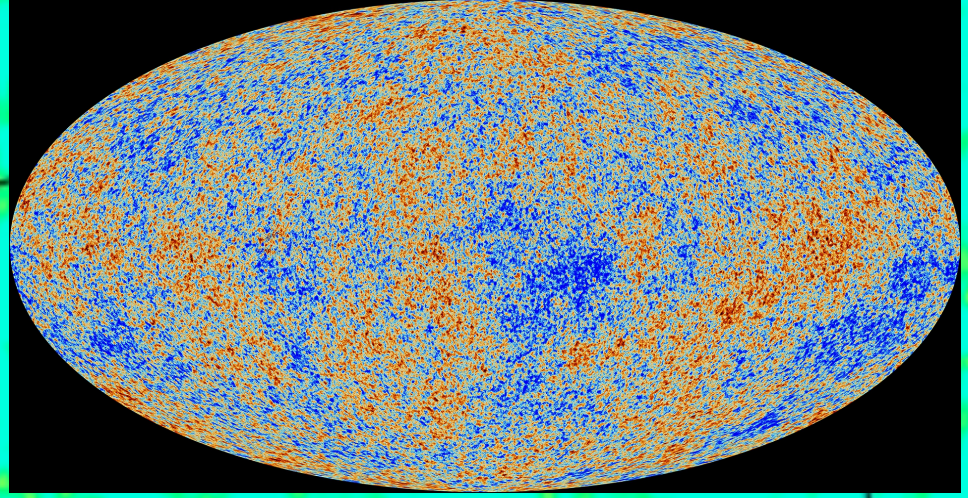
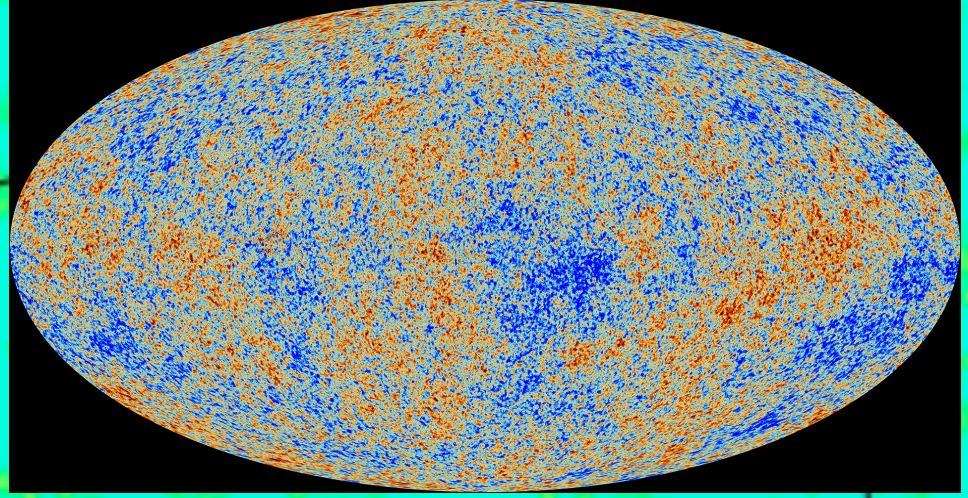


GPE@60
Cambridge,
September 2015

Putting your foot on the gas: the quickest way to find what was never lost

Simon White
Max Planck Institute for Astrophysics



GPE@60
Cambridge,
September 2015

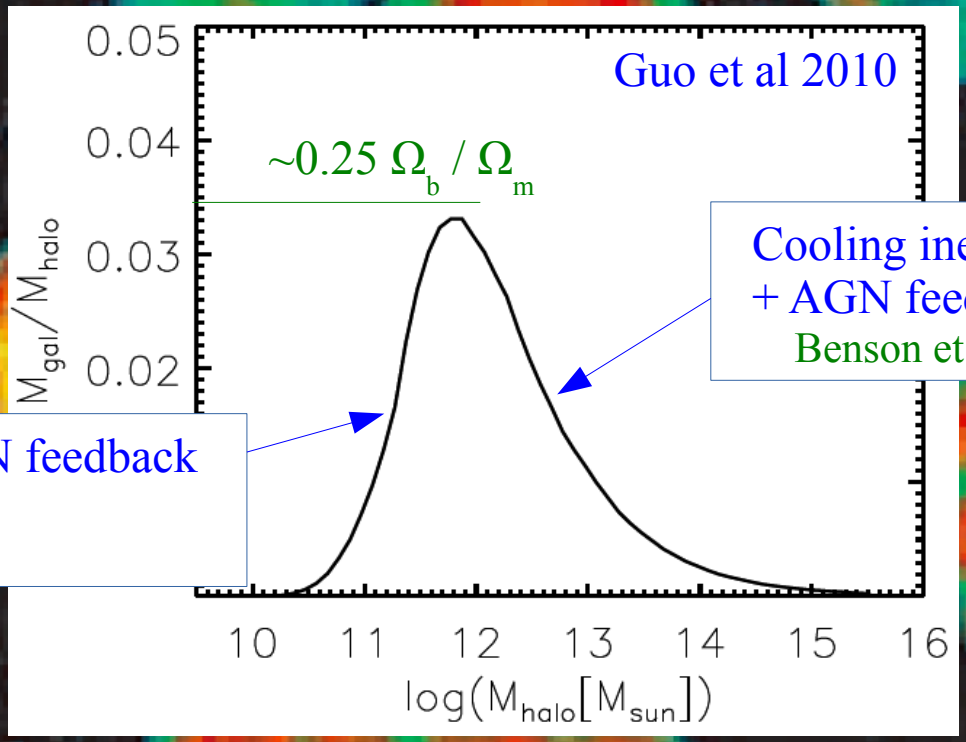
The gas content of dark halos

Simon White
Max Planck Institute for Astrophysics

Central galaxies contain <25% of the expected baryons within halos

In rich clusters most of the expected baryons are in the IGM, but in lower mass halos most are “missing”

Blown out? How far? What state are they in? How to see them?



Cooling inefficiency
+ AGN feedback
Benson et al 2002

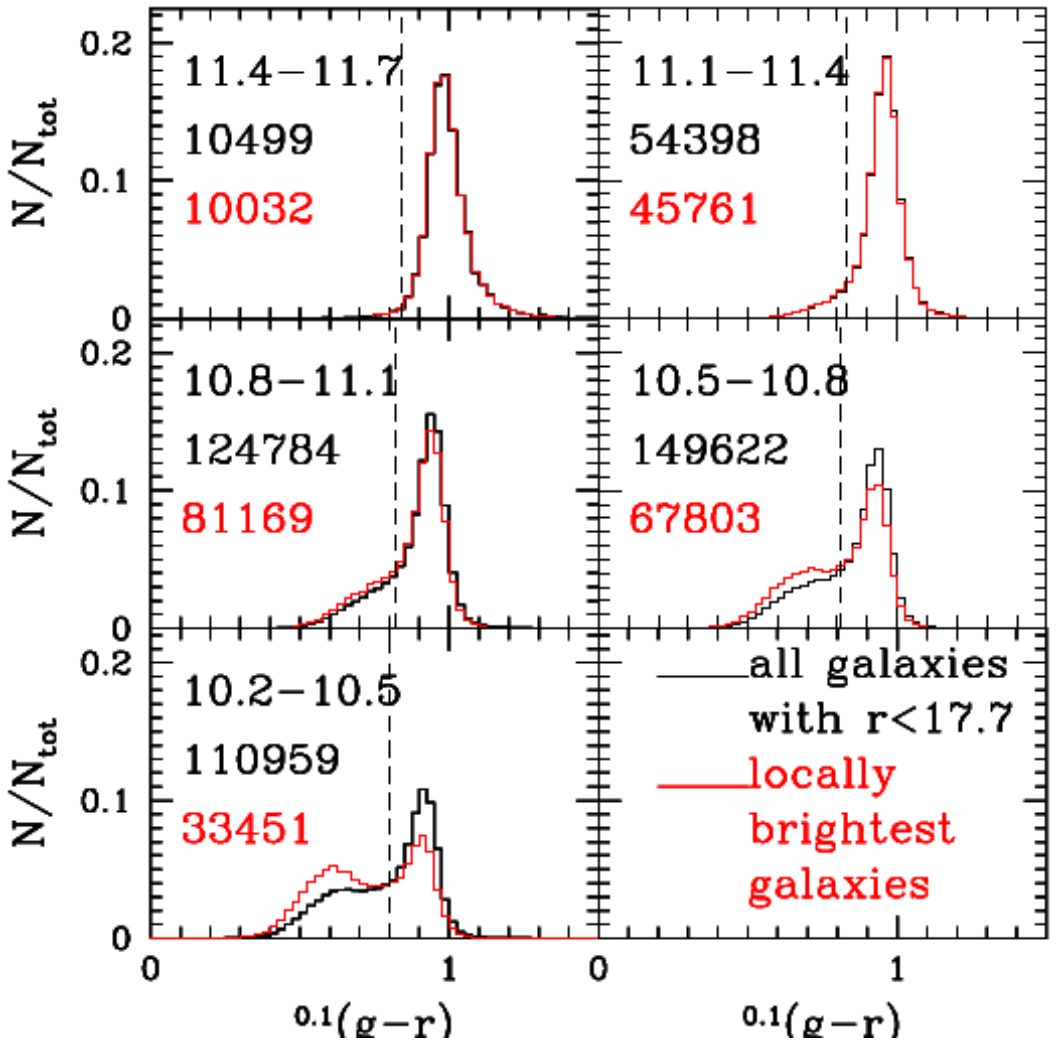
Reionisation and SN feedback
Larson 1974
Efstathiou 1992

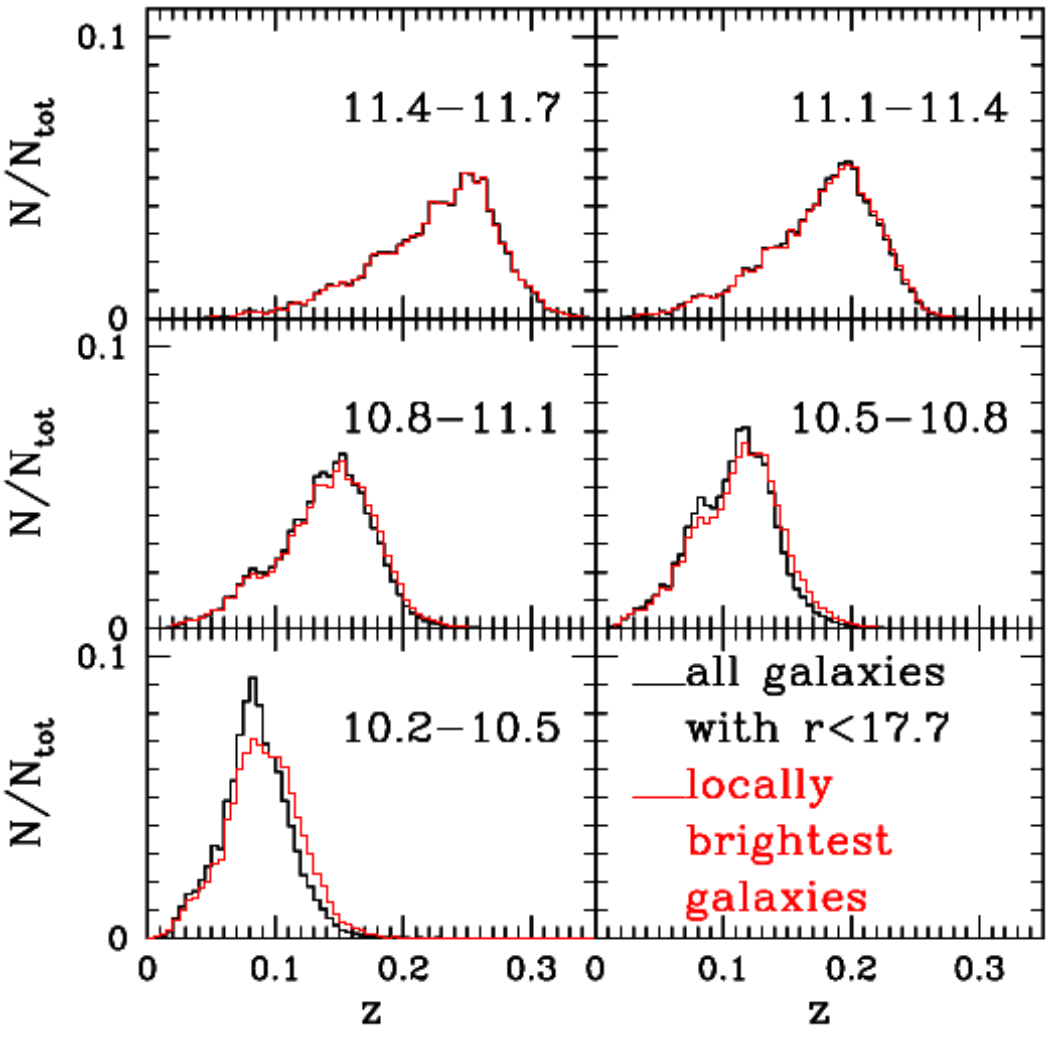
Locally brightest galaxies as halo proxies

