ESLAB – Planck Symposium
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Planck and wide-field galaxy surveys

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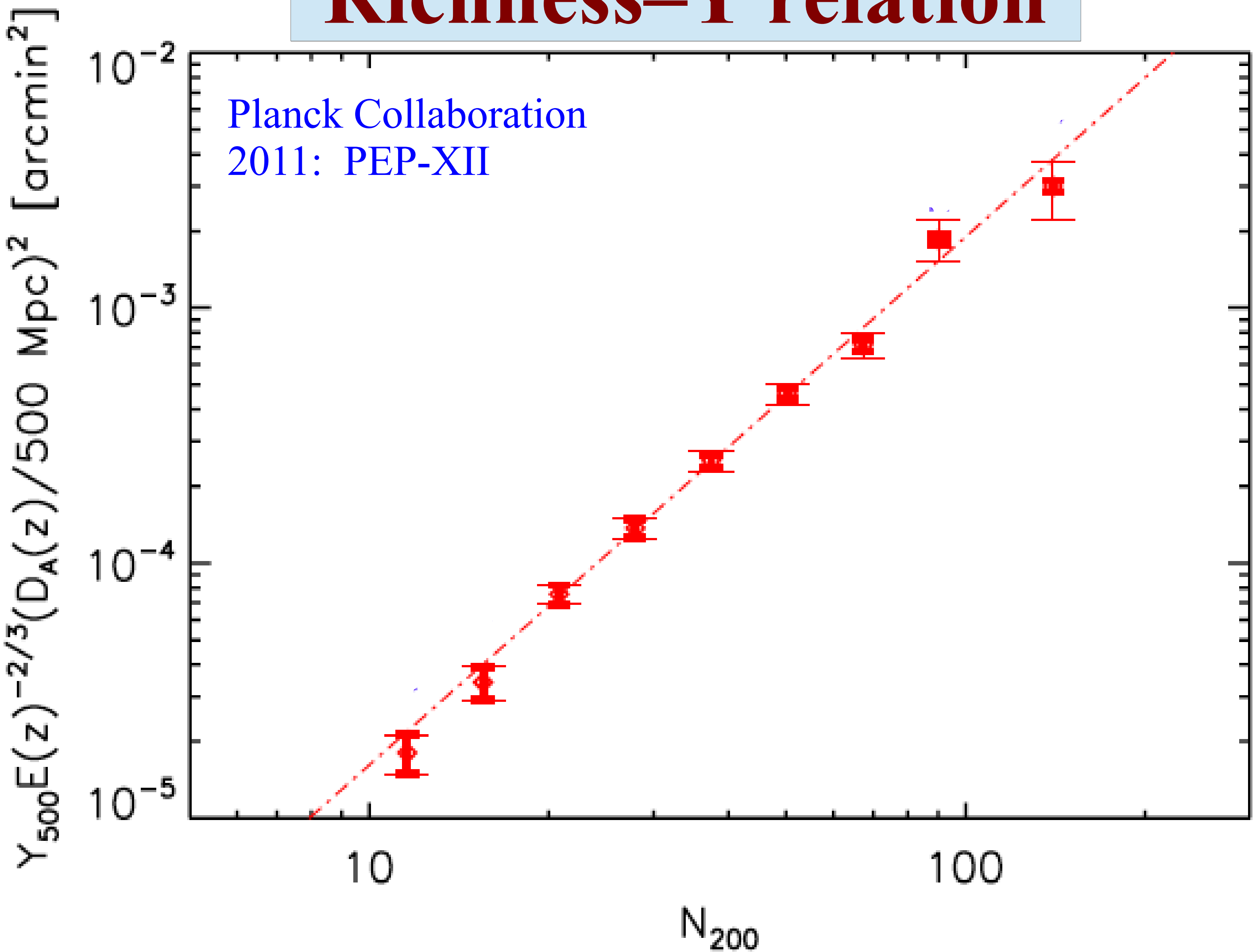
on behalf of the Planck Collaboration

- Combination of Planck maps with wide-angle optical surveys allows high S/N detection of mean stacked signals due to
  - total mass (through lensing)
  - total hot gas content (through the SZ effect)
  - dust emission (through high frequency channels)
  - radio emission (through low-frequency channels)

- Here I will concentrate on results from stacking of SZ signals around objects defined from the Sloan Digital Sky Survey
  - cluster scaling relations for optically selected clusters
  - halo baryon content of dark halos down to galaxy scales

