Non-thermal pressure support in the MOO J1142+1527 cluster at z=1.2

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Observing the millimeter Universe with the NIKA2 camera

28/06/2021

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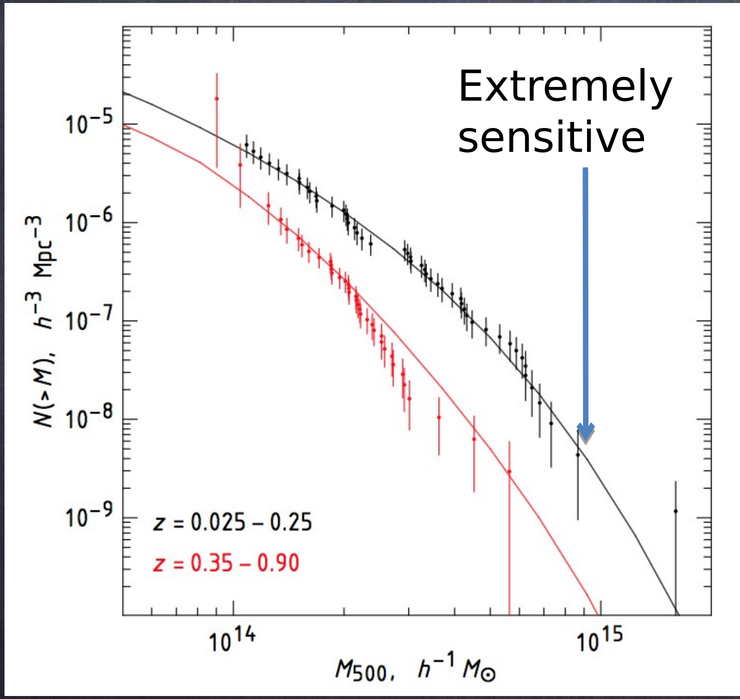
- XMM-*Newton*/*Chandra*/*NIKA2* combination
- Radial properties and NTP
- Conclusions

- Update on the NIKA2-LP XMM follow-up

Introduction: massive high redshift clusters

Massive galaxy clusters ($M_{500} > 5 \times 10^{14}\ M_{\odot}$) are interesting for

Cosmology



Vikhlinin et al 2009

Physics

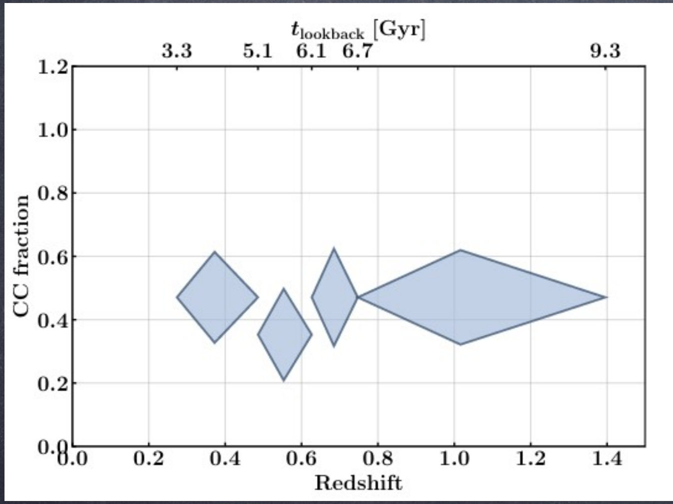
In high mass objects non-gravitational processes are negligible (simple gravitational heating dominates)

Mass

Introduction: compelling science case

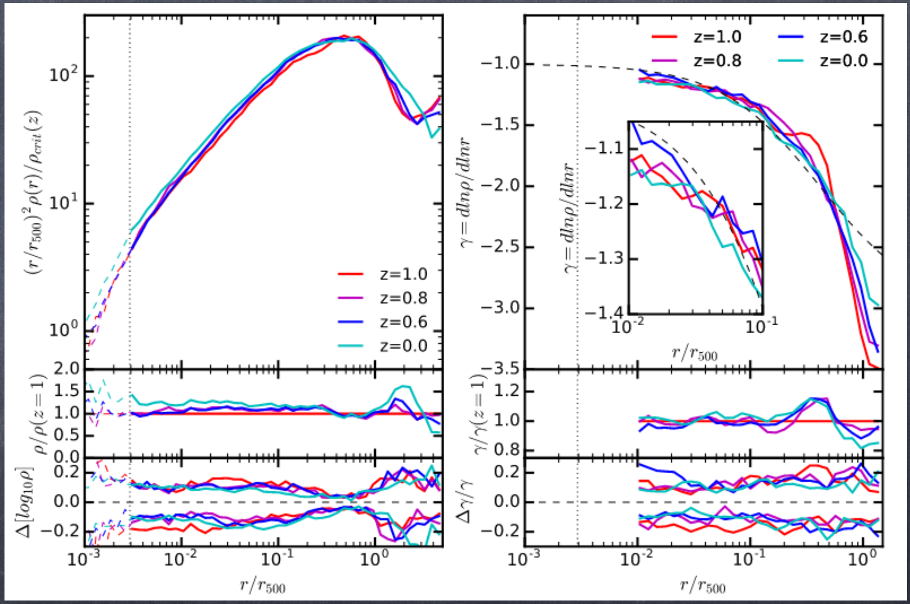
Recent works obtained surprising results on high-z clusters

Cool-core stability.
67 SPT clusters 0.3<z<1.2
(SPT+*Chandra*)



Ruppin et al. 2021

Dark matter profiles show little evolution with redshift
$M > 6 \times 10^{14} M_\odot$ from cosmological simulations



Le Brun et al. 2018

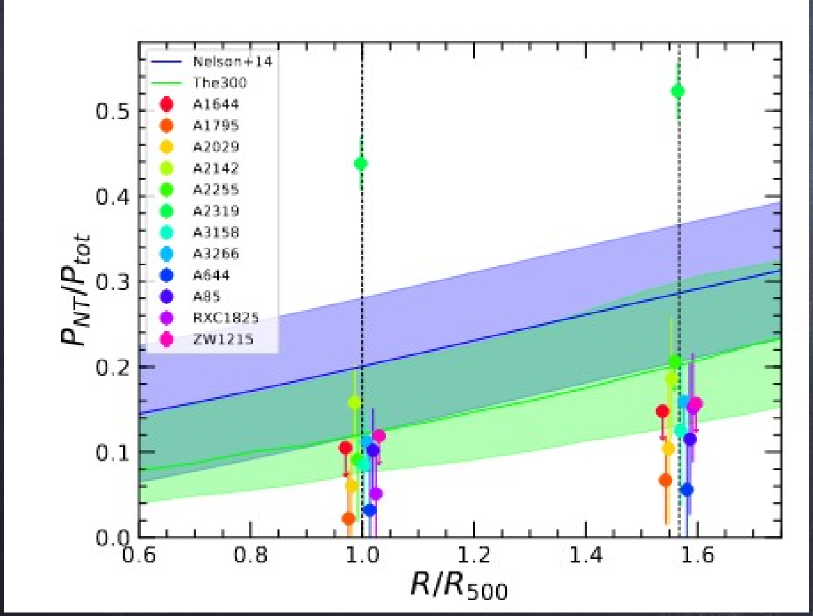
Introduction: non-thermal pressure support

Massive clusters are the ideal target to study non-thermal pressure support (NTP, e.g. magnetic fields, turbulence, bulk motions...)

