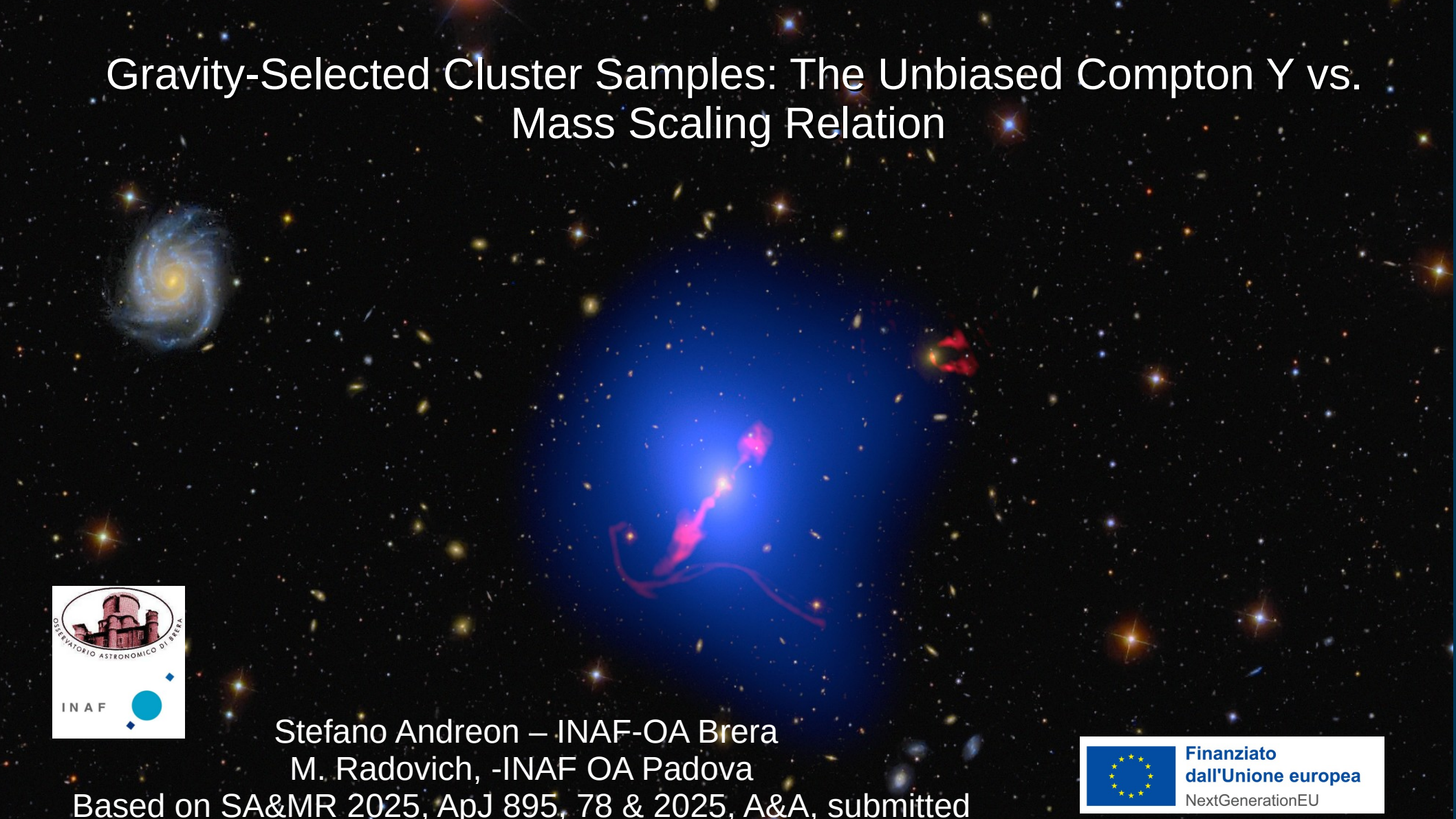
Gravity-Selected Cluster Samples: The Unbiased Compton Y vs. Mass Scaling Relation



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Based on SA&MR 2025, ApJ 895, 78 & 2025, A&A, submitted

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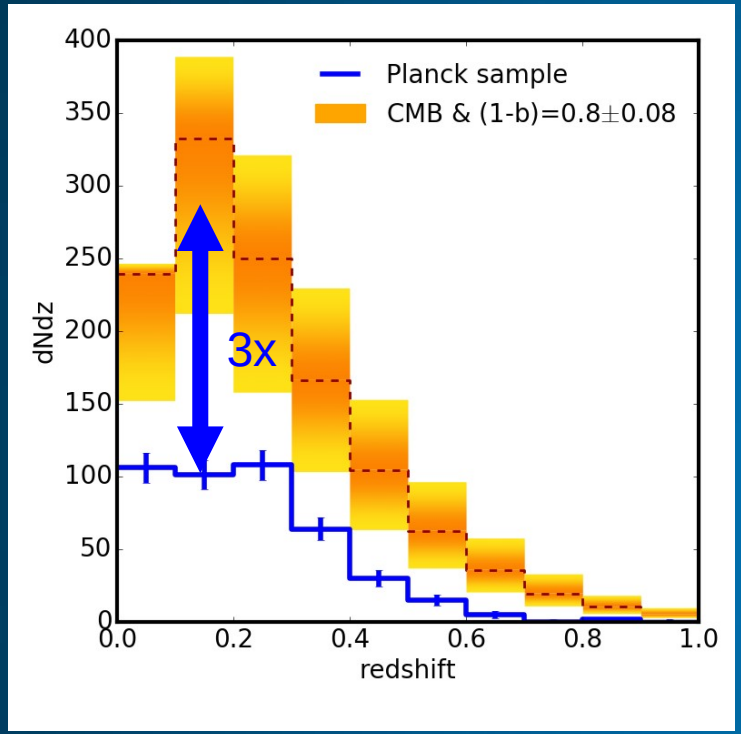
Cluster populations selected via different methods appear to differ

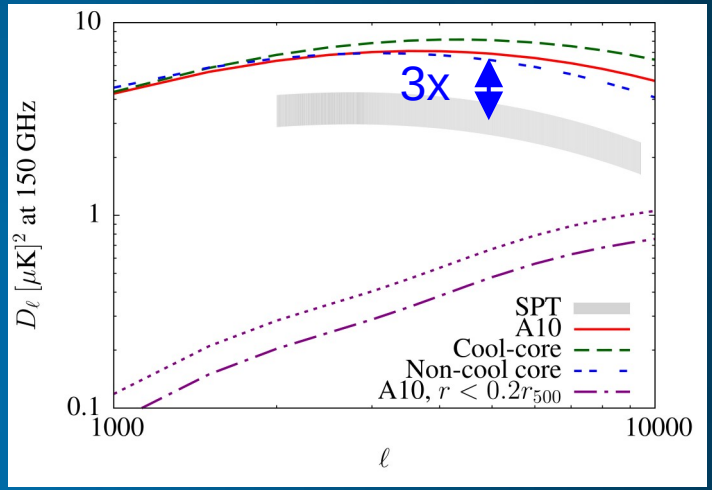
- Distint scaling relations: L_X-M (SA+11, SA+16, SA+24, Ghirardini+24); L_X-Y (SA+19,); T-M (SA+22); Y-M (SA+25, Pandey+25)
- Gas fraction (SA+17, Ragagnin+2022, Bigwood+24 & Hadzhiyska+24)
- X-ray core radius distribution (SA+22)
- Central X-ray brightness distribution (SA+24, see also Eckert+11; O'Sullivan+17, Pearson+17, Xu+18, Capasso+20, Crosset+22)
- X-ray morphological composition (e.g. Eckert+11; Rossetti+17)
- Radial n_e and P_e profiles (SA+19,21,22,23; see also Dicker+20, Di Mascolo+20; Sayers+22; Hilton+18)

Trusting ICM-selected samples accounting for selection function:

Predicted vs Observed SZ cluster counts



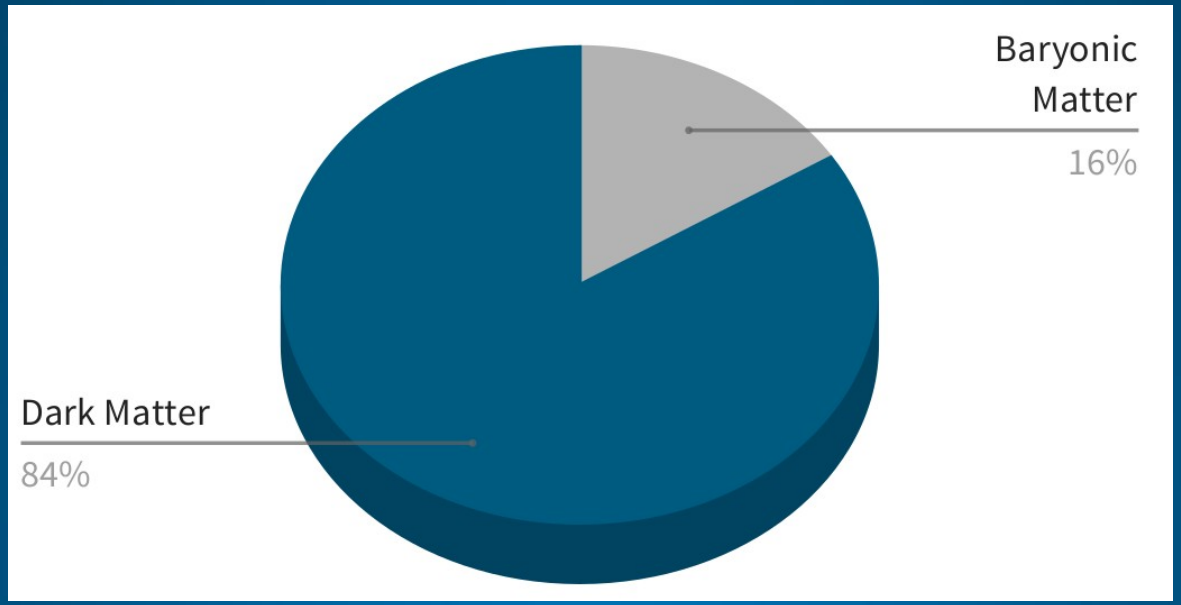
Predicted vs Observed tSZ power spectrum



Ramos-Ceja et al. 15 (and several later papers)

Figure from Salvati et al. 2018, see also Planck Coll, XX 2014

Using ICM or stars (~10% in mass)
we are selecting on a minor property.



