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Automatic optical monitoring of 10 blazars*

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Abstract. — We report the BVR_cI_c data for 10 blazars observed in the first phase of a long–term photometric monitoring program of about 30 objects. The observations were carried out with a 0.40–m automatic imaging telescope, recently developed by our group at the Perugia University Observatory. During our period of observation 1215+303 and 1424+240 were at their highest values of magnitude, while 0754+100 and 0829+043 displayed large amplitude flares. We further report optical data of Mrk 501 during the same period in which TeV γ-rays were detected by the Whipple Observatory.

Key words: galaxies: active — BL Lacertae objects: general

1. Introdution

Blazars, namely BL Lacertae objects and optically violent variable (OVV) quasars, are a subclass of active galactic nuclei (AGN) characterized by flat radio spectra, high and variable polarization and rapid and large variability at every observed frequency (Angel & Stockman 1980). Many blazars show superluminal motion (see e.g. Vermeulen & Cohen 1994) and form the largest subset of extragalactic sources emitting high energy γ–rays (von Montigny et al. 1995). In order to explain the blazar phenomenon, beamed emission from a relativistic jet aligned with our line of vision has been proposed (see e.g. Blandford & Rees 1978 and Blandford & Königl 1979). The study of the variability shown by this class of objects is therefore one of the most important tools for exploring the physics of the AGN central engine.

Over the last few years numerous monitoring programs have been devoted to characterizing very rapid and long–term variability of blazars (i.e. typical time scales and eventual periodicity or quasi–periodicity in the light curve) and to understanding the emission mechanisms. Important optical monitoring campaigns have been set up, for example, at the Rosemary Hill Observatory (e.g., Pica et al. 1980; Webb et al. 1988; Pica et al. 1988) at the Asiago Observatory (e.g., Barbieri et al. 1979); at the Turku University Observatory (e.g., Sillanpää et al. 1988; Sillanpää et al. 1991) and at the Yunnan Observatory (e.g., Xie et al. 1994). Moreover the Hamburg Quasar Monitoring Program has recently been carried out at the Calar Alto Observatory (e.g. Schramm et al. 1994).

It must be pointed out, however, that there are not sufficient data in the optical band, so that it is quite difficult to compare the optical light curve with radio observations (see e.g. Hufnagel & Bregman 1992). Moreover, many of the outbursts observed in the X and γ bands are not well covered at optical frequencies, with the lost of important information relevant to understanding the emission mechanism of blazars. One of the causes of the lack of optical data is related to the difficulties of having telescope access for the large amount of time required to obtain a good sampling of the extreme variability (from days to years) shown by these objects.

Optical monitoring of many relatively bright blazars may be performed efficiently by small automatic telescopes, equipped with a CCD camera. With this in mind, at the Perugia University Observatory we have developed an automatic imaging telescope (AIT) able to observe, in an unattended mode, predefined lists of objects and to reduce automatically the raw CCD images. This instrument is fully dedicated to our monitoring program of blazars so that only weather conditions can hinder the observations.

Starting in 1992, and during the implementation phase of our system, we began to observe a sample of blazars which have at some time been brighter than 17 mag in the V band. Obviously during the work of automatization we monitored only a small number of objects without a perfect temporal coverage and with the loss of some exposures. Since October 1994 the AIT has been fully operative and is observing about 30 blazars in the VR_cI_c bands. A B filter is also used but only for the brightest sources. A great amount of photometric data have already been

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*Table 2 is only available in electronic form at the CDS via anonymous ftp 130.79.128.5

collected for 19 of the brighter ones. Up to date only a small number of data have been obtained for the other blazars either because they are faint or because they have been included only recently in our monitoring program.

In this paper we present BVR_cI_c observations of nine BL Lac objects and one OVV quasar. The data for the other nine well–sampled blazars (OJ 287, Mrk 421, 3C 66A, PKS 0422+04, PKS 0735+178, S4 0954+65, S5 0716+71, BL Lac and W Com) will be published in forthcoming papers because they are still the subject of observation in collaboration with other observatories and astronomical institutes. However, large flares or high luminosity states for some of these objects have been promptly announced in IAU circulars (e.g. Fiorucci & Tosti 1992, 1994a, b) to encourage observations at other wavelengths too.

In Sect. 2 we briefly describe the characteristics of the automatic telescope and of the photometric system. In Sect. 3 we present the observations and results. The conclusions follow in Sect. 4.

2. The automatic imaging telescope

In manually operated telescopes the observer points, finds and centers the object, moves the dome, guides the telescope, moves the dome during the exposure, checks the weather conditions, stores and reduces the data. Our AIT performs all these tasks automatically. It has been developed during the last three years and a full description of the system will be given elsewhere (Tosti et al. 1996); here we illustrate briefly only its general characteristics.

The telescope is a 0.40 m Newtonian reflector (f/5) with an equatorial mount. The RA and DEC axes are closed–loop controlled by a two–axis motor controller connected to a 386 PC (PC1) via an RS232 serial line. The pointing accuracy is better than $1'$ without centering procedures. The system is equipped with an autoguider based on a CCD camera applied at the 0.15 m refractor (f/15) which is joined to the main telescope on the same mount. The camera is mounted on a motorized X/Y translational stage so that the guide star (selected automatically from the SAO Catalogue) can be chosen within a sufficiently large region of sky around the target object.

A 486 PC (PC2) controls the CCD camera, applied at the Newtonian focus of the main telescope. The CCD camera used is based on the Texas Instrument TC211 chip with 192×165 pixels, cooled by Peltier stages that reduce the CCD temperature by almost 50°C with respect to the ambient temperature. It has a good quantum efficiency, is cheap, not bulky and very uniform ($> 99\%$). Nevertheless the main limits are readout noise and, in particular, the high dark signal. For this reason a dark frame, with the same exposure time, must be taken near the object image. At the Newtonian focus of the telescope the camera field of view is of about $5' \times 5'$.

