

The Extended Chandra Deep Field–South Survey: Optical Properties of X–ray Detected Sources

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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, astro-ph/0506551).

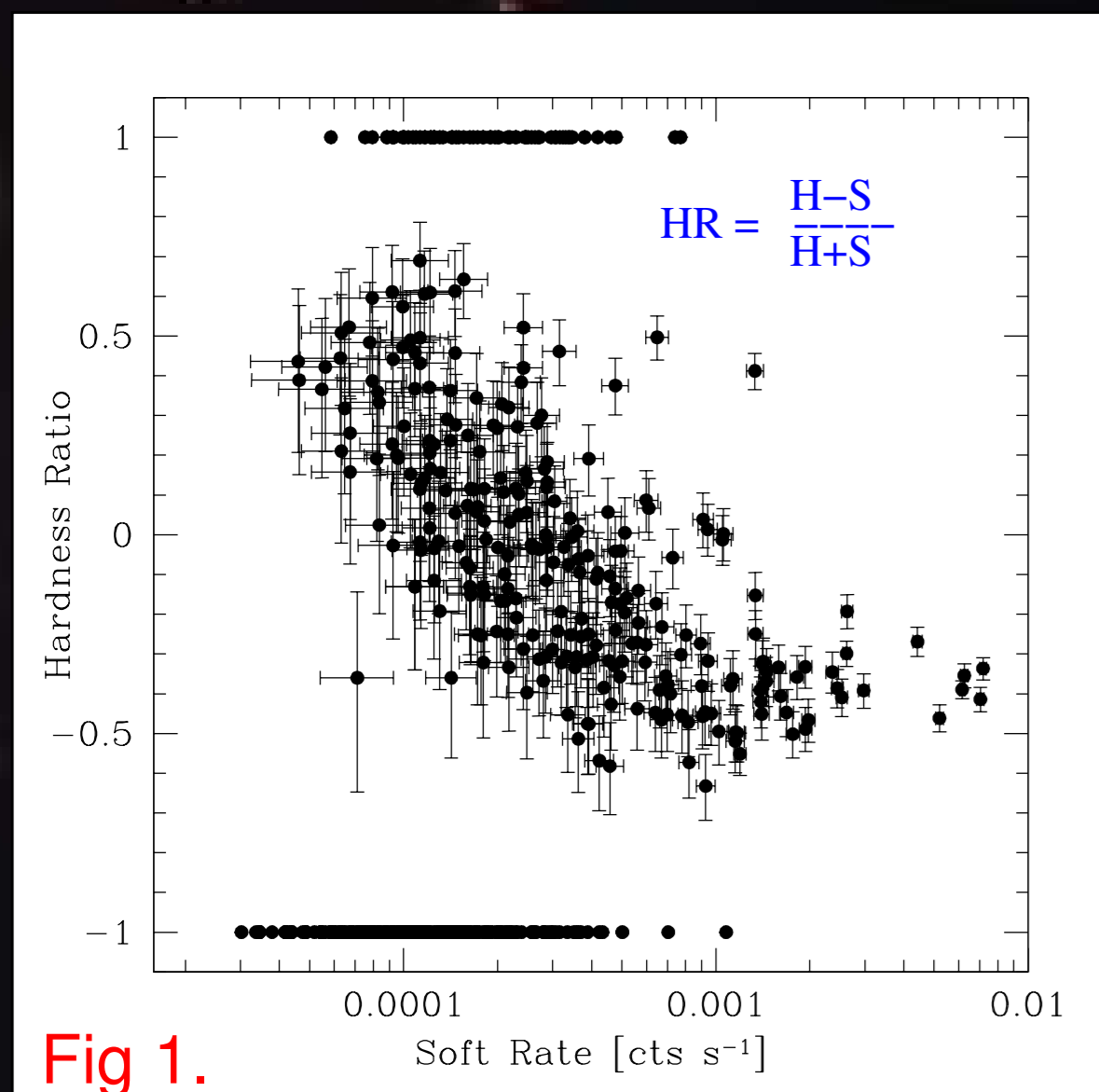


Fig. 1.

