RevMexAA (Serie de Conferencias), **9**, 308–315 (2000)

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco

THE BROAD LINE REGION IN ACTIVE GALACTIC NUCLEI

D. Dultzin-Hacyan,[1] P. Marziani,[2] and J. W. Sulentic[3]

RESUMEN

Revisamos las limitaciones observacionales a los modelos sobre la estructura de las regiones que emiten las líneas anchas en los Núcleos Activos de Galaxias. La comparación entre las líneas de alta y baja ionización con FWHM H$\beta \leq 4000$ km s^{-1} sugiere que la emisión proviene de una geometría aplanada (el disco de acreción?) y de un viento asociado. No es claro si estos resultados pueden extenderse a todos los Núcleos Activos radio callados, sobre todo, a los radio fuertes.

ABSTRACT

We review constraints on models of the broad line region that are imposed by observations of the emission lines in Active Galactic Nuclei. Comparison of high and low ionization lines in sources with FWHM H$\beta \leq 4000$ km s^{-1} point toward low ionization line emission produced in a flattened geometry (the accretion disk?) with an associated high ionization wind. It remains unclear whether these results can be extended to all radio quiet AGN and particularly to radio loud AGN.

Key Words: **GALAXIES: ACTIVE — LINES: PROFILES — QUASARS: EMISSION LINES**

1. INTRODUCTION

The Broad Line Region (BLR) in Active Galactic Nuclei (AGN) is unresolved with present day imaging detectors and it will remain so for the foreseeable future. This is why "*one quasar spectrum is really worth a thousand images*" as stressed by Gary Ferland at this meeting. In response we would add that *a thousand spectra are better than one average spectrum.* Understanding the diversity in optical spectroscopic properties of AGN is the key to any realistic AGN modeling (Boroson & Green 1992; Sulentic, Marziani, & Dultzin-Hacyan 2000a). The ideal of reconstructing the BLR velocity field from a single profile is not realistic (Penston et al. 1990).

Determination of BLR structure and kinematics can be approached in two ways. It has been recognized for a long time that strong broad and narrow emission lines coming from both high and low ionization species are present in Seyfert galaxies and quasars. This is considered a defining spectroscopic property of AGN. Restricting attention to broad lines: *(a)* typical (i.e., strongest and most frequently observed) high ionization lines (HIL: ionization potential $\gtrsim$ 50 eV) are C IV λ1549, He II λ4686, and He II λ1640 lines; while *(b)* observed low ionization lines (LIL: ionization potential $\lesssim$ 20 eV) include H I Balmer lines, Fe II multiplets, Mg II λ2800, and the Ca II IR triplet.

The first approach involves the study of line variability in response to continuum changes. This approach has been pursued through a number of successful monitoring campaigns using Reverberation Mapping (RM) techniques. RM requires a large amount of telescope time and, consequently, has been achieved only for a handful of sources. RM confirms that photoionization is the main heating process in the BLR and that a large part of the BLR is optically thick to the ionizing continuum (e.g., Baldwin 1997). RM studies have quantified a main difference between HIL and LIL; HIL respond to continuum changes with a time delay of a few days while the LIL respond with a delay of tens of days. This implies that the LIL are emitted at larger distance from the continuum source (Ulrich, Maraschi, & Urry 1997; Korista et al. 1995; an exhaustive list of references

[1]Instituto de Astronomía, Universidad Nacional Autónoma de México.
[2]Osservatorio Astronomico, Padova, Italy.
[3]Department of Physics and Astronomy, University of Alabama, USA.

can be found in Sulentic et al. 2000a). RM applied to line profiles suffers from uncertainty in our knowledge about the physics of continuum and broad line formation, so that conflicting models can still describe the same lag times (Penston 1991; Wanders & Peterson 1996).

The second approach involves statistical analysis of large samples of line profiles which differ because of properties that may affect the BLR structure, for example samples of radio quiet (RQ) and radio loud (RL) AGN. Statistical studies can be done for a single line or by comparing lines sensitive to different physical parameters (e.g., strongest LIL and HIL). The statistical approach, on which we will focus here, is more empirical and therefore requires a conceptual framework for interpretation. This approach is often criticized as relying on several assumptions including that the profile variability does not influence profile shapes and that the non-simultaneity of the observations of LIL and HIL are unimportant. Actually, as the size of high quality data samples grow these effects become less and less important.

2. BARING THE BROAD PROFILES

The collection of moderate resolution ($\lambda/\Delta\lambda \sim 10^3$) optical and UV spectra of good quality (S/N $\gtrsim$ 20 in the continuum) has become possible only in recent years thanks to the widespread use of CCD detectors and the unprecedented sensitivity and resolution of the UV spectrographs on board HST. For practical purposes, H I, Hβ, and C IV λ1549 can be considered representative of HIL and LIL, respectively. They are also the best lines for statistical studies because they permit comparison in the same sources out to z=1.0. The linearity of response of the currently employed detectors has made possible a reliable correction for emission features contaminating Hβ and C IV λ1549, which are: (1) Fe II emission; significant Fe II$_{\rm UV}$ emission contaminates the red wing of C IV λ1549, and has been identified in I Zw 1 by Marziani et al. (1996) and later confirmed by Laor et al. (1997); (2) He II λ4686 emission for Hβ, and He II λ1640 + O III]λ1663 for C IV λ1549; (3) [O III]$\lambda\lambda$4959,5007 for Hβ; (4) narrow component, present in several cases in both Hβ and C IV λ1549.

