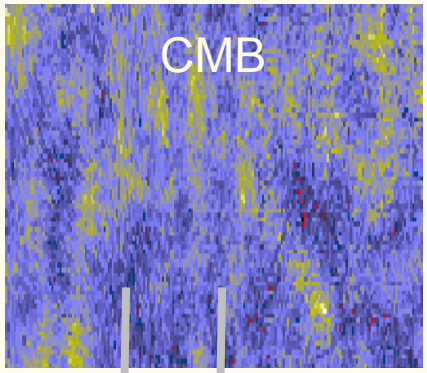
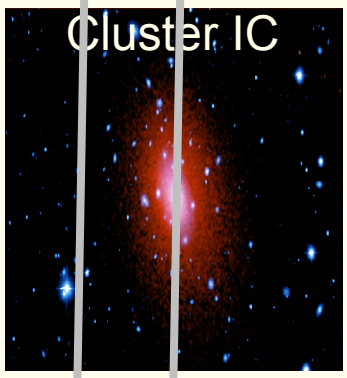
Overview of the SZ effect observed by Planck

Monique ARNAUD (CEA Saclay)
on behalf of The Planck Collaboration

X-rays obsevations and predicted SZ effect

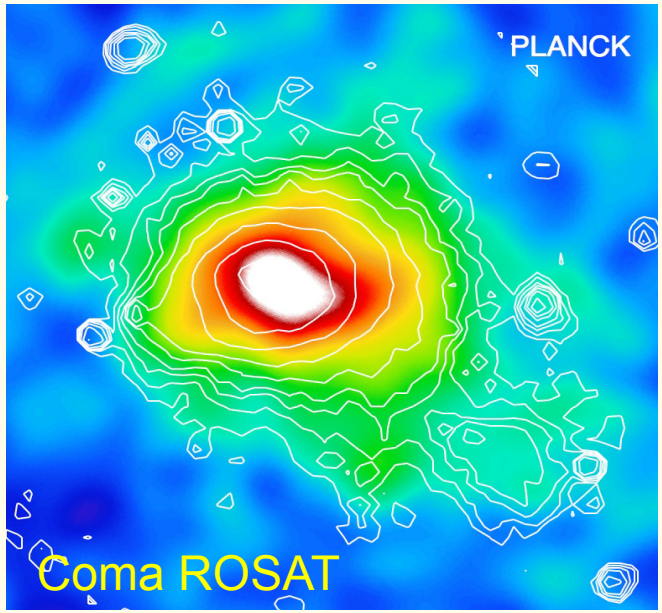
X-ray and SZ probing the same component





$$\Delta i_\nu \;\alpha\; y \;\alpha \int_{los} n_e T dl$$

$$E_X \;\alpha \int_{vol} n_e^2 \Lambda(T) dv$$

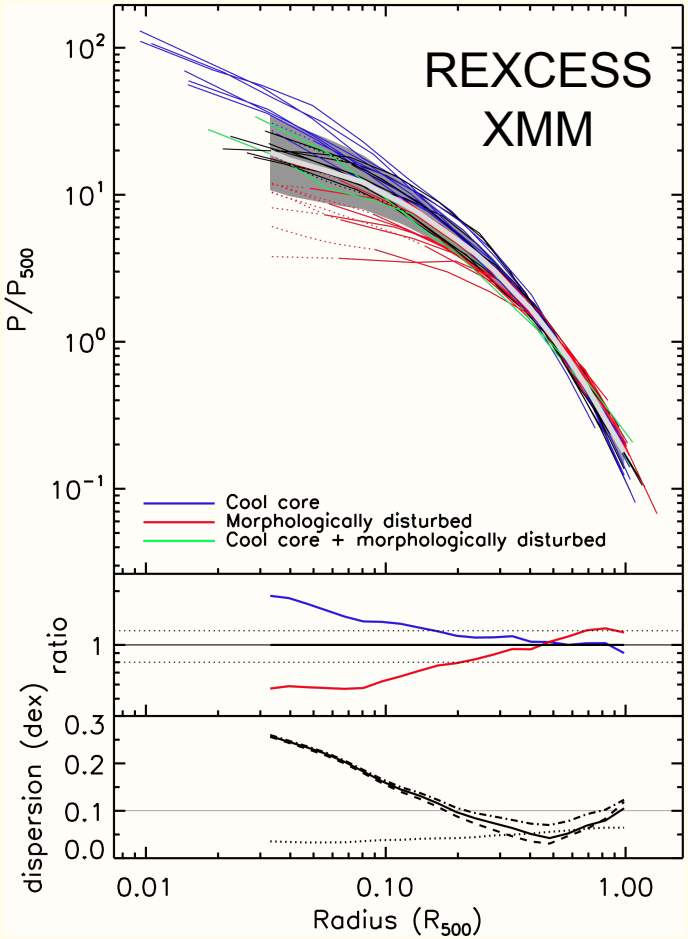


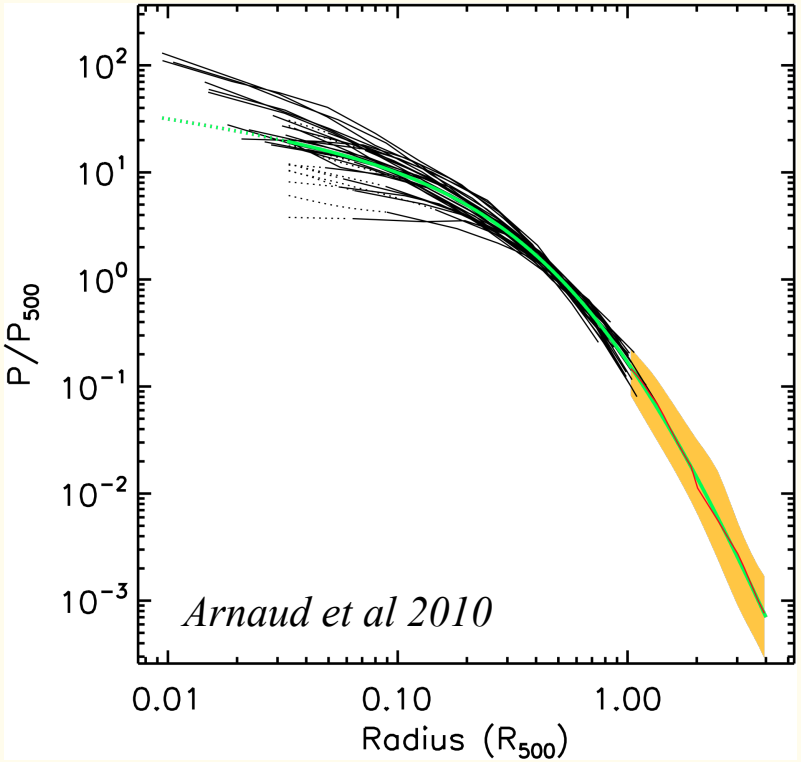
Relation between X and SZ properties expected

