Galaxy clusters vs. Planck+BAO: an X-ray view

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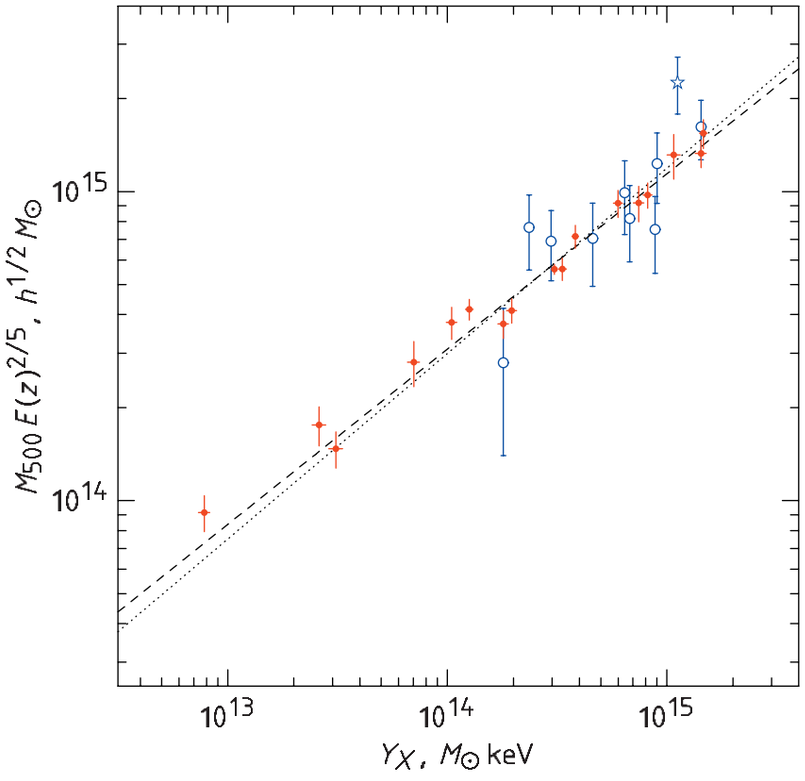
What goes into the X-ray *N*(*M*)

- Clusters are detected well above the *ROSAT* sensitivity limit, hand-checked, etc., strictly f_x-limited sample of 50 objects created.
- *Chandra* data obtained for all clusters, deep *Chandra* data for a subset.
- Deep *Chandra* data used for hydrostatic masses, which normalize scaling relations with a low-scatter proxy (Y_X). Scaling relation cross-checked with weak lensing data.
- Derived proxy-vs.-Lx relation used to compute the selection function and estimate individual *M*'s.

1.



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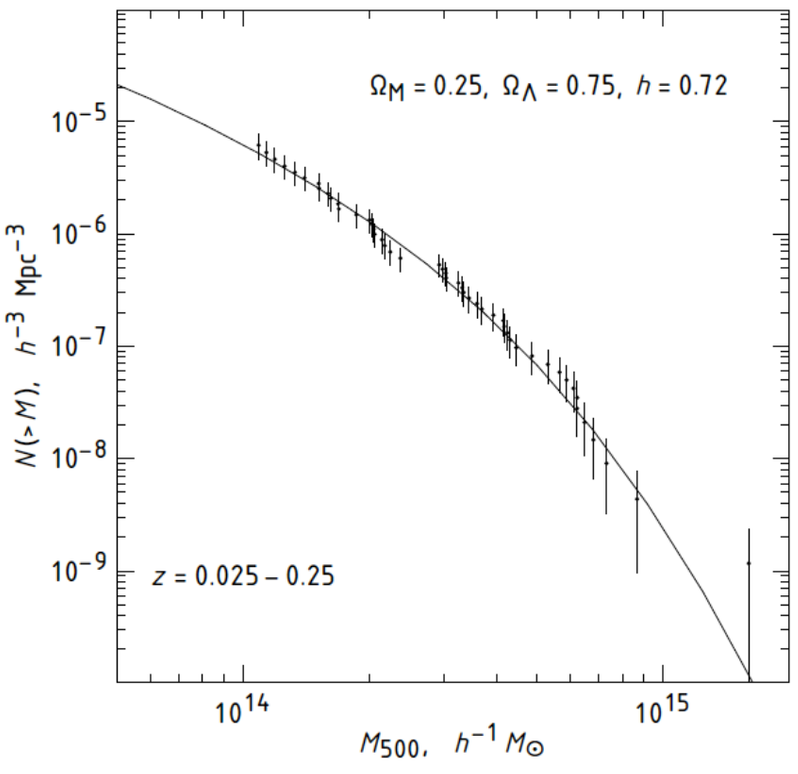