NTP is crucial for:

- Accuracy of hydrostatic mass in X-ray (i.e. hydrostatic bias)

- Thermodynamic properties of the ICM (fraction of thermalised energy)



Eckert et al 2018

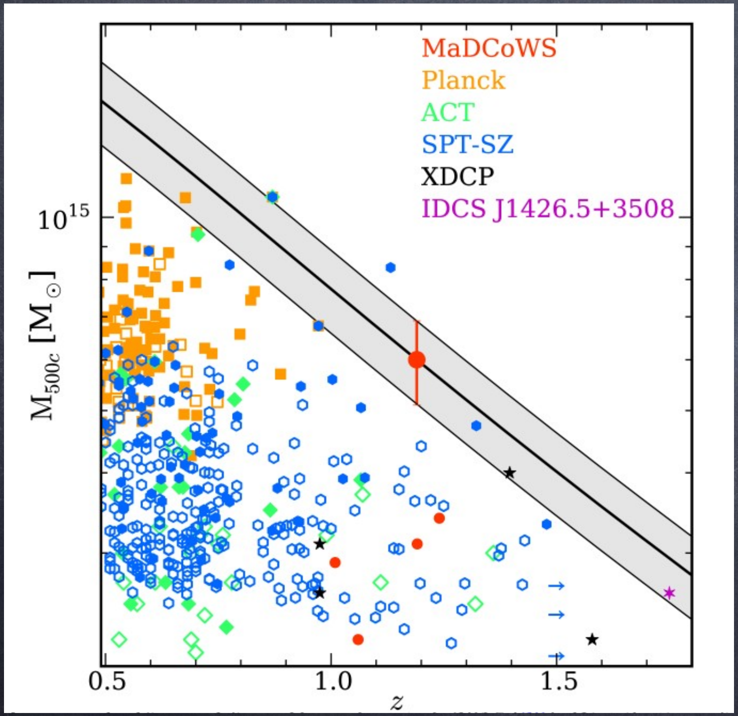
The XCOP collaboration (PI D. Eckert) measured the NTP on 13 objects at z<0.1...

What about higher z?

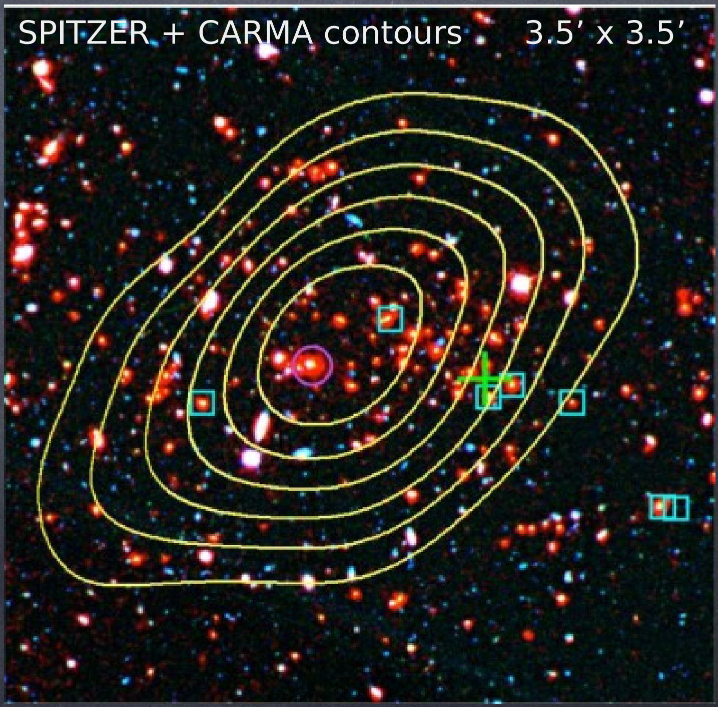
Introduction: MOO J1142+1527

Most massive cluster, $M_{500} \sim 5.5\ 10^{14} M_{o}$, detected at z=1.2 in the Massive and Distant Clusters of WISE Survey (MaDCoWS) i.e. IR selected

According to Planck cosmologly only ~ 7 objects as massive @ z>1.2



Gonzalez et al. 2015

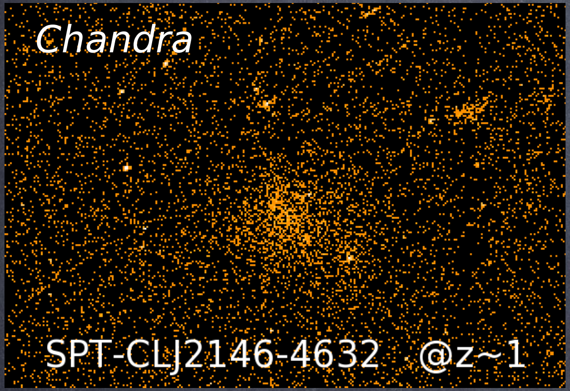


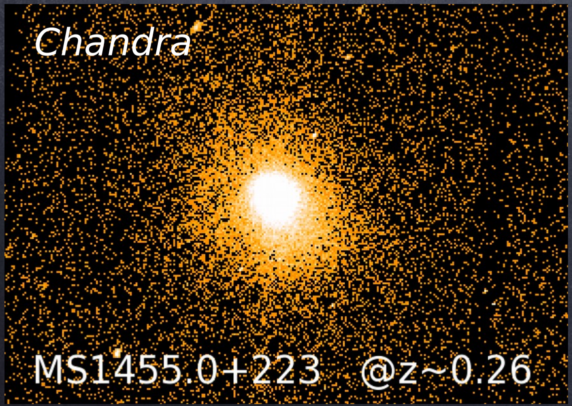
Gonzalez et al. 2015

XMM/*Chandra*: why?

High-z clusters are instrically rare and X-ray observations of high-z (>0.7) clusters suffer from cosmological dimming:

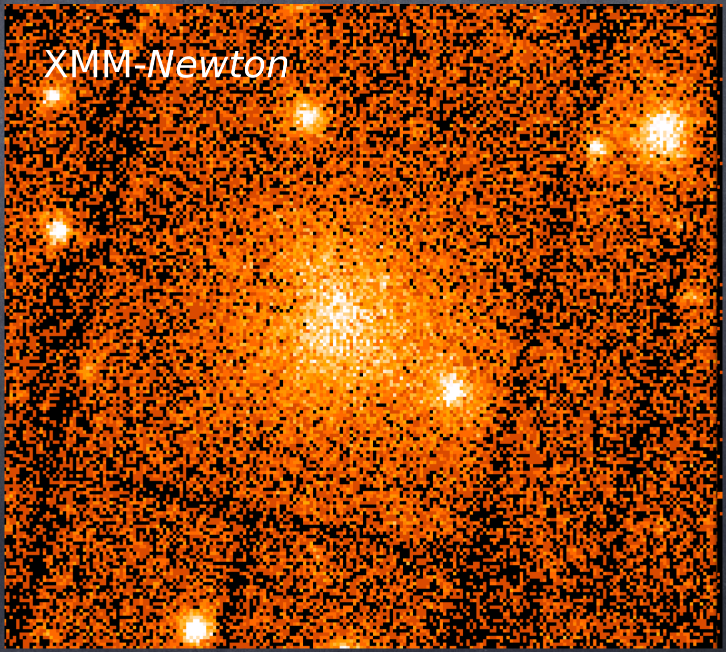
$$S_X \propto (1+z)^{-4}$$





Bartalucci et al 2018

XMM-Newton bigger effective area!



