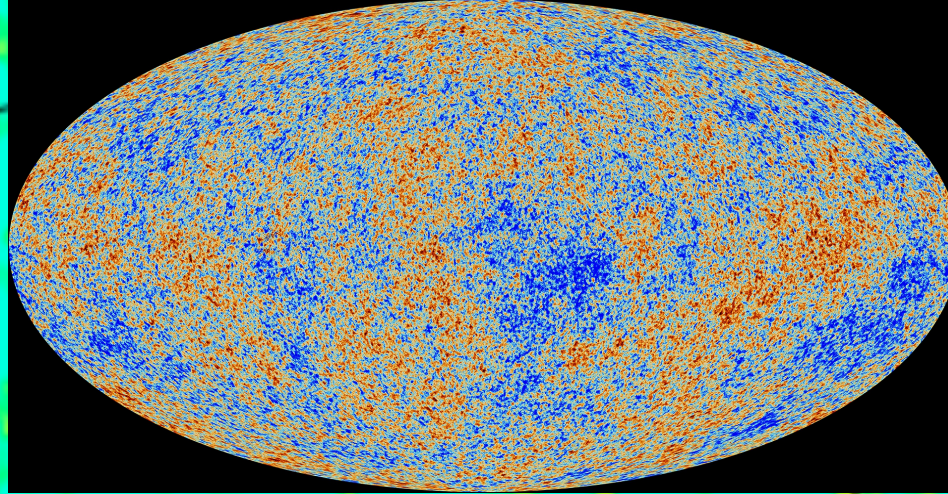


*Aspen
March 2015*



The gas content of dark halos

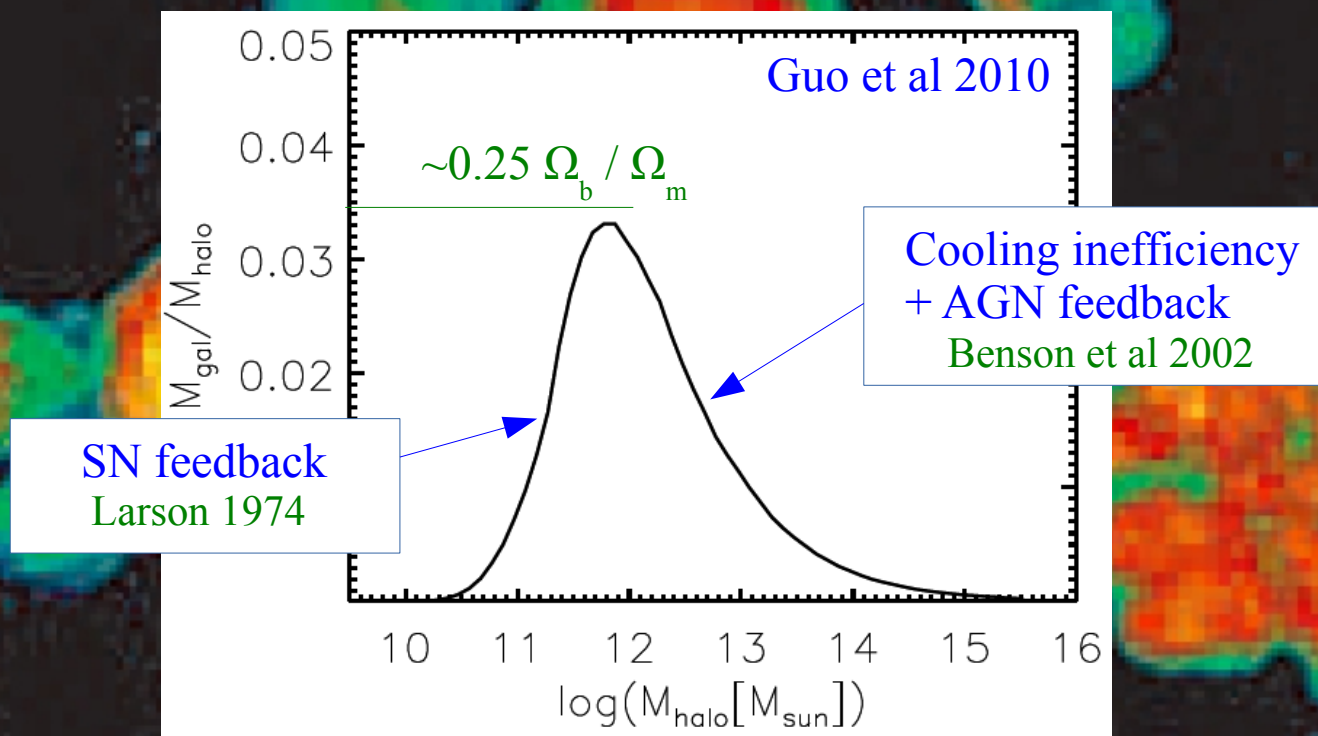
Simon White

Max Planck Institute for Astrophysics

Central galaxies contain $<25\%$ of the expected halo baryons

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?

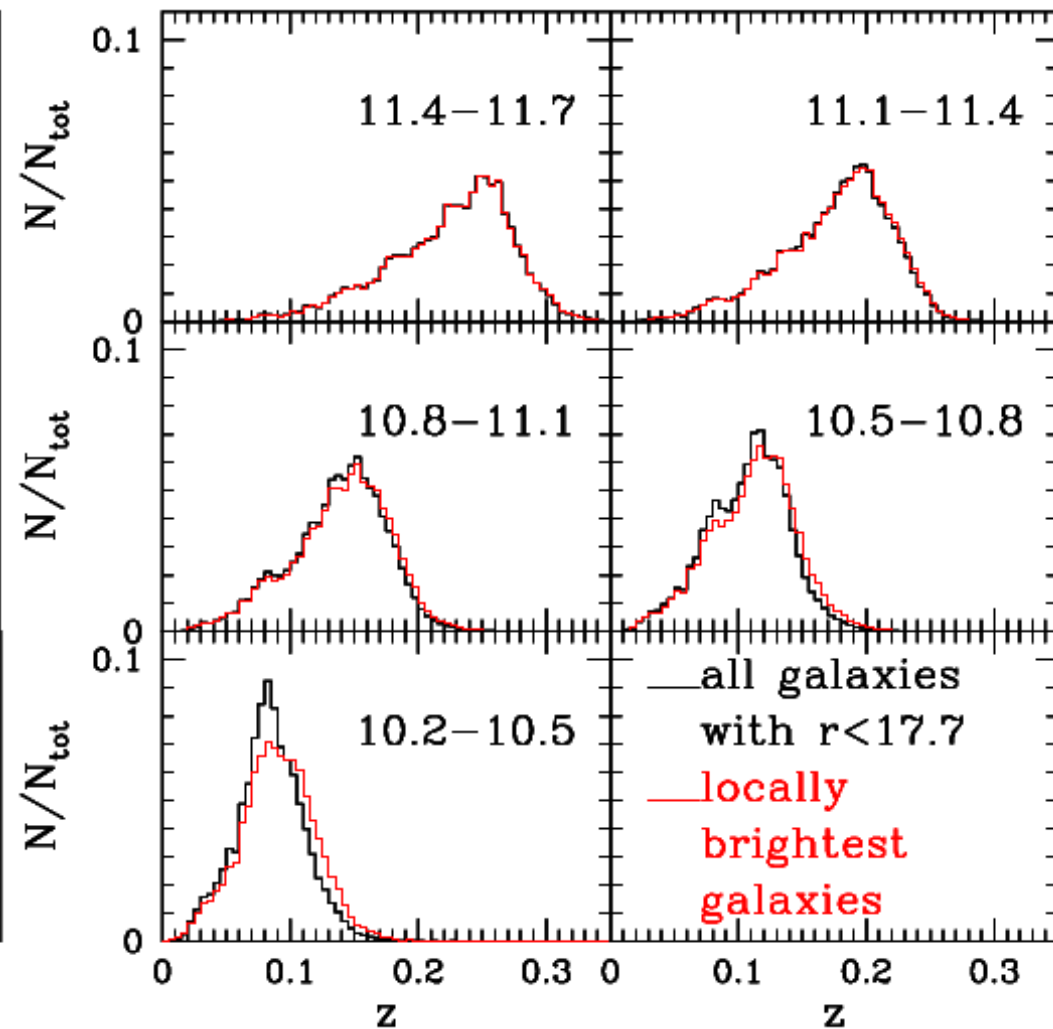
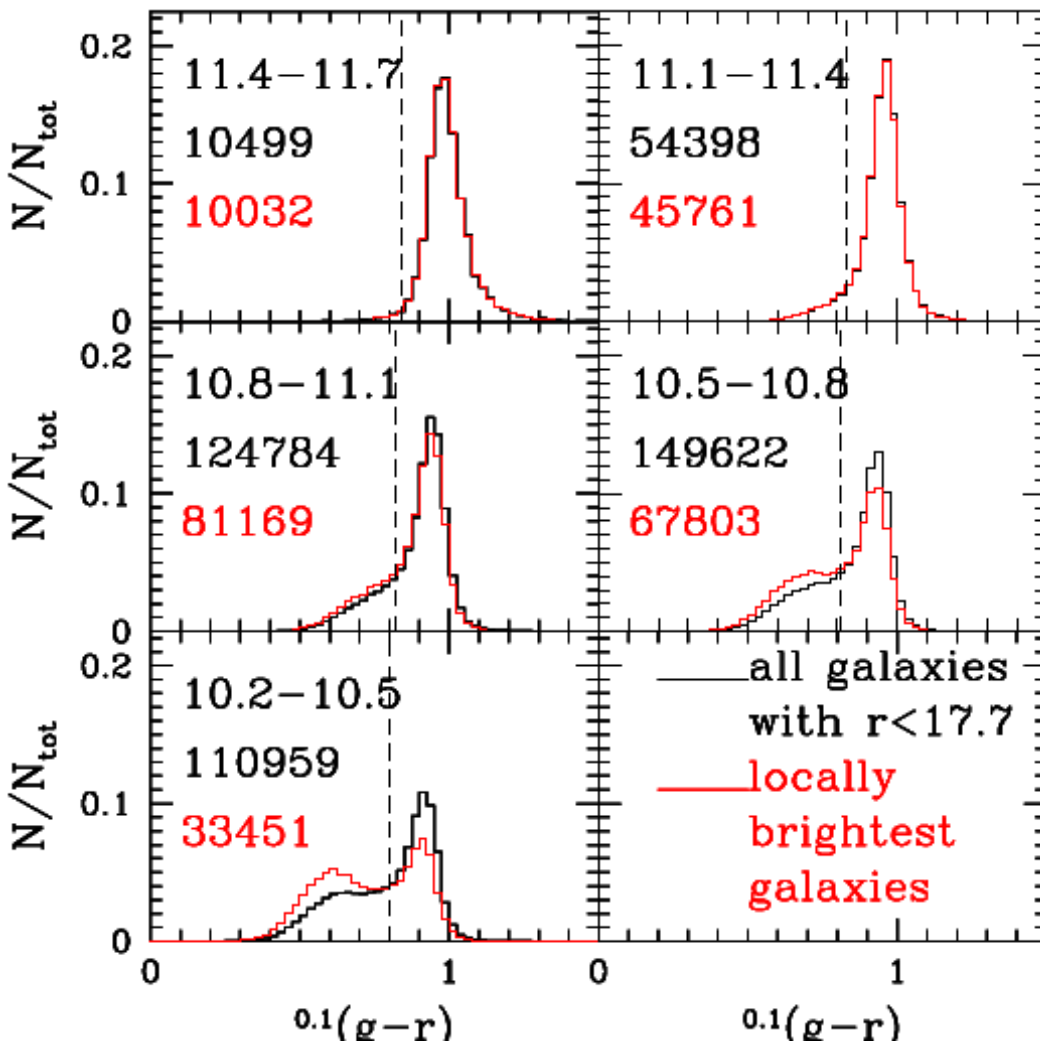


