Active Galactic Nuclei and Related Phenomena
IAU Symposium, Vol. 194, 1999
Yervant Terzian, Daniel Weedman, Edward Khachikian, eds.

Broad Emission Lines in AGN: Phenomenology and Models

Jack W. Sulentic

Department of Physics and Astronomy, University of Alabama, Tuscaloosa, AL, USA 35487

Paolo Marziani and Massimo Calvani

Osservatorio Astronomico, vicolo dell'Osservatorio 5, Padova, Italy

Deborah Dultzin-Hacyan

Instituto de Astronomia, UNAM, Apdo. 70-264, Mexico D. F. 04510, Mexico

Abstract.

We review the phenomenology of broad emission lines in AGN. We show that velocity displacements relative to the local rest frame of Hβ and CIVλ1549 are real. The most significant line displacement result involves a systematic blueshift for CIV, seen only in radio-quiet sources. We find some evidence that the amplitude of this displacement may correlate with source orientation. We show that disagreement between different studies of the CIV line properties is due to whether or not a narrow line component was subtracted. Finally, we consider evidence that optical and X-ray broad lines arise in an accretion disk. We show that the evidence for a disk origin is far from overwhelming for both Hβ and FeKα.

1. Introduction

The current phenomenology of emission lines in AGN suggest that three distinct emitting regions are present in at least some and possibly all sources at certain viewing angles. In other words, some AGN show inflections in their line profiles consistent with three kinematical/geometric emission zones. Figure 1 shows the profile of Hβ for the radio-quiet source PG1138+222 (see Marziani & Sulentic 1993) where we identify: a) a narrow line (NLR) component with FWHM=300 km/s, b) a broad line (BLR) component with FWHM=2700 km/s and c) a very broad (always redshifted?) line component (VBLR) with FWHM$\sim$8000 km/s. The VBLR component is not easy to study because it is so broad and frequently obscured by Fe line emission. Its reality is not in doubt (see e.g. Ferland, Korista & Peterson 1990) but its frequency of occurence is unclear. The NLR component must be subtracted from a line profile before the BLR component can be effectively studied.

We focus here on: 1) BLR properties as the most promising insight into the central source structure, 2) BLR Hβ because it is the most studied low ionization

https://doi.org/10.1017/S0074180900162114 Published online by Cambridge University Press

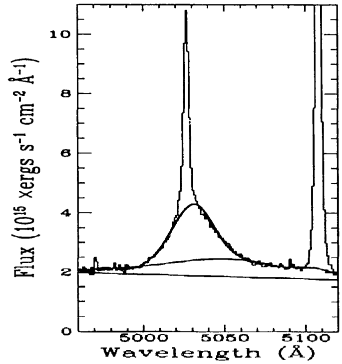

Figure 1. Hβ line profile of PG 1138+222 showing three well separated narrow, broad, and very broad components.

(LIL) line (13.6eV) that can be seen over a fairly wide redshift range and 3) BLR CIV as the least contaminated and most studied of the high ionization (64eV) lines. Our studies have been statistical in nature and, therefore, complement the reverberation studies involving a much smaller sample of sources. We ask, and attempt to answer, three BLR related questions. Do the HIL and LIL arise in the same emitting region? Are BLR internal velocity shifts real and why is there disagreement among the principal studies on this issue? Finally, do the observations support a model where the bulk of the emission arises in a region dominated by rotational motions (specifically, an accretion disk)?

2. HIL and LIL From the Same BLR?

Two years ago we reported on a direct comparison of Hβ and CIV broad line properties using FOS archival spectra for the latter and matching ground-based spectra for the former (Marziani et al. 1996). Figure 2 summarizes the velocity displacement results from that study. We measured the broad line profile displacement relative to the local source rest-frame inferred from NLR [OIII]λ5007. The most striking result we found was that CIV in radio-quiet quasars always shows a blueshift relative to the local rest frame. If we can generalize from our small sample, we suggest that the majority of AGN (∼90%) should show this effect which is most simply attributed to some kind of outflow (disk wind or more collimated flow). The fact that Hβ does not show the same effect is strong evidence for a two-component BLR. We found lower order correlations that suggest the amplitude of the CIV blueshift may be related to source orientation. This result and the results of reverberation studies, which place CIV emitting clouds closer to the central engine, are easier to understand if CIV emission is concentrated in some sort of collimated outflow.

