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1E 1415.6+2557: AN X-RAY–SELECTED BL LACERTAE OBJECT IN A LUMINOUS GALAXY[1]

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ABSTRACT

A bright, serendipitous *Einstein* X-ray source is identified with a new BL Lacertae object in a highly luminous galaxy. The resolved component is well fitted by an exponential disk with scale length 18 kpc and absolute r magnitude $M_r \approx -24.2$ ($H_0 = 50$). The redshift of 0.237 is derived from stellar absorption features. No emission lines are seen in the wavelength range 3200–9000 Å. Decomposition of the optical spectrum into a standard galaxy plus a power law yields a spectral index of $\alpha_0 = 0.5 \pm 0.5$, significantly flatter than in the average BL Lac object. Linear polarization of the nonstellar component is $\sim 6\%$ in the wavelength range 4500–7000 Å. The X-ray flux in the 0.3–3.5 keV band is 1.16×10^{-11} ergs cm^{-2} s^{-1}, corresponding to a luminosity of 3.5×10^{45} ergs s^{-1}. The radio flux density is 85.6 mJy at 20 cm and 54.5 mJy at 6 cm. The overall distribution of power between the radio, optical, and X-ray indicates that the synchrotron break frequency must be in the ultraviolet, a situation which is favorable to X-ray selection. It is suggested that the tendency for BL Lac objects discovered by *Einstein* to be much brighter than the flux limit for detection implies that some of the fainter sources which are identified with "normal" galaxies, weak emission-line galaxies, or clusters are actually BL Lac objects.

Subject headings: BL Lacertae objects — polarization — X-rays: sources

I. INTRODUCTION

Only four new BL Lac objects have been identified (Gioia *et al.* 1984) among the ~ 200 active galaxies discovered by the *Einstein Observatory.* Their properties were described by Stocke *et al.* (1985), and implications for the luminosity function and cosmological evolution of BL Lac objects were discussed by Maccacaro *et al.* (1984). Gioia *et al.* (1984) stated the defining criteria of BL Lac objects to be detectable radio emission, featureless optical continuum, and detectable optical polarization (even though only one of their objects actually possesses all three characteristics). However, a persistent obstacle to the statistical analysis of samples of BL Lac objects has been the difficulty in specifying a unique set of properties which define the class. All the criteria are matters of degree and are shared to some extent by other classes of active galactic nuclei. Some BL Lac objects do have forbidden lines, which can be used to determine the redshift. An object once classified as a BL Lac has now developed a broad Hα emission line (Ulrich 1981). Polarization can be reduced in proportion to the amount of stellar light contributed by the host galaxy. The featureless optical continuum, being essentially a negative attribute, is in addition a function of the quality of the data, such as signal-to-noise ratio and wavelength coverage. Furthermore, it is not clear that X-ray–selected BL Lac objects must have the same defining criteria as radio-selected ones. In particular, the radio to optical flux ratio is smaller in X-ray–selected BL Lac objects, and the X-ray to optical flux ratio is larger, than in radio-selected ones (Stocke *et al.* 1985).

In this paper we report the identification of a fifth serendipitous *Einstein* source with a new BL Lac object in a very luminous galaxy. The source was not included in the complete sample of Gioia *et al.* (1984) because it fell outside the support ribs of the detector (see § II). All three criteria for classification as a BL Lac object are satisfied. The observed properties are summarized in Table 1. We compare the properties of this object with other X-ray–selected BL Lac objects and typical radio-selected ones.

II. X-RAY AND RADIO OBSERVATIONS

A serendipitous X-ray source appeared at the edge of the *Einstein* imaging proportional counter (IPC) during an observation of the Seyfert galaxy NGC 5548 on 1979 June 29. (The analysis of NGC 5548 was done in Halpern 1982). The position of the serendipitous source is

$$\alpha(1950) = 14^{\mathrm{h}}15^{\mathrm{m}}40^{\mathrm{s}}.2\ , \quad \delta(1950) = +20°57'5''\ ,$$

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TABLE 1

OBSERVED PROPERTIES OF 1E 1415.6+2557
($H_0 = 50$, $q_0 = 0$)

Parameter	Value
α(1950)	$14^{h}15^{m}41^{s}.3$
δ(1950)	$+25°57'15''$
z	0.237 ± 0.001
m_r(disk)	16.8
M_r(disk)	−24.2
m_r(total)	16.2
α_o	0.5 ± 0.5
Polarization:	
red	$3.33\% \pm 0.33\%$
blue	$4.98\% \pm 0.35\%$
nonstellar	6%
f_x(0.3–3.5 keV)	1.16×10^{-11} ergs cm^{-2} s^{-1}
L_x(0.3–3.5 keV)	3.5×10^{45} ergs s^{-1}
S(20 cm)	85.6 mJy
S(6 cm)	54.5 mJy
α_{ro}	0.51
α_{ox}	0.71

with a 90% confidence error radius of 47″. This position is 35′ north of NGC 5548.

