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The 2XMMi/SDSS Galaxy Cluster Survey

The first cluster sample and X-ray luminosity-temperature relation

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Abstract

We present a catalogue of X-ray selected galaxy clusters and groups as a first release of the 2XMMi/SDSS Galaxy Cluster Survey. The survey is a search for galaxy clusters detected serendipitously in observations with XMM-Newton in the footprint of the Sloan Digital Sky Survey (SDSS). The main aims of the survey are the identification of new X-ray galaxy clusters, to investigate their X-ray scaling relations, to study the correlation of X-ray and optical properties, to identify distant cluster candidates beyond the SDSS limit, and to prepare for the eROSITA cluster surveys.
In this poster we describe our basic strategy to identify our cluster sample which currently comprises almost 1200 objects. A cross-match of the X-ray selected cluster candidates with 4 recent optical cluster catalogs from SDSS data revealed a photometric redshift for 275 objects. Among them 182 with spectroscopic confirmation. We developed an automated method to reprocess the X-ray observations, extract the X-ray spectra and to derive the temperature, luminosity and flux for the optically confirmed clusters. Here we present the X-ray properties of the first cluster sample which comprises 175 clusters, among them 139 objects are new X-ray clusters while the others have been already known as X-ray sources. The first cluster sample from the survey covers a wide range of redshifts from 0.09 to 0.61. We extend the relation between the X-ray bolometric luminosity L_{500} and the X-ray temperature towards significantly lower T and L_{500} and still find the slope of the linear L-T relation consistent with published ones.

X-ray cluster candidates

X-ray cluster candidates are selected from the XMM-Newton Source catalogue (2XMMi-DR3). We applied several selection steps to arrive at a number of X-ray extended sources that were then screened individually. We include in our study only sources at high galactic latitudes, |b| > 20°, and discarded those that were flagged as spurious in the 2XMMi-DR3 catalogue by the screeners of the XMM-Newton SSC (Survey Science Centre). Since our main aim is the generation of a serendipitous cluster sample we removed sources that were the targets of the XMM-Newton observation. We also discarded fields containing large extended sources and selected only those fields within the footprint of SDSS. The multiple detections of the same extended sources are removed after choosing the one which has higher photon counts.
The resulting list still contained spurious detections, therefore we screened the X-ray images of these detections using the FLIX upper limit server (http://www.ledas.ac.uk/flix/flix.html) to remove the obvious spurious cases.

We then made use of the SDSS to remove further non-cluster sources. To that end we downloaded the XMM-Newton EPIC X-ray images from the XMM-Newton Science Archive and created summed EPIC (PN+MOS1+MOS2) images in the energy band 0.2 – 4.5 ,keV. Using these we created smoothed X-ray contours which were overlaid onto co-added r, i, and z-band SDSS images. Visual screening of those optical multi-color images with X-ray contours overlaid (see Figure 1) allowed us to remove extended sources corresponding to nearby field galaxies as well as those objects which are likely spurious detections. The resulting list which passes these selection criteria contains 1180 cluster candidates, about 75 percent of these objects are newly discovered.