Figure 2 shows that the situation for radio-loud sources is less clear. In radio-loud sources, it is Hβ that shows large shifts rather than CIV. Our sample suggests a preponderance of redshifts but this may well reflect the small sample size because we know of radio loud sources with very large blueward displacements (e.g. 3C227; Gaskell 1983). The preliminary results suggest that BLR

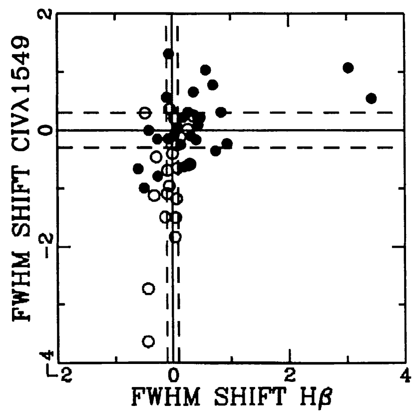

Figure 2. Distribution of Balmer line vs CIV line centroid shifts at half maximum (in units of 10^3 km s^{-1}). Open circles are radio-quiet and filled circles are radio-loud sources. Two σ error bars are shown.

structure and/or kinematics in radio-loud sources is significantly different from radio-quiet AGN.

3. Are BLR Velocity Shifts Real?

Our CIV vs Hβ comparison suggests that large velocity displacements in broad lines are concentrated in the LIL for radio-loud sources and HIL for radio-quiet ones. The LIL in radio-quiet and HIL in radio-loud objects appear to show only small displacements (typically less than 600 km/s) about the local rest frame. The displacements are equally divided between red and blue. We believe that even these line shifts are real and Figure 3 shows an example of our evidence. It shows the LIL (Hβ) profiles for three radio-quiet sources. The profiles in these sources are reasonably symmetric, making it difficult to ascribe any line shift to profile asymmetry or some other effect. At least two of these sources show clear bulk displacement of the majority of the line emission. The redshifted VBLR component affects our estimates of the amplitude of these shifts.

Studies of the CIV profile have been more conflicted, in part, because CIV rarely shows a clear inflection between BLR and NLR components. There have been several independent statistical studies of the CIV profile (Wills et al. 1993ab, Brotherton et al. 1994ab; Corbin & Francis 1994, Corbin & Boroson 1996; Marziani et al. 1996). Most important differences between these studies can be traced back to whether or not an NLR component was subtracted from the CIV profile. We subtracted such a component and find that it varies from zero to 20% of the total line flux. The NLR component may be negligible in high luminosity AGN (Wills et al. 1993a) but our sample is dominated by lower luminosity sources. Wills et al identified two-components in the profile of CIV: i) an intermediate (ILR) and ii) a VBLR line component. They find no velocity displacement for the ILR component and showed that most of its properties were identical to the NLR. We argue that this is the NLR component of CIV. It

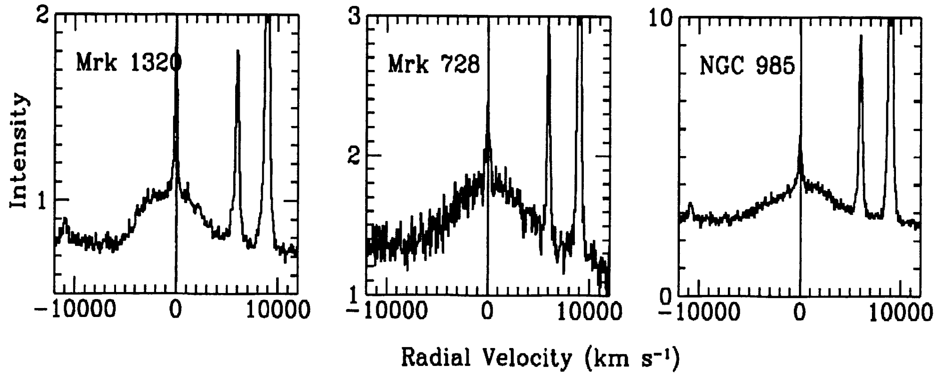

Figure 3. Examples of broad profiles with: moderate (565 km s^{-1}) blueshift (Mark 1320; left panel); small (270 km s^{-1} redshift (Mark 728; middle panel); moderate (420 km s^{-1} redshift (NGC 985) all relative to the NLR ($1\sigma \approx 60$ km s^{-1}).

