

Optical Monitoring Observations of BL Lac Objects and Quasars

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Abstract

V-band photometric monitoring observations of four BL Lac objects and two quasars have been in progress at Nishi-Harima Astronomical Observatory since October, 1991. Observations were carried out using a CCD camera system attached to the 0.6m reflector. Results of these observations between October, 1991 and March, 1993 are presented. Five objects except for 3C273 showed high activities during the period. We also detected large flares in light curves of OI090.4 ($\Delta V = 1.4$) and 3C345 ($\Delta V = 2.0$).

Key words: BL Lac Objects; Quasars; CCD photometry

1. Introduction

Long term photometric monitoring observations with high accuracy and uniformity are important in understanding the behaviour of active galactic nuclei (AGNs). Since observing time available at large telescopes is limited, long term monitoring programs are usually carried out using small telescopes. In recent years, thanks to the high sensitivity of CCD cameras, even a small telescope has become a powerful tool in observations of faint objects such as quasars.

Presently, only a few monitoring programs aimed at AGNs have been running (e.g. Webb et al., 1988, Sillanpää et al., 1991). Unfortunately, light curves obtained by these authors for AGNs are usually fragmentary. In the radio region, data obtained in monitoring programs of AGNs are more frequent than optical observations (e.g., Teräsanta et al. 1992). Consequently, it is not easy to detect physical connections between radio and optical activities. There is thus a very strong need for more optical data on even the most frequently observed sources.

The variations in light curves of AGNs have timescales of hours (e.g. Miller et al., 1989) to years. Our aim in the present observational program is to study the variations on a timescale of days to years.

2. Observations

A V-band photometric monitoring project is in progress at Nishi-Harima Astronomical Observatory since October, 1991. A CCD (EEV P8603) camera system is attached to the f/12 Cassegrain focus of the 60-cm reflector. The CCD camera with 578×385 pixels yields a field of view of 6×4 arc minutes. The V-band filter approximates the standard Johnson V system. The chip is cooled with liquid nitrogen to -130 C. Exposures were taken with integration times of 2 to 3 minutes. The images are bias corrected and flat-fielded and synthetic aperture photometries were performed using the APPHOT package in IRAF¹.

We selected four BL Lac objects and two quasars. The objects and relevant data are listed in table 1. The catalogue data were taken from the Sky Catalogue 2000.0 Vol. 2 (Hirshfeld

¹IRAF is distributed by the National Optical Astronomy Observatories, U. S. A.

Table 1. Catalogue data of observed objects.

Designation	Name	R.A.(2000)	Dec.(2000)	z	Type
0754+100	OI090.4	07 57 07	+09 56 34		BL
0851+202	OJ287	08 54 49	+20 06 32	0.306	BL
1226+023	3C273	12 29 07	+02 03 07	0.158	QSO(LPQ)
1418+546	OQ530	14 19 47	+54 23 14		BL
1641+399	3C345	16 42 59	+39 48 37	0.595	QSO(HPQ)
2200+420	BL Lac	22 02 43	+42 16 40	0.07	BL

