

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

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

# 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

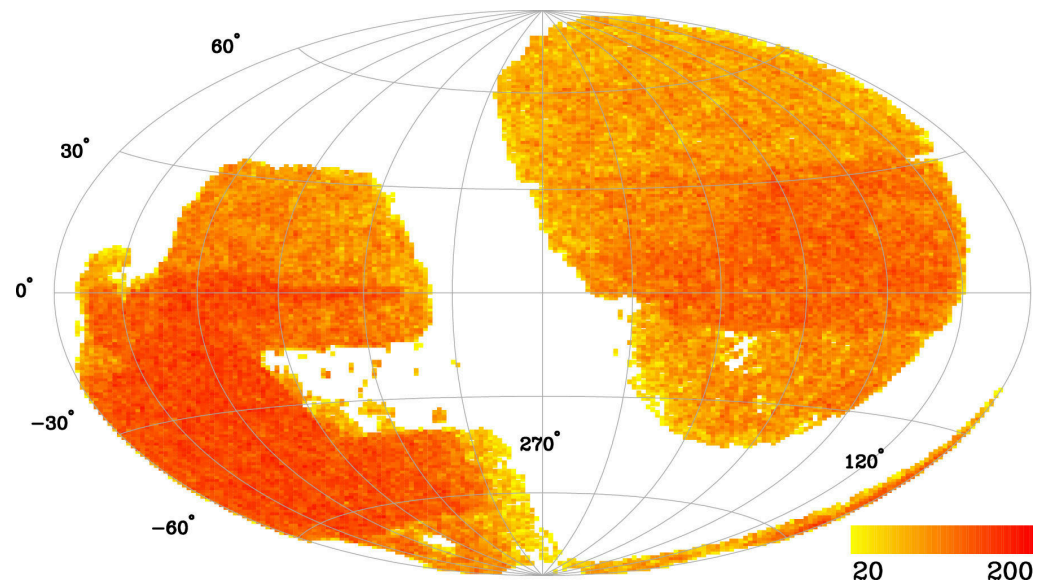


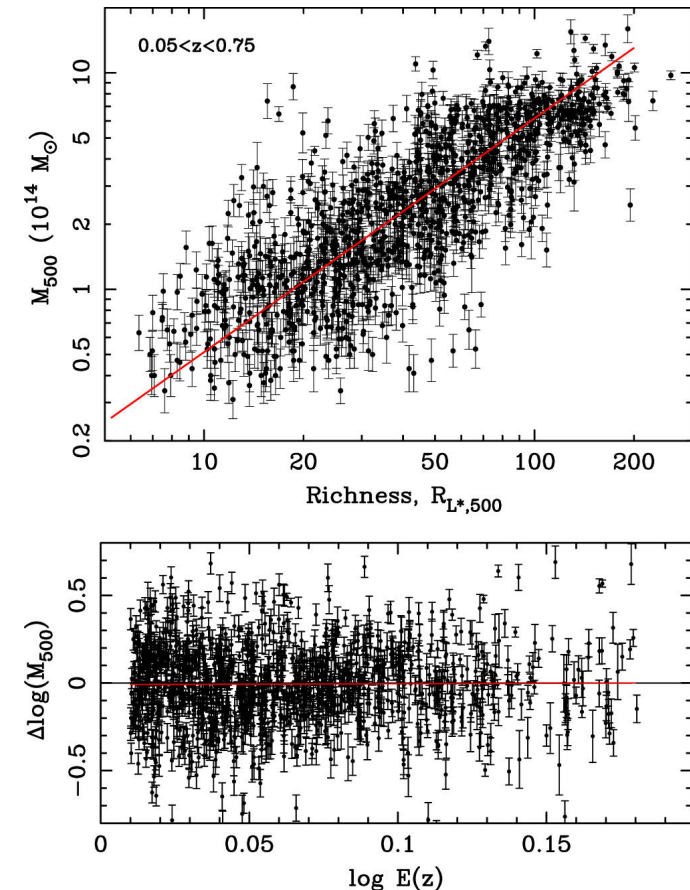
Figure 1: Density map of clusters from Wen and Han (2024, Fig. 6)

