3C 57 as an Atypical Radio-Loud Quasar: Implications for the Radio-Loud/Radio-Quiet Dichotomy

J.W. Sulentic†, M. A. Martínez-Carballo, P. Marziani, A. del Olmo, G. M. Stirpe, S. Zamfir, I. Plauchu-Frayn

1 Instituto de Astrofísica de Andalucía, IAA-CSIC, Glorieta de la Astronomía s/n, Granada, 18008, Spain
2 INAF, Osservatorio Astronomico di Padova, vicolo dell’ Osservatorio 5, Padova, 35122, Italy
3 INAF-Osservatorio Astronomico di Bologna, via Ranzani 1, Bologna, 40127, Italy
4 Department of Physics & Astronomy, University of Wisconsin, Stevens Points, USA

Abstract
Lobe-dominated radio-loud (LD RL) quasars occupy a restricted domain in the 4D Eigenvector 1 (4DE1) parameter space which implies restricted geometry/physics/kinematics for this subclass compared to the radio-quiet (RQ) majority of quasars. We discuss how this restricted domain for the LD RL parent population supports the notion for a RQ-RL dichotomy among Type 1 sources. 3C 57 is an atypical RL quasar that shows both uncertain radio morphology and falls in a region of 4DE1 space where RL quasars are rare.

We present new radio flux and optical spectroscopic measures designed to verify its atypical optical/UV spectroscopic behaviour and clarify its radio structure. The former data confirms that 3C 57 falls off the 4DE1 quasar “main sequence” with both extreme optical Fe II emission ($R_{FeII} \sim 1$) and a large Crv,1549 profile blueshift ($\sim -1500$ km s$^{-1}$). These parameter values are typical of extreme Population A sources which are almost always RQ. New radio measures show no evidence for flux change over a 50+ year timescale consistent with compact steep-spectrum (CSS or young LD) over core-dominated morphology. In the 4DE1 context where LD RL are usually low $L/L_{Edd}$ quasars we suggest that 3C 57 is an evolved RL quasar (i.e. large Black Hole mass) undergoing a major accretion event leading to a rejuvenation reflected by strong Fe emission, perhaps indicating significant heavy metal enrichment, high bolometric luminosity for a low redshift source and resultant unusually high Eddington ratio giving rise to the atypical Crv,1549.

Key words: quasars: general – quasars: emission lines – quasars: line: profiles – quasars: individual: 3C 57

1 INTRODUCTION

The origin of radio-loudness in quasars remains a perplexing question fifty years after their discovery. Ironically radio-loud (RL) quasars were the first to be discovered despite the fact that today they account for only 8% of the low redshift quasar population. After 50+ years we do not know if RL quasars represent a distinct physical subset of the radio-quiet (RQ) quasar population or simply episodes through which all or most quasars pass. There is even confusion about the definition of a RL (or a RQ) quasar. In this paper we simplify the problem by focussing only on low redshift ($z \lesssim 0.7$) Type 1 AGN/quasars that show broad (most in the range FWHM Hβ =1000 – 12000 km s$^{-1}$) emission line spectra including optical Fe emission. We assume that they represent the parent population of highly accreting AGN and interpret them in the 4DE1 context (Sulentic et al. 2000a, 2007; Zamfir et al. 2008, hereafter Z08).

We can unambiguously define a RL Type 1 quasar if we consider only the lobe-dominated (LD) RL sources which we assume to be the parent population of classical Type 1 RL quasars. They show radio/optical flux ratios $R_K > 70$, or better, log $L_{1415MHz}$ $> 31.6$ erg s$^{-1}$ Hz$^{-1}$. “Better” because we avoid sensitivity of optical flux measures to internal extinction/galaxy orientation effects. No bona fide LD sources are found below our specified limits. Our RQ-RL boundary is set by the radio luminosities of the weakest sources showing LD radio morphology (Sulentic et al. 2003). At low redshift ($z < 0.7$) LD structure is seen only in quasars with bolometric luminosity brighter than log $L_{bol}$ = 44.0 erg s$^{-1}$. The 46 LD sources analysed by Z08 using an SDSS DR5 subsample of 470 quasars ($z < 0.7$ and brighter than $g=17.5$ or $i=17.5$) show a radio luminosity range of nearly 3 dex (log $L_{1415MHz}$ =31.7-34.4 erg s$^{-1}$ Hz$^{-1}$) and also a 3dex optical range (log $L_{bol}$ =44-47 erg s$^{-1}$).
Core-dominated (CD) radio sources cannot be used to define a RQ-RL boundary because they span a radio luminosity range of 6 dex ($\log L_{1415MHz} = 29 - 35$) from weak radio-detected RQ to the most luminous RL sources found in SDSS DR5 (Z08 supplemented by de Vries et al. 2004). This corresponds to $R_K$ values from less than 10 to several thousand. The highest luminosity CD sources are interpreted as relativistically boosted LD sources oriented preferentially to our line of sight. Such sources often show apparent superluminal motions (e.g. Zensus et al. 2002). As we proceed from the strongest towards weaker CD sources, and approach radio luminosities $\log L_{1415MHz} \approx 31.6 \ erg \ s^{-1} \ Hz^{-1}$ the problem becomes acute. They are not luminous enough to be aligned or misaligned LD sources. Across our adopted RQ-RL boundary ($R_K=70$) only CD (and weak core-jet) sources are found and in numbers increasing with decreasing radio power. A survey of radio emission for PG quasars (Kellermann et al 1989) led to a suggested RQ - RL boundary near $R_K=10$ using both LD and CD detections. The choice of this boundary rather than $R_K=70$ can have strong effects on statistical inferences when searching for differences between RL and RQ sources.

Contextualization can be helpful in relating quasar subclasses as well as the relation of individual sources to specific subclasses. Towards this goal we adopted a 4D Eigenvector 1 parameter space (Sulentic et al. 2000, 2007) based on four diagnostic measures: 1) Full width half maximum (FWHM) of broad (BC) $H\beta$; 2) Flux ratio of optical Fe$\lambda$4570 blue blend and broad $H\beta$ ($R_{Fe\beta}$); 3) profile shift at half maximum of high ionization C IV $c(1/2)$ and 4) soft X-ray photon index ($\Gamma_{soft}$). In the 4DE1 domain RL sources do not distribute like the RQ majority but instead show a preference for FWHM$H\beta > 4000 \ km \ s^{-1}$, $R_{Fe\beta}<0.5$, unshifted C IV profile and absence of a soft Xray excess (i.e., $\Gamma_{soft} \approx 2$). This is especially true for the LD RL parent population. Figure 1 shows the 4DE1 optical plane for the SDSS DR5 quasar sample (Z08) with LD RL marked as filled red squares, luminous CD sources ($\log L_{1415MHz} > 32.0$) as filled blue squares and RQ quasars as filled grey circles. We designate sources above and below FWHM$H\beta > 4000 \ km \ s^{-1}$ as Population B (Pop B) and Population A (Pop A) respectively. The difference in 4DE1 domain occupation can be argued to be evidence that RL sources (the majority are Pop B) are fundamentally different from RQ quasars. However this interpretation is complicated by the fact that ~40% of RQ sources also occupy the same (Pop B) domain as the RL sources.