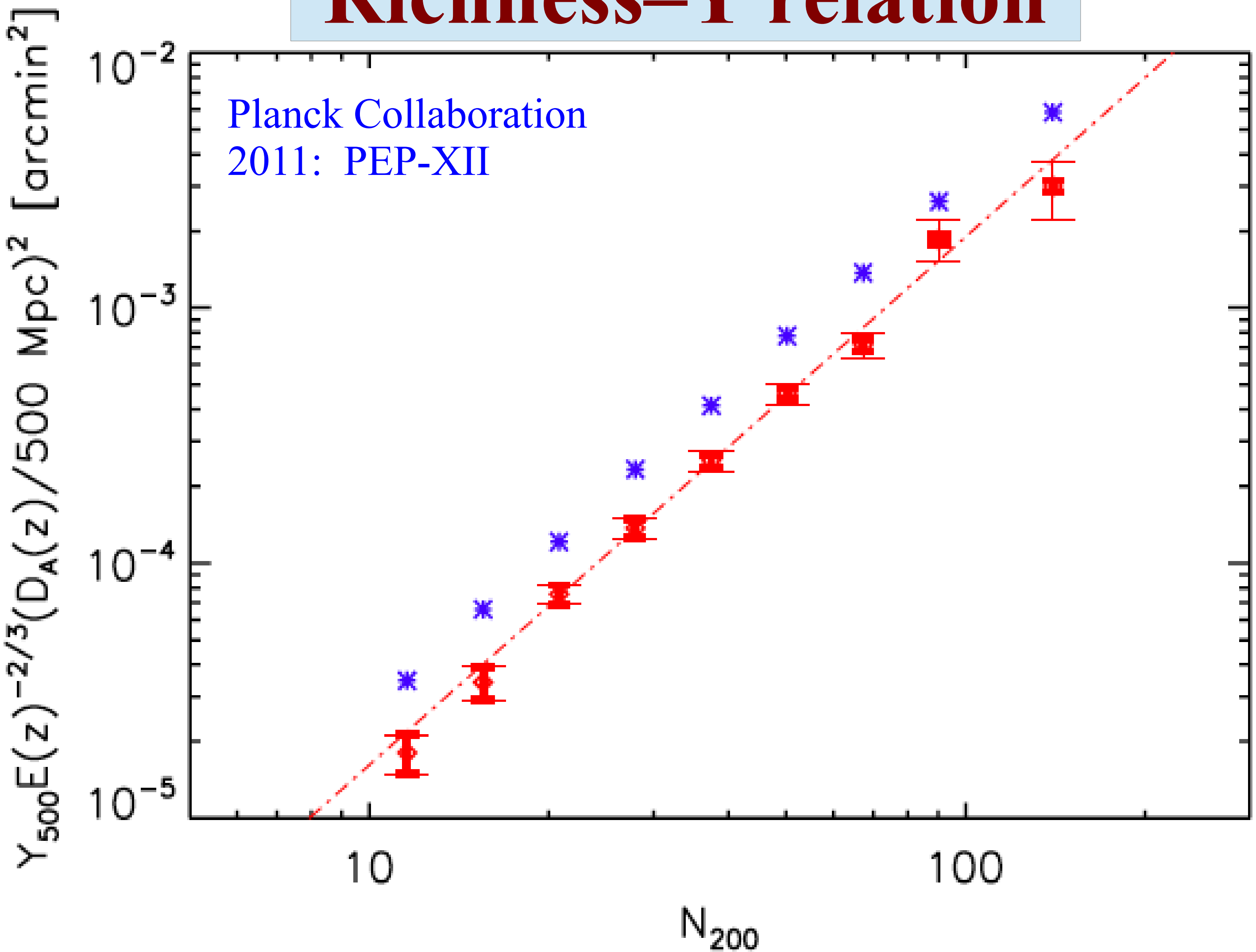
Richness–Y relation



The MaxBCG catalogue, based on SDSS/DR5 contains ~14,000 galaxy clusters with richness $N_{200} > 10$ over 7,500 squ.deg.

Stacking Planck SZ measurements based on a multi-frequency matched filter detects the mean $Y_{500} - N_{200}$ relation at high significance.

Richness–Y relation



The result disagrees with the prediction from

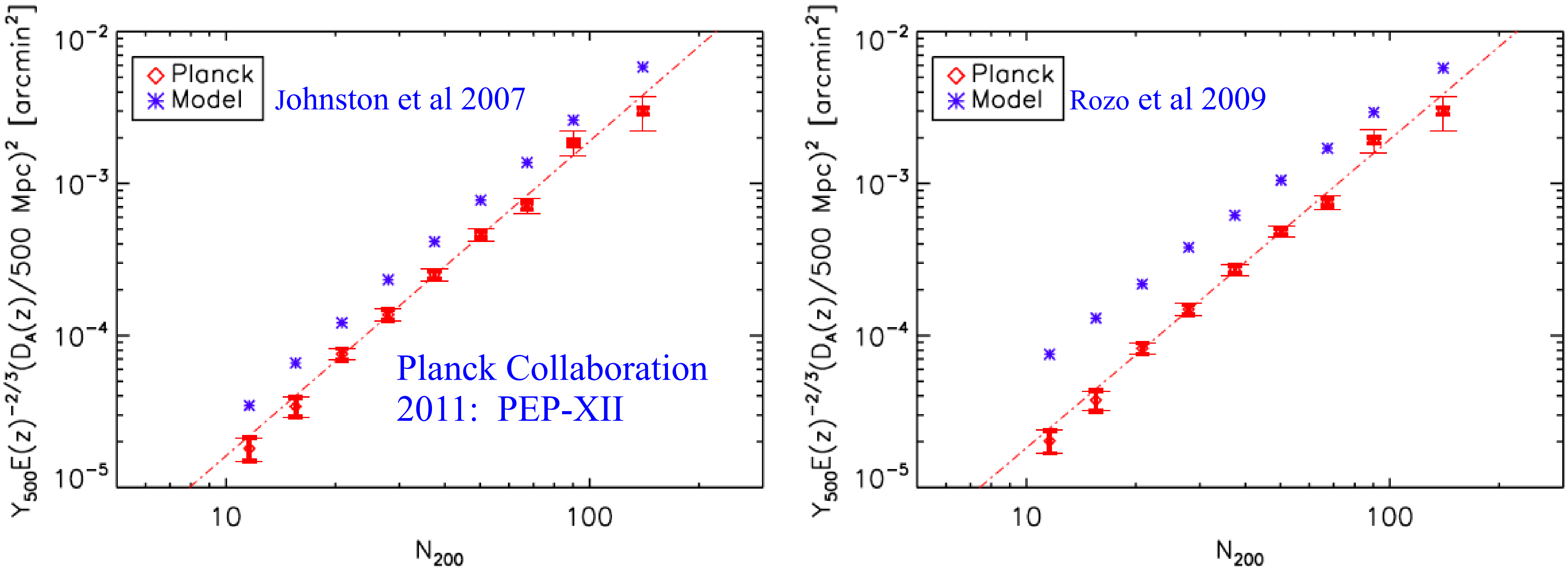
N_{200} → M_{500} → $Y_{X,500}$ → Y_{500}

gravitational lensing of maxBCG stacks Johnston et al 2007

universal pressure profile of Arnaud (2010)

assumed equal

Richness–Y relation



The result disagrees with the prediction from

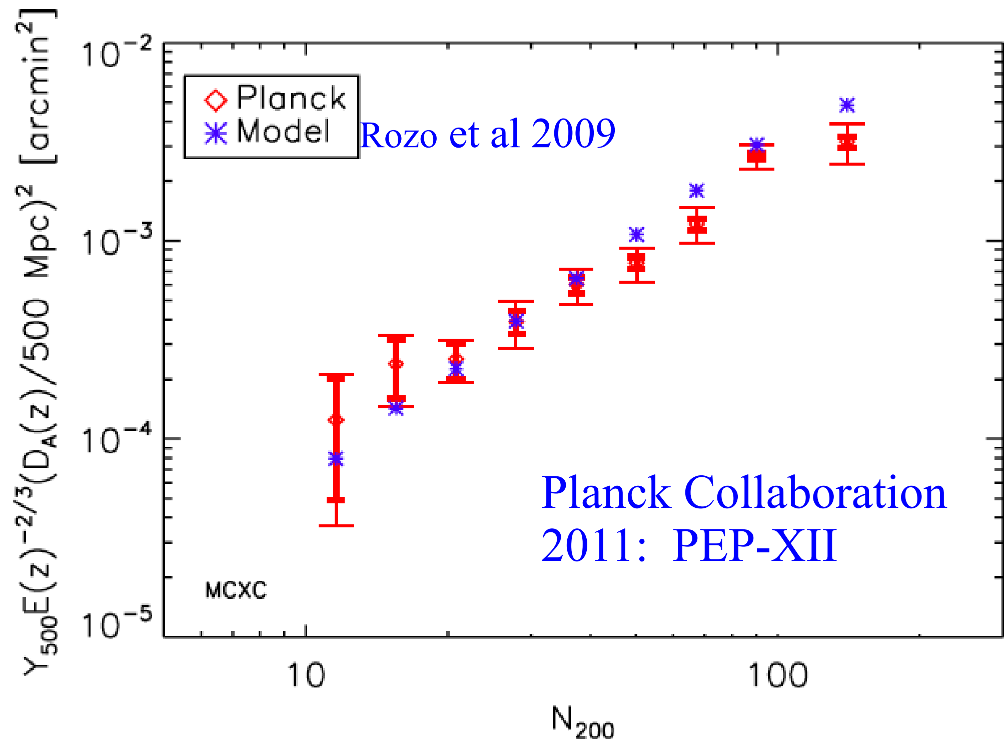
N_{200} → M_{500} → $Y_{X,500}$ → Y_{500}

- N_{200} → M_{500}: gravitational lensing of maxBCG stacks
- M_{500} → $Y_{X,500}$: universal pressure profile of Arnaud (2010)
- $Y_{X,500}$ → Y_{500}: assumed equal

Richness–Y relation

Yet when sample is restricted to clusters which also appear in an X-ray selected sample, the discrepancy disappears

Malmquist bias transferred from the X-ray to the SZ!



