C iv λ1549 AS AN EIGENVECTOR 1 PARAMETER FOR ACTIVE GALACTIC NUCLEI

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ABSTRACT

We are exploring a spectroscopic unification for all types of broad-line emitting AGNs. The four-dimensional Eigenvector 1 (4DE1) parameter space organizes quasar diversity in a sequence primarily governed by Eddington ratio. This paper considers the role of C iv λ1549 measures as 4DE1 diagnostics. We use HST archival spectra for 130 sources with S/N high enough to permit reliable C iv λ1549 broad-component measures. We find a C iv λ1549BC profile blueshift that is strongly concentrated among (largely radio-quiet [RQ]) sources with FWHM(HβBC) ≤ 4000 km s^{-1} (which we call Population A). Narrow-line Seyfert 1 (NLSy1; with FWHM Hβ ≤ 2000 km s^{-1}) sources belong to this population but do not emerge as a distinct class. The systematic blueshift, widely interpreted as arising in a disk wind/outflow, is not observed in broader line AGNs (including most radio-loud [RL] sources), which we call Population B. We find new correlations involving FWHM(C iv λ1549BC), C iv λ1549 line shift, and equivalent width only among Population A sources. Sulentic et al. suggested C iv λ1549 measures enhance an apparent dichotomy between sources with FWHM(HβBC) less and greater than 4000 km s^{-1}, suggesting that it has more significance in the context of broad-line region structure than the more commonly discussed RL versus RQ dichotomy. Black hole masses computed from FWHM C iv λ1549BC for about 80 AGNs indicate that the C iv λ1549 width is a poor virial estimator. Comparison of mass estimates derived from HβBC and C iv λ1549 reveals that the latter show different and nonlinear offsets for Population A and B sources. A significant number of sources also show narrow-line C iv λ1549 emission that must be removed before C iv λ1549BC measures can be made and interpreted effectively. We present a recipe for C iv λ1549 narrow-component extraction.

Subject headings: line: profiles — quasars: emission lines — quasars: general

Online material: Machine-readable tables

1. INTRODUCTION

The search for a parameter space that might provide spectroscopic unification for all classes of broad line emitting active galactic nuclei (AGNs) motivated the “four-dimensional Eigenvector 1” (4DE1) concept (Sulentic et al. 2000b, 2000c). Such a correlation might serve as an equivalent to the stellar Hertzsprung-Russell diagram. Domain space occupation differences and parameter correlations might then provide the empirical clues from which underlying physics could be inferred. At the very least it can be used to highlight important differences between sources that can also drive our physical understanding of the geometry, kinematics, and physics of the broad line emitting region (BLR). From the outset it was expected that a parameter space for AGNs would require more than two dimensions, because source orientation and “physics” (e.g., black hole mass MBH and Eddington ratio) drive AGN parameter values and correlations. A suitably chosen n-dimensional space should help to remove the degeneracy between these two drivers.

4DE1 has roots in the Rossi X-Ray Timing Explorer (RXTE) PCA analysis of the Bright Quasar Sample (87 sources; Boroson & Green 1992, hereafter BG92) as well as in correlations that emerged from Röntgenstellel (ROSAT; e.g., Wang et al. 1996). 4DE1 as we define it involves BG92 measures: (1) full-width at half maximum of broad Hβ (FWHM Hβ) and (2) equivalent-width ratio of optical Fe ii and broad Hβ: R_{Fe ii} = W(Fe ii λ4570)/W(H(λ1549BC)).

We added a measure defined in Wang et al. (1996) involving (3) the soft X-ray photon index (Γ_{soft}) and a measure of (4) C iv λ1549 broad line profile velocity displacement at half-maximum (c(½)) to arrive at our 4DE1 space. Other points of departure from BG92 involve our comparison of radio-quiet (RQ) and radio-loud (RL) sources as well as subordination of BG92 measures (although, see Zamanov et al. 2002; Marziani et al. 2003a). Finally, we divide sources into two AGN populations using a simple division at FWHM HβBC = 4000 km s^{-1} with sources narrower and broader than this value designated Populations A and B, respectively. It was motivated by the observation that almost all RL sources show FWHM HβBC ≥ 4000 km s^{-1} (Sulentic et al. 2000b). This division appears to be more effective than the more traditional divisions into: (1) RQ-RL sources as well as (2) narrow-line Seyfert 1 (NLSy1) sources defined with FWHM(H(λ1549BC)) ≤ 2000 km s^{-1} and broader line sources above this value. Results presented in this paper strongly support the Population A-B distinction. Exploration of possible physical drivers of source occupation/correlation in 4DE1 (Marziani et al. 2001, 2003b; Boroson 2002) suggest that it is primarily driven by the luminosity to black hole mass (M_{BH}) ratio which is proportional to the Eddington ratio (L_{bol}/L_{Edd}) with Population A sources being high accreting/low M_{BH} AGNs and Population B being low accreting/large M_{BH} AGNs.

Past 4DE1 studies focused on the optical 4DE1 plane (FWHM Hβ vs. R_{Fe ii}) at low redshift because more high signal-to-noise ratio (S/N) optical spectra exist than UV or X-ray measures. Complementary high-z measures of the Hβ region at infrared (IR) wavelengths are ongoing (Sulentic et al. 2004, 2006a). This paper focuses on an expanded sample of C iv λ1549 measures and explores their utility as 4DE1 parameters. The work is supplemental to a recent paper (Bachev et al. 2004) that discusses data processing and analysis of 123 C iv λ1549 spectra from the
Hubble Space Telescope (HST) archive. The new C iv \( \lambda 1549 \) sample is almost twice the size of that discussed in the defining 4DE1 paper (Sulentic et al. 2000c). We present (§ 2) new 4DE1 correlation diagrams involving measures of the C iv \( \lambda 1549 \) line shift and then look (§ 2.3) at the implications of C iv \( \lambda 1549 \)–defined source occupation for BLR structure and for the hypothesized AGN populations (A and B; § 3). Section 4 discusses the reality of a significant narrow-line C iv \( \lambda 1549 \) component in many sources and compares our C iv \( \lambda 1549 \) measures with other recent studies utilizing the same spectra. Section 5 considers the implications of our C iv \( \lambda 1549 \) results on the use of FWHM C iv \( \lambda 1549 \) to estimate black hole masses.

2. C iv \( \lambda 1549 \) LINE MEASURES AND CORRELATIONS

2.1. Sample Definition and Data Analysis

We searched the HST archive\(^5\) and found usable C iv \( \lambda 1549 \) spectra for 130 of 141 low-redshift sources. Excluded sources are mostly C iv \( \lambda 1549 \) BAL quasars where reliable measures of the C iv \( \lambda 1549 \) emission profile are difficult. OI 363 was not included because of low S/N. IRAS 13218+0552 (J132421.9+053705) was excluded, because it shows no broad lines that would warrant a type 1 AGN designation. We assume that our sample is large enough to reasonably represent the broad emission line properties of low-\( z \) AGNs. It is likely to be the only UV data set of reasonable-quality quasar spectra in the foreseeable future. The sample should be particularly valuable for RQ versus RL comparisons because the two populations are almost equally represented in a complete sample only \( \approx 10\% \) are found to be RL (Jiang et al. 2007; Cirasuolo et al. 2003; Sulentic et al. 2003). A PG quasar subsample was identified and includes 43 sources with 26\% RL reflecting the overrepresentation of RL sources in the HST archive.

The uncertainty due to instrumental errors in wavelength calibration are estimated to be \( \approx 200 \) km s\(^{-1}\) (Marziani et al. 1996). In order to reduce wavelength calibration errors HST spectra were “re-aligned” using expected rest-wavelengths of strong low-ionization, Galactic absorption lines including Mg \( n \) 7296.35, 2803.53 \( \AA \), Fe \( n \) 2600.17, 2586.65, 2382.77, 2374.46, 2344.21 \( \AA \), Al \( n \) 1670.79 \( \AA \), Si \( n \) 1526.71 \( \AA \), C \( n \) 1334.53 \( \AA \), and Si \( n \) 1260.42 \( \AA \) (Savage et al. 2000). In case only one or two Galactic lines were available in the spectra, any shift between expected Galactic line wavelength and the wavelength measured on the spectra was double checked to avoid spurious results due to low S/N. Suitable Galactic lines were found for 110 sources in our sample with three or more lines available for 71 sources. The average rms of the residuals between measured line wavelengths after realignment and tabulated wavelengths is (rms) \( \approx 40 \) km s\(^{-1}\). This provides an estimate of the wavelength calibration uncertainty (at 1 \( \sigma \) confidence level) for the realigned spectra.

The broad component of C iv \( \lambda 1549 \) (C iv \( \lambda 1549_{BC} \)) was extracted after correction for contaminating lines (N iv \( \lambda 1486 \), and especially He ii \( \lambda 1640 \) and O iii \( \lambda 1663 \)) and subtraction of Fe \( h/\alpha \) emission (details of data reduction are given in Bachev et al. [2004] and Marziani et al. [1996]). The continuum underlying C iv \( \lambda 1549 \) was estimated from nearby regions that are free of strong emission lines (between the \( \lambda 1400 \) blend and N iv \( \lambda 1486 \) on the blue side as well as 1700–1800 \( \AA \) on the red side). A narrow component (C iv \( \lambda 1549_{NC} \)) was subtracted from the profile when warranted. There is still disagreement about the existence, frequency of occurrence, and strength of any C iv \( \lambda 1549_{NC} \). We discuss the evidence for narrow-line region (NLR) C iv \( \lambda 1549 \) and describe our C iv \( \lambda 1549_{NC} \) subtraction procedure in § 4.

