CLUSTERS OF GALAXIES IN THE PLANCK SURVEY

Etienne Pointecouteau

IRAP

(Toulouse, France)

on behalf of the Planck Collaboration

THE PLANCK MISSION AND THE SUNYAEV-ZEL'DOVICH EFFECT IN THE PLANCK SURVEY

ETIENNE POINTECOUTEAU X-RAY UNIVERSE, BERLIN, JULY 2011

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THE PLANCK MISSION

The scientific results that we present today are a product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency – ESA – with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

THE PLANCK MISSION

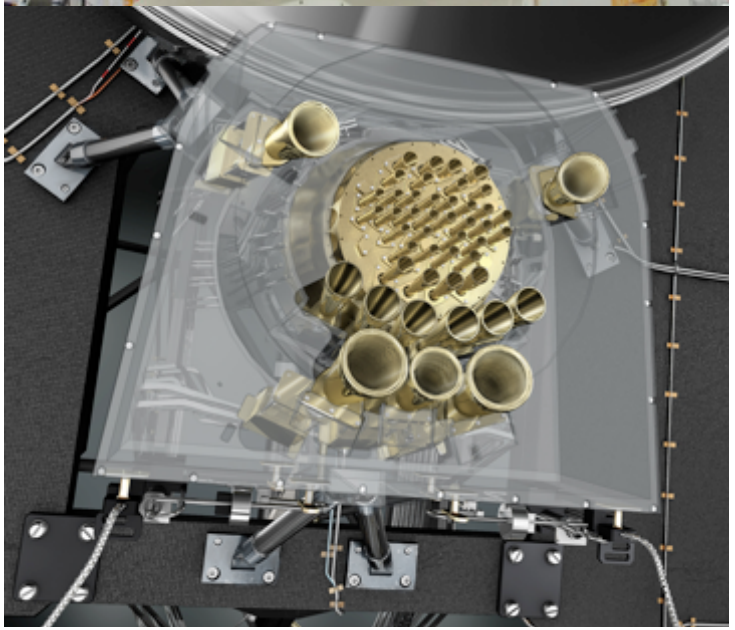
- Launch in May 2009 ; L2 orbit
- 1.5m gregorian telescope
- 9 frequency bands 30-857GHz
- ~5-30 arcmin resolution

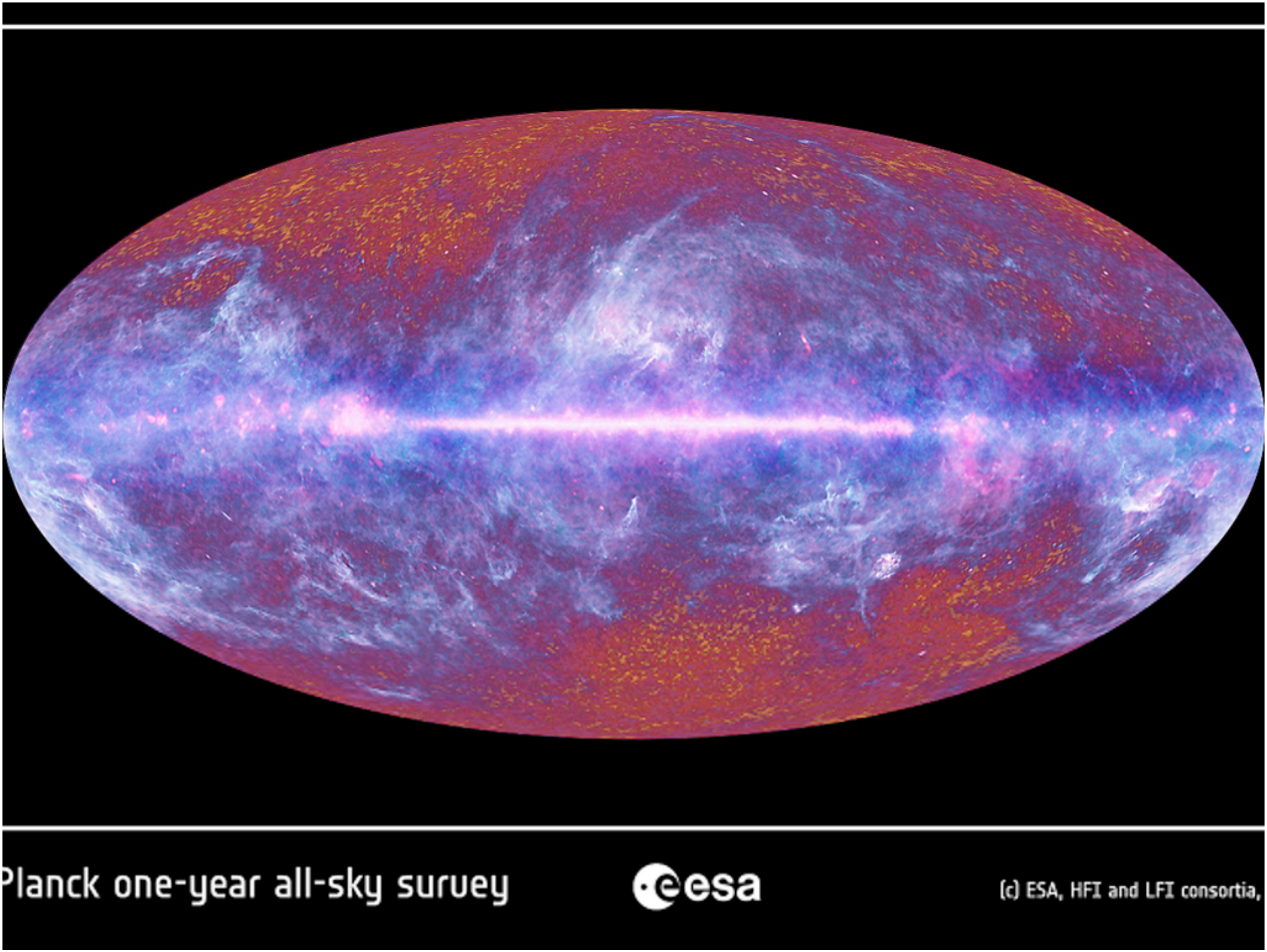
- LFI 22 radiometers, 3 frequencies
- HFI 72 bolometers+thermometers cooled down to 0.1 K, 6 frequencies

(PLANCK 1101.2048)

Frequency [GHz]	NET [μK_{CMB} $s^{1/2}$]	Goal
100P	65	100
143P	53	82
143S	41	62
217P	79	132
217S	68	91
353P	329	404
353S	220	277
545S	1410	1998
857S	41220	91000

- nominal mission = 2 full sky surveys
  extended mission = 4 surveys+
  early results based on 1st sky survey (~7 months)