The result now agrees with the prediction from

N_{200} → M_{500} → $Y_{X,500}$ → Y_{500}

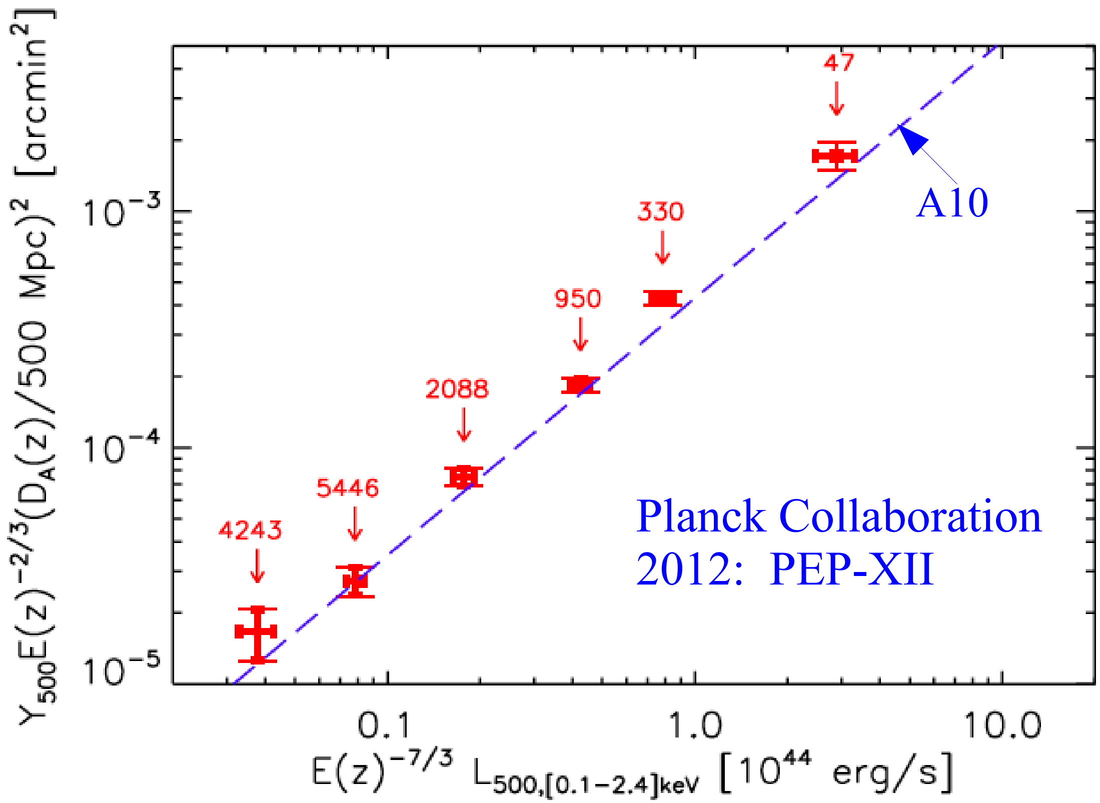
gravitational lensing of maxBCG stacks

universal pressure profile of Arnaud (2010)

assumed equal

$Y - L_X$ relation

Yet for stacks of given N_{200} in the full maxBCG sample, mean $L_{X,500}$ is related to mean Y_{500} as predicted by the Arnaud (2010) "universal" profile derived from X-ray clusters.



The Y – L relation is the same for X-ray-selected and non-X-ray-selected cluster samples

Thus the Malmquist bias in X-ray-selected samples shifts Y and L along the mean relation

Problems with scaling relations?

Cluster selection by optical, X-ray and SZ methods leads to samples with systematically different properties.

X-ray selection picks clusters which are systematically more regular and centrally concentrated than SZ selection which in turn picks clusters which are more regular than optical selection

These differences can shift scaling relations between observables, and between observables and a fiducial cluster mass, by amounts which are significant compared to cosmology dependences.

Such shifts are likely to be redshift-dependent and must be understood before cluster abundances can be used for cosmology

→ **Sample selection and calibration are critical.**
Scatter and evolution must be <u>fully</u> characterised

Problems with scaling relations?

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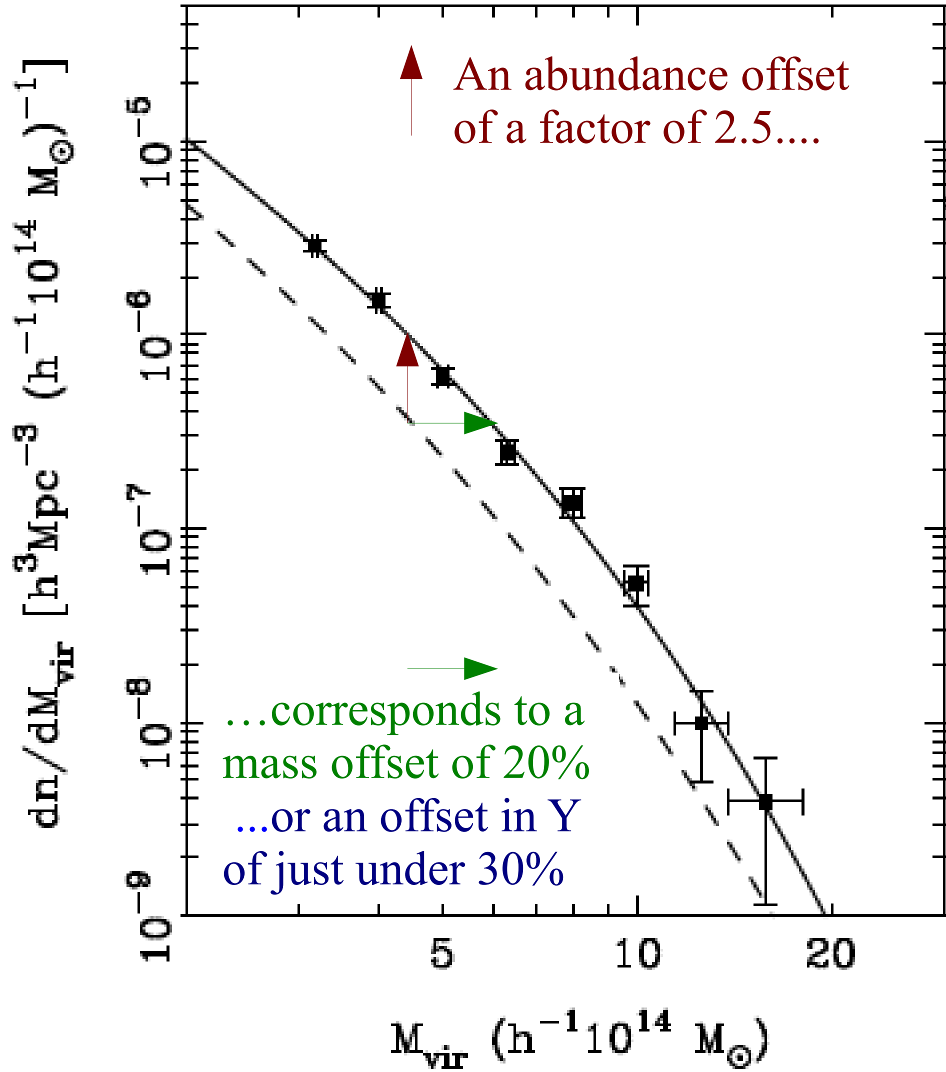

