Astronomical Notes
Astronomische Nachrichten

Photometric monitoring of the blazar 3C 345 for the period 1996–2006

B. Mihov, R. Bachev, L. Slavcheva-Mihova, A. Strigachev, E. Semkov, and **G. Petrov**

Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarigradsko Chausse Blvd., 1784 Sofia, Bulgaria

Received 2007 Apr 13, accepted 2007 Jul 14
Published online 2007 Dec 28

Key words quasars: individual: (3C 345) – techniques: photometric

We present the results of the blazar 3C 345 monitoring in Johnson-Cousins $BVRI$ bands for the period 1996–2006. We have collected 29 V and 43 R data points for this period; the BI light curves contain a few measurements only. The accuracy of our photometry is not better than 0.03 mag in the VR bands. The total amplitude of the variability obtained from our data is 2.06 mag in the V and 2.25 mag in the R band. 3C 345 showed periods of flaring activity during 1998/99 and 2001: a maximum of the blazar brightness was detected in 2001 February – 15.345 mag in the V and 14.944 mag in the R band. We confirm that during brighter stages 3C 345 becomes redder; for higher fluxes the colour index seems to be less dependent on the magnitude. The intra-night monitoring of 3C 345 in three consecutive nights in 2001 August revealed no significant intra-night variability; 3C 345 did not show evident flux changes over timescales of weeks around the period of the intra-night monitoring. This result supports the existing facts that intra-night variability is correlated with rapid flux changes rather than with specific flux levels.

Astron. Nachr. / AN **329**, No. 1, 77 – 83 (2008) / **DOI** 10.1002/asna.200710792

WILEY-VCH

Astron. Nachr. / AN **329**, No. 1, 77 – 83 (2008) / **DOI** 10.1002/asna.200710792

Photometric monitoring of the blazar 3C 345 for the period 1996–2006*

B. Mihov**, **R. Bachev, L. Slavcheva-Mihova, A. Strigachev, E. Semkov,** and **G. Petrov**

Institute of Astronomy, Bulgarian Academy of Sciences, 72 Tsarigradsko Chausse Blvd., 1784 Sofia, Bulgaria

Received 2007 Apr 13, accepted 2007 Jul 14
Published online 2007 Dec 28

Key words quasars: individual: (3C 345) – techniques: photometric

We present the results of the blazar 3C 345 monitoring in Johnson-Cousins $BVRI$ bands for the period 1996–2006. We have collected 29 V and 43 R data points for this period; the BI light curves contain a few measurements only. The accuracy of our photometry is not better than 0.03 mag in the VR bands. The total amplitude of the variability obtained from our data is 2.06 mag in the V and 2.25 mag in the R band. 3C 345 showed periods of flaring activity during 1998/99 and 2001: a maximum of the blazar brightness was detected in 2001 February – 15.345 mag in the V and 14.944 mag in the R band. We confirm that during brighter stages 3C 345 becomes redder; for higher fluxes the colour index seems to be less dependent on the magnitude. The intra-night monitoring of 3C 345 in three consecutive nights in 2001 August revealed no significant intra-night variability; 3C 345 did not show evident flux changes over timescales of weeks around the period of the intra-night monitoring. This result supports the existing facts that intra-night variability is correlated with rapid flux changes rather than with specific flux levels.

1 Introduction

Blazars are a sub-class of active galactic nuclei (see the review paper of Angel & Stockman 1980). The most notable feature of blazars is their violent variability at all wavelengths on time scales from about an hour or less to years. It is now believed that the physical processes in relativistic jets are responsible for the observed behaviour of blazars (e.g. Schramm et al. 1993a; Wagner et al. 1995; Otterbein et al. 1998; Lobanov & Roland 2005).

The violent variability of blazars is very helpful in understanding their nature; so, they were targets of a number of monitoring campaigns like Hamburg Quasar Monitoring (HQM; Borgeest & Schramm 1994; Schramm et al. 1994a, 1994b) in the past and Whole Earth Blazar Telescope (WEBT) in the present days. In particular, the international coordinated programme WEBT proved to be very effective in obtaining blazar light curves of dense temporal coverage (e.g. Villata et al. 2006).

We started to monitor selected blazars with the 2.0-m telescope of the Rozhen National Astronomical Observatory (NAO), Bulgaria, in 1996 inspired by Dr. K.-J. Schramm and following the international collaborations MEGAPHOT (Schramm et al. 1993b) and Joint Optical Monitoring Programme of Quasars (JOMPQ; Schramm et al. 1994c). The blazar 3C 345 (1641+399, $z = 0.5928$) is among the most highly variable blazars in our list. Regular photometric monitoring of 3C 345 has been carried out since 1965; the historical light curve of the source was constructed and studied by Schramm et al. (1993a), Zhang et al. (1998) and Howard et al. (2004, hereafter H04). We present in this paper the results of our monitoring of the blazar 3C 345 for the period 1996–2006.

Another aim of this study is to present our results of the intra-night monitoring of 3C 345; note that the characteristics of 3C 345 intra-night variability are not well established. Kidger (1989) was the first one who drew attention to the intra-night variability of 3C 345: he detected flickering on time scales of hours with amplitudes of about 0.1–0.2 mag. Furthermore, Kidger & de Diego (1990) reported 0.47 B mag brightness drop in 13 minutes, whereas H04 detected no significant intra-night variability; H04 found that the occurrences of intra-night variability are correlated temporally with long-term optical activity of the objects studied. Thus, intra-night monitoring of 3C 345 was undertaken by us in order to shed more light on the intra-night variability characteristics of this source.

