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REDDENING IN THE BROAD-LINE RADIO GALAXY 3C 234[1]

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ABSTRACT

A measurement of the Paschen-α flux from the broad-line radio galaxy 3C 234 shows a line strong enough to demand reddening ($A_V = 2.6^{+0.6}_{-1.0}$) as a crucial part of the explanation of the observed hydrogen line ratios. Since the narrow-line region appears strongly photoionized and only slightly reddened, the obscuring material is neither in our line of sight to this region nor between this region and the central source. A high-resolution profile of [O III] λ5007 shows attenuation of the red wing, consistent with obscuration of outflowing material that is moving directly away from us. An extrapolation of the observed optical continuum cannot provide the necessary ionization for even the narrow forbidden lines, but a continuum corrected for reddening can provide all of the ionizing photons and sufficient luminosity to explain the infrared emission. Existing radio and X-ray observations and optical polarimetry are discussed in the context of the suggested reddening.

Subject headings: galaxies: individual (3C 234) — galaxies: nuclei — interstellar: matter — radio sources: galaxies

I. INTRODUCTION

The N galaxy 3C 234 ($z = 0.1848$) has a visible emission-line spectrum with both narrow and broad components of the Hα line. The line luminosity is at the upper end of the distribution for active galaxies. The narrow-line spectrum is not out of the ordinary, showing strong [O III], the Balmer series, Mg II, and other lines. The continuous spectrum has a steep slope ($\alpha \approx -2$, where $f(\nu) \propto \nu^\alpha$) and shows little or no evidence of a stellar component (Yee and Oke 1978; Miller 1981). This slope continues into the mid-infrared (Lilly and Longair 1982; Elvis *et al.* 1984). The broad-line spectrum suggests possible strong reddening effects, since Hα shows a broad component, but Hβ and higher Balmer lines do not (Grandi and Phillips 1979; Grandi and Osterbrock 1978). The visible continuum appears to vary by a magnitude or so (Yee and Oke 1978; Miller 1981), but little is known of the variability of the emission lines. The radio properties of 3C 234 have been studied by Riley and Pooley (1975) and Preuss and Fosbury (1983), and the X-ray flux has been measured (Feigelson and Berg 1983).

One key question is whether reddening by dust is responsible both for the steep continuum slope and for the large ratio of Hα to Hβ in the broad component. The alternative explanation for the large Balmer decrement is radiative transfer effects (Canfield and Puetter 1980; Kwan and Krolik 1981), but if the continuum is intrinsically as steep as observed, another source of ionizing photons is required even to account for the observed narrow lines (§ III*f*; see also Elvis *et al.* 1984).

[1] Part of this work used the Multiple Mirror Telescope Observatory, a joint facility of the University of Arizona and the Smithsonian Institution.

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A possible test of the reddening hypothesis is to measure the Paschen-α line. If the broad lines are actually emitted in ratios typical of quasars, and reddening accounts for the large Balmer decrement, the Paα line should be strong. This paper reports a measurement of Paα in 3C 234 and also of [O III] λ5007 at 25 km s^{-1} resolution, so that the asymmetry of this line may be related to possible reddening.

In addition to analyzing these measurements, we have attempted to integrate all the data on 3C 234 to show how it may be related to other broad-line radio galaxies and quasars. Most of these show less steep continuum slopes in the visible and near-infrared than does 3C 234. They usually show a rise into the blue that Malkan and Sargent (1982; see also Malkan 1983) have interpreted as emission from an accretion disk and have modeled as blackbody emission at a temperature around 27,000 K. These galaxies also show both broad-line and narrow-line systems with no very strong evidence of reddening. They have (0.5–4.5 keV) X-ray fluxes that lie not far below an extrapolation of a ν^{-1} power law from the visible, and the inferred EUV flux is more than sufficient to ionize the gas that produces the emission-line spectrum. The X-ray and nuclear radio fluxes are well correlated (Fabbiano *et al.* 1984).

Our conclusion is that all of the observations on 3C 234 are consistent with the idea that a typical quasar-like nucleus lurks behind a blanket of dust at the center of the galaxy. The apparent smooth UV to IR continuum trend is well explained as a fortuitous combination of a highly reddened nuclear continuum and a thermal emission spectrum. The narrow-line region apparently lies outside the region of heavy obscuration and itself has a clear view of the central source. The narrow-line fluxes bear a normal ratio to the dereddened broad-line and central components. The nuclear radio flux density is also normal. The X-ray flux is low unless we assume a substantial column density ($\approx 10^{23}$ cm^{-2}) in our line of sight to the X-ray

TABLE 1

INFRARED PHOTOMETRY OF 3C 234

Date (UT)	Beam Size (arcsec)	*J*	*H*	*K*	*L*	*M*	*N*	*Q*
1981 Mar 8[a]	10.8	14.95	13.85	12.65	...	...	...	...
Dec 7	9	14.87	13.86	12.52	10.48[b]	...	...	...
Dec 15	9	...	14.04	...	...	...	...	...
Dec 16	9	...	14.03	12.80	...	...	...	...
1983 Jan 21	8	...	...	...	...	...	6.39 ±0.12	3.67 ±0.21
Feb 5[c]	6	...	...	...	...	...	6.72 ±0.09	3.96 ±0.12
Feb 7[c]	6	15.44	14.30	13.00	10.91 ±0.08	9.29 ±0.17	...	...
Feb 16	8	...	...	...	...	...	6.20 ±0.13	3.80 ±0.14

[a] Lilly and Longair 1982.
[b] Filter centered at 3.4 μm, bandwidth 0.2 μm, 5″ beam.
[c] Elvis *et al.* 1984.

source, but such a column density is typically demanded in broad-line cloud models (Kwan and Krolik 1981).

