Cluster Mass Estimations And Their Importance For Cosmology

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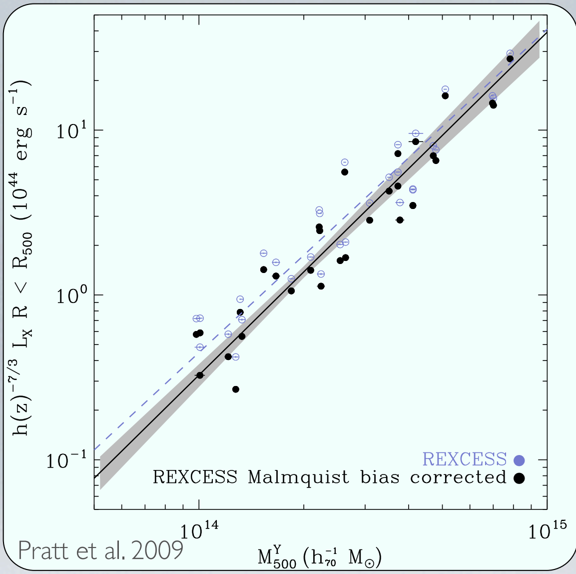
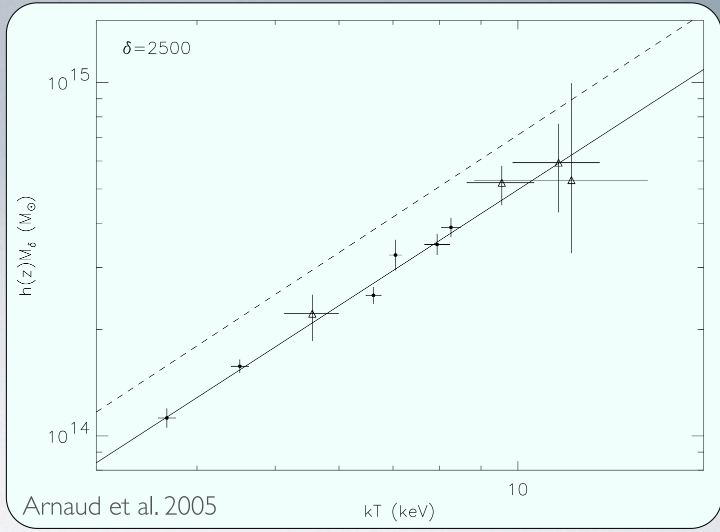
in collaboration with CEA/SAp, CEA/SPP and IAS

- The mass is the most significant characteristic of a cluster:
  - ➡ all the cluster physics depend on it

- It is strongly correlated to the other physical parameters:
  - gas mass
  - temperature
  - X-ray luminosity
  - SZ signal
  - number of galaxies
  - peculiar velocities...



