EXPLORING THE PROPERTIES OF HOT GAS IN GALAXY GROUPS FROM THE CGM TO THE IGRM

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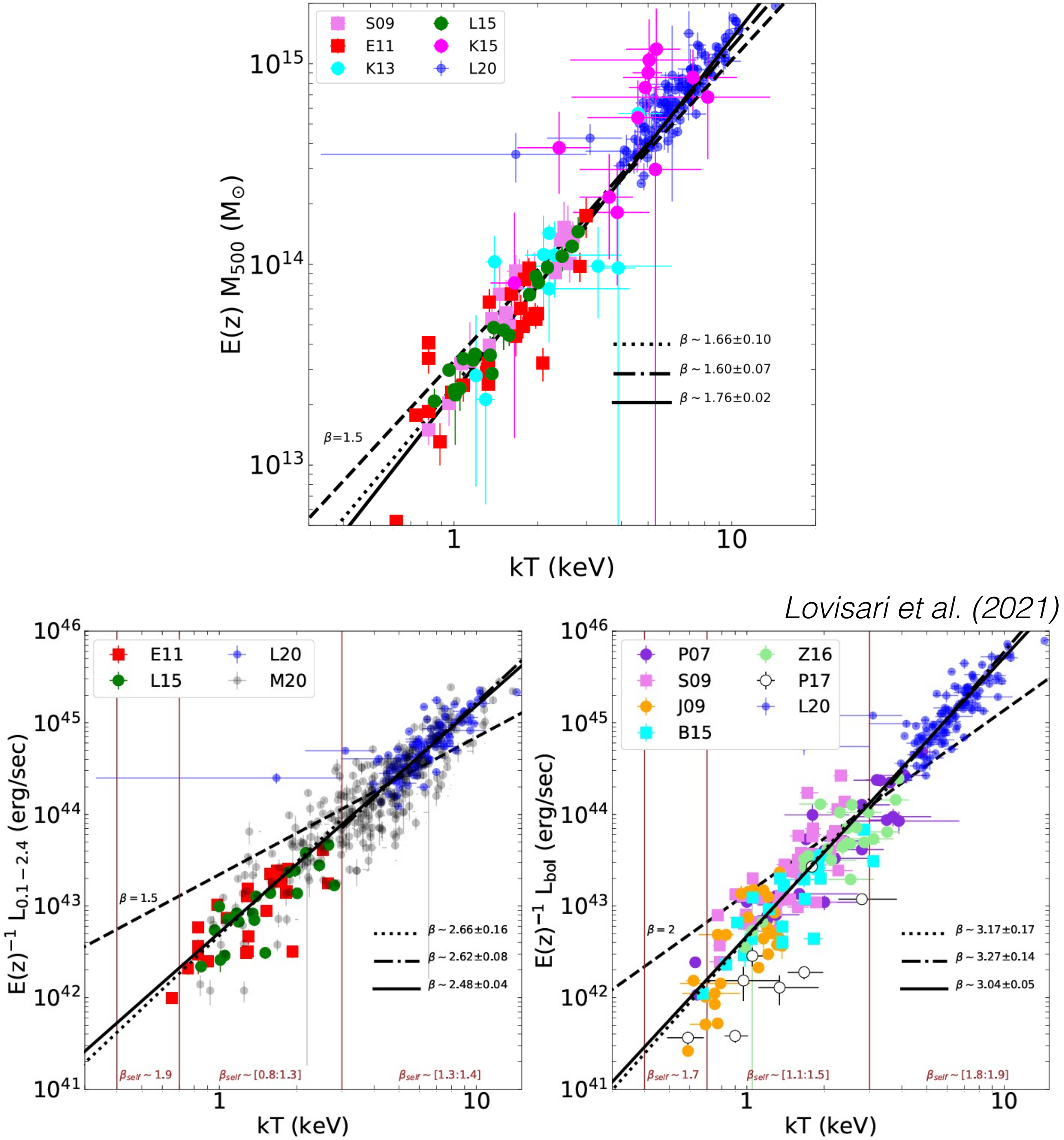
First Results from the SRG/eROSITA All-Sky Survey
17 September 2024, Garching, Germany

WHY ARE THE SCALING RELATIONS IMPORTANT?

Tool for

- understanding physical properties of ICM and IGrM
- testing non-gravitational processes



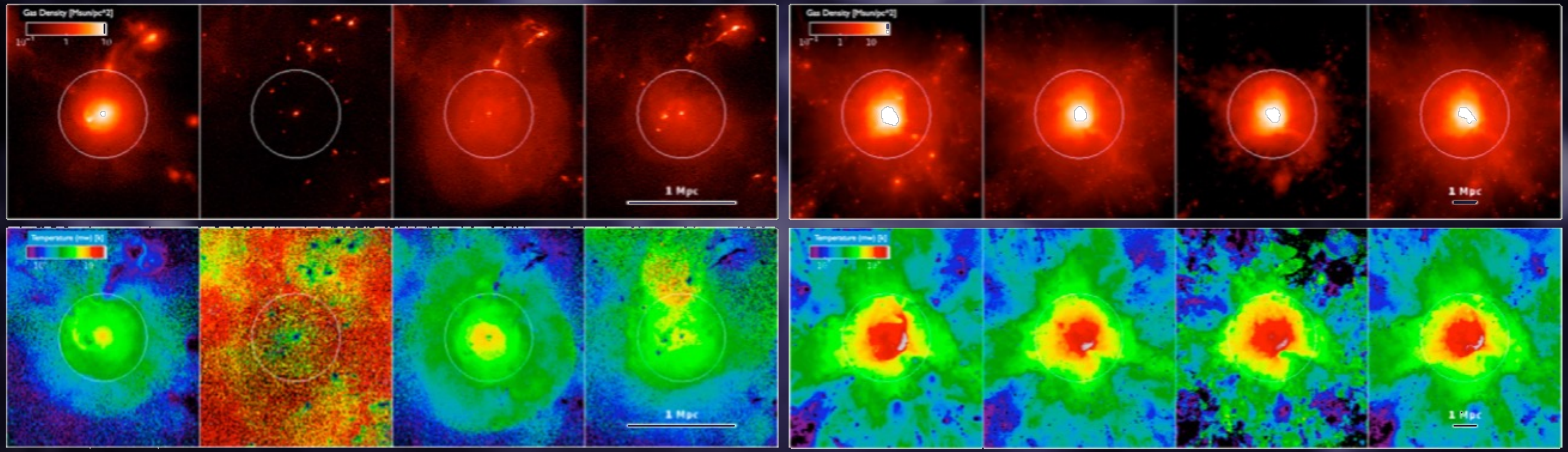
Lovisari et al. (2021)

HOW WILL GROUPS BEHAVE?

Galaxy group: $M_h \sim 2\times10^{13}\,M_\odot$

Galaxy cluster: $M_h \sim 2\times10^{15}\,M_\odot$

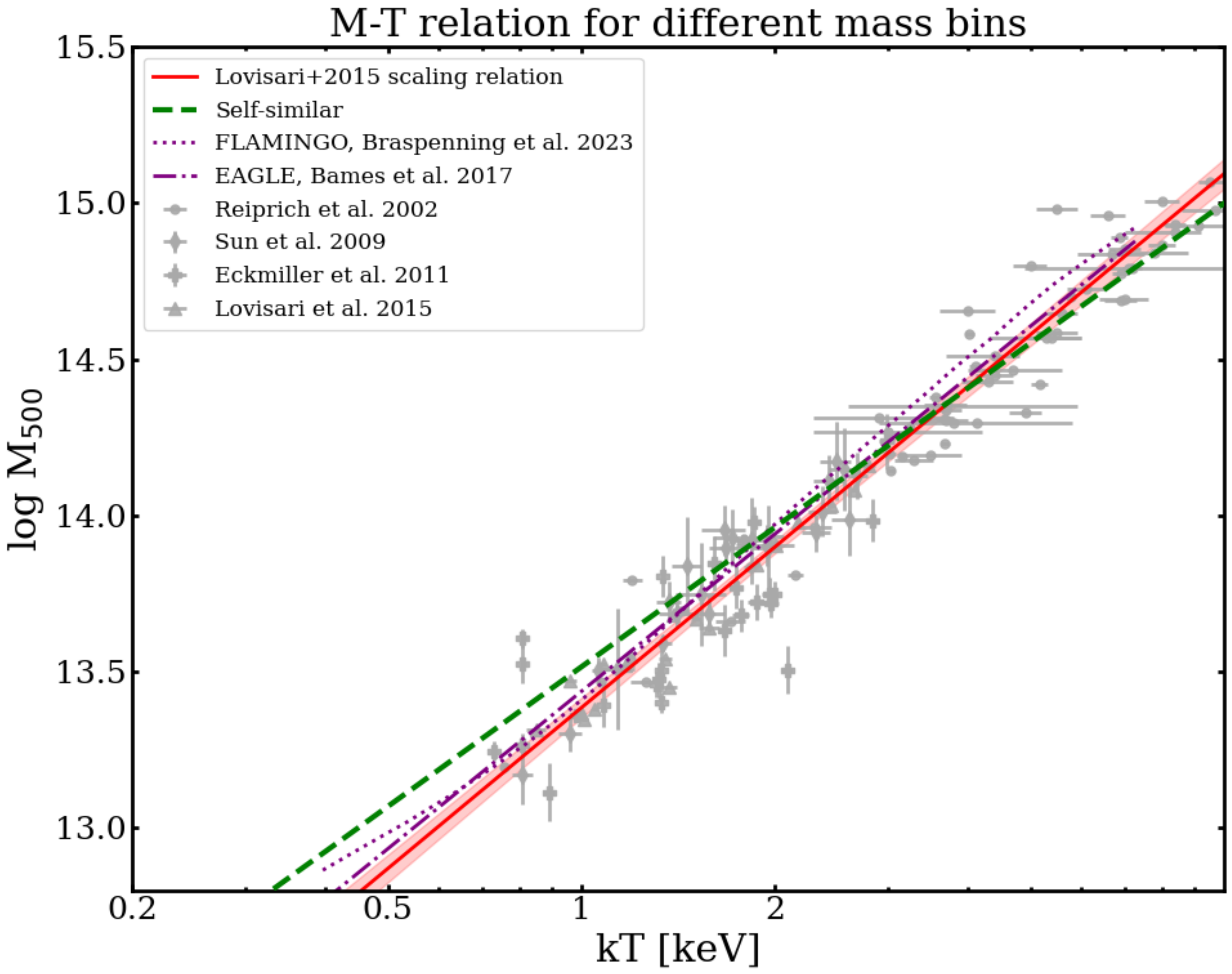
Non-radiative | Illustris | Illustris-TNG | Auriga | Non-radiative | Illustris | Illustris-TNG | Auriga



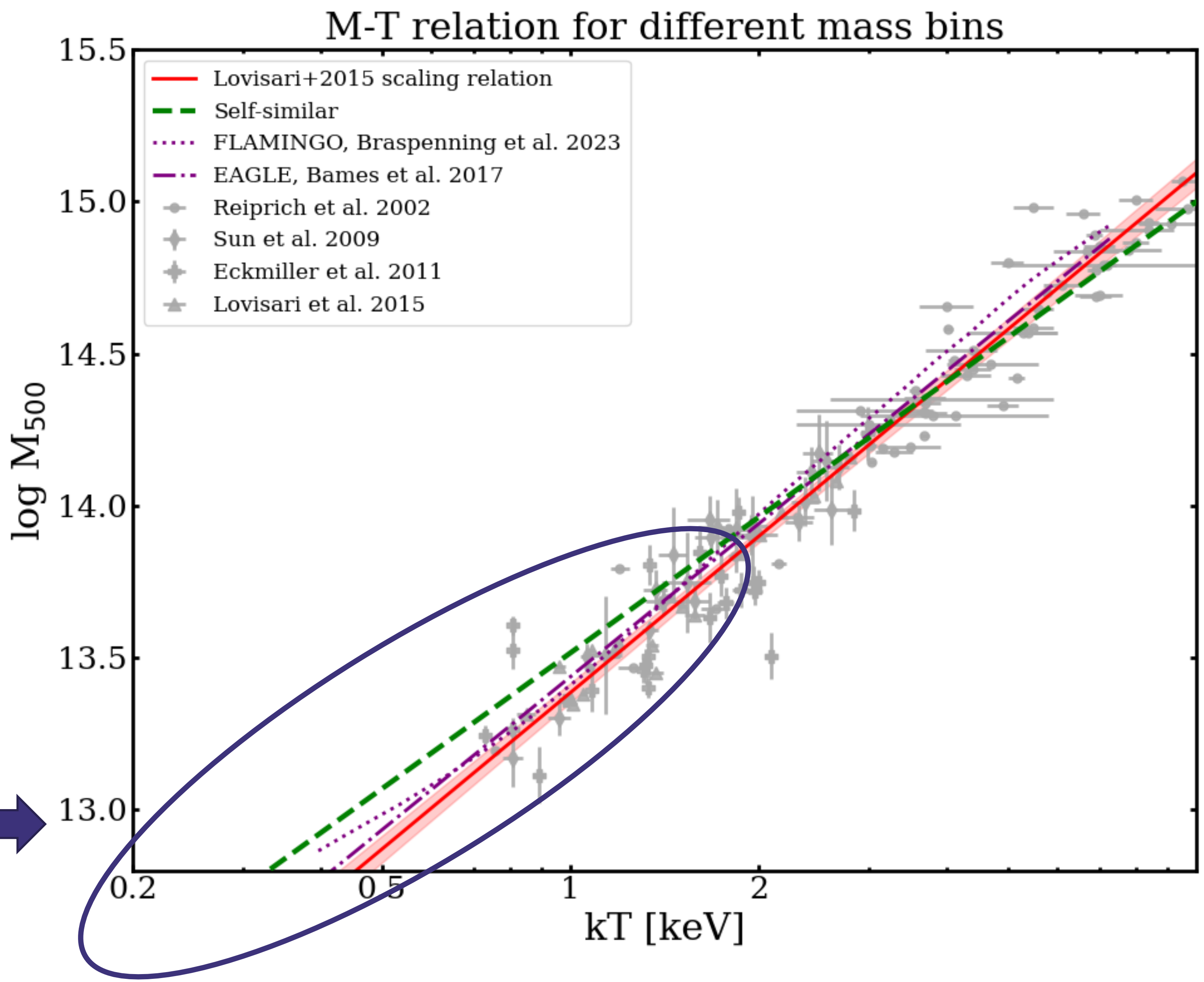
Plot by A. Pillepich

Feedback can affect strongly on the gas properties

Feedback has marginal effect on temperature and density



M-T relation for different mass bins
Lovisari+2015 scaling relation
Self-similar
FLAMINGO, Braspenning et al. 2023
EAGLE, Bames et al. 2017
Reiprich et al. 2002
Sun et al. 2009
Eckmiller et al. 2011
Lovisari et al. 2015
log M_{500}
15.5
15.0
14.5
14.0
13.5
13.0
0.2
0.5
1
2
kT [keV]

