Chin. J. Astron. Astrophys. Vol. 4, No. 2, (2004) 133–142
(http://www.chjaa.org or http://chjaa.bao.ac.cn)

Chinese Journal of
Astronomy and
Astrophysics

Optical Photometric Observations of γ-Ray Loud Blazars *

Jun-Hui Fan[1], O. M. Kurtanidze[2,3,4], M. G. Nikolashvili[2], A. C. Gupta[5],
Jiang-Shui Zhang[1] and Yu-Hai Yuan[1]

[1] Center for Astrophysics, Guangzhou University, Guangzhou 510400; fjh@gzhu.edu.cn
[2] Abstumani Observatory, 383762 Abstumani, Republic of Georgia
[3] Landessternwarte Heidelberg-Koenigshtuhl, D-69117, Heidelberg, Germany
[4] Astrophysikalisches Institute Potsdam, An der Sternwarte 16, D-14482, Germany
[5] Harish-Chandra Research Institute, Chhatnag Road, Jhunsi, Allahabad – 211019, India; agupta@mri.ernet.in

Received 2003 June 30; accepted 2004 January 5

Abstract We report results of our optical photometric observations of ten gamma-ray loud blazers, namely: 0219+428 (3C66A), PKS 0420–014 (OA 129), S5 0716+714, 0754+100 (OI 090.4), 0827+243 (OJ248), 1652+398 (Mrk 501), 2200+420 (BL Lacertae), 2230+114 (CTA 102), 2251+158 (3C 454.3) and 2344+514. The observations were carried out in September–October, 2000 using the 70 cm optical telescope at Abstumani Observatory, Georgia. We found intra-day variations in 0420–014, S5 0716+714, BL Lacertae and CTA 102. A variation of 0.3 magnitude over a time scale of about 3 hours was observed in the R passband in BL Lacertae on JD 2451827. We did not detect any variation in 3C 66A, Mrk 501, or 3C 454.3 during our observations. Nor did we detect any clear evidence of variation in 1ES 2344+514 during our two weeks' observing run of the TeV gamma-ray source.

Key words: galaxies: active — Blazars: individual: PKS 0219+428 (3C 66A), PKS 0420–014 (OAl29), S5 0716+714, 0754+100 (OI090.4), 0827+243 (OJ248), 1652+398 (Mrk 501), 2200+420 (BL Lacertae), 2230+114 (CTAl02), 2251+158 (3C 454.3), and 1ES 2344+514 — galaxies: photometry

1 INTRODUCTION

Over the years, two major classes of AGNs have been established. Roughly 85% of the AGNs are radio-quiet, with $F_{\rm radio} \leq F_{\rm optical}$. The remaining $\sim 15\%$ are radio loud, of which a small subset shows often flux variability at almost all wavelengths and the emission is strongly polarized. Such AGNs are called blazars; their radiation at all wavelengths is predominantly non-thermal (e.g., Tagliaferri et al. (2003) and references therein). Optical Photometric observations of blazars are important for constructing their light curves and studying their flux

* Supported by the National Natural Science Foundation of China.

variation behavior on different time scales ranging from minutes to years.

More than 60 AGNs were detected with EGRET on GRO. They show some common observational properties: Flat radio spectrum, violent variation, and a two-component structure in the spectral energy distribution with the lower frequency component from synchrotron emission and the higher from inverse Compton process, for which the seed photons are yet unclear (e.g., Comastri et al. 1997, and references therein). Various models for the γ-ray emission from AGNs have been proposed. Generally, they are of two kinds: leptonic and hadronic models. In the leptonic model, high energy γ-rays are produced by inverse Compton scattering of high energy electrons in a soft photon field. The soft photons may be emitted from a nearby accretion disk (Dermer et al. 1992; Zhang & Cheng 1997) or they may arise from disk radiation reprocessed in some region of the AGN (e.g., a broad emission line region) (Sikora et al. 1994), or they may come from synchrotron emission in a jet (Maraschi et al. 1992). In the hadronic model, high energy γ-rays are produced by synchrotron emission from ultra relativistic electrons and positrons created in a proton-induced cascade (PIC) (Mannheim & Biermann 1992; Cheng & Ding 1994). TeV radiation has been observed in some X-ray-selected BL Lac objects (XBLs), for example Mrk 421 (Punch et al. 1992), Mrk 501 (Quinn et al. 1996), 1ES 2344+514 (Catanese et al. 1998), PKS 2155–304 (Chadwick et al. 1999), and 1ES 1959+650 (Aharonian et al. 2003).

Gamma-ray flares are also found correlated with flares in lower energy bands, e.g., the 1996 Gev/X-ray flares in 3C 279 (McHardy 1996), the Gev/optical flares in 1406–076 (Wagner et al. 1995), the TeV flare (Gaidos et al. 1996) and the similar optical flare in Mrk 421 (Xie et al. 1998).

