# Intensive optical monitoring of the BL Lac object PKS 2155-304: the July 1998 campaign

**E. Poretti**[1], **E. Pian**[2], **A. Treves**[3]

[1] *Osservatorio di Brera, Via E. Bianchi 46, I-23807 Merate (LC), Italy – email: poretti@merate.mi.astro.it*
[2] *ITESRE, CNR, Via Gobetti 101, I-40129, Bologna, Italy – email: pian@tesre.bo.cnr.it*
[3] *University of Como, Via Lucini 3, I-22100 Como, Italy – email: treves@uni.mi.astro.it*

**Abstract.**

Fast blazar variability on interday and intraday time scales is an extremely powerful tool to investigate the structure of the AGN emitting regions and the nature of the processes responsible for energy production. Since PKS 2155–304 is the brightest BL Lac at the optical and UV wavelengths, we have undertaken a program of systematic intensive optical monitoring of this blazar in search of fast variability events. We present here the results of a CCD photometric campaign conducted at ESO (La Silla, Chile) on 6-14 July 1998, for a total time on the source of $\sim$ 30 hours.

## 1. Introduction

Optical fast variations in blazars could be the signature of physical or geometrical variations within the jet on small scales, and therefore can trace the propagation of disturbances and help in mapping the emission regions in detail. PKS 2155–304 is the brightest and best monitored BL Lac at the optical and UV wavelengths. Significant variability in this spectral region on various time scales (from days to few hours) has been commonly observed in this source (Smith & Sitko 1991; Carini & Miller 1992; Smith et al. 1992; Urry et al. 1993; Courvoisier et al. 1995; Heidt et al. 1997; Bai et al. 1998).

Some studies (Paltani et al. 1997, Pesce et al. 1997, Pian et al. 1997) have shown that rapid (time scales of $\sim$1 hour or less) optical and UV flux variability events can occur. Spectral variability is modest, and weakly or not clearly correlated with flux. When a correlation is found, this suggests flatter spectral shapes during brighter states, in qualitative agreement with models based on radiative cooling (Paltani et al. 1997).

Well and regularly sampled optical light curves on long time intervals are necessary to apply the correlation methods in search of typical time scales. Therefore, we have started a systematic program of fast variability monitoring of PKS 2155–304 specifically aimed at sampling its rapid optical variations. Since the optical spectral continuum is likely produced in the inner jet, variability in this spectral region provides the clearest evidence for dynamic processes occurring near the active nucleus. Results from campaigns conducted as part of this project at ESO and Las Campanas telescopes in 1996 and 1997 have been presented by Mantegazza et al. (1999).

Here we report on the photometric monitoring of PKS 2155–304 in July 1998.

## 2. Observations and data reduction procedure

CCD photometry of PKS 2155–304 was obtained with the ESO Dutch 0.91–m telescope in 8 consecutive nights from July 6 to 14, 1998. The CCD detector was the ESO N 33, a 512 pixels x 512 pixels TEK chip. PKS 2155–304 and the two field stars measured by Smith et al. (1991, see their Tab.3 where they are quoted as Number 2 and 3) could be included in the 3.77x3.77 arcmin$^2$ field of view. As in classical differential photometry, we used the brighter star (i.e. the number 2) as the comparison one and the number 3 as the check one. We collected 351 images in $R$ and 331 in $V$ (see Tab. 1). Exposure times were set to have a high signal from PKS 2155–304 and comparison stars; usually they are shorter than 60 sec.

