Surveying galaxy clusters in the X-ray Universe

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On behalf of the eROSITA Cluster and Cosmology Working Group

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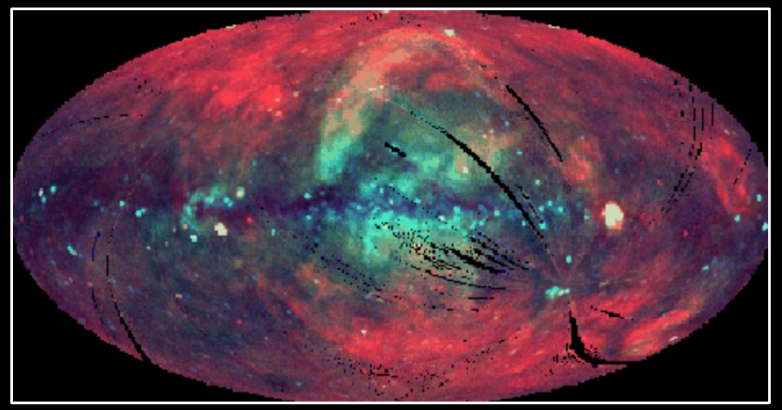
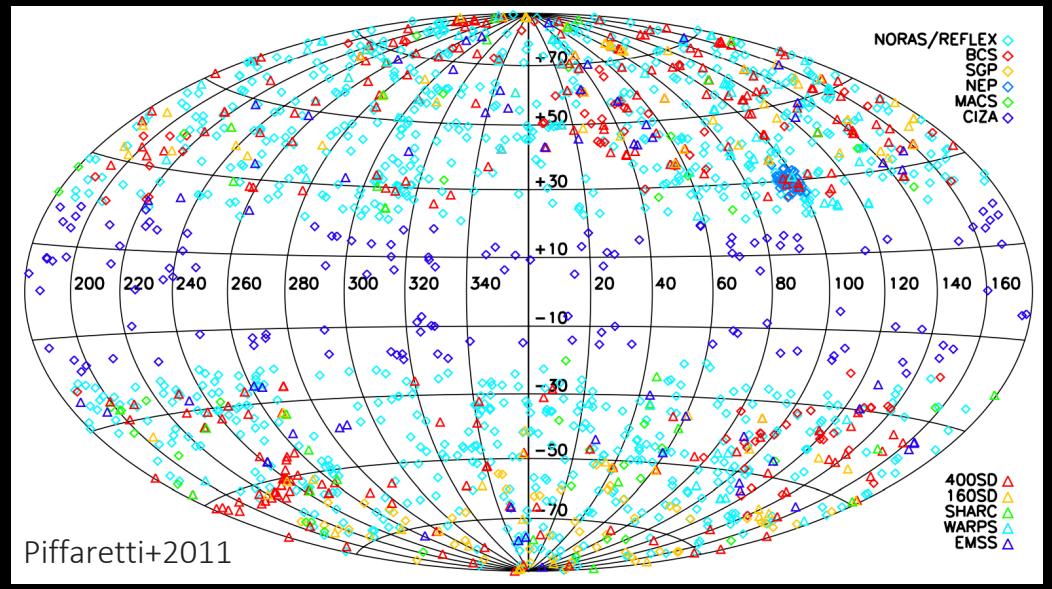
Dissecting Cluster Cosmology: toward a roadmap for forthcoming cluster surveys
07/2023 Trieste, Italy

Pre-eROSITA X-ray cluster surveys

ROSAT clusters

~2000 clusters from the ROSAT All-Sky Survey, pointed deeper surveys, and serendipitous detections.

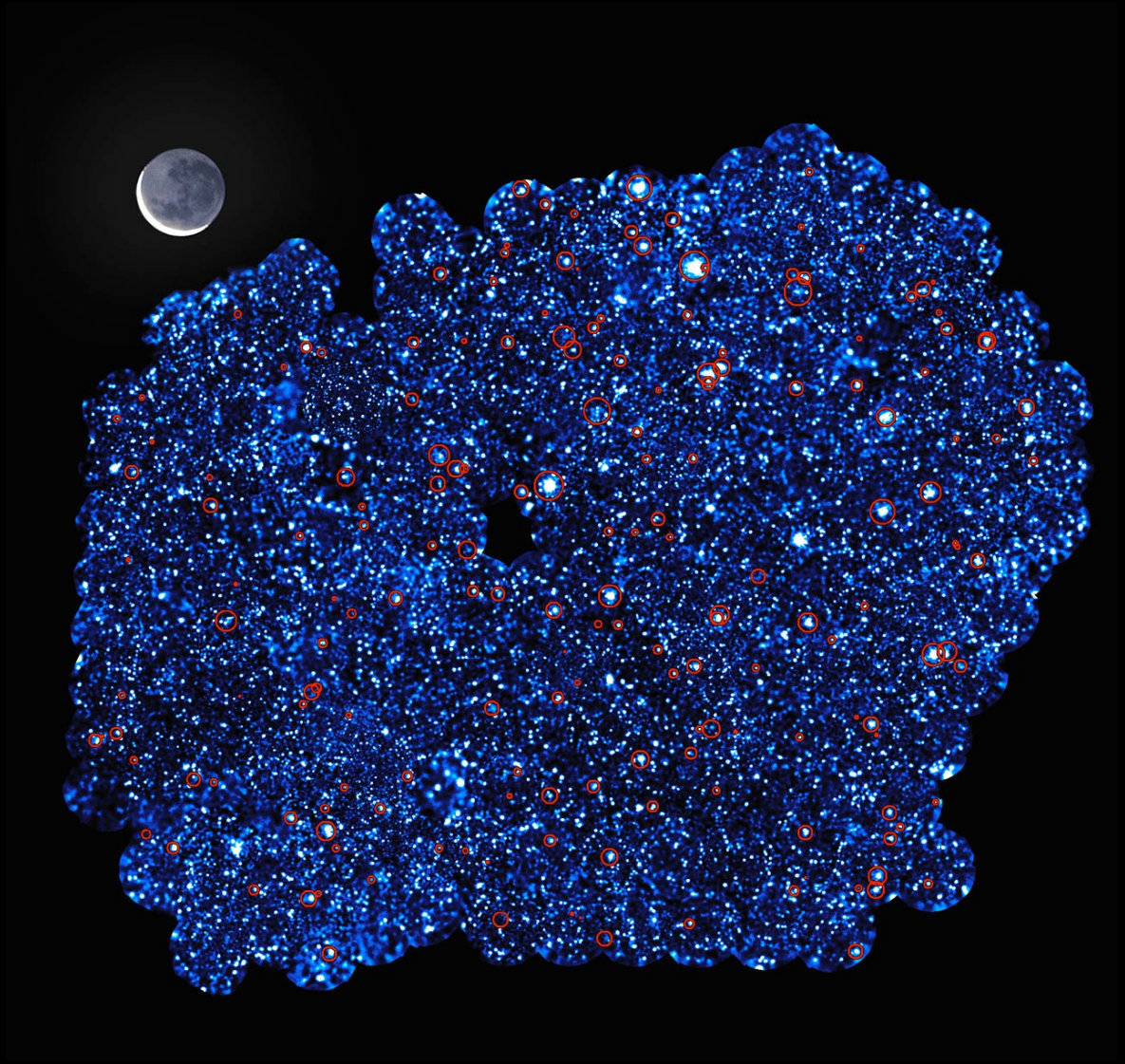




Piffaretti+2011

- Mostly flux-limited (Boehringer+2001,2004,2014,2017)
- Recent efforts to include surface brightness (morphology) in the selection: RXGCC (Xu+2022), 149 new clusters with flatter SB profile

