THE NEAR–IR–OPTICAL–UV EMISSION OF BL LACERTAE OBJECTS

E. Pian¹, R. Falomo², R. Scarpa³, and A. Treves¹

¹ Scuola Internazionale Superiore di Studi Avanzati, via Beirut 2–4, 34014 Trieste, Italy
² Osservatorio Astronomico di Padova, v. Osservatorio 5, 35122, Padova, Italy
³ Dipartimento di Astronomia dell’Università di Padova, v. Osservatorio 5, 35122 Padova, Italy

To appear in The Astrophysical Journal

¹ Based on observations obtained at the European Southern Observatory, La Silla, Chile, and with the International Ultraviolet Explorer collected at the ESA Tracking Station at Villafranca
ABSTRACT

Near-infrared, optical and ultraviolet quasi-simultaneous observations of 11 BL Lacertae objects are reported. For all but one source the dereddened spectral flux distribution in the $8 \cdot 10^{13} - 2 \cdot 10^{15}$ Hz frequency range can be described by a single power law $f_\nu \propto \nu^{-\alpha}$ with average spectral index $<\alpha> = 0.88 \pm 0.42$ (standard deviation) plus, where relevant, the contribution of the host galaxy. In most cases the non-simultaneous soft X-ray fluxes obtained by the Einstein Observatory lie on or below the extrapolation of the power law. The results are compared with the average spectral properties of other samples of BL Lacs studied separately in the IR-optical and in the UV bands. The implications for existing models of the objects are shortly discussed.

Subject headings: BL Lacertae objects: general — infrared: galaxies — ultraviolet: galaxies — multifrequency observations: galaxies
1. INTRODUCTION

The spectral flux distribution (SFD) of BL Lacertae objects (BL Lacs) from the far–IR to X–ray range is supposedly dominated by non thermal emission due to synchrotron radiation with possible contribution, at the higher frequencies, of the Compton mechanism. The existence of breaks or of spectral curvature is important for constructing models for acceleration and radiation of electrons, and for constraining the emitting region, in particular to ascertain if it has an anisotropic structure where relativistic beaming possibly takes place.

The overall SFD is generally described either by broken power laws or by continuous steepening (see e.g. Cruz–Gonzalez & Huchra 1984; Landau et al. 1986; Ghisellini et al. 1986; Brown et al. 1989; Ballard et al. 1990). Most of previous papers refer to non simultaneous observations, not systematically corrected for extinction due to dust inside our Galaxy and for the thermal contribution produced by the host galaxy starlight. The stellar contribution, if non negligible with respect to the non thermal emission, produces a steepening of the energy distribution in the optical and a flattening in the near–IR, while reddening extinction introduces a steepening of the continuum mainly at optical–UV frequencies. For instance, the spectral break observed in some objects between near–IR and optical is completely removed when proper reddening corrections are applied (see e.g. Falomo et al. 1993b).

We report here on quasi–simultaneous ($\Delta t \lesssim 1$ day) near–IR, optical
and UV ($8 \cdot 10^{13} - 2 \cdot 10^{15}$ Hz) observations of 11 BL Lacs obtained in the course of our 10 years systematic multifrequency study of blazars (see Falomo et al. 1993a,b,c and references therein). Most of them have been previously published, but are here reconsidered and analysed using a homogeneous procedure which takes into account the galactic extinction and the host galaxy contribution. The main aim of the paper is to derive the intrinsic shape of the non thermal emission from near–IR to UV frequencies, based on a relatively extended sample, though not complete from the statistical point of view.

The plan of the paper is as follows: In §2 the modes of observation and of data analysis are described. In §3 the general characteristics of the near–IR–optical–UV SFDs are outlined and their extrapolations are compared with non simultaneous far–IR (IRAS) and soft X–ray (Einstein) data. In §4 the results are discussed and the spectral slopes of the 11 considered objects are compared with those of two samples of 33 and 24 objects observed, respectively, in the near–IR–optical and in the UV ranges.