SDSS/DR7: $r < 17.7$, $z > 0.03$

Brighter than all neighbours with $r_p < 1.0$ Mpc, $\Delta z < 1{,}000$ km/s

Planck Collaboration 2013





Locally brightest galaxies as halo proxies

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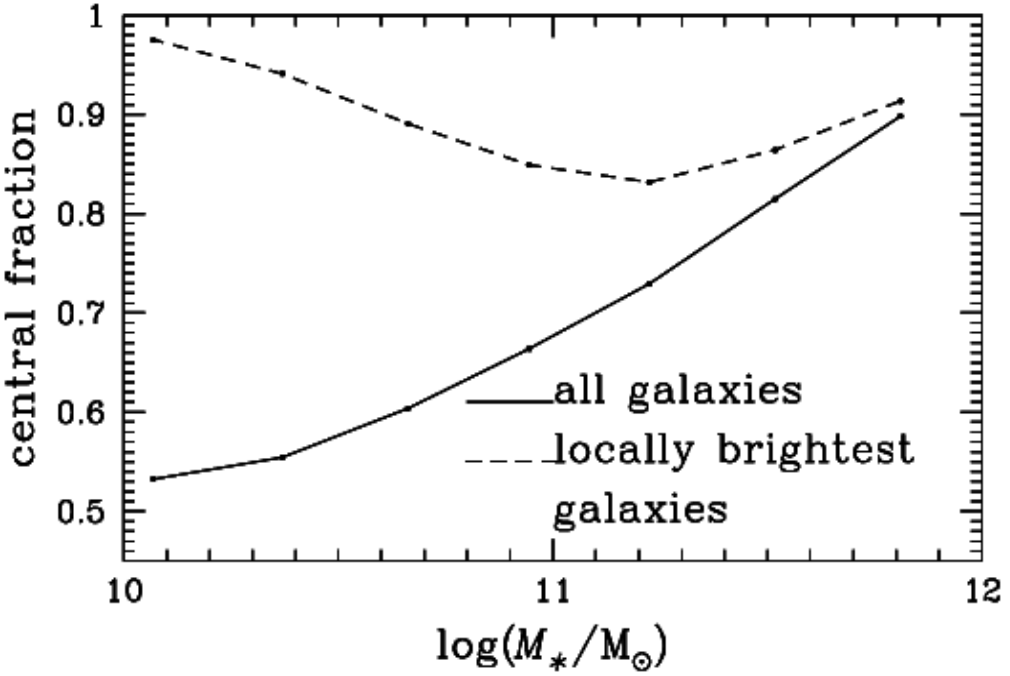
Brighter than all neighbours with $r_p < 1.0$ Mpc, $\Delta z < 1{,}000$ km/s

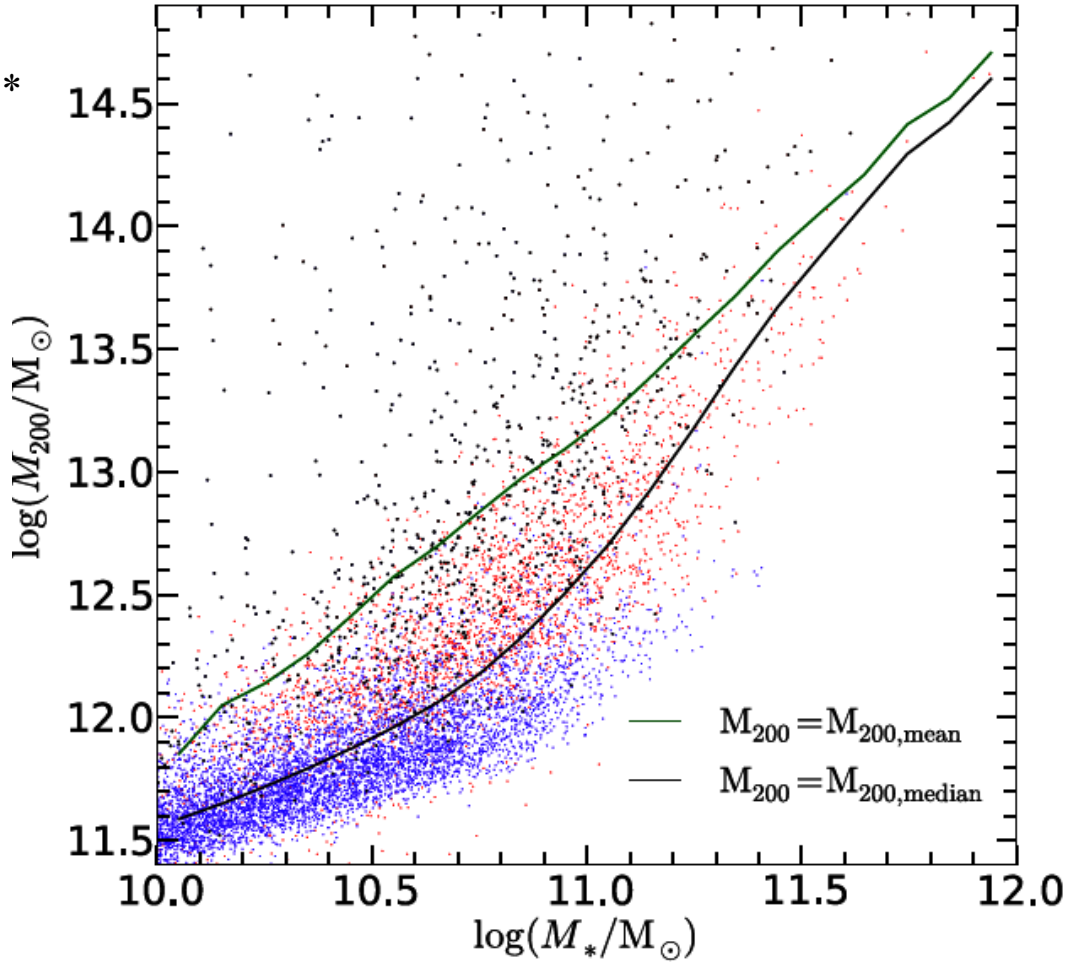
Mock light-cone: Guo et al (2013) simulation in the WMAP7 cosmology

