Evolution of massive cluster profiles with XMM and Chandra and status of the NIKA2-LP X-ray follow-up

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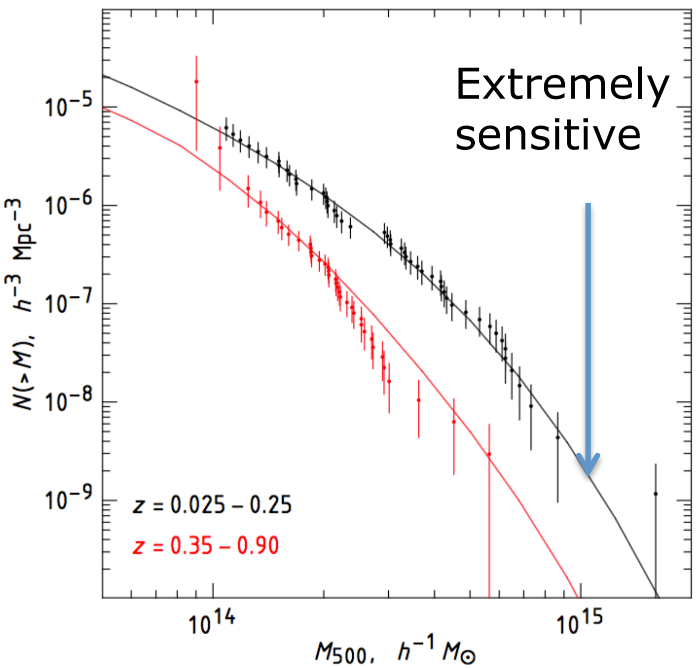
Contents:

- The sample
- XMM-*Newton*/*Chandra* combination
- Evolution of galaxy clusters
- Report on the NIKA2-LP

Why massive clusters?

Massive galaxy clusters (M_{500}>5x10^{14} $M_{\odot}$) are interesting for

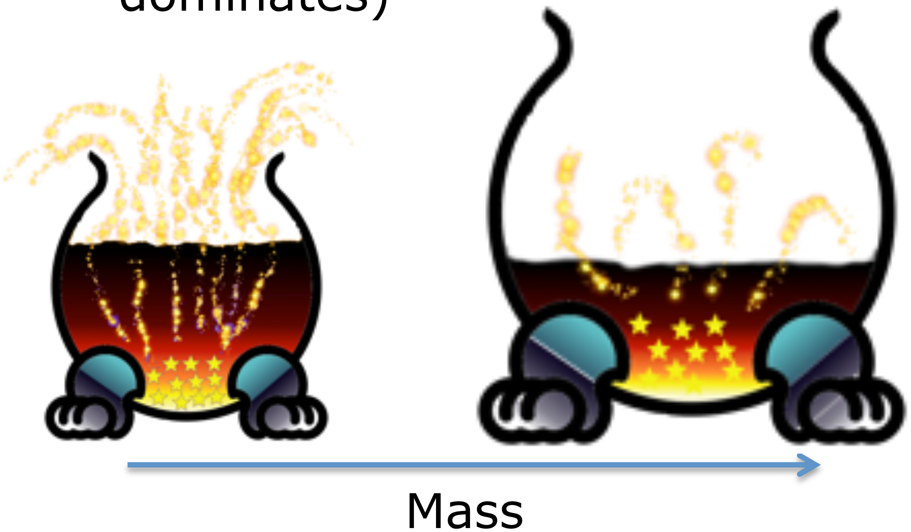
Cosmology



Vikhlinin et al 2009

Physics

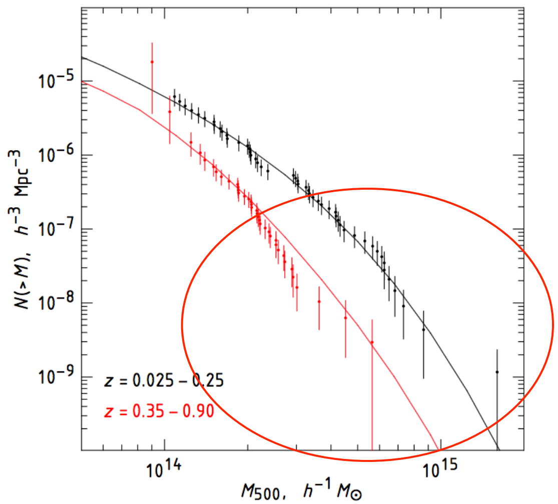
In high mass objects non-gravitational processes are negligible (simple gravitational heating dominates)



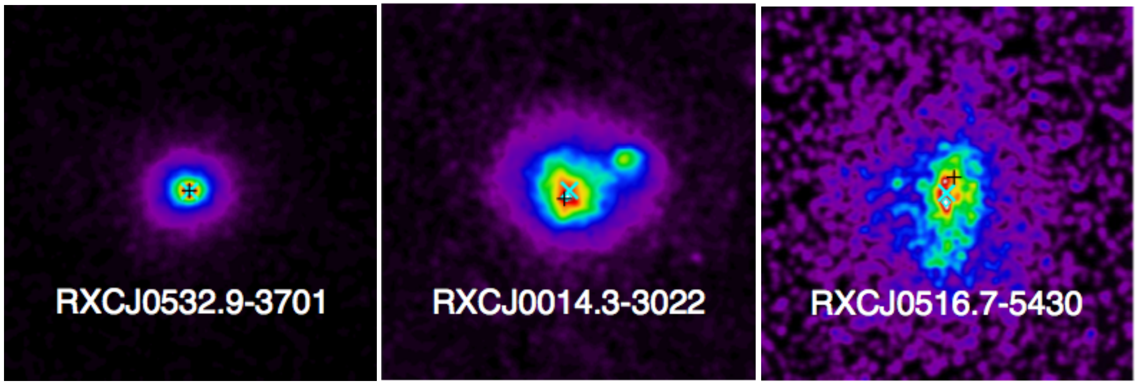
Construction of the sample I

The study of evolution needs 3 key elements

I. statistically representative sample
→ high-z clusters are intrinsically rare & faint



II. representative of the underlying population.



III. unbiased → mass selected

Construction of the sample I

The study of evolution needs 3 key elements

I. statistically representative sample
→ high-z clusters are intrinsically rare & faint!

SZ does not depend on redshift → samples at all z (e.g. Planck all sky, SPT, ACT)

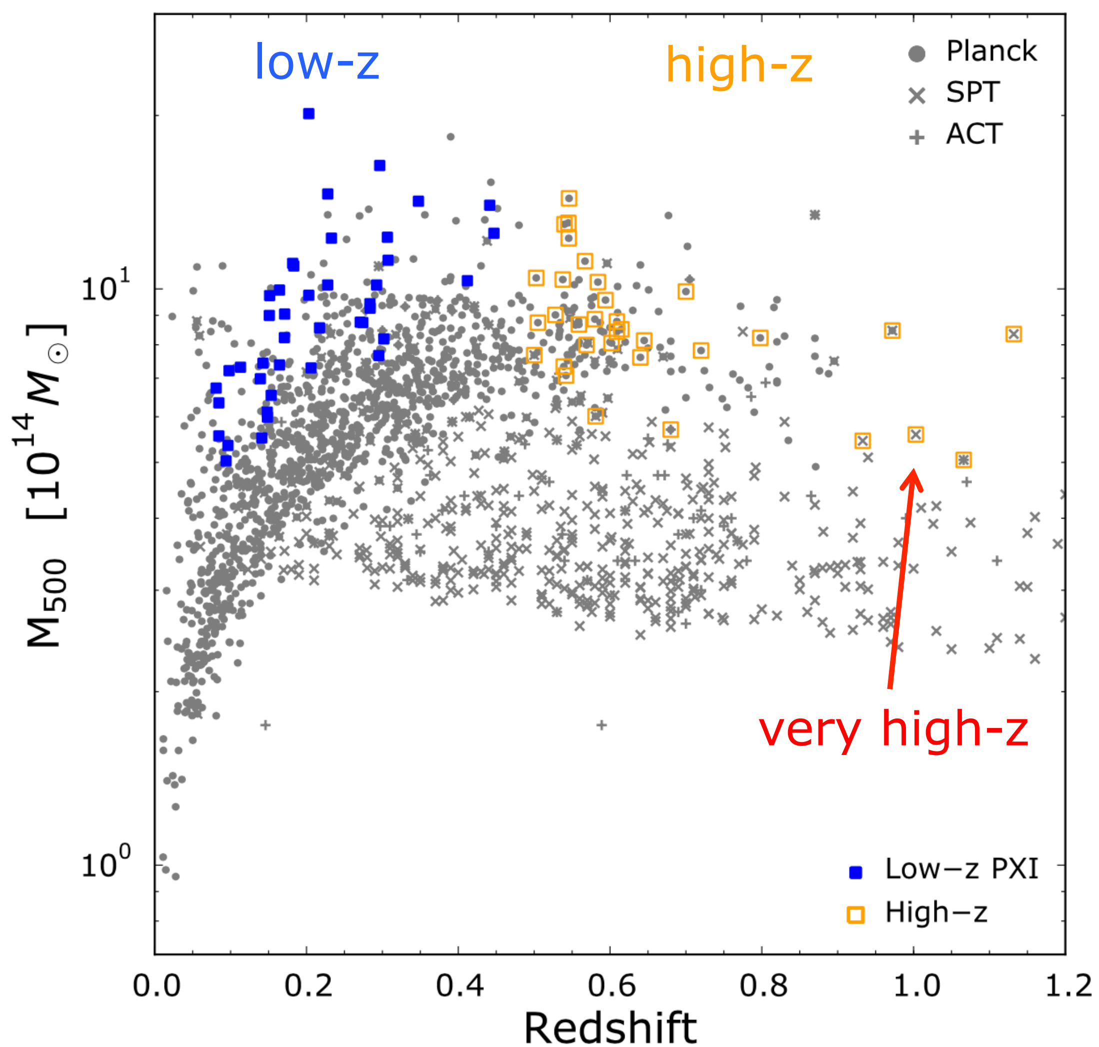
II. representative of the underlying population.

