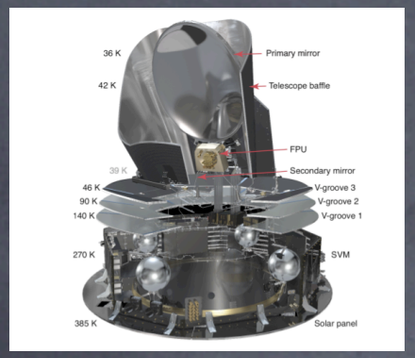
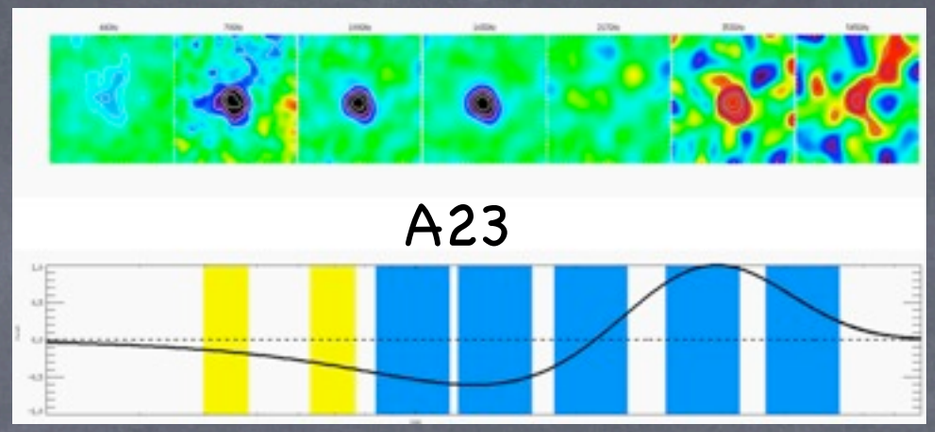




Observing Galaxy clusters via the SZ effect with the Planck satellite

The Planck collaboration

based on A&A, 536 Planck early results special issue and Planck intermediate results

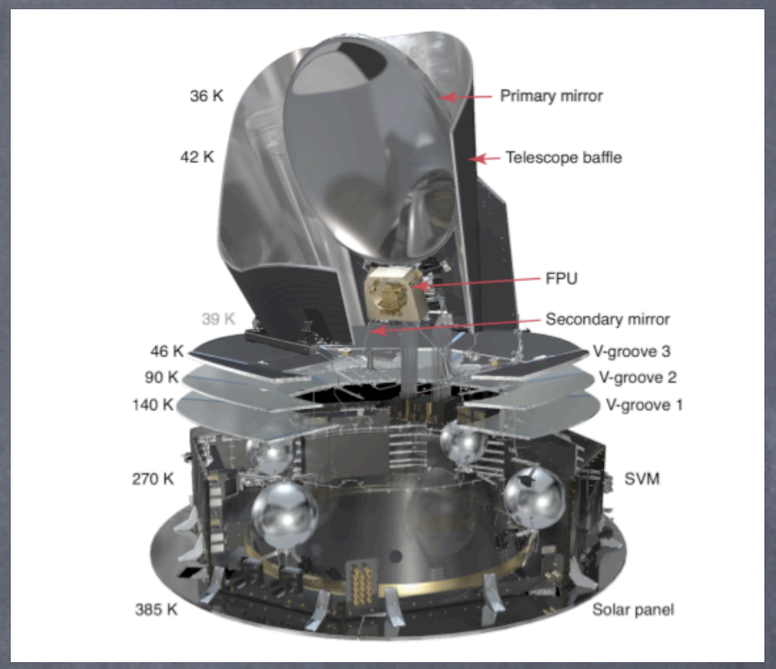
arXiv:1205.3376P, 1204.2743P, 1204.1318P, 1112.5595P

Planck Collaboration: N. Aghanim45, M. Arnaud55, M. Ashdown53,76, J. Aumont45, C. Baccigalupi67, A. Balbi28, A. J. Banday75,6,60, R. B. Barreiro50, M. Bartelmann73,60, J. G. Bartlett3,51·, E. Battaner78, K. Benabed46, A. Beno ̂ıt46, J.-P. Bernard75,6, M. Bersanelli26,40, R. Bhatia33, J. J. Bock51,7, A. Bonaldi36, J. R. Bond5, J. Borrill59,71, F. R. Bouchet46, M. L. Brown76,53, M. Bucher3, C. Burigana39, P. Cabella28, J.-F. Cardoso56,3,46, A. Catalano3,54, L. Cayo ´n19, A. Challinor77,53,10, A. Chamballu43, L.-Y Chiang47, C. Chiang18, G. Chon61,76, P. R. Christensen64,29, E. Churazov60,70, D. L. Clements43, S. Colafrancesco37, S. Colombi46, F. Couchot58, A. Coulais54, B. P. Crill51,65, F. Cuttaia39, A. Da Silva9, H. Dahle48,8, L. Danese67, R. J. Davis52, P. de Bernardis25, G. de Gasperis28, A. de Rosa39, G. de Zotti36,67, J. Delabrouille3, J.-M. Delouis46, F.-X. De ´sert42, J. M. Diego50, K. Dolag60, S. Donzelli40,48, O. Dore ´51,7, U. Do ¨rl60, M. Douspis45, X. Dupac32, G. Efstathiou77, T. A. Enßlin60, F. Finelli39, I. Flores49,30, O. Forni75,6, M. Frailis38, E. Franceschi39, S. Fromenteau3,45, S. Galeotta38, K. Ganga3,44, R. T. Ge ´nova-Santos49,30, M. Giard75,6, G. Giardino33, Y. Giraud-He ´raud3, J. Gonza ´lez-Nuevo67, K. M. Go ´rski51,80, S. Gratton53,77, A. Gregorio27, A. Gruppuso39, D. Harrison77,53, S. Henrot-Versille ´58, C. Herna ´ndez-Monteagudo60 , D. Herranz50, S. R. Hildebrandt7,57,49, E. Hivon46, M. Hobson76, W. A. Holmes51, W. Hovest60, R. J. Hoyland49, K. M. Huffenberger79, A. H. Jaffe43, W. C. Jones18, M. Juvela17, E. Keiha ¨nen17, R. Keskitalo51,17, T. S. Kisner59, R. Kneissl31,4, L. Knox21, H. Kurki-Suonio17,35, G. Lagache45, J.-M. Lamarre54, A. Lasenby76,53, R. J. Laureijs33, C. R. Lawrence51, S. Leach67, R. Leonardi32,33,22, M. Linden-Vørnle12, M. Lo ´pez-Caniego50, P. M. Lubin22, J. F. Mac ´ıas-Pe ´rez57, C. J. MacTavish53, B. Maffei52, D. Maino26,40, N. Mandolesi39, R. Mann68, M. Maris38, F. Marleau14, E. Mart ´ınez-Gonza ´lez50, S. Masi25, S. Matarrese24, F. Matthai60, P. Mazzotta28, S. Mei74,34,7, A. Melchiorri25, J.-B. Melin11, L. Mendes32, A. Mennella26,38, S. Mitra51, M.-A. Miville-Desche ̂nes45,5, A. Moneti46, L. Montier75,6, G. Morgante39, D. Mortlock43, D. Munshi69,77, A. Murphy63, P. Naselsky64,29, P. Natoli28,2,39, C. B. Netterfield14, H. U. Nørgaard-Nielsen12, F. Noviello45, D. Novikov43, I. Novikov64, I. J. O'Dwyer51, S. Osborne72, F. Pajot45, F. Pasian38, G. Patanchon3, O. Perdereau58, L. Perotto57, F. Perrotta67, F. Piacentini25, M. Piat3, E. Pierpaoli16, R. Piffaretti55,11, S. Plaszczynski58, E. Pointecouteau75,6, G. Polenta2,37, N. Ponthieu45, T. Poutanen35,17,1, G. W. Pratt55, G. Prezeau7,51, S. Prunet46, J.-L. Puget45, R. Rebolo49,30, M. Reinecke60, C. Renault57, S. Ricciardi39, T. Riller60, I. Ristorcelli75,6, G. Rocha51,7, C. Rosset3, J. A. Rubino-Martın49,30, B. Rusholme44, M. Sandri39, G. Savini66, B. M. Schaefer73, D. Scott15, M. D. Seiffert51,7, P. Shellard10, G. F. Smoot20,59,3, J.-L. Starck55,11, F. Stivoli41, V. Stolyarov76, R. Sudiwala69, R. Sunyaev60,70, J.-F. Sygnet46, J. A. Tauber33, L. Terenzi39, L. Toffolatti13, M. Tomasi26,40, J.-P. Torre45, M. Tristram58, J. Tuovinen62, L. Valenziano39, L. Vibert45, P. Vielva50, F. Villa39, N. Vittorio28, B. D. Wandelt46,23, S. D. M. White60, M. White20,D. Yvon11, A. Zacchei38, and A. Zonca22

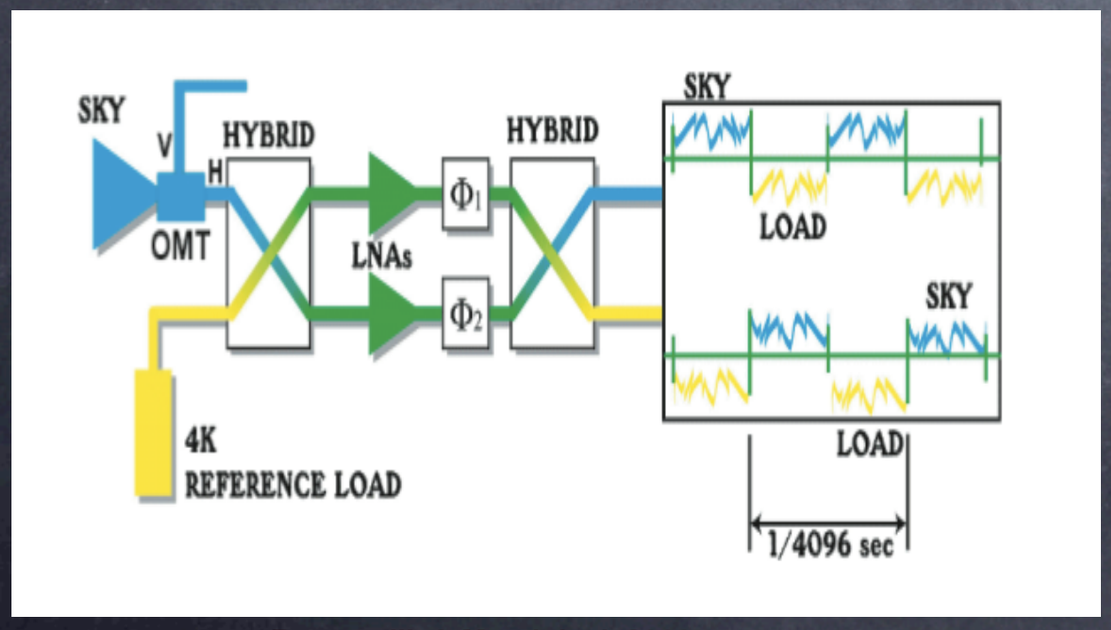
The Planck satellite

Tauber et al. 2010
Planck collaboration 2011

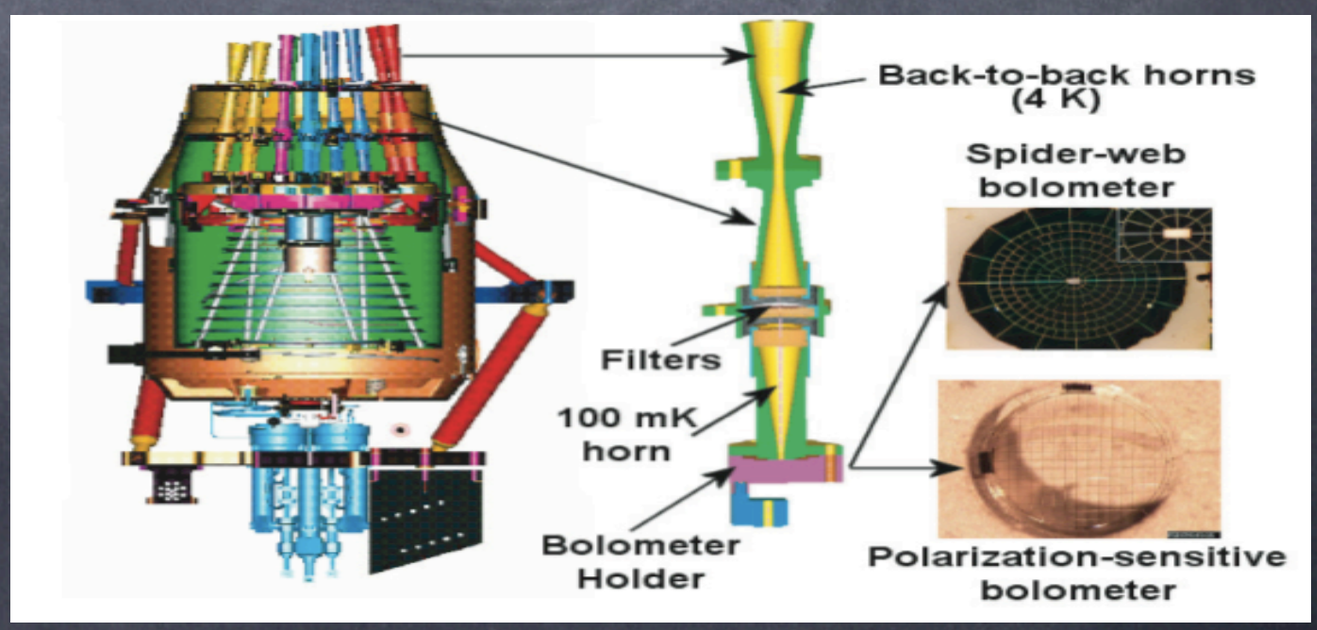
- 3rd generation of satellite for CMB studies (after COBE and WMAP)
  Launched by ESA 14th May 2009 from the Lagrange L2 point
- Scanning strategy on big circles on the sky (1 rpm, 40 minutes)
  Full-sky coverage in 6-7 months
- 1.5 m hors axis Gregorian telescope
- Stellar sensor for pointing reconstruction
- Observations back to the sun and the earth
- Two instruments:
  LFI : radiometers (OMT) cooled down to 18 K
  30 [4], 40 [6] et 70 [12] GHz
  HFI : bolometers (SW and PSB) cooled down to 100 mK
  100 [8], 143 [8+4], 217 [8+4], 353[8+4], 545 [4] et 857 [4] GHz + 2 Dark



- Complex cryogenic system:
  50 (V-grooves), 18 (H sorption cooler), 4 (JT ^{4}He), 1.4 et 0.1 K (dilution ^{3}He-^{4}He)



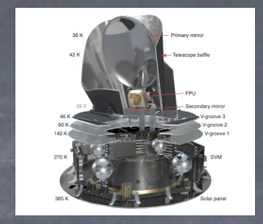
Bersanelli & Mandolesi 2000



Planck HFI Core Team 2011
Lamarre et al. 2003

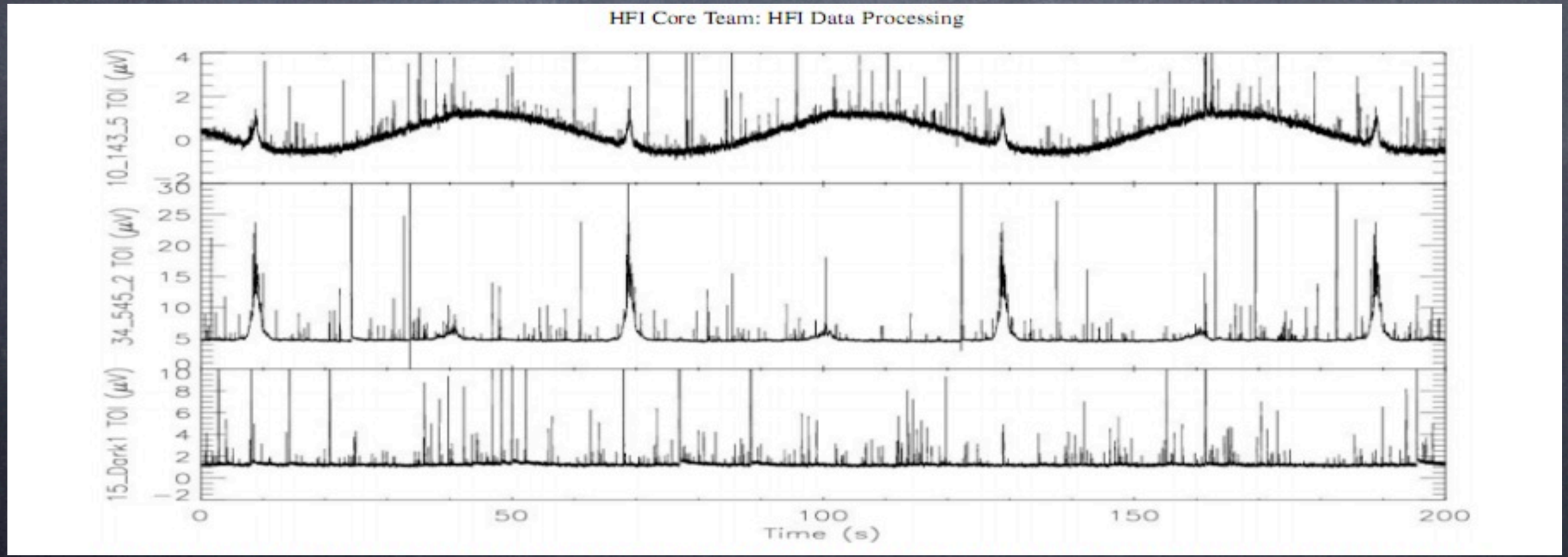
Tauber et al. 2010
Planck collaboration 2011

The Planck satellite



Instrument performances:

	30	44	70	100	143	217	353	545	857
Resolution (arcmin)	32	28	13	9	7	4.7	4.5	3.8	3.6
Sensitivity ($\mu K_{CMB}\ s^{1/2}$)	146	173	152	23	20	28	116	814	23798

