

The Role of XMM for Present and Next Generation SZ Experiments

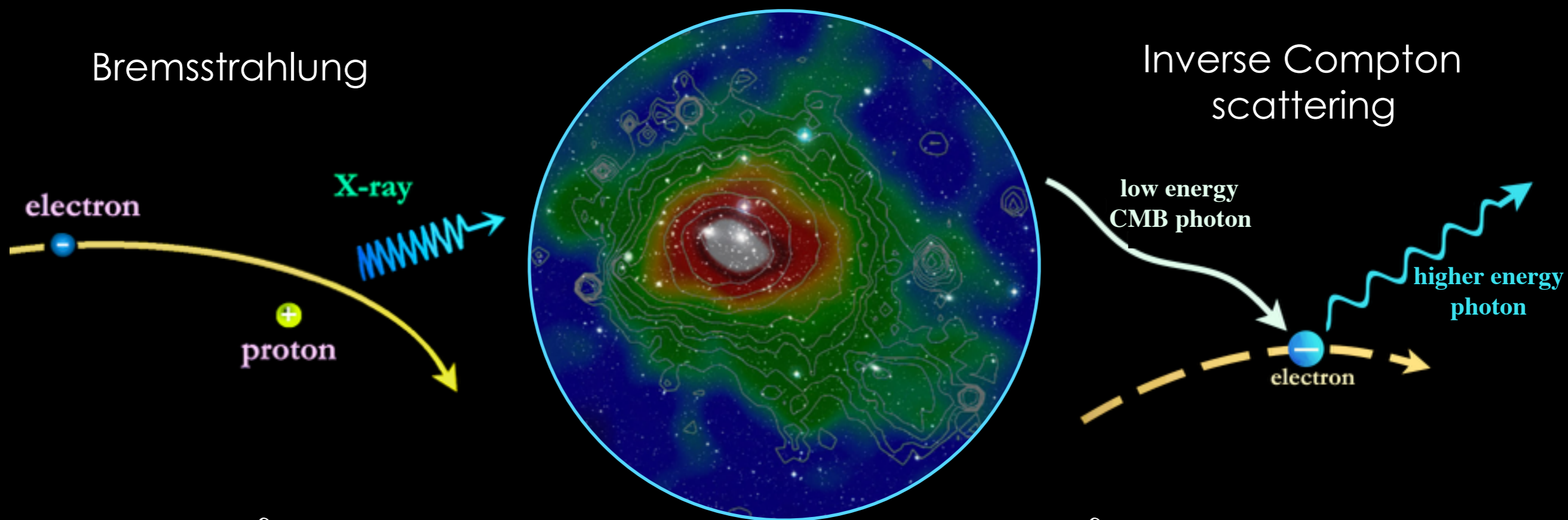
Etienne Pointecouteau

IRAP

(Toulouse, France)

Intra-cluster gas emission

Hot gas represents 85% of the baryons content of clusters of galaxies



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

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

Two independent and complementary probes of the same physical component

SZ surveys (and XMM)

Blind SZ surveys

ACT

780 sqd

148 GHz

1,5'

91

Mariage+10, Hasselfield+13

PLANCK

41253 sqd

857, 545, 353, 217, 143, 100 GHz

4.5-10'

1963

Planck Collaboration+11+13+15

SPT

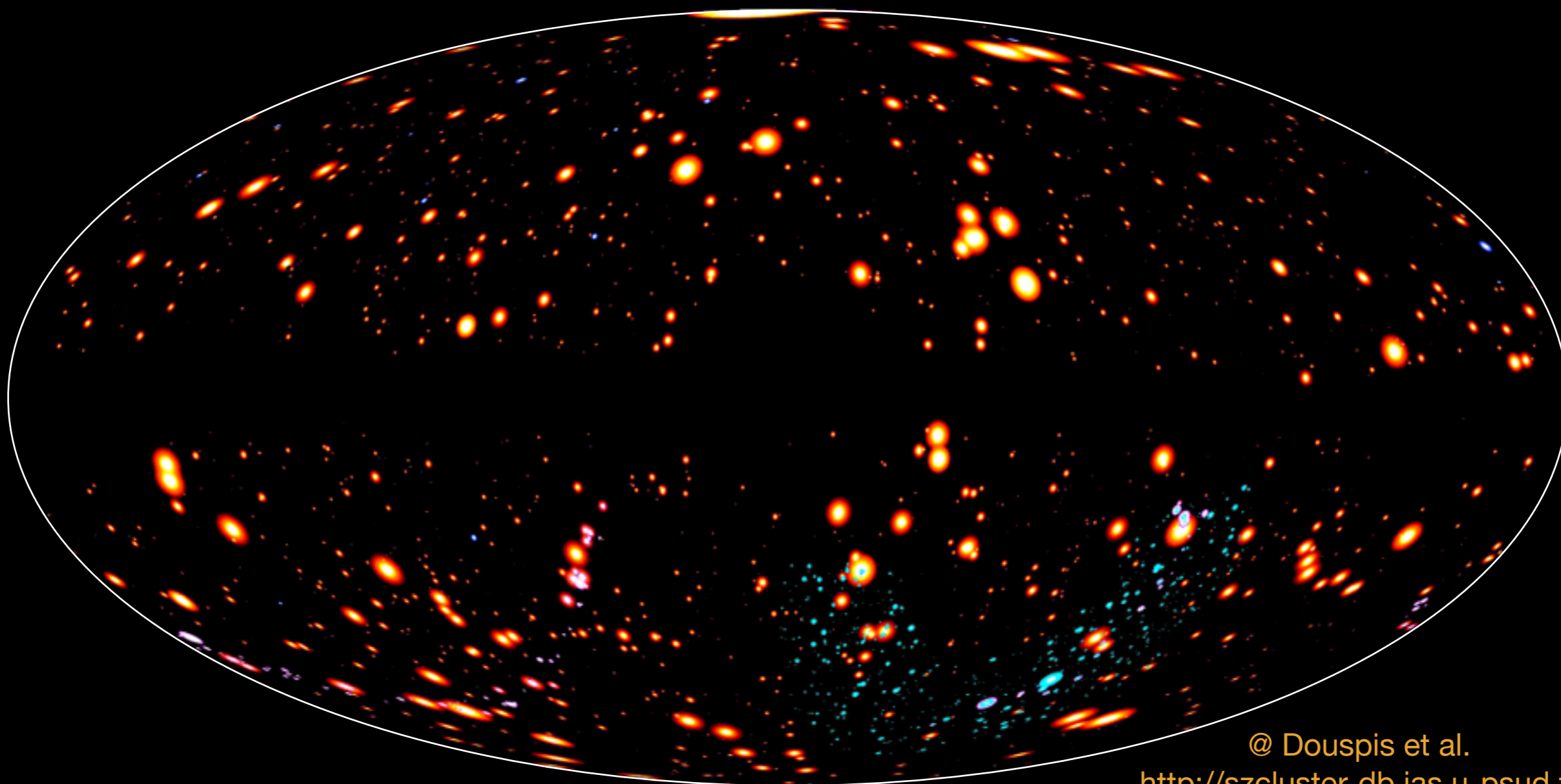
2500 sqd

150 GHz

1.6'

747

Reichardt+12, Bleem+15



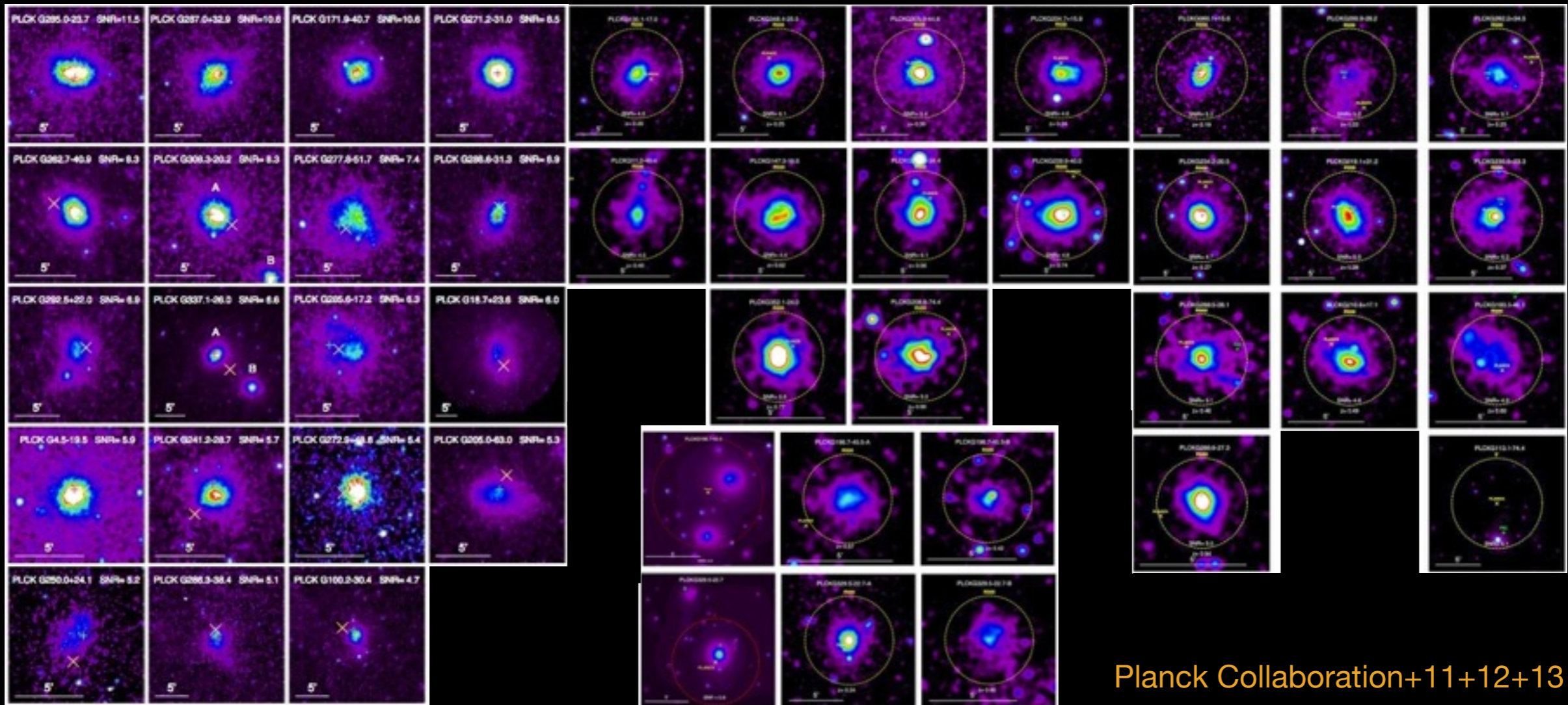
@ Douspis et al.