The camera is equipped with Johnson-Cousins BVR_cI_c filters obtained by joining Schott filter glasses in the following combinations:

B: BG12 (2 mm) + BG39 (1 mm) + GG385 (1 mm)

V: GG495 (2 mm) + BG39 (2 mm)

R_c: OG570 (2 mm) + KG3 (2 mm)

I_c: RG9 (3 mm)

Taking into account the CCD spectral response, the photometric system is a good match to the standard system described by Bessell (1979).

The AIT can operate either in an interactive mode, with the presence of the observer, or unattended. In the unattended mode the system needs only the list of the objects to be observed. This list is an ASCII file containing the basic data for each object (coordinates, filters to be used, exposure times etc.). During the night the file is analyzed by the control software and an ordered pointing sequence is generated taking into account the best observational conditions for each object. After each pointing a guide star is searched and, if it is found, PC1 sends a command to PC2 to begin the exposure. At the end of the exposure the image is saved on the hard–disk of PC2. The observation process continues until the last object in the list is observed.

The system can however be operated directly by the astronomer by means of an interactive menu-driven software, running on PC1, which also allows on-line access to some standard catalogues (Bright Stars, GCVS, Landolt Stars, RNGC, SAO Catalogue) or personal databases. The photometric CCD camera can also be controlled by an interactive software, running on PC2.

At the end of the night a procedure for automatic data reduction is activated by the PC2 so that the astronomer can obtain a file containing the photometric data for each observed object. For each CCD image the procedure performs dark and bias correction, automatic star finding, automatic recognition of the field and evaluation of the comparison stars and blazar instrumental magnitudes.

3. Observations and results

Table 1 gives a list of the ten observed blazars, with a summary of the observations. Column (1) reports the source designation, while Col. (2) gives the name (or names) commonly used in literature. Columns (3) and (4) give the coordinates of the object; Col. (5) gives the intervals of observation while Col. (6) reports the total number of BVR_cI_c photometric points.

The exposure integration times varied from 3 to 8 minutes, and sometimes we took 2 images for each filter. The duration of each photometric run is always less than 1 hour for each blazar, so we can consider these

Table 1. Summary of the observations

Source	Common name(s)	A.R. (1950.0)	DEC. (1950.0)	ΔT	$N_{\rm tot}$
0323+022	H	03 23 38.0	02 14 47	93/02/02 ÷ 95/01/09	26
0754+100	PKS, OI090.4	07 54 22.6	10 04 40	93/02/02 ÷ 95/04/07	55
0829+046	PKS, OJ049	08 29 10.9	04 39 51	94/03/06 ÷ 95/04/22	76
0912+297	B2, OK222	09 12 53.5	29 45 55	94/03/06 ÷ 95/03/05	29
1147+245	B2, OM280	11 47 44.0	24 34 35	94/03/04 ÷ 95/06/15	75
1215+303	B2, PKS, ON325	12 15 21.2	30 23 40	94/05/21 ÷ 95/06/19	87
1226+023	3C 273, PG, PKS, H, ON044	12 26 33.2	02 19 43	93/03/04 ÷ 95/06/17	114
1424+240	PKS, PG, OQ240	14 24 44.3	24 01 26	94/03/04 ÷ 95/06/28	98
1652+398	Mrk 501, PKS, B2, H, OS387	16 52 11.7	39 50 25	94/03/04 ÷ 95/06/27	239
1727+502	IZW187, PKS, B2, OT546	17 27 04.3	50 15 32	94/06/06 ÷ 95/06/27	53

observations as almost simultaneous also if it is well known the rapid variability of blazars.

The CCD frames were corrected for bias and dark signal. Because of the high grade of uniformity of our CCD chip the usual flat–field correction of the images was not required. Instrumental magnitudes were obtained in simulated aperture photometry using a radius of 5 arcsec for all sources. Internal checks were carried out to eliminate possible imperfections in the frames, e.g. cosmic ray traces. The photometric data were obtained prevalently in differential photometry with comparison stars reported by Fiorucci & Tosti (1996), Smith et al. (1985) and Smith et al. (1991). For 0323+022 and 0912+297 the comparison stars will be published in a forthcoming paper. Each color correction was neglected because it makes a smaller contribution than the typical error.

The Perugia program is ongoing, so, for practical reasons, we established June 1995 as a cutoff date for observations to be included in this paper. Each object monitored was prevalently observed in the $VR_{\rm c}I_{\rm c}$ because of the better efficiency of our photometric system in these bands. However some B band data are available for the brighter objects.

Table 2 (available in electronic form) lists the photometric data. Column (1) gives the UT date of the night of observation: for the exposures done after midnight the precedent date is reported. Column (2) gives the mean Julian day of the CCD exposures. Columns (3)–(6) give the $BVR_{\rm c}I_{\rm c}$ magnitudes and the relative standard deviations. In the presence of more consecutive observations in the same filters, the data reported are the weighted means.

3.1. *Notes on individual objects*

0323+022. This BL Lac was discovered during the HEAO 1 all–sky survey, (Doxsey et al. 1983; Margon & Jacoby 1984) and is characterized by extremely rapid variability at high frequencies (Feigelson et al. 1986). A redshift of $z = 0.147$ was measured by Filippenko et al. (1986), who also confirmed an $M_V \simeq -22$ for the giant elliptical host galaxy, as previously observed by Feigelson et al. (1986). The host galaxy contribution is quite evident in the optical–near IR range and causes a reddening when the BL Lac is fainter (Pian et al. 1994). The V magnitude of this object varies from 15.5 to 17.5 (Doxsey et al. 1983; Feigelson et al. 1986; Falomo et al. 1993b; Jannuzi et al. 1994). The Rosemary Hill Observatory started to observe this object in 1986 and only a few B data have been reported by Pica et al. (1988).