# Wen and Han (2015) – Calibration

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

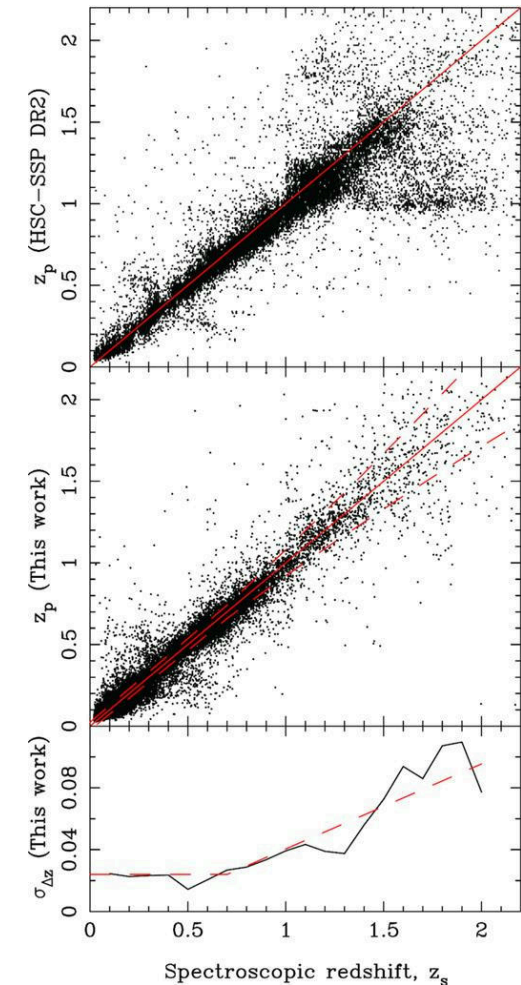
$$\lambda_{*,500} = \frac{L_{500}}{L_*} E(z)^{1.4}$$

- 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



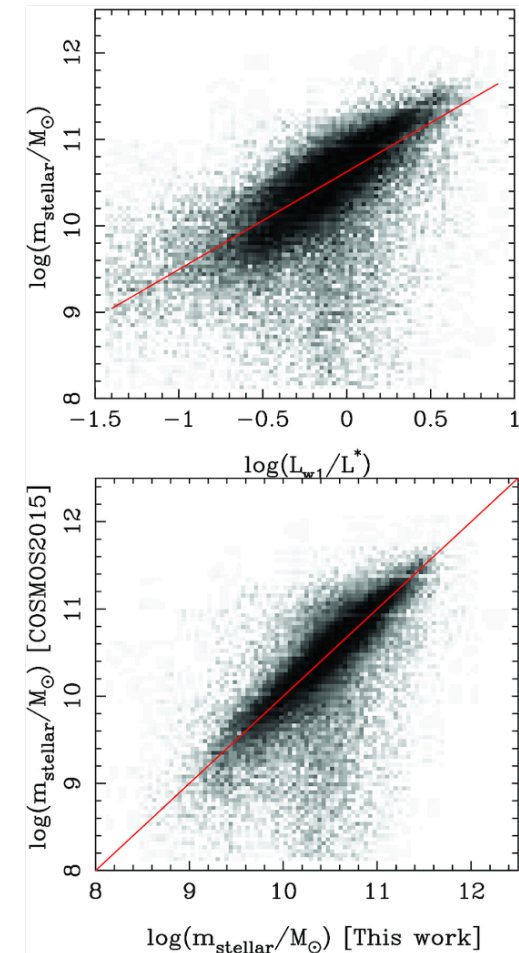
# Wen and Han (2021) – Masses

- Links stellar mass and luminosity:

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

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

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



# 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

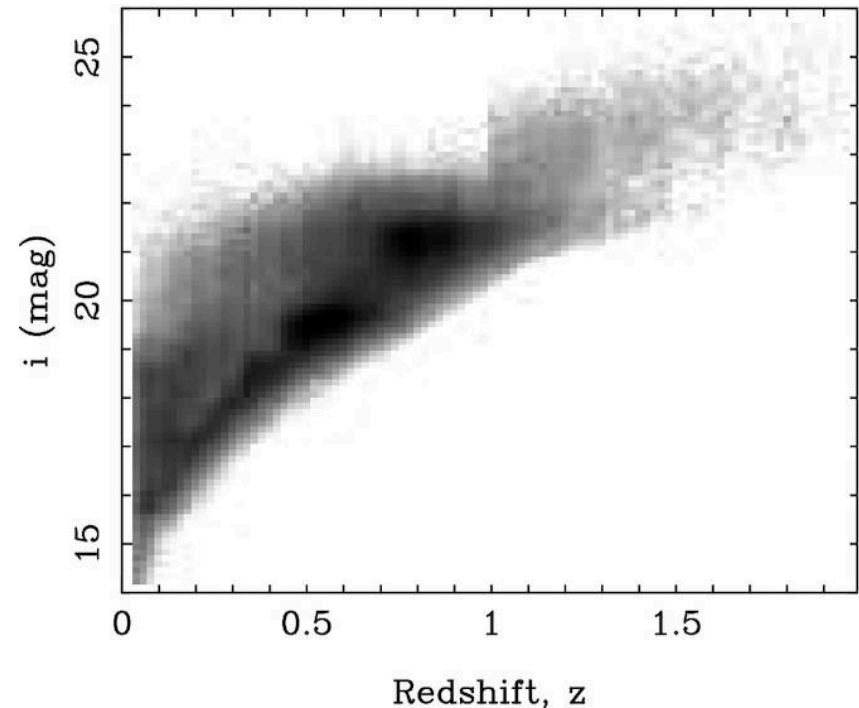


Figure 5: *i*-band magnitudes of the training sample as a function of redshift. Taken from Wen and Han (2022, Fig. 1)

# 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  $m_{\text{stellar}}$ , using  $r - z_m$  colour instead of W1 luminosity

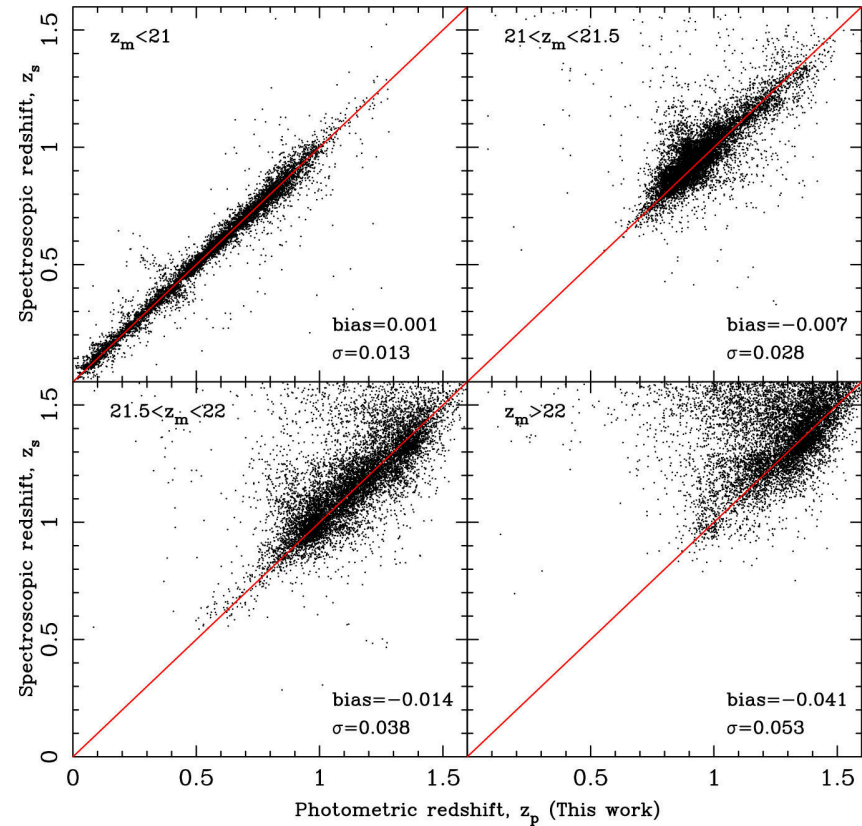


Figure 6:  $z_m$ -band magnitude binned comparisons of spectro- and photo- $z$ s. From Wen and Han (2024, Fig. 1)