II. OBSERVATIONS

a) *Paschen* α

We observed the Paα line with the infrared photometer at the Multiple Mirror Telescope (MMT) on the nights of 1981 December 7, 15, and 16 (UT). The spectral resolution of the circular variable filter was 1%, the diaphragm size was 9″, and the chopper throw was 10″ in elevation. Some of the observations were made through this clouds with SAO 081143 (m_V = 7.0, K2, about 7′ from 3C 234) as a secondary standard that was measured when the weather was clear. Broad-band observations were also made and are given in Table 1. In addition to published measurements, Table 1 also gives 10 and 20 μm measurements made at the IRTF in 1983 January. The chopper throw was 15″, and α Tau was used as a standard star, for which $N = -2.99$ and $Q = -3.09$ were adopted. Figure 1 shows all other available broad-band photometric data.

Figure 2 shows the spectrophotometric data. The line flux was determined by least squares fitting to an assumed line profile of a Gaussian that represents the instrument profile convolved with another Gaussian of variable width, position, and amplitude. The continuum was assumed to be a power law. Through this procedure we conclude that we see a Paα line consistent with $z = 0.1848$ having a FWHM of 4300 km s^{-1} and an integrated flux of $(5.0 \pm 1.0) \times 10^{-14}$ ergs cm^{-2} s^{-1}.

b) [O III] λ5007

We also obtained a high-resolution (25 km s^{-1}) profile of the [O III] λ5007 line. The observations were made by F. H. Chaffee using the echelle spectrometer and Reticon detector at the MMT on 1982 March 20. The entrance diaphragm was 2″.5 in diameter, and the integration time was 30 min. The results

