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Multi band optical micro-variability of BL Lac objects.

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We present preliminary analysis for PKS 2254+074 and S5 1803+784 from a multiband optical photometric monitoring programme of BL Lacertae objects carried out during 3 nights observing runs in 2001. The observations resulted in almost evenly sampled light curves 6-9 h long. We found inter-day variations with average amplitudes of 7-10 % and 2-6% respectively.

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1. Introduction

BL Lac objects or simply “BL Lacs” define together with flat spectrum radio quasars, an extreme class of active galactic nuclei known as blazars. BL Lacs are characterized by featureless optical spectrum, strong and rapid continuum variability from radio up to γ-rays, high degree of linear polarization and radio jets which often exhibit superluminal motion. Their γ-ray emission indicates a double-peak structure in the overall spectral energy distribution with two broad spectral components. The first, lower frequency component is generally interpreted as being due to synchrotron emission and the second-higher frequency one-as being due to inverse Compton emission, produced by relativistic electrons in a jet oriented at small angles to the observer’s line of sight.

The study of the flux and spectral variability in the optical region allow us to derive information on the radiating relativistic electrons and on the emission region (Ghisellini et al. 1997) and although may complicate the situation by revealing the presence of other components in addition to the synchrotron emission (thermal emission from the accretion disk around the central engine) could put constraints to theoretical models (Vagnetti, Traverse & Nesci 2003).

In this work we continue the optical monitoring program of BL Lacs at Skinakas Observatory, Crete, Greece by presenting preliminary results of PKS 2254+074 and S5 1803+784. Our main aim is to study the intra-night flux and energy spectral variations over a period of 3 nights in 2001. The quality of the light curves is similar to those presented by Xilouris et al. (2006) in the case of S5 2007+777 and 3C 371.

2. Observations and data reduction

Optical images in the B,R,I bands were acquired for the two BL Lacs through the standard Johnson B and Cousins RI filters with the 1.3 m f/7.7 Ritchey-Cretien telescope at Skinakas Observatory in Crete, Greece. The CCD used was a 1024x1024 SITe chip with a 24 μm^2 pixel size (corresponding to 0.5 arcsec on the sky). The log of observations is given in Table 1 where we list the observation dates and the number of frames that we obtained each night in each filter.

Table1. List of the four BL Lac sources in the optical monitoring sample

Date	Object	Filters (number of frames)			Total number of frames
		B	R	I	
02/10/01		14	14	14	
03/10/01	PKS 2254+074	17	19	18	B (49), R (51), I (50)
04/10/01		18	18	18	
02/09/01	S5 1803+784	22	21	22	B (65), R (65), I (66)
03/09/01		21	22	22	
04/09/01		22	22	22	

Typical seeing during the observations ranged from 1 to 2 arcsec. Exposure times varied between 420-600 s for B filter, 300 s for R, and 180-300 s for I filter depending on the brightness of the object and the sky conditions. Standard image processing was applied to all frames (debiased and flat-fielded) using standard IRAF routines. In order to detect weak fluctuations we have performed aperture photometry by intergrading counts within a circular aperture of 7.5 arcsec centered on the objects

Standard stars from Landolt (1992) were observed during the nights of 5, 6 October 2001 and calibration of 5field stars close to the objects (and subsequently of the sources) to the standard system was made, using DAOPHOT.

The calibrated magnitudes of the sources were corrected for galactic reddening using the values of A_B=0.269, A_R=0.166 and A_I=0.120 for PKS 2254+074 and A_B=0.214, A_R=0.133, A_I=0.096 for S5 1803+784, converted into flux and corrected for the contribution of the host galaxy to the measured flux in each band as described in Xilouris et al. (2006). The subtraction of the host galaxy contribution was not possible in the case of S5 1803+784 since it was unresolved in Pursimo et al. (2002).