→ **Sample selection and calibration are critical.**
Scatter and evolution must be <u>fully</u> characterised

A complete sample of locally brightest galaxies

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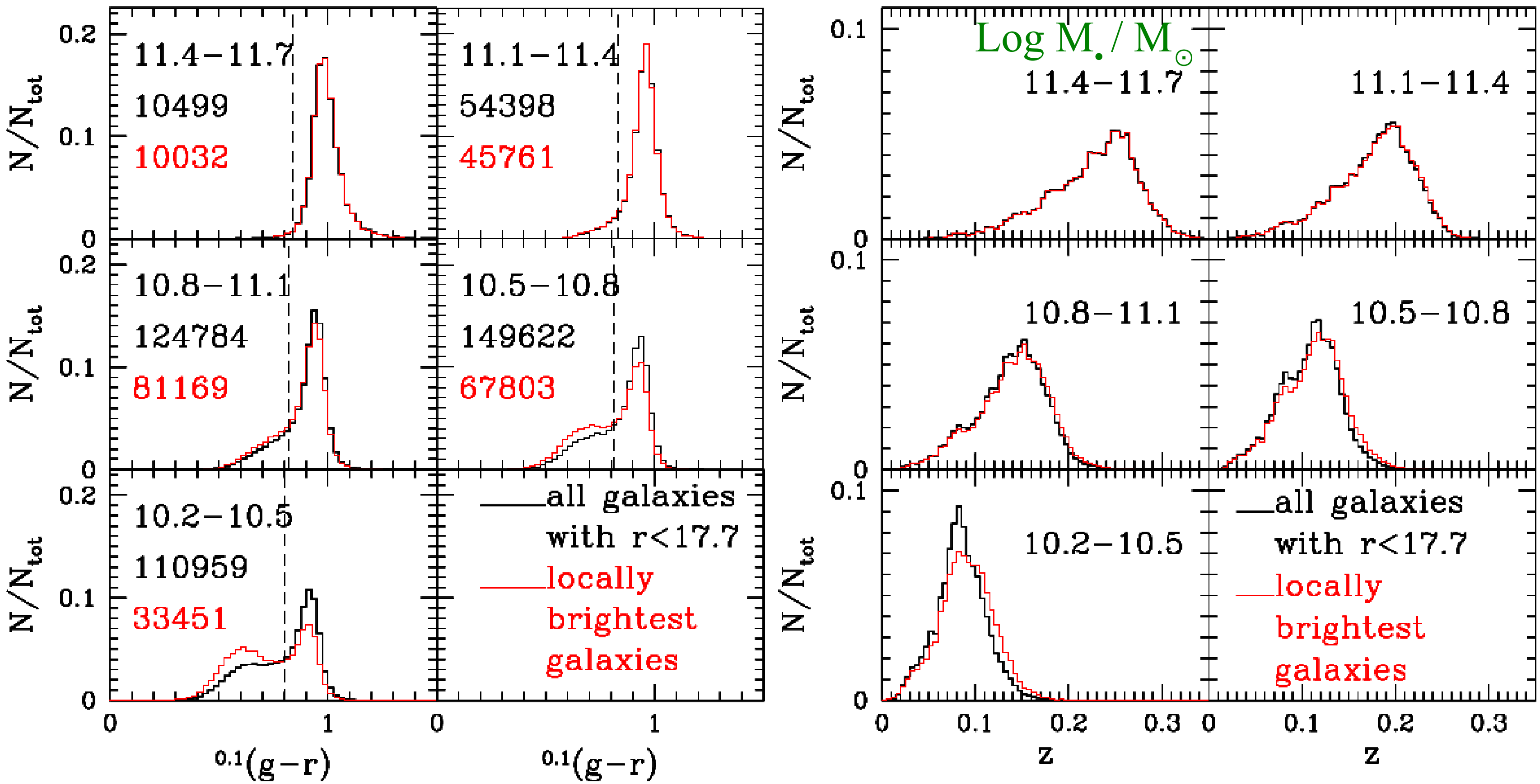
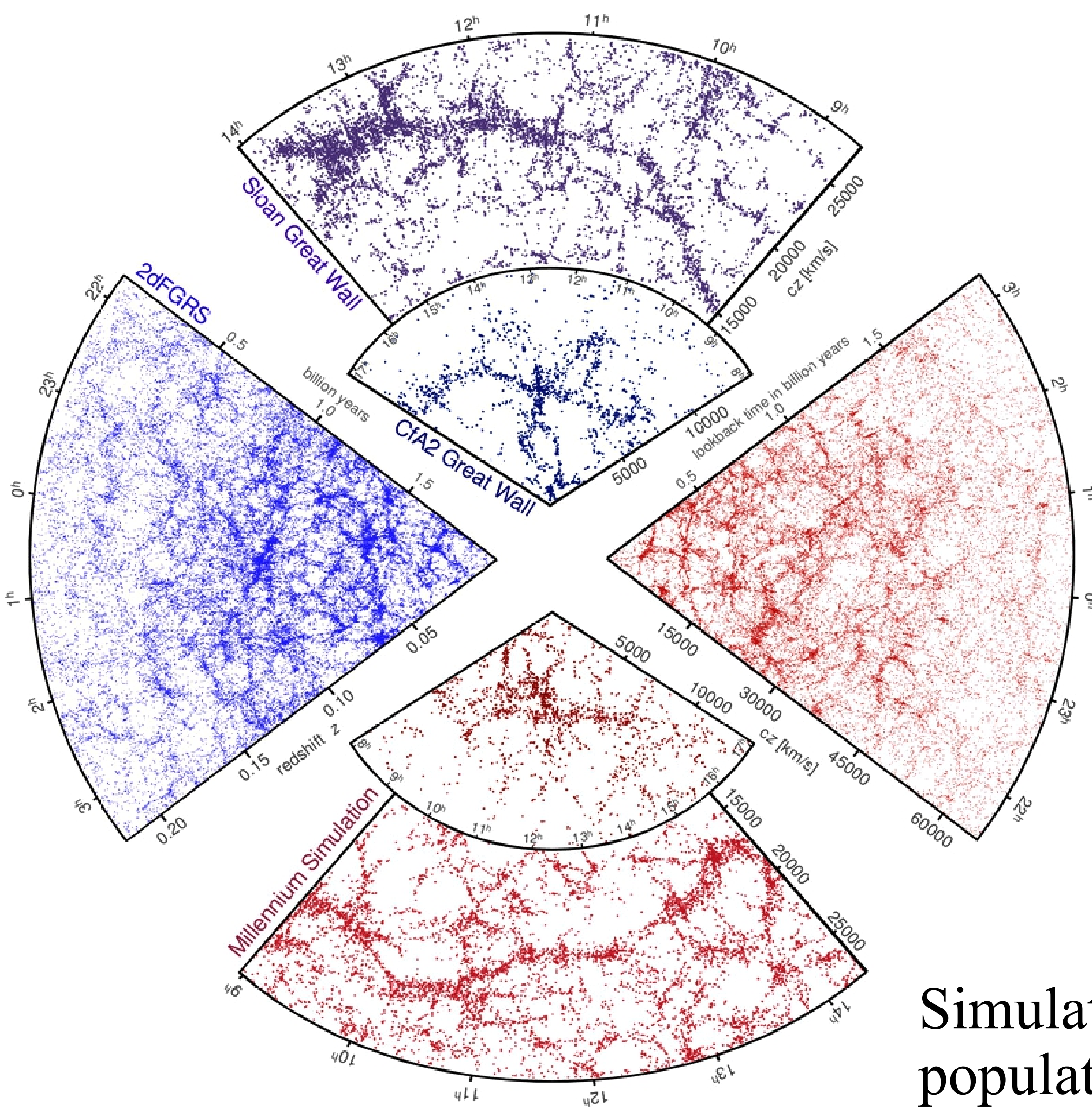
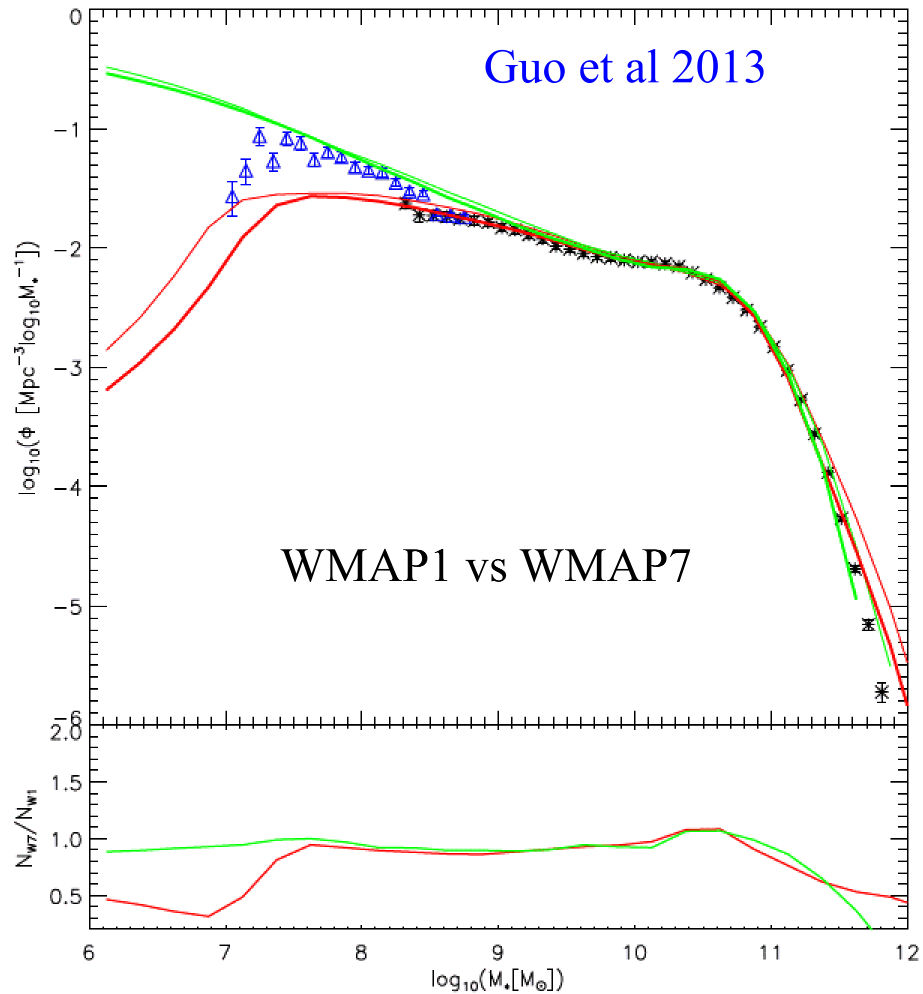


