The CYDER Survey: First Results

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Abstract. We present the Calán-Yale Deep Extragalactic Research (CYDER) Survey. The broad goals of the survey are the study of stellar populations, the star formation history of the universe and the formation and evolution of galaxies. The fields studied include Chandra deep pointings in order to characterize the X-ray faint populations. Here we present the results on the first fields studied. We find that the redshift distribution is consistent with that found in the Chandra Deep Field North. The distribution of hardness ratios is, however, softer in our sample. We find a high redshift quasar, CXOCY J125304.0-090737 at $z=4.179$, which suggests that the abundance of low luminosity high redshift quasars may be larger than what would be expected from reasonable extrapolations from the quasar optical luminosity function.

Key words: surveys — quasars: general — galaxies: active — X-rays — galaxies: evolution

1. Introduction: the CYDER Survey

The Calán-Yale Deep Extragalactic Research (CYDER) Survey is a collaborative effort between the Universidad de Chile and Yale University to study in detail faint stellar and extragalactic populations in survey mode. The broad scientific goals are directed towards the core observing goals of the new generation of large optical and millimeter facilities. The program takes full advantage of these facilities by combining deep optical and near-IR photometric and spectroscopic observations on wide field cameras and spectrographs using a wide variety of 4-m and 8-m class telescopes.

1.1. Strategy

Fields were selected at high galactic latitude to minimize the effects of extinction. They were also spread out in right ascension to allow flexibility in the allocation of telescope time. Amongst our fields, we selected fields observed by the Chandra X-ray Observatory satellite with exposure times longer than 50 ks.

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The CYDER survey original design goal was to cover 1 square degree down to limiting magnitudes $U \sim 26$, $B \sim 26.5$, $V \sim 26$, $R \sim 25.5$, $I \sim 25$, $z \sim 24$, $J \sim 22$ and $K \sim 20$ at $S/N \sim 10$. So far, the optical coverage is larger than 1 square degree in some filters while there is no area coverage in others. In the near infrared only 1/2 of a square degree has been imaged. Optical spectroscopy is underway in a few selected fields, while near infrared spectroscopy has not started yet.

2. Observations

The first fields studied were three of the earliest deep Chandra pointings to become publicly available. One of these field is in the Northern hemisphere. It is the Chandra pointing towards the blazar 1156+295. The X-ray exposure time was 75ks. The other two fields are in the South. They were pointing to the Hickson compact group HCG62 (exposure time 50ks) and the blazar Q1127-145 (30ks). These two Southern fields will be the ones discussed in this paper.
2.1. X-ray data

Both the HCG62 and Q1127-145 fields were observed with the Chandra ACIS-S instrument. We retrieved these images from the archive and analyzed them using standard techniques with the CIAO package. In the HCG62 field we detect 34 X-ray sources in the s3 ACIS CCD and 16 sources in the s4. In Chandra pointing towards Q1127-145, the s3 CCD was the only CCD read. It was read in subraster mode and therefore only 5 X-ray sources are detected in that field.

2.2. Optical and Infrared Imaging

We have observed both X-ray fields with the CTIO 4m MOSAIC-II camera. The total integration time for the HCG62 field is 200 minutes in U, 36 min in B, 80 min in V and 25 min in I under 1.0-1.5” conditions. In the Q1127-145 field the integration times are 80, 75 and 25 minutes in V, R and I respectively. Images were reduced using standard techniques with the IRAF/MSCRED package.

In the near infrared we have observed both fields at Las Campanas Observatory with the DuPont 2.5m telescope using the Wide Field InfraRed Camera during 60 minutes in J and 120 minutes in Ks under typical 0.6-0.7” seeing conditions. We have reduced the data with the IRAF DIMSUM package following standard procedures.

2.3. Optical Spectroscopy

Follow up spectroscopy of these fields was obtained at the ESO Cerro Paranal Observatory with the UT4/Yepun telescope using the FORS2/MXU instrument and at the Las Campanas Observatory with the LDSS-2 instrument at the Magellan Baade telescope. Several masks were designed which included slits for most, but not all, of the X-ray sources in these fields. Masks were observed for approximately two hours. The instrument configuration used resulted in a spectral resolution of $R \sim 520$ at VLT and $R \sim 350$ at Magellan. The spectra were reduced using standard techniques with IRAF and calibrated in wavelength using He-Ar comparison lamps exposures and the night sky lines.

3. First Results

In our first two Southern fields we have spectroscopically identified 25 X-ray sources which corresponds to approximately half of the total X-ray sources detected. Table 1 summarizes the percentages of the different type of objects in our sample. For comparison we also present the results for the Chandra Deep Field North (CDF-N; Brandt et al. 2001, Barger et al. 2002) and the Chandra Multiwavelength Project (ChaMP; Green et al. 2003). We have grouped the different object types in broad classes and have translated the source types of Barger et al. (2002) into these types. The CDF-N, CYDER and ChaMP surveys reach different X-ray flux limits; the CDF-N survey reaching the faintest, the ChaMP survey, the brightest. Table 1 demonstrates how the source composition changes with flux limit in an X-ray survey, although the identification incompleteness may hide or enhance certain trends. At bright flux limits, the broad line active galactic nuclei/quasars dominate the extragalactic sources. Their percentage contribution diminishes as the flux limit lowers due to the appearance of a new population of X-ray fainter narrow emission lines AGN/QSOs and normal galaxies.