Although the source is relatively bright (~4800 net counts), quantitative analysis is hampered by the fact that it is close to the edge of the detector (35′ off axis) and close to the support structure (ribs) of the IPC. For this reason, the gain is not known accurately enough to enable a meaningful spectral fit to be done. It would also be difficult to detect time variability, since small changes in aspect could be responsible for variable obscuration by the rib and positional fluctuations in gain. The analysis was limited to a derivation of the total flux in the 0.3–3.5 keV band under the assumption that the spectrum is described by a power law of $\alpha_x = 1.0$ and a column density $N_H = 3 \times 10^{20}$ cm^{-2}, the same parameters used by Maccacaro *et al.* (1984). Standard background subtraction and corrections for vignetting, scattering, and point response function were applied. The net flux is 1.16×10^{-11} ergs cm^{-2} s^{-1}, corresponding to a luminosity of 3.5×10^{45} (at $z = 0.237$ with $H_0 = 50$ km s^{-1} Mpc^{-1}, $q_0 = 0$ assumed throughout).

The normalization corresponds to a monochromatic flux of 3.44×10^{-3} keV cm^{-2} s^{-1} keV^{-1} at 1 keV. This is 55% of the flux of NGC 5548 in the same observation (6.22×10^{-3} keV cm^{-3} s^{-1} keV^{-1}). Depending on the actual spectrum and variability of the BL Lac object, previous hard X-ray spectra of NGC 5548 (Hayes *et al.* 1980; Mushotzky *et al.* 1980; Rothschild *et al.* 1983) may be significantly contaminated. Note that the simultaneous *Einstein* MPC spectrum is not significantly affected; since the collimator response falls to ~20% at 35′ off axis, the net contribution of the BL Lac object is only 10%.

Radio continuum observations were made on 1985 August 3 using the C configuration of the VLA in "snapshot" mode. A source was detected inside the X-ray error circle with flux densities of 85.6 mJy at 20 cm and 54.5 mJy at 6 cm. The radio position obtained from the higher resolution 6 cm data is

$$\alpha(1950) = 14^{h}15^{m}41^{s}.11 \pm 0^{s}.08 ,$$

$$\delta(1950) = +25°57'15''.0 \pm 1''.0 .$$

There is a suggestion in the 6 cm map that the source is extended, but observations of higher spatial resolution are needed for confirmation.

The radio source was also detected during an observation of NGC 5548 with the Westerbork Synthesis Radio Telescope. The flux density at the time of the observation, 1977 October 25, was 80 ± 14 mJy at 1.4 GHz, consistent with the VLA measurement.

III. OPTICAL OBSERVATIONS

a) Spectroscopy

The brightest object on the Palomar Observatory Sky Survey print which falls in the X-ray error circle is a ~16 mag, extended object at position

$$\alpha(1950) = 14^{h}15^{m}41^{s}.3 , \quad \delta(1950) = +25°57'14''.8 ,$$

with uncertainties of 1″.5 in either coordinate. The optical and radio source positions agree to within 3″, consistent with the joint errors. A spectrum was taken on the night of 1984 April 7 using the double spectrograph (Oke and Gunn 1982) on the Hale 5 m telescope. The spectrum covered the range 3200–9000 Å with an RCA CCD in the blue and a TI CCD in the red. A dichroic filter split the beam at 4700 Å. Instrumental resolution was ~12 Å in the blue and 18 Å in the red. A 3000 s exposure was obtained through a 2″ wide slit at position angle 90°. The airmass was 1.05 or smaller during the observation. An instrumental problem (condensation on the red CCD) resulted in a nonuniform loss of sensitivity of up to a factor of 3, as well as some scattered light. However, a standard star observed immediately before the object was used for flux calibration, and the resulting spectrum does not appear to be adversely affected. In particular, the blue and red spectra match in flux at the crossover wavelength, and the equivalent widths of absorption lines in the standard star are normal.

The red spectrum (Fig. 1) shows absorption lines typical of a normal galaxy, except that the Ca II H and K features are very weak, as is the *G* band. The measured wavelengths of Ca II H and K, Mg *b*, and Na D are all consistent with a redshift of 0.237 ± 0.001. No emission lines are visible. The weak features redward of 8000 Å are due to imprecise removal of water vapor absorption. The overall spectrum is unusually blue for a normal galaxy. A determination of the flux contributed by a blue continuum is discussed in § IV.

