An investigation of the relation between the spectral energy distributions and the emission lines in low-redshift quasars.[1]

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ABSTRACT

We investigate the relations between the observed emission line strengths, widths and continuum properties of a sample of 41 low redshift ($z < 1$) quasars for which contemporaneous IR-soft-X-ray spectral energy distributions (SEDs) are available. This includes investigating correlations between optical/UV lines with both the luminosity and the shape of the quasars' continuum, as well as correlations between the various lines. The sample is heterogeneous, primarily selected upon the existence of good quality *Einstein* X-ray data and includes 18 radio-loud and 23 radio-quiet quasars.

We find anticorrelations between the equivalent-width (EW) and various UV luminosities (the Baldwin effect) for the Lyα and Hβ lines and a marginal anticorrelation for CIII]. Exclusion of narrow line, low luminosity AGN reveals a significant Baldwin effect for the CIV and CIII] lines. A significant anticorrelation of EW(CIV) with α_{ox} is also present. We find no correlations between any lines and the X-ray luminosity or X-ray slope. The FeII optical multiplet shows no simple relationship with luminosity or continuum slope, however there is a tendency for objects with flat X-ray spectra and/or strong X-ray luminosities to have weak FeII.

Our data do not favor a model in which changes in continuum shape (due to e.g. a decreasing ionization parameter) cause the Baldwin effect. The data can instead be explained by an accretion disk (AD) model in which limb darkening and the projected surface area of an optically thick, geometrically thin disk combine to cause a viewing-angle dependent UV luminosity and a more isotropic X-ray luminosity. The scatter in our correlations is larger than that expected from this AD model, suggesting the presence of dust, which reddens both the continuum and the broad emission lines. The CIV and CIII] carbon lines show flatter slopes and larger scatter in the line - continuum relations than predicted by the AD + dusty torus model. This may be due to a significant contribution from collisional excitation which is not directly related to the ionising continuum.

Subject headings: quasars:general — quasars:emission lines

1. Introduction

The strong, broad emission lines which characterize quasar spectra are generally believed to be generated in a large number of small gas clouds photoionized by the central continuum source of a quasar. This region is known as the broad emission line region (BELR). To date photoionization models have been reasonably successful in predicting the average emission line properties of a quasar using an average continuum shape. However, it has become clear that, while the emission line properties are largely similar from quasar to quasar, the observed spectral energy distributions (SEDs) are not (Elvis et al. 1994, hereafter E94). If photoionization models are generally applicable, we would expect systematic relations between the observed lines and continuum in different objects (Krolik & Kallman 1988) and, at first glance at least, the dichotomy between continuum and the line behavior looks surprising.

The most enduring relation between the lines and continua in quasars is the inverse correlation between line equivalent width (EW) and continuum luminosity known as the Baldwin effect (Baldwin 1977). This relation is not predicted in a simple photoionization scenario and explanations range from luminosity-dependent continuum shape, which affects the BELR ionization, to geometric effects. Another intriguing set of correlations, which have caused a flurry of activity in recent years, centers around an inverse relation between the strengths of the broad FeIIλ4570 and narrow [OIII]λ5007 lines and includes soft X-ray slope and luminosity and broad line width (Boroson and Green 1992, Boller, Brandt and Fink 1996, Lawrence et al. 1997). Again a simple photoionization scenario fails. The current popular explanation involves the mass flow into the central black hole, this is attractive since it would imply an observational link into the central power house (Pounds, Done and Osbourne 1996). Despite the general success of photoionization models, these results suggest that other factors also play a role in determining the emission line properties of quasars.

Most studies of line and continuum properties of quasars to date have centered around large samples, often including non-uniform datasets from a variety of sources and generally utilising global continuum parameters such as L_{opt}, L_X and α_{ox}. Since the photoionization of any individual ion and its resulting relation with the ionizing continuum is unique to that ion, the use of global parameters has obvious limitations for investigating photoionization models. The current study takes a different, complementary approach in concentrating on uniform, high-quality continuum and emission line data for a small sample of quasars. This dataset facilitates a study of the relation of each emission line to various parts of the continuum and, potentially, allows differentiation between ionization and other effects.

We have obtained far-infrared (IR) through soft X-ray (100 μm – 3.5 keV) continuum data for a sample of 41 quasars. Spectral energy distributions (SEDs) for 30 of these objects were presented in E94, the remaining 11 are compiled here from a combination of our own and published data. We also present low-resolution (5-20Å), optical spectrophotometry which was obtained within a few months of the optical/IR continuum measurements. Ultra-violet (UV) spectra from IUE and/or HST have been obtained either by ourselves or from their respective archives. The range in shapes of the IR–UV continuum is large even in this small, low-redshift sample (E94), allowing investigation of whether the range in continuum shapes produces any corresponding range in the emission line properties.

2. Observations and data reduction

2.1. The sample

Our sample is a heterogeneous sample of 41 low redshift quasars (z<1), where 23 are radio-quiet (RQQ) and 18 are radio-loud (RLQ). The radio-quiet objects dominate at lower redshifts, while the radio-loud dominate at higher redshifts (see Fig.1). All but three quasars (PG1012+008, PG1121+422, PG2304+042) have *Einstein* X-ray observations with sufficient counts to define the X-ray spectral index. This selection introduces a bias towards objects with strong X-ray emission relative to the optical (small α_{ox}). The spectral energy distributions (SEDs) for 30 objects were presented in E94. For the remaining 11 objects, the SEDs were assembled from existing data as described below. The list of all quasars with their redshifts is given in Table 1.

2.2. Optical Spectroscopy

The quasars were observed during the period 1985-91 mostly with the Multiple Mirror Telescope (MMT) on Mt. Hopkins in Arizona. Both blue and red spectrographs were used as far as possible to provide full coverage (3200–8400 Å) of the optical continuum. Southern objects were observed with the CTIO 1.5m and CCD spectrograph. The observational details are given in Table 1, including the instrument and wavelength range covered in each case.

In photometric conditions, spectrophotometry was carried out by observing each quasar twice, first through a large aperture, $\gtrsim 5''$, and second through a small aperture $\sim 1.5''$ for a longer time in order to obtain high spectral resolution and signal-to-noise. A standard star was observed through the wide aperture, at similar air mass, immediately before/after the quasar observation, to provide flux calibration. The data were reduced in the standard manner using IRAF. The continuum of the small aperture data was then normalized to match the shape and absolute flux level of the large aperture observation yielding a final spectrum with resolution $\sim 5 - 20$ Å (depending on the instrument) and a photometric accuracy of $\sim 5\%$. Except where noted in Table 1, all spectra have been flux calibrated using a large aperture spectrum, observed in photometric conditions as described above.

