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THE STRENGTH OF PASCHEN-ALPHA IN THE SEYFERT 1.9 GALAXY V ZWICKY 317[1]

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ABSTRACT

This *Letter* reports a measurement of the Paschen-α flux in the Seyfert 1.9 galaxy V Zwicky 317. Seyfert 1.9 galaxies are characterized by steep broad-line Balmer decrements, and V Zw 317 has the steepest decrement (Hα/Hβ = 15.1) of any member of this class yet studied. The Paα is less than one-sixth the case B value modified by reddening. Thus for the object, and possibly for the class as a whole, reddening alone cannot account for the observed line ratios. Radiative transfer effects are probably the dominant factor in producing the observed broad-line Hα/Hβ value. Recent models suggest that the required optical depths, temperatures, and densities in the broad-line region necessary to produce such a steep Balmer decrement are smaller than those thought typical for quasars.

Subject headings: galaxies: nuclei — galaxies: Seyfert — infrared: spectra

I. INTRODUCTION

Seyfert galaxies were originally classified as type 1 or 2, principally from the widths of their permitted lines (Khachikian and Weedman 1971, 1974). More recently, Osterbrock (1981) has noted that Seyfert galaxies display a "continuum" of behavior from type 1 to type 2. Among these intermediate Seyfert galaxies are the types 1.8 and 1.9. These galaxies display strong, broad emission at Hα which is weak or not readily detectable at Hβ, superposed on narrow-line spectra which are similar to those of type 2 Seyfert galaxies (Osterbrock 1981).

The most straightforward explanation of the broad-line spectra, and one advanced by Osterbrock, is that the regions from which the broad lines arise are heavily obscured by dust. This produces considerable differential extinction between Hα and Hβ, accounting for the steep Balmer decrement. If this explanation is correct, it has important implications about the energetics of these galaxies. Consider as an illustration the Seyfert 1.9 galaxy Markarian 423 which has a measured broad-line Hα/Hβ value of 9.9 (Osterbrock 1981). Assuming the intrinsic ratio is 2.85, the value given by recombination theory for $T = 10^4$ K, $n_e = 10^4$ cm^{-3} (Brocklehurst 1971), then an extinction of $E(B - V) = 1.2$ mag (assuming extinction follows that given for our own Galaxy by Savage and Mathis 1979) is necessary to produce the observed decrement. This corresponds to an extinction of a factor of 18 at Hα. Increasing the Hα flux measured by Osterbrock by this amount yields a line luminosity of 7×10^{42} ergs s^{-1} ($H_0 = 75$ km s^{-1} Mpc), placing Mrk 423 among the more luminous Seyfert 1 galaxies (Adams and Weedman 1975). In addition, Osterbrock attributed 36% of the flux in the continuum near Hβ to "featureless continuum" (presumably nonthermal emission) and the remainder to stars. If the nonthermal emission is extinguished by an identical amount as the broad emission lines with little or no extinction of the surrounding galaxy, then the stellar contribution, which is the majority of the observed flux, is only a small fraction of intrinsic emission at this wavelength. Thus, if the broad-line region in Mrk 423 is heavily reddened, there is a drastic modification of the galaxy's intrinsic properties, from that of a luminous Seyfert 1 with strong emission lines and a large nonthermal continuum to an object of modest line fluxes and a strong stellar continuum (and large thermal emission somewhere in the infrared).

In order to test the hypothesis that the steep Balmer decrements are produced by heavy obscuration of the broad-line region, we have searched for Paschen-α in the Seyfert 1.9 galaxy V Zwicky 317. This galaxy is the single object of the five galaxies observed by Osterbrock with a redshift sufficient to move Paα out of the telluric

[1]The research reported in this *Letter* is based on observations using the Multiple Mirror Telescope Observatory (MMTO), a joint facility of the University of Arizona and the Smithsonian Institution.

water vapor feature that precludes measurement of Paα in low-z objects.

II. OBSERVATIONS

The measurements of V Zw 317 were obtained on the night of 1982 October 10, UT, at the Fred Lawrence Whipple Observatory with the Multiple Mirror Telescope (MMT). The instrument used was the MMT Infrared Photometer, which incorporates a liquid-helium–cooled InSb detector and a circular variable filter (CVF) with a spectral resolution ($\Delta\lambda/\lambda$) of 0.01. The aperture size and chopper throw were 9″ and 16″ respectively.

Observations were made by combining the six separate images on a nearby bright star, then offsetting to the galaxy nucleus. The position of the source was initially determined by peaking the signal through a broad-band filter because the source was too faint optically to be visible. An entire spectral scan was obtained before returning to the star to recombine the images. The final data are the average of six spectral scans.

The spectrophotometric observations along with broad-band photometric observations at J, H, and K (1.25 μm, 1.65 μm, and 2.2 μm) are shown in Figure 1. The J, H, and K flux densities correspond to magnitudes of 14.08, 13.33, and 12.83 respectively.

III. DISCUSSION

Figure 1 shows the Paschen-α emission expected if the feature were to display the same line width as Hα and Hβ and were described by recombination theory and a galactic reddening law. This calculation is identical to the one outlined in § I using Osterbrock's (1981) broad Hα/Hβ value of 15.1 and an intrinsic Paα/Hα ratio of 0.12. The value of $E(B-V)$ calculated from Hα/Hβ is 1.6 mag, and the corresponding Paα flux is 1.8×10^{-13} ergs cm^{-2} s^{-1}. Our data indicate that, at most, no more than about one-sixth of this flux is actually present. In fact, the narrow component expected to be present but unresolved in our data can account for all of the observed flux. Thus, the observations do not support the hypothesis of a luminous, heavily obscured broad-line region (BLR).

