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Optical spectroscopy of 1 Jy BL Lacertae objects and flat spectrum radio sources

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Summary. — Optical spectroscopy is reported for a number of flat spectrum radio sources, most of which are either classified as BL Lacertae objects or have been described as BL Lac candidates. We present a total of ten new redshifts, confirm the suggested redshifts for three objects and give spectroscopic data for eight additional objects with already known redshifts. A variety of emission features and emission line strengths is found reaching from strong lines characteristic for high redshifts quasars to very weak lines typical for classical BL Lac objects.

Key words : BL Lacertae objects — quasars — active galaxies — radio sources — redshifts — optical spectroscopy.

1. Introduction

Flat spectrum radio sources with unknown or uncertain redshifts comprise the classical BL Lac objects (Stein *et al.*, 1976) as well as so far insufficiently observed normal and highly polarized quasars (HPQ) (Moore and Stockman, 1981 ; 1984). As long as spectroscopic observations are not available, objects from the latter two groups may be described as potential BL Lac candidates. BL Lac objects show only weak emission features or appear to have completely featureless spectra even if they are observed with large telescopes and long integration times. Among the two groups of quasars, however, there may be objects with easily detectable emission lines when observed in the same way.

Because a more rigorous definition of BL Lac objects is not at hand, the same highly polarized object is sometimes classified as BL Lac object or as HPQ. This depends not only on the particular observer but also on the state of the object during the observation. To circumvent this difficulty, both groups of objects have been combined into the blazar class (Angel and Stockman, 1980). This emphasizes the common properties of BL Lac objects and HPQs, namely the smooth broad band spectra, the high optical polarization and variability, rather than the differences in emission line strengths. This unification, however, could not only mask physical differences between BL Lac objects and HPQs but may also prevent the distinction of different models which have been proposed to explain the weak or absent emission lines of BL Lac objects : a central engine without surrounding gas or without Broad and Narrow Line Regions (Guilbert *et al.*, 1983), beaming (Blandford and Rees, 1978), gravitational lensing (Ostriker and Vietri, 1985), and evolution of the active nucleus (Weiler and Johnston, 1980). Therefore, the determination of redshifts and the appearence of the optical spectrum is vital for the understanding of all objects included in the blazar class.

In this paper we present optical spectroscopy of 21 flat spectrum radio sources from the 1 Jy catalogue (Kühr *et al.*, 1981). For most of the sources reliable redshifts are not available ; some have been described to show continuous optical spectra ; others have not been observed before. With a few exceptions these objects are included in various lists of possible and confirmed BL Lac objects (Ledden and O'Dell, 1985 ; Véron-Cetty and Véron, 1987 ; Burbidge and Hewitt, 1987), in the catalogue of QSO spectra of Wilkes *et al.* (1983), and in the recent compilation of blazar (BL Lac objects and HPQs) candidates compiled by Impey and Neugebauer (1988). Spectroscopic data of a few objects with already known redshifts have also been added. The observations were obtained in the course of a study of the complete sample of BL Lac objects (Kühr and Fried, 1986 ; Stickel *et al.*, 1989) derived from the 1 Jy catalogue of radio sources.

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2. Observations and data reduction.

The observed flat spectrum radio sources are listed in table I, which gives for each object the 1 Jy catalogue name (Col. 1), other designations (Col. 2), the radio position taken from the 1 Jy catalogue (Col. 3, 4), the optical brightness (Col. 5), and references for the optical identifications and finding charts (Col. 6). The listed magnitudes are either taken from the 1 Jy catalogue or, for known variable objects, were gathered from the literature. Column 7 gives references to various compilations, from which further information about the observed sources can be obtained. It should be noted that the magnitudes given in column 6 do not refer to the same wavelength band. In addition, differences between these magnitudes and estimates from the spectra are due to variability of the objects.

Spectroscopic observations of the flat spectrum radio sources were obtained with the 3.5 m telescope on Calar Alto, Spain and the 2.2 m telescope on La Silla, Chile using different spectrograph settings during various observing runs. In all cases a CCD was used as a detector. In table II for each object (Col. 1), the used telescope (Col. 2), the date of the observation (Col. 3), the total integration time (Col. 4), and the wavelength scale of the final spectrum (Col. 5) is given. For 1652+398, we present two different spectra labeled (a) and (b) in tables II and III, and in Figure 1.

The reduction of the two-dimensional spectroscopic data included de-biasing and flatfield-correction. The algorithms given by Horne (1986) and Robertson (1986) were then used to extract the optimal one-dimensional spectra from the two dimensional data. For each object the wavelength calibration was accomplished by fitting a third order polynomial to the dispersion curve of a comparison spectrum taken immediately before or after the object exposure. Flux calibration of the spectra were performed using observations of standard stars treated in the same way. Finally, the individual spectra of each object were coadded to improve the signal-to-noise – ratio.

3. Results and discussion.

Spectra for all objects listed in table I are shown in figure 1. The emission lines are identified and absorption lines have been marked by asterisks. Absorption features which have not been indicated in figure 1 are due to the atmospheric B and A band (≈ 6850 Å and ≈ 7600 Å, respectively), interstellar Na I $\lambda5893$ at zero redshift and in some cases caused by the night sky subtraction procedure.

Table III lists for each object its catalogue name (Col. 1) and redshift (Col. 2), measured emission lines (Col. 3) together with their restwavelengths (Col. 4), the observed wavelengths (Col. 5), and their individual redshifts (Col. 6). The uncertainty of the redshifts of the individual emission and absorption lines may be as high as $\Delta z \approx \pm 0.005$. Nevertheless, for objects were redshifts have already been published, our measurements agree remarkably well with the values found by other observers. For the listed emission lines, FWHMs (Col. 7), equivalent widths (Col. 8) and line fluxes (Col. 9), accurate to about a factor of two, have been estimated from fits of single Gauss components to the reduced spectra. Absorption lines are indicated in column 10 and generally have been identified with Mg II $\lambda2798$. In addition, the multiple absorption line systems of 0454−234 and 1638+398 have also been assigned to Mg II $\lambda2798$ and Fe II at a single redshift.