During our monitoring campaign the brightness of 0323+022 was close to the limits of detectivity of our system, and we were able to collect $VR_{\rm c}I_{\rm c}$ data with good signal to noise ratio on only a few photometric nights. In the V band we collected photometric data from February 1993 to January 1995; during this interval it did not show any dramatic event. In the $R_{\rm c}$ band (Fig. 1) we have a better temporal coverage from late 1994 to early 1995, but we observed variations of only a few tenths of a magnitude.

0754+100. This is one of the most widely observed BL Lacs. It was identified as a BL Lac object by Tapia et al. (1977) on the basis of polarization studies. Falomo et al. (1993a) observed this blazar in the optical–near IR and did not detect a significant contribution of the host galaxy. An archival research using the Harvard plate collection (Baumert 1980) showed significant rapid optical flares of ~ 0.8 mag with time scales ranging from a few days to one month. Flickering of about 0.8 mag superimposed on long term trends spanning 1–2 years was also observed by Pica et al. (1988). In any case, its entire range of variability is almost 2 mag in the B band (Zekl et al. 1981).

Other recent observations in the optical bands are reported by Moles et al. (1985); Adam (1985); Smith et al. (1987); Mead et al. (1990); Sitko & Sitko (1991); Takalo (1991); Sillanpää et al. (1991); Takalo et al. (1992); and Xie et al. (1994, and references therein). A rapid optical flare (0.56 mag/80 min) was observed in the B-band by Xie et al. (1991) but this is to be considered a rare phenomenon (Xie et al. 1994).

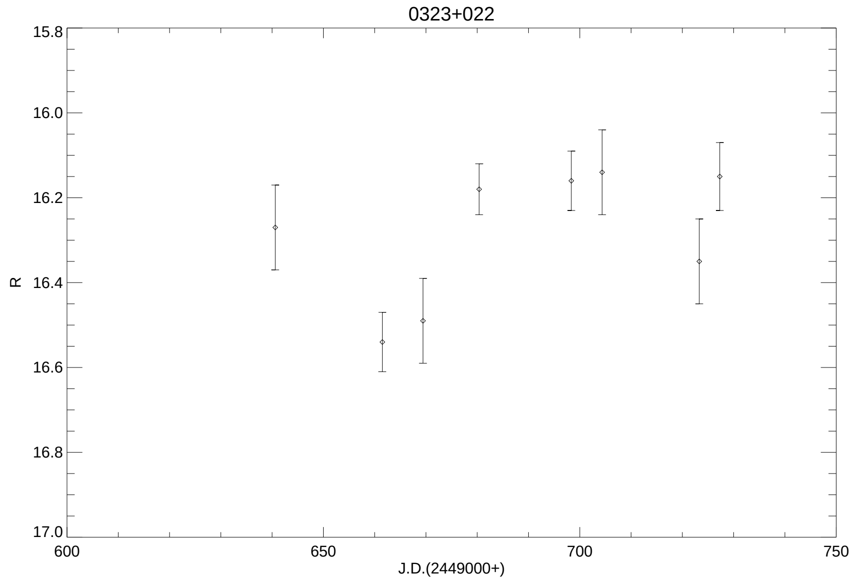

Fig. 1. R_c light curve of 0323+022 from 1994/10/14 to 1995/01/09

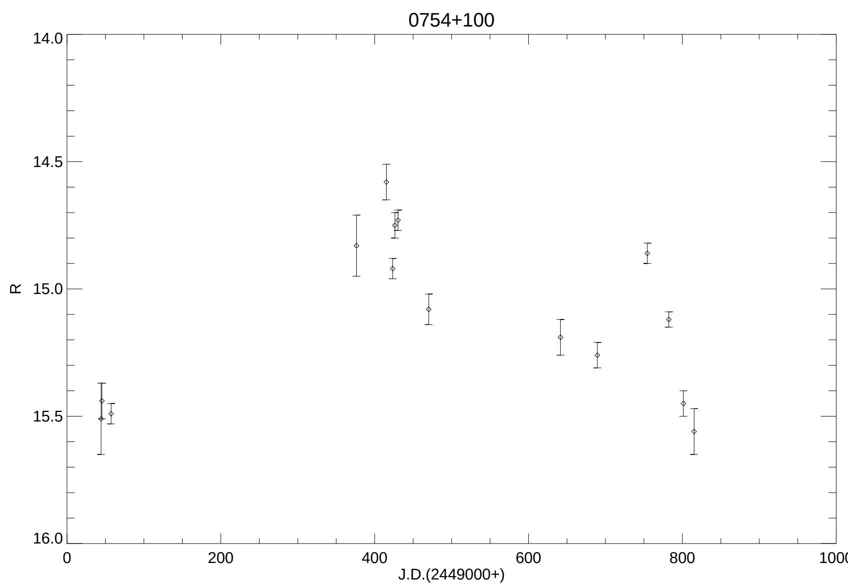

Fig. 2. R_c light curve of 0754+100 from 1993/02/25 to 1995/04/07

We observed 0754+100 from February 1993 to April 1995 in the VR_cI_c, while only two data are available in the B band. Two optical flares in March 1994 and February 1995 are visible in the light curve (Fig. 2). Another high brightness state is evident in early February 1993, for which only the V data are available. During all these variations the color indices remained very stable, even if the brightness level varied by almost a magnitude. Pian et al. (1994) recently suggested that BL Lac objects have a constant spectral slope in the UV–near IR region when the contribution of the host galaxy is subtracted from the spectral flux distribution. In this framework the constant color indices observed in 0754+100 can be correlated to the scarce contribution of the host galaxy.