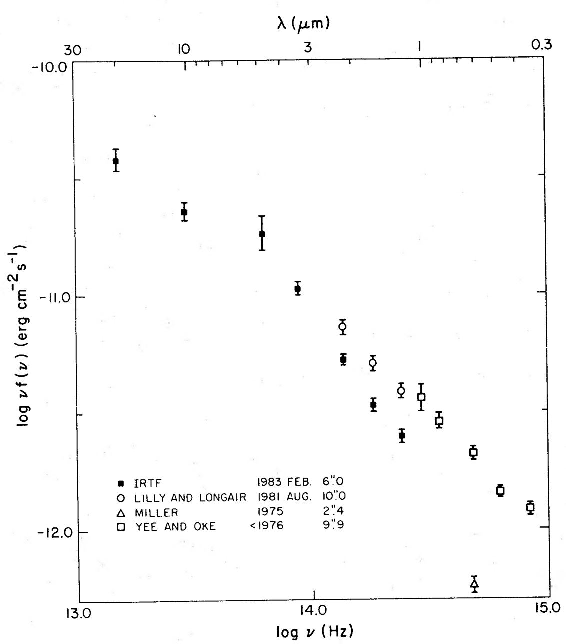

FIG. 1.—Summary of continuum observations of 3C 234

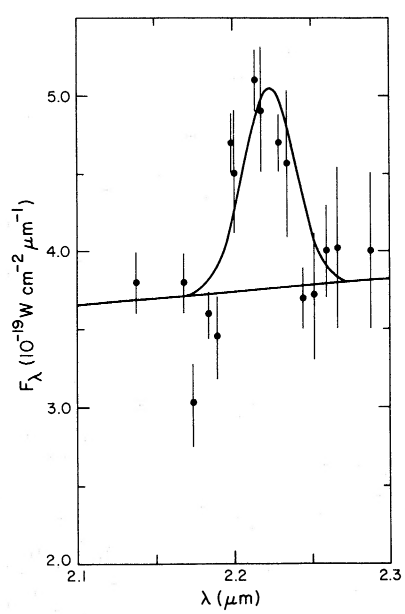

FIG. 2.—Observations of the Paschen-α line in 3C 234

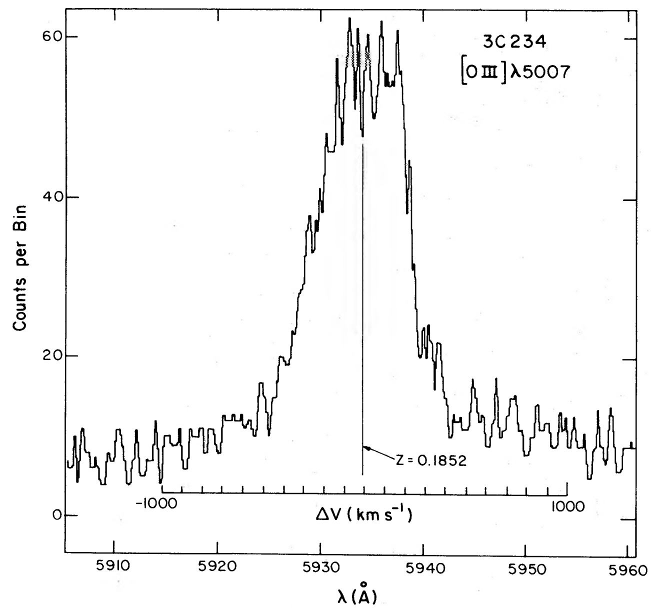

FIG. 3.—High-resolution profile of the [O III] λ5007 line in 3C 234. The spectrum has been smoothed to a resolution of 25 km s^{-1}, but the ordinate scale refers to a bin size of 0.04 Å, which has been retained for plotting. The apparent continuum is almost entirely dark counts.

are presented in Figure 3. The dark count has not been subtracted and accounts for nearly all of the apparent continuum. The dark count is nearly constant with wavelength, and the steeper slope of the red wing of the line is real. Most of the structure near the line peak is likely to be noise.

The placement of the zero velocity point was derived from the [O III] profile itself, because there are no other data with such high resolution. We have simply split the peak of the line about evenly. The mark in Figure 3 corresponds to $z = 0.1852 \pm 0.0005$, which is consistent with Schmidt's (1965) value of 0.1848. The main uncertainty in the wavelength calibration is that it is not known that the comparison lamp illuminates the slit in the same way as the galaxy image.

III. ANALYSIS

a) *Variability*

Figure 1 shows that the *JHK* measurements made in 1983 at the IRTF and Miller's (1981) visible point are discrepant with the rest of the points shown. We interpret these differences as due to variability rather than to instrumental effects such as differences in aperture size. Yee and Oke's (1978) measurements were taken before 1976 with a 9''.9 diaphragm and detected no galaxy component. Miller reports observations taken with a 2''.4 × 4''.0 diaphragm that show a 30% galaxy component, measured by the strength of the Mg *b* λ5180 absorption, in spite of the smaller beam size. Miller's absolute flux lies about a factor of 3.5 below Yee and Oke's. The apparent increase in the fraction of galactic radiation in the smaller beam is consistent with a genuine decrease in the nonthermal component.

Lilly and Longair's (1982) *JHK* measurements lie on a reasonable extrapolation of Yee and Oke's visible spectrum and also connect well to the Elvis *et al.* (1984) *L* and longer-wave points. The latter's *JHK* points, however, fall below the others by a factor of 1.6–1.8. Since they used a smaller aperture, we might expect less galactic light, but Yee and Oke saw no galactic light even in their larger aperture. It would appear that we are seeing a genuine variation in the *JHK* bands that took place between 1981 August and 1983 February.

We shall argue below that what we see in these bands could be reddened nuclear nonthermal continuum or thermal emission from hot, close-in dust, so that variability is not surprising. The pattern of variation is that the nonthermal source was high before 1976 (Yee and Oke 1978), low between then and 1981 (Miller 1981), high again in 1981 (Lilly and Longair 1982; our MMT data), and low in 1983 (Elvis *et al.* 1984).

b) *Broad-Line System Reddening*

The data that are available on the hydrogen line system in 3C 234 give values or limits for the broad- and narrow-line fluxes in Hβ, Hα, and Paα (albeit with some uncertainty). Grandi and Osterbrock (1978) recorded the spectrum at 10 Å resolution and could deconvolve the Hα complex of lines fairly well. Because of their 2''.7 × 4''.0 beam, however, they do not quote absolute spectrophotometry. Yee and Oke (1978) used a 9''.9 diaphragm and a bandwidth of 80 Å around Hβ, and 160 Å around Hα, so that they have good spectrophotometric accuracy in the continuum. They must make some assumptions to assign intensities to [O III] $\lambda\lambda$5007, 4959 and Hβ, however, and cannot resolve the Hα complex of lines at all.

The ratios measured for the major features are (Hα +):Hβ:[O III] = 1.0:0.111:1.06 (Yee and Oke 1978); 1.0:0.108:1.43 (Grandi and Osterbrock 1978). Lumping the latter two features, we have the ratios 1.0:1.17 (Yee and Oke 1978); 1.0:1.54 (Grandi and Osterbrock 1978). These ratios, which should be independent of assumptions on relative intensities, disagree beyond the expected error (perhaps 15%–20% for Yee and Oke, and appreciably less for Grandi and Osterbrock). This may be additional evidence for variability, suggesting that the broad Hα was stronger at the time of Yee and Oke's measurements (before 1976) than at the time of Grandi and Osterbrock's (around 1977). If we take literally the essentially constant (Hα+):Hβ ratio and assume that the narrow lines do not vary, we would conclude that Yee and Oke's spectrum had a small contribution from broad Hβ.