|                | CDFN | CYDER | ChaMP |
|----------------|------|-------|-------|
| Stars          | 5%   | 5%    | 10%   |
| Broad line AGN/QSO | 25%  | 40%   | 65%   |
| Narrow line AGN/QSO | 50%  | 40%   | 15%   |
| Galaxies       | 20%  | 15%   | 10%   |
| **Total Number of Identified Sources** | 170  | 25    | $\sim$200 |
| **Total Number of Detected Sources** | 370  | 55    | -     |

Figure 1 shows the I band and total X-ray flux of our Chandra sources. For comparison we also plot the CDF-N sources. In our sample we find that approximately 30% of our sources do not show an optical counterpart down to $I \sim 24$. In the case of the CDF-N 16% are undetected down to $I \sim 26$ and 35% down to $I \sim 24$. Overall, the distribution of our sources in the I vs. X-ray flux plane occupy the same parameter space as the CDF-N sources cut at our same X-ray flux limit.
We compare the CYDER and CDF-N source redshift distributions in Figure 2. A Kolmogorov-Smirnov (KS) test shows that both distribution are compatible with having been drawn from the same parent population and are therefore statistically indistinguishable. Given that the CDF-N sources are typically fainter, we have cut their sample at the effective X-ray flux limit of our sample. If we compare the redshift distribution in this case, they remain to be statistically compatible. It is worth noting that in our sample there are 5 QSOs at a redshift $z \sim 1.2$ in the same field. This large scale structure feature is noticeable in our redshift distribution and stresses the need to study sufficient sources and fields as to not be biased by such structures.

We have also compared the X-ray properties of our sample to the CDF-N sources. We find that our sources are in general softer than those in the CDF-N (see Treister & Castander 2003). A KS test indicates that the hardness ratio distributions are incompatible with being drawn from the same parent population. This results may be expected as the CDF-N sources are typically fainter and fainter sources are in general harder (e.g., Giacconi et al 2001; Tozzi et al 2001; Brandt et al 2001; Stern 2002). However, if we impose our effective flux limit to the CDF-N sample we still find that our sources are significantly softer than the reduced brighter CDF-N subsample.

We also investigate what the optical properties of our sample are. Figure 3 is a colour-colour plot including our X-ray sources counterparts (see the figure caption for an explanation of the symbols). Two sources lie on the stellar locus. One is spectroscopically identified as a star, while the other has not been observed spectroscopically. The rest of the sources populate the region of colour-colour space of extragalactic sources. Some of our broad emission line AGN/QSOs are close to the expected location of typical quasars. Others, on the other hand, deviate from their expected position indicating that they are probably reddened. The majority (although not all) of our soft sources lie close to the expected locus of early-type galaxies. The hardest sources populate the regions of mildly active galaxies at redshifts $z \sim 0.5 - 1.0$. They may be at such locations because they are indeed this type of galaxies or because they have been reddened to that part of colour-colour space.

We compare the photometric and X-ray properties of our sources. We find that the hardest sources are preferentially redder than the rest of the objects. However, we also find soft sources that are red, implying that while blue sources
are preferentially soft, red sources can be either X-ray hard or soft. Given the reduced number of sources in our sample, this effect could simply be a statistical fluctuation.

The spectra of our sources reveal a diverse variety of type of objects. We find typical examples of broad and narrow population spectral energy distributions. There are also examples of poststarburst galaxies and objects whose spectral classification is difficult as they have broad emission lines typical of quasars and spectral characteristics of old stellar population with some moderate on-going star formation. Some of our objects show obvious signs of strong absorption.

Here we comment on two of our X-ray sources. CXOCY J125241.0-091622 is a quasar at redshift $z = 2.282$ (Figure 4) with a harder than usual X-ray spectrum $\Gamma \sim 1.3$. In the optical its $V - K$ color is 4.0 which is one magnitude redder than the expected colour of a prototype quasar at this redshift (Figure 5). Both X-ray and optical data thus indicate that this is an obscured object. Such objects are predicted in models as contributors to the X-ray Background at faint fluxes.

CXOCY J125304.0-090737 is the only quasar above $z = 4$ found so far in the CYDER survey. However, the space density implied by its discovery is higher than reasonable extrapolations of the quasar optical luminosity function to fainter luminosities at high redshifts (Fan et al 2001). Although this object by itself does not constrain the faint end of the luminosity function at high redshift, it demonstrates the possibilities that X-ray surveys have to achieve this goal.

4. Summary

We have briefly presented the CYDER survey, which is currently underway. We have focused in the first fields studied that were chosen to coincide with moderately deep Chandra X-ray pointings. We have investigated the nature of the X-ray sources in these fields. We find that the broad X-ray and optical properties of our sources are similar to the ones studied in the CDF-N. The only difference is that our sources appear to be softer. We also stress the fact that our X-ray sources are of diverse optical spectral types and have highlighted the discovery of a high redshift X-ray selected quasar.

The current X-ray surveys (most of which are presented in this volume) that have flourished with the launch of the new X-ray observatories promise to be key to our understanding of the faint X-ray populations. The CYDER survey will be one of the surveys contributing to pin down the evolution of accretion material on to black holes which seems to be closely related to the star formation history of the universe.

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