

X-ray Properties of Galaxy Clusters with *e*ROSITA

Joseph Hall

Astro Lunch Meeting

30 July 2025

News?

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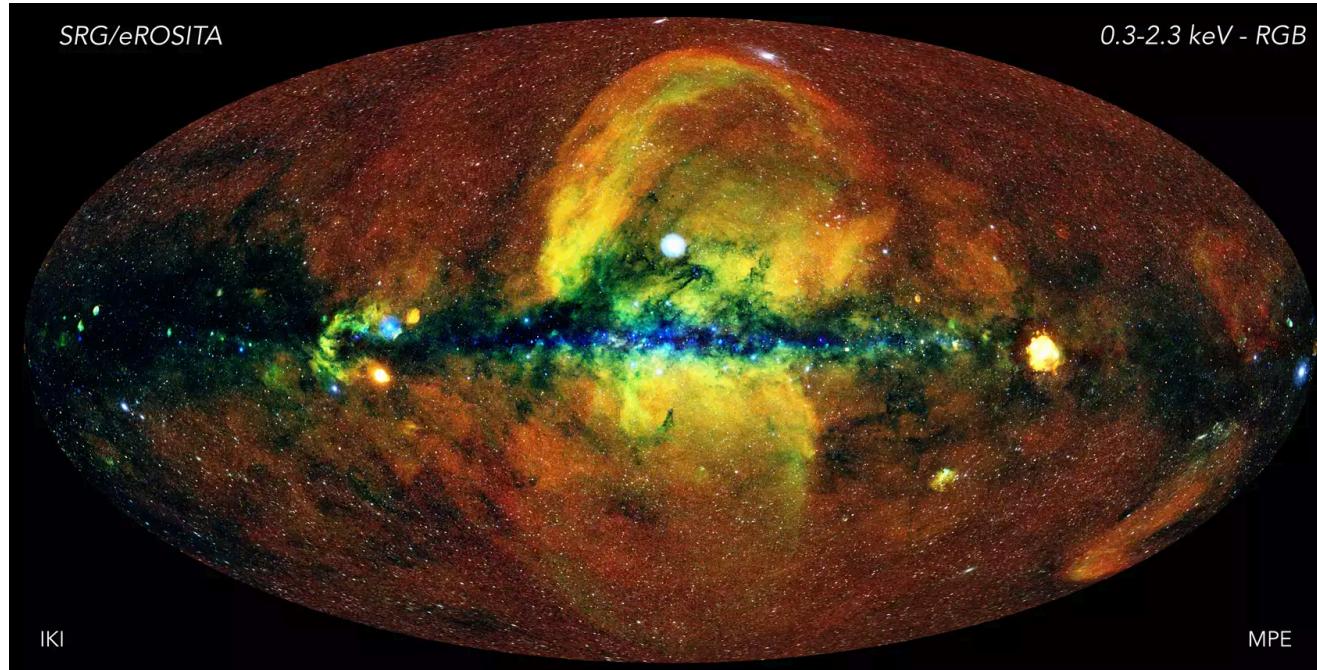
BACKGROUND

A New Era

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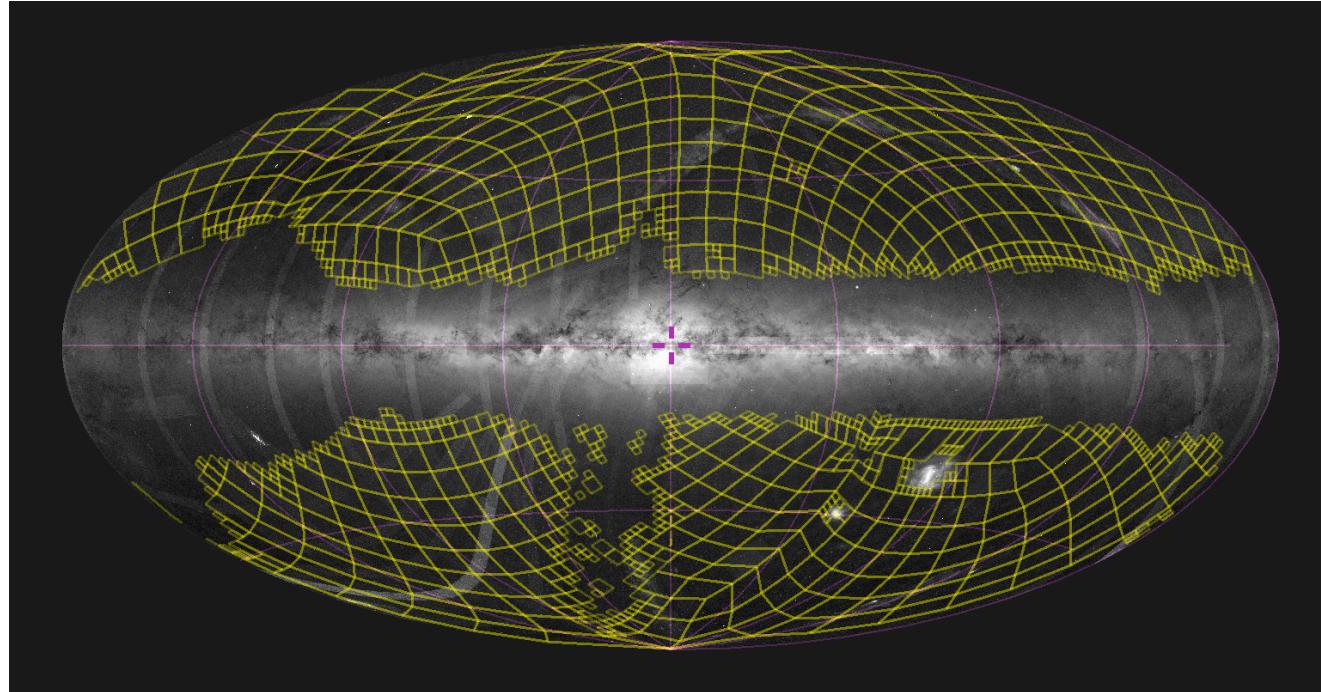
For 2.5 years from 2019 **eROSITA** mapped the X-ray sky, so far providing 2 data releases

Brunner et al. 2022, Merloni et al. 2024

Image Credit: Jeremy Sanders, Hermann Brunner and the eSASS team (MPE); Eugene Churazov, Marat Gilfanov (on behalf of IKI)

A New Era

This is an exciting time for wide field cosmological surveys:



The optical sky has been well-mapped by **DES** and **DESI**, with **Euclid** Q1 data providing a preview of the full data coming next year

*DES Collaboration 2021, Dey et al. 2022, Euclid Collaboration 2025
Image credit: Wen & Han 2024 via VizieR*

Galaxy Clusters: They're Like Dragons.

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They're the *largest gravitationally bound objects*, only 20% of their baryons are in stars, the rest is in the X-ray emitting **ICM**.



Image Credit: ESA/XMM-Newton/DSS-II/J. Sanders et al. 2019

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Assuming that only gravity dictates these properties, the scaling relations can be fit by the **self-similar model**.

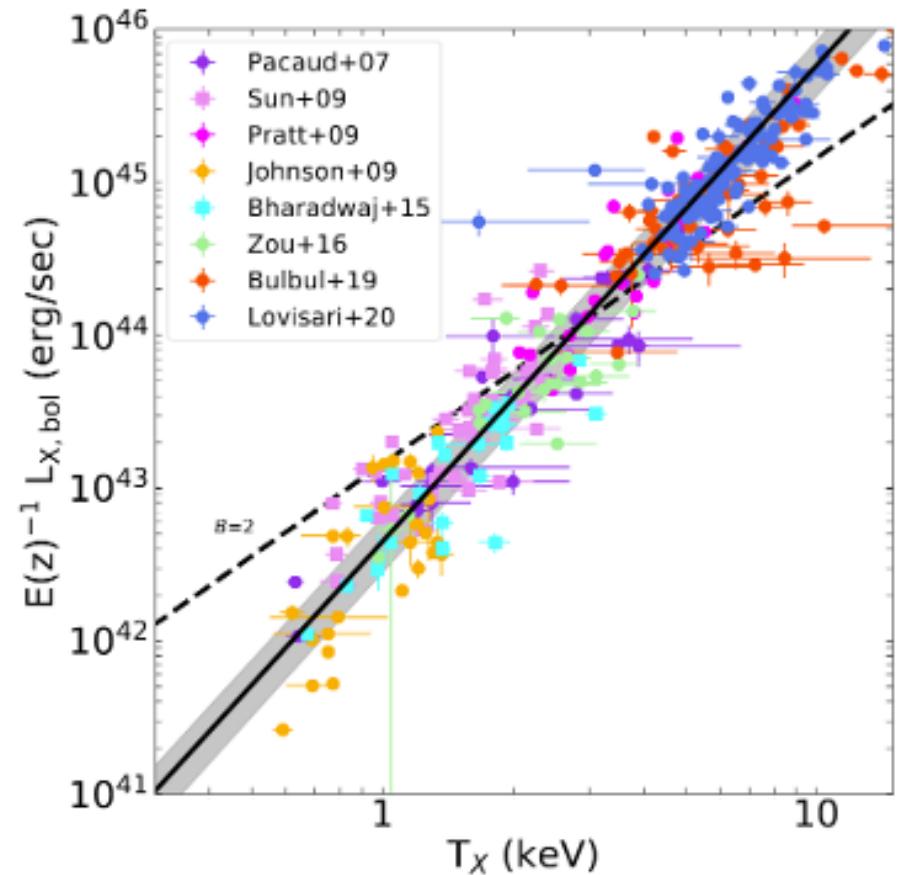


Image Credit: Lovisari & Maughan 2022

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Deviations from the model are the result of extra astrophysics.

