Constraints on Hydrostatic Mass Bias from the 400d WL Survey

Holger Israel

Durham University

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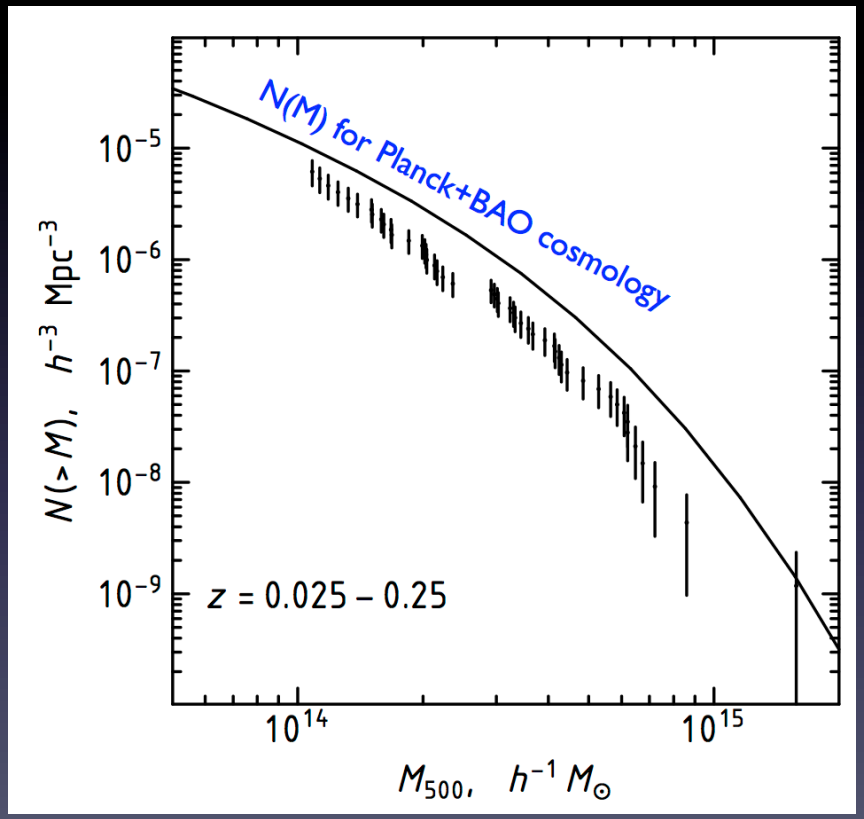
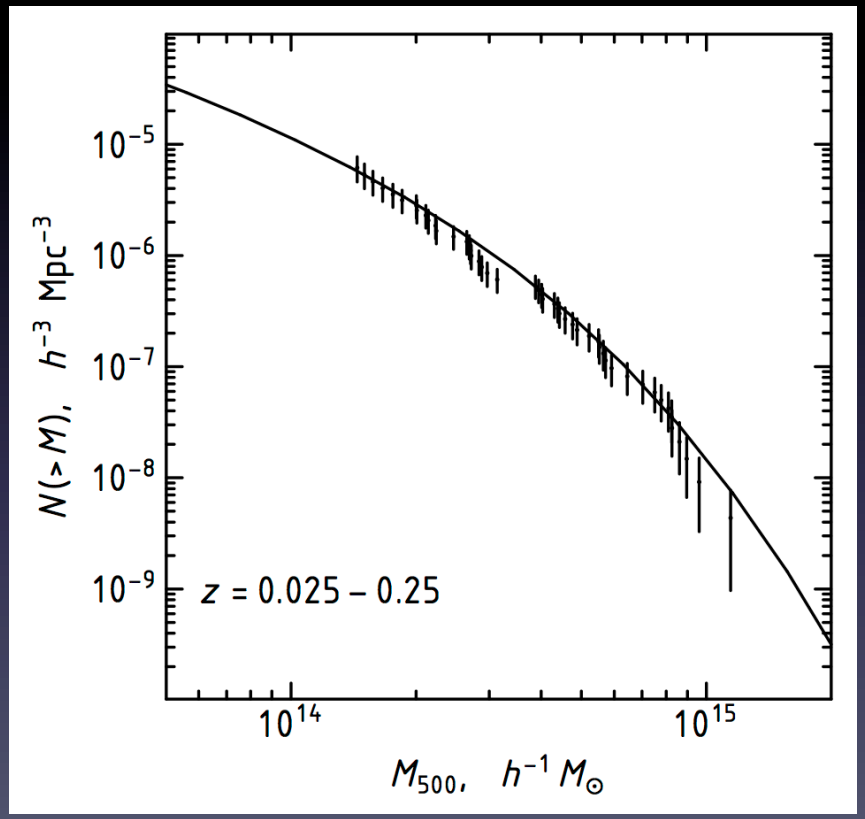
Planck cosmology inconsistent with cluster counts