0829+046. This is a very active BL Lac object, which shows a large amplitude and rapid flux variability. Its

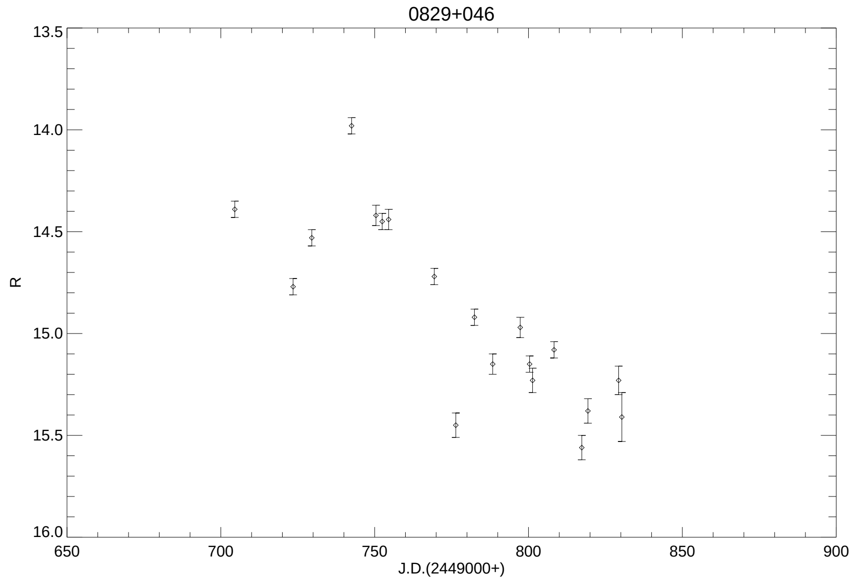

Fig. 3. R_c light curve of 0829+046 from 1994/12/17 to 1995/04/22

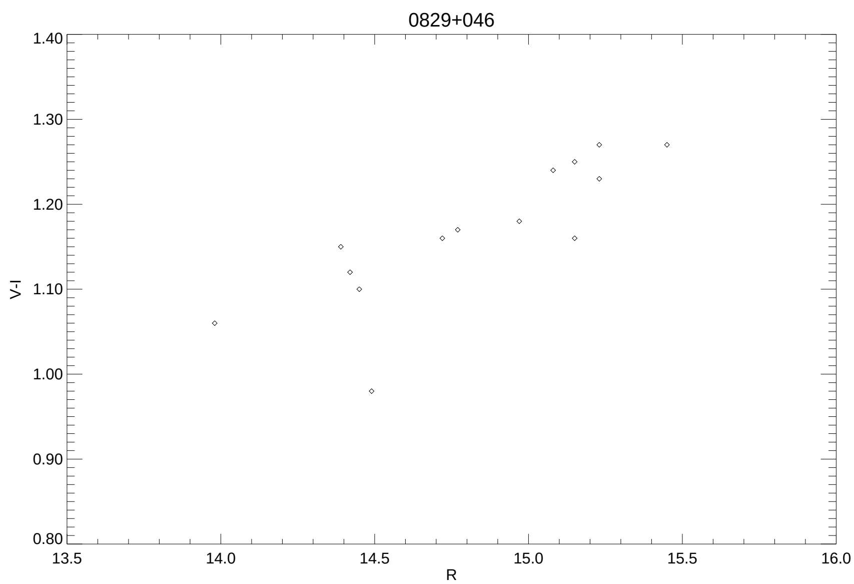

Fig. 4. Color index $V - I_c$ with respect to the R_c magnitude for 0829+046

redshift has been recently measured by Falomo (1991) who found a value of $z = 0.18$. Optical to near–IR observations are reported by Falomo, Bersanelli, Bouchet et al. (1993) who detected an important contribution of the $M_V \simeq -22.6$ host galaxy. An archival research using the Harvard photographic plate collection gives a range of variability for this object of ΔB=3.6 (from B=14.2 to B=17.8), with a short term variation as fast as 0.8 mag in 1 day (Liller & Liller 1975). From the observations done at Rosemary Hill Observatory it can be noted that this object shows flares of more than 2 mag with a time scale of a month (Pica et al. 1988). It was also observed, though only four times, by Adam (1985) in the UBV bands, from 1977 to 1980.

Except for a night in March 1994, when the object was in a high state, we observed 0829+046 only after the end of

