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X-RAY AND UV OBSERVATIONS OF TWO RADIO-BRIGHT QUASARS

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ABSTRACT

We observed the two quasars PKS 10004+13 (4C 13.41, $V \sim 15.2$, $z = 0.140$) and PKS 0637−75 ($V = 15.75$, $z = 0.651$) in 1980 December with *IUE*. Both were detected in the short-wavelength region. Our X-ray upper limit for PKS 1004+13 gives the lowest $L_x/L_{\rm opt}$ measured in quasars. PKS 0637−75 was observed nearly simultaneously with the *Einstein Observatory* and a spectrum obtained with the IPC. The UV and soft X-ray data have been combined and are discussed together with the optical and infrared data for both objects.

The extreme $L_x/L_{\rm opt}$ ratio of PKS 1004+13 may be the result of an exceptionally large "blackbody" UV excess superposed on a power-law continuum of slope about 1.1. An alternative would be a large hydrogen column absorbing low-energy X-rays although we argue that this is unlikely. PKS 0637−75 shows no evidence for any UV excess. The two quasars seem to be at opposite ends of the degree of dominance of the UV spectrum by a "blackbody" component.

The lack of a Lyman limit discontinuity in PKS 0637−75 at the redshift of an intervening galaxy implies that the optically detected, intervening hydrogen is ionized.

Subject headings: quasars — ultraviolet: spectra — X-rays: sources

I. INTRODUCTION

Only one decade of frequency separates the softest X-rays and the shortest wavelength UV seen by the *Einstein* and *IUE* satellites. This unobserved region is very important to our understanding of active galaxies and quasars since it is here that the bulk of the ionizing flux exists that produces the strong optical emission lines. The short-wavelength UV is also important because of the possibility that a "blackbody" or "accretion disk" spectrum dominates there over other mechanisms, at least in some quasars (Malkan and Sargent 1982; Malkan 1983).

Toward the end of the *Einstein Observatory* mission we initiated a program of quasi-simultaneous X-ray and UV measurements of quasars to put the best possible constraints on this region of the spectrum. The quasars chosen had to be both optically bright and have a high X-ray count rate which limited the available targets. Two quasars were successfully observed with *IUE*, and, for one of them, a nearly simultaneous X-ray spectrum was obtained. The two quasars seem to be examples of the opposite extremes of "blackbody" dominance. The results are reported here.

We use $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0$ throughout.

II. OBSERVATIONS

a) *PKS 0637−75*

A radio-loud, flat spectrum quasar at moderate redshift ($z = 0.651$; Hunstead, Murdoch, and Shobbrock 1978), this object seemed a good candidate for simultaneous *IUE* and *Einstein* observations. It had an Imaging Proportional Counter (*IPC*; Giacconi *et al.* 1979) count rate of 0.25 counts s^{-1} (Zamorani *et al.* 1981) and an accessible magnitude of $V = 15.75$ (Adam 1978).

Other estimates of magnitudes of $V \sim 16.9$ (epoch 1976.9; Hunstead, Murdoch, and Shobbrock 1978) and "J" $= 17.5 \pm 1.0$ (from UK Schmidt IIIa-J plates; Savage 1976) may indicate long-term variability. No light curve has been published for this quasar. *Einstein* and *IUE* spectra were obtained within 4 days of each other.

M. Pettini and M. V. Penston (1982, private communication) have recently found optical absorption lines in PKS 0637−75 characteristic of a galaxy at a redshift of 0.469. At this redshift, Lyman limit absorption due to the galaxy could be detected with *IUE*.

i) *Ultraviolet*

A low-dispersion 416 minute exposure (SWP 10832) of PKS 0637−75 was taken on 1980 December 18 with the short-wavelength primary (SWP) camera on the *International Ultraviolet Explorer* (*IUE*; Boggess *et al.* 1978) during a low background shift. The large aperture was used. The spectrum was extracted and flux calibrated by the GSFC team using the 1980 May calibration (Bohlin and Holm 1980). A strong featureless continuum is clearly seen (Fig. 1). We can place only weak limits on any possible emission lines. We estimated the noise level from the typical deviation from the average continuum. Our upper limit is then given by 3 times that noise over a 10 Å band. This gives a conservative 3 σ upper limit of $< 10^{-13}$ ergs cm^{-2} s^{-1} for any emission line in our spectrum. The strongest line expected would be O VI λ1034 at a *maximum* flux of $\sim 5 \times 10^{-14}$ ergs cm^{-2} s^{-1} (Kwan and Krolik 1981; Hunstead, Murdoch, and Shobbrock 1978). The depression for ~ 50 Å shortward of O VI could be a broad O VI absorption feature as in Q2227.6−3928 (Smith *et al.* 1981; Osmer 1979) but is not clearly real. No discontinuity greater than 50% is seen between the quasar rest wavelength of 912 Å and the