The date of the spectrophotometry, sometimes different from that of the higher S/N, small aperture spectrum, is also noted in Table 1.

In some cases several spectra covering largely overlapping wavelength ranges were obtained. If no significant change in continuum shape was apparent, these spectra were combined to improve the final S/N. Spectra with continuum shapes which did not agree within the errors were not combined, instead the discrepant or lower quality spectrum was discarded. Blue and red spectra of the same object were not combined since this adds uncertainty in the small overlap region of the spectra and is not required for our analysis. Table 1 lists observational details for all the individual spectra (i.e. before being combined). The final, combined spectra are presented in Figure 2 in order of increasing right-ascension with blue and red spectra displayed separately.

The fluxes, equivalent widths (EW) and full-width at half maximum intensity (FWHM) were measured for all the prominent optical and UV emission lines: OVIλ1034+Ly$\beta\lambda$1025, Ly$\alpha\lambda$1216+NVλ1240, SiIVλ1397+OIV]λ1402, CIVλ1549, CIII]λ1909+SiIII]λ1892+AlIIIλ1857, MgIIλ2798, [NeV]λ3426, [OII]λ3727, [NeIII]λ3869+HeIλ3889, [NeIII]λ3967, H$\delta\lambda$4102, H$\gamma\lambda$4340, FeIIλ4570, H$\beta\lambda$4861, [OIII]λ5007. The EW and fluxes were measured by the summation procedure detailed in Robertson (1986), which provides a better estimate of the line wings than Gaussian fitting. All fluxes and EW were re-measured using the *splot* task in IRAF. Rather than fitting a Gaussian function to these lines, which frequently does not work well, we measured the actual data by fitting a linear continuum and integrating across the observed emission line (keystroke 'e'). If the EW and fluxes derived by both methods agreed within 10% the values obtained by the summation procedure were used for the subsequent analysis, if they disagreed the values from the *splot* task were used. For the FeII optical multiplet, which is especially difficult to measure if the line is weak, the summation procedure was used to determine the EW. The FWHM were measured using only the IRAF *splot* task by fitting a linear continuum, measuring the line peak flux above the continuum, determining the half-maximum intensity and measuring the width at that level. By measuring all the data ourselves we minimize the scatter generally introduced by combining datasets from different measuring techniques and different authors. The equivalent widths of optical and UV lines are listed in Tables 4 and 5, the UV and optical line fluxes in Tables 6,7 and the UV and optical FWHM in Tables 8,9. All values are in the rest-frame.

2.3. Spectral Energy Distributions (SEDs).

The SEDs for the 11 quasars, not presented in E94, were compiled here from a combination of our own ground-based optical and near-infrared photometry (from the 0.6 m FLWO telescope, the MMT, the Mount Lemmon 61" and the IRTF, for details see Table 3 and E94) as well as from the *Einstein* X-ray data, archival IUE or HST ultra-violet data and IRAS far-infrared data. The various datasets were combined following the method described in E94. When no optical photometry was available the MMT spectrophotometry was used. For inclusion in the SEDs, prominent emission lines were subtracted from the optical and UV spectrum and the spectrum binned into broader wavelength bands. A correction for galactic extinction was applied to the SEDs based upon the Galactic neutral hydrogen column and assuming a fixed conversion of $N(HI)/E(B-V) = 5.0 \times 10^{21}\ cm^2 mag^{-1}$ (Burstein & Heiles 1978). The Galactic HI column has been accurately measured by Elvis et al. (1986) for 7 of the 11 objects. For the remaining 4 objects it was determined using the dereddening values from Neugebauer et al. (1987). After correcting for galactic extinction the data were blueshifted to the rest frame using a cosmological model with $\Omega_o = 1$ and $H_o = 50$ kms^{-1}Mpc^{-1}. No k-corrections and no assumptions about the intrinsic spectrum were required since we were working with the complete spectral energy distributions. The contribution from the host galaxy was then subtracted using the method and template of E94 (based on the Sbc galaxy model of Coleman, Wu and Weedman 1980) and normalized by the host galaxy monochromatic luminosity in the H band, which was taken from the literature or, when not available, set to 1/3 of the luminosity of the quasar in that band (McLeod and Rieke 1994a,b). The final SEDs for the 11 objects are displayed in Figure 3 in order of right-ascension.

To allow comparison with earlier studies, in Table 2 we list several standard continuum parameters taken from the literature and determined in the usual way (i.e. not from the SEDs). These include: L_{opt} (luminosity at 2500Å), L_X (X-ray luminosity at 2 keV), α_{ox} (effective optical to X-ray slope) from Wilkes et al. (1994), α_x (X-ray energy index, where $f_\nu \propto \nu^{-\alpha_x}$) from Wilkes and Elvis (1987), α_{ouv} (optical slope, $f_\nu \propto \nu^{-\alpha_{ouv}}$ taken between 1285Å and 5100Å) from Kuhn (1996) and radio class (quasar considered radio-loud (L) if $R_L > 1$, after E94). We also list the blue-bump strength measured from the SEDs, $C_{UV/IR}$ (E94). In order to better characterize the SEDs, we directly measured the decade and octave luminosities, as defined in E94 (given in Table 10,11). In Table 12 we give several broad-band luminosities: L_{UVOIR}, L_{BOL}, Lycon, L_{Ion} (ionizing continuum), all defined as in E94. All SEDs parameters were measured using the TIGER software package written by J. McDowell (Wilkes & McDowell 1995). We have also measured the driving continuum for each line following Krolik & Kallman (1988; Table 4).

3. Correlation Analysis

We studied correlations between the various line and continuum properties in Tables 14,15 using the ASURV statistical package (Isobe, Feigelson & Nelson 1986) which includes allowance for the presence of upper limits in the sample. Specifically we applied the following tests to each pair of parameters: the Generalized Kendall Rank test and the

Spearman Rank test, which is insensitive to outlying points. We considered a correlation real only if the probability of it occurring by chance was $<$2% in *both* of these tests. We present the percentage probability of a chance correlation in the Generalized Kendall Rank test followed by that for the Spearman Rank test in Tables 14,15 for probabilities $< 5\%$. Significant correlations ($P < 2\%$) are given in bold text. When multiple correlations were found we tested for the primary relation using ASURV bivariate Spearman ranks as input to partial Spearman rank (PSR) analysis (Kendal & Stuart 1976). The primary correlations, i.e. the strongest pairwise correlations when the other variables are held constant, are underlined in Tables 14 and 15.

