New insights on nuclei of nearby galaxies from high angular resolution mid-IR observations

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International Top Young Fellow

with

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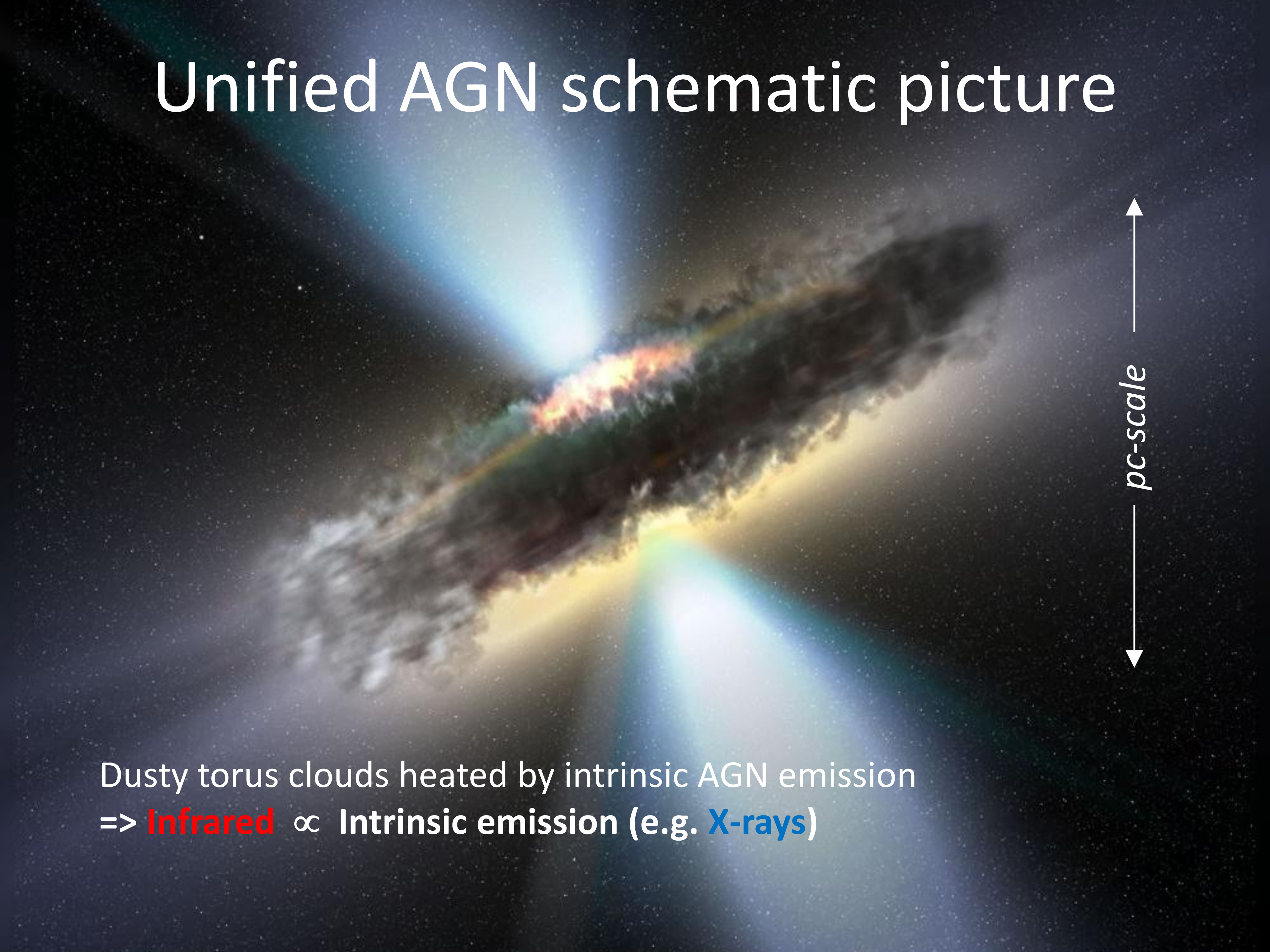
A. Comastri, R. Gilli, C. Vignali, R. Vasudevan

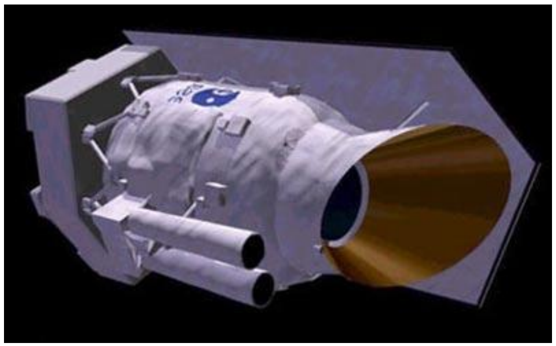
Unified AGN schematic picture



Dusty torus clouds heated by intrinsic AGN emission

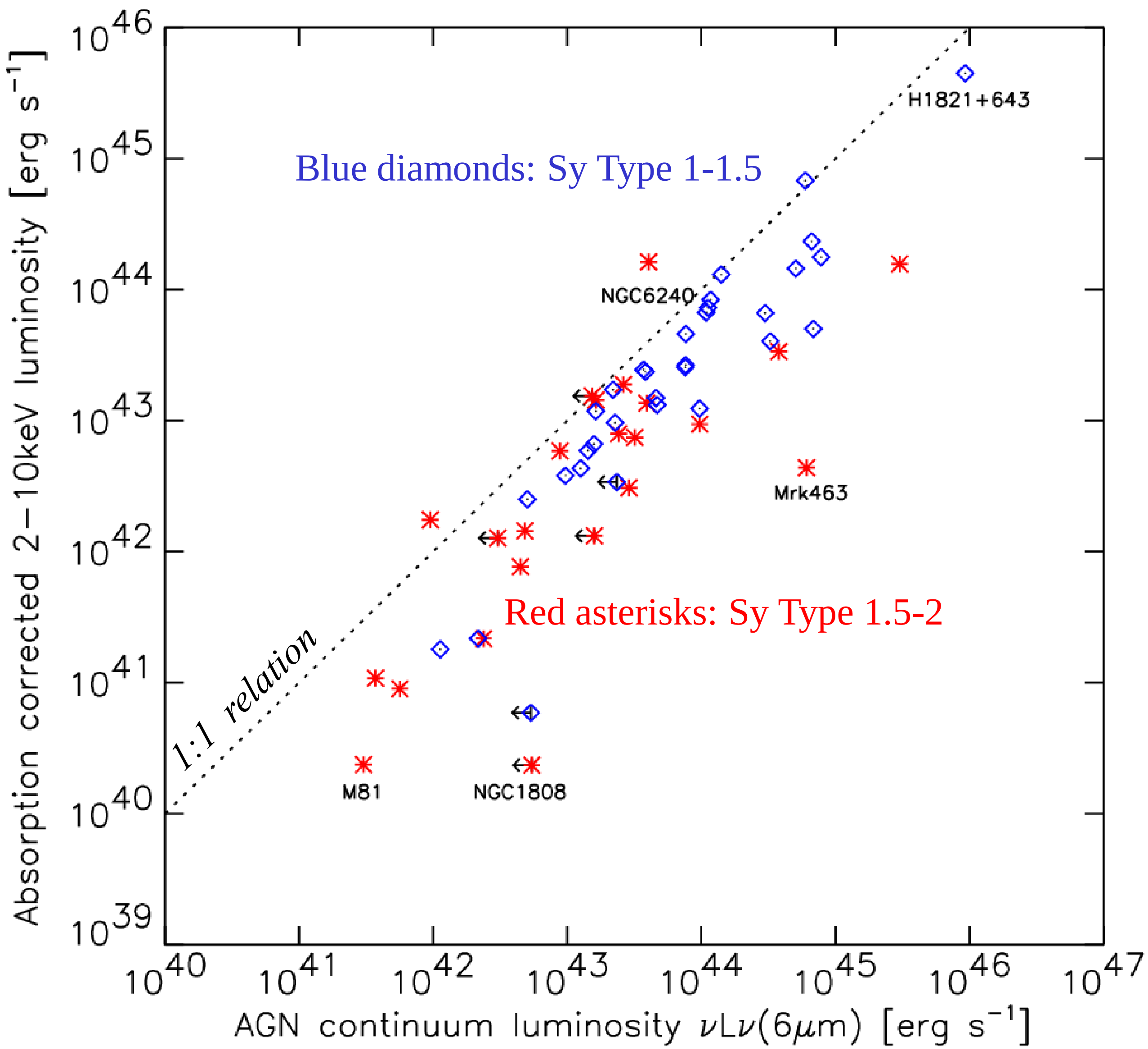
=> Infrared $\propto$ Intrinsic emission (e.g. X-rays)

Mid-IR/X-ray relation for local Seyferts



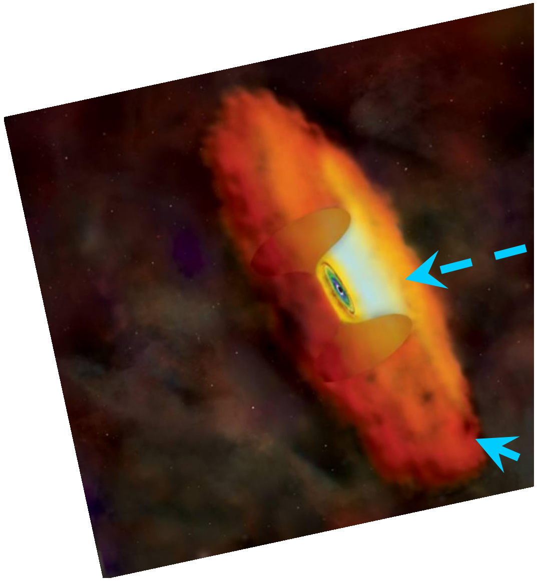
$$L_{\mathrm{IR}} \propto L_{\mathrm{X}}$$

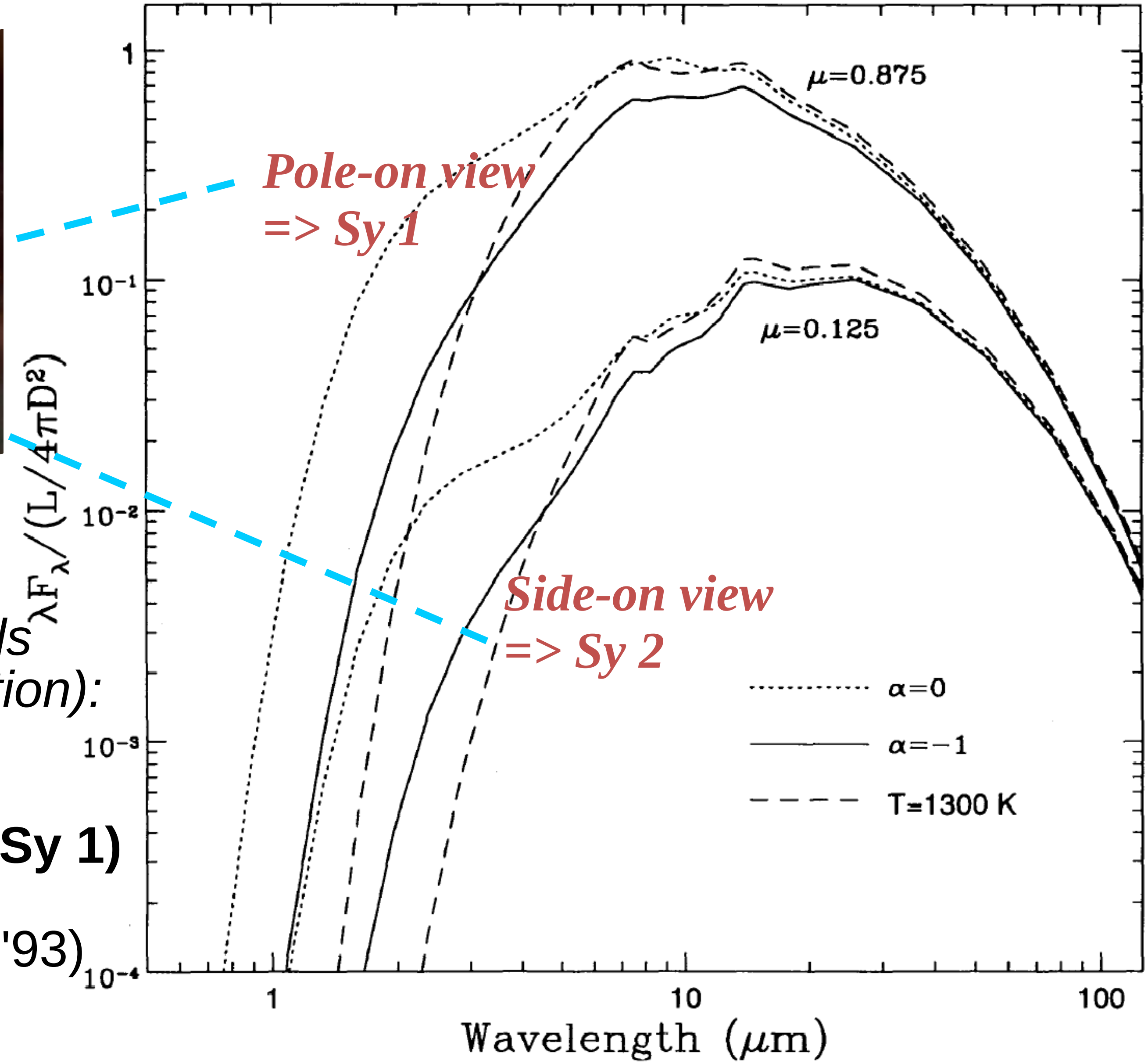
ISO studies found **no difference** between AGN types



(Lutz et al. 2004)

Mid-IR difference between obscured/unobscured AGN



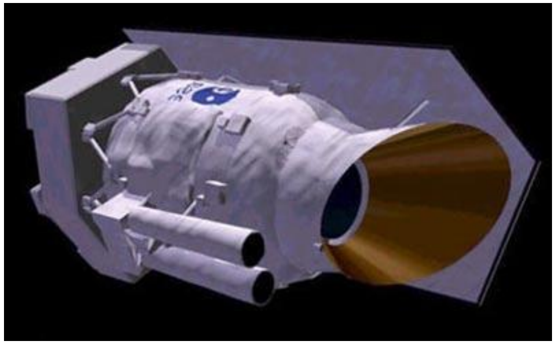


Canonical models
(smooth dust distribution):

Same $L_{X\text{-ray}}$ =>
L_{MIR} (Sy 2) << L_{MIR} (Sy 1)

(e.g., Pier & Krolik '93)

