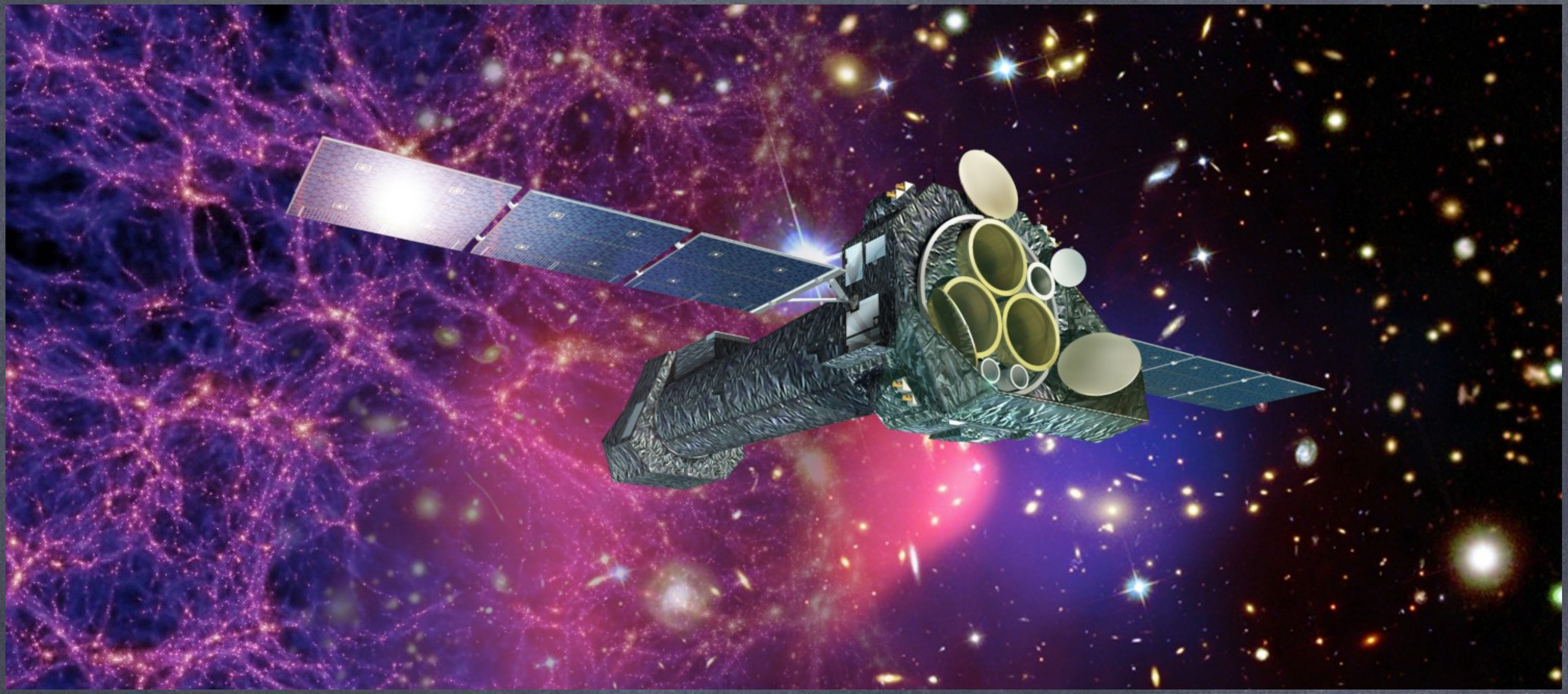
Surface brightness profiles of the CHEX-MATE galaxy clusters



Iacopo Bartalucci
on behalf of the CHEXMATE collaboration

in collaboration with:
M. Arnaud, F. Gastaldello, S. Ghizzardi, S. De Grandi, S. Molendi, M. Rossetti, M. Arnaud, D. Eckert, G.W. Pratt, E. Rasia

mm Universe @ NIKA2
30/06/2021

Outline

Introduction

The CHEX-MATE sample

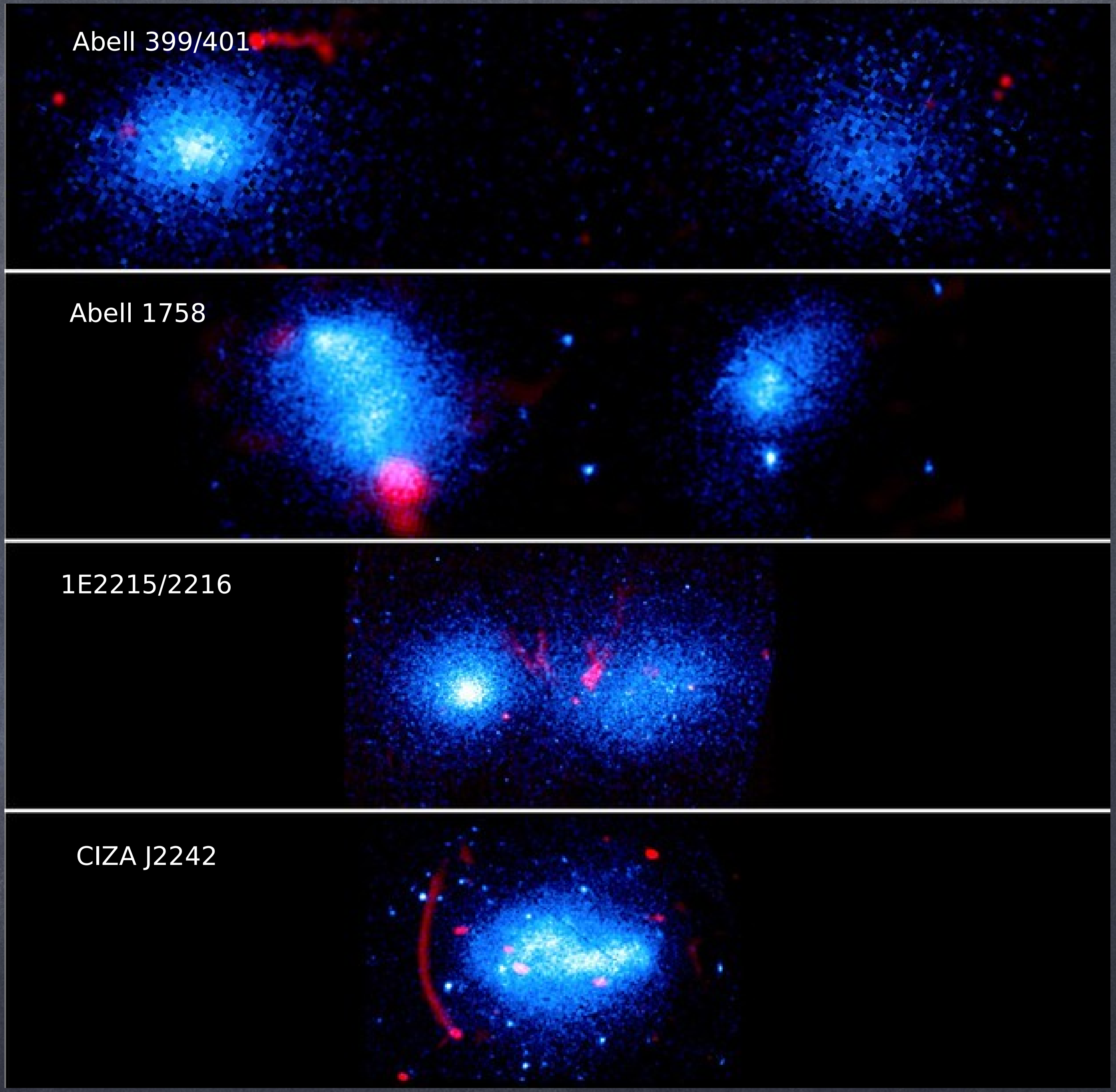
1D Morphology

SX profile intrinsic scatter

Results and Future prospects

Introduction: cluster X-ray characteristics

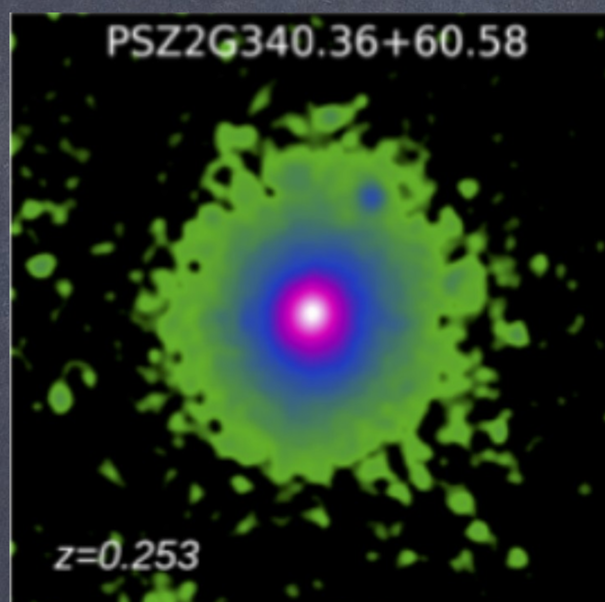
The IntraCluster-Medium (ICM) retains information on the cluster formation history