>83% of LBGs are halo centrals

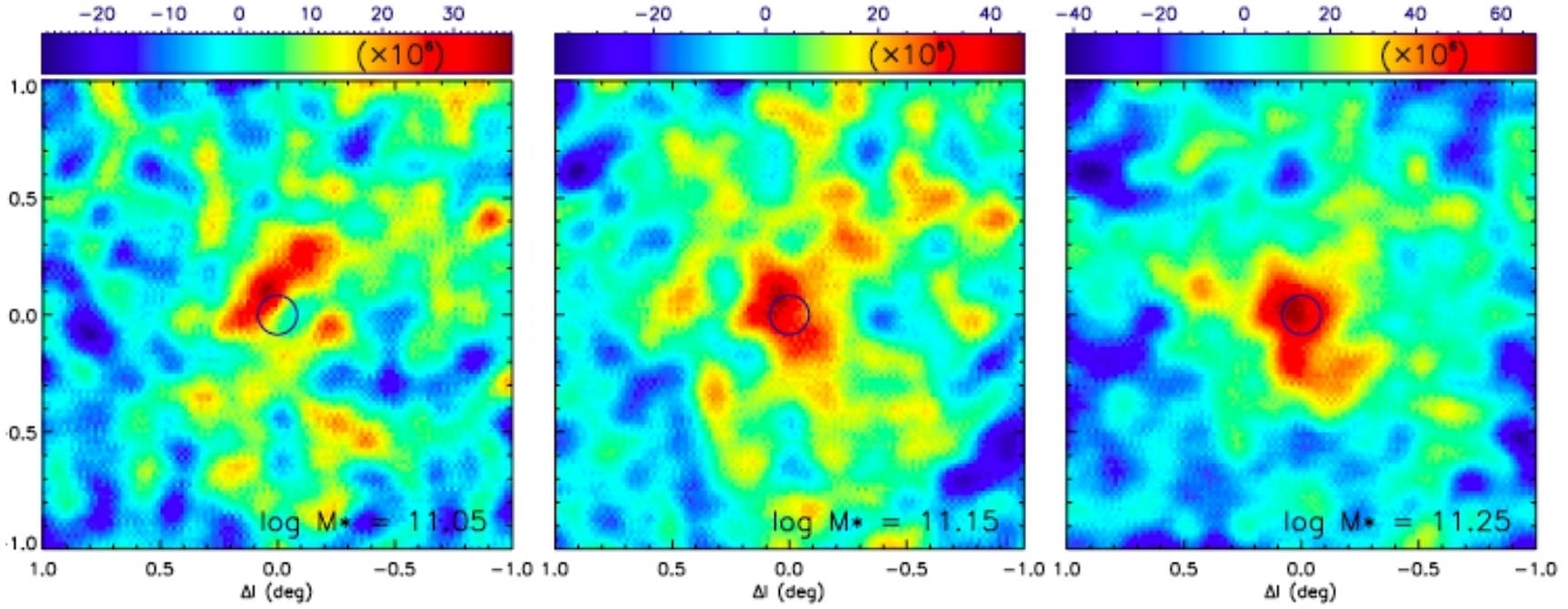
Large spread in M_{200} at given M_*

Planck Collaboration 2013

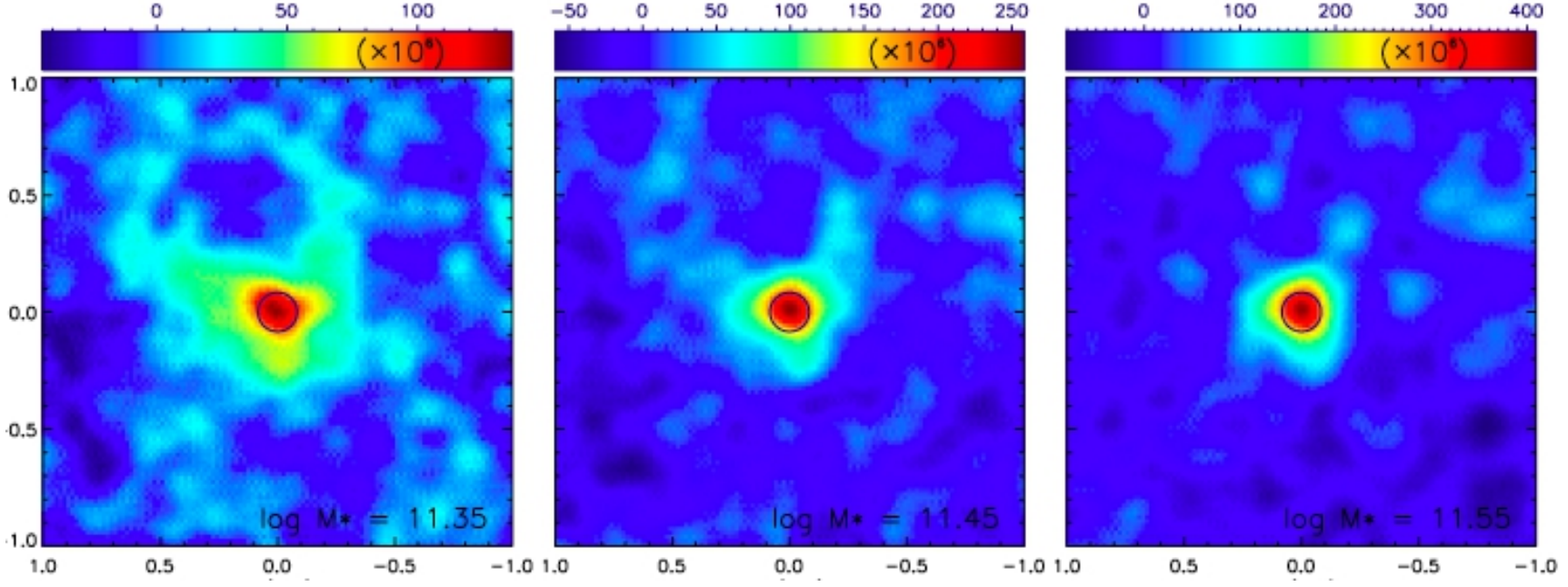




Stacked images of the Planck SZ signal from LBGs

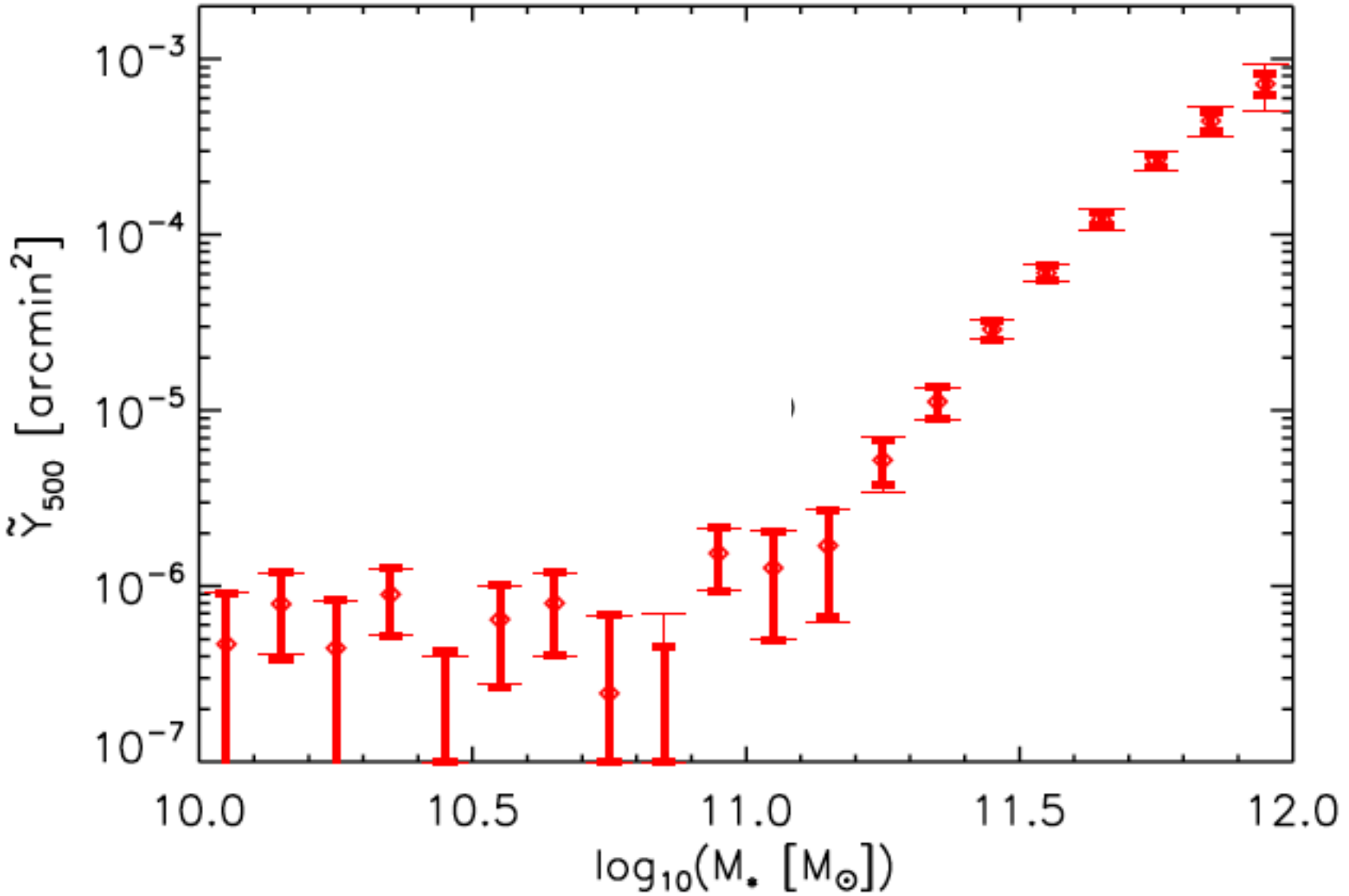


Planck Collaboration 2013



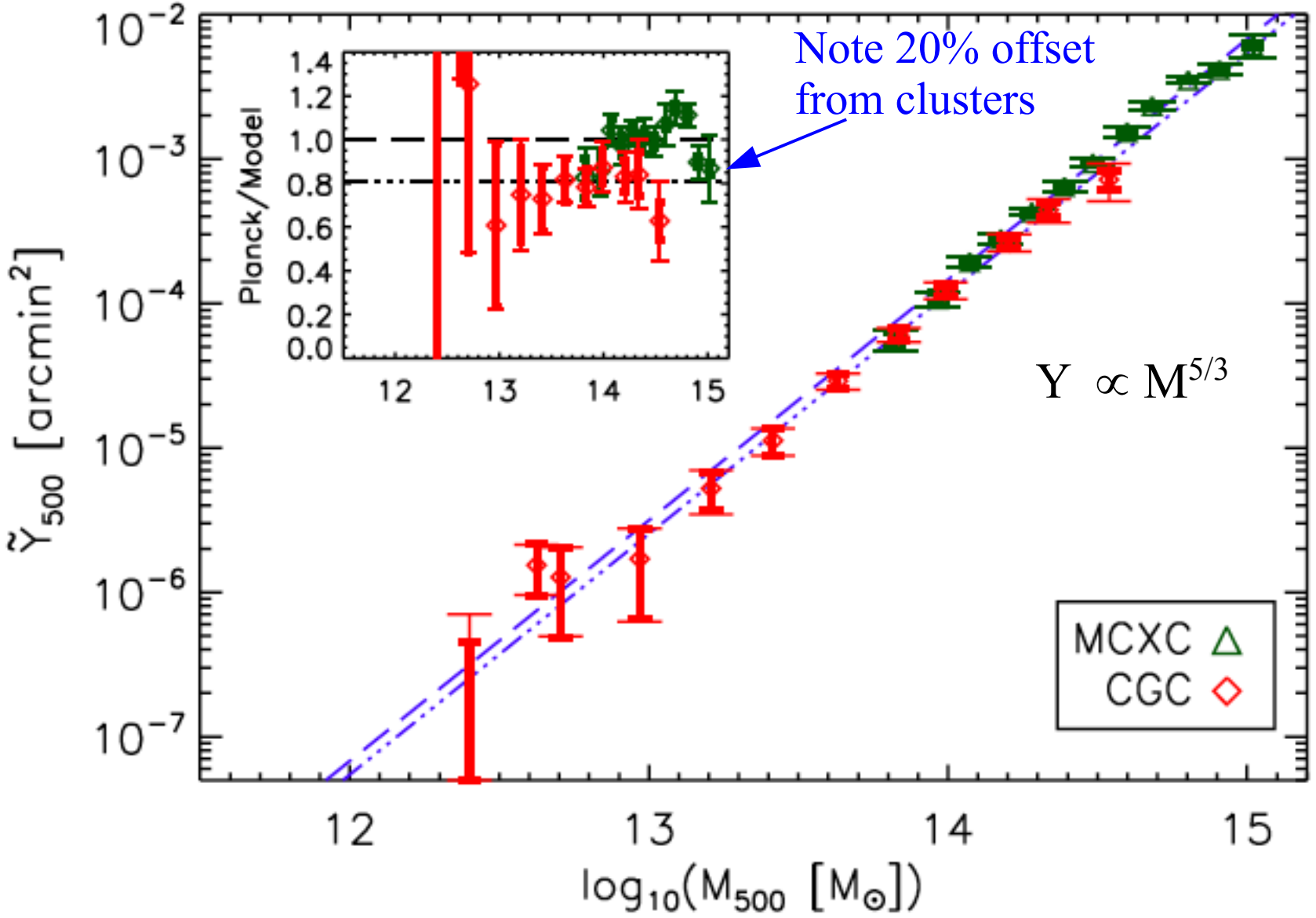
Stacked Planck SZ signal from LBGs

Planck Collaboration 2013



Stacked Planck SZ signal from LBGs

Planck Collaboration 2013



Stacked Planck SZ signal from LBGs

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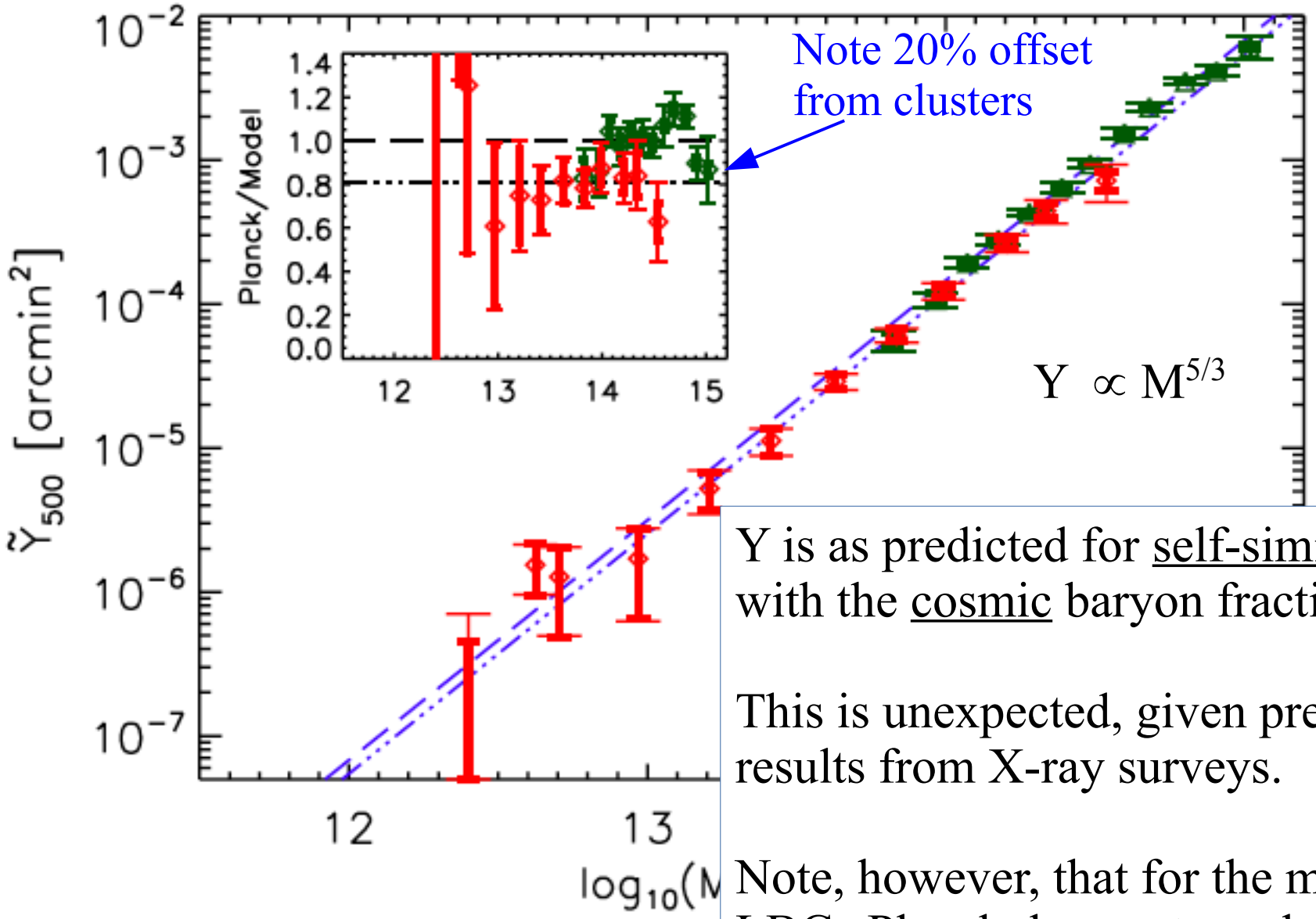


Y is as predicted for <u>self-similar</u> halos with the <u>cosmic</u> baryon fraction

This is unexpected, given previous results from X-ray surveys.

Note, however, that for the majority of LBGs Planck does <u>not</u> resolve R_{500}