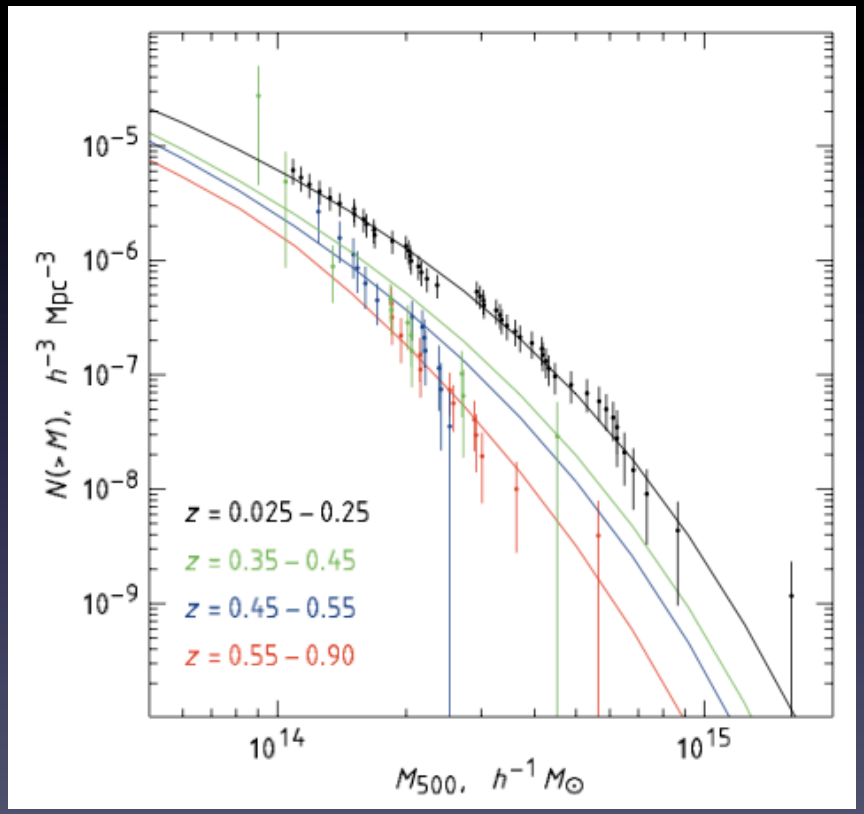


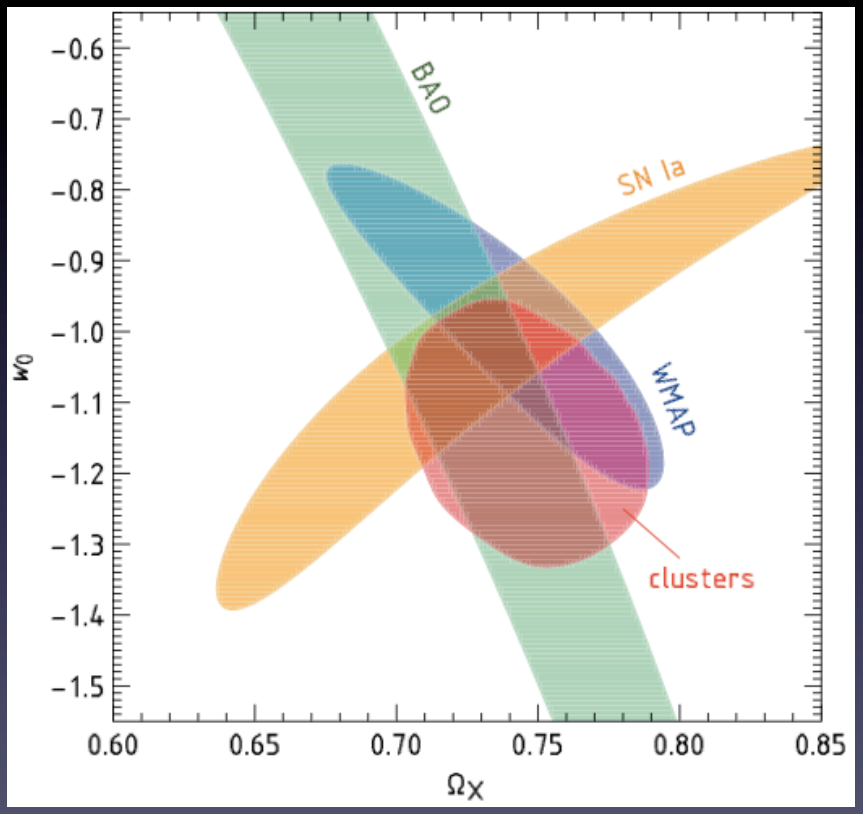


cluster masses scaled up by 1.45

Figure credits: A. Vikhlinin

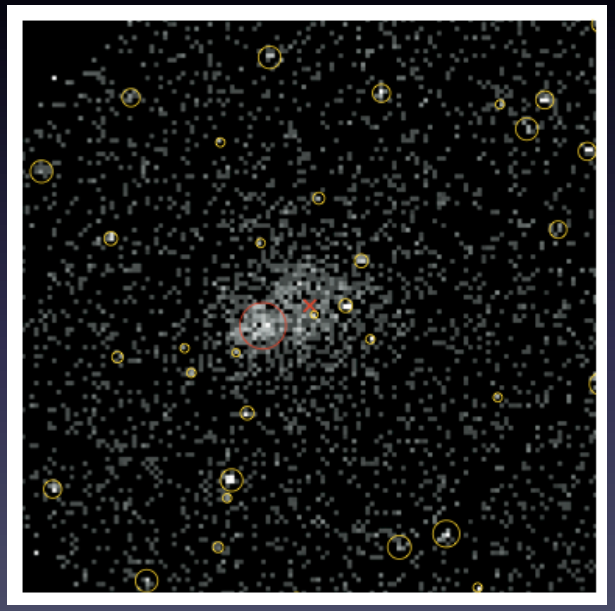
Constraining cosmology with the 400d X-ray Survey





Vikhlinin et al. 2009 a,b

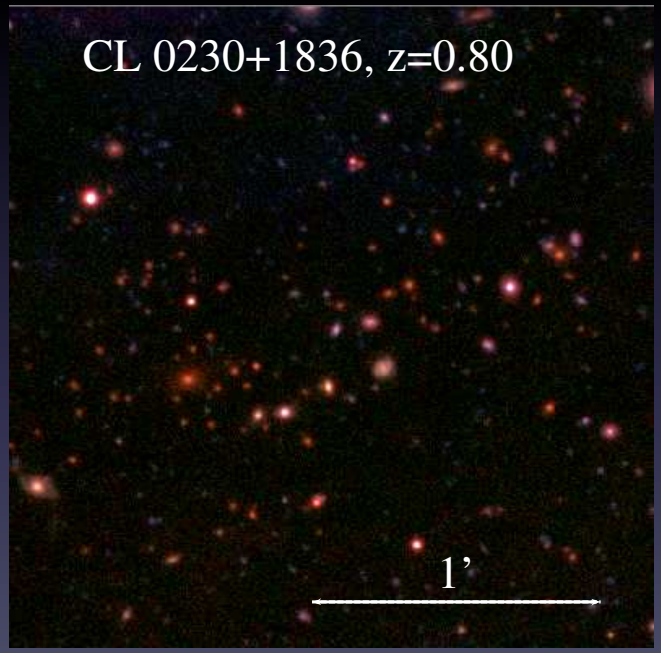
The 400d X-ray cluster survey



Chandra image of CL J0230+1836, z=0.80 (Vikhlinin+09a)

- Serendipitous cluster detections in all suited Rosat/PSPC pointings (~400 deg^2): Burenin+07
- Chandra analysis, mass determination for cosmo-subsample of 36 X-ray luminous clusters z>0.35: Vikhlinin+09a
- Constraints of cosmological parameters comparing cosmo-subsample mass function to local clusters: Vikhlinin+09b

