X-raying the Planck legacy: X-ray properties of SZ-selected clusters

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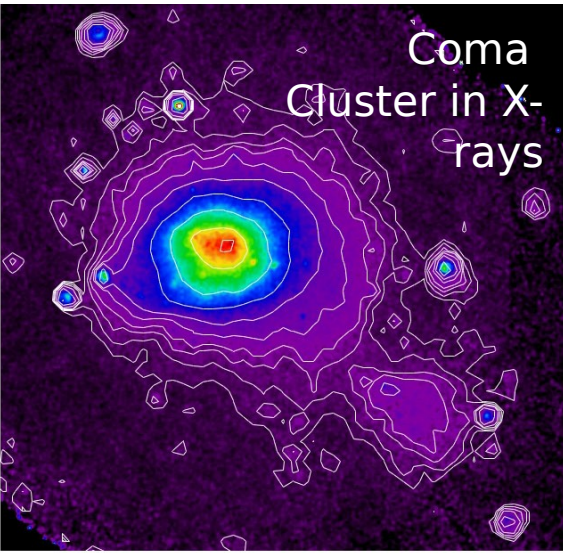
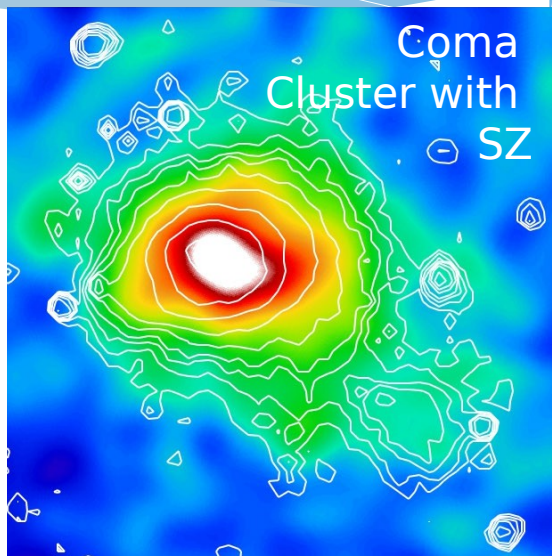
Observing the hot and diffuse baryons



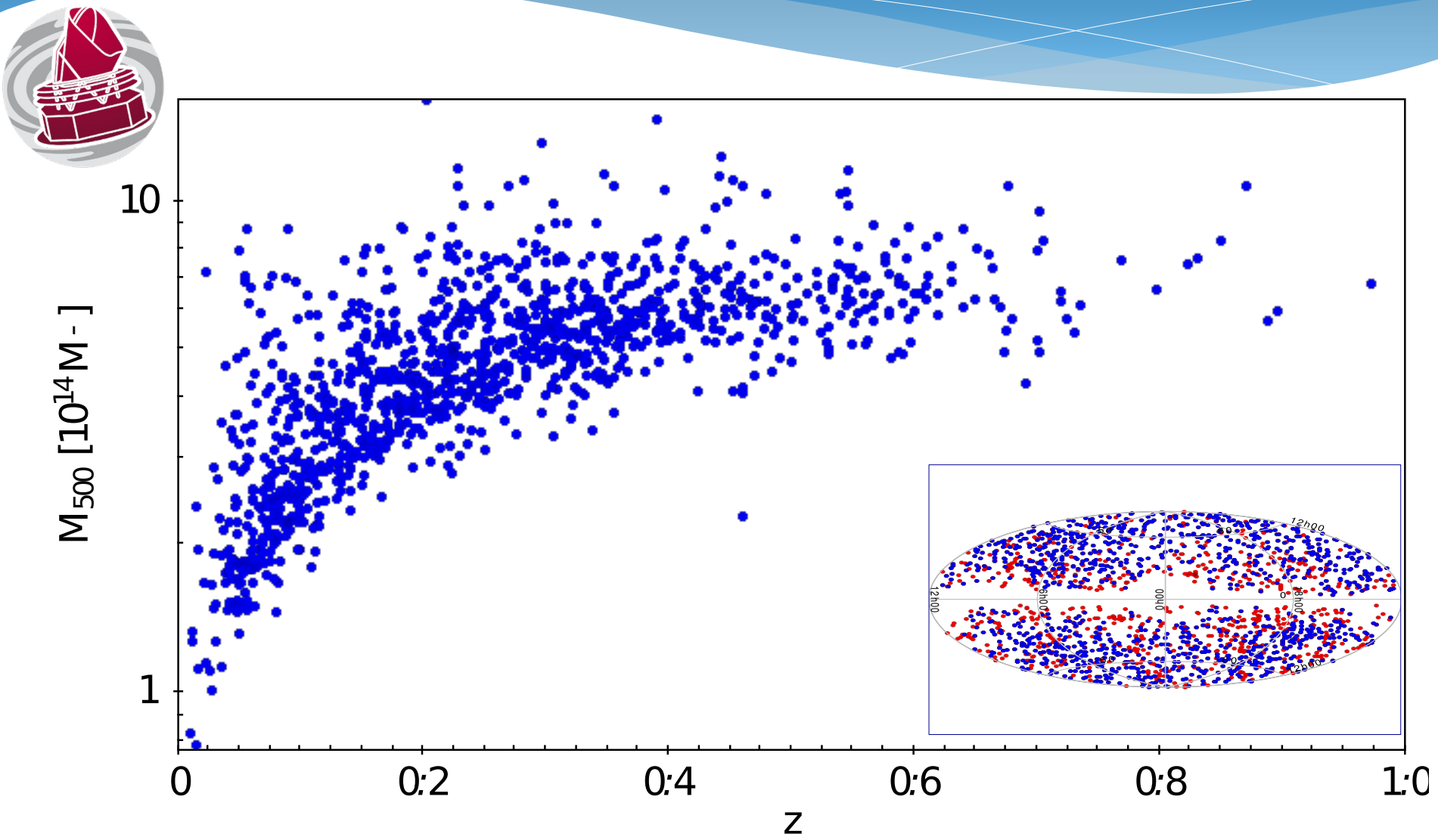
Hot and diffuse baryons in galaxy clusters (ICM) can be observed in X-rays and in the microwave band through the Sunyaev-Zeldovich effect (SZ)



- ✓ Very sensitive to dense cluster regions ($I_X \sim n_e^2 T^{0.5}$)
- ✓ Mature field
- ✓ The primary way to characterize the ICM thermodynamical properties

- ✓ Also sensitive in the low density regions ($I_{SZ} \sim n_e T$)
- ✓ Rapidly evolving field
- ✓ Proven very effective to detect clusters (redshift independent): SZ cluster catalogues

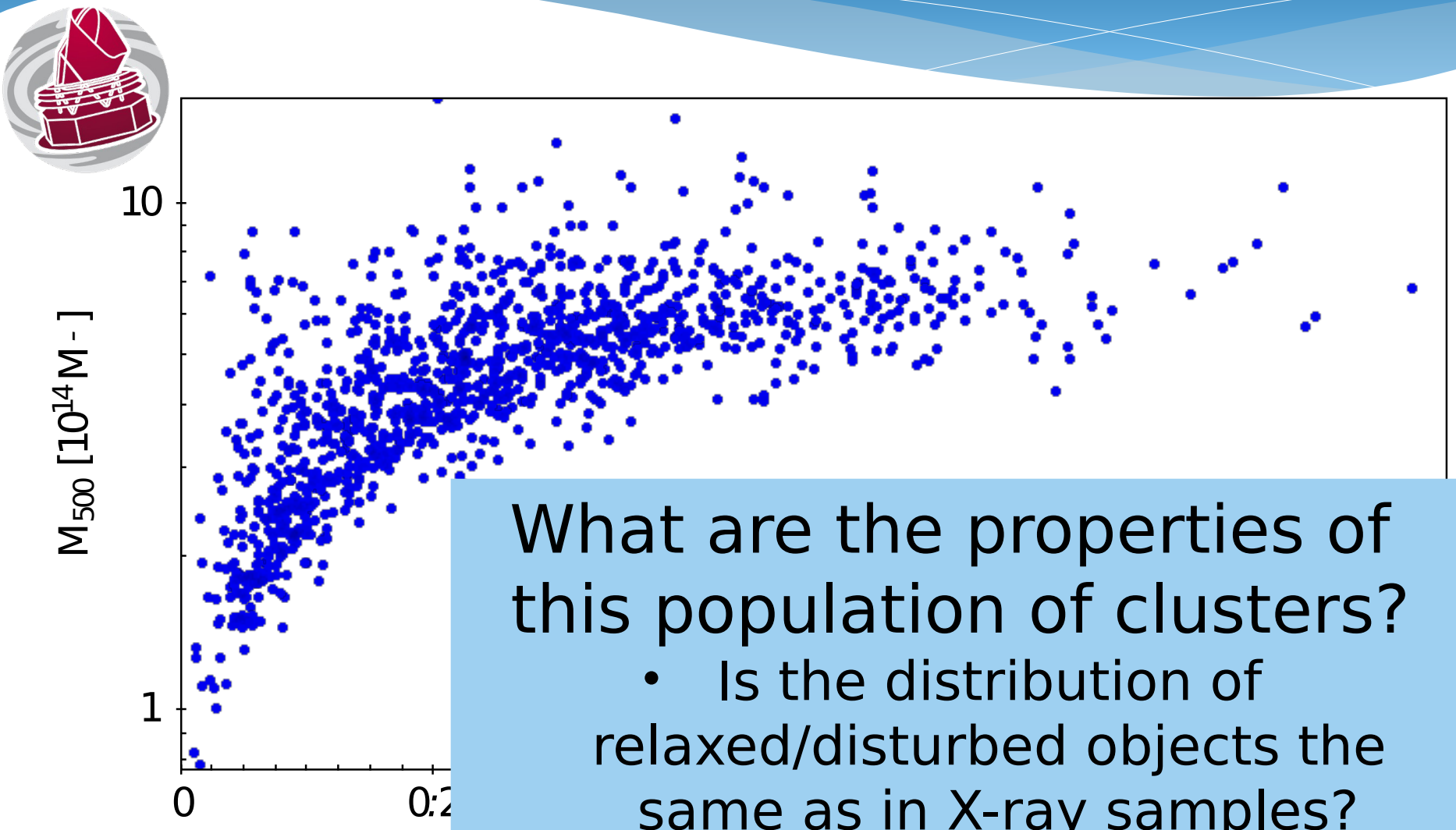
The Planck (clusters) legacy



1963 Sunyaev-Zeldovich sources in 3 catalogues

>1200 confirmed clusters (z measured)

