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THE ROLE OF OPTICAL Fe II ^{4}F, ^{6}S AND ^{4}G GROUP OF LINES IN AGN SPECTRA

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Abstract. In order to investigate the Fe II emission lines we have used sample of 111 AGN (SDSS). The strongest Fe II (λλ4400-5400 Å) lines are separated into three group according to the lower level of transition (^{4}F, ^{6}S and ^{4}G) and fited with calculated template. We analyzed correlations between properties of those Fe II groups and other considered lines in spectra. We found that Fe II emission probably originate from Intermediate Line Region (ILR), which is between NLR and BLR.

1. INTRODUCTION

Optical Fe II (λλ4400-5400 Å) lines are one of the most interesting features of AGN spectra. Origin of the optical Fe II - their extreme emission and geometrical place of the Fe II emission region in AGN, are still open questions. Extreme Fe II emission can not be explained with standard photoionization models. Those models may account only for the line ratio of Fe II 4570/Hβ < 6, but in observed spectra it goes from 0 to 30. Also, there are many correlations of the Fe II lines and other AGN spectra properties which need physical explanation. It is established that Fe II emission depends on the radio, X and IR properties of AGN (Joly, 1991; Lawrence et al., 1998; Terlevich and Macchetto, 1993). Boroson and Green (1992) have found a few new correlations among equivalent width (EW) of Fe II and some properties of other lines. The most interesting are anticorrelations among EW Fe II and EW [O III]/EW Hβ .

In order to investigate correlations of properties of Fe II emission lines, we separated the 29 strongest Fe II (λλ4400-5400 Å) lines into three groups of lines, according to their lower levels of transition: $3d^6(^3F2)4s$ ^{4}**F**, $3d^54s^2$ ^{6}**S** and $3d^6(^3G)4s$ ^{4}**G** (in further text ^{4}**F**, ^{6}**S** and ^{4}**G** group of lines). We analyzed separately relations of each group of Fe II lines with other lines in AGN spectra, in order to connect the Fe II atom structure with physical properties of AGN.

2. THE SAMPLE AND ANALYSIS

We selected 111 AGN spectra from the Date Release Six (DR6) of the SDSS Database. Our sample is chosen by the following criteria: high signal to noise ratio (S/N>20), good quality of pixels, small contribution of stellar component and a good coverage (near uniform) of redshifts from 0 to 0.7. As result, our sample contains 111 spectra, from which 58 have all Balmer lines, and the rest have no Hα line because of redshifts. Spectra are corrected for Galactic reddening, using procedure described in paper Schlegel et al. (1998), Appendix B. Continuum emission is substracted by DIPSO software. We considered two spectral ranges: λλ4400-5500 Å and λλ6400-6800 Å. In the first range, dominant lines are numerous Fe II lines, [O III] λλ4959, 5007 Å, Hβ and He II λ4686 Å. In the second range, we observed Hα and [N II] λλ6548, 6583 Å.

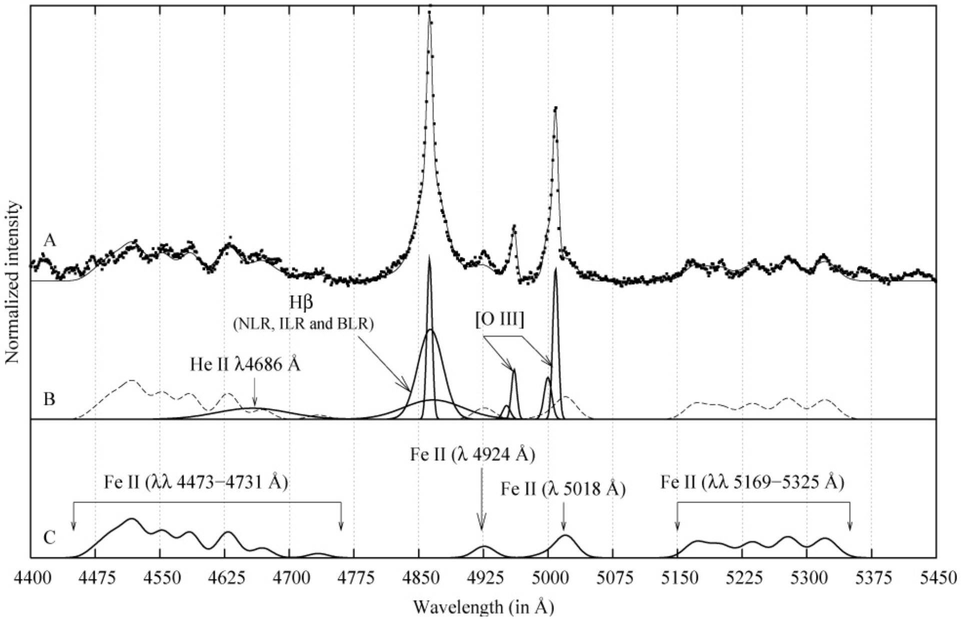

Figure 1: Example of fit of the SDSS J075101.42+29174000.00 in the λλ4400 - 5450 Å range.

We fit all considered lines with a sum of Gaussian functions of different shifts, widths and intensities, which reflects physical conditions of emission regions where those components arise (Fig. 1 and 2). We assume that Balmer lines have three components: NLR, ILR and BLR (Ilić et al., 2006; Bon et al., 2006; Chen Hu et al., 2008), and we fited them with three Gaussians of different width. Optical Fe II lines were fited with calculated template.