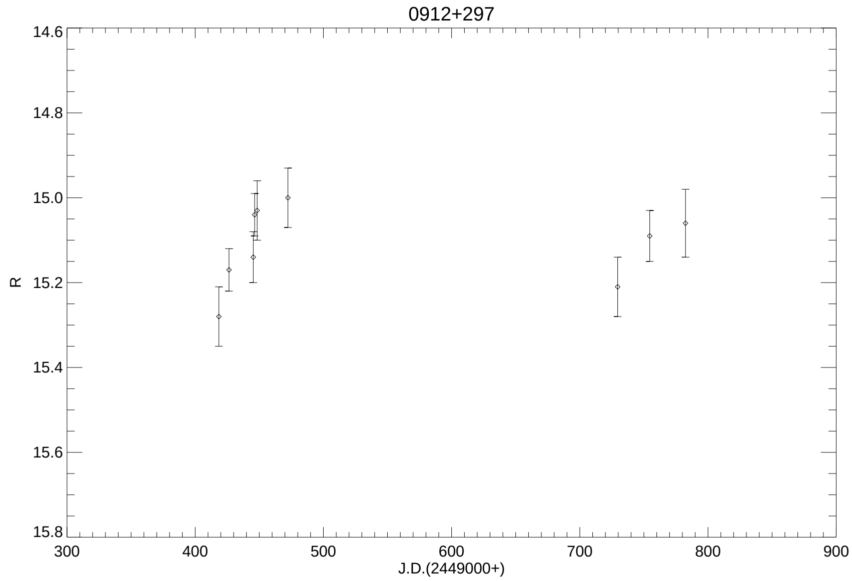

Fig. 5. R_c light curve of 0912+297 from 1994/03/06 to 1995/03/05

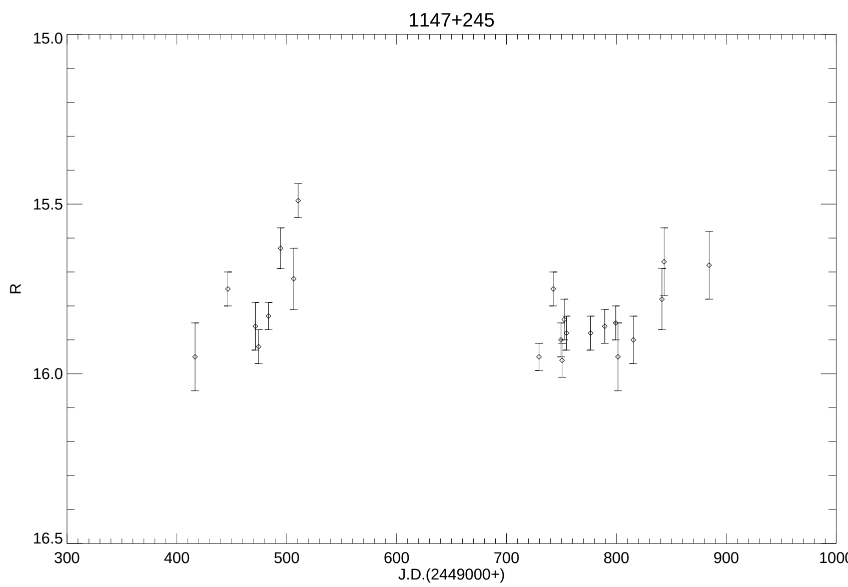

Fig. 6. R_c light curve of 1147+245 from 1994/03/04 to 1995/06/15

the AIT test phase in the VR_cI_c. Nevertheless, from our data it is quite evident the rapid variability characteristic of this object. We observed a large outburst at the end of January 1995 (Fig. 3) having the same temporal characteristics of the flares observed by Pica et al. (1988). From our data there is also evident a dependence of the color index $V - I_c$ from the brightness level (Fig. 4). This effect can be explained by considering the starlight contribution from the host galaxy.

0912+297. This BL Lac object varies with an amplitude of more than 2 mag in the B band; nevertheless this is not one of the most observed blazars. The historical light curve shows a maximum in 1917 (m_{pg}=14.8) followed by a minimum in 1947 ($m_{pg} \simeq 17$) without dramatic fluctuations (Zekl et al. 1981, and references therein). Subsequent

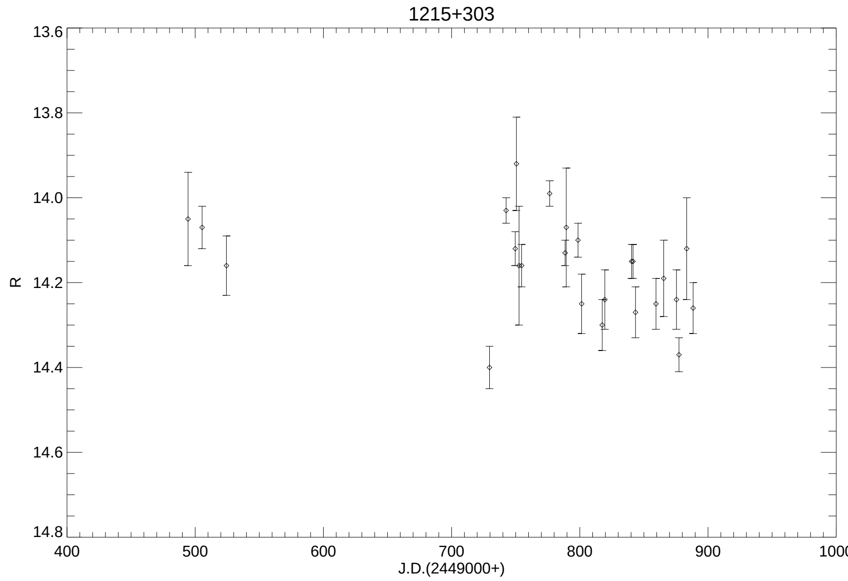

Fig. 7. R_c light curve of 1215+303 from 1994/05/21 to 1995/06/19

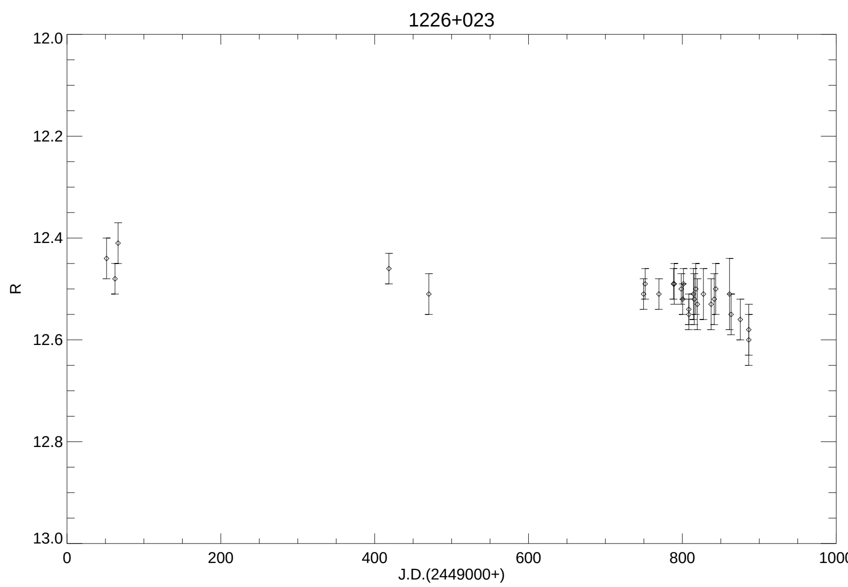

Fig. 8. R_c light curve of 1226+023 (3C 273) from 1993/03/04 to 1995/06/17

observations indicate a moderate increase in the brightness (e.g. Battistini et al. 1974; Tapia et al. 1976).
We have observed 0912+297 from March 1994 to March 1995 prevalently in the R_c. The scarcity of data obtained for this object is due to the lack of a guide star within the limits of our auto–guider X/Y stage, so the object was observed manually just for a few nights. During this period we observed no variation of importance (Fig. 5). The source remained at around a quite high brightness level, with a V magnitude similar to that reported by the more recent observations (Moles et al. 1985; Worrall et al. 1986).