Since we are considering a large number of parameters (3 parameters for each of 15 emission lines: EW, FWHM, flux; and 33 continuum parameters - see previous section), we divide our results up by emission line parameters, first discussing the equivalent width vs continuum luminosity correlations (Section 3.1) followed by the flux (Section 3.2) and the FWHM (Section 3.3). We then discuss the correlations between the various line parameters (Section 3.4) and between the various continuum parameters (Section 3.5). The number of correlations studied and found and the number of spurious correlations expected with $P < 2\%$ are shown in Table 13.

3.1. Equivalent width - continuum luminosity correlations

3.1.1. UV lines

The best known line-continuum correlation for quasars is the inverse correlation between the emission line equivalent widths (EW) and the continuum commonly known as the Baldwin effect. It was detected for the first time by Baldwin (1977) in a sample of high-redshift quasars in which the EW of the CIVλ1549 line decreased with increasing UV continuum luminosity, L(1450Å). The Baldwin effect has since been reported for a large number of lines (OVI, NV, HeII, CIII], MgII and Lyα) in a number of different samples (eg. Tytler & Fan 1992, Zamorani et al. 1992, Green 1996). Baldwin et al. (1978) showed, however, that the correlation is much stronger in a sample of flat-spectrum, radio-loud quasars (RLQs). This was later confirmed by Wampler et al. (1984), and Baldwin, Wampler & Gaskell (1989). On the other hand, the analysis of optically-selected quasar samples (Osmer 1980, Crampton et al. 1990, Boyle et al. 1991) shows that the Baldwin effect is less pronounced. It has been suggested that there exist two kinds of the Baldwin effect: a global, or object-to-object, effect and an intrinsic effect due to variability of the object (Pogge & Peterson 1992, Murdoch 1983). The slope of the intrinsic effect is different from that of the global one, adding scatter to the global relationship. However as the result of variability and selection effects some regions of the EW-L diagram may be left unpopulated and hence result in a more pronounced Baldwin effect for the radio-loud quasars.

The correlation results, between EW and continuum luminosity, are presented in Table 14 with coding explained in Section 3. The primary correlations are underlined and are displayed for the Lyα, Hβ and CIII] lines in Figure 4 a,b,c.

The Baldwin effect is present in our sample for the Lyα line, for which the EW anticorrelates with all the various OUV luminosities. The primary correlation is with L(0.1-0.2μm) luminosity.

The EW(CIII]) shows a very strong (primary) correlation with $L(1-2keV)$ and a marginal correlation with L(0.1-0.2μm). A CIII]-X-ray correlation was reported by Green (1996) in a sample of quasars observed by the *Einstein* and IUE satellites. However our CIII] line sample has more than 50% upper limits, the correlation looks unconvincing (Fig.4b), and no related correlation between the CIII] flux and X-ray flux is seen (Section 3.2). This suggests that the EW(CIII]) vs L(1-2keV) correlation is spurious and we cannot confirm the correlation reported by Green (1996).

The traditional Baldwin effect for the CIV line is not present in our sample (Figure 5a). However, a significant correlation ($P < 1\%$ in all cases) is found for both CIV and CIII] lines if we omit seven objects with low log$\nu L_\nu(0.1 - 0.2\mu)$ i.e. IZw1, NAB0205+024, PG 0844+349, PG 1012+008, PG1211+143, PG 1351+640, IIZw136. These objects have relatively weak carbon lines (EW(CIV)/EW(Lyα) <0.55) as can be seen in Figures 5a,b,c where they are indicated by filled circles. They also have narrow FWHM of Hβ (< 2500km s^{-1}, Table 9) falling into the range of narrow line Sy1 objects (NLSy1, Osterbrock & Pogge 1985; exept for PG 0844+349 and PG 1351+640 which are broad-absorption line QSOs). This suggests that NLSy1s may have systematically lower carbon line EW and so do not follow the general Baldwin effect for the rest of the sample.

The only significant correlation involving α_{ox} is a strong anticorrelation with EW(CIV) relation (Fig. 6a). A marginal correlation with EW(Hβ) becomes significant when one object, PG1001+054, is omitted (Table 14). For the OVI line, marginal anticorrelations of EW(OVI) with L$_{opt}$ (P$_K$=1.7%, P$_S$=3.8% and with α_{ox} ($P_K = 3.1\%$, $P_S = 4.1\%$) are present in our sample. The latter correlation was reported by Zheng, Kriss & Davidsen (1995) in their sample of 30 QSOs and 2 Sy1 (z>0.15), which had both IUE and *Einstein* X-ray fluxes. However with only 10 points in our sample we cannot draw strong conclusions from our lack of a correlation here.

3.1.2. Balmer lines

The primary correlation for EW(Hβ) is with L(0.4-0.8μm) (Figure 4c). The EW(Hβ) also anticorrelates with the L(100-10μm) infra-red luminosity, L(0.1-0.2μm), OUV luminosities and X-ray L(1-10keV) luminosity (Table 14). A closer look shows that the "correlation" between EW(Hβ) and L(1-10keV) is due to a systematically higher L(1-10keV) for RLQs (Figure 4d). The L(1-10keV) luminosities are determined by extrapolating the *Einstein* soft-X-ray (0.1-3.5 keV) flux and energy index. The systematically flatter α_x and stronger X-ray flux of the RLQs (Wilkes and Elvis 1987) exaggerates the systematic difference between L(1-10keV) in the two classes.

Similar to Hβ, the equivalent-widths of the other Balmer lines anticorrelate with the far-IR luminosity, L(10-100μ).

3.1.3. FeII line

No significant correlations are found for the EW of the FeIIλ4570 optical multiplet. The one with the lowest probability of chance occurrence (P_K=2.1%, P_S=3.5%) is an anticorrelation with L(1-2keV) (reported as significant by Boroson & Green 1992 and others). However Fig. 7a does show a trend for objects with larger L(1-2keV) luminosity and smaller EW(FeII) to be radio-loud quasars, while radio-quiet objects have a much larger range in EW(FeII) and concentrate towards smaller X-ray luminosities.

No correlation between the EW(FeII) line and α_x is present in our sample (see Fig. 7b) nor in the RQQ and RLQ subsamples. Such correlations have been found by Wilkes et al. (1987) and Shastri et al. (1993) in samples observed by the *Einstein* satellite. However Boroson (1989) studying a radio selected sample, Walter and Fink (1993), who studied the Seyfert galaxies observed in the ROSAT All Sky Survey (RASS), and Zheng & O'Brien (1990) failed to confirm this correlation. 31 objects in our sample are also included in the Shastri et al. (1993) sample, however only 16 of them have FeII measurements. A comparison of our Fig. 7b, with their Fig. 5a shows small disagreements between the measured values and one incorrect slope. PG0844+349 has an X-ray energy index α_x of 1.6

in Shastri et al. (1993) whereas the correct value from the Einstein data is 0.6 (E94).

