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INTRA-NIGHT VARIABILITY OF 1722+119

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Abstract. Blazars (subclass of active galactic nuclei) eject relativistic jets near the observer's line of sight. Their flux is highly variable in the whole electromagnetic spectrum. Variability time-scales can be divided into three classes: intra-night variability, short-term variability, and long-term variability. The one subclass of blazars is BL Lac. These are blazars with rapid and large-amplitude flux variability. Source 1722+119 is BL Lacertae. The observations have been performed from July 2013 using telescopes located at the Astronomical station Vidojevica of Astronomical Observatory of Belgrade, Serbia. During more than ten years of flux monitoring of source 1722+119 amplitude brightness change by about 2 magnitudes in V and R bands. We monitored this source for about 3 hours per night on several nights to investigate the intra-night variability, and the results are presented here.

1. INTRODUCTION

Blazar 1722+119 is one of the 47 candidate sources for the link between International Celestial Reference Frame and Gaia Celestial Reference Frame (Bourda et al. 2011). Blazars are subclass of active galactic nuclei (AGN) which eject relativistic jets near the observers line of sight. Their flux is highly variable in the whole electromagnetic spectrum, and show variability on diverse time-scales. Variability time-scales can be divided into three classes: intra-night variability (from a few minutes to a less than a day), short-term variability (from a few days to a few months), and long-term variability (from a few months to several years); see Gupta (2014). The source 1722+119 is BL Lacertae. BL Lacertae are blazars which are characterized by rapid and large-amplitude flux variability.

2. METHODS AND RESULTS

We performed the optical photometric observations of 47 candidate sources, since July 2013. Observations were performed in V and R bands. 1722+119 is the most variable source. The brightness changed by about 2 magnitudes in both bands. We investigated intra-night variability of the source. Intra-night observations were performed using telescopes located at the Astronomical station Vidojevica (ASV) of Astronomical Observatory of Belgrade, Serbia (λ=21 $^{\circ}_{.}$ 5 E, φ=43 $^{\circ}_{.}$ 1 N). Telescope with the mirror diameter of 1.4 m (ASV 1.4 m) was equipped with Andor iKon-L, and 60 cm telescope (ASV 60 cm) with ProLine PL23042 CCD camera. CCD cameras specifications (name, CCD resolution, pixel size, pixel scale, field of view) are: Andor iKon-L CCD, 2048×2048, 13.5×13.5 μm, 0.244 arcsec/pix, 8.3×8.3 arcmin (for ASV 1.4 m), and ProLine PL23042, 2048×2064, 15.0×15.0, 0.512, 17.5×17.6 (for ASV 60 cm).

The brightness of the source was calculated using differential photometry with two comparison stars A, and B. The details about photometry (finding chart, and selection of the stars) are presented in paper Jovanović et al. 2023. During the four nights, the intra-night brightness of the source 1722+119 did not change significantly. The average V magnitude was 16.153 ± 0.011 mag, and R was 15.725 ± 0.019 mag. The intra-night data were tested using Abbe's criterion, and F − test.

2. 1. ABBE'S CRITERION

Abbe's criterion is often used for checking the absence of systematic changes in a series of measurements. The statistics were calculated for differences of the magnitude of source (S) and stars A, and B (q_A and q_B). The hypothesis about stochastic independence of the sample units is accepted under $q_{A,B} > q_c$, otherwise the elements of the sample cannot be accepted as random and independent. The q statistic was calculated:

$$q = \frac{1}{2}(\sum_{i=1}^{n-1}(x_{i+1} - x_i)^2)/(\sum_{i=1}^{n}(x_i - \bar{x})^2)\,, \tag{1}$$

Statistics q_A and q_B were calculated: $q_A : x = S - A$, $q_B : x = S - B$. The critical value is defined as $q_c = 1 + u_\alpha/\sqrt{n + 0.5(1 + u_\alpha^2)}$, where u_α is the quantile of normal distribution for the significance level α.

2. 2. F–TEST

F–test examines variances of two data sets X and Y to test if they are equal to each other. The test hypothesis was $H_0 : VarX = VarY$,, and alternative $H : VarX > VarY$. We calculated statistics $F_A : X = S - A$, $F_B : X = S - B$, and $F_{A/B} = F_A/F_B$; $Y = A - B$, where S, A, and B, are magnitude of source, comparison star A, and B.

If Abbe's statistics ($q_{A,B}$) are less than critical, and F–test statistics $F_{A,B}$ are greater than the critical value, for significance level 0.001, and N number of data, we consider that the source is variable (V). For the opposite ($q_{A,B} > q_c$, and $F_{A,B} < F_c$) source is nonvariable (NV). In other cases we consider that the source is possibly variable (PV). The statistical results are presented in Table 1: date of observation (with telescope which was used), band, number of data (N), Abbe's and F–test statistics, and variability. The night with the highest number of observations is March 29^{th} 2020 (32 points in V, and 33 points in R bands). The light curves of V and R bands of March 29^{th} 2020 are presented in Fig 1. With green diamonds is presented the light curve of V band, and with red squares the light curve of R band.