In order to estimate line fluxes, we adopt the intensity ratios of Grandi and Osterbrock (1978), since they have a spectrum with a high signal-to-noise ratio and good resolution. We assume that the narrow lines are the least variable component and take Yee and Oke's absolute value for the [O III] lines as a photometric calibration point. Grandi and Osterbrock give no formal upper limit for a broad Hβ component, but inspection of their spectrum and one of comparable quality obtained at the MMT suggests that a broad component with 5% of the height of the narrow one (but about 10 times the width) could go undetected. Table 2 summarizes all of this information.

The observed Paα flux must be mostly due to the broad component. The flux for the narrow component can be estimated from the case B ratio Paα_n/Hα_n = 0.120 (Osterbrock 1974). Correction for $A_V = 0.35$ mag derived from Hβ_n/Hα_n = 3.18 ± 0.50 slightly increases the expected Paα to (0.85 ± 0.2) × 10^{-14} ergs cm^{-2} s^{-1}. If this is subtracted from the observed flux, a flux of (4.2 ± 1.0) × 10^{-14} ergs cm^{-2} s^{-1} is assignable to the broad component. The observed line width of 4300 km s^{-1} (FWHM) also suggests that most of the flux is from the broad component. Grandi and Osterbrock (1978) give a value of 13,000 km s^{-1} for the FW0I of Hα_b. Because of the

TABLE 2

SUMMARY OF INFORMATION

	[O III] λλ5007, 4959	Hβ	Hα	Paα[a]
a) Line Fluxes Derived from Spectra (ergs cm^{-2} s^{-1})				
Broad component	...	$<1.1\times10^{-14}$	$(9.30\pm1.4)\times10^{-14}$	$[(4.2\pm1.0)\times10^{-14}]$
Narrow component	$(2.77\pm0.42)\times10^{-13}$	$(2.10\pm0.32)\times10^{-14}$	$(6.68\pm1.0)\times10^{-14}$	$[(0.85\pm0.2)\times10^{-14}]$
Total	...	...	...	$(5.0\pm1.0)\times10^{-14}$
b) Dereddened Line Fluxes, with $A_V = 2.6$ (ergs cm^{-2} s^{-1})				
Broad component	...	1.9×10^{-13}	6.7×10^{-13}	6.4×10^{-14}
Narrow component	4.0×10^{-13}	3.1×10^{-14}	8.7×10^{-14}	0.90×10^{-14}

[a] Measurement gives total flux; narrow component calculated from Balmer lines.

blending with the [N II] lines, the FWHM of $H\alpha_b$ is difficult to estimate, but it is probably ≤ 6000 km s^{-1}, while the narrow lines are only 600 km s^{-1} wide.

In order to estimate the intrinsic broad-line ratios, we make a comparison with quasars, which we assume to include at least some unreddened specimens. Canfield and Puetter (1981) quote a value of $H\alpha/H\beta = 3.9 \pm 1.1$ as an average of published measurements on quasars. Kwan and Krolik (1981) do likewise, giving an average value of 3.6. Neither sample is identified. On an incomplete sample of radio-loud objects with $z \leqslant 0.5$, Steiner's (1981) tabulated data (plus a few added objects for a total of 52) give $H\alpha/H\beta = 4.3 \pm 1.0$ if we exclude nine objects that have $H\alpha/H\beta \geq 8$ and are very likely reddened. If we assume that part of the scatter of the remaining points is due to reddening, then we should be looking toward the low end of the distribution for a typical value for unreddened objects. In Steiner's sample 30% of the objects lie below Kwan and Krolik's value of 3.6. This value seems a reasonable one to take as an average value produced by radiative transfer effects with no reddening.

For the ratio $Pa\alpha/H\alpha$, not many data are available. An average over 10 quasars measured by Puetter *et al.* (1981) gives $Pa\alpha/H\alpha = 0.095 \pm 0.05$, which is consistent with the bulk of the values for 16 Seyfert 1 galaxies measured by Lacy *et al.* (1982). Although the Paα lines are unresolved, the narrow components in the visible spectra of these objects are small enough that we may take $Pa\alpha_b/H\alpha_b = 0.095 \pm 0.05$. Our value for 3C 234 is $Pa\alpha_b/H\alpha_b = 0.45 \pm 0.13$.

Among Canfield and Puetter's (1981) model calculations, there is no combination that comes close to representing the raw 3C 234 broad-line intensity ratios. Most cases predict $Pa\alpha/H\alpha$ in the range of 0.1–0.2. Certain combinations of parameters raise it as high as 0.3, but these combinations predict $H\alpha/H\beta \approx 2.5$, while the observed $H\alpha/H\beta$ exceeds 8.5.

Our observed value of $Pa\alpha_b/H\alpha_b = 0.45$, compared to a nominal value of 0.095, gives a reddening corresponding to $A_V = 2.6$. This, together with an $H\alpha/H\beta$ ratio of 3.6, would predict $H\beta_b = 1.07 \times 10^{-14}$ ergs cm^{-2} s^{-1}, which is just within our upper limit, so that there is no need to make any special assumptions about the unreddened $H\alpha/H\beta$ ratio. Combining observational uncertainties with the range of model prediction, we may state with fairly high confidence that A_V lies between 1.6 and 3.2. The Hβ, Hα, and Paα observations on 3C 234 are thus consistent with its having a "standard" broad-line region which we view through effective reddening corresponding to $A_V = 2.6^{+0.6}_{-1.0}$.