AGN confusion problem

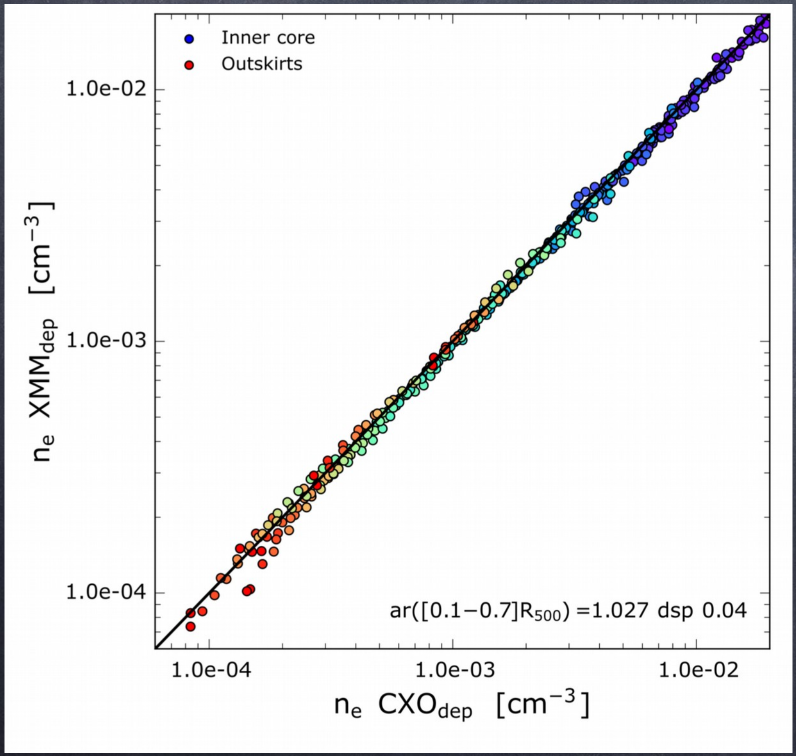
XMM/*Chandra*: can we do it?

Are we able to combine *Chandra* and *XMM* radial profiles?
The answer is:

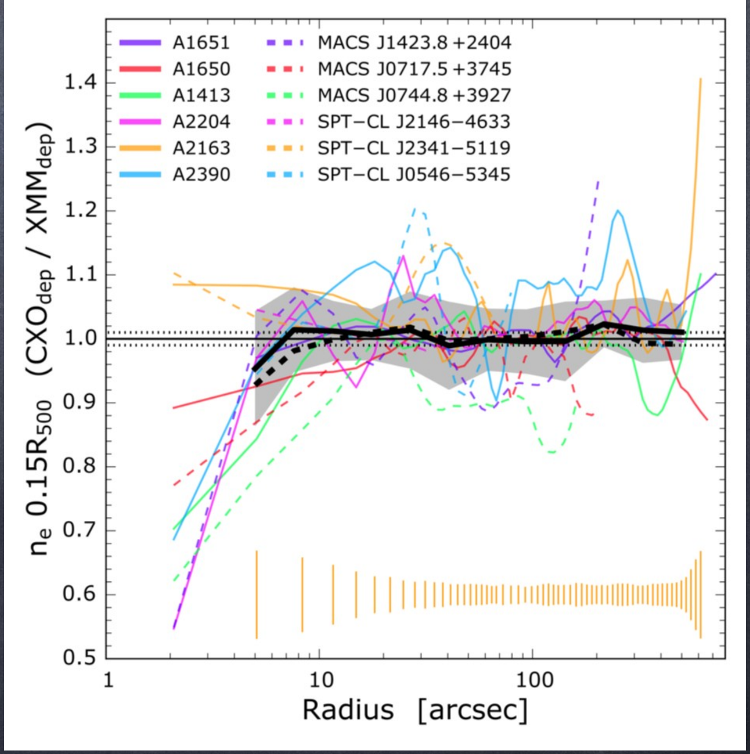
- **Yes** for density profiles;
- **No** for temperature profiles (10-15% bias between the two).

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

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



Bartalucci et al 2017



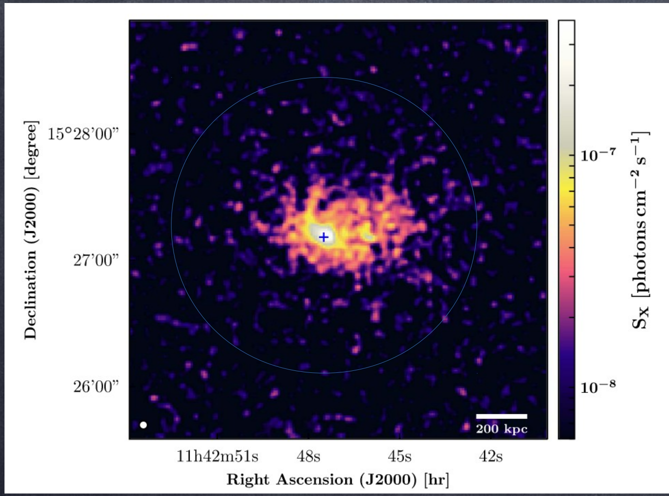
Bartalucci et al 2017

XMM/*Chandra*: why?

Ruppin et al. 2020 studied morphology using Chandra:
disturbed cluster with a strong cool core

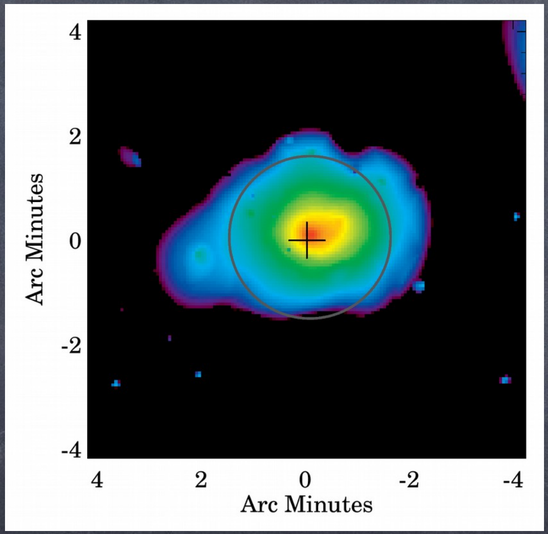
We extended the work on the outskirts with a XMM long observation

Chandra

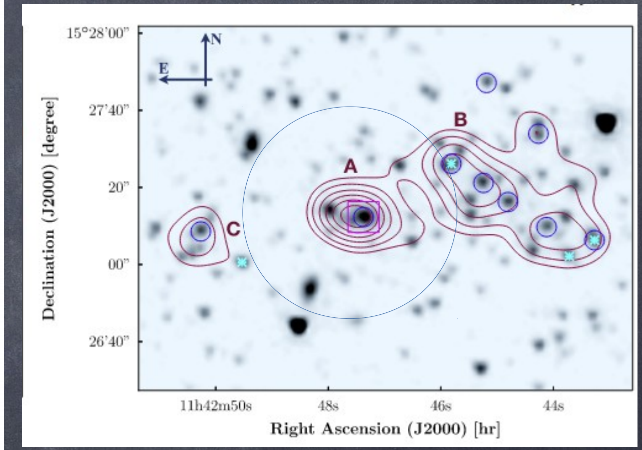


Ruppin et al. 2020

XMM wavelet image
(Bourdin et al. 2004)