The paper is organized as follows. The observations and data reduction are described in Sect. 2. The photometry and resulting light curves are presented in Sect. 3. The results are discussed in Sect. 4. A brief summary of our results is presented in Sect. 5.

* Based on observations obtained with the 2-m and 50/70-cm telescopes of the Rozhen National Astronomical Observatory, and the 60-cm telescope of the Belogradchik Astronomical Observatory, which are operated by the Institute of Astronomy, Bulgarian Academy of Sciences, and with the 1.3-m telescope of the Skinakas Observatory, Crete, Greece; Skinakas Observatory is a collaborative project of the University of Crete, the Foundation for Research and Technology – Hellas, and the Max-Planck-Institut für Extraterrestrische Physik.

** Corresponding author: bmihov@astro.bas.bg

Table 1 Johnson-Cousins $BVRI$ magnitudes of stars #4 and #19 in the field of 3C 345.

Star	B	V	R	I
	σ_B	σ_V	σ_R	σ_I
#4	16.044	15.245	14.768	14.337
	0.017	0.007	0.006	0.011
#19	16.452	15.228	14.470	13.806
	0.016	0.006	0.006	0.014

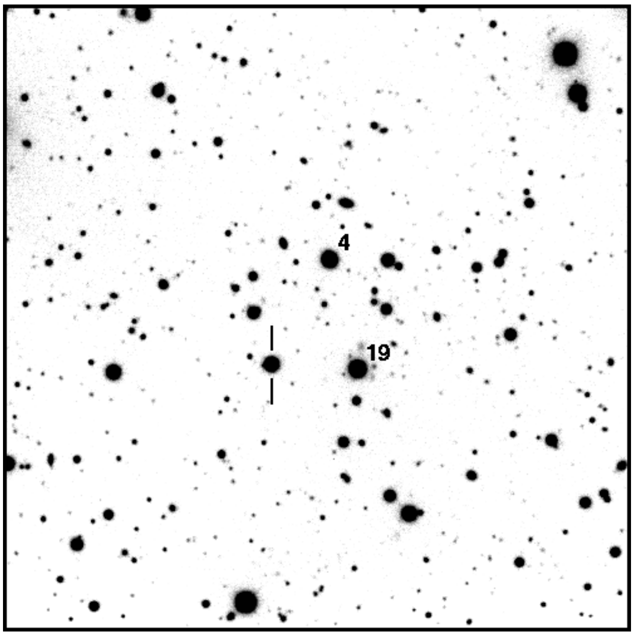

Fig. 1 The field (8.3×8.3 arcmin wide) containing the blazar 3C 345, reference star #19, and control star #4. This image was taken by AS at SO through the R filter; East is to the left, North is at the top.

2 Observations and data reduction

The observational data of 3C 345 were obtained using the 2.0-m Ritchey-Chrétien and the 0.5/0.7-m Schmidt telescopes of NAO, the 0.6-m Cassegrain telescope of the Belogradchik Astronomical Observatory (BAO), Bulgaria, and the 1.3-m Ritchey-Chrétien telescope of the Skinakas Observatory (SO), Crete, Greece. Standard Johnson-Cousins $BVRI$ filters were used in all observations. Focal reducers were occasionally used at NAO (FoReRo) and BAO. The following CCD cameras were used as detectors of the 2.0-m telescope of NAO: 375×242 SBIG ST-6, 1024×1024 Photometrics AT200, and 1340×1300 Princeton Instruments VersArray:1300B. The CCD cameras ST-6 and VersArray:1300B were used in single nights: 1996 August 12/13 and 2005 March 12/13, respectively. The 0.5/0.7-m telescope of NAO and the 0.6-m telescope of BAO were equipped with identical 1530×1020 SBIG ST-8 CCD cameras. The 1.3-m telescope of SO was equipped with 1024×1024 Photometrics CCD camera.

Multiple VR frames of the 3C 345 field were taken in each night allocated for the monitoring; BI frames were taken occasionally. Twilight flat field, zero exposure, and dark current frames were taken as well. Dark frames were taken when ST-6/8 CCD cameras were used and zero frames were taken in the case of the other cameras. The binning factor of the CCD cameras was changed depending on the observing conditions.

The intra-night monitoring of 3C 345 was performed at BAO by RB during three nights of 2001 August: 18/19, 19/20, and 20/21. The blazar was imaged through VRI filters for a period of about 3–4 hours each night; the exposures were 120 s for all passbands.

Reduction of the 3C 345 frames was done depending on the CCD camera used: ST-6/8 CCD data were dark subtracted and flat fielded using the camera software, whereas the data acquired by means of the other cameras were debiased and flat fielded using ESO-MIDAS package. The cosmic ray hits were cleaned and the individual frames were aligned and co-added using ESO-MIDAS. The frames obtained in the course of the intra-night monitoring were dark subtracted and flat fielded only.