The redshift for each object (Col. 2) is the unweighted mean of the individual redshifts of all emission lines given in table III, unless mentioned otherwise in the notes of the objects given in this chapter. Some emission lines identified in figure 1 are not listed in table III because they are only marginally detected or heavily confused.

In the following we give special notes for each individual object.

0003−066 : A continuous spectrum devoid of any emission lines was shown by Wilkes *et al.* (1983). An uncertain redshift of $z = 0.347$ was suggested by Wright *et al.* (1983), which is confirmed by our observation. Besides the oxygen emission lines the spectrum shows extremely narrow Hα emission (FWHM $\approx$ 1300 km/sec) and almost no Hβ.

0119+115 : This object was classified as a galaxy by Hunstead and Jauncey (1970), Hoskins *et al.* (1974), and Edwards *et al.* (1975). Fugmann *et al.* (1988) pointed out, however, that the radio source is coincident with a highly polarized ($P \approx 10\%$) stellar object which has a nearby extended companion. Our spectrum of the stellar object shows broad Mg II $\lambda2798$ as well as [O II] $\lambda3727$ at a redshift of $z = 0.57$.

The redshift was derived only from the [O II] $\lambda3727$ emission line, because the wavelength of the Mg II $\lambda2798$ emission line is somewhat ill-defined due to the noise of the data. Furthermore, this value agrees with that measured in a spectrum taken in January 1986 with the telescope 3.5 m on Calar Alto which shows only the [O II] $\lambda3727$ line.

0256+075 : This is a BL Lac object from the catalogue of Véron-Cetty and Véron (1987). The classification is due to Strittmatter *et al.* (1974) and Wills and Wills (1976). Baldwin *et al.* (1981) have reported a possible emission line or a continuum break near $\lambda \approx 5275$ Å. Our spectrogram shows that this feature is relatively narrow Mg II $\lambda2798$ emission. From this emission line and [O II] $\lambda3727$, we derive a redshift of $z = 0.893$.

Optical variability of this object was noted by Strimatter *et al.* (1974), Wills and Wills (1976), and Condon *et al.* (1977).

0454−810 : The radio source is tentatively identified with a compact galaxy (object #1 in Fugmann (1988)). Our spectrum of this optical counterpart shows broad Balmer emission lines and only weak [O III] $\lambda5007$ at a redshift of $z = 0.444$.

0454−234 : A featureless optical spectrum was shown by Wilkes *et al.* (1983). Ledden and O'Dell (1985) list this object as a possible BL Lac candidate. The uncertain redshift of $z = 1.009$ suggested by Wright *et al.* (1983) is confirmed. The spectrum shows at least four absorption line systems blueward or the Mg II $\lambda 2798$ emission line. The absorption feature with the highest redshift, $z_{abs}= 0.89$, has also been noted by Allen *et al.* (1982).

Besides the possibility that all absorption lines are due Mg II $\lambda 2798$ with different redshifts, three of the four absorption lines may be identified with Mg II $\lambda 2798$, Fe II $\lambda 2593$ and Fe II $\lambda 2378$ at a single redshift of $z_{abs}= 0.891$ (see Tab. III). In the latter case the absorption line at 4562 Å is unaccounted for. Further observations of this object should be done with higher spectral resolution.
Optical polarization of up to 27% and optical variability of 3.2 mag was reported by Impey and Tapia (1988). The broad band energy distribution for this object was given by Impey and Neugebauer (1988).

0511−220 : Wilkes *et al.* (1983) showed this object to have a featureless optical spectrum. Our spectrogram reveals relatively strong emission lines of C IV $\lambda 1549$, C III] $\lambda 1909$ and Mg II $\lambda 2798$ at a redshift of $z = 1.296$. There is also an absorption feature blueward of the Mg II $\lambda 2798$ emission line.

0743−006 : No evidence for emission lines has been found by Fricke *et al.* (1983), who classified this radio source as a BL Lac object. Only a single broad emission line is found in our spectrum. If this line is identified with Mg II $\lambda 2798$, we derive a redshift of $z = 0.996$. This value is in agreement with that recently reported by White *et al.* (1988).

0745+241 : A BL Lac candidate from the work of Wilkes *et al.* (1983). Our spectrogram shows [O II] $\lambda 3727$ and [O III] $\lambda\lambda 4959,5007$ at a redshift of $z = 0.409$. A possible redshifted Hβ $\lambda 4861$ emission is blended with the atmospheric B band.
The radio structure at cm wavelength of this object is a classical triple source (Perley, 1982).

0851+202 : Sitko and Junkkarinen (1985) confirmed the tentative redshift of $z = 0.306$ suggested by Miller *et al.* (1978) for this well-known BL Lac object. Our observation agrees with these measurements and our spectrum shows Hβ $\lambda 4861$ as well as [O III] $\lambda\lambda 4959,5007$ more clearly than that of Sitko and Junkkarinen (1985). There is also an indication of a blueshifted Hβ absorption. The broad band energy distribution for this object was given by Impey and Neugebauer (1988), and Webb *et al.* (1988) have reported optically violent variability with a total range of more than 5 mag.

1034−293 : A featureless optical spectrum was reported by Condon *et al.* (1977) and shown by Wilkes *et al.* (1983) and Christiani and Koehler (1987), which leads to its classification as a BL Lac object (Véron-Cetty and Véron, 1987 ; Burbidge and Hewitt, 1987). Our observations show emission lines of oxygen and hydrogen with strong Hα $\lambda 6563$ at a redshift of $z = 0.312$.

It should be noted that this radio source had been incorrectly identified by Radivich and Kraus (1971). Optical polarization of $\dot{P} \approx 7\%$ has been reported by Impey and Tapia (1988) and the broad band energy distribution was given by Impey and Neugebauer (1988).

1144−379 : The classification of this source as a BL Lac object is due to Nicolson *et al.* (1979). Only one emission line appears in our spectrogram. Its most probable identification is Mg II $\lambda 2798$ at a redshift of $z = 1.048$.
Optical variability ($\Delta V = 1.9$ mag) and polarization ($P \approx 8\%$) has been reported by Impey and Tapia (1988). The broad band energy distribution for this object is given by Impey and Neugebauer (1988).