This paper considers an apparently nonconformist quasar 3C 57 ($z=0.67$) that is unambiguously RL ($\log L_{1415MHz} \approx 34.4 \ erg \ s^{-1} \ Hz^{-1}$ and $R_K \sim 3.0$). As such we expect it to show RL typical (average) 4DE1 parameter measures: 1) FWHM $H\beta_{BC} \approx 6940 \ km \ s^{-1}$; 2) $R_{Fe\beta} \approx 0.22$; 3) C IV $c(1/2) \approx +50 \ km \ s^{-1}$ and 4) $\Gamma_{soft} \approx 2.15$ (Sulentic et al 2007). In two of the four measures, 3C 57 is wildly discordant showing: $R_{Fe\beta} \approx 1$ and C IV blueshift $c(1/2) \approx -1500 \ km \ s^{-1}$ (Sulentic et al 2007 and this paper). These values are even extreme for RQ Pop A quasars. RL sources have average values of C IV $c(1/2) \approx -580 \ km \ s^{-1}$ and $R_{Fe\beta} \approx 0.48$ (Marziani et al. 1996; Sulentic et al 2007; Richards et al 2011).

New spectra were obtained for 3C 57 with three motivations: 1) to verify FWHM $H\beta$ and confirm the previous unusually high $R_{Fe\beta}$ measures, 2) to search for changes in the $H\beta$ profile that are sometimes observed in RL sources (Corbin & Smith 2000) and 3) to obtain high S/N line profile measures of MgII$\lambda$2800 for use as a potentially more reliable Black Hole (BH) mass estimator (Marziani et al 2013). New radio observations were also obtained to shed light on the ambiguous morphological interpretations of 3C 57. It is very radio luminous and its apparent core-jet structure leads us to expect flux variations over the 50+ year time span since its discovery.

The HST archive contained usable spectra for 130 low $z$ quasars as of late 2006 with a strong bias for RL sources. Figure 2 shows a UV-optical plane of 4DE1 where FWHM $H\beta_{BC}$ vs. $R_{Fe\beta}$. Filled red squares are LD RL sources, filled blue square CD RL sources following the definition of Zamfir et al. (2008) with weaker CD RL ($\log L_{1415MHz} < 32.0 \ erg \ s^{-1} \ Hz^{-1}$) omitted for clarity. Filled grey circles correspond to RQ quasars. The HST archive contained usable spectra for 130 low $z$ quasars as of late 2006 with a strong bias for RL sources. Figure 2 shows a UV-optical plane of 4DE1 where FWHM $H\beta_{BC}$ vs. $R_{Fe\beta}$. Filled red squares are LD RL sources, filled blue square CD RL sources following the definition of Zamfir et al. (2008) with weaker CD RL ($\log L_{1415MHz} < 32.0 \ erg \ s^{-1} \ Hz^{-1}$) omitted for clarity. Filled grey circles correspond to RQ quasars.

The HST archive contained usable spectra for 130 low $z$ quasars as of late 2006 with a strong bias for RL sources. Figure 2 shows a UV-optical plane of 4DE1 where FWHM $H\beta_{BC}$ vs. $R_{Fe\beta}$. Filled red squares are LD RL sources, filled blue square CD RL sources following the definition of Zamfir et al. (2008) with weaker CD RL ($\log L_{1415MHz} < 32.0 \ erg \ s^{-1} \ Hz^{-1}$) omitted for clarity. Filled grey circles correspond to RQ quasars.

New optical and radio observations are presented in Section 2 along with details of spectral analysis in 2.3. Section 3 presents results from analysis of new and literature data. Section 4 discusses the relation between RL quasars, C IV blueshifts, and the possible RQ-RL dichotomy. 4.3 considers how winds might be affected by radio outbursts while section 5 summarizes our inferences and conclusions.

### 2 OBSERVATIONS

New long slit optical spectroscopic observations of 3C 57 were carried out in three different telescopes: Calar Alto Observatory (CAHA, Almería Spain), El Roque de los Muchachos Observa-
3C 57 as an Atypical Radio-Loud Quasar: Implications for the Radio-Loud/Radio-Quiet Dichotomy

Figure 2. Location of 3C 57 and PKS 1252+11 in a 4DE1 UV-optical plane defined by normalized FWHM C ivλ1549 vs. R FeII. RL and RQ sources are marked as filled and open symbols respectively. Pop A sources are represented by black circles while Pop B by red squares.

Figure 3. New spectra for 3C 57 covering Mgiiλ2800 and Hβ in the rest frame. Abscissa is wavelength in Å and ordinate corresponds to specific flux in units of erg s⁻¹ cm⁻² Å⁻¹. NOT and Asiago spectra have been vertically displaced by -1×10⁻¹⁵ erg s⁻¹ cm⁻² and -2×10⁻¹⁵ erg s⁻¹ cm⁻² respectively for presentation.

Table 1. 3C 57 Optical Observations

| Observatory | ORM | CAHA | Asiago |
|------------|-----|------|--------|
| Tel        | NOT2.5m | 3.5m | 1.82m  |
| Instr.     | ALFOSC  | TWIN | AFOSC  |
| Scale      | 0.19"/px | 0.56"/px | 0.26"/px |
| Grism      | GR5     | T13 and T11 | GR4   |
| Slit       | 1.3"   | 1.2"   | 1.26"  |
| Disp       | 3.15Å/px | 2.14Å/px | 4.92Å/px |
| Range      | 5550-9400Å | 3400-5800Å | 5450-10150Å |
| Date       | 29Aug2011 | 22Oct2012 | 05Dec2012 |
| Texp       | 4x900s  | 3x900s | 3x1200s |

Table 2. Radio Measurements at 5 GHz

| Flux (mJy) | Reference |
|------------|-----------|
| 3C 57      |           |
| 1390 ±80   | Kuehr et al. 1981 |
| 1350       | Wright et al. 1990 |
| 1372 ±72   | Griffith et al. 1994 |
| 1441 ±30   | This paper (Observed in 2011) |
| PKS 1252+11|           |
| 1140 ±50   | Kuehr et al. 1981 |
| 1030 ±70   | Kuehr et al. 1981 |
| 641 VLA    | Laurent-Muehleisen et al. 1997 |
| 961 ±30    | This paper (Observed in 2011) |

tory (ORM La Palma, Spain) and Asiago Observatory (Italy), in three different runs within a 15 month period. Table1 summarizes the new data where we tabulate the instrumental setup for each observation as follows: telescope, spectrograph, spatial scale in arcsec/px, used grism, slit width in arcsec, spectral dispersion in Å/pix and wavelength range. We also report the date of observation and the total integration time. The slit was oriented at parallactic angle to minimize effects of atmospheric differential refraction in the spectra. In the case of the TWIN spectrograph at CAHA with two arms, the observations were obtained simultaneously in the blue (grism #T13) and red (#T11) spectral regions. The three new spectra are plotted in Figure 3 with CAHA, NOT and Asiago spectra shown in black, green and red respectively. NOT and Asiago spectra have been vertically shifted to avoid confusion.