SZ depends linearly on density → no morphological bias (e.g. Rossetti el al. 2017, Lovisari et al. 2017…)

III. unbiased → mass selected

SZ signal is proportional to P integrated along the line of sight → energy

The sample



Bartalucci et al. 2019

SZ vsurveys are game-changers → sample

- Unbiased
- large
- representative

- z<0.5: 42 objects
- z>0.5: 33 PSZ1 objects

$M>5x10^{14}\ M_{\odot}$

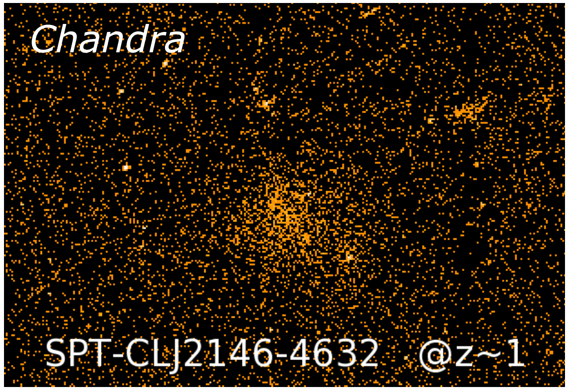
Deep X-ray XMM follow-ups!

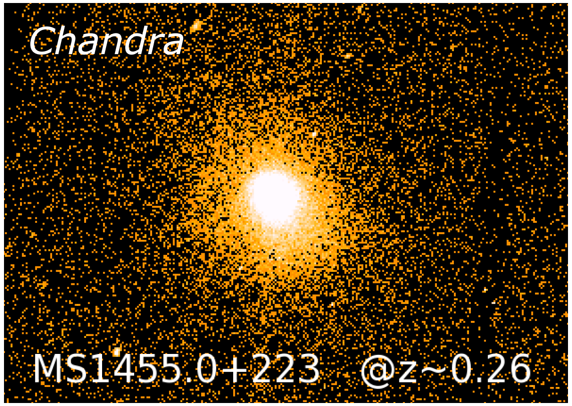
- Thermodynamic & HE radial profiles
- Morphology

Observational challenges at z~1

X-ray observations of high-z (>0.7) clusters suffer from cosmological dimming:

$$S_X \propto (1+z)^{-4}$$

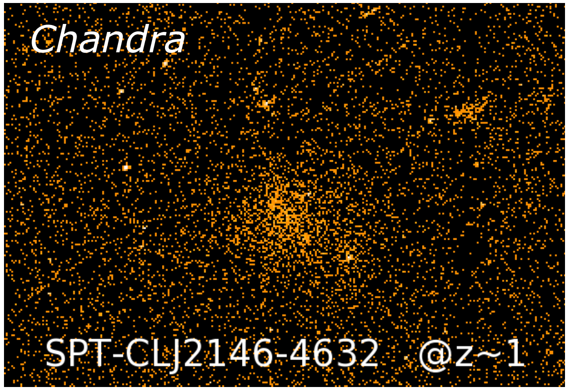


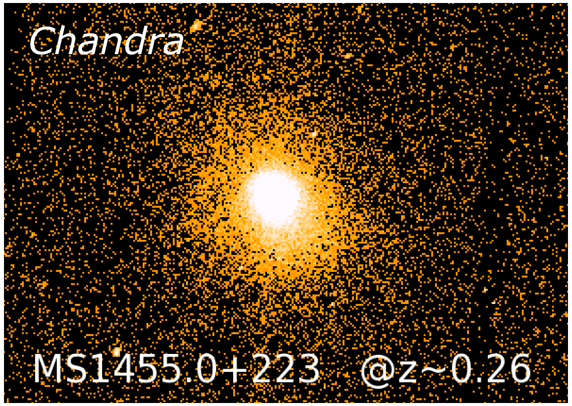


Observational challenges at z~1

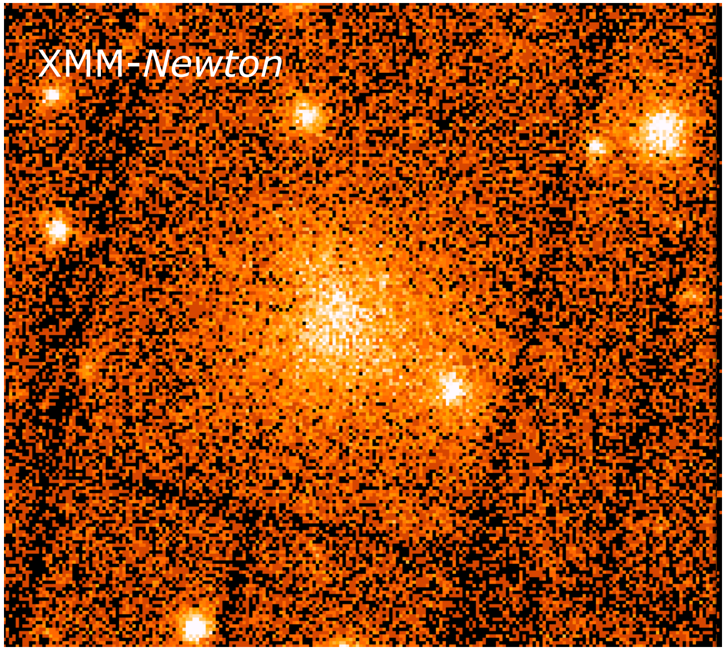
X-ray observations of high Z clusters suffer from cosmological dimming:

$$S_X \propto (1+z)^{-4}$$





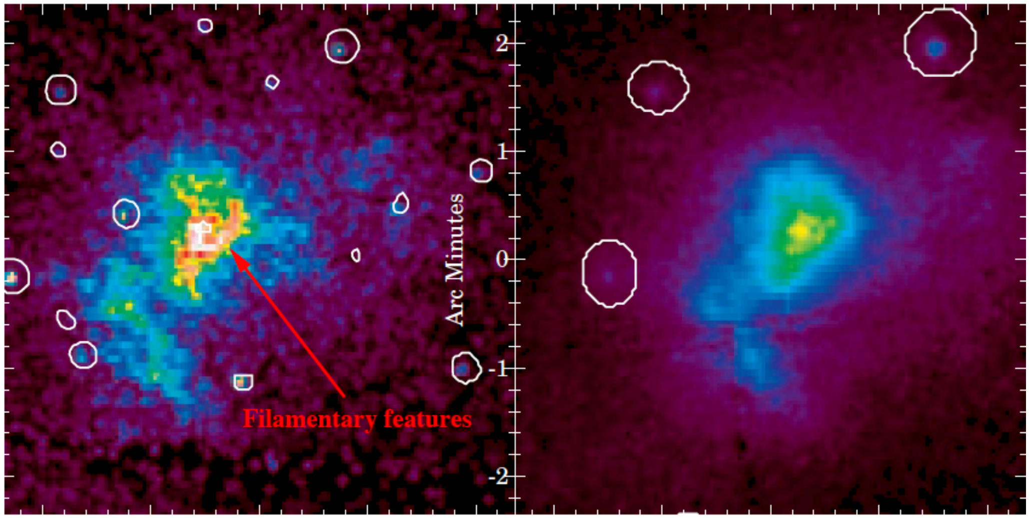
XMM-Newton bigger effective area!