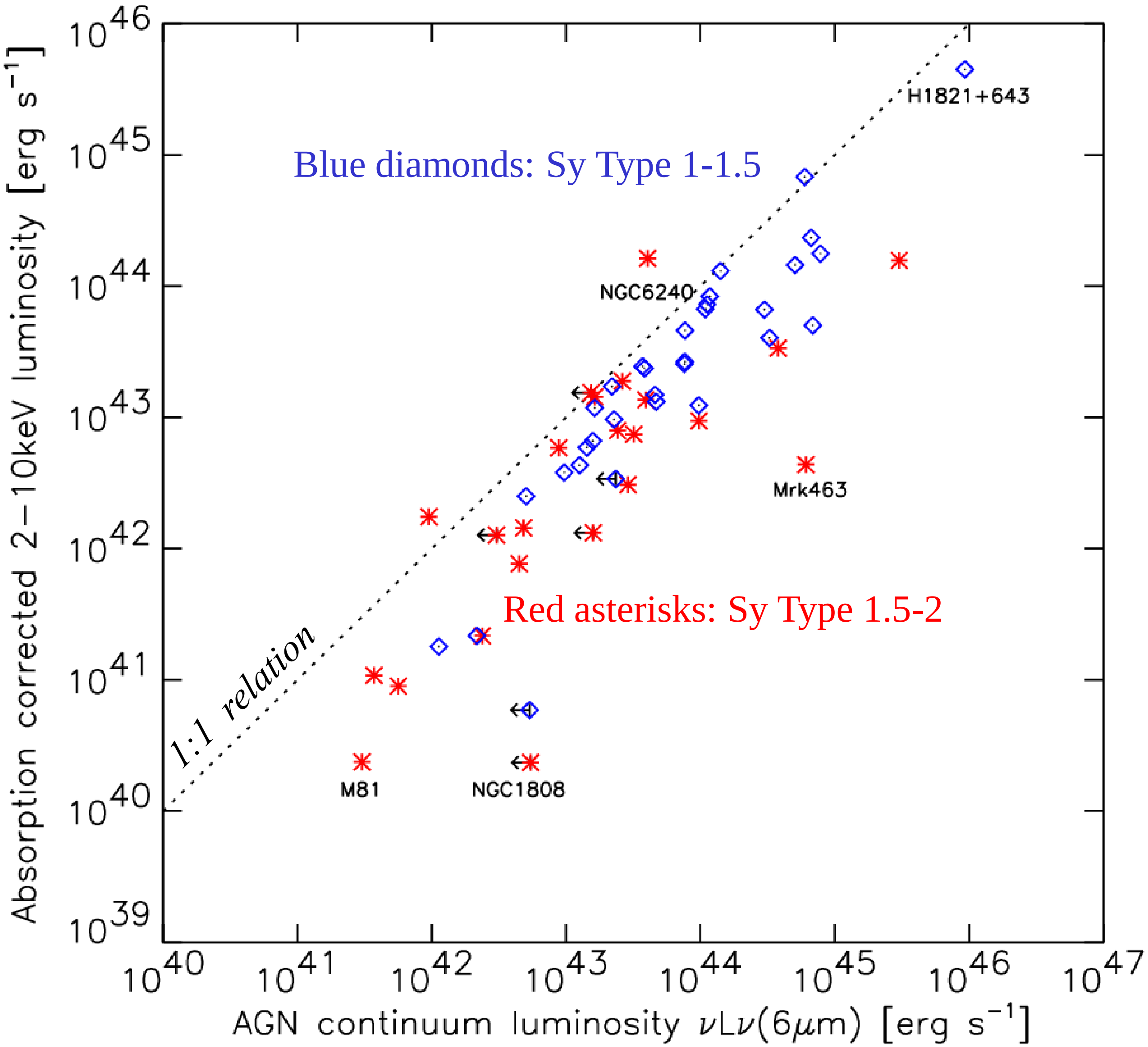
Mid-IR/X-ray relation for local Seyferts



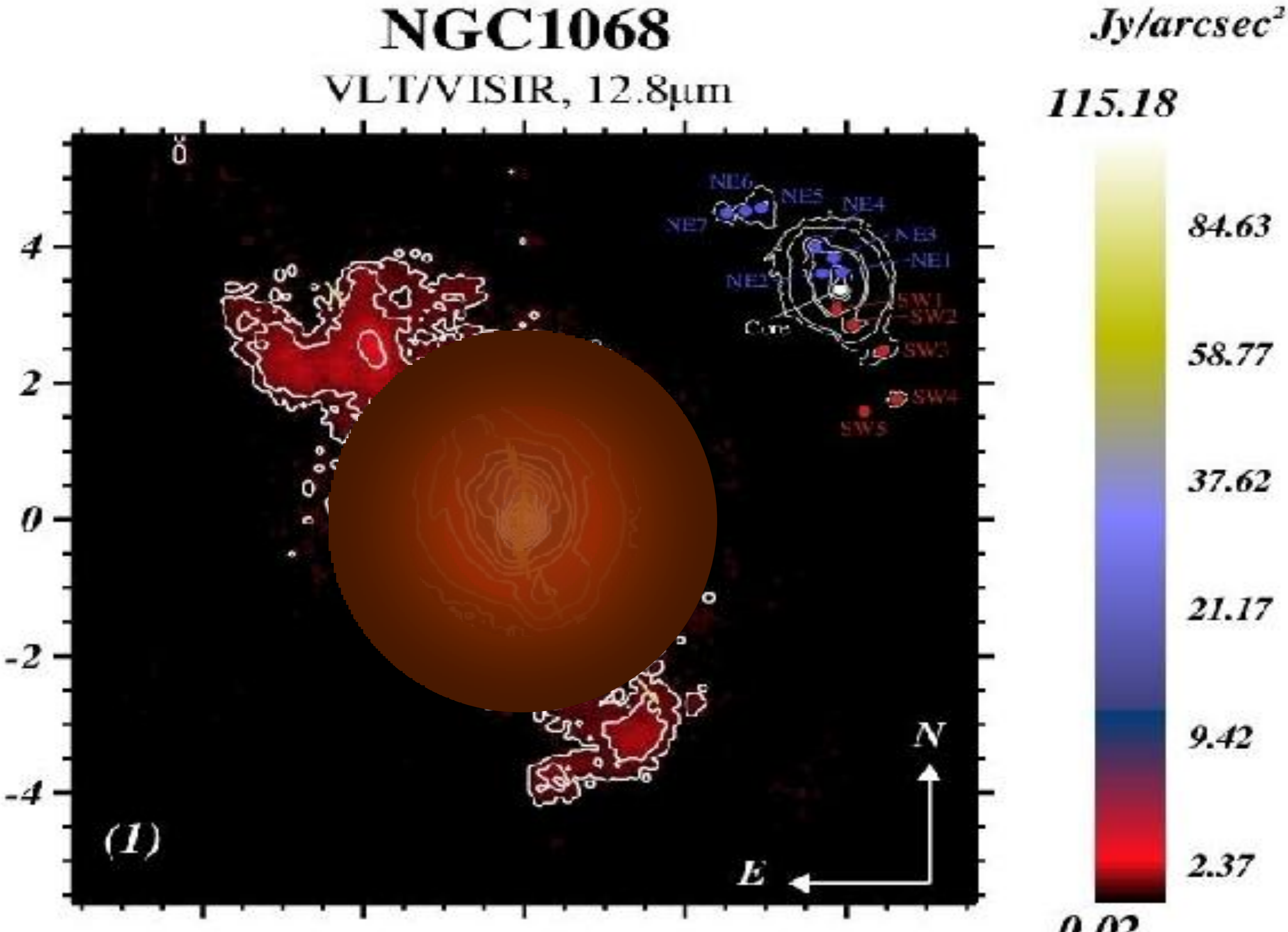
$L_{\mathrm{IR}} \propto L_{\mathrm{X}}$

ISO studies found **no difference** between AGN types,

Cause:
- Intrinsic?
- Selection effect due to low resolution?



(Lutz et al. 2004)



(Galliano et al. 2005)

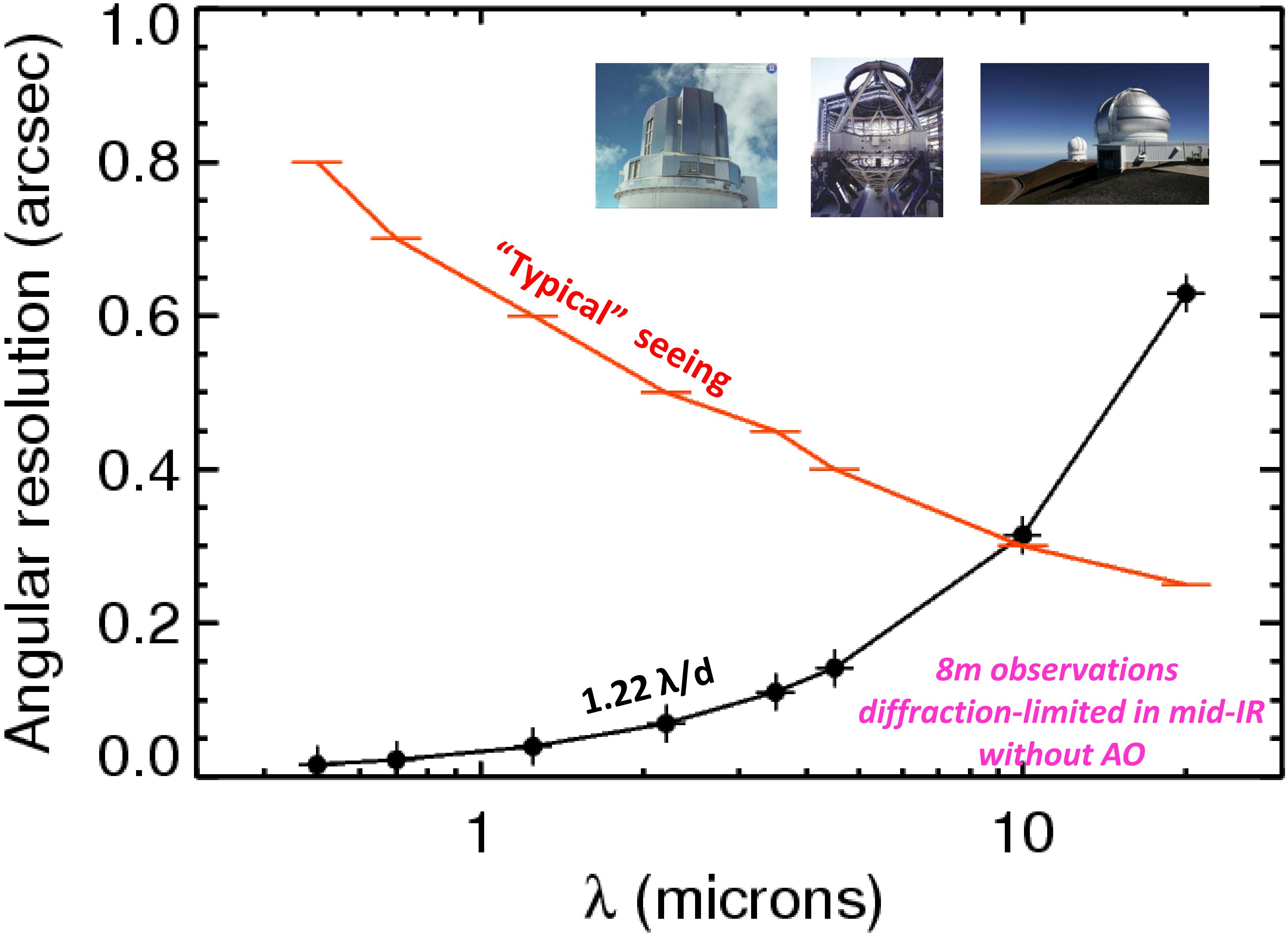
VLT Imager & Spectrograph for the mid IR (VISIR)

- 8-13 µm (N band)
- VLT is diffraction-limited in N band

VISIR under the Cassegrain Focus of the 8.2-m VLT Melipal Telescope

ESO PR Photo 16a/04 (12 May 2004)

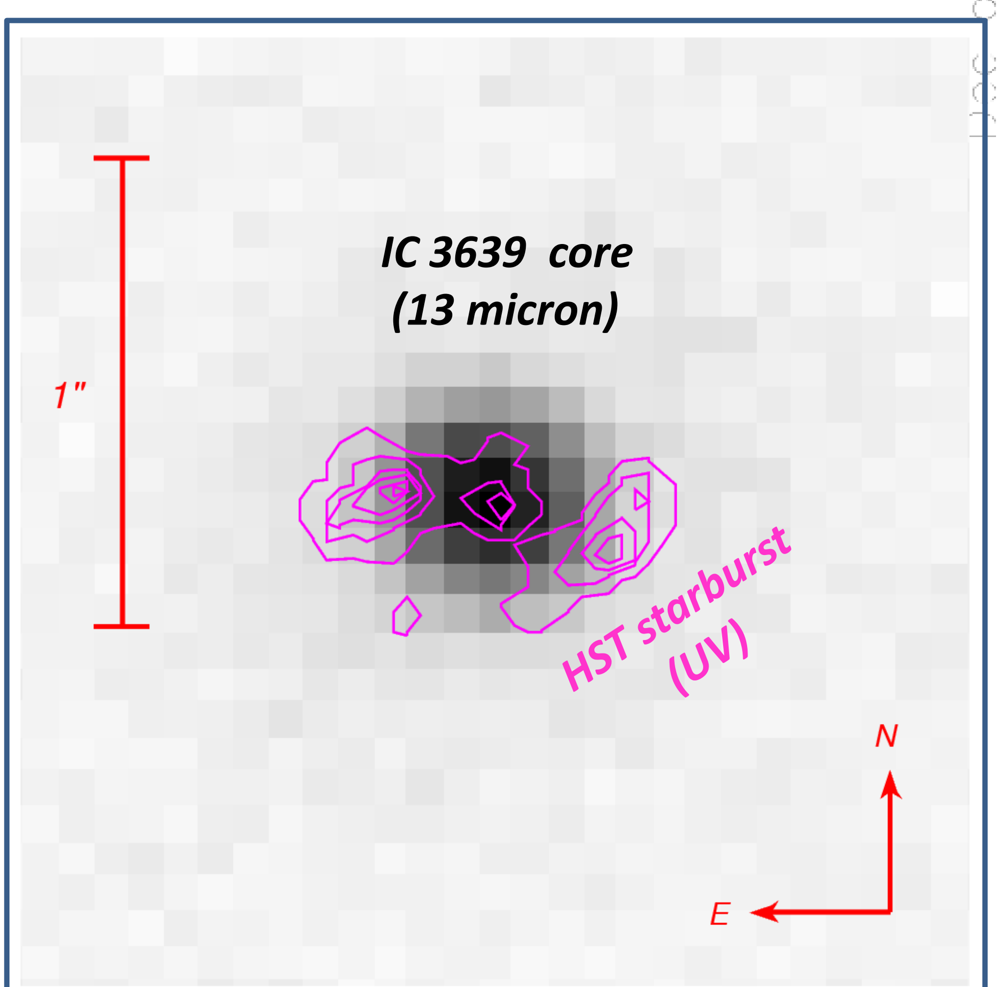
Ground telescope (8m) angular resolution

