A Catalogue of 1.58 Million Clusters of Galaxies from the DESI Legacy Survey

Z . L. Wen and J. L. Han (2024)

Joseph Hall

2025-02-19

News?

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Background

(In which Joe speed reviews 3 older papers)

Context

- Clusters are big, biggest virialised things going
- We need to be able to find and characterise clusters
- This is an optical approach
- Culmination of over a decade of work

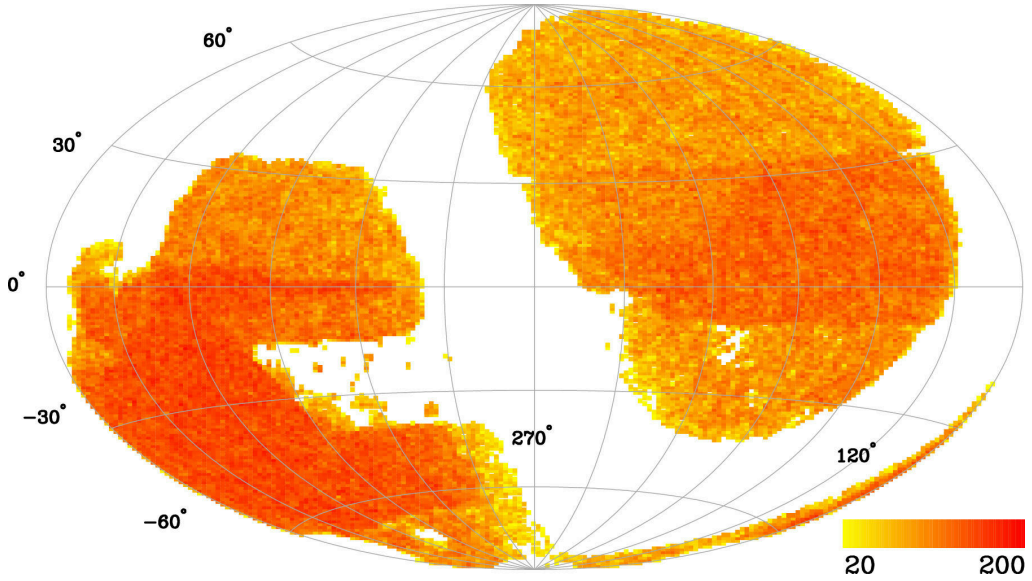


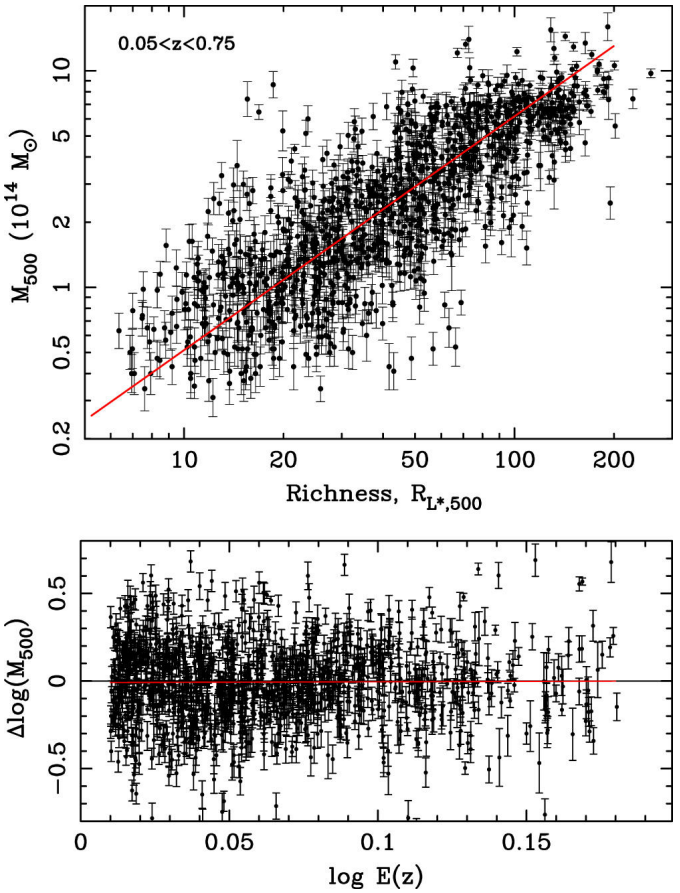
Figure 1: Density map of clusters from Wen and Han (2024, Fig. 6)

