LoCuSS: Weak-lensing mass calibration of galaxy clusters and hydrostatic bias

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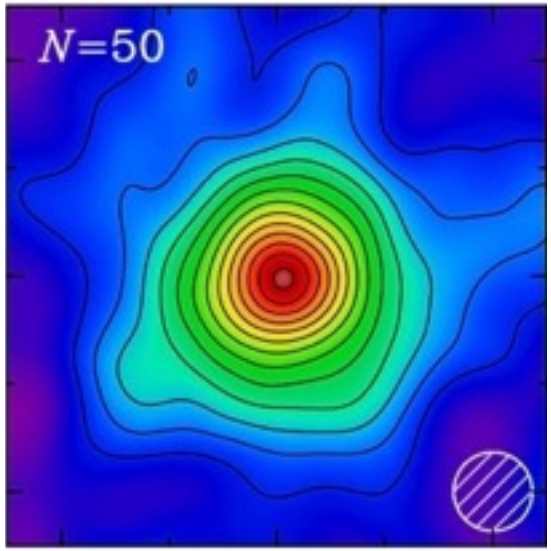
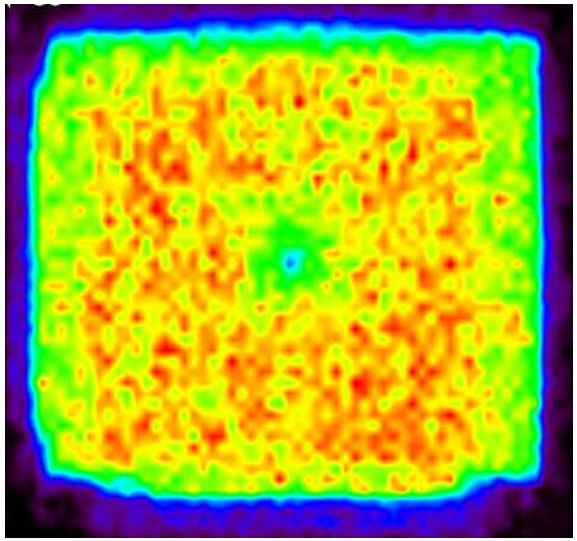
Okabe & Smith, 1507.04493



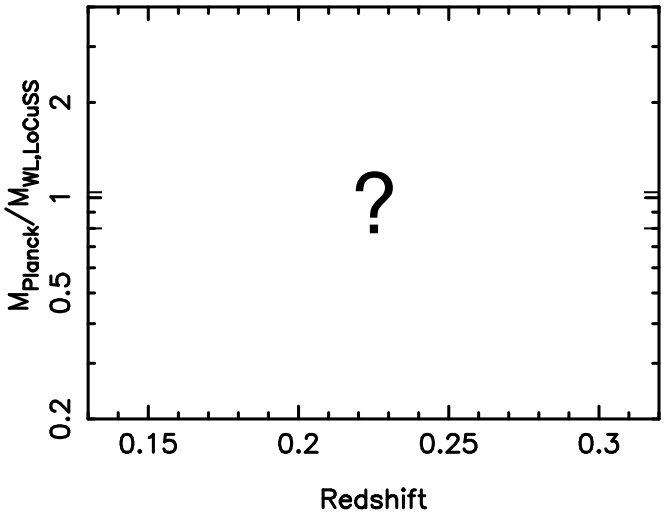
Okabe, Smith, et al., 2013, ApJ, 769, L35

Ziparo, et al., 1507.04376



+ POSTER THIS WEEK

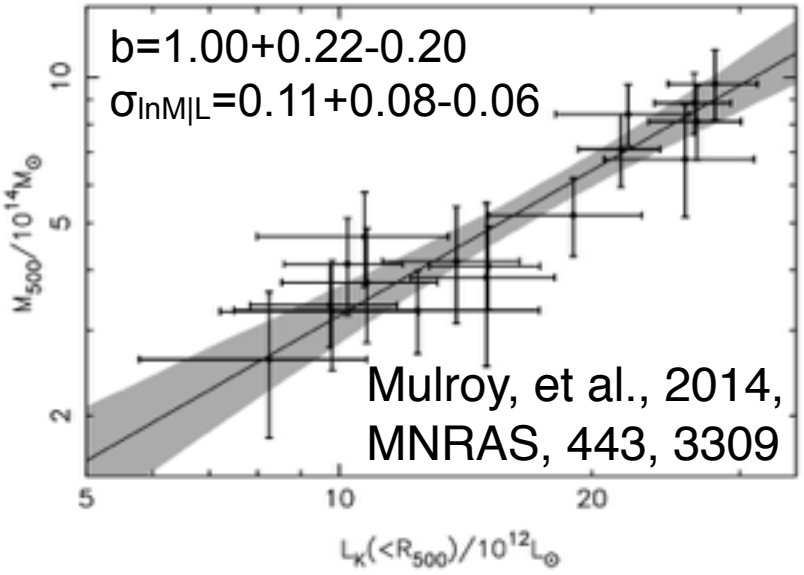
Smith, et al., 2015, subm.

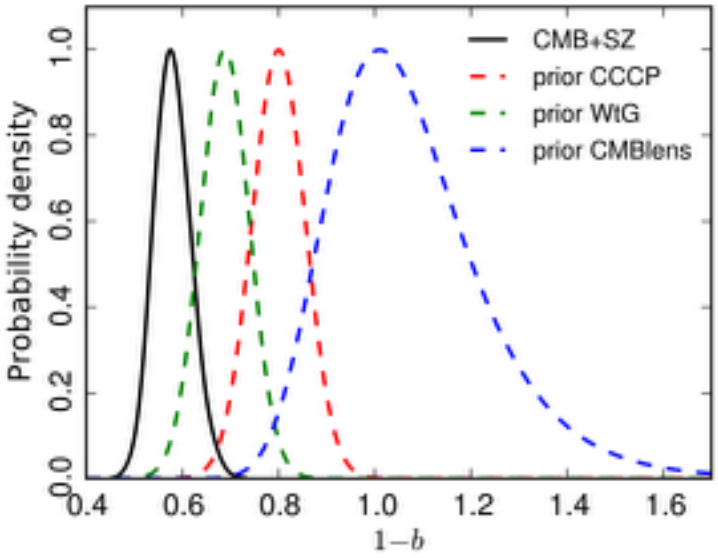


Motivation: counting clusters to measure cosmological parameters

- we **want** to count clusters as a function of mass and redshift
- we **can** count clusters as a function of a mass-like observable
- we **need** accurate scaling relations and mass calibration

$$\frac{M_{\rm WL}}{10^{14} M_\odot} = a \left(\frac{L_K}{10^{12} L_\odot} \right)^b$$





