ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **132**, 361–365 (1998)

Optical observations of eight X-ray selected BL Lacertae objects⋆

C.M. Raiteri[1], M. Villata[1], G. De Francesco[1], L. Lanteri[1], M. Cavallone[2], and G. Sobrito[2]

[1] Osservatorio Astronomico di Torino, Strada Osservatorio 20, I-10025 Pino Torinese, Italy
[2] Istituto di Fisica Generale dell'Università di Torino, via P. Giuria 1, I-10125 Torino, Italy

Received February 23; accepted May 6, 1998

Abstract. We present optical data in the Johnson's BV and Cousins' R bands for eight X-ray selected BL Lacertae objects (BL Lacs) that have recently been pointed by the Satellite per Astronomia X "Beppo" (BeppoSAX). The observations were done with the 1.05 m telescope of the Torino Astronomical Observatory and the observational periods include, or are close to, the satellite pointings. These data provide optical information on sources that have been rarely observed in the optical band. Moreover, they can be compared to the X-ray ones for a better understanding of the emission properties of these objects. Variability on short time scales (a few days) was found for MS 0317.0+1834, 1ES 0347−121, and MS 0737.9+7441.

Key words: galaxies: active — BL Lacertae objects: general

1. Introduction

The BL Lacertae objects (BL Lacs) belong to the class of blazars, which are the active galactic nuclei showing the most extreme features: intense and variable emission and large and variable polarization. According to the current interpretation, their radiation is produced in a relativistic jet and is beamed towards us. However, many important questions about the mechanisms that are responsible for the emission at the various wavelengths are still to be answered and a big observational effort is required to shed light on this matter. In recent years it has become clear that useful information can be derived by the simultaneous observation of these objects in different bands, in order to reveal possible correlations and to discriminate among the theoretical models. The launch of satellites for astronomical studies has made this kind of study possible.

Since fall 1994 the Torino blazar monitoring group is performing optical observations of blazars, in particular during satellite pointings (see e.g. Villata et al. 1997; Raiteri et al. 1998; Ghisellini et al. 1997). In this paper we present BVR data for eight objects that are part of the X-ray selected BL Lacs core program of the Satellite per Astronomia X "Beppo" (BeppoSAX). Observations were done during or close to the satellite pointings. The X-ray data are reported in Wolter et al. (1998), where the spectral energy distributions of all the eight BL Lacs are also shown.

2. Observations

The observations were done in the standard Johnson's BV and Cousins' R bands with the 1.05 m REOSC telescope of the Torino Astronomical Observatory. The instrument is endowed with a 1242×1152 CCD device with a scale of 0.47 arcsec per pixel. Flat field frames are taken every night and the median is used for image correction. The data are reduced with the Robin procedure locally developed. This includes bias subtraction and flat field correction; a circular gaussian fit is performed after background subtraction through an inclined plane. We made BVR photometry in order to calibrate the source magnitude: Landolt's fields (Landolt 1992) were observed during photometric nights and the BVR magnitudes of a number of reference stars in the fields of the BL Lacs were estimated. The transformation to the standard system was obtained with the Calib procedure written locally. The resulting photometric sequences are published in Villata et al. (1998a).

The coordinates of the observed BL Lacs are given in Table 1.

Send offprint requests to: C.M. Raiteri. E-mail: raiteri@to.astro.it

⋆ Tables 2–9 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

Table 1. List of the observed BL Lacs

Source	Name	RA (2000)	Dec. (2000)
0158+003	MS 0158.5+0019	02 01 06.11	+00 34 00.4
0317+185	MS 0317.0+1834	03 19 51.83	+18 45 34.9
0347−121	1ES 0347−121	03 49 23.20	−11 59 27.0
0414+009	[HB89] 0414+009	04 16 52.46	+01 05 23.5
0502+675	1ES 0502+675	05 07 56.20	+67 37 24.0
0737+746	MS 0737.9+7441	07 44 05.12	+74 33 58.1
1133+704	Mkn 180	11 36 26.41	+70 09 27.3
1517+656	1ES 1517+656	15 17 47.58	+65 25 23.3

3. Results

The results of our observations are presented in Tables 2–9 and Figs. 1–7, these latter showing light curves in the R band, since it is the best sampled one. The BeppoSAX pointings are indicated.

