XCS: Cluster Candidate Selection and Automated Optical Follow-up

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The XMM Cluster Survey

The XMM Cluster Survey (XCS; Romer et al. 2001) is currently being assembled based on the serendipitous detection of galaxy clusters in X-ray images taken by the XMM-Newton satellite. We present here a discussion of the source detection and classification algorithms along with some preliminary results including re-detection of high redshift clusters. The possible benefits of cross-identification with SDSS for cluster confirmation and photometric redshift estimation is explored, using the z=0.78 cluster MS1137.5+6625 as an example.

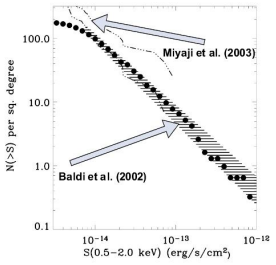
Source Detection and Classification Algorithms

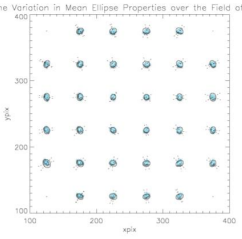
There is a vast quantity of publicly available data in the XMM archive. Hence for a project such as XCS robust and efficient algorithms must be developed to automate the reduction of the data sets and the detection of sources in them. Work has been carried out to filter and merge event lists (see poster by K. Sabirli) and produce exposure maps. These data are then passed to analysis pipelines.

The chosen detection algorithm is wavelet-based and has at its core the MR/1 (www.multiresolution.com) *task* mr_detect. *This allows scale information to be used to construct objects in a given image. The pipeline can then automatically find any associations in the NASA Extragalactic Database* (http://nedwww.ipac.caltech.edu).

The wavelet data for an object can further be used for classification of sources as extended (in essence, extended objects have more power at large scales). Currently, the ratios of these coefficients are used to define extent criteria.

The effectiveness of our processing pipeline is highlighted by the derived logN-logS using an area of only 3.1 deg^2. Note that the mos1 image alone was used and that merged data should probe much deeper.

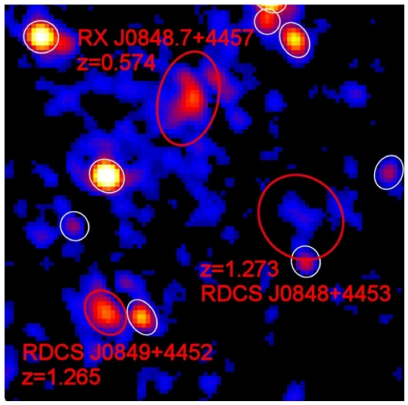




Classification of a source as extended requires a firm understanding of the instrument point spread function. A study of the mean properties of point sources resulted in the conclusion that the model of the PSF based on numerical simulation of the mirror modules was adequate to use.

Three High Redshift Clusters

❖ **One of the first tests of the sensitivity of the detection algorithm was to attempt to rediscover some known confirmed high redshift clusters.**



The detection was carried out on the mos1 data alone (pn data shown with mos1 sources overlaid for clarity). As expected, not only were these three high-z clusters detected in one field, but they were all correctly flagged by the classification algorithm as being extended.

Several improvements to the algorithms are in the process of being implemented:

❖ *Images from the three cameras (mos1, mos2 and pn) are to be merged and this image used for detection. This, combined with a more sophisticated filtering of events to take emission lines into account (see poster by K. Sabirli), ought to significantly boost the signal to noise of sources*

❖ *Classification will use more of the wavelet coefficient data and knowledge of the wavelet profile of the PSF. This should greatly enhance the discovery of slightly extended sources*

❖ *Simulations will permit us to further understand the selection function and sensitivity*

The Archival Sources with SDSS Coverage

More sets of observations are added to the XMM archive every day and since the mission has been running for several years there are now over 1500 available.

As of July 2003 there were 42 such sets of suitable XMM observations with Sloan Digital Sky Survey (SDSS) coverage, as provided in the first data release (Abazajian et al., 2003).

Even restricting the field of view to off-axis distances of less than 11 arcmin (where the PSF of XMM is least distorted), masking out large extended areas and removing duplicate area and sources this still leaves an area of 3.1 square degrees.

In this area, we find 636 X-ray sources of which 101 are flagged as extended.

Can SDSS help us with optical follow-up?

With several thousand cluster candidates expected to be discovered in the XMM data it becomes unfeasible to carry out dedicated optical follow-up on more than a small fraction. One possibility is to make use of the robotic telescopes coming online, for example Faulkes.

However, the SDSS is a large area, moderately deep survey and contains much image and spectroscopic (redshift) data. This would assist in automatically finding optical counterparts to our X-ray sources. From 2004 the near-infrared survey, UKIDSS, will help push theredshift limit higher.

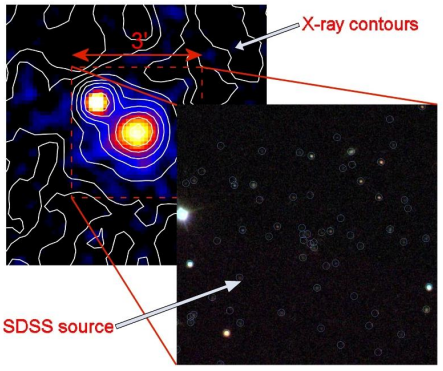
By confirming or removing candidates in this manner we will be able to focus observing time on the remaining candidates which may be the ones at the highest redshifts.

Preliminary Results from XMM/SDSS Matching

In order to look for associations between the X-ray and SDSS sources a matching radius of 3.8 arcseconds was used. This allowed counterparts between many sources detected as points in X-ray to be found (I.e. quasars/AGN).

At each source position overdensities in the number of SDSS-detected galaxies relative to the background were searched for. Several of the sources classified as extended in X-rays also had galaxy overdensities and are therefore likely to be clusters.

Shown below is an illustrative example of one of these associations. This z=0.78 cluster (MS 1137.5+6625) is clearly visible in the SDSS data.



XCS is set to compile a cluster catalogue of unprecedented depth and size. It will both provide strong constraints on cosmology (see talk by P. Viana) and shed light on cluster physics.

References

Romer et al., 2001, *ApJ, 547, 594-608*
Baldi et al., 2002, *ApJ, 564, 190-195*
Miyaji et al., 2003, *AN, 324, 24-27*
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