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CCD photometry of 10 BL Lacertae objects

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Abstract. — CCD photometric data for 10 BL Lacertae objects are given. The main results are the following: 1) A short timescale variability exists for OI 090.4 with a characteristic time of 80 minutes and an amplitude of $\Delta B = 0.56$ mag ($\pm$ 0.11 mag). 2) An outburst of 0.72 mag ($\pm$ 0.1 mag) within 40 minutes has again been recorded in the V band for ON+231; its morphology strongly resembles that of the two previously reported outbursts of 1987 and 1988. 3) A large amplitude outburst of 0.87 mag ($\pm$ 0.10 mag) within 96 minutes has been recorded for OJ-131 in the B band. 4) Evidence of a correlation between colour index $B - V$ and B has been obtained for OI 090.4 and OJ-131. The spectrum appears flatter when the source is brighter. 5) Evidence for relativistic beaming in 6 BL Lacertae objects is discussed.

Key words: photometry — quasars — BL Lacertae objects.

1. Introduction.

Much interest has been raised in the study of rapid optical and radio variability of active galactic nuclei. Due to the short timescale of variability and the high energy outputs involved, important constraints can be derived on the energy conversion mechanism and its efficiency (Elliot and Shapiro, 1974; Fabian and Rees, 1979). BL Lac objects form a subset of active galactic nuclei. Large amplitude, rapid optical variability are well-known characteristics of BL Lac objects. In order to search for optical variation at short time scales, we have been monitoring BL Lac objects with the 102-cm telescope at the Yunnan Observatory since 1980. Our observational results (Xie *et al.*, 1987, 1988a, 1988b, 1989), together with other previously published results, show that large amplitude variability on timescale ranging from several hundred seconds to several hours is a relatively rare phenomenon. On the basis of these results we obtained the following conclusions:

1) a further search for large amplitude variability on timescale ranging from several hundred seconds to several hours is needed as the duration of the quiescent phase of some BL Lacs may be very large.

2) the search for large amplitude variability on timescale of several days should be strengthened. Some BL Lac objects have perhaps no large-amplitude variability on timescale ranging from several hundred seconds to several hours, but may have large amplitude variability on a timescale of days.

3) although large-amplitude variability on timescale ranging from several hours to several days for some BL Lac objects has been observed, this result should be confirmed by further observations. On the basis of above-mentioned ideas, we have undertaken a new observational program and report here the results of 10 months of observations.

2. Observations.

The observations reported here were obtained with the 102-cm RCC telescope at the Yunnan Observatory equipped with a direct CCD camera. The filters we used are as follows:

B — GG385 (2mm) + BG12 (1mm) + BG18 (1mm)
V — GG495 (2mm) + BG18 (2mm)
R — RG610 (3mm) + 66.2500 (1mm)

The standard stars in the field of these BL Lac objects are taken from the literature (Craine, 1977; Miller *et al.*, 1983; Stocke *et al.*, 1985). Since the field of view of our CCD is very small ($4' \times 2.5'$) we can only use 2 to 4 calibration stars within the CCD field. The list of the standard stars is given in Table 1.

The integration times are 3-10 minutes for most observed BL Lac objects and 30 minutes for IE 0317+186. The magnitudes of the BL Lac objects have been derived, using the standard stars within the same CCD field, with a computer program from Kitt Peak National Observatory. The results of the observations are summarized in Table 2. The *first column* gives the date, the *second column* the ju-

TABLE 1. *The standard stars in the field of the BL Lac objects*

object	star	B	V	R	reference
OI 090.4	C	15.42	14.71		Miller,1983
	D	16.36	15.87		
OJ 287	10	15.27	14.56		Craine,1977
	11	15.62	14.94		
	4	15.20	14.30		
OJ-131	A	16.02	15.43		Miller,1983
	H	16.14	15.61		
	I	17.94	16.89		
HE0317+186	C	17.16	16.24	15.49	Stocke,(1985)
	D	16.14	16.09	15.52	
	B	18.18	17.34	16.75	
ON+231	A	12.67	12.08		Craine,(1977)
	F	16.98	16.63		
3C66A	E	17.78	16.90	16.10	Craine,(1977)
	F	17.84	17.08	16.33	
	G	17.98	17.22	16.70	
OF038	A	13.19	12.52		Miller,1983
	B	14.58	13.96		
	I	16.76			
PKS0735+178	J	17.13			Craine,1977
	F	17.01			
OT+081	G	18.32	17.61		Craine,1977
	E	18.14	17.21		
3C232	A	16.47	16.40		Craine,1977

lian date, the *third column* the observed magnitude, *column four* the total error of each observation and *column five* the magnitude system.

