Optical spectral variability of 12 blazars

Miljana D. Jovanović and Goran Damljanović

Astronomical Observatory, Volgina 7, 11060 Belgrade 38, Serbia

e-mail: miljana@aob.rs, gdamljanovic@aob.rs

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Introduction

Blazars form a subclass of radio loud (RL) Active Galactic Nuclei (AGNs) which eject relativistic jets along the observer’s line of sight. BL Lacertae objects (BL Lacs) and flat spectrum radio quasars (FSRQs) are collectively referred to as blazars. Blazars in general show variability on diverse timescales, ranging as short as a few minutes to as long as several decades. Variability timescales of blazars can be broadly divided into three classes: timescale from a few minutes to a less than a day is commonly known as intra-day variability (IDV). Variability timescales ranging from a few days to a few months are called short-term variability (STV), and those from a few months to several years are termed as long-term variability (LTV).

On June 13, 2022 the third data release (DR3) of Gaia mission was made available for public. The Gaia uses astrometric observations of optical counterparts of sources from the radio catalogue International Celestial Reference Frame (ICRF) to adjust its reference frame. 105 sources (not included in the ICRF) were observed with a global VLBI array which detected 47 point-like sources on VLBI scales and classified as Active Galactic Nuclei - AGNs (Bourda et al. 2011). From 2013 to 2019, we conducted optical photometric observations in the V and R bands for all 47 AGNs, to investigate their brightness variability.
For the 12 blazars (6 BL Lacs, 4 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).

Methods and results

The optical photometric observations of the blazars were performed using eight telescopes located in Europe. Out of these eight telescopes, two are stationed at Astronomical Station Vidojevica (ASV) of Astronomical Observatory of Belgrade, Serbia; one robotic Joan Oró telescope at the Montsec Astronomical Observatory, Catalonia, Spain; four telescopes in Bulgaria of which three at Rozhen, NAO and one in Belogradchik; and one telescope at Leopold Figl observatory at Vienna, Austria. The details about these telescopes, their mirror aperture, mounted CCD cameras and optical filters are presented in paper Jovanović et al. 2023.

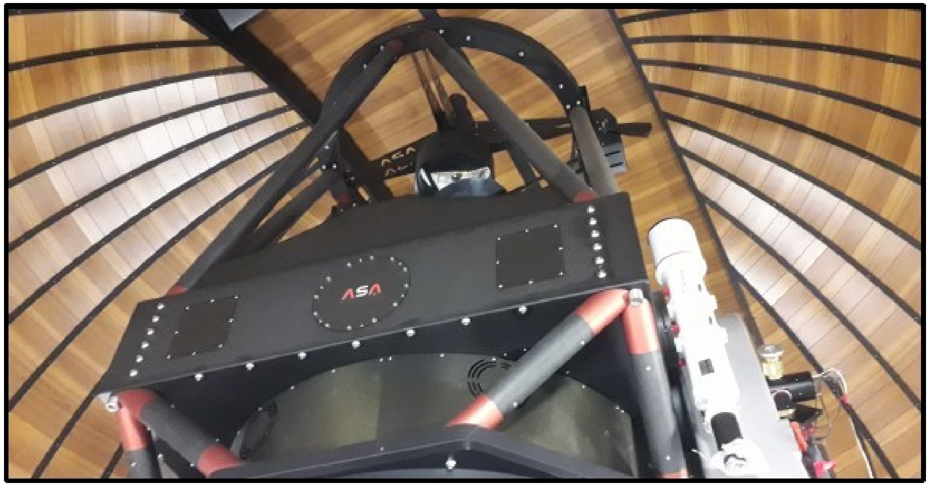

Figure 1. The ASV 1.4 m telescope in dome.

Optical spectral index: The flux density can be described by power-law $F_\nu \propto \nu^\alpha$, where ν is frequency, and α is the spectral index. For the optical V and R bands, we calculated optical spectral index (Zajaček et al. 2019):

$$\alpha = \frac{c - 0.4(V - R)}{\log(\nu_V/\nu_R)} \qquad \sigma_\alpha = \frac{1}{|\log(\nu_V/\nu_R)|}\sqrt{(\sigma_{F_V}/F_V)^2 + (\sigma_{F_R}/F_R)^2}$$

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, Castelli & Plez (1998).

Abbé's criterion: The criterion is often used for checking the absence of systematic changes in a series of measurements (Malkin 2013). Abbé's statistic q is defined as the ratio of the Allan variance σ_{AV} and unbiased sample variance σ_D

$$q = \frac{1}{2}\frac{\sum_{i=1}^{n-1}(x_{i+1} - x_i)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad q_c = 1 + u_\alpha/\sqrt{n + 0.5(1 + u_\alpha)^2}$$

The hypothesis about stochastic independence of the sample units is accepted under $q > qc$, otherwise the elements of the sample cannot be accepted as random and independent.

The detailed information about these blazars: their International Earth Rotation Service (IERS) name, coordinates, redshift, AGN type, and results of Abbé's criterion, with n number of data are provided in Table 1. (sources with variable α are marked in gray). In Fig. 2 are presented graphs for α vs time for sources 0049+003, and 1612+378.

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
1612+378	243.69564	37.76869	1.531239	FSRQ	0.63 , 0.74	37

Conclusion

The optical band is quite narrow in comparison to the other spectral bands over the entire EM spectrum. Nevertheless 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, most of the blazars have shown significant flux and colour variations on STV and LTV time-scales, and the variability pattern in V and R bands found to be similar. The non-variable blazars are 1429+249, and 1556+335, remaining sources show variability in the both bands. The maximum variation of about 2.0 mag (in V and R bands) is found in 1722+119, and 1741+597 (both 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 are FSRQs). For those sources α vs time are presented in Fig. 2. We did not find relationship between variability in brightness and spectral index (in optical domain). We will continue with observations and investigations of ITV, STV, and LTV changes in brightness, colour, and spectral index of these and several other AGNs.

Reference

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Thanks!