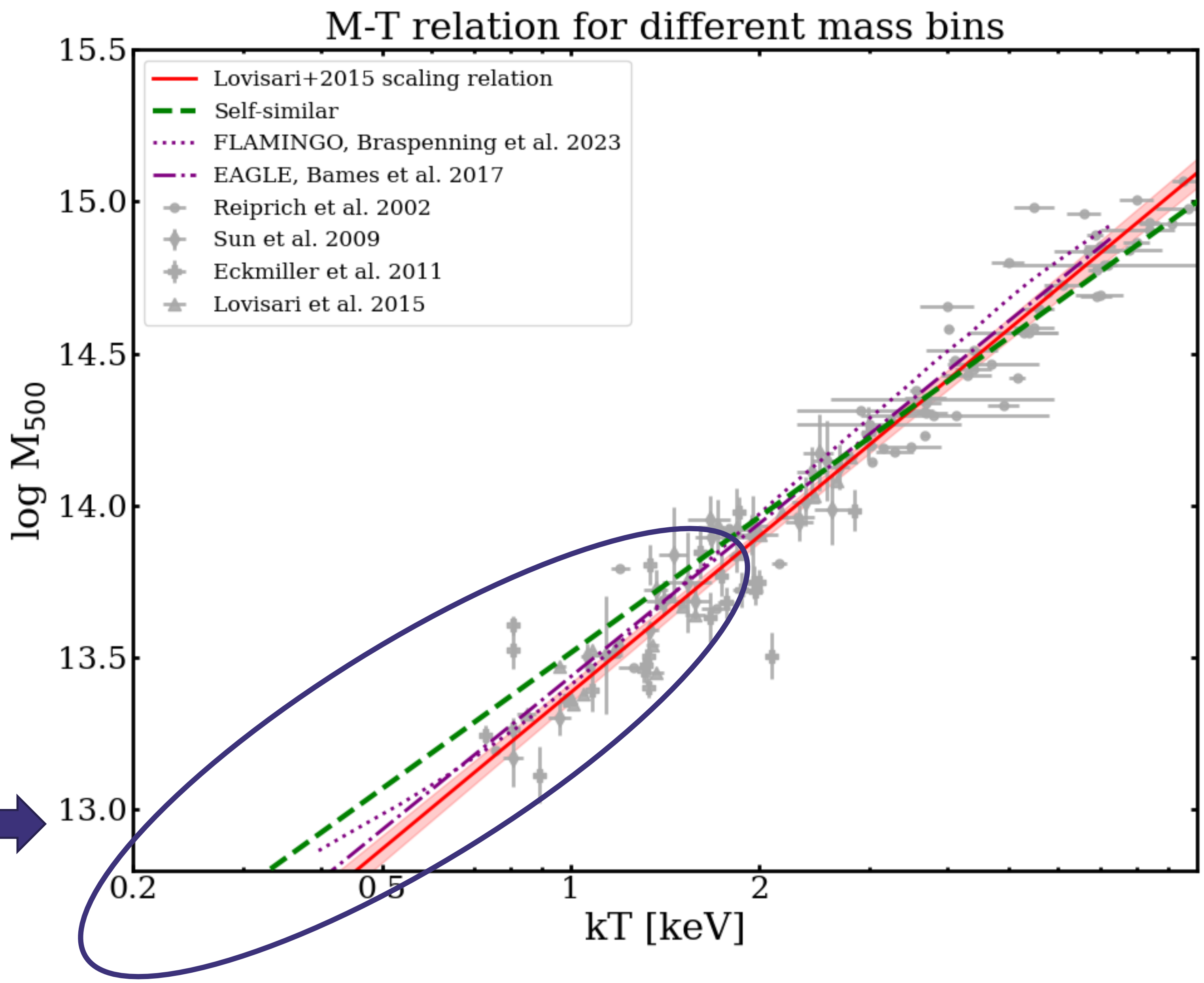


What do we see and expect to see from this area?

if there will be more groups…

We can compile the sample of groups to populate the relation and estimate the temperatures by modeling of their X-ray spectra

The M–Tx relation is expected to show the same behavior for groups and clusters
At the same time that may not be true for groups where the gas can be heated by AGN feedback



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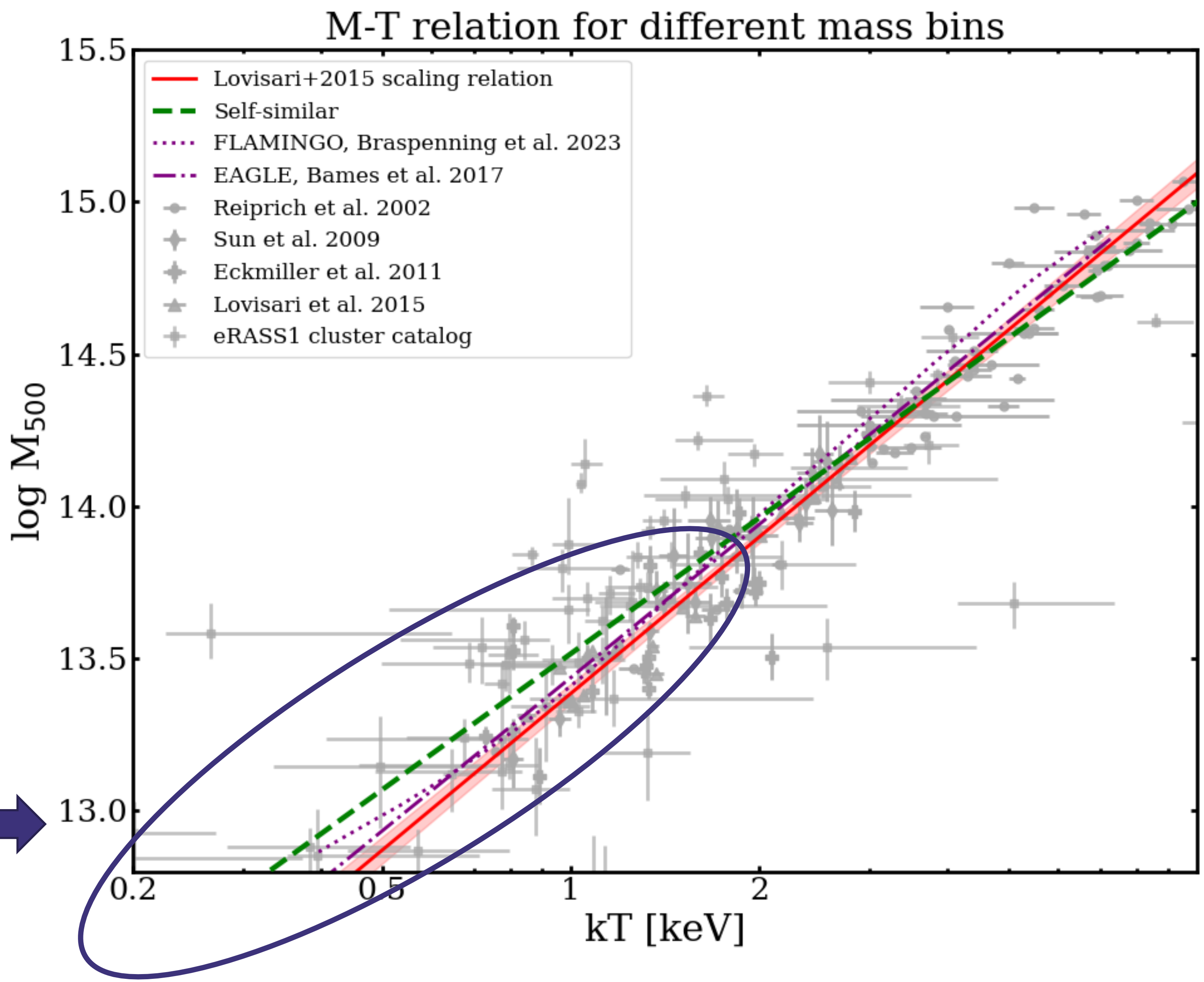
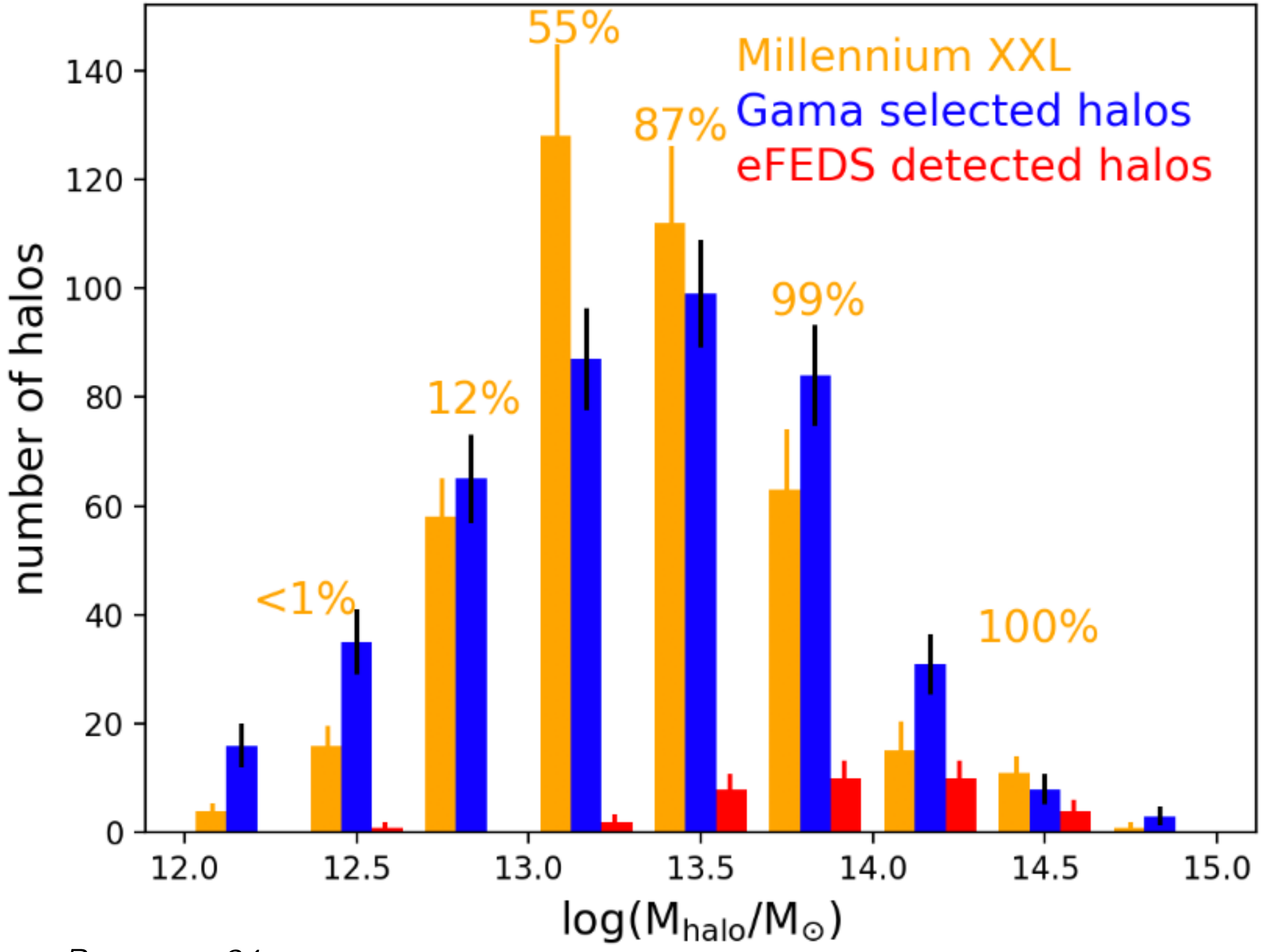


OBSERVATIONAL BIASES



Popesso+24

Only the brightest groups can be studied with X-ray -> low-mass end of scaling relations populated poorly

\+

It causes significant biases as far as selecting the brightest X-ray groups and then study their X-ray properties

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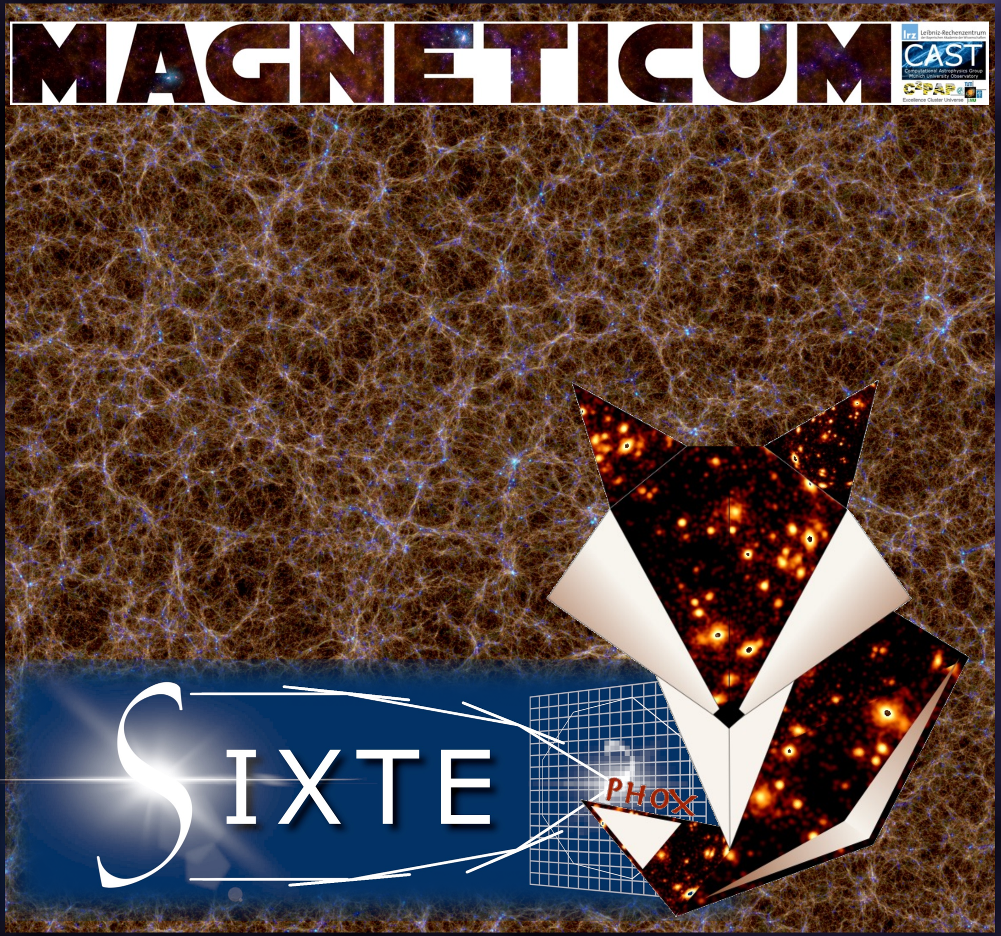
We should look for other approaches of sample selection and add X-ray faint groups