The dereddened line intensities are listed in Table 2. The total Hβ luminosity, using $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0$, is 4×10^{43} ergs s^{-1}, placing 3C 234 well up into the luminosity range of quasars (Yee 1980).

These statements on reddening are all based on a conventional galactic extinction curve (Savage and Mathis 1979). Since the clouds responsible for the reddening presumably lie within our beam, we are receiving some radiation that was scattered but not absorbed. This means that the actual line-of-sight extinction through the clouds would be greater than $A_V = 2.6$.

c) *Narrow-Line Region*

There are a number of constraints on the geometry of the narrow-line region. Since its spectrum shows little reddening, we conclude that the material responsible for the heavy broad-line reddening is distributed on a smaller scale than is the case for the narrow-line region. Furthermore, the narrow-line spectrum shows a wide range of ionization states (Grandi and Phillips 1979), as do most active galactic nuclei (AGNs) except the so-called Liners (low-ionization nuclear emission-line regions) (Heckman 1980). This is characteristic of photoionization by a strong power-law spectrum extending from the Lyman limit to higher frequencies. If the EUV spectrum were blocked off, ionization by X-rays would produce incomplete ionization and lower states of ionization would dominate (Ferland and Netzer 1983; Halpern 1982). We conclude that the narrow-line regions in 3C 234 have clear lines of sight to the ionizing source, as well as fairly clear lines outward in our direction. The inner obscuration might produce a jack-o'-lantern pattern, with beams coming through randomly distributed holes, or possibly a large-scale pattern. The work of Lawrence and Elvis (1982) suggests that an axially symmetric pattern may exist.

The profile of the [O III] line shown in Figure 3 indicates that some reddening affects the narrow lines. The observed asymmetry (blue side of the line more extended than red side; see Heckman *et al.* 1981) is often found in forbidden lines in AGNs. One explanation of this is to have radial outflow of the narrow-line material, so that obscuration within the region would reduce the intensity from the back, positive-velocity part of the gas. If this obscuration is concentrated near the center of the region, it ought to attenuate most strongly the highest positive velocities. The [O III] λ5007 profile in Figure 3 appears to show this effect.

d) *Reddening of the Central Source*

The material that causes the broad-line reddening may attenuate the central source as well. Figure 4 shows a contin-

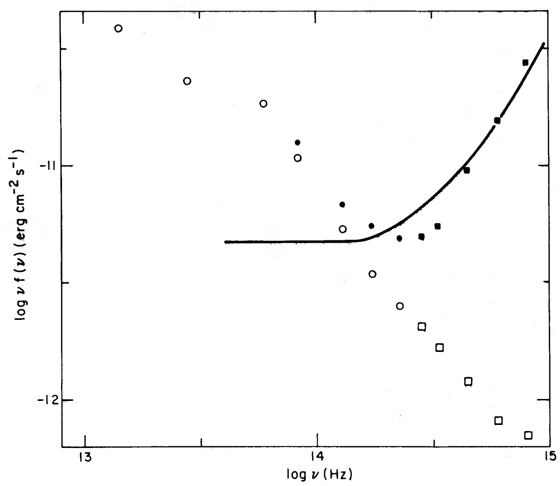

FIG. 4.—3C 234 continuum points from different epochs, adjusted to fit to each other. Upper symbols are the observed values dereddened by amounts corresponding to $A_V = 2.6$, using the reddening curve of Savage and Mathis (1979). The solid line represents a model consisting of a ν^{-1} power law, a 15,000 K blackbody to represent the Balmer continuum, and a 30,000 K blackbody as postulated for a number of active galactic nuclei by Malkan and Sargent (1982).

uum spectrum, constructed by arbitrarily dropping Yee and Oke's (1978) points by a factor of 1.8 so that they connect fairly well with the *JHK* points of Elvis *et al.* (1984). The spectrum is shifted into the rest frame of 3C 234. The figure also shows these points dereddened by $A_V = 2.6$, and a fit to the latter points with a model of the type of Malkan and Sargent (1982). This consists of a ν^{-1} power law, a 15,000 K blackbody spectrum to represent a Balmer continuum equal in intensity to the power law at log $\nu = 15.0$, and a 30,000 K blackbody equal to 0.75 of the power law at log $\nu = 14.75$.

The hot blackbody contribution required here, relative to the power law, is on the high side: about 2.5 times the typical value found by Malkan and Sargent (1982) and Malkan (1983), but a little less than the value they found for 3C 273. The compendium of AGN spectra by Neugebauer *et al.* (1979) shows several other objects (e.g., 3C 334, Mrk 132, PHL 957) that require a contribution of the order of what we are postulating. The model spectrum is clearly not a good detailed fit to the dereddened data points, but considering the many uncertainties in the problem, it is in the right neighborhood.

