

eROSITA all-sky survey Overview of DR1 and science examples

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On behalf of the eROSITA-DE team





The All-Sky Surveys by Numbers



- Completed ~4.4 all-sky survey (12/2019 – 2/2022)
- Uniform exposure, avg. ~800s; up to 120ks at the Ecliptic Poles (confusion limited)
- Very few background flares, flexible mission planning: no gaps in exposure
- ~**1.7 Billion** 0.2-5keV calibrated photons (~380 Gb telemetry)
- Typical (point-source) sensitivity:
 - Single pass (eRASS1,2,3,4)
 - $\sim 5 \times 10^{-14}$ erg/s/cm² [0.2-2.3 keV]; **4-5x deeper than RASS**
 - $\sim 7 \times 10^{-13}$ erg/s/cm² [2.3-5 keV]
 - Cumulative (eRASS:4)
 - $\sim 2 \times 10^{-14}$ erg/s/cm² [0.2-2.3 keV]
 - $\sim 2 \times 10^{-13}$ erg/s/cm² [2.3-5 keV]
- eRASS1 (half-sky): 0.9M point sources ~doubles the number of known X-ray sources!
- eRASS:4 (half-sky): 2.8M point sources; 87k extended; ~45k confirmed clusters



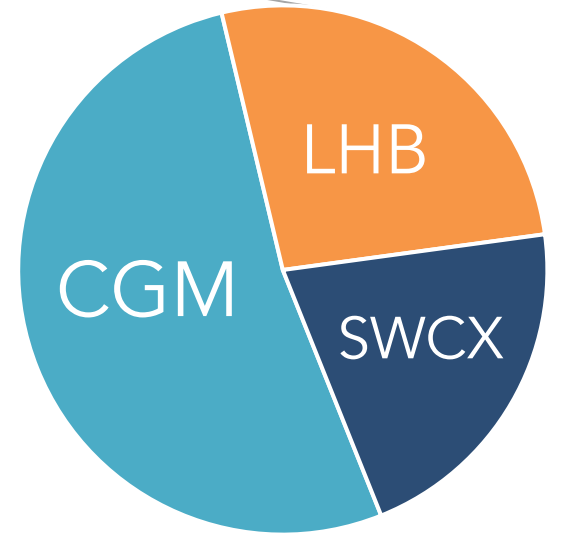
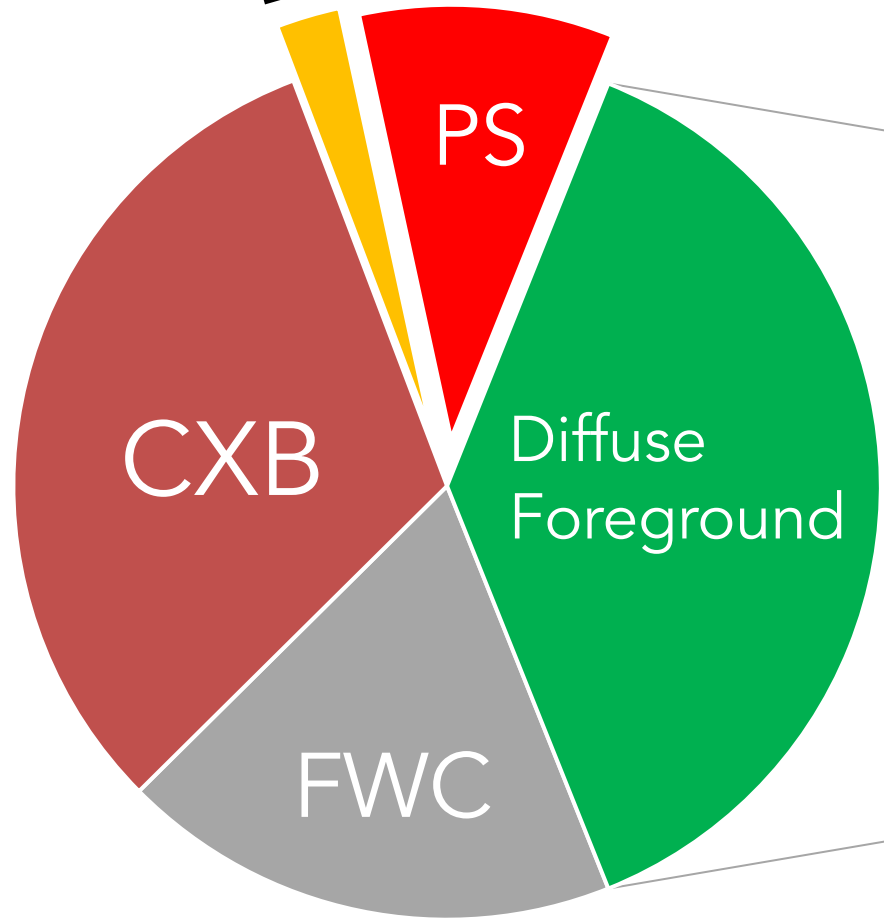
The eRASS1 (soft) photon Pie



~340 Million calibrated events

- 107 Million CXB photons
- 67 Million MW Hot CGM photons (58M halo + 9M 'Corona'; Ponti+'22)
- 63 Million Instrumental BKG photons (FWC)
- 34 Million Local Hot Bubble photons
- 27 Million Solar Wind Charge Exchange photons
- 32 Million Point Sources' photons
 - 24 Million AGN photons; 8 Million Stars photons
- 8 Million Extended Sources' photons (3.5 from Clusters)

Ext. → Only ~1% of the detected photons from clusters of galaxies



0.2-2.0 keV
(Merloni et al. 2024)

eRASS1: 11.12.2019 - 11.6.2020



eRASS1 cts rate image
Movie courtesy
of J. Sanders (MPE)



eROSITA-DE: Data Release 1 site

- DR1 Home
- DR1 data**
- Data analysis
- eROSITA technical details
- eROSITA known issues
- FAQ
- Help Forum
- EDR site
- Back to eROSITA Portal

Welcor

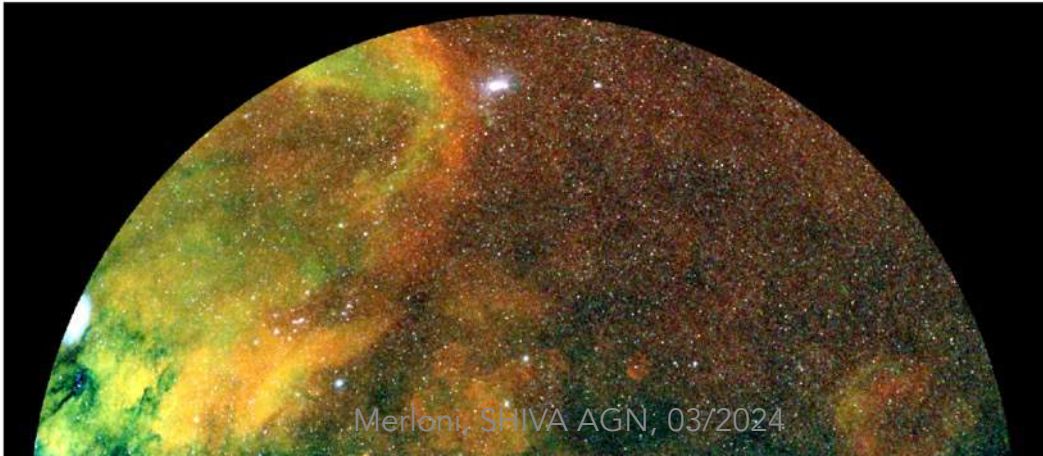
- All-sky survey data
- eRODat
- Source catalogues
- Half sky maps
- Filter wheel closed data
- Upper limits
- SRG orbit files
- SRG attitude files
- Mirroring archive
- APIs
- eROSITA acknowledgement

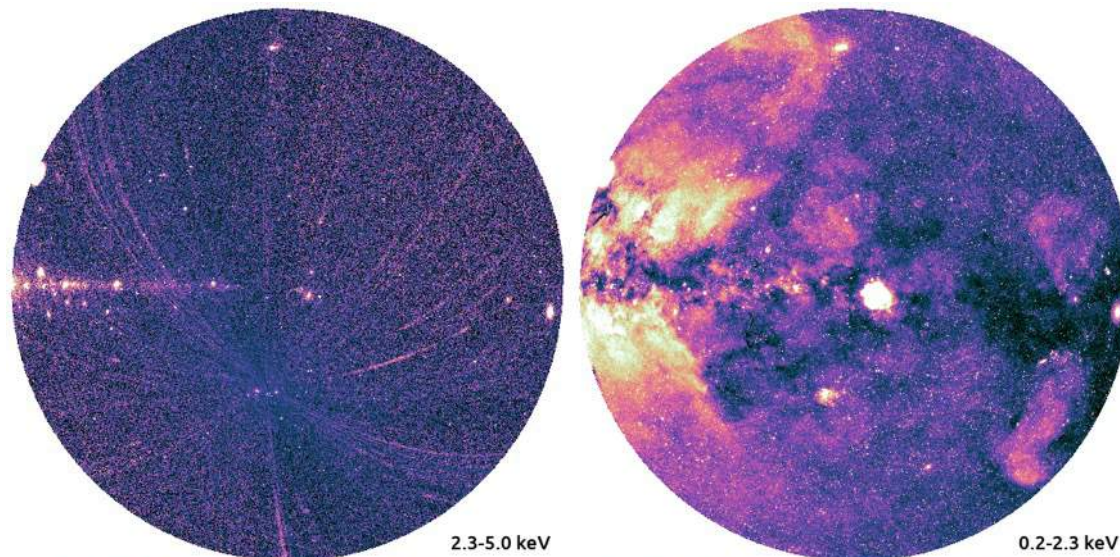
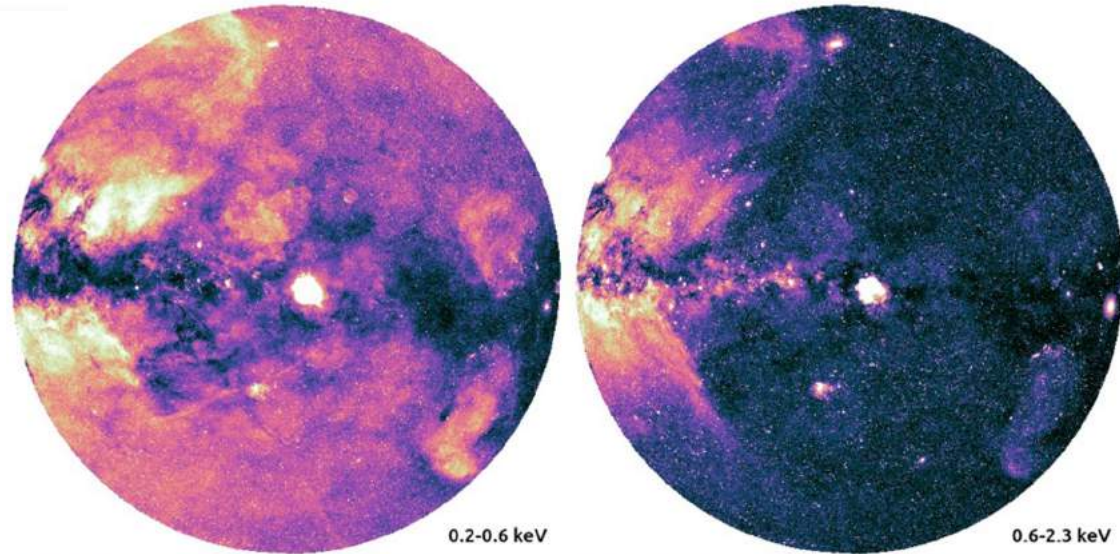
Data Release 1 (DR1) site!

eROSITA-DE) makes public the first six months of the SRG/eROSITA all-sky survey (eRASS1) with the German eROSITA consortium. This public data release is called eROSITA-DE Data

eROSITA All-Sky Survey (eRASS) data is shared equally between a German and a Russian sky have been defined, over which each team has unique scientific data exploitation rights. share of both Galactic and extragalactic areas.

gitude (l) and latitude (b), with a division marked by the great circle passing through the and the Galactic Center SgrA* (l, b)=(359.94423568,-0.04616002): data with $-0.05576432 < l < 179.94423568$ degrees (Eastern Galactic consortium, while data with $359.94423568 > l > 179.94423568$ degrees (Western Galactic hemisphere) belong to eROSITA-DE. The ations were released to the public through this site on 31. January 2024.

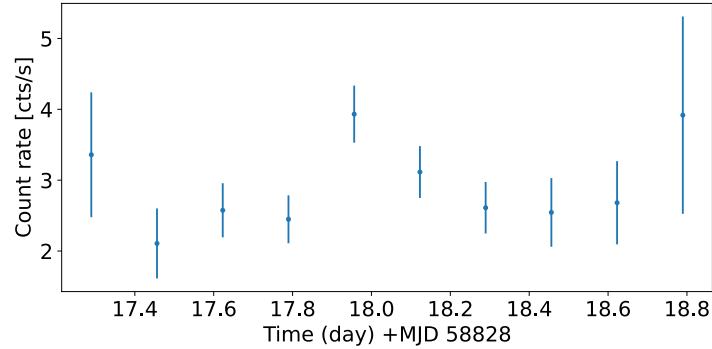




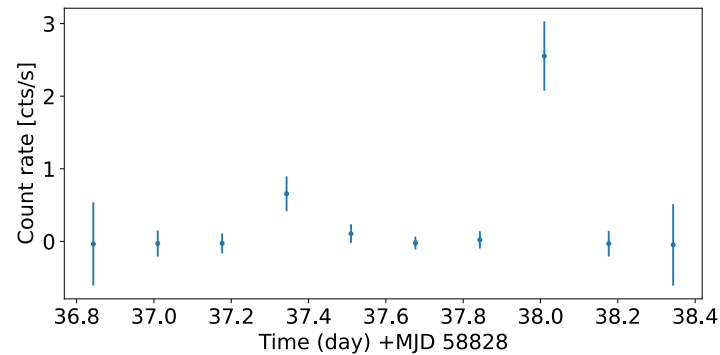
- Software
- Calibration DB
- Attitude files
- Exposure maps
- Events
- Count rate maps
- Source catalogues
- Light curves
- X-ray Spectra

Merloni et al. (2024)

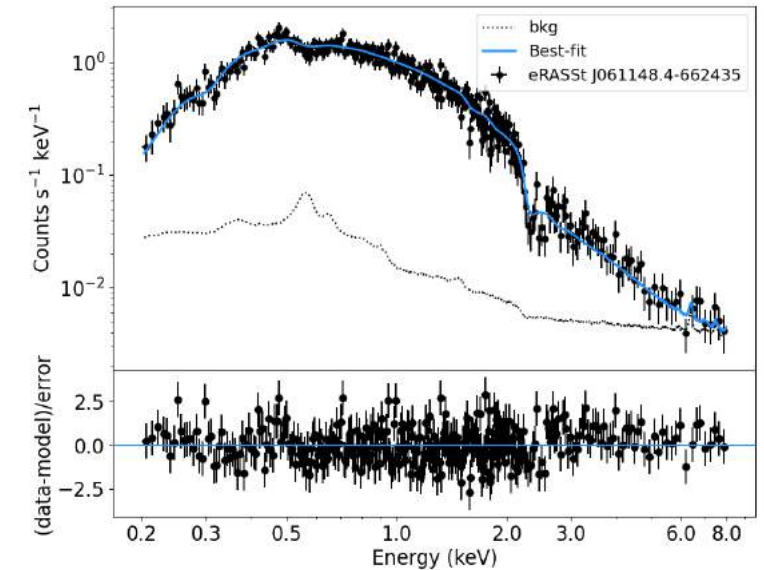
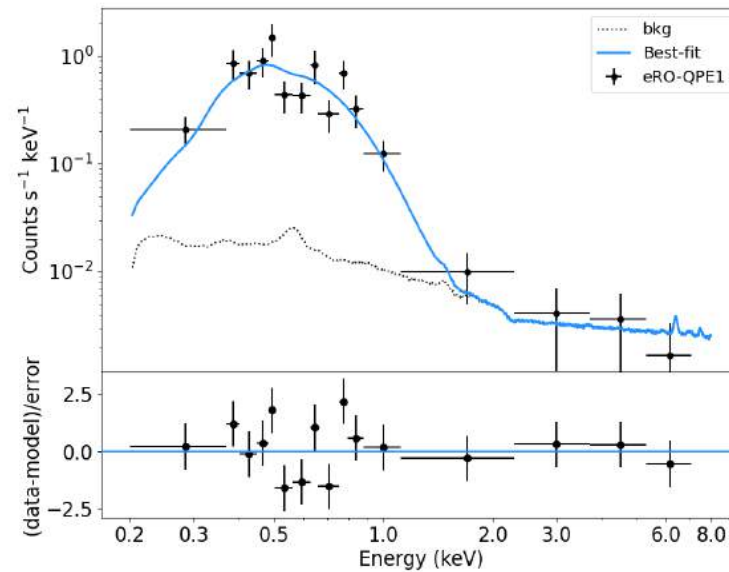
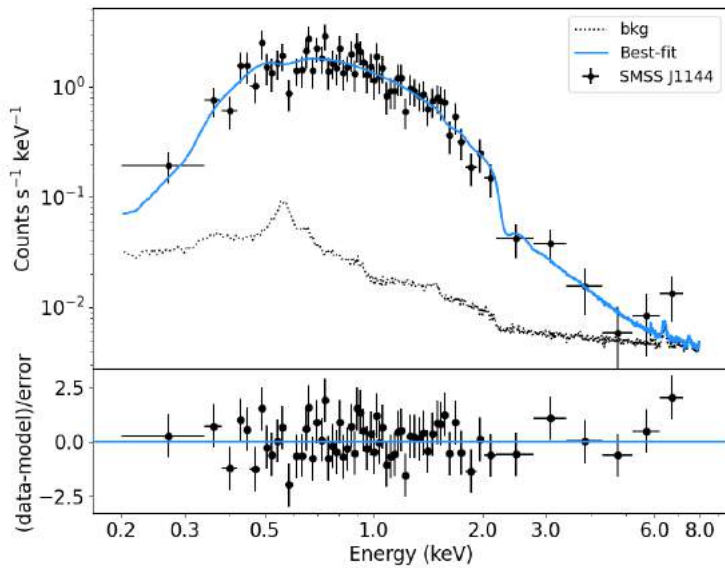
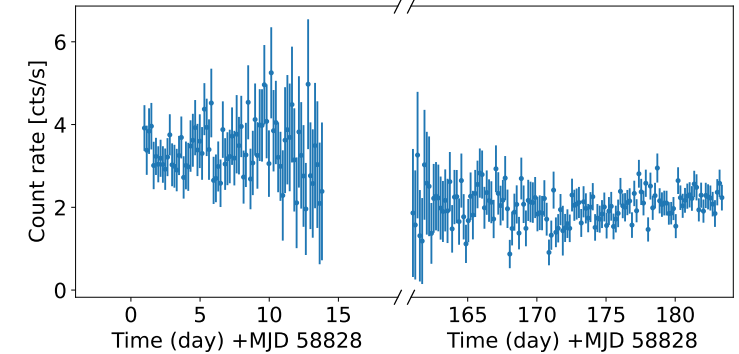
SMSS J1144; $z=0.89$
(Onken+ '22; Kammoun+ '23)



eROQPE1 (Arcodia+ '21)