Predicting the SZ signal

$$\Delta i_\nu \;\alpha\; y \;\alpha \int_{los} n_e T dl$$

⇒ Pressure is the fundamental quantity



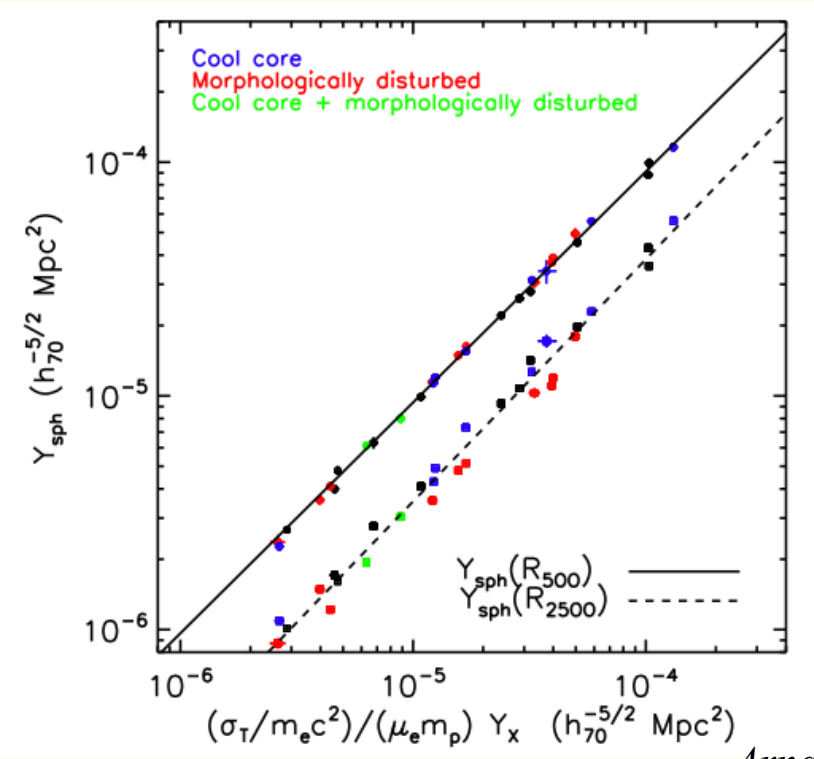


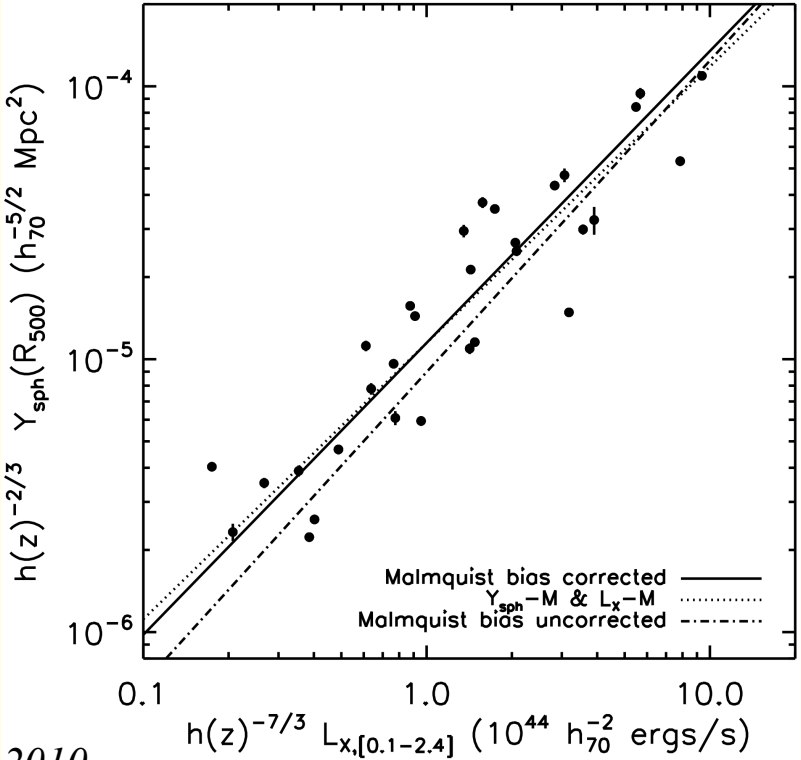
Universal pressure profile

$$Y_{SZ} \propto \int (P = neT) dV$$

$Y_X = M_{gas} T_X$ *[Kravtsov et al 06]*

$L_X = \int n_e^2 \, \Lambda(T) dV$





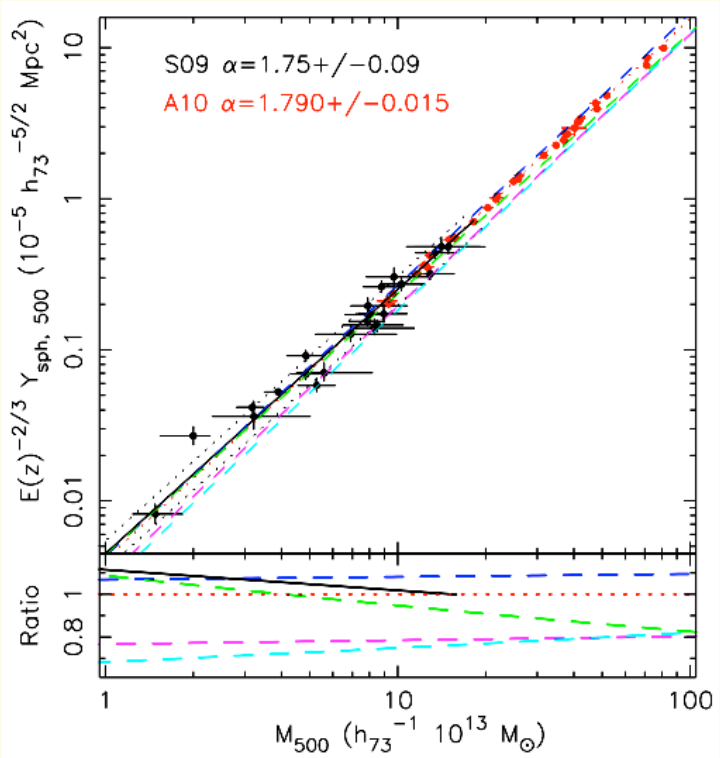
Arnaud et al 2010

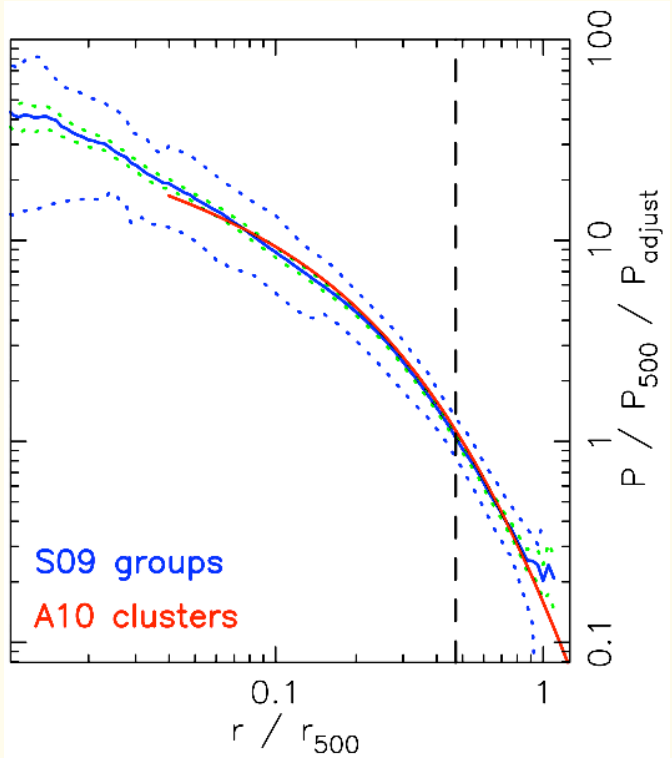
Tight Y_{SZ} –Y_X relation

depends on T_{mw}/T_X (+clumpiness)

Y_{SZ} - L_X relation with more scatter

Depends on density distribution

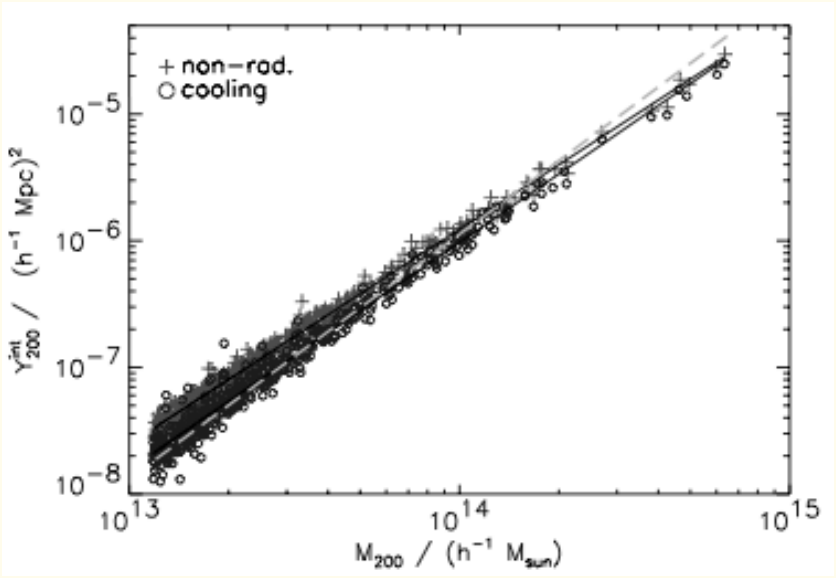




Sun et al 2011

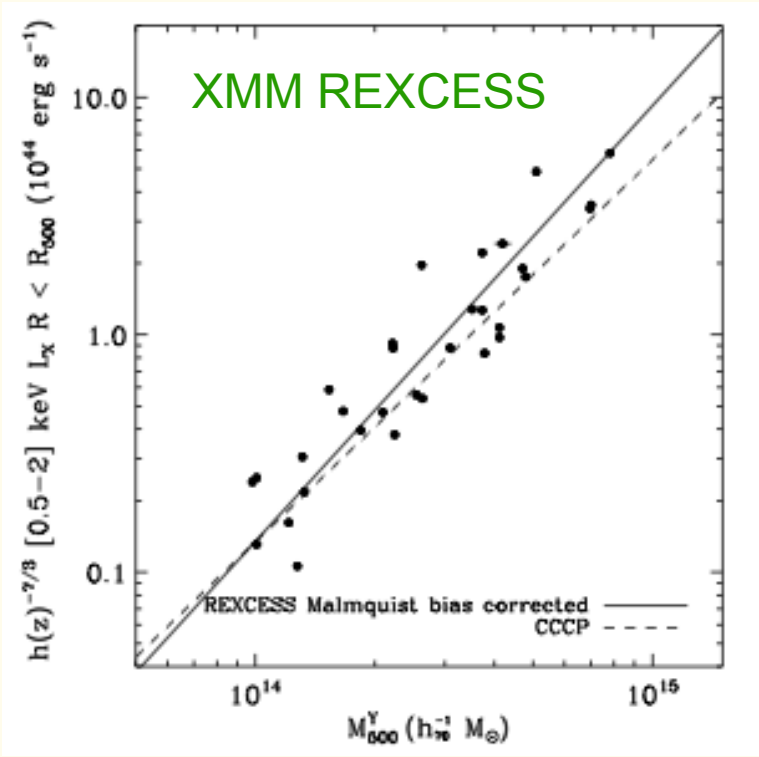
Scaling law and universal profile down to group regime