In conclusion, taking into account the historical light curve, 0912+297 seems to belong to the blazar class characterized by long–term changes without a significant flare

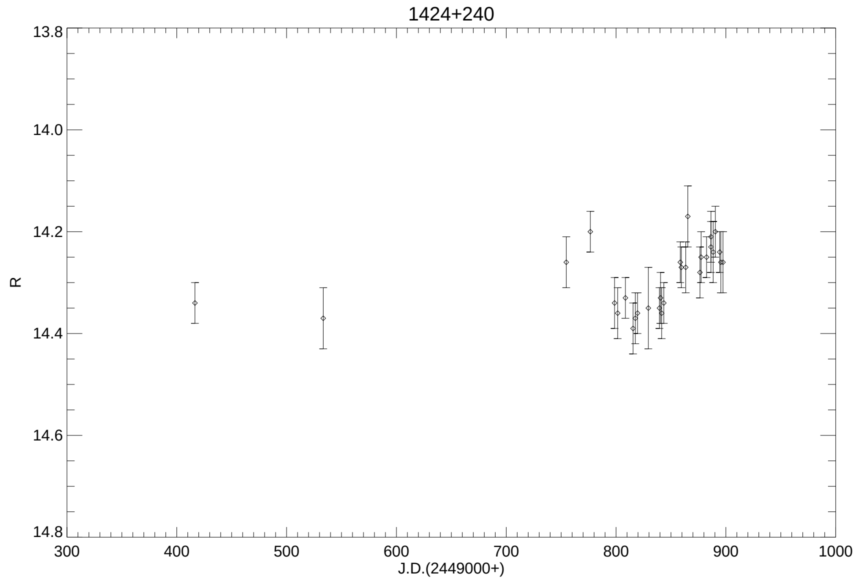

Fig. 9. $R_{\rm c}$ light curve of 1424+240 from 1994/03/04 to 1995/06/28

activity. In any case, a more intensive monitoring may lead to a better understanding of the variability of this object.

1147+245. Confirmed as a BL Lac object by Angel & Stockman (1980), it belongs to the 1 Jy catalogue of Stickel et al. (1993). Although radio–selected BL Lacs are considered particularly active (Jannuzi et al. 1994), its optical variability is fairly small with an amplitude of only 0.77 mag in the B band (Pica et al. 1988; Zekl et al. 1981, and references therein) around a mean value of $B \simeq 16.66$. Recently, just a few optical observations have been reported by Moles et al. (1985) and Mead et al. (1990).

We have observed 1147+245 in the $VR_{\rm c}I_{\rm c}$ since early 1994. From our data it turns out to be in a low state of activity, although sometimes rapid flickering in a range of only a few tenths of magnitude is present in the light curve (Fig. 6). Taking into account the typical $B-V$ color index (see e.g. Kinman 1976) to deduce the B mean value from our data, we can note that the mean brightness level of this object has remained quite constant over the last decades.

1215+303. This radio source was identified with a quasi stellar object by Browne (1971, see also Véron & Véron 1973). The amplitude of its variability is more than 3 mag in the B band (Zekl et al. 1981, and references therein). From the observations taken at Rosemary Hill Observatory it can be argued that its average magnitude increased by 0.1 mag per year, over the period 1975–1985, from $B \sim 16$ to $B \sim 15$, with superimposed short term fluctuations of more than a magnitude on a time scale of months (Pica et al. 1988). Other observations in the optical band are reported by Moles et al. (1985), Xie et al. (1987), Barbieri et al. (1988) and Valtaoja et al. (1991a). Xie et al. (1987) also observed a rapid variation of ΔB=0.38 with a characteristic time scale of about 3 days.
We have observed 1215+303 in the $VR_{\rm c}I_{\rm c}$ since May 1994. Only two data in the B band are available. In some nights we obtained decentered frame images of the object and, as a consequence, the brighter comparison star was outside of the field. In these cases we made use of differential photometry utilizing faint stars, so that large errors in the magnitude values were obtained. Figure 7 shows the light curve of this object in the $R_{\rm c}$ band. 1215+303 was quite stable and in a very bright state. Flickering is however present in the light curve and a major fluctuation of about 0.5 mag is evident in early 1995.

1226+023 (3C 273). This is a low polarization quasar with characteristics that have led some authors to consider it a miniblazar (Impey et al. 1989; Valtaoja et al. 1990). It is also considered a typical variable quasar but, despite its reputation, it is not exceptionally variable. The historical B light curve shows little variation around a mean value of $B \simeq 13.2$ (Lloyd 1984). The data collected at the Rosemary Hill Observatory reports a range of B variability of 0.87 mag in 17 years (Pica et al. 1988). Generally it is very stable, but sometimes it becomes unusually active, as in February 1979, when it reached $B = 12.59$ (Pica et al. 1980), and in the outburst of February 1983 (Sadun 1985; Sillanpää et al. 1988). Other recent optical observations are reported by Cutri et al. (1985), Corso et al. (1987), Courvoisier et al. (1987), Smith et al. (1987), Sillanapää et al. (1991),