Magnitude calibration was obtained by adopting our own photometry (Villata et al. 1998a) for all sources but MS 0158.5+0019 and MS 0317.0+1834, for which we used the photometric sequences published by Smith et al. (1991). The source magnitude is calculated with respect to two reference stars in the same field; in the subsets to the figures we plot the magnitude difference between these two stars normalized to their mean magnitude difference. This gives information on the reliability of the reference stars in each frame. Most of the eight BL Lacs examined here are very faint, so that the magnitude uncertainties are often of the order of 0.1 mag.

3.1. MS 0158.5+0019

BL Lac MS 0158.5+0019 is a very faint source. Previous estimates of its V magnitude are: 17.96 (Stocke et al. 1991), 18.30 and 18.60 (Jannuzi et al. 1993), and 18.39 (Xie et al. 1996). Recently, in a study on the intraday variability in X-ray selected BL Lacs, Heidt & Wagner (1998) measured an average brightness $R = 18.5$. They found no evidence of variability for this source during fifteen observations.

Our results are shown in Table 2. We have only one datum in the V band, indicating a magnitude of 18.60 on October 22, 1996.

The BeppoSAX pointing occurred on August 16–17, 1996.

3.2. MS 0317.0+1834

Stocke et al. (1991) reported $V = 18.12$ for this source, and $V = 18.13$ was detected by Jannuzi et al. (1993). Xie et al. (1992) found $V = 18.01 - 18.54$ and recently $V = 17.82 - 18.28$ (Xie et al. 1996); in this last work they noticed variability on short time scales. Variability was also found by Heidt & Wagner (1998), who give an average R magnitude of 17.7.

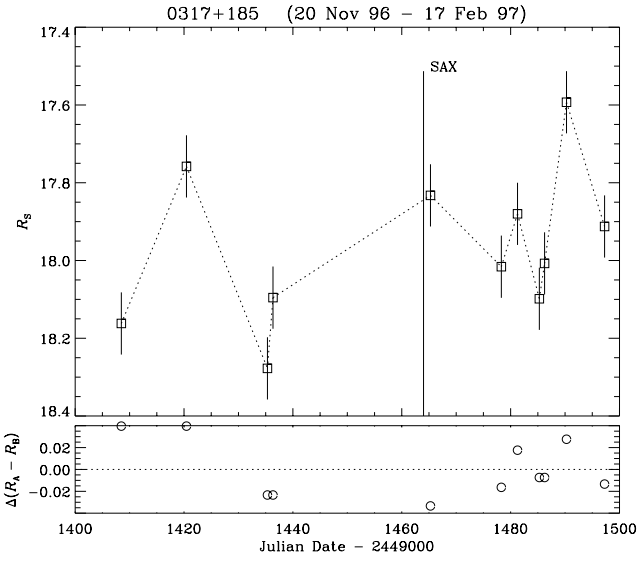

Fig. 1. Light curve in the R band of MS 0317.0+1834

We have collected 11 data in the R band and 4 data in the V band from October 19, 1996 to February 17, 1997 (see Table 3 and Fig. 1). Our observations give $R = 17.59 - 18.28$ and $V = 17.97 - 18.72$. A brightness increase of 0.51 mag in 5 days was detected on February 5–10, 1997.

The BeppoSAX satellite pointed this source on January 15, 1997, within our observational period.

3.3. 1ES 0347−121

As far as we know, the only optical photometric information on this source can be found in Schachter et al. (1993), who give a UK Schmidt B_J magnitude of 19.1.

Ten data in the R band ($R = 17.29 - 18.04$) and two data in the V band ($V = 18.10 - 18.39$) were taken between November 9, 1996 and February 10, 1997 (see Table 4 and Fig. 2). A brightness decrease of 0.75 mag in a week is visible in the R light curve after the BeppoSAX pointing of January 10, 1997.

3.4. [HB89] 0414+009

Observations of this BL Lac were done by Pica et al. (1988) in the B band from September 1984 to January 1987: they found $B = 17.16 - 18.09$. McHardy et al. (1992) give $R = 16.64$ and $V = 17.21$; Hewitt & Burbidge (1993) report $V = 17.59$ and $B - V = 0.48$.

The BeppoSAX satellite pointed this source on September 21–22, 1996; our data cover the period October 19, 1996 – February 10, 1997 (see Table 5). The R light curve is shown in Fig. 3. With respect to the previous observations our data reveal a higher optical state: $R = 16.18 - 16.40$, $V = 16.65 - 16.86$, $B - V = 0.45 - 0.47$.