3 Photometry and light curves

We used differential photometry technique to obtain the 3C 345 light curves in order to be independent of the photometric conditions. Field stars #4 and #19, calibrated by González-Pérez, Kidger & Martín-Luis (2001), were used as a control star and as a reference one, respectively (see Table 1 and Fig. 1). Stars #4 and #19 are designated as D and E, respectively, in Smith's et al. (1985) paper.

The flux measurements of all objects of interest were performed using the DAOPHOT package (Stetson 1987) run within ESO-MIDAS. Instrumental magnitudes were measured through a set of apertures with radii of $1/2/3 \times$ FWHM pixels; the sky background value was estimated in a centred annulus with an inner radius of $7 \times$ FWHM pixels and containing 1000 pixels. The calibrated magnitudes of 3C 345 were calculated relative to star #19 without taking into account the colour term in the transformation equations; the light curves of star #4 were obtained in the same way as the blazar ones and were used to estimate the accuracy of the photometry.

We adopted as final magnitudes the ones measured through $1 \times$ FWHM radius aperture – using this aperture the control star light curves show the smallest clipped standard deviation in all passbands. The 3σ clipping technique was used to eliminate the deviant data points – if such are present – in the control star light curve under the assumption of the control and reference star non-variability. The blazar data points corresponding to the eliminated control star points were also eliminated. We got a total of three V band and three R band data points removed from the light curves by this technique. The formal errors of the final blazar and control star magnitudes include the errors of the

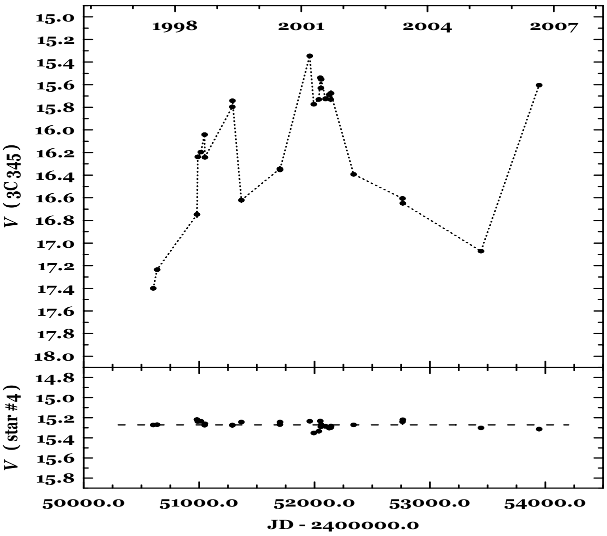

Fig. 2 V band light curves of the blazar 3C 345 and of control star #4. The dashed line represents the standard V band magnitude of star #4 (see Table 1). For most of the data points the error bars are smaller than the symbols.

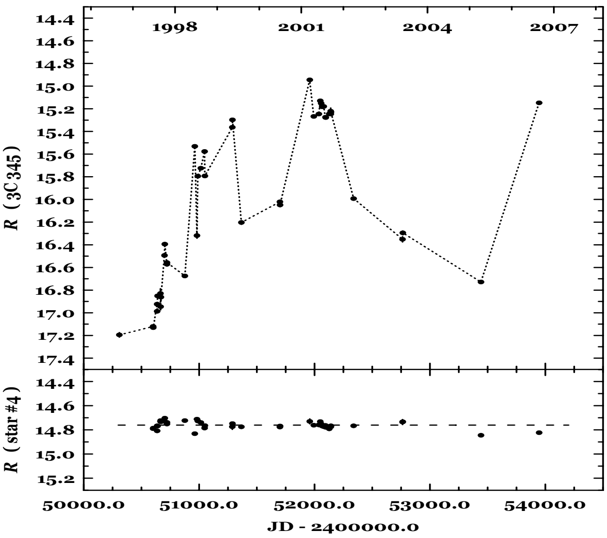

Fig. 3 The same as in Fig. 2, but for the R band.

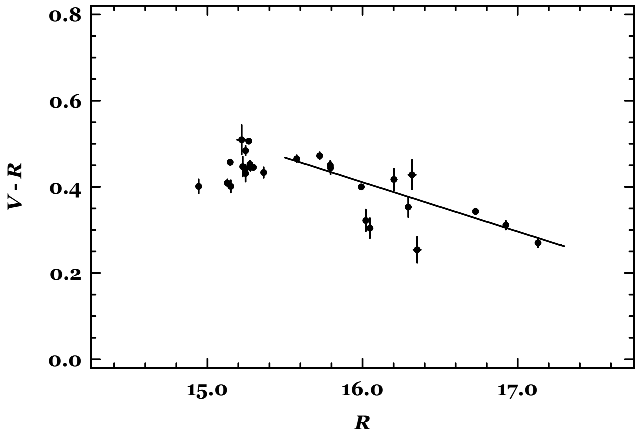

Fig. 4 Colour index $V - R$ plotted against the R magnitude. One can see that 3C 345 is redder when it is brighter; a weighted linear fit is overplotted. Note that for higher fluxes the colour index seems to be less dependent on the R magnitude.

