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BVI microvariability in BL Lacertae during the summer 1997 outburst

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Abstract. BL Lac has been observed during the outburst which occurred during the 1997 summer (Noble et al. 1997; Bloom et al. 1997) in three optical bands (BVI$_C$), with the aim of studying the intranight colour variations on very short timescales. Due to the high luminosity of the source we could perform quasi-simultaneous measurements in the three bands with a resolving time of about 5 minutes using one single telescope. We have detected several microvariability events occurring on timescales ranging from 30 min up to 3.5 hours. The magnitude changes had different amplitudes in the three bands being larger for shorter wavelengths, and the source showed a marked trend to become bluer when brigther. There was no evidence of quasi-periodic oscillations in our multicolour light curves.

Key words: BL Lacertae objects: general – BL Lacertae objects: individual: BL Lac – techniques: photometric

1. Introduction

Recent simultaneous multifrequency observations in blazars (Wagner et al. 1990; Clements et al. 1995), have shown rapid variability in all the wavebands across the spectrum. Sometimes important correlations between intraday optical and radio variations were found (Quirrenbach et al. 1991; Wagner et al. 1996). Observations of BL Lacertae objects in the near infrared (Lorenzetti et al. 1990; Takalo et al. 1992), reported cases where the sources showed a trend to get bluer as they brighten on short timescales. Quasi-simultaneous JHK measurements of the BL Lac object OJ-287 (Kidger et al. 1994), with a resolution time of 20 min, confirmed this trend for intranight variations.

Variability in BL Lac has been largely investigated by many groups at different wavelengths (see Bregman et al. 1990). Variations on timescales of a few days or less were detected in both luminosity and polarization by Moore et al. (1982, 1987). Microvariability as large as 0.14 mag in BL Lac was detected by Miller et al. (1989) performing high sample rate observations (1.5 min) in the V band. Larger intranight variations in BL Lac up to 0.2 mag h^{-1} together with a general tendency of the source to become bluer for increasing magnitude values, were also reported by Carini et al. (1992).

Due to the undersampled optical multicolour observations, the intranight behaviour of the light curves in different optical bands is still not well known. In the effort to better investigate both rapid luminosity variations and the colour-luminosity relationship in BL Lac, we performed optical multiband observations during the high luminosity state of BL Lac. The time resolution of our measurements was similar to the optical monoband microvariability observations mentioned above.

2. Observations and data reduction

The photometric data were obtained with the 0.7 m Ritchey-Chretien telescope (TRC70) of the Monteporzio Station (Rome - Italy). The telescope was equipped with a LN$_2$ cooled CCD camera TH7882 UV-coated and with a set of Johnson and Cousins filters.

In order to obtain in real time the photometry of BL Lac in the BVI$_C$ optical bands we developed an automatic procedure (AUTOPHOT). This procedure provides both the repeated exposures in the three bands and all data reductions performing a real time aperture photometry. To account for the intranight fluctuations due to atmospheric variations, AUTOPHOT computed the differential magnitude between BL Lac and a set of comparison stars present on the same frame, The position of the source, of the comparison stars, and of the areas suitable for sky backgrounds, were selected on the first frame at the beginning of the automatic run. Each frame, to minimize the processing time and, therefore,the time interval between two different exposures,was automatically bias-subtracted and flat-fielded only on the selected areas of the image. All the flat-field frames were previously taken on twilight.

The exposure times ranged from 40 sec in I band up to 2 min in B band, and then the time requested to obtain the entire filter sequence was about 5 min. In this way it was possible to realize quasi-simultaneus optical measurements in the three bands using only one telescope, therefore, avoiding the technical problems that sometimes affect the multiwavelength campaigns involving several telescopes.

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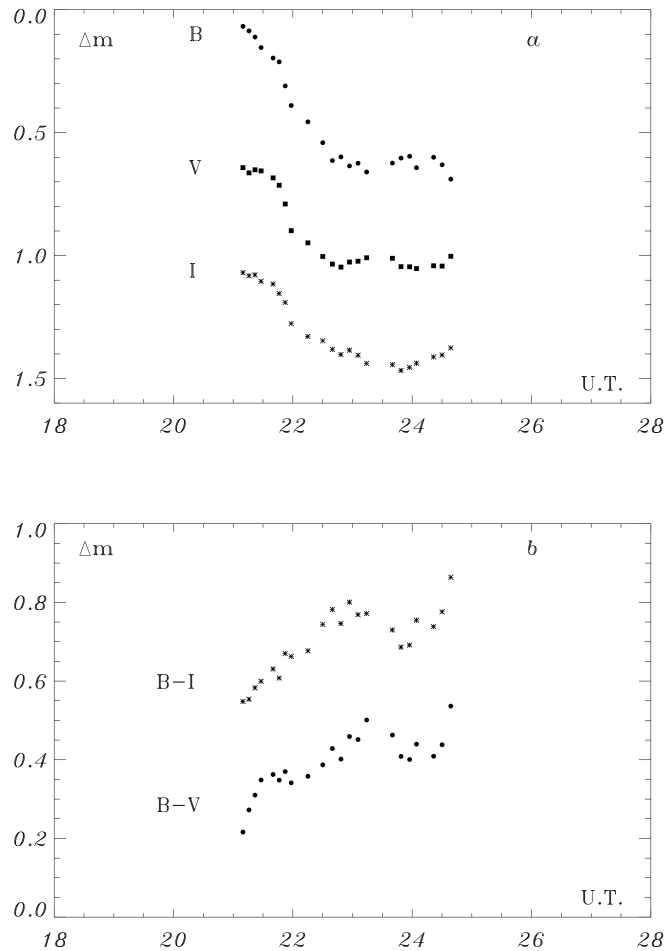

