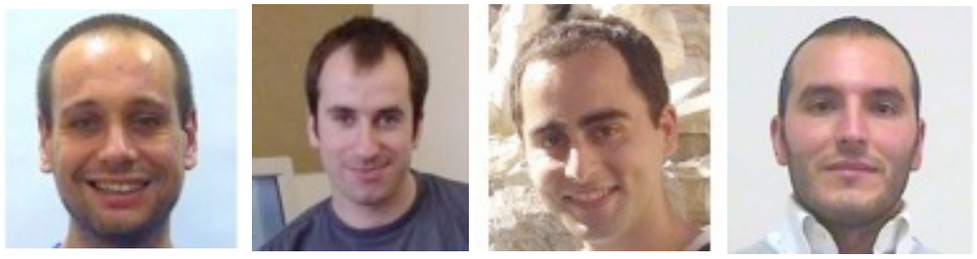
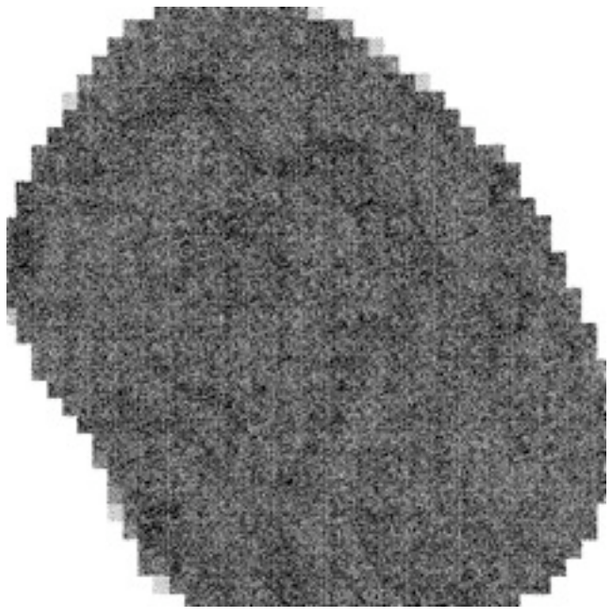
The simulated SZ-richness relation for clusters

