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PG 1411+442: THE NEAREST BROAD ABSORPTION LINE QUASAR

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ABSTRACT

IUE observations reveal strong, moderately broad absorption troughs in the blue wings of the C IV and N V emission lines of the quasar PG 1411+442. No absorption from weakly ionized gas is detected. The emission-line strengths and overall shape of the ultraviolet/optical/near-infrared/far-infrared continuum of the new broad absorption line quasar are within the range normally measured in quasars. Its redshift is low enough ($Z_{em} = 0.089$) to allow us to study the morphology of the host galaxy in deep broad-band and intermediate-band CCD images. The galaxy appears to be a large spiral with a very long arm or tail. The inclination angle is 57°, which rules out the possibility that our line of sight to the nucleus intersects a large path length in a galactic disk.

Subject headings: galaxies: structure — quasars — ultraviolet: spectra

I. INTRODUCTION

A small subset of quasars is known to have broad absorption line troughs in their spectra (hereafter referred to as BALQSOs). The blueshifts of this absorption indicate that gas is flowing outward from the nucleus at velocities which can exceed one-tenth the speed of light. The absorbing gas clouds are highly ionized and produce detectable absorptions only in resonance lines with rest wavelengths in the ultraviolet (but see Hazard *et al.* 1984 for a possible exception). Thus, optical studies can discover BALQSOs only at high redshifts. Nearly all the approximately four dozen published BALQSO's have Z_{em} of 2–3. Most quasar surveys, especially at $Z_{em} < 2$, are extremely deficient in BALQSO's. Before the start of the current work, the only BALQSO known with an emission redshift less than 1.0 was PG 1700+518 ($z = 0.29$), which was discovered optically by its Mg II absorption trough, an unusual feature for BALQSOs. In the course of this work, a survey by Turnshek and Grillmair (1986) discovered new BALQSOs, but only one has a redshift of less than 1.0.

A few Seyfert 1 galaxies are also known to have blueshifted absorption lines in their nuclear spectra. However, they are either narrow (less than 1000 km s^{-1} wide, as in NGC 3516 and NGC 4151), or not highly ionized (as in Markarian 231), and some do not arise from the ground state. The maximum outflow velocities are no more than a few thousand km s^{-1}.

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II. OBSERVATIONS

a) Ultraviolet

The quasar 1411+442, discovered in the Palomar Green Bright Quasar Survey, was observed with the *International Ultraviolet Explorer (IUE)* as a backup target during high background radiation US 2 shifts. The 88 minute exposure covering the 1200–2000 Å portion of the spectrum, SWP 19314, shows strong absorption in the blue wings of the C IV λ1550 and N V λ1240 emission lines. They are unquestionably real, and they are clearly visible in the raw photowrites of the two-dimensional spectrum, which is quite free of cosmic-ray hits or other nonstatistical noise. A more recent 170 minute exposure of 1411+442, SWP 26588, was obtained by C. Wu for a separate investigation.

At the Goddard Regional Data Analysis Facility, we merged the two SWP spectra. The result is shown in Figure 1, where the strong absorption troughs can be seen easily. The quasar appears to have been well centered in the aperture, in the spatial and wavelength directions. Thus, the peaks of Lyα emission (1325 Å) and the He II emission (1785 Å) are within 1 Å of the wavelengths at which they would be expected, based on the optical redshift of 0.0895 ± 0.0001. The peaks of C IV and N V emission appear shifted, to redshifts of 0.0902 and 0.0915, respectively. Since the blue sides of these lines are noticeably steeper than the red sides, we are confident that the velocity shifts are due to absorption of the blue emission wings. Evidently, the absorbing gas clouds have velocities extending down to essentially zero in the quasar rest frame. (Wavelength uncertainties make this estimate of the lowest absorption velocity uncertain by 200–300 km s^{-1}.)

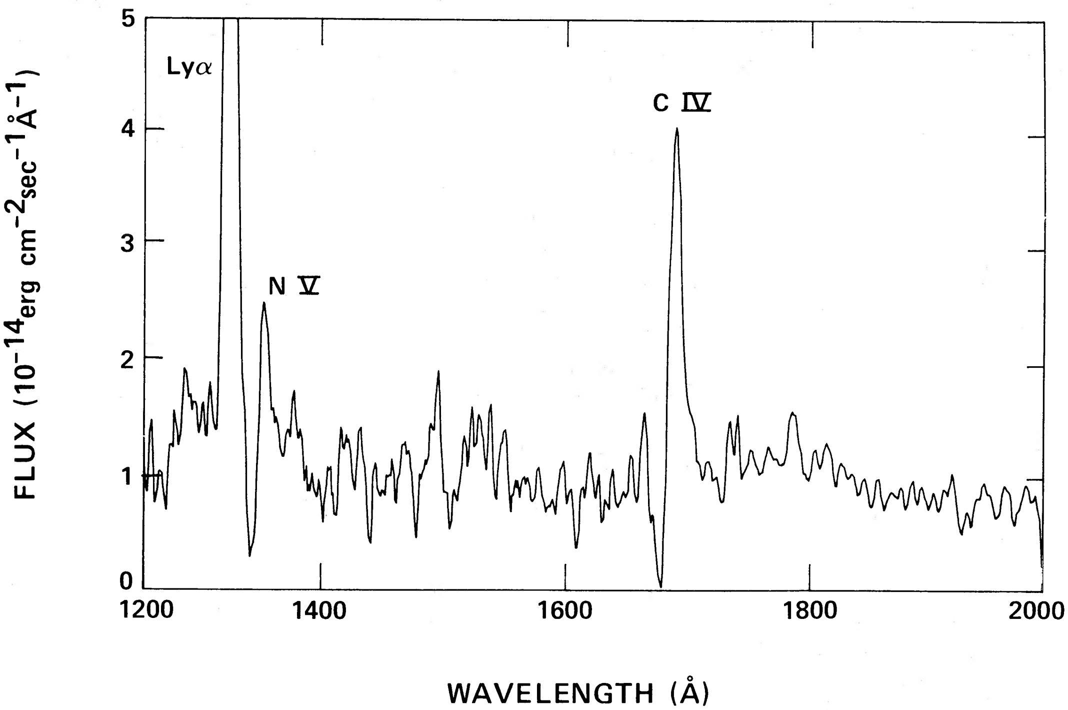

FIG. 1.—The merged *IUE* spectra SWP 19314 and 26558. The flux per unit wavelength is plotted vs. wavelength in angstroms, both on linear scales. Strong emission lines are identified.

