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VIRILIZATION OF THE BROAD Hα EMISSION REGION IN ACTIVE GALACTIC NUCLEI TYPE 1

SLADJANA MARČETA-MANDIĆ[1,2], JELENA KOVAČEVIĆ-DOJČINOVIĆ[1], and LUKA Č. POPOVIĆ[1,2]

[1]*Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia*

[2]*Department of Astronomy, Faculty of Mathematics, Univeristy of Belgrade, Studentski Trg 16, 11000 Belgrade, Serbia*
E–mail sladjana@aob.rs

Abstract. Here we investigate the virialization of the broad Hα emission region using the sample of 68 Type 1 Active Galactic Nuclei (AGN) taken from the Sloan Digital Sky Survey (SDSS). This was done by comparing kinematical parameters of the broad Hα lines with those of the broad Hβ, for which it is assumed that are originating from the virialized emission region. Our results are indicating that other mechanisms should be responsible for the Hα profile broadening and asymmetry, besides black hole gravitation, i.e. the broad Hα emission region is probably not with the same geometry as Hβ one.

1. INTRODUCTION

Active galactic nuclei (AGN) is a compact region in the center of a galaxy with a luminosity over 10^4 higher than those of a normal galaxy, which is attributed to the accretion of gas into the super-massive black hole (SMBH) ($10^6 - 10^{10} M_{\odot}$) situated in AGN core. Most of the AGNs have a similar structure (Antonucci 1993): SMBH in its center is surrounded by a geometrically thin and optically thick accretion disc (AD) which expands into a dusty torus. Above and below the AD spreads the broad line region (BLR), with optically thick gas, where broad emission lines (BELs) arise (see Osterbrock 1989). Gas in the BLR is ionized by the continuum radiation emitted from the AD and influenced by the gravitational field of SMBH, which causes complexity of structure and kinematics of BLR and affects BELs shapes (Sulentic et al. 2000).

As BELs are originating from the regions close to the SMBH, it is assumed that the BLR emission gas kinematics is virialized, i.e. gas is following the gravitationally driven rotation (see e.g. Sulentic et al. 2000). Such motion of the gas affects the BELs profile, and, in the case of Keplerian-like motion, broadens BELs. Therefore, based on the virial theorem, BELs Full Width at Half Maximum (FWHM) are often used for the estimation of SMBH mass ($M_{\rm BH}$) (Peterson 2014).

The FWHM of the broad Hβ line is most frequently used for $M_{\rm BH}$ estimation (see Peterson et al. 2004), since it is assumed that Hβ is emitted from virialized parts of the BLR. Also, there is an assumption that the red asymmetry frequently seen in the broad Hβ line profile can be caused by the gravitational redshift, and therefore, it can be $M_{\rm BH}$ indicator as well (Zheng et al. 1990).

Several authors (Green et al. 2005, Mejia-Restrepo et al. 2016, Woo et al. 2015) used the FWHM of Hα line as a virial estimator of $M_{\rm BH}$, relying their calculations on the high correlation of the broad Hα FWHM and the broad Hβ FWHM. This approach is based on their assumption that these two lines have similar profiles, and that Hα region is virialized as Hβ ones. However, there are some indications that broad Hα profiles can be affected by the starburst-driven galactic winds (Shapiro et al. 2009) or by AGN outflows (Eun et al. 2017).

In this work we wanted to investigate: (1) if the assumption that the broad Hα and the broad Hβ profiles are similar is correct; (2) if the broad Hα line is virialized as the broad Hβ is, and (3) is there an influence of the gravitational redshift to the broad Hα line profile.

For this purpose, we compared the broad Hα line profiles with those of the broad Hβ, and the correlations between kinematical line parameters for each of these two lines which should indicate gravitational influence to their emission regions.

2. THE SAMPLE AND ANALYSIS

For our research, we used the sample of AGNs Type 1 spectra taken from the SDSS database, analyzed in Shen et al. 2015 and Harris et al. 2012. We removed several objects with low signal-to-noise ratio, and with the blue asymmetry in the broad Hβ profile, assuming that it is caused by outflows of the gas in Hβ emitting region (see Jonić et al. 2016, Popović et al. 2019). We also removed spectra with no Hα line due to the cosmological redshift of the object, and the final sample consists of 68 AGNs.

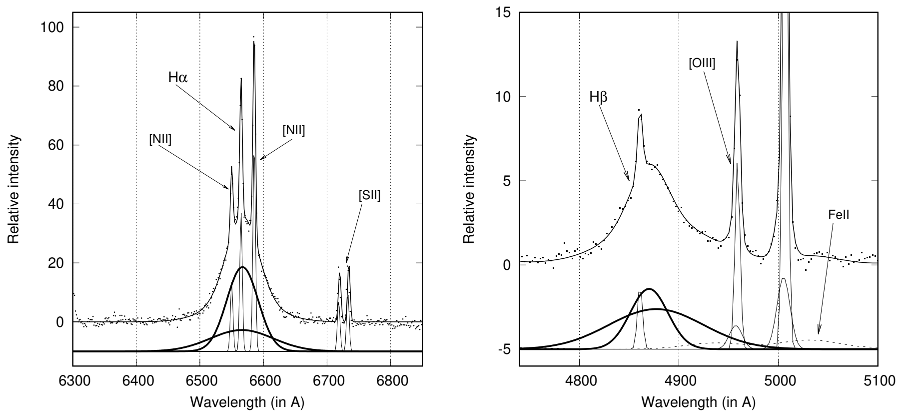

Figure 1: The examples of the decomposition of the Hα and Hβ for object 0439-51877-0566 (SDSS plate-mjd-fiber). The Hα and Hβ are decomposed to one narrow and two broad Gaussians. The observations are denoted with dots, the model with a solid line, an optical Fe II template with a dashed line. The narrow emission line components are denoted with thin, and the broad components with a thick solid line.