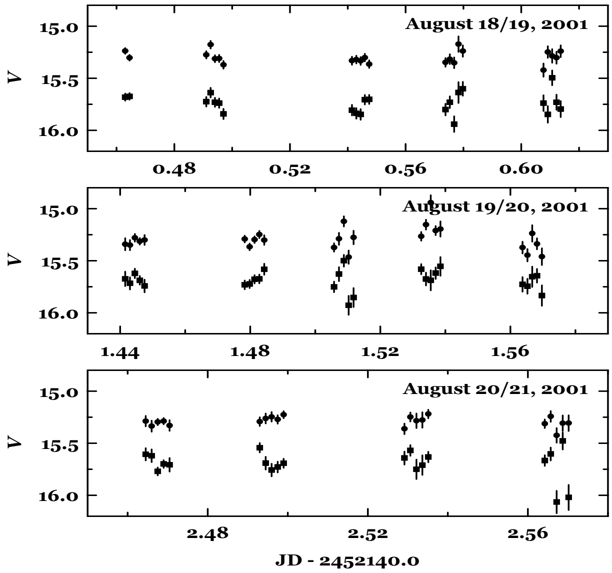

Fig. 5 Intra-night V light curves for three consecutive nights in 2001 August. Filled squares are the blazar magnitudes and filled circles those of star #4. No significant intra-night variability could be identified.

instrumental magnitudes as returned by DAOPHOT and the errors of the standard magnitudes of reference star #19.

The nightly weighted mean VRI magnitudes of the blazar were obtained from the intra-night data and added to the long-term light curve. The errors of the weight-mean magnitudes were calculated taking the larger between (i) the error estimate based on the individual magnitude errors, and (ii) the error estimate based on the scatter of magnitudes involved in averaging about their weight-mean value.

The measured light curves of 3C 345 are tabulated in Table 2 (B band), Table 3 (V band), Table 4 (R band), and Table 5 (I band) and are presented in Fig. 2 (V band) and in Fig. 3 (R band). The final light curves contain a total of 4 data points in the B band, 29 in the V band, 43 in the R band, and 6 in the I band. The Universal Time is taken at the middle of each $(B)VR(I)$ observing set; Julian Days are geocentric. The telescopes used are abbreviated in a self-explanatory way in the tables. The suffix FR used in the tables means that a focal reducer has been employed.

Note that due to the small number of BI data points throughout the paper the computed statistical parameters of the blazar and the control star BI light curves are approximate and should be used with care.

4 Discussion

4.1 Accuracy of the photometry

The mean $BVRI$ magnitudes of the control star are 16.090, 15.272, 14.761, and 14.355, respectively. These magnitudes

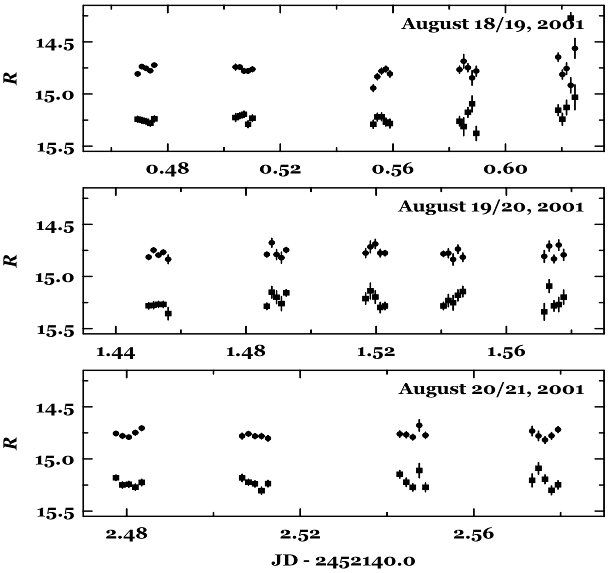

Fig. 6 The same as in Fig. 5, but for the R band.

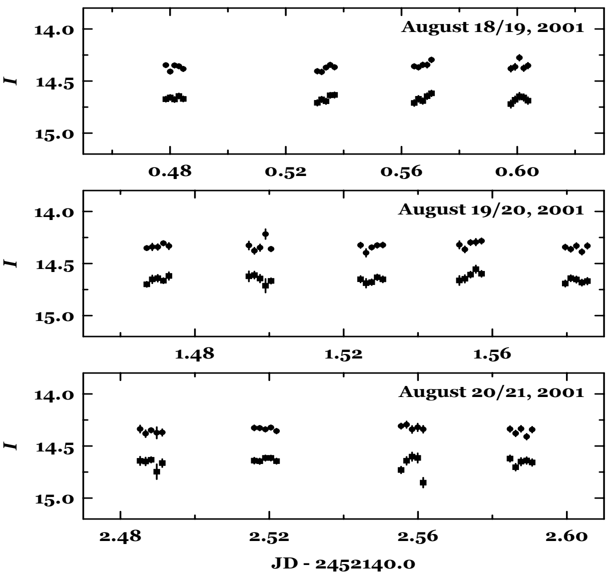

Fig. 7 The same as in Fig. 5, but for the I band.

are in good agreement with those presented in Table 1. Consequently, the systematic errors introduced due to the colour term skipping in magnitude calculation are rather negligible.

The standard deviations of the control star $BVRI$ light curves are 0.014 mag, 0.033 mag, 0.031 mag, and 0.013 mag, respectively. We found that the standard deviations of the VR bands are larger than the mean formal errors of the calibrated 3C 345 VR magnitudes by factors of 2.7 and 2.1, respectively. Based on the scatter of the control star magnitudes, we conclude that the accuracy of our VR photometry is not better than 0.03 mag; actually, the accuracy should be worse because control star #4 was brighter than the blazar during the monitoring period.