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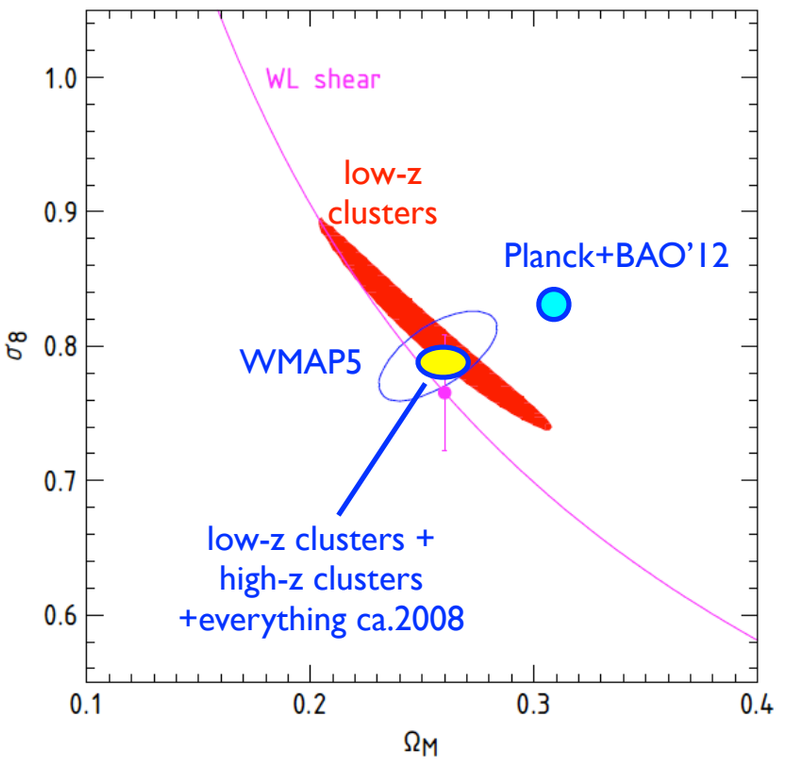
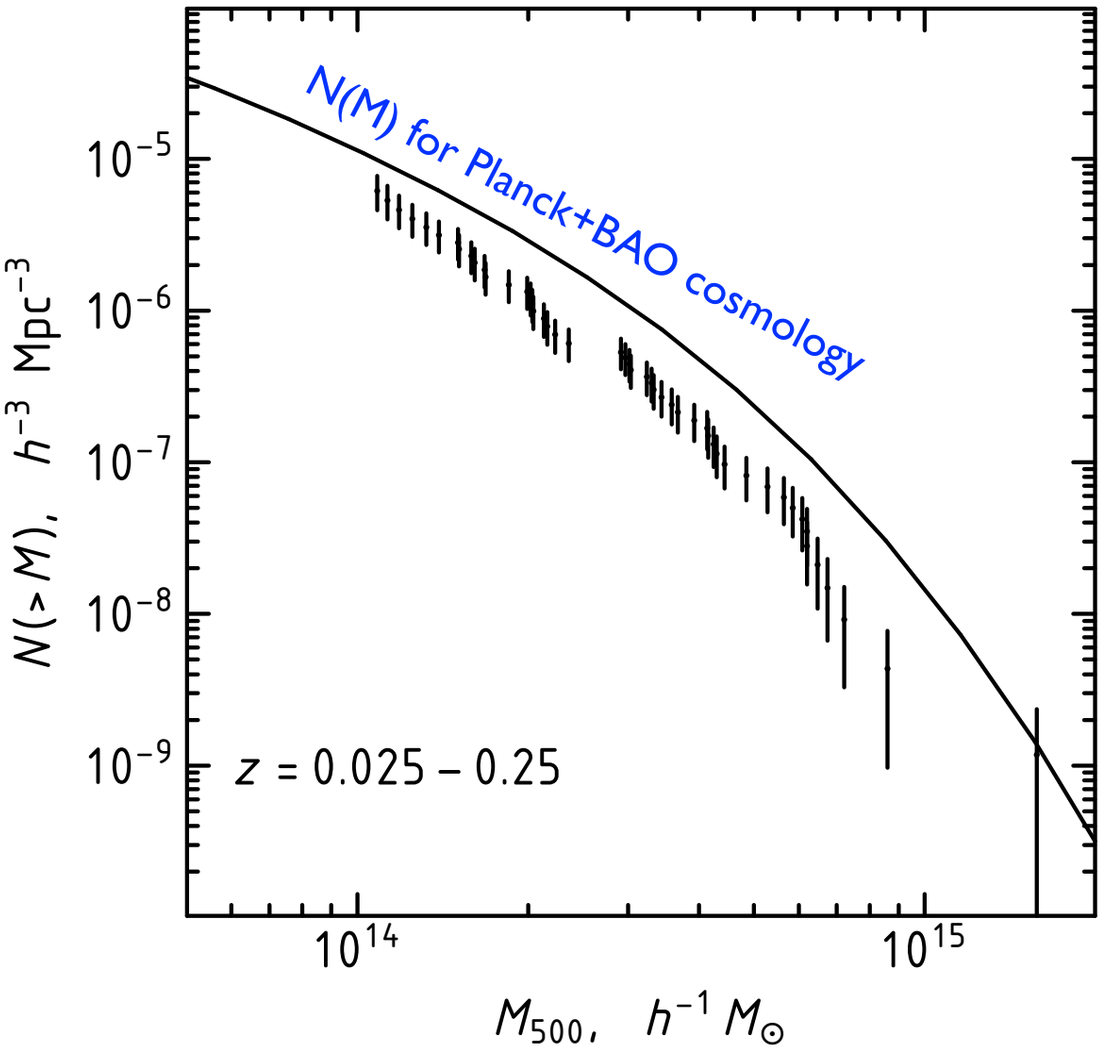
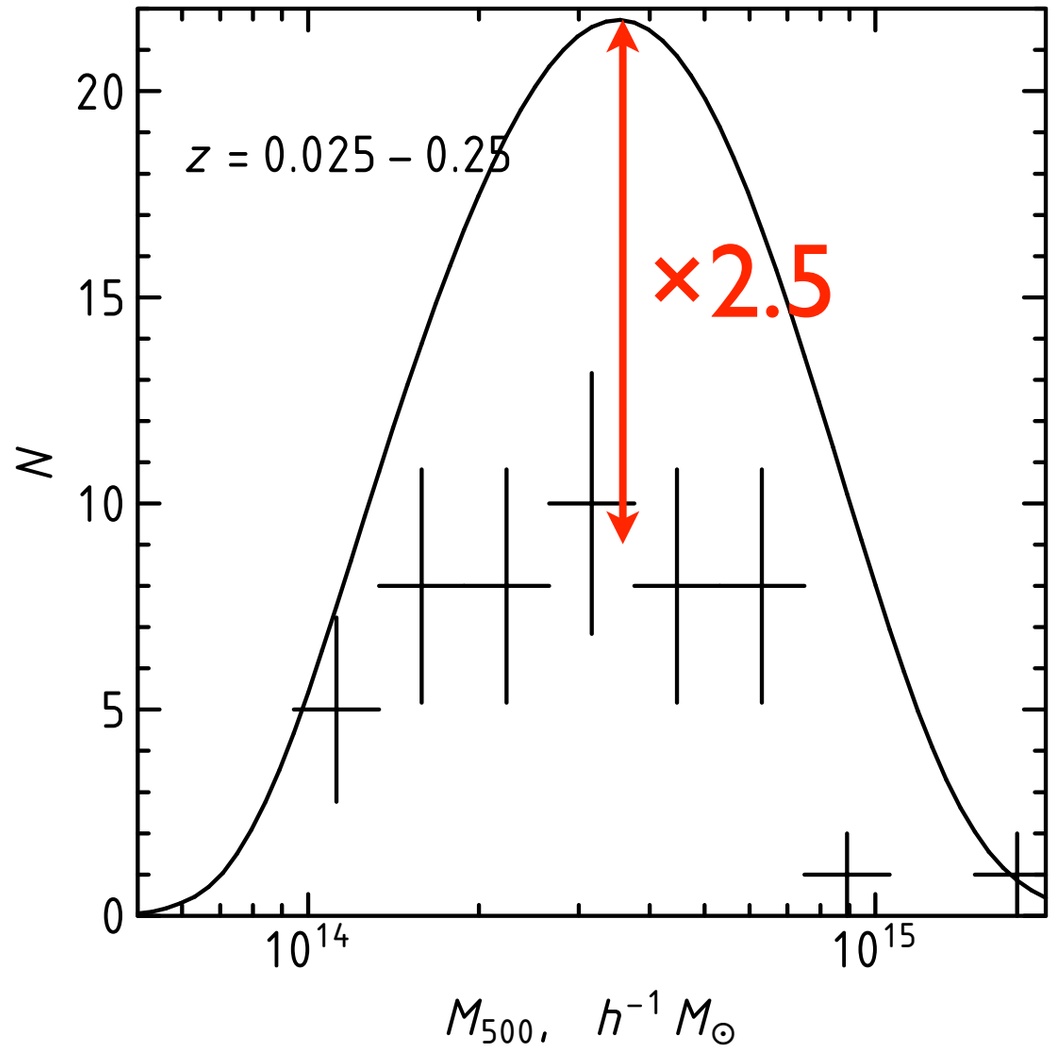