Observations show that the gamma-ray sources vary over time scales of hours to months in the gamma-ray regions, which set some constraints on the basic parameters of their source (e.g., Cheng et al. 1999; Fan et al. 1999; Mattox et al. 1997) The time scales in the gamma-ray bands are about the same as in the optical and X-ray bands. So, the short time scales detected in the lower energy bands can be used to constrain the basic parameters of the gamma-ray loud sources as was done by Dondi & Ghisellini (1995), Cheng et al. (1999), Fan et al. (1999)and Fan & Cheng (2001). Therefore, optical monitoring is important for the understanding of the physical process of the sources not only in the optical band itself but also in other bands.

Blazars have been monitored at the Yunnan Astronomical Observatory (YAO), Shanghai Astronomical Observatory (ShAO) of China (e.g., Dai et al. 2001; Cheng et al. 2002; Xie et al. 2002; Fan et al. 1997, 1998a, b, c; Fan & Cheng 2001; Qian et al. 2002; Qian & Tao 2003), Observatory of Physical Research Laboratory at Gurushikhar, Mount Abu, India (Gupta et al. 2002), Torino Observatory and Mt. Maidanak Observatory (Ciprini et al. 2003). Since 1997, some blazars have been monitored at the Abstumani observatory, Gorgia (e.g., Nikolashvili & Kurtanidze 2003; Kurtanidze & Nikolashvili 2002a, b, c, 2003). Some authors have made interesting investigations of the blazars (Efimov et al. 2002; Hanski et al. 2002; Romero et al. 2000, 2002; Massaro et al. 2003; Rector et al. 2003; Clements et al. 2003, and reference therein).

In September–October, 2000, we monitored some gamma-ray loud blazars with the 70-cm telescope of Abstumani Observatory, Georgia. In this paper, we present our observational and analytic results. Section 2 describes the observations and data reduction, Sect. 3 shows our results, Sect. 4 gives a discussion and our conclusions.

2 OBSERVATIONS AND DATA REDUCTION

Abstumani Observatory is located at the top of Mount Kanobili in the South West part of Georgia. Mount Kanobili is 1700 meters above the sea level. Its longitude and latitude are 41.8051° E and +42.8254°. The weather and seeing conditions are excellent (about 130 nights per year, 30% nights have seeing better than 1 arcsec). The mean night sky brightness is $B = 22.0$, $V = 21.2$, $R = 20.6$, and $I = 19.8$.

The observations were carried out with a Peltier cooled ST-6 CCD detector attached to the Newtonian focus of the 70-cm meniscus telescope. The ST-6 CCD detector has a TC 241 CCD chip (375 × 242 pixels, pixel size $23 \times 27\,\mu\mathrm{m}^2$, maximum quantum efficiency 0.7 at 675 nm). The entire CCD chip covers a field of $14.9 \times 10.7\,\mathrm{arcmin}^2$. The read out time of an image frame is 37 seconds. Observations were made using glass-combination filters. These filters matched well the standard B, V (Johnson) and R_C, I_C (Cousins) passbands (e.g., Kurtanidze & Nikolashvili 1999). Initial processing of image frames (bias correction, flat fielding, cosmic rays removal, ... etc.) and processing (photometry of image frames) were carried out using standard routines in the IRAF, MIDAS and STARLINK software on a Pentium PC (Linux Pentium III computers). Differential photometry of blazars was done using local photometric standard stars in the blazar field. Data of standard stars in blazars field are given in Table 2 (Table 2 is available in electronic form (see *http://www.chjaa.org/2004/...*).

We determined the differential magnitudes between the target (O) and the comparison standard (S_1) and between the standards (S_1, S_2, etc.). When there are more than two standard stars in the field, we calculated their mutual differential magnitudes and then determine their deviations. We then chose the two standard stars which show minimum deviation as our comparison stars, S_1 and S_2. The differential light curve $S_1 - S_2$ is a measure of the observational uncertainties and the intrinsic variability of the stars. The variability of the target object is investigated by means of the variability parameter, C, introduced by Romero et al. (1999, see also Cellone et al. (2000); Fan et al. (2001)). To do so, we in turn determine the scatter of the differential magnitudes $O - S_1$ and $S_1 - S_2$, $\sigma_{(O-S_1)}$ and $\sigma_{(S_1-S_2)}$, then the variability parameter C is expressed as $\frac{\sigma_{(O-S_1)}}{\sigma_{(S_1-S_2)}}$. If $C > 3$, then the target is taken to be variable.