1424−418 : Our redshift of $z = 1.524$, derived from C III] $\lambda 1909$ and Mg II $\lambda 2798$, agrees with that given by White *et al.* (1988).
Impey and Tapia (1988) reported optical polarization of up to 9.4% for this object.

1638+398 : For this object we present two different spectra labeled (a) and (b) in tables II, III and in figure 1. Spectrum (a) shows Mg II $\lambda 2798$ and C III] $\lambda 1909$ emission lines and also at least four absorption lines all of which may be identified with Mg II $\lambda 2798$ at different redshifts, but also with Mg II $\lambda 2798$, Fe II $\lambda\lambda 2599,2586$ and Fe II $\lambda 2382$ at a single redshift of $z_{abs} = 0.936$ (see Tab. III). Spectroscopic observations with higher resolution are needed to clarify the situation.
Two of these absorption lines are very close to the C III] emission line and therefore may affect an accurate measurement of its line flux and wavelength. In addition, the data of the Mg II emission line given in table III may be uncertain due to the influence of the atmospheric A band.
Spectrum (b), which was obtained when the source was about a factor of 3 fainter compared to spectrum (a), shows strong C IV $\lambda 1549$ as well as C III] $\lambda 1909$ emission.
Shapiro *et al.* (1979) suggested a redshift of $z = 1.67$, which is also found by Browne and Perley (1986), whereas Hewitt and Burbidge (1987) give a redshift of $z = 1.66$. We adopt a redshift of $z = 1.666$ for this object, which is the mean of all detected emission lines.
Optically violent variability of this object has been reported by Webb *et al.* (1988) with a total range of about 3 mag.

1732+389 : This radio source is also included in the IRAS point source catalogue (Chini *et al.*, 1987), but had so far not been observed spectroscopically. Our spectrum shows a single broad emission line which is most likely identified as Mg II $\lambda 2798$ at a redshift of $z = 0.976$.

1741−038 : From a single broad emission line identified with Mg II $\lambda 2798$ we derive a redshift of $z = 1.057$. This value agrees with the recent observations of White *et al.* (1988). Blueward of the Mg II emission line there are two absorption lines.

1749+701 : A tentative redshift of $z \approx 0.76$ for this well-known BL Lac object was suggested by Arp *et al.* (1976) from the identification of a single weak line as [O II] $\lambda 3727$.

Walsh and Carswell (1982) and Lawrence *et al.* (1987), however, failed to detect any emission lines. Our spectrum shows a single weak and narrow emission line which, if identified as [O II] λ3727, gives a redshift of $z = 0.77$, close to the value of Arp *et al.* (1976). Although the continuum had brightened, this emission line was also found in a second spectrum taken nearly one year later. The alternative identification of this emission line, [O III] λ5007, seems unlikely because we do not find the redshifted [O II] λ3727 and Balmer emission lines. Therefore the redshift of $z = 0.77$, derived from the identification of the weak emission line as [O II] λ3727, seems plausible. No emission feature, however, could then be found at the position of the redshifted Mg II λ2798 emission line. This was already mentioned by Walsh and Carswell (1982).

1823+568 : Walsh *et al.* (1984) reported a featureless spectrum for this radio source and classified it as a BL Lac object. Lawrence *et al.* (1986) give a tentative redshift of $z = 0.664$ based on [O II] λ3727 and Mg II λ2798. Our observations, however, show only a single weak emission feature which if identified as [O II] λ3727 confirms the uncertain redshift of $z = 0.664$. The same emission line is also detected in a spectrum taken in August 1988 with the Calar Alto 3.5m telescope when the object was fainter compared to the observations presented herein. In both spectra, however, we found no emission feature at the expected position of the redshifted Mg II λ2798 emission line.

The arc second scale radio structure at cm wavelengths of this object consists of a compact core with a strongly bent jet (O'Dea *et al.*, 1988).

2007+777 : A BL Lac object with a featureless and polarized optical spectrum according to Biermann *et al.* (1981). Our spectrum shows very weak [O III] $\lambda\lambda$4959,5007 and extremely weak [O II] λ3727 at a redshift of $z = 0.342$, which puts this object definitely into the class of superluminal radio sources (Witzel *et al.*, 1988).

2155−152 : The classification as a BL Lac object is due to Craine *et al.* (1976) and Peterson *et al.* (1978). The redshift of $z = 0.672$ determined from our observations coincides with the value given by White *et al.* (1988). An absorption line appears at the blue edge of the Mg II λ2798 emission line.

VLA observations of this object have shown a triple radio source at cm wavelengths (Perley, 1982). Wardle *et al.* (1984) and Fugmann (1988) have detected very high optical polarization of up to $\approx 33\%$. This object has undergone optical brightness variations of about 6.5 mag (Craine *et al.*, 1976), which is one of the largest amplitudes of all optically violently variable extragalactic objects.

2203−188 : A near featureless spectrum was shown by Wilkes *et al.* (1983). The redshift of $z = 0.619$ derived from our observation agrees with the measurements of Morton and Tritton (1982) and Wilkes (1986). Our spectrum reaches further to the red than that of Morton and Tritton (1982) and shows also Hγ λ4340 / [O III] λ4363 and [O III] $\lambda\lambda$4959,5007.

This object is the only strong radio source of a close group of four quasars. It is remarkable that the nearest neighbour object of 2203−188, only 6.8 arcmin away, has a similar redshift (Morton and Tritton, 1982).

2311−452 : This radio source, identified by Savage and Bolton (1977), had so far not been observed spectroscopically. Our spectrum shows strong emission lines at a redshift of $z = 2.883$.

4. Concluding remarks.

The observational results presented in this paper provide a substantial increase of spectroscopic data and redshifts for objects which are either classified as BL Lac objects or tentatively identified as BL Lac candidates. Of the 21 objects discussed, about two third fell into these two categories. In addition, we give redshifts for 4 objects for which so far no spectroscopic observations were available.