b) Direct Imaging

An CCD image with an "*r*" filter (Thuan and Gunn) was kindly taken for us on the night of 1984 April 19 by Todd Boroson using the Palomar 1.5 m telescope. Figure 2 (Plate 21) shows the resolved galaxy, as well as a companion located 5″ away at position angle 200°. The redshift of the companion has not been measured, although it seems likely that the two galaxies are associated. Several other faint objects in the field are galaxies. Surface photometry was performed on the BL Lac object host galaxy after removal of the companion. The procedures were outlined in Smith *et al.* (1985). The point spread function (PSF) can be represented as the sum of two Gaussians, one due to seeing and the other (the wings of the PSF) representing instrumental effects (see also Hoessel and Schneider 1985). The seeing in this image is 0″.85 FWHM. The radial brightness profile (Fig. 3) is well described by a PSF (*dotted line*) plus an exponential disk of scale length $3''.54 \pm 0.5$ (18 kpc) and central surface brightness 21.5 ± 0.1 mag arcsec^{-2}. Note that the PSF contribution must include unresolved bulge light as well as the nuclear component. The integrated *r* magnitude of the disk is 16.8 ± 0.35. The companion galaxy is ~2 mag fainter than the BL Lac object host.

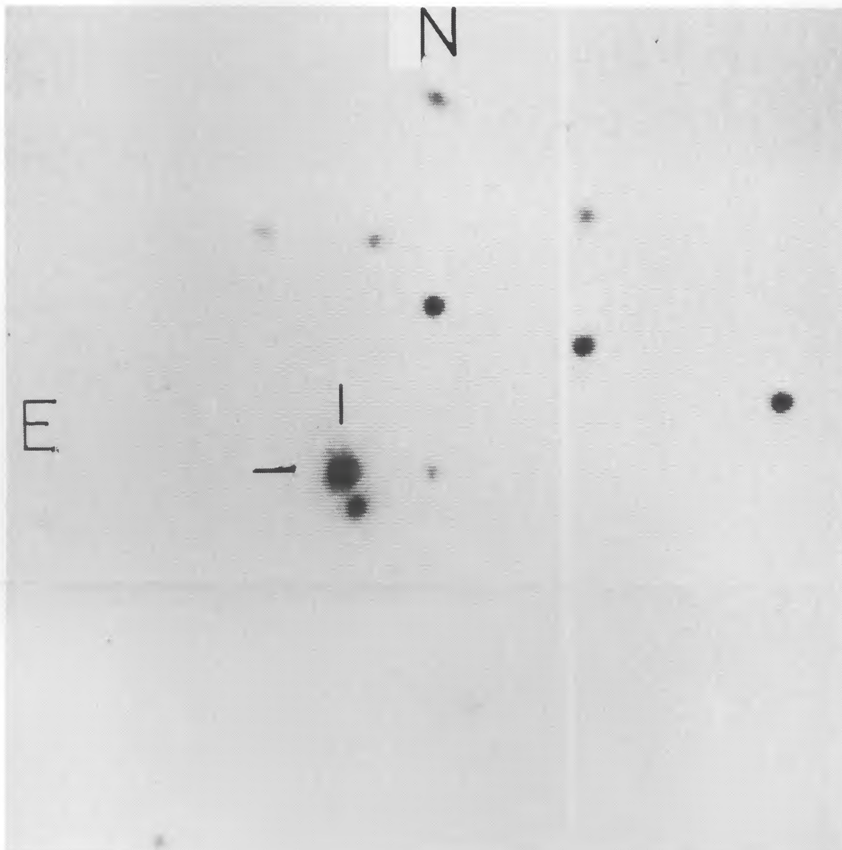

FIG. 2.—An r-band image of the field of 1E 1415.6+2557 taken with an RCA CCD on the Palomar 1.5 m telescope. The picture is $2' \times 2'$. Tick marks indicate the BL Lac object host galaxy at position $\alpha(1950) = 14^h15^m41^s.3$, $\delta(1950) = +25°57'15''$. Another galaxy lies $5''$ from the BL Lac object at position angle 200°.