Mismatch with Planck+BAO is ***profound***





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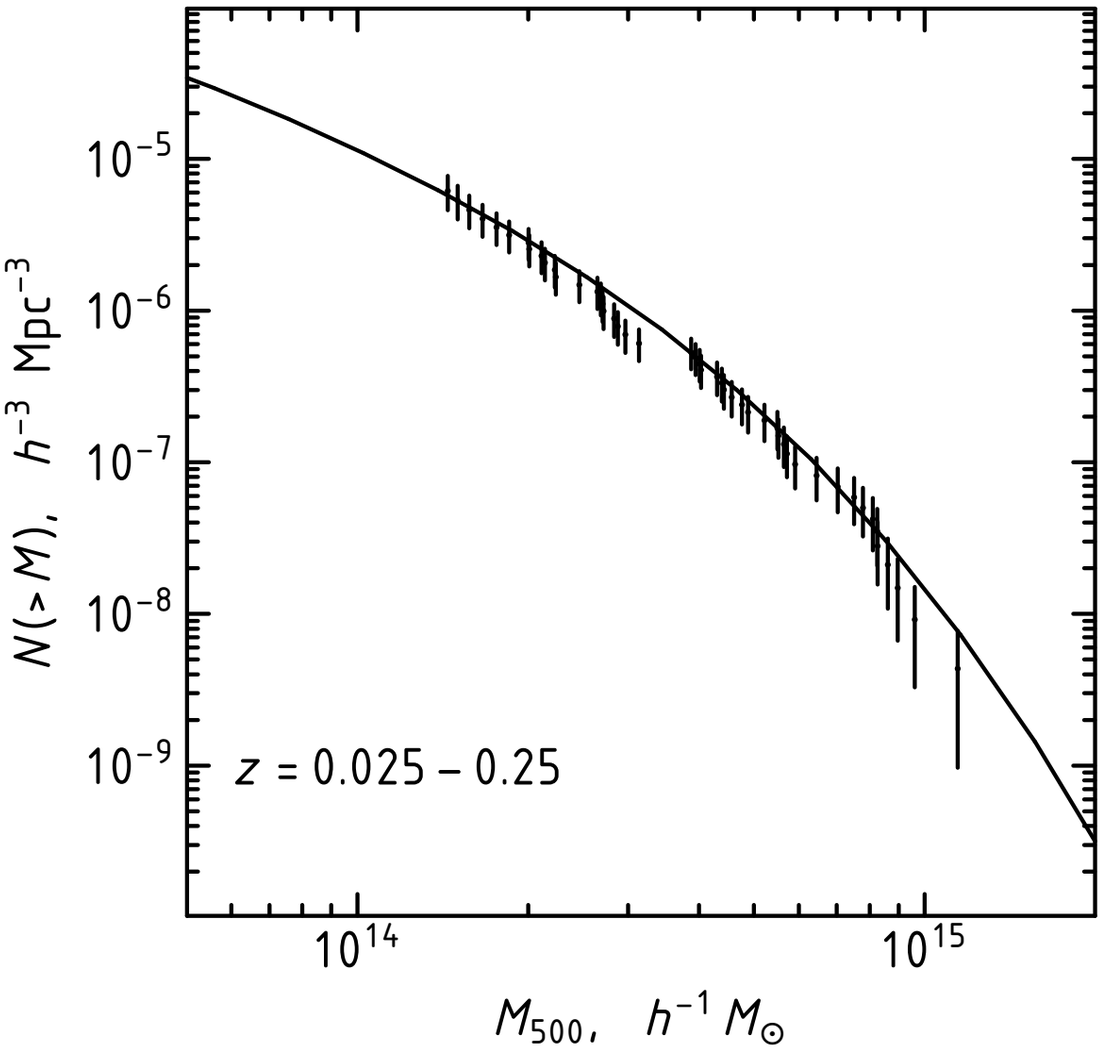
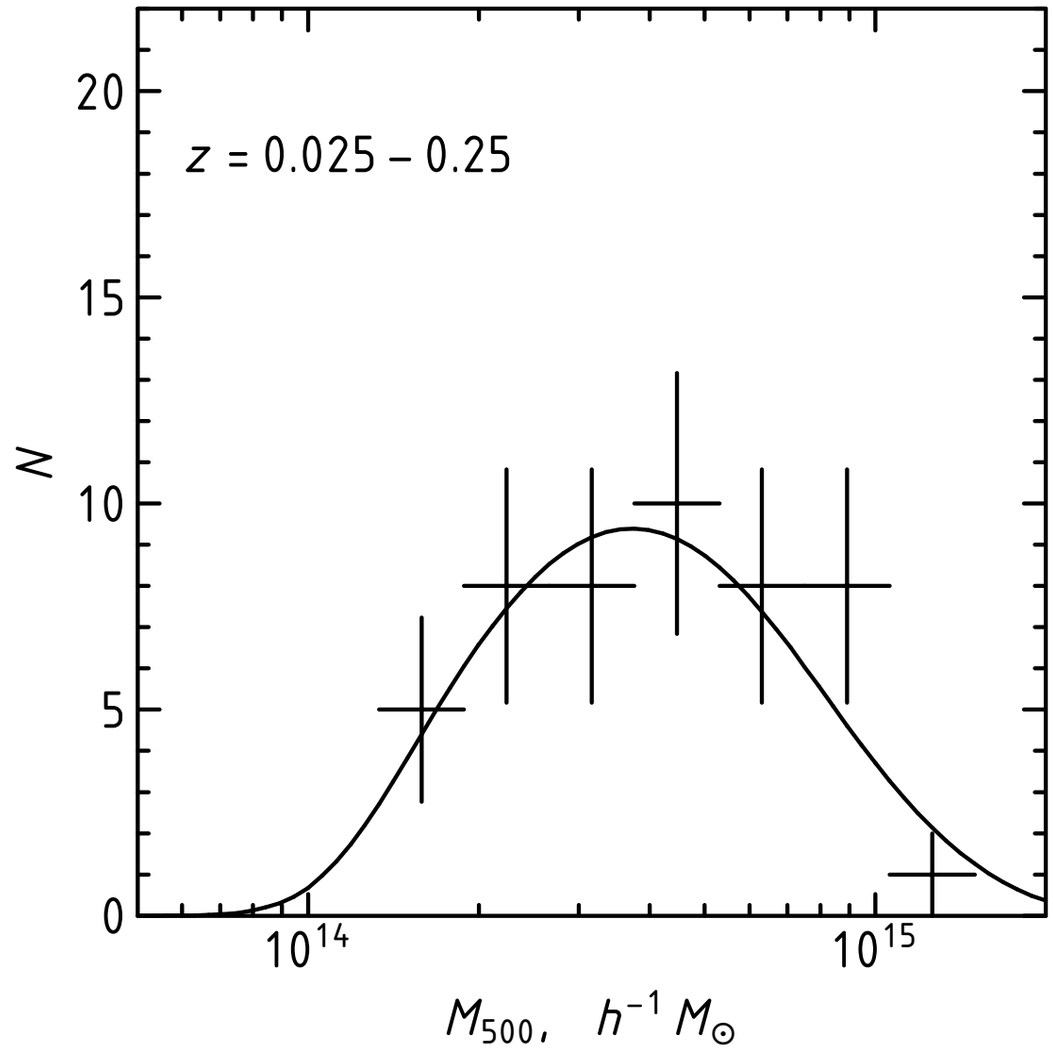
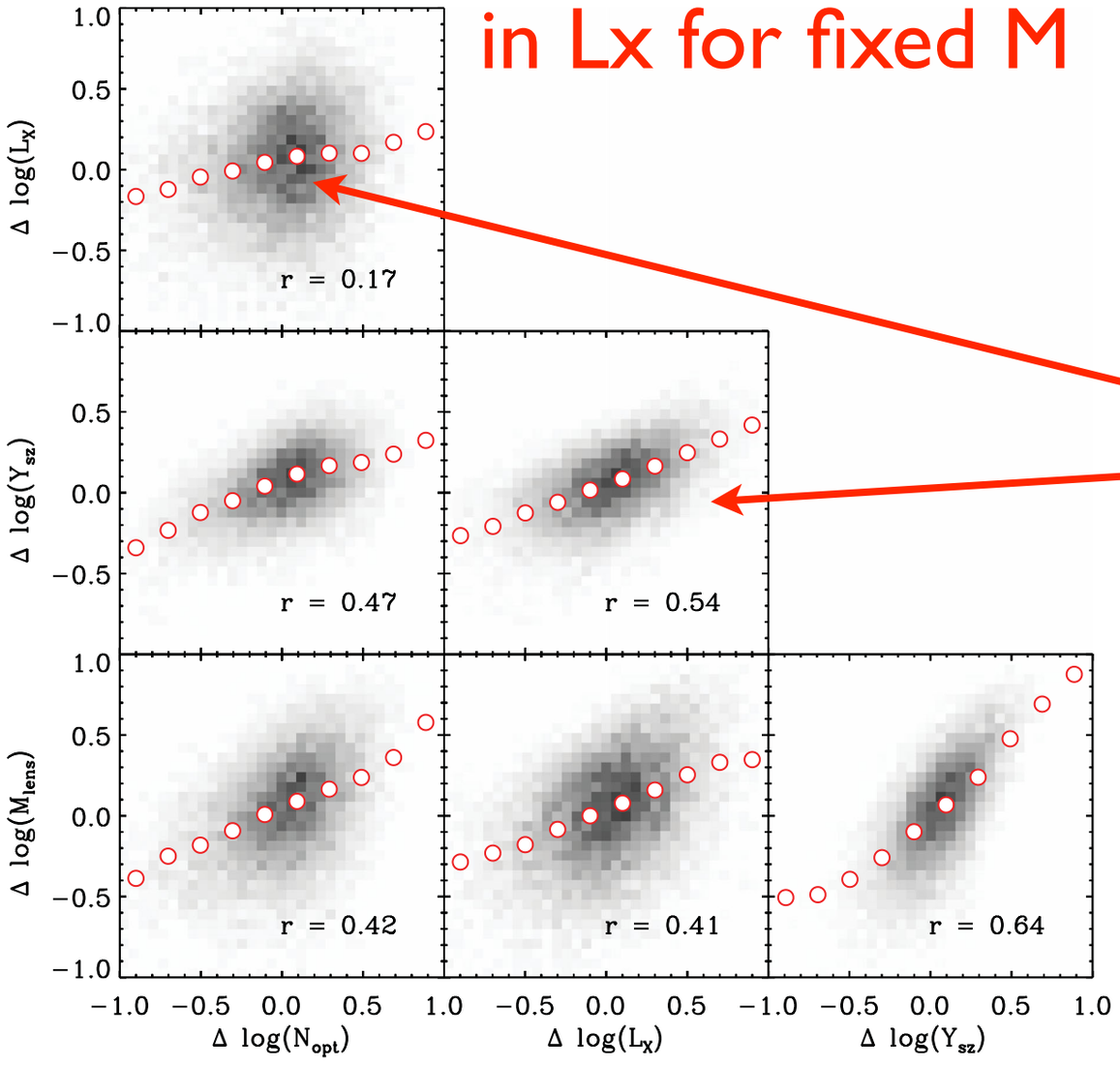




