UV/optical emission line profiles as diagnostic tools for structure and kinematics in the BLR of AGN

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Abstract

Broad emission line profiles can be characterized by their line width ratios FWHM/σ_{line} (Table 1). The broad UV/optical emission line profiles - observed in the spectra of Active Galactic Nuclei (AGN) - follow systematic trends in FWHM vs. FWHM/σ_{line} graphs (Figs. 1, 2). We tried to model those observed characteristics by multiple combinations of different line profiles (see Table 1) in a simple way. Finally, all observed trends in different emission line diagrams could be explained in a simple and unique way by intrinsic Lorentzian profiles that are broadened by rotation (Figs. 1-4). Other combinations of line profiles were less unambigously and/or could be excluded. Individual turbulent velocities belong to the different emission lines in their line emitting regions (Figs. 1, 2, Table 2): they range from 500 to 5,000 km/s. The ratio of the turbulent velocities with respect to the rotational velocities in the line emitting regions gives us information on the geometrical thickness of the accretion disk. Slow rotating accretion disk are ten times thinner than fast rotating disks (Fig. 5). If one is calculating the central black hole masses in AGN on basis of their emission line widths one has first to correct for the contribution of the turbulence onto the widths of the line profile. Otherwise black hole masses are overestimated by a factor of two to ten (Fig. 6) without correction for the turbulent velocity share on the line profile width. Especially the broad UV emission lines have to be corrected for this effect as they are more affected by the additional turbulence component in comparison to the optical lines (see Table 2).

Table 1: Broad emission line profile types, their associated motions, and their characteristic line width ratio FWHM/σ_{line} (with σ_{line} = line dispers.):

Profiles	Motions	FWHM/σ_{line}
Gaussian	Doppler	2.35
Lorentzian	turbulence	$\rightarrow 0$
exponential	electr. scattering	0.98
logarithmic	in-/outflow	$\rightarrow 0$

Table 2: Intrinsic turbulent velocities connected to the line emitting regions of the strongest emission lines:

emission line	turbulent vel. [$\mathrm{km\,s^{-1}}$]
Hβ	500 ± 200
Hγ	500 ± 200
Hα	$1,000 \pm 500$
He II λ4686	$1,000 \pm 200$
C III] λ1909	$1,500 \pm 700$
C IV λ1549	$3,000 \pm 1,000$
Si IV λ1400	$3,000 \pm 1,000$
He II λ1640	$3,000 \pm 1,500$
Lyα+N V λ1240	$5,000 \pm 2,000$

Accretion disk geometry

The accretion disk height *H* relative to their radius *R* is proportional to the turbulence velocity in the accretion disk with respect to their rotational velocity:

$$H/R = (1/\alpha)(v_{turb}/v_{rot})$$

α is the unknown viscosity parameter of the order of one (Pringle, 1981).

BH Masses in AGN

The black hole masses can be derived from the broad emission line widths under the assumption that the gas dynamics is dominated by the central massive object:

$$M_{BH} = f\, c\, \tau_{cent}\, \Delta v^2\, G^{-1}$$

The characteristic distance cτ of the line emitting regions is known from reverberation mapping studies for our galaxy sample. The factor f depends on the kinematics and geometry of the BLR. The line width Δv should depend on the rotation velocity only and has to be corrected for the additional width of the Lorentzian profile.

References

1. Kollatschny W., Zetzl M. (2011) Nature 470, 366

2. Kollatschny W., Zetzl M. (2012) A&A subm.

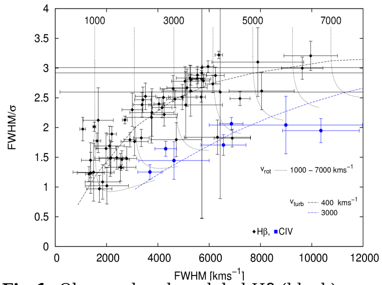

Fig.1: Observed and modeled Hβ (black) as well as CIVλ1549 (blue) line width ratios FWHM/σ_{line} versus line width FWHM in our sample of 35 Seyfert galaxies. The dashed curves show theoretical line width ratios of rotational broadened Lorentzian line profiles; their FWHMs are 400 km/s (Hβ) and 3,000 km/s (CIVλ1549) respectively. The associated rotation velocities range from 1,000 to 7,000 km/s (curved dotted lines, from left to right).

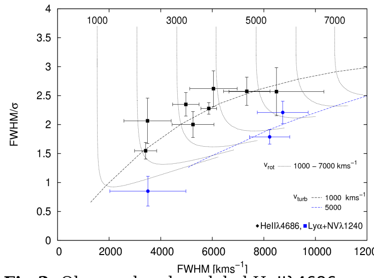

Fig.2: Observed and modeled HeIIλ4686 (black) as well as Lyα+NV (blue) line width ratios FWHM/σ_{line} versus line width FWHM. The dashed curves show theoretical line width ratios of rotational broadened Lorentzian line profiles; their FWHMs are 1,000 km/s (HeII) and 5,000 km/s (Lyα+NV) respectively. The associated rotation velocities range from 1,000 to 7,000 km/s (curved dotted lines, from left to right).

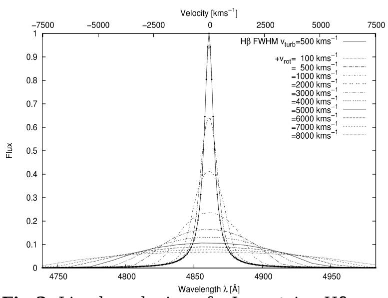

Fig.3: Line broadening of a Lorentzian Hβ profile due to rotation. The rotation velocities range from 100 to 8,000 km/s. The intrinsic turbulent velocity of the Hβ line corresponds to 500 km/s.

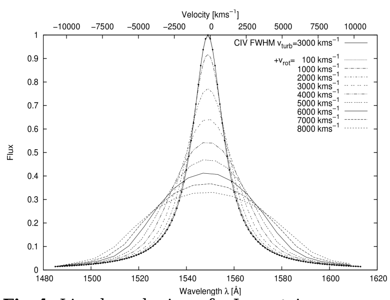

Fig.4: Line broadening of a Lorentzian CIVλ1549 profile due to rotation. The rotation velocities range from 100 to 8,000 km/s. The intrinsic turbulent velocity of the CIV line corresponds to 3,000 km/s.

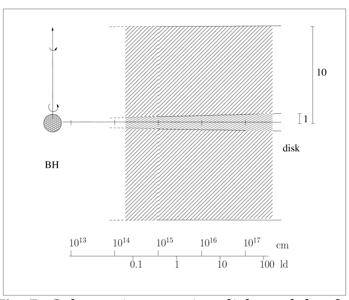

Fig.5: Schematic accretion disk models of AGN: Slow rotating AGN have an accretion disk ten times thicker than fast rotating AGN.

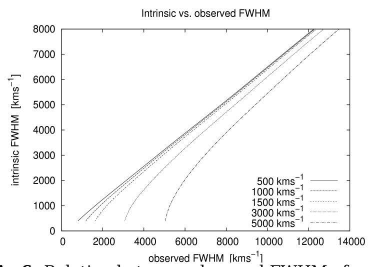

Fig.6: Relation between observed FWHM of the emission line profiles and the intrinsic FWHM caused by rotation only. The relation is shown for different turbulent velocities ranging from 500 to 5,000 km/s.