C IV λ1549 often shows a narrow core with FWHM $\sim 1000 - 2000$ km s^{-1}, which is systematically broader than the narrow component of Hβ (H$\beta_{\rm NC}$). The separation between the broad component C IV $\lambda1549_{\rm BC}$ and the core component is often ambiguous. This core, however, shows no shift with respect to the AGN rest frame (Brotherton et al. 1994), no variations (Türler & Courvoisier 1998), and correlates with [O III]$\lambda\lambda$4959,5007 prominence (Francis et al. 1992). It can therefore be ascribed to the NLR and considered as the narrow line component of C IV λ1549 (C IV $\lambda1549_{\rm NC}$). The different width between C IV $\lambda1549_{\rm NC}$ and H$\beta_{\rm BC}$ can be understood in terms of density stratification (Sulentic & Marziani 1999) without invoking an additional emitting region such as the so-called "intermediate line region". Even if C IV $\lambda1549_{\rm NC}$ fractional intensity is small ($\sim$ 10%), and in some cases obviously absent, failure to account for C IV $\lambda1549_{\rm NC}$ has led to the erroneous conclusions that FWHM C IV $\lambda1549_{\rm BC}$ > FWHM H$\beta_{\rm BC}$ and that the C IV λ1549 peak shows no shift with respect to Hβ (Corbin & Boroson 1996).

3. A DIFFERENT BLR STRUCTURE IN RADIO LOUD AND RADIO QUIET AGN?

Marziani et al. (1996) made a comparison between C IV $\lambda1549_{\rm BC}$ and H$\beta_{\rm BC}$ for a sample of 52 AGN (31 RL). They presented measures of radial velocity for the blue and red sides of H$\beta_{\rm BC}$ and C IV $\lambda1549_{\rm BC}$ at 5 different values of fractional intensity which provide a quantitative description of the profiles. The reference frame was set by the measured velocity of [O III]$\lambda\lambda$4959,5007 (IZw1 was the only exception). Standard profile parameters like peak shift, FWHM, asymmetry index and curtosis can be extracted from these measures. Representative profiles constructed from the *median values* of C IV $\lambda1549_{\rm BC}$ and H$\beta_{\rm BC}$ v_r are reproduced in the left panels of Figures 1 and 2 for the radio quiet (RQ) and radio loud (RL) samples, respectively.

C IV $\lambda1549_{\rm BC}$ is broader than H$\beta_{\rm BC}$ in both RQ and RL samples and it is *almost always* blueshifted relative to H$\beta_{\rm BC}$. However, Figures 1 and 2 show significant differences between RQ and RL AGN. In RQ AGN, C IV $\lambda1549_{\rm BC}$ is significantly blueshifted with respect to the source rest frame while H$\beta_{\rm BC}$ is symmetric and unshifted. Contrarily, in RL AGN C IV $\lambda1549_{\rm BC}$ is more symmetric, while H$\beta_{\rm BC}$ is shifted to the red at peak intensity and redward asymmetric as well (the median profile corresponds to the type AR,R according to Sulentic 1989). There are two important results which are not displayed in the figures: *(i)* in RQ AGN, C IV $\lambda1549_{\rm BC}$ blueshifts are apparently uncorrelated with respect to any H$\beta_{\rm BC}$ line profile parameter and the largest C IV λ1549 blueshifts are associated with the lowest W(C IV λ1549); *(ii)* in RL AGN, on the contrary,