Brightest SEP AGN



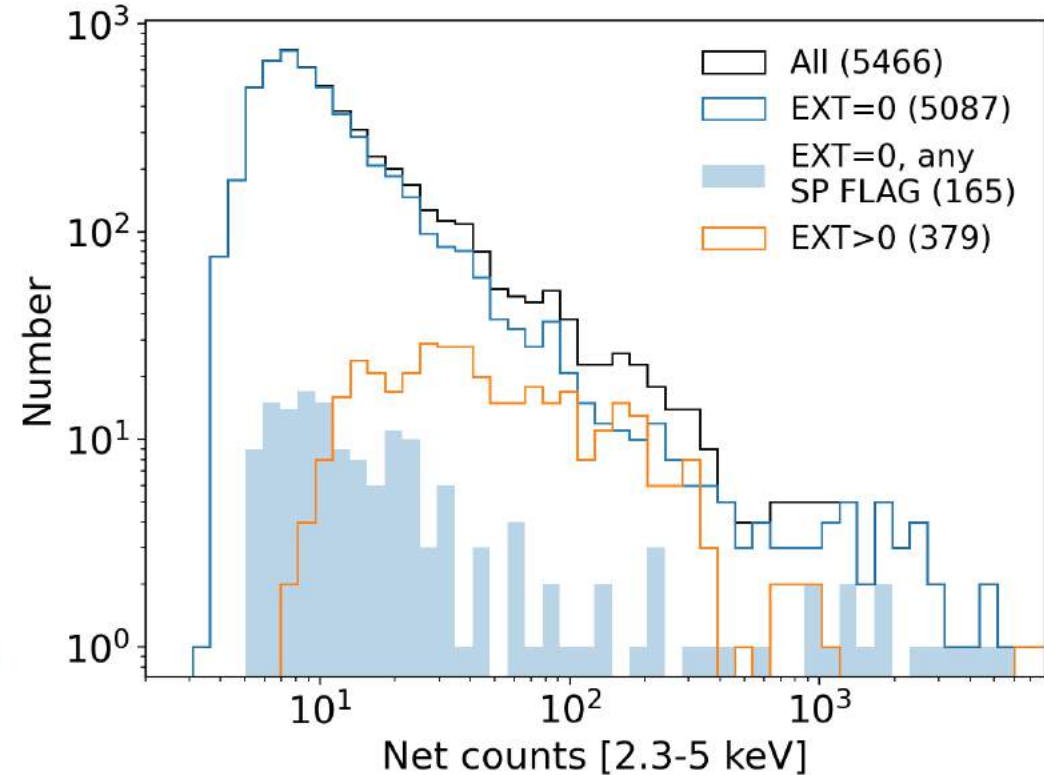
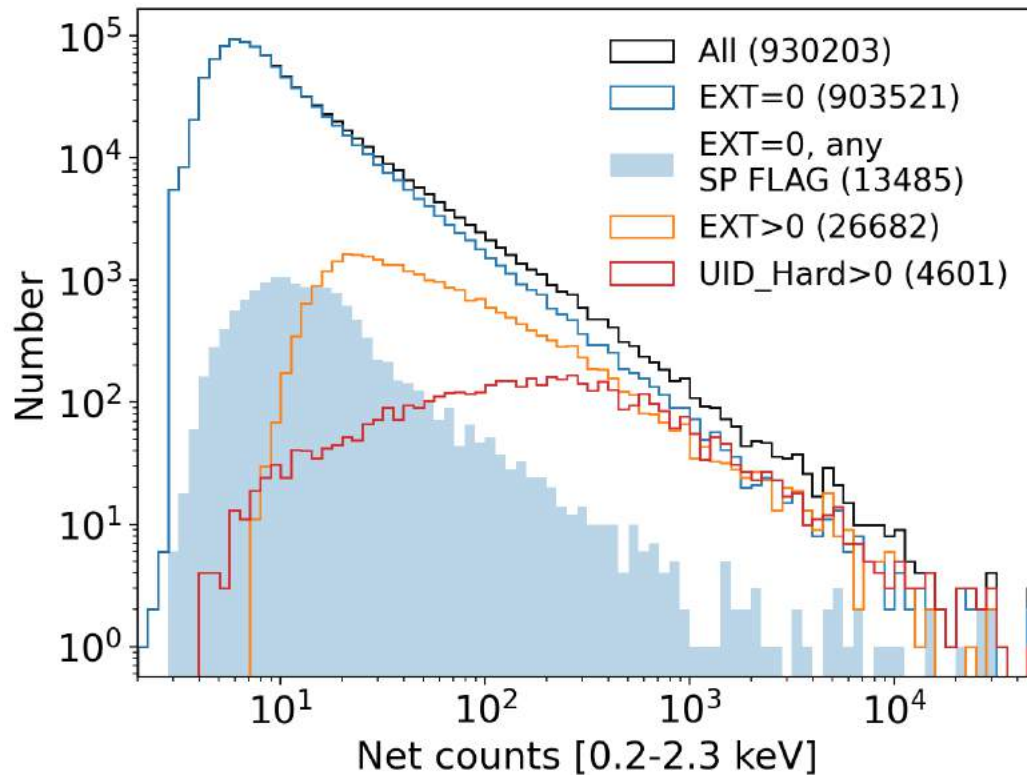
eRASS1 Catalogues

Soft band 0.2-2.3 keV, Point sources: 903k

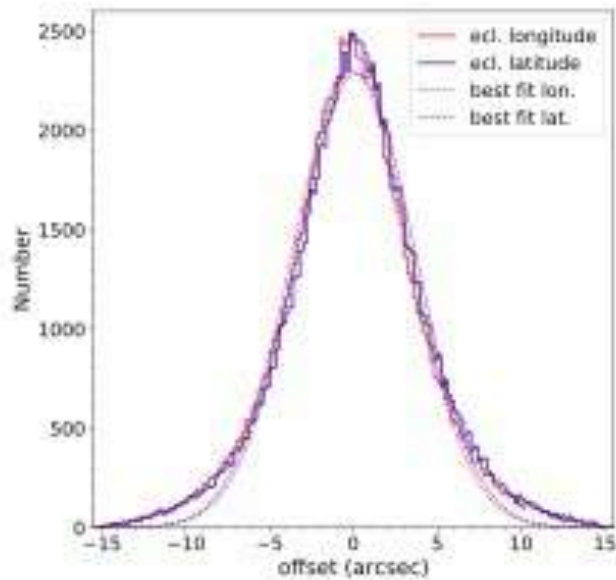
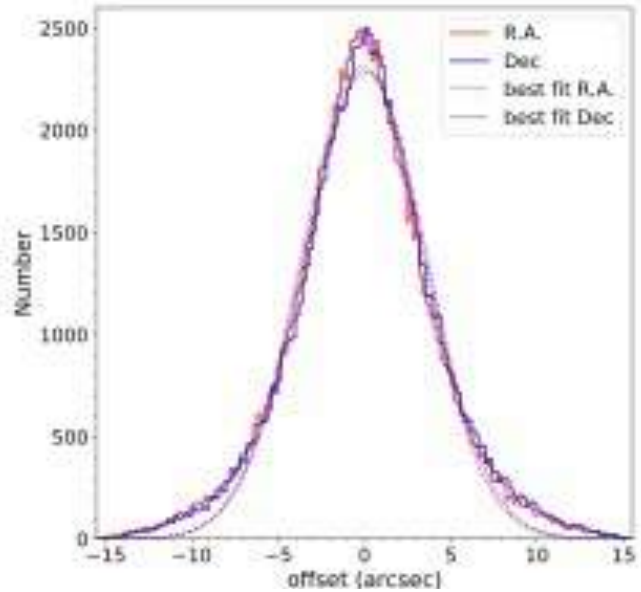
Soft band 0.2-2.3 keV, extended: 26.6k (of which 12k optically confirmed clusters)

Hard band 2.3-5 keV, Point Sources: 5k

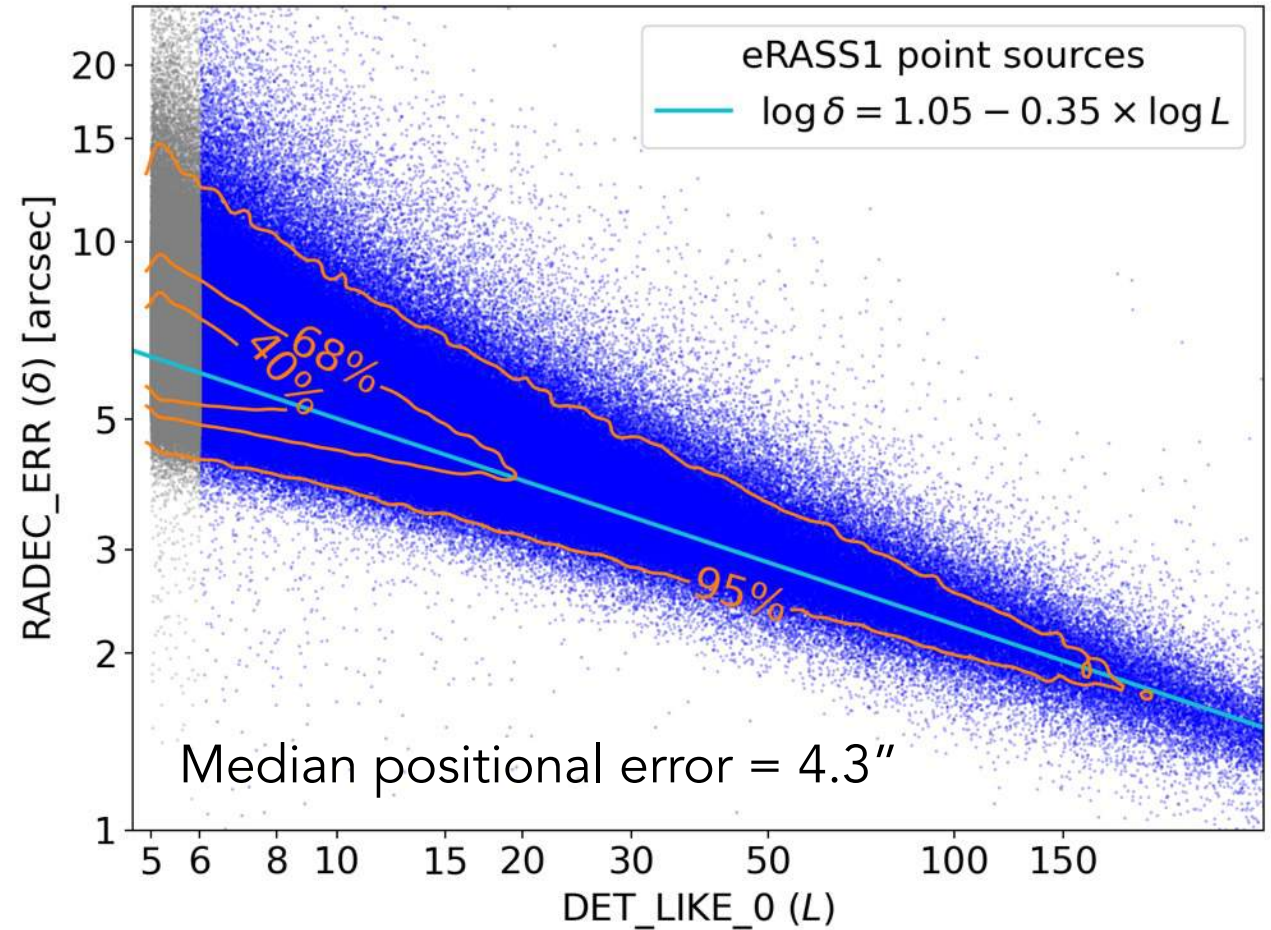
Hard band 2.3-5 keV, Extended: 380



Merloni et al. (2024)



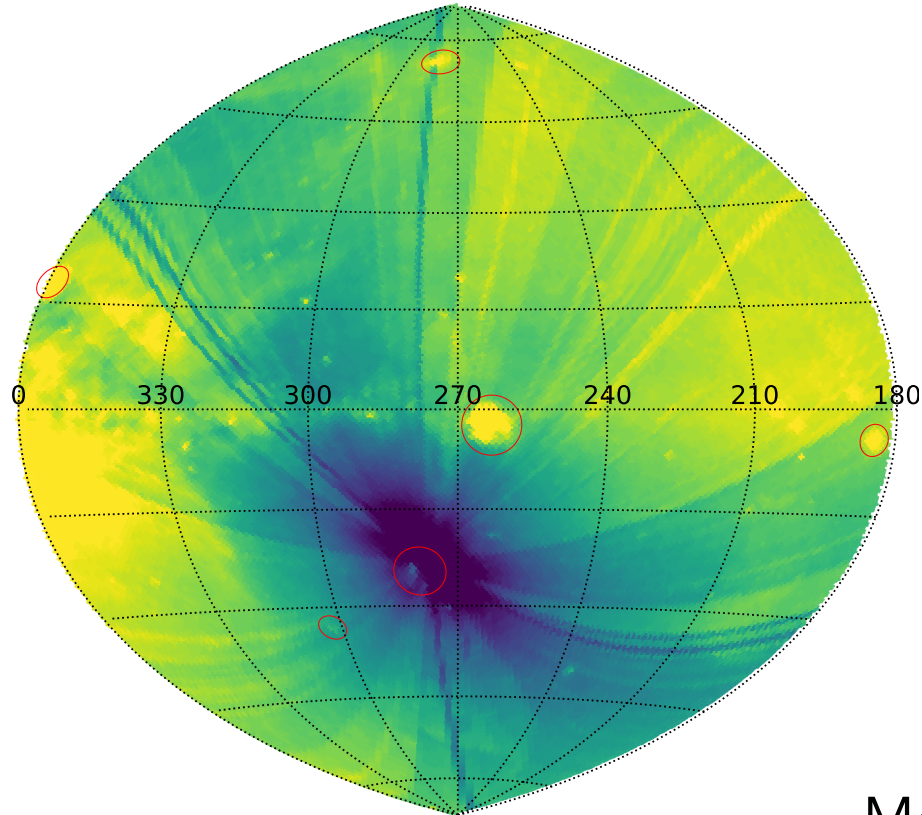
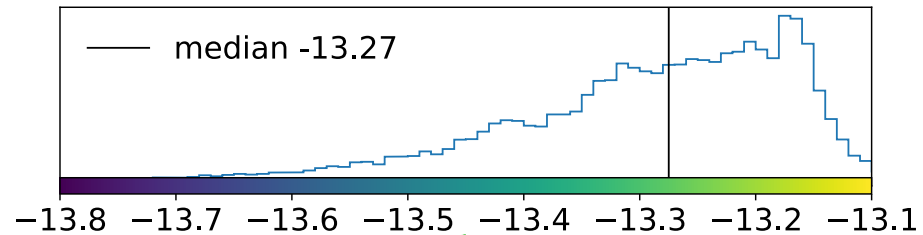
Point sources astrometric accuracy



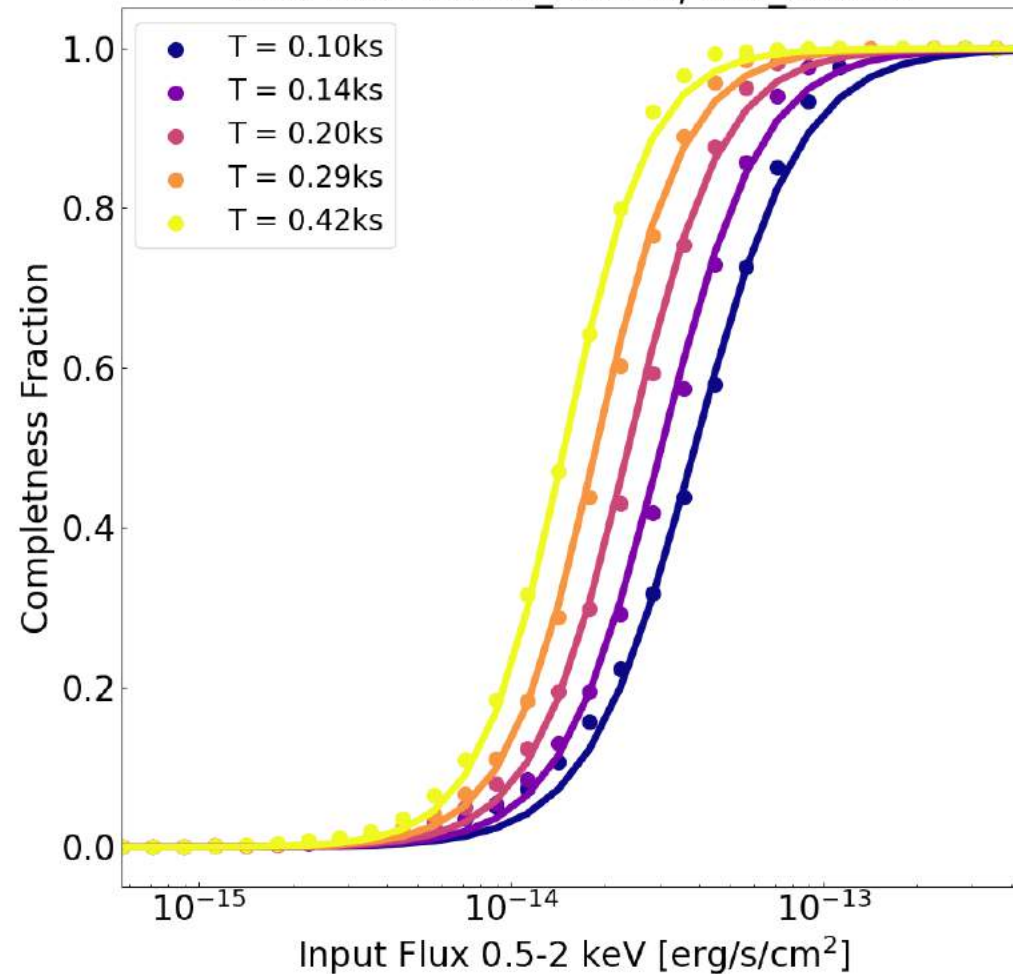
Merloni et al., A&A, in press

eRASS1 Main Catalogue: flux limit

Log of 0.5-2 keV flux limit

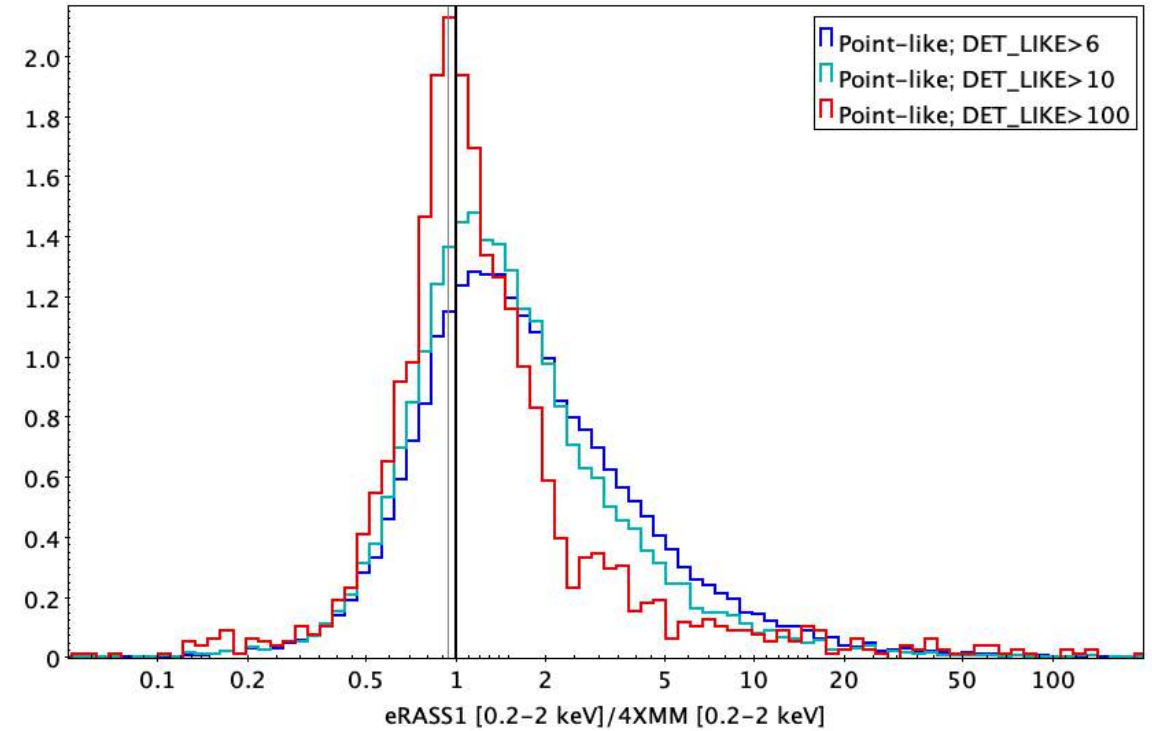
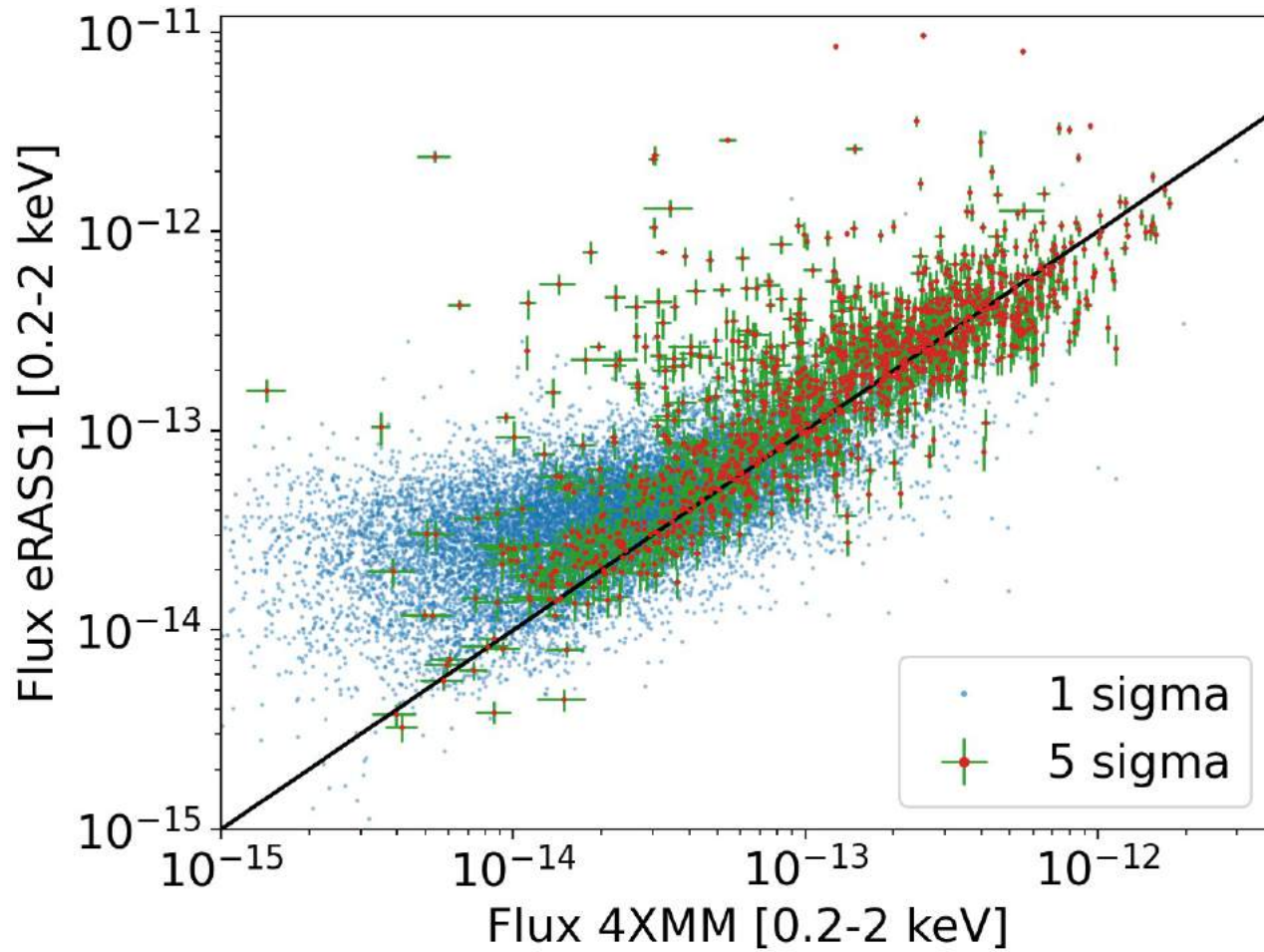