Locally brightest galaxies as halo proxies

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



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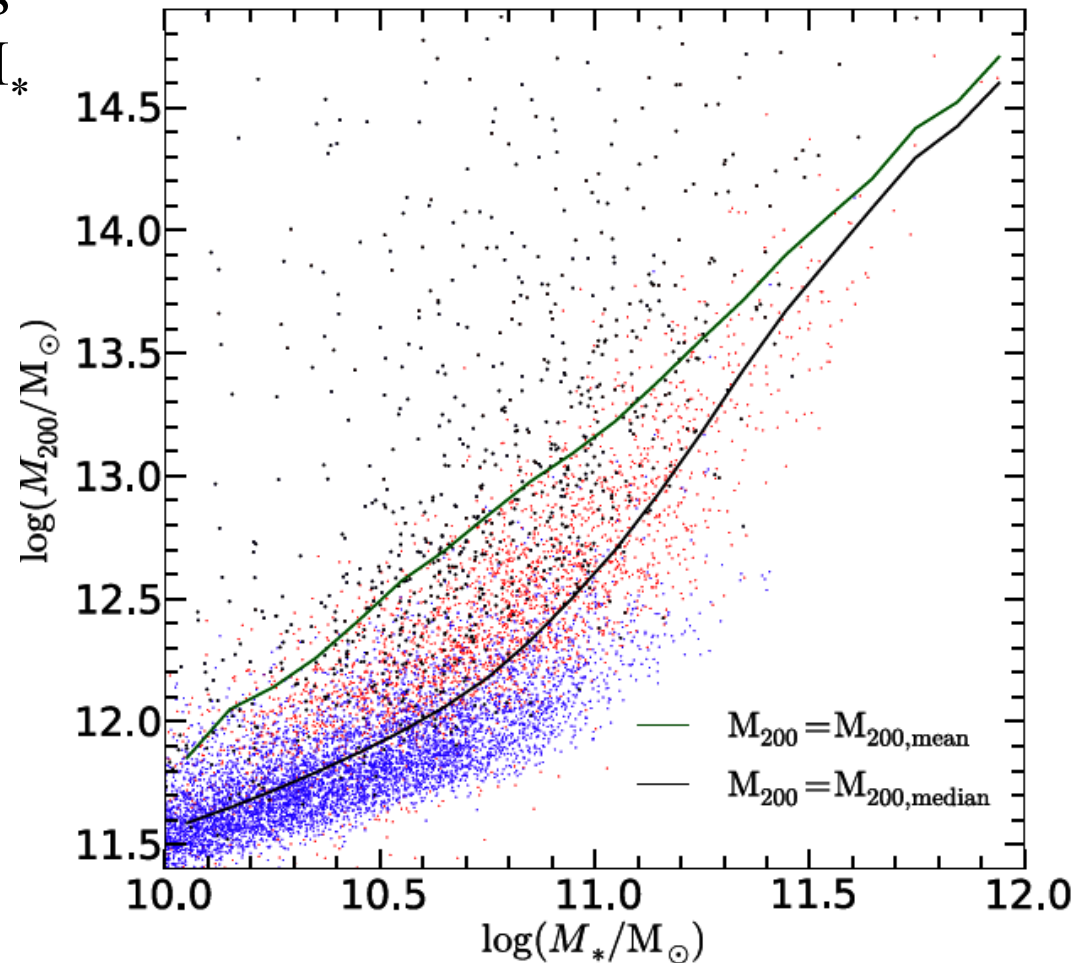
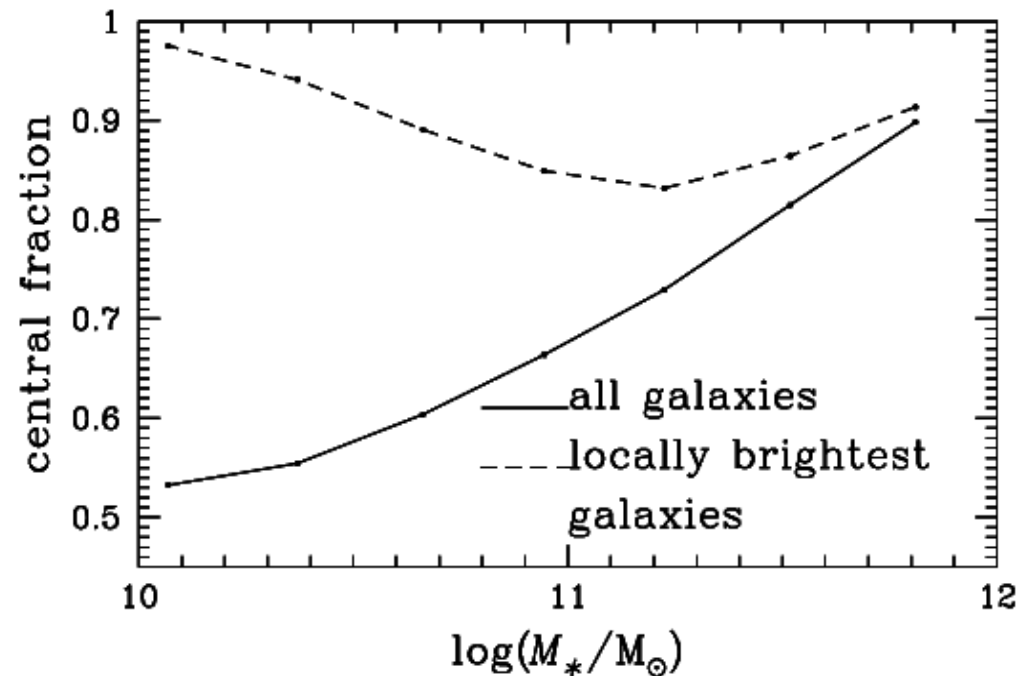
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Mock light-cone: Guo et al (2013) simulation in the WMAP7 cosmology

>83% of LBGs are halo centrals

Large spread in M_{200} at given M_*

Planck Collaboration 2013



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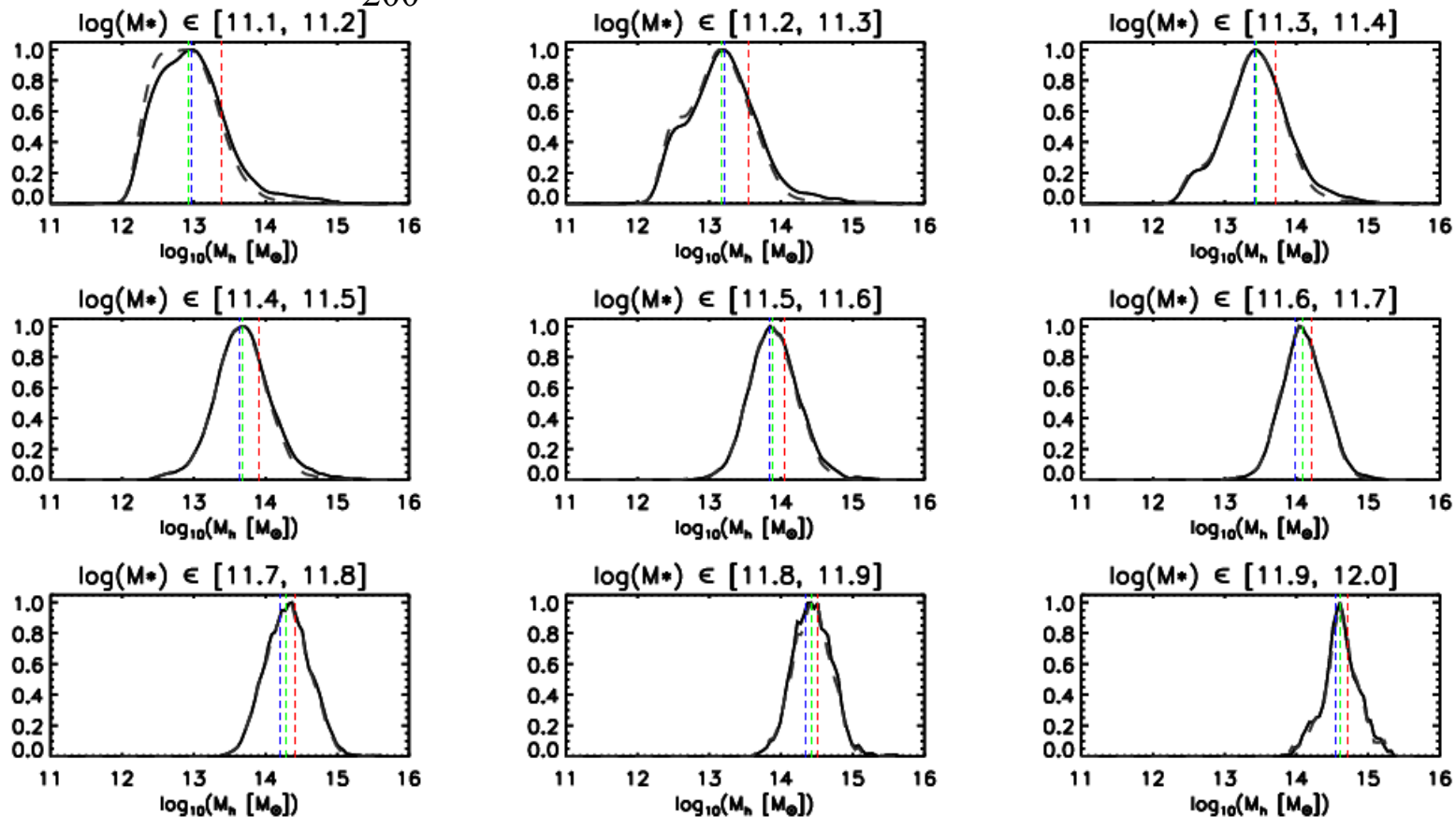
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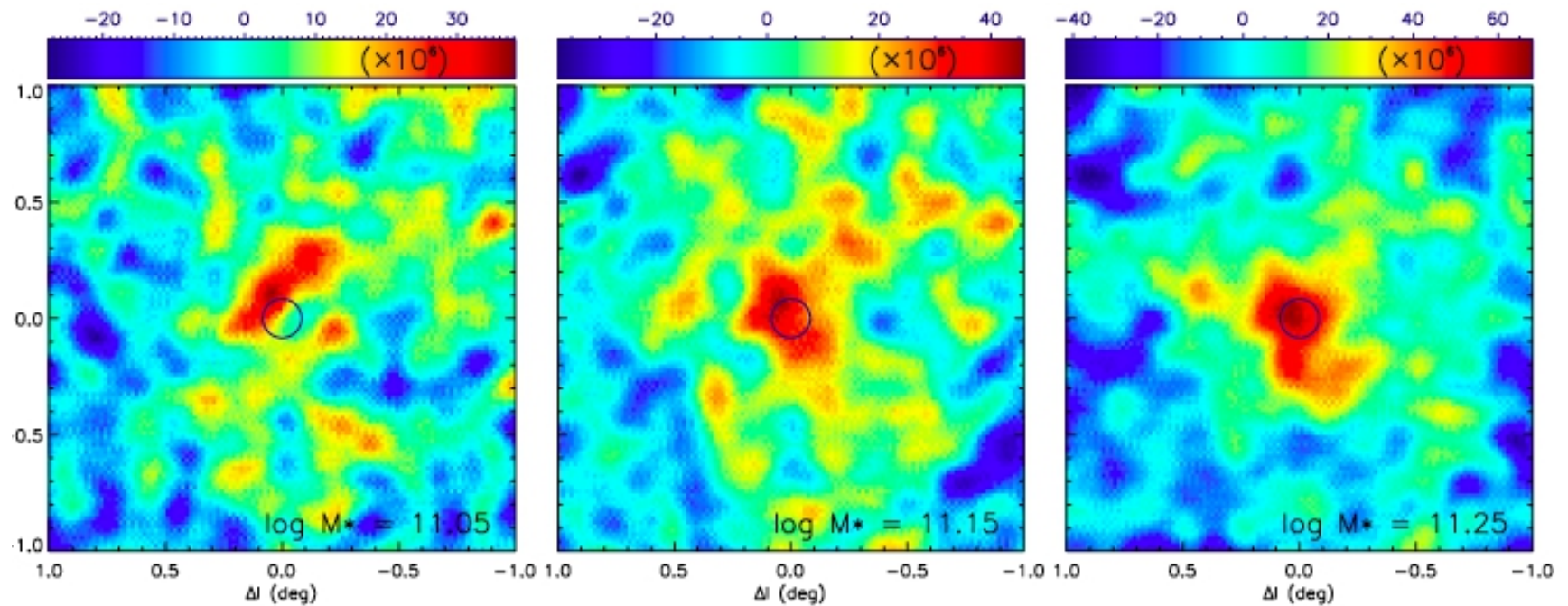
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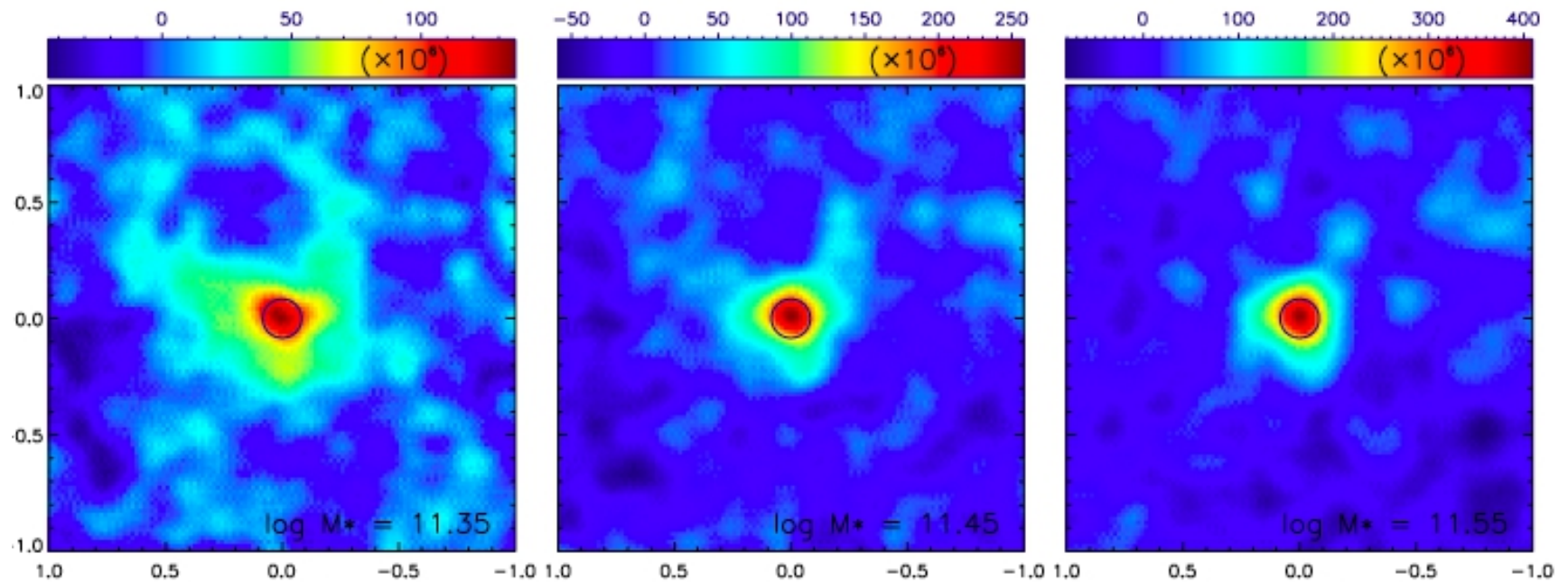
Planck Collaboration 2013