Fig. 1. – Hardness ratio versus soft X-ray count rate for sources in the E-CDF-S. Error bars correspond to 84% confidence level on the count rates (Gehrels 1986). Fainter sources in the soft band have harder X-ray spectra, supporting the hypothesis that these sources are mainly obscured AGN (as required by CXB models).

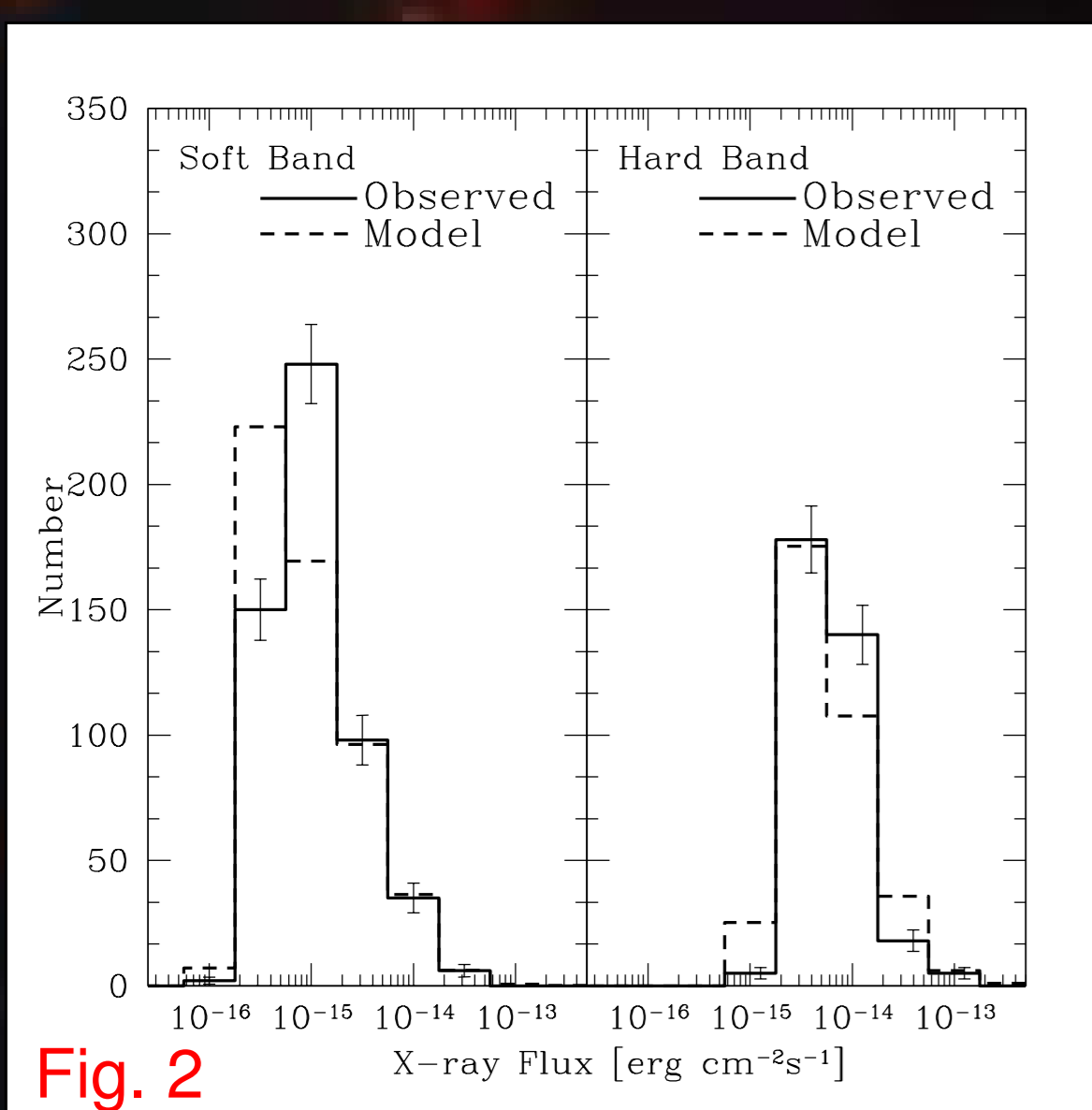


Fig. 2

Fig. 2. – Solid lines: Differential flux distribution for sources in the E-CDF-S in the soft and hard bands. Dashed lines: The distribution predicted by an AGN unification model that also explains the X-ray background (Treister et al. 2004, Treister & Urry 2005) agrees well in the bright to intermediate flux range for both bands. At lower fluxes, incompleteness is important.

Fig. 3. – Cumulative flux distributions for the soft and hard bands. Filled circles present data for the E-CDF-S catalog with error bars corresponding to the 84% confidence levels (Gehrels 1986). For comparison, we show the Moretti et al. (2003) distributions (hashed region) as well as the distribution for sources in the CDF-N,S (Bauer et al. 2004; dashed line).

