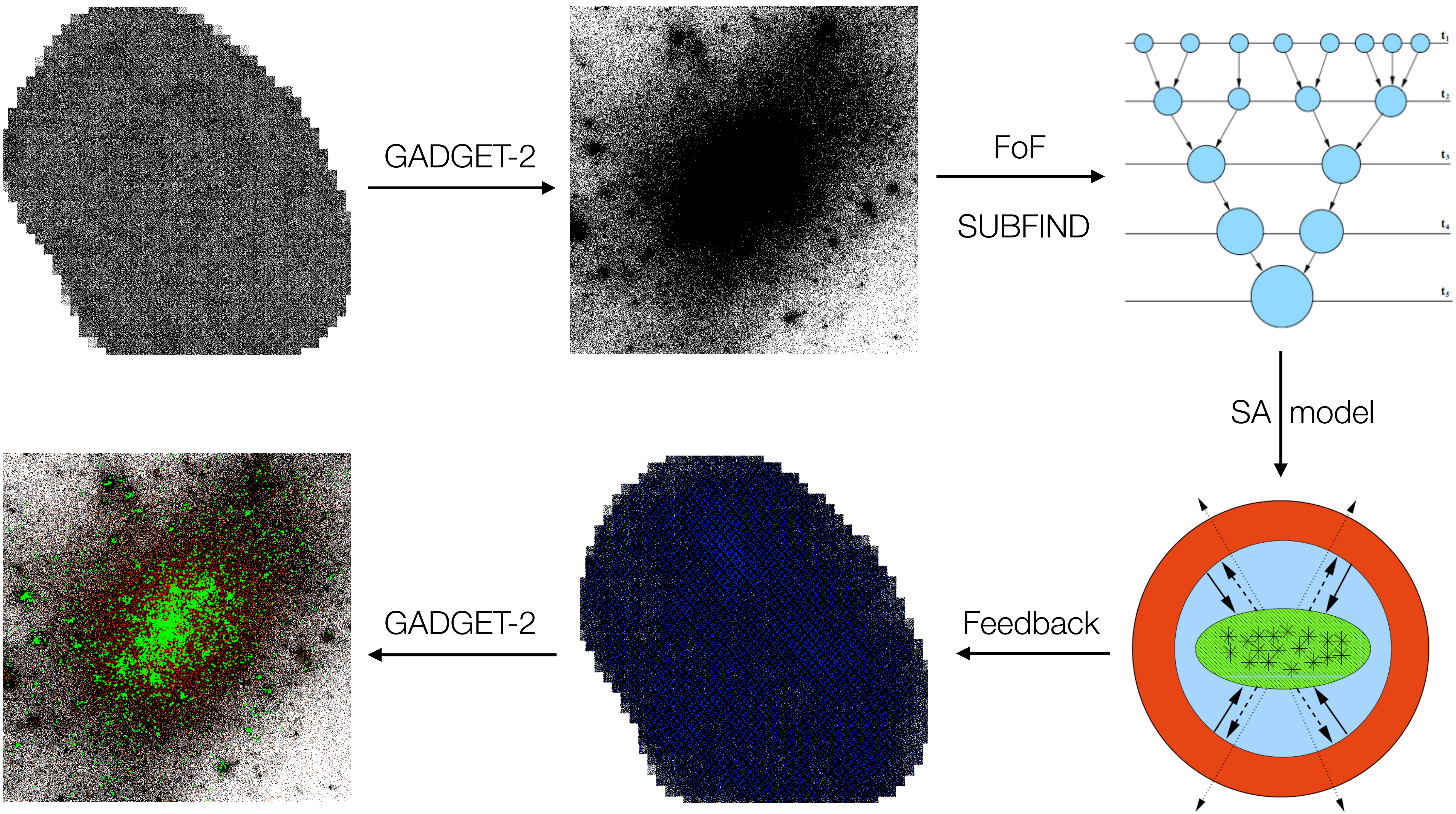
Simulated cluster evolution

Peter Thomas

Combining semi-analytics with simulations

Chris Short, Peter Thomas, 2009, ApJ, 704, 915



Pros and cons

- Pros:
  - Source of feedback is a realistic population of galaxies
  - AGN feedback from black hole accretion
  - Large numbers of clusters at all relevant redshifts
- Cons:
  - Zero gravitational mass for gas
  - Non-radiative, so no cool cores

