

CHEXIMATE: constraining the origin of the scatter in galaxy cluster radial X-ray surface brightness profiles

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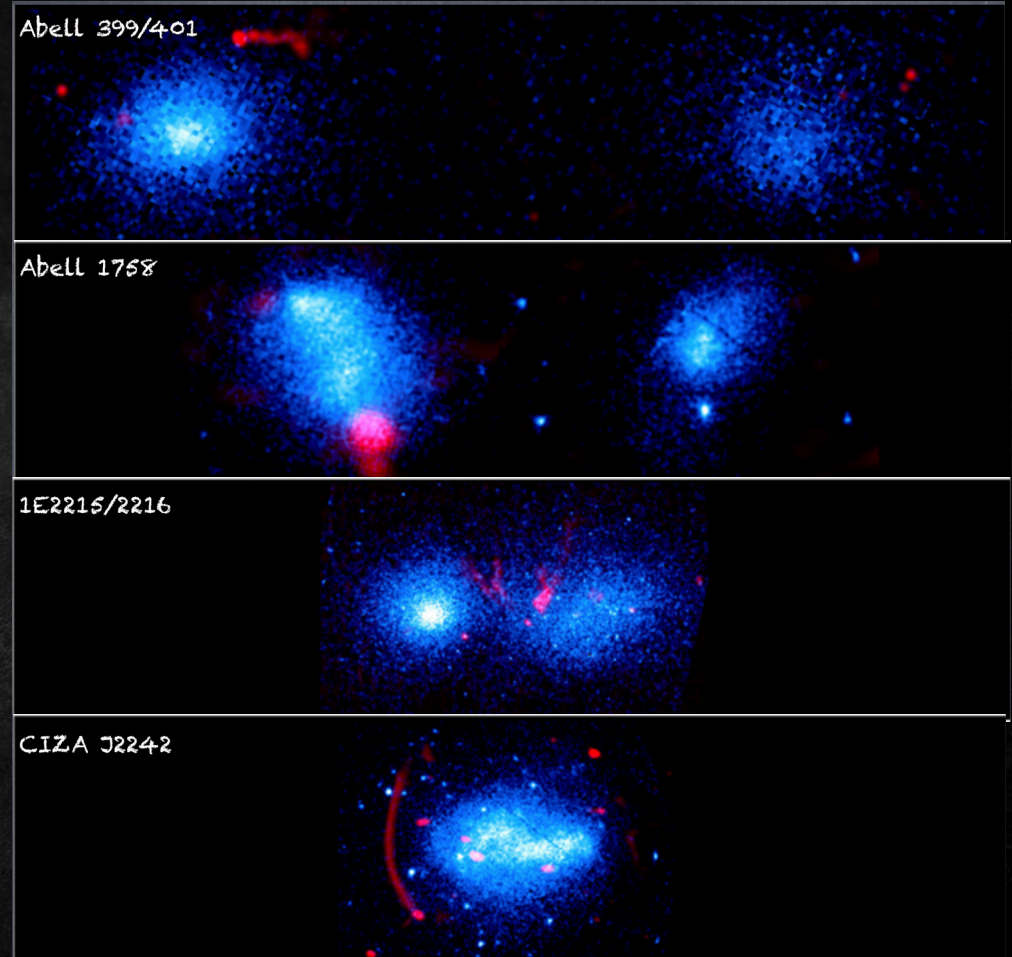
INAF-IASF(Milan)