| Night | CCD Images | | Net time on PKS 2155–304 | Magnitudes of the check star | | Standard deviations [mmag] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Check star | | PKS 2155–304 | |
| [JD] | $V$ | $R$ | [hours] | $V$ | $R$ | $V$ | $R$ | $V$ | $R$ |
| 2451001 | 22 | 22 | 2.4 | 13.027 | 12.512 | 2.6 | 2.9 | 4.6 | 4.1 |
| 2451002 | 57 | 74 | 5.3 | 13.023 | 12.503 | 5.4 | 3.4 | 6.2 | 10.0 |
| 2451003 | 8 | 11 | 0.2 | 13.022 | 12.508 | 2.4 | 1.5 | 5.3 | 5.1 |
| 2451004 | 33 | 38 | 3.4 | 13.024 | 12.510 | 5.8 | 2.8 | 8.4 | 8.1 |
| 2451005 | 21 | 20 | 7.2 | 13.023 | 12.505 | 5.5 | 3.5 | 11.7 | 13.1 |
| 2451006 | 106 | 90 | 7.2 | 13.023 | 12.505 | 5.3 | 3.4 | 6.5 | 7.4 |
| 2451007 | 44 | 44 | 1.9 | 13.025 | 12.510 | 3.9 | 2.7 | 3.5 | 4.3 |
| 2451008 | 38 | 50 | 2.0 | 13.021 | 12.506 | 3.9 | 3.4 | 5.7 | 3.8 |

Table 1: Log of the optical observations from July 6, 1998 to July 14, 1998. $V$ and $R$ magnitudes refer to the measurements of the check star; standard deviations (in thousandths of mag) both to the check star and to PKS 2155–304 .

The reduction of the images was performed by using MIDAS package. Since targets stars are bright, the aperture photometry technique could be successfully applied. The flux was calculated in a 12 arcsec circle centered on each object. Sky background was subtracted by measuring local values; this strongly reduced the effects of the moonlight. Moreover, flat fields on the sky were taken at the beginning and at the end of each night: as a result, the images were satisfactorily corrected and a very stable photometric system could be maintained, as can be noted looking at the magnitudes of the check star listed in Tab. 1. Magnitude differences were transformed into $V$ and $R$ magnitudes by using $V$=12.07 and $R$=11.69 for the comparison star, as determined on the basis of our previous CCD campaigns. These values are in good agreement with the photoelectric magnitudes reported by Smith et al. (1991), i.e. $V$=12.04 and $R$=11.64.

## 3. Photometric results

Figure 1 (left panel) shows the light curve in $V$ as obtained by averaging the magnitudes in each night: a rather regular increase (0.15 mag) was observed during the first seven nights, followed by a decline during the last night. The simultaneous $V-R$ colour curve is shown in the right panel of Fig. 1: it is practically constant for most of time (mean value around 0.28 mag), with an indication that it was somewhat redder (∼0.30 mag) in the first two nights.