3. Results.

In this paper, we call $\Delta t_{\min}$ the minimum variability timescale for a given object. This time scale corresponds to a nominal change of intensity of 50% or more in the B, V and R wave bands (Bassani *et al.,* 1983). In addition, the amplitude of optical variability on this time-scale must be more than 5σ, where σ is the total observational rms error.

3.1. OI 090.4.

This object was identified as a BL Lac object by Tapia *et al.* (1977). A search on archival plates at Harvard College Observatory (Baumert, 1980) has demonstrated that this object exhibits significant optical variation with timescales ranging from a few days to several decades, but has no optical variability on timescale significantly shorter than a day. In our monitoring program of 5 years, long-term variations with amplitudes of $\Delta B = 0.82$ Mag and $\Delta V = 0.64$ Mag have been observed. No short-timescale variations (~ hours) with a large amplitude has been observed (Xie *et al.,* 1988a, 1988b, 1989), but a smaller-amplitude variation ($\Delta B = 0.38$ Mag) with a timescale of about 100 m has been observed on 23 February 1987 (Xie *et al.*, 1988b). In order to check this result, we carried out new observations during the last 10 months. On December 11, 1988, we have again observed a similar variation in the B band within 80 m, with an amplitude of $\Delta B = 0.56$ mag. The confidence level is larger than 5σ. The light curve is shown in Figure 1. On the other hand, the observations on January 6-11, 1989, show that the variations are less than 0.22 Mag in 6 days (see Tab. 2). No medium timescale variability has been detected in our monitoring program.

3.2. ON + 231.

This objects has not been detected in X-rays. The archival data show a variability with characteristic time of the order of years (Pollock, 1975). However in 1975 the source brightened from 17.32 Mag to 15.75 Mag within 120 days (Pollock, 1979). A variation with a timescale of 6 days has been seen in 1983 (Xie *et al.*, 1987). In our monitoring project, an outburst of 0.77 Mag within 85 m has been recorded on April 19, 1987 in the B band (Xie *et al.,* 1989), and a similar outburst of 0.59 Mag within 75 m on March 13, 1988 (Xie *et al.,* 1989). Their confidence levels are larger than 5σ. In order to check these results, we carried out new observations. Another outburst of 0.72 Mag within 40 m has been recorded on April 9, 1989 in the V band. The light curve is shown in Figure 2. The morphology of the 1989 outburst (Fig. 5) strongly resembles that of the two previous outbursts. The three outbursts are compared in Figure 3.

3.3. OJ-131.

It was identified by Tapia (1977) on the basis of the presence of a high percentage of linear polarization in its optical flux. A search on archival plates at the Harvard College Observatory (Baumert, 1980) has demonstrated significant optical variability with timescales from a few days to decades. In our 1988 observational program, optical variability has been seen on a period of 25 days with amplitudes of $\Delta B = 0.62$ mag and $\Delta V = 0.47$ mag (Xie *et al.,* 1989). But large-amplitude optical variation of short timescale (hours) has not been seen from November 1987 to February 1988 (Xie, *et al.,* 1989). Figure 4 of the present paper shows a large amplitude short timescale outburst in the B band on December 12, 1988.

3.4. 3C66A.

Possible optical variation with a 126 s time scale has been reported by Bassani *et al.* (1983), but this result has not been confirmed by our monitoring program (Xie *et al.,* 1989). Large amplitude variations on other short time scales have not been seen during our monitoring of 1982-1987. However, during our 1988 observations, a rapid decline of 0.46 mag within 43 m and an optical outburst of 0.45 mag within 63 m in the R band have been obtained, but their confidence level is smaller than 5σ (Xie *et al.,* 1989). In order to check this result, we carried out new observations during the last 10 months. Two similar variations have been obtained again on December 10, 1988, but their confidence level is also smaller than 5σ. The results are shown in Figure 5. On the other hand, no large amplitude outbursts at medium timescales have been seen during 5 days of observations in January 1989 (see Tab. 2).