<http://szcluster-db.ias.u-psud.fr>

51 observed candidates ; 43 confirmed incl. 4 doubles & 2 triples ; 51 new clusters

→ 32 good redshifts X from FeK line

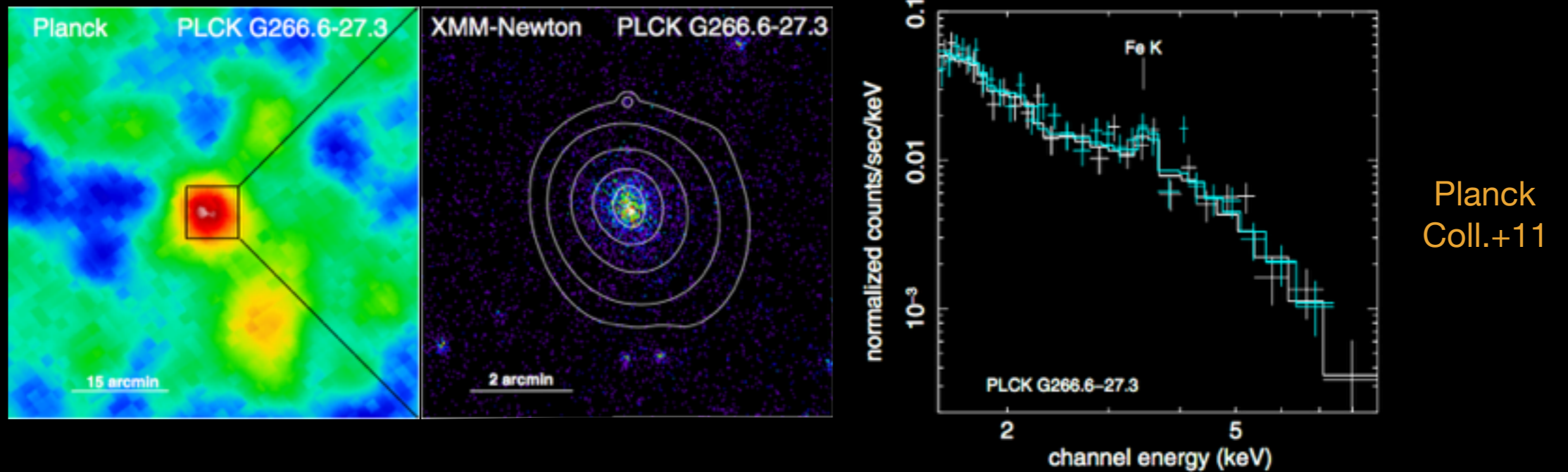
→ Mandatory performance verification and validation optimisation



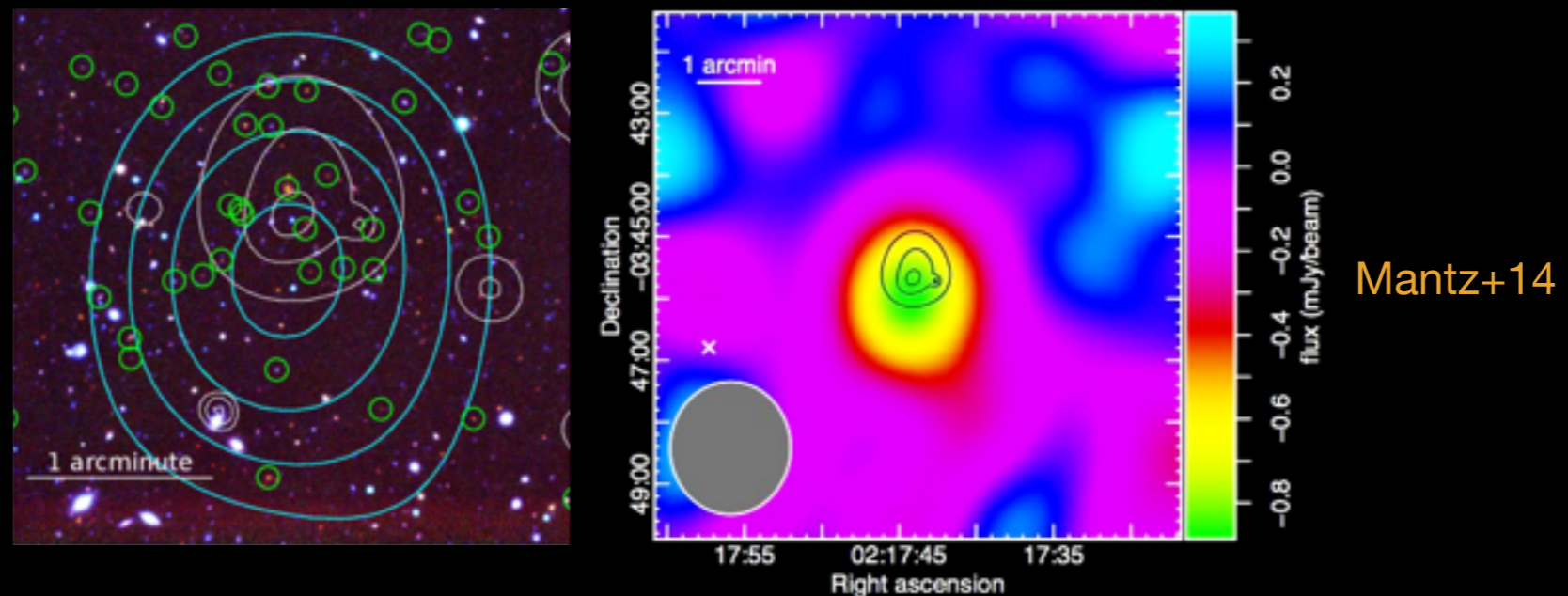
Planck Collaboration+11+12+13

Distant clusters

PLCK G266.6-27.3 : SZ detected — Confirmed in X-ray by XMM $z = 0.94 \pm 0.02$



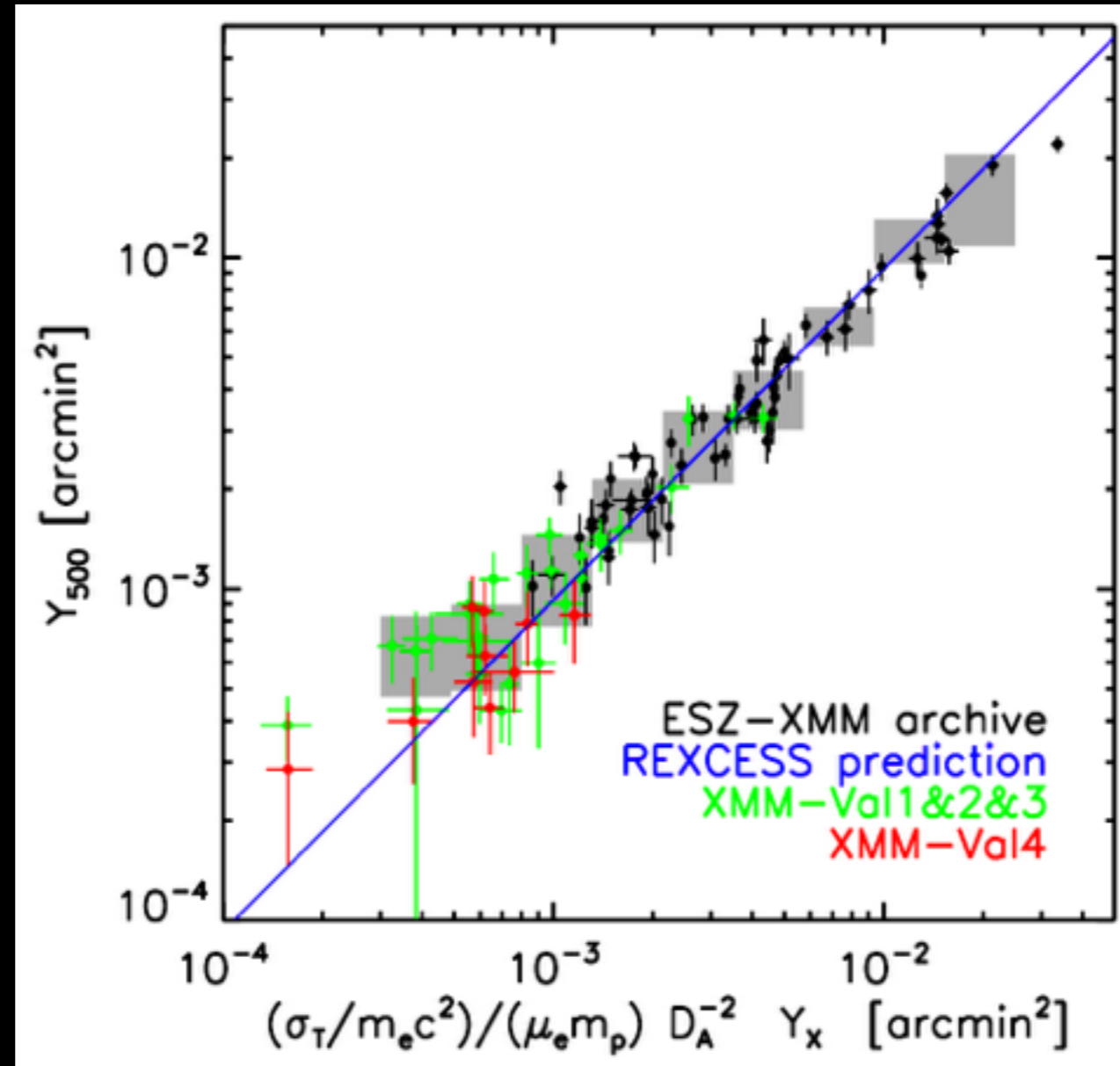
XLSSU J021744.1–034536 : X-ray detected at $z \sim 1.9$ — Confirmed in SZ by CARMA



see also e.g, Foley+11, Brodwin+12, Stalder+13, Bayliss+14

Physical characterisation of SZ cluster

Consistent view of the gas content of clusters of galaxies from the joint XMM and Planck studies

