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# THE SIGNATURE OF THE GAS OUTFLOW IN THE ACTIVE GALACTIC NUCLEI TYPE 2 SPECTRA

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**Abstract.** We analyse a large sample of the AGNs Type 2 spectra which have a specific spectral characteristic that beside expected narrow emission lines, one broad emission line, H$\alpha$, is observed, which is not expected for the Type 2 AGNs. We focus on the fraction of these objects for which some authors (Eun at al. 2017) proposed that observed 'broad H$\alpha$' is actually the sum of the wing components of the close narrow emission lines H$\alpha$ and [N II] doublet, which is misinterpreted as the 'broad H$\alpha$'. They propose that wing components of the H$\alpha$+NII arise in a gas outflow. In order to check these claims, we search for the outflow signature in the other strong, narrow emission lines in the spectra (H$\beta$, [O III] and [S II]) and we examine if there are some correlations between the kinematical parameters, widths and shifts, of the wing components of these lines with the H$\alpha$+[N II] wing components. We found the significant correlations between the widths and shifts of wing components of all considered emission lines (H$\alpha$+[N II], H$\beta$, [O III] and [S II]) which implies their same origin from the Narrow Line Region outflow, and supports the claims of Eun at al. 2017. However, it seems that H$\alpha$ line is less affected with outflow kinematics, comparing to the [O III] lines.

## 1. INTRODUCTION

The most simple scheme of the Active Galactic Nuclei (AGN) structure assumes that in the center of an AGN there is a super-massive black hole surrounded by the high velocity gas of the Broad Line Region (BLR), where broad emission lines arise (with Full Width at Half Maximum - FWHM $\sim$ 4000 km s$^{-1}$). Around BLR there is a torus of the dust, and out of the dusty torus, there is the Narrow Line Region (NLR), where the narrow emission lines arise (FWHM $\sim$ 400 km s$^{-1}$). According to the Standard Unified model (Antonucci 1993, Urry & Padovani 1995), the difference in spectral properties between the AGN Type 1 and Type 2, is caused only by the orientation effect. The AGNs Type 2 are observed through dusty torus (edge-on), which covers the broad emission lines from BLR, so only the narrow emission lines can be observed in their spectra. On the other hand, in the spectra of the AGNs Type 1, which are observed with higher inclination angle ($\sim$ 45 degrees), both the narrow and the broad emission lines can be observed.

However, some exceptions are found in some spectra of the AGNs type 2, which challenge the classical Unified Model of the AGNs. In these objects, beside the expected narrow emission lines, the broad emission H$\alpha$ line is observed. Some authors proposed that these objects are Hidden Type 1 AGNs (Greene & Ho 2005, Oh et al.

2015), while Eun et al. 2017 proposed that one fraction of these objects are indeed the Hidden AGNs Type 1, with the true broad H$\alpha$, while in the other fraction of these objects, the broad H$\alpha$ can be explained as the sum of the wing components of the narrow H$\alpha$ and nearby [N II]$\lambda\lambda$ 6548, 6583 Å doublet, which have the close wavelengths and therefore the sum of their wing components can be misinterpreted as one broad line. They supposed that these wing components arise in the gas kinematically connected with an AGN outflow (Woo et al. 2016).

In this work, we focus to this second fraction of the AGNs Type 2, in which the broad H$\alpha$ is observed in order to check is it really 'quasi-broad H$\alpha$', i.e. the sum of the wing components of the narrow lines, which arise in the gas outflows.

## 2. THE SAMPLE AND ANALYSIS

We searched the Sloan Digital Sky Survey database (SDSS) DR 14, and found the 314 high quality (signal-to-noise > 20) AGN Type 2 spectra which have 'broad H$\alpha$'. Since narrow lines in these spectra have complex shapes and can not be fitted with only one Gaussian, we adopted the fitting model of two Gaussians (narrow core + slightly broader wing component) for each narrow emission line in these spectra. This two-component model of narrow lines is usually applied for [O III] lines in AGN Type 1 spectra (see Dimitrijević et al. 2007). In this way, we fit successfully 258 spectra, in which 'broad H$\alpha$' is fitted well with sum of the H$\alpha$ and [N II] wing components. The rest of the objects are excluded from the sample since they have too broad H$\alpha$ line, which can not be fitted with sum of the three wing components, and therefore these objects are candidates for the Hidden Type 1 objects. Note, that in this sample of 258 objects, the emission under H$\alpha$ line can be fitted equally well with one broad Gaussian which can be interpreted as emission of H$\alpha$ from BLR as well.