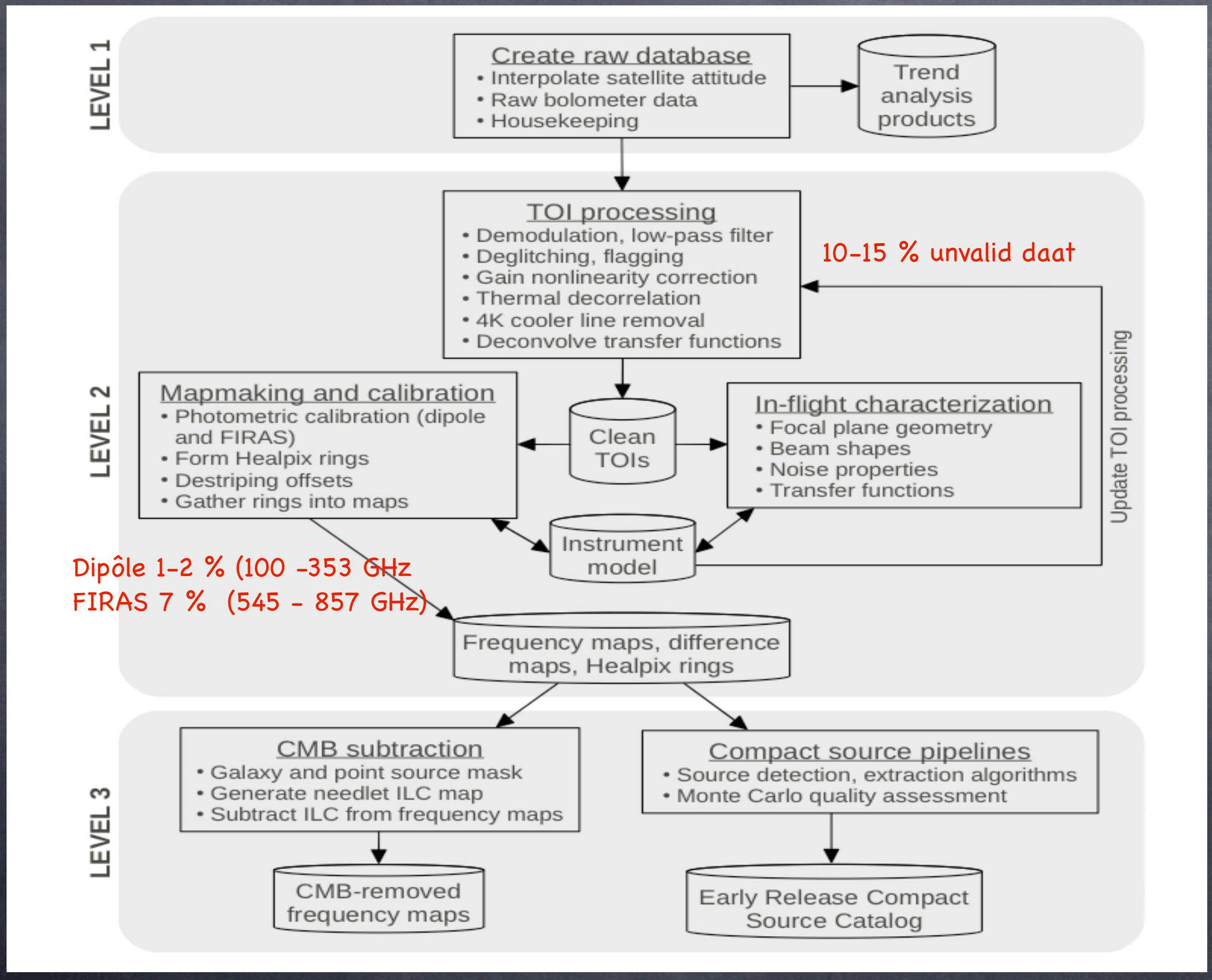


Bersanelli & Mandolesi 2000

Planck HFI Core Team 2011
Lamarre et al. 2003

Planck HFI Core Team 2011

Planck data analysis

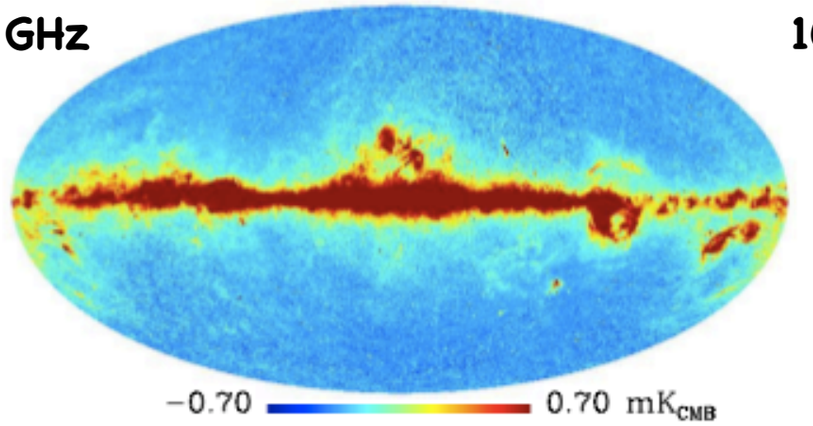


Planck HFI Core Team 2011
Zacchei et al. 2011

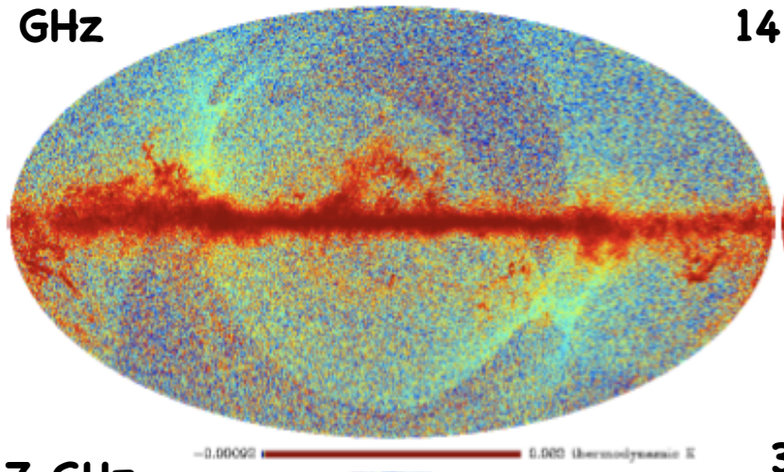
Planck all-sky maps

First all-sky maps from 30 to 857 GHz

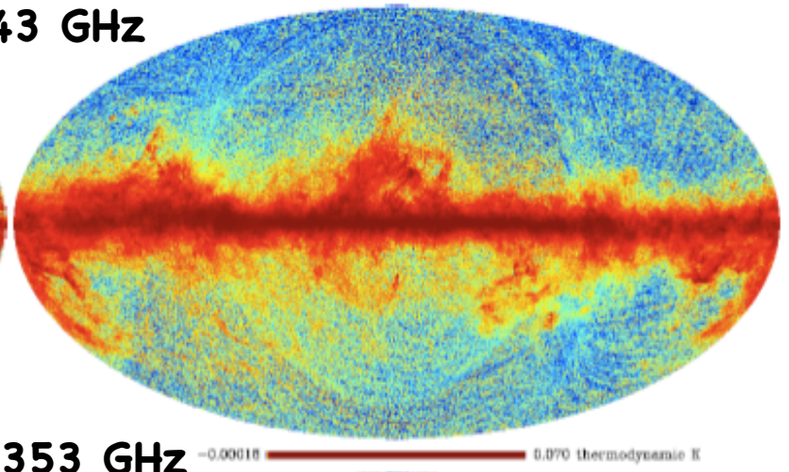
30 GHz



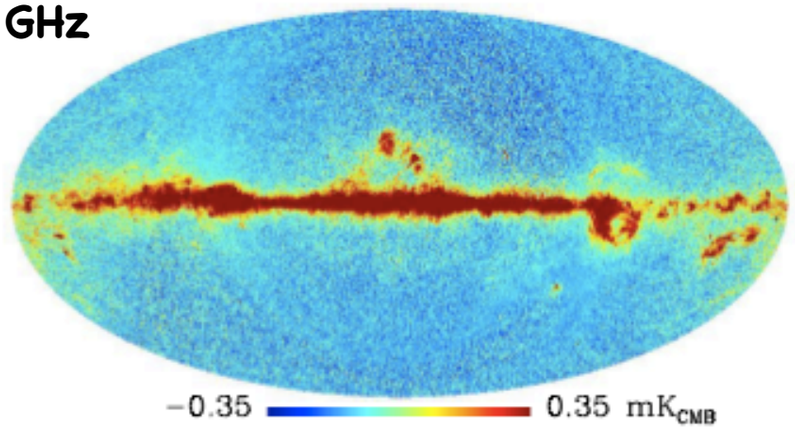
100 GHz



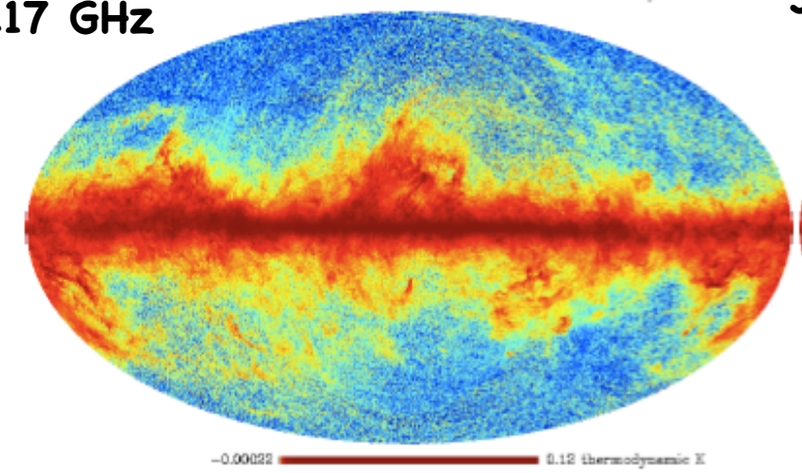
143 GHz



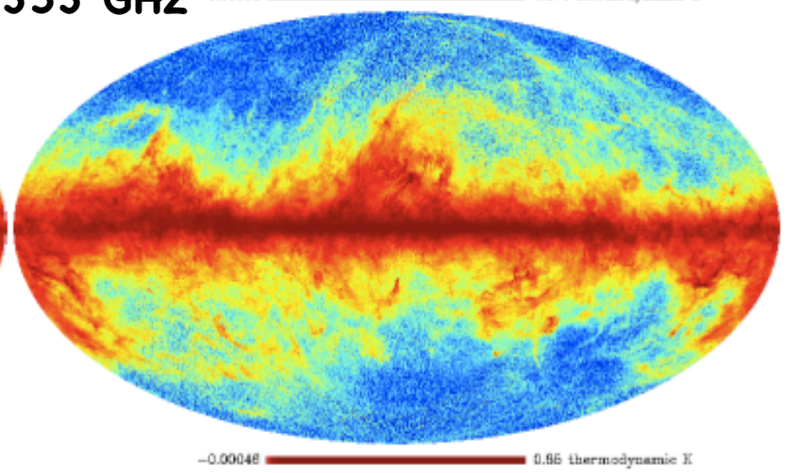
40 GHz



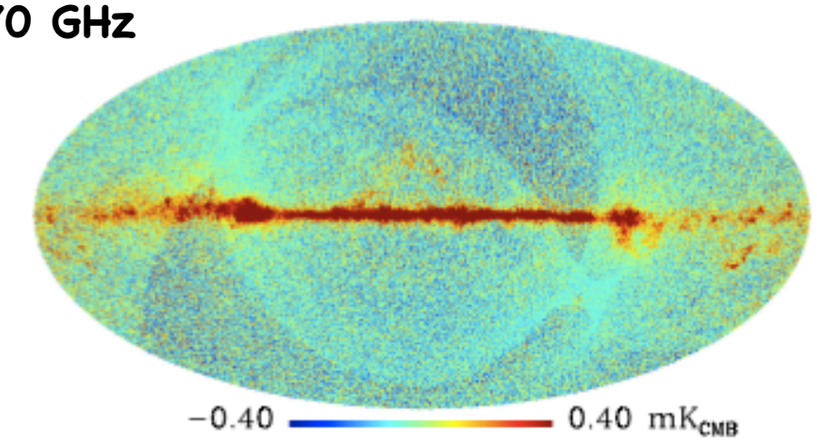
217 GHz



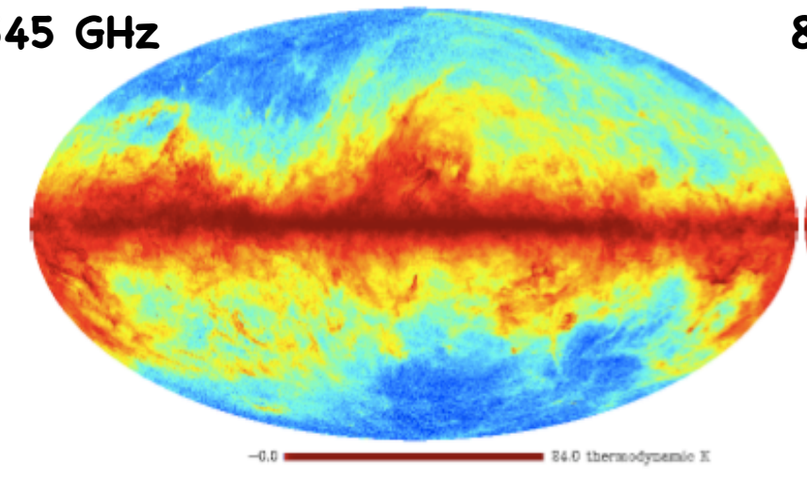
353 GHz



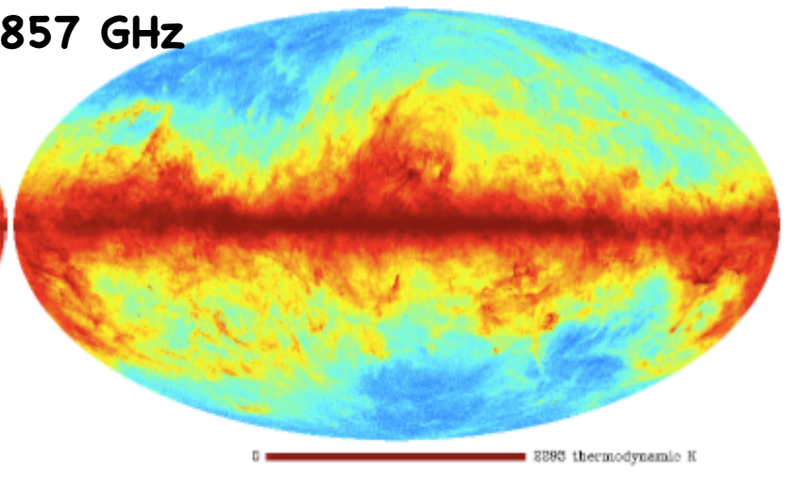
70 GHz



545 GHz



857 GHz



Calibration:
Dipole based 1-2 % 100-353 GHz
EIRAS based 7 % 545-857 GHz)

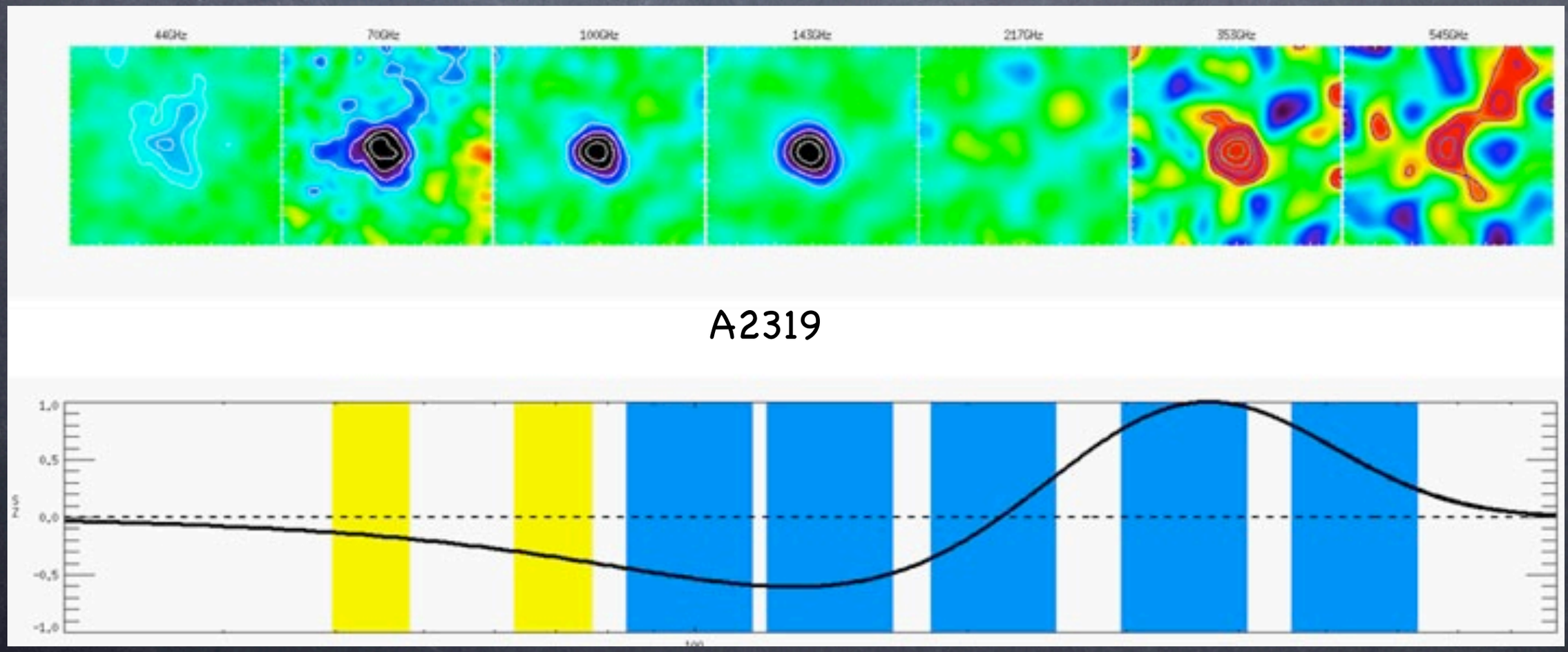
Thermal Sunayev-Zeldovich (tSZ) effect with Planck

Inverse Compton between CMB photons and hot electrons on cluster of galaxies

x= hν/ ($k_B T_{CMB}$)

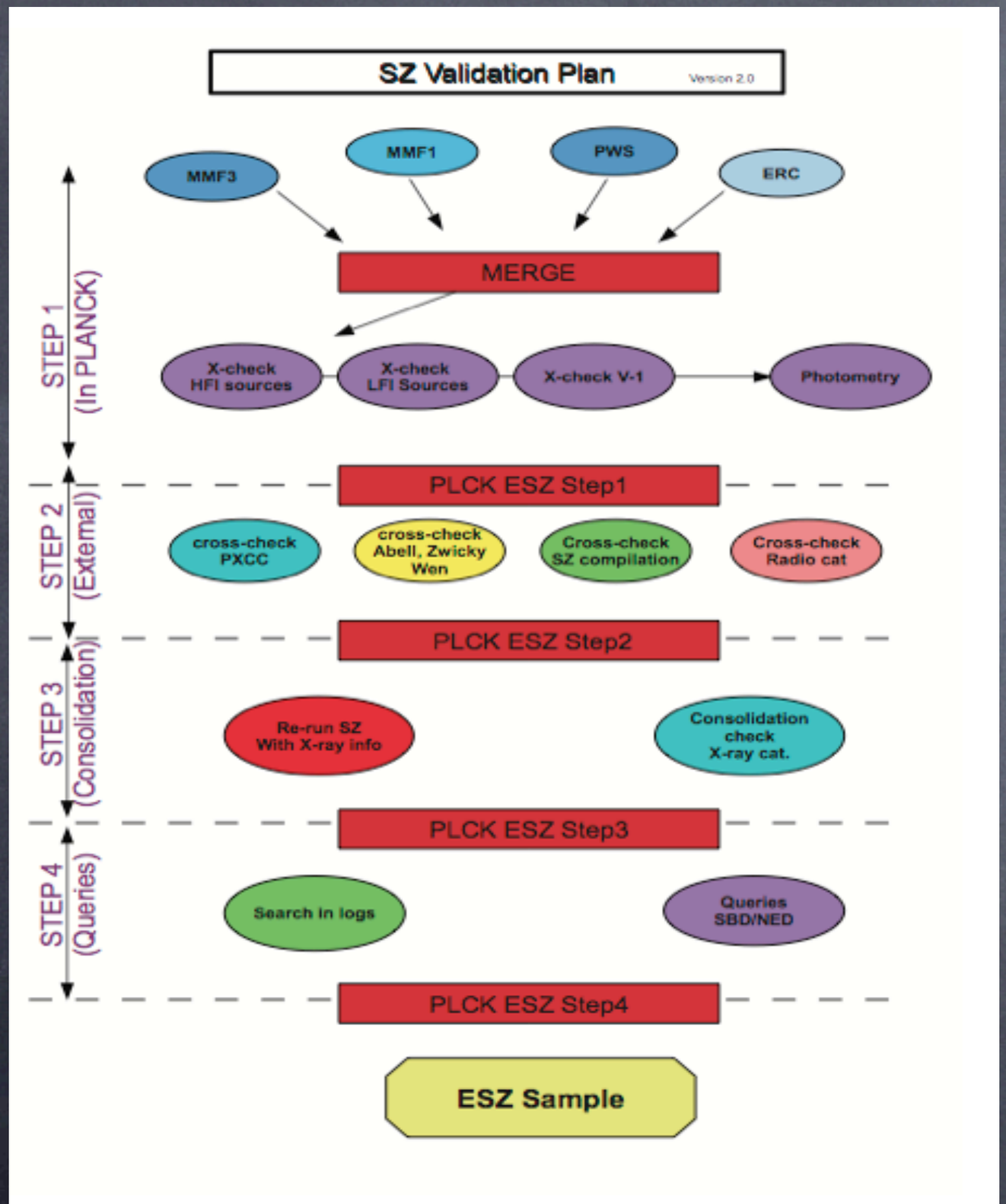
$$\frac{\Delta T_{TSZ}}{T_{CMB}} = f(x)y = f(x)\int n_e \frac{K_B T_e}{m_e c^2}\sigma_T d\ell \qquad f(x) = \left(x\frac{e^x+1}{e_x-1} - 4\right)$$