Data reduction was carried out in a standard way using the IRAF package. Spectra have been overscan corrected, nightly bias subtracted and flat-fielded with the normalized flat-field obtained after median combination of the flats. Wavelength calibration was obtained using standard lamp exposures. The APALL task was used for object extraction and background subtraction. Instrumental response and flux calibration were obtained each night through observations of spectrophotometric standard stars from the list of Oke (1990) that we also use to remove telluric absorption bands.

New 5 GHz radio observations of 3C 57 were also carried out during November 14, 2011 using the single dish 32 m IRA-INAF antenna at Medicina in on-the-fly cross-scan mode. PKS 1252+11, the other known RL with a large C ivλ1549 blueshift, was also observed on Nov. 15 2011. Flux calibration was achieved using standard sources from the list of Ott et al. (1994). Fluxes and uncertainties that include calibrator uncertainty are reported in Table2

UV data have been taken from the HST-FOS archive. A re-analysis of UV spectra is presented in this paper. The 3C57 spectrum covers Siivλ1397, C ivλ1549 and Ciiiλ1909 and was presented in Sulentic et al. (2007).

2.1 Multicomponent $\chi^2$ analysis

All strong emission lines in the spectra were fit using the IRAF task SPECFIT which employs a $\chi^2$ minimization technique appropriate for nonlinear multicomponent analysis (Kriss 1994, Marziani et al 2009) provide a thorough description of analysis procedures for the optical spectral range. Marziani et al 2013 of the
Mg ii 2800 range and Negrete et al. (2014) for the UV spectral range.

All broad components were fit with Lorentzian profiles and the remaining lines with Gaussians (see 3.2 for a justification of this procedure). The specfit script task adopted a power-law continuum dominating over any host galaxy contribution (Mg II absorption band was not detected), as well as Fe v templates in both the optical and UV. We use the Fe templates obtained by Marziani et al. (2009) for the Hβ spectral region and Bruhweiler & Verner (2008) for the UV. The specfit script then scales and chooses an optical broadening factor for the template that minimises $\chi^2$. The $\chi^2$ minimisation procedures involve all components (continuum, Fe v, emitting line components, etc.) simultaneously in order to construct a model of the spectrum. This allows us to consider the [O iii] 4959 and [O iii] 5007 lines with proper physical constraints (same shift and FWHM and a ratio 1.3) (Dimitrijev et al. 2007), and to avoid any subjectivity in the placement of continuum. Spectral coverage was wide enough to ensure that a portion of continuum with no or faint emission features was available to the fitting routine. Since we are mainly interested in a detailed reproduction of line profiles, a local continuum was fit for each spectral region considered in this study. Fig. 4 shows the continuum and Fe v placement from the specfit analysis of the Hβ spectral range as an example of our approach. The fitting routine allows for the pseudo continuum created by Fe v emission and the fitted spectral range is wide enough to include wavelength intervals where the pseudo-continuum is low. Note that the continuum and Fe v emission were not set a priori, but computed in the same minimum $\chi^2$ fits that allowed us to retrieve Hβ and other emission line parameters. Line fits (after continuum subtraction) are shown in Fig 5. All fits were carried out over a wide wavelength range; however, we show four windows restricted to a lower range of the Hβ (CAHA), Mg ii 2800 (CAHA), [C ii] 15090 blend (FOS) and C iv 1549 (FOS) centroids to facilitate comparison. Residuals are shown below each fit.

We used a window from 4200Å to 5500 Å to fit Hβ which include Hγ+[O iii] 4363, Hε and [O iii] 4959, 5007. Fits (see Fig 5) assume that [O iii] 4959 and [O iii] 5007 have the same FWHM for narrow and blueshifted semibroad components and that their flux ratio is $\phi$4959/[O iii] 5007=1/3. Two components, narrow (NC) and broad (BC), were considered to model Hβ. We also fit Hγ assuming the same components (narrow and broad) as Hβ (and same FWHM values). From the Hβ fits we obtain also an optical Fe ii flux (9x10^15 erg s⁻¹ cm⁻²) that together with measures of Hβ (9x10^15 erg s⁻¹ cm⁻²) yields an estimate of 4DE1 parameter $R_{\mathrm{Feii}}$ (~1).

Modelling of Mg ii 2800 used a 2600Å – 3050Å window where only this blend was detected. Each line of the Mg ii 2800 doublet was fitted by assuming broad, narrow and semi-broad blueshifted components (Fig 5b). The spectral window 1720Å – 1960Å includes C iv 1909, Si iv 1814 (in yellow), Al iii 1860 (in green), Si iii 1892 (in orange) and Fe ii 1914. FWHM of broad components of Si iv 1814, the doublet of Al iii 1860, and Si iii 1892 are assumed to have the same value as C iv 1909. We also assume a narrow component for C iv 1909. For the sake of comparison we expand the window to 2045Å in Fig 5c.

The C iv 1549 model (Fig 5d) includes unshifted and blue components (in black and blue respectively) and the fits to N iv 11486 (in cyan), Si iv 1533, He i 1640 and O ii 1665. We assume that He i 1640 also shows broad and blue components (shown in brown and violet respectively) with the same FWHMs and shifts as broad and blue C iv 1549. All these measurements are listed in Table 4 where we include measures of equivalent width, flux, FWHM and shift (with respect to the narrow component). We give broad, blue and total fitting parameters for C iv 1549. Reported uncertainties have been computed by measuring the effect, on each parameter, of the change of continuum placement. To do that we repeat the specfit analysis changing the continuum by +/- 1 sigma level, that for the S/N accounted in the spectra means 2-3%. We also add quadratically the formal fitting error provided by specfit. The corresponding uncertainties are in agreement with those obtained for similar S/N data by Marziani et al. (2003a, 2013b, 2014) and Marziani & Sulentic (2014). For the heavily blended lines at 1900Å FWHM and intensity uncertainties were estimated through a $\chi^2$ analysis of a mock spectrum with the same S/N and intensity ratio and line width (as done in Negrete et al. 2014).