Wen and Han (2015) – Calibration

- Calibrated a relationship between r_{500} and $L_{1\ \mathrm{Mpc}}$
- Established **richness** as an optical mass proxy:

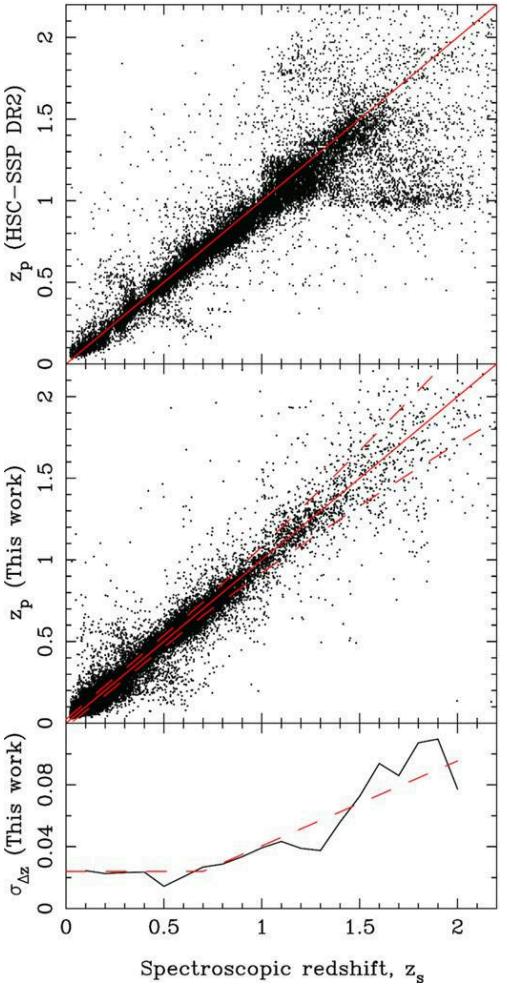
$$\lambda_{*,500} = \frac{L_{500}}{L_*} E(z)^{1.4}$$

- This is redshift independent & a good proxy



Wen and Han (2021) – Redshifts

- Combines spectroscopic and multi-band imaging surveys
- Places galaxies with spectro-z in colour space
- Uses a **nearest neighbour** algorithm to estimate the photo-z of galaxies only in imaging survey



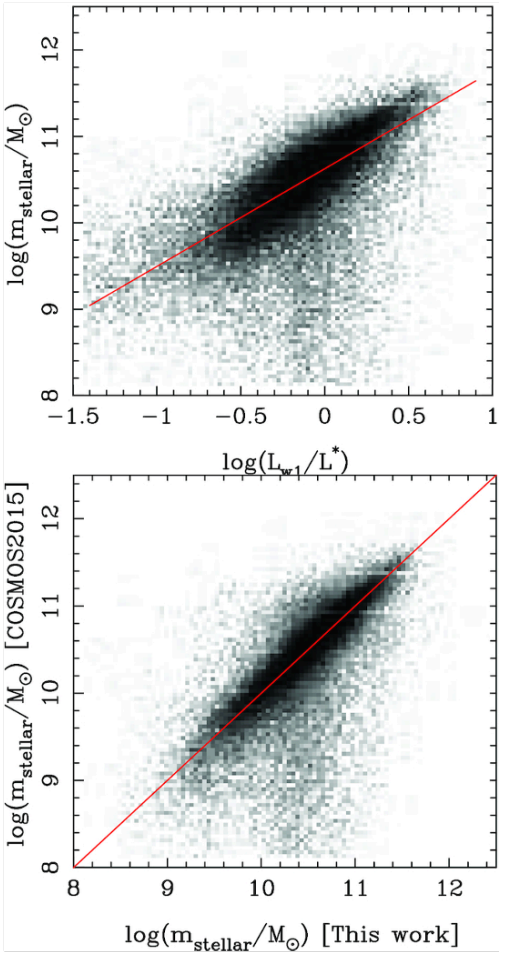
Wen and Han (2021) – Masses

- Links stellar mass and luminosity:

$$\log\left(\frac{m_{\rm stellar}}{M_\odot}\right) = \gamma \log\left(\frac{L_{\rm W1}}{L_*}\right) + f(z, Z)$$