Planck 2015 XXIV 1502.01597

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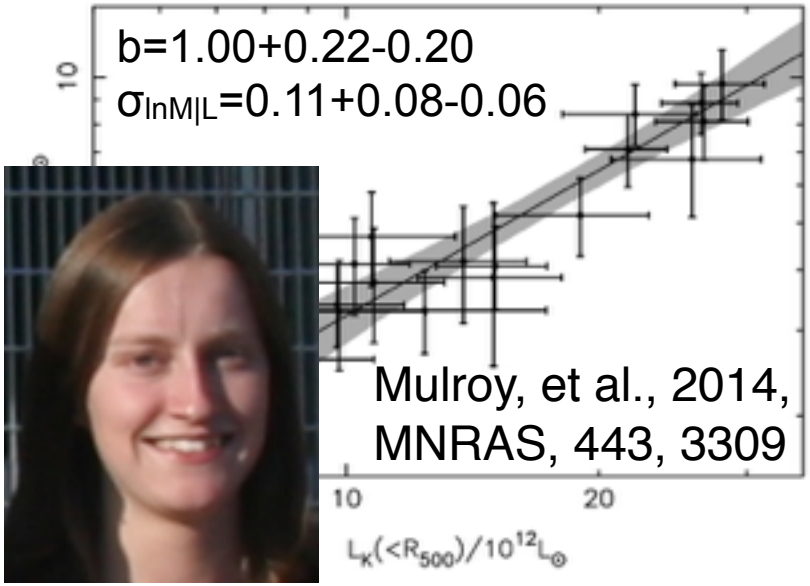
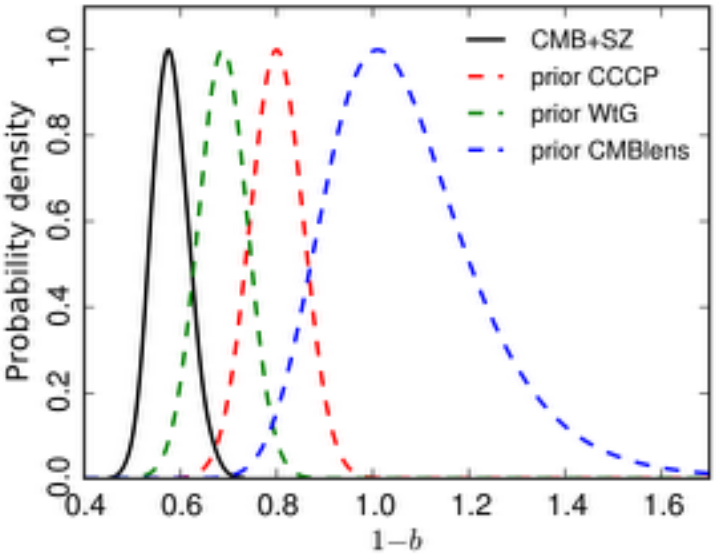


Mulroy, et al., 2014, MNRAS, 443, 3309



Planck 2015 XXIV 1502.01597

Local Cluster Substructure Survey

A low redshift baseline study of clusters as a cosmological probe

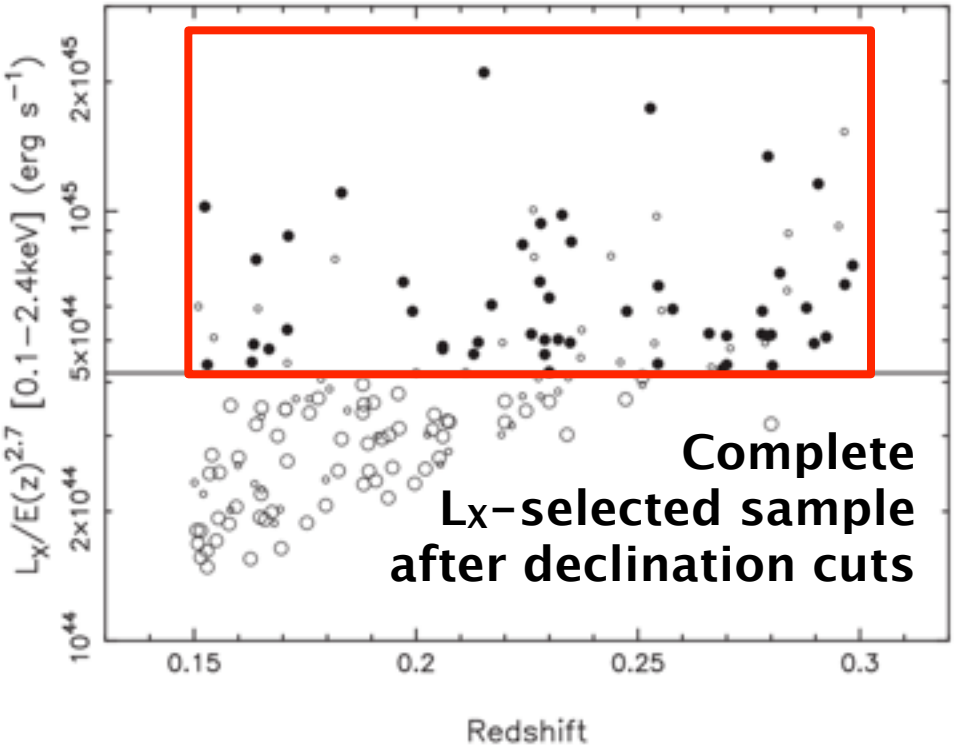
Goals relating to cluster cosmology include:

- To test the reliability of cluster mass measurement methods at low-z: M_{WL}, M_{HSE}, M_{Dyn}, ...
- To measure the shape, normalization, and intrinsic scatter of scaling relations: $P(M_{WL}|O)$
- To test theoretical “predictions”: NFW profile, mass-concentration relation, adiabatic contraction, …
- …

Local Cluster Substructure Survey

A low redshift baseline study of clusters as a cosmological probe

- L_X-limited sample of 50 "High-L_X" clusters:
  - $L_X/E(z)>4.1\times10^{44}$ erg/s, $-25°<\delta<+65°$, $0.15<z<0.3$
- Subaru (Gemini) [50]:
  - V/i-band, i(5σ)=26
  - $FWHM_{median}$=0.7arcsec
- Chandra [44], XMM [39]



... and lots of data from SZA, HST, UKIRT/WFCAM, MMT/Hectospec, Spitzer, GALEX, Herschel: Marrone et al., 2012; Mulroy, et al., 2014; Richard et al. 2010; Zhang et al. 2008, 2010; Haines et al., 2014, 2013, 2010, 2009b, 2009a; Smith et al. 2010a,b; Okabe et al., 2010a,b; …

Local Cluster Substructure Survey

A low redshift baseline study of clusters as a cosmological probe

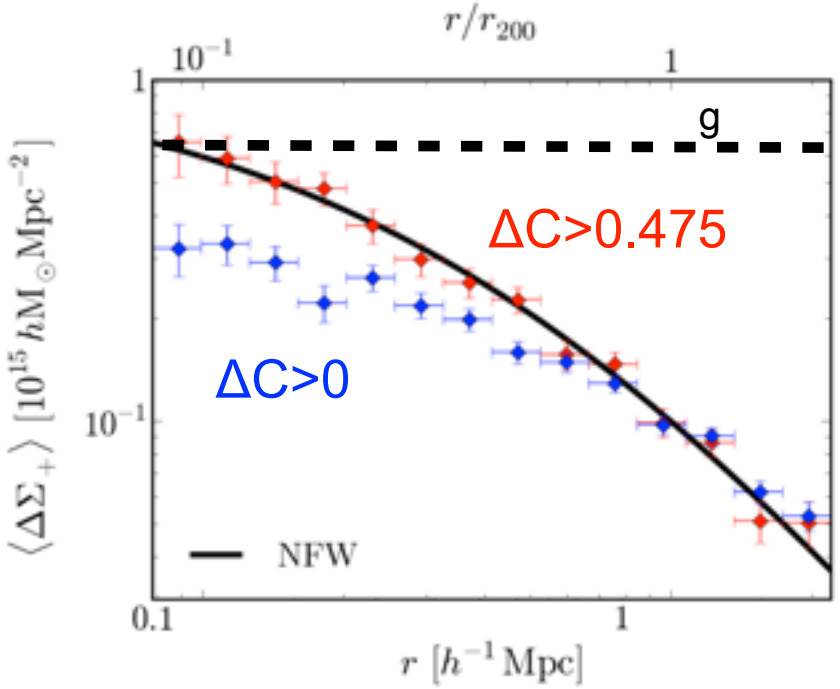
Goal = control systematic bias in ensemble cluster cluster mass calibration at sub-4% [30%/sqrt(50)]