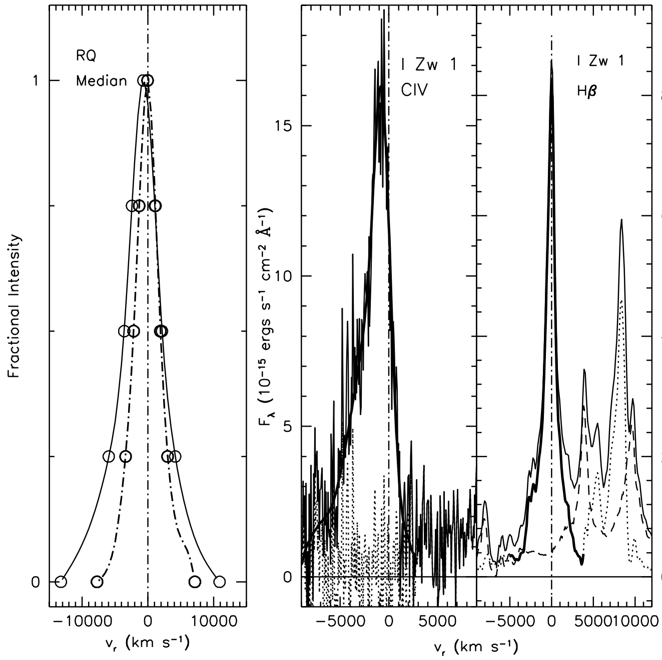

Fig. 1. Profiles of C IV $\lambda1549_{\rm BC}$ (solid lines) and H$\beta_{\rm BC}$ normalized to the same peak intensity and constructed from median values of the radial velocities measured on the blue and red sides of the profiles for the 21 RQ AGN of Marziani et al. (1996) (*left panel*). Emission line profiles of C IV $\lambda1549$ (middle panel) and Hβ (*right panel*) of the prototype NLSy1 galaxy I Zw 1, adapted from Marziani et al. (1996). The thick and the dotted lines trace Hβ and [O III]$\lambda\lambda$4959,5007 after Fe $\rm II_{opt}$ (dashed line) subtraction.

C IV $\lambda1549_{\rm BC}$ and H$\beta_{\rm BC}$ line profile parameters (FWHM and peak shift) appear to be correlated. Asymmetry index of C IV $\lambda1549_{\rm BC}$ and H$\beta_{\rm BC}$, even if not correlated, shows a clear trend toward asymmetries of the same kind (symmetric or redward asymmetric). These findings on C IV $\lambda1549_{\rm BC}$ have been confirmed by other authors (Wills et al. 1995, save the difference in terminology and line profile decomposition) and especially by an analysis of archival *HST*/FOS observations, which have become publicly available since 1995 (Sulentic et al. 2000b).

The LIL and HIL emitting regions are apparently de-coupled in at least some RQ sources. The "de-coupling" is well seen in I Zw 1, the prototype Narrow Line Seyfert 1 Galaxy (NLSy1; see Fig. 1). The Hβ profile is very narrow, slightly blueward asymmetric and unshifted with respect to the rest frame defined by 21 cm observations, while the C IV $\lambda1549$ profile is almost totally blueshifted. At least in the case of I Zw 1 the distinction between LIL and HIL emitting regions appears to be observationally established (it was actually suggested because of the difficulty to explain the relative strengths of LIL and HIL emission using a photoionized "single cloud;" Collin-Souffrin et al. 1988). There is a very important zeroth-order result here: since I Zw 1 is a strong Fe $\rm II_{UV}$ emitter, we have HIL C IV $\lambda1549$ and LIL Fe $\rm II_{UV}$ in the same rest-frame wavelength range. We see that Fe $\rm II_{UV}$ is obviously unshifted (this can be very well seen by shifting an Fe $\rm II_{UV}$ template to the peak radial velocity of C IV $\lambda1549$). This result disproves models that see an (unknown) wavelength dependent mechanism accounting for the quasar broad line shifts relative to the quasar rest frame.

RL AGN apparently mirror RQ AGN in a curious way: C IV $\lambda1549_{\rm BC}$ is more symmetric, while H$\beta_{\rm BC}$ shows preferentially redshifted profiles and increasingly redward asymmetries. Large peak redshifts ($v_r \gtrsim 1000$ km s^{-1}, as in the case of OQ 208, Fig. 2) are rarely observed; H$\beta_{\rm BC}$ peak shifts are usually small (Δv_r/FWHM $\ll 1$, median profile of Fig. 2). RL C IV $\lambda1549_{\rm BC}$ and H$\beta_{\rm BC}$ data leave open the possibility that both lines are emitted in the same region. C IV $\lambda1549_{\rm BC}$ shows a red-wing (very evident in the latest, higher S/N spectra analyzed by Sulentic et al. [2000b]), which cannot be entirely accounted for by Fe $\rm II_{UV}$ emission. It is interesting to note that superluminal sources with apparent radial velocity $\beta_{\rm app} \sim 5-10$ (whose radio axis is probably oriented close to the line of sight in the sample of Marziani et al. (1996) show very strong C IV $\lambda1549$ redward asymmetries, low W(C IV $\lambda1549$) and W(H$\beta_{\rm BC}$). This result suggests that redshifts are maximized in RL objects at "face-on" orientation (we assume that any disk is perpendicular to the radio axis).