- Uses this to get a mass based **richness** similar to Wen and Han (2015):

$$\lambda_{500} = m_{500,\rm stellar} \frac{(1+z)^{0.21}}{m_{*,\rm stellar}}$$



Wen and Han (2022) – Extending Deeper

- Takes what they were doing before and uses **DES** to find clusters to $z = 1.5$
- …
- Not much else different but proves validity of methods to deeper data

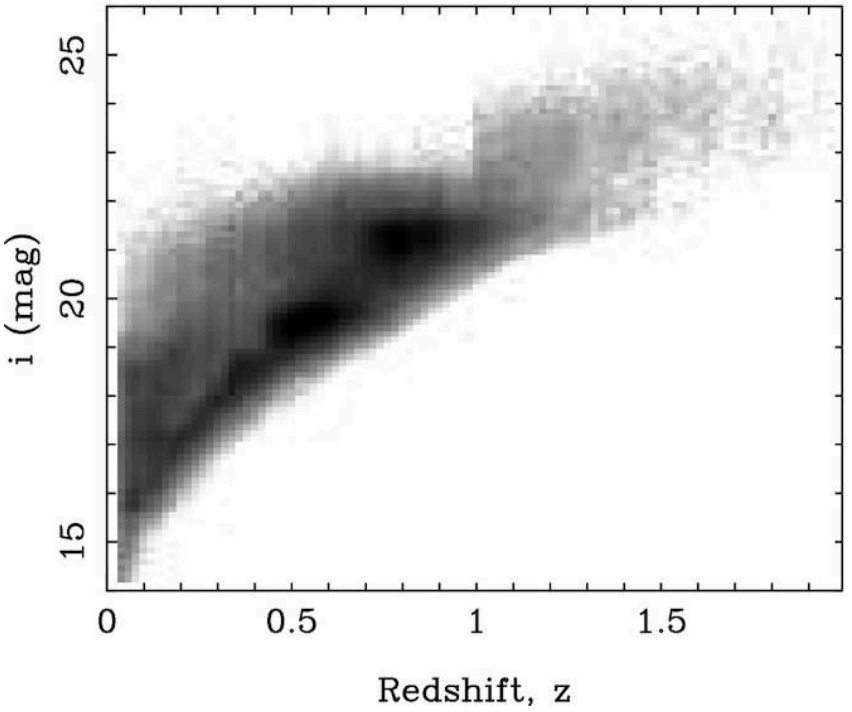


Figure 5: i-band magnitudes of the training sample as a function of redshift. Taken from Wen and Han (2022, Fig. 1)

The Actual Paper

*(Trust me, it's **definitely** a pre-print)*

The Initial Data Processing

- Using **DESI** Legacy Imaging Surveys as the photometric base
- Same processes as before for finding redshifts, with spectro-z from past work
- Slight tweak to finding m_{stellar}, using $r - z_m$ colour instead of $\mathrm{W1}$ luminosity