Given the apparently discrepant results in the literature, we conclude (as did Lawrence et al. 1997) that there is no direct correlation between FeII and α_x, but rather a zone of avoidance such that objects with flat X-ray spectra do not have strong FeII. A similar effect, that objects with stronger X-ray luminosities do not have strong FeII, would also explain our marginal correlation between FeII and L(1-2keV) (Fig. 7a). This also agrees with the long-established tendency towards weak FeII in RLQs (Peterson, Foltz, and Byard 1981, Phillips 1977, Osterbrock 1977).

Lawrence et al. (1997) note a much stronger correlation between FeII and the near-IR-X-ray slope α_{ix}. We tested for this in our sample and found no significant correlation (P_K=5.0%, P_S = 6.9%). However our data cover only about 60% of the range in α_{ix} and a smaller range in log(FeII/Hβ) than that of Lawrence et al. (1997) (-1.5 to 0 in our sample cf. -1 to 0.7 in theirs).

3.2. Line flux vs continuum flux correlations.

The optical/UV line flux – continuum flux correlations are presented in Table 15, with similar coding to Table 14. This analysis was performed identically in both flux and luminosity space to guard against purely redshift-induced results. However, given the small range in redshift (z<0.4 for all but 5 sources, Figure 1), there is no significant difference between the two sets of results. All the primary correlations for these lines are shown in Figure 8. For Lyα and CIV lines the primary correlations are with the continuum regions closest to the driving continuum, as expected. However we note that simultaneous measurements of both UV lines and UV continuum (as is the case in our sample) will result in smaller scatter and lower probabilities for these correlations. In other bands small continuum variations or systematic shifts between the measurements will add scatter.

For the CIII] line the primary correlation is with the optical flux, far from its driving continuum. No conclusions can be drawn for the SiIV line as it is not clear what the driving continuum is for this line (T. Kallman, private communication). Correlations for Lyα flux and EW are the most significant (usually $P << 0.1\%$ cf. $P >> 0.3\%$; see Table 15) and have the smallest scatter among the UV lines (Table 16). The predominance of the EW(Lyα) correlations reported in the previous section may be due to the primary correlation being with the local continuum for this line (Table 15). Thus, the EW is determined by only two parameters, the line flux and the local continuum, whereas for lines whose primary correlation is not with the local continuum, non-simultaneity and calibration uncertainties between the different continuum regions can induce additional scatter.

3.2.1. Line flux vs. driving continuum correlations

We investigate the correlations between the strengths of the broad emission lines such as Lyα, OVI, CIV, CIII], Balmer lines, FeII and their driving continua. To determine the driving continua, the SEDs were linearly interpolated between observational points in the OUV. In the X-rays the observed α_x was used and the EUV continuum was determined by a linear interpolation between the lowest energy point in the X-ray range and the highest in the UV. Then the spectrum was integrated over the energy range of the driving (ionizing) continuum of each line (see Table 15) following the definitions of Krolik and Kallman (1988; see their Table 4). The probability of a correlation between each line and its driving continuum, as given by the Kendall and Spearman rank tests, is shown in Table 15. The slopes of the linear regression, and the scatter of the observational points around the regression line are shown in Table 16. All correlations between the lines and driving continuum are shown in Fig 9. While these correlations are strong, surprisingly in no case were they the primary line vs continuum correlations. In addition the slopes of the regression lines were always smaller than the expected value of 1. Possible explanations include differing line and continuum reddening, optically thin (matter bounded) clouds and continuum emission from an accretion disk (see discussion in Section 4.1.3).

3.3. Line FWHM vs. Continuum Luminosity Correlations

Only two significant correlations were found between opt/UV line widths and continuum luminosity parameters: FWHM(NeHe) with far-IR (10-100μm) luminosity (P_K=1.9%, P_S=1.5%), and second for FWHM([OIII]) with L_{Ion} (1.3%,1.3%). NeHe also correlates but less significantly with L(0.1-0.2μ) (2.4,2.7%) and L_{BOL} (2.2%,1.7%).

As has been noted in Table 13, the number of spurious correlations with a probability of a chance correlation less than 2% is expected to be 6 for the 315 correlations tested. Since we found less than 6 significant correlations we consider it likely that they are spurious.

3.4. Correlations between emission line parameters

We have also studied correlations between the various parameters of each emission line. We shall present here only those correlations which are significant and/or interesting.

The equivalent widths of the Balmer lines correlate with each other and the FWHM(Hβ) correlates with FWHM(Hγ). This is consistent with photoionization models, as the Balmer lines are expected to form in the same region.

The Lyα and CIV line EW and FWHM also correlate with each other (Fig 10). These correlations are easily understood in the light of standard photoionization models, as it is generally believed that these lines originate in clouds located at the same distance from the continuum source. However the presence of a correlation, also reported by Corbin (1991) and Corbin & Boroson (1996), between the EW(Lyα), EW(CIV) and EW(Hβ) as well as FWHM(Lyα), FWHM(CIV) and FWHM(Hβ) (and also FWHM of Hγ) is interesting. Hβ (and Hγ) is a low-ionization line and is expected to form in a different region than the CIV and Lyα lines. If both the high and low-ionization components scale similarly with luminosity, two models are applicable. First, the Collin-Souffrin et al. (1988) model, where low-ionization lines (LILs) are formed in the atmosphere of the accretion disk, while high-ionization lines (HILs) form in a distinct spherical component. Second, the standard model, where LILs and HILs are formed in the same cloud but in zones of differing ionization.

We see no correlations between the EW and FWHM of individual lines in our sample. An anti-correlation has been reported for CIV in some samples (eg. Francis et al. 1992, Wills et al. 1993, Corbin & Francis 1994).

The EW([OIII]) anticorrelates with EW(FeII). This relation was noted by Boroson and Green (1992) and dominates their first eigenvector. They rule out an interpretation based on the standard beaming model partly due to the strong dependence on [OIII], which is thought to be isotropic, and partly to the positive correlation of absolute continuum magnitude with the magnitude of [OIII], which is not expected if beaming causes the range in optical continuum flux. Instead they favor a model based on a geometric effect intrinsic to the quasar such as shadowing of the NLR by a co-planar, toroidal-shaped BLR so that the covering factor, perhaps determined by the ratio of accretion rate to the Eddington rate, drives the correlations. Eddington-limited flow was also suggested to explain those objects with extremely strong FeII emission (Pounds, Done and Osbourne 1996) based primarily upon their unusually steep, soft X-ray spectra.