S. Molendi, E. Rasia, G.W. Pratt, M. Arnaud,
M. Rossetti, F. Gastaldello, D. Eckert, and the
CHEXIMATE collaboration

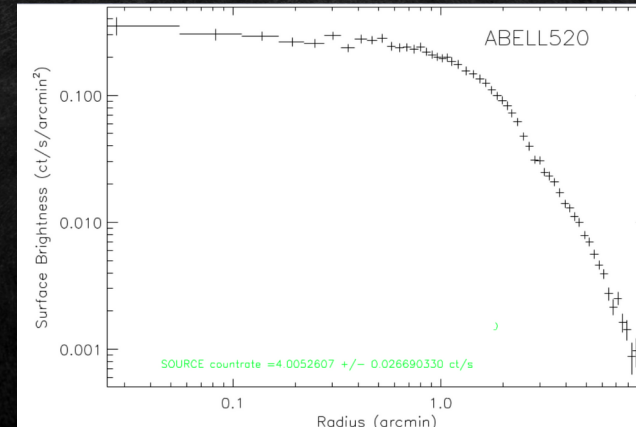
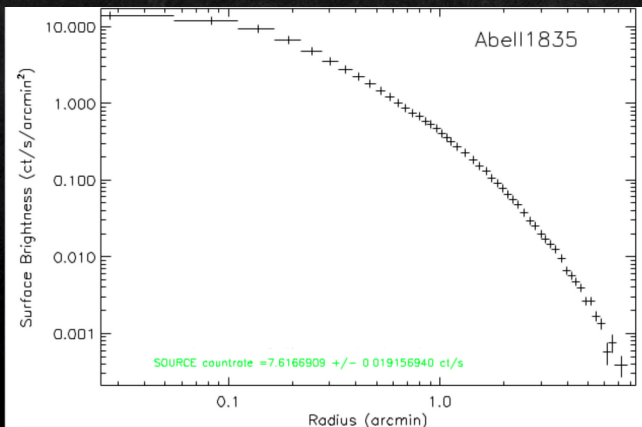
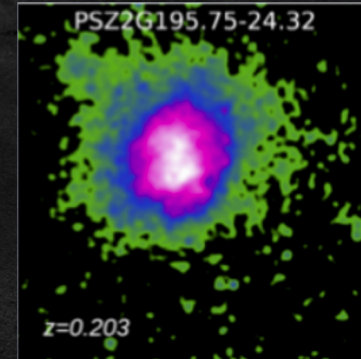
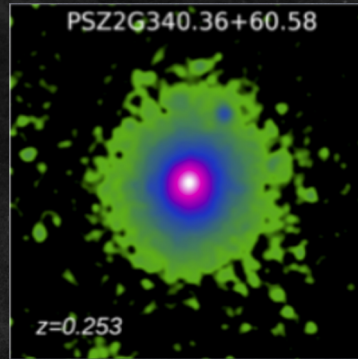
1. Introduction

The intracluster medium (ICM) retains information on the individual formation history of galaxy clusters



1. Introduction

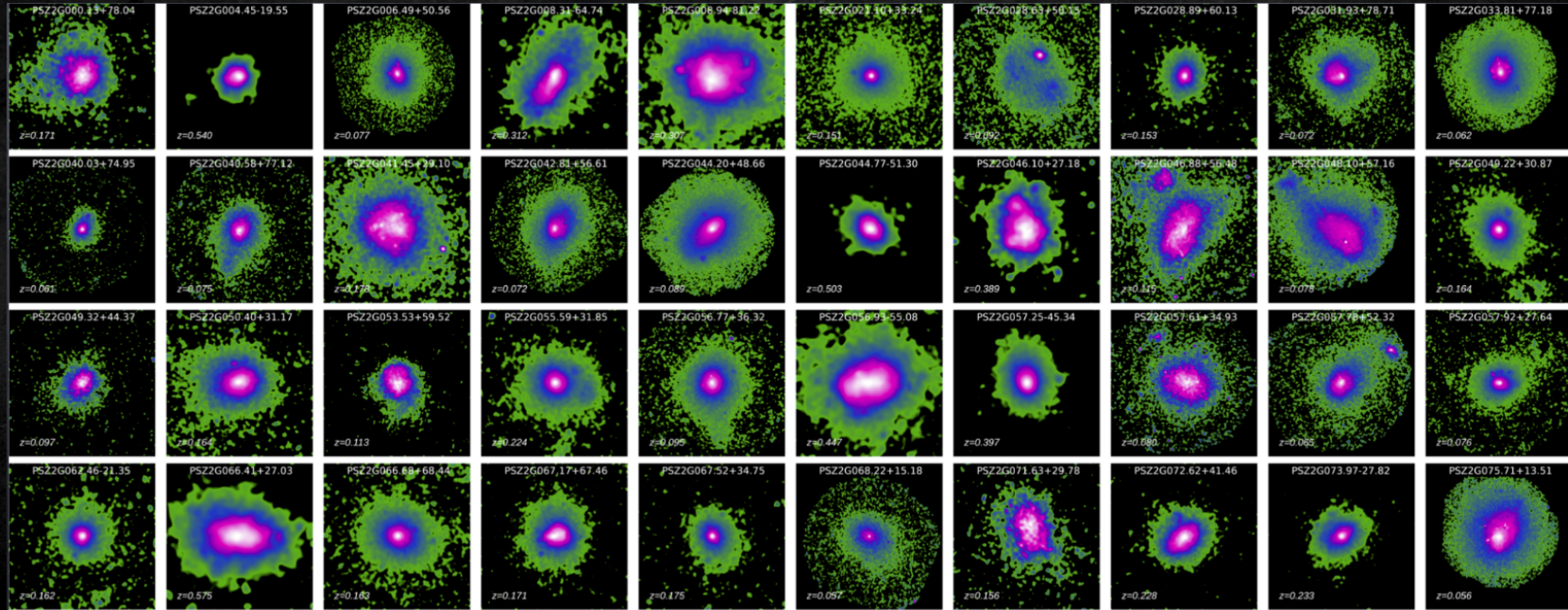
Surface brightness profiles are the most *direct*, *cheap* and *non-parametric* probe of the ICM spatial distribution