The Planck (clusters) legacy



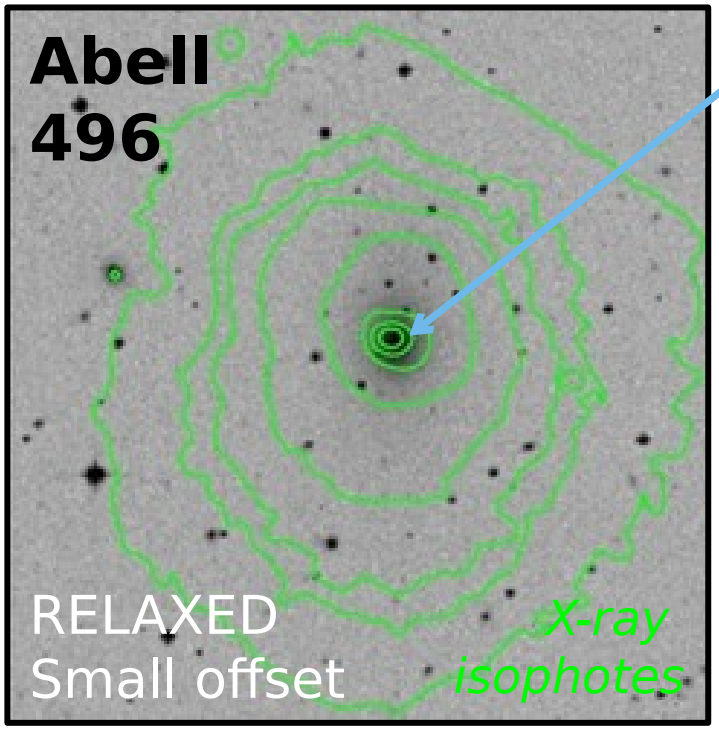
What are the properties of this population of clusters?

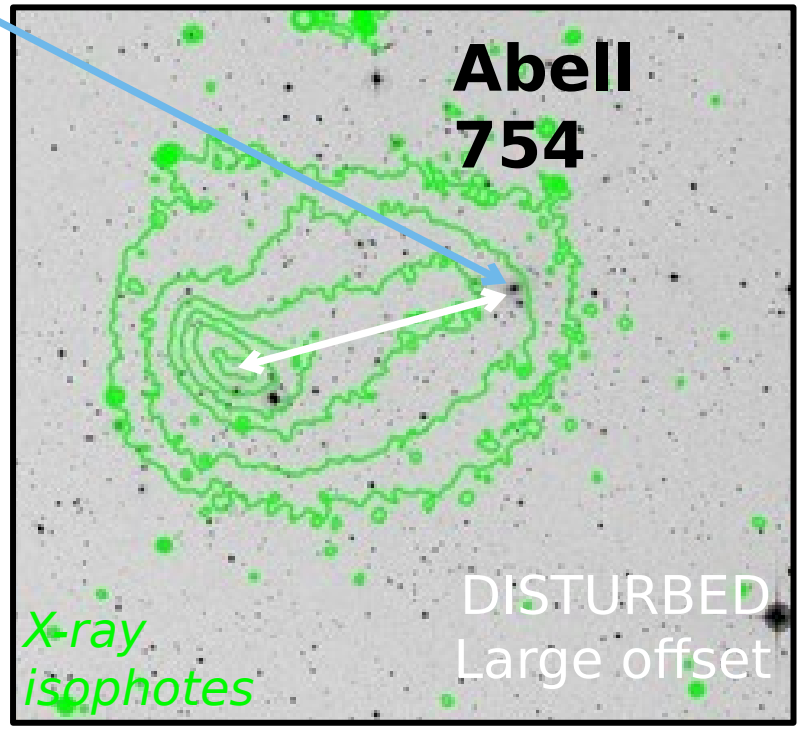
- Is the distribution of relaxed/disturbed objects the same as in X-ray samples?
- Do they obey the same scaling laws?

The dynamical state of Planck clusters

Offset between X-ray peak and BCG* position as a dynamical indicator *(Hudson et al 2010, Sanderson et al 2009, Mann & Ebeling 12)*

*BCG= Brightest Cluster Galaxy





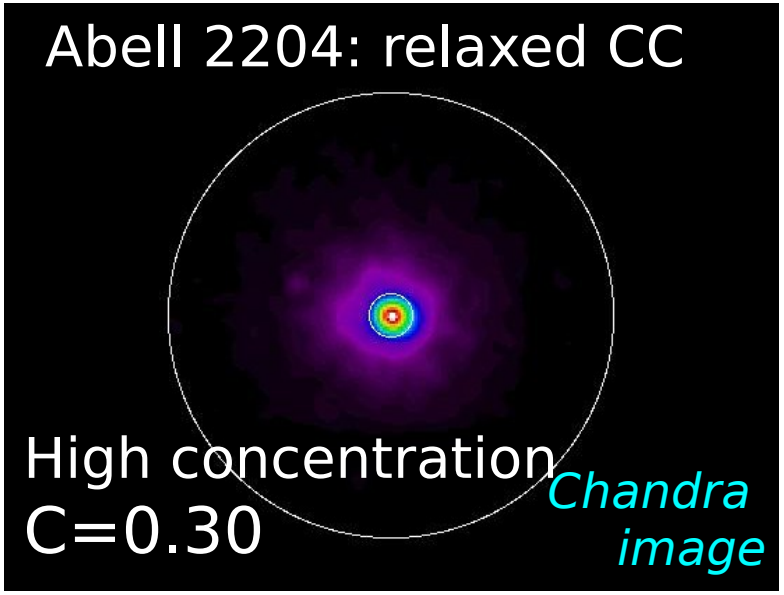
MR et al (2016) MNRAS 457, 4515

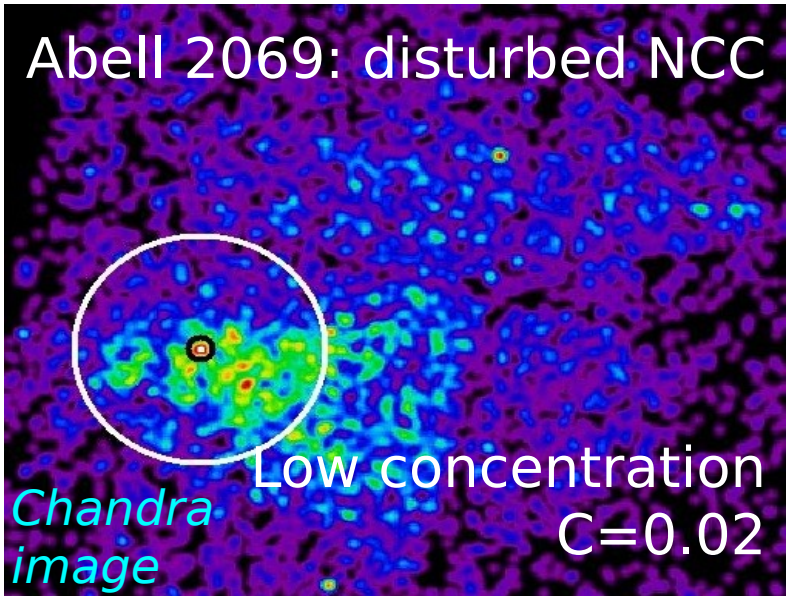
The dynamical state of Planck clusters

$$c = \frac{I(R < 40\ \mathrm{kpc})}{I(R < 400\ \mathrm{kpc})}$$

Concentration parameter as an indicator of cool core* and dynamical state *(Santos et al 08)*

*cool core (CC) = central regions of typically relaxed galaxy clusters featuring a prominent intensity peak, lower T, high metal abundance

