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# Optical Variability Monitoring for Gamma-ray Blazars: preliminary results

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We report preliminary results of a long term optical ($V$, $R$) monitoring program of blazars that includes 2 well-known objects: 3C 279 (1253−055) and CTA 102 (2230+114). The observations were obtained with the 1.52m Spanish telescope at the Calar Alto Observatory during 2006−2007. Although no significant intra-night variations were detected in any of the objects, we found inter-day variations with amplitudes of $\sim 0.15$ mag in these gamma-ray blazars.

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## 1. Introducction

In the context of the unified AGN model, blazars are believed to be viewed close to the axis of the relativistic jet. These objects display compact flat spectra at radio frequencies and apparent superluminal motions at VLBI scales (see e.g. Urry 1999). In particular, gamma-ray blazars are characterized by high variability on different timescales ranging from minutes to months in the optical band. Among them, 3C 279 (1253-055) and CTA 102 (2230+114) are two of the most studied objects.

The blazar 3C 279 ($z = 0.538$) was considered the first superluminal source (Whitney et al. 1971) and the first discovered to emit gamma rays by the EGRET telescope (Hartman et al. 1992). This object is variable at all wavelengths from radio to high gamma-ray energies (Wehrle et al. 2001; Grandi et al. 1996). Optically, 3C 279 varies dramatically on many different timescales. During 2001−2002 this blazar underwent the most intense outburst seen in the last fourteen years (Kartaltepe & Balonek 2007).

The quasar CTA 102 has a redshift of $z = 1.037$. Multi-wavelength monitoring and imaging revealed correlated variability, and radio jet speeds of up to 21 c were derived from VLBI observations (Rantakyro et al. 2003). This source has displayed optical variability with an oscillating behavior (Raiteri et al. 1998), but from 1997 May through June the object did not vary during the interval of optical observations (Ghosh et al. 2000).

In this work, we present preliminary results of a long term optical ($V$,$R$) monitoring program for blazars, that includes these 2 well-known gamma-ray blazars: 3C 279 and CTA 102. The remaining ones will be reported in a future paper (Andruchow et al. 2008).

## 2. Observations and data reduction

We observed a sample of 10 gamma-ray blazars over 13 months, from 2006 March to 2007 April. Optical images in the $R$ and $V$ bands were acquired using a wheel of standard $VR$ Johnson-Kron-Cousins filters with the 1.52m Spanish telescope at the Calar Alto Observatory. This telescope is equipped with a 1024 × 1024 pixel CCD, which provides a field of view (FOV) of $6.'9 \times 6.'9$, with a pixel scale of 0.40 arcsec pixel$^{-1}$. The absolute calibration of the photometry was performed by observing several standard stars from Landolt (1992) over a wide range of air masses during the best acceptable photometric nights. The seeing conditions ranged from 2.3 arcsec to 3.7 arcsec. The images were debiased and flat-fielded in the standard way using the IRAF reduction package.

The images range in exposure time from 120 to 600 seconds (most images being 360 seconds). The photometry for all of the images was extracted using the IRAF APPHOT package with aperture diameters of 8 arcsec and 10 arcsec for 2230+114 and 3C 279, respectively, and a sky annulus with an inner diameter of 20 arcsec and an outer diameter of 30 arcsec. All error bars are 1-sigma and were calculated using the IRAF APPHOT package. Table 1 presents source name, position, redshift, visual magnitude and type (quasar or BL Lac). The sources studied in this paper are marked in bold face in Table 1.



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**Table 1:** The complete source list of observed Blazars

| Object | $\alpha_{J2000}$ | $\delta_{J2000}$ | $z$ | $m_V$ | Type |
|---|---|---|---|---|---|
| 0048−090 | 00:50:41.3 | −09:29:05 | 0.200 | 17.44 | BL-Lac |
| 0757+100 | 07:57:06.6 | +09:56:35 | 0.266 | 14.5 | BL-Lac |
| 0827+243 | 08:30:52.1 | +24:11:00 | 0.940 | 17.2 | Q |
| 0851+202 | 08:54:48.8 | +20:06:31 | 0.310 | 14.0 | BL-Lac |
| 1222+041 | 12:22:22.5 | +04:13:15 | 0.965 | 17.98 | Q |
| **1253−055** | **12:56:11.1** | **−05:47:21** | **0.538** | **17.75** | **BL-Lac** |
| 1510−089 | 15:12:50.5 | −09:06:00 | 0.360 | 16.54 | Q |
| 1749+096 | 17:51:32.8 | +09:39:01 | 0.322 | 16.78 | BL-Lac |
| **2230+114** | **22:32:36.4** | **+11:43.50** | **1.040** | **–** | **Q** |
| 2251+158 | 22:53:57.7 | +16:08:53 | 0.860 | – | Q |

## 3. Results

The differential light-curves for 3C 279 and 2230+114 are shown in Figure 1. These were obtained in the usual way, using a non-variable star in the field as comparison, while another star was used to construct a second differential light-curve against the non-variable star, to be used for control purposes.

As can be seen, both gamma-ray blazars displayed no significant intranight variability. On the contrary, night-to-night variability with similar behavior in both bands ($V$ and $R$) and amplitudes of $\sim 0.15$ mag was observed in both objects. The variability results are presented in Table 2. Column 1 gives the object name, Column 2 the date, Columns 3 indicates the filter ($V$ or $R$), Column 4 gives the observational errors obtained from the standard deviation of the comparison differential light-curve, Column 5 indicates the variability classification, and Columns 6 and 7 show the confidence parameter ($C$) and corrective factor ($\Gamma$, see Howell et al. 1988), respectively.