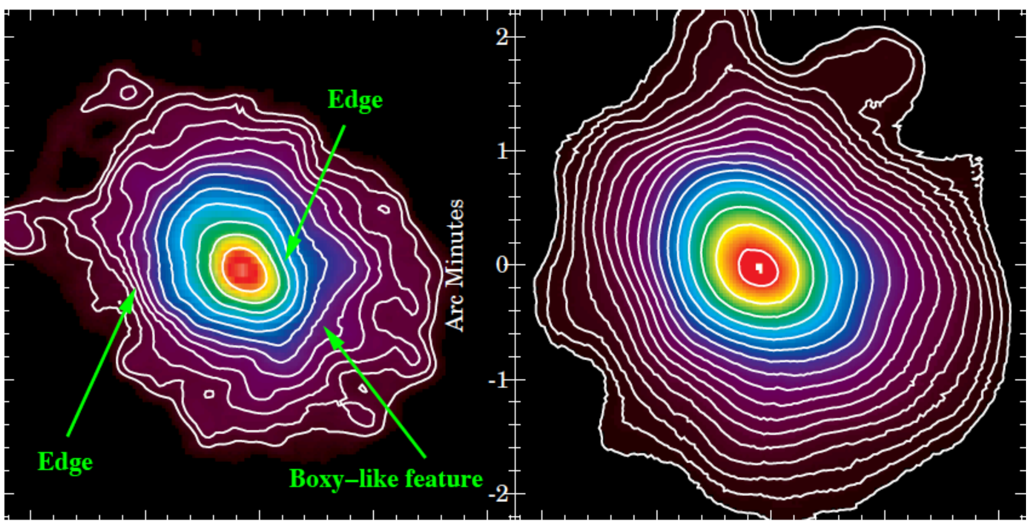
AGN confusion problem

XMM/Chandra synergy

CHANDRA *XMM-NEWTON*



MACS J0717.5+3745
Z = 0.55



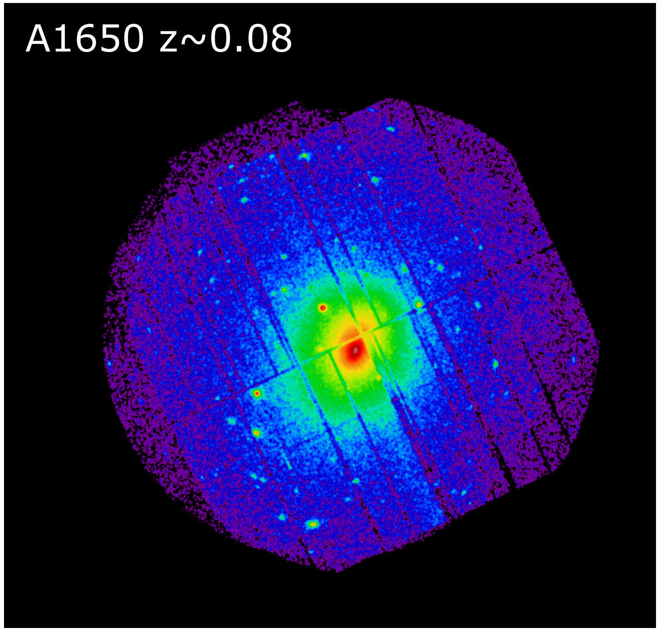
Cl0016+16
Z = 0.55

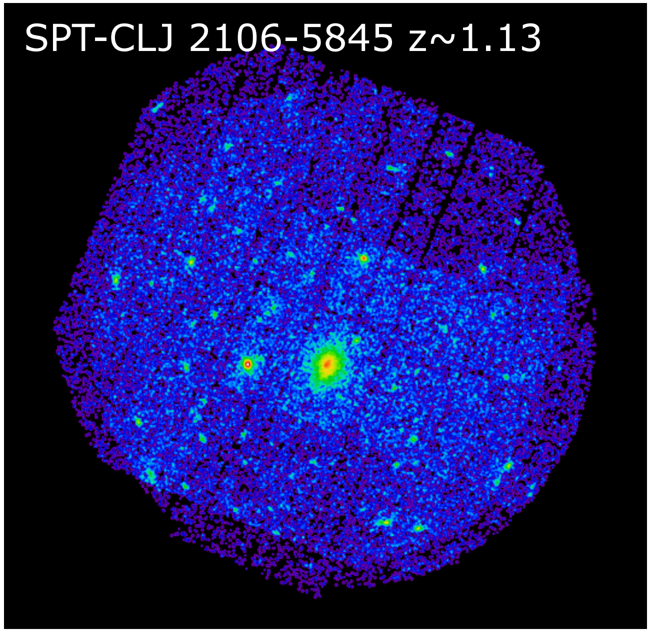
Chandra & *XMM-Newton*

Are we able to combine *Chandra* and *XMM*?
The answer from several papers is:
- **Yes** for density profiles (small biases ~0-4%);
- **No** for temperature profiles (10-15% bias between the two).

(see e.g. Martino et al 2014, Schellenberger 2014…)

We extended the question:
Are we able to combine *Chandra* and *XMM* density profiles for a very heterogeneous sample?

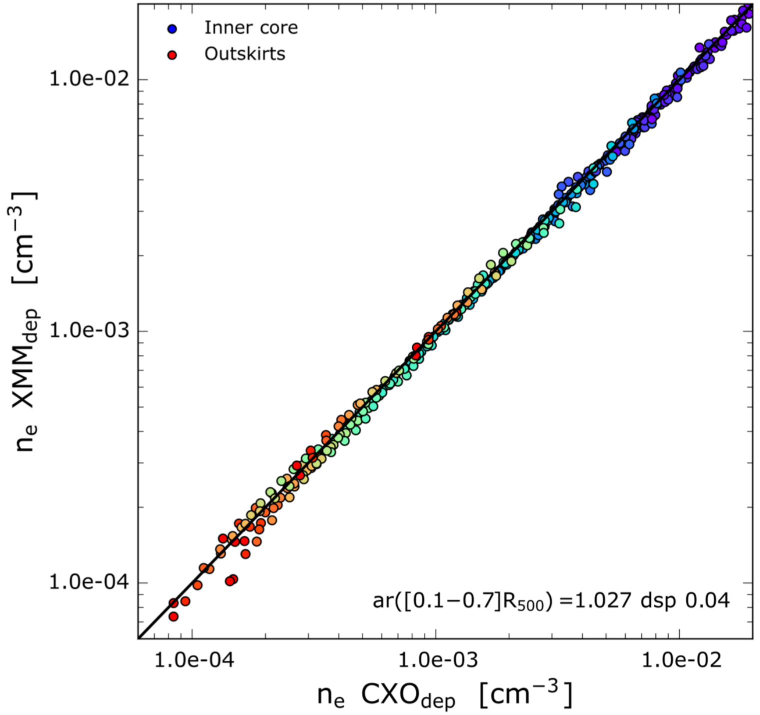


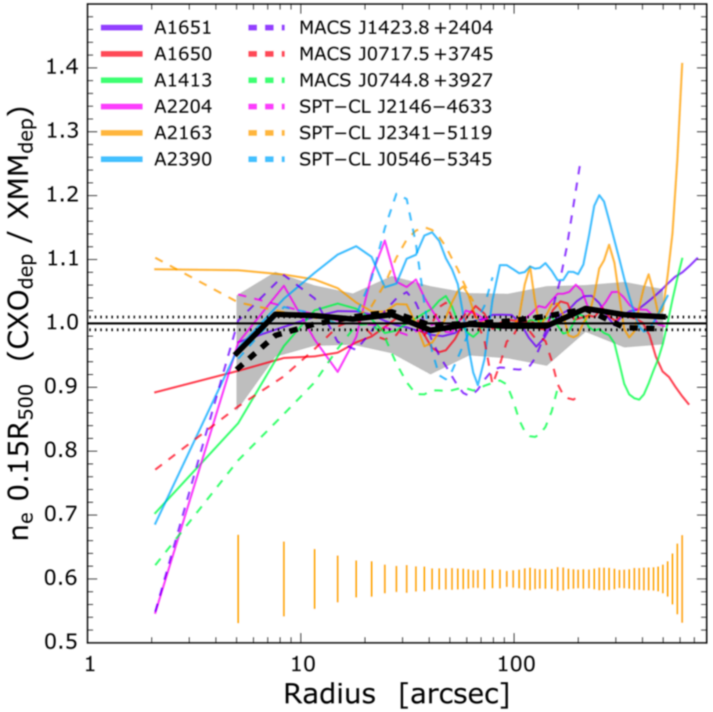


Chandra & XMM-*Newton*

The results from Bartalucci et al. 2017:

yes! **&** *XMM* PSF **is not an issue**

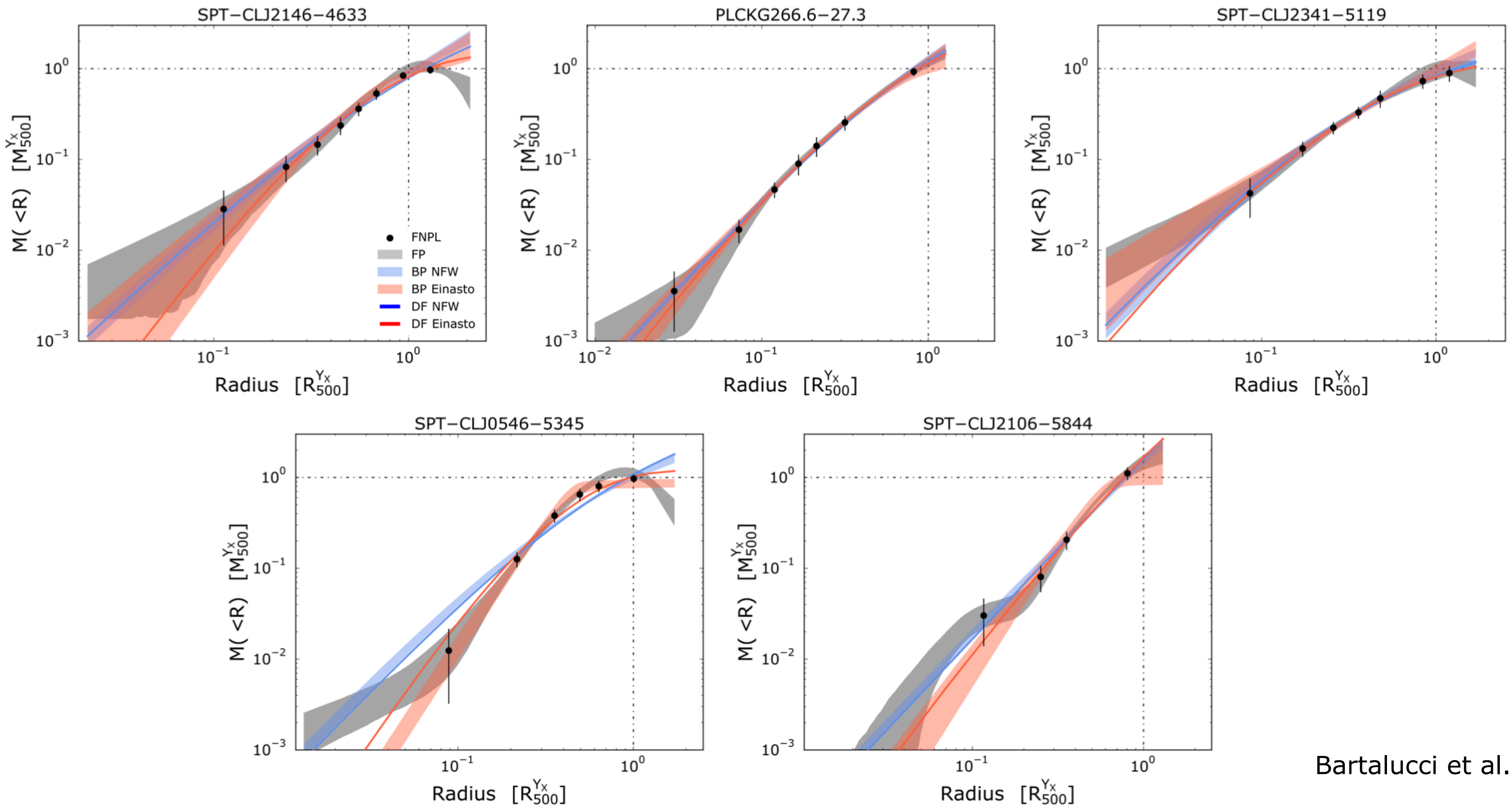




But small differences on individual basis

fundamental for z>0.5

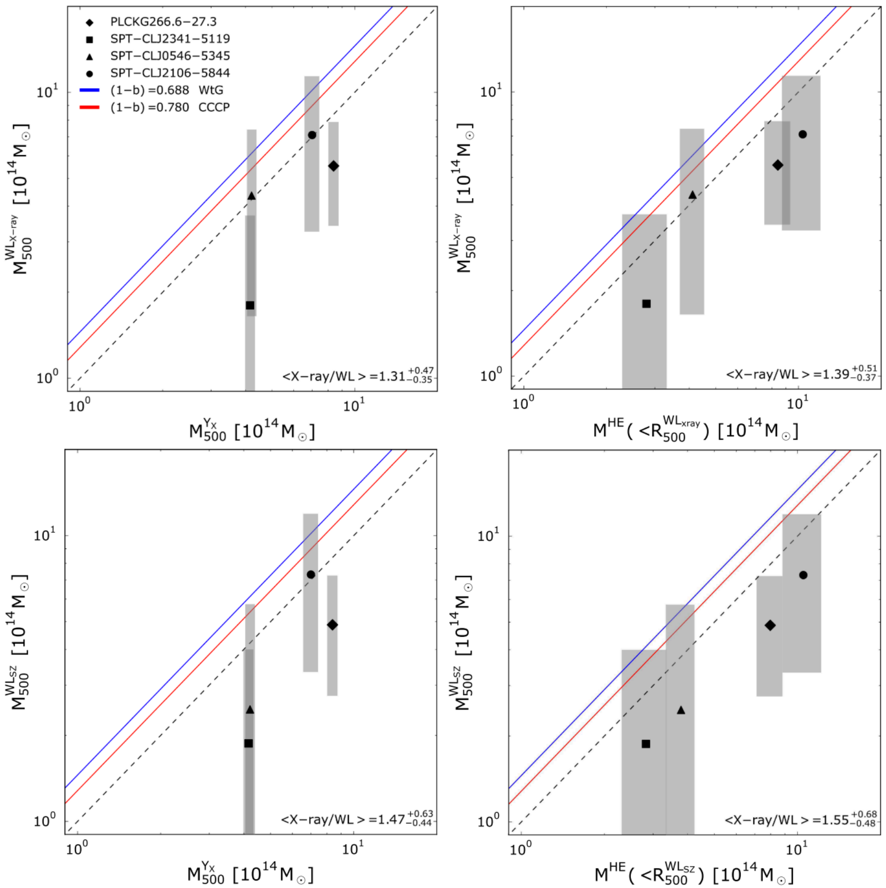
X-ray HE mass profiles at z~1



Bartalucci et al. 2018

Individual HE mass profiles (for the first time) up to R_{500}…
and they are quite robust! (given good quality data)

X-ray HE mass profiles at z~1



Bartalucci et al. 2018

Mass determination from profiles is essential!

Comparison with weak lensing shows an opposite bias to what is expected (X-ray masses < WL)

Weak lensing biases at such redshift?

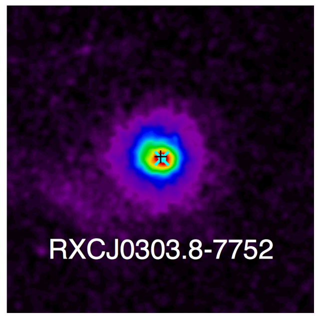
Evolution: dynamical status

The dynamical status of the cluster can be studied via the gas morphology

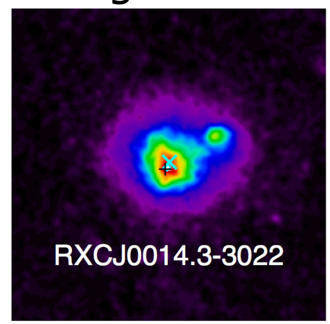
We used three morphological indicators:

