Optical Confirmation of eRASS1 Galaxy Cluster Candidates

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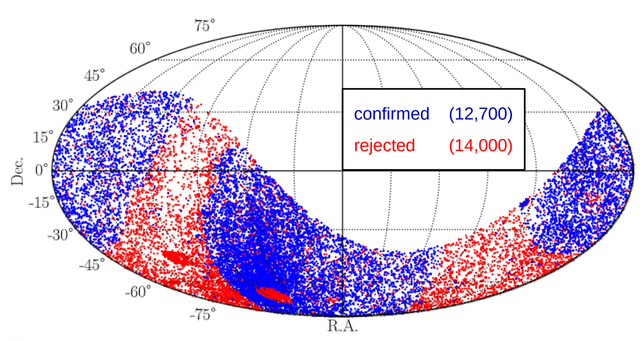
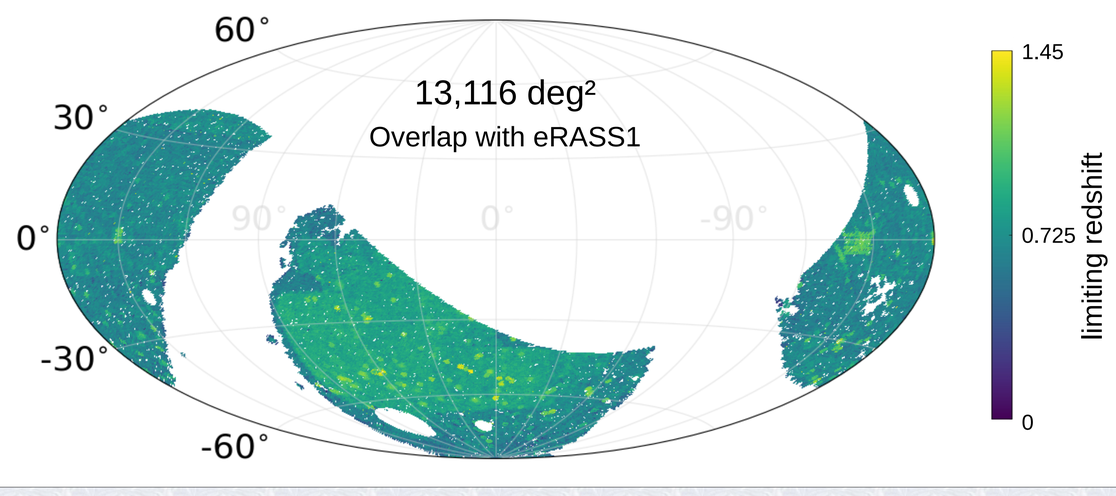
We present the largest, statistically well defined X-ray-selected galaxy cluster and group catalog to date. The sample is based on the first eROSITA All Sky Survey (eRASS1). Cluster candidates are confirmed by identifying overdensities of red-sequence galaxies around the eRASS1 extended sources. Therefore, we run the optical cluster finder eROMaPPer on the DESI Legacy Imaging Surveys DR9 and DR10.
We provide richnesses and photometric redshifts with a precision of $(\Delta z)/(1+z) < 0.005$ for 12,200 confirmed clusters. The highest redshift is z=1.32 and the median is z=0.3. For a subsample of ~3200 mostly low-z clusters, we also calculate spectroscopic redshifts and velocity dispersions for ~1800 clusters. The contamination is estimated using a mixture model to be 14% mostly by AGNs and random background fluctuations.

Clusters candidates are selected as extended eRASS1 sources [1,2]. The German eROSITA consortium has access to data in the western galactic hemisphere between 180° ≲ gal. longitude ≲ 360°. The sample properties are summarized as:



- ~12,200 clusters
- 68% new discoveries
- z < 1.32 (median z=0.3)
- 86% purity
- 0.5% photo-z uncertainty
- ~3200 spec-z & ~1800 velocity dispersions

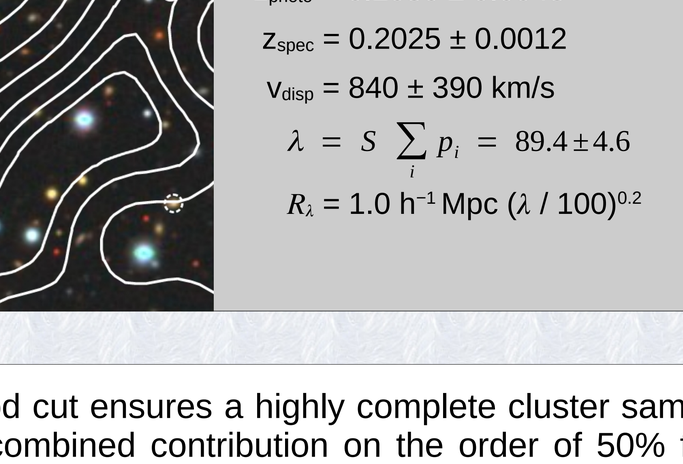
Galaxy magnitudes and colors taken from the Legacy Surveys DR9 & DR10 [4]. For low-redshift clusters (z<0.8), we utilize the *g r z* filter bands to minimize the photo-z bias. For higher redshift clusters (z>0.8), we use *g r i z w1* to increase the sensitivity. The luminosity cut for selecting member galaxies is chosen to include homogeneously fainter galaxies with L>0.2L* for low-z clusters while for the higher-z clusters, we restrict to brighter galaxies with L>0.4L* motivated by the limited survey depth.



