THE UV-TO-X-RAY EMISSION RATIO IN AGN: LUMINOSITY DEPENDENCE AND NO REDSHIFT EVOLUTION

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ABSTRACT

We compiled a relatively homogeneous sample of 332 optically-selected, radio-quiet, unabsorbed AGN with the largest redshift range coverage (0 < z < 6) and X-ray detection fraction to date (88%). Using partial-correlation analysis, we confirm that the soft X-ray emission from AGN is strongly correlated with their UV emission (partial Kendall’s $\tau = 0.52$ at 15.4$\sigma$) despite the dependence of luminosity on redshift in flux-limited samples. The UV-to-X-ray emission ratio, $\alpha_{\text{ox}} \equiv -0.384 \log \left( \frac{L_{2500 \text{\AA}}}{L_{2\text{keV}}} \right)$, 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.

Key words: active galactic nuclei; X-ray/UV/optical emission of AGN; AGN evolution.

1. INTRODUCTION

Precise knowledge of the relationship between UV and X-ray emission in Active Galactic Nuclei (AGN) is important for testing energy generation models of AGN, deriving bolometric corrections, identifying X-ray weak AGN, and for proper comparison between the AGN evolution scenarios derived independently in the UV and X-ray bands.

1.1. Sample

We assembled a sample of 332 optically-selected, radio-quiet (RQ) AGN with correspondingly deep soft X-ray coverage. The largest subsample (155 objects) contains Sloan Digital Sky Survey (SDSS) AGN serendipitously observed in medium-deep \textit{ROSAT} PSPC exposures. In order to increase the coverage of the luminosity-redshift plane without sacrificing X-ray detection fraction, which is crucial for determining the relation between UV and X-ray emission, we include subsamples of 52 COMBO-17 AGN with $R < 23$ (Wolf et al., 2003; Steffen et al., 2006), 46 BQS AGN with $M_B < -23$ (Brandt et al., 2000), 25 Seyfert 1 galaxies from Walter & Fink (1993), and 54 high-redshift AGN (Steffen et al., 2006). Optical/UV spectra were used, when available, to subtract the host-galaxy continua and to identify and remove AGN with broad UV absorption lines (BALs). We explored the effect of any remaining BALs through Monte-Carlo simulations and found it statistically insignificant. By removing the radio-loud (RL) and BAL AGN we ensure that our observations measure the intrinsic rest-frame UV and soft X-ray emission of AGN, unaffected by nuclear absorption or jet emission. Figure 1 shows the luminosity-redshift plane coverage of the full sample. To our knowledge, this is the cleanest (controlling for RL, BAL, host-galaxy contribution, etc.) large sample of optically-selected AGN with the highest X-ray detection fraction (88%) to date.

1.2. Statistical Methods

While our sample provides good coverage of the luminosity-redshift plane, both the UV and X-ray luminosities are still correlated with redshift. To measure the strengths of correlations between $L_{2500 \text{\AA}}$, $L_{2\text{keV}}$, $\alpha_{\text{ox}}$, and redshift, we use partial-correlation methods, which allow us to determine the correlation between any two variables while controlling for the effects of a third variable. We use rank-correlation coefficient analysis, developed by Akritas & Siebert (1996), which also accounts for the presence of upper/lower limits.

To obtain the linear-regression parameters of the correlations, we use the Astronomy Survival Analysis package (ASURV; Isobe et al., 1986). We used Monte Carlo simulations to confirm the robustness of the present correlations (see La Franca et al., 1995; Strateva et al., 2005).
2. RESULTS

- We confirm that rest-frame soft X-ray and UV emission of AGN are strongly correlated (partial Kendall’s \( \tau = 0.52 \), significant at 15.4\( \sigma \), see Figure 2).

- The slope of the \( \log(L_{2500\text{\AA}}) - \log(L_{2\text{keV}}) \) correlation is less than one, which means that less luminous AGN emit relatively more X-ray emission (in comparison with their UV emission) than their more luminous counterparts. The best bisector line fit for the \( \log(L_{2500\text{\AA}}) - \log(L_{2\text{keV}}) \) relation is: \( \log(L_{2\text{keV}}) = 0.73 \log(L_{2500\text{\AA}}) + 4.40 \). To estimate the X-ray emission from the UV emission, the linear regression minimizing the X-ray residuals must be used: \( \log(L_{2\text{keV}}) = 0.64 \log(L_{2500\text{\AA}}) + 6.87 \). Conversely to obtain the best UV emission estimate from X-ray data, the linear regression minimizing the UV residuals must be used: \( \log(L_{2\text{keV}}) = 0.82 \log(L_{2500\text{\AA}}) + 1.71 \).

- The primary dependence of \( \alpha_{\text{ox}} \) is on \( \log(L_{2500\text{\AA}}) \): \( \alpha_{\text{ox}} = -0.14 \log(L_{2500\text{\AA}}) + 2.64 \), significant at 13.6\( \sigma \). There is no dependence on redshift (1.2\( \sigma \)).

- We find a weaker, but significant (3.1\( \sigma \)) correlation between \( \alpha_{\text{ox}} \) and \( \log(L_{2\text{keV}}) \).

- Using the \( \alpha_{\text{ox}} \) residuals as a function of redshift, we estimate that the ratio of UV to soft X-ray emission of AGN has not changed by more than 30\% since the Universe was \( \sim \)1 Gyr old.

For more detailed results, we refer the reader to Steffen et al. (2006) and Strateva et al. (2005).

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