AGN eRASS1 EXT_LIKE=0, DET_LIKE>6



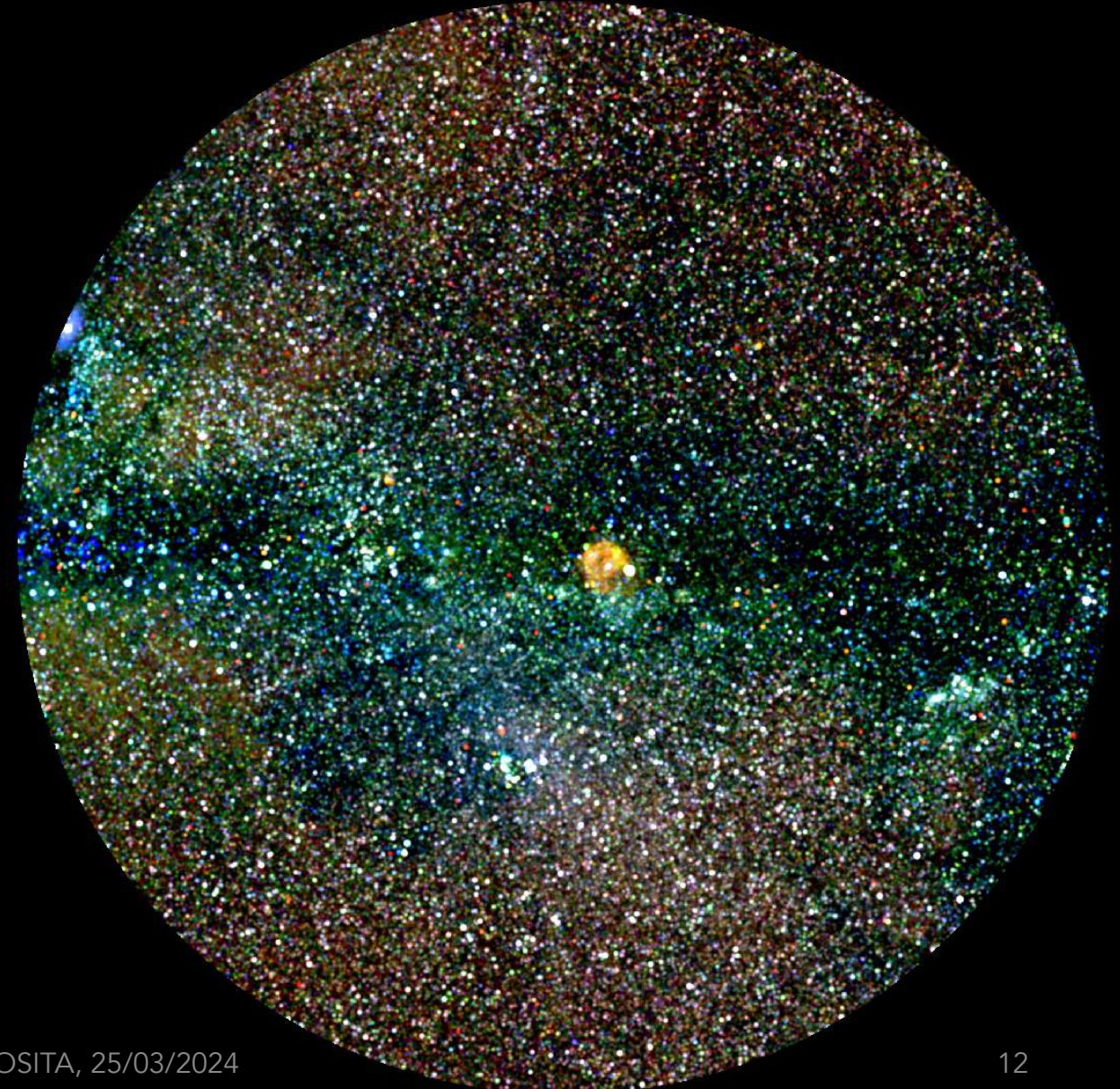
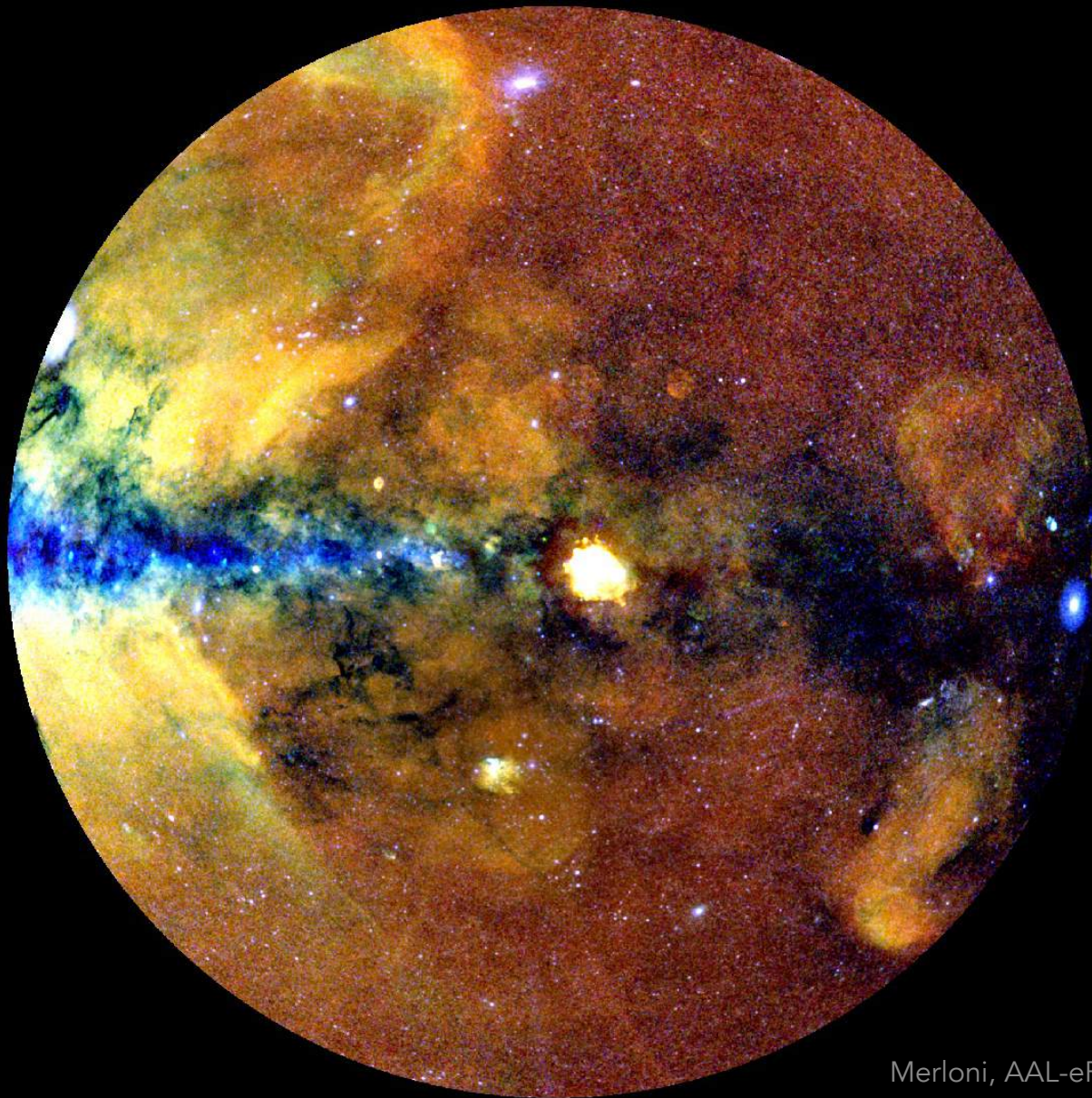
Merloni et al., A&A, in press

eRASS1: Comparison with 4XMM



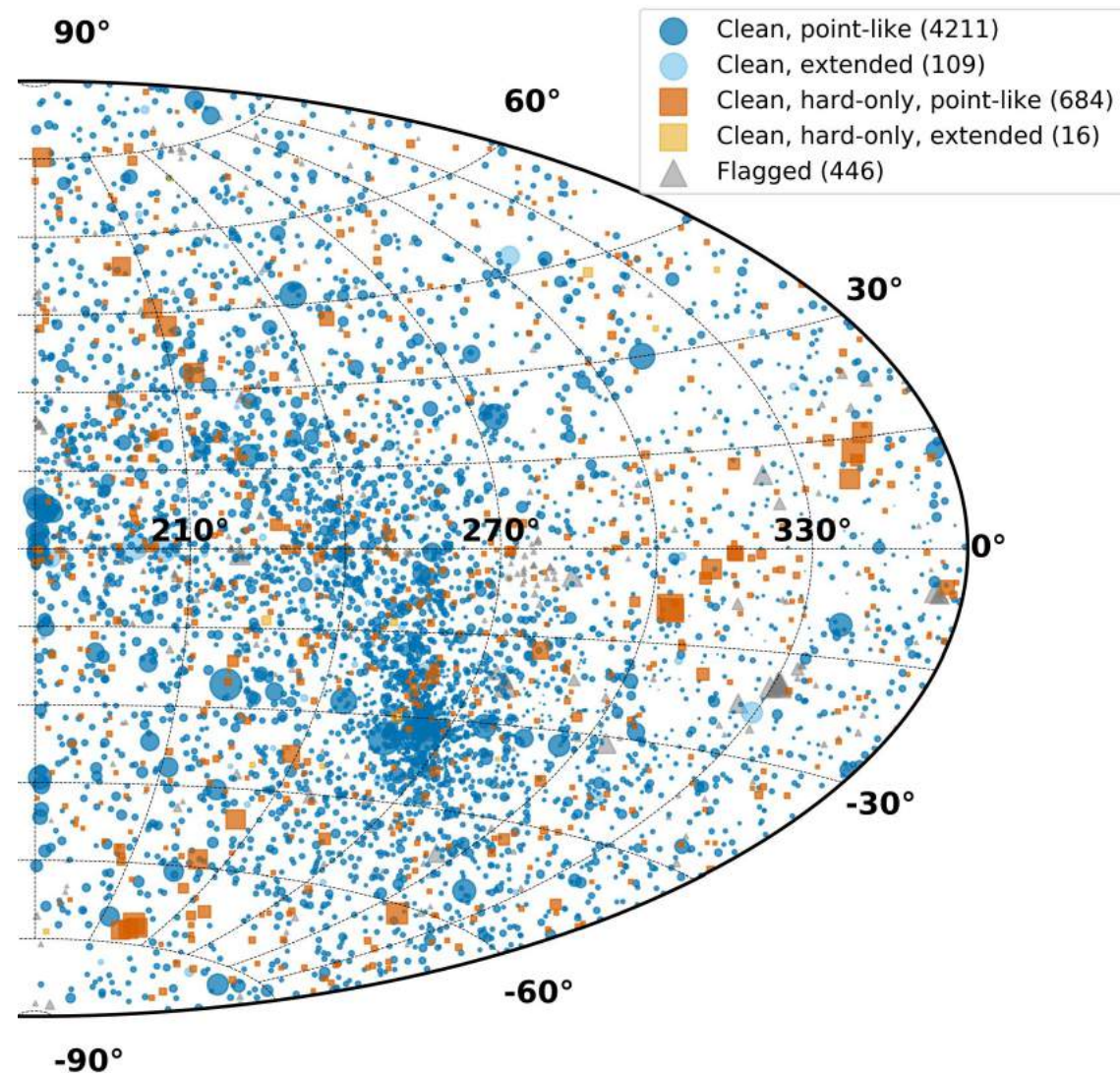
Photometric consistency with 4XMM better than $\sim 10\%$ in 0.2-2 keV [expected mis-calibration $\sim 6\%$]; much larger offset in 2.3-5 keV (up to 30% A_{eff} mis-calibration?)

Selected Science highlights from DR1

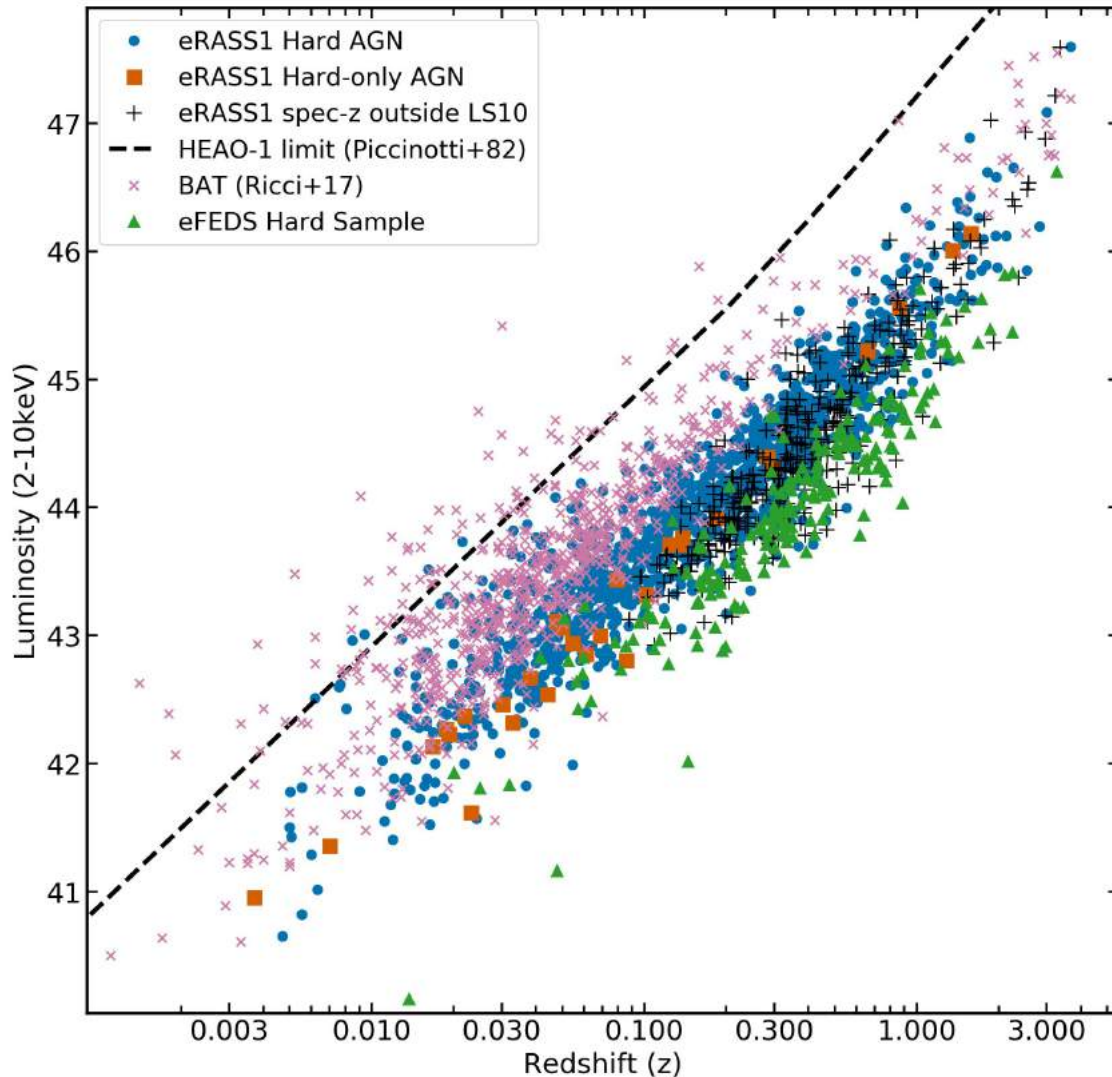


The eRASS:1 hard (2.3-5keV) sample: **5466 sources**

- 22 times more sources than eFEDS
- Divided into X-ray point-like vs. extended
- Divided into hard + soft detections vs. only above 2.3keV



Luminosity - redshift space



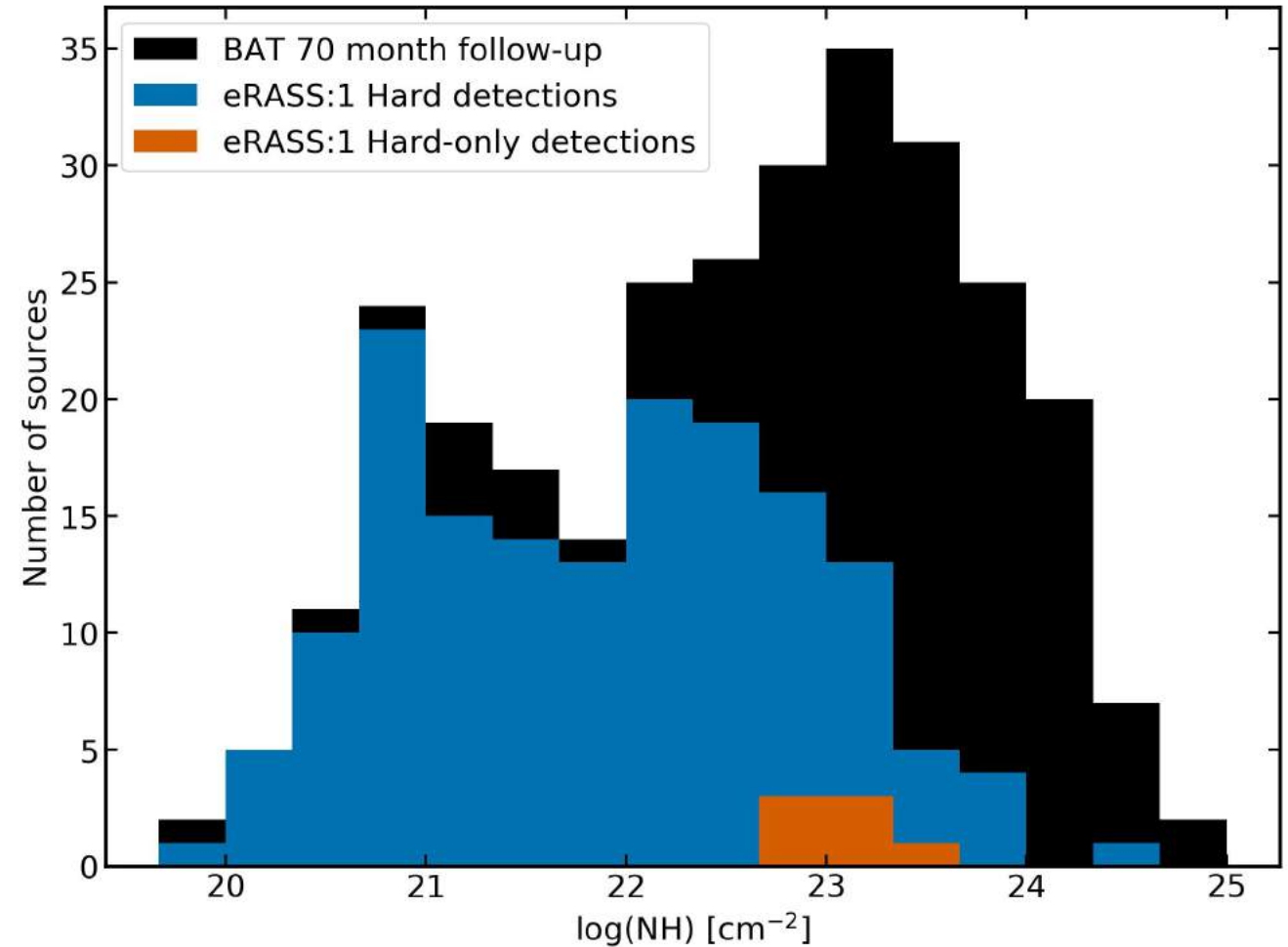
- Luminosity redshift for eRASS1 hard, hard-only, including sources in Galactic plane
- HEAO-1 limit (previous all-sky hard X-ray survey) and BAT AGN also shown
- eRASS1 is deeper, higher redshift than other hard X-ray selected AGN samples
- Redshifts span 3 orders of magnitude, luminosity spans 7