Redshift	Model		
	Gravitational heating	Preheating/cooling	Feedback
1.5	25	14	18
1.0	145	102	75
0.5	549	410	148
0.0	1109	881	187

Minimum cluster mass $M_{500} \geq 10^{14} h^{-1} M_{\odot}$

The feedback model

- Type II supernova feedback:

$$\Delta E_{\rm ejected} = \frac{1}{2}\epsilon_{\rm halo} v_{\rm SN}^2 \Delta M_* - \frac{1}{2}\epsilon_{\rm disk} v_{\rm vir}^2 \Delta M_*$$

Total energy available — Energy used to reheat cold disk gas

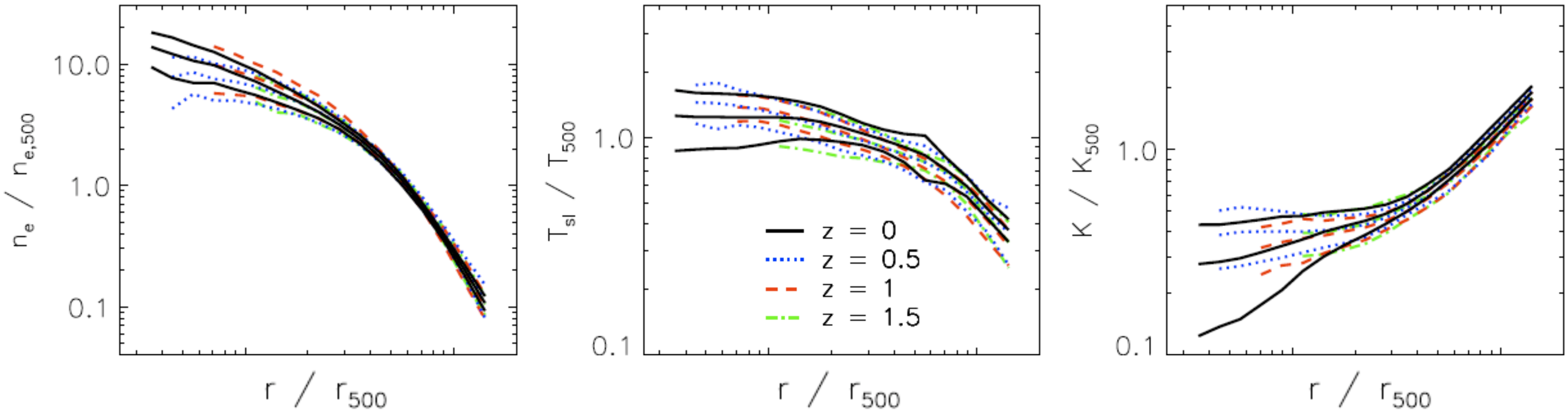
- AGN feedback:
  - Adopt the Bower et al. (2008) AGN feedback prescription used in GALFORM
  - Available heating energy is given by:

$$\Delta E_{\rm BH} = \min \begin{cases} 0.1 \Delta M_{\rm BH} c^2 & \text{Radio mode} \\ \epsilon \Delta E_{\rm Edd} & \text{Quasar mode} \end{cases}$$