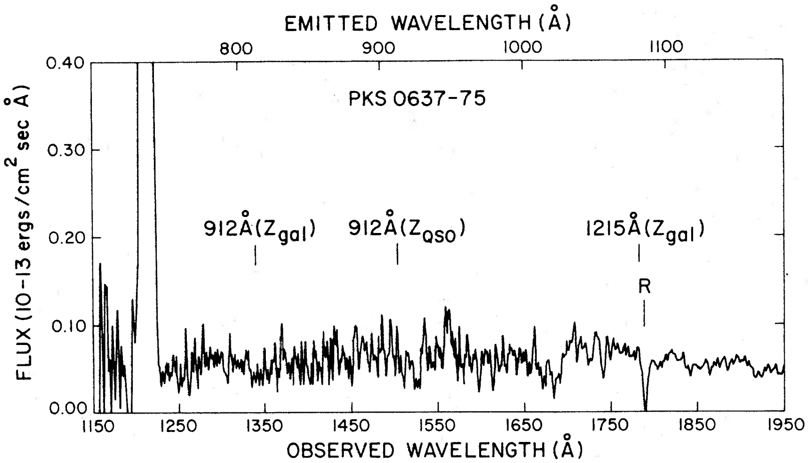

FIG. 1.—*IUE* wavelength spectrum of the $z = 0.651$ quasar PKS 0637−75. The Lyman limit (912 Å) at the redshifts of the quasar (Z_{QSO}) and of the intervening galaxy (Z_{gal}) are shown. The wavelength of Lyα at the galaxy is shown, coinciding with the position of a reseau feature (R).

geocoronal Lyα line. This corresponds to a limit on the intervening H I column of $< 1 \times 10^{17}$ cm^{-2} for $0.4 < Z < 0.65$.

Figure 2 shows the observed *IUE* data for PKS 0637−75 plotted (*dots* and *solid line*) in log F_ν versus log ν space together with the available optical and near infrared photometry. The observed UV data are clearly steeper than the optical and even steeper within its wave band. However, the effects of reddening are very important. Burstein and Heiles (1982) give $E(B-V) \sim 0.12$ for PKS 0637−75. Removing this galactic reddening using the normalization of Seaton (1979) to the Whitford (1958) reddening law gives the plot shown by the crosses and the dashed lines in Figure 2. Absorption within the quasar is probably small (see below). We show the effect of an additional $E(B-V) = 0.1$ at the quasar redshift (Fig. 2, *open circles* and *dotted line*). The slope within the *IUE* data after allowing for $E(B-V)_{\rm galactic}$ of 0.1 is 1.8 with an error of about ± 0.3 (1 σ) and is consistent with being constant across this band. The infrared-optical slope, with the same correction, is 0.70 ± 0.05 (1 σ).

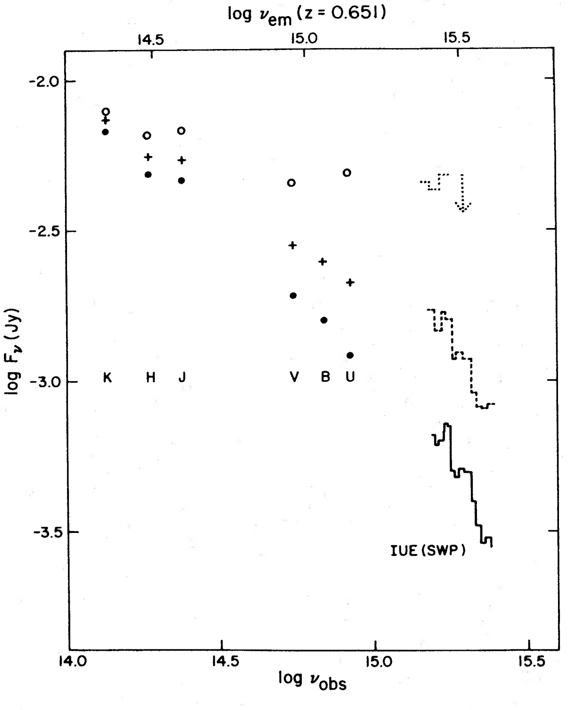

FIG. 2.—Composite infrared to ultraviolet observed spectra for PKS 0637−75. *JHK* photometry is from Hyland and Allen (1982). *UBV* photometry is from Adam (1978). *IUE* (SWP) is the ultraviolet data presented here. The solid line and circles show the observed points. The dashed line and crosses show the effect of correcting for $E(B-V) = 0.12$ at zero redshift. A further correction for $E(B-V) = 0.1$ at the quasar redshift is shown by the dotted line and the open circles.