3.5. IE0317+186.

It is a X-ray selected BL Lac object. Short time-scale variability has not been found previously in this object (Stocke, 1985). A rapid decline of 0.77 mag in 1.7 h in the V band has been recorded in our monitoring program (Xie *et al.,* 1988b). A similar decline of 0.65 mag in 1.7 h has again been obtained on December 25, 1987 (Xie *et al.,* 1989). An outburst of 0.55 mag within 2.8 h in the V band has also been recorded on November 22, 1987 in our monitoring program (Xie *et al.,* 1989). Figure 6 of the present paper shows a rapid outburst in the V band of 0.41 mag within 50 m followed by a fading from $V = 17.57$ to $V = 18.20$. The variability amplitude is thus 0.63 mag in 40 m, with a confidence level larger than 5σ.

An outburst of 0.34 mag within 2.2 h in R band has been marginally seen on December 12, 1988, with an amplitude smaller than 3σ (see Tab. 2).

3.6. OJ 287.

The optical variability of OJ 287 has been detected by Visvanathan *et al.* (1973) and Fröhlich *et al.* (1974). Optical linear polarization was observed by Kinman *et al.* (1974) and Williams *et al.* (1972). Radio observations indicate that OJ 287 might vary regularly with a periodicity of 15.7 m (Carrasco, 1985). Our optical observations in 1986 and 1988 (Xie *et al.*, 1988b, 1989) show that there is no optical variability with this periodicity (Xie *et al.*, 1990). The possibility of a 26-day periodic optical variation has been raised by Tsesevich (1972), but not confirmed by Elliot and Visvanathan (1973). Kinman *et al.* (1974) found evidence of a 8 days periodicity in the optical flux and in the Stokes parameters. Our data of 1980 January-March also suggest a variability on a timescale of about 8 days with an amplitude of $\Delta B = 0.37$ mag (Xie *et al.*, 1987), but the observed variations are smaller than 5σ. In order to check this result, we carried out new observations. No significant variations have been seen in the period of January 6-11, 1989 (see Tab. 2).

3.7. OF 038.

Photographic monitoring of this object (Pica *et al.*, 1980) has shown that it has exhibited variations within a range of approximately 2.0 mag since late 1976. In our CCD photometry monitoring, a rapid optical variation of 0.6 mag in 20 h has been recorded in 1985 (Xie *et al.*, 1988a). The observations on February 15 and 20, 1988 show no variation larger 0.3 mag within 5 days (Xie *et al.*, 1989). The new observations show no variations either (see Tab. 2).

3.8. PKS0731+178.

Observations during 1970-1982 revealed an optical variation of 0.5 mag in a timescale of about one week (McGimsey *et al.,* 1975; Xie *et al.,* 1987). Infrared observations reported a variation on a timescale of about 16.7 hours (Worrall *et al.*, 1981) During our 1985-1988 observations, a rapid optical outburst of 0.35 mag within 33 m in the B band has been recorded on December 7, 1985 (Xie *et al.*, 1988a) and a rapid decline of 0.68 mag within 24 m on November 1, 1986 has been seen in the B band (Xie *et al.*, 1988b).

In order to check these results, we carried out new observations. No significant variation has been seen (see Tab. 2).

3.9. 3C232.

This is a QSO. Historical optical observations during 1967-1970 revealed only a variation of 0.25 mag (Tritton *et al.,* 1971). No short variation timescale had been seen (Craine, 1977).

Our observations on January 6-11, 1989 show no variation either. This can be considered as a check of the reliability of our equipment.

3.10. OT+081.

The source is strongly variable in both flux density and polarization at centimeter wavelengths. The variability timescale increases with increasing radio wavelength (O'Dea *et al.*, 1986) ; it made an outburst on 11 April, 1977 (Epstein 1980, A.J. 85,1427). Our observations of 1 May, 1989 show no variation (see Tab. 2).

4. Colour. Magnitude correlation.

As BL Lac objects are violent variables, their color indices should ideally be derived from simultaneous observations in the various colors. However, if the interval between the B and V observations is sufficiently small, these observations could be regarded as quasi-simultaneous. In our observations, the time interval for completing one set of observations was generally 5-8 m. We selected those observations in Table 2 when the B and V photometry is obtained within less than 9 m, which is one order of magnitude smaller than the variability time scale. The results for two objects are plotted in Figures 7 and 8.