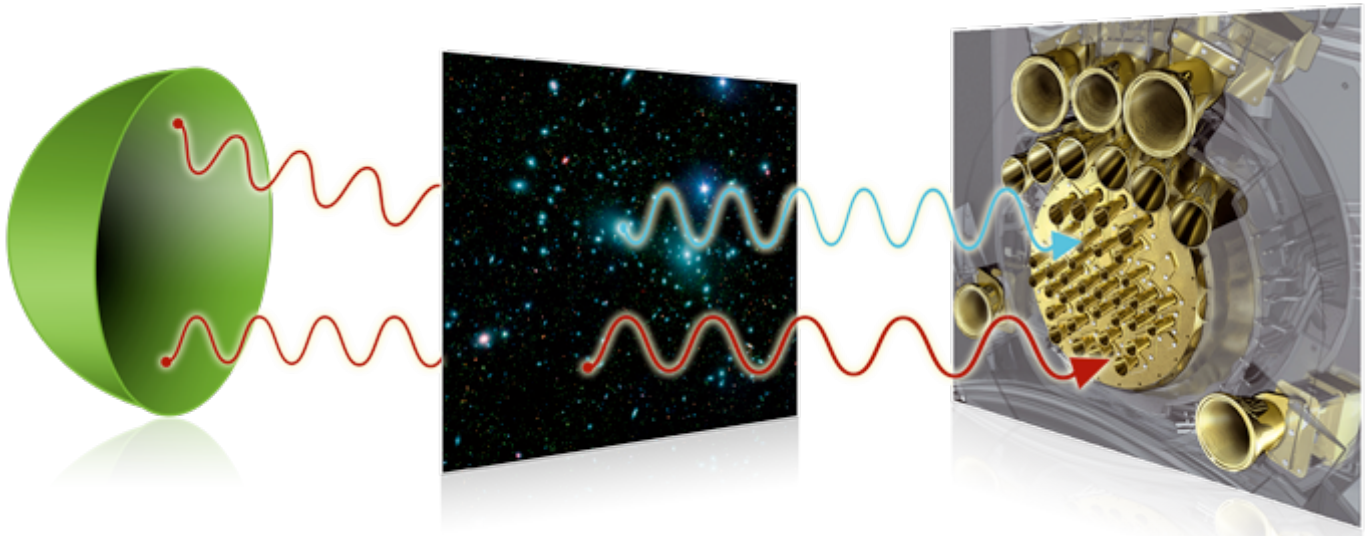


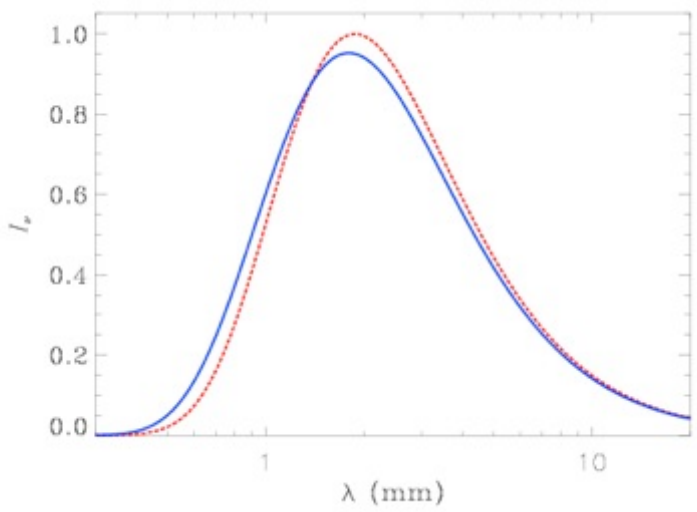

Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia,

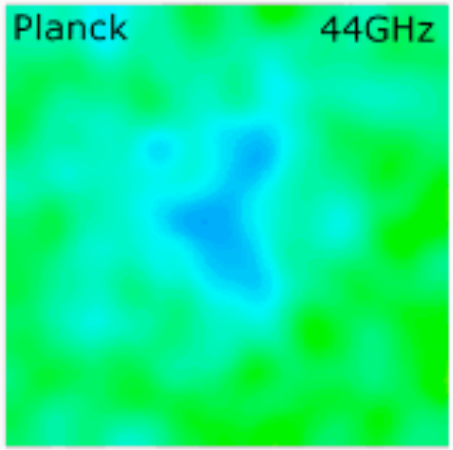
THE SZ EFFECT IN A NUTSHELL

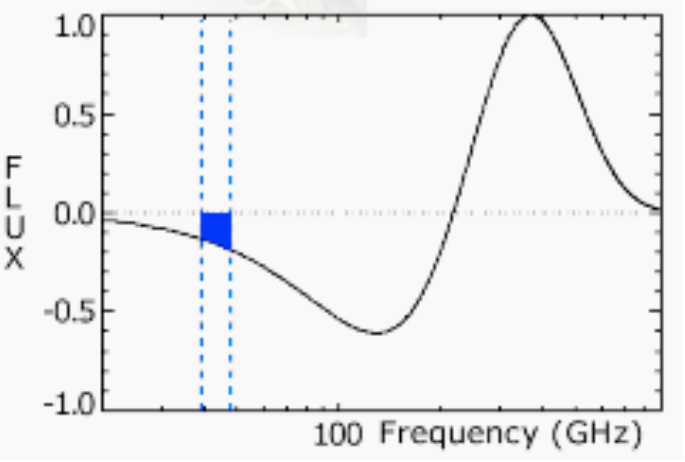
Inverse Compton scattering of CMB photons by ICM e^-

$$F_\nu \propto Y \propto \int_\Omega P_{th} d\Omega \int_\Omega n_e T d\Omega$$









DETECTION OF CLUSTERS

Based on Matched Multi-Filter algorithm

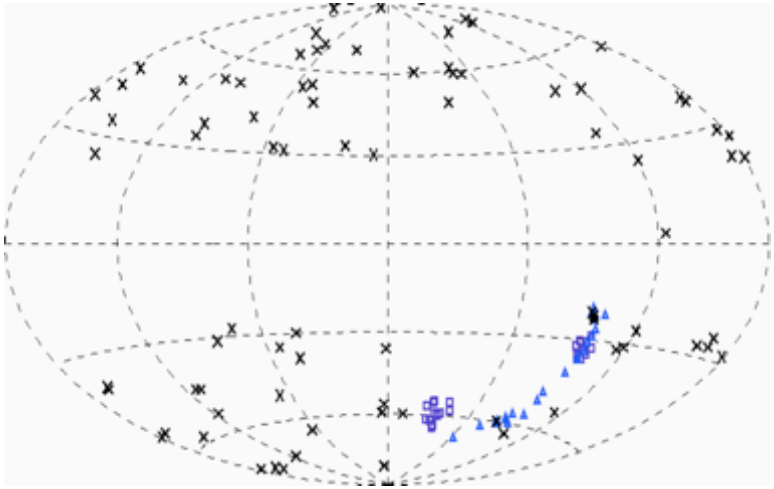
[Melin et al. 2006]

- known spectral shape
  → non-relativistic SZ
  [Sunyaev & Zel'dovich 69, 72]

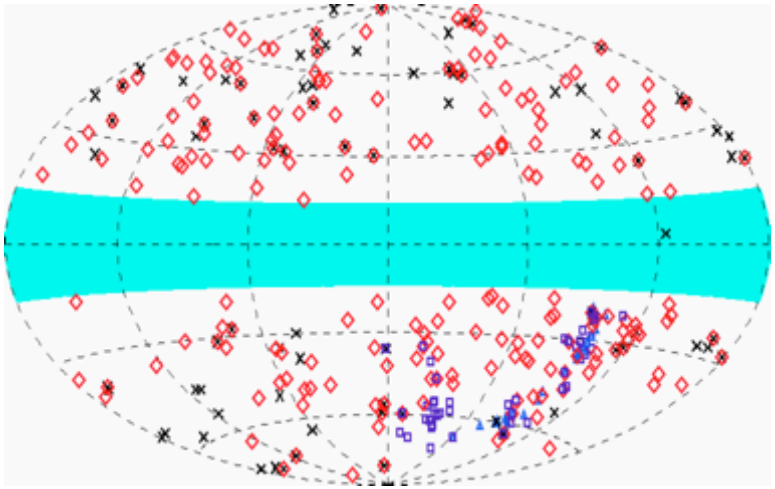
- known cluster spatial distribution
  → GNFW pressure profile
  [Arnaud+10]