2. OBSERVATIONS AND DATA ANALYSIS

The target objects are reported in Table 1, sorted by increasing right ascension (Col. 1), along with dates of observations (Col. 2), redshift (Col. 3), galactic extinction values (Col. 4, see below). Col. 5 labels
whether the source is radio–strong (RS) or radio–weak (RW), following the criterion of Ledden & O’Dell (1985). RS objects substantially correspond to radio selected ones, and RW to X–ray selected ones. A journal of observations is given in Table 2, where fluxes in selected bands are reported. All observations were obtained with the same instrumentation and analysed using a uniform procedure. For most objects, observations in the near–IR, optical and UV bands were taken within \(~1\) day. In two cases (2005–489 and 2155–304) we combined simultaneous IR–optical and optical–UV observations taken at different epochs to study the IR–optical–UV emission (see next section). For two sources (0048–097 and 0422+004), more than one overall spectrum has been obtained, allowing a comparison of the spectral shape at different states.

2.1 Near–IR Photometry

J,H,K and L photometry was obtained at the European Southern Observatory (ESO) 2.2m telescope (+ InSb photometer). A 15 arcsec circular aperture with chopper throw of 20 arcsec in the E–W direction was used. Statistical 1–\(\sigma\) errors are less than 0.1 mag in all bands. Conversion to flux units is made according to the zero–magnitude fluxes given in Bersanelli, Bouchet & Falomo (1991).

2.2 Optical Spectrophotometry
Optical spectrophotometry of the sources was gathered at the ESO 1.5m telescope equipped with a Boller and Chivens spectrograph and CCD detector. Spectra were taken at a resolution of ≈ 15 Å (FWHM) through a long slit of 8 arcsec width. Standard reduction procedures were applied to obtain flux calibrated spectra. From repeated observations of standard stars (Stone 1977; Baldwin & Stone 1984) during each night, we derived a photometric accuracy better than 10%. To increase the signal-to-noise ratio, we averaged the fluxes binning the spectra over bands of 100 Å.

2.3 Ultraviolet Spectra

UV spectra derive from the Short Wavelength Primary (SWP; range: 1200–1950 Å) and the Long Wavelength Primary (LWP; range: 2000–3200 Å) cameras onboard of the International Ultraviolet Explorer (IUE). IUE line-by-line images were flux calibrated using curves provided by Bohlin & Holm (1980) and Bohlin et al. (1990) for the SWP camera and Cassatella, Lloyd & Gonzalez–Riestra (1989) for the LWP camera. Net spectra were extracted using an implementation of the Gaussian extraction procedure (GEX, Urry & Reichert 1988) running within the MIDAS interactive analysis system (see Falomo et al. 1993a). We added a 10% photometric error to the statistical flux errors.

The UV spectra of 2005–489 and 2155–304 were retrieved from the ULDA archive. We note that IUE spectra extracted with the IUESAIPS
procedure, show systematic flux differences by 5 to 10 % with respect to extraction with the SWET method of Kinney, Bohlin & Neill (1991). In order to avoid such flux distortion due to different extraction methods, we have applied correction on IUESIPS extraction based on comparison with the UV data reported by Edelson et al. (1992).

Overall data were corrected for galactic interstellar reddening using the extinction values listed in Table 1. They were deduced from the hydrogen column density (Stark et al. 1992) assuming $N_H/E_{B-V} = 5.2 \cdot 10^{21}$ (Shull & Van Steenberg 1985) and $R = 3.1$ (Rieke & Lebofsky 1985). The interstellar extinction curve of Cardelli, Clayton & Mathis (1989) was used.

3. SPECTRAL FLUX DISTRIBUTIONS

A composite SFD was constructed for each object from quasi–simultaneous IR, optical and UV observations. For many objects, we have some more optical observations, spaced of $\sim 1$ day from the one presented here for a given epoch (see Falomo, Scarpa & Bersanelli 1994). Because no significant flux variations during day time scales are found, we do not expect that intra–day variability substantially affects our results.

For all sources we attempted a decomposition of the SFD in terms of a power law plus the contribution of a host galaxy (see Fig. 1). As a model for the starlight contribution we assumed the energy distribution of
a standard giant elliptical galaxy (Yee & Oke 1978) for the optical region, extended to the near–IR using the colors for ellipticals given by Arimoto & Yoshii (1987). To subtract the host galaxy component, the redshift of the object is needed. This is not available for 2 objects, therefore we assumed a rough estimate of $z$ based on fit optimization. Parameters of the decomposition are: the spectral index $\alpha$ of the power law component and the percentage $P_g$ of starlight contribution at 5500 Å. We performed a least squares fit of the SFDs and report in Table 1 the best fit values. Col. 9 gives the estimated absolute magnitude of the host galaxy.