Stacked images of the Planck SZ signal from LBGs

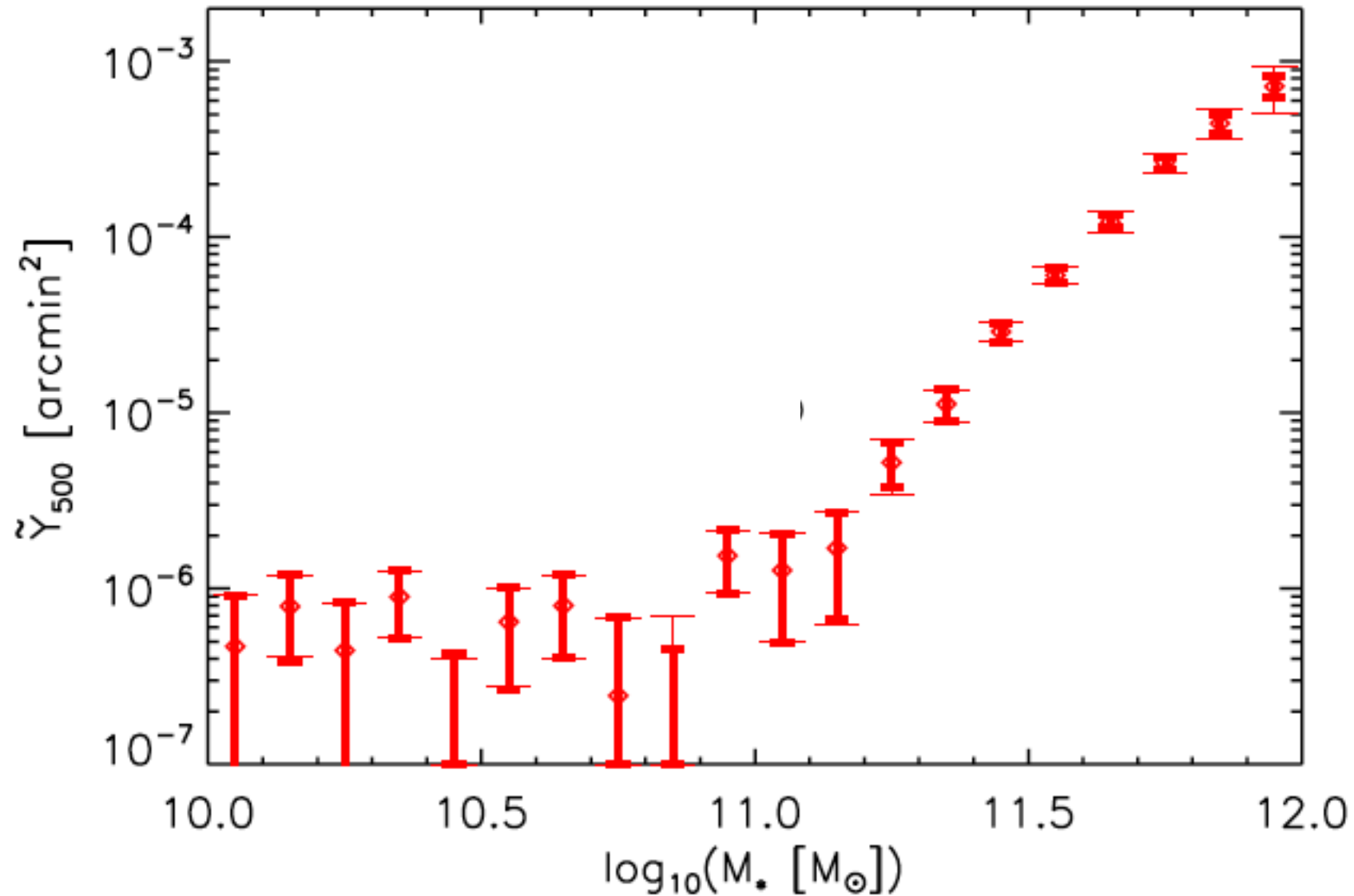


Planck Collaboration 2013



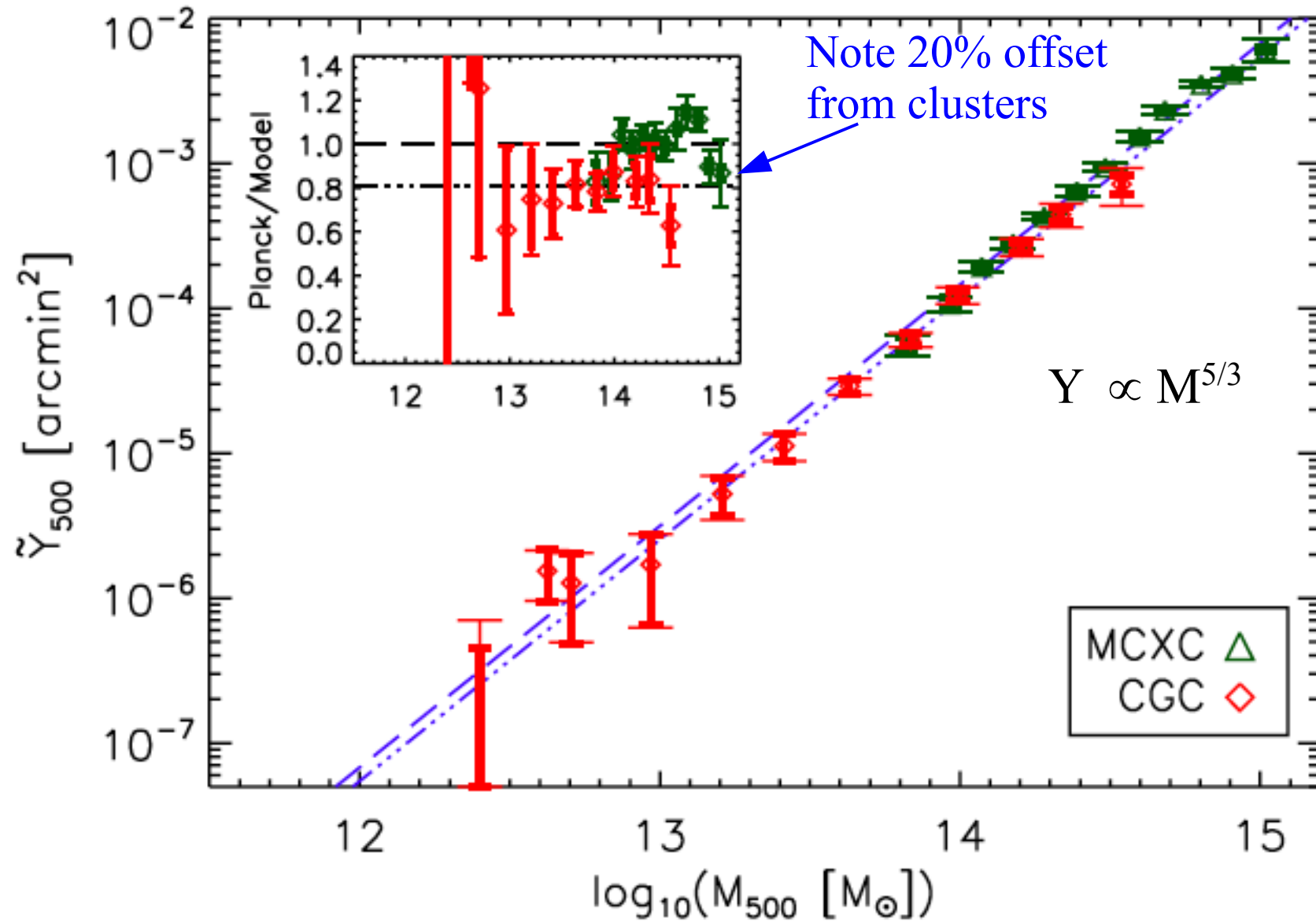
Stacked Planck SZ signal from LBGs

Planck Collaboration 2013



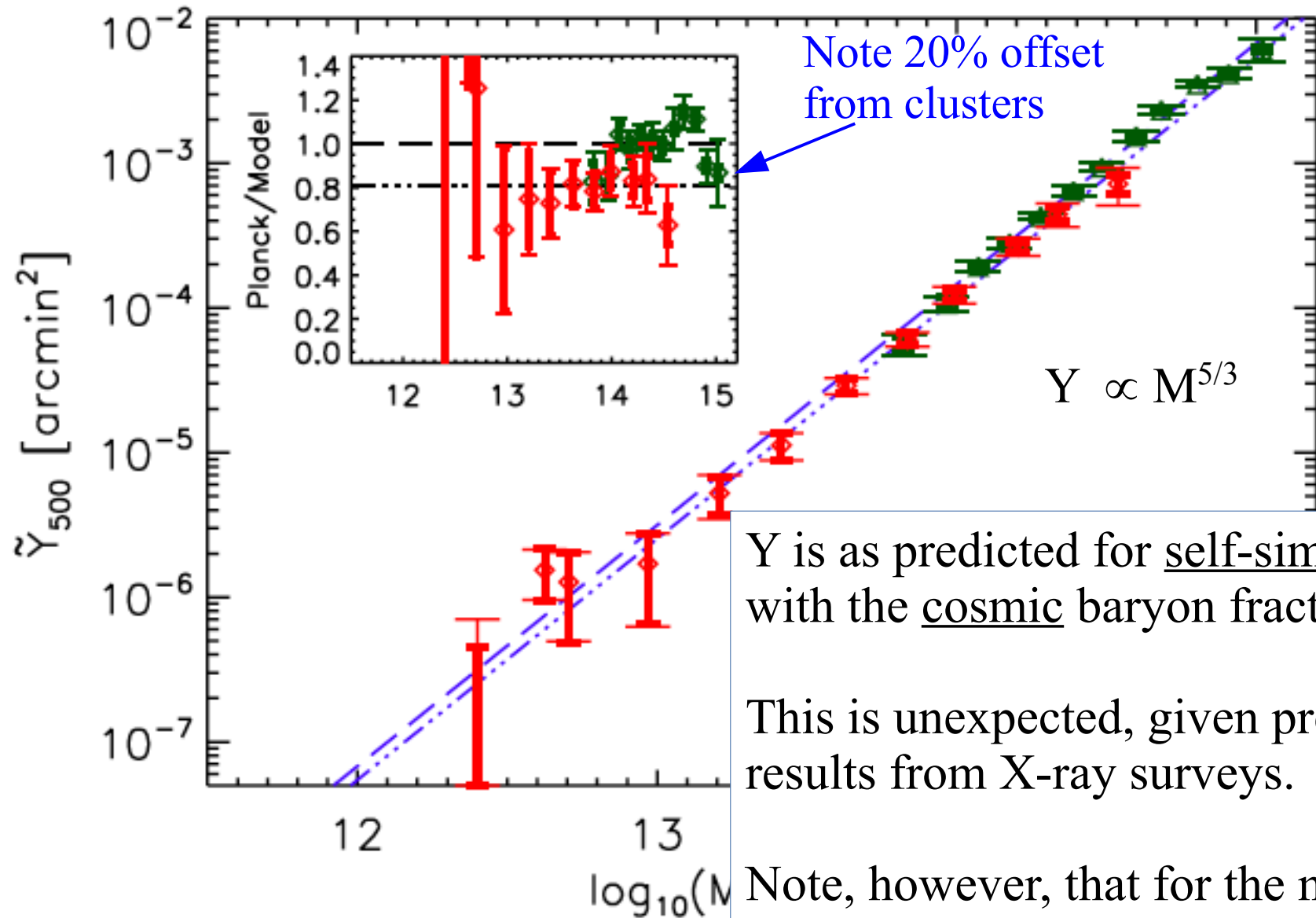
Stacked Planck SZ signal from LBGs

Planck Collaboration 2013



Stacked Planck SZ signal from LBGs

Planck Collaboration 2013



Y is as predicted for self-similar halos with the cosmic baryon fraction

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

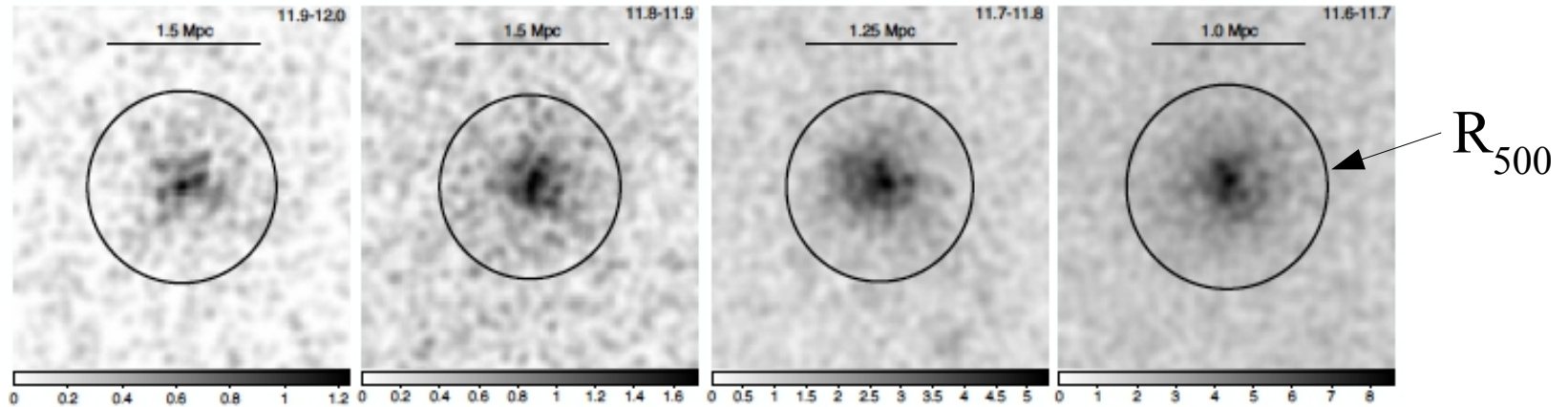
Note, however, that for the majority of LBGs Planck does not resolve R_{500}