All SDSS/DR7 galaxies in the main spectroscopic sample with:
r < 17.7 (extinction-corrected Petrosian mag.), $z > 0.03$, and no brighter companion with $\Delta r_p < 1$ Mpc, $|c\Delta z| < 1000$ km/s in either the spectroscopic or photometric catalogues

Galaxy population simulations as calibrators



Springel et al 2006



Simulations of the formation of the galaxy population can reproduce the abundance and clustering of galaxies in any viable ΛCDM cosmology (here WMAP7)

LBG's are predominantly halo central galaxies

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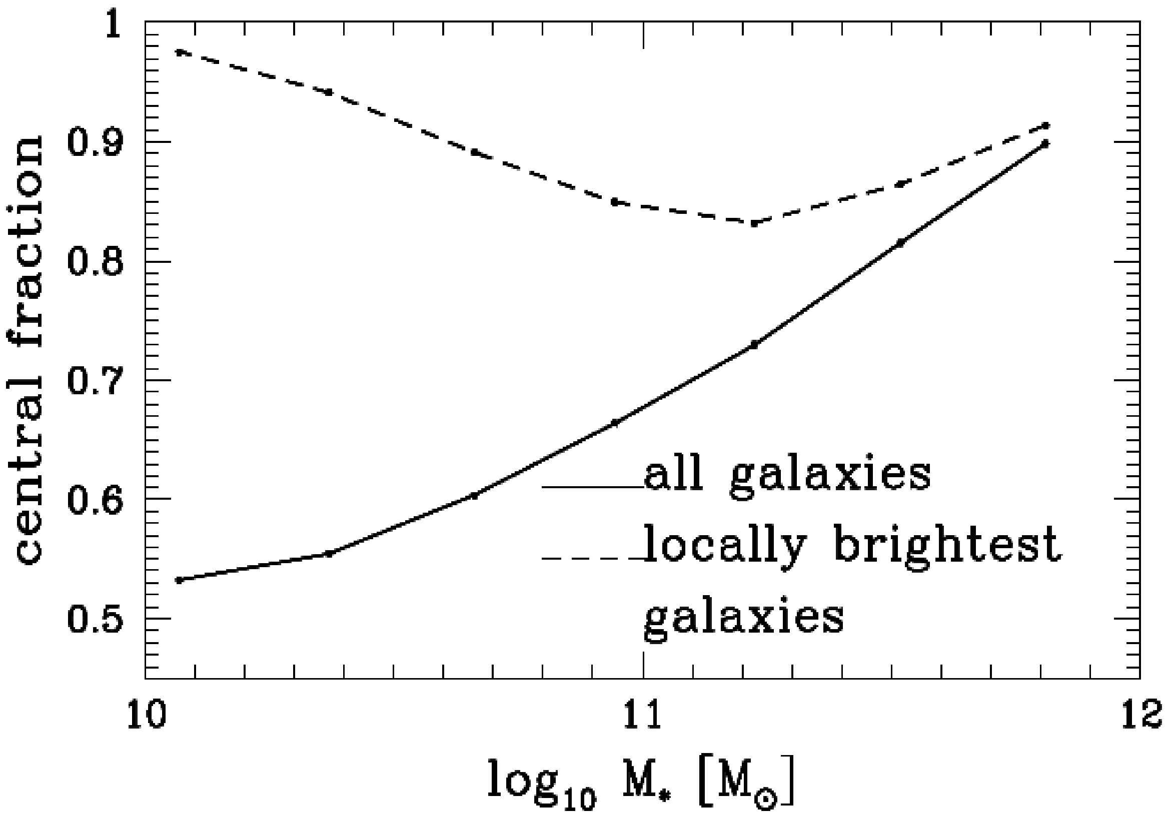