X-ray versus SZ selection



Da Silva et al, 2009

Y_{SZ} expected low scatter mass proxy



Pratt et al, 2009

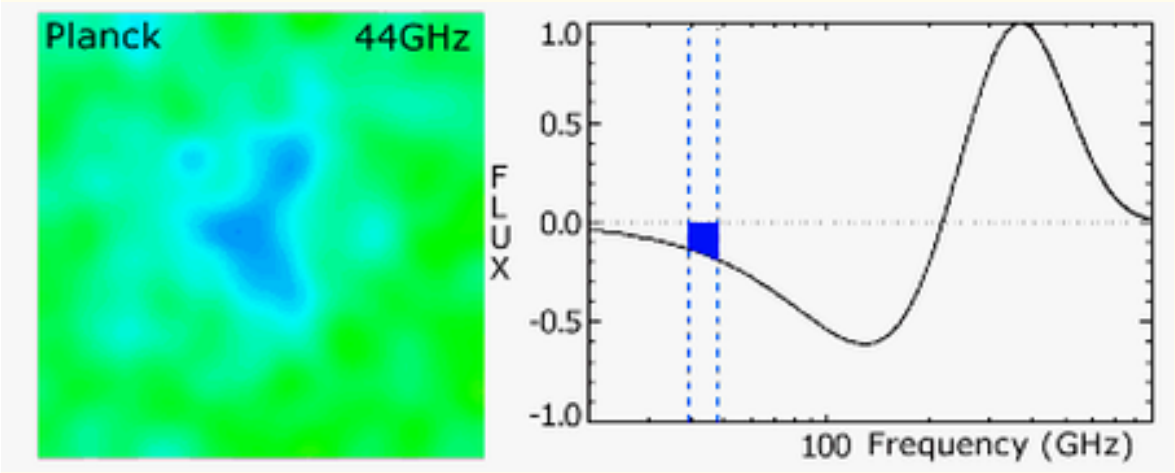
L_X high scatter mass proxy

SZ surveys expected to provide close to unbiaised mass selected samples

The Planck ESZ sample

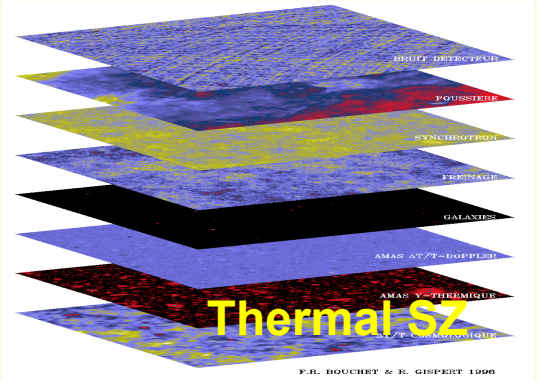
The Planck Collaboration, 2011, arXiv:1101.2024

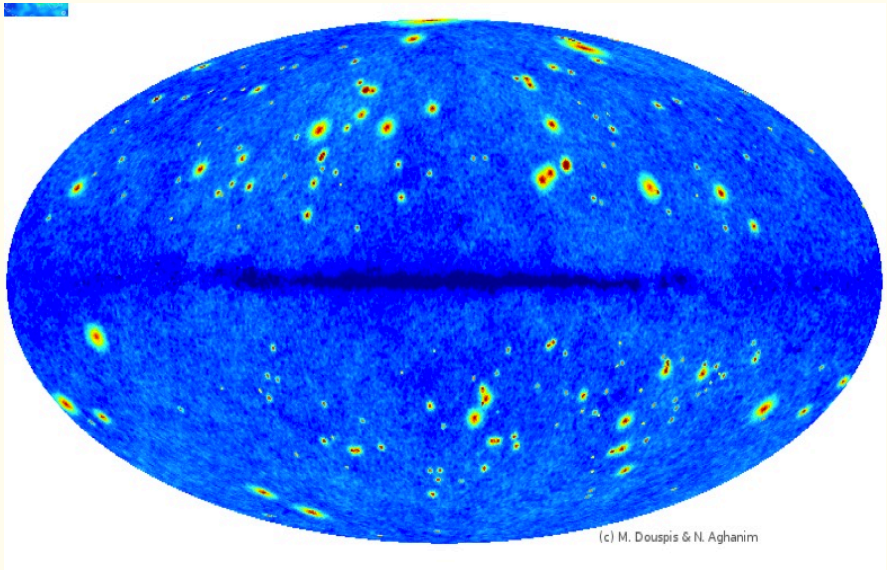
Planck's uniqueness for SZ detection



Plancl's frequency coverage on A2319

* 9 frequency bands from 30 to 857 GHz





* All sky survey

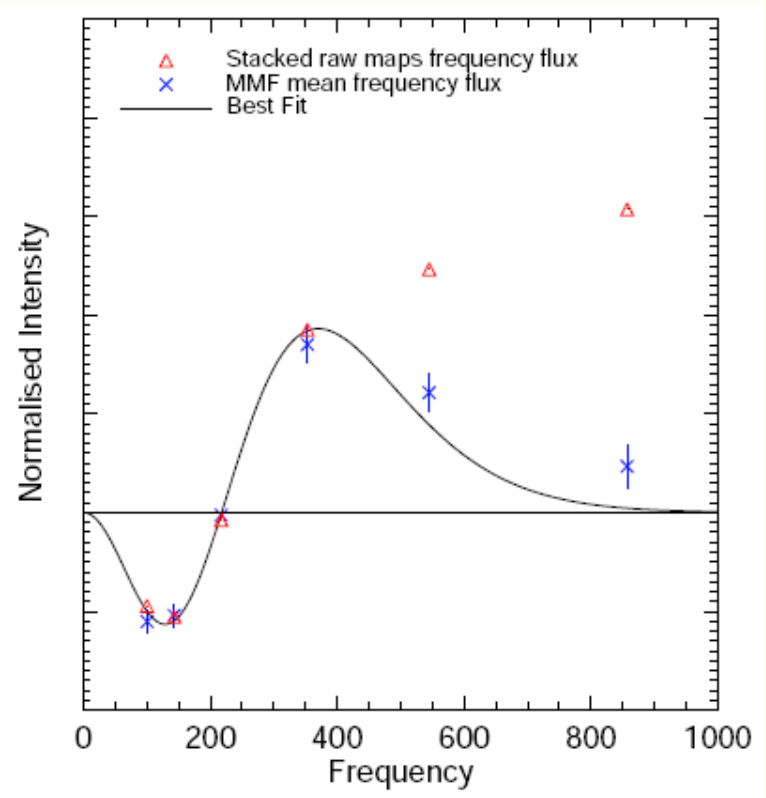
Unique catalogue ; only all sky cluster catalogue since RASS

Detection of clusters

ESZ based on Matched Multi-Filter algorithm [Melin et al. 2006]

- known spectral shape
  → non-relativistic SZ
- known cluster spatial distribution
  → GNFW pressure profile
  [Arnaud et al. 2010]