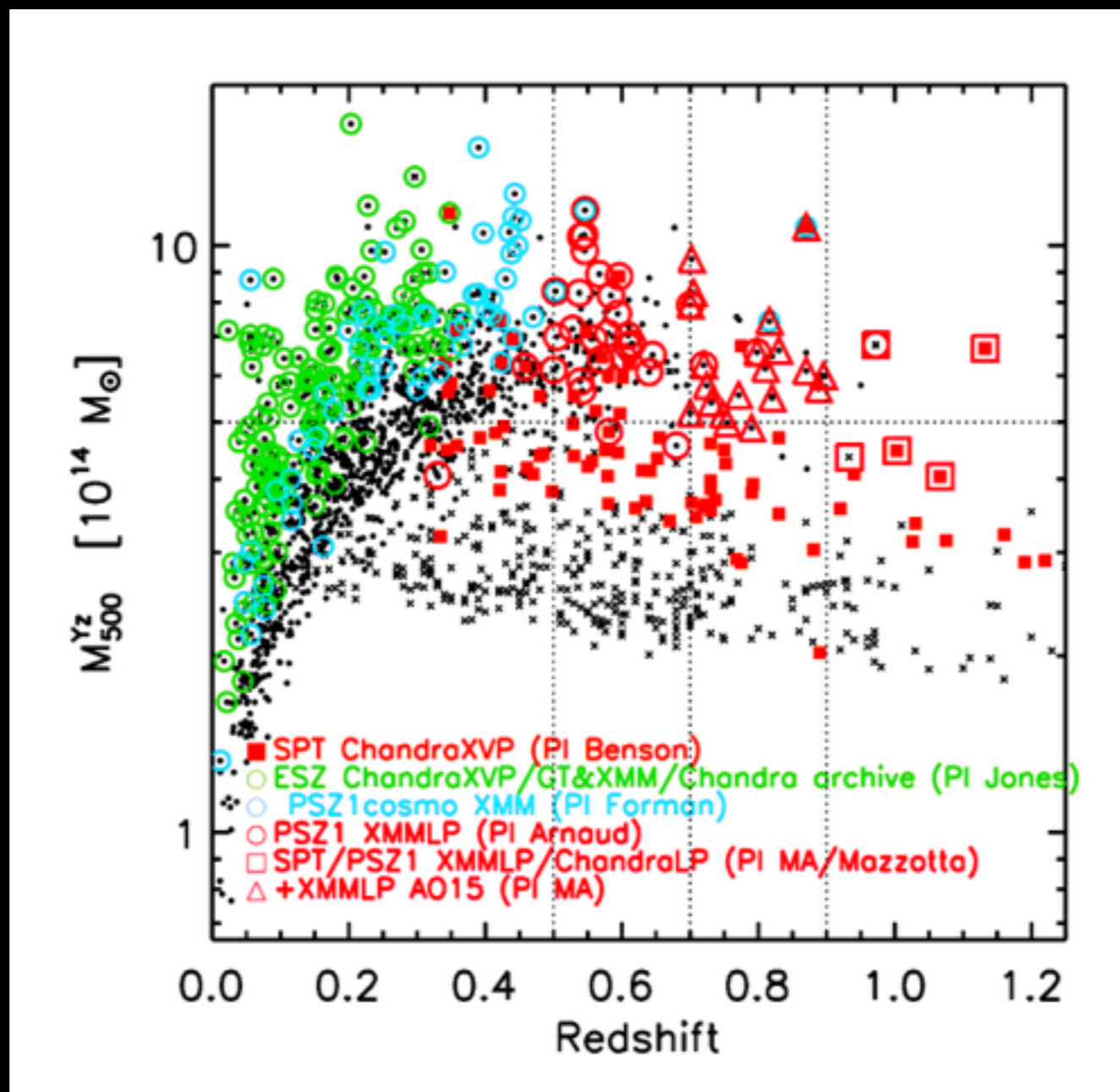


Planck Collaboration +11+12+14

see also: Anderson+09. Bender+14, Sifon+13, Czakon+14

Complementarity of SZ and X-ray surveys

Definition of mass selected samples from SZ catalogues



Courtesy of M. Arnaud

see talks by M. Arnaud, M. Pierre, T. Reiprich

X-ray view of SZ selected clusters

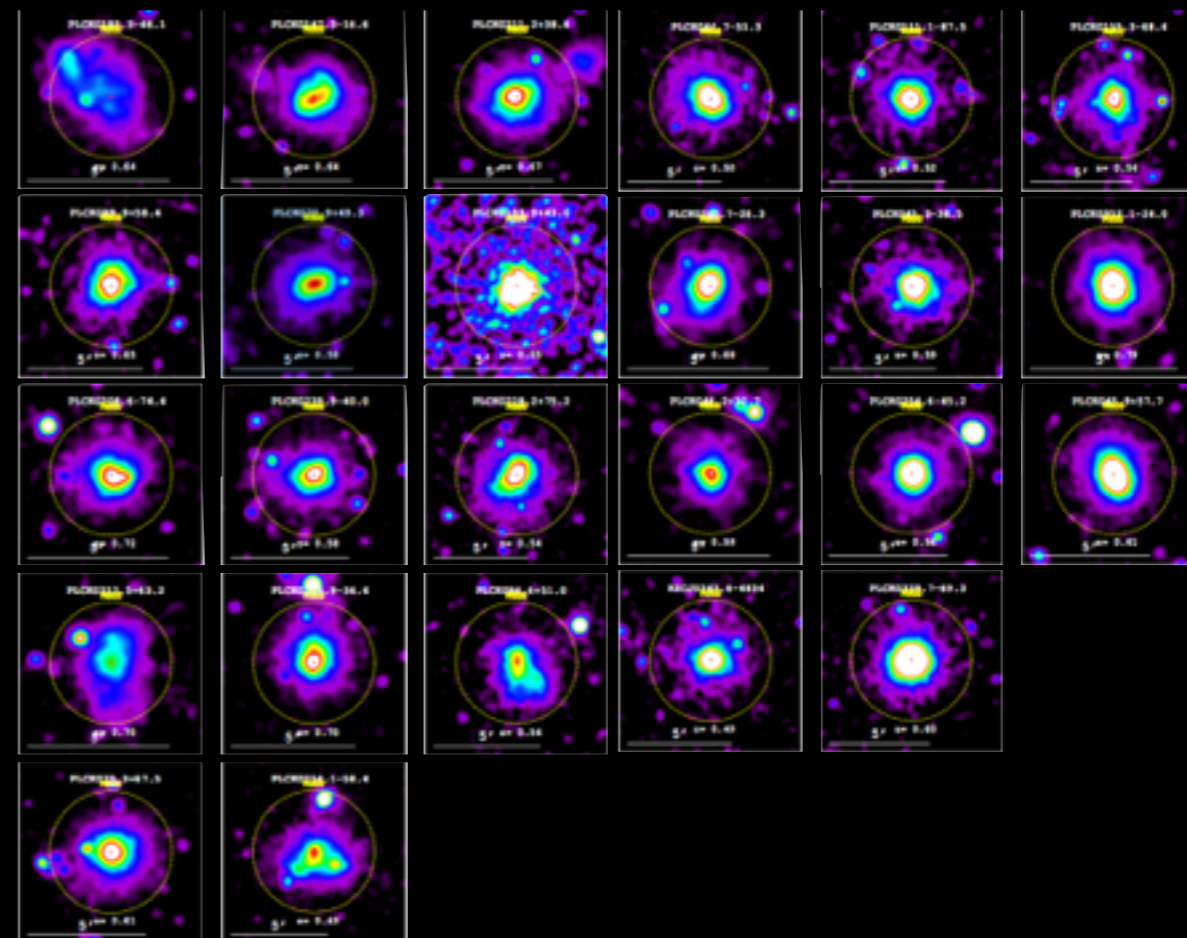
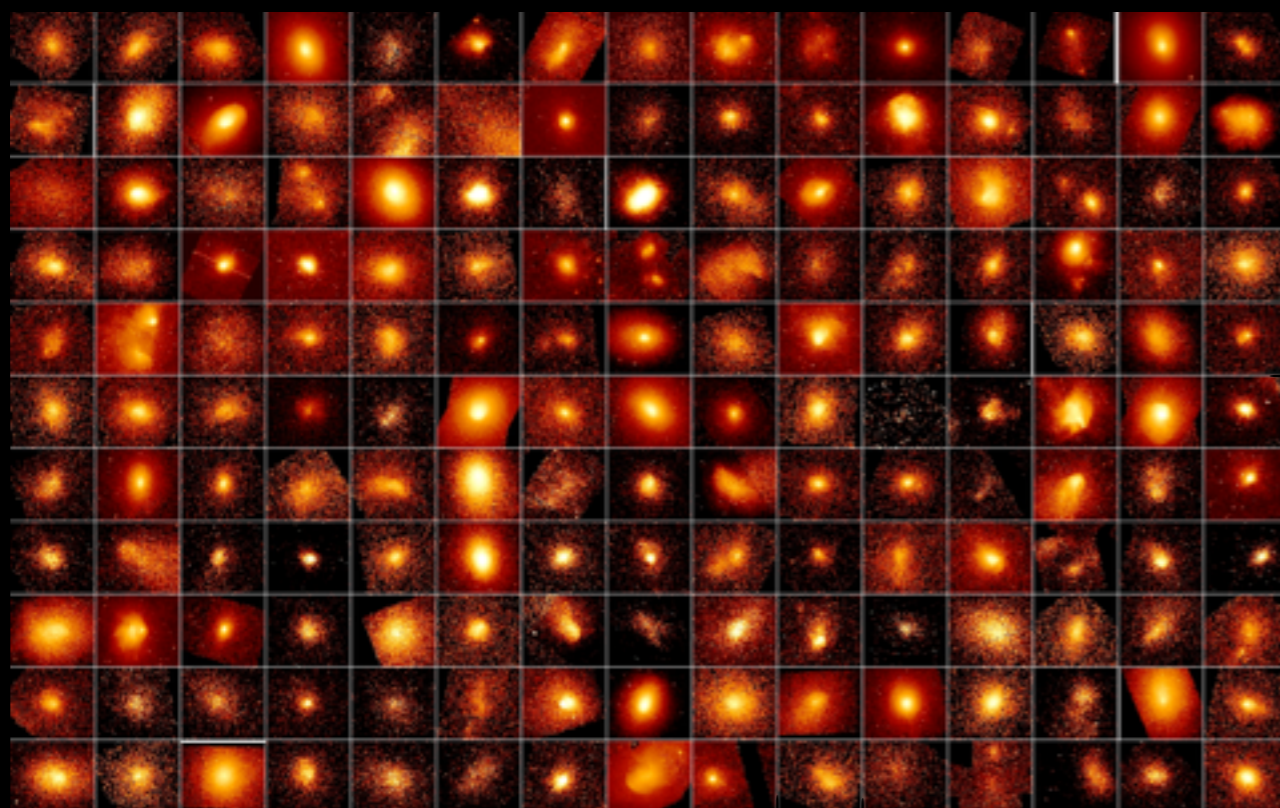
Local reference: all ESZ clusters with $z < 0.35$

Chandra XVP (PI C. Jones) + Chandra GT

+ XMM & Chandra Archives

Evolution : clusters with $0.5 < z < 1.2$ clusters

XMM LPs (PI: M. Arnaud)



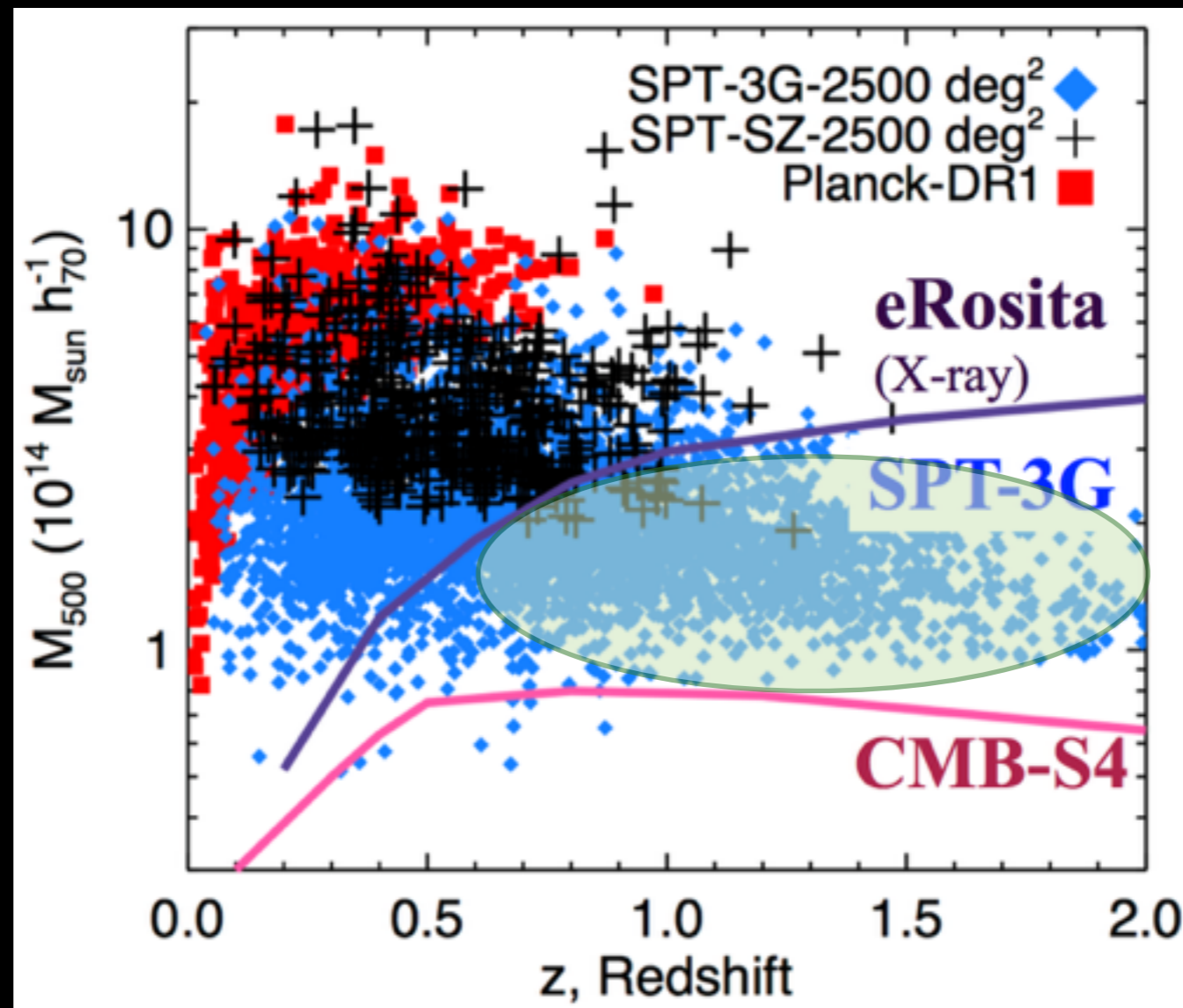
→ Astrophysics of massive halo formation and evolution

→ Inputs for cosmology

see talks by M. Arnaud, I. Bartolucci, L. Lovisari

Next generation of SZ surveys

In depth studies from deep XMM follow-up of faint and distant clusters ($z > 1$)
Cosmology and evolution studies



