High-Redshift AGNs: Preliminary Results of a Long-Term Optical Study

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Abstract. We present and discuss preliminary results of a photometric study of a different type AGNs with the 2-meter RCC and the 50/70cm Schmidt telescopes at National Astronomical Observatory (NAO) – Rozhen, and the 35cm Newton telescope at Student Astronomical Observatory (SAO) – Plana. We have observed 11 sources with standard Johnson-Cousins photometric filters for a period of 15 years. We have obtained differential light curves with variability up to 0.4 magnitude. One of the sources (QSO B1312+7837) shows signs of periodic variability and can be used for reverberation mapping analysis.

Keywords: AGN, Photometry, Astronomy.

1. INTRODUCTION

All types of active galaxy nucleus show variability in different time scales. (Ulrich, Maraschi & Urry, 1997). AGNs at high redshift are difficult to observe but they can give us information for a better understanding of the processes and physics of the early Universe. Observations of this type of objects can give us more information about the most powerful processes in the Universe. This is the way that we can explore supermassive black holes and their evolution with time. The flux changes of AGNs are unpredictable and every observation is valuable. Since now there are two AGNs with known periodic variability – OJ287 (Villforth et al, 2010) and PKS 2155-304 (Zhang et al, 2014). According to the theoretical models these two AGNs contain a system of binary black holes rotating around the gravitational center of masses (Valtonen & Ciprini, 2012).

This work is a part of a long-term optical study of high-redshift AGNs of different types. We choose dozen of sources with near-polar coordinates that we can observe all over the year because of our observing location with latitude 42° N. The selection includes only objects with redshift $z > 1$ and due to this they are not well studied yet. As part of this study, we have observed two more high-redshifted quasars – Q2203+292 (Ovcharov et al, 2008) and SDSS J07548.86+303355.1 (Valcheva et al, 2009).

2. OBSERVATIONS

We have obtained observations in a period of 15 years (2005 – 2019) with 3 telescopes equipped with 7 CCD cameras in National Astronomical Observatory (NAO) Rozhen and Student Astronomical Observatory (SAO) Plana (Ovcharov et al, 2014). All configurations are shown in Table 1. We used standard photometric BVRI Johnsons-Cousins filters and took exposures in a range of 120 sec for 2m RCC telescope and 300 sec for smaller ones. The typical seeing varied between 1.5 and 2 arcsec. The distribution of observing nights during the years is shown in Fig. 1. Information about all observed objects is summarized in Table 2.

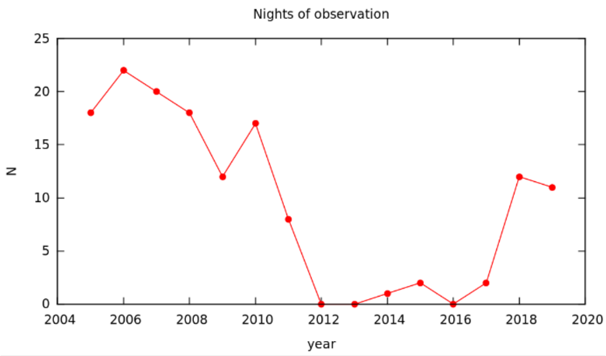

Fig. 1 QSO observing nights 2005 – 2019.

3. DATA REDUCTION

For data reduction and analysis, we used IRAF[1]. We performed dark or bias (for the 2 m telescope images) substraction, flat-fielding and alignment of individual frames for each quasar. After this calibration, we measured the PSF value for every image and performed aperture photometry of the quasar and 3 to 7 reference stars that are close to the object of interest and have similar magnitudes to it. Using differential photometry, we checked the difference in magnitudes of each reference star and choose the most stable ones in time. In Fig. 2 are shown the instrumental magnitude differences of QSO 09 and two reference stars (A and B) in the first and second frame and the instrumental magnitude difference of comparison stars in the third frame. Using this method for measurement of the relative flux, we obtained light curves for all 11 quasars (Fig. 3) in all photometric filters (for example QSO 09 in Fig. 4).

TABLE 1. Instruments used for observations.

Observatory	Telescope	Camera
NAO Rozhen	2m RCC	Photometrics CE200A
NAO Rozhen	2m RCC	VersArray 1300 B
NAO Rozhen	2m RCC	VersArray 512 B
NAO Rozhen	2m RCC	Andor iKon-L
NAO Rozhen	50/70cm Schmidt	SBIG ST-8
NAO Rozhen	50/70cm Schmidt	SBIG STL-11000M
NAO Rozhen	50/70cm Schmidt	FLI PL-16803
SAO Plana	35cm Newton	SBIG STL-11000M

TABLE 2. Selected near-polar quasars (NASA/IPAC Extragalactic Database).

