Using the E-CDF-S and COMBO-17 to Examine the X-ray-to-Optical Properties of Optically-Selected Active Galaxies

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Abstract

Using the optically-selected AGN from the COMBO-17 survey of the E-CDF-S field (which extends 3 magnitudes fainter than the SDSS) and the corresponding E-CDF-S X-ray data, we supplement more luminously-optical AGN surveys and compile a relatively homogeneous sample of 332 optically-selected, radio-quiet, unabsorbed AGN with the largest X-ray detection fraction to date (88%). Using partial correlation analyses we confirm that the UV emission of AGN is strongly correlated with their soft X-ray emission (15.3σ), while controlling for effects of redshift. The UV-to-X-ray emission ratio, \( \alpha = 0.384 \log(l_{2500\text{Å}})/l_{2 keV} \), is related to the AGN luminosity (in the sense that less luminous AGN emit more soft X-rays per unit UV), but remains unchanged with cosmic time (\( \approx 0.5 \)-25σ). Precise knowledge of this relationship is important for testing energy generation models of AGN, deriving bolometric corrections, identifying X-ray weak AGN, and comparing AGN luminosity functions derived from X-ray and optically-selected samples.

Results

- The rest-frame UV and X-ray luminosities of AGN are strongly correlated (15.3σ; Figure 2), controlling for the effects of redshift.
- We find the slope of the \( l_{2500\text{Å}}-l_{2 keV} \) relation is less than one (\( \approx 0.73 \pm 0.01 \), Figure 2).
- The primary dependence of \( \alpha \) on \( l_{2500\text{Å}} \) (13.5σ; Figure 3) and not on \( l_{2 keV} \).
- The residuals of the best-fit \( \alpha \) vs. \( \log(l_{2500\text{Å}})/l_{2 keV} \) relation suggest this relation may be non-linear (Figure 3).
- We find a weaker, but significant correlation between \( \alpha \) and \( \log(l_{2500\text{Å}})/l_{2 keV} \), controlling for the effects of redshift.
- The ratio of UV to X-ray emission of AGN has changed by less than 30% since the Universe was \( \approx 1 \) Gyr old (Figure 4).
- Less luminous AGN emit relatively more X-rays than their more luminous counterparts.
- Optical AGN surveys must cover a larger range in luminosity to observe the AGN population revealed in X-ray surveys.
- Our results imply that optical luminosity functions will undergo luminosity-dependent density evolution (LODE) at faint optical magnitudes.

Statistical Tools

While our sample provides good coverage of the luminosity-redshift plane, both the UV and X-ray surveys contain strong luminosity-redshift correlations. To measure the strength of correlations between \( l_{2500\text{Å}} \) and \( l_{2 keV} \), we used rank correlation coefficient analysis, developed by Akritas & Babu (1996), which accounts for the presence of censored data.

Comparison with Earlier Studies

The \( \alpha \) vs. \( \log(l_{2500\text{Å}})/l_{2 keV} \) relation was first suggested in AGN studies performed in the early 1980s. While these studies found no correlation between \( \alpha \) and \( \log(l_{2500\text{Å}})/l_{2 keV} \), the analogous AGN samples with lower X-ray detection fractions, (10-50%) yielded larger errors. As seen in Figure 5 below, our study tightly constrains the \( \alpha \) parameters, conclusively showing no significant redshift dependence. To facilitate comparison we plot the \( \alpha \) vs. \( \log(l_{2500\text{Å}})/l_{2 keV} \) relation in terms used by Avni & Tananbaum (1996), where \( 10 \) is the fractional cosmological look-back time extending from today (\( \alpha = 0 \)) to the Big Bang (\( \alpha = 1 \)).