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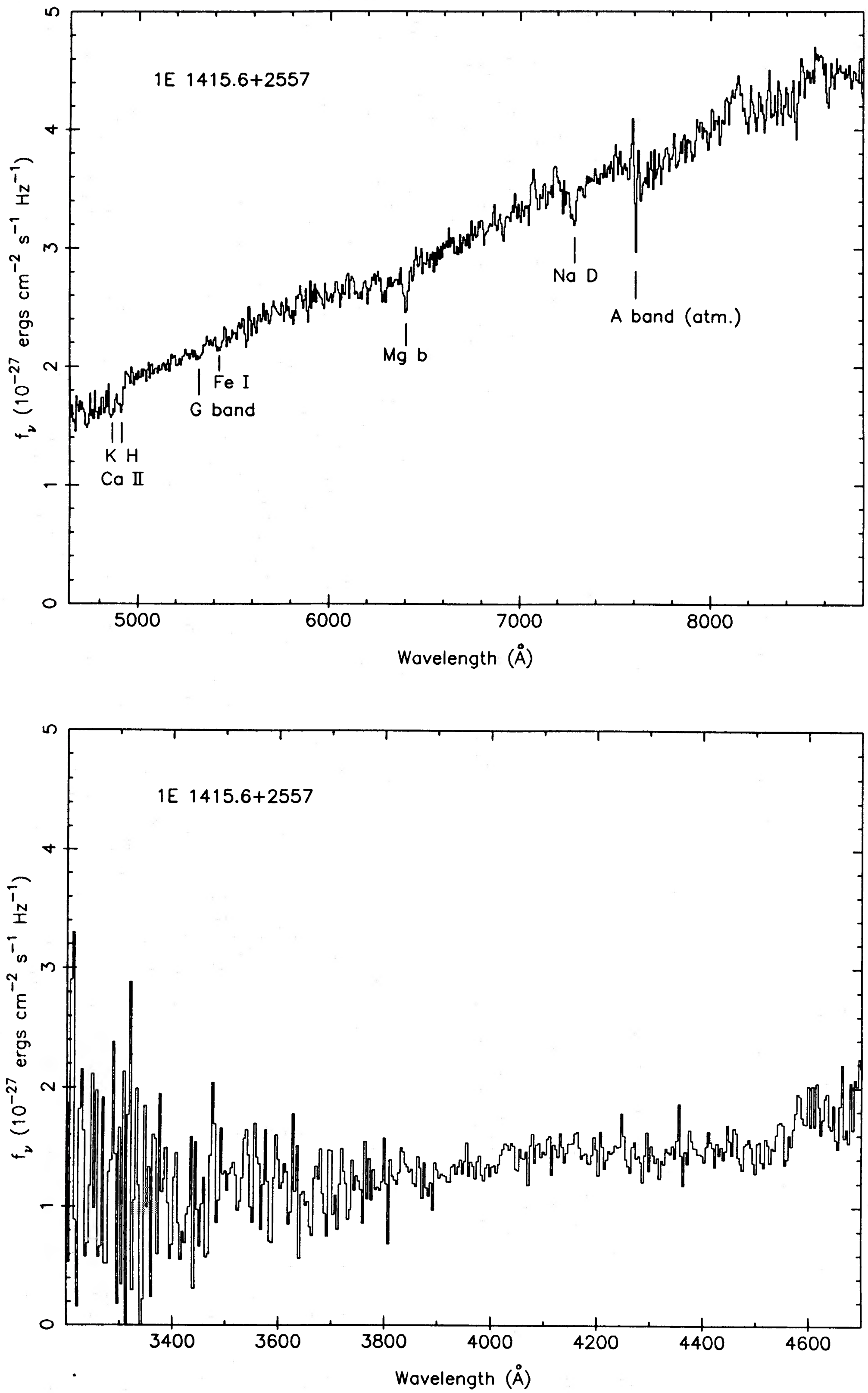

FIG. 1.—Spectra of 1E 1415.6−2557 obtained through a 2″ slit. Exposure time was 3000 s with the double spectrograph on the Hale 5 m telescope. The spectra were extracted from a region 4″ in length along the slit, centered on the nucleus of the galaxy. Expected positions of stellar absorption features at $z = 0.237$ are indicated.