Stacked Rosat X-ray signal from LBGs

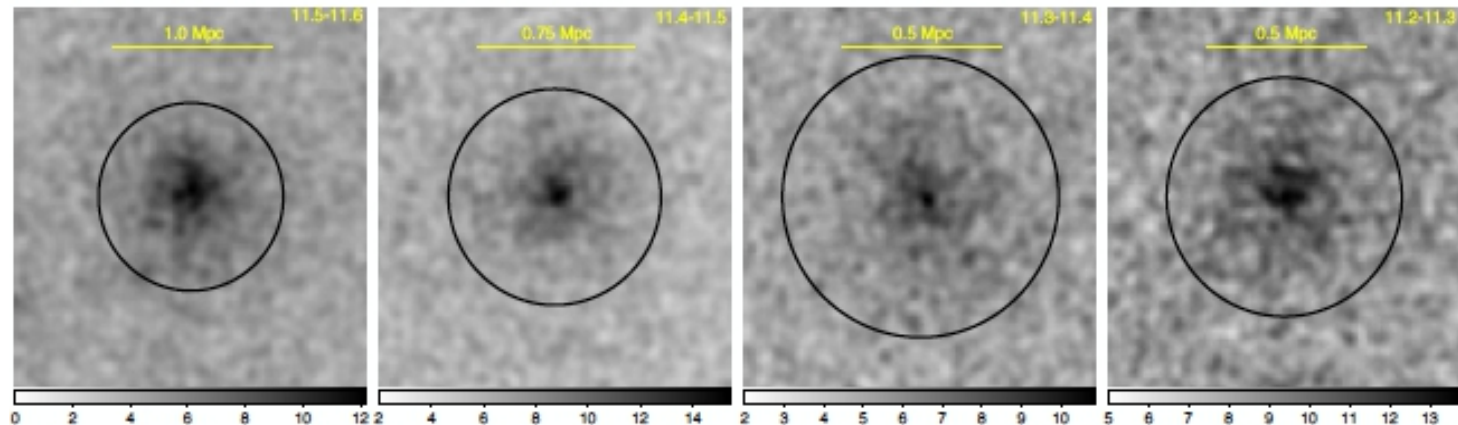
Anderson et al 2015

$\log M_*$

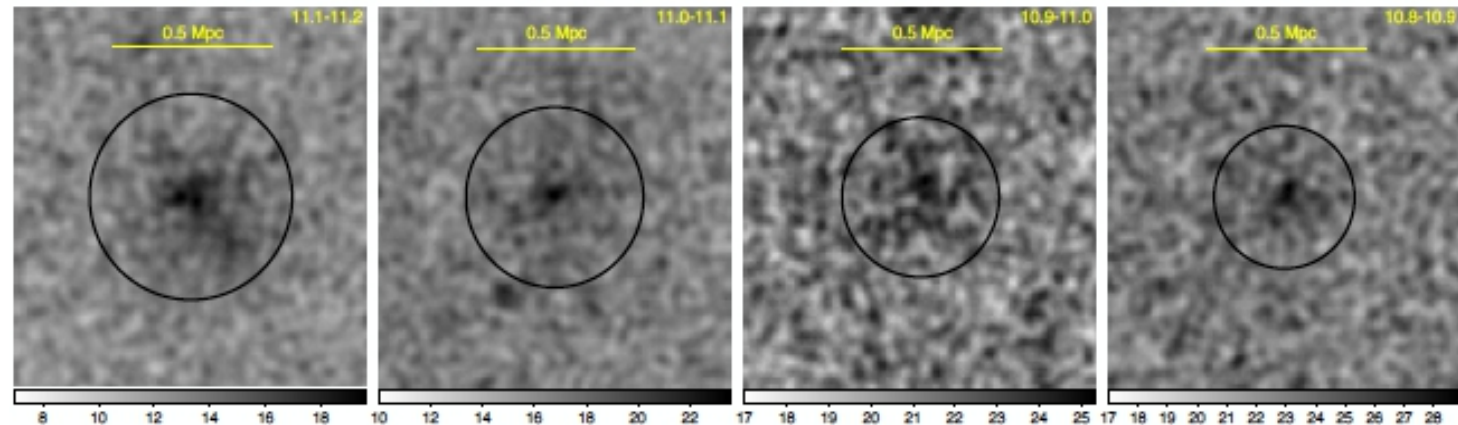
11.9 – 12.0



11.5 – 11.6



11.1 – 11.2



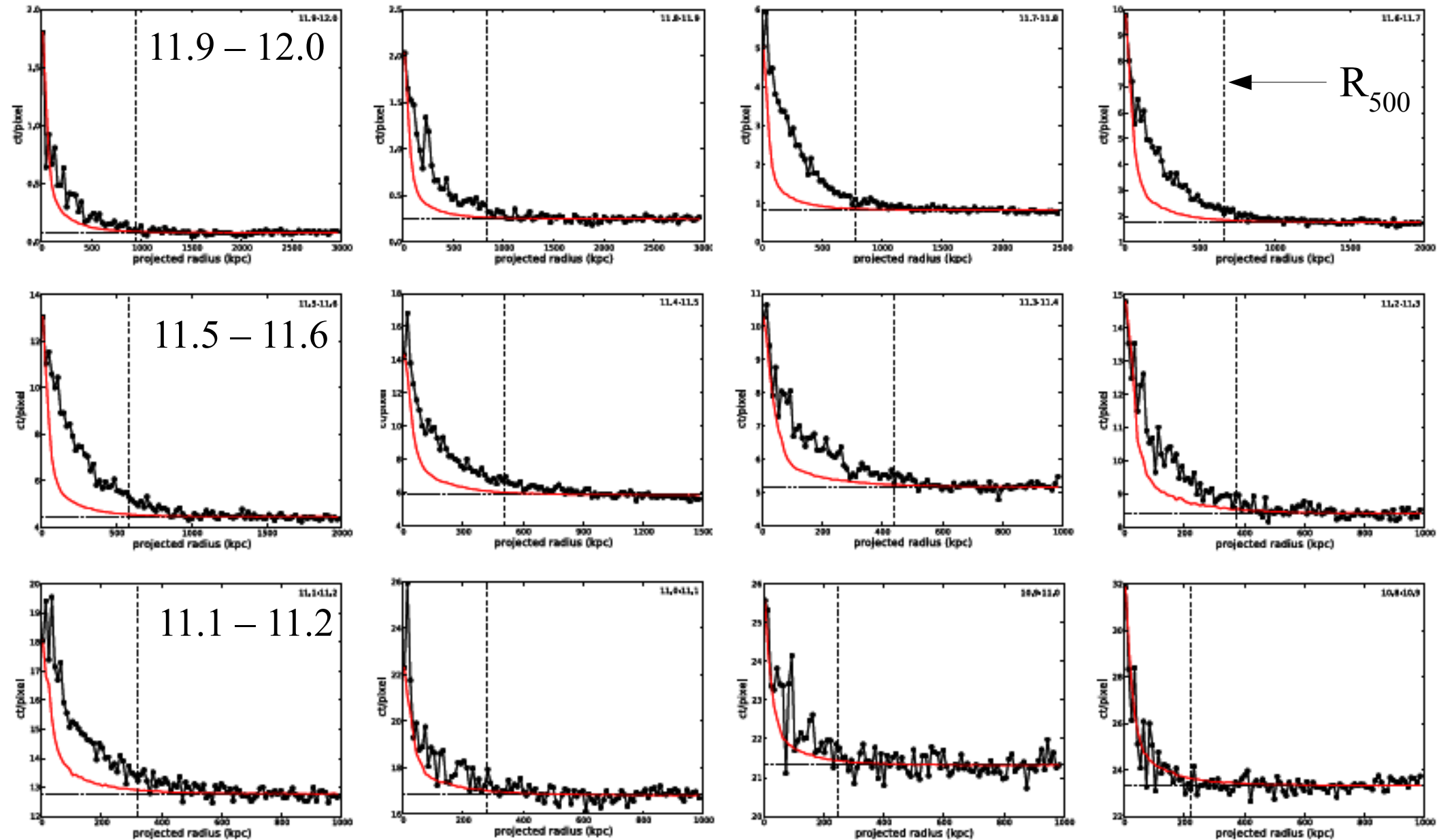
Stacked Rosat X-ray signal from LBGs