→ Unique catalogue ; only all sky cluster catalogue since RASS

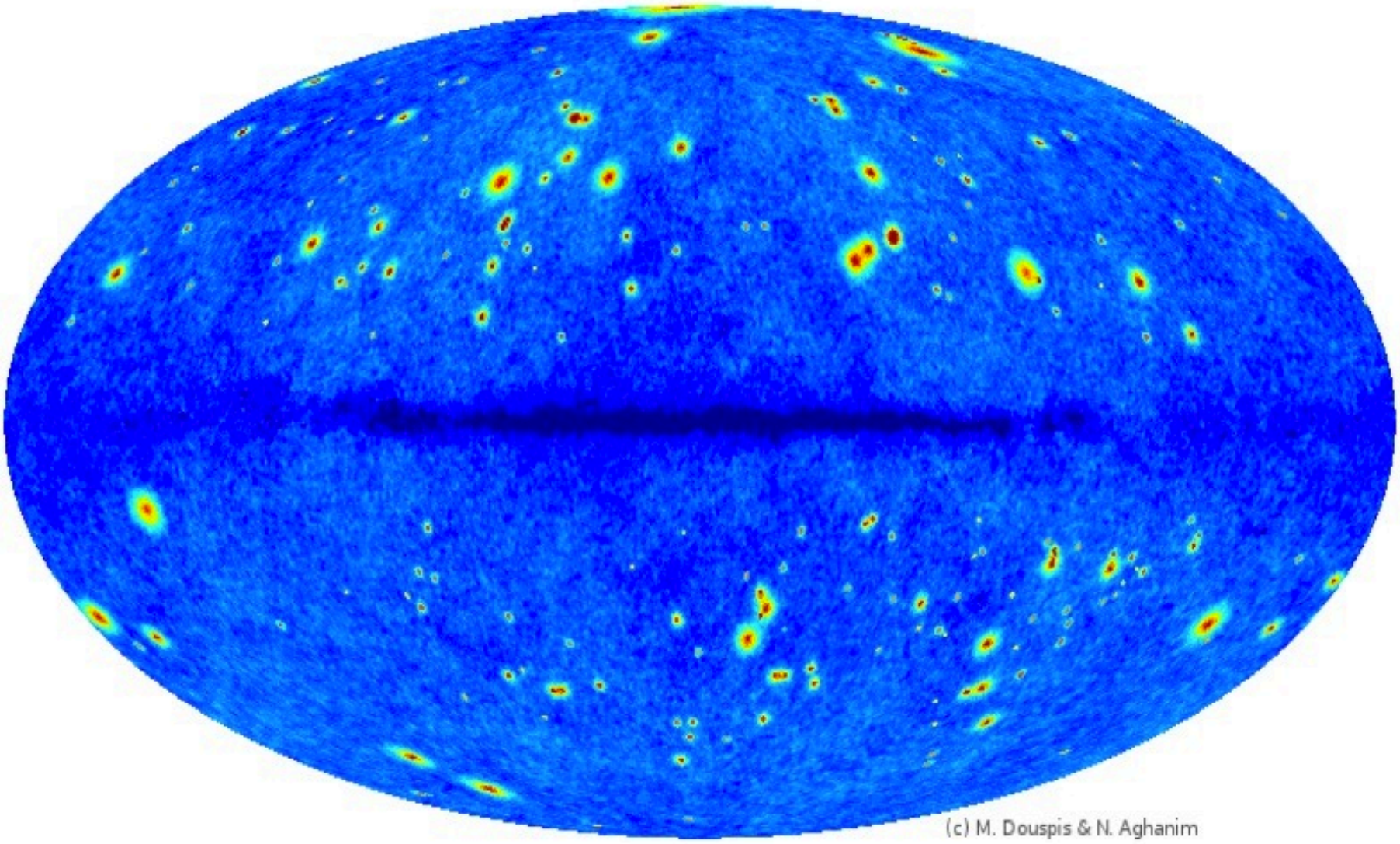
Before PLANCK



After PLANCK ESZ

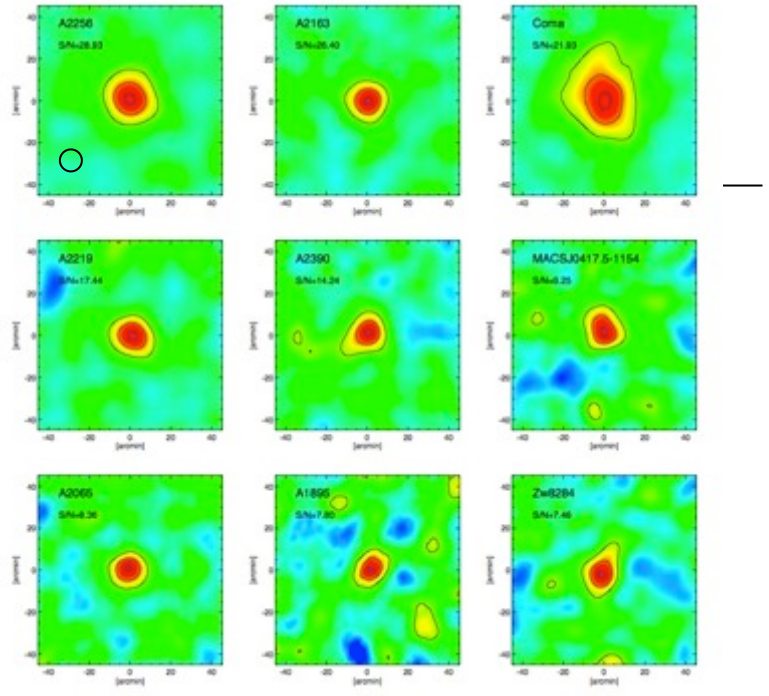


THE EARLY RELEASE SZ SKY



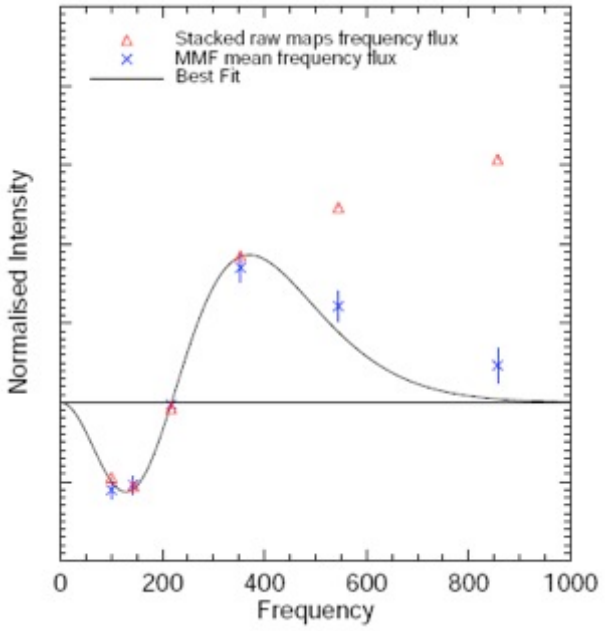
(c) M. Douspis & N. Aghanim

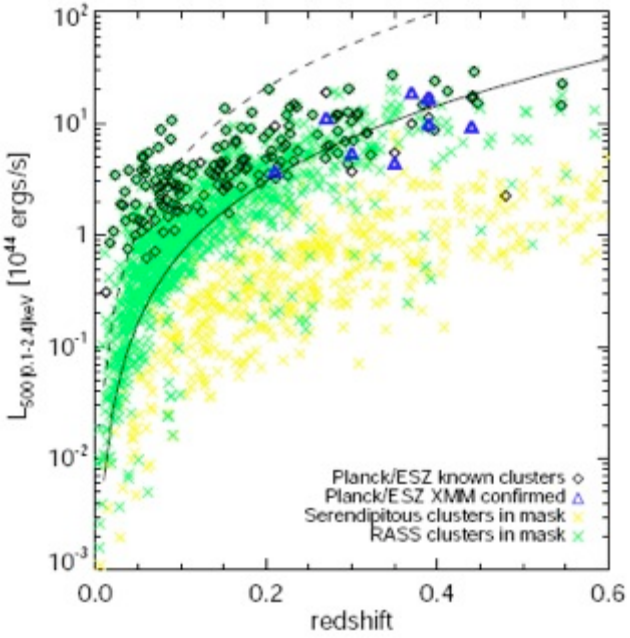
THE ESZ SAMPLE

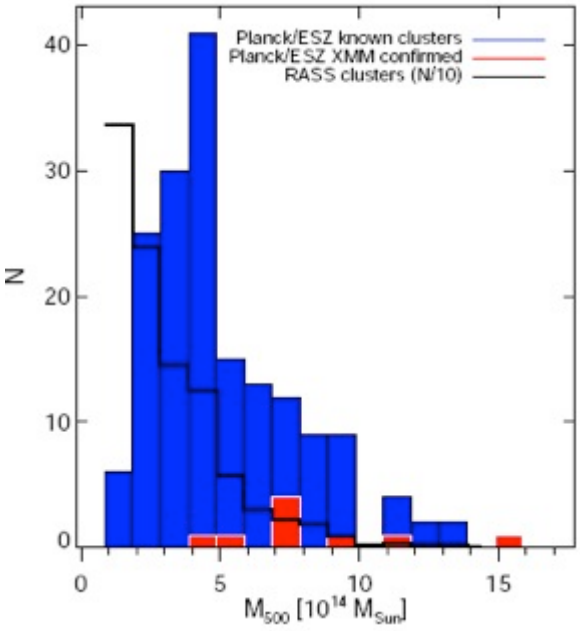


189 SZ sources with S/N > 6

- First SZ measure for ~80% of the known clusters
- 20 new clusters
  - 10 XMM confirmed
  - 1 AMI confirmed
  - 8 unconfirmed (01/2011) → now: 6 confirmed with SPT & AMI







SZ (PLANCK) / X-RAY (XMM) VIEW OF HOT BARYONS IN THE UNIVERSE

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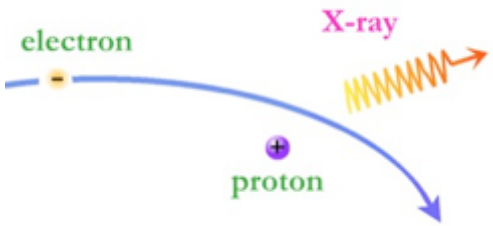
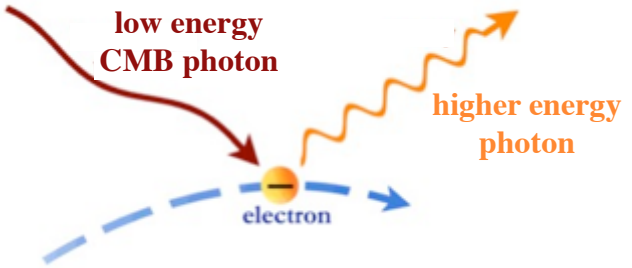
X-RAYS and SZ PROBING THE ICM

Bremsstrahlung



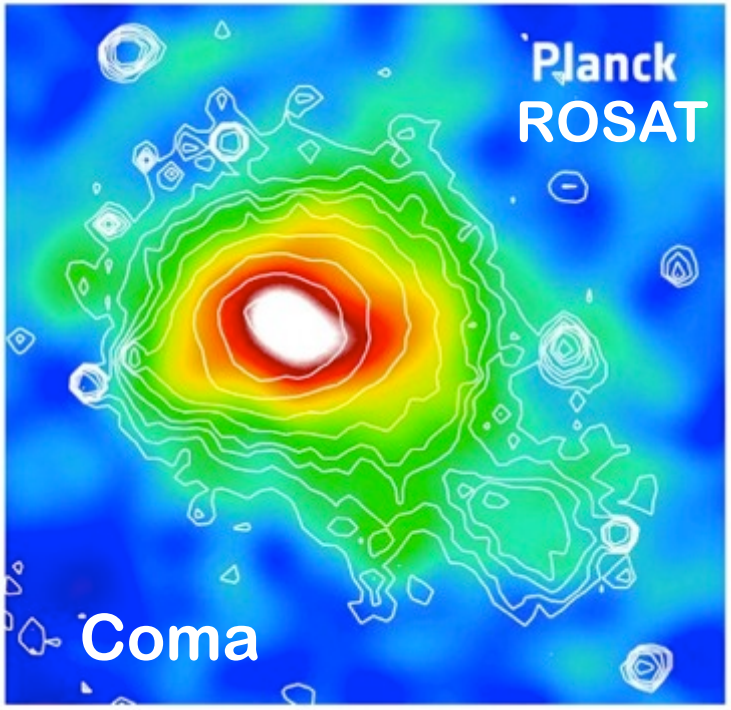
$$E_X \propto \int_V n_e^2 \Lambda(T) dV$$