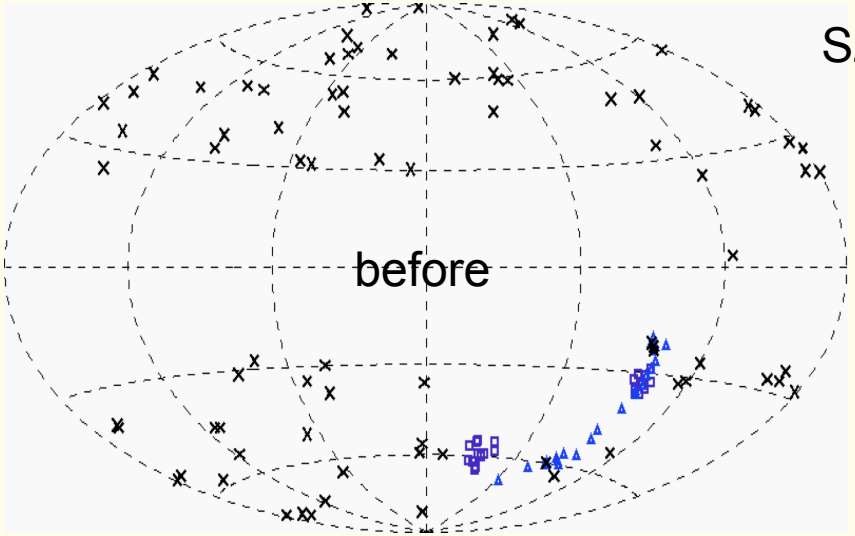
- free parameters: position, size, Y



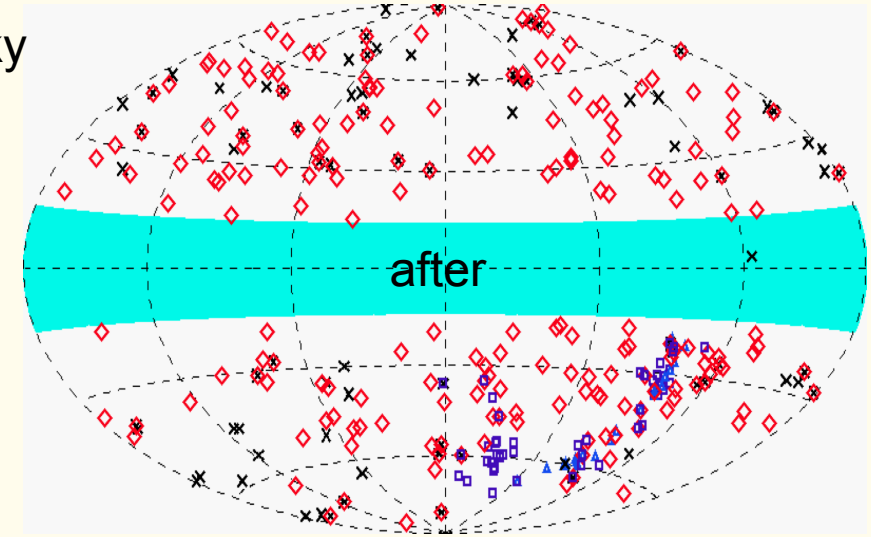
Thorough validation process

- Internal check
- X-check/ID with ancillary data
- XMM DDT validation

The ESZ catalog



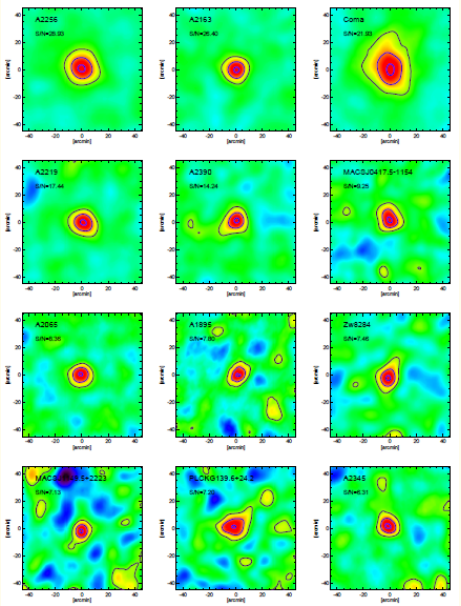
SZ sky

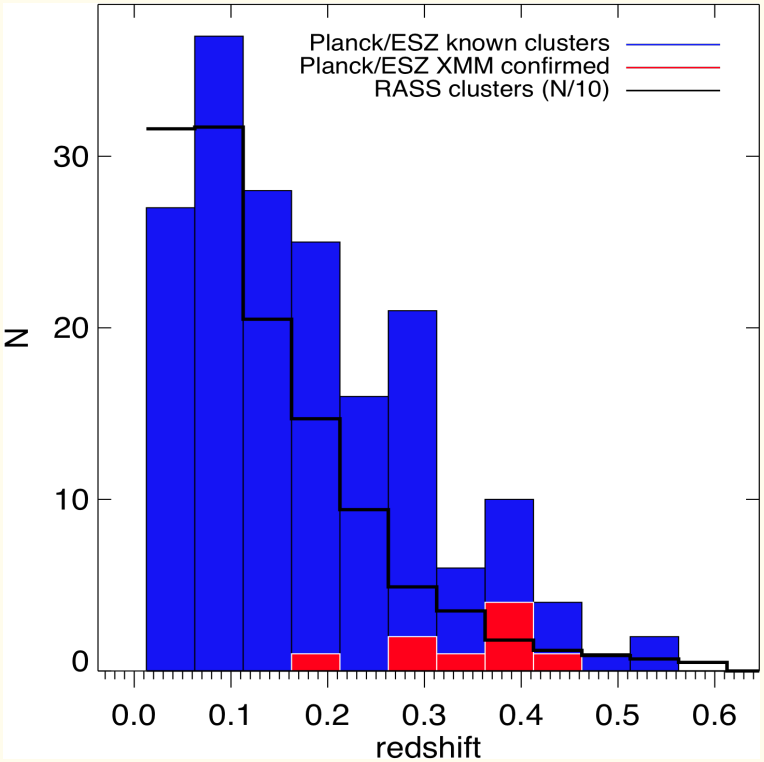


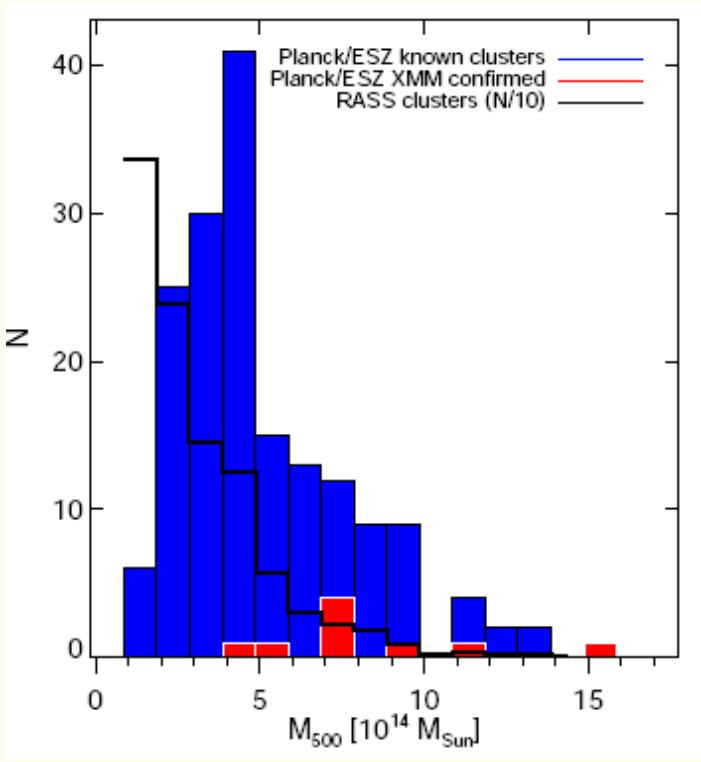
189 SZ sources with S/N > 6

- First SZ measure for ~80% of the known clusters
- 20 new clusters; 10 XMM + 1 AMI confirmed; 8 unconfirmed
  (now 6 confirmed with SPT & AMI)

⇒ Position & S/N for all clusters and candidates
⇒ Y from blind detection
⇒ Improved reextracted Y for clusters with known X-ray size







Higher mean z and M than RASS

detect rarest and most massive clusters over the whole sky

Planck view of the hot baryons

X-ray prediction versus SZ data

THE ASTROPHYSICAL JOURNAL, 648:176–199, 2006 September 1
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THE SUNYAEV-ZEL'DOVICH EFFECT IN A SAMPLE OF 31 CLUSTERS: A COMPARISON BETWEEN THE X-RAY PREDICTED AND *WMAP* OBSERVED COSMIC MICROWAVE BACKGROUND TEMPERATURE DECREMENT

RICHARD LIEU,[1] JONATHAN P. D. MITTAZ,[1] AND SHUANG-NAN ZHANG[1,2,3,4]
Received 2005 October 6; accepted 2006 April 30

ABSTRACT

The *WMAP* Q-, V-, and W-band radial profiles of temperature deviation of the cosmic microwave background (CMB) were constructed for a sample of 31 randomly selected nearby clusters of galaxies in directions of Galactic latitude $|b| > 30°$. The profiles were compared in detail with the expected CMB Sunyaev-Zel'dovich effect (SZE) caused by these clusters, with the hot gas properties of each cluster inferred observationally by applying gas temperatures as measured by *ASCA* to isothermal β-models of the *ROSAT* X-ray surface brightness profiles, with the *WMAP* point-spread function fully taken into consideration. After co-adding the 31 cluster fields to significantly reduce the systematic and random uncertainties, it appears that *WMAP* detected the SZE in all three bands. Quantitatively, however, the observed SZE only accounts for about 1/4 of the expected decrement. The discrepancy represents too much unexplained extra flux: in the W band, the detected SZE corresponds on average to 5.6 times less X-ray gas mass within a 10′ radius than the mass value given by the *ROSAT* β-model. We critically examined how the X-ray prediction of the SZE may depend on our uncertainties in the density and temperature of the hot intracluster plasma, and emission by cluster radio sources. Although our comparison between the detected and expected SZE levels is subject to a margin of error, the fact remains that the average observed SZE depth and profile are consistent with those of the primary CMB anisotropy, i.e., the overall *WMAP* temperature decrement among the 31 rich clusters is too shallow to necessitate an interpretation in terms of an additional effect like the SZE. A unique aspect of this SZE investigation is that because all the data being analyzed are in the public domain, our work is readily open to scrutiny by others.