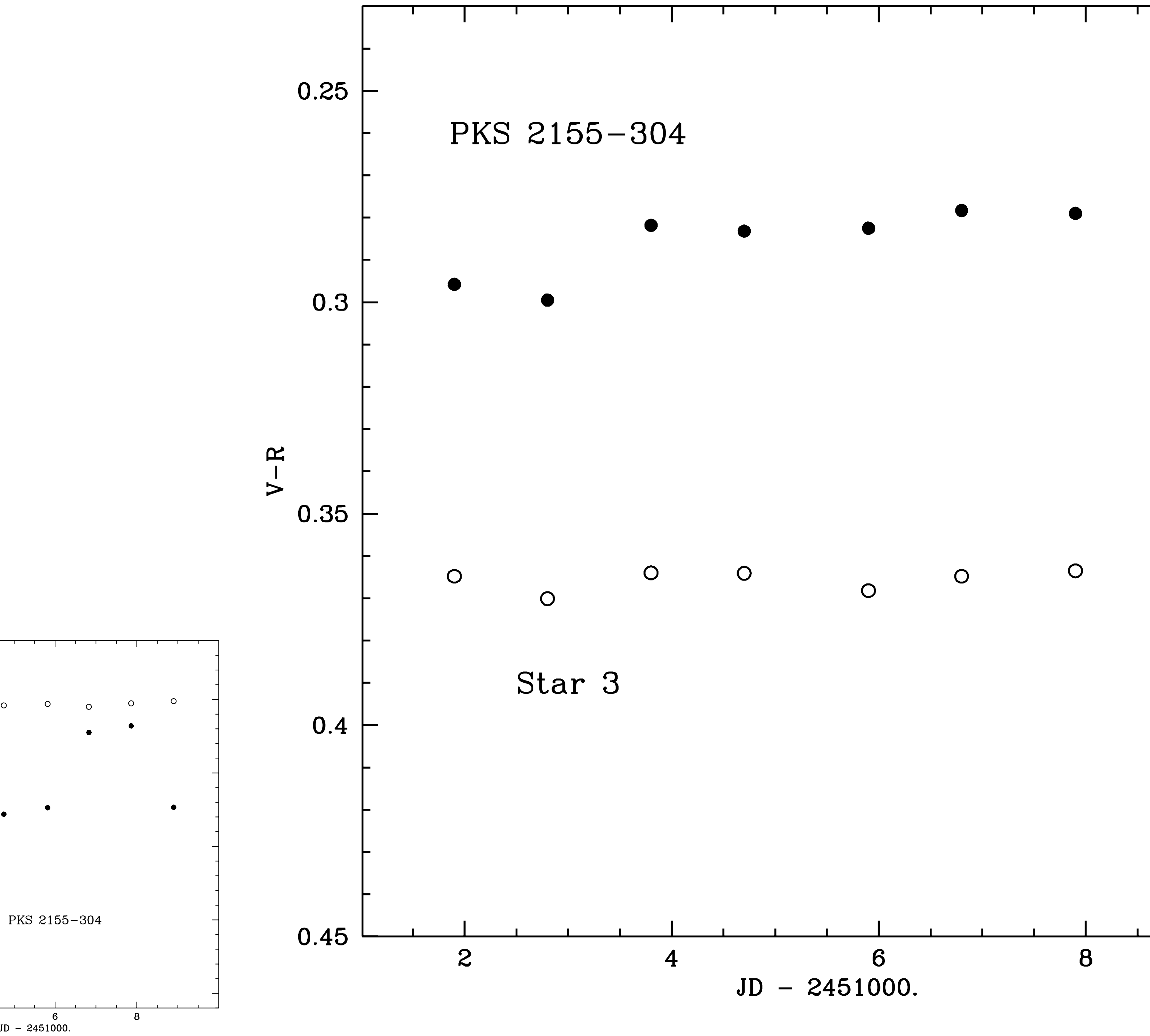


Figure 1: The $V$ (left panel) and $V-R$ (right panel) curves of PKS 2155–304 (filled dots) as observed in the ESO run in July 1998. $V$ magnitudes and $V-R$ colours of the check star (open circles) are reported for comparison purposes.

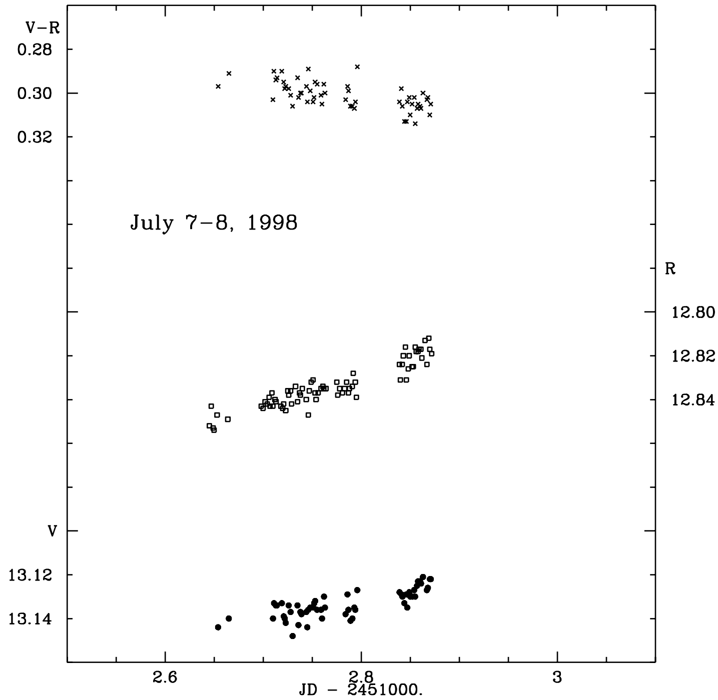


Figure 2: The $V$, $R$ and $V-R$ curves of PKS 2155–304 as observed in the second night of our 1998 campaign.