The effects of reddening as large as $A_V = 2.6$ mag are appreciable out to $\nu = 1.5 \times 10^{14}$ Hz or so ($\lambda = 2$ μm). At that frequency, we might expect that thermal emission from dust at several hundred K could begin to be important. Thus, the observed rather smooth continuum could indeed be a connection of a highly reddened nonthermal spectrum with a thermal emission spectrum from dust.

If the spectrum below log $\nu = 14.2$ is thermal, then its breadth requires a range of temperatures. The pronounced shoulder at log $\nu = 13.8$ (5 μm) suggests that we try a sum of two blackbodies, and in Figure 5 we show a fit produced with a 175 K spectrum and a 700 K spectrum. Figure 5 plots $\nu L(\nu)$ on a linear scale against log ν, so that the area under the curve between any two values of log ν represents the power emitted in that band. We plot luminosity here as well as flux (using $H_0 = 50$ km s^{-1} Mpc^{-1} and $q_0 = 0$), to place 3C 234 on a scale with other objects.

For log $\nu > 14.2$ the smooth curve is the model spectrum described above. The area shown hatched under this curve represents the total power removed from the central-source continuum by the assumed absorption (exclusive of X-rays), if our line of sight is representative of the average. In addition, reddening of the broad lines removes 10%–15% more power. This power should reappear as thermal emission, and the area representing this is also hatched in Figure 5. The two areas are indeed quite comparable. The total thermal power radiated

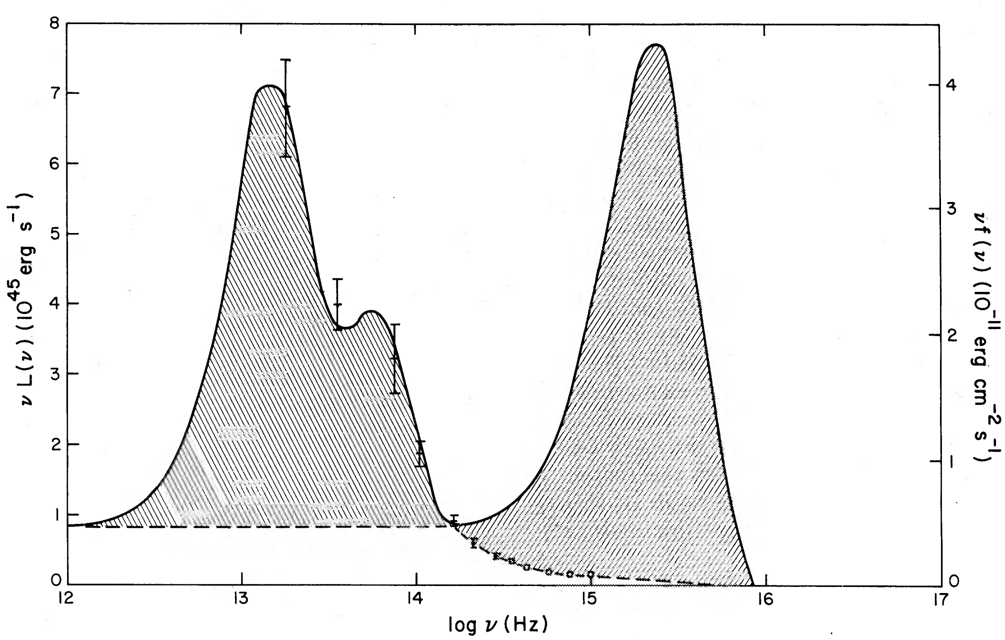

FIG. 5.—3C 234 continuum observations plus model fits. The ordinate is linear in νL_ν, and the area under any portion of a curve is proportional to the luminosity in that portion of the spectrum. The 3000 Å bump is much more prominent in this plot than in typical logarithmic plots. The solid line for log $\nu < 14.2$ is a two-temperature thermal emission spectrum. For log $\nu > 14.2$ the line is a model fit to the dereddened observations, as in Fig. 4, extrapolated to higher frequencies.

under our assumptions is 5×10^{45} ergs s^{-1}. The comparison suggests that our line of sight is typical of a large solid angle, rather than a small cloud that chances to obscure our view.

If longer-wavelength observations than are presently available show appreciable thermal emission at temperatures lower than 175 K, then there must be an additional source of power. More reddening in other lines of sight would hardly help, since $A_V = 2.6$ mag already removes almost all of the visible and UV light. We shall discuss the X-rays below; another source would be a nuclear concentration of hot stars. It is certainly of interest to observe 3C 234 and similar objects at longer wavelengths in order to find out whether additional power sources are needed.