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco

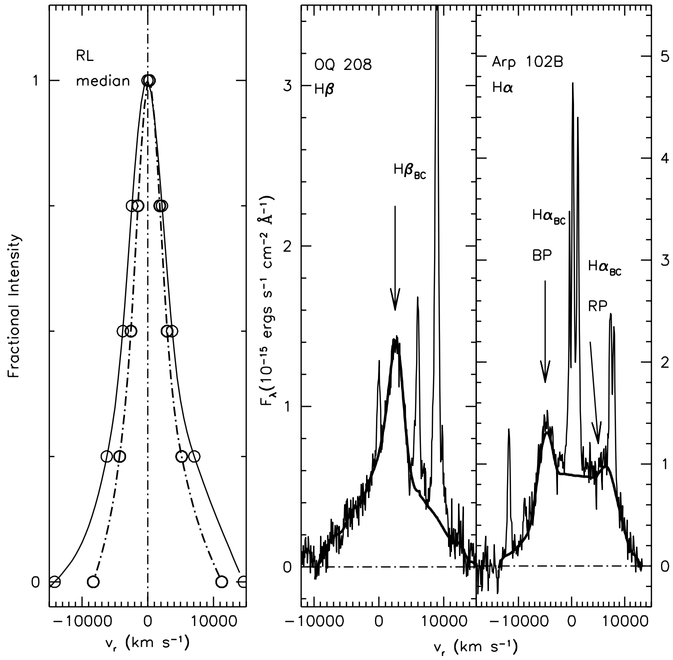

Fig. 2. *Left panel:* Profiles of C IV $\lambda1549_{\rm BC}$ (solid lines) and $\mathrm{H}\beta_{\rm BC}$ normalized to the same peak intensity and constructed from median values of the radial velocities measured on the blue and red sides of the profiles for the 31 RL AGN of Marziani et al. (1996). *Middle panel:* Hβ spectrum of OQ 208, showing a single, widely displaced $\mathrm{H}\beta_{\rm BC}$ peak (adapted from Marziani et al. 1993). *Right panel:* Hα profile of the prototype of "wide-separation double peakers" Arp 102B. Unpublished spectrum obtained at the 1.82-m telescope of the Asiago observatory on March 25, 1989. The thick solid line traces $\mathrm{H}\beta_{\rm BC}$.

4. NLSY1 NUCLEI ARE NOT A DISJOINT RQ POPULATION

NLSy1 are neither peculiar nor rare. The 8[th] edition of the Véron-Cetty & Véron (1998) catalogue includes 119 NLSy1 satisfying the defining criterion FWHM Balmer $\lesssim$ 2000 km s^{-1}. They account for $\approx$ 10% of all AGN in the same redshift and absolute magnitude range. Attention toward NLSy1 remained dormant after their identification as a particular class (Osterbrock & Pogge 1985) until it was discovered that they may represent $\approx$1/3–1/2 of all soft X-ray selected Seyfert 1 sources (e.g., Grupe et al. 1998). NLSy1 are also apparently favored in AGN samples selected on the basis of color. They account for 27% of the RQ Boroson & Green (1992) sample, probably because of an optical continuum that is steeply rising toward the near UV. NLSy1 do not occupy a disjoint region in parameter space. They are at an extremum in the FWHM(Hβ) vs. $\mathrm{R}_{\rm FeII}$ (= I(Fe IIλ4570)/I($\mathrm{H}\beta_{\rm BC}$)) and in the "Eigenvector 1" parameter spaces (Boroson & Green 1992; Brotherton & Francis 1999; Sulentic et al. 2000a). Also, the soft X-ray spectral index $\Gamma_{\rm soft}$ shows a continuous distribution which includes NLSy1 at the high end (Wang, Brinkmann, & Bergeron 1996; Sulentic et al. 2000a; Sulentic et al. 2000b).

Orientation can easily explain much of the RQ phenomenology observed by Marziani et al. (1996). I Zw 1 can be considered as an extremum with an accretion disk seen face-on (i = 0°), and an outflowing wind observed along the disk axis. We can infer that the opening angle of any C IV λ1549 outflow is probably large (i.e., the wind is quasi spherical) because C IV λ1549 profiles like I Zw 1 are rare. Other NLSy1 show low W(C IV λ1549), and strong Fe $\mathrm{II}_{\rm opt}$, but do not always show large C IV λ1549 blueshifts (Rodriguez-Pascual, Mas-Hesse, & Santos-Lleo 1997). Nonetheless, it is still possible that NLSy1 may be structurally different from other RQ AGN. If the soft X-ray excess of NLSy1 is due to high accretion rate, then a slim accretion disk is expected to form (Abramowicz et al. 1988). Line correlations presented in (Sulentic et al. 2000b) appear to hold until FWHM(Hβ) $\lesssim$ 4000 km s^{-1}. For FWHM $\gtrsim$ 4000 km s^{-1} line parameters appear to be uncorrelated; however, it is at present unclear because of the difficulty in measuring weak and broad Fe $\mathrm{II}_{\rm opt}$ sources and/or because of a BLR structural difference. This limit may be related to the possibility of sustaining a particular disk structure and an HIL outflow. A second parameter, independent from orientation is needed to account for the FWHM($\mathrm{H}\beta_{\rm BC}$) vs. $\mathrm{R}_{\rm FeII}$ vs. $\Gamma_{\rm soft}$ sequences (see Sulentic et al. 2000a; Sulentic et al. 2000b for a detailed discussion).