Peter Thomas

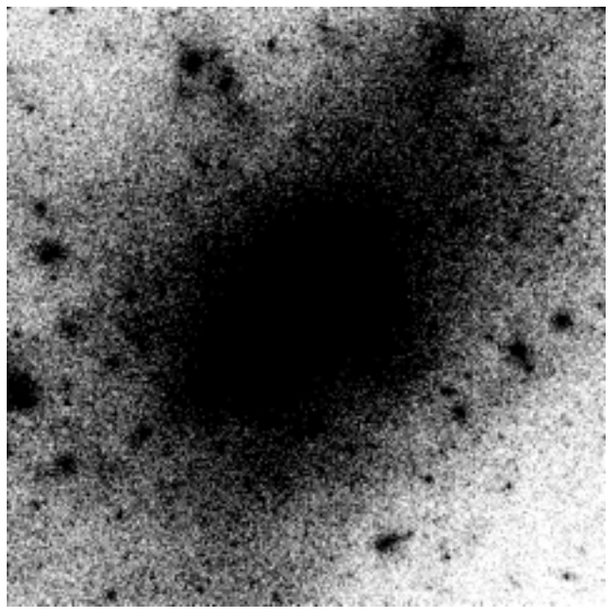


Combining semi-analytics with simulations

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

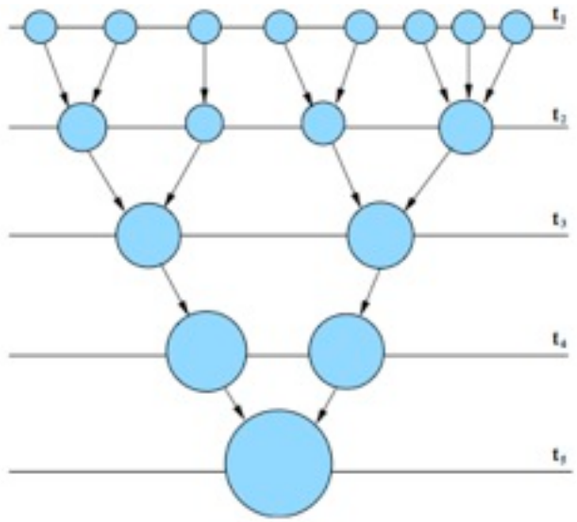


GADGET-2

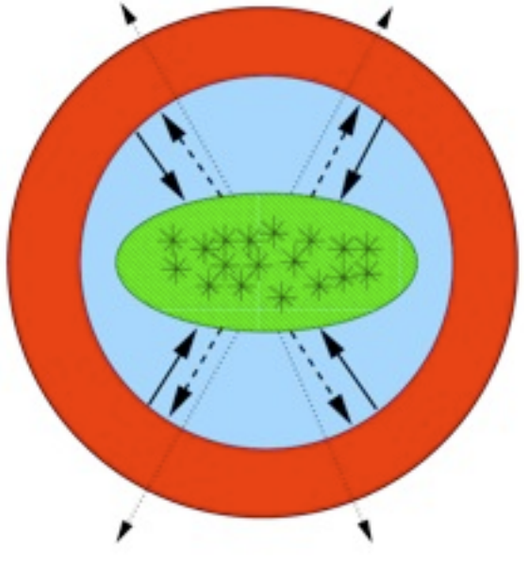


FoF