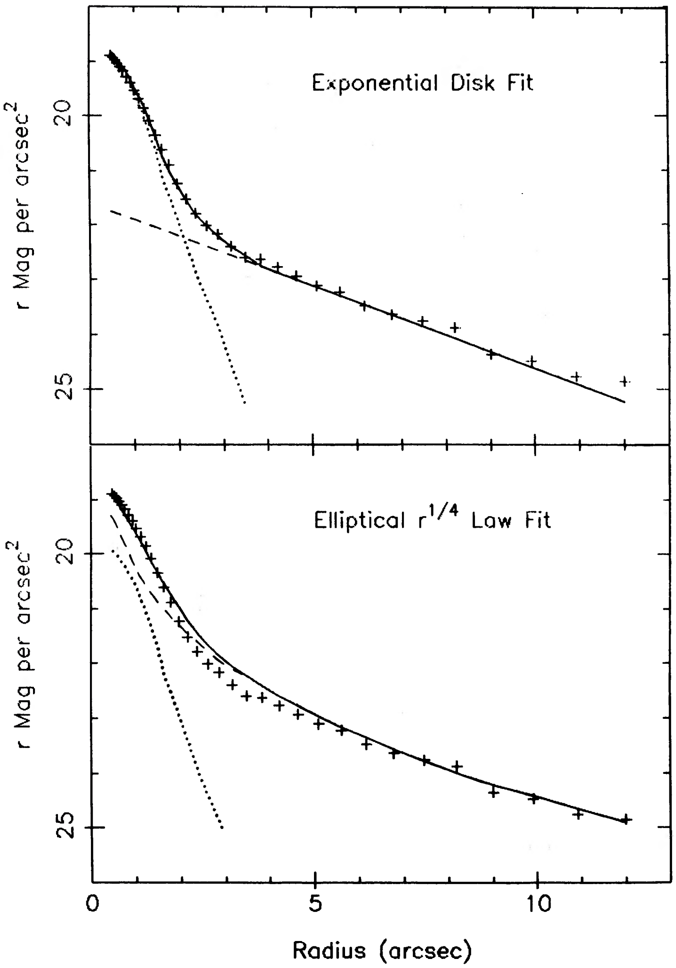

FIG. 3.—Surface brightness profile of 1E 1415.6+2557 after removal of the companion galaxy. The solid lines are the best fits to the data (*plusses*) for the sum of a stellar profile (*dotted line*) plus an exponential disk (*top figure, dashed line*) or an elliptical $r^{1/4}$ law (*bottom figure, dashed line*).

Alternatively, an $r^{1/4}$ law, constrained to fit the outer parts of the surface brightness profile, produces a poor fit for radii less than 5″. The parameters of the $r^{1/4}$ fit are $r_e = 6'' \pm 1''$ and $I_e = 23.3 \pm 0.2$ mag arcsec^{-2}. Hoessel and Schneider (1985) have shown that in the Gunn r band there is a well-defined relation between r_e and I_e for brightest cluster galaxies. With respect to this calibration, the $r^{1/4}$ fit shown in Figure 3 has I_e 1.2 mag too bright for r_e. In other words, we cannot extract a profile which resembles that of any elliptical galaxy. We conclude that the host is most likely a very luminous disk galaxy. It is not unique in the respect, however, as it is similar to the luminous disk galaxy of the QSO Mrk 1014 (Smith *et al.* 1985).

c) Polarimetry

The galaxy was observed twice in 1985 April, with the University of Arizona MINIPOL polarimeter on the Du Pont 100 inch (2.5 m) telescope at Las Campanas. The MINIPOL is a high-precision photoelectric polarimeter with rapid modulation and a very low instrumental polarization (Frecker and Serkowski 1976). Twin GaAs photomultiplier tubes are used to measure linear polarization over the entire optical wavelength range. On the night of 1985 April 12, the linear polarization measured without a filter was 2.92% ± 0.11% at position angle 163° ± 1°. The unfiltered magnitude corresponds approximately to $V \approx 17.5$. On the night of 1985 April 15, the linear polarization through a $CuSO_4$ filter ($\lambda_{\rm eff} \approx 4500$ Å) was 4.54% ± 0.35% at 178° ± 2°. Both these measurements were made with a 2″.5 circular aperture in seeing of 1″–1″.5. The data have been corrected for the modulating efficiency of the superachromatic half-wave plate (an adjustment factor of 1.02, determined using a Glan prism).

Since the polarization is relatively low for a BL Lac object, two nearby field stars also received an unfiltered measurement. One star 100″ west and 7″ north of the object yielded 0.59% ± 0.33% at 87° ± 15°, and another 90″ west and 55″ south yielded 0.33% ± 0.12% at 104° ± 10°. These two stars are similar in brightness to the BL Lac object, and their low polarization is a confirmation that the polarization in the X-ray source is not due to interstellar scattering in the Galaxy. The unfiltered polarization measurement of the BL Lac object can be corrected for foreground interstellar scattering by subtracting the mean Stoke's parameters of the two field stars. The resulting polarization is 3.33% ± 0.23% at 165° ± 2°. The polarization measurement through the $CuSO_4$ filter can also be corrected if we assume that the $p(\lambda)$ curve peaks at 6000 Å and follows the dependence given by Serkowski (1972). The corrected blue polarization is 4.98% ± 0.35% at 177° ± 2°.

As with other BL Lac objects, the observed polarization is probably due to synchrotron emission from a power law energy distribution of relativistic electrons. The true polarization of the power-law component can be determined by correcting for the dilution due to unpolarized starlight from the host galaxy. In the next section, a decomposition into power-law and stellar components will be described; the results are applied here. The assumption is made that the relative amounts of starlight and nonstellar continuum in the 2″ slit (spectroscopy) and the 2″.5 circular aperture (polarimetry) are similar. At 4500 Å, the effective wavelength of the $CuSO_4$ measurement (3640 Å rest wavelength), the proportion of power-law flux to total flux is 87%, so the intrinsic polarization of the power-law component is ~5.7%. At 7000 Å, the effective wavelength of the unfiltered measurement (5660 Å rest wavelength), the fraction of power-law flux is 52%, so the power-law polarization at 7000 Å is ~6.4%. Within the errors of this decomposition procedure, the polarization is wavelength-independent.