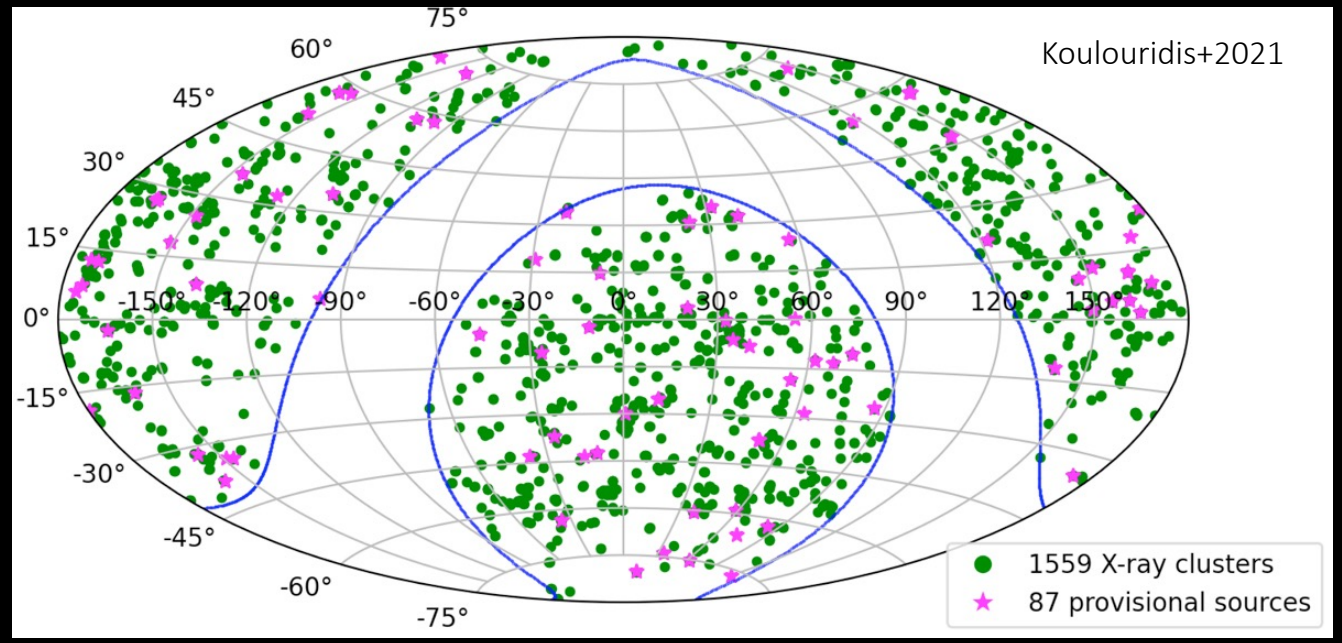
XMM-Newton XXL Survey



- Total Area: 50 deg^2
- 7Ms
- 365 clusters (Adami+2018)
- $z < 2$
- Flux limit: a few x 10^{-15} erg s^{-1} cm^{-2}
- 10^{13} $M_{sun} < M_{500} < 5 \times 10^{14}$ M_{sun}

Pierre+2016

X-CLASS



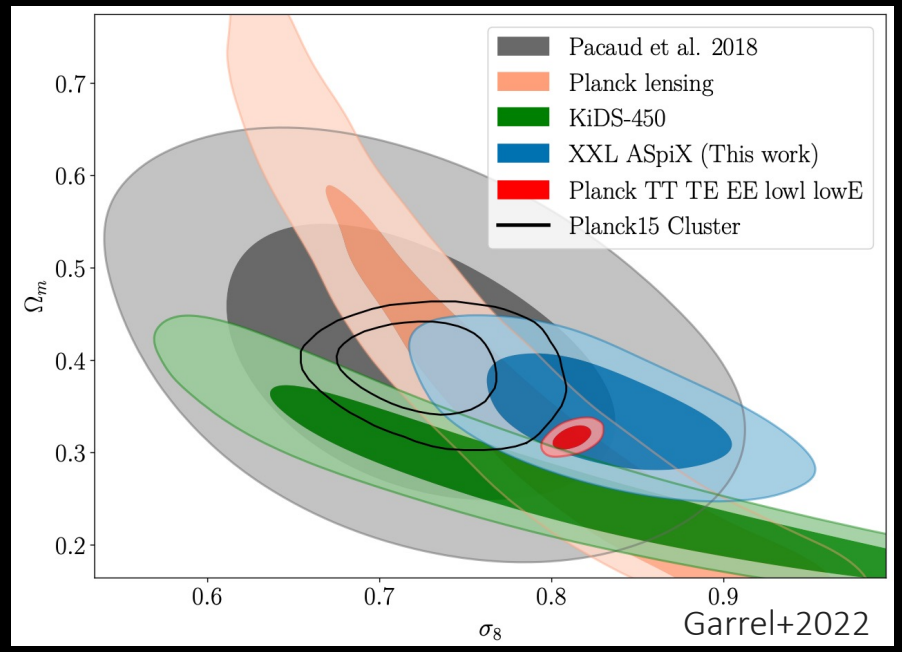
- 4176 archival observations with 10-20 ks
- 1646 clusters over 269 deg^2
- z<1.5

XMM Cluster Survey (Mehrtens+2012): 503 confirmed clusters

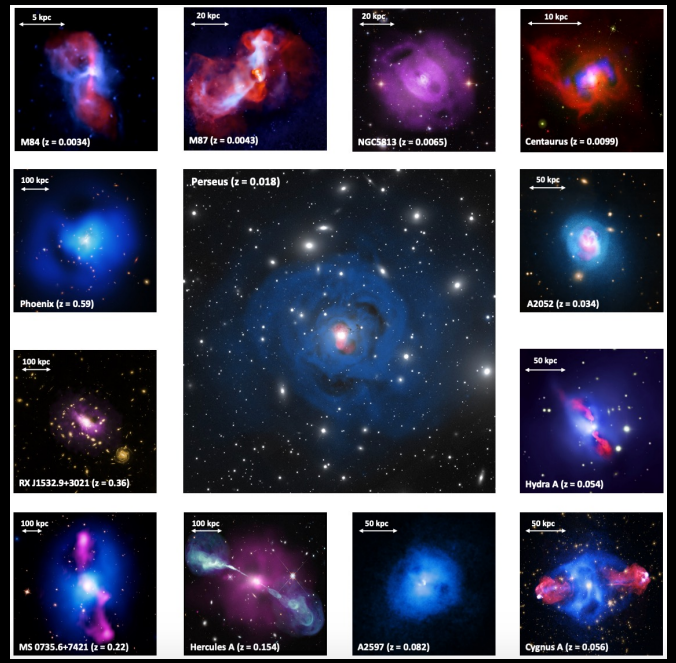
(Smaller X-ray surveys with XMM-Newton and Chandra: COSMOS, CDFS, etc.)