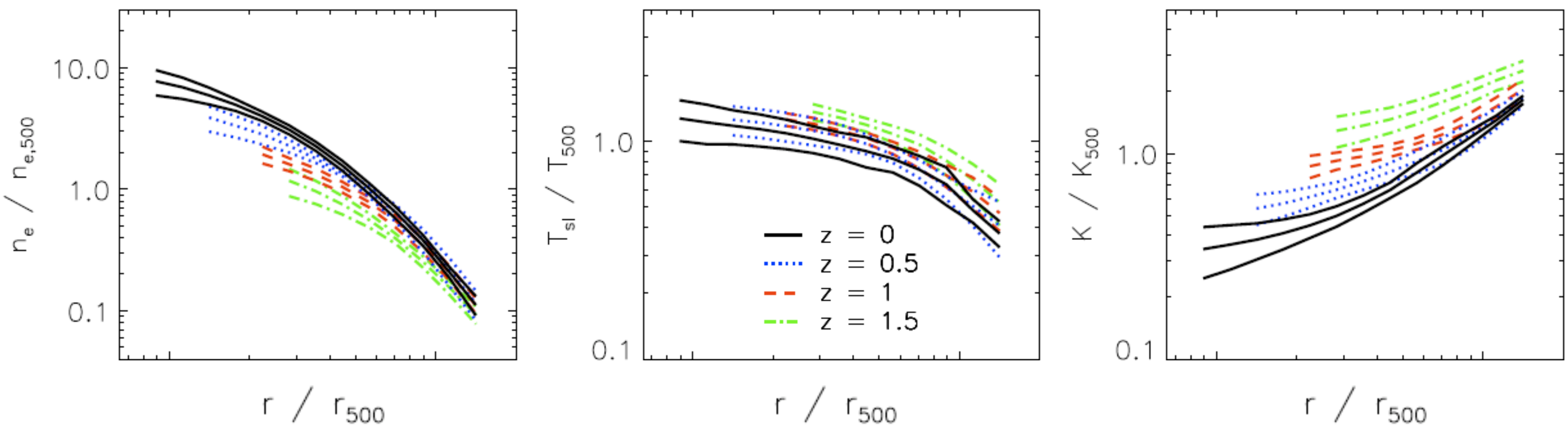
where $\epsilon = 0.02$ is the disk structure parameter