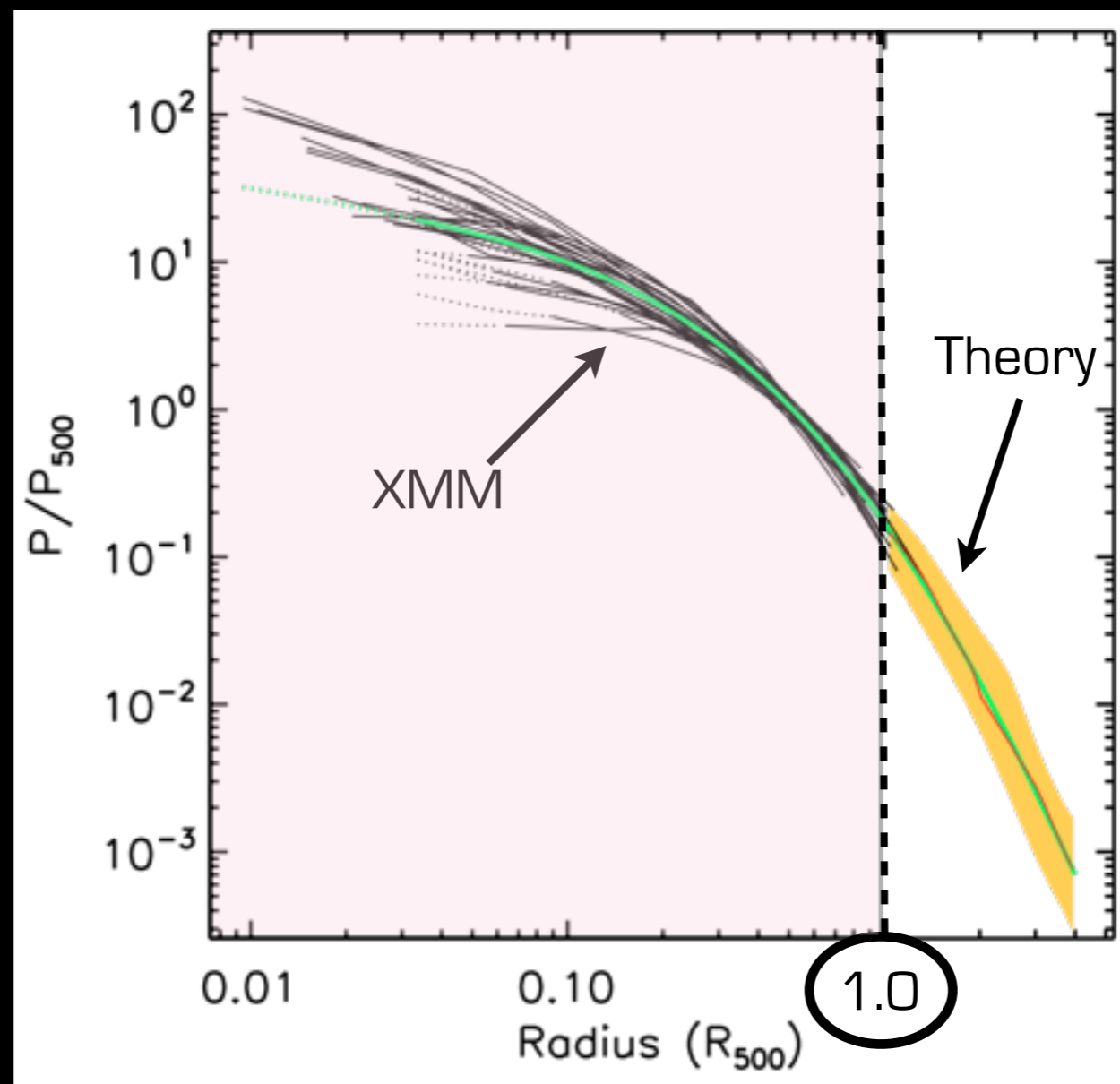
Benson+14

ICM physics (from SZ & XMM observations)

Structural properties

R500 routinely traced by X-ray

Tremendous effort to reach clusters outskirts with X-rays

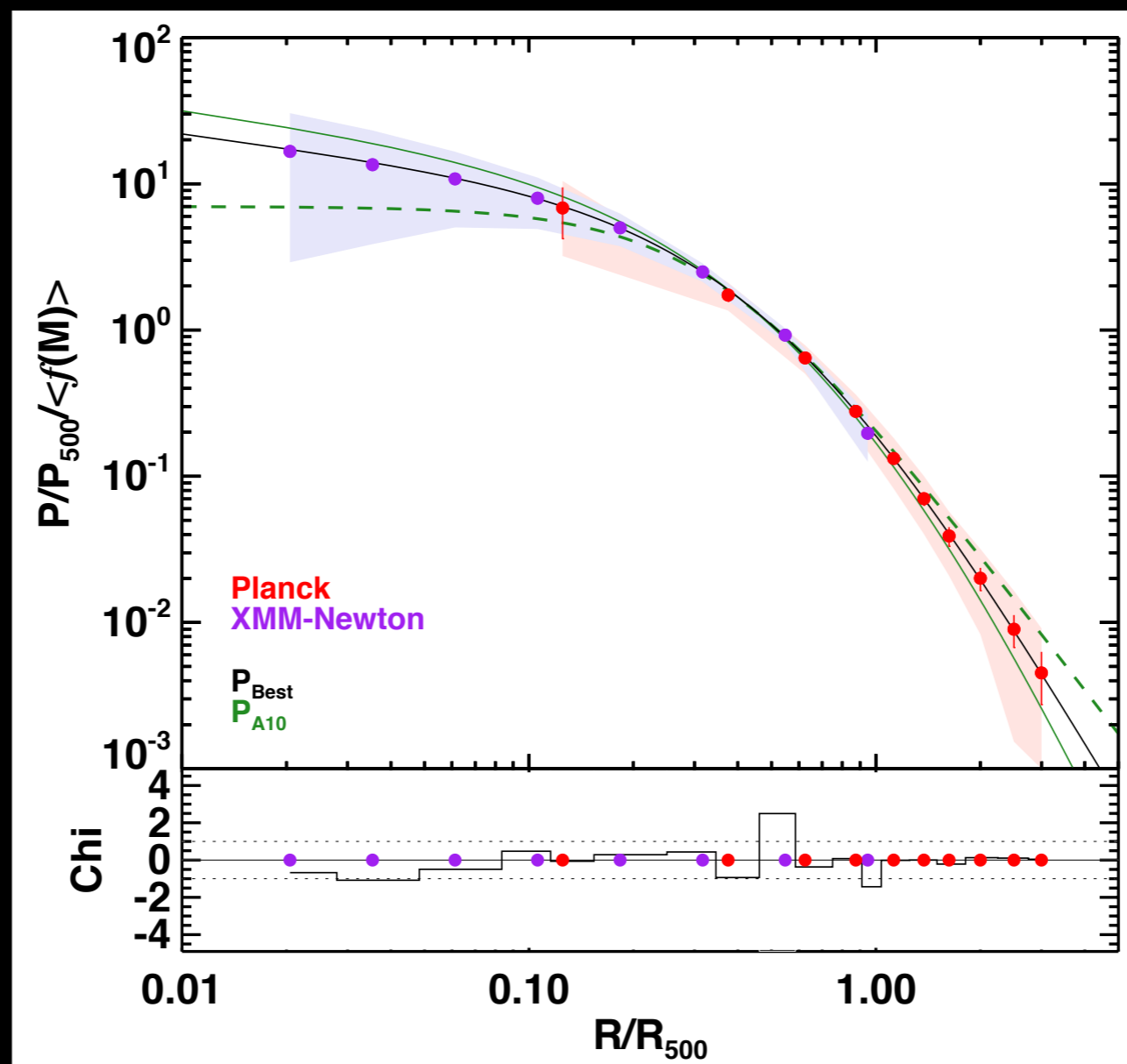


Arnaud+10

see also, Reiprich+13 (for a review)

Structural properties

Coherent view of the gas content properties (e.g., thermal pressure, entropy) from joint X-ray and SZ studies from the centre of clusters to their outskirts



Planck Collaboration+13

see also Eckert+12+13, McDonald+14

The XMM-Newton Cluster Outskirts Project

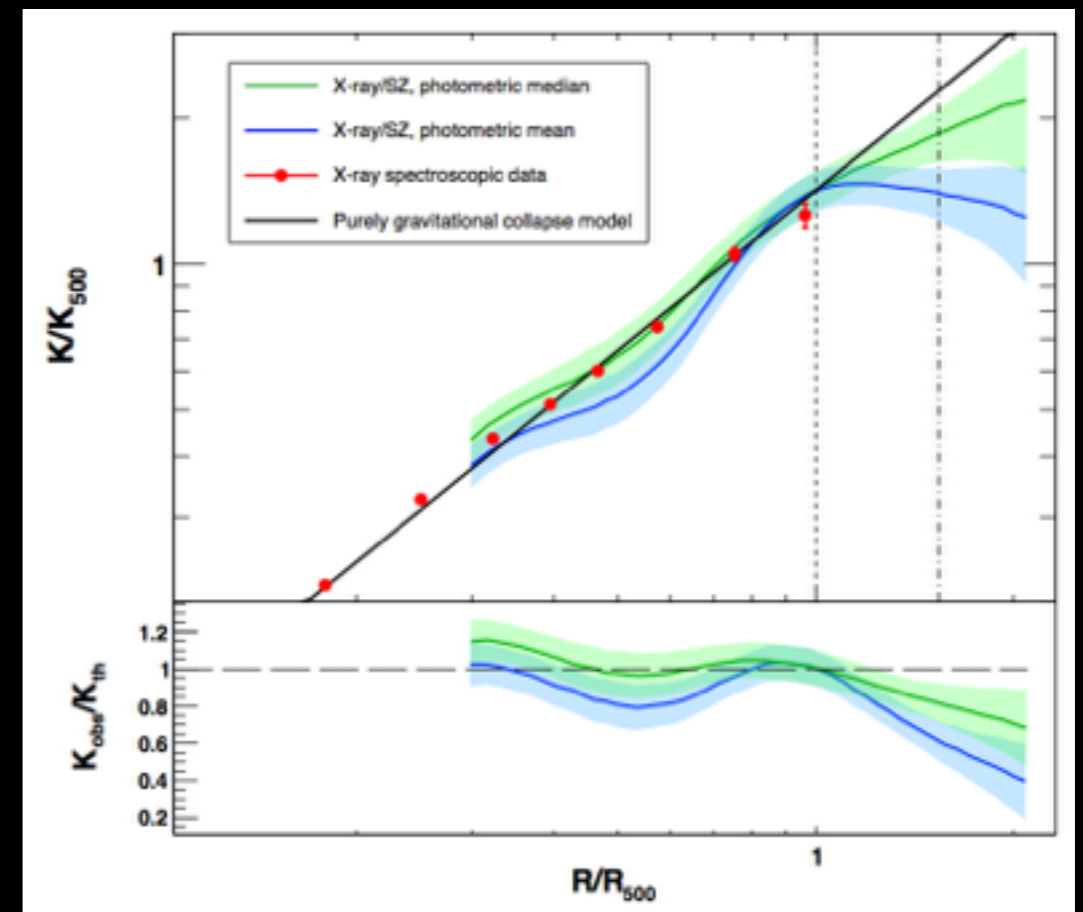
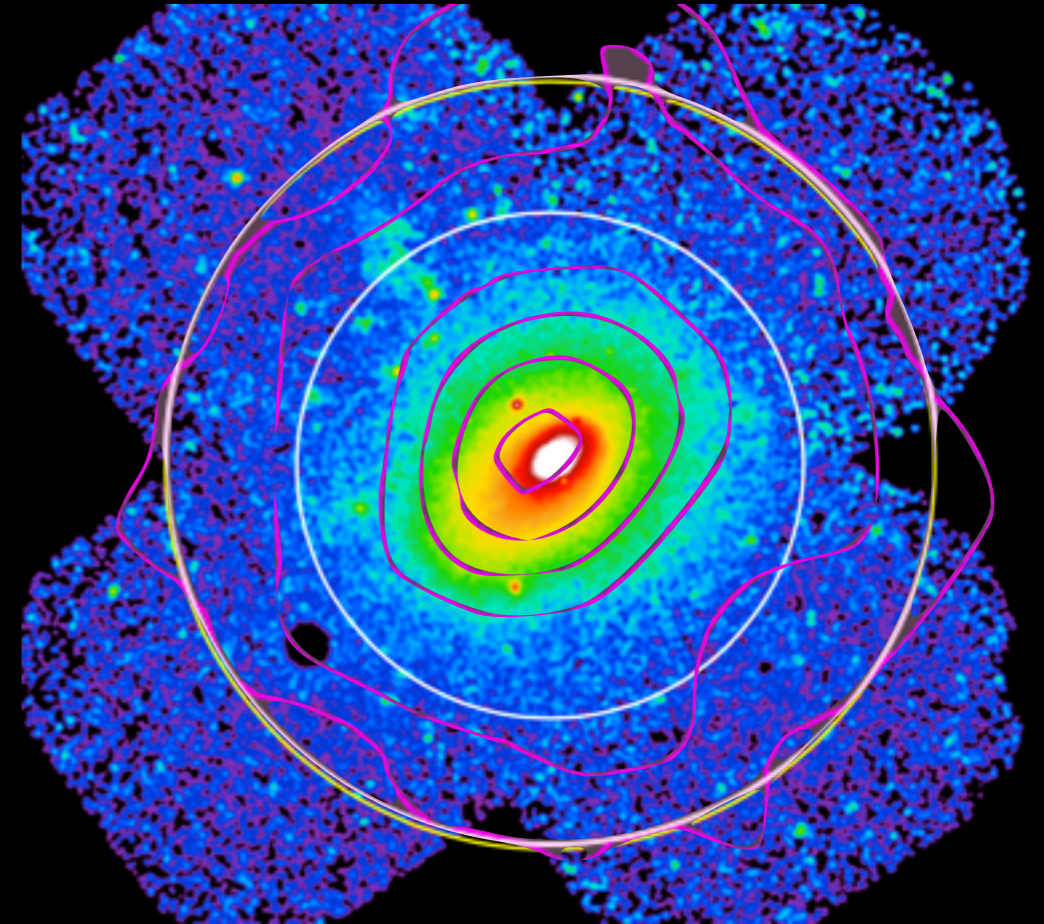
(XMM-Newton VLP, PI: D. Eckert)