Anderson et al 2015

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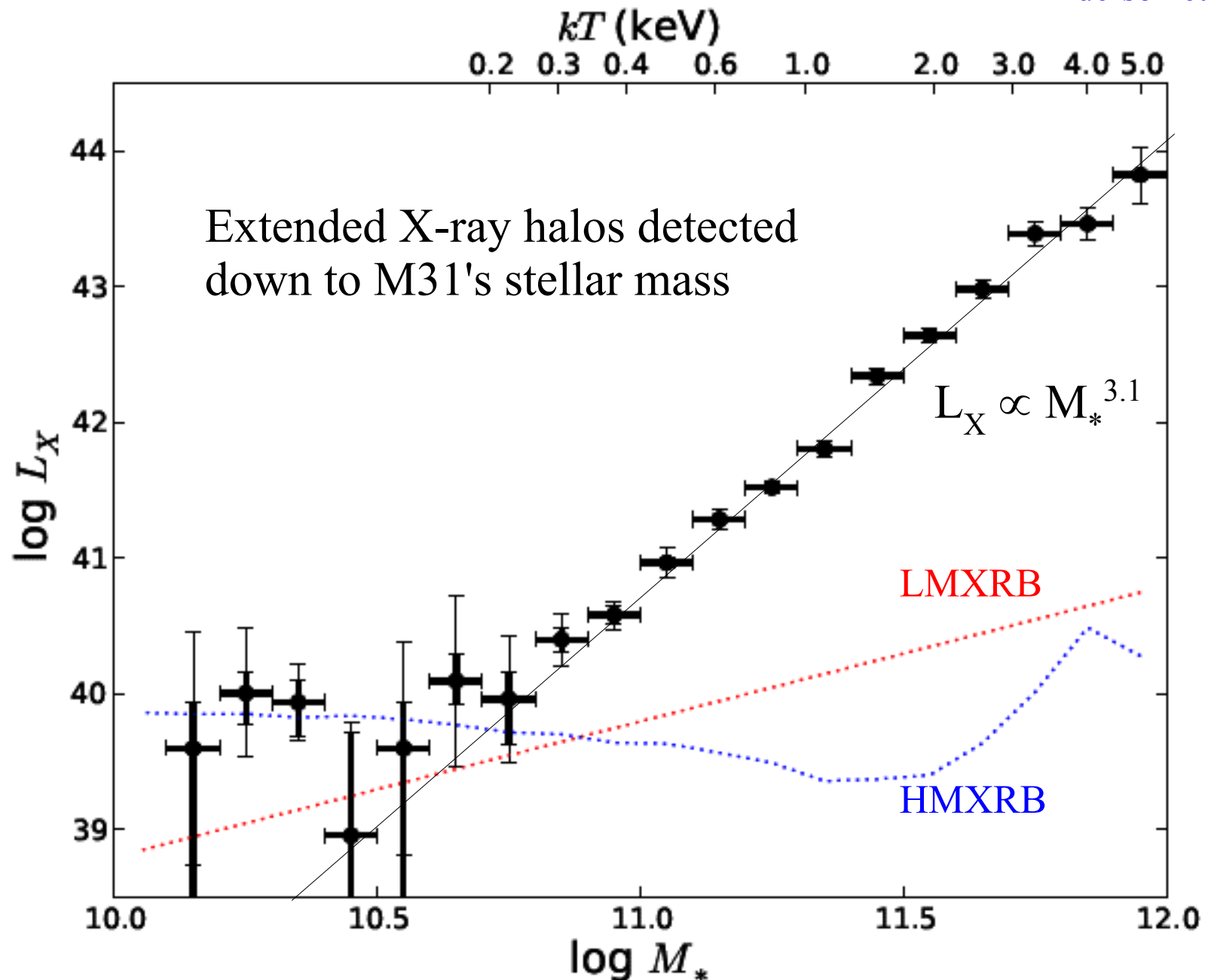
11.9 – 12.0

R_{500}



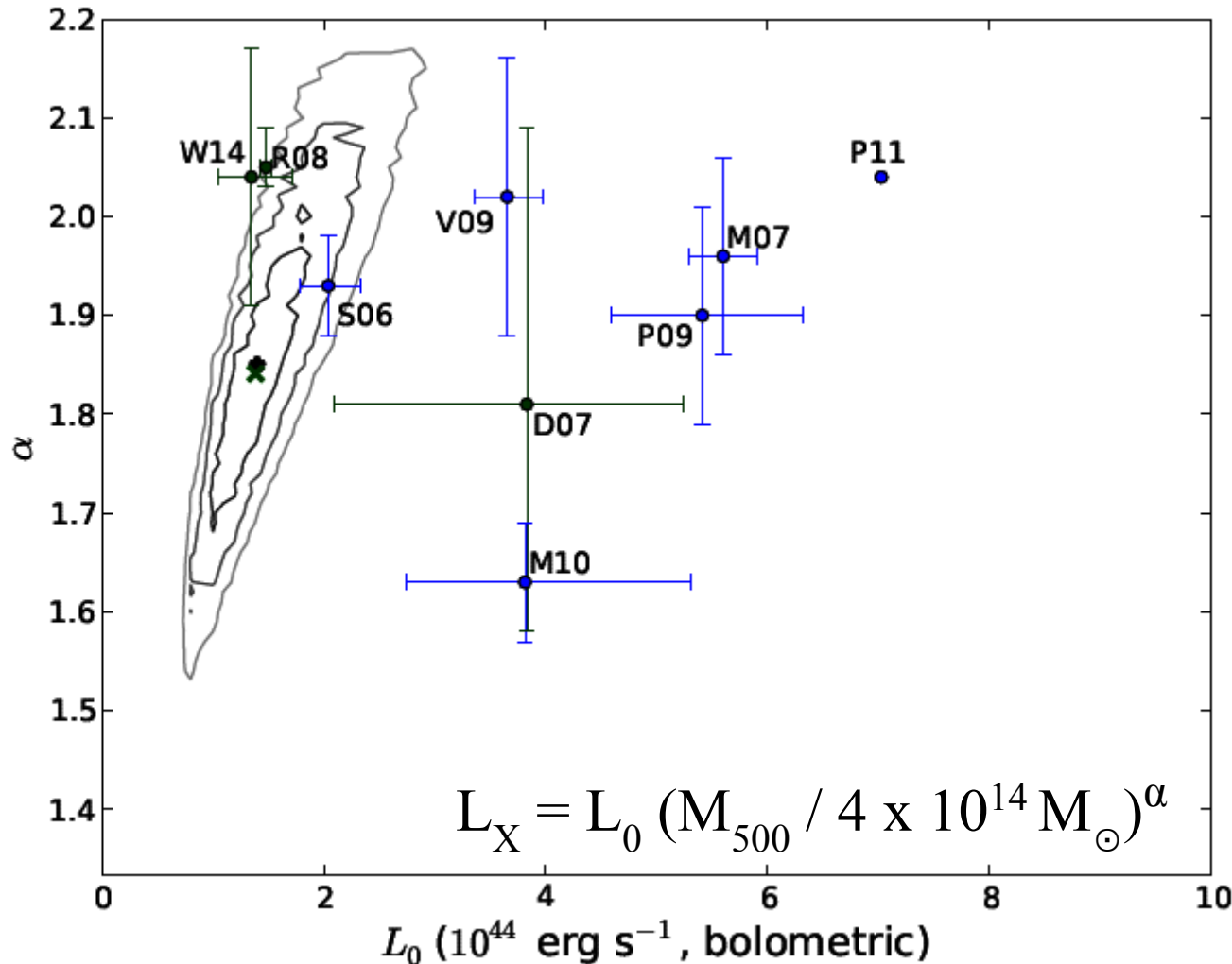
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Anderson et al 2015



