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Variability of OI 090.4

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Abstract. OI 090.4 was monitored on 21 nights from 2006 to 2012 for studying the variability. Strong variations occurred during the past 6 years. The long-term variability amplitude is consistent with previous results. Microvariability was analysed for 43 intra-night light curves. 30 out of 43 light curves showed microvariability by C and F test analysis.

Key words. BL Lacertae objects: individual: OI 090.4—blazar: variability.

1. Introduction

Blazars are a subclass of Active Galactic Nuclei (AGN), known to be variable on different time-scales across the whole electromagnetic spectrum (Ulrich *et al.* 1997). It consists of Flat Spectrum Radio Quasars (FSRQs) and BL Lacertae objects (BL Lacs). Until now, except for the Mpc scale radio-jets and lobes, the other components within the canonical model remain spatially unresolved to astronomical observations in the vast majority of AGNs, but variability study could constrain the size and physical mechanism of the emitting regions. So variability becomes a powerful tool to study those innermost regions.

OI 090.4 (PKS 0754 + 100) was identified as a BL Lac object by Tapia *et al.* (1977). Ghosh & Soundararajaperumal (1995) suggested it to be a low frequency-peaked BL Lac object (LBL) by its multifrequency spectrum. This is another BL Lac whose redshift is still uncertain (Falomo & Ulrich 2000). Baumert (1980) reported a ∼2 mag optical variation over long time scales. Fan & Lin (2000) reported a ∼3 mag variability in 10 yr, with smaller variations up to 1 mag in about 1 year. Other authors reported its variability on different time-scales (e.g. Pica *et al.* 1988; Smith *et al.* 1987; Ghosh *et al.* 2000; Xie *et al.* 2004). But most observations were sparse for microvariability study. Cellone *et al.* (2007) investigated its inter-night and intranight variability (microvariability) by monitoring for 5 nights. It varied by 0.36 mag in the R band and 0.42 mag in the V band, respectively. Microvariability was detected on 4 out of 5 nights. In order to investigate the properties of variability, we carried out the monitoring of OI 090.4 from 2006 to 2012. In section 2, the observations and data reduction is given, while in section 3, the results and discussion are given.

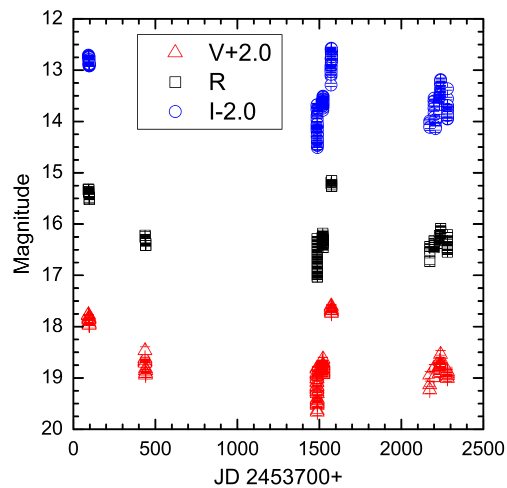

Figure 1. Light curves of OI 090.4 from Feb. 2006 to Feb. 2012.

2. Observations and data reduction

OI 090.4 was monitored from 2006 Feb. to 2012 Feb. using 1.0-m telescope at Weihai Observatory of Shandong University, and 2.16-m and 80-cm telescopes at Xinglong station of NAOC. In order to study the microvariability and color behavior of the source, we observed it repeated with Johnson/Cousins filters V, R and I sequentially as long as possible within one night, and we did observations as quickly as possible for high temporal resolution. For obtaining enough signal-to-noise ratio, the exposure time was set between 80s and 480s depending on the size of the telescope, filters and weather conditions. 886 images were obtained on 21 nights. The images were processed automatically using an Interactive Data Language (IDL) procedure

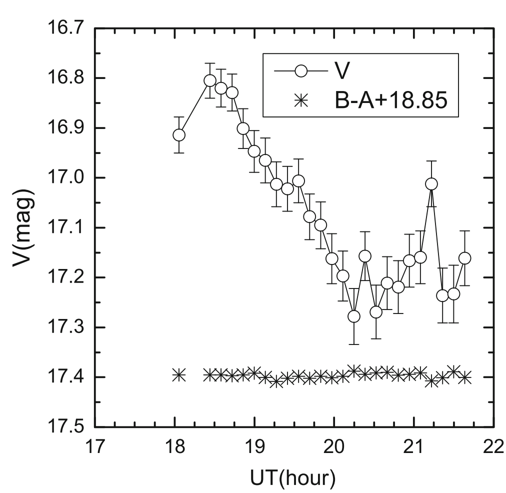

Figure 2. Light curve in the V band on 20 Dec. 2009.

Table 1. Microvariability of OI 090.4.