2.2. Immediate Results

Figure 1 shows individual cleaned C iv \( \lambda 1549_{BC} \) profiles fit with high-order spline functions to minimize effects of noise and to preserve the complexity of the shape (following Marziani et al. 1996, 2003a). The spline fit is shown as a thick line in Figure 1 while identified narrow components (that were subtracted in this analysis) are seen above the spline. Table 1 gives an identification list of all sources shown in Figure 1 along with 4DE1 optical and X-ray parameters. Table 1 includes column (1): IAU code identification; column (2): a common name for the source; column (3): available source redshift with number of significant figures indicating accuracy of the determination; column (4): redshift reference. Column (5): an asterisk (*) indicates that the sources belong to the BG92 PG sample; a “B” indicates that the source is a “blue outlier” (Zamanov et al. 2002). Column (6): Galactic absorption (\( A_{\beta} \), in magnitudes); column (7): available measures of FWHM for H\( \beta \) broad component [FWHM(H\( \beta \)BC), units \( \text{km s}^{-1} \)] taken from Marziani et al. (2003b) measures of Sloan Digital Sky Survey (SDSS\(^6\)) spectra or, as a last resort, literature spectra; column (8): measures of the ratio \( R_{Fe} \), from same sources as column (7); column (9): decimal logarithm of the specific flux at 4400 \( \AA \) over the flux at 6 \( \text{cm} \) (a source is assumed RL if \( \log R_{Fe} \geq 1.8 \)); column (10): a measure of the soft X-ray excess (photon index \( \Gamma_{s,0n} \)), from Sulentic et al. (2000b, 2000c) and from various literature sources.

The reported optical redshifts come from measures of low-ionization optical emission lines (LILs), typically H\( \beta \)NC, H\( \gamma \)NC, and H\( \epsilon \)NC supplemented by values derived from [O iii] \( \lambda 4959 \), 5007 if the source is not a blue outlier (see Marziani et al. 2003a; Zamanov et al. 2002). In these cases, the agreement between LILs and high-ionization lines (HILs) is reasonable within the accuracy limits of the present study. We remind the reader that “blue outliers,” i.e., sources with large [O iii] \( \lambda 4959 \), 5007 blueshift relative to optical LILs, tend to be extreme Population A sources with very weak [O iii] \( \lambda 4959 \), 5007 and are relatively rare. The recipe described in Marziani et al. (2003a) is applied for all sources with references indicated as ESO (unpublished European Southern Observatory spectra), SPM (unpublished spectra obtained with the 2.2 m telescope at San Pedro Martir), M03 (Marziani et al. 2003a), M96 (Marziani et al. 1996), SDSS (spectra retrieved from SDSS Web site), and G99 (Grupe et al. 1999). All other sources have redshift measured on the basis of the optical lines. None of the remaining sources are likely to be blue outliers on the basis of published spectra so redshift computed using optical lines should be a reliable estimate even if [O iii] \( \lambda 4959 \), 5007 lines were used.

Table 2 presents our C iv \( \lambda 1549 \) parameter measures with format as follows: column (1): IAU code; column (2): specific continuum flux at 1550 \( \text{A} \) (units \( \times 10^{14} \) ergs s\(^{-1}\)cm\(^{-2}\)); column (3): flux in the C iv \( \lambda 1549_{NC} \) (units \( \times 10^{13} \) ergs s\(^{-1}\)cm\(^{-2}\)); column (4): peak C iv \( \lambda 1549_{NC} \) radial velocity, in \( \text{km s}^{-1} \); column (5): flux in the C iv \( \lambda 1549_{NC} \) (same units as col. [3]); columns (6), (7), (8): centroid profile shift at \( \frac{1}{2} \) maximum [\( c(\frac{x}{2}) \) followed by the estimated uncertainties on the blue and red wings of the

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\(^5\) Data sets covering the C iv \( \lambda 1549 \) sources listed in Table 1 can be all identified and retrieved from the Web site at http://archive.stsci.edu/hst and are not reported here. A list with the actual data sets employed is available from the authors at http://web.oapd.inaf.it/marziani.

\(^6\) The SDSS Web site is http://www.sdss.org/.
profile (units km s\(^{-1}\)); columns (9), (10), (11): same at half-
maximum \(c(\frac{1}{2})\), which is an adopted 4DE1 parameter; columns (12), (13): centroid at \(\frac{1}{2}\) maximum \(c(\frac{1}{2})\) with symmetric uncertainty; columns (14), (15): centroid at the 90\% intensity level of the C\(\text{iv}\) \(\lambda 1549\) broad line \(c(0.9)\), with symmetric uncertainty; columns (16), (17): FWHM(C\(\text{iv}\) \(\lambda 1549\)BC) and estimated uncertainty (units km s\(^{-1}\)) columns (18), (19), (20): C\(\text{iv}\) \(\lambda 1549\)BC asymmetry index with estimated uncertainties on the blue and red profile wings; columns (21), (22): C\(\text{iv}\) \(\lambda 1549\)BC kurtosis measure and estimated uncertainty.

No C\(\text{iv}\) \(\lambda 1549\)NC measures are given in Table 2 if the profile is affected by partial (a) or strong (A) absorption. In sources labeled “a” in Table 2 residual C\(\text{iv}\) \(\lambda 1549\)NC is sometimes visible but the NC width and flux cannot be recovered. NC shifts and fluxes are accurate (within \(\pm 40\\%\) at a 2 \(\sigma\) confidence level) only if C\(\text{iv}\) \(\lambda 1549\)NC emission shows an intensity at least 0.05 C\(\text{iv}\) \(\lambda 1549\)BC.

Note that our adopted C\(\text{iv}\) \(\lambda 1549\)NC component is often not “[O\text{iii}] \(\lambda 4959, 5007\)–like.” It is often significantly broader and stronger than would be subtracted if we used [O\text{iii}] \(\lambda 5007\) as a template for the C\(\text{iv}\) \(\lambda 1549\) doublet. See § 4 for both empirical and theoretical justifications for our procedure.

Measured centroids at different fractional intensities were defined as

\[
c(\frac{i}{4}) = \frac{\lambda_B + \lambda_R - 2\lambda_0}{2\lambda_0} c, \quad \forall i = 0, \ldots, 4
\]

where \(c\) is the speed of light. Values \(c(\frac{i}{4})\) for \(i = 0\) are not listed in Table 2 due to the difficulty of assessing \(\lambda_B\) and \(\lambda_R\) at zero intensity. We give \(c(9/10)\) instead of peak radial velocity. This has been shown to be a good surrogate and less dependent on C\(\text{iv}\) \(\lambda 1549\)NC.
subtraction as well as line profile irregularities (Marziani et al. 2003a). The asymmetry index is defined as

\[ AI = \frac{\lambda_R(1/4) - \lambda_B(1/4) - 2\lambda_p}{\lambda_p}, \]  

(2)

where for \( \lambda_p \) we use \( c(9/10)/c \). The kurtosis index is defined as (cf. Marziani et al. 1996)

\[ kurt = \frac{\lambda_R(3/4) - \lambda_B(3/4)}{\lambda_R(1/4) - \lambda_B(1/4)}. \]  

(3)

Uncertainties reported in Table 2 were estimated by measuring the wavelengths \( \lambda_R \) and \( \lambda_B \) at \( \pm 5\% \) fractional intensity and then quadratically propagating the errors in the relationships reported above. All uncertainties reported in Table 2 represent a 2 \( \sigma \) confidence level. Uncertainties in estimating the rest-frame velocity, relative to which the centroids are computed, can be as large as \( 300 \text{ km s}^{-1} \) or as small as \( \sim 30 \text{ km s}^{-1} \) (at 1 \( \sigma \) confidence level) depending on the availability of moderate-resolution spectra (SDSS is, or will be, improving the situation for about 50\% of the sample). The error in estimating the local rest frame \( \Delta z \approx 0.00014 \pm 0.0006 \) was derived from the distribution of differences between \( z \) values used in this work and those given in the NASA/IPAC Extragalactic Database (NED). Combining the typical uncertainty on systemic velocity, on UV wavelength calibration, and the average of the measurement uncertainty reported in Table 2, the typical uncertainties (at a 2 \( \sigma \) confidence level) are \( \approx 230 \) and \( \approx 170 \text{ km s}^{-1} \) for \( c(3/4) \) and \( c(1/4) \), respectively.

2.3. \( \text{C IV} \lambda 1549 \) Line Parameters in the RQ-RL Context

Figure 2 shows source occupation in 4DEi planes involving the \( c(1/4) \) parameter (as defined in Sulentic et al. 2000b; \( c(1/4) \) was chosen from among possible \( \text{C IV} \lambda 1549 \) profile measures.
FWHM, $c(\frac{1}{2})$, and equivalent width] because (1) it is not obviously luminosity dependent, (2) it showed the largest intrinsic dispersion, and (3) it showed possible correlations with the other principal 4DE1 parameters. As a luminosity-normalized measure $W(C_{iv} \lambda 1549_{BC})$ is ruled out even if the well-known “Baldwin effect” now appears to be driven by dependence on the Eddington ratio (Bachev et al. 2004; Baskin & Laor 2004). This does not mean that we regard it as an unimportant measure but only that we reject it as one of the principal 4DE1 parameters. A surrogate measure might involve a direct measure of $C_{iv} \lambda 1549_{BC}$ line flux, but the parameter dispersion of that measure is less than for $c(\frac{1}{2})$. The same is true for FWHM($C_{iv} \lambda 1549_{BC}$), which also shows less dispersion than FWHM($H_{\beta C}$). Line broadening may be due to both rotational and nonrotational velocity components, especially if a disk + wind model is applicable to our sources. On the contrary, $c(\frac{1}{2})$ is most likely related to the amplitude of any nonvirial motions in the BLR. It is this parameter that adds a new element that can be argued to be physically orthogonal to previously defined E1 parameters: FWHM($H_{\beta C}$) estimates the virial broadening in the LIL-emitting part of the BLR; $R_{Feii}$ measures the ionization conditions, while $\Gamma_{soft}$ provides a measurement of the continuum shape.