Or, ×1.45 correction of cluster masses

×3 error in selection function?

Scatter ± factor of 1.36
in Lx for fixed M

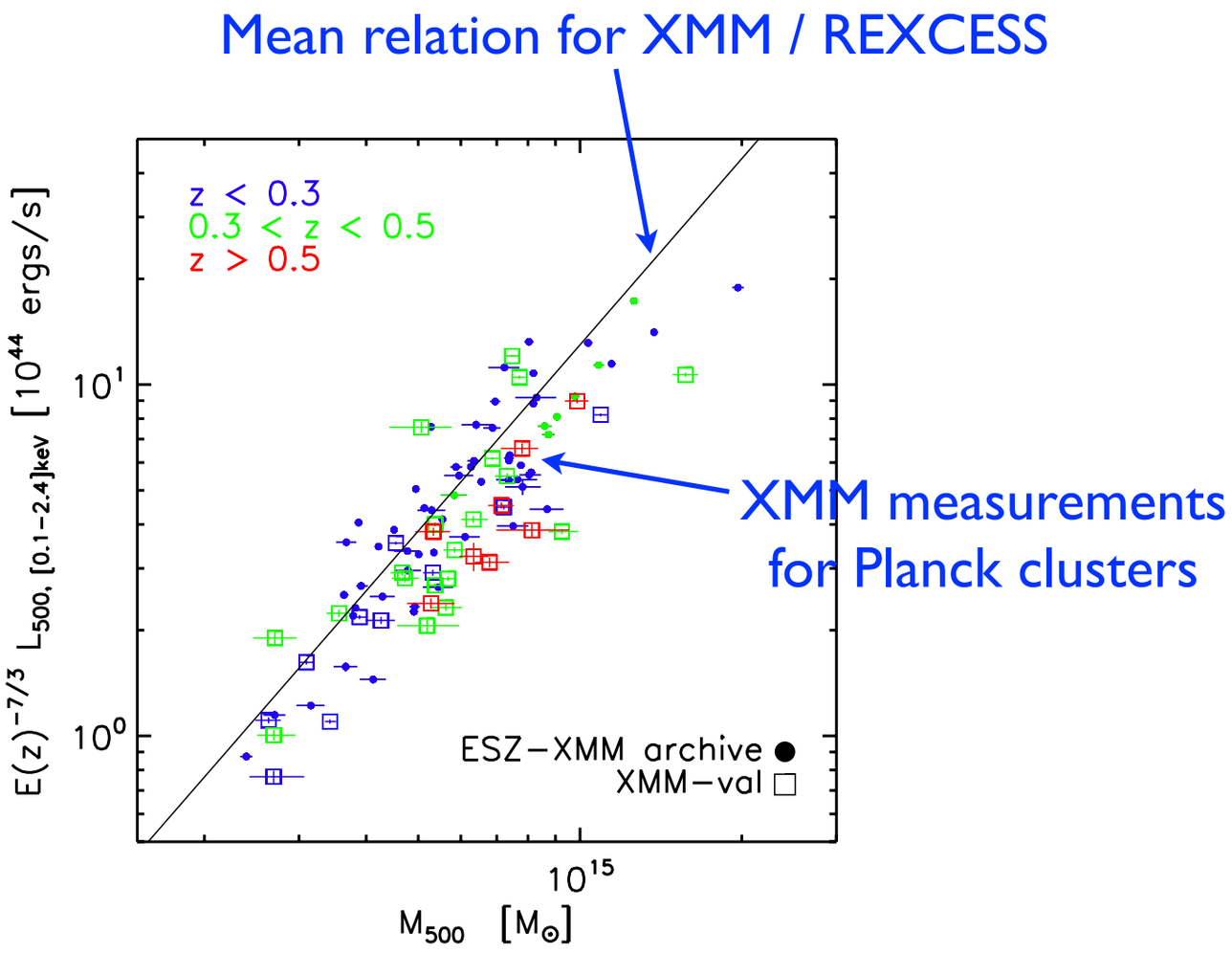


No bimodality or negative tails
in the p(Lx) or p(Y)

From Angulo et al. 2012
results for $M_{200}>4\times10^{14}$
median mass in the X-ray sample is
$M_{500}=4\times10^{14}\ h^{-1} \rightarrow M_{200}=9\times10^{14}$

×3 error in selection function?