IV. STELLAR AND NONSTELLAR CONTINUUM

A quantitative estimate of the nonstellar continuum was made with the aid of two different properties of the "average" giant elliptical galaxy spectrum. The first involves a decomposition into the standard giant elliptical galaxy spectrum of Yee and Oke (1978) plus a power law of the form $f_\nu \propto \nu^{-\alpha}$. Although the host galaxy does not appear from its surface brightness profile to be an elliptical, the spectrum of the bulge which probably dominates in the 2″ slit is similar to that of an elliptical galaxy. The procedure is identical to the one used in Halpern and Filippenko (1984) and is described in that paper. A reddening of $E_{B-V} = 0.03$ in our Galaxy was assumed. This method is sensitive to the overall slope of the spectrum as well as certain broad features such as the "H and K break" at 4000 Å. Because of the limited spectral coverage (a factor of ~2 in wavelength), it is not possible to determine α with high precision. For each assumed value of α, the relative contribution of the standard galaxy and power law changes. Table 2

TABLE 2

PARAMETERS OF THE CONTINUUM DECOMPOSITION

ASSUMED SLOPE α	FRACTION OF FLUX CONTRIBUTED BY POWER LAW AT[a] 3800 Å	4000 Å	5460 Å
0.0	0.80	0.69	0.40
0.3[b]	0.82	0.73	0.48
0.5[b]	0.85	0.77	0.54
0.7[b]	0.87	0.80	0.61
1.0	0.92	0.86	0.72
1.5	0.989	0.984	0.967

NOTE.—Spectra are dereddened by $E_{B-V} = 0.03$.
[a] Rest wavelengths.
[b] Fit acceptable by visual inspection.

gives the power-law contribution for a range of trial values of α, expressed as monochromatic fractions at rest wavelengths of 5460 Å, 4000 Å, and 3800 Å. For example, $\alpha = 0.5$ requires the power law to contribute 54% of the total flux at 5460 Å. In all cases, the power law contribution dominates in the blue, which accounts for the strong ultraviolet excess. The best overall fit has $\alpha = 0.5$ (see Fig. 4), with a range of ± 0.5 as a fairly conservative uncertainty. The reasons for this are given below.

The strongest spectral feature in the standard elliptical galaxy is the break around 4000 Å which amounts to a decrease of about 50% in flux. In the actual spectrum of the object, the corresponding decrease has an amplitude of only $\sim 12\%$. This means that the actual stellar contribution at 4000 Å is 20%–25% (power-law contribution 75%–80%), which would agree with the spectral decomposition for values of α between 0.3 and 0.7. Note that $\alpha > 1.0$ is strongly ruled out because the stellar contribution in this decomposition would be negligible (see Table 2), and the break would not be visible.

A second, independent estimate of the nonstellar contribution relies on the fairly narrow distribution of equivalent widths of Mg *b* and Na D in elliptical and S0 galaxies. The observed rest frame equivalent widths of these features in 1E 1415.6+2557 are 2.6 and 2.7 Å respectively. The dilution of these lines by a nonstellar continuum provides another measure of the monochromatic power-law contribution at the rest wavelengths of 5175 and 5892 Å. For comparison, we use the data of Tonry and Davis (1981) on the equivalent widths (average of Mg *b* and Na D) in elliptical and S0 galaxies. There