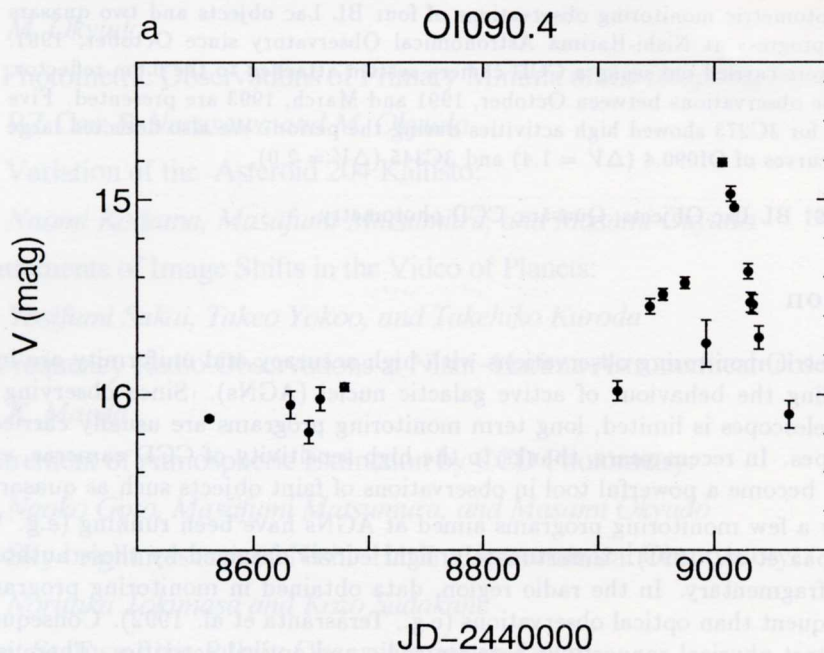


Fig. 1. Light curves of four BL Lac objects and two quasars between October, 1991 and March, 1993.

and Sinnott, 1985). Comparison stars for all of our targets are contained simultaneously in the same fields with the objects. V magnitudes of the comparison stars were taken from Smith et al. (1985).

We also estimated errors of our observations using comparison stars. The estimated error in photometry at $V = 15$ is 0.02 mag under the usual condition.

3. Results and Discussion

Results of photometric observations are listed in table 2. Light curves of all objects are shown in figures 1a - f. All observed objects are briefly discussed one after another in following remarks.

OI090.4: This object was identified as a BL Lac object by Tapia et al. (1977). According to their measurements, it had varied in the range of 13.8 - 14.8 in the V -band between February, 1976 and January, 1977. However, between 1984 and 1989 its range in the V -band has been 15.22 - 16.1 (Sillanpää et al., 1991). Xie et al. (1991) detected a variation on a timescale of

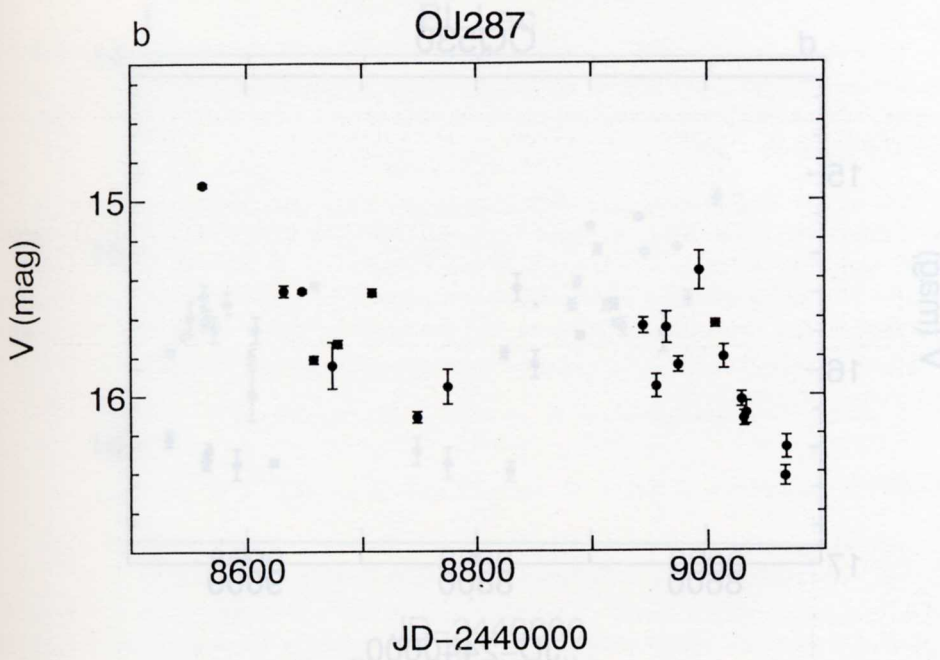


Fig. 2. (Continued)