The continuity between the IR and optical points and our *IUE* data suggests that the possible variability noted above is not frequent (Fig. 2).

ii) *X-Ray*

A 6512 s observation was made of PKS 0637−75 with the IPC on board the *Einstein Observatory* on 1980 December 14 (sequence number 8494). A total of 976 ± 31 source counts were recorded. The count rate was ~ 0.15 counts s^{-1} and thus lower than in the first observation reported in Zamorani *et al.* (1981; seq. 5404). The earlier observation was made on 1979 October 30. The source is thus probably variable on a time scale of 1 year as discussed by Zamorani *et al.* (1984). We derive a flux of 4.6×10^{-12} ergs cm^{-2} s^{-1} and a luminosity (0.5–4.5 keV) of 1.2×10^{46} ergs s^{-1} using the same spectral assumptions as Zamorani *et al.* (1981; $\alpha_E = 0.5$, $N_H = N_H$ (galactic).

The IPC covers the energy range 0.15 to 3.0 keV at low spectral resolution ($E/\Delta E \sim 1$) which allows intrinsic source spectra to be estimated via model fitting. The data have been reprocessed ("Rev 1") to reduce the uncertainties in the instrumental gain. With these new data we derive a best fit to a power-law energy index to be $0.6^{+0.4}_{-0.6}$ (90% confidence for two parameters) for the later observation. The value of the absorbing column, N_H, must be less than 5×10^{21} cm^{-2} with 99% confidence, consistent with a purely galactic value (Burstein and Heiles 1982).

The Monitor Proportional Counter (MPC; Giacconi *et al.* 1979; Grindlay *et al.* 1980; Halpern 1982) is a conventional 2–10 keV detector co-aligned with the telescope and has a

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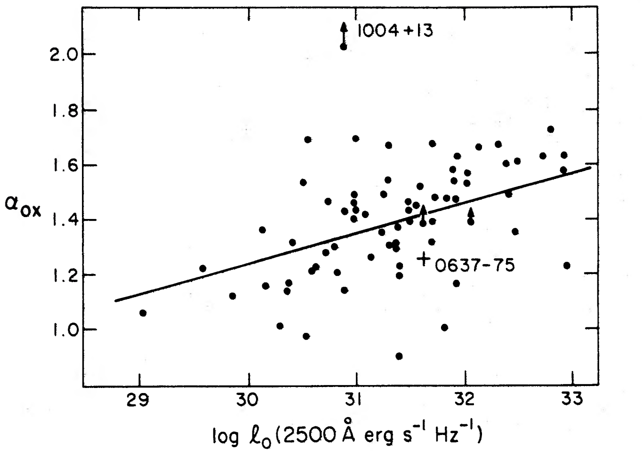

FIG. 3.—α_{ox} vs. optical luminosity (l_o) for radio-loud quasars adopted from Zamorani (1982). The position of PKS 0637−75 and the upper limit for PKS 1004+13 are marked.

40′ × 40′ FWHM collimation. During the first IPC observation (seq. 5404) it detected a marginal source at 0.33 ± 0.07 counts s^{-1} (9.2×10^{-12} ergs cm^{-2} s^{-1}, 2–10 keV). This corresponds to a 5.6 keV flux of 0.46 μJy. No source was detected during the second observation (seq. 8494) which supports the evidence for variability derived from the IPC as mentioned above.

b) PKS 1004+13 (4C 13.41, PG 1004+13)

This nearby quasar ($z = 0.241$; Bolton, Kinman, and Wall 1968) has not been detected as an X-ray source. Indeed, it is notable for having an optical to X-ray slope $\alpha_{ox} > 1.82$ (2500 Å–2 keV) which is the largest value of all the 107 quasars in Zamorani *et al.* (1981). This can clearly be seen in Figure 3 (adapted from Zamorani 1982) where we have used the new IPC observation described below. The 0.3–10 μm photometry of Neugebauer *et al.* (1979) gives an optical slope of ~0.4, a value in agreement with the *UBV* photometry of Bolton, Kinman, and Wall (1968). A spectral break somewhere in the UV or extreme UV thus seems to be implied.

