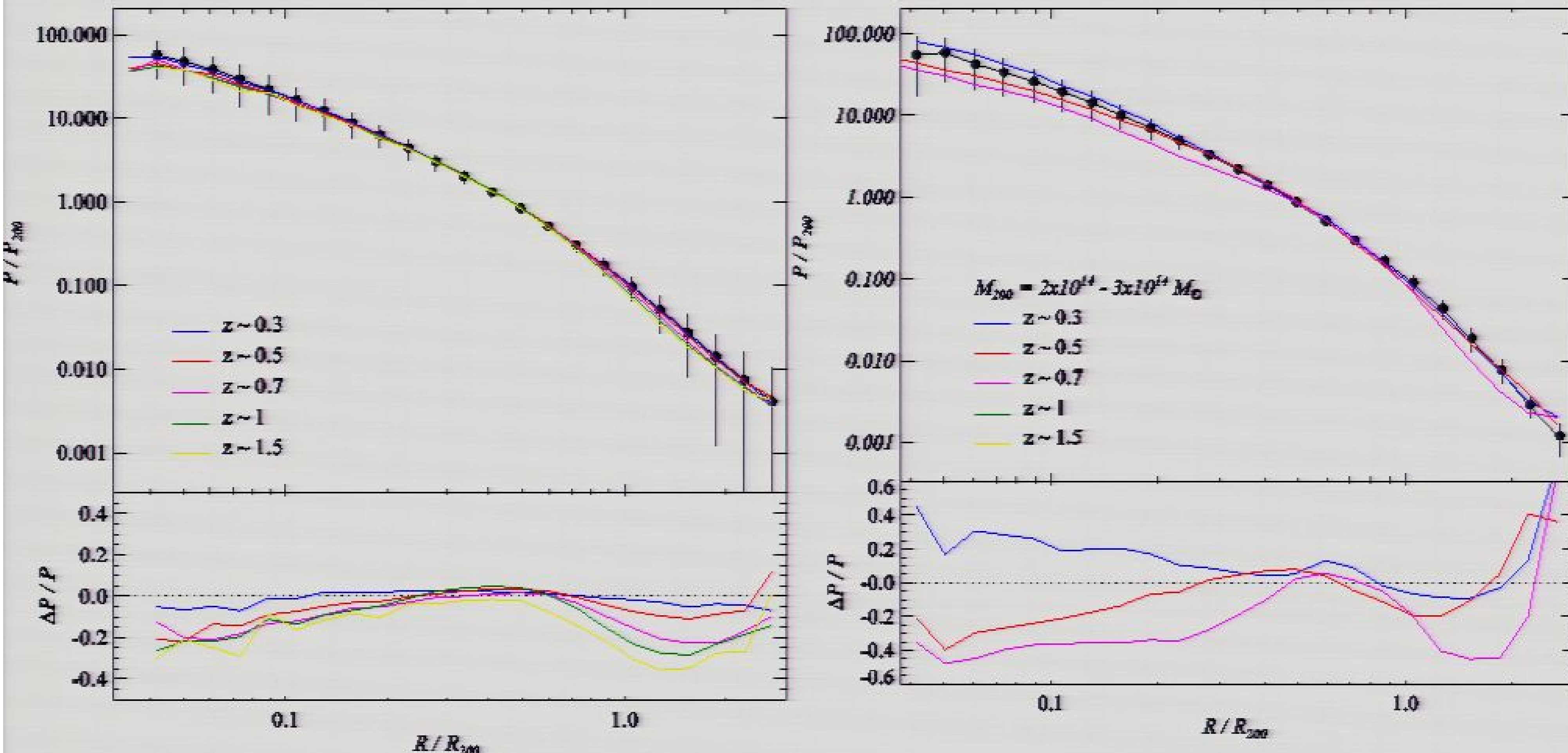


Redshift evolution

- •Central pressure decrease
- •Clusters become "fluffier" and Steeper
- •Influence of small clusters?
- •Why? What is driving this?