LBG's selected according to the observational criteria in a mock catalogue constructed from the Guo et al (2012) model of galaxy formation in the Millennium Simul'n (scaled to WMAP7)

At least 83% of LBGs are the central galaxies of their dark haloes

2/3 of the rest are <u>brighter</u> than the central galaxy of their halo

LBG stellar mass is related to halo mass

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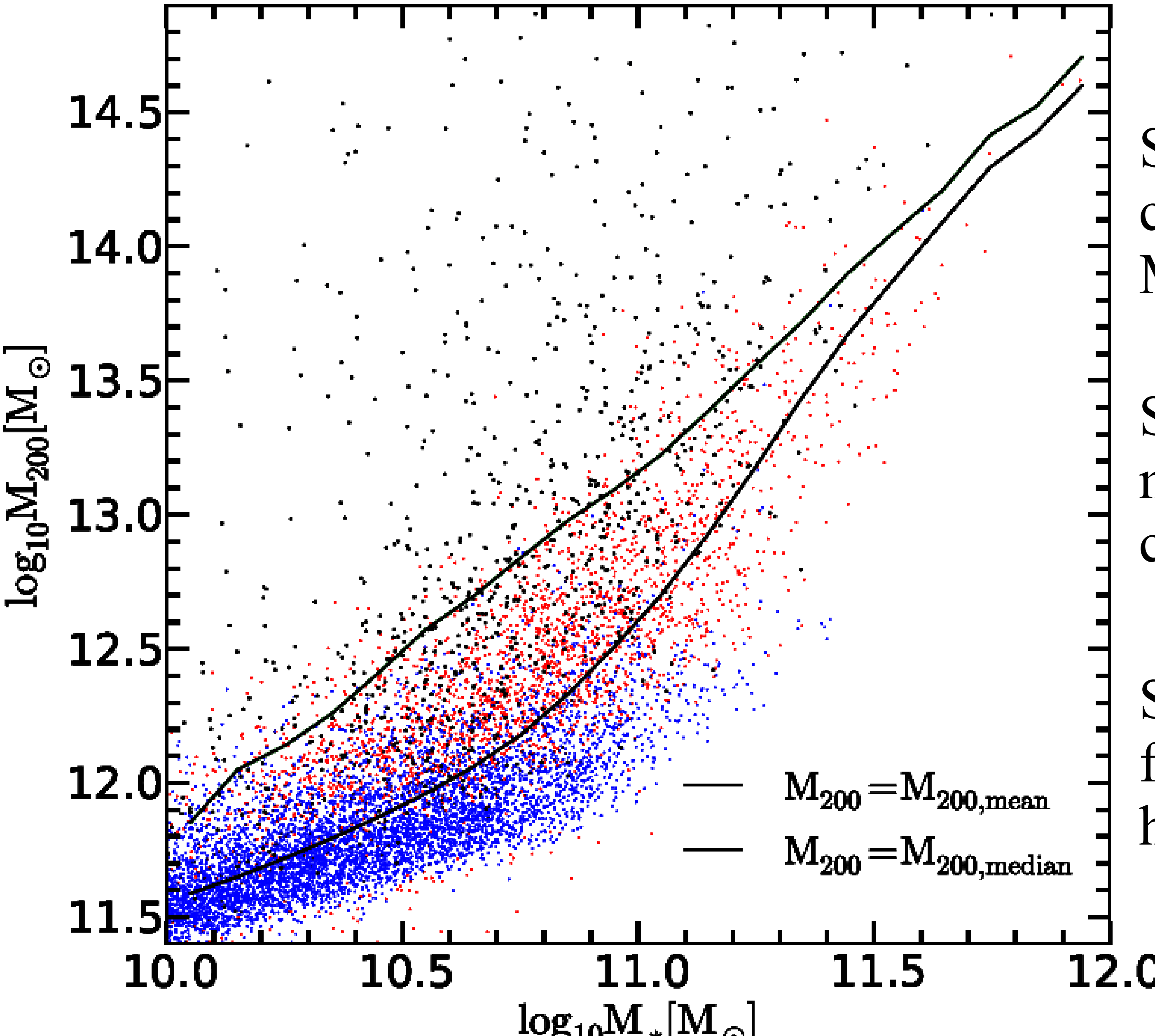

Star-forming and passive centrals lie on different M_* --M_h relations

Satellites tend to have more massive halos than centrals of the same M_*

Satellites are also offset from the centres of their halos

Stacked Planck y-maps for LBGs

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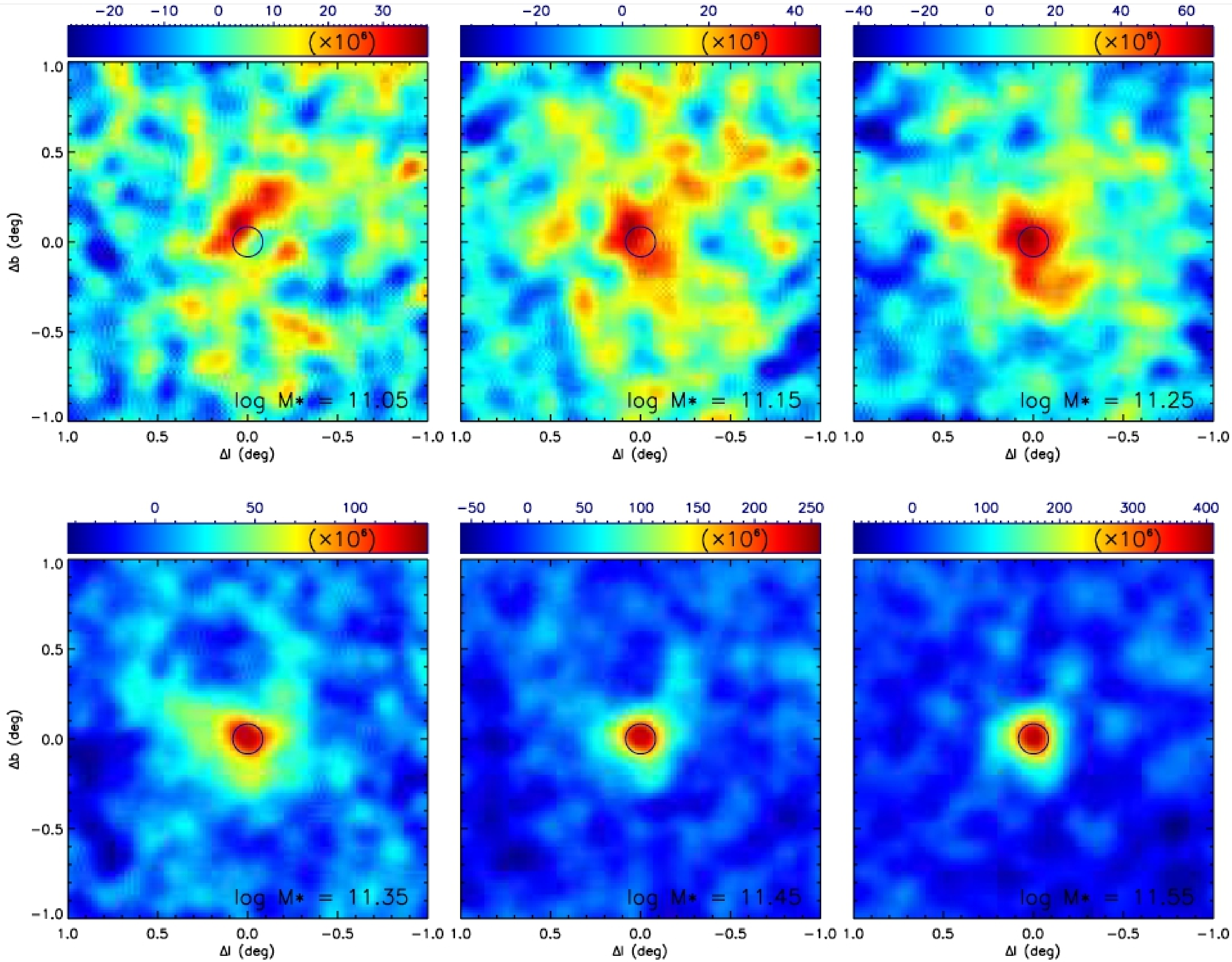

