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Optical monitoring of FRII-type radio quasars

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Abstract. We present preliminary results of optical monitoring of sample of FRII-type radio quasars. The optical observations were made with three telescopes, among them one robotic, spanning a time interval longer than two years. Variability in the range of a fraction of a magnitude was observed for all eight targets. We applied the structure function to analyse the brightness changes. The slope of the structure function is only consistent with the disk instability model for two sources; the other sources show values between of the disk instability and starburst models. Finally we argue that such monitoring would be most suitable as a long-term, complementary program for robotic telescopes.

Keywords : galaxies: active – galaxies: jets – galaxies: photometry – quasars: general – quasars: individual: J0713+3656, J0952+2352, J1007+1248, J1158+6254, J1427+2632, J1504+6856, J1723+3417, J2042+7508

1. Introduction

The multi-wavelength variability of quasars was reported since their discovery, and many correlations between variation in quasar luminosity and various physical parameters have been known for decades (for a summary see e.g. Helfand et al. (2001)). Monitoring of flux changes of quasars helps us to understand the physics of the central black hole and the accretion disk. For example, there is growing evidence suggesting

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that the variability could be linked to the mass of the central black-hole, (e.g. Wold et al. (2007); Wilhite et al. (2007)).

In this study, we are interested particularly in the central black hole and the physics of the accretion disk, which is associated with long-term variability. Therefore, we have excluded blazars, which are the most violently variable type in the optical domain, as these objects exhibit intra-night or even shorter period variations believed to be caused by synchroton radiation in the jet. These objects have jets directed at very small angles to the line of sight, and the short period variations appear to be due to high Lorentz factors, see (e.g. Villata et al. (2008); Urry & Padovani (1995)) .

Several models have been proposed to explain the sources of quasar long-term variability: the instability of the accretion disk surrounding the supermassive black hole (SMBH), e.g. Wallinder et al. (1992), Kawaguchi et al. (1998), Pereyra et al. (2006), violent starburts in the innermost regions of the host galaxy, e.g. Artexaga & Terlevich (1994), Artexaga et al. (1997) and microlensing by compact bodies on the path, e.g. Hawkins (1993), Hawkins (1996), Zackrisson et al. (2003). These three main models – one connected to the AGN itself, one related to the host galaxy's properties and one describing geometrical effects – compete to be the factor primarily responsible for quasar variability. Distinguishing between these models and identifying the one which plays the most significant role in quasar variability can only be done using data gathered over a long period of time.

There have been numerous projects undertaken in the past to study quasar optical activity, aimed at explaining the physics behind the observed flux changes. These have been based either on analysis of large samples of objects for which data have become available from recent optical surveys, sometimes supplemented with archival data from photographic plates to enlarge the time span to few decades (see e.g. Bauer et al. (2009) and references therein), or on smaller samples of a specific class of targets, e.g. Peterson et al. (1999). While the former approach provides a huge amount of data, it inevitably suffers from calibration problems if different sets of data are to be compared; the latter one consists of data of better accuracy but the time span is much shorter – usually only a few years.

In this study, we follow the approach of investigating the light curves of a small sample of carefully selected objects, chosen to be FRII-type radio quasars (Fanaroff & Riley 1974). Radio-loud quasars with extended radio structures can be used to study dependence of the optical variability on the obscuration by the dusty torus. Assuming that the disc axis and the jet axis are aligned, one can use the asymmetries in lobe luminosity to infer the information about the disk projection. At high inclinations, the dusty torus present in FRII radio quasars can partially or totally obscure the accretion disc. Therefore, in high inclination sources any variability due to disc instabilities should disappear. The light curves published in previous studies indicate that the