5. INFERENCES ON BLR MODELS FOR RQ AGN

Models developed almost independently of the data through the 80's and early 90's. The situation has now changed because of three main developments: (1) the "Eigenvector 1" correlations allow a systematic view of the change in optical emission line properties for different classes of AGN (Boroson & Green 1992; Brotherton & Francis 1999; Sulentic et al. 2000a); (2) the C IV λ1549 – Hβ comparison has yielded direct clues about the structure of the BLR (Marziani et al. 1996; Sulentic et al. 2000b) and (3) data collected for RM projects provide a high-sampling description of line variations. For instance, binary black hole scenarios (Gaskell 1996) were recently challenged by the failure to detect the radial velocity variations expected from previous observations and model predictions (Eracleous et al. 1997).

A model in which C IV λ1549 is emitted by outflowing gas (e.g., a spherical wind) while H$\beta_{\rm BC}$ is emitted in a flattened distribution of gas (observed in a direction that minimizes velocity dispersion) such as an optically thick disk (obscuring the receding half of the C IV λ1549 flow, Livio & Xu 1997) or at the wind base is immediately consistent with the I Zw 1 data. The big question is whether the results for I Zw 1 can be straightforwardly extended to other RQ AGN.

An accretion disk (AD) provides a high density and high column density medium for Fe II production (e.g., Dumont & Joly 1992), and possibly other low ionization lines such as CaII (e.g., Dultzin-Hacyan, Taniguchi, & Uranga 1999). AD avoid conflict with the stringent restrictions on line profile smoothness imposed by the first extremely high s/n Balmer line observations (Arav et al. 1997; Arav et al. 1998) of—incidentally—two NLSy1. They place a lower limit of (10^{7-8}) on the number of discrete emitters needed to explain the observed profiles.

Winds arise as a natural component of an AD model when the effects of radiative acceleration are properly taken into account (Murray et al. 1995; Murray & Chiang 1998) or when a hydromagnetic or hydrodynamic treatment is performed (Bottorff et al. 1997; Williams, Baker, & Perry 2000). A signature of radiative acceleration is provided by observations of "double troughs" in $\approx \frac{1}{5}$ of BAL QSOs, i.e., of a hump in the absorption profiles of N V λ1240 and C IV λ1549 at the radial velocity difference between Lyα and N V λ1240, 5900 km s^{-1}. Such a feature indicates that Lyα photons are accelerating the BAL clouds (Arav & Begelman 1994, and references therein). Additional evidence is provided by the radial velocity separation in the narrow absorption components of Lyα and N V λ1240 which show the same Δv_r of the two doublet components of C IV λ1549 (e.g., Wampler 1991).

6. THE TROUBLE WITH BARE ACCRETION DISKS AND BIPOLAR FLOWS

Relativistic Keplerian disks (Chen & Halpern 1989; Storchi-Bergmann, Baldwin, & Wilson 1993) may explain unusual profile shapes (e.g., double-peaked profiles of Balmer emission lines; Eracleous & Halpern 1994; Sulentic et al. 1995). Uniform axisymmetric disk models produce double-peaked line profiles with the blue peak stronger than the red peak because of Doppler boosting, a feature that is not always observed in these already rare profiles. To solve this problem, Storchi-Bergmann et al. (1995) and Eracleous et al. (1995), proposed that the lines can originate in an eccentric (i.e., elliptical) disk. Simple disk illumination models can also produce single peaked LIL, provided they are produced at large radii ($\gtrsim 10^3$ gravitational radii) or that the disk is observed at small inclination (Dumont & Collin-Souffrin 1990; Rokaki, Boisson, & Collin-Souffrin 1992; Sulentic et al. 1998). The first of these conditions may be met in all NLSy1 galaxies; both of them seem to be met in I Zw 1.

Aside from NLSy1 sources, there is general disagreement between observations and model predictions for externally illuminated Keplerian disks in a lineshift-asymmetry parameter space (Sulentic et al. 1990). Only a minority ($\lesssim$ 10 %) of RL and a handful of RQ AGN show double peaked Balmer lines suggestive of a Keplerian velocity field (Eracleous & Halpern 1994; Sulentic, Marziani, & Dultzin-Hacyan 1999). Double-peakers (e.g., Arp 102B in Fig. 2, FWHM(H$\beta_{\rm BC}$) $\gtrsim$ 10,000 km s^{-1}) cannot be like the classical cases because the line widths are much smaller. The peaks often vary out of phase (Arp 102B: Miller & Peterson 1990; 3C 390.3: Zheng, Veilleux, & Grandi 1991). Double peaks (NGC 1097) (Storchi-Bergmann et al. 1993; Storchi-Bergmann et al. 1995) or one of the peaks (Pictor A) (Sulentic et al. 1995) sometimes appear quite suddenly. Profile variability studies of Balmer lines force us to introduce second order modifications to the basic scheme, such as: eccentric rings and precession (Eracleous et al. 1995; Storchi-Bergmann et al. 1997), inhomogeneities such as orbiting hot spots (Zheng et al. 1991), and warps (Bachev 1999). Not even these *epicycles* are always capable of

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco

explaining the observed variability patterns. Even if elliptical AD models do well in explaining the integrated profiles, they face important difficulties in explaining variability patterns.

