eROSITA X-ray properties of galaxy clusters selected with different methods

Joseph Hall[1]*, Ben Maughan[1]

[1]HH Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol, BS8 1TL

University of Bristol

– Joseph.Hall@bristol.ac.uk

𝕏 – @SpaceAndPizzas

Background image: Abell 478 from the ACCEPT project (Cavagnalo et al. 2009)

1. Background

- Clusters are the largest gravitationally bound structures, forming at the intersections of cosmic web
- Only ~20% of baryonic matter in stars, the rest is in hot **X-ray emitting ICM**
- Assuming a "**self-similar**" model for clusters predicts simple power-law scaling relations between properties which can be tested observationally, traditionally with X-ray selected samples

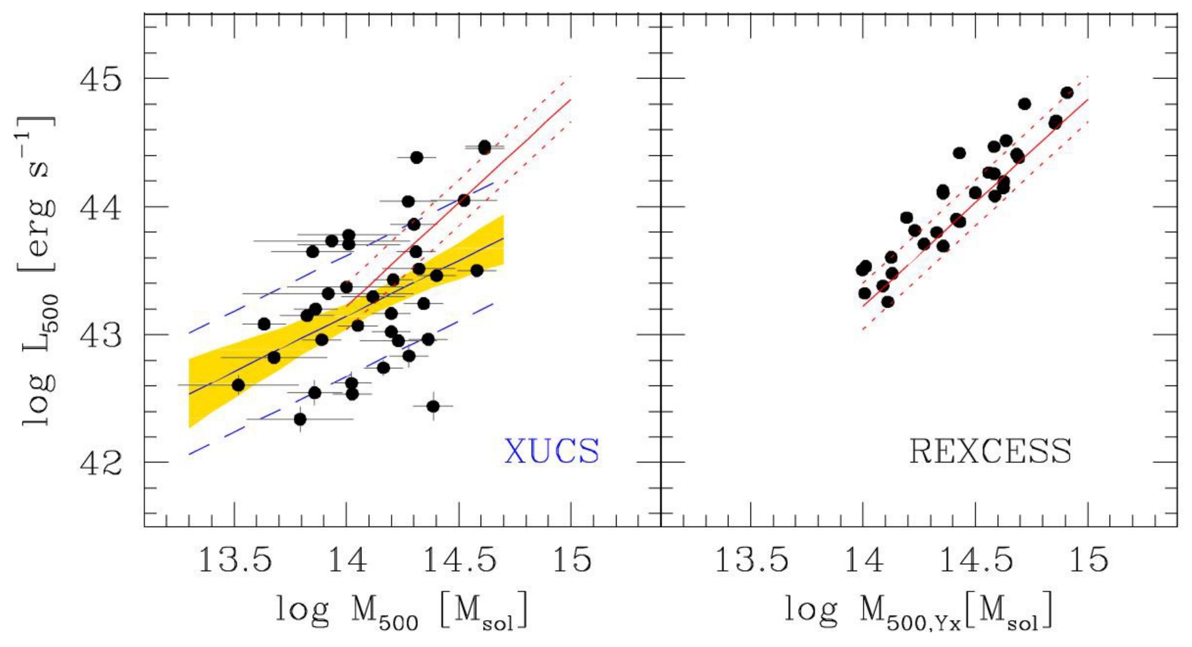

Figure 1: from Andreon et al. (2016) showing the difference between X-ray Luminosity (L) and cluster mass (M) scaling relations when using optically (left) and X-ray (right) selected samples. The datasets are very different, with the X-ray selected sample having much tighter correlation and with much less scatter in L at a given M. But the interpretation is not simple as both the luminosity and mass measurements were not done the same way for both datasets.