The Planck satellite has been designed to extract the tSZ effect signal on clusters:



A2319

The all-sky early Sunyaev-Zeldovich (ESZ) cluster sample



Extraction methods:
- MMF1/3
- Powell snakes

Artifacts and Planck sources
- SSO objects
- cold cores, radio and IR sources

Component separation methods:
- MILCA
- NILC
- GMCA

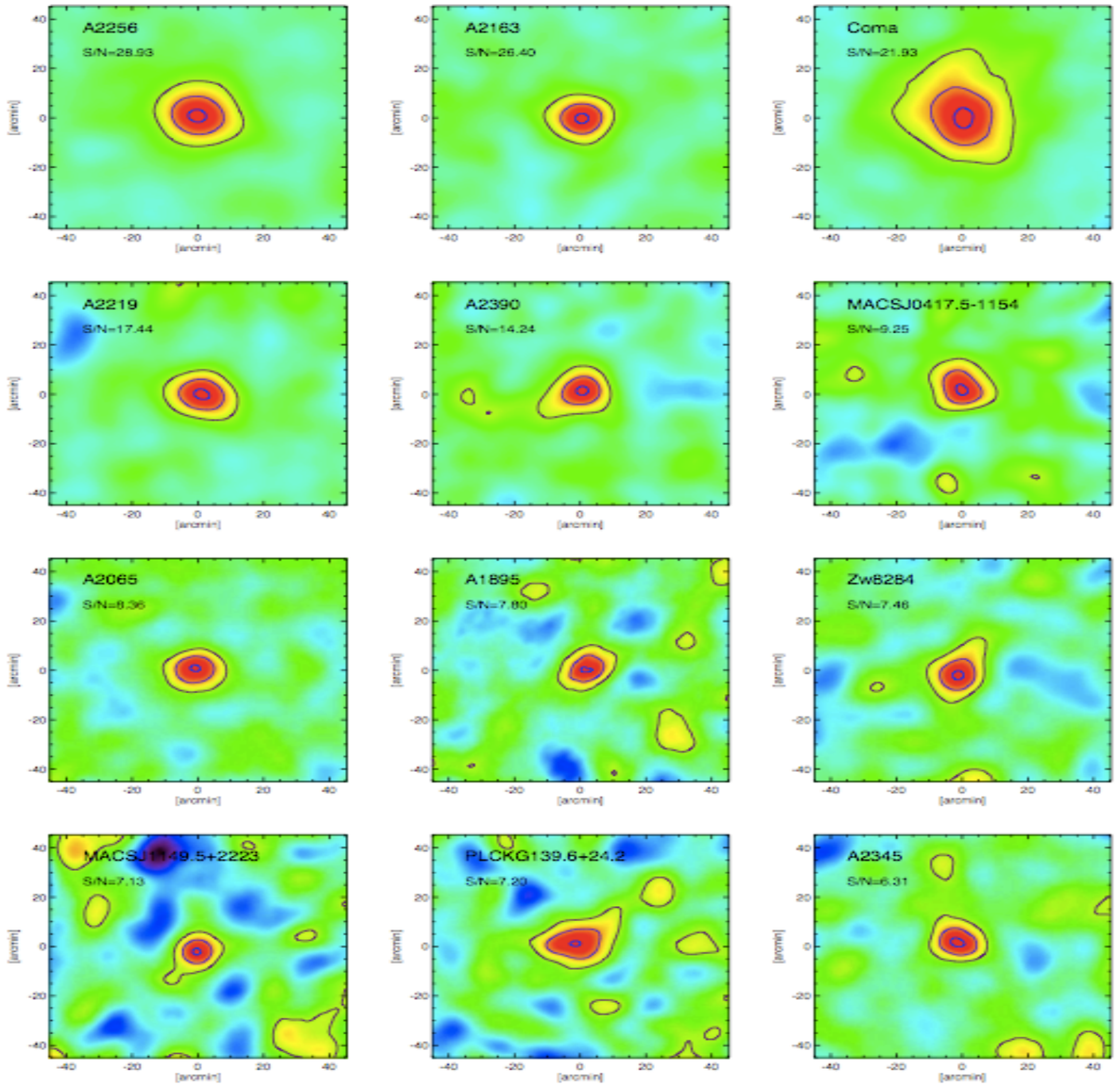
X-ray data
- XMM
- ROSAT
- RECESS MCXC catalogue

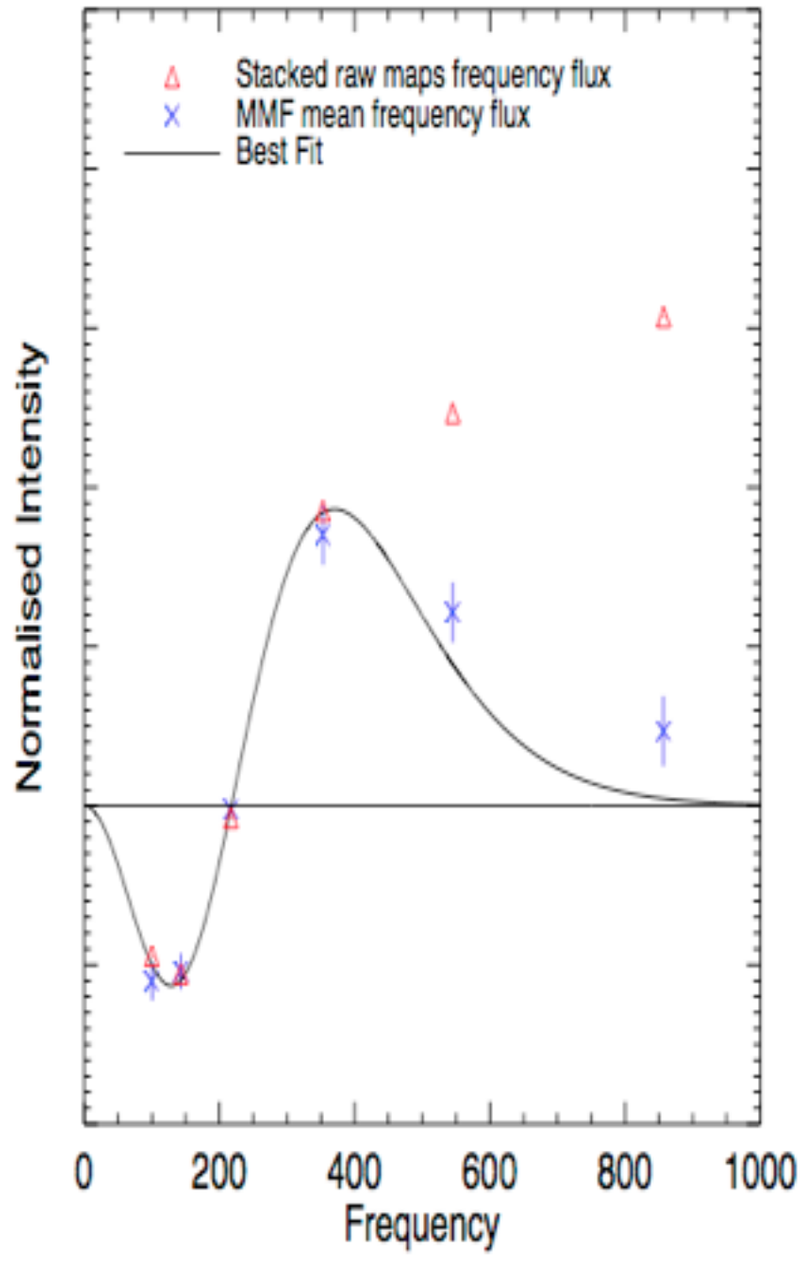
Optical data:
- MaxBCG

tSZ data:
- AMI

The all-sky early Sunyaev-Zeldovich (ESZ) cluster sample

- 169 (already known) + 20 (new) robust cluster detections (S/N > 6)
  + 10 new extra clusters