DUAL APPROACH



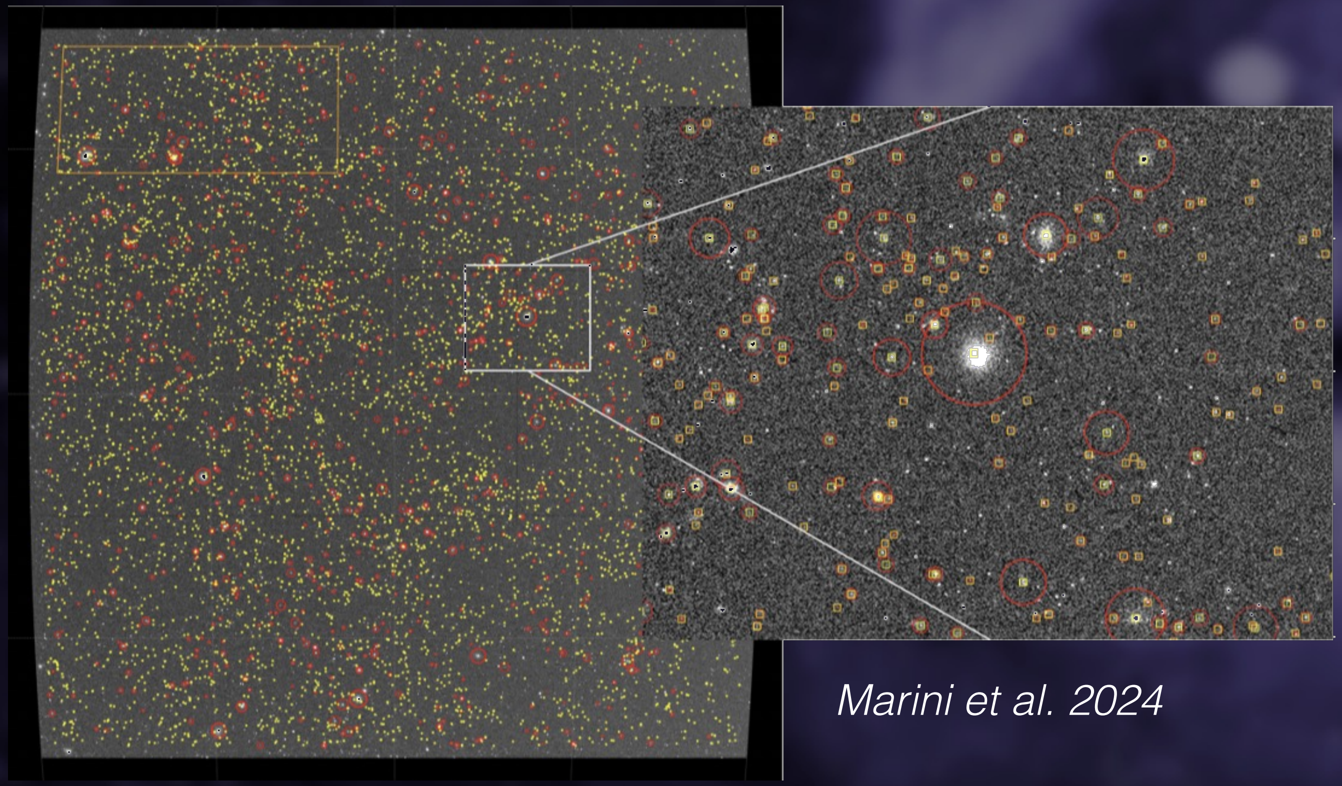
Simulations

eROSITA

Observations

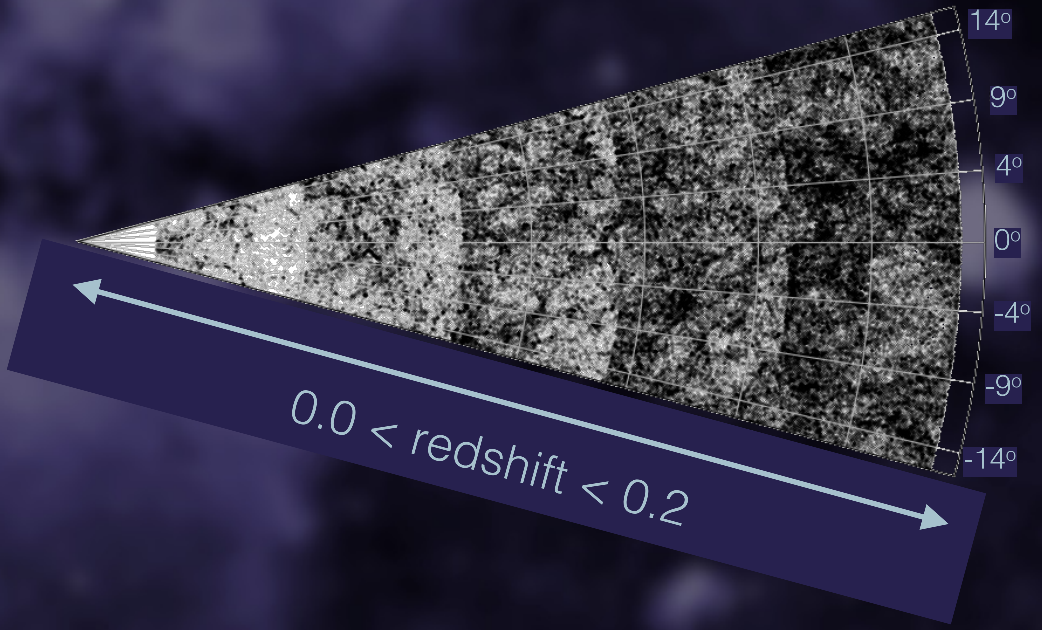
SIMULATIONS WITH MAGNETICUM

For more info see poster by Ilaria Marini



30 deg

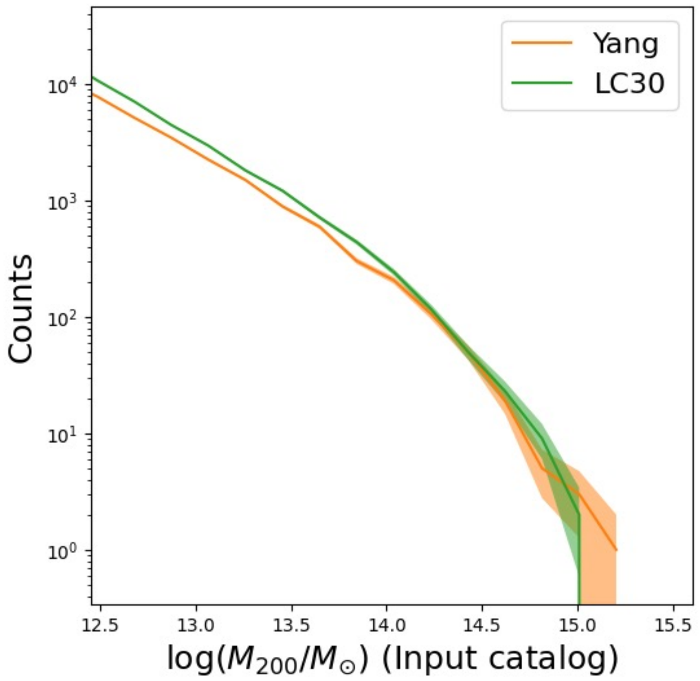
Marini et al. 2024



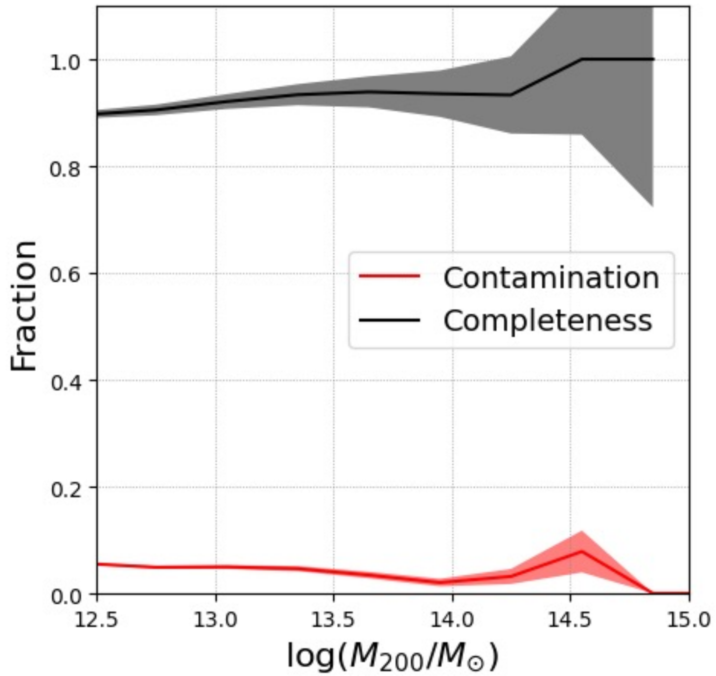
X-ray mock observations (eRASS4 depth)

Magneticum lightcone

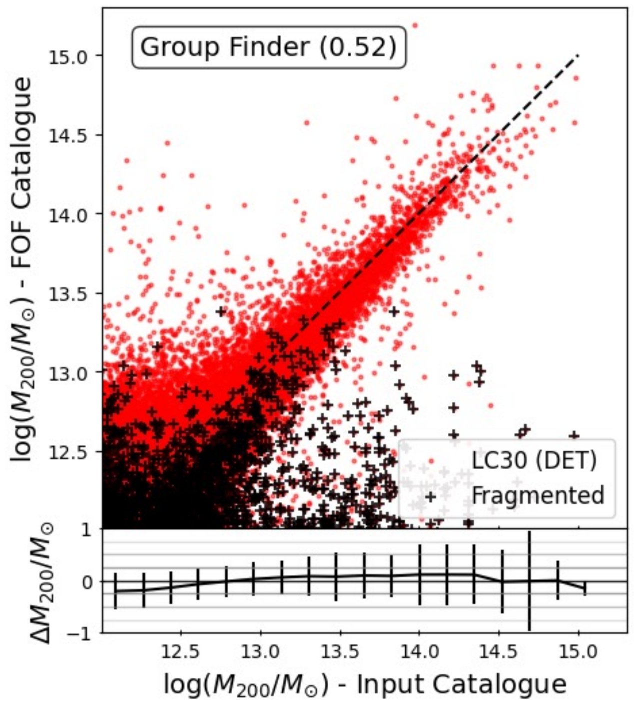
OBSERVATIONS: SAMPLE SELECTION



Halo mass function from Yang+2007 catalog agrees with Magneticum input halo masses



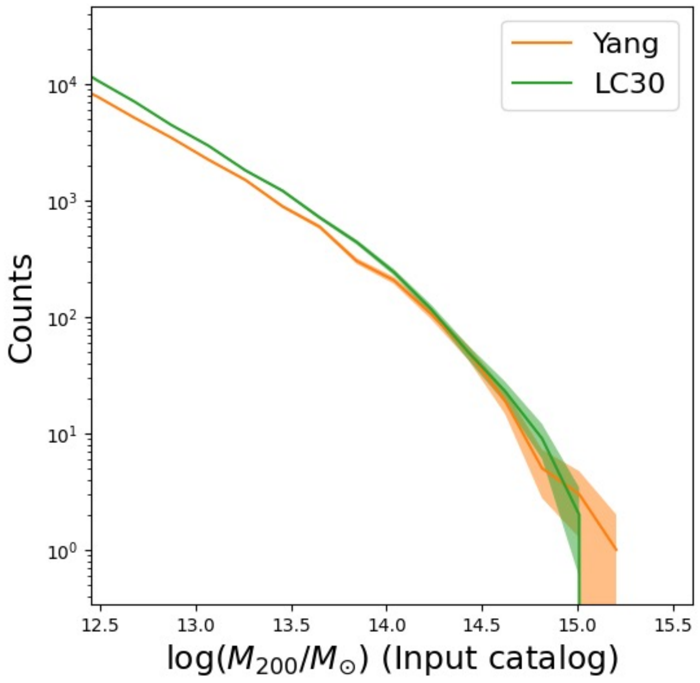
Completeness and contamination of Yang+2007 catalog selection function. The completeness is rather constant at 90% at all masses. The contamination is very low (~7%) and it increases at the cluster scale due to fragmentation

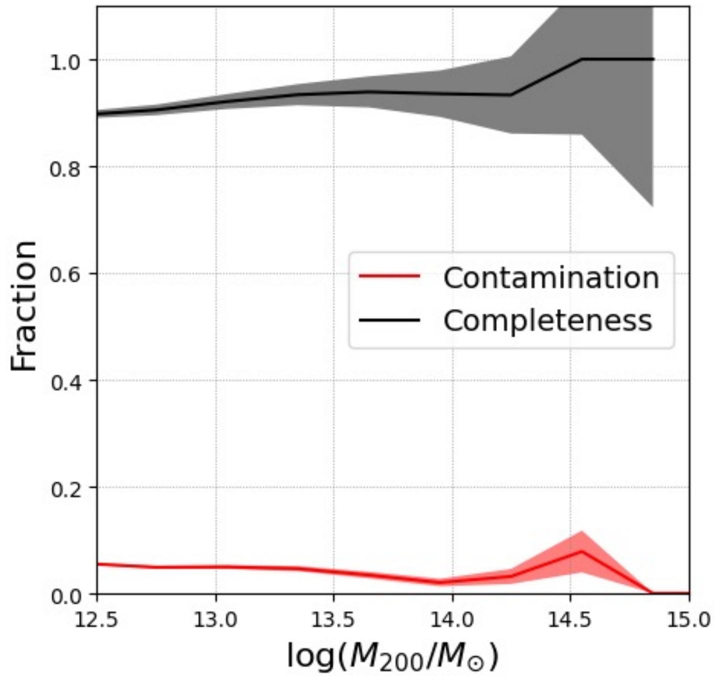


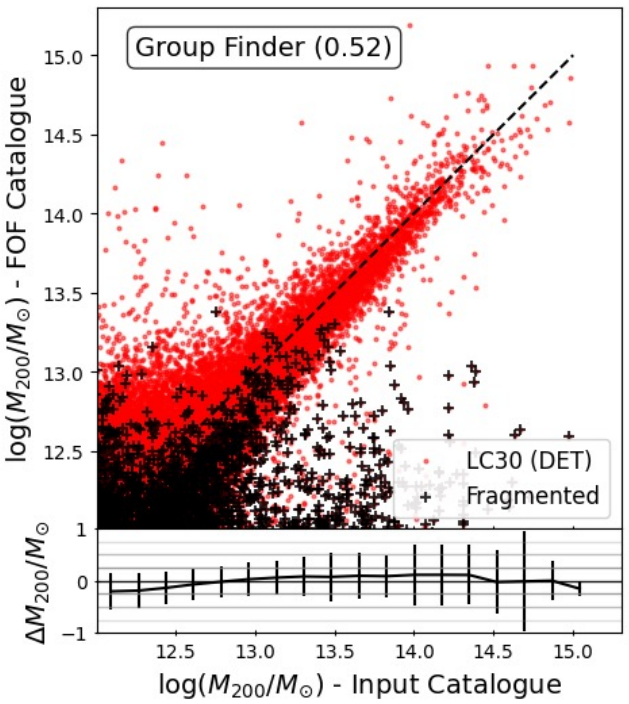
Comparison of the input Magneticum M200 and the measured M_{halo} of Yang+2007 based on system total luminosity as mass proxy.