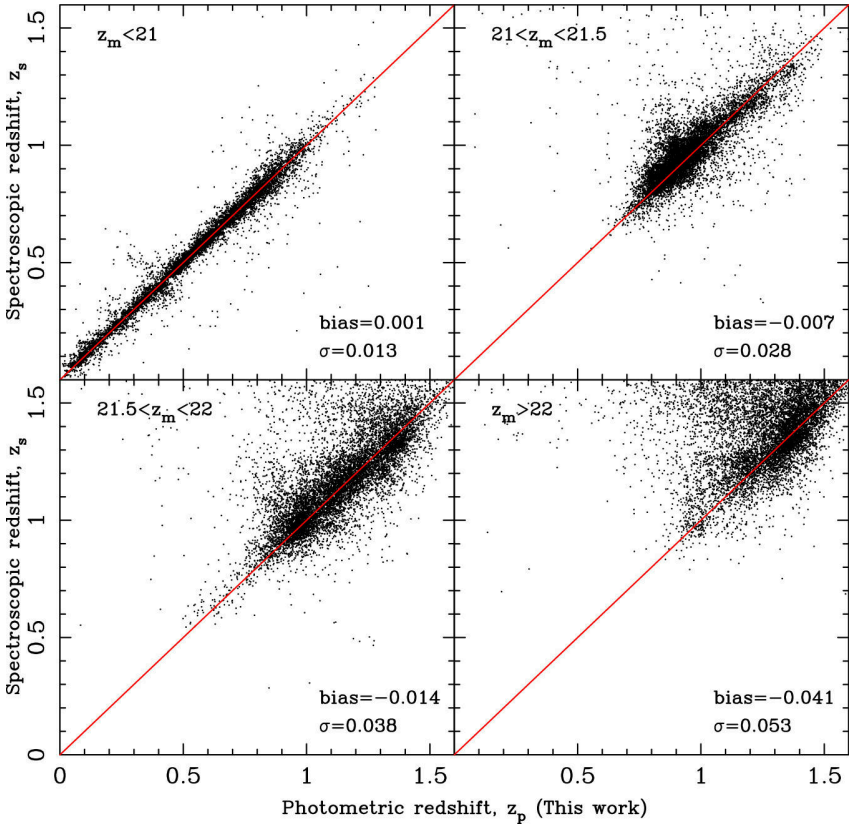


Figure 6: z_m-band magnitude binned comparisons of spectro- and photo-zs. From Wen and Han (2024, Fig. 1)

The Initial Data Processing

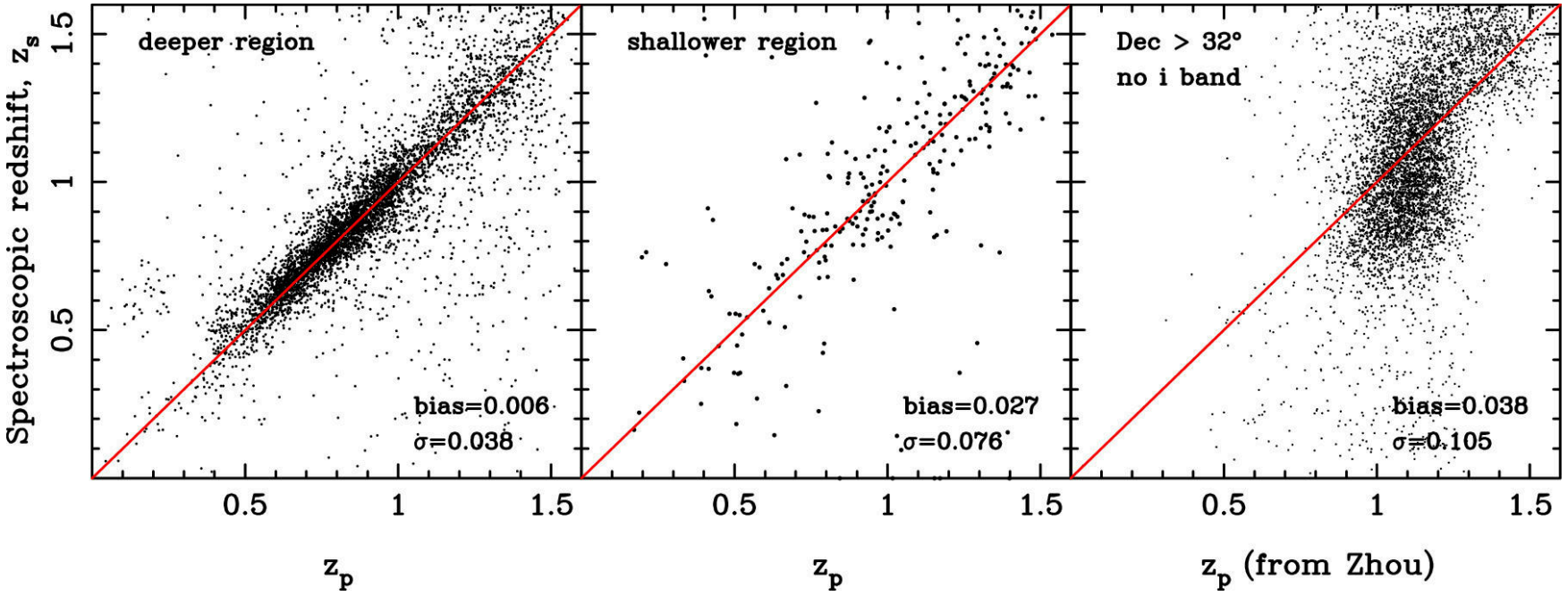


Figure 7: Comparisons of Wen and Han (2024) photo-z and those published by DESI in Zhou et al. (2021) without i-band mags

