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H1722+119: A HIGHLY POLARIZED X-RAY–SELECTED BL LACERTAE OBJECT

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ABSTRACT

We report the discovery of a 15th magnitude X-ray–selected BL Lacertae object as part of a program to identify X-ray sources observed by the Scanning Modulation Collimator experiment during the *HEAO 1* all-sky survey. The BL Lac object, H1722+119, is a strong and persistent X-ray source originally discovered by *Uhuru* and located by the HRI instrument on the *Einstein Observatory*, The *Einstein* HRI and MPC observations indicate a steep X-ray spectrum with a power-law energy index near 1.3. The optical spectrum shows no obvious emission or absorption features, and the $U-B$ and $B-V$ indices are typical of BL Lac objects. There is no evidence of a host galaxy in CCD images with broad-band R and I filters, implying that the X-ray and optical luminosities are both greater than 10^{45} ergs s^{-1}. Radio measurements indicate a variable, compact source with a power-law energy index (1.4 to 4.9 GHz) of $\alpha = 0.04$. Broad-band spectral indices from radio to UV, and UV to X-ray are consistent with other X-ray selected blazars, both being flatter than for radio-selected objects. We have difficulty connecting the optical, UV, and X-ray flux densities with a single power law, but this assessment is hampered by uncertainties due to source variability and the precise correction for interstellar absorption and reddening. The optical-infrared polarization of H1722+119 reaches a maximum of 17%, which is much higher than other X-ray–selected BL Lac objects. The degree of polarization is found to be wavelength-dependent, decreasing in a smooth and monotonic way toward the infrared. We find no significant variation in position angle with wavelength.

Subject headings: BL Lacertae objects — galaxies: individual (H1722+119) — polarization — X-rays: sources — radio sources: galaxies

I. INTRODUCTION

BL Lacertae objects are a class of active galactic nuclei (AGN) well known for their X-ray emission (Schwartz *et al.* 1979; Schwartz and Ku 1983). They are classified by their featureless optical spectra, strong linear optical and radio polarization, compact radio emission, and variability at all wavelengths (Angel and Stockman 1980; Urry, Mushotzky, and Holt 1986). The spectrum of BL Lac objects is generally smooth and continuous from radio to X-ray frequencies. The synchrotron mechanism has been used extensively to account for both the power-law spectral shape (over limited frequency ranges) and the polarization of the radiation. The two-component X-ray spectra seen in a few BL Lac objects (steep at low energy and flat at high energy) have been explained with the synchrotron self-Compton (SSC) model (Urry, Mushotzky, and Holt 1986), whereas Madejski (1985; also Madejski and Schwartz 1988) interpret *Einstein* IPC spectra (0.5 to 4.5 keV) as an extension of the optical synchrotron emission for many objects. Relativistic beaming and synchrotron emission have been used to account for the short time-scale variations seen in some BL Lac objects (most dramatically a 30 second variation in H0323+022; Doxsey *et al.* 1983; Feigelson *et al.* 1986) as well as the high degree and variability of polarization (Moore and Stockman 1981, 1984; Blandford and Rees 1974). Wavelength dependence of polarization has been observed in some cases, with polarization in general decreasing toward the infrared (Bailey, Hough, and Axon 1983; Sitko, Stein, and Schmidt 1985; Brindle *et al.* 1986). However, wavelength dependence of position angle is much rarer.

Surprisingly few BL Lac objects have been discovered through X-ray surveys, the majority being radio-selected (Maccacaro *et al.* 1984; Stocke *et al.* 1985; Giommi, Tagliaterri, and Angenlini 1988). The properties of X-ray–selected BL Lac objects (XSBL) have been shown to differ from those blazars (BL Lac objects, highly polarized quasars [HPQ] and optically violently variable [OVV] quasars) selected in other ways. Studies of the known XSBL suggest that they are less polarized, exhibit less violent optical variability, and have a well-defined, distinct range of broad-band spectral indices compared to radio-selected BL Lac objects (RSBL) (Stocke *et al.* 1985; Ledden and O'Dell 1985). Also, the comparison of X-ray, optical, and radio luminosity distributions (Maraschi *et al.* 1986) shows that XSBL and RSBL have the same X-ray luminosities but that XRSB have lower optical and radio luminosities, leading to the conclusion that XSBL are radio weak rather than X-ray strong. Maraschi *et al.* also suggest that since there is no *a priori* reason why strong radio emitters should not have been selected through their X-ray emission, and all XSBL have weak radio emission, they must dominate the blazar population in space density. In this picture the X-ray emission is isotropic, and RSBL are then only those BL Lac objects whose beamed radio emission is aligned with our direction. They are then detected preferentially because the radio emission is enhanced by relativistic beaming.

In this paper we report the seventh X-ray discovered BL Lac object detected in the all-sky survey by the experiments of the first *High Energy Astronomy Observatory* (*HEAO 1*) (Mushotzky *et al.* 1978; Schwartz *et al.* 1979; Ulmer *et al.* 1983; Feigelson *et al.* 1986; Remillard *et al.* 1989). The object was identified during a program to locate optical counterparts

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of X-ray sources detected by the *HEAO 1* modulation collimator (MC) experiment (Gursky *et al.* 1978; Remillard *et al.* 1986).