# The Initial Data Processing

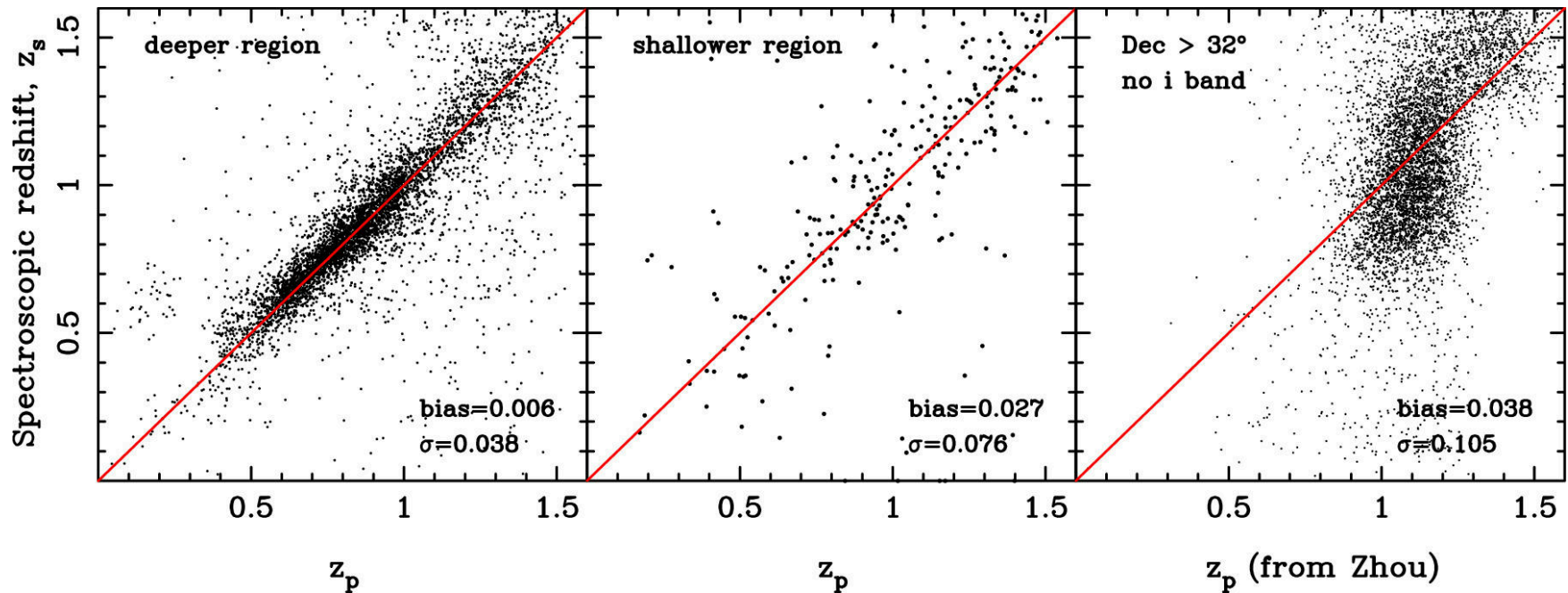


Figure 7: Comparisons of Wen and Han (2024) photo- $z$  and those published by DESI in Zhou et al. (2021) without  $i$ -band mags