Waddell et al. arXiv:2401.17306

Comparison with Swift-BAT

- Comparison to the Swift-BAT AGN in eROSITA_DE sky (70 month catalog; Ricci et al.)
- NH is measured from spectral fitting using soft X-ray follow up (e.g. with Swift or XMM-Newton)
- Hard-only sources have high NH of $\log(\text{NH}) \sim 23$

Waddell et al. arXiv:2401.17306

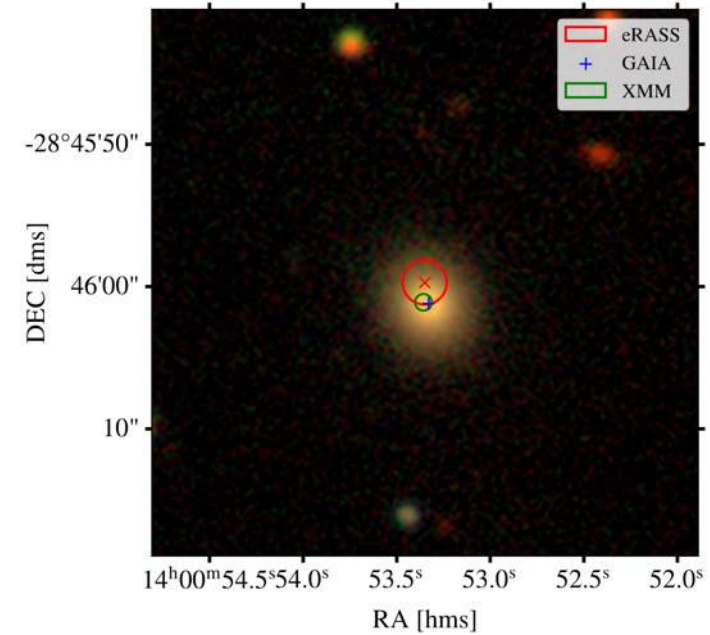
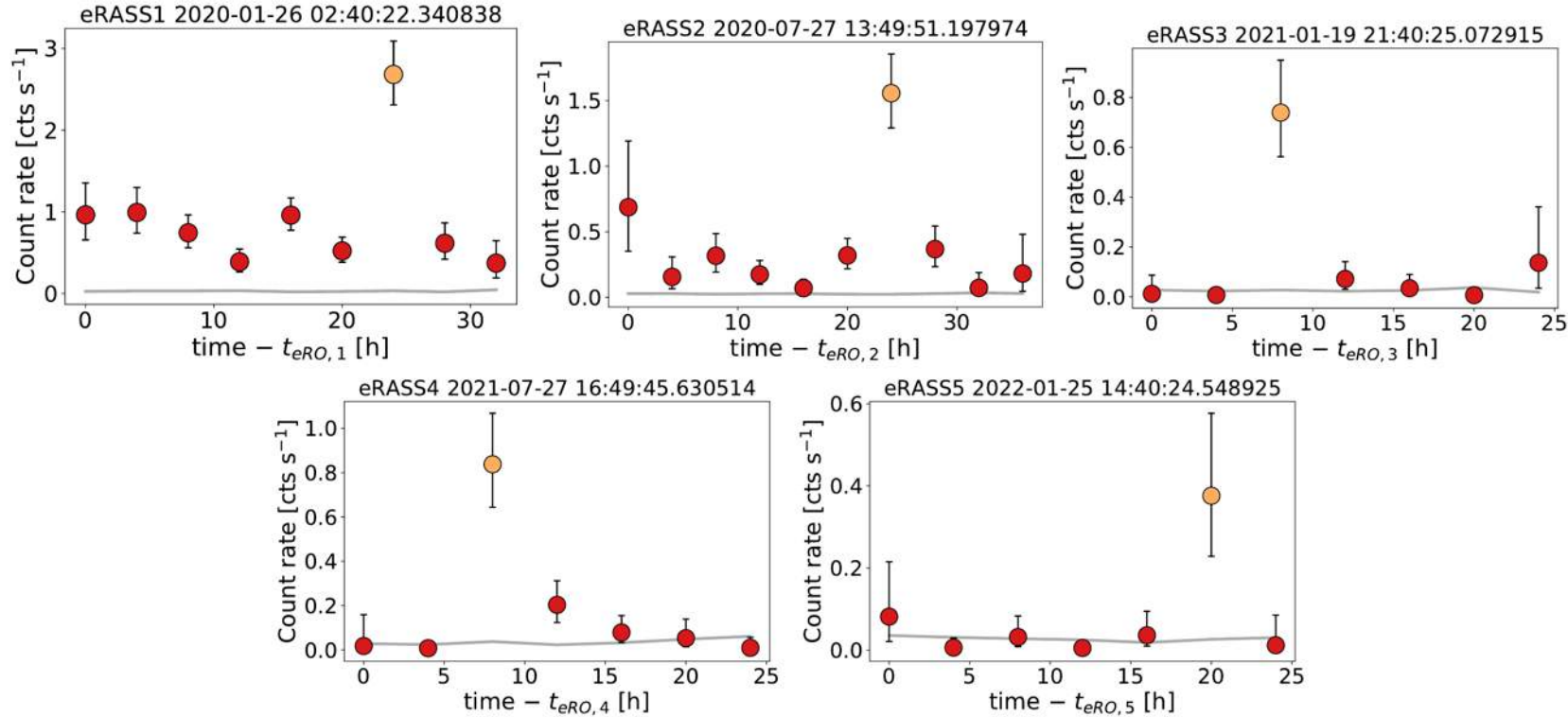




Two new QPEs with eROSITA

- Multiple surveys (4-5) can be used: eRO-QPE3!

eRO-QPE3



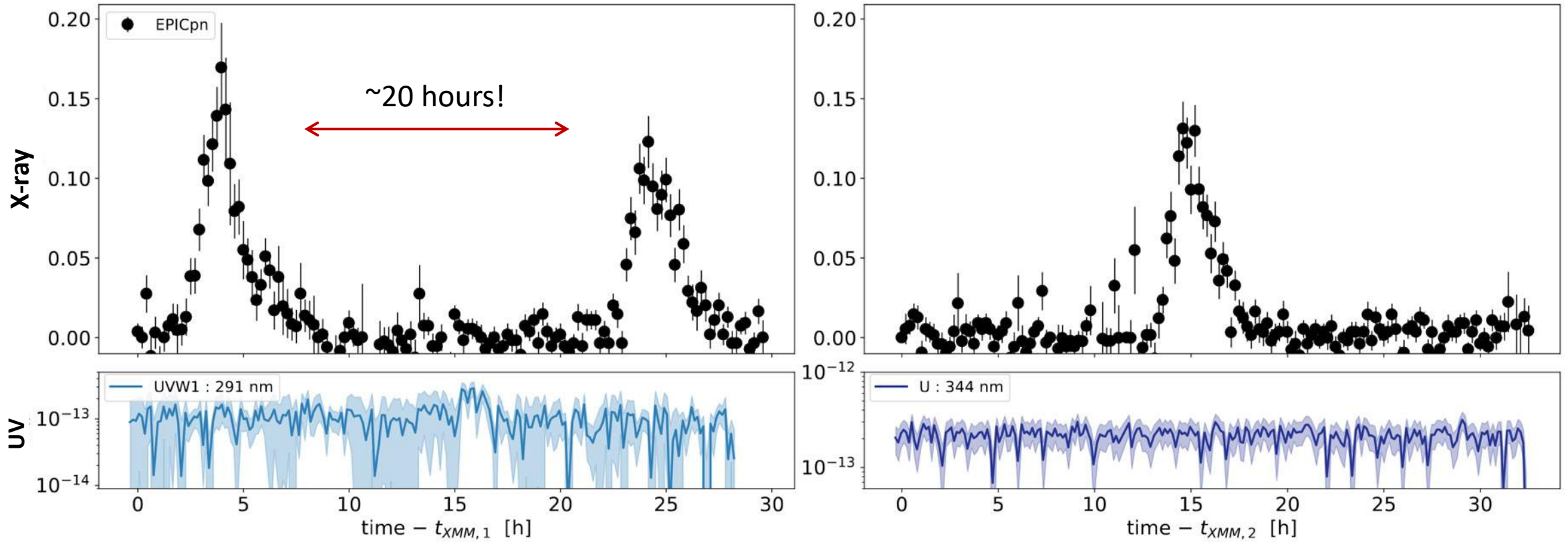
Arcodia e al. (2024)



Two new QPEs with eROSITA

- Multiple surveys (4-5) can be used: eRO-QPE3!

eRO-QPE3

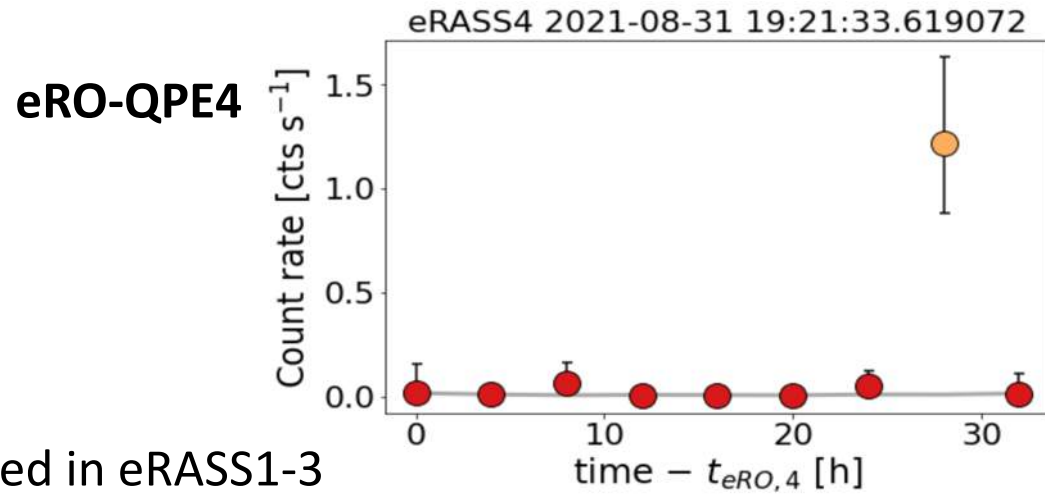


Arcodia+ (2024)

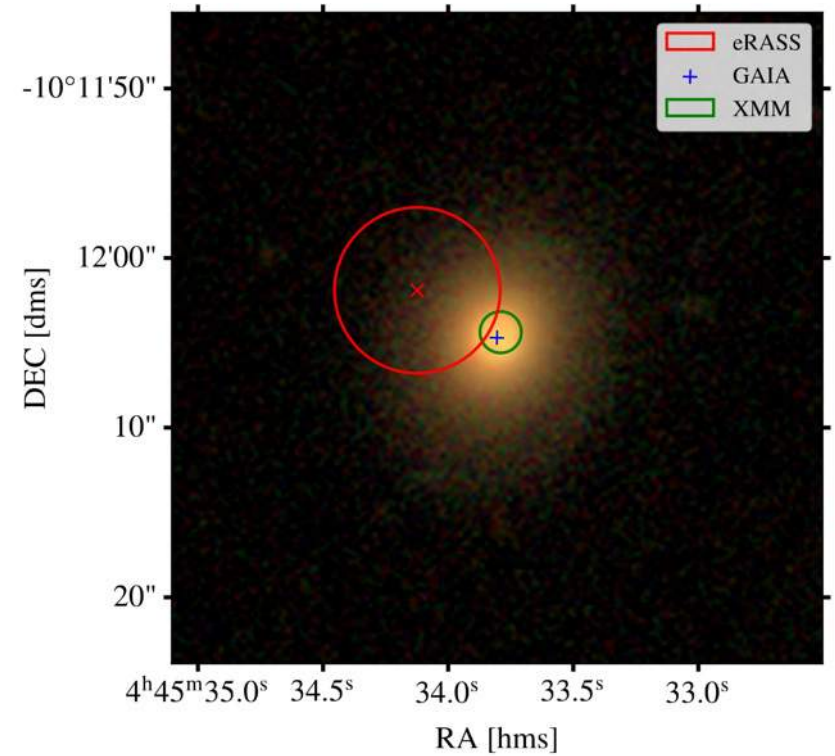
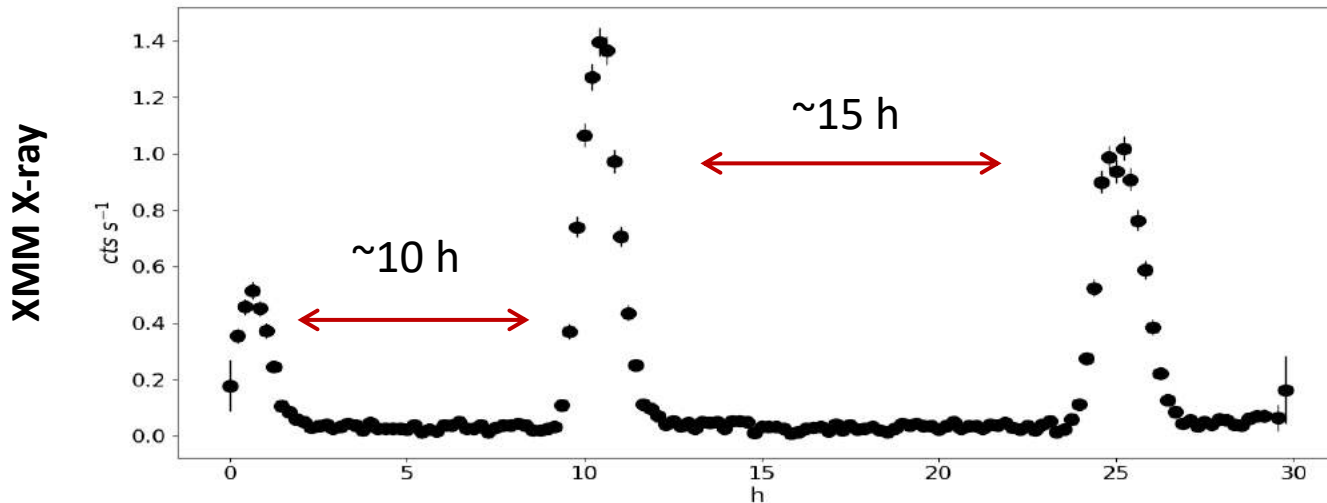


Two new QPEs with eROSITA

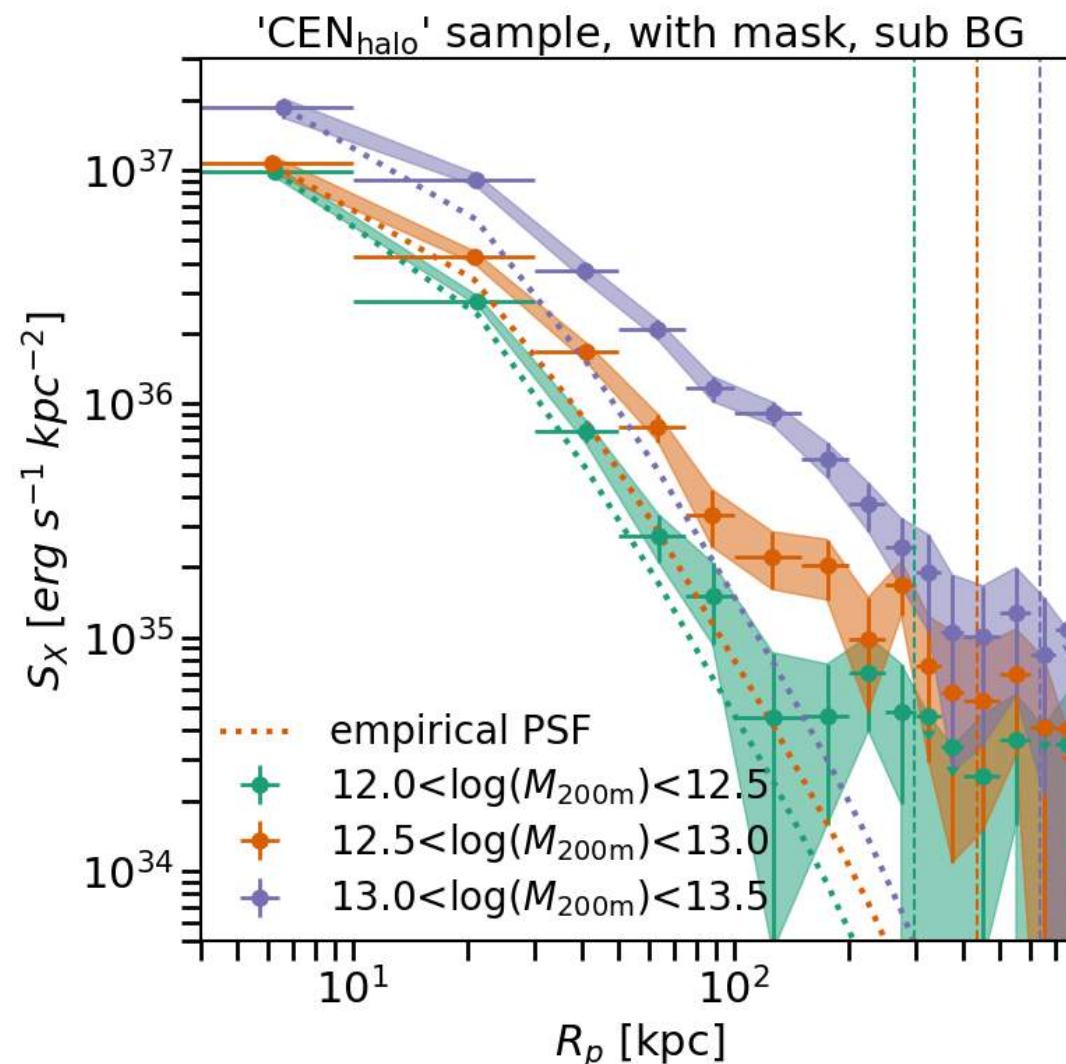
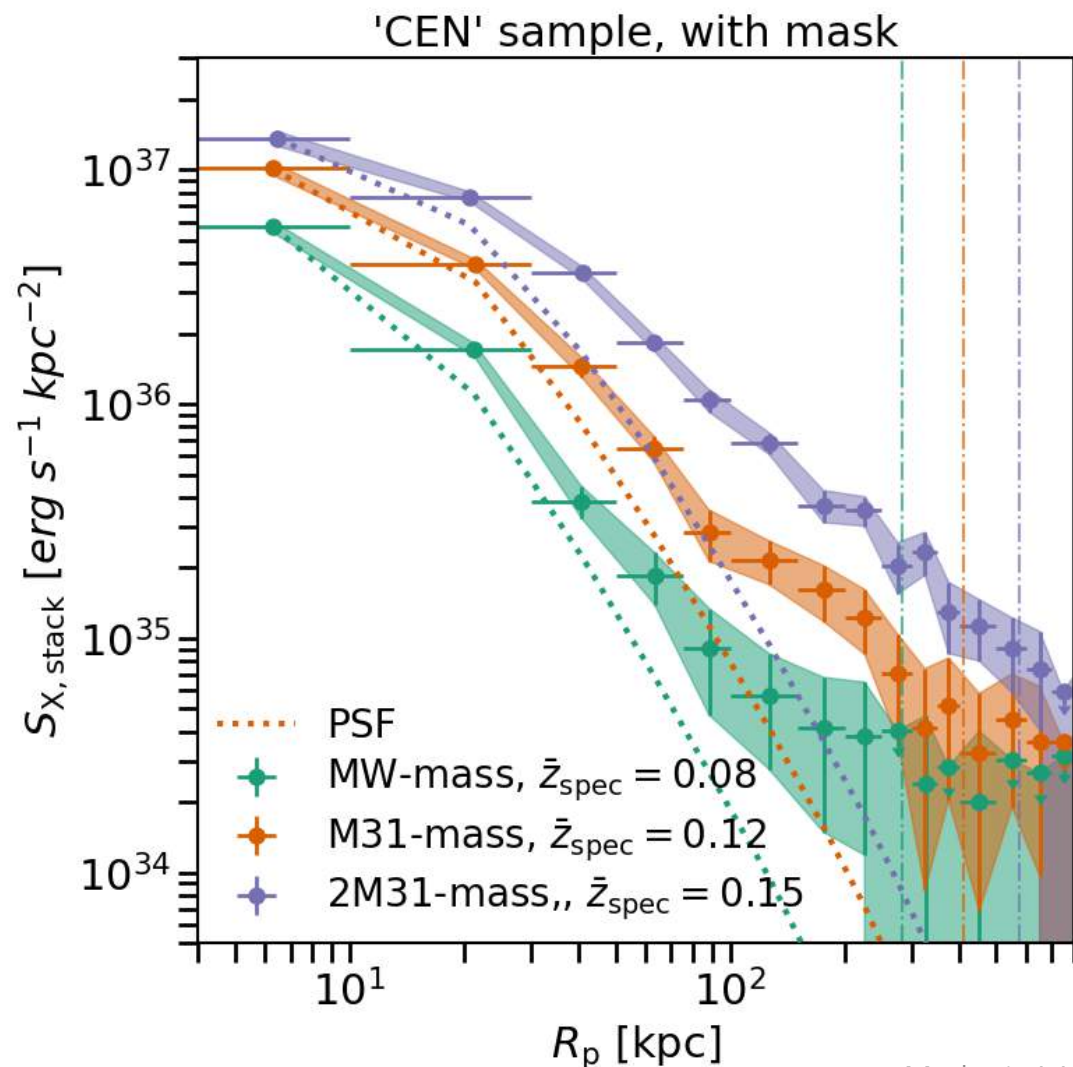
- Multiple surveys (4-5) can be used: eRO-QPE4!