X-ray (XMM-Newton) and SZ (Planck)
synergy on 13 nearby clusters

Investigate the dynamics, baryons content
and properties in the outer regions of
clusters where accretion and virialisation is
happening

Tchernin+16, Eckert+16

see talk by D. Eckert

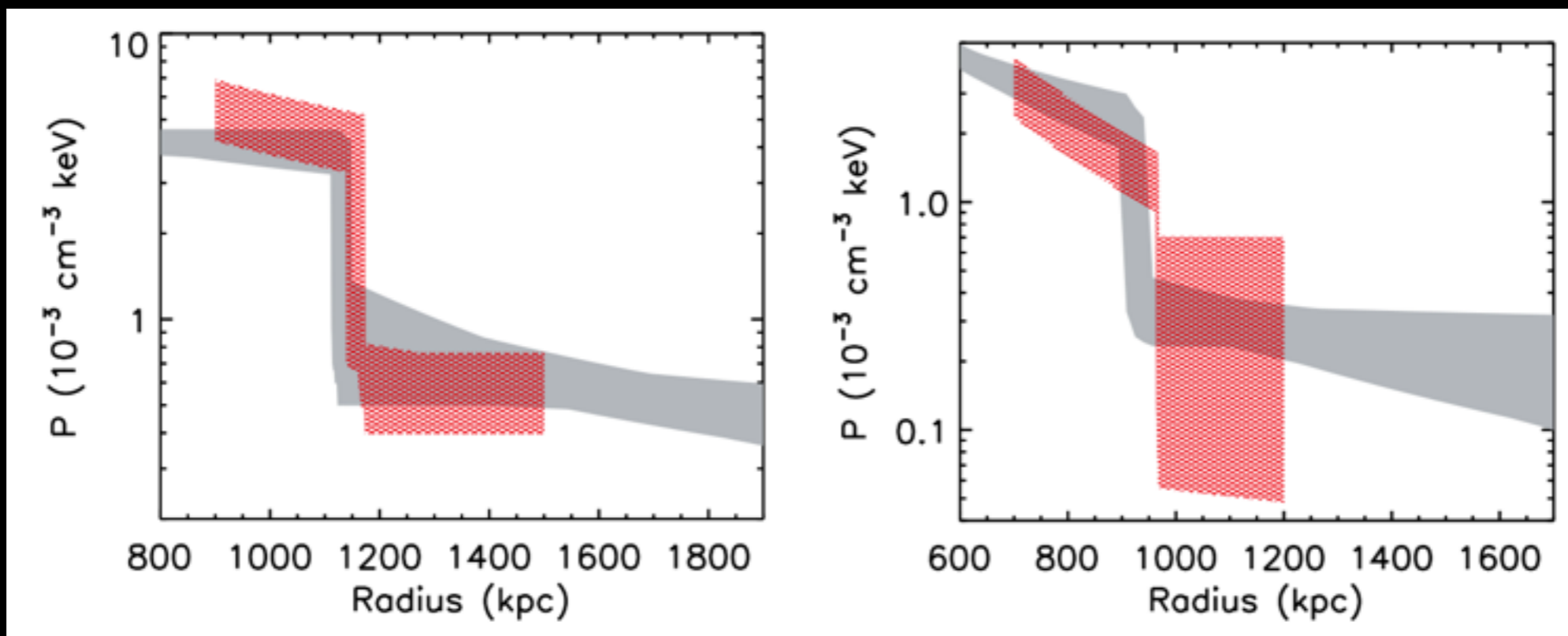
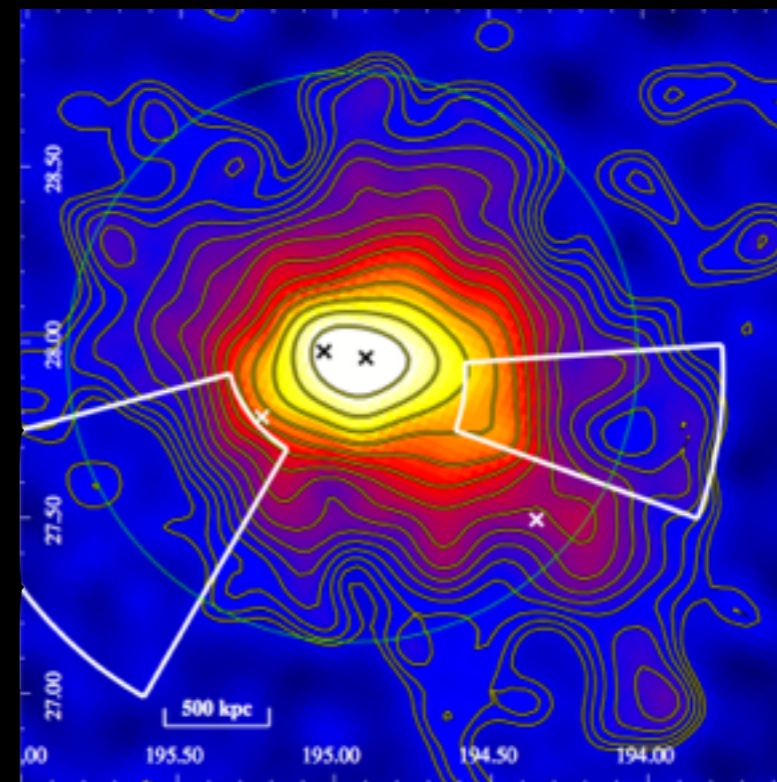


Shocks in the Coma clusters

→ Consistent constraint from XMM and Planck

→ X-rays + SZ + radio

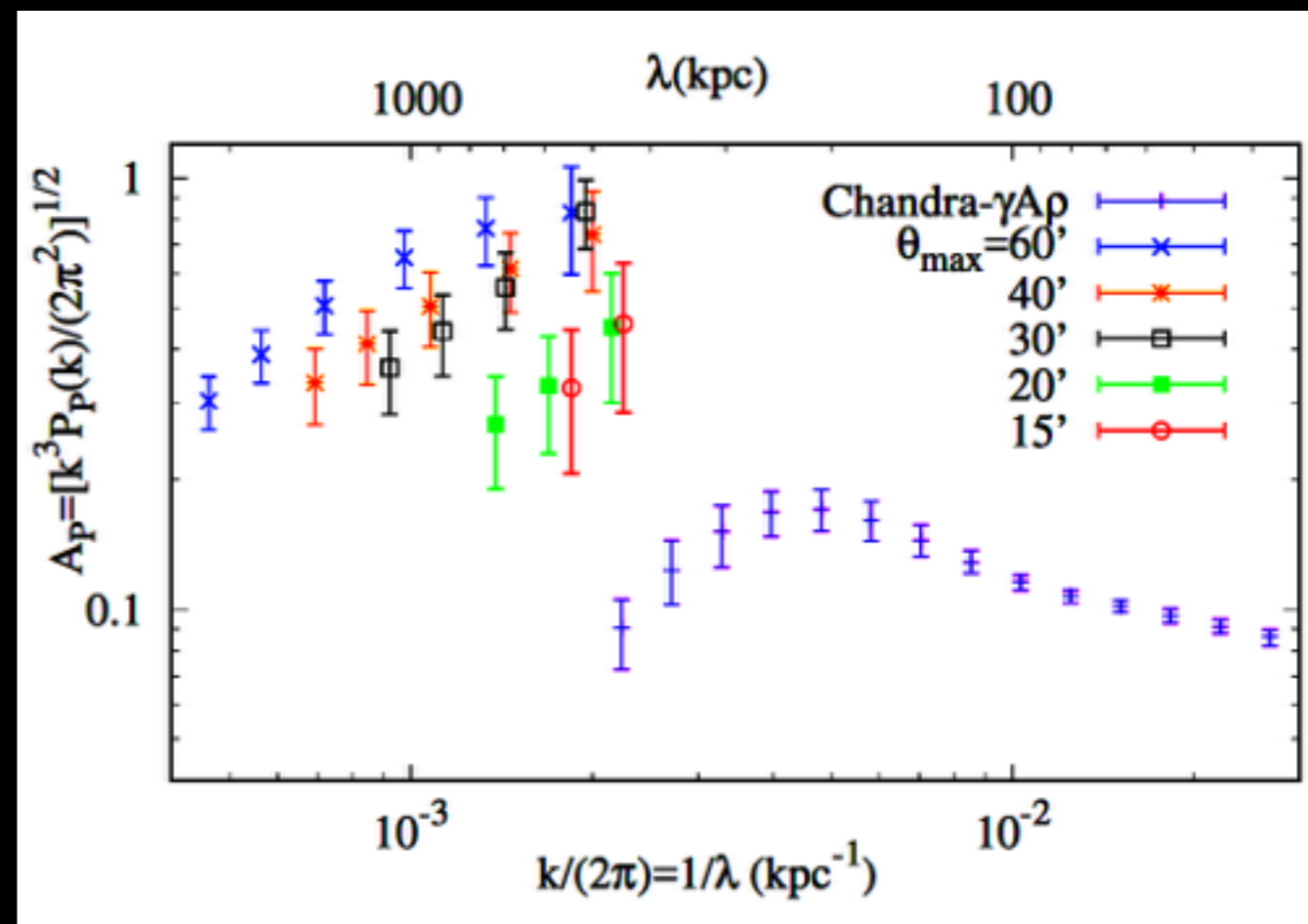
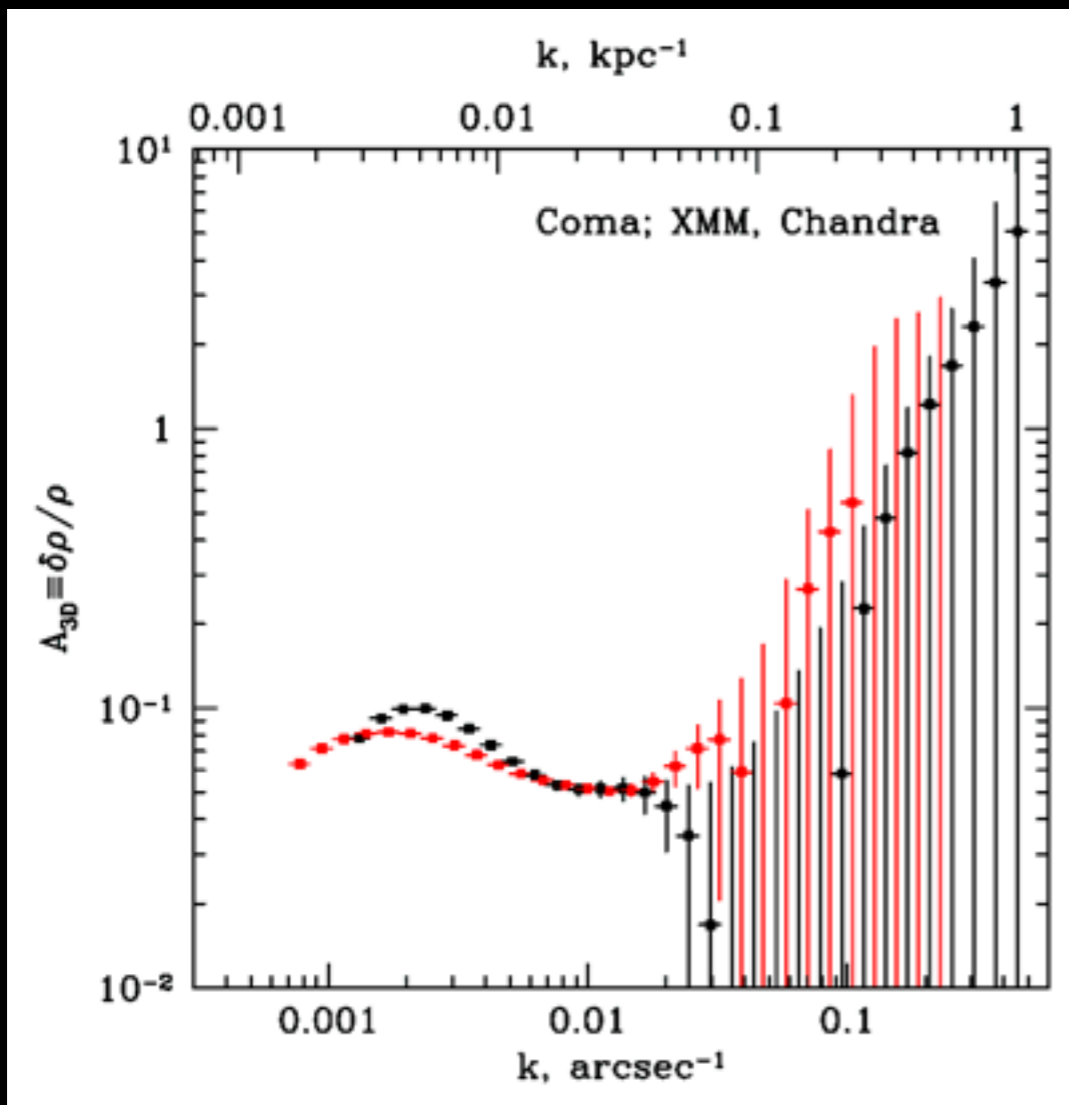
Planck Collaboration+13