# 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  $\lambda_{500} \geq 10$  **and**  $N_{\text{gal}} \geq 6$

# Found Clusters

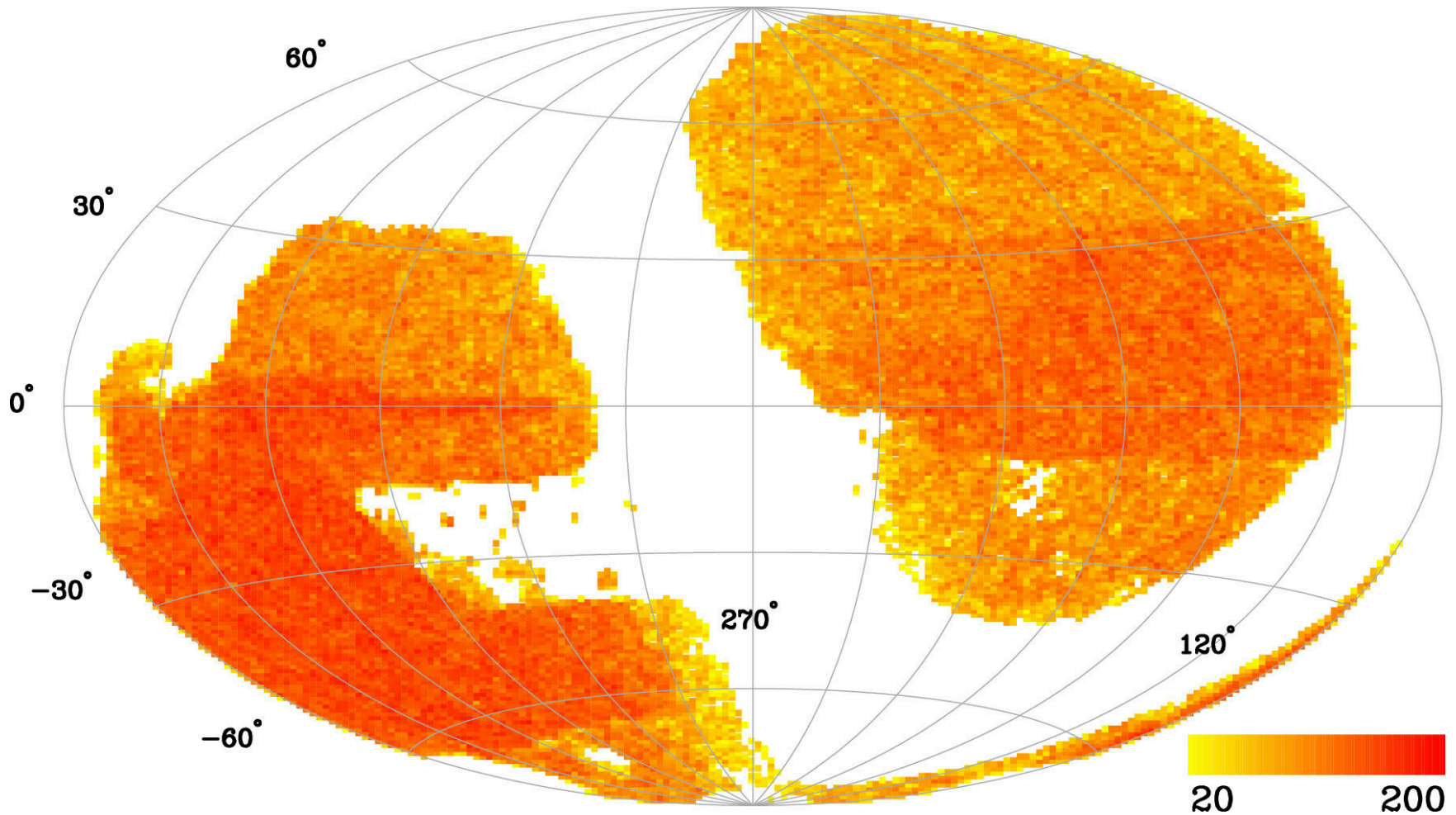
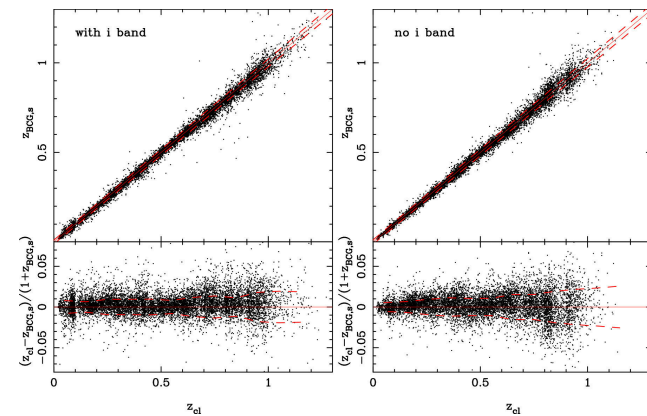
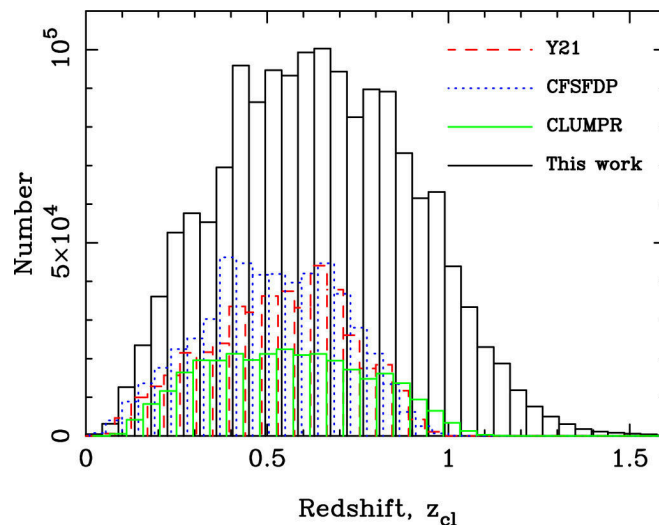