Optical image



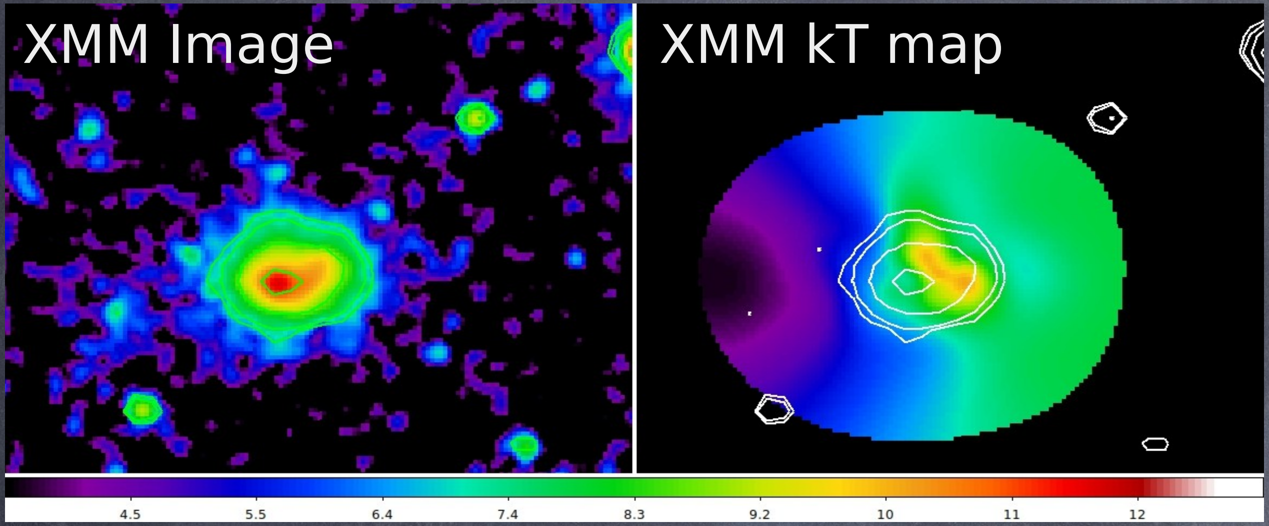
Ruppin et al. 2020

- C substructure is visible in XMM, ellipsoidal shape confirmed

- *Chandra* used to verify the cool-core

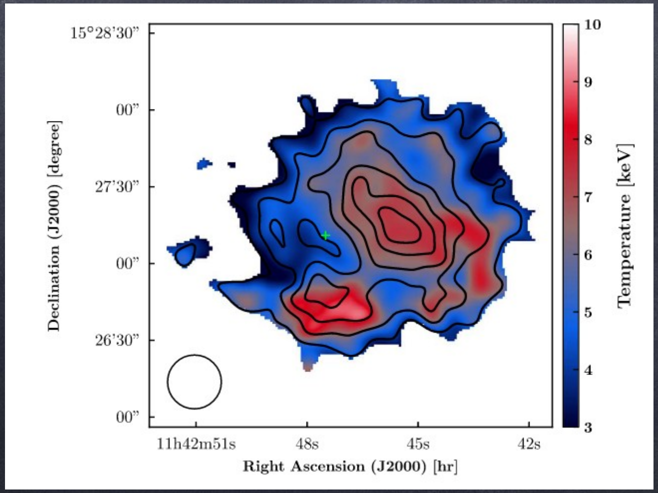
XMM/*Chandra/NIKA2*: why?

NIKA2 offers an unique opportunity!



Very long observation! (~100 ks)

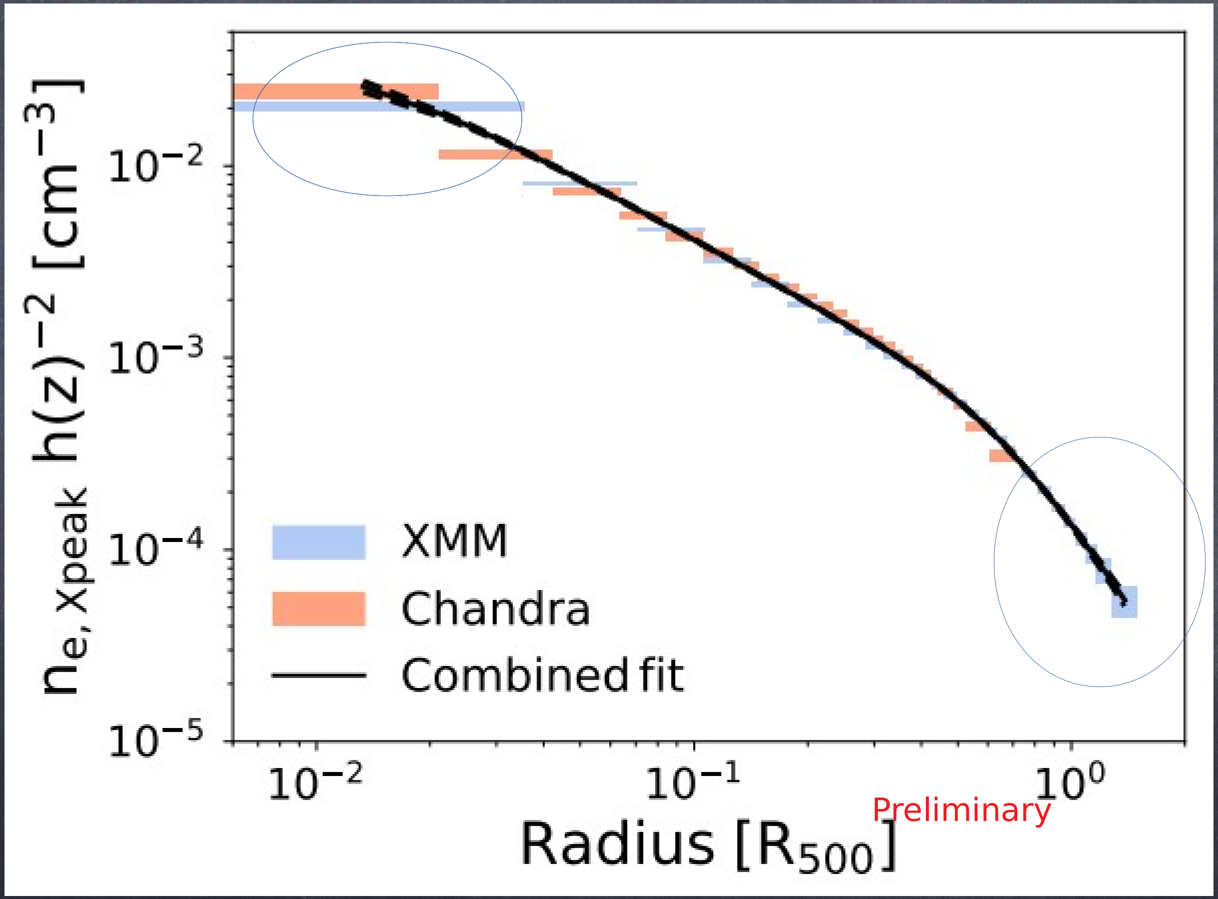
Chandra + NIKA2



Ruppin et al. 2020

XMM/*Chandra/NIKA2*: density combination

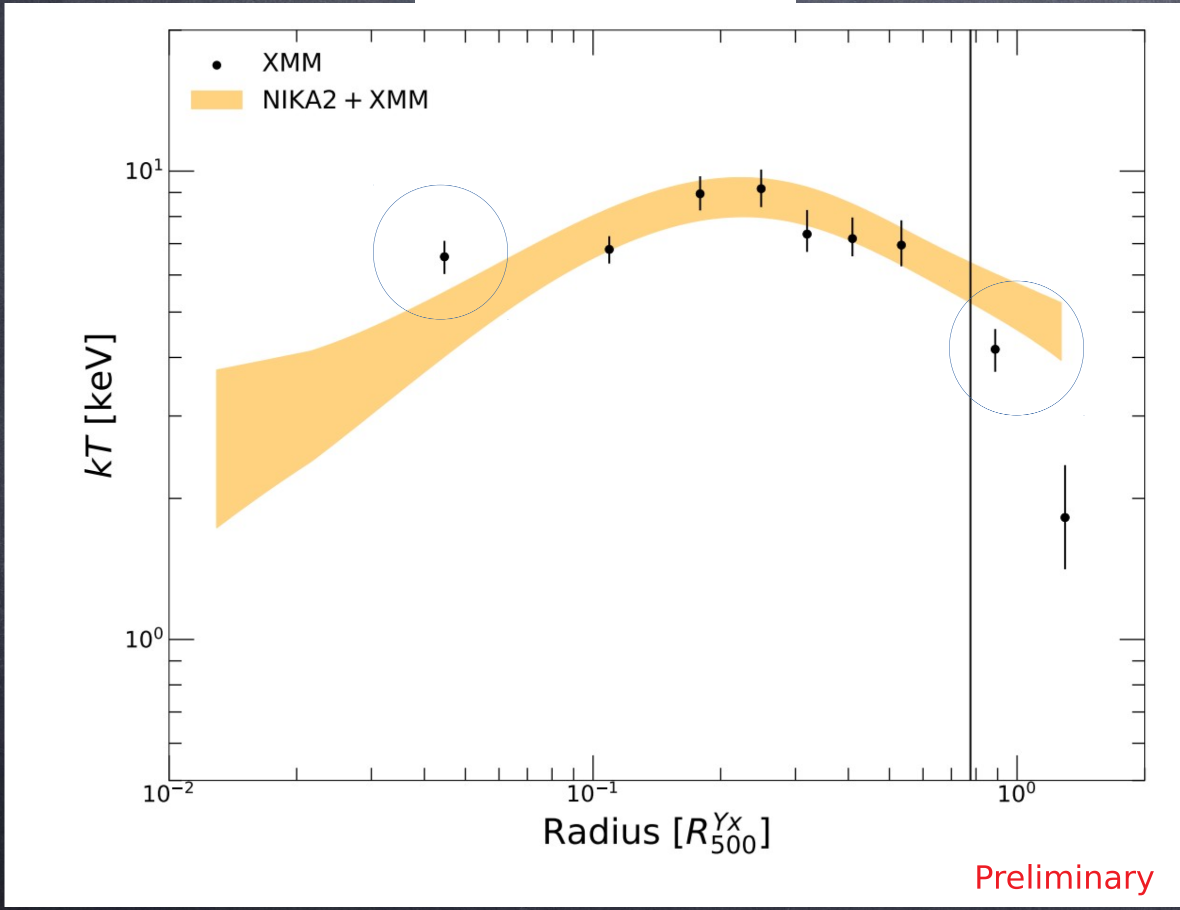
We used the same technique adopted succesfully in Bartalucci et al. 2018