TABLE 1

OPTICAL PHOTOGRAPHIC PHOTOMETRY[a] FOR PKS 1004+13

Date (1980)	m_{pg}
May 6/7 (1)	14.93
May 10/11 (2)	14.49
May 11/12	14.80
Dec 5/6 (3)	14.63

[a] Source: A. Smith, University of Florida.

We therefore obtained a short-wavelength *IUE* spectrum in an attempt to constrain this break. Problems with the *Einstein* spacecraft prevented us from obtaining simultaneous observations in this case. Fortunately PKS 1004+13 is not optically a strong variable. The largest observed magnitude change is ~0.8 (Pica *et al.* 1980). It is one of the objects regularly monitored by the University of Florida group. Their photometry for dates close to the *IUE* and the *Einstein* observations is given in Table 1 (A. Smith 1981, private communication). The errors due to variability in combining the *Einstein*, *IUE*, and Neugebauer *et al.* (1979) observations are thus probably less than 0.3 in the log.

Recent VLA observations by E. Feigelson and A. Kembhavi (1982, private communication) show that the radio core of PKS 1004+13 has a flat spectrum with a 1.4–5 GHz spectral slope of −0.14, similar to PKS 0637−75.

i) *Ultraviolet*

The *IUE* observation of PKS 1004+13 was made on 1980 December 22 with the short-wavelength camera at low

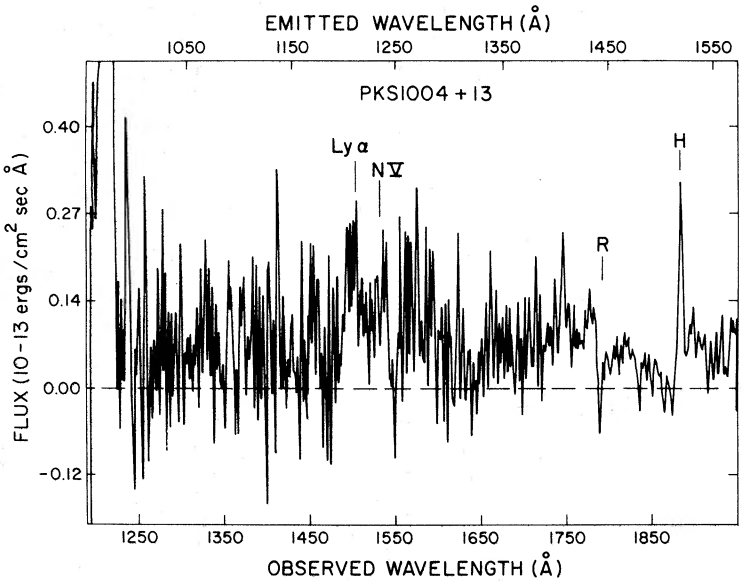

FIG. 4.—*IUE* short-wavelength spectrum of the $z = 0.241$ quasar PKS 1004+13. "R" and "H" mark the positions of reseau and of cosmic ray ("hit") features, respectively.

TABLE 2

IUE FLUXES FOR PKS 1004+13

$F(0.13\text{–}0.14\ \mu\text{m}) = 4.2 \times 10^{-4}$ Jy
$F(0.16\text{–}0.18\ \mu\text{m}) = 6.5 \times 10^{-4}$ Jy
$F(\text{Ly}\alpha) = 1.6 \times 10^{-13}$ ergs cm^{-2} s^{-1}

dispersion using the large aperture (SWP 10850). The same reduction procedure was used as for PKS 0637−75. Although the exposure was only 32 minutes long, a continuum can be seen, as can probable Lyα emission (Fig. 4). Possibly N v emission is also seen. Flux values for two continuum bins of about 200 Å width and for Lyα are given in Table 2. The observed continuum points imply an ultraviolet (0.17–0.13 μm) slope of 1.8 although this value is uncertain given that the fluxes in Table 2 are poorly determined. Galactic reddening is unimportant for this quasar. Heiles and Burstein (1982) give $E(B-V)_{\text{galactic}} < 0.03$ for PKS 1004+13. Figure 5 shows the infrared to ultraviolet photometry both as observed (*solid circles*) and as corrected for $E(B-V)_{\text{galactic}} = 0.03$ (*open squares*).

ii) *X-Ray*

Taken on 1980 May 9, this new IPC observation of PKS 1004+13 (seq. 563) had an effective exposure time of 8366 s, a factor of 6 longer than that reported in Zamorani *et al.* (1981). The quasar was still not detected, and a 3 σ upper limit of $< 1.4 \times 10^{-13}$ ergs cm^{-2} s^{-1} (0.5–4.5 keV) can be set. Being a broad-band limit, this limit is not significantly affected by gain uncertainties. The new IPC observation yields $\alpha_{ox} > 2.01$ and a luminosity $< 5 \times 10^{43}$ ergs s^{-1} (0.5–4.5 keV).