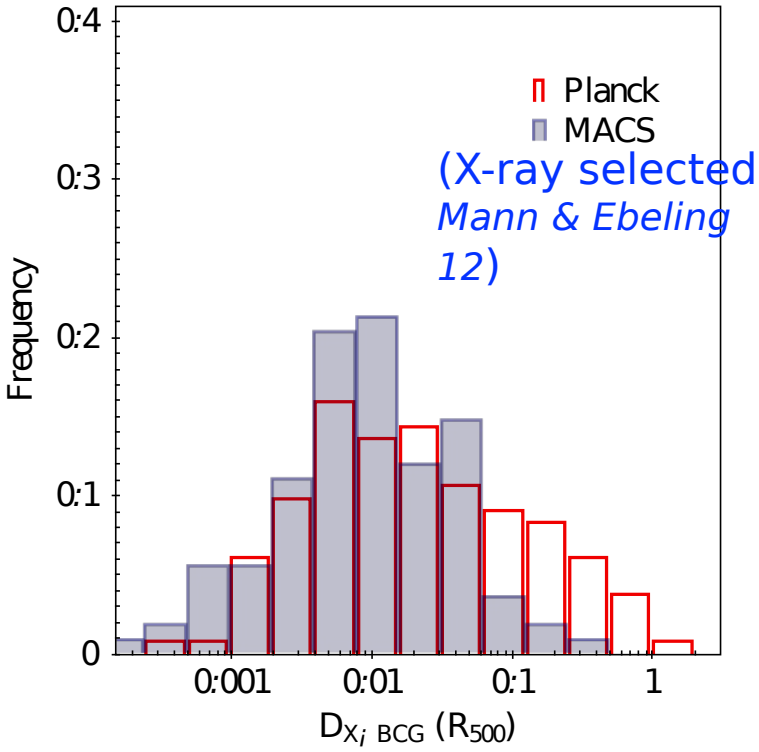




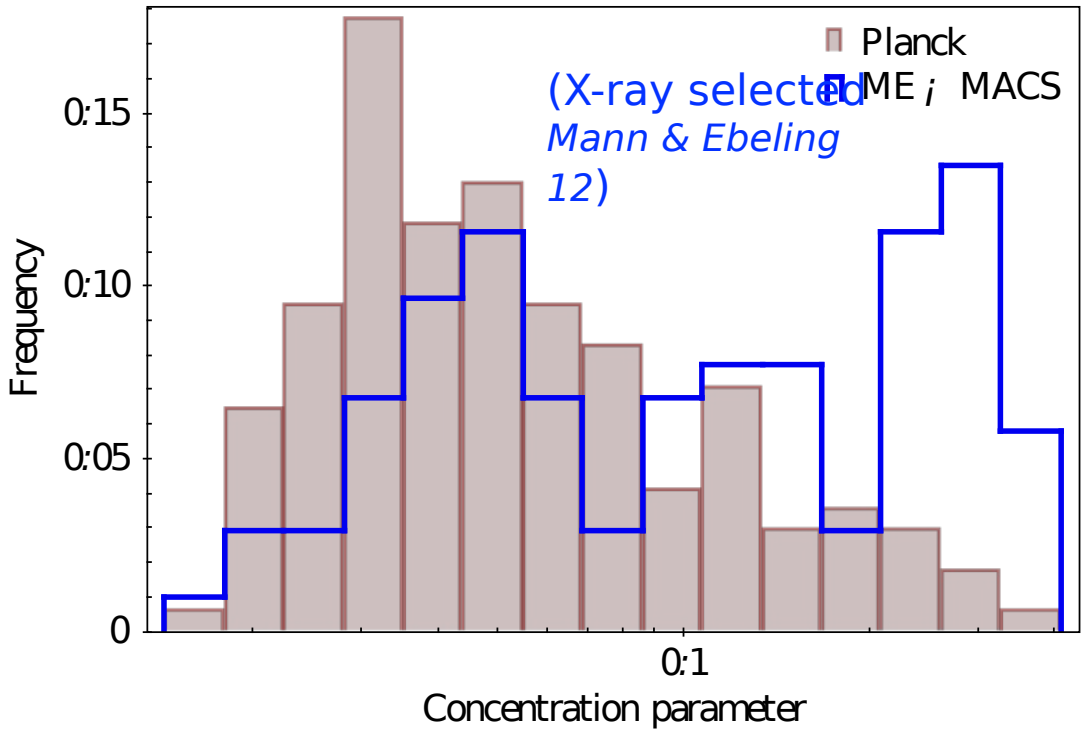
MR et al (2017) , MNRAS 468, 1917

The dynamical state of Planck clusters

MR et al (2016)

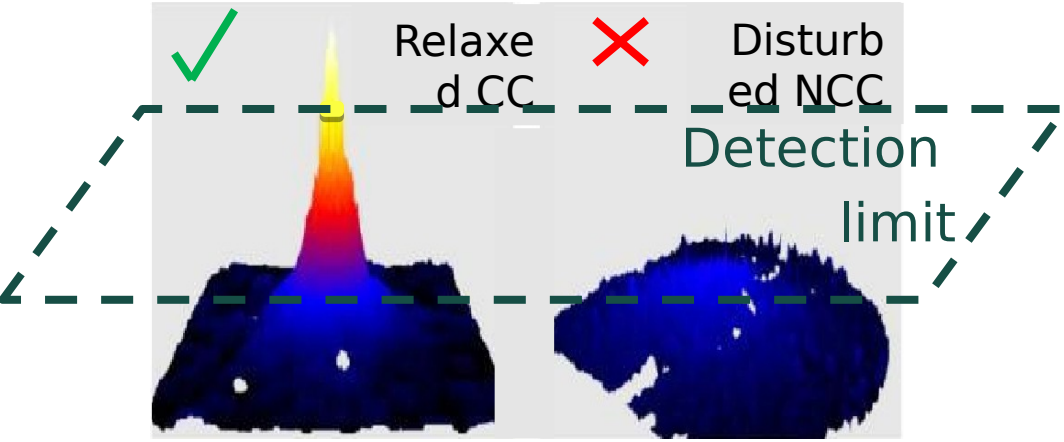


MR et al (2017)



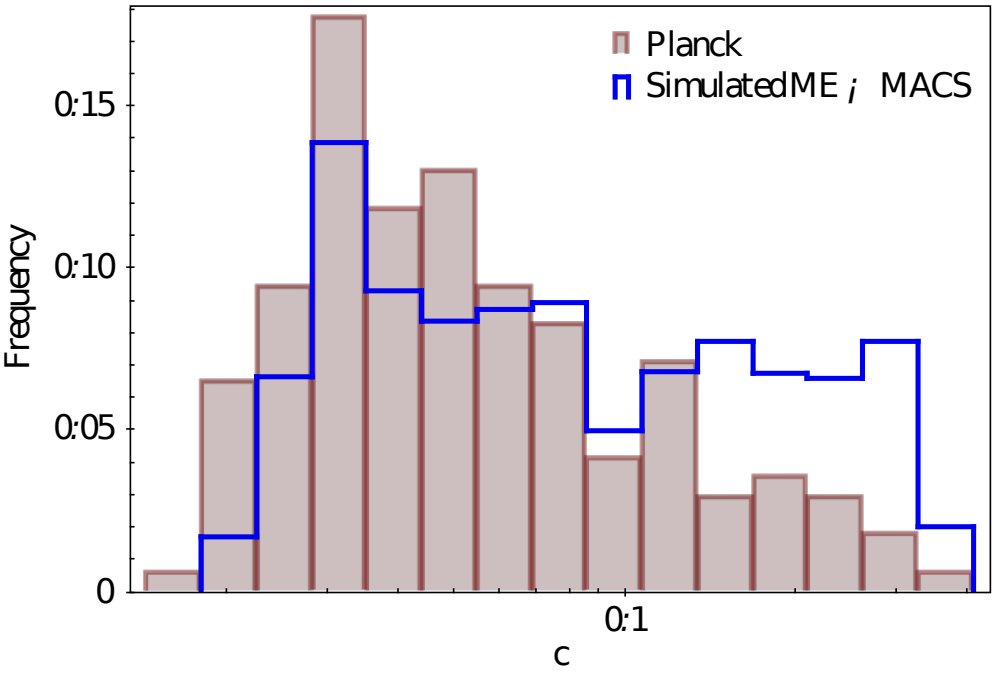
Significant differences in dynamical state of Planck-selected clusters with respect to X-ray based samples (see also Andrade-Santos et al 2017, Lovisari et al 2017): Selection effects in X-ray flux-limited surveys?

Simulating selection effects



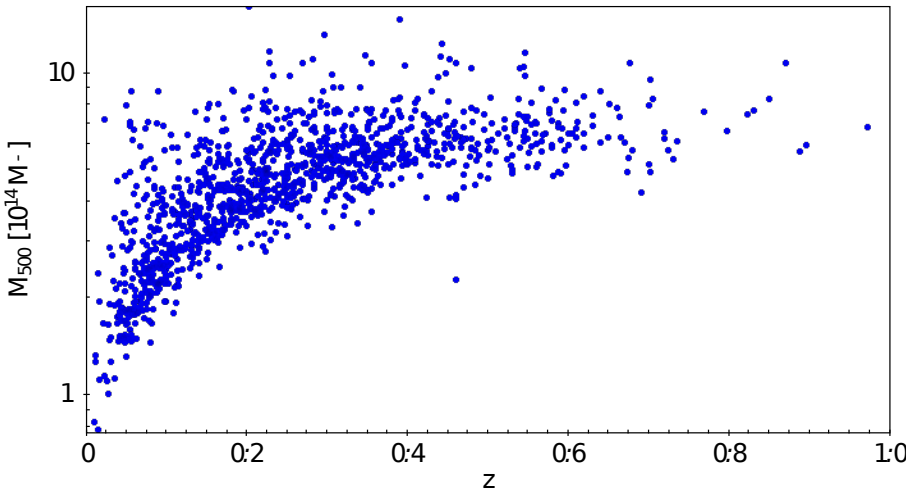
Relaxed CC clusters (peaked SB profile) are easier to detect in X-ray surveys:
CC-bias (e.g. Eckert+ 11)

MR et al (2017)



Simulations to reproduce CC-bias starting from a Planck-like sample:
Secondary CC peak emerges in simulated distribution
Difference largely due to CC bias