Constraints on the power spectrum of turbulence in the Coma cluster

Churazov+12

Khatri & Gaspari+16



see also: Zhuravleva+14+15, Gaspari+13+14

see talks by E. Churazov, M. Gaspari

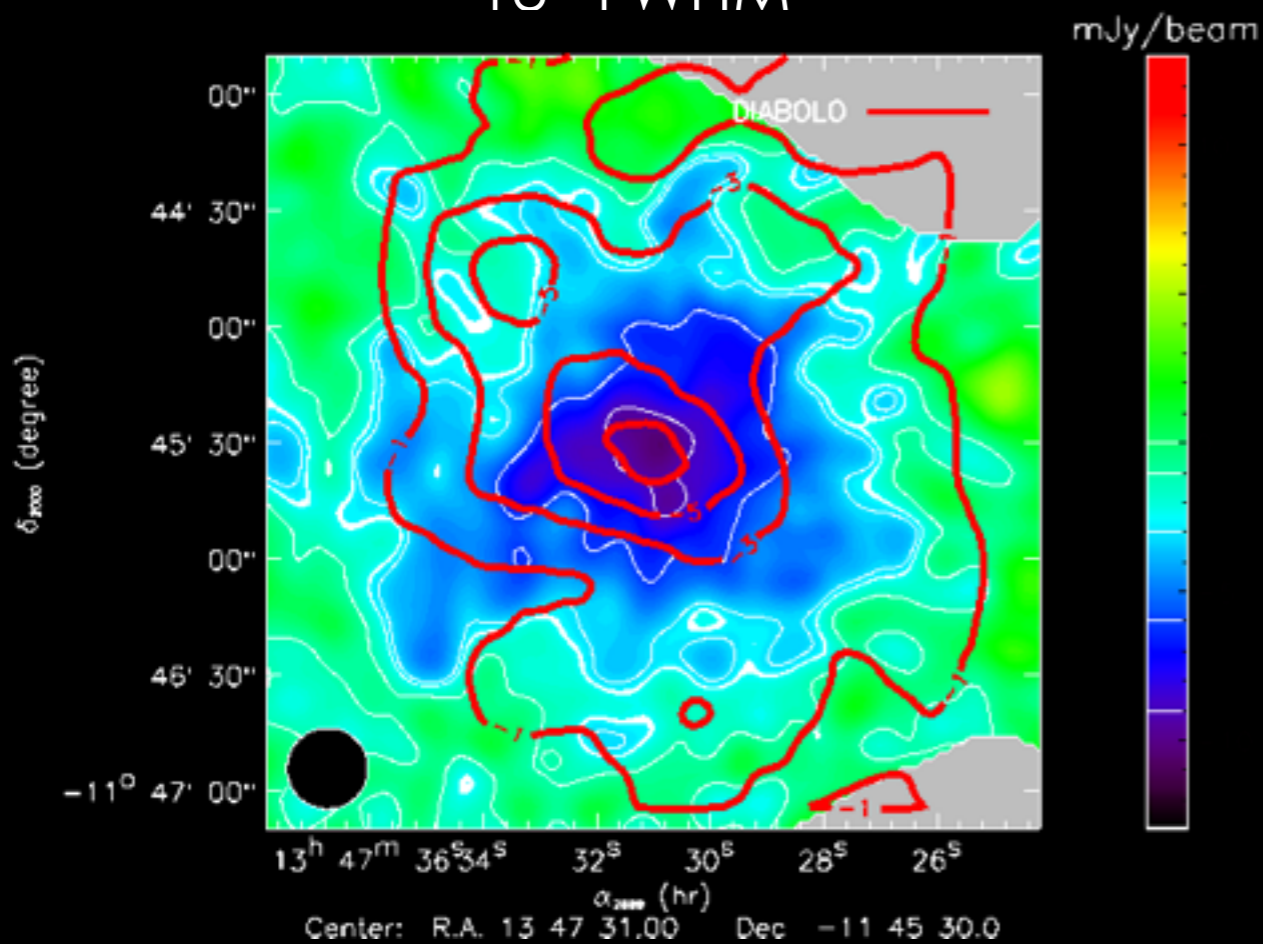
Evolution (of SZ observations)

High spatial resolution SZ imaging

- High spatial resolution for SZ is needed :
 - to go beyond the most local and massive system
 - capture smaller spatial structures