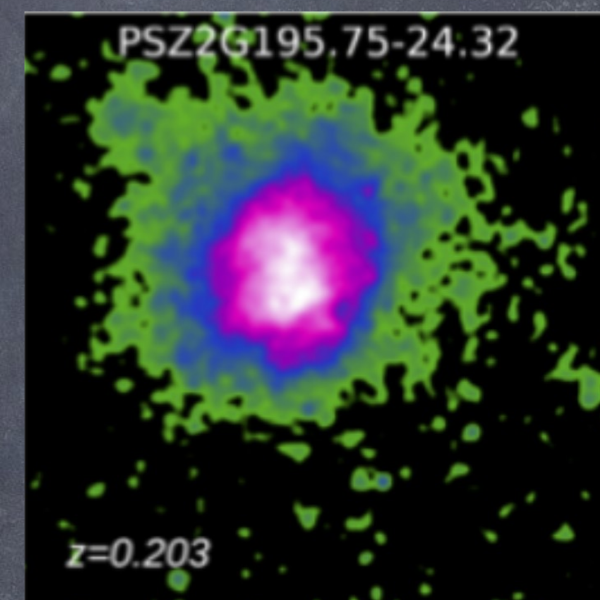


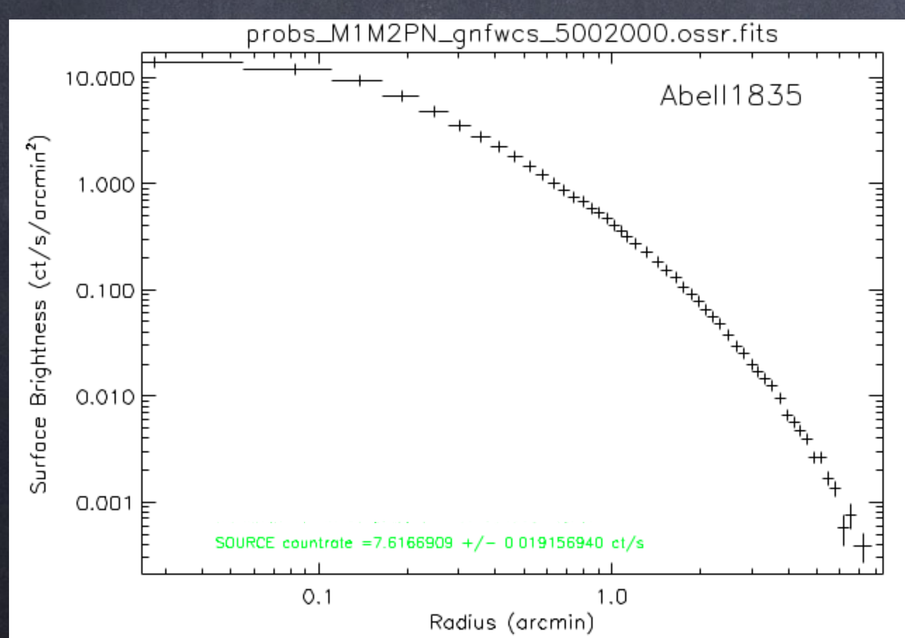
Credit: NASA

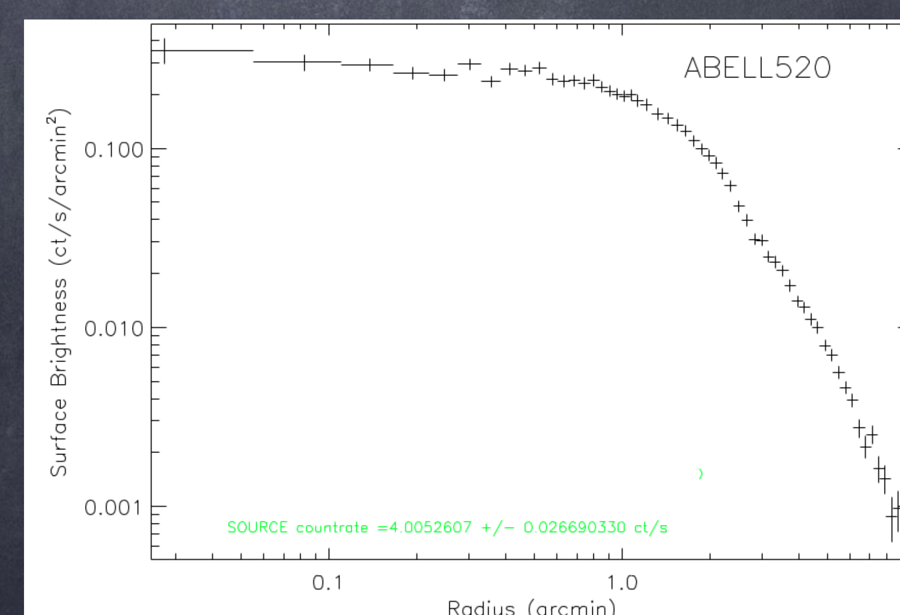
Introduction: the surface brightness profile

X-ray surface brightness profile is the most direct (and “cheap”) probe of the ICM spatial distribution







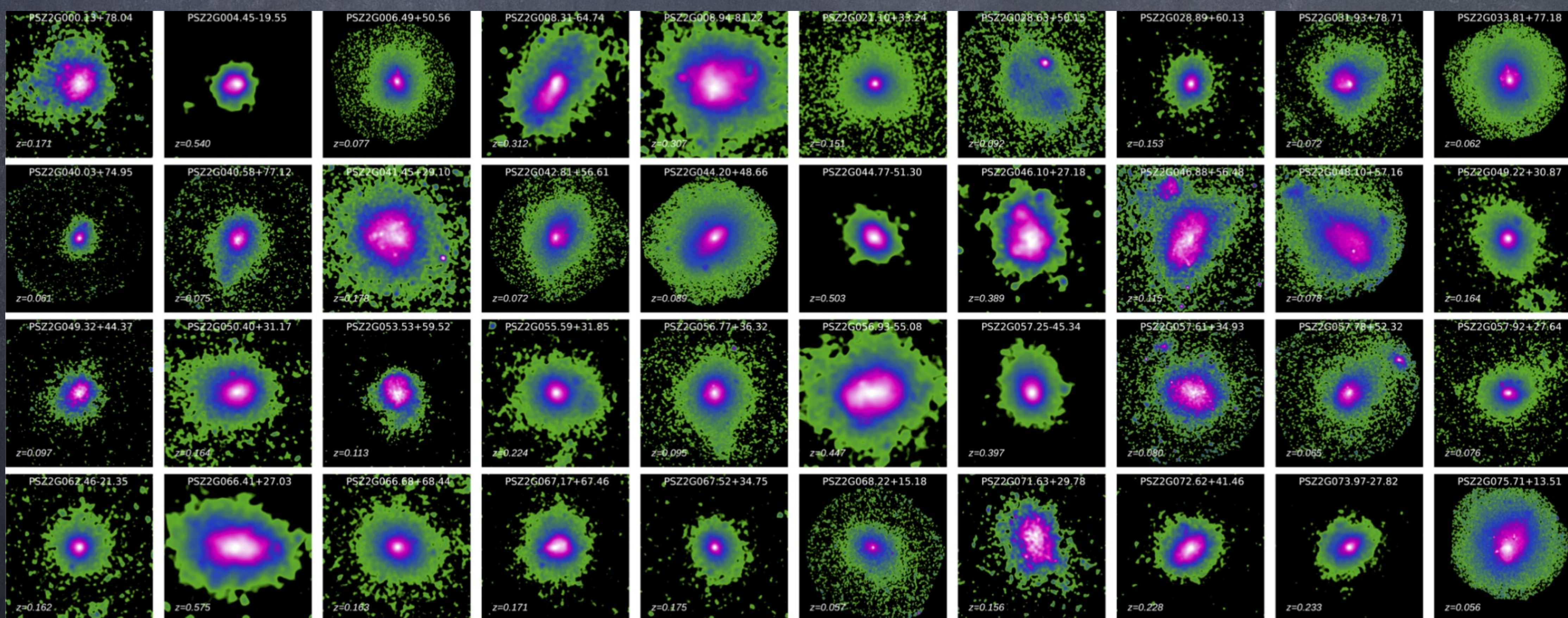


Credit: G. W. Pratt and A. Iqbal

Introduction: the cluster population

The statistical characterisation of the SX profiles probes the formation history of GC population

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

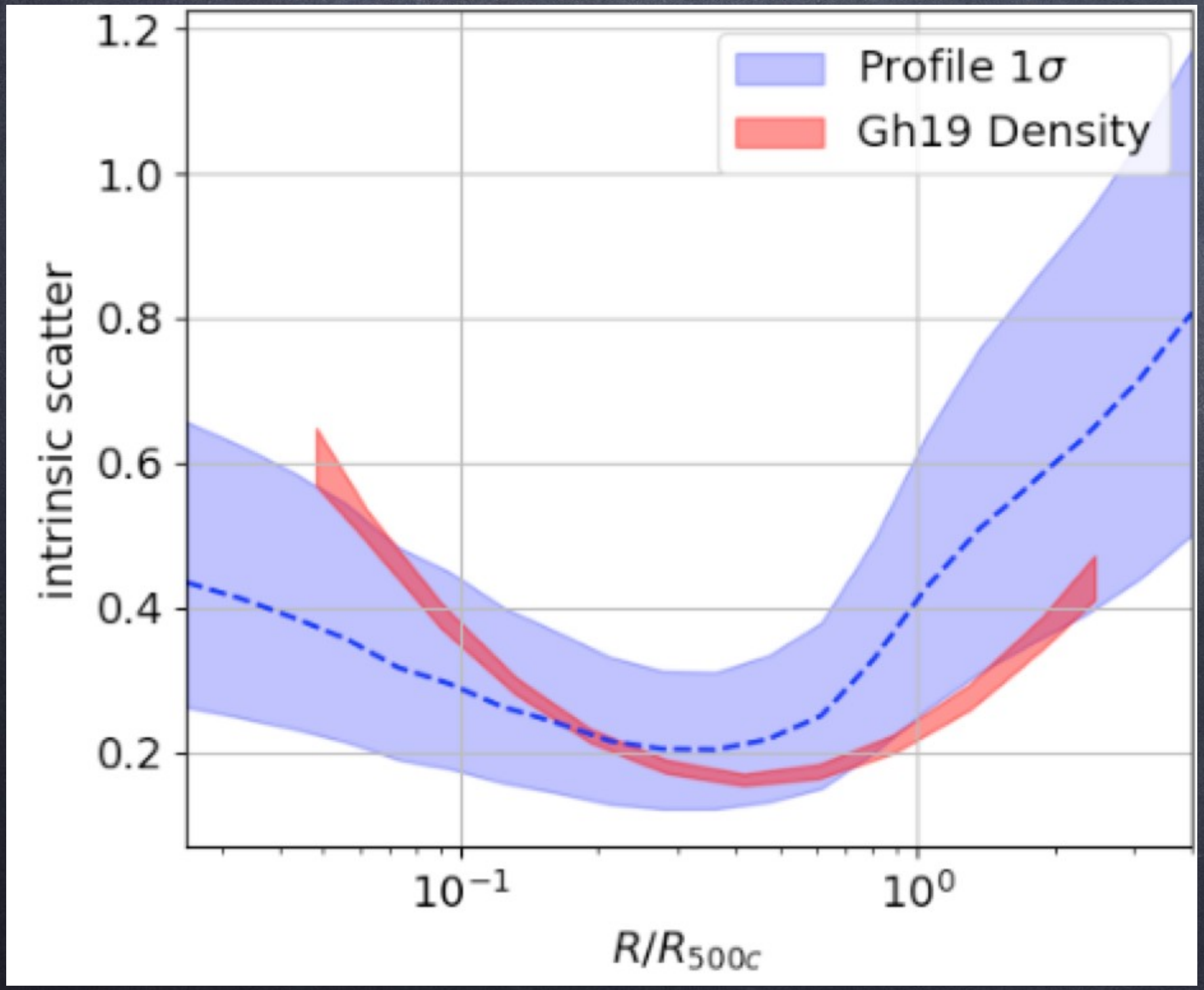


The CHEX-MATE coll. 2021

Introduction: the cluster population

The statistical characterisation of the SX profiles probes the formation history of GC population

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



Comparat et al. 2020

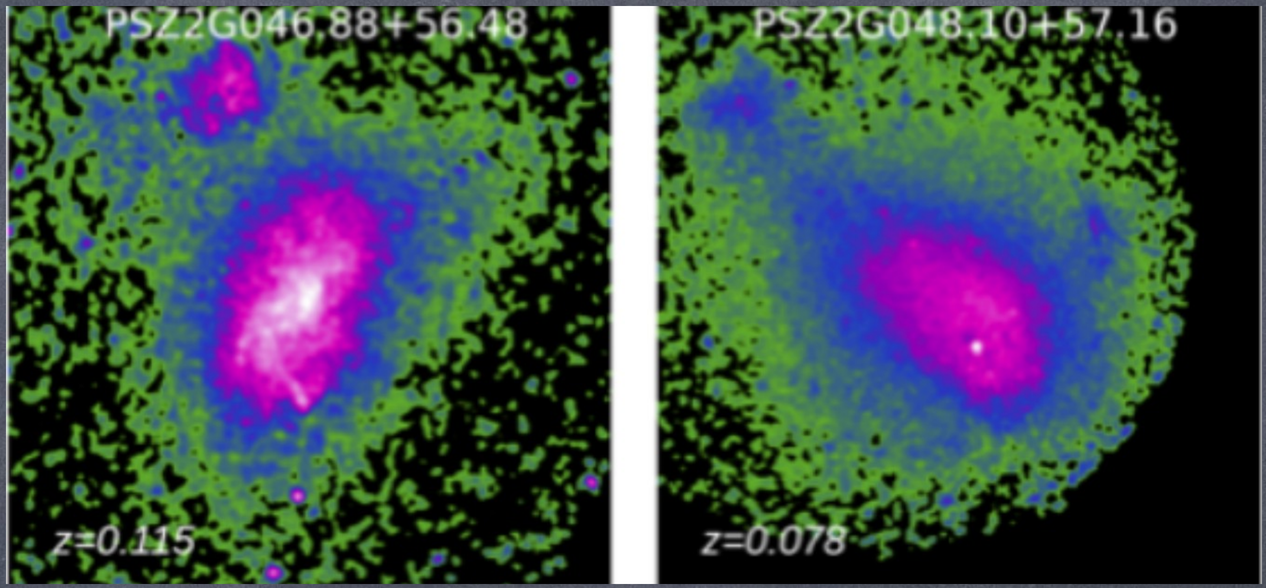
Putting toghether cluster samples to simulate SX profiles for eRosita