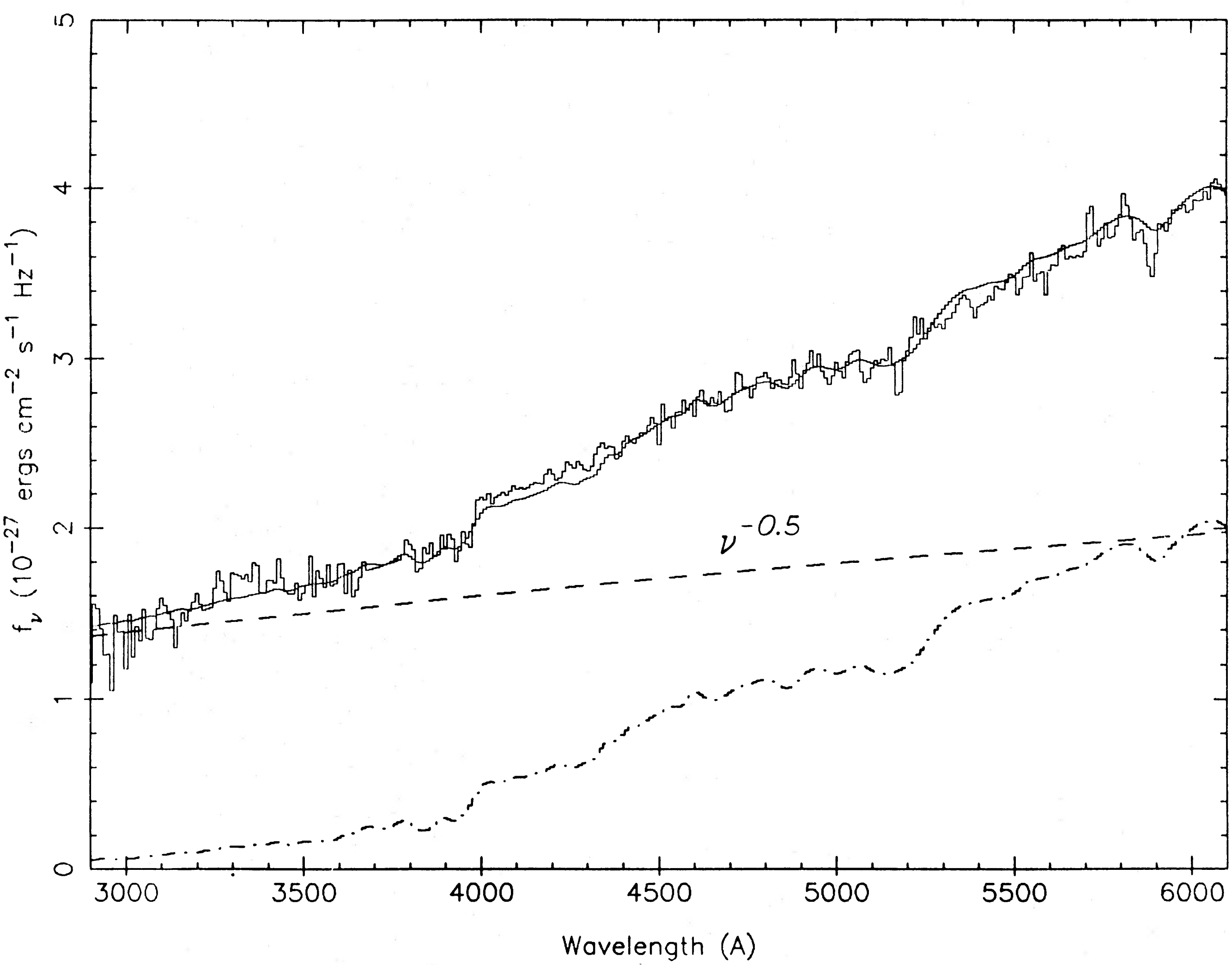

FIG. 4.—The best fit (*solid line*) for a decomposition of the spectrum into a power law (*dashed line*) plus the standard giant elliptical galaxy of Yee and Oke (*dot-dash line*). $E_{B-V} = 0.03$ in our own Galaxy is assumed. The region of the spectrum around the crossover wavelength of the dichroic was not used in the fit.

is a slight correlation of equivalent width with absolute luminosity between 10^9 and 10^{11} $L_\odot$. A least-squares fit gives the relation $W = 4.08 + 0.79 \log L_{10}$, where W is the equivalent width in Å and L_{10} is the luminosity in units of 10^{10} $L_\odot$. The distribution of equivalent widths for the 38 highest luminosity galaxies appropriate to our case has a mean of 4.7 and a standard deviation of 0.7. In no case is the equivalent width greater than 6.3 Å. The observed equivalent widths of ~ 2.7 Å would therefore seem to limit the power-law contribution to less than 60% at ~ 5500 Å. Table 2 indicates that only those decompositions with $\alpha \leq 0.7$ are consistent with this restriction.

Both methods described above yield results which are consistent with $\alpha \approx 0.5$ and strictly reject power laws with $\alpha \geq 1.0$. This spectral index is flatter than that found in most radio- and optically selected BL Lac objects ($\alpha_o \approx 2.0$). A tendency for α_o to be flatter in X-ray–selected BL Lac objects has already been noted by Stocke *et al.* (1982). An index of 0.5 is flat with respect to other X-ray–selected BL Lac objects which have $\alpha_0 \approx 1.0$ (Stocke *et al.* 1982). However, it is possible that a proper subtraction of the stellar component in other X-ray–selected BL Lac objects will yield a similarly flat power law. The analysis of Mrk 501 (effectively X-ray–selected by all-sky surveys) by Snijders *et al.* (1979) found an index of 0.5 extending from the optical to the ultraviolet after an elliptical galaxy was subtracted. Similarly, Weistrop, Smith, and Reitsema (1979) found that $\alpha \approx 0.4$ fits the radio through optical spectrum of PKS 0548−322 after subtraction of a giant elliptical galaxy. One caveat to this analysis is the assumption that the underlying galaxy has the same spectral shape as the standard giant elliptical. If the actual galaxy is bluer because of the presence of younger stars, then the slope of the nonstellar component will be underestimated (i.e., it will be too flat).

The absolute magnitude of the underlying galaxy can be estimated from the r image. The observed magnitude of the disk ($m_r = 16.8$) corresponds to an absolute magnitude of $M_r = -24.2$ for $q_0 = 0$, $H_0 = 50$. The colors and K-correction for this object are unknown. If we apply the results of Oke and Sandage (1968) for the standard giant elliptical galaxy and the transformation to the Johnson system of Kent (1985), then $M_V = -24.1$ results. This is one magnitude brighter than the first-ranked cluster galaxies ($M_V = -23.1 \pm 0.4$ when transformed to $H_0 = 50$) of Wilkinson and Oke (1978). Some BL Lac objects are located in luminous elliptical galaxies (Oke 1978).