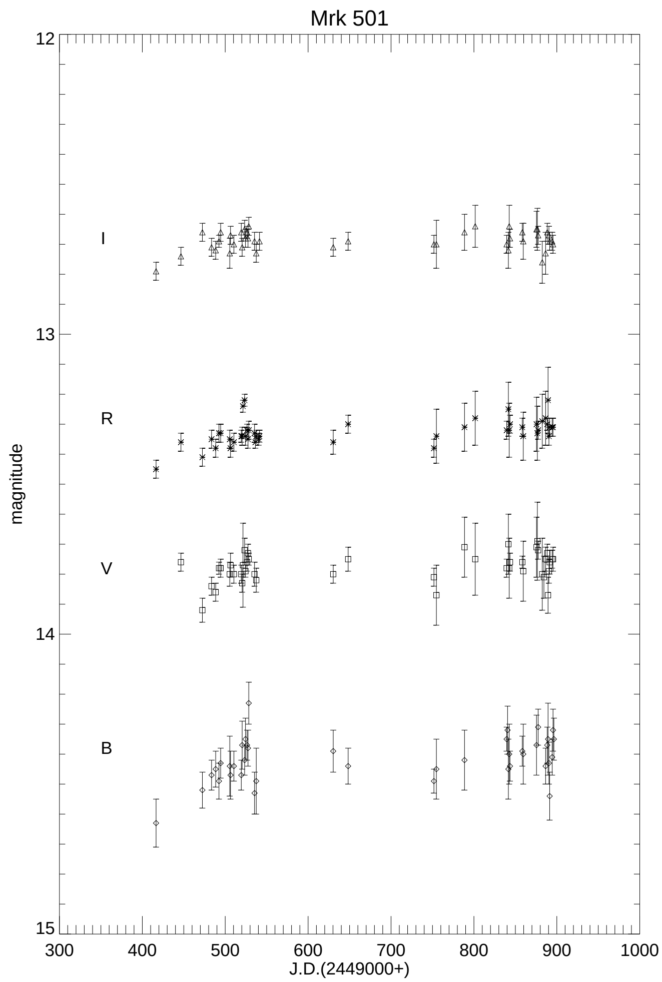

Fig. 10. BVR_cI_c light curves of 1652+398 (Mrk 501) from 1994/03/04 to 1995/06/26

Valtaoja et al. (1991b) and Takalo et al. (1992). Smith et al. (1993) studied the longer optical time scale of this object, but they found no base level changes during 16.5 years.

During our BVR_cI_c observations, from March 1993 to March 1995, 3C 273 remained very stable, practically without any variation of importance, except for a small descending trend more evident in the last part of the light curve (Fig. 8). In any case the brightness level was higher than the historical mean level by some tenths of a magnitude. It must also be noted that, during the same time, the observations done at longer wavelengths showed great brightness and activity (Stevens et al. 1994). The low variability in the optical band is perhaps due to the different regions of emission, with the synchrotron radiation which contributes significantly to the radio – middle infrared regime, and the accretion disk thermal radiation which contributes to the blue bump. However this is in partial contrast with the good correlation observed between some optical and radio flares (Tornikoski et al. 1994). Probably the phenomenon is more complex, as indicated by the gross difference in morphology at different frequencies after 1990 (Robson et al. 1993; Stevens et al. 1994); our observations during 1993/1994 are not numerous enough to be useful for a clear understanding.

1424+240. This is a well–known radio source (Condon et al. 1977) identified as a blazar from the optical polarization study of Impey & Tapia (1988). Initially it was misclassified as a white dwarf in the Palomar–Green Survey, but recent observations of the ROSAT All–Sky Survey have confirmed this source unequivocally as a BL Lac object (Fleming et al. 1993). Recently this source has been observed in the optical band solely by Mead et al. (1990).

During our BVR_cI_c observations 1424+240 remained very stable and appeared to be, as far as we know, at the highest level of brightness so far recorded. Low amplitude fluctuations over a timescale of a few months are, however, visible in the light curve (Fig. 9).

1652+398 (Mrk 501). This BL Lac object is the nucleus of a bright elliptical galaxy. It belongs to the 1 Jy catalogue of radio–selected BL Lacs (Stickel et al. 1993) but its spectral energy distribution is more similar to X-ray selected BL Lacs (see e.g. Giommi et al. 1995). The total amplitude of variation is 1.3 mag in the B band (Pica et al. 1988; Zekl et al. 1981, and references therein), but it shows only a marginal variability, with sporadic flares or fades of a few tenths of a magnitude. In the optical it was recently also monitored by Moles et al. (1985), Sillanpää et al. (1988), Takalo (1991), Sillanpää et al. (1991), Valtaoja et al. (1991a) and Jannuzi et al. (1993, 1994). Rapid variations in the optical and near–IR emission of this object have been observed by Kidger et al. (1992) and by Kidger & De Diego (1992).

We have observed Mrk 501 from March 1994 and no dramatic events were detected. Figure (10) shows its BVR_cI_c light curves. In the 1994 observations it varied by about 0.5 mag in the B band and it may be noted that the amplitude of this variation decreases on passing from the V to the I_c bands. This effect may be connected with the dilution of the blazar emission by the host galaxy, as also remarked by some authors (e.g. Mufson et al. 1984; Kidger et al. 1992).

In the period between March and June 1995 Mrk 501 was also observed with the high resolution imaging camera on the Whipple Telescope, and TeV γ–rays have been detected from this source (Quinn et al. 1995). Mrk 501 is, then, one of the few sources (together with Mrk421) which emits at TeV energies but, different from Mrk 421, it shows no variability at these energies. We have observations of this source in the same period in which it was monitored by the Whipple collaboration, and TeV emission does not coincide with any particular optical activity.