Introduction: selection effects

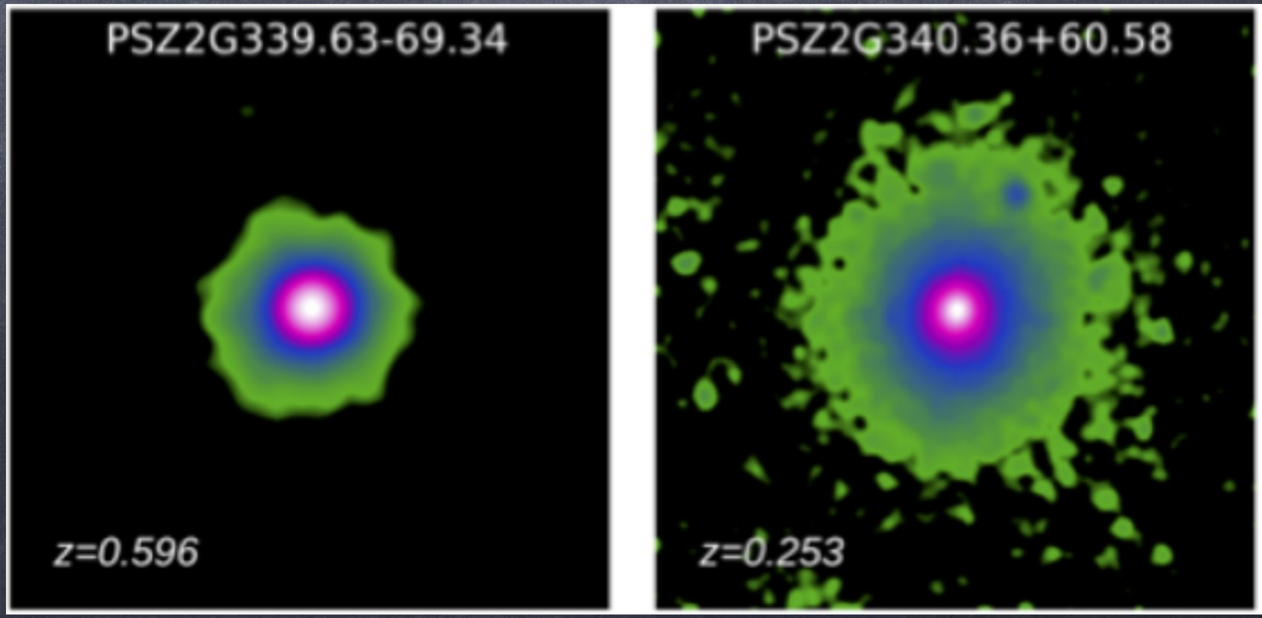
X-ray surveys tend to detect “relaxed” and bright objects

CC bias (see e.g. Rossetti et al. 2017)

($I_x \approx n_e^2$, Eckert et al 2011)



Morphologically disturbed

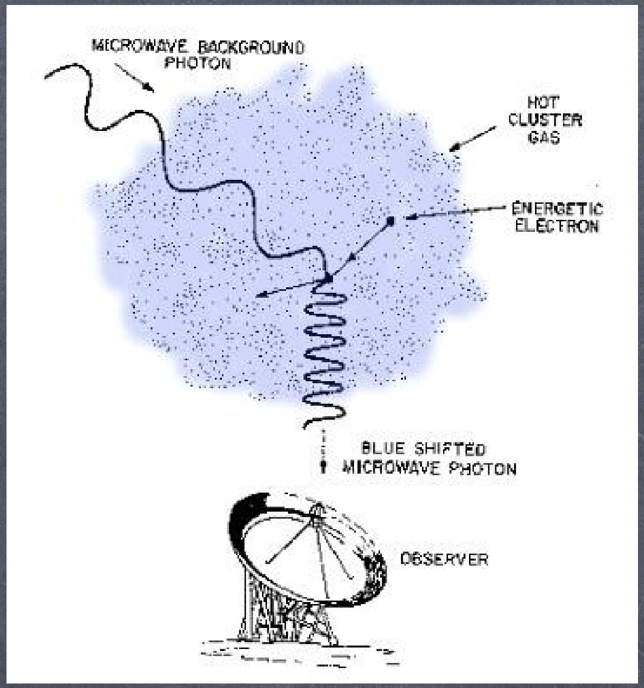


Relaxed Cool-Core

The CHEX-MATE coll. 2021

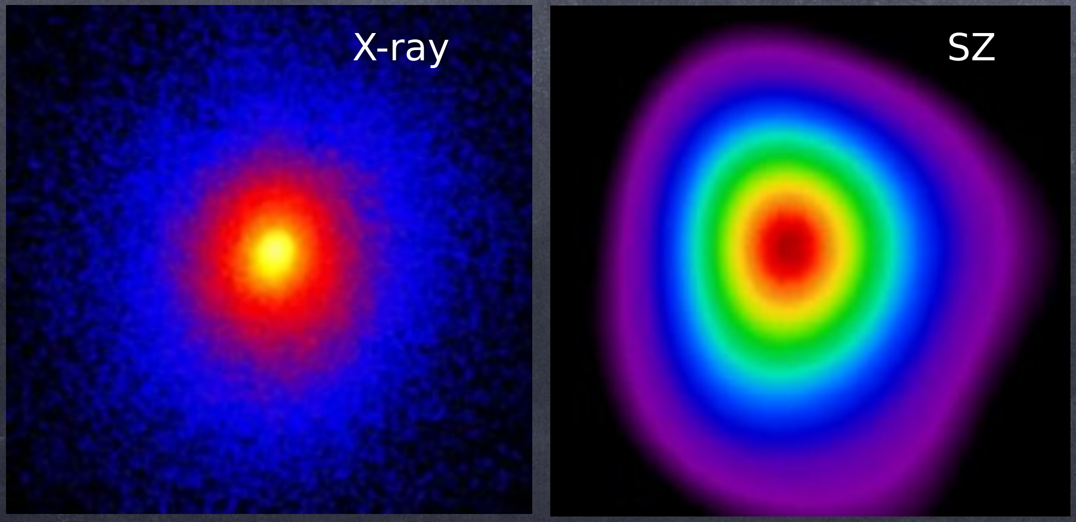
Introduction: SZ surveys

SZ surveys are game changers!



Probing same component

$I_x \approx n_e^2$



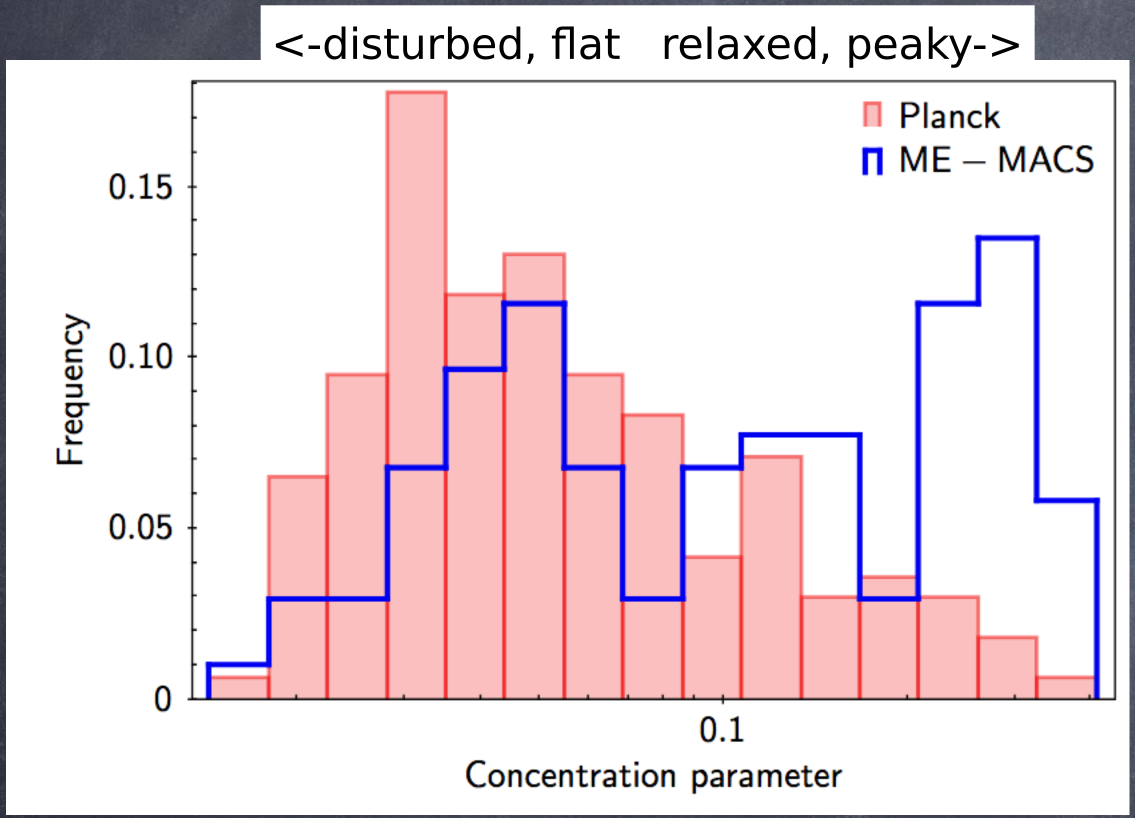
$I_{SZ} \approx P(n_e)$

Abell 1835

different properties

Introduction: SZ surveys

X-ray vs SZ selection



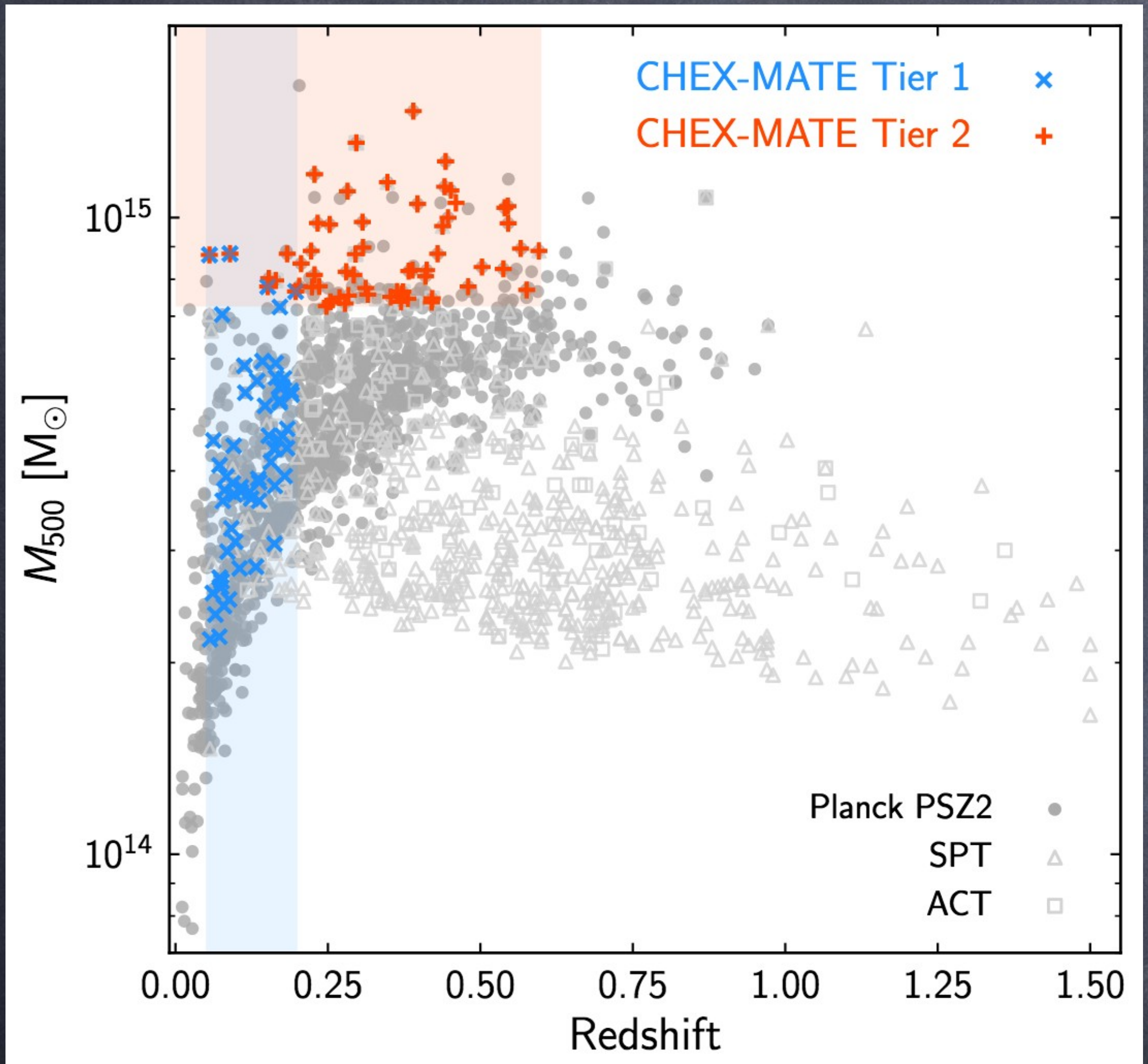
Rossetti et al. 2017

Planck — SZ selected
Planck coll. XX 2014

ME – MACS — X-ray selected
Mann and Ebeling 2012

Generally speaking:
SZ selected samples: ~30% CC clusters
(no evoution with redshift e.g. Ruppin et al. 2020)