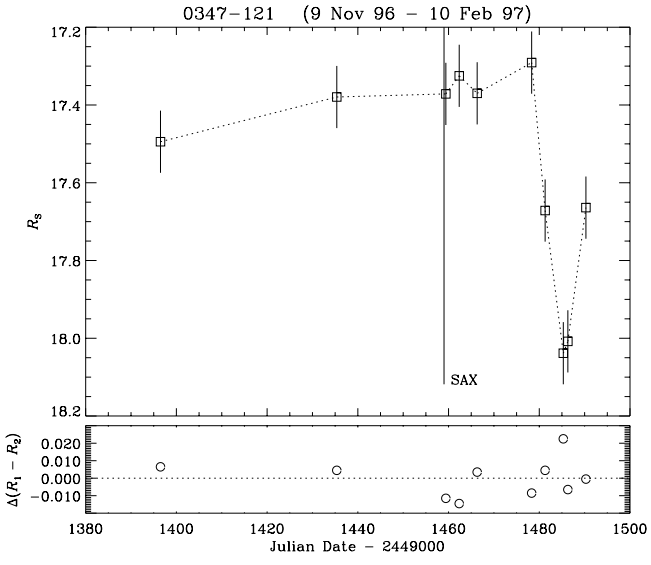

Fig. 2. Light curve in the R band of 1ES 0347−121

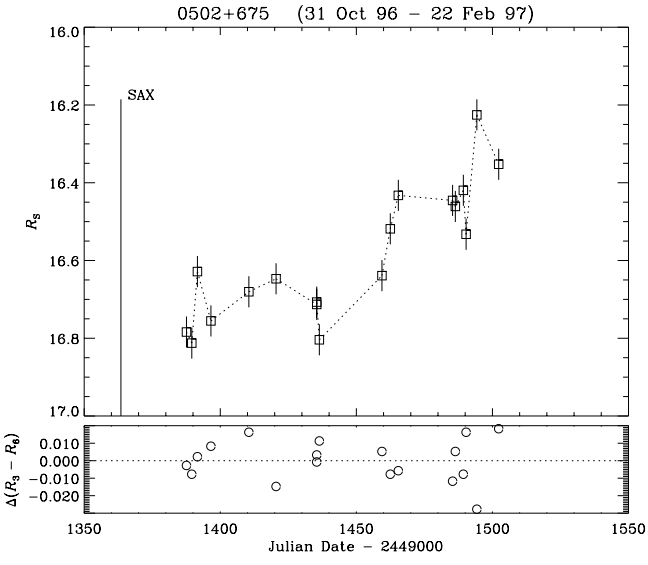

Fig. 4. Light curve in the R band of 1ES 0502+675

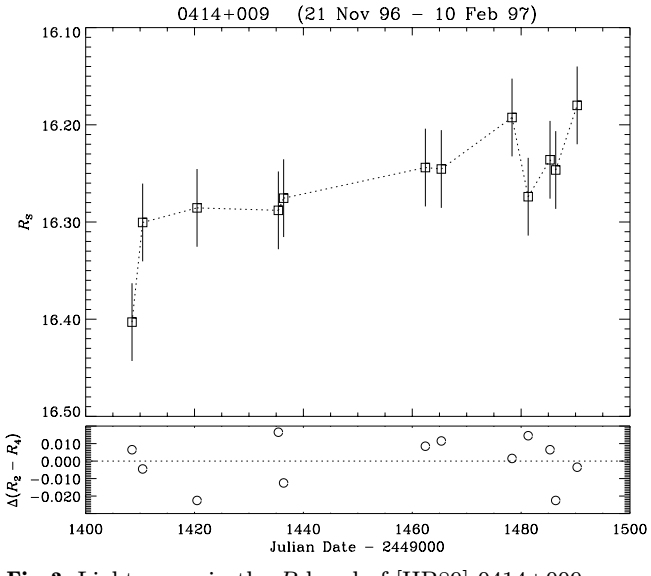

Fig. 3. Light curve in the R band of [HB89] 0414+009

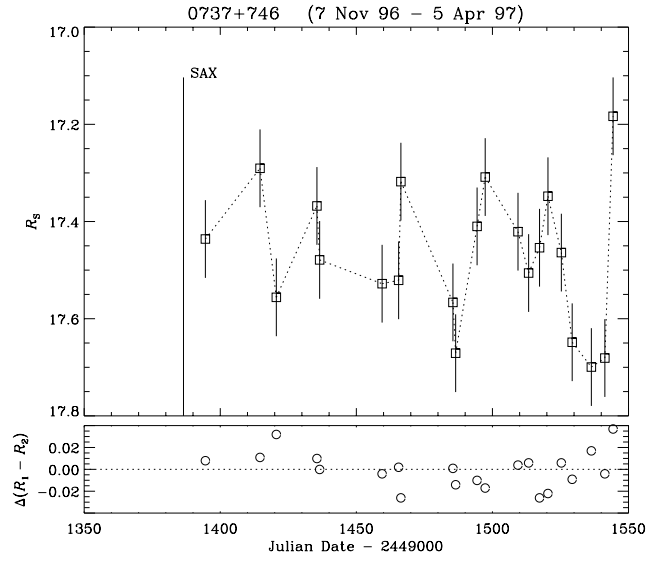

Fig. 5. Light curve in the R band of MS 0737.9+7441

3.5. 1ES 0502+675

Only two sources of optical photometric data for this BL Lac can be found in the literature: a POSS O magnitude of 18.5 ($V \sim 18.0$) is found in Schachter et al. (1993), while Perlman et al. (1996) report $V = 17.0$.

The BeppoSAX pointing occurred on October 6–7, 1996; we started to observe this source on October 18, 1996 (see Table 6). An increasing trend appears from the light curve in the R band shown in Fig. 4, with a maximum variation $\Delta R = 0.58$.

3.6. MS 0737.9+7441