The absorption troughs are moderately resolved and do not extend blueward of -4000 km s^{-1} in the quasar's rest frame. The C IV and N V absorptions are very dark at the line centers, with no more residual flux than 15% of the total continuum plus emission-line level. This requires that the absorbing clouds cover most of the continuum and possibly part of the broad-line region as well. The absorption equivalent widths for N V and C IV are at least 7 and 8 Å, respectively, considerably larger than those ever seen in Seyfert 1 galaxies such as NGC 3516 or NGC 4151. Yet these absorbers probably have a low area covering factor (as argued, for example, by Turnshek *et al.* 1987). Si IV appears present with a P Cygni emission profile, but the spectra are too noisy to measure it. There is no detectable absorption in the Lyα or Mg II resonance lines, down to a level of 1 Å equivalent width. As in many other BALQSOs, the absorbing gas clouds are evidently too highly ionized to have significant column densities ($>10^{14}$ cm^{-2}) of neutral or singly ionized atoms.

The sharp profiles of the ultraviolet emission and absorption lines are unusual, but not unique, among BALQSOs. The sharp strong C IV emission line is reminiscent of those seen in H1413+113 and RS 23, although these quasars have broad absorption troughs which extend to much larger outflow velocities (cf. Weymann and Foltz 1983). The Lyα/N V region in 1411+442 is strikingly similar to that of the high-redshift BALQSO 0302+170 (Hazard *et al.* 1986), which also has unusually narrow and strong emission and absorption lines.

b) Optical Spectroscopy

We have supplemented the *IUE* observations, which included our 90 minute LWR 12504 exposure, and the 220 minute LWP 6638 exposure obtained by C. Wu, with further ground-based spectroscopy and direct imaging at longer wavelengths, and also obtained some continuum measurements from Neugebauer *et al.* (1987). Low-resolution spectrophotometry was obtained on 1982 February 19 and on 1983 April 8 with the SIT spectrograph on the Palomar 1.5 m telescope. With 512 wavelength pixels, the detector covered the 3500–7000 Å range at a FWHM resolution of approximately 19 Å. A wide (9″ × 20″) slit was used to ensure that absolute fluxes were measured accurately to 5% or 10%. The spectrum obtained in 1 hr of integration in 1982 is shown in Figure 2.

Optical spectroscopy with high signal-to-noise ratios was obtained at higher resolution (FWHM ≈ 200 km s^{-1}) with the Cassegrain "echism" CCD spectrograph on the Lick Observatory 3 m telescope. With the large 800 × 800 pixel detector format, three orders are well measured simultaneously, providing complete spectral coverage from 5000 to 8000 Å at 3–4 Å resolution in a single exposure. The Hα and Hβ emission line profiles measured in 1 hr of integration are displayed in Figure 3. The flux scale is linear, and both profiles are plotted on a common velocity scale for comparison. The peaks of the [O III], Hβ, and Hγ lines give an emission redshift of $z = 0.0895 \pm 0.001$, in agreement with the redshift measured from C III] λ1909 and Mg II λ2800. The Balmer profiles are similar, but not identical. The Hβ line appears to have a stronger red wing, part of which could be due to contamination from Fe II λ4924. The FWHM of Hβ is about 15% larger than that of Hα, as Shuder and Osterbrock (1983) observed in several Seyfert 1 galaxies. Both profiles are smooth, with no evidence of any absorption features stronger than a few tenths of an angstrom.

Unlike NGC 4151 and Mrk 231, PG 1411+442 has no strong He I λ3889, Ca II H and K, or Na I absorption lines and not even weak (EW ≈ 0.1 Å) Balmer absorption. Their absence indicates that the absorbing clouds in 1411+442 have a higher degree of ionization or perhaps a lower density.