Science from cluster surveys: cosmology, astrophysics

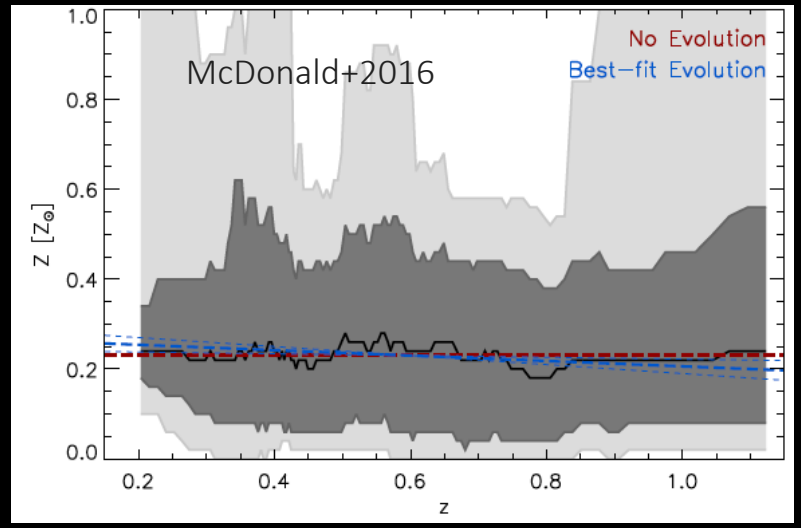
Cluster counts

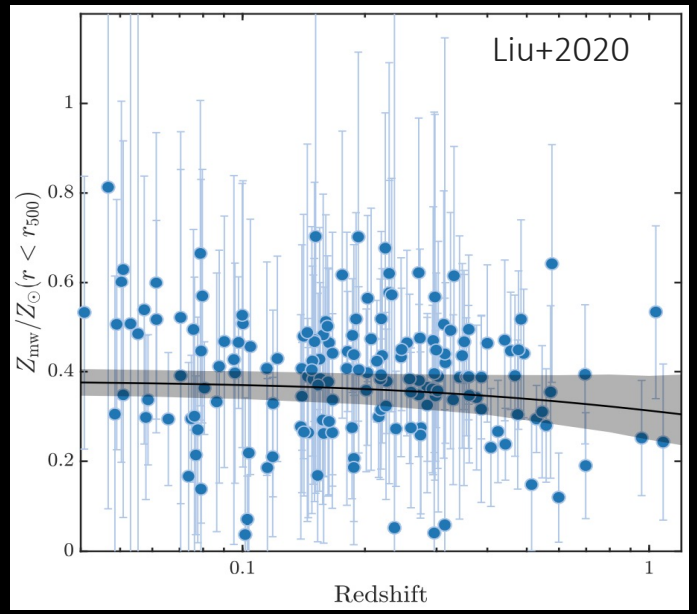


AGN feedback

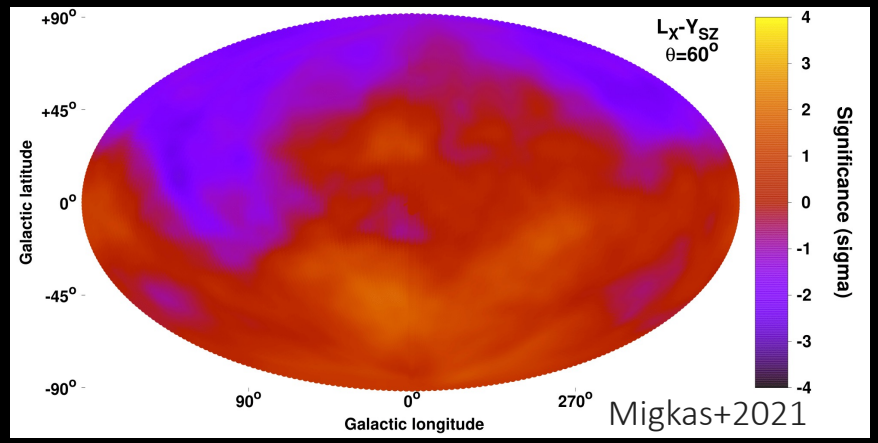


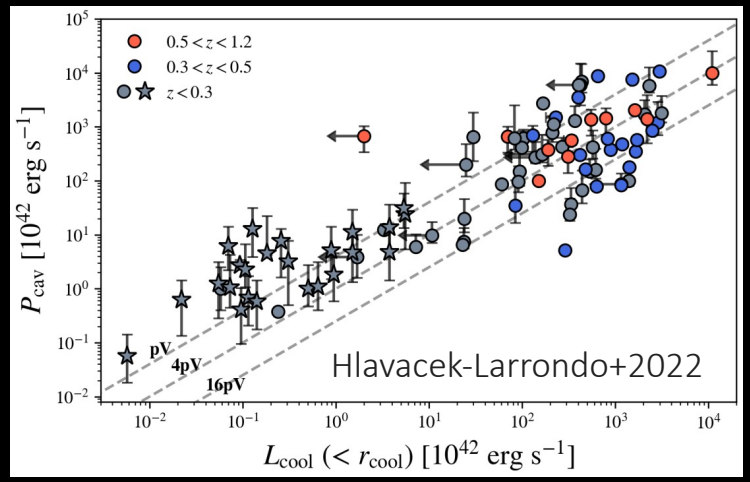
Evolutionary studies





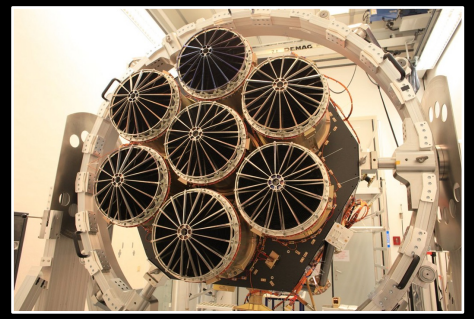
Cosmic anisotropy

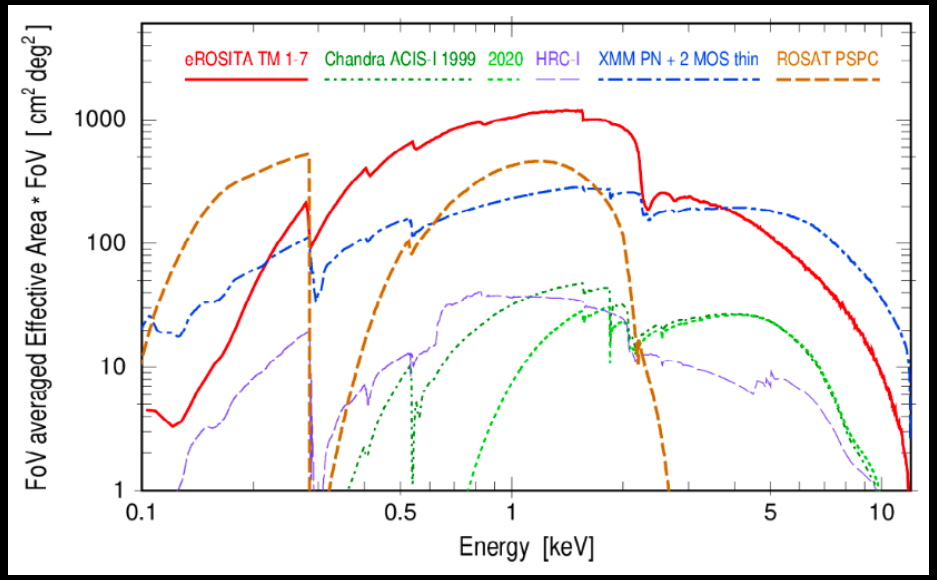


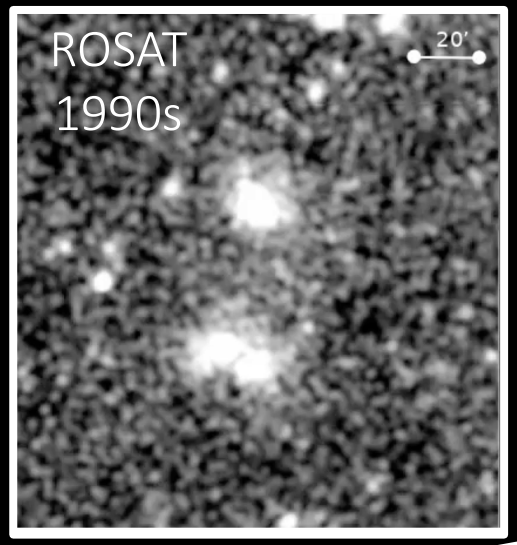


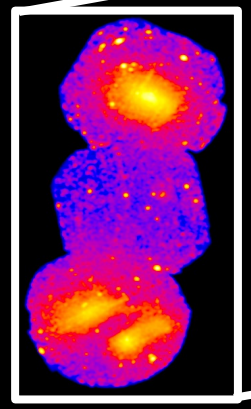
eROSITA X-ray telescope on SRG

- 8 All-Sky Surveys in 4 years (4.5 completed)
- 25x sensitivity than RASS
- Study cosmology by detecting 100,000 galaxy clusters