Since [OIII] and [OII] originate in similar parts of the NLR, we expect their emission line profiles to be similar. We find a correlation between their equivalent widths, but we do not see a correlation for their FWHM. However we do not place much weight on this latter result since the narrow lines are often close to the spectral resolution, [OII] is weak and we have only 19 measurements of variable quality.

3.5. Continuum-continuum correlations

All the continuum luminosities correlate with one another. The regression slopes, for L_1 vs. L_2 and L_2 vs L_1 relations, are presented in Table 17. Most of the relations have regression slopes near unity. The exception is the L(0.1-0.2μm) vs. L(0.2-0.4μm) relation whose slope is less than 1, indicating that L(0.1-0.2μm) increases faster with increasing bolometric luminosity than any other luminosity. This could be explained if the peak of the big blue bump (BBB) moves from the EUV into the UV as the luminosity increases.

Correlations with the spectral indices were also investigated. The only correlations found were those between L_X, L(1-2keV) and α_{ox} (regression slope = –1.51±0.83 and –1.88±0.7 respectively) showing the steepening of α_{ox} with decreasing X-ray luminosity and the correlation between L_X and L_{opt} (regression slope = 0.74±0.15 in agreement with the Wilkes et al. 1994 slope of 0.71). We do not find the correlation between α_{ouv} and α_x reported by Puchnarewicz et al. (1996) or that of α_{ox} with α_x also reported by Laor et al. (1997) (see Section 4.1.5).

The mean SEDs for high and low luminosity quasars in our sample are shown separately in Fig.12. The quasars that contribute to the high luminosity mean are: 0637-752, 1226+023, 1407+265, 1704+608 (L(0.8-1.6μm)>45.5) and those that contributed to the low luminosity mean are: 0007+106, 0026+129, 0804+761, 1416-129, 1501+106 (L(0.8-1.6μm)<44.2 and EW(Hβ) > 70Å. The low luminosity object 1001+054 was omitted while making the mean, as we had no information on the X-ray slope and the large errors in starlight caused large uncertainties in the $\sim 1\mu m$ region. The higher luminosity SEDs show less dispersion around the median in the IR to UV bands than the lower luminosity SEDs. The range in X-rays is systematically shifted to lower X-rays for the higher luminosity SEDs and the big blue bump (BBB) is stronger (in the UV) for lower luminosity SEDs (meaning, as was also noticed from the slope analysis, that the peak of the BBB moves from the EUV into the UV as the luminosity increases). However the range in the SEDs present is broad and overlaps significantly between the two samples.

4. Discussion

4.1. The Baldwin Effect

In a simple, radiation-bounded photoionization model, one would expect the line flux in the high-ionization lines, such as CIV, Lyα, to be proportional to the strength of the ionizing continuum as a larger fraction of emitting material reaches the ionization state of the line. Since EW is the ratio of line flux to that in the local continuum (i.e. in the same wavelength region as the line), the Baldwin effect indicates that the line flux is increasing more slowly than the local continuum (or is constant). One possible interpretation is that the ionizing/heating continuum for the emission line (i.e. its driving continuum) is increasing more slowly than the local continuum, suggesting that the continuum shape correlates with the luminosity of a quasar. A number of papers have reported such a correlation. Tananbaum et al. (1986), Wilkes et al. (1994), as well as Green et al. (1995) note that the power law between UV and soft X-rays, α_{ox}, increases significantly with luminosity. This results in the soft X-ray luminosity being weaker relative to the UV in higher luminosity quasars.

4.1.1. Zheng & Malkan model

Zheng & Malkan (1993), studying optical and UV properties of quasars and Seyfert galaxies, interpreted their color-luminosity relations as the result of a shift of the BBB towards lower energies in higher OUV luminosity objects. In this scenario higher luminosity quasars are predicted to have a lower fraction of higher energy ionizing photons available relative to the opt/UV continuum. This change in continuum shape would cause the equivalent widths of high ionization emission lines sensitive to the X-ray continuum, such as CIV and HeII, to decrease at high luminosities relative to lower-ionization emission lines, such as Lyα, CIII] and the Balmer lines. The scenario predicts a stronger and more easily detectable Baldwin effect for higher-ionization lines. We do see a shift in the SEDs, but our data do not favor this model as we see the Baldwin effect in both high and low-ionization lines.

4.1.2. Mushotzky and Ferland model

Mushotzky and Ferland (1984) explain the Baldwin effect as due to a systematic decrease in ionization parameter, U, as the luminosity increases. As the ionization parameter depends on the number of ionizing photons, U depends on the continuum shape. Their model assumes a single zone broad line region i.e. determines the ionization for one "slab" at a given distance from the central source and assumes spherical symmetry. The model predicts the presence of a Baldwin effect for the CIV line, as the CIV luminosity increases rapidly with increasing U (decreasing UV luminosity and α_{ox}) in the range 30 to 32 in L_{1450}. This relation flattens around $L_{1450} < 30$ and so predicts a weaker/or no Baldwin effect for lower luminosity AGN (see Fig.1 in Mushotzky and Ferland 1984). In addition their calculation showed that there should *not* exist a Baldwin effect in Lyα, CIII], Hα and Hβ lines as the luminosity of these lines decreases with increasing U (i.e. decreasing luminosity) in the same luminosity range. It also follows that the equivalent widths of Lyα, CIII], CIV should, in this scenario, be relatively independent of both α_{ox} and α_x as the lines do not originate in the X-ray heated zones deep in the emission line clouds.

In our sample, this model matches only the CIV line for which we see the Baldwin effect for $L_{1450} > 29.7$ ($L(0.1 - 0.2\mu m) > 45$) . The four narrow line low luminosity AGN which have $L(0.1 - 0.2\mu m) < 45$ destroy the anticorrelation (with these objects the probablity of a chance correlation is $P > 5\%$, without $P < 1\%$), and fall into the region where the model predicts no Baldwin effect (as it is the region where CIV remains fairly constant with increasing U). However we see a strong correlation for EW(CIV) with α_{ox}, as well as less significant correlations for Lyα, Hβ and OVI with spectral shape, none of which are consistent with the Mushotzky and Ferland model. Our data also show a Baldwin effect for Lyα and the Balmer lines which the model does not predict. The model also predicts that the CIV/Lyα ratio should decrease with increasing luminosity but no such relation is found in our sample. We conclude that this model does not provide a good explanation for the relations present in our sample and so reject a pure photoionisation scenario for the BELR.