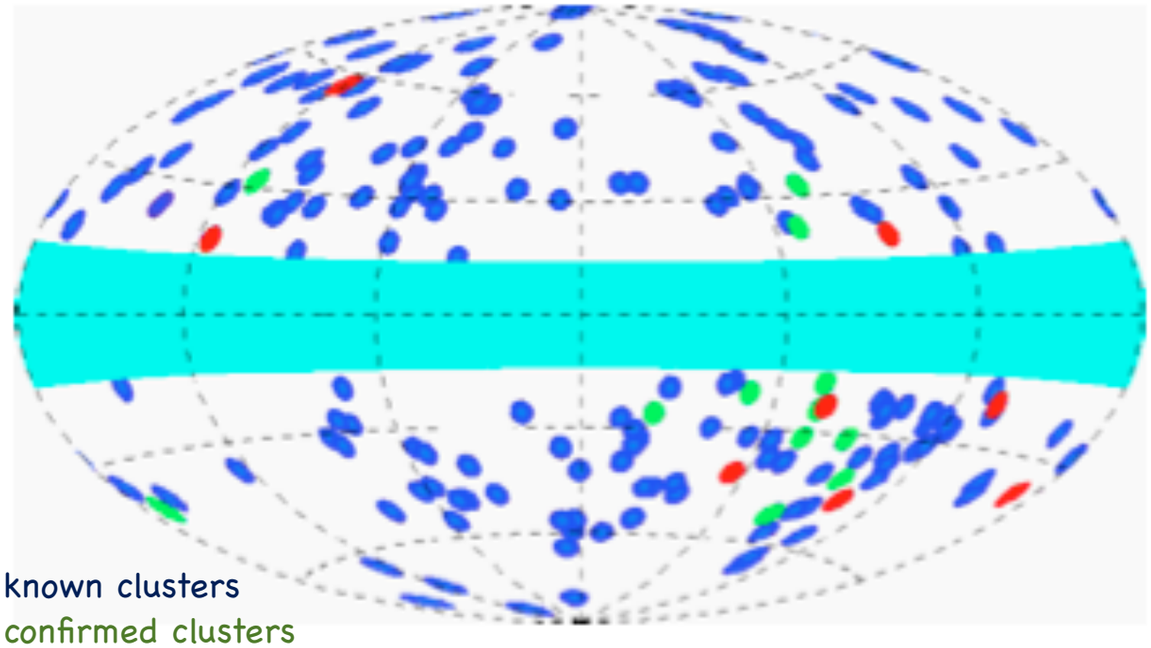




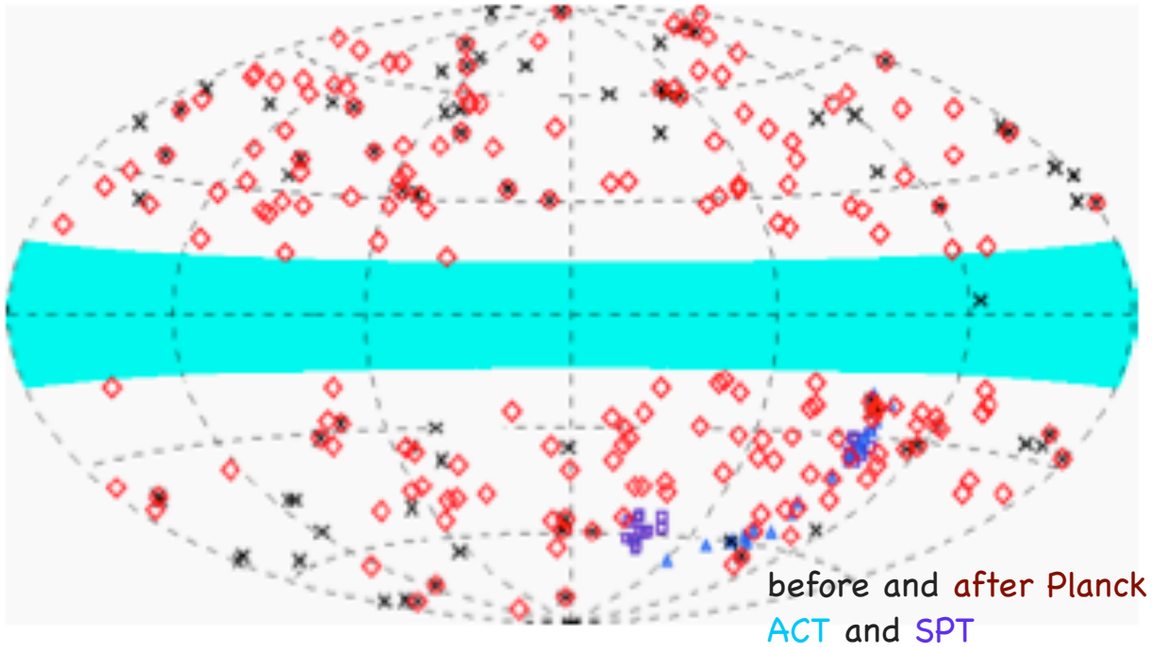
ESZ catalog properties

189 clusters z=0-0.6, M=1-13 10^{14} M_{sun}

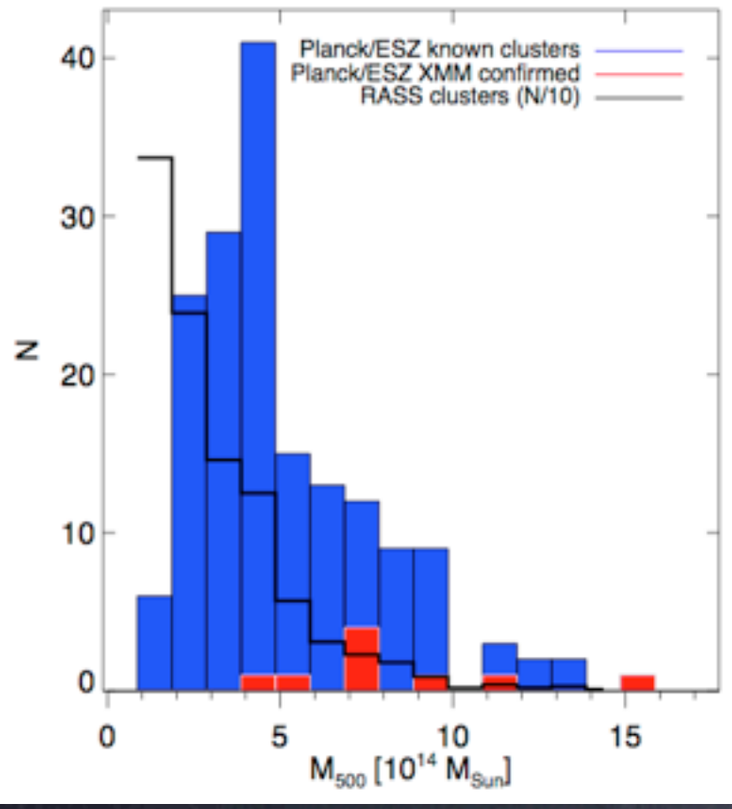
Text

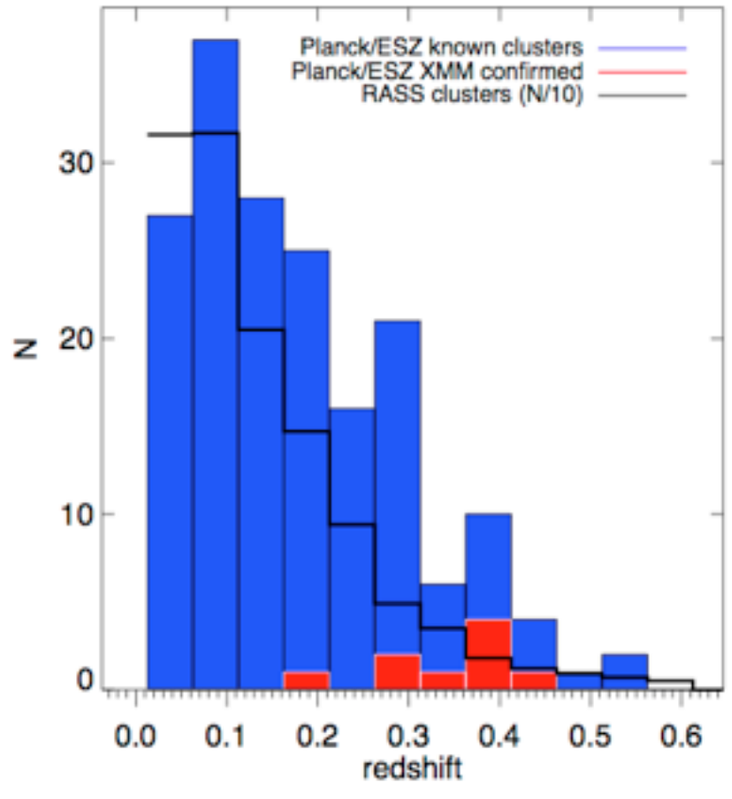


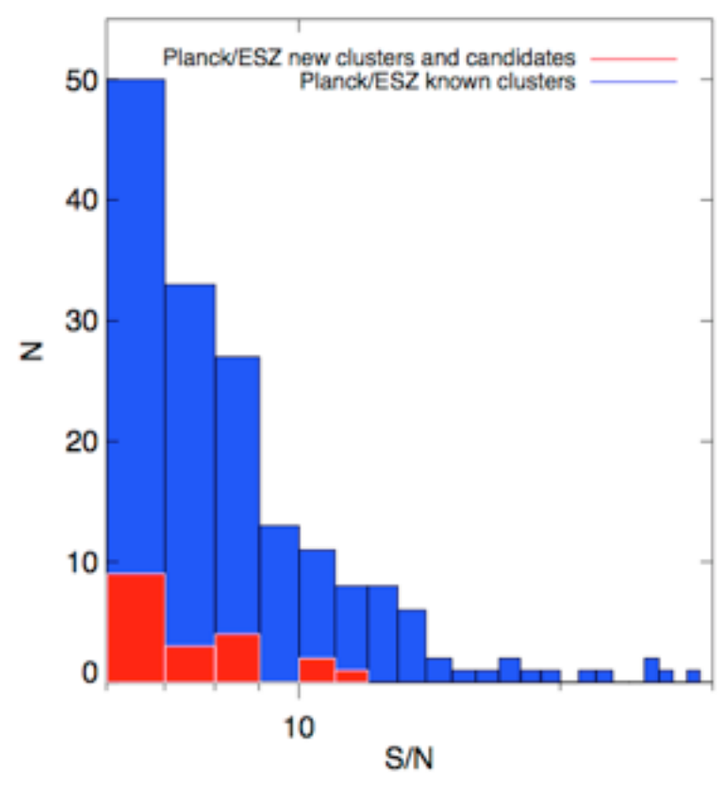
known clusters
confirmed clusters



before and after Planck
ACT and SPT





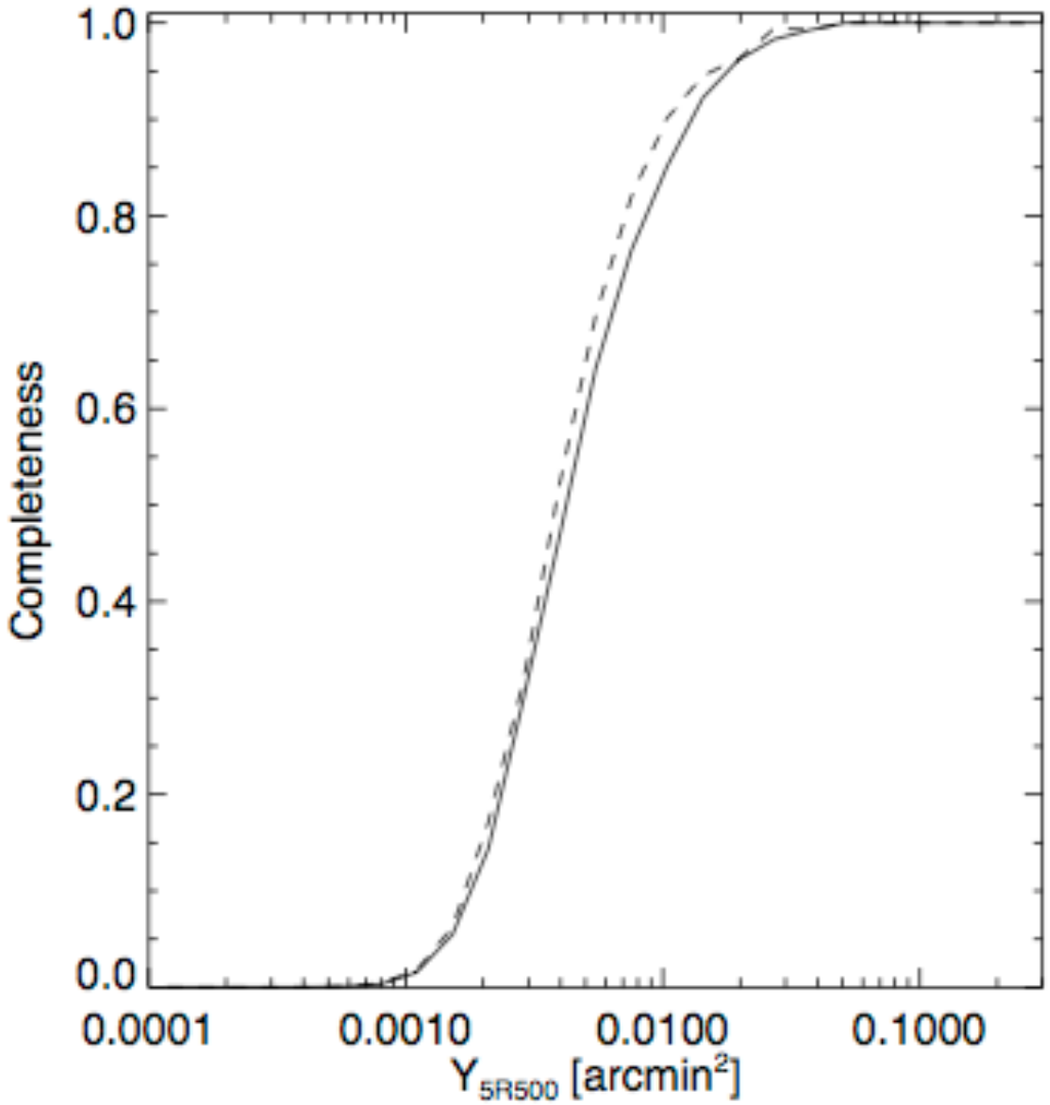


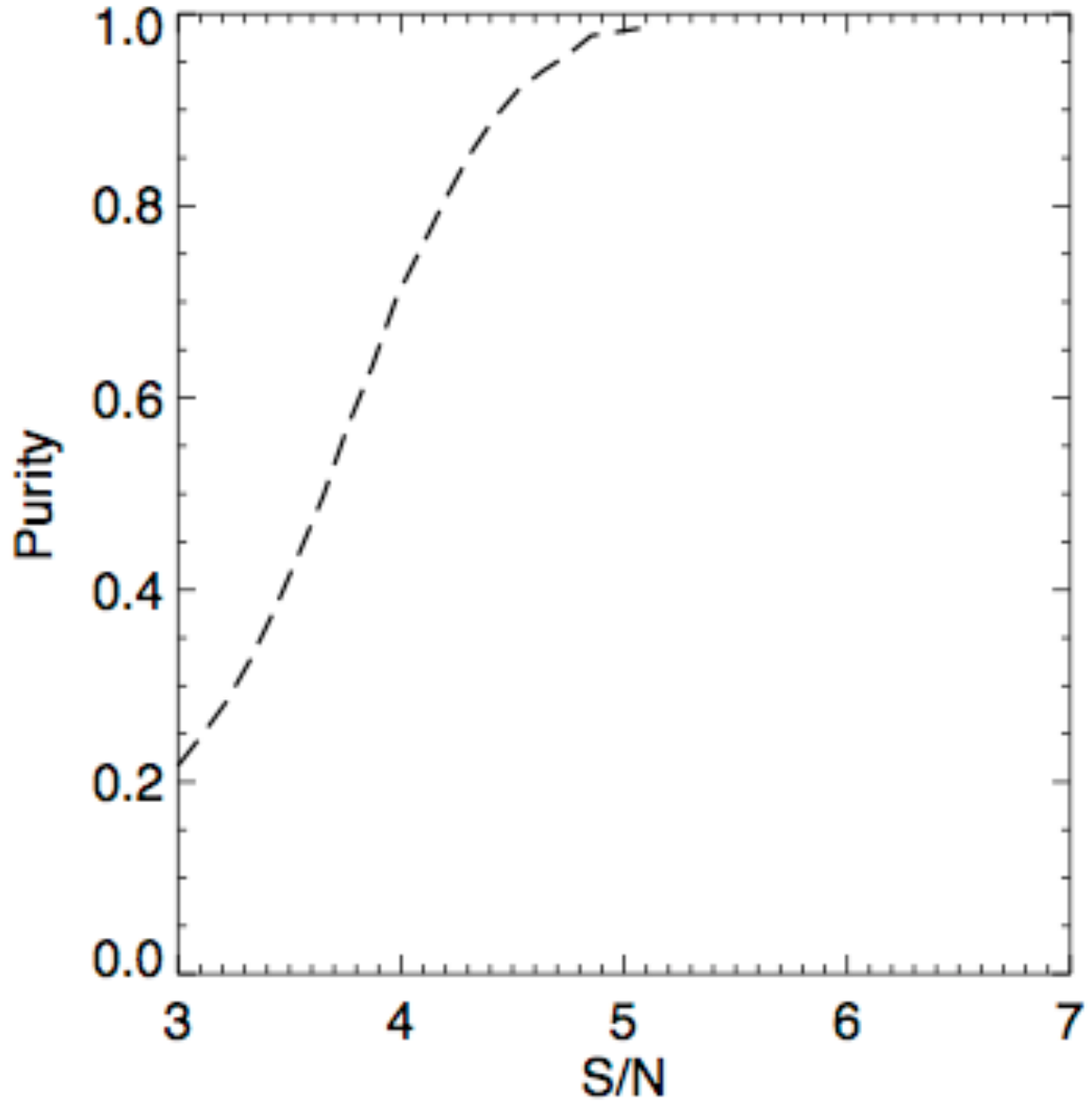
ESZ catalog properties: completeness and purity

Using MC simulations of the catalogue we find:

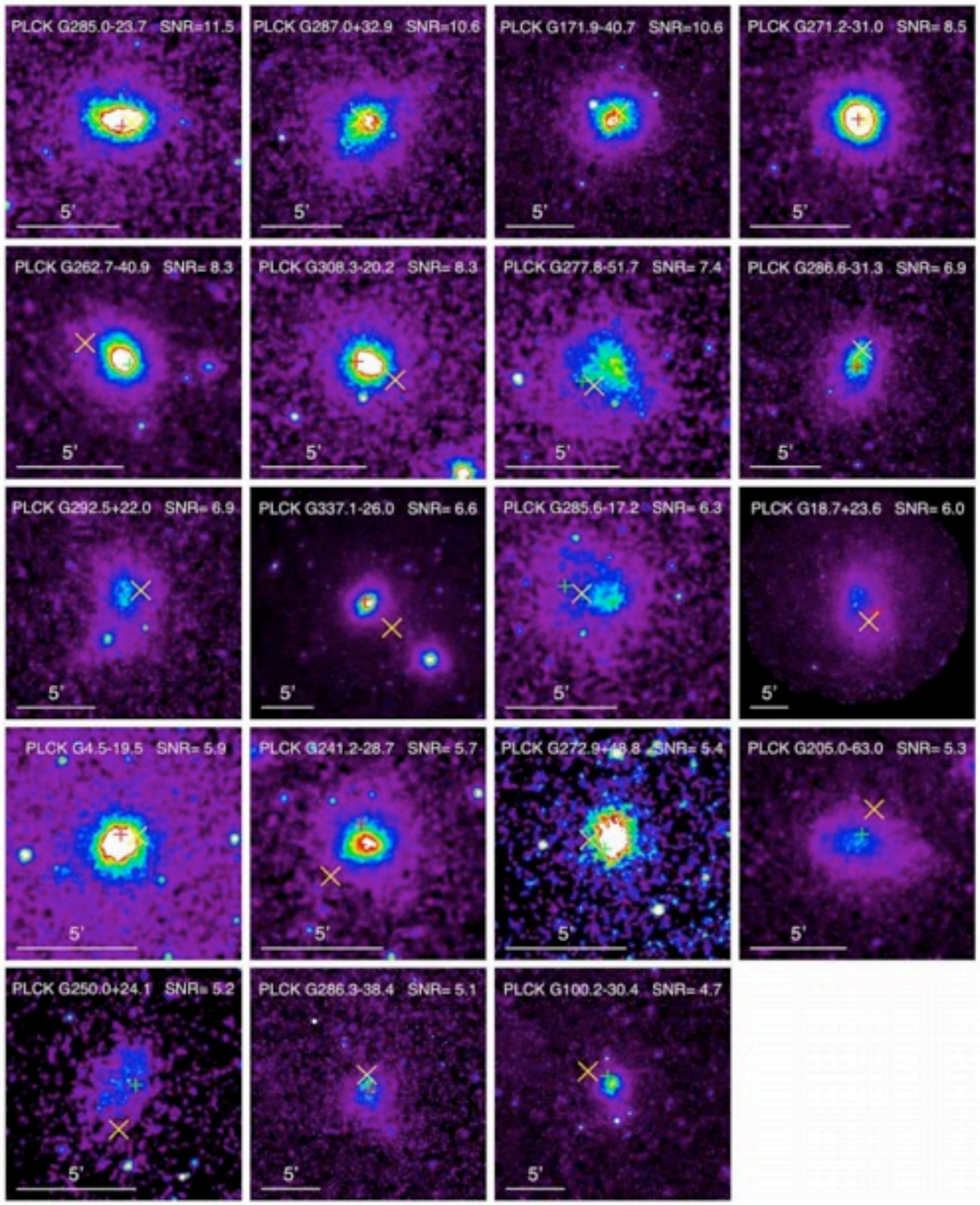
100 % purity for S/N > 6

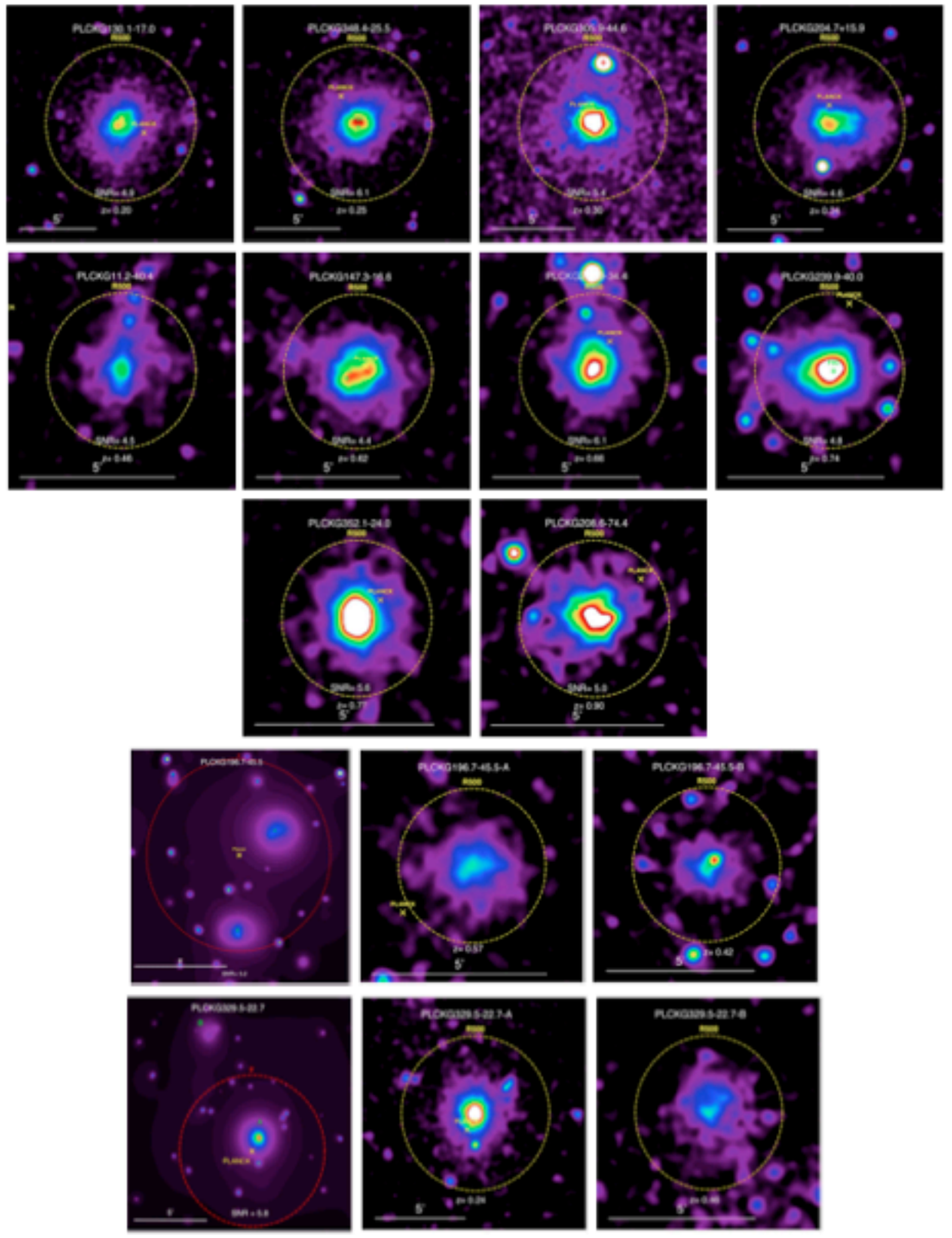
90 % complete for $Y_{5R500} > 0.01$ arcmin^2





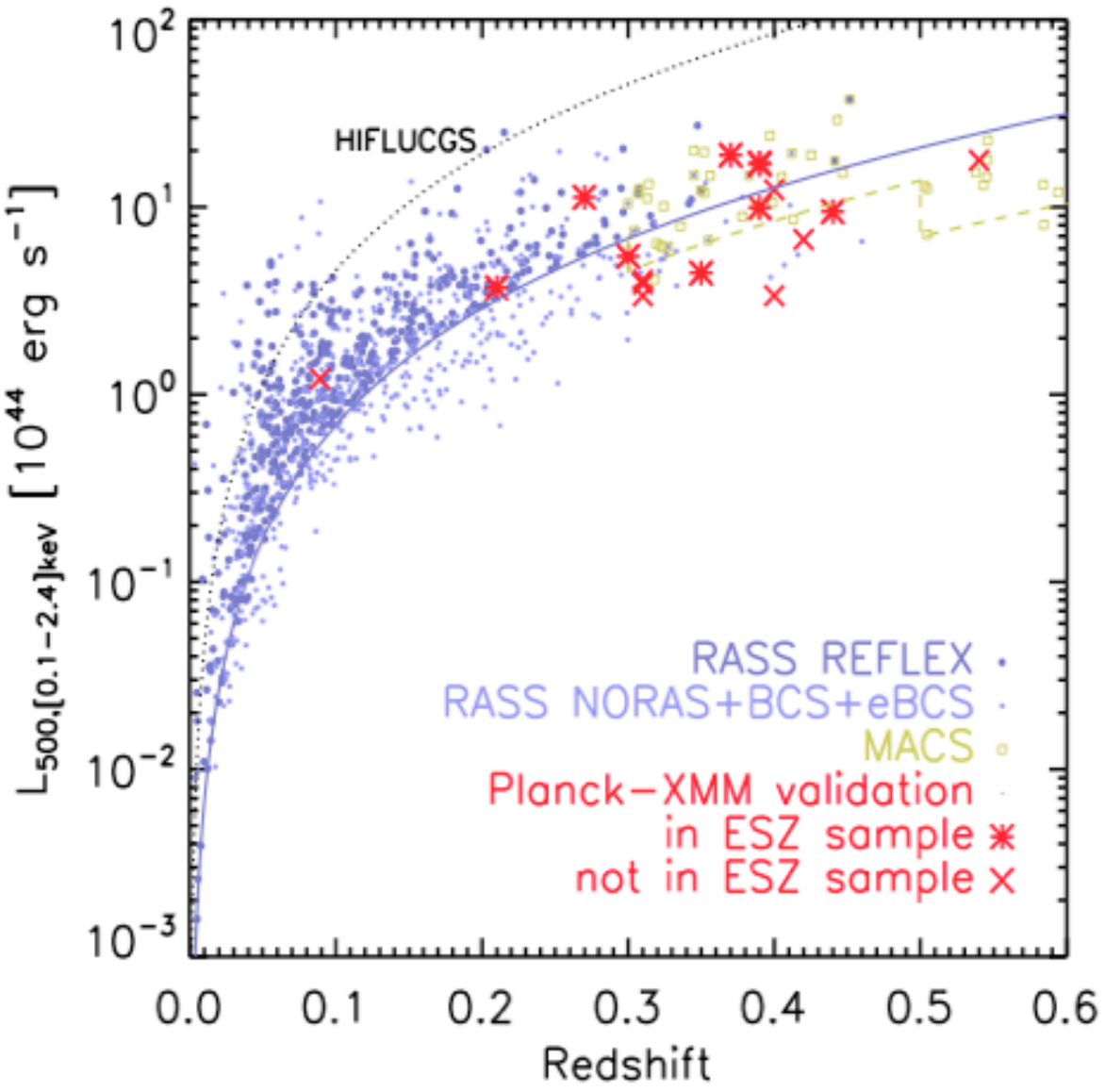
X-ray validation using XMM

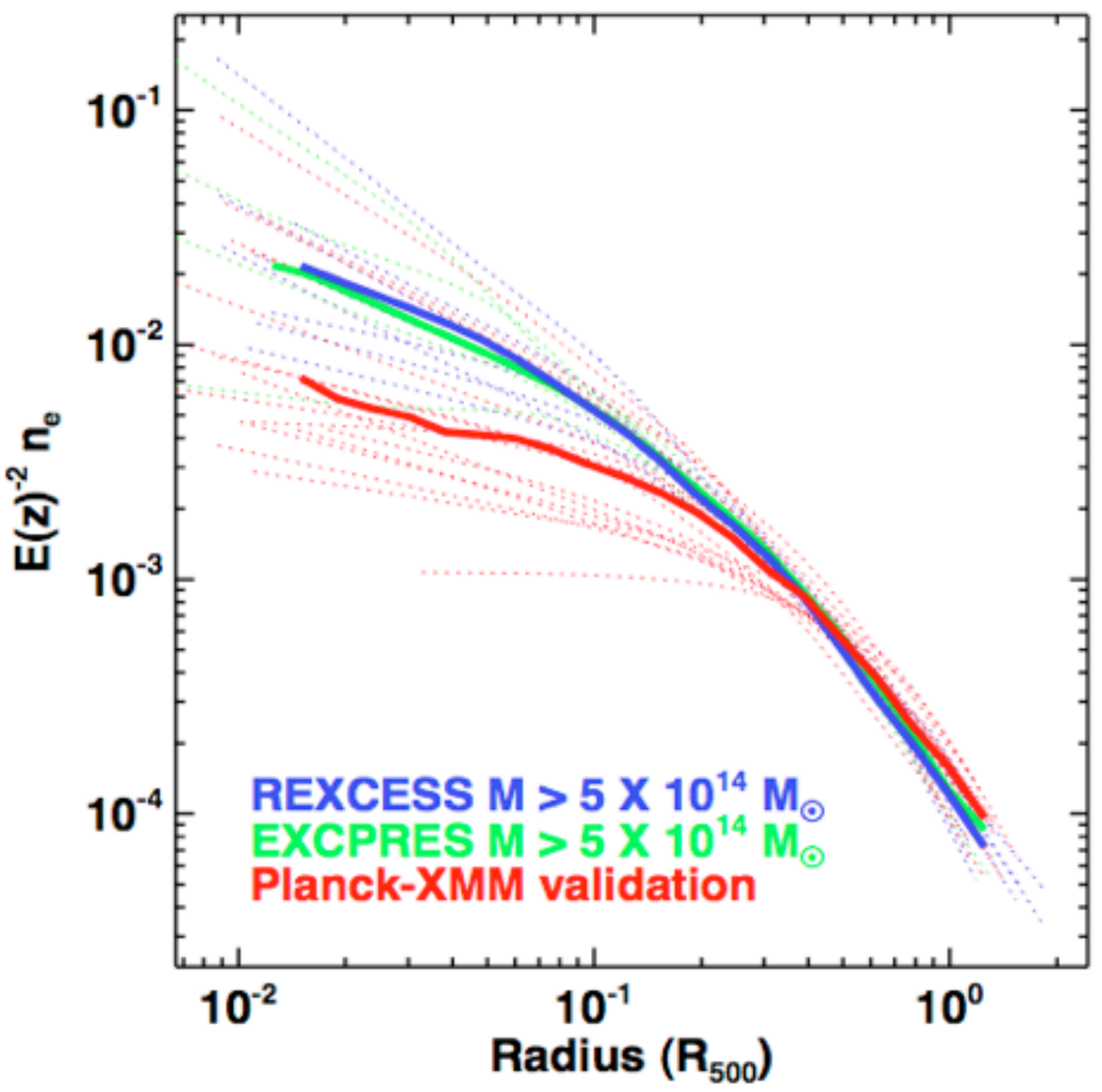




Intensive and continuos follow-up using XMM : up to date, 21 (Early) + 14 (Intermediate) candidates confirmed
False detections (up to date 6): very useful feedback on figures of merit for the extraction methods