From the spectra shown in figure 1 and the data listed in table II it is evident that there is a large range of the emission line strength relative to the continuum with 2311−452 and 2007+777 representing the extreme ends of the objects with strong and weak emission lines, respectively. The spectrum of 2311−452 shows emission lines characteristic of normal high redshift quasars, whereas in the spectrum of 2007+777 only very weak emission lines of [O II] λ3727 and [O III] $\lambda\lambda$4959,5007 are found which corroborates its classification as a BL Lac object.

It is noteworthy that 1034−293 which is classified as a BL Lac object (Véron-Cetty and Véron, 1987 ; Burbidge and Hewitt, 1987) on the basis of its featureless optical continuum (Wilkes *et al.*, 1983 ; Christiani and Koehler, 1986) appears to have an optical spectrum with emission lines quite similar to that of 0454-810, a flat spectrum radio source which so far has escaped any attention.

Four objects, 0743−006, 1144−379, 1732+389 and 1741−038 show only a single broad emission line in their spectra, which in all cases is most likely identified with Mg II λ2798. For 0743−006 and 1741−038, this is supported by the observations of White *et al.* (1988). For 1144−379 and 1732+389, any other identification seems to be ruled out because other emission lines would be expected to be present in the spectra if the single emission lines were identified for example with Hβ λ4861 or CIV λ1549.

In two cases (1749+701, 1823+568) only a single narrow and weak emission line is found in the spectrum. In both objects the identification as [O II] λ3727 gives redshifts which agree with the values previously suggested by other observers. In either case, however, no emission feature could be found at the position of the redshifted Mg II λ2798 emission line. On the other hand, if the weak lines found in the spectra of 1749+701 and 1823+568 were attributed to [O III] λ5007 we expect to find also the redshifted [O II] λ3727 and Balmer emission lines, which are indeed present in most of the other objects where the spectra cover the appropriate wavelength range. A careful inspection of the spectra of 1749+701 and 1823+568, however, revealed in neither case an emission feature at the expected positions of the redshifted [O II] λ3727 and Balmer lines. Therefore, the identification of the single weak and narrow emission line in the spectra of 1749+701 and 1823+568 with [O III] λ5007 appears rather unlikely.

A large fraction of the spectra in figure 1 apparently have a power-law component underlying the optical continuum. From the polarization data given in the notes of the individual objects, it is found that in most cases the power-law component is accompanied by a high optical polarization.

It is conspicuous from the spectra in figure 1 and the data given in table III, that the permitted lines in most objects are relatively narrow and their FWHM are rather small. Neglecting the Mg II emission line of 1638+398 which may be affected by the atmospheric A band, the lowest values are found in the spectrum of 0003−066 with a FWHM of Hα of about 1300 km/s and in the spectrum of 0256+075 with a FWHM of the Mg II λ2798 emission line of about 2260 km/s. With the exceptions of 0454−810, 2203−188 (weak Mg II lines) and 0119+115 (FWHM (Mg II) ≈ 8850 km/s) the broad lines of all other objects are smaller than 5000 km/s. This predominance of small line width of the permitted emission lines in flat spectrum radio sources has already been described by Wills and Browne (1986), and is supported by the observations presented in this paper.

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Note added in proof: 0454-810 has recently been identified with a 19.6 mag QSO by Jauncey *et al.*, 1989, *Astron. J.* **98**, 54 ; and a finding chart is given there, too.

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TABLE I. — *Observed BL Lac objects and flat spectrum radio sources.*

Object (1)	other Name (2)	RA (1950) (3)	Dec (1950) (4)	m (5)	fc (6)	ref. (7)
0003-066	PKS, NRAO 5 PHL 2625	00 03 40.31	-06 40 17.0	19.7	14,17	35
0119+115	PKS	01 19 03.08	+11 34 09.6	19.	1,2,27	
0256+075	PKS, OD 094.7	02 56 46.98	+07 35 54.4	18.-19.5	24,14	33,35
0454-810	PKS	04 54 17.50	-81 05 55.0	19.2	21	
0454-234	PKS, OF -292	04 54 57.32	-23 29 28.9	16.6-18.9	15,16	32,33,35
0511-220	PKS, OG -220	05 11 49.94	-22 02 44.8	19.5	17	
0743-006	PKS, 4C 00.28 OI -072	07 43 21.04	-00 36 55.3	17.5	14,24	30,31,33
0745+241	B2, PKS, OI 275	07 45 35.70	+24 07 55.2	19.	8,17	
0851+202	B2, PKS, OJ 287 VRO 20.08.01	08 51 57.25	+20 17 58.4	12.8-17.8	3,25,26	30,31,32, 33,34,35
1034-293	PKS, OL -259	10 34 55.86	-29 18 27.7	15.6-18.	9	30,31,32,33,35
1144-379	PKS	11 44 30.87	-37 55 30.5	16.2-18.6	10,11	30,31,32,33,35
1424-418	PKS	14 24 46.53	-41 52 52.0	17.-17.5	22	34
1638+398	NRAO 512, S4 OS 264.4	16 38 48.17	+39 52 30.1	16.3-19.3	12	31
1732+389	OT 355, S4	17 32 40.49	+38 59 47.0	19.	13	
1741-038	PKS, OT -068	17 41 20.62	-03 48 49.0	18.5	20,29	34
1749+701	S4, S5	17 49 03.38	+70 06 39.5	16.8-18.2	4,5,6,7	30,31,32,33,35
1823+568	4C 56.27, S4, OU 539	18 23 14.99	+56 49 18.0	18.4	4,5	31,33,35
2007+777	S5	20 07 20.42	+77 43 58.0	16.5	18	30,31,32,33,35
2155-152	PKS, OX -192	21 55 23.36	-15 15 28.1	12.5-19.	19,20	30,31,32,33,35
2203-188	PKS, OY -106	22 03 25.71	-18 50 16.6	18.5	28	31,34
2311-452	PKS	23 11 21.80	-45 12 10.0	19.	23	