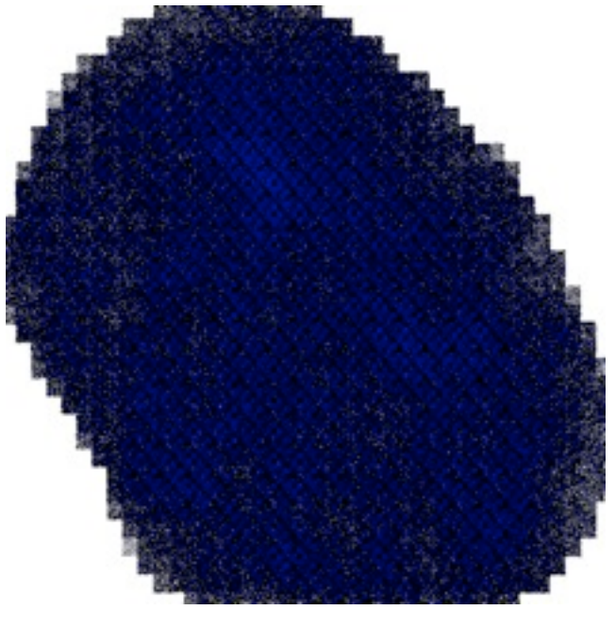
SUBFIND



SA model



Feedback



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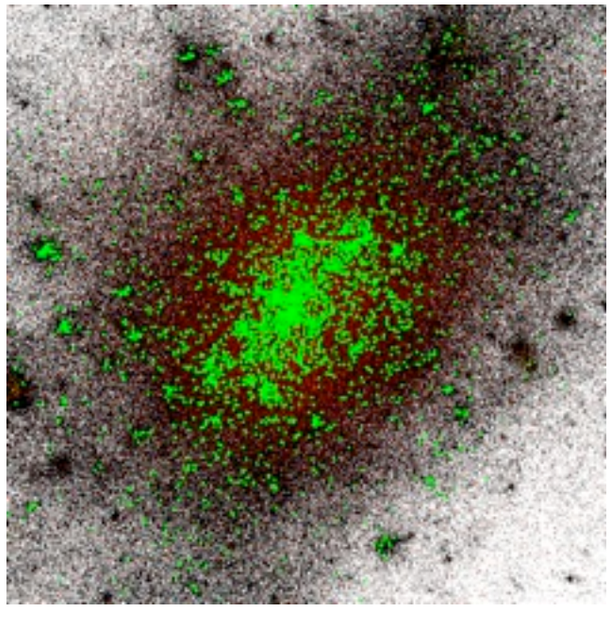
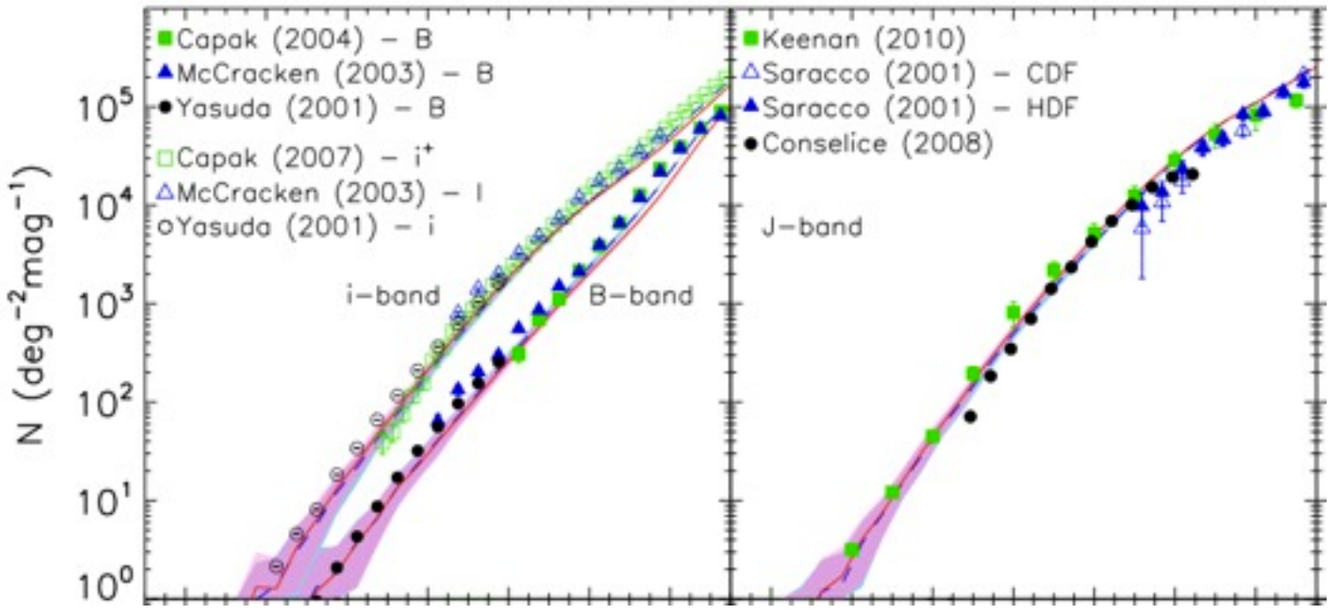
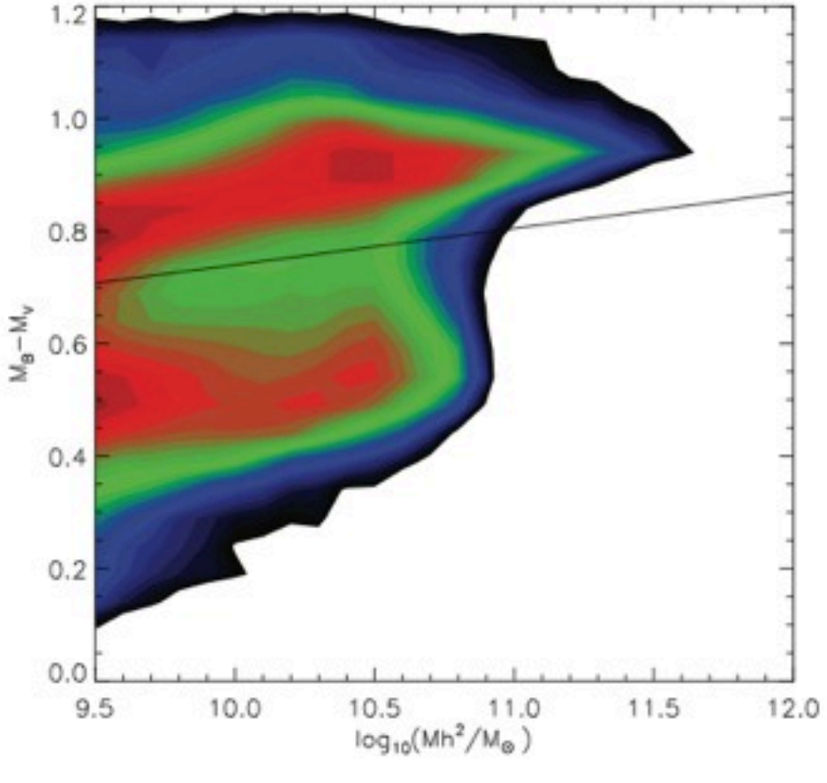
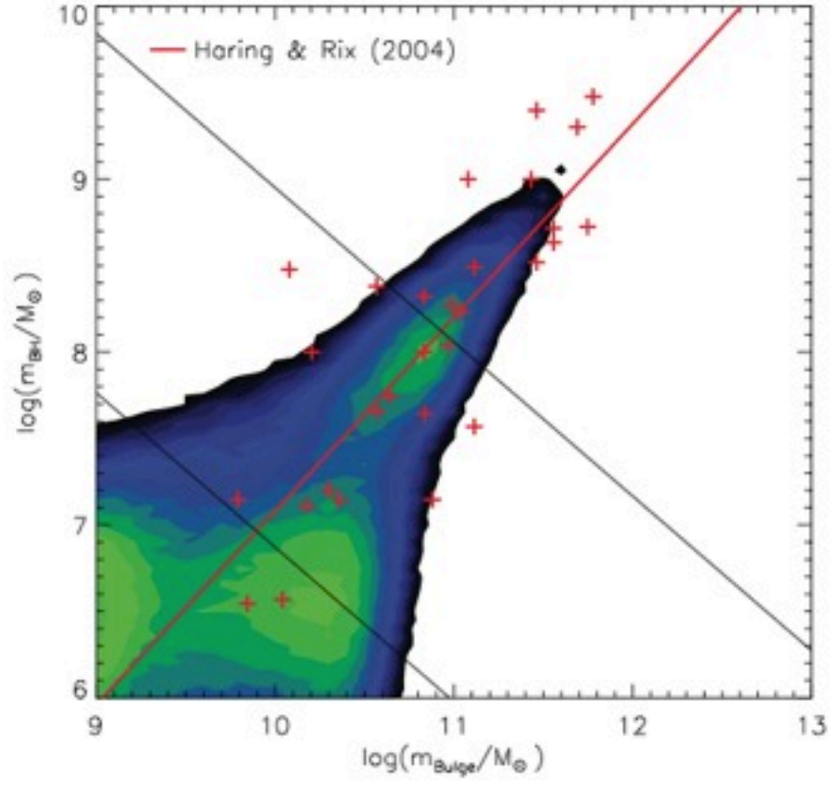