Marini+24 (submitted)

OBSERVATIONS: SAMPLE SELECTION







Optical group catalogs are the good choice as they are not affected by large contamination and at the same time complete

For more info see poster by Ilaria Marini

Marini+24 (submitted)

SAMPLE

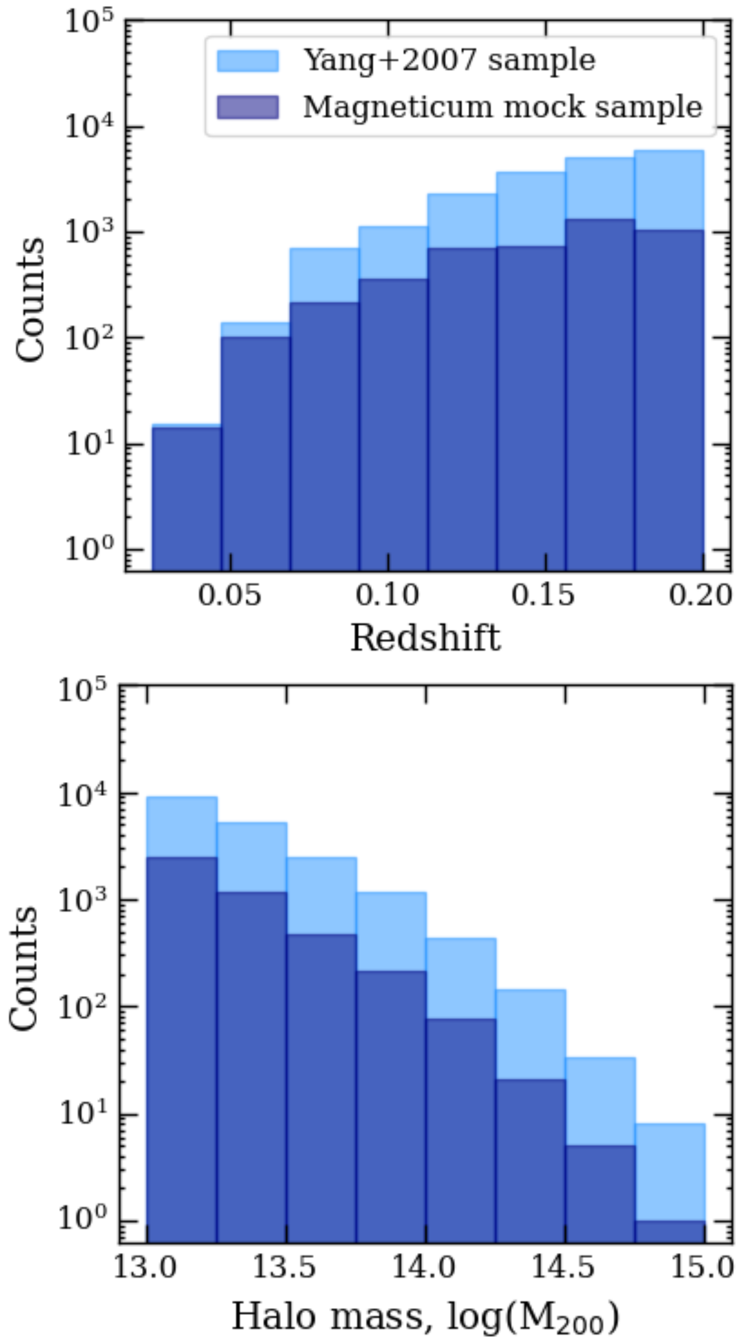
- Only local Universe up to z=0.2
- Removed all sources that contain other sources inside R_{500}
- Only sources without point-sources inside R_{500} in eRASS1 catalog

Observations:

- Yang+2007 groups sample selected by SDSS; all targets in SDSS field
- eRASS1 publicly available data

Simulations:

- Magneticum sample
- Mocks of eRASS4 obsevations

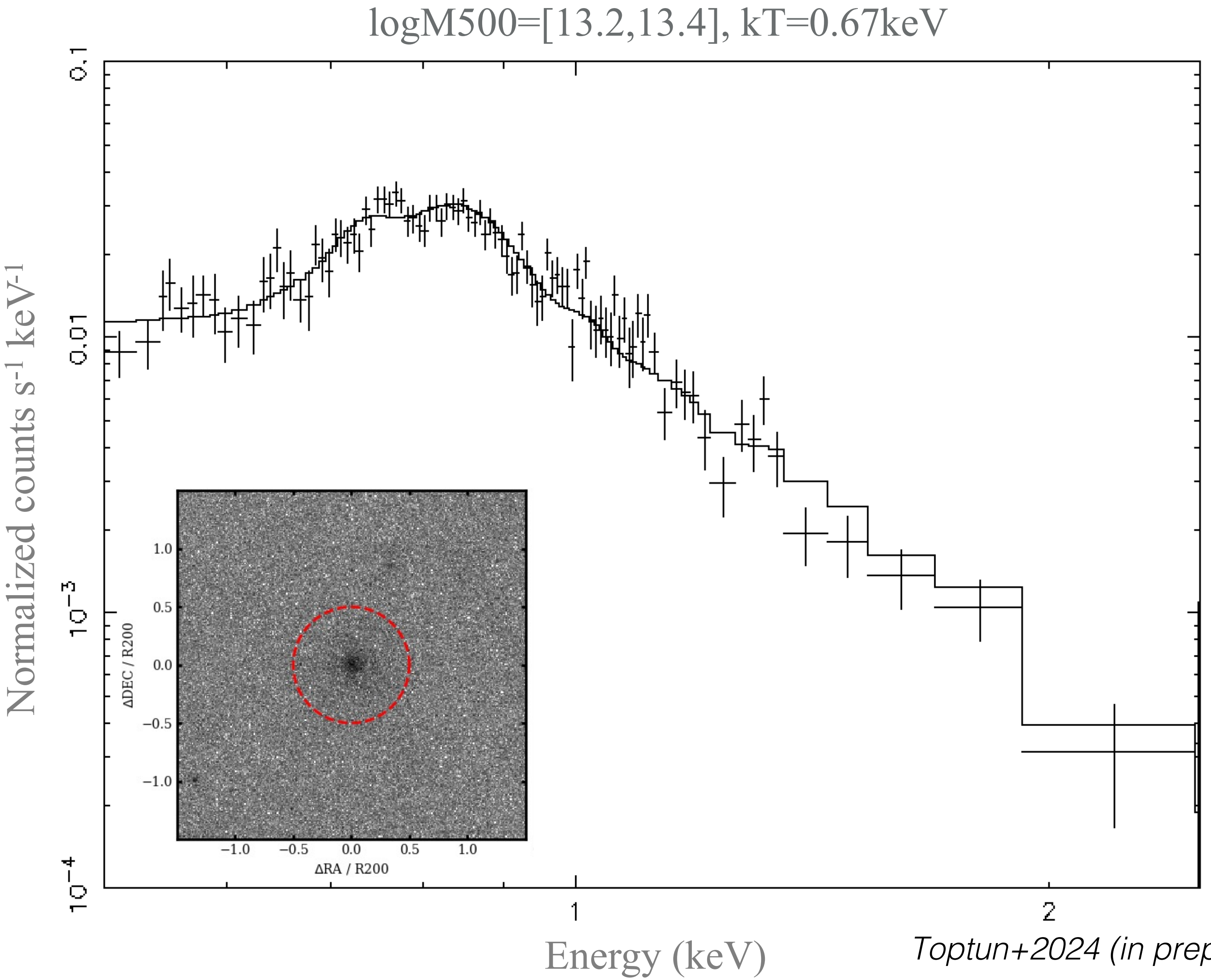


The use the sample of faint sources will lead to lack of photons that will not allow us to model the spectrum and estimate the temperature for most of the sources

MAIN TECHNIQUE: STACKING

The use the sample of faint sources will lead to lack of photons that will not allow us to model the spectrum and estimate the temperature for most of the sources

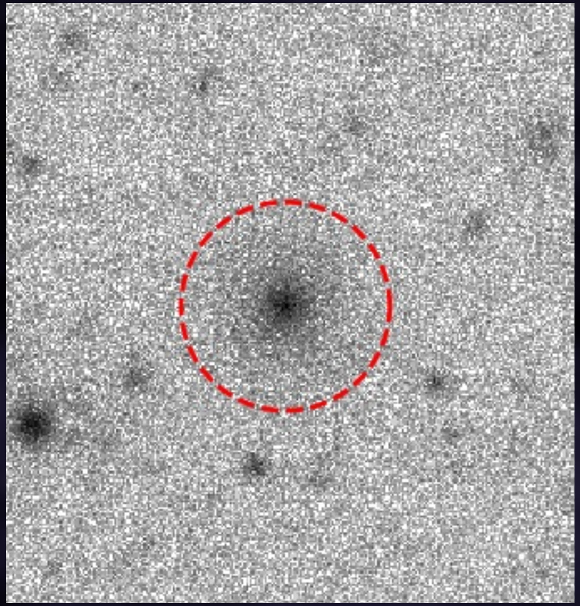
but it could be avoided by stacking all the spectra together in the bins with same properties



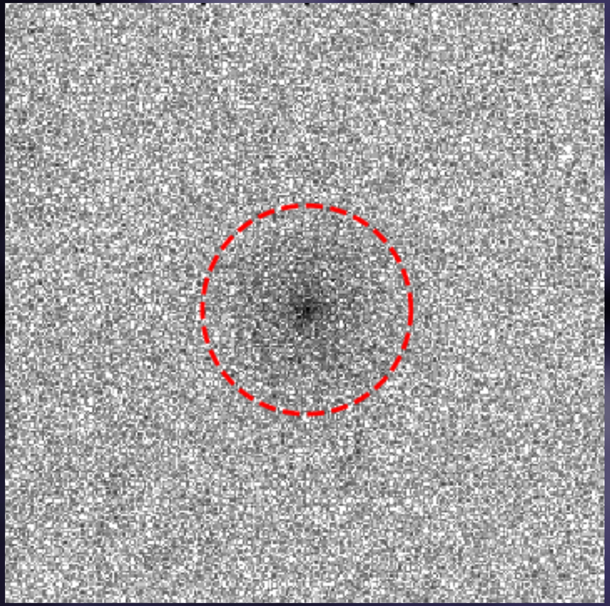
Toptun+2024 (in prep)

MAIN TECHNIQUE: STACKING

Example on simulated stacked data, logM500=13.4



before

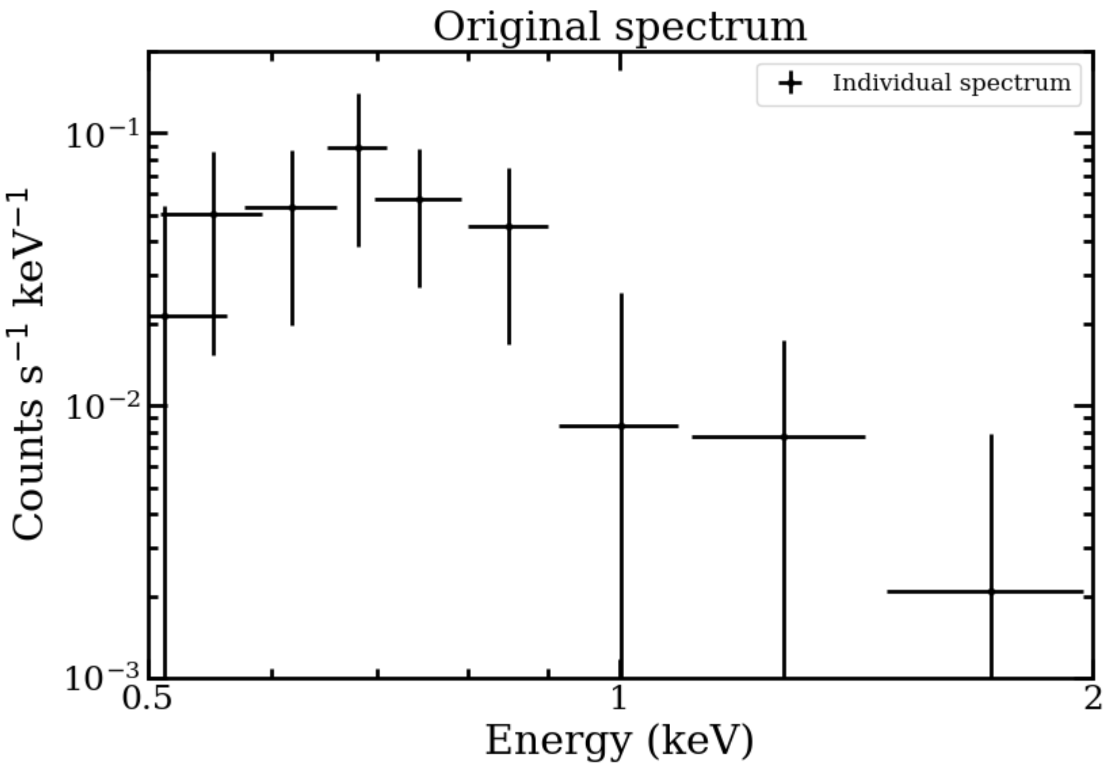


after

All point sources, previosly detected in produced event list (for simulations) or in eRASS1 catalog (for observations) masked with size of average eROSITA psf to clean source and background spectra from bright AGN's photons