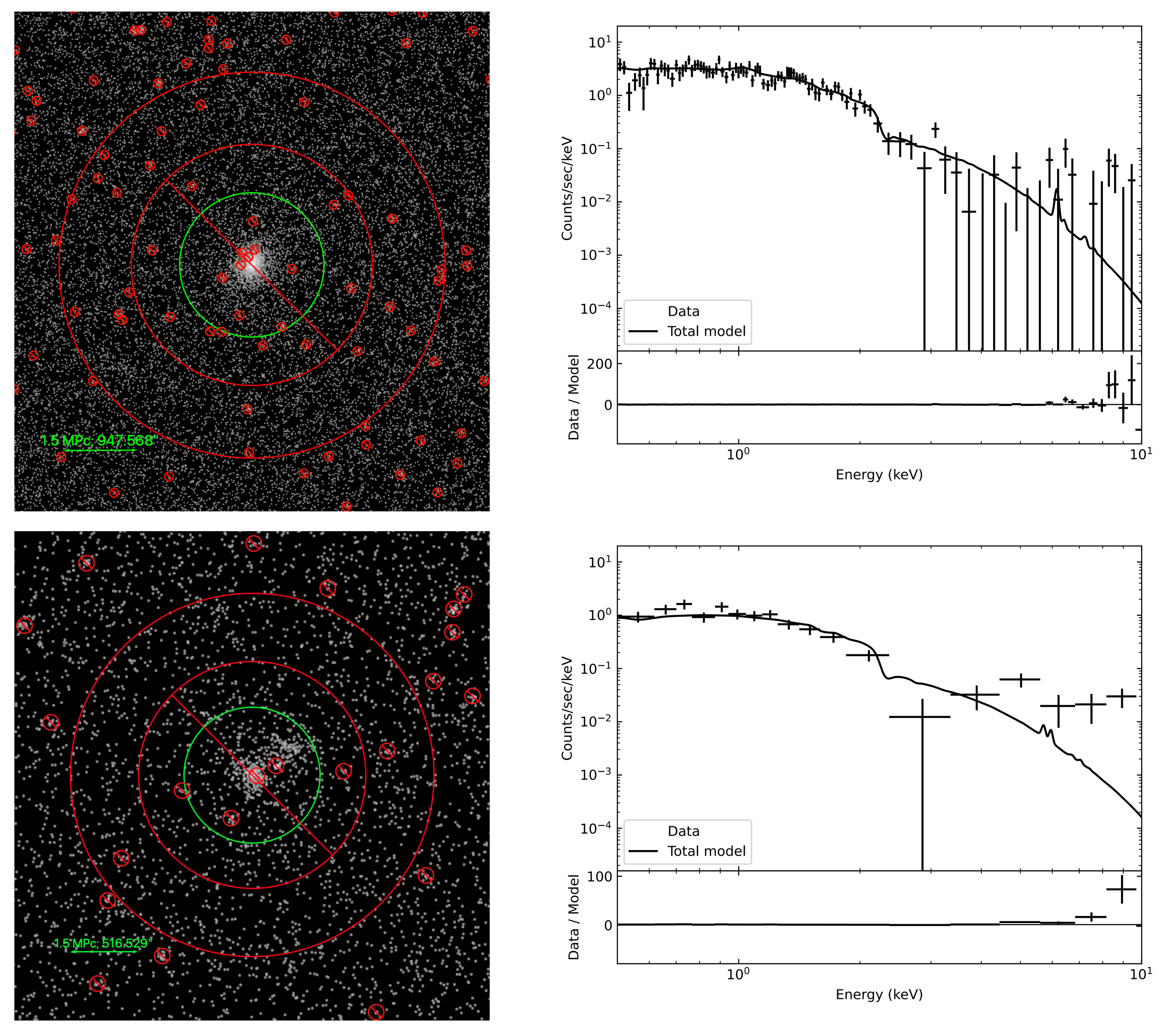

Figure 2: Example images from eSASS (left) showing the regions used and fitted spectra (right) for an eRASS selected cluster at z = 0.0843 (top) and a RedMapper cluster at z = 0.174 (bottom). The inner green region is our 1.5 Mpc source radius, the annulus is our background area, and the smaller red regions are excluded background point sources