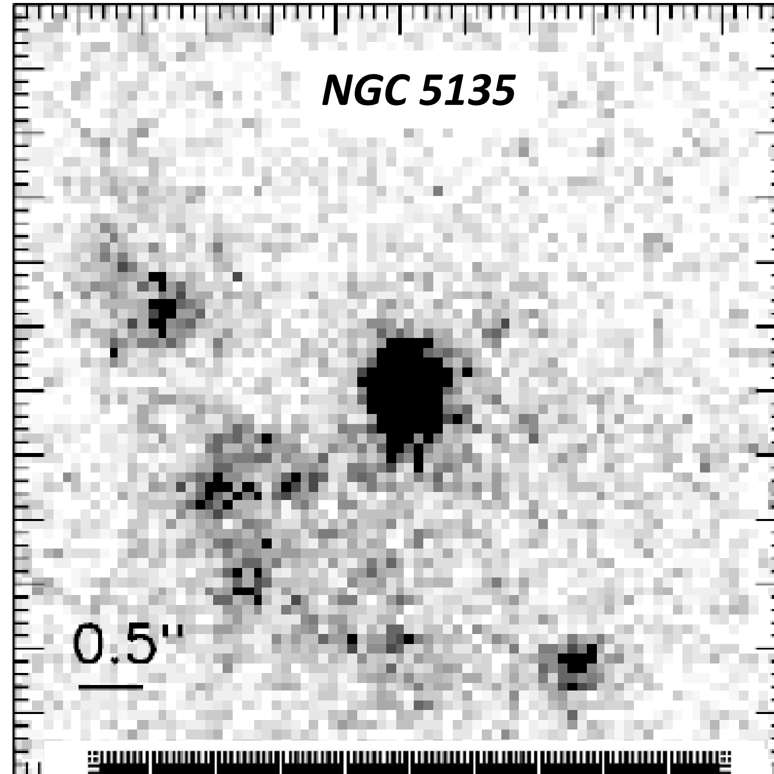


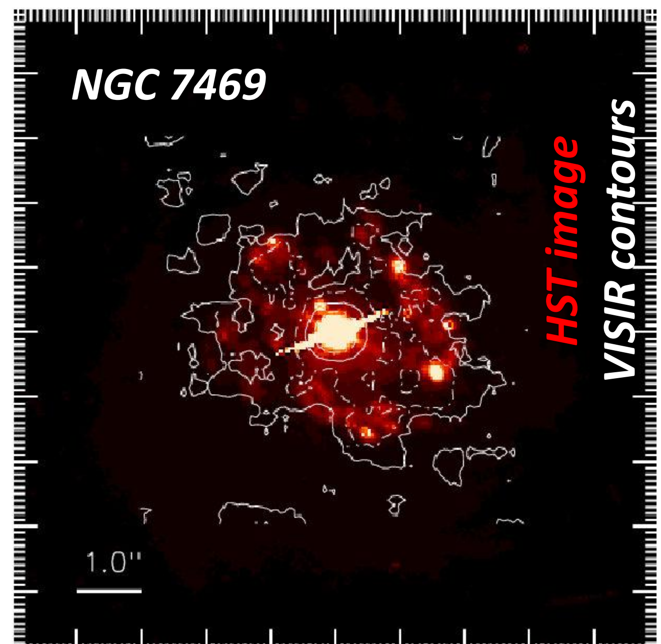
Local Seyfert survey

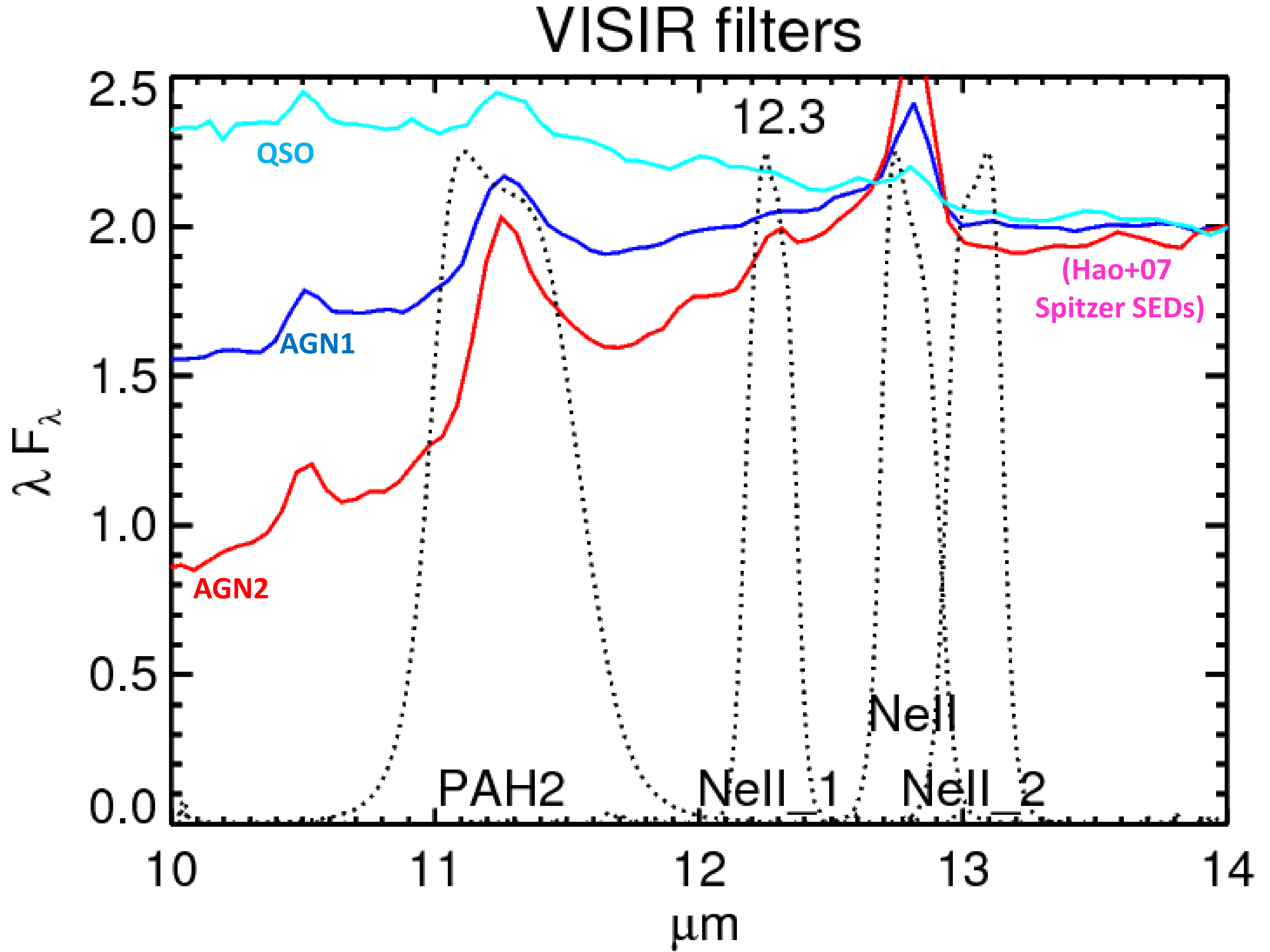
Sources with published intrinsic L_X or N_H.
43 initially.

(Gandhi+2009, Horst+09+08+06)





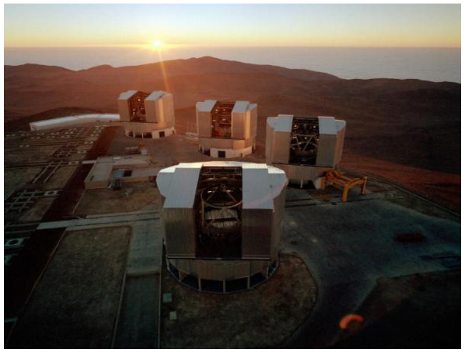


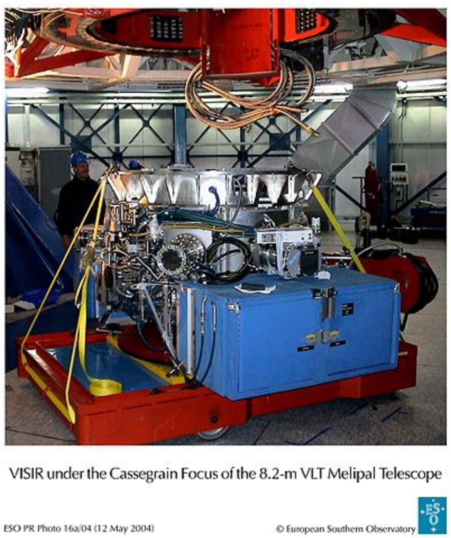


VISIR filters
2.5
2.0
1.5
1.0
0.5
0.0
λ F_λ
10
11
12
13
14
µm
QSO
AGN1
AGN2
12.3
PAH2
NeII_1
NeII
NeII_2
(Hao+07
Spitzer SEDs)

Target selection : Sources with published intrinsic L_X, N_H.

IR : VLT in Chile



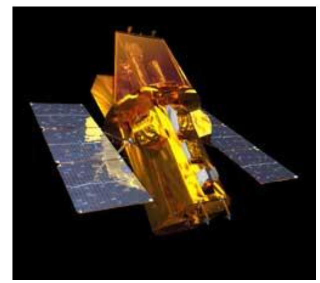


VLT Imager & Spectrograph for the mid IR (VISIR)

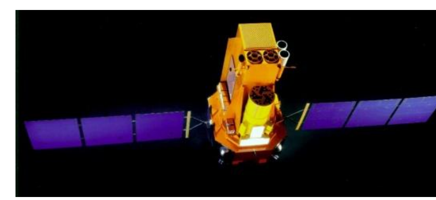
8-13 µm (N band)

X-rays : variety of missions

Chandra



Swift



INTEGRAL

XMM-Newton

ASCA

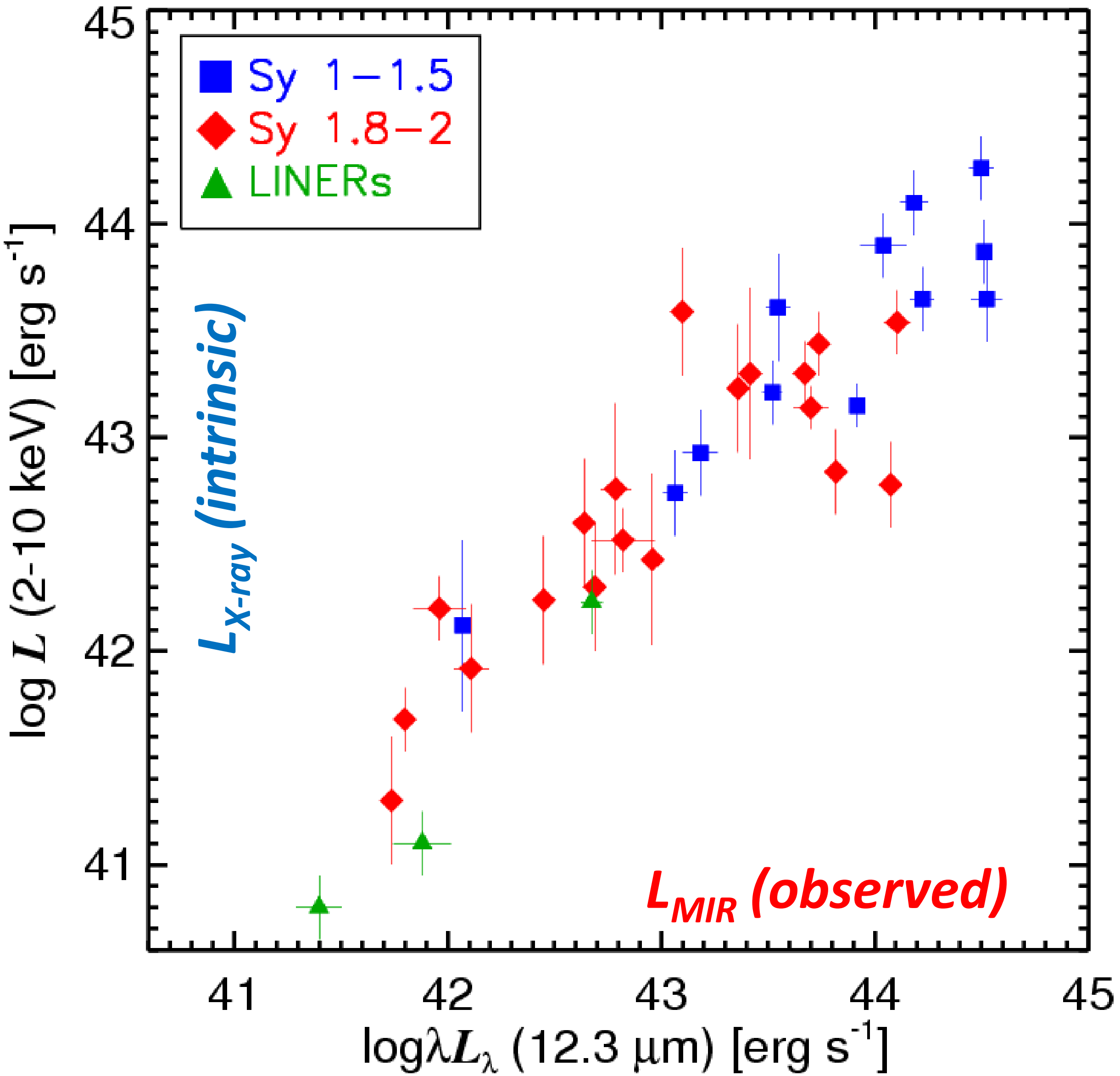
Mid-IR/X-ray relation for local Seyferts

VISIR/VLT:
Gandhi+09, Horst+2008

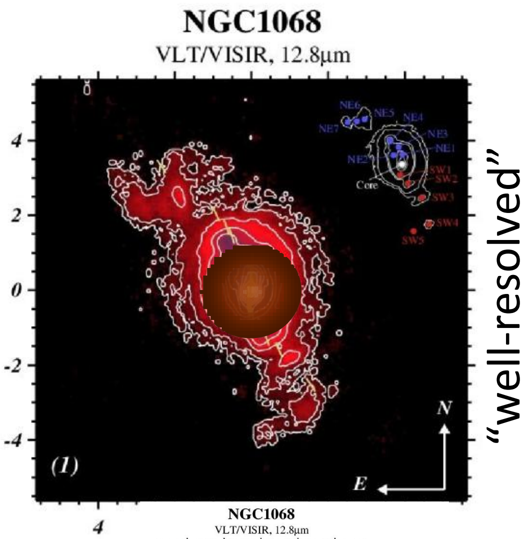
Results:

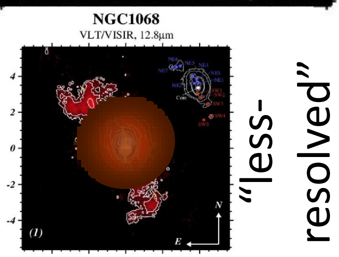
- $L_{IR} \propto L_X$

  (as expected in Unification)