Figure 7 refers to the result on OI090.4 on December 11, 1989. There is a clear correlation between color and magnitude. The regression is $B - V = 0.809B - 13.32$ and the correlation with a highly significant correlation coefficient is $\gamma = 0.936$. Figure 8 refers to the result of OJ-131 on December 12, 1988. The regression is $B - V = 0.876$ $B - 14.6$ and the correlation coefficent is $\gamma = 0.949$. Hence the color-magnitude correlation is highly significant also in this case.

Thus, OI 090.4 and OJ−131 show a correlation between intensity and the slope of the optical spectrum, in the sense that the spectrum appears flatter when the source is brighter.

5. Light variations and models of BL Lac objects.

BL Lac objects show no direct evidence for accretion disks: there are no blue bumps in the broad-band spectra, and a periodic behavior, if real, involves only a small fraction of their total intensity. However, there might be accretion disks in BL Lac objects in analogy to galactic sources. In contrast, jets in BL Lac objects have been discussed extensively.

The efficiency of conversion of matter into energy for a spherical, homogeneous, non-relativistically beamed region is given by Fabian and Rees (1978) as:

$$\eta \geq 5.0 \times 10^{-43} \Delta L / \Delta t_{\min} \quad (1)$$

Where ΔL is the variation of energy within the time interval $\Delta t_{\min}$; $\Delta t_{\min}$ corresponds to a source radius such that $\tau_{es} = 1$ (τ_{es} is the electron scattering optical depth). If η is found to be larger than 0.1, the relativistic beaming model is believed to be supported. In contrast, if $\eta < 0.1$, the accretion disk model is suggested.

The observations show that the optical variations for these objects are generally 0.6-0.8 mag. So we have,

$$\Delta L = L_{\max} - L_{\min} = (0.7\text{-}1.1) L_{\min}.$$

We will assume that the bolometric luminosity L_{bol} varies like the optical luminosity in order to estimate η. The results for η are listed in Table 3.

From Table 3, we see that the efficiency η is larger than 0.1 for 6 BL Lac objects whose short timescale variability has been observed. It is, therefore, reasonable to conclude that the relativistic beaming model is appropriate for these objects.

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TABLE 2. *Result of CCD photometry of BL Lac objects*

UT date	JD 24470000+	Mag	RMS error	color	B − V
(1) OI090.4					
12/10/88	506.211	17.12	0.05	B	
12/11/88	507.220	17.05	0.05	B	
	507.226	17.03	0.06	B	
	507.230	17.07	0.05	B	
	507.234	17.04	0.05	B	
	507.241	16.58	0.11	V	
	507.246	17.04	0.08	B	0.46
	507.252	16.68	0.08	V	
	507.256	17.10	0.05	B	0.42
	507.263	16.52	0.09	V	
	507.268	17.12	0.05	B	0.60
	507.273	16.58	0.07	V	
	507.279	17.16	0.05	B	0.58
	507.285	16.56	0.09	V	
	507.290	17.01	0.05	B	0.45
	507.295	16.65	0.05	V	
	507.305	16.52	0.11	V	
	507.310	16.80	0.05	B	0.28
	507.316	16.60	0.07	V	
	507.321	17.06	0.06	B	0.46
	507.327	16.66	0.11	V	
	507.332	17.36	0.07	B	0.70
	507.342	17.22	0.05	B	0.67
	507.347	16.56	0.07	V	
	507.363	17.23	0.05	B	0.58
	507.369	16.65	0.06	V	
	507.375	17.26	0.05	B	0.67
	507.380	16.59	0.06	V	
01/06/89	533.213	16.85	0.05	B	
01/10/89	537.185	16.96	0.11	B	
	537.190	16.54	0.09	V	
01/11/89	538.133	17.00	0.10	B	
	538.139	16.33	0.08	V	
(2) ON+231					
02/12/89	570.228	14.69	0.10	V	
	570.233	15.24	0.10	B	
	570.239	14.66	0.05	V	
	570.243	15.26	0.10	B	
	570.250	13.51	0.05	R	
	570.284	14.70	0.14	V	
	570.289	15.20	0.10	B	
02/28/89	586.225	15.94	0.05	B	
	586.230	15.53	0.10	V	
	586.243	15.98	0.06	B	
	586.249	15.41	0.10	V	
04/09/89	626.143	15.50	0.10	V	
	626.155	15.44	0.10	V	
	626.159	15.21	0.10	V	
	626.169	14.78	0.10	V	
	626.174	14.79	0.09	V	
	626.179	15.48	0.10	V	
	626.183	15.33	0.09	V	
05/01/89	648.165	15.95	0.10	B	
	648.169	15.42	0.11	V	
	648.174	15.96	0.10	B	
	648.179	15.49	0.10	V	
	648.183	15.93	0.10	B	
(3) OJ-131					
12/12/88	508.220	17.39	0.10	B	0.61
	508.225	16.78	0.05	V	
	508.231	17.08	0.09	B	0.38
	508.236	16.70	0.05	V	
	508.241	17.30	0.09	B	0.51
	508.246	16.79	0.10	V	
	508.256	16.70	0.05	V	
	508.260	17.88	0.10	B	1.02
	508.267	16.86	0.08	V	
	508.272	17.57	0.10	B	0.67
	508.277	16.90	0.05	V	
	508.283	17.52	0.09	B	0.74
	508.288	16.78	0.05	V	
	508.295	17.45	0.05	B	0.56
	508.300	16.89	0.05	V	
	508.305	17.28	0.05	B	0.55
	508.310	16.73	0.07	V	
	508.316	17.14	0.08	B	0.20
	508.323	16.94	0.09	V	
	508.329	17.01	0.09	B	0.25
	508.335	16.76	0.06	V	
	508.341	17.32	0.10	B	
	508.353	17.00	0.08	V	
	508.365	17.20	0.05	B	
01/10/89	537.263	17.13	0.05	V	
	537.271	17.50	0.10	B	