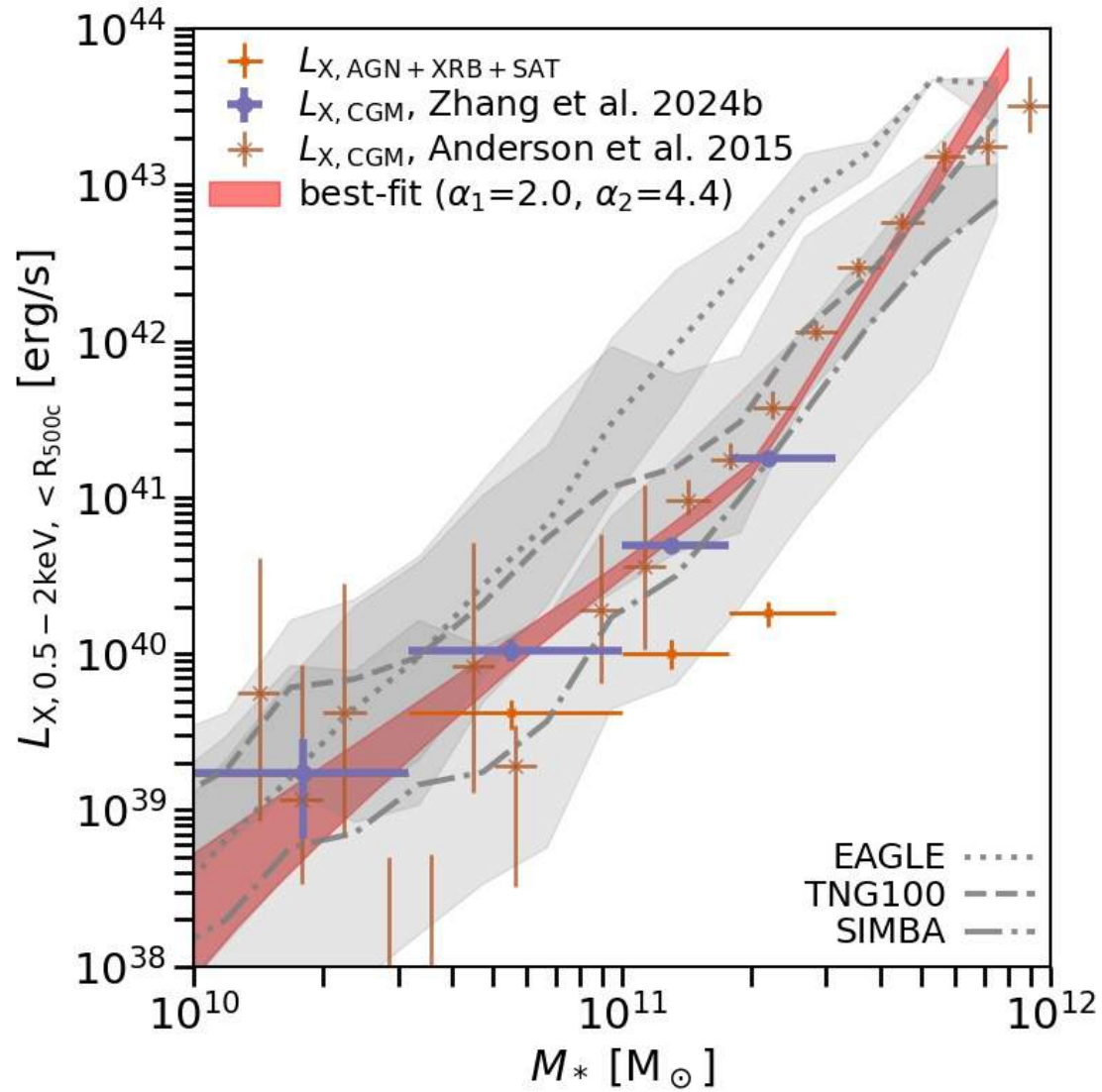
Undetected in eRASS1-3



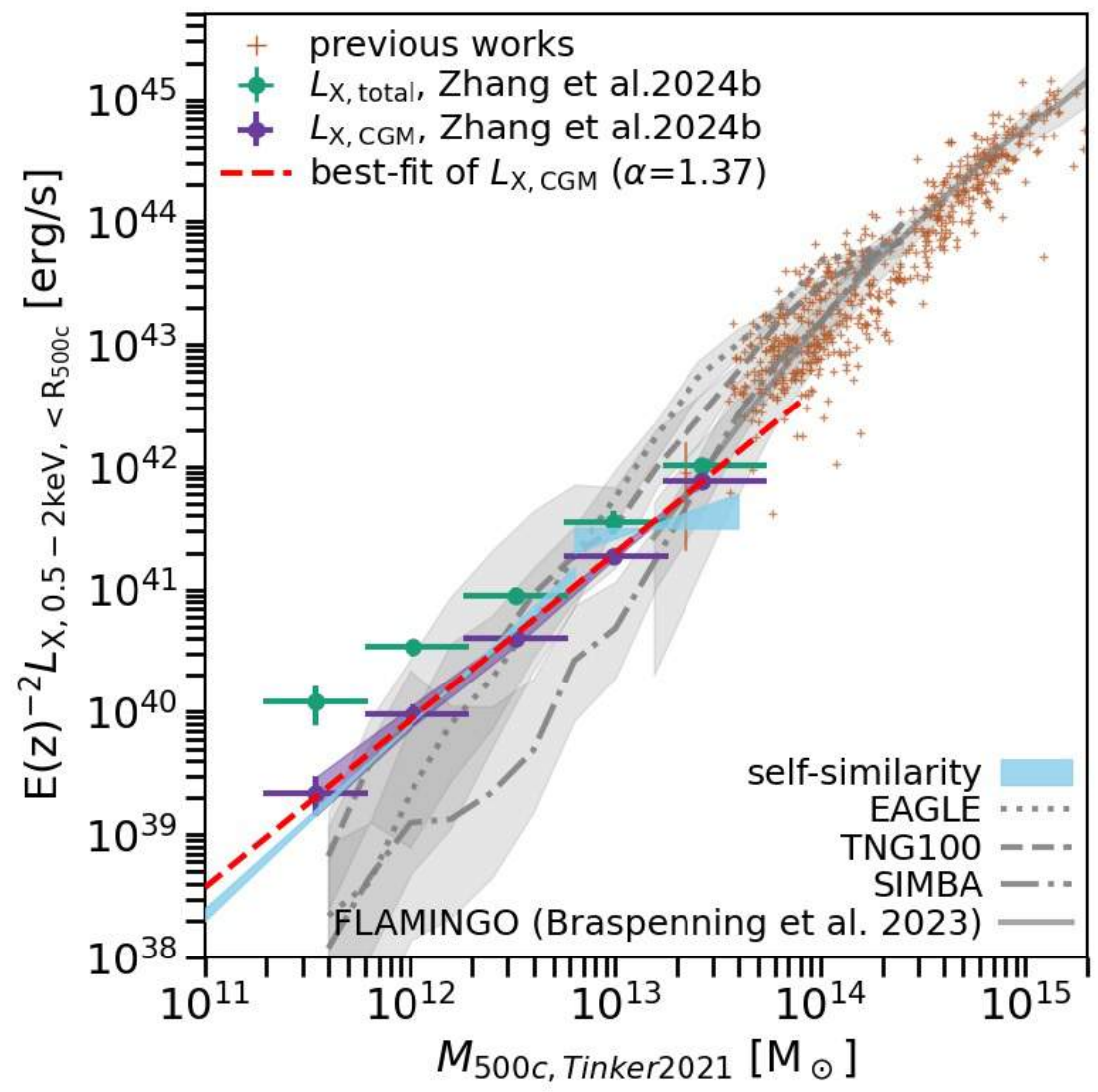
The hot CGM in eRASS1: I. X-ray brightness profiles (Yi et al.)



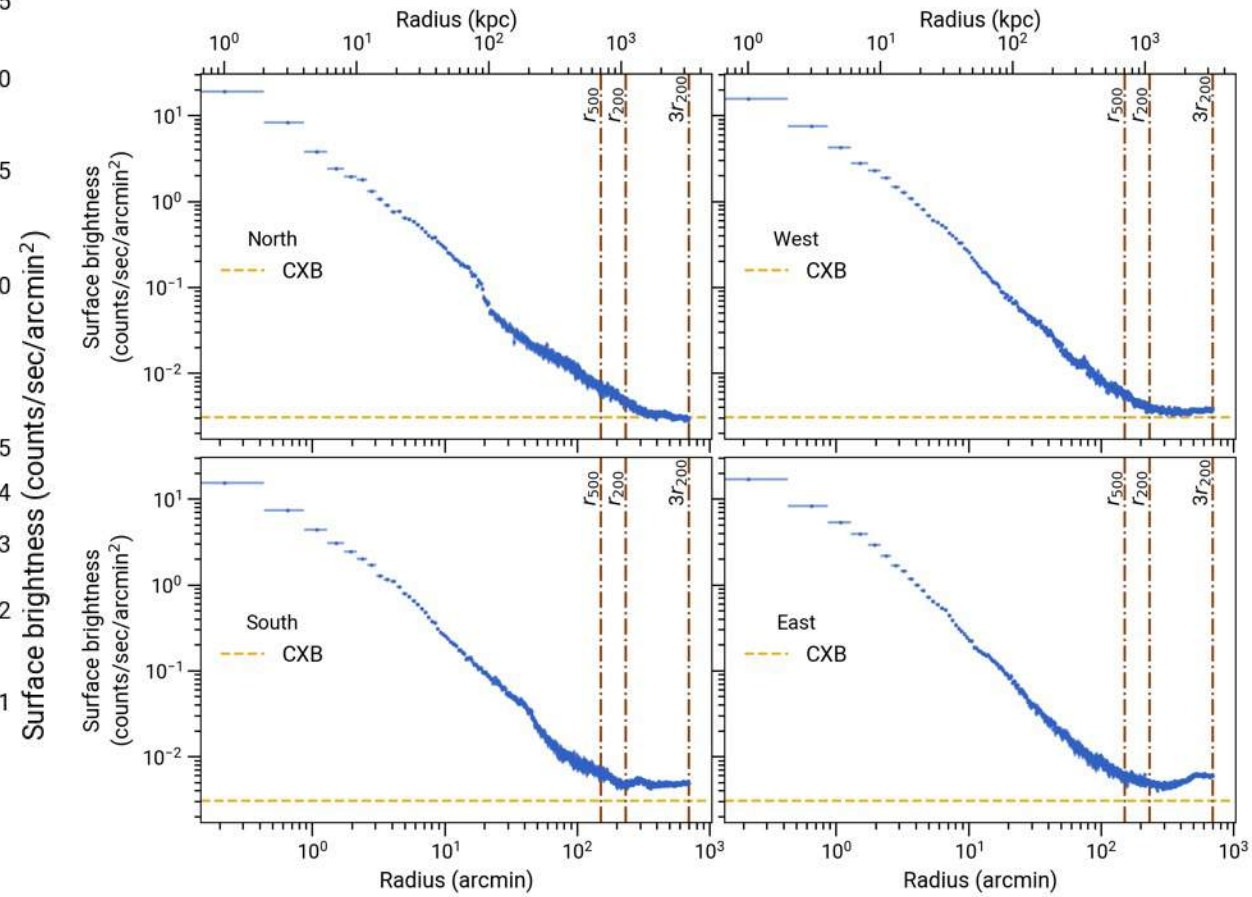
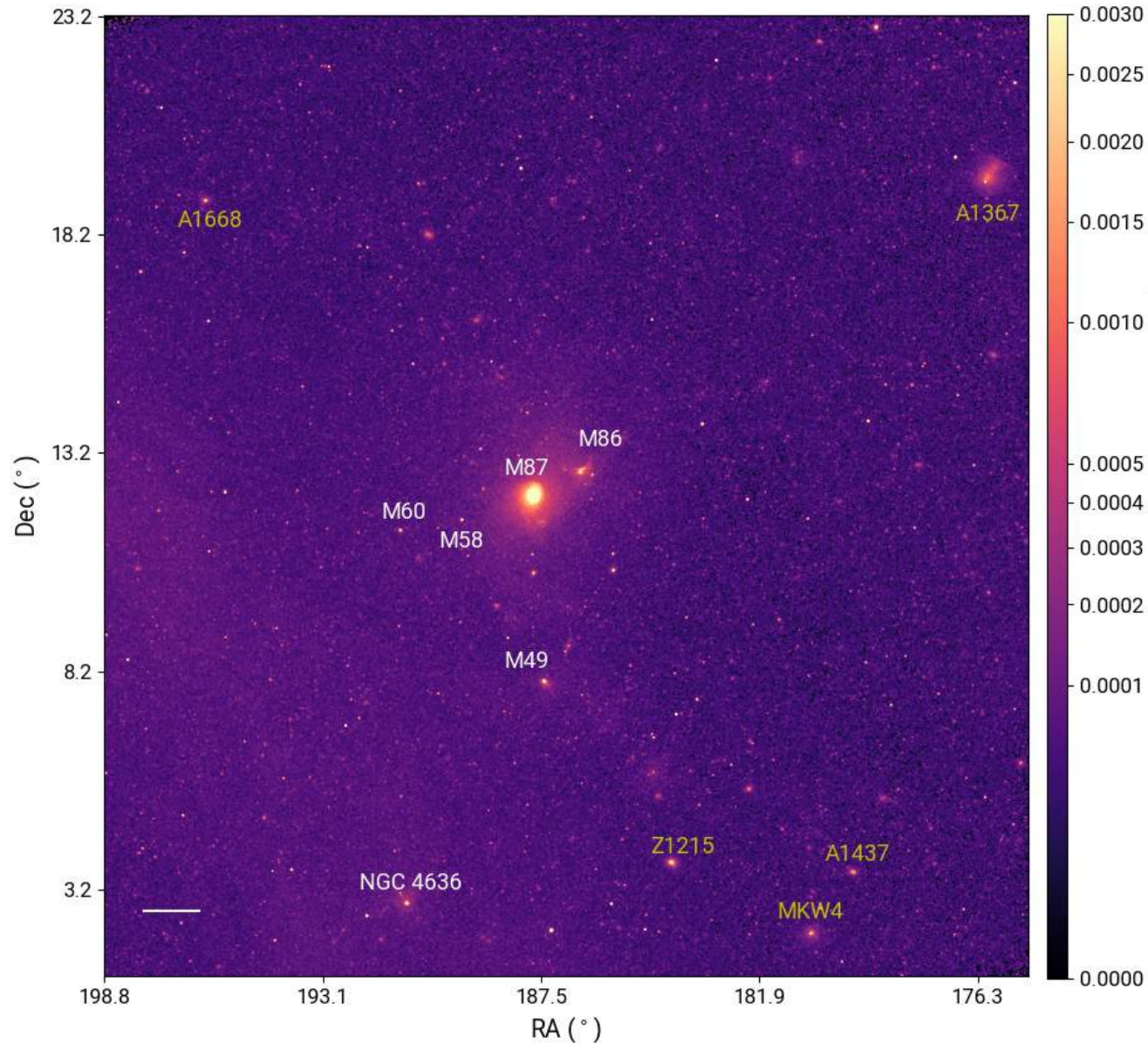
The hot CGM in eRASS1: II. Scaling Relations (Yi et al.)



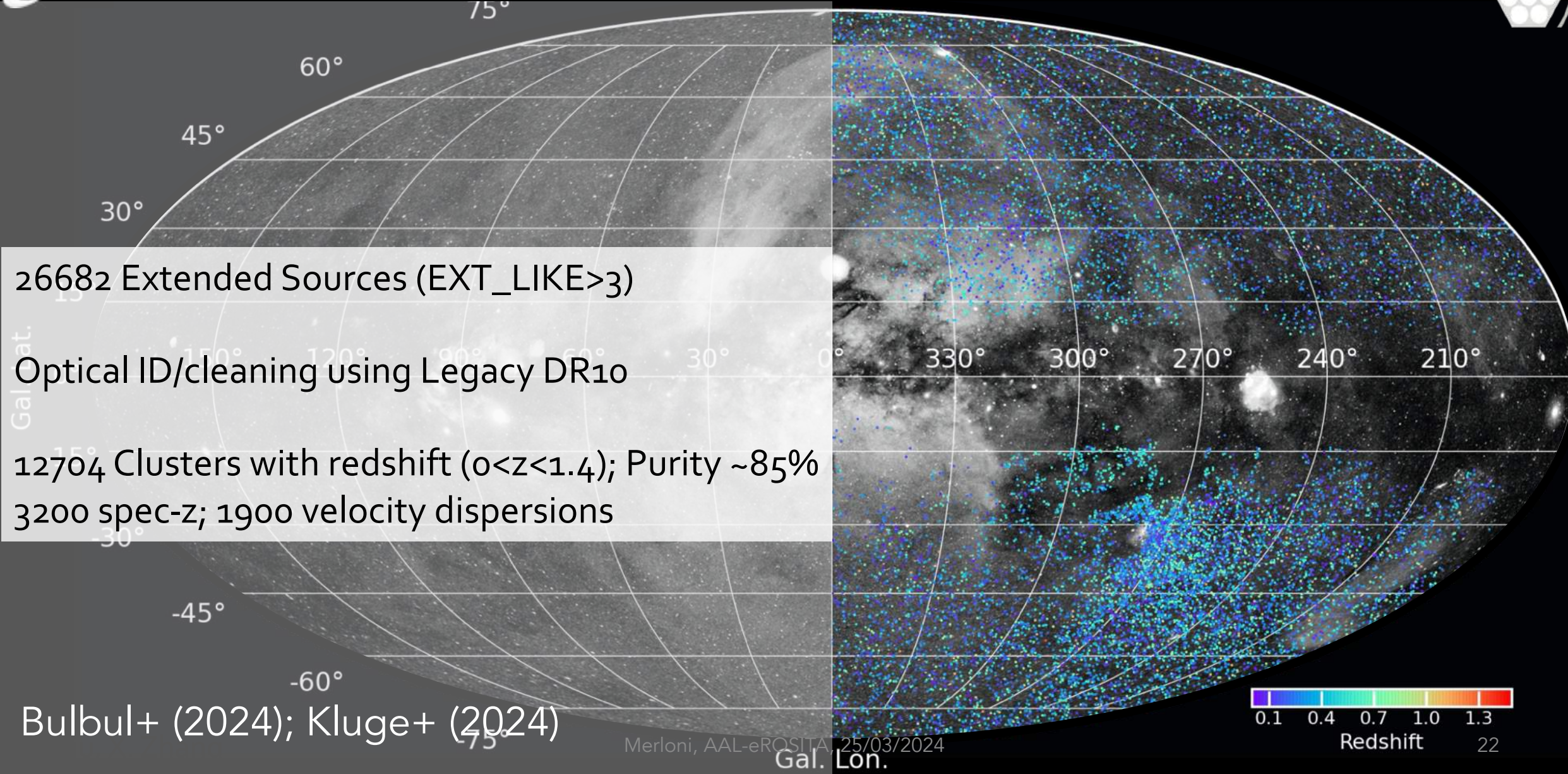
RC



The X-ray view of the Virgo Cluster with SRG/eROSITA (McCall et al.)



