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DECOMPOSITION OF THE BLENDED Hα+[N II] LINES IN SPECTRA OF THE ACTIVE GALACTIC NUCLEI TYPE 1.8-2

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Abstract. Here we present the procedure for decomposition of the blended [N II]+Hα wavelength band in spectra of Active Galactic Nuclei (AGN) Type 1.8-2, which could be the sum of the three strong wing components of narrow [N II] and Hα lines, hidden broad Hα component, or all these combined. For establishing this procedure and for setting the line parameter constraints in decomposition, we use the results of the outflow kinematics analysis done on the large AGN sample. We apply this procedure to the sample of 219 AGN spectra with blended [N II]+Hα, to demonstrate the complex and sophisticated decomposition and to check its physical validity.

1. INTRODUCTION

Active galactic nuclei (AGNs) are very strong sources of energy. Enormous amount of energy is radiated during the process of accretion of matter around a super-massive black hole in an AGN center. This process is followed by the gravitationally bounded motion of the emitting gas and appearance of gas outflows. The main characteristics of AGN spectra are strong emission lines. In the case of the AGNs Type 2, only narrow emission lines are present. The core of narrow lines dominantly originates from the gravitationally bounded gas, while outflow emission contributes in the narrow lines wings (Kovačević-Dojčinović et al. 2022, hereafter KD22). In AGNs Type 1.9 and 1.8, beside narrow lines, some broad lines are present, which originate from gravitationally bounded gas closer to the black hole. In the case of the AGNs Type 1.9 it is broad Hα, and in the case of the AGNs Type 1.8, the broad Hα and Hβ lines are present in spectra (see Osterbrock & Ferland 2006).

It seems that distinguishing between AGNs Type 2 or AGNs Type 1.9/1.8 is not always simple, since in some objects typically classified as Type 2 AGNs, [N II]6548, 6583 Å and Hα lines overlap, making the blended [N II]+Hα wavelength band. In these spectra, one cannot be sure without very careful spectroscopic analysis whether the blended [N II]+Hα is the sum of the three strong wing components of narrow

[N II] and Hα lines, or hidden broad Hα component (see Woo et al. 2014, Oh et al. 2015, Eun et al. 2017), or even a mixture of the two.

The correct decomposition of the blended [N II]+Hα wavelength band is important, since in the case of the presence of the broad Hα, its line parameters could be used for estimation of the black hole mass (M_{BH}), following the virial theorem (Greene & Ho 2005). On the other hand, the wing components of the narrow lines originate from the outflowing gas, which is not gravitationally bounded (KD22) and potential misinterpretation of the sum of the three wing components of the narrow [N II] and Hα as broad Hα could lead to fake estimation of M_{BH}.

In this work we will present the procedure for decomposition of the blended [N II]+Hα in spectra of Type 1.8-2 AGNs. The procedure is established using the outcomes of the outflow kinematics investigation on the large sample of AGN spectra, which is described in KD22.

2. THE SAMPLE AND ANALYSIS

For this research we used the sample of AGN spectra obtained from Sloan Digital Sky Survey (SDSS) Data Release 14. The spectra were chosen to have high signal-to-noise ratio and presence of the several narrow emission lines (see details in KD22). Using these selection criteria, we obtained 577 predominantly Type 2 AGNs, but also with the possible presence of Type 1.9 and Type 1.8 AGN spectra. Afterwards, we kept in the sample only the objects with blended [N II]+Hα wavelength band, which makes $\sim$40% of initial sample, i.e. 219 objects.

In these objects, the spectra were corrected for Galactic reddening, redshift and host-galaxy contribution (see KD22). Then, [O III]4959, 5007 Å, Hβ and [S II] narrow lines were fitted with two component Gaussian model - one Gaussian which fits the core of the line and the other which fits the wings of the line and represents the outflow emission. In this way, we got the data about the outflow contribution in the other lines in spectra, which will be used in [N II]+Hα decomposition procedure.

3. PROCEDURE FOR DECOMPOSITION OF THE BLENDED Hα+[N II] lines

KD22 analyzed the outflow kinematics following several narrow emission lines ([O III], Hβ, Hα, [N II] and [S II]) in AGN sample where [N II] and Hα lines do not overlap, i.e. could be fitted independently, without any fitting constrains. They found that: shifts and widths of wing components (which represent the outflow contribution) correlate between all analyzed emission lines, specially between Hα and [N II] lines, where they follow one-to-one relationship. The shifts of [S II] wing components, are also in strong correlation and follow one-to-one relationship with shifts of the Hα and [N II] wing components, but the wing component widths are sistemically smaller. On the other hand, the widths and the shifts of the [O III] wing components are sistemically larger than the same of the Hα and [N II] lines.

These results imply that the outflow kinematics systemically affects the line profiles in AGN spectra, but it reflects with different strength in profiles of different lines, and therefore multiple lines should be analyzed as one system in order to achieve physically correct spectral decomposition of blended [N II]+Hα wavelength band. In accordance with this findings, following procedure is established.