Chandra helps the fit in the centre and XMM dominates in the outskirts

XMM/*Chandra*/*NIKA2*: kT combination

$$kT = \frac{P_{SZ}}{n_{e,Xray}}$$



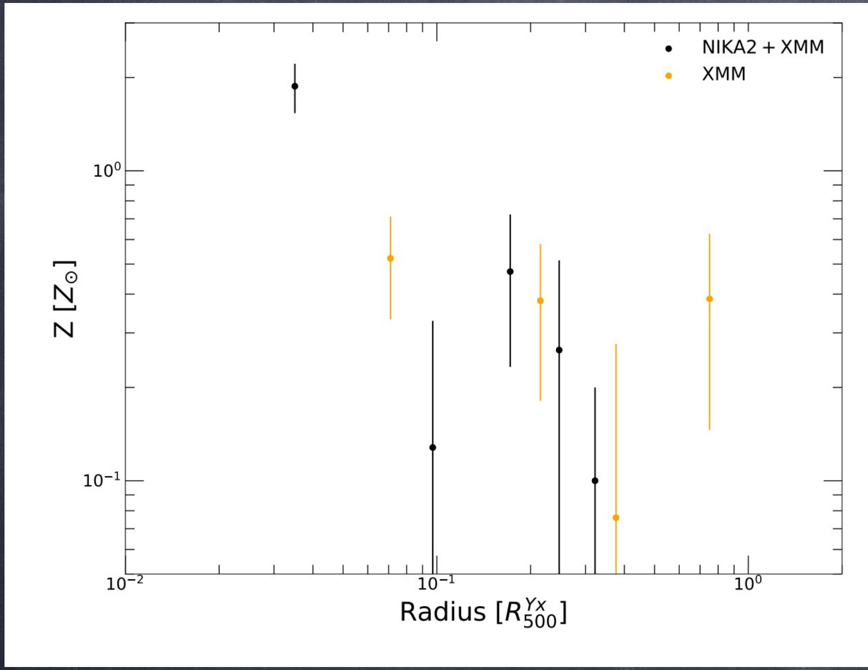
Excellent agreement

Fundamental check at such z

Chandra/XMM combination of n_e becomes extremely useful

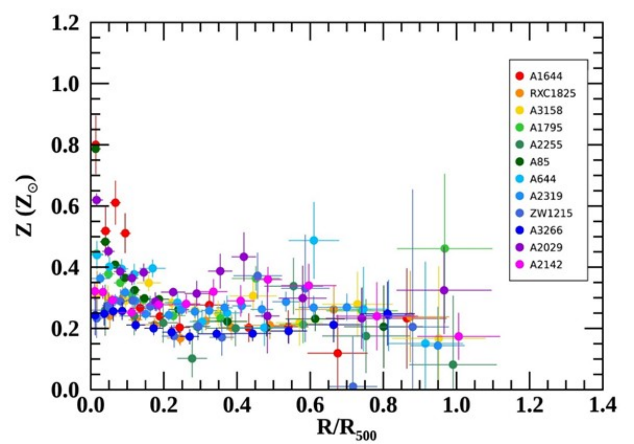
- Small radii: peaked density of *Chandra*?
- Large radii: systematic and/or extrapolation?

XMM/*Chandra/NIKA2*: abundance

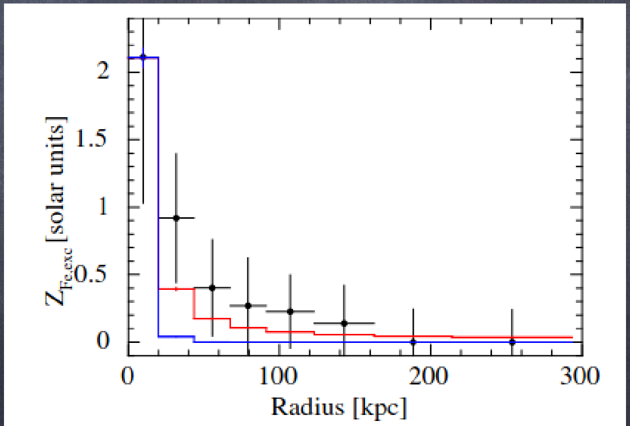


XCOP clusters z<0.3

Ghizzardi et al. 2021



WARPJ1415.1+3612 z~1

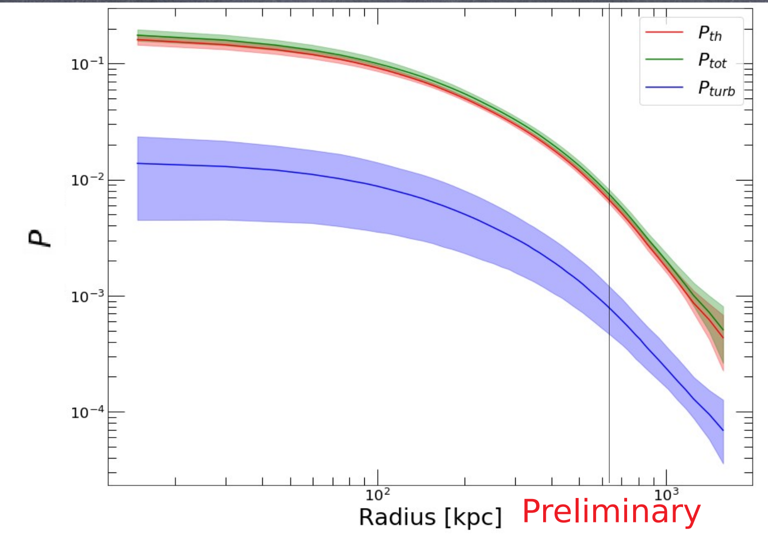


De Grandi et al. 2014

- Very high values (1.8!) in the centre (cool-core with strong BCG) similar to De Grandi 2014 z~1 cluster!
- flattens in the outskirts at Z~0.3