In our opinion, the weak optical variability showed by this object cannot be explained only by the host galaxy

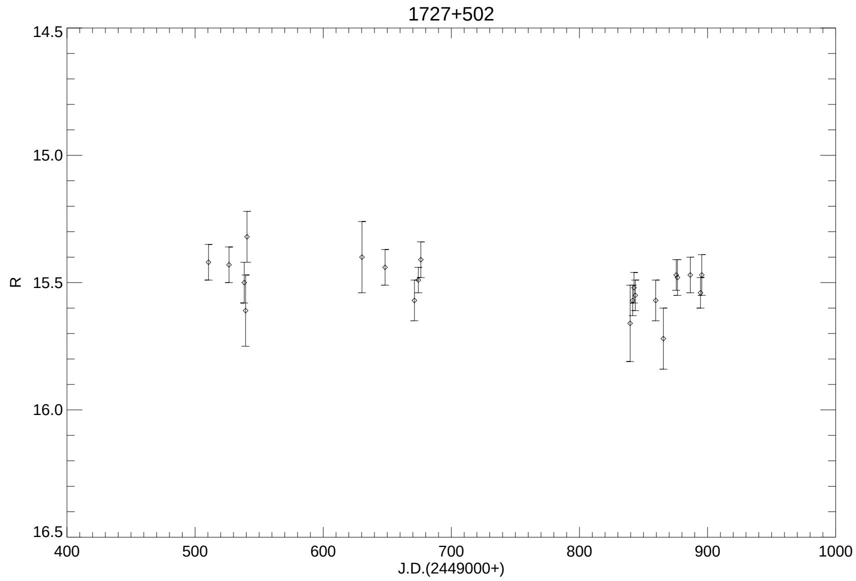

Fig. 11. R_c light curve of 1727+502 (I ZW 187) from 1994/06/06 to 1995/06/26

dilution effect, but it may be an intrinsic property of the source. This is also supported by the fact that important variability events have not yet been observed at higher energies, where the galaxy contribution is irrelevant.

1727+502 (I ZW 187). This source, sometimes erroneously reported as I ZW 186, was confirmed as a BL Lac object by Angel & Stockman (1980). It is at the center of a large elliptical galaxy which contributes to the observed flux. The amplitude of its historical variability is almost 2 mag in the B band (Usher 1975, and references therein), but currently its range of variability is smaller. The observations made at the Rosemary Hill Observatory from May 1975 to April 1987 show rapid short term variability with a range of variation of 0.8 mag and a mean value of $B \simeq 16.7$ (Pica et al. 1988). I ZW 187 is less variable than most BL Lac objects at optical, infrared and X–ray frequencies (Bregman et al. 1982). This object has been recently observed in the optical solely by Moles et al. (1985) and Mead et al. (1990).

During our VR_cI_c observations, from June 1994 to June 1995, I ZW 187 remained quite stable with possible fluctuations within the error limits (Fig. 11). Taking into account the typical $B-V$ color index (see e.g. Kinman 1976) to deduce the mean B magnitude from our data, we can note that the mean brightness level of this object has remained quite constant during the last decades.

4. Conclusions

In this paper we have reported preliminary BVR_cI_c data for 9 BL Lac objects and 1 OVV quasar obtained during our blazar monitoring program. For all these objects our data can be considered a substantial contribution to their optical database. This is particularly true for 0912+297, 1147+245 and 1424+240, for which only sparse observations can be found in the literature. Furthermore, we observed each object in three photometric bands and, thus, our data allow a study to be made of the temporal behavior of the color–indices and their relations with the flux levels.

Table 3 gives, for each object, the mean VR_cI_c magnitudes (Cols. 2, 4 and 6), the range of variability in these bands (Cols. 3, 5 and 7) and the mean color indices (Cols. 8-10).

Most of the ten observed blazars do not show the dramatic variability characteristic of the whole class. Among these, 1147+245, 1226+023, 1652+398 and 1727+502 show only small amplitude fluctuations, with the value of the mean magnitude that, analysing their historical light curves, seems to remain the same for many years. The level of brightness of 1215+303 and 1424+240 was among the highest ever observed, and no sign of rapid and large amplitude variability is evident from our data. Only 0754+100 and 0829+046 changed the optical intensity at all temporal scales without a real "quiescent" level. Moreover, the color indices of 0829+046 appeared to vary as a function of the brightness level. This effect can probably be explained by the starlight contribution from the host galaxy.

A good example of the importance of having continuous optical data for making a comparison possible with data obtained at other frequencies is represented by Mrk 501. From our data, it can be argued that the TeV

Table 3. Summary of monitoring results

Source	Vmean	ΔV	$R_c$mean	ΔR_c	$I_c$mean	ΔI_c	$B-V$	$V-R_c$	R_c-I_c
0323+022	16.70	0.30	16.28	0.40	15.68	0.32		0.36	0.57
0754+100	15.65	0.78	15.12	0.98	14.54	0.86		0.45	0.58
0829+046	15.44	1.44	14.90	1.58	14.22	1.49	0.43	0.54	0.62
0912+297	15.51		15.11	0.28	14.64	0.12		0.47	0.53
1147+245	16.15	0.42	15.82	0.47	15.14	0.48		0.35	0.66
1215+303	14.51	0.79	14.17	0.48	13.75	0.39	0.37	0.35	0.43
1226+023	12.72	0.25	12.51	0.19	12.06	0.21	0.15	0.20	0.45
1424+240	14.64	0.31	14.29	0.22	13.83	0.23	0.36	0.35	0.46
1652+398	13.78	0.23	13.33	0.23	12.69	0.15	0.64	0.46	0.64
1727+502	15.98	0.36	15.50	0.40	14.96	0.22		0.48	0.55

emission detected by the Whipple Observatory does not coincide with any particular optical activity of Mrk 501.

This paper demonstrates how the heavy and repetitive work of monitoring can be optimized with the help of automatic systems such as that operating at the Perugia University Observatory. In the future we hope that a dedicated World–Wide network of AITs will be set up to obtain a better understanding of blazar variability.

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