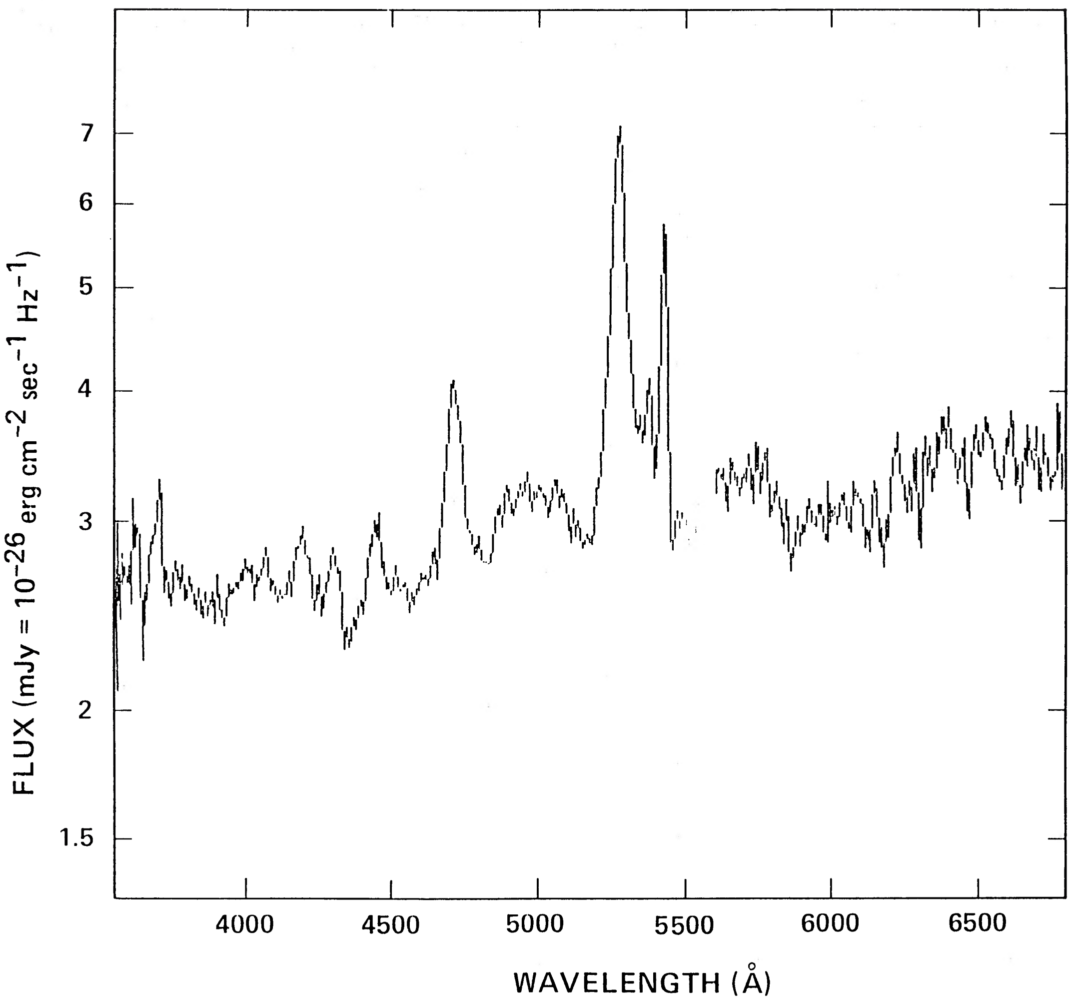

FIG. 2.—The optical spectrum obtained in an integration of 1 hr with the Palomar 1.5 m telescope and SIT spectrograph on 1982 February 19. The wavelength scale, in angstroms, is linear. The flux scale, in milliJanskys (= 10^{-26} ergs cm^{-2} s^{-1} Hz^{-1}), is logarithmic. The channels near an observed wavelength of 5577 Å were deleted due to the poor subtraction of strong [O I] night sky emission.

c) Emission Lines

We have examined several emission-line ratios (see line flux measurements in Table 1) which are relatively insensitive to reddening. They all show that the emission-line spectrum of 1411+442 does not differ significantly from the range normally observed in quasars. The optical Fe II emission blends are quite strong, but not uniquely so, with $\lambda5250/H\beta = 0.28$ and $\lambda4570/H\beta = 0.4$. Strong Fe II emission may well be a general characteristic of all BALQSOs, and possibly of any quasar which is not a strong extended radio source (cf. Hartig and Baldwin 1986; Weymann *et al.* 1987; Anderson *et al.* 1987). The line flux ratios of C III]/C IV, C IV/Lyα, and Mg II/C III], of 0.6, 0.3, and 0.5, respectively, are all within the admittedly wide ranges observed in normal quasars. The N V/Lyα and N V/C IV ratios of 0.1 and 0.35 appear to be lower than usual, but we believe that nearly one-half the total N V emission is missing due to the strong absorption trough. Thus, our result could perhaps be reconciled with Turnshek's (1984) claim that N V is relatively strong in high-Z BALQSOs.

The Lyα and C IV emission lines are remarkably centrally peaked. The FWHM of Lyα is only 2400 km s^{-1} (and this value is certainly not altered by N V absorption if the N^{+4} ions have the same velocity distribution as the C^{+3} absorbers). Since C IV $\lambda1550$ is so strongly centrally peaked, it has a peak intensity/continuum intensity ratio of 3, which is extremely large for any quasar. Most BALQSOs have ratios of less than 1. The largest systematic exception is for those BALQSOs with "P Cygni" profiles, which have C IV peak/continuum intensity

TABLE 1

EMISSION LINE FLUXES (10^{-14} ergs cm^{-2} s^{-1})

Line	Rest Wavelength (Å)	Observed Flux
Lyα	1216	150
N V	1240	17:
Si IV + O IV]	1400	14:
C IV	1550	50
He II	1640	4:
C III]	1909	30:
Mg II	2800	15
Hγ	4340	12
Fe II + He II	4570–4686	13
Hβ	4861	32
[O III]	5007	8
Fe II	5100–5400	9
He I	5876	4.5
Hα	6563	110

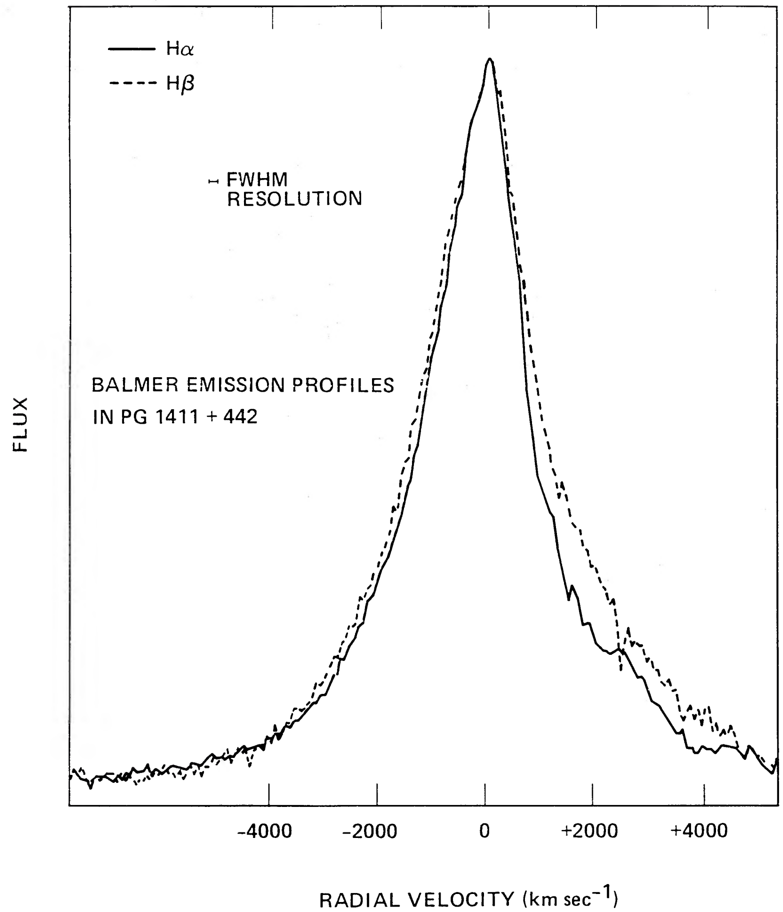

FIG. 3.—A comparison of the Hα and Hβ emission-line profiles simultaneously measured on the Lick 3.0 m telescope with the "echism" CCD spectrograph on 1985 July 10. The flux scale is arbitrary; the wavelengths have been shifted to a radial velocity scale.