Finding Clusters

- Looking for overdensity in redshifts
- Take slices on **candidate "BCGs"** defined with half slice thickness:

$$\Delta z = \begin{cases} 0.04(1+z) \text{ for } z \leq 0.7 \\ 0.15z - 0.037 \text{ for } z > 0.7 \end{cases}$$

- Only using massive clusters ($M_* \geq 10^{10} M_\odot$)
- Use the equations calibrated before to find cluster radii and richness
- Define a cluster when $\boldsymbol{\lambda_{500} \geq 10}$ **and** $\boldsymbol{N_{\rm gal} \geq 6}$

Found Clusters

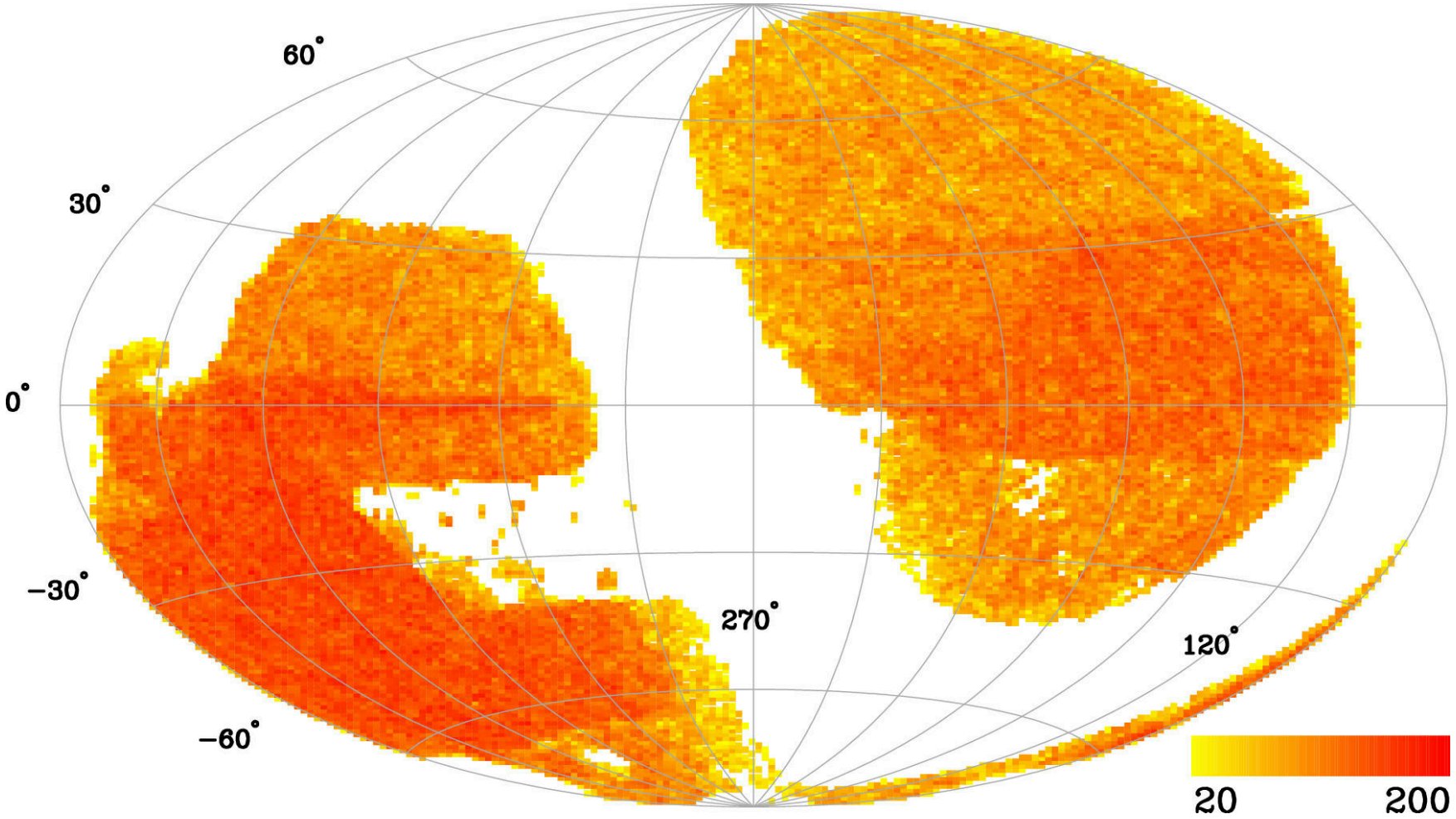
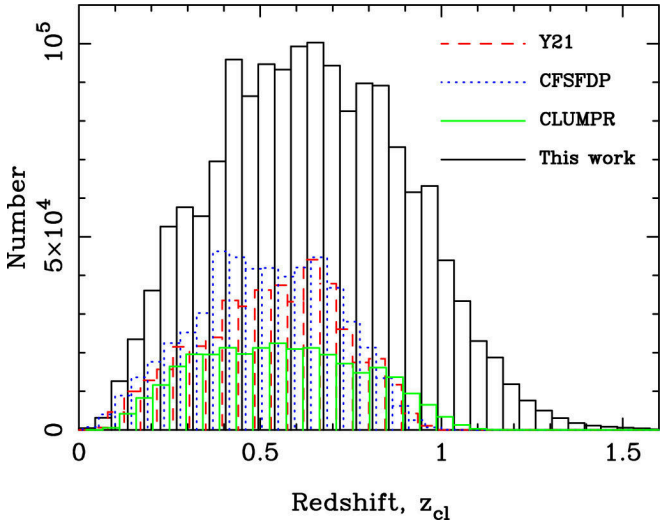