Cleaning the exposures from point sources

MAIN TECHNIQUE: STACKING

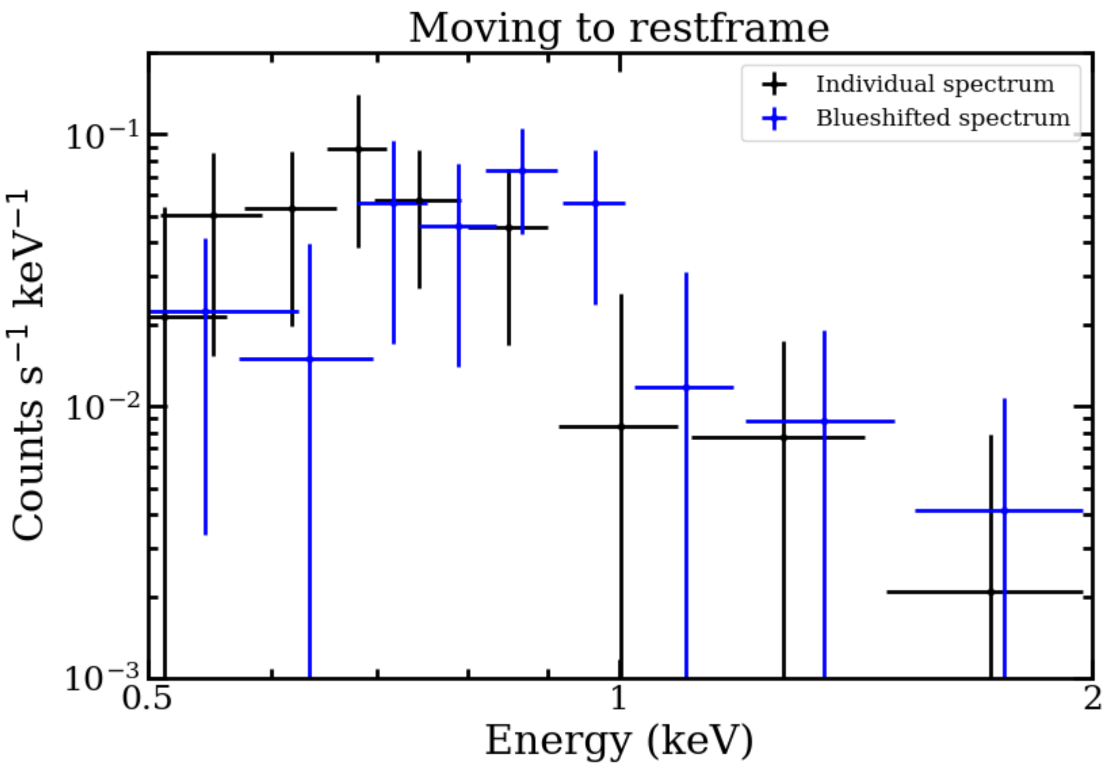


Using eSASS with radius of extraction R500

Cleaning the exposures from point sources

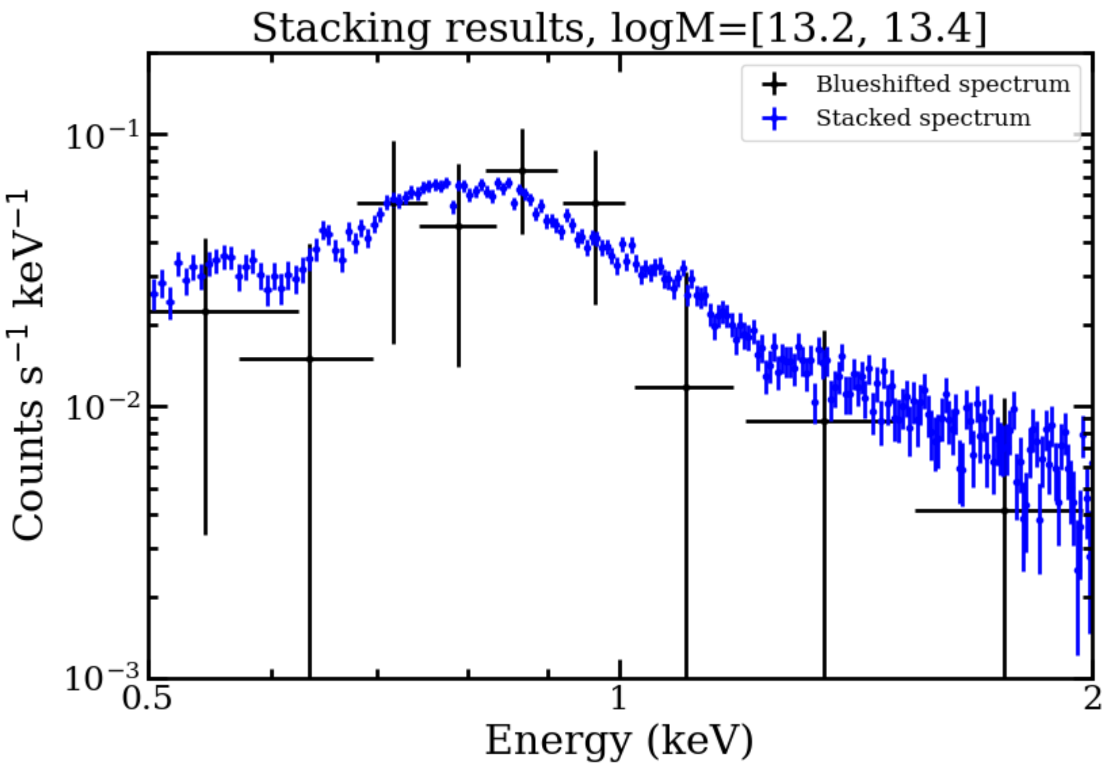
Extracting individual spectra

MAIN TECHNIQUE: STACKING



Moving to restframe (red) to avoid “blurring” of stacked spectra

MAIN TECHNIQUE: STACKING



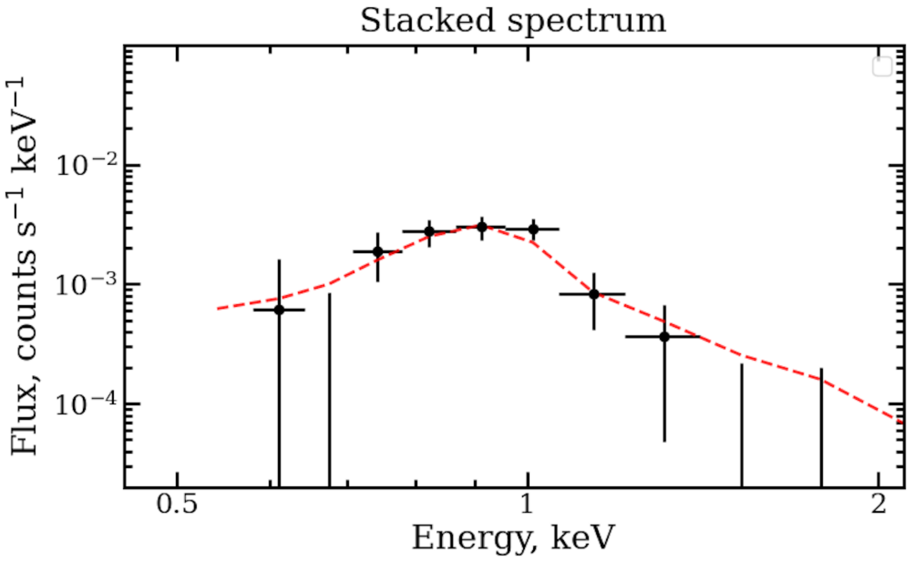
Result: significant increasing of signal-to-noise with saving of original spectrum shape

Cleaning the exposures from point sources → Extracting individual spectra → Moving spectra to restframe → Stacking all spectra inside mass bin