Date	Band	N	ΔT	C	F	F_{99}	Var?	A
2009-12-20	I	27	3.78	5.742	32.974	2.554	Y	3.868
2009-12-20	R	27	3.77	18.944	358.883	2.554	Y	3.059
2009-12-20	V	24	3.58	31.681	1003.717	2.719	Y	2.770
2009-12-21	I	18	4.01	3.930	15.447	3.242	Y	2.803
2009-12-21	R	17	4.02	1.212	1.469	3.372	N	
2009-12-21	V	15	3.78	2.867	8.221	3.698	Y	2.033
2010-01-21	I	11	1.39	1.679	2.820	4.849	N	
2010-01-21	R	11	1.39	4.872	23.737	4.849	Y	0.835
2010-01-21	V	11	1.39	6.301	39.697	4.849	Y	1.080
2010-01-23	I	34	4.60	1.204	1.450	2.287	N	
2010-01-23	R	34	4.60	6.902	47.631	2.287	Y	1.527
2010-01-23	V	35	4.75	7.083	50.172	2.258	Y	1.667
2010-01-25	I	39	5.66	2.482	6.160	2.157	?	
2010-01-25	R	39	5.91	10.485	109.936	2.157	Y	1.512
2010-01-25	V	40	6.10	12.211	149.116	2.135	Y	1.826
2010-03-16	I	20	4.51	2.410	5.808	3.027	?	
2010-03-18	I	14	3.54	0.712	0.507	3.905	N	
2010-03-18	R	9	3.26	4.099	16.798	6.029	Y	0.749
2010-03-18	V	9	2.99	2.143	4.594	6.029	N	
2011-12-03	I	8	1.08	9.261	85.772	6.993	Y	2.372
2012-01-13	I	12	3.17	2.139	4.575	4.462	?	
2012-01-13	R	9	2.46	4.733	22.398	6.029	Y	1.333
2012-02-23	I	14	3.35	3.783	14.313	3.905	Y	3.707
2012-02-23	R	15	3.35	16.108	259.464	3.698	Y	2.044
2012-02-23	V	12	3.59	5.439	29.586	4.462	Y	0.818
2007-02-07	V	8	2.11	20.501	420.274	6.993	Y	1.466
2007-02-09	R	8	2.63	5.236	27.417	6.993	Y	0.267
2007-02-09	V	8	3.01	7.592	57.635	6.993	Y	0.763
2006-02-25	I	9	3.22	5.111	26.124	6.029	Y	0.223
2006-02-25	R	10	3.24	2.412	5.817	5.351	?	
2006-02-25	V	10	3.29	2.693	7.252	5.351	Y	0.106
2006-02-26	I	9	2.72	7.952	63.228	6.029	Y	0.985
2006-02-26	R	10	2.74	2.435	5.928	5.351	?	
2006-02-28	I	9	2.67	4.070	16.566	6.029	Y	0.767
2006-02-28	R	9	2.69	4.646	21.583	6.029	Y	0.271
2006-02-28	V	10	2.75	4.880	23.812	5.351	Y	0.333
2006-03-01	I	10	2.45	2.478	6.140	5.351	?	
2006-03-01	R	9	2.47	4.364	19.043	6.029	Y	0.199
2006-03-01	V	10	2.47	1.725	2.974	5.351	N	
2006-03-02	I	10	2.30	2.696	7.269	5.351	Y	0.417
2006-03-02	R	10	2.31	5.481	30.042	5.351	Y	0.309
2006-03-02	V	9	2.33	2.886	8.328	6.029	Y	0.185

developed by us based on the NASA IDL astronomical libraries. All images were reduced by bias, flat correction and aperture photometry. The aperture size was set to 6.3″ for images from Weihai and Xinglong 80-cm telescope, and 8″ was set for images from 2.16-m telescope because of relative larger seeing. Stars A and B (Fiorucci *et al.* 1998) were chosen for comparison to do differential photometry.

3. Results and discussion

The data were filtered for analysis accuracy. Firstly, we discarded the data whose photometry error is larger than 0.08 mag. Then we discarded the data whose related check star magnitude is two times their standard deviation within the whole night. 746 observations in V, R and I bands remained. Long-term light curves are shown in Fig. 1. Red triangles, black boxes and blue dots indicate the variations in the V, R and I bands, respectively. Strong variability occurred during the past 6 years. It changed 2.07 mag (from 15.59 to 17.66), 1.88 mag (from 15.15 to 17.03), and 1.93 mag (from 14.57 to 16.50) in the V, R and I bands, respectively. These variability amplitudes are consistent with the results reported by Baumert (1980), Noble *et al.* (1997) (2.67mag in the V band) and Fan & Lin (2000).

Small variations superposed on the long term variability. Our intense observations enabled us to study the microvariability. C test (Romero *et al.* 1999) and F test (Diego 2010) were used to detect the microvariability for light curves, whose data points were more than 8 within one night. We will claim that microvariability was detected (not detected) if it was a judged variable (not variable) by both tests (taken 99% as the confidence level). Figure 2 shows an example of microvariability light curve in the V band on 20 Dec. 2009. Variability amplitude was calculated for light curves with microvariability (Heidt & Wagner 1996). All results were listed in Table 1. 30 light curves out of 43 have microvariability, and the duty cycle is about 70%. Our result supports the result of Cellone *et al.* (2007) (80%).

Physical causes of blazar variability are still under debate. But intrinsic models (e.g. hotpots models, shock-in-jet models and geometrical models) could widely explain optical variability, and we prefer shock-in-jet plus geometrical model. Many investigations (Heidt & Wagner 1996, 1998; Gaur *et al.* 2012) showed that HBLs have less optical variability than that of LBLs. The scenario of stronger magnetic fields in HBLs (Romero *et al.* 1999) is a possible physical reason. More research in this field is crucial to study the mechanism of variability.

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