3 RESULTS

3.1 3C 57: A Steep Spectrum Radio-Loud Source

3C 57 shows strong radio emission with log $L_{1415MHz}$ = 34.4 erg s⁻¹ (Griffith et al. 1994) and $R_d$ ~ 1400 (see Table 4). Both parameters indicate a classical RL quasar. 3C 57 has been a dangerous source in the past because of its compact structure leading to inclusion in samples of CD sources (Wills et al. 1993) while its steep spectrum (SS: $\alpha = -0.7$) warned that it was resolved (Morganti et al. 1993). More recent VLA maps (Reid et al. 1999) finally resolved the central core source into an elongated structure. The optical position of the quasar lies near the centre (see Fig 6) of the elongated source suggesting that it could be an LD RL with lobe separation of ~1.5 arcsec. If the two peaks are interpreted as lobes then the flux ratio suggests some degree of alignment towards our line of sight. If the quasar coincides with the weaker (north) peak then a core-jet morphology would be implied putting it in the same class as PKS 1252+11. The small separation (17 kpc projected) also suggests either a preferred alignment and/or a young LD. A satellite component about 15 arcsec distant may be the relic of a past outburst. It shows no connection to the central elongated source which contains the bulk of the radio flux.

3C 57 is not included in the 470 brightest SDSS-DR quasar sample because it lies outside the SDSS fields. It is useful to compare it with the ~46 LD RL sources in the SDSS-DR5 sample.
Figure 5. Multicomponent fits for 3C 57. Hβ and Mg ii λ2800 from CAHA spectrum and C iii λ1909 and C iv λ1549 from HST spectrum. The upper abscissa is rest-frame wavelength in Å, the lower abscissa is in radial velocity units, and the ordinate is specific flux per unit wavelength in arbitrary units. The vertical long dashed line indicates the adopted rest frame. The black lines show the original continuum-subtracted spectra while the dashed magenta indicates the fit to the entire spectrum. The thick black and thin green lines show the broad and narrow components respectively. The blue-shifted component is indicated by a dashed blue line when detected. The light grey lines trace Fe ii UV and Fe ii opt emission which is considered in all four fittings. In some of them (as Hβ and Mg ii λ2800) the contribution is very important but in others (as C iii λ1909 and C iv λ1549) it is negligible. In panel (C) apart of C iii λ1909 we show Si iii λ1892, Al iii λ1860 and Si ii λ1814 in orange, dark green and yellow respectively. In panel (D) together with C iv λ1549 we plot the N iv λ1486 component in cyan and the He ii λ1640 broad and blue component in brown and violet respectively.

Considering the distribution of all these sources in the plane defined by optical and radio luminosities (log Lbol vs log L1.4GHz; see Figure 6 in Z08) we find that 3C 57 is located in the upper right corner revealing extreme radio and optical properties relative to this local RL sample. Actually the bolometric luminosity of 3C 57 (log Lbol = 46.98) is higher than all 470 sources in the SDSS-DR5 sample. In the upper corner of this plane we find the most luminous CD RL quasars which are the best candidates for relativistically boosted sources while LD in this corner are the best candidates for young RL sources. Our motivation for new radio observations was to search for variability which might be expected if 3C 57 (or PKS 1252+11) were an aligned CD source. The 5 GHz specific fluxes reported in Table 2 show no evidence for changes in radio power over 30+ years. The high and stable radio power favours the idea that 3C 57 is a young LD quasar (instead of a relativistically boosted source) oriented with jet lobe axis far from our line-of-sight. Since the radio power did not change we can assume that the large radio power and the unusually large C iv λ1549 blueshift coexist at the same time. Spectral index and linear size of 3C 57 meet defining criteria for CSS sources (O'Dea 1998). Absence of variability and resolved double radio morphology are consistent with 3C 57 as a young somewhat aligned lobe-dominated source.

The new and older radio observations for PKS 1252+11 (Table 2) show evidence for possible changes (fading) consistent with its Flat Spectrum (FS) CD morphology.

3.2 Optical and UV properties

The new spectroscopic measurements confirm that 3C 57 shows mixed characteristics of a Pop A (R FeII ≈ 1) and Pop B (FWHM Hβ = 4500 km s⁻¹) source. Coming back to Figure 4 the marked CD RL are the sources most likely connected to the LD parent population in an orientation-unification scenario. If the radio axis is oriented perpendicular to a broad line emitting accretion disk in such a scenario, the CD tend to show smaller FWHM Hβ and stronger Fe ii expected if the disk is oriented closer to face-on. 3C 57 is clearly an outlier in this plot. Technically it falls in 4DE1 bin B2 (Sulentic et al. 2002) but the bin boundaries shift upwards for higher luminosity quasars (Marziani et al. 2009). The bolometric luminosity of 3C 57 is high enough to place it in bin A2 which would be more consistent with measured R FeII and C iv λ1549.
The shape of broad Hβ. Pop A and Pop B profiles are best fit with Lorentzian and (double) Gaussian models respectively. Given that the optical/UV data are consistent with a Pop A source we report in Table 3 intensity values derived from Lorentzian fits. Normalized Cv.11549 blueshifts with amplitude greater than 1000 km s\(^{-1}\) are relatively frequent among largely RQ Pop A sources (Figure 2). They are rare among RL sources not only at low-\(z\) but also at high \(z\) for sources of similar luminosity (Sulentic et al. 2014). Higher luminosity (log \(L_{bol} > 47\)) RL quasars no longer exist in the local Universe. Results for high redshift quasars from an SDSS analysis suggest that Cv.11549 blueshifts may be much more common even among RL sources (Richards et al. 2011). At lower \(z\) or \(L\), as can be seen in Figure 2 there is a strong concentration of mostly Pop B RL around mean values \(R_{eff} = 0.2\) and \(c(\frac{\lambda}{2}) = \pm 0\) km s\(^{-1}\). The RQ Pop A sources show a much wider parameter space dispersion towards larger \(R_{eff}\) and Cv.11549 blueshifts. 3C 57 in this plot (and PKS 1252+11) is located in the Pop A domain and shows the most extreme properties for a RL quasar in the HST low \(z\) sample.

3C 57 was monitored in the Catalina Real-time Transient Survey (CRTS, Drake et al. 2012) for almost seven years (from JD 53705.20724 – 56250.55267). No large V magnitude variations were detected with an average V magnitude (computed from 269 observations) \(m_{V} = 16.061 \pm 0.09\). The rms scatter was 0.09 which is comparable to the quoted uncertainty of individual measurements (0.08 - 0.1). There is evidence for small amplitude nonrandom variability (possibly sinuosoidal, amplitude 0.1) but a more detailed study would be needed. There is no observational evidence of a significant change in the line profiles in our spectra. We verify this by scaling the NOT and CAHA spectra that cover Hβ and the CAHA and Asiago spectra that cover Mg ii 2800. A difference between CAHA and NOT on the red side is due to the poor correction because of telluric absorption in the NOT. The Asiago spectrum is not well corrected for atmospheric extinction at its blue end. The line profiles look consistent if data quality is taken into account.