The Semi-analytic model

Guo etal 2011
Simultaneously fits the luminosity function, galaxy colours and black hole masses







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

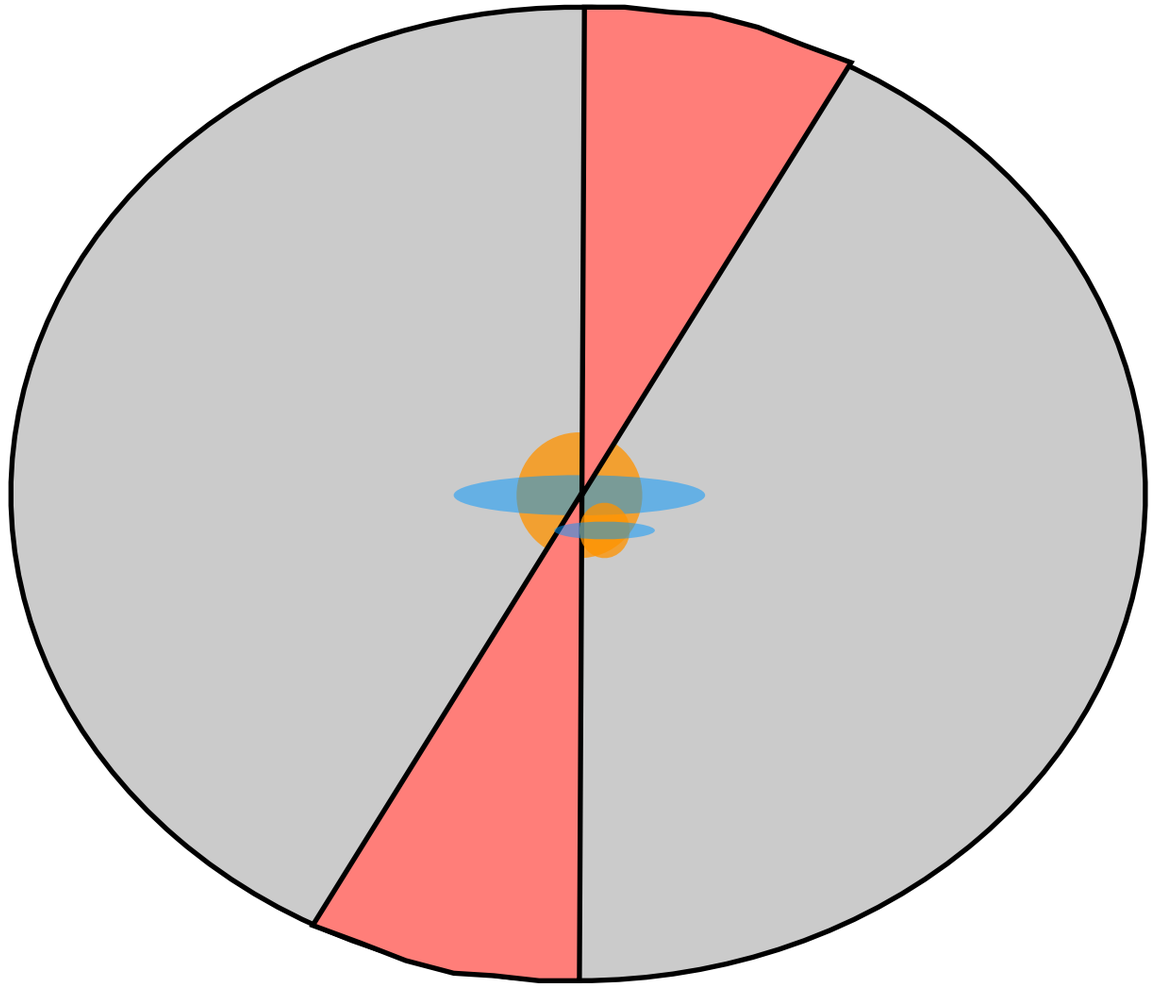
An improved feedback mechanism

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



Entropy

Density

Temperature

Metallicity

r / r_{500}

Non-cool-core clusters

New feedback scheme

Entropy slope

$K(r_{1000}) / K(0.1 r_{200})$

10

1

Observations

New feedback scheme

Entropy normalisation

$E(z)^{4/3} K(r_{1000})$ [$h^{-1/3}$ keV cm^2]

1000

L_X - T_{sl}

$E(z)^{-1} L_{x,bol}$ [10^{44} h^{-2} erg s^{-1}]

10.0

1.0

0.1

10

T_{sl} [keV]

Metallicity slope

$Z(0.25r_{180}) / Z(0.045r_{180})$

1

10

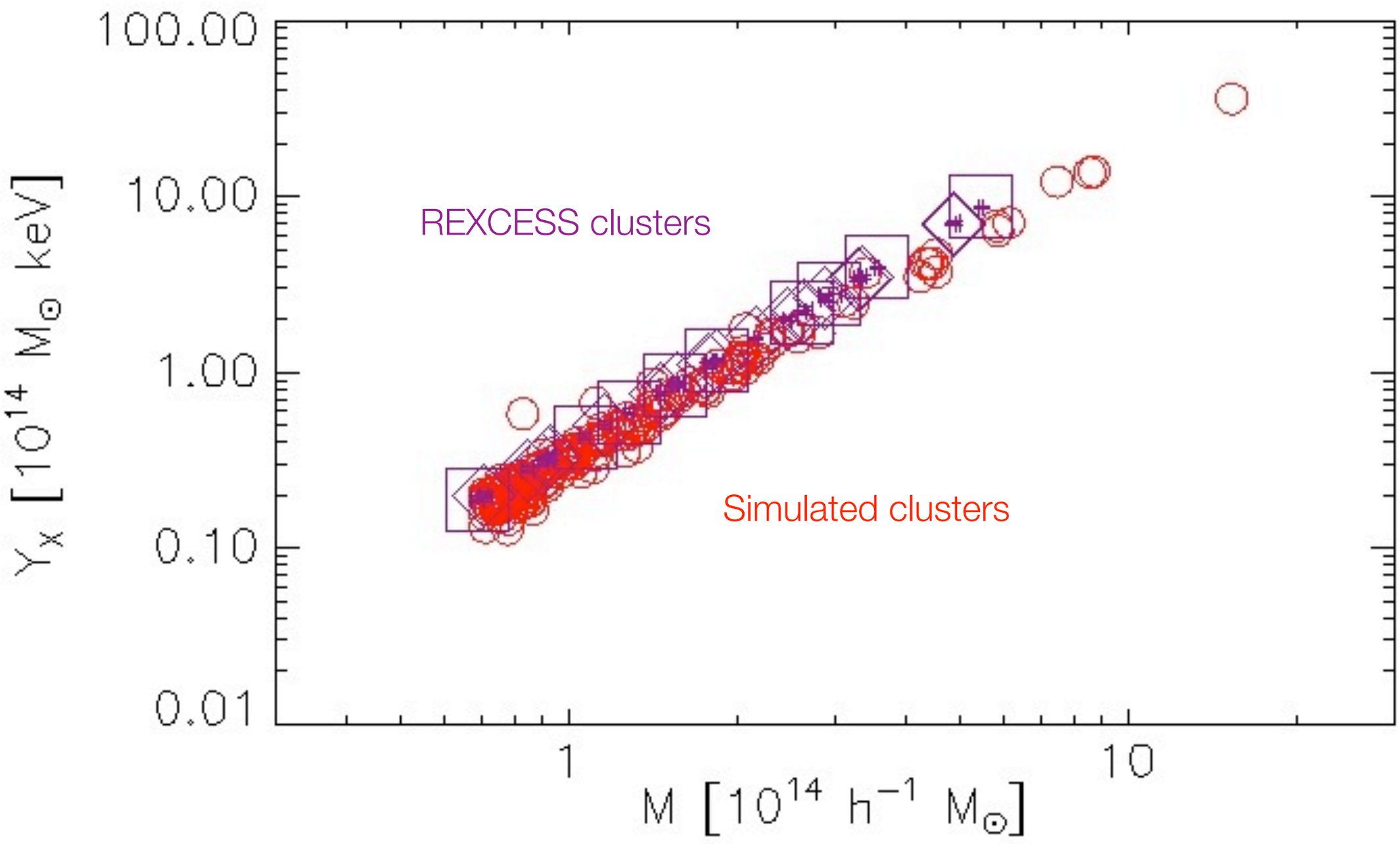
T_{sl} [keV]