RQ and RL sources are indicated by circles and squares respectively in Figure 2 (sources with radio/optical flux ratio $log R_K \geq 1.8$ are considered RL; Sulentic et al. 2003). The large number of squares reflects the overrepresentation of RL sources in our sample. Figure 2a shows that sources with $C_{iv} \lambda 1549$ profile blue-shifts strongly favor RQ AGN with FWHM($H_{\beta C}$) $\leq 4000$ km s$^{-1}$. RL sources show a large scatter of both red and blue $C_{iv} \lambda 1549$ shifts. Figures 2b and 2c show that sources with $C_{iv} \lambda 1549$ blue-shift especially favor RQ sources with large $R_{Feii}$ (strong optical Fe ii emission) and $\Gamma_{soft}$ (a soft X-ray excess) measures, respectively. RL sources are much more strongly concentrated in the latter two 4DE1 planes.
Table 3 gives mean parameter values (sample standard deviations in parenthesis) for total sample, RQ, RL, and our previously defined Population A-B subsamples that will be considered in § 3. Values are given for column (2): number of sources; column (3): equivalent width measure of the C iv λ1549 line; column (4): $c(\frac{1}{2})$ of C iv λ1549; column (5): FWHM(C iv λ1549); column (6): FWHM(H/BC); column (7): $R_{Fe}$; column (8): $\Gamma_{soft}$. Columns (4), (6), (7), and (8) represent the principal parameters in 4DE1. We find that RL sources show broader H/BC and C iv λ1549 profiles than RQ AGNs, while RQ sources show stronger $R_{Fe}$, $\Gamma_{soft}$, and $c(\frac{1}{2})$ (blueshift) than the RL sample. FWHM C iv λ1549 is on average (17%) broader than FWHM H/BC for RQ sources while FWHM H/BC is (16%) narrower than FWHM C iv λ1549 for RL sources. These differences relate to one of the most significant results of our earlier work where a restricted optical domain space occupation was found for RL sources. Figure 2 also shows this restricted occupation as a strong concentration of RL sources in a small region of the $c(\frac{1}{2})$ versus $R_{Fe}$ and $\Gamma_{soft}$ planes. RL sources are rarely found with 4DE1 parameter values: FWHM(H/BC) ≤ 4000 km s^{-1}, $R_{Fe}$ ≥ 3, $\Gamma_{soft}$ ≥ 2.5, and $c(\frac{1}{2})$ ≤ 0 km s^{-1}. The expanded C iv λ1549 sample confirms and strengthens this result which likely indicates a fundamental difference in BLR structure, kinematics, and/or physics between RL and RQ populations (see Sulentic et al. [2003] for discussion in the context of a RQ-RL dichotomy).

Spearman rank correlation coefficients and associated probabilities are given in Table 4 for C iv λ1549 equivalent width, FWHM, and centroid measures versus the three other principal 4DE1 parameters. The total-sample correlation coefficients for this sample are larger than corresponding values given for the smaller sample of sources in Sulentic et al. (2000b) as one might hope to see if the correlations are in some sense real. Table 4 emphasizes the spectroscopic differences between RQ versus RL sources by showing no evidence for correlations among 4DE1 parameters.
parameters for RL sources. Real or marginal correlations are only found among RQ sources with the strongest correlations involving $c(\frac{1}{2}), R_{Fe}$, and $\Gamma_{soft}$. Restriction to a BG92 overlap subsample shows no significant difference in correlation coefficients.

3. EVIDENCE FOR TWO POPULATIONS OF BROAD-LINE AGNs

So far we have compared sources on the conventional basis of a RQ versus RL dichotomy; however, it is important to point out that about 25% of RQ sources in our sample occupy the same 4DE1 parameter domain as the RL AGNs. If 4DE1 parameters reflect broad-line physics/kinematics, then this overlap may be important. The restricted 4DE1 parameter space occupation for RL sources motivated us (Sulentic et al. 2000b) to hypothesize the existence of two AGN “populations” (A and B) defined in an optical spectroscopic context (4DE1) rather than on the basis of radio loudness. Following our scheme, Population A sources show $\text{FWHM}(H_{\alpha}/C_{12BB}) \leq 4000$ km s$^{-1}$, strong $R_{Fe}$, strong $\Gamma_{soft}$ (a soft X-ray excess), and a $c(\frac{1}{2})$ blueshift with estimated probability of radio loudness $P \leq 0.01$. Population B sources show $\text{FWHM}(H_{\alpha}/C_{12BB}) \geq 4000$ km s$^{-1}$, weak $R_{Fe}$, no soft X-ray excess, or $C_{iv} \lambda 1549$ blueshift with estimated probability of radio loudness $P \approx 0.30$. Revisiting Figure 2a in the Population A-B context shows that $C_{iv} \lambda 1549$ blueshifts are strongly concentrated among Population A sources with $\text{FWHM}(H_{\alpha}/C_{12BB}) \leq 4000$ km s$^{-1}$. Filled and open symbols in Figure 2 identify Population A and B sources, respectively. It is important to point out that $\text{FWHM}(H_{\alpha}/C_{12BB}) = 4000$ km s$^{-1}$ was chosen as a Population A-B boundary before $c(\frac{1}{2})$ was selected as an 4DE1 parameter. Population A-B is more effective than the RQ-RL distinction for highlighting spectroscopic differences.

Population B sources show a scatter of line shifts within $c(\frac{1}{2}) = \pm 2000$ km s$^{-1}$ (Table 2) with mean value in Table 3 consistent with zero shift. A large part of the Population B scatter...
may be associated with C iv \( \lambda 1549 \) measurement uncertainties (the 3 \( \sigma \) shift uncertainty is \( \approx 400 \) km s\(^{-1}\)). Figure 2 shows that Population A sources have a wider parameter dispersion than Population B sources. The majority of Population B sources are so concentrated that one can assign unique (within measurement errors) values of \( R_{\text{Fe}^{II}} \): 0.15 and \( \Gamma_{\text{soft}} \approx 2.1 \pm 0.5 \) to the entire population. These two values along with \( c(\frac{1}{2}) = -70 \pm 1000 \) km s\(^{-1}\) (consistent with 0) represent the 4DE1 coordinates with highest probability of radio-loudness.

The strong parameter concentration of Population B sources relative to the Population A RQ majority reinforces the interpretation (Sulentic et al. 2003) that RL quasars represent a distinct AGN population and perhaps the endpoint of quasar activity in sources with largest \( M_{\text{BH}} \) and lowest \( L_{\text{bol}} / L_{\text{Edd}} \). The obvious question then involves the relationship between Population B RQ sources and Population B RL AGNs. RQ sources in our sample have an average negative asymmetry index \((\approx 0.1)\), and a \( K - S \) test confirms a significant difference with the distribution for RL sources (whose average is +0.08). The simplest answer to the above question then would be that for a given \( M_{\text{BH}} \), RL sources lie at the extreme low end of an \( L_{\text{bol}} / L_{\text{Edd}} \) sequence; perhaps they are expiring quasars. Perhaps Population B RQ sources with lowest values of C iv \( \lambda 1549_{\text{BC}} \) shift are the RQ expiring quasars. In that case our Population B designation has a physical significance, although
we do not yet know what physical property allows/inhibits RL activity.

3.1. Population A and NLSy1s

The distinction between Populations A and B may be more fundamental than RQ-RL or NLSy1-BLSy1. Figure 2 shows that C iv k 1549 blueshifts are equally divided between sources with FWHM(Hβ) ≤ 2000 km s⁻¹ (traditional NLSy1) and sources with FWHM(Hβ) in the range 2000–4000 km s⁻¹ (BLSy1). A K – S test reveals no significant distribution difference between the two groups of sources suggesting that the 2000 km s⁻¹ cutoff for NLSy1 is artificial. The same is true for comparisons involving W(C iv λ1549), FWHM(C iv λ1549), and Γ soft parameter distributions. Only R Fe ii seems to show possible evidence for a difference (DKS ≈ 1.65 with probability P ≈ 0.01 that the two R Fe ii data sets are not drawn from the same parent population). Caution is needed because the precision of the R Fe ii measure depends on both S/N and the line width (Marziani et al. 2003a). Considering the similarity in Γ soft and C iv k 1549 centroid shifts (which are likely related accretion rate and disk wind properties) the Population A-B distinction can be viewed as a physically motivated redefinition of the NLSy1-BLSy1 boundary originally introduced by Osterbrock & Pogge (1985) and subsequently adopted by 4DE1 for different (RL) reasons.

![Fig. 1—Continued](image)

| IAU Code (1) | Common Namea (2) | zb (3) | z Ref. (4) | PG/BOc (5) | Aγ (mag) (6) | FWHM(Hβ) (km s⁻¹) (7) | RFe ii (8) | log(RX) (9) | Γ soft (10) |
|-------------|--------------------|--------|------------|------------|--------------|------------------------|------------|------------|------------|
| J00057+0203... | LBQS 0003+0146    | 0.234  | C97        |            | 0.10         | 3315                   | 0.26       | -1.00      | 3.08       |
| J00059+1609... | PG 0003+158       | 0.4504 | M03        | *          | 0.22         | 5519                   | 0.14       | 2.53       | 2.34       |
| J00063+2012... | Mrk 0335           | 0.0252 | M03        | *          | 0.15         | 1950                   | 0.28       | -0.54      | 2.90       |
| J00204+0226... | LBQS 0017+0209    | 0.401  | F89        |            | 0.10         | 2535                   | 1.07       | -1.00      | ...        |
| J00292+1316... | PG 0026+129       | 0.1451 | M03        | *          | 0.31         | 2405                   | 0.28       | -0.10      | 2.07       |
| J00392–5117... | [WPV85] 007       | 0.0290 | G99        |            | 0.05         | 1205                   | 0.68       | ...        | 9.00:      |
| J00449+1026... | [HBB99] 0042+101  | 0.5857 | SPM        |            | 0.29         | 8978                   | 0.40       | 0.00       | 2.48       |
| J00470+0319... | PG 0044+030       | 0.6231 | M03        |            | 0.09         | 5759                   | 0.19       | 1.83       | 1.72       |
| J00535+1241... | UGC 00545         | 0.0605 | M03        | *          | 0.28         | 1151                   | 1.30       | -0.47      | 3.10       |
| J00548+2525... | PG 0052+251       | 0.1543 | M03        | B          | 0.21         | 5772                   | 0.15       | -0.39      | 2.49       |

Notes.—A colon indicates a very unusual published measure. Table 1 is published in its entirety in the electronic edition of the Astrophysical Journal. A portion is shown here for guidance regarding its form and content.

a In a format recognized by NED.

b Accuracy of z-values can be in general assumed to be ±0.0001 at a 1σ confidence level in case four decimal digits are provided; ±0.001 otherwise.

c An asterisk (‘’) indicates that the sources belongs to the BG92 PG sample; a “B” indicates that the source is a “blue outlier” (Zamanov et al. 2002).

d From Schlegel et al. (1998).