### 3.3 RL Sources With Large Cv.11549 Blueshifts.

3C 57 is not unique as a RL source showing a significant Cv.11549 profile blueshift. It is one of six RL sources in the HST-FOS archive with Cv.11549 blueshift \(c(\frac{\lambda}{2}) < -1000\) km s\(^{-1}\) (Sulentic et al. 2007). Observational properties are presented for these sources in Table 4. For each object we list the 4DE1 parameters (FWHM Hβ, R\(_{eff}\), Cv.11549 shift, the normalized shift using FWHM Hβ, and \(\Gamma_{bol}\)), EW(Cv.11549), accretion parameters (log \(L_{bol}\), log \(M_{BH}\) and log \(L_{bol}/L_{edd}\)) and the radio properties (log \(R_{s}\), log \(P_{20cm}\), morphology, spectral index (\(\alpha\)) and lobe separation). The 4DE1 parameters and EW(Cv.11549) were taken from Sulentic et al. (2007). In the case of 3C 57 we have recalculated FWHM Hβ, R\(_{eff}\), Cv.11549 shift and EW(Cv.11549) using the new data. In the accretion parameters the bolometric luminosity (log \(L_{bol}\)) is estimated from the luminosity at 5100A assuming the standard bolometric correcting factor (10; Richards et al. 2006), the \(M_{BH}\) have been computed with the L-FWHM scaling from Vestergaard & Peterson (2006).

The radio parameters for 3C 57 and PKS 1252+11 have been updated to the values derived in this paper while those for the remaining objects have been calculated from the best available data in the literature (FIRST data preferred).

The sources in Table 4 show a large diversity in 4DE1 optical/UV/X-ray measures as well as radio properties. Four of them fall in the Pop B optical domain of 4DE1 as expected for RL sources. The two associated with sources showing FWHM Hβ...
radio SEDs. The former and latter are sometimes referred to as "young" and "frustrated" radio sources respectively. The former come in two flavours. Those with steep (CSS) and flat (FS) with a flat spectrum and core-jet (CJ) morphology. CD sources can be regarded as post-cursors or dying frustrated sources. The other three LD sources show wide enough lobe separations to preclude the onset of radio activity. RQ quasar properties, in particular the quenching of the outflows by scarcity of large CIV blueshifts in RL sources, point towards a near ubiquity of CIV blueshifts including, albeit with some scatter, in Pop B sources below log L/\(L_{\text{edd}}\) = 46.5 erg s\(^{-1}\) and are even more so in RL sources. Is CIV blueshifts correlated with source luminosity? Our main study (Sulentic et al. 2007) - that is the considerable advantage of reliable rest frame estimations based on narrow emission lines - suggests that the answer is "no". 4DE1 parameters can be shown to be a good candidate for a young LD.

Three of the sources in Table 4 can be argued to show "young" radio morphology - two (3C 57 and PKS 2349-01) with very closely-spaced LD structure and PKS 1252+11 interpreted as an LD precursor or dying frustrated source. The other three LD sources show wide enough lobe separations to preclude the assumption of a recent outburst. If we focus on 3C 57 and PKS 1252+11 as the sources with largest normalized CIV blueshift then we can argue that these sources should be considered separately from the others. The outburst age might be related with the surprisingly large CIV blueshifts for 3C 57 and PKS 1252+11 as the sources with largest normalized CIV blueshift, compared to RQ where they are common, involves quenching of the outflows by the onset of radio activity.

For the sake of comparison, one can also consider superluminal 3C 273 arguably the first quasar. It shows log(P_{21cm})\(\sim\) 34.31 erg s\(^{-1}\) Hz\(^{-1}\) similar to 3C 57 with a core-jet (or core-lobe) morphology similar to PKS 1252+11. The CIV blueshift \(\lambda_{\text{c}}\) = 552 km s\(^{-1}\) while \(R_{\text{eff}}\) = 0.57 and FWHM H\beta\ = 3500 km s\(^{-1}\) places it in bin A2 of the 4DE1 optical plane. These properties make 3C 273 a Pop A source consistent with the interpretation that is an aligned LD with undetected far-side lobe. In the optical plane of 4DE1 (Figure 1) it lies at the transition region between LD and CD sources. One can search for additional RL sources showing large CIV blueshifts in the SDSS archive. The catalogue of Shen et al. (2011) reveals (among 2347 RL quasars with \(R_{\text{K}}\) > 100 and \(z > 1.4\)) a total of 43 sources with CIV blueshift \(\lambda_{\text{c}}\) > 2000 km s\(^{-1}\). Visual examination of the spectra suggests that perhaps ten have high enough S/N to make the blueshift credible and to tentatively assign them (using the UV criteria of Negrete et al. 2014, Marziani & Sulentic 2014) to 4DE1 bins A2/A3. 3C 57 is not unique but apparently belongs to a tiny minority of RL sources showing significant CIV blueshifts and extreme (high \(L/\text{edd}\)) bin A2/A3 properties.

### 4 DISCUSSION

#### 4.1 CIV blueshifts and RL quasars.

Low redshift quasar samples (Sulentic et al. 2000a; Marziani et al. 2003a; Zamfir et al. 2010) show LD RL sources occupying a restricted zone in Eigenvector plane (Figure 1). RL sources are largely what we call Pop B quasars which are characterised by: 1) broad Balmer line profiles (FWHM H\beta\ > 4000 km s\(^{-1}\)), 2) weak FeII optical emission (\(R_{\text{eff}}\) < 0.5), 3) absence of a CIV blueshift and 4) absence of a soft-X-ray excess. RL sources show the Pop B zone with the RL also show weak or absent CIV blueshifts (Kuraszkiewicz et al. 2004). Perhaps the absence of CIV blueshifts is related to Pop B rather than to radio-loudness, or perhaps the RL Pop B sources are post-cursors of RL activity. Do they all possess the same trigger (BH spin and/or host galaxy morphology) that enables radio-loudness?

There is of course also the issue of quasar luminosity. A recent comparison between low z sources (HST-FOS spectra) and 20 quasars at \(z \sim 2.3 ± 0.2\) using the GTC (in a narrow bolometric luminosity log L = 46.0 ± 0.5 erg s\(^{-1}\) range) shows no evidence for significant CIV blueshifts in either sample. Apparently CIV blueshifts are not common in Pop B sources below log L < 46.5 erg s\(^{-1}\) and are possibly even rarer in RL sources. Is CIV blueshift correlated with source luminosity? Our main study (Sulentic et al. 2007) - that has the considerable advantage of reliable rest frame estimations based on narrow emission lines - suggests that the answer is "no". 4DE1 parameters do not directly correlate with source luminosity which was found to be an Eigenvector 2 parameter (Boroson & Green 1992). All of our studies involving low z samples, and also a higher redshift VLT sample of 53 quasars (Marziani et al. 2009), point towards Eddington ratio as the principal driver of 4DE1 diversity and hence of the CIV blueshift. The Pop A end of the 4DE1 main sequence shows systematically higher values of Eddington ratio than the Pop B end. Indeed we find that 3C 57 shows an unusually high Eddington ratio (Table 4).