Fig. 1. a Differential magnitude between BL Lac and the comparison star 3 for the night of 02 August 1997. $rms_{star2/star3}$:B=0.05 mag, V=0.04 mag, I=0.03 mag. **b** colour indexes B-V and B-I of BL Lac for the same night.

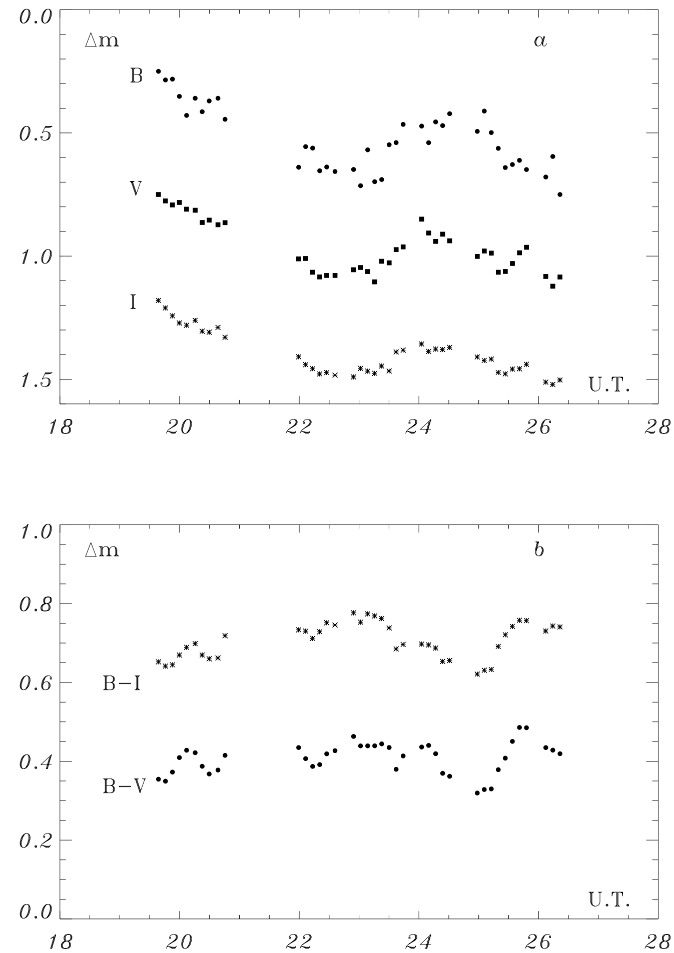

Fig. 2. a Differential magnitude between BL Lac and the comparison star 1 for the night of 29 August 1997. $rms_{star1/star2}$: B=0.05 mag, V=0.02 mag, I=0.01 mag. **b** colour indexes B-V and B-I of BL Lac for the same night.

3. Results

In this paper we present the multicolour data obtained on the nights of August 02, 29 and 30, 1997. The light curves, plotted with the same axis scales, are presented in Figs. 1,2 and 3 respectively. The differential magnitudes in the three bands between BL Lac and a comparison star, are displayed in the upper part of each figure, while the two colour indexes, B-I and B-V, referred to the time of the V band, are shown in the lower parts. As photometric errors, we have considered the rms of the differential magnitude between two comparison stars and the errors are reported in the captions of each figure. Every point of the colour plots is obtained with a three-point average on the original data points. The error on the time scale is included in the dimension of the symbols.

On August 02 (Figs. 1a and b) BL Lac showed a large fading reaching the minimum luminosity level at about 22:45 UT. Very different amplitudes were detected during the dimming in the three bands. The minimum was characterized by a plateau lasting over one hour, and, at the end of the observations, the source exhibited a flux increase of 0.1 mag just in the I band. During the decreasing phase, BL Lac markedly reddened with Δ(B-V)=0.30 mag and Δ(B-I)=0.25 mag.

