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1011+496 and 1217+348: two new candidate BL Lacertae objects

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Summary. This paper presents recent optical and infrared observations of the extragalactic radio sources 1011+496 and 1217+348. These observations indicate that the two sources are BL Lacertae objects.

1 Introduction

BL Lacertae objects offer astronomers perhaps the most undiluted view of the workings of the central engines in compact active extragalactic objects. At the present time only about 100 such objects are known and only a fraction of these have known redshifts.

As part of a programme to secure optical photometry of a set of extragalactic radio sources from the list of Machalski & Condon (1983) which had flat or inverted radio spectra near 1400 MHz, one of us (WZW) noticed that two of these objects, 1011+498 and 1217+348, had spectral energy distributions resembling objects dominated by non-thermal emission. One of them, 1011+498, is also inside the error box of the *HEAO-1* X-ray source 1H1013+498 (Wood *et al.* 1984) and might be a member of the galaxy cluster A950, at a redshift of Z=0.20 (Leir & van den Bergh 1977). The combined optical and radio data on these two sources made them good candidates for membership in the class of BL Lacertae objects (hereafter referred to as BL Lacs), and further optical polarimetry, infrared photometry and optical spectroscopy were done on them.

In this paper we report the results of these observations and show how the data indicate that 1011+496 and 1217+348 are BL Lacs.

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2 Observations

Photometric observations in the *UBVRI* system of Johnson (1966) were obtained in 1985 April 13 (UT) using the 1.5-m telescope of the University of Arizona Observatory on Mt Lemmon. The observations were made using a 12.5-arcsec entrance aperture. The magnitudes and resultant fluxes (in mJy) are presented in Table 1(a). Each column gives the frequency (in THz), magnitude and flux for each observation. Due to the high galactic latitudes of these objects (53° and 80° for 1011+496 and 1217+348, respectively) these data have not been corrected for foreground galactic extinction.

Photometric observations in the *JHK* system were obtained in 1985 May 23 and 24 using the KPNO 1.3-m telescope and the 'Hermann' InSb photometer. All of the observations were made with an 11-arcsec aperture. The magnitudes and fluxes are presented in Table 1(b). The mean values for the two nights are also given.

The polarimetric observations were obtained in 1985 May 21 using the 'Two-Holer' photopolarimeter on the 1.5-m telescope of the Mt Lemmon Observing Facility of the University of Minnesota and the University of California, San Diego. The instrument and its operation are briefly described by Sitko, Schmidt & Stein (1985). The observations presented here were made without coloured glass filters, providing a 'white-light' bandpass from 3200 to 8600 Å. Both

Table 1.

(a) Optical magnitudes and fluxes (mJy)[1]

Object (date UT)[2]	U 833 THz	B 682 THz	V 545 THz	R 428 THz	I 333 THz	Spectral index
1011+496	15.88	16.56	16.15	15.49	14.99	
(85.04.13)	0.76	1.07	1.27	1.77	2.26	1.16
1217+348	17.19	17.71	17.09	16.52	15.77	
(85.04.13)	0.23	0.37	0.53	0.68	1.10	1.62

(b) Infrared magnitudes and fluxes (mJy)[1]

Object (date UT)[2]	J 244 THz	H 181 THz	K 135 THz	Spectral index
1011+496				
(85.05.23)	14.70±0.10	13.51±0.08	12.87±0.08	
	3.7±0.4	4.2±0.3	4.7±0.4	
(85.05.24)	14.46±0.14	13.79±0.08	13.02±0.10	
	2.6±0.4	3.2±0.3	4.1±0.4	
(Mean)	14.20±0.08	13.65±0.06	12.93±0.06	
	3.3±0.3	3.7±0.2	4.4±0.3	0.52±0.16
1217+348				
(85.05.23)	14.85±0.27	14.24±0.19	13.77±0.17	
	1.8±0.5	2.1±0.4	2.0±0.4	
(85.05.24)		14.42±0.20	13.04±0.13	
		1.8±0.4	4.0±0.5	
(Mean)	14.85±0.27	14.32±0.14	13.31±0.10	
	1.8±0.5	2.0±0.3	3.1±0.3	1.18±0.38