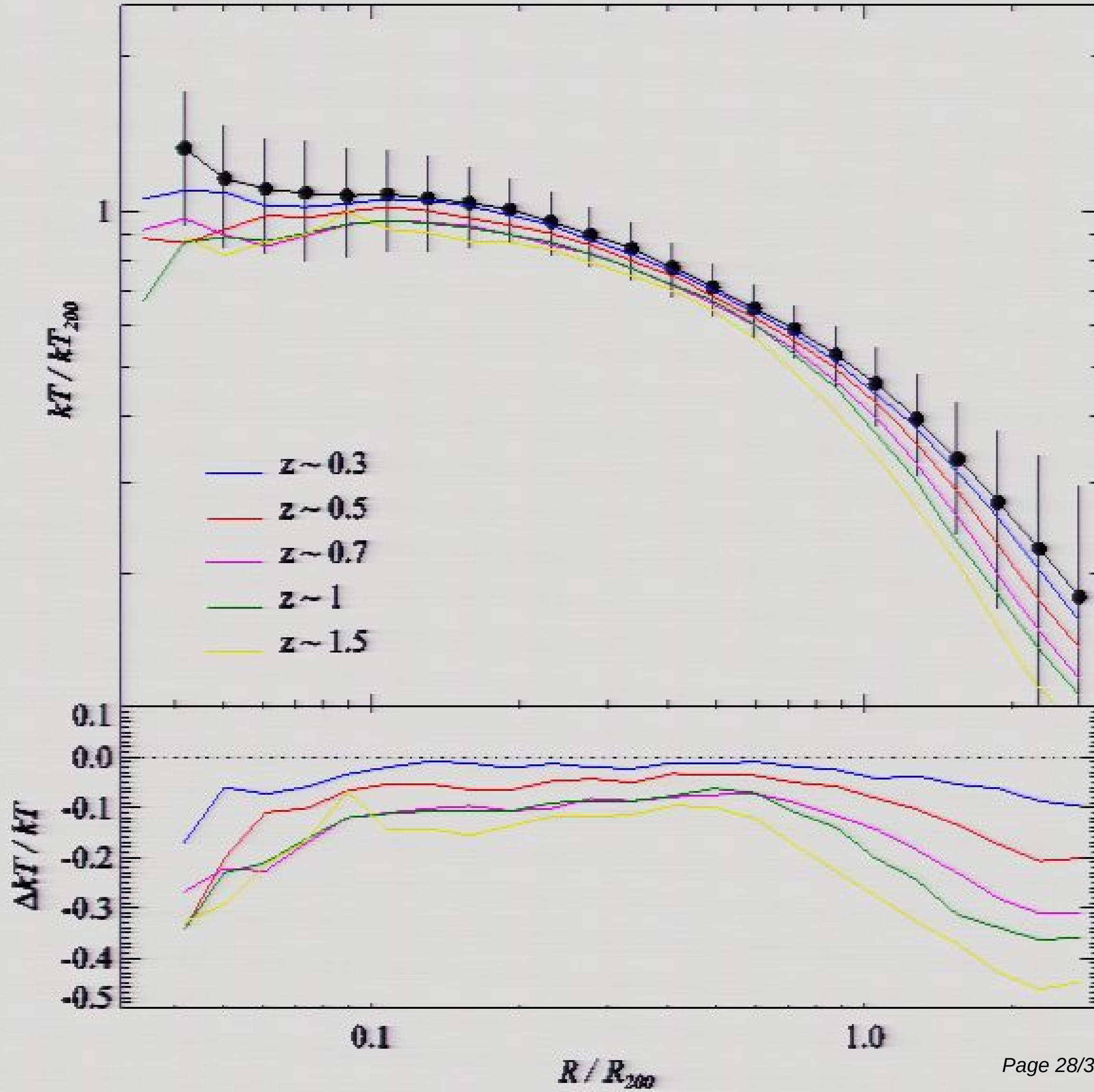
Redshift evolution



- Evolution seen in the higher mass clusters
- Not driven by the low mass clusters

Temperature profiles

- Same trend in temperature
- Clusters are cooler at higher z
- Profiles are steeper