XMM/*Chandra/NIKA2*: non-thermique

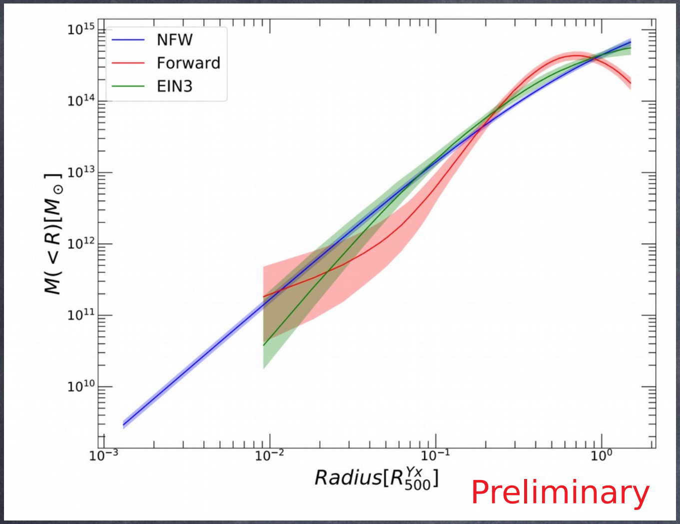
The pressure support is predicted from simulations (Angelinelli et al. 2020) and included for mass estimation
credit: D. Eckert



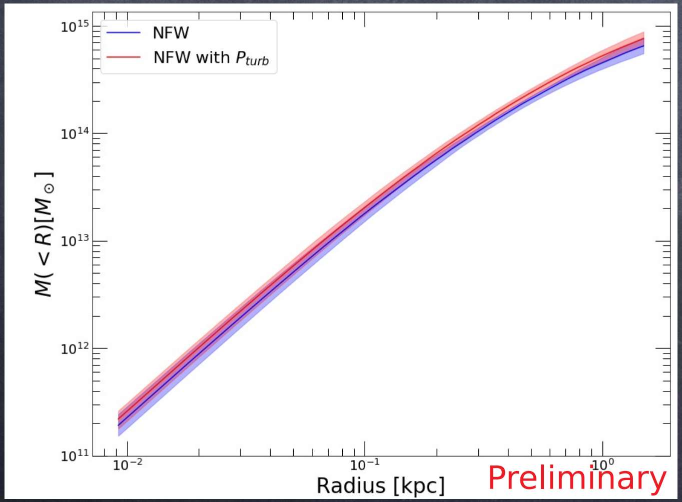
The turbulence term is predicted to be 10% on average over the full radial range considered

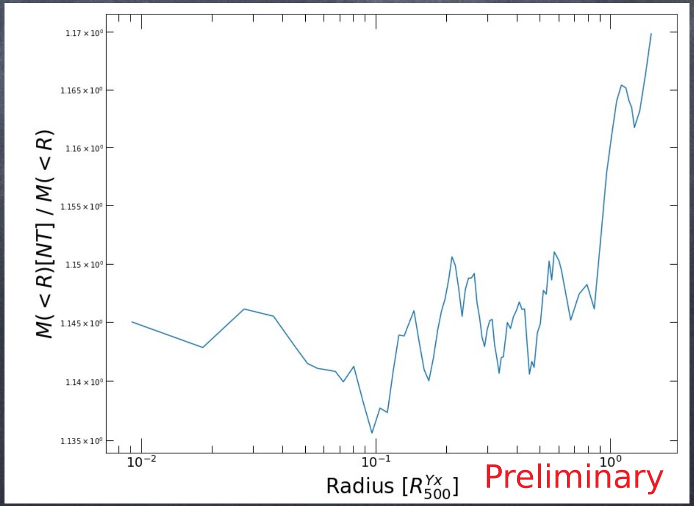
Similar to what has been found by XCOP

XMM/*Chandra/NIKA2*: mass



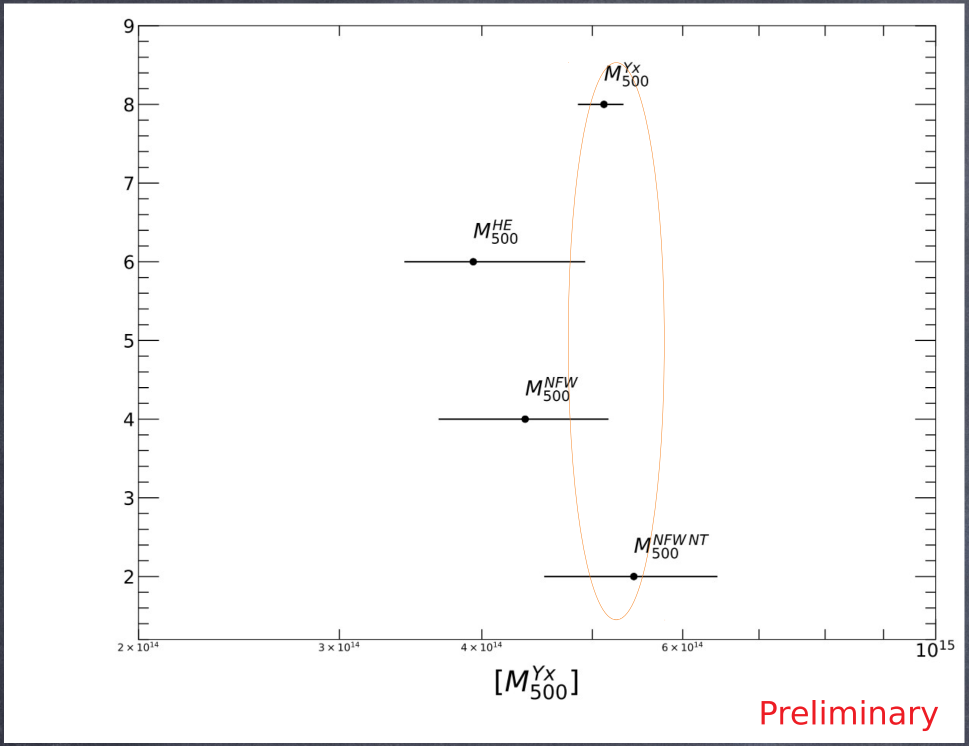
Mass estimation using HE is difficult. Ruppin et al. 2020 performed a sector analysis –> large scatter





The non-thermique yields on average a 15% factor to the mass estimation

XMM/*Chandra*/*NIKA2*: mass



All the values are consistent, but:

- the Yx is close to the NFW considering the NT

- the HE term is the lowest one

- the NFW is 25% smaller than the NFW considering the NT

- effect of the NIKA2 temperature also important!

If we take in account the NT support to alleviate the systematic we are in perfect agreement with the Yx proxy!

Note that M_{yx} assumes self-similar evolution

Conclusions

Exploratory work:

-Morphological and thermodynamic using Chandra/XMM/NIKA2 up to R_{500}

-Spec and NIKA2 kT profiles are consistent. NIKA2/Xray mandatory to get kT & systematics

-Abundance profile hint for same behaviour as for local cluster (peak in the centre)

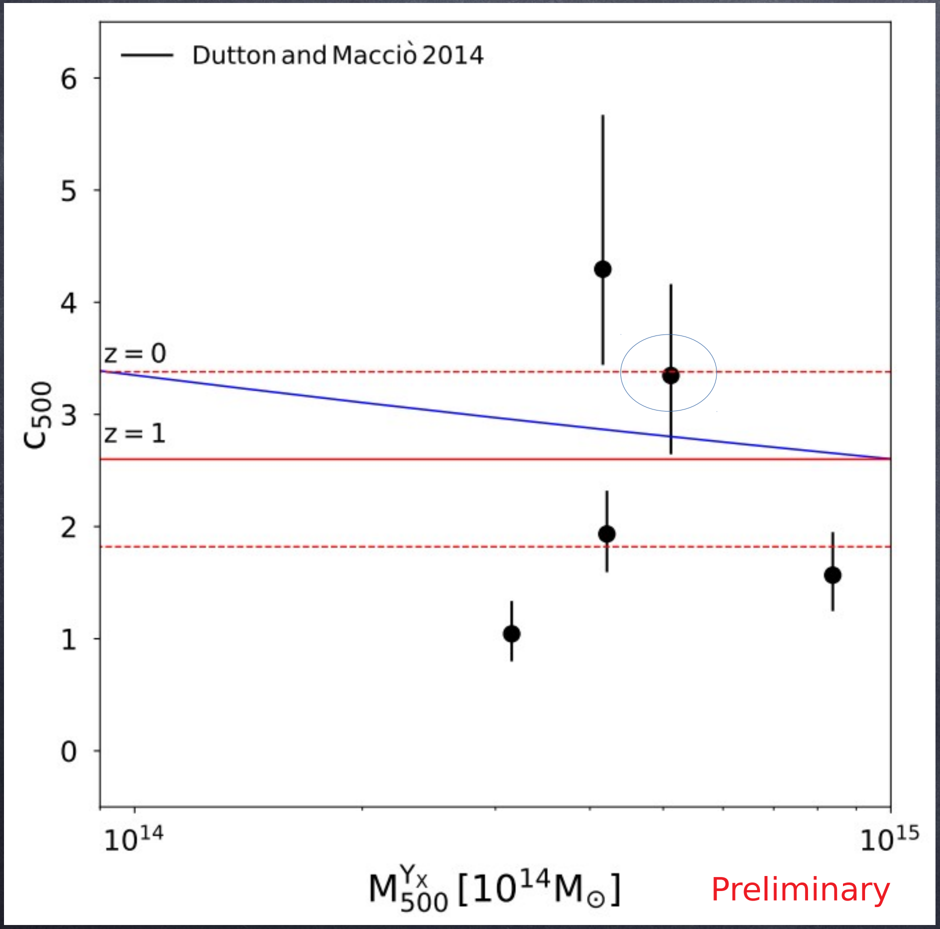
-The non-thermal support precited to be 10% of the total pressure, as for XCOP clusters