4.2 $V - R$ colour index

The $V - R$ colour index dependence on the R magnitude is plotted in Fig. 4. Using a weighted linear fit in the interval of the R magnitudes fainter than $R_0 = 15.5$ mag, we got the following anti-correlation:

$$V - R = (2.242 \pm 0.226) - (0.114 \pm 0.014)R,$$

with a correlation coefficient $r = -0.718$, i.e. during the brighter stages 3C 345 becomes redder. The cut-off magnitude R_0 was introduced by us as the dependence of the colour index on the flux seems to be less pronounced for brighter stages of the source (see Fig. 4). The value of R_0 was determined by eye and should be considered as approximate because the region where the "colour index–magnitude" relation changes its slope is not well covered with data points. Schramm's et al. (1993a) Fig. 4 could be regarded as a support in favour of the cut-off magnitude introduction. However, the presence of a cut-off magnitude is not so obvious inspecting Zhang's et al. (2000) "colour index–magnitude" figures.

Fitting over the entire range of magnitudes, we got

$$V - R = (1.762 \pm 0.179) - (0.085 \pm 0.011)R,$$

with a correlation coefficient $r = -0.734$. In this case the fitted coefficients are in good agreement with those obtained by Schramm et al. (1993a) who used 1991/92 data and by Zhang et al. (2000) who used 1991/92 and 1996/97 data.

4.3 Intra-night variability

The VRI intra-night monitoring light curves are presented in Figs. 5, 6, and 7, respectively. No significant intra-night variability patterns or gradients could be identified by eye. To quantify the intra-night variability of 3C 345 we used the variability parameter C proposed by Jang & Miller (1997). Given the standard deviations of the blazar and of the control star light curves, $\sigma(\text{3C 345})$ and $\sigma(\text{star \#4})$, respectively, the variability parameter is defined as

$$C = \frac{\sigma(\text{3C 345})}{\sigma(\text{star \#4})}.$$

If $C > C_0$ ($C_0 = 2.576$), then the source is considered variable at the 99% confidence level. Note that for the period of the intra-night monitoring the blazar and the control star were of compatible brightness; so, the parameter C cannot be a subject to significant systematic errors due to the different flux densities of the objects considered. A further complication of the above simple criterion for variability could be considered when multi-colour observations are available: one could expect correlated variations in different passbands to be observed, i.e. the median value of C over all passbands for a given night to be larger than C_0. The criterion $C > C_0$ was met in the first night ($C = 2.7$ in the R band) and in the third night ($C = 2.9$ in the V band) of the intra-night monitoring. However, the computed median values of C over the VRI bands are 1.6, 1.0, and 2.1 for the consecutive nights, respectively. So, we could conclude that

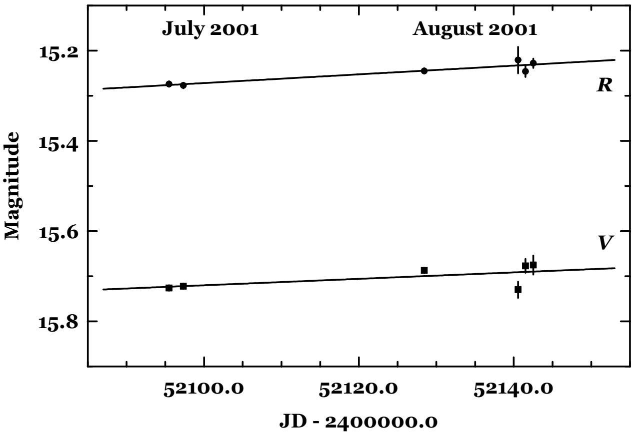

Fig. 8 VR light curves of 3C 345 for the period 2001 July/August. The weighted linear fits used to estimate the light curve gradients are overplotted.

for the period of the intra-night monitoring 3C 345 did not show significant intra-night variations.

The gradients of the VR long-term light curves for the period 2001 July/August, i.e. around the dates of the intra-night monitoring, are -0.32 ± 0.07 and -0.29 ± 0.06 mag per year, respectively; the weight-mean magnitudes computed for the nights of intra-night monitoring were also included in the gradient calculation. The gradients were estimated using a weighted linear fit to the 2001 July/August VR data points; this part of the light curves and the corresponding fits are presented in Fig. 8. The standard deviations of the VR long-term light curves for the period 2001 July/August are 0.026 and 0.023 mag, respectively; the same data points were used as in the gradient calculation. Therefore, 3C 345 did not show significant flux changes over timescales of weeks around the period of the intra-night monitoring[1]. This result is in agreement with H04's conclusion that the presence of intra-night variability occurs more frequently while the flux is changing. We observed no evident intra-night variability while the source was in a bright stage. This supports H04's finding of no correlation between the presence/absence of intra-night variability and the flux level of sources; the intra-night variability observations used by H04 were performed when 3C 345 was fainter compared to the period of our intra-night observations.