The rms errors are calculated from the two standard stars using the the following equation:

$$\sigma = \sqrt{\frac{\Sigma(m_i - \overline{m})^2}{N-1}},$$

where $m_i = (m_{S_1} - m_{S_2})_i$ is the differential magnitude of stars S_1 and S_2 while $\overline{m} = \overline{m_{S_1} - m_{S_2}}$ is the differential magnitude averaged over the entire data set, and N is the number of observations on the given night. The results are given in Table 3 for the filters B, V, R and I. Column (1) gives the source name, Column (2) the Julian Date, Column (3) the magnitude, Column(4) the uncertainty (Table 3 is available in electronic form (see *http://www.chjaa.org/2004/...*). The R light curves are shown in the relevant Figures.

3 RESULTS

Some objects have shown variation during our observations. The detailed results of individual sources now follow.

0219+428, 3C66A It is a variable object. A rapid decline of 1.2 mag in 6 days was observed by Takalo et al. (1992). Variations over two magnitudes in one year were found by Kurtanidze & Nikolashvili (2002c). Different properties for the color and brightness have been found in this source. Takalo et al. (1992) found that the spectral index was considerably flat when the source was in its bright state. No clear correlation was found between the color index and magnitude in the long near-infrared data (Fan & Lin 1999). Lainela et al. (1999) found a possible 65-day period in the optical light curve in the observations from 1993 to 1998. We observed the object in R band on 2000 September 29 and October 5, and detected no clear variations.

PKS 0420–014, OA 129 This is a strongly variable quasar in the optical band. A light curve from 1969 April to 1986 January was given in Webb et al. (1988). Variations over time scales from a few to about 20 days were detected in the source. Wagner (1995) reported fast flux variations with time scale of the order of 1–10 days. Villata (1997) observed a fall of 2.64 mag over 40 days from 1995 September 15 to October 15, as well as a short time scale (40 min) variability of 0.12 mag. Variation over similar short time scale was also noticed by Xie et al. (2001). They detected a fall of 0.62 mag within 49 minutes.

In our observation period from JD 2451820 to JD 2451825, it showed intra-day variation. A fall of 0.42 mag in the R band from $R = 15.52$ mag to $R = 15.94$ mag was detected between JD 2451823.5 and JD 2451824.6 (see Table 2 and Fig. 1), which suggests a doubling time of $\Delta t_D = 2.85$ days. It is consistent with the time scale suggested by Wagner (1995). For the comparison stars, we found the magnitude differentials in the I band between star 1 and the rest of comparison stars; specifically, $\langle S_2 - S_1 \rangle = 0.65 \pm 0.00$, $\langle S_3 - S_1 \rangle = 0.72 \pm 0.00$, $\langle S_4 - S_1 \rangle = 2.72 \pm 0.01$, $\langle S_5 - S_1 \rangle = 2.08 \pm 0.01$, $\langle S_6 - S_1 \rangle = 2.50 \pm 0.00$, $\langle S_7 - S_1 \rangle = 2.67 \pm 0.01$, $\langle S_8 - S_1 \rangle = 3.13 \pm 0.01$, and $\langle S_9 - S_1 \rangle = 3.16 \pm 0.00$.

S5 0716+714 S5 0716+714 is classified as a BL Lacertae object. A large amplitude variation of 3.3 mag based on a long time light curve, was noticed by Biermann et al. (1981). A burst with a duration of 6 hours was detected on 1995 January 8 (Qian, Tao & Fan 2002; Raiteri et al. 2003). Intra-day variations were also found in the radio band (Quirrenbach et al. 1992).

During the period JD 2451825–JD 2451834, this source showed brightness fluctuations. A fall of 0.7 magnitudes over a time scale of 3.1 days followed by a brightness increase of of 0.73 mag over a time scale of 3.0 days is clearly shown in Fig. 2, suggesting resepctive doubling time scales of 4.79 days and 4.35 days. It is interesting that the falling and rising doubling time is quite similar for this object, we can take the average, 4.57 days as the doubling time for this source.

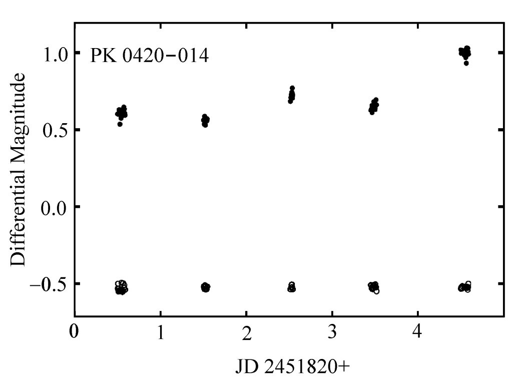

Fig. 1 Differential light curves of $O-S_7$ (filled circles in the upper part) and $S_7 - S_5$ (open circles in the lower part) in R band for PKS 0420–012.