1. Introduction

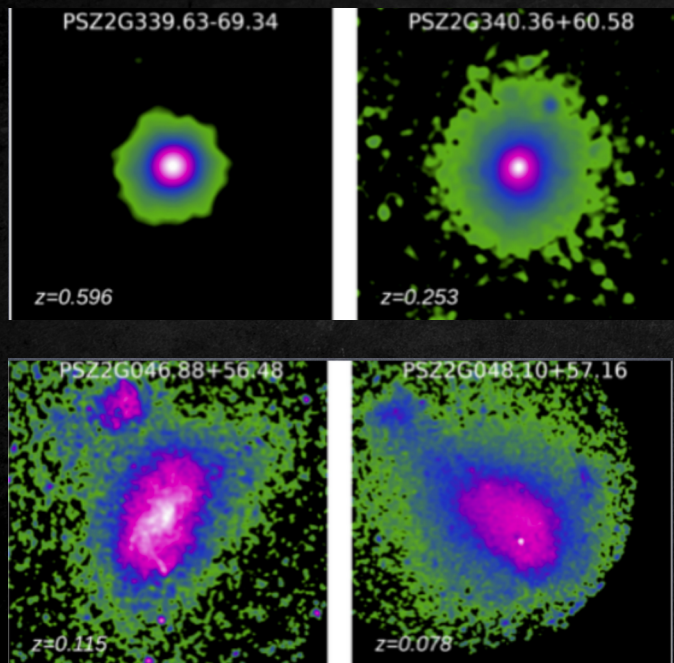
The statistical characterisation of the SX profiles and their scatter probe the formation history of GC population...

...but what is the *true* galaxy cluster population?

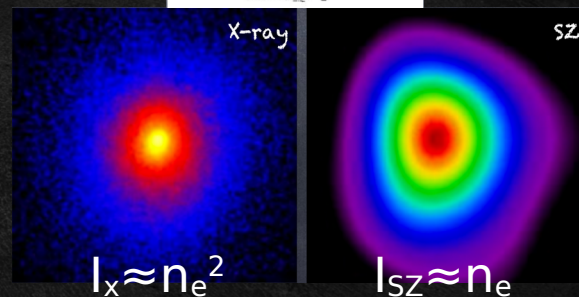
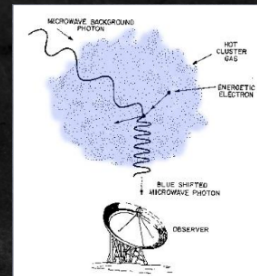


1. Introduction

X-ray surveys tend to detect “relaxed” and bright objects
($I_x \approx n_e^2$, Eckert et al 2011)



Surveys based on the Sunyaev Zel'Dovich (SZ,) effect are game changers!



Probing same component,
different properties

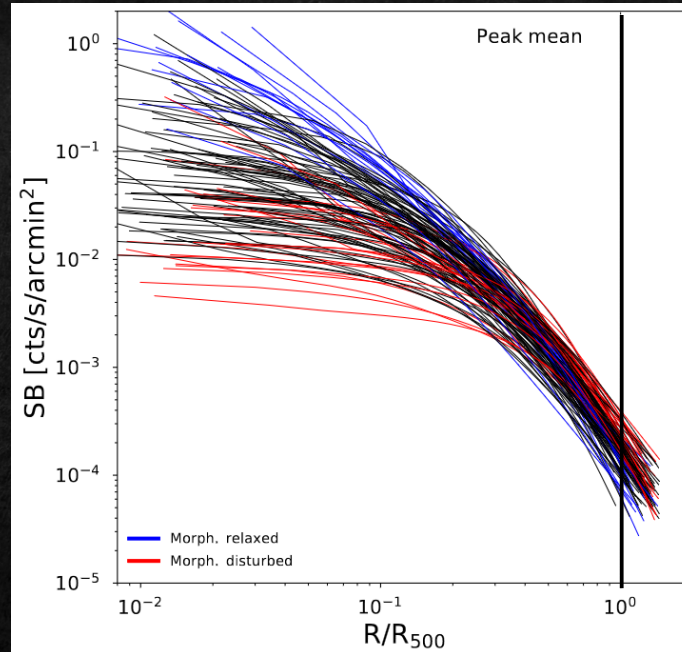
2. CHEXMATE and 300

CHEXMATE offers the opportunity to do that!