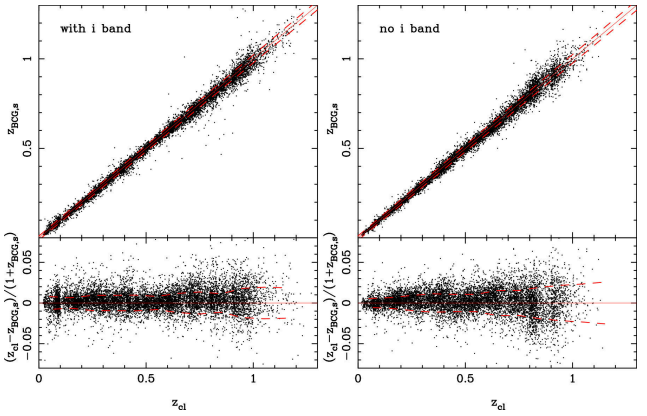
Figure 8: Density map of clusters from Wen and Han (2024, Fig. 6)

Cluster Redshifts

Defined in one of the following ways:

1. The **spectroscopic** redshift of the BCG, if available
2. Available spectroscopic redshifts of other galaxies, if within $0.025(1+z)$ of cluster photo-z
3. Unclear, but I think using the average photo-z of members as in Wen and Han (2022)