4.1.3. The Accretion Disk (AD) Model

Netzer (1985,1987) and Netzer, Laor and Gondhalekar (1992), using an optically thick and geometrically thin accretion disk, explain the Baldwin effect in a different way. The model assumes a distribution of identical clouds at distances from the center of the disk greater than the size of the UV-emitting part of the disk. The incident ionizing flux from the accretion disk is composed of two components: the UV continuum, which is viewing angle-dependent due to limb darkening and change in projected surface area, and the X-ray component, which is viewing angle independent. The UV emission is strongest when the disk is viewed face-on. Because the BELR radiates more isotropically than the UV disk, a random selection of objects differing only in viewing angle would result in measurements of constant line luminosities but varying UV continuum luminosities, producing an anticorrelation of EW with L_{UV}. In addition, an anticorrelation between EW and α_{ox} is expected as objects viewed face-on would have steeper α_{ox} (due to relatively higher UV to X-ray emission) and smaller EW than those seen edge-on. Correlations of the more isotropic X-ray emission with line EW would be much weaker.

The continuum viewed by the BLR clouds themselves is a function of viewing angle. As a result, clouds at small viewing angles produce strong Lyα, OVI and Balmer continuum emission due to the stronger UV ionising continuum. Clouds at large viewing angles, where the fraction of high-energy X-ray photons is largest, emit low-excitation lines such as FeII and MgII. The model predicts that, in clouds at these viewing angles, FeII emission can reach an intensity comparable to that of Lyα and more than 10 times that of Hβ. Under our assumption of optically thin emitting clouds, this viewing angle dependence will not affect the observed line strengths unless external effects, such as viewing-angle dependent reddening, are also present.

In general the results presented here show good agreement with the predictions of the AD model. We see an anticorrelation of EW with UV luminosity for Lyα, Hβ, Hδ and a less significant relation for CIII], although this becomes significant after excluding the low luminosity narrow line AGN (probably NLSy1 - see Section 3.1.1). A similar relation for CIV (the traditional Baldwin effect) also appears when these NLSy1s are omitted. We see a strong correlation between EW and α_{ox} for CIV *only* and less significant relations for Lyα, Hβ and probably for OVI (although we do not have enough data to draw strong conclusions here). None of the lines correlate with X-ray luminosity, agreeing with the model predictions.

To make a more quantitative comparison between the model and our data, we assume that the AD and BELR are hidden by a dusty torus similar to that postulated for Seyfert 1 and Seyfert 2 galaxies. Adopting an opening angle of $\sim 60°$ (Phillips, Charles & Baldwin 1983) and following Netzer et al. (1992), the AD model predicts that the range in disk inclination yields a range in OUV luminosity of a factor of 2 (0.3 in log). This modifies the slope α, of the line luminosity vs driving continuum correlations in the following way:

$$\alpha = 1 - 0.3/(logF_{cont}^{max} - logF_{cont}^{min})$$

The range in flux continuum F_{cont} in our sample is $\sim$ 2.5 orders-of-magnitude so the expected slope is $\sim 1 - 0.12{=}0.88$. Most of the lines fit into this scenario (Lyα, Hγ, and probably Hβ, Hδ, FeII, OVI although the errors are large, see Table 16). However CIV and CIII] have flatter slopes (0.57$\pm$0.14 for CIV and 0.69$\pm$0.19 for CIII]). Exclusion of the seven discrepant NLSy1 objects (see Section 3.1.1) yields slopes still not steep enough (0.64$\pm$0.14 for CIV and 0.64$\pm$0.25 for CIII]). (We note that the CIII] line sample has $>$ 50% upper limits so the errors in the regression slopes are probably under-estimated.) This may be due to a significant contribution from collisional excitation, which is not directly related to the ionising continuum. In contrast, the FeII line flux vs continuum flux correlations are too steep ($\sim$ 1.3; see Table 16) to fit this scenario. One possible explanation for this behavior is reddening by dust which increases with increasing viewing-angle. Given the predominance of FeII emission from large viewing-angles described above, this line would be reddened more than the continuum. This could lead to a stronger viewing-angle dependence than the continuum and so a steeper relation, as observed.

Another discrepancy between our results and the predictions involves the scatter around the mean slope in the line vs. continuum correlations which is larger than that expected (i.e. $>$0.15 around the mean, Table 16). Effects that could increase the scatter include a non-spherical geometry of the BLR clouds, random obscuration by dust in the NLR or a different opening angle for the dusty torus. These possibilities are discussed in the following sections.

4.1.4. The two-zone BLR

The BLR is sometimes suggested to include two distinct regions: the high ionization line (HIL) region (Lyα, CIV, CIII]) and low ionization line (LIL) region (Balmer, FeII and MgII lines). Collin-Soufrin et al. (1988) assumed, for example, that the LILs have a disk geometry while the HILs do not. In this scenario, a random selection of objects differing only in disk inclination would lead to a scatter around the mean in a plot of F_{line} vs F_{DRIV} which is larger and a slope which is flatter for the HILs (as these lines have a spherical symmetry), than for the LILs. In our sample the mean slopes for the LIL Balmer and FeII lines are indeed steeper than those for the HILs (i.e. Lyα, CIV and CIII]) (see Table 16). However the scatter in the correlations is larger for LILs than HILs, contrary to the predictions. This scenario potentially offers an explanation for the steepness of the FeII vs OUV flux correlations if distributions of FeII and OUV continuum emission from the AD differ. However, given the partial agreement between model predictions and the observations and the large uncertainties in the derived slopes, we are unable to draw strong conclusions on the applicability of this model.

4.1.5. The role of dust

The presence of dust in quasars has been discussed by many authors (eg. Webster et al. 1995, Rawlings et al. 1995, Sprayberry & Foltz 1992, Low et al. 1989, McLeod & Rieke 1994a,b). Baker (1997), for example, studied a complete sample of radio-loud quasars and found correlations between optical continuum and emission lines and the orientation indicator R (the ratio of radio-core to lobe flux density). These correlations and the result that core-dominated quasars are 3-5 mag brighter in the optical region than lobe-dominated quasars were explained as due to viewing-angle dependent dust extinction. In addition strong correlations of the equivalent widths of [OII] and MgII and the [OII]/[OIII] ratio with R, the lack of significant trends for CIII], CIV, Hβ and a weaker trend for [OIII] suggest that the broad line region and the inner part of the narrow line region suffer extinction similar to the continuum. The Balmer decrements (Hα/Hβ and Hβ/Hγ) also correlate with R, although for Hβ/Hγ the correlation is less significant, probably due to contamination of Hγ by [OIII]λ4363. Given the lack of measured R values for the quasars in our sample, we can provide only weak, direct support for this scenario by confirming the lack of any relation between the Balmer decrement, Hβ/Hγ, and the EW of the broad emission lines expected from the above correlations with R.

