The AGN Source Population in the Chandra Deep Field-North Survey: Constraints from X-ray Spectroscopy and Variability


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1. Introduction
With the 0.5-10.0 keV background nearly resolved (e.g., Giacconi et al. 2000; Cowie et al. 2002), the emphasis has shifted towards understanding the nature of the faint X-ray population — a clear necessity if we wish to understand the formation and evolution of active galactic nuclei (AGN). Here we report on preliminary spectral and temporal X-ray studies of AGN in the 2 Ms Chandra Deep Field-North Survey (CDF-N; D.M. Alexander et al. in prep). Our sample is comprised of 136 CDF-N sources with > 200 net counts (~30% of the total CDF-N sample), spanning $10^{-13}$ ergs cm$^{-2}$ s$^{-1}$; 72 sources have known redshifts.

2. Spectra
We initially fitted each source with a fixed Galactic $N_H$ (1.6 $\times$ 10$^{20}$ cm$^{-2}$; Stark et al. 1992), a variable intrinsic $N_H$ at the source redshift if known, and a simple powerlaw with variable photon index $\Gamma$. Approximately 70% of the sources fitted by this model have $\chi^2 < 1.3$, with the remaining sources often exhibiting soft excess residuals (i.e., due to a partial covering or thermal component). The median spectral parameters are $\Gamma = 1.61$ and $N_H = 1.7 \times 10^{21}$ cm$^{-2}$ for all 136 sources, or $\Gamma = 1.55$ and $N_H = 2.6 \times 10^{21}$ cm$^{-2}$ for the 61 sources with > 500 counts. The intrinsic $N_H$ distribution for the sample and a comparison of $L_X$ vs. $N_H$ are shown in Fig. 1. The $N_H$ distribution is strongly skewed towards low/Galactic values with only a small fraction of sources lying above $10^{23}$ cm$^{-2}$. The 27 optically identified broad-line AGN (BLAGN) trace the overall sample.

3. Emission Lines
Ten of the 136 AGN ($\approx$7%) exhibit obvious Fe K$\alpha$ emission-line features, with equivalent widths (EWs) of 0.1–1.3 keV. Two of the emission-line sources appear to be Compton thick AGN, displaying both large EWs and extremely flat spectral slopes $\Gamma < 1.0$ characteristic of pure reflection (e.g., Maiolino et al. 1998). We have also constrained the number of potential Compton thick sources among the 72 sources with known redshifts. By adding a Gaussian component in the source spectrum ($E = 6.4$ keV, $\sigma = 0$ keV), we can place upper limits on the Fe K$\alpha$ EWs. Only 8 of the 72 sources ($\approx$11%) have 90% confidence EW upper limits above 1 keV, and, of these, none has a measured photon index $\Gamma < 1.0$.

Since $\sim 50\%$ of all known Compton thick sources have $\Gamma < 1.0$ and large EWs can also arise from anisotropic ionizing radiation or variability lags between continuum and line emissions (e.g., Maiolino et al. 1998; Bassani et al. 1999), the true number of Compton thick sources among our spectroscopically identified sources may be even smaller.

4. Variability
The 20 individual CDF-N observations span approximately 27 months and offer an unprecedented probe of long-term X-ray variability in distant AGN. Using both Kolmogorov-Smirnov and $\chi^2$ statistics, we find that $\sim$94% of the BLAGN, $\sim$90% of the > 500 count sources, and $\sim$60% of the overall sample show indications of variability.

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References