A serious problem for AD models of emission lines is emerging from spectropolarimetric observations. If profile broad line shapes are orientation dependent then, in principle, the profile shape in polarized light will depend on the distribution of the scatterers relative to the principal axis and to our line of sight. Early spectropolarimetric results showed a discrepancy with the simple disk + electron-scattering-dominated atmosphere models, which predicted polarization perpendicular to the radio axis. The observed polarization is low, parallel to the disk axis, and shows no statistically significant wavelength dependence (Antonucci 1988). Recently, Antonucci, Hurt, & Agol (1996) and Corbett et al. (1998) included double-peakers in their samples, and obtained troublesome results for disk emission models because the polarized Hα profiles are centrally peaked (Corbett et al. 1998). They investigated the case of disk emission where the scattering particles are located above and below an obscuring torus, along its poles. This "polar scattering model" is successful in explaining the polarized profiles *but not the position angle of the polarization vector*.

The same polarization studies indicate that the *only* scenario that can account for both the shapes of the scattered line profiles and the alignment of the optical polarization with the radio jet in wide separation double peakers like Arp 102B (Fig. 2) involves a *biconical* BLR within an obscuring torus. Hα photons emitted by clouds participating in a biconical flow are scattered towards the observer by dust or electrons in the inner wall of the surrounding torus. The particular case of biconical outflow was first developed to reproduce observed profiles by Zheng, Binette, & Sulentic (1990). This model has been successfully applied to fit observed profiles in double-peaked objects (Zheng et al. 1991; Sulentic et al. 1995).

Double peaked or single blueshifted peak LIL profiles fitted with bi-cone outflow models require that the receding part of the flow is also seen. Self-gravity may be important beyond $\sim$ 1 pc, and the disk may be advection-dominated and optically thin (Livio & Pringle 1996). Recent work by Shaviv, Wickramasinghe, & Wehrse (1999) models the vertical structure of AD and the origin of thermal winds above AD. They not only find that a wind powered by a thermal instability develops in all disks with certain opacity laws but also that in disks dominated by bremsstrahlung radiation, a time-dependent inner hole develops below a critical accretion rate. This scenario provides a natural explanation for transient double-peakers, such as NGC 1097 (Storchi-Bergmann et al. 1995; Storchi-Bergmann et al. 1997), but low accretion rate is a requirement for *both* advection dominated disks and hole formation.

Sulentic et al. (1995) explored the idea that the double-peaked emitters represent a geometrical extremum where an outflow is viewed close to pole-on. However, double-peakers are associated with double-lobe radio-sources suggesting that the line of sight has a considerable inclination to the axis of the jets. The problem arises *only* if the core (pc scale) jets is related to the much larger (100 kpc scale) jets. There is both theoretical (e.g., Valtonen 1999) and observational evidence against this assumption.

7. EMISSION FROM CLOUDS ILLUMINATED BY AN ANISOTROPIC CONTINUUM

Models based on radiative acceleration of optically thick clouds with small volume filling factor gained wide acceptance in the Eighties (Osterbrock & Mathews 1986, and references therein; see also Binette, Wilson, & Storchi-Bergmann 1996). However, problems with cloud confinements and stability (Mathews & Doane 1990) have made them increasingly less frequently invoked to explain observations.

First RM studies on Balmer lines excluded radial, and favored orbital or chaotic motions (e.g., Koratkar & Gaskell 1991; Korista et al. 1995). Goad & Wanders (1996) applied RM techniques to one of the most extensively monitored objects: NGC 5548. They ruled out radial motions, and found that the C IV λ1549 line variations are broadly consistent with a spherical BLR geometry, in which clouds following randomly inclined circularly Keplerian orbits are illuminated by an anisotropic source of ionizing continuum. A RM result favoring Keplerian motion may be approximately correct also for models in which the emitting gas is not bound, such as a wind, since most of the emission occurs near the base of the flow, when the velocity is still close to the escape velocity, which is similar to the Keplerian velocity (Murray & Chiang 1998).

8. IS THE DISK + WIND MODEL APPLICABLE TO ALL AGN?

Emission from a terminal flow can explain the recent observations of Goad et al. (1999) who reported that LIL (Mg II λ2800+ Fe II_{UV}) in NGC 3516 do not respond to continuum variations which did induce detectable variability in the HIL (Lyα and C IV λ1549) lines. Hydromagnetic wind models such as those developed by Emmering, Blandford, & Shlosman (1992) and Bottorff et al. (1997) exhibit these basic properties. A two-zone wind provides another scenario for the different origins of LIL and HIL.