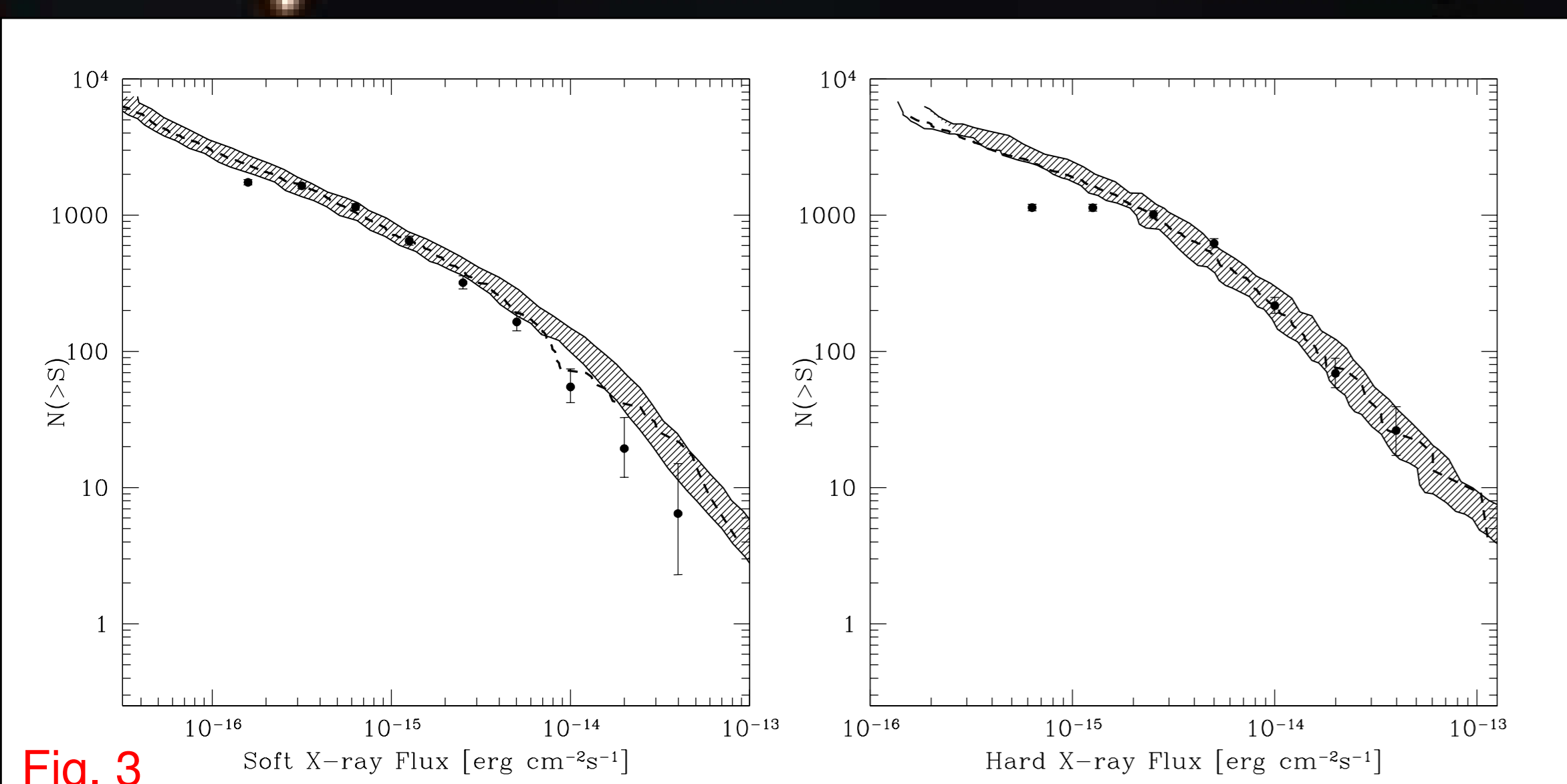


Fig. 3

ABSTRACT

The Extended *Chandra* Deep Field-South (E-CDF-S) survey consists of 4 *Chandra* ACIS-I pointings and covers ≈ 1100 square arcminutes ($\approx 0.3 \text{ deg}^2$) surrounding 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 and only one XMM-Newton survey reaches a lower flux limit in the hard 2.0–8.0 keV band. 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 $1.7 \times 10^{-16} \text{ erg cm}^{-2} \text{ s}^{-1}$ and $3.9 \times 10^{-16} \text{ erg cm}^{-2} \text{ s}^{-1}$ in the 0.5–2.0 keV and 2.0–8.0 keV bands, respectively. We present the differential and cumulative flux distributions, which are in good agreement with the number counts from previous deep X-ray surveys and with the predictions from an AGN population synthesis model that can explain the X-ray background. In general, fainter sources have harder X-ray spectra, consistent with the hypothesis that these sources are mainly obscured AGN (Virani et al. 2005, astro-ph/0506551).