-Inclusion yields 15% on average larger mass (M_{HE} ~30% lower than M_{Yx}

Future prospects

Start Xray/SZ analysis of z~1 individual clusters, extending Bartalucci et al. 2018 results

C-M is a formidable cosmological tool, never explored at such redshift regimes (first results from Amodeo et al. 2016)



Concentration of 4 SPT clusters (Bartalucci et al. 2018) + MOOJ1142 VS simulations

30% scatter expected (Bhattacharya et al. 2013)

4 out of 5 consistent with predictions

First time we measure these values with errors lower than actual scatter

NIKA2 LP XMM follow up: briefly

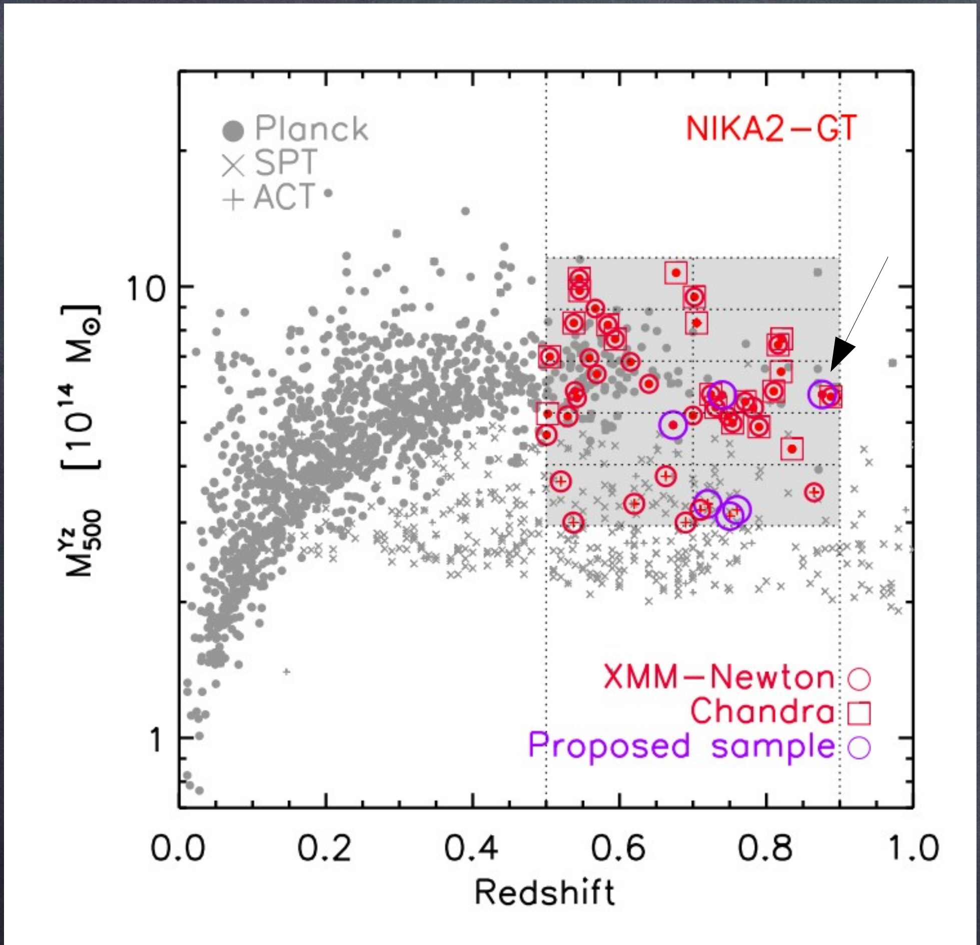
NIKA2LP: 300h of NIKA2 guaranteed time to observe a representative sample of 45 clusters:

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

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 XMM follow up: status



XMM-*Newton (Chandra)* follow-up program

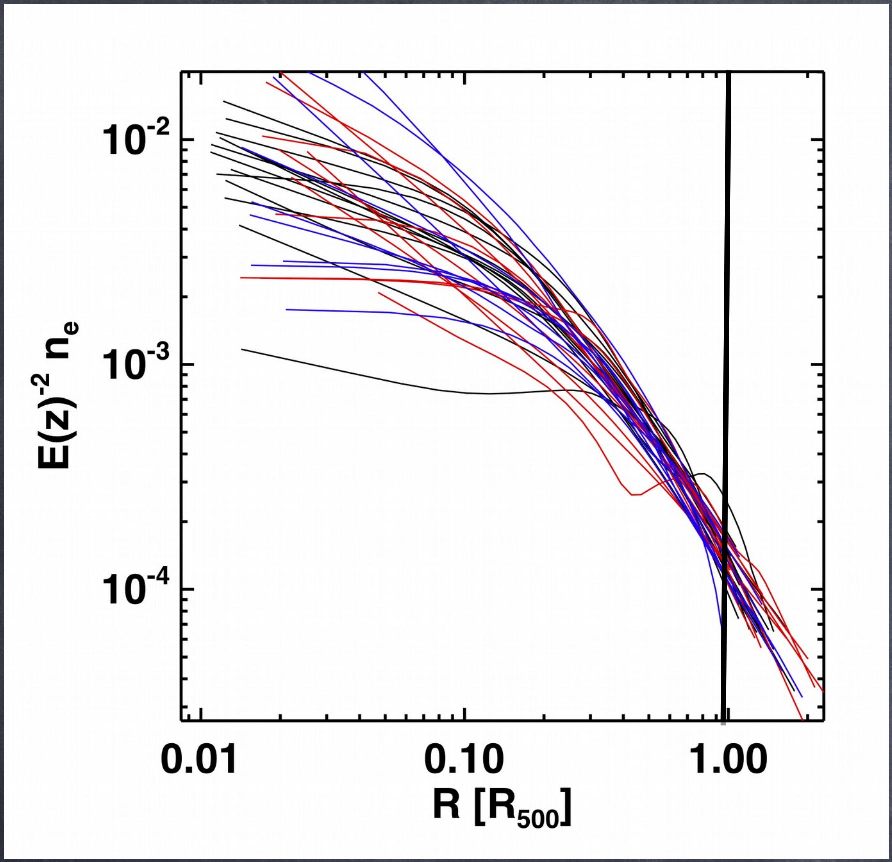
PI 2017-18: G.W. Pratt
PI 2019-21: I. Bartalucci