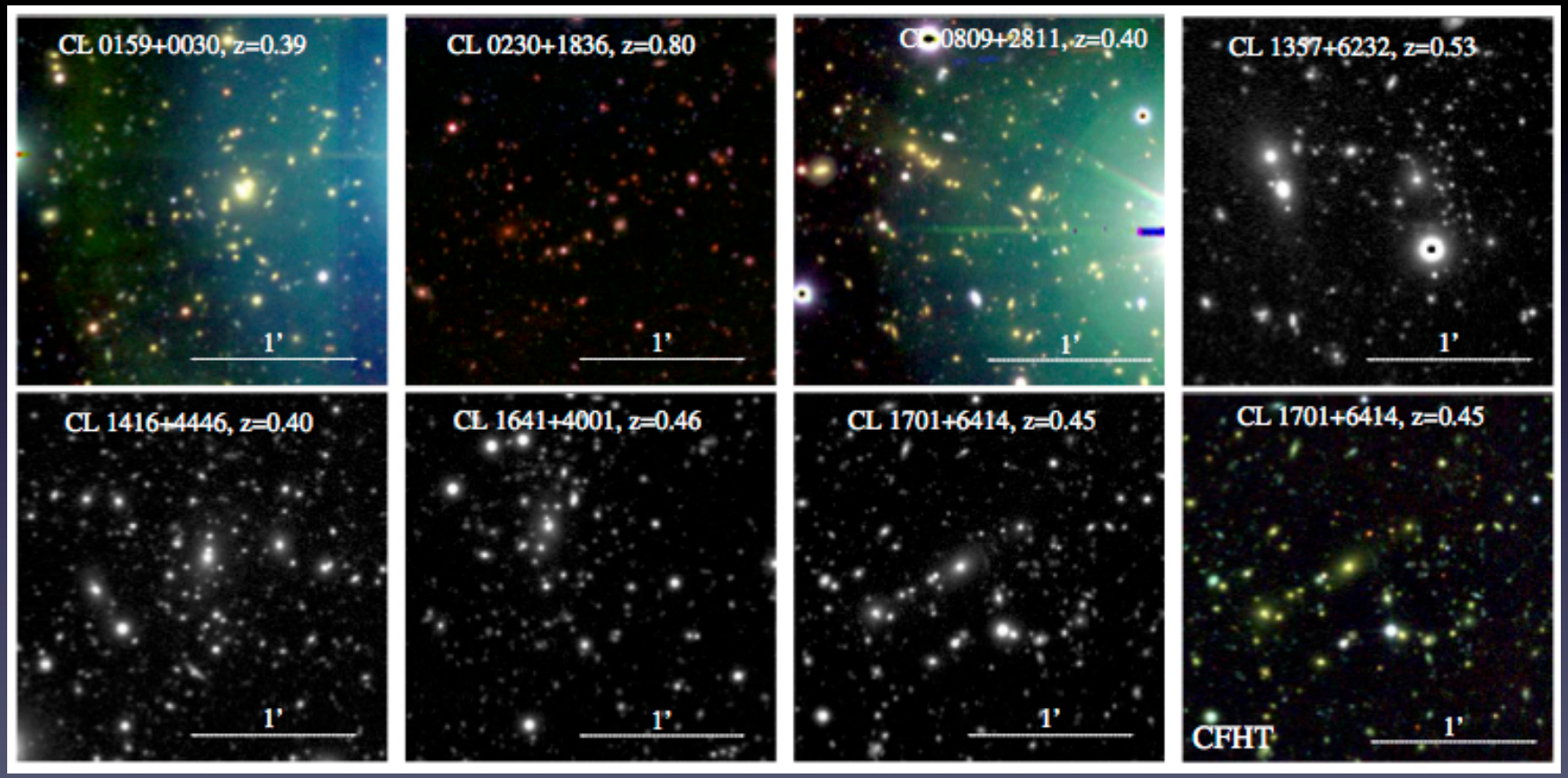
The 400d weak lensing survey



MMT/Megacam g'r'i' image of CL J0230+1836, *z*=0.80 (HI+12)

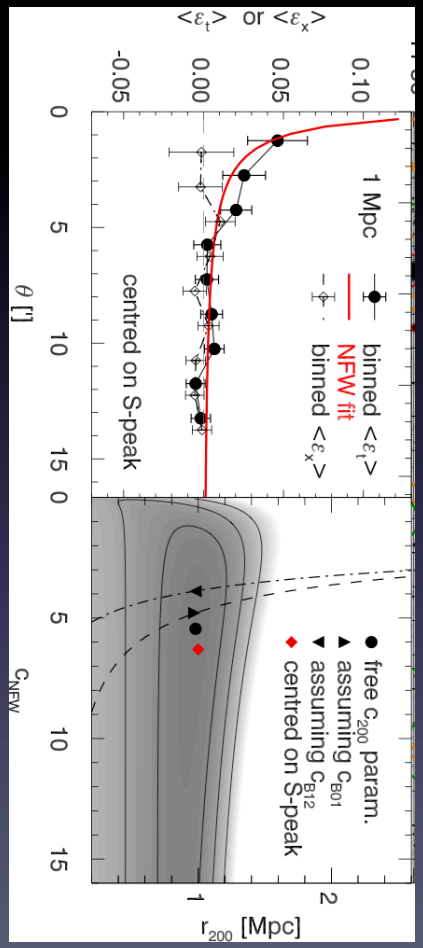
- Independent measurement of cosmo-subsample cluster mass function
- Aiming at consistency check of Vikhlinin+09b cosmology constraints
- Providing mass-observable scaling relations for intermediate-*z*, few 10^{14} M_{sun} cluster population Euclid and eROSITA are going to see.

The 400d Weak Lensing Survey



Weak lensing masses for first 8 clusters: HI+10,12

WL masses from profile fitting



Mass model for CL J1416+4446, HI+12

- Shear catalogue: KSB+ using STEP calibration from deep MMT *r'* stacks
- Selection of background sources using MMT *g'r'i'* colours where available
- Distance calibration $\langle D_{ds}/D_s \rangle$ using CFHTLS Deep fields as proxy
- NFW fit to tangential ellipticities in $0.2<r<5$ Mpc range from Rosat centre.
- Marginalising over Bhattacharya+13 *c*-*M* relation

Hydrostatic Masses

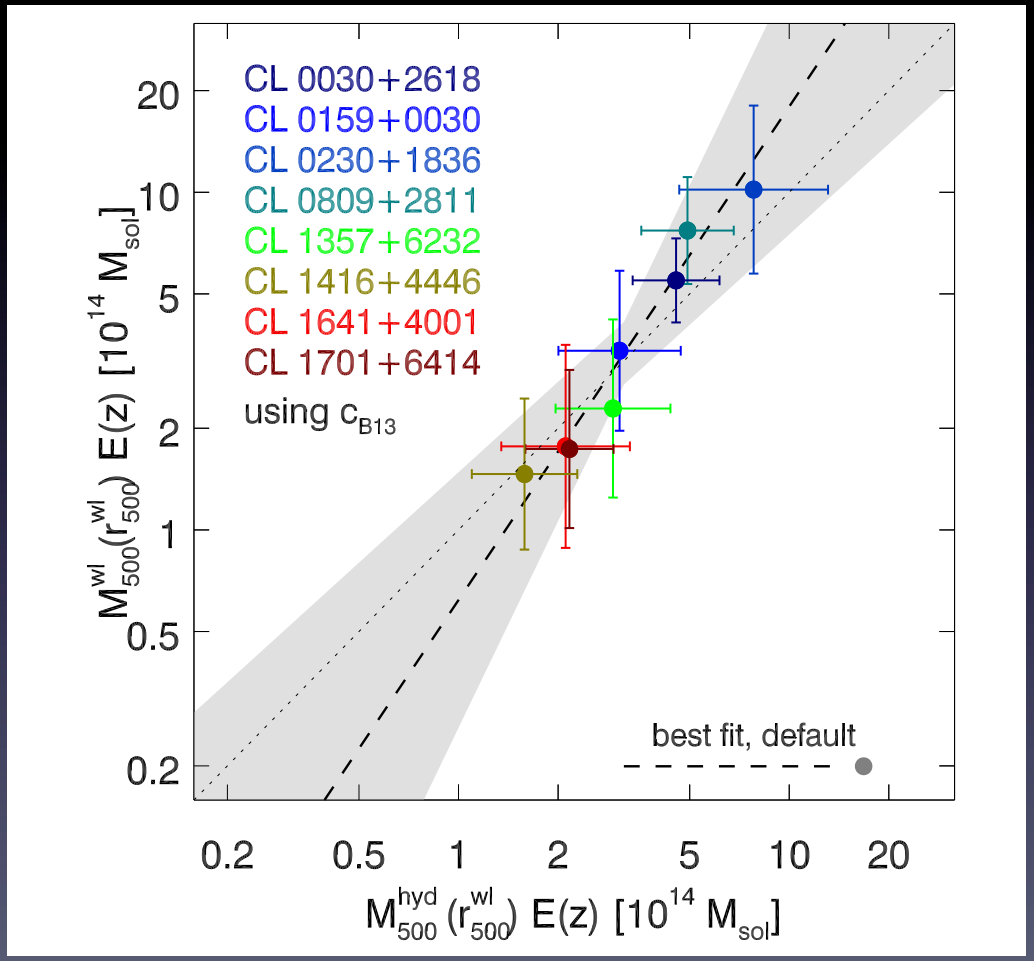
- Direct calculation of integrated mass profile
- Inputs: Vikhlinin+09a Chandra T_X and density profile, using Vikhlinin+06 parametrisation
- Chandra calibration based on Vikhlinin+05
- Reiprich+13 temperature profile

