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The intrinsic Baldwin effect in NLSy 1 galaxies

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The intrinsic Baldwin effect is an anti-correlation between the line equivalent width and the flux of the underlying continuum detected in a single variable active galactic nucleus (AGN). This effect, in spite of the extensive research, is still not well understood, and might give us more information about the physical properties of the line and continuum emission regions in AGNs. Here we present preliminary results of our investigation of the intrinsic Baldwin effect of the broad Hβ line in several Narrow-line Seyfert 1 (NLSy 1) galaxies, for which data were taken from the long-term monitoring campaigns and from the Sloan Digital Sky Survey Reverberation Mapping project.

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1. Introduction

Broad line region (BLR) of active galactic nuclei (AGNs) is found relatively near to the energetic source of ionization that comes from the accretion disk, thus the conditions of the BLR gas are such that it is hard to compare them with those in other well studied astrophysical objects. As a consequence many of the standard techniques, previously derived to probe the physics of e.g. photoionized nebulae, are often unable to give reliable results when applied to the BLR. The intrinsic Baldwin effect (Beff) is an anti-correlation between the emission line equivalent width and the flux of the underlying continuum detected in a single variable AGN [1]. Recently, we studied intrinsic Beff on sample of six type 1 AGNs, including two Seyfert 1, two AGNs with very broad double-peaked lines, one NLSy1 galaxy and one high-luminosity quasar [2]. We found that all six galaxies exhibit intrinsic Beff, including the NLSy1 Ark 564, and that this effect is probably not caused by the geometry of the broad line region (BLR). Additionally, we showed that there is no connection between global and intrinsic Beff [2].

Taking into account our first small sample of only 6 objects (with only one NLSy1), our findings should be tested on a larger number of different AGNs. Therefore, we aim to study the intrinsic Beff on a sample of type 1 AGN taken from the Sloan Digital Sky Survey Reverberation Mapping project (SDSS-RM). Here we present our preliminary results of our study of the intrinsic Beff of broad Hβ line in five NLSy1 galaxies from SDSS-RM, compared to the findings in Ark 564 from [2].

2. Data and Methods

We selected objects from SDSS-RM explained in [3] with $z < 0.8$ and we cross-matched with NLSy 1 catalog of [4]. Additionally, we used the data of long-term monitored NLSy1 galaxy Ark 564 published in [2, 5]. The information on selected objects is given in Table 1.

Name	RA	DEC	z	Period	No. of Spectra	S/N	Our notation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
J141308.10+515210.3	213.28377	51.86955	0.288	56660–57518	48	13	N1
J141721.80+534102.6	214.34082	53.68406	0.193	56660–57518	48	33	N2
J141427.88+535309.6	213.6162	53.88602	0.242	56660–57518	48	10	N3
J141419.84+533815.3	213.58268	53.6376	0.164	56660–57518	48	45	N4
J141408.76+533938.2	213.5365	53.66063	0.191	56660–57518	48	23	N5
Ark 564	340.6625	29.72530	0.025	51424–54414	92	>50	–

Table 1: Selected NLSy 1 galaxies. The columns are denoted in following way: (1) Name of the galaxy; (2) R.A. in degrees; (3) DEC. in degrees; (4) redshift; (5) monitored period in MJD; (6) number of spectra;(7) averaged signal to noise; (8) notation used in this paper

We rescale spectra taking that the flux of [OIII]λ5007 remained constant within the monitored period [6]. To remove the host galaxy contribution we used Simple Stellar Population method (SSP) [4, 7]. With this method observed spectrum $F(\lambda)$ (where we used median smoothing to mask emission lines) can be approximated with:

$$F(\lambda) = \left[\sum_{n=1}^{39} a_n \times F_{ssp}(\lambda) \right] \otimes G(\sigma) + F_{AGN}(\lambda).$$

The left part of the previous equation represents the host galaxy contribution, where a_n is the amplitude of individual SSP template (F_{ssp}), which is broadened with Gaussian broadening function $G(\sigma)$ (σ being stellar velocity dispersion), while, on the right side, AGN is represented as F_{AGN} in the form of the power law λ^{α}.

In order to subtract narrow and satellite lines and extract the broad component, we simultaneously fitted emission lines including the local continuum, in the wavelength region from 4200 Å to 5500 Å. Lines included in the fit were: Hγ (two components: broad and narrow), HeII (broad and narrow), Hβ (broad and narrow), forbidden lines [OIII]λ4363,4959,5007 Å and the FeII template[1] from [8] and [5]. For further investigation of the intrinsic Beff we followed methods from [2].