X-ray validation

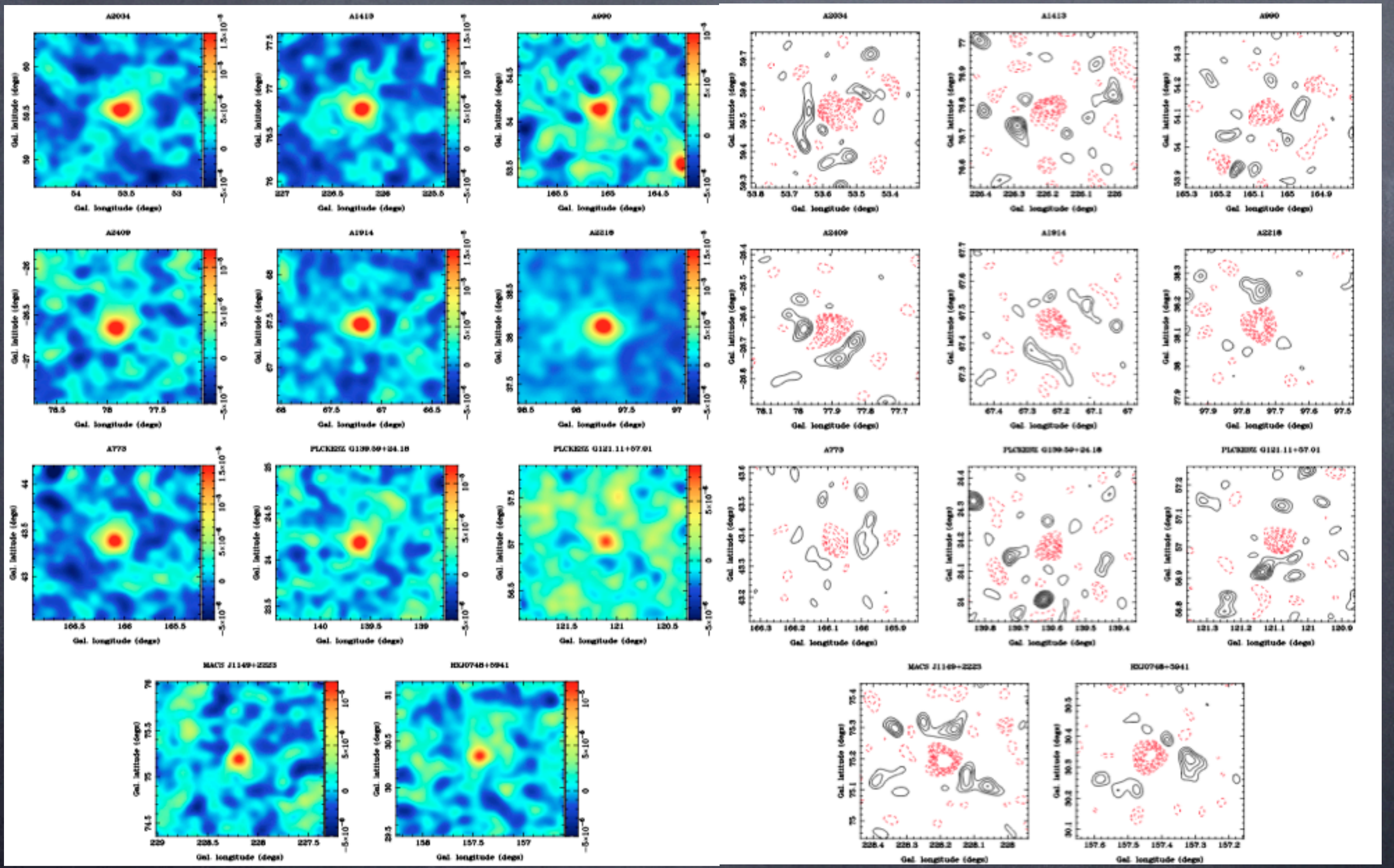




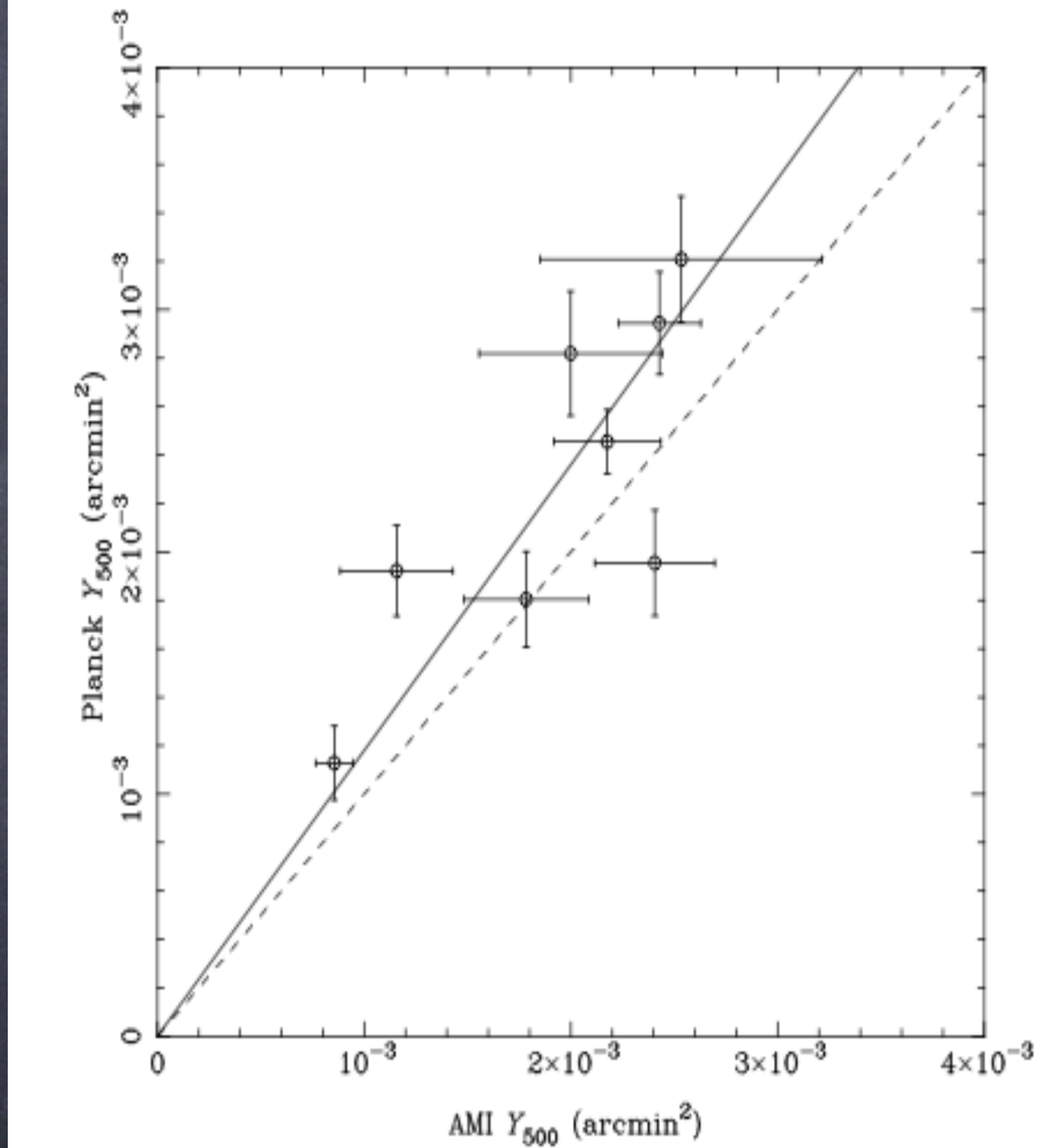
- Planck detected clusters spans in the redshift range 0.1 < z < 0.6 + 1 cluster at z=0.9
- Large dispersion in the electron density profile but compatible with X-ray detected clusters

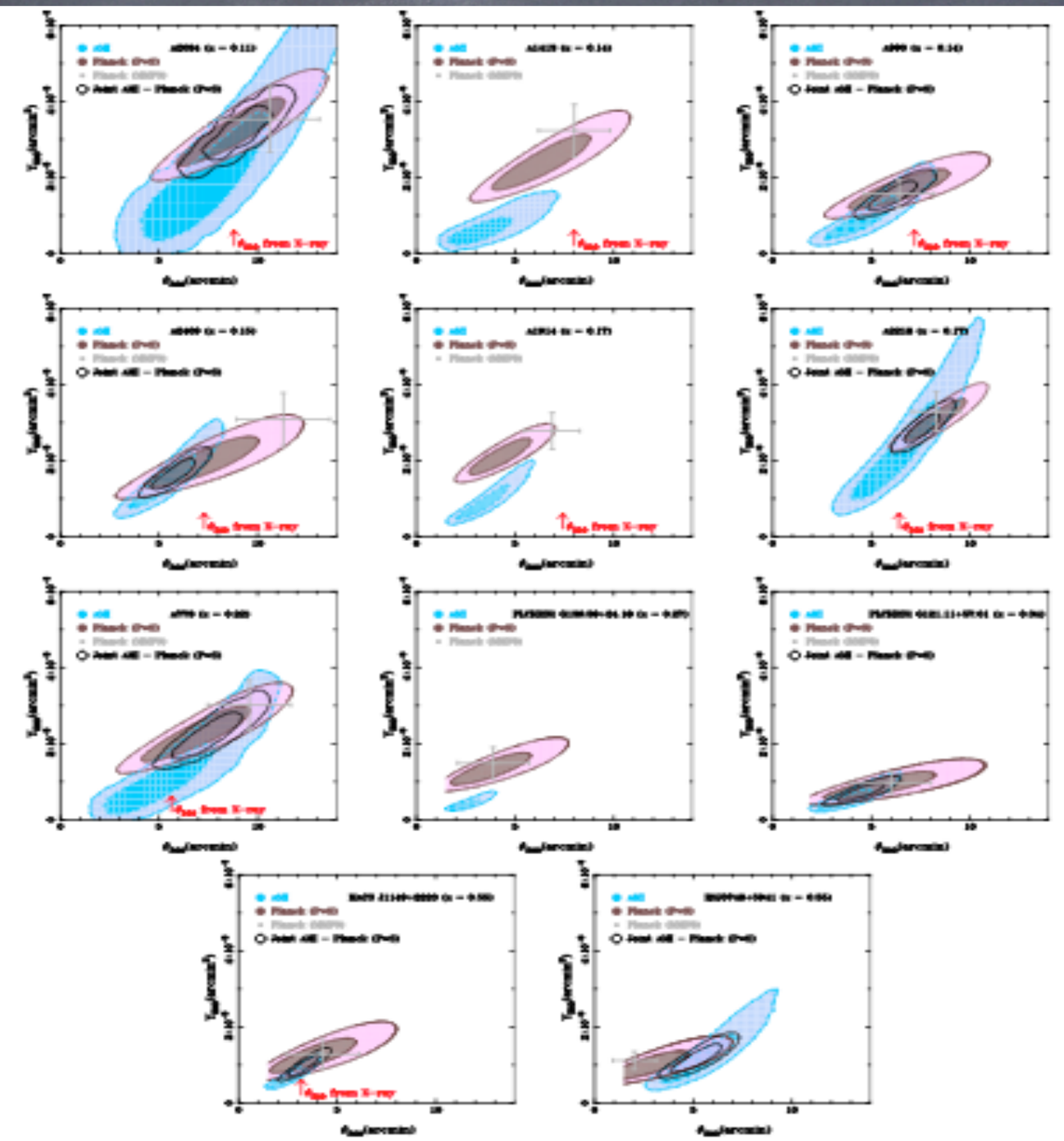
tSZ validation: AMI (Arcminute Microkelvin Imager) vs PLANCK

Comparison of 11 clusters with dedicated AMI observations



tSZ validation: AMI vs PLANCK

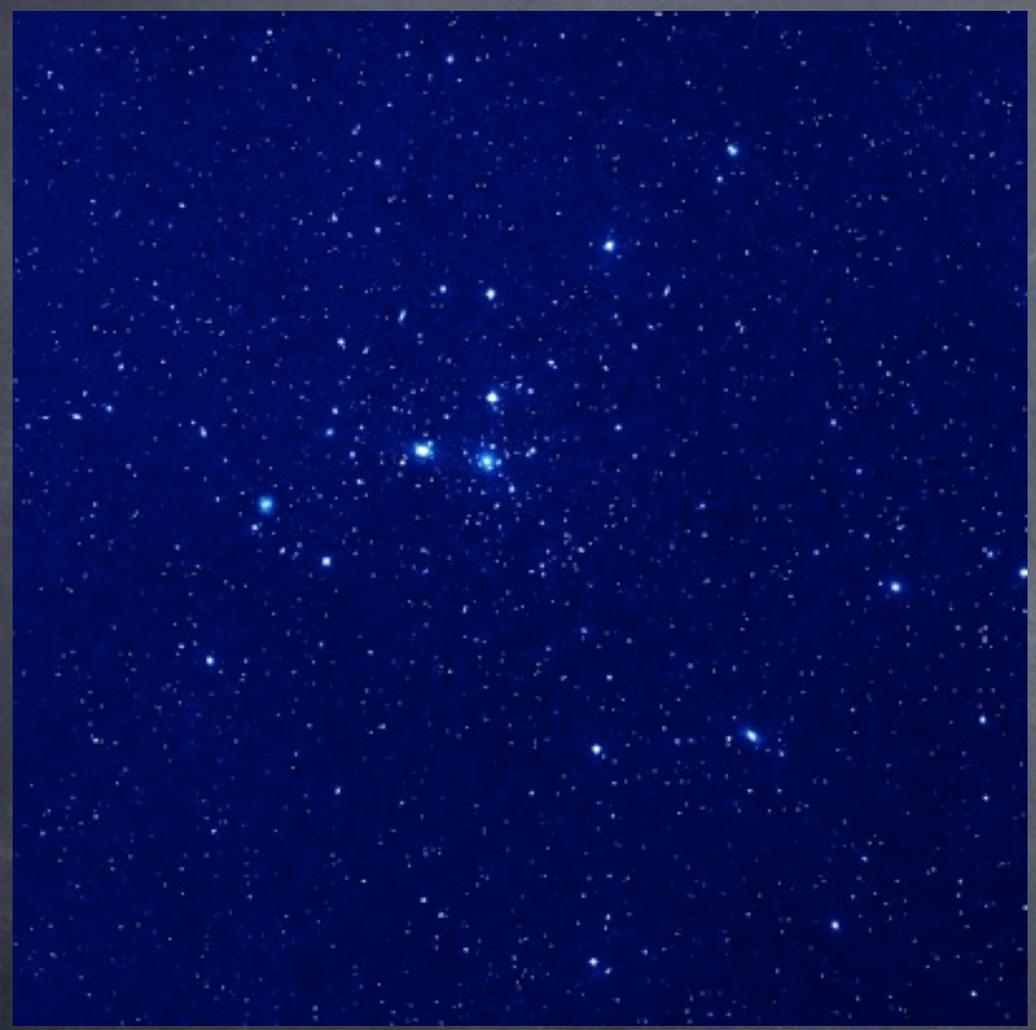




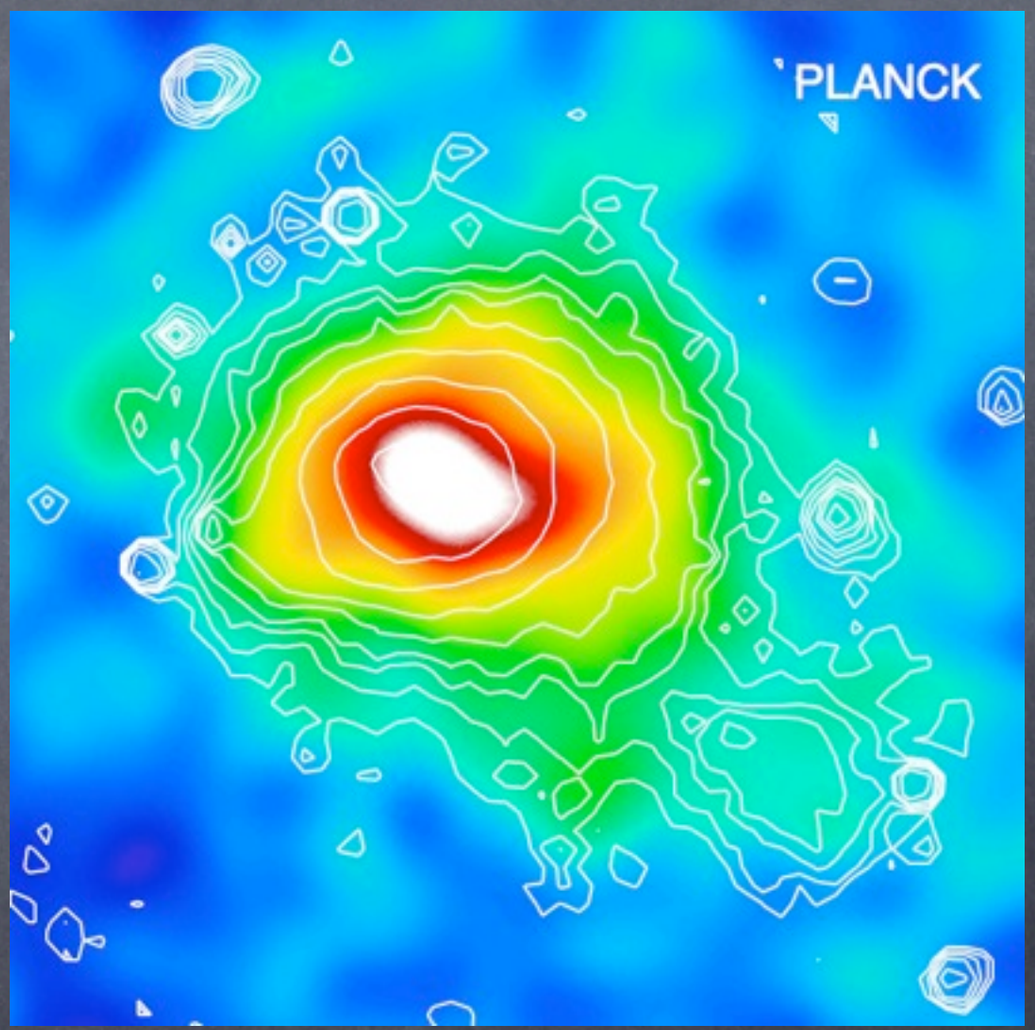
- Planck tSZ flux larger than AMI one (maybe due to large angular scale removal)
- Cluster parameters compatible but for 3 of the clusters for which the difference is not understood