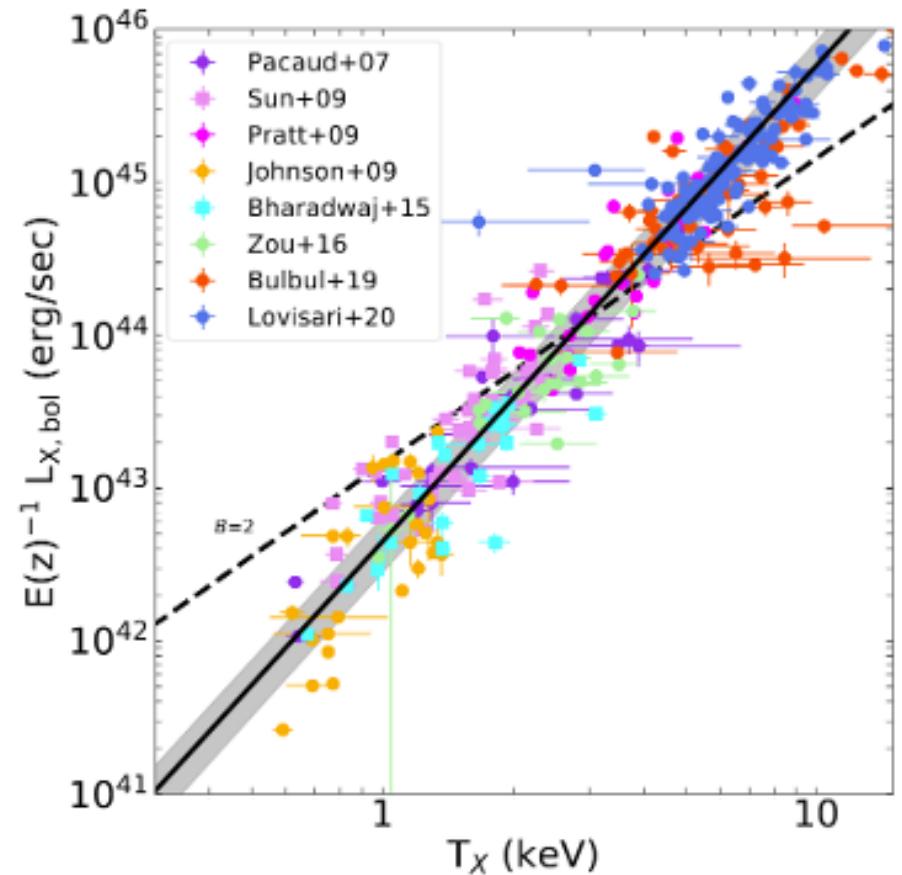


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Cluster Cosmology

Counting the number of clusters in the universe can help to constrain cosmological parameters, particularly σ_8 and Ω_M

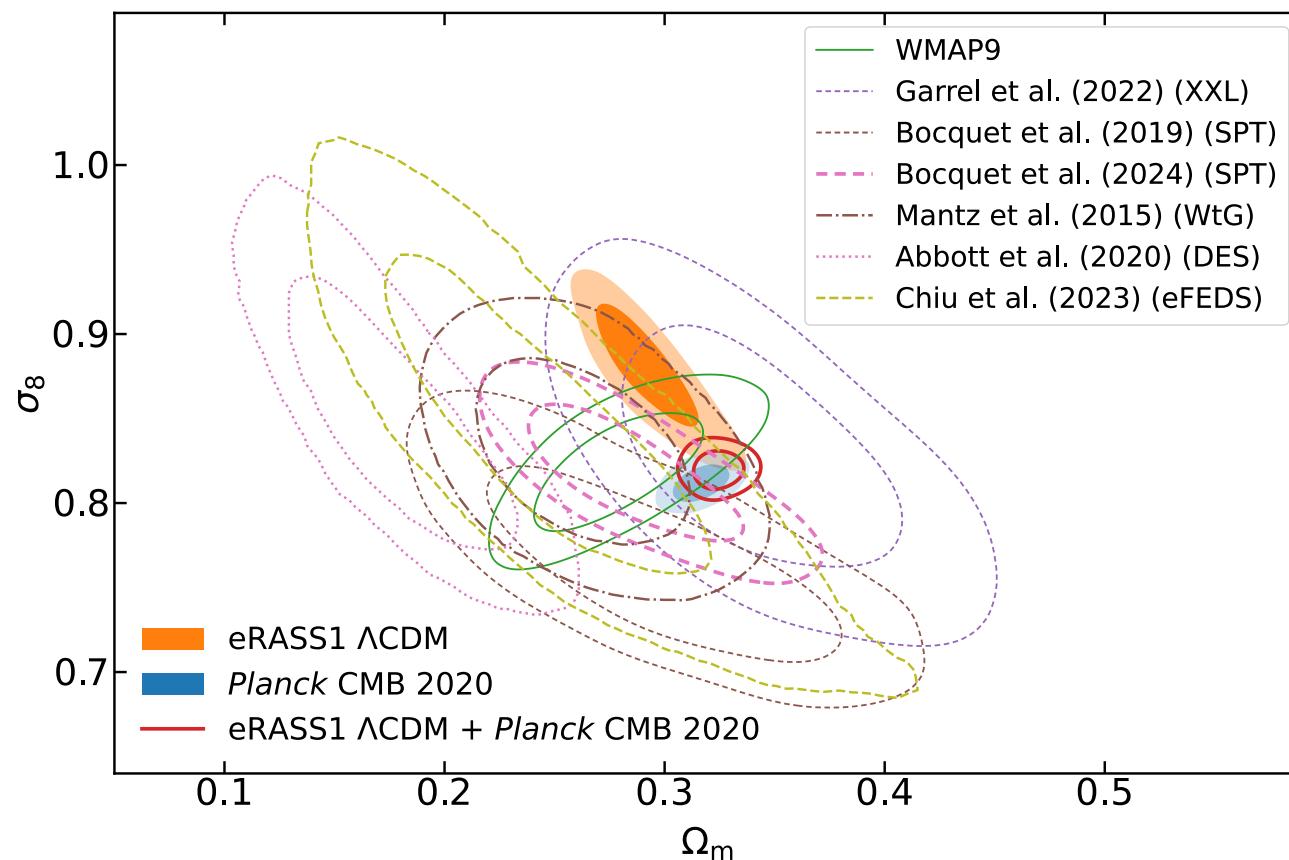


Image Credit: Ghirardini et al. 2024

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To do this effectively we need accurate **selection functions**

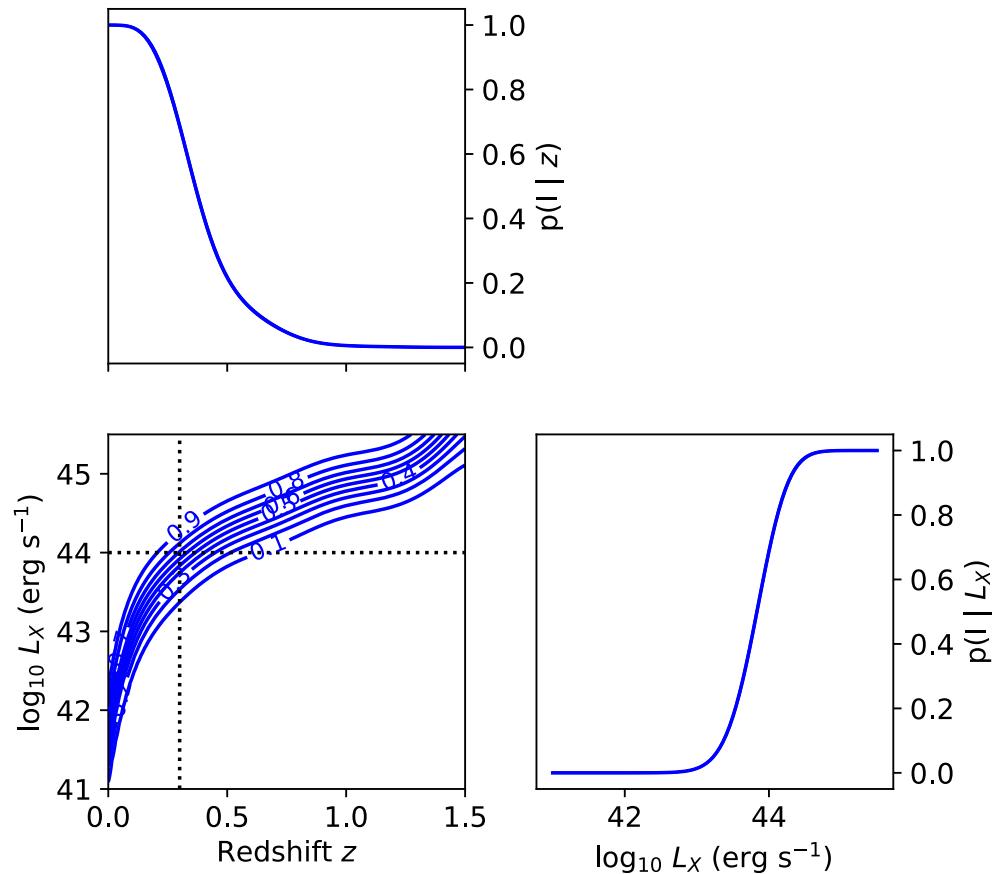


Image Credit: Clerc et al. 2024

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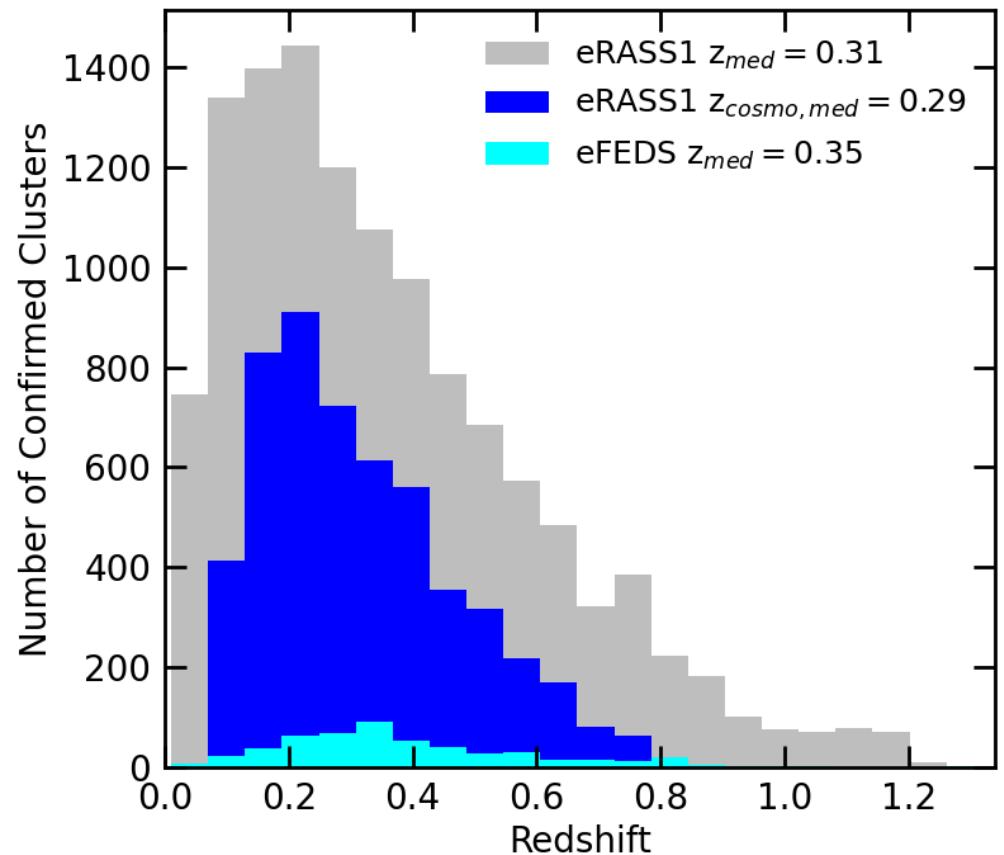


Image Credit: Bulbul et al. 2024

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Andreon et al. (2016) found diff's in scaling rels for **optical and X-ray clusters**