Pratt et al. 2009

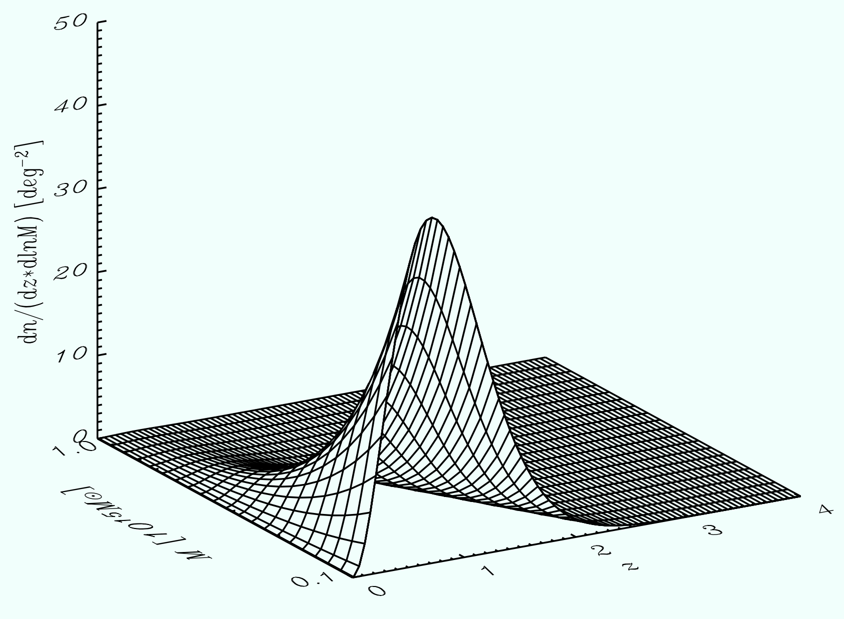


Arnaud et al. 2005

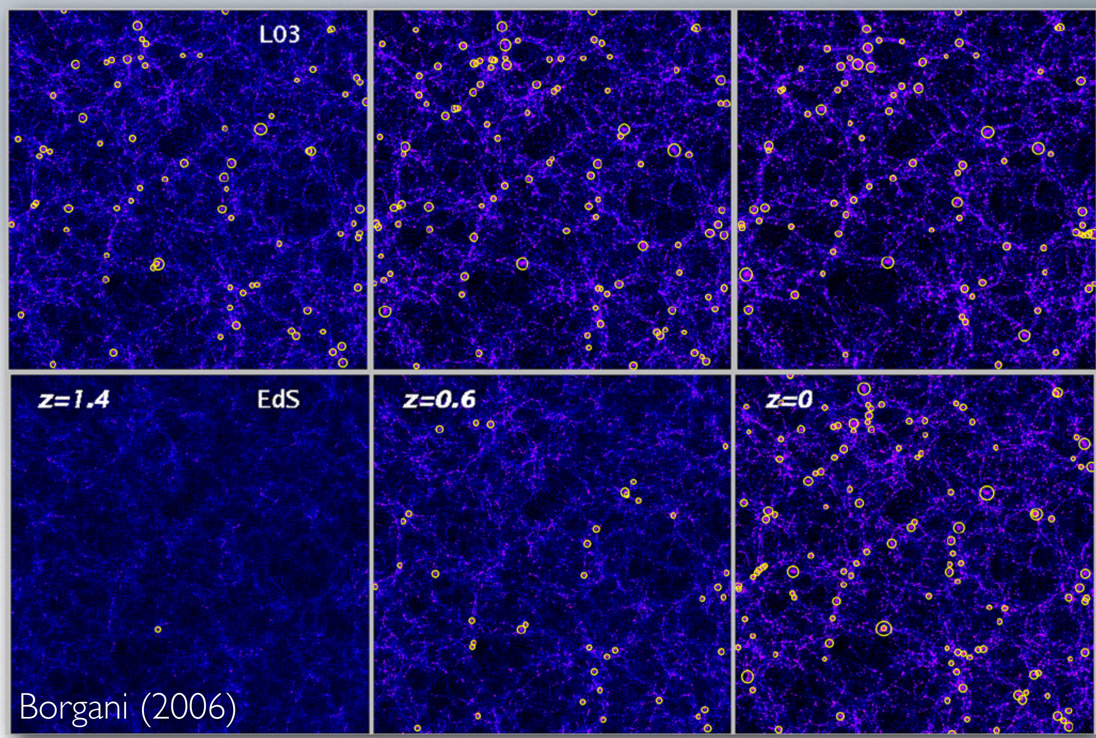
- Unfortunately, *it cannot be directly observed*

- Galaxy clusters are powerful cosmological probes, sensitive to both cosmic expansion and growth

- Among other methods, cluster counts as a function of redshift and/or mass allow to produce cosmological constraints



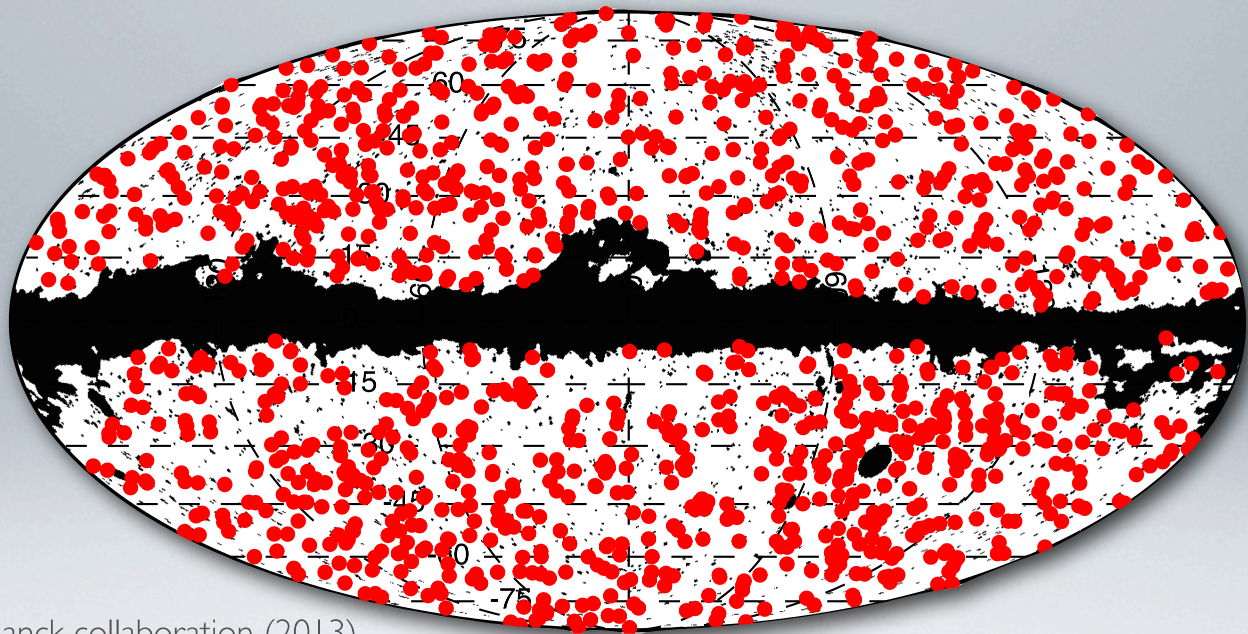
Cosmology-dependent mass function



Borgani (2006)

The *Planck* satellite observed (and, in many cases, discovered) a great number of massive and distant clusters.