Intranight variability can be clearly noted by comparing the standard deviations of the PKS 2155–304 measurements and those of the check star (see Tab. 1): they are greater by a factor ∼2 in the first five nights. Figure 2 shows the light curve observed during the night between July 7 and 8: a continuous increase is observed. It should be noted that the brightening is larger in $R$–light than in $V$–light, as appears in the $V-R$ colour curve. Such a reddening is quite unusual in the brightening of a BL Lac object.

## 4. Conclusions

The 1998 observations described here correspond to a state of the source slightly weaker than in the 1997 Las Campanas campaign (Mantegazza et al. 1999): in $V$–light the range was 12.90–12.95 in 1997, while it was 13.02–13.17 in 1998. Moreover, the colour index $V-R$ was slightly redder in 1998 (0.28–0.30 mag) than in 1997 (0.26–0.28 mag).

However, in correspondence of the highest state detected by us ($V$=12.83 in the ESO observations performed in July 1997 just after the Las Campanas run), the $V-R$ colour curve was unexpectedly high ($V-R$=0.30). This fact, joined with the behaviour observed in the night of 7–8 July, 1998, indicates that the magnitude–colour dependance is rather complex, being related to the intensity state of the source and to the temporal sampling.

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# Optical Polarization of PKS 2155-304

**A. Treves[1], E. Pian[2], F. Scaltriti[3], E. Palazzi[2], L. Tommasi[4] and E. Poretti[5]**

[1] *Università dell'Insubria, Dipartimento di Scienze, Via Lucini 3, I-22100 Como, Italy – email: treves@uni.mi.astro.it*

[2] *Consiglio Nazionale delle Ricerche, Istituto di Tecnologie e Studio delle Radiazioni Extraterrestri, Via Gobetti 101, I-40129 Bologna, Italy – email: pian@tesre.bo.cnr.it*

[3] *Osservatorio Astronomico di Torino, Strada Osservatorio 20, I-10025 Pino Torinese (TO), Italy – email: scaltriti@to.astro.it*

[4] *Università di Milano, Dipartimento di Fisica, Via Celoria 16, I-20133 Milano, Italy – email: tommasi@ifctr.mi.cnr.it*

[5] *Osservatorio Astronomico di Brera, Via Bianchi 46, I-23807 Merate (LC), Italy – email: poretti@merate.mi.astro.it*

**Abstract.** Linear polarization of the bright BL Lac object PKS 2155-304 was studied in the UBVRI bands with the Torino photopolarimeter at the 2.15 m CASLEO telescope. Observations were performed in June and August 1998 for a total of ≈45 hours. Between the two epochs, the linear polarization in the V band increased from ≈3.5% to ≈5.5%, and the position angle decreased from 100° to 70°. Significant day-to-day variations of both quantities are also observed. An isolated "dip" of the polarization percentage occurred between 17 and 19 June in all bands: a decrease and subsequent rise of a factor of 2 is seen in the linear polarization, accompanied by a variation of the position angle by 90°. Occasionally, significant intraday variations are seen, not exceeding 20%. Further monitoring in November, 1998 indicates that the blazar does not show significant circular polarization.

## 1. Introduction

PKS 2155-304 is a bright closeby BL Lac object (V=12-13, z=0.116), which has been studied in the entire electromagnetic spectrum (e.g. Chiappetti et al. 1999). Variability with time scales as short as 1000 s has been detected in the UV and X-ray bands (e.g. Urry et al. 1997).

Many polarimetric observations are available in literature, in optical and UV bands (Smith & Sitko 1991; Smith et al. 1992; Allen et al. 1993; Courvoisier et al. 1995; Pesce et al. 1997, Visvanathan & Wills 1998). All of them report variability both in polarized flux (P) and position angle (PA), with approximate ranges $2\% < P < 13\%$ and $85° < \theta < 155°$. Different values of PA are reported in Visvanathan & Wills (1998), who found 31° and 32°, in May and June 1979, respectively. The maximum rates of variations can be roughly estimated in 1.5%/day and 30°/day. A small wavelength dependence is usually present in data, showing polarization increasing with frequency, while such a clear dependence cannot be established for the position angle.