Stocke et al. (1991) measured $V = 16.89$ for this source, while Heidt & Wagner (1998) found an average R magnitude of 18.0 over 24 observations and no evidence of variability.

We collected 21 frames in the R band, 2 in the V band, and 1 in the B band between November 7, 1996 and April 5, 1997 (see Table 7); the BeppoSAX pointing was on October 29–30, 1996. The light curve in the R band is characterized by rapid flickering (see Fig. 5); in particular, an increase of 0.50 mag in 3 days was detected at the end of the observational period.

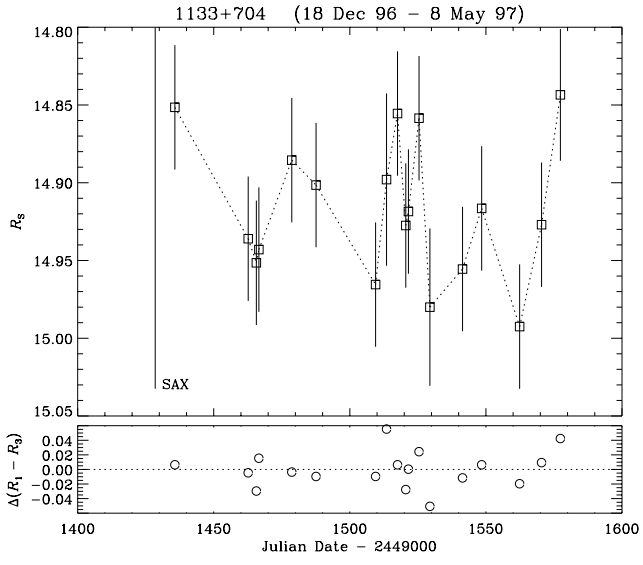

Fig. 6. Light curve in the R band of Mkn 180

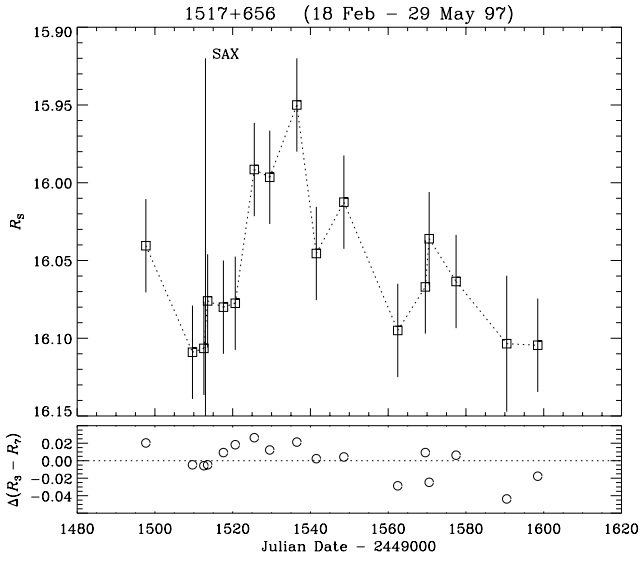

Fig. 7. Light curve in the R band of 1ES 1517+656

3.7. Mkn 180

This is the most luminous object among the BL Lacs we are considering: Mufson & Hutter (1981) and Hutter & Mufson (1981) measured $V = 15.03$ and $B - V = 0.76$, while Hewitt & Burbidge (1993) report $V = 14.49$ and $B - V = 0.67$.