The CHEX-MATE sample



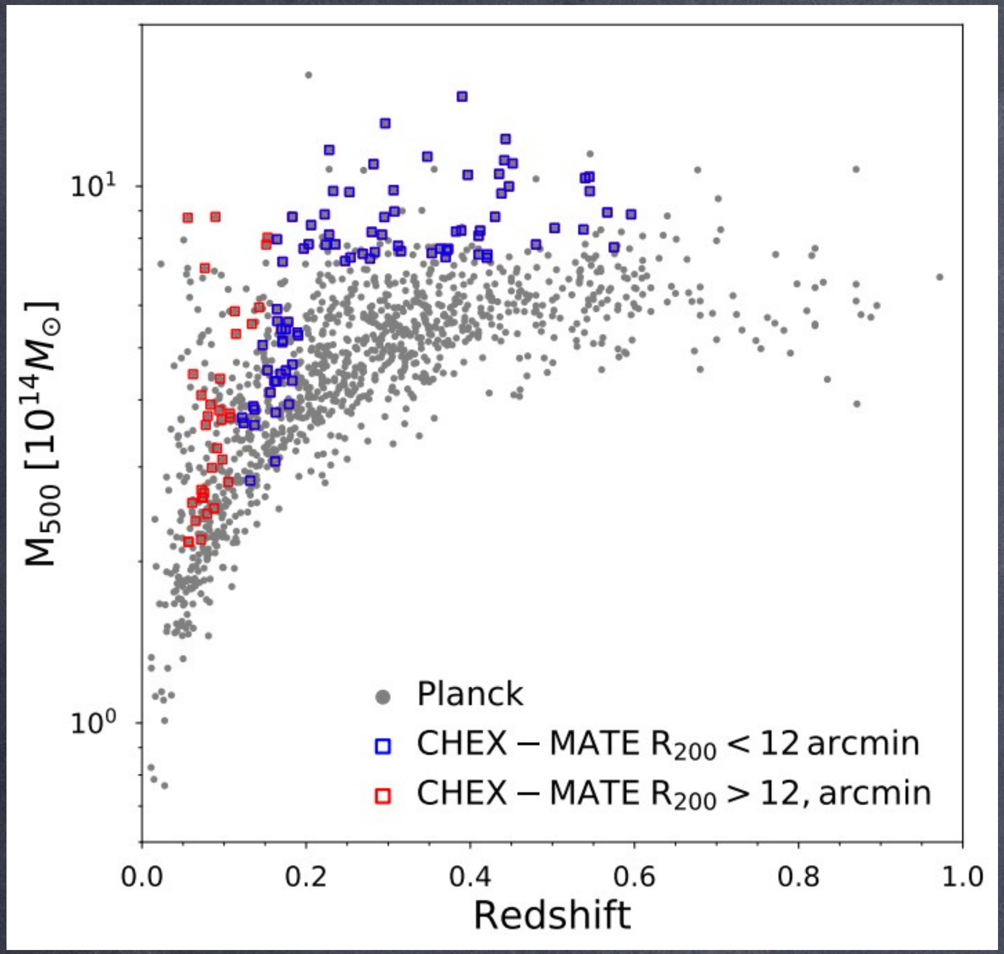
The CHEX-MATE coll. 2021

XMM <u>deep</u> and <u>homogenous</u> coverage of 118 clusters detected by Planck at high S/N

- Tier 1: census of the cluster population at most recent times
- Tier 2 most massive systems to have formed so far in the Universe

A low and intermediate redshift anchor for cluster evolution studies

The CHEX-MATE sample: this work subsample

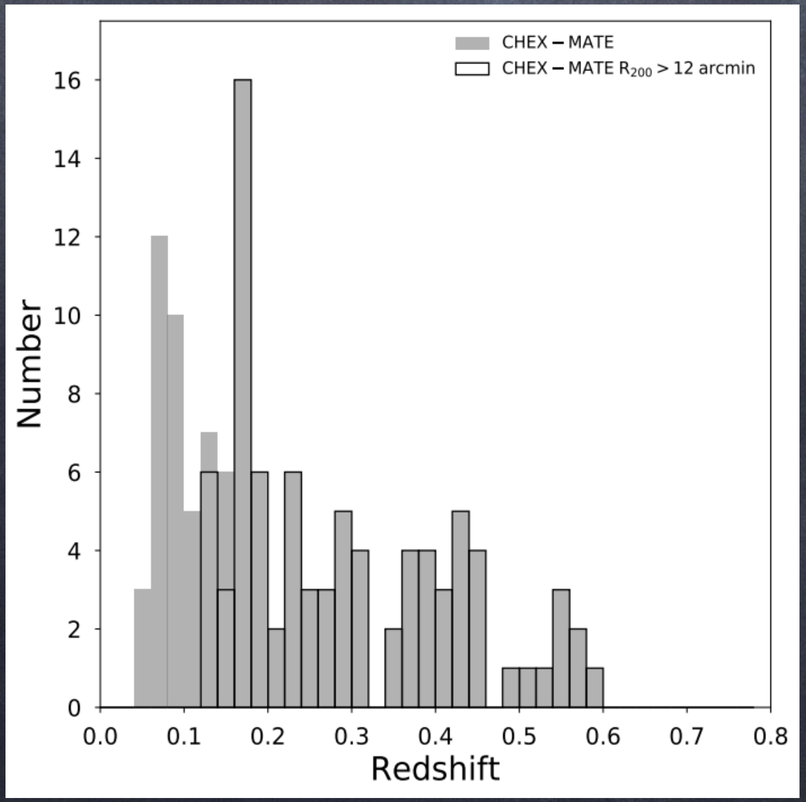


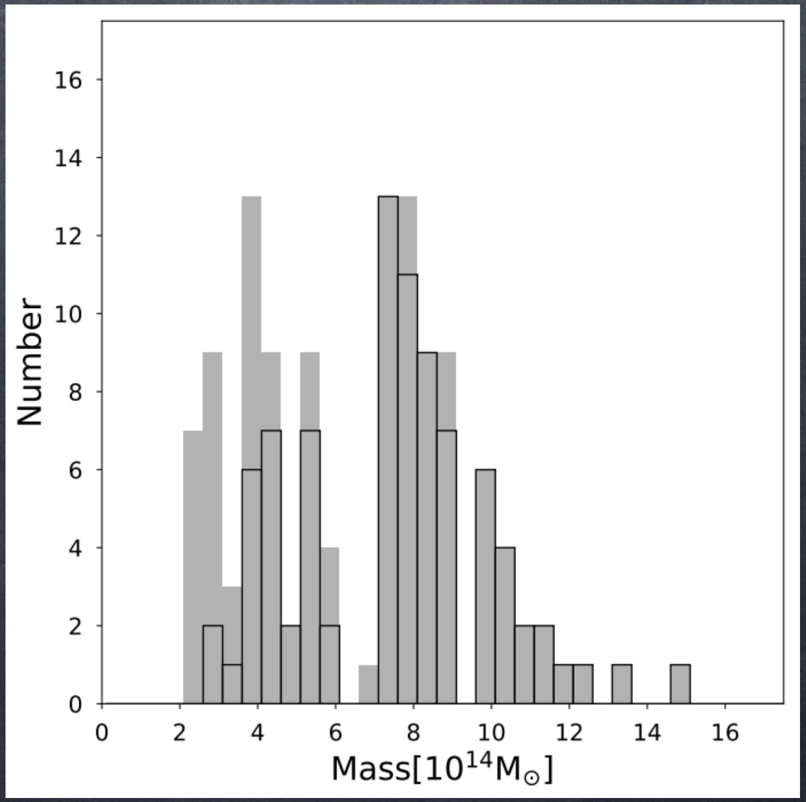
Bartalucci et al. in prep

For this work, we cut clusters for which R200 > 12 arcmin

Analysis is particularly chalenging for clusters filling the fielf of view

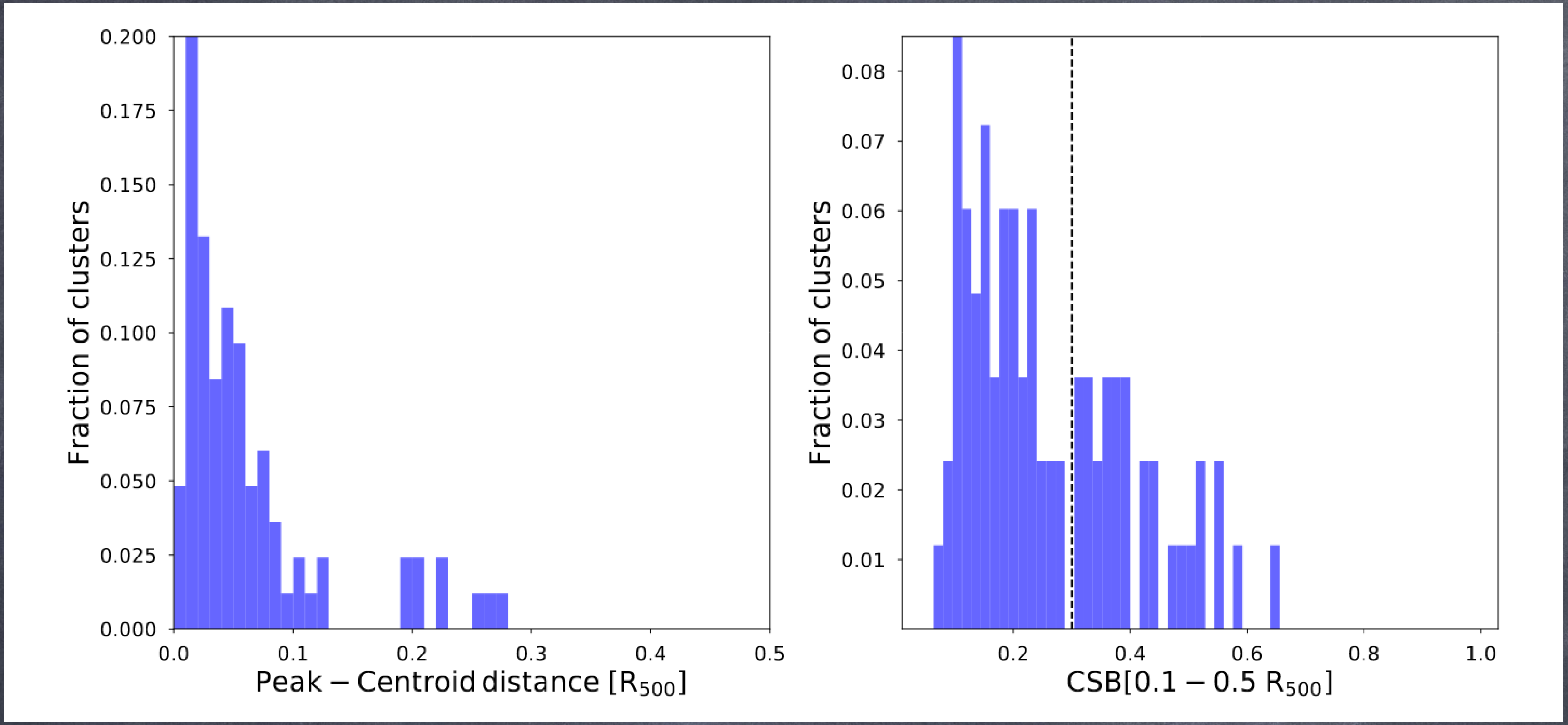
This cut yields 89 objects (~75% of the whole sample!)