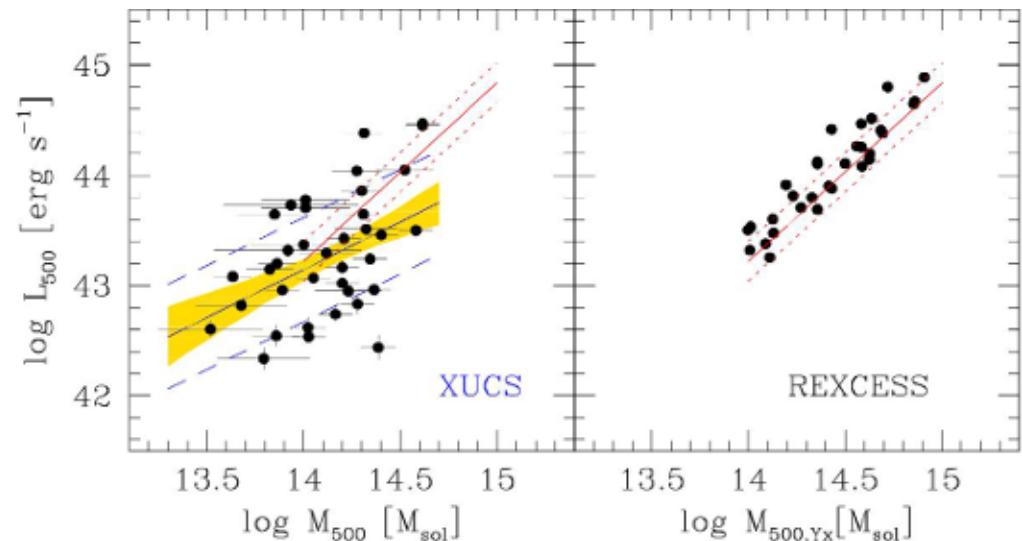
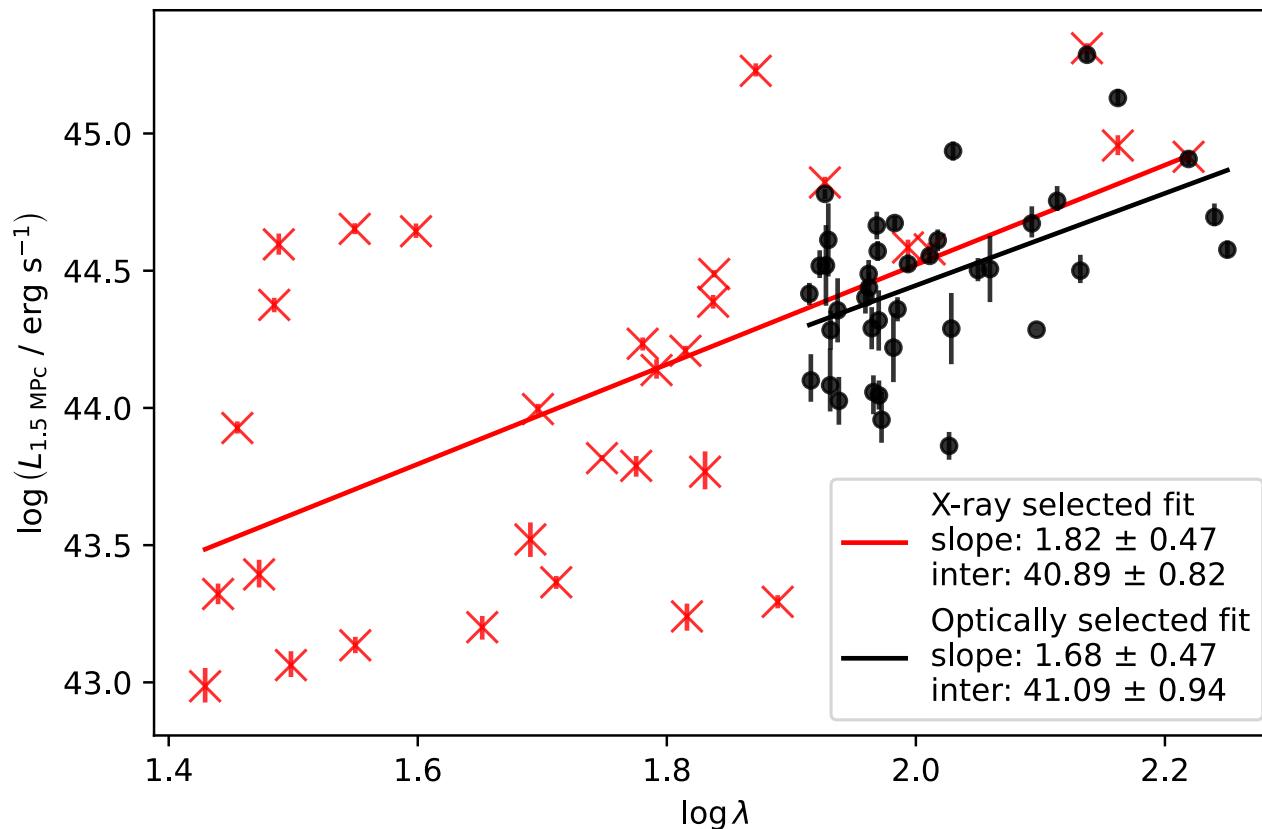


Image Credit: Andreon et al. 2016

**Combining eROSITA data with
clusters found in wide optical
surveys gives the ideal platform to
test these biases**

Last Update

In September, I presented these results from eRASS flux selected clusters and **richness (λ)** selected from the SDSS survey analysed by a pipeline I wrote.

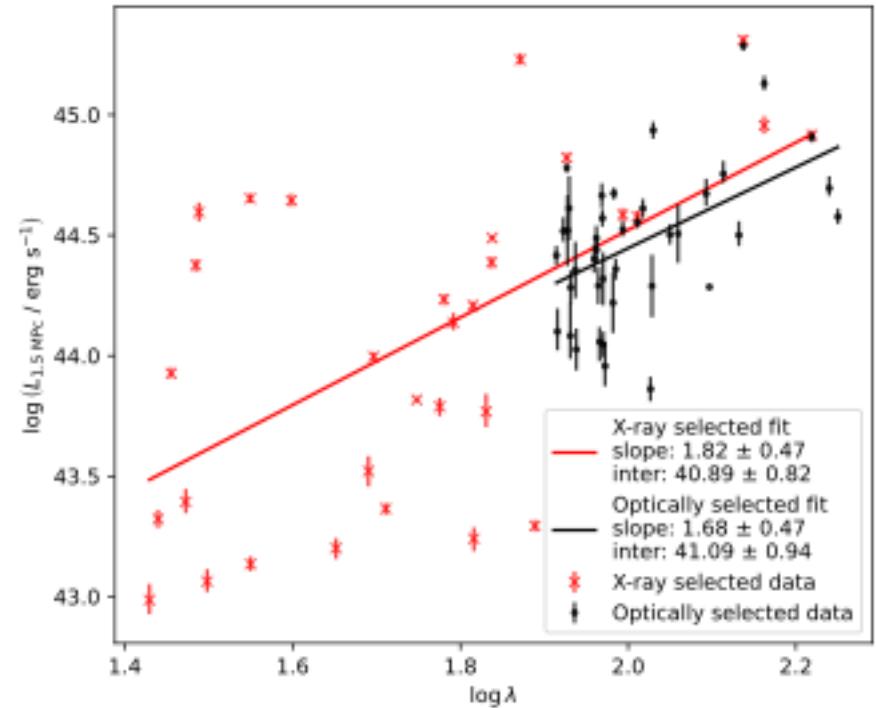


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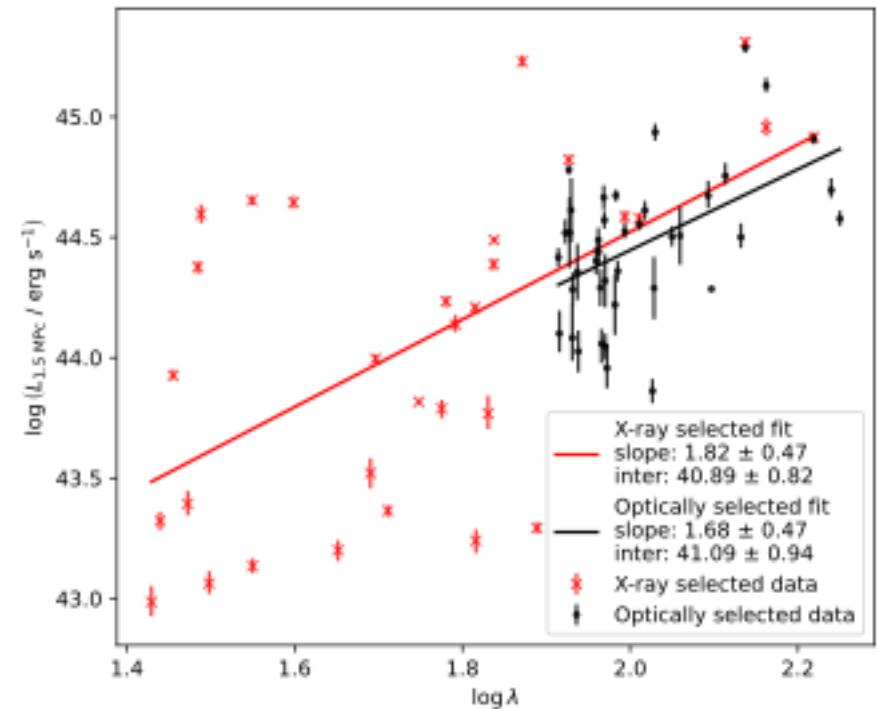
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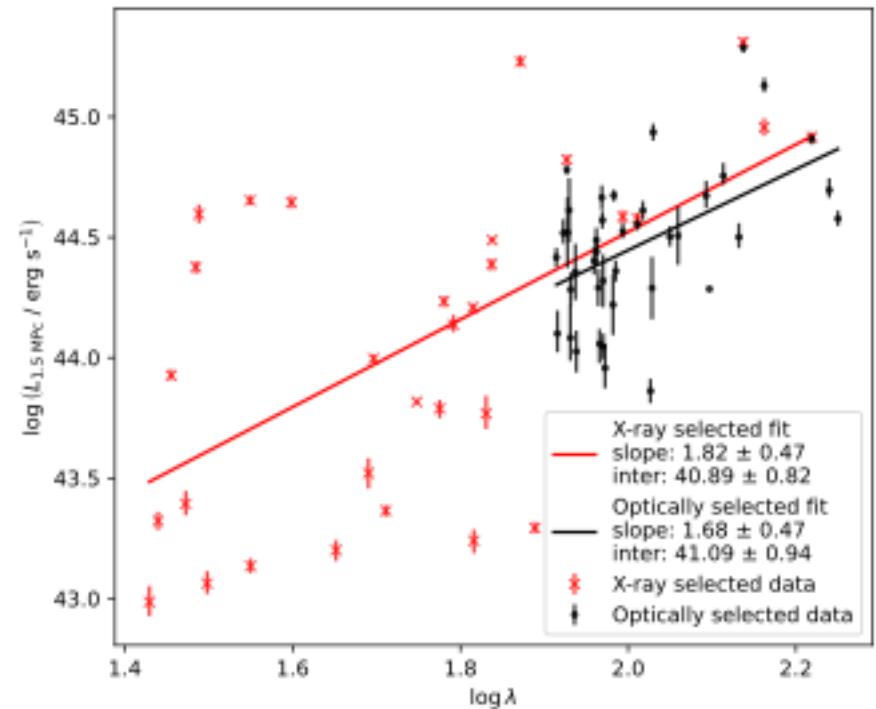
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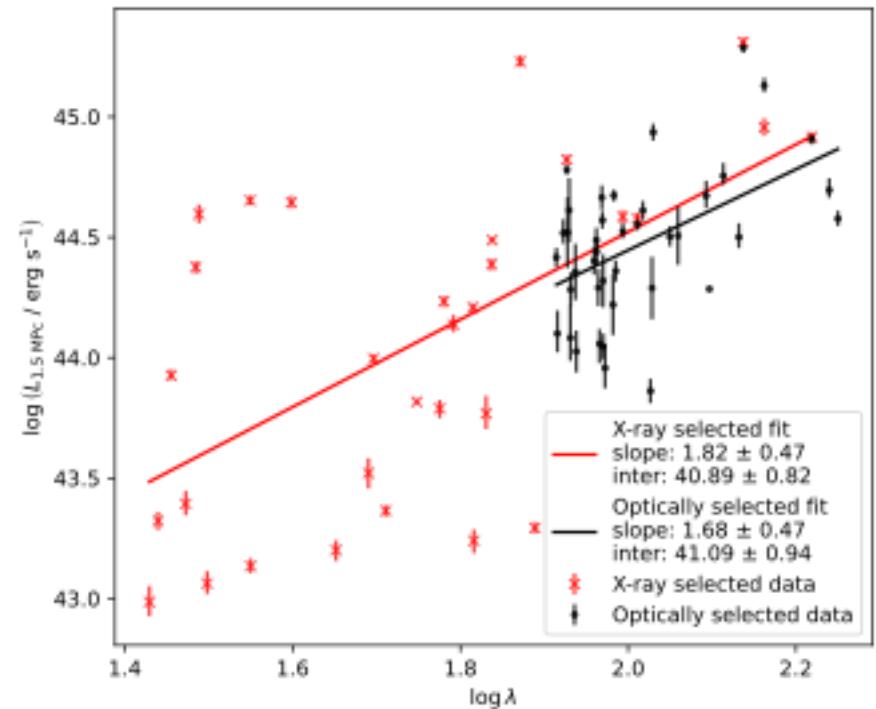
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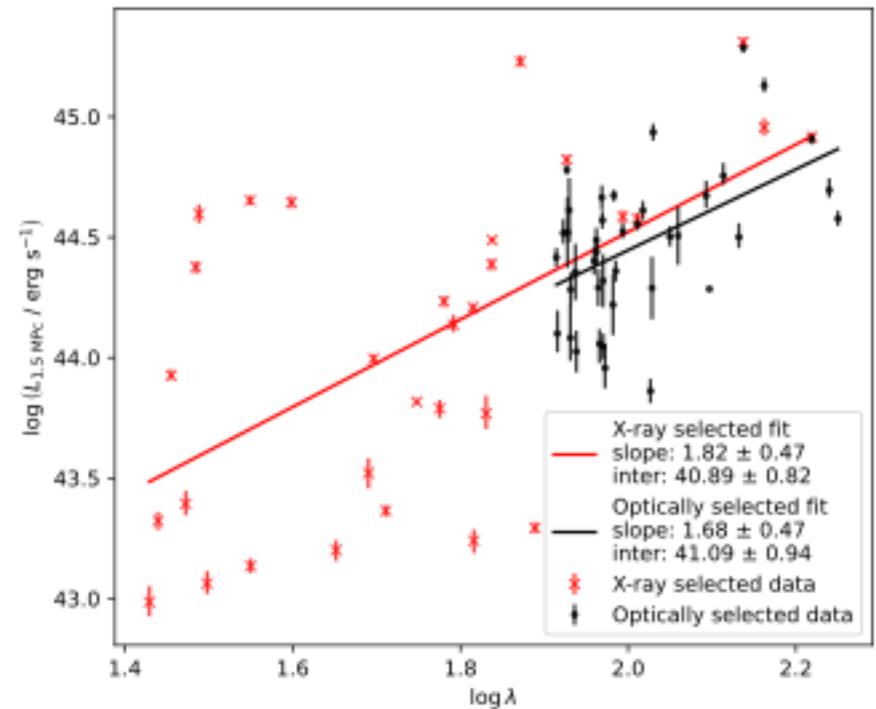
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Over the past year I have been addressing these issues