- the centroid shift <w>

low <w>



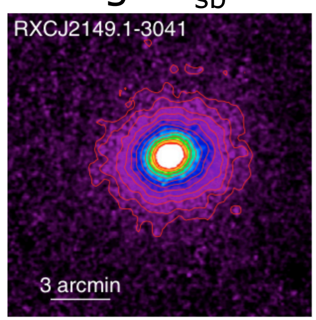
high <w>



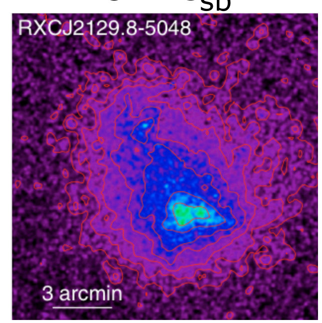
large scales

- the surface brightness profile concentration c_{sb}

high c_{sb}



low c_{sb}

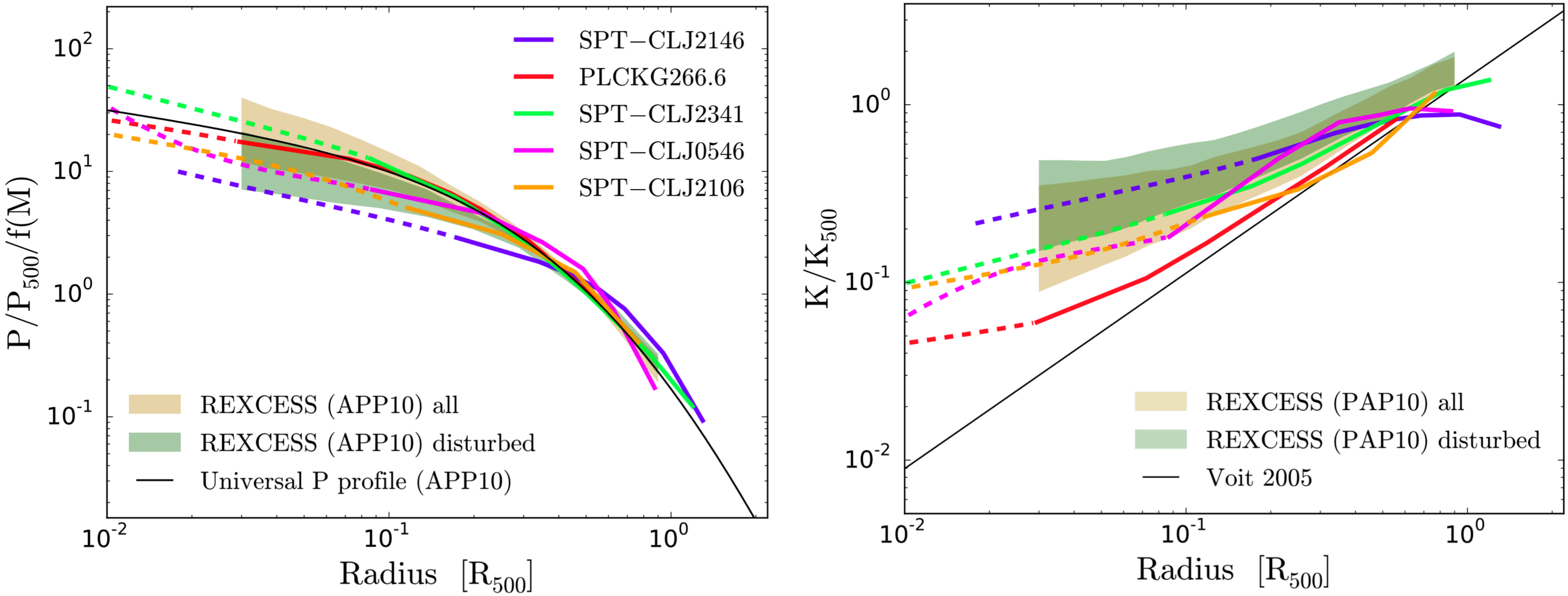


small scales

- the combination of the two M → small +large scales

Evolution: thermodynamic

Hints of evolution? Taking as reference the REXCESS sample
(Boehringer et al 2007,Pratt et al 2009, Arnaud et al 2010)

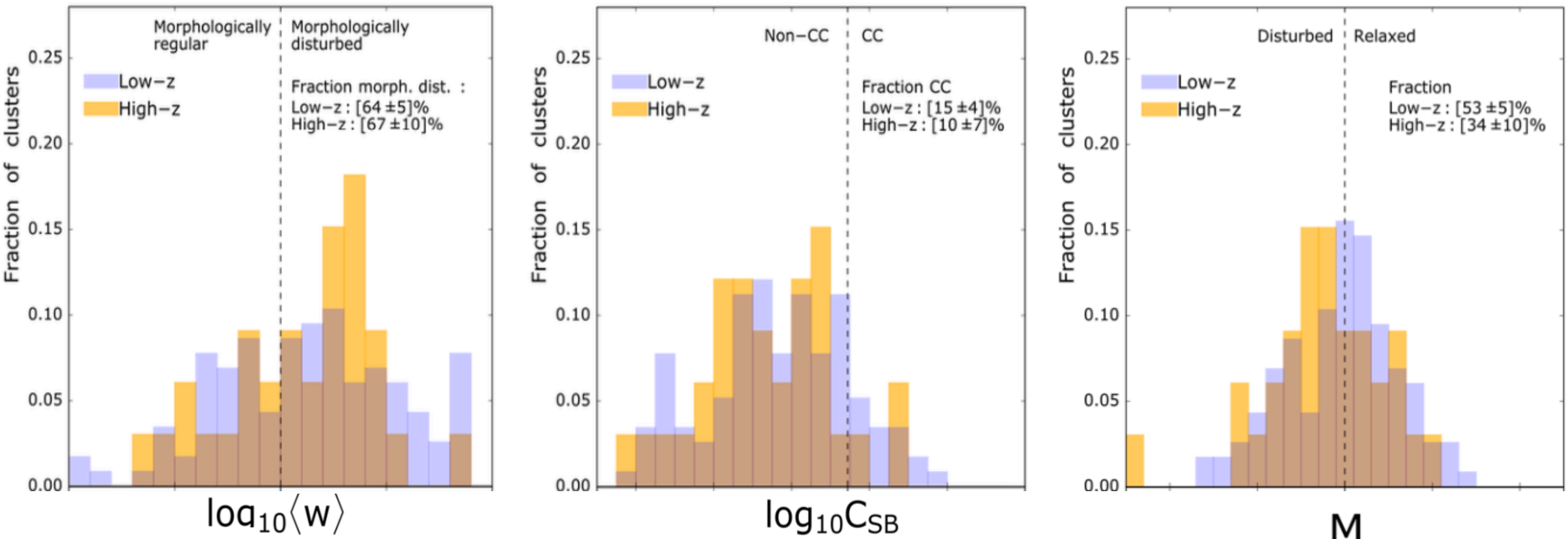


Bartalucci et al. 2017

- Pressure profiles are in excellent agreement
- Entropy profiles are, on average, lower than local