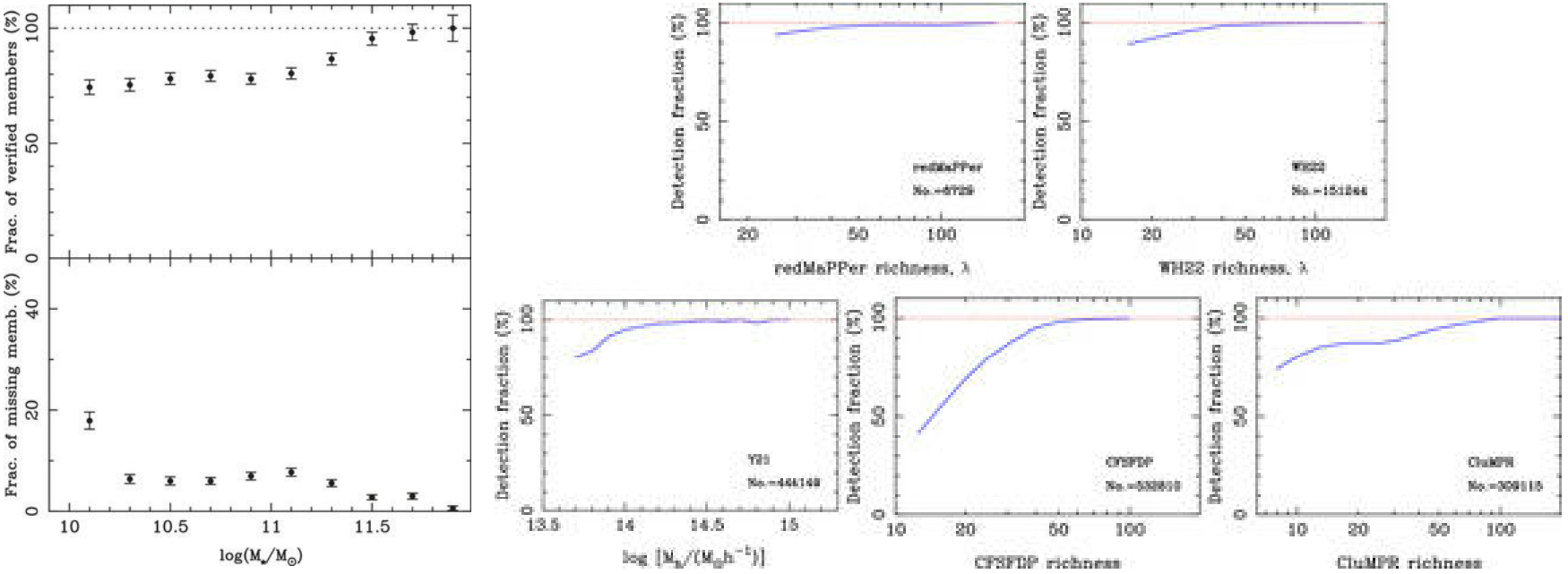


Verification

- Very important step when finding $> 800,000$ new clusters
- Compare results with clusters found and measured using X-ray and SZ observations
- Good completeness with X-ray – 82% of eRASS1 clusters detected in sample overlap
- 95% of SZ clusters overlap (in the ACT catalogue)
- No verification of cluster properties comparing with these measurements

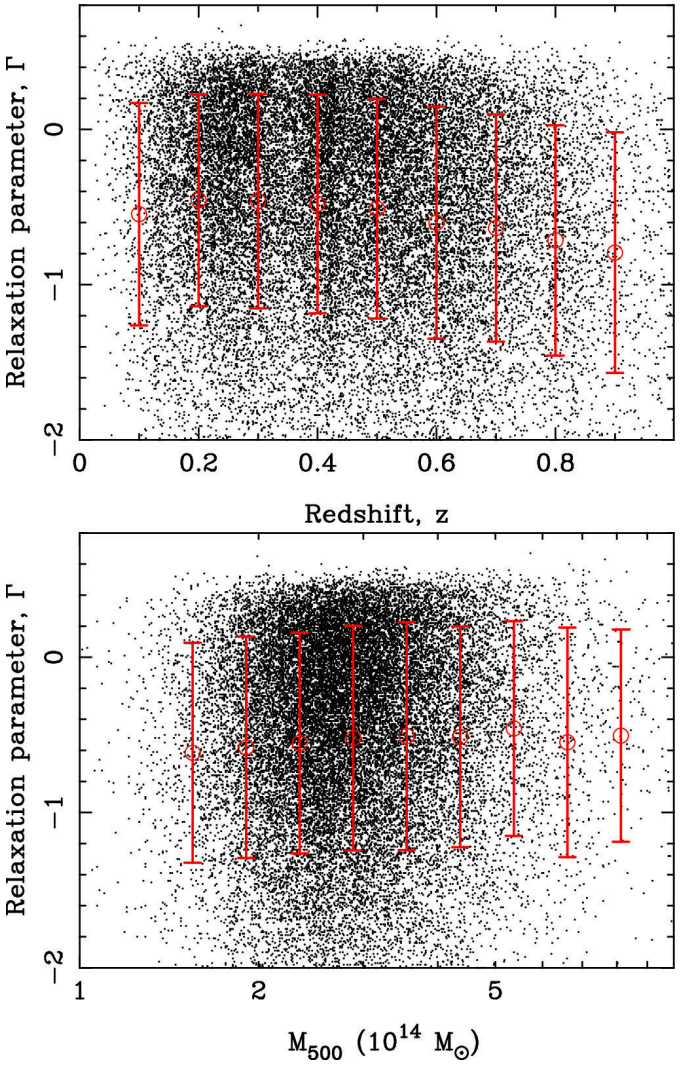
Verification

But do verify against other optical catalogues:



Evolution

- Apparently, clusters evolve
- They look at two particular evolutions:
  - Dynamical states
  - BCG growth



(I maybe didn't get round to reading this bit)

