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RELATIONS AMONG EMISSION LINES AND CONTINUUM LUMINOSITY IN ACTIVE GALACTIC NUCLEI

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Abstract. We have investigated the line-continuum relations by using an AGN SDSS sample. For the first time we have considered $H\alpha$ and [N II] emission lines in the line-continuum analysis. Also, in order to find more details, we decomposed complex profiles of Balmer lines ($H\alpha$ and $H\beta$) on three components (NLR, ILR and BLR) which are coming from different line emission regions and we examine line components-continuum relations. Numerous Fe II lines ($\lambda\lambda$ 4450-5350 Å) are separated in the three groups (^4F, ^6S and ^4G), according to atomic properties of their transitions, and each Fe II line group is compared separately with continuum luminosity. Indications of Baldwin effect are found for the [O III], [N II] and NLR component of $H\beta$, but trends of inverse Baldwin effect are observed for the Fe II ^6S line group, $H\beta$ BLR, $H\alpha$ ILR and specially for the $H\alpha$ BLR component. Different trends in line-continuum relations required further investigations, to explain their physical background.

1. INTRODUCTION

Investigation of emission lines and continuum luminosity relations may help in understanding AGN structure and physics. In 1977. Baldwin discovered an anticorrelation between equivalent width (EW) of C IV λ1549 Å line and the continuum luminosity L_λ1450 Å (Baldwin 1977). Later, it is detected that majority of emission lines in the UV and V spectral range, and also some lines from the X range are showing the Baldwin effect, i.e. their equivalent width decreases with increase of continuum luminosity. Dietrich et al. (2002) have found Baldwin Effect in almost all lines from O VI λ1034 Å to [O III] λ5007 Å. Only a few lines from considered range, show no correlation or they are showing weak inverse Baldwin Effect (N V λ1240 Å, $H\beta$, $H\gamma$ and Fe II optical lines). Baldwin Effect could be described by function: $EW_{line} \sim L_\lambda^\alpha$, $\alpha < 0$, where EW_{line} is the line equivalent width, L_λ is continuum luminosity for given λ and α is index of the slope. It is noticed that different lines are showing different slopes in the EW versus L diagram. Higher ionization lines usually have steeper slopes than low ionization lines.

The physical explanation of Baldwin effect is still an open question. It is proposed that the continuum shape is luminosity-dependent, i.e. that the UV and X spectra are softer in more luminous AGNs. This results in weaker ionization and heating of emission gas around central engine which cause decreasing of line equivalent widths (Netzer et al. 1992, Korista et al. 1998).

It is also proposed that Baldwin Effect may be driven by an increase of metallicities in more luminous AGNs (Korista et al. 1998). Very interesting question is whether the Baldwin Effect is caused by some stronger, more fundamental relation among equivalent widths and another AGN property, which correlates with AGN luminosity, such as: redshift, the Eddington ratio (L/L_{Edd}) or black hole mass M_{BH}. Baskin & Laor (2004) have found that EW (C IV) better correlate with L/L_{Edd}, then with continuum luminosity, which is also confirmed from other authors using different lines (Warner et al. 2004).

It is observed that Baldwin Effect is connected with group of correlations "Eigenvector 1" (E1), identified by Boroson & Green (1992) in optical AGN spectra. The proposed physical causes which lie under E1 correlations are the same as those proposed for Baldwin Effect (L/L_{Edd}, M_{BH} or inclination angle), which make connection between this two phenomena.

The importance of Baldwin Effect is that it could be used as cosmological standard candle and it could help in studying metal abundances (Korista et al. 1998) as evolution and physics of AGNs.

2. THE SAMPLE AND ANALYSIS

We selected 79 AGN spectra from the Date Release Four (DR4) of the SDSS Database. Our sample is chosen by criteria of high signal to noise ($S/N > 30$), and $z < 0.7$. Spectra are corrected for Galactic reddening and continuum emission is substracted by DIPSO software.