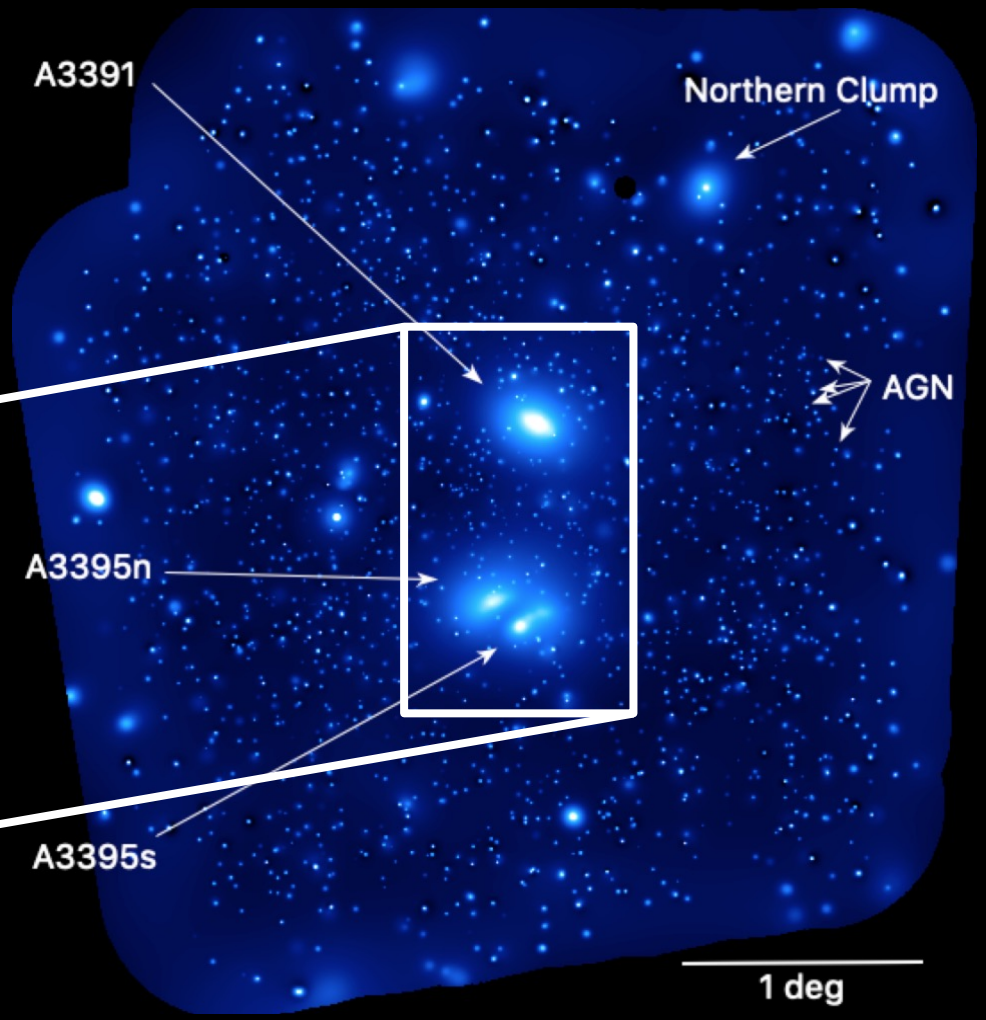






XMM-Newton
2000s

eROSITA
2019



eROSITA's Schedule

eRASS = eROSITA All-Sky Survey

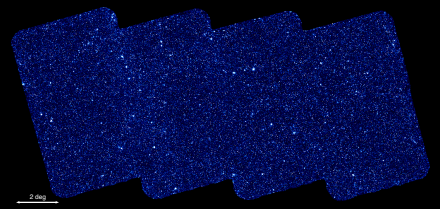
26.2.2022
eROSITA in safe mode

CalPV | eRASS1 | eRASS3 | eRASS4.5 | We are here

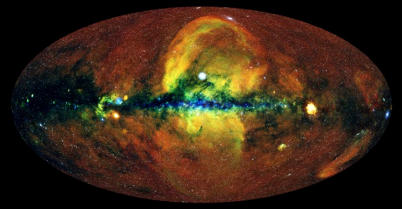
2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025

Launch

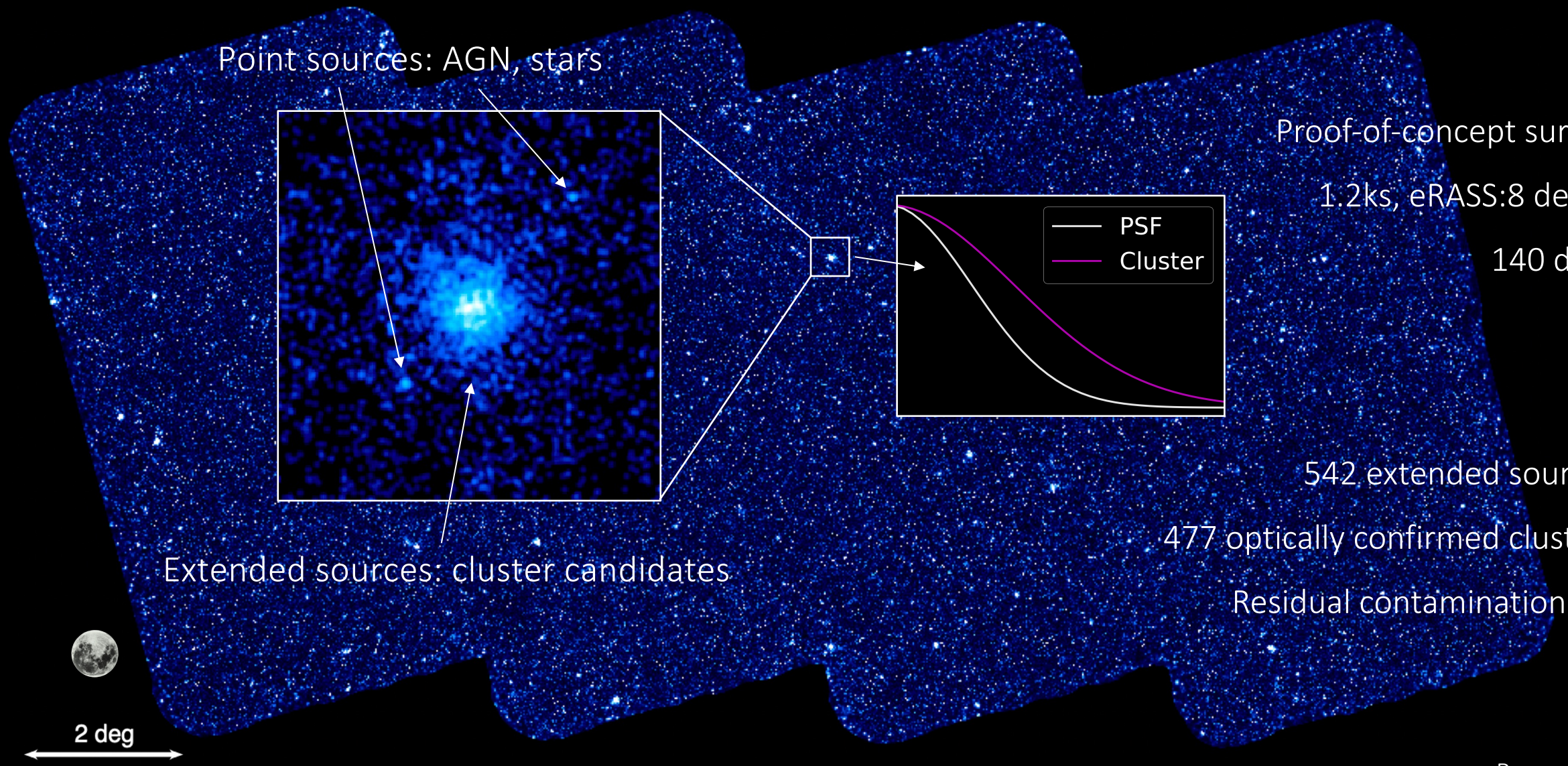
July 1st 2021: EDR
CalPV data, catalogs
and associated papers



DR1:
eRASS1 data, catalogs
and associated papers



The eROSITA Final Equatorial-Depth Survey (eFEDS)