II. X-RAY OBSERVATIONS AND IDENTIFICATION

The X-ray source was detected in both the *Uhuru* survey (Forman *et al.* 1978) and *HEAO 1* Large Area Sky Survey (LASS; Wood *et al.* 1984). 4U 1722+11 was listed with a flux (2–10 keV) of 4×10^{-11} ergs cm^{-2}, averaging all scans across the source position. The flux of 1H1720+117, using the LASS counting rate and the conversion for BL Lac spectra given by Remillard *et al.* (1989), is 1.7×10^{-11} ergs cm^{-2} s^{-1} in the same band. An investigation of archival data from the *Einstein Observatory* revealed a 2500 s pointing by the high resolution imager (HRI) at the center of the *Uhuru* error box during 1979 February 23. A strong, unresolved X-ray source was detected with a position accurate to approximately 5 arcsec. Subsequent optical and radio observations led to the discovery of a BL Lac object at the HRI position as will be shown in §§ III and IV. A previous, independent search of the HRI position led R. Griffiths and collaborators to the identification of the same object, leading to its inclusion in studies such as the near-infrared measurements of BL Lac objects by Allen, Ward, and Hyland (1982) and the *IUE* observations discussed in § IV*c*.

To further demonstrate that the source observed with the HRI (0.3–3.5 keV sensitivity) is the correct identification of the LASS detection (1–20 keV sensitivity), we show that the HRI position is also consistent with one of the error "diamonds" produced by the *HEAO 1* MC experiment. All of the scanning observations by the MC within ±3.0 degrees of the HRI position were superposed and fit for an unresolved X-ray source. There were three scanning sequences, and each occurred during an interval of 8 days (1977 September 8–16, 1978 March 6–14, and 1978 September 8–16). The sum of all the MC observations produced the most significant detection, indicating persistent X-ray emission. With the 30 arcsec collimator, MC 1, the X-ray source has a statistical significance of 4.8 σ (units of standard deviations in the X-ray background) in the energy range of 1–13 keV. In the 2 arcmin collimator, MC 2, the detection is 2.4 σ, and the energy range is confined to the lowest PHA channel, corresponding to a range of 1–3 keV. The intersection of the positional bands derived from the MC 1 and MC 2 detections produces the set of error diamonds shown in Figure 1. The BL Lac object lies at the edge of one of these allowed positions, and it is within the *Uhuru* error box and very near to the LASS error box.

The MC detection is suggestive of a "soft" X-ray source, but a far better representation of the X-ray spectrum can be gained by combining the HRI detection with the simultaneous observation by the nonimaging *Einstein* monitor proportional counter (MPC), which also detected a strong X-ray source within its 1° × 1° field of view and 2–10 keV range of sensitivity. The *Einstein* HRI corrected counting rate is 0.251 ± 0.012 s^{-1}, while the MPC rate is 1.22 ± 0.15 s^{-1}. A spectral fit with the MPC alone gives a power-law energy index, α, ($F_\nu \propto \nu^{-\alpha}$) of 1.7 ± 0.7 with insignificant absorption column density (i.e., $N_\mathrm{H} < 10^{22}$ cm^{-2}). The 21 cm radio measurements of neutral gas in the Galaxy in the direction of the X-ray source implies $N_\mathrm{H} = 8.56 \times 10^{20}$ cm^{-2} (Stark *et al.* 1989). If we fix the column density to that value, the HRI count rate then determines $\alpha = 1.3$. Thus, the simplest model (viz, a single power-law X-ray spectrum modified by galactic absorption) results in a steep X-ray spectrum that is typical of BL Lac objects. The integrated flux is extrapolated to be 1.6×10^{-11} ergs cm^{-2} s^{-1} in the 2–10 keV band. All of the X-ray flux measurements are compiled in Table 1, together with other basic information, including the optical celestial position, radio position, radio flux, and various broad-band spectral indices. Table 2 contains the optical polarimetry and photometry.

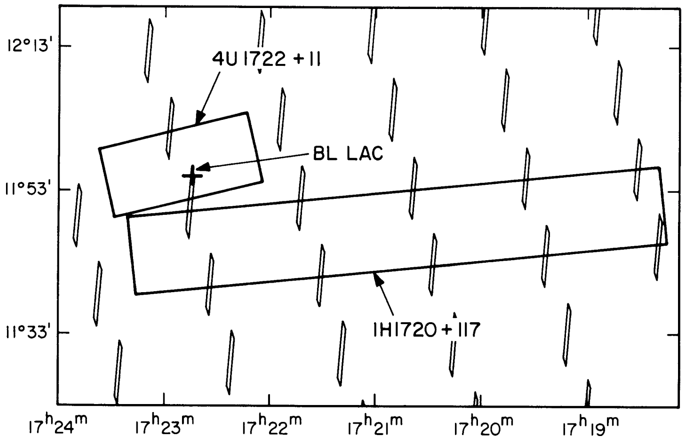

FIG. 1.—X-ray detections of H1722+119 showing the multiple positions ("diamonds") of the *HEAO* A3 experiment and the error boxes of *HEAO* A1 ("1H") and *Uhuru* ("4U"). The position of the BL Lac object is marked by a cross and is coincident, at this scale, with the point source detected by the HRI instrument of the *Einstein Observatory*.

