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SPECTRAL INDEX VARIABILITY OF 12 BLAZARS

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Abstract. We present the results from the spectral index variability analysis for a sample of 12 newly discovered blazars. The blazars are selected from the sample of 47 Active Galactic Nuclei suggested for the link between Gaia Celestial Reference Frame and International Celestial Reference Frame. Blazars flux and spectra are highly variable in the whole electromagnetic spectrum. The amplitude of variability could depend on a number of parameters, including luminosity and spectral properties of the source. We tested optical spectral index for variability, to see if there is any correlation with the flux variability. For two sources 0049+003 and 1612+378 spectral index variability is detected. Both sources are flat spectrum radio quasars, and have confirmed flux variability. For the other sources we did not find correlations between their flux and spectral index variability.

1. INTRODUCTION

Blazars are a subclass of Active Galactic Nuclei (AGNs) which eject relativistic jets close to the observer's line of sight. They show variability on diverse timescales: from a few minutes to several decades. Variability timescales of blazars can be divided into: timescale from a few minutes to a less than a day (intra-day variability), from a few days to a few months (short-term variability), and from a few months to several years (long-term variability); (Gupta 2014).

On June 13, 2022 the Gaia third data release was made available for public. Gaia observations have been performed in the optical G domain. The link between Gaia Celestial Reference Frame and International Celestial Reference Frame (ICRF) will be established using quasars visible in the optical and radio domains. 105 sources (not included in the ICRF) were observed with a global VLBI array which detected 47 point-like sources suitable for the mentioned link (Bourda et al. 2011). These candidate sources are AGNs with high astrometric quality in the radio domain. As AGNs are active sources, their brightness (and photocenter) variability could affect the accuracy of their astrometric positions. For that reason, monitoring and investigation of the brightness variability in the optical domain is necessary. From 2013 to 2019, we conducted optical photometric observations, mostly in the V and R bands, for the mentioned 47 sources to investigate their brightness variability. For the 12 blazars (6 BL Lacertae - BL Lacs, 4 Flat Spectrum Radio Quasars - FSRQs, and 2 with characteristics of both BL Lacs and FSRQs) we published the results of the analysis of their light curves and colour variability (Jovanović et al. 2023). For ten sources we have confirmed brightness variability in this period of observations. In this paper we present optical spectral index variability of 12 blazars for the period from 2013 until 2019.

2. OBSERVATIONS AND DATA REDUCTION

Observations in V and R bands were made by eight optical telescopes: two are stationed at Astronomical Station Vidojevica (ASV) of Astronomical Observatory of Belgrade (Serbia), one robotic Joan Oró telescope (TJO) at the Montsec Astronomical Observatory in Catalonia (Spain), three at NAO Rozhen and one in Belogradchik (Bulgaria), and one telescope at Leopold Figl observatory at Vienna (Austria). The details about these telescopes, mounted CCD cameras and optical filters, as well as reduction and calibration process are presented in Jovanović et al. (2023).

After performing differential photometry (with aperture radius of about 6 arcsec), we calculate V and R magnitudes, colour $V - R$ index and optical spectral index of 12 blazars. The optical spectral index was calculated assuming that the flux density can be described by power law $F_\nu \propto \nu^\alpha$, where ν is frequency, and α is the spectral index, as in Zajaček et al. (2019), and Jovanović et al. (2023):

$$\alpha = \frac{c - 0.4(V - R)}{\log(\nu_V/\nu_R)}\,, \tag{1}$$

where $c = \log(ZP_V/ZP_R)$, ZP_V, and ZP_R are fluxes for magnitudes $V = 0$, and $R = 0$, respectively. The values ν_V, ν_R, ZP_V, and ZP_R were taken from Bessell et al. (1998).

3. ANALYSIS METHODS AND RESULTS

We used Abbé's criterion to analyse optical spectral index variability. The criterion is used to determine whether the elements of the sample are stochastically independent or not, see Malkin (2013). Abbé's statistics is defined as:

$$q = \frac{1}{2}\frac{\sum\limits_{i=1}^{n-1}(\alpha_{i+1} - \alpha_i)^2}{\sum\limits_{i=1}^{n}(\alpha_i - \bar{\alpha})^2}\,, \tag{2}$$

where $\bar{\alpha}$ is the mean value of the α - optical spectral index, and n is number of data. The critical point is defined as $q_\mathrm{c} = 1 + u_s/\sqrt{n + 0.5(1 + u_s)^2}$, where u_s is quantile of normal distribution for a given significance level s. We tested α for each source. If Abbé's statistics is lower than critical value for the significance level of 0.001, we conclude that there are statistically significant systematic variations in the data. It means that the hypothesis concerning stochastic independence of the sample is discarded.