<http://www.astro.yale.edu/svirani/ecdfs>

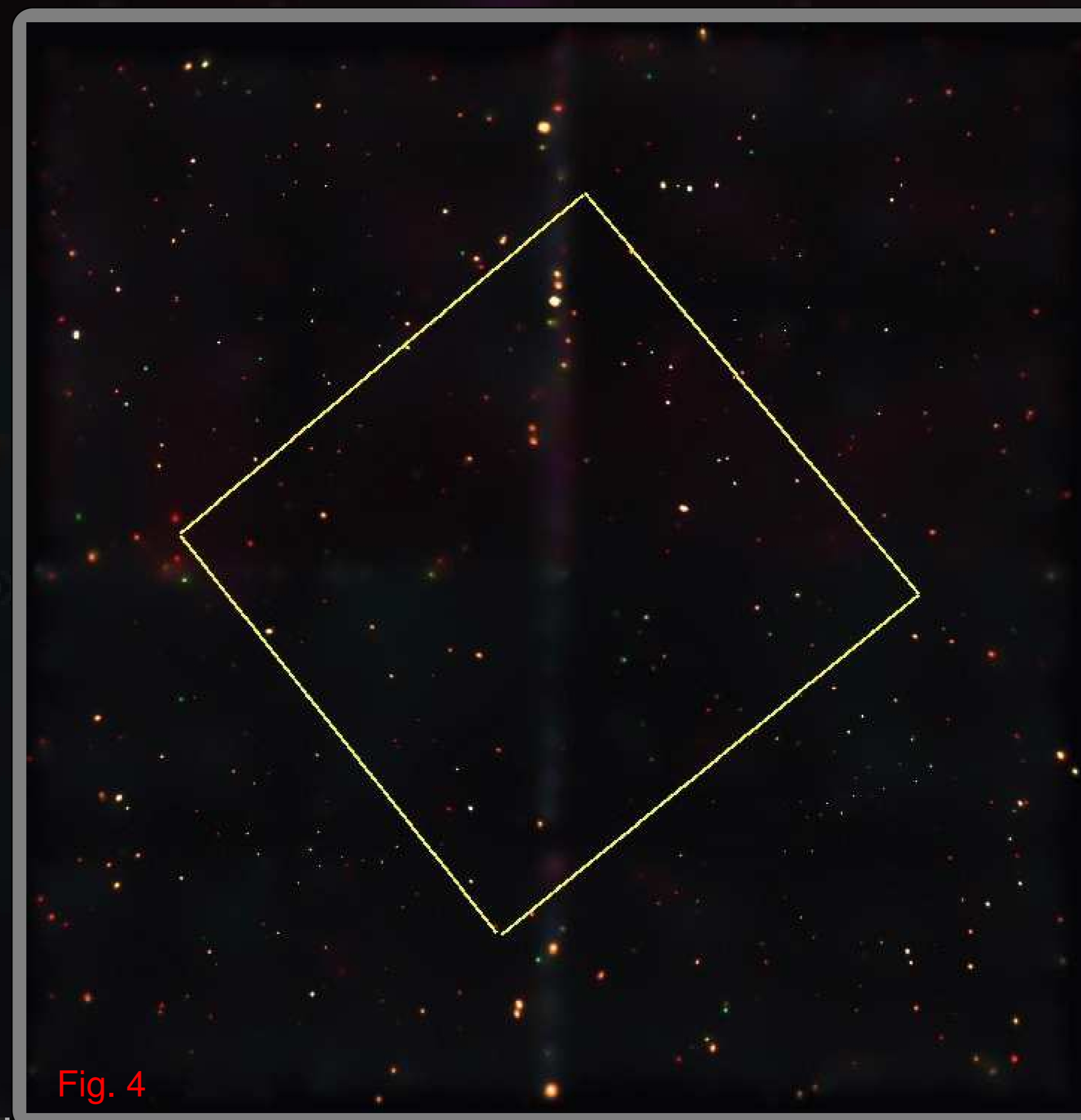


Fig. 4

Fig. 4. – Adaptively smoothed, false-color image of the E-CDF-S. Yellow box is the approximate footprint of the 1 Ms CDF-S proper.

MUSYC Optical Counterparts

Table 1: 57 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

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 multiple optical counterparts) in the deep *BVR* MUSYC imaging. In the secondary (10^{-6}) catalog, 26 out of 64 sources (41%) have unique optical counterparts. Figure 8 shows the *R*-band magnitude distribution for these sources.

Multiwavelength Survey by Yale-Chile (MUSYC)

MUSYC is a 1 square-degree survey to AB limiting depths of U,B,V,R, ≥ 26 and K=22 (K=23 in the central $10' \times 10'$ of each field), with extensive follow-up spectroscopy (Gawiser et al. 2005, astro-ph/0509202). The project comprises four $30' \times 30'$ fields, of which the E-CDF-S is one. Ground-based imaging has been completed and deep follow-up spectroscopy (to $R \sim 25$) is underway (Magellan/IMACS, VLT/VIMOS, Gemini/GNIRS).