III. OPTICAL SPECTRUM AND POLARIMETRY

a) Spectral Observations

The optical counterpart was selected on the basis of its UV excess and its position with respect to the HRI error circle and the X-ray survey error boxes. The UV discrimination was gained from a double-exposed photographic plate made with *U* and *B* filters, using the Burrell Schmidt telescope at Kitt Peak National Observatory (Remillard *et al.* 1986). There are no other UV objects or bright stars that are viable candidates for the optical identification of this LASS X-ray source. A 1500 s optical spectrum (4000–7500 Å) was taken with the 1.3 m McGraw-Hill telescope using the Mark II Reticon Scanner on 1986 June 1. The featureless and "flat" appearance of the spectrum prompted further observations leading to the classification as a BL Lac type object. In the catalog of identified, hard X-ray sources detected with *HEAO 1*, this object will be designated H1722+119. A finding chart for H1722+119 is given in Figure 2 (Plate 9) and its celestial coordinates are given in Table 1.

We observed H1722+119 on 1988 February 22 with the 3.9 m Anglo-Australian telescope (AAT). A wavelength coverage of 3400–10000 Å was achieved with simultaneous measurements by the Royal Greenwich Observatory image photon counting system (RGO/IPCS) spectrograph and the Faint Object Red Spectrograph (FORS) using a dichroic filter which split the beam at 5500 Å. The spectral resolution is 3 Å and 20 Å for the IPCS and FORS respectively. Several flux standards were observed during the night to allow flux calibration of the data and smooth spectrum standards were observed to remove the atmospheric absorption features. The combined IPCS/FORS spectrum is shown in Figure 3. The spectrum is smooth and shows no obvious absorption or emission features.

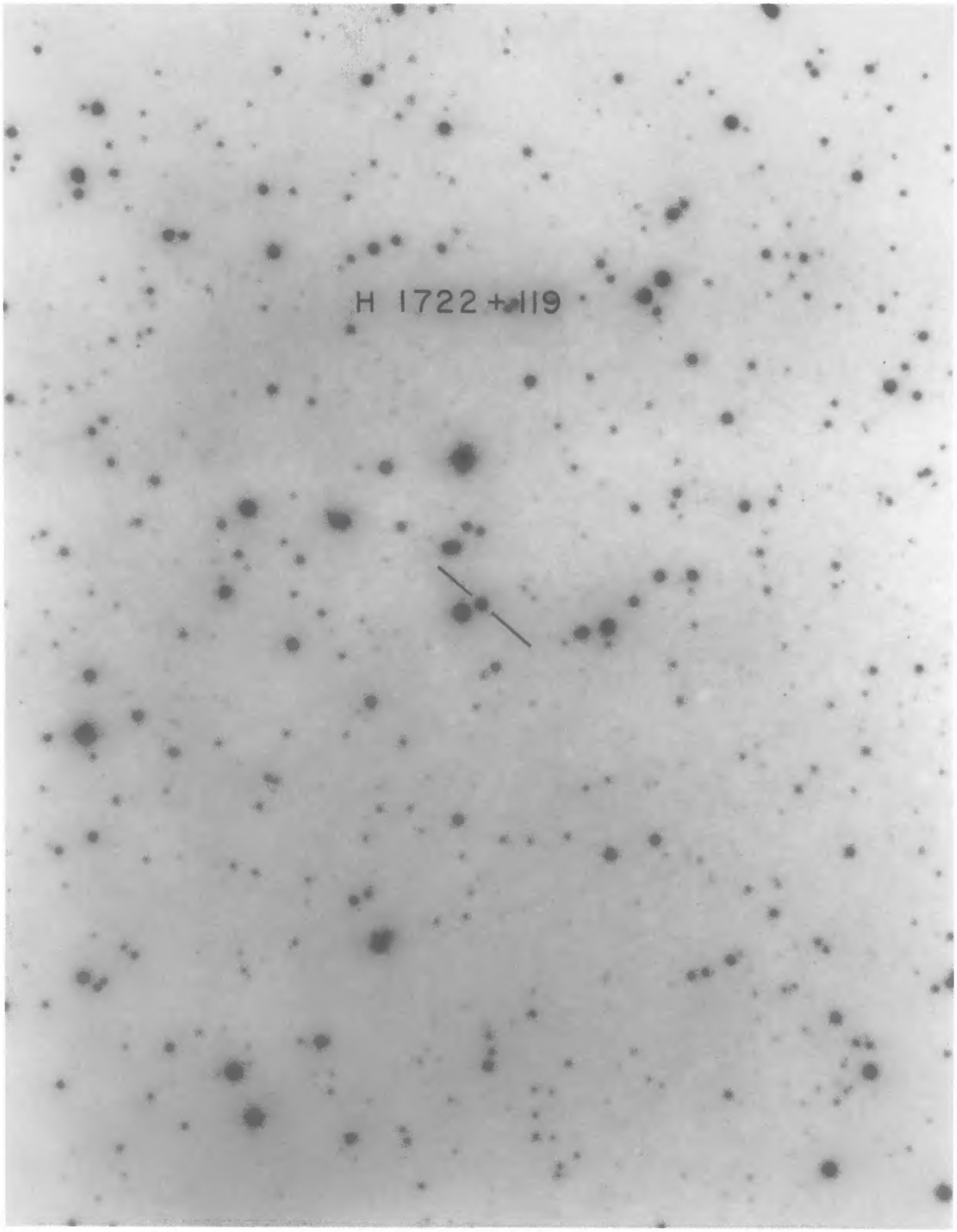

FIG. 2.—Finding chart for H1722+119 reproduced from the Palomar Observatory Sky Survey E print. The chart dimensions are approximately 15 arcmin × 15 arcmin, with north to the top and east to the left. The coordinates (1950.0) measured by the VLA are $\alpha = 17^h22^m44^s.39 \pm 0.02$, $\delta = +11°54'52'' \pm 1$.