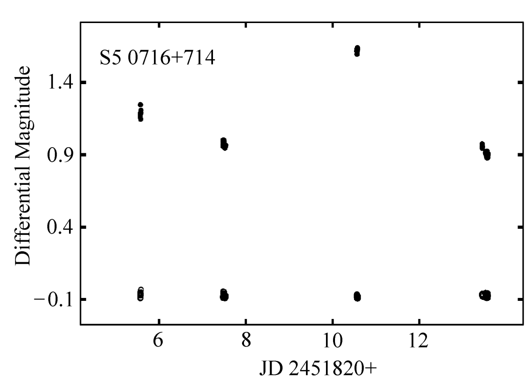

Fig. 2 Differential light curves of $O - S_6$ (filled circles in the upper part) and $S_5 - S_6$ (open circles in the lower part) in R band for S5 0716+714.

For the comparison stars, we measured their I magnitudes: $I_2 = 10.91 \pm 0.01$, $I_4 = 12.65 \pm 0.01$, $I_7 = 13.01 \pm 0.01$, and $I_8 = 13.50 \pm 0.01$. Star 1 displayed a 0.16 mag variation between Oct 8 and 13.

0754+100, OI 090.4 0754+100 has shown rapid variability in the infrared ($P_{\rm ir} = 4\% - 19\%$) and in the visual ($P_{\rm opt} = 4\% - 26\%$) polarizations. It is interesting that although there is a recorded variability of about 1 mag, there is no statistically significant change of the spectral index (Massaro et al. 1995). It displayed variability on different time scales from hours to years (see Smith et al. 1987; Ghosh et al. 2000a, b; Fan et al. 2002). A 3.16 mag variation was found from the compilation of B passband data (Fan & Lin 2000). We only obtained one set of observation for the object on 2000 October 3. The magnitudes we found are $V = 16.88 \pm 0.02$, $R = 16.37 \pm 0.02$, and $I = 15.81 \pm 0.01$.

0827+243, OJ248 For this source, there was not much optical photometric data before 1997. Villata et al. (1997) noticed a fall of 1.16 mag over a time scale of 63 days, which was followed by an increase of 1.05 mag in 58 days. Short time scale variation was reported by Xie et al. (2001). On 2000 October 5, we obtained a set of optical photometric data, $V = 17.49 \pm 0.03$ and $R = 17.13 \pm 0.03$. The V magnitude is the same as that by Maoz (1993) who reported $V = 17.5$.

1652+398, Mrk 501 Mrk 501 is an X-ray selected BL Lacertae object and a TeV emitting source (Quinn et al. 1996; Bradbury et al. 1997). The simultaneous observations in X-ray and TeV γ-ray indicate that the variation in these two bands are correlated (Sambruna et al. 2000). Variations of 1.3 mag in the optical band (Stickel et al. 1993) and 2.37 mag in the infrared band (Fan & Lin 1999) were obtained. On 2000 October 15, we observed the source for about 2 hours, but no clear variation was detected, the variability parameter was not significant at $C = 1.3$.

2200+420, BL Lacertae The prototypical object of its class lies in a giant elliptical galaxy at a redshift of ~ 0.07. It has been observed for about 27 years in the infrared (see Fan et al. 1998a) and about 100 years in the optical (Fan et al. 1998b). A 14 year period and a maximum optical variation of $\Delta B = 5.31$ have been found in the B light curve (Fan et al. 1998b). It is a well studied object in the optical band (see Bloom et al. 1997; Miller et al. 1999; Nikilashvili et al. 1999a, b; Tosti et al. 1999a, b; Ghosh et al. 2000a, b; Fan et al. 2001; Kurtanidze et al. 2002d; Kurtanidze et al. 2003 and references there in). In October 2000, it showed intra-day variations (see Fig. 3). A rapid change of 0.3 mag over a time scale of 3 hours was detected on 2000 Oct 9, (Fig. 4), which corresponds to a doubling time scale of $\Delta t_D \sim 11.0$ hours.

2230+114, CTA102 This well-known quasar is located at a redshift of $z = 1.037$, the long-term B light curve shows that its variation is slow (Pica et al. 1988). The X-ray emission is at a level of 0.4 μJy near 1 keV (e.g., Nolan et al. 1993). In 2000 October, we acquired three sets of photometric data.

On Oct. 4: $V = 16.71 \pm 0.03$, $R = 16.32 \pm 0.02$, $I = 15.83 \pm 0.01$

On Oct. 5: $V = 16.81 \pm 0.02$, $R = 16.39 \pm 0.02$, $I = 15.90 \pm 0.01$

On Oct. 6: $V = 16.66 \pm 0.01$, $R = 16.33 \pm 0.01$, $I = 15.80 \pm 0.01$

There was a ~ 0.1 mag intra-day variability during the three days we observed.