We considered two spectral ranges: $\lambda\lambda$ 4400-5500 Å (Fe II lines, [O III] $\lambda\lambda$4959, 5007 Å, $H\beta$, He II λ4686 Å) and $\lambda\lambda$ 6400-6800 Å ($H\alpha$ and [N II] $\lambda\lambda$6548, 6583 Å) (Fig. 1). We assume that emission lines arise in two or more emission regions, so we fit their profiles with sum of Gaussian functions. Shifts, widths and intensities of Gaussian functions are reflecting physical conditions of emission regions where those components arise. $H\alpha$ and $H\beta$ are decomposed with three Gaussians, which represent emission from BLR (Broad Line Region), ILR (Intermediate Line Region) and NLR (Narrow Line Region).

Parameters of shift and width of the [O III], [N II] and NLR components of $H\beta$ and $H\alpha$, have the same value for a particular AGNs spectrum, because all those lines originate from the same Narrow Line Region. Optical Fe II lines were fited with template calculated by using of the 29 strongest Fe II lines within the $\lambda\lambda$ 4450-5350 Å, and they are separated into three line groups according to the lower level of transition: $3d^6$ ($^3F2$) $4s$ $^\mathbf{4}\mathbf{F}$, $3d^5 4s^2$ $^\mathbf{6}\mathbf{S}$ and $3d^6$ (^3G) $4s$ $^\mathbf{4}\mathbf{G}$ (in further text ^4F, ^6S and ^4G groups of lines). Detailed description of fitting procedure and Fe II calculated template is given in Kovačević et al. (2008).

3. PRELIMINARY RESULTS

We analyzed the relations of equivalent widths (EW) of considered lines and continuum luminosity (λ5100 Å). For the first time we considered $H\alpha$ and [N II] emission lines in the line-continuum analysis. In order to find more details, we analyzed the relations of the line components (NLR, ILR and BLR of $H\alpha$ and $H\beta$) and continuum. EW Fe II lines-continuum relation is examined by comparing continuum luminosity with three Fe II line groups (^4F, ^6S and ^4G). In this way, we connected Fe II atomic

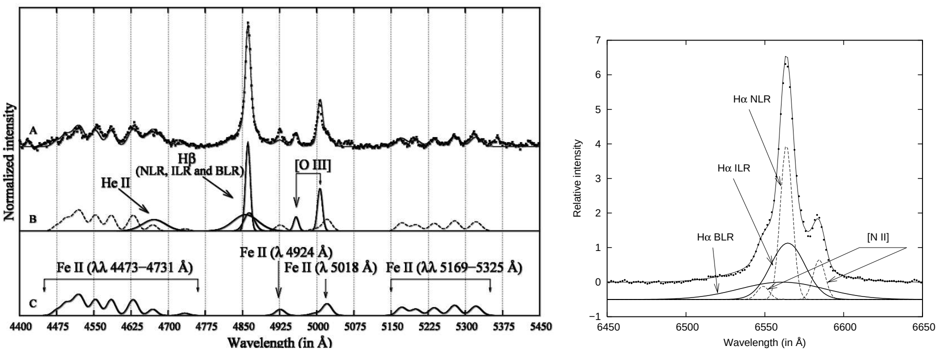

Figure 1: Example of fit of Mrk 493 in the $\lambda\lambda$ 4400-5500 Å range (Fe II lines, [OIII], $H\beta$, He II) (left) and in $\lambda\lambda$ 6400-6800 Å range ($H\alpha$ and [N II]) (right). Lines are decomposed on Gaussians and Fe II lines were fited with calculated template.

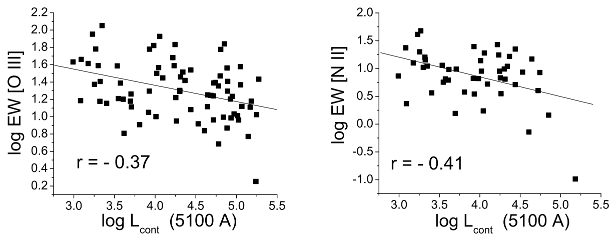

Figure 2: Correlation among continuum luminosity (λ5100 Å) and EW [O III] lines (left) and EW N II (right). Significant negative trend is present (Baldwin effect).

