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Simultaneous optical-NIR observations of four BL Lacertae objects

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Abstract. We present preliminary simultaneous optical-NIR observations of 4 low-energy peaked (LBL) BL Lac objects, namely S2 0109+22, 3C 66A, S5 1803+784 and BL Lac. The spectral slope in the optical (BVRI) range is steeper than the infrared (JHK) one for all our objects, as expected for a synchrotron-emission dominated energy distribution peaked at mid-infrared frequencies.

Key words. BL Lacertae objects– optical photometry – infrared photometry

1. Introduction

The energy distribution of BL Lacertae objects ranges from the radio to the γ-ray and is characterized by a large and fast variability. In the frequency ranges where rapid photometry is possible with present detectors, even intraday variability has been detected, with time scales of about one hour and in some cases even shorter (Nesci et al. 1998). Determining the shape of their spectral energy distribution, a key point to understand the physical processes and the overall structure of these sources, requires therefore simultaneous observations over a wide frequency range. According to the current models, the dominant emission process responsible for the emission of BL Lac objects from the radio to the UV frequency range is synchrotron emission from relativistic electrons, moving down a jet pointing at a small angle with the observer's line of sight. The resultant Doppler boosting may explain the high apparent luminosity and the fast variability of these sources, avoiding the so-called Compton catastrophe Blandford & Rees (1978). The spectral energy distribution is expected to be approximated by a power law, $F_\nu = A\nu^{-\alpha}$ over relatively large frequency ranges.

Despite the importance of achieving simultaneous multifrequency observations of BL Lac objects, few observations of this kind have been secured up to now, mainly due to the difficulty of coordinating observations with different telescopes (e.g. radio and optical, optical and X-rays, optical and infrared) generally operated by different Institutions.

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In this paper we report some preliminary simultaneous optical and near infrared observations of four radio-selected BL Lac objects.

2. Observations and data reduction

2.1. Optical observations

The optical observations were performed on August 26 2001, with the 50 cm f/4.5 newtonian telescope at Vallinfreda (Roma) with an ST6-SBIG CCD camera, with a scale of 2.35 arcsec/pixel. Standard B,V (Johnson) and R,I (Cousins) filters were used, with exposure times of about 300 s. Differential photometry with respect with 3 or 4 reference stars in the same frame of each object was performed using the IRAF/daophot package, using an aperture of 5 arcsec radius. Typical internal errors of 0.02 mag were obtained.

Magnitudes for the reference stars were taken from the following authors: S2 0109+22: Tosti (2001) (BVRI); 3C 66A (1ES 0219+428): Gonzalez-Perez et al. (2001) (BVRI); S5 1803+784: Nesci et al. (2002) (BVRI); BL Lac: Bertaud et al. (1969) (B,V), Fiorucci & Tosti (1996) (R,I).

The photometric results are collected in Table 1.

2.2. Near-Infrared observations

Observations in the Johnson JHK bands were performed with the AZT24 telescope at Campo Imperatore (110 cm f/7.9, Cassegrain) and a PICNIC type HgCdTe 256x256 camera, actually made of 4 128x128 chips, with a scale of 1 arcsec/pixel. Exposure times of 180 s were used.

Preliminary data reduction was made with the PREPROCESS task developed at the Roma Observatory, and photometry was made with IRAF/daophot using a 4 arcsec radius aperture. Primary photometric standard stars (AS 02-0, AS 06-0, AS 32-0, AS 37-1) were taken from Hunt et al. (1998). All the observations were made at airmass smaller than 1.2; the standard error of our JHK observations is $\sim$0.05 mag. In the case of 3C 66A the zero point of the JHK magnitudes is of lower quality due to flat-fielding problems. The log of the observations and the measured magnitudes are given in Table 2. Reliable variability in the JHK bands (about 0.25 mag) was found for BL Lac and S2 0109+22.

3. Data analysis and results

Corrections to the apparent magnitudes for the foreground absorption by the Milky Way was made following the extinction law by Schlegel et al. (1998), assuming A_V=3.3 E(B-V). Conversion from magnitudes to fluxes was made assuming the zero-point values by Elvis et al. (1994) for the case of a power law spectral energy distribution with α=1. A further (small) correction for the host galaxy contribution has been applied to the data of BL Lac, assuming for the galaxy a De Vaucouleurs profile following the results of Urry et al. (2000) and the typical colors for an elliptical galaxy. The resultant energy distributions are plotted in Figure 1. The mismatch of the JHK data of 3C 66A with respect to the optical ones is likely due to the non uniform response of the individual chips of the IR camera.