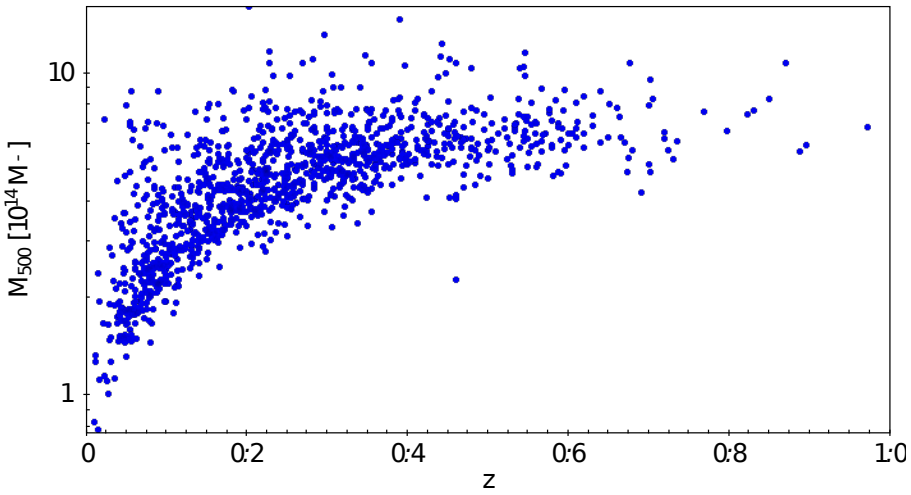
X-raying the Planck (clusters) legacy

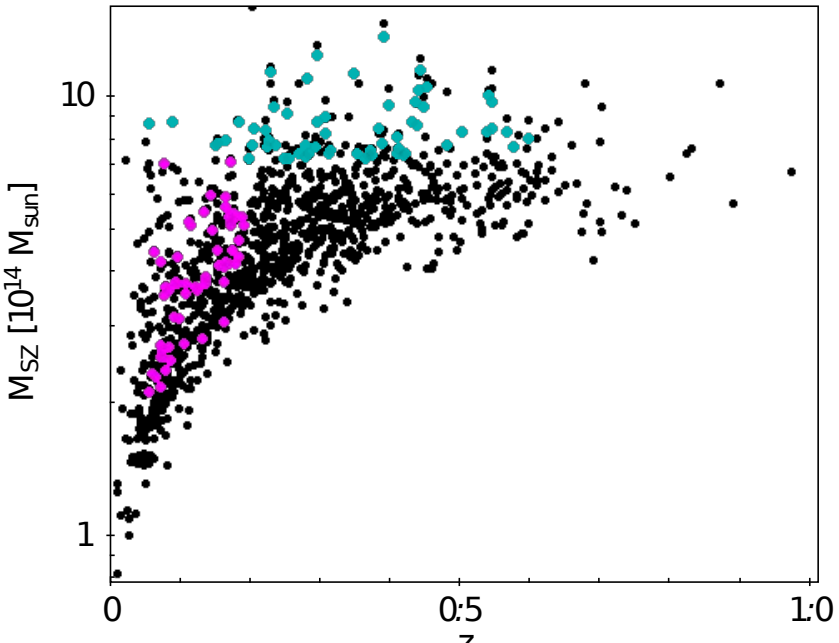


The population detected by Planck is **more representative** of the cluster population in the Universe than most X-ray samples.

We need X-ray obs. to study them

X-raying the Planck (clusters) legacy





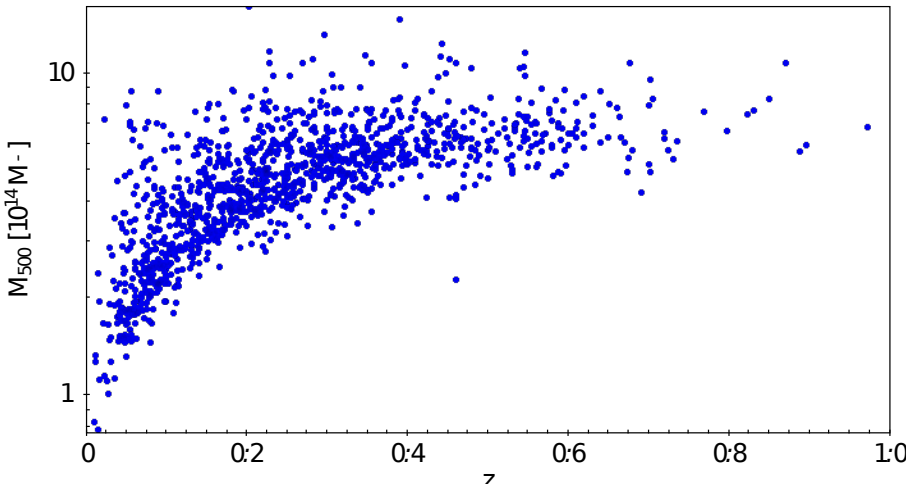
The population detected by Planck is **more representative** of the cluster population in the Universe than most X-ray samples.

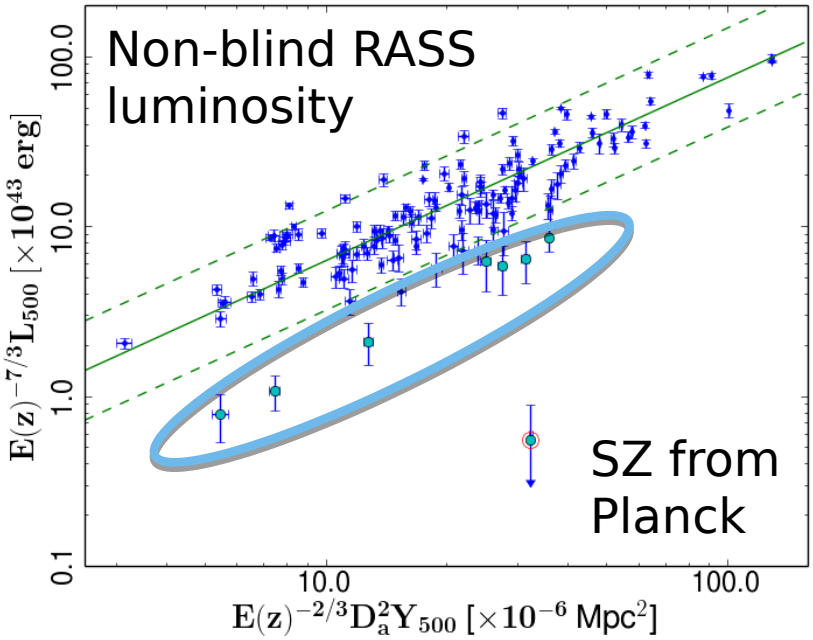
We need X-ray obs. to study them

Follow up observations of large well-defined subsamples.

An XMM-Newton Heritage program:
Witnessing the culmination of structure formation
P.I.s: M. Arnaud & S. Ettori
118 clusters, 3 Ms
See Stefano's talk and Lorenzo's poster

X-raying the Planck (clusters) legacy





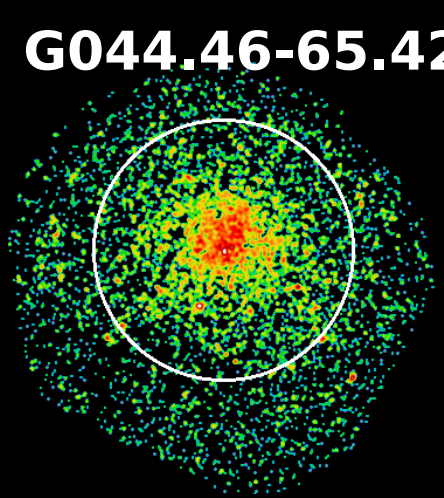
The population detected by Planck is **more representative** of the cluster population in the Universe than most X-ray samples.

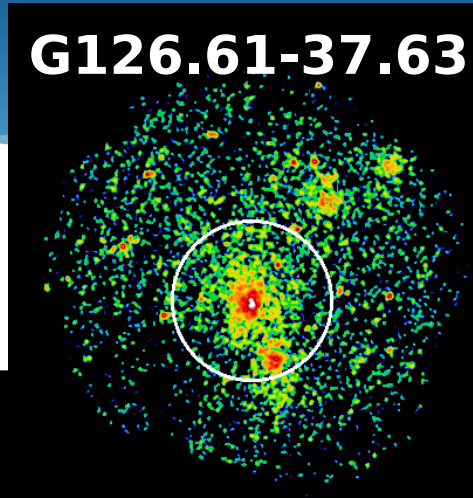
We need X-ray obs. to study them

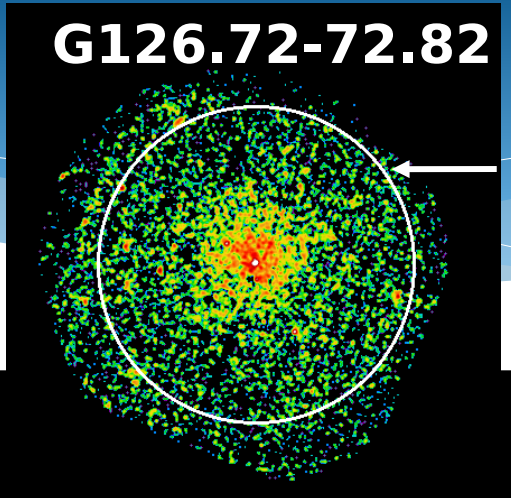
Follow up observations of interesting and peculiar objects, such as *outliers* in scaling relations

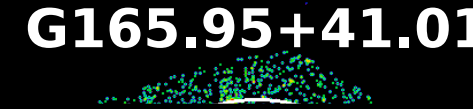
21 Candidate X-ray underluminous objects
(out of 473 clusters at z<0.2)