3. Flux variability

For each object, the historical photometric results are briefly presented. The dereddened B, R, I light curves for each object are presented together with the B band light curve of faintest comparison star. For each frame the error on the BL Lacs mag was computed using the standard propagation of errors formula, taking into account the photometry error of the source's measurement and the standard deviation (σ) of the comparison stars. The overall magnitudes variations are on time scales of days or on shorter time scales. In order to compare the amplitude of the variations that we observe in the various light curves we computed their fractional variability amplitude f_{rms} (defined as in Papadakis et al. 2003). In order to reduce the scatter in the light curves and examine how well agree with each other we binned them using bins of size 1.6-1.7 h and normalized them to their mean flux level..

3.1 PKS 2254+074

PKS 2254+074 (OY 091) is a rapidly variable source with a flat radio and steep optical spectrum. The host galaxy of the source which has a redshift =0.19 (Stickel et al. 1988) is clearly resolved in direct images (Stickel et al.1993a). This source has one of the brightest cores and is surrounded by a number of galaxies, one of which appears to be physical companion (Stickel et al. 1993a).

Its historical brightness variations have been 1.6 mag (Pollock, 1975), 2.37 mag during 1.39 years from July 1979 to November 1987 (Pica et al. 1988) whereas a flare of 1.8 mag was observed by the same authors. After that flare the brightness faded 1.3 mag in 18 days (B band) and continued fading to mag 18 where it stayed for years (Pica et al. 1988). In November 1990, Xie et al (1994) observed a fall of 0.69 mag in 52 minutes when the source reached the minimum brightness (B=18.44). However a steepest variation has been registered by the same authors in November 1987: a decrease of 1.0 mag in 40 minutes.

During 1991-1992 the object was faint (V=17.2) (Guibin & Xuefan, 1998) and no variations beyond the three standard deviations was seen on timescales of tens of minutes of three nights. There were variations δR~0.17±0.036 mag in a interval of three days. But at the end of 1994 the luminosity of the object increased to V~15.56 mag and 8 variations with an amplitude 0.24±0.04 mag were observed in 20 minutes in the V band. In the period July 23-Aug 1st 1995 the UBVRI light curves of Villata et al (1997) show noticeable night to night changes up to more than 1 mag in 1 day and spectral changes more pronounced in the U and B bands. The maximum variation in the period was 0.60 mag in 3 days. On November 1995 intranight variations were also observed with the steepest one being an increase of 0.21 mag in 10 minutes. During the Tuorla quasar monitoring (1995-1997) the maximum V-band brightness value was 16.30 and minimum 16.82 (Katajaimen et al, 2000). The source was in active state during September 1998 when Xie et al. (2002) reported maximum variations of 0.64 mag in 91 min in the B band and 0.37 mag in the V band within 3.7 hours.

The B, R, I light curves during the three observing nights are shown in Fig.1 and the average magnitude is B~ 17.6 , R~17.5 and I ~16.6. During the 3 day October 2001 observations the flux increases from the first to second night and then descreases in all filters. The overall flux min to max variations are of the order of ~7-10% on a time scale of 1 day with the smallest variations in the I band. Variations of 10-30% are also noticed intra-night. Looking at the data we notice fluctuations in flux of comparison star (2 October) which might be responsible for the apparent variations although the standard deviation of the light curves of the comparison star is slightly smaller.

The average variability amplitude f_{rms} of the B, R, and I band taken as a whole in our 3 days period, is 10% , 11 % and 6.7% respectively. Within each night the average amplitude of the observed variations (intranight) is : f_{rms} (B) 9.6%, 6 % and 1.1% , f_{rms} (R) 7.1%, 12% and 6.3% and f_{rms} (I) 6.3%, 7%, 3.5%. for the 2-3-4 October respectively.

Fig. 2 show the binned and normalized light curves to the average flux level which show the same variability pattern with the ones in Fig.1 but more clearly.

In order to investigate if the intra-night low amplitude variations in B, R and I light curves are intrinsic more statistical tests are needed.