$$T_{\rm X}(r) = T_{\rm X}\,(1.19{-}0.84r/r_{200})$$

- Integration to r_{500} taken from WL, or physical radius

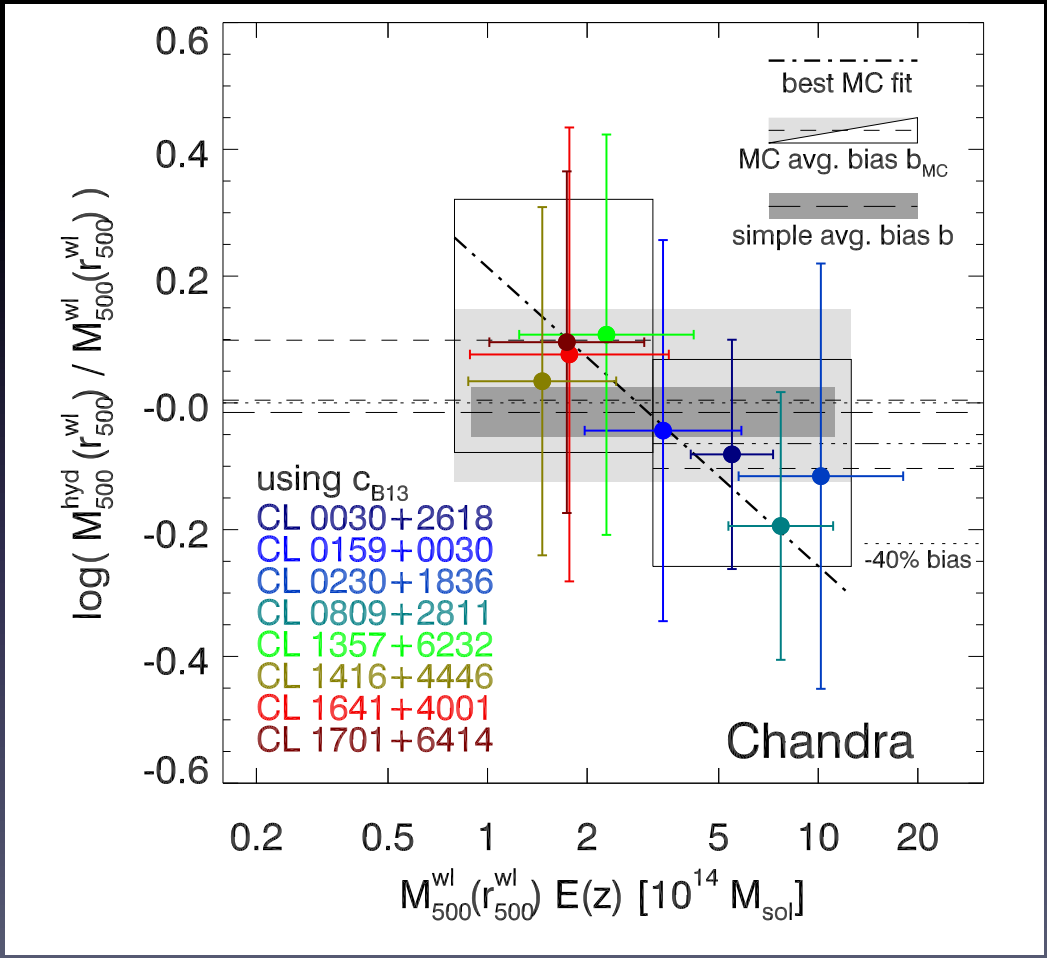
$$M^{\rm hyd}(r) = \frac{-k_{\rm B}T_{\rm X}(r)\,r}{\mu m_{\rm p}G}\left(\frac{{\rm d}\ln\rho_{\rm g}(r)}{{\rm d}\ln r} + \frac{{\rm d}\ln T_{\rm X}(r)}{{\rm d}\ln r}\right)$$

HI+14 WL-hydro scaling relation



HI+14

Hydrostatic Mass Bias



HI+14

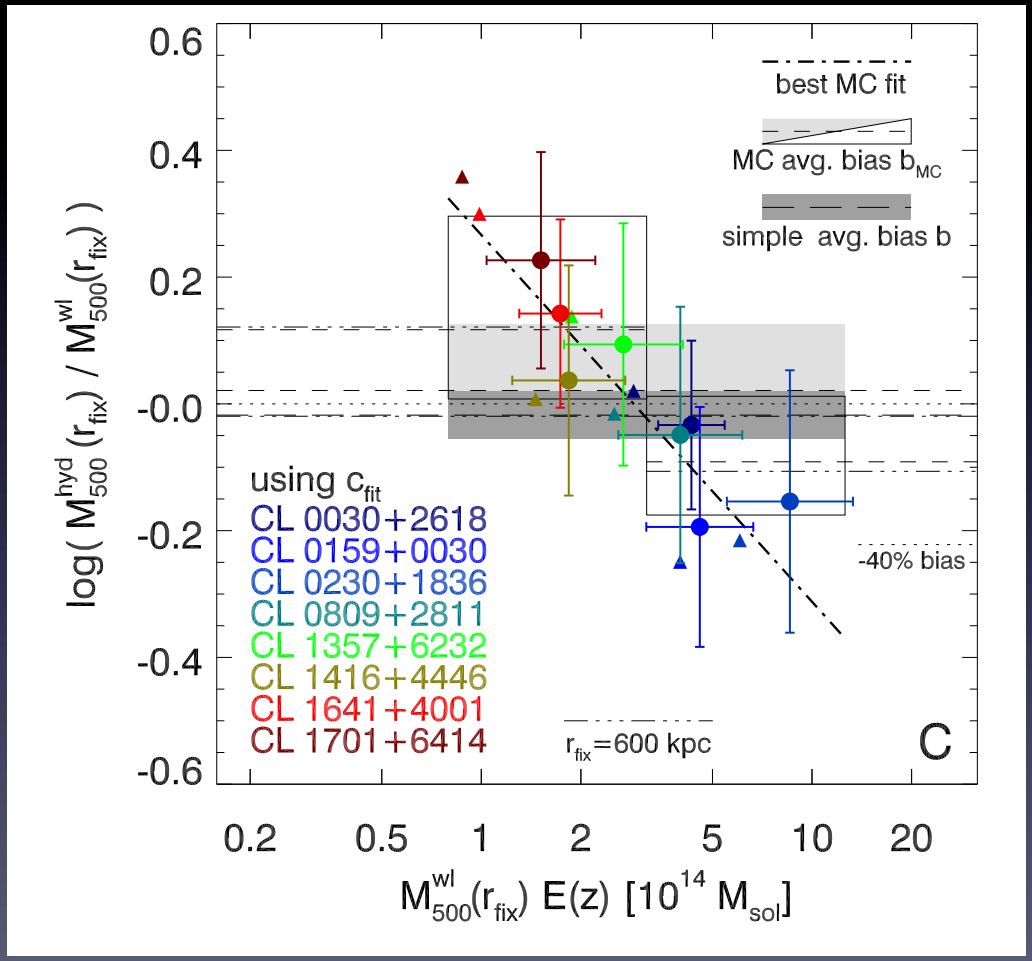
Hydrostatic bias weak, but could be mass-dependent