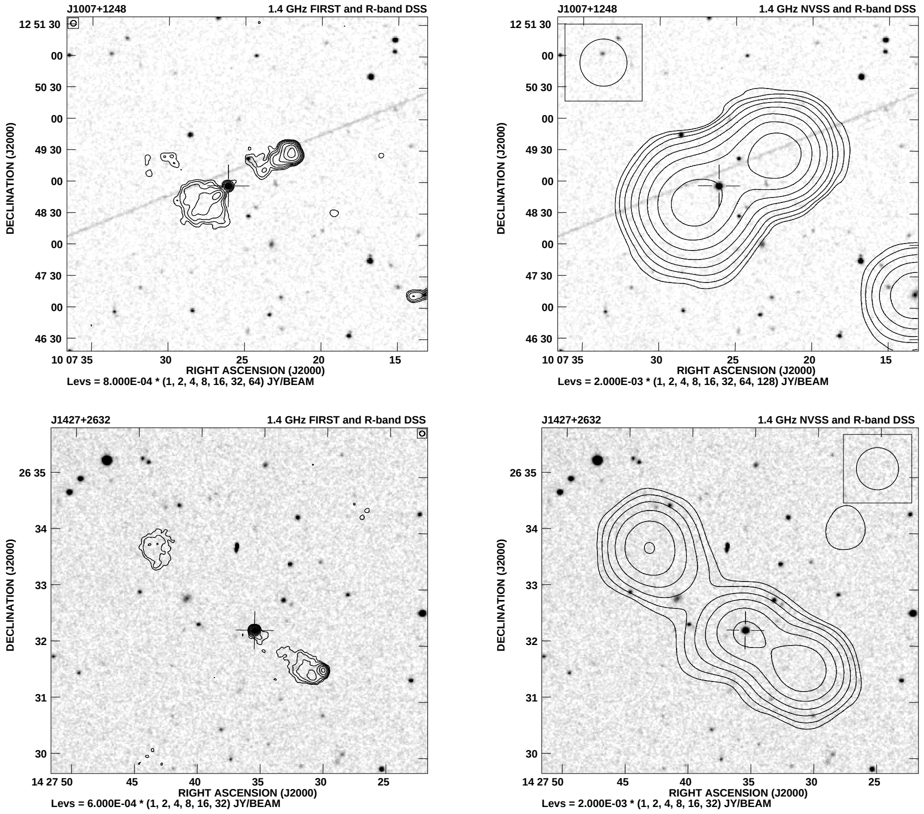

Figure 1. Radio contours overlayed on an optical DSS image of two targets from our sample. The upper panel shows J1007+1248, which has the smallest linear size (about 370 kpc) among objects in our sample, while the bottom panel shows J1427+2632, with a giant linear size of 1.16 Mpc. The FIRST and NVSS maps are shown on the left and right panel, respectively. Crosses show the location of the parent quasar, and the circles in the upper corners the resolution of the maps.

brightness of quasars changes on time scales of months, and that the amplitude is typically a fraction of a magnitude but can sometimes be larger.

2. Sample selection

Our sample consists of bright quasars which show strong radio emission. We selected them from different catalogs of radio quasars, e.g. Helfand et al. (2001). On the basis of the NVSS (Condon et al. 1998) and FIRST (Becker et al. 1995) radio maps, we selected only those powerful sources which possess extended radio structure (angular size > 20 arcsec) and FRII-type morphology. Based on their lobes' brightness asymmetries, the inclination angle (i.e. the angle between the line of sight and the jet

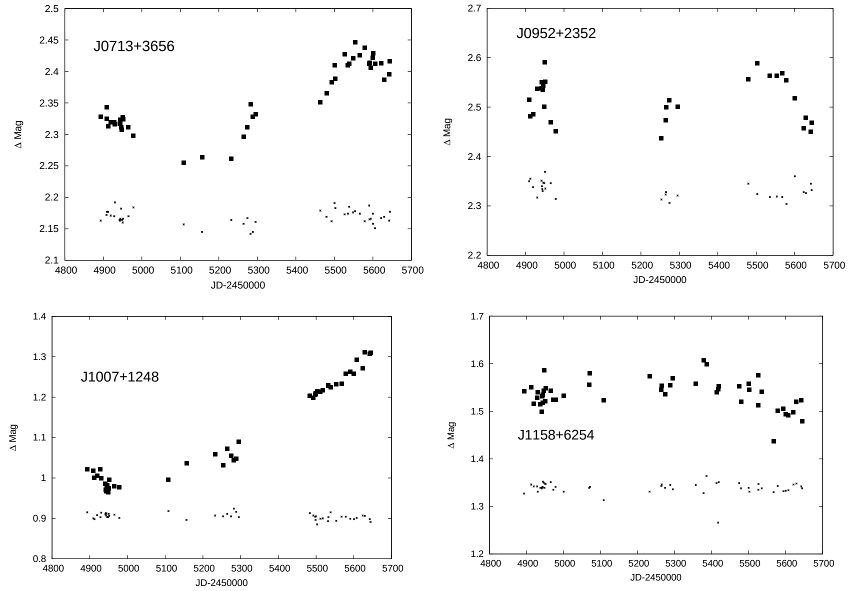

Figure 2. Light curves of four quasars from our sample. The upper panel shows variability of J0713+3656 and J0952+2352, while the bottom one that of J1007+1248 and J1158+6254. Squares denote (comparison star − target) measurements and asterisks comparison and check star differences.