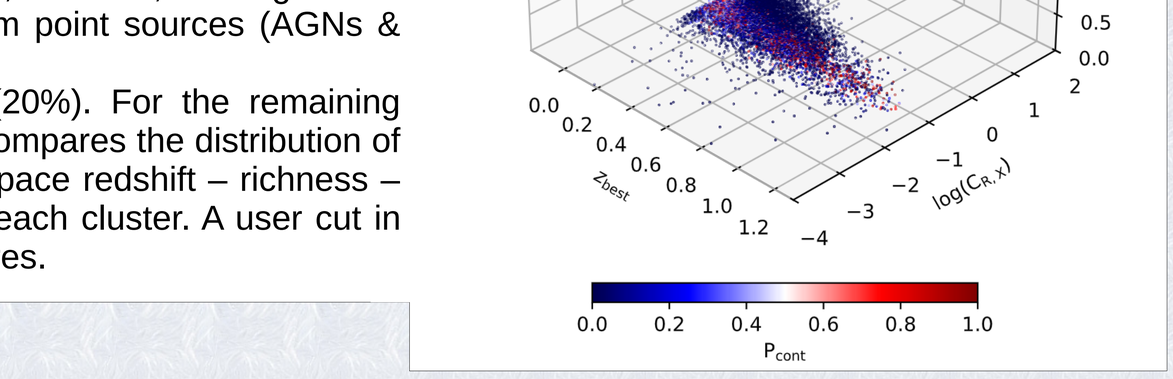
Cluster candidates are confirmed using the optical cluster finder eROMaPPer [3]. It identifies overdensities of red-sequence galaxies around the X-ray signal. Using the galaxy colors, we measure ~12,200 photometric cluster redshifts with a precision of

$$\frac{|z_{photo} - z_{spec}|}{1 + z_{spec}} < 0.005.$$

Spectroscopic redshifts for ~3200 clusters are calculated using a compilation of literature galaxy redshifts and dedicated observational follow-up programs.



We compare the redshift distribution of the eRASS1 clusters with catalogs from the literature. The number of clusters per redshift interval surpasses XMM-Newton-based catalogs (green) because of the larger survey area. It also surpasses most ROSAT-based catalogs (orange) because of the higher sensitivity. The eRASS1 selection is cleaner than the CODEX selection because we select X-ray sources by their extent.



In addition to the eRASS1 catalog, we will make available our eROMaPPer results for the literature catalogs and optical-only runs.

BCG, CG,
X-ray center, optical center
X-ray contours
Phot. members
Spec. members

$M_{500} = 10 \hat{} 14.8\ M_{\odot}$
$z_{photo} = 0.2036 \pm 0.0048$
$z_{spec} = 0.2025 \pm 0.0012$
$v_{disp} = 840 \pm 390$ km/s
$\lambda = S \sum_i p_i = 89.4 \pm 4.6$
$R_\lambda = 1.0\ h^{-1}\ \mathrm{Mpc}\ (\lambda / 100)^{0.2}$

An applied low extent likelihood cut ensures a highly complete cluster sample, however, with significant contamination. We expect a combined contribution on the order of 50% from point sources (AGNs & stars) and random background fluctuations [5].
The catalog is cleaned by rejecting clusters with no optical counterpart (20%). For the remaining clusters, we estimate the contamination to be 14% using a mixture model. It compares the distribution of clusters to those of point sources and random sky points in 3-D parameter space redshift – richness – X-ray count rate. A probability P_{cont} for being a contamination is assigned to each cluster. A user cut in this parameter cleans the sample as strictly as the specific science case requires.

Contributors:
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Sources:
[1] Merloni et al., in prep.; [2] Bulbul et al., in prep.; [3] Ider Chitham et al. (2020): 2020MNRAS.499.4768I; [4] Dey et al. (2019): 2019AJ....157..168D; [5] Seppi et al. (2022) 2022A&A...665A..78S