[1]For the infrared data, the errors listed are the internal accuracy of each observation (in the case of an individual observation) or the uncertainty in the weighted mean value (for the mean values), assuming the observations belong to the same parent normal distribution. For the optical data, we assume an error of 0.03 mag and do not quote it.
[2]The date is given in year, month, day as (yy.mm.dd).

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Table 2. Polarimetry of 1011+496 and 1217+348.

Object	P(%)[1]	θ(°)
1011+496	4.6±0.4	108.2±2.2
1217+348	8.2±0.8	131.2±2.6

[1]The instrumental polarization was measured to be 0.07±0.04 per cent.

objects were observed twice during the night, with each observation separated in time by about 80 min. Observations were made using apertures of 4 and 8 arcsec. No dependence of polarimetric properties on time nor aperture were apparent, and the combined results are given in Table 2.

Optical spectra of both objects were obtained on 1985 June 22 with the KPNO 2.1-m telescope using the Intensified Image Dissector Scanner (IIDS). The observations were made with a 2.7-arcsec circular aperture, giving an effective spectral resolution of 8 Å. The exposure on 1011+496 was terminated due to high airmass (1.8) and that of 1217+348 due to clouds.

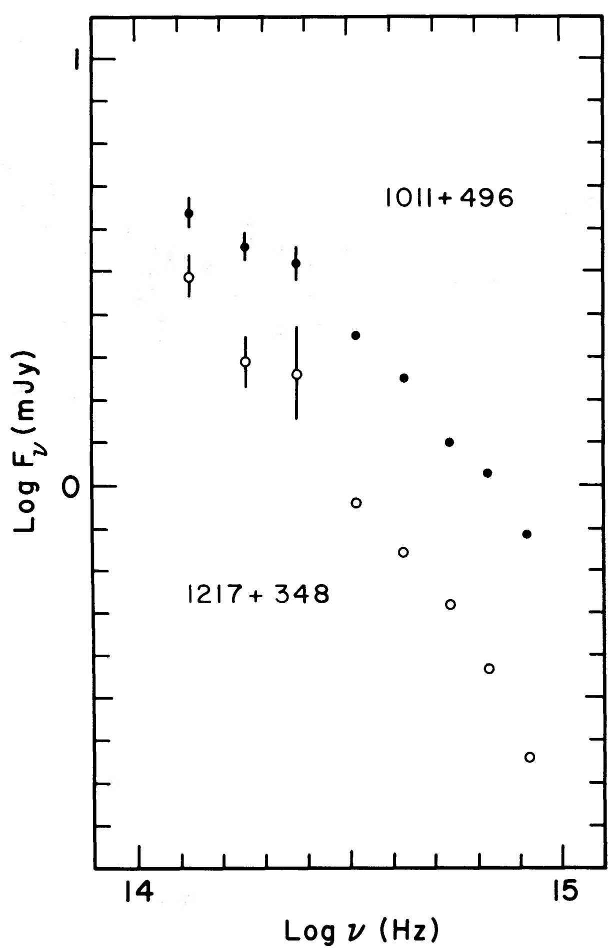

Figure 1. The spectral energy distributions of 1011+496 and 1217+348, in log F_ν (mJy) versus log ν(Hz). The mean fluxes for the two nights of infrared photometry are shown.

