THE EXTENDED CHANDRA DEEP FIELD-SOUTH SURVEY: OPTICAL PROPERTIES OF X-RAY DETECTED SOURCES

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ABSTRACT

The Extended *Chandra* Deep Field-South (E-CDF-S) survey consists of 4 *Chandra* ACIS-I pointings and covers ≈1100 square arcminutes (≈0.3 deg^2) centered on the original CDF-S field to a depth of approximately 228 ks (PI: Niel Brandt; Lehmer et al., 2005). This is the largest *Chandra* survey ever conducted at such depth. In our analysis (Virani et al., 2005), we detect 651 unique sources — 587 using a conservative source detection limit and 64 using a lower source detection limit. Of these 651 sources, 561 are detected in the full 0.5–8.0 keV band, 529 in the soft 0.5–2.0 keV band, and 335 in the hard 2.0–8.0 keV band. For point sources near the aim point, the limiting fluxes are approximately 1.7×10^{-16} erg cm^{-2} s^{-1} and 3.9×10^{-16} erg cm^{-2} s^{-1} in the 0.5–2.0 keV and 2.0–8.0 keV bands, respectively. We present the optical properties of these X-ray sources, specifically the R-band magnitude distribution and a preliminary spectroscopic redshift distribution. One exciting result is the discovery of 7 new Extreme X-ray-to-Optical flux ratio objects (EXOs) found in the E-CDF-S field.

Key words: diffuse radiation — surveys: observations.

1. SOURCE DETECTION

We report on the sources detected in three standard X-ray bands: 0.5–8.0 keV (full band), 0.5–2.0 keV (soft band), and 2.0–8.0 keV (hard band). To perform X-ray source detection, we applied the CIAO wavelet detection algorithm *wavdetect* using a "$\sqrt{2}$ sequence" of wavelet scales; scales of 1, $\sqrt{2}$, 2, $2\sqrt{2}$, 4, $4\sqrt{2}$, and 8 pixels were used. Our criterion for source detection is that a source must be found with a false-positive probability threshold (p_{thresh}) of 1×10^{-7} in at least one of the three standard bands. We also produced a second catalog using a more liberal probability threshold of 1×10^{-6}. This scheme resulted in a total of 651 unique X-ray sources detected in the E-CDF-S survey field (Virani et al., 2005)[1]. Figure 1 presents the hard X-ray flux versus the R-band magnitude.

[1]X-ray catalog and images available at http://www.astro.yale.edu/svirani/ecdfs

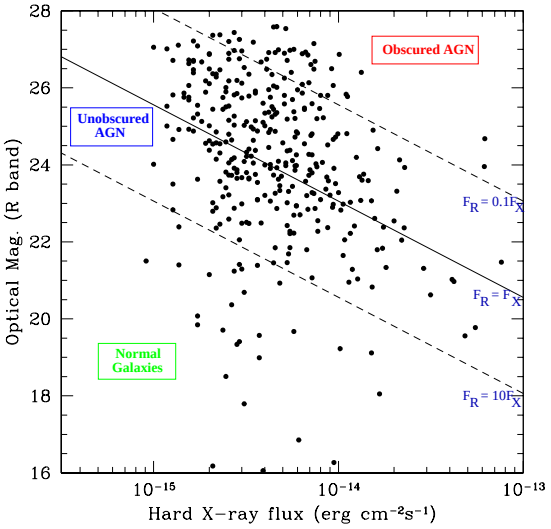

Figure 1. 2–8 keV flux vs. R-band magnitude (AB) for sources in the E-CDF-S. Unobscured AGN typically populate the region between the dashed lines, while obscured AGN typically lie above this region, and "normal" galaxies lie below this region.

2. MULTIWAVELENGTH SURVEY BY YALE-CHILE (MUSYC)

MUSYC is a square-degree survey to AB limiting depths of U,B,V,R=26 and K=22 (K=23 in the central $10'\times10'$ of each field), with extensive follow-up spectroscopy (Gawiser et al., 2005). Table 1 lists the 5σ point source limits in each of the filters for the E-CDF-S field. The project comprises four $30'\times30'$ fields, of which the E-CDF-S is one. Ground-based imaging has been completed and deep follow-up spectroscopy (to R∼25) is underway (Magellan/IMACS, VLT/VIMOS, Gemini/GNIRS).