Stacked Rosat X-ray signal from LBGs

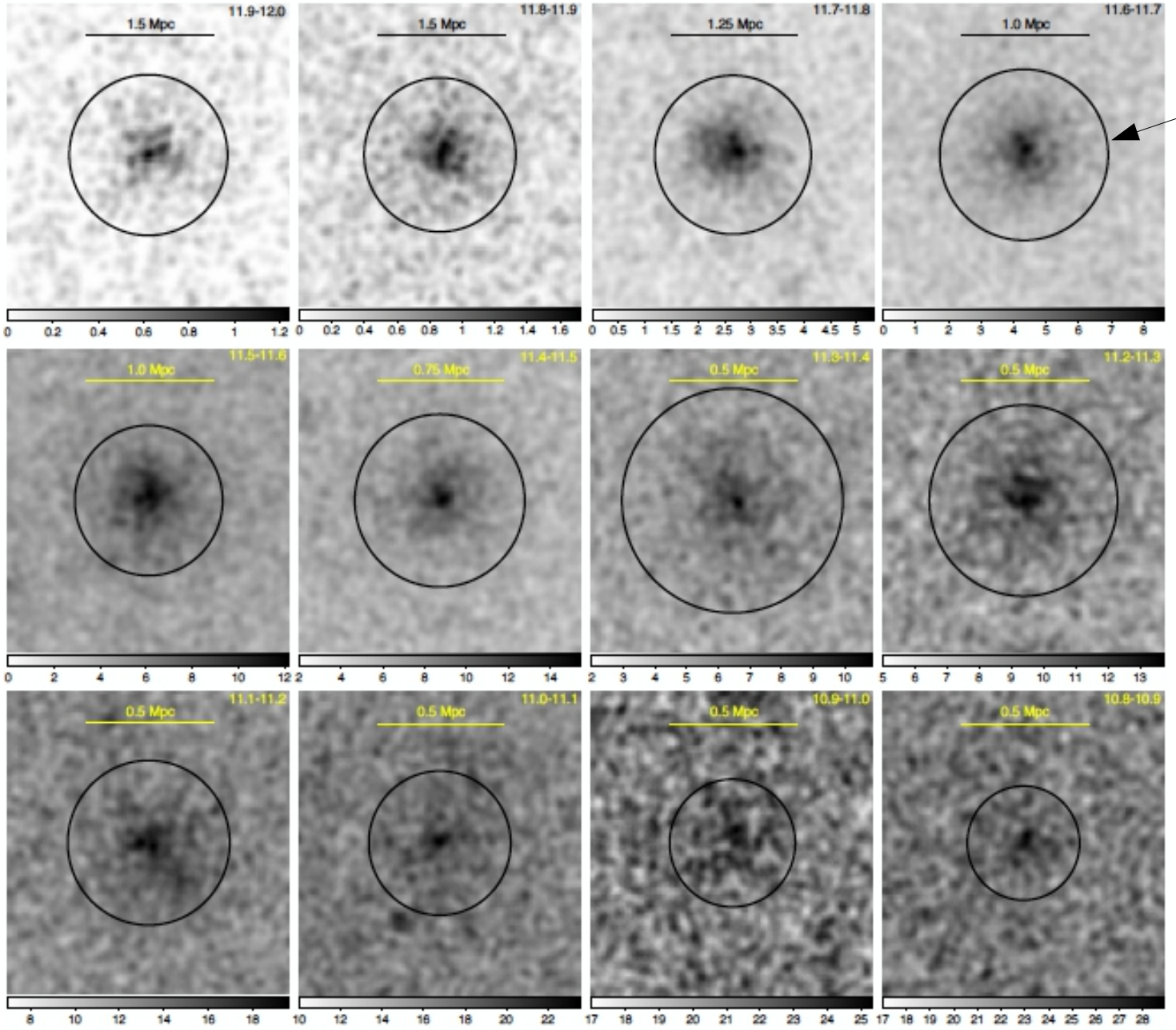
log M_*

Anderson et al 2015

11.9 – 12.0

11.5 – 11.6

11.1 – 11.2

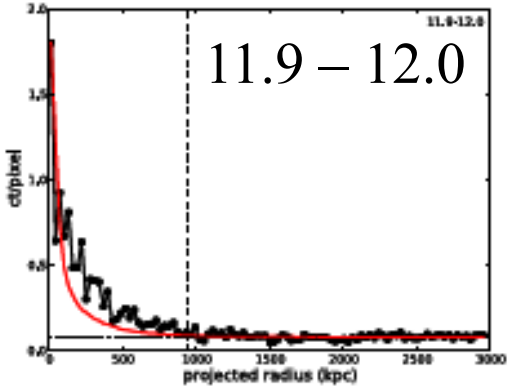


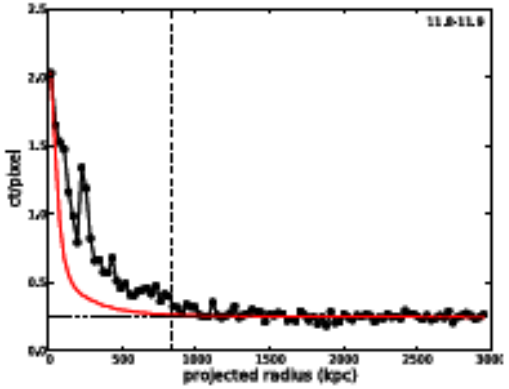
R_{500}

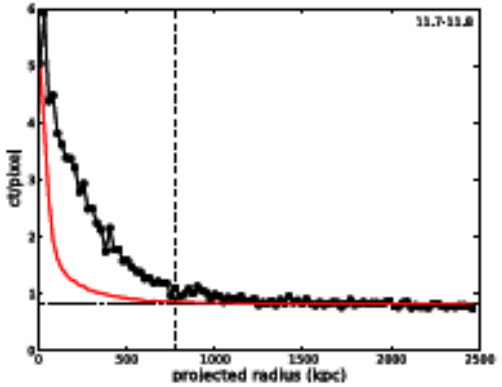
Stacked Rosat X-ray signal from LBGs

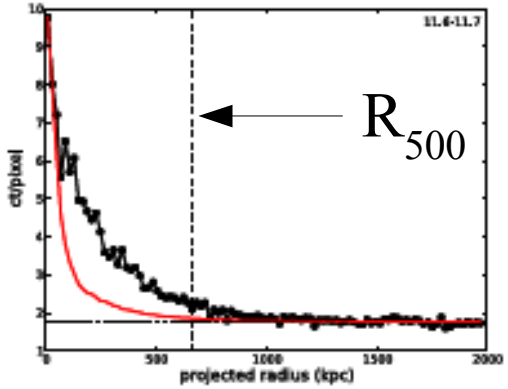
log M_*

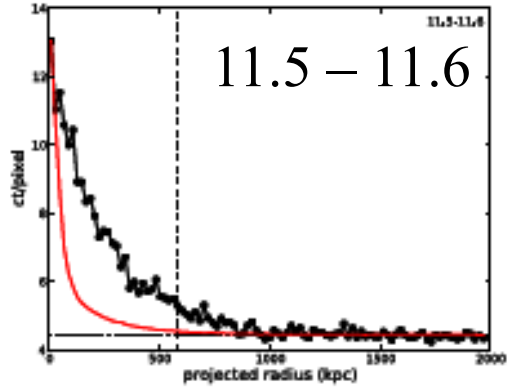
Anderson et al 2015

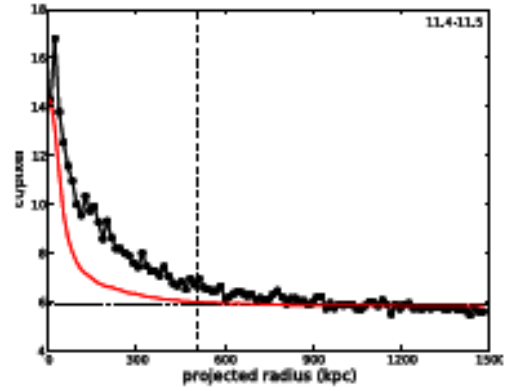