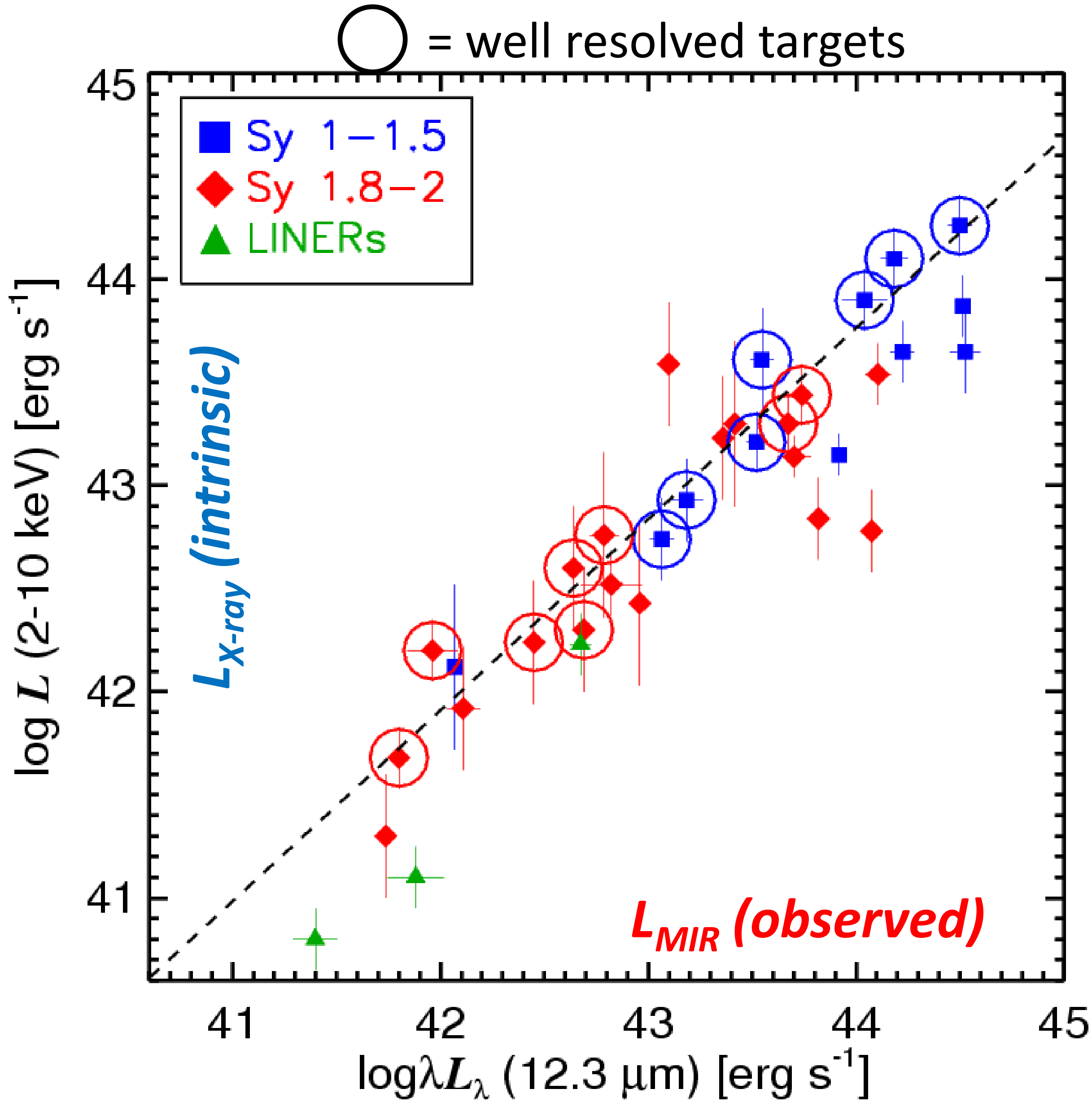
Mid-IR/X-ray relation for local Seyferts



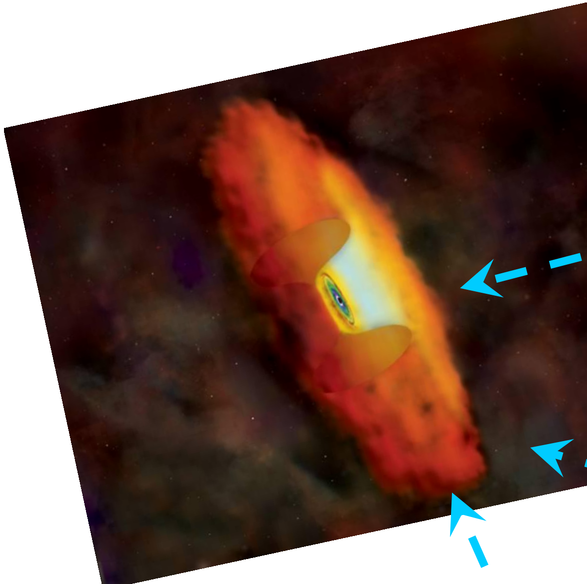


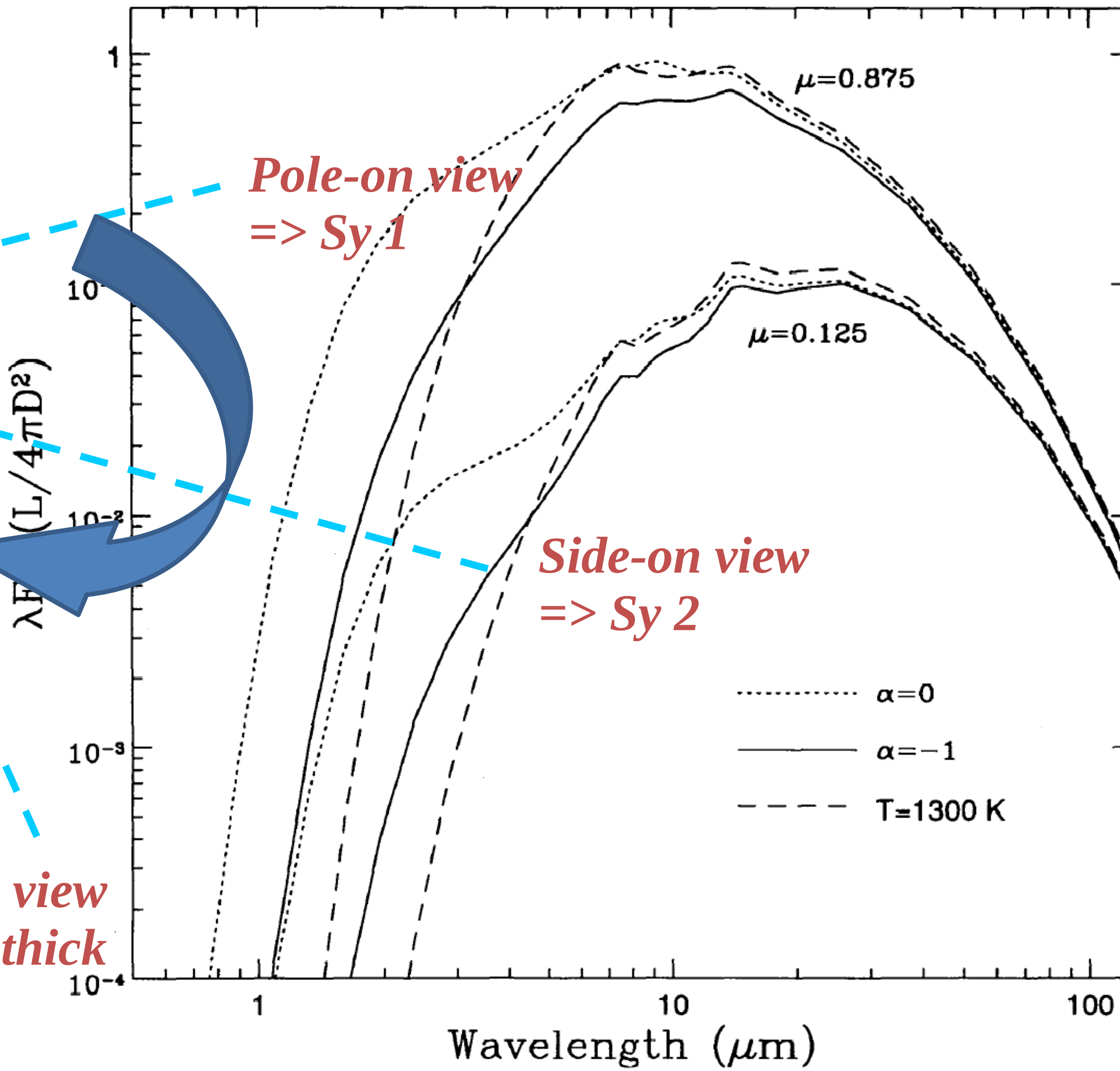
Results:

- Small dispersion in L_X/L_{IR} relation
- Type 1 and Type 2 follow same relation



Mid-IR difference between obscured/unobscured AGN





Mid-IR:X-ray difference should increase with viewing angle

Mid-IR/X-ray relation for local Seyferts

VISIR/VLT:
Gandhi+09

Results:

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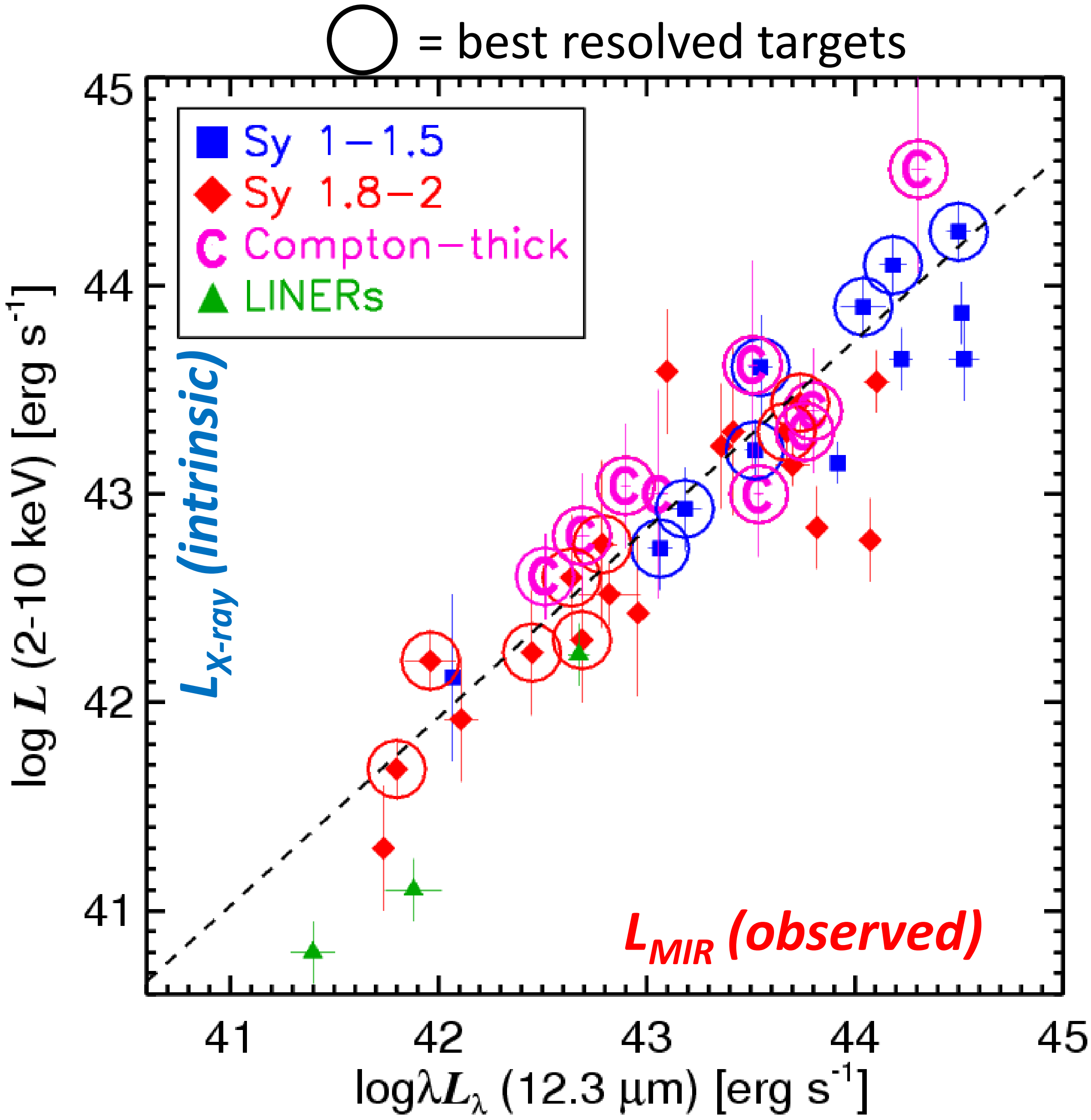
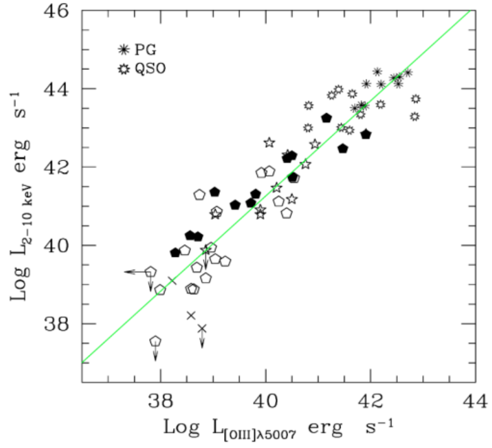
- Type 1 and Type 2 follow same relation



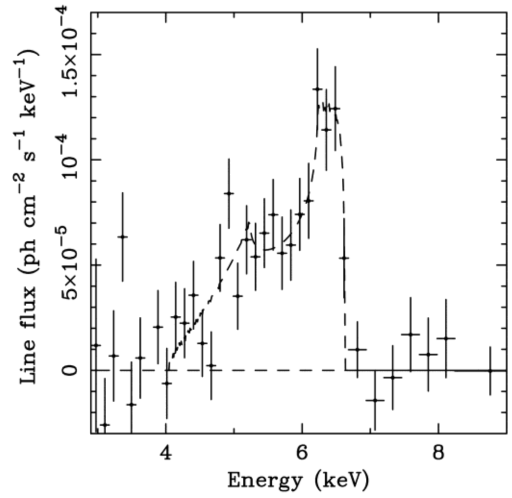
Estimating intrinsic powers of Compton-thick AGN

1. [OIII] forbidden emission line as an isotropic indicator



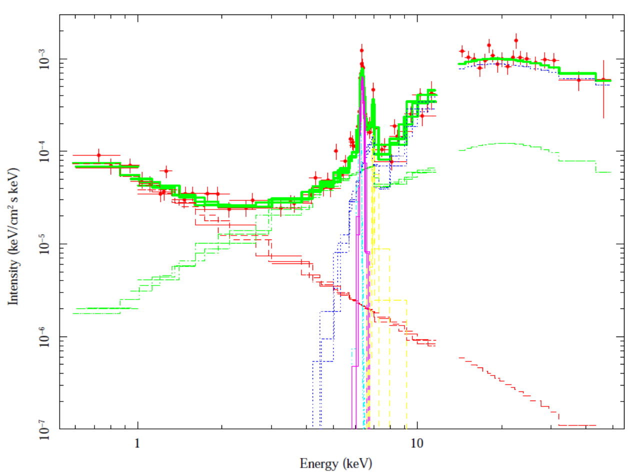
(Panessa+06)

2. Fe Kα line equivalent width depends on intrinsic continuum and column density



(George+Fabian 91)