The near-infrared colors also argue against high extinction. Although the $J-K$ color of 1.25 meets the criteria set by Balzano and Weedman (1981) for being a Seyfert galaxy ($J-K > 1.1$), about three-fourths of the Seyfert 1 galaxies have redder colors (Rudy, LeVan, and Rodriguez-Espinosa 1982). Although it is possible that the obscuration of the BLR is due to a localized region of dust along the line of sight which intercepts only a small fraction of the total nuclear emission, if the dust is uniformly distributed in or near the BLR it is likely to be quite hot, that is, $T > 1000$ K (Rudy and Puetter 1982). Such dust would radiate a sizable fraction of its emission in the near-infrared. This would result in very red $J-K$ and $H-K$ colors, contrary to what is observed.

Because of the observed Paα strength and the near-infrared colors, it seems likely that the steep Balmer decrement in V Zw 317 is not due to simple reddening of the BLR. This may be true for the steep decrements in two similar galaxies as well. The near-infrared hydrogen lines of the Seyfert 1.5 galaxy Mrk 6 and Seyfert 1.8 galaxy Mrk 372 are significantly weaker than can be explained by reddened case B values (McAlary and G. Rieke, private communication).

An alternate explanation to reddening is that the observed decrement in V Zw 317 is due at least in part to optical depth effects within the BLR. The existence of such effects would not be surprising in light of their importance in Seyfert 1 galaxies (Lacy *et al.* 1982), QSOs (Puetter *et al.* 1981; Soifer *et al.* 1981), and broad-line radio galaxies (Ferland *et al.* 1979). Extensive theoretical discussions of optical depth effects are present in the literature; just a few of the references are Kwan and Krolik 1979, 1981; Canfield and Puetter

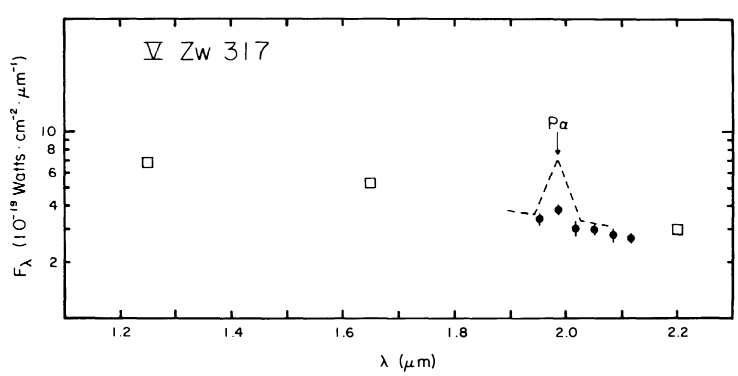

FIG. 1.—Spectrophotometric and photometric observations of V Zw 317. The squares denote the J, H, and K broad bands, while the dots are the narrow-band (CVF) points. The arrow shows the center of Paschen-α. The dashed line is the Paα flux expected if the spectrum were described by case B recombination theory and modified by reddening sufficient to produce the observed Hα/Hβ value.

1981*a*, *b*; Phillips 1978; Collin-Souffrin *et al.* 1979; and Netzer 1980. Canfield and Puetter (1981*b*) present a range of models for which, as the optical depth increases, the Balmer decrement increases from its case B value and may become as extreme as 25. It is only as the optical depth increases further that the Balmer decrement decreases back toward the case B value; for QSOs, it is at these optical depths that the models achieve agreement with the observations. The models vary such parameters as the temperature, density, and ionization, and there is a range of these parameters, rather than a unique set, which produce the steep Balmer decrements observed in the Seyfert 1.8 and 1.9 galaxies. However, the models which do so are characterized by lower temperatures ($< 10^4$ K), smaller densities ($\sim 10^8$ cm^{-3}), and smaller optical depths than the values predicted for the broad-line regions of QSOs.

The models of Canfield and Puetter (1981*a*, *b*) which produce large Hα/Hβ also predict Lyα/Hα in the range from 1 to 10 with the majority of the models yielding values near the upper end of this range. The intrinsic Lyα fluxes could be reduced considerably by dust in the narrow-line regions if the narrow-line regions veil the BLRs. The reddening values of these regions for the five galaxies in Osterbrock's (1981) sample are $E(B - V) \geqslant 0.42$. This corresponds to a differential extinction of $\geqslant 12$ between Lyα and Hα, if the Savage and Mathis (1979) reddening curve is applicable. Nevertheless, Lyα should be sufficiently strong to be detected in a few of the galaxies.

In summary, the Paα flux from the Seyfert 1.9 galaxy V Zw 317 is much smaller than would be expected if the broad emission line spectrum were described by simple recombination theory and reddening. This conclusion is supported by the comparatively blue near-infrared colors, which do not indicate a large amount of thermal dust emission. The steep Balmer decrement may result from a broad-line region with a smaller density, temperature, and optical depth than the broad-line regions in quasars. The models suggest that such a region is likely to be a fairly strong emitter of Lyα radiation.

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