The 1D Morphology

Bartalucci et al. in prep



Offset between Peak and Centroid in terms of R_{500}

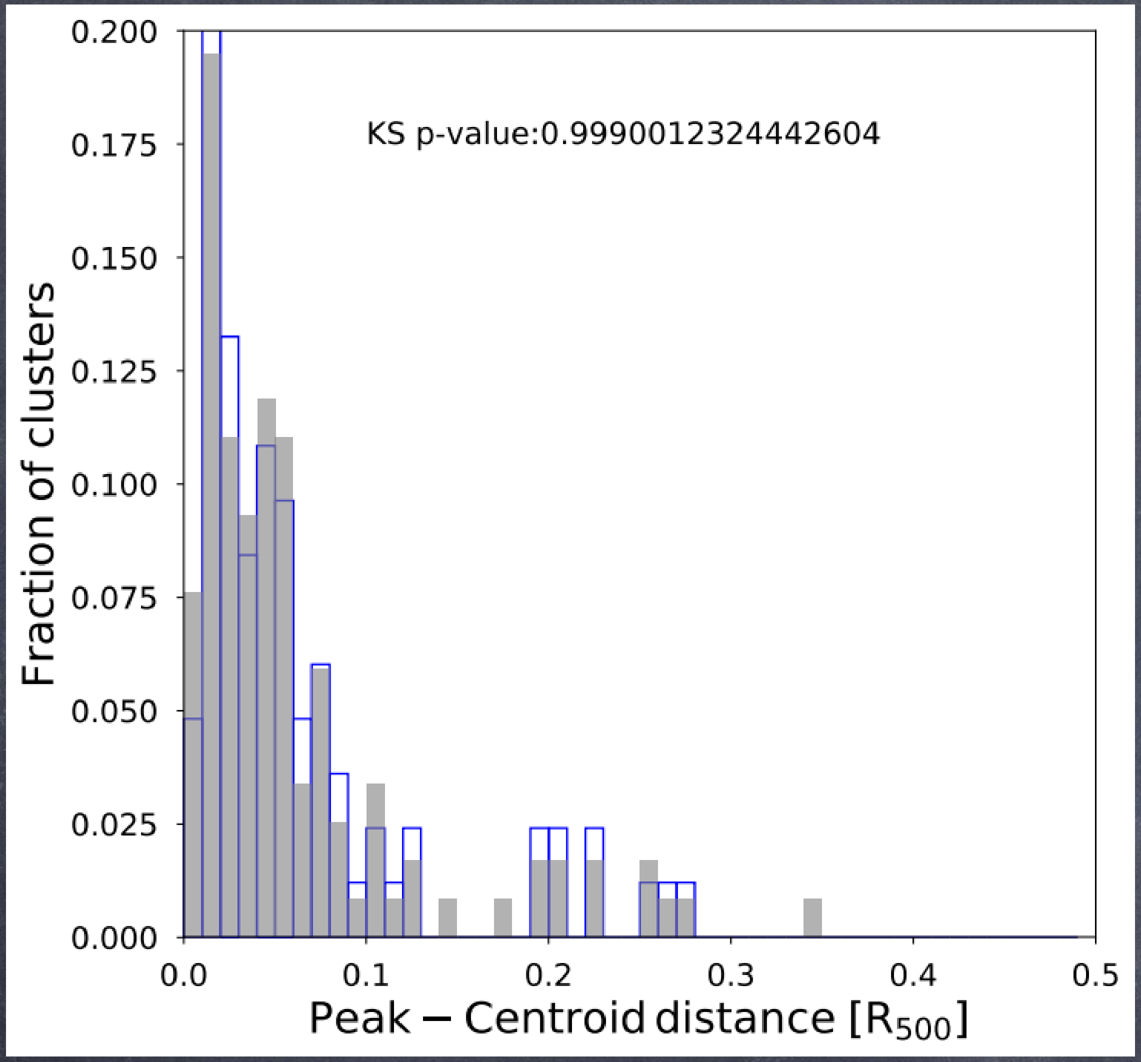
CSB = concentration of Surface brightness → flux ratio within fixed apertures

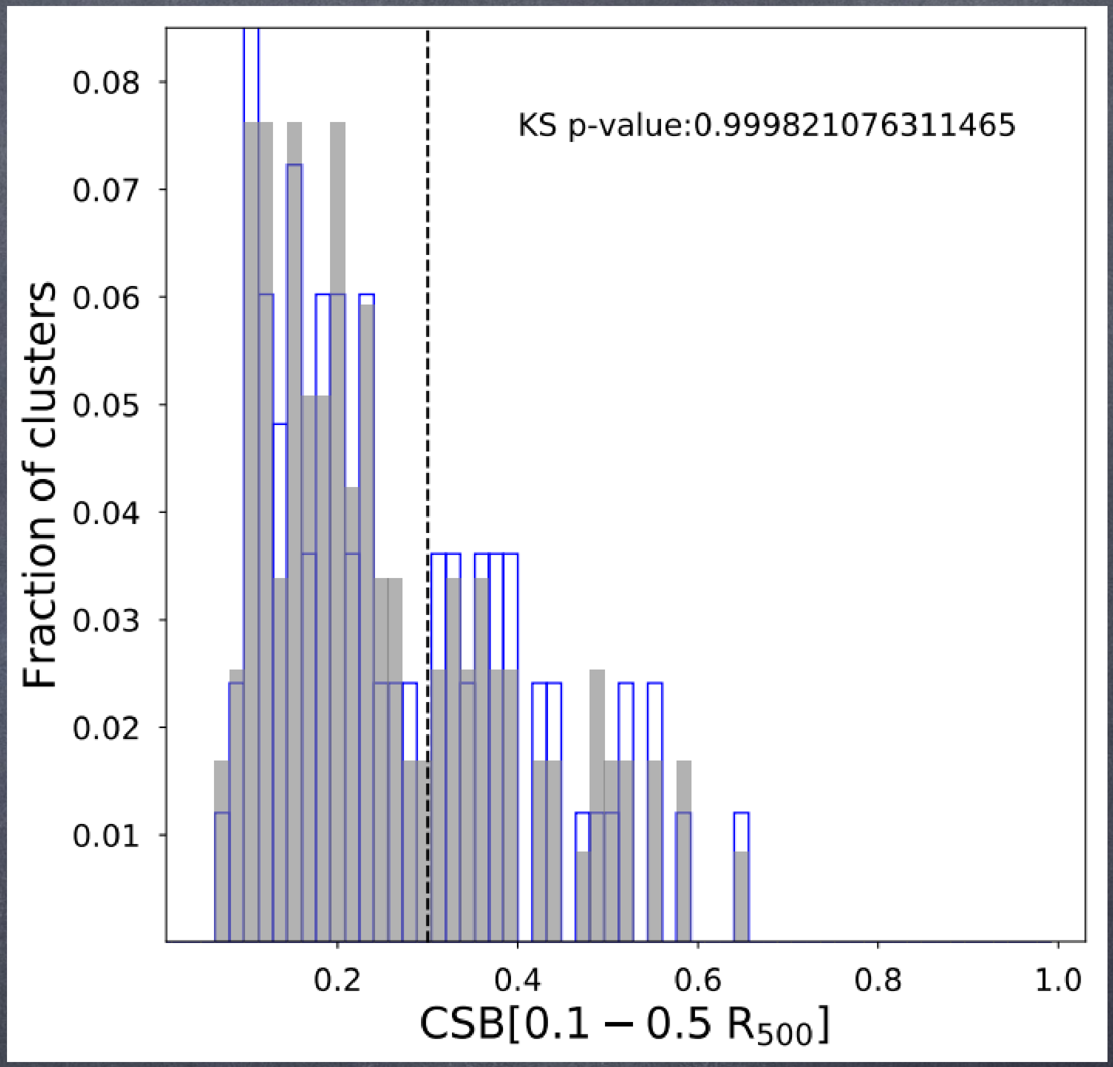
If we take as CC/nCC threshold =0.3 → (CC fraction ~30%)

Continuous distribution, no hint for population segregation

The 1D Morphology: representativity

Bartalucci et al. in prep





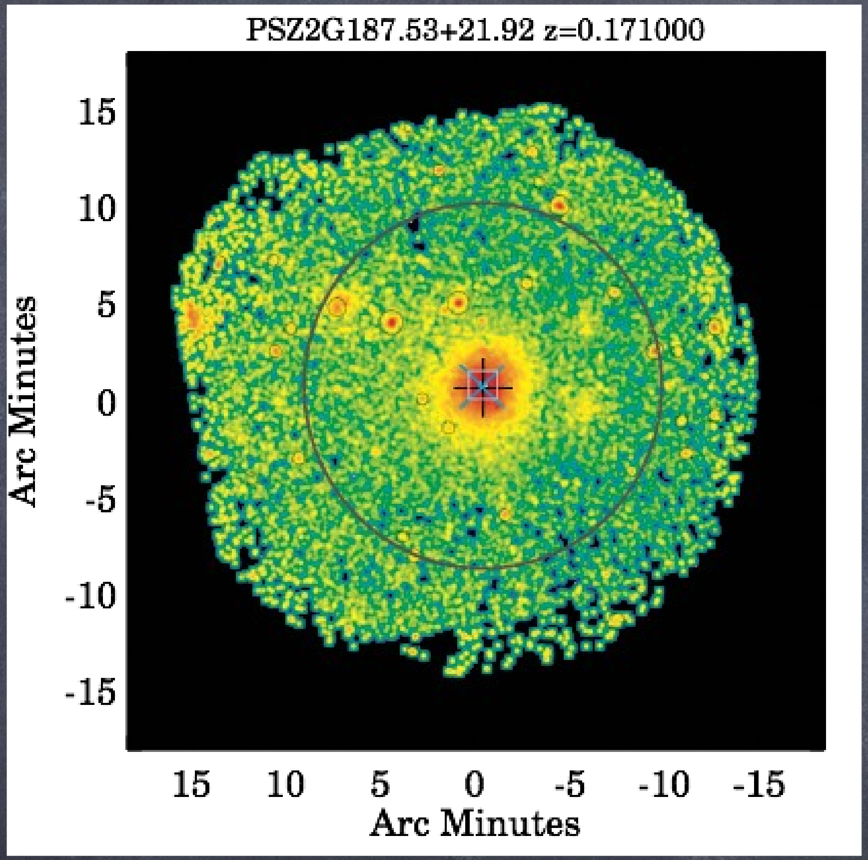
Is the cut a problem? From a morphological point of view no!