Is it advisable a selection by a minority?

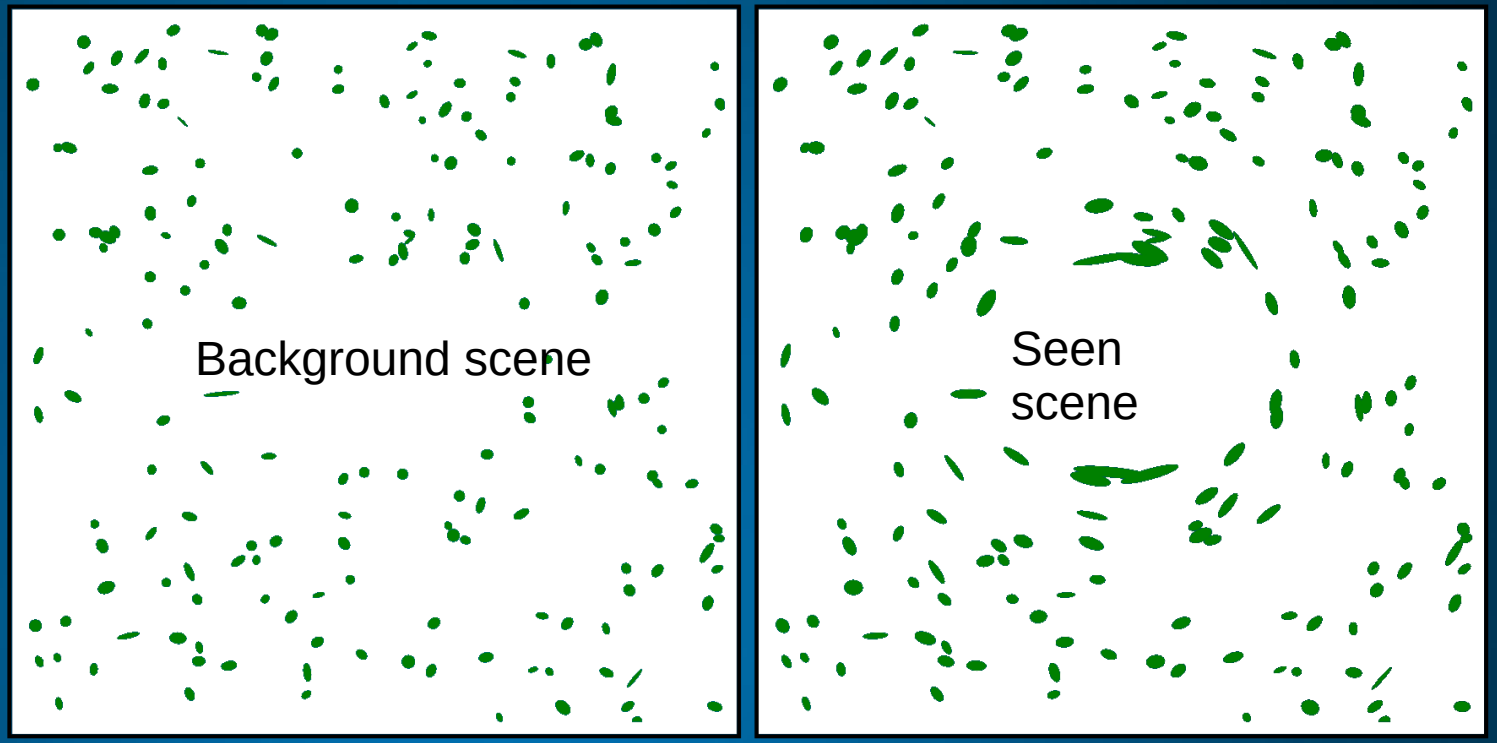
Let’s select by (baryon+dark) mass:

Gravitational lensing

(gravity-selected clusters)

Shear deformation is produced by mass, regardless of type

Figure credit:wikipedia



Amount of distortion is proportional to total mass

Started a number of observational programs

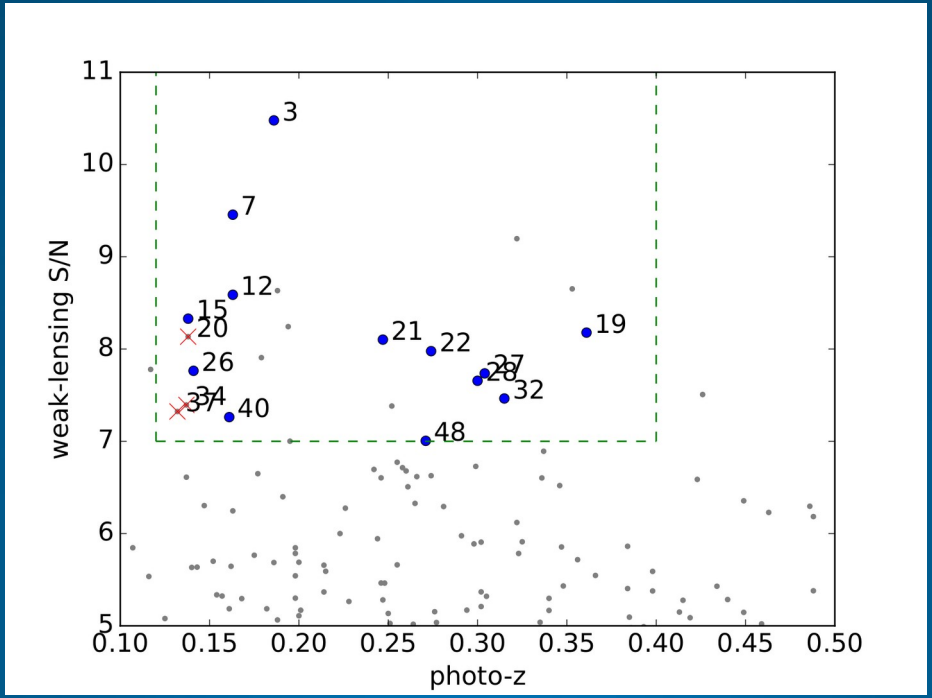
X-ray and SZ observations of weak-lensing selected clusters

- from HSC (pilot sample SA+25, MNRAS)
- from HSC statistical sample (this talk: SA&MR25a,b (ApJ & A&A)

Pilot (SA+25)

- 4 clusters weak-lensing selected have been followed up in X-ray and SZ
- The closest (z=0.25), massive (lgM=14.8) and with strongest WL signal (wl S/N=7), with hundreds of spectroscopic members, detected in X-ray follow-up observations and in SZ, is undetected by eROSITA (5 photons, inclusive of bkg). Mass selection is intrinsically different from L_X-selection, even at the massive end.
- Found on average 2 outliers (>2σ), when expectation is 0.2, 7 times in a row: L_X-M, Y-M, n_{200}-M,$n_e(r)$,$P_e(r)$
- ICM-selection is more biased than appreciated.

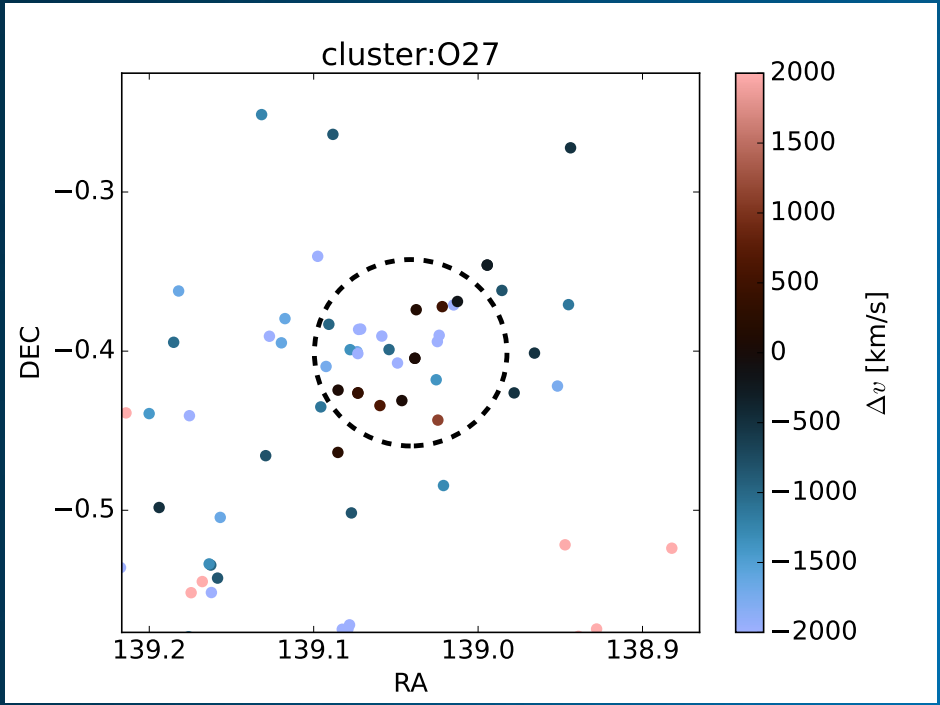
Current, statistical, sample: Sample selection