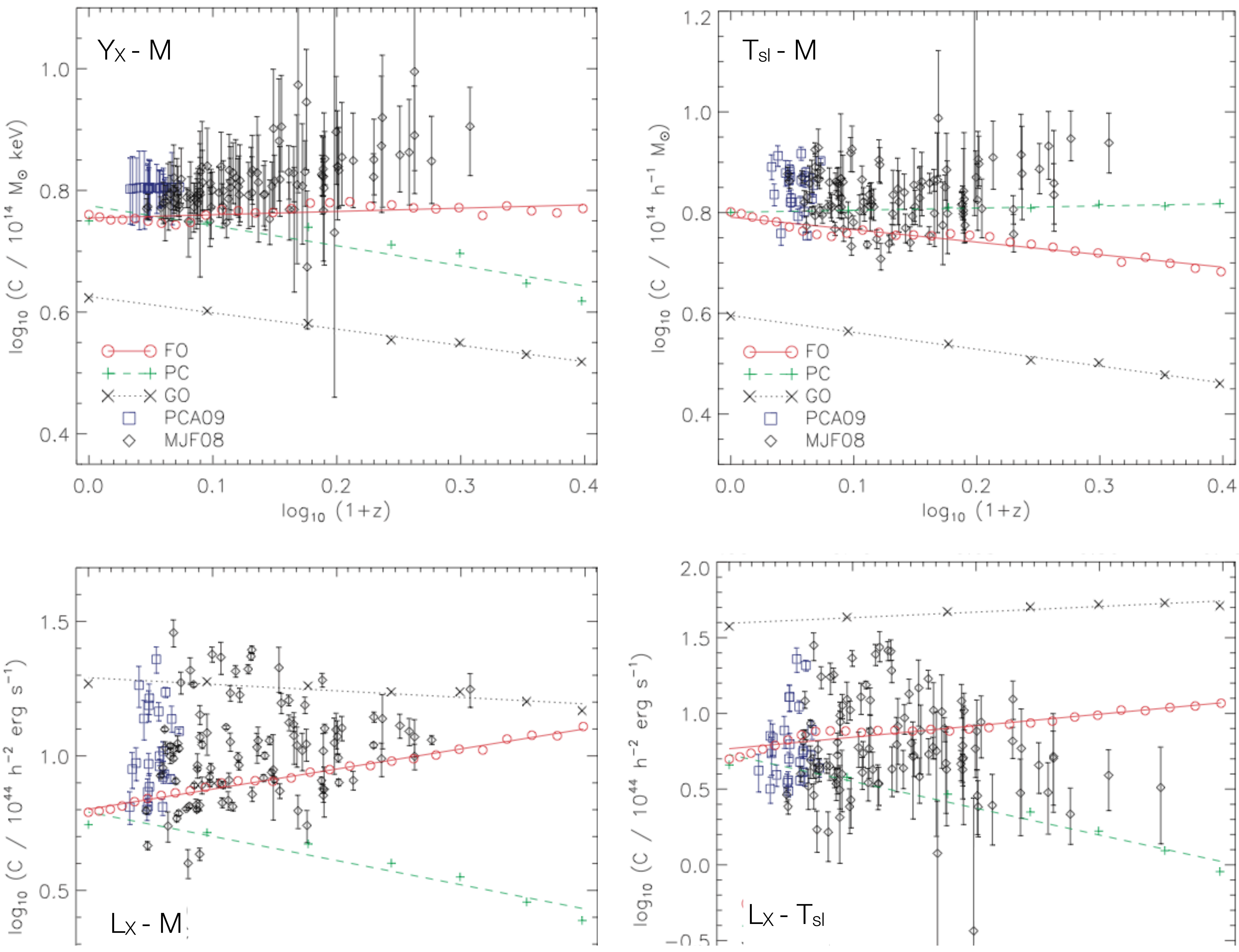
Evolution of profiles, Short et al 2010, MNRAS, 408, 2213