Proof-of-concept survey

1.2ks, eRASS:8 depth

140 deg^2

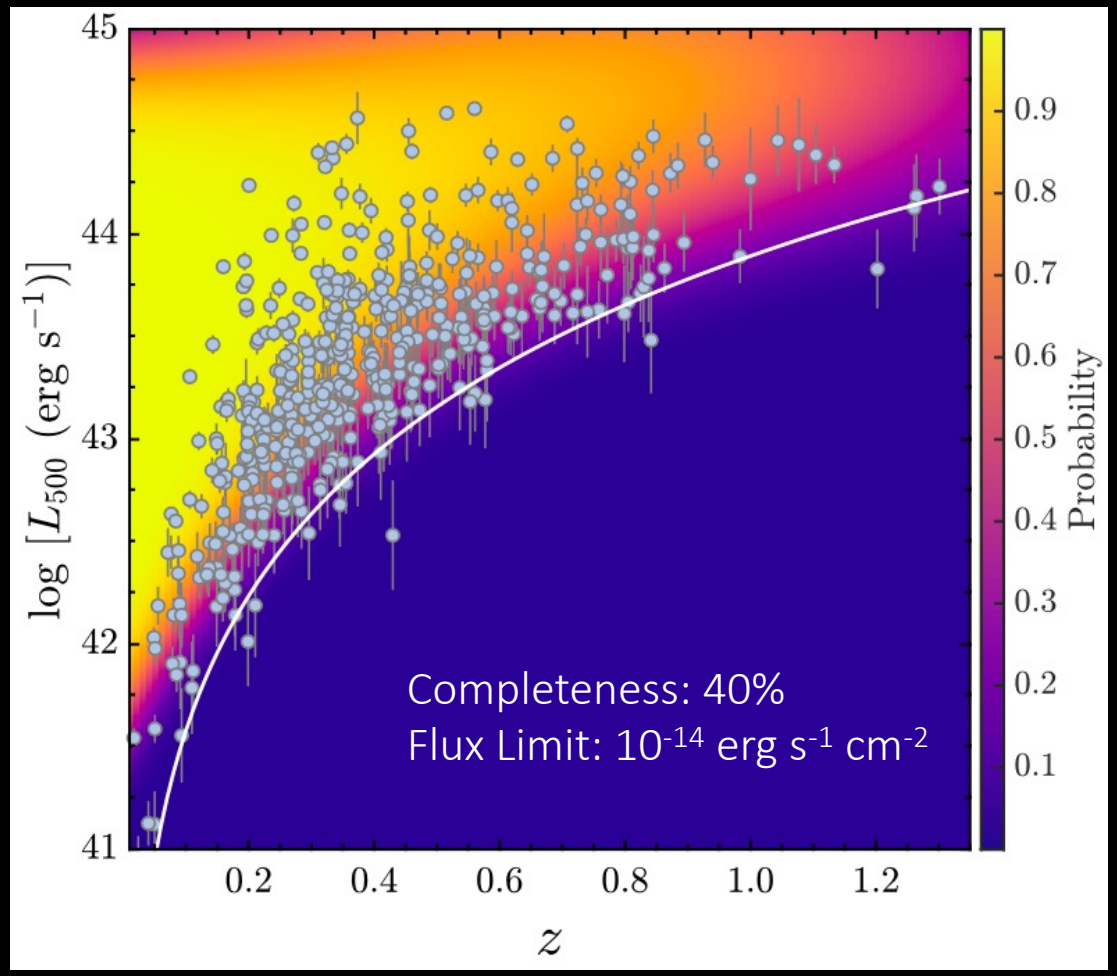
542 extended sources

477 optically confirmed clusters

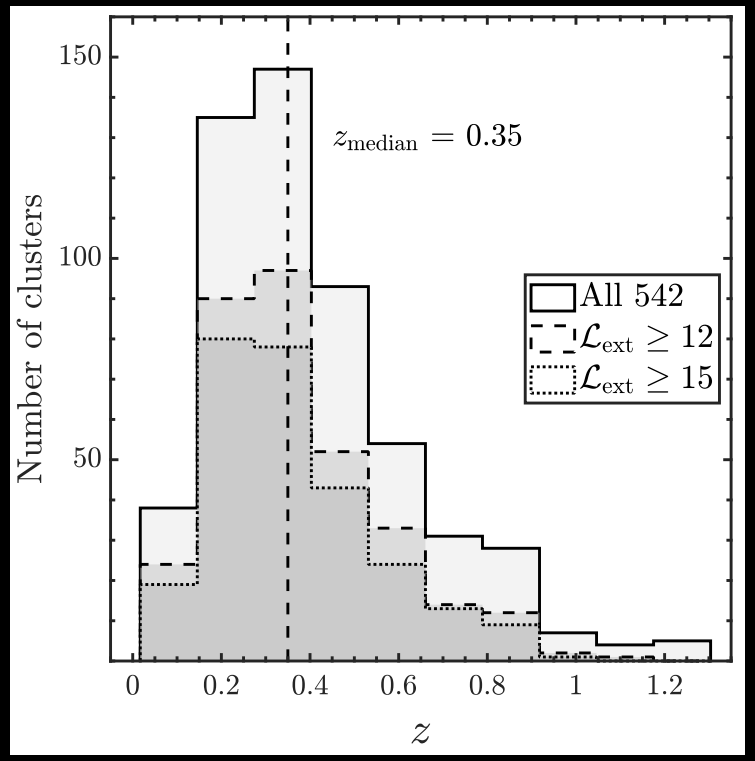
Residual contamination 6%

Brunner+2022

Clusters and Groups in eFEDS

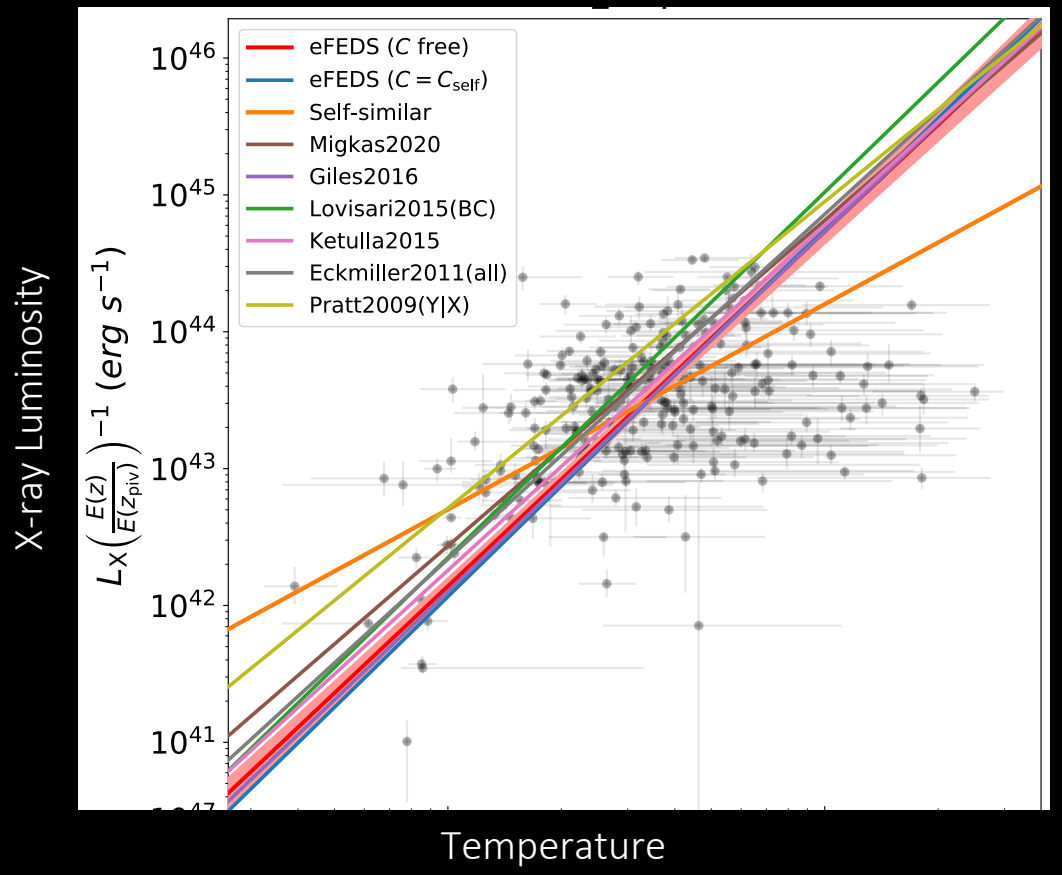


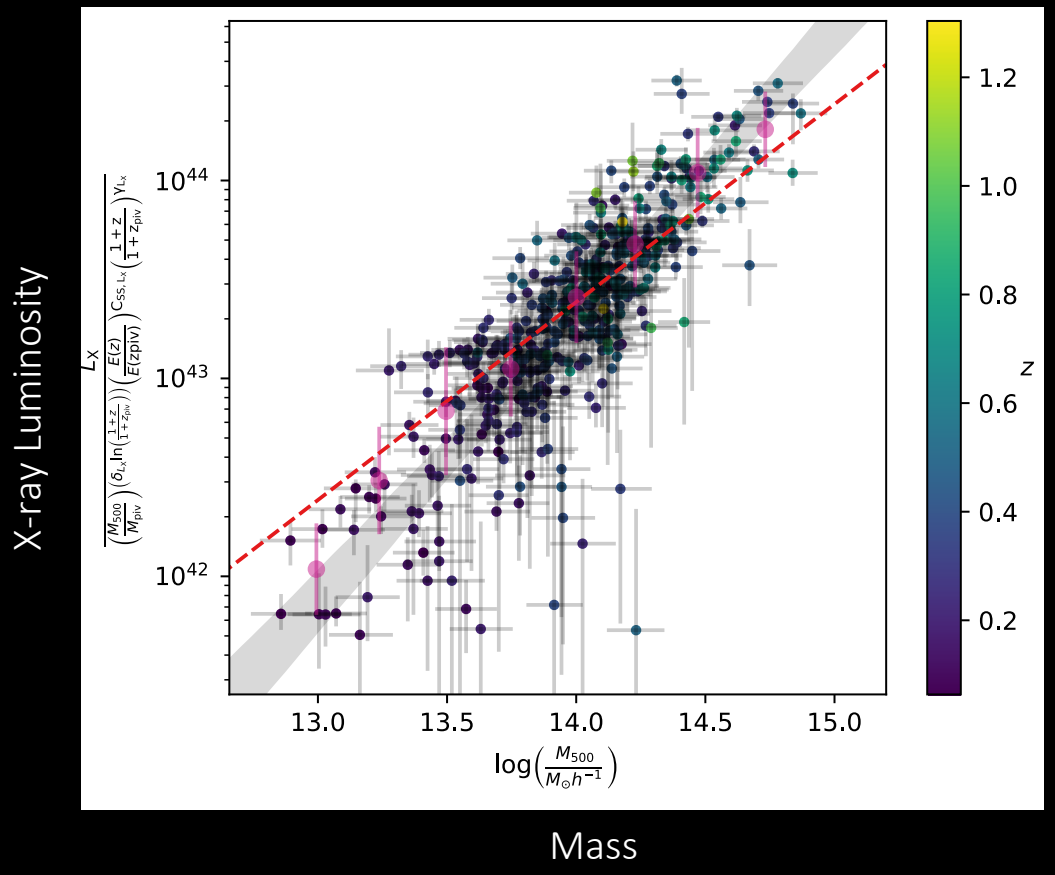