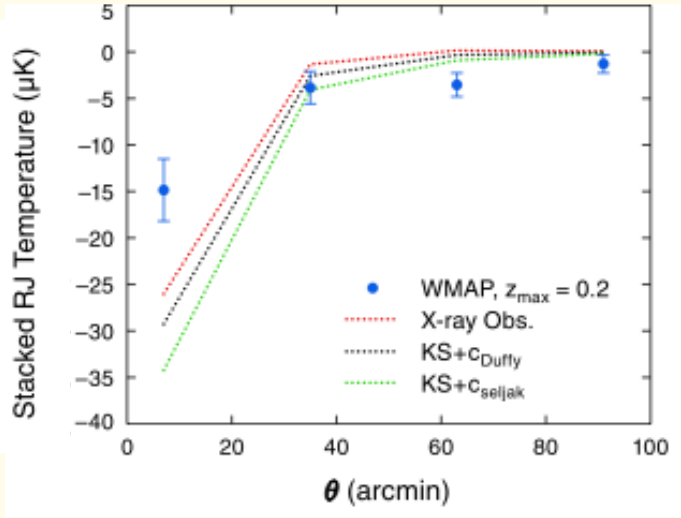
ACCEPTED FOR PUBLICATION IN THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES
Preprint typeset using LaTeX style emulateapj v. 11/10/09

SEVEN-YEAR WILKINSON MICROWAVE ANISOTROPY PROBE (*WMAP*[1]) OBSERVATIONS: COSMOLOGICAL INTERPRETATION

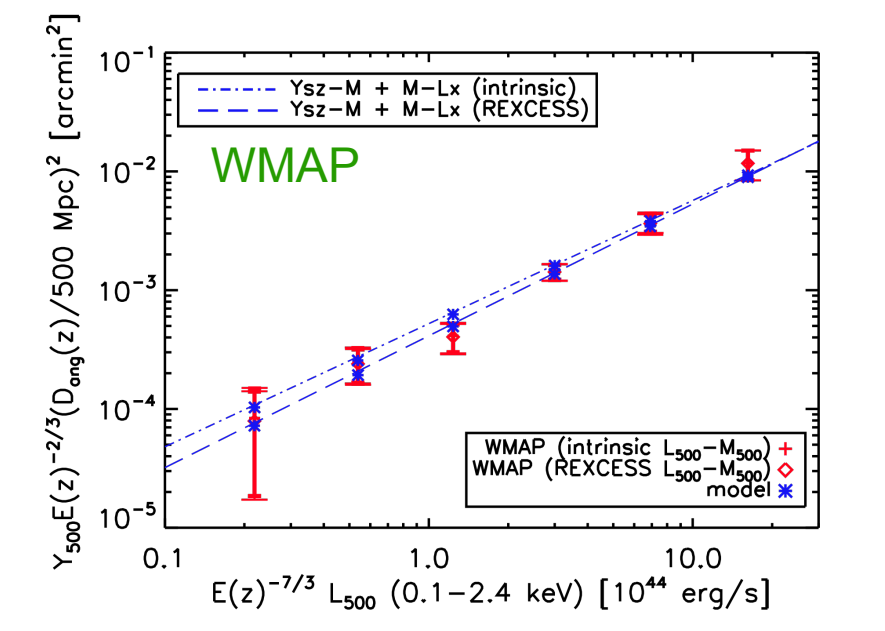
E. KOMATSU[2], K. M. SMITH[3], J. DUNKLEY[4], C. L. BENNETT[5], B. GOLD[5], G. HINSHAW[6], N. JAROSIK[7], D. LARSON[5], M. NOLTA[8], L. PAGE[7], D. N. SPERGEL[3,9], M. HALPERN[10], R. S. HILL[11], A. KOGUT[6], M. LIMON[12], S. S. MEYER[13], N. ODEGARD[11], G. S. TUCKER[14], J. L. WEILAND[11], E. WOLLACK[6], AND E. L. WRIGHT[15]

Accepted for Publication in the Astrophysical Journal Supplement Series

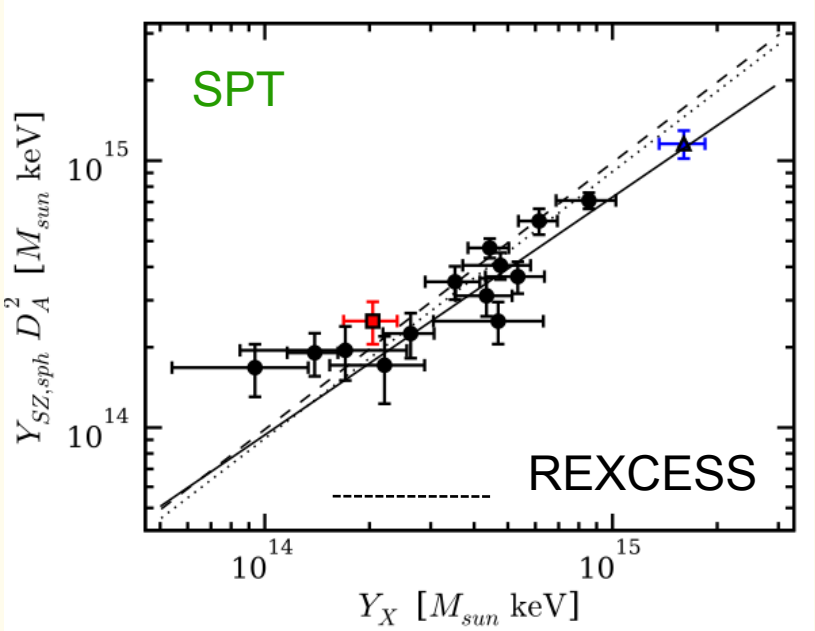
Zel'dovich (SZ) effect at the locations of known clusters of galaxies. The measured SZ signal agrees well with the expected signal from the X-ray data on a cluster-by-cluster basis. However, it is a factor of 0.5 to 0.7 times the predictions from "universal profile" of Arnaud et al., analytical models, and hydrodynamical simulations. We find, for the first time in the SZ effect, a significant difference between the cooling-flow and non-cooling-flow clusters (or relaxed and non-relaxed clusters), which can explain some of the discrepancy. This lower amplitude is consistent with the lower-than-theoretically-expected SZ power spectrum recently measured by the South Pole Telescope collaboration.



missing hot baryons ?



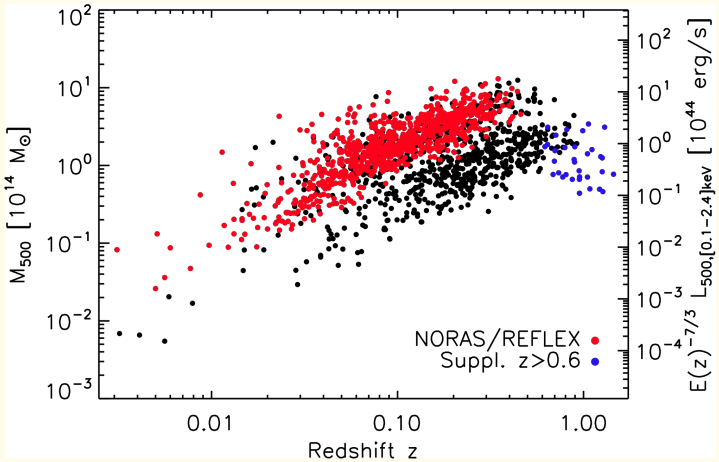
Melin et al. 2010



Andersson et al. 2009

Or not missing hot baryons ?