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

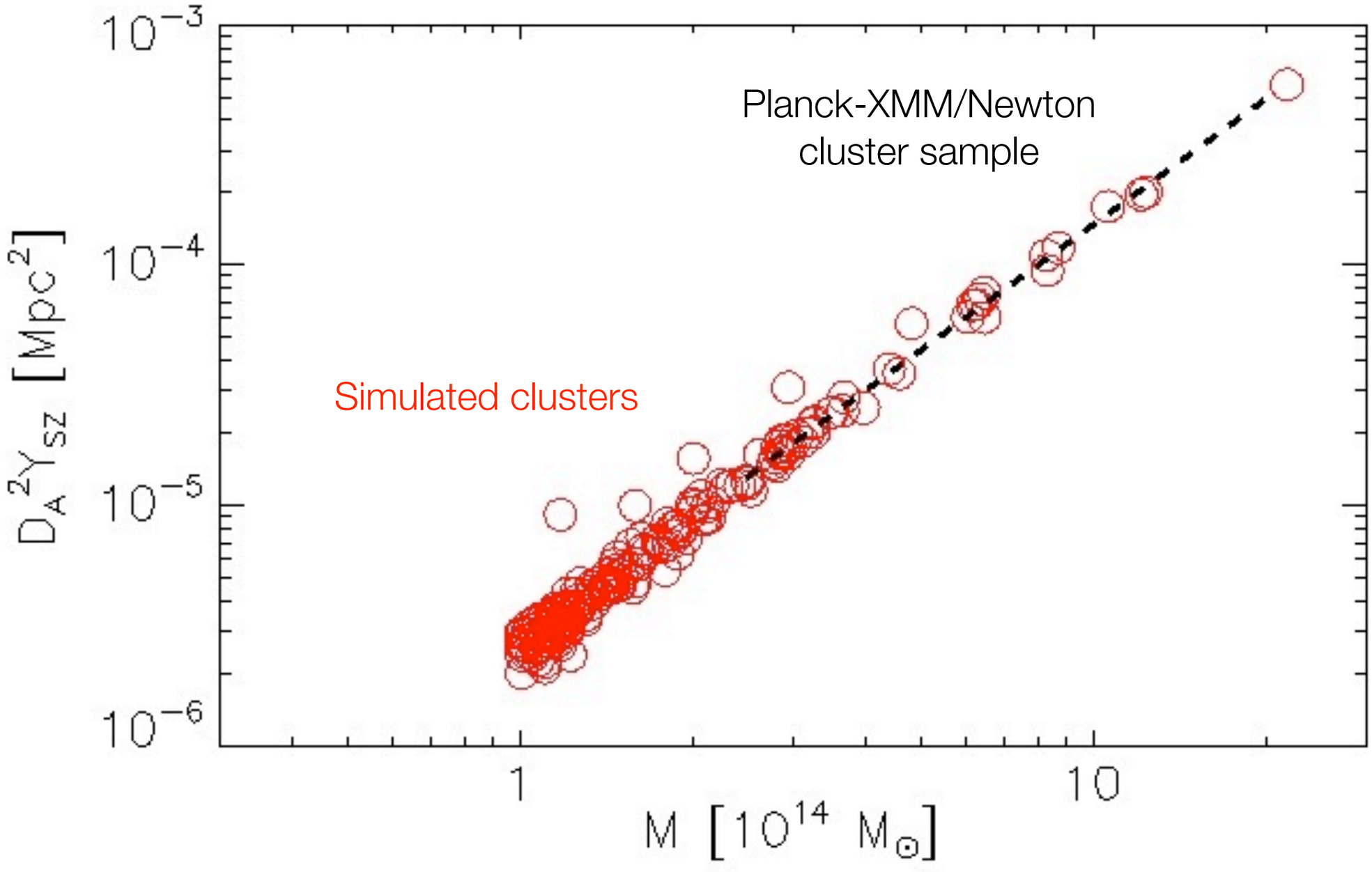
The new Millennium Gas Feedback Simulation

- WMAP-7 cosmology
- Guo et al 2011 semi-analytics
- Improved AGN feedback scheme
- Combined galaxy and ICM catalogues