Bulbul et al. 2024, Rykoff et al. 2014

SAMPLE SELECTION

Choosing a Catalogue – X-rays

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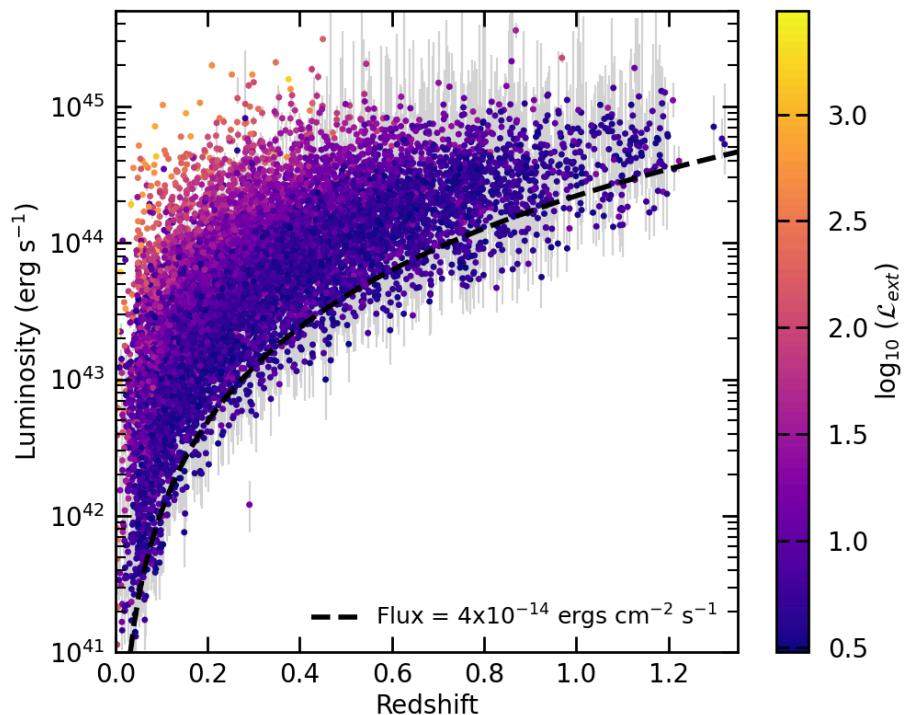


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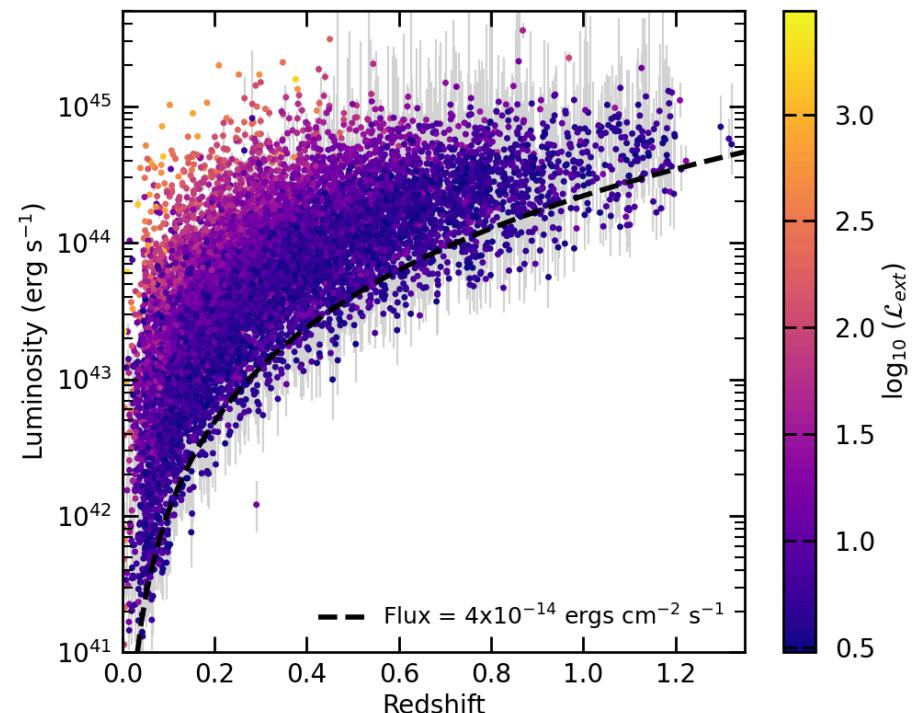


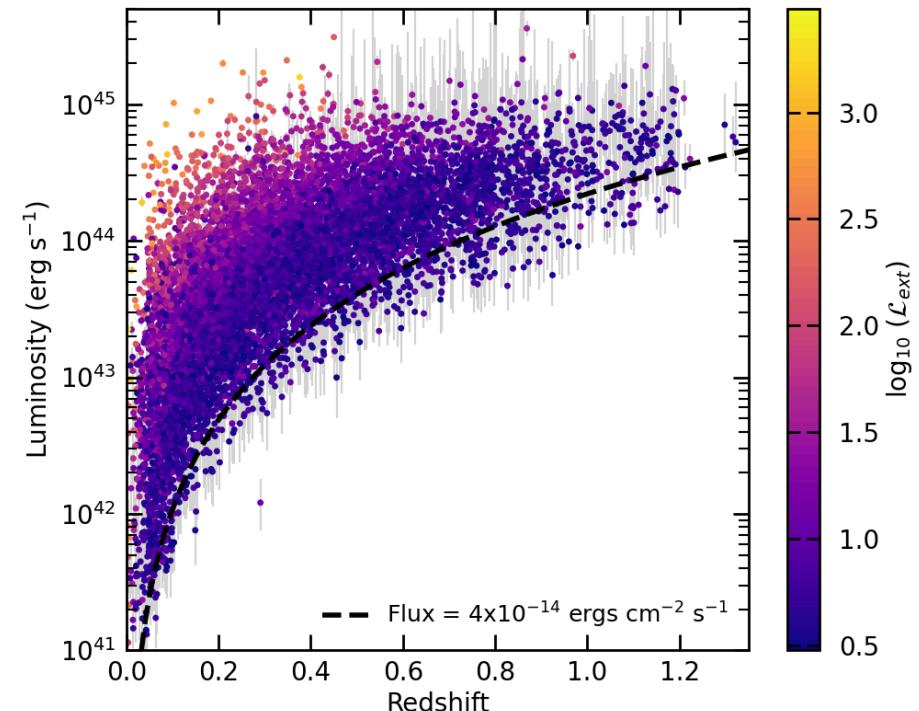
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Recent work in Balzer et al. (2025) has identified **1,000s** more clusters in the eRASS1 data

Image Credit: Bulbul et al. 2024

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DES MOC

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But the only catalogue available in September was for “Science Validation” and contained a mere **787 clusters**.

Not nearly enough!