On August 29 (Figs. 2a and b) the source was observed for nearly 7 hours and large intranight oscillations were detected. Luminosity decreased in about 3.5 hours showing again higher amplitudes towards shorter wavelengths. But on this night, even if the source largely faded, we observed a modest reddening trend of Δ(B-V)=Δ(B-I)=0.10 mag. More rapid changes of colours were detected in the last part of the night when BL Lac had a flare starting at 23:30 UT, becoming bluer during the rising time (90 min) and reddening again after the flare.

On August 30 (Figs. 3a and b) the microvariability was characterized by a very peculiar pattern. Two contiguous maxima were detected at 24:25 and 25:18 UT. A very rapid and linear increase of about 0.50 mag in less than 90 min was observed in the three bands before the first maximum. After the second peak, the source faded in one hour reaching the same luminosity level it had before the two flares. High amplitudes and rapid variations in the colour indexes were detected on this night as

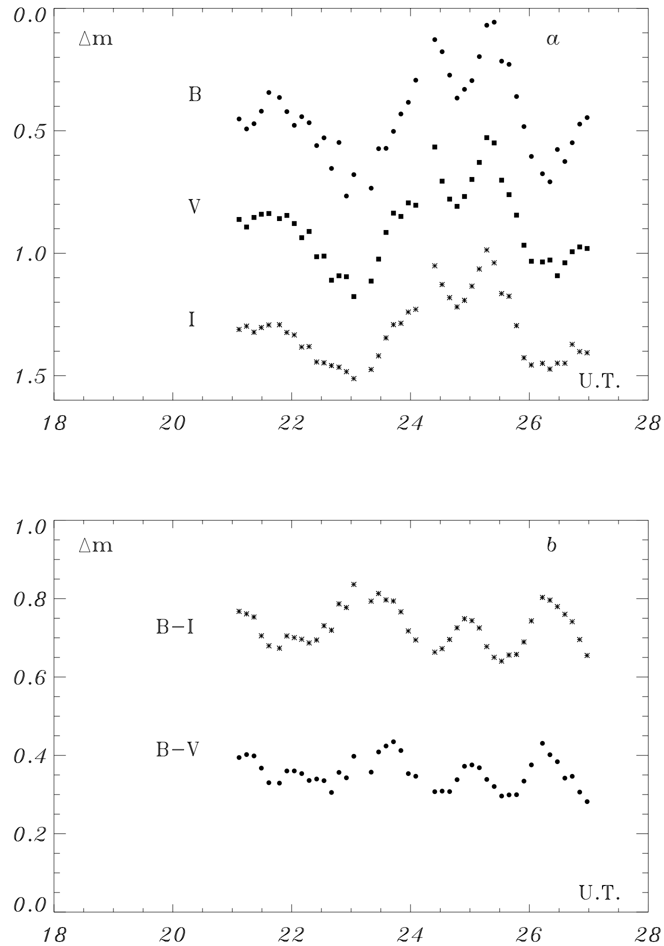

Fig. 3. a Differential magnitude between BL Lac and the comparison star 1 for the night of 30 August 1997. $rms_{star1/star2}$: B=0.04 mag, V=0.03 mag, I=0.02 mag. **b** colour indexes B-V and B-I of BL Lac for the same night.

well. A delay of about 45 minutes in the colour change is evident in the first part of the night.

4. Conclusions

Our observations revealed that intranight light curves in the three optical bands, while having almost the same shape and timescale present different amplitude. We detected rapid colour changes occurring during the luminosity variations on very short timescales. A definite trend in the source to become bluer when brighter and viceversa was revealed for very rapid variations.

In general the variations in the B band were larger than in the V and I bands. The luminosity fluctuations we have detected (up to 0.4 mag hr^{-1}) are among the largest and fastest intranight variations ever seen in a blazar. Different rates in colour change were observed from night to night and inside a single run.

Medium and long term variability of BL Lac objects are explained by the recent theoretical models as a consequence of phenomena associated to relativistic jets (Wagner & Witzel 1995; Marsher 1996; Ghisellini & Maraschi 1996) and large and rapid intranight variations in blazars represent an extreme aspect of these models.

Even if the light curves of Aug 30 are very similar to the quasi-periodic variations observed in Wagner et al. (1996), we found no evidence of quasi-periodicity (Camenzing & Krockenberger 1992) from a power spectrum analysis of the multicolour photometric data of each night.

The very short timescales of the variations we observed, together with the colour changes, suggest they are not due to achromatic microlensing (Nottale 1986). Moreover the relationship between the two colour indexes, $\Delta(B-I) \approx \Delta(B-V)$, rules out thermal emission as a main origin of these fluctuations (Natali et al. 1994), therefore variability may be originated by plasma accelerated in small regions near the central engine.

For very rapid events we found that the luminosity values are very near to the Eddington limit, then some of the rapid variations we observed may partly be explained by relativistic beaming.

The symmetrical shape for time reversal of the two maxima observed on the night of the Aug 30 suggests that even microvariability light curves could be affected by extrinsic mechanisms, such as geometrical modulations similar to a light house effect.

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