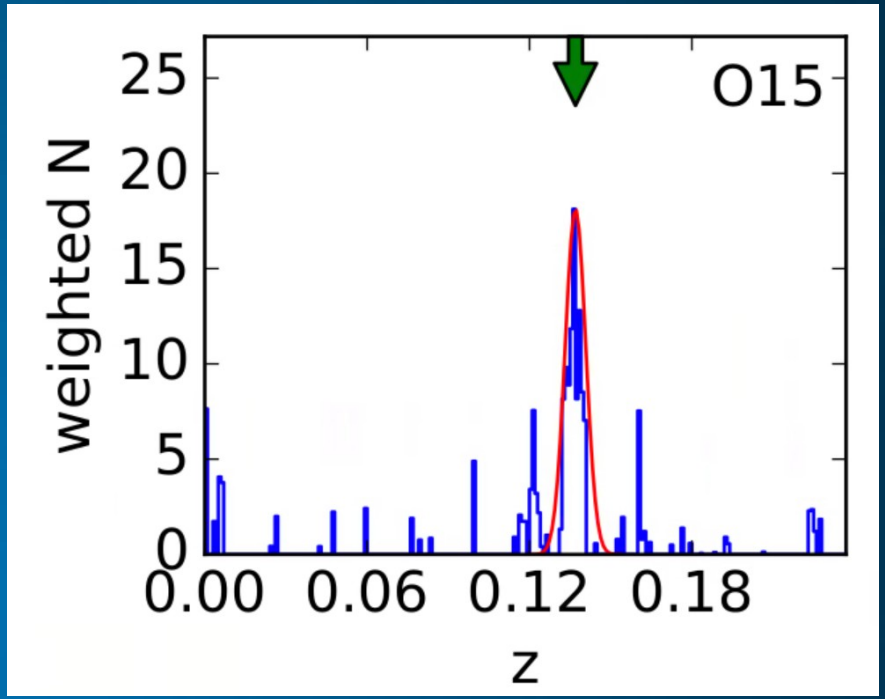


SA&Radovich (2015a)

WL S/N>7 & 0.12<z_{phot}<0.4 in HSC DR1 footprint (from Oguri et al. 2021). Three objects (x) removed because part of a complex system (lack of sphericity on r_{200} spatial scale)

Spectroscopy



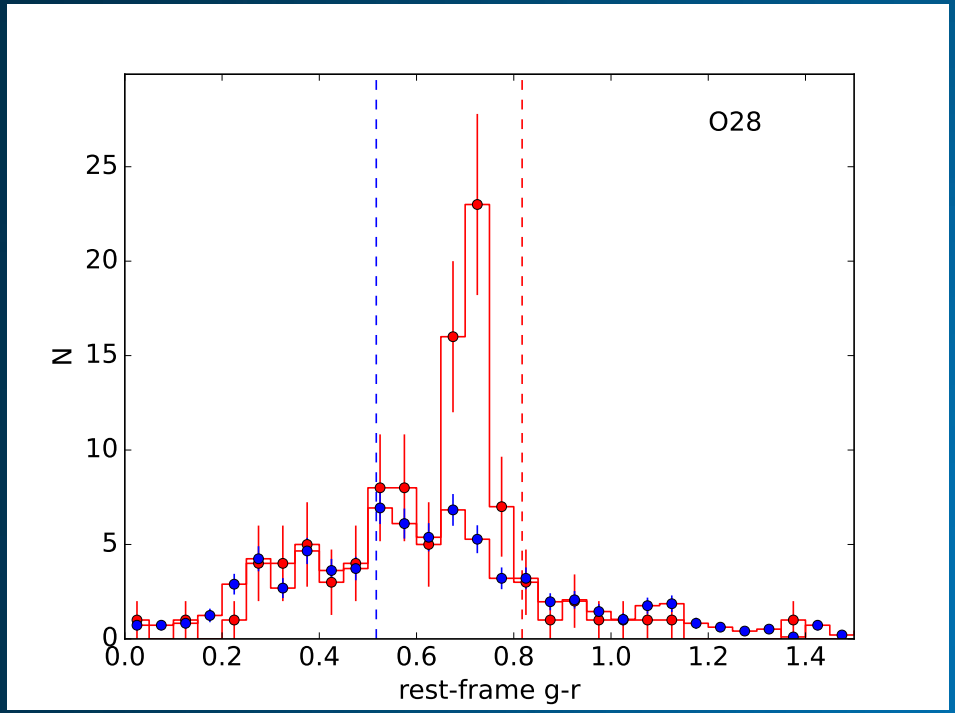


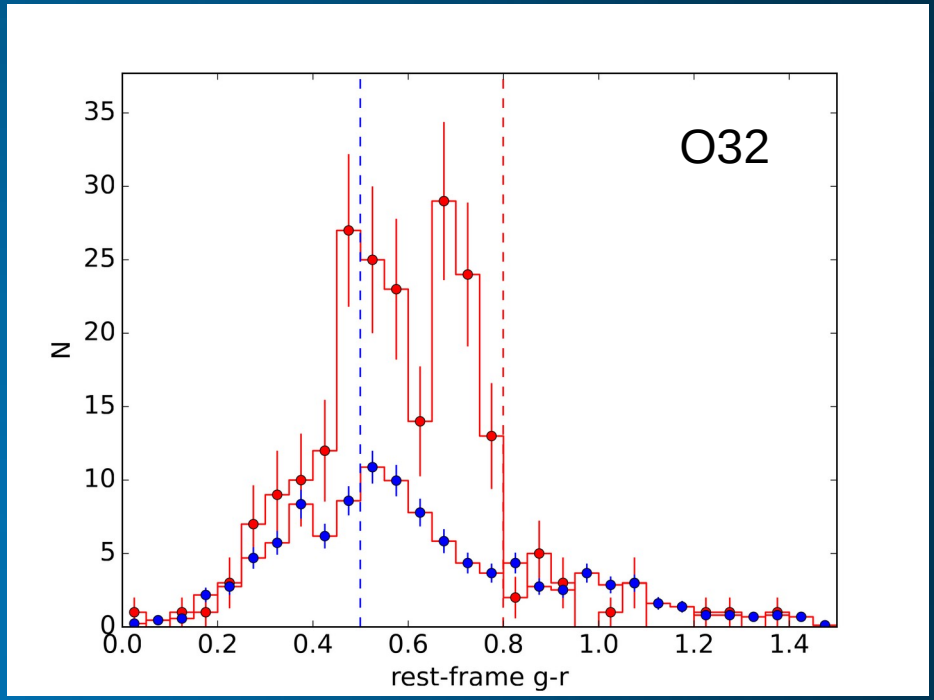
1 major merger in progress (Δv~2000 km/s)

12 cases of non major-mergers

z_{spec} most from SDSS and DESI

Photometry and richness





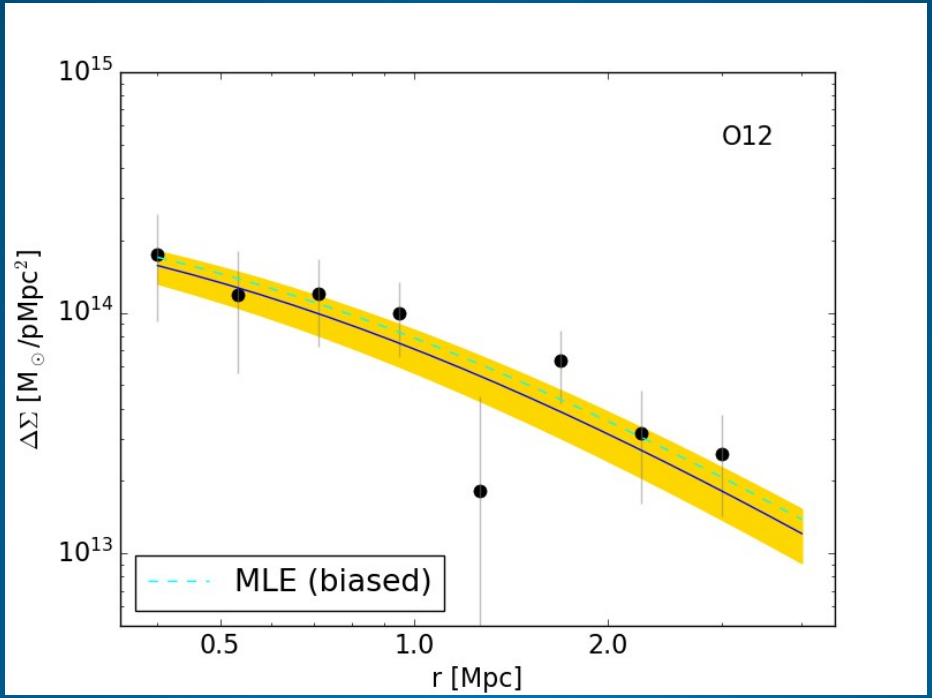
11 cases of clean l.o.s.

