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Likelihood Source Matching Applied to the Extended Chandra Deep Field-South

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Abstract. In deep optical/IR data there are a large number of objects with accurate positions. In contrast, X-ray data sets contain fewer sources with larger positional uncertainties. We describe a routine for the matching of objects between different catalogs using a likelihood ratio technique[1]. Matching objects in a high source density catalog to sources in a catalog with larger positional uncertainties requires a statistical matching technique. We develop this technique in a field with Chandra data for later application to fields with XMM data that have even greater positional uncertainties. We describe application of this method to Chandra, Spitzer and ground based data in the Extended Chandra Deep Field-South. We recover $\sim 80\%$ of the X-ray sources in our optical and infrared catalogs and more then $\sim 90\%$ in the Spitzer IRAC catalog. We are interested in finding counterparts to X-ray sources as our research program explores multi-wavelength properties of AGN.

1. Introduction

The MUltiwavelength Survey by Yale-Chile (MUSYC; http://www.astro.yale.edu/MUSYC/; Gawiser et al. 2006) is a square-degree survey of four fields to limiting depths of $R_{AB} = 26$ and $K_{AB} = 22$ ($K_{AB} = 23$ in the central areas), with extensive follow-up spectroscopy. Satellite coverage of these fields includes Chandra, XMM, GALEX, HST and Spitzer. MUSYC science goals include studies of AGN clustering, EXOs, fractions of obscured AGN and the connection between galaxies and their central black holes.

The Extended Chandra Deep Field-South (ECDF-S) has been imaged by four ~ 250 ks Chandra pointings, the largest Chandra survey ever to this depth (Lehmer et al. 2005, Virani et al. 2006). The sensitivity and area of the Chandra data allow for detection of luminous AGN out to large redshifts and more modest luminosity AGN back to the Quasar era ($z \sim 2$). The imaging from all of the orbiting 'Great Observatories' combined with a large spectroscopic follow-up campaign makes this MUSYC field ideal for the study of distant AGN.

2. The Likelihood Ratio Technique

The likelihood ratio is the ratio between the probability of finding the true optical counterpart near a particular X-ray source divided by the probability of finding a background object. When matching an X-ray source, i, to a possible optical counterpart, j, we can calculate:

$$LR_{ij} = \frac{q(m_j) \times f(r_{ij})}{n(m_j)} \tag{1}$$

[1]The Likelihood Ratio Technique was developed by Sutherland & Saunders (1992) and modified by Ciliegi et al. (2003) and Brusa et al. (2005). Our implementation of this technique follows the Brusa et al. method.

Here q(m) is our empirically determined optical counterpart probability distribution as a function of magnitude, f(r) is the positional error as a function of angular distance r between the X-ray source and the proposed optical counterpart and n(m) is the surface density of background objects. Both q(m) and n(m) depend on the depth of the data. This technique is inherently Bayesian, and the resulting likelihood ratio assumes the priors q(m), n(m) and f(r) are known. Given the position of an X-ray source, we compute the likelihood ratio for each optical object located near the source. We then identify the optical object most likely to be the true counterpart.

3. Results

With more than 600 X-ray sources in the field, we split our detections into a primary catalog and an additional secondary catalog (Virani et al. 2006). The primary catalog minimizes false detections, while the secondary catalog includes lower S/N X-ray sources found by relaxing our detection threshold. In Table 1, we list the percentage of X-ray sources with a counterpart in each catalog. We include our matching to a preliminary catalog of IRAC sources which cover the full ECDF-S field.

Table 1. Results of X-ray source matching in the ECDF-S

Image	Primary	Secondary
R-band	82 %	51 %
K-Band	79 %	50 %
IRAC	95 %	68 %

Note that since we would expect roughly 2/3 of the sources in the secondary catalog to be real detections, this agrees nicely with our recovery rate of counterparts in the secondary catalog.

In comparison to a straight nearest-neighbor selection of all optical counterparts within 1.5 arc seconds, the likelihood ratio technique gains a total of 21 additional optical counterparts, increasing our sample by 4%. Most of these counterparts are for off-axis sources where the positional errors of the X-ray sources are greatest. Though useful with our Chandra data, this technique is vital for XMM data where the PSF is much larger across the entire field.

4. Future Work

We will match the list of Spitzer objects to the X-ray sources in the ECDF-S as soon as the IRAC catalogs are finalized. Next, we will begin work on a second MUSYC field, SDSS 1030, for which XMM data exists. The PSF of XMM is much larger than that of Chandra, making the use of a statistical matching technique even more important.

References

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