<http://www.astro.yale.edu/MUSYC>

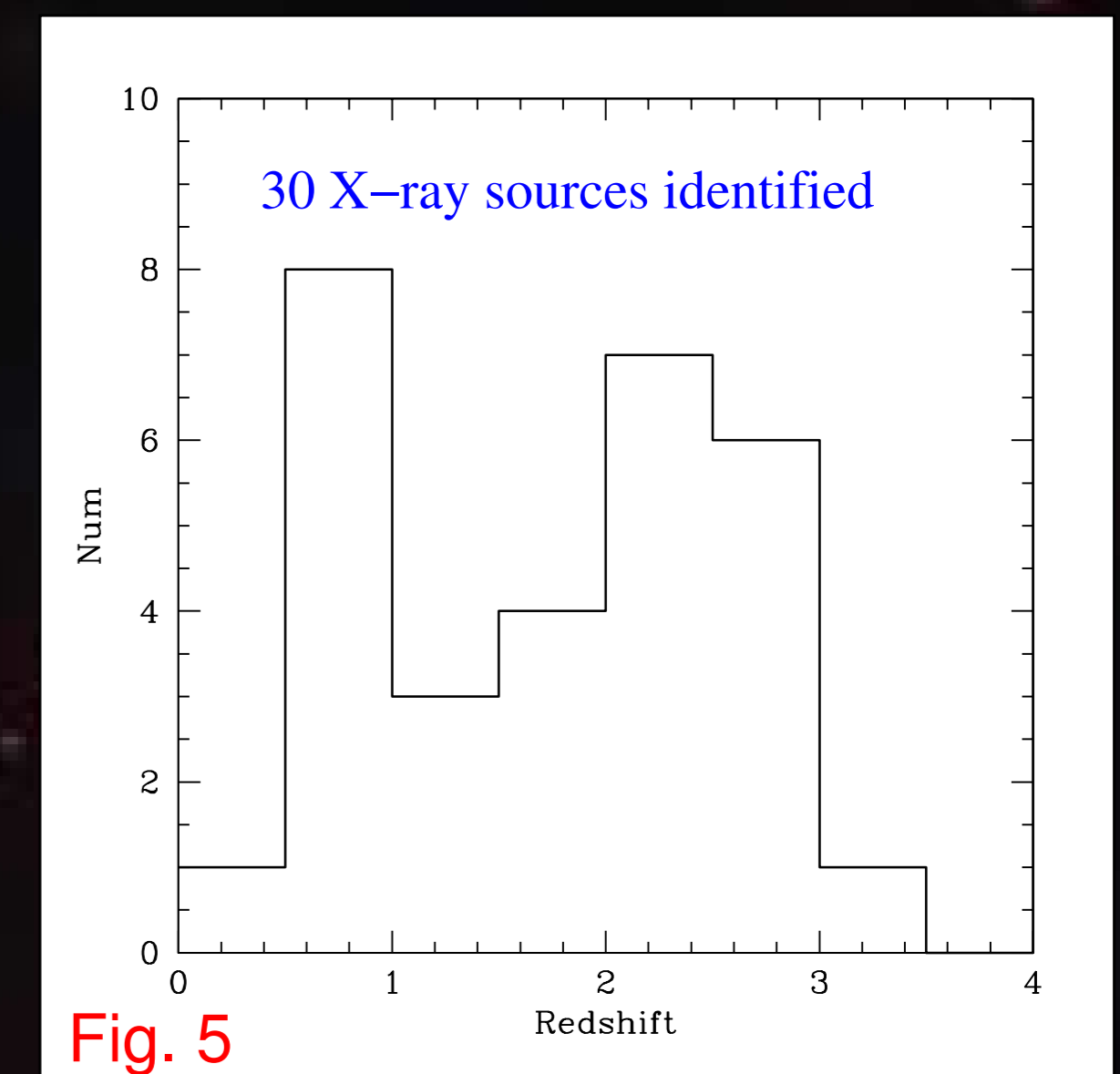


Fig. 5

Fig. 5. – 64 X-ray sources were observed with Magellan/IMACS in Feb. 2005. Of these, 30 X-ray sources were identified: \rightarrow 3 abs. line galaxies/obscured AGN (Additional spectroscopic runs are scheduled for Sept., Nov., and Dec.) \rightarrow 10 emission line galaxies/obscured AGN \rightarrow 17 broad line/unobscured AGN