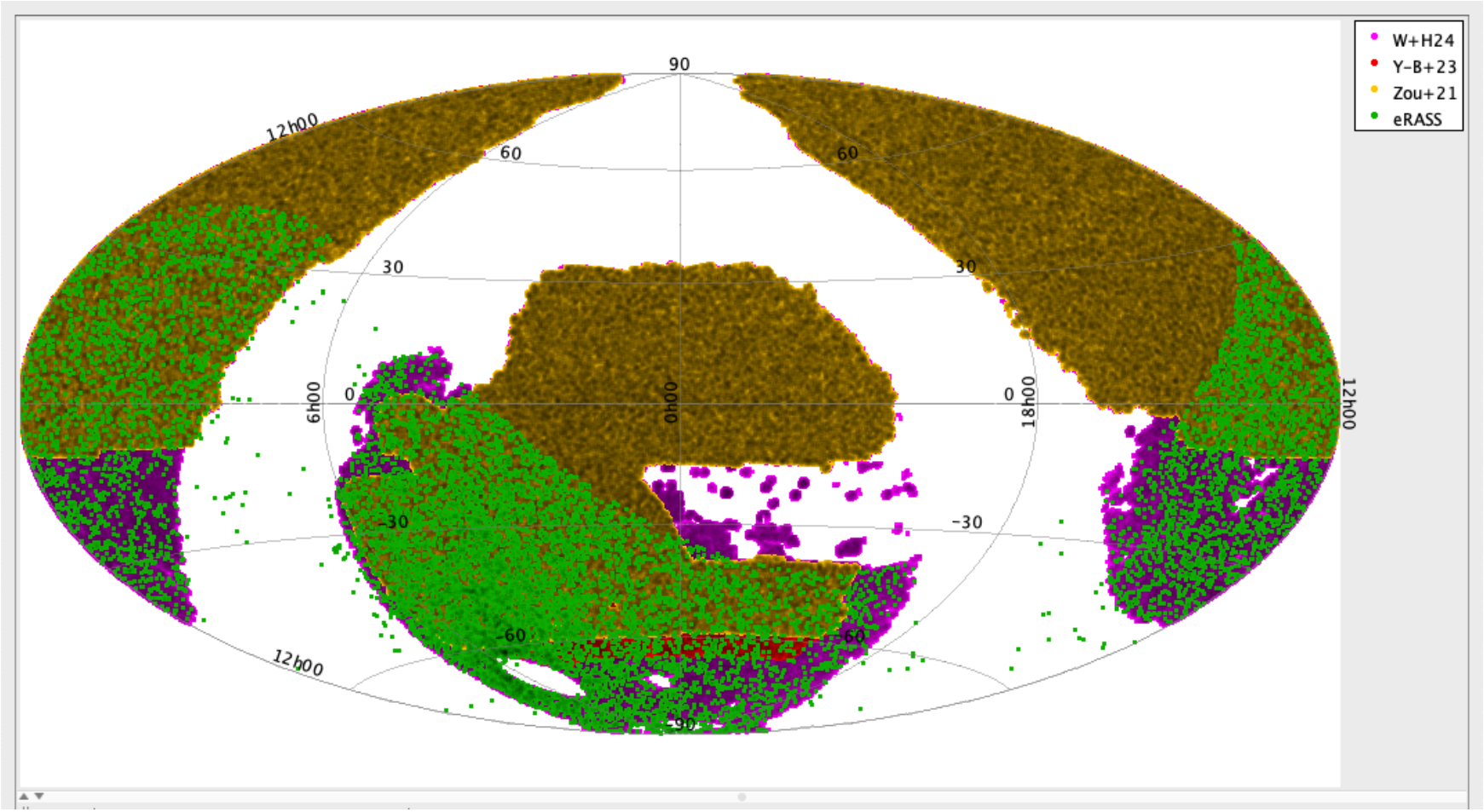
Why do *I* care?

(Yeah, why do you? Aren't you an X-ray astronomer?)

Why I care:

- My research looks at trying to understand differences in properties based on selection method
- I have an X-ray catalogue (eRASS)
- Need an optical and this one is:
  a. Really big
  b. Really well overlapped with eRASS

Why I care:



Summary

- This is a big catalogue (**1.58 Million!**) with reliable results
- Methods developed over a decade help to guarantee robustness of results
- Fantastic for work on cluster population studies
- Also does stuff with cluster evolution

Any Questions?

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Wen, Z. L., Han, J. L., 2024. A Catalog of 1.58 Million Clusters of Galaxies Identified from the DESI Legacy Imaging Surveys. The Astrophysical Journal Supplement Series 272, 39.. https://doi.org/10.3847/1538-4365/ad409d

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