1. Edwards et al. (1975)
2. Hunstead and Jauncey (1970)
3. Véron and Véron (1975)
4. Cohen et al. (1977)
5. Kühr (1977)
6. Craine and Price (1976)
7. Arp et al. (1976)
8. Hoskins et al. (1974)
9. Bolton et al. (1975)
10. Walter and West (1980)
11. Nicolson et al. (1979)
12. Folsom et al. (1970)
13. Kapahi (1979)
14. Radivich and Kraus (1971)
15. Peterson et al. (1976)
16. Savage and Wall (1976)
17. Condon et al. (1977)
18. Kühr et al. (1987)
19. Craine et al. (1976)
20. Peterson and Bolton (1973)
21. Fugmann (1988)
22. Lü (1970)
23. Savage and Bolton (1977)
24. Browne et al. (1973)
25. Blake (1970)
26. Smith et al. (1985)
27. Fugmann et al. (1988)
28. Morton and Tritton (1982)
29. Véron et al. (1976)
30. Burbidge and Hewitt (1987)
31. Hewitt and Burbidge (1987)
32. Ledden and O'Dell (1985)
33. Impey and Neugebauer (1988)
34. Wall and Peacock (1985)
35. Véron-Cetty and Véron (1987)

TABLE II. — *Journal of the observations.*

Object (1)	telescope* (2)	date (3)	int. time [sec] (4)	scale [Å/pixel] (5)	
0003-066	LS 2.2	Nov. 27, 1986	5400	13.0	
0119+115	CA 3.5	Aug. 16, 1988	7600	6.6	
0256+075	CA 3.5	Aug. 15, 1988	7600	6.6	
0454-810	LS 2.2	Oct. 28, 1986	3600	13.0	
0454-234	LS 2.2	Oct. 26, Nov. 8, 1986	13500	13.0	
0511-220	LS 2.2	Oct. 27, Nov. 7, 1986	8400	13.0	
0743-006	LS 2.2	Nov. 7, 1986	1200	13.0	
0745+241	LS 2.2	Mar. 15, 1985	2400	13.2	
0851+202	CA 3.5	Feb. 11/20, 1986	7200	9.8	
1034-293	LS 2.2	Nov. 7, 1986	4800	13.0	
1144-379	LS 2.2	Mar. 28, 1985	3900	13.2	
1424-418	LS 2.2	Mar. 14, 1985	8100	13.2	
1638+398	CA 3.5	Jul. 1, 1986	10800	6.6	(a)
1638+398	CA 3.5	Aug. 15, 1988	7000	6.6	(b)
1732+389	CA 3.5	Jul. 3, 1986	9900	6.6	
1741-038	CA 3.5	Jul. 5, 1986	3600	6.6	
1749+701	CA 3.5	Oct. 29, 1987	7200	6.6	
1823+568	CA 3.5	Jun. 3, 1987	5400	6.6	
2007+777	CA 3.5	Aug. 12, 1988	7200	6.6	
2155-152	LS 2.2	Oct. 26, 1986	5400	13.0	
2203-188	LS 2.2	Nov. 27, 1986	3600	13.0	
2311-452	LS 2.2	Feb. 28, 1986	7600	13.0	

* CA 3.5 and LS 2.2 denote the 3.5 m telescope on Calar Alto, Spain, and the 2.2 m telescope on La Silla, Chile, respectively.

TABLE III. — *Emission and absorption line data.*

Object	⟨z⟩	ID	λ_0 [Å]	λ_{obs} [Å]	z_{ind}	FWHM [Å]	EW_{obs} [Å]	Flux [10^{-16} erg/s/cm^2]	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0003-066	0.347	OII	3727	5019	0.347	18.8	5.6	9.4	
		OIII	4959	6682	0.347	34.5	6.5	13.4	
		OIII	5007	6746	0.347	24.4	11.3	23.1	
		Hα	6563	8835	0.346	37.4	23.6	47.8	
0119+115	0.570	MgII	2798	4420	(0.580)	130.4	90.9	20.7	
		OII	3727	5853	0.570	14.0	19.1	2.3	
0256+075	0.893	MgII	2798	5300	0.894	39.9	45.7	5.1	
		OII	3727	7048	0.891	14.9	13.2	1.1	
0454-810	0.444	MgII	2798	4039	0.444	129.2	115.0	46.1	
		Hβ	4861	7025	0.445	96.1	30.1	24.4	
		OIII	5007	7227	0.443	7.7	17.2	13.8	
		Hα	6563	9467	0.443	95.3	93.2	66.2	
0454-234	1.003	CIII	1909	3815	0.999	48.1	38.6	14.9	
		MgII	2798	5616	1.007	73.7	63.8	31.7	
		MgII	2798	4493	0.606				abs
		MgII	2798	4562	0.630				abs
		MgII	2798	4902	0.752				abs
		MgII	2798	5292	0.891				abs
		alternative identification for three absorption lines :							
		FeII	2378	4493	0.889				abs
		FeII	2593	4902	0.891				abs
		MgII	2798	5292	0.891				abs
0511-220	1.296	CIV	1549	3562	1.300	46.1	265.2	157.6	
		CIII	1909	4373	1.291	51.9	76.5	27.9	
		MgII	2798	6429	1.298	71.0	100.8	41.2	
		MgII	2798	5053	0.806				abs
0743-006	0.996	MgII	2798	5585	0.996	56.5	15.7	90.7	
0745+241	0.409	OII	3727	5254	0.410	7.6	8.5	16.	
		OIII	4959	6985	0.409	16.8	6.5	13.1	
		OIII	5007	7056	0.409	18.6	15.3	30.7	
0851+202	0.306	Hβ	4861	6353	0.307	55.8	1.1	10.1	
		OIII	4959	6473	0.305	22.6	0.7	6.2	
		OIII	5007	6538	0.306	12.7	1.6	14.2	
1034-293	0.312	OII	3727	4879	0.309	15.4	3.6	5.4	
		Hβ	4861	6401	0.317	87.5	9.7	16.3	
		OIII	4959	6502	0.311	31.1	4.5	7.6	
		OIII	5007	6564	0.311	24.0	8.8	14.9	
		Hα	6563	8619	0.314	108.8	51.5	84.3	
1144-379	1.048	MgII	2798	5730	1.048	47.6	5.1	24.9	
1424-418	1.524	CIII	1909	4813	1.521	40.3	15.3	16.6	
		MgII	2798	7067	1.526	85.4	34.8	38.8	
1638+398	1.666	CIII	1909	5083	1.662	61.0	5.4	6.4	(a)
		MgII	2798	7461	1.666	46.4	6.2	6.1	(a)
		CIV	1549	4137	1.671	66.0	56.1	30.5	(b)
		CIII	1909	5082	1.662	48.7	7.9	2.7	(b)
		MgII	2798	4608	0.647				abs (a)
		MgII	2798	5003	0.788				abs (a)
		MgII	2798	5032	0.798				abs (a)
		MgII	2798	5421	0.937				abs (a)
		alternative identification for the absorption lines :							
		FeII	2382	4608	0.935				abs (a)
		FeII	2586	5003	0.935				abs (a)
		FeII	2599	5032	0.936				abs (a)
		MgII	2798	5421	0.937				abs (a)
1732+389	0.976	MgII	2798	5528	0.976	60.5	15.3	6.9	
1741-038	1.057	MgII	2798	5755	1.057	108.1	53.7	32.6	
		MgII	2798	5343	0.909				abs
		MgII	2798	5450	0.948				abs
1749+701	0.770	OII	3727	6598	0.770	12.5	0.4	4.8	
1823+568	0.664	OII	3727	6201	0.664	16.6	1.0	2.6	
2007+777	0.342	OII	3727	5006	0.343	13.4	0.5	1.8	
		OIII	4959	6656	0.342	14.5	0.4	1.4	
		OIII	5007	6720	0.342	14.0	1.2	4.5	
2155-152	0.672	MgII	2798	4679	0.672	64.3	23.1	21.2	
		OII	3727	6230	0.672	24.7	6.8	6.2	
		Hβ	4861	8114	0.669	44.7	5.2	4.7	
		OIII	5007	8370	0.672	22.3	12.0	10.7	
		MgII	2798	4559	0.629				abs
2203-188	0.619	MgII	2798	4535	0.620	81.7	28.6	54.8	
		OII	3727	6033	0.619	30.8	14.8	24.5	
		OIII	5007	8106	0.619	38.5	61.6	87.8	
2311-452	2.884	OVI	1034	4020	2.888	50.7	55.8	11.9	
		Lα	1216	4718	2.880	53.4	145.3	29.6	
		SiIV/OIV	1400	5440	2.885	75.6	29.3	6.3	
		CIV	1549	6014	2.882	74.9	83.3	17.9	
		CIII	1909	7414	2.884	173.2	97.4	17.0	