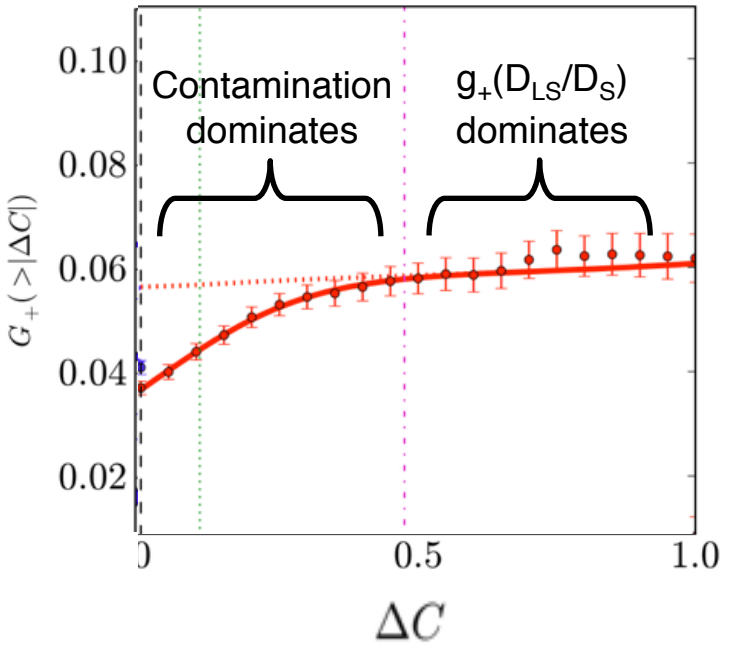
- ***Weak-lensing mass calibration of galaxy clusters***
  Okabe & Smith, MNRAS, submitted, 1507.04493
- ***Exploring the selection of faint background blue galaxies for cluster weak-lensing***
  Ziparo, Smith, Okabe, et al., MNRAS, submitted, 1507.04376
- ***Testing hydrostatic equilibrium in galaxy clusters***
  Smith, Mazzotta, Okabe, Ziparo, et al., MNRAS, submitted
- Also relevant:
  - Martino, Mazzotta, Bourdin, Smith et al., 2014, MNRAS, 443, 2342
  - Mulroy, Smith, Haines, Marrone, et al., 2014, MNRAS, 443, 3309
  - Okabe, Smith, Umetsu, Takada, Futamase, 2013, ApJ, 769, L35

Sources of bias in cluster weak-lensing

- Contamination of background galaxy samples, i.e. dilution of shear signal by faint cluster members
- Uncertainty in the redshift distribution of the background galaxies
- Shear calibration, i.e. biases in measurement of galaxy shapes
- Extracting mass measurements from shear profiles, i.e. mass modelling biases

A new low bias method to select red background galaxies





Model of color-dependence of shear:
$G_+(\Delta C) = A \times D(\Delta C) \times (1 - Bf(\Delta C))$

Lensing kernel:
$D(\Delta C) \equiv \langle D_{LS}/D_S \rangle$

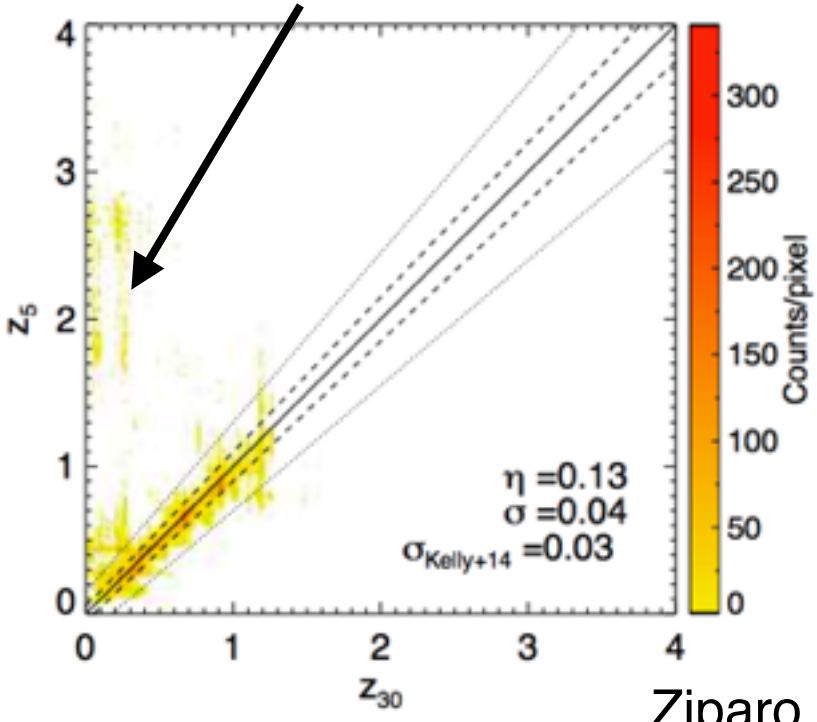
Contamination:
$f(\Delta C > 0) = \left[1 - erf\left(\Delta C/\sqrt{2}\sigma\right)\right]/2$

Color cut tuned to achieve 1% contamination… gives 5 arcmin^{-2}

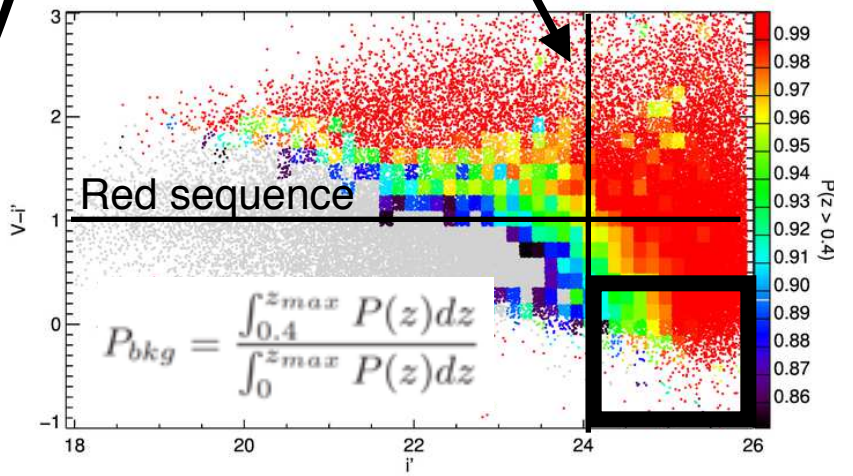
Okabe, Smith, et al., 2013, ApJ, 769, L35

Blue galaxies cannot be selected as safely as red galaxies

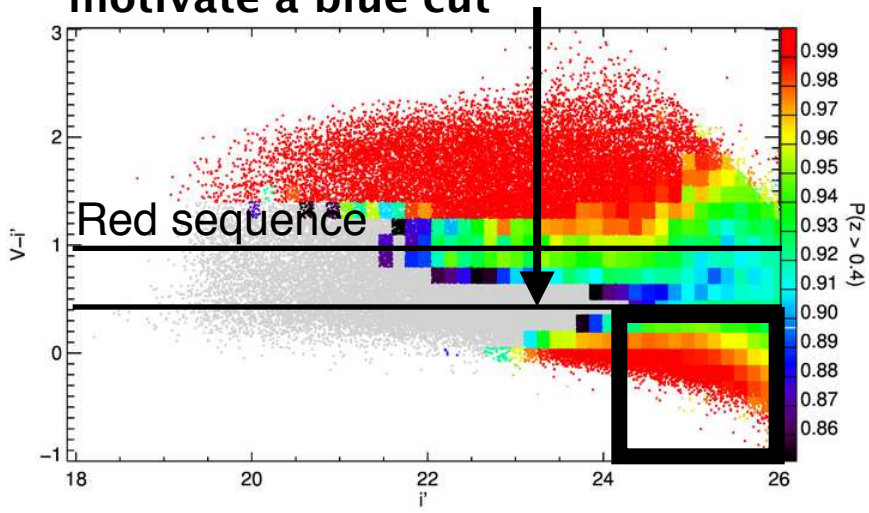
Faint blue galaxies dominate catastrophic failures of 5-band photo-z's at z<~0.3



