Resolved mid-IR emission as an isotropic luminosity probe in AGN at all powers

We present results from a program of imaging AGN in N-band filters with the VLT/VisIR instrument. We have previously found a strong correlation between mid-IR (12.3 μm) and 2-10 keV intrinsic X-ray luminosities for local Seyferts: \( L_{\text{IR}} \propto L_{\text{X}}^{1.1 \pm 0.07} \), with a small scatter in luminosities. We now show that extension to both low and high powers conserves this correlation. The fact that unobscured, obscured and Compton-thick sources all closely follow the same luminosity correlation, both in the low-luminosity and in the quasar regimes, has important implications for the structures of AGN cores. The typical resolution-limit of our imaging corresponds to ~70 pc at a median \( z = 0.01 \), and comparison with Spitzer spectroscopy proves that we are resolving out most of the emission from surrounding starbursts. This suggests that uncontaminated mid-IR continuum imaging of AGN is an accurate proxy for their intrinsic power, and we derive various intrinsic AGN spectral parameters, such as Bolometric luminosity conversion factors and broad-band spectral indices.

1. Aim.
X-ray luminosities are regarded as accurate isotropic proxies of the intrinsic powers of AGN. Our aim is to investigate whether the mid-IR luminosity may also be a similarly good probe of the inner AGN power.

2. Our Survey
14 Seyfert 1 - 1.5
37 Seyfert 1.8 - 2
10 LINERs
incl. 13 Compton-thick (\( N_{\text{H}} > 1.5 \times 10^{24} \text{ cm}^{-2} \))

Imaged in N-band continuum filters around 12.3 μm with VLT/VisIR (diffraction-limited @ 0.35 resolution)

X-ray intrinsic luminosities were carefully selected from the literature. Good available X-ray measurements were a primary selection criterion.

3. \( L_{\text{MIR}} \) vs \( L_{\text{X}} \) correlation

- The histograms above show the small dispersion in \( \log (L_{\text{MIR}}/L_{\text{X}}) \):
  - Pink crossed region: 15 best-resolved Compton-thin sources showing smallest dispersion;
  - Black hatched region: all 22 best-resolved sources;
  - Unfilled dashed outline region: all our 42 sources.

- Compare these with the broader distributions of
  - Light-blue hatched region: \( \log (L_{\text{MIR}}/L_{\text{X}}) \) from Lutz et al. (2004) ISO data;

- Our small dispersion \( \Rightarrow \) starbursts are not significantly biasing the cores that remain unresolved with the VLT, i.e. Our observations are dominated by the AGN themselves.

- Comparison with Spitzer IRS spectroscopy shows much lower mid-IR fluxes with VisIR in many cases, proving that we are resolving out the bulk of extended star formation occurring on scales which cannot be resolved by Spitzer. See Fig. on right for NGC 4261. Green points are our VisIR fluxes, solid curve is IRS spectrum.

4. Small dispersion in the correlation

5. From Sy to Quasars

- We compared luminosities from our Gandhi et al. sample to the ISOCAM survey of Lutz et al. (2004) which includes quasars as well as ULIRGs. See Fig. on right.

- We find that type 1 quasars smoothly fall onto our correlation line. Thus, our results can be extended to quasar luminosities. ULIRGs (luminous AGN 2 in the plot on the right) deviate from our correlation line, probably due to strong contamination from powerful ongoing star-formation.

6. Bolometric luminosity estimation

- Marconi et al. (2004) have derived a relation between \( L_{\text{IR}} \) and \( L_{\text{X}} \). We can combine this with our \( f_{\text{MIR}}/f_{\text{X}} \) relation to derive mid-IR bolometric correction factors (\( f_{\text{MIR}} \)). See Fig. on right.

- We find \( f_{\text{MIR}} \) varies over 10-30 for Seyferts.

This is very useful to obtain total AGN power from mid-IR observations. The corresponding power-law intrinsic spectral index between rest-frame 2 keV and 12.3 μm \( (\alpha_{\text{MIR}} = 1.10 \pm 0.01) \) (cf. Vignali et al. 2003).

References
Ballantyne D. R. 2000 A&A 365 797
Hoenig S. et al. 2006 A&A 438 459
Horst H. et al. 2003 A&A 372 L15
Lutz et al. 2004 A&A 420 306
Vignali C. et al. 2003 A&AS 141 433

\( L_{\text{MIR}} \) is the X-ray luminosity of the intrinsic luminosity. Solid line is fit to all 48 detected AGN sources. Outlined line is corrected fit to all.

- Our full sample of 61 sources shows a strong \( L_{\text{IR}} \) vs \( L_{\text{X}} \) correlation above.
- The relation for all 48 detected AGN sources, irrespective of spatial resolution, is

\[
\log L_{\text{MIR}} = (0.41 \pm 0.03) + (1.12 \pm 0.04) \log L_{\text{X}}
\]

where the luminosities in the equation are expressed in units of \( 10^{44} \text{ erg s}^{-1} \).

- Sy 1, Sy 2, Compton-thick ALL closely follow the same correlation, which is not predicted by smooth dust torus models. Clumpy torus models are instead preferred (e.g. Hoenig et al. 2006).