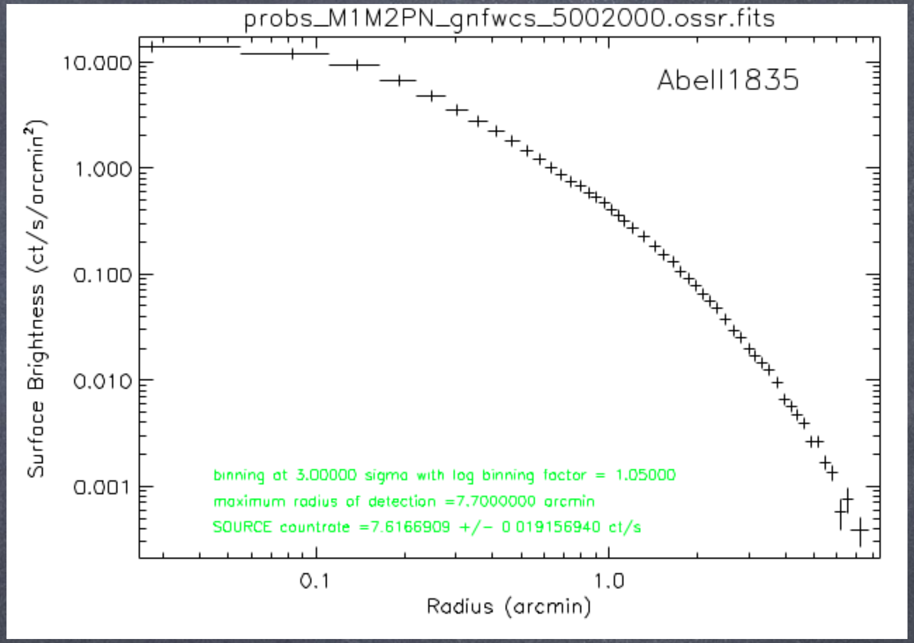
the sub-sample still representative of CHEX-MATE sample

KS tests yields 99% both for Peak-Centroid and CSB

Surface brightness profiles: production

Data analysis and SX production are already a new result: combining pipelines/expertise



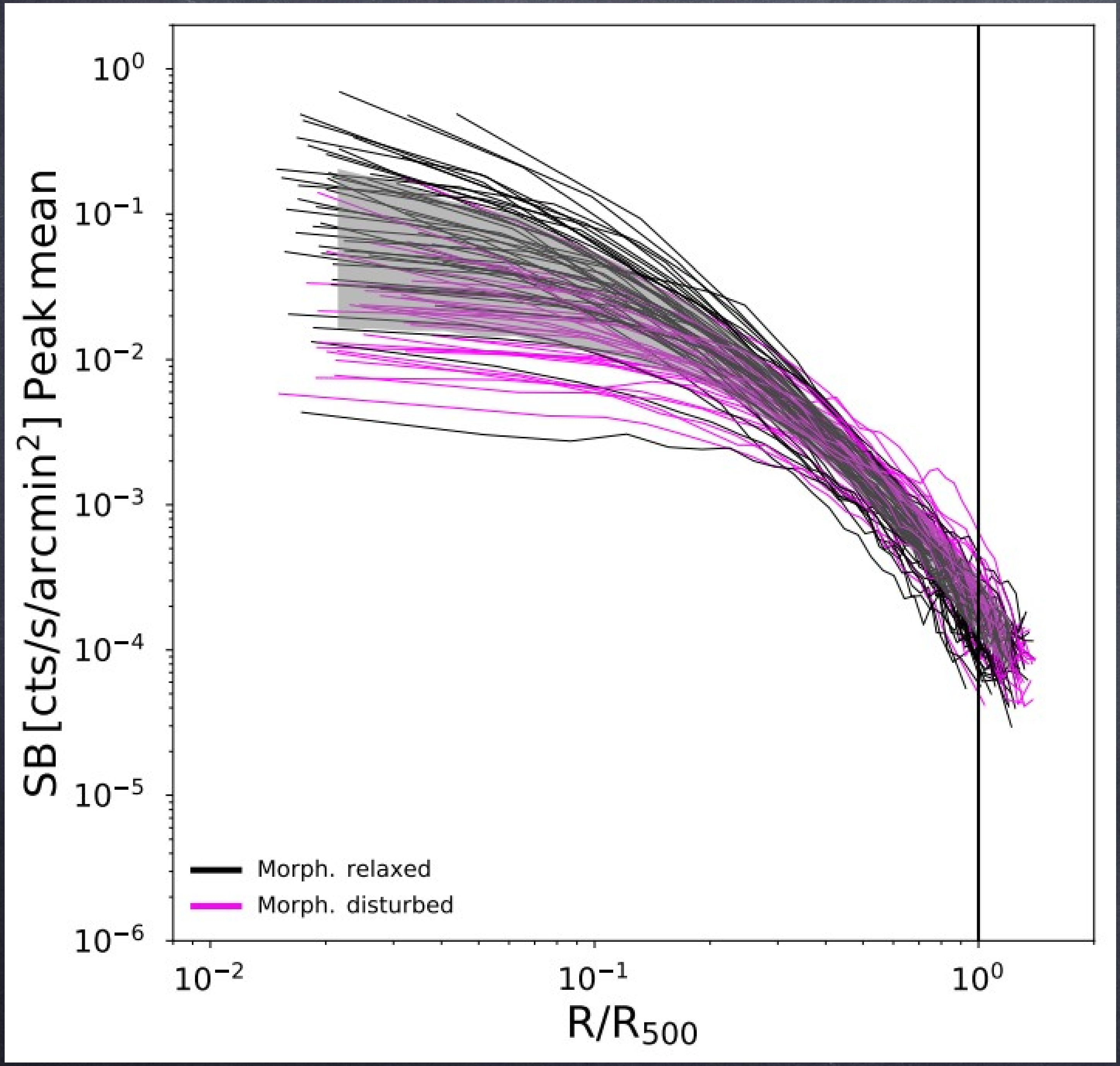


- For this work e.g.
  - improved background subtraction
  - improved point source detection/masking
  - spatial resolution of profiles

Surface brightness profiles: the data quality

Data quality

SX profile



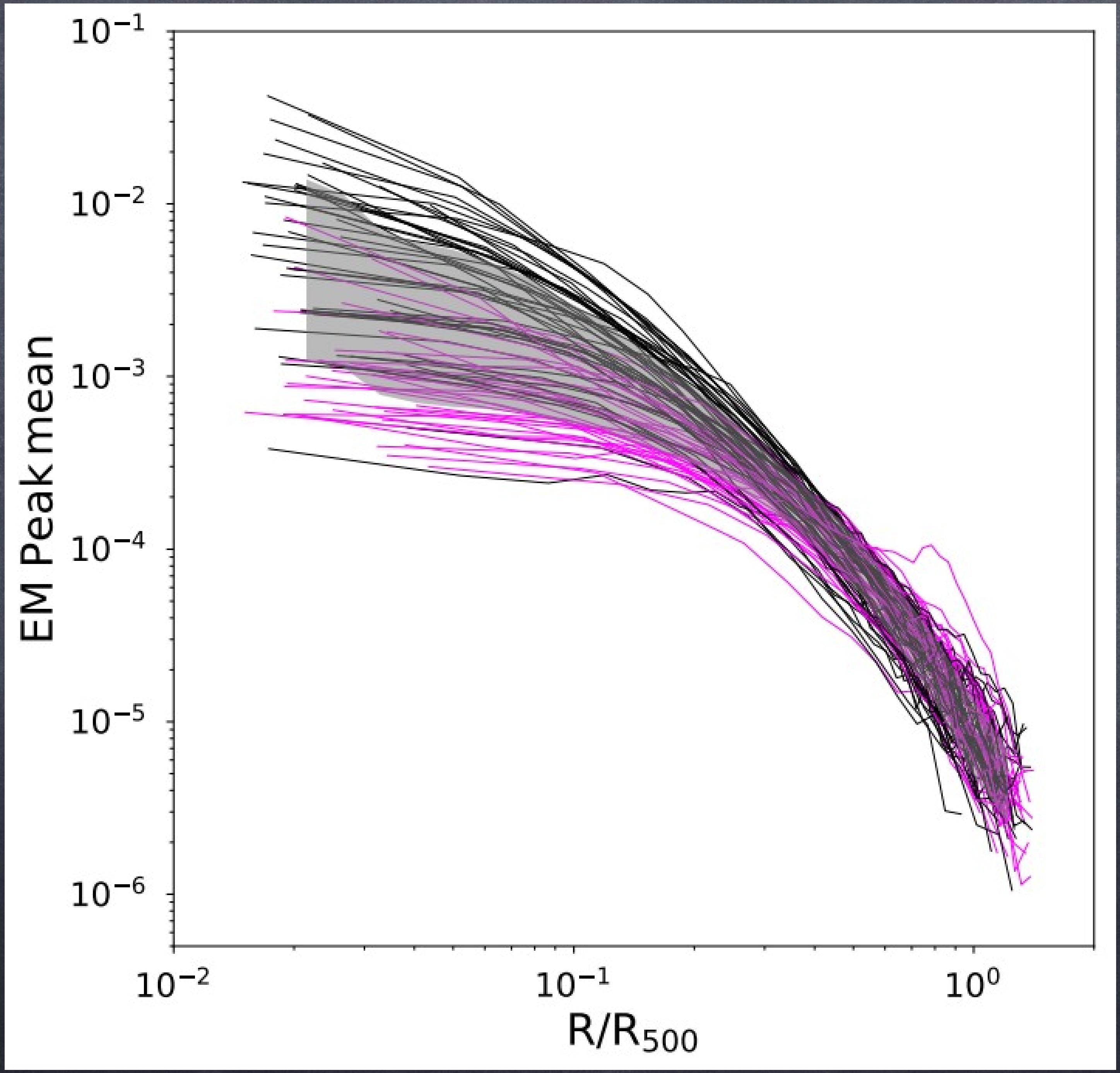
Bartalucci et al. in prep

- 90% of profiles above R_{500}
- Error @ R500 ≈35%
- Determined the dispersion above R_{500}

Surface brightness profiles: distribution?

EM profiles obtained by scaling for factor from MEKAL model (accounting for kT and redshift)

Temperature estimated from M-T ($M_{200\ Planck}$)



Bartalucci et al. in prep

Surface brightness profiles: scatter

At first order, one could imagine that the total scatter of the cluster population can be written as

$$\sigma_{tot}^2 = \sigma_{stat}^2 + \sigma_{syst}^2 + \sigma_{proj}^2 + \sigma_{int}^2$$

Where:

- stat is the statistic term

- syst is the systematic term

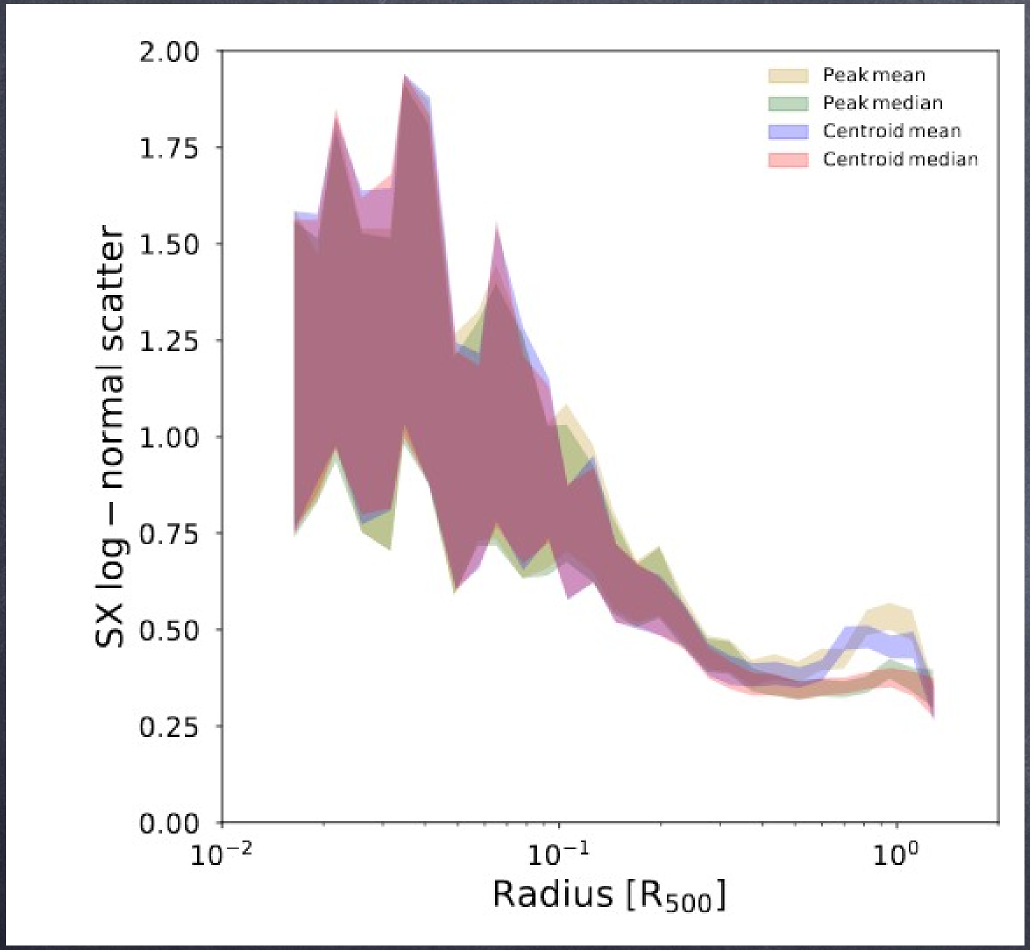
- proj is the projection term. We see the projection of the cluster, but it can have VERY different morphology depending on line of sight