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TABLE 1

H1722+119 PROPERTIES

Parameter	Value	
X-ray Survey Names		
Uhuru	4U 1722+11	
HEAO 1 LASS	1H 1720 + 117	
Coordinates (1950)		
Measured optical position	$\alpha = 17^{\rm h}22^{\rm m}44^{\rm s}.5 \pm 0.1$ $\delta = +11°54'52'' \pm 1$	
VLA radio position	$\alpha = 17^{\rm h}22^{\rm m}44^{\rm s}.39 \pm 0.02$ $\delta = +11°54'52'' \pm 1$	
2–10 keV X-ray Flux (ergs cm^{-2} s^{-1})		
Uhuru	4.0×10^{-11}	
HEAO 1 LASS	1.7×10^{-11}	
Einstein MPC	1.6×10^{-11}	
Radio Flux (mJy)		
1985 Sep 30 VLA 1.4 GHz	63.7 ± 1	
1987 Feb, 19 FST 1.4 GHz	78.0 ± 8	
1987 Mar 16 Parkes 8.4 GHz	108.0 ± 5	
1988 Apr 7 Parkes 8.4 GHz	143.0 ± 7	
1988 May 7 VLA 1.4 GHz	99.7 ± 0.1	
1988 May 7 VLA 4.9 GHz	94.7 ± 0.1	
Broad-Band Spectral Indices[a]	Corrected[a]	Uncorrected
Optical/X-ray index $\beta_{\rm ox}$	1.07	0.97
Extrapolated $\alpha_{\rm ox}$	1.02	0.84
Radio optical index $\beta_{\rm ro}$	0.22	0.28
Extrapolated $\alpha_{\rm ro}$	0.29	0.37

[a] The index $\beta_{\rm ox}$ connects the flux densities between 4000 Å and 2 keV, $\alpha_{\rm ox}$ connects 2500 Å and 2 keV, $\beta_{\rm ro}$ connects 20 cm and 4000 Å, and $\alpha_{\rm ro}$ connects 6 cm and 2500 Å. The first column includes a correction for optical extinction. The correction factor is 2.0 at 4000 Å and 3.0 at 2500 Å, estimated from the column density of neutral H as described in § V.

A power law ($f_\lambda \propto \lambda^{-\epsilon}$) with index $\epsilon \sim 0.1$ gives an excellent fit to the optical continuum.

b) *Polarization Measurements*

Linear polarization data were taken on 1987 February 26 with the AAT using the three-channel Hatfield Polarimeter (Bailey and Hough 1982). Measurements were taken in the *B*, *V*, *R*, *I*, *J*, and *H* bands through a 6 arcsecond aperture. The errors were derived from the statistics of many short integrations, and the calibration against both the polarization standard HD 147084 and an internal calibrator were used to fix the position angle. Polarization and position angle data are presented in Table 2.

The variation of polarization (P) and position angle (θ) with frequency is shown in Figure 4. A χ^2 test indicates that the probability that the polarization is actually constant with frequency is less than 2.5×10^{-4}. The position angle is consistent with a mean of 64.0 ± 0.8 degrees at all wavelengths. Following Brindle *et al.* (1986), we calculate a weighted least squares regression fit for both P and θ. We find $dP/d\lambda = -5.84 \pm 0.71\%$ (μm)$^{-1}$ and $d\theta/d\lambda = 3.3 \pm 2.0$ degrees (μm)$^{-1}$, indicating a clear wavelength dependence of fractional polarization and none (at the 3 σ level) for position angle. In their polarization study of blazars, Brindle *et al.* found wavelength dependence (>3 σ) in 10 out of 28 objects of which five displayed "strong" (>3.7 σ) wavelength dependence. These five were among the most luminous of the sample and had a mean $dP/d\lambda = -5.7 \pm 1.2\%$ (μm)$^{-1}$ (error is the standard deviation of the mean) which is similar to the value obtained for H1722+119.

The featureless optical spectrum, compact radio emission (see next section), and strong optical-infrared linear polarization compel the classification of H1722+119 as a BL Lac object. The association of this bright BL Lac object with the

TABLE 2

H1722+119: OPTICAL POLARIMETRY AND PHOTOMETRY

Filter	P(%) (1987 Feb 26)	θ°	Color	Magnitude (1987 May 21–25)	Magnitude (1988 Jun 1)
B	17.6 ± 1.0	64.3 ± 1.4	$U-B$	−0.50 ± 0.04	
V	17.4 ± 1.3	61.2 ± 2.1	$B-V$	0.52 ± 0.03	0.48 ± 0.04
R	15.7 ± 1.0	63.1 ± 1.7	V	15.77 ± 0.01	14.95 ± 0.02
I	14.5 ± 1.5	61.8 ± 2.7	$V-R$	0.45 ± 0.01	
J	11.9 ± 1.1	67.4 ± 2.1	$V-I$	0.97 ± 0.02	0.91 ± 0.04
H	11.7 ± 1.5	66.5 ± 2.6	J	13.76 ± 0.05	
			$J-H$	0.76 ± 0.08	
			$H-K$	0.75 ± 0.07	

