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 15.4σ) despite the dependence of luminosity on redshift in flux-limited samples. The UV-to-X-ray emission ratio, $\alpha_{\rm ox} \equiv -0.384 \log[L_{2500\,\text{Å}}/L_{2\,\rm keV}]$, 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.

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 *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 $M_{\rm B} < -23$ (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 $L_{2500\,\text{Å}}$, $L_{\rm 2keV}$, $\alpha_{\rm ox}$, 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).

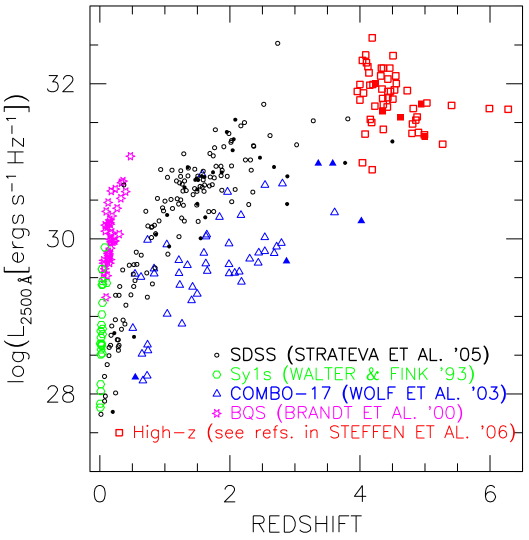

Figure 1. Distribution of rest-frame UV monochromatic luminosity with redshift. The inclusion of both large-area and deep, pencil-beam samples allows us to break the strong dependence of luminosity on redshift, characteristic of flux-limited samples without compromising the X-ray detection fraction. X-ray upper limits are indicated with solid symbols in this plot only.

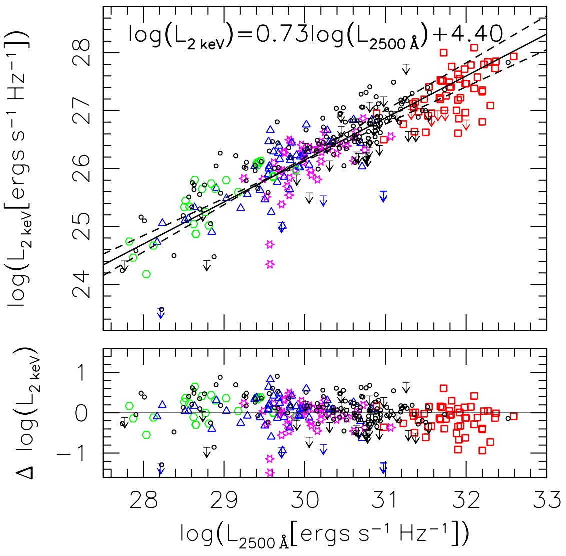

Figure 2. The soft X-ray and UV monochromatic luminosities are strongly correlated (partial Kendall's $\tau = 0.52$ with 15.4σ significance) with slope less than one. Symbols are as in Figure 1, except for the X-ray upper limits which are indicated with arrows. The solid line is the best-fit bisector line, with parameters given above and residuals plotted below; the two dashed lines are the best-fit linear regressions minimizing the x- or y-axis residuals.

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 15.4σ, see Figure 2).

– The slope of the $\log(L_{2500\,\text{Å}})$–$\log(L_{2\,\text{keV}})$ 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 $\log(L_{2500\,\text{Å}})$–$\log(L_{2\,\text{keV}})$ relation is: $\log(L_{2\,\text{keV}}) = 0.73\log(L_{2500\,\text{Å}}) + 4.40$. To estimate the X-ray emission from the UV emission, the linear regression minimizing the X-ray residuals must be used: $\log(L_{2\,\text{keV}}) = 0.64\log(L_{2500\,\text{Å}}) + 6.87$. Conversely to obtain the best UV emission estimate from X-ray data, the linear regression minimizing the UV residuals must be used: $\log(L_{2\,\text{keV}}) = 0.82\log(L_{2500\,\text{Å}}) + 1.71$.

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

– We find a weaker, but significant (3.1σ) correlation between α_{ox} and $\log(L_{2\,\text{keV}})$.

– Using the α_{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 ∼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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