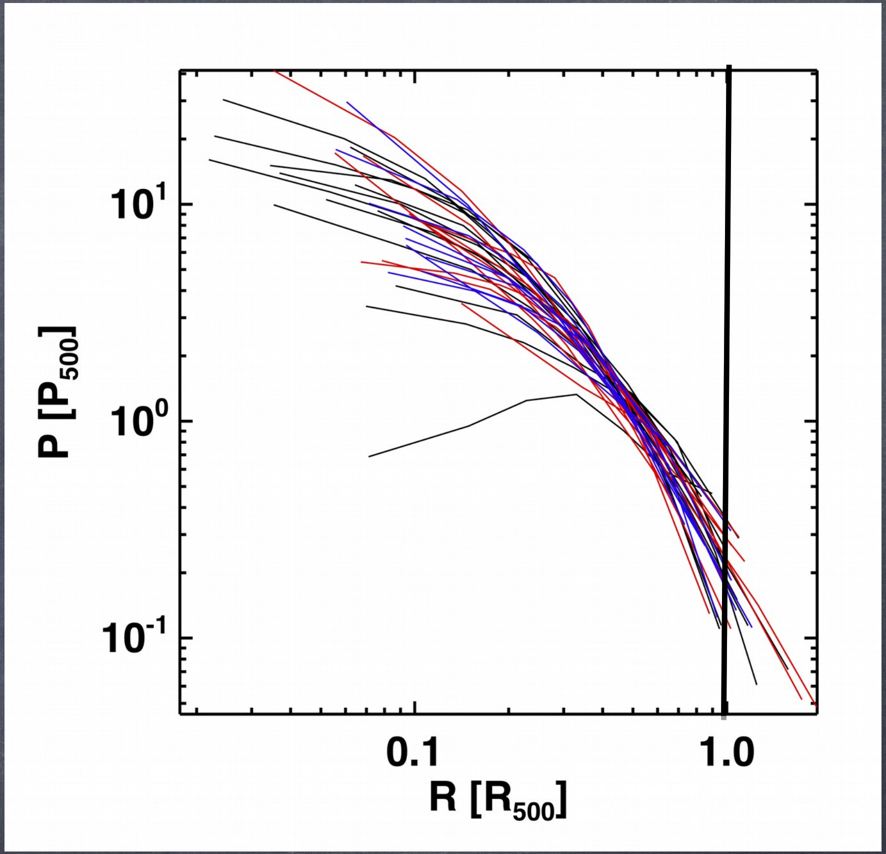
- 36 objects XMM
- 3 with Chandra

- In AO 20 we proposed succesfully to observe the remaining 6 clusters with a “filler program” i.e. observed during empty telescope times

- Only one got observed: PSZ2 G112.54+59.53 (35.7 ks)

NIKA2 LP XMM follow up: data quality





Credit: GW Pratt

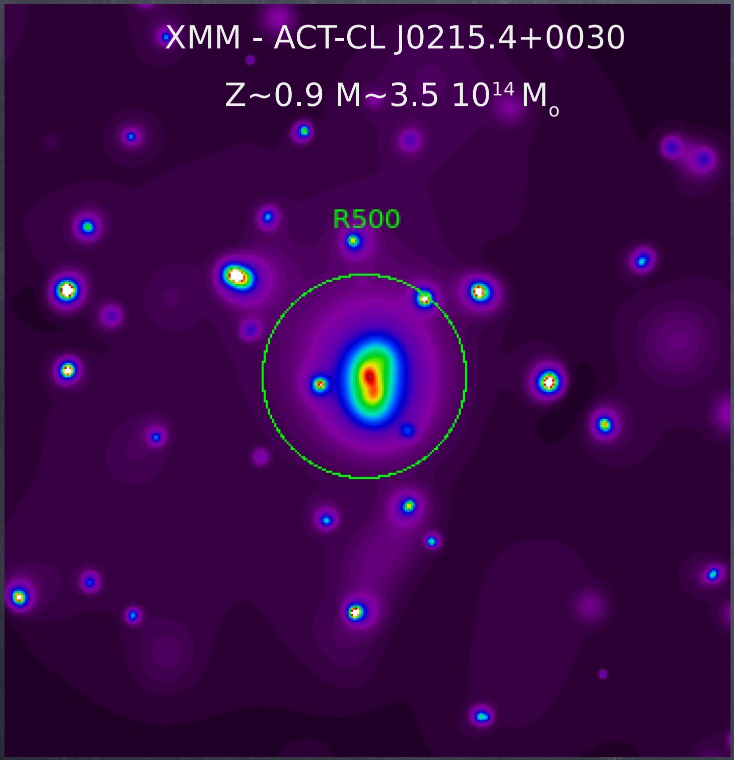
- Density for most clusters above R_{500}
- Pressure (Temperature) much less extended…

"easy" to measure in SZ

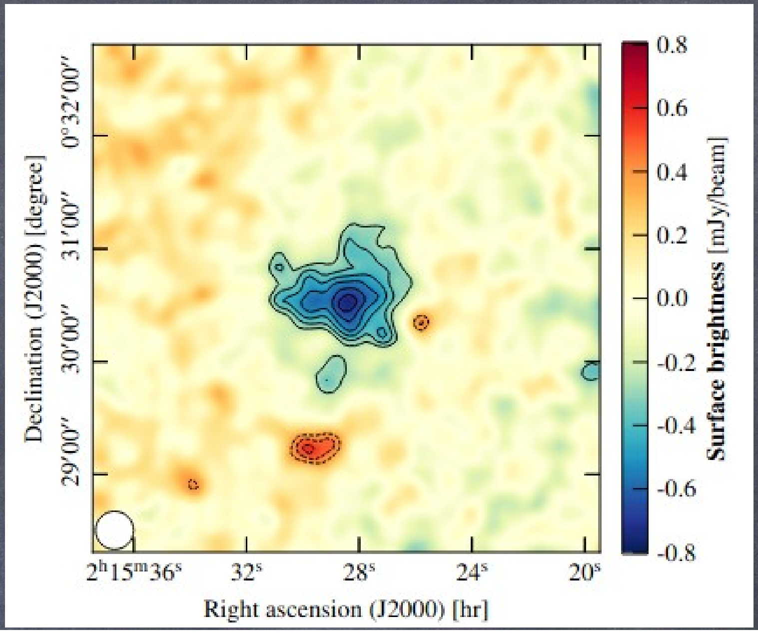
but temperature can be derived as

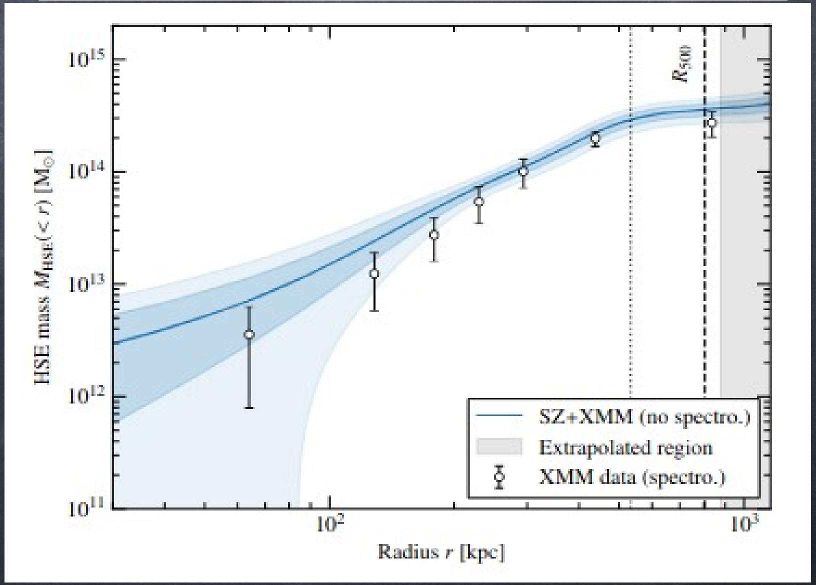
$$kT = \frac{P_{SZ}}{n_{e,Xray}}$$

NIKA2 LP XMM follow up: data quality



Credit: GW Pratt





Kéruzoré et al. 2020