Scaling Relation $\eta - \xi$	Model	$c_{\rm NFW}$	Slope B	Intercept A	$b_{\rm MC}$ from Monte Carlo	$b = \langle \log\xi - \log\eta \rangle$	$\chi^2_{\rm red,M-M}$
$M^{\rm wl}_{500}(r^{\rm wl}_{500})$–$M^{\rm hyd}_{500}(r^{\rm wl}_{500})$	default	$c_{\rm B13}$	$-0.47^{+0.26}_{-0.25}$	$-0.02^{+0.07}_{-0.08}$	$0.00^{+0.14}_{-0.13}$ ($0.10^{+0.23}_{-0.18}$; $-0.10^{+0.17}_{-0.15}$)	-0.02 ± 0.04	0.52
$M^{\rm wl}(r_{\rm fix})$–$M^{\rm hyd}(r_{\rm fix})$	$r_{\rm fix} = 600$ kpc	$c_{\rm B13}$	$-0.68^{+0.19}_{-0.21}$	-0.11 ± 0.05	$0.01^{+0.10}_{-0.07}$ ($0.12^{+0.16}_{-0.10}$; $-0.11^{+0.10}_{-0.08}$)	-0.02 ± 0.04	0.82
	$r_{\rm fix} = 800$ kpc	$c_{\rm B13}$	$-0.58^{+0.19}_{-0.21}$	-0.02 ± 0.04	$0.02^{+0.10}_{-0.07}$ ($0.12^{+0.18}_{-0.11}$; $-0.09^{+0.10}_{-0.08}$)	-0.02 ± 0.04	0.72
	$r_{\rm fix} = 1000$ kpc	$c_{\rm B13}$	$-0.52^{+0.19}_{-0.21}$	0.01 ± 0.05	$0.01^{+0.11}_{-0.08}$ ($0.10^{+0.20}_{-0.11}$; $-0.09^{+0.11}_{-0.09}$)	-0.03 ± 0.03	0.69
$M^{\rm wl}_{500}(r^{\rm Y}_{500})$–$M^{\rm Y}_{500}(r^{\rm Y}_{500})$	default	$c_{\rm B13}$	$-0.75^{+0.12}_{-0.13}$	0.07 ± 0.03	$0.08^{+0.10}_{-0.07}$ ($0.23^{+0.18}_{-0.11}$; $-0.08^{+0.10}_{-0.07}$)	0.04 ± 0.06	1.21
$M^{\rm wl}_{500}(r^{\rm T}_{500})$–$M^{\rm T}_{500}(r^{\rm T}_{500})$	default	$c_{\rm B13}$	-0.63 ± 0.23	0.04 ± 0.06	$0.05^{+0.11}_{-0.08}$ ($0.17^{+0.18}_{-0.12}$; $-0.08^{+0.11}_{-0.10}$)	0.02 ± 0.05	0.88
$M^{\rm wl}_{500}(r^{\rm G}_{500})$–$M^{\rm G}_{500}(r^{\rm G}_{500})$	default	$c_{\rm B13}$	$-0.89^{+0.18}_{-0.31}$	$0.01^{+0.03}_{-0.04}$	$0.04^{+0.10}_{-0.07}$ ($0.21^{+0.17}_{-0.10}$; $-0.15^{+0.09}_{-0.07}$)	0.00 ± 0.07	2.11

- Monte Carlo/jackknife method
- Most of our clusters consistent with $M^{\rm hyd}=M^{\rm wl}$
- No evidence for hydrostatic bias >~25%, if $M^{\rm wl}$ unbiased
- Surprisingly low level of scatter in mass-mass SR
- Low- and high-mass bins offset by ~2 σ