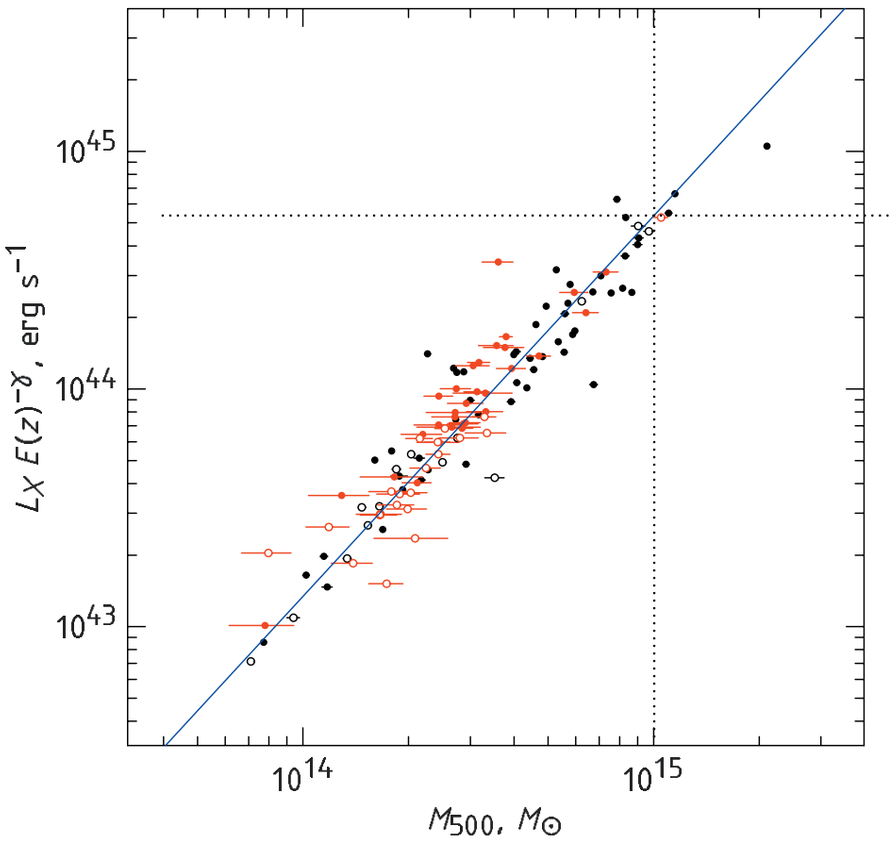
Possible indication of a problem in the Lx-Yx relation for X-ray selected and SPT selected clusters?

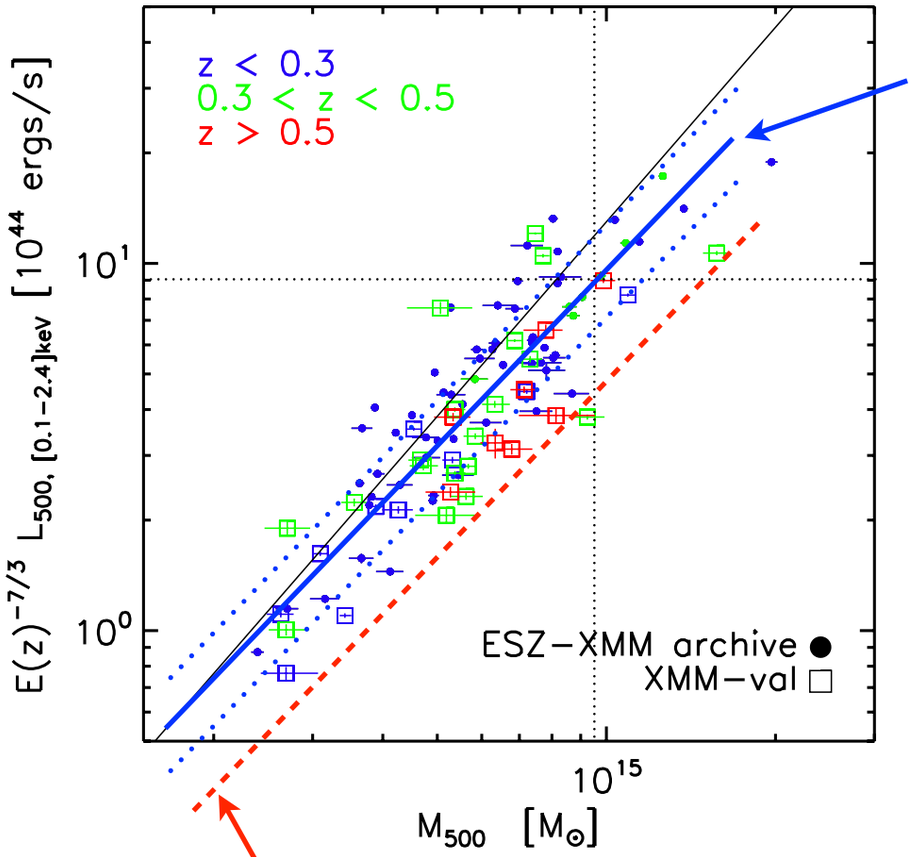


M.Arnaud's talk yesterday

×3 error in selection function?

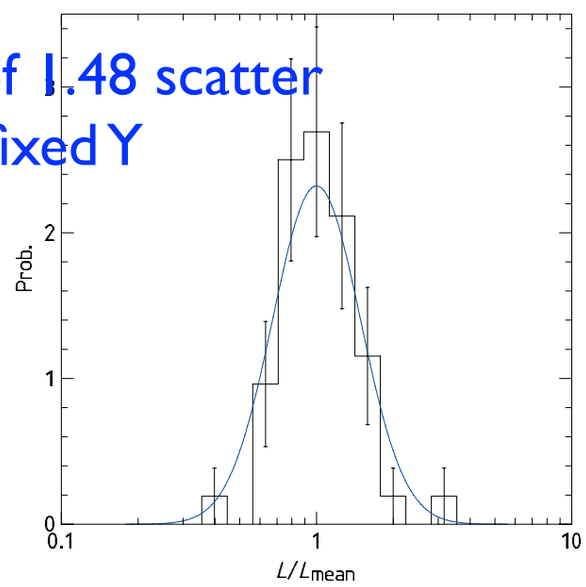
But, perfect agreement with Lx-Yx derived for the *Chandra* sample