We present simultaneous UBVRI linear polarimetry of this source, obtained in June 17-22 and August 26-28, 1998 from Complejo Astronomico el Leoncito (CASLEO, Argentina), for a total amount of 45 hours, and circular polarimetry, obtained in 1998 November 15,16, 18 and 19 for 1.1 hours in total.

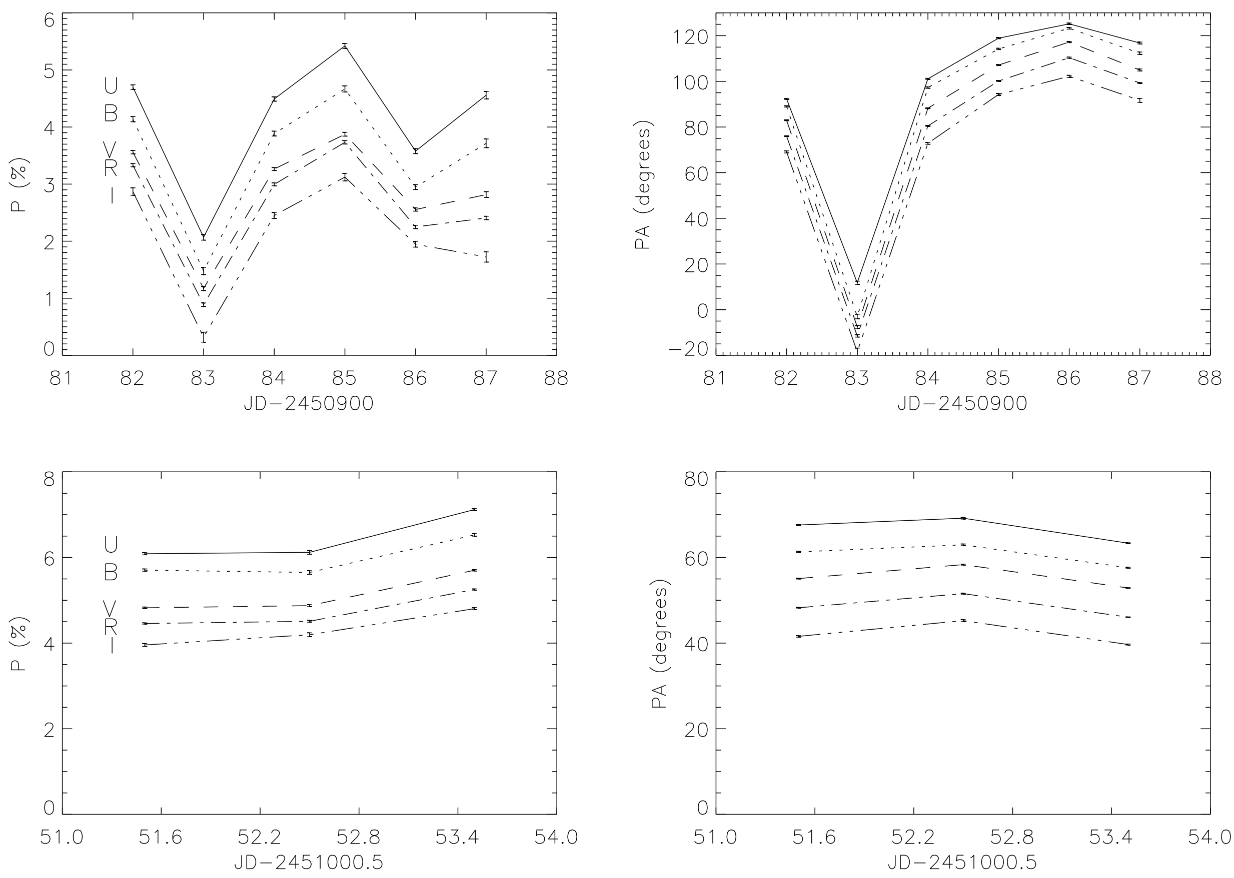


Figure 3: Night weighted averages of linear polarization P and position angle PA in the U, B, V, R, I bands ($1\sigma$ error bars) for June 17-22 (upper two panels) and August 26-28, 1998. Y-axis scales correspond to the U data. B, V, R, I are arbitrarily shifted down with respect to U and to each other by 0.3% for P and 7° for PA. Lines have been added to guide the eye only.