Inverse Compton scattering



$$F_\nu \propto \int_\Omega (P = n_e T) d\Omega$$

Hot intracluster gas probed by two different physical processes and signals



Expected relations between SZ and X-ray properties

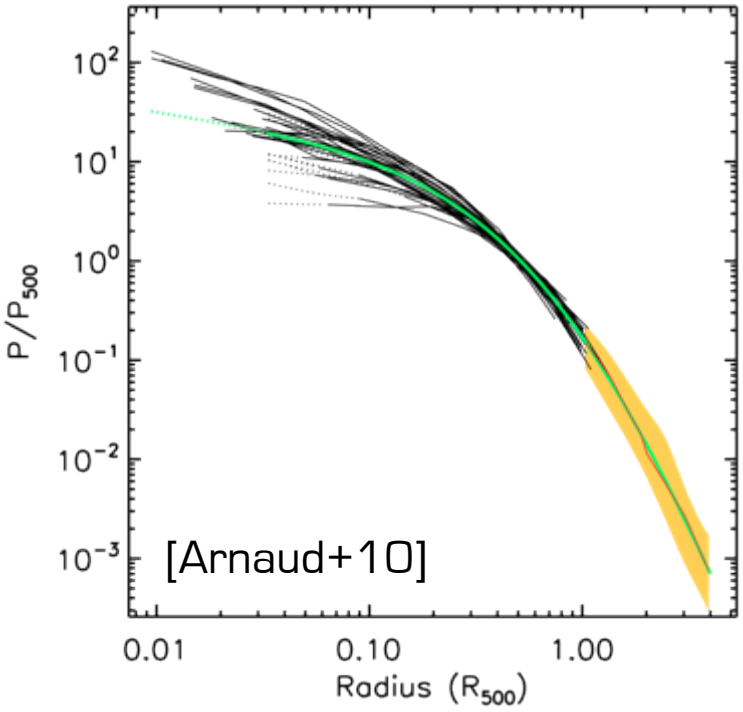
CLUSTER PRESSURE FROM X-RAYS

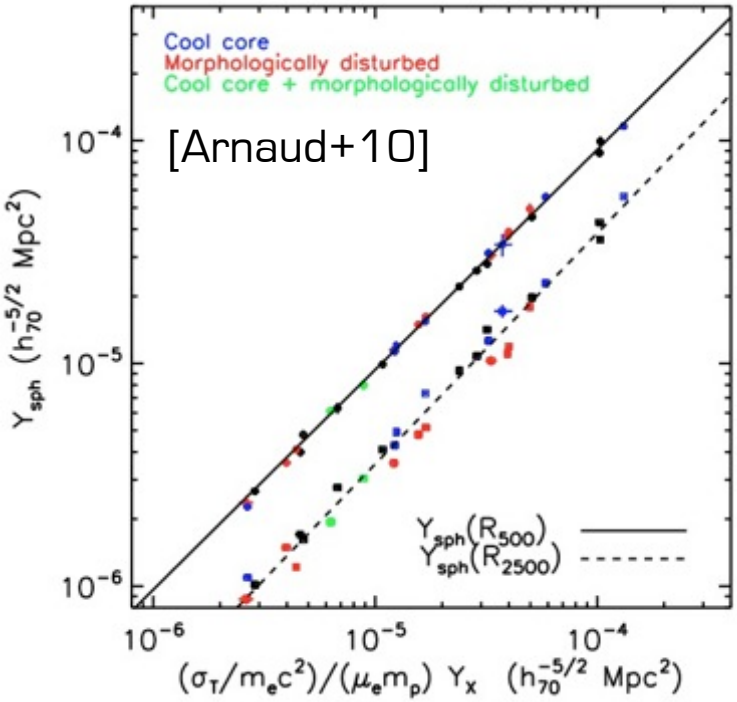
→ Pressure is the fundamental quantity

$$F_\nu \propto Y \propto \int_\Omega (P_{th} = n_e T) d\Omega$$

$$Y_X = M_{gas} T_X$$

(Kravtsov+06)





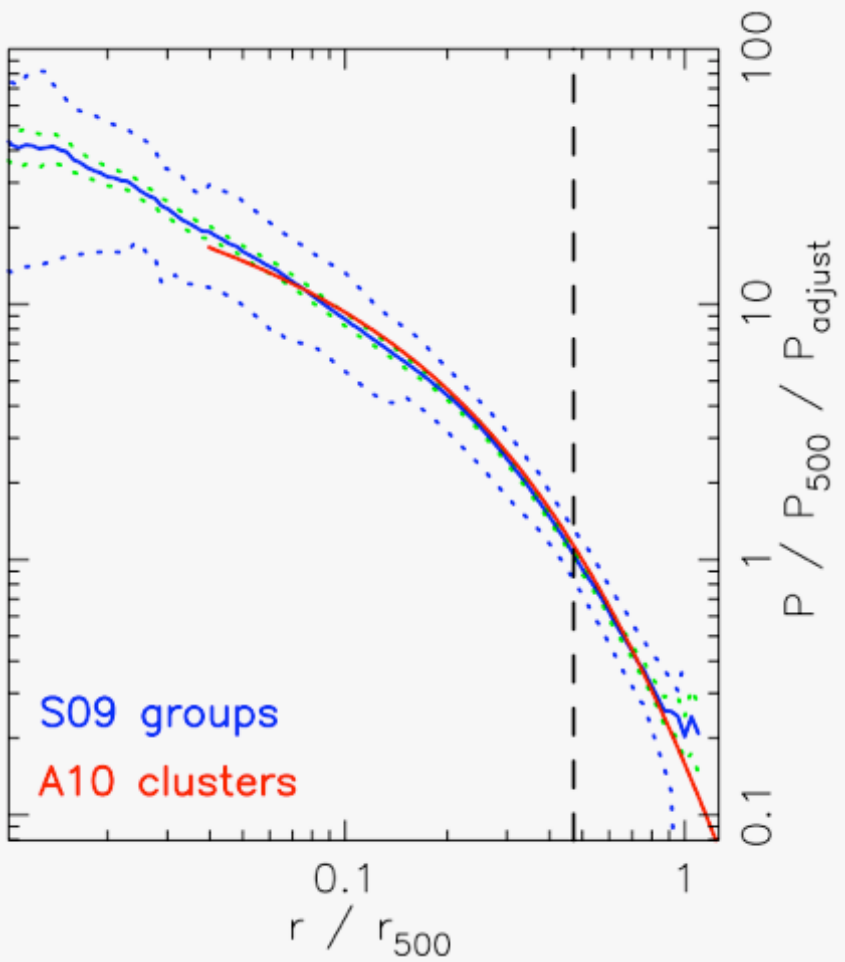
from the REXCESS sample

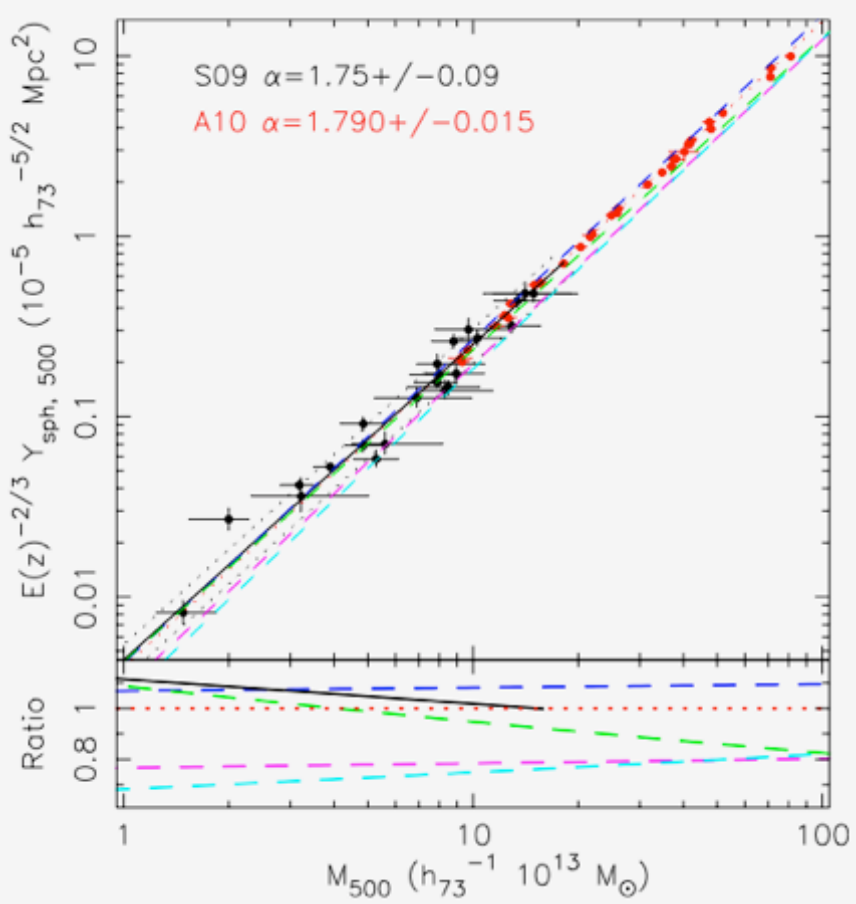
[see also: Böhringer+07, Croston+08, Pratt+09]

Tight Y_{SZ} – Y_X relation

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

FROM CLUSTERS TO GROUPS





(Sun+11)

Scaling law and universal profile down to group regime

MISSING HOT BARYONS ?

