THE INFRARED SPECTRA OF QUASARS - A LUMINOSITY DEPENDENCE

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The IR-optical-UV continua of quasars are often represented by two components: (i) a flat spectrum component dominating in the optical-UV (the "Big Bump") and sometimes attributed to thermal radiation from an accretion disk with temperatures of about 20000 to 40000 K - we will call it the "disk" component - and (ii) a near IR component characterized by a steep rise, $\alpha \sim 1$ for $\lambda > 1$ μm, often thought to be a synchrotron spectrum - an extrapolation of the cm or mm wavelength radio spectrum - although some have preferred an explanation in terms of thermal re-radiation of the ionizing continuum by hot dust (e.g., Hyland and Allen 1982, Neugebauer et al. 1979).

We have undertaken a survey of the near IR spectra of about 40 optically bright radio quasars ($< 17^m$) with redshifts < 1.3, using the NASA-University of Hawaii IRTF 3.0 m telescope. We have measured most quasars between 1.25 and 5 μm, and many at 10 and 20 μm. The rms uncertainties range from 3 to 6 % at 1.25 to 2.2 μm, and increase with wavelength. We have combined these with IRAS data, where available, at 12, 25, 60 and 100 μm (although these observations were often not simultaneous with the near IR). The IR spectra of the optically violent variable (OVV) quasars, when bright, are like the BL Lac spectra, with a variable power-law spectrum in the near IR ($0.8 < \alpha < 2$) and are well studied by others also. Here I report results for the non-OVV quasars.

The near IR spectra are remarkably similar from one quasar to another. Typical spectra are shown in Fig. 1. F_ν vs. ν is plotted in the upper panels. In 16 of 22 non-OVV quasars **the spectra between rest wavelengths 1.5-3 μm have α = 1.7** within ±0.2 and 4 others are consistent with this but have larger uncertainties. This is much steeper than the canonical $\alpha \sim 1$. The lower panels show the same data plotted as the power per unit logarithmic frequency interval (νL_ν) as a function of ν. They show that **the near IR power output peaks between 3 and 3.5 μm.** (Neugebauer et al. (1979) show this '3 μm bump' for the quasar 3C273). The power in this IR component is about the same as the sum of the power emitted in the broad emission lines.

This similarity in the shape of quasars' spectral energy distribution has been noted before for the optical-UV continua > 1200 A (e.g., Soifer et al. 1983) and suggests that the spectral components are

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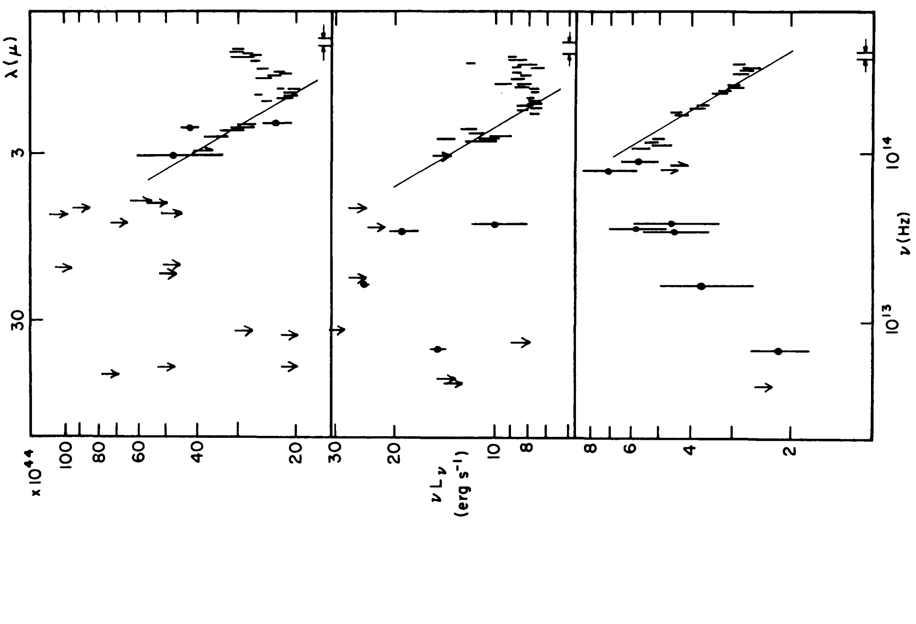

Figure 2. Composite spectra representing different average luminosities.