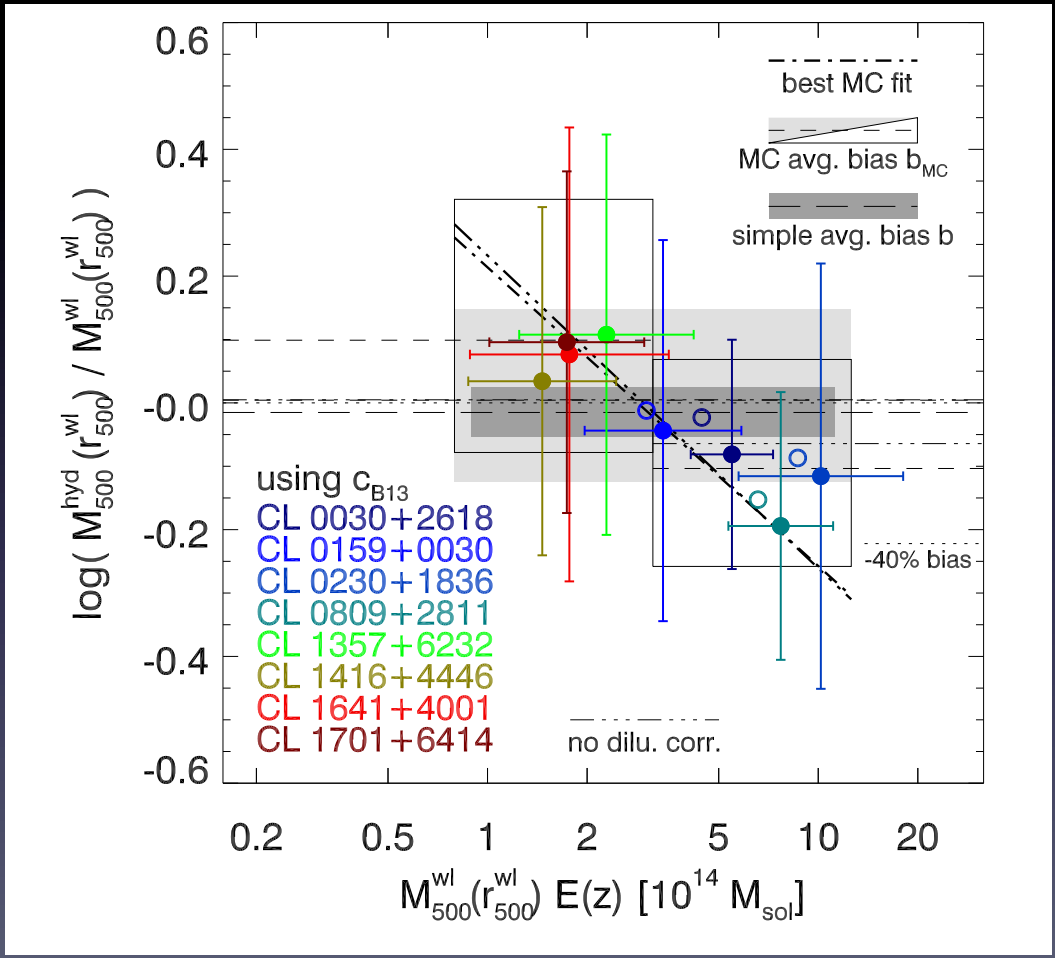
HI+14

Same observations at fixed physical radius



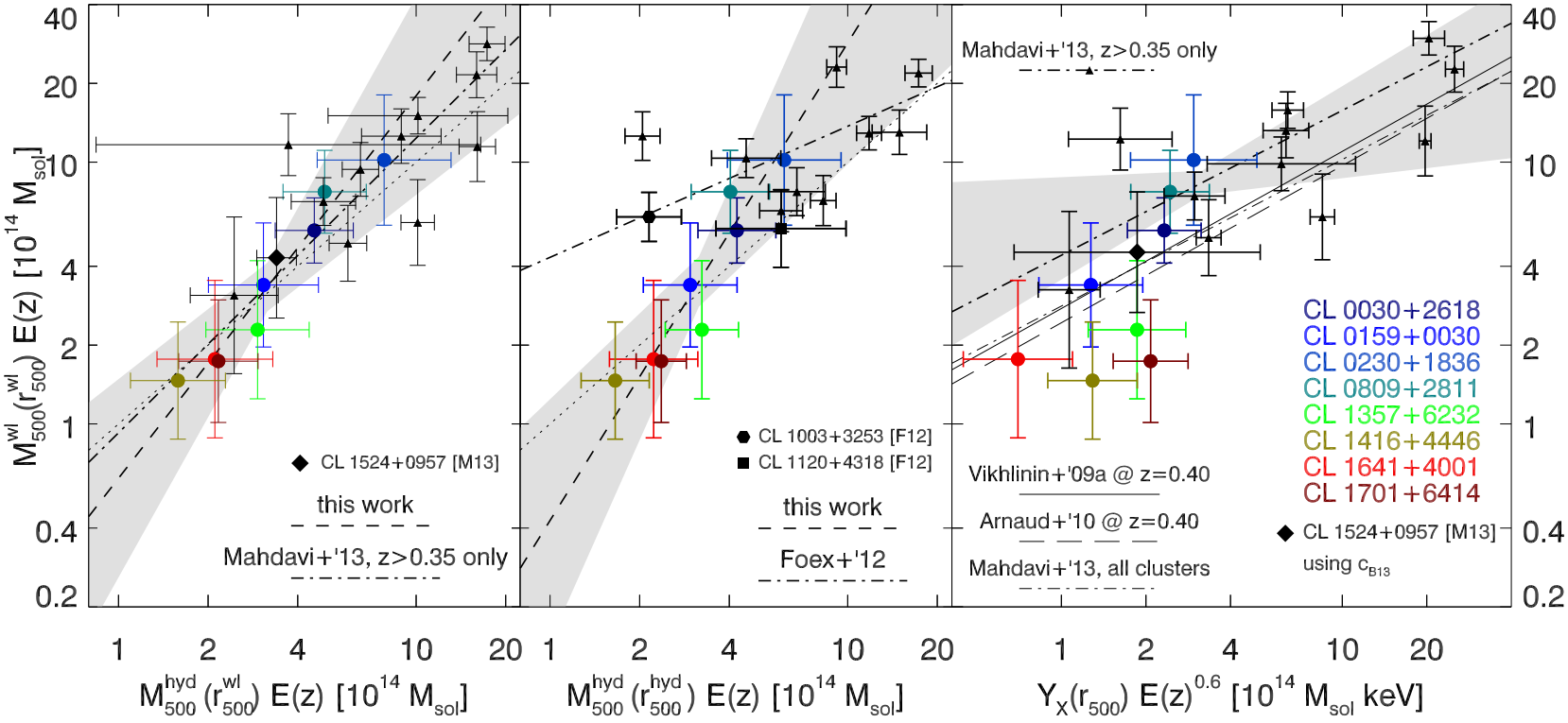
HI+14

Mass-dependent no artifact of account for cluster members



HI+14

400d Clusters are rather low-mass

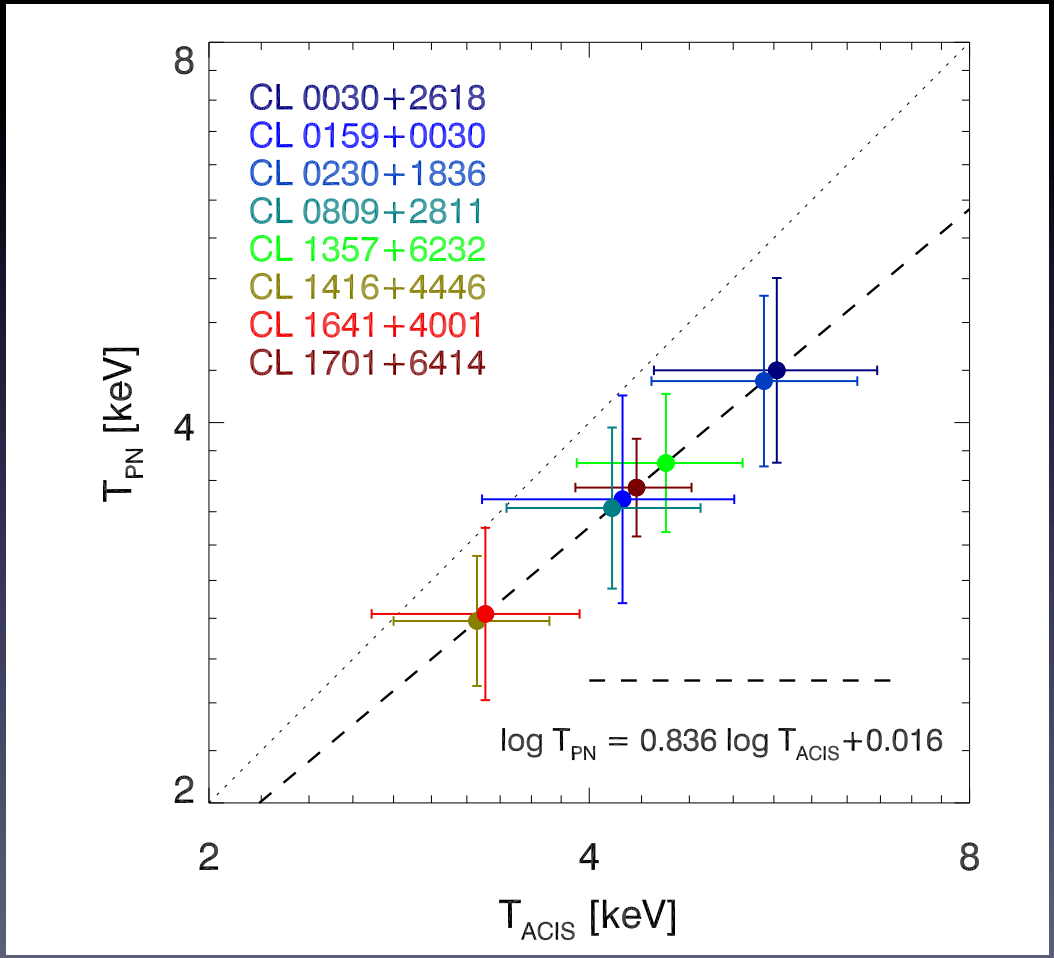


HI+14

Conclusions of HI+14

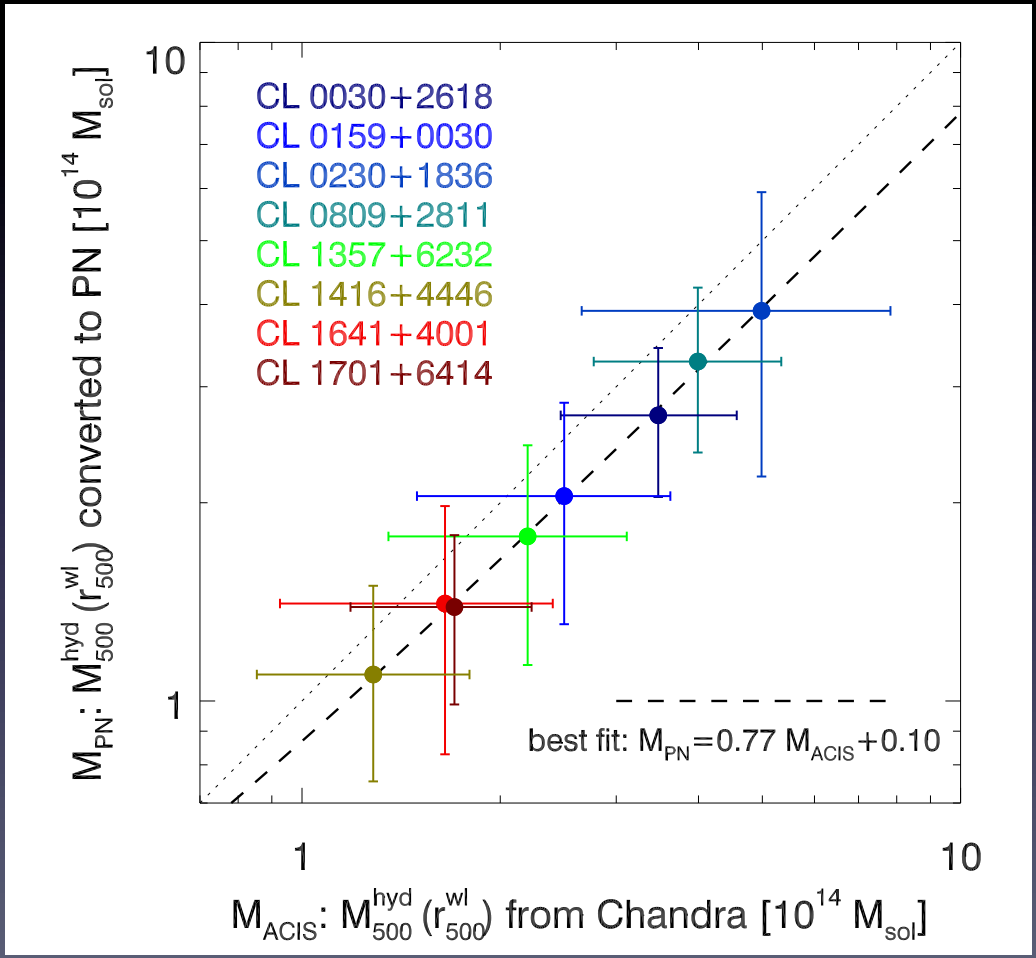
- Probing an unexplored region of parameter space: 0.4~z~0.5 clusters, down to 10^{14} M_{sun}
- WL and hydrostatic masses consistent; no evidence for hydrostatic bias of >~25%
- Mass-dependent hydrostatic mass bias robust against WL analysis settings
- MMT clusters well representative of 400d cosmo-sample (8 of 36)
- Mass-dependent bias due to small number statistics, very subtle analysis artefacts, or physically different low-mass cluster population