Choosing a Catalogue – Optical

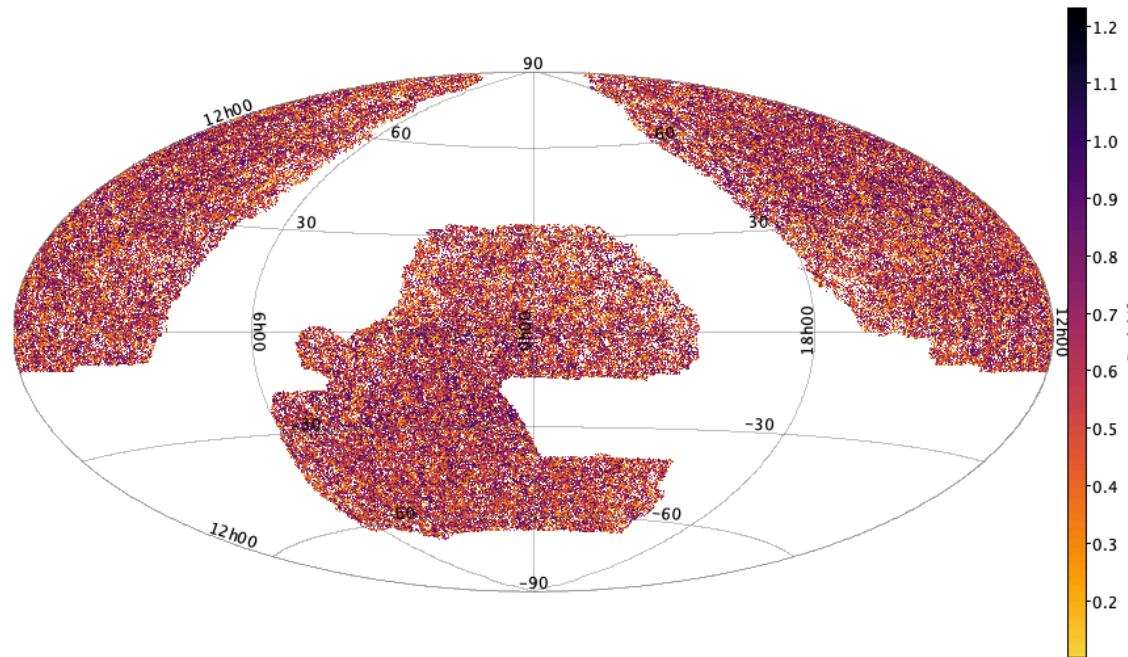
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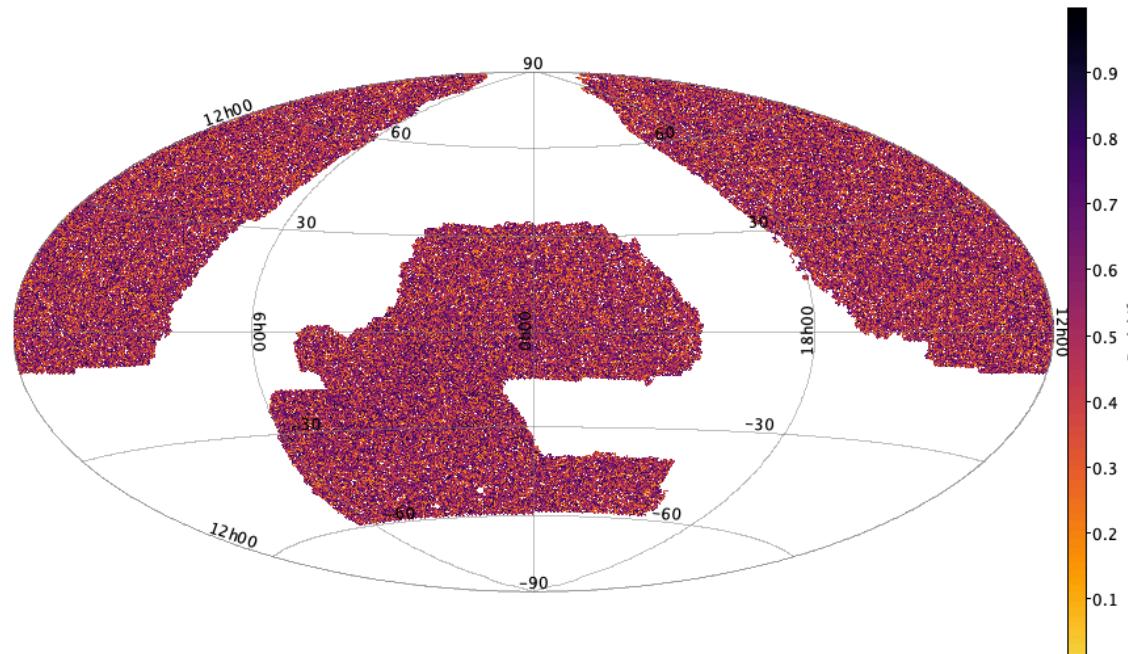


Yantovski-Barth et al. (2023) – ~300,000 clusters

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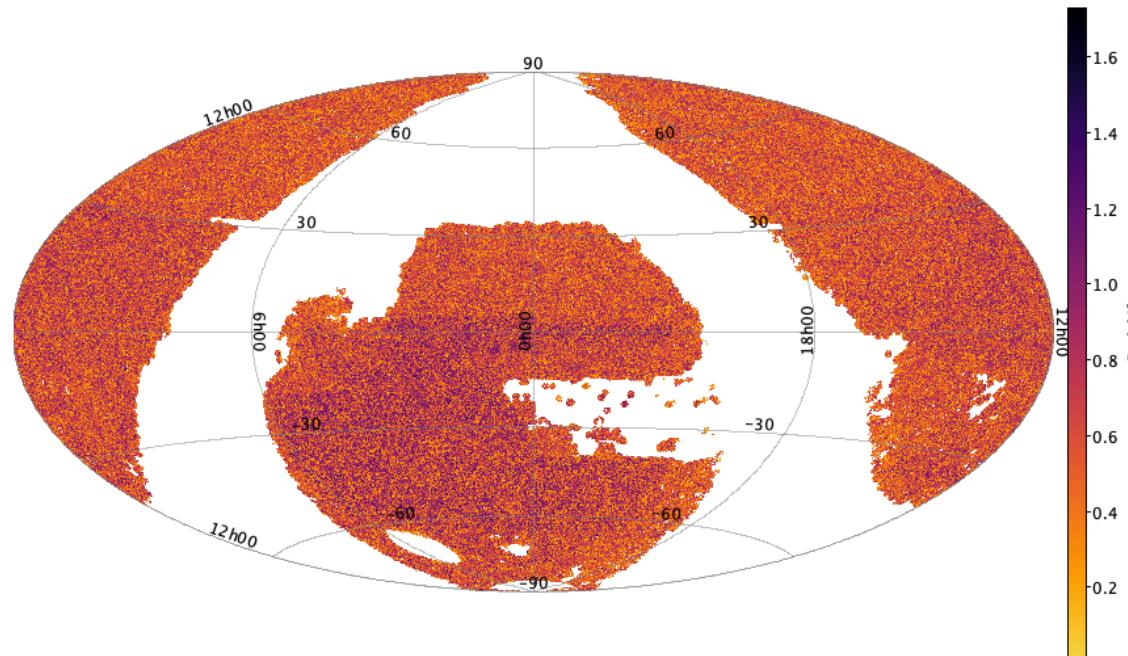


Zou et al. (2021) – 540,432 clusters

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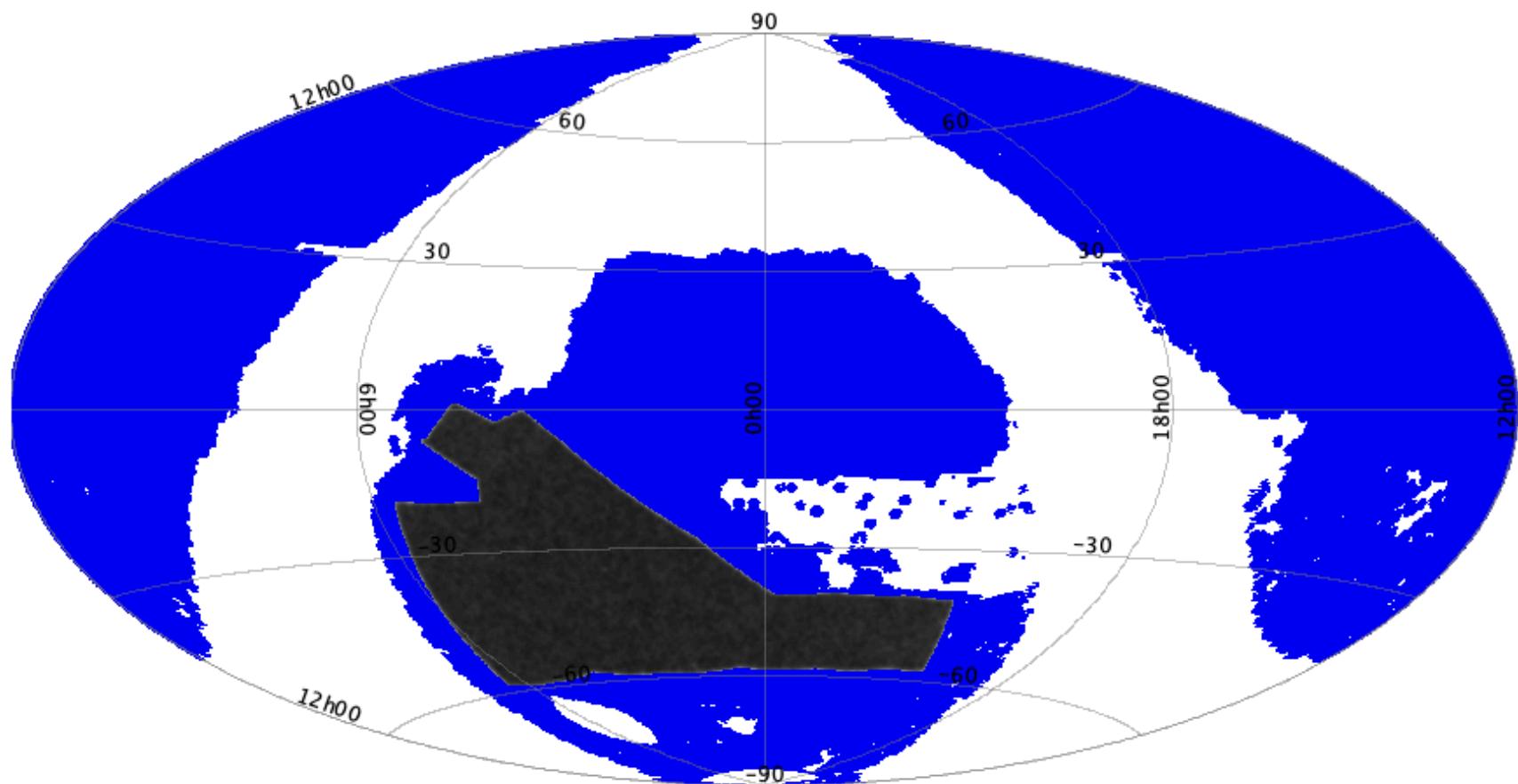
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Wen & Han (2024) – >1.5 million clusters