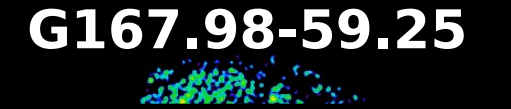
Planck 2015 Results.XXIV





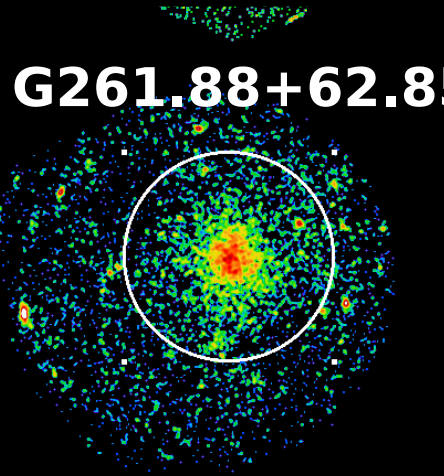


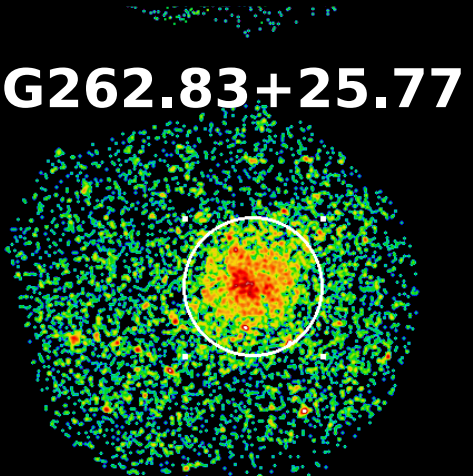


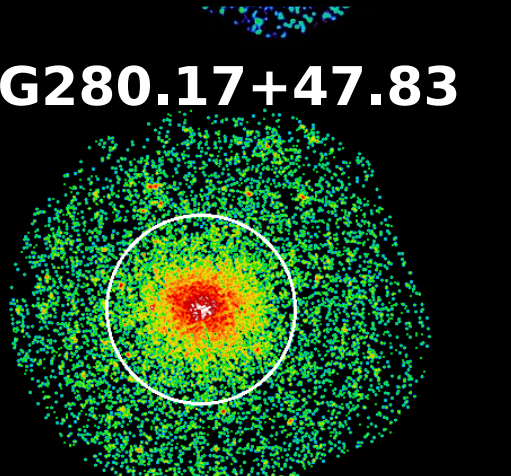


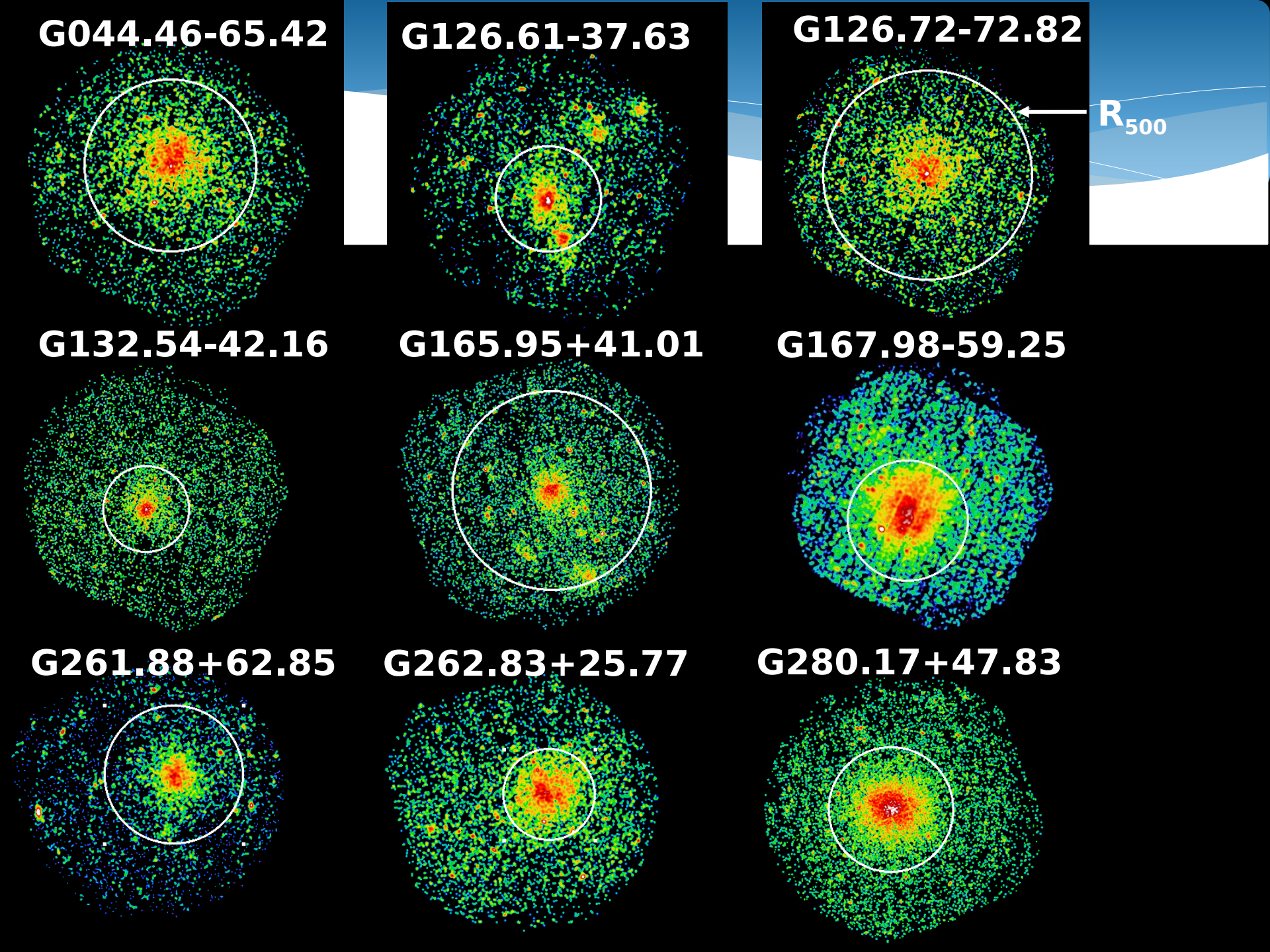
XMM-Newton short observations for 9/21 clusters

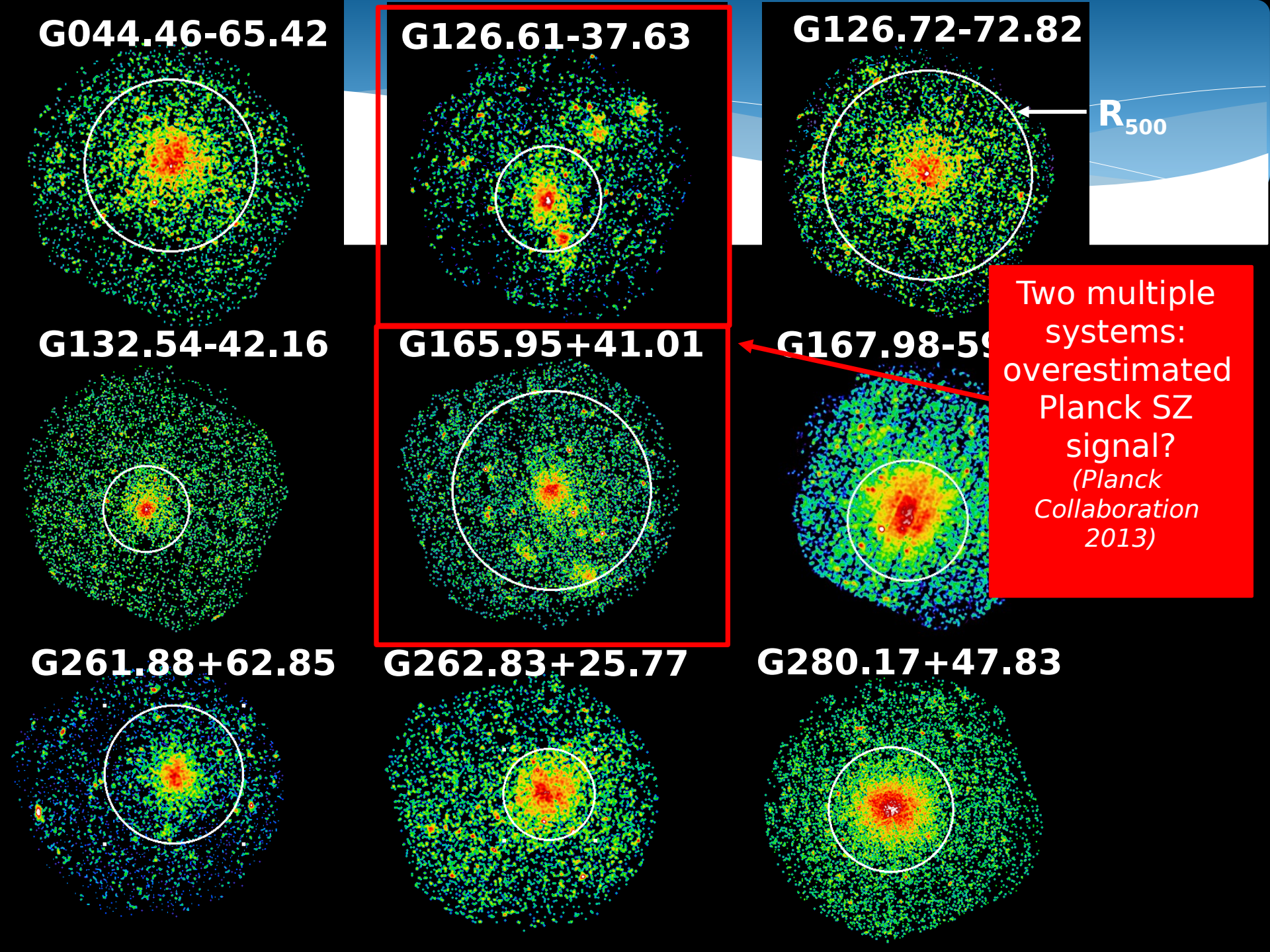
Very contaminated data!