Feedback



Preheating





Y_X - M
T_{sl} - M
L_X - M
L_X - T_{sl}
FO
PC
GO
PCA09
MJF08
$\log_{10}$ (C / 10^{14} $M_\odot$ keV)
$\log_{10}$ (C / 10^{14} h^{-1} $M_\odot$)
$\log_{10}$ (C / 10^{44} h^{-2} erg s^{-1})
$\log_{10}$ (1+z)

Conclusions of scaling relation evolution

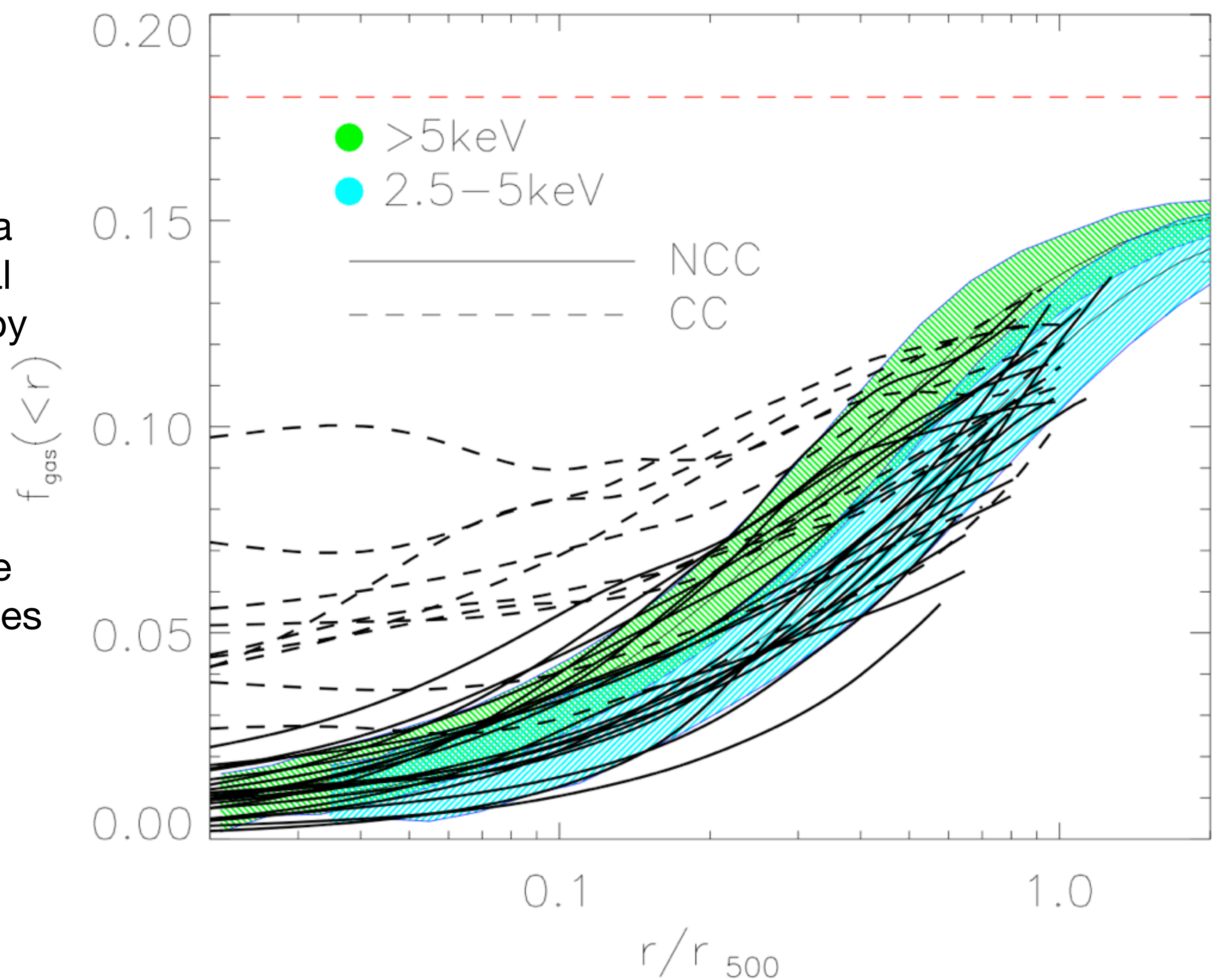
- Our model for SN and AGN feedback can reproduce observed local scaling laws, at least for non-cool core clusters
- Simple preheating yields almost identical results at low redshift
- Feedback from galaxies predicts opposite evolutionary behaviour
- Current data seems to favour feedback model at $z<0.5$ and preheating at higher redshift...
- ...but plagued by selection biases
- Need a cleanly selected sample to place meaningful constraints - XCS

Evolution of the baryon fraction - ruling out preheating

Owain Young, Peter Thomas, Chris Short, Frazer Pearce, 2011, MNRAS, 413, 691

We resimulate clusters from the Millennium simulation using a variety of physical models for entropy generation.

Both preheating and feedback models match the gas fraction profiles of non-cool-core (NCC) clusters.