References.—(M03) Marziani et al. 2003a; (G99) Grupe et al. 1999; (SDSS) Spectra retrieved from http://www.sdss.org; z-values were measured as described in the text of the paper and may differ from those reported in NED; (L67) Lynds 1967; (SPM) unpublished spectra obtained with the 2.2 m telescope at San Pedro Martir; (B96) Brotherton 1996; (ESO) unpublished ESO spectra; (KPN) unpublished KPNO spectra; (T93) Tadhunter et al. 1993; (JB91) Jackson & Browne 1991; (C97) Corbin 1997; (M96) Marziani et al. 1996; (W00) Wisotzki et al. 2000; (K96) Keel 1996; (EH04) Eracleous & Halpern 2004; (A91) Allen et al. 1991; (HB89) Hewitt & Burbidge 1989; (HB80) Hewitt & Burbidge 1980; (F89) Foltz et al. 1989.
| IAU Code       | $f_a^a$ | $F_{NC}^b$ | $\Delta_{NC}^c$ | $\epsilon_+^{(4)}$ | $\Delta_1^d$ | $\Delta_2^e$ | $\epsilon_0^{(9)}$ | $c(\Delta)$ | $\Delta$ | FWHM | $\Delta^f$ | Kurt. | $\Delta$ |
|---------------|---------|------------|-----------------|--------------------|--------------|--------------|--------------------|------------|---------|-------|---------|-------|---------|
| J00057+0203    | 0.55    | 0.23       | -726            | 4.0                | -824         | 331          | 560                | -455       | 121     | 120   | -404   | 110   | -365   | 78     | 4168     | 252   | -0.12 | 0.10  | 0.16   | 0.16  | 0.35   | 0.06   |
| J00059+1609    | 2.53    | 1.94       | -66             | 22.5               | 866          | 591          | 522                | 35         | 200     | 228   | -8     | 143   | -1     | 92     | 5347     | 455   | 0.16  | 0.12  | 0.10   | 0.12  | 0.29   | 0.04   |
| J00063+2012    | 7.97    | 7.33       | 314             | 50.7               | -221         | 259          | 229                | 19         | 98      | 94    | 147    | 81    | 195    | 53     | 2927     | 195   | -0.17 | 0.11  | 0.10   | 0.11  | 0.37   | 0.05   |
| J00204+0226    | 0.44    | 0.00       | ...             | 1.2                | -2426        | 174          | 155                | -2144      | 122     | 117   | -2063 | 140   | -2064  | 106    | 5378     | 244   | -0.10 | 0.07  | 0.07   | 0.07  | 0.50   | 0.05   |
| J00292+1316    | 2.82    | 1.64       | 95              | 8.5                | 1035         | 1077         | 244                | -501       | 199     | 215   | -201  | 261   | -19    | 160    | 8595     | 429   | 0.14  | 0.17  | 0.06   | 0.17  | 0.36   | 0.06   |
| J00392−5117    | 0.20    | A          | ...             | 2.0                | 338          | 262          | 265                | -78        | 108     | 186   | -54    | 81    | -6     | 55     | 3056     | 371   | 0.11  | 0.09  | 0.09   | 0.09  | 0.28   | 0.03   |
| J00449+1026    | 0.12    | 0.18       | 56              | 2.3                | 1433         | 846          | 705                | -37        | 268     | 281   | -124  | 203   | -144   | 125    | 7385     | 563   | 0.20  | 0.10  | 0.09   | 0.10  | 0.26   | 0.04   |
| J00470+0319    | 1.09    | 0.22       | 126             | 8.2                | -418         | 322          | 490                | -750       | 203     | 229   | -568  | 143   | -591   | 91     | 6274     | 458   | 0.03  | 0.07  | 0.10   | 0.10  | 0.33   | 0.04   |
| J00535+1241    | 3.25    | A          | ...             | 8.7                | -2264        | 338          | 212                | -1669      | 110     | 211   | -875  | 68    | -954   | 47     | 3804     | 422   | -0.47 | 0.07  | 0.06   | 0.07  | 0.27   | 0.04   |
| J00548+2525    | 2.11    | 0.74       | -378            | 27.7               | -104         | 767          | 649                | -800       | 292     | 289   | -624  | 177   | -604   | 107    | 6659     | 585   | 0.08  | 0.12  | 0.10   | 0.12  | 0.28   | 0.04   |

Note.—Table 2 is published in its entirety in the electronic edition of the *Astrophysical Journal*. A portion is shown here for guidance regarding its form and content.

$^a$ Specific continuum flux at 1550 Å in units of $10^{14}$ erg s$^{-1}$ Å$^{-1}$ cm$^{-2}$.

$^b$ Flux of C iv $\lambda 1549_{NC}$ in units of $10^{13}$ ergs s$^{-1}$ cm$^{-2}$.

$^c$ Flux of C iv $\lambda 1549_{NC}$ in units of $10^{13}$ ergs s$^{-1}$ cm$^{-2}$. The letter "A" indicates major absorptions (typically of mini-BALs) affecting the profile of C iv $\lambda 1549_{BC}$. The "a" indicates narrow absorptions that "eat away" C iv $\lambda 1549_{NC}$ but that do not hamper C iv $\lambda 1549_{BC}$ measurements.

$^d$ Flux of C iv $\lambda 1549_{BC}$ in units of $10^{13}$ ergs s$^{-1}$ cm$^{-2}$.

$^e$ Flux of C iv $\lambda 1549_{BC}$ in units of $10^{13}$ ergs s$^{-1}$ cm$^{-2}$.
3.2. Population Subdivision and Quasar Structure

Tables 3 and 4 show that the Population A-B discrimination is more effective than the RQ-RL distinction for emphasizing source differences. Table 3 shows that almost all sample mean differences between Populations A and B are larger than equivalent differences between RQ and RL. Since the entire RQ source population shows a larger parameter spread than Population A RQ sources alone, it should be more sensitive to correlation than Population A RQ alone. Table 4 confirms that in no case does the entire RQ sample show a higher correlation coefficient than Population A sources alone. In all cases the correlation coefficient improves (or remains the same) when we restrict the RQ sample to Population A RQ alone. We interpret these results as support for our hypothesis that the Population A-B distinction is more fundamental than that of RQ-RL. So far we have distinguished between

![Diagram](image-url)

Fig. 2.—4DE1 parameter planes involving C IV λ1549 BC profile shift at half-maximum [c(½), see text] vs. FWHM(Hβ_BC) in km s⁻¹ (top left), RFe ii (top right), and ΓFe ii (bottom left). Bottom right: c(½) normalized by EW C IV λ1549 BC in order to emphasize the difference between Population A and B sources which are denoted with filled and open symbols, respectively; RL sources are represented by squares and RQ by circles. The vertical line in the top left and bottom right panels marks the nominal Population A-B boundary. Dotted lines indicate ±2 σ confidence intervals for c(½) (see §2.2) meaning that sources within that range do not show significant C IV λ1549 line shift.

### Table 3

| AGN Pop          | Nsources | EW(C IV λ1549 BC) | c(½) C IV λ1549 BC | FWHM(C IV λ1549 BC) | FWHM(Hγ_BC) | RFe ii | ΓFe ii |
|------------------|----------|------------------|-------------------|--------------------|-------------|--------|--------|
| (1)              | (2)      | (3)              | (4)               | (5)                | (6)         | (7)    | (8)    |
| All QSO          | 130      | 93 ± 66          | −294 ± 837        | 5284 ± 1787        | 5387 ± 3268 | 0.36 ± 0.38 | 2.41 ± 0.58 |
| RQ only          | 71       | 84 ± 69          | −582 ± 860        | 4733 ± 1482        | 4100 ± 2681 | 0.48 ± 0.43 | 2.64 ± 0.63 |
| RL only          | 59       | 104 ± 60         | +52 ± 667         | 5946 ± 1905        | 6936 ± 3259 | 0.22 ± 0.25 | 2.15 ± 0.38 |
| Population A     | 52       | 57 ± 34          | −677 ± 966        | 4451 ± 1269        | 2604 ± 891  | 0.60 ± 0.45 | 2.67 ± 0.68 |
| Population B     | 78       | 117 ± 71         | −39 ± 627         | 5839 ± 1871        | 7242 ± 2943 | 0.20 ± 0.22 | 2.24 ± 0.43 |
Population A and B sources using FWHM $H_\beta_{BC}$ alone. The mean values given in Table 3 allow us to give best estimates for the Population A-B boundary using the other three principal 4DE1 parameters: $R_{Fe_{II}} \approx 0.4$, $\Gamma_{soft} \approx 2.60$, and $c(\frac{1}{2}) \approx 0$ km s$^{-1}$. One-dimensional projections of the 4DE1 space like Figures 2a–2c show a main sequence of source occupation/ correlation. The Population A-B concept reflects either a continuous variation in physical/geometric/kinematic properties along this sequence or a true source dichotomy possibly driven by a critical value of $L_{bol}/L_{Edd}$ (with Population B RQ-RL dichotomy due perhaps to BH spin, host galaxy properties, and a role for secular evolution in BH growth). In the former case Population A-B remain useful as a vehicle for emphasizing source extrema providing a valuable challenge to models of BLR structure/kinematics as well as changes in them due to physics and/or source evolution (Marziani et al. 2001, 2003b; Boroson 2002). In the past few years we have favored the possibility of two disjoint AGN populations on the basis of multifold evidence:

1. A possible gap or paucity of sources with FWHM($H_\beta_{BC}$) $\approx 4000$ km s$^{-1}$, which is also appreciable in, e.g., Figure 6 of Wang et al. (1996), Figure 2 of Boller (2004), Figure 1 of Sulentic et al. (2000b), Figure 3 of Baskin & Laor (2005), and most impressively in Figure 7 (right) of Corbin & Boroson (1996); see also Collin et al. (2006).