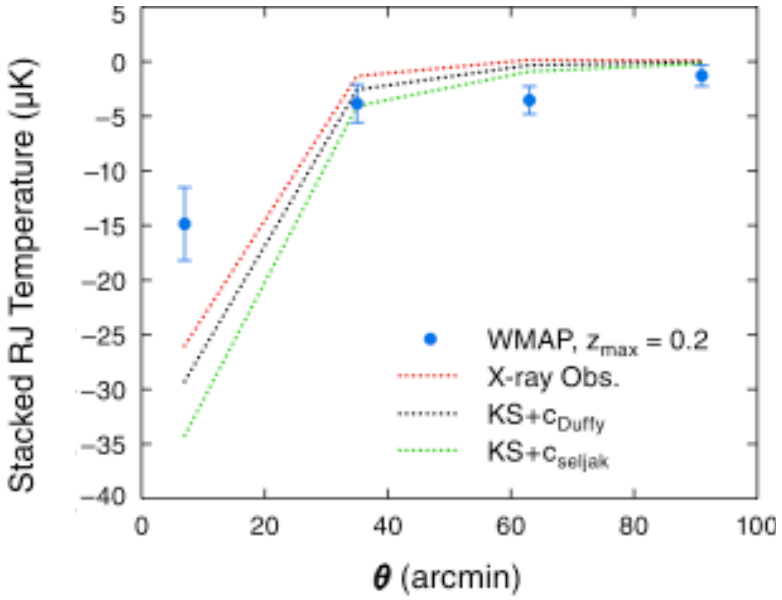
The Astrophysical Journal, 648:176–199, 2006 September 1

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,



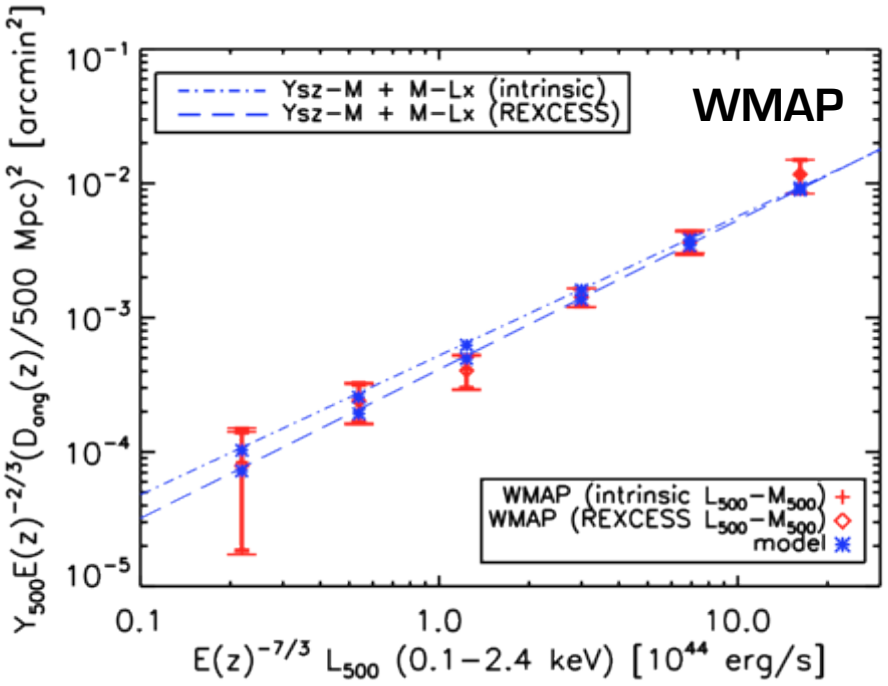
Accepted for Publication in the Astrophysical Journal Supplement Series
Preprint typeset using LaTeX style emulateapj v. 11/10/09

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

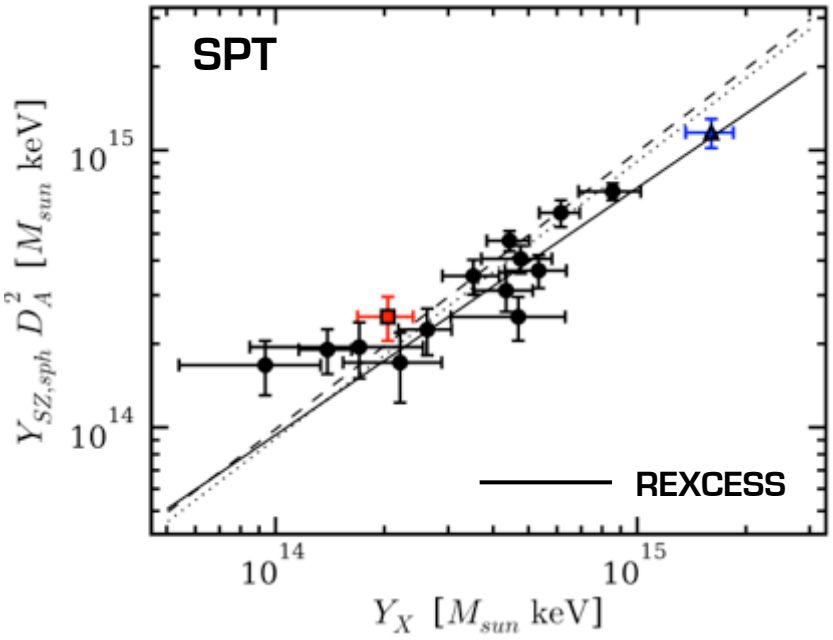
E. Komatsu[2], K. M. Smith[3], J. Dunkley[4], C. L. Bennett[5], B. Gold[5], G. Hinshaw[6], N. Jarosik[7], D. Larson[5], M. Nolta[8], L. Page[7], D. N. Spergel[3,9], M. Halpern[10], R. S. Hill[11], A. Kogut[6], M. Limon[12], S. S. Meyer[13], N. Odegard[11], G. S. Tucker[14], J. L. Weiland[11], E. Wollack[6], 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.

OR NO MISSING HOT BARYONS ?



(Melin+10)



(Andersson+09)

THREE COMPLEMENTARY STUDIES

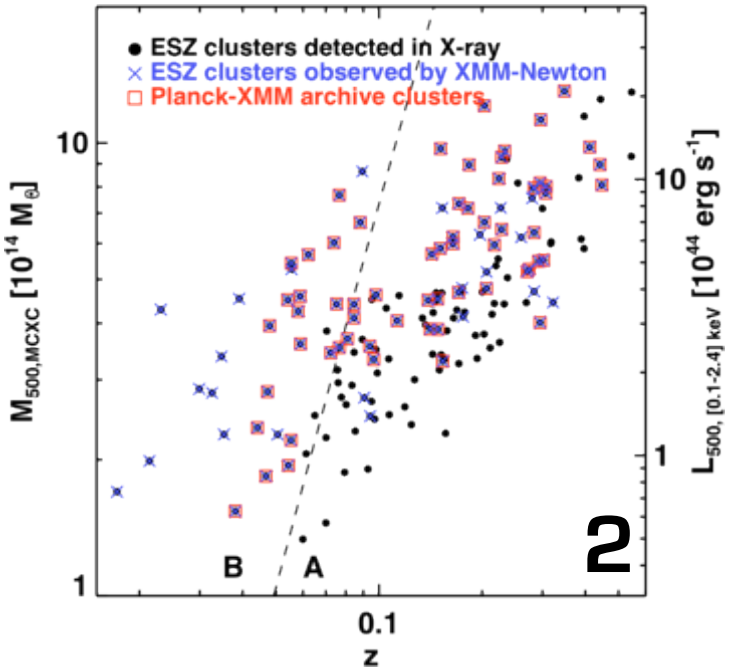
1. Statistical approach

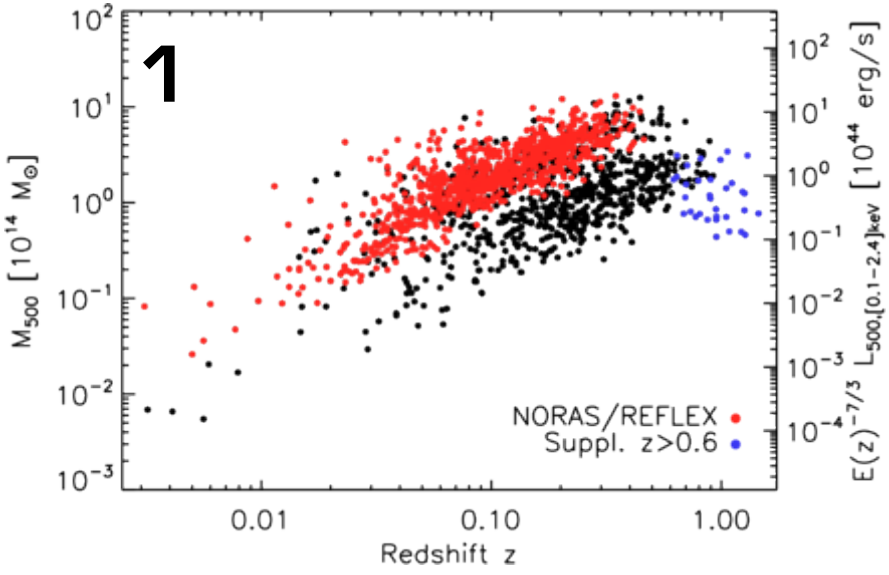
- 1882 X-ray selected clusters (MCXC, Piffaretti +11), with homogenised L_{500}, z

