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REDSHIFTS OF THREE BL LACERTAE OBJECTS: PKS 0118−27, PKS 0829+04, AND MC 1057+10[1]

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ABSTRACT

We present optical spectroscopy of three BL Lacertae objects which allows to derive the previously unknown redshift of the objects. For PKS 0118 − 27 an absorption doublet of Mg II at $z = 0.559$ is found. For PKS 0829 + 04 spectral signature of stellar population is detected at $z = 0.18$. Spectra of MC 1057 + 10 show broad emission lines which, identified with Mg II 2800 and C III] 1909, yield $z = 1.317$.

1. INTRODUCTION

The knowledge of the redshift of BL Lac objects and of the properties of their absorption/emission lines is of great importance for both the physical models of the sources and the study of the class. Spectroscopic observations of appropriate signal-to-noise and resolution are able to detect weak emission and/or absorption lines in the virtually lineless spectra of BL Lacertae objects. These features come either from the underlying galaxy or from the active nucleus or, for distant objects, from intervening material. The detection of these lines, which are often observed superposed onto a strong emission in the continuum, depends also on the brightness state of the objects during the observation. During low states of the sources, the nonthermal contribution of the active nucleus is weaker allowing to detect the spectral signature of a stellar population of the host galaxy. On the other hand, during bright states the contrast for intervening absorption lines is higher, rendering their detection more feasible. Broad emission lines from the active nucleus are usually observed with larger equivalent width when the objects are in a faint state.

To find the redshift for a sizable sample of BL Lac objects, and to study the properties of the emission and absorption features, we have undertaken a spectroscopic program at low and medium resolution. Objects are taken mainly from the more recent compilations of BL Lacs of Burbidge & Hewitt (1987) and Veron-Cetty & Veron (1989). Some of the results for this program have been already published (Falomo *et al.* 1987; Falomo *et al.* 1989; Falomo 1990; Falomo 1991). In this paper we report on observations of three BL Lac objects with previously unknown redshift.

2. OBSERVATIONS

Optical spectroscopy was obtained at the European Southern Observatory (ESO) using the 1.5 and 2.2 m telescopes equipped with a Boller and Chivens spectrograph and CCD detector in either case. Spectra were taken at both low (FWHM$\approx$15 Å) and medium (FWHM$\approx$4) resolution, through a long slit of, respectively, 8 and 4 arcsec width. Optimal extraction methods, following the procedure outlined by Horne (1986), were adopted in order to improve the detectability of faint features. To reduce the contamination by cosmic rays and to improve detectability of real faint features we obtained double exposures for almost each observation. The low resolution spectra were secured in good photometric conditions whose accuracy derived from observations of several standard stars (Stone 1977) was always better than 10%. This allows the brightness state of the objects and the luminosities of emission lines to be derived.

3. RESULTS AND DISCUSSION

PKS 0118−27. An absorption feature at ~4365 Å was first noted in low resolution spectra obtained in 1989 August 7–12 and it is also slightly visible in spectra obtained in 1987–1988 at a lower S/N. The feature is seen superposed onto a power law ($f_\lambda \propto \lambda^{-\alpha}$) continuum emission of spectral index $\alpha = 0.9$. Tentative identification with Mg II 2800 doublet yielded $z_a = 0.56$ (Falomo 1989). Further medium resolution spectra, secured in 1990 September 18 and 21, allow the resolution of the feature into two lines at 4359.8 and 4370.5 Å (see Fig. 1). Identification with Mg II doublet ($\lambda_1 = 2796.35$, $\lambda_2 = 2803.5$) yields, respectively, $z_1 = 0.5591$ and $z_2 = 0.5589$ which agree very well within the measurement errors (± 0.0003). The redshift of the absorption system is thus $z_{abs} = 0.5590 \pm 0.0005$ (including errors of wavelength calibration).

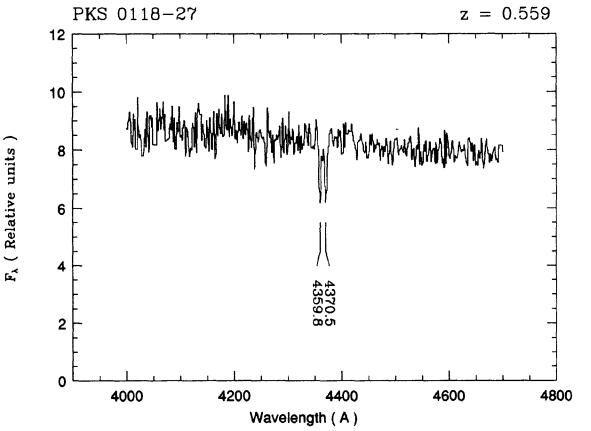

FIG. 1. Portion of the medium resolution spectrum of PKS 0118 − 27 obtained in 1990 September 21 (exp. time 5400 s). The Mg II 2800 absorption doublet at $z = 0.559$ is indicated.

[1] Based on observations obtained at the European Southern Observatory, La Silla, Chile.

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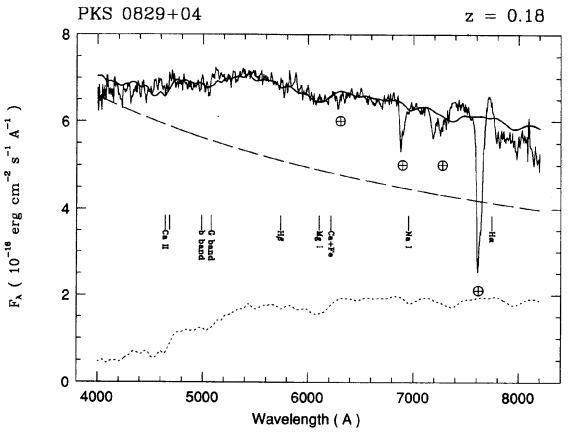

FIG. 2. The optical spectrum of PKS 0829 + 04 obtained in the (average of 1990 February 18,19) faint state is decomposed into a power law (dashed line) with $\alpha = 0.7$ plus a standard elliptical galaxy (dotted line) redshifted at $z = 0.18$. The solid line represent the sum of the two components.