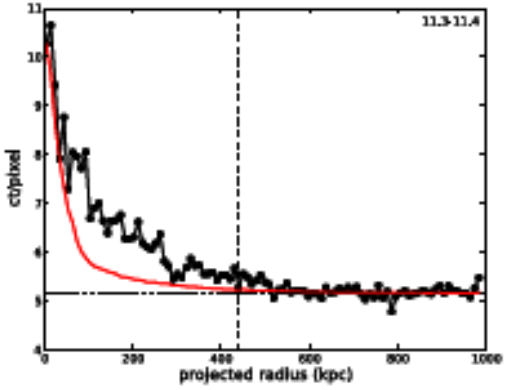


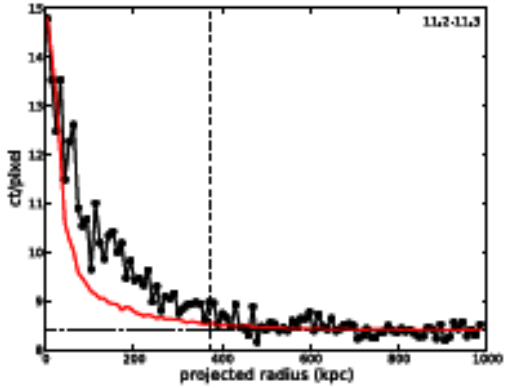


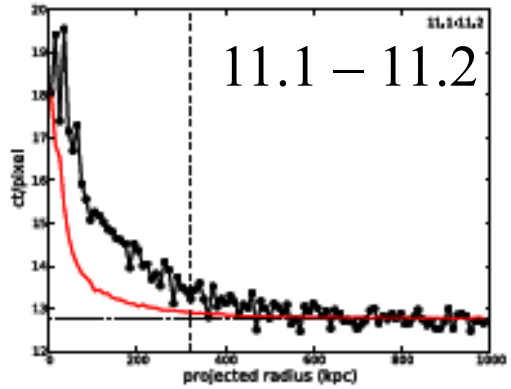


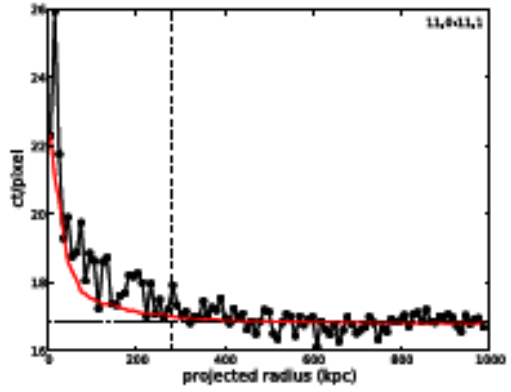


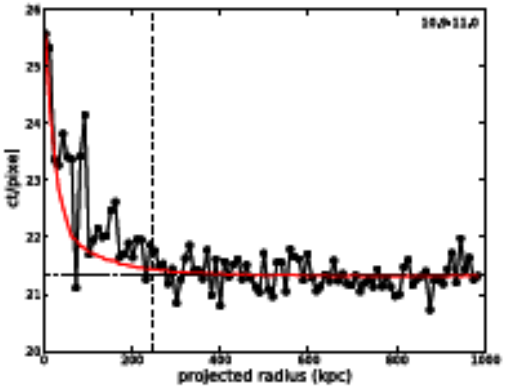


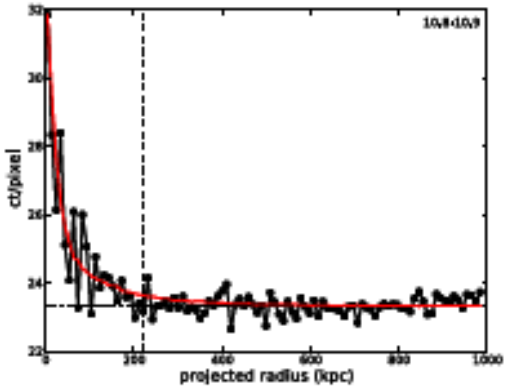






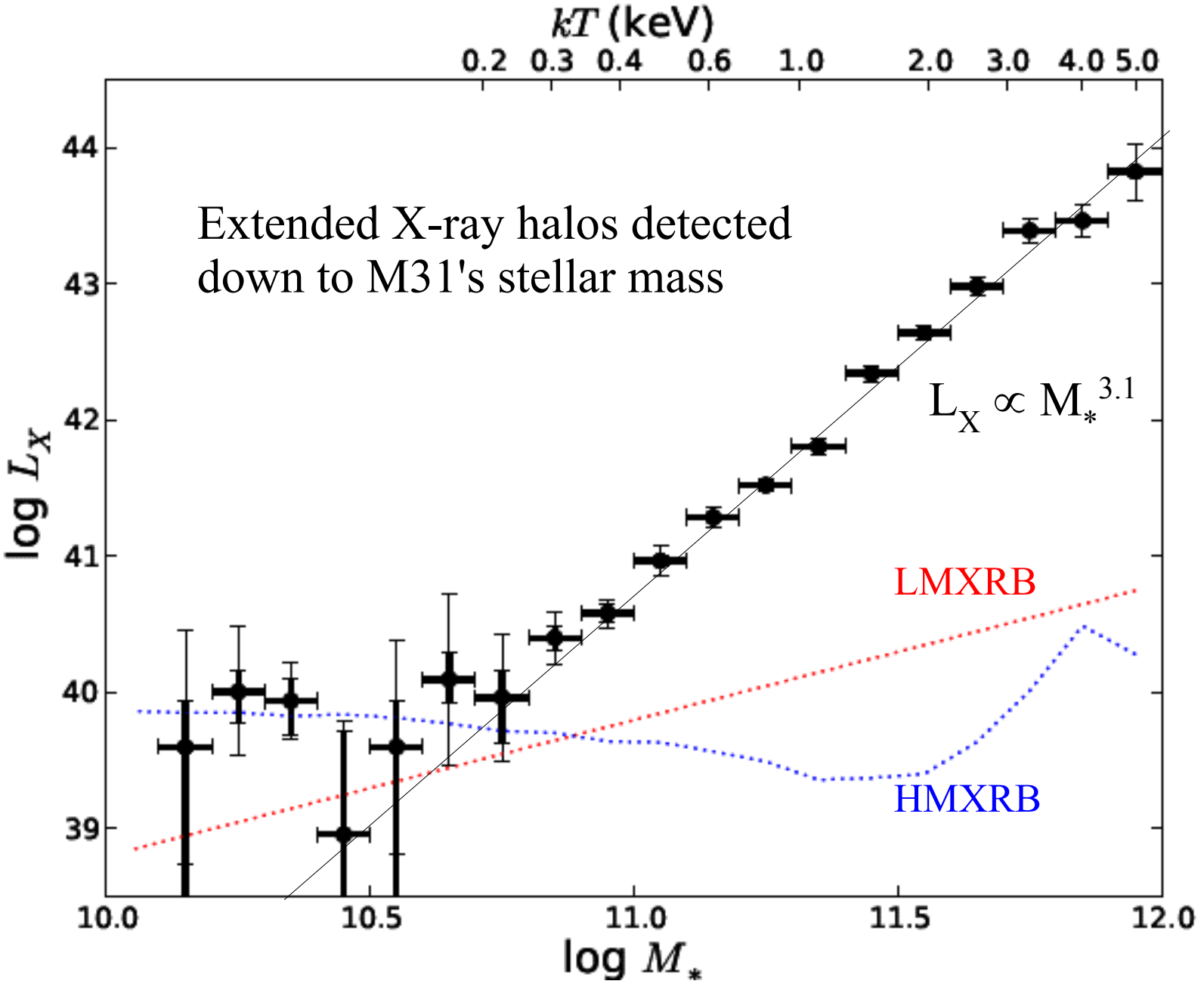






Stacked Rosat X-ray signal from LBGs

Anderson et al 2015



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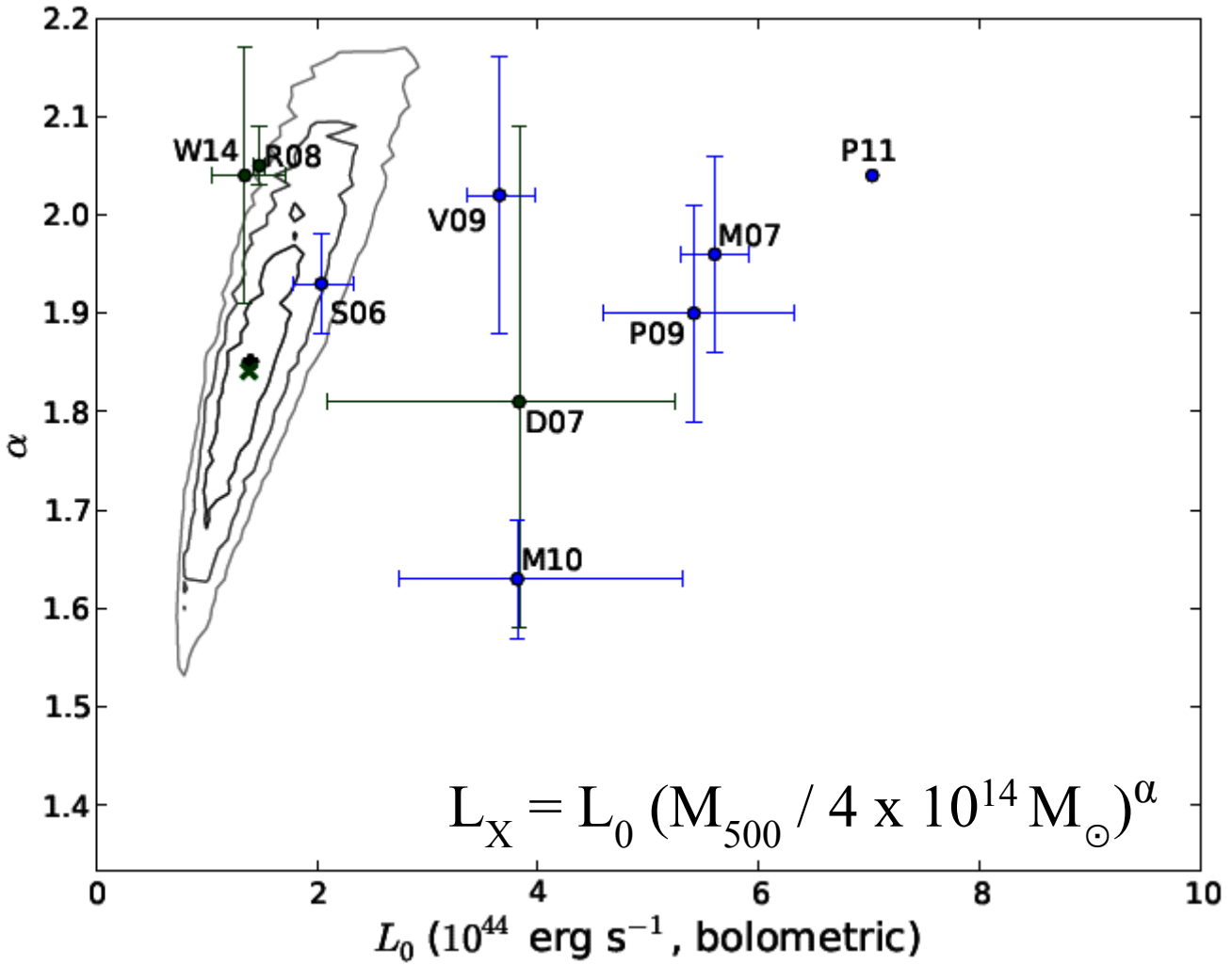