2. Most RL sources lie above FWHM $H_\beta_{BC}$ $\approx 4000$ km s$^{-1}$ while most RQ sources lie below this value. The few RL sources with FWHM $H_\beta_{BC} \leq 4000$ km s$^{-1}$ are likely viewed at an orientation that minimizes any rotational component associated with BLR motions (Sulentic et al. 2003; they fall there because of orientation rather than physics).

3. Sources with FWHM($H_\beta_{BC}$) $\leq 4000$ km s$^{-1}$ show average profiles well fit by a Lorentzian function, while broader line sources show profiles that are frequently redward asymmetric and that require two Gaussians for a reasonable fit (Sulentic et al. 2002).

4. Sources with FWHM($H_\beta_{BC}$) $\leq 4000$ km s$^{-1}$ often show a soft X-ray excess ($\Gamma_{soft} \approx 2.8$) while those above this limit almost never show one (Boller 2004; Sulentic et al. 2000c).

5. Sources with weak (usually less than 10 Å equivalent width) and blueshifted [O iii] $\lambda$5007 (the so-called blue outliers) are found only in sources with FWHM($H_\beta_{BC}$) $\leq 4000$ km s$^{-1}$ (Zamanov et al. 2002; Marziani et al. 2003b).
6. All sources with C iv $\lambda 1549$ $c(1/2) \leq -3000$ km s$^{-1}$ show FWHM $H_\beta_{BC} \leq 4000$ km s$^{-1}$ (Fig. 2a). Most sources with C iv $\lambda 1549$ $c(1/2) \leq -1000$ km s$^{-1}$ also lie below the same FWHM limit. Sources with broader $H_\beta_{BC}$ show a scatter of values between C iv $\lambda 1549$ $c(1/2) \pm 2000$ km s$^{-1}$. The $W$(C iv $\lambda 1549$) measures also show a strong difference (not correlation) in mean values for source greater and less than FWHM $H_\beta_{BC} = 4000$ km s$^{-1}$.

7. Comparison of C iv $\lambda 1549$ and $H_\beta_{BC}$ profiles suggests a discontinuity at FWHM($H_\beta_{BC}$) $\approx 4000$ km s$^{-1}$. FWHM($H_\beta_{BC}$) and FWHM(C iv $\lambda 1549$) are correlated above this value but not below (Marziani et al. 1996; Baskin & Laor 2005; see also our Table 4).

8. Figure 3 shows a possible new correlation between C iv $\lambda 1549$ FWHM and $c(1/2)$ measures. Comparison of Figures 3a and 3b for Population B and A sources, respectively, indicates that the correlation exists only for sources with FWHM($H_\beta_{BC}$) $\leq 4000$ km s$^{-1}$ (Population B sources show a scatter diagram). This C iv $\lambda 1549$ intercorrelation for Population A sources shows a reasonably strong correlation (correlation coeff. 0.5). The best-fit relation is $c(1/2) = 963 - 0.426FHW$C iv $\lambda 1549_{BC}$ in km s$^{-1}$.

The correlation in Figure 3 might be expected from (and constraining of) models that view Population A sources as the highest accreting AGNs that generate a disk wind (Murray et al. 1995; Bottorff et al. 1997; Proga & Kallman 2004). Previous results may also indicate a change in BLR structure, perhaps at a critical value of $L_{bol}/L_{Edd}$ [corresponding to FWHM($H_\beta_{BC}$) $\approx 4000$ km s$^{-1}$] with an accretion disk + outflowing high-ionization wind required to explain Population A source measures (Marziani et al. 1996, 2001, 2003a). Population B sources do not allow us to rule out the possibility of a single stratified emission region producing both LILs and HILs. Population A and B sources differ both mean properties that can be defined. Table 5 summarizes both phenomenological differences (mean values given where available) as well as some physical differences that can be inferred from the empiricism. Note that not all of the cited works make a distinction between Population A and B.

Table 3 shows that $W$(C iv $\lambda 1549_{BC}$) differs by a factor of $\approx 2$ between Population A and B sources, with Population A sources showing lower values. Since Populations A and B do not show a significant difference in mean source luminosity (Bachev et al. 2004), we ascribe the EW difference to a difference in $L_{bol}/L_{Edd}$ which is known to be stronger than the luminosity dependence (Bachev et al. 2004; Baskin & Laor 2004). Populations A and B differ systematically in $L_{bol}/L_{Edd}$, as shown by Marziani et al. (2003b, 2006). While not a principal 4DE1 parameter, it is clear that $W$(C iv $\lambda 1549_{BC}$) is an important measure.

4. C iv $\lambda 1549$ NARROW-LINE EMISSION

All tabulated parameter means and correlation coefficients discussed above depend on proper processing of the C iv $\lambda 1549$ spectra. Confusion exists about the reality and strength of a narrow-line C iv $\lambda 1549$ component (C iv $\lambda 1549_{NC}$) presumably arising from the same NLR as, e.g., [O iii] $\lambda 4959$, 5007 and narrow $H_\beta$. There is now no doubt that C iv $\lambda 1549_{NC}$ emission is common in AGNs (see also Sulentic & Marziani 1999). High- and low-redshift type 2 AGNs with obvious C iv $\lambda 1549_{NC}$ emission have recently been found in significant numbers (Barger et al. 2002; Jarvis et al. 2005; Norman et al. 2002; Stern et al. 2002; Szokoly et al. 2004; Mainieri et al. 2005; Severgnini et al. 2006). According to Meiksin (2006) only four confirmed high-redshift ($z > 1.6$) type 2 AGNs are known (references marked with an asterisk above). All four show prominent C iv $\lambda 1549_{NC}$ (see also Dawson et al. 2001).

In contrast to H$\beta$ a clear, unique NLR/BLR inflection is less often seen in the C iv $\lambda 1549$ profiles making NLR correction less certain. This is not surprising when one considers that the intrinsic velocity resolution at C iv $\lambda 1549$ is 3 times lower than at H$\beta$. NLR C iv $\lambda 1549$ can also be broader than other narrow lines because (1) it is a doublet with $\Delta v \approx 500$ km s$^{-1}$ and (2) it can arise in denser-than-average parts of the NLR (as for O iii $\lambda 4363$; e.g., Marziani et al. 1996; Sulentic & Marziani, 1999). We argue
that cautious subtraction of a suitable narrow component is essential for exploiting the information content in the C iv λ1549 line (see Bachev et al. 2004). We subtracted a significant (W > 1 Å) NLR component from 76 of 130 sources in this sample. Figure 1 shows the individual C iv λ1549 profiles with narrow components indicated in order to assist visual assessment of the component on a source-by-source basis.

Baskin & Laor (2005) recently pointed out that our earlier C iv λ1549NC and C iv λ1549NC measurements (Marziani et al. 1996) were “nonunique.” Every experimental measure is nonunique, and the lack of uniqueness is customarily indicated by error bars. Rather than uniqueness, the question we are addressing is the motivation for relatively high density emission in the NLR. It is probably emitted by a reddening-free high-density origin and relationship to other narrow lines, it is present in the NLR component on a source-by-source basis.

The strong and relatively narrow core (FWHM ≤ 2000 km s⁻¹) observed in many C iv λ1549 profiles was previously noted and an ad hoc intermediate line region (ILR) was introduced in order to account for it (Brotherton et al. 1994; Brotherton & Francis 1999). The ILR was defined as having some properties typical of the canonical BLR necessitating the postulation of an additional VBLR component in order to explain the broad wings often seen in C iv λ1549 spectra (e.g., Fig. 1). Unfortunately, the ILR approach is not fully consistent because narrow C iv λ1549 cores are significantly narrower than corresponding HβRC profiles (Sulentic & Marziani 1999) which are a canonical BLR feature. They are sometimes as narrow as the [O iii] λ5007 lines. Intermediate ionization lines of C iv λ1909 and Si iii λ1892 measured in average spectra (Bachev et al. 2004) show widths that are more consistent with HβRC and much broader than the narrow cores of C iv λ1549 that we ascribe to the NLR. In addition density-sensitive ratios measured near the C iv λ1909 blend are consistent with BLR density (n, 10⁷ cm⁻³; see Brotherton et al. 1994; Bachev et al. 2004). This reinforces our interpretation that the hypothesized ILR+VBLR components as simply the more canonical NLR + BLR. The larger width of C iv λ1549NC compared to HβNC or [O iii] λ5007 can be easily explained within the framework of a density/ionization gradient within the NLR, as further described below.