In order to check is the broad H$\alpha$ in these spectra the true broad line or it is the sum of the gas outflow wing components, we analysed several prominent narrow emission lines (H$\beta$, [O III]$\lambda\lambda$ 4959, 5007 Å, H$\alpha$, [N II]$\lambda\lambda$ 6548, 6583 Å and [S II]$\lambda\lambda$ 6717, 6731 Å). The wing components of all these lines have the free parameters for width and shift, except wing components of H and [N II], for which we assume to have the same wing parameters. The example of the fit is shown in Fig. 1.

In the case that 'broad H$\alpha$' is the sum of the wing components, which arise in an outflow, we expect the same signature of the gas outflow in the other emission lines as well. Therefore, we search for the correlations between the kinematical parameters (widths and shifts) of the H$\alpha$ wing component and wing components of the other analysed emission lines. Note that widths of emission lines are given in km s$^{-1}$, since we assume that main broadening mechanism of emission lines in AGN spectra is Doppler broadening.

## 3. RESULTS AND CONCLUSIONS

We found the strong correlations between velocity shift of the H$\alpha$ wing component and velocity shifts of the wing components of all other considered emission lines (H$\beta$, [O III], [S II]). Also, we found the strong correlation between the width of H$\alpha$ and [S II] wing components, and weak correlations with widths of the H$\beta$ and [O III] wing components. The coefficients of correlations are given in the Table 1.

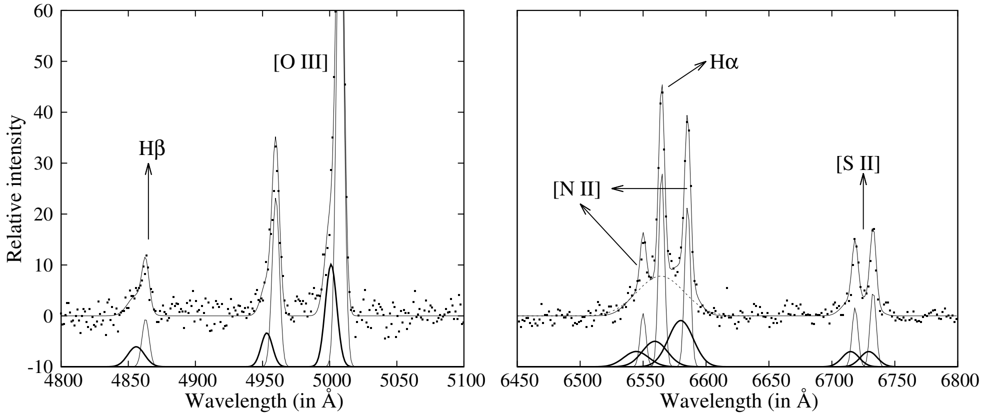


Figure 1: The example of fit of SDSS J112135.17+042647.1. Solid tin Gaussian - core component of narrow lines, solid thick Gaussian - wing component, dashed Gaussian - 'quasi-broad H$\alpha$' (FWHM = 2840 km$^{-1}$)

Table 1: (A): The correlations between the shift of the H$\alpha$ wing component (wc) and shifts of H$\beta$, [O III] and [S II] wing components (r = Spearman coefficient of correlation, P = significance of correlation). Note, that only 53 objects from this sample have H$\beta$ wing component. (B): The same as in (A), just for the widths.

| (A) | shift H$\beta$ wc | shift [O III] wc | shift [S II] wc |
|---|---|---|---|
| shift H$\alpha$ wc | r = 0.53, P = 4.1E-5 | r = 0.46, P = 1.1E-14 | r = 0.77, P = 0 |

| (B) | width H$\beta$ wc | width [O III] wc | width [S II] wc |
|---|---|---|---|
| width H$\alpha$ wc | r = 0.31, P = 0.02 | r = 0.28, P = 8.0E-6 | r = 0.66, P = 0 |