2251+158, 3C 454.3 This optically violently variable (OVV) quasar is located at $z = 0.859$. A polarization of $P_{\rm opt} = 0 - 16.0\%$, and a large amplitude variations of $\Delta m = 2.3$ are reported in Angel & Stockman (1980). Variability of 0.5 mag over a time scale of one day has also been observed (Lloyd 1984) and a historic light curve was given by Su (1999). We observed this source in 2000 0ctober. It did not show any clear variations (Fig. 5). The variability parameter is $C = 1.6$. We also measured the I magnitudes of star F and star G: $I = 14.37 \pm 0.01$ for F, and 14.33 ± 0.02 for G.

1ES 2344+514 1ES 2344+514 ($z = 0.044$) was recently identified as a BL Lac object (Perlman et al. 1996). It was discovered in TeV γ-rays ($> 350\,\mathrm{GeV}$) with the Whipple Observatory telescope and identified as a TeV BL Lac object (Catanese et al. 1998). However, there are little data in other bands. Miller et al. (1999) observed this object in the optical band and found a positive detection of micro-variability. Kurtanidze et al. (2002b) carried out extensive time-series photometry during ten nights. They detected intra-day variability within 0.05 magnitude. Variability is not detected on short time scales (minutes to hours). Since this source has not been monitored extensively, it will be a prime candidate for future intra-night monitoring to look for variability on short time scales. In 2000 October, we observed this source for two weeks, no clear variation was detected with $C = 1.2$ (Fig. 6).

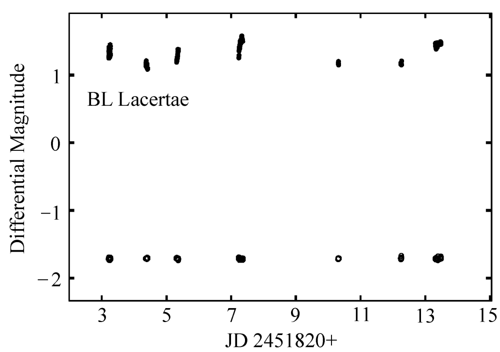

Fig. 3 Differential light curves of $O-B$ (filled circles in the upper part) and $B-G$ (open circles in the lower part) in R band for BL Lacertae.

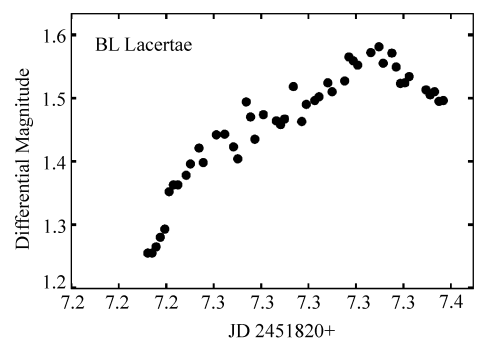

Fig. 4 Differential light curves of $O-B$ in R band for BL Lacertae on 2000 October 9.

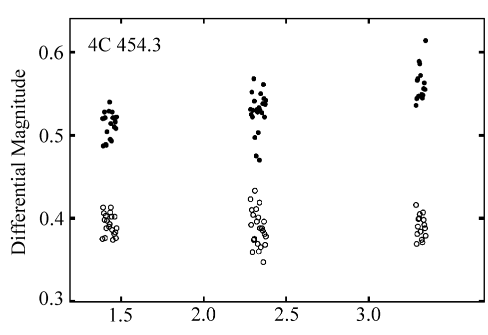

Fig. 5 Differential light curves of $O-Sa$ (filled circles in the upper part) and $Sa-Se$ (open circles in the lower part) in R band for 4C 454.3.

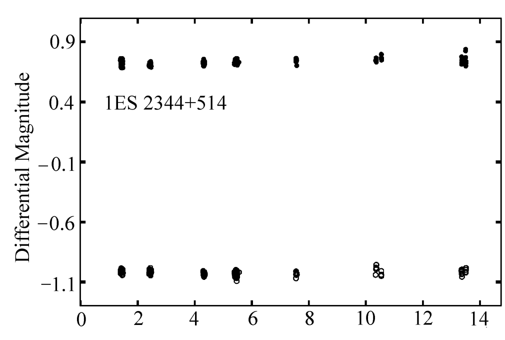

Fig. 6 Differential light curves of $O-S_2$ (filled circles in the upper part) and S_2-S_4 (open circles in the lower part) in R band for 1ES 2344+514.