Why do large SDSS samples (Richards et al. 2011) point toward a near ubiquity of CIV blueshifts including, albeit smaller, CIV blueshifts in the majority of RL quasars? Our mean/median CIV blueshift (600±100 km s\(^{-1}\)) values for RQ sources is in general agreement with their SDSS results in the log L
= 45-47 erg s⁻¹. The systematic discrepancy appears in RL sources. The explanation can be due two effects: 1) they do not use the improved redshift determinations from [Hewett & Wild 2010] for RLs (only for RQ) and 2) they use the old definition for the RQ-RL boundary $R_k = 10$. As explained earlier we adopt $R_k = 70$ (and/or $log L_{1415 MHz} = 31.6$ erg s⁻¹ Hz⁻¹) for this boundary. In Figure 1 we adopt a more extreme boundary ($log L_{1415 MHz} = 32.0$ erg s⁻¹ Hz⁻¹) for RL CD sources only—under the assumption that marginally strong CD sources are unlikely to be aligned LDs. We argue that the pure CD population between $R_k = 10$ and 70 are not classical RLs. Many may be LD precursors but they are still growing. There are a lot of sources in [Richards et al. 2011] with $R_k$ between 10 and 70. If our interpretation is correct then we expect them to show Cnv.1549 properties similar to the RQ majority. This would add a large number of Cnv.1549 blueshifts to the “RL” population that do not belong there. A new and larger SDSS based sample of LD sources [Kimball et al. 2011] fully confirms our adopted log $L_{1415 MHz}$ RL limit.

4.2 The nature of 3C 57 and implications for the RQ/RL Dichotomy.

The outstanding property of 3C 57 involves the coexistence of a large Cnv.1549 blueshift with a RL source showing young core-jet (or aligned LD) structure. This implies that powerful relativistic ejection and a high ionization wind, thought to be associated with the jet (or aligned LD) structure. This implies that powerful relativistic activity. This would add a large number of $C_r$, i.e., young or rejuvenated sources in the 4DE1 scheme. The wide majority of these sources are RQ and associated with higher accretion rates, enhanced star formation and chemical enrichment [Marziani et al. 2001; Sani et al. 2010; Marziani & Sulentic 2014]. These are the sources that most frequently show a Cnv.1549 blueshift in excess of -1000 km s⁻¹. [Zamanov et al. 2002] suggest that [OIII]λ4959,5007 blueshifts are also associated with the high-ionization outflow originating in these highly accreting sources. 3C 57 is not a blue outlier however, the [OIII]λ5007 profile shows a striking blueward asymmetry that can be modelled assuming a core plus semibroad component with a relatively large blueshift. This is at variance with evolved Pop B LD (FRII) sources that show large EW [OIII]λ5007 along with a narrow and symmetric core that appears to be consistent with dominance of the gravitational field of the host spheroid (e.g., Boroson 2003; Marziani et al. 2000a, 2006; Buttiglione et al. 2011). The relatively low equivalent width of [OIII]λ5007 as found in 3C 57 has also been associated with a relatively young, not fully developed narrow line region [Zamanov et al. 2002; Komossa et al. 2008].

4.3 Is the wind ubiquitous and how are outflow properties affected by radio-loudness?

The jet kinetic power can be written as

$$L_j = P_j \rho v_j \Omega_j r_j^2$$

(1)

where $\Omega_j$ is the front end surface of the jet of solid angle $\Omega_j$, $v_j$ is the jet bulk expansion velocity and $P_j$ the jet pressure within $\Omega_j$.

$$P_j = 10^7 L_{44} \Omega_j^{-1} \rho_j^{-2} v_j^{-1} c^{-2} \text{dyne cm}^{-2}$$

(2)

where $L_{44}$ is in units of $10^{44}$ erg s⁻¹ (typical RL values are $log L_j > 44$), $\rho_j$ is in units of $10^{-4}$ kg m⁻³, $r_j$ is at 0.1 pc ($r_0$), and $v_j$ is the jet bulk expansion velocity in units of $10^4$ km s⁻¹. $P_j$ exceeds the thermal pressure of the Broad Line Region (BLR) gas:

$$P = \frac{\rho_k T}{\mu m_p} = n_k T_k \approx 1.38 \times 10^8 n_0 T_4 \text{dyne cm}^{-2}$$

(3)

where $\rho$ is the mass density, $T_4$ the temperature in units of $10^4K$, and $n_0$ the number density in units of $10^7$ cm⁻³, as well as the hydrostatic pressure of a column of gas like the one expected to emit the blueshifted component ascribed to the accretion disk wind:

$$P_{\text{hyd}} \approx \mu m_p \frac{GM}{r^3} \approx \mu m_p N_r \frac{GM}{r^3} \approx \mu m_p N_{12, 22} M_0 r_0^{-2}$$

(4)

where $N_{12,22}$ is ambient gas column density in units of $10^{22}$ cm⁻², and $M_0$ is the black hole mass in units of $10^7$ solar masses. The first implication is that there should be a zone of avoidance close to the radio axis. A second implication is that the cocoon associated with the powerful relativistic ejection is also expected to sweep the gas within the broad line region. Elementary considerations based on the model of [Begelman & Cioffi 1989] would suggest a cocoon pressure in directions perpendicular to that of the jet propagation:

$$P_c \approx \left( \frac{\rho \nu \gamma A_j}{\mu m_p} \right)^2 \frac{\gamma^2}{\gamma - 1} \sim 3 \left( \frac{L_{44} \lambda_0 n_0 v_j \Omega_j}{P_j} \right)^2 r_0^{-1} \text{dyne cm}^{-2}$$

(5)

Therefore, if the cocoon side pressure is as strong as inferred from these elementary computations (that neglects general relativistic and magnetohydrodynamical effects associated with the jet tight collimation), we expect a strong, destructive effect on a high ionization wind, especially in the innermost BLR.
Observations of powerful RL sources reported in [42, 42] indicate that the high-ionization outflow producing C iv\(1549\) and other lines is not suppressed, even if hampered or altered. There is a different dependence on luminosity of the median and average C iv\(1549\) shift in [42, 42] (Shen et al. 2011) data for both RQ and RL: for RL, C iv\(1549\) shifts are smaller amplitude and the luminosity dependence is shallower, with shifts above \(-1000\) km s\(^{-1}\) being very rare for RL sources (c.f. Richards et al. 2011).