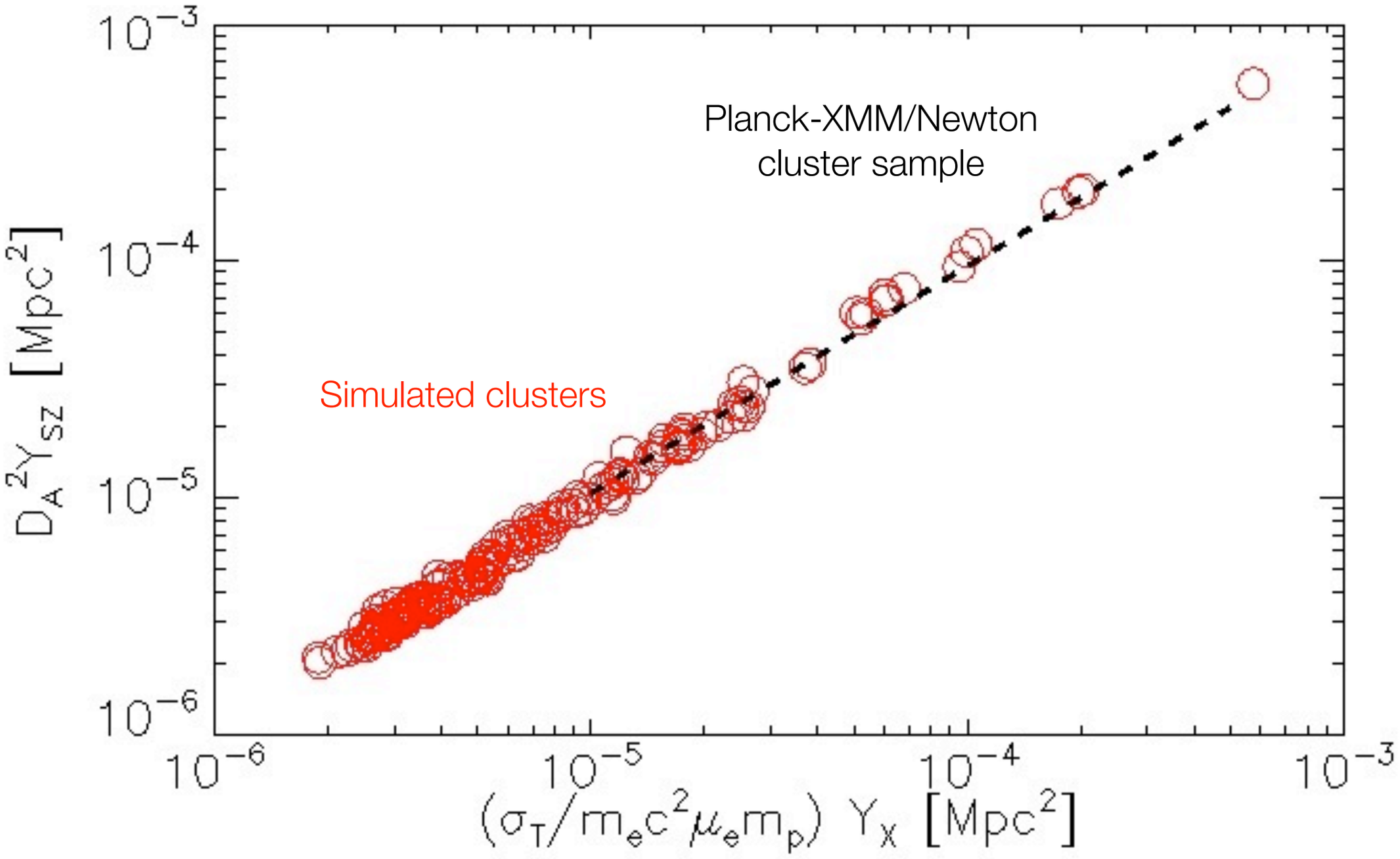
Y_X- M_{500}


100.00
10.00
1.00
0.10
0.01
1
10
Y_X [10^{14} $M_\odot$ keV]
M [10^{14} h^{-1} $M_\odot$]
REXCESS clusters
Simulated clusters