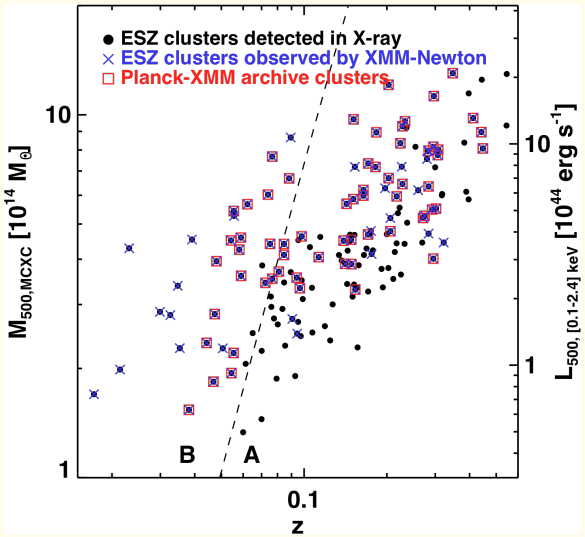
Three complementary Planck studies



Planck consortium arXiv:1101.2043

1882 X-ray selected clusters
with homogenised L_{500}, z
MCXC (*Piffaretti et al 2010*)

Extraction and binning of Planck signal

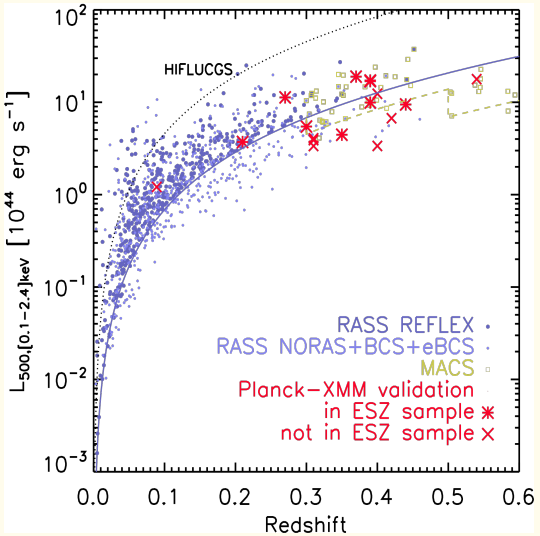


PC arXiv:1101.2026

Planck selected clusters
High quality SZ signal

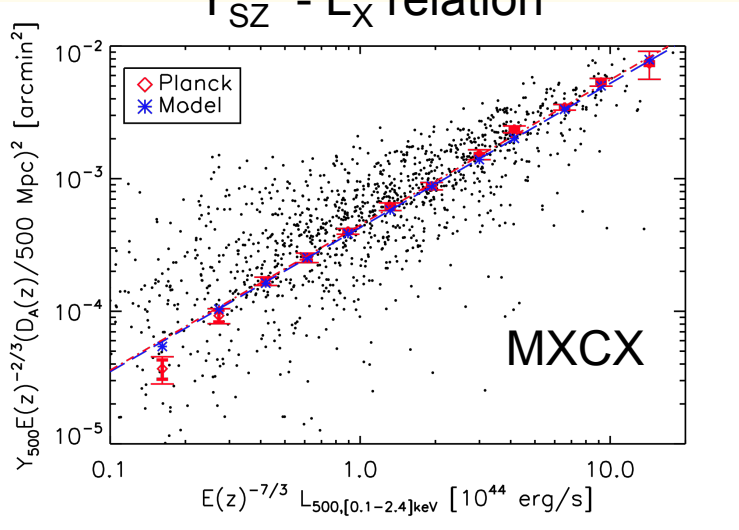
Known clusters
with good XMM
archival data

Newly confirmed
with XMM



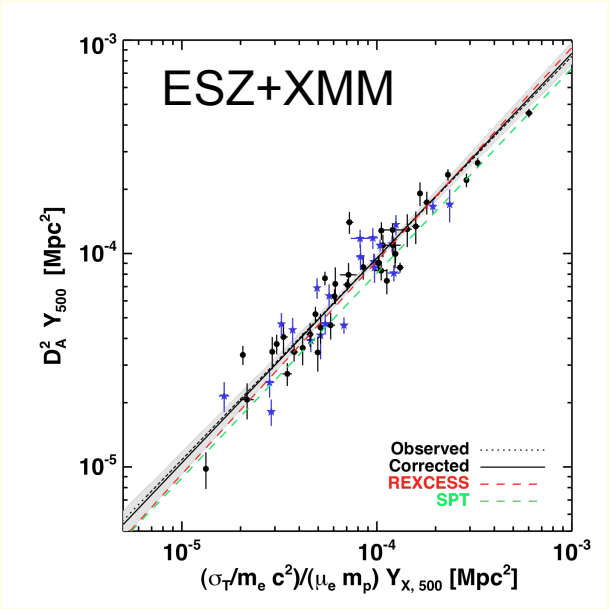
PC arXiv:1101.2025

Y_{SZ} - L_X relation



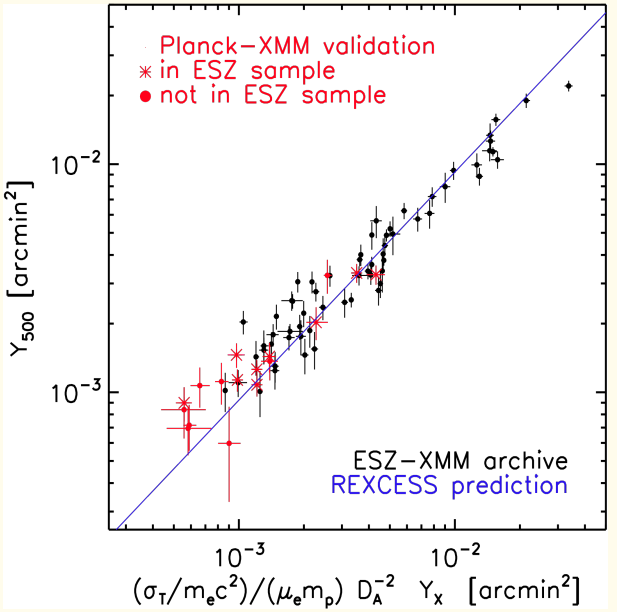
NO MISSING HOT BARYONS

More on calibration of SZ-X ray scaling properties in G.Pratt talk (inc . scatter and evolution..)

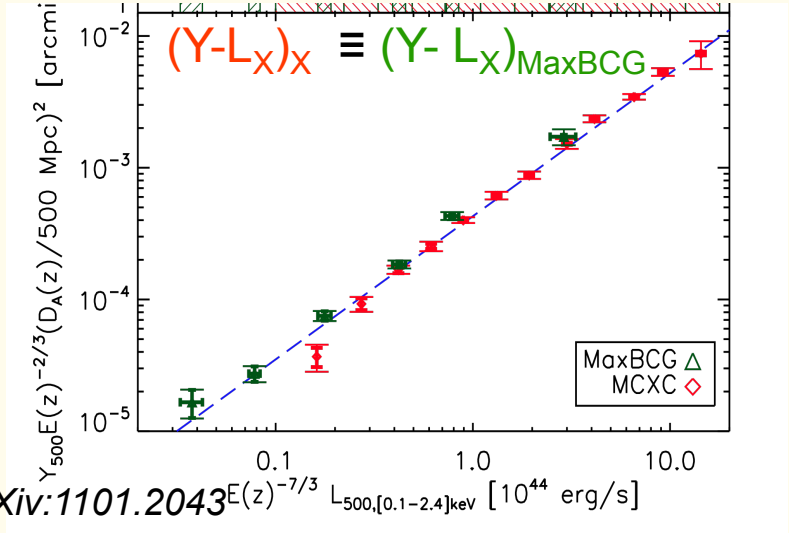


Y_{SZ} - Y_X relation

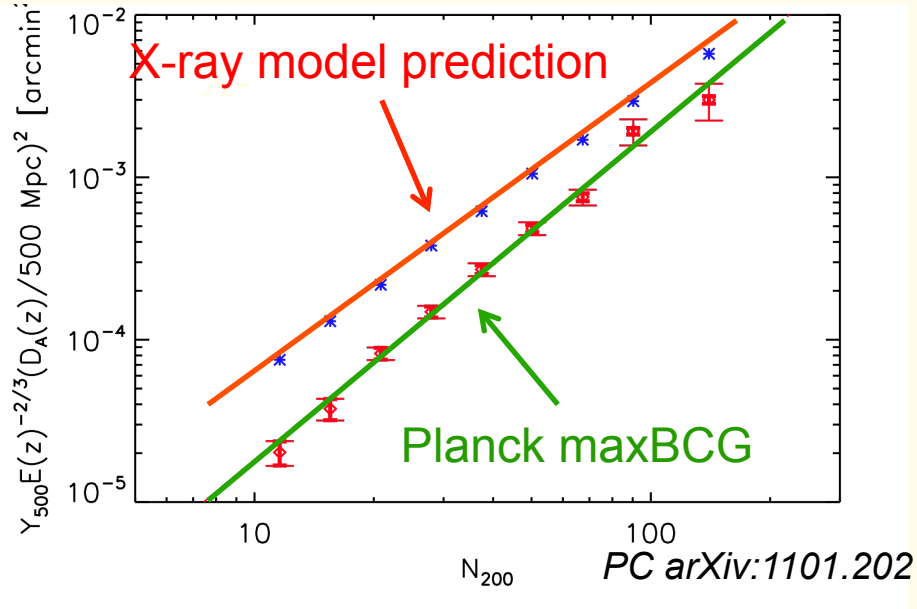
Real SZ data and X-ray based prediction consistent