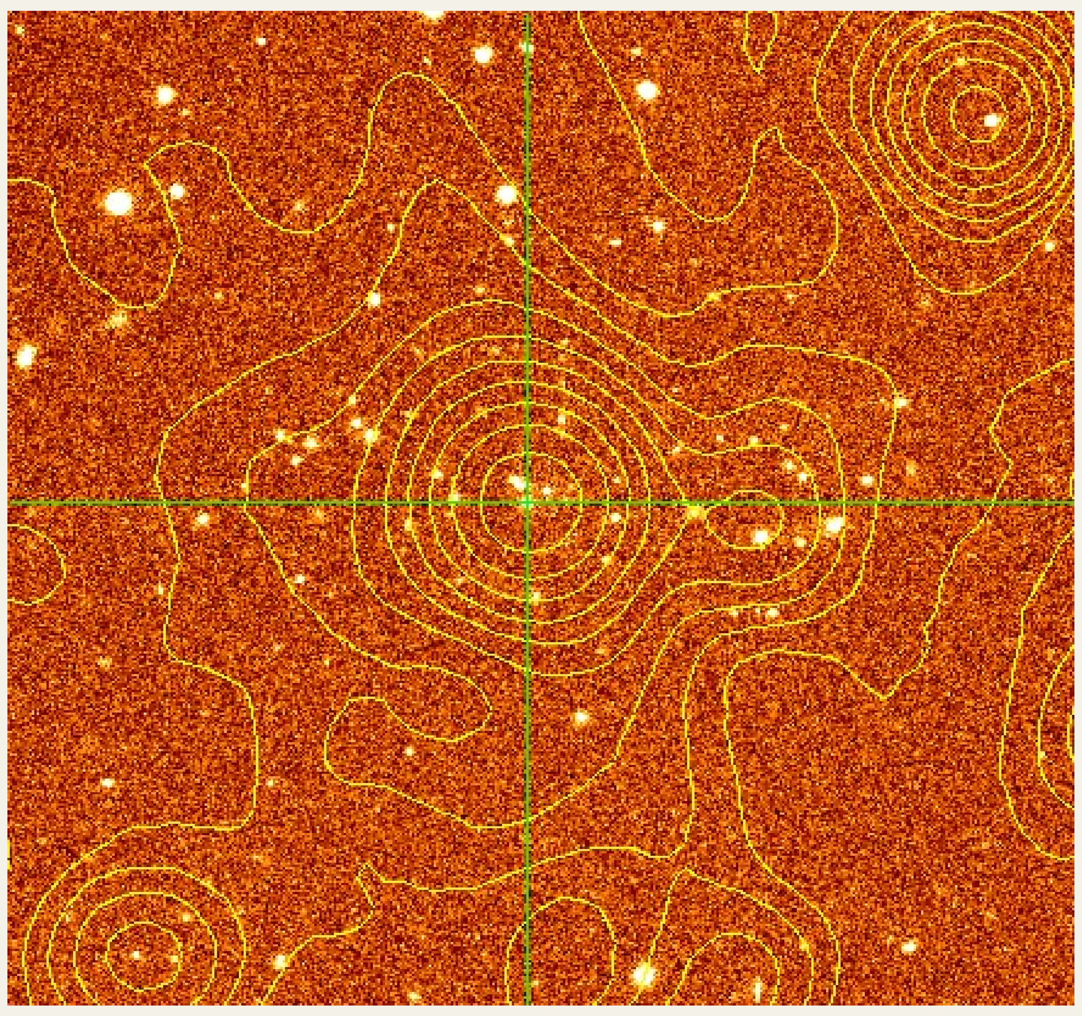


Figure 1. The X-ray-optical overlay of the representative cluster 2XMM J104421.8+213029 at photometric redshift = 0.4975. The X-ray contours are overlaid on the SDSS co-added image obtained in r, i, and z-bands. The field of view is 4'x4' centered on the X-ray cluster position. The cross-hair indicates the cluster mass center as given by Szabo et al. (2010).

The optically confirmed sample

The SDSS offers the opportunity to produce large galaxy cluster catalogues. Several techniques were applied to identify likely clusters from multiband imaging and SDSS spectroscopy. We use those published catalogues to cross-identify common sources in our X-ray selected and those optical samples. All those optical catalogues give redshift information per cluster which we use in the following to study the X-ray properties of our sources. Table 1. lists the main properties of the optical cluster catalogues which we used to confirm our X-ray selection as well as the number of matching X-ray sources per optical catalogue individually.

CLG Catalogs	Nr CLG	Redshift range	SDSS	X-ray CLG r<1'	Reference
GMBCG	55,000	0.1 - 0.55	DR7	136	Hao et al. 2010
WHL	39,668	0.05 – 0.6	DR6	150	Wen et al. 2009
MaxBCG	13,823	0.1 – 0.3	DR5	54	Koester et al .2007
AMF	69,173	0.045 – 0.78	DR6	127	Szabo et al. 2010

The unique optically confirmed X-ray cluster sample obtained by cross-matching with the four catalogues consists 275 objects having photometric redshifts, of these 120 BCGs with spectroscopic redshifts from the optical catalogs. Among the confirmed cluster sample, 182 clusters are with spectroscopic redshifts for at leat one galaxy member from the recent SDSS data. The distribution of these optical redshifts is shown in Figure 2.

