WIRE 'Filler' Proposal: Mid-Infrared Colours of the "Reddest" Quasars

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Summary

I am proposing WIRE filler observations of a number of radio-quasars at 25 and 12μm. The class of quasars to be studied have extremely red optical–to–near-infrared colours, very unlike those of normal quasars selected optically. We have claimed that the red colours are due to extinction of the optical-UV continuum by dust intrinsic to the sources. Our previous studies suggest that such dust should also give rise to a thermal emission signature peaking in the mid-infrared. This emission is expected to modify the observed 25-12μm colours of these sources. Those with the reddest optical colours (with presumably greatest dust extinction) are predicted also to be 'reddest' on average in $25 - 12\mu$m colour. Most of our quasars are predicted to have 25μm flux densities 0.001 to 0.1 Jansky, well below the sensitivity limits of previous infrared surveys. WIRE's bandpasses and its contemporaneous imaging at these wavelengths will be well suited for this project.

Background

A recent near-IR (K-band) and optical imaging study of a complete sample of bright radio-quasars (The Parkes Half-Jansky Flat Spectrum Sample; Drinkwater *et al.* 1997) has revealed that a large fraction are unusually red in optical-to-near-IR colour (Webster *et al.* 1995; Masci *et al.* 1998). A broad and flat distribution in colours with $2 \leq B - K \leq 10$ as compared to $B - K \sim 2.3$ for an optically-selected quasar sample was found. Spectroscopic observations reveal that this same fraction are also red in optical-UV continuum slope. These quasars are far redder and fainter optically than any previously known and suggests that existing optical surveys may be severely incomplete.

The principal question we have been investigating is the following: What is the physical mechanism responsible for the extreme reddening observed in $B-K$ colour for these quasars? There are two competing theories: The first and most favoured mechanism prior to our deep optical follow-up studies was that the red colours were due to "intrinsically red" synchrotron emission dominating in the near-IR. This component may be characteristic to such sources, possibly associated with an enhancement of emission from a relativistic jet directed close to the line-of-sight (Rieke, Lebofsky & Wisniewski, 1982; Serjeant & Rawlings, 1996).

The second mechanism, motivated by our new observations, is that the relatively red colours are due to extinction of the optical-UV continuum by dust. This hypothesis is strongly supported from our recent analysis of the optical spectral line and optical–to–soft X-ray continuum properties of these sources (Webster *et al.* 1995; Masci *et al.* 1997; Masci *et al.* 1998). The data favours a mechanism where the high frequency (optical-UV) emission must be depressed relative to the near-IR. We claimed that reddening by dust offered the best and simplest explanation.

Our analysis suggested that the amount of extinction required to explain the observed reddening is typically $\langle A_V \rangle \simeq 2$ mag ($E_{B-V} \sim 0.5$), considerably smaller than that invoked for obscuring molecular tori in AGN. This however is fully consistent with unified models for radio-loud AGN, since our line-of-sight to the central AGN in flat-spectrum radio quasars is not expected to intercept a torus. The data argues in favour of an 'optically thin' (and possibly hot) diffuse dust component dominated by small grains, similar to that invoked for diffuse HII regions of the local ISM.

This Project

To further test the dust hypothesis, we plan to search for a thermal emission signature expected from reprocessing in some of our reddest sources. For dust that is distributed on scales comparable to the narrow-line emitting region where typically $R \sim 0.1-1$kpc, thermal emission from 'optically thin' dust is expected to peak at wavelengths $\lambda \sim 20-50\mu$m in the rest frame, corresponding to effective temperatures: $50 \lesssim T \lesssim 200$K. Since WIRE will observe at bandpasses centered on $\sim 12\mu$m and $\sim 25\mu$m, we will attempt to explore this signature indirectly using the broad-band $25-12\mu$m colours alone. For dust distributed on scales $\gtrsim 0.5$kpc and heated by a typical quasar continuum $L_{UV} \simeq 10^{46}\mathrm{erg\,s^{-1}}$, thermal emission will peak most strongly at $\sim 50\mu$m (eg. Sanders *et al.* 1989). This implies that we will be sampling the high frequency (Wien) limit of the blackbody spectrum, and for sources at high redshifts ($z \gtrsim 1$), we will be observing even shorter rest frame wavelengths.

If thermal dust emission was the dominant emission mechanism in these sources, then due to the steepness of the radiation spectrum at $\lambda \lesssim 25\mu$m, we would expect to observe extremely red $25-12\mu$m colours. For example, the log of the ratio of flux densities at these wavelengths for a pure thermal spectrum will scale as:

$$\mathrm{Log}\left[\frac{F_\nu(25\mu\mathrm{m})}{F_\nu(12\mu\mathrm{m})}\right] \simeq 2.7(1+z)\left(\frac{T_d}{100\mathrm{K}}\right)^{-1} - 0.9$$

A 'pure' thermal radiation spectrum from dust however is unlikely to dominate the observed mid-IR continuum in radio-quasars since they are also known to exhibit significant amounts of non-thermal emission at those wavelengths. Signifcant levels of *polarised* emission, believed to be synchrotron in origin has been detected in the near-IR and is also expected at longer (mid-IR) wavelengths. This component is often in the form of a power-law and is relatively flat in νf_ν. Allowing for this inevitable contamination of non-thermal emission, we can nonetheless still infer the presence of an underlying 'steep thermal' spectrum in the mid-IR. Such a component will be superimposed on any non-thermal emission, therefore causing on average, a steeper overall radiation spectrum.

The basis of this experiment therefore predicts that quasars with the 'reddest' optical continua, indicative of significant extinction by dust, should also on average display the reddest 25-12 colours. This is primarily due to the presence of a steep thermal emission spectrum emitted from the same dust component. For comparison, quasars that are 'bluest' in the optical (with little or no extinction) should then have 25-12μm colours that are bluer on average.

This project will provide a definitive test of the dust reddening hypothesis in our sample of radio quasars and thus strengthen the claim that a large fraction of radio-quiet quasars have been missed in optical surveys due to extinction by dust.