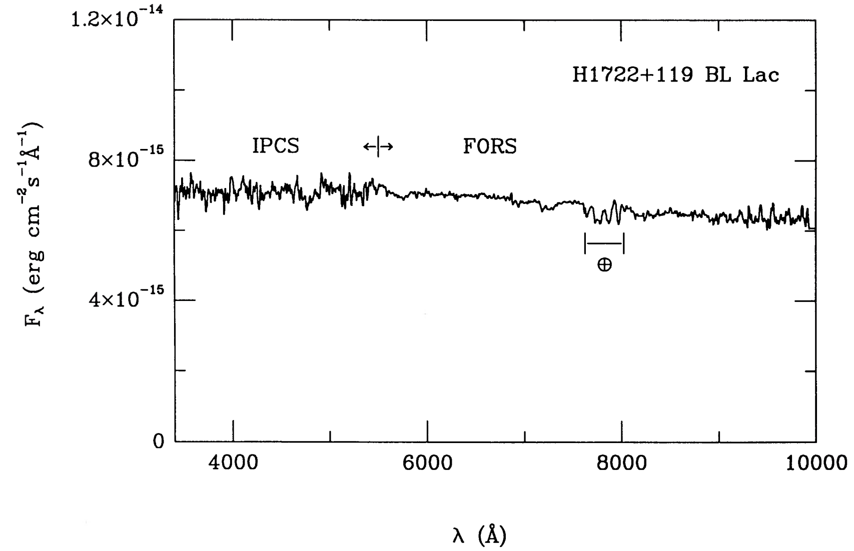

FIG. 3.—AAT spectrum of H1722+119 obtained on 1988 February 22 showing the combined RGO/IPCS (3400 Å < λ < 5500 Å) and FORS (5500 Å < λ < 10000 Å) data. Residual features resulting from sky subtraction are marked (⊕). No other obvious absorption or emission features are evident.

HRI source is unequivocal. We can also estimate the probability of accidentally identifying the BL Lac object with the particular LASS source as $<4 \times 10^{-4}$ by considering that the surface density of BL Lac objects up to 10 times weaker than H1722+119 is $<10^{-2}$ deg^{-2} (Maccacaro *et al.* 1984), and that the total area subtended by four rows of nine diamonds (cf. Fig. 1) is 150 arcmin^2.

IV. THE MULTIWAVEBAND SPECTRUM

a) *Radio Observations*

A 2 minute "snapshot" measurement at 1.4 GHz was made of H1722+119 with the VLA in the C-configuration on 1985 September 30, as part of a radio survey seeking to identify *HEAO 1* sources. The observations revealed a compact radio source with a flux of 63.7 ± 1.0 mJy at a position coincident with the optical position (i.e., within 1 arcsecond). The source was unresolved by the 12″ × 15″ synthesized beam. The flux at 8.4 GHz (3.6 cm) was measured with the Parkes 64 m telescope during 1987 March 16–17 and found to be 108 ± 5 mJy. At 8.4 GHz the half-power beam width of the telescope is 2.7 arcminutes. The flux measured during a second observation at 8.4 GHz with Parkes on 1988 April 7 was 143 ± 7 mJy. Additional VLA measurements at 1.4 GHz and 4.9 GHz were made on 1988 May 7, also with the C-array, and fluxes of 99.7 ± 0.1 mJy and 94.7 ± 0.1 mJy at 1.4 GHz and 4.9 GHz respectively were observed. A further measurement at 1.4 GHz was made with the Fleurs Synthesis Telescope (Bunton, Jones, and Brown 1985; Jones *et al.* 1984) during 1987 February 19. The source was unresolved by the 20″ × 30″ synthesized beam with a flux of 78 ± 8 mJy. The radio data are included in Table 1 and indicate a steady increase in radio flux between 1985 and 1988.

The only radio observations having different frequencies that were measured simultaneously (1.4 and 4.9 GHz) are the VLA data of 1988 May 7. However, each Parkes measurement