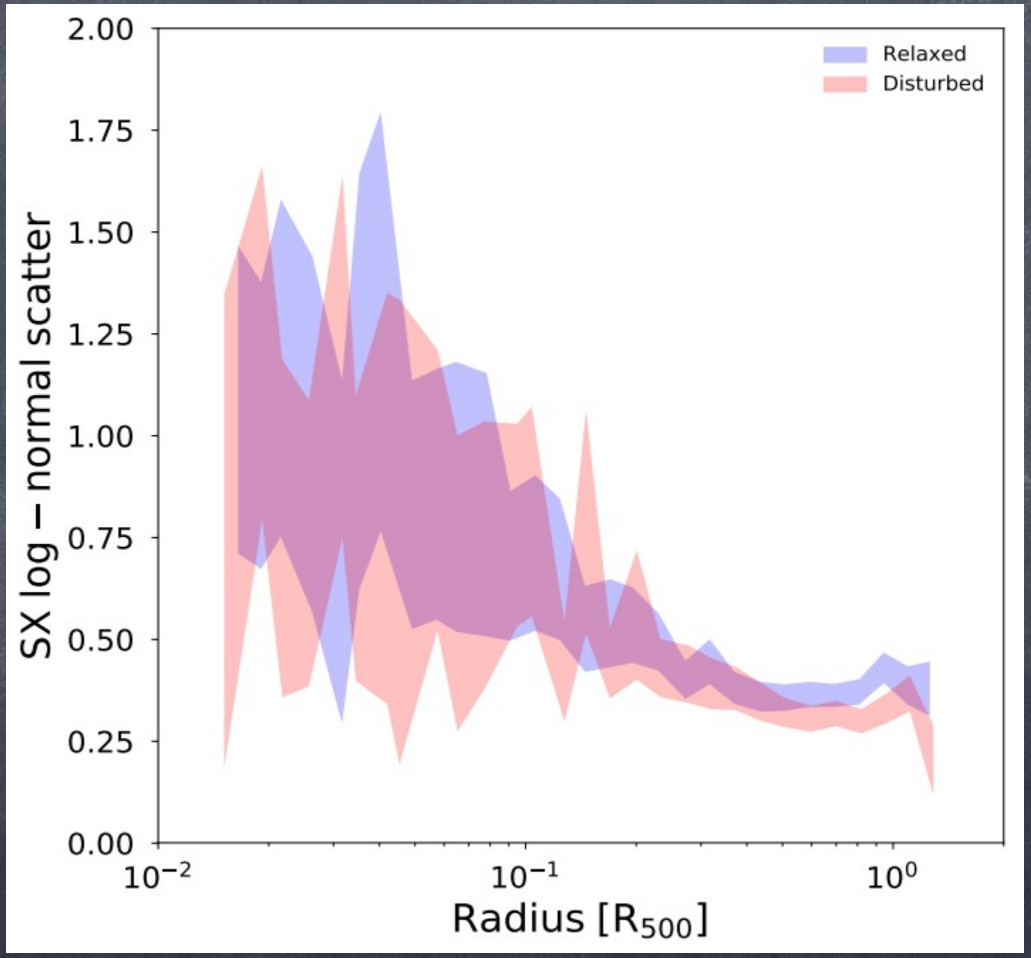
- int instrinsic scatter of the population

Surface brightness profiles: total scatter

- took all the SX profiles of the CHEXMATE subsample

- fitted the distribution within radial bins with log-normal distribution.





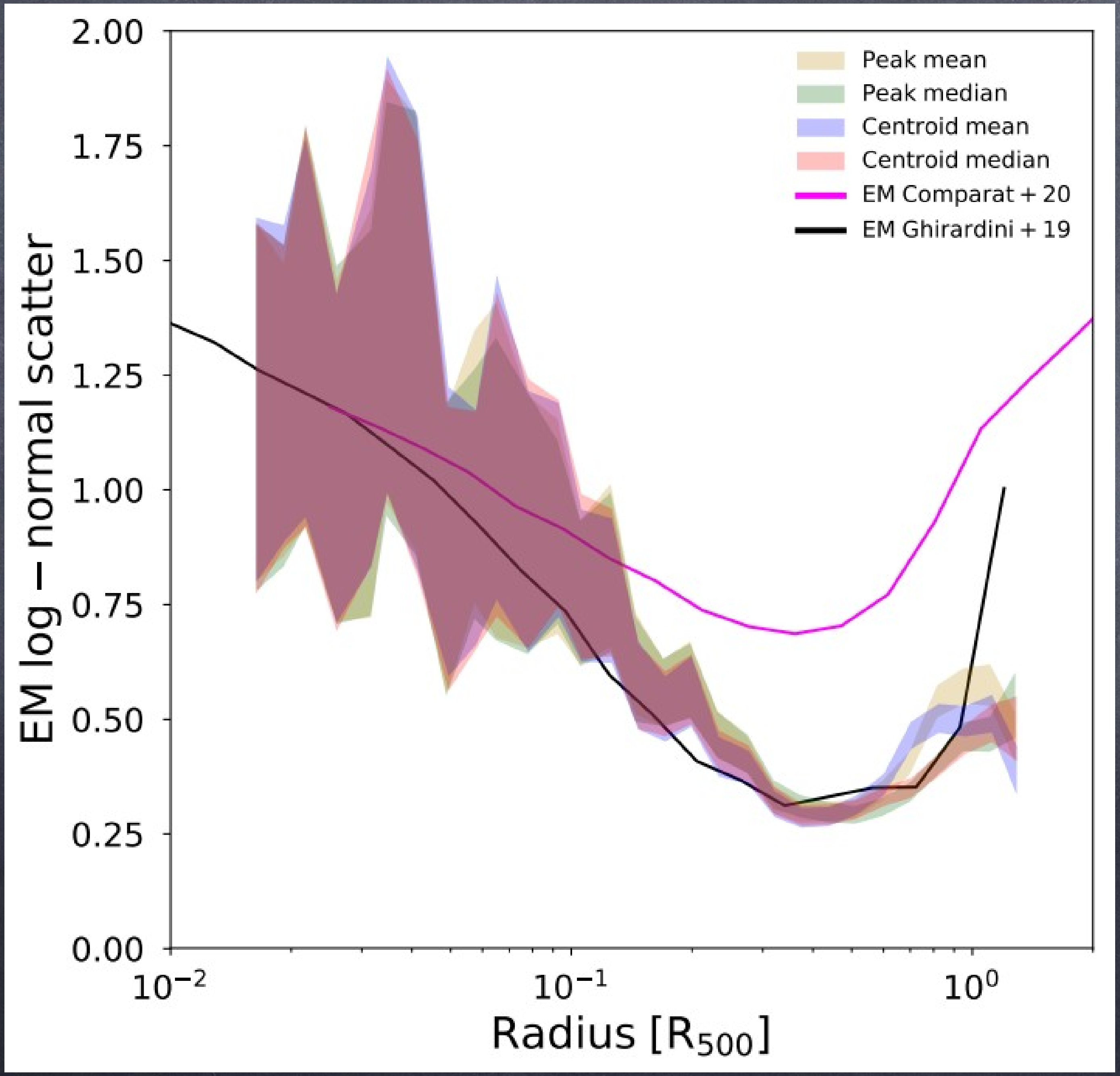
Bartalucci et al. in prep

Need other morphological indicators (see Giulia’s talk)

Surface brightness profiles: comparisons

- took all the SX profiles of the CHEXMATE subsample

- fitted the distribution within radial bins with log-normal distribution.



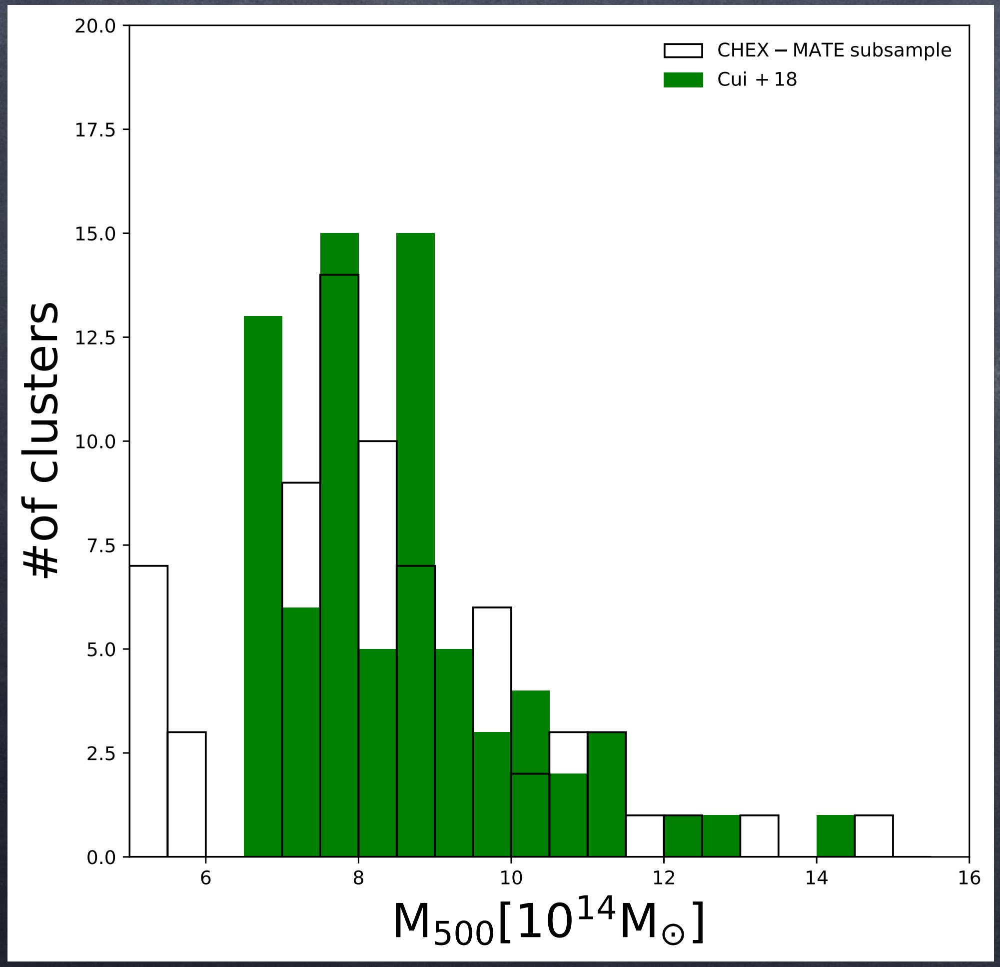
Bartalucci et al. in prep

Surface brightness profiles: simulations

$$\sigma^2_{tot} = \sigma^2_{stat} + \sigma^2_{syst} + \sigma^2_{proj} + \sigma^2_{int}$$

Statistic term are already taken in account..syst work in progress..

For the spurious let's use simulations!