Mean Y_{500} as a function of M_* for LBGs

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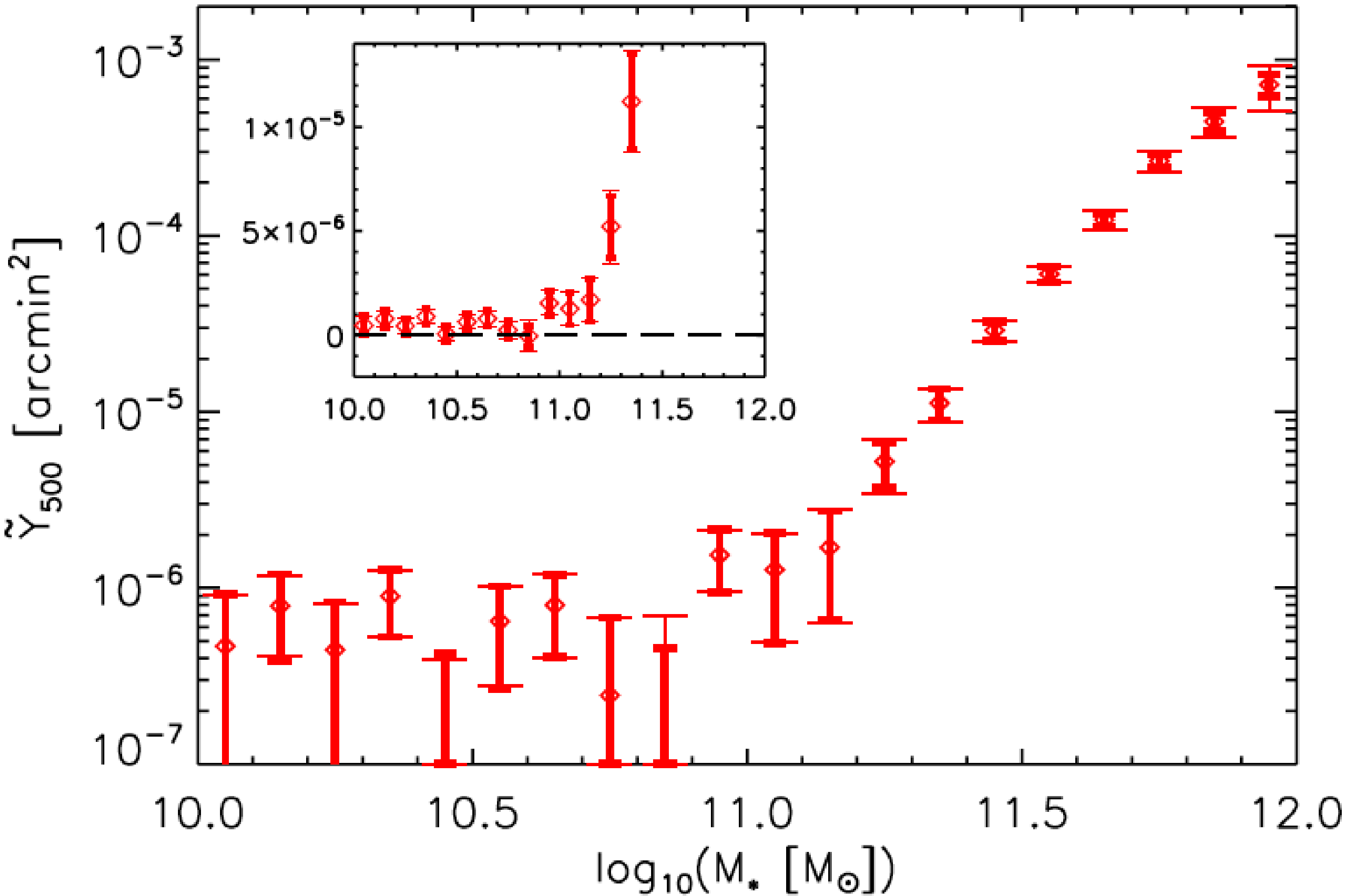