Our observations began on December 18, 1996, a week after the BeppoSAX pointing of December 10–11, 1996, and ended on May 8, 1997 (see Table 8 and Fig. 6). The source did not show a noticeable variability, but a weak flickering around a level lower than the previously reported ones ($R = 14.84 - 14.99$, $V = 15.27 - 15.38$, $B - V = 0.63 - 0.74$).

3.8. 1ES 1517+656

This BL Lac is another object seldom observed in the optical band: the only photometric information is given by Perlman et al. (1996), who quote a V magnitude of 15.91.

We observed this source from February 18 to May 29, 1997, and have data simultaneous with the BeppoSAX pointing of March 5, 1997 (see Table 9). As can be seen from the light curve in the R band shown in Fig. 7, no relevant variability was detected. This source shows the flattest spectrum in the present sample: $V - R \sim B - V \sim 0.35$.

4. Conclusions and discussion

Eight X-ray selected BL Lacertae objects were observed in the Johnson's BV and Cousins' R bands with the 1.05 m telescope of the Torino Astronomical Observatory from October 1996 to May 1997. In some cases (MS 0317.0+1834, 1ES 0347−121, and MS 0737.9+7441) variability on a time scale of a few days was detected.

Most of these objects have been seldom observed in the past, so that their optical behaviour is still largely unknown. The data presented in this paper represent a contribution to their study.

The observational periods include, or are close to, the BeppoSAX satellite pointings, so that the optical data can be compared to the X-ray ones and to others taken at different wavelengths in order to derive information on the emission processes that are at work in the BL Lacs jets.

Our data confirm that in general the X-ray selected BL Lacs do not present strong optical variability, in comparison with the radio selected ones. However, some of them have shown strong variability at X-ray energies. This kind of behaviour can find a possible interpretation as a purely geometric effect, without the need of an intrinsic flux variation. As shown in Villata et al. (1988b), one can assume that the synchrotron-emitting relativistic jet presents some kind of curvature (maybe with a helical shape); in this case only one (or some) part of the emission is strongly beamed towards us: the X-ray bright sources would be those whose X-ray emitting portion is more collimated with the line of sight with respect to lower-energy emitting parts. Small displacements of the jet would produce large variations of the X-ray flux, whereas the less-beamed optical radiation would not be affected by a corresponding variation. A detailed study of this scenario will be presented in Villata & Raiteri (1998).

Acknowledgements. This research has made use of the NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory, California Institute of Technology,

under contract with the National Aeronautics and Space Administration.

References

Ghisellini G., Villata M., Raiteri C.M., et al., 1997, A&A 327, 61
Heidt J., Wagner S.J., 1998, A&A 329, 853
Hewitt A., Burbidge G., 1993, ApJS 87, 451
Hutter D.J, Mufson S.L., 1981, AJ 86, 1585
Jannuzi B.T., Smith P.S., Elston R., 1993, ApJS 85, 265
Landolt A.U., 1992, AJ 104, 340
McHardy I.M., Luppino G.A., George I.M., Abraham R.G., Cooke B.A., 1992, MNRAS 256, 655
Mufson S.L., Hutter D.J., 1981, ApJ 248, L61
Perlman E.S., Stocke J.T., Schachter J.F., et al., 1996, ApJS 104, 251
Pica A.J., Smith A.G., Webb J.R., et al., 1988, AJ 96, 1215
Raiteri C.M., Ghisellini G., Villata M., et al., 1998, A&AS 127, 445
Schachter J.F., Stocke J.T., Perlman E., et al., 1993, ApJ 412, 541
Smith P.S., Jannuzi B.T., Elston R., 1991, ApJS 77, 67
Stocke J.T., Morris S.L., Gioia I.M., et al., 1991, ApJS 76, 813
Villata M., Raiteri C.M., 1998, A&A (in preparation)
Villata M., Raiteri C.M., Ghisellini G., et al., 1997, A&AS 121, 119
Villata M., Raiteri C.M., Lanteri L., Sobrito G., Cavallone M., 1998a, A&AS 130, 305
Villata M., Raiteri C.M., Sillanpää A., Takalo L.O., 1998b, MNRAS 293, L13
Wolter A., Comastri A., Ghisellini G., et al., 1998, A&A 335, 899
Xie G.Z., Li K.H., Liu F.K., et al., 1992, ApJS 80, 683
Xie G.Z., Zhang Y.H., Li K.H., et al., 1996, AJ 111, 1065