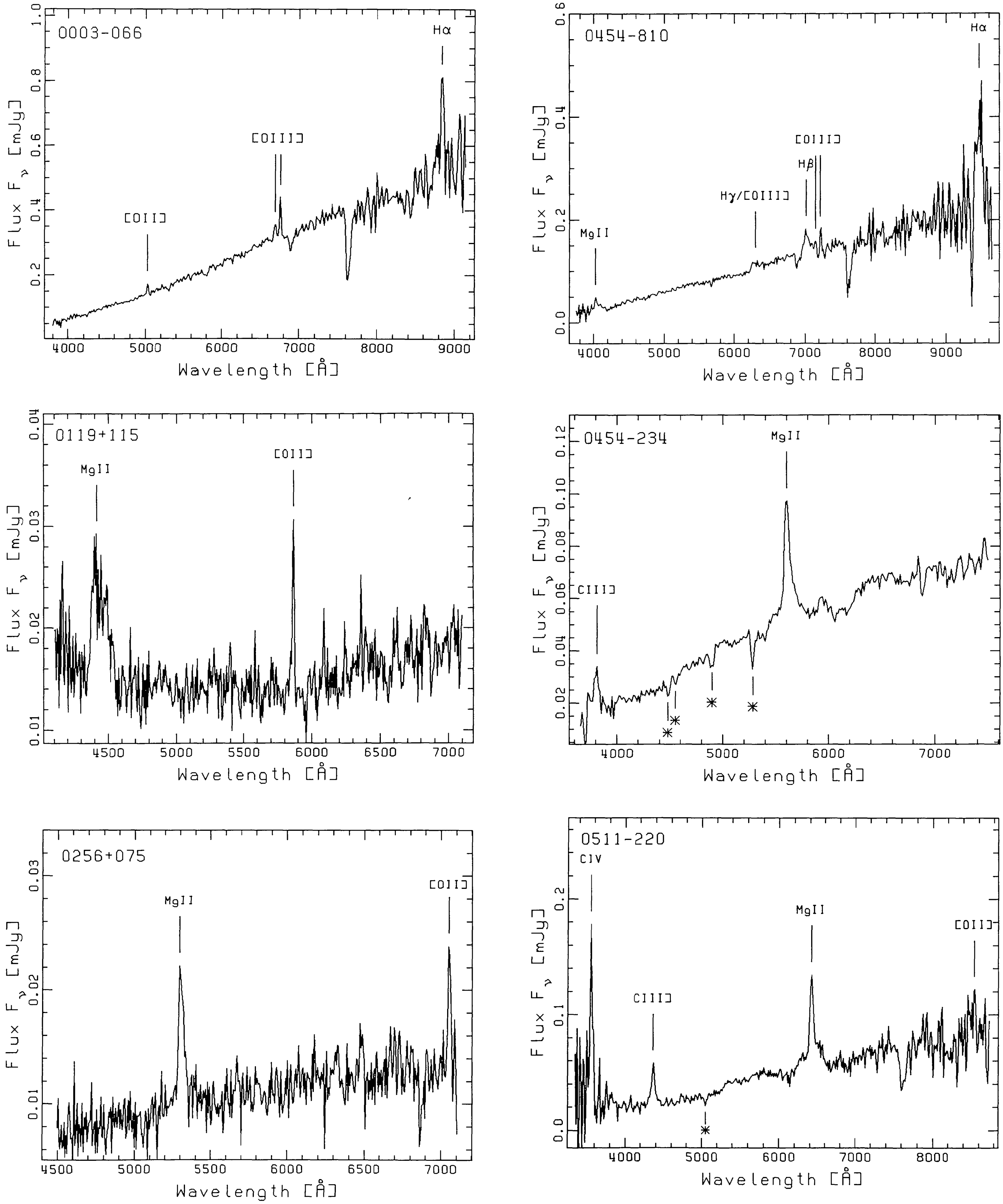

FIGURE 1. — Spectra of the BL Lac objects and flat spectrum radio sources, labelled with the source designation. Identified spectral features are indicated.