ratios greater than 2 and appear to be most spectroscopically similar to 1411+442 (Turnshek 1984). Like other emission lines, C III] λ1909 is relatively narrow and shows no evidence of contamination from Al III] λ1857, in contrast to many other BALQSOs (Hartig and Baldwin 1986). The FWHM of the Balmer lines is only 3500 km s^{-1}, while their FW0I is approximately 11,000 km s^{-1}. Although the optical and ultraviolet emission line profiles are not identical, there is no evidence in our repeated observations that they are variable. Most of the ultraviolet emission-line cores must arise from a high-density region, since the forbidden lines are moderately weak, with [O III] 5007/Hβ = 0.26 ± 0.01, a typical value for radio-quiet quasars (Steiner 1981).

There is no evidence for any broad wings on the λ5007 line profile. Based on the absence of broad [O III] emission wings from the broad absorption-line region (BALR) in PG 1700+518, Turnshek *et al.* (1985) were able to set a statistical lower limit on the BALR electron density of $n_e > 10^{5.5}$ cm^{-3}. We repeated the calculation for PG 1411+442 on the assumption that the [O III] luminosity from the BALR is less than 3×10^{41} ergs s^{-1} and that the number of ionizing photons is 5×10^{54} s^{-1}. Distance-dependent calculations throughout this paper assume a Hubble constant of 100 km s^{-1} Mpc^{-1}. Then in the low-density limit, ($n_e < 10^6$ cm^{-3}), this implies an upper limit to the BALR covering factor of $q_c < 10^{16}/N_{O^{++}}$, where $N_{O^{++}}$ is the column density of O^{++} ions in the BALR clouds. Unfortunately, in 1411+442 this column density is highly uncertain and easily could be as small as a few times 10^{16} cm^{-2}. At electron densities higher than approximately 10^8 cm^{-3}, we cannot limit q_c to any value less than 1. Thus, the absence of broad [O III] emission in 1411+442 does not lead to a significant constraint on the electron density of the broad absorption-line clouds.

d) *Continuous Energy Distribution*

A complete listing of our continuum flux measurements is given in Table 2. The repeated optical spectrophotometry indicates that PG 1411+442 is weakly variable, with an amplitude of approximately 0.1–0.3 mag on time scales of 1 yr. As in other quasars, the variability is somewhat stronger at shorter wavelengths.

The energy distribution analyzed below is a composite of *IUE* observations on 1982 February 3 and 1983 February 23 and optical observations on 1982 February 19 and infrared observations from Neugebauer *et al.* (1986, 1987). No shifts were applied to the data, since they appear to match satisfactorily around 0.3, 1.0, and 12 μm. The spectrum in Figure 4 represents 1411+44 at an intermediate brightness; when it was observed optically on 1983 April 8, it was brighter, but when it was observed by *IUE* on 1985 August 11, it was fainter.

PG 1411+442 is at a high galactic latitude. The Burstein and Heiles (1982) 21 cm H I maps confirm that Galactic reddening should be negligible in that direction. The observed Balmer decrement Hα/Hβ = 3.4 and Lyα/Hα ratio of 4.7 are also suggestive of relatively little nuclear reddening (Lacy *et al.*

1982). Similarly, Malkan, Weymann, and Rieke (1987) concluded that the optical/ultraviolet colors of a dozen other BALQSOs are indistinguishable from those of normal quasars. They compared the narrow-band fluxes at three rest wavelengths, 4220, 1770, and 1460 Å, which are relatively free from contamination due to emission lines. After correction for Milky Way reddening, the optical/ultraviolet colors $f_{\nu 4220}/f_{\nu 1770}$ and $f_{\nu 4220}/f_{\nu 1460}$ are very sensitive to internal continuum reddening. The colors of luminous Seyfert 1 galaxies and quasars cluster strongly near the limiting values of $f_{\nu 4220}/f_{\nu 1770} = 1.55$ and $f_{\nu 4220}/f_{\nu 1460} = 1.8$, which Malkan (1984) identified as the average intrinsic colors of an essentially unreddened quasar continuum. In 1411+442, the low observed values of $f_{\nu 4220}/f_{\nu 1770}$ and $f_{\nu 4220}/f_{\nu 1460}$, 2.5 and 3, respectively, imply that PG 1411+442 is not reddened by more than $\sim$0.13 mag in E_{B-V}. Furthermore, 1411+442 has a relatively flat far-infrared spectrum ($\alpha = -1.1$). As discussed by Edelson and Malkan (1986, hereafter EM), this is good evidence against the presence of significant thermal infrared emission from dust grains. A moderate amount of internal reddening, corresponding to $E_{B-V} = 0.09$ mag, was applied to the fits described below to match the inflection in the spectrum around 2200 Å better. This estimate could be in error by ± 0.05 mag, but this does not lead to very large uncertainties in the parameters of the fit.