Clusters and Groups in eRASS1



26682 Extended Sources (EXT_LIKE>3)
Optical ID/cleaning using Legacy DR10
12704 Clusters with redshift ($0 < z < 1.4$); Purity ~85%
3200 spec-z; 1900 velocity dispersions

Bulbul+ (2024); Kluge+ (2024)



LS10 photometric redshift accuracy

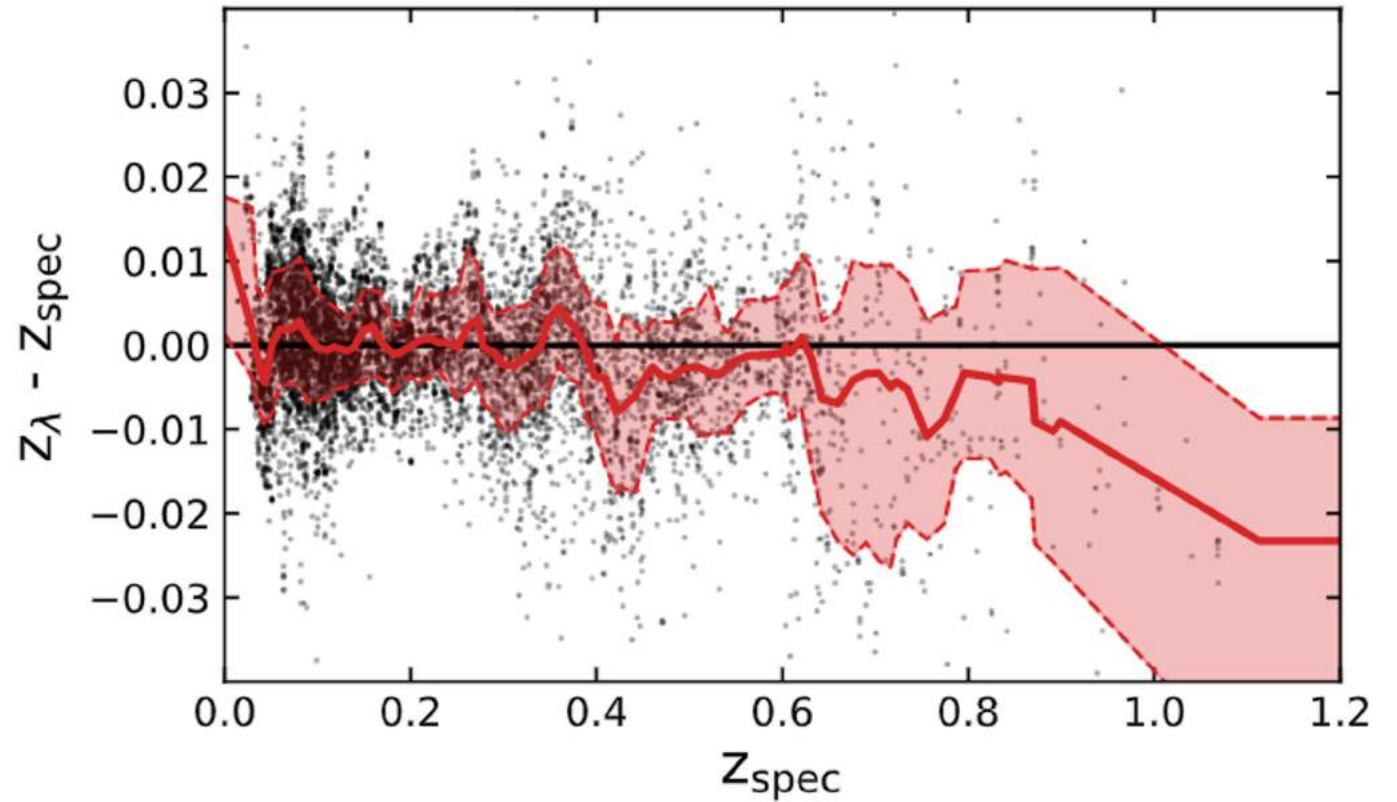
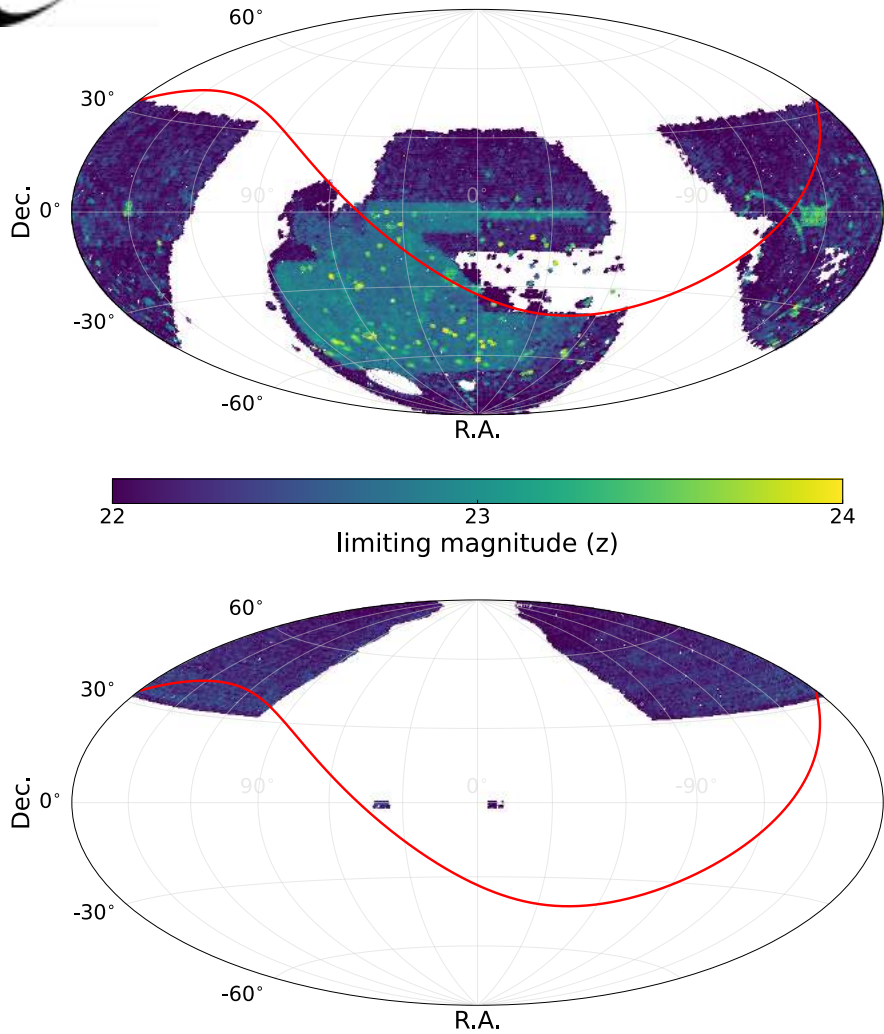
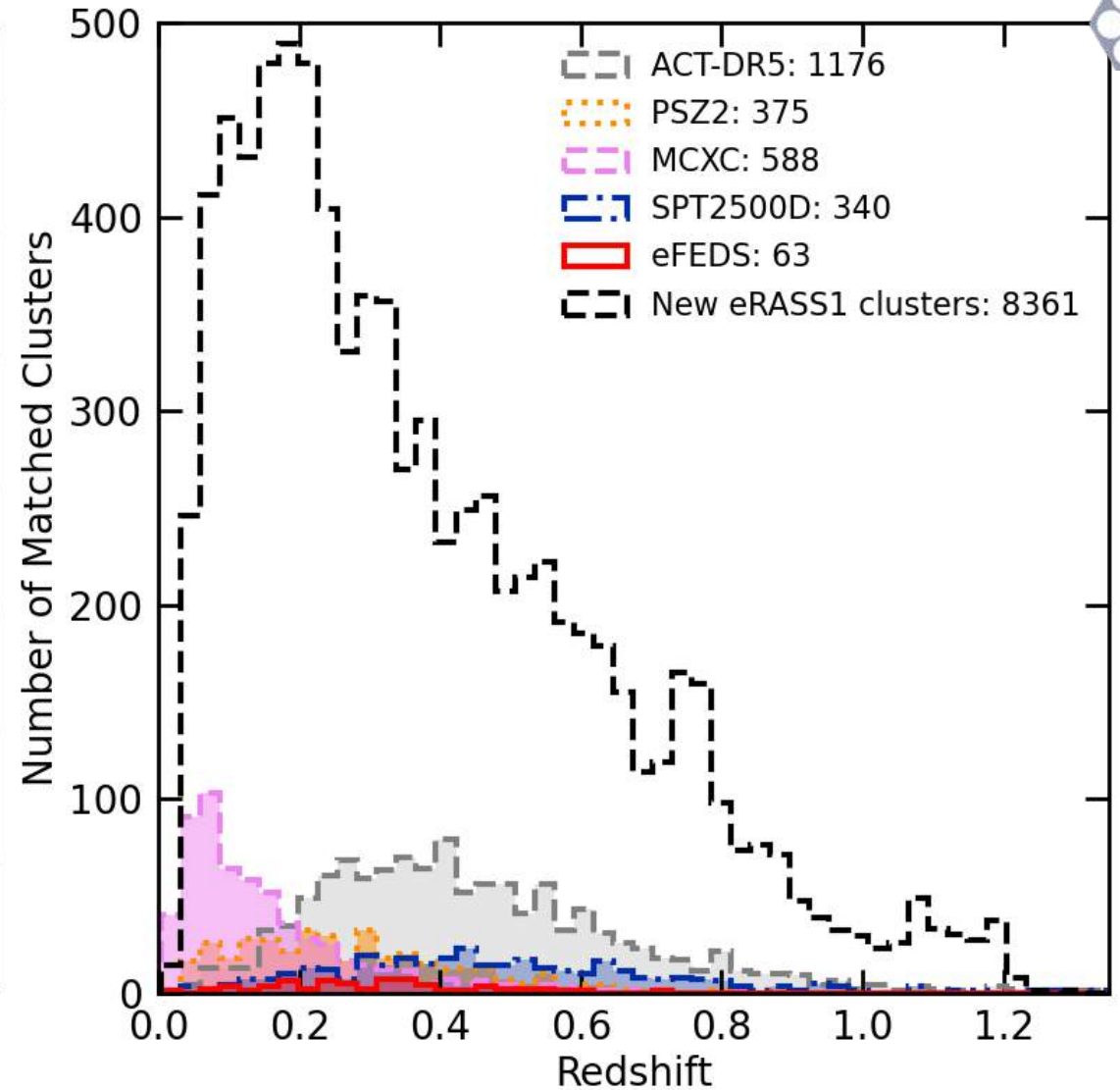
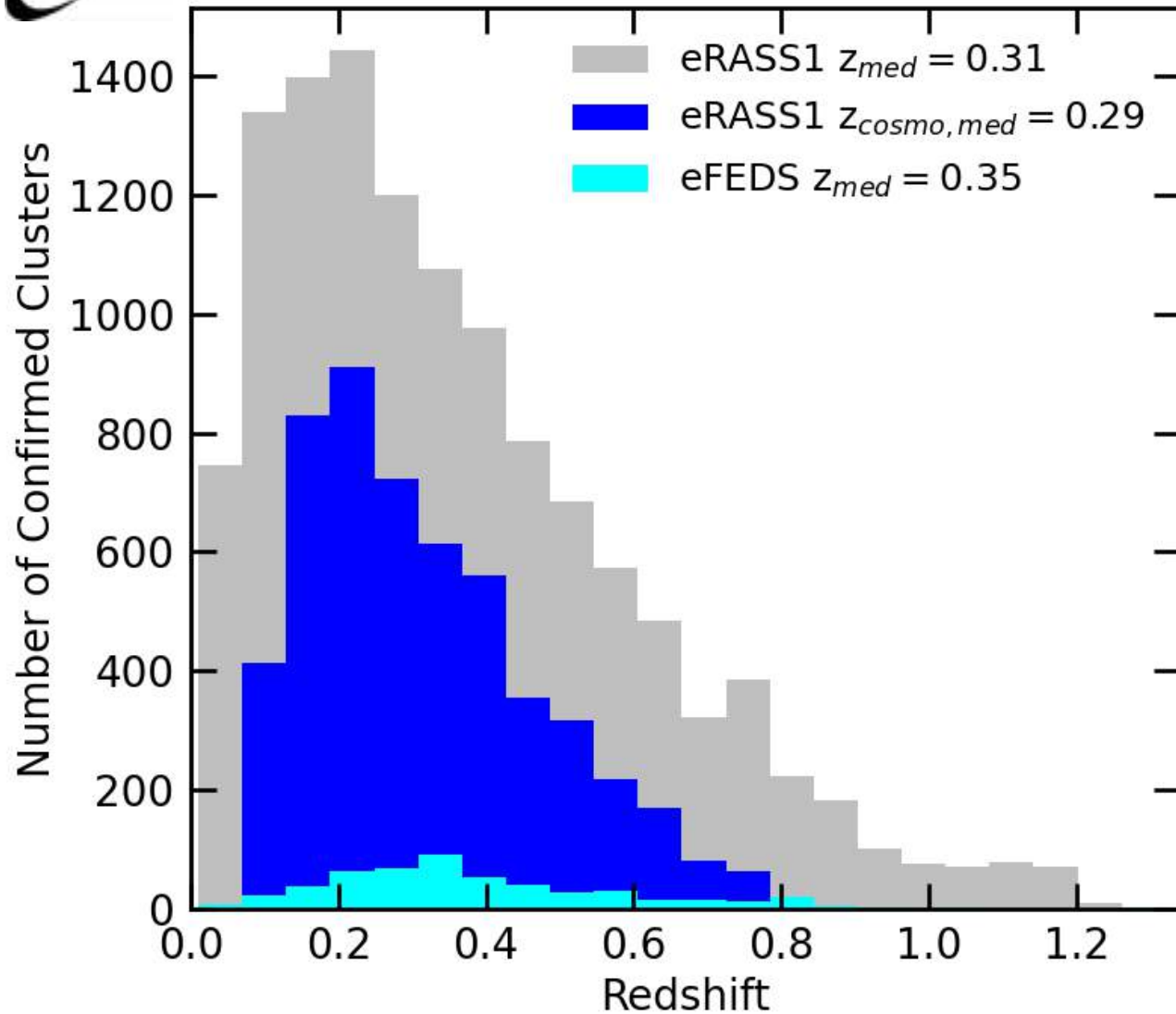


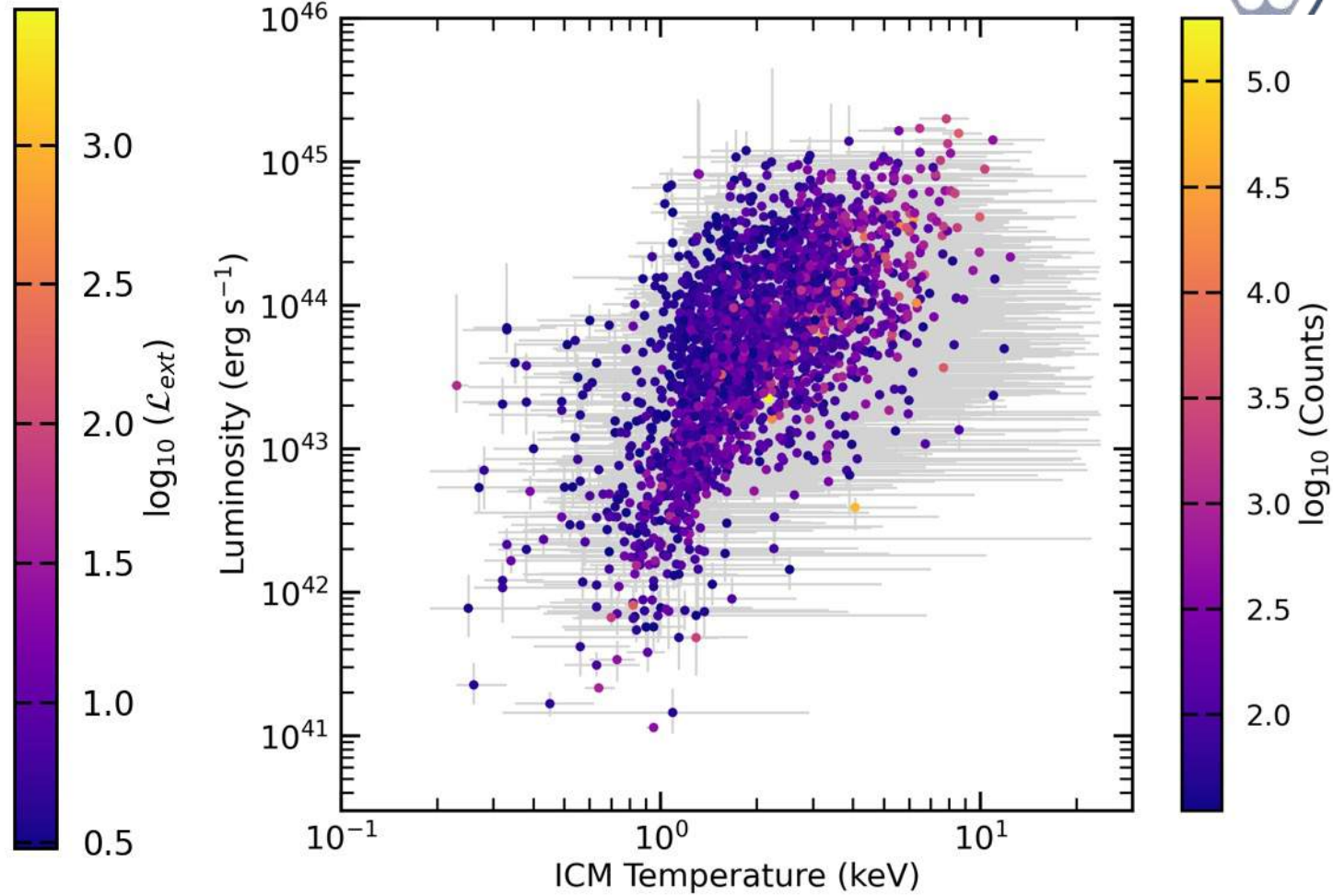
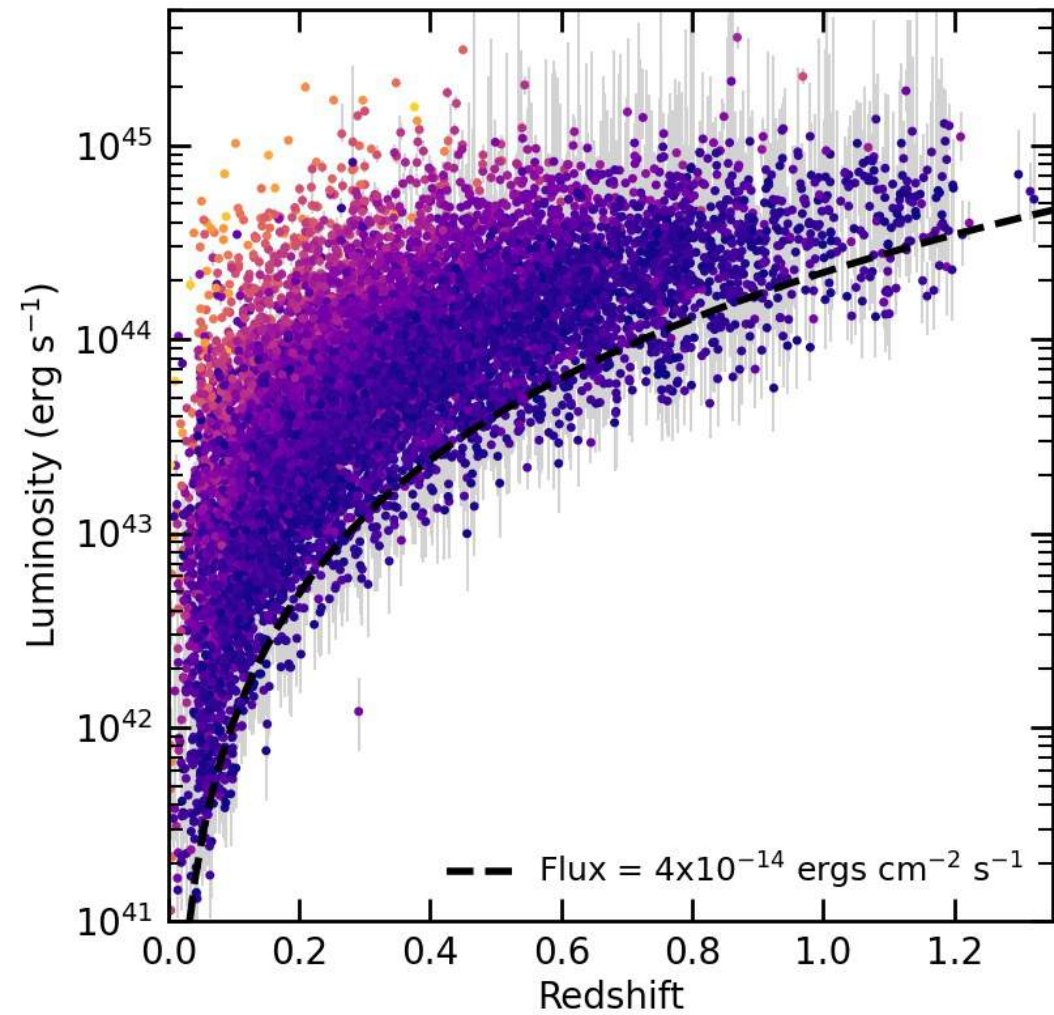
Photo-z uncertainty $\sim 0.5\%$ (over $0.1 < z < 0.8$) [Kluge et al. 2024]