3. Results and Discussion

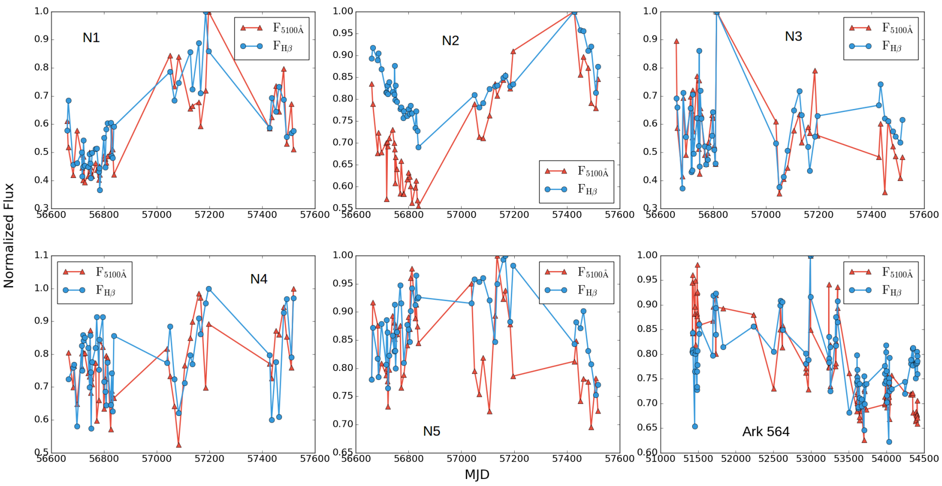

Figure 1: Light curves of 5 NLSy1 galaxies from SDSS-RM project with Ark 564. All fluxes are normalized to the maximum value. The light curve of continuum is represented with red triangles, while light curve of Hβ with blue circles. Names of objects are denoted on the plots.

In Fig. 1 the light curves of the continuum and Hβ fluxes of the five NLSy1 galaxies selected from SDSS-RM are shown together with the light curves of Ark 564 [2]. In order to compare changes in the light curve of $F(\mathrm{H}\beta)$ with corresponding changes in light curves of F_{5100} we show fluxes normalized to the maximum value. It is straightforward to see that the flux of Hβ is not strictly following the changes in the continuum flux, e.g. where we have local minimum in $F(\mathrm{H}\beta)$ we have a local maximum in F_{5100} (see for e.g. light curve of N5 in Fig. 1) and vice versa. This might suggest the existence of an additional continuum emission, which we previously discussed in [2].

[1]Fe II template is available on http://servo.aob.rs/FeII_AGN/

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In Fig. 2 we showed relationship between continuum flux at 5100 Å and flux of the Hβ. The strongest correlation (0.782) is found in N1 object, while weakest in N5 object (0.442). In case of all objects there is the linear correlation between the line and continuum flux.

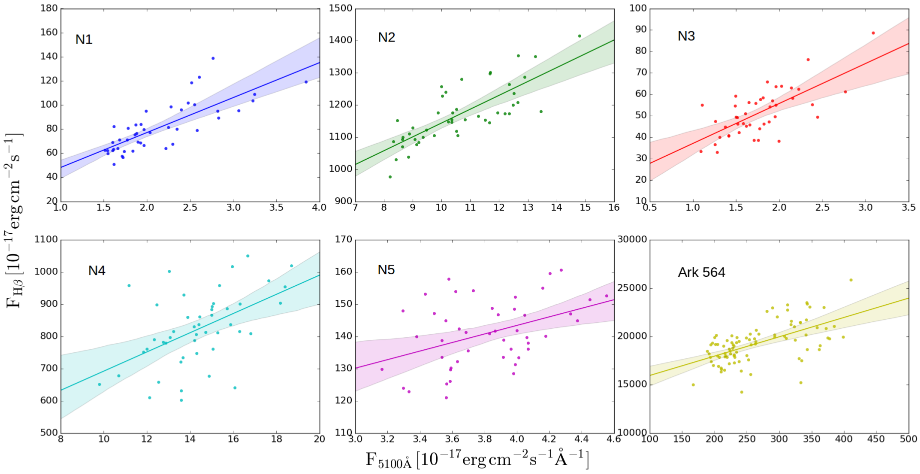

Figure 2: Flux of continuum at 5100 Å vs. flux of the broad Hβ line. The linear best fit is presented with solid line, while shaded area represents confidence interval of 95 %. The names are denoted on plots.