Large and minimally
biased: 118 SZ clusters

&
(1st time)

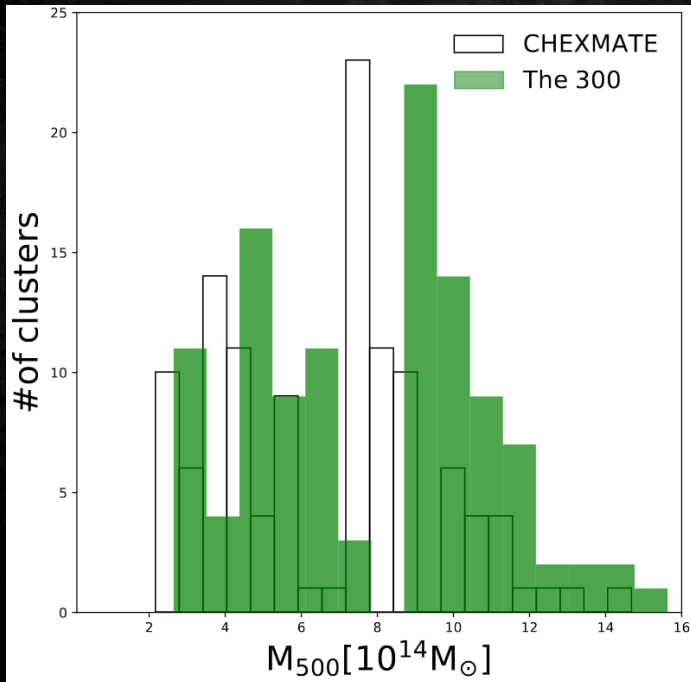
Deep and homogeneous
X-ray follow up



2. CHEXMATE and 300

We contrast our results with cosmological simulations drawn from the **THE THREE HUNDRED** project (Cui et al. 2018)

The key quantity for selection is the mass



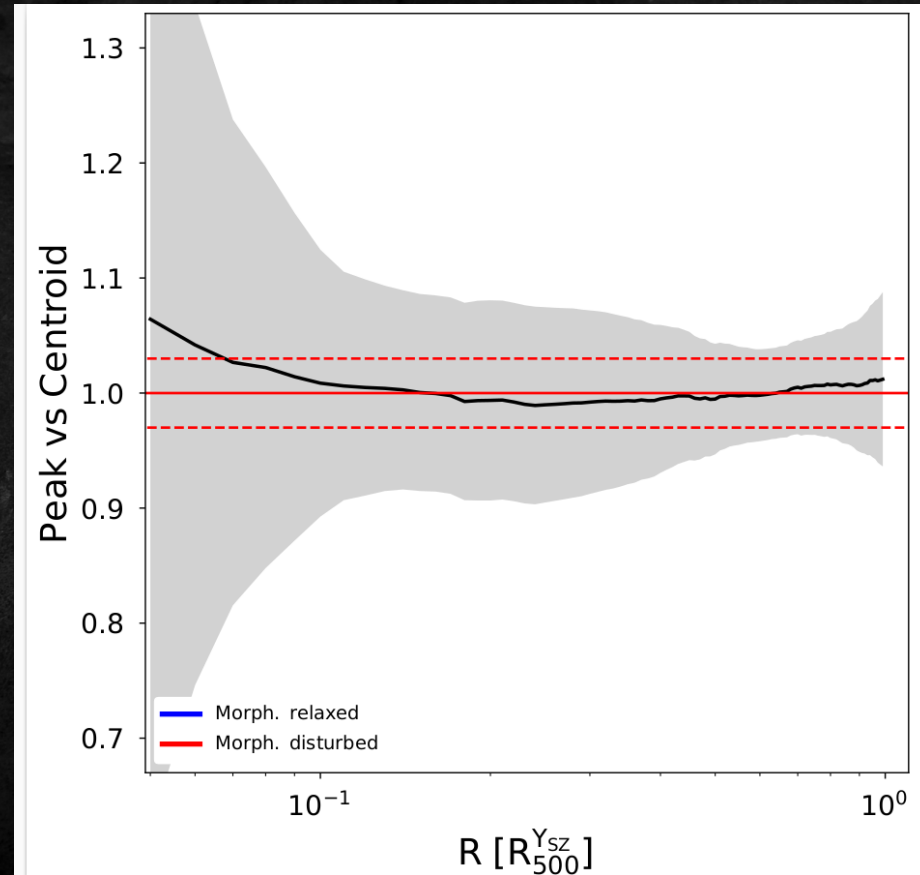
We created a “CHEXMATE like” sample of 103 simulated objects in the same CHEXMATE redshift range.

