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The Spectra of Dusty Quasars

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Abstract. Flat radio spectrum quasars from the Parkes half-Jansky survey show an enormous range of optical to near-IR colors. The spectra of these quasars suggest that this diversity is probably due to variable amounts of dust somewhere along the line of sight.

1. Introduction

Luminous optically selected QSOs have remarkably uniform continuum slopes in the rest-frame optical/UV (Francis 1996). The same is *not* true for radio-selected quasars with flat radio spectra (Webster et al. 1995). In Fig. 1, we show the distribution of observed-frame optical to near-IR colors ($B_J - K_n$; i.e., 0.44 μm to 2.1 μm) of radio-selected quasars from the Parkes flat-spectrum sample ($f_{2.7\,\mathrm{GHz}} > 0.5$ Jy, $\alpha > -0.5$, where $f_\nu \propto \nu^\alpha$; see Drinkwater's contribution). As a comparison, the colors of optically selected QSOs with comparable redshifts and absolute magnitudes drawn from the Large Bright QSO Survey (Hewett, Foltz, & Chaffee 1995) are also shown (from Francis 1996).

The optically selected QSOs have $B-K$ colors of ~ 2.5 (corresponding to a power-law continuum of the form $f_\nu \propto \nu^{-0.3}$). The bluest radio-selected QSOs have similar colors, but many are much redder.

Webster et al. (1995) noted this difference, and suggested that the range of colors shown by the radio-selected QSOs was caused by differing amounts of dust along the line of sight. The paucity of red optically selected QSOs could be caused by a lack of dust in radio-quiet AGN, but more plausibly it could also be a selection effect; any dust along the line of sight will drastically depress the observed-frame B-band fluxes, causing QSOs to drop out of an optical magnitude-limited sample. The dust might lie in intervening galaxies along the line of sight (Masci & Webster 1995), or in the quasar host galaxy. Note that the amounts of dust required are relatively small ($E(B-V) \approx 0.5$) compared to those normally invoked for obscuring molecular tori, and that the

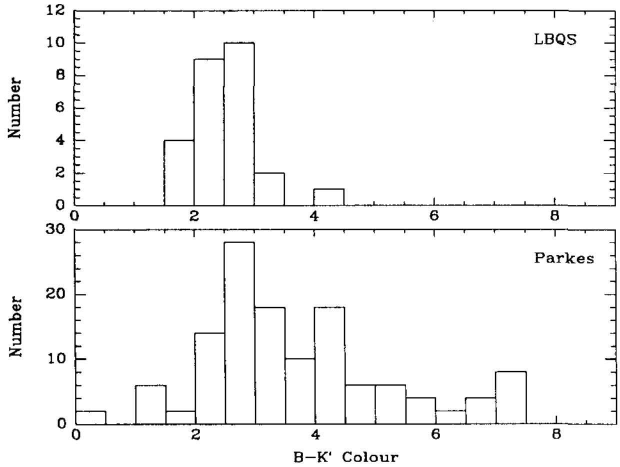

Figure 1. The distribution of $B-K$colors of optically selected (LBQS) and flat spectrum radio-selected (Parkes) quasars (red to the right).

torus is not expected to be anywhere near the line of sight in these flat-spectrum sources, according to unified models. The dust model has generated considerable controversy, as it implies that very large numbers of undetected dusty radio-quiet QSOs might exist, perhaps outnumbering all known QSOs.

Serjeant & Rawlings (1996) presented an alternative model. They note that flat-spectrum sources are thought to have their continuum emission (at least in the radio) enhanced by a relativistically beamed jet. They suggested that if the synchrotron emission from such a jet extended into the near-IR, and had a very red spectral energy distribution between the near-IR and optical, it could explain the red colors of some of the Parkes quasars. As this process is unique to radio-loud quasars, no population of red undetected radio-quiet QSOs is implied.

In this paper, we show that the spectra of the red Parkes quasars suggest that the dust model is the correct one.

2. Data

The Parkes flat-spectrum survey consists of 323 sources, of which 321 are currently identified, and 277 have measured redshifts (Drinkwater et al., these proceedings). We have spectra of 206 of these; some from the compilation of Wilkes et al. (1983), and others from our own observations on the AAT and Siding Spring 2.3-m (Drinkwater et al. 1996). Published spectra of this sample are strongly biased towards the bluest, optically brightest quasars, but when combined with our data on the fainter, redder objects, the resulting sub-sample is unbiased. A paper on this sample and its spectral properties is in preparation.