We fitted the continuous energy distribution in Figure 4 with a simple model described in EM. The fluxes of numerous blended Fe II emission lines were included in the fits. The strengths were not varied in the fitting but were fixed relative to the Hβ flux according to the "standard model" of Wills, Netzer, and Wills (1985). The strongest component is a power law with slope -1.15 ± 0.1. The measured *IRAS* fluxes (and upper limit at 100 μm) require that the power law have a sharp low-frequency turnover, interpreted by EM as synchrotron self-absorption. The frequency at which the power-law slope flattens to zero, ν_t, is $8(\pm 1) \times 10^{12}$ Hz, similar to the values seen in other quasars and bright Seyfert 1 galaxies (EM). Their discussion of the turnover, including its attribution to synchrotron self-absorption, should be equally relevant to 1411+442.

Although the power-law component dominates the spectrum at wavelengths longward of 5000 Å, there is an additional bump, or region of downward curvature, around 3–5 μm. EM

TABLE 2A

DEREDSHIFTED ULTRAVIOLET CONTINUUM FLUXES FROM *IUE*

log Rest Frequency (Hz)	First Observation Date: log f_{ν_0} (mJy)	Second Observation Date:[c] log f_{ν_0} (mJy)
15.417	−0.16[a]	−0.28
15.353	−0.09[a]	−0.22
15.312	−0.07[a]	−0.08
15.225	0.01[a]	−0.10
15.169	0.03[b]	0.04
15.142	0.08[b]	0.03
15.122	0.20[b]	0.12
15.096	0.25[b]	0.21
15.084	0.26[b]	0.23
15.058	0.26[b]	0.25
15.016	0.37[b]	0.29

[a] 1983 Feb 23.
[b] 1982 Feb 3.
[c] 1985 Aug 11.

TABLE 2B

DEREDSHIFTED OPTICAL CONTINUUM FLUXES FROM GROUND-BASED TELESCOPES

log Rest Frequency (Hz)	First Observation Date:[a] log f_{ν_0} (mJy)	Second Observation Date:[b] log f_{ν_0} (mJy)	Third Observation Date:[c] log f_{ν_0} (mJy)
14.951	0.38	...	...
14.942	0.38	...	...
14.933	0.36	...	...
14.915	0.37	...	...
14.897	0.36	...	...
14.881	0.36	0.42	...
14.873	0.35	0.42	...
14.851	0.36	0.43	...
14.829	0.40	0.45	0.33
14.803	0.41	0.45	0.32
14.772	0.42	0.45	0.32
14.742	0.43	0.49	0.36
14.735	0.44	0.50	0.33
14.728	0.45	0.50	0.35
14.723	0.46	0.51	0.35
14.716	0.48	0.51	0.36
14.690	0.50	0.59	0.39
14.680	0.52	0.60	0.38
14.645	...	...	0.50
14.627	...	...	0.50
14.617	...	...	0.46
14.606	...	...	0.48
14.596	...	...	0.48
14.585	...	...	0.52
14.574	...	...	0.48

NOTE.—A three-dot ellipsis indicates flux was not observed at that frequency.
[a] 1982 Feb 19; Palomar 1.5 m telescope.
[b] 1983 Apr 8; Palomar 1.5 m telescope.
[c] 1985 Jul 9; Lick 3.0 m telescope. This low-resolution spectrum was obtained on the night preceding the echism observation.

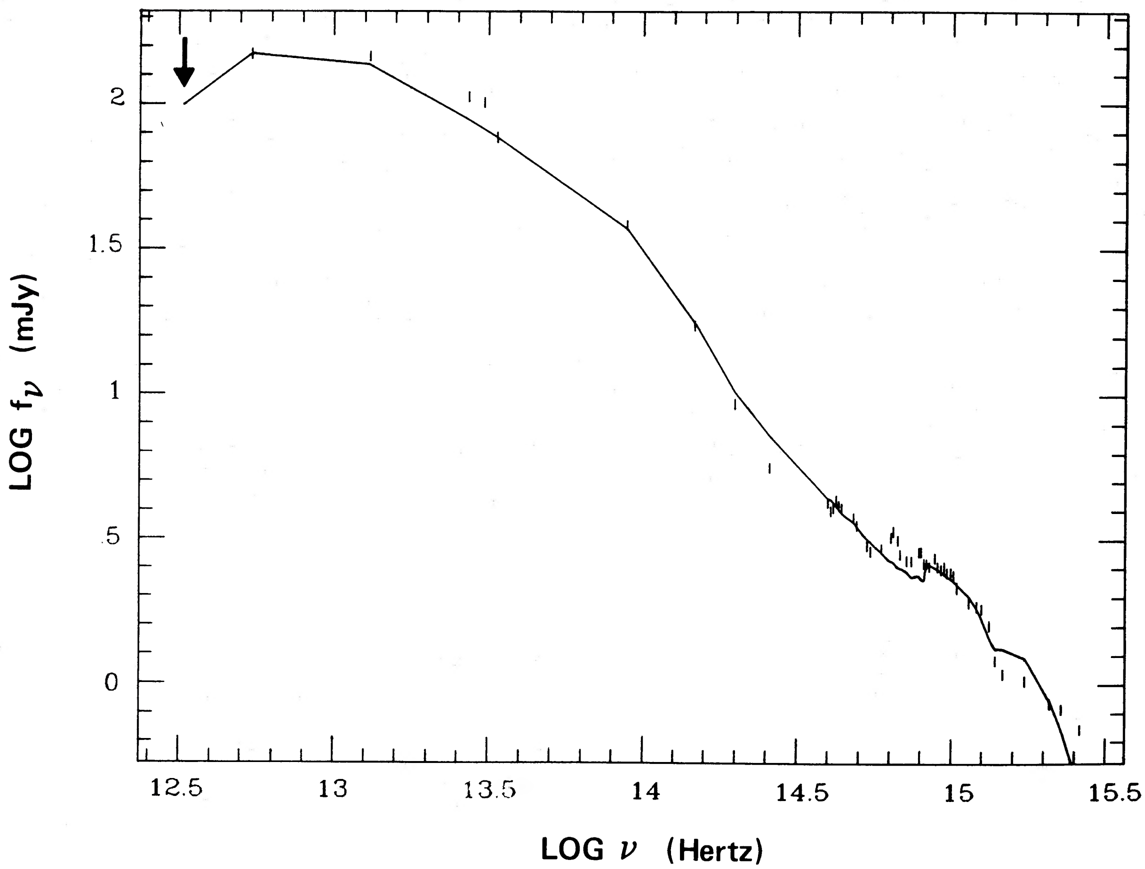

FIG. 4.—The multiwavelength continuous energy distribution from the far-infrared to the ultraviolet. Here both the vertical flux scale (in mJy) and the horizontal frequency scale (in hertz) are logarithmic. The data points, shown by vertical bars, have been fitted by the model (*solid line*) described in the text. The downward pointing arrow near the upper left corner represents the *IRAS* 3 σ upper limit on the 100 μm flux.