LoCuSS 5-band photo-z's motivate a faint cut

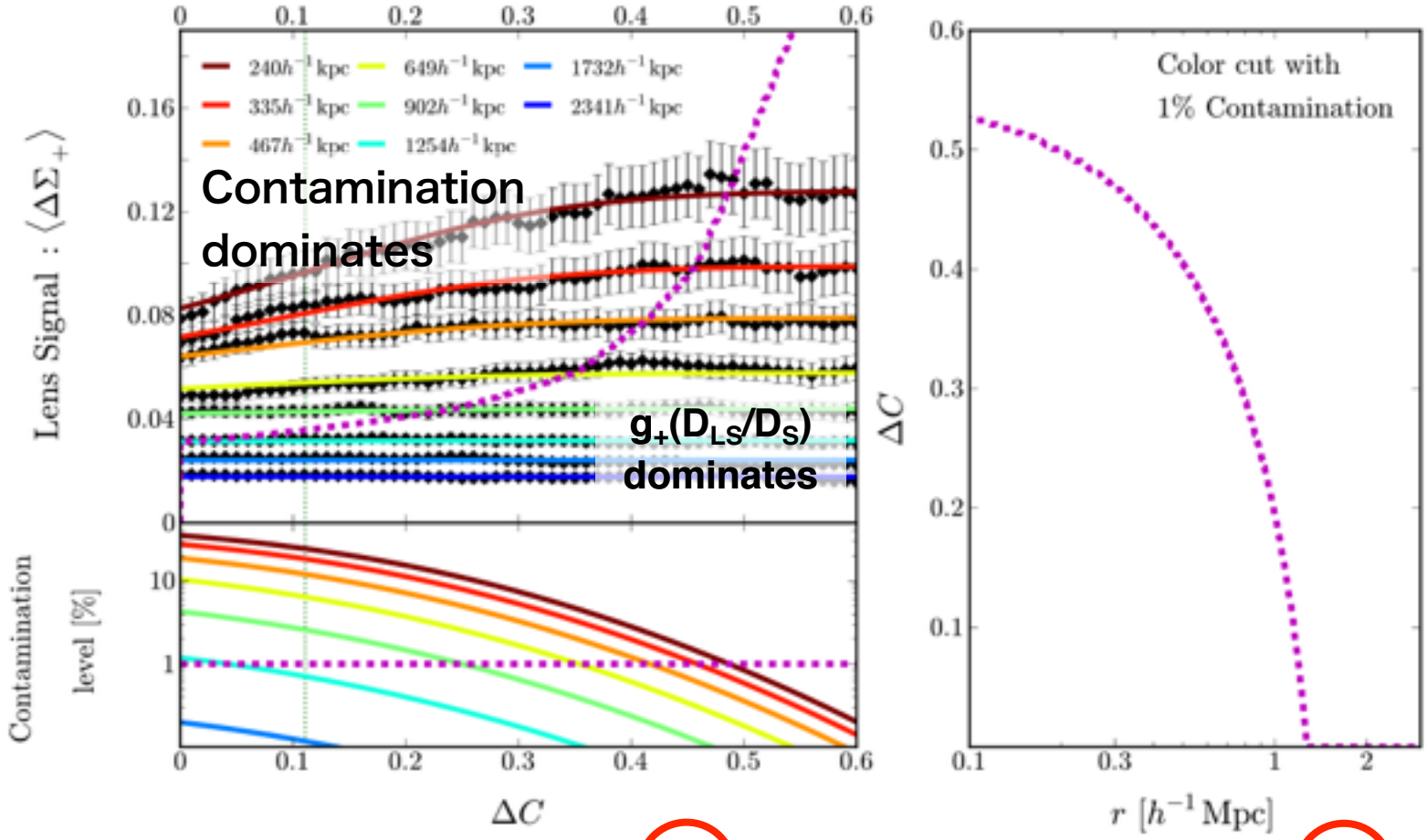


COSMOS 30-band photo-z's motivate a blue cut



Ziparo et al. 1507.04376 **+ POSTER THIS WEEK**

Number of red galaxies improved via radius-dependent colour cut



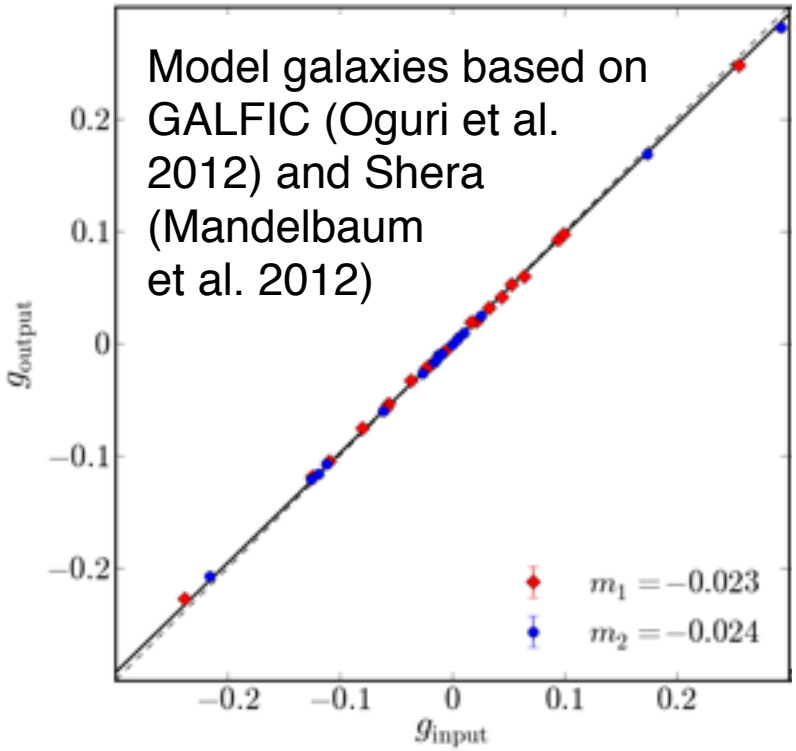
Color cut tuned to achieve 1% contamination… gives 13 arcmin^{-2}

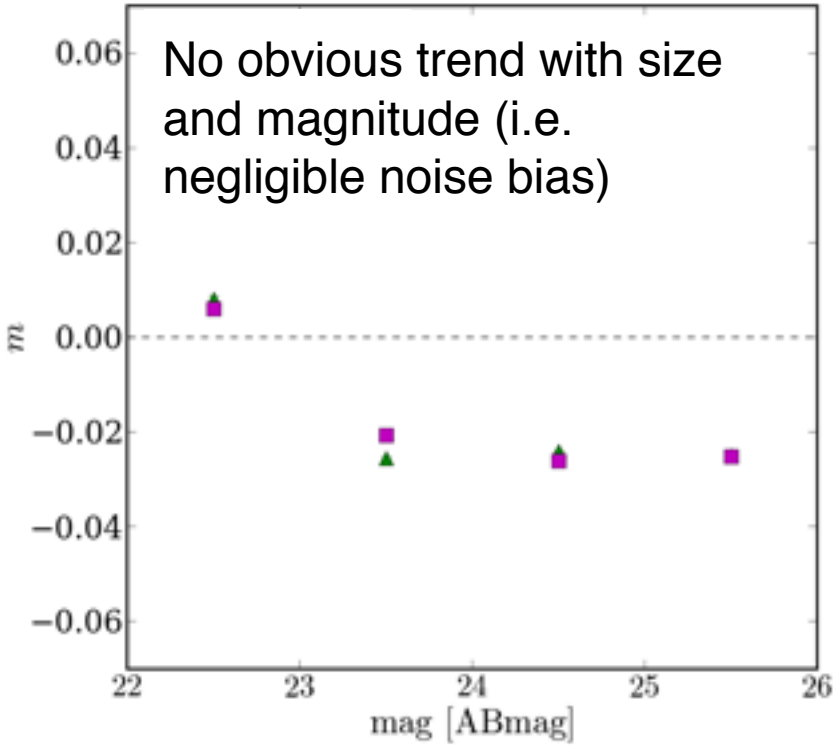
Okabe and Smith, 1507.04493

Image simulations **matched** to our cluster observations:

$g_{out} - g_{in} = \mathbf{m}\, g_{in} + \mathbf{c}$

$m \backsimeq -0.03 \quad c \backsimeq 10^{-4}$





Simulations match LoCuSS data:

FWHM = 0.7arcsec

$0 < |g| < 0.3$

S/N > 10

$22 < i_{AB} < 26$

$2 < r_g < 5$pix

FoV = 30x42arcmin

Okabe and Smith, 1507.04493

Tests of NFW model fitting on hydro simulations: sub-1% bias on M_{500}

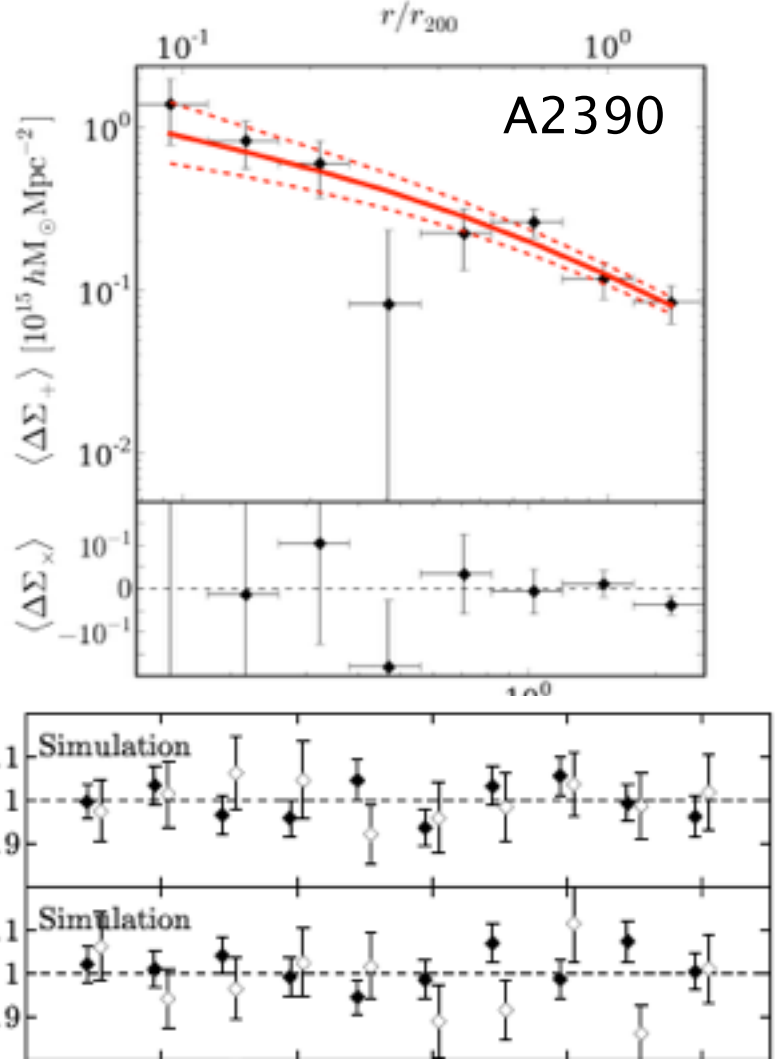
Suite of NFW model fits:

- $50\text{kpc/h} < r_{\text{inner}} < 300\text{kpc/h}$
- $2\text{Mpc/h} < r_{\text{outer}} < 3\text{Mpc/h}$
- $4 < N_{\text{bin}} < 8$
- M_{200} and c_{200} are free params

M_Δ, c_Δ for each cluster is based on the fit that is closest to geometrical mean of the suite of fits

- Simulations are Cosmo-OWLS (McCarthy et al. 2014, Le Brun et al. 2014; see also Joop Schaye's talk)

Okabe and Smith, 1507.04493



Sources of bias in cluster weak-lensing

- Contamination of background galaxy samples, i.e. dilution of shear signal by faint cluster members

  Contamination of red background galaxies = 1%

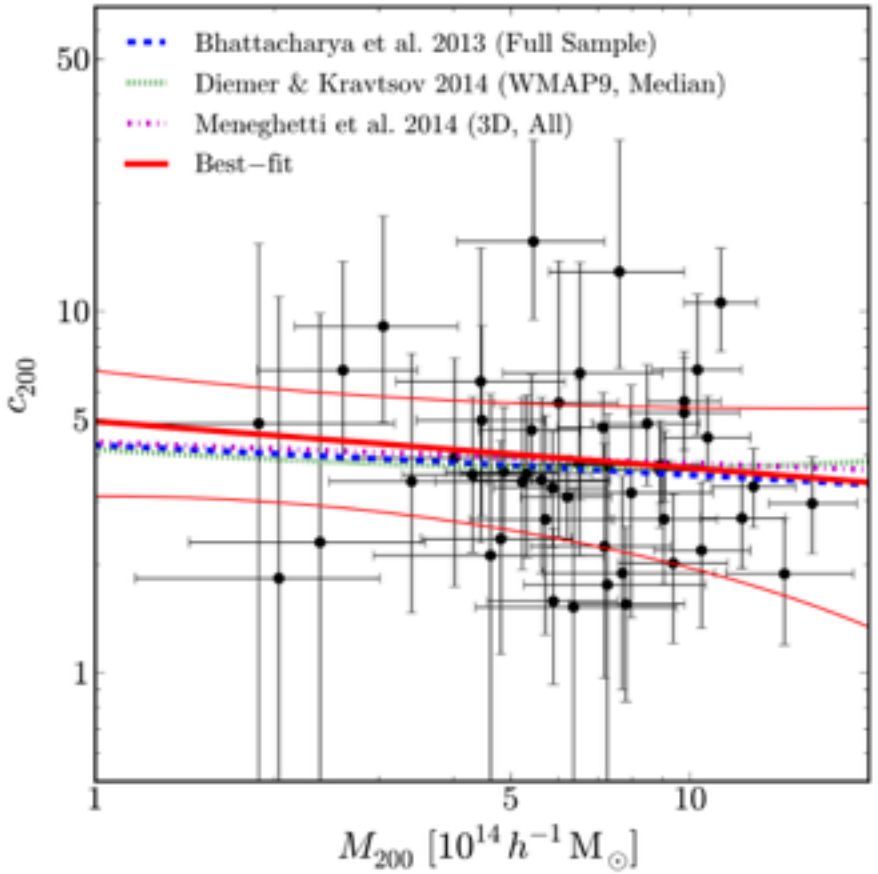
- Uncertainty in the redshift distribution of the background galaxies **Folded into our shear measurement errors**