is slightly broader than [OIII]5007 because it is a partially resolved doublet and because it may arise in a slightly denser environment like NLR [OIII]4363. CIV is a collisional line. We interpret their (blueshifted) VBLR component as the "classical" BLR signature of CIV (note that this is not the same as the VBLR feature discussed above and in Ferland et al. 1990). While they recognize these two components, Wills et al. analyze their results in terms of the relative contributions of these two components. It is difficult to interpret data that includes the variable contribution of NLR and BLR gas.

Corbin & Boroson (1996) argue that no significant NLR CIV component exists. A comparison of sources in common with that study (Sulentic et al. 1998c) yield completely different conclusions about profile width and velocity displacement. We believe that insights into the HIL BLR can only be obtained if an NLR component is subtracted from CIV. The narrow component, if not subtracted, obscures first-order BLR properties. Corbin (1997) finds no significant (see Figure 2) CIV shifts for 2/3 of a sample of 18 sources in common with our sample (Marziani et al. 1996). This is consistent with the peak of the CIV profile being dominated by NLR emission.

4. BLR Emission From an Accretion Disk?

Many recent papers have discussed the possibility that both optical Balmer (e.g. Chen & Halpern 1989) and X-ray FeK (see e.g. Nandra et al. 1997ab) BLR emissions arise from an accretion disk. No matter how one looks at it, the double-peaked Balmer line profiles are rare. Model fits to those profiles require that we view the disk from an intermediate angle where many more such sources should be observed. Thus they are much more consistent with a biconical flow seen near pole-on where their statistical rarity is expected. Double-peaked sources cannot be the extremum of a population where an additional central component fills in the "valley" between the peaks because no population of single-peaked sources with very broad steep-sided profiles is observed. If the majority of sources do show lines that arise from a disk then the rare population of double-peaked sources are inconsistent with the disk illumination models needed to explain the majority. However one looks at it, double-peaked sources would be a miraculous minority in a disk scenario.

We have recently considered a disk illumination model (Sulentic et al. 1998a) that can simultaneously produce both broad Balmer and FeKα emission. The model profile predictions are in poor agreement with the data, and disk inclination (the only free parameter in our model) values required to fit the observed profiles are inconsistent for the two lines. Finally we showed recently (Sulentic et al. 1998b) that the FeK line is likely composed of two (Gaussian) components: i) narrow and unshifted feature with E=6.4keV and FWHM$\leq$0.25keV and ii) broad and redshifted feature with E=5.9keV and FWHM$\geq$1.6keV. Neither of these components are easily fit by the kinds of disk models that have been discussed so far.

References

Brotherton, M. et al. 1994a, ApJ, 423, 131

Brotherton, M. et al. 1994b, ApJ, 430, 495

Chen, K., & Halpern, J. 1989, ApJ, 344, 115

Corbin, M. 1997, ApJS, 113, 245

Corbin, M. & Boroson, T. 1996, ApJS, 107, 69

Corbin, M. & Francis, P. 1994, AJ, 108, 2016.

Ferland, G., Korista, K. & Peterson, B. 1990, ApJ, 363, L21

Gaskell, M. 1983, ApJ, in Proc. Liege Conf. "Quasars and Gravitational Lenses", 473.

Marziani, P. & Sulentic, J. W. 1993, ApJ, 409, 612

Marziani, P., et al. 1996, ApJS, 104, 37

Nandra, K., et al. 1997a, ApJ, 476, 70

Nandra, K., et al. 1997b, ApJ, 477, 602

Sulentic, J., Marziani, P., & Calvani, M. 1998b, ApJ, 497, L65

Sulentic, J., et al. 1998a, ApJ, 501, 54

Wills, B. et al. 1993, ApJ, 410, 534

Wills, B. et al. 1993, ApJ, 415, 563

https://doi.org/10.1017/S0074180900162114 Published online by Cambridge University Press