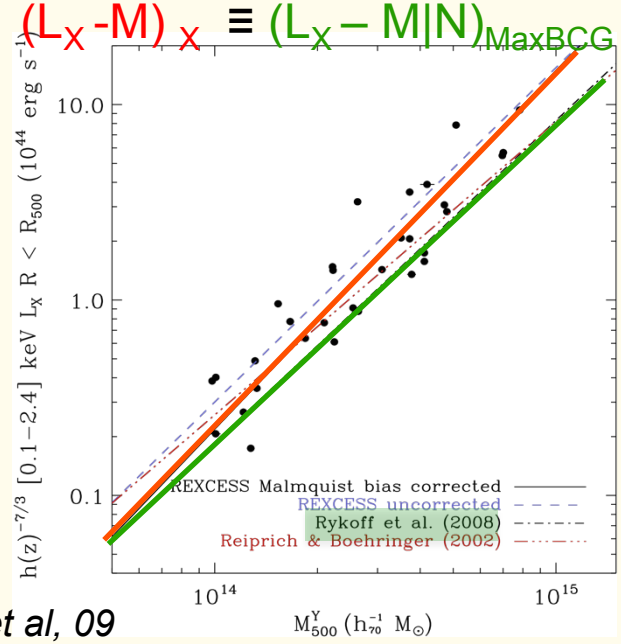
Optical versus X-ray selected samples



PC arXiv:1101.2043



PC arXiv:1101.2027



Pratt et al, 09

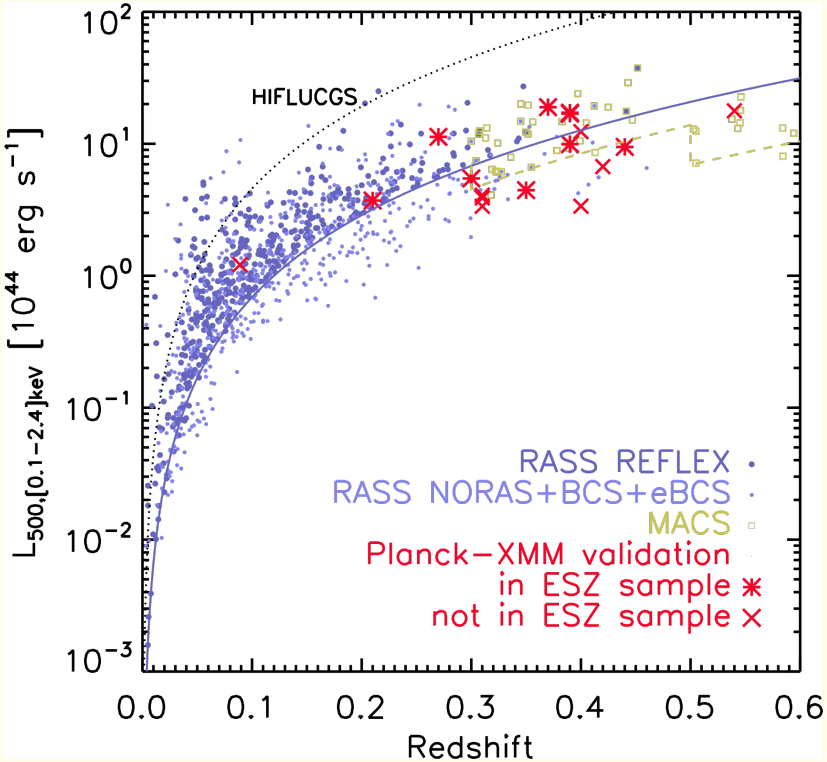
? BUT ? $(Y\text{-}N|M)_{MaxBCG} \neq (Y\text{-}N|M)_X$

See also Rozo et al, 09

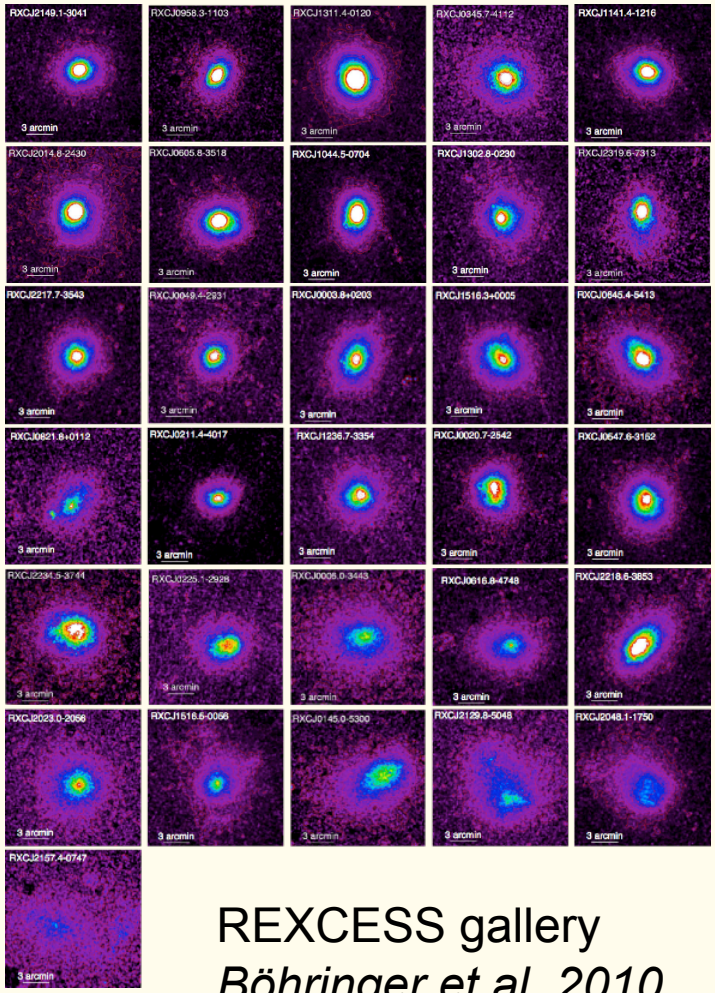
Some X-ray/SZ/lensing data
Unconsistency to be solved

See J.Bartlett talk for more about MaxBCG/Planck

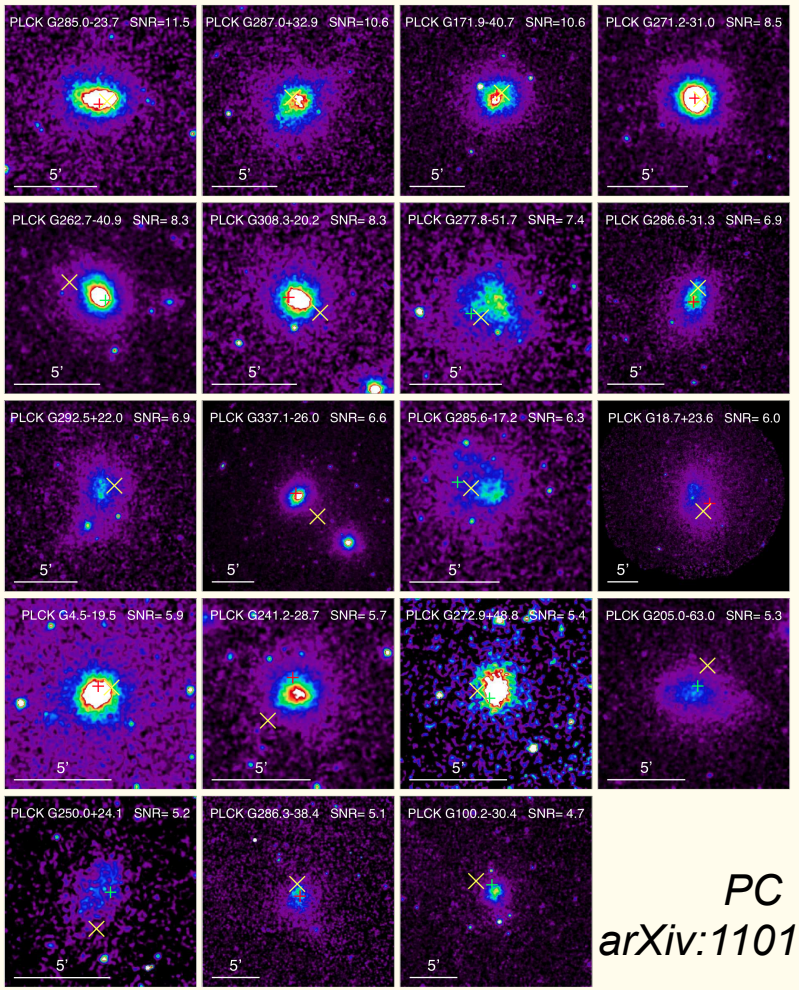
What new clusters Planck is detecting? Preview from XMM validation follow-up