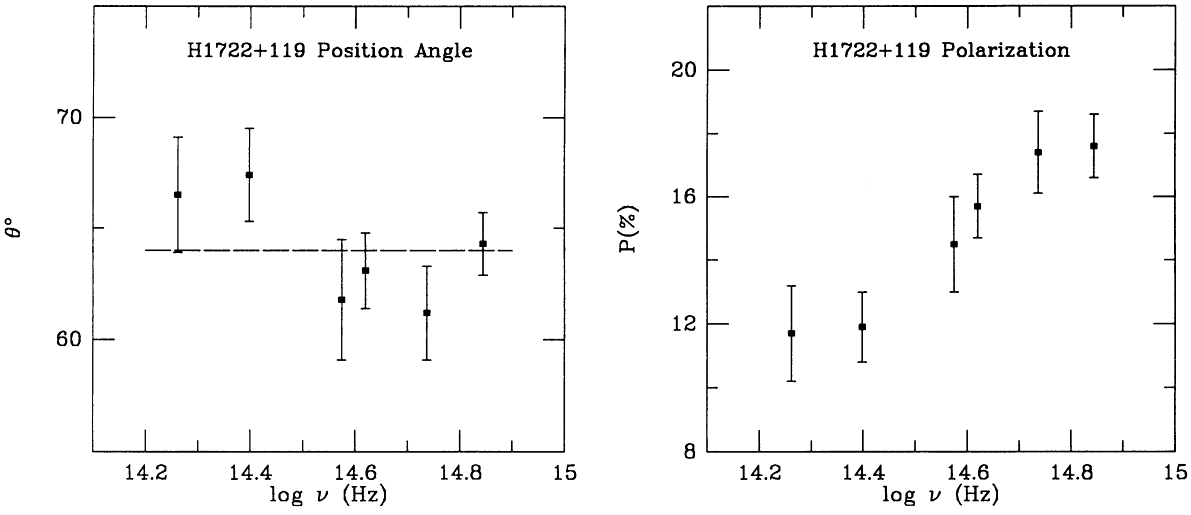

FIG. 4.—The polarization level (P) and position angle (θ) variation with frequency for H1722+119 in the bands B, V, R, I, J, and H. A clear wavelength dependence of P, but not θ, is evident.

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at 8.4 GHz was taken within one month of measurements at other frequencies. If we combine the radio measurements obtained within any one month period, we find that the spectral index remains constant while the radio continuum brightens. The spectral index α_r (defined in § II) between 1.4 GHz and 8.4 GHz measured in 1987 is $\alpha_r = -0.18 \pm 0.11$ and in 1988 is $\alpha_r = -0.20 \pm 0.05$. The 8.4 GHz flux increased by a factor of 1.8 during that period. We note however, that the April 1988 measurement at 8.4 GHz does not lie on a smooth power-law extrapolation of the simultaneous 1.4 GHz–4.9 GHz VLA data from 1988 May 7, ($\alpha_r = 0.04 \pm 0.01$), which suggests that the radio spectrum may be more complex than a single power-law component.

b) *Photometry*

Near simultaneous optical (*UBVRI*) and infrared (*JHK*) photometry of H1722+119 was obtained using the ANU 2.3 m telescope during 1987 May 21–25. All observations were made through a 10 arcsecond circular aperture in clear moonless conditions with seeing less than 3 arcseconds.

JHK measurements were made on four nights (1987 May 21–24) using the infrared photometer system (IRPS) with a chopping secondary. Standard stars were observed (McGregor 1987) and a standard reduction technique used to obtain colors on the MSO system (Jones and Hyland 1982; Elias *et al.* 1983). The four independent sets of photometry agreed to within 1 σ error limits from night to night, and we conclude that no significant variation occurred in these bands during the four days. We may then combine the observations to form mean colors using a weighted average. Errors are determined from the weighted standard deviation of the means. The infrared data are presented in Table 2.

UBVRI measurements were taken on 1987 May 25 using the two-channel chopper photometer with a 10 arcsec aperture. Photometric standards of Graham (1982) and Landolt (1983) were observed, and a standard reduction technique was used. The optical photometry is included in Table 2.

Additional imaging photometric observations were obtained with the MASCOT CCD instrument (Ricker *et al.* 1981). The images in the *V*, *R*, and *I* bands show no indication of the host galaxy, with an estimated limit $V > 18.5$ for a typical galaxy having a late-type stellar spectrum and a spatial extent > 4 arcsec. Since virtually all of the AGN with known redshifts < 0.08 show clear evidence of their host galaxies in high-resolution images, the lack of extended emission in the optical image of H1722+119 implies a distance of $z > 0.1$, with optical and X-ray luminosities each $\geq 10^{45}$ ergs s^{-1}. Furthermore, if the host galaxy of H1722+119 is similar to the giant ellipticals ($M_v < -21.5$) associated with several other X-ray-bright BL Lac objects (e.g., Weistrop *et al.* 1981; Ulrich 1988; Remillard *et al.* 1989), the redshift of H1722+119 would be >0.5, and the luminosity would exceed 10^{46} ergs s^{-1}.

c) *UV Spectrum*

To complement the multifrequency observations of H1722+119 given above, we investigated the archival spectra of H1722+119 in the data bank of the *International Ultraviolet Explorer* (*IUE*). The observations were made on 1986 September 25 (long wavelength prime camera; LWP), 1986 September 27 (short wavelength prime camera; SWP), 1987 May 7 (LWP) and 1987 May 8 (SWP). The integration times for the four spectra were 170, 300, 250, and 405 minutes respectively. The data were retrieved at the *IUE* guest observer facility at Goddard Space Flight Center, and the data reduction was accomplished using the Gaussian extraction routine ("bgex"; Urry and Reichart 1988). All the spectra are flat in the f_λ–λ plane and exhibit no obvious emission or absorption features over the combined SWP–LWP wavelength range (1230–3250 Å). Taking the 1986 September 25, 27 and 1987 May 7, 8 observations as two quasi-simultaneous spectra, the data were binned into 50 Å bins and the power-law (α_{uv}) slope was determined. For the 1986 September data we find $\alpha_{uv} = 2.35 \pm 0.11$ with a normalization of 0.46 ± 0.15 mJy at 2000 Å while the May 1987 spectrum is flatter, with $\alpha_{uv} = 1.69 \pm 0.12$ and a normalization of 0.31 ± 0.19 mJy at 2000 Å. The spectral indices corrected for reddening are $\alpha_{uv} = 1.80 \pm 0.11$ and 1.13 ± 0.12 respectively assuming a gas-to-dust ratio of 5.2×10^{21} cm^{-2} mag^{-1} (see § V).