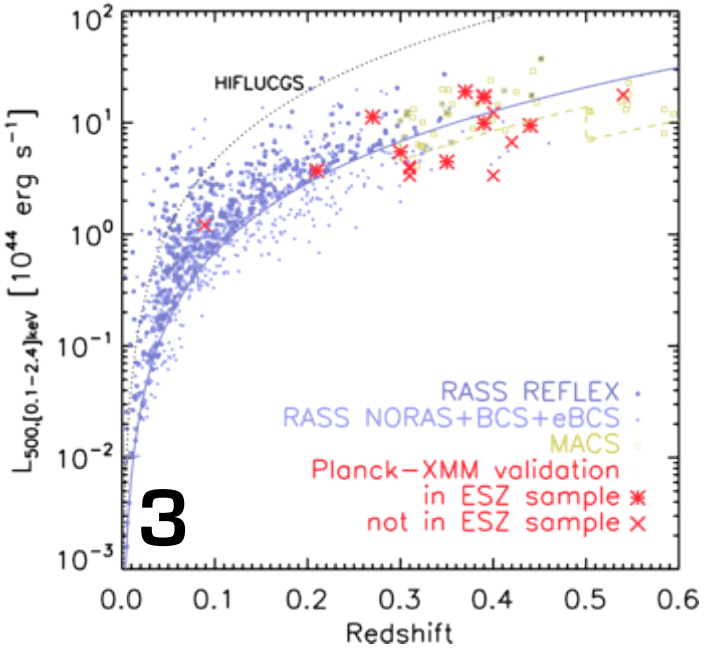
2. Planck ESZ clusters

- high quality SZ signal
- clusters with good XMM archive data

3. New Planck clusters, XMM confirmed

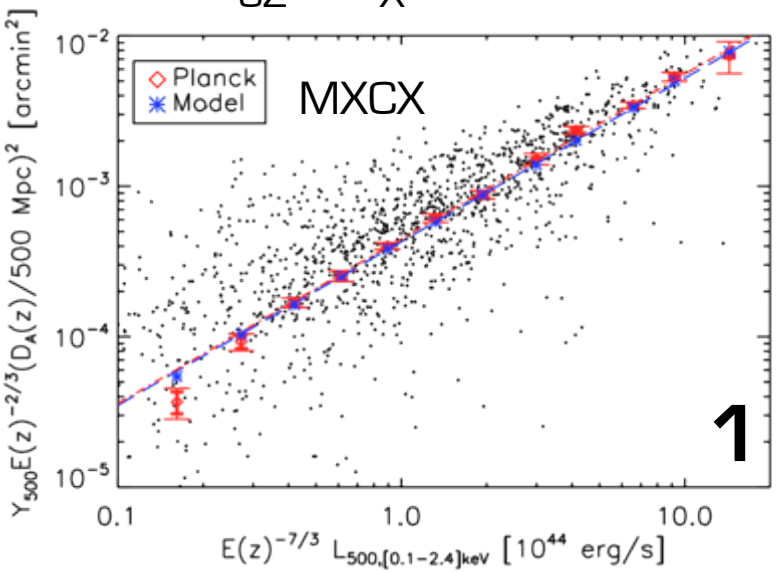




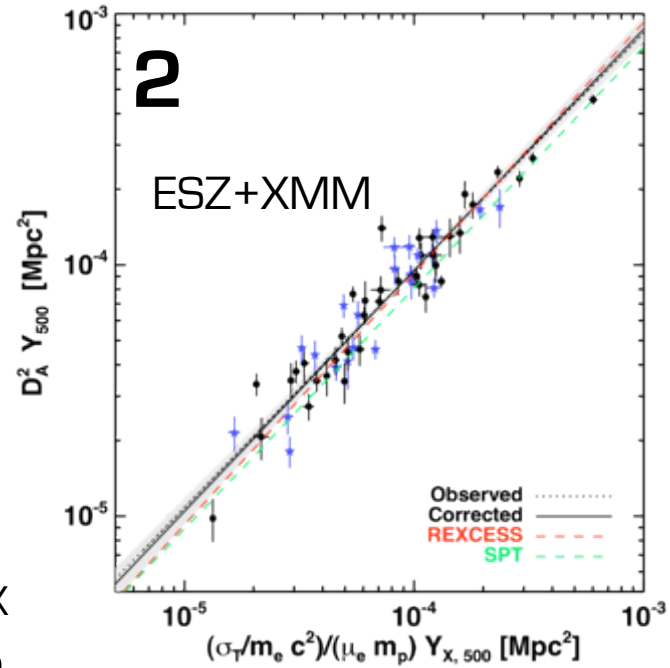


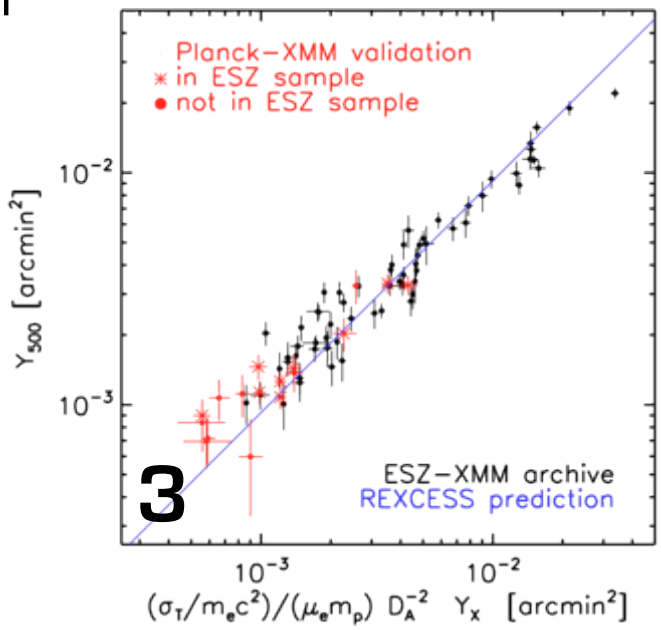
SZ - X SCALING RELATIONS

Y_{SZ} - L_X relation



Y_{SZ} - Y_X relation





Real SZ data and X-ray based prediction consistent

NO MISSING HOT BARYONS

NEW CLUSTERS DETECTED BY PLANCK AND CONFIRMED WITH XMM

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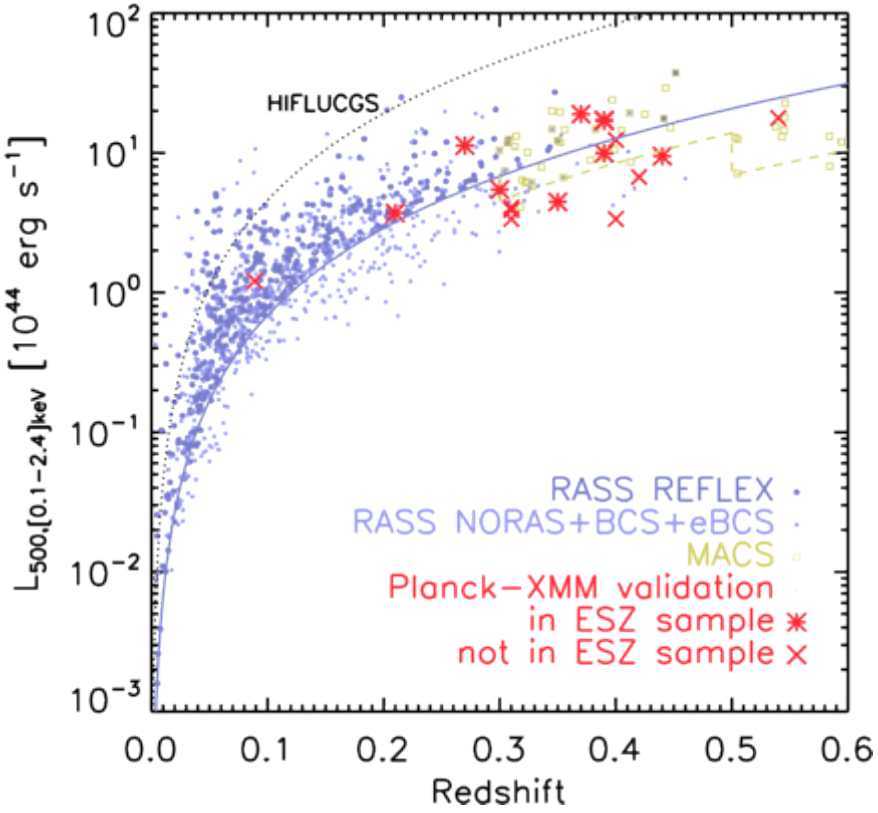
VALIDATION PROGRAM WITH XMM