Pre-view from XMM validation follow up



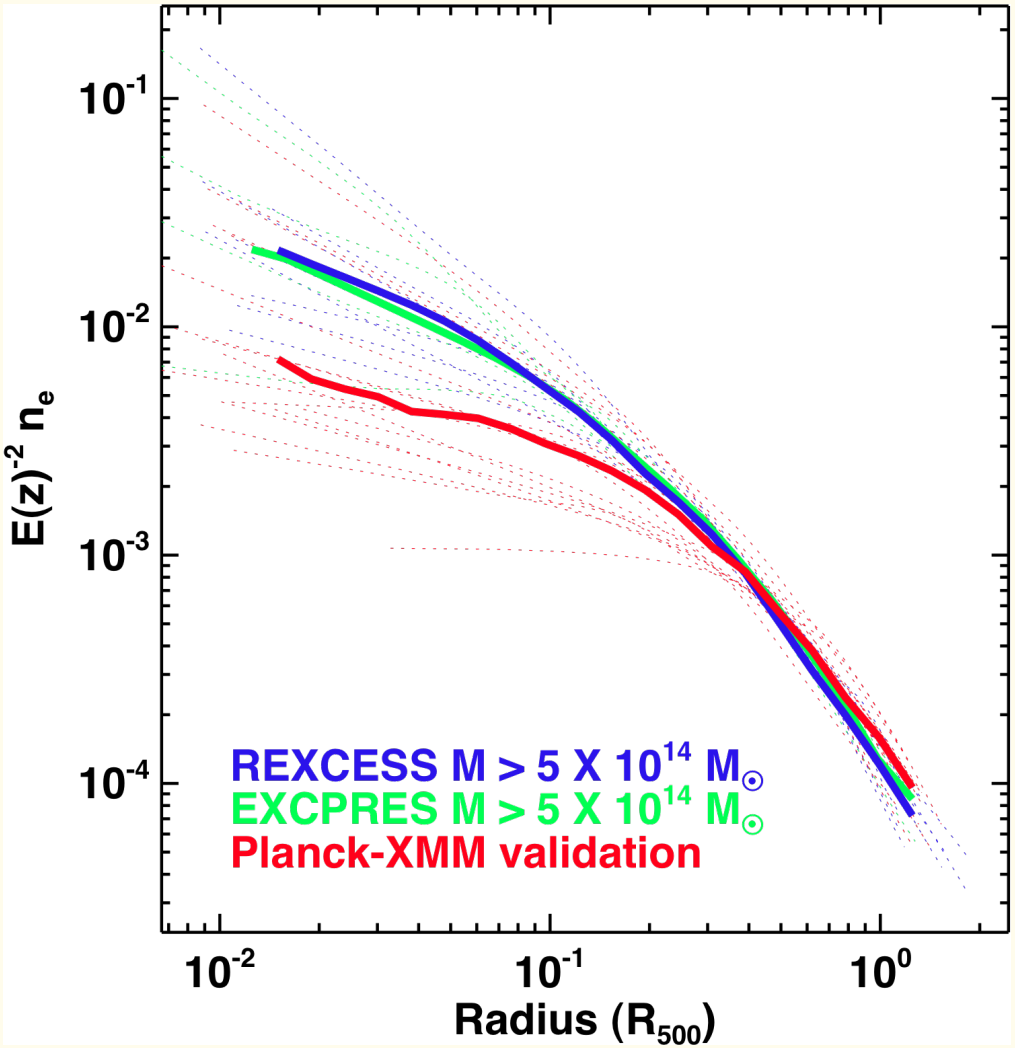
REXCESS gallery
Böhringer et al, 2010
Pratt et al, 2009



PC
arXiv:1101.2025

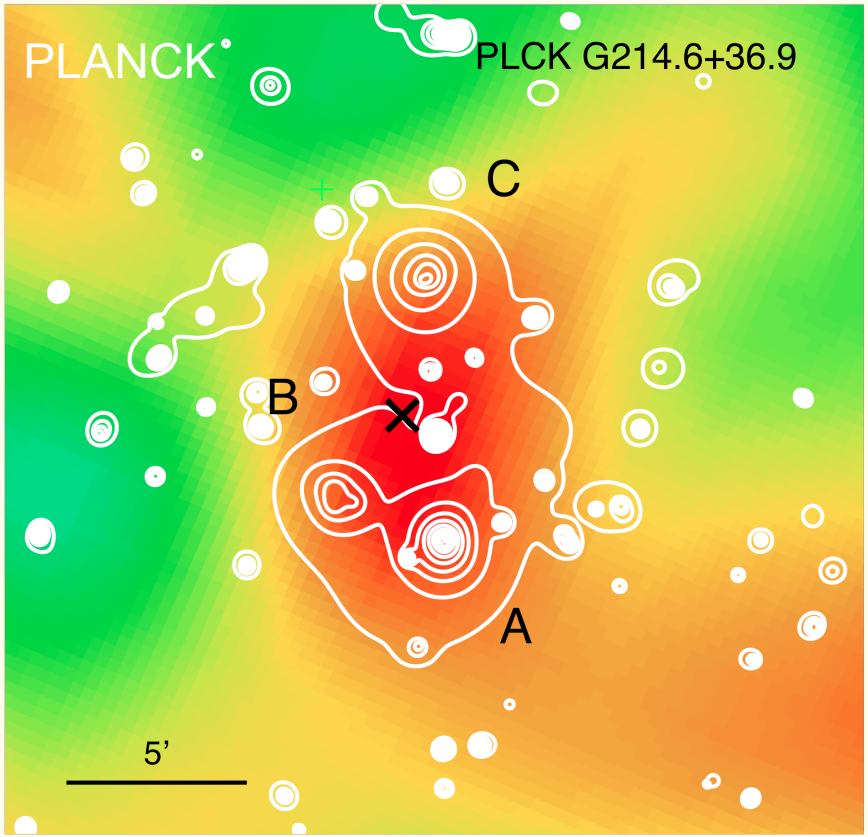
XMM confirmed Planck candidates (ESZ+)

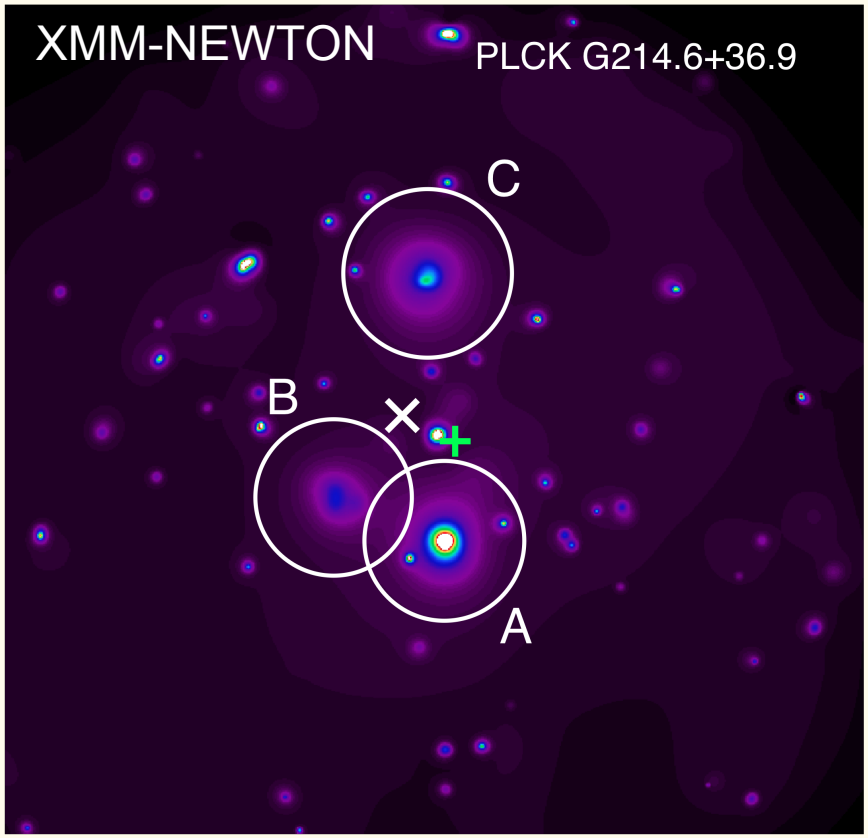
More disturbed morphology



A non-negligible population of massive dynamically perturbed systems, under-represented in X-ray surveys @ z>0.3 ?

First super-cluster(s) blinded detected in SZ





z_{opt}=0.45/0.46±0.02/0.45; z_X =0.45 (A) A:kT ~3.6 keV θ_{500}=2.2’

Physics : boosted by merger shocks? Contribution of filaments ?

Cosmology: how many ? must we take SC in the ‘selection’ function?

Conclusions

Planck ESZ : a unique All Sky SZ sample of 189 clusters

⇒ most complete set of the rarest and most massive clusters in the z < 0.5 Universe

⇒ First SZ measure for ~80% of the known clusters in the ESZ.

Unveiling a population of dynamically perturbed clusters @ z>0.3, possibly under-represented in X-ray surveys

from XMM validation follow-up of Planck SZ sources

Improved robustness of our overall view of ICM properties.

from complementary high precision X-ray/SZ studies

⇒ Close long standing issue of the « missing hot baryons » from excellent agreement between *observed* Y_{SZ} and X-ray-based predictions

⇒ High precision calibration of the $Y_{SZ} - Y_X$ and $Y_{SZ} - L_X$

⇒ first measurement of intrinsic scatter and evolution

.