found the same feature in the near-infrared spectra of many quasars and bright Seyfert 1 nuclei. Fitting it as a parabola, they found it has an average frequency peak at 6×10^{13} Hz ($\lambda_{\rm max} = 5$ μm) and an average full width at half-maximum of three frequency octaves. Since there was little detectable scatter in these values, we assumed the averages would also describe the near-infrared bump seen in 1411+442. Thus, only the overall strength of the bump was varied to fit the observations; its central wavelength and shape were fixed. The fitted bump strength is moderate compared to other AGNs analyzed by EM. Yet the logarithmic excess flux at 3.5 μm which EM call ΔL is 0.12, indicating that 1411+442 has a relatively strong near-infrared bump.

As Malkan and Sargent (1982, hereafter MS) and EM found for many Seyfert 1 galaxies and quasars, we find the ultraviolet flux in 1411+442 is stronger than the fitted power law, even with the inclusion of the Balmer continuum and Fe II emission lines. Following MS, we fitted this "ultraviolet excess" as a single-temperature Planck function. Its temperature in 1411+442 is 20,000 $\pm$ 5,000 K, and it is 0.25 as strong as the power law at 5500 Å. The thermal ultraviolet component is not extremely strong, so its shape is not precisely determined. Nonetheless, it is evident that a single-temperature Planck function is an inadequate description; it fails to predict enough flux at $\lambda < 1500$ Å. This is the same situation Malkan (1983) found in high-redshift quasars.

As in MS and EM, we fitted the strength of Balmer continuum emission. The flux at the Balmer edge (at log $\nu = 14.822$) is well determined and is free from any contamination of blended Fe II emission lines. Since the shape of the Balmer continuum emission at higher frequencies is not so well determined, we assumed it is optically thin at $T_e = 13{,}000$ K, to derive an integrated flux of 1.6×10^{-12} ergs cm^{-2} s^{-1}, or 5.0 times the flux of Hβ. This value is only slightly less than the average found by EM.

Like nearly all other BALQSOs, PG 1411+442 is not a strong radio source. VLA observations by Kellerman *et al.* (1987) showed that it is only 0.5 mJy at 5 GHz, with no evidence for any resolved structure.

e) Direct Imaging

Hickson and Hutchings (1987) could barely resolve the image of the other nearby BALQSO, PG 1700+518. The low redshift of 1411+442 makes it the best BALQSO for detailed study of its host galaxy. Direct images of 1411+442 were recorded at the prime focus of the Canada-France-Hawaii Telescope, on an RCA single density CCD. Broad-band *B* and *R* filters and medium-band (700 Å) Corion filters centered at 5500 and 7000 Å were used. The latter two filters were chosen to separate line-emitting regions of [O III] and Hα by comparison with the broad-band images, which are more dominated by continuum emission. The object was observed some $3^{\rm h}$ from the meridian, on different nights for each color (because of telescope time allocation constraints); therefore, seeing was not optimum and star images in some were exposures not very circular. Nevertheless, the measured FWHM of stellar images

TABLE 3

IMAGING RESULTS

Color	Seeing (FW HM arcsec)	Depth (mag arcsec^{-2})	L_n/L_g	L_n/L_g (corr)	D25	m	$-M_n$[a]	$-M_g$[a]	b/a	Scale Length[a] (kpc)
R	1.1	25.0	4.4	2.4	24″	14.9	21.9	21.1	0.54	4.0
B	1.3	24.8	18.5	6.5	17	15.1	21.9	20.4	0.56	2.3
5500 Å	1.0	23.7	12.6	4.5	22	...	...	...	0.59	2.5
7000 Å	1.7	24.7	11.4	2.5	21	...	...	...	0.6	2.7

[a] $H_0 = 100$.

was generally close to 1″ (see Table 3). Exposure times were all close to 10 minutes, taken in two shorter exposures at R to reduce nuclear saturation effects. The pixel size is 0″.41. The B and R exposures were photometrically calibrated by frames of a standard field in the cluster NGC 2419.

Data were processed using the Preppy and Vista software packages, at CFHT and DAO, respectively, and did not involve any unusual difficulties. The figure shows some of these results. These include direct B and R images, sky-subtracted, and smoothed with a 1.3 pixel FWHM Gaussian. Figure 5 also shows differences between the 7000 Å and R band image and between the 5000 Å and B band images. We attribute the significant differences to line emission of Hα and [O III] which have different spatial distributions from the continuum radiation. Since the narrow-band images were not photometrically calibrated, and there is significant continuum radiation in them, too, no attempt is made to derive line luminosities. Nevertheless, the differences probably delineate the areas of strong line emission in the images. Figure 5 also shows a color plot giving approximate $B-R$ contours, obtained by dividing the broad-band images. These contours have decreasing significance toward the edge of the object where the signal is very weak. Finally, Figure 5 contains a sketch in which all the features are delineated and superposed.

Luminosity profiles were generated by fitting elliptical contours to the images and also by azimuthally averaging them. These profiles were analyzed similarly to the data of Hutchings, Crampton, and Campbell (1984, hereafter HCC) to derive measures of the resolved and unresolved luminosity (host galaxy and nucleus) in all colors. These were corrected for differences in seeing and image depth, and were reduced to zero redshift as in HCC. Measures of scale length of the resolved light and its axis ratio were also made.