NIKA-1 @ IRAM 30m

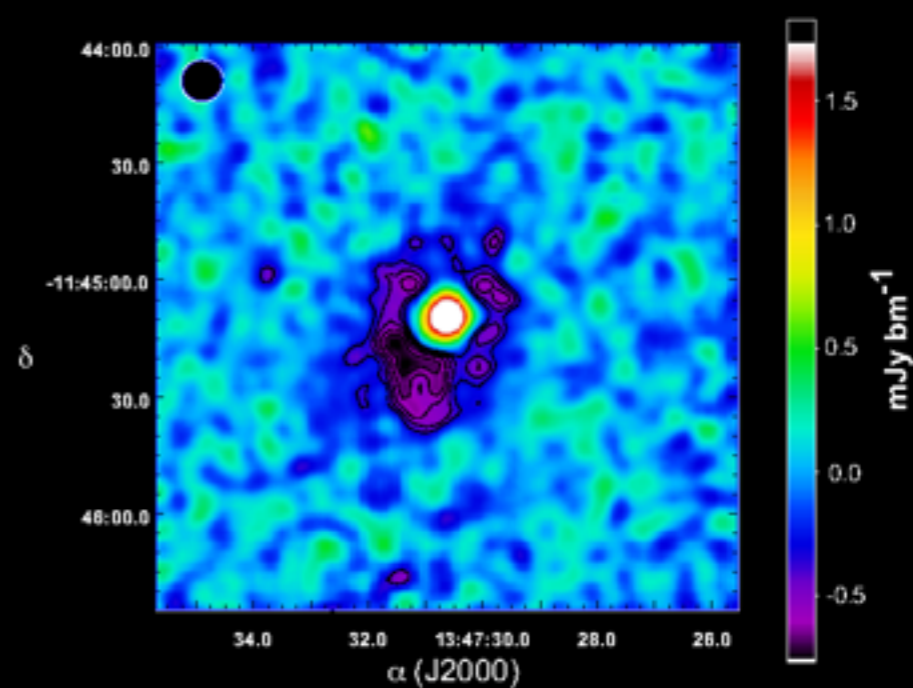
18" FWHM



Adam+2014

MUSTANG-1 @ GBT 100m

9" FWHM



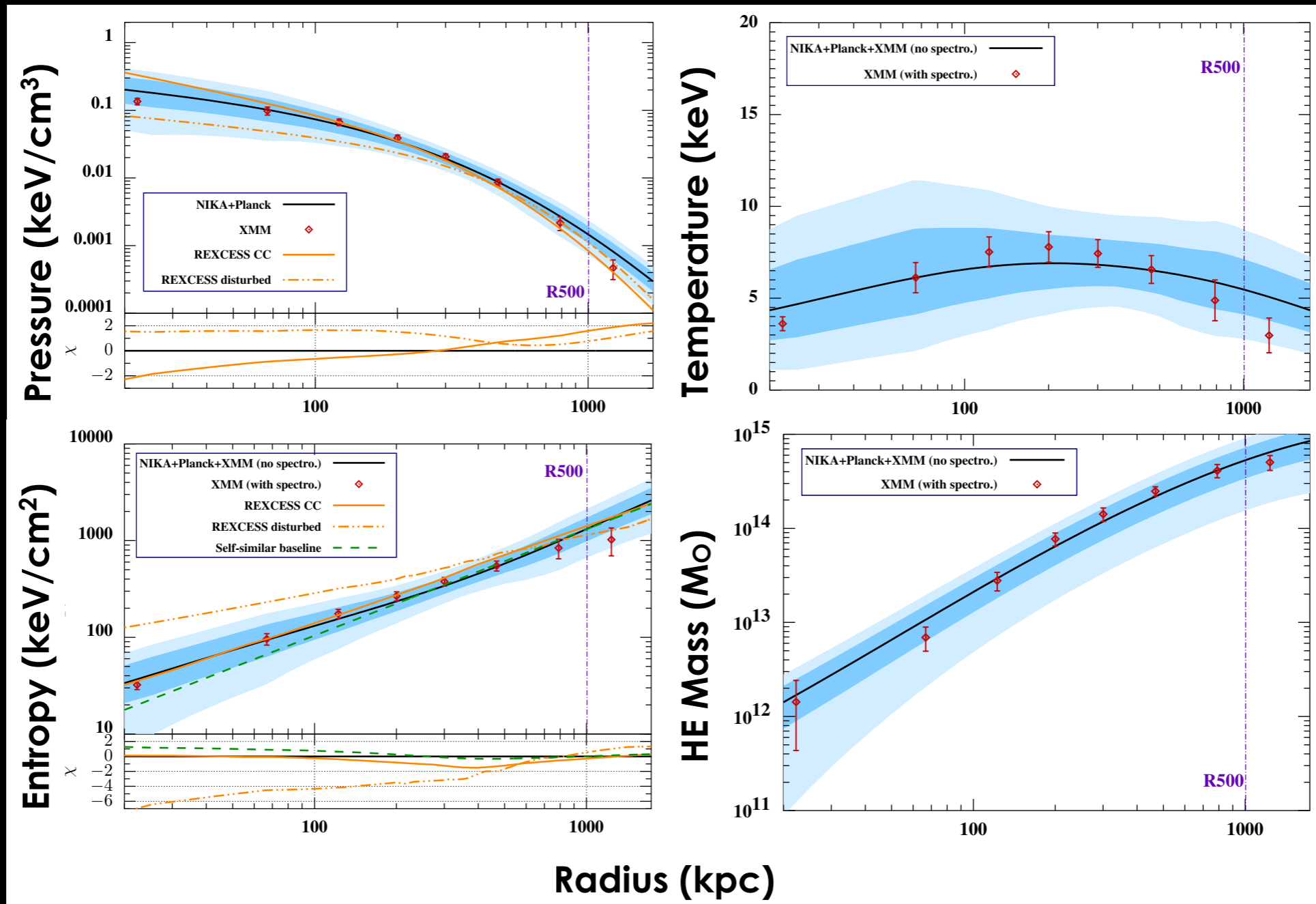
Mason+10, Korngut+11

see also: Pointecouteau+99+01, Komatsu+99+00, Kitayama+04

Joint X-ray and SZ imaging

PSZ1 G045.85+57.71 at $z=0.61$ — NIKA + XMM

Ruppin+16

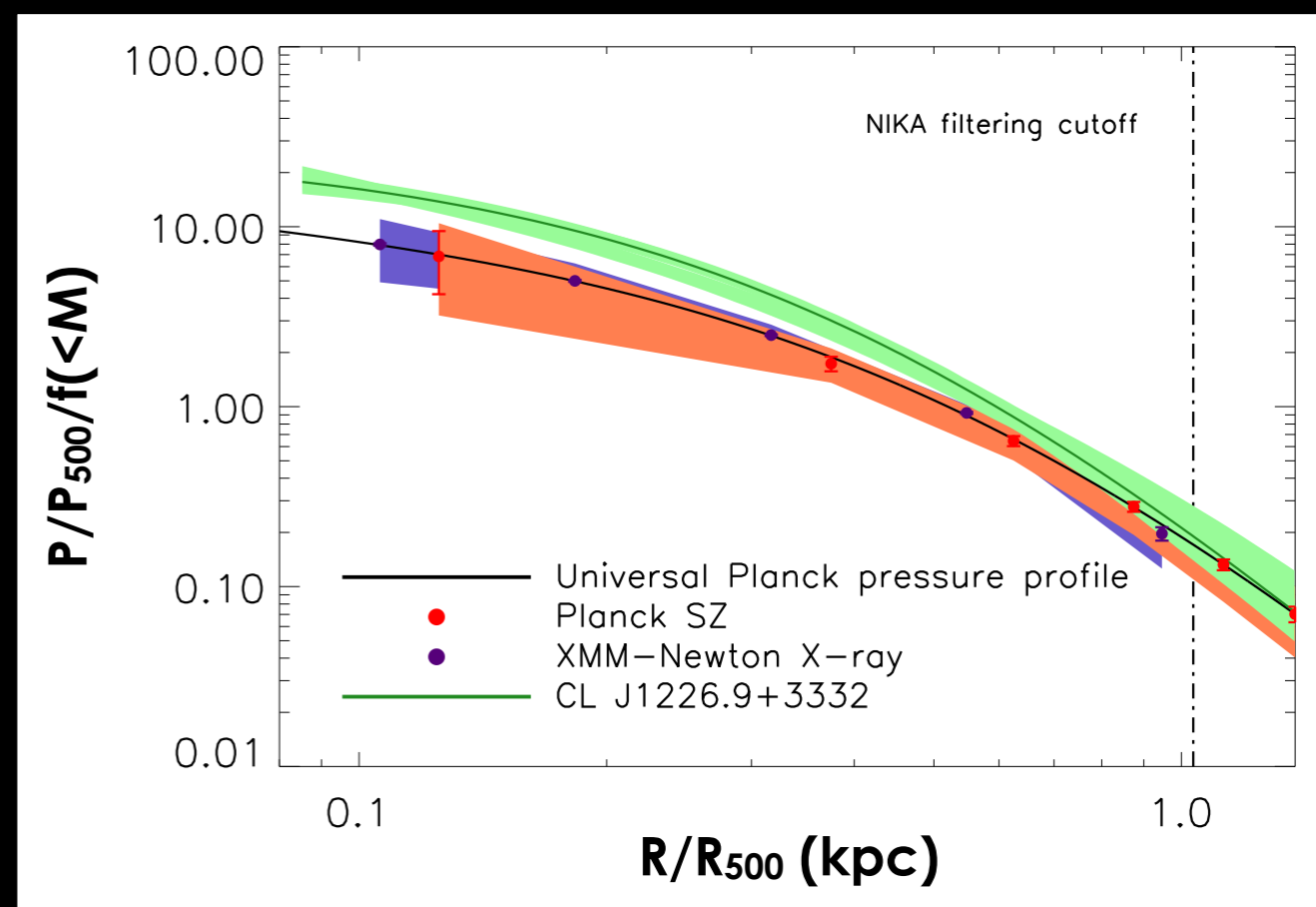
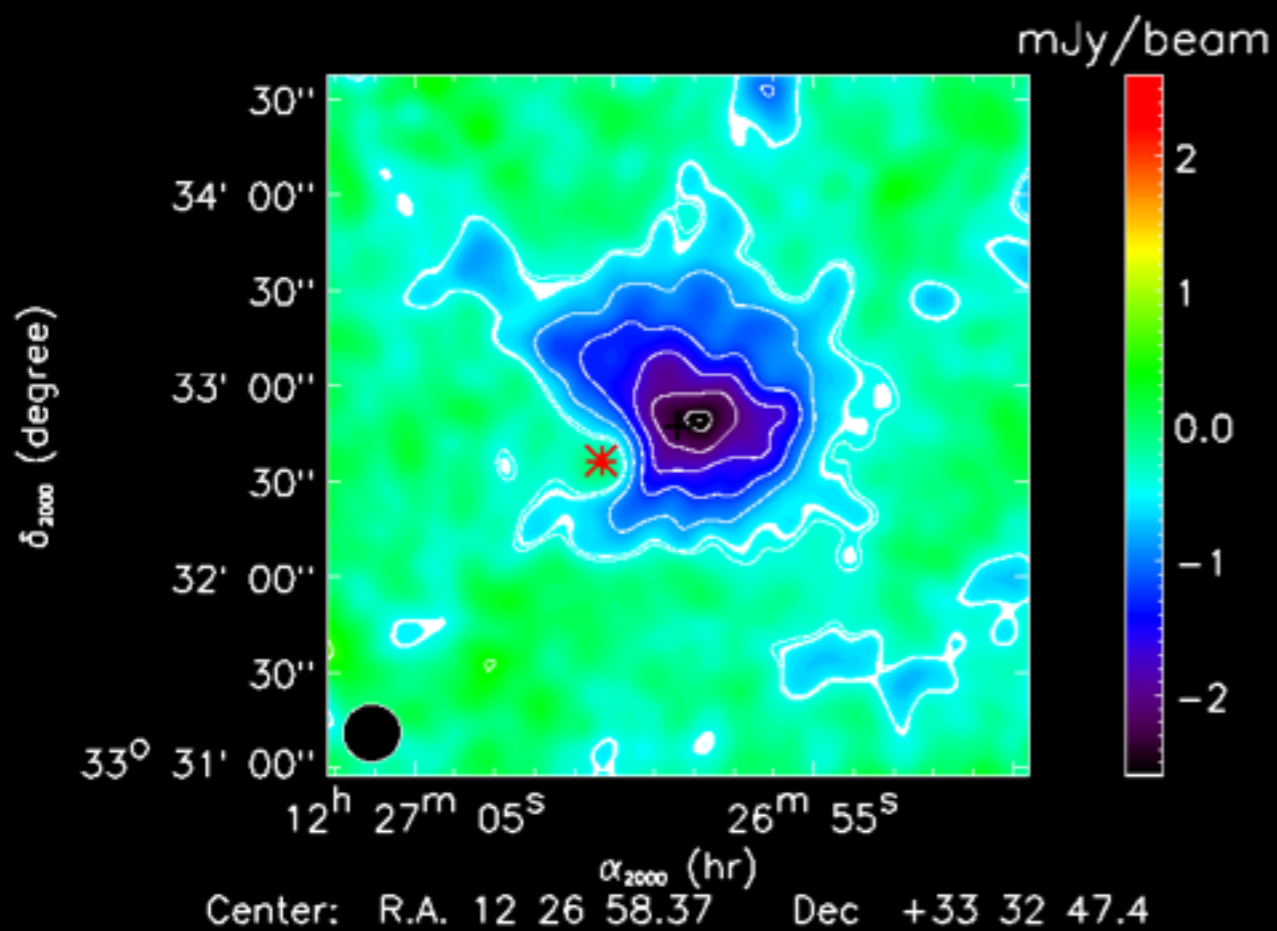


Courtesy of F. Ruppin and the NIKA consortium

see also: Pointecouteau+02, Kitayama+04, Amaglio+07, Nord+09, Basu+10, Adam+15, Tchernin+16