Almost all other studies of C iv λ1549 line properties (Wills et al. 1995, 1999; Corbin & Boroson 1996; Vestergaard 2002; Warner et al. 2004) do not subtract C iv λ1549NC emission. Baskin & Laor 2005 assume that the width and strength of C iv λ1549NC and [O iii] λ5007 are correlated. In most cases this implies that the ratio C iv λ1549NC/O iii λ5007 ≤ 1. The physical relationship between forbidden [O iii] λλ4959, 5007 and permitted C iv λ1549NC is however unclear leaving little basis for assuming a fixed relation. The [O iii] λλ4959, 5007 lines often show a strong blue wing that might be described as a semibroad component. So-called blue outlier sources show this component and it is expected to be a strong C iv λ1549 emitter (Zamanov et al. 2002).

Our analysis suggests that C iv λ1549NC is likely absorbed by dust or is intrinsically weak in ≈50% of sources. Among the remainder, about 1/3 of the sources show C iv λ1549NC significantly broader than narrow Balmer and [O iii] λλ4959, 5007 emission. It is probably emitted by a reddening-free high-density (or high-ionization) innermost region of the NLR. Whatever its origin and relationship to other narrow lines, it is present in the spectra of many sources and will affect our efforts to parameterize C iv λ1549NC.

The motivation for relatively high density emission in the NLR stems from the clear evidence of relatively large C iv λ1549NC/O iii λ5007 intensity ratios in several sources: NGC 5548, NGC 7674, and I Zw 92 (Kraemer et al. 1994, 1998), with C iv λ1549NC/O iii λ5007 ≈ 2. In addition, even if Baskin &
Laor (2005) subtracted little C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$, the average nonzero subtraction for the 16 sources in common with the present study implies C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$/O$_{\text{iii}}$$\lambda 5007$ /O$_{\text{iii}}$$\lambda 5007$ /C$_{138}$$\lambda 5007$/C$_{25}$$\lambda 5007$. This value already indicates bulk emission from log $n_e$ = 5.5, much above the “standard” NLR density $n_e \sim 10^4$ cm$^{-3}$. The C$_{\text{iv}}$$\lambda 1549$/O$_{\text{iii}}$$\lambda 5007$ intensity ratio increases with density around the [O$_{\text{iii}}$] $\lambda\lambda 4959, 5007$ critical density because of the drastic collisional quenching that suppresses [O$_{\text{iii}}$] $\lambda\lambda 4959, 5007$ but not C$_{\text{iv}}$$\lambda 1549$. The observed FWHM differences between [O$_{\text{iii}}$] $\lambda\lambda 4959, 5007$, H$\beta_{\text{NC}}$ and C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ are recovered under standard assumptions if a density gradient is assumed for the NLR, with $3 \leq \log n_e \leq 7.8$ (Sulentic & Marziani 1999).

We suggest the following C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ subtraction procedure as the most reliable way to obtain reasonable and reproducible C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ measures.

**Step 1: Inflection.**—Sources showing a C$_{\text{iv}}$$\lambda 1549$ NLR/BLR inflection can be treated the same as H$\beta$ as long as the width/shift/intensity constraints given below are not violated. See the profiles in Figure 1 and Appendix discussion of PG 0026+126, which shows a strong profile inflection. There was no simultaneous fitting. The underlying C$_{\text{iv}}$$\lambda 1549_{\text{BC}}$ was fit with an high-order spline function. The overlying narrow component was set by bordering the fitting range at inflection points which defined a core that met the FWHM and flux ratio criteria described below. The FWHM was measured using a Gaussian fit or by measuring the half-maximum wavelengths if the profile was absorbed or very different from Gaussian.

**Step 1a: No inflection or multiple inflections.**—Most sources do not show an inflection or sometimes show multiple inflections between reasonable limits of width and strength. This motivates us to set a conservative limit on FWHM C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$. Simple models suggest that lines like C$_{\text{iv}}$$\lambda 1549$ can be significantly broader than [O$_{\text{iii}}$] $\lambda\lambda 4959, 5007$ but not C$_{\text{iv}}$$\lambda 1549$. The observed FWHM differences between [O$_{\text{iii}}$] $\lambda\lambda 4959, 5007$, H$\beta_{\text{NC}}$ and C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ are recovered under standard assumptions if a density gradient is assumed for the NLR, with $3 \leq \log n_e \leq 7.8$ (Sulentic & Marziani 1999).

We suggest the following C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ subtraction procedure as the most reliable way to obtain reasonable and reproducible C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ measures.

![Figure 4: C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ analysis. Top left: Luminosity distribution of C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ components identified in our HST sample [log L(C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$) in units of ergs s$^{-1}$; shaded histogram]; top right: FWHM distribution for C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$ components; bottom left: distribution of the ratio L(C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$)/L(O$_{\text{iii}}$$\lambda 5007$) for our HST sample (corrected for Galactic extinction) and for the sample of Baskin & Laor (2005). Bottom right: FWHM(C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$) vs. log L(C$_{\text{iv}}$$\lambda 1549_{\text{NC}}$) for our HST sample. Filled circles indicate Population A sources; open circles indicate Population B sources.](image-url)
FWHM $\approx 1200 \pm 300$ km s$^{-1}$ in 95% of sources with significant narrow emission (Fig. 4).

Step 2: Nebular Physics and Observations.—There is no strong upper limit for the expected C IV $\lambda1549$/O III $\lambda5007$ intensity ratio in the absence of internal dust extinction. Both high ionization and high density can produce an arbitrarily large ratio (Contini & Viegas 2001; Kraemer et al. 1998; Baldwin et al. 1995). We adopt C IV $\lambda1549$/O III $\lambda5007 \approx 10$, derived for the high-ionization region of NGC 5548 (Kraemer et al. 1998), as a strict upper limit. Using again observational results as a guideline, we consider Seyfert 1 sources in our sample that show prominent, unambiguous C IV $\lambda1549_{NC}$ (NGC sources, PKS 0518-45, and 3C 390.3). We find a large dispersion in the reddening-corrected C IV $\lambda1549_{NC}$/[O III] $\lambda5007$ ratio with a mean value $\approx 2$ and a maximum $\approx 5$ (NGC 3783). Therefore, we can safely regard an C IV $\lambda1549_{NC}$/[O III] $\lambda5007$ intensity ratio $\approx 5$ as an observationally defined boundary. If this condition is appropriate the ($A_g$-corrected) distribution of C IV $\lambda1549$/[O III] $\lambda5007$ intensity ratios (shown in Fig. 4) does not pose any special challenge, including the few sources for which $5 \leq C_{IV} \lambda1549_{NC}$/[O III] $\lambda5007 < 10$ (with an uncertainty of $\pm 50\%$ these sources are not significantly above our adopted limit of $5$).

Step 3: NRL shift.—In most sources the [O III] $\lambda5007$ and/or H$\beta_{NC}$ profile centroid is used to define the rest frame of a source. Limited available H I and CO measures of host galaxy emission support this definition except for a few extreme Population A (some but not all formally NLSy1s) blue outlier sources. We use the peak of H$\beta$ to define the source rest frame of blue outliers. The C IV $\lambda1549_{NC}$ profile centroid (Table 2) agrees with the optically defined rest frame in most sources. Of our sources, 90% show a C IV $\lambda1549_{NC}$ centroid within $\pm 400$ km s$^{-1}$. This is reasonable considering that the average FWHM(C IV $\lambda1549_{NC}$) = 1120 km s$^{-1}$ and that C IV $\lambda1549_{NC}$ is strongly sensitive to S/N. Shifts of several hundred km s$^{-1}$ are occasionally observed and may be due to (1) an intrinsic C IV $\lambda1549_{NC}$ blueshift, (2) narrow-line absorption that creates a spurious shift to the red (and, indeed, inspection of Fig. 1 reveals that this is the case for most sources where C IV $\lambda1549_{NC}$ appears to be significantly redshifted), and (3) poor rest-frame determination. However only five sources out of 29 with $|\Delta v_C|$(C IV $\lambda1549_{NC}$) $\geq 300$ km s$^{-1}$ show a $\Delta z \approx \pm 0.001$.

Figure 4 summarizes our C IV $\lambda1549_{NC}$ measures: line luminosity distribution of C IV $\lambda1549_{NC}$ (Fig. 4, top right), distribution of C IV $\lambda1549_{NC}$/[O III] $\lambda5007$ luminosity ratios (Fig. 4, bottom left), distribution of C IV $\lambda1549_{NC}$ FWHM measures (Fig. 4, top right), and distribution of C IV $\lambda1549_{NC}$ measures in the line luminosity–FWHM plane (Fig. 4, bottom right). Application of the above procedures resulted in a subtracted NLR component usually less than $W(CIV \lambda1549_{NC}) \approx 10$ A but with a few extreme cases, usually low-luminosity Seyfert 1s. RL sources show the largest fraction of detectable C IV $\lambda1549_{NC}$ components (0.71) compared to 0.48 for RQ AGNs. Our Population B sources show a slightly larger fraction of C IV $\lambda1549_{NC}$ components (0.63) than Population A (0.51). Some sources do not allow an unambiguous C IV $\lambda1549_{NC}$ subtraction with a significant range of acceptable solutions. This ambiguity and its effect on C IV $\lambda1549_{BC}$ are usually within the adopted errors (even if the effect on C IV $\lambda1549_{NC}$ is much larger), that have been estimated changing the fractional intensities levels by $\pm 5\%$. As described earlier, the random scatter in Galactic line radial velocity after realignment is just $\approx 40$ km s$^{-1}$. Therefore, it is possible that several C IV $\lambda1549_{NC}$ shifts are significant, because they show values larger than the expected calibration and measurement uncertainties.

Examining spectra in Figure 1 one will occasionally see a C IV $\lambda1549$ profile with a peak as narrow as some subtracted C IV $\lambda1549_{NC}$ (e.g., J13253$-$3824 and J15591+3501). In these cases subtraction of the sufficiently narrow peak would violate other selection rules (e.g., in the above two cases C IV $\lambda1549_{NC}$/[O III] $\lambda5007 > 10$). Note that we also verified a posteriori that the C IV $\lambda1549_{NC}$ FWHM was less than FWHM(H$\beta_{NC}$).