Puchnarewicz et al. (1996), studying a sample of X-ray selected Seyfert 1 galaxies and quasars covering a wide range in redshift and X-ray spectral slope, reported that the optical to X-ray spectra change from convex to concave as the X-ray slope, α_x, hardens (i.e. α_x and α_{ox} anticorrelate). This was interpreted in terms of an intrinsic convex spectrum being absorbed by differing amounts of cold gas and dust, possibly depending on viewing-angle and so similar to the Baker (1997) scenario. Given the small range of α_X in our sample (-0.3 to 0.9 cf. -2 to 3 for Puchnarewicz et al. 1996) and the large scatter in the correlation, we do not see a significant correlation here. However, dividing our sample according to α_X and applying the median test reveals a significant trend ($>$ 99 %) for α_{ox} to be smaller when α_x is hard. We do not find a significant correlation between α_{opt} (i.e. α_{ouv} in our sample) and α_x, again this is not surprising given our small range of α_X. We also note that Puchnarewicz et al. (1996) show a weak correlation for the high redshift objects only ($z > 1.0$, $P_S = 4\%$), their lower redshift objects do not show a correlation, consistent with our sample.

There are a number of other properties of our sample which could potentially be explained by dust reddening. These include: the larger than canonical "case B" Balmer decrements: $2.85 < \mathrm{H}\alpha/\mathrm{H}\beta < 7$ (case B Hα/Hβ=2.85), and $2.1 < \mathrm{H}\beta/\mathrm{H}\gamma < 5.3$ (case B Hβ/Hγ=2.1) implying a reddening of $A_v < 2.04$ mag; the existence of primary correlations for optical and UV lines which are not with the driving continuum (see Section 4.1.3); the increased scatter in the line luminosity vs driving continuum relations above that predicted by the disk model; the larger scatter within the line/continuum correlation of Hγ compared to Hβ (see Table 16). We investigate dust as a contributor to the correlations in detail in the next section.

4.1.6. Simulations of the Effects of Reddening.

We investigate the effects of dust on the results of our analysis by applying random amounts of dust redenning to a simulated sample of quasars with properties similar to our actual sample. First we selected the quasar in our sample with the largest BBB i.e. the one with largest difference: L(0.1-0.2μm)$-$L(0.8-1.6μm) (PG1426+015). Since this object also has a ratio Hβ/Hγ equal to the unreddened "case B" value (2.1), we assume it is unreddened. A hypothetical sample of 26 objects was then constructed with the continuum shape of PG1426+015 but covering the range in bolometric luminosity present in the current sample (2.5 in L(0.8-1.6μm)), spaced by 0.1 in logνL$_\nu$. The maximum reddening was determined from the difference in strength of the strongest and weakest BBBs in the real sample. Assuming the dust lies outside the BELR, a random amount of reddening up to the maximum was applied to both the SED and the two extreme emission lines (in λ): Lyα and Hβ. The process was performed twice, using two extinction curves: the standard Galactic extinction curve (Seaton 1979) and the Small Magellanic Cloud (SMC) extinction curve (Prévot et al. 1984), which corresponds well to the extinction by dust dominated by amorphous carbon grains (Czerny et al. 1995). The estimated maximum reddening was $E(B-V) = 0.32$ for the Seaton extinction curve and $E(B-V) = 0.20$ for the SMC extinction curve. We note that this is much less than that estimated from the Balmer decrement, implying a different amount of obscuration. We then performed a correlation analysis similar to that applied to the real sample to look for the primary correlations between Lyα and Hβ and various parts of the SED and to estimate the scatter in the resulting line vs. driving continuum correlations. The results are as follows: for the Seaton extinction curve the primary correlation for Lyα was with the driving continuum and for Hβ with L(0.2-0.4μm), the scatter for the line vs. driving continuum correlation for Lyα was $\sigma = 0.12$ and for Hβ $\sigma = 0.42$; for the SMC extinction curve the primary correlation for Lyα was with L(0.1-0.2μm) and for Hβ was with L(0.2-0.4μm), the line vs. driving continuum correlation scatter for Lyα was $\sigma = 0.12$ and for Hβ $\sigma = 0.20$.

A comparison of these results with the current sample (Table 15,16) reveals that the simulation using the SMC extinction curve has the same primary correlations for Lyα and Hβ lines as the real sample and the scatter in the line vs. driving continuum correlations is comparable to the additional scatter required to bring the results into agreement with the AD model (see Table 16). The scatter introduced by the Netzer AD model (Section 4.1.3) for both Lyα and Hβ is $\sigma = 0.15$. The addition of dust yields an overall scatter, $\sigma \sim 0.27$ for Lyα and $\sigma \sim 0.35$ for Hβ which is slightly larger than in the real sample (compare with $\sigma = 0.22$ and $\sigma = 0.33$ respectively). However this slightly larger scatter is probably due to the simplifying assumption that the difference between objects with larger BBB and those with smaller BBB is entirely due to dust, neglecting any component due to the viewing angle of the accretion disk. Taking this into account would reduce the maximum E(B-V) and improve agreement with the observations.

We conclude that the Netzer AD disk model surrounded by an optically thick dusty torus, with addition of small amounts of dust outside the BELR fits well into our line-continuum correlations. Our conclusion that the SMC dust extinction curve, which corresponds well to extinction by dust dominated by small amorphous carbon grains (see Czerny et al. 1995), fits better than the Seaton extinction curve, is consistent with previous results that the dust in Seyfert galaxies and quasars may differ from the dust in our Galaxy, showing a depletion of silicates (Czerny, Loska, Szczerba 1991, Laor & Draine 1993).

4.1.7. The Torus

The assumption that quasars have the same dusty torus as the Sy1/Sy2 galaxies (Section 4.1.3) may not be valid. Perhaps the opening angle and radius or thickness of a torus depends on the luminosity of the central engine. More luminous quasars would then have larger opening angles and larger radius/thinner tori. A large torus opening angle would naturally explain the flat slope and large scatter for the carbon CIV and CIII] line vs. driving continuum correlations. This scenario could also explain why we see the Seyfert 1/Seyfert 2 dichotomy, while there is nothing similar for quasars. However, the other lines would then be too steep for the AD model so this scenario would require a different emitting region for the carbon lines. This seems contrived and an unlikely possibility given the generally similar behavior of the UV lines.