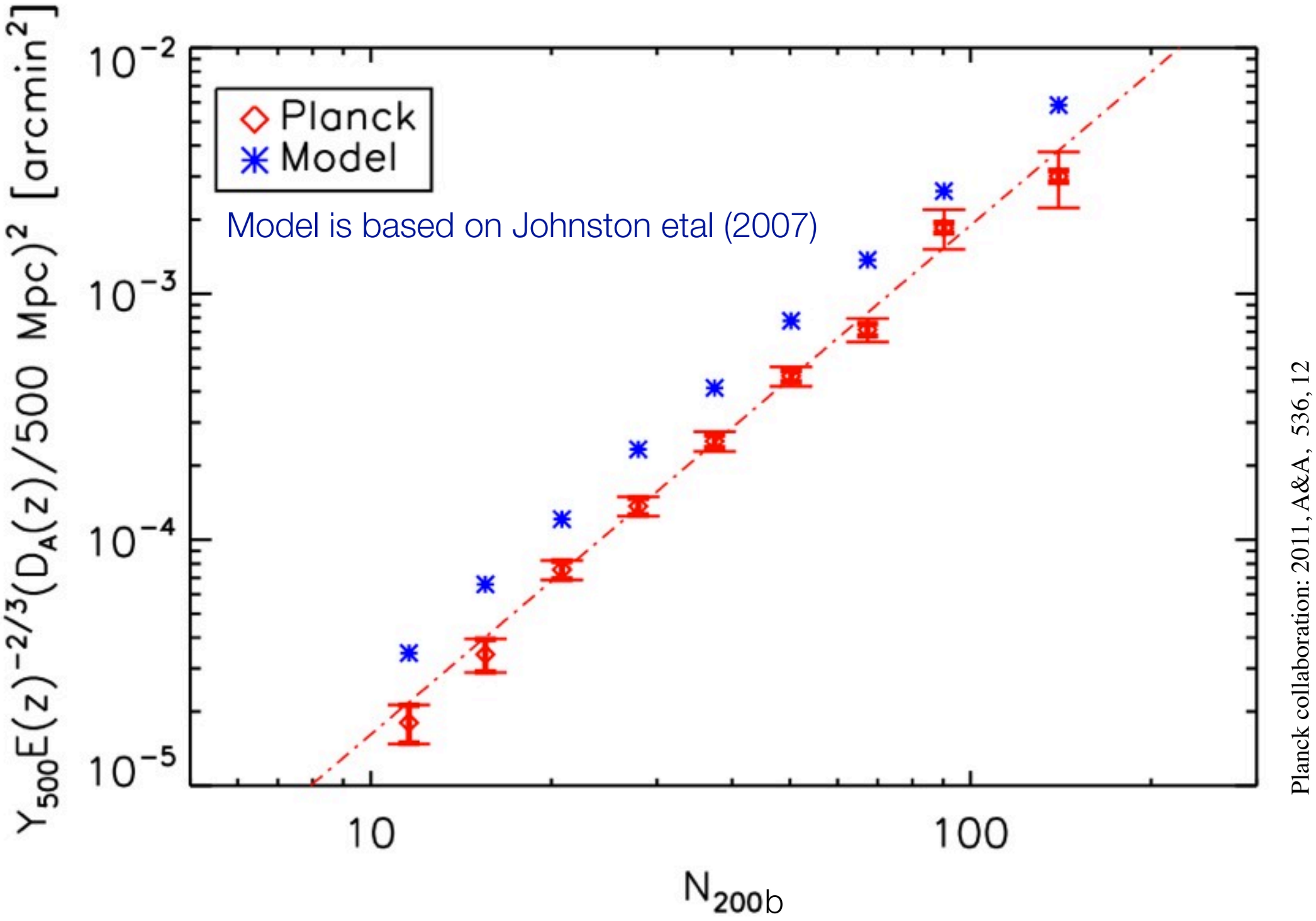
Y_{SZ} - M_{500}


Planck-XMM/Newton
cluster sample
Simulated clusters
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$D_A^2 Y_{SZ}$ [Mpc^2]
1
10
M [10^{14} $M_\odot$]

Y_{SZ} - Y_X

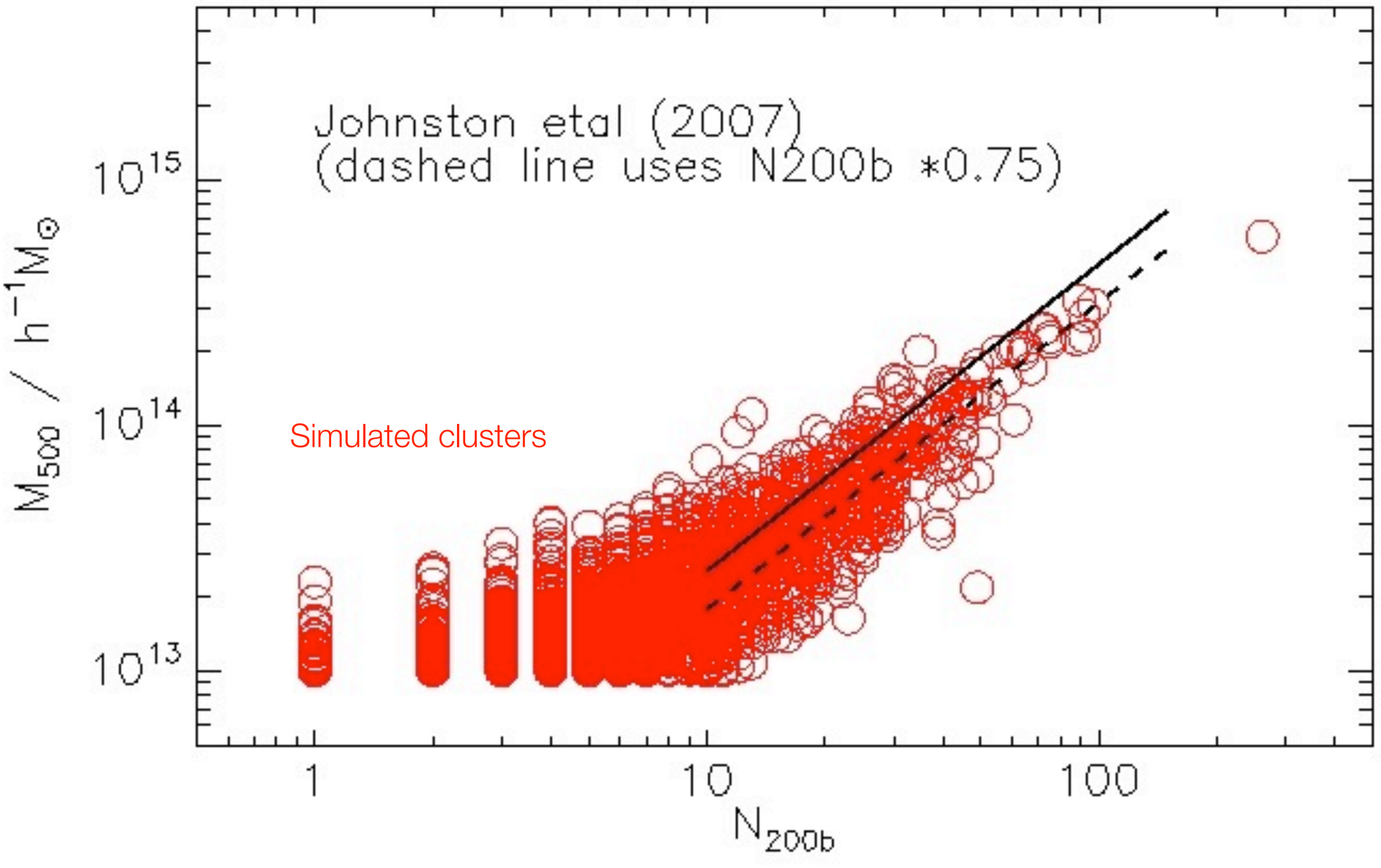

Planck-XMM/Newton
cluster sample
Simulated clusters
$D_A^2 Y_{SZ}$ [Mpc^2]
$(\sigma_T/m_e c^2 \mu_e m_p)\ Y_X$ [Mpc^2]
10^{-3}
10^{-4}
10^{-5}
10^{-6}