4 DISCUSSION AND CONCLUSIONS

From EGRET on GRO, about 60 AGNs have been observed to emit high- energy γ-rays. These sources show variations at entire electromagnetic spectrum. The variability time scales, however, are different from radio to $\gamma-$ray bands. Simultaneous monitoring of some of the sources have shown interesting results. Simultaneous variability in optical and high-energy γ-ray bands are seen (see Wagner et al. 1995; Fan & Cheng 2001 and references therein). Those observational results imply that either high-energy γ-ray emissions are likely from the same region of optical emissions. If this is right, we can expect that we can use the optical band time scale to represent that in γ-ray band to constrain some important parameters for the high-energy γ-ray bands. It is difficult to detect the variability time scale in γ-ray bands (see Cheng et al. 1999; Fan et al. 1999). Detection of the optical time scale is one of the main goal of our observations. Optical observations are also very important in the light curve construction, which shed some lights on the nature and structure of the central region of AGNs. Long-term historic light curves suggest that the variations are composed of two time scales with the short time scale variations superimposed on the slowly varying long-term variations (see Fan et al. 1997, 1998, 2002; Sillanpaa et al. 1988). A source generally shows very rapid variation during the outburst period while it shows very small variation or no obvious variation during its quiescent stage. Therefore, we can expect rapid time scale when a source is in its outburst period but it is hard for us to obtain rapid variation detection when it is in its faint stage.

In our 2000 Sep.–Oct. observational period in Georgia, we observed several gamma ray loud blazars at Abstumani Observatory, and found some GeV blazars are variable. Variability was found in PKS 0420–014, S5 0716+714, BL Lacertae and CTA 102. We found rapid variations in S5 0716+714. Rapid variation is also found in the same source at the same time by Raiteri et al. (2003). We did not find any variations in the other observed objects, which may be partly due to the fact that we did not acquire enough data. It is also possible that those objects were in their quiescent state or that they are relatively stable during our observation period as was the case for 3C 454.3 (Zhang et al. 2001). Regarding the TeV γ-ray loud blazars, very rapid variations were detected (see Xie et al. (1998) for Mrk 421, McHardy (l996) for Mrk 50l and Geoganopoulous & Marscher (1998) for PKS 2155–304), but for lES 2344+514 no clear variability was detected during our two weeks of observation. Does it mean that there are two types of TeV γ-ray sources? Obviously, more detailed monitoring is important for answering this question.

Some γ-ray loud blazars have been observed with EGRET to display variability on time scales of hours to days while four XBLs have been observed to show TeV radiations. Since the variability timescale corresponds to different variation amplitude for different source and/or different observation periods, we use the doubling timescale, $\Delta T_D = (F_{\rm initial}/\Delta F)\Delta T$, as the variability timescale. In our observation, the light curves of few sources show clear rapid variation. The rapid time scale perhaps shed some lights on the emission size. In 1995 Wagner et al. found that the optical outburst happened in the same period of the gamma-ray outburst. Therefore, we can use optical timescale as the gamma-ray timescale. If we assume that the emissions are located at a distance of $200R_g$ (Fan et al. 1999), then we can estimate the central black hole mass, $M = 4.3 \times 10^7(\frac{\Delta T_D}{\rm Day})$, for PKS 0420–014, S5 0716+714, BL Lacertae and CTA l02 as listed in Table 1. They are in the range $2 \times 10^7\,M_\odot$ to $2 \times 10^8\,M_\odot$, which is consistent with the central black hole mass estimates by other authors (Woo & Urry 2002; Komossa 2003; Barth et al. 2003 and reference therein).

Table 1 Central Black Hole Mass for Some γ-ray Loud Blazars

Object	ΔT_D	$10^7\ M_\odot$
(1)	(2)	(3)
0420–014	2.85 days	12.26
0716+714	4.57 days	19.65
BL Lacertae	11 hours	1.97
CTA 102	1.0 day	4.3

In this paper, we have presented the observations carried out for 10 γ-ray loud blazars in September–October of 2000 at Abstumani Observatory, Georgia. Variations was detected in 4 sources (PKS 0420–014, S5 0716+714, BL Lacertae and CTA 102) out of 10. The derived time scales led to estimates of the central black hole masses in the range $2 \times 10^7\ M_\odot$ to $2 \times 10^8\ M_\odot$.

Acknowledgements This work is supported by the National Natural Scientific Foundation of China (19973001), National 973 project (NKBRSF G19990754), the National Science Fund for Distinguished Young Scholars (10125313), and the Fund for Top Scholars of Guangdong Provience (Q02114). J. H. Fan thanks Prof. K. S. Cheng in the University of Hong Kong to support him to visit Abstumani Observatory, Georgia in 2000.