These results show clear kinematical connection between the wing components of the H$\alpha$ and wing components of the other emission lines, [O III], H$\beta$ and [S II]. Since forbidden narrow [O III] and [S II] lines originate from the NLR (they cannot arise in BLR because of the high density in that region), this kinematical connection implies that observed 'broad H$\alpha$' in this AGN Type 2 fraction is not emission which originate from the BLR, but indeed the sum of the H$\alpha$+[N II] wing components, which arise in the NLR and which are affected with the gas outflow kinematics.

Furthermore, we examined in more details the influence of the gas outflow kinematics to the H$\alpha$ profile, by comparing it with the [O III] lines which are the most frequently used to trace gas outflows in AGN spectra (Green & Ho 2005, Woo et al. 2016). We compared the distributions of shifts and widths of H$\alpha$ wing components with the same of [O III] wing components (see Figures 2 and 3). We found that these distributions are similar: H$\alpha$ wing components are blueshifted in 72% of objects from the sample while [O III] wing components are blueshifted in 75% of objects. However, [O III] wing components have larger blueshifts comparing to the H$\alpha$ wing components: -108.2$\pm$176.9 km s$^{-1}$ (mean $\pm$ standard deviation), while for H$\alpha$ wing components it is: -47.2$\pm$84.0 km s$^{-1}$. The distribution of widths of [O III] wing components is broader than for H$\alpha$ wing components, and mean FWHM value is slightly larger as

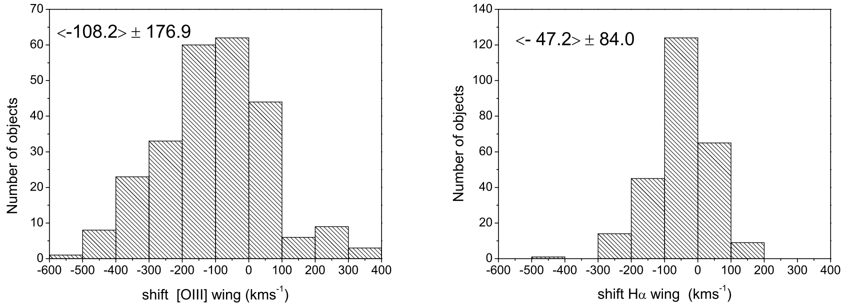


Figure 2: The distribution of the wing component velocity shifts for [O III] lines (left), and for the H$\alpha$ lines (right).

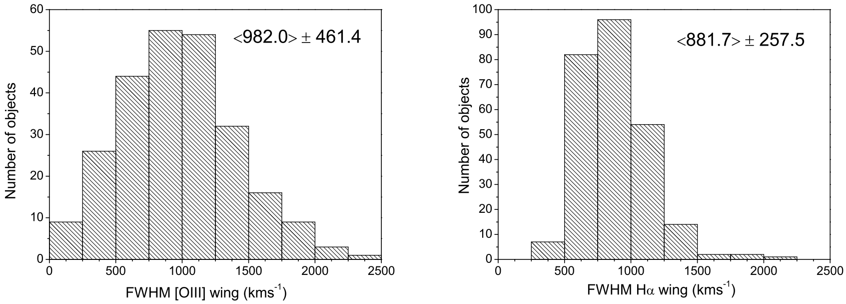


Figure 3: The same as in the previous figure, just for the widths of wing components.

well (982.0±461.4 km s$^{-1}$ for [O III] wing components, and 881.7±257.5 km s$^{-1}$ for H$\alpha$ wing components). These results imply that influence of the gas outflow to the H$\alpha$ shape is slightly smaller than to the shape of the [O III] lines.

Our future investigation will be directed towards development of the method for separation of the Type 2 objects with the 'true broad H$\alpha$' (Hidden Type 1 objects) from those with 'pseudo-broad H$\alpha$', using some differences in their spectral properties. We will focus to the Type 2 objects with 'true broad H$\alpha$', because they represent the exception from the Unified model of AGNs, and therefore modelling of their structure is important for understanding the nature of the AGNs.

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