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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: $L_{MIR} \propto L_{X\text{-}ray}^{1.11\pm0.07}$, 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.

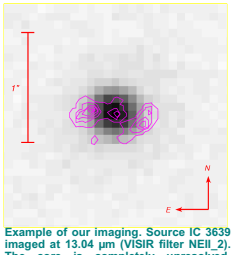
2. Our Survey

14 Seyfert 1 - 1.5
37 Seyfert 1.8 – 2
10 LINERs
incl. **13** Compton-thick (N_H>1.5x10^{24} cm^{-2})

imaged in *N*-band continuum filters around 12.3 μm with VLT/VISIR *(diffraction-limited @ 0".35 resolution)*.

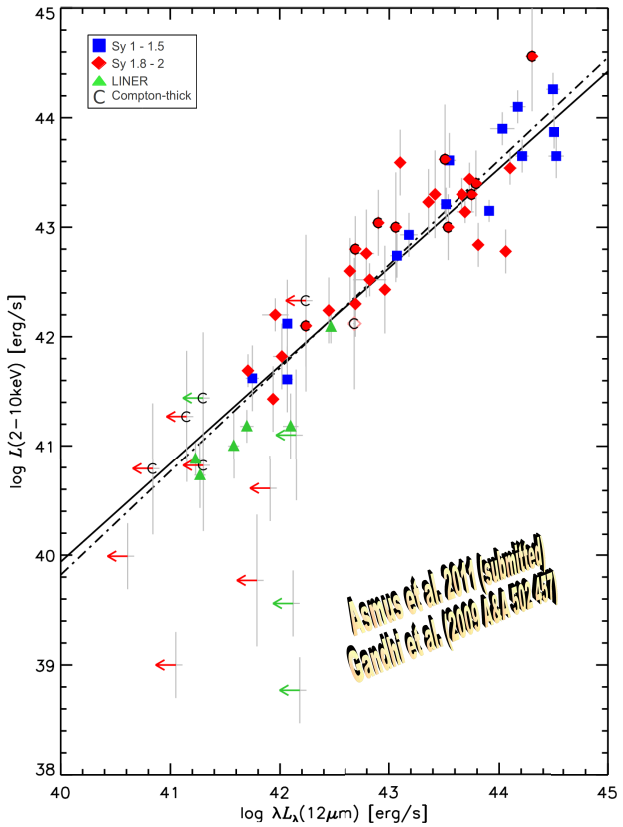
X-ray intrinsic luminosities were carefully selected from the literature. Good available X-ray measurements were a primary selection criterion.

Our imaging was carried out with VLT/VISIR in filters probing source continuum around 12 μm.



Example of our imaging. Source IC 3639 imaged at 13.04 μm (VISIR filter NEII_2). The core is completely unresolved, compared to star-forming knots seen as the magenta contours (created from HST archival images).

3. L_{MIR} vs L_X correlation



Luminosity correlation for all 61 sources of our sample. L_X=$L_{2\text{-}10}$ refers to intrinsic luminosity. Solid line is fit to all 48 detected AGN sources. Dot-dash line is censored fit to all.

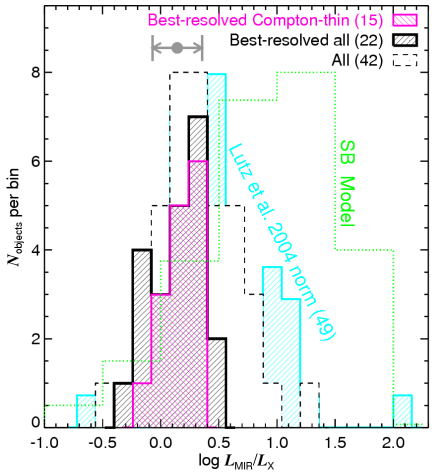
- Our full sample of 61 sources shows a strong L_{MIR} vs. L_X correlation above.
- The relation for all 48 detected AGN sources, irrespective of spatial resolution, is

$$\log L_{MIR} = (0.41\pm0.03) + (1.12\pm0.04) \log L_X$$

where the luminosities in the equation are expressed in units of 10^{43} 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).

4. Small dispersion in the correlation



Histograms of log-luminosity ratio (L_{MIR}/L_X), showing the very small scatter in our correlation.

- The histograms above show the small dispersion in log (L_{MIR}/L_X):

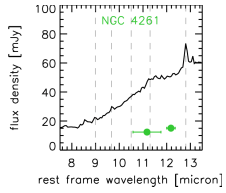
  - Pink crossed region: 15 best-resolved Compton-thin sources showing smallest dispersion;
  - Black hatched region: all 22 best-resolved sources;
  - Unfilled dashed outline region: all our 42 sources.

- Compare these with the broader distributions of

  - Light-blue hatched region: log(L_{MIR} [6 μm]/L_X) from Lutz et al. (2004) *ISO* data;
  - Green dotted histogram: Nuclear starburst model prediction from Ballantyne (2008).

- Our small dispersion => 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.

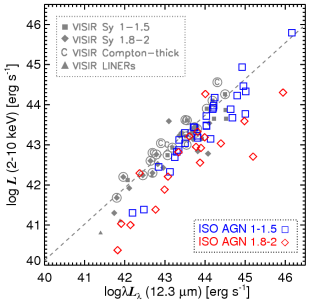


5. From Sy to Quasars

- We compared luminosities from our Gandhi et al. 2009 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 on-going star-formation.

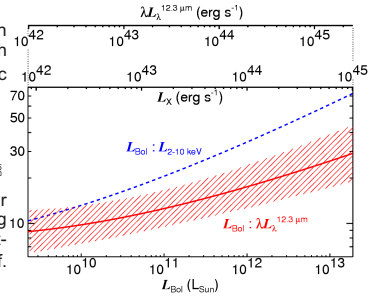


6. Bolometric luminosity estimation

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

- **We find f_{Bol} 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 (α_{IX})=-1.10±0.01 (cf. Vignali et al. 2003).



References *Ballantyne D. R. 2008 ApJ 685 787* *Gandhi P. et al. 2009 A&A 502 457* *Hoenig S. et al. 2006 A&A 452 459* *Horst H. et al. 2008 A&A 479 389* *Lutz et al. 2001 A&A 372 L25* *Vignali C. et al. 2003 AJ 125 433* **References**