Anderson et al 2015

$\alpha = 4/3$ is expected for self-similar halos with constant baryon fraction

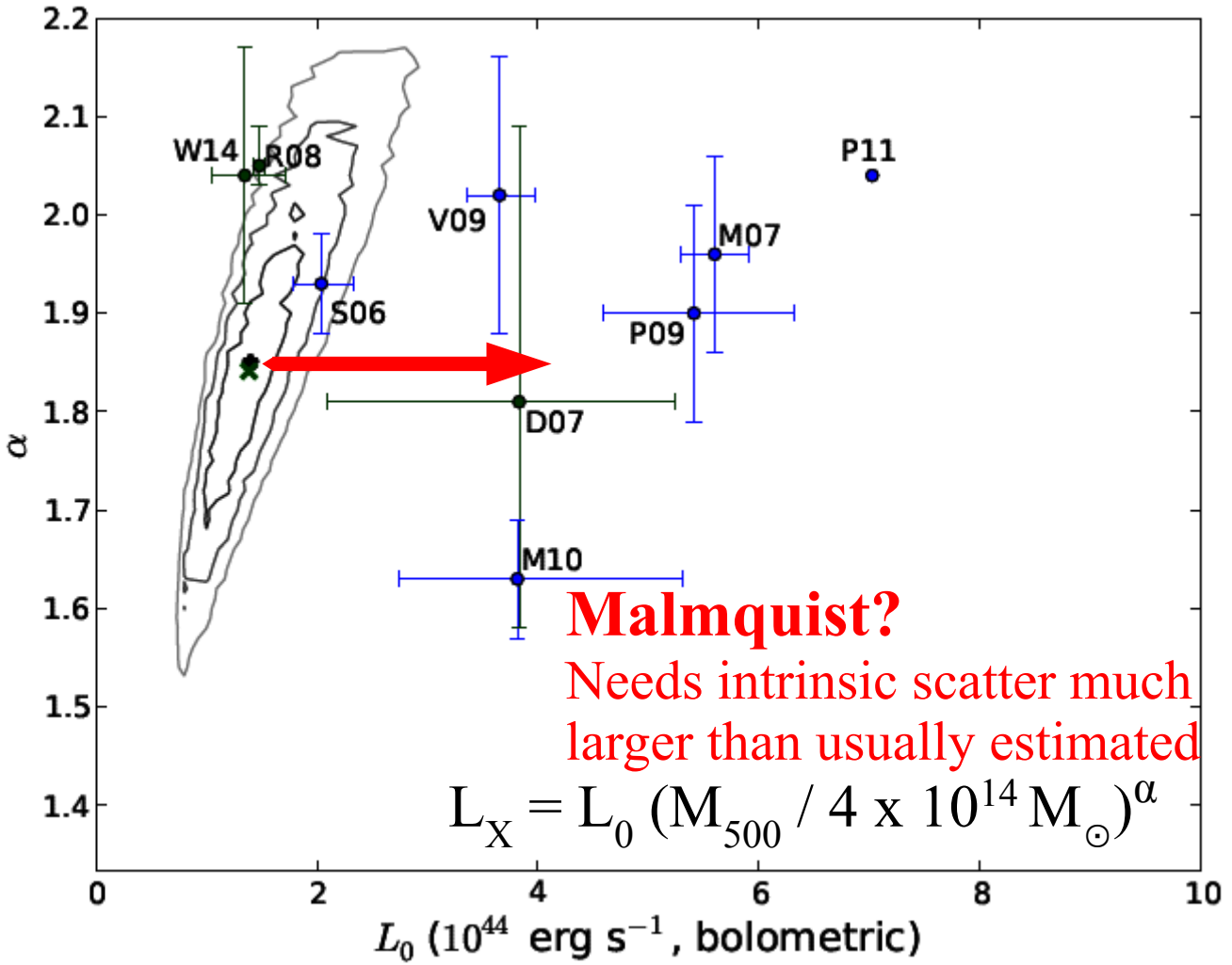
X-ray luminosity grows much faster with mass than this

Forward modelling using the Guo13 mock LBG catalogue gives 1, 2 and 3σ ranges for the parameters of the $L_X - M_{500}$ relation

→ rough agreement with results for optically selected clusters

<u>disagreement</u> in normalisation with results for X-ray selected clusters

Stacked Rosat X-ray signal from LBGs



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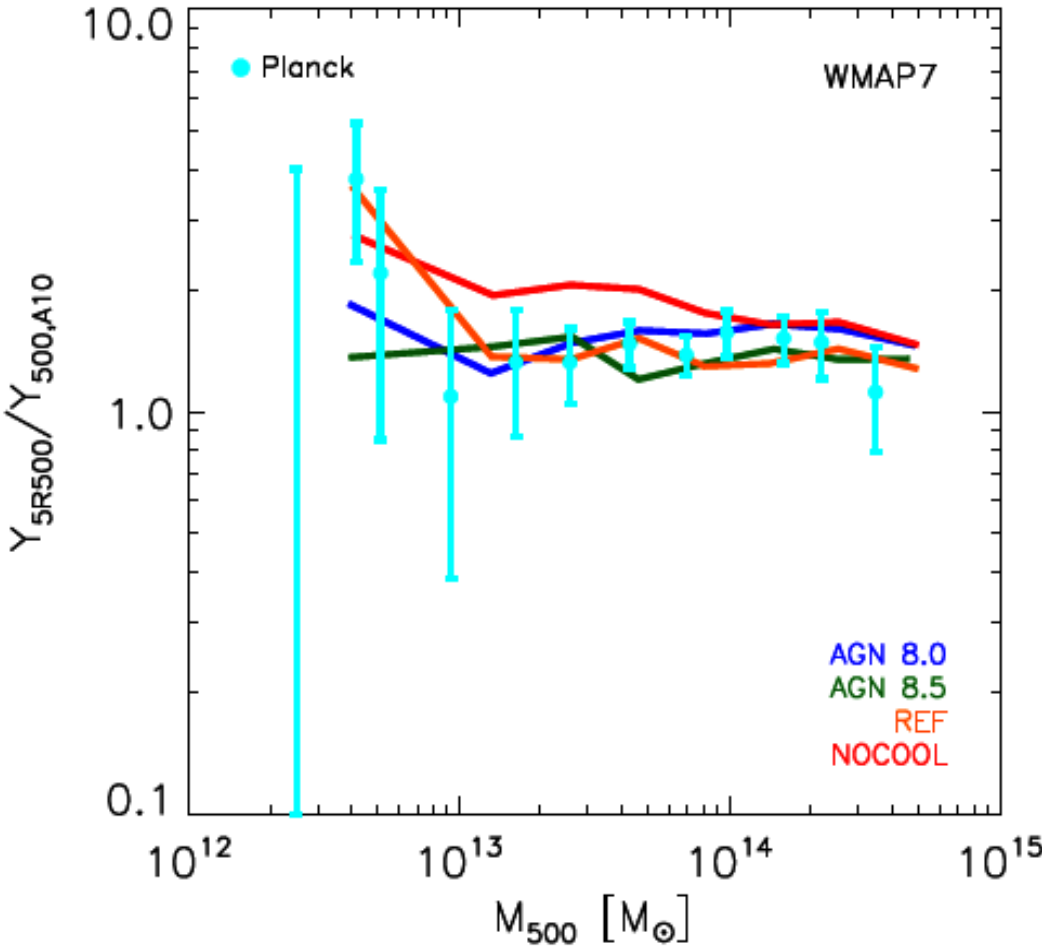
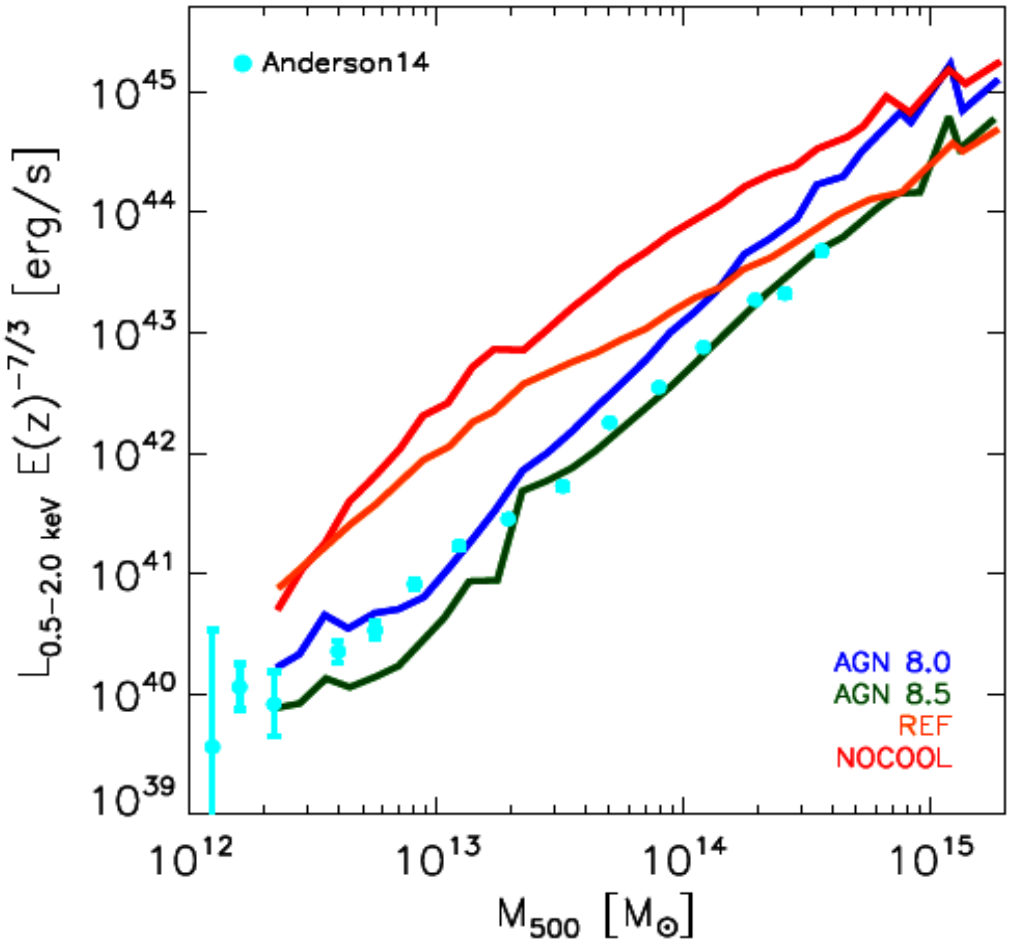
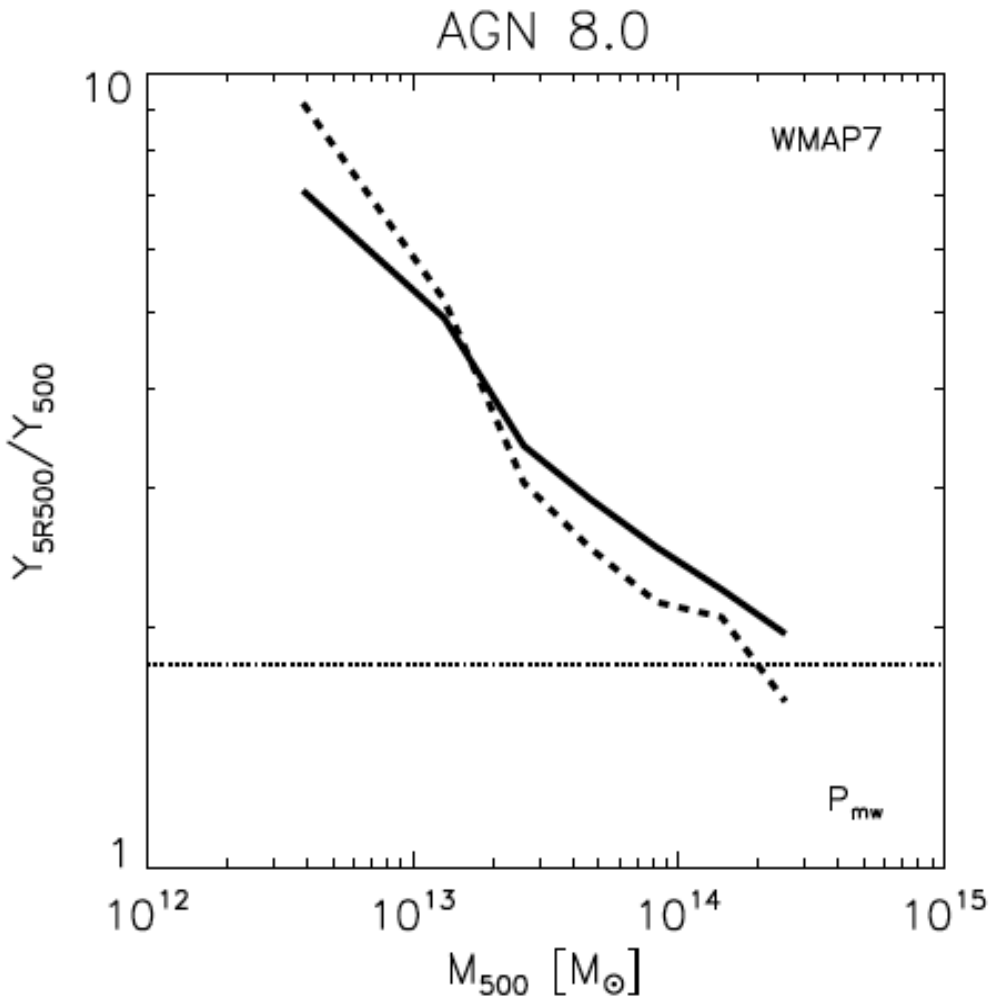
Le Brun, McCarthy & Melin 2015