Reaching high-z clusters

NIKA observation of CL J1226.9+3332 at $z=0.9$

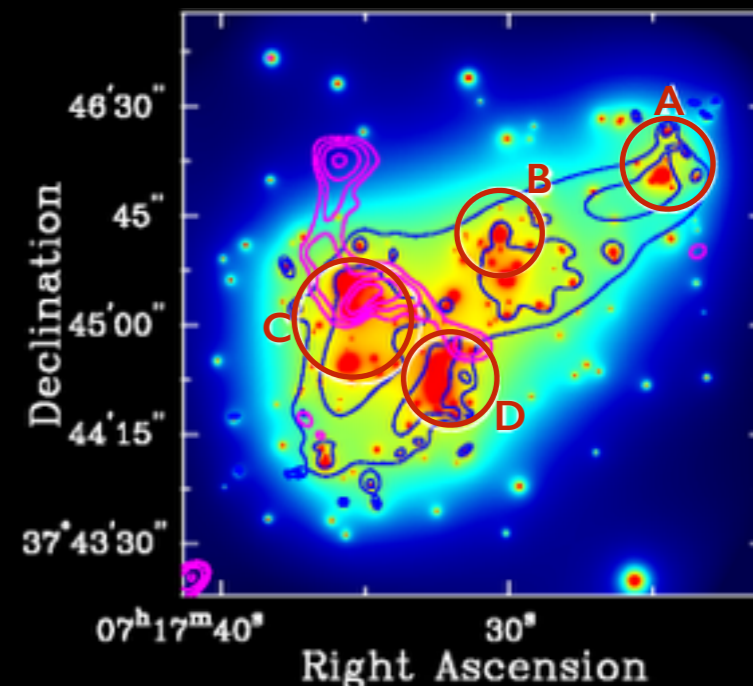


Adam+15

MACS J0717.5+3745 at $z=0.55$ a triple merger system with a complex dynamics

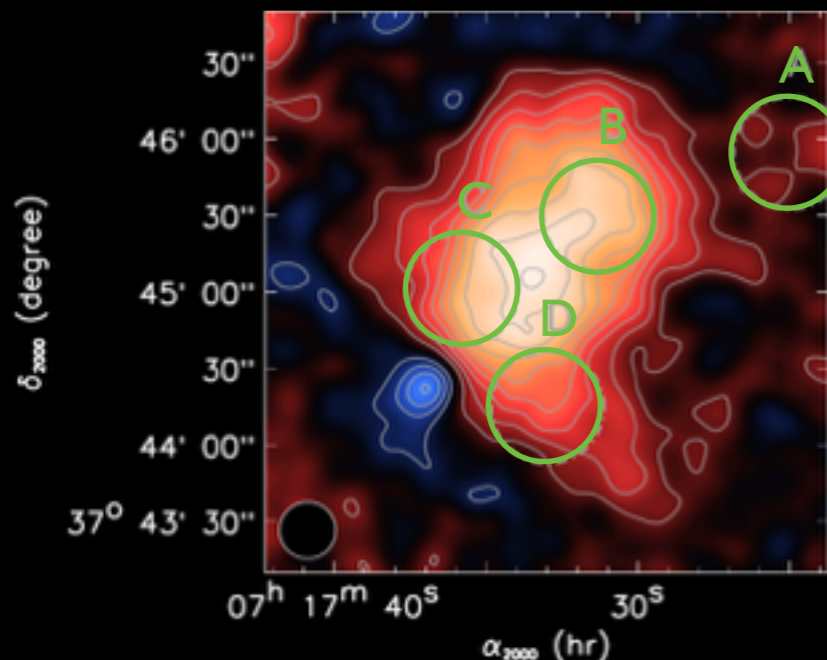
Mapping the kinetic SZ effect with NIKA

Mroczkowski+12

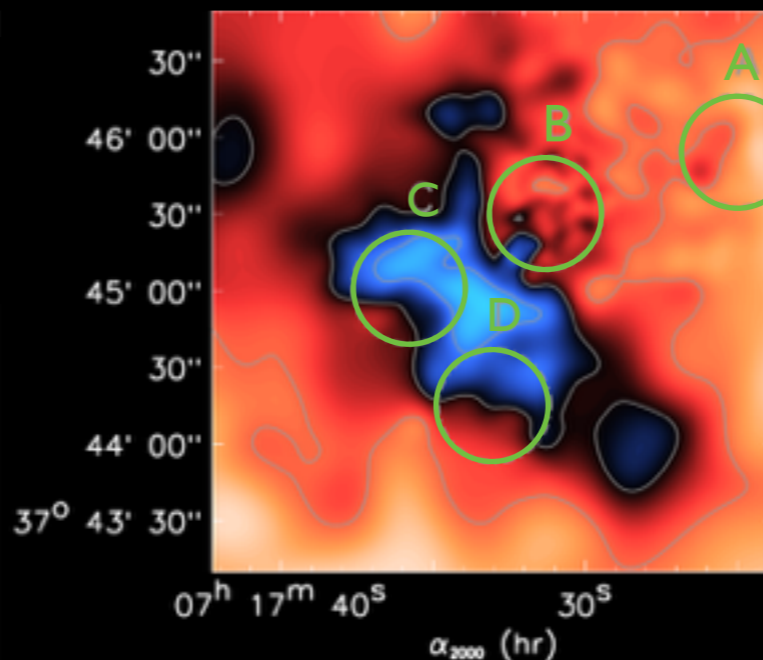


Adam+16

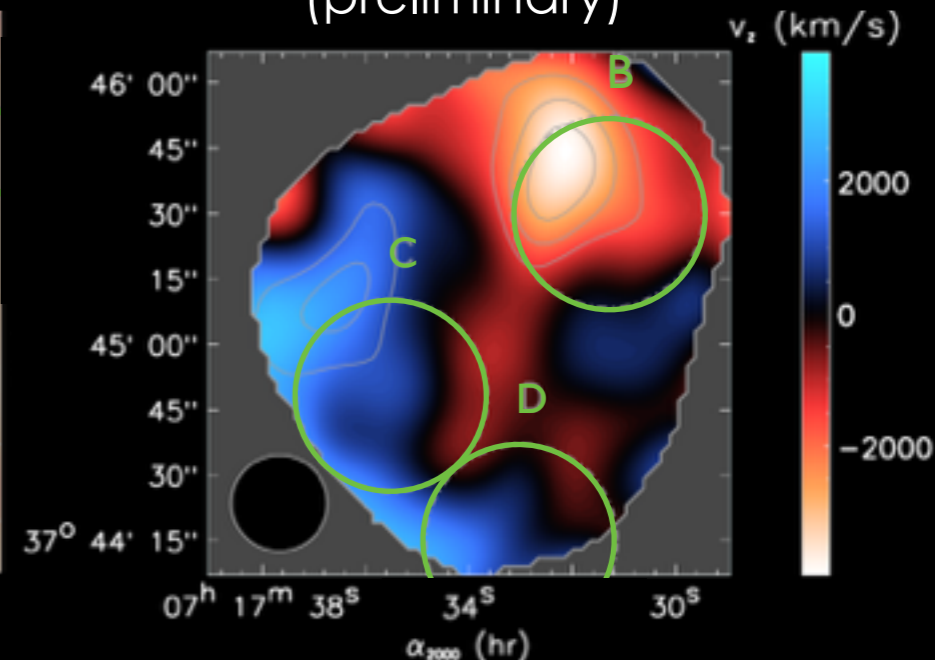
NIKA SZ



XMM kT



reconstructed kSZ
(preliminary)

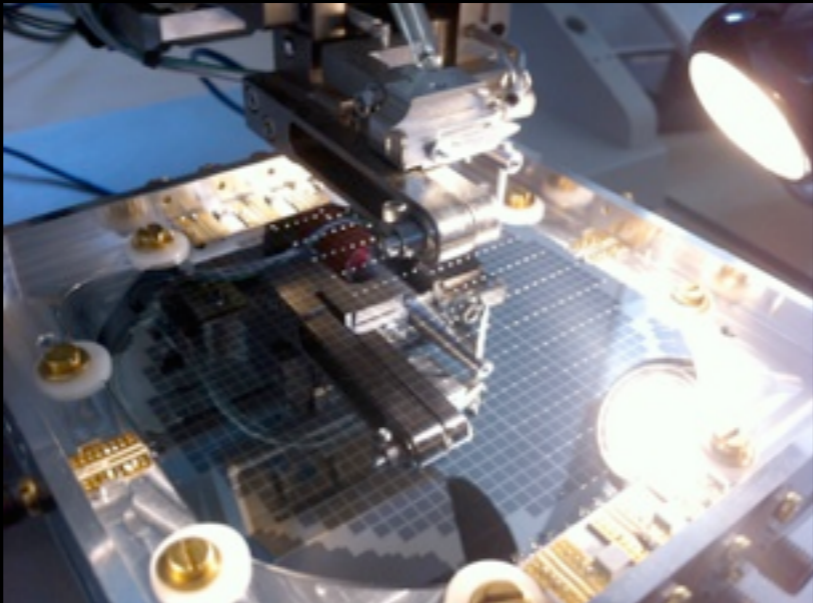
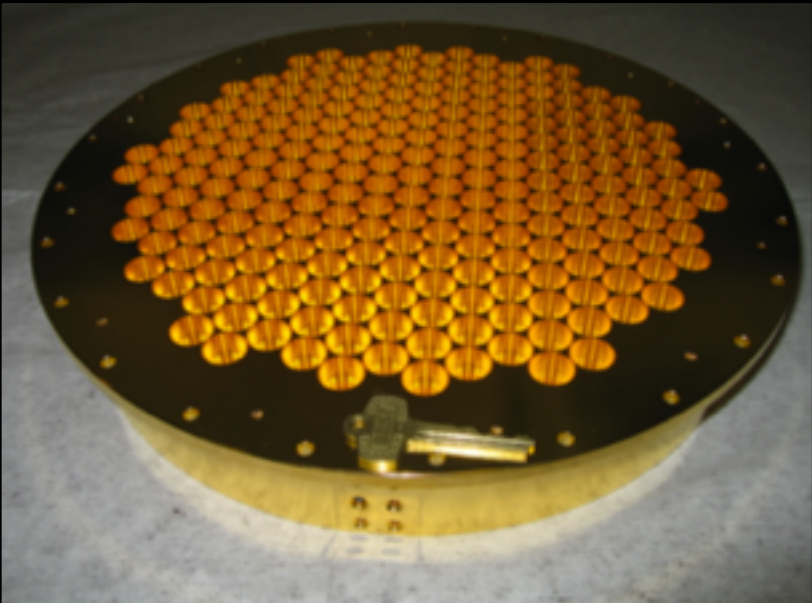


Courtesy of R. Adam and the NIKA consortium

Lensing: Zitrin+09, Limousin+09 ; Light distribution: Ma+09 ; Radio: van Weeren+09 ; SZ: Mroczkowski+12

Upcoming SZ instruments

Instrument	NIKA-2	MUSTANG-2
Telescope	IRAM 30m	GBT 100m
Detectors	1000/2000 KIDs	223 TES
FWHM	18"/12"	9"
Frequency	150 GHz (2 mm) 260 GHz (1 mm)	90 GHz (3.3mm)
FoV	6.5'	4.5'

Test the evolution of the baryons content and properties in clusters

300 h of GT to the NIKA consortium

A representative sample of ~50 clusters SZ selected

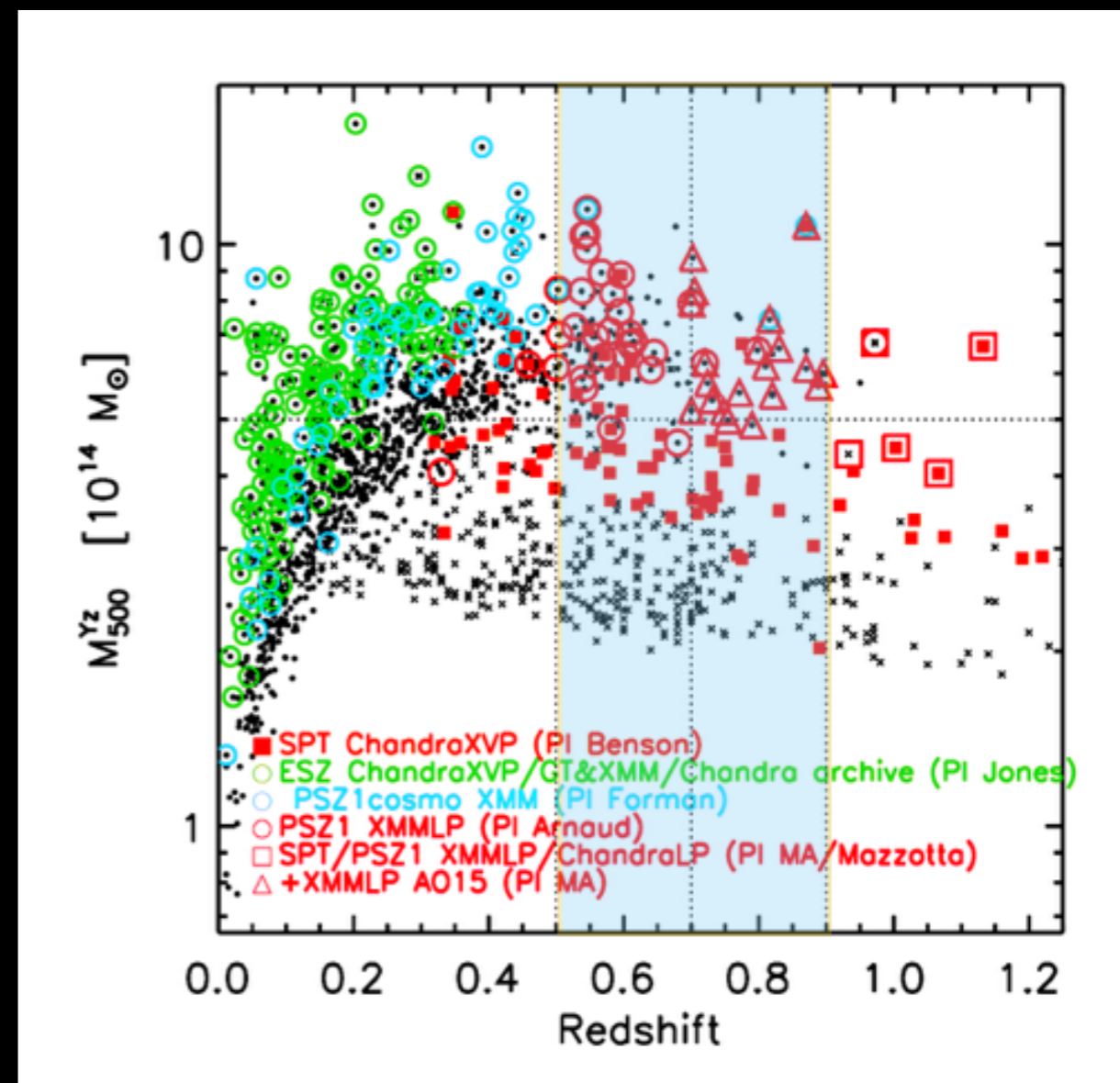
→ 2 bins of redshifts 0.5-0.7 and 0.7-0.9

→ 5 bins in mass

SZ observation starting late 2016

Partial overlap with XMM LPs (PI: M. Arnaud)

→ Need for a complete XMM coverage to maximise the scientific exploitation of this NIKA-2 GT large programme



Courtesy of M. Arnaud

Large catalogues of SZ clusters complementing the X-ray catalogues and providing mass limited samples

→ XMM follow-ups to constrain the properties of clusters from $z=0$ to $z\sim 1$

Consistent physical properties of the hot gas from both X-rays and SZ

→ XMM FoV to serve studies on local clusters in combination with arcminute scale SZ data (Planck, SPT, ACT, Bolocam, AMI)

Evolution of the ICM towards the epoch of cluster formation

→ XMM sensitivity crucial in upcoming evolution studies out to $z=1$ and beyond together with the new generation of SZ instruments (NIKA-2, MUSTANG-2)

XMM has a key role to play in the coming years for combined X-rays and SZ studies of the population of clusters of galaxies