Chandra relation ± scatter

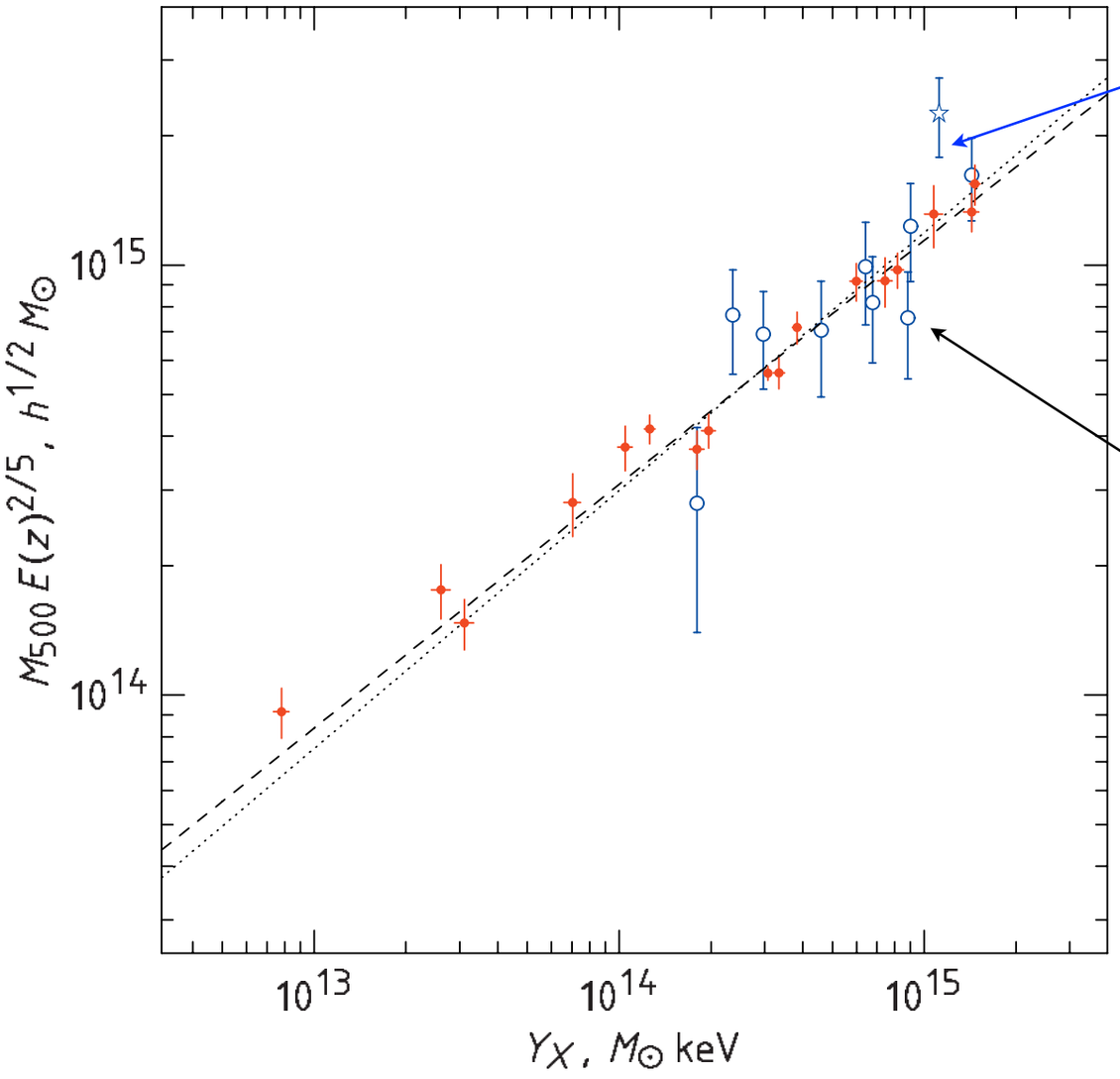
± factor of 1.48 scatter in Lx for fixed Y



Correction needed to revise sample volume by a factor of 3

Same story for *Chandra* observations of SPT clusters (Benson, McDonald et al. in prep)

×1.45 bias in mass calibration?



Weak lensing masses from Hoekstra '07, no offset relative to hydrostatic masses (±10% unc.)

However, Hoekstra '12 WL masses lower,
H12/H07 = 0.87±0.08 for 19 objects in common

... but very little change for these 10 clusters:
H12/*Chandra* = 0.98±0.08

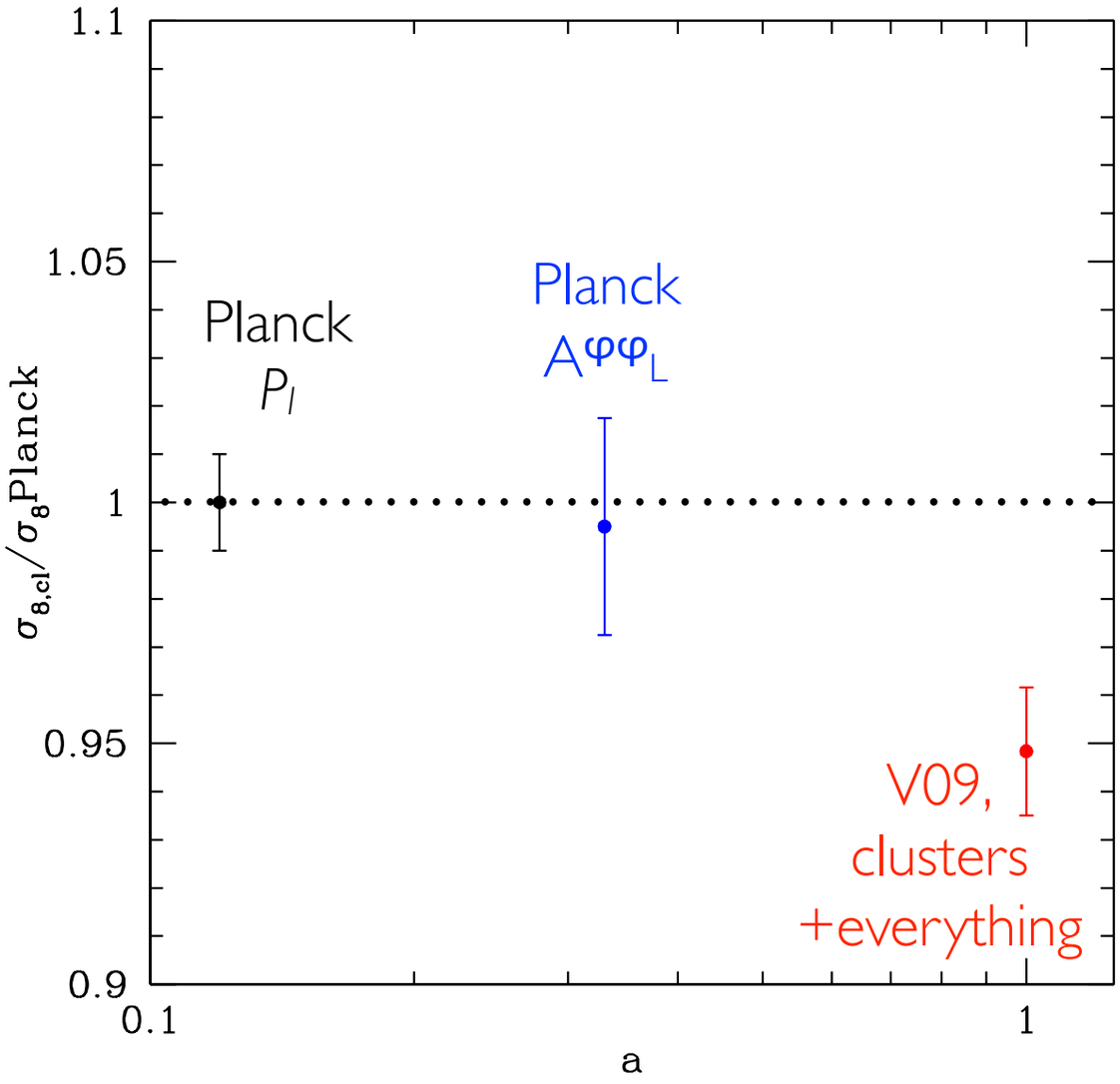
... but another large sample (von der Linden, Applegate et al.) goes higher than H12,
A12/H12 = 1.2±??