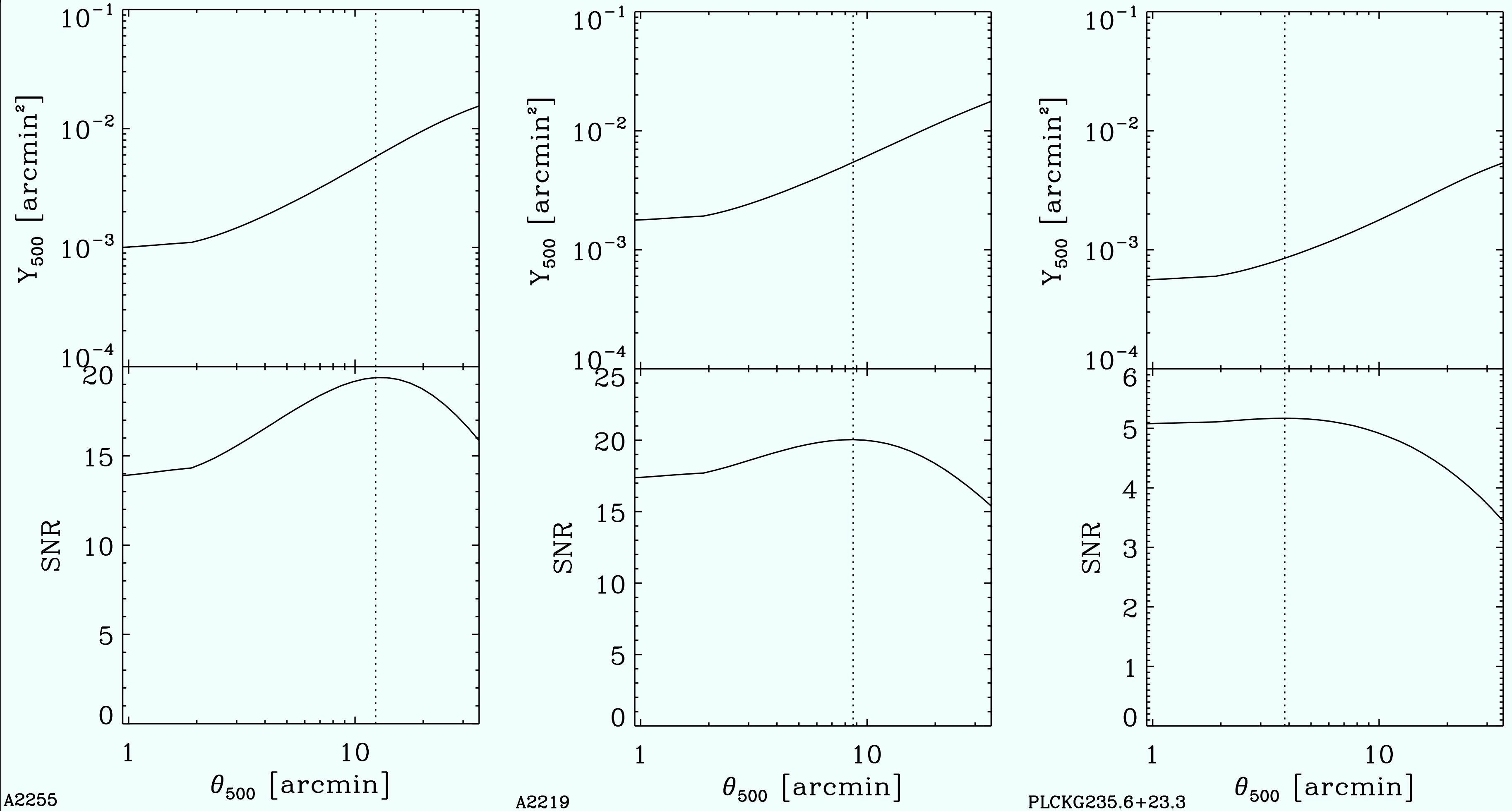
➡ 1227 *Planck* clusters and candidates over 83.7% of the sky



Planck collaboration (2013)

A *cosmological sample* was constituted (100% purity and redshift measurements) in order to derive cosmological constraints.

... but its relatively low resolution (~cluster size) leads to weak constraints of their size/flux if no other constraint is used (e.g. from X-ray observations)



Variation of the SNR with θ_{500} and resulting Y_{500} imprecision

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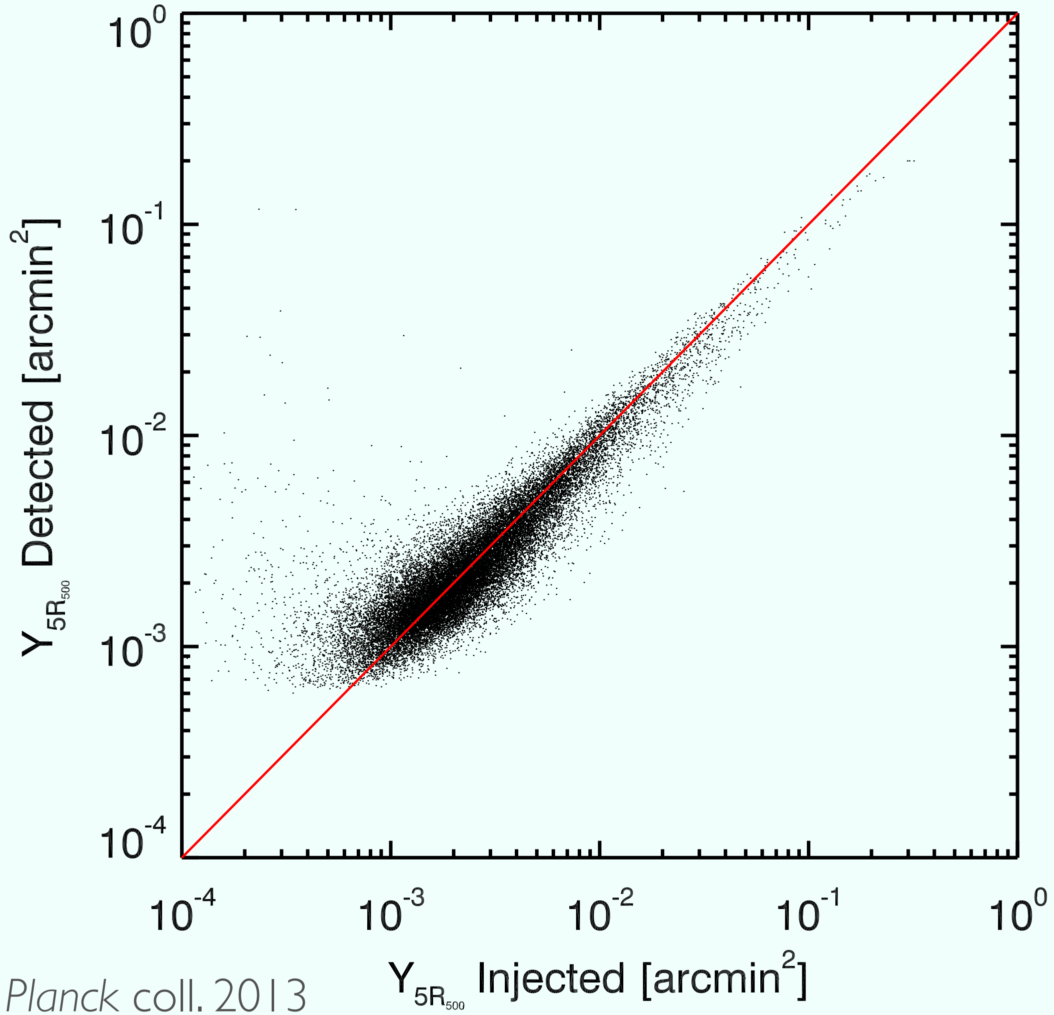