4.4 Long-term variability

One could see from Figs. 2 and 3 that 3C 345 was in a bright stage during 1998/99 and 2001, i.e. the blazar showed periods of flaring activity. In particular, a maximum in the 3C 345 brightness was detected in 2001 February: 15.345 mag in V and 14.944 mag in R – values compatible with the 1991/92 outburst ones (see Schramm et al. 1993a). Another flare of brightness could be seen at the end of July 2006. Unfortunately, our measurements are too sparse to be able to follow the individual flares accurately.

The total amplitude of variability detected by us for the period 1996–2006 is 1.40 mag in B, 2.06 mag in V, 2.25 mag in R, and 1.00 mag in I. One should keep in mind the very different sampling of the BI and VR light curves.

The high brightness level observed during 2001 is in agreement with Zhang's et al. (1998) prediction that the following large outburst of 3C 345 should be at its maximum around 2002 January. This prediction was made on the basis of the period of 10.1 ± 0.8 years found by them.

5 Summary

We have presented the results of the blazar 3C 345 monitoring in Johnson-Cousins $BVRI$ bands for the period 1996–2006. The total amplitude of variability obtained out of our data is 2.06 mag in the V band and 2.25 mag in the R band. 3C 345 showed periods of flaring activity during 1998/99 and 2001: a maximum of the blazar brightness was detected in 2001 February – 15.345 mag in V and 14.944 mag in R. The intra-night monitoring of 3C 345 in three consecutive nights in 2001 August did not reveal significant intra-night variability.

Our measurements should be considered as a part of the international efforts aimed to obtain a dense temporal coverage of the light curve of 3C 345. The availability of well sampled multi-frequency light curves is of importance to reveal the source of the blazar activity (e.g. Schramm et al. 1993a; Lobanov & Roland 2005).

The tabulated long-term $BVRI$ and intra-night VRI light curves of 3C 345 and of star #4 can be found at www.astro.bas.bg/∼bmihov.

Acknowledgements. The authors are thankful to the anonymous referee whose constructive suggestions and criticism helped us to improve this paper. The authors are thankful to Prof. Y. Papamastorakis and I. Papadakis for the telescope time at Skinakas Observatory. The European Southern Observatory Munich Image Data Analysis System (ESO-MIDAS) is developed and maintained by the European Southern Observatory. The design and manufacturing of the the Focal Reducer Rozhen (FoReRo) were performed in the workshop of the Institute of Astronomy, Bulgarian Academy of Sciences, with financial support by the Ministry of Education and Science, Bulgaria (contract F-482/2201). The SBIG ST-8 model CCD camera at the Belogradchik Astronomical Observatory is provided by the Alexander von Humboldt Foundation, Germany. We also acknowledge the support by UNESCO-ROSTE for the regional collaboration.

References

Angel, J.R.P., Stockman, H.S.: 1980, ARA&A 18, 321
Borgeest, U., Schramm, K.-J.: 1994, A&A 284, 764
González-Pérez, J.N., Kidger, M.R., Martín-Luis, F.: 2001, AJ 122, 2055

[1] One could see that 2001 July/August part of the long-term light curves is not well sampled; so, our conclusion should be used with some caution: its truthfulness depends on the blazar behaviour during the gaps in our monitoring.

Table 2 B band light curves of the blazar 3C 345 and of control star #4.

Civil Date	UT	JD − 2400000	B (3C 345)	B (star #4)	Telescope
1997 Jul 05	22:39	50635.4438	17.327 ± 0.017	16.077 ± 0.017	ROZ2.0
2001 May 07	22:36	52037.4417	16.075 ± 0.018	16.096 ± 0.018	SKI1.3
2001 May 08	00:18	52037.5122	16.078 ± 0.017	16.106 ± 0.017	SKI1.3
2006 Jul 29	19:14	53946.3012	15.928 ± 0.013	16.080 ± 0.017	ROZ2.0

Table 3 V band light curves of the blazar 3C 345 and of control star #4.