2. Motivation & Previous Work

- Self-similar predictions assume only gravity dictates the properties of clusters and their ICM, deviations suggest extra astrophysical processes, e.g. AGN feedback
- Large, **unbiased samples** are needed to explore these processes
- Works like Andreon et al. (2016) suggest that using traditional X-ray selection methods are biasing the samples (fig. 1)

We use eROSITA to compare scaling relations of X-ray and optically-selected clusters of galaxies, based on consistent measurements

3. Selection Methods

- Used the overlapping region of the **eRASS1** clusters catalogue (Bulbul et al. 2024), and a **RedMapper** produced catalogue for SDSS (Rykoff et al. 2014)
- We took the 40 highest **X-ray flux** clusters from eRASS, and 40 highest **optical richness** clusters from RedMapper
- Redshift of the clusters were constrained to the same range for the two samples: 0.01 < z < 0.3. The low-end cut was to exclude nearby AGN mischaracterised as clusters in eRASS, while the high-end was to ensure good signal to noise ratio of the eROSITA data

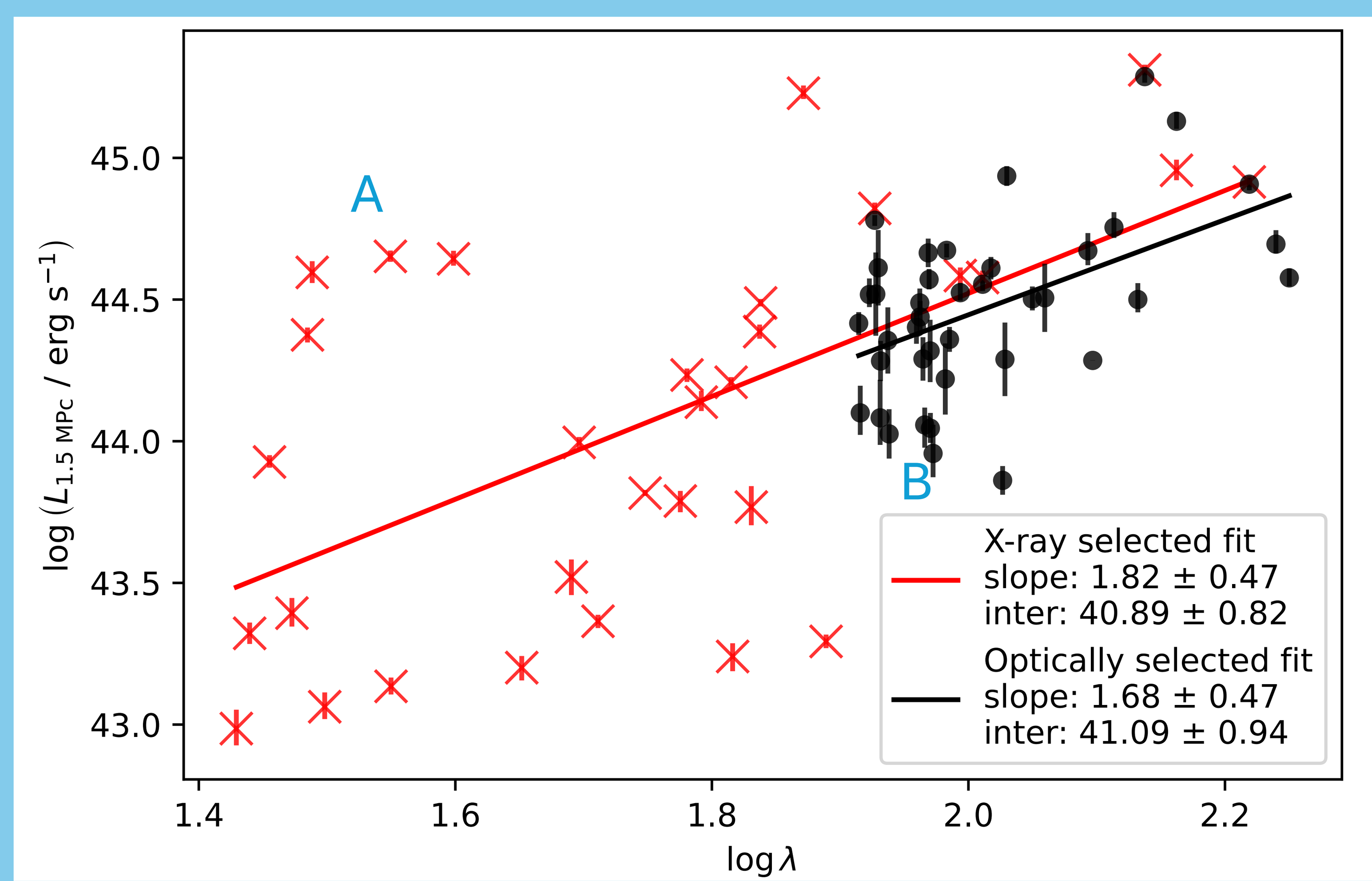

Figure 3: Comparing our preliminary **Luminosity-Richness (L- λ)** scaling relations for the X-ray selected (red, marked with ×) and optically selected (black, marked with •) samples. Very similar relations have been found, but the fits have been done with simple linear regression. We have marked two outliers, **A** and **B**, which we look at in more detail in **Fig. 4** below.

4. Data Processing