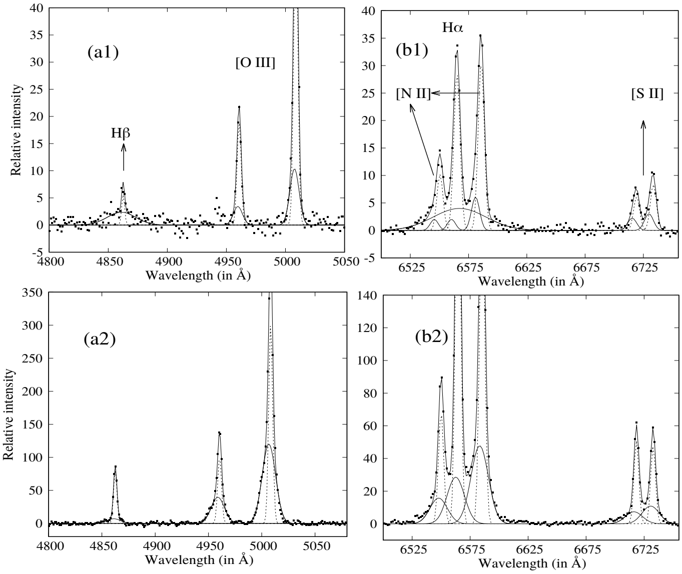

Figure 1: Example of decomposition of blended [N II]+Hα as mixture of the wing components and broad Hα (a1, b1) and as the sum of the three strong wing components (a2, b2). The wing components and broad Hα are denoted with solid line, and core components with dotted line.

In the case if there is no flux that extends significantly out of the [N II] doublet, i.e. the presence of the broad Hα in the blended [N II]+Hα wavelength band is uncertain, we propose to:

(1) Check if the broad Hβ is present. If it is present in the spectrum, the broad Hα component should be included as well. Hα and [N II] wing components should be additionally included (with reduced fitting parameters as defined below) if obvious asymmetry is present in narrow lines.

(2) If [O III] lines have no wing components detected, or if they have weak and narrow wing components (their width is not much broader than the width of the [O III] core), that implies that the broad Hα dominantly fits blended [N II]+Hα, and Hα and [N II] wing components should be included only if needed to fit the shape of the narrow lines.

(3) Contrary, if the [O III] lines have strong and broad wing components, then we expect that the sum of the three wing components of [N II] and Hα dominates in the blended region. Therefore, the blended [N II]+Hα should be fitted with the three wing components using the following fitting constraints.

shift Hα wing = shift [N II] wing = shift [S II] wing.

width Hα wing = width [N II] wing.

If there are no [S II] wing components detected, then the shift of Hα and [N II] wing components is one free parameter. Following empirical results from KD22, it is recommended to keep Hα and [N II] wing component widths to do not exceed much the width of the [O III] wing component. If the fit with three wing components, limited with the mentioned fitting constraints, cannot accurately describe the shape

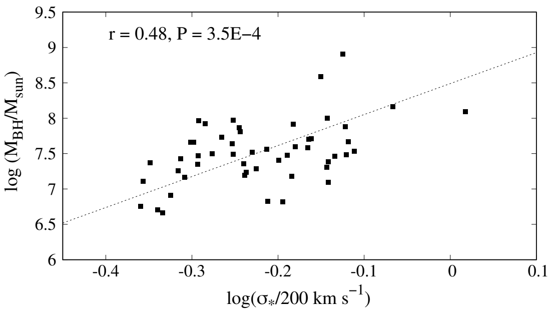

Figure 2: M_{BH} estimated using broad Hα vs. stellar velocity dispersion σ_*. σ_* - M_{BH} relation of Kormendy & Ho (2013) is denoted with dashed line.

of the complex [N II]+Hα wavelength band, then the broad Hα should be included.

The objects where the presence of the broad Hα is certain (the flux extend distinctly from both sides of the [N II] doublet) should be fitted with one broad component, and the wing components should only be included if narrow lines show asymmetry. In the case where they are needed, the wing components should be fitted with parameter constraints as defined above.

4. RESULTS OF THE DECOMPOSITION

By applying this procedure of decomposition in our sample of 219 AGNs with blended [N II]+Hα, we found that 55 objects (∼25% of sample) belong to the Type 1.9/1.8 AGNs, i.e. they have hidden the broad Hα line in blended [N II]+Hα. The rest of objects are Type 2 AGNs with strong wing components whose sum could be misinterpreted as broad Hα, as also noticed in Woo et al. (2014) and Eun et al. (2017). The detected broad Hα lines have Full Widths at Half Maximum (FWHMs) in the range of 2050-10600 km s^{-1}. The examples of decomposition are shown in Figure 1.

In order to check validity of [N II]+Hα decomposition in 55 objects where the broad Hα is detected, we estimated M_{BH} using the parameters of the broad Hα line (see Greene & Ho 2005) and we compared the obtained values with σ_* - M_{BH} relation (see Kormendy & Ho 2013). We found that estimated masses follow well σ_* - M_{BH} relation with scatter up to ∼0.5 dex (see Figure 2), while the correlation coefficient between estimated M_{BH} and σ_* is r=0.48, P=3.5E-4. These results imply that presented procedure gives the physically correct decomposition of the blended [N II]+Hα wavelength band.

References

Eun, D., Woo, J.-H. & Bae, H.-J.: 2017, *ApJ*, **842**, 5

Greene, J. E. & Ho, L. C.: 2005, *ApJ*, **630**, 122.

Kovačević-Dojčinović, J., Dojčinović, I., Lakićević, M., Popović, L.Č.:2022, *A&A*, **659**, 130.

Kormendy, J., Ho, L.C.: 2013, *ARA&A*, **51**, 511.

Oh, K., Yi, S.K., Schawinski, K., Koss, M., Trakhtenbrot, B., Soto, K.: 2015, *ApJS*, **219**, 10

Osterbrock, D., Ferland, G., 2006, Astrophysics of gaseous nebulae and active galactic nuclei, Sausalito, CA: University Science Book

Woo, J.-H., Kim, J.-G., Park, D., Bae, H.-J., et al.: 2014, *JKAS*, **47**, 167.