## 4. Discussion

Gamma-ray emission of blazars is thought to be the result of inverse Compton interactions with either external or synchrotron photons produced in the jet. In the latter case we can expect that the regions where the optical synchrotron emission is produced should be co-spatial with the gamma-ray emitting zones of the jet. Timescales for 3C 279 flares at gamma rays seem to have similar duration as the optical timescales here reported, suggesting a common origin. In the case of CTA 102, although we have found no intra-night variability, such events were reported in the past (Romero et al. 2002). It could be the case that the emission region is more compact and the gamma rays are produced at larger distances, e.g. through interactions beyond the broad-line region. Observations of variability of this source by GLAST, along with simultaneous optical microvariability monitoring could help to put the competing models to test.



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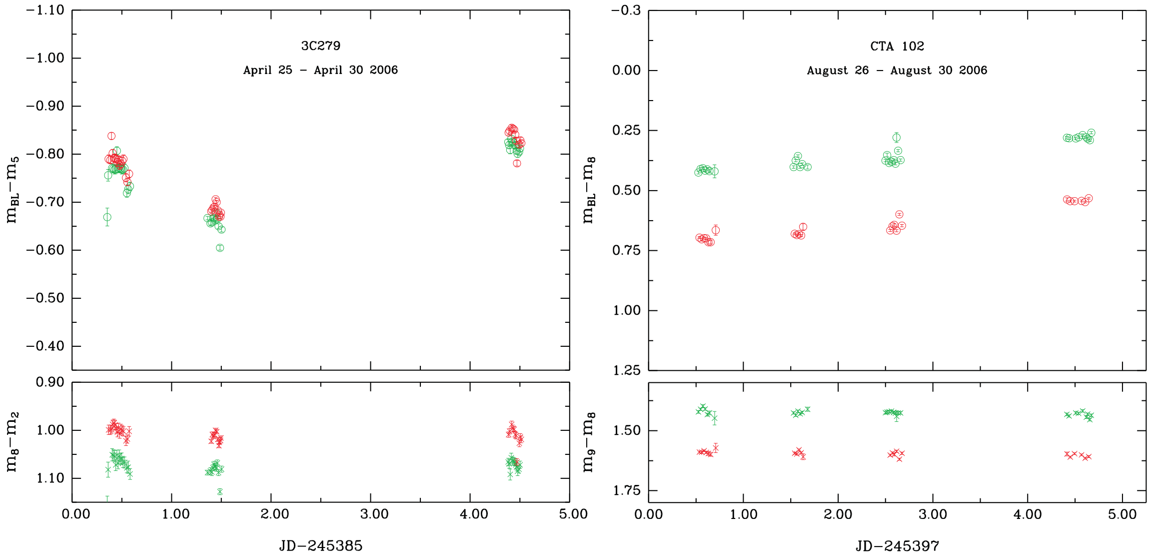


**Figure 1:** Left: Light curve for 3C 279. The control curve in the $V$ filter has an arbitrary offset of $-0.3$ mag for presentation purposes only. Right: Light curve for PKS 2230+114 (CTA 102).

**Table 2:** Microvariability results. $C$: confidence parameter; $\Gamma$: corrective factor.

| Object | UT Date [m/d/y] | Filter | $\sigma$ mag | Variable? | $C$ | $\Gamma$ |
|---|---|---|---|---|---|---|
| 3C279 | 04/25/06 | $V$ | 0.018 | NV | 1.73 | 0.67 |
| | 04/25/06 | $R$ | 0.008 | V | 2.76 | 0.81 |
| | 04/26/06 | $V$ | 0.011 | NV | 1.77 | 0.68 |
| | 04/26/06 | $R$ | 0.008 | NV | 1.46 | 0.82 |
| | 04/29/06 | $V$ | 0.007 | NV | 1.47 | 0.66 |
| | 04/29/06 | $R$ | 0.017 | NV | 1.30 | 0.80 |
| | All nights | $V$ | 0.014 | V | 4.88 | 0.67 |
| | All nights | $R$ | 0.012 | V | 5.07 | 0.81 |
| 2230+114 | 08/26/06 | $V$ | 0.017 | NV | 0.40 | 1.01 |
| | 08/26/06 | $R$ | 0.009 | NV | 1.79 | 1.08 |
| | 08/27/06 | $V$ | 0.008 | NV | 2.23 | 0.98 |
| | 08/27/06 | $R$ | 0.011 | NV | 1.32 | 1.07 |
| | 08/28/06 | $V$ | 0.006 | V | 5.99 | 0.97 |
| | 08/28/06 | $R$ | 0.012 | NV | 2.10 | 1.04 |
| | 08/30/06 | $V$ | 0.010 | NV | 0.95 | 0.91 |
| | 08/30/06 | $R$ | 0.007 | NV | 0.79 | 0.95 |
| | All nights | $V$ | 0.011 | V | 5.22 | 0.95 |
| | All nights | $R$ | 0.011 | V | 5.82 | 1.2 |

## 5. Conclusions

The optical lightcurves for both gamma-ray blazars included in this preliminary report do not show significant intra-night variations. However, inter-night variations are clearly detected, with amplitudes $\sim 0.15$ mag in 72 to 96 hs, and showing similar behavior in $V$ and $R$.

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