2 cases of contaminated l.o.s. but clean n_{200}

HSC photometric data

Mass determination from HSC shear

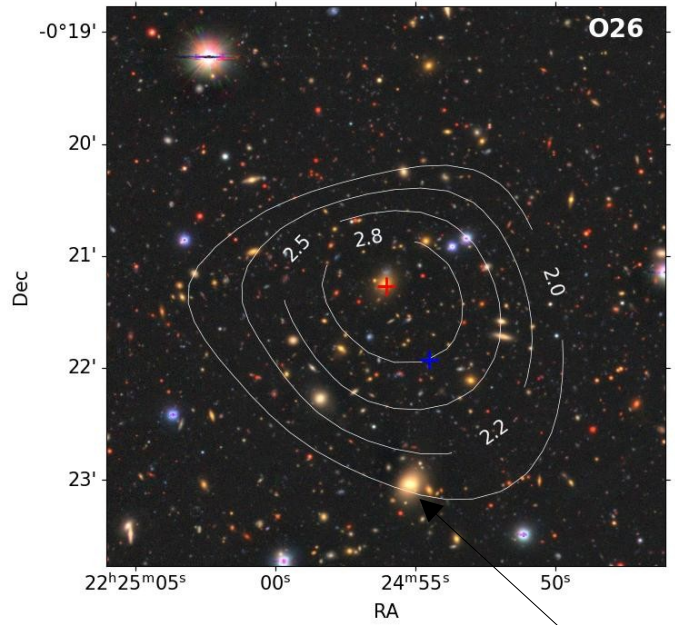
Tangential shear profile



Accounts for (negligible by design) Eddington bias, 20% scatter (elongation, triaxiality & correlated halos), shape noise. Assumes MD14 c-M. Uses HSC shear data.