4.1. The Narrow Cores of C IV $\lambda1549$ Do Not Reverberate

An ideal check on our NRL results would involve reverberation mapping where any NLR component would be expected to remain stable. One International Ultraviolet Explorer (IUE) based study (Turler & Courvoisier 1998) reported PCA analysis on 18 AGNs with 15 or more independent spectra. Ten of the sources are included in our sample. The principal component in their study was interpreted to involve the parts of the C IV $\lambda1549$ line profile that varied with zero lag time. The approach of Turler & Courvoisier was to isolate the principal component dominated by continuum and broad-line variability. This was then subtracted from the mean spectrum to isolate the remaining information content (rest spectrum). Two things are seen in the rest spectrum: a narrow unshifted peak and more complex and extended wings. The nature of the wings will depend on the complexity and timescale of variations as well as the number and temporal spacing of source spectra. Component 1 can be reasonably argued to be the NLR component of the line, the correlated intensity component that dominated our two-dimensional analogy above.

In the case of 3C 273, only the continuum was present in the principal component. We identified and subtracted an NLR component in all 10 overlap cases. A narrow component of similar strength and width is seen in the second principal component spectra for nine of these cases (except 3C 273). The least ambiguous case involves 3C 390.3, where there is a clear inflection between NLR and BLR. In that case agreement is perfect. Other sources like QG Com, NGC 3783, and NGC 5548 also show strong agreement. The range of FWHM for the second principal component C IV $\lambda1549$ profiles $1-5000$ km s$^{-1}$, suggesting that the NLR is often blended with additional broad-line emission. However, the overall agreement between the central cores and our own estimates of NLR C IV $\lambda1549$ emission gives us confidence that we have developed a reasonable approach to correcting the C IV $\lambda1549$ line profiles. The alternative is to ignore the problem which we argue will lead to spurious results.

4.2. Comparison with Previous Work

Other recent studies of the C IV $\lambda1549$ profile, using the same HST archival spectra, subtracted little (Baskin & Laor 2005) or no (Wills et al. 1993; Corbin & Boroson 1996; Vestergaard 2002; Kuraszkiewicz et al. 2002, 2004; Warner et al. 2004) NLR component. Figure 5 compares our C IV $\lambda1549_{BC}$ FWHM and centroid shift $|c+\gamma|$ measures with equivalent values for sources in common with some of these studies. The bottom left panel of Figure 4 shows that Baskin & Laor (2005) subtracted a ($\sim 2-4$ times) smaller and more constant NLR component. Direct comparison with Kuraszkiewicz et al. (2002, 2004) is not possible, because they model the C IV $\lambda1549$ profile with multiple Gaussian components that do not correspond to our NLR and BLR interpretation. FWHM measures are strongly affected by undersubtraction of C IV $\lambda1549_{NC}$. The top left panel of Figure 5 compares our FWHM C IV $\lambda1549_{NC}$ measures with those of Baskin & Laor (2005) and Warner et al. (2004). Symbols for comparisons with Baskin & Laor (2005) (and Corbin & Boroson 1996) retain the Population A-B and RQ-RL distinctions used in
earlier figures. Our measures are systematically larger with the amplitude of FWHM increasing systematically with FWHM C\textsc{iv} \textsc{k}\textsc{i}n 1549BC. The bottom left panel compares our FWHM measures with Corbin & Boroson (1996) and shows similar disagreement. Correlations such as FWHM H\beta versus FWHM C\textsc{iv} \textsc{k}\textsc{i}n 1549 (Corbin 1991; Baskin & Laor 2005; Warner et al. 2004) found using uncorrected C\textsc{iv} \textsc{k}\textsc{i}n 1549 measures will likely be spurious, except possibly for the Population B sources. The most striking evidence for correlation is found in Figure 7 (right) of Corbin & Boroson (1996) involving NC-corrected H\beta\textsc{bc} and uncorrected C\textsc{iv} \textsc{k}\textsc{i}n 1549\textsc{bc} measures. One sees two groups of sources (Population A and B) each showing a positive trend but with different slopes for the two trends. The trends are displaced by \(\Delta\text{FWHM(C\textsc{iv} \textsc{k}\textsc{i}n 1549\textsc{bc})} = 3000 \text{ km s}^{-1}\) at about FWHM(H\beta\textsc{bc}) = 4000 km s\(^{-1}\). The “Population B” trend can be described as displaced toward smaller values of FWHM(C\textsc{iv} \textsc{k}\textsc{i}n 1549\textsc{bc}). Since narrow-line emission is systematically stronger in Population B (especially RL) sources we might expect those FWHM(C\textsc{iv} \textsc{k}\textsc{i}n 1549\textsc{bc}) measures to be more strongly affected by NC subtraction. Is the displacement entirely due to the lack of NC-corrected FWHM(C\textsc{iv} \textsc{k}\textsc{i}n 1549\textsc{bc}) measures? Much of the displacement disappears in our equivalent FWHM-FWHM plot, but the correlation seen for Population B sources (\(r_5 \approx 0.5\)) is stronger than for Population A (\(r_5 \approx 0.3\); not significant) and its extrapolation into the Population A domain predicts much smaller (3000 km s\(^{-1}\)) values for FWHM(C\textsc{iv} \textsc{k}\textsc{i}n 1549\textsc{bc}) than are observed. The right panels of Figure 5 compare our \(c(\frac{3}{4})\) measures with those from Baskin & Laor (2005; see also our Fig. 5, top) and Corbin & Boroson (1996; see also our Fig. 5, bottom). There is a systematic displacement of uncorrected shift measures toward smaller or even redshifted values in both comparisons. This will tend to diminish the Population A-B (or RQ vs. RL) differences that are highlighted in this paper. The systematic C\textsc{iv} \textsc{k}\textsc{i}n 1549 blueshift for Population A sources becomes much less obvious using NC-uncorrected C\textsc{iv} \textsc{k}\textsc{i}n 1549 measures and especially using shift measures taken closer to the profile peak [e.g., \(c(0.9)]\). Figure 5 shows systematic differences between corrected and
uncorrected measures that will erase or obscure important C iv λ1549 results like the ones discussed in this paper.

5. $M_{\text{BH}}$ CALCULATIONS USING C iv λ1549 WIDTH

C iv λ1549 has become the line of choice for black hole mass estimation in high-z quasars. It is a dangerous choice for at least two reasons: (1) it shows a systematic blueshift in many sources, and (2) FWHM C iv λ1549 BC does not correlate strongly or monotonically with FWHM Hβ BC, the line of choice for low-redshift $M_{\text{BH}}$ estimation. Reason (1) does not necessarily rule out a virialized distribution of emitting clouds, but it certainly motivates caution when using the line to infer black hole mass. Blueshifted C iv λ1549 profiles are thought to arise in a high-ionization wind resulting in a velocity flow that is not negligible relative to any rotational component (Murray et al. 1995; Proga & Kallman 2004). We think use of C iv λ1549 warrants even more caution, because we see different line properties for Population A and B (or alternatively RQ and RL) sources. This raises the possibility that the geometry/kinematics of the C iv λ1549 emitting region may be fundamentally different in Population A and B sources. The population distinction is at least useful and possibly fundamental, because it maximizes source discrepancies. FWHM Hβ BC and C iv λ1549 BC are most similar (Table 3) for RQ sources that show mean FWHM(C iv λ1549 BC) only ≈600 km s$^{-1}$ larger than FWHM(Hβ BC). The RQ source distinction will therefore yield reasonable agreement between the two $M_{\text{BH}}$ estimators. The same is true for sources under the RL distinction where FWHM(C iv λ1549 BC) is ≈900 km s$^{-1}$ broader. Both differences are approximately 15%–16% of the mean RQ and RL profile widths, respectively.

The two lines show larger differences when sources are divided using the Population A-B distinction where ∆FWHM(Hβ BC) = FWHM(C iv λ1549 BC) – FWHM(C iv λ1549 BC) ≈−1900 km s$^{-1}$ and ≈±1400 km s$^{-1}$ for Population A and B, respectively. These discrepancies amount to ~56% and ≈±21% of FWHM(C iv λ1549 BC) + FWHM(Hβ BC)/2 for Population A and B, respectively. This is larger than the measurement uncertainties for FWHM measures of both lines and further supports the utility of the Population A-B concept. The two estimators will yield $M_{\text{BH}}$ estimates that are more discrepant. Adopting the Population A-B distinction as more useful than the RQ-RL one then finds the largest Population A-B differences using FWHM(Hβ BC) where ∆FWHM(A-B) ≈−4600 km s$^{-1}$ compared to −1400 km s$^{-1}$ using FWHM(C iv λ1549 BC). The corresponding differences for the RQ-RL distinction are ∆FWHM(RQ-RL) ≈−2800 km s$^{-1}$ (Hβ BC) and −1200 km s$^{-1}$ (C iv λ1549 BC).

As already pointed out (e.g., Marziani et al. 1996) the intrinsic dispersion of FWHM C iv λ1549 BC is less than for FWHM Hβ BC making it less sensitive to differences between source populations. Since FWHM C iv λ1549 BC measures are less accurate than FWHM Hβ BC values derived from BH masses, using the former will blur out any trends obtained with Hβ BC measures. FWHM C iv λ1549 BC-derived masses will yield much larger $M_{\text{BH}}$ estimates for Population A and smaller values for Population B. If one prefers to avoid the Population A-B distinction then one will find smaller C iv λ1549 BC–Hβ BC differences using the RQ-RL distinction perhaps encouraging the incorrect assumption that a simple correlation exists between the two sets of $M_{\text{BH}}$ measures. The smaller difference between mean FWHM values has also caused some to conclude that RQ and RL sources have similar $M_{\text{BH}}$ distributions and mean values. Even if FWHM(C iv λ1549 BC) could be measured with equal accuracy and confidence about viriality, like FWHM(Hβ BC), it would be a less useful $M_{\text{BH}}$ estimator, because it shows less dispersion. The main source of disagreements about $M_{\text{BH}}$ similarities and differences among AGN samples involves Population B RQ sources. Combining them with narrower lined RQ sources will raise the mean value of $M_{\text{BH}}$ for that population with only a small effect on the RL results. It will tend to equalize the means.