UT date	JD 24470000+	Mag	RMS error	color
01/11/89	538.165	17.19	0.05	V
	538.170	17.55	0.08	B
	538.176	17.76	0.09	B
	538.187	17.57	0.08	B
	538.200	17.59	0.08	B
01/16/89	543.253	16.81	0.05	V
	543.259	17.81	0.05	B
	543.267	17.12	0.05	V
	543.271	17.59	0.11	B
02/08/89	566.120	17.24	0.05	V
	566.127	17.28	0.05	V
	566.136	17.67	0.06	B
	566.148	17.32	0.06	V
	566.167	18.01	0.10	B
	566.179	17.17	0.05	V
	566.188	17.95	0.13	B
	566.200	17.32	0.07	V
	566.219	17.74	0.12	B
02/27/89	585.063	17.86	0.05	B
	585.088	17.75	0.06	B
	585.130	17.75	0.05	B
02/28/89	586.012	17.47	0.08	V
	586.030	17.46	0.07	V
	586.041	17.86	0.10	B
	586.054	17.39	0.08	V
	586.063	17.84	0.11	B
	586.075	17.38	0.08	V
	586.084	17.87	0.11	B
	586.097	17.13	0.05	V
	586.106	17.67	0.08	B
	586.118	17.33	0.05	V
(4)3C66A				
12/10/88	506.040	15.43	0.09	B
	506.045	15.49	0.05	B
	506.052	15.54	0.07	B
	506.059	15.88	0.08	B
	506.066	15.57	0.13	B
	506.072	15.52	0.13	B
	506.086	15.51	0.10	B
	506.092	15.48	0.10	B
	506.098	15.40	0.10	B
	506.105	15.49	0.10	B
	506.110	15.44	0.09	B
	506.117	15.47	0.10	B
01/11/89	538.996	15.27	0.10	B
	539.004	15.16	0.10	B
	539.009	14.67	0.10	V
01/16/89	542.988	14.14	0.07	R
	542.997	14.77	0.05	V
	543.006	15.40	0.09	B
(5)IE0317+186				
12/11/88	507.066	17.03	0.11	R
	507.071	17.24	0.08	R
	507.077	18.00	0.05	V
	507.095	17.05	0.05	R
	507.113	17.97	0.05	V
	507.120	17.15	0.08	R
	507.125	17.47	0.05	R
	507.132	17.30	0.05	R
	507.149	17.18	0.05	R
	507.156	17.32	0.05	R
12/12/88	507.996	17.19	0.10	R
	508.001	17.15	0.14	R
	508.007	17.34	0.05	R
	508.014	17.15	0.05	R
	508.022	17.98	0.05	V
	508.030	17.14	0.08	R
	508.039	17.86	0.06	V
	508.056	17.57	0.07	V
	508.064	17.14	0.08	R
	508.072	17.76	0.05	V
	508.080	17.15	0.05	R
	508.088	18.20	0.05	V
	508.096	17.00	0.08	R
	508.107	18.84	0.20	B
	508.119	17.13	0.05	R
(6) OJ287				
01/06/89	533.281	15.83	0.05	B
	533.292	15.17	0.12	V
	533.307	15.66	0.06	B
01/10/89	537.287	15.80	0.08	B
	537.292	15.12	0.05	V