III. DISCUSSION

In Figures 6 and 7 we present the composite radio to soft X-ray spectra of PKS 0637−75 and PKS 1004+13, respectively. The two figures show very different behaviors between the UV and the X-ray, as was implied by their very different α_{ox} values. A second clear difference is that PKS 1004+13 has a pronounced excess in the optical range peaking near log $\nu_{\text{em}} = 15.0$ ($\lambda_{\text{em}} \sim 3000$ Å) when compared with a power law joining the infrared and the UV. No such excess is seen in PKS 0637−75. Each quasar is now discussed in turn.

a) *PKS 0637−75*

i) *The Lyman Limit*

The lack of a discontinuity at the Lyman limit in the quasar rest frame is not uncommon. In their recent summary Smith *et al.* (1981) find an absorption jump near the emission-line

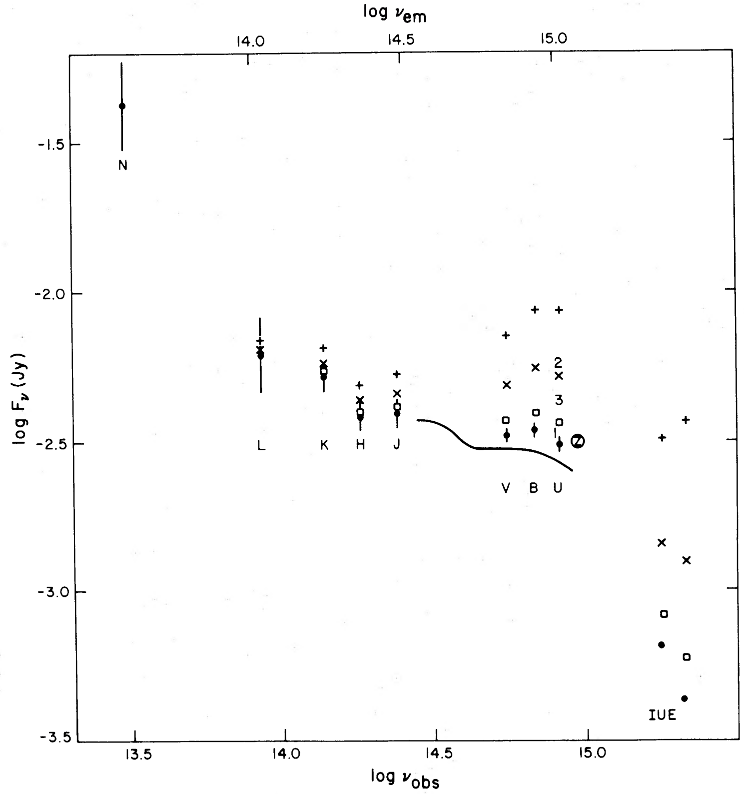

FIG. 5.—Composite infrared to ultraviolet observed spectra for PKS 1004+13 (4C 13.41). The infrared photometry (*JHKLN*, *solid circles*) and Oke scanner optical continuum (*solid line*) are from Neugebauer *et al.* (1979). The optical photometry (*UBV*, *solid circles*) is that of Bolton, Kinman, and Wall (1968). The ultraviolet continuum from this paper is marked "*IUE*" (*solid circles*). The effect of removing a zero redshift reddening of $E(B-V) = 0.03$ is shown by the open squares. Removing $E(B-V) = 0.1$ and 0.2 gives the points shown by X and + signs, respectively. The optical photometry labeled "F, 1, 2, 3" are from A. Smith (University of Florida, 1981, private communication), where the numbers refer to the photometry in Table 1: "Z" is the extrapolated flux at 2500 Å used by Zamorani *et al.* (1981).