Estimates of $M_{\text{BH}}$ were obtained from the UV flux density and FWHM C iv λ1549 BC reported in Table 2, as well as for the corresponding data from Baskin & Laor (2005, their Table 1), assuming Hubble constant $H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$ and relative energy density $\Omega_M = 0.7$ and $\Omega_{\Lambda} = 0.3$. Values of $M_{\text{BH}}$ were derived following the latest normalization of Vestergaard & Peterson (2006) which uses the same cosmological parameters. The top panel of Figure 6 compares C iv λ1549−based $M_{\text{BH}}$ estimates of Baskin & Laor (2005; based on slightly C iv λ1549 NC−corrected C iv λ1549 measures) with the NC-corrected estimates derived from this paper. We see that Baskin & Laor (2005) measures are systematically low and that the difference from our results increase with $M_{\text{BH}}$. This comparison involves only sources in common between the two studies and involves only a 2 dex range in $M_{\text{BH}}$. The differences between our measures and completely uncorrected C iv λ1549 profiles will be larger. We note that both Population A and B sources show this disagreement. The middle panel of Figure 6 compares $M_{\text{BH}}$ measures based on FWHM C iv λ1549 BC and Hβ BC. We show the ratio of C iv λ1549 BC/Hβ BC−derived $M_{\text{BH}}$ measures as a function of Hβ BC−derived $M_{\text{BH}}$. The Hβ BC and continuum flux density measures come from Marziani et al. (2003a). The latest normalization of Vestergaard & Peterson (2006) was applied to these data, too.

We suggest a corrected FWHM(Hβ BC) measure [reduced by a fraction dependent on FWHM(Hβ BC)] as likely to be the most reliable virial estimator for reasons described in Sulentic et al. (2006a). The middle panel of Figure 6 suggests that (NC-corrected) C iv λ1549−based $M_{\text{BH}}$ estimates for Population B sources are more consistent with ones computed from the corrected Hβ BC width. However, the scatter is large and our C iv λ1549 regression line is 0.2 dex higher than for $M_{\text{BH}}$ derived from Hβ BC. The most serious disagreement involves Population A sources (≈60% of RQ sources) which show a trend where the $M_{\text{BH}}$ ratio increases with decreasing $M_{\text{BH}}$. This does not allow one to easily correct C iv λ1549−computed $M_{\text{BH}}$ for Hβ BC values unless information on the optical spectrum (rest-frame and Hβ BC line width) is available. We made several attempts to deduce a correction for C iv λ1549−derived $M_{\text{BH}}$ values from properties intrinsic to the C iv λ1549 profile shape (i.e., width, asymmetry, and kurtosis) but were unable to find an effective relationship. Perhaps the most effective relationship we found involves the one shown in the bottom panel of Figure 6, which shows that the ratio of $M_{\text{BH}}$ derived from C iv λ1549, and Hβ BC is loosely correlated with $W(C$ iv λ1549 BC) [for $W(C$ iv λ1549 BC) $\leq$ 10 Å], C iv λ1549 BC and Hβ BC estimates of $M_{\text{BH}}$ show better agreement for larger values of $W(C$ iv λ1549 BC). Caution is advised because equivalent width measures may be affected by continuum reddening. We also suffer from a relatively small sample of sources with $W(C$ iv λ1549 BC) $\geq$ 100 Å. Our fears about C iv λ1549−derived estimates for $M_{\text{BH}}$ have motivated us to pursue Hβ to the highest possible redshift, and we have recently presented Hβ BC−derived $M_{\text{BH}}$ estimates out to z = 2.5 (Sulentic et al. 2004 2006a).

If NLR C iv λ1549 follows [O iii] λ5007, then we expect the strongest and most frequent C iv λ1549 NLR to affect Population B sources. Uncorrected C iv λ1549 profiles in Population B sources will then be measured with systematically narrow FWHM C iv λ1549. Using this measure for $M_{\text{BH}}$ estimation will result in systematic underestimation. This explains why many previous studies found little or no difference in $M_{\text{BH}}$ estimates for RQ and
AGNs are widely compared and contrasted in two ways: (1) RQ versus RL and (2) NLSy1 versus broad-line Seyferts/quasars. We suggest an alternate approach that unifies both of these distinctions and that is supported by differences in C iv \( \lambda 1549 \) line measures. We find that sources above and below FWHM H\( \beta \) show the most significant spectroscopic (and broadband) differences. RL sources lie largely above this limit, while NLSy1 lie below it. We find that all or most sources below 4000 km s\(^{-1}\) show properties similar to NLSy1s. Figure 2 (top left) in this paper particularly reinforces this similarity by showing that almost all sources with FWHM H\( \beta \) \( \leq 4000 \) km s\(^{-1}\) show a systematic C iv \( \lambda 1549 \) blueshift. Our Population A-B concept simply reflects a unification where Population A sources show NLSy1-like properties and Population B sources show RL-like properties.

This paper addresses two thorny problems involving C iv \( \lambda 1549 \) measures and their interpretation: (1) when and how to correct C iv \( \lambda 1549 \) for NLR contamination and (2) whether C iv \( \lambda 1549 \) measures support previous claims, based on optical spectra (and radio loudness), for two populations (A + B) of broad-line AGNs. The second result actually clarifies the answer to the first problem. Evidence is now ubiquitous at both high and low redshift for significant C iv \( \lambda 1549 \) NLR emission in many sources. If we used [O iii] \( \lambda 5007 \) as a line template, then we would find fewer C iv \( \lambda 1549 \) components and those found would be narrower and weaker (i.e., lower EW). In several cases we find such an [O iii] \( \lambda 5007 \)–like component but in many sources our inferred C iv \( \lambda 1549 \) component is broader and hence stronger. We argue that empirical evidence (e.g., inflations in some sources and broader C iv \( \lambda 1549 \) in type 2 AGNs) as well as simple models support our hypothesis that C iv \( \lambda 1549 \) is often not "[O iii] \( \lambda 5007 \)–like.”

We argue that correlations found without NLR correction are very often spurious while real correlations (Figs. 2 and 3) require NLR correction to be seen clearly. We propose a simple recipe for C iv \( \lambda 1549 \) NLR correction. C iv \( \lambda 1549 \) proves to be a valuable 4DE1 space discriminator that provides evidence in support of our two population hypothesis in the sense that the C iv \( \lambda 1549 \) blueshift is ubiquitous only in previously defined Population A sources. These results have strong implications for any attempt to use C iv \( \lambda 1549 \) measures for black hole mass (and \( L_{\text{bol}} / L_{\text{Edd}} \)) estimation. We suggest that any use of C iv \( \lambda 1549 \) line measures can be facilitated by interpreting them within the 4DE1 + Population A-B context.

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APPENDIX

NOTES ON INDIVIDUAL OBJECTS

Most sources follow the 4DE1 trends described here and in previous papers. However, a few sources appear to be genuinely pathological. We mention a couple of such sources that appear as outliers in 4DE1 space and that are particularly relevant to the discussion involving C iv λ1549 measures.

3C 57.—c(\(\lambda_2\)) C iv λ1549 and \(R_{Fe}\) parameters typical of a Population A (even extreme Population A, NLSy1s) source \([c(\lambda_2) = -1605\, \text{km s}^{-1}, R_{Fe} \approx 1.25]\). The \(W(C iv \lambda1549)\) and profile shape are also typical of Population A (even similar to the ones of I Zw 1). At the same time it is RL, shows no soft X-ray excess, and FWHM(H\(\beta_{GC}\)) ≈ 4700 km s\(^{-1}\) all consistent with Population B.

PG 0026+126.—This quasar is moderate RQ Population A, following the current 4DE1 empiricism, because FWHM(H\(\beta_{GC}\)) ≈ 2400 km s\(^{-1}\) and \(R_{Fe} \approx 0.28\). There are two possible interpretations of the C iv λ1549 profile: (1) FWHM C iv λ1549 ≈ 1860 km s\(^{-1}\) and \(c(\lambda_2) = +140\, \text{km s}^{-1}\) if the strong narrow peak is not subtracted or (2) FWHM C iv λ1549 ≈ 7000 km s\(^{-1}\) and \(c(\lambda_2) = -1000\, \text{km s}^{-1}\) if the narrow peak is subtracted as a NLR component. This last approach seems especially appropriate, since FWHM of the C iv λ1549 narrow core only slightly exceeds (10%–20%) FWHM([O iii] λ5007). The source is a FWHM C iv λ1549 “outlier,” whichever C iv λ1549 measure is adopted, either unusually narrow or unusually broad (see Fig. 3). \(R_{Fe}\) and \(\Gamma_{Th}\) measures are intermediate for the source and therefore unconstraining. Note that an erroneous rest frame is often assumed for this source (Gelderman & Whittle 1994). The most accurate redshift for the source corresponds to the centroid of the narrow component which is consistent with the NLR interpretation. This also yields a modest blueshift for the broader component which is also unconstraining. The strong profile inflection and small FWHM for the unshifted narrow component lead us to subtract it as NLR emission. RQ sources like NGC 4253 and 4395 show further evidence of a NLR component.

PKS 1252+119.—Is the highest-z quasar in our sample. H\(\beta\) is consequently located at the edge of an excellent SDSS spectrum, making measures of FWHM(H\(\beta_{GC}\)) uncertain. The reported \(R_{Fe}\) is the only upper limit in our sample (marked with an arrow in our Fig. 2). This source may be located in an area of the 4DE1 optical plane where other core-dominated RL sources are found (Fig. 1 of Sulentic et al. 2003), but confirmatory optical data are needed.

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