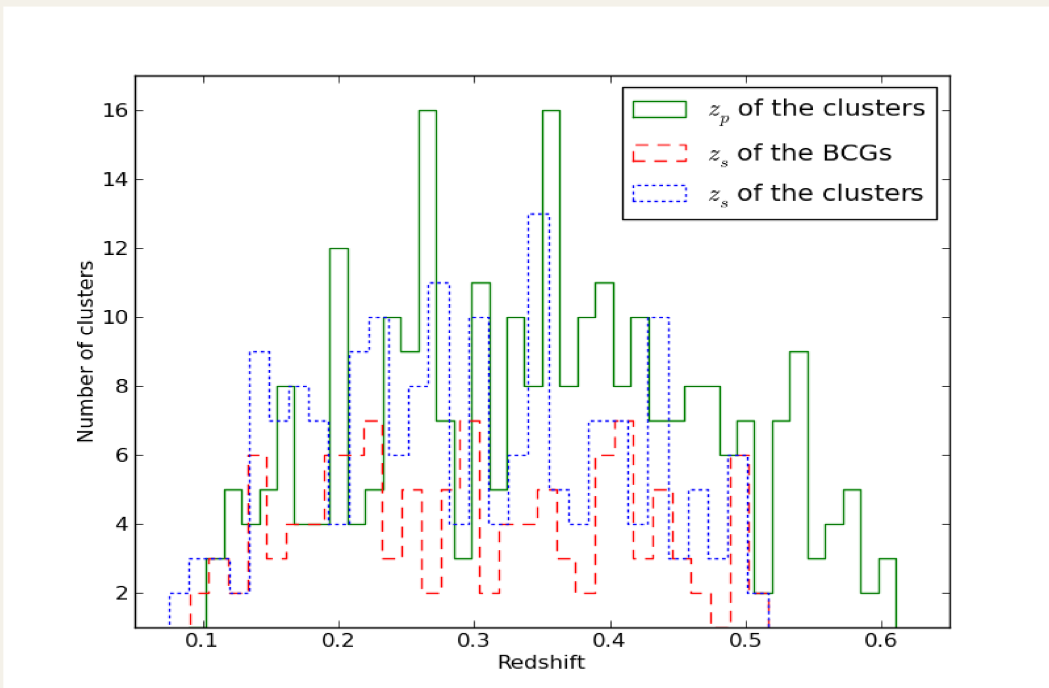
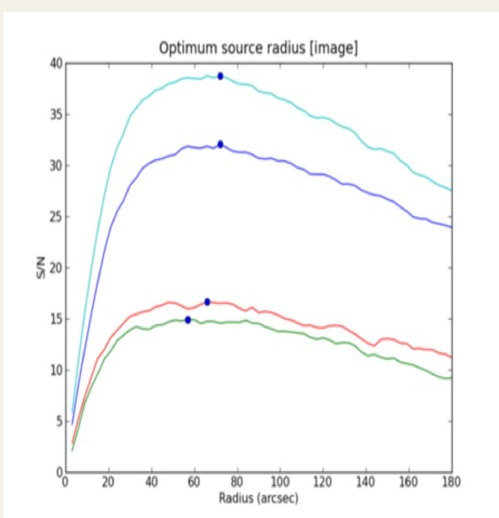


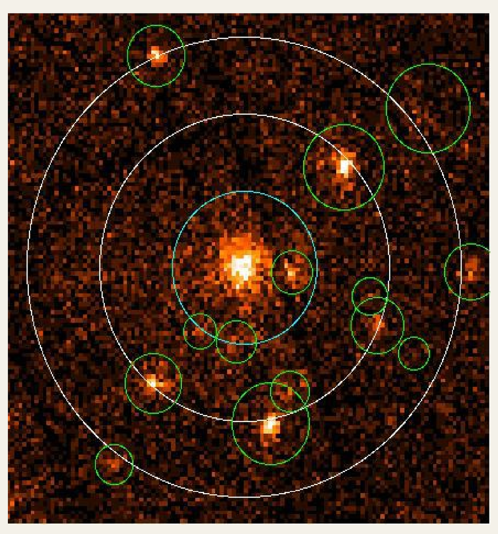
Figure 2. The distribution of the optical redshifts for the confirmed clusters sample. The distribution includes the cluster photometric redshifts z_p (solid line) with a median 0.36, spectroscopic redshifts of the BCGs z_s (dashed line) with a median 0.3 from the optical cluster catalogues and the cluster spectroscopic redshifts z_s (dotted line), as the average redshift for the cluster galaxies with spectroscopic redshifts, with a median 0.3 from the SDSS data.