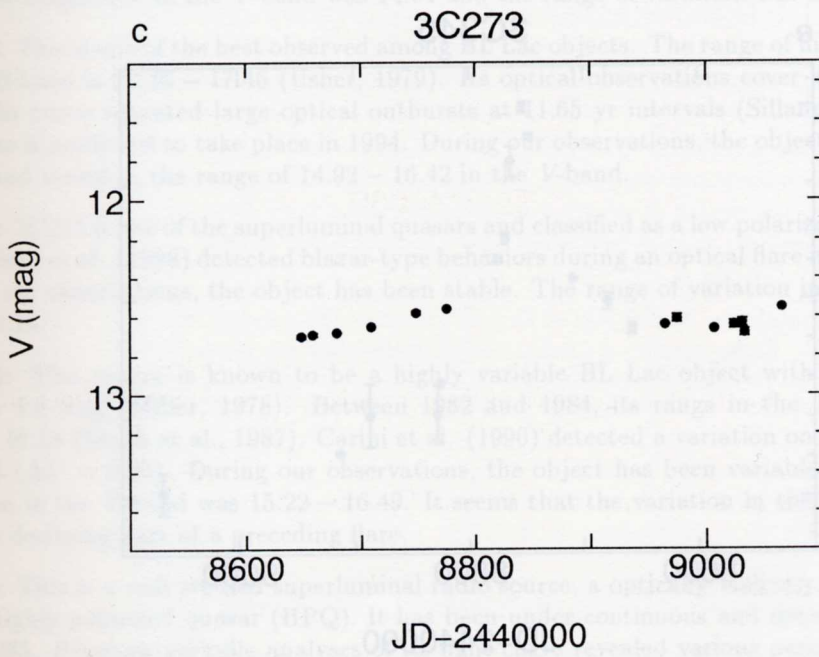


Fig. 2. (Continued)

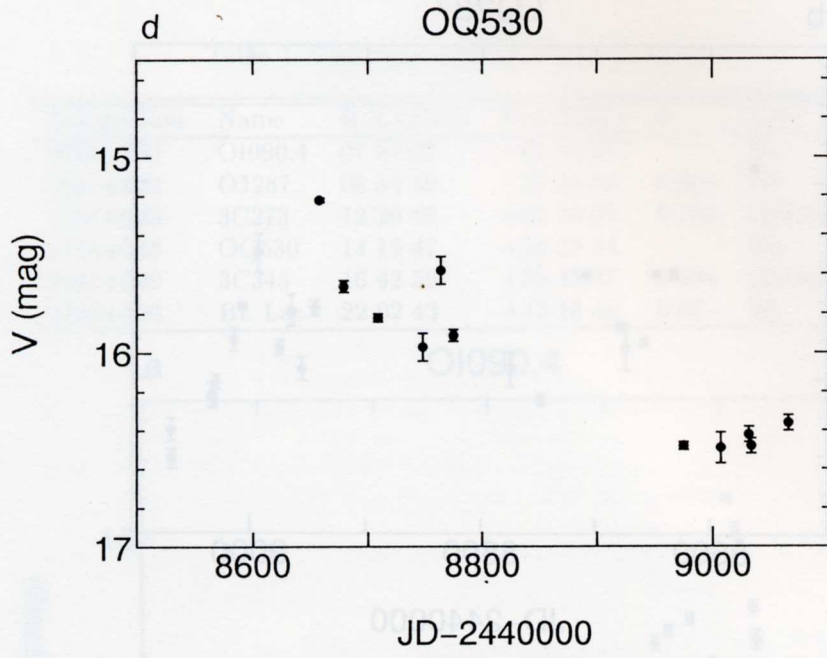


Fig. 2. (Continued)