XMM-like temperatures for 400d clusters

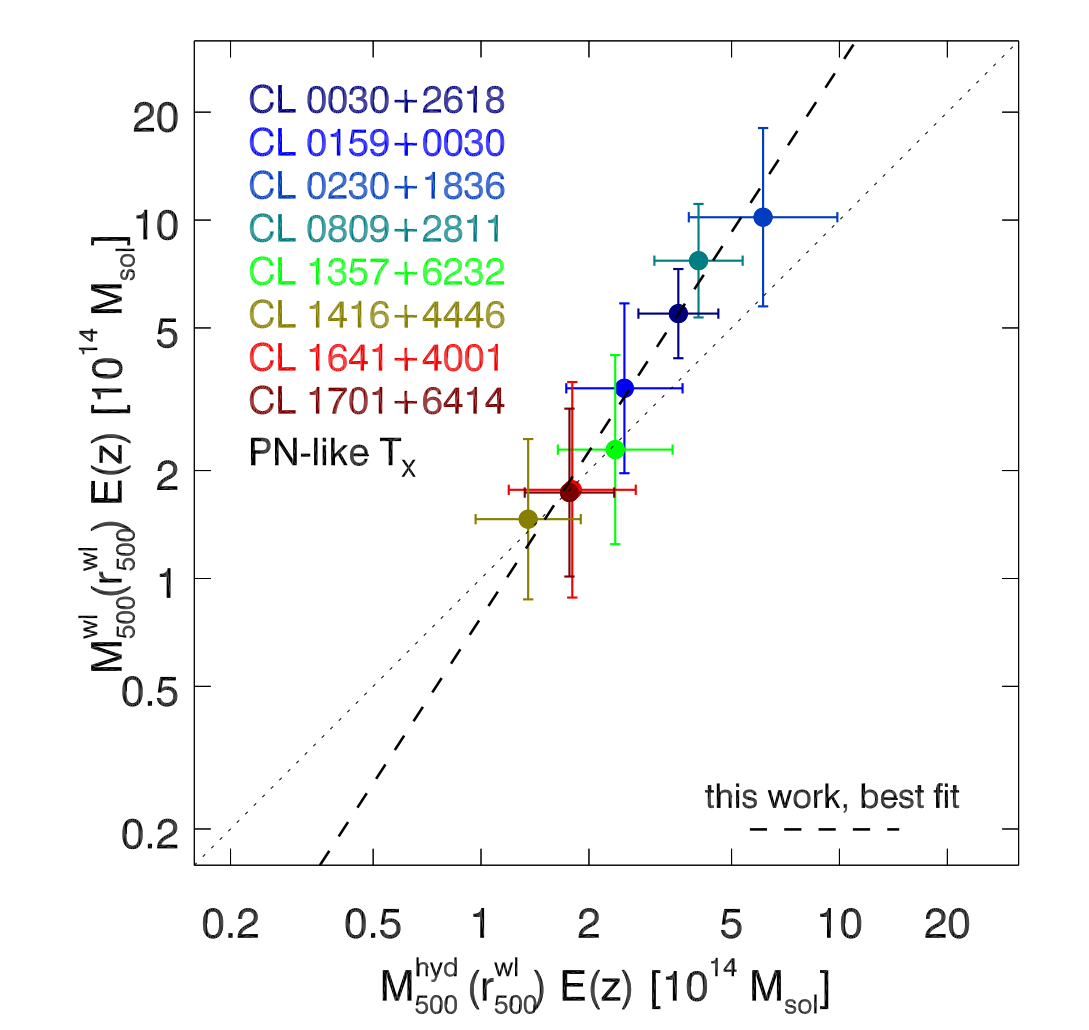


Schellenberger+14 conversion

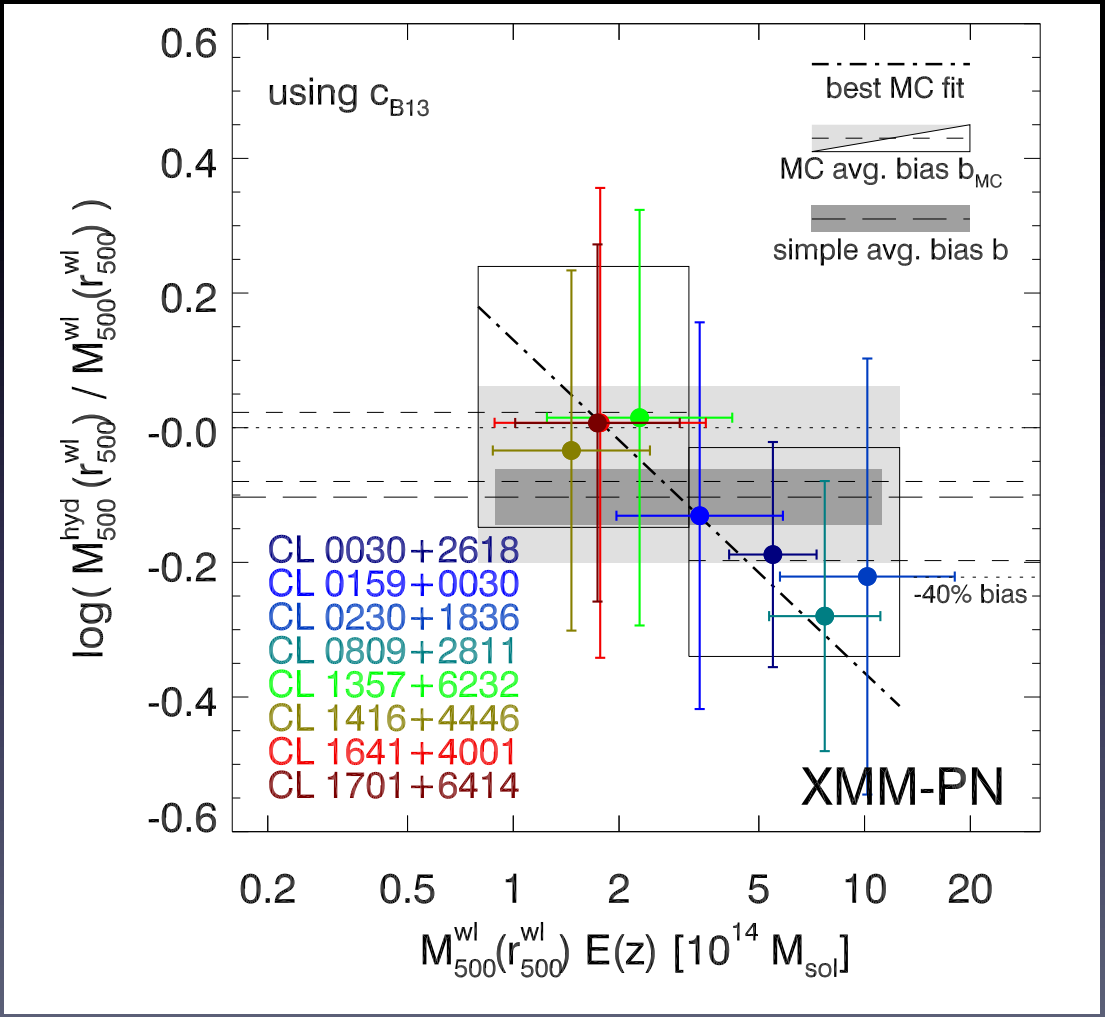
Recovering lower XMM hydro masses



XMM-like WL-hyd scaling relation



A stronger hydro mass bias



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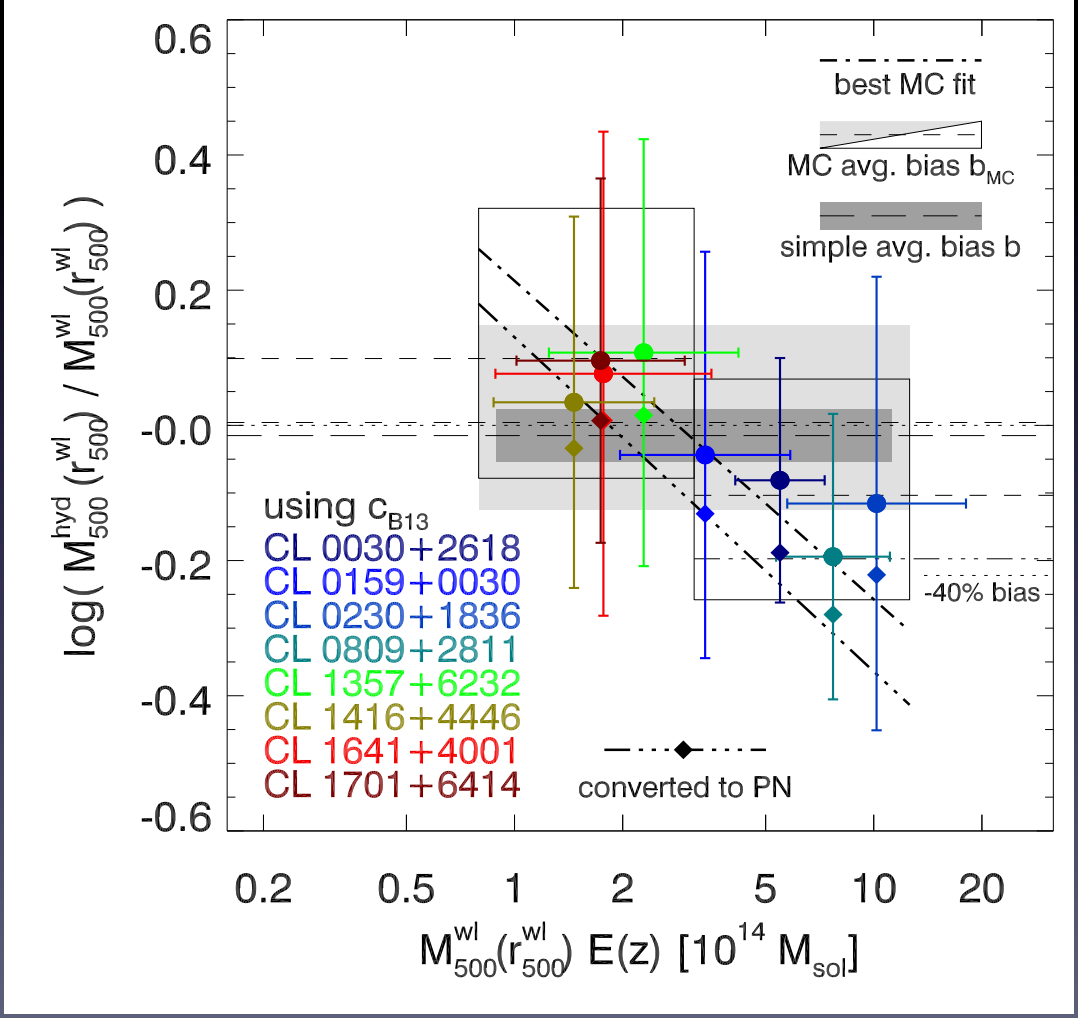

Summary & Conclusions

- ~20% lower hydrostatic masses converting temperatures to XMM-Newton PN
- Overall hydrostatic bias ~20% for all clusters, ~-5% for low mass clusters, ~35% for high-mass clusters
- Mass-dependent bias persists (cluster physics?)
- Preliminary results, ignoring different calibration timestamps and energy ranges
- Pointing towards consistency with von der Linden+14
- ~40% bias for massive “Planck”-clusters not ruled out

Thanks!