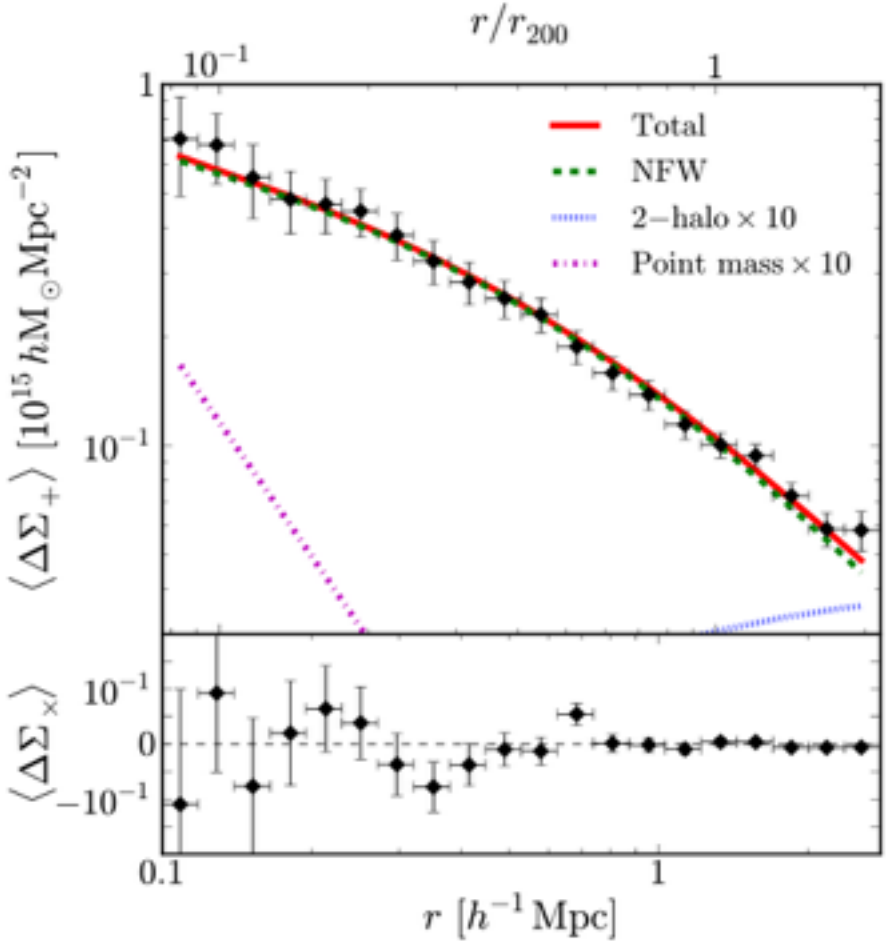
- Shear calibration, i.e. biases in measurement of galaxy shapes **Multiplicative bias of 3%**

- Extracting mass measurements from shear profiles, i.e. mass modeling biases **Sub-1% bias**

Okabe and Smith, 1507.04493

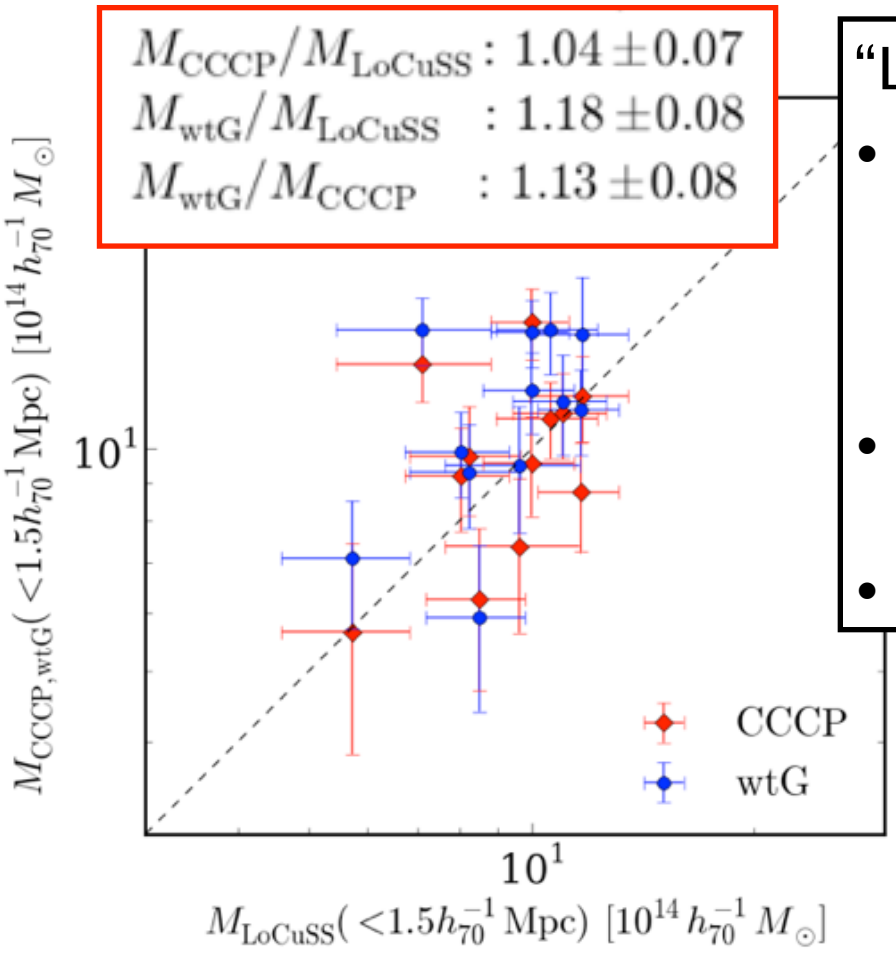
Mass-concentration relation in excellent agreement with predictions





Okabe and Smith, 1507.04493

LoCuSS, CCCP, CLASH masses are agree at <~1σ; WtG are ~2σ higher



"Like for like" comparison

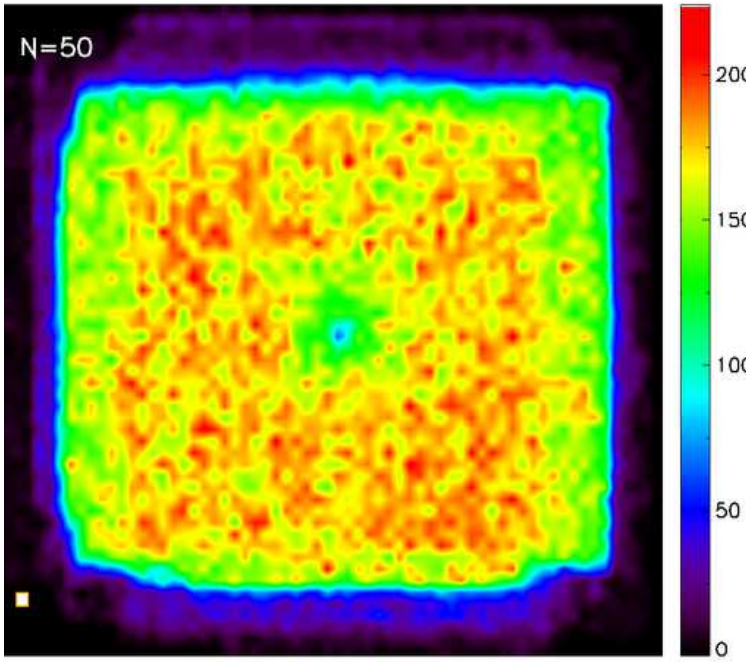
- 12 cluster overlap between:
  LoCuSS (Okabe & Smith 2015)
  CCCP (Hoekstra et al 2015)
  WtG (Applegate et al. 2014)
- Match the modeling method to WtG: c200=4, 0.75<R<3Mpc/h
- Measure M(<1.5Mpc/h_{70})