TABLE 2. *(continued)*

UT date	JD 24470000+	Mag	RMS error	color
01/11/89	538.220	15.16	0.05	V
	538.224	15.83	0.09	B
	538.239	15.88	0.10	B
	538.245	15.86	0.10	B
	538.249	15.87	0.12	B
03/09/89	594.973	15.56	0.12	V
(7)OF038				
12/10/88	506.163	16.62	0.05	B
	506.188	16.71	0.05	B
12/12/88	508.153	16.16	0.05	V
	508.159	16.17	0.05	V
	508.164	16.84	0.06	B
	508.168	16.81	0.05	B
01/10/89	537.110	17.06	0.05	B
	537.116	16.34	0.05	V
01/11/89	538.066	16.93	0.06	B
01/15/89	542.047	16.26	0.05	V
	542.053	16.23	0.05	V
	542.059	16.92	0.06	B
(8)PKS0735+178				
01/10/89	537.164	16.88	0.05	B
01/11/89	538.110	16.66	0.05	B
	538.120	16.65	0.08	B
01/15/89	542.079	16.78	0.08	B
	542.087	16.92	0.05	B
	542.095	16.94	0.09	B
	542.103	16.73	0.08	B
	542.111	16.85	0.10	B
	542.119	16.66	0.14	B
01/16/89	543.144	16.87	0.09	B
	543.163	17.05	0.08	B
	543.180	16.78	0.09	B
	543.189	16.89	0.05	B
05/01/89	648.021	16.70	0.14	B
	648.031	16.26	0.14	V
(9)3C232				
01/06/89	533.315	16.12	0.08	B
	533.321	16.05	0.05	V
01/10/89	537.319	16.23	0.06	V
	537.323	16.36	0.10	B
01/11/89	538.290	16.26	0.05	V
	538.295	16.33	0.10	B
(10)OT+081				
05/01/89	648.280	16.45	0.10	V
	648.296	16.52	0.07	V
	648.301	15.76	0.05	R
	648.312	16.40	0.13	V
	648.316	15.73	0.06	R
	648.322	16.43	0.05	V
	648.332	15.72	0.06	R
	648.343	16.46	0.16	V
	648.347	15.82	0.08	R
	648.365	16.33	0.15	V
	648.370	15.70	0.05	R

TABLE 3.

object	z	Δt_{min} (s)	Ref.	L_{bol} (erg/s	Ref.	η
OI090.4	0.67	4.8×10^3	1	3.1×10^{47}	9-12	32.00
ON + 231	0.102	3.8×10^3	1, 2	2.0×10^{45}	6, 7	0.27
3C66A	0.444	4.6×10^3	1-3	1.5×10^{47}	5	16.5
IE0317 + 186	0.19	1.4×10^4	2	3.4×10^{45}	8, 2	0.12
OJ 287	0.306	0.9×10^3	4	2.5×10^{46}	5	13.4
PKS0735 + 178	0.424	6.0×10^4	5	4.1×10^{47}	5	3.38

References: 1: present results; 2: Xie *et al.* (1989); 3: Xie *et al.* (1988a); 4: Carrasco (1985); 5: Bassai *et al.* (1983); 6: Weistrop *et al.* (1985); 7: Worrall *et al.* (1986); 8: Giomni *et al.* (1987); 9: Allen (1982); 10: Ghisellini *et al.* (1986); 11: Brindle *et al.* (1986); 12: Marschi (1986).