Clusters redshift



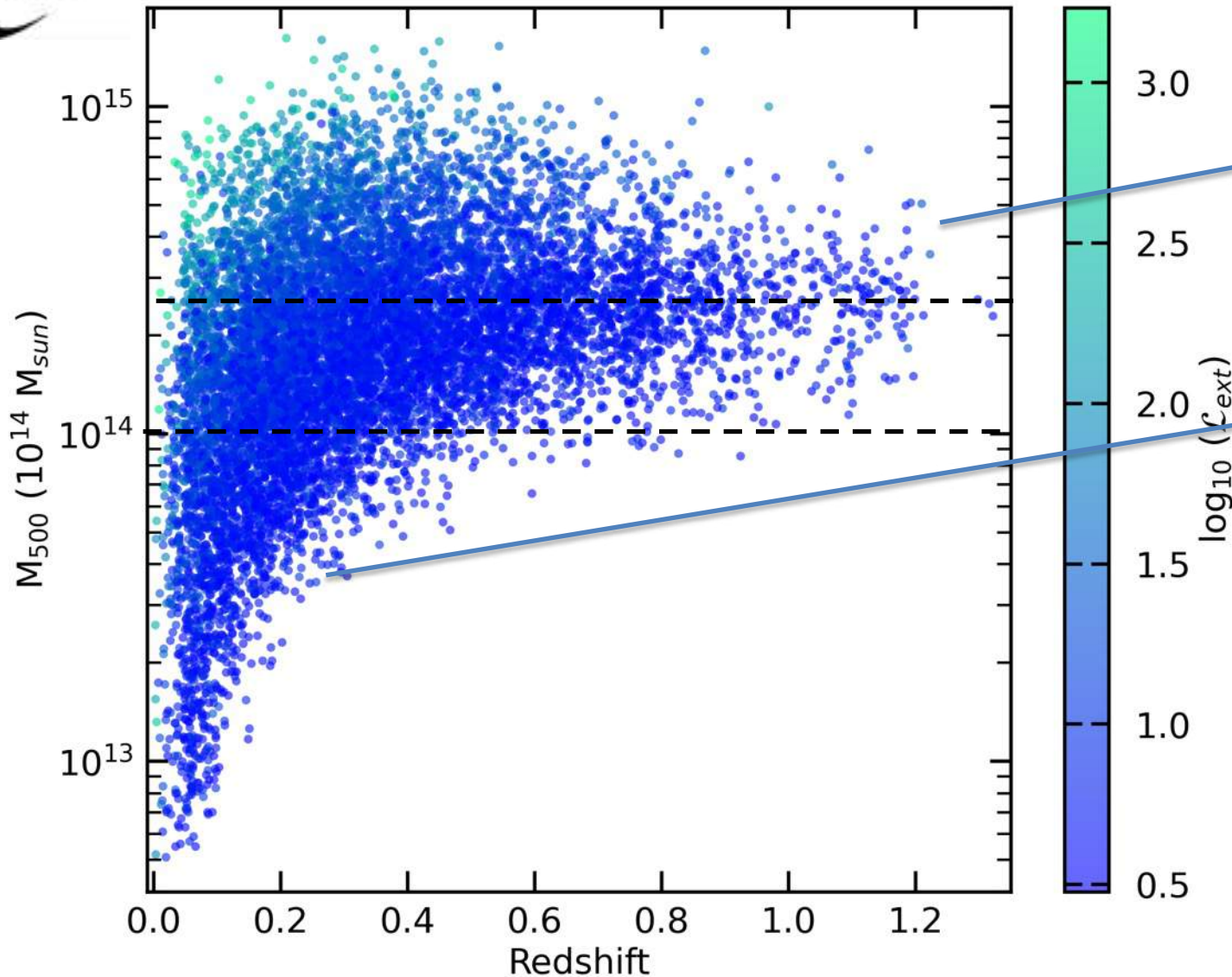
Bulbul et al. (2024)

Clusters Luminosity, temperature



Bulbul et al. (2024)

Clusters 'X-ray' masses



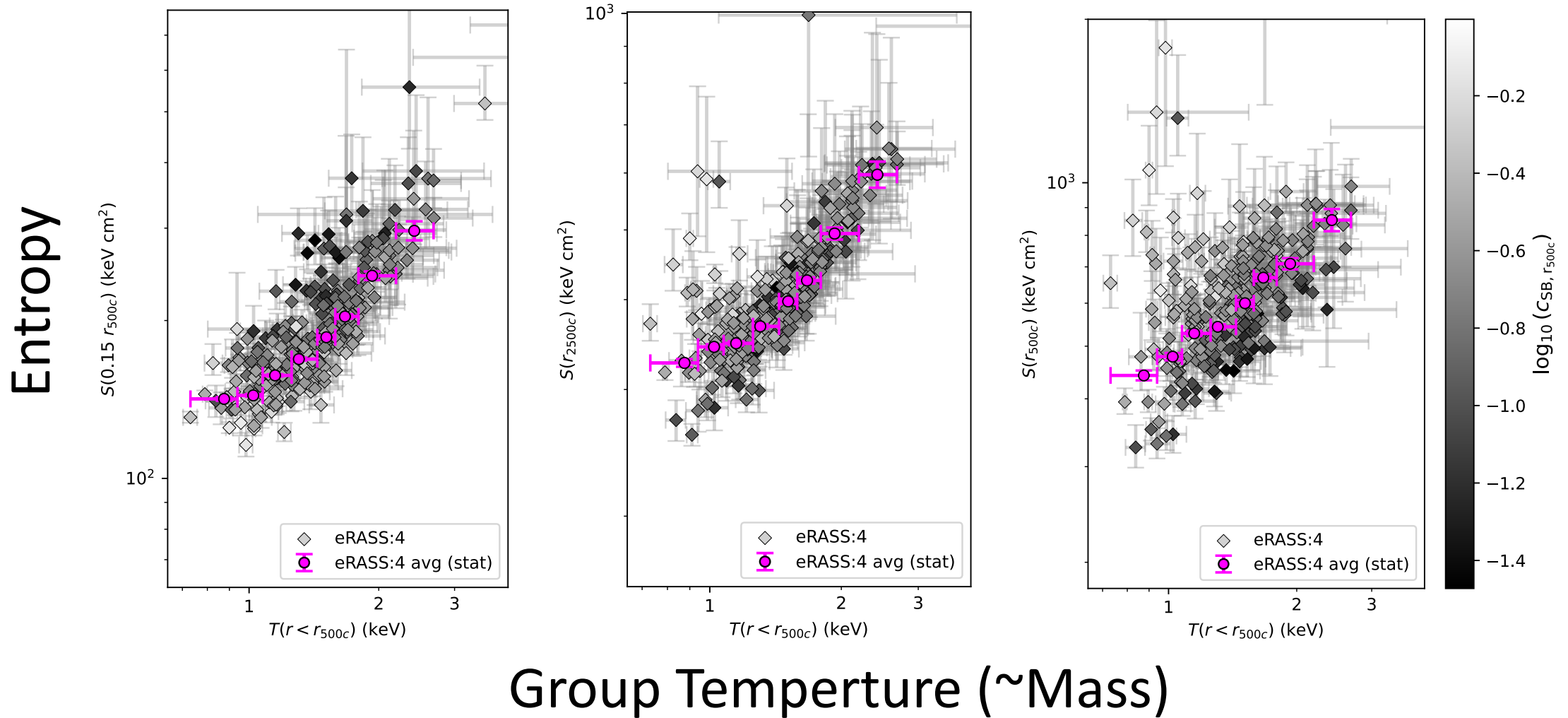
ALL Massive clusters

Hundreds of X-ray groups!

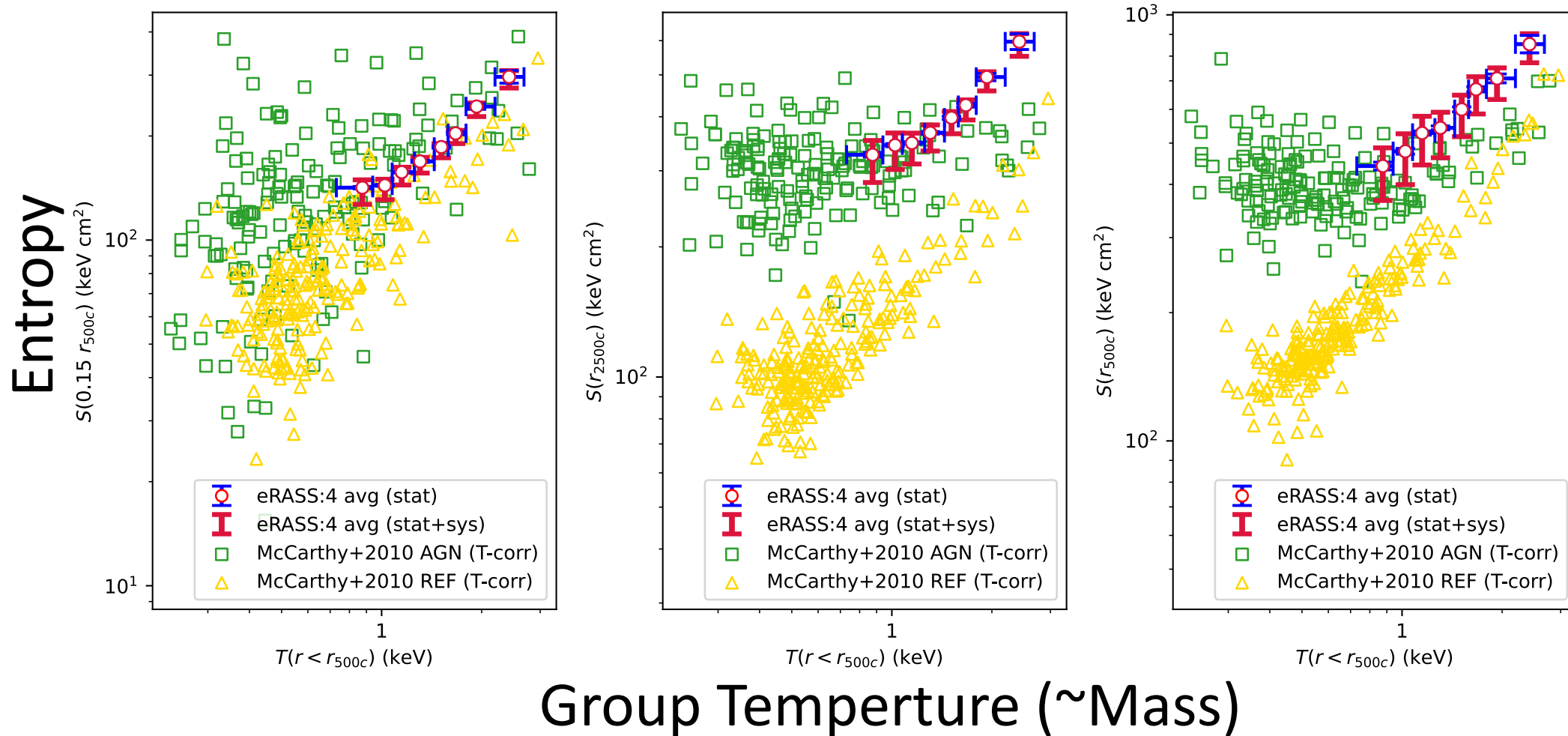
See Bahar et al. (2024) on using groups entropy profiles to constrain AGN feedback models

Bulbul et al. (2024)

Constraints on AGN Feedback in Galaxy Groups (Bahar et al.)



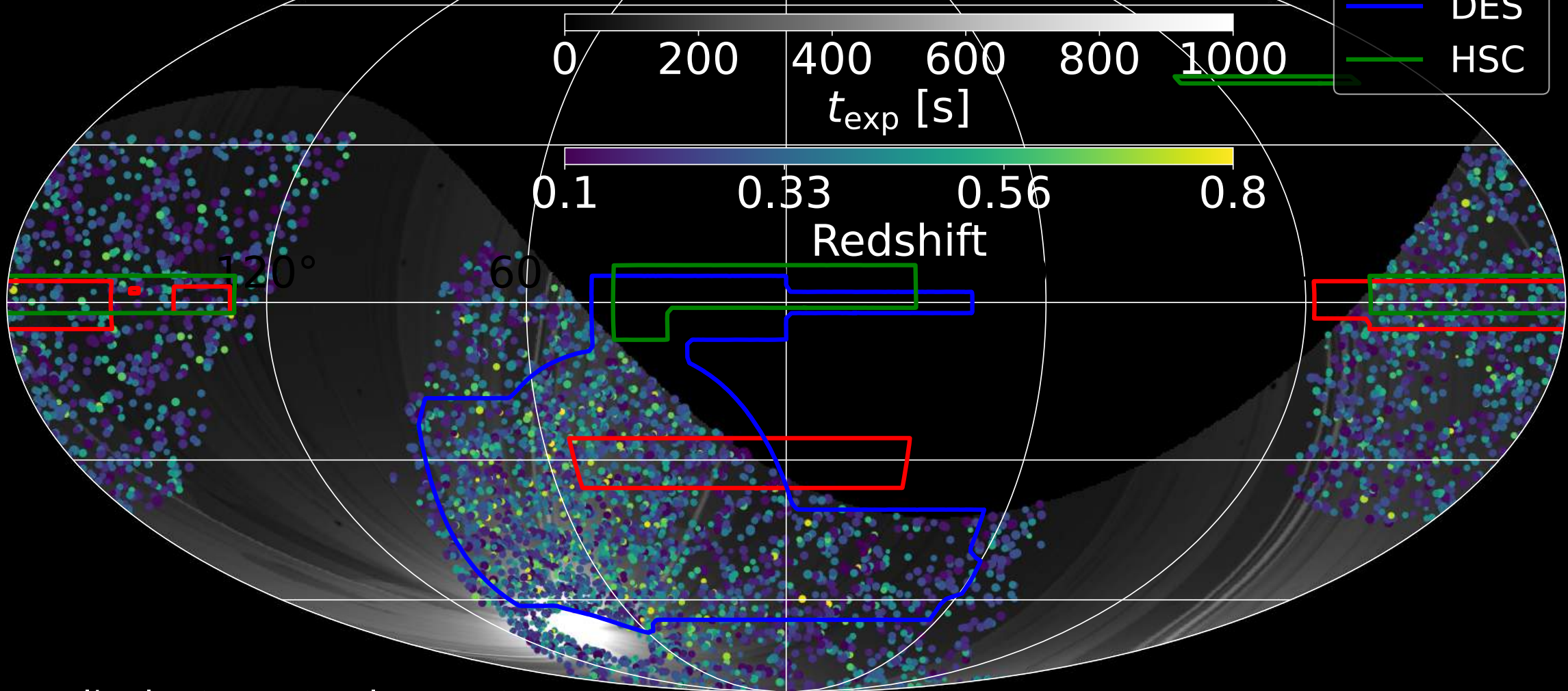
Constraints on AGN Feedback in Galaxy Groups (Bahar et al.)



Clusters Cosmology sample

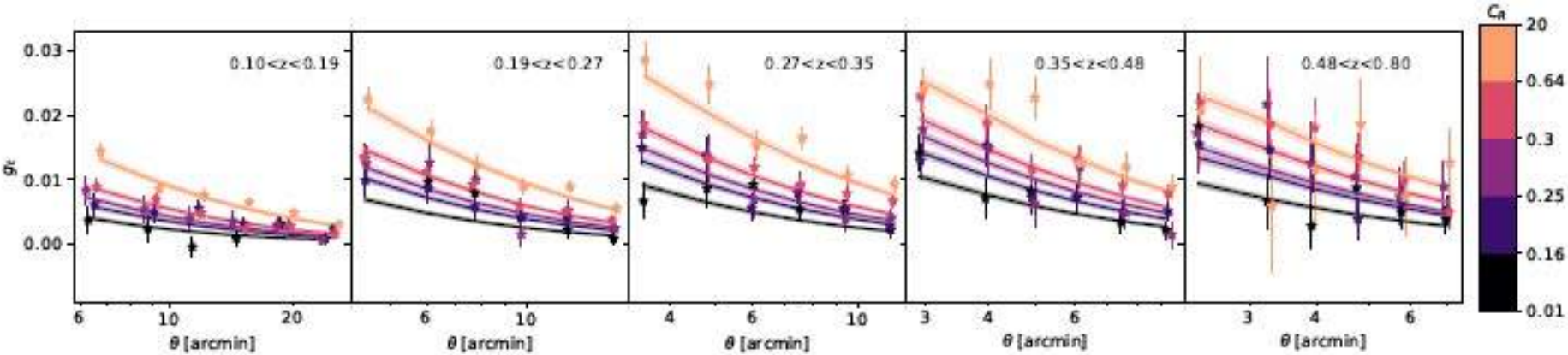
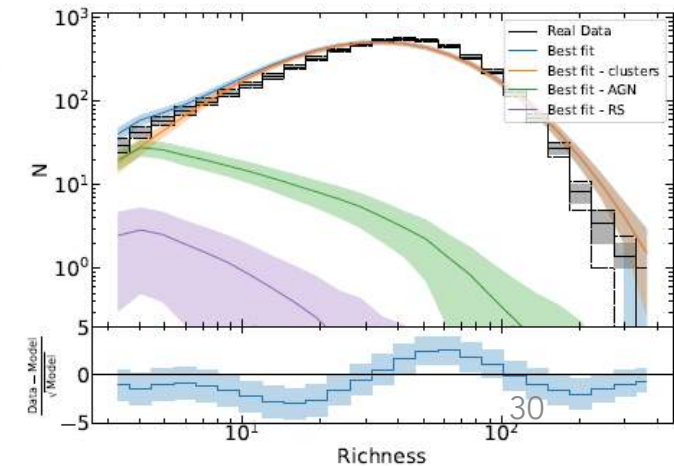
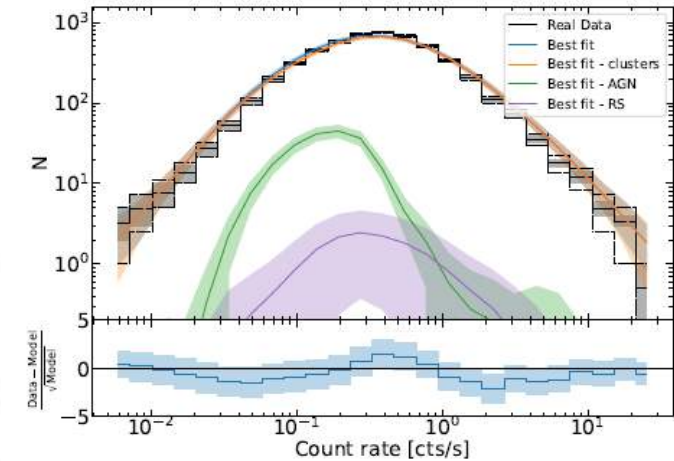
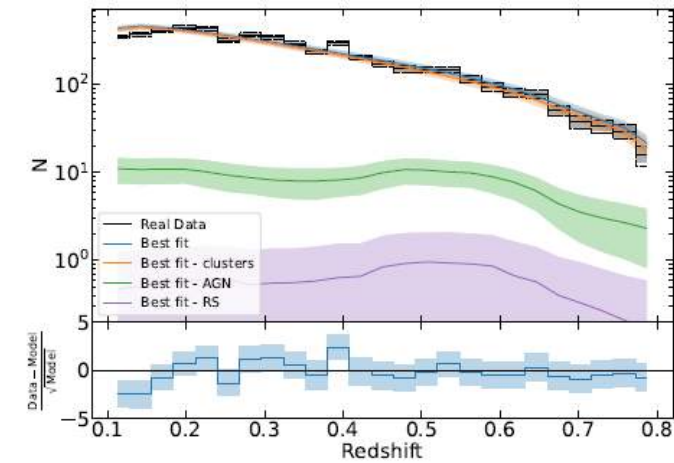
5263 Extended Sources (EXT_LIKE>6) in LS10 area with redshift ($0.1 < z < 0.8$); Purity $\sim 95\%$