Planck Y_{500} - N_{200b} relation

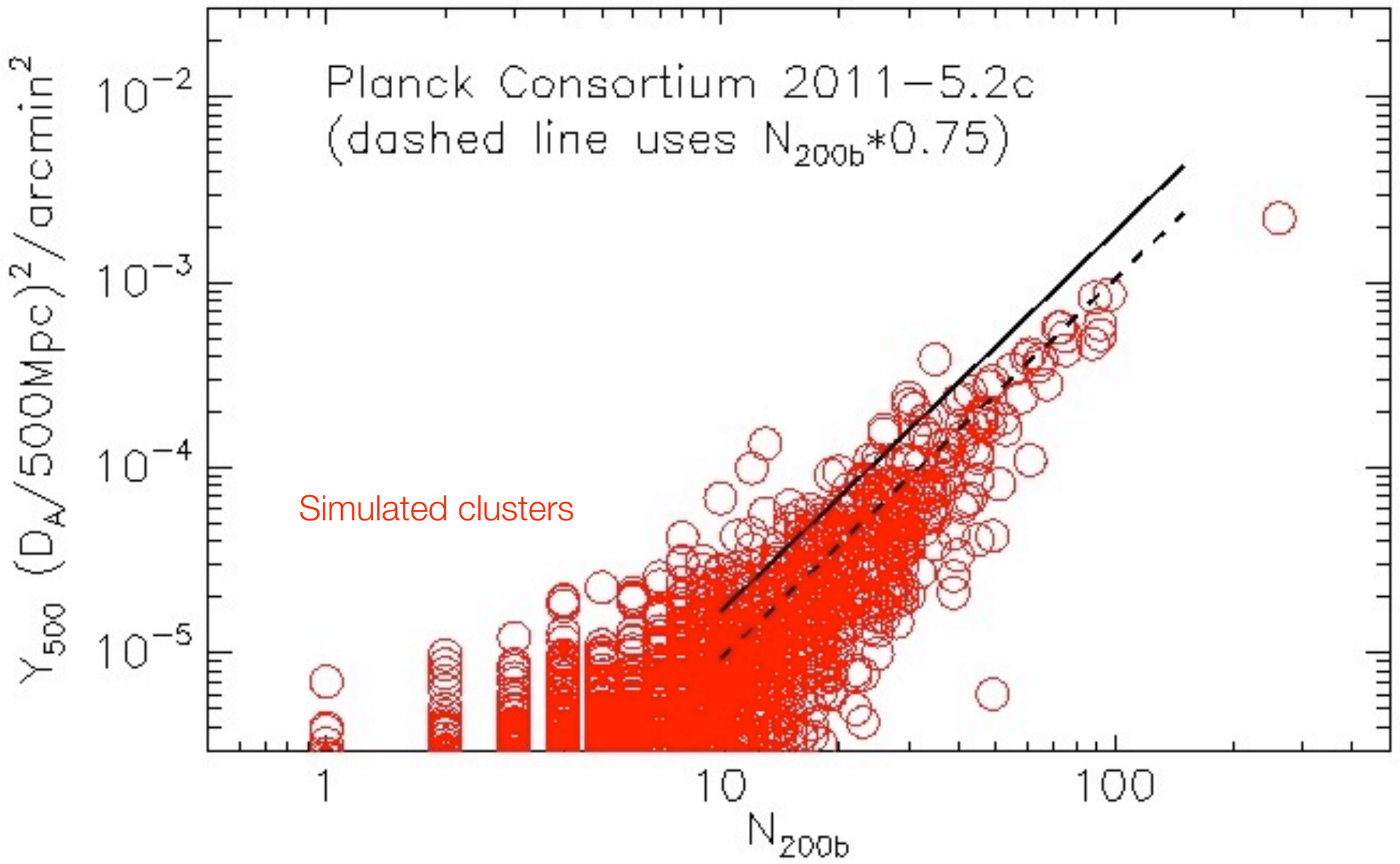


Planck collaboration: 2011, A&A, 536, 12

M_{500} - N_{200b}


Johnston etal (2007)
(dashed line uses N200b *0.75)
Simulated clusters
10^{15}
10^{14}
10^{13}
M_{500} / $h^{-1}M_\odot$
1
10
100
N_{200b}

Y_{500} - N_{200b}


Planck Consortium 2011–5.2c
(dashed line uses N_{200b}*0.75)
Simulated clusters
Y_{500} (D_A/500Mpc)^2/arcmin^2
10^{-2}
10^{-3}
10^{-4}
10^{-5}
1
10
100
N_{200b}

Conclusions

- We have presented some results from the Millennium Gas Feedback runs
- Galaxies and the ICM are modelled consistently, with metal and energy injection from ANR and AGN
- We successfully reproduce the X-ray properties of clusters
- Preliminary results on richness show no signs of the M-N vs Y-N discrepancy shown by the initial Planck analysis