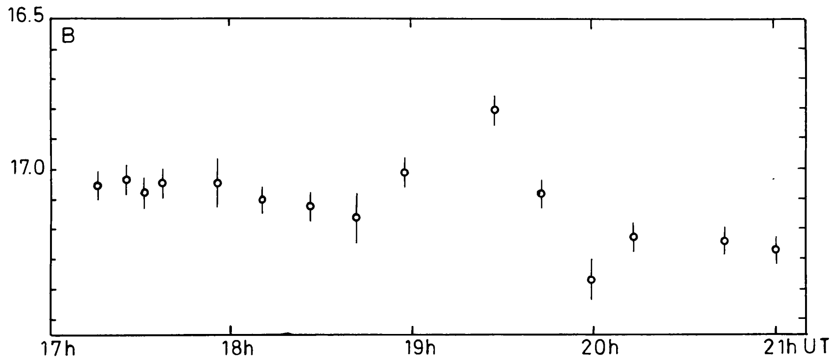

FIGURE 1. The light curve of OI090.4 in the *B* band on December 11, 1988, Error bars are total 1σ error.

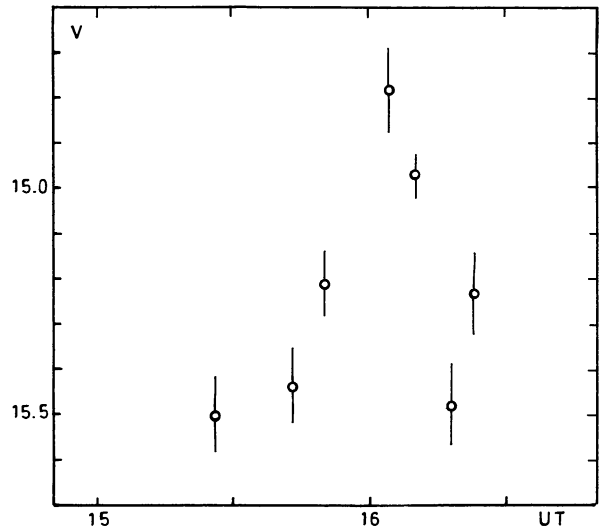

FIGURE 2. The outburst of ON+231 in the *V* band on April 9, 1989.

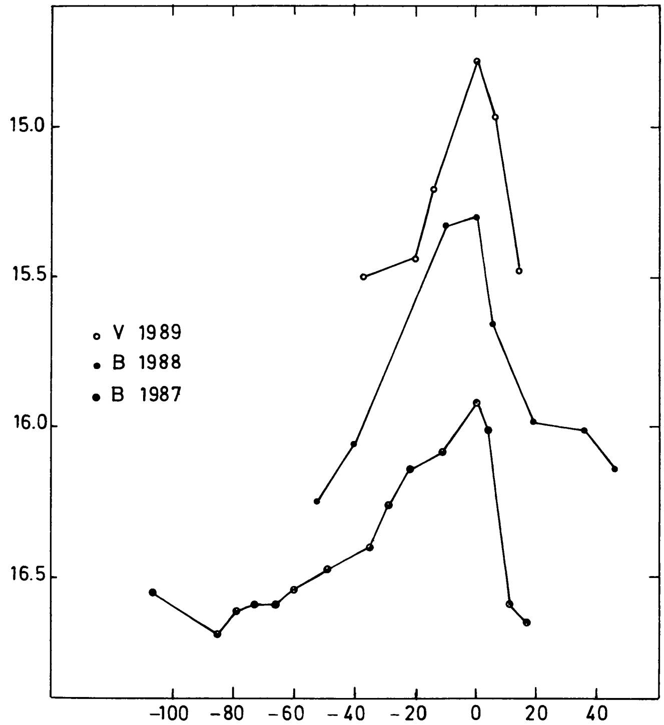

FIGURE 3. The light curves of the 1987, 1988 and 1989 outburst for ON+231 in the *V* band or the *B* band. The origin of time is peak of the light in each case. Time is in minutes.

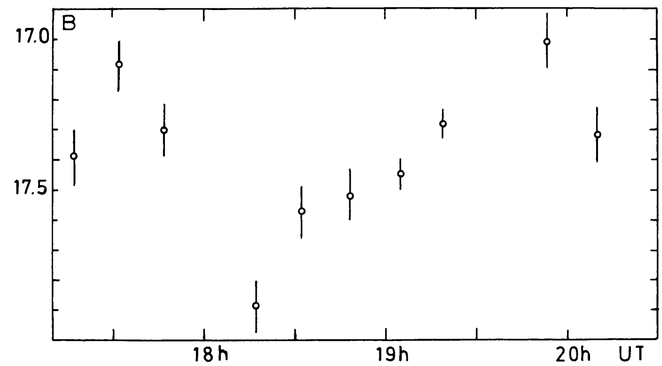

FIGURE 4. The light curve of OJ-131 in the *B* band on December 12, 1988.