3. Broad-band SED modelling if not severely Compton-thick



(Comastri+10)

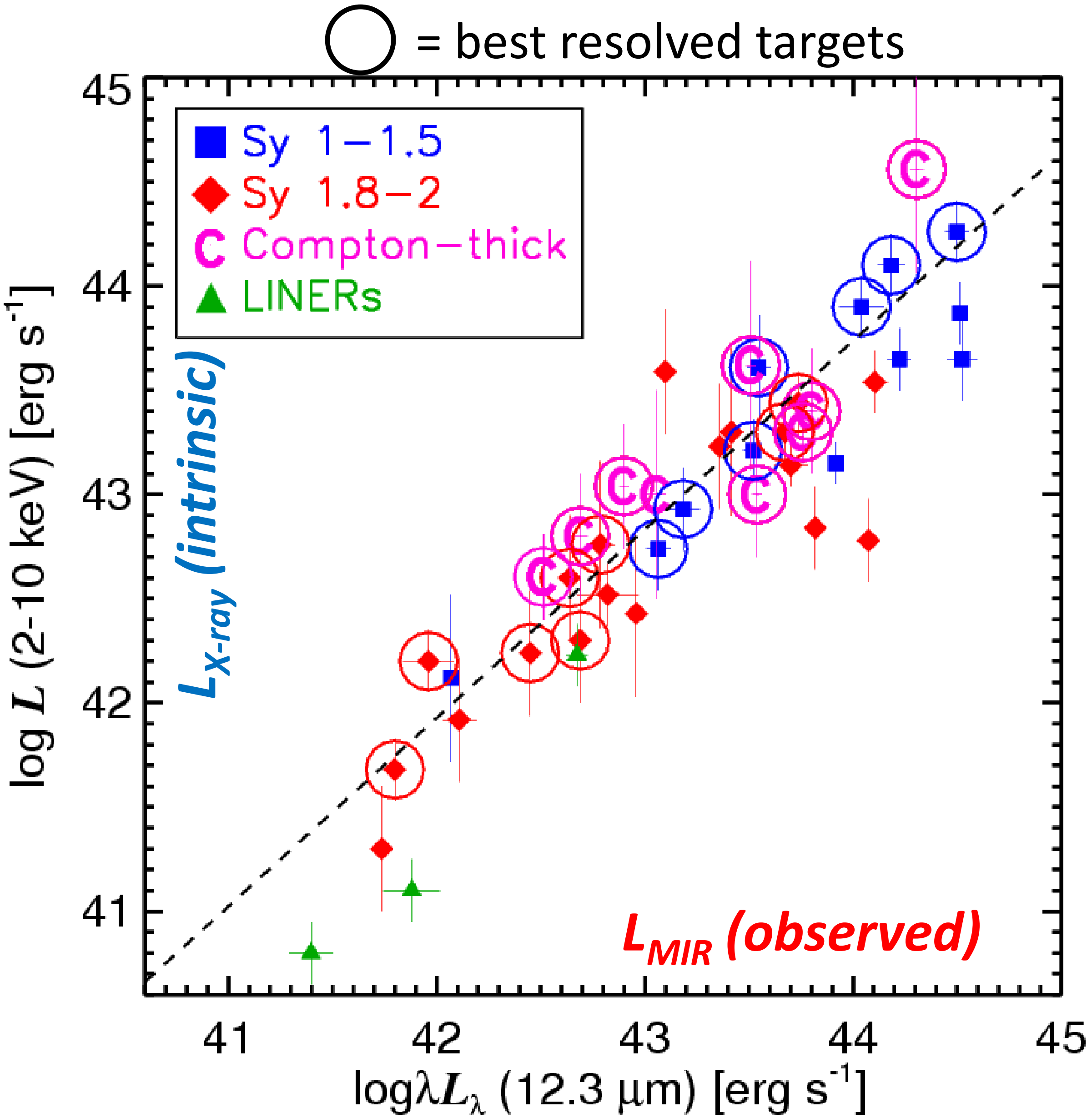
Mid-IR/X-ray relation for local Seyferts

VISIR/VLT:
Gandhi+09

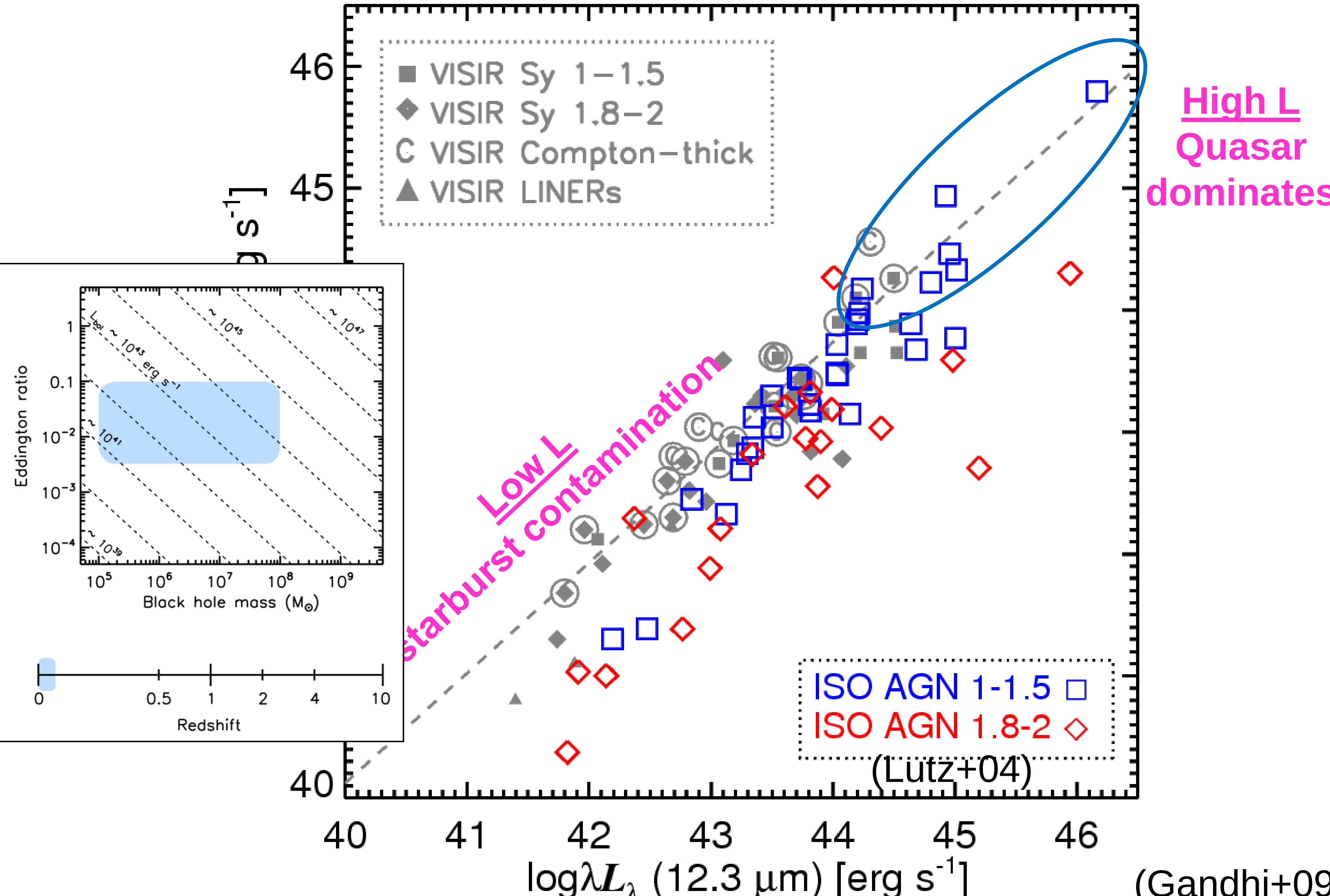
Results:

- Small dispersion in L_X/L_{IR} relation
- Type 1 and Type 2 follow same relation

Intrinsic



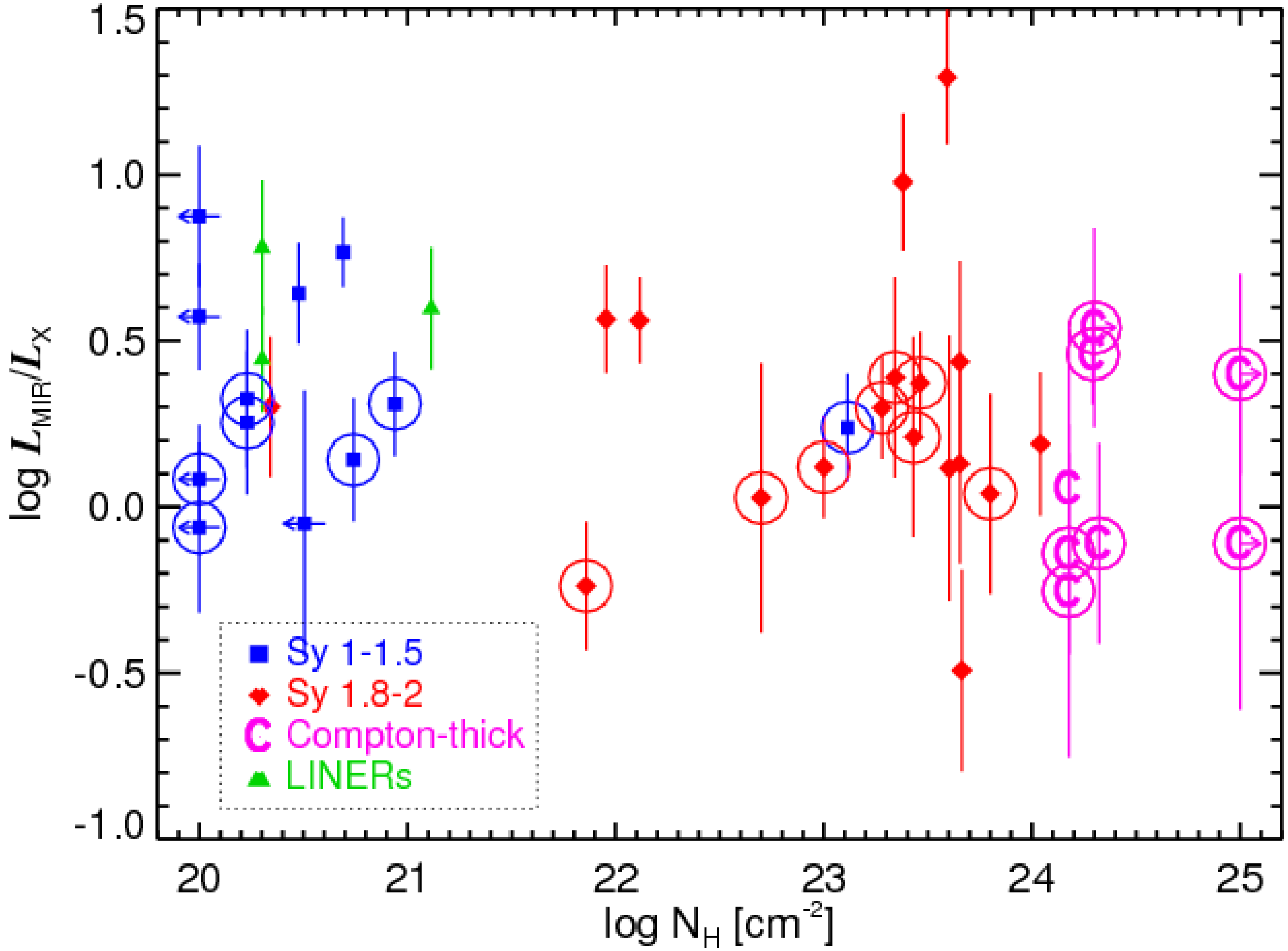
From Seyferts to Quasars



(Gandhi+09)

Mid-IR/X-ray relation for local Seyferts

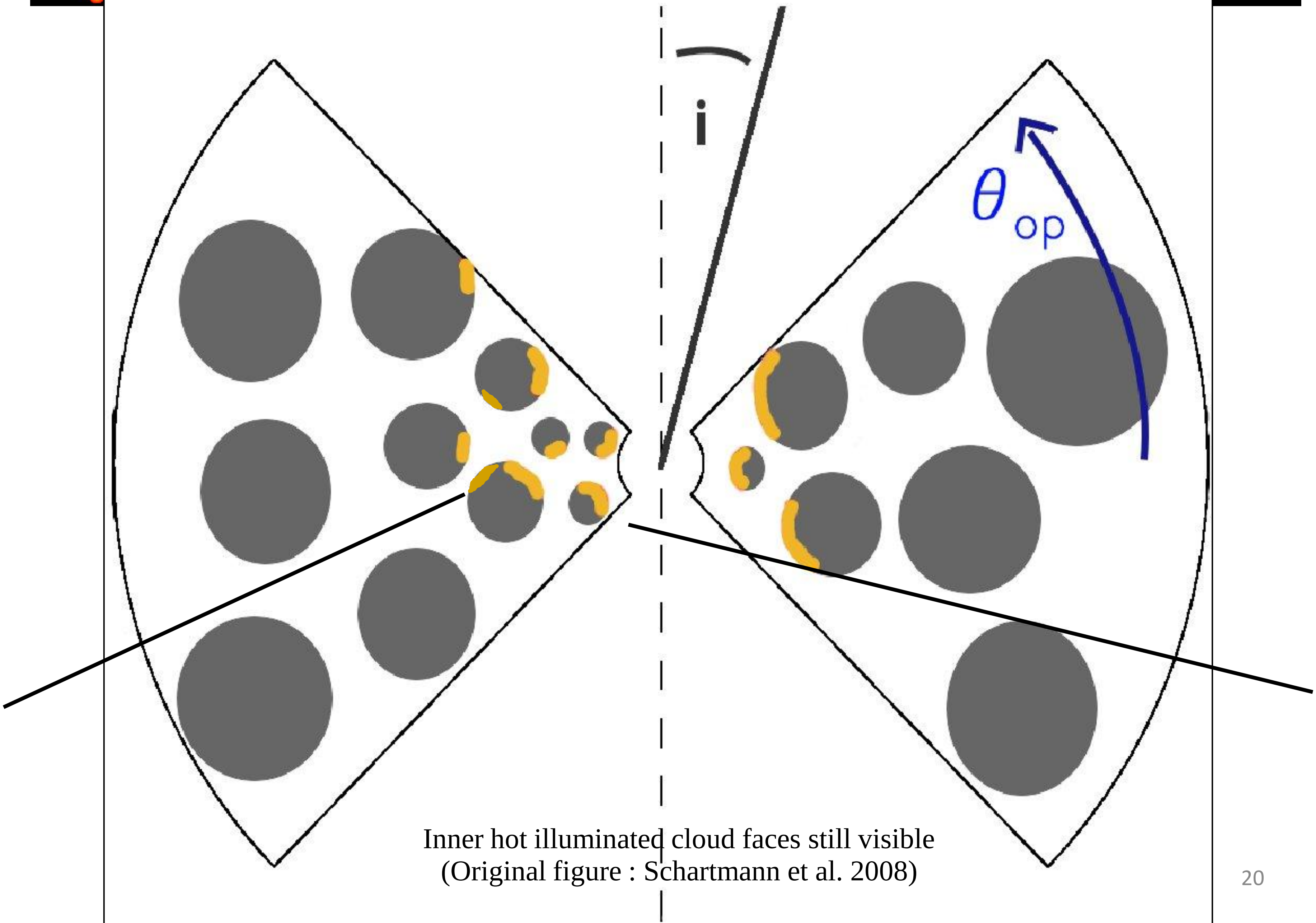
◯ = best resolved targets



How to produce a very tight correlation independent of N_H?