Turning to the general population of RL AGN, the predominance of redshifts and redward asymmetric profiles is difficult to explain. Several lines of evidence suggest a significant role of gravitational redshift in RL AGN (Corbin 1997) possibly related to a lower distance (in units of gravitational radii) between BLR and central black hole, which may be systematically more massive in RL than in RQ AGN. If this is the case, then a double zone wind may be present also in RL AGN, since C IV $\lambda1549_{\rm BC}$ is still systematically blueshifted with respect to H$\beta_{\rm BC}$. The "correlation" between C IV $\lambda1549_{\rm BC}$ and H$\beta_{\rm BC}$ parameters could be due to the impossibility of maintaining a radial flow along the disk axis, where a relativistic jet is instead propagating. This will make any HIL outflow possible only at lower latitudes over the disk plane and, therefore, will produce more similar H$\beta_{\rm BC}$ and C IV $\lambda1549_{\rm BC}$ profiles.

9. CONCLUSION

While observations support emission from an accretion disk and an associated spherical wind in RQ AGN with FWHM(H$\beta_{\rm BC}$) $\lesssim$ 4000 km s^{-1}, there is not enough observational support to warrant the same conclusion for RL AGN (and possibly RQ with FWHM $>$ 4000 km s^{-1}), although a disk + wind model is a viable possibility also in this case. Wide separation double peakers (mostly RL) do not provide conclusive evidence in favor of LIL disk emission; rather, there is evidence against disk emission as well as against every other reasonably simple scenario.

DD-H acknowledges support through grant IN109698 from PAPIIT-UNAM. PM acknowledges financial support from MURST through grant Cofin 98-02-32, as well as hospitality and support from IA-UNAM.

REFERENCES

Abramowicz, M., Czerny, B., Lasota, J. P., & Szuszkiewicz E. 1988, ApJ, 332, 646
Antonucci, R. 1988, in Supermassive Black Holes, ed. M. Kafatos (Cambridge: Cambridge University Press), 26
Antonucci, R. R. J., Hurt, T., & Agol, E. 1996, ApJ, 456, L25
Arav, N., Barlow, T. A., Laor, A., & Blandford, R. D. 1997, MNRAS, 288, 1015
Arav, N., Barlow, T. A., Laor, A., Sargent, W. L. W., & Blandford, R. D. 1998, MNRAS, 297, 990
Arav, N., & Begelman, M. C. 1994, ApJ, 434, 479
Bachev, R. 1999, A&A, 348, 71
Baldwin, J. A. 1997, in ASP Conf. Ser. Vol. 113, Emission Lines in Active Galaxies: New Methods and Techniques, ed. B. M. Peterson, F.-Z. Cheng, & A. S. Wilson (San Francisco: ASP), 80
Binette, L., Wilson, A. S., & Storchi-Bergmann, T. 1996, A&A, 312, 365
Boroson, T. A., & Green, R. F. 1992, ApJS, 80, 109
Bottorff, M., Korista, K. T., Shlosman I., & Blandford R. D. 1997, ApJ, 479, 200
Brotherton, M. S., & Francis, P. J. 1999, in ASP Conf. Ser. Vol. 162, Quasars and Cosmology, ed. G. Ferland & J. Baldwin (San Francisco: ASP), 395
Brotherton, M. S., Wills, B. J., Steidel, R., & Sargent, W. L. W. 1994, ApJ, 423, 131
Chen, K., & Halpern J. P. 1989, ApJ, 344, 115
Collin-Souffrin, S., Dyson, J. E., McDowell, J. C. & Perry, J. J. 1988, MNRAS, 232, 539
Corbett, E. A., Robinson, A., Axon, D. J., Young, S., & Hough, J. H. 1998, MNRAS, 296, 721
Corbin, M. R. 1997, ApJ, 485, 517
Corbin, M. R., & Boroson, T. A. 1996, ApJS, 107, 69
Dultzin-Hacyan, D., Taniguchi, Y., & Uranga, L. 1999, in ASP Conf. Ser. Vol. 175, Structure and Kinematics of Quasar Broad Line Regions, ed. C. M. Gaskell, W. N. Brandt, M. Eracleous, M. Dietrich, & D. Dultzin-Hacyan (San Francisco: ASP), 303
Dumont, A. M., & Collin-Souffrin, S. 1990, A&A, 229, 313
Dumont, A. M., & Joly, M. 1992, A&A, 263, 75
Emmering, R. T., Blandford, R. D., & Shlosman, I. 1992, ApJ, 385, 460
Eracleous, M., & Halpern, J. P. 1994, ApJS, 90, 1
Eracleous, M., Halpern, J. P., Gilbert, A. M., Newman, J. A., & Filippenko, A. V. 1997, ApJ, 490, 216
Eracleous, M., Livio, M., Halpern, J. P., & Storchi-Bergmann, T. 1995, ApJ, 438, 610