## 2. The observations

Observations have been performed with the 2.15 m telescope of CASLEO Observatory using the Photopolarimetric System of Torino Observatory. It has the capability to perform simultaneous observations in UBVRI bands, thanks to four dichroic plus bandpass filters combinations that select suitable bandpasses (equivalent to that of the standard UBVRI system) to be analyzed by 5 different dedicated photomultipliers. A double diaphragm rotating wheel switches continuously between the two images of the star (ordinary and extraordinary rays) produced by a calcite slab of suitable thickness. Both components of the sky background pass both diaphragms and polarization of the sky is directly eliminated. The original design of the instrument can be found in Piirola (1973). The integration time for each measurement, consisting of 8 positions of the retarding plate, is 3.5 minutes. Observations were then binned together in groups of four to improve statistics. The final time resolution is about 15 minutes. Standard stars for PA calibration and instrumental polarization subtraction have been observed.

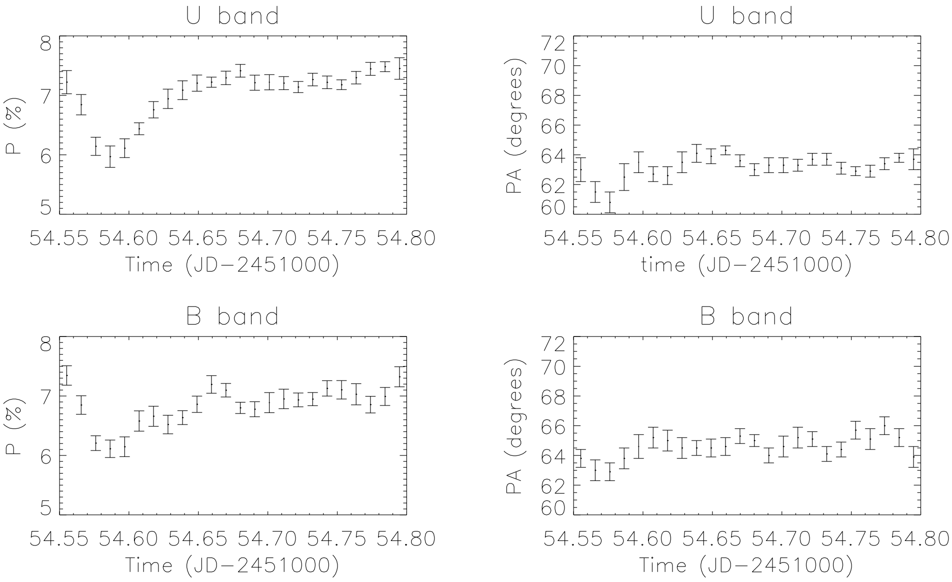


Figure 4: A regular variation of P and PA recorded within the night of Aug. 28 in the U and B band ($1\sigma$ error bars).

**3. Results**

Fig. 3 reports the night weighted averages of linear polarization together with the position angle for June and August, 1998. The most noticeable feature is the sharp decrease of P on the second night of June, corresponding to a drastic change of PA. Fig. 4 shows a rather regular variation of P within one night in the U and B bands. Similar trends occur also in V, R, I bands. The dependence of P on the wavelength is illustrated in Fig. 5. Polarization decreases with wavelength with a flattening above 5000 Å.