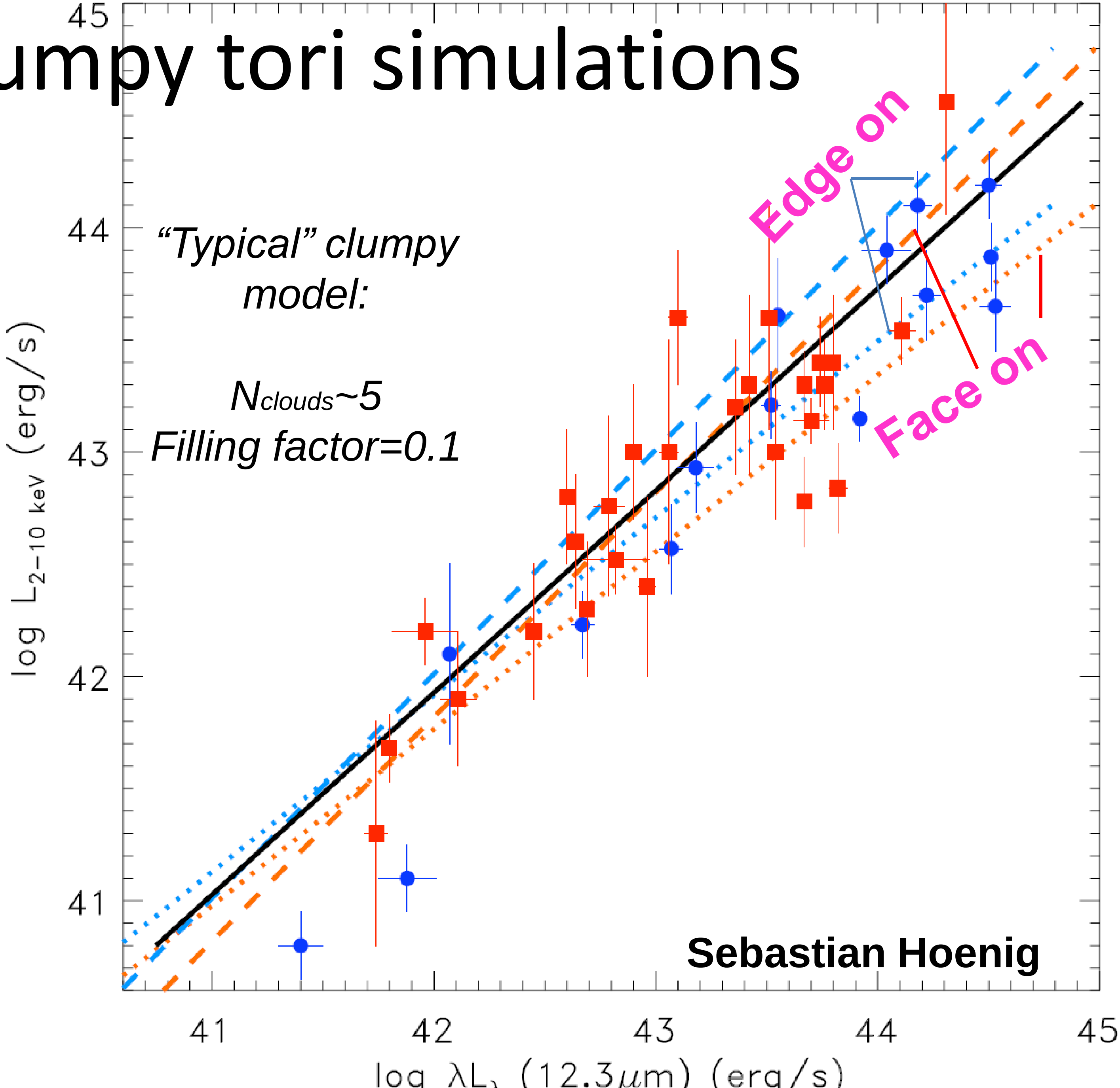
(Gandhi+09)

CLUMPY TORUS



Inner hot illuminated cloud faces still visible
(Original figure : Schartmann et al. 2008)

Clumpy tori simulations

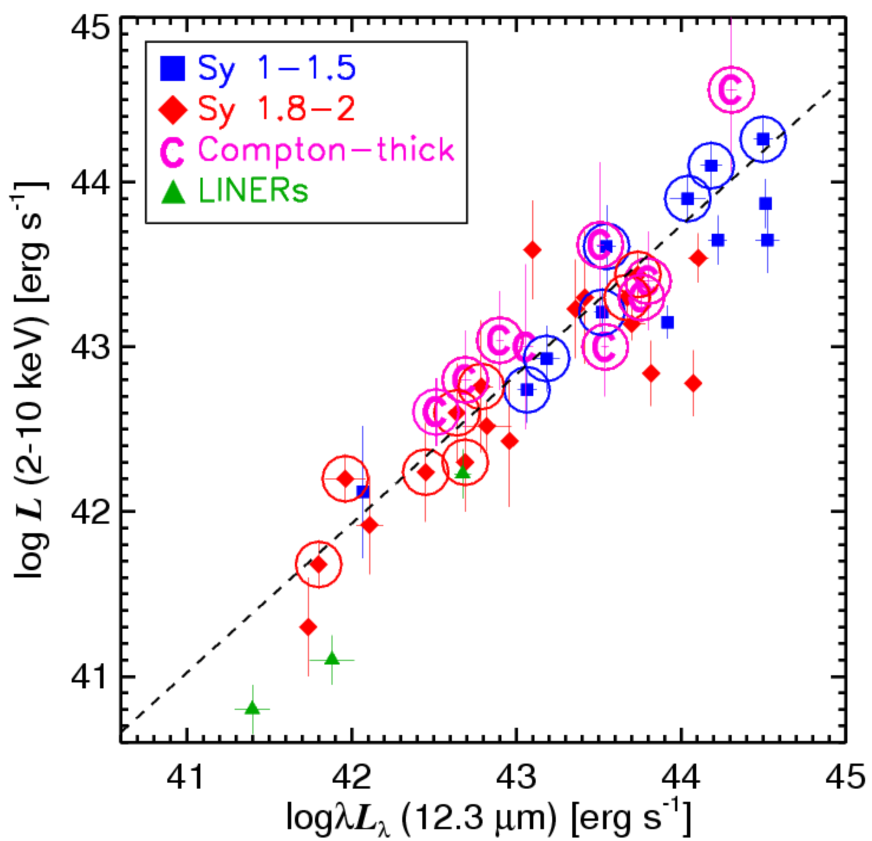


Implications

Theoretically, constrain dusty tori properties (see Hoenig+09, +10…).

Observationally very useful.

1. Mid-IR (especially resolved) : excellent isotropic probe of the intrinsic AGN power



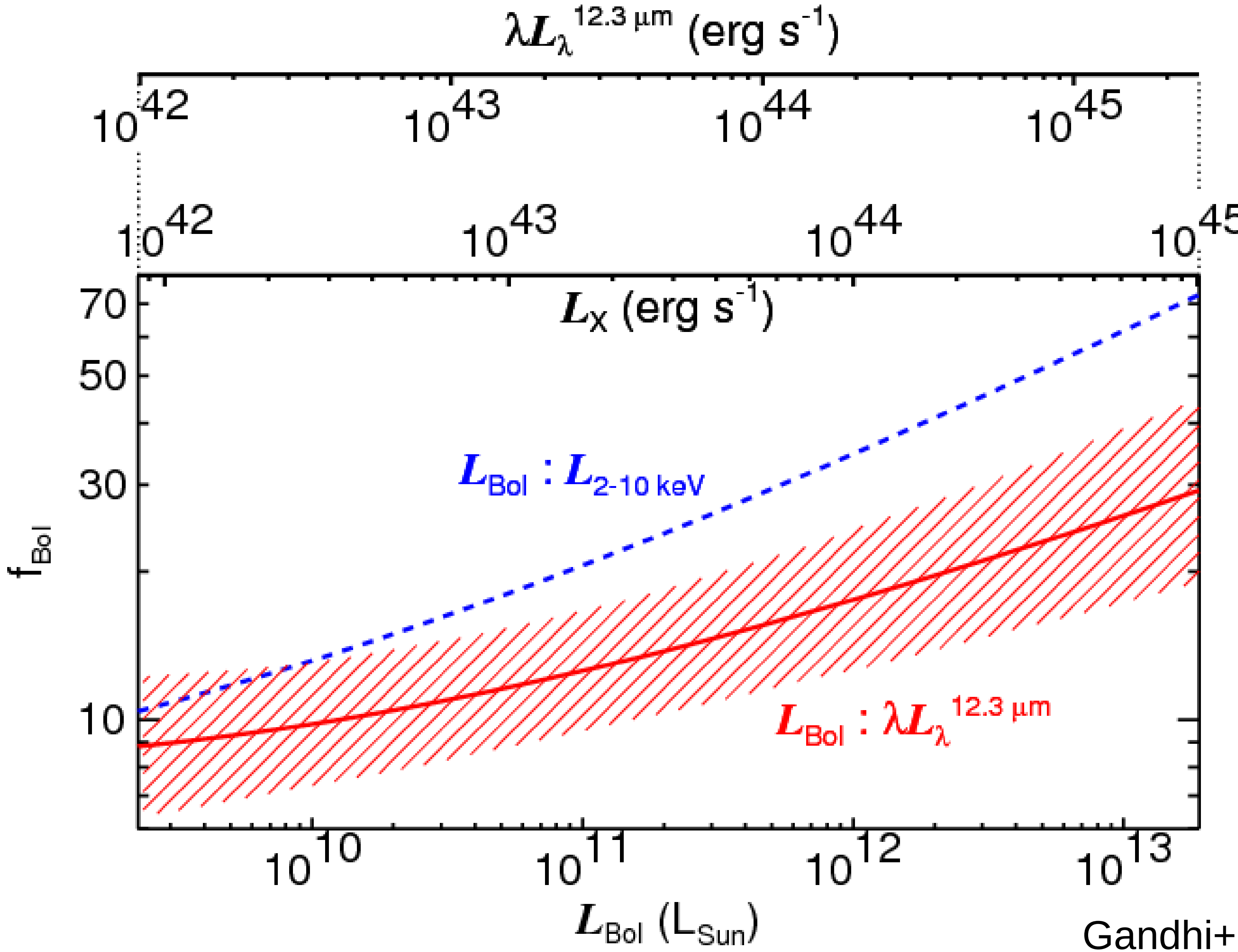
Implications

Observationally very useful.

1. Mid-IR (especially resolved) : excellent isotropic probe of the intrinsic AGN power

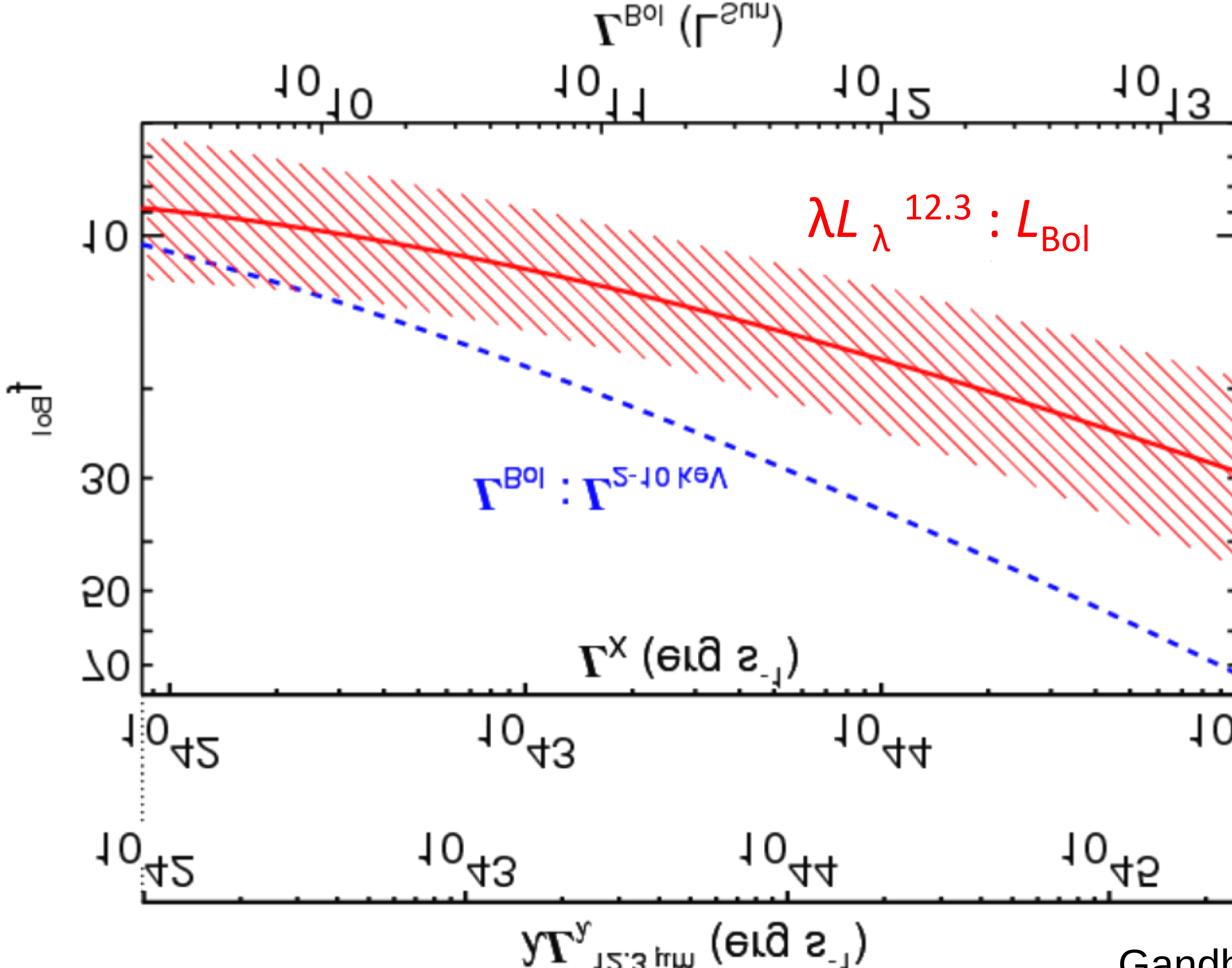
2. Cleanly measure intrinsic AGN powers for first time.