One possible case of case of wl contamination

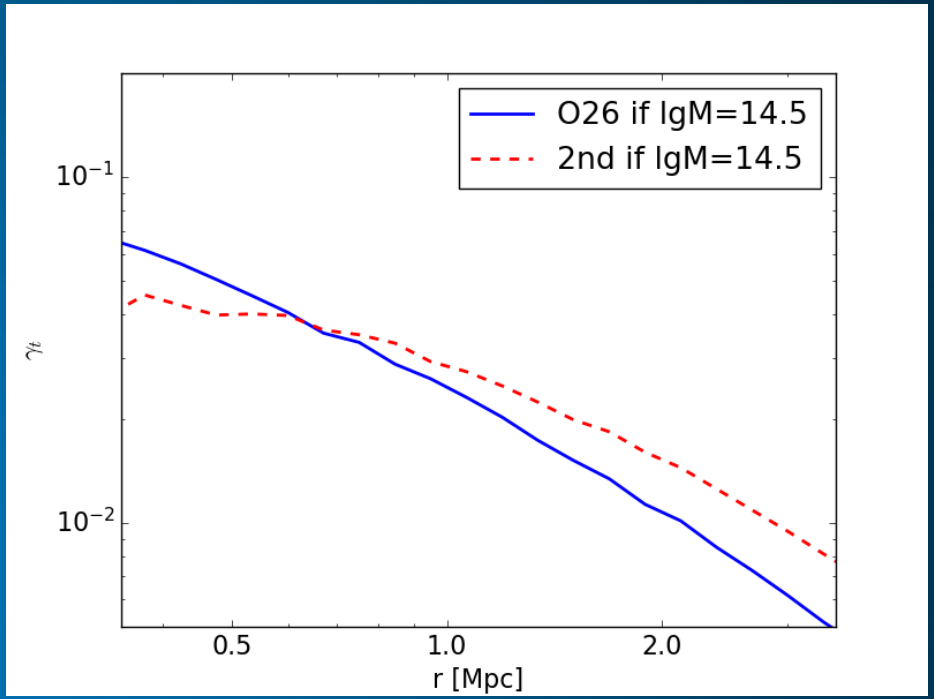
White contours: shear



WL Contaminant

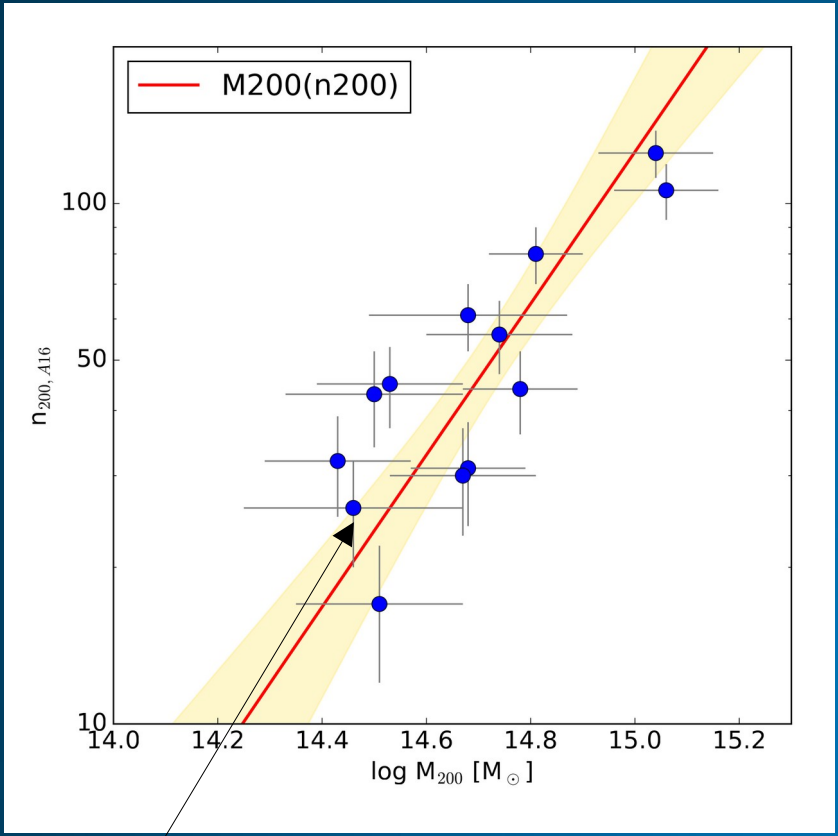
X-ray co-centered with shear

Tangential shear profile

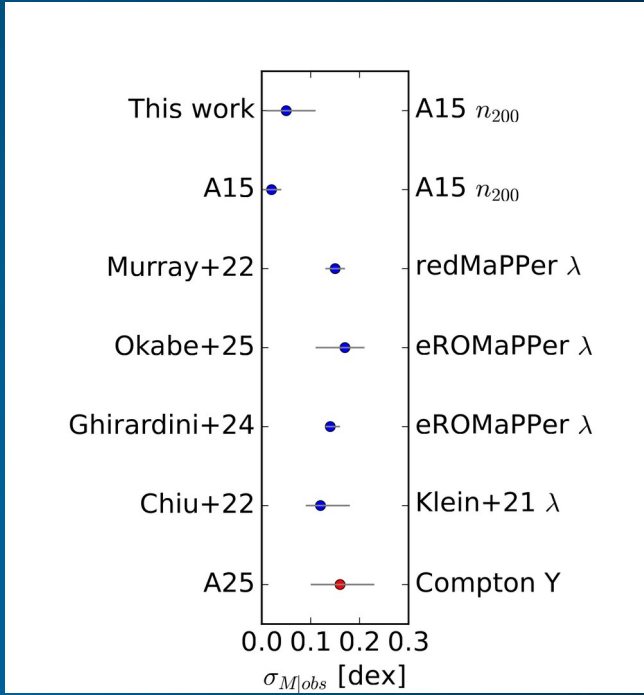


Predicted masses based on richness

Tight richness-mass scaling

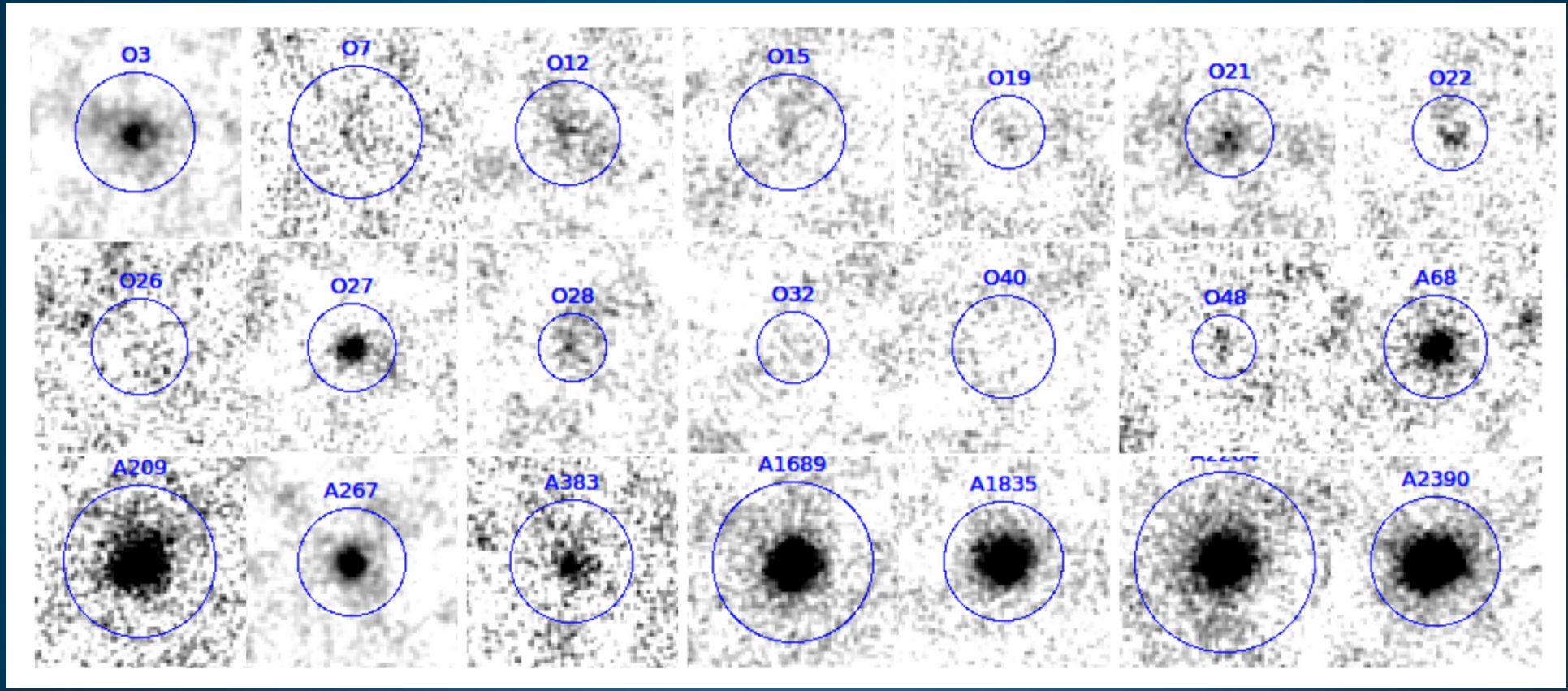


Zero outliers (whether or not you put the contaminated cluster in the sample)



The lowest-scatter richness-based mass proxy available in literature. One of the two richnesses adopted by Euclid collab.

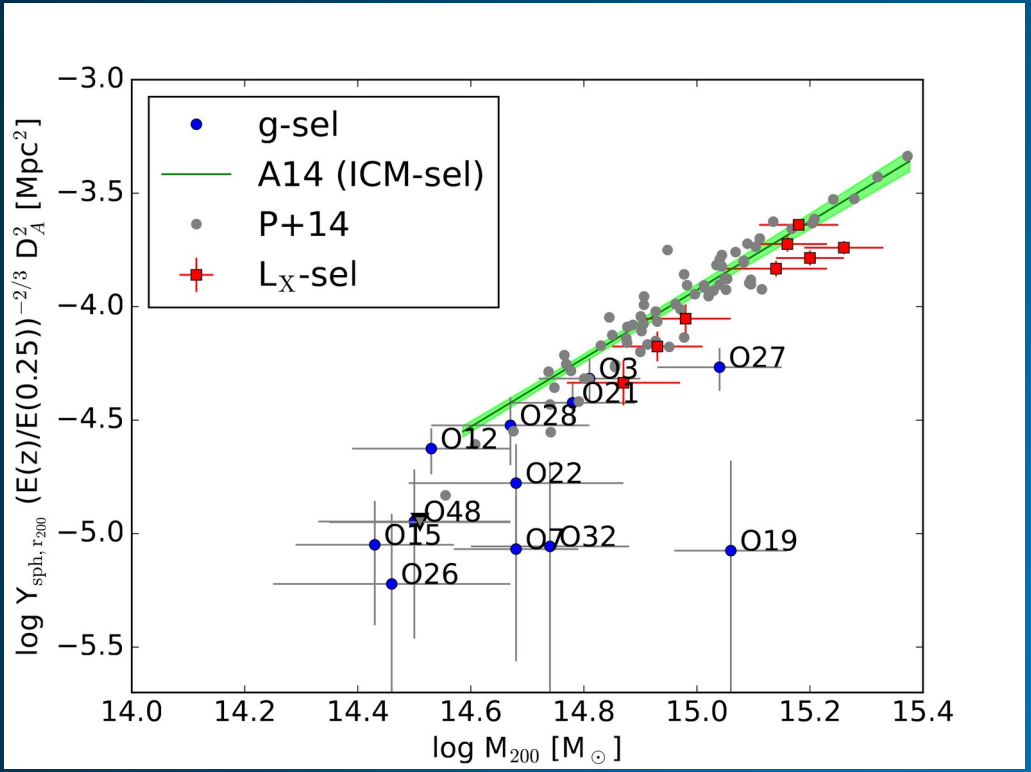
ACT+Planck Compton-Y mosaic



O40 is undetected

All images have identical scales and limits to eye-ball Compton Y

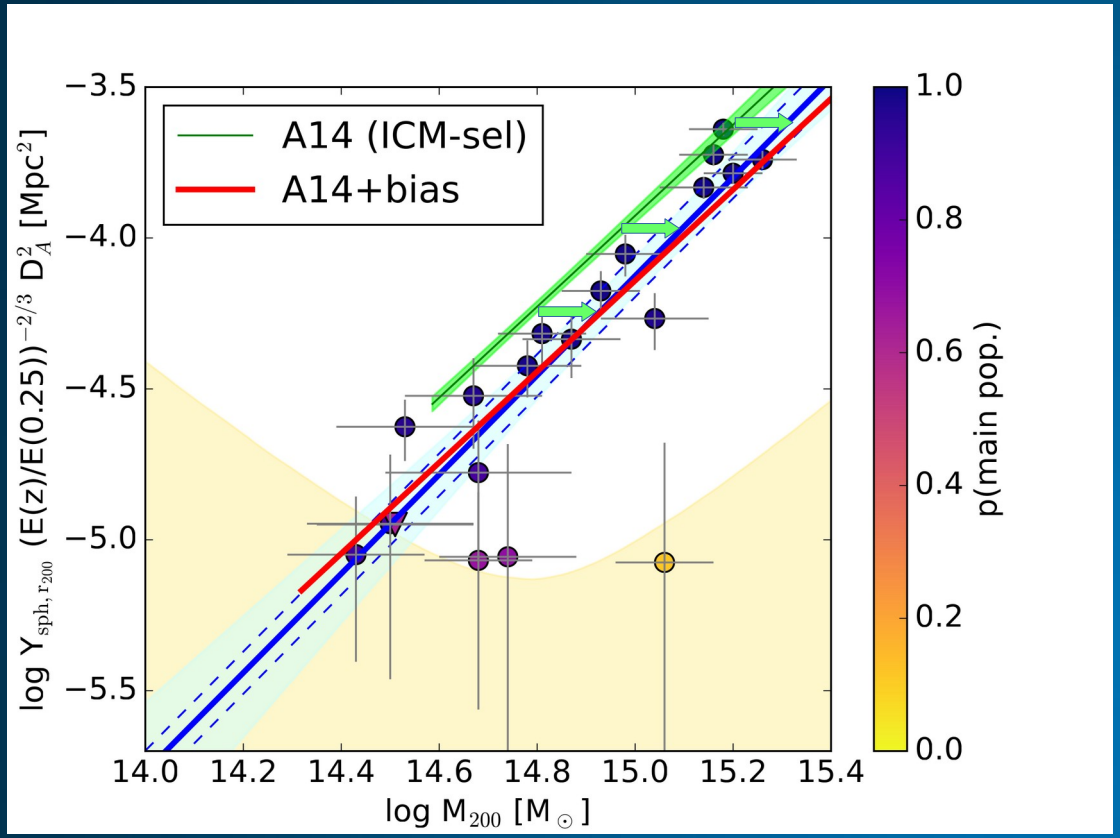
Empirical, qualitative, comparison



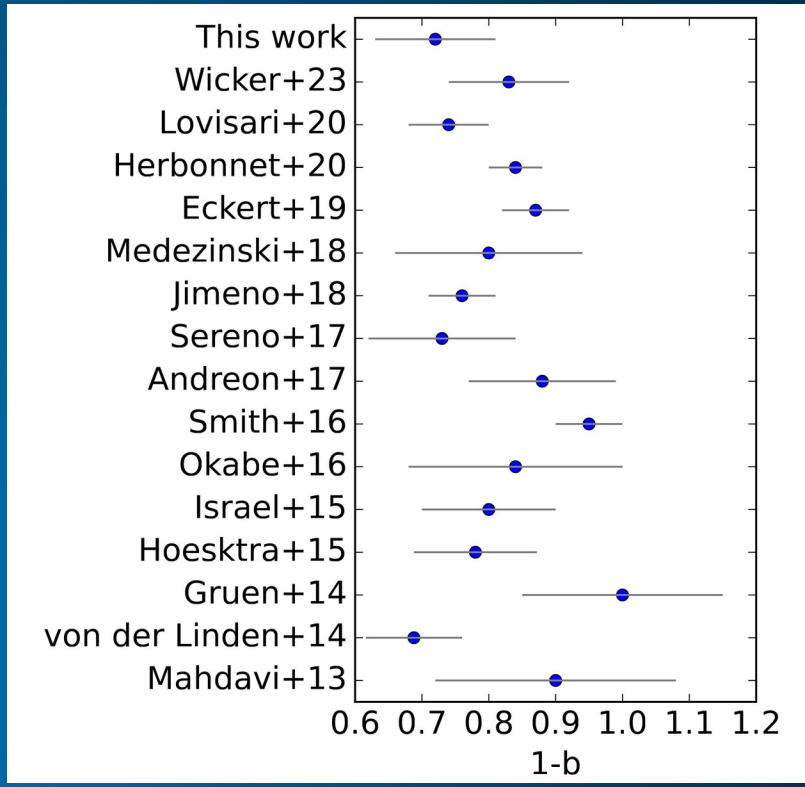
- Mass bias needed (comparison sample with X-ray masses)
- Outliers
- Scatter too wide

checked that ACT and Planck photometry agree each other (ask for details in Q&A)