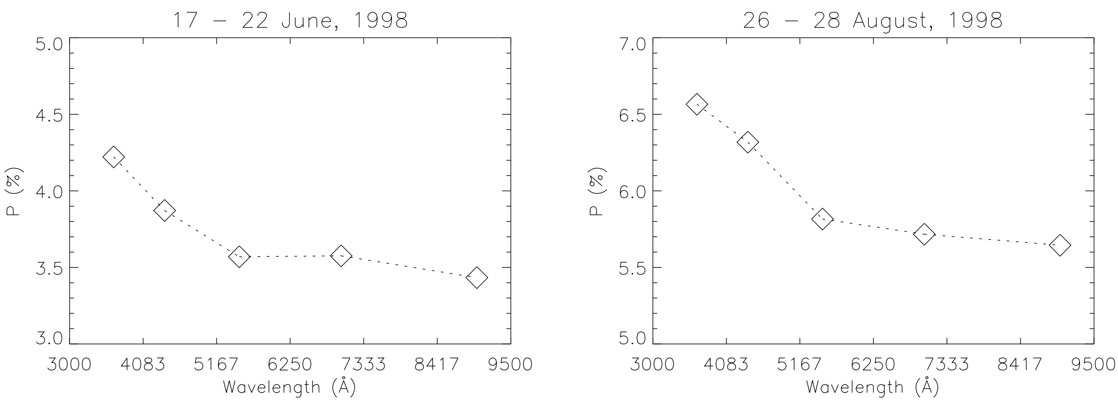


Figure 5: Wavelength dependence of polarization. Error bars are smaller than symbols used. Lines have been added to guide the eye only.

Circular polarization was searched for in November 15,16,18 and 19, 1998 with a total integration time of 1.1 hours. Results are plotted in Fig. 6. Upper limits in the five bands are ≈0.3 percent, consistent with the results of Allen et al. (1993).

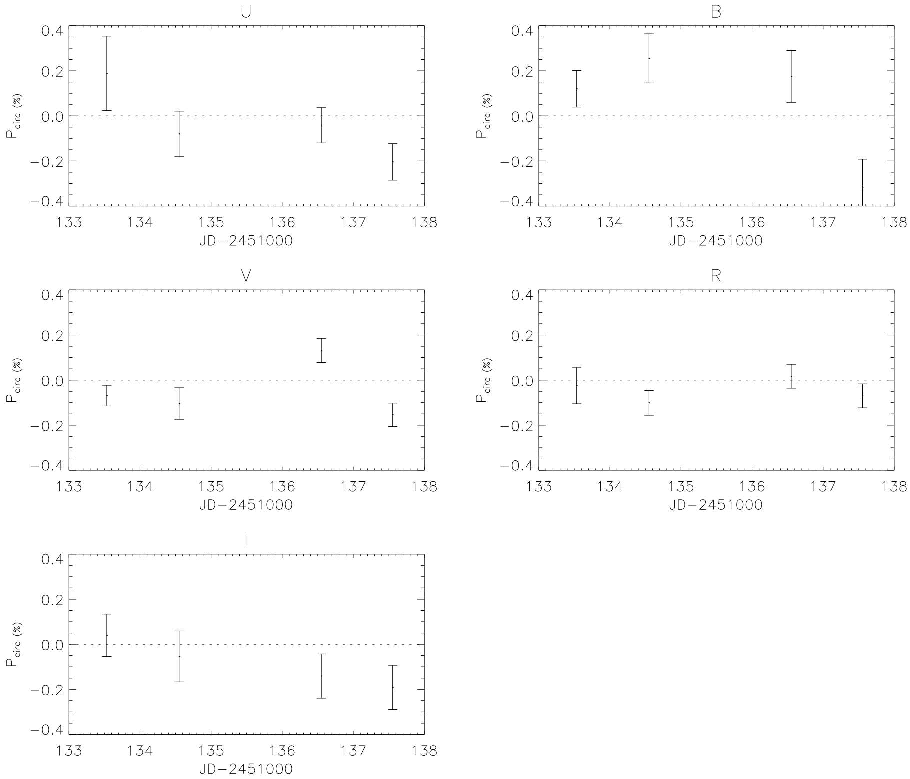


Figure 6: Circular polarization vs. Julian Days in U, B, V, R, I bands in November 15-19, 1998.

## 4. Discussion

The variability and wavelength dependence indicate that the polarization is mainly due to the BL Lac, rather than to the host galaxy, whose magnitude, according to Falomo et al. (1991), is $m_I$=14.8. The abrupt decrease of P in June 18, accompanied by a drastic variation of PA, suggests to us that the jet contains several components of different polarization. The fading of one exalts the contribution of another. This picture seems more natural than considering a modification of the magnetic structure of the jet, i.e. an actual rotation of the field orientation in 1-day time scale.

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