References

Aharonian F. et al., 2003, astro-ph/0305275
Angel J. R. P., Stockman H. S., 1980, ARA&A, 18, 321
Barth A. J., Ho L. C., Sargent Wallace L. W., 2003, ApJ, 583, 134
Biermann P., Preuss E., Kronberg P. P. et al., 1981, ApJ, 250, 49
Bradbury S. M., Dckers T., Petry D. et al., 1997, A&A, 320, L5
Bloom S. D., Bertsch D. L., Hartman R. C. et al., 1997, ApJ, 490, L145
Catanese M., Akerlof C. W., Badran H. M., 1998, ApJ, 501, 616
Cellone S. A., Romero G. E., Combi J. A., 2000, AJ, 119, 1534
Chadwick P. M., Lyons K., McComb T. J. L. et al., 1999, ApJ, 521, 547
Cheng K. S., Ding W. K. Y., 1994, A&A, 288, 97
Cheng K. S., Fan J. H., Zhang L., 1999, A&A, 352, 32
Cheng L.-P., Zhao Y.-H., Wei J.-Y., 2002, Chin. J. Astron. Astrophys., 2, 117
Ciprini S., Tosti G., Raiteri C. M., 2003, A&A, 400, 487
Clements S. D., Jenks A., Torres Y., 2003, AJ, 126, 37
Comastri A. et al., 1997, ApJ, 480, 534
Dai B. Z., Xie G. Z., Li K. H. et al., 2001, AJ, 122, 2901
Dermer C. D., Schlickeiser R., Mastichiadis A., 1992, A&A, 256, L27
Dondi L., Ghisellini G., 1995, MNRAS, 273, 583
Efimov Y. et al., 2002, A&A, 381, 408
Fan J. H., Xie G. Z., Lin R. G. et al., 1997, A&AS, 125, 525
Fan J. H., Xie G. Z., Pecontal E. et al., 1998a, ApJ, 507, 173
Fan J. H., Xie G. Z., Lin R. G., Qin Y. P., 1998b, A&AS, 133, 217
Fan J. H., Adam G., Xie G. Z. et al., 1998c, A&AS, 133, 163
Fan J. H., Xie G. Z., Bacon R., 1999, A&AS, 136, 13
Fan J. H., Lin R. G., 1999, ApJS, 121, 131
Fan J. H., Lin R. G., 2000, ApJ, 537, 101

Fan J. H., Cheng K. S., 2001, In: S. Ritz, N. Gehrels, C. R. Shrader, eds., AIP Conf. Proc., Vol. 587, NY: AIP, 291

Fan J. H. et al., 2002, A&A, 381, 1

Gaidos J. A., Akerlof C. W., Biller S. D. et al., 1996, Nature, 383, 319

Geoganopoulous M., Marscher A. P., 1998, ApJ, 506, L11

Ghosh K. K., Ramsey B. D., Sadun A. C. et al., 2000a, ApJS, 127, 11

Ghosh K. K., Ramsey B. D., Sadun A. C. et al., 2000b, ApJ, 537, 638

Gupta A. C., Joshi U. C., Fan J. H., 2002, ApSS, 282, 655

Hanski M. T., Takalo L., Valtaoja E., 2002, A&A, 394, 17

Heidt J., Wagner S. J., 1996, A&A, 305, 42

Komossa S., 2003, astro-ph/0306439

Kurtanidze O. M., Nikolashvili M. G., 1999, In: OJ-94 Annual Meeting 1999, C. M. Raiteri, M. Villata, L. O. Takalo, eds., p.25

Kurtanidze O. M., Nikolashvili M. G., 2003, In: S. Ikeuchi, J. Hearnshaw, T. Hanawa, eds., The Proceedings of the IAU 8th Asian-Pacific Regional Meeting, Volume II, Astronomical Society of Japan, 389

Kurtanidze O. M., Nikolashvili M. G., 2002a, In: P. Giommi, E. Massaro, G. Palumbo, eds., Blazar Astrophysics with BeppoSAX and Other Observatories, Proceedings of the International Workshop, ESA-ESRIN, p.189

Kurtanidze O. M., Nikolashvili M. G., 2002b, In: P. Giommi, E. Massaro, G. Palumbo, eds., Blazar Astrophysics with BeppoSAX and Other Observatories, Proceedings of the International Workshop, ESA-ESRIN, p.197

Kurtanidze O. M., Nikolashvili M. G., 2002c, In: P. Giommi, E. Massaro, G. Palumbo, eds., Blazar Astrophysics with BeppoSAX and Other Observatories, Proceedings of the International Workshop, ESA-ESRIN, p.201

Kurtanidze O. M., Nikolashvili M. G., Sigua L. A. 2002d, in AGN Spectroscopy, MPE Report, 279, 303