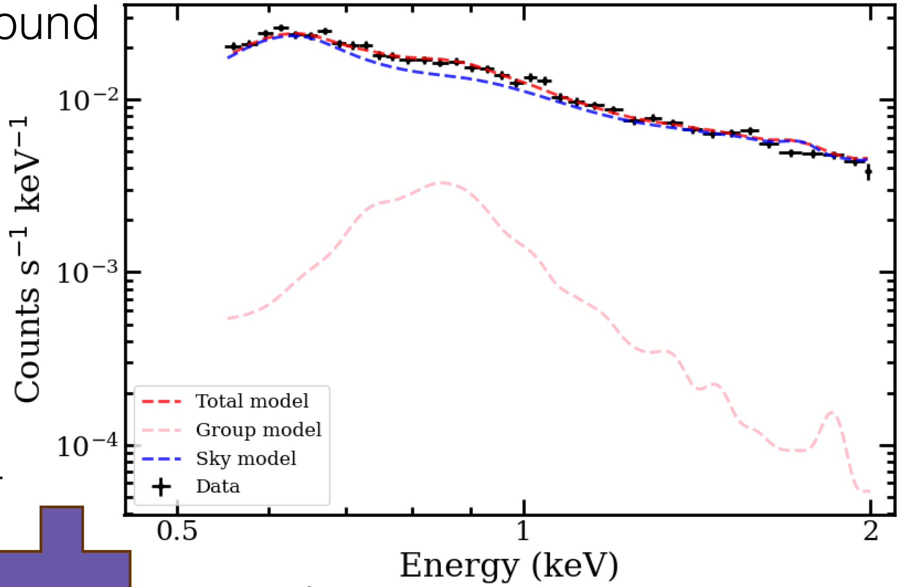
BACKGROUND:
SUBTRACTING vs MODELING

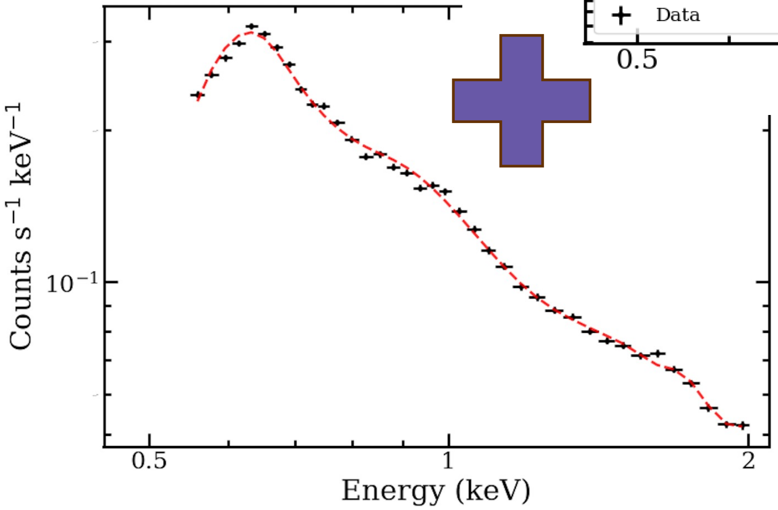
Source without background

$\log M_{500}$ = [13.4,13.6] $M_\odot$, 2875 sources



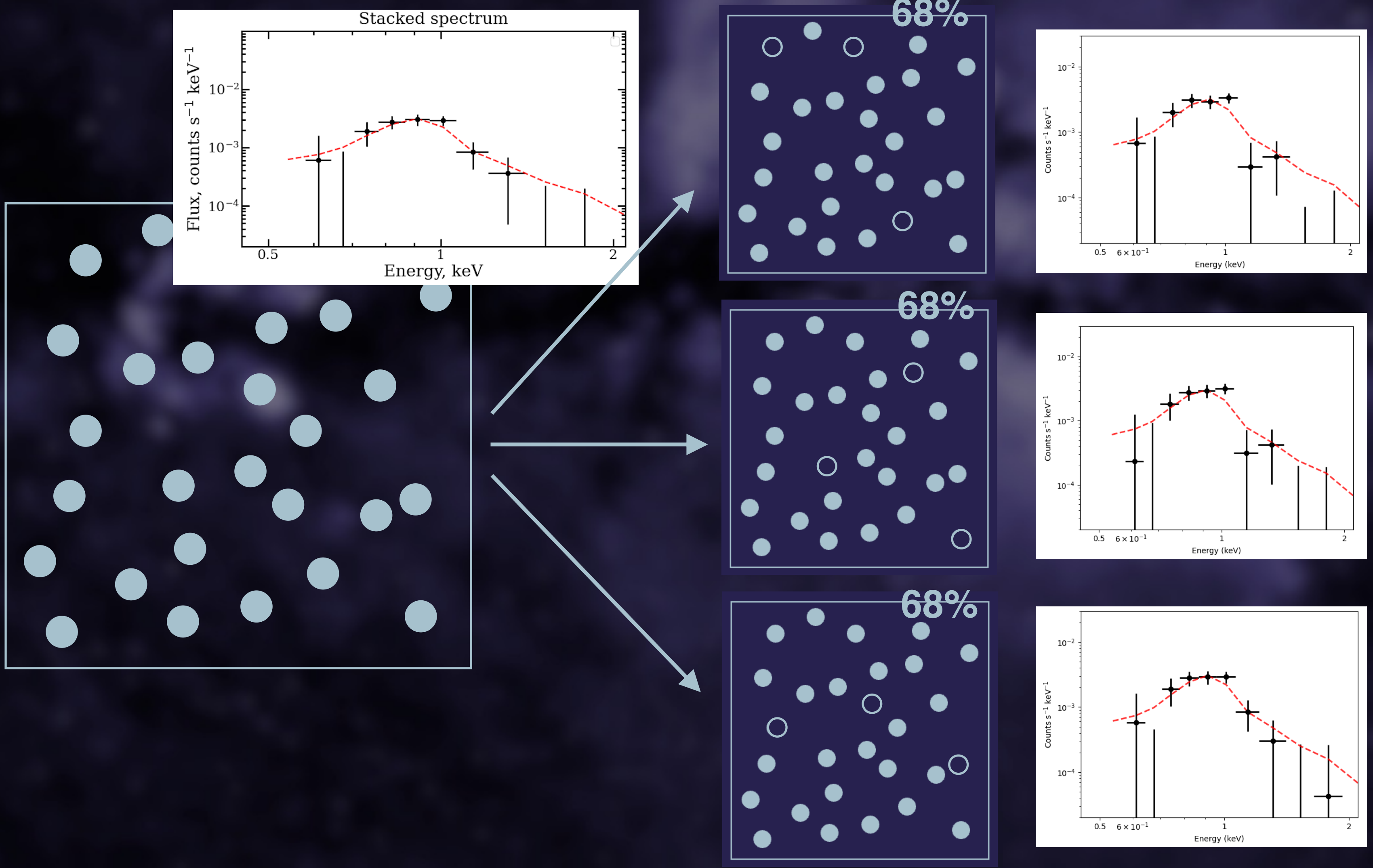
Source + background



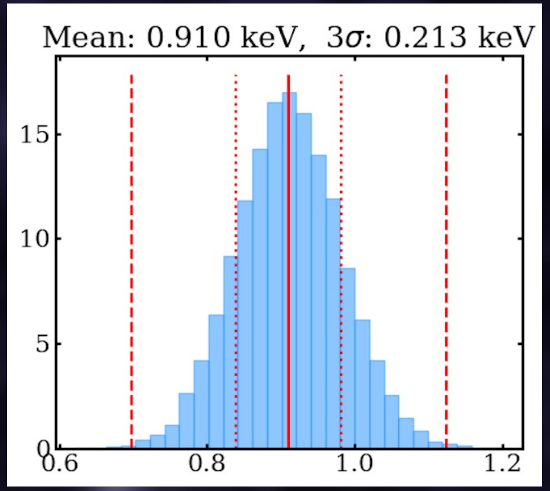


Only background

ESTIMATION OF STATISTICAL ERRORS



Slightly different temperatures for different subsamples

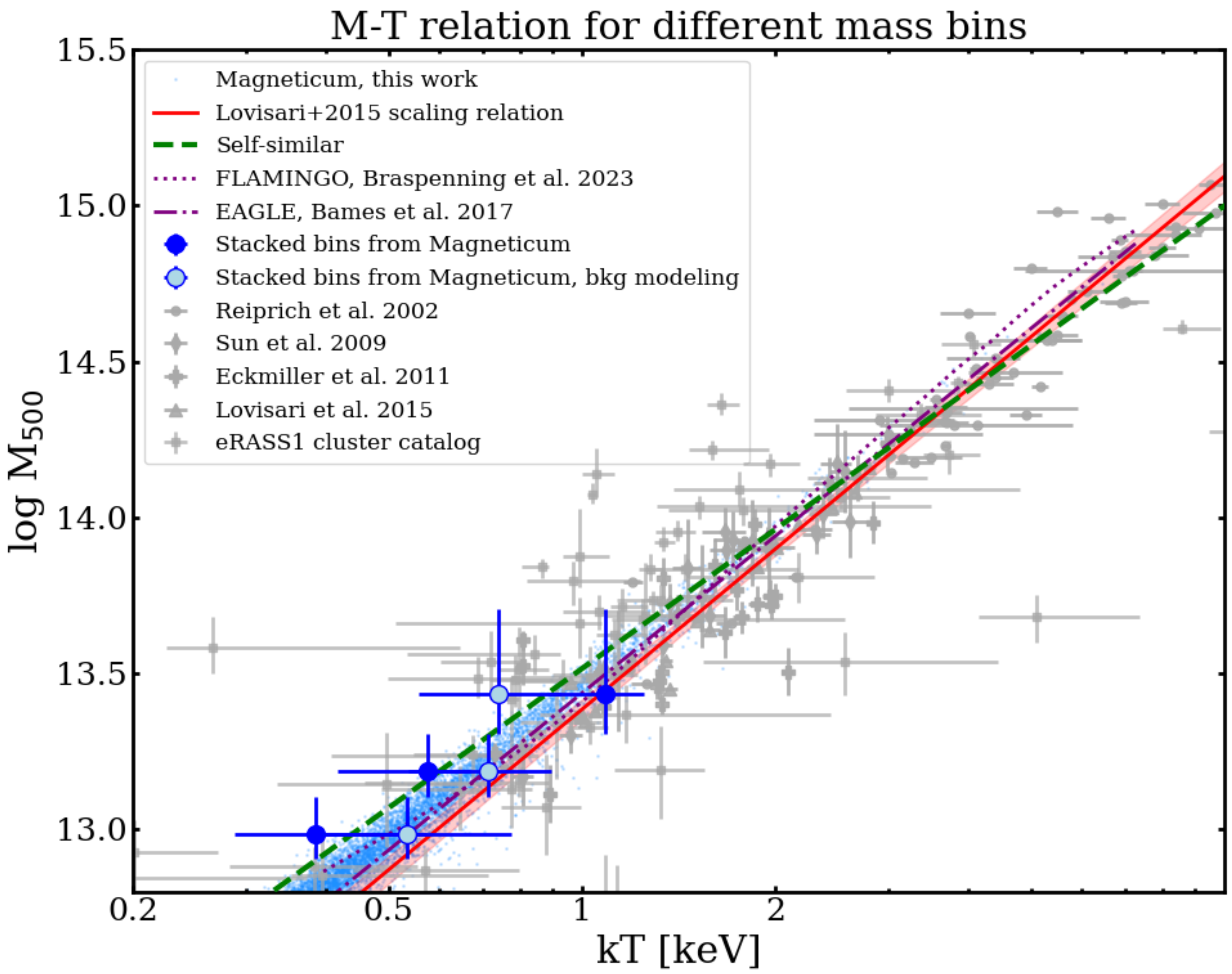


Temperatures by modeling with gadem model

SIMULATIONS: STACKING RESULTS

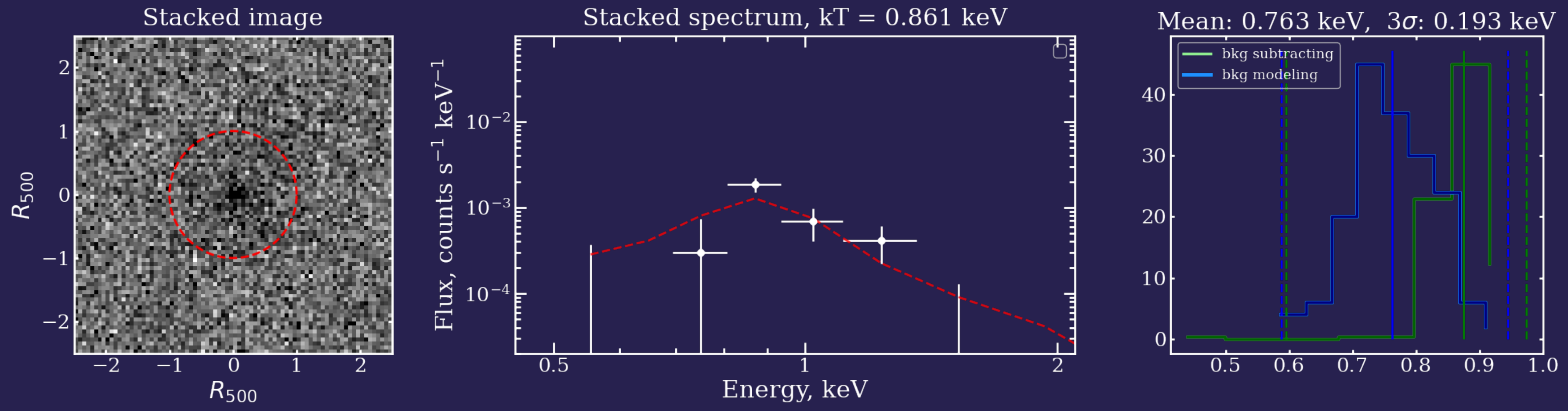
Temperatures in stacked bins corresponds perfectly to individual mass-weighted temperatures from simulations ⇢ stacking is reliable and can be used for observational data

ICM in Magneticum in both low and medium masses can reproduce M-T known from the literature

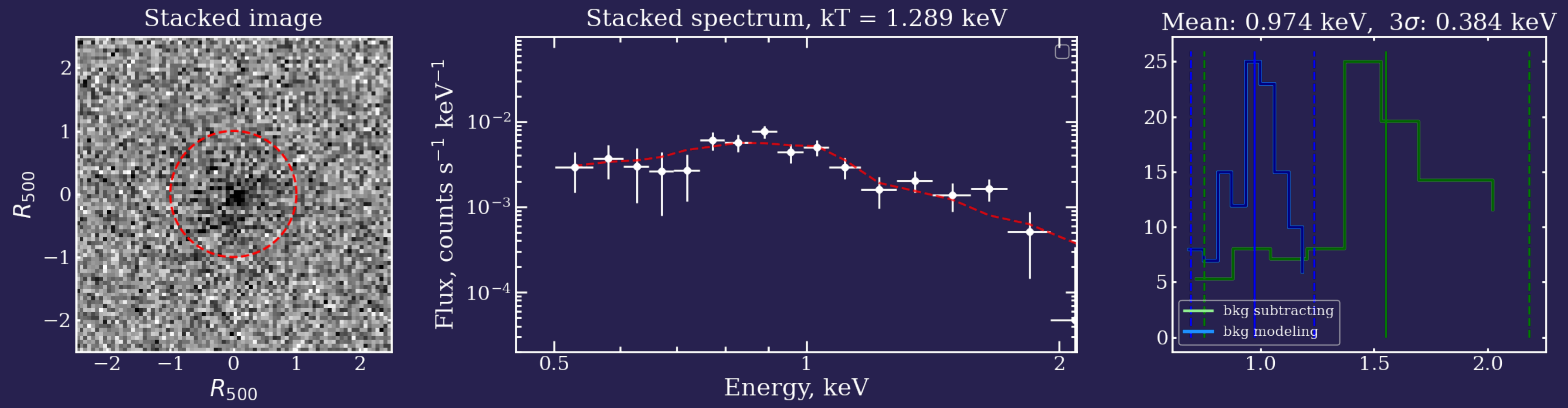


OBSERVATIONS: STACKING RESULTS

$\log M_{500}$ = [13.2,13.4] $M_\odot$, 5059 sources



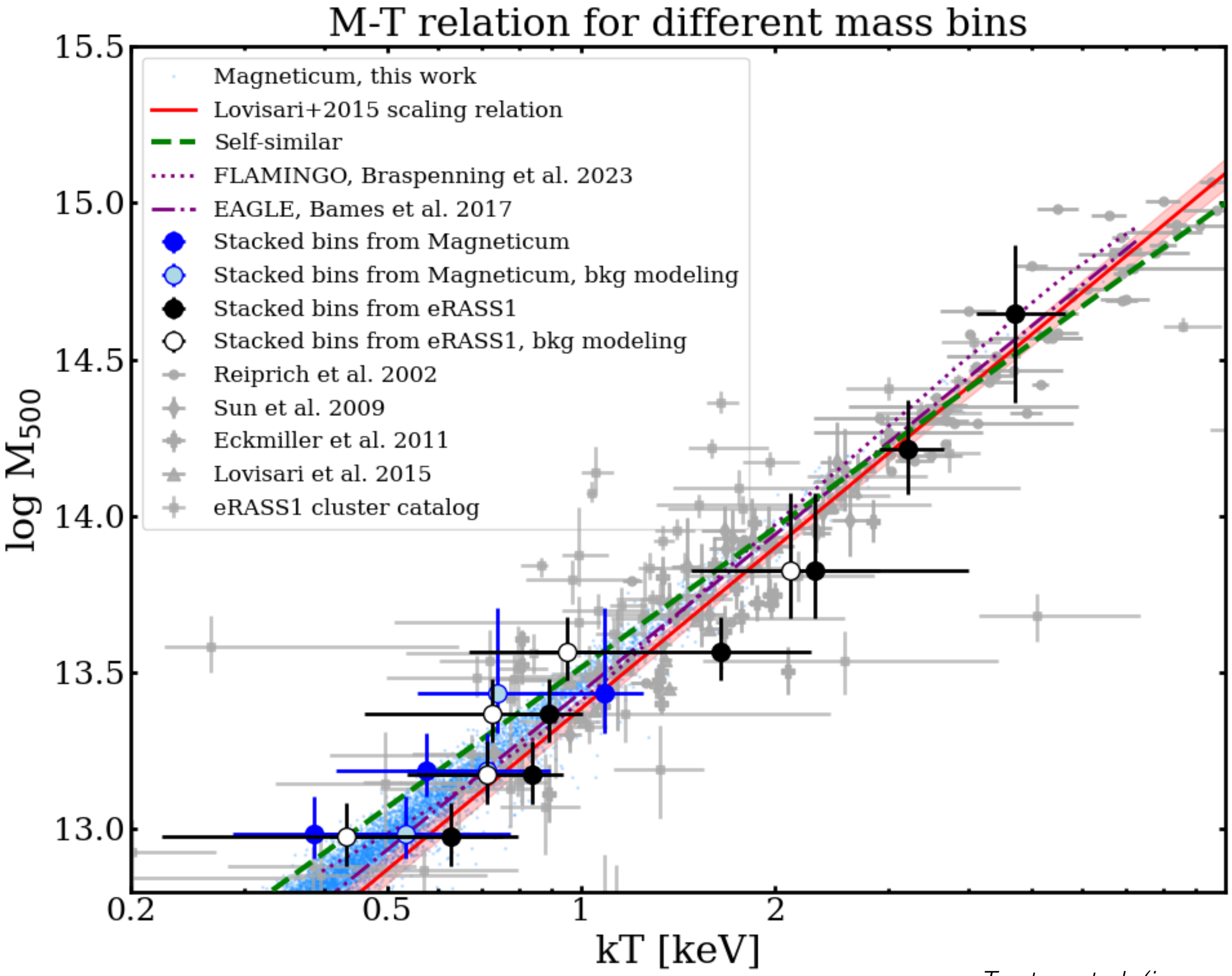
$\log M_{500}$ = [13.6,13.8] $M_\odot$, 1652 sources



Toptun et al. (in prep)

RELATION REVEALED

Stacking + wide-field data allows us to look up to $\log M_{500} \approx 13.0$



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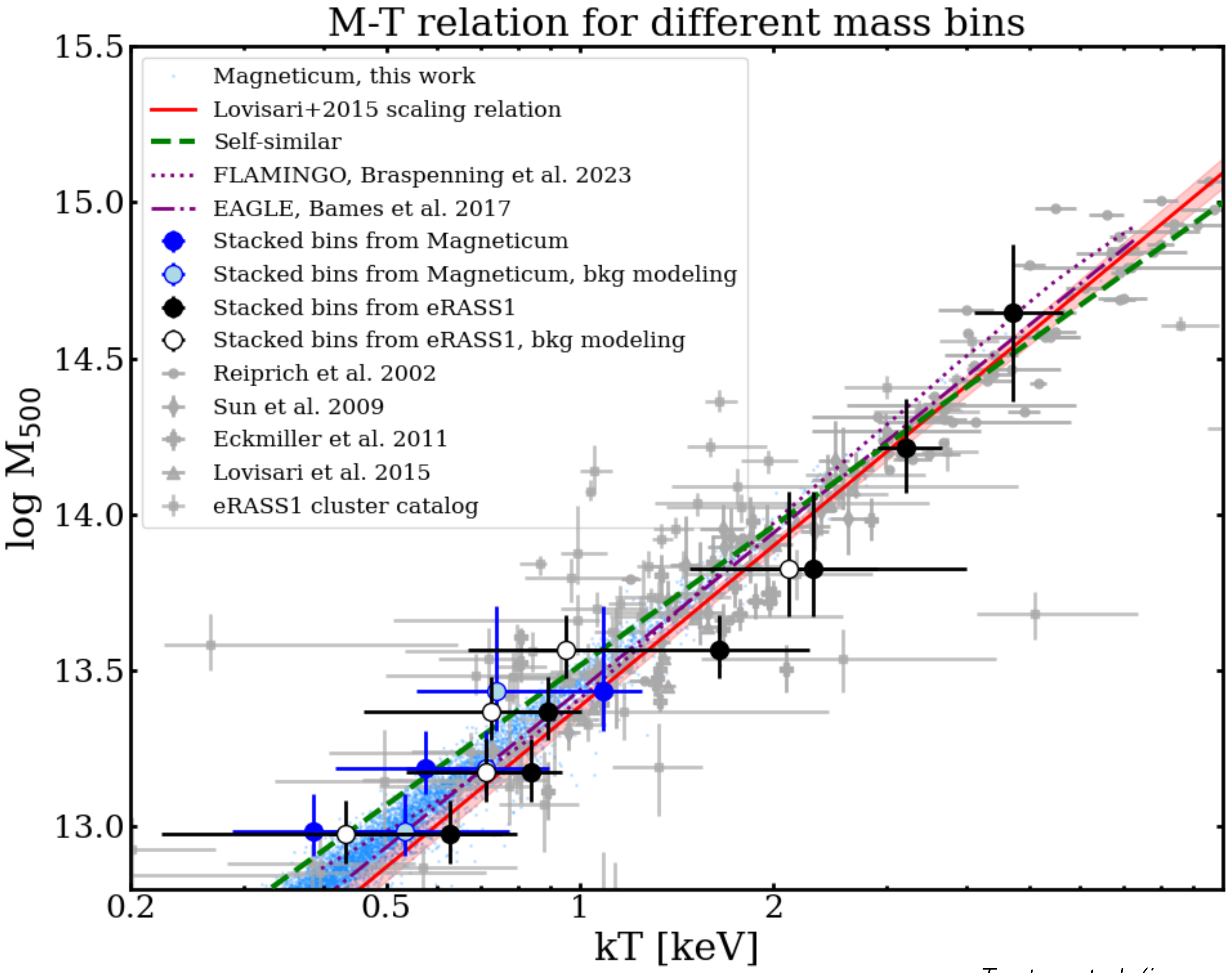
RELATION REVEALED