Planck coll. 2013

How is mass computed?

M_{500} is defined as the mass enclosed in R_{500}, where the density is 500 times the critical density of the Universe:

$$M_{500} = \frac{4\pi}{3} 500\, \rho_c(z)\, R_{500}^3$$

Using *Planck* clusters with known masses (e.g. measured from X-ray observations), one can calibrate the scaling law between the mass and the SZ flux:

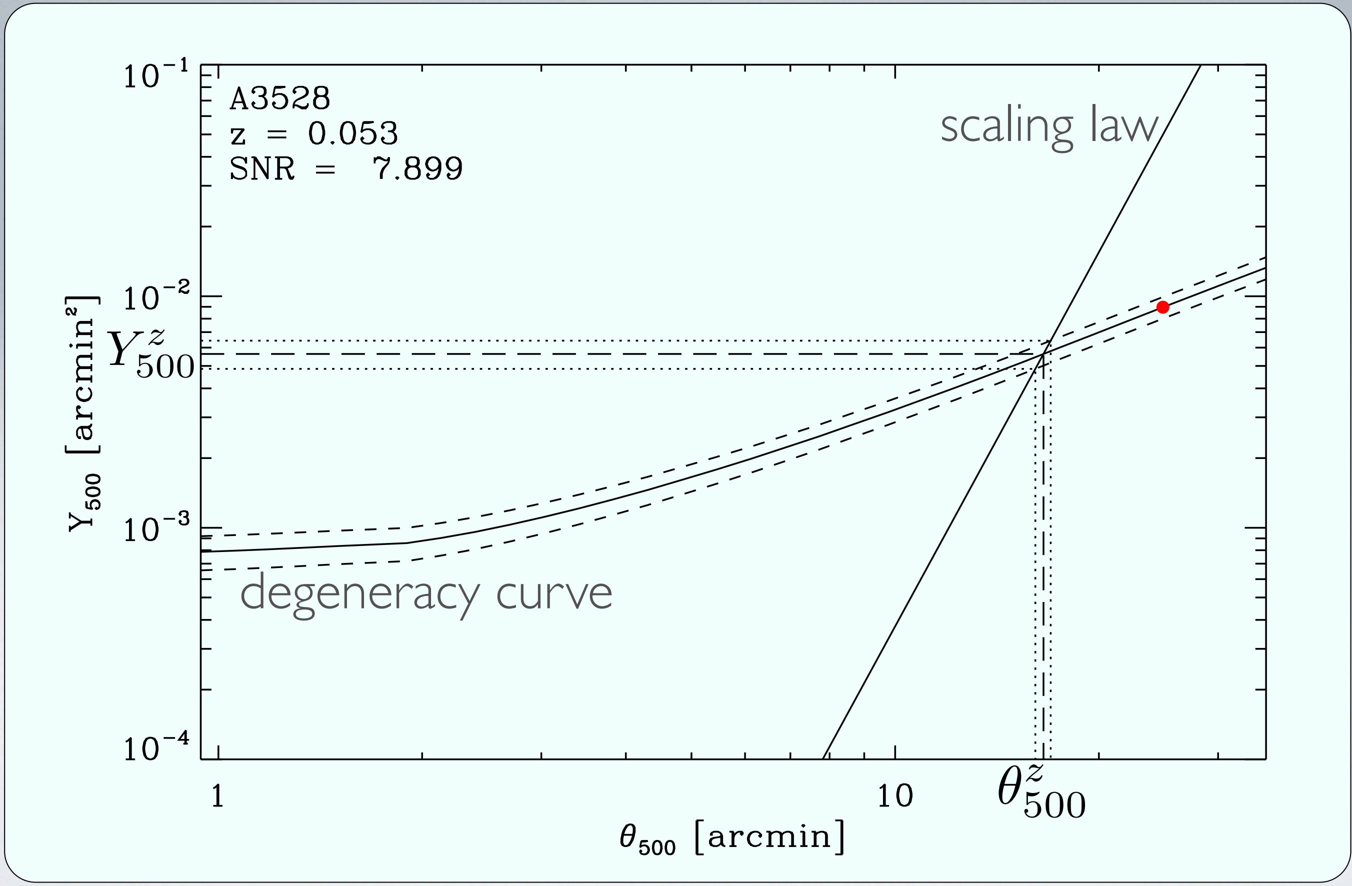
$$M_{500} = A \times Y_{500}^{\alpha} \times f(\Omega, z)$$

➡ Any error on the SZ flux will propagate to the mass estimate, and the cosmological constraints