axis) has been estimated by assuming that Doppler boosting is the dominant factor for any observed asymmetry. Our sample comprises radio quasars with inclination angles ranging from 45° (J1427+2632) to 90° (J0952+2352), required to investigate the role of a dusty torus in AGNs. Since the proposed optical observations were intended for small telescopes located on the northern hemisphere, we applied the additional criteria that targets not be fainter than 17th magnitude in the R-band and have positive declination ($\delta > 0$). We initially chose eleven sources, but after the first observations the 3 faintest targets were dropped. All objects in our sample have known redshifts, covering distances from $z = 0.1$ to $z = 0.97$, and having a projected linear size of the entire source from 370 kpc to about 1.1 Mpc. We have limited the sample to such a small number due to the initial planned use of a manual-mode telescope. The radio maps and optical images for two of our targets are shown in Fig. 1, while the properties of all quasars in the sample are listed in Table 1.

3. Observations

Observations of the targets from our sample started in March 2009 using the 50 cm Cassegrain telescope of the Astronomical Observatory of the Jagiellonian University. Later, two other 60 cm telescopes joined our campaign, one at Mt. Suhora Obser-

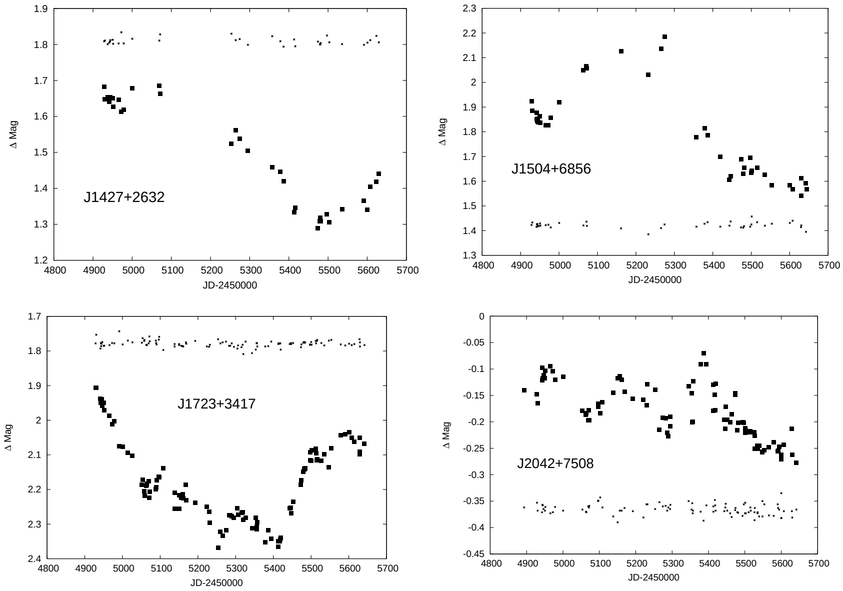

Figure 2. (continued) Light curves of four other quasars: J1427+2632, J1504+6856 (upper panel), J1723+3417 and J2042+7508 (bottom panel).

vatory and the other one at the Tubitak Observatory, Turkey. The latter telescope works in a fully robotic mode. All telescopes are equipped with CCD cameras and a set of wide-band, UBVRI (Cousins) filters. The observations were performed by taking a number of frames (10–12) in the R filter for each target, with (V-R) and (R-I) colors also measured on occasion. Calibration images (bias, dark and flatfield) were acquired every night. The frames were reduced using the IRAF package, and the magnitude differences between each target and nearby comparison and check stars were then derived through aperture photometry with the *CMunipack* program. To ensure uniformity of the results, all the reduction was performed by one person. On several occasions, simultaneous observations were performed to exclude/measure any offsets between the sites. As a result, we derived a mean point per night, the accuracy of which was not worse than 0.01–0.02 magnitude. Only on a few dates, when observations were made at very high zenith distance, was the accuracy slightly worse. The light curves of our targets are shown in Fig. 2 where squares denote the magnitude difference between comparison stars and targets, while asterisks that between comparison and check stars.