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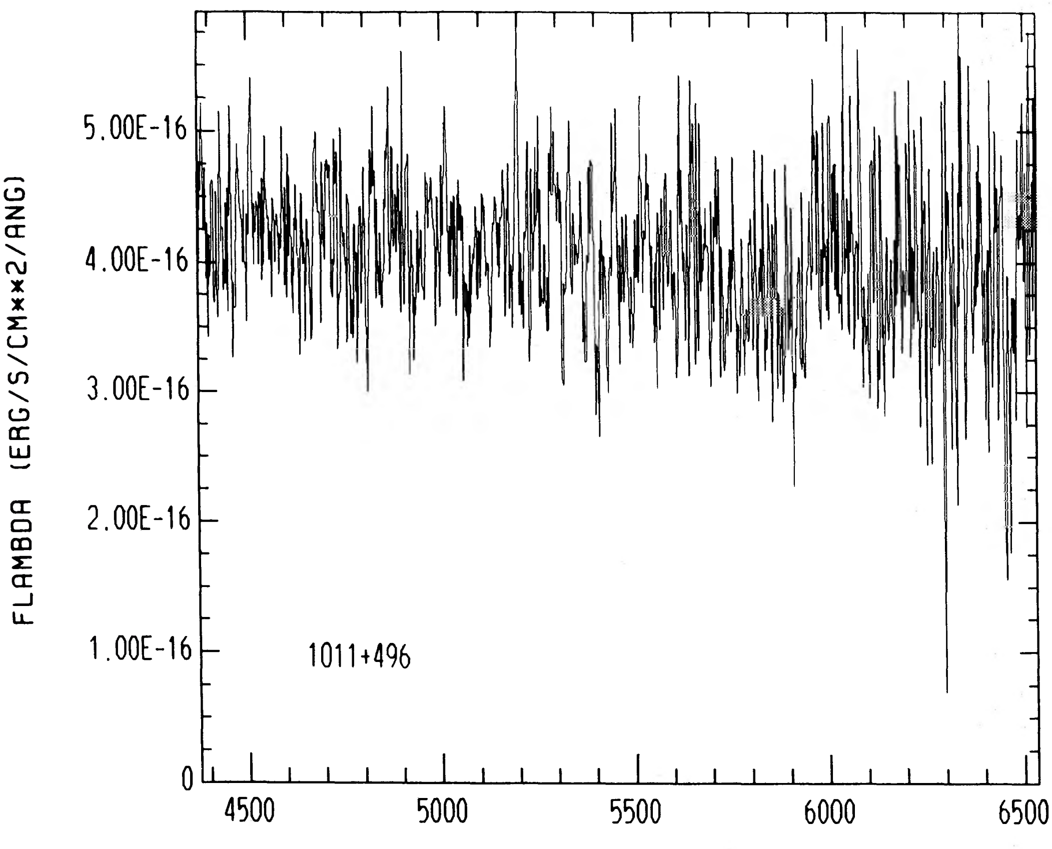
3 Discussion

It is not our intent to derive a definitive classification for 1011+496 and 1217+348, simply because the boundaries that separate various classes of compact active extragalactic objects are becoming less well-defined with time. Because such classifications are useful in giving a quick description of the general characteristics of an object, however, we will classify these objects in such a way that best characterizes their observed properties.

The combined optical-infrared spectral energy distributions of these two objects are shown in Fig. 1. Although the optical and infrared data were obtained nearly 6 weeks apart, they are reasonably continuous from one wavelength region to another. The shape of their continua resemble those seen in compact active extragalactic objects such as BL Lacs, optically violent variable quasars (OVVs) and broad-line radio galaxies (BLRGs). All these types of objects (which are probably related) may show similar spectral shapes, with nearly power-law energy distributions that steepen at higher frequency in the optical-infrared spectral region. The spectral index α (defined as $F_\nu \propto \nu^{-\alpha}$) for the optical and infrared data, are given in Table 1. In addition, if 1011+496 is the source of the X-ray emission detected by *HEAO-1* its optical-to-X-ray spectral index α_{ox}~0.9.