For most sources, after proper correction for the galactic extinction and subtraction of the starlight component, the IR–optical–UV non thermal emission is adequately well fitted by a single power law. In four objects (0048–097, 0118–272, 1538+149, 1553+113) the host galaxy is not detectable, thus no decomposition of the SFD was performed. The SFDs of the first three objects are well described by a single power law (see Fig. 1 and Table 1). For 1553+113 a single power law does not account for the SFD but a considerable discontinuity is apparent ($\Delta \alpha \sim 0.8$) at $\sim 3000$ Å, which makes this source the only case where a marked spectral change is observed (see also Falomo & Treves 1990). For seven objects we observe a bending of the SFD, which we ascribe to the host galaxy. After decomposition of the thermal component, the data are satisfactorily represented by a single power law. In two cases (0323+022 and the high state of 0422+004) the fit is however poor ($\chi^2 \sim 2$).
For two sources (0048–097 and 0422+004) we obtained SFDs at two different epochs. As for 0048–097, the two SFDs differ by a factor 1.5 in the optical range and a slightly steeper spectrum ($\Delta \alpha \sim 0.3$) is exhibited in the lower state (see Fig. 1). In the low state the UV data appear systematically below the power law fit, suggesting a possible further steepening of the SFD in the UV. However, due to the low flux level of this IUE spectrum, its steepening must be regarded with caution.

Similarly, 0422+004 shows an optical flux variability of a factor $\sim 1.5$. After subtraction of the host galaxy, the non thermal component is described at both epochs by a single power law. No significant changes of spectral index are found here (see Table 1). The source had been observed also in a previous occasion (1987, Falomo et al. 1989), but the lack of a correction for reddening and for the host galaxy contribution led to the interpretation of the 1987 and 1988 SFDs in terms of broken power laws or of logarithmic parabolas.

For 2005–489 and 2155–304 we do not have IR, optical and UV simultaneous observations, therefore we combined simultaneous IR–optical observations (Falomo et al. 1993b) with simultaneous optical–UV observations obtained at different epochs. Optical–UV observations were scaled to match near–IR–optical data in the optical range. This is justified by the property that the optical spectral index remains rather constant, even if the flux level changes sizeably with time (Falomo et al. 1994). The combined SFD of 2005–489 (see Table 2 and Fig. 1) exhibits
a clear bending in the near–IR due to host galaxy. The decomposition of the SFD in terms of power law plus host galaxy is not very satisfactory \( (\chi^2 \sim 3) \), because far–UV data appear to be systematically below the fit. A similar situation occurs in the case of 2155–304, although the bending is here less evident. Also in this case, far–UV fluxes lie systematically below the overall fit. This, similarly to the case of 1553+113, might be due to an intrinsic spectral break of the power law component at \( \log(\nu) \sim 15.1 \). Although an intrinsic spectral steepening in the UV band of these two sources appears an acceptable explanation, we believe that other causes as IUE flux extraction and calibration, proper reddening correction and the lack of a single epoch observation may build up a similar effect. Based only on these data, we cannot draw a firm conclusion on this point.

In order to extend our SFDs to adjacent bands (far–IR and X–rays) we collected from the literature IRAS data (Impey & Neugebauer 1988) and soft X–ray fluxes gathered by the Einstein Observatory (Owen, Helfand & Spangler 1981; Madejski & Schwartz 1983; Ulmer et al. 1983; Ledden & O’Dell 1985; Worrall & Wilkes 1990; Elvis et al. 1992). The IRAS fluxes represent in four cases only upper limit values. The overall (non simultaneous) SFDs from far–IR to X–rays of our target objects are reported in Fig. 2. We note that the extrapolation of our IR–to–UV power law fit to far–IR is consistent with IRAS fluxes (and upper limits) taking into account the variability regime of the objects. On the other hand,
in all cases but 0521–365 the observed X–ray flux lies on or below our extrapolations.

4. DISCUSSION

The main result of the paper is that in all of the examined objects but 1553+113 the SFD in the IR–optical–UV band is properly represented by a unique power law, when corrections for reddening and host galaxy are taken into account. This is at variance with previous results, which found a turnover in blazar spectra between IR and UV wavelengths (e.g. Cruz–Gonzalez & Huchra 1984; Ghisellini et al. 1986) or a smooth curvature from the radio to the UV domain (e.g. Landau et al. 1986; Brown et al. 1989). We believe that most of the difference is due to the use of simultaneous observations and proper corrections for extinction and for the stellar contribution. This is illustrated by the case of 0422+004, for which the proper account of the severe galactic extinction and of the host galaxy contribution, determines a radical change in the description of the emission components. Due to the higher, and more reliable, value of the extinction coefficient adopted here for 0323+022, the fit decomposition parameters for this object are slightly different than those previously obtained (Falomo et al. 1993a).