In agreement with self-similar evolution! gravity dominates

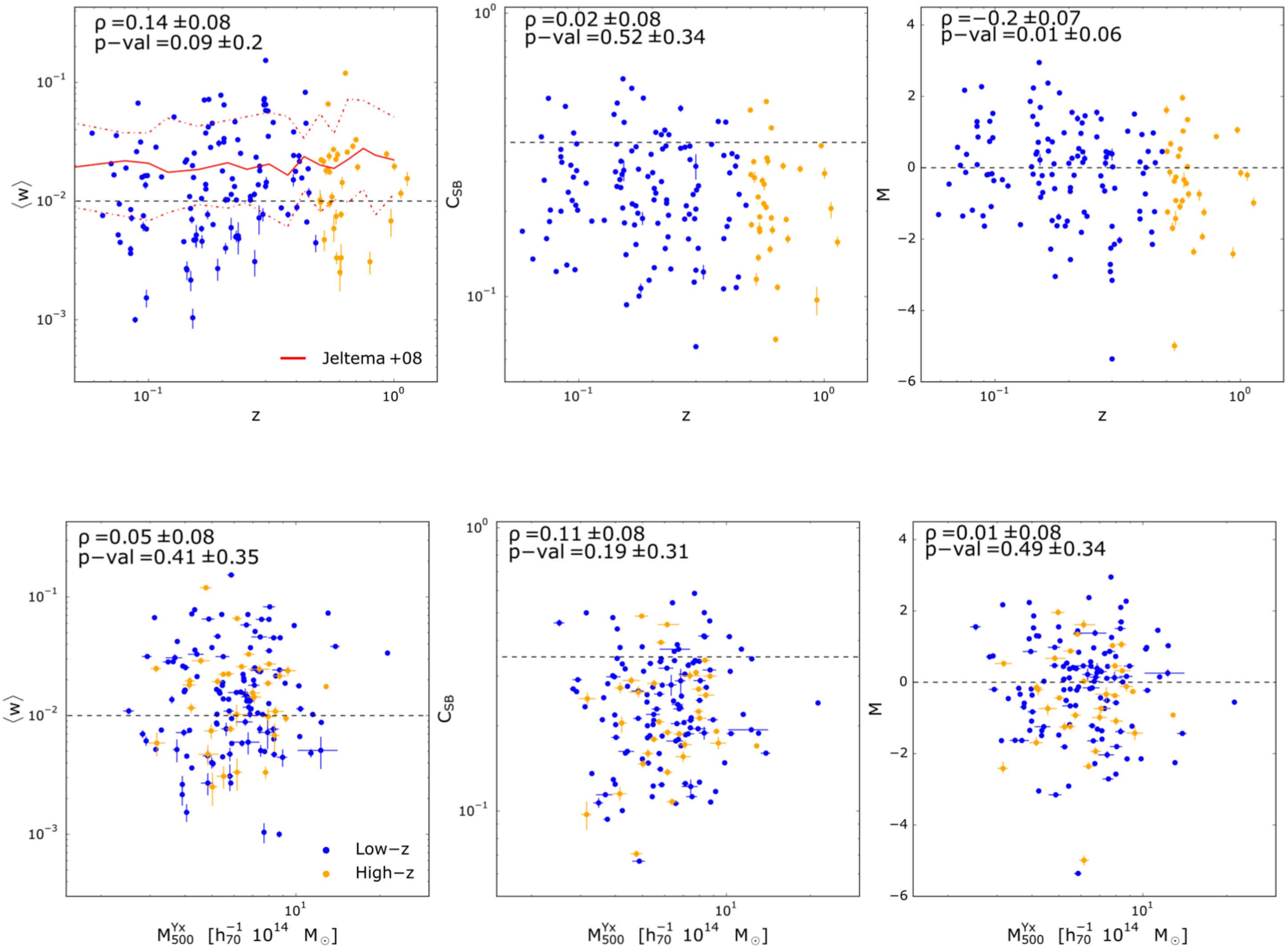
Evolution: morphology



Bartalucci et al. 2019

- Dominated by morphologically relaxed and non-CC objects (see e.g Lovisari et al. 2017, Rossetti et al. 2017…)
- <w> and c_{sb} distributions are identical for low-z and high-z samples →no evolution (Nurgaliev 2017)
- M mild evolution

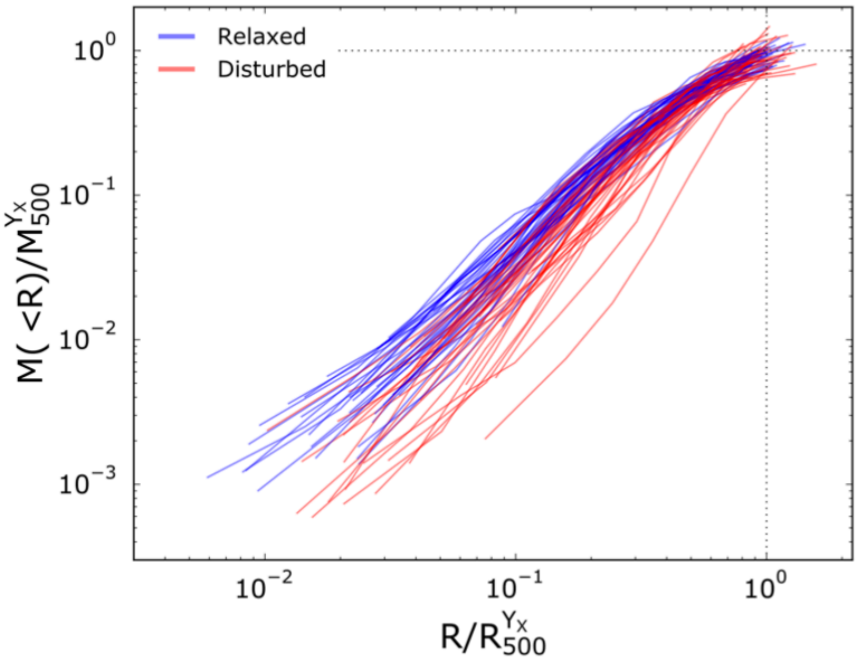
Evolution: morphology

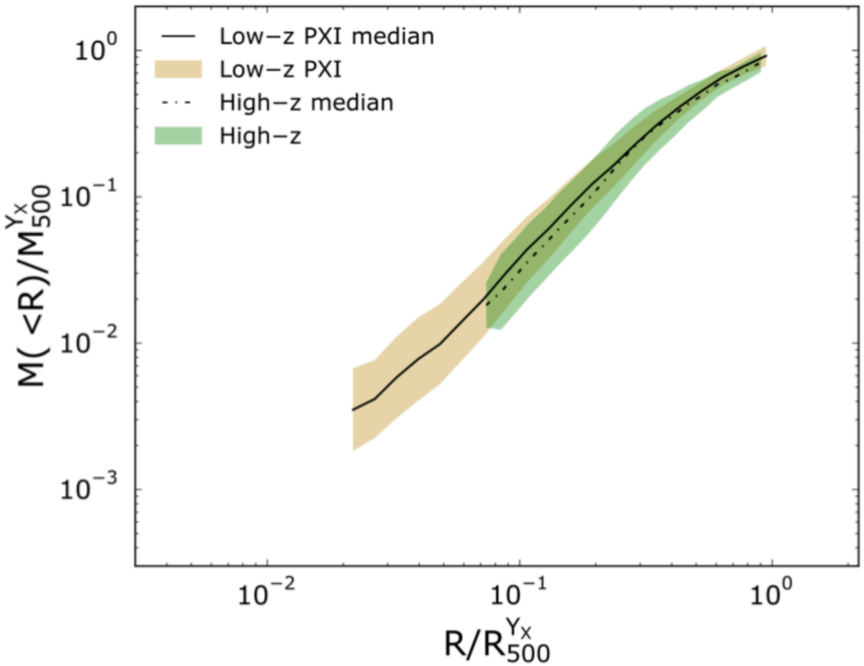


- lack of evolution of <w> and c_{sb}
- mild evolution of M
- No mass dependence

Bartalucci et al. 2019

Evolution: mass profile shape





Bartalucci et al. 2019

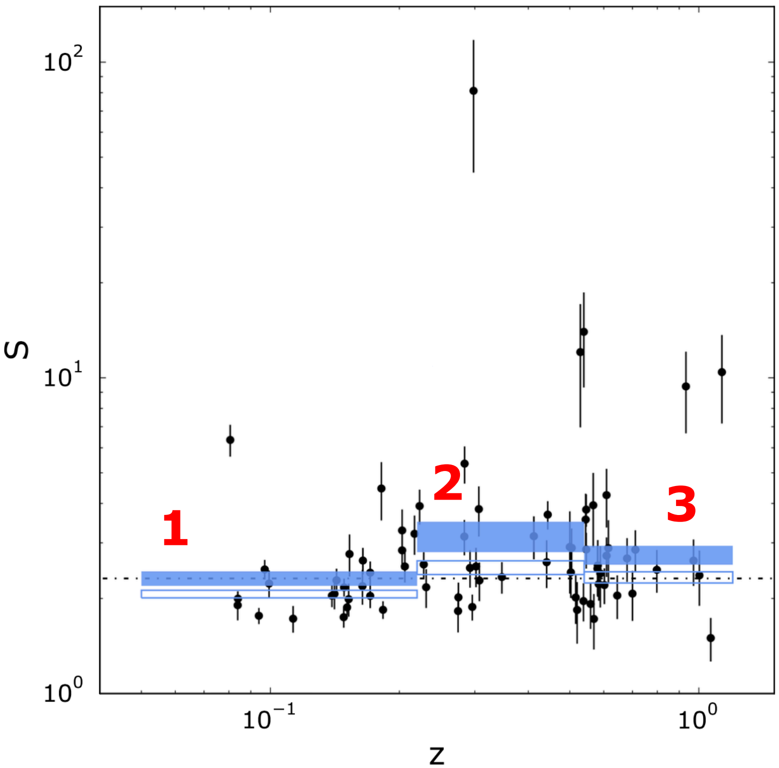
- Mass profile shape strongly depends on the dynamical status
- The median of the low-z sample is slightly shallower, much less than dispersion