4.1.8. LOC model

As mentioned earlier, the majority of existing BELR models have been based on one or two-zones of clouds. In recent papers, Baldwin et al. (1995) and Korista et al. (1996) model the BELR from many clouds covering a wide range in distance r from the ionizing source and with a wide range in gas density n_H at each r. The integrated BELR spectrum is determined by integrating over the full distribution function of clouds at all radii and densities. This is called the "locally optimally emitting cloud" (LOC) model. This model predicts that the integrated spectrum depends only weakly on the shape of the ionizing spectrum, the column density of the clouds and the cloud distribution with r (see Fig.2 in Baldwin 1997). This implies that the BLR spectrum is determined more by selection effects than by details of the cloud properties. Since we have concluded that the behavior of the emission lines in our sample is not purely due to photoionization effects, it seems likely that a combination of a BELR based on the LOC model, an accretion disk providing the ionising continuum and a distribution of dust external to both AD and BELR would be able to fully describe our sample.

Conclusions

We investigate the relations between various emission line parameters and continuum parameters in a sample of low redshift ($z < 1$) quasars. The sample consists of radio-loud and radio-quiet objects for which IR to soft-X-ray SEDs are available, and is biased towards AGN with strong X-ray emission relative to the optical. Eleven newly compiled SEDs as well as optical spectra for all the quasars are presented. We have measured all the emission line parameters uniformly to minimize the scatter generally introduced when combining datasets from different techniques and different authors. We use survival analysis which allows for the presence of upper limits.

We find anticorrelations between the line equivalent-widths and UV luminosities, i.e. the Baldwin effect, for the Lyα and Hβ lines. Exclusion of narrow line low luminosity AGN reveals the Baldwin effect also for the CIV and CIII] lines. This suggests that NLSy1 objects may have systematically lower carbon EW. We also find a significant correlation between CIV and α_{ox}.

No correlations between the EW and the X-ray luminosity or slope are reported. However FeIIλ4750 shows a tendency for objects with flat X-ray spectra and/or strong X-ray luminosities to have weak FeII (consistent with Peterson et al. 1981, Phillips 1977, Osterbrock 1977). The anticorrelation between the EW([OIII]) and EW(FeII) (i.e. the first Boroson and Green 1992 eigenvector) is present in our sample.

Correlations between the various parameters for each line were also studied. We confirm the correlations between the FWHMs and EWs of CIV, Lyα and Hβ lines previously found by Corbin (1991) and Corbin & Boroson (1996), indicating that the high and low-ionization line components in the BLR scale similarly with luminosity. This is consistent with both a model where low and high-ionization lines are formed in the same clouds but in zones of differing ionization as well as a model were low-ionization lines are formed in the atmosphere of an accretion disk, while high-ionization lines form in a distinct spherical component.

The continuum-continuum correlations reveal that the peak of the big blue bump strengthens and perhaps shifts from the EUV into the UV as the luminosity increases. We confirm that the X-rays are systematically lower relative to the optical for higher luminosity objects (Wilkes et al. 1994). However both high and low luminosity objects show a broad range in continuum shapes and the distributions of SEDs for these subsamples overlap.

We investigate correlations between the line flux and various continuum fluxes including the driving continuum flux i.e. the part of the continuum responsible for ionizing each line. While the line - driving continuum correlations are strong, in no case were they the primary line vs. continuum correlations. In a pure photoionisation scenario, this is surprising but can be explained by the presence of dust which reddens both the lines and continuum similarly.

All the above correlations fit into the accretion disk model of Netzer et al. (1992 and references therein) where an optically thick, geometrically thin accretion disk is composed of two components: a viewing-angle dependent UV continuum, due to limb darkening and the change in projected surface area, and a viewing-angle independent X-ray continuum. The model is consistent with our data as both the predicted EW anticorrelations with UV luminosity and α_{ox} and the lack of correlations with the X-ray continuum are seen in our sample. A quantitative look at the line flux vs. continuum flux correlations (i.e. the primary correlations, regression slopes and scatter) reveals discrepancies which can be explained if dust is present, reddening both the lines and the continuum. Simulations suggest that the composition of the dust matches that of the SMC rather than our Galaxy i.e. showing a depletion of silicates (consistent with previous studies: Czerny et al. 1995, Laor & Draine 1993). The slopes of the line flux vs. driving continuum flux correlations for CIV and CIII] lines are flatter than predicted and with too large a scatter to fit into the AD + dust model. This can be explained if, as is typical, there is a significant contribution from collisional excitation. The correlation would then be flatter as only a part of the line flux would be directly related to the ionizing continuum.

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Fig. 1.— L_{opt} (2500Å luminosity) vs. redshift for our sample. In this and all subsequent figures stars indicate radio-loud quasars and circles radio-quiet quasars.

Fig. 2.— Optical spectrophotometry of the quasars in our sample in order of increasing right ascension and on a scale of F_ν (erg cm^{-2} s^{-1} Hz^{-1}) as a function of λ (Å). Observational details are given in Table 1.

Fig. 3.— Radio-X-ray Spectral energy distribution (SEDs) for the 11 new objects (Table 3) on a logνL$_\nu$ vs logν scale.

Fig. 4.— Primary correlations for UV and optical line equivalent widths vs continuum luminosities. Radio-loud quasars are indicated by stars and radio-quiet by circles.

Fig. 5.— a) The lack of Baldwin effect for EW(CIV). b) CIV/Lyα and c) CIII]/Lyα vs. UV luminosity relations. Filled circles denote low luminosity, narrow-line objects (NLSy1s) which decrease the significance of the CIV Baldwin effect in our sample

Fig. 6.— a) EW(CIV) vs. α_{ox} correlation. b) EW(Hβ) vs α_{ox} relation. Notice quasar 1001+054 in the upper-right corner, which drastically spoils this correlation

Fig. 7.— a) The relation between the EW(FeII) and the soft-X-ray luminosity b) The relation between EW(FeII) and α_x. We see no correlations but rather zones of avoidance such that objects with stronger X-ray luminosities and/or flat spectra do not have strong FeII

Fig. 8.— Primary correlations for the line vs. continuum fluxes.

Fig. 9.— Correlations for UV and optical line fluxes vs driving continuum fluxes.

Fig. 10.— Correlations between the EW (in Å) and FWHM (in units of $10^{-3} kms^{-1}$) of Lyα, CIV and Hβ lines

Fig. 11.— The correlation between [OIII] and optical FeII equivalent widths (the first

Boroson & Green eigenvector)

Fig. 12.— a) Mean energy distributions for high luminosity quasars, normalized at 1.5 μm and the 68, 90, and 100 (dashed line) Kaplan-Meier percentile envelopes, b) similar mean energy distributions for low luminosity quasars