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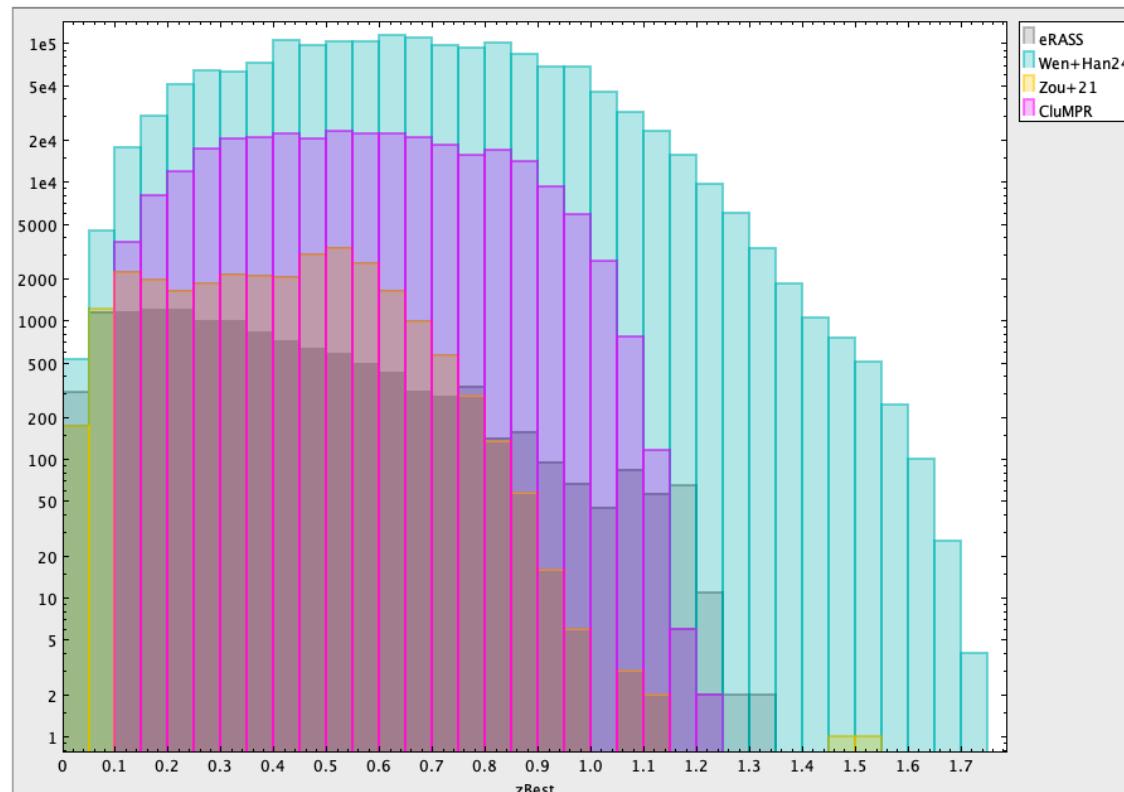
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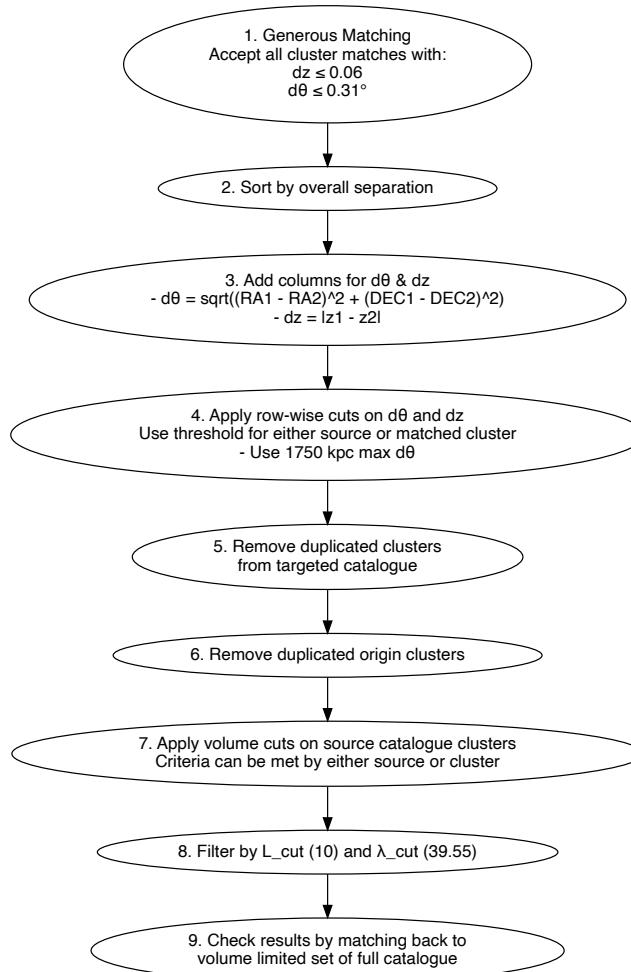
I then checked the **redshift** overlap with the eRASS1 catalogue:



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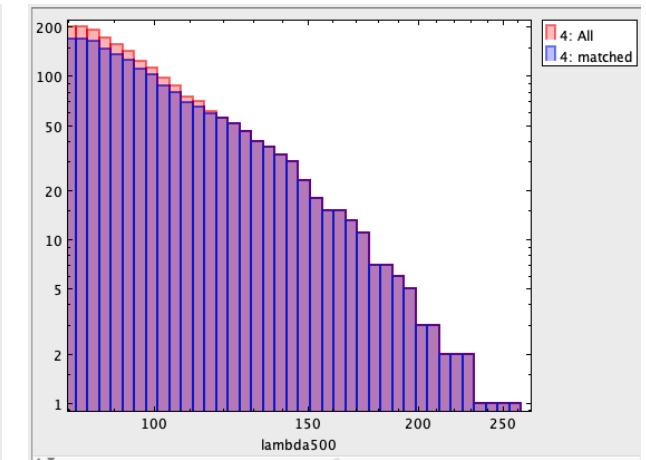
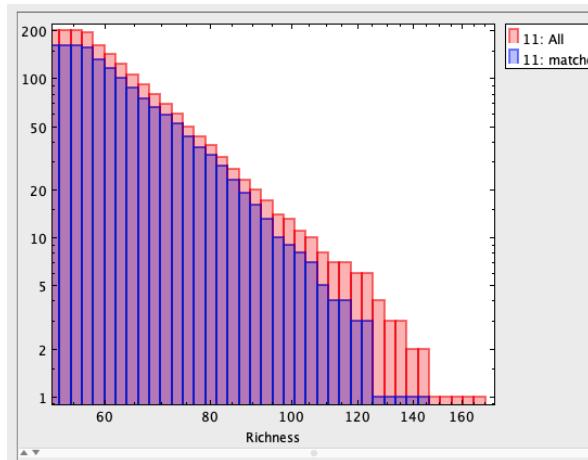
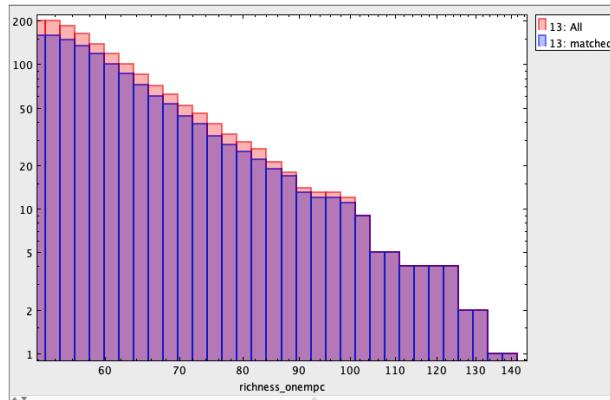
And then cross-matched to it to estimate **purity and completeness**:



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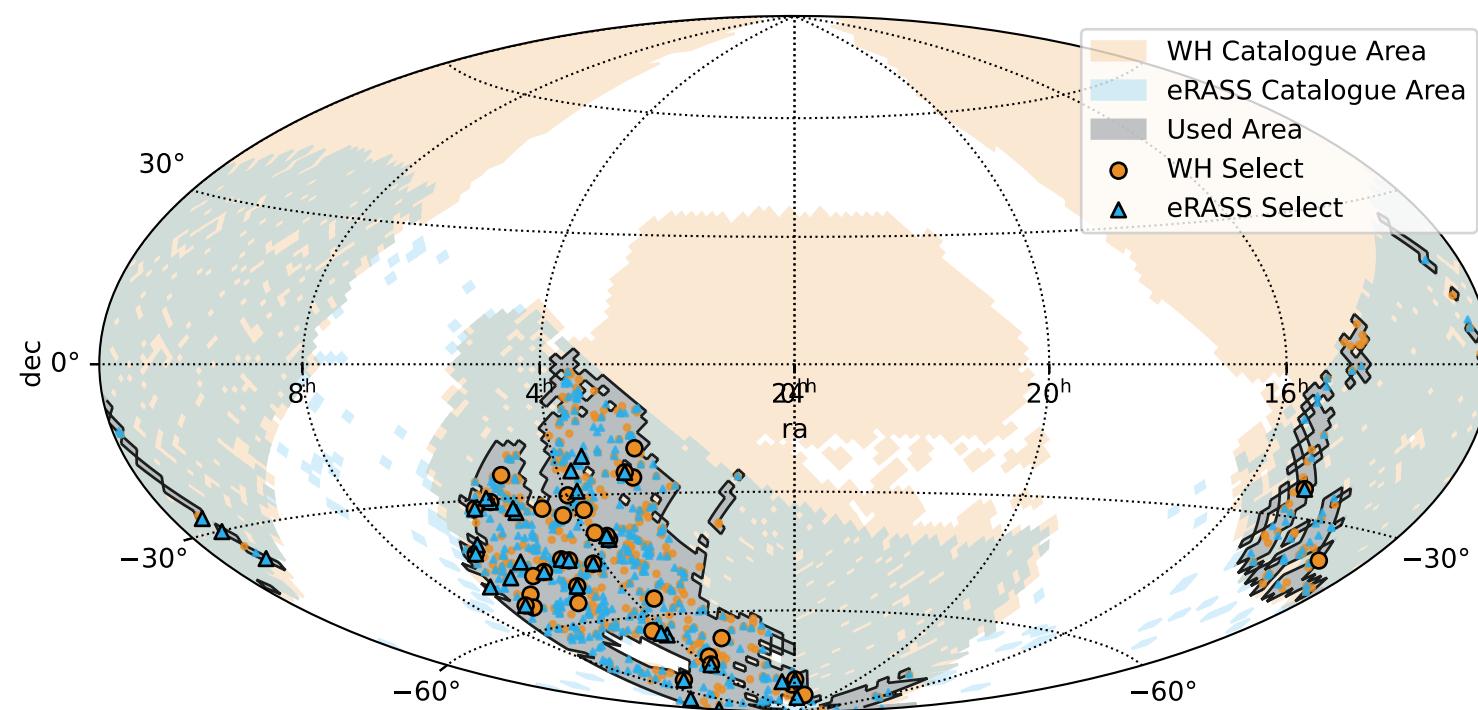
**Wen & Han (2024) is the
best optical catalogue for the work
I want to do.**

Final Samples

Redid the cross-matching but changed the search area to be where the eRASS1 exposure > 170 s & where the **eRASS sky** intersects with the **Wen & Han field** for $0.1 < z < 0.2$.

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DATA ANALYSIS

X-rays Generate and Analyse

A mission agnostic platform for processing and analysing X-ray data.