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

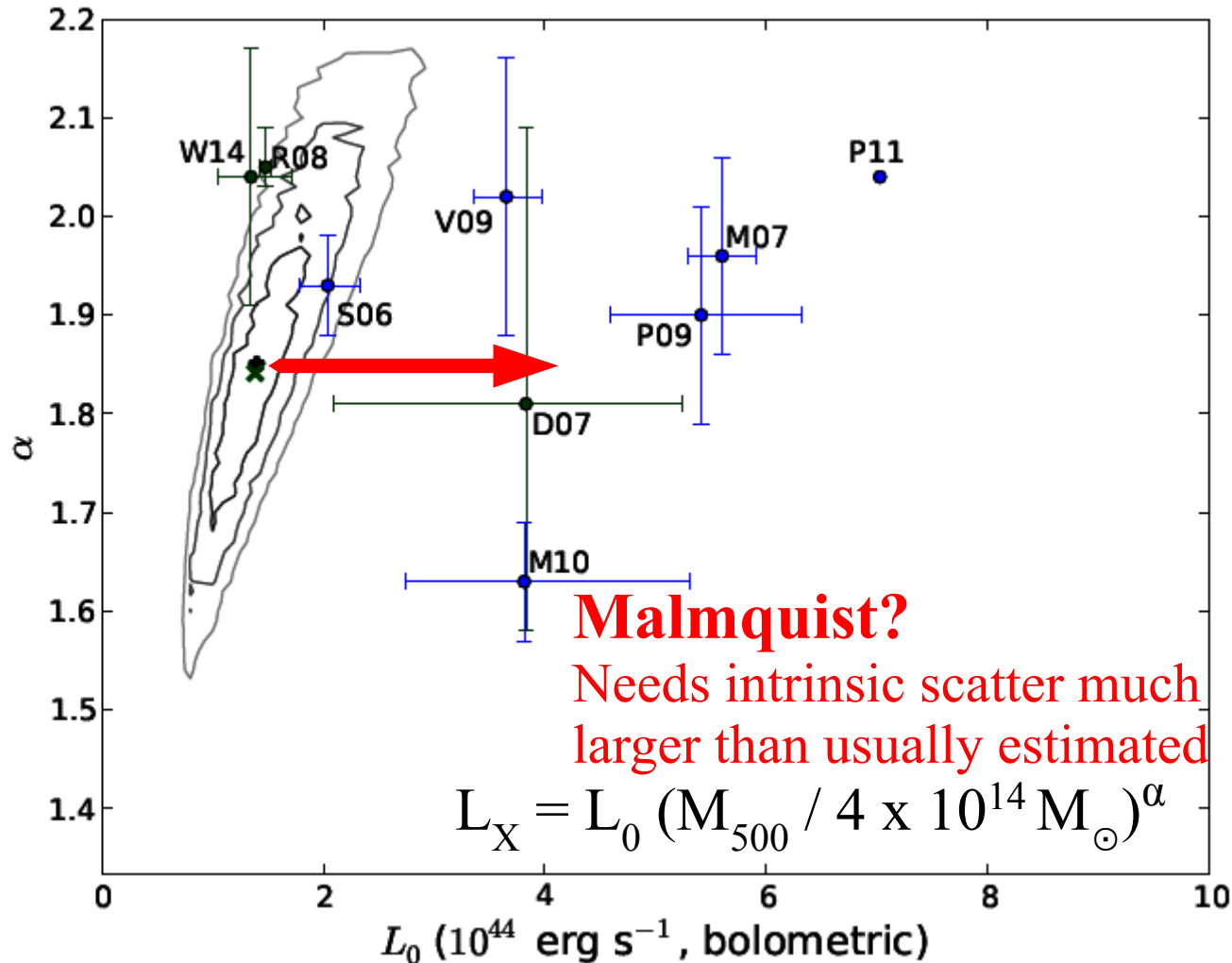
X-ray luminosity grows much faster with mass than this

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
disagreement in normalisation with results for X-ray selected clusters

Stacked Rosat X-ray signal from LBGs

Anderson et al 2015

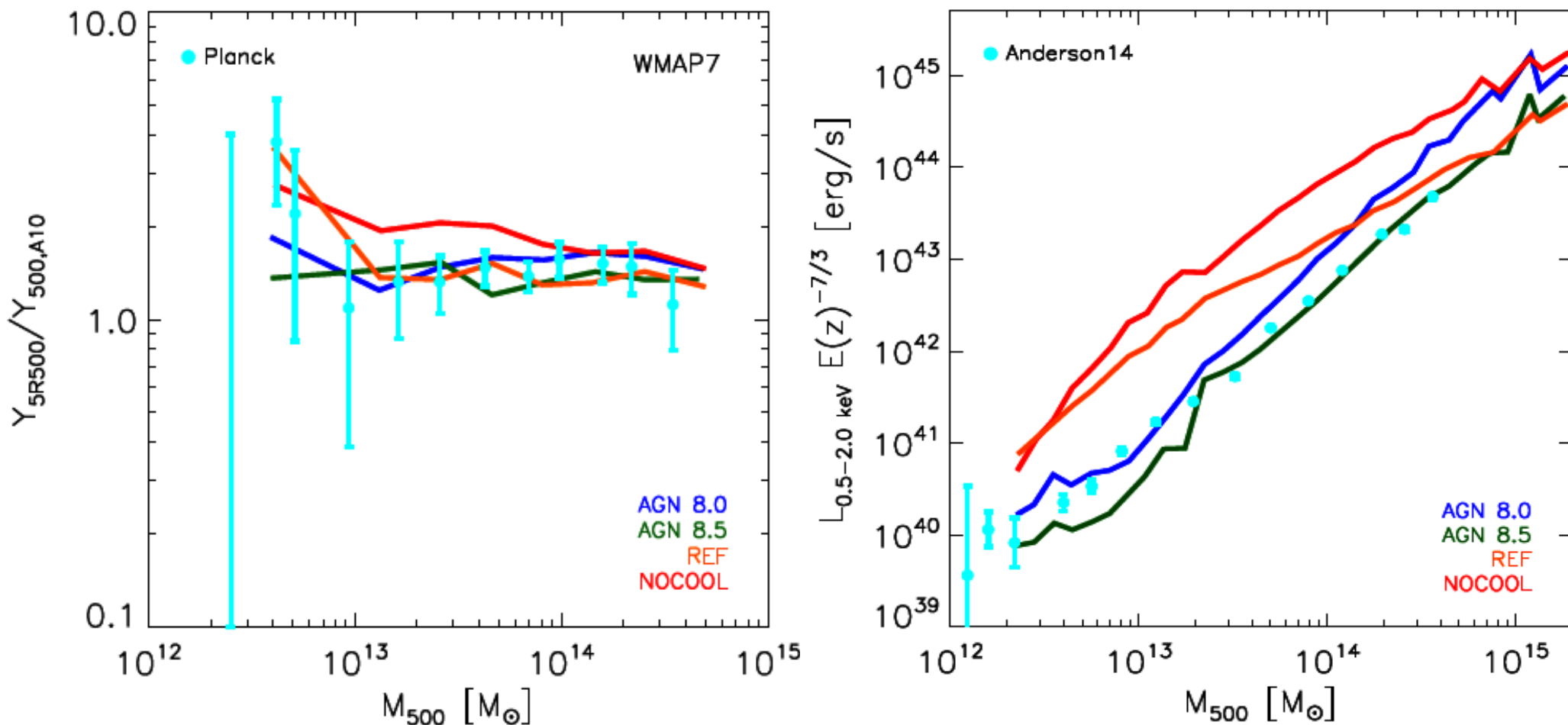


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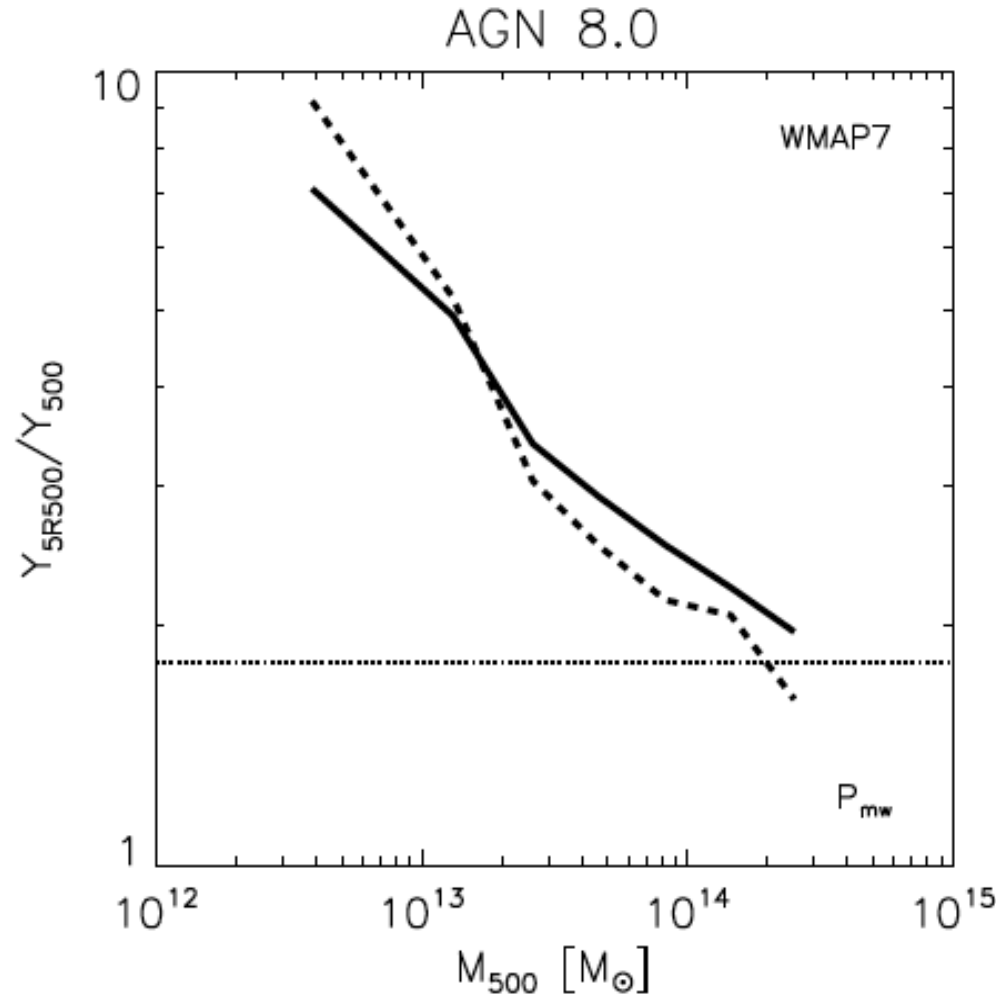
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With AGN feedback, the cosmo-OWLS simulations come close to reproducing *both* the nearly self-similar behaviour of the Planck SZ measurements and the non-self-similar behaviour of the ROSAT stacks