Our decomposition of the SFD allows to estimate also the starlight contribution of program objects. The derived absolute magnitudes cor-
respond to an $8 \times 8$ arcsec$^2$ effective aperture. They are in general good agreement with those obtained from direct imaging studies, considering the aperture correction, which is crucial for low redshift objects (see e.g. the cases of 0323+022 studied by Filippenko et al. 1986; 0521–365, Keel 1986; 0414+009, Falomo & Tanzi 1991; 2155–304, Falomo, Pesce & Treves 1993). Furthermore, recent optical imaging of 0301–243 confirmed the presence of a diffuse nebulosity surrounding the object (Falomo 1994, in preparation).

The average spectral index of the power law component in our sample is $\langle \alpha \rangle = 0.88 \pm 0.42$ (standard deviation), with a marked tendency for RW objects to be flatter than RS ones at $\sim 3\sigma$ probability level; the average spectral slopes are in fact, respectively, $\langle \alpha \rangle = 0.45 \pm 0.15$ (s.d.) and $\langle \alpha \rangle = 1.17 \pm 0.22$ (s.d.). Comparison with the results from two broader samples of BL Lacs supports our finding that the average spectral slope in the IR–optical–UV band has no discontinuities. We refer to a list of 33 objects (Falomo et al. 1993b), whose simultaneous IR–optical data were properly corrected for reddening and host galaxy contribution. The second sample has been considered by Pian & Treves (1993) containing 24 BL Lacs simultaneously observed in the two IUE bands. In Table 3 we report the average spectral indices of the different samples, which appear very similar. It is noticeable that also in the broader samples RW objects have average harder spectra than RS ones. This subdivision, which is known since some time, was tested with
the Kolmogorov–Smirnov method at the 99% significance level by Pian & Treves (1993) and received further observational support (Giommi, Ansari & Micol 1993). In the framework of jet emission models, it can be interpreted as related to a different beaming angle in the two classes, and to a decreasing opening angle of the jet with decreasing emission frequency and increasing distance from the nucleus. RS BL Lacs are more beamed toward us, and then present a more relativistically enhanced lower frequency emission than RW ones (Maraschi et al. 1986; Celotti et al. 1993; Maraschi, Ghisellini & Celotti 1993).

The absence of breaks or curvature in the spectral shape in the \(8 \cdot 10^{13}\) to \(2 \cdot 10^{15}\) Hz frequency interval suggests that a single mechanism is responsible for the radiation in the whole range. The obvious candidate is thin synchrotron radiation, as specifically indicated by the optical and UV polarization. We note that the observed X–ray fluxes lie systematically on or below the extrapolation of the non thermal emission. Although the X–ray data were not taken simultaneously, this is indicative that no component in addition to the synchrotron one is present in the soft X–rays, and in particular the synchrotron self–Compton process is probably negligible. Instead, the data suggest a steepening of the spectrum toward soft X–ray frequencies. This means that the electron acceleration mechanism at the higher energies has a typical time scale longer than the electron lifetimes, so that injection of high energy particles is less efficient than radiative losses.
Finally, we note that both IR–optical and UV observations of BL Lacs indicate that the spectral slope changes only modestly with the flux level (Falomo et al. 1993b; Falomo et al. 1994; Edelson 1992; Urry et al. 1993). This fact, together with our results, suggests that the whole IR–optical–UV slope is unique and constant even when the intensity varies by large factors. Such lack of spectral variability does not arise in a natural way in any of the proposed models for BL Lacs, apart from those implying gravitational lensing (Ostriker & Vietri 1985; 1990). This very constancy seems to us a key constraint in a theoretical progress of our understanding of BL Lac emission.
We have reconsidered in this work the results of a 10 years observing program realized in collaboration with P. Bouchet, L. Chiappetti, L. Maraschi and E.G. Tanzi, who are here gratefully acknowledged. We thank the anonymous referee for many useful suggestions. This research has made use of the graphics package Super Mongo by R. Lupton and P. Monger.
REFERENCES