X-ray data analysis

The most critical step in generating the cluster X-ray spectra is to determine the source extraction radius. We have developed a method to optimize the signal-to-noise ratio (SNR) of the spectrum for each cluster (see Figure 3). The spectra of each cluster candidate are extracted from a region with an optimum extraction radius which is corresponding to the maximum SNR value. The background spectra are extracted from a circular annulus around the cluster with inner and outer radii equaling two and three times the optimum radius, respectively. Other unrelated nearby sources were masked and excluded from the source and background regions that were finally used to extract the X-ray spectra.



Figur 3. The signal-to-noise ratio (SNR) profiles of 2XMM J104421.8+213029 in MOS1 (green), MOS2 (red), PN (blue) and EPIC (MOS1+MOS2+PN) (cyan) data. The cluster optimum extraction radius (72") is corresponding to the highest SNR as indicated by a point in the EPIC SNR profile.



Figur 4. The representative cluster extraction region is the inner circle with color Cyan. The background region is the annulus with white color. The excluding field sources are indicated by green circles. The field of view is 8'x 8' centered at the cluster position.

X-ray spectral fitting

For each cluster, the available EPIC spectra are fitted simultaneously. The fitting model is a multiplication of a TBABS absorption model and a single-temperature optically thin thermal plasma component (MEKAL code) to model the X-ray plasma emission from the ICM (see Figure 5). The metallicity was fixed at 0.4 Z_{sun}. The fitting was done using the Cash statistic with one count per bin. The cluster temperature, its flux in the [0.5-2] keV band, its X-ray luminosity in the [0.5-2] keV band, the bolometric luminosity and the corresponding errors are derived from the best-fitting model.

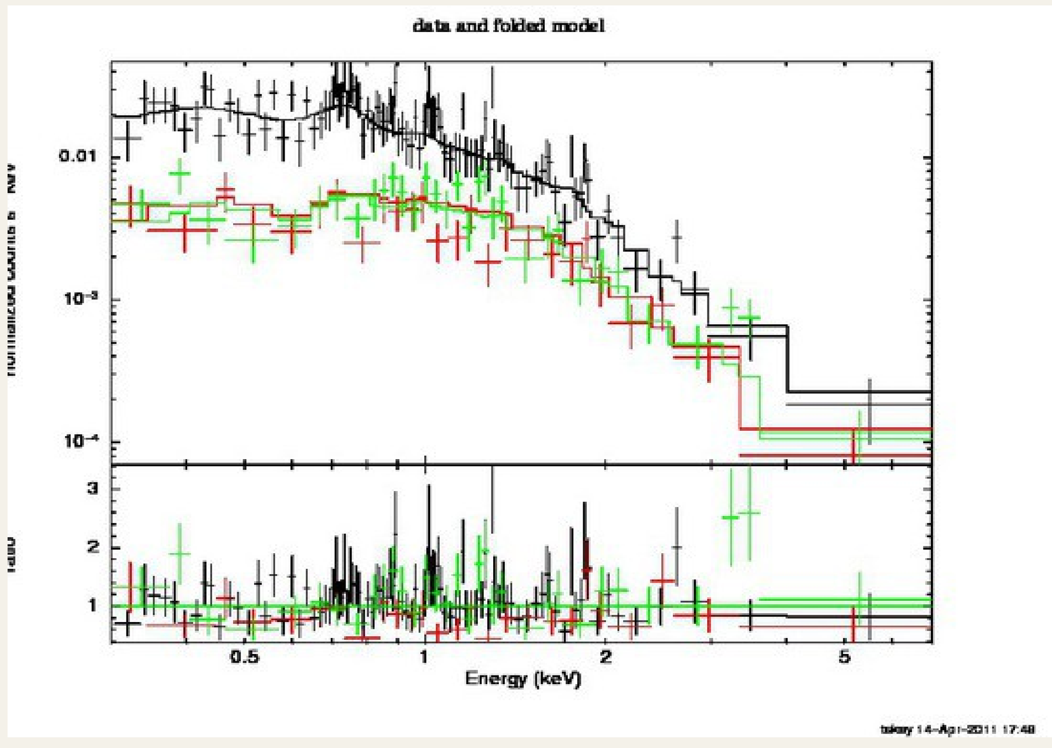


Figure 5. The EPIC PN (black), MOS1 (green) and MOS2 (red) data with the best fitting MEKAL model for the representative cluster.