S5 1803+784

This source classified variously as BL Lac object or QSO (z=0.684) (Rector and Stocke 2001, Veron-Cetty & Veron 2003) is a compact flat spectrum radio source and it has been observed for more than 30 years since 1970's at different frequencies and with different resolution. Based on VLBI data, Kudryavtseva et al (2006) found evidence for 5 stationary jet components whose position angle changes with time whereas the period of the total flux density changes is ~4 years. The proposed explanation of this behavior is a twisted rotating helix. The published photometric data however are very few. Nesci et al (2002) reported an overall variation greater than 3 mag in R band in Sep1999- July 2001 and the largest changes occurred in three strong

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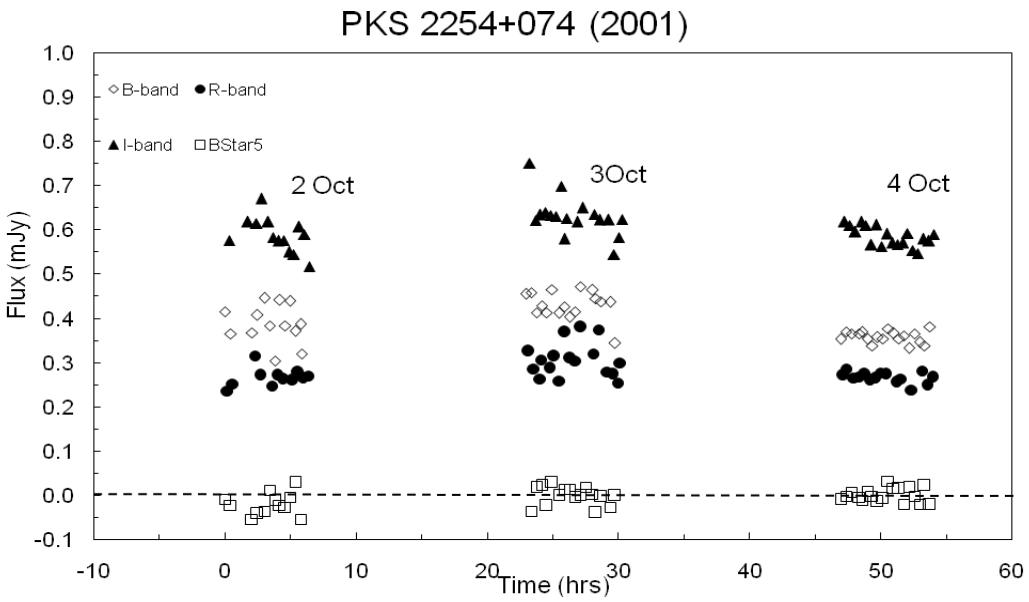

Fig. 1 . B, R and I band light curves for PKS 2254+074 during 2001 observations. The filled circles show the B band light curve of one of the comparison stars, shifted to the mean flux level of zero mJy for clarity reasons