A first inference could be that RL activity produces a wider cone of avoidance around the disk axis: i.e. suppresses emission along radial lines of flow close to the jet axis. In this case the outflow may be more equatorially confined giving rise to more symmetric profiles and to systematically lower shifts for RL, especially for CD RLs where the flow should be viewed pole on. It is not clear whether this is the case: the sample of Sulentic et al. (2007) is small, while Richards et al. (2011) include many core sources that may not be RL (\(R_k\sim 10-70\)). In this interpretation the radio morphology of 3C 57 may hint at a favourable orientation, coupled with a significant outflow due to the high \(L/L_{Edd}\). Another possibility (not conflicting with the previous one) is that the wind is forced to start at larger distances from the central black hole (the cono-on pressure decreases with \(r^{-2}\) reaching a lower terminal velocity (still significantly above the escape velocity from the system). Larger emitting distances may also be consistent with the models of Zamanov et al. (2002) and Komossa et al. (2008).

Large (above \(1000\) km s\(^{-1}\)) C iv\(1549\) blueshifts appear to be rare: the tentative estimates of Sulentic et al. (2007) yield a prevalence 0.5 % – 2%. The rarity of these sources suggests another possible explanation for the 3C 57 (and PKS 1252+11) blueshift: the radio activity ignited too recently to have yet disrupted the wind. For 3C 57 (log \(M_{BH}\approx 9\)) the dynamical timescale of the BLR is \(< 100\) yr. The derived \(M_{BH}\) is large this indicates that 3C 57 is a rejuvenated quasar. If the duty cycle of rejuvenated quasars is \(< 10^4\) yr [Czerny et al. 2009], then one may expect \(< 1\) % of sources whose BLR has not been yet fully affected by the onset of radio activity.

5 CONCLUSIONS

The 4D Eigenvector formalism reveals that the majority of RL quasars show a restricted zone of parameter space occupation compared to the RQ majority. This restriction is clearest when we focus on the unambiguously RL LD sources. They show restricted ranges of radio power (log \(L_{1415MHz}\) > 31.6 erg s\(^{-1}\)Hz\(^{-1}\)), bolometric luminosity (log \(L_{bol}\) > 44.0 erg s\(^{-1}\)), FWHM H\(\beta\) (> 4000 km s\(^{-1}\)), \(R_{FeII}\) (< 0.5), \(\Gamma_{Ion}\) (< 2.5) and modest C iv\(1549\) blueshifts. Since the defining 4DE1 parameters are assumed to measure aspects of BLR physics and source geometry/kinematics this implies either: 1) If all quasars are capable of radio-loudness then important physical and/or kinematic properties of the BLR must change before the onset of a RL event or, 2) as an alternative reflected in the Pop A-Pop B distinction, RL represent a distinct class of quasars driven perhaps by different BH spin and/or host galaxy morphology. The RL sources sharing the same 4DE1 parameter domain with the RL might represent currently radio-inactive Pop B quasars. We see a RQ-RL dichotomy if we consider only LD sources (as the RL parent population). CD sources are likely a mix of (rare) aligned LD sources, LD precursors and frustrated cores incapable of producing classical LD structure. CD sources above log \(L_{1415MHz}\) < 32 – 32.5 erg s\(^{-1}\)Hz\(^{-1}\) distribute in 4DE1 as expected if they are aligned LD (e.g. FWHM H\(\beta\) near lower limit of LD) in an orientation unification scenario while CD with log \(L_{1415MHz}\) < 32 – 32.5 do not. The weaker CD sources also distribute in 4DE1 space the same as the RQ majority.

There are always exceptions to the rule. The cases of 3C 57 and PKS 1211+11 show that a prominent high-ionization outflow probably driven by radiation pressure can coexist with powerful radio emission, although the simultaneous detection of both phenomena appears to be rare. This result suggests that high accretion and relativistic radio ejection may not be mutually exclusive for supermassive black holes, as found in the case of stellar mass black holes, and, at the same time, that radio emission has a quantitative effect on the high-ionization outflows.

3C 57 shows extreme optical and radio properties compared to the local RL population and is therefore unambiguously RL (log \(L_{1415MHz}\) ≈ 34.4 erg s\(^{-1}\)Hz\(^{-1}\) and log \(R_k\) ~ 3). However it shows two 4DE1 parameters that are highly discordant with the RL majority: unusually strong optical Fe emission (\(R_{FeII}\) ~ 1) and a large C iv\(1549\) blueshift ~ \(-1500\) km s\(^{-1}\). It also shows an estimated Eddington ratio (log \(L/L_{Edd}\approx -0.26\) much higher than the majority of RL quasars and typical of a Population A2 source. VLA maps resolve it leading to an interpretation of 3C 57, which shows a CSS radio SED, as a core-jet or aligned LD source. The radio flux stability favours a young LD quasar. The C iv\(1549\) profile blueshift implies that there is a wind or outflow from a highly accreting disk. The general absence of C iv\(1549\) blueshifts in RL sources suggested the onset of radio activity somehow disrupts or confines the wind. A search of the SDSS quasar catalogue suggests that 3C 57 belongs to a tiny minority of RL sources with significant C iv\(1549\) blueshift and high Eddington ratio.

It is clear that whatever the physical properties of the BLR in normal quasars, the RL show a restricted range in those properties presumably connected to their large \(M_{BH}\) and low \(L/L_{Edd}\). 3C 57 is then likely hosted by an early-type galaxy if the large BH mass implies a large bulge mass via the BH mass – bulge mass correlation. The unusual properties are most easily understood if 3C 57 is undergoing an apparently rare major accretion event. This assumes that the rare unusually strong FeII emission in a RL is a signature of such events. This causes 3C 57 to show properties typical of the opposite end of the 4DE1 main sequence (higher BLR density, metallicity and accretion disk wind). The CIV wind is either too strong to be disrupted or the event is so recent that this disruption has not yet occurred.

ACKNOWLEDGEMENTS

We acknowledge Dra Simona Righini for observations in INAF-IRAM radiotelescope station in Medicina (Italy). We would like to thank Drs. Jaime Perea and Isabel Márquez for all the fruitful discussions on the subject and their help with the observations. We also thank the anonymous referee for many useful comments which helped to significantly improve the presentation of our analysis. Part of this work was supported by Junta de Andalucía through Grant TIC-114 and by the Spanish Ministry for Science and Innovation through Grants AYA2010-15169, AYA2011-1544-E and AYA2013-42227-P. This research is based in part on data obtained with the 1.82m Copernico Telescope at the Asiago Observatory. Based partially on observations made with the 3.5m telescope at the Spanish-German Observatory in Calar Alto (CAHA, Almería Spain) jointly operated by the Max-Planck-Institut für Astronomie Heidelberg and the Instituto de Astrofísica de Andalucía (CSIC). We thank all the CAHA staff for their high professionalism and support with the observations. Some data presented here were obtained
REFERENCES