As is indicated in Table 2, both objects are highly polarized, with polarizations in excess of that seen in normal quasars (i.e.>3 per cent; see Stockman, Moore & Angel 1984), and comparable to those seen in BL Lacs and OVVs (Angel & Stockman 1980), and in a few, but not most, BLRGs



(a)

Figure 2. (a) The IIDS spectrum of 1011+496. (b) The IIDS spectrum of 1217+348. (c) The IRS spectrum of 3C 390.3, a broad line radio galaxy (BLRG). The telluric absorption band has not been removed from the broad Hα emission line.

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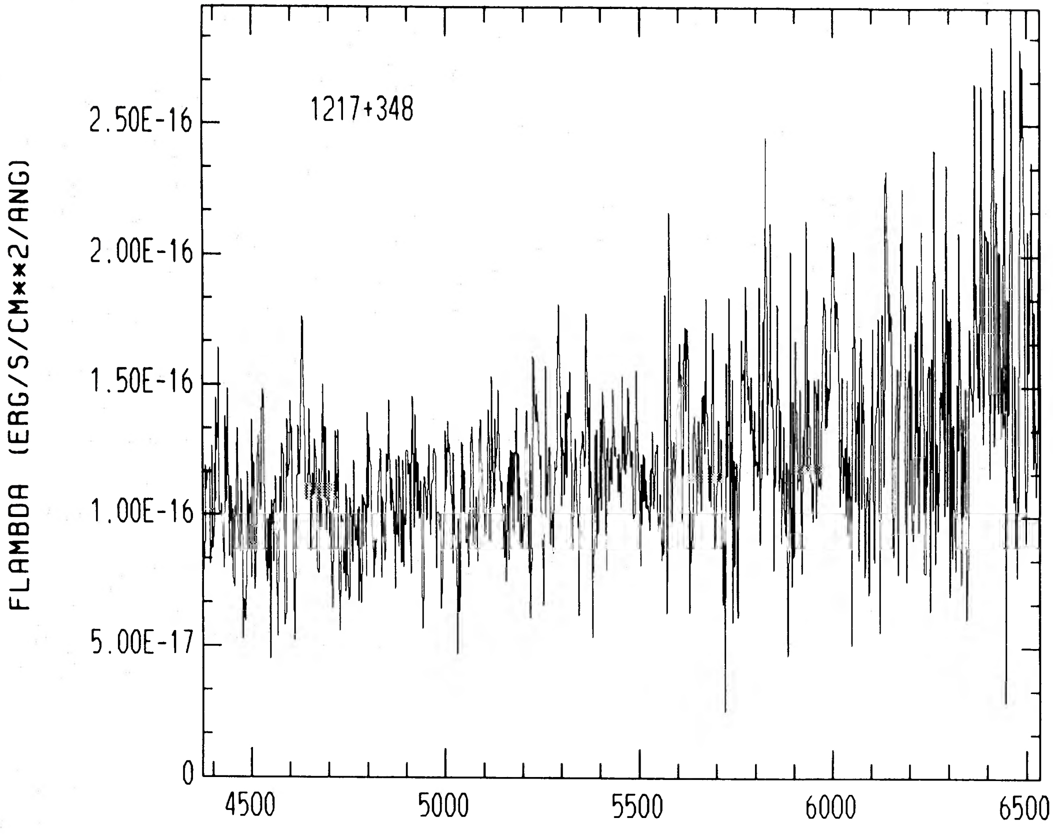
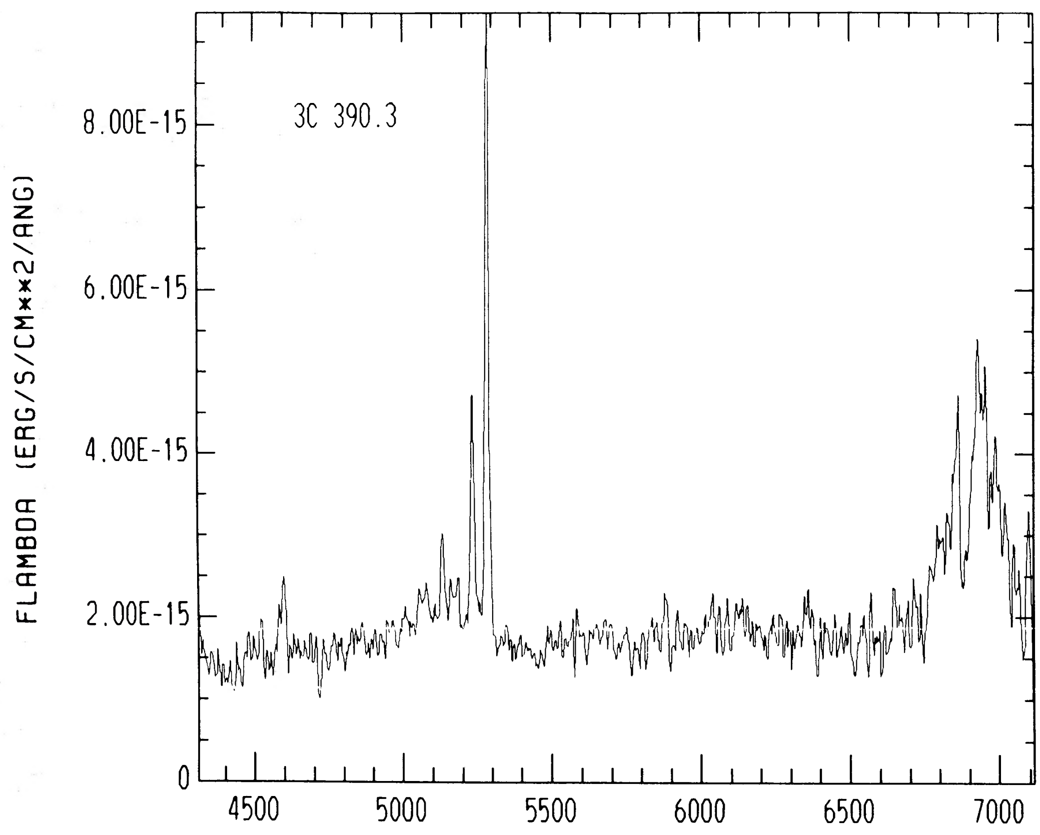