Median redshift: 0.35
Max redshift: 1.3



Liu+2022
Bulbul+2022
Klein+2022

X-ray scaling relations

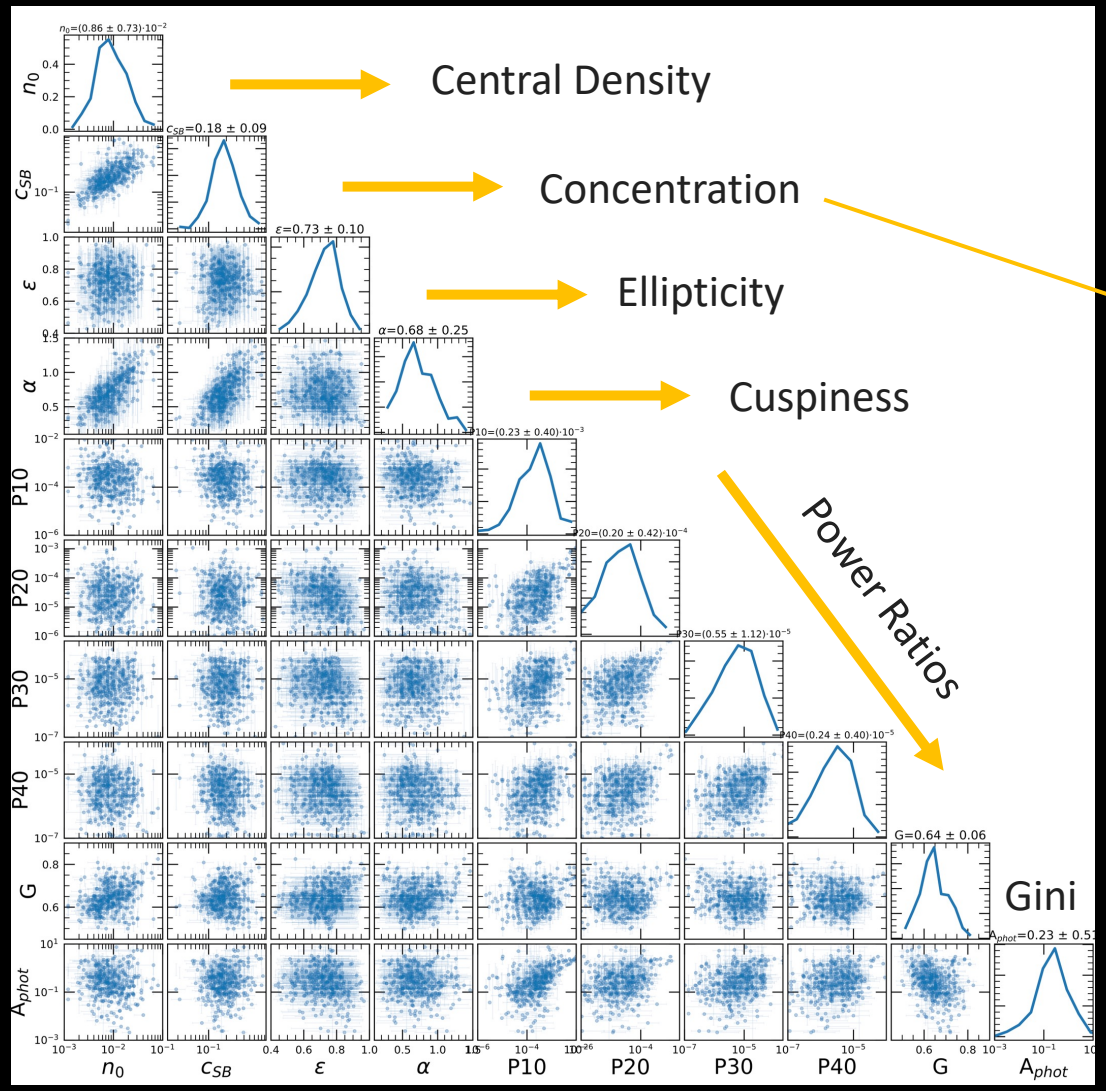




- Broad agreement with recent results.
- Significant tension with self-similar model predictions.

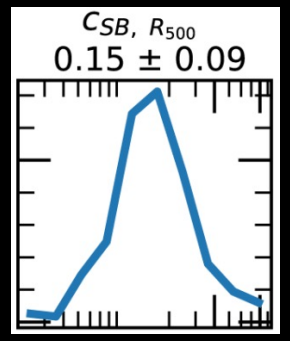
(Bahar+2022, Chiu+2022, Ramos-Ceja+2022)