Begelman, M. C. & Cioffi, D. F. 1989, ApJ, 345, L21
Boroson, T. A. 2003, ApJ, 585, 647
Boroson, T. A. & Green, R. F. 1992, ApJS, 80, 109
Bruhweiler, F. & Verner, E. 2008, ApJ, 675, 83
Buttiglione, S., Capetti, A., Celotti, A., et al. 2011, A&A, 525, A28
Corbin, M. R. & Smith, P. S. 2000, ApJ, 532, 136
Czerny, B., Siemiginowska, A., Janiuk, A., Nikiel-Wroczyński, B., & Stawarz, L. 2009, ApJ, 698, 840
de Vries, W. H., Becker, R. H., & White, R. L. 2006, AJ, 131, 666
Dimitrijević, M. S., Popović, L.Ć., Kovačević, J., Dačić, M., & Stamenković, R. 2000, A&A, 364, 70
Drake, A. J., Djorgovski, S. G., Mahabal, A., et al. 2012, IAU Symposium, 285, 306
Fanti, C., Fanti, R., Dallacasa, D., et al. 1995, A&A, 302, 317
Fender, R. & Belloni, T. 2004, ARA&A, 42, 317
Griffith, M. R., Wright, A. E., Burke, B. F., & Ekers, R. D. 1994, ApJS, 90, 179
Gu, M., Cao, X., & Jiang, D. R. 2009, MNRAS, 396, 984
Hewett, P. C. & Wild, V. 2010, MNRAS, 405, 2302
Kellermann, K. I., Sramek, R., Schmidt, M., Shaffer, D. B., & Green, R. 1989, AJ, 98, 1195
Kimball, A. E., Ivezic, Z., Wiita, P. J., & Schneider, D. P. 2011, AJ, 141, 182
Komossa, S., Xu, D., Zhou, H., Storchi-Bergmann, T., & Binette, L. 2008, ApJ, 680, 926
Kotilainen, J. K. & Falomo, R. 2000, A&A, 364, 70
Kriss, G. 1994, Astronomical Data Analysis Software and Systems III, A.S.P. Conference Series, 61, 437
Krolik, J. H. 1999, Active galactic nuclei: from the central black hole to the galactic environment (Princeton University Press)
Kuehr, H., Witzel, A., Pauliny-Toth, I. I. K., & Nauber, U. 1981, A&AS, 45, 367
Kuraszkiewicz, J. K., Green, P. J., Crenshaw, D. M., et al. 2004, ApJ, 150, 165
Laurent-Muehlesien, S. A., Kollgaard, R. I., Ryan, P. J., et al. 1997, A&AS, 122, 235
Marziani, P., Dultzin-Hacyan, D., & Sulentic, J. W. 2006, Accretion onto Supermassive Black Holes in Quasars: Learning from Optical/UV Observations (New Developments in Black Hole Research), 123
Marziani, P. & Sulentic, J. W. 2014, MNRAS, 442, 1211
Marziani, P., Sulentic, J. W., Dultzin-Hacyan, D., Calvani, M., & Moles, M. 1996, ApJS, 104, 37
Marziani, P., Sulentic, J. W., Plauhu-Frayn, I., & del Olmo, A. 2013a, A&A 555, A89
Marziani, P., Sulentic, J. W., Plauhu-Frayn, I., & del Olmo, A. 2013b, ApJ, 764, 150
Marziani, P., Sulentic, J. W., Stirpe, G. M., Zamfir, S., & Calvani, M. 2009, A&Ap, 495, 83
Marziani, P., Sulentic, J. W., Zamanov, R., et al. 2003a, ApJS, 145, 199
Marziani, P., Sulentic, J. W., Zwitter, T., Dultzin-Hacyan, D., & Calvani, M. 2001, ApJ, 558, 553
Marziani, P., Zamanov, R. K., Sulentic, J. W., & Calvani, M. 2003b, MNRAS, 345, 1133
Morganti, R., Killeen, N. E. B., & Tadhunter, C. N. 1993, MNRAS, 263, 1023
Negrete, C. A., Dultzin, D., Marziani, P., & Sulentic, J. W. 2013, ApJ, 771, 31
Negrete, C. A., Dultzin, D., Marziani, P., & Sulentic, J. W. 2014, ApJ, 794, 95
Neilsen, J. & Lee, J. C. 2009, Nature, 458, 481
Netzer, H. 2013, The Physics and Evolution of Active Galactic Nuclei (Cambridge University Press)
O’Dea C. P., 1998, PASP, 110, 493
Oke, J. B. 1990, AJ, 99, 1621
Ott, M., Witzel, A., Quirrenbach, A., et al. 1994, A&A, 284, 331
Ponti, G., Fender, R. P., Begelman, M. C., et al. 2012, MNRAS, 422, L11
Reid, R. I., Kronberg, P. P., & Perley, R. A. 1999, ApJS, 124, 285
Richards, G. T., Kruczak, N. E., Gallagher, S. C., et al. 2011, AJ, 141, 167
Richards, G. T., Lacy, M., Storrie-Lombardi, L. J., et al. 2006, ApJS, 166, 470
Roeser, S., Demleitner M., Schilbach E., 2010, AJ, 139, 2440
Sani, E., Lutz, D., Risaliti, G., et al. 2010, MNRAS, 403, 1246
Shen, Y., Richards, G. T., Strauss, M. A., et al. 2011, ApJS, 194, 45
Sulentic, J. W., Bachev, R., Marziani, P., Negrete, C. A., & Dultzin, D. 2007, ApJ, 666, 757
Sulentic, J. W., Marziani, P., del Olmo, A., et al. 2014, A&A 570, A96
Sulentic, J. W., Marziani, P., & Dultzin-Hacyan, D. 2000a, ARA&A, 38, 521
Sulentic, J. W., Marziani, P., Zamanov, R., et al. 2002, ApJ, 566, L71
Sulentic, J. W., Marziani, P., Zwitter, T., Dultzin-Hacyan, D., & Calvani, M. 2000b, ApJ, 545, L15
Sulentic, J. W., Zamfir, S., Marziani, P., et al. 2003, ApJ, 597, L17
van Breugel, W., Riley, G., & Heckman, T. 1984, AJ, 89, 5
Vestergaard, M. & Peterson, B. M. 2006, ApJ, 641, 689
Wills, B. J., Wills, D., Breger, M., Antonucci, R. R. J., & Barvainis, R. 1992, ApJ, 398, 454
Wright, A. E., Wark, R. M., Troup, E., et al. 1990, Proceedings of the Astronomical Society of Australia, 8, 261
Wu, Q. 2009a, ApJ, 701, L95
Wu, Q. 2009b, MNRAS, 398, 1905
Zamanov, R., Marziani, P., Sulentic, J. W., et al. 2002, ApJ, 576, L9
Zamfir, S., Sulentic, J. W., & Marziani, P. 2008, MNRAS, 387, 856
Zamfir, S., Sulentic, J. W., Marziani, P., & Dultzin, D. 2010, MNRAS, 403, 1759
Zensus, J. A., Ros, E., Kellermann, K. I., et al. 2002, AJ, 124, 662

This paper has been typeset from a T eğX/L<thead<êX file prepared by the author.