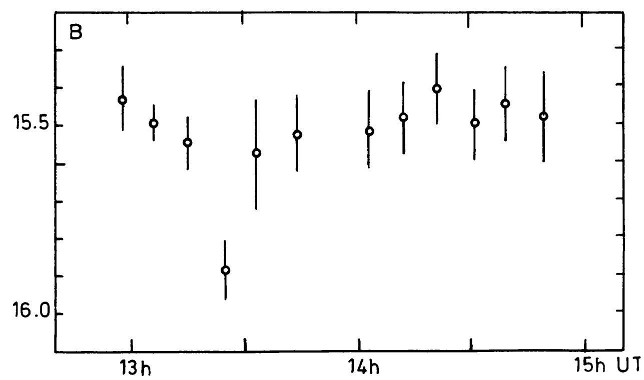

FIGURE 5. The light curve of 3C66A in the *B* band on December 10, 1988.

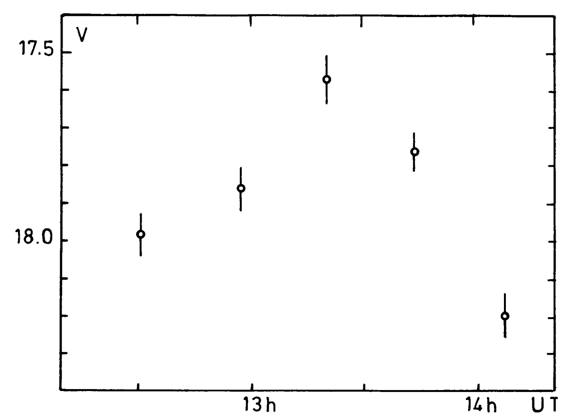

FIGURE 6. The outburst of IE0317+186 in the *V* band on December 12, 1988.

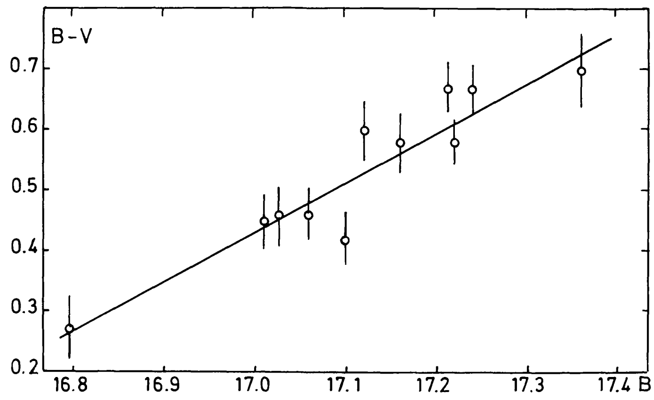

FIGURE 7. The correlation between $B-V$ and B of OI090.4 on December 11, 1988.

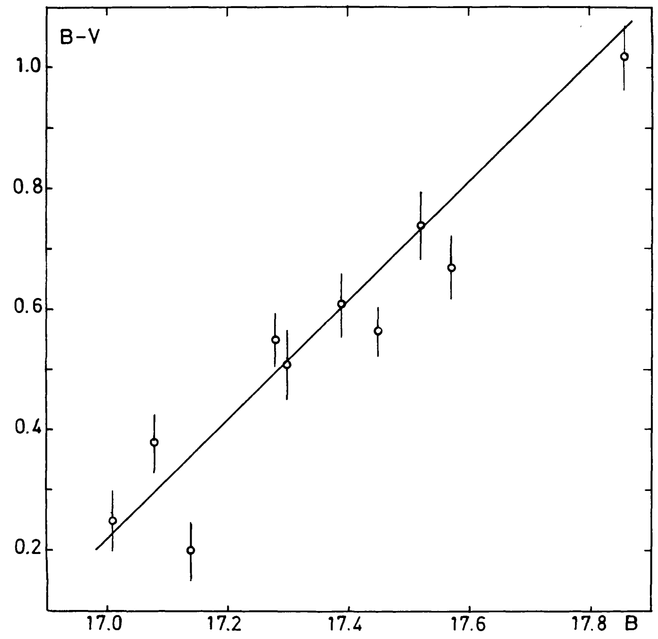

FIGURE 8. The correlation between $B-V$ and B of OJ-131 on December 12, 1988.