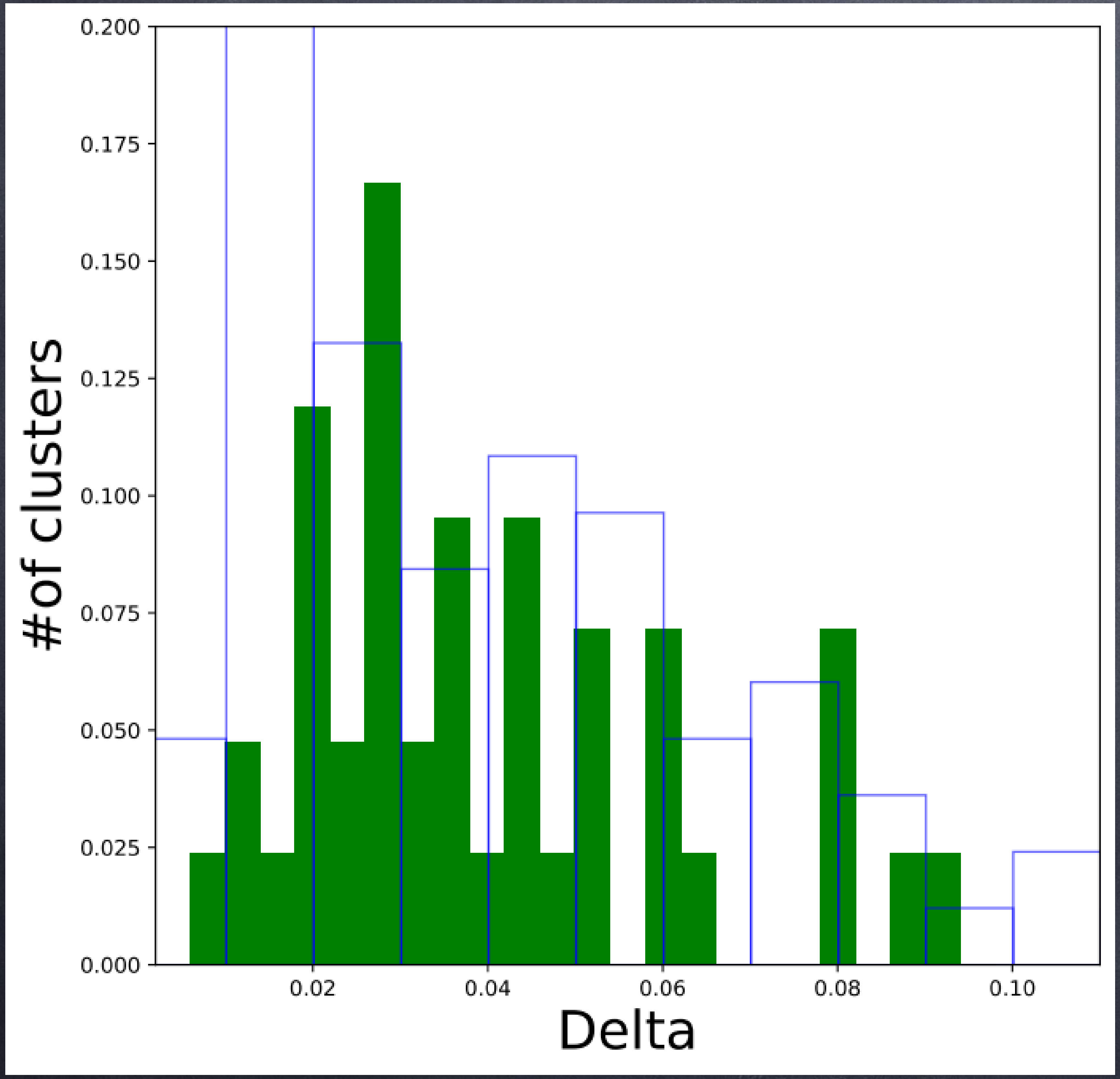
Bartalucci et al. in prep

Simulation sample consists of 70 objects drawn from the 300 project (Cui et al+18, credits E. Rasia).

The mass range is similar to us, but no very low mass objects

Surface brightness profiles: matchin sim to reality

Assumption on the offset:
Centroid-Xpeak ~ Mass centroid-Tot. density peak



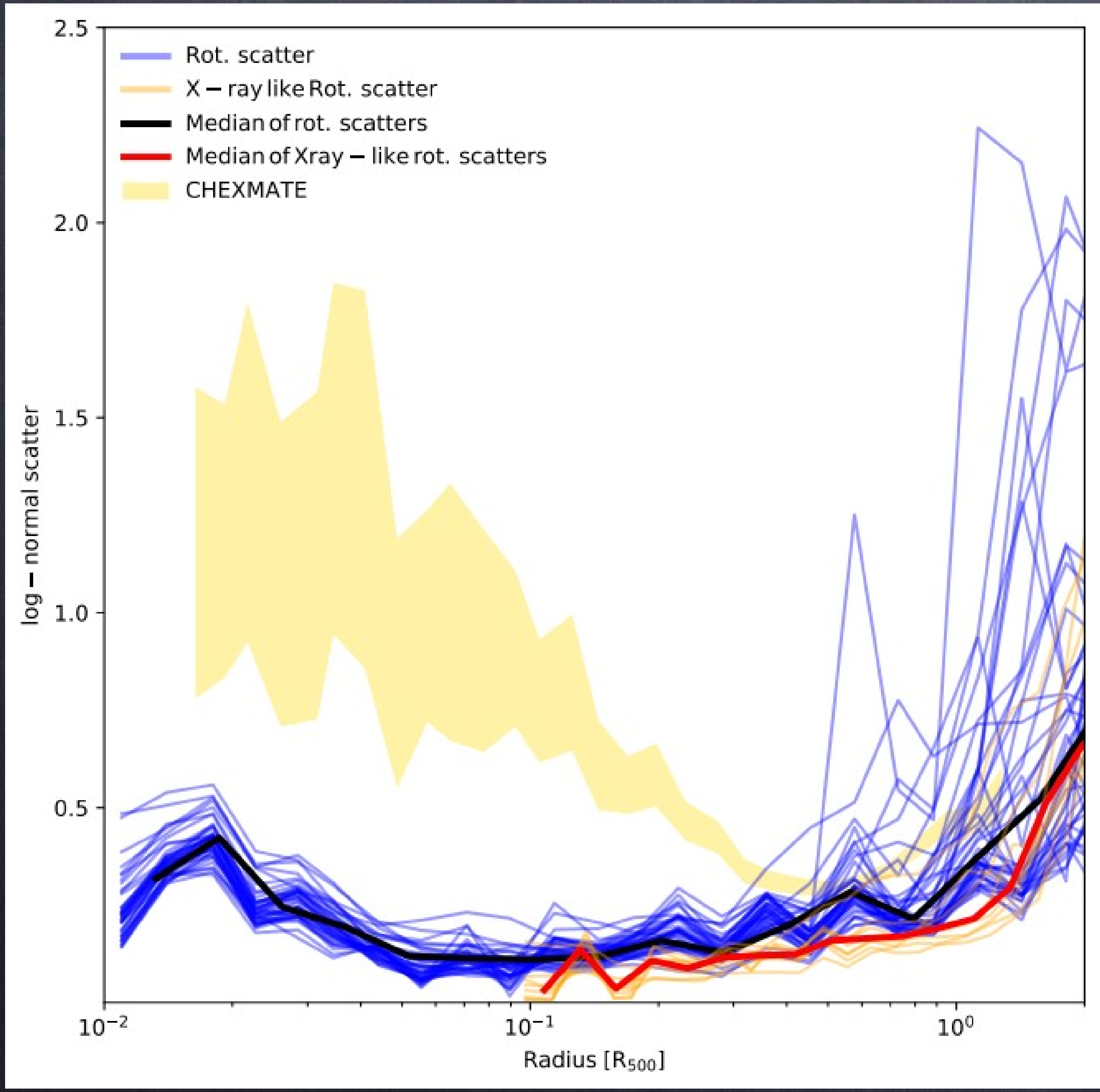
Cherry-picked 42 simulated clusters to “match” CHEX- MATE

Selected a random direction from each cherry-picked object.

Surface brightness profiles: scatter terms

Projection term from scatter of lines of sight for each cluster

Used 40 lines of sight and extracted EM profiles



Bartalucci et al. in prep

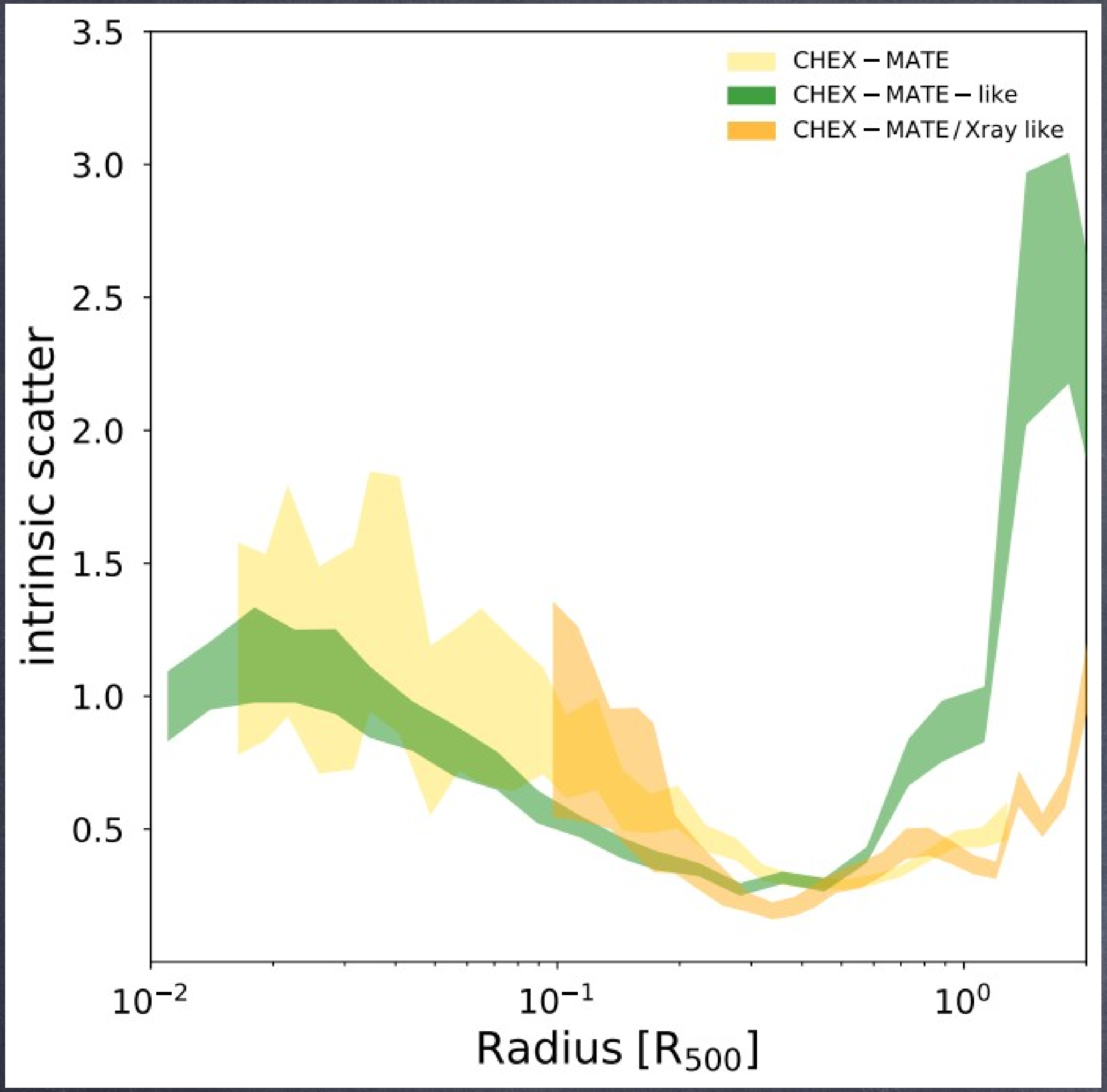
Each line represents the log-normal scatter between 40 projections of the same objects

- Explosion of the scatter above R500...

- no If we consider X-ray effects (orange lines)

- projection scatter contributes to 10-20% of the total, increasing in the outskirts

Surface brightness profiles: total scatter



Bartalucci et al. in prep

- Using the Xray like profiles we computed the total scatter chosing random directions

- We obtain very similar profiles!

- Small discrepancies due to systematic term

Need to refine the morphology selection

Xray mocking machinery works, but no AGN confusion

Conclusions

- High quality SX and EM profiles produced for a large, representative and high quality data sample
- Handling systematics at best and deliver products for the collaboration
- Full characterisation of the statistical properties
- For the first time, we were able to investigate the scatter terms and will soon quantify these values