4. Preliminary results and conclusions

After two years of observations we have found all of the chosen targets to be variable in the optical wavelength. The amplitude of changes ranges from 0.1^m (J0952+2352)

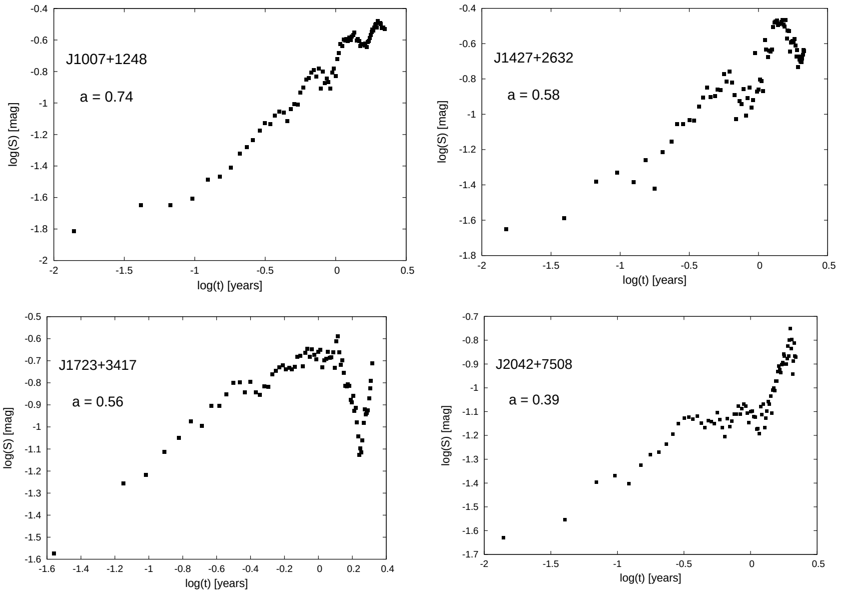

Figure 3. Structure functions of four targets: J11007+1248, J1427+2632, J1723+3417 and J2042+7508.

to 0.5^m (J1723+3417). The amplitude decreases with increasing inclination as expected if torus obscures the accretion disk and the disk is the source of variability. There is, however, one exception: J1504+6856 exhibits brightness variations of about 0.4^m despite its high (81deg) inclination angle. We can speculate that this might be due to the absence of a torus in this quasar, or that the torus is misaligned relative to the accretion disk.

Several tools have been used to extract information about the nature of the AGN variability, including Fourier analysis, the autocorrelation function or the structure function (S). The structure function has been widely used to derive information from the light curve of quasars, e.g. Cid Fernandez et al. (1997), Hawkins (2002), Bauer et al. (2009). We have also applied the structure function method to quantitatively characterize the light curves of six targets with the best data coverage. The structure functions for J1007+1248, J1427+2632, J1723+3417 and J2042+7508 are presented in Fig. 3. The coefficients a of the flat part of the structure functions have been calculated and are listed in Table 1. The theoretically predicted slopes of the structure functions are equal to 0.44, 0.83 and 0.25 for disk instability, starbursts and microlensing, respectively (Hawkins 1996). Considering slopes of the structure functions derived from our two year-long light curves, the properties of two targets (J0713+3656 and J2042+7508) are consistent with the prediction that disk instability is the mechanism of their variability. The others are in between the values expected for the disk instability and starbust mechanisms, but neither is consistent with the microlensing model.

Table 1. Sample of radio quasars chosen for optical monitoring.

name	D^a	i^b	z^c	Δm^d	a^e
J0713+3656	414	80	0.49	0.2	0.48
J0952+2352	702	90	0.97	0.1	-
J1007+1248	370	67	0.24	0.4	0.74
J1158+6254	385	75	0.59	0.2	-
J1427+2632	1158	45	0.36	0.4	0.58
J1504+6856	867	81	0.32	0.4	0.56
J1723+3417	760	51	0.21	0.5	0.56
J2042+7508	1138	61	0.10	0.2	0.39

Notes: (a) linear size in kpc; (b) inclination in degrees; (c) redshift; (d) amplitude of variation; (e) slope of the structure function

Finally, we conclude that such a long-term program could be very well suited for small robotic telescopes. Such observations are not time-critical and, as such, they can be done as a supplementary program to the observations of any primary targets. This would provide much denser coverage of the light curves and enlarge the number of targets, which in turn would allow for more reliable conclusions about the nature of the optical variations of FRII-type radio quasars.

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