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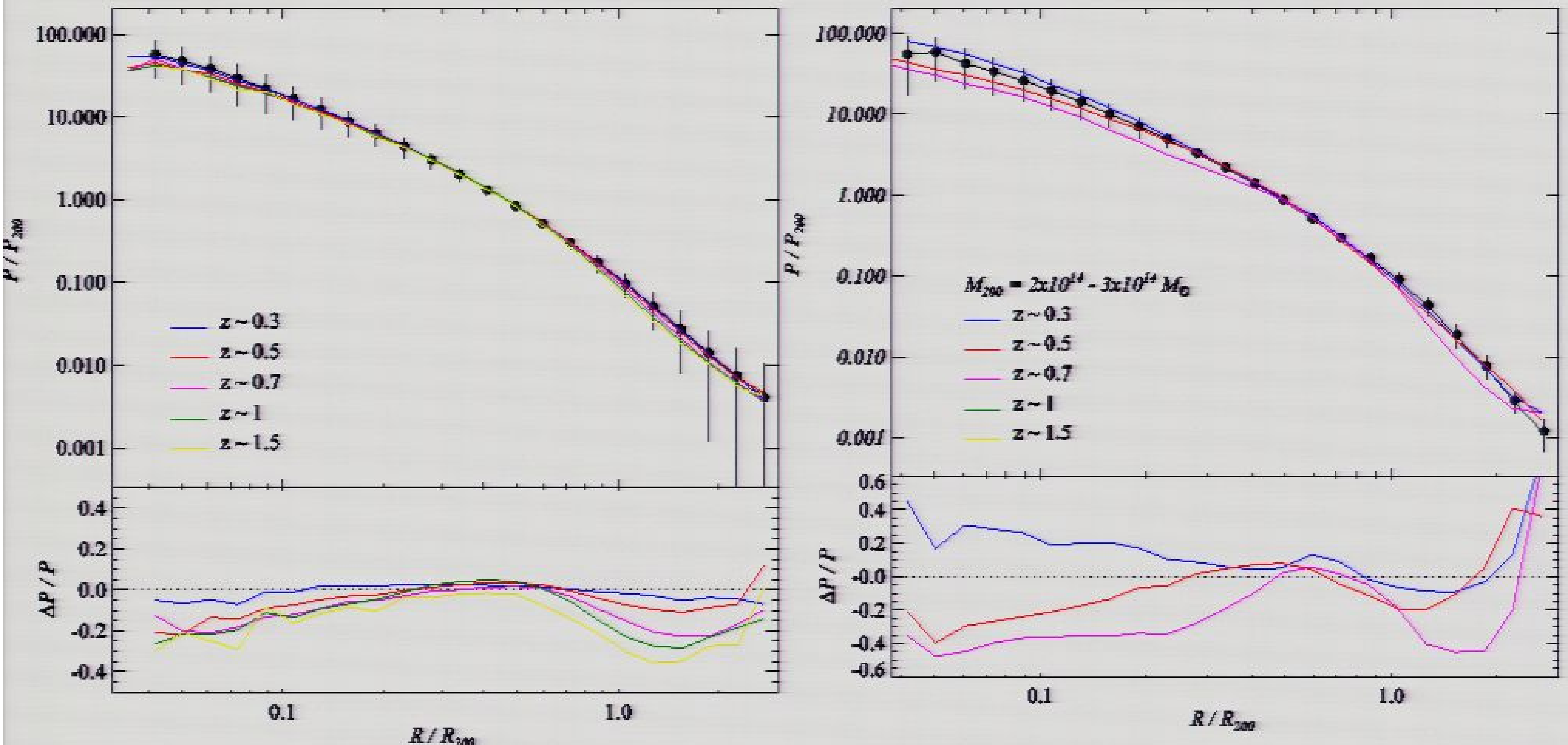