(b)



(c)

Figure 2 – *continued*

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(Rudy *et al.* 1983). Thus, the polarizations suggest that 1011+498 and 1217+348 are either BL Lacs or OVVs, and probably not BLRGs.

What distinguishes 1011+498 and 1217+348 most from the BLRGs are their spectra, shown in Fig. 2. Although of low quality these spectra show no hint of the λ5007 line of [O III] which is usually very strong in BLRGs (Grandi & Osterbrock 1978). For comparison we show a spectrum of the BLRG 3C 390.3 [taken with the KPNO No. 2–0.9-m telescope and the Intensified Reticon Scanner (IRS)]. If 1011+498 and 1217+348 were BLRGs their redshifts must exceed 0.26 and all other emission lines must be weak. Similarly, the lack of strong emission lines indicate that they are not OVVs unless $0.3 \leq Z \leq 0.6$ since both [O III] λ5007 and Mg II λ2800 are absent (unless they are OVVs in a very bright phase, which look like BL Lacs).

Finally, the radio morphology of 1011+496 is that of a compact core with a faint extended halo (Machalski & Condon 1983), while the high-polarization BLRGs which it resembles in other ways (3C 109, 3C 234 and 3C 390.3) are all multiple-component radio sources (Riley & Pooley 1975; Laing 1981). It does resemble those seen in most BL Lacs, however (Antonucci & Ulvestad 1985).

Thus, the continuum shapes, polarizations, lack of strong emission lines, and in one case the radio structure, lead us to conclude that 1011+496 and 1217+348 are most likely BL Lacertae objects. Further monitoring of their continuum flux levels and polarizations is warranted.

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