Obscured quasars at high redshift

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In collaboration with

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Mostly based on the work by Pozzi et al., A&A, 517, A11 (2010)

Talk outline

- Obscured accretion in luminous quasars at z≈1-2: the HELLAS2XMM sample and source multi-wavelength coverage
- The accretion bolometric luminosity using the infrared reprocessed emission and the "flared disk" model: estimates of bolometric corrections and Eddington ratios for Type 2 quasars and comparison with optically (SDSS) and X-ray (XMM-COSMOS) selected Type 1 quasars
- Case of coeval obscured accretion and intense star formation at z≈2
- Open issues & census of heavily obscured quasars

Luminous obscured (Type 2) quasars selected in hard X-rays from the HELLAS2XMM survey: the *Spitzer* perspective

Sample selection: mostly, extreme X/O sources

SAMPLE: **HELLAS2XMM**