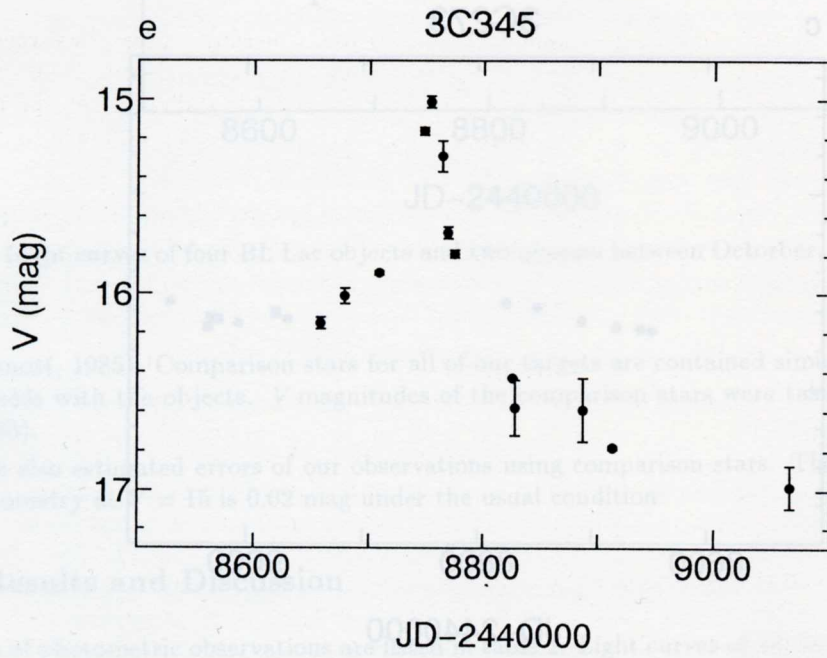


Fig. 2. (Continued)

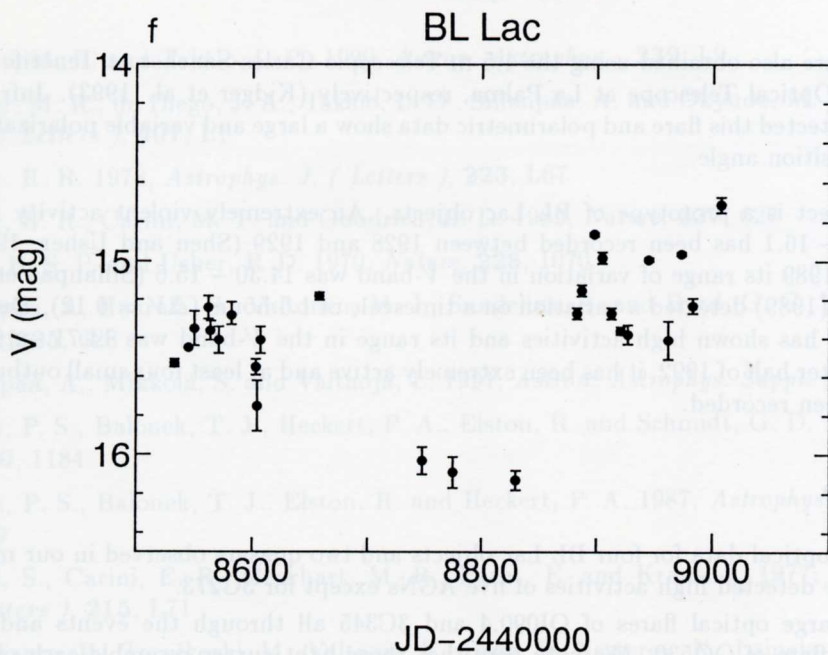


Fig. 2. (Continued)

one hour ($\Delta B = 0.56$). During our observations, we detected a large flare in the light curve. Its brightest magnitude in the V -band was 14.81 and the range of variation was $\Delta V = 1.4$.

OJ287: This is one of the best observed among BL Lac objects. The range of historical variation in the B -band is 12.36 – 17.46 (Usher, 1979). Its optical observations cover almost 100 years. The light curve repeated large optical outbursts at 11.65 yr intervals (Sillanpää et al., 1988). Next one is predicted to take place in 1994. During our observations, the object has been highly active and varied in the range of 14.92 – 16.42 in the V -band.

3C273: 3C273 is one of the superluminal quasars and classified as a low polarized quasar (LPQ). Courvoisier et al. (1988) detected blazar-type behaviors during an optical flare in February, 1988. During our observations, the object has been stable. The range of variation in the V -band was $\Delta V = 0.15$.

OQ530: This source is known to be a highly variable BL Lac object with a total range of at least 4.8 mag (Miller, 1978). Between 1982 and 1984, its range in the V -band has been 14.94 – 16.18 (Smith et al., 1987). Carini et al. (1990) detected a variation on a timescale of 20 minutes ($\Delta V = 0.06$). During our observations, the object has been variable and its range of variation in the V -band was 15.22 – 16.49. It seems that the variation in the first half of 1992 was the declining part of a preceding flare.