Civil Date	UT	JD − 2400000	V (3C 345)	V (star #4)	Telescope
1997 Jun 03	01:07	50602.5464	17.401 ± 0.007	15.272 ± 0.006	ROZ2.0
1997 Jul 05	22:39	50635.4438	17.235 ± 0.008	15.269 ± 0.006	ROZ2.0
1998 Jun 17	00:23	50981.5162	16.747 ± 0.025	15.218 ± 0.010	BEL0.6
1998 Jun 23	22:59	50988.4578	16.238 ± 0.009	15.238 ± 0.007	ROZ2.0
1998 Jul 20	22:00	51015.4168	16.196 ± 0.006	15.235 ± 0.006	ROZ2.0
1998 Aug 20	20:31	51046.3545	16.041 ± 0.006	15.274 ± 0.006	ROZ2.0
1998 Aug 23	20:05	51049.3368	16.242 ± 0.007	15.260 ± 0.007	ROZ2.0
1999 Apr 19	00:27	51287.5188	15.796 ± 0.009	15.275 ± 0.020	ROZ2.0
1999 Apr 20	01:54	51288.5795	15.742 ± 0.004	15.273 ± 0.004	ROZ2.0
1999 Jul 06	22:52	51366.4527	16.620 ± 0.019	15.243 ± 0.009	BEL0.6
2000 Jun 03	22:05	51699.4201	16.343 ± 0.020	15.268 ± 0.012	BEL0.6FR
2000 Jun 04	21:50	51700.4097	16.352 ± 0.017	15.243 ± 0.010	BEL0.6FR
2001 Feb 17	01:53	51957.5784	15.345 ± 0.009	15.235 ± 0.010	ROZ0.5/0.7
2001 Mar 24	22:22	51993.4318	15.773 ± 0.003	15.352 ± 0.003	ROZ2.0FR
2001 May 07	22:36	52037.4417	15.730 ± 0.008	15.334 ± 0.008	SKI1.3
2001 May 20	01:16	52049.5528	15.538 ± 0.006	15.233 ± 0.006	SKI1.3
2001 May 25	00:16	52054.5115	15.630 ± 0.006	15.290 ± 0.006	SKI1.3
2001 May 27	21:26	52057.3933	15.552 ± 0.008	15.269 ± 0.010	ROZ0.5/0.7
2001 Jul 04	23:37	52095.4844	15.726 ± 0.006	15.285 ± 0.006	SKI1.3
2001 Jul 06	19:49	52097.3260	15.722 ± 0.006	15.286 ± 0.006	SKI1.3
2001 Aug 06	22:46	52128.4490	15.687 ± 0.006	15.303 ± 0.006	SKI1.3
2001 Aug 19	01:08	52140.5469	15.730 ± 0.018	15.299 ± 0.012	BEL0.6
2001 Aug 20	00:22	52141.5156	15.677 ± 0.015	15.293 ± 0.017	BEL0.6
2001 Aug 21	00:39	52142.5273	15.675 ± 0.021	15.283 ± 0.010	BEL0.6
2002 Mar 05	23:31	52339.4796	16.392 ± 0.003	15.271 ± 0.003	ROZ2.0FR
2003 May 02	21:12	52762.3837	16.606 ± 0.019	15.240 ± 0.025	ROZ0.5/0.7
2003 May 05	21:16	52765.3858	16.648 ± 0.015	15.220 ± 0.011	ROZ0.5/0.7
2005 Mar 12	23:58	53442.4989	17.072 ± 0.004	15.301 ± 0.003	ROZ2.0
2006 Jul 29	19:14	53946.3012	15.604 ± 0.005	15.313 ± 0.005	ROZ2.0

Howard, E.S., Webb, J.R., Pollock, J.T., Stencel, R.E.: 2004, AJ 127, 17 (H04)

Jang, M., Miller, H.R.: 1997, AJ 114, 565

Kidger, M.R.: 1989, A&A 226, 9

Kidger, M.R., de Diego, J.A.: 1990, A&A 227, L25

Lobanov, A.P., Roland, J.: 2005, A&A 431, 831

Otterbein, K., Krichbaum, T.P., Kraus, A., Lobanov, A.P., Witzel, A., Wagner, S.J., Zensus, J.A.: 1998, A&A 334, 489

Schramm, K.-J., Borgeest, U., Camenzind, M., et al.: 1993a, A&A 278, 391

Schramm, K.-J., Borgeest, U.: 1993b, in: J. Surdej, D. Fraipont-Caro, E. Gosset, S. Refsdal, M. Remy (eds.), *Gravitational Lenses in the Universe*, LIAC 93, p. 161

Schramm, K.-J., Borgeest, U., Kühl, D., von Linde, J., Linnert, M.D.: 1994a, A&AS 104, 473

Schramm, K.-J., Borgeest, U., Kühl, D., von Linde, J., Linnert, M.D., Schramm, T.: 1994b, A&AS 106, 349

Schramm, K.-J., Bian, Y. L., Borgeest, U., Swings, J.P.: 1994c, Publ. Beijing Astron. Obs. 25, 1

Smith, P.S., Balonek, T.J., Heckert, P.A., Elston, R., Schmidt, G.D.: 1985, AJ 90, 1184

Stetson, P.B.: 1987, PASP 99, 191

Villata, M., Raiteri, C.M., Balonek, T.J., et al.: 2006, A&A 453, 817

Wagner, S.J., Camenzind, M., Dreissigacker, O., et al.: 1995, A&A 298, 688

Zhang, X., Xie, G.Z., Bai, J.M.: 1998, A&A 330, 469

Zhang, X., Xie, G.Z., Bai, J.M., Zhao, G.: 2000, Ap&SS 271, 1

Table 4 R band light curves of the blazar 3C 345 and of control star #4.