Evolution: dark matter profile shape

We studied the dark matter profile shape using the sparsity (Balmes et al. 2014)

$$S_{\Delta_1,\Delta_2} \equiv \frac{M_{\Delta_1}}{M_{\Delta_2}}$$

i.e. non parametric concentration measure



Bartalucci et al. 2019

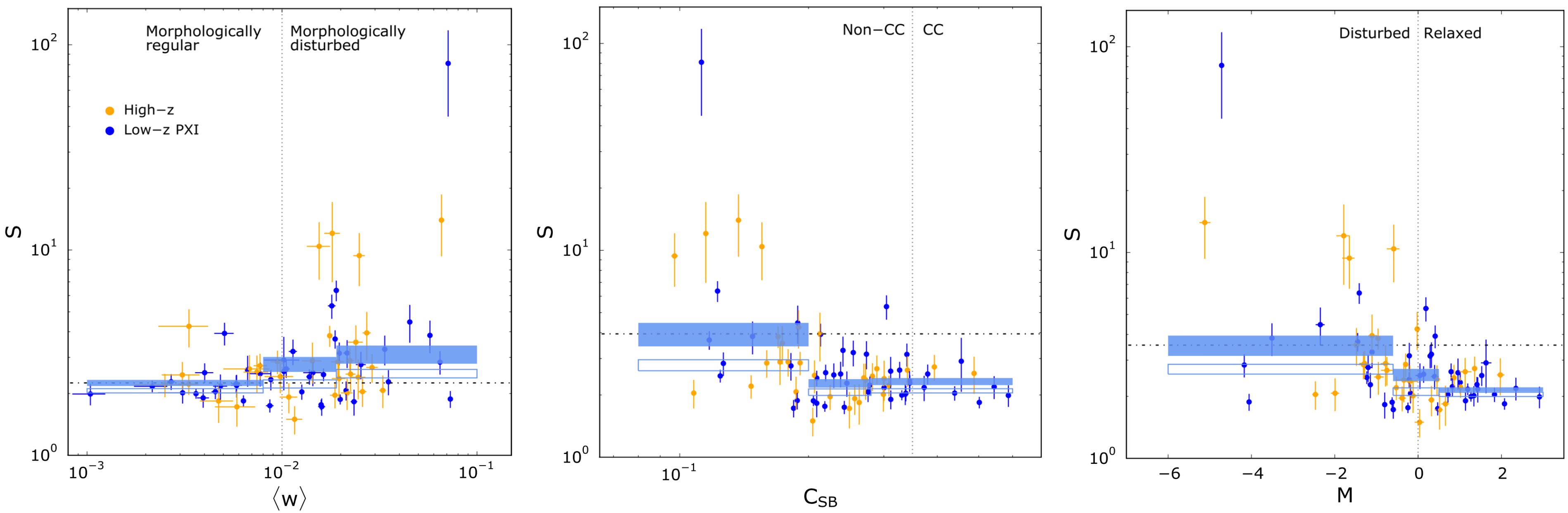
	z	Mean
1	$[0.05, 0.22]$	2.32 ± 0.12
2	$[0.22, 0.54]$	3.11 ± 0.33
3	$[0.54, 1.20]$	2.73 ± 0.19

increase of ~20%

The shape depends mildly on redshift…
to be compared with simulations!
(in progress..Arnaud et al.)

Evolution: dark matter profile shape

Bartalucci et al. 2019



- The shape of the dark matter profile strongly depends on the morphological status --> compare always similar populations
- sparsity increases ~50% from bin **1** to **3** → disturbed clusters are less concentrated
- intrinsic scatter is larger for disturbed objects

Conclusions

- Detail radial profiles and morphology of z>0.5 massive clusters combining XMM-*Newton* with *Chandra* are feasible!
- HE X-ray mass profiles are robust (with data)
- Self-similar evolution of thermodynamic radial profiles
- Mild evolution of the HE mass profile and shape of the dark matter…
- …but strong dependence on the dynamical status of the cluster

NIKA2 LP briefly

(see F. Mayet talk)
NIKA2LP: 300h of NIKA2 guaranteed time to observe a representative sample of 45 clusters:

- $0.5<z<0.9$
- $M_{500} > 3x10^{14}M_{\odot}$

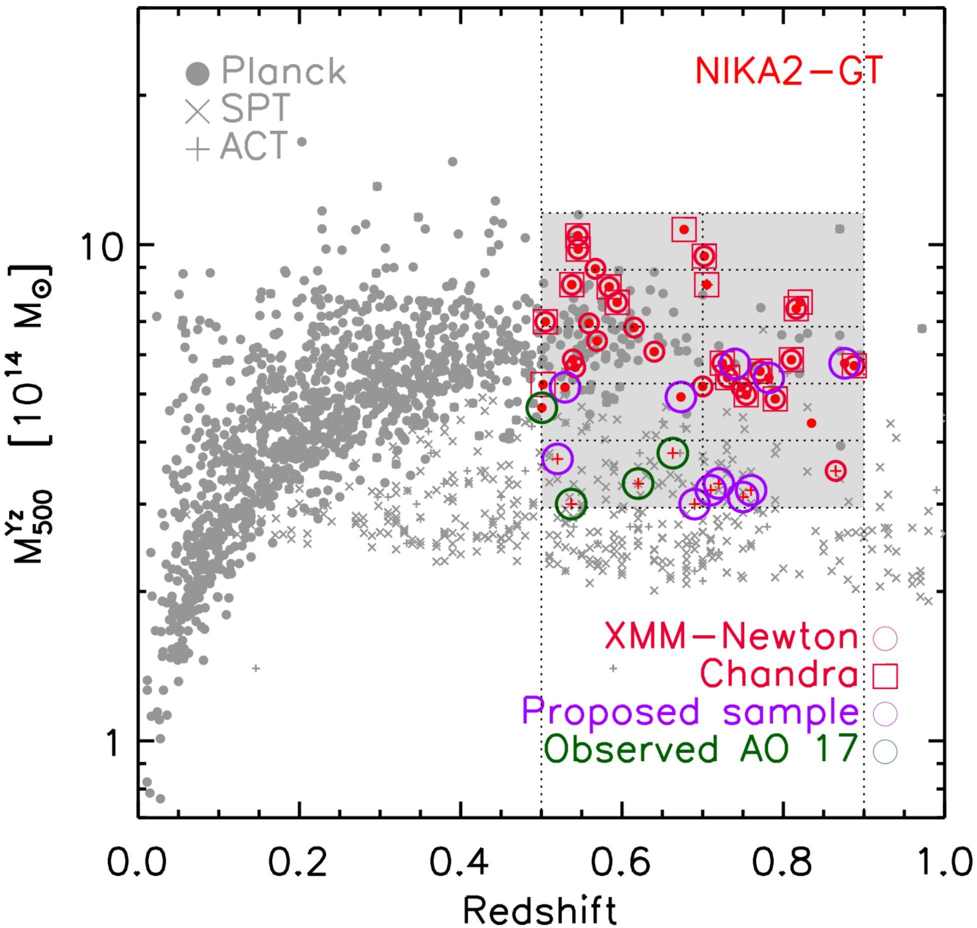
Major scientific objective:

- study the dispersion and the evolution of thermodynamic profiles in an unprecented mass and redshift range
- study the dispersion of scaling relations

Methods:

- leverage the synergy between the X-ray and NIKA2 to obtain spatially resolved thermodynamic profiles

NIKA2 LP status



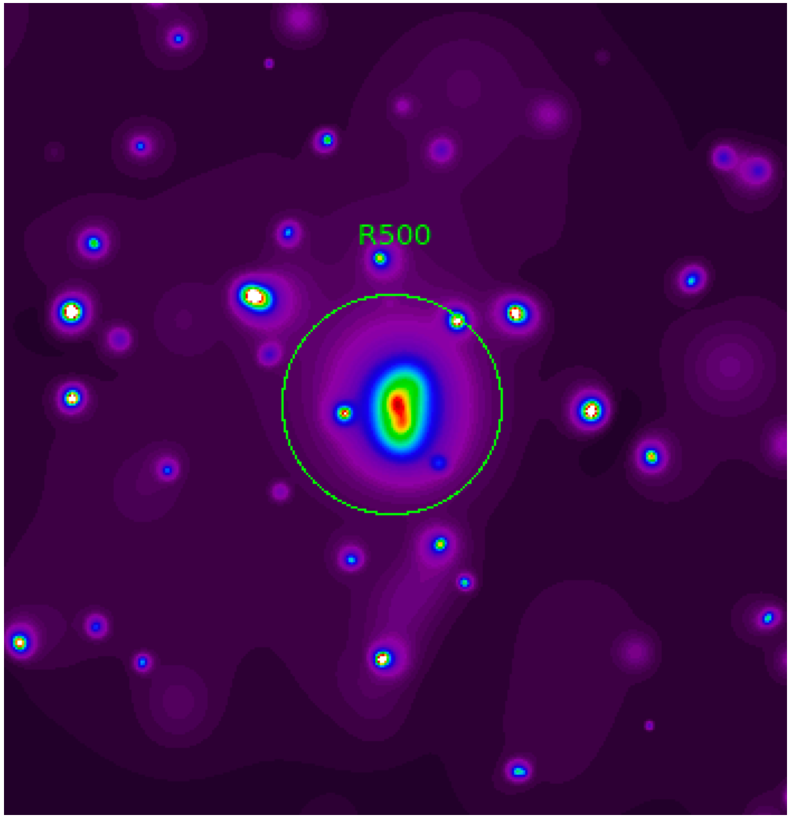
XMM-*Newton* follow-up program
→ extension of our follow-up of massive clusters