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

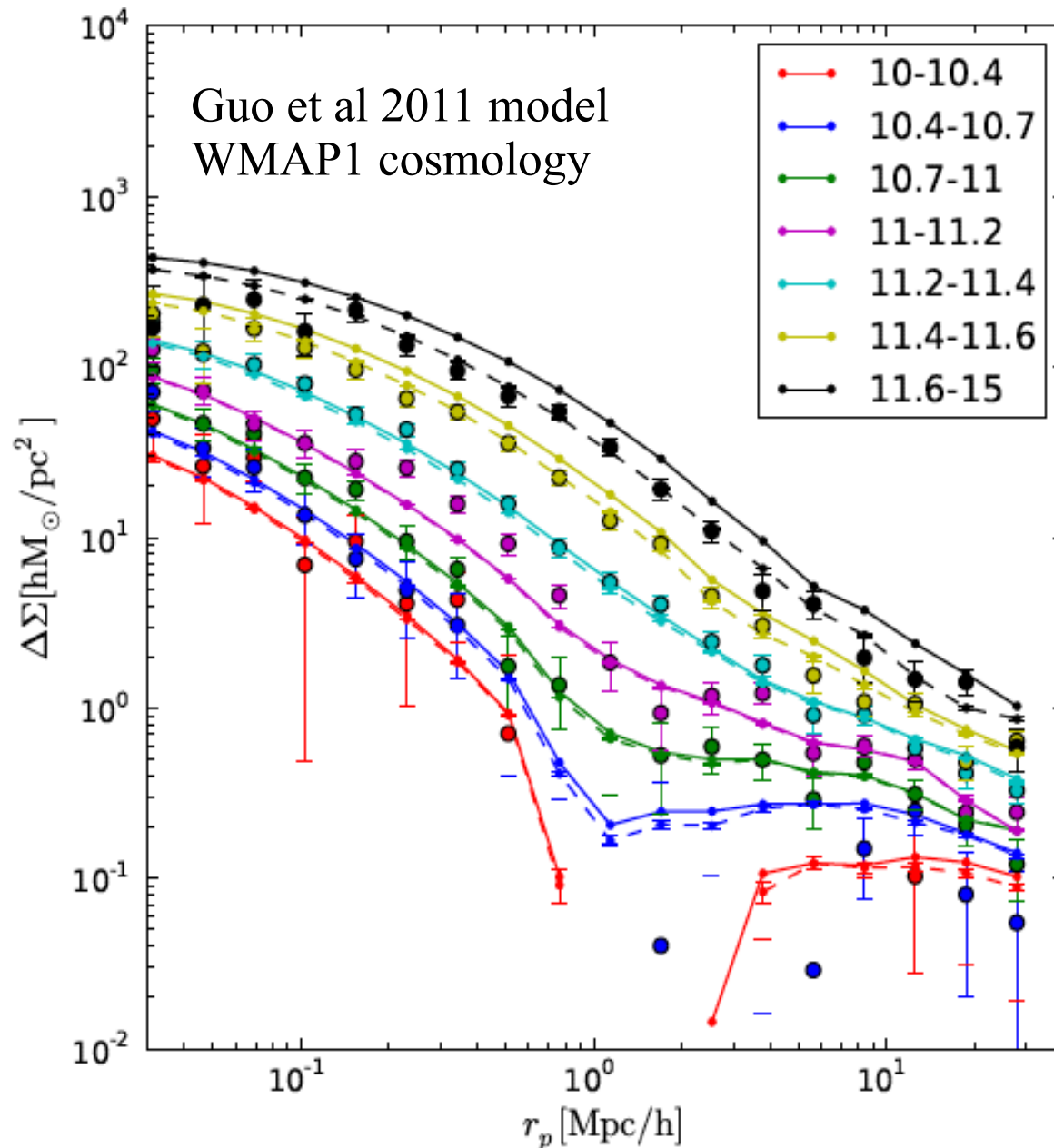
Wang, Mandelbaum et al (2015)

Points are results for SDSS/DR7

Dashed lines are results for the original published simulation

Solid lines are results when stellar mass is corrected by $\Delta M_*(M_*)$ chosen so that the simulated stellar mass function agrees exactly with SDSS

Typically $\Delta M_* < 0.1$ dex



Stacked weak lensing signal from LBGs

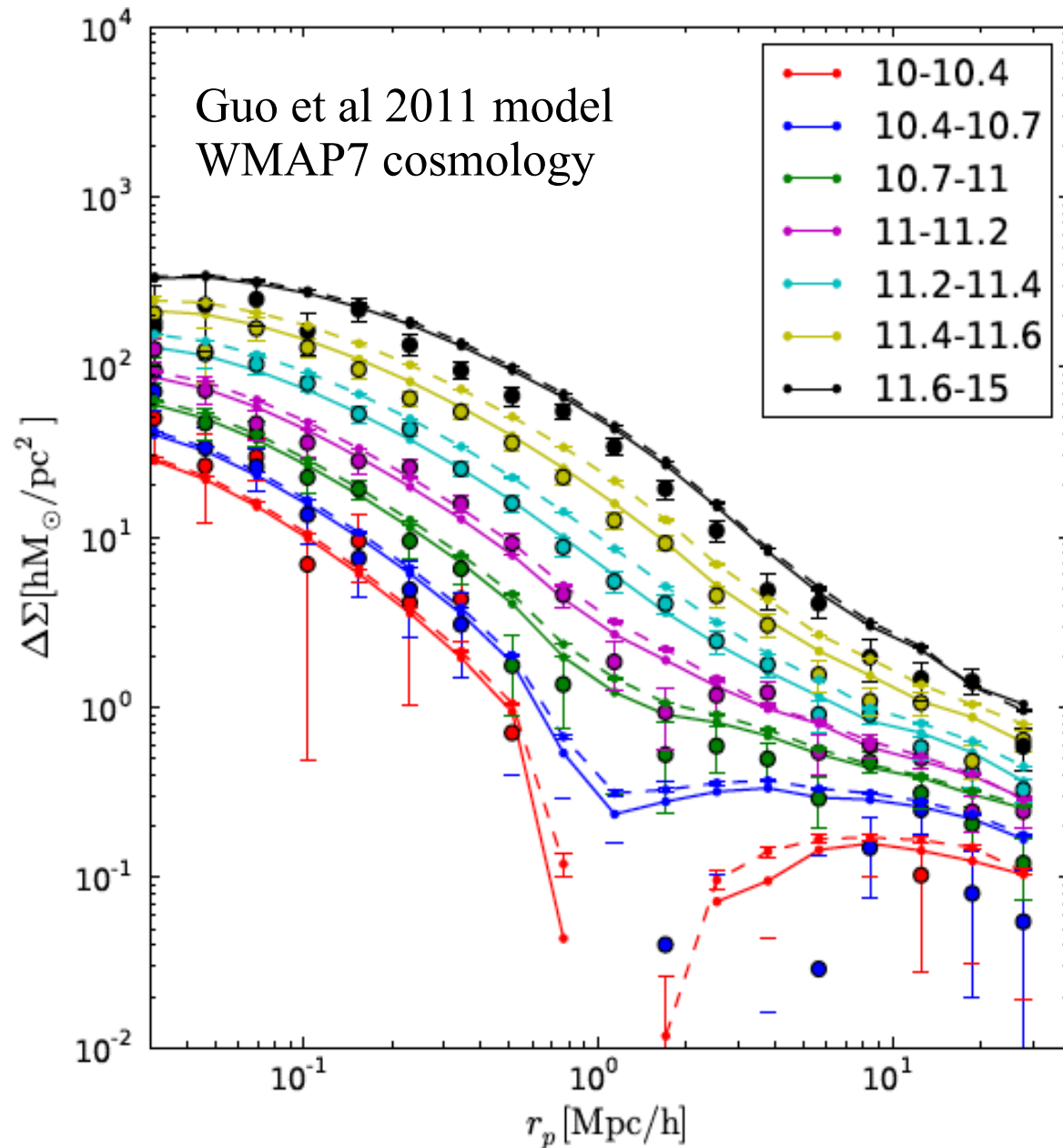
Wang, Mandelbaum et al (2015)

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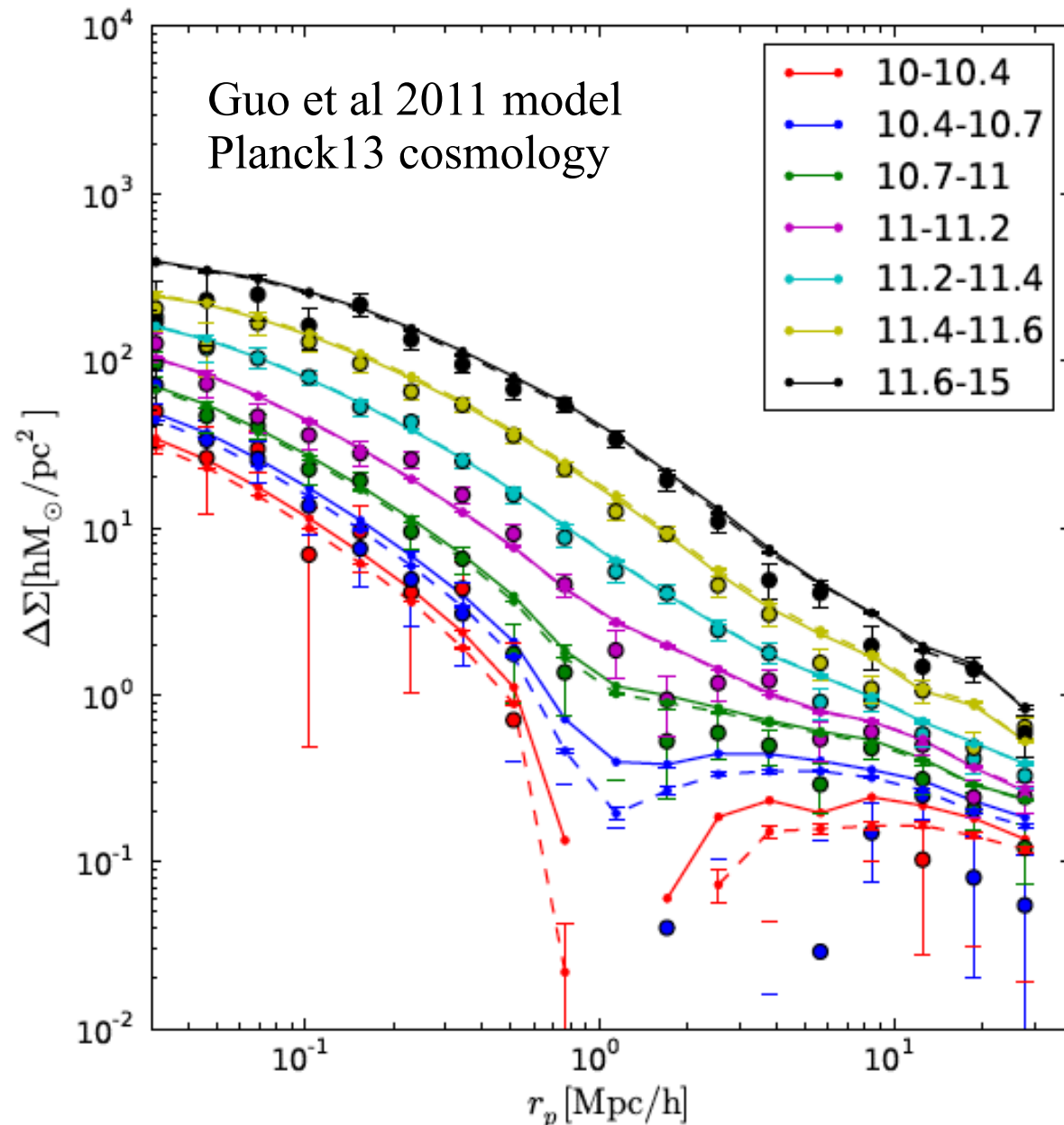
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The lensing prediction is sensitive to cosmology!