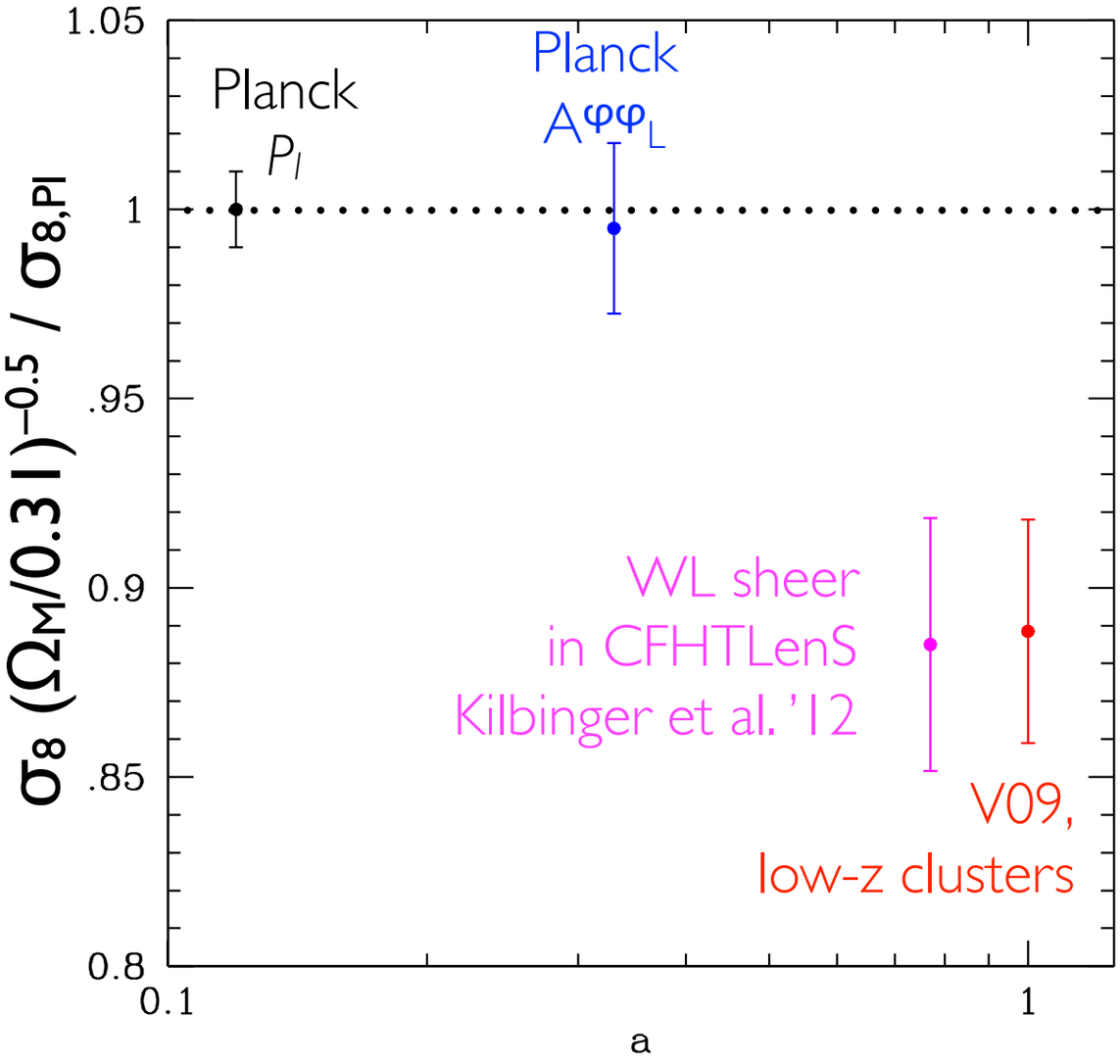
... but A12 is consistent with H07

... and –(5-10)% biases in Mwl expected at least for some reconstructions methods (Becker & Kravtsov)

TODO: Get more data; apply identical Yx-Mwl approach to all H12 and A12 clusters; test irreducible biases due to LSS for actual WL reconstruction methods; understand the difference between H12 and A12. At present, ~20% corrections to M's are not excluded.

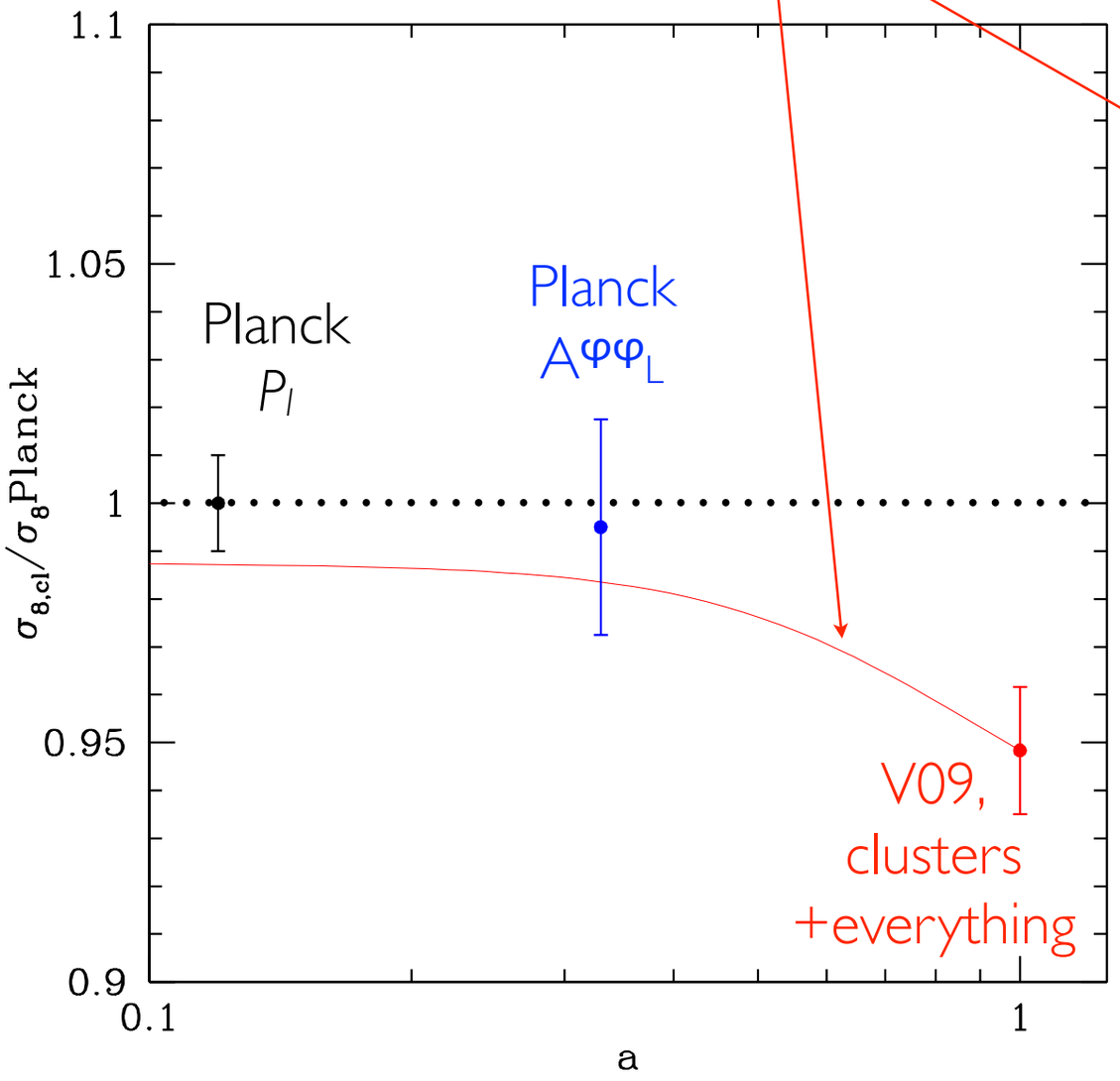
Disagreement in the density fluctuations, or?