Mass bias

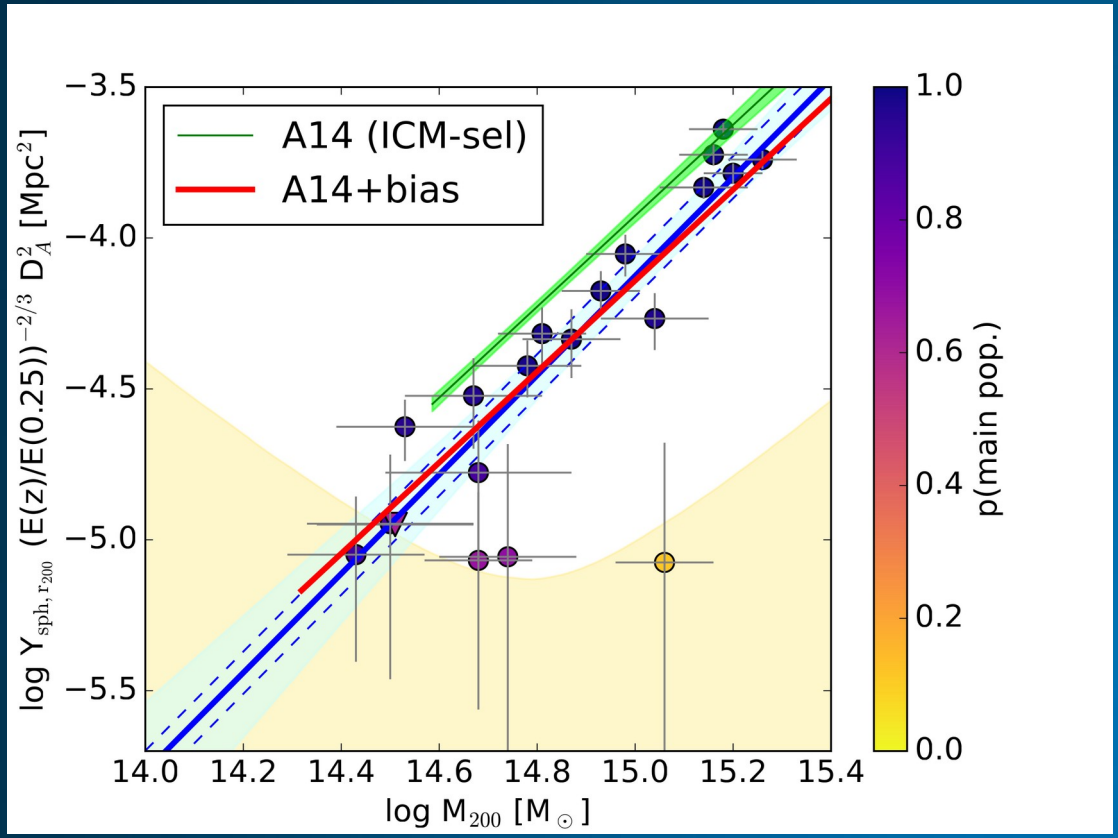


Fit with mixure of regressions with independent slope, intercept, and intrinsic scatter

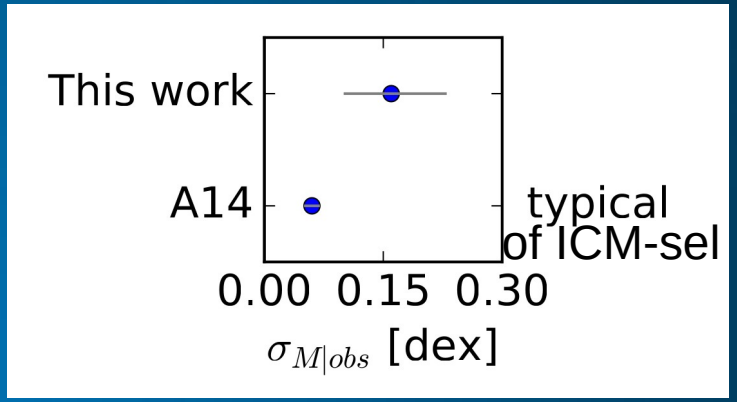


1-b~0.6 is needed to reconcile SZ clusters counts and CMB

Wider scatter

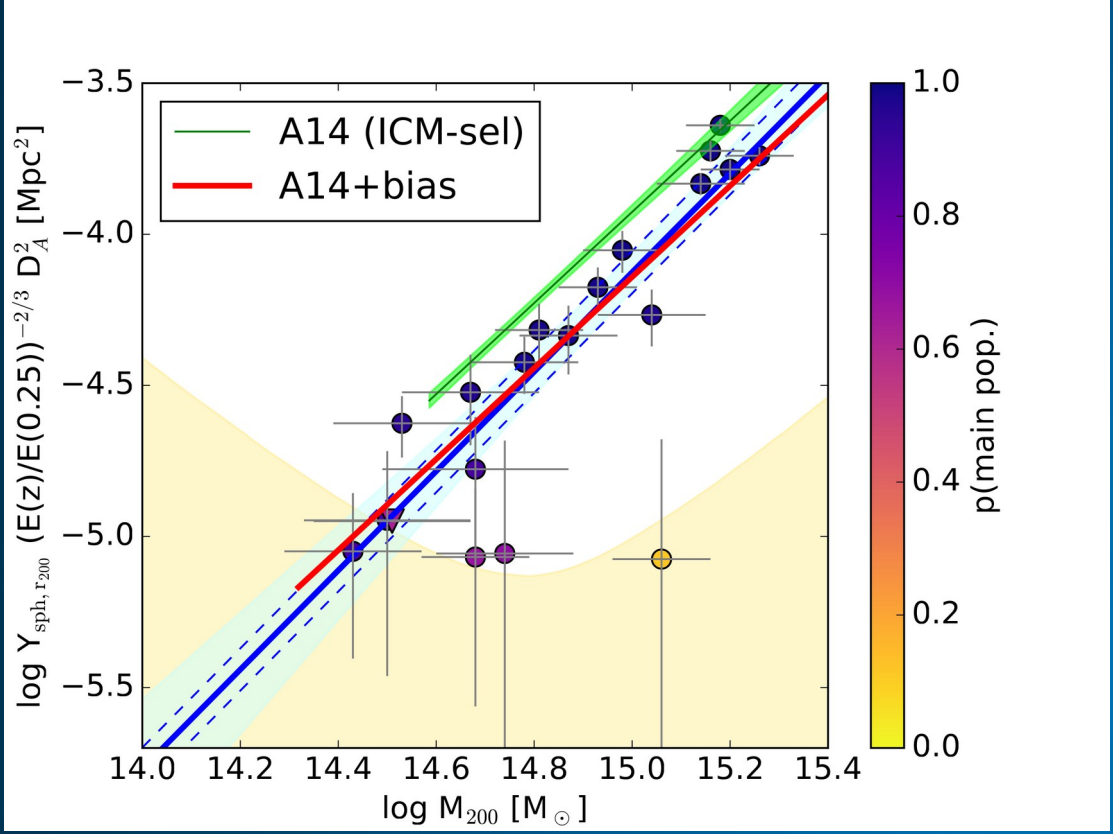


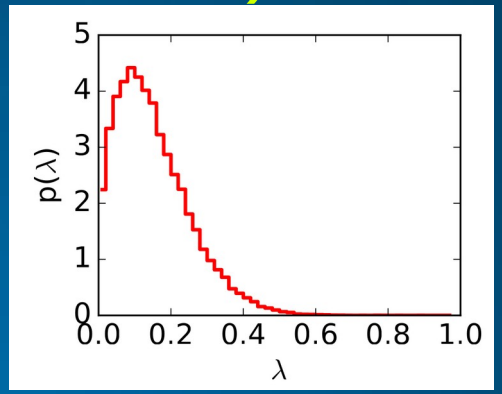
Scatter



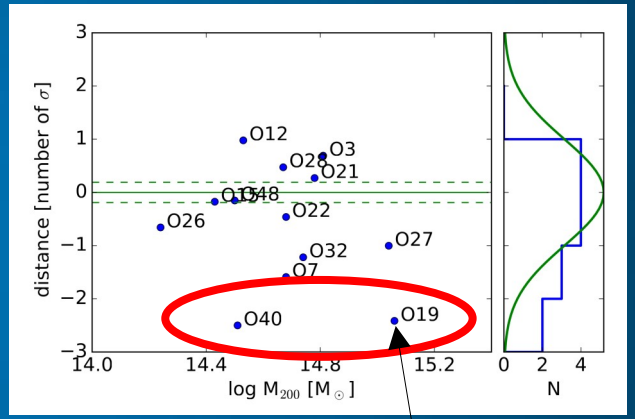
Not such a good mass proxy, then.