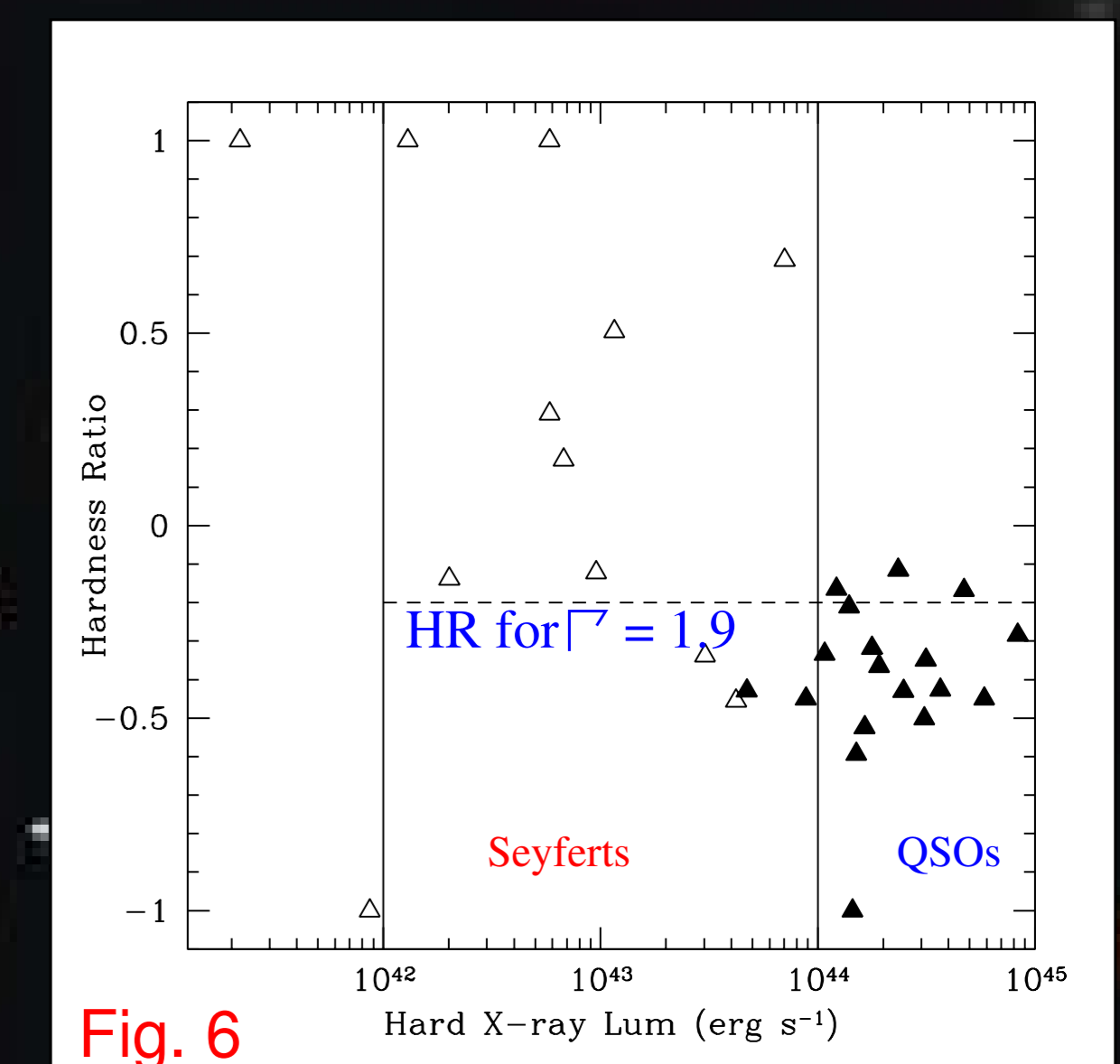


Fig. 6

Fig. 6. – Utilizing the spectroscopic redshifts determined for the above 30 sources, below is a plot of HR vs. the hard X-ray luminosity. The horizontal line at $\text{HR} = -0.2$ corresponds to what you would expect for an unobscured AGN of slope 1.9.

Fig. 7–8. – 2–8 keV flux vs. *R*-band magnitude (AB) for sources in the E-CDF-S. Unobscured AGN typically populate the region between the sloping lines, while obscured AGN typically lie above this region, and “normal” galaxies lie below this region. The adjacent plot shows the *R*-band magnitude distribution (Fig. 8).