Lloyd C., 1984, MNRAS, 209, 697

Lainela M., Takalo L. O., Sillanpaa A. et al., 1999, ApJ, 521, 561

Madejski G. M., Sikora, M., Jaffe, T., et al., 1999, ApJ, 521, 145

Maraschi L., Ghisellini G., Celotti A. et al., 1992, ApJ, 397, 5

Maoz E., 1993, ApJ, 414, 877

Mannheim K., Biermann P. L., 1992, A&A, 253, L21

Massaro E., Nesci R., Perola G. C. et al., 1995, A&A, 299, 339

Massaro E., Giommi P., Perri M. et al., 2003, A&A, 399, 33

Mattox J. R., Wagner S. J., Malkan M. et al., 1997, ApJ, 476, 692

McHardy I., 1996, In: H. R. Miller, J. R. Webb, J. C. Noble, eds., ASP Conf. Series, 110, p.293

Miller H. R., Ferrara E. C., Daya A. B. et al., 1999, in OJ-94 Annual Meeting 1999, eds., C. M. Raiteri, M. Villata, L. O. Takalo, p.20

Nikolashvili M. G., Kurtanidze O. M., 2003, In: S. Ikeuchi, J. Hearnshaw, T. Hanawa, eds., The Proceedings of the IAU 8th Asian-Pacific Regional Meeting, Volume II, Astronomical Society of Japan, 397

Nikolashvili M. G., Kurtanidze O. M., Richter G. M., 1999a, In: C. M. Raiter et al. eds., OJ-94 Annual Meeting 1999, p.33

Nikolashvili M. G., Kurtanidze O. M., Richter G. M., 1999b, In: C. M. Raiter, et al., eds., OJ-94 Annual Meeting 1999, p.36

Nolan P. L., Bertsch D. L., Fichtel C. E. et al., 1993, ApJ, 414, 82

Perlman E. S., Stocke J. T., Schachter J. F. et al., 1996, ApJS, 104, 251
Pica A. J., Smith A. G. et al., 1988, AJ, 96, 1215
Punch M., Akerlof C. W., Cawley M. F. et al., 1992, Nature, 358, 477
Qian B. C., Tao J., Fan J. H., 2002, AJ, 123, 678
Qian B. C., Tao J., 2003, PASP, 115, 490
Quinn J., Akerlof C. W., Biller S. et al., 1996, ApJ, 456, L83
Quirrenbach A., Witzel A., Kirchbaum T. P. et al., 1992, A&A, 258, 279
Raiteri C. M., Villata M., Tosti G., 2003, A&A, 402, 151
Rector T. A., Perlman E. S., 2003, AJ, 126, 47
Romero G. E., Torres D. F. et al., 1999, MNRAS, 308, 799
Romero G. E., Cellone S. A., Combi J. A., 2000, AJ, 120, 1192
Romero G. E., Cellone S. A., Combi J. A., Andruchow I., 2002, A&A, 390, 431
Sambruna R. M., Aharonian F. A. et al., 2000, ApJ, 538, 127
Sikora M., Begelman M. C., Rees M. J., 1994, ApJ, 421, 153
Sillanpaa A., Haarala S., Valtonen M. J. et al., 1988, ApJ, 325, 628
Smith P. S., Balonek T., Elston R., Heckert P. A., 1987, ApJS, 64, 459
Stickel M., Fried J. W., Kuehr H., 1993, A&AS, 98, 398
Su C. Y., 2000, Acta Astropys. Sin., 20, 11
Tagliaferri G., Ravasio M., Ghisellini G. et al., 2003, A&A, 400, 477
Takalo L. O. et al., 1992, A&AS, 94, 37
Tosti G., Luciani M., Frorucci M. et al., 1999a, Blazar Data 2, 1
Tosti G., Luciani M., Frorucci M. et al., 1999b, In: L. O. Takalo, A. Sillanpaa, eds., ASP Conf. Ser. Vol. 159, p.145
Villata M., Raiteri C. M., 1997, MmSAI, 68, 203
Wagner S. J., Camenzind M., Dreissigacker O. et al., 1995, A&A, 298, 688
Webb J. R., Smith A. G., Leacock R. J. et al., 1988, AJ, 95, 374
Woo J. H., Urry C. M., 2002, ApJ, 579, 530
Xie G. Z., Bai J. M., Zhang X., Fan J. H. et al., 1998, A&A, 334, L29
Xie G. Z., Qin Y.-P., Zheng X.-T., Liang E.-W., 2001, A&A, 369, 537
Xie G. Z., Zhou S. B., Dai B. Z. et al., 2002, MNRAS, 329, 689
Xie G. Z., Liang E. W., Xie Z. H., Dai B. Z., 2002, AJ, 123, 2352
Zhang L., Cheng K. S., 1997, ApJ, 488, 94
Zhang S., Collmar W., Schnfelder V. et al., 2001, In: S. Ritz, N. Gehrels, C. R. Shrader, eds., AIP Conf. Proc., Vol. 587, NY: AIP, 343