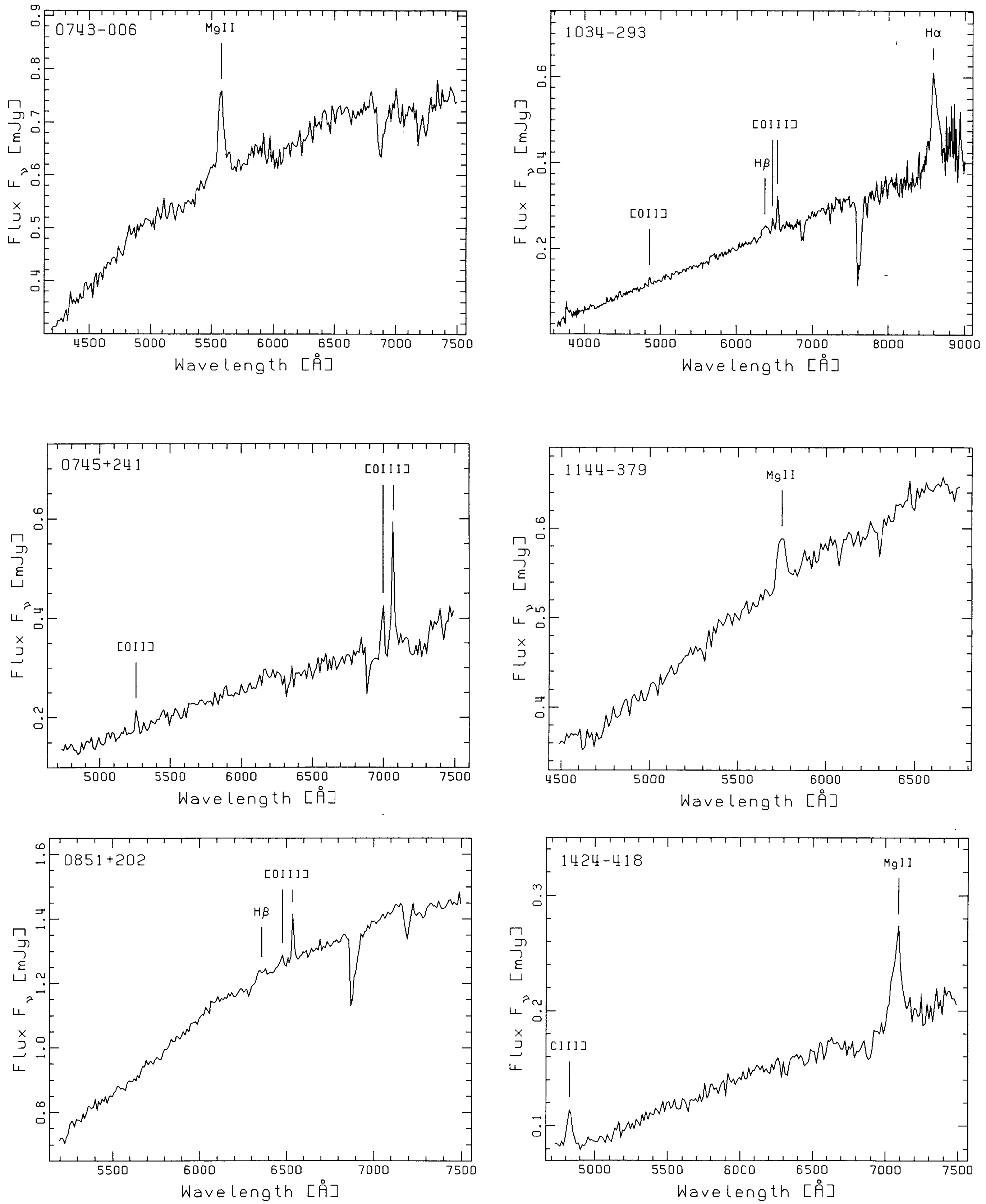

FIGURE 1 (*continued*)