➡ So far, only counts as a function of *z* have been used

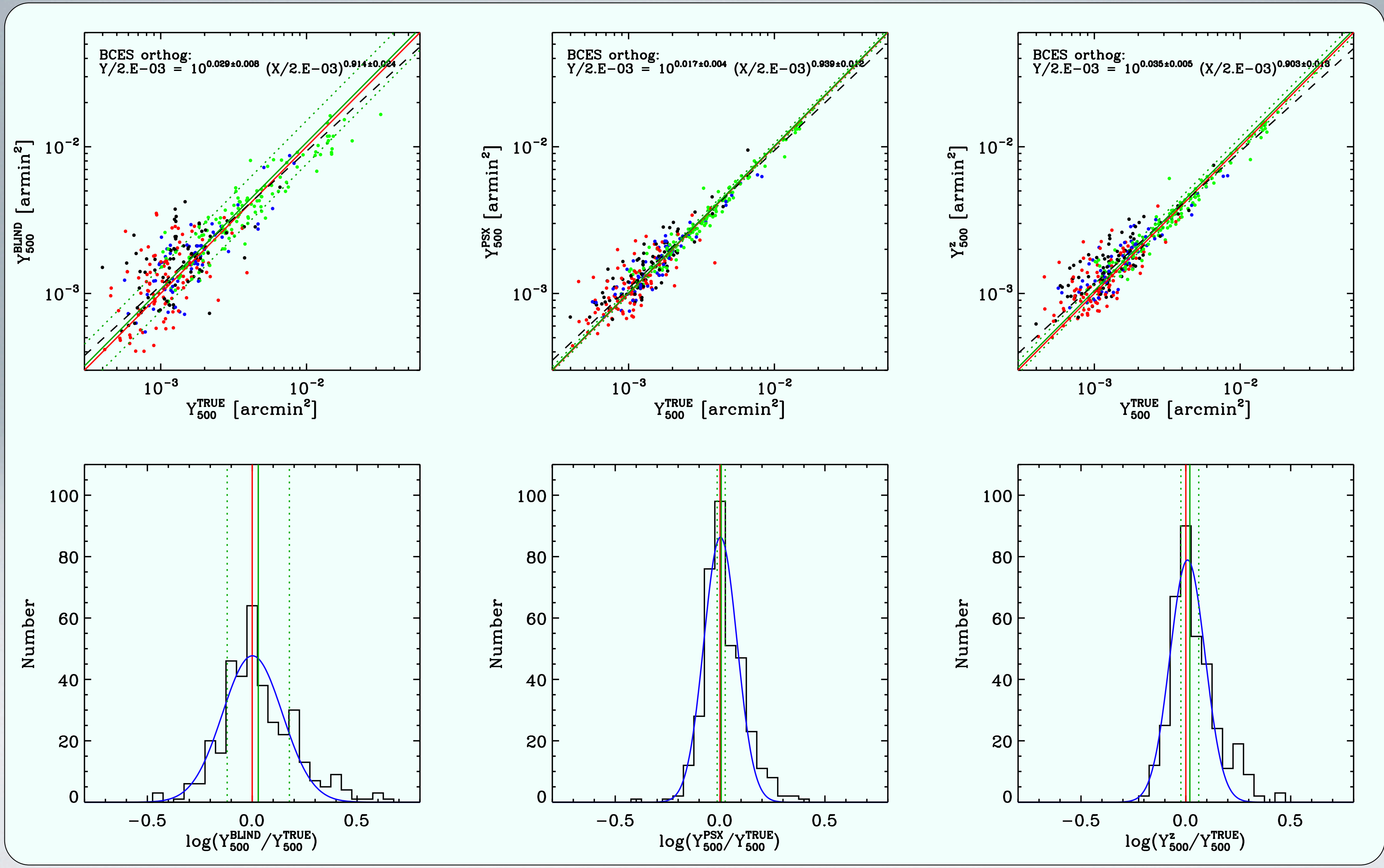
How can one get a better estimate of the size and flux without using unrealistically costly X-ray follow-up?

➡ solve for Y_{500} and $\boldsymbol{\theta}_{500}$ using both the degeneracy curve and $Y_{500} = f(\boldsymbol{\theta}_{500}, z)$ derived from sub-catalogs with already existing X-ray observations