G044.46-65.42
G126.61-37.63
G126.72-72.82
R500
G132.54-42.16
G165.95+41.01
G167.98-59.25
G261.88+62.85
G262.83+25.77
G280.17+47.83


G044.46-65.42
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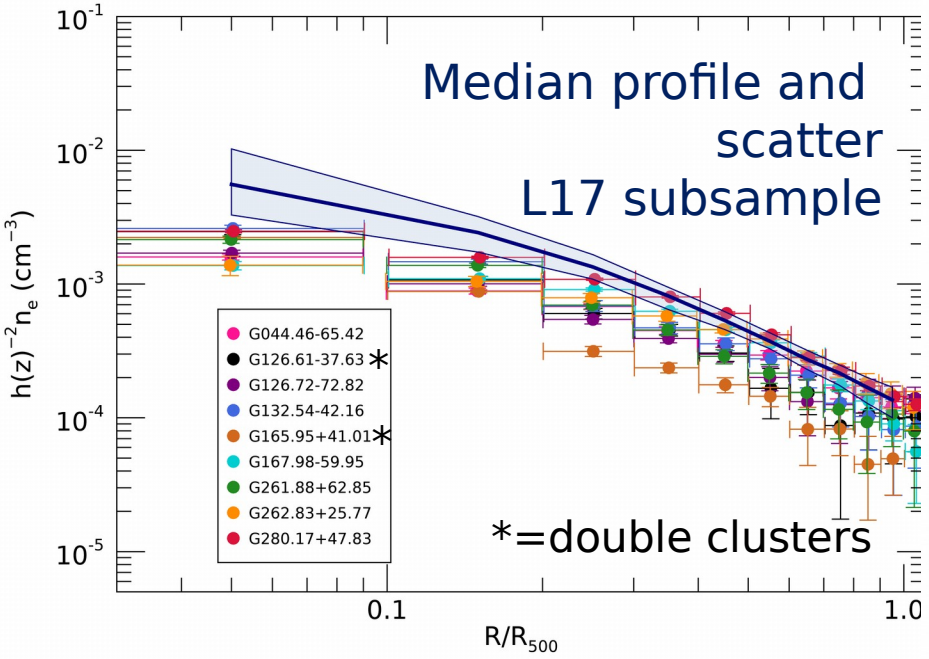
R500
G132.54-42.16
G165.95+41.01
G167.98-59
Two multiple systems: overestimated Planck SZ signal?
(Planck Collaboration 2013)
G261.88+62.85
G262.83+25.77
G280.17+47.83

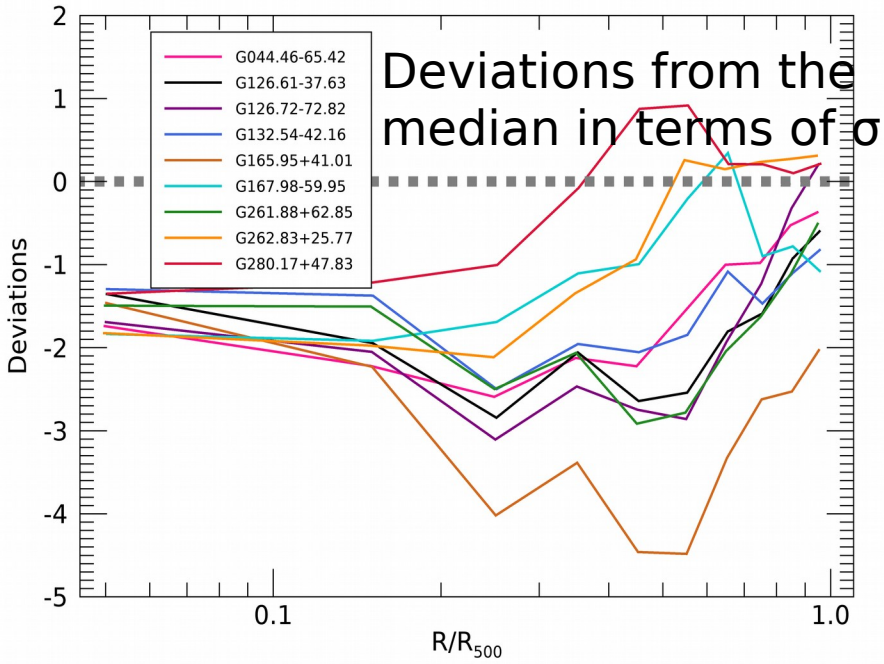
Density profiles

Need of a comparison sample:
representative, SZ-selected, analysed and scaled in the same way

Waiting for Heritage, quick subsample from Lovisari+17

PRELIMINARY





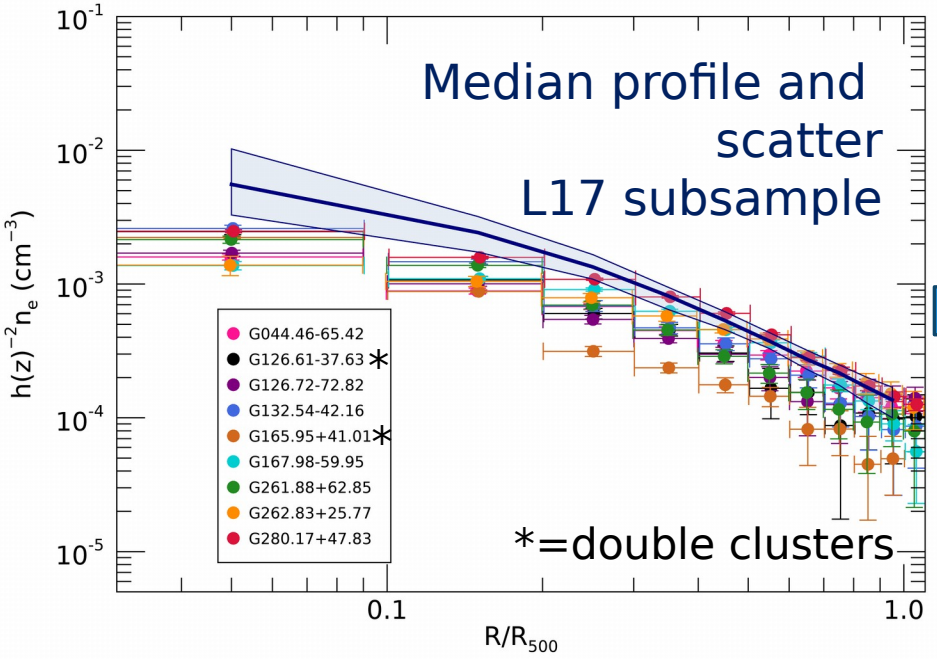
Most density profile lie below the median one at all radii, but deviations between 2-3 σ for ~4% of the population

Not significant outliers

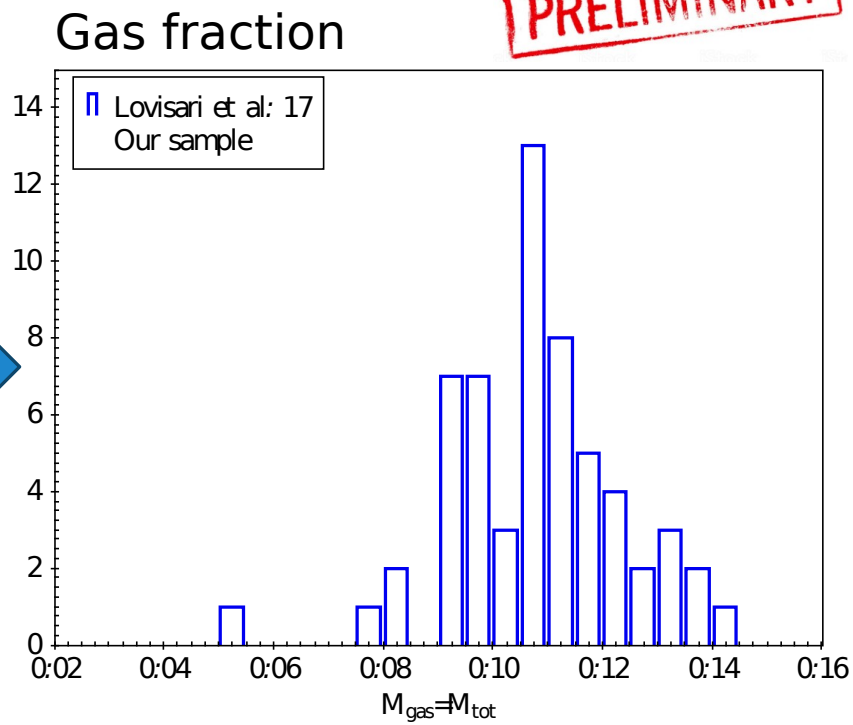
Density profiles

Need of a comparison sample:
representative, SZ-selected, analysed and scaled in the same way