Incidentally, a 175 K blackbody producing the 20 μm luminosity indicated in Figure 5 would have an area of 2×10^{41} cm^2 ($\sim$150 pc diameter). Similarly, at 700 K the 5 μm luminosity would require an area of 3×10^{38} cm^2 ($\sim$7 pc diameter). Since the clouds are probably not optically thick at these wavelengths, these are lower limits on the actual areas. Thus it is only the hotter part of the dust that is intimately associated with the central source and the interior of the narrow-line region.

e) *Polarization*

Recent polarimetry of 3C 234 by Antonucci (1982) and Rudy *et al.* (1983) reveals a large polarization (>7%) over a broad wavelength range. Spectropolarimetry by Antonucci (1984) showed that the Hα emission was polarized similarly to the adjacent continuum, suggesting that intrinsic polarization of the continuum is not the dominant effect. Antonucci (1984) attributed the polarization to electron scattering, while Rudy *et al.* (1983, 1984) concluded that the polarizations observed in a number of broad-line radio galaxies were due to extinction by aligned dust grains.

The polarization of 3C 234 is probably too large to be explained by absorption by aligned grains. For galactic stars, $P < 9E(B-V)$ (Serkowski, Mathewson, and Ford 1975). Our suggested reddening then implies $P < 8\%$, compared with up to 11% observed and possibly as much as 17% if the contribution of unpolarized starlight is subtracted (Antonucci 1984). Moreover, the geometry applicable to 3C 234 is different from that for stars in that the absorbing dust is very close to the source. The result is that scattered light originally emitted in other directions is included in our beam and will tend to dilute the polarization even more.

The orientation of the polarization perpendicular to the radio axis (Antonucci 1983) is naturally explained by scattering. The line of sight from the radio lobes to the nucleus is presumably transparent to whatever initiated the radio emission. If it is also transparent to visible light, which is then scattered in our direction, the polarization would have the observed direction and could have considerable magnitude, as demonstrated by galactic sources where the structure can be directly resolved (e.g., Cohen *et al.* 1975). Since the narrow-line region must also have a clear line of sight to the center, it would be plausible if it were aligned with the radio structure. High-resolution images might show whether this geometry exists.

f) *Inferred Ionizing Power*

If the visible continuum in 3C 234 is nonthermal in origin, it might be expected to supply the ionizing radiation. The raw spectrum, without any of the assumptions about reddening that we have been making, is not sufficient to supply the ionization for even the narrow emission lines. At one recombination per ionizing photon, and 0.1 narrow-line Hβ photons per recombination, extrapolation of the $f(\nu) \propto \nu^{-2}$ spectrum in Figure 1 gives a flux in Hβ_n of 2.0×10^{-15} ergs cm^{-2} s^{-1} (for complete covering of the ionizing source), while the observed flux is 2.1×10^{-14} ergs cm^{-2} s^{-1}. Thus some additional source of ionizing radiation beyond the extrapolation of the visible spectrum is required. The presence of [Ne V] lines in the spectrum further requires that the ionizing spectrum be fairly hard.

The dereddened picture cures the ionization problem, however. The total Hβ flux of 2.2×10^{-13} ergs cm^{-2} s^{-1}, produced at the case B efficiency, would require $\nu f(\nu)$ at the Lyman edge ($\log \nu = 15.52$) to be $\sim 2 \times 10^{-11}$ ergs cm^{-2} s^{-1}. Figure 4 shows that sufficient flux would be available. If radiation transfer effects in the dense broad-line gas are important, even less flux would be required because such effects put extra energy into Hβ. Kwan and Krolik (1981) find the optically thick regions to be about 2.3 times more efficient than case B, so that the required $\nu f(\nu)$ is perhaps only 1×10^{-11} ergs cm^{-2} s^{-1}. This is still not low enough, however, for the observed continuum to produce the ionization if reddening is unimportant.

g) *X-Ray and Radio Continua*

The X-ray and radio continua of 3C 234 give two more points of comparison with other objects. The nuclear radio flux was measured to be 90 mJy at 5 GHz by Riley and Pooley (1975), and by VLBI measurements of Preuss and Fosbury (1983). The X-ray flux was measured from Einstein imaging proportional counter data (bandwidth 0.5–4.5 keV) by Feigelson and Berg (1983) and by Fabbiano *et al.* (1984). They give the monochromatic flux at 2 keV as 1.9×10^{-8} Jy and 4.0×10^{-8} Jy, respectively, the difference being due to different assumptions about the shape of the spectrum and the details of the image.

Fabbiano *et al.* (1984) show the distribution of the ratio of nuclear X-ray (2 keV) flux to nuclear radio (5 GHz) flux for their sample of 40 3CR radio galaxies and also for a quasar sample of higher luminosity. The radio systematically decreases with increasing luminosity, but for its radio luminosity 3C 234 is right at the bottom of the distribution, which peaks around the value $\log (f_x/f_r) = -5.3$, and extends from -6.4 (the value for 3C 234) to -5.0.