Mid IR: isotropic probe of intrinsic AGN power



Gandhi+09

Dust covering factor decreases with L



Gandhi+09

Implications

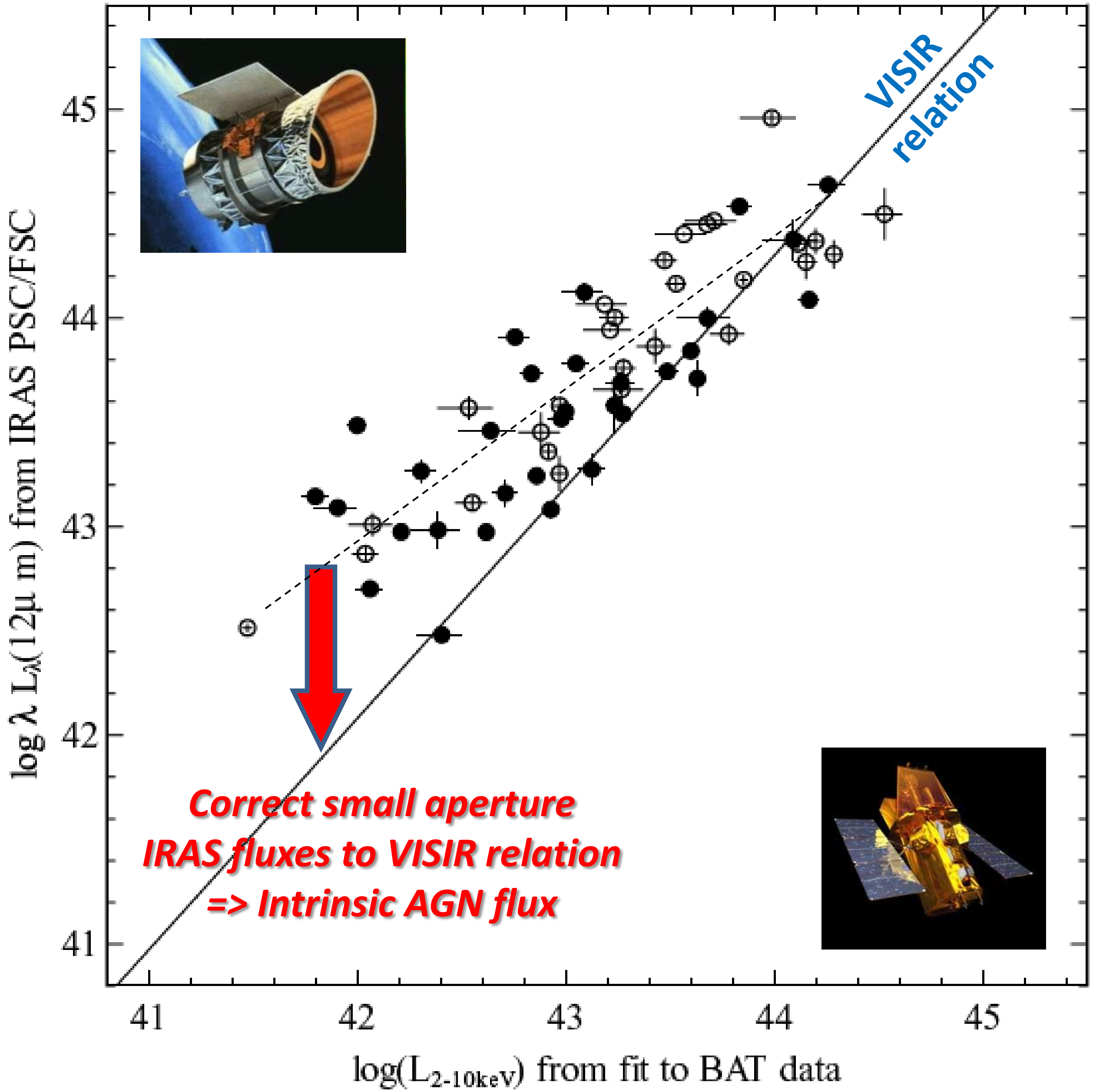
Observationally very useful.

1. Mid-IR (especially resolved) : excellent isotropic probe of the intrinsic AGN power

2. Cleanly measure intrinsic AGN powers for first time

   => decontaminate small aperture infrared data

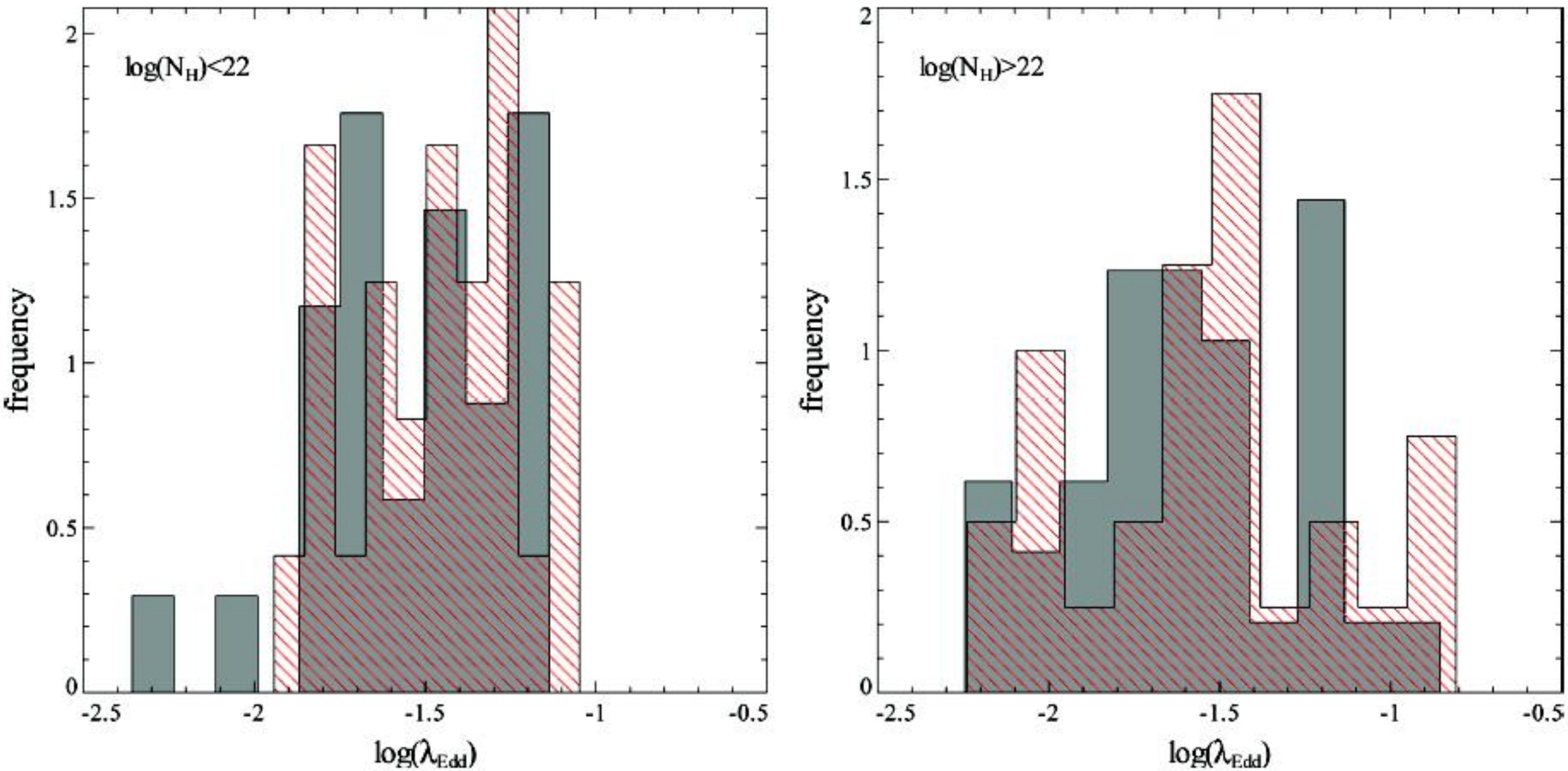
Correcting small aperture data



(Vasudevan+10)

Complete sample of Swift/BAT AGN

$\lambda = L_{\mathrm{bol}} / L_{\mathrm{Eddington}}$



Low Eddington fractions => local AGN accreting inefficiently
(Vasudevan+10)

Implications

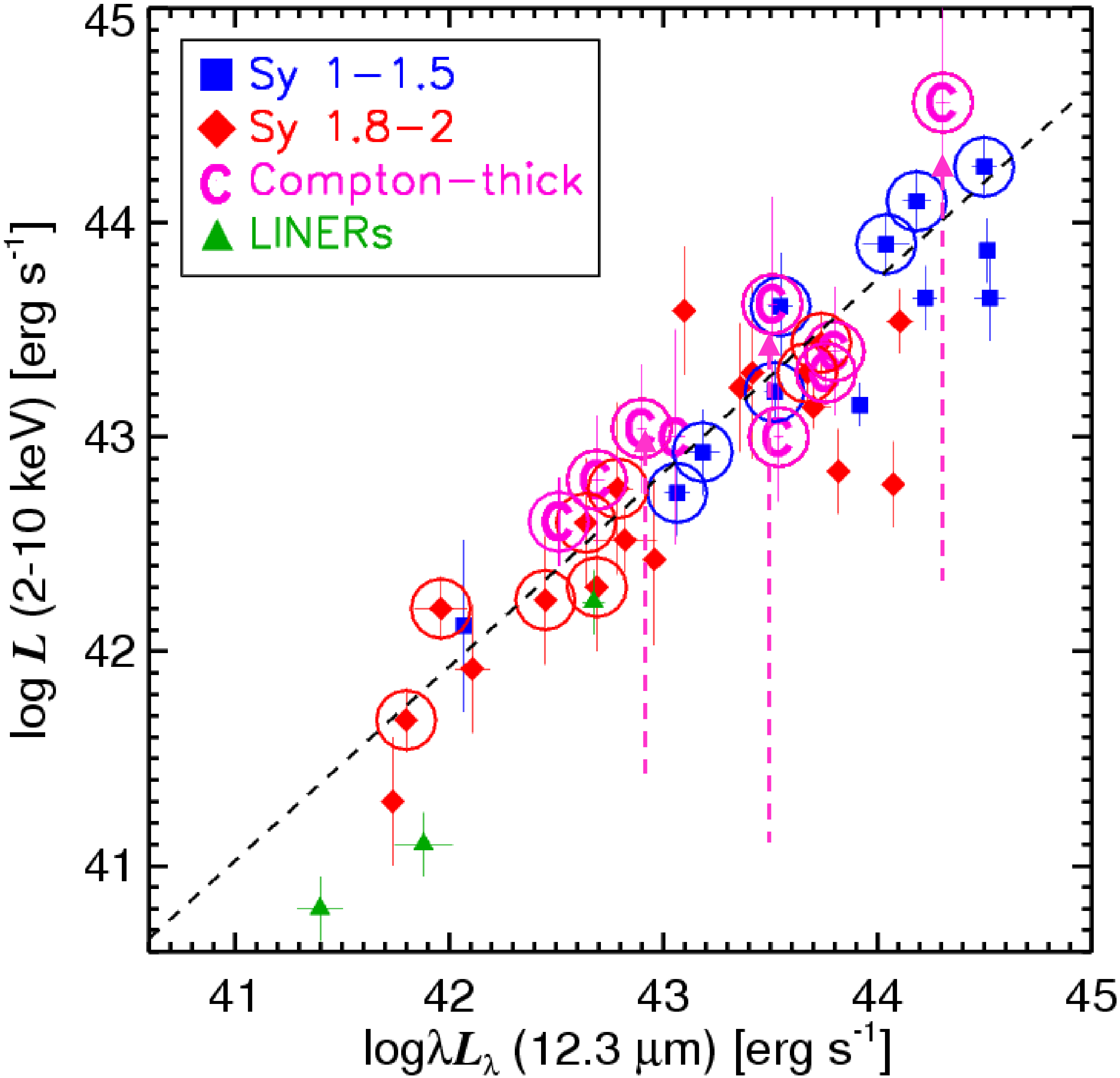
Observationally very useful.

