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Exploring Observed Over-densities in the eRASS XLF

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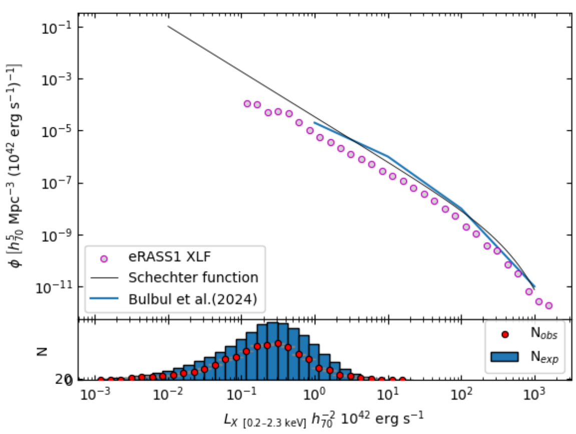
This project investigates the significant excess of galaxy clusters detected at $L_X \approx 2\times10^{43}$ erg s^{-1} in the X-ray Luminosity Function (XLF) determined using the Wide Angle *ROSAT* Pointed Survey (WARPS; Koens et al. 2013, hereafter K13) and the 160 Square Degree (160SD; Mullis et al. 2004) cluster catalogues. We take advantage of the recent cluster catalogue from the first *eROSITA* All Sky Survey (eRASS:1; Bulbul et al. 2024) to attempt to determine the origin and validity of this excess.

Background:

Galaxy clusters comprise tens to thousands of galaxies plus an X-ray emitting intra-cluster medium (ICM) bound by a dark-matter-dominated gravitational potential well. X-ray observations provide crucial information on similarity-breaking properties of the ICM, which is driven and regulated by feedback loops involving ICM cooling, star formation, and Active Galactic Nuclei accretion. Investigating these processes is essential for understanding how they shape cluster growth and evolution (e.g. Pratt et al. 2019).

The X-ray luminosity of a cluster highly depends on the density and distribution of the ICM, and therefore the impact of feedback will also be apparent in the XLF. Studies based on all-sky surveys give the best determination of the XLF for the local Universe, while serendipitous surveys extend our knowledge out to higher redshifts and fainter luminosities (i.e. lower masses).

Project Outcomes:



K13 observed a significant excess of clusters in the WARPS sample at $0.1 < z < 0.3$ and $L_X \approx 2 \times 10^{43}$ erg s^{-1} compared to expectations from the best-fit Schechter function. The eRASS:1 cluster catalogue includes 12 247 confirmed galaxy clusters in the Western Galactic half of the *eROSITA* sky, with ~ 1000 clusters populating the same region of X-ray luminosity - redshift space where K13 identified a significant excess.

This project fit the eRASS:1 XLF ($\phi(L_{\mathrm{X}_j}, z)$) using the same binning as in K13, and applied the method of Page & Carrera (2000) to calculate the co-moving number density n of objects per luminosity interval:

$$\phi(L_{\mathrm{X}_j}, z) = \frac{N_j}{\int_{L_{\mathrm{X,min}}}^{L_{\mathrm{X,max}}} \int_{z_{\mathrm{min}}}^{z_{\mathrm{max}}} \Omega(f_{\mathrm{X}}, r_\theta) \frac{\mathrm{d}V(z)}{\mathrm{d}z} \mathrm{d}z \mathrm{d}L_{\mathrm{X}}} \quad (1)$$

where $\Omega(f_{\mathrm{X}}, r_\theta)$ is the sky coverage and $\frac{\mathrm{d}V(z)}{\mathrm{d}z}$ is the differential, co-moving volume. The sky coverage was taken as the $13116\,\mathrm{deg}^2$ region of eRASS:1 data, multiplied by the selection function given in Figure 8 of Clerc et al. (2024). To attempt to observe such an excess as in the WARPS sample, we plotted the XLF along with the best-fitting Schechter function (Schechter 1976),

$$\phi(L_{\mathrm{X}}, z)\mathrm{d}L_{\mathrm{X}} = \phi^* \left(\frac{L_{\mathrm{X}}}{L_{\mathrm{X}}^*}\right)^{-\alpha} \exp\left(-\frac{L_{\mathrm{X}}}{L_{\mathrm{X}}^*}\right) \left(\frac{\mathrm{d}L_{\mathrm{X}}}{L_{\mathrm{X}}^*}\right) \quad (2)$$

which presents the canonical, parametric representation of the XLF, where the parameter ϕ^* normalises the XLF, and α determines the steepness at $L_{\mathrm{X}} < L_{\mathrm{X}}^*$.

We found that the excess does not persist in this data. This suggests a deeper look into the WARPS sample is required. It is worth noting that the selection function extrapolated from Clerc et al. (2024) is in a different energy band, and cannot account for variations of the detection probability as a function of sky position. Cosmic variance, though disregarded by K13, could explain why the excess does not come up in our analysis. To investigate this further, it would be beneficial to observe the WARPS patches of sky using *eROSITA*, to determine the cause of the excess.

Summary:

The large eRASS:1 cluster catalogue provides an independent dataset with which we investigate the significant excess of clusters detected in the local WARPS sample by K13 at $L_X \approx 2 \times 10^{43}$ erg s^{-1}. This project constructs and fits the eRASS:1 XLF, and concludes that the excess does not persist . Further analysis is required to understand the origin of the excess in K13, along with an improved selection function to better analyse the eRASS:1 catalogue.

References:

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