X-ray luminosity-temperature relation

In this poster, we present the first cluster sample from our survey which comprises 175 clusters with reliable X-ray parameters. We estimated several physical parameters for each cluster based on the bolometric luminosity within the optimum aperture. These parameters are R_{500}, L_{500}, and M_{500}. We used an iterative procedure to estimate the physical parameters using published L - T and L - M relations by Pratt et al. (2009). The cluster spectroscopic temperature within the optimum aperture T_{ap} and L_{500} are used to investigate the L - T relation for the first cluster sample (see Figure 6). The best fitting linear relation derived from Orthogonal Distance Regression fit between their logarithms is:

$$\log (h(z)^{-1} L_{500}) = (0.57 \pm 0.05) + (3.41 \pm 0.15) \log (T_{ap})$$

The ODR slope (present work), 3.41 ± 0.15, is consistent with BCES orthogonal slope (Pratt et al. 2009) of the REXCESS sample, 3.35 ± 0.32.
Our sample includes cluster temperature ranging from 0.45 to 5.92 keV and bolometric luminosity L_{500} range 1.9 x 10^{42} – 1.2 x 10^{45} erg s^{-1} in a wide redshift range 0.1 – 0.6. The current relation is derived from our sample which includes clusters and groups with low temperatures and luminosities in a wide redshift range up to z = 0.6.

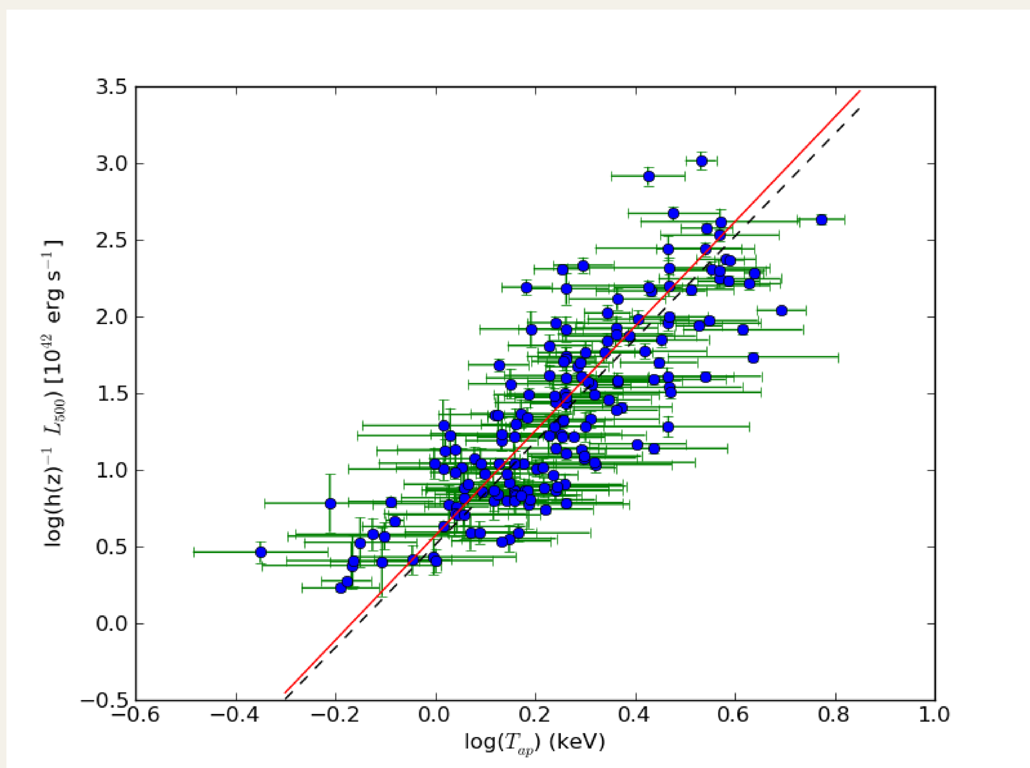


Figure 6. The relation between the X-ray bolometric luminosities L_{500} and aperture temperatures T_{ap} of the first cluster sample. The solid line indicates the best fit of the sample using Orthogonal Distance Regression (ODR). The dashed line is the extrapolated relation for REXCESS sample (Pratt et al .2009) using a BCES orthogonal fit.

References

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