In Fig. 3 we present the intrinsic Beff of selected galaxies together with Ark 564. We found that all galaxies except N1 are exhibiting intrinsic Beff. Calculated Pearson correlation of line flux versus continuum flux and parameters of linear fit together with the calculated Pearson correlation for the intrinsic Beff for all considered objects are given in the Table 2. Interestingly, in Ark 564 there is a weak correlation between line and continuum flux, but there is the strongest intrinsic Beff present. We note that Ark 564 has been monitored for 11 years, while SDSS galaxies for only about 2.5 years, this might be the reason behind weaker correlation found in SDSS galaxies.It is also important to emphasize that in the case of SDSS objects, line fluxes are not corrected for the time delay with respect to the continuum. However, we do not expect this will have significant impact on the Baldwin effect results, since in NLSy1 the time delay is small and the variability is weak, e.g. we tested this effect in case of Ark 564 which has the time delay of $\sim$5 days and weak variability of $\sim$ 10% [5], and there is no difference in the result. But in general, it is necessary to determine EW so that it represents the real emission line response to the continuum that actually hit the BLR at time when the line was emitted (see [2, 9, 10]). We notice that objects showing weaker correlation between line and continuum flux, are on the other hand having stronger intrinsic Beff. It may be that the stronger intrinsic Beff is explained with the presence of an additional continuum emission, as previously discussed in [2].

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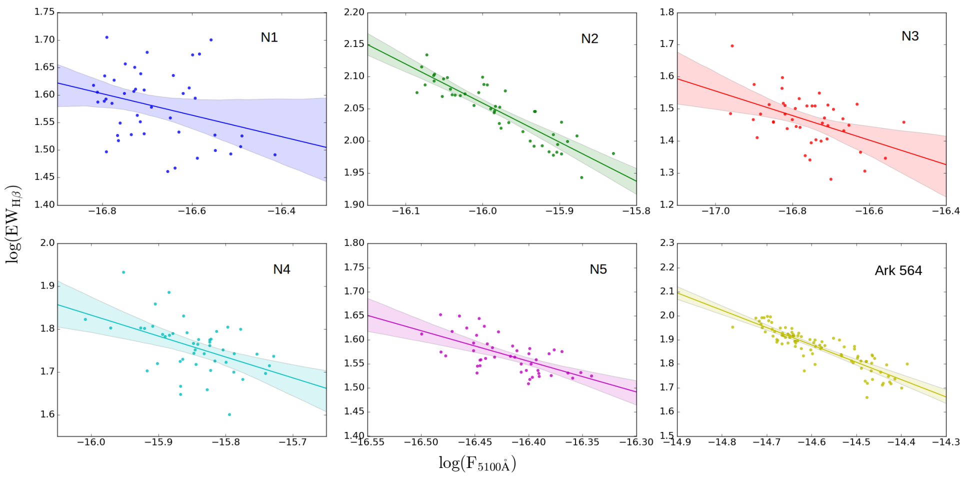

Figure 3: Intrinsic Beff for the sample of five AGNs form SDSS-RM project together with Ark 564. The solid line represents the best linear fit, while shaded area corresponding confidence interval of 95%.

Table 2: Parameters of the intrinsic Baldwin effect

Object	Line flux vs. cnt. flux				Intrinsic Beff			
Name	Pearson correlation		Linear fit		Pearson correlation		Linear fit	
	r	P	slope	intercept	r	P	β	A
J141308.10+515210.3	0.782	3×10^{-10}	29.0	2×10^{-16}	-0.309	4×10^{-2}	-0.195	-1.677
J141721.80+534102.6	0.781	1×10^{-10}	43.1	7×10^{-15}	-0.891	9×10^{-17}	-0.608	-7.671
J141427.88+535309.6	0.697	1×10^{-7}	18.6	2×10^{-16}	-0.483	1×10^{-4}	-0.382	-4.946
J141419.84+533815.3	0.5158	2×10^{-4}	29.9	4×10^{-15}	-0.484	5×10^{-4}	-0.498	-5.990
J141408.76+533938.2	0.442	3×10^{-3}	13.3	9×10^{-16}	-0.635	2×10^{-6}	-0.636	-8.875
Ark 564	0.592	7×10^{-10}	20.1	10^4	-0.879	2×10^{-30}	-0.721	-8.642

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