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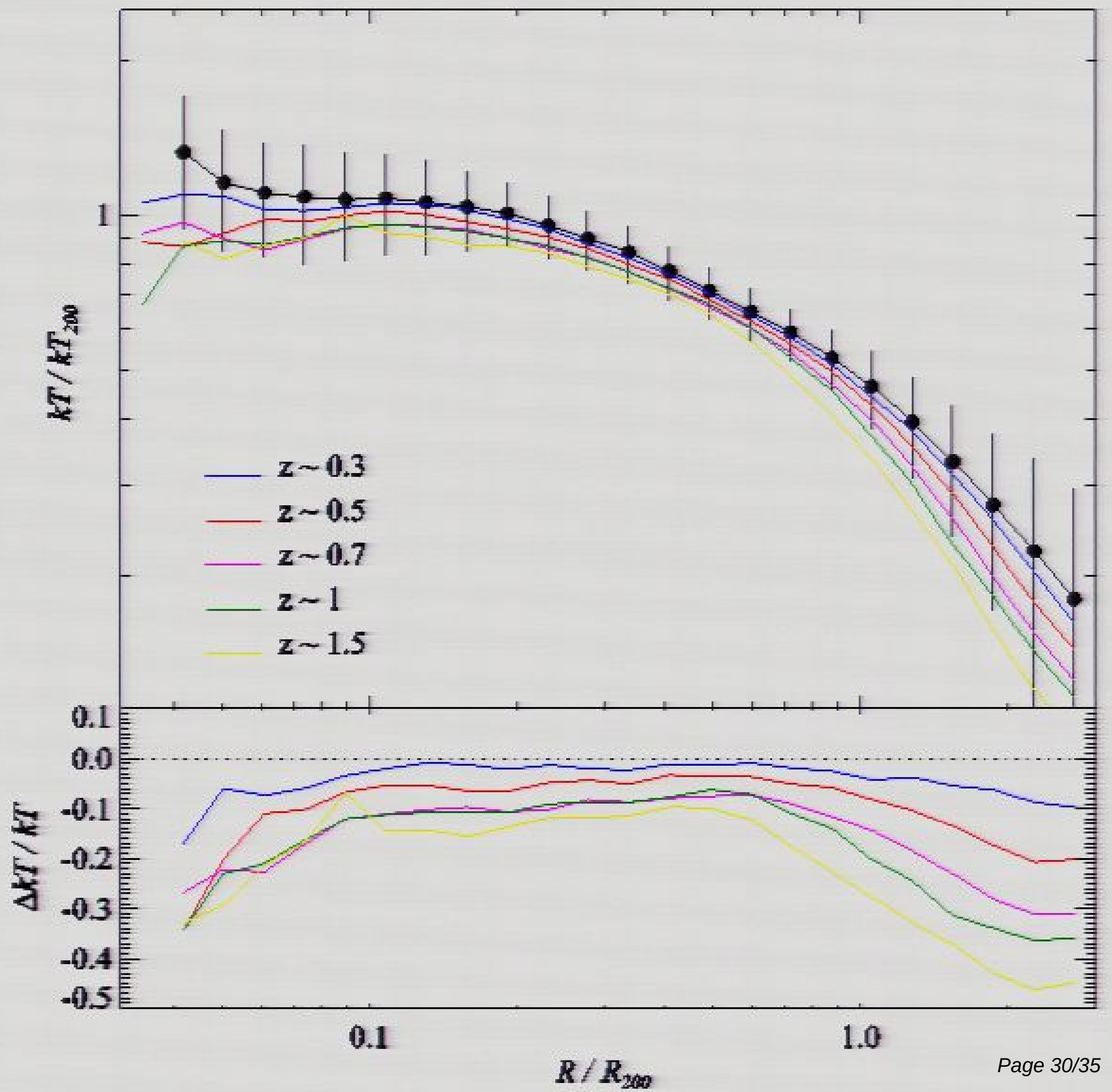