Cluster morphology

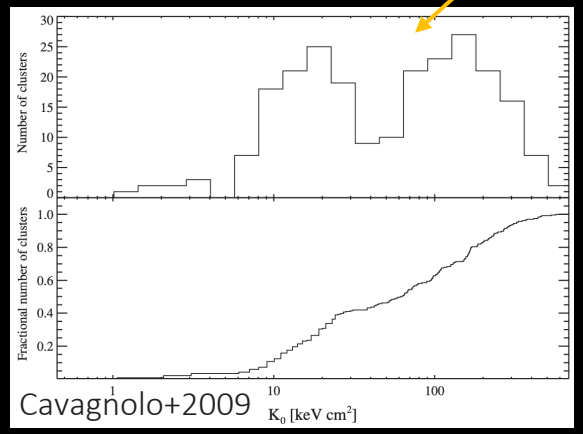


Ghirardini+2022

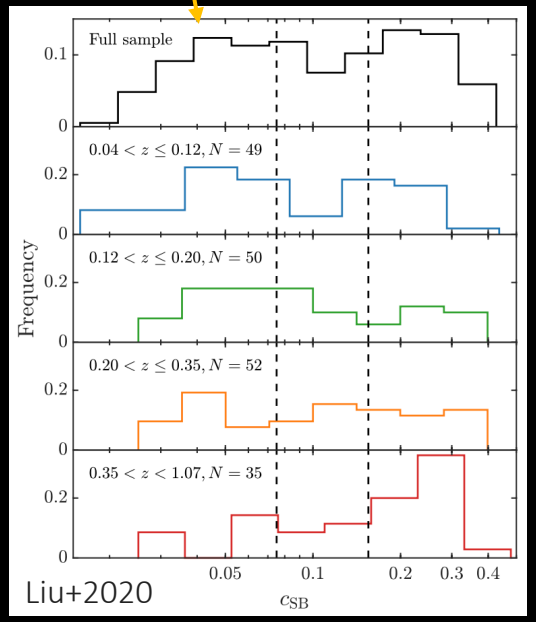
- No bias towards CC
- No indication of bi-modal cool core and non-cool core distribution



Chandra clusters



Cavagnolo+2009



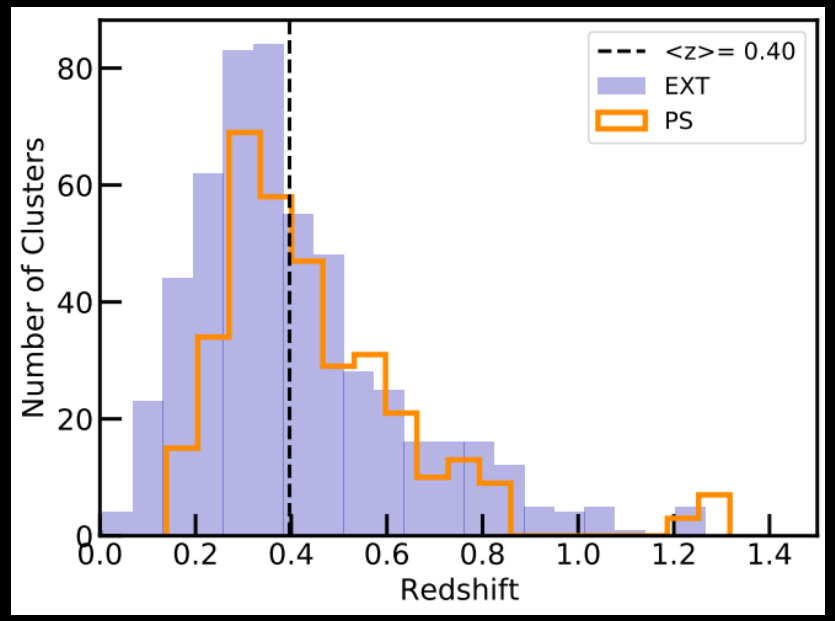
Liu+2020

Revisit the eFEDS selection: finding the unresolved clusters

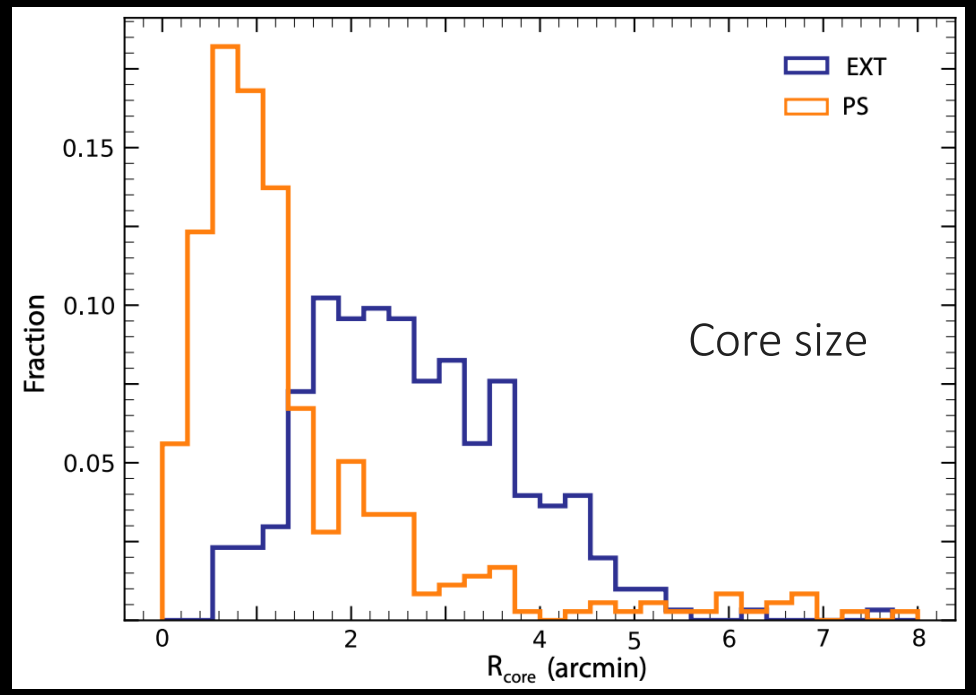
Due to the large PSF (HEW=18”), some clusters can be misclassified as point sources:

- Clusters with bright central AGN or compact core
- High redshift clusters with small angular sizes

346 clusters (selected in optical) are classified as X-ray PS.



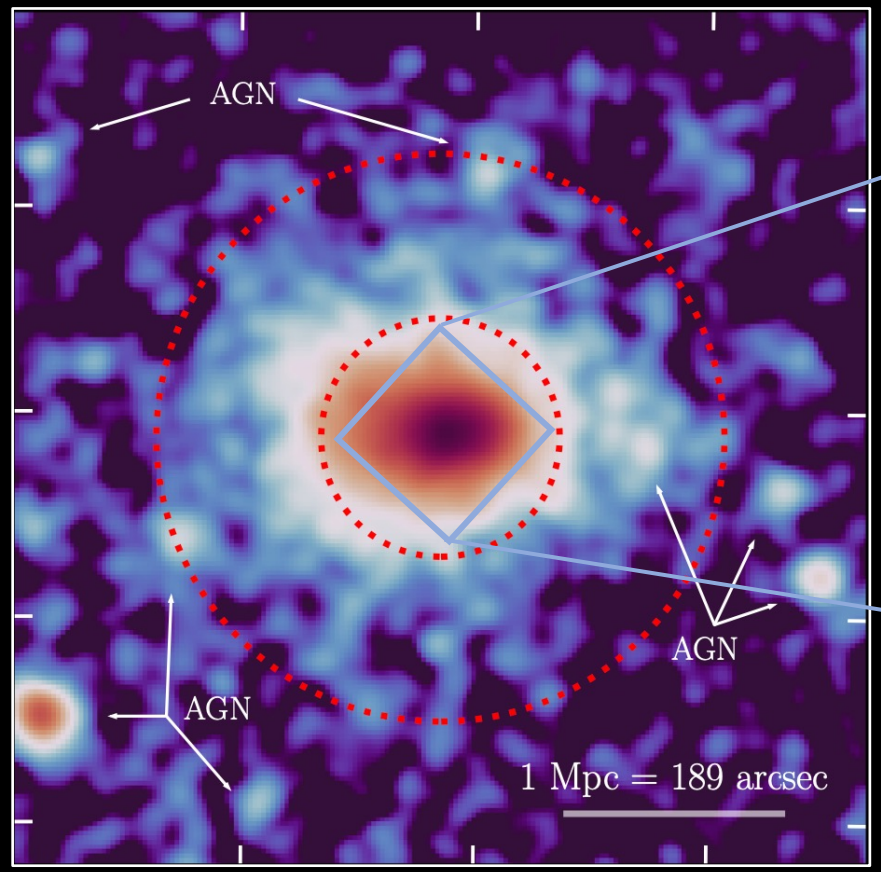
Unresolved clusters are more compact than the resolved clusters