3. SUMMARY

We have observed 47 candidate sources for the link between ICRF and Gaia CRF, since July 2013. These sources are active galactic nuclei (AGN). The one of the most variable AGN are blazars (with detected intra-night, short-term, and long-term variability). The observational results were obtained with ASV telescopes, in V and R bands. For 12 sources the brightness variability was published in Jovanović et al. (2023). The most variable source is BL Lacertae 1722+119, with a change in brightness of almost 2 magnitudes, in both bands; during 2013 2019. In June 2015 during three hours of monitoring, the object did not show the variability in V band,

Table 1: Statistical results.

Date Telescope	Band	N	Abbe q_A, q_B, q_c	F–test $F_{A/B}$, F_A, F_B, F_c	Variabile
02.09.2019.	V	11	0.53, 1.08, 0.26	1.10, 3.15, 2.88, 8.75	–
ASV 1.4 m	R	11	0.51, 0.39, 0.26	1.10, 1.56, 1.41, 8.75	–
29.03.2020.	V	32	0.50, 0.70, 0.49	1.34, 5.14, 6.90, 3.15	PV
ASV 60 cm	R	33	0.27, 0.32, 0.50	1.19, 19.24, 16.18, 3.09	V
27.07.2020.	V	14	0.44, 0.70, 0.31	1.01, 4.57, 4.53, 6.41	NV
ASV 1.4 m	R	14	0.62, 1.01, 0.31	1.11, 1.41, 1.26, 6.41	NV
09.04.2021.	V	9	1.18, 1.35, 0.22	1.51, 2.84, 1.89, 12.05	–
ASV 60 cm	R	10	0.81, 0.69, 0.24	1.13, 10.54, 9.33, 10.11	–

Notes. In the Variable column, V represents variable, NV nonvariable, and PV possibly variable source.

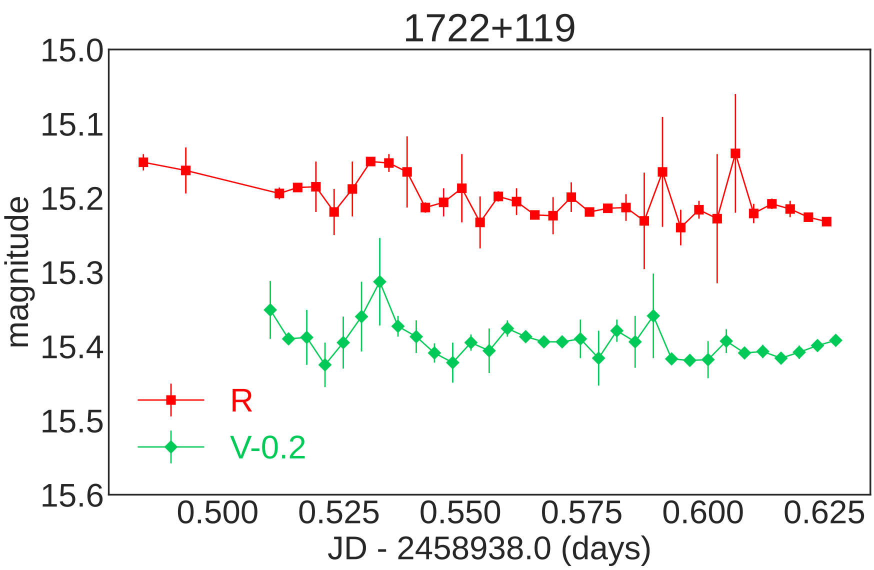

Figure 1: V (green diamonds) and R (red squares) bands light curves of 1722+119 (March 29^{th} 2020).

it showed possible variability in R band, and a strong redder-when-brighter trend of the optical spectrum (Kalita, Gupta & Gu (2021)).

Here we presented the intra-night variability of the source during 4 nights: September 2^{nd} 2019 (2.5 h), March 29^{th} 2020 (3.5 h), July 27^{th} 2020 (4 h), and April 9^{th} 2021 (1 h). The brightness of the source was determined using differential photometry with 2 comparison stars, and 5 control stars. In V band the brightness reached about 16.2 mag, in R 15.7 mag, and did not change significantly during the mentioned 4 nights.

We tested the data for each night separately with Abbe's criterion and F – test. During the night of July 27^{th} 2020 tests show that the source was nonvariable in both bands. During March 29^{th} 2020 the source was variable in R band. In V band source was variable only with F – test. For September 2^{nd} 2019 and April 9^{th} 2021 were obtained only a small number of data (less than 12). We cannot conclude anything based on the test results. In order to better examine the activity of the source, we will continue with observations of this and the other sources.

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