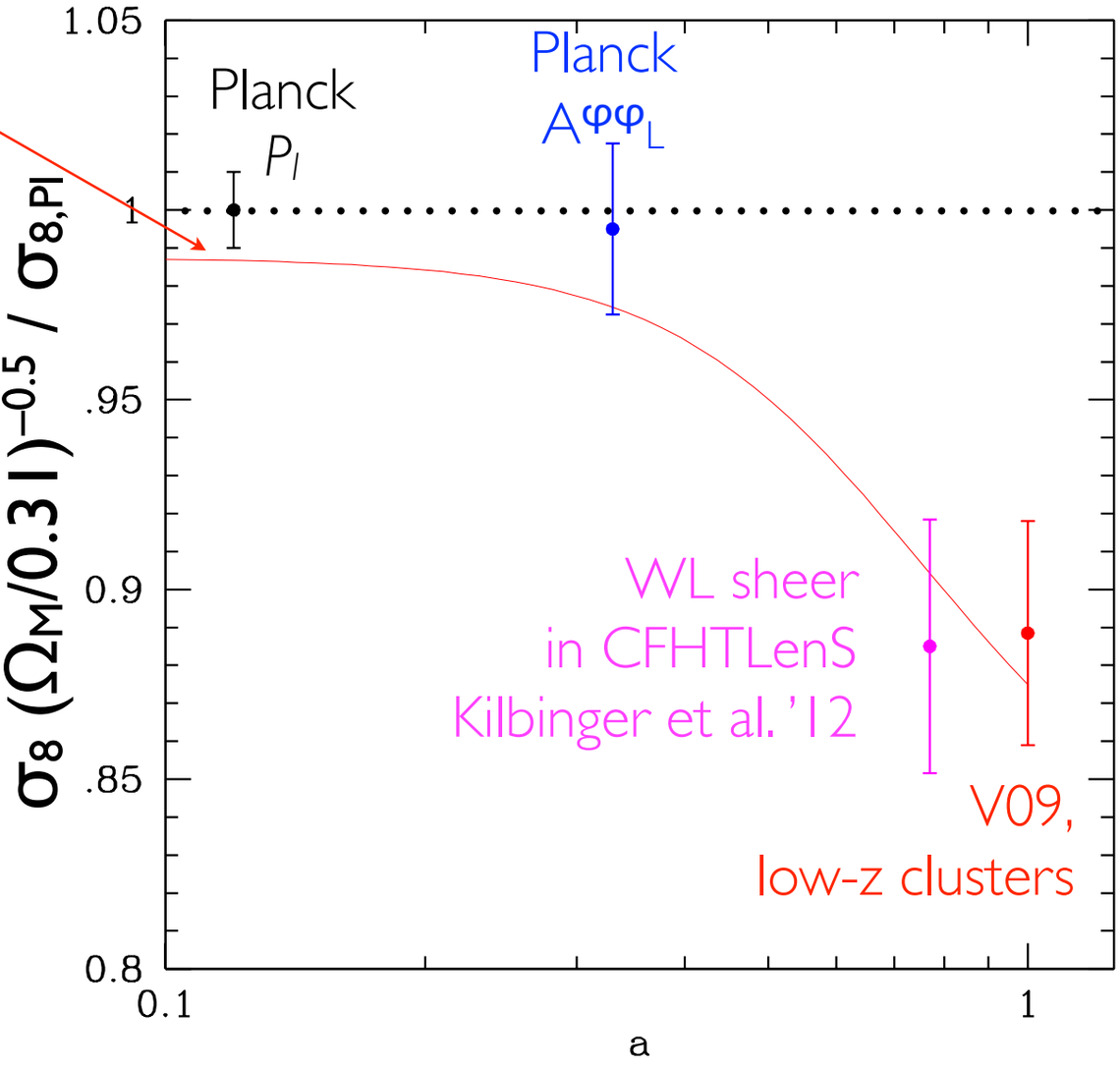




Disagreement in the density fluctuations, or?

V09 (clusters+everything ca.2008)
fit as a function of *z*

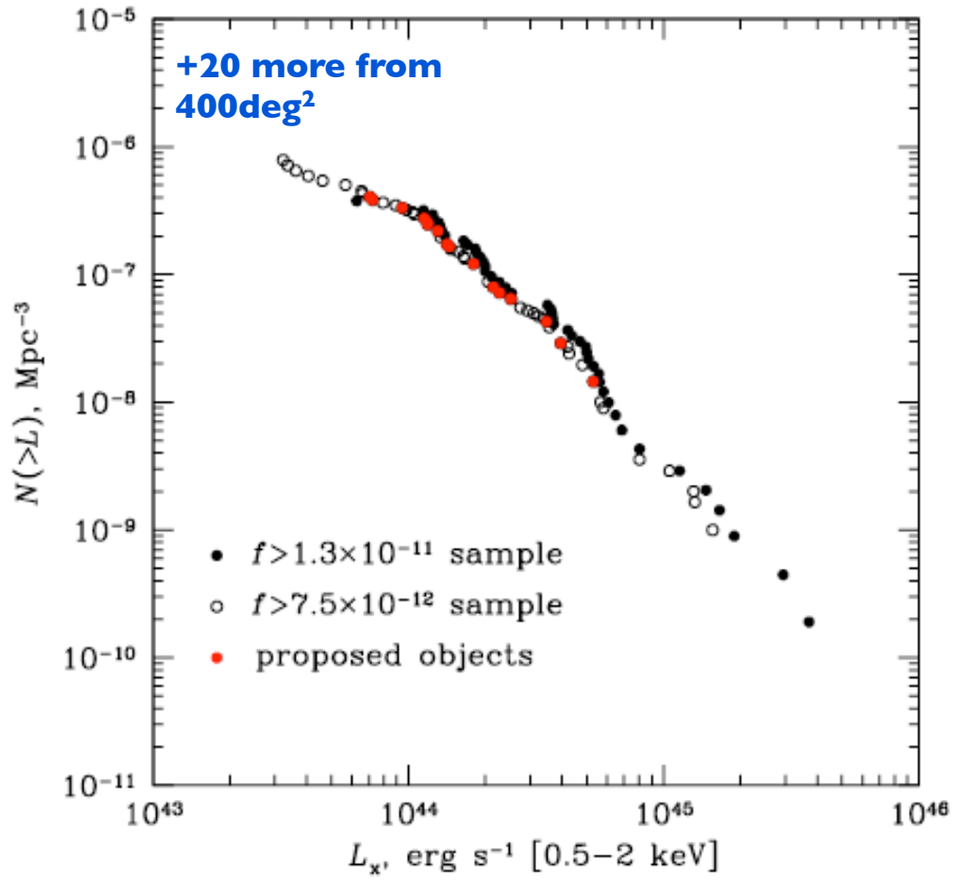




Conclusions

- Profound, factor of ~ 2.5, mismatch between observed *N*cl and prediction of the Planck+BAO model
- Sample selection function revisions of this magnitude implausible
- No concrete evidence for any significant hydrostatic bias from comparison of *Chandra* and WL masses. But ~20% revisions of *M*'s in the near future not excluded (half-way to fix the problem).
- No direct evidence for mismatch in σ_8 *at the same z*. Possibly, tension with clusters is of same nature as with direct-H0, SN, WMAP (want lower Ω_M, higher *h*)
- If we fit ΛCDM with, e.g. $\Omega_M \equiv 0.28$ and $\sigma_8 \equiv 0.79$, will we see big (×2) problems in any cosmological dataset?

“Centennial” low-z X-ray sample: plans



- Completely uniform Chandra analysis (internal X-ray measurement biases < 2%)
- We’ll publish a CosmoMC module (btw, the module for CCCP is now available at http://hea-www.harvard.edu/400d/cosm/combined/en)
- We’ll provide a method to easily account for changes in $M_{wl}/M_{X\text{-}ray}$ or Y_{SZ}/Y_X etc.
- Expected *statistical* accuracy:
  - ±0.01 in σ_8,
  - ±0.06 eV in $\sum m_\nu$ assuming perfect CMB amplitude and perfect cluster masses