DDT program

maximize the synergy between the two ESA missions

Short snapshot exposures

10ksec

25 Planck candidates

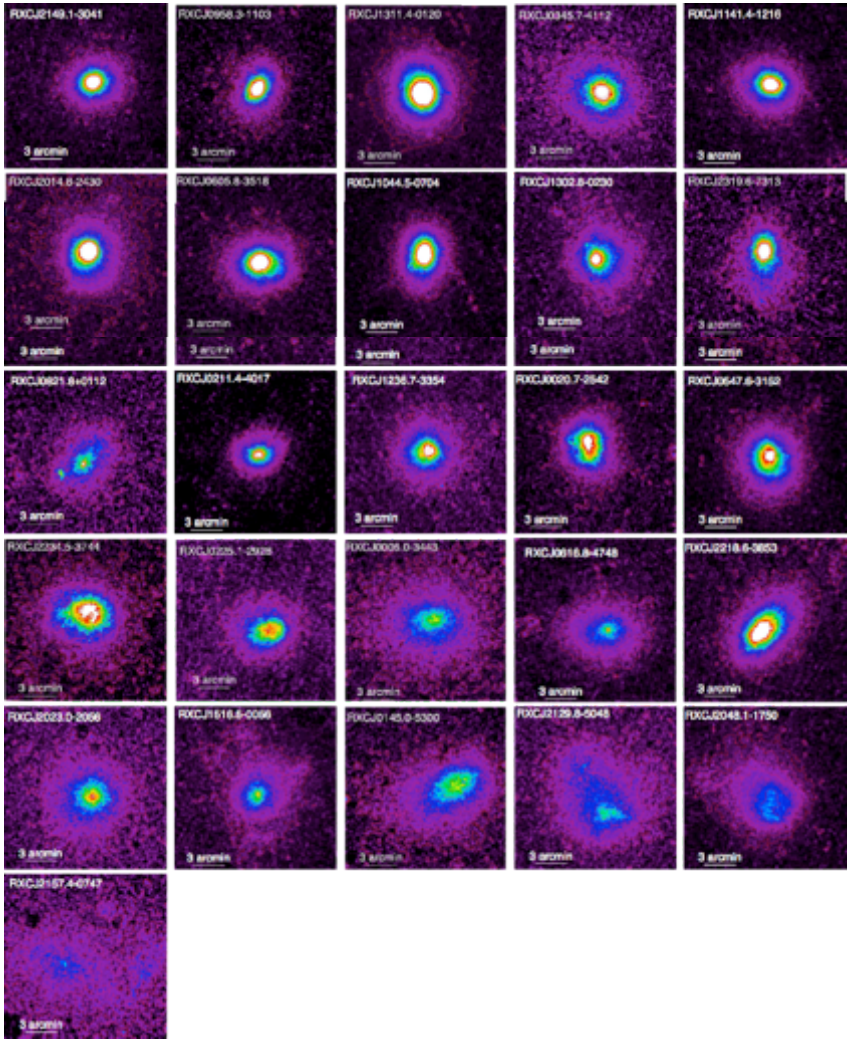
- 17 single clusters
- 2 double systems
- 2 triple clusters
- 4 false detection (SNR<4.1)

0.1< z < 0.6

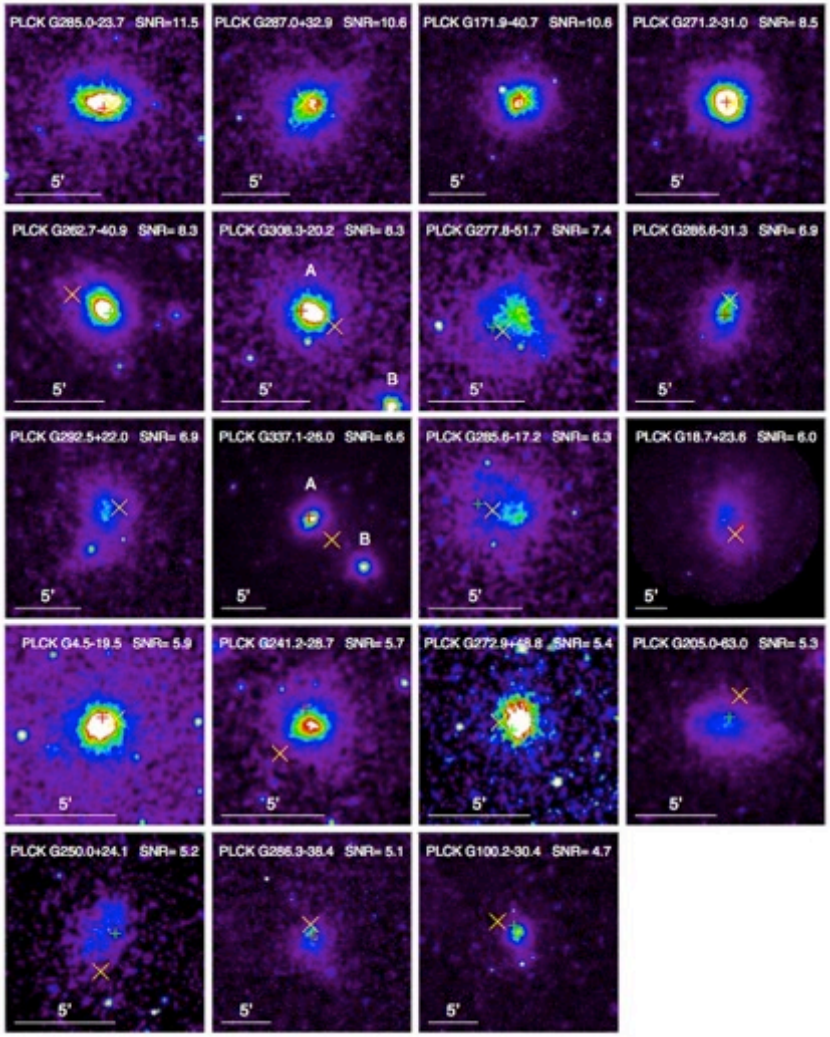
- redshift from FeK line

PLANCK vs REXCESS CLUSTERS

REXCESS (Böhringer+10)



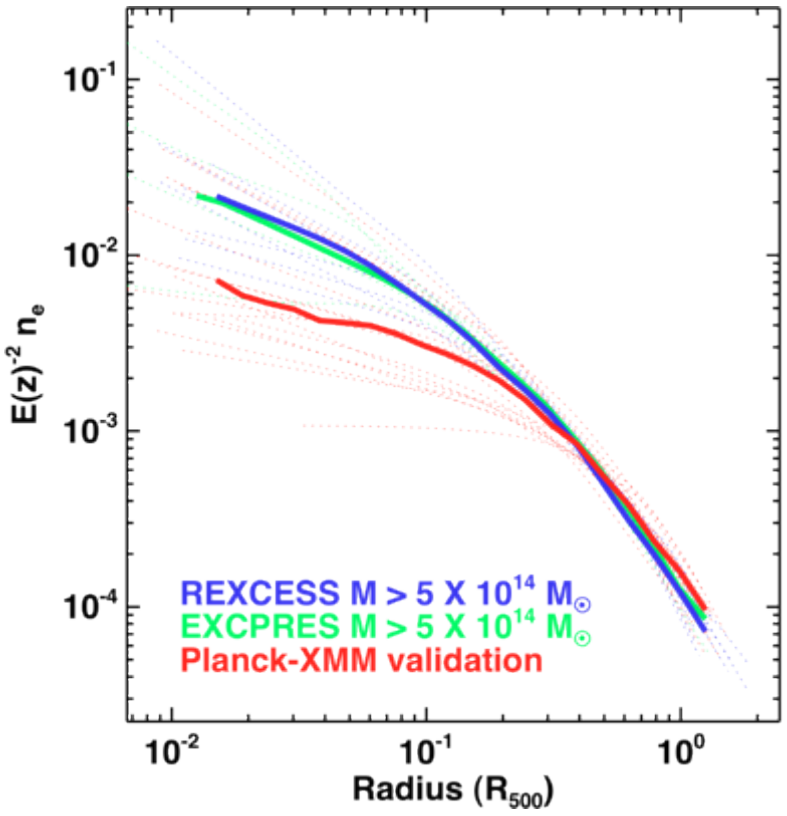
PLANCK



~30% (REXCESS) vs ~70% (PLANCK) morphologically disturbed

X-RAY PROPERTIES

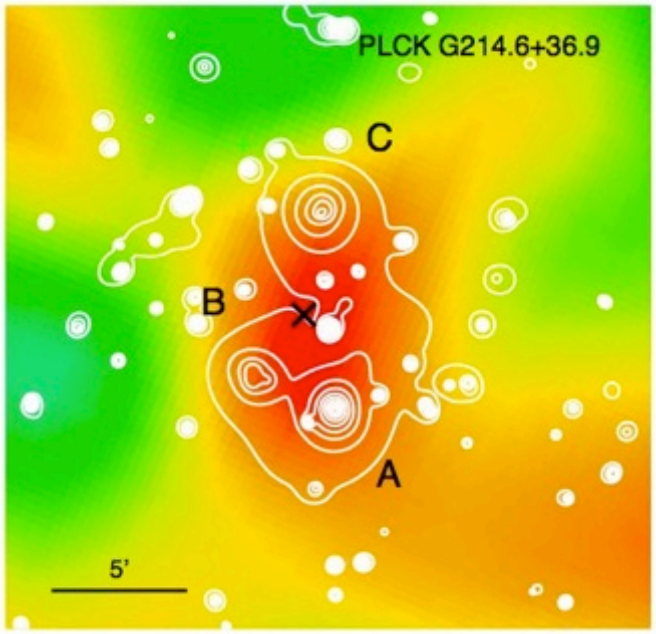
A non-negligible population of massive dynamically perturbed systems, under-represented in X-ray surveys @ z>0.3 ?