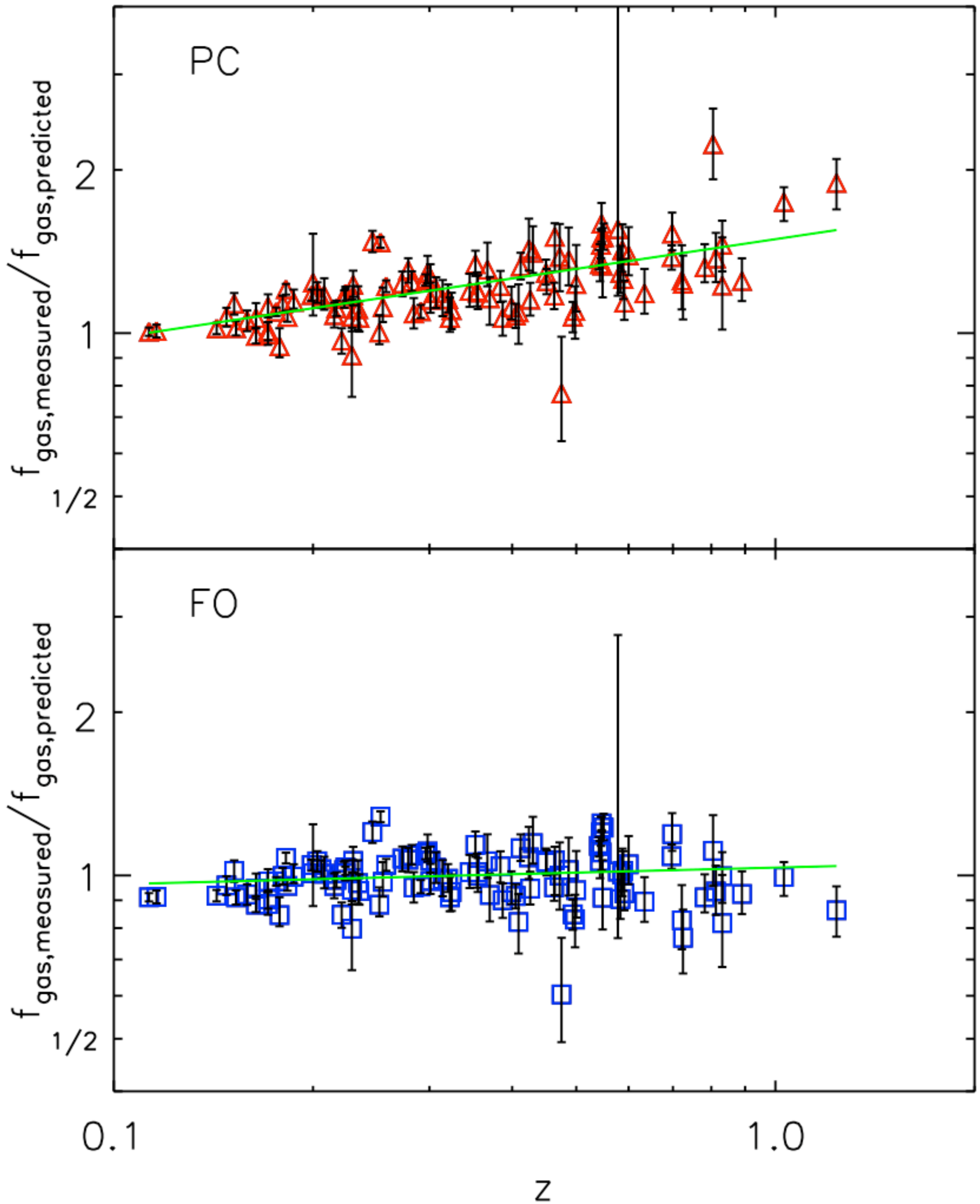


Observational data from Pratt et al. 2010, A&A, 511, 85

This figure shows the ratio of the observed to predicted gas fractions within r_{500}.

The feedback (FO) model is consistent with a constant value of unity. However, this is ruled out for the preheating (PC) model with high significance.

This argues strongly against a preheating model for entropy generation in the intracluster medium.