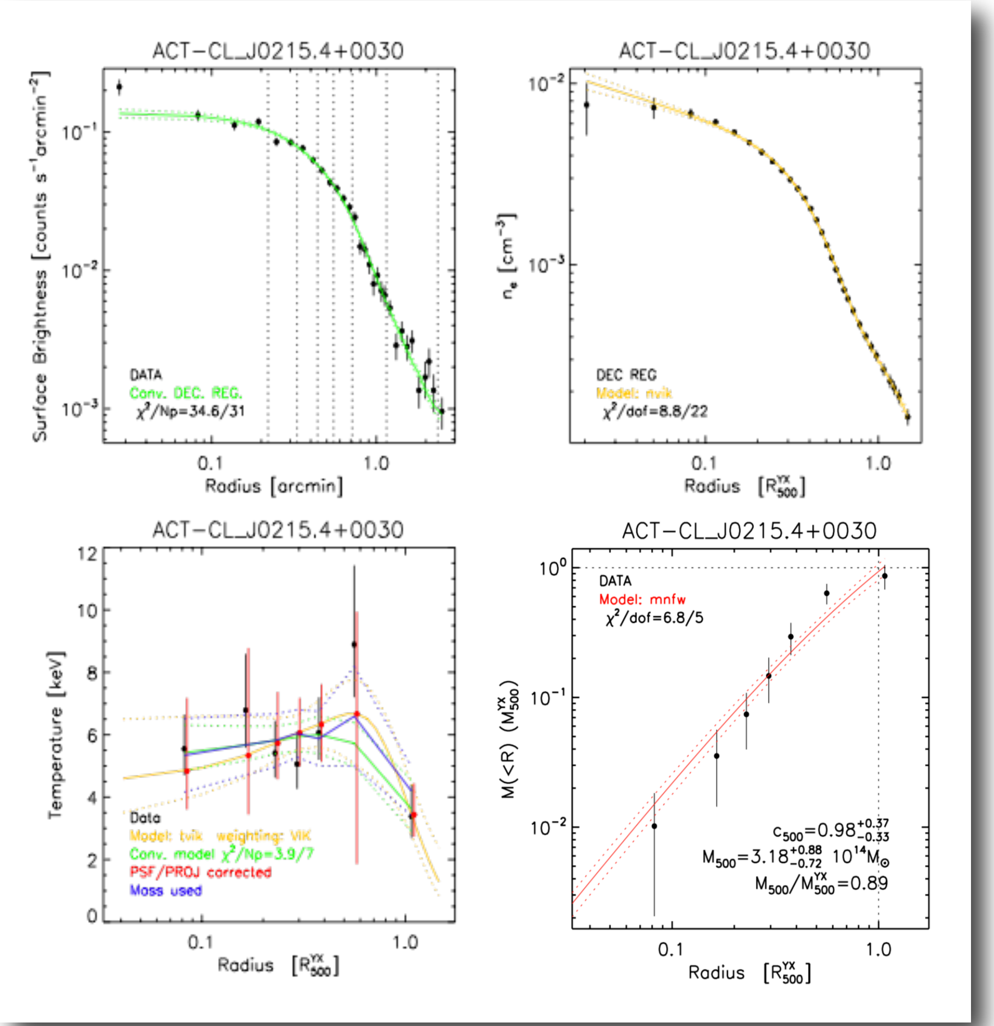
PI 2017-2018: G.W. Pratt
PI 2019: I.Bartalucci

- 35 objects XMM
- 3 with Chandra

- Proposal in previous AO to complete last 7 objects has not been accepted.
  We will try next AO!

NIKA2 data quality





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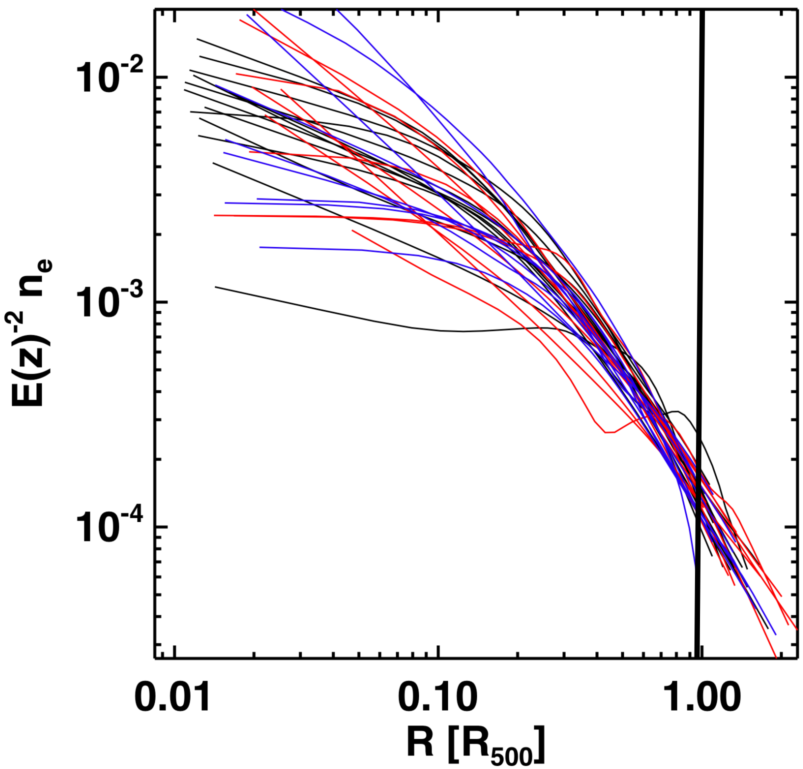

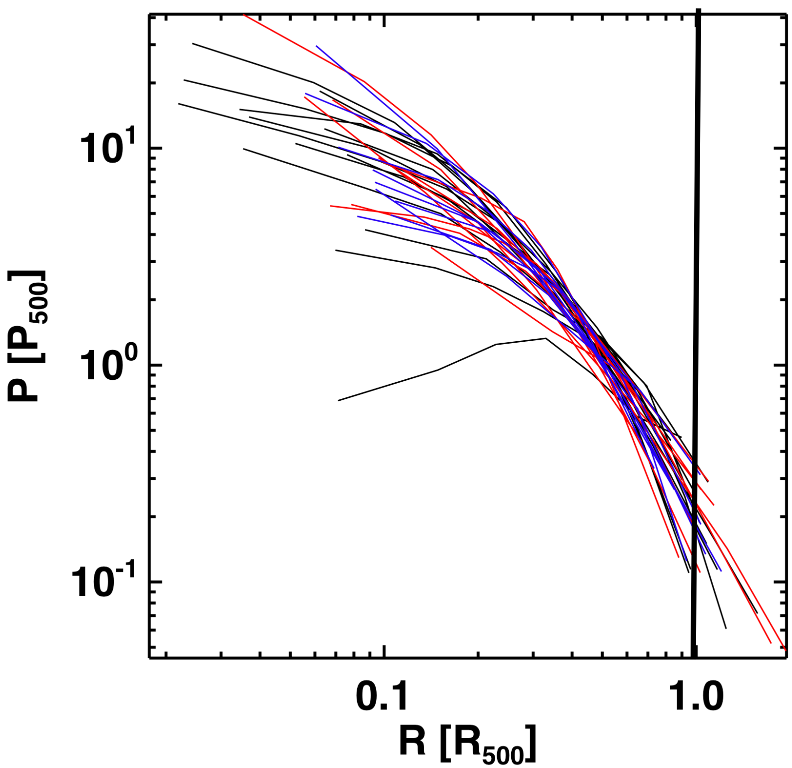

- Density for most clusters up to $\sim 2R_{500}$
- Pressure (Temperature) much less extended…

"easy" to measure in SZ

but temperature can be derived as $$kT = \frac{P_{SZ}}{n_{e,Xray}}$$

Thank you!