Signal is detected down to $\log M_* / M_\odot \sim 11.0$

Mean Y–M_* expected for self-similar Y–M_h

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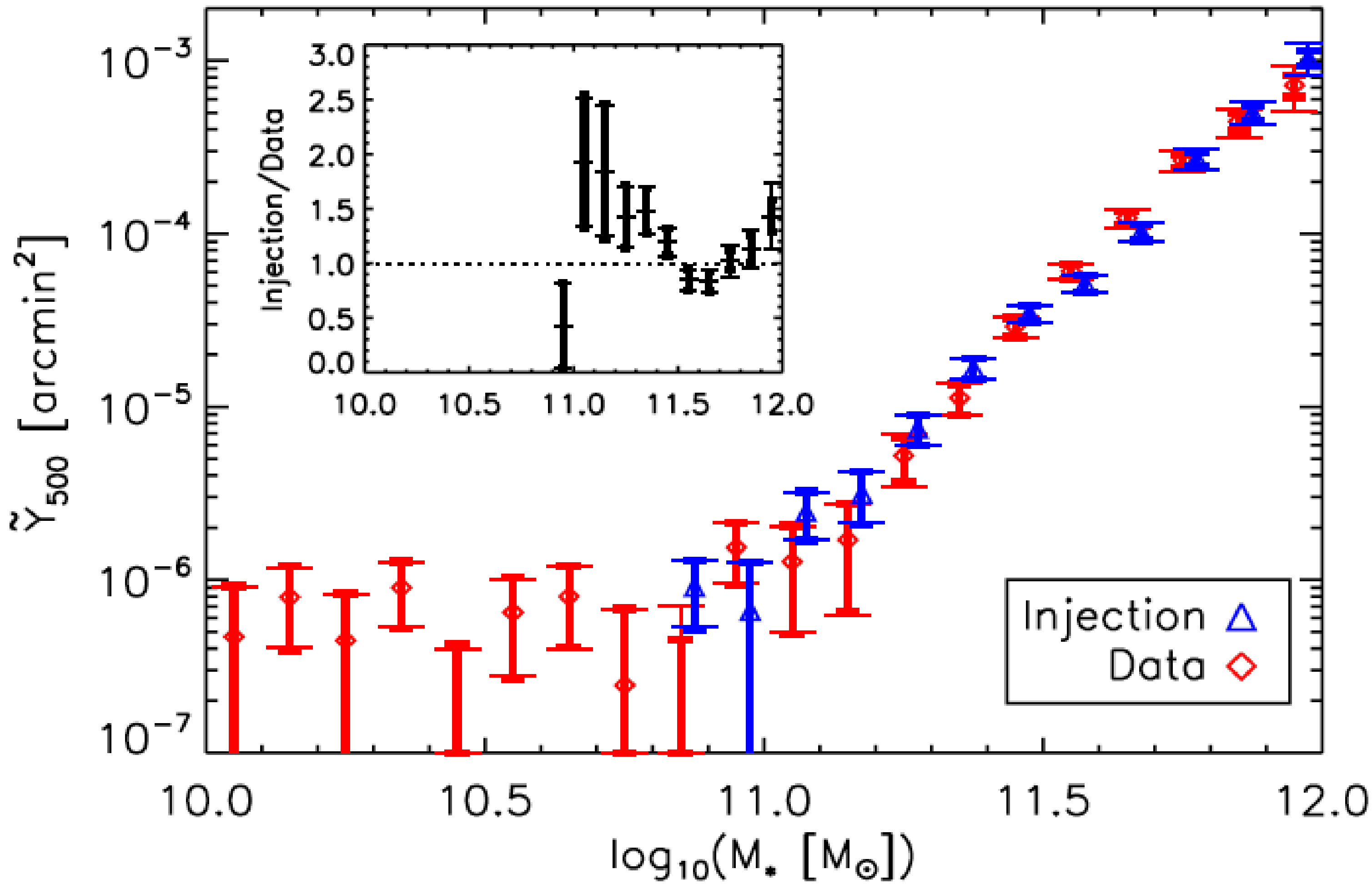

To each real LBG assign a random mock LBG of the same M_*

Use offset and M_h of mock LBG with $Y = A\,M_h^{\beta}$ + A10 profile

"Detect" using same filter as for observations, stack and compare

Fit for A and β ⟶ cosmic baryon fraction + self-similar β !

Inferred Y–M_h compared to X-ray cluster result

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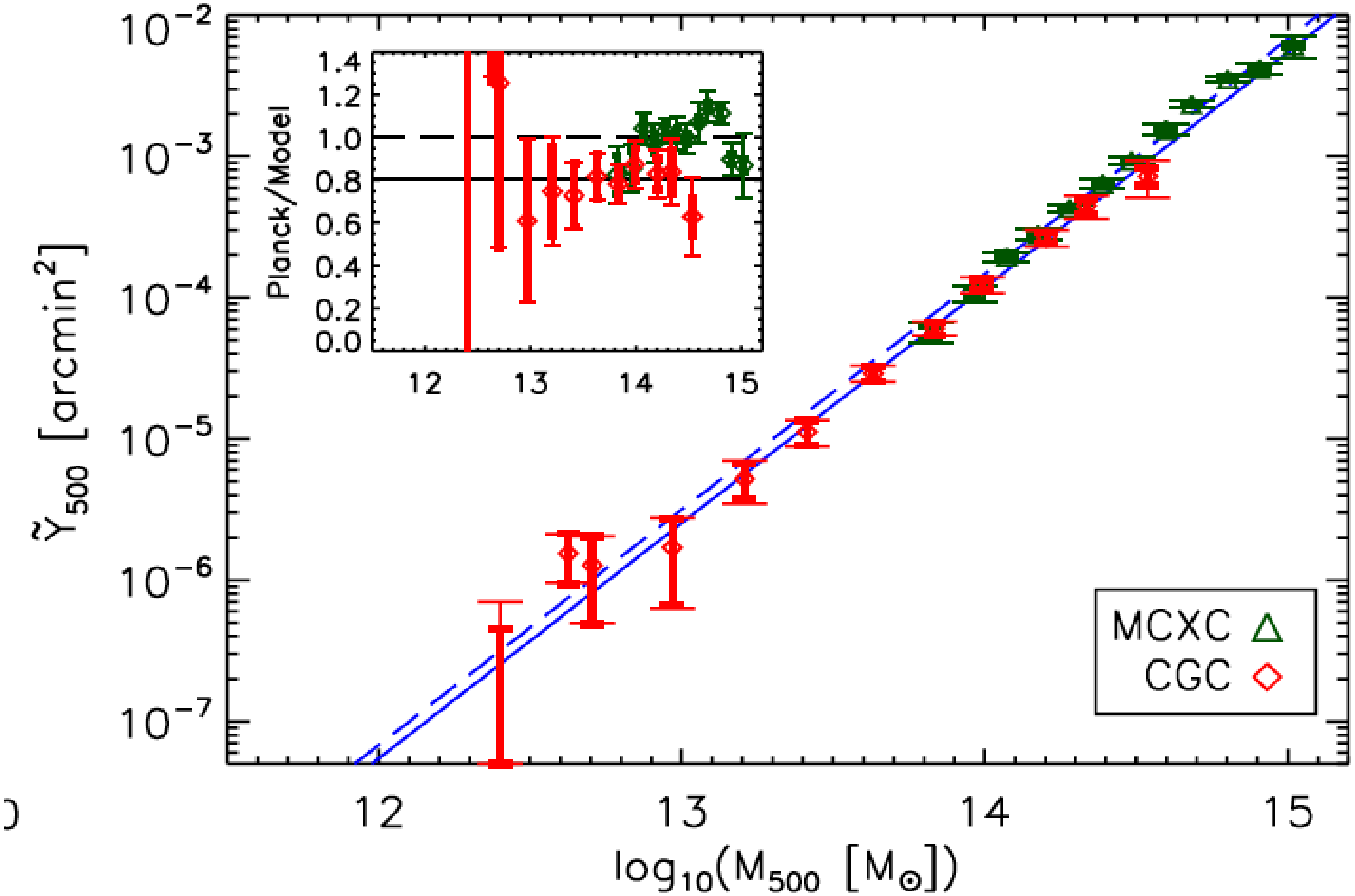

LBG and MCXC results consistent to 20% – Malmquist bias in MCXC?

Scaling continues down to log M_h / $M_\odot$ ~ 12.5 <u>with no break</u>.

Planck has seen about 25% of all cosmic baryons in this SZ signal!

Conclusions

Cluster scaling relations and their evolution are the critical factor in using cluster abundances for cosmology

- Scatter in mass proxies can interact with sample selection to produce seriously biased results. The multi-dimensional scatter in the observables–mass relation must be fully modelled

Adopting a cosmology allows cluster physics to be studied

- By stacking LBGs, Planck detects Y down to $M_h \sim 10^{12.5}\ M_\odot$ with no break in the self-similar $Y - M_h$ scaling relation

- SZ-detected hot gas in halos accounts for ~25% of all baryons

- Future work should measure evolution in the $Y - M_h$ relation