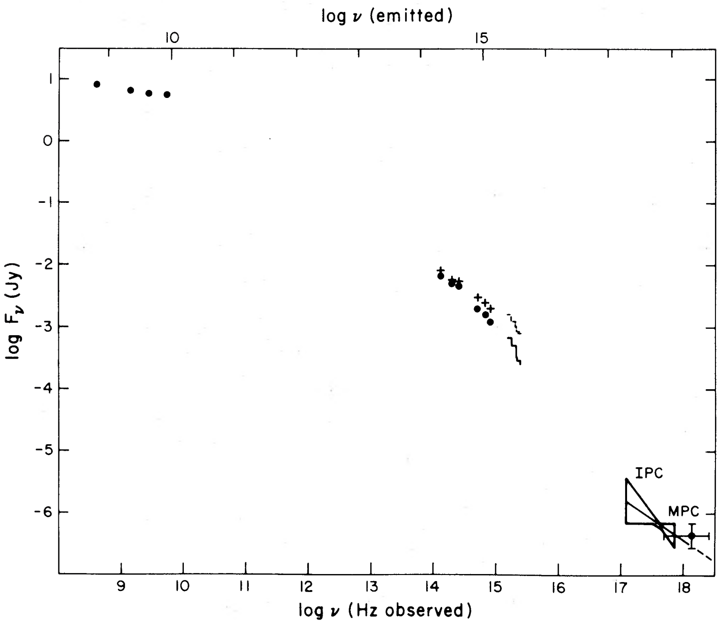

FIG. 6.—Radio to X-ray distribution for PKS 0637−75 at $z = 0.651$. IPC shows the best fit energy power law ($\alpha_E = 0.7$) to the IPC data. The systematic error on this slope of ± 0.7 is shown by the "hourglass" shape. The cross labeled "MPC" shows the 2–10 keV flux measured by the MPC during the earlier observations. The infrared to ultraviolet continuum of Fig. 2 for $E(B-V) = 0.0$ and $E(B-V) = 0.12$ are repeated here with the same symbols. The radio data are that of Hunstead, Murdock, and Shobbrock (1978, 408 MHz), Price and Milne (1965, 1410 MHz), and Savage (1976, 2700, 500 MHz).

redshift in only 14 out of 32 quasars. The lack of X-ray absorption in the X-rays is thus expected. It would be interesting to search for a correlation between X-ray columns and Lyman limit jumps near the quasar redshift. If any such correlation were found it would imply $\tau_{912} \gg 1$ in these clouds and argue that, at least in some cases, the absorber is intrinsic to the quasar. Existing *Einstein* data are not sufficient to perform this study.

Our *IUE* spectrum also covers the Lyman limit down to $z \sim 0.4$ and shows no strong cutoff at any point. This sets a limit to absorption in the halo of a galaxy at $z = 0.469$ that lies 5″ (~50 kpc) off the line of sight (M. Pettini and M. V. Penston 1982, private communication). Our current limit implies a low neutral hydrogen column through this halo and may require that the optically discovered intervening gas is ionized as would be expected if it lay in an H II region.

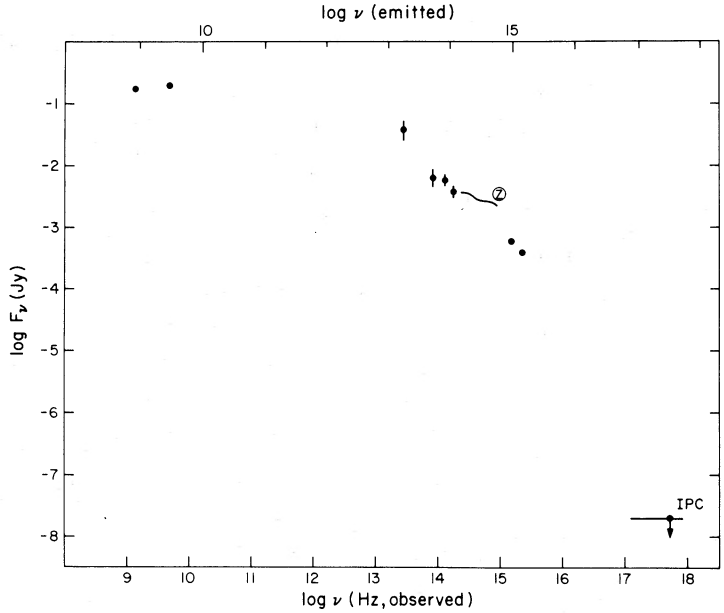

FIG. 7.—Radio to X-ray distribution for PKS 1004+13 at $z = 0.241$. The nuclear radio fluxes are from E. Feigelson and A. Kembhavi (1982, private communication). The new *Einstein* upper limit is marked "IPC." The infrared to ultraviolet continuum of Fig. 5 for $E(B-V) = 0.0$ is repeated here with the same symbols.