3. OPTICAL COUNTERPARTS AND SPECTROSCOPY

In the primary (10^{-7}) catalog, 420 out of 587 sources (72%) have a unique optical counterpart within 1.5″ of the X-ray source position (3 X-ray sources have multi-

Table 1. ***MUSYC-ECDFS 5σ AB Point Source Limits***

BVR	U	B	V	R	I	z	NB5000
27.1	26.0	26.9	26.4	26.4	24.6	23.6	25.5

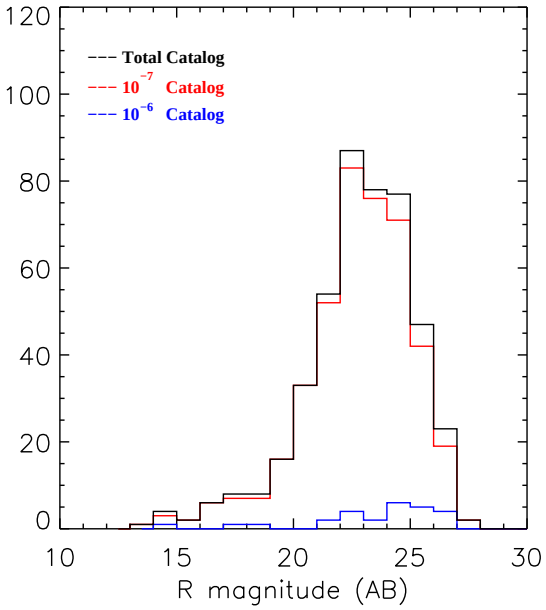

Figure 2. R-band magnitude distribution for the optical counterparts to the X-ray detected sources. Most of the sources have R-band magnitudes < 25 mag making them suitable for spectroscopic follow-up.

ple optical counterparts) in the deep MUSYC catalog of 84,410 BVR-selected sources. In the secondary (10^{-6}) catalog, 26 out of 64 sources (41%) have unique optical counterparts. Figure 2 shows the R-band magnitude distribution for these sources. Figure 3 shows the spectroscopic redshift distribution for 91 X-ray sources obtained thus far. Most are broad line, unobscured AGN (Figure 4). Additional spectroscopic observation runs are scheduled. Lastly, there are 7 sources, referred to as Extreme X-ray-to-Optical flux ratio objects (EXOs; Koekemoer et al., 2004), that are undetected in the deep BVR imaging but are robustly detected in MUSYC K-band imaging of this field (Virani et al, in prep).

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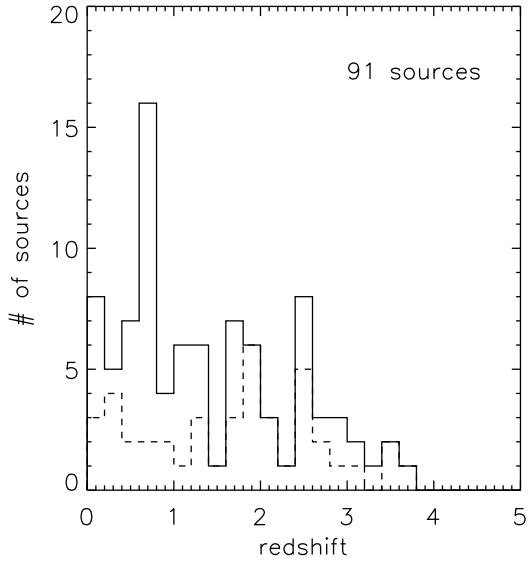

Figure 3. Spectroscopic redshifts for 91 X-ray sources in the E-CDF-S (solid line). This plot includes ∼50 redshifts from the Szokoly et al. (2004) catalog, as well as ∼40 redshifts determined from Magellan/IMACS spectroscopy (dashed line) performed as part of the MUSYC survey.

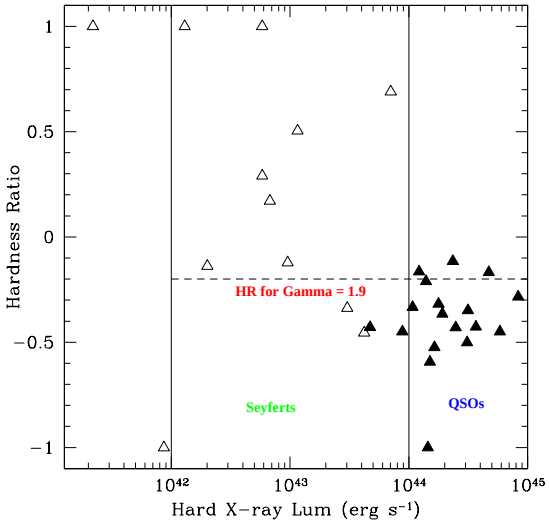

Figure 4. Hardness ratio vs. the hard X-ray luminosity for the ∼40 sources for which spectroscopic redshifts were determined as part of the MUSYC survey. Early results indicate that luminous AGN are less obscured; more obscured AGN at low luminosities. This is partly a selection effect and partly real.