In Table 1, we present details about the sources: IERS name, coordinates, redshift z, type, and results of Abbé's criterion with number of data n. For two sources, 0049+003 and 1612+378, the test shows that α is variable. For these sources, we present the optical spectral variability during time, and correlation between α and R magnitude in Fig 1; a straight line is indicating a linear fit.

Table 1: Statistical results of objects spectral index variability

IERS name	$\alpha_{J2000.0}(\circ)$	$\delta_{J2000.0}(\circ)$	z	AGN type	Abbé's criterion q, q_c	n
0049+003	13.02321	0.59393	0.399714	FSRQ	0.40 , 0.71	30
0907+336	137.65431	33.49012	0.354000	BL Lac	0.79, 0.74	39
1034+574	159.43461	57.19878	1.095700	BL Lac	0.77, 0.76	46
1212+467	183.79143	46.45420	0.720154	FSRQ	0.94, 0.77	50
1242+574	191.29167	57.16510	0.998229	BL Lac	1.23, 0.77	49
1429+249	217.85787	24.70575	0.406590	BL Lac / FSRQ	0.77, 0.74	39
1535+231	234.31043	23.01127	0.462515	BL Lac / FSRQ	0.94, 0.75	40
1556+335	239.72993	33.38850	1.653598	FSRQ	1.00, 0.75	40
1607+604	242.08560	60.30784	0.178000	BL Lac	0.91, 0.75	42
1612+378	243.69564	37.76869	1.531239	FSRQ	0.63, 0.74	37
1722+119	261.26810	11.87096	0.340000	BL Lac	0.81, 0.75	43
1741+597	265.63334	59.75186	0.415000	BL Lac	1.04, 0.78	53

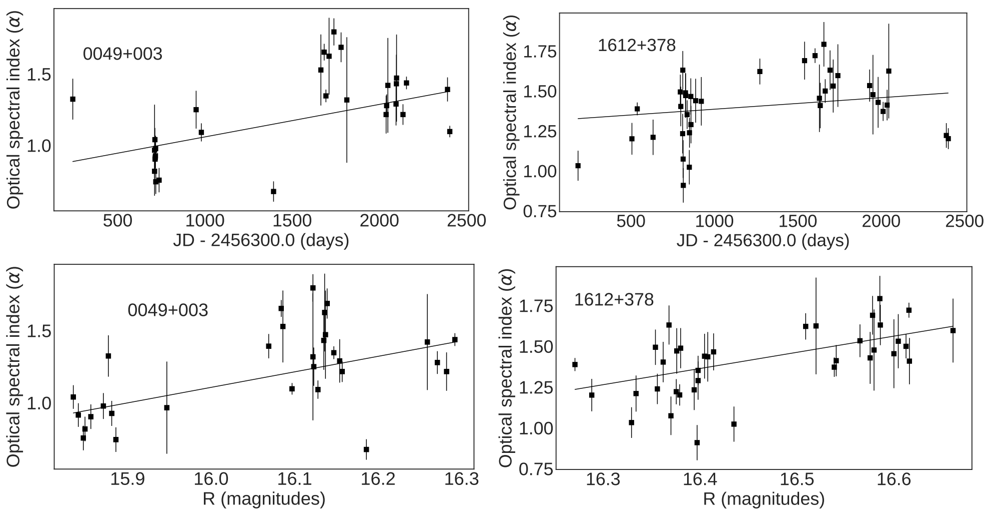

Figure 1: Variations of optical spectral index during time (top) and with respect to R magnitude (bottom) for the objects 0049+003 and 1612+378.

4. CONCLUSION

AGNs brightness variations, on time scales of less than a day to years, are very important to understand physical properties of massive black holes in their centers. The optical band is quite narrow in comparison to the other spectral bands, but it helps us obtain important information regarding non-thermal synchrotron emission as well as possible thermal emission from accretion disc. In our about six years of observations, ten blazars have shown significant flux and colour variations, the analysis results are presented in the paper Jovanović et al. 2023. The non-variable blazars are

1429+249 and 1556+335, the remaining sources show variability in the both bands. The maximum variation of about 2.0 mag is found in 1722+119 and 1741+597 (both sources are BL Lacs).

In the case of optical spectral index (α) variability, we found that α is variable for two sources 0049+003 and 1612+378 (both sources are FSRQs). For those sources, α vs time and vs R magnitude are presented in Fig. 1. We did not find a relationship between variability in brightness and spectral index (in optical domain). We will continue with observations and investigations of intra-night, short-term, and long-term variability changes in brightness, colour, and optical spectral index of these and several other AGNs.

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