Unfortunately Lyα at $z = 0.469$ falls onto a reseau mark at 1785 Å (observed) so that we cannot put a limit on the ionized hydrogen column density.

ii) *The Shape of the Continuum*

Except at implausibly large reddenings PKS 0637−75 shows no flattening in the optical-UV range that could indicate the presence of a "blackbody" component (Malkan and Sargent 1982). The infrared to ultraviolet spectrum is significantly steeper than both the optical and the X-ray spectra. This has been noted previously for a number of Seyfert galaxies (Wu, Boggess, and Gull 1983).

b) *PKS 1004+13 (4C 13.41)*

The cause of the extreme α_{ox} value is the major puzzle for this quasar. One problem occurs if the true slope in the ionizing ultraviolet to soft X-ray bands exceeds 2. In this case the two-phase instability, which could produce the dense broad line region clouds (Krolik, McKee, and Tarter 1981), can no longer occur (Guilbert, Fabian, and McCray 1983). Since broad lines are seen in this quasar our $\alpha_{ox} = 2.01$ is not likely to be the ionizing continuum slope. Another problem is that the number of ionizing photons provided by a continuum of slope 2 fails by a factor of 5 (for unity covering factor) to provide enough photons to produce the observed emission line fluxes. To explain this puzzle we can look either for an unusual excess in its optical flux, unrelated to the ionizing continuum, or a peculiar deficit in its X-ray flux.

The simplest explanation would be that this quasar possessed a large low-energy cutoff in its X-ray spectrum causing a reduction of flux in the soft *Einstein* band of a factor $\gtrsim 20$ over that which would be registered in an instrument with a higher energy response. Such large line of sight column densities (10^{22}–10^{23} atoms cm^{-2}) are common in low-luminosity Seyfert galaxies (Mushotzky 1982; Maccacaro, Perola, and Elvis 1982). However, a hard X-ray luminosity of $>10^{45}$ ergs s^{-1} would be implied for PKS 1004+13. No large cutoff has been seen in any other active nucleus with a hard X-ray luminosity $>10^{44}$ ergs s^{-1} (Lawrence and Elvis 1982), except perhaps in MR 2251−179 (Halpern 1982), so that this explanation is unlikely. For any individual object, though, it cannot be ruled out.

A further argument makes this explanation less plausible. Figure 5 shows that for any de-reddening greater than $E(B-V) = 0.1$ the ~3000 Å flux of PKS 1004+13 exceeds that at J. None of the quasars in the large compendium of Neugebauer *et al.* (1979) has this property. If it is then correct to limit $E(B-V)$ to less than 0.1, then the column density needed in X-rays must be more than 80 times the column density in the optical. Large discrepancies in the same sense have been seen in other active galaxies (Maccacaro, Perola, and Elvis 1982) but only up to about a factor of 20. A value of $E(B-V) = 0.4$ is needed to reach "normal" values of X-ray to optical column densities. A value of $E(B-V) = 0.4$ would produce a remarkable and unique optical continuum shape. This reddening is just allowed by the Lα:Hα:Hβ ratios (3.1:4.6:1) but only if the unlikely case B (Kwan and Krolik 1981) is assumed. The observed line ratios are comparable to those seen for a few other, normal α_{ox}, active objects (e.g., Mrk 79; Wu, Boggess, and Gull 1980).

A large obscuring column density at low X-ray energies thus seems unlikely. A fairly direct test for the existence of soft X-rays in the quasar is possible through a search for high-excitation emission lines in the optical and ultraviolet. Several lines that imply the existence of ionizing photons with energies $\gtrsim 0.1$ keV have been seen in X-ray bright active galaxies (e.g., [Ne V] λ3426, [Fe VII] λ5721, 6087) even in those with large X-ray column densities (Ward *et al.* 1978, 1980). The [Fe XI] λ7892 line even requires the presence of ionizing photons with energies above ~0.25 keV and is now accessible through the use of CCD detectors. Unfortunately, the currently available optical and ultraviolet spectra for PKS 1004+13 do not have sufficient signal to noise to make a search for these lines. New optical spectra are clearly needed.