Figure 8: Density map of clusters from Wen and Han (2024, Fig. 6)

# 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)

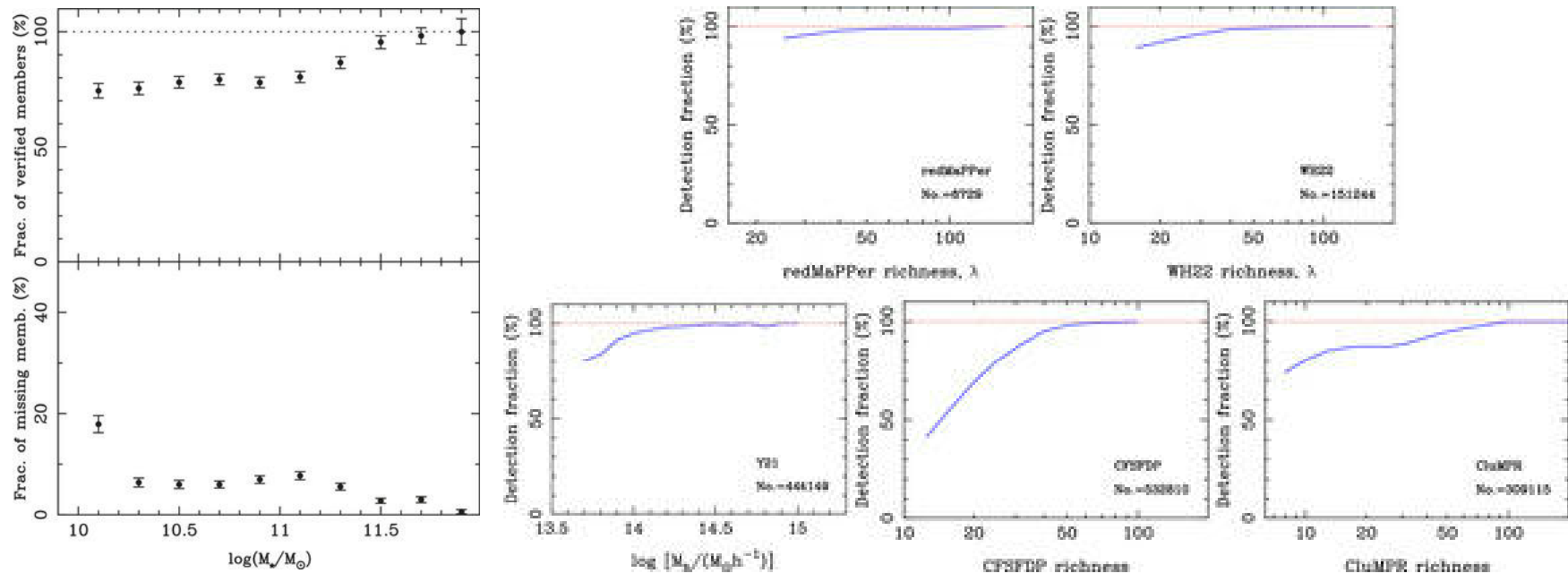


# Verification

- 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

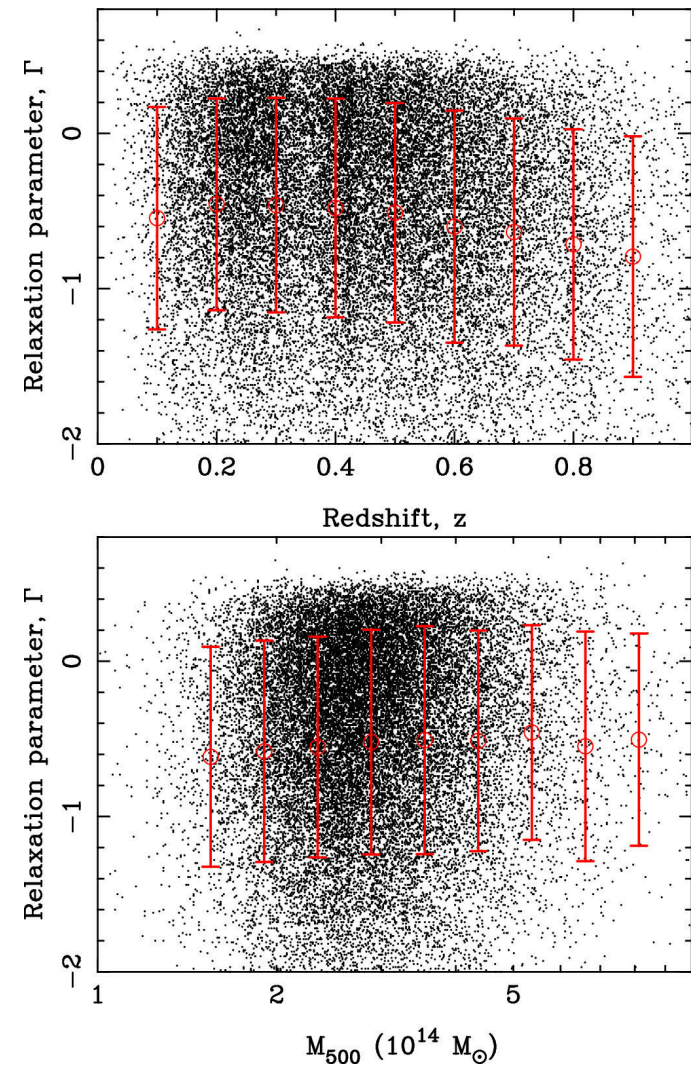
But do verify against other optical catalogues:





# 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?)*

# Bibliography

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>

Wen, Z. L., Han, J. L., 2022. Clusters of galaxies up to  $z = 1.5$  identified from photometric data of the Dark Energy Survey and unWISE. Monthly Notices of the Royal Astronomical Society 513, 3946–3959.. <https://doi.org/10.1093/mnras/stac1149>

Wen, Z. L., Han, J. L., 2021. Photometric redshifts for galaxies in the Subaru Hyper Suprime-Cam and unWISE and a catalogue of identified clusters of galaxies. Monthly Notices of the Royal Astronomical Society 500, 1003–1017.. <https://doi.org/10.1093/mnras/staa3308>

Wen, Z. L., Han, J. L., 2015. Calibration of the Optical Mass Proxy for Clusters of Galaxies and an Update of the WHL12 Cluster Catalog. The Astrophysical Journal 807, 178.. <https://doi.org/10.1088/0004-637X/807/2/178>

Zhou, R., Newman, J. A., Mao, Y.-Y., Meisner, A., Moustakas, J., Myers, A. D., Prakash, A., Zentner, A.

R., Brooks, D., Duan, Y., Landriau, M., Levi, M. E., Prada, F., Tarle, G., 2021. The clustering of DESI-like luminous red galaxies using photometric redshifts. *\mnras* 501, 3309–3331.. <https://doi.org/10.1093/mnras/staa3764>