The COMA cluster

High sensitivity maps of nearby clusters like COMA: reliable outskirt detection
(keep tune for new exciting COMA results from Planck in the following months)

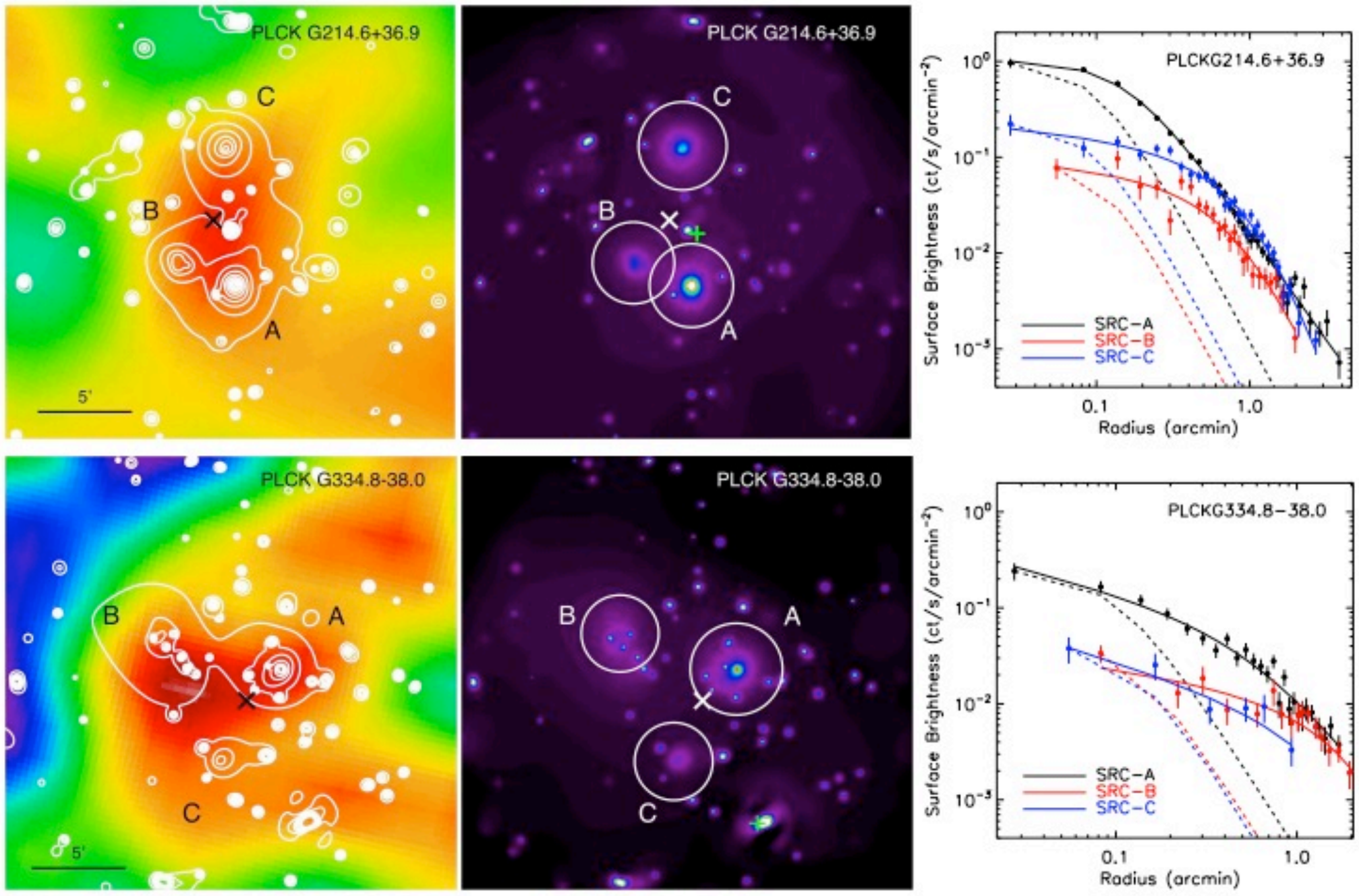


HST - Visible

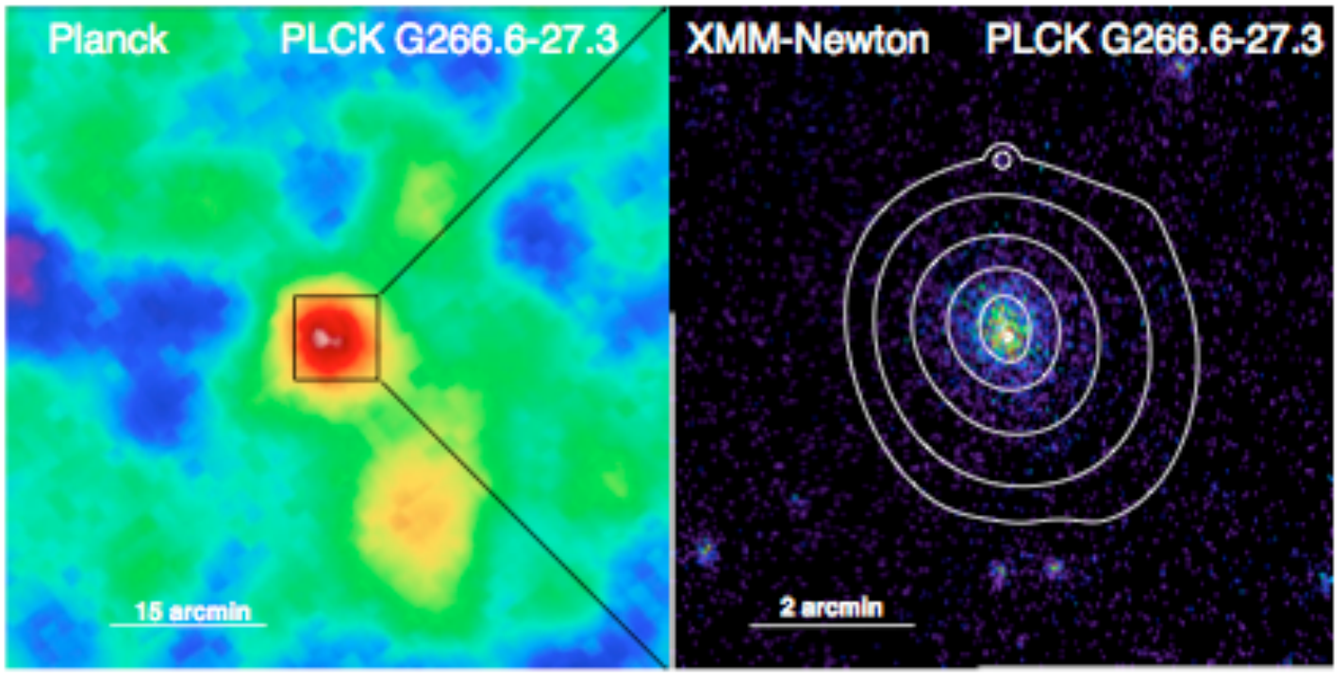


Planck (color) & XMM (contours)

Multiple cluster systems



PLCK G266.6-27.3 a high redshift cluster



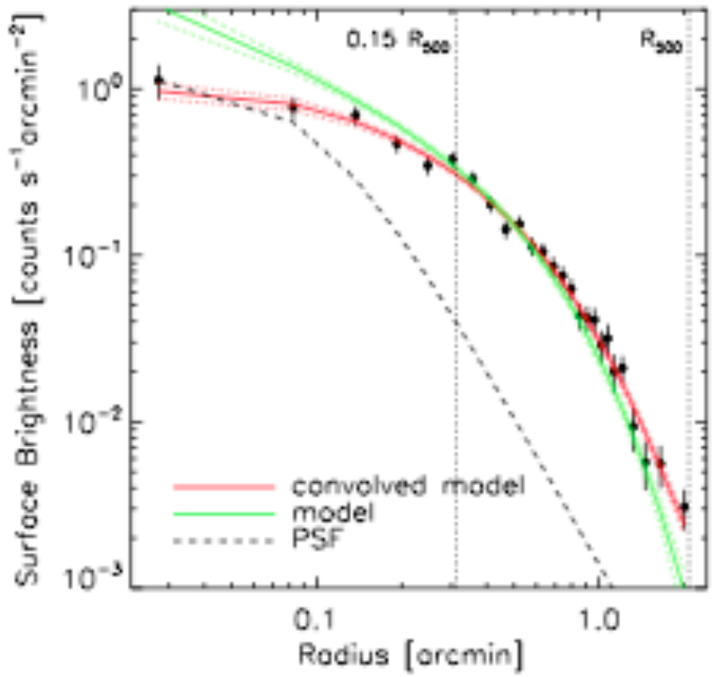


Table 1: Physical properties of PLCK G266.6−27.3 derived from *XMM-Newton* data.

Parameter	Value
z	0.94 ± 0.02
Abundance	0.44 ± 0.17 solar
R_{500}	0.98 ± 0.03 Mpc
M_{500}	$7.8^{+0.8}_{-0.7} \times 10^{14}\,M_\odot$
Y_X	$1.10^{+0.20}_{-0.17} \times 10^{15}\,M_\odot$ keV
T_X	$10.5^{+1.6}_{-1.4}$ keV
$T(< R_{500})$	$11.4^{+1.4}_{-1.2}$ keV
L_{500}([0.5–2.0] keV)	$14.2 \pm 0.5 \times 10^{44}$ erg s^{-1}
L_{500}([0.1–2.4] keV)	$22.7 \pm 0.8 \times 10^{44}$ erg s^{-1}

Table 2: SZ flux derived from *Planck* data with the reference value indicated in boldface.

Method	Definition	Value (10^{-4} arcmin^2)	θ_{500} (arcmin)
MMF blind	Y_{500}	5.6 ± 3.0	3.3 ± 2.8
PWS blind	Y_{500}	6.5 ± 1.8	3.9 ± 1.6
MMF X-ray prior	Y_{500}	$\mathbf{4.1 \pm 0.9}$	fixed
PWS X-ray prior	Y_{500}	5.3 ± 0.9	fixed
MILCA	Y_{tot}	5.9 ± 1.0	...

Notes. Uncertainties on the blind values take into account the size uncertainty.

- Very peculiar cluster : very luminous in X and very massive with respect to previously known clusters at z > 0.5

Scaling relations for cluster physics

[Kratsov et al. 2006, Pratt et al. 2009, Arnaud et al. 2010]

- **SELF-SIMILAR evolution: only gravitational processes**

ICM: isothermal and hydrostatic equilibrium → $k_B T_e = \mu m_p \frac{GM_{tot}}{r}$ *[Kaiser (1986)]*

$$M_{tot}(r_\Delta) = \frac{4}{3}\pi\rho_c \Delta r_\Delta^3$$

$$r_\Delta \propto \left(\frac{M_{tot}(r_\Delta)}{E(z)^2}\right)^{1/3}$$

$$k_B T_e \propto \frac{GM_{tot}}{r}$$

$$T_e \propto M_{tot}(r_\Delta)^{2/3} E(z)^{2/3}$$

$$\rho_c = \frac{3H_0^2 E(z)^2}{8\pi G} \qquad E(z) = \frac{H(z)}{H_0}$$

$$Y = \int_\Omega y d\Omega = \frac{1}{D_A^2}\left(\frac{k_B \sigma_{Th}}{m_e c^2}\right)\int_0^\infty dl \int n_e T_e dA$$

$$YD_A^2 \propto T_e \int n_e dV = M_{gas} T_e = f_{gas} M_{tot} T_e$$

$f_{gas} = M_{gas}/M_{tot}$

$$YD_A^2 \propto f_{gas} T_e^{5/2} E(z)^{-1}$$

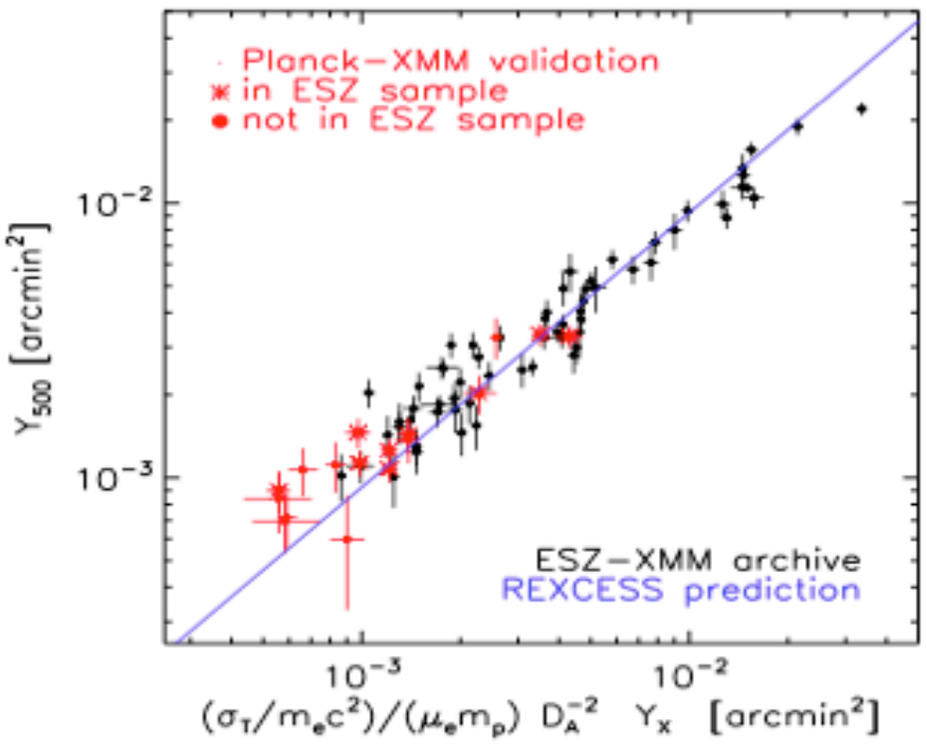
$$YD_A^2 \propto f_{gas} M_{tot}^{5/3} E(z)^{2/3}$$

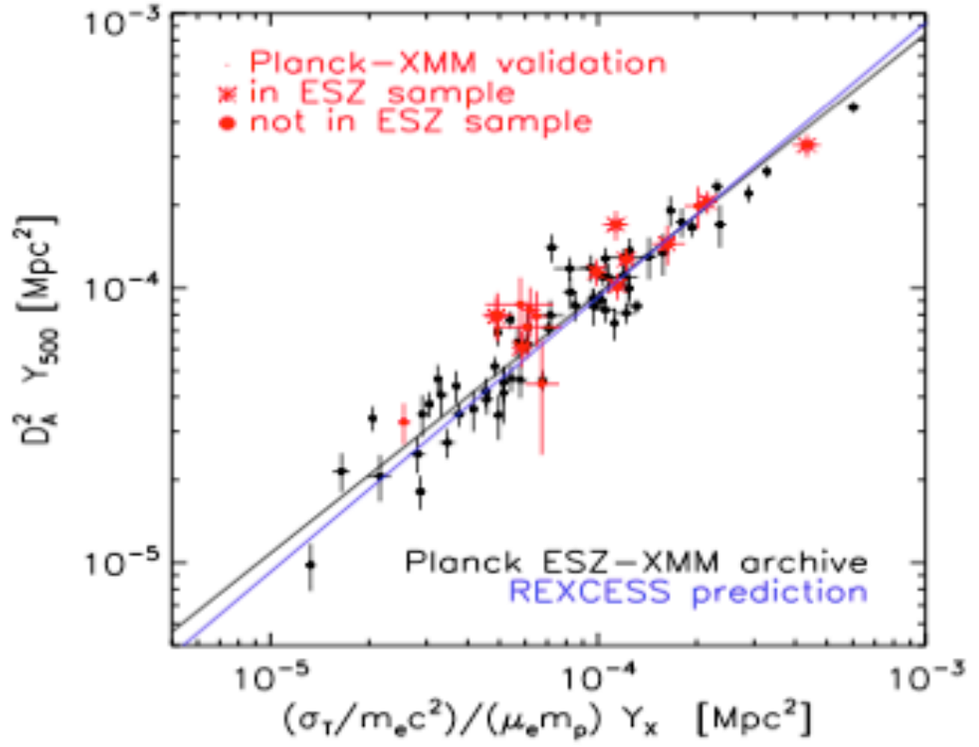
$$YD_A^2 \propto f_{gas}^{-2/3} M_{gas}^{5/3} E(z)^{2/3}$$

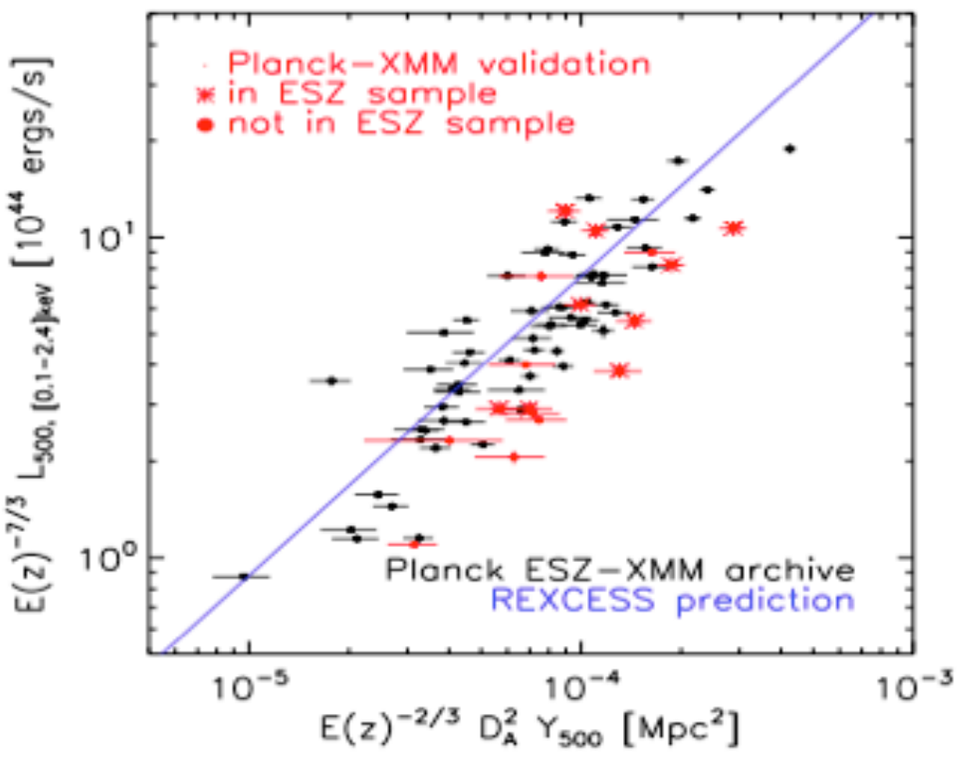
$$E(z)^2 = \left(\frac{H(z)}{H_0}\right)^2 = \Omega_M (1+z)^3 + \Omega_\Lambda$$