1. Mid-IR (especially resolved) : excellent isotropic probe of the intrinsic AGN power

2. Cleanly measure intrinsic AGN powers for first time => dust covering factors decrease with *L*.

3. New easy way to measure Compton-thick AGN powers.

Estimating Compton-thick intrinsic powers

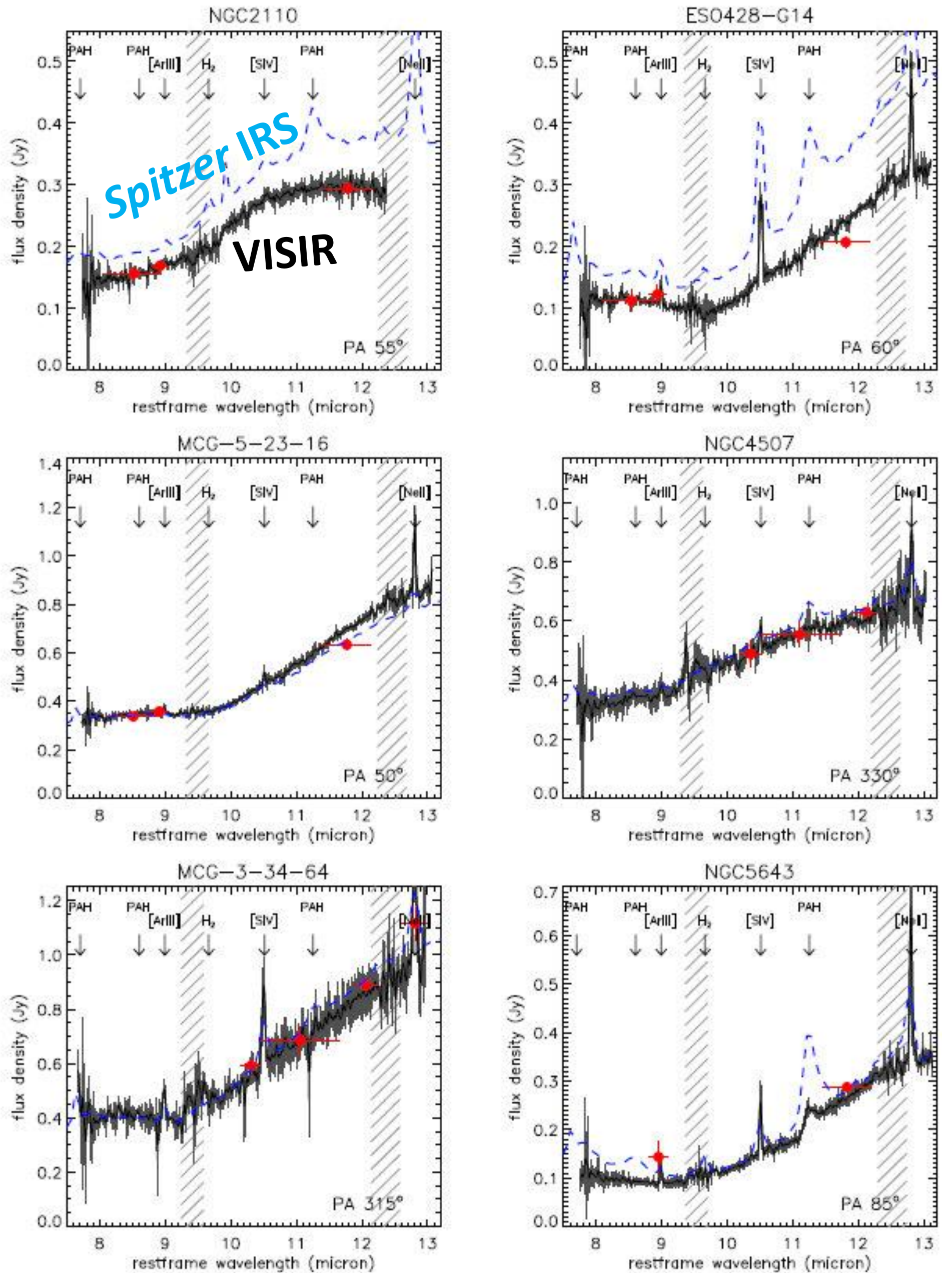


Gandhi+09

Mid-IR spectroscopy: 0".75 slits

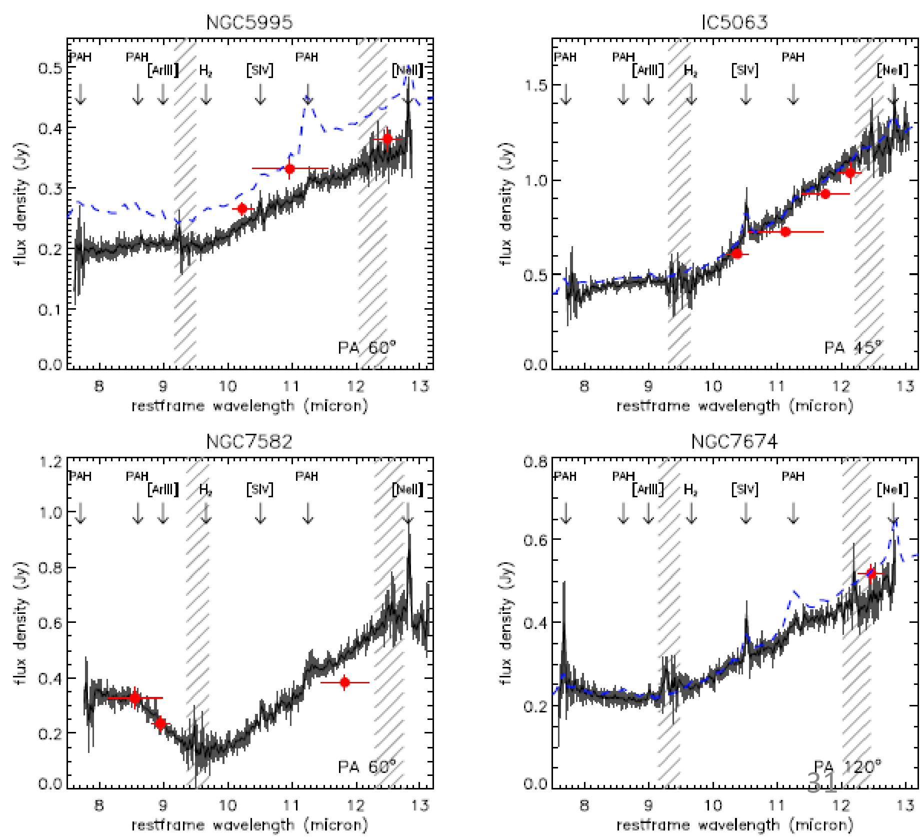
(Hoenig+10)

(Sy 2s)

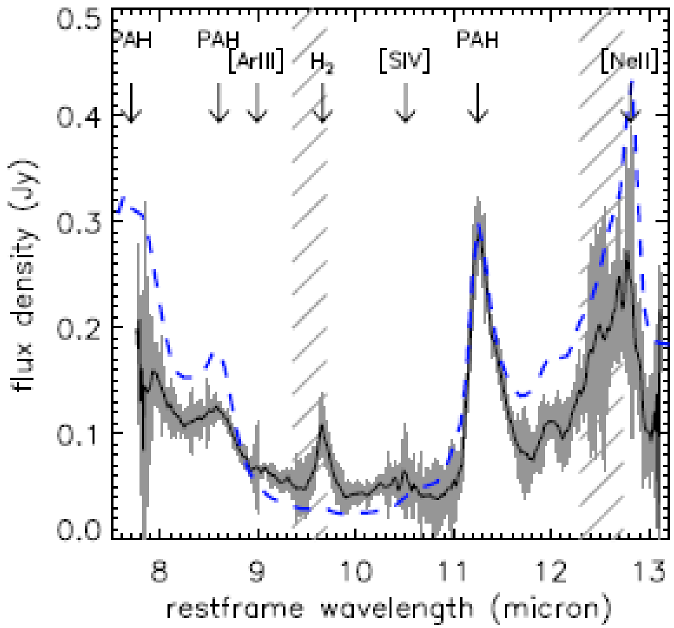


1. Resolve out extended emission

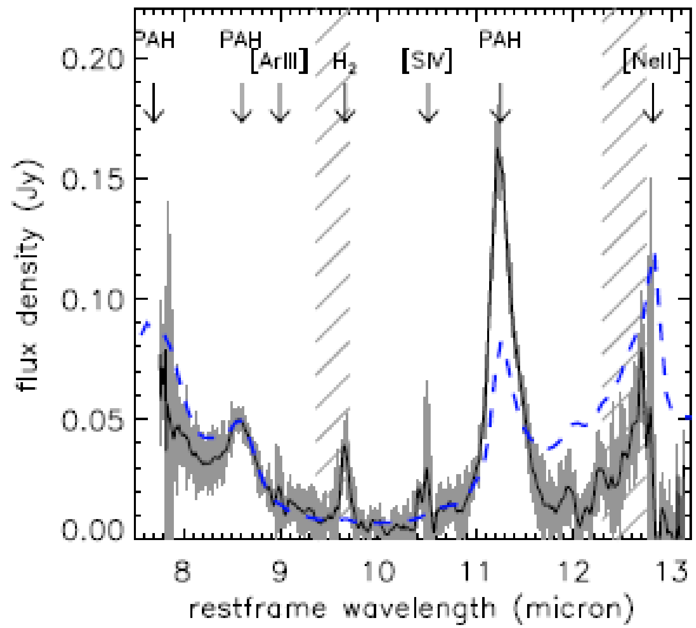
2. PAHs drastically reduced on small scales



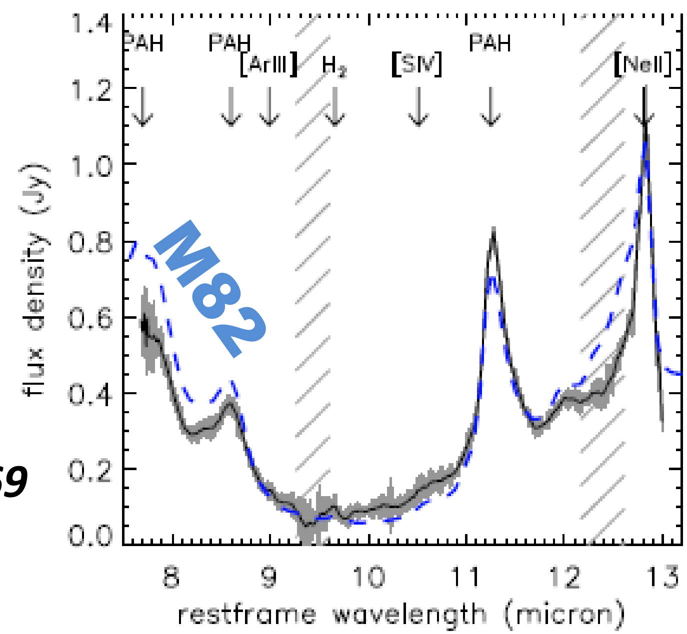
Residual *Spitzer* – VLT spectra = star formation



NGC 3227



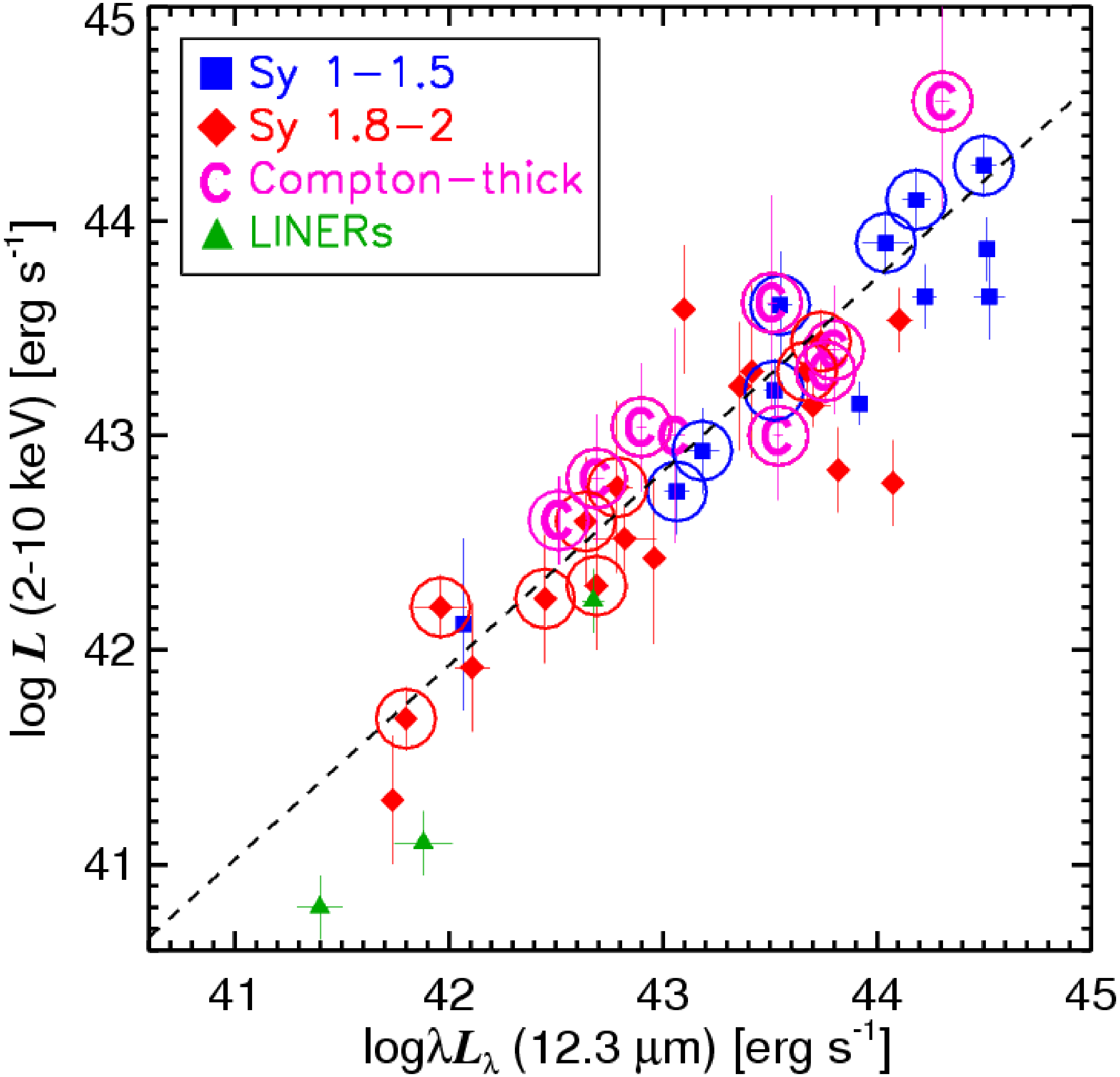
NGC 5643



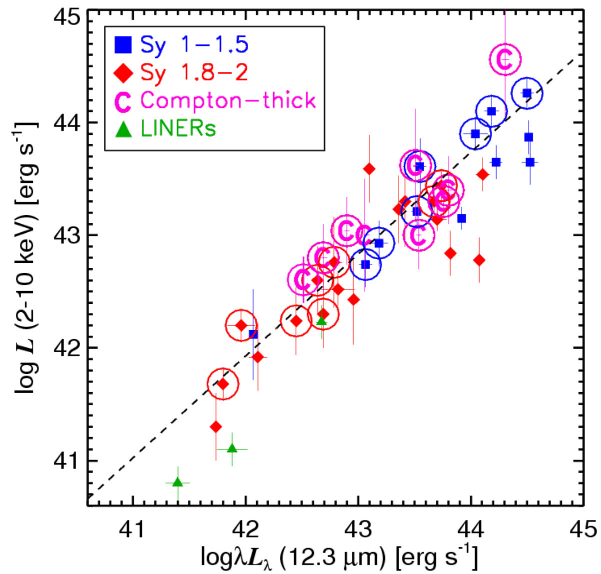
NGC 7469

(Hoenig+10)

Limitation : highly incomplete
=> Need larger complete samples



Summary

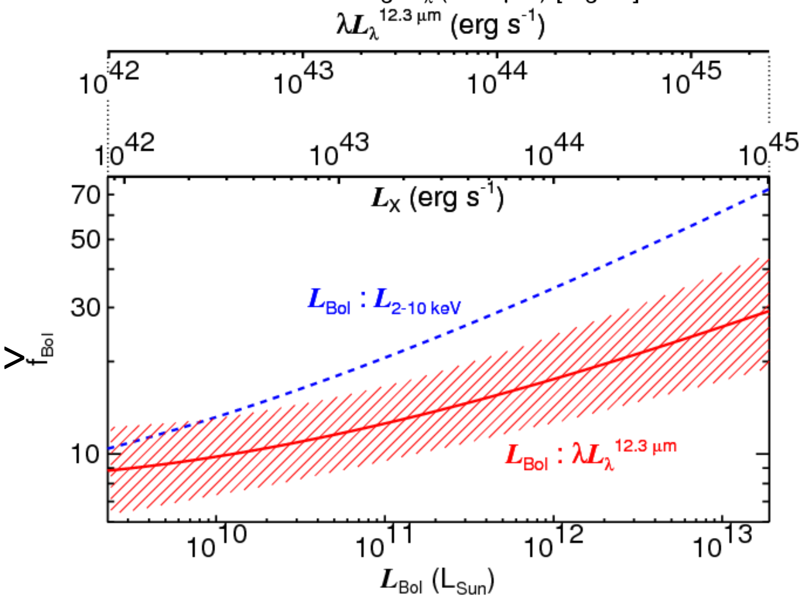


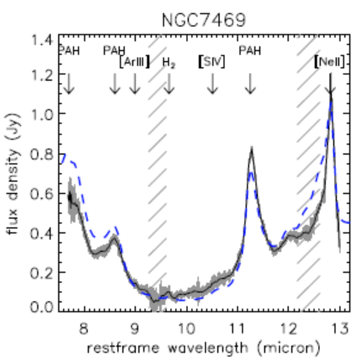
1. Mid-IR (especially resolved) : isotropic probe of the intrinsic AGN power of Seyferts and quasars.

2. Good estimator of Compton-thick AGN powers.

3. Tight correlation may be explained by clumpy tori.

4. Cleanly measure intrinsic AGN powers for first time => dust covering factors decrease with *L*.





5. High resolution observations are resolving out nuclear star formation.