The object is clearly extended and shows considerable structure. It is unusually elongated, but not as much as two other resolved QSOs at redshifts < 0.1: 2130+099 = II Zw 136 and 1059+730. Neither of these objects has broad absorption lines. The absolute magnitudes of the nucleus and host galaxy are given in Table 3 and are not particularly unusual for objects of this redshift (see HCC). The scale lengths are large. Figure 6 shows the comparison between properties of 1411+442 and other resolved QSOs on the redshift range 0.07–0.12 from HCC.

There are two clearly visible spiral arms emerging from the nucleus along the direction of elongation of the image, and there is the obvious outer arm to the south, with a blob near its end. In addition, there is a linear feature to the east south east, seen more clearly in B light, which emerges from the nucleus and becomes invisible as it merges with the outer arm. There is extended R light to the west, which envelopes two resolved faint objects to the northwest. The inner of these two is brighter and considerably redder. The blob of light on the end of the large arm is also red.

The linear feature is quite blue ($B-R = 0.6$ or less), and otherwise the object becomes redder with distance away from its nucleus along the long axis. The Hα emission line region is quite linear and one-sided, emerging from the nucleus in the opposite direction from the blue feature; [O III] appears to be enhanced along and behind the two inner spiral arms and near the outer arm, particularly in the outer parts of the latter. It appears to avoid both the Hα and blue feature regions.

It is quite possible that the resolved objects to the northwest are interacting objects, and that the long arm and blob are tidal results of an encounter. The linear blue feature may be a nuclear jet or just another "spiral" arm. To help assess these possibilities, we examined the galaxies in the paper of de Ruiter, Willis, and Arp (1977) for similar morphologies and found many, including M81, M101, NGC 2403, 2903, 3359, 3718, 4088, and 4258. All these galaxies have arms and/or axial ratios very similar to those of 1411+442. They have a mean color ($B-V$) of 0.66 ± 0.12 and a long diameter of 26 ± 8 kpc, to a luminosity level comparable with that in our 1411+442 data. The colors of 1411+442 are similar to these and the long diameter is approximately 26 kpc to 25 mag arcsec^{-2}. The long arm is also similar in length to those arms seen in several of these normal galaxies. The luminosity of 1411+442's galaxy is a little higher than the normal galaxies.

The host galaxy of 1411+442 is unusual but not unique in its degree of flattening, in the clarity of its spiral arms, and in its large scale length, compared with other QSO hosts. Compared with nearby non–QSO galaxies, it may be unusual in its linear blue "jet," and the blob near the end of its arm, reminiscent of tidal tails (e.g., Mrk 231; Hutchings and Neff 1987). However, the arm does seem to continue and to bend around the blob. The faint companions appear to be connected by red luminosity and may well be the interacting companion bodies. The Hα and [O III] morphology suggest complex distribution of gas and ionizing radiation, and the blue jet and Hα region both suggest association with the nucleus.

If the galaxy is a circular disk, the axial ratio indicates an inclination of approximately 57°. Therefore, our line of sight to its nucleus does not pass through a large path length of a spiral galactic disk. In this object we can rule out the suggestion of Schiano (1985) that broad absorption troughs are produced by interstellar clouds in the plane of a spiral galaxy.

The imaging and spectrophotometry both demonstrate that the nucleus of 1411+442, like those of most BALQSOs, is not heavily reddened. This is in sharp contrast to the luminous Seyfert 1 galaxy Mrk 231, which has strong blueshifted absorption lines and a highly reddened nucleus. It may not be a