- KiDS
- DES
- HSC

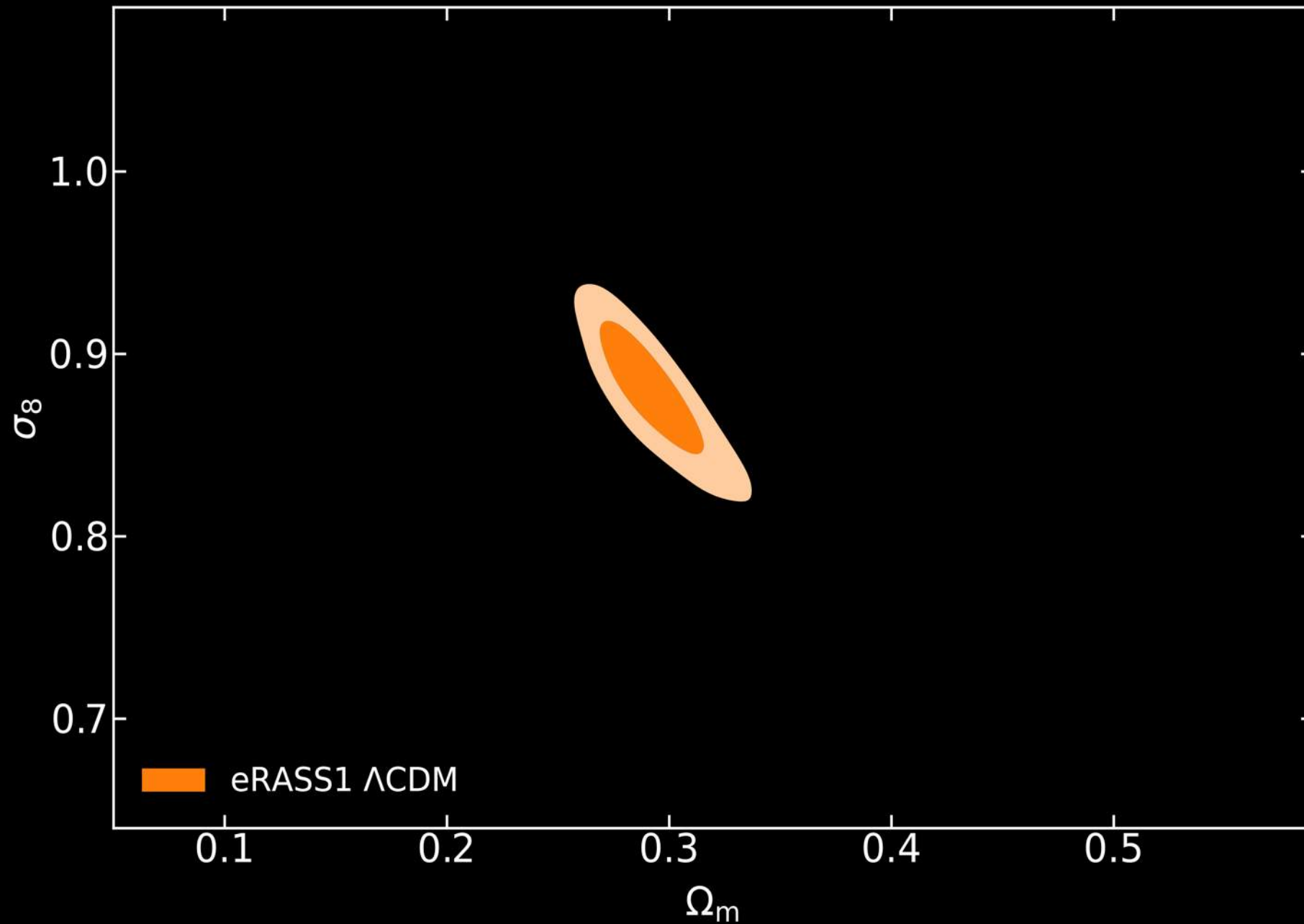


Mass function experiment

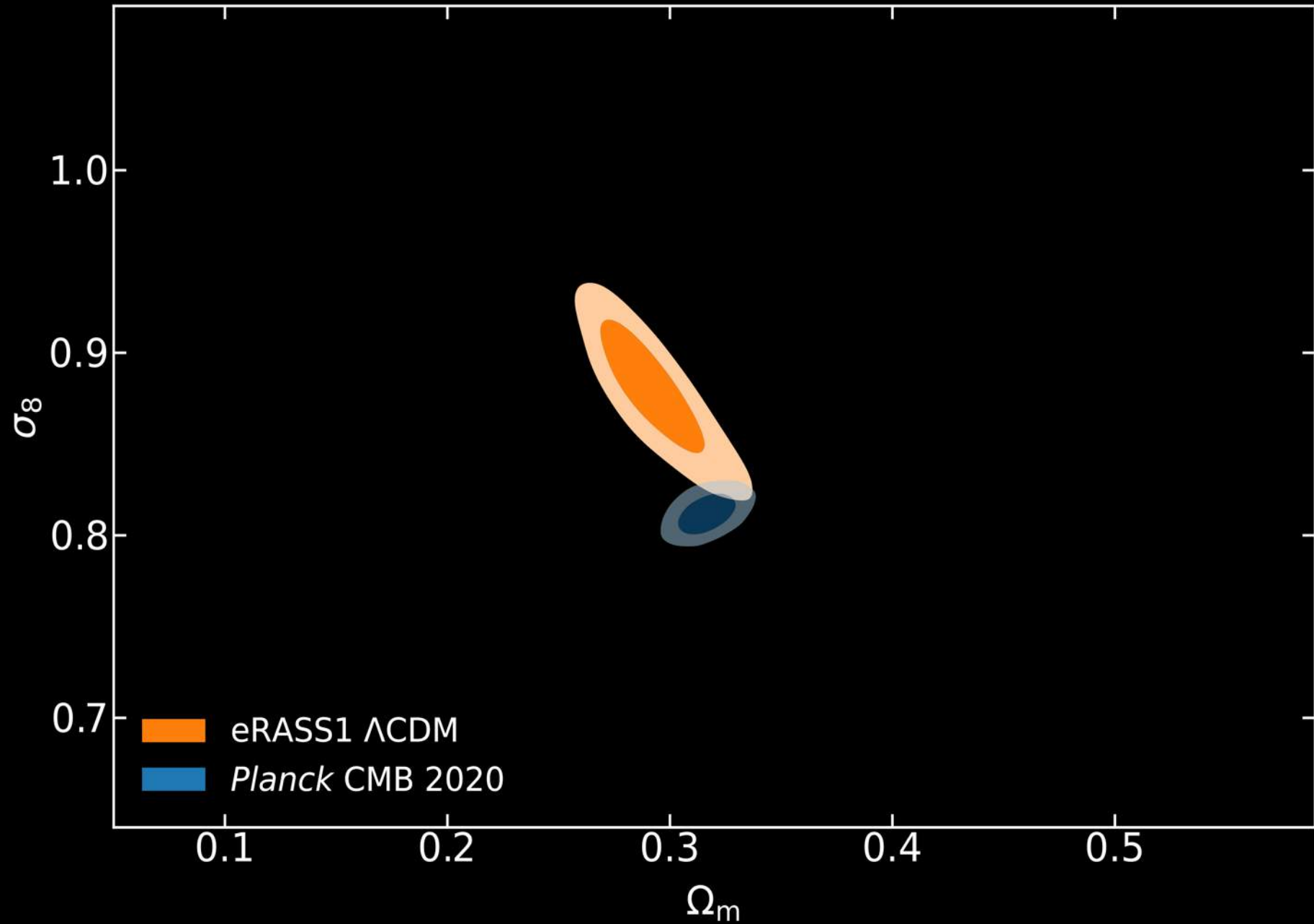
- Observables: unabsorbed CR, z , richness
- Shear profiles from WL (DES, HSC, KIDS)
- WL bias (Triaxiality, Mis-centering, AGN feedback, substructures) calibrated with simulations
- Contamination (from mis-classified AGN) treated with a mixture model [Note: 5% contamination > stat. error]



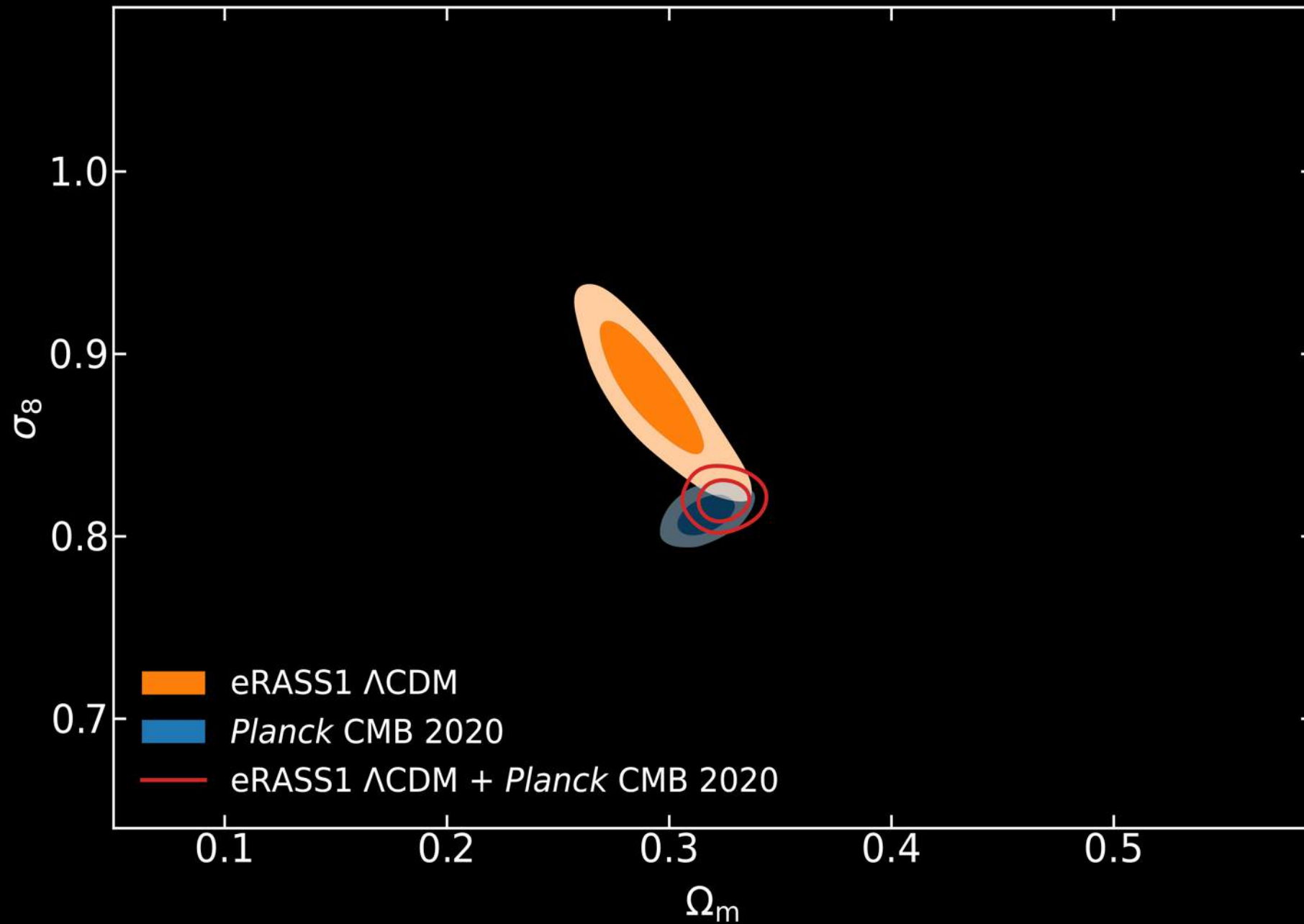
Grandis + 2024
 Kleinebrei + 2024
 Chiu + 2022
 Ghirardini + 2024



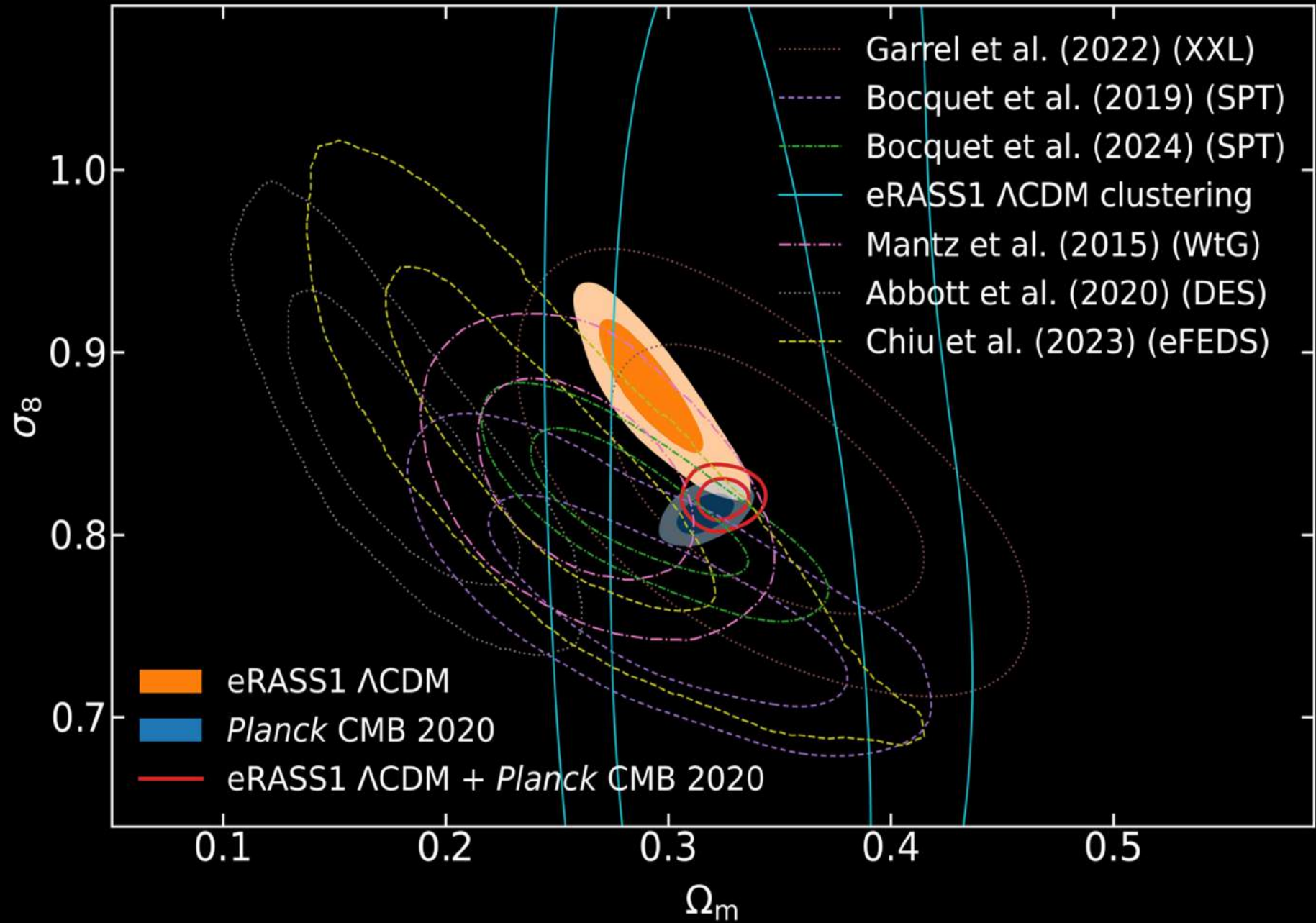
■ eRASS1 Λ CDM



 eRASS1 Λ CDM
 Planck CMB 2020

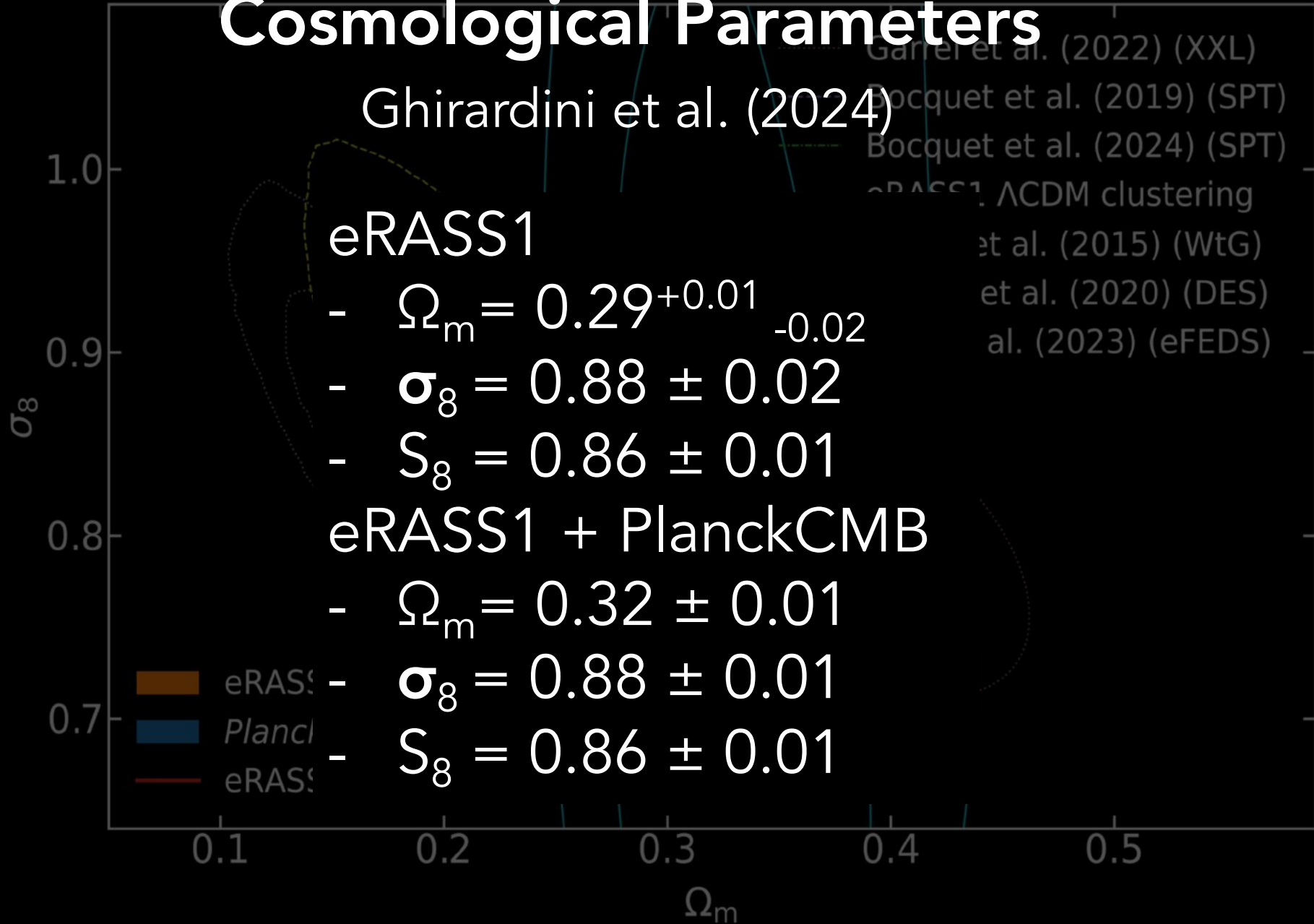


■ eRASS1 Λ CDM
■ *Planck* CMB 2020
— eRASS1 Λ CDM + *Planck* CMB 2020



Cosmological Parameters

Ghirardini et al. (2024)



Garber et al. (2022) (XXL)
 Bocquet et al. (2019) (SPT)
 Bocquet et al. (2024) (SPT)
 eRASS1, Λ CDM clustering
 et al. (2015) (WtG)
 et al. (2020) (DES)
 et al. (2023) (eFEDS)



Conclusions



eROSITA on SRG has been in operation since Q3 2019, for more than 2 years. We have completed 4.4 all-sky surveys. eROSITA is in safe/idle mode since 26.2. Science operations are suspended.

Thanks to its large Grasp, stable background and observing cadence eROSITA opens up new parameter space for X-ray astronomy

eRASS1 marks the coming of age of clusters cosmology as a Stage IV experiment

Numerous science highlights from DR1!

eRASS1 is now fully public! <https://erosita.mpe.mpg.de/dr1/>



www.mpe.mpg.de/eROSITA

Thank you