Keeping in mind that measured masses are **lower** than real masses

3. The shape of the profiles

The uniqueness of the CHEXMATE sample allows us to answer this question:

Peak Vs Centroid ?

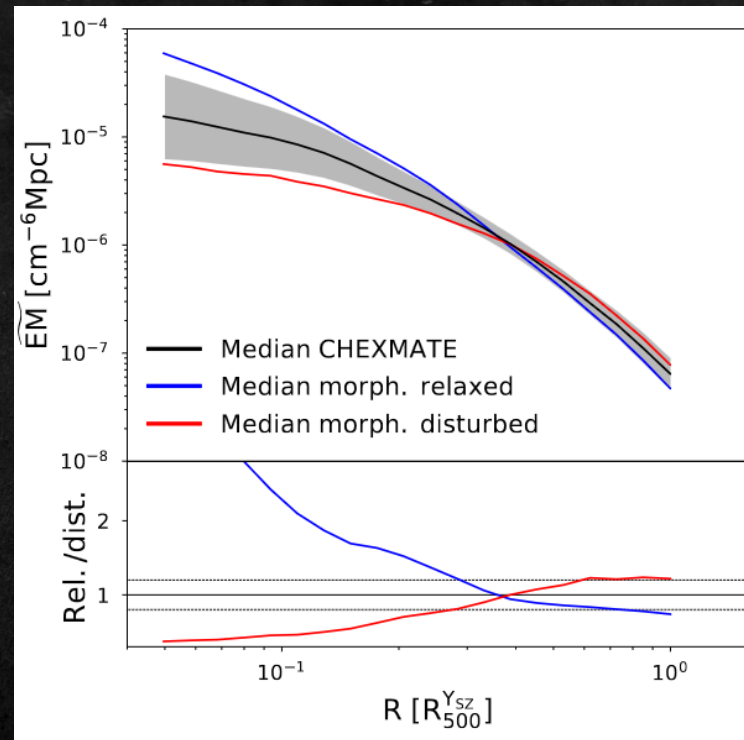


No difference!