3. Tests

The dust and synchrotron models make different predictions for the optical continuum slopes, emission-line ratios and emission-line equivalent widths of the Parkes quasars.

3.1. Continuum Slopes

A substantial majority of the red Parkes quasars show quite normal broad emission lines. This implies that these objects have a blue photoionizing continuum, albeit one that is either reddened or swamped in the K-band by a red synchrotron component. If dust is responsible for the red $B-K$ colors, the continuum we observe in the spectra is an intrinsically blue one (as seen in optically selected QSOs) absorbed by some dust law. For any realistic dust law, the optical continuum will be at least as red as a power-law extrapolated from K through to B, and probably redder. If, on the other hand, the red $B-K$ colors are caused by a red synchrotron emission component, the optical spectra will be the combination of the short wavelength tail of the synchrotron component and the underlying blue photoionizing continuum. The optical continuum slope will thus be bluer than a power-law extrapolated from K through to B.

Our observations show that the optical continuum slopes, as measured from the spectra, are systematically slightly redder than a power-law extrapolated from K to B — evidence for the dust hypothesis.

3.2. Line Ratios

Possibly the most direct test of the dust model would be to look for correlations between continuum redness and emission-line ratios. Unfortunately, most of our spectra, especially of the reddest sources, have low signal-to-noise ratios, so only a few strong lines can be measured. The ratios of C IV/C III] and C III]/Mg II both anticorrelate with the continuum redness, as predicted by the dust model, but the scatter around both correlations is so large that the data is also marginally consistent with no correlation, as predicted by the synchrotron model. Line ratios are thus inconclusive.

3.3. Equivalent Widths

If the redness is caused by dust, and the dust has a scale length larger than the BLR, the continuum and emission-lines will be reddened equally, and the equivalent widths will thus be independent of continuum slope. If, however, the redness is caused by the addition of a red synchrotron continuum component, this component will raise the continuum without affecting the emission lines, resulting in a very strong anti-correlation between equivalent width and continuum redness.

As Fig. 2 shows, the equivalent width of Mg II does not anticorrelate with continuum redness. The few sources with $\alpha \approx -2$ and equivalent widths < 20 Å may be the beamed equivalents of the blue quasars with $\alpha \approx -0.3$ and equivalent widths ~ 50 Å, but most of the red objects have quite substantial equivalent widths, in clear contradiction of the synchrotron model. Lyα, C IV, and C III] behave similarly (the forbidden-line equivalent widths actually *correlate* with

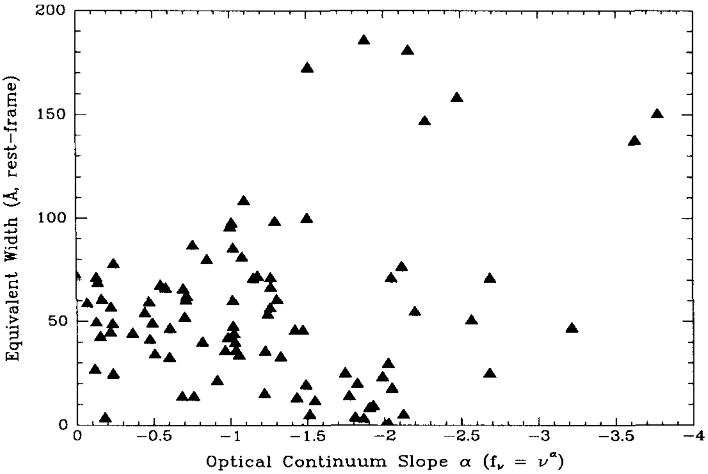

Figure 2. Mg II λ2798 rest-frame equivalent widths as a function of optical continuum slope (red to the right). BL Lacs are included in the plot, and have equivalent widths near zero.

redness, perhaps due to patchy dust obscuration; see Drinkwater et al., these proceedings).

4. Conclusions

On the basis of our three tests, it appears that the dust model explains the data better than the synchrotron model, though the latter may apply to a minority of our sources, the classical BL Lacs. If these radio-loud quasars are dusty, it seems quite probable that many radio-quiet QSOs are also hidden by dust, and thus that optical QSO surveys are seriously incomplete.

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