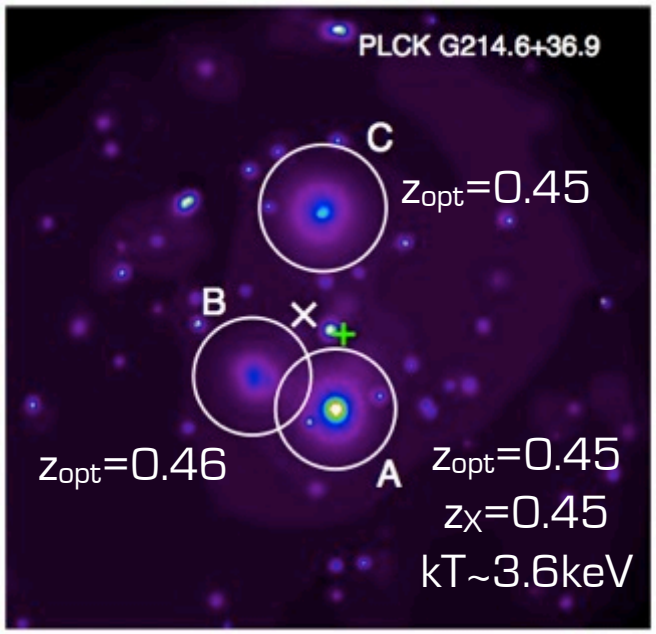


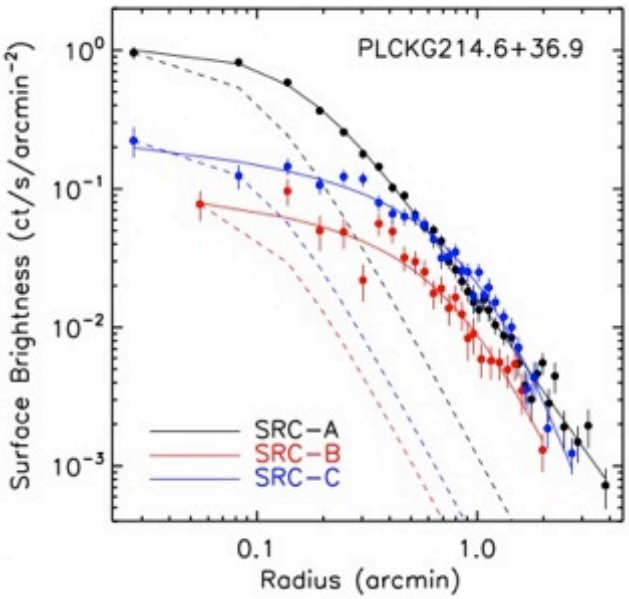
→ A010 XMM-Newton LP

FORMING CLUSTERS

Blind SZ detection of super-cluster(s)







Physics : boosted by merger shocks? Contribution of filaments ?

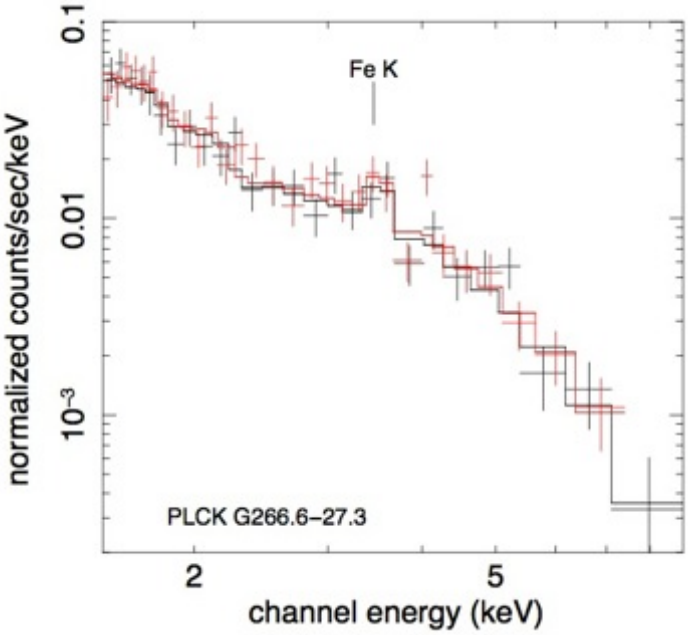
Cosmology: how many ? must we take SC in the 'selection' function?

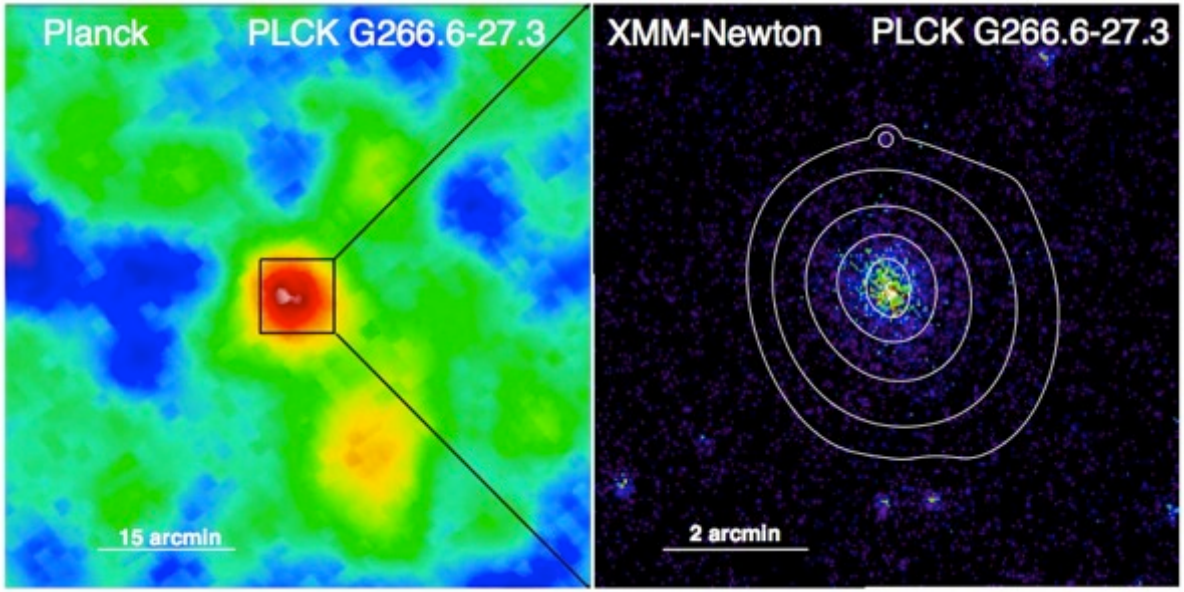
→ A010 XMM-newton/VLT GO follow-up accepted

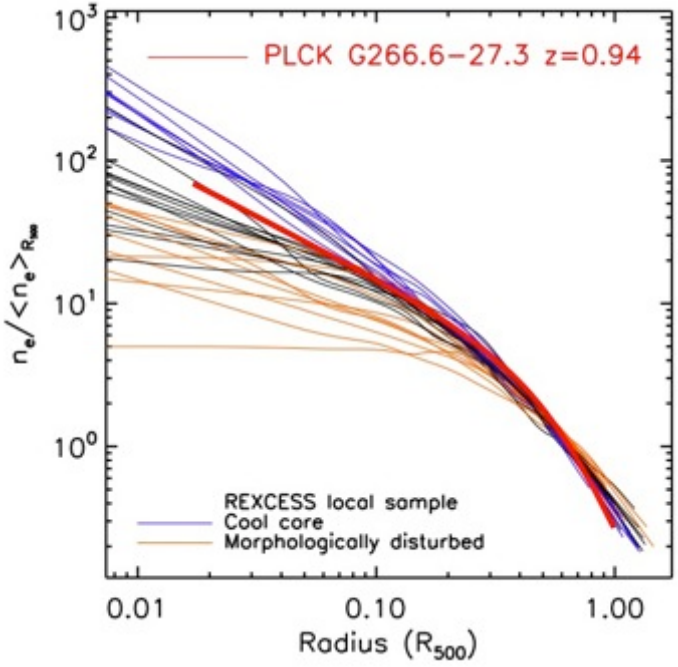
DISTANT CLUSTERS

PLCK G266.6-27.3

- SNR_{PLCK} = 5
- z_{FeK}=0.94
- L_X[0.5-2keV]=(1.4±0.5)×10^{45} erg/s
- M_{500}=(7.8±0.8)×10_{14} $M_\odot$
- Highly relaxed







CONCLUSIONS

PLANCK ESZ: A UNIQUE ALL SKY SZ SAMPLE OF 189 CLUSTERS

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

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

UNVEILLING 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 $Y_{SZ} - L_X$

DETECTION OF NEW DISTANT VERY MASSIVE CLUSTERS

PLANCK RESULTS ON CLUSTERS

1. Planck Early Results VIII: The all-sky Early Sunyaev-Zeldovich cluster sample (arXiv:1101.2024)

2. Planck early results IX: XMM-Newton follow-up for validation of Planck cluster candidates (arXiv:1101.2025)

3. Planck early results X: statistical analysis of SZ scaling relations for X-ray galaxy clusters (arXiv:1101.2043)

4. Planck Early Results XI: Calibration of the local galaxy cluster Sunyaev-Zeldovich scaling relations (arXiv:1101.2026)

5. Planck Early Results XII: Cluster SZ-Optical Scaling Relations (arXiv: 1101.2027)

6. Planck Early Results XXVI: Detection with Planck and confirmation by XMM-Newton of PLCK G266.6−27.3, an exceptionally X-ray luminous and massive galaxy cluster at z~1 (arXiv:1106.1376)

→ **MORE TO COME FROM 02/2012 ; STAY TUNED !**
→ **PLANCK NOMINAL MISSION DATA RELEASE : 01/2013**