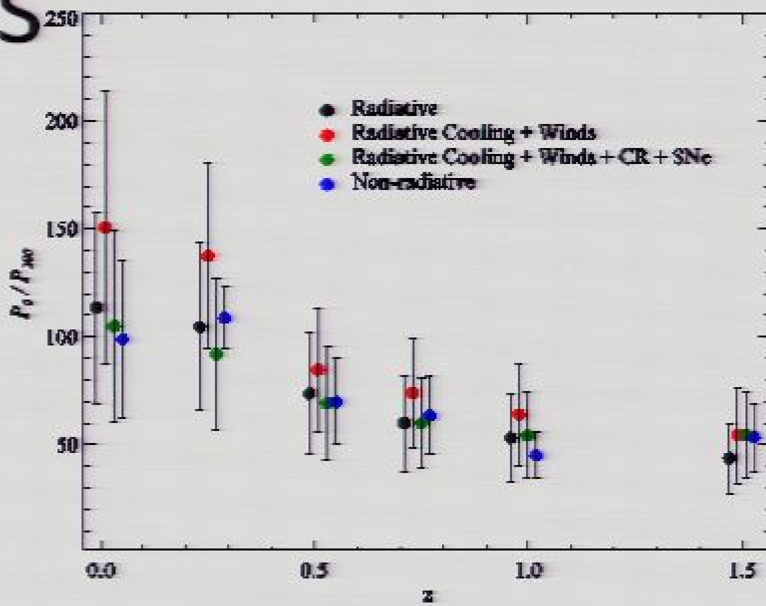
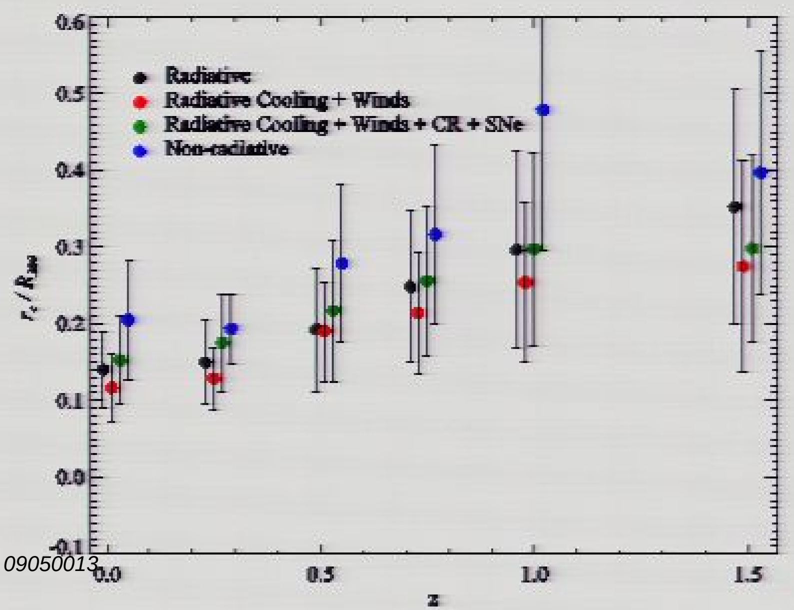
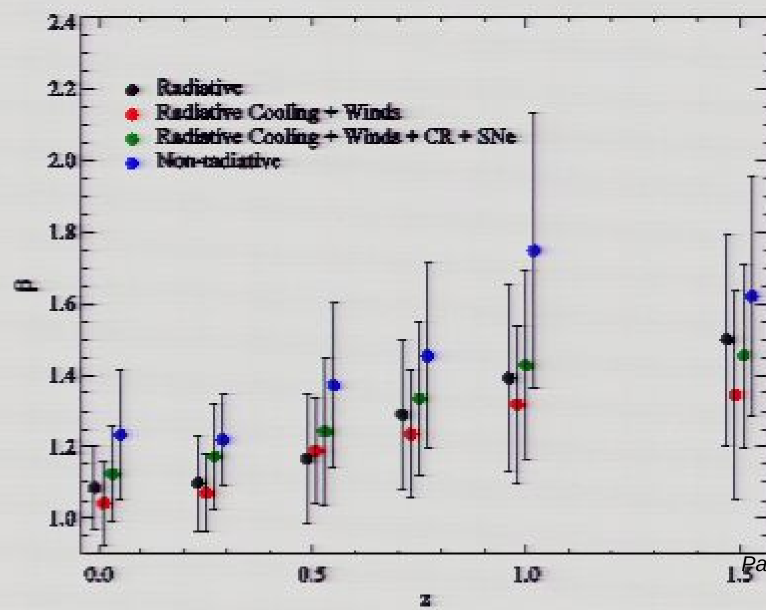