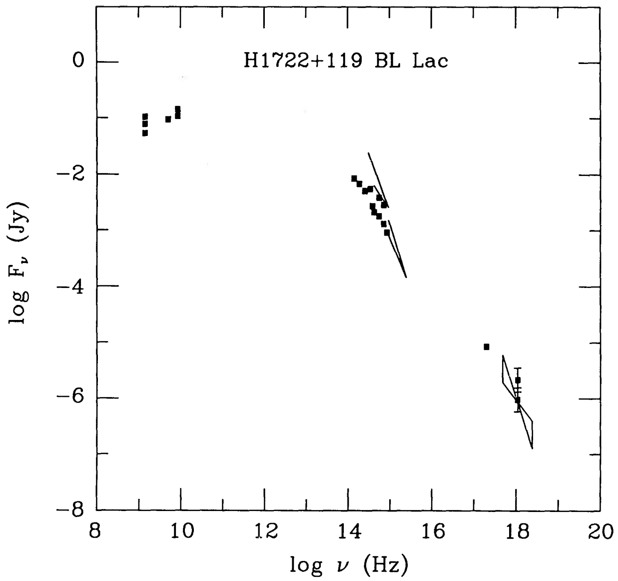

FIG. 5.—The broad-band spectrum of H1722+119 from radio to X-ray wavelengths. The data were not taken simultaneously, but all of the results have been plotted to illustrate the combined measurements and to indicate the evidence of variability. The monochromatic flux for both *HEAO 1* and *Uhuru* is shown at 4.5 keV, the logarithmic center of the 2–10 keV energy band. The MPC spectrum is indicated by the "bowtie" error box between 2 and 10 keV and shows 95% confidence limits for the power-law slope. The *IUE* and optical spectra are indicated by solid lines, while the photometric results are shown as filled squares. With the exception of the spectra, all error bars (1 σ) are smaller than the plotted symbols unless indicated otherwise.

The combined X-ray, UV, optical, IR, and radio spectral distribution is shown in Figure 5. Fluxes were calculated from the optical and infrared photometry using the zero magnitude calibration of Allen (1973) and Campins, Rieke, and Lebofsky (1985) respectively. All the available radio data have also been plotted. No corrections for galactic absorption or reddening have been made at any frequency. The average 2–10 keV X-ray flux and 3000–7000 Å optical flux of H1722+119 determine a ratio, $f_x/f_{\rm opt} = 1.2$ (given in the observers rest frame, since z is unknown). This value is typical of other BL Lac objects.

V. DISCUSSION

The three 2–10 keV observations of H1722+119 suggest that the X-ray source is persistent, with an average flux of

2.5×10^{-11} ergs cm^{-2} s^{-1} and variability less than a factor of 2. Optical observations show definite variability in both continuum level and shape, with a range of 14.9–15.8 in V mag. The optical spectrum taken in 1985 June and the 1987 photometric results both describe an optical power-law index of 1.2, while the 1988 February spectrum is both brighter and shows a steeper index of 2.0. We have observed a continuous rise in radio flux during the time we have monitored the BL Lac object, from 63.7 ± 1.0 mJy in 1985 September to 99.7 ± 0.1 mJy in 1988 May, each at 1.4 GHz. The radio spectral index between 1.4 GHz and 8.4 GHz seems to have remained constant at $\alpha_r = -0.2$ during this time; however the VLA 4.9 GHz–1.4 GHz spectral index is $\alpha_r = 0.04$, which indicates either a substantial change in radio flux between 1988 April and May, or a greater complexity in the radio spectrum than we have assumed here. All of these observations from X-ray to radio frequencies suggest frequent variability, but the amplitude is within a factor of 2 of the mean values, and the changes in spectral shape have been relatively minor.

Since both UV and X-ray spectral data are available for H1722+119, we investigate the extrapolation of the UV continuum to X-ray energies. The mean flux density at 2 keV, assuming an energy index of 1.3, is 4.0 μJy. The mean, corrected flux density of 1.68 mJy at 2500 Å is obtained by averaging the *IUE* spectra and correcting for galactic absorption by assuming (1) a neutral gas column density of 8.56×10^{20} cm^{-2} (see § II), (2) a gas-to-dust ratio, $N_H/E(B-V) = 5.2 \times 10^{21}$ cm^{-2} mag^{-1} (Van Steenberg and Shull 1988), and (3) the reddening curve of Seaton (1979). Taking the most conservative case, we compare the lowest 2 keV flux (MPC) with the extrapolation of the flattest UV spectrum (1987 May), and we find that thc extrapolated, corrected UV spectrum underestimates the X-ray flux density by a factor of 2. If a gas-to-dust ratio of 5.8×10^{21} cm^{-2} mag^{-1} is used (Savage and Mathis 1979), the X-ray flux is underestimated by a factor of 3. The lack of simultaneous observations precludes any direct conclusions whether there is a single power-law component at UV/X-ray frequencies. However, the signs of a UV deficiency warrant further investigation.