Waiting for Heritage, quick subsample from Lovisari+17

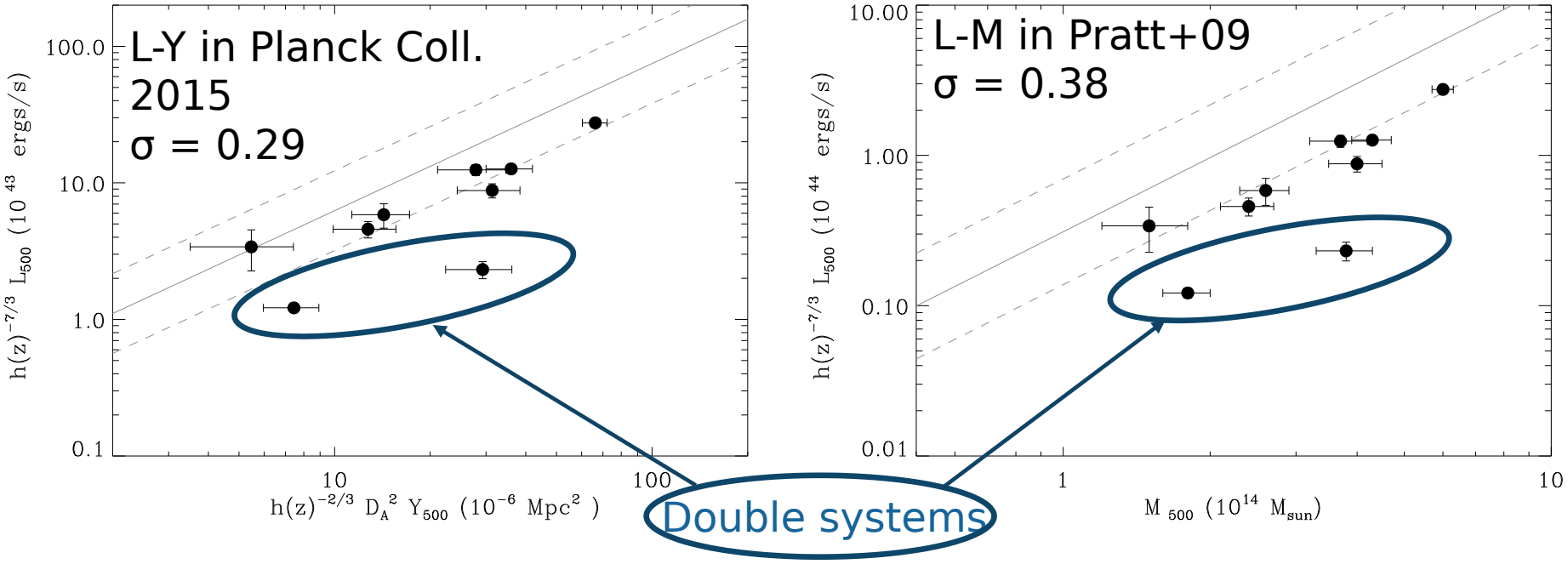


PRELIMINARY



Most density profile lie below the median one at all radii: gas poor systems but in the tail of the distribution

Scaling relations



Excluding double systems, consistent within 1-2σ with scaling relations

Not expected to produce a significant effect on cosmological results

Take home messages

- Difference in the clusters dynamical state in Planck and most X-ray selected samples, largely due to selection biases in X-rays
- Planck and SZ catalogues are a gold mine for cluster studies
- No indication of a ‘‘deviant’’ population from scaling relation

Backup slides

A selection bias in Planck?

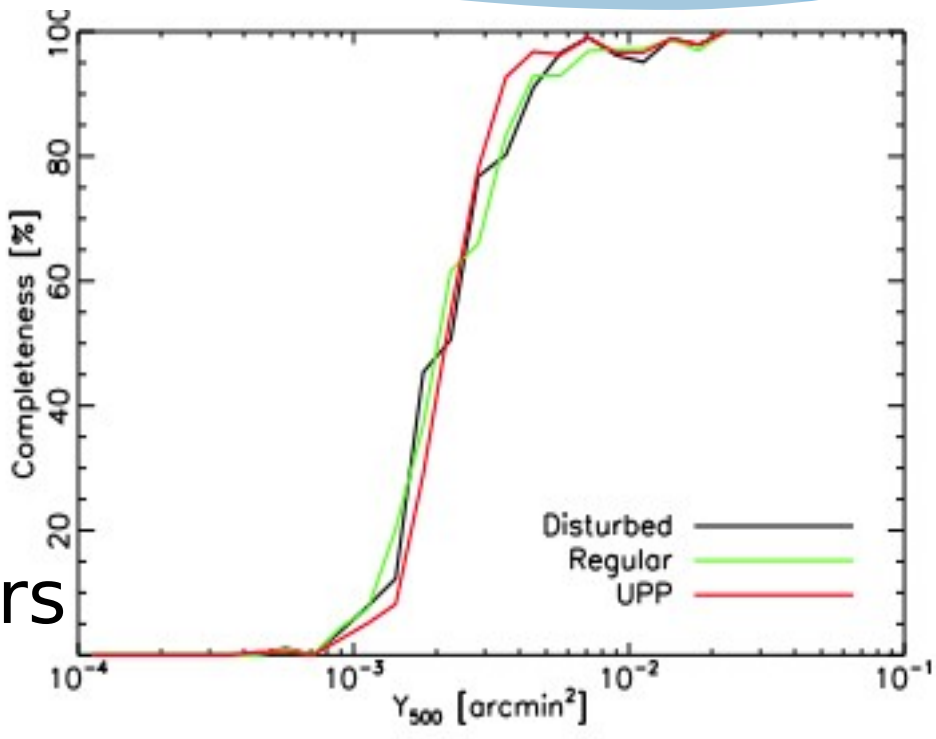
* **Is the Planck selection biased towards disturbed objects?**

Test with simulations:

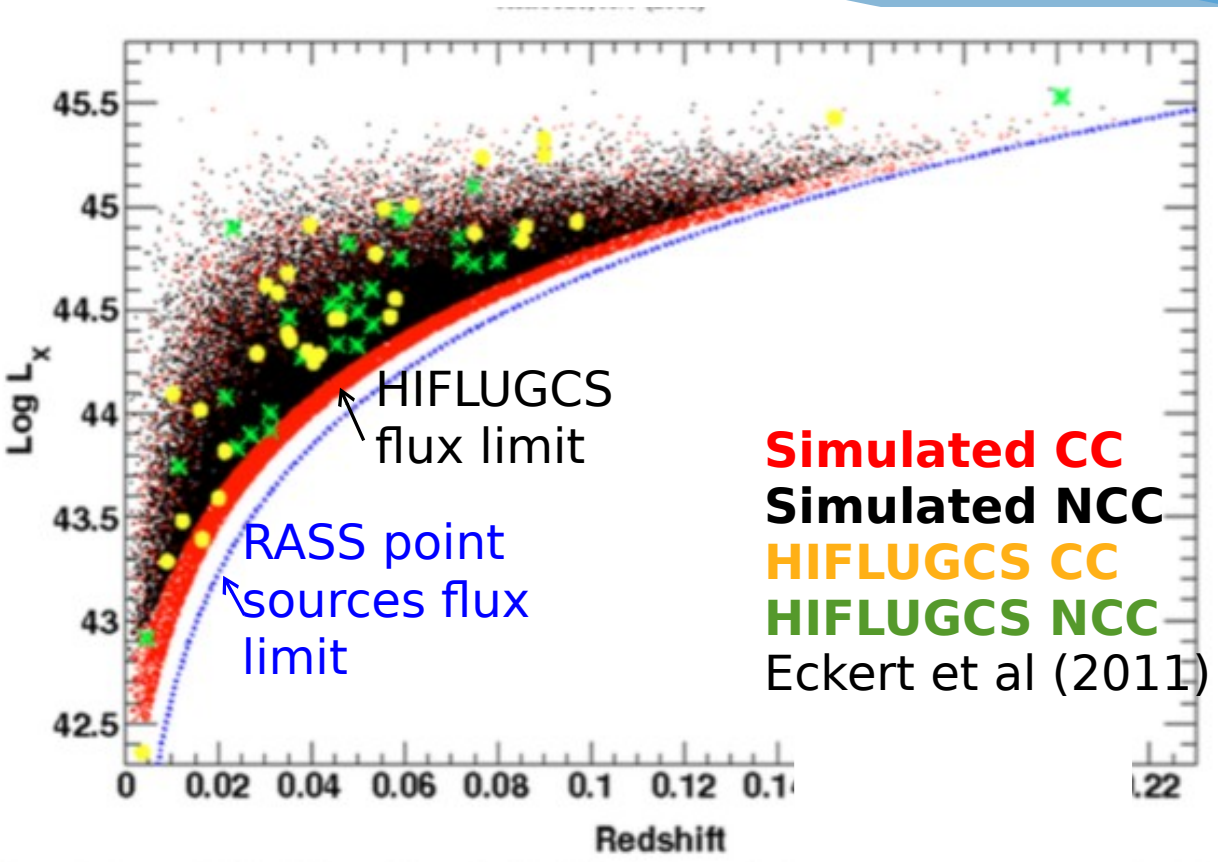
Injection of SZ maps of disturbed/relaxed clusters in simulated sky.

No significant differences in the selection function.

(Planck 2015 Results, XXVII)



Cool core bias



Simulations of CC bias from Eckert et al 2011

The effect is stronger close to the detection limit of the survey

It affects X-rays surveys ($I_x \approx n_e^2$,Pesce et al 1990,Eckert et al 2011) and is predicted to be small in SZ-surveys ($I_{SZ} \approx n_e$, Lin et al 2015, Pipino & Pierpaoli 2010), especially with Planck

SZ vs X-ray samples

Literature information on the BCG – Xray peak offset available for many samples, often with heterogeneous selection.