Stacking + wide-field data allows us to look up to $\log M_{500} \approx 13.0$

No significant impact of feedback into average temperature inside R_{500}



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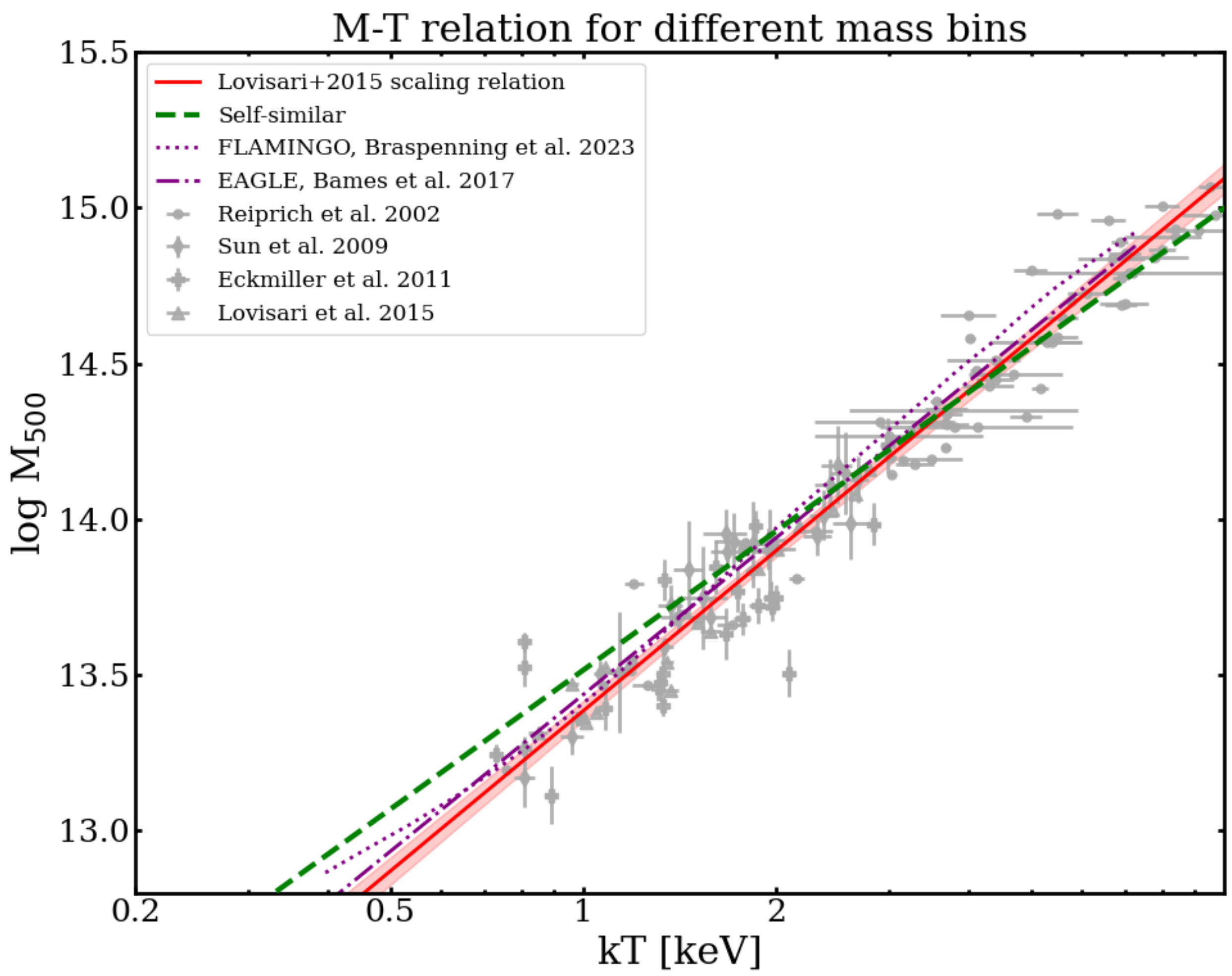
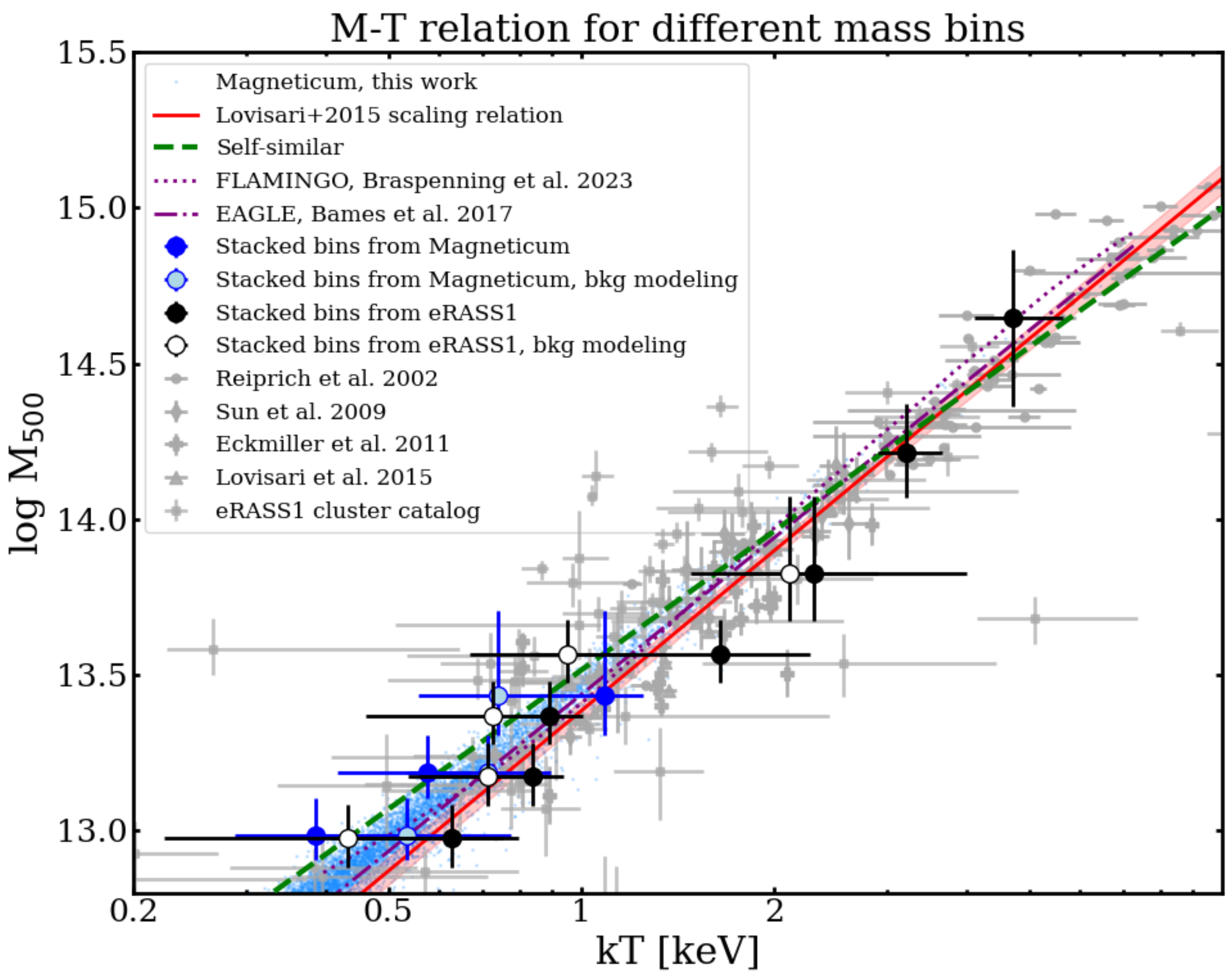
BEFORE

AFTER





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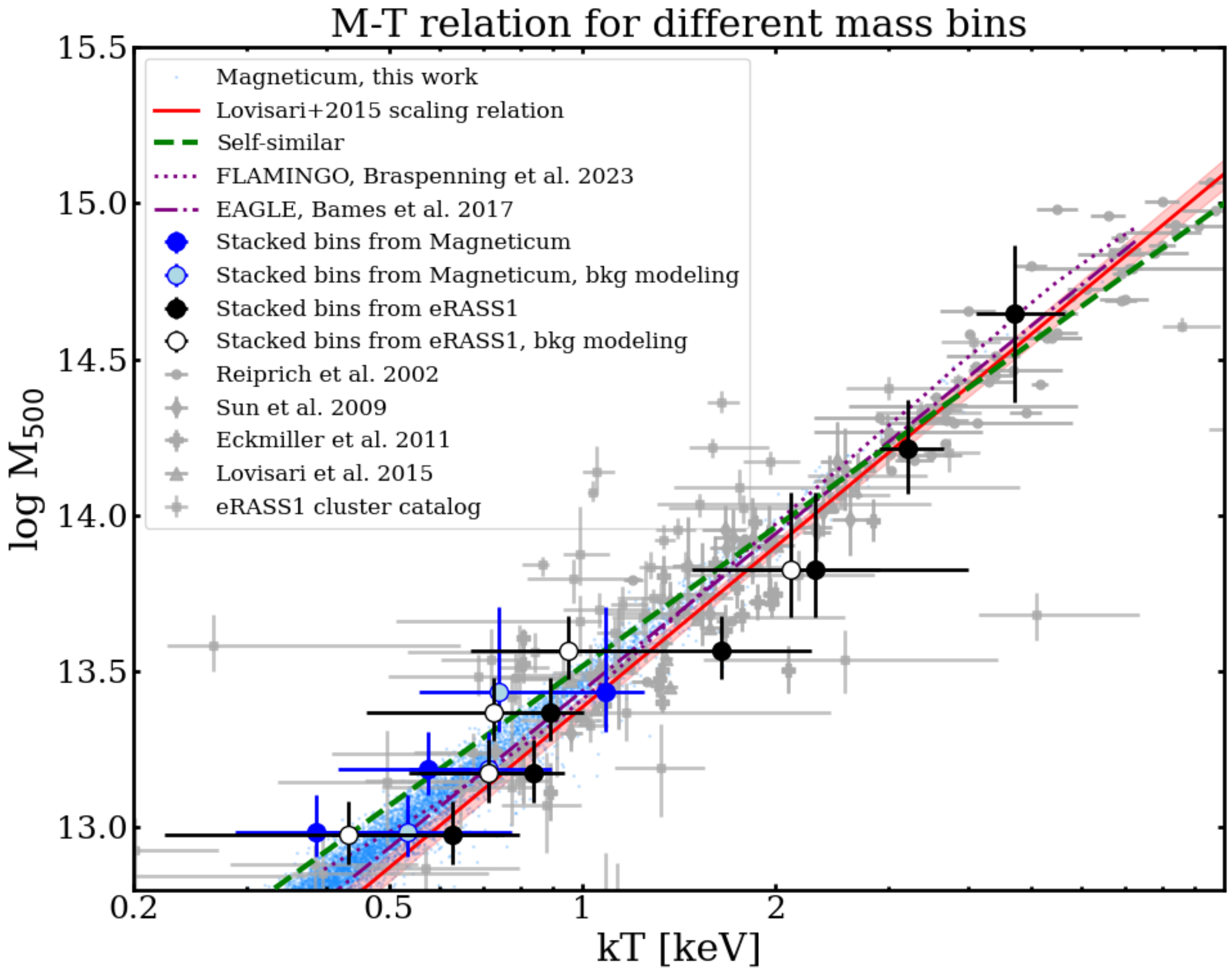
RESULTS & TAKE-HOME MESSAGES

- From logM500=13.0 groups show dependence between mass and temperature close to previously known for clusters and self-similarity



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17 September 2024
Questions, ideas and collaborations are welcome!

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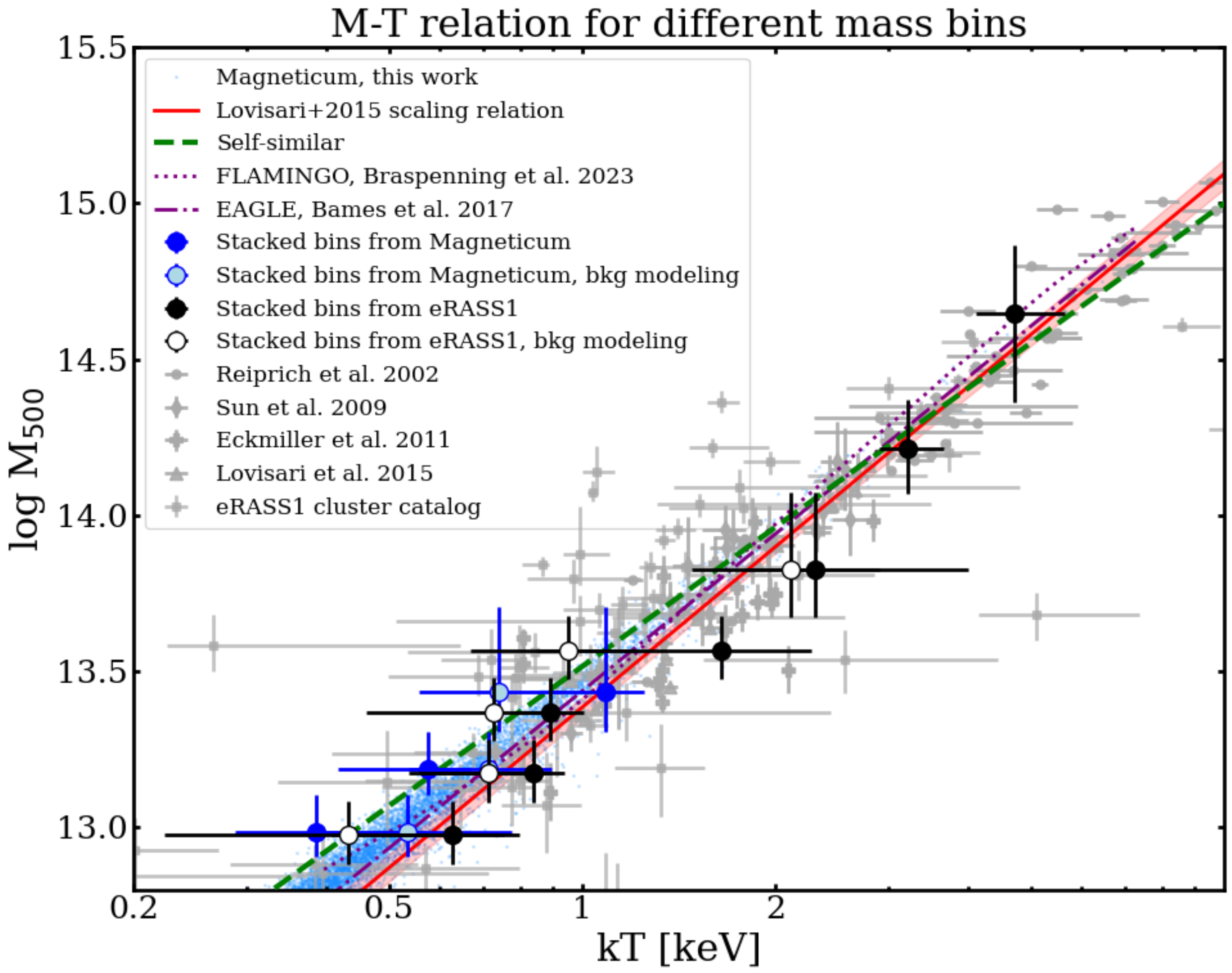
- From logM500=13.0 groups show dependence between mass and temperature close to previously known for clusters and self-similarity
- Stacking is reliable technique that allows us to dig much deeper than from we did from individual observations