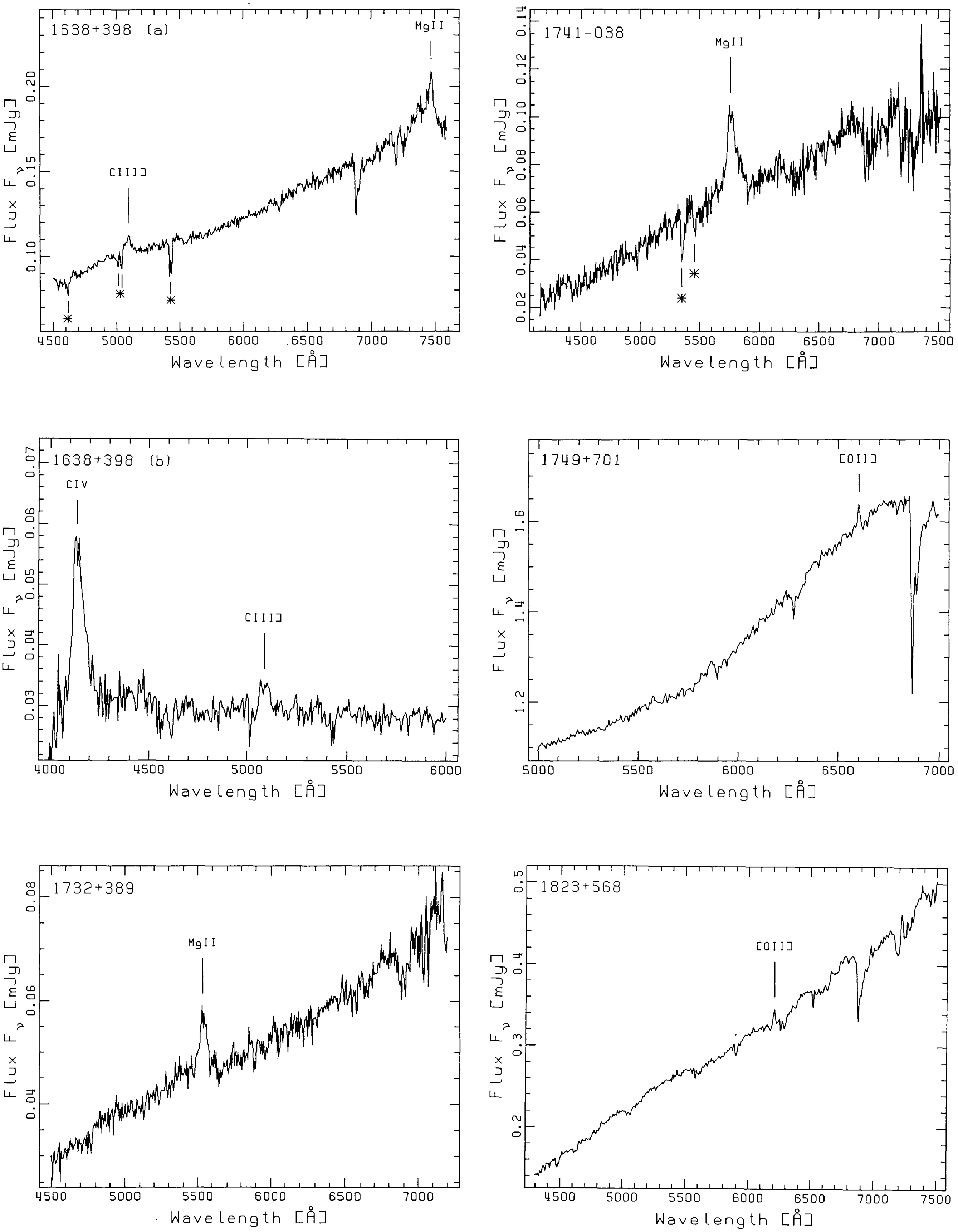

FIGURE 1 (*continued*)

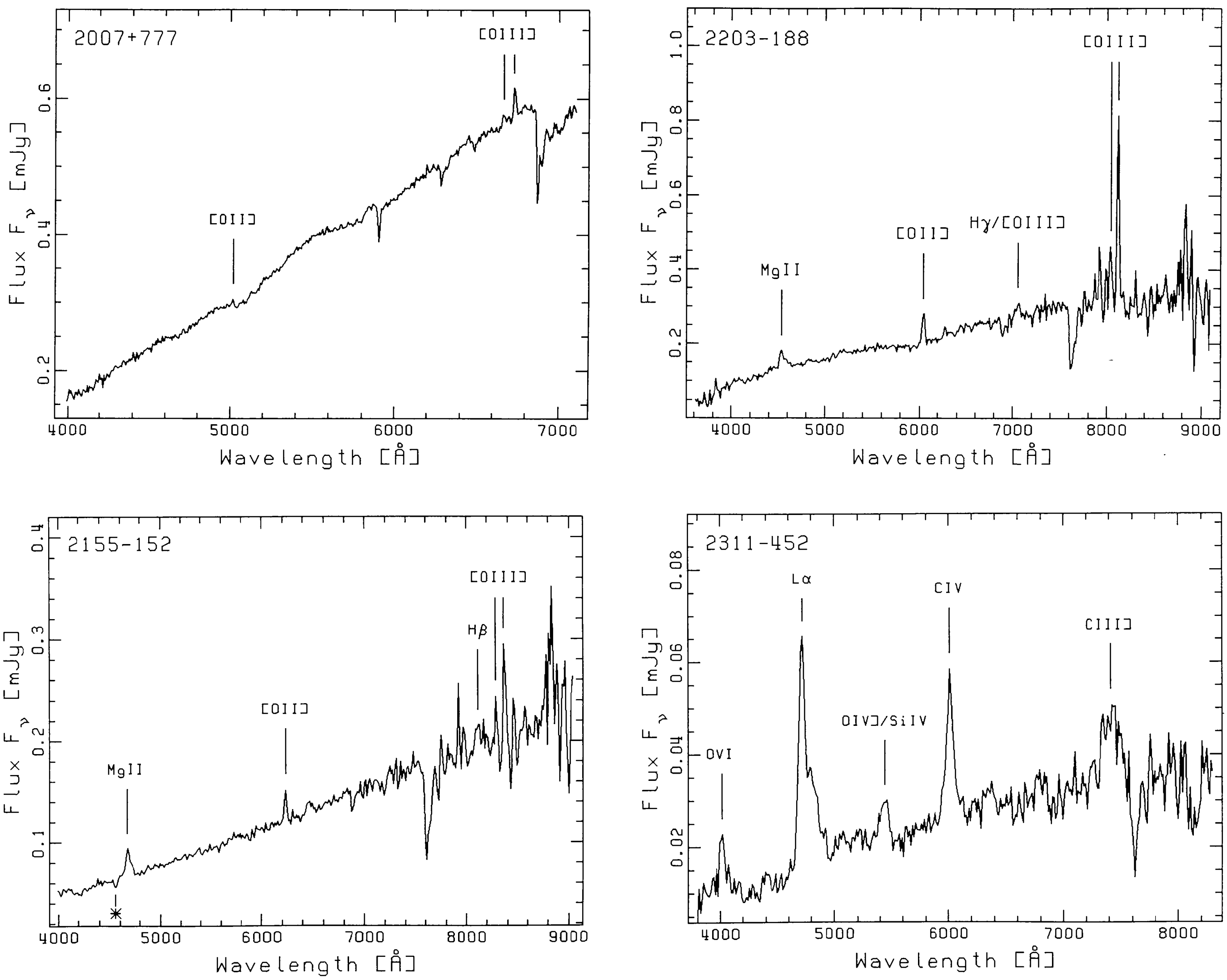

FIGURE 1 (*continued*)