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco

Francis, P. J., Hewett, P. C., Foltz, C. B., & Chaffee, F. H. 1992, ApJ, 398, 476
Gaskell, C. M. 1996, ApJ, 464, L107
Goad, M. R., Koratkar, A. P., Axon, D. J., Korista, K. T., & O'Brien, P. T. 1999, ApJ, 512, L95
Goad, M., & Wanders, I. 1996, ApJ, 469, 113
Grupe, D., Beuermann, K., Thomas, H. C., Mannheim, K., & Fink, H. H. 1998, A&A, 330, 25
Koratkar, A. P., & Gaskell, C. M. 1991, ApJ, 375, 85
Korista, K. T., et al. 1995, ApJS, 97, 285
Laor, A., Jannuzi, B. T., Green, R. F., & Boroson, T. A. 1997, ApJ, 489, 656
Livio, M., & Pringle, J. E. 1996, MNRAS, 278, L35
Livio, M., & Xu, C. 1997, ApJ, 478, L63
Marziani, P., Sulentic, J. W., Calvani, M., Pérez, E., Moles, M., & Penston, M. V. 1993, ApJ, 410, 56
Marziani, P., Sulentic, J. W., Dultzin-Hacyan, D., Calvani, M., & Moles, M. 1996, ApJS, 104, 37
Mathews, W. G., & Doane, J. S. 1990, ApJ, 352, 443
Miller, J. S., & Peterson, B. M. 1990, ApJ, 361, 98
Murray, N., & Chiang, J. 1998, ApJ, 494, 125
Murray, N., Chiang, J., Grossman, S. A., & Voit, G. M. 1995, ApJ, 451, 498
Osterbrock, D. E., & Mathews, W. G. 1986, ARA&A, 24, 171
Osterbrock, D. E., & Pogge, R. W. 1985, ApJ, 297, 166
Penston, M. V. 1991, in Variability of Active Galactic Nuclei, ed. H. R. Miller & P. J. Wiita (Cambridge: Cambridge University Press), 343
Penston, M. V., Croft, S., Basu, D. & Fuller, N. 1990, MNRAS, 244, 357
Rodriguez-Pascual, P. M., Mas-Hesse, J. M., & Santos-Lleo, M. 1997, A&A, 327, 72
Rokaki, E., Boisson, C., & Collin-Souffrin, S. 1992, A&A, 253, 57
Shaviv, G., Wickramasinghe, D., & Wehrse, R. 1999, A&A, 344, 639
Storchi-Bergmann, T., Baldwin, J. A., & Wilson, A. S. 1993, ApJ, 410, L11
Storchi-Bergmann, T., Eracleous, M., Livio, M., Wilson, A. S., Filippenko, A. V., & Halpern, J. P. 1995, ApJ, 443, 617
Storchi-Bergmann, T., Eracleous, M., Ruiz, M. T., Livio, M., Wilson, A. S., & Filippenko, A. V. 1997, ApJ, 489, 87
Sulentic, J. W. 1989, ApJ, 343, 54
Sulentic, J. W., Calvani, M., Marziani, P., & Zheng, W. 1990, ApJ, 355, L15
Sulentic, J. W., & Marziani, P. 1999, ApJ, 518, L9
Sulentic, J. W., Marziani, P., & Dultzin-Hacyan, D. 1999, in ASP Conf. Ser. Vol. 175, Structure and Kinematics of Quasar Broad Line Regions, ed. C. M. Gaskell, W. N. Brandt, M. Eracleous, M. Dietrich, & D. Dultzin-Hacyan (San Francisco: ASP), 175
——————. 2000a, ARA&A, in press
Sulentic, J. W., Marziani, P., Zwitter, T., & Calvani, M. 1995, ApJ, 438, L1
Sulentic, J. W., Marziani, P., Zwitter, T., Calvani, M., & Dultzin-Hacyan, D. 1998, ApJ, 501, 54
Sulentic, J. W., Zwitter, T., Marziani, P., & Dultzin-Hacyan, D. 2000b, ApJ, submitted
Türler, M., & Courvoisier, T. J. L. 1998, A&A, 329, 863
Ulrich, M.-H., Maraschi, L., & Urry, C. M. 1997, ARA&A, 35, 445
Valtonen, M. J. 1999, ApJ, 520, 97
Véron-Cetty, M.-P., & Véron, P. 1998, Quasars and Active Galactic Nuclei, ESO Sci. Rep (Munich: ESO), 18, 1
Wampler, E. J. 1991, ApJ, 368, 40
Wang, T., Brinkmann, W., & Bergeron, J. 1996, A&A, 309, 81
Wanders, I., & Peterson, B. M. 1996, ApJ, 466, 174
Williams, R. J. R., Baker, A. C., & Perry, J. J. 2000, MNRAS, 310, 913
Wills, B. J., et al. 1995, ApJ, 447, 139
Zheng, W., Binette, L., & Sulentic, J. W., 1990, ApJ, 365, 115
Zheng, W., Veilleux, S., & Grandi, S. A. 1991, ApJ, 381, 418

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco

D. Dultzin-Hacyan: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510 México, D. F., México (deborah@astroscu.unam.mx).

P. Marziani: Osservatorio Astronomico di Padova, Vicolo dell' Osservatorio 5, I–35122 Padova, Italy (marziani@pd.astro.it).

J.W. Sulentic: Dept of Physics And Atronomy, University of Alabama, Tuscaloosa, AL 35487, USA (giacomo@merlot.astr.ua.edu).