Civil Date	UT	JD − 2400000	R (3C 345)	R (star #4)	Telescope
1996 Aug 12	23:08	50308.4637	17.195 ± 0.020	...	ROZ2.0
1997 Jun 01	22:48	50601.4500	17.121 ± 0.007	14.790 ± 0.006	ROZ2.0
1997 Jun 03	01:07	50602.5464	17.131 ± 0.007	14.786 ± 0.006	ROZ2.0
1997 Jul 05	22:39	50635.4438	16.924 ± 0.006	14.808 ± 0.006	ROZ2.0
1997 Jul 06	21:27	50636.3934	16.987 ± 0.007	14.767 ± 0.006	ROZ2.0
1997 Jul 10	19:17	50640.3032	16.851 ± 0.007	14.768 ± 0.006	ROZ2.0
1997 Aug 03	23:14	50664.4680	16.830 ± 0.043	14.730 ± 0.011	BEL0.6
1997 Aug 04	21:31	50665.3965	16.946 ± 0.028	14.723 ± 0.008	BEL0.6
1997 Aug 07	22:44	50668.4474	16.862 ± 0.033	14.733 ± 0.009	BEL0.6
1997 Sep 07	19:42	50699.3210	16.494 ± 0.006	14.728 ± 0.006	ROZ2.0
1997 Sep 10	19:42	50702.3212	16.394 ± 0.009	14.703 ± 0.006	ROZ2.0
1997 Sep 28	18:10	50720.2567	16.572 ± 0.014	14.738 ± 0.007	BEL0.6
1997 Sep 29	18:27	50721.2690	16.557 ± 0.016	14.752 ± 0.007	BEL0.6
1998 Mar 04	01:09	50876.5479	16.675 ± 0.006	14.723 ± 0.006	ROZ2.0
1998 May 28	23:43	50962.4882	15.531 ± 0.010	14.832 ± 0.008	BEL0.6FR
1998 Jun 17	00:23	50981.5162	16.319 ± 0.023	14.712 ± 0.010	BEL0.6
1998 Jun 23	22:59	50988.4578	15.794 ± 0.012	14.727 ± 0.009	ROZ2.0
1998 Jul 20	22:00	51015.4168	15.724 ± 0.006	14.739 ± 0.006	ROZ2.0
1998 Aug 20	20:31	51046.3545	15.576 ± 0.006	14.785 ± 0.006	ROZ2.0
1998 Aug 23	20:05	51049.3368	15.792 ± 0.007	14.765 ± 0.006	ROZ2.0
1999 Apr 19	00:27	51287.5188	15.363 ± 0.008	14.774 ± 0.022	ROZ2.0
1999 Apr 20	01:54	51288.5795	15.297 ± 0.004	14.748 ± 0.005	ROZ2.0
1999 Jul 06	22:52	51366.4527	16.203 ± 0.017	14.775 ± 0.009	BEL0.6
2000 Jun 03	22:05	51699.4201	16.021 ± 0.015	14.777 ± 0.009	BEL0.6FR
2000 Jun 04	21:50	51700.4097	16.048 ± 0.016	14.768 ± 0.009	BEL0.6FR
2001 Feb 17	01:53	51957.5784	14.944 ± 0.013	14.730 ± 0.020	ROZ0.5/0.7
2001 Mar 24	22:22	51993.4318	15.267 ± 0.003	14.762 ± 0.003	ROZ2.0FR
2001 May 07	22:36	52037.4417	15.246 ± 0.008	14.759 ± 0.007	SKI1.3
2001 May 20	01:16	52049.5528	15.129 ± 0.006	14.732 ± 0.006	SKI1.3
2001 May 27	21:26	52057.3933	15.151 ± 0.011	14.751 ± 0.006	ROZ0.5/0.7
2001 Jun 05	23:27	52066.4771	15.182 ± 0.006	14.768 ± 0.006	SKI1.3
2001 Jun 19	20:40	52080.3608	15.179 ± 0.006	14.773 ± 0.006	SKI1.3
2001 Jul 04	23:38	52095.4844	15.274 ± 0.006	14.763 ± 0.006	SKI1.3
2001 Jul 06	19:50	52097.3260	15.277 ± 0.006	14.779 ± 0.006	SKI1.3
2001 Aug 06	22:46	52128.4490	15.245 ± 0.006	14.792 ± 0.006	SKI1.3
2001 Aug 19	01:08	52140.5469	15.221 ± 0.029	14.769 ± 0.010	BEL0.6
2001 Aug 20	00:22	52141.5156	15.246 ± 0.012	14.775 ± 0.008	BEL0.6
2001 Aug 21	00:39	52142.5273	15.228 ± 0.010	14.767 ± 0.007	BEL0.6
2002 Mar 05	23:31	52339.4796	15.992 ± 0.003	14.767 ± 0.003	ROZ2.0FR
2003 May 02	21:12	52762.3837	16.352 ± 0.023	14.735 ± 0.021	ROZ0.5/0.7
2003 May 05	21:16	52765.3858	16.295 ± 0.017	14.733 ± 0.013	ROZ0.5/0.7
2005 Mar 12	23:58	53442.4989	16.729 ± 0.004	14.845 ± 0.003	ROZ2.0
2006 Jul 29	19:14	53946.3012	15.147 ± 0.004	14.823 ± 0.009	ROZ2.0

Table 5 I band light curves of the blazar 3C 345 and of control star #4.

Civil Date	UT	JD − 2400000	I (3C 345)	I (star #4)	Telescope
2000 Jun 04	21:50	51700.4097	15.548 ± 0.018	14.364 ± 0.015	BEL0.6FR
2001 May 07	22:36	52037.4417	14.704 ± 0.015	14.361 ± 0.015	SKI1.3
2001 Aug 19	01:08	52140.5469	14.668 ± 0.006	14.361 ± 0.007	BEL0.6
2001 Aug 20	00:22	52141.5156	14.650 ± 0.007	14.335 ± 0.006	BEL0.6
2001 Aug 21	00:39	52142.5273	14.650 ± 0.010	14.343 ± 0.006	BEL0.6
2006 Jul 29	19:14	53946.3012	14.547 ± 0.010	14.368 ± 0.010	ROZ2.0