- We used a 1.5 Mpc circular region for our source spectra, and a nearby annulus for the background. To detect and and handle background point sources, we utilised the eSASS software
- For our spectra, we subtracted the backgrounds and then fit an absorbed thermal emission spectra. **Fig. 2** shows the result of this for two clusters
- We evaluated the fluxes of our fitted spectra and used these to calculate the **luminosities ($L_{1.5\,Mpc}$)** of the clusters
- **Richness (λ)** values were taken from the RedMapper catalogue, crossmatching based on position and redshift to get values for the X-ray selected clusters

5. Preliminary Results

- Our initial scaling relations are shown in **Fig. 3**, the fitting has been done with simple least squares regression, in the future we will use more robust methods.
- The difference in the relations is less dramatically obvious than seen in **Fig. 1**, but our results roughly agree, having similar best fitting results.
- In the overlap region, the X-ray sample is lacking lower luminosity cluster seen in the optical sample (like in Andreon et al. 2016), however this will be at least partly because of the flux limit of our current X-ray sample which we have not yet accounted for
- These are still very early results and there is plenty we want to do to improve them. In particular:
  - Expanding our coverage to more than just the top 40 brightest and highest richness clusters
  - Changing our optical catalogue to one with more coverage around the southern eROSITA pole where eRASS has the most depth,
  - Investigate other selection methods, for example using an SZ catalogue such as Planck (Planck Collaboration 2018)