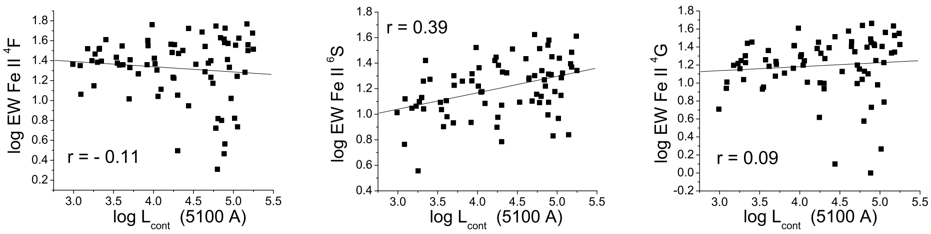

Figure 3: Relation among continuum luminosity (λ5100 Å) and EW ^{4}**F**, ^{6}**S** and ^{4}**G** line groups (up) and total EW Fe II (down). The correlation is not observed, but weak positive trend is present only in the case of ^{6}**S** group.

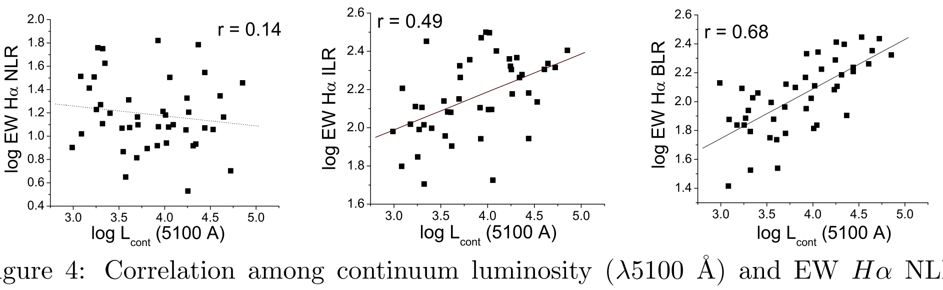

Figure 4: Correlation among continuum luminosity (λ5100 Å) and EW $H\alpha$ NLR (left), ILR (middle) and BLR (right) components. Significant positive trend is observed in the case of EW $H\alpha$ ILR and strong correlation in the case of EW $H\alpha$ BLR.

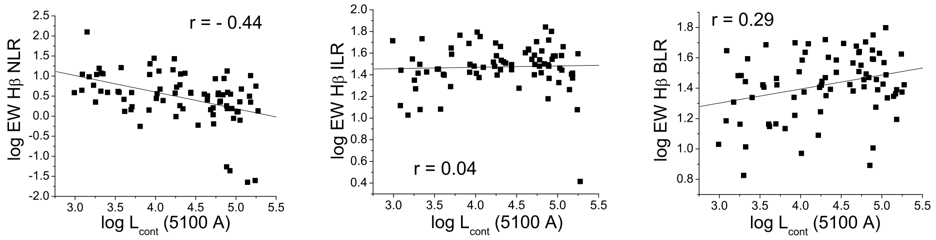

Figure 5: Correlation among continuum luminosity (λ5100 Å) and EW $H\beta$ NLR (left), ILR (middle) and BLR (right) components. Significant negative trend is observed in the case of EW $H\beta$ NLR and weak positive trend in case of EW $H\beta$ BLR.

structure with physical properties of AGN, which brings more information about the Fe II emission region.

Baldwin effect is noticed for the [O III] (the coefficient of correlation r=-0.37) and [N II] (r=-0.41) lines (Fig. 2), as significant negative trends. There is no correlation among log EW Fe II ^{4}**F**, ^{6}**S**, ^{4}**G** and log L_{cont} (Fig. 3), only weak positive trend is noticed in the case of log EW FeII ^{6}**S** (0.29). This difference may originate in diverse multiplicity of Fe II line groups (M=6 for ^{6}**S** and M=4 for ^{4}**F** and ^{4}**G**). Trends of Balmer lines vs. continuum luminosity are shown in Fig. 4 and Fig. 5. BLR and ILR components of $H\alpha$ and BLR $H\beta$ are showing indications of inverse Baldwin Effect, which is specially strong in the case of the BLR $H\alpha$ (0.68). Contrary, the NLR $H\beta$ is showing Baldwin Effect (-0.44). No trends are noticed in case of the NLR $H\alpha$ and ILR $H\beta$.

For explanation of those different trends and correlations and finding their physical cause, more detailed analysis is required, and it will be presented in future work.

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