3C345: This is a well studied superluminal radio source, a optically violently variable (OVV), and a highly polarized quasar (HPQ). It has been under continuous and detailed observations since 1965. Previous periodic analyses of its light curve revealed various periods ranging from days to years. Webb et al. (1988) found a period of 11.4 yr. The range of historical variations in the B -band was 14.70 – 17.65 (Kidger, 1989). Recently, Kidger and Takalo (1990) detected a large anti-flare in the light curve in May, 1990 and its faintest magnitude was 17.54 in the V -band. In our observations, we detected a large flare in the light curve. Its maximum magnitude in the V -band was 15.01 and the range of variation was $\Delta V = 2.0$. Infrared and polarimetric

data of this flare were also obtained using the 1.5-m Telescopio Carlos Sánchez at Tenerife and the 2.56-m Nordic Optical Telescope at La Palma, respectively (Kidger et al. 1993). Infrared observations also detected this flare and polarimetric data show a large and variable polarization, especially in the position angle.

BL Lac: This object is a prototype of BL Lac objects. An extremely violent activity with a range $B = 12.4 - 16.1$ has been recorded between 1928 and 1929 (Shen and Usher, 1970). Between 1985 and 1989 its range of variation in the V -band was $14.30 - 15.6$ (Sillanpää et al., 1991). Miller et al. (1989) detected a variation on a timescale of 1.5 hours ($\Delta V = 0.12$). During our observations, it has shown high activities and its range in the V -band was $14.71 - 16.13$. Especially in the latter half of 1992, it has been extremely active and at least four small outbursts ($\Delta V \sim 0.5$) have been recorded.

4. Conclusion

We have presented optical data for four BL Lac objects and two quasars observed in our monitoring program. We detected high activities of five AGNs except for 3C273.

We observed large optical flares of OI090.4 and 3C345 all through the events and the declining part of a flare of OQ530. We note here that these light curves resemble each other. Especially, the flare light curves of OI090.4 and 3C345 have strong similarities. If one puts figure 1a upon figure 1e, their light curves almost coincide each other. At first, the brightness increases slowly, then it increases dramatically, and after its maximum it decreases linearly to the faint state. Babadzhanlyants and Belokon (1987) point out that some outbursts of 3C345 in the B -band between 1965 - 1984 are remarkably similar in their shapes. They call these outbursts "f-outbursts". However, we don't attempt here to make a further discussion, because there are only two examples of such flares in our data. Further observations will increase examples of optical flares.

We can not get much physical information of AGNs from only a single channel photometric monitoring. Then, combinations with other observations at different wavelengths, polarimetry, and spectroscopy are important in deriving more information from our observations. We hope that our data contribute to an understanding of the behaviour of AGNs.

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Table 2. Photometric results of BL Lac objects and quasars.

OI090.4						
	Date		JD (-2440000)	V (mag)	n	rms (mag)
1991	Nov.	1	8562	16.21	4	0.01
1992	Jan.	10	8632	16.05	3	0.07
	Jan.	26	8648	16.19	4	0.06
	Feb.	5	8658	16.02	4	0.06
		26	8679	15.96	4	0.02
	Oct.	21	8917	15.98	4	0.05
	Nov.	18	8945	15.55	4	0.04
		29	8956	15.49	3	0.03
	Dec.	18	8975	15.43	4	0.03
1993	Jan.	5	8993	15.74	3	0.12
		19	9007	14.81	4	0.02
		26	9014	14.97	4	0.04
		29	9017	15.04	1	—
	Feb.	10	9029	15.37	4	0.04
		12	9031	15.53	4	0.05
		14	9033	15.54	4	0.05
		19	9038	15.71	4	0.06
	Mar.	17	9064	16.10	4	0.07