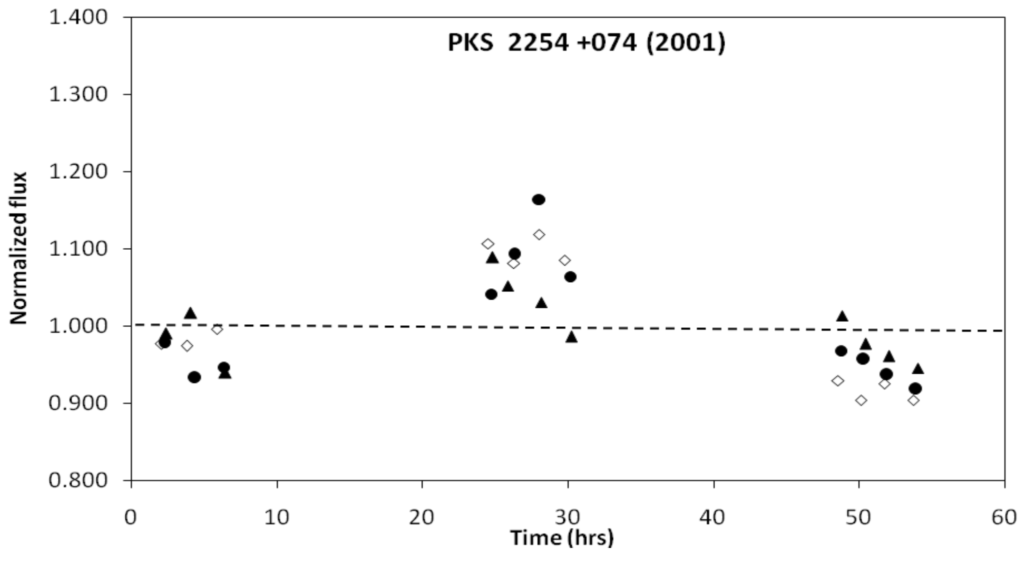

Fig. 2 B , R and I band light curves of PKS 2254+074 in 2001 binned in 1.6-1.7 h and normalized to their average flux level

flares by comparable rise and decay of about 20 days. They didn't find any periodicity on time scales up to a year. The spectral index showed small variations and there was an indication of a positive correlation with the source luminosity.

Our B, R and I band light curves indicate low level variations (Fig.3) which probably suggest that during our observing run appears to be in a quiescent state. The average variability amplitude f_{rms} of the B, R, and I band taken as a whole in our 3 days period, is 6% , 1.5 % and 3% respectively.

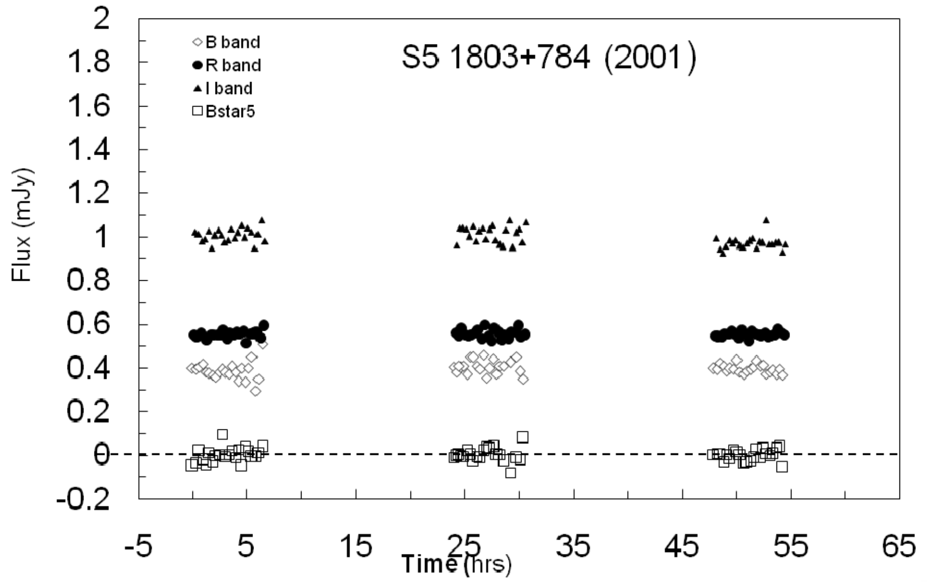

Fig.3 . As in Fig. 1 but for S5 1803+784 observations.

5. Conclusions

These two objects are "Low frequency peaked BL Lacs" i.e the synchrotron peak in their spectrum is located at mm/IR/optical wavelengths. Inter-day variations are detected but further reduction is needed in order to examine their correlation and the intra-night variations. Furthermore the study of their spectral variability will enable us to establish its relation with the flux variations. The fact that in many BL Lacs we do not observe the same variability behavior at all times within each source or between different sources, is fully consistent with the hypothesis that the observed variations are caused by perturbations which affect different regions in the jet of the sources and they do not always evolve on the same time scale.

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