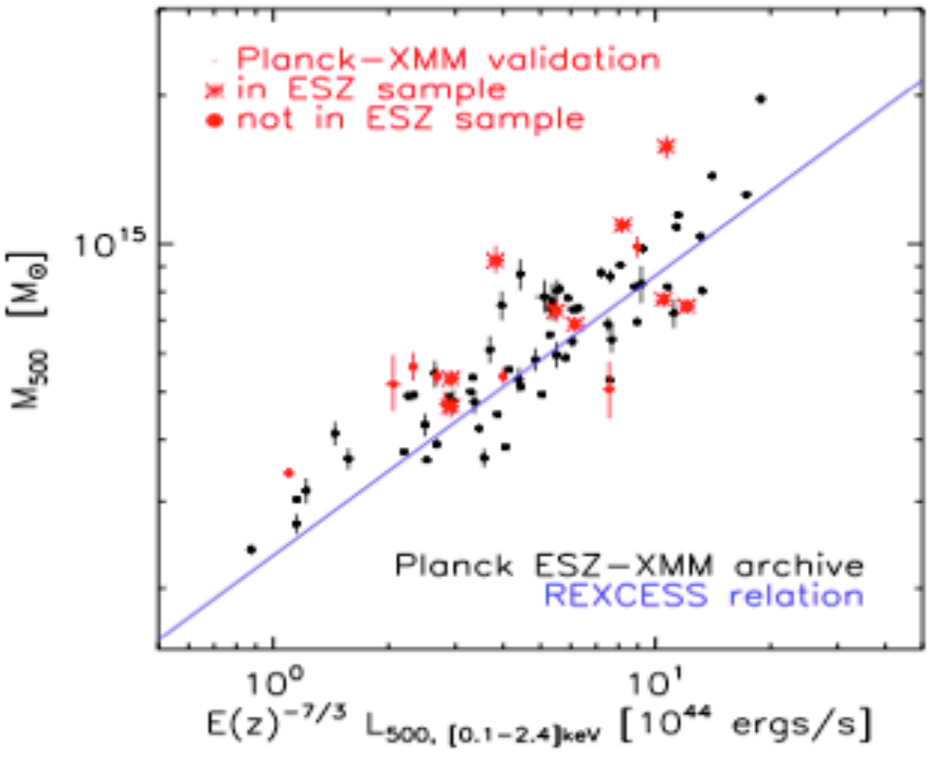
$$\Omega_M = 0.3,\ \Omega_\Lambda = 0.7,\ \Omega_k = 0$$

ESZ clusters scaling relations



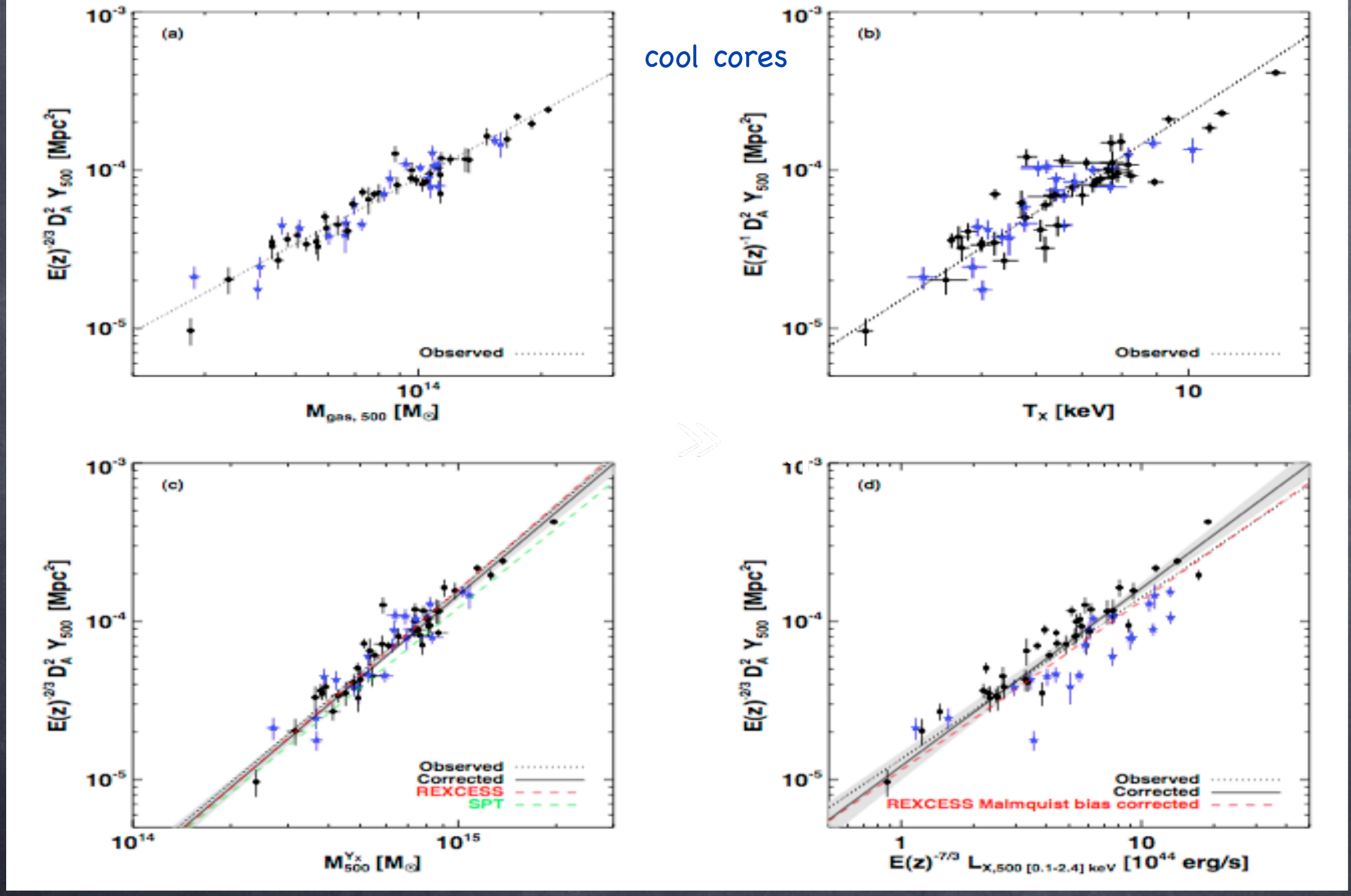






Local scaling relations

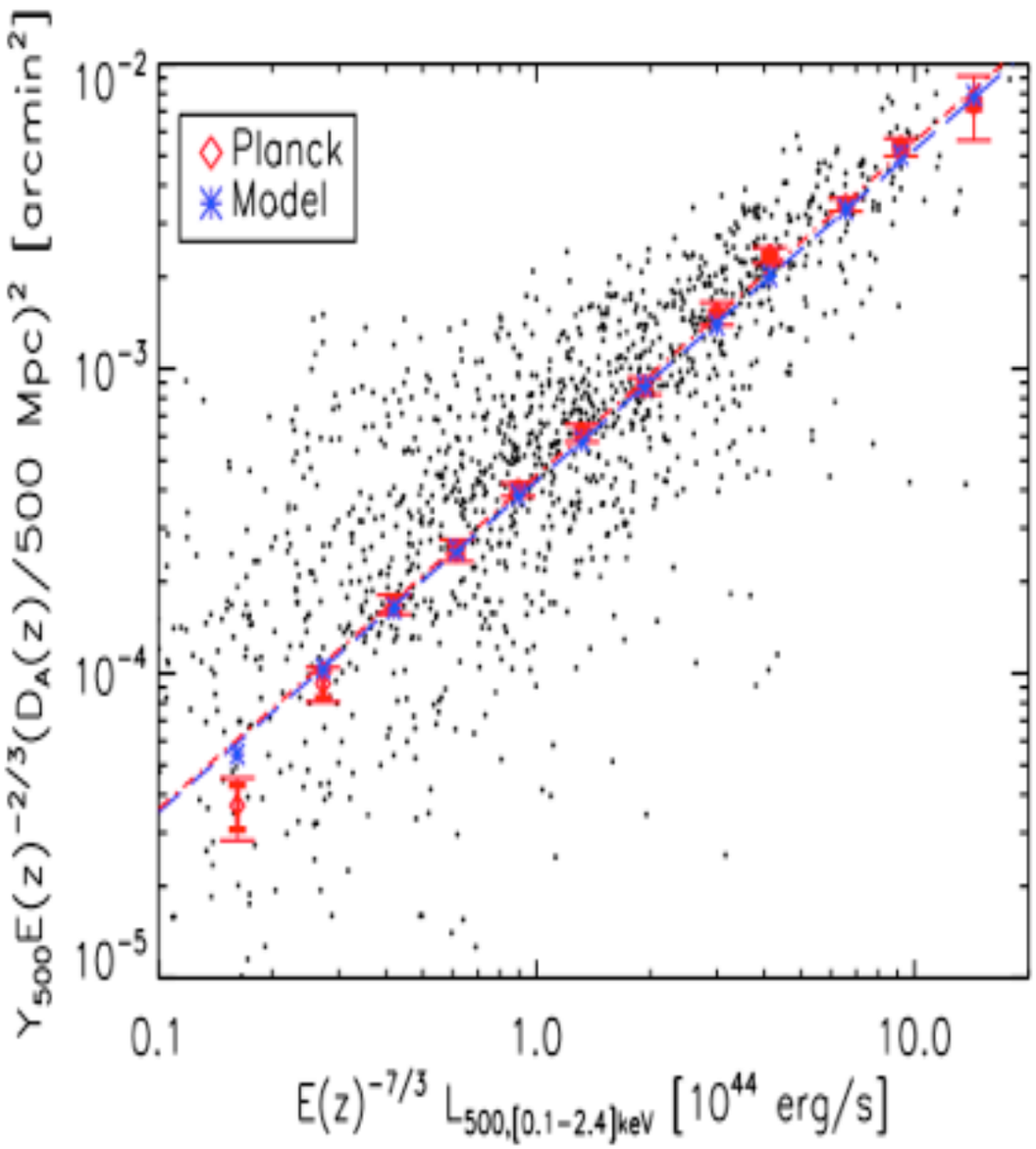
- 62 nearby clusters (Z < 0.5), with total masses from 2 x 10^{14} M_{sun} to 2 x 10^{15} M_{sun}

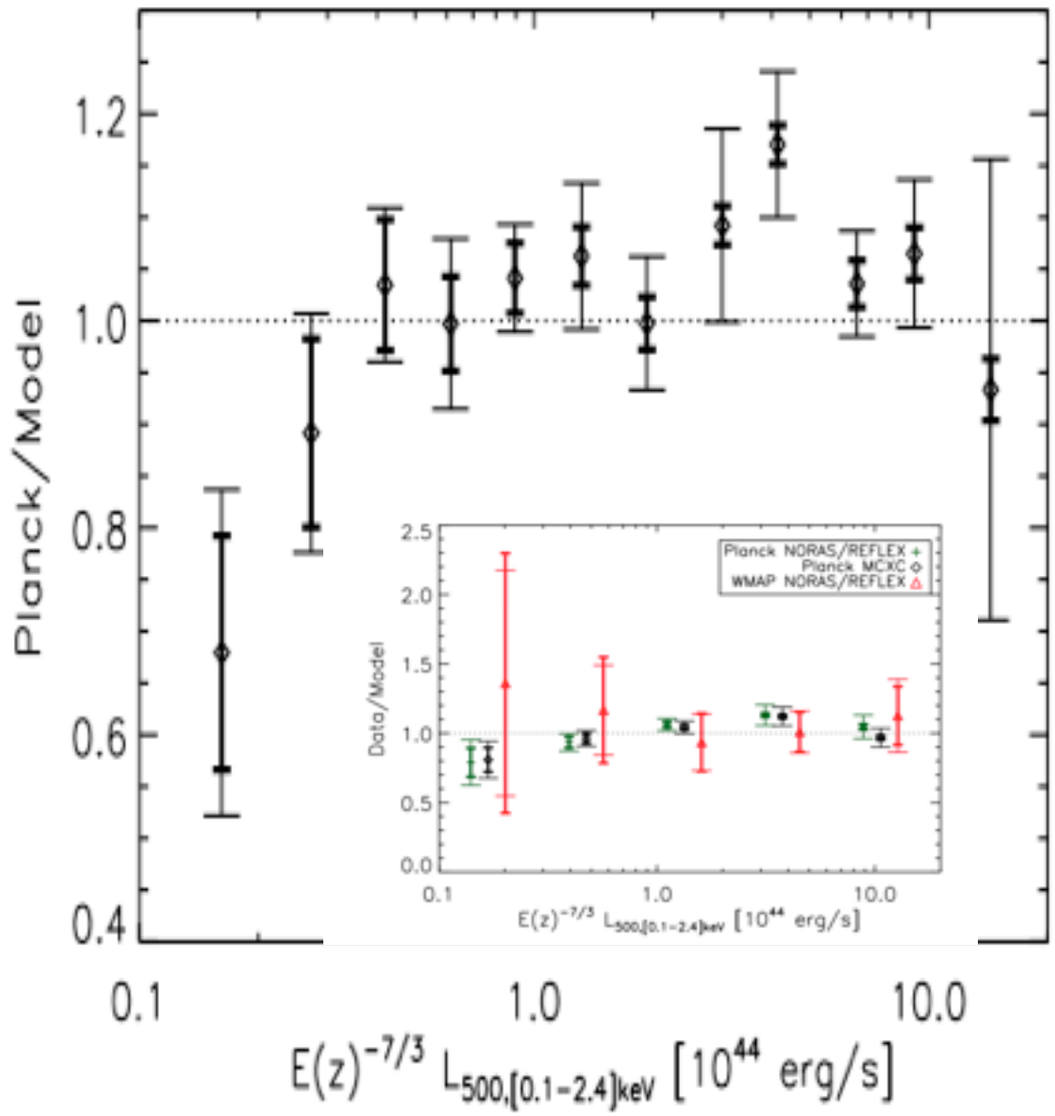


X-ray do not over-predict tSZ flux as previously indicated

Statistical scaling relations

- SZ flux in the direction of 1600 objects from the MCXC (Meta-Catalogue of X-ray detected cluster of galaxies) [Piffaretti et al. 2011]
- Compute scaling relation on bins of the wanted quantity.



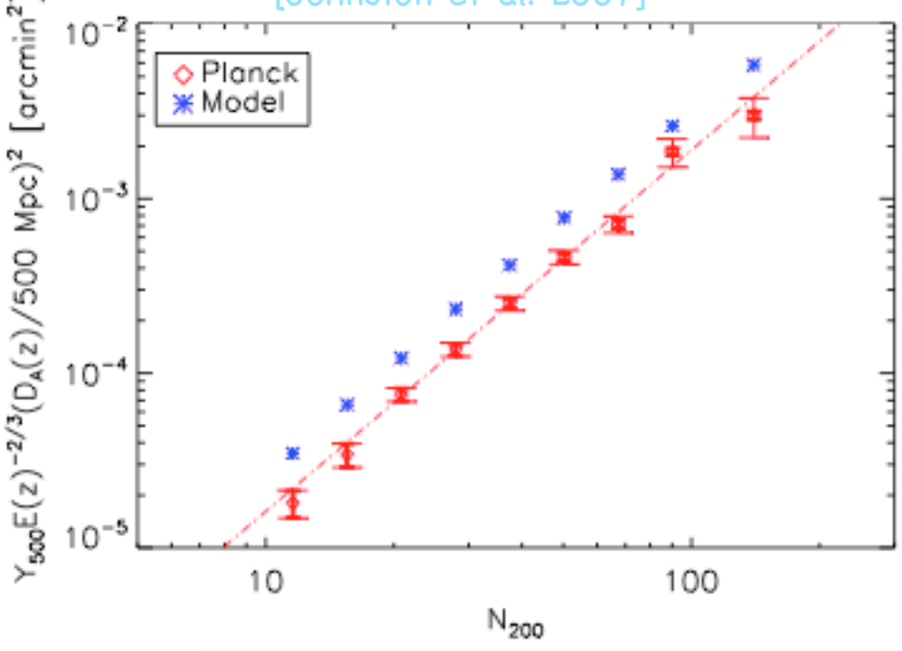


X-ray do not over-predict tSZ flux as previously indicated

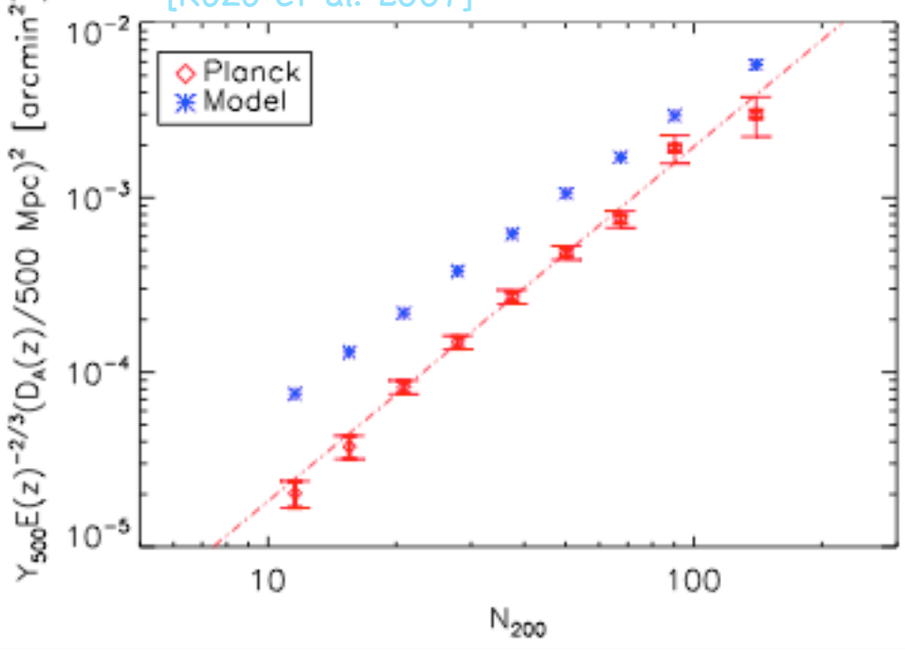
Optical scaling relations

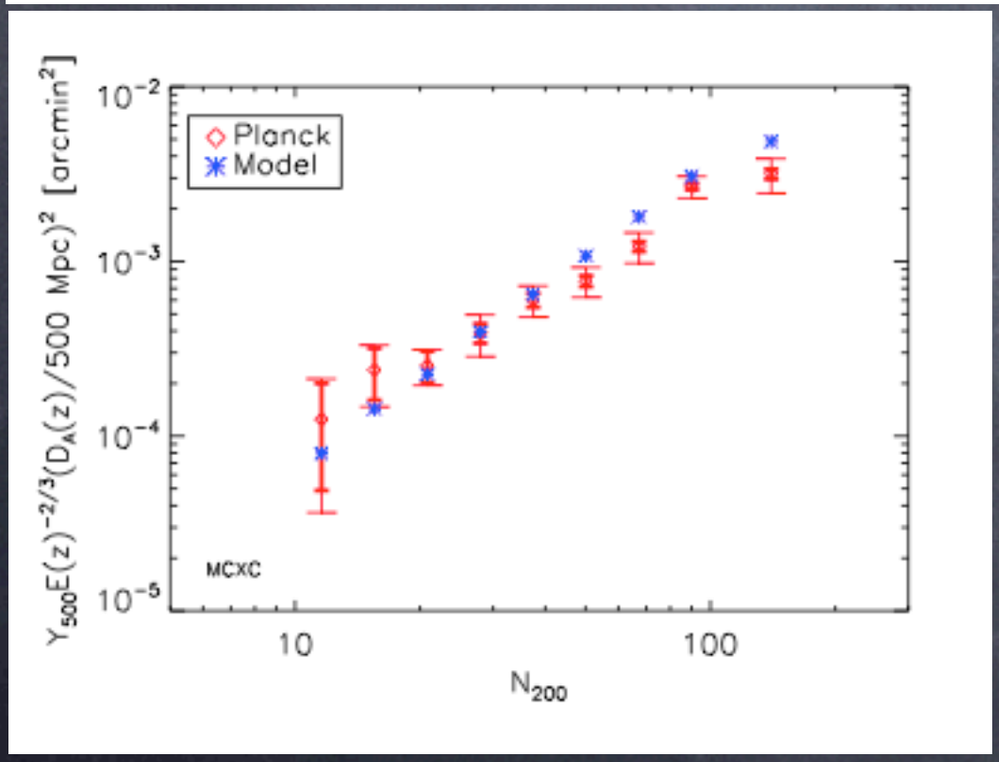
- SZ flux in the direction of 13000 objects in the MaxBCG cluster catalogue 0.1 < z < 0.3; 10< N200 <190
- Compute scaling relation on bins of the wanted quantity. [Koester et al. 2009]