We compared only with purely X-ray selected samples

ME-MACS *(Mann & Ebeling 2012)*:

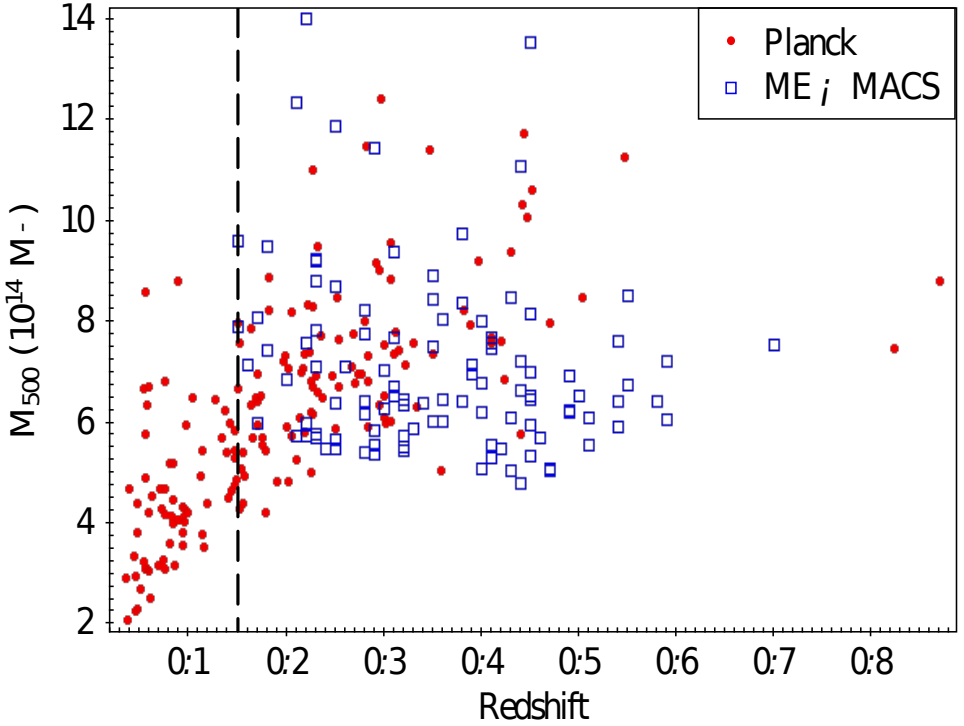
108, most massive high-z (>0.15) objects in RASS data

HIFLUGCS *(Zhang+, 2011)*:

62, Brightest X-ray clusters, local, low mass objects

REXCESS *(Haarsma+2010)*:

30, intermediate mass and z



MR et al (2016) MNRAS

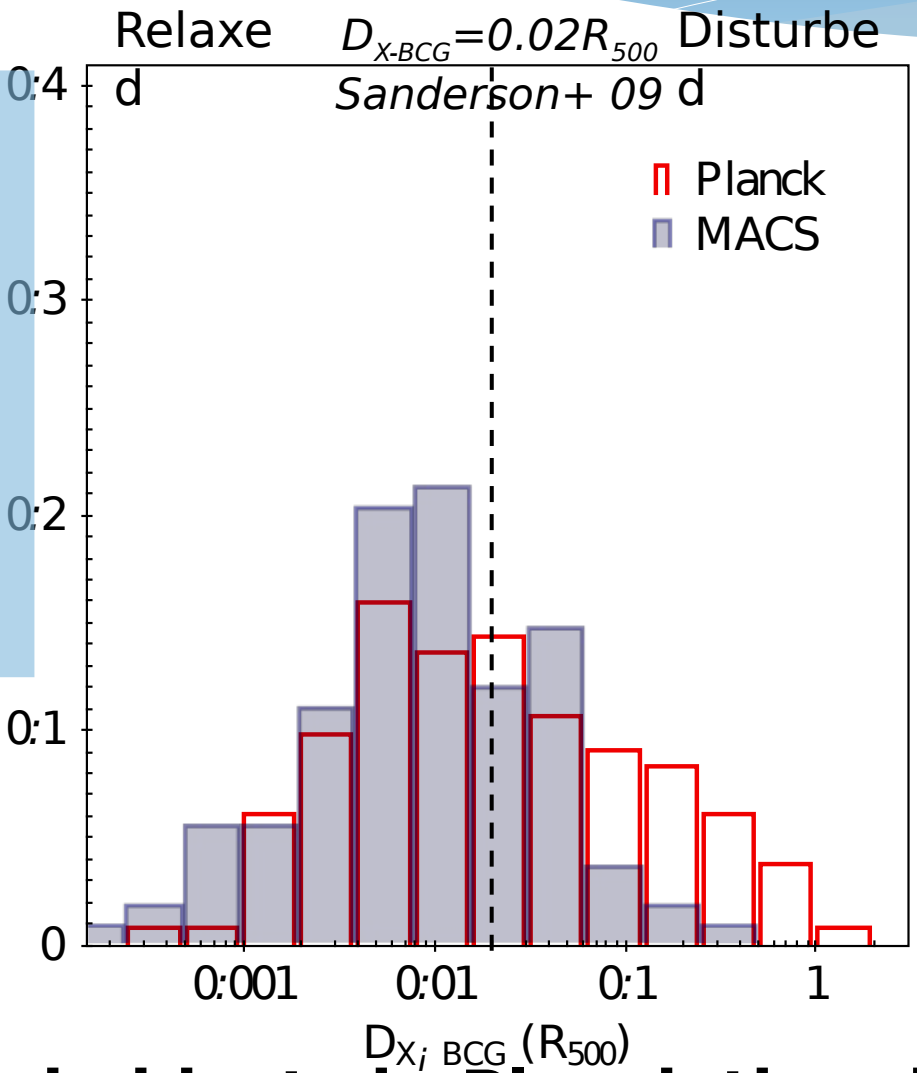
SZ vs X-ray samples

Kolmogorov-Smirnov test

KS Statistic=0.228

Null hypothesis probability=

0.4%



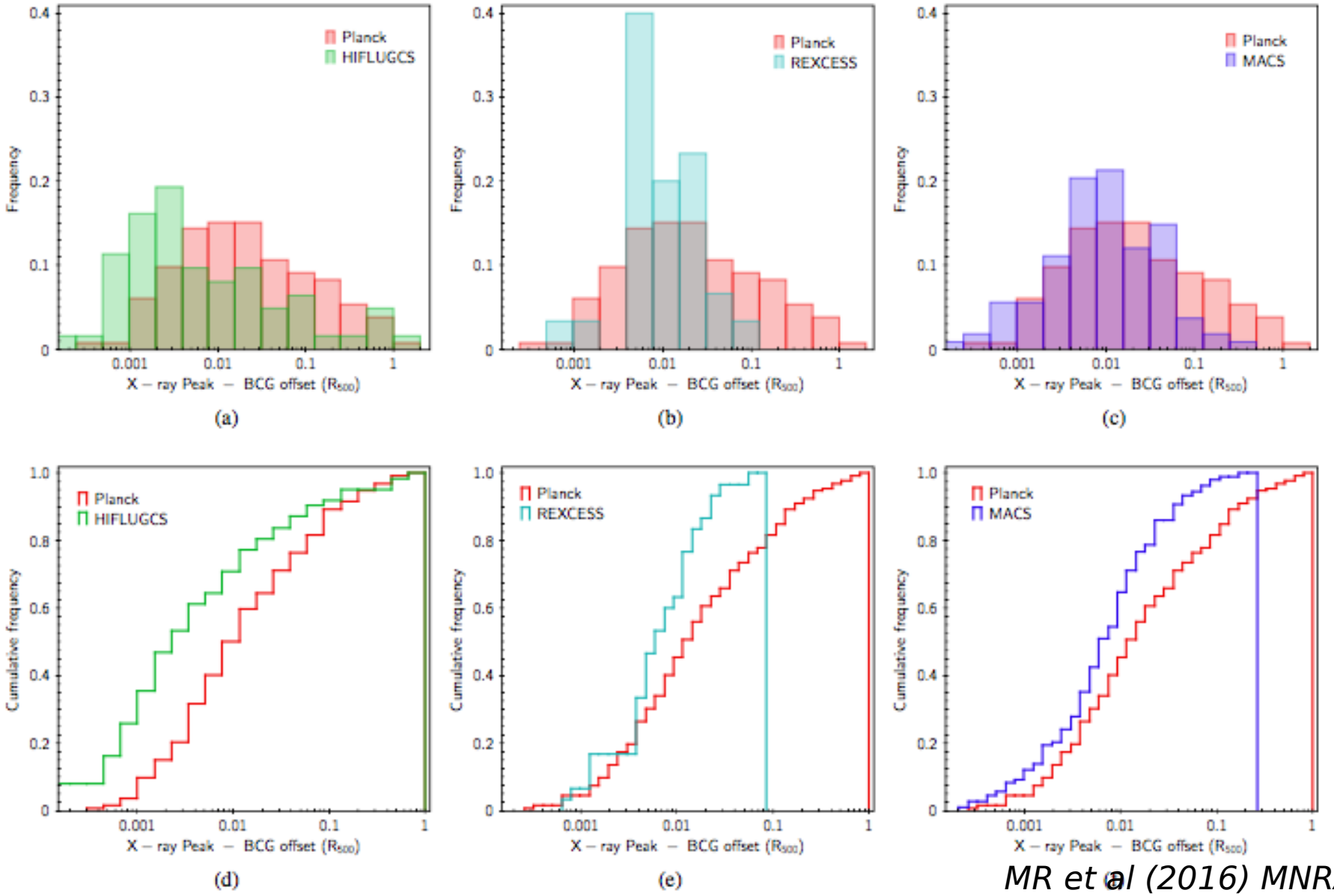
Relaxed fraction

Planck: 52±4%

ME-MACS: 73±4%

Fewer relaxed objects in Planck than in ME-MACS

Results



MR et al (2016) MNRAS