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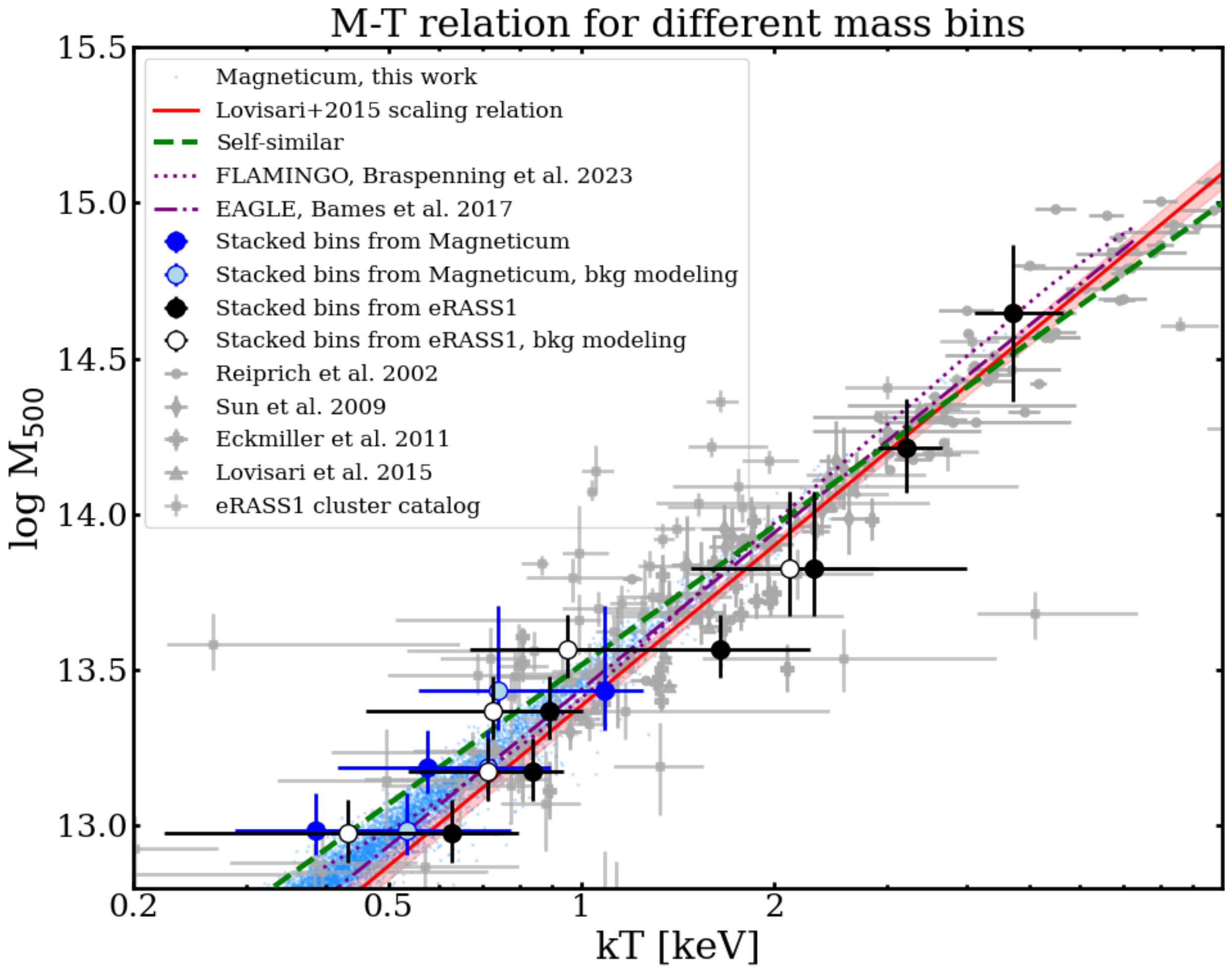
RESULTS & TAKE-HOME MESSAGES

- From logM500=13.0 groups show dependence between mass and temperature close to previously known for clusters and self-similarity
- Stacking is reliable technique that allows us to dig much deeper than from we did from individual observations
- Magneticum simulated sample shows the same result as we can observe with eROSITA



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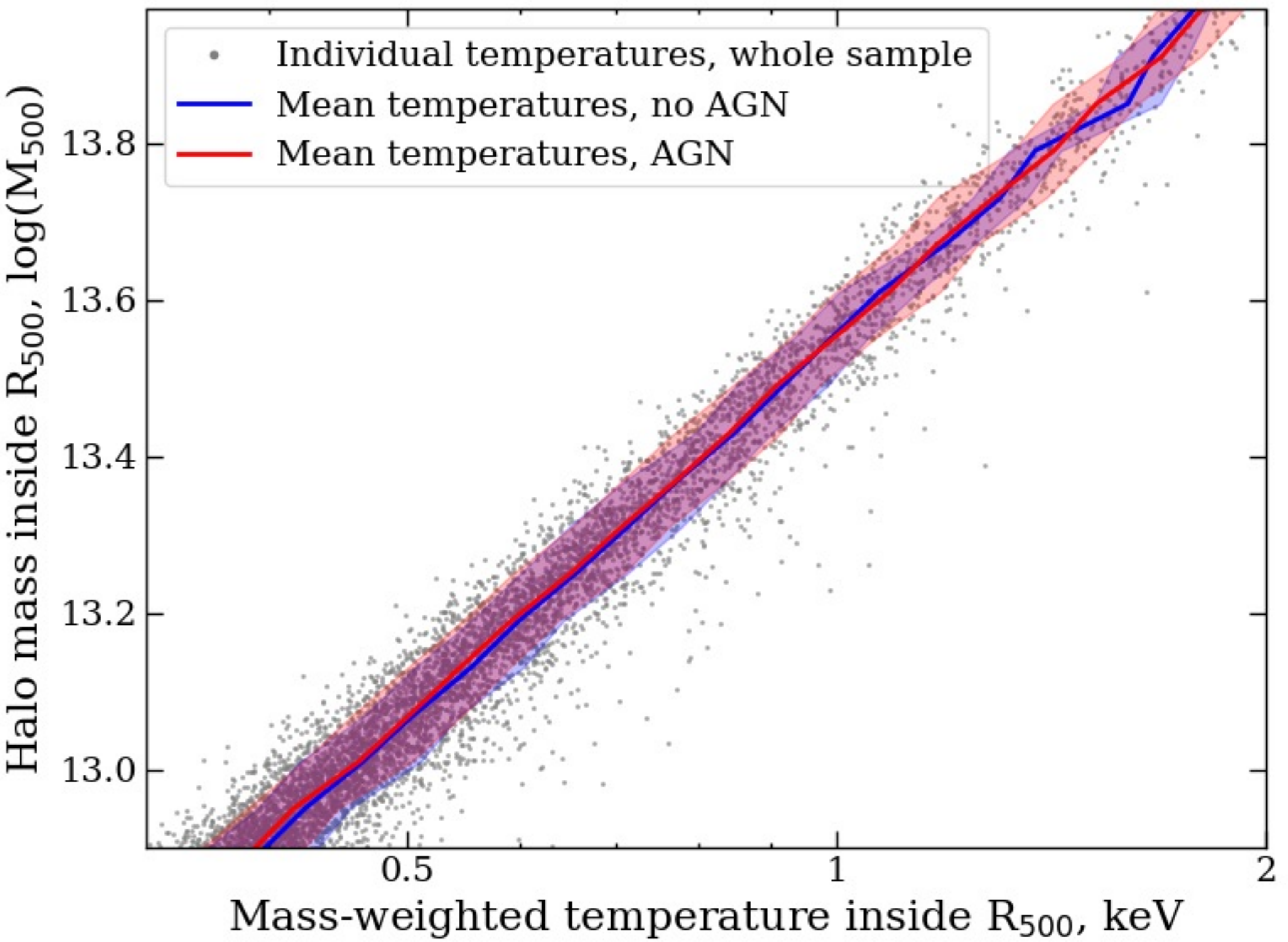
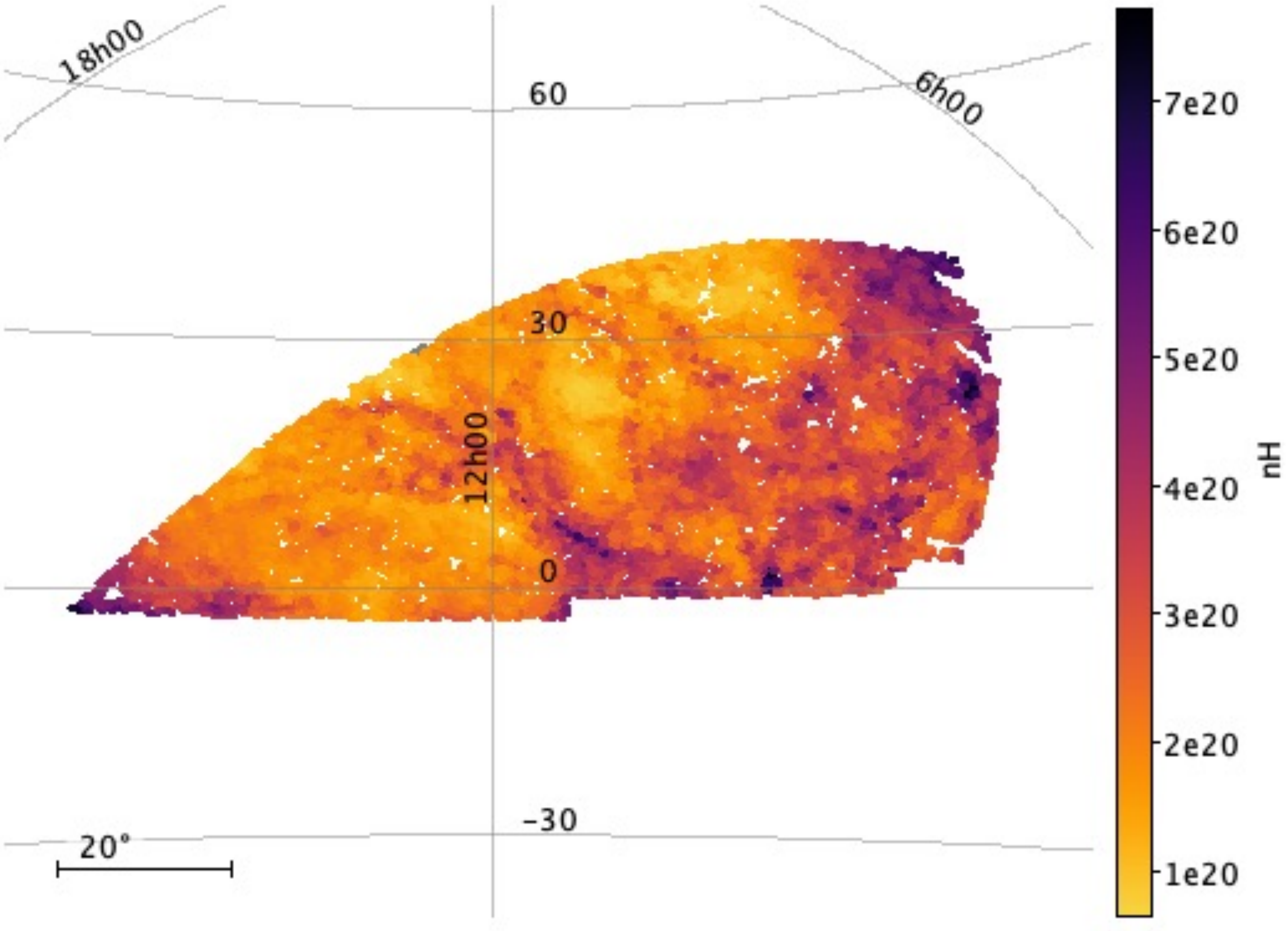
ADDITIONAL SLIDES

IMPACT OF AGN

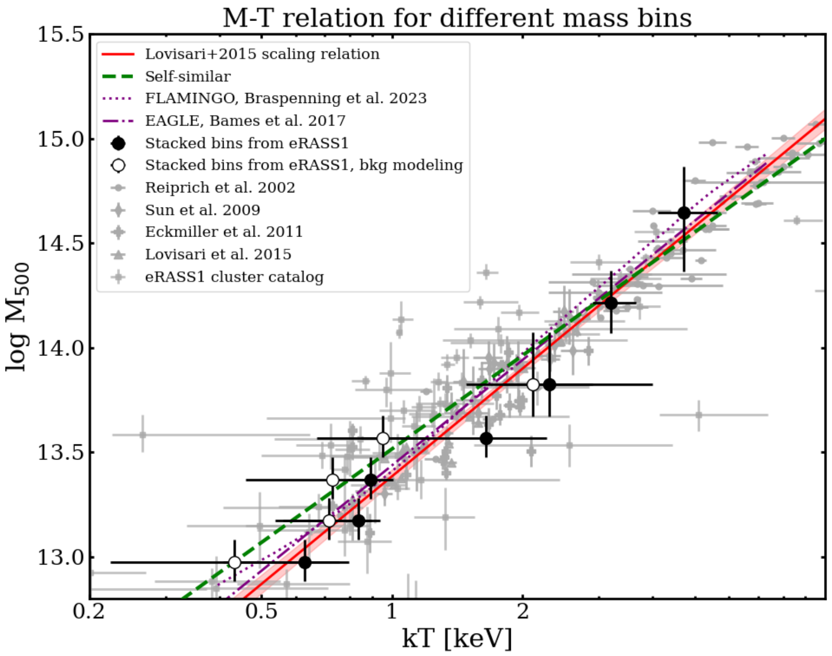


FOREGROUND ABSORPTION

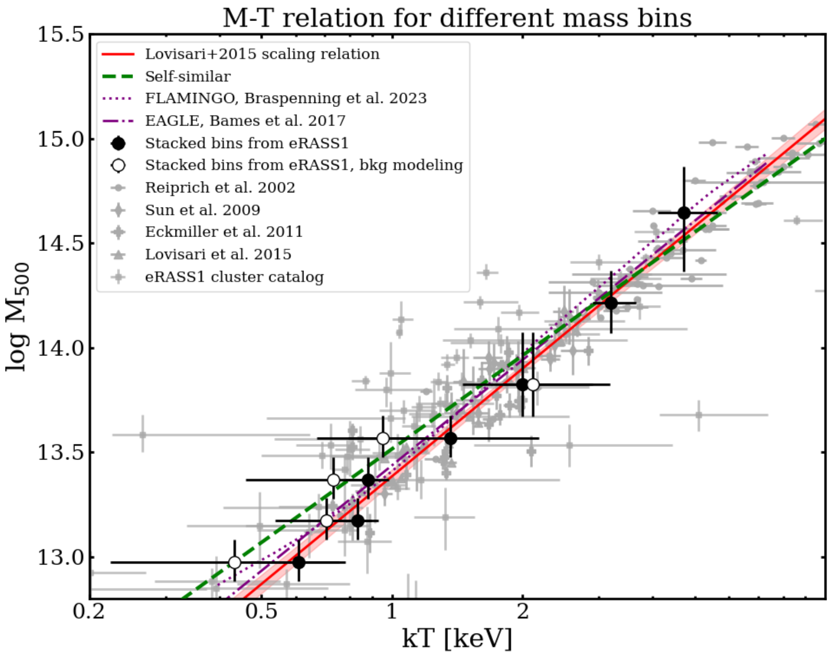


ASSUMPTION OF ABUNDANCE

A=0.3



A=0.2



A=0.4