3. The shape of the profiles

Emission measure $\text{EM} \propto \text{SX}$ scaled for self similar evolution

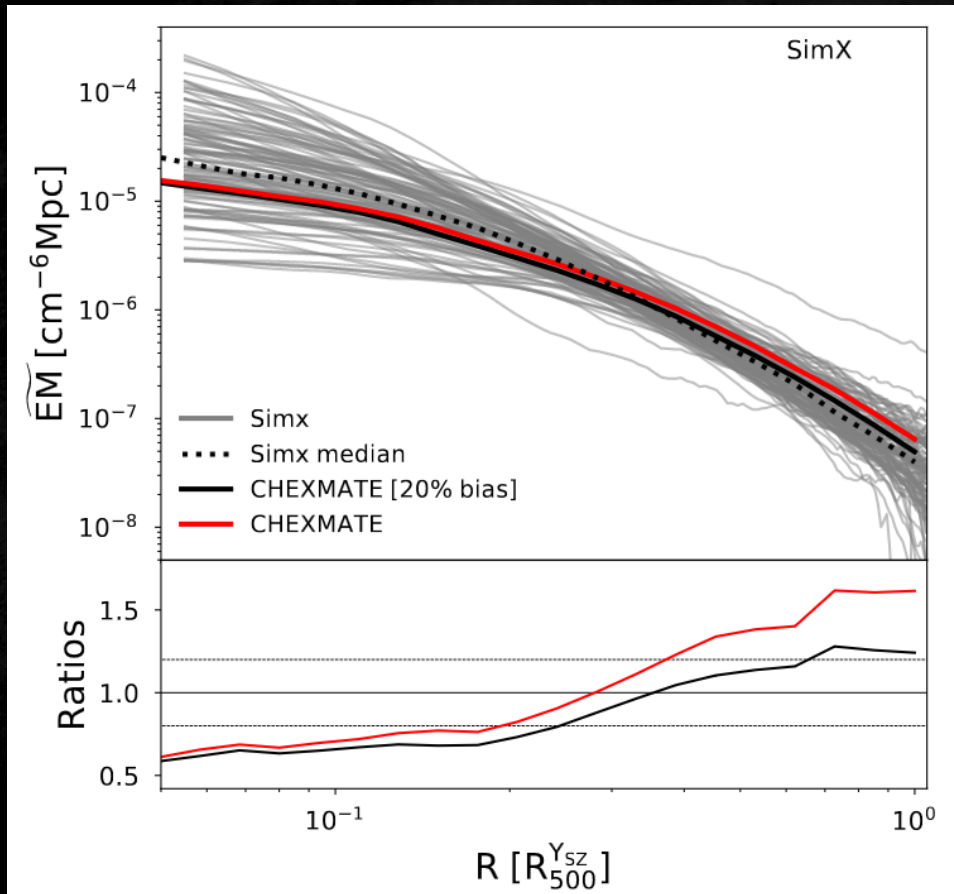
Morphology



Bartalucci et al. 2023

$R < 0.4 R_{500}$: big differences
 $R > 0.4 R_{500}$: $\sim 20\%$

3. The shape of the profiles



Bartalucci et al. 2023

Comparison with the 300 sample

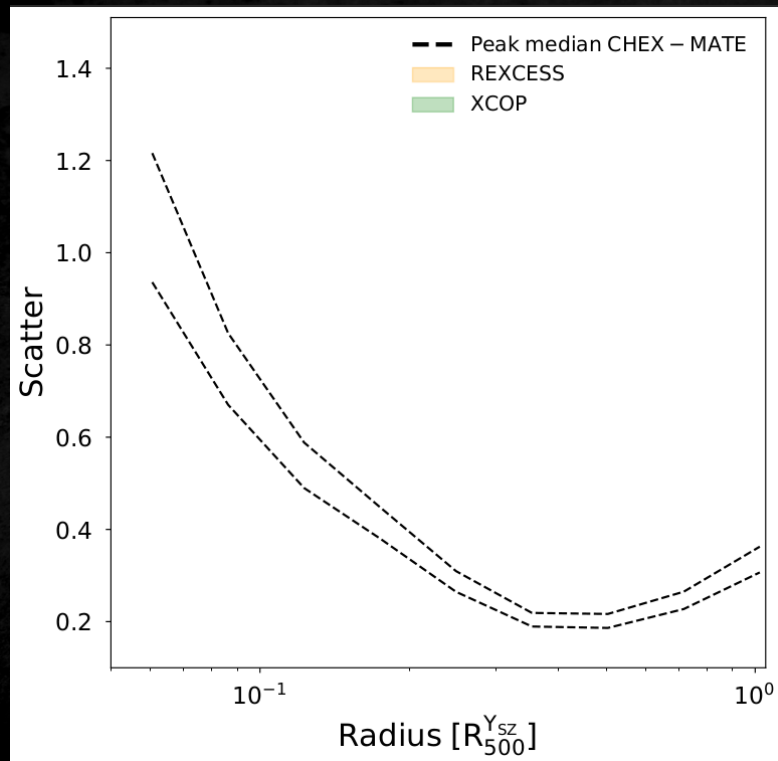
Applied X-ray typical effects
(background, PSF, vignetting...)

On average, simulations predict
steeper profiles...still
understanding

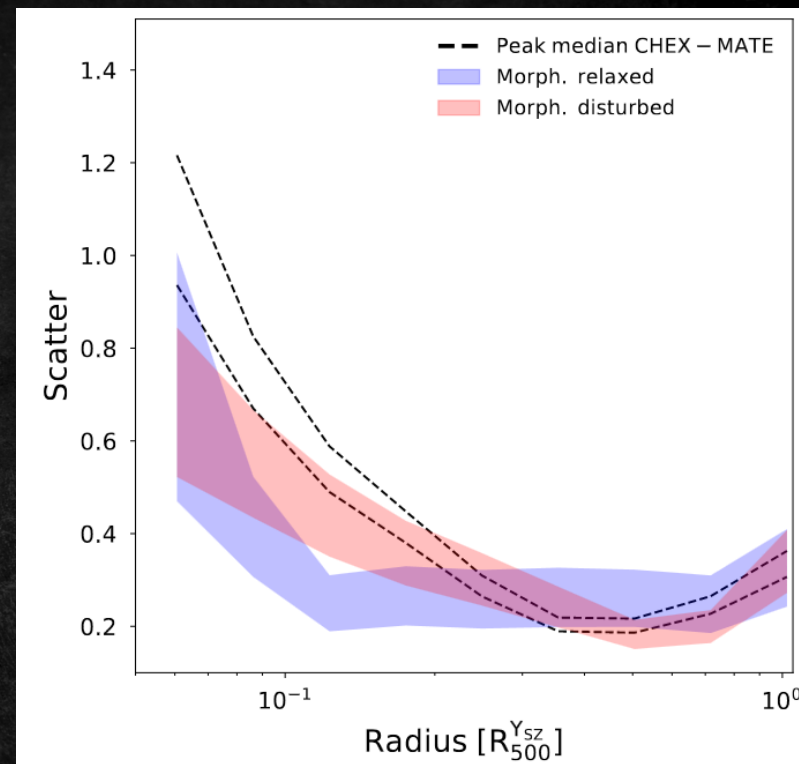
Considering the mass bias
mitigates the differences!