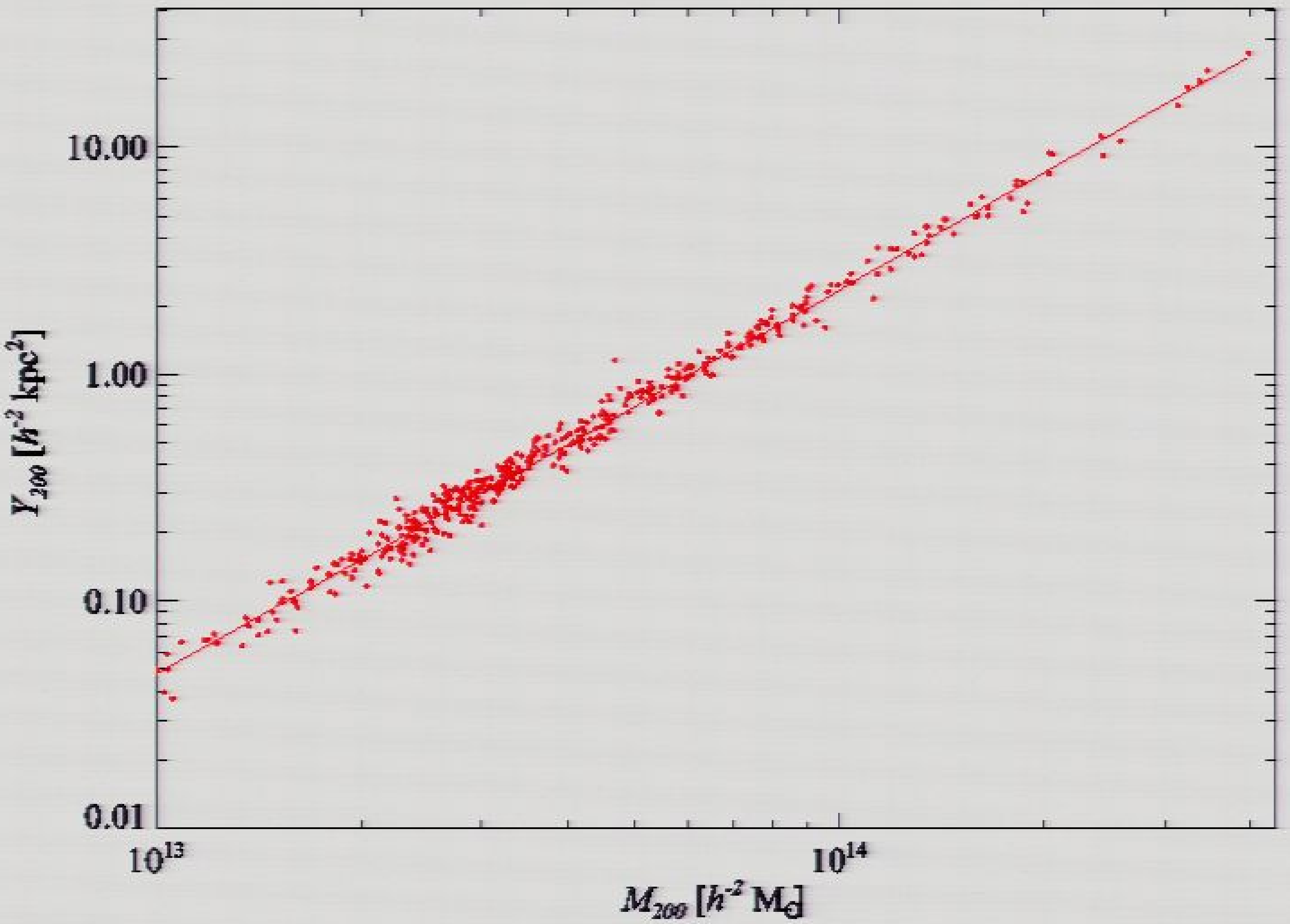
Fits

$$P = \frac{P_0}{(1 + r / r_c)^{3\beta}}$$



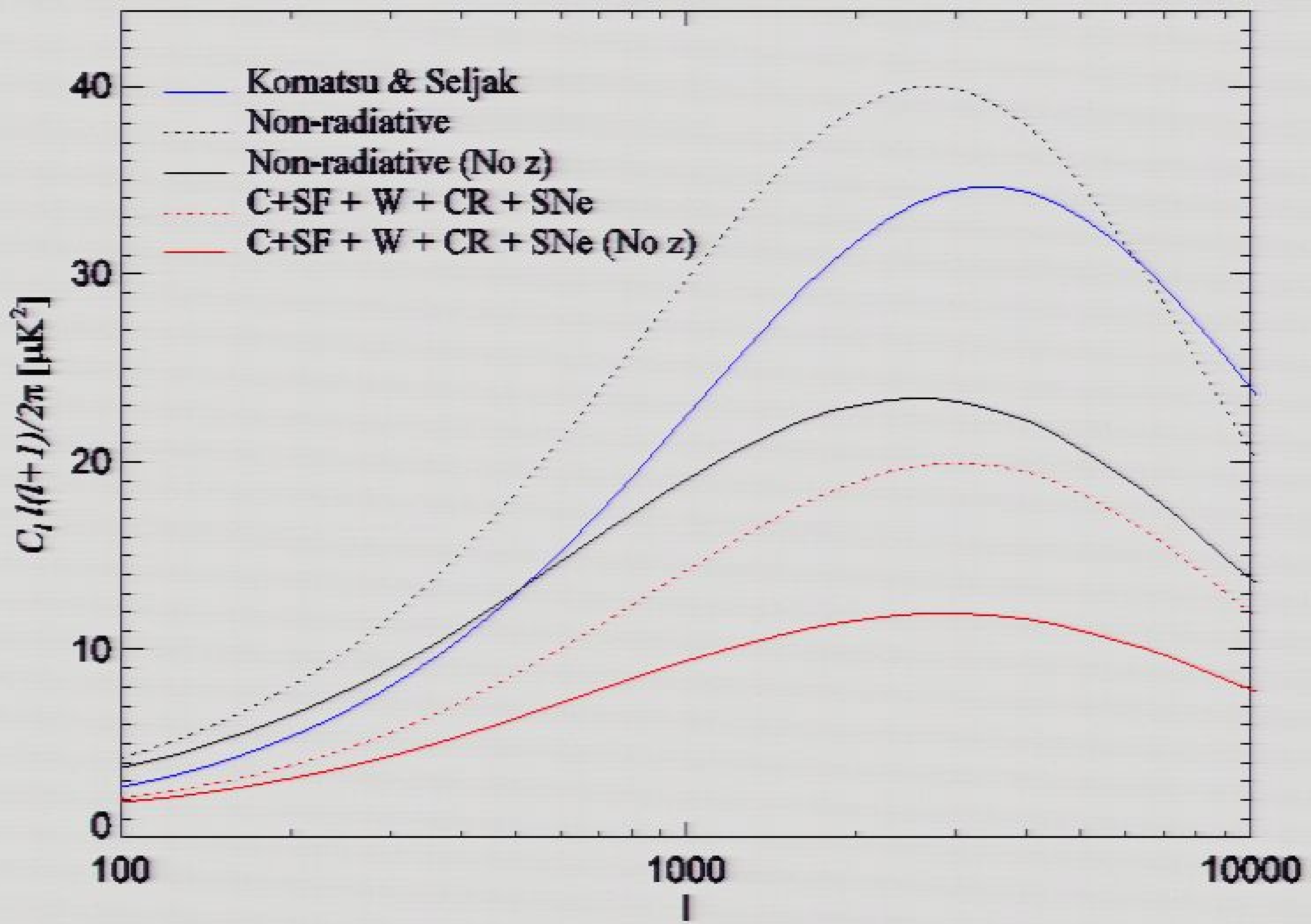






- Y-M relation, our slope is 1.67
- Will look data to see if there is an additional redshift evolution of this scaling relation