Turner et al. 2022, 2024a, 2024b

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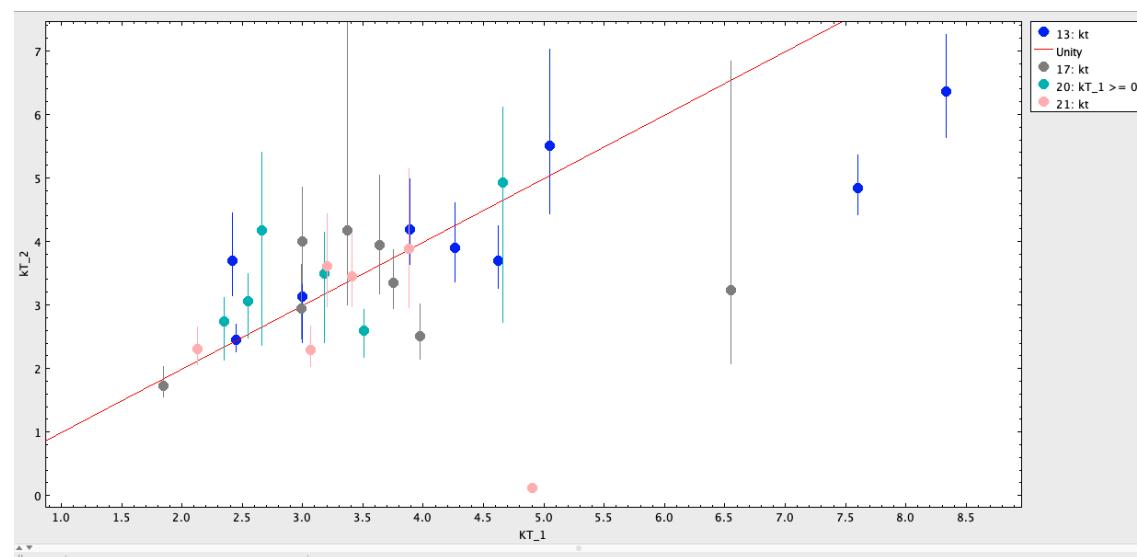
More advanced and mature than my pipeline and can handle data from other missions.



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Validated XGA results by comparing its cluster temperatures with those from the eRASS catalogue.

Turner et al. 2022, 2024a, 2024b

Scaling Relations – Set-up

I measured luminosities (L) with **XGA** and took richnesses (λ) from the **Wen & Han (2024)** catalogue for all clusters in the samples.

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Accounted for cluster evolution by dividing L for each cluster by:

$$E(z)^\gamma = \left(\sqrt{\Omega_M(1+z)^3 + \Omega_k(1+z)^2 + \Omega_\lambda} \right)^\gamma.$$

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To aid LIRA and **reduce degeneracies**, I set pivots on my data at: $L_0 = 10^{43}$ erg s⁻¹, $kT_0 = 3.55$ keV, and $\lambda_0 = 109$.

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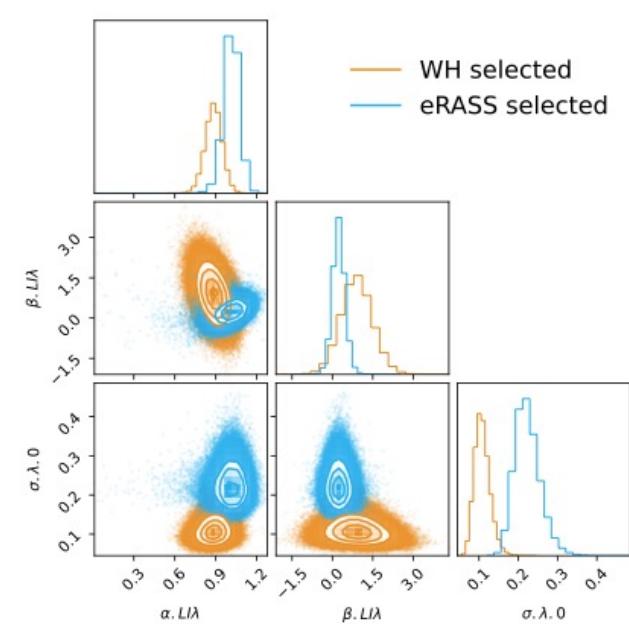
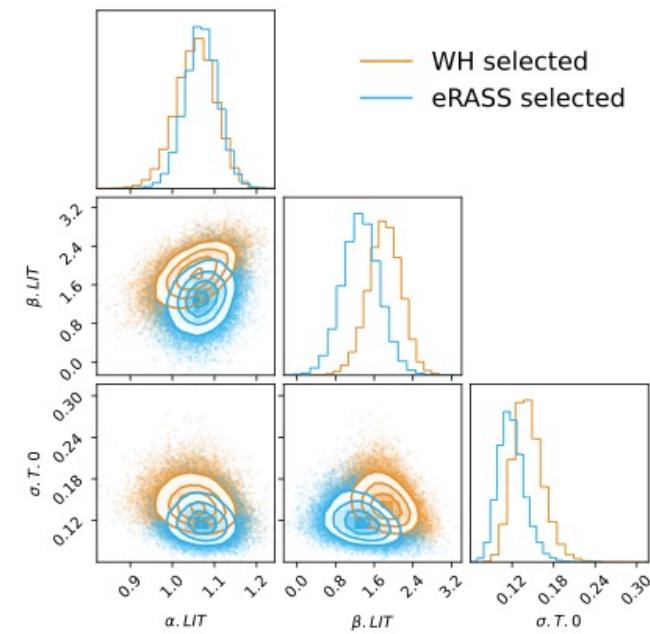
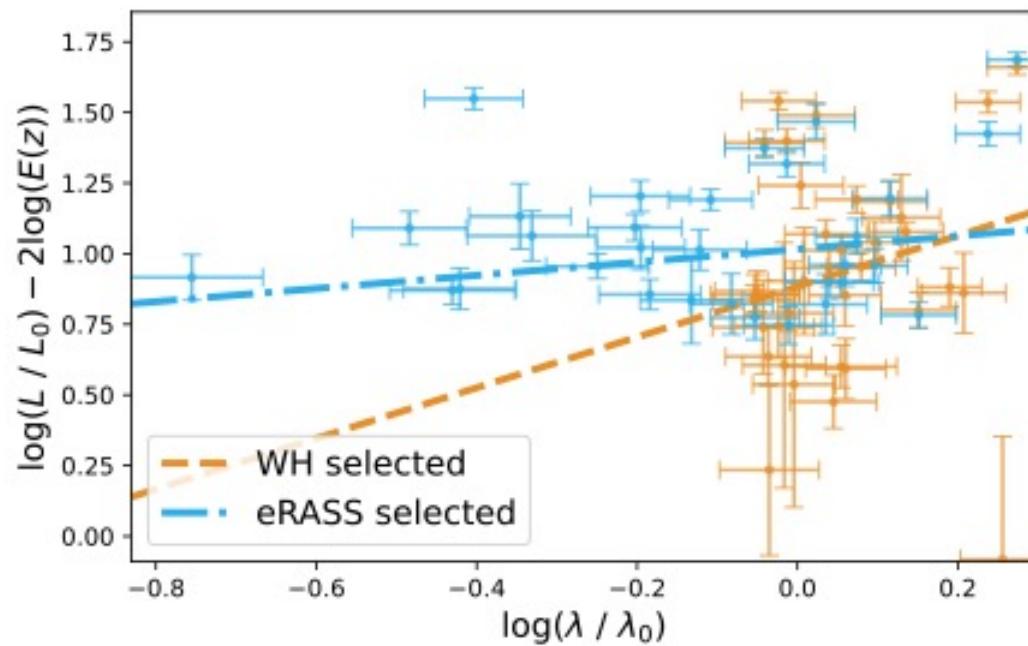
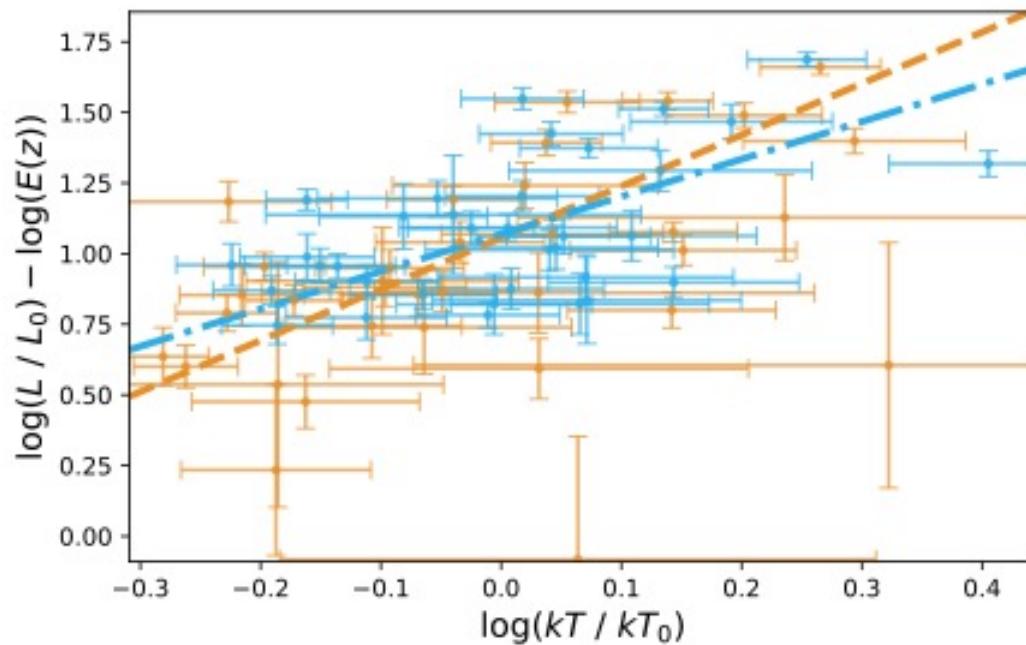
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For bias modelling, I set these thresholds: $L_{\text{thresh}} = 10^{43.5}$ erg s⁻¹ and $\lambda_{\text{thresh}} = 10$ for the **eRASS selected** clusters, and $\lambda_{\text{thresh}} = 43.7$ for the **optically selected** sample.

RESULTS

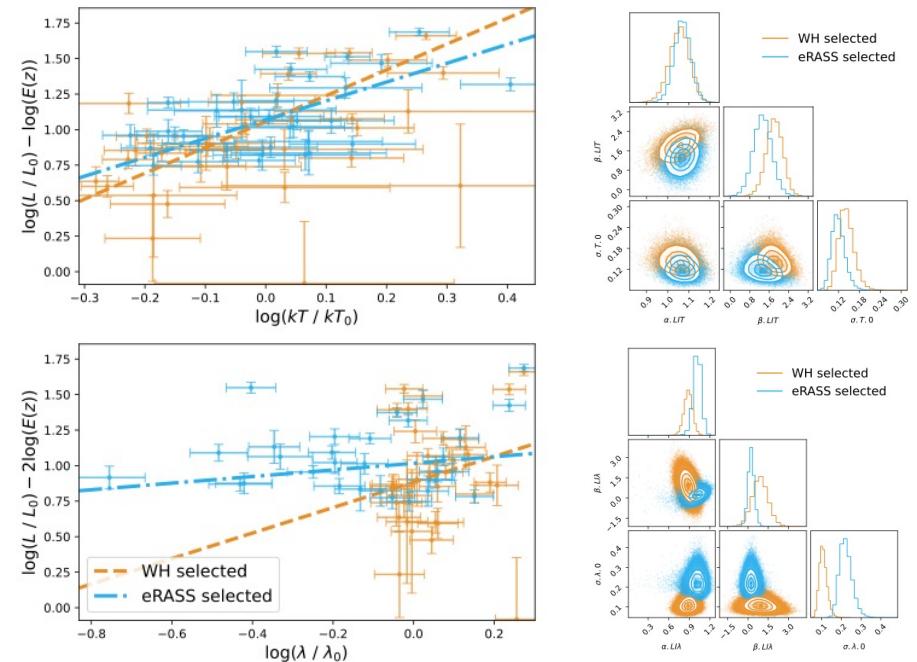
Results



Discussion

The optical sample has a **steeper slope (β)** for both relations.