Stacked weak lensing signal from LBGs

Wang, Mandelbaum et al (2015)

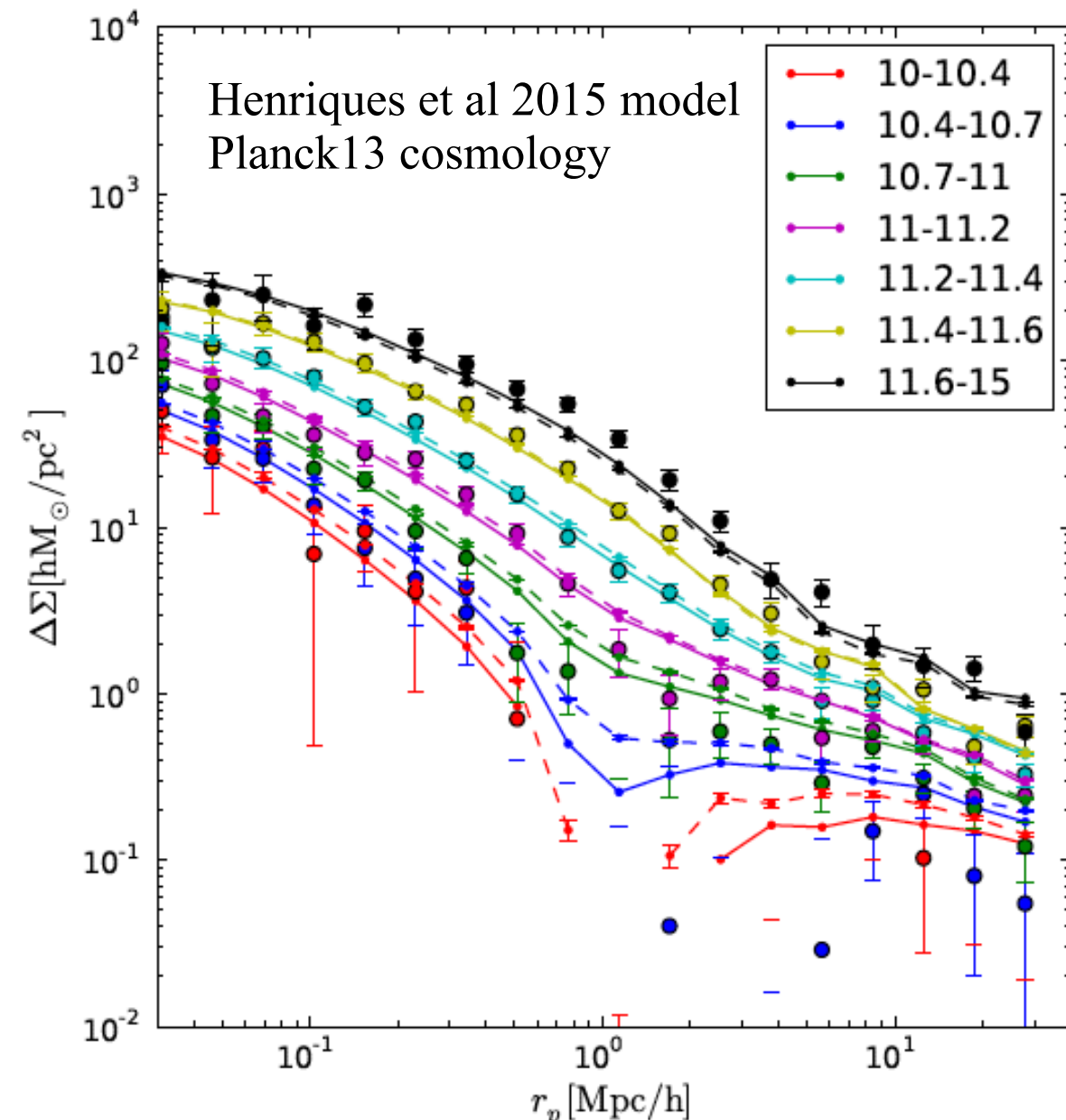
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...but it is also sensitive to galaxy formation model, even for fixed stellar mass function



Cross-correlation of LBGs with other galaxies

Wang, Mandelbaum et al (2015)

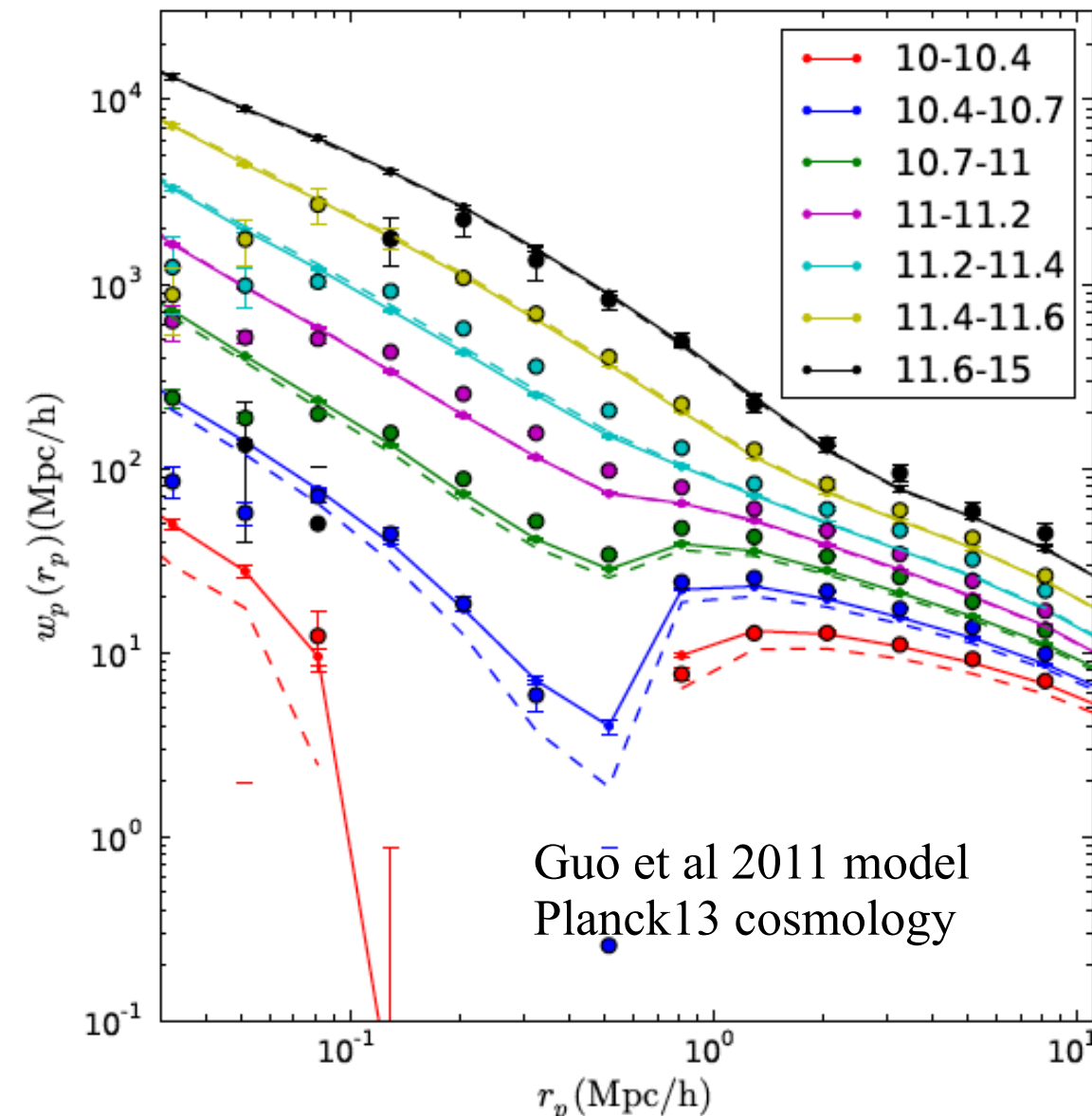
Cross-correlation of LBGs with all galaxies with $\log M_* > 10.0$

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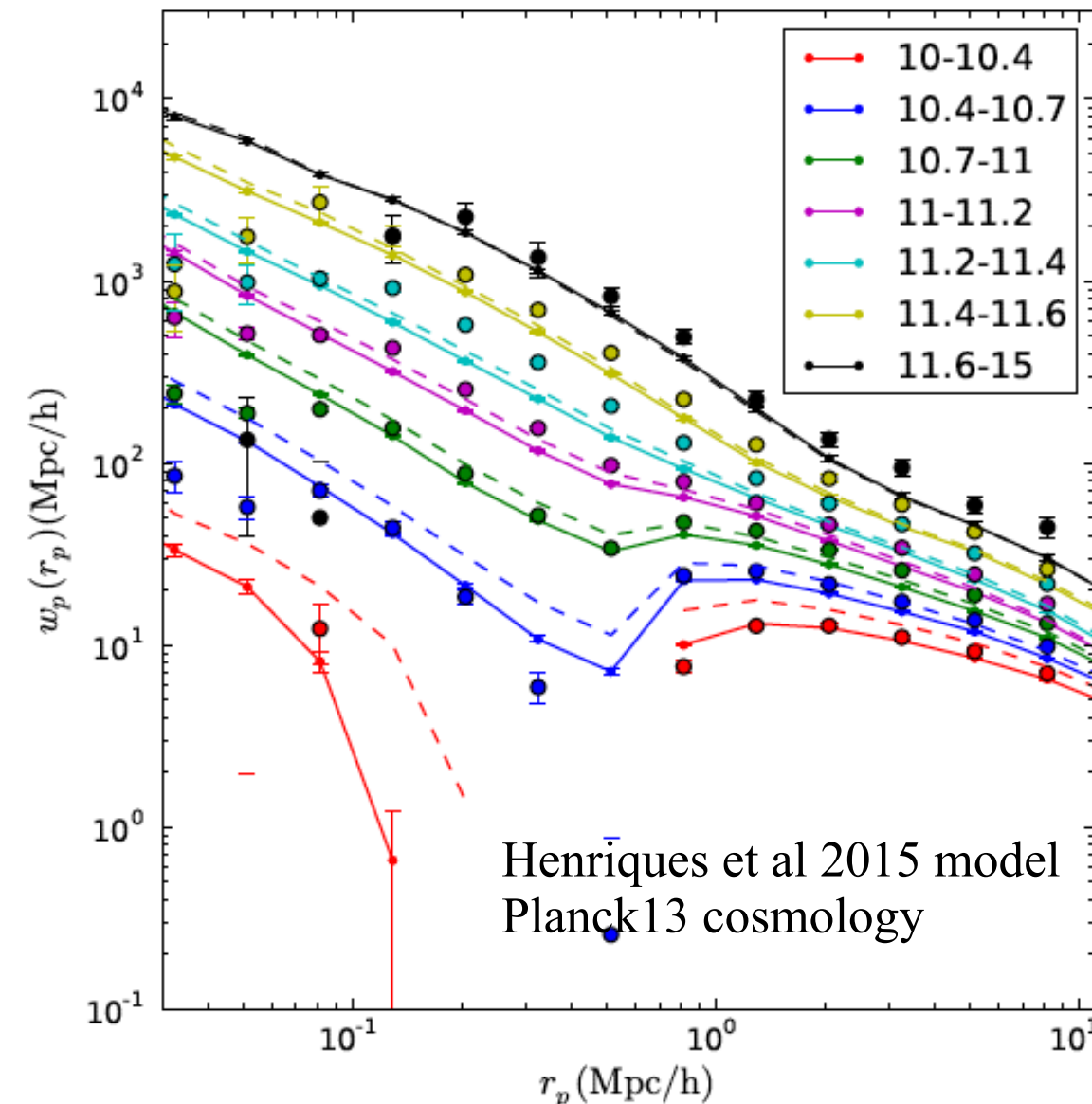
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Conclusions for Locally Brightest Galaxies in SDSS/DR7

- 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
 - $Y - M_{\text{halo}}$ as expected for self-similarity at the cosmic baryon fraction
 - $L_X - M_{\text{halo}}$ substantially steeper than the self-similar prediction
- These can be reconciled if halo baryons are more extended in lower mass halos but still hot. This is consistent with AGN feedback simulations.
 - Planck has found the “missing” baryons from low-mass halos
- Lensing signal of LBG stacks is as predicted by a simulation matching SDSS stellar mass function and clustering in the Planck cosmology
 - No obvious “cluster abundance problem” ?