All our objects show BVRI and JHK energy distributions separately consistent with a power law, with spectral indexes listed in Table 1 and Table 2, respectively. Furthermore, in the latter we reported also the values of $\Delta\alpha = \alpha_{opt} - \alpha_{nir}$. For S5 1803+78 and S2 0109+22 the optical spectral slope reported is that typical for their R luminosity at the date of observation, as derived from our data archive. The optical slopes are generally moderately steeper than the infrared ones.For 3C 66A we compared the infrared slope with those obtained by some of us Massaro et al. (1995) several years ago at the TIRGO telescope with an InSb photometer and found that the new results are within the range of the

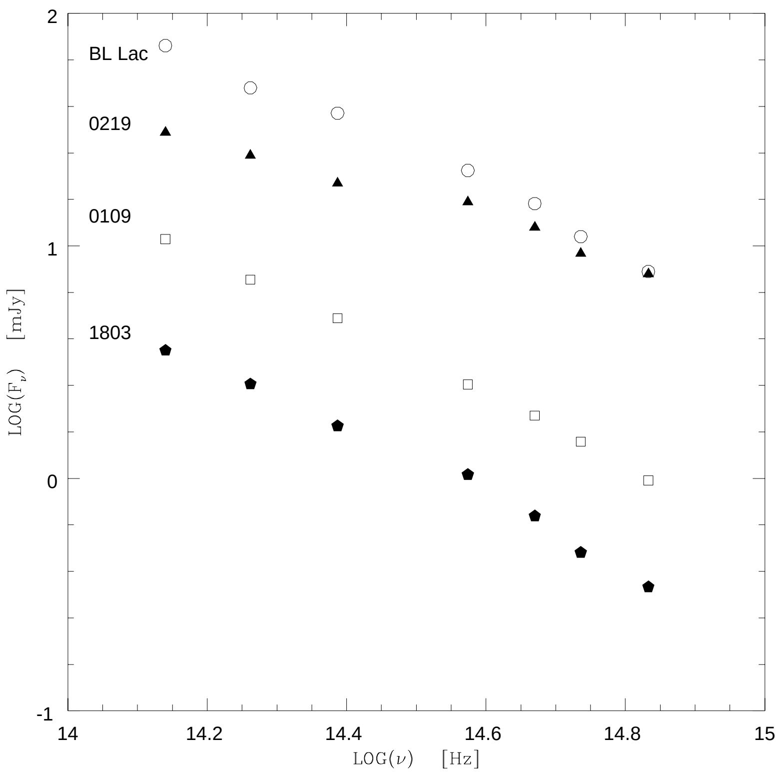

Fig. 1. Energy distributions of the 4 objects. The size of the data points is approximately equal to the error bar.

Table 1. Optical observations.

Source name	B	V	R	I	α_{opt}
S2 0109+22			15.66		1.60 ± 0.11
3C 66A	14.68	14.23	13.76	13.23	1.22 ± 0.06
S5 1803+78			16.78		1.90 ± 0.06
BL Lac	15.66	14.77	14.06	13.26	1.70 ± 0.09

previous ones. The spectral energy distribution of this source, in the $\log(\nu F_\nu)$ *vs* $\log(\nu)$ plane has therefore its peak around $3\ 10^{14}$ Hz (1 μm) while the other three peak at frequencies below the K band.

No infrared excess with respect to the extrapolation of the optical slope has been found in any object. A single power law fit to the full B to K range is satisfactory only for S2 0109+22 (χ^2_r=0.57), while the most marked curvature was found for BL Lac (χ^2_r=5.13 for a single power law fit).

Table 2. Infrared observations.

Source name	$DD-MM$	J	H	K	α_{nir}	$\Delta\alpha$
S2 0109+22	$24-8$	13.57	12.68	11.81	1.33 ± 0.11	
	$25-8$	13.76	12.84	11.95	1.41 ± 0.11	
	$26-8$	13.86	12.94	12.07	1.37 ± 0.11	0.23
3C 66A	$22-8$	12.43				
	$23-8$	12.35	11.62	10.88	0.82 ± 0.11	
	$24-8$	12.36	11.56	10.86	0.87 ± 0.11	
	$26-8$	12.45	11.63	10.94	0.88 ± 0.11	0.24
S5 1803+78	$23-8$	14.99	14.09	13.26	1.26 ± 0.11	
	$24-8$	15.06	14.04	13.27	1.36 ± 0.11	
	$26-8$	15.00	14.00			0.54
BL Lac	$22-8$	12.11	11.22	10.29	1.31 ± 0.14	
	$25-8$	11.90	11.03		1.20 ± 0.14	
	$26-8$	11.81	10.95	10.05	1.18 ± 0.14	0.52

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