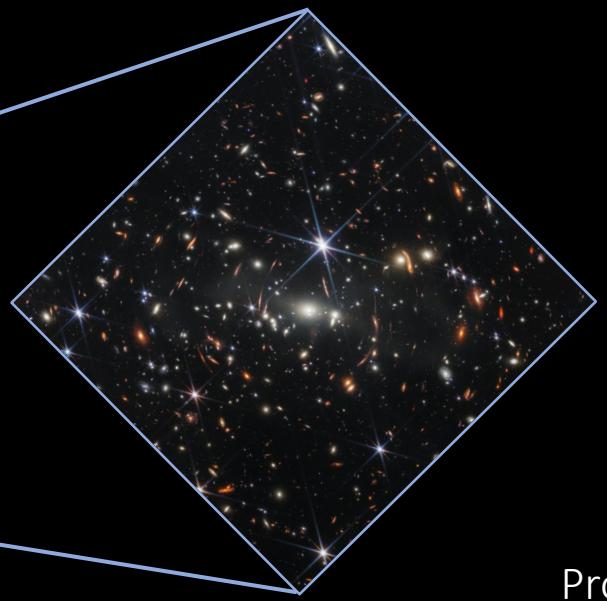
Bulbul+2022

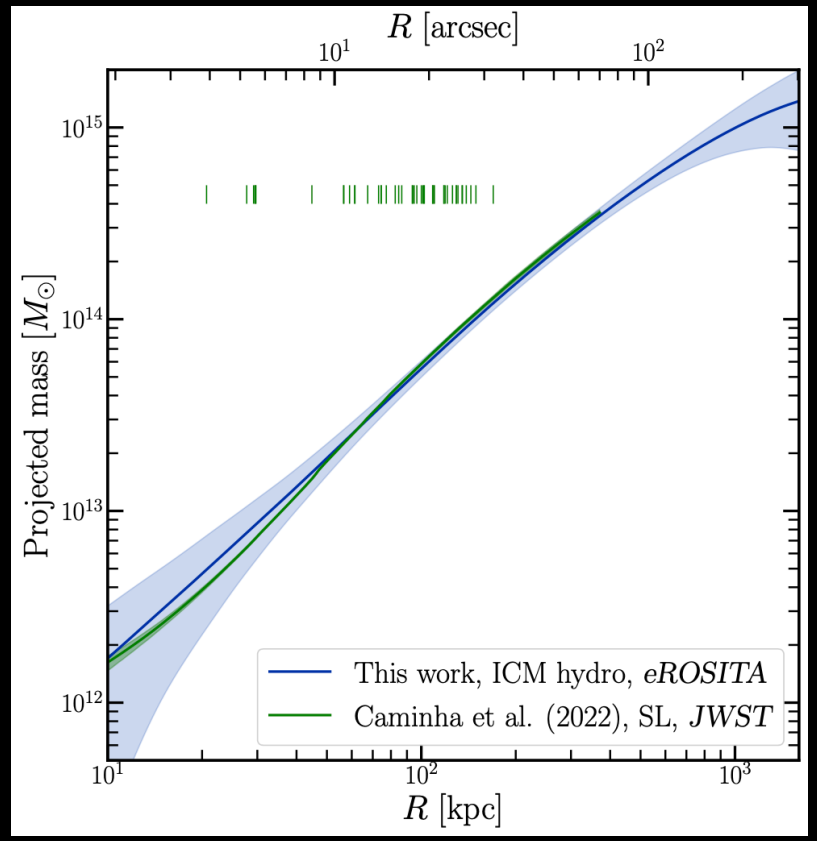
X-ray analysis of JWST's first galaxy cluster lens SMACS J0723.3-7327

eRASS:5, 4.4ks



JWST





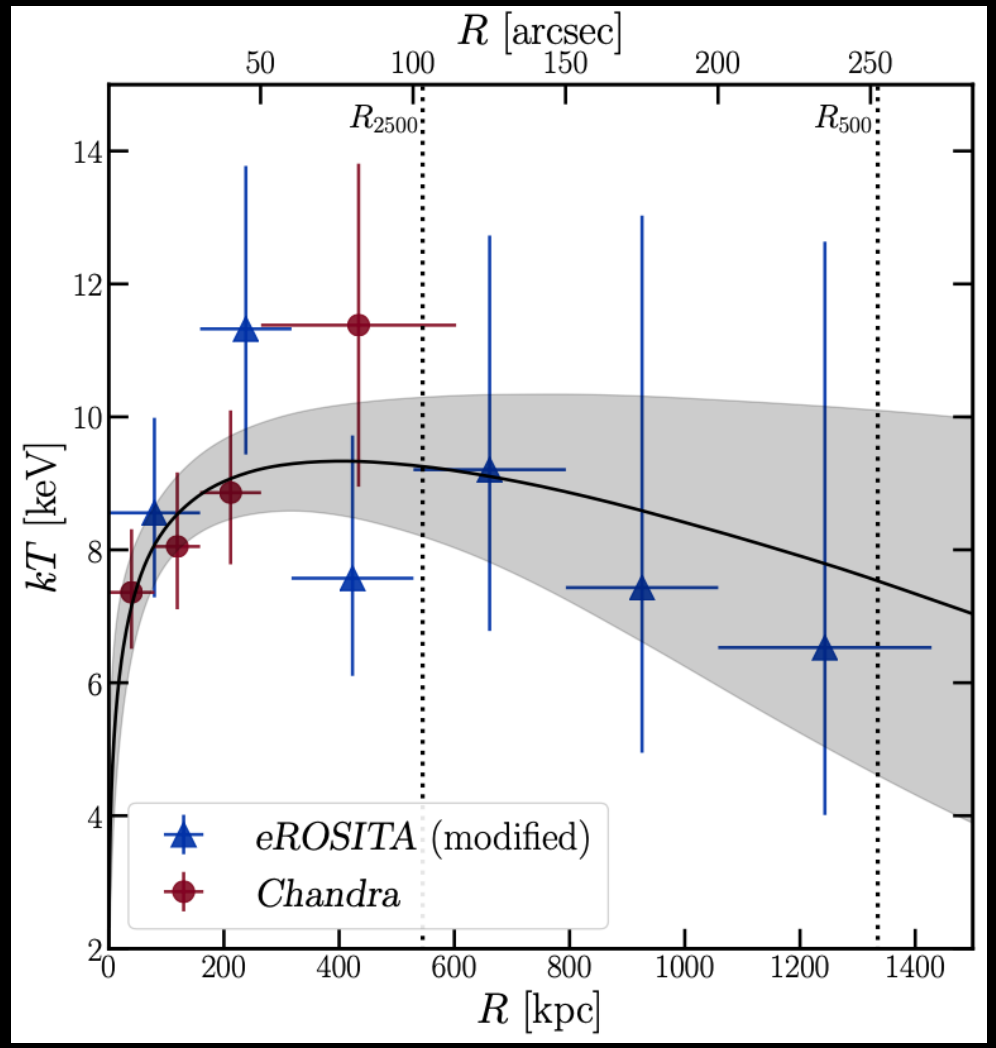
Projected mass within Einstein radius (128kpc):

- eROSITA, hydrostatic: M = 8.1±0.7 x 10^{13}Msun
- JWST, strong lensing: M = 8.6±0.2 x 10^{13}Msun

Liu+2023

X-ray analysis of JWST's first galaxy cluster lens SMACS J0723.3-7327

Region	kT (full-band) [keV]	kT (modified) [keV]
0″–30″	$4.54^{+0.52}_{-0.49}$	$8.56^{+1.43}_{-1.27}$
30″–60″	$5.54^{+0.82}_{-0.67}$	$11.32^{+2.45}_{-1.89}$
60″–100″	$4.17^{+0.80}_{-0.59}$	$7.57^{+2.15}_{-1.47}$
100″–150″	$4.78^{+1.23}_{-0.93}$	$9.21^{+3.52}_{-2.43}$
150″–200″	$4.11^{+2.00}_{-1.03}$	$7.43^{+5.60}_{-2.48}$
200″–270″	$3.75^{+2.23}_{-1.09}$	$6.53^{+6.11}_{-2.52}$



XMM (~7.6keV), Chandra (~9keV)

- eROSITA tends to measure lower temperature than XMM-Newton and Chandra for hot clusters, possibly due to its higher sensitivity on cooler gas.
- Possible solution: fit hard-band only

Liu+2023