With AGN feedback, the cosmo-OWLS simulations come close to reproducing *both* the nearly self-similar behaviour of the Planck SZ measurements and the non-self-similar behaviour of the ROSAT stacks

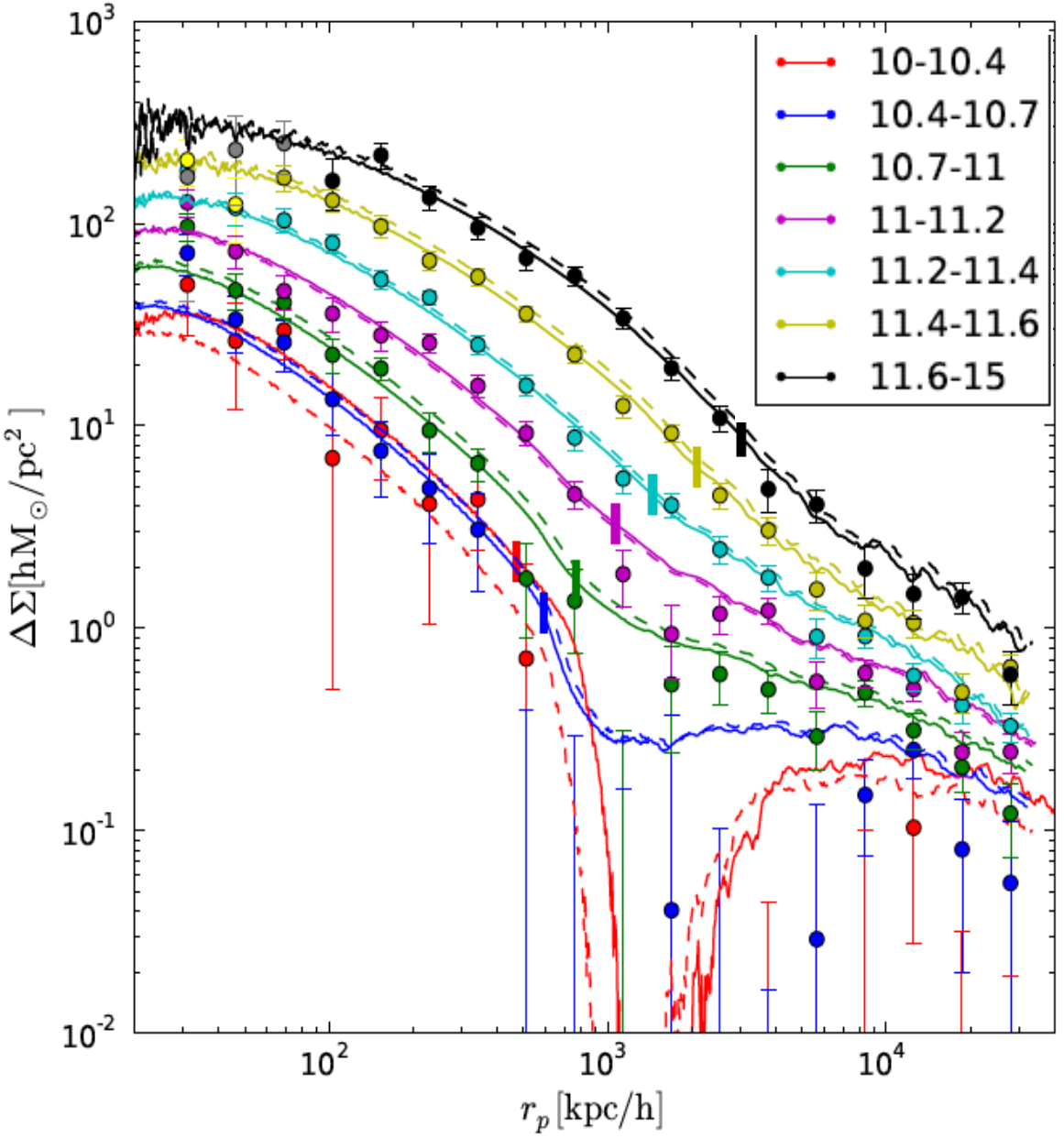
Le Brun, McCarthy & Melin 2015



With AGN feedback, the cosmo-OWLS simulations come close to reproducing *both* the nearly self-similar behaviour of the Planck SZ measurements and the non-self-similar behaviour of the ROSAT stacks

They predict the Y signal to be much less concentrated in low-mass halos

Stacked weak lensing signal from LBGs



Wang, Mandelbaum et al (2015)

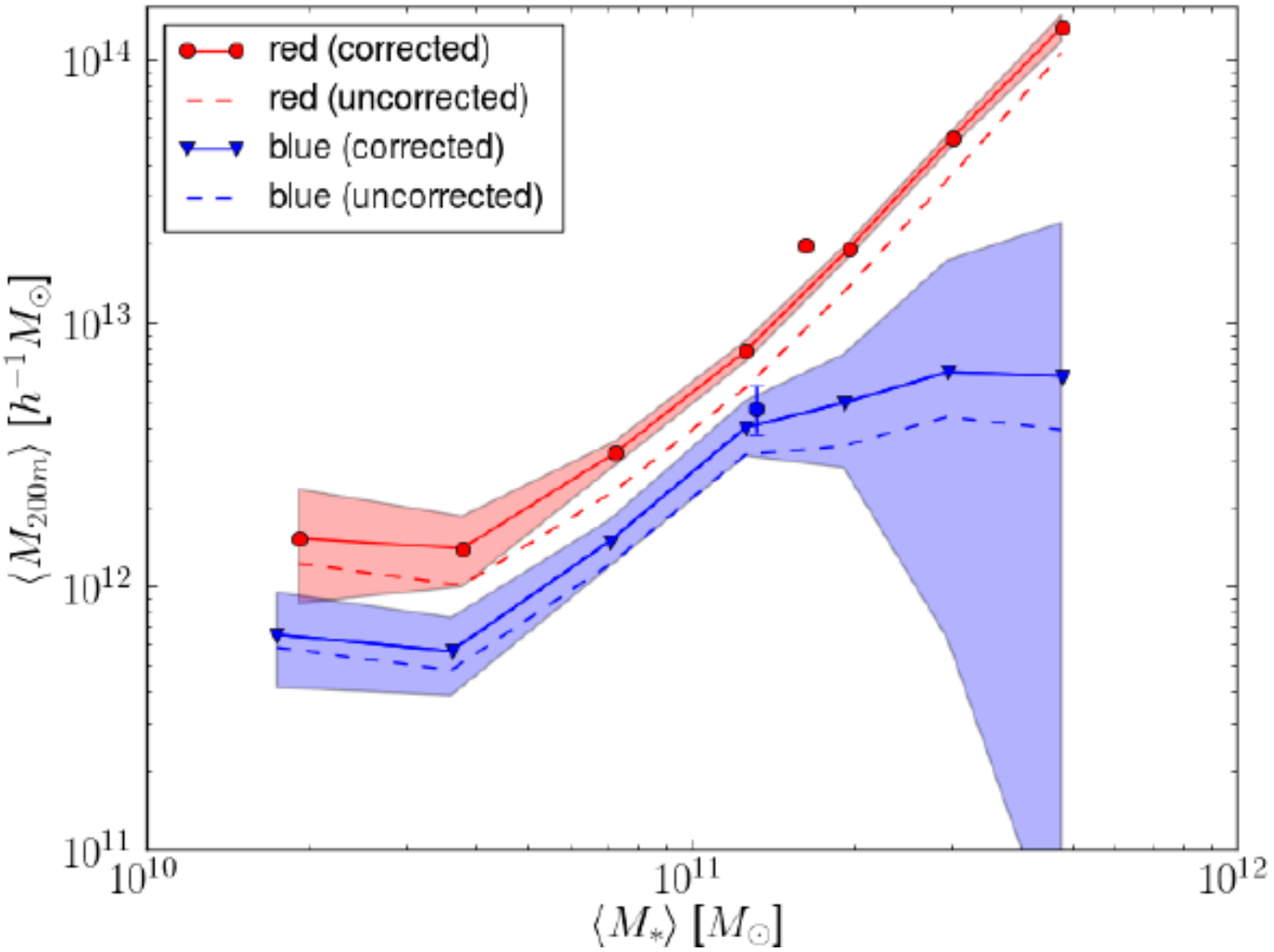
Points are results for SDSS/DR7

Dashed lines are predictions for locally brightest galaxies from the simulation used to calibrate the SZ/X-ray scaling relations

Shifting to match the lensing data externally recalibrates the these scaling relations over their full mass range, removing almost all cosmology and model dependences.

