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New Astronomy Reviews 50 (2006) 792–795

New Astronomy Reviews

www.elsevier.com/locate/newastrev

Classification and obscuration effects in quasars and galaxies of the CDF-N

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Available online 8 August 2006

Abstract

We present a classification scheme for Chandra Deep Field-North (CDF-N) sources with spectroscopic redshifts based upon their broadband spectral energy distributions. A substantial fraction of the faint sources can be identified as normal/star-forming galaxies. The AGN in the sample divide into four classes: luminous, apparently unabsorbed QSOs; objects with reddened optical spectra and no signs of X-ray absorption; apparently X-ray absorbed AGN with no signs of reddening in their optical spectra; and optically reddened sources with X-ray spectra indicative of substantial obscuration. The observed column density distribution for the complete sample shows a significant rise of the number of sources with $N_H > 10^{22.5}\,cm^{-2}$ when we include objects fainter than $f_{0.5\text{–}8.0\ keV} = 3.0 \times 10^{-15}\,erg\,s^{-1}\,cm^{-2}$. Our results indicate that a full X-ray spectral analysis of the complete sample is crucial in mapping out the underlying absorbing column density distribution, and thus the effects of obscuration on the number counts and luminosity functions.

Keywords: Quasars; AGNs; Galaxies; Obscuration

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1. Introduction

In recent years, surveys such as COMBO-17 (Wolf et al., 2003), 2dF (Croom et al., 2004), and SDSS (Schneider et al., 2005), have led to very significant progress in our knowledge of the evolution of optically selected quasars.[1] Surveys such as these represent the current state of the art. Going forward, a crucial question in the determination of quasar evolution is how many obscured quasars may be missing from optical surveys. Work on answering this question also connects to the host galaxies in which quasars and AGNs reside in at least two ways: (1) some of the obscuration likely arises in the hosts themselves and (2) the contribution of light from the hosts becomes an increasing fraction of the total emission from the nuclear region of the galaxy as the obscuration increases and/or the AGN luminosity decreases. The first effect may be

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[1] In this paper, the term quasar refers to the most luminous objects in the family of active galactic nuclei, or AGN.

1387-6473/$ - see front matter
doi:10.1016/j.newar.2006.06.075

connected to starburst activity in the hosts. The second effect is an observational complication and limitation for the study of low-luminosity AGNs, which are much more numerous than quasars and represent the bulk of the AGN population. The Chandra Deep Fields (CDF) offer important new opportunities to study these questions because (1) they provide the highest surface density of AGNs observed to date, (2) there are multi-wavelength data from radio to X-ray wavelengths for many of their sources, and (3) they cover redshifts up to 5 and luminosities down to 10^{40} erg/s. The CDFs contain quasars, AGNs, and apparently normal galaxies, thereby providing an opportunity to study both AGN evolution and AGN/host galaxy questions.

Here we present a condensed version of initial results on quasars, AGNs, and galaxies in the CDFs that will be described in detail by Frank, Osmer, and Mathur (in preparation). We cover three aspects of the work: (1) a classification of the multiwavelength spectral energy distributions (SEDs) of the sources in the CDFs, where we show that working in the emitted frame of the objects is very effective for visualising the intrinsic similarities and differences of the objects, (2) estimates from the X-ray data of the absorbing column densities for the individual objects and how they compare with previous studies, and (3) how the absorption produces a redshift-dependent selection effect in the flux-limited samples that has to be taken into account in making estimates of the true luminosity functions of the sources.

2. Classification of objects in the CDF-N

We begin by making use of the Alexander et al. (2003) point-source catalog of 503 objects, which provides X-ray data in seven bands and estimates of the photon index Γ_{eff} for each source. We combine these data with the NIR–optical–UV data of Barger et al. (2003) and obtain spectral energy distributions (SEDs) for all the sources. By using the available spectroscopic redshifts, we can convert to observed luminosities and display results in the emitted frame. This has the important advantages of enabling us to see the differences in luminosities of the different sources and to allow for their substantial range in redshifts, which in turn is critical for considerations of the effect of absorbing gas and dust on the SEDs. For a given column density, the observed X-ray fluxes of the high-redshift sources are much less affected than the low-redshift ones.

Inspection of the data shows that five distinct classes of objects are readily seen. We plot representative examples in Fig. 1. These classes are: (1) luminous, apparently unabsorbed AGN, (2) optically normal and X-ray steep AGN, (3) red and X-ray flat AGN, (4) red and X-ray steep AGN, and (5) apparently normal galaxies. Note that a luminous unabsorbed AGN has a SED very similar to that of the standard AGN SED compiled by Elvis et al. (1994). Note also that the objects span six orders of magnitude in X-ray luminosity, i.e., the bulk of the range of known AGNs.

A main value of the approach of Fig. 1 is that it provides an effective way in one graph to classify and compare the

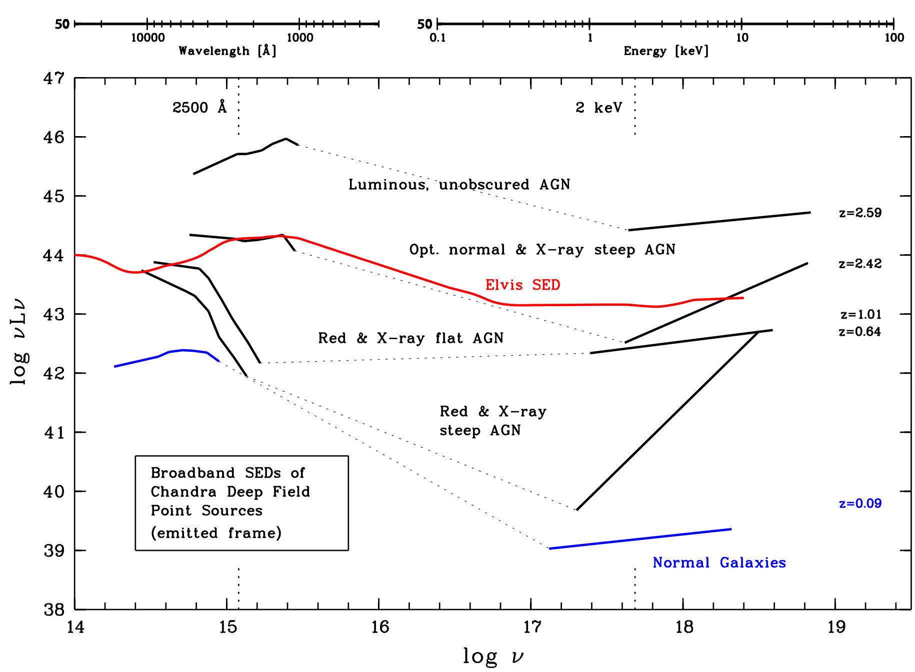

Fig. 1. Broadband spectral energy distributions of five typical CDF-N point sources in the emitted frame. Photometric data are shifted from the observed HK′, z′, I, R, V, B and U bands to the emitted frame. The X-ray part of the spectrum is assumed to be a power-law with an observed effective photon index Γ_{eff}. Overplotted in red is the standard AGN SED of Elvis et al. (1994). Source redshift is on the right. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)