Two cluster populations at a given M (or one plus outliers)





Fraction belonging to the population faint for their mass



Minimal distance from the bright population

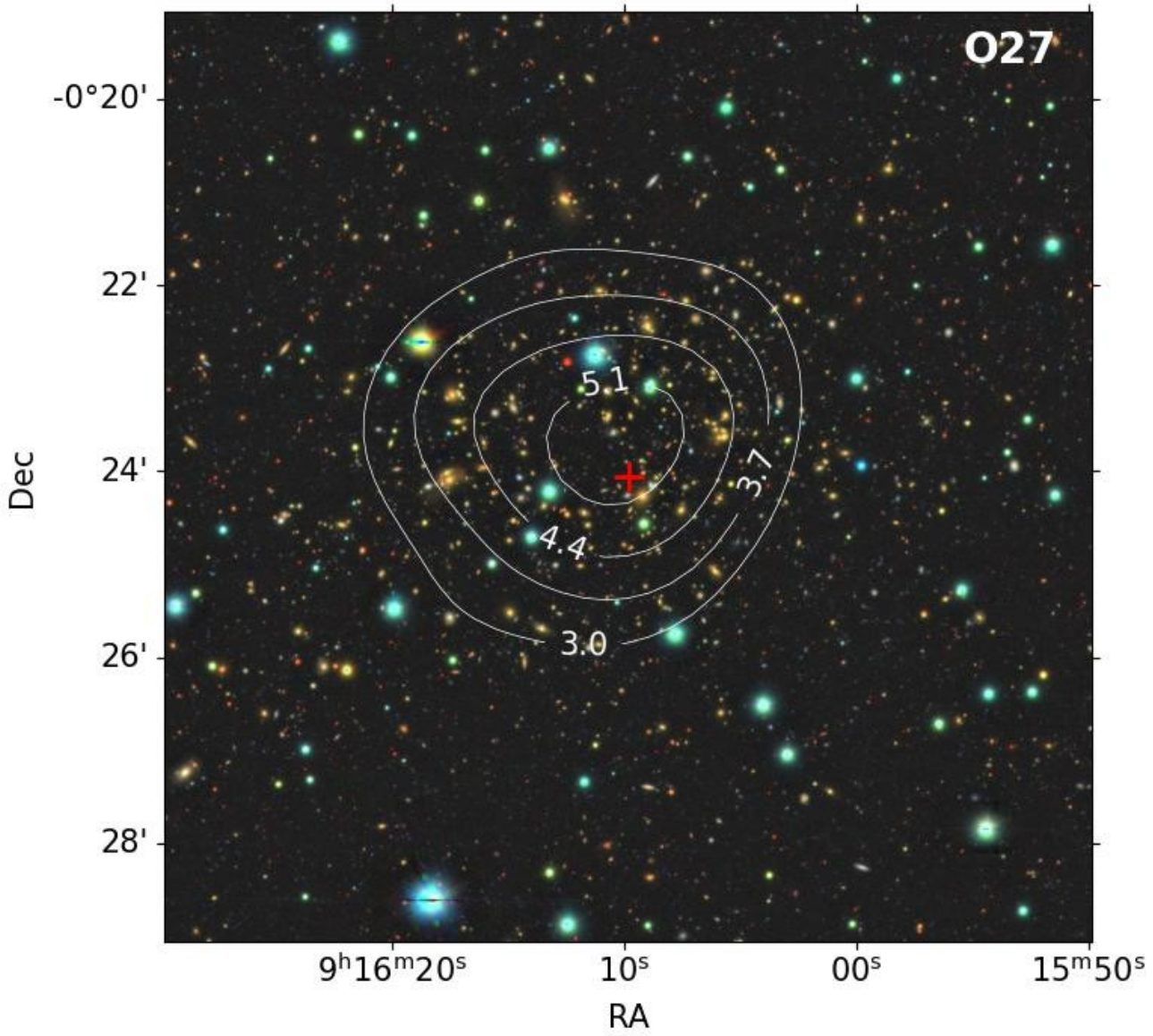
Follow-up in X-ray with Einstein probe, stay tuned

Summary & Perspective

- New way of selecting clusters: by gravity.
- Studied 13 clusters, 12 l.o.s are clean, 1 wl mass is potentially contaminated.
- Very tight $n_{200}|M$, much tighter than Y|M for the very same sample. n_{200} is a more precise mass estimator.
- A more variegate population in Y than in ICM-selected samples.
- Two cluster populations in Y|M, the main has lower Y|M than ICM-sel samples (mass bias) and larger scatter. The second population has even lower Y|M
- (Unclear $Y|n_{200}$ on a reduced sample)
- More results expected soon:
  - Pointed NIKA2, Swift XRT & EP of other gravity-selected (few) clusters
  - x100 larger sample with Euclid gravity-selected sample (+SPT & ACT)

Thanks

The merging cluster earlier mentioned



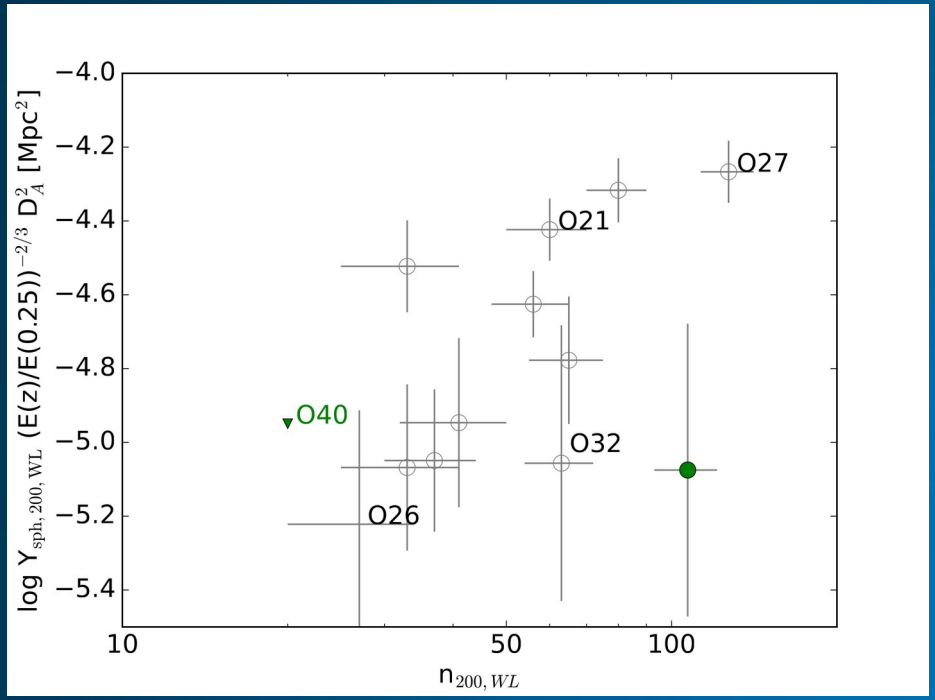
Back up slides

Truism

If a sample is selected irrespective of the Compton-Y signal (being studied), its analysis should not account for a never-applied Compton-Y selection.

PS: assuming selection is uncorrelated with Compton Y at fixed mass. A selection in L_X requires modeling the selection function.

Unclear Compton Y-richness (on a reduced sample)