Arimoto, N., & Yoshii, Y. 1987, A&A, 173, 23

Baldwin, J. A., & Stone, R. P. S. 1984, MNRAS, 206, 241

Ballard, K. R., Mead, A. R. G., Brand, P. W. J. L., & Hough, J. H. 1990, MNRAS, 243, 640

Bersanelli, M., Bouchet, P., & Falomo, R. 1991, A&A, 252, 854

Bohlin, R. C., & Holm, A. V. 1980, IUE NASA Newsletter, 10, 37

Bohlin, R., Harris, A. W., Holm, A. V., & Gry, C. 1990, ApJS, 73, 413

Brown, L. M. J., et al. 1989, ApJ, 340, 129

Cardelli, J. A., Clayton, G. C., & Mathis, J. S. 1989, ApJ, 345, 245

Cassatella, A., Lloyd, C., & Gonzalez–Riestra, R. 1989, IUE ESA Newsletter, 35, 225

Celotti, A., Maraschi, L., Ghisellini, G., Caccianiga, A., & Maccacaro, T. 1993, ApJ, 416, 118

Cruz–Gonzalez, I., & Huchra, J. P. 1984, AJ, 89, 441

Edelson, R., Pike, G. F., Saken, J. M., Kinney, A., & Shull, J. M. 1992, ApJS, 83, 1

Edelson, R. 1992, ApJ, 401, 516
Elvis, M., Plummer, D., Schachter, J., & Fabbiano, G. 1992, ApJS, 80, 257

Falomo, R., Bouchet, P., Maraschi, L., Tanzi, E. G., & Treves, A. 1988, ApJ, 335, 122

Falomo, R., Bouchet, P., Maraschi, L., Tanzi, E. G., & Treves, A. 1989, ApJ, 345, 148

Falomo, R., & Treves, A. 1990, PASP, 102, 1120

Falomo, R., & Tanzi, E. G. 1991, AJ, 102, 1294

Falomo, R., Treves, A., Chiappetti, L., Maraschi, L., Pian, E., & Tanzi, E. G. 1993a, ApJ, 402, 532

Falomo, R., Pesce, J. E., & Treves, A. 1993, ApJ, 411, L63

Falomo, R., Bersanelli, M., Bouchet, P., & Tanzi, E. G. 1993b, AJ, 106, 11

Falomo, R., Pian, E., Scarpa, R., & Treves, A. 1993c, in Proc. of IAU Symp. 159, Active Galactic Nuclei across the Electromagnetic Spectrum, in press

Falomo, R., Scarpa, R., & Bersanelli, M. 1994, ApJS, in press

Filippenko, A. V., Djorgovski, S., Spinrad, H., & Sargent, W. L. W. 1986, AJ, 91, 49
Ghisellini, G., Maraschi, L., Tanzi, E.G., & Treves, A. 1986, ApJ, 310, 317

Giommi, P., Ansari, S.G., & Micol, A. 1993, in Proc. of IAU Symp. 159, Active Galactic Nuclei across the Electromagnetic Spectrum, in press

Impey, C. D., & Neugebauer, G. 1988, AJ, 95, 307

Keel, W. C., 1986, ApJ, 302, 296

Kinney, A. L., Bohlin, R. C., & Neill, J. D. 1991, PASP, 694, 103

Landau, R., et al. 1986, ApJ, 308, 78

Ledden, J. E., & O’Dell, S. L. 1985, ApJ, 298, 630

Madejski, G. M., & Schwartz, D. A. 1983, ApJ, 275, 467

Maraschi, L., Ghisellini, G., Tanzi, E. G., & Treves, A. 1986, ApJ, 310, 325

Maraschi, L., Ghisellini, G., & Celotti, A. 1993, in Proc. of IAU Symp. 159, Active Galactic Nuclei across the Electromagnetic Spectrum, in press

Ostriker, J. P., & Vietri, M. 1985, Nature, 318, 446

Ostriker, J. P., & Vietri, M. 1990, Nature, 344, 45

Owen, F. N., Helfand, D. J., & Spangler, S. R. 1981, ApJ, 250, L55
Pian, E., & Treves, A. 1993, ApJ, 416, 130