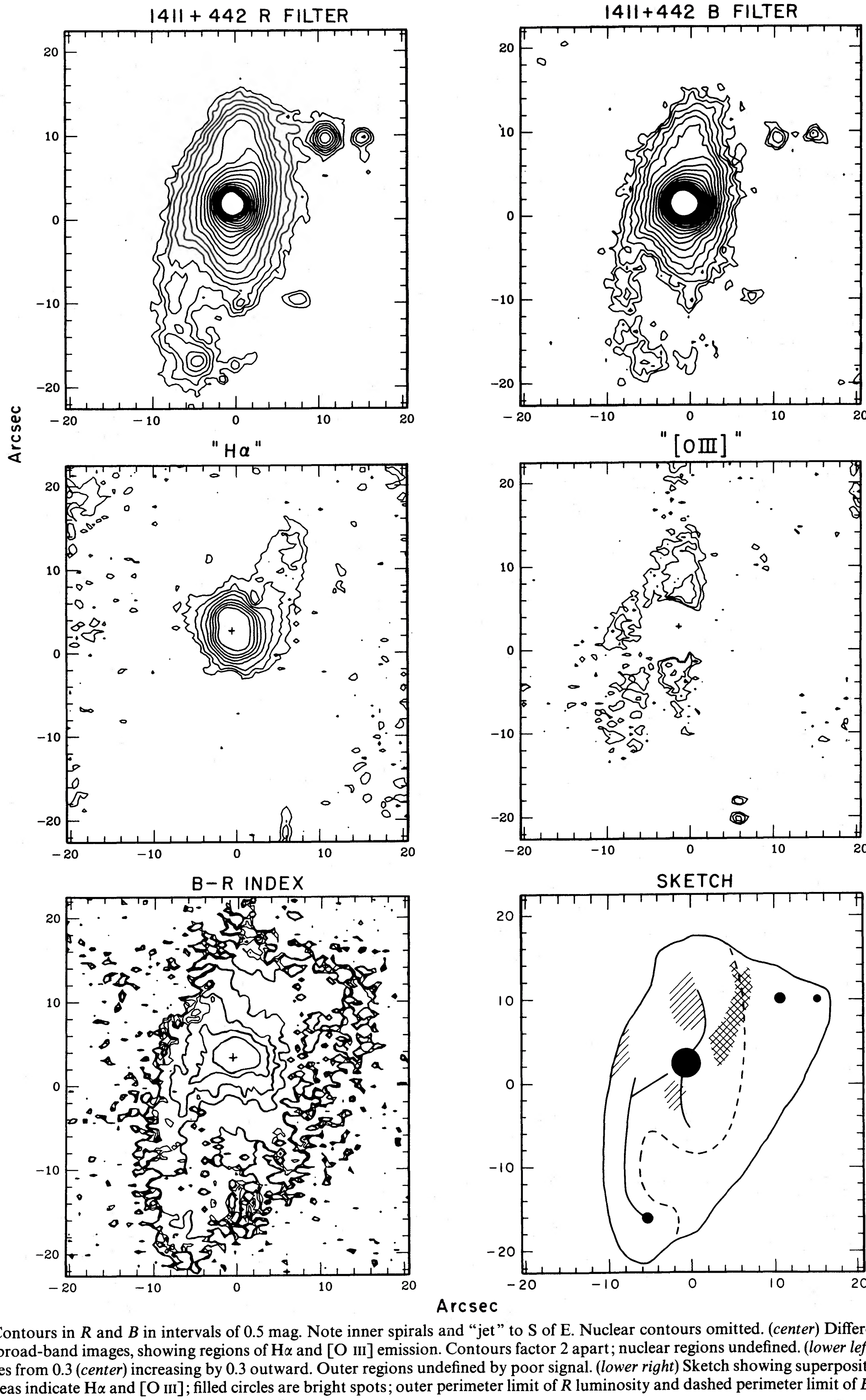

FIG. 5.—(*top*) Contours in R and B in intervals of 0.5 mag. Note inner spirals and "jet" to S of E. Nuclear contours omitted. (*center*) Difference images between narrow-band and broad-band images, showing regions of Hα and [O III] emission. Contours factor 2 apart; nuclear regions undefined. (*lower left*) $B-R$ index (image division) with values from 0.3 (*center*) increasing by 0.3 outward. Outer regions undefined by poor signal. (*lower right*) Sketch showing superposition of features in top panels. Hatched areas indicate Hα and [O III]; filled circles are bright spots; outer perimeter limit of R luminosity and dashed perimeter limit of B.

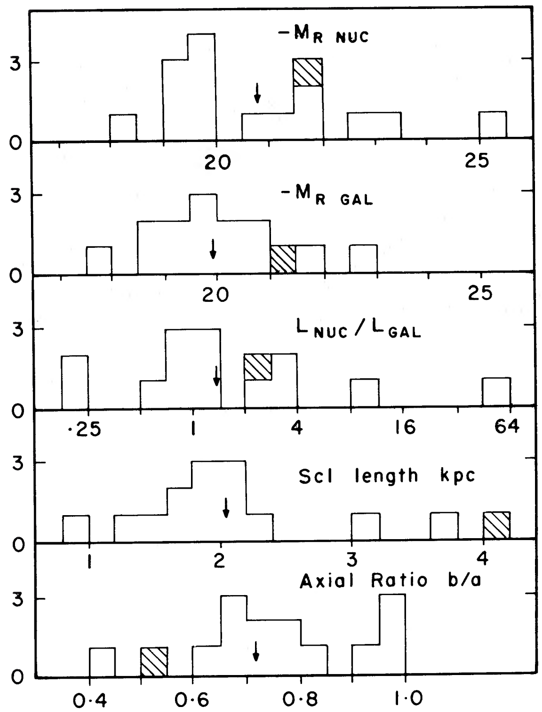

FIG. 6.—Histograms comparing properties of 1411+442 and host galaxy (*hatched*) with all similar redshift (0.07–0.12) QSOs from HCC. Arrows indicate median values of distributions without 1411+442.

coincidence that the ionization of the absorbing clouds of Mrk 231 is far lower than in any BALQSO; only H I, He I, Na I, and Ca II ions have been detected (Boksenberg *et al.* 1977).

III. CONCLUSIONS

Given the severe selection effects, it is extremely difficult to estimate the true frequency of broad absorption troughs in quasars with $Z < 2$. The first discovery of BAL troughs in a quasar by *IUE* extends the search for these objects to low redshifts. We have examined good *IUE* SWP spectra of about 30 bright Seyfert 1 galaxies and low-redshift quasars. The signal-to-noise ratios in the continuum were comparable to that of our PG 1411+442 discovery spectrum. Thus, we believe that other BALQSOs would have been detected if they were present in this sample. The fact that none were discovered implies that no more than several percent of all low-redshift quasars may show BAL properties. Our independent study of the *IUE* archives overlapped substantially with that of Turnshek and Grillmair (1986) who found two new BALQSOs at redshifts below 1.2. Within the large uncertainties, it is possible that the frequency of broad absorption troughs in quasars is independent of redshift. (Hazard *et al.* 1985 estimated that 3%–10% of all quasars with $Z_{em} > 2.1$ have broad absorption.) However, broad absorption troughs are not this common in active galactic nuclei of lower luminosity.

Our results are consistent with the view that broad absorption troughs are produced close to the active galactic nucleus, probably on the outskirts of the BLR. Since the galaxy is not highly inclined, the absorbing clouds could *not* lie in the galactic disk further than a few hundred parsecs from the nucleus. The emission and absorption velocity widths may provide further evidence that the absorbers are kinematically related to the BLR. The unusually small spread in the velocities in the emission-line clouds is matched by the small width and low relative velocity of the absorbers. The observations are interpreted easily if the absorption troughs are produced by clouds in the outer parts of the BLR.

At $M_B = -22.2$ (nuclear $M_B = -21.9$), PG 1411+442 is by far the least luminous BALQSO known. (Note that it is assigned $M_B = -23.7$ by Schmidt and Green 1983, who used $H_0 = 50$.) The next faintest, 1700+518, has $M_B = -23.5$ and most of the remaining BALQSOs are much more luminous still. It is possible that a low-luminosity quasar nucleus such as that in PG 1411+442 cannot accelerate absorption clouds to very high velocities. This could be consistent with the relatively modest outflow velocities seen in those few absorption systems which have been identified in Seyfert 1 spectra (e.g., NGC 3516, Ulrich and Boisson 1984; NGC 4151, Bromage *et al.* 1985). This hypothesis can be confirmed if more low-luminosity quasars are found with strong absorption troughs which also have relatively small outflow velocities.

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