OJ287						
	Date		JD (-2440000)	V (mag)	n	rms (mag)
1991	Nov.	1	8562	14.92	4	0.01
1992	Jan.	10	8632	15.46	4	0.03
		26	8648	15.46	4	0.01
	Feb.	5	8658	15.81	4	0.02
		21	8674	15.84	8	0.12
		26	8679	15.73	4	0.02
	Mar.	27	8709	15.47	4	0.02
	May	5	8748	16.11	3	0.03
	Jun.	1	8775	15.95	3	0.09
	Nov.	18	8945	15.64	4	0.04
		29	8956	15.95	4	0.06
	Dec.	8	8965	15.65	2	0.08
		18	8975	15.84	4	0.04
1993	Jan.	1	8993	15.36	2	0.10
		19	9007	15.63	4	0.02
		26	9014	15.80	4	0.06
	Feb.	10	9029	16.02	3	0.04
		12	9031	16.12	4	0.04
		14	9033	16.09	4	0.06
	Mar.	19	9066	16.42	10	0.05
		20	9067	16.27	6	0.06

Table 2. (Continued)

3C273						
	Date		JD (-2440000)	V (mag)	n	rms (mag)
1992	Jan.	26	8648	12.70	4	0.01
	Feb.	5	8658	12.69	4	0.01
		26	8679	12.68	4	0.00
	Mar.	27	8709	12.65	4	0.00
	May	5	8748	12.58	4	0.01
	Jun.	1	8775	12.56	4	0.00
	Dec.	8	8965	12.64	2	0.00
		18	8975	12.61	4	0.02
1993	Jan.	19	9007	12.66	4	0.00
	Feb.	5	9024	12.64	4	0.02
		12	9031	12.63	4	0.02
		14	9033	12.68	4	0.02
	Mar.	18	9065	12.55	4	0.00
OQ530						
	Date		JD (-2440000)	V (mag)	n	rms (mag)
1992	Feb.	5	8658	15.22	4	0.01
		26	8679	15.66	4	0.03
	Mar.	27	8709	15.82	4	0.02
	May	5	8748	15.97	3	0.07
		21	8764	15.58	4	0.07
	Jun.	1	8775	15.91	4	0.03
	Dec.	18	8975	16.48	2	0.02
1993	Jan.	19	9007	16.49	2	0.08
	Feb.	12	9031	16.42	2	0.04
		14	9033	16.48	4	0.04
3C345						
	Date		JD (-2440000)	V (mag)	n	rms (mag)
1992	Feb.	5	8658	16.15	4	0.03
		26	8679	16.01	4	0.04
	Mar.	27	8709	15.89	4	0.01
	May	5	8748	15.16	4	0.02
		11	8754	15.01	30	0.03
		21	8764	15.29	5	0.08
		26	8769	15.68	4	0.03
	Jun.	1	8775	15.79	4	0.02
	Jul.	22	8826	16.43	2	0.00
		24	8828	16.58	2	0.14
Sep.	21	8887	16.59	4	0.16	
1993	Mar.	18	9065	16.98	4	0.11

Table 2. (Continued)

BL Lac							
	Date		JD (-2440000)	V (mag)	n	rms (mag)	
1991	Oct.	3	8533	15.53	2	0.02	
		15	8545	15.45	2	—	
		20	8550	15.35	4	0.09	
	Nov.	1	8562	15.24	3	0.06	
		3	8564	15.36	4	0.05	
		10	8571	15.41	4	0.07	
	Dec.	21	8582	15.28	2	0.05	
		12	8603	15.55	2	0.04	
		13	8604	15.75	2	0.13	
		16	8607	15.41	4	0.07	
1992	Feb.	5	8658	15.18	3	0.02	
		May	5	8748	16.03	3	0.07
	Jun.	1	8775	16.09	4	0.08	
	Jul.	26	8830	16.13	4	0.05	
		Sep.	17	8883	15.27	2	0.03
		21	8887	15.15	4	0.03	
		Oct.	2	8898	14.86	2	0.01
	9		8905	14.98	2	0.03	
	17		8913	15.27	3	0.03	
		25	8921	15.36	4	0.02	
		30	8927	15.38	4	0.05	
		Nov.	18	8945	14.99	4	0.01
			Dec.	5	8962	15.41	5
16		8973		14.96	2	0.01	
1993	Jan.	26	8983	15.23	4	0.04	
		19	9007	14.71	4	0.04	