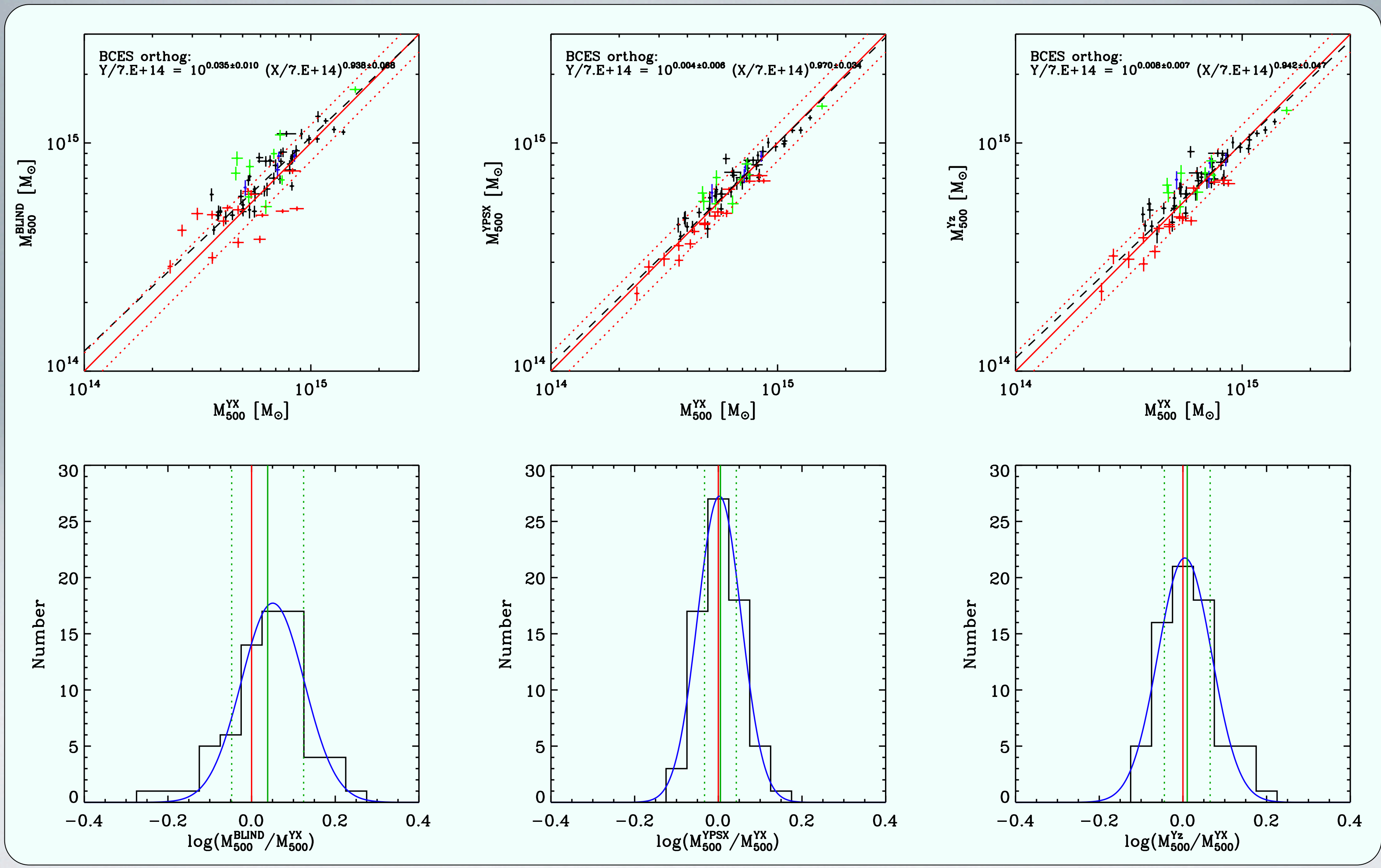
Results on simulations

- scatter reduced by 70%;
- if same position is assumed, our estimate and the PSX one are virtually identical;



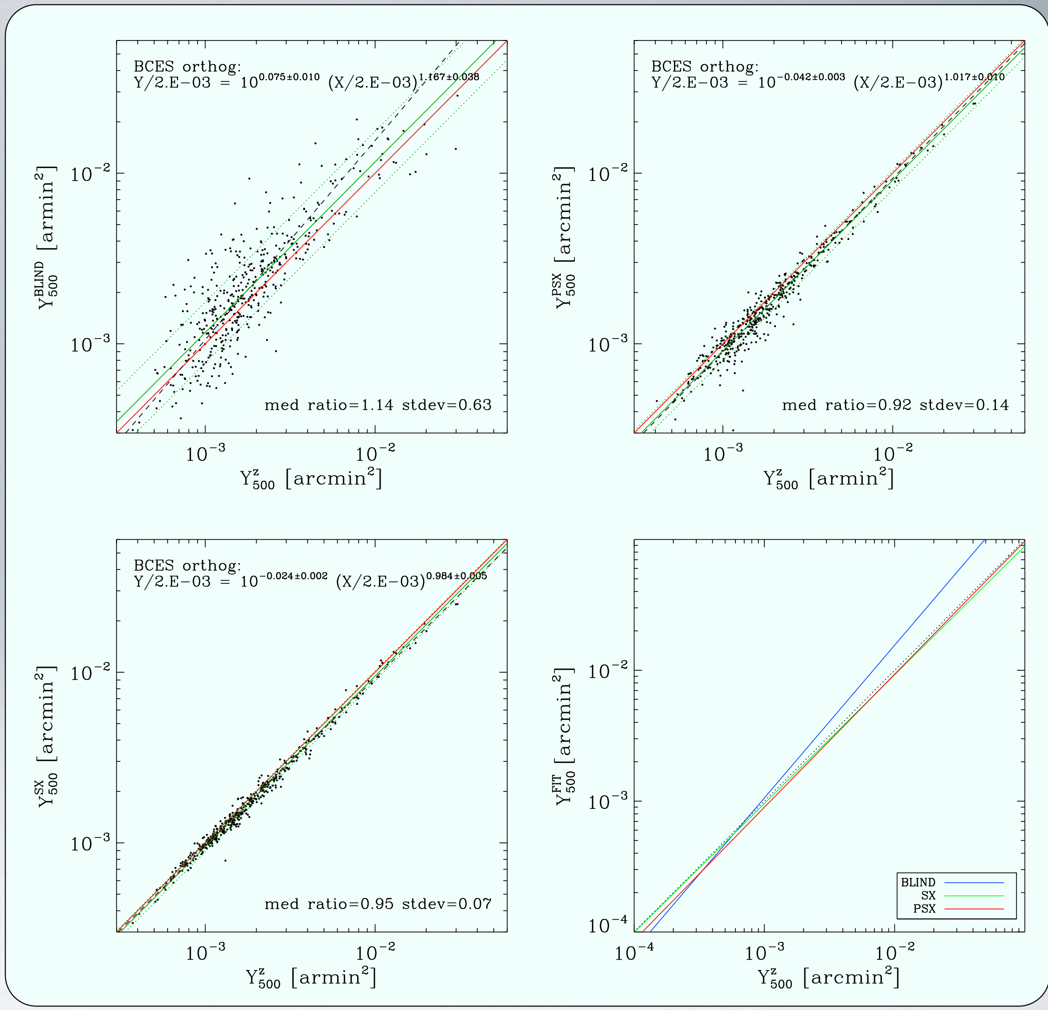
Results on cosmological sample clusters with X-ray ancillary data

- close to no bias in all cases but the blind estimate;
- scatter reduced by 40% between the blind estimate and ours.