Object ID	SIMBAD ID	Z	Type
QSO 03	QSO B0014+812	3.4	FSRQ
QSO 04	QSO B0153+744	2.3	LPQ/RLQ
QSO 05	8C 0546+726	1.6	QSO
QSO 06	4C 71.07	2.2	Blazar/LPQ
QSO 07	QSO B0933+733	2.5	RQQ
QSO 08	QSO B1039+811	1.3	LPQ/FSRQ
QSO 09	QSO B1312+7837	2.0	QSO
QSO 10	QSO B1634+706	1.4	RQQ/HyLIRG
QSO 11	QSO B1759+756	3.0	DLyA
QSO 12	HS 1803+7517	1.1	QSO
QSO13	QSO B1946+770	3.1	QSO

4. DISCUSSION

The differential light curves for 11 quasars show flux changes of 0.2 – 0.4 magnitudes for a period of 15 years. In the case of QSO 09, the light curves indicate a sign of a periodic variability. In these preliminary results, we can estimate a period of about 5.5 – 6.0 years but more precise data analysis is needed. We also obtained a color-flux diagram and we found a correlation between V-R color and V magnitude. Linear fit shows a slope of 0.38 with increasing V magnitude (Fig. 5). This means that with increasing of flux in V-band the difference between fluxes in V and R bands also increases, i. e. flux in R-band increase much more than flux in V-band. Most likely this can be a reverberation effect due to the C II] λ2326 emission line contribution. (Peterson, 1997). For a source with redshift $z = 2.00$ like QSO 09 (Hagen, 1999) this line is observed in R filter at wavelength 6978Å. In photometric V filter no emission lines can be found for a quasar with that redshift and the flux comes only from the continuum. With the obtaining of additional data, including spectra, and after the intended absolute calibration of our instrumental magnitudes using standard fields (Stetson, 2000), more analysis will be performed. Furthermore, the calibration for systematical dependence in the images, taken with some of the observational systems (Ovcharov et al, 2008) is necessary. The periodogram and reverberation mapping analysis will be performed and some of the central supermassive black hole parameters can be defined. We are going to build a structure function for each quasar and check for color-flux dependence. Using broad line emission line components and reverberation mapping (Peterson, 1993) we can understand the ongoing processes in the central region of active galactic nuclei.

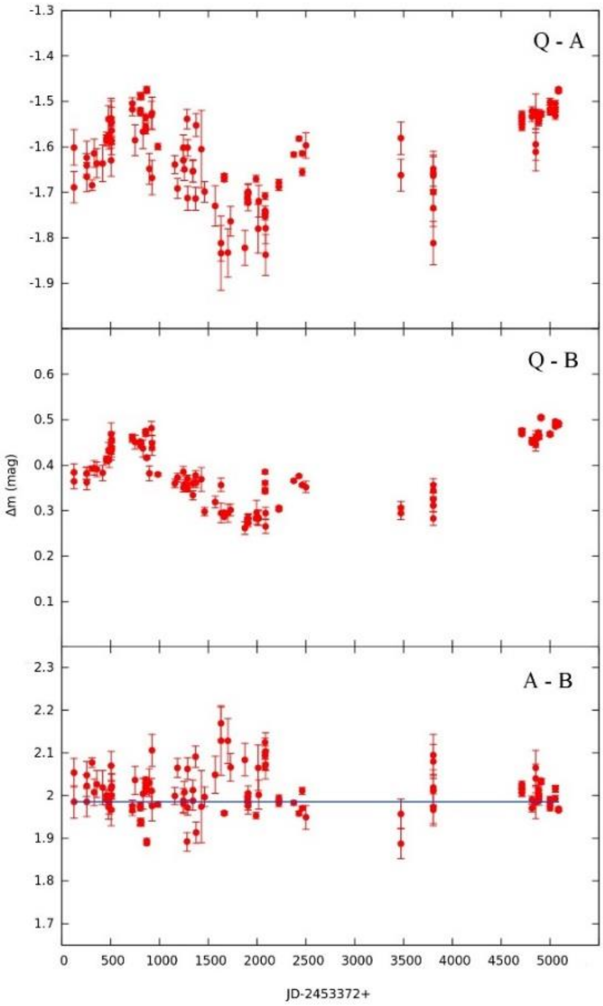

Fig. 2 Differential photometry for QSO 09. On the top and middle panel are shown the differences between the instrumental magnitudes of the quasar and the reference stars A and B. On the bottom panel is shown the difference between A and B reference stars. The solid line is a linear fit to the data.