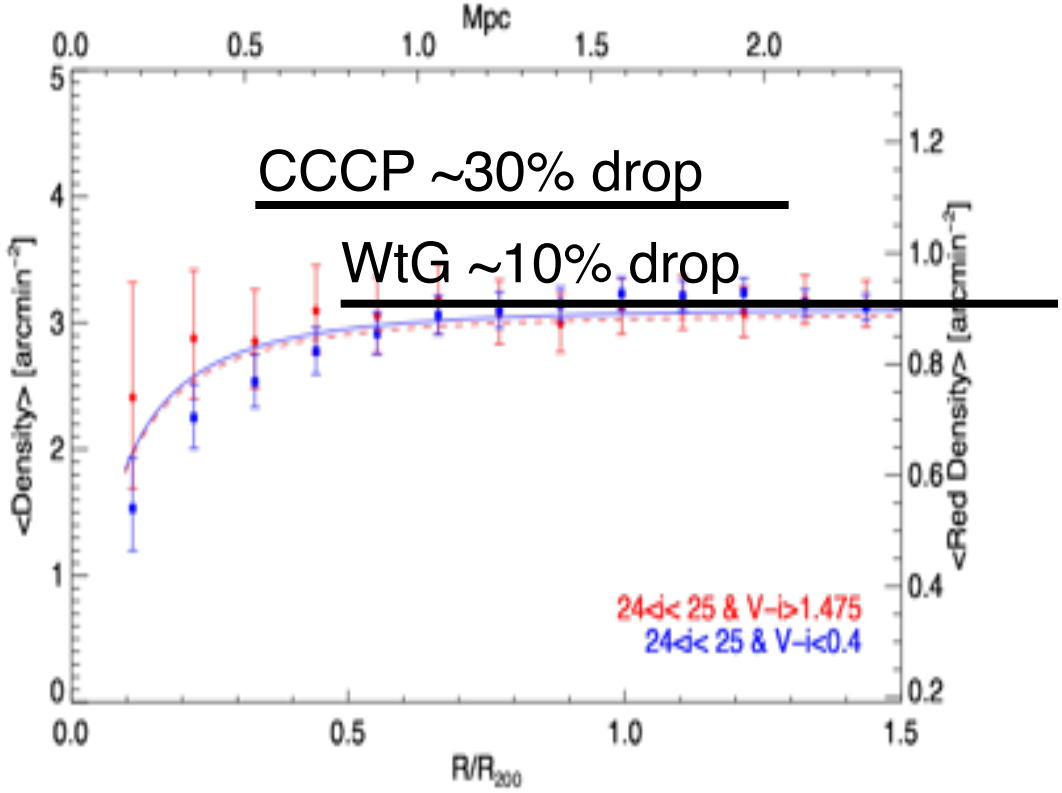
The pairwise comparison of surveys in our paper and in the literature is consistent with this result, i.e. it is **more general than for clusters within LoCuSS**

Okabe and Smith, 1507.04493

Observed number density profile of background galaxies is **not** flat…

Stacked number density of blue galaxies



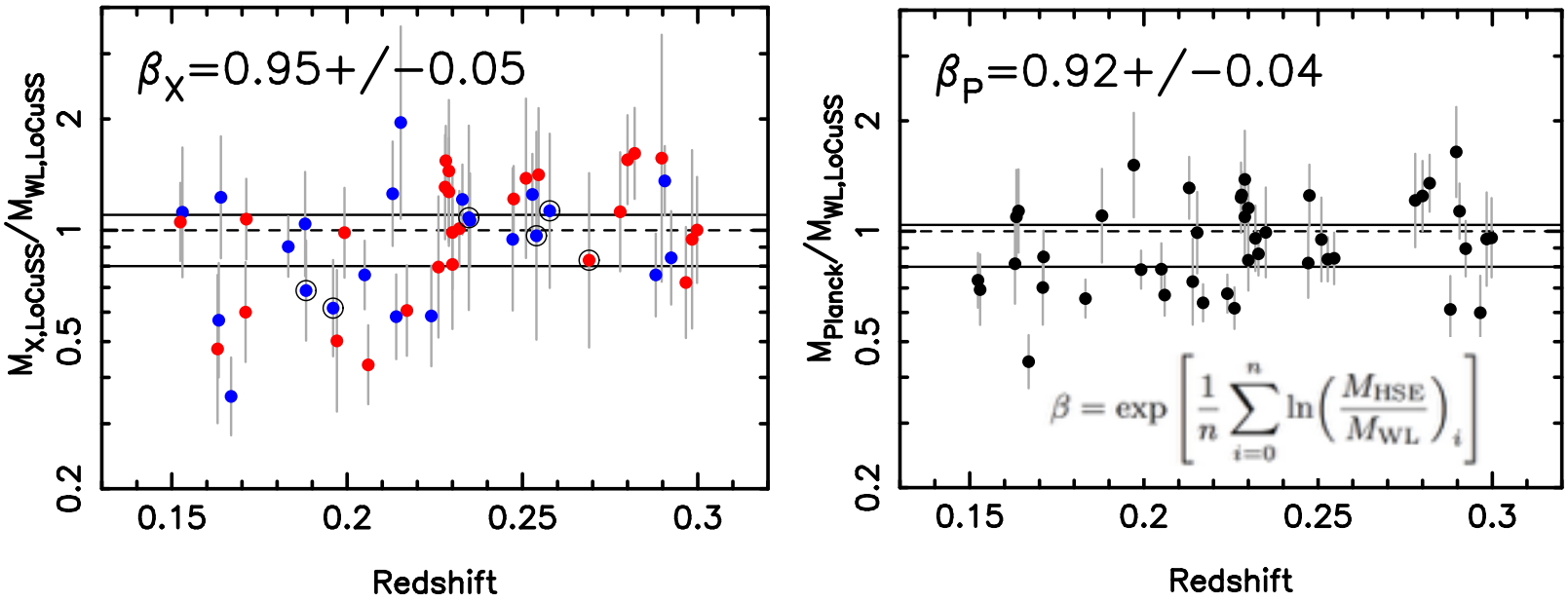


Ziparo, et al., 1507,04376 +
POSTER THIS WEEK

Curves: number density profile expected from 0% contamination + magnification bias based on best-fit NFW model to shear.

Data: measured stacked number density profile based on colour-magnitude selections

Testing hydrostatic equilibrium with Subaru, XMM/Chandra, and Planck



11 cluster overlap between LoCuSS, CCCP, WtG, and Planck:

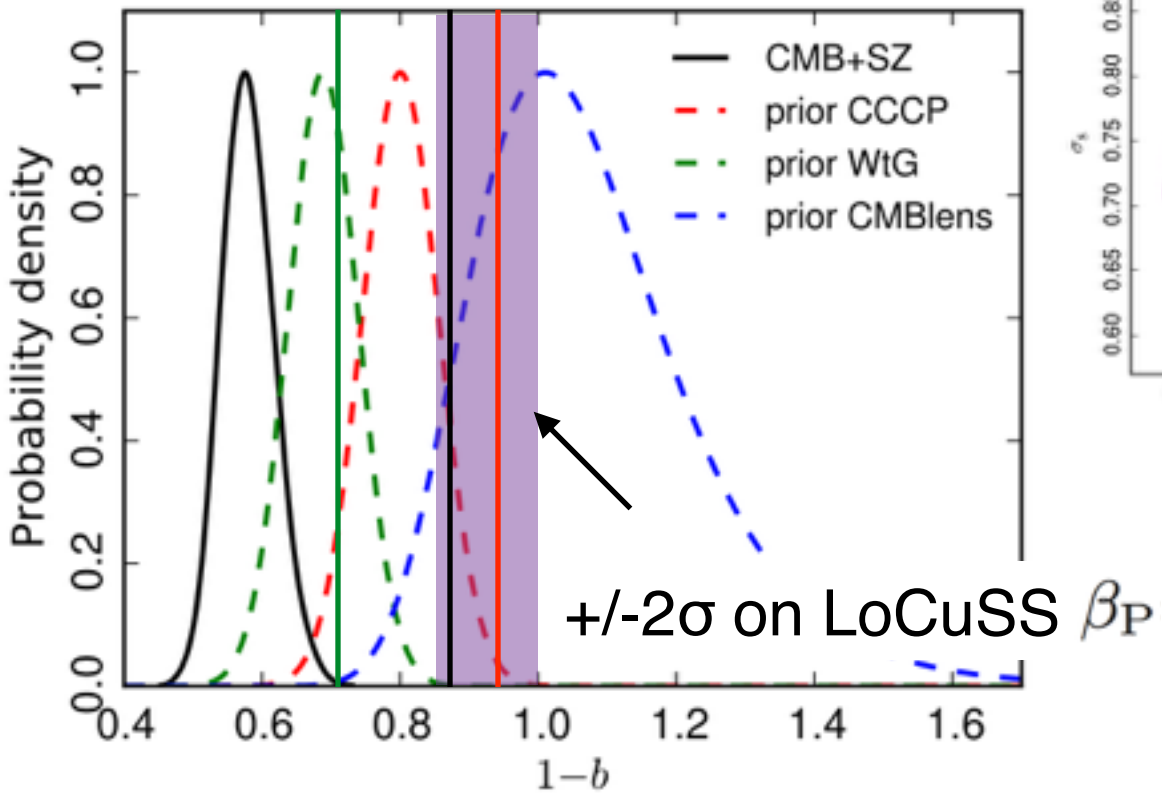
LoCuSS: $\beta_X = 1.00 \pm 0.12$ WtG: $\beta_P = 0.72 \pm 0.08$