The X-ray and radio fluxes can be compared to the [O III] λ5007 flux to see whether the X-ray flux is low or the radio flux is high. For 3C 234, $\log (f_{[O\,III]}/\nu f(\nu)_{5\,GHz})$ equals 1.8, and we have shown that the observed [O III] flux is probably not much affected by reddening. For other objects, the ratio appears to decrease with radio luminosity, but a sample of six objects nearest 3C 234 in luminosity (out of 41 for which both fluxes have been measured) gives an average value $\log (f_{[O\,III]}/\nu f(\nu)_{5\,GHz}) = 1.7 \pm 0.5$. The objects compared were 4C 25.40, Ton 202, Ton 256, 3C 390.3, 3C 445, and PKS 2349−01, which are all broad-line radio objects. The [O III] fluxes were obtained from references tabulated by Steiner (1981) and the radio fluxes from Preuss and Fosbury (1983), Miley and Hartsuijker (1978), and Sramek and Weedman (1980). By this comparison, 3C 234 is not unusual. Also, our inferred flux for a dereddened Hβ line (broad plus narrow) gives $\log (f_{H\beta}/\nu f(\nu)_{5\,GHz}) = 1.8$ for 3C 234, whereas the average value for the seven comparison objects is 1.6 ± 0.5. This agreement was expected from the agreement of the dereddened Hβ/[O III] flux ratio with the average of other objects.

The comparison of optical line luminosity with X-rays shows that 3C 234 is underluminous in soft X-rays. Using data tabulated by Steiner (1981), supplemented by some further X-ray data from Fabbiano *et al.* (1984), we find that for an average over eight objects near to 3C 234 in X-ray luminosity, log $(f_{[\mathrm{O\,III}]}/\nu f(\nu)_{2\,\mathrm{keV}}) = -1.5 \pm 0.8$. Similarly, for the nine objects close to 3C 234 in [O III] luminosity, the value is -1.6 ± 0.7. For 3C 234 itself, log $(f_{[\mathrm{O\,III}]}/\nu f(\nu)_{2\,\mathrm{keV}}) = 0.0$. Thus both radio and optical comparisons suggest that 3C 234 is underluminous in soft X-rays. In this it is similar to Seyfert 2 galaxies (Kriss, Canizares, and Ricker 1980).

Halpern (1982) has analyzed X-ray spectra of many AGNs from 1.5 to 10 keV, including three narrow-line objects, NGC 2110, NGC 5506, and NGC 7582. All of these show considerable attenuation of the softer X-rays, implying column densities of 5.9×10^{22}, 4.3×10^{22}, and 8.0×10^{22} cm^{-2}, respectively. Their hard X-rays, however, have the same ratio to the [O III] lines and to the nuclear radio flux as does the average broad-line object.

If it is indeed an absorbing column of gas that is reducing the soft X-rays in 3C 234 by a factor of $10^{1.7}$ (= 50), the required column density would be 1–2 $\times 10^{23}$ cm^{-2}. This is just the range suggested by Kwan and Krolik (1981) for a typical broad-line cloud, and so it is a reasonable value to find if our line of sight passes right through one or more clouds. This is a much greater column density than would be associated with $A_V = 2.6$ for typical galactic conditions, but in active galactic nuclei like 3C 234 the gas-to-dust ratio may be considerably higher than is typical of galactic sources (Rudy and Puetter 1982).

IV. CONCLUSIONS

The observed flux of the Paschen-α line in 3C 234 is strong enough to rule out any explanation of the broad hydrogen line ratios that does not include substantial reddening. Our best estimate of this reddening is $A_V = 2.6$. In addition, our broad-band near-infrared observations indicate variability of 3C 234 in these wavelengths on time scales of one year or so.

All the observations on 3C 234 seem to be consistent with the picture of a nucleus emitting a continuum and broad lines, but blanketed by dust and gas in our line of sight. The agreement between the energy removed by reddening and the energy emitted in the infrared indicates that our line of sight is typical of a large solid angle. Conversely, a substantial solid angle about the source must be clear so that radiation may escape and provide the photoionization for the strong narrow-line spectrum.

An important new datum would be the measurement of the continuum of 3C 234 and similar objects at wavelengths beyond 20 μm to determine the total thermal luminosity. An integrating observation by the Infrared Astronomical Satellite (*IRAS*) should give very meaningful measurements or upper limits for a number of objects.

How common is it that reddening plays a major role in determining the observed properties of active galactic nuclei, as it does in 3C 234? Two other objects (3C 109 and 3C 445) measured by Elvis *et al.* (1984) show the same extensive steep continuum as 3C 234, and also have large broad-line Balmer decrements. The Paschen-α line has been measured in each of these (Kollatschny and Fricke 1981; Rudy and Tokunaga 1982), and in both objects all observations again seem consistent with the hypothesis that there is obscuring material near the nucleus. We shall discuss these and others in a subsequent paper.

On the other hand, measurements of Paα in one Seyfert 1.9 galaxy (V Zw 317) indicate that reddening is not absolutely required to explain the observed hydrogen line ratios (Rudy and Willner 1983). More measurements of Paschen α are urgently needed, since the ratios Hα/Hβ are too strongly influenced by radiative transfer effects to indicate the amount of reddening.

The question of the geometry of these objects (and of all AGNs) is of extreme interest. The only sub-arcsecond information that we now have is from radio VLA and VLBI mapping. Imaging in very good seeing (or, far better, speckle imaging) of nearby AGNs in the light of the [O III] line can provide spatial information to compare with the radio data.

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