Rieke, G. H., & Lebofsky, M. 1985, ApJ, 288, 618

Shull, J. M., & Van Steenberg, M. E. 1985, ApJ, 294, 599

Stark, A. A., Gammie, C. F., Wilson, R. W., Bally, J., Linke, R. A.,
Heiles, C., & Hurwitz, M. 1992, ApJS, 79, 77

Stone, R. P. S. 1977, ApJ, 218, 767

Ulmer, M. P., Brown, R. L., Schwartz, D. A., Patterson, J., & Cruddace,
R. G. 1983, ApJ, 270, L1

Urry, C. M., & Reichert, G. 1988, IUE NASA Newsletter, 34, 96

Urry, C. M., et al. 1993, ApJ, 411, 614

Worrall, D. M., & Wilkes, B. J. 1990, ApJ, 360, 396

Yee, H. K. C., & Oke, J. B. 1978, ApJ, 226, 753
# Table 1

| Object     | Date          | $z^a$ | $A_V$ | RS/RW | $\alpha^b$ | $P_{\frac{g}{\chi^2}}^c$ | $\chi^2$ | $M_V^d$ |
|------------|---------------|-------|-------|-------|-------------|------------------|--------|--------|
| 0048−097   | 87 Jan 8      | ⋯     | 0.22  | RS    | 0.93 ± 0.06 | ⋯                | 0.87   | ⋯      |
| 88 Aug 3   |               |       |       |       | 1.20 ± 0.06 | ⋯                | 1.39   | ⋯      |
| 0118−272   | 89 Aug 10     | 0.559 | 0.09  | RS    | 1.20 ± 0.03 | ⋯                | 0.40   | ⋯      |
| 0301−243   | 89 Aug 9      | (0.2) | 0.11  | RS    | 0.79 ± 0.06 | 11               | 0.90   | −22.2  |
| 0323+022   | 89 Aug 10     | 0.147 | 0.50  | RW    | 0.23 ± 0.12 | 30               | 1.92   | −22.2  |
| 0414+009   | 89 Feb 15     | 0.287 | 0.51  | RW    | 0.54 ± 0.15 | 3                | 0.06   | −21.3  |
| 0422+004   | 88 Jan 10     | (0.1) | 0.42  | RS    | 1.20 ± 0.15 | 10               | 1.88   | −21.5  |
| 89 Feb 13  |               |       |       |       | 1.19 ± 0.15 | 15               | 0.70   | −21.5  |
| 0521−365   | 87 Jan 8      | 0.055 | 0.21  | RS    | 1.43 ± 0.09 | 51               | 1.39   | −21.7  |
| 1538+149   | 88 Aug 2      | 0.605 | 0.20  | RS    | 1.34 ± 0.06 | ⋯                | 0.23   | ⋯      |
| 1553+113$^e$| 88 Aug 2      | ⋯     | 0.22  | RW    | ⋯             |                  | ⋯      | ⋯      |
| 2005−489   | 86 Sep/89 Aug | 0.071 | 0.33  | RW    | 0.57 ± 0.06 | 12               | 3.21   | −22.2  |
| 2155−304   | 84 Nov/89 Aug | 0.116 | 0.10  | RW    | 0.47 ± 0.06 | 3                | 0.94   | −22.2  |

---

$^a$ Values in parentheses are from the best fit optimization procedure.

$^b$ Errors correspond to 3–σ uncertainties.

$^c$ Percentage of host galaxy contribution at 5500 Å (observer frame).

$^d$ Values are not K–corrected and computed assuming $H_0=50$ km s$^{-1}$ Mpc$^{-1}$; $q_0=0$.