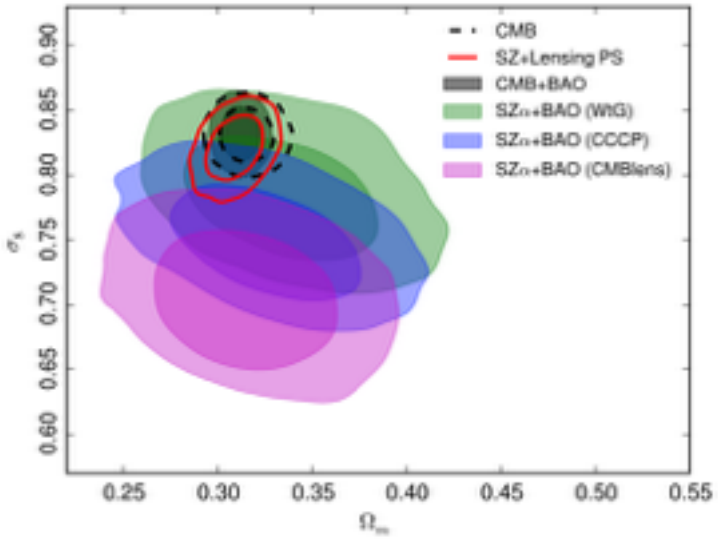
$\beta_P = 0.86 \pm 0.07$ CCCP: $\beta_P = 0.93 \pm 0.12$

Smith et al., 2015, submitted; Okabe & Smith 1507.04493;
Martino et al., 2014, MNRAS, 443, 2342: Chandra/XMM = 1.02+/-0.05

New constraints on hydrostatic bias disagree with “best-fit” (1-b) at ~5σ

Vertical lines show β_P from like-for-like comparison: WtG, LoCuSS, CCCP



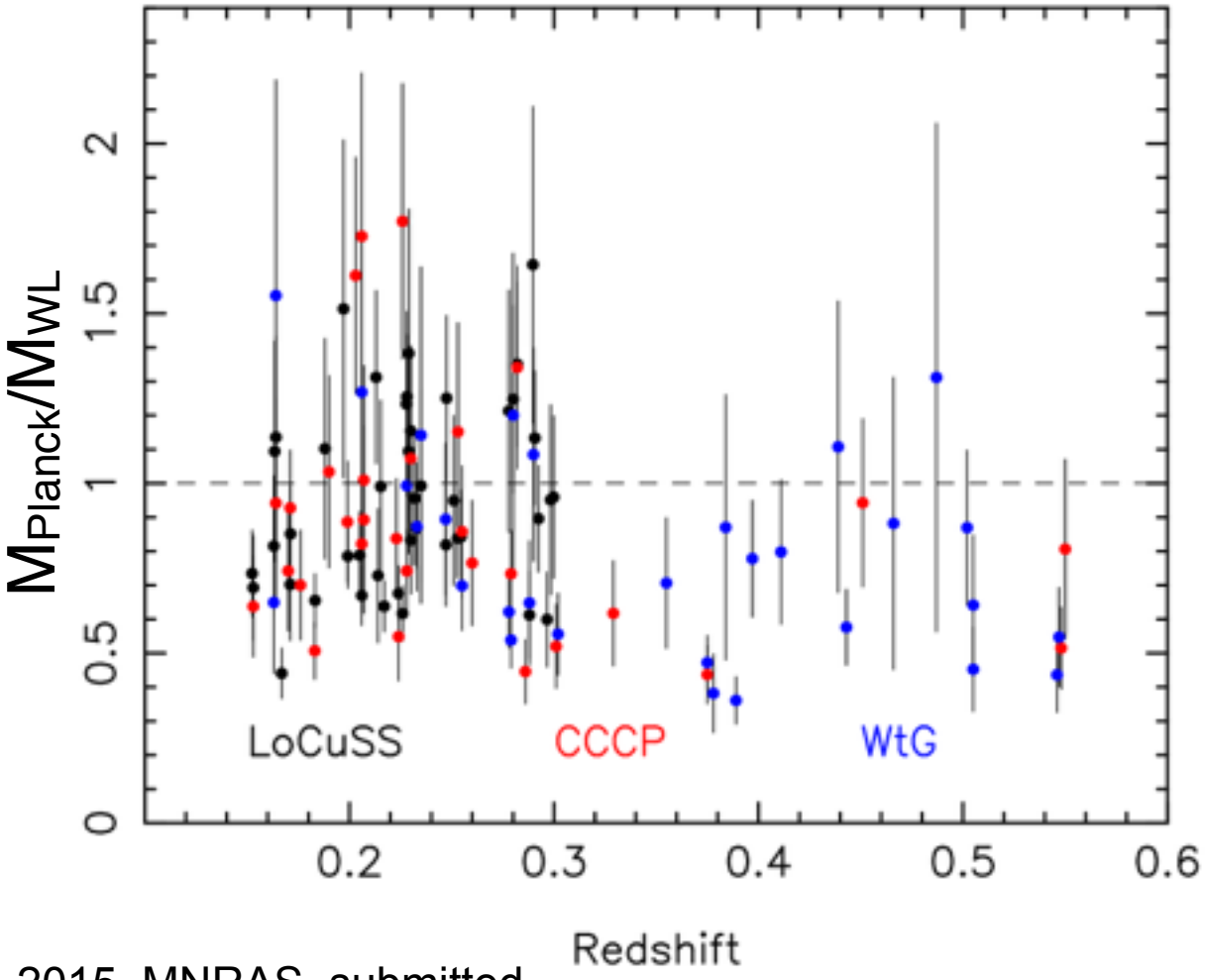


(1-b)~0.9 is consistent with all simulation studies — see Nick Battaglia’s talk

Figures from Planck 2015 XXIV 1502.01597

Smith et al., 2015, submitted

Hydrostatic bias, lensing biases, (or SZ biases?) change with redshift?



Smith et al., 2015, MNRAS, submitted

LoCuSS: Weak-lensing mass calibration of galaxy clusters and hydrostatic bias

- LoCuSS weak-lensing systematic biases calibrated to sub-4%
- LoCuSS, CCCP, CLASH mass calibrations are consistent at ~1σ
- WtG mass calibration is ~8-15% higher at ~1-2σ
- LoCuSS hydrostatic bias: $\beta_X = 0.95 \pm 0.05$ $\beta_P = 0.92 \pm 0.04$
- LoCuSS/X-ray, LoCuSS/Planck and CCCP/Planck hydrostatic bias measurement consistent at $z<0.3$
- We need: larger overlap between lensing surveys, especially at $z>0.3$ and lower mass (**see Marguerite Pierre's talk**)
- Stay tuned: LoCuSS scaling relations and selection function

Okabe and Smith, 2015, MNRAS, submitted, arXiv:1507.04493

Ziparo, Smith, et al., 2015, MNRAS, submitted, arXiv:1507.04376 **+ POSTER THIS WEEK**

Smith, Mazzotta, Okabe, Ziparo, et al., 2015, MNRAS, submitted

Mulroy, Smith, Haines, Marrone, et al., 2014, MNRAS, 443, 3309

Martino, Mazzotta, Bourdin, Smith et al., 2014, MNRAS, 443, 2342


The end