If the X-ray emission is not cut-off it may be "intrinsically" low for some reason not understood. A radio/X-ray comparison suggests that this might be the case. PKS 1004+13 has the classical double structure of radio galaxies (E. Feigelson and A. Kembhavi 1982, private communication) and, although somewhat complex could probably be classed as Fanaroff-Riley class 2 (Fanaroff and Riley 1974). We can compare this quasar with other Fanaroff-Riley class 2 quasars and galaxies in the correlation of l_x versus $l_{\rm RN}$(5 GHz, nuclear) of Fabbiano *et al.* (1984, Fig. 9, *triangles* and *crosses*). In this plot it has a lower X-ray luminosity than would be expected for its nuclear radio luminosity. This suggests that X-rays are deficient.

The remaining possibility is that there is excess optical emission in the blue. Our data show that the optical (0.3–2.3 μm) slope of roughly −0.3 (Fig. 5, Neugebauer *et al.* 1979) steepens to about −1.9 [for $E(B-V) = 0.03$] in the ultraviolet. In the infrared beyond 2 μm the continuum slope is again steep, around −1.3.

Many quasars show a "3000 Å bump" (at log $\nu = 15.0$; Richstone and Schmidt 1980; Neugebauer *et al.* 1979) that raises the blue part of the optical spectrum. This is often ascribed largely to Balmer continuum emission (Grandi 1982). The flatness of the PKS 1004+13 optical spectrum extends too far to the red to be explained solely by this means. A study of eight active galaxies by Malkan and Sargent (1982) concluded that another component was generally needed both in the red and in the near-ultraviolet. They find that the addition of a blackbody component with a temperature of 20,000–30,000 K gave a good fit to the data. The power-law slope for all their objects was fitted as 1.1 ± 0.2.

For PKS 1004+13 we can draw a rough power law connecting the infrared and ultraviolet data points with a slope of about 1.3. This would leave a large optical excess with a shape similar to that of other objects (e.g., 3C 273; Malkan and Sargent 1982). It is then a possibility that the extreme α_{ox} of PKS 1004+13 is due to an oversize "blue bump" of Balmer continuum and "blackbody" emission.

If we accept this "excess blackbody" interpretation, then joining the presumed power law at 2500 Å to the upper limit at 2 keV would give $\alpha_{ox} \geq 1.7$. This is still a high value although it touches on a region occupied by other quasars. It is comparable with OX 169 (log $l_0 = 30.58$, $\alpha_{ox} = 1.68$; Zamorani *et al.* 1981). A thorough Malkan and Sargent–type analysis is needed to know if this model will fit in detail. A long-wavelength *IUE* spectrum would help this analysis greatly. In the meantime it seems likely that a "UV excess" acts in combination with another cause to yield the extreme α_{ox} in PKS 1004+13.

IV. CONCLUSIONS

We have detected two 15 mag quasars at short wavelengths with *IUE*.

The extreme α_{ox} value (≥ 2.01) found for PKS 1004+13 may be the result of X-ray absorption. In this case an extremely low optical reddening relative to the X-ray column is probably required. A search for high-excitation emission lines is the simplest test for the presence of soft X-ray photons in the quasar. An alternative explanation lies in the possibility of PKS 1004+13 having a large "UV excess." PKS 1004+13 has a steeper continuum in the UV than in the optical, and similar to that in the infrared. The UV and infrared may show the nonthermal continuum, while the optical is dominated by Balmer continuum and "blackbody" components (Malkan and Sargent 1982; Malkan 1983). Unless the "nonthermal" continuum is unusually steep, a large "UV excess" will only account for part of the anomalous α_{ox} value. A combination of factors seems to be required to give a full explanation. The Lyα:Hα:Hβ ratios for PKS 1004+13 are somewhat small but not extreme.

PKS 0637−75 shows a featureless UV continuum without any Lyman limit discontinuity. The IPC X-ray spectrum is clearly flatter than the short-wavelength UV. This quasar does not show any large "blackbody" hump as seen in PKS 1004+13 and other quasars. No Lyman limit absorption is seen in PKS 0637−75 at the redshift of the intervening galaxy. This implies that the intervening material probably lies in a halo H II region.

These two quasars probably lie at opposite ends of the range of "blackbody" strength. As such they may provide convenient tests for theories of the origin of this component. More cases in which the "blackbody" is strong should be sought out for the same purpose. The few quasars in the sample of Richstone and Schmidt (1980) with positive optical slopes (4C 31.63, 4C 37.43, and R206) are strong candidates.

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