$^e$ IR–Optical region: $\alpha = 0.78 ± 0.06$ ($\chi^2 = 0.38$); UV region: $\alpha = 1.56 ± 0.12$ ($\chi^2 = 0.21$).
| Name     | MJD<sup>a</sup> | F<sub>k</sub><sup>b</sup> | Δt<sup>c</sup> | F<sub>v</sub><sup>d</sup> | F<sub>LWP</sub><sup>e</sup> | Δt<sup>c</sup> | F<sub>SWP</sub><sup>f</sup> | Δt<sup>c</sup> | Refs.<sup>g</sup> |
|----------|-----------------|-----------------|-------------|-------------|-----------------|-------------|-----------------|-------------|----------------|
| 0048 − 097 | 46804.074       | 10.38           | −0.016      | 2.31        | 1.23            | 0.986       | 0.59            | −0.046      | 1              |
|          | 47377.336       | 6.98            | 0.012       | 1.51        | 0.25            | 1.092       | 0.25            | 1.092       | 2,3           |
| 0118 − 272 | 47748.289       | 6.71            | 0.078       | 1.25        | 0.50            | −0.120      | 0.012           | −0.120      | 4              |
| 0301 − 243 | 47749.277       | 4.32            | 0.066       | 1.16        | 0.53            | −1.985      | 0.31            | −1.062      | 4              |
| 0323 + 022 | 47749.367       | 2.65            | −0.012      | 0.67        | 0.26            | −1.011      | 0.15            | 0.906       | 4              |
| 0414 + 009 | 47570.000       | 2.31            | 4.100       | 0.64        | 0.26            | 4.917       | 0.19            | 3.856       | 5              |
| 0422 + 004 | 47171.078       | 16.41           | −0.020      | 2.38        | 0.24            | 0.898       | 0.24            | 0.898       | 6              |
|          | 47571.031       | 12.79           | 0.012       | 1.66        | 0.33            | 1.899       | 0.19            | 0.827       | 2,3           |
| 0521 − 365 | 46803.152       | 18.20           | 0.043       | 2.38        | 0.17            | 1.754       | 0.17            | 1.754       | 2,3           |
| 1538 + 149 | 47377.035       | 2.93            | −0.031      | 0.39        | 0.12            | 0.384       | 0.12            | 0.384       | 4              |
| 1553 + 113 | 47376.969       | 28.31           | 0.023       | 8.43        | 3.44            | 0.348       | 1.37            | −0.552      | 7              |
| 2005 − 489 | 46683.102       | 8.93            | 4.11        | 0.291       | 1.97            | 0.171       | 1.97            | 0.171       | 2,3,8         |
|          | 47748.105       | 26.79           | 0.000       | 8.32        | 1.18            | −0.047      | 0.98            | 0.107       | 2,3,8         |
| 2155 − 304 | 2,3,8           | 2,3,8           | 2,3,8       | 2,3,8       | 2,3,8           | 2,3,8       | 2,3,8           | 2,3,8       | 2,3,8         |

<sup>a</sup> Modified Julian Day of the optical observation.

<sup>b</sup> Flux at 2.19 μm in mJy.

<sup>c</sup> Time lag with respect to the optical observation (days).

<sup>d</sup> Flux at ~ 5500 Å in mJy.

<sup>e</sup> Flux at ~ 2800 Å in mJy.

<sup>f</sup> Flux at ~ 1400 Å in mJy.

<sup>g</sup> References to papers where some of the data have been presented:

1. Falomo et al. 1988.
2. Falomo et al. 1993b.
3. This paper.
4. Falomo et al. 1993a.
5. Falomo & Tanzi 1991.
6. Falomo et al. 1989.
7. Falomo & Treves 1990.
8. Falomo, Scarpa & Bersanelli 1994.
|                  | \(< \alpha_{IROP} >\) | \(< \alpha_{UV} >\) | \(< \alpha_{IROPUV} >\) |
|-----------------|------------------------|----------------------|--------------------------|
| Falomo et al. 1993b | 1.08 ± 0.34 (33) | 0.97 ± 0.41 (24) | 0.88 ± 0.42 (10) |
| Pian & Treves 1993  | 0.68 ± 0.28 (8)    | 0.66 ± 0.30 (10) | 0.45 ± 0.15 (4)  |
| This paper          | 1.20 ± 0.30 (25)   | 1.20 ± 0.33 (14) | 1.17 ± 0.22 (6)  |

\(^a\) The quoted errors represent the standard deviations from the mean quantities and values in parentheses refer to the number of objects.
FIGURE CAPTIONS

FIGURE 1

Spectral flux distributions of BL Lac objects observed simultaneously at near–IR, optical and UV frequencies. Data (filled squares) are corrected for galactic interstellar extinction. The solid line is the best fit model, which is either a single power law or the combination of a host galaxy (dotted line) and a power law component (dashed line). Open squares represent the spectrum of the standard elliptical after rebinning in conformity to the observed data points.

FIGURE 2

Overall spectra from far–IR to soft X–rays. Comparison of the non thermal component (dashed line) with non simultaneous far–IR and X–ray data (open squares). Near–IR–optical–UV data from our dereddened observations are also reported (filled squares).