Cls



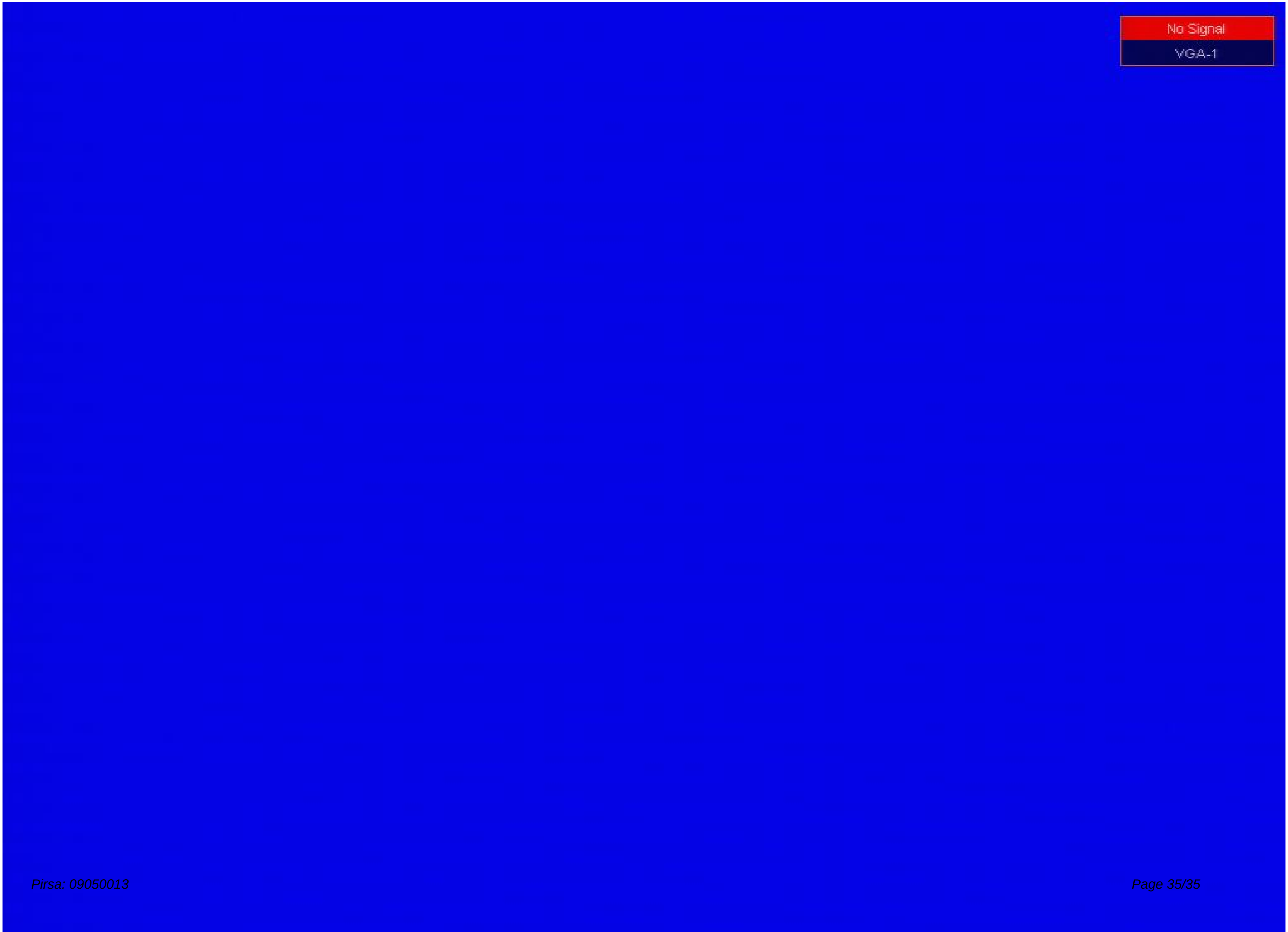
Profiles put into ACT code provided by Hy Trac

Summary

- •Besides "there is much more work to be done"
- •Phemonenological fits works better than the standard beta model
- •Large differences between radiative and non-rad
- •Redshift additional evolution of pressure profiles will have an impact on the Cls

Future work

- •Need sub grid model for AGN feedback
- •Larger simulations (Higher mass clusters)
- •Power spectrum calculation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VGA-1