V. DISCUSSION

1E 1415.6+2557 does not appear to differ from the other X-ray–selected BL Lac objects in its ratio of radio flux to optical flux. A flux of ~ 100 μJy at 2500 Å rest wavelength is found from Figure 1, implying $\alpha_{ro} = 0.51$. Interestingly, α_{ro} is close to the best-fit $\alpha_o \approx 0.5$ for the nonstellar optical continuum, perhaps implying that a single synchrotron power law is responsible for the radio through optical spectrum. The optical to X-ray index α_{ox} is 0.71, somewhat flatter than in the other objects, but the optical flux corresponds to the UV light in a 2″ slit, and not the total V magnitude as in Stocke *et al.* (1985). If the flux at 2500 Å were as much as a factor of 2 higher, then α_{ro} would be 0.45 and α_{ox} would be 0.82. We note that the α_{ox} values for two additional BL Lac objects discovered by *HEAO 1* are also approximately 0.8 (Ulmer *et al.* 1983; Doxsey *et al.* 1983; Margon and Jacoby 1984; Feigelson *et al.* 1986).

It appears that most if not all X-ray–selected BL Lac objects have radio emission, with the average α_{ro} being around 0.4, at the low end of the distribution of all BL Lac objects (Chanan *et al.* 1982; Stocke *et al.* 1985). Several authors have described the spectra of BL Lac objects as simple synchrotron power laws with a single break frequency due to energy loss. Under this interpretation, there appears to be a systematic difference in the energy distribution between radio- and X-ray–selected BL Lac objects. The radio-selected objects have steeper spectral indices for the optically thin power laws in the optical and infrared regions. From a sample of 26 BL Lac objects with photometry from 1 to 10 μm (Cruz-Gonzales and Huchra 1984; Impey 1986), the mean infrared spectral index is $\alpha_{\rm IR} = 1.12 \pm 0.18$. Since this power law continues smoothly out to the high-frequency radio emission, it is presumably the optically thin spectral index of the most compact synchrotron component. However, the mean spectral index in the optical region is $\alpha_o = 1.54 \pm 0.64$ for the same objects. For the half of the objects in Cruz-Gonzales and Huchra (1984) where a spectral break is observed, the mean wavelength of the steepening is about 1 μm. In contrast, the synchrotron break frequency in 1E 1415.6+2557 and other X-ray–selected BL Lac objects must be in the ultraviolet, as evidenced by the flat optical slopes and high ratios of X-ray to optical emission. For example, if we assume that the spectrum of 1E 1415.6+2557 is described by indices of $\alpha_0 = 0.5$, $\alpha_{ox} = 0.8$, and $\alpha_x = 1.0$, then the break frequency is ~ 2.0 ryd. It may be that radio emission necessarily accompanies the other properties of BL Lac objects, but that X-ray selection merely favors the detection of objects in which the synchrotron break frequency is the highest. We note that Ledden *et al.* (1981) speculated that such objects might exist and that they would be most easily discovered by their X-ray emission.

Maccacaro *et al.* 1984 found that the X-ray fluxes of the four BL Lac objects in the Medium Sensitivity Survey are all above the flux limit for detection by at least a factor of 10. (This is also true for 1E 1415.6−2557 but not significant, since it was chosen for further study precisely because of the high flux). The possibility should be considered that some BL Lac objects remain unrecognized among the fainter sources. Gioia *et al.* (1984) pointed out that ~ 10 of the optical counterparts are "normal" or weak-lined galaxies which are unlike the usual quasars or Seyfert galaxies. It may be that some of these will actually turn out to be BL Lac objects upon careful decomposition of the optical continuum. It is also possible that some of the 18 sources attributed to clusters may be due in part to a BL Lac object in a giant cluster galaxy. These possibilities were also considered by Stocke *et al.* (1985) and Schwartz *et al.* (1985). As in the case of 1E 1415.6+2557, spectrophotometry covering a large wavelength range will be necessary to search for these hypothesized BL Lac objects. The extreme luminosity of this host galaxy ($M_V \approx -24.1$) indicates that even high-luminosity BL Lac objects can be camouflaged by the stellar light.

Work remains to be done on 1E 1415.6+2557 which can advance our understanding of the galaxian environment of BL Lac objects and the optical identification of BL Lac X-ray sources. Imaging and photometry of the unusually luminous host galaxy in several colors will undoubtedly be informative. Optical spectroscopy of other faint objects in the field, including the companion galaxy, will determine whether they are physically associated. We plan to pursue these investigations.

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