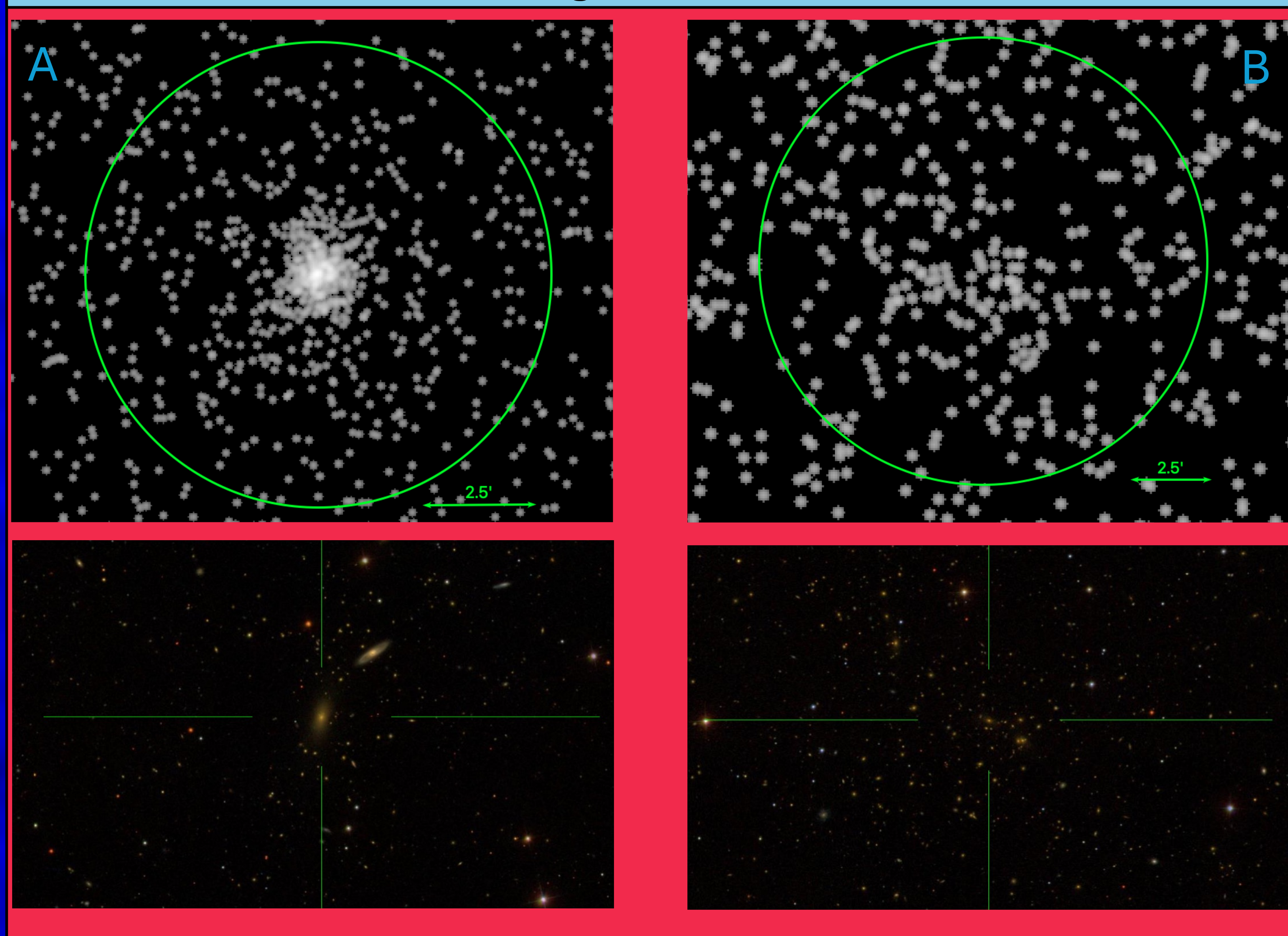

Figure 4: the two outliers highlighted in **Fig. 3** as seen with eROSITA (top) and SDSS (bottom) at roughly the same scale. "**A**" is on the left and "**B**" is on the right. The distribution of X-ray emission from **A** is typical for a high L cluster, but its optical richness is very low: qualitatively speaking it looks mainly dominated by a large elliptical galaxy with a nearby, large spiral galaxy and a few smaller galaxies. By contrast, **B** has much more distributed and overall lower X-ray emission when compared to the number of galaxies. This highlights the importance of understanding biases and scatter when creating samples. Optical images are from: https://skyserver.sdss.org/dr18

6. Summary

- We need well understood cluster samples for both cosmology and astrophysics
- Previous works have suggested that low X-ray luminosity clusters are being missed from samples
- Preliminary results of this work roughly agree with previous studies, but there are many improvements we can make to improve or results
- Watch this space.

References

Andreon S., Serra A. L., Moretti A., Trinchieri G., 2016, Astronomy and Astrophysics, 585, A147

Bulbul E., et al., 2024, Astronomy and Astrophysics, 685, A106

Cavagnolo K. W., et al., 2009, The Astrophysical Journal Supplement Series, 182, 12

Lovisari L., Maughan B. J., 2022, Springer Nature Singapore, pp 1–50, doi:10.1007/978-981-16-4544-0_118-1

Planck Collaboration, 2020, Astronomy and Astrophysics, 641, A1

Rykoff E. S., et al., 2014, The Astophysical Journal, 785, 104