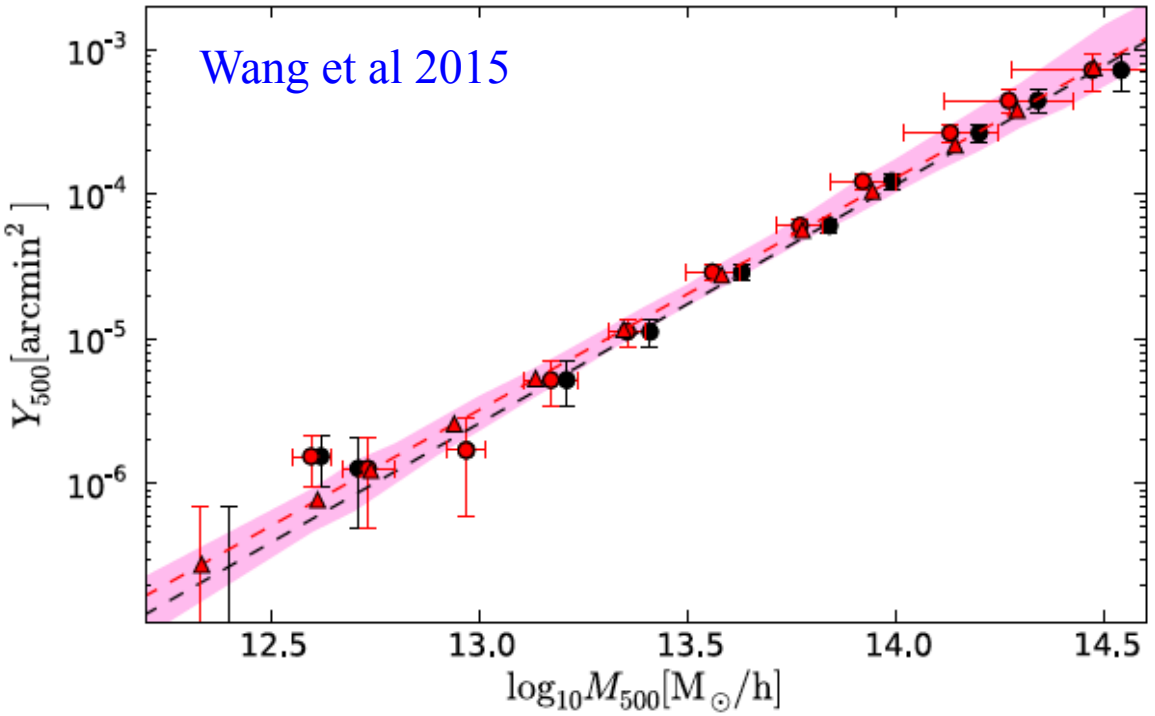
Stacked weak lensing signal from LBGs as a function of their colour

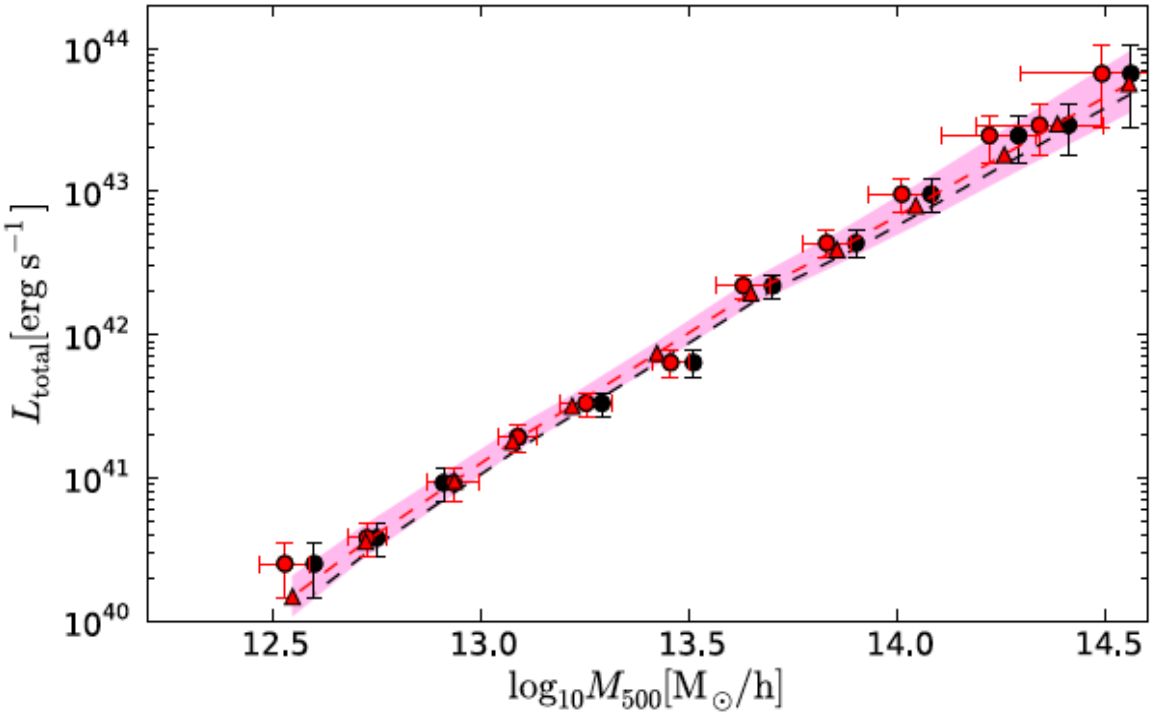
Mandelbaum et al 2015



At given stellar mass the mean halo mass of passive LBGs is more than twice that of star-forming LBGs

This is inconsistent with most current simplified models for populating halos with galaxies.

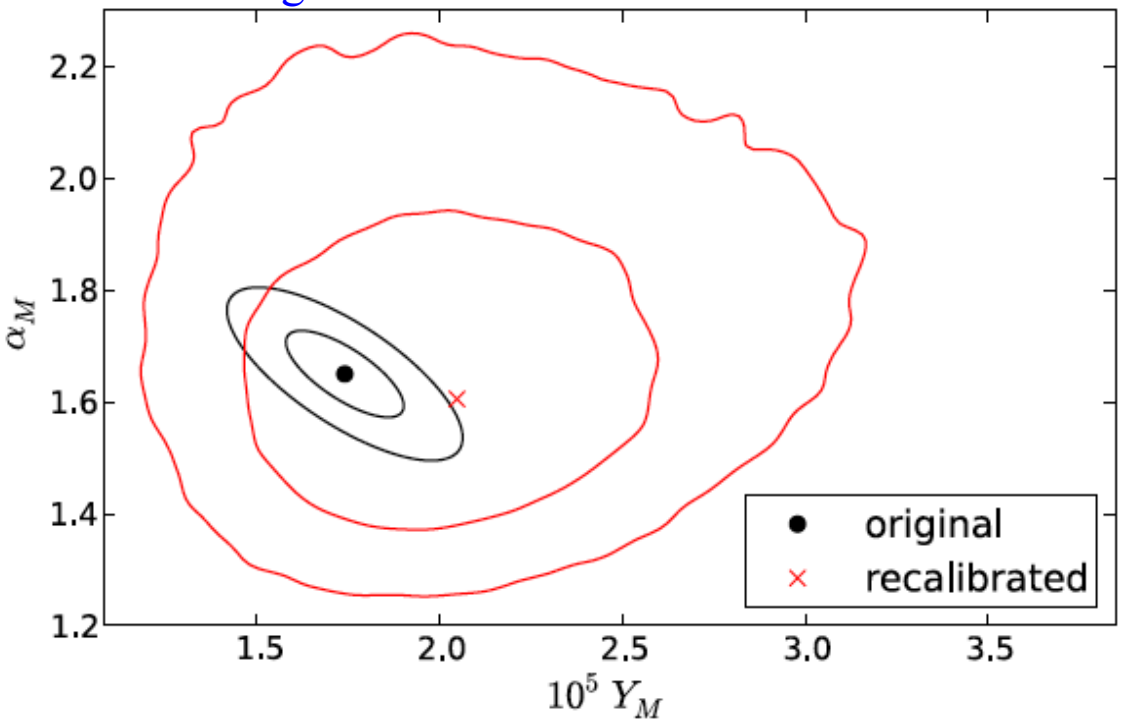


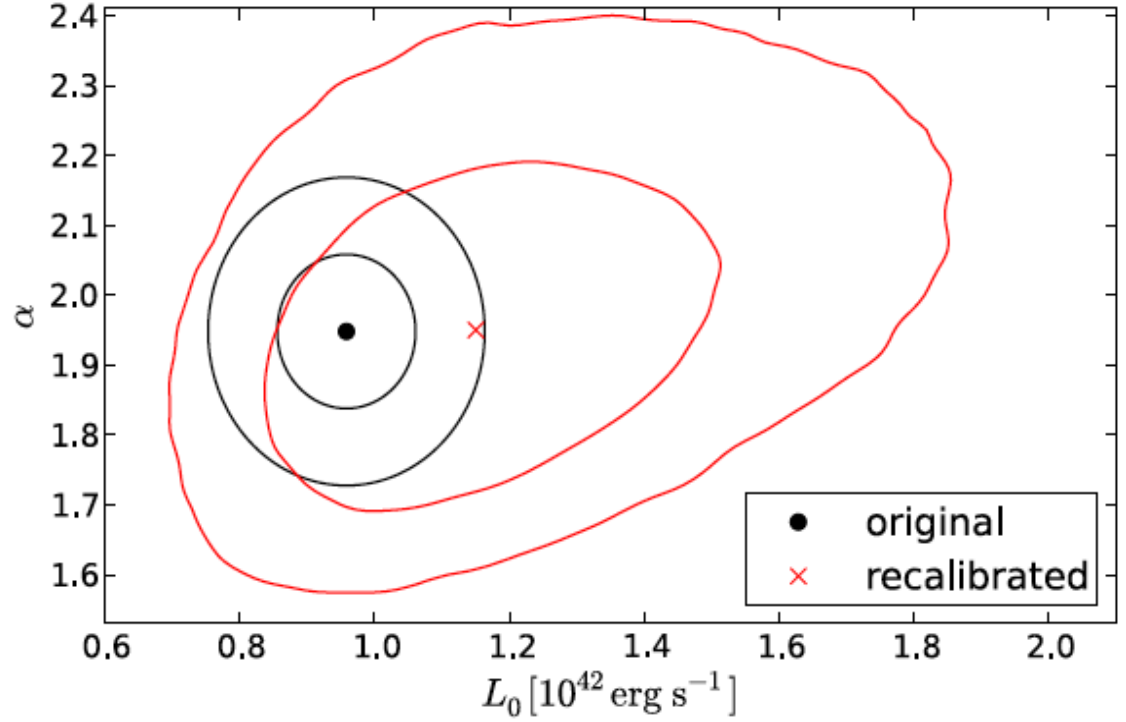


Recalibrated scaling relations

- Almost independent of modelling assumptions
- Full treatment of errors in both masses and SZ/X-ray signals
- Mean values for a representative population of halos
- Covering the halo mass range $10^{12.5}\,\mathrm{M}_\odot < \mathrm{M}_{\mathrm{halo}} < 10^{14.5}\,\mathrm{M}_\odot$ which accounts for ~25% of all the expected baryons

Wang et al 2015





Recalibrated scaling relations

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- Mean values for a representative population of halos
- Covering the halo mass range $10^{12.5}\,M_\odot < M_{halo} < 10^{14.5}\,M_\odot$ which accounts for ~25% of all the expected baryons
- High-mass agreement with X-ray clusters only slightly improved

Conclusions for Locally Brightest Galaxies in SDSS/DR7

- Planck detects SZ signal for LBG stacks with log M_* > 11.0
  ROSAT detects X-ray halos for stacks with log M_* > 10.8
  Both signals vary approximately as powers of M_* with no break

- Calibrating to halo mass with a simulation which matches the SDSS stellar mass function in a WMAP7 cosmology
  → $Y - M_{halo}$ as expected for self-similarity at the cosmic baryon fraction
  $L_X - M_{halo}$ substantially steeper than the self-similar prediction

- The gravitational lensing signal of the LBG stacks is detected at high S/N leading to an almost model- and cosmology- independent recalibration of these scaling relations.

- The SZ and X-ray relations can be reconciled if halo baryons are more extended in lower mass halos but still hot, as predicted for strong AGN feedback models. .
  → Planck has found the baryons "missing" from lower mass halos