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# Broad Line Region Structure Along Eigenvector 1

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**Abstract.** We present the main results from a spectroscopic study of more than 200 low-z luminous Seyfert 1 nuclei and quasars. We studied the spectral region around H$\beta$ and measured FeII, HeII$\lambda$4686 and H$\beta$ line parameters. We find clear trends along the Eigenvector 1 (E1) parameter space especially for the broad component of H$\beta$. Several observed properties show monotonic variations in the space; however, at FWHM(H$\beta_{BC}$)$\approx$ 4000 km s$^{-1}$ there is a discontinuity which motivates the suggestion that two type-1 AGN populations exist (Population A and B) with fundamentally different broad line region structure.

The optical and UV spectra of luminous Seyfert 1 and low redshift quasars are not all the same. The diversity of broad line AGN is made obvious by their distribution in the optical plane of E1 (Sulentic et al. 2000a,b) where we plot FWHM H$\beta$ (broad component) vs. $\mathrm{R_{FeII}}$ = W(FeII$\lambda$4570)/W(H$\beta_{\rm BC}$). In this plane our sample of $\approx$ 220 AGN with z$\lesssim$ 0.8, and $-29 \lesssim M_B \lesssim -20$ occupies the region with $\mathrm{R_{FeII}} \lesssim 0.5$ for FWHM(H$\beta_{\rm BC}$)$\gtrsim$ 4000 km s$^{-1}$, and $\mathrm{R_{FeII}} \lesssim 1.5$ if FWHM(H$\beta_{\rm BC}$) $\lesssim$ 4000 km s$^{-1}$ (Sulentic et al. 2002, and references therein). Many additional properties – several of them related to structural differences in the Broad Line Region (BLR) – correlate with the E1 parameter space.

We computed median spectra in bins of $\Delta\mathrm{R_{FeII}} = 0.5$ and $\Delta$ FWHM (H$\beta_{\rm BC}$) = 4000 km s$^{-1}$ (see Sulentic et al. 2002 for details). We subtracted continuum and FeII emission to the median spectra in order to obtain high S/N H$\beta$ line profiles. Taking advantage of the above-average resolution ($\lambda/\Delta\lambda \sim 1000$), we were able to deconvolve H$\beta_{\rm BC}$ from H$\beta_{\rm NC}$ and other nearby lines. The median H$\beta_{\rm BC}$ profiles are well fit by a Lorentzian for sources with FWHM(H$\beta_{\rm BC}$) < 4000 km s$^{-1}$. Sources with "Narrow Line Seyfert 1" spectra which are included in our sample also show a median profile well fit by a Lorentz function. At FWHM(H$\beta_{\rm BC}$)$\gtrsim$4000 km s$^{-1}$, median profiles are markedly different showing a prominent redward asymmetry. These profiles can be most simply modeled with two Gaussians.

Large CIV$\lambda$1549 blueshifts occur preferentially in sources with FWHM(H$\beta_{\rm BC}$) < 4000 km s$^{-1}$ suggesting that the BLR contains high and low ionization emitting region that are kinematically and structurally decoupled (Sulentic et al. 2000b). There is little statistical evidence for disjoint regions in sources with FWHM(H$\beta_{\rm BC}$) > 4000 km s$^{-1}$. In fact H$\beta_{\rm BC}$ and CIV$\lambda$1549 line profile parameters are correlated in these sources (Marziani et al. 1996; Sulentic et al. 2000a,b). The change in line profile properties near FWHM(H$\beta_{BC}$) ≈4000 km s$^{-1}$ suggests a structural change in the BLR that motivates the Population A-B hypothesis: Population A [FWHM(H$\beta_{BC}$) $\lesssim$4000 km s$^{-1}$], and Population B [FWHM(H$\beta_{BC}$) $\gtrsim$4000 km s$^{-1}$].

Population B sources are more enigmatic in terms of BLR structure. In order to better understand their physical conditions, we studied the high ionization HeII$\lambda$4686 broad line and the low ionization FeII blend centered at $\lambda$4570. It is known that HeII$\lambda$4686 is usually broader than H$\beta_{BC}$ and that FWHM(FeII$\lambda$4570) correlates with FWHM(H$\beta_{BC}$). Analysis of our sample suggests that:

- Pop. A: FWHM(HeII$\lambda$4686)$\gg$ FWHM(H$\beta_{BC}$);
  FWHM(FeII$\lambda$4570) $\approx$ FWHM(H$\beta_{BC}$).
- Pop. B: FWHM(HeII$\lambda$4686) is systematically larger than FWHM(H$\beta_{BC}$). FWHM (FeII$\lambda$4570) is, surprisingly, lower (on average) than FWHM(H$\beta_{BC}$) by ≈20%.

The most straightforward implication is that the BLR in Population B objects involves an emitting single region but that ionization is strongly "stratified": the emissivity-weighted distance of the HeII and FeII lines may correspond to the innermost and outermost zones of the BLR respectively (HI lines are emitted across the entire BLR). The moderate or weak FeII emission (all Pop. B sources have $R_{\rm FeII} \lesssim 0.5$) and the relatively high degree of ionization in Pop. B sources do not pose a special challenge to photoionization modeling. Pop. B H$\beta_{BC}$ median profiles can be decomposed into two Gaussian components: an H$\beta_{BC}$ proper, with FWHM 4000–5000 km s$^{-1}$ and a broader, redshifted Gaussian base (FWHM$\sim$ 10000 km s$^{-1}$; see Sulentic et al. 2000c for a good example). HeII$\lambda$4686, on the other hand, tends to show only a very broad, flat-topped profile. This is an indication that HeII may come almost exclusively from the very broad component. In some sources, the emitting region (referred to by Sulentic et al. 2000c as the Very Broad Line Region) has been successfully modeled as an optically thin (to the HI ionizing continuum) shell of gas with large covering factor. It remains to be seen if emission from a VBLR as defined by Sulentic et al. (2000c) is a major contributor to the H$\beta_{BC}$ line wings in a sizeable fraction of AGN. These results are crucial to an understanding of the Population B BLR kinematics through a synthesis of reverberation mapping and statistical studies.

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## References

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