Results on the PXCC (437 clusters)

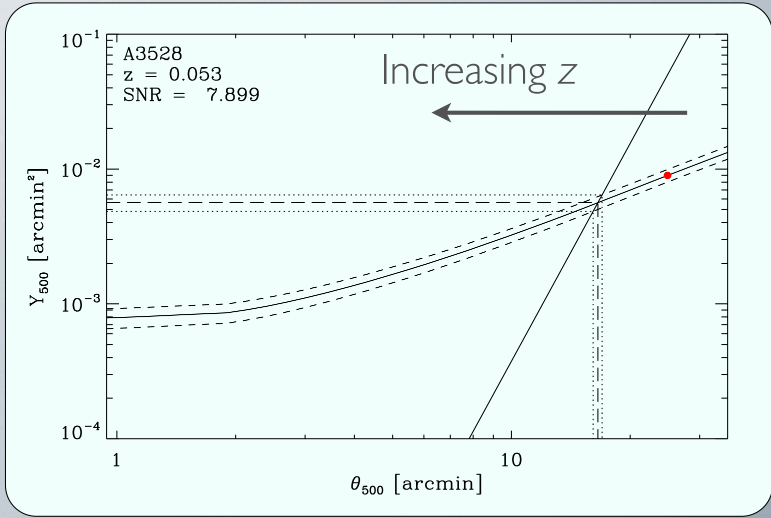
- This new method does its job, but not more:
  - Very tight relation between our estimates and the ones obtained using the X-ray measurement of the size: ***the size of the clusters is well recovered***
  - When comparing our estimates to the ones obtained assuming the X-ray size *and* position, it appears that the bias is marginally larger (but still low) and the scatter is doubled: ***the effects of a different position between blind SZ and X-ray cannot be canceled by this method***



- So far, we have considered the redshift to be perfectly known. This is not realistic.

➡ How will our estimates be affected by errors on the redshift?

➡ Assuming a goal on the error on the SZ flux, what is the highest allowed error on the redshift?

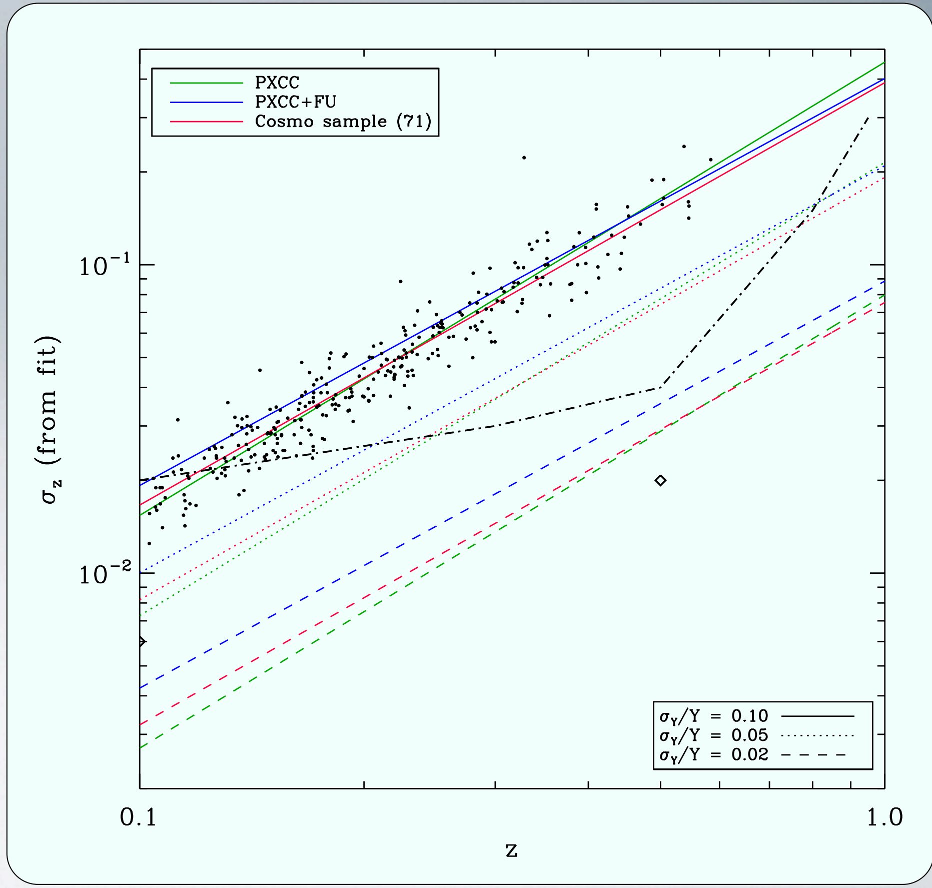


- Monte Carlo simulations were realised for several goals on σ_Y and various catalogs