The spectra were corrected for the Galactic extinction, cosmological redshift, and host galaxy contribution. Further, continuum emission was removed, and spectra were fitted using the multi-Gaussian model of optical emission in $\lambda\lambda 4000 - 5500 \mathring{A}$ and $\lambda\lambda 6200 - 6900 \mathring{A}$ ranges, as it was described in Kovačević et al. 2010. The BLR emission is described with the two-component model, as assumed that BLR consists of two different sub-regions: very broad line region (VBLR) closer to the SMBH, and intermediated line region (ILR), further away from SMBH (see Kovačević et al. 2010 and references therein).

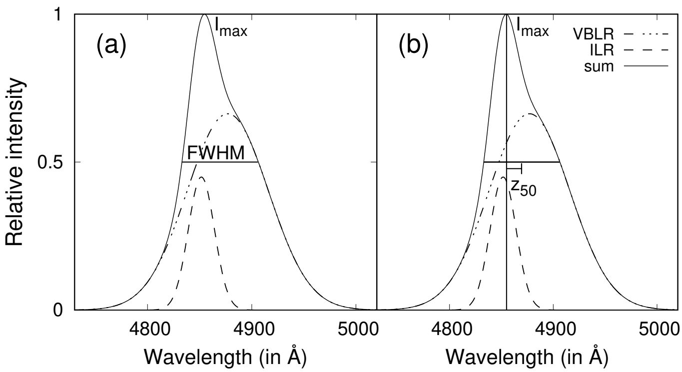

Figure 2: An example of measuring FWHM (a) and intrinsic redshift z_{50} (b) of the broad line component (VBLR + ILR), represented with a different dashed line.

An example of decomposition of the optical emission is shown in Fig. 1. The BEL profile is obtained as a sum of two broad Gaussians, and afterward, the FWHM and asymmetry (intrinsic redshift, z_{50}) of the BEL are measured as shown in Fig. 2. The z_{50} is measured as a difference between the centroid shift and the broad component peak at 50% of I_{max} (see Jonić et al. 2016).

3. RESULTS

We compared the broad Hα and broad Hβ profiles for the sample of 68 objects (see Fig. 3, left). The mean Hα profile is narrower than Hβ one, which may indicate that broad Hα arises in the emission region slightly further away from the SMBH than Hβ emission region. Mean Hα profile shows no asymmetry while mean Hβ profile has red asymmetry indicating a possible influence of the gravitational redshift.

Also, for both lines, we compared the relationships between the width $FWHM^2$ and the intrinsic shift z_{50} of the lines, which are expected to be linearly correlated in the case that line emitting region is virialized and influence of gravitational redshift is not negligible (Popović et al. 2019).

As can be seen in Fig. 3, right, for the Hα profiles there is no correlation between $FWHM^2$ and z_{50} (Spearman correlation coefficient, ρ=-0.09 and P-value of the null-hypothesis, P_0=0.44). On the other hand, the correlation of these profile parameters for the Hβ is significant (ρ=0.69 and $P_0 = 9 \cdot 10^{-11}$).

Furthermore, although there is significant asymmetry measured for the broad Hα profiles, 35% of these profiles are blueshifted and 65% are redshifted, which is not the case with the broad Hβ profiles, as they are only redshifted in this sample, as shown in Fig. 3 (right). As it can be seen in Fig. 3 (left) there is a difference between the

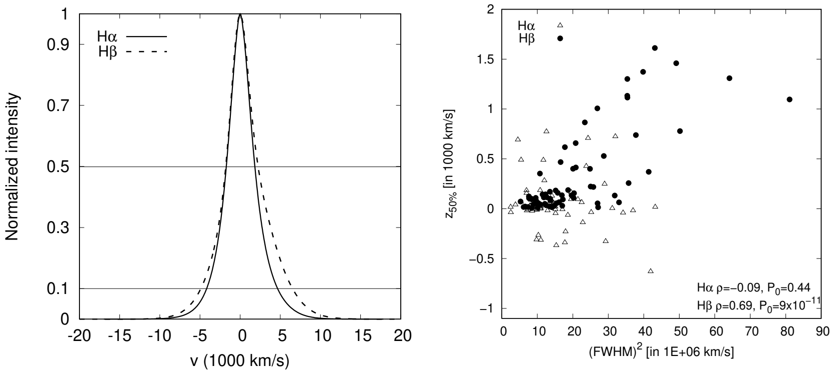

Figure 3: *Left:* Mean normalized profiles for Hα and Hβ. *Right:* The relationship between the $FWHM^2$ and z_{50} of the line measured at 50% of the maximal line intensity. The triangles denote the Hα and the full circles the Hβ lines. Spearman correlation coeff., ρ, and P_0, for both relationships, are given.

mean Hα and Hβ line profiles, especially in the red wing. This indicates that one cannot take 'apriori' that the geometry of the broad Hα and Hβ emission region is the same. The non-existence of the correlation between the Hα FWHM and Hα z_{50} indicates that these two line features probably are not influenced by the same physical mechanism in the case of the Hα line.

It seems that other mechanisms should be partly responsible for the Hα profile broadening and asymmetry, such as AGN outflows or starburst-driven galactic winds (as suggested i.e. in Shapiro et al. 2009), unrelated to the dominant influence of SMBH. Thus, the Hα line emitting region is probably less virialized than Hβ one, and the effect of the gravitational redshift is not observed in the Hα broad profiles in this sample.

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