Selecting AGN from the WIRE Deep Survey

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The following ideas are very much qualitative. Due to some uniformity in the properties of currently known AGN (both types I and II) as compared to normal starbursts, these diagnostics may provide a first cut at selecting potential candidates.

1 R-band Imaging and WIRE?

1.1 Type I AGN:

Emission from face-on torus (with warm dust visible) strongly peaks within 3-20μm where spectra are relatively flat in νf_ν (eg. Pier & Krolik '92). There is also strong evidence that 12μm luminosity (warm dust) strongly correlates with bolometric luminosity (eg. Pier & Krolik '92; Spinoglio & Malkan '95). This means that towards high z, Malmquist bias and selection at 12μm will bias us in favour of luminous AGN at short rest wavelengths, and hence warm 25/12 colours. The colours expected should lie within $0 < \log(f_{25}/f_{12}) < 0.5$ as observed for PG QSOs (Sanders et al.) and IRQSOs (selected with blue 60/25 colours) from Cutri et al. Note that most of these QSOs are at $z < 0.2$.

Given $f_{25} \simeq 0.8$mJy for WIRE and $\log(f_25/f_R) \simeq 1.5$ from optically selected quasars, all existing optical QSOs to $R \simeq 21.5$ mag should be detected by WIRE. Thus, with Palomar Imaging to $R \simeq 25$ mag, we should in addition be able to detect QSOs with extinctions of up to $A_R \simeq 3.5$ mag (observed frame), or $A_V \simeq 3$ mag (rest frame for $z \lesssim 1.5$.)

Can further explore effects of extinction using a simple model: If we add extinction by optically thin dust (eg. spherical distribution of $\sim 1kpc$ radius) around optically detected QSOs, its emission will peak at 25μm in the rest frame. As shown in the attached figure 1, we expect that at low z ($z < 0.5$), both 25/12 and 25/R ratios will be red, but at $z > 1$, we should find that 25/12 will become blue and 25/R redder due to increased extinction in optical in observed frame. However, this is a very simple model which assumes a single temperature. Realistically, we expect a mix of temperatures throughout this dust distribution, which will have the affect of broadening and flattening the blackbody emissivity curve about 25μm rest frame. Thus, its more likely that we'll observe blue 25/12 and red 25/R colours for type-I AGN at all redshifts $z \gtrsim 0.2$.

Will stars be a problem? First guess at avoiding these can be done by avoiding regions with $\log(f_{25}/f_{12}) < -0.1$ and $\log(F_{25}/F_R) < 0$ (eg. Shupe et al.'98; Clements et al. '99).

1.2 Type II AGN:

It will be very difficult to distinguish these from Luminous starbursts using 12, 25 and R-band fluxes alone. Emission from near edge-on torus is red in 25/12 and overlaps significantly with those of starbursts as observed for at least nearby Seyfert IIs.

Best strategy: From torus models, can select extreme cases where we have the "coldest" tori (eg. most edge on systems with no hot dust visible). These will also be very red in $25/R$ colour due to heavy optical extinction in the rest frame. High z sources will also be reddest in $25/R$ since stellar emission will not dominate in the optical. From existing semi-empirical models, we should confine our selection to $\log(25/R) > 3$, $\log(25/12) > 1$ (eg. upper right corner of figure 1).

These are expected to (hopefully) be similar to existing ULIG-like sources. To determine then whether these are actually starburst or AGN driven is another question. Perhaps X-rays (see secton 4), radio (section 2), or near-IR spectroscopy (or optical if not too faint) can provide a clue.

2 Radio (20cm or other) and WIRE?

Due to torus emission peaking strongly in mid-IR, we know that most AGN (**both** types I and II) are separable from Starbursts in f_{60}/f_{25} color. We also know of the strong correlation between L_{radio} and L_{60} for starbursts and ULIGs with or without embedded radio quiet AGN. We're also familiar with the strong evidence that SB processes are the prime driver for this correlation.

If a Radio-Quiet! AGN is present and the orientation of the toroidal dust distribution is such that its observable, it will contribute an excess at 12 or 25 μm. This emission is expected to be independent of f_{radio} dominated by SB processes. Thus, it's possible that the f_{radio}/f_{mid-IR} ratios can be smaller than the average SB value if radio-quiet AGN contribute an excess in the mid-IR. In other words, can we confidently say that $f_{radio}/f_{25} \propto f_{60}/f_{25}$? If so, it would then be a simple task to select AGN using blue (relatively small) f_{radio}/f_{mid-IR} ratios.

Some extreme cases are expected: There'll be sources with unusually large f_{radio}/f_{mid-IR} ratios, much larger than that allowed by a pure starburst. Thus, their radio emission must be dominated by a central radio-loud AGN (or classical radio galaxy) (eg. Condon '95).

3 Near-IR (J,H,K) and WIRE?

For WIRE's limits $f_{12} > 0.3$mJy, $f_{25} > 0.8$mJy and the ratios $f_{12}/f_K < 8$, $f_{25}/f_K < 18$ for quasars at all observable z (eg. Sanders '89), we need to go as faint as $K \simeq 18.5$, $H \simeq 19.5$ and $J \simeq 20$.

As hinted by Spinoglio et al. '95, its possible to separate type Is and some type IIs from SBs on a $25/K$ versus $H - K$ (or $12/H$) plot. Since starbursts have a peak at H (from red giant photospheres) they are bluer in $H - K$ (or $12/H$) than AGN dominated emission which peaks in the mid-IR–to–K and hence are redder in $H - K$. Note this may only hold at low z where stellar emission can domintate.

At high z ($z \gtrsim 1$), observed stellar emission will not be as strong, also, K-corrections together with extinction will steepen $H - K$ (or $12/H$) for SBs. For AGN (with type-I orientation visible), there should be a contribution at 12 or K due to hot dust, making $H - K$ (or $12/H$) much redder. Extinction will also add to this reddening.

Hence, best strategy for selecting type I's at most redshifts: Select them using red $H-K$ (or $12/H$) and blue $25/(12 or K)$. At low z, SBs will have bluer $H-K$ (or $12/H$), and redder $25/12$ colours. At high z, SBs will be red in both $H - K$ and $25/12$. Type II's will be difficult to separate from SBs (but, see sect. 1).

We can also combine these colour criteria with the radio/mid-IR ratio discussed in section 2 or involving the optical passband (section 1).

4 Hard X-rays and WIRE?

Have the ratios: $\log(f_{12}/f_{5kev}) < 6.5$ for RQQs (from Elvis et al.) (smaller for RLQs) and $\log(f_{12}/f_{5kev}) > 8$ for SBs. (eg. Schmitt et al. '97).

XMM or AXAF sensitivity: $F(0.1 - 15keV) > 10^{-16} erg\, s^{-1} cm^{-2}$. With above ratio for RQQs and $f_{12} > 0.3$mJy, implies that most RQQs will be safely detected down to $F(0.1 - 15keV) \simeq 5 \times 10^{-15} erg\, s^{-1} cm^{-2}$.

At high z, observed mid-IR corresponds to short rest wavelengths, which will suffer greater extinction and observed X-rays correspond to harder radiation, thus they will suffer less extinction. Therefore, expect ratio f_{mid-IR}/f_{5kev} to decrease with inc. z if extinction is severe as in type II AGN. It's predicted that extinctions of up to $A_V \simeq 60$ mag can be probed with hard X-rays and WIRE.

Strategy would then be to select AGN from small mid-IR/X-ray ratios and other ratios such as 25/12 (see section 1) or radio/mid-IR (see section 2).