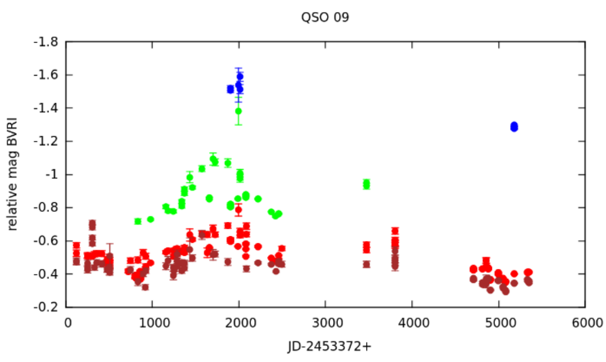

Fig. 4 BVRI-band differential light curves of QSO09.

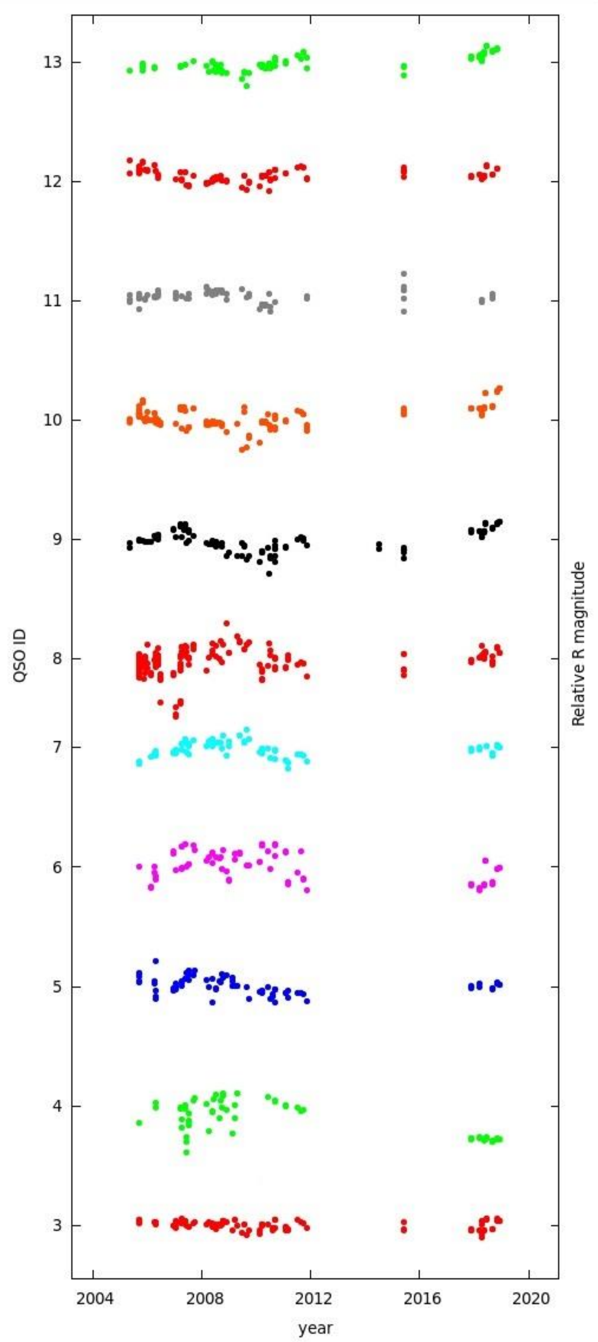

Fig. 3 R-band differential light curves for QSO 03-13, shifted with a constant.

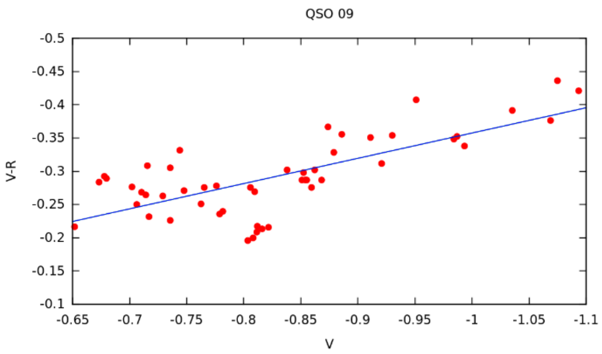

Fig. 5 Color-flux diagram of QSO 09. The solid line is a linear fit to the data with a slope of 0.38. The magnitudes are result of the differential photometry.

5. CONCLUSION

The presented results are preliminary but we can see long-term variability of 0.2 – 0.4 magnitudes in all observed quasars. Relative magnitudes are measured in BVRI-bands. For the quasar QSO B1312+7837, we obtained a color-flux diagram and we found a correlation between (V-R) magnitude and V-band relative flux. The reason can be the contribution of the emission line CII] λ2326 in R-band at the redshift of $z = 2.00$. This object also shows variability with a probable period of about 5.5-6 years.

Thorough analysis is planned with additional data and absolute calibration of the instrumental magnitudes.

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