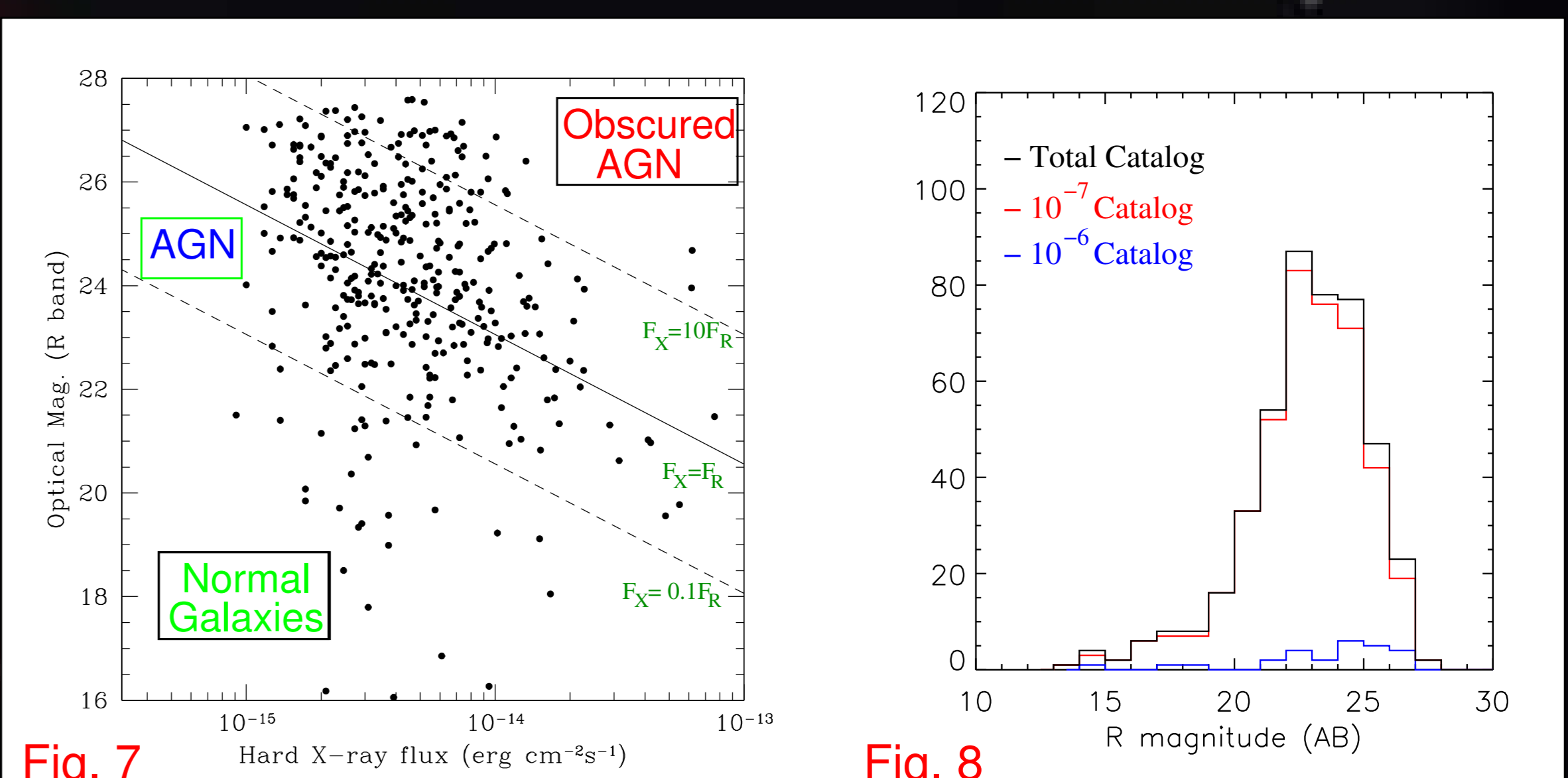


Fig. 7

Fig. 8