[Johnston et al. 2007]



[Rozo et al. 2007]



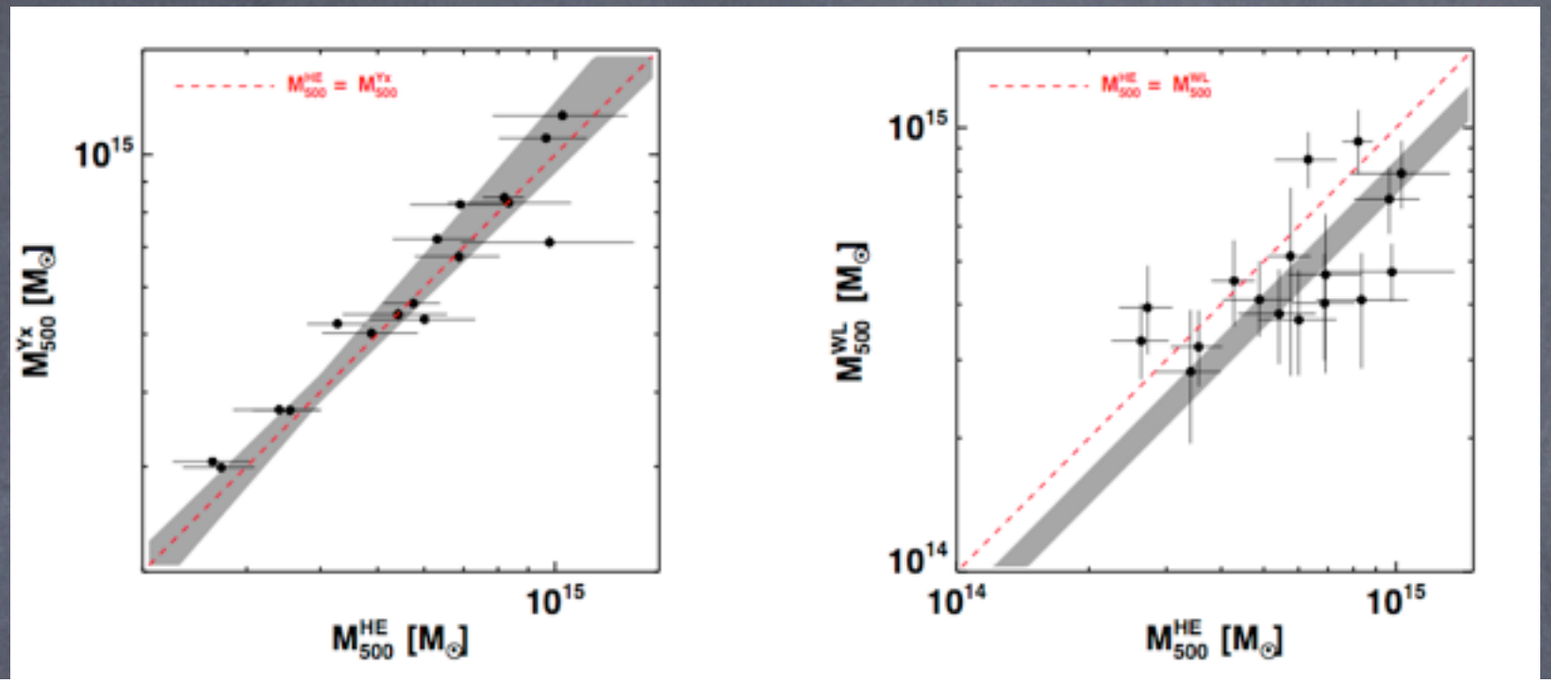


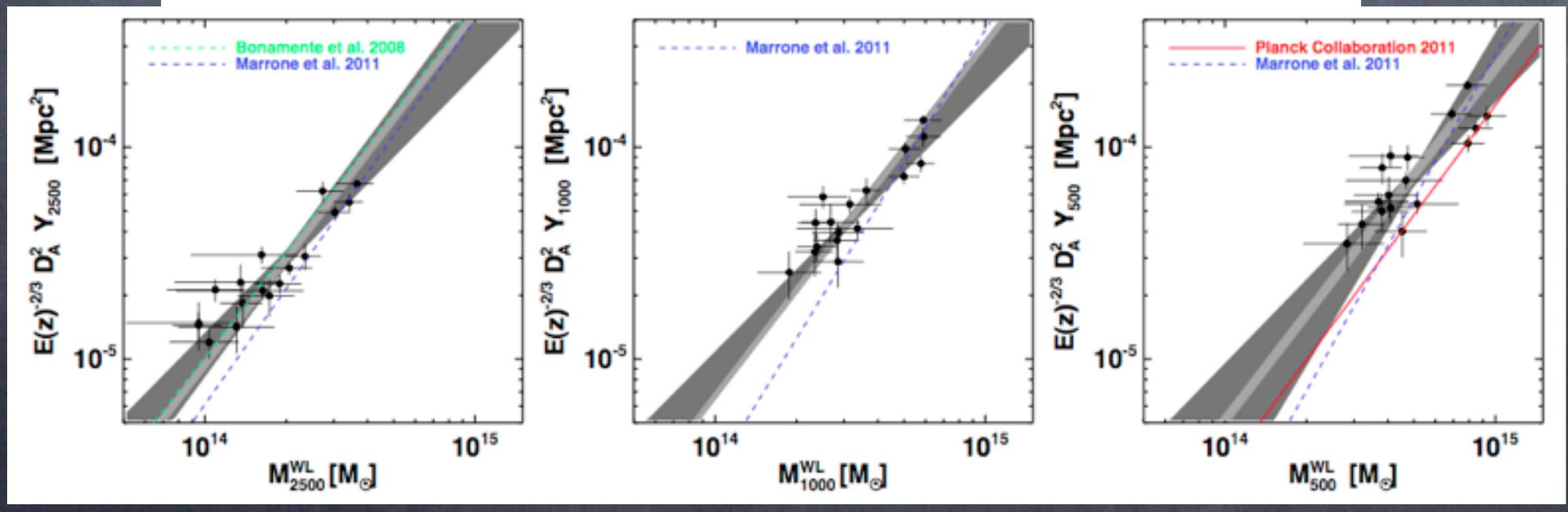
- Clear discrepancy between model and data
- For the MCXC sample the agreement is better
- One possible explanation is the existence of two population of clusters: X-ray under-luminous and X-ray normal
- This might have consequences in structure formation

Mass scaling relations

- Use 19 clusters with WL from the LoCuSS sample

Okaku & Umetsu 2008, Okabe et al. 2010]





X-ray based masses 22 % larger than WL masses, related to differences in concentration

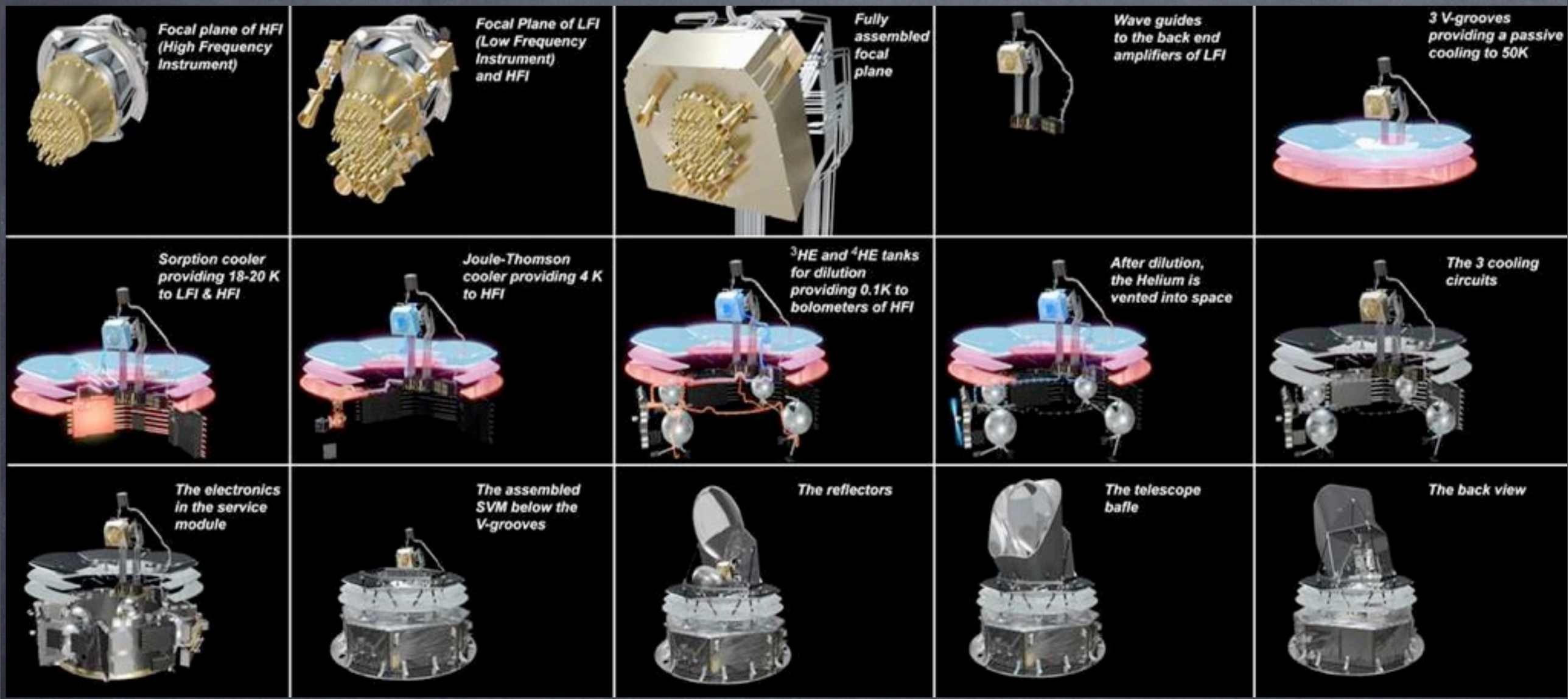
Conclusions and perspectives

- Planck has provided the largest tSZ selected cluster catalogue ever (199 clusters)
- New interesting detections with Planck: multicomponent systems, high redshift luminous clusters
- X-ray, tSZ scaling relations seems to work
- optical, tSZ scaling relations needs to be understood yet
- tSZ detection on the outskirts of clusters : see for example COMA

More exciting physics to come very soon (December 2012-January 2013):

- New cluster catalogue et cosmological cluster catalogue
- pressure profiles from tSZ measurements
- detailed study of COMA
- kinetic SZ effect

Sat + 20K + 4K + Dil + LFI + HFI



Incidents:4K, CR, Scanning,Transponder

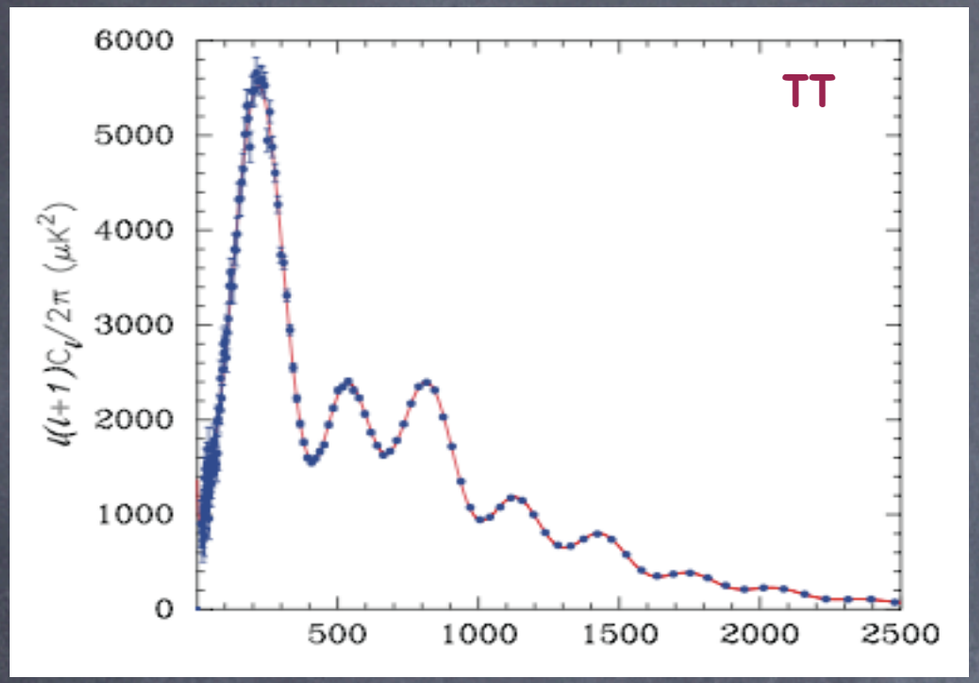
J.F. Macías-Pérez - LPSC

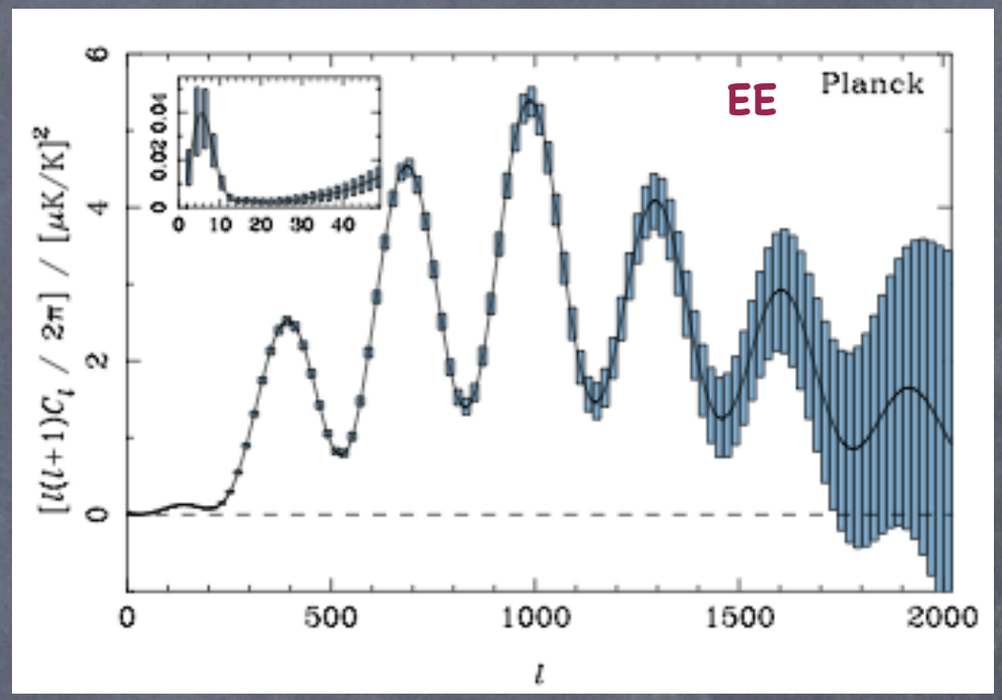
Mesure des spectres de puissance du CMB avec Planck

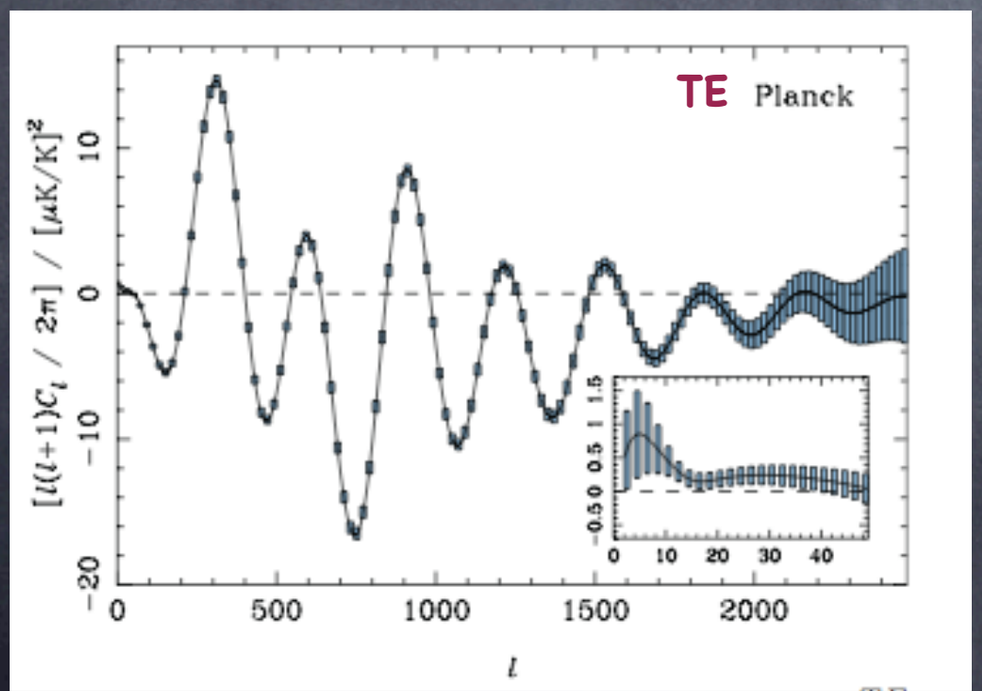
Mesure ultime en température : limitée par variance cosmique

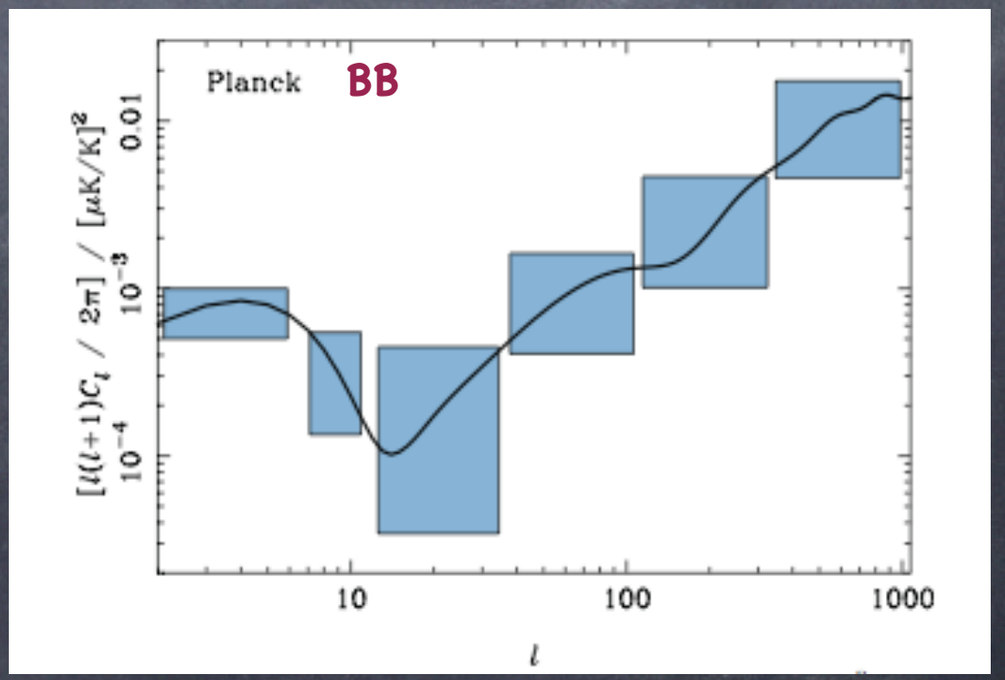
Mesure de précision en polarisation: TE et EE (contrôle des effets systématiques)

Peut-être une première mesure des modes primordiaux: r < 0.03









Planck bluebook 2005

Planck Collaboration: The thermal performance of *Planck*