Observational data from Maughan et al. 2008, ApJSupp, 174, 117

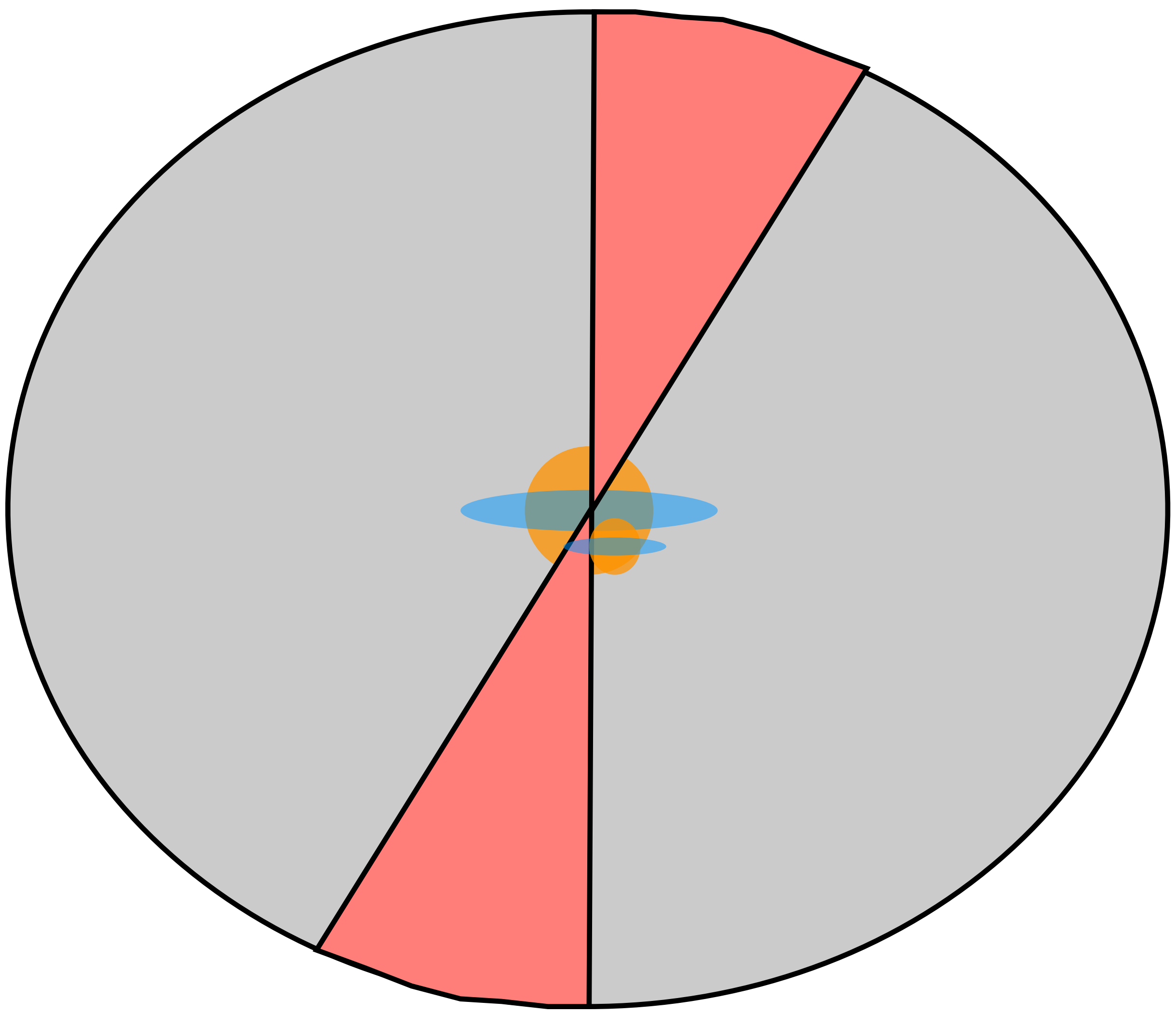
An improved feedback mechanism

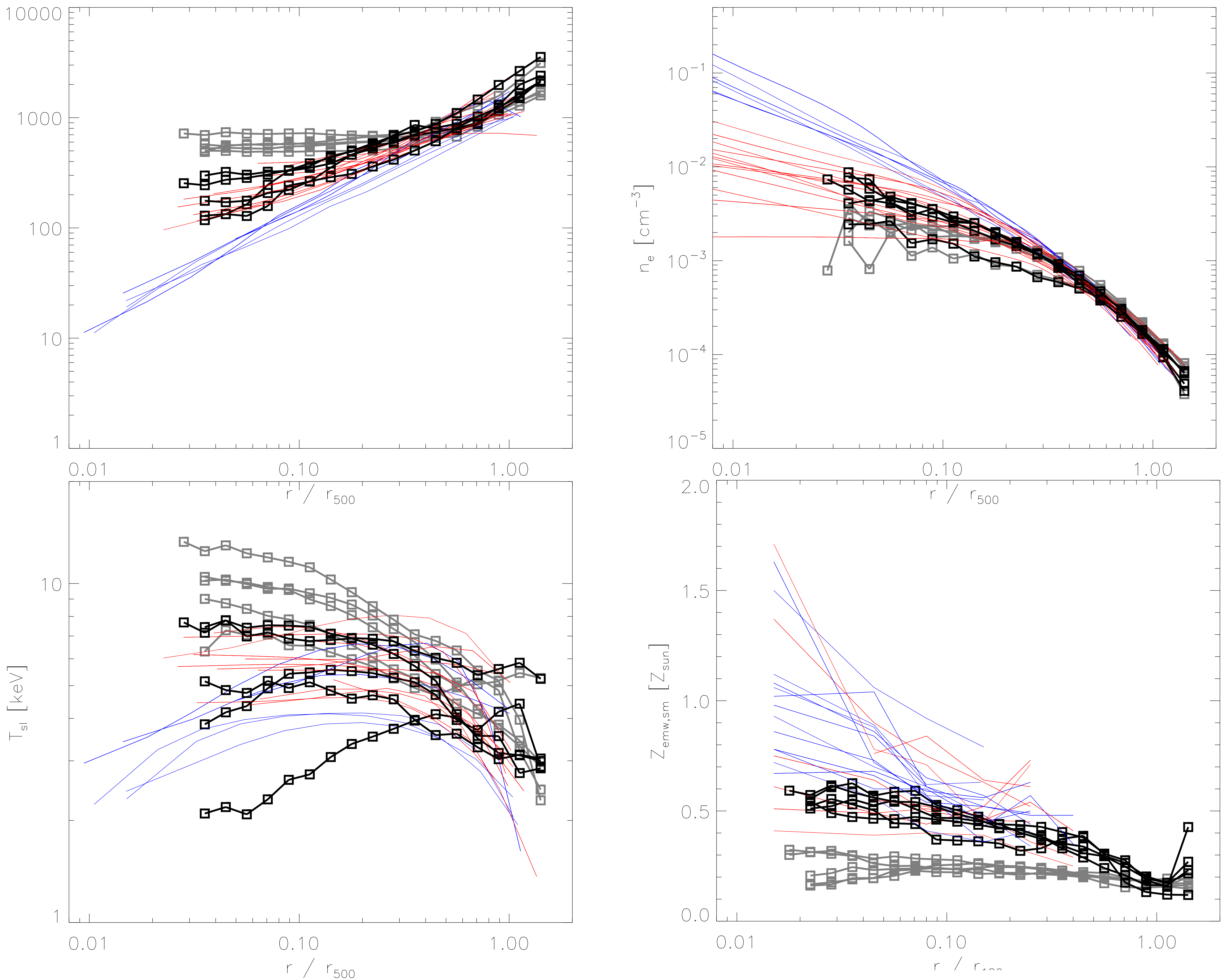
Chris Short, Peter Thomas

- Heating dominated by AGN.
- Radio jet/bubble affects only a fraction of particles
- Heating occurs with a duty cycle of 10^8 yr
- Heats out to R_{vir}

- SNR important for injection of metals
- In clusters most metals are accreted
  — so inject within R_{vir}

- Optimal parameters:
  - Heating efficiency = 0.75
  - Radial extent affected = R_{vir}
  - Heating fraction per duty cycle = 0.1





K [keV cm2]
10000
1000
100
10
1
0.01
0.10
1.00
r / r500
ne [cm-3]
10-1
10-2
10-3
10-4
10-5
0.01
0.10
1.00
r / r500
Tsl [keV]
10
1
0.01
0.10
1.00
r / r500
Zemw,sm [Zsun]
2.0
1.5
1.0
0.5
0.0
0.01
0.10
1.00

The new Millennium Gas Simulation

- WMAP-7 cosmology
- Guo et al 2011 semi-analytics
- Improved AGN feedback scheme
- Combined galaxy and ICM catalogues will be available later this year

Simulating cool-core systems Owain Young