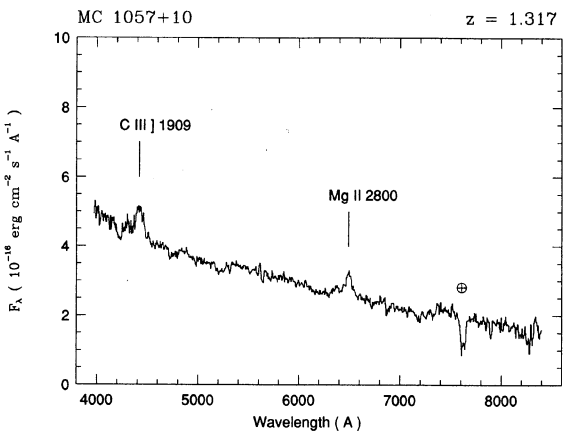

FIG. 3. Average (1990 February 18,19) optical spectrum of MC 1057 + 10. The two broad and weak emission lines of Mg II 2800 and C III 1909 are marked.

The observed equivalent widths, derived assuming a linear continuum fitting the mean flux measured in two 100 Å bands at each side of the doublet, are $W_1 = 1.2 \pm 0.2$ Å and $W_2 = 1.2 \pm 0.2$ Å. This can be used to estimate the column density of the Mg II absorber. However, because the doublet ratio DR $= W_1/W_2$ is ~ 1, the lines are in the saturated part of the curve of growth and only extreme limits of $N(\mathrm{Mg}^+)$ can be derived (e.g., Wolfe & Wills 1977; Peterson *et al.* 1977).

Assuming as limits for DR = 1.0–1.2 we obtain the following:

$$2\times10^{14}\ \mathrm{cm}^{-2} < N(\mathrm{Mg}^+) < 6\times10^{16}\ \mathrm{cm}^{-2},$$

in agreement with those expected in the commonly assumed hypothesis that Mg II absorptions arise in intervening material likely associated with a halo of galaxies. In this respect we note that, although high resolution direct imaging failed to resolve the object (Falomo *et al.* 1990), there are ~ 15 faint galaxies in the field of PKS 0118 − 27 which are roughly symmetrically distributed around the BL Lac object within ~ 30 arcsec. The nearest galaxy is located at ~ 8 arcsec from the BL Lac, giving a projected distance (at $z = 0.559$) of ~ 70 Kpc ($H_0 = 50$; $q_0 = 0$).

PKS 0829+04. This object is known to be optically very active. Liller & Liller (1975) report light curves showing large amplitude (~ 4 mag) and rapid (~ 1 mag in 1 day) flux variability. Spectra obtained during bright states ($V \sim 15$–16) exhibit a featureless nonthermal emission. Low dispersion spectra obtained during a relatively low state of the source ($V \sim 16.8$) show clearly the signature of an underlying stellar population (see Fig. 2). The spectral resolution of these observations is low (FWHM ~ 25 Å) and prevent to distinguish clearly individual absorption lines. Nevertheless the contribution of the underlying galaxy, which depresses the continuum at the Ca II break and in the regions of the *G* band and of Mg I plus Ca I Fe I absorptions is well apparent. We have decomposed the observed spectrum into a power law ($f_\lambda \propto \lambda^{-\alpha}$) plus the spectrum of a standard elliptical galaxy (Yee & Oke 1978). The decomposition depends on the percentage of galaxy contribution, the spectral index α, and to some extent on the assumed redshift. The best decomposition (see Fig. 2) is obtained for $z = 0.18 \pm 0.01$, $\alpha = 0.7$, and a galaxy contribution of 25% at 6000 Å. Although decompositions which differ for α and galaxy contribution can adequately fit the data well, the redshift parameter does not change more than 0.01.

A rough estimate of the absolute magnitude of the host galaxy can be derived assuming it contributes to 25%–30% of the total light in the V band. The magnitude of the surrounding galaxy would thus be $m_V \sim 18$ corresponding (at $z = 0.18$) to $M_V \sim -22.5$ which is a typical value for giant ellipticals hosting BL Lacs (see, e.g., Ulrich 1989)

MC 1057+10. Spectroscopy of this object was first reported by Strittmatter *et al.* (1974) who find a featureless spectrum. Optical variability (Kinman 1976; Tapia *et al.* 1976; Adam 1985; Beskin *et al.* 1985) and optical polarization (Kinman 1976) suggest a BL Lac classification of the source. Our low resolution spectra (see Fig. 3) show two broad emission lines at 4420 and 4490 Å which are identified respectively with C III] 1909 and Mg II 2800 at $z = 1.317 \pm 0.001$. The optical continuum is well described by a single power law ($f_\lambda \propto \lambda^{-\alpha}$) of $\alpha = 1.45$ and the magnitude derived from the spectrophotometry is $V = 17.7$.

The observed equivalent widths of the emission lines are W_λ(C III]1909) $= 18 \pm 3$ Å and W_λ(Mg II 2800) $= 23 \pm 4$ Å, considerably smaller than those normally found in quasars (e.g., Oke *et al.* 1984). The luminosity of Mg II 2800 L(Mg II) $\sim 5\times10^{43}$ ergs s^{-1} appears significantly lower than the average value found in normal quasars (see, e.g., Oke *et al.* 1984) while it is comparable to those seen in other BL Lac objects (Stickel *et al.* 1991).

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