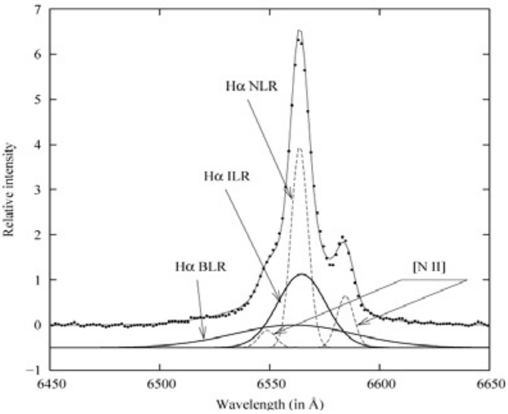

Figure 2: Example of fit of the SDSS J075101.42+29174000.00 in the λλ6450 - 6650 Å range.

Since all Fe II lines from the template probably originate from the same region, with the same kinematical properties, we assume that width and shift is the same for all Fe II lines, but intensities are different. We calculated relative intensities between the lines which belong to the same group (^{4}**F**, ^{6}**S** and ^{4}**G**) by using the formula for the intensity ratios within the transitions which have the same lower level:

$$\frac{I_1}{I_2} = (\frac{\lambda_2}{\lambda_1})^3 \frac{f_1}{f_2} \cdot \frac{g_1}{g_2} \cdot e^{-(E1-E2)/kT}$$

where I_1 and I_2 are intensities of the lines with the same lower level of transition, λ_1 and λ_2 are line wavelengths, g_1 and g_2 are corresponding statistical weights, and f_1 and f_2 are oscillator strengths, E_1 and E_2 are energies of upper level of transitions, k is Boltzman constant and T is the excitation temperature.

According to that, the template of Fe II is described by 6 parameters of fit: parameter of the width, parameter of the shift, three parameters of intensity - for ^{4}**F**, ^{6}**S** and ^{4}**G** group of lines, and excitation temperature.

RESULTS

Correlations among Fe II line groups. We have investigated relations between the Fe II group of lines by comparing their luminosities and equivalent widths. Correlation among luminosities (and EW) ^{4}**F** and ^{4}**G** are significantly stronger (0.98) than correlations of those groups with ^{6}**S** lines (0.91 and 0.92) . We suppose that these differences probably originate from complex Fe II atomic structure, namely from different multiplicity numbers of line groups (^{4}**F** and ^{4}**G** groups of lines have multiplicity number 4, and ^{6}**S** has multiplicity number 6).

Connection between kinematical properties of Fe II lines and Balmer lines (Hα and Hβ). We assume that broadening of the lines arise by Doppler effect caused by random velocities of emission clouds, and shift of the line, by systemic moving of emission gas. The widths and shifts of Fe II are compared with widths and shifts of NLR, ILR and BLR Hβ and Hα component. We found significant correlation among widths of Fe II lines and ILR Hα (0.76) and ILR Hβ (0.62) components (Fig. 3) . We also compared the shifts, and as in previous case, we found trend among Fe II and ILR components of Hα (0.54) and Hβ (0.47). These kinematical connections among Fe II emission region and ILR components of Balmer lines imply that Fe II emission arise in ILR,

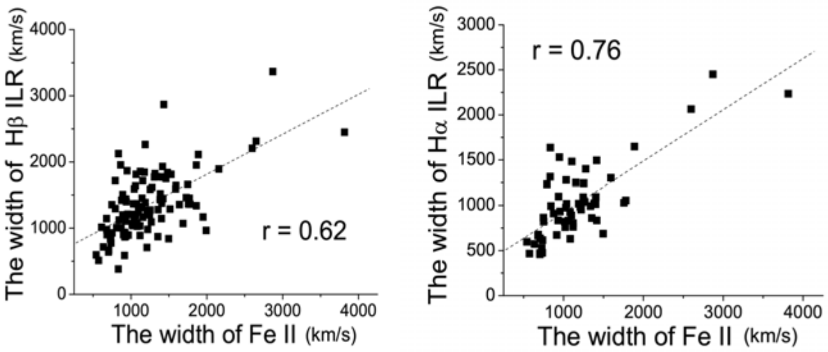

Figure 3: Correlations among the width of Fe II lines and the width of Hβ (left) and Hα (right).

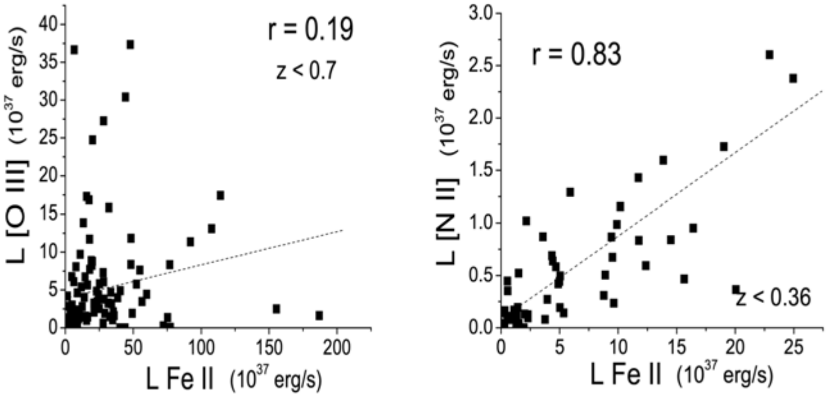

Figure 4: Relations among total Fe II luminosity and luminosity of [O III] (left) and luminosity of [N II] (right).

Correlations among luminosities of Fe II line groups and other considered emission lines. Correlations among luminosities of Fe II (total Fe II, **^{4}F**, **^{6}S**, **^{4}G** line groups), and luminosities of Hα, Hβ components, [N II] and [O III] lines are examined. In all cases, except in the case of [O III] lines, we found significant or strong correlations (Fig. 4). Pearson coefficient for Fe II – [O III] relation is ~0.2, and this exception needs physical explanation, which will be investigated in future work.

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