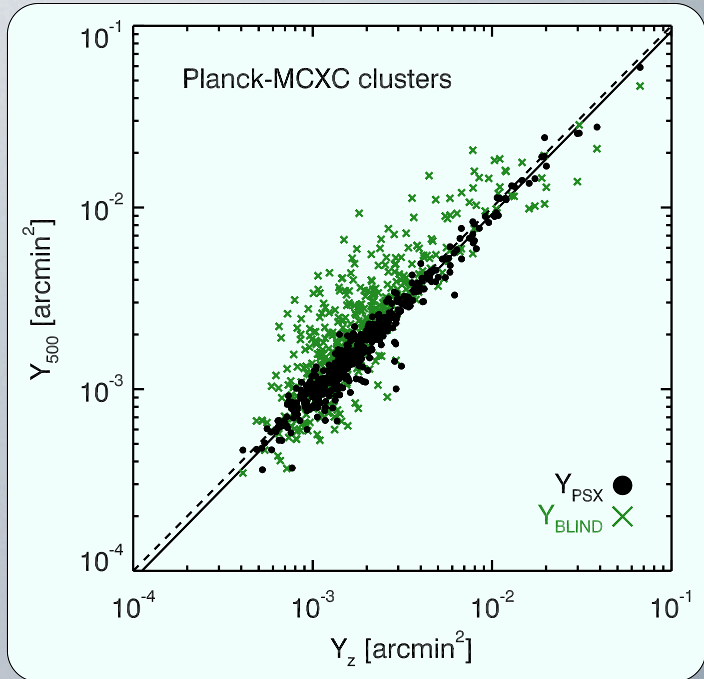
- Results summarised in one relation:

$$\sigma_z = A \left(\frac{\sigma_Y}{Y} \right)^{\alpha_Y} z^{\alpha_z}$$

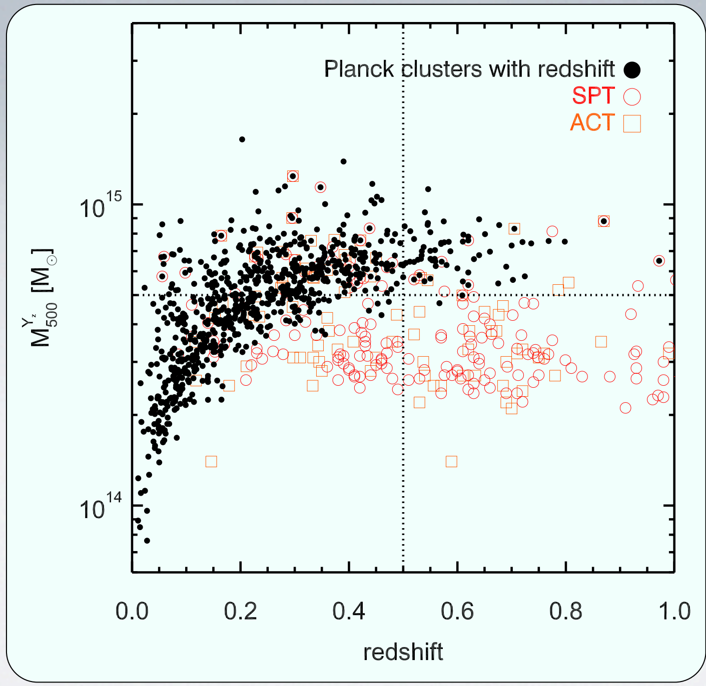
and compared to current capabilities (SDSS DR6 (Oyaitzu et al. 2008) and redMaPPer (Rykoff et al. 2013))

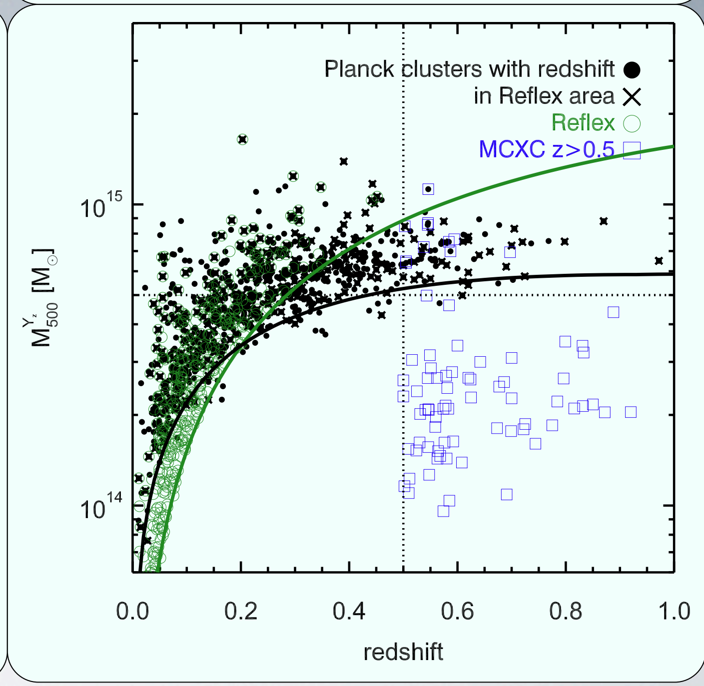


- *Planck* Collaboration (arXiv:1303.5089)
  - Masses derived using this method for all clusters with a redshift estimate
  - This allowed a direct comparison with:
    - other SZ surveys, namely ACT and SPT
    - existing X-ray catalogs
    - ➡ complementarity of *Planck* with others



- Work done in close collaboration with IAS, Nabila Aghanim being in charge of the SZ catalog.





Conclusion

- Reliable mass (and redshift) measurements are indispensable for precise cosmology; *Planck*'s resolution is too low to allow blind precise mass measurements
- We developed a new method to estimate cluster SZ flux (from which the mass is derived) from blind observations for clusters with known redshifts
- This method was extensively tested on both simulations and *Planck* data; it proved almost as reliable as results obtained using X-ray information
- Uncertainty on redshift measurement doesn't seem to be a relevant limitation
- Results were used and published by the *Planck* collaboration

➡ The implications in terms of cosmological constraints are to be investigated