Parameter	$L - T$		$L - \lambda$	
	WH	eRASS	WH	eRASS
α	$1.055^{+0.046}_{-0.049}$	$1.070^{+0.039}_{-0.039}$	$0.884^{+0.060}_{-0.062}$	$1.016^{+0.053}_{-0.057}$
β	$1.819^{+0.336}_{-0.342}$	$1.325^{+0.384}_{-0.337}$	$0.897^{+0.584}_{-0.573}$	$0.233^{+0.227}_{-0.222}$
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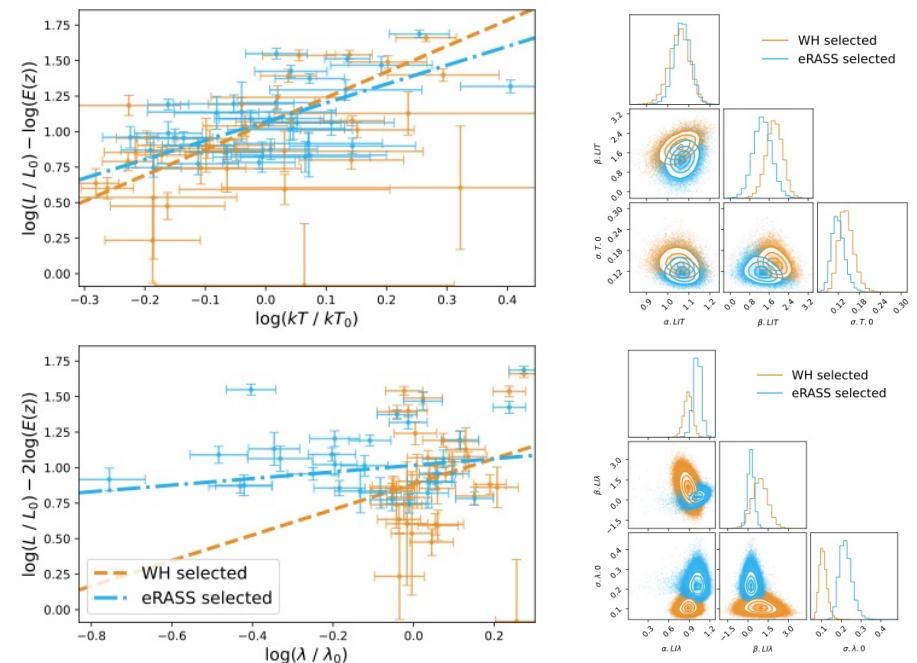


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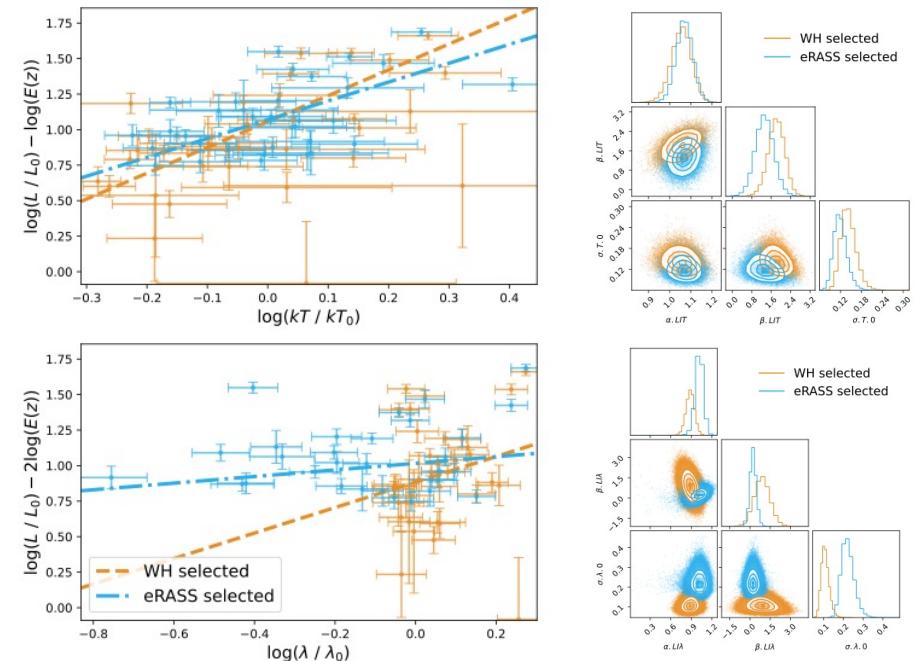
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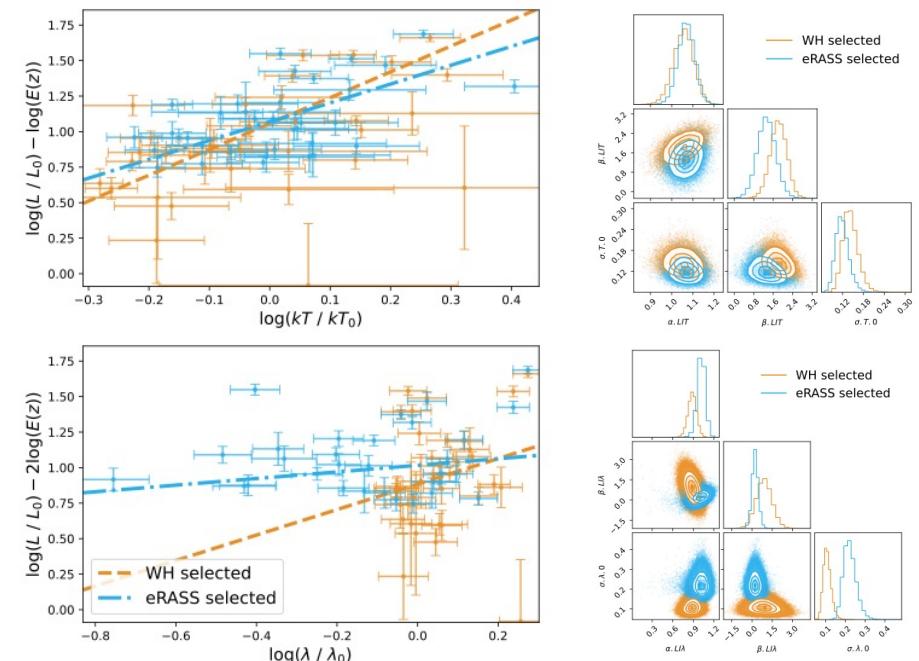
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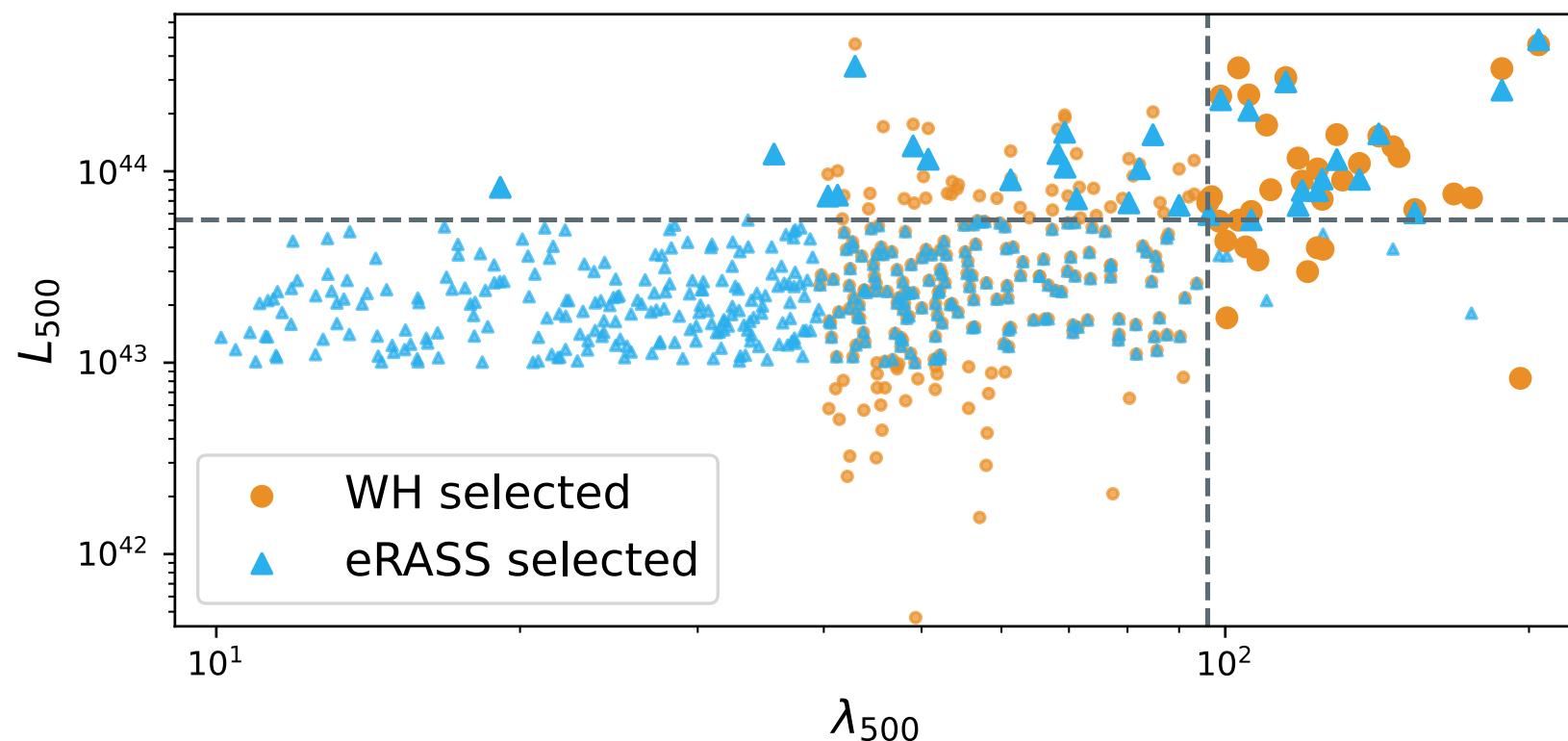
Similar to Andreon et al. (2016), we see a lot of high λ , low L clusters in the optical sample missed by the X-ray

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Future Work

My samples are currently very **incomplete**. I have used only 35 from each selection method of a possible 500 that I identified during sample selection:



SUMMARY

- ▶ Previous works have suggested that we are missing clusters, impacting cosmology
- ▶ I am trying to investigate this by comparing scaling relations of cluster properties
- ▶ Currently, the results are inconclusive but indicate that there might be something going on
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ANY QUESTIONS?