A commonly employed method for comparing emission at X-ray, optical-UV, and radio frequencies is to compute the broad-band spectral indices between continuum points in these three regions. Stocke *et al.* (1985) used the flux at 2 keV, 2500 Å, and 5 GHz to form an X-ray to optical index, α_{ox} and an optical to radio index, α_{ro} (α defined as above), to compare the properties of a sample of blazars. They found that the X-ray–selected BL Lac objects lie in a well-defined region of the α_{ox}–α_{ro} plane with $\alpha_{ox} < 1.0$ and $\alpha_{ro} \approx 0.4$ and distinct from the radio-selected objects which have steeper indices. Since simultaneous observations at all of these frequencies are not available, we estimate the spectral indices for H1722+119 using the average measurements. The radio flux density at 5 GHz is the single (VLA) measurement (94.7 mJy) available at that frequency. Similarly, we calculate the broad-band indices between 2 keV, 4000 Å, and 1.4 GHz, denoted in the literature as β_{ox} and β_{ro}, and we use the average radio flux density at 1.4 GHz from Table 1. The values of all of these broad-band indices are included in Table 1, and we report both the uncorrected values and those corrected for extinction and absorption, as outlined in the preceding paragraph.

In order to minimize the effects of variability, the indices given in Table 1 were calculated from average flux values at the various continuum points rather than specific values. Spectral indices may also be determined for the extreme values of the flux to describe an observational envelope for the spectral indices. We find that $0.21 \leq \beta_{ro} \leq 0.33$; $0.82 \leq \beta_{ox} \leq 1.13$ for uncorrected and $0.15 \leq \beta_{ro} \leq 0.27$; $0.92 \leq \beta_{ox} \leq 1.24$ for corrected data.

We may also compare the near-infrared properties of H1722+119 with other BL Lac objects. The IR colors (Table 2) allow comparison with the work of Allen, Ward, and Hyland (1982) and placement on the $J-H$, $H-K$ plane. We transform our colors from the MSO to the AAO color system (Elias *et al.* 1983) and find that the position of H1722+119 is consistent with their radio-selected sample, lying in the power-law locus with $\alpha = 0.77$. The radio spectral index $\alpha_r = 0.04$ (1.4 to 4.9 GHz) is also similar to the mean value of the sample of Allen, Ward, and Hyland (1982), $\alpha_r = -0.01$ (2.7 to 4.9 GHz), suggesting that H1722+119 has both IR and IR-radio properties similar to radio-selected BL Lac objects.

H1722+119 is the first example of a highly polarized, X-ray–selected BL Lac object. While its optical polarization is at a level much more typical of radio-selected objects, the X-ray to optical luminosity ratio (~ 1.2) is comparatively much higher and is similar to the values among the X-ray–selected group. The mean level of optical polarization of all the X-ray–selected objects with published polarimetry is $<5\%$ and none have measured wavelength dependence of polarization. The polarization of H1722+119 is highly wavelength-dependent (Fig. 4), decreasing into the infrared. The combination of broad-band spectral indices typical of XSBL and polarization more characteristic of RSBL suggests that H1722+117 may be the first example of a transitional case. Other transitional objects may possess broad-band spectral indices that place them in the unpopulated region of the α_{ox}–α_{ro} plane, where BL Lac objects may be continuously distributed. The present bimodality in the plane may then be explained by survey selection effects, with X-ray and radio surveys sampling the extremes of the continuous distribution.

The polarization properties of H1722+119 are consistent with previous statistical studies of blazars which found that for those objects displaying significant wavelength dependence of polarization, the fractional polarization generally decreased with increasing wavelength, and that wavelength dependence of position angle was rare (Sitko, Stein, and Schmidt 1985; Brindle *et al.* 1986). Explanations for wavelength-dependent polarization have focused on either multiple or single component synchrotron source models. In the former case, independent emission regions possessing different polarization properties vary in both flux and polarization and sum to produce the observed wavelength-dependence (e.g., Puschell *et al.* 1983; Brindle *et al.* 1986). The latter model is similar but relies on varying field and particle parameters within a single plasma of relativistic electrons to produce regions of differing polarization properties (Nordsieck 1976; Björnsson 1985). The dilution of the polarized synchrotron component by a host galaxy may also produce wavelength-dependent polarization; however lack of a host galaxy detection in the CCD image and an implied redshift $z > 0.1$ (§ IV*b*) suggests this is not the origin of the dependence for H1722+119.

In the case of H1722+119 the lack of position angle dependence on wavelength suggests that the different regions of a multiple component model must possess similarly aligned magnetic fields but varying polarization fractions. Brindle *et al.* (1986) have considered a two-component model in the context of the aligned jet interpretation of BL Lac objects (see also

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Holmes *et al.* 1984). In this model, the two components are associated with the inner region of the jet, one with the steady part of the jet and the other with the variable instabilities of the jet flow. The applicability of this model could be strengthened if spectral breaks or significant curvature were observed in the IR–UV spectrum of H1722+119. However, the investigation of multiple emission components requires contemporaneous, multifrequency observations, which are unavailable at present.

In summary, the BL Lac object H1722+119 is the optical identification for the *HEAO 1* X-ray source 1H1720+117 (=4U 1722+11). The object possesses all the properties of the BL Lac class, including a smooth and featureless optical spectrum, strong optical-infrared polarization, and variable optical and radio emission. H1722+119 differs from other X-ray–selected BL Lac objects in its high optical-infrared polarization and strong wavelength dependence of polarization, but is similar in other properties. The object may be an example of a transitional case between X-ray and radio-selected BL Lac objects.

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