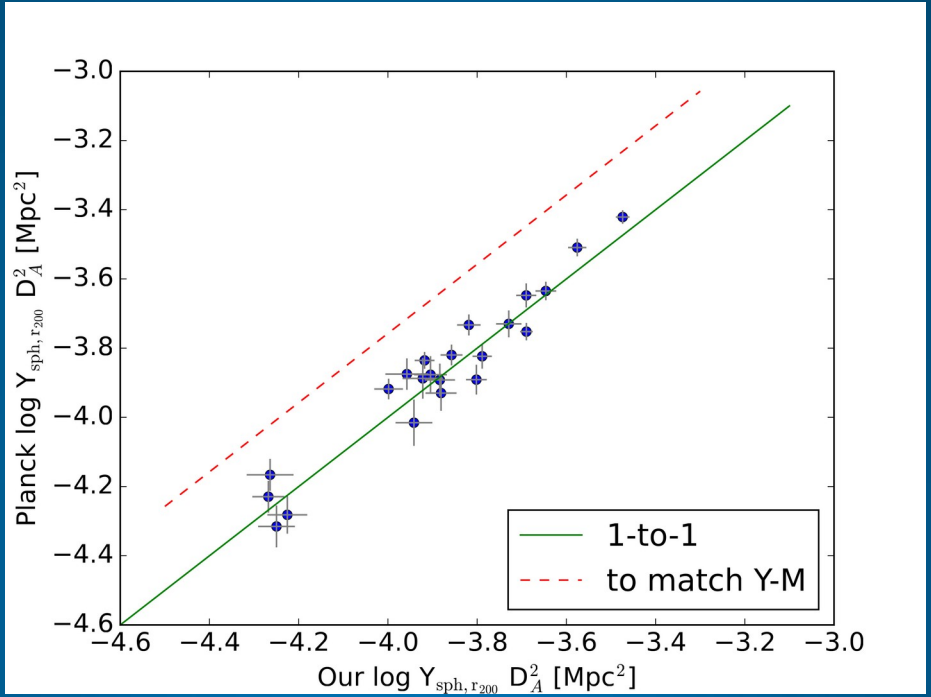


for the 13 gravity-selected clusters only

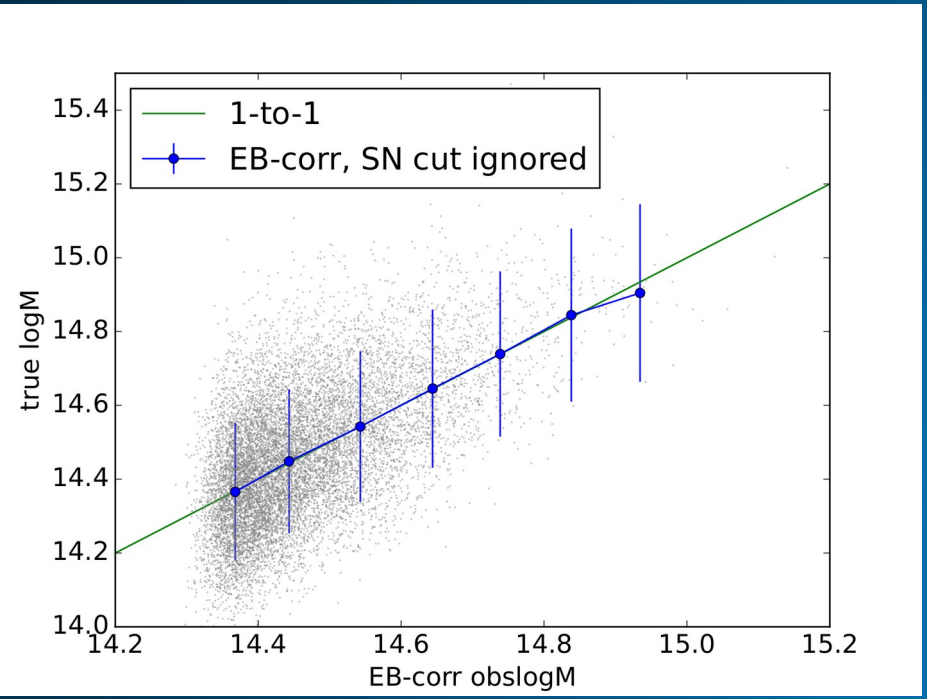
Uncertain modeling: fit depend on prior on modeling itself.

It's not just small sample size: p-value of the Pearson correlation coeff: 0.18 (i.e. no statistically significant correlation). For the same 11 clusters is 0.0002 for M-n_{200}.
Very scattered or more complex relation.

Agreement between our vs Planck photometry



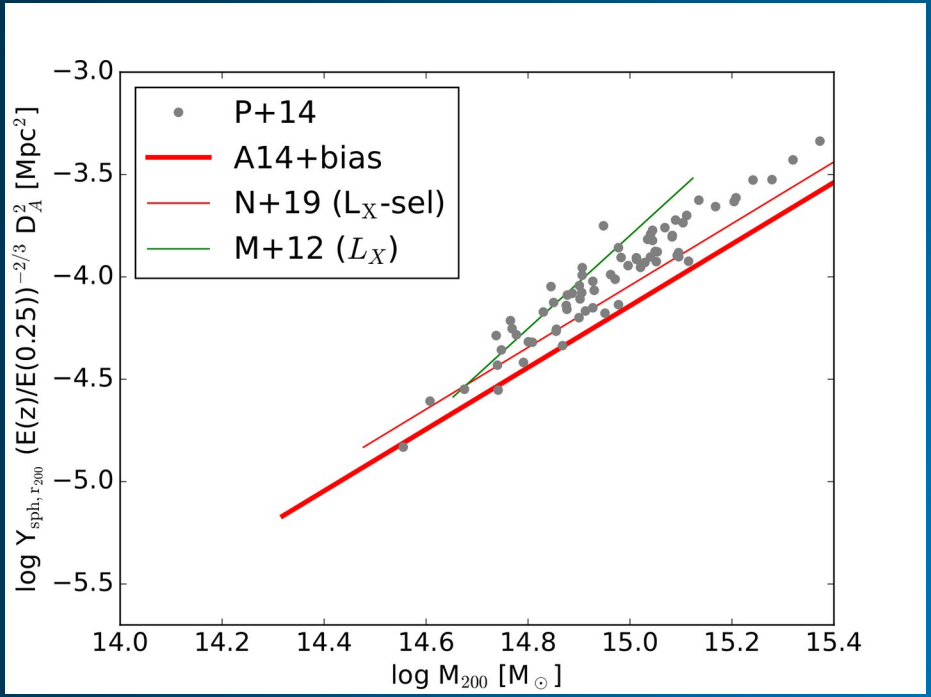
Do we need to model the S/N cut?



Simulated the whole process: generated halos from Thinker MF, noised as real data, computed S/N, selected S/N>x, Eddington-corrected ignoring the S/N cut modeling.

Anyway, even if the simulation is wrong, whole Eddington correction is negligible, and effect of the S/N cut is at most a fraction of it.

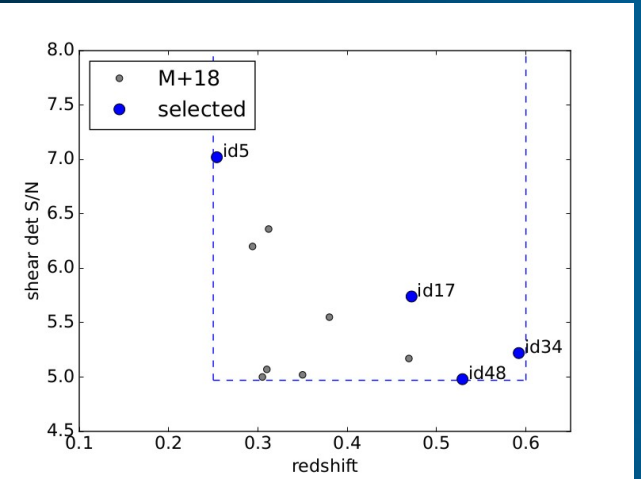
Do I pick up a wrong reference Y-M relation?

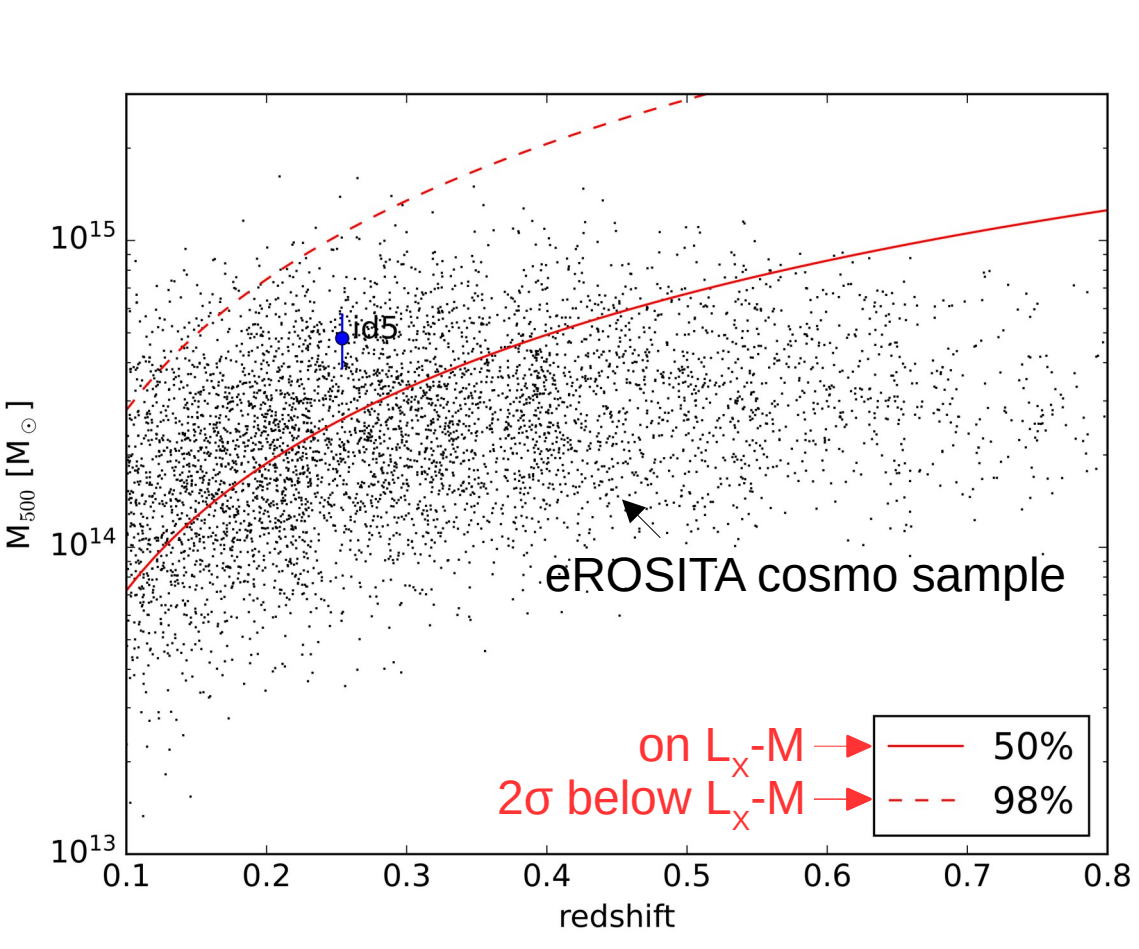


Used bias-corrected A14, based on Planck, corrected for mass bias.

Literature relations have larger Compton Y|M than it, making gravity-selected cluster even fainter than we claim.

Mass selection is intrinsically different from X-ray selection, even at the massive end





eROSITA inferences are made making assumptions on the unseen 70% (based on Bulbul+24)


Thanks
Image credit: ESA/Euclid ...