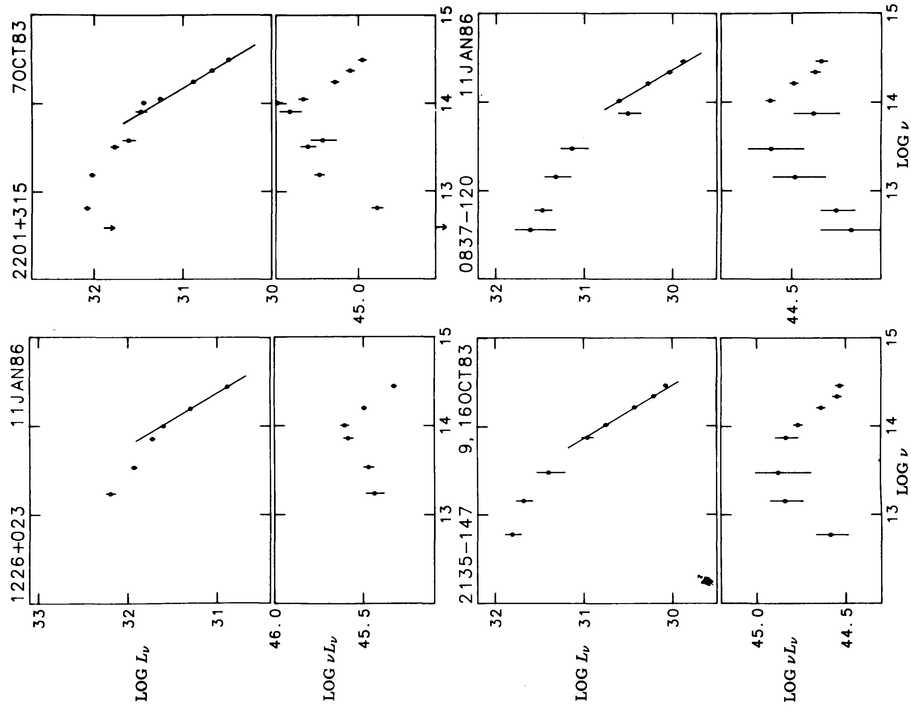

Figure 1. Typical IR spectra for non-OVV quasars. A power-law of α = 1.7 is shown in each upper panel. Cgs units are used, frequencies are in the rest frame and error bars are ± 1σ.

also very similar. Addition of a BL Lac-type power-law spectrum would destroy the observed similarity, so its contribution must be small.

The 3 μm bump may be either free-free emission from high density gas, $n_e \sim 10^{11}$ cm^{-3} (Puetter and Hubbard 1985), or thermal radiation from dust at 1200 K heated by the strong optical-UV continuum. This is close to the expected evaporation temperature of the grains, and nicely explains the similar spectra.

Figure 3 shows composite spectra for non-OVV quasars plotted on a rest wavelength scale, and for three luminosity ranges. Luminosity is defined at 1 μm and we use H_0 = 100 km s^{-1}Mpc^{-1} and q_0 = 0. The spectrum in the lower panel is representative of 12 low luminosity quasars of which 4 are shown. The middle panel combines 6 spectra, and the upper panel, 7. Compare the spectra at λ_0 = 1 μm. **The relative strength of the disk component** (with $\alpha \sim 0$, a slope of +1 on this plot) **increases with increasing 1 μm luminosity**. Extrapolating the 1.7 slope to 1 μm we can roughly separate the "3 μm component" and the disk component. If we assume a power law relation between the strengths of the two components we find

$$L_\nu(3\ \mu\text{m component}) \propto L_\nu(\text{disk})^{+0.5}$$

Interestingly this is somewhat reminiscent of the Baldwin relation between the strength of the CIV λ1549 line and the underlying continuum- the continuum of the same disk component to which we are referring here.

Explanations for the luminosity dependence may be the same as those proposed for the Baldwin effect, i.e., differences in the disk continuum- either the result of time-variability or different inclinations of the disk to the line-of-sight (Netzer 1985, and references therein).

A more detailed account of this work may be found in Wills (1986).

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DISCUSSION

ROWAN-ROBINSON: If the 3μ feature is to be interpreted as radiation from dust then from the narrow width of the feature we can deduce that the dust must be in the form of a shell of rather narrow linear extent (it can also not have very high optical depth in dust). For dust located at a fixed distance from the central source, we would also expect a significant variation in the spectrum with the luminosity of the quasar. For a very luminous quasar, the dust may be totally destroyed and the 3μ feature might be expected to disappear.