4. The origin of the scatter

Scatter of CHEXMATE!



<0.4 R_{500} : large scatter
>0.4 R_{500} : minimum
~ R_{500} : mild increase



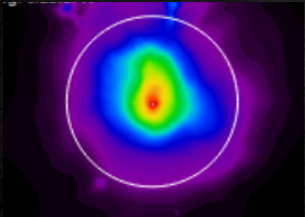
Morphology contribution
~0.4 R_{500} critical scale

4. The origin of the scatter

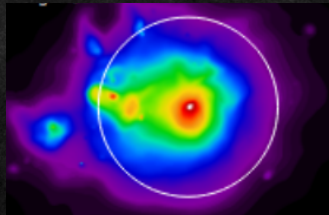
With simulations in hand, we can break down the contributions to the origin of the scatter

- Total: genuine difference between objects

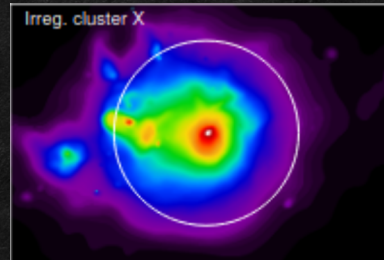
- Projection: same object seen from different directions



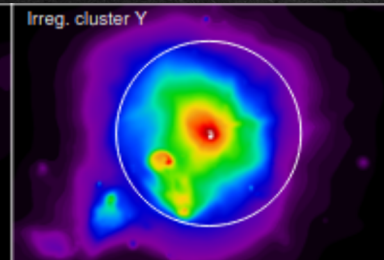
Regular Sim cluster



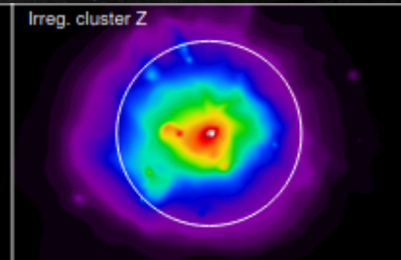
Irregular Sim cluster



Irr. Cluster X projection



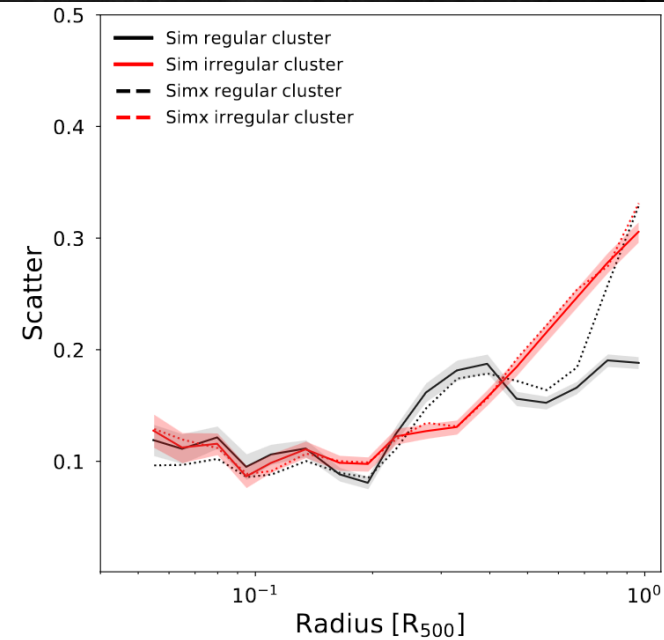
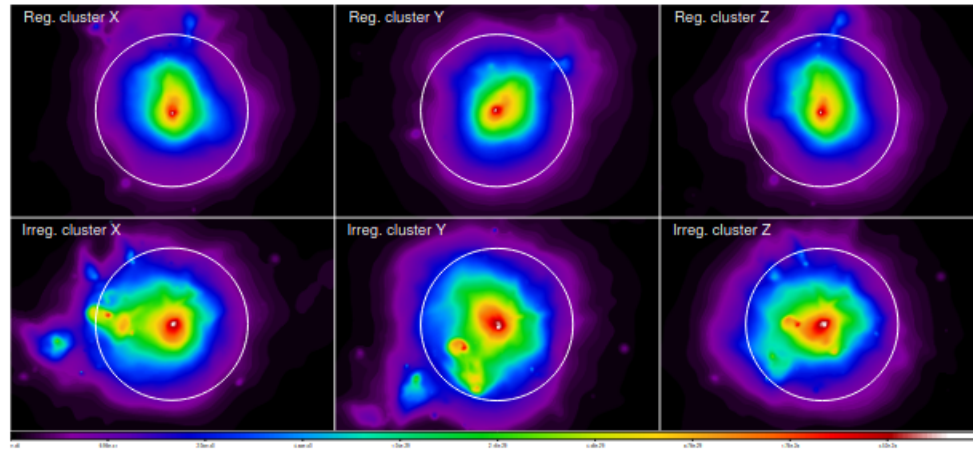
Irr. Cluster Y projection



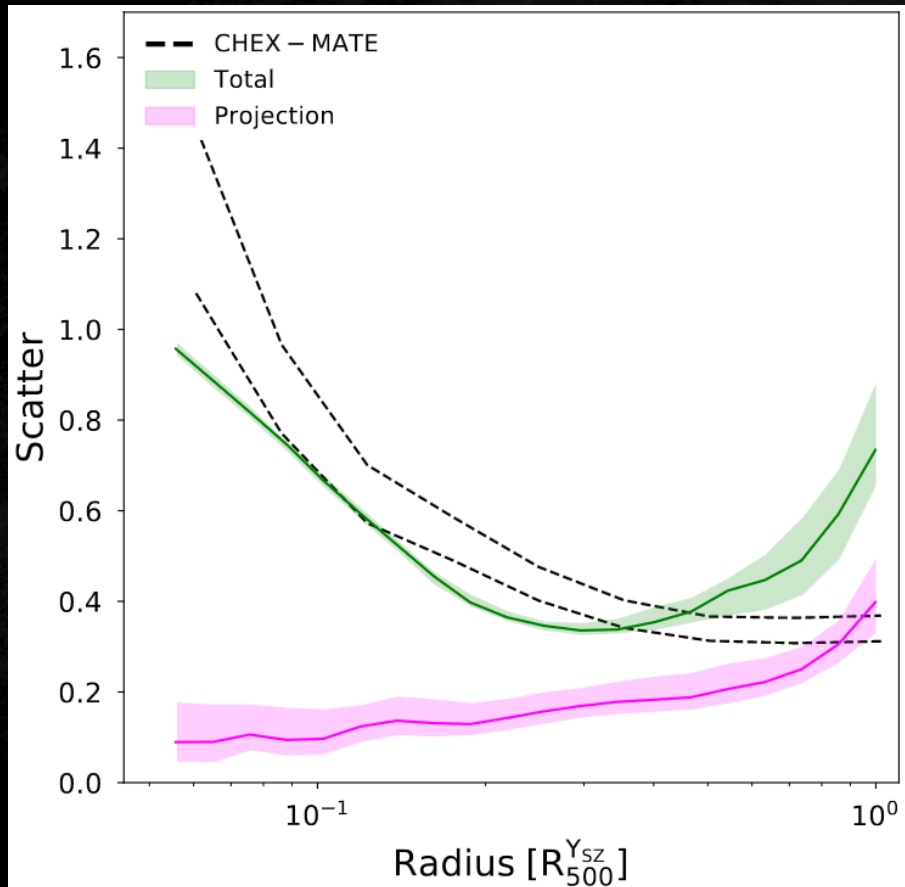
Irr. Cluster Z projection

4. The origin of the scatter

With simulations in hand, we can break down the contribution to the origin of the scatter



4. The origin of the scatter



Bartalucci et al. 2023

Overall, excellent agreement of the behaviour at all scales!

With observations we are able to see the real scatter between clusters!

Larger scatter at R_{500} ...

- different treatment between obs and Sim
- Sim predicting more structures?

5. Results & conclusions

We derived the SX/EM profiles of the 118 clusters of the CHEXMATE sample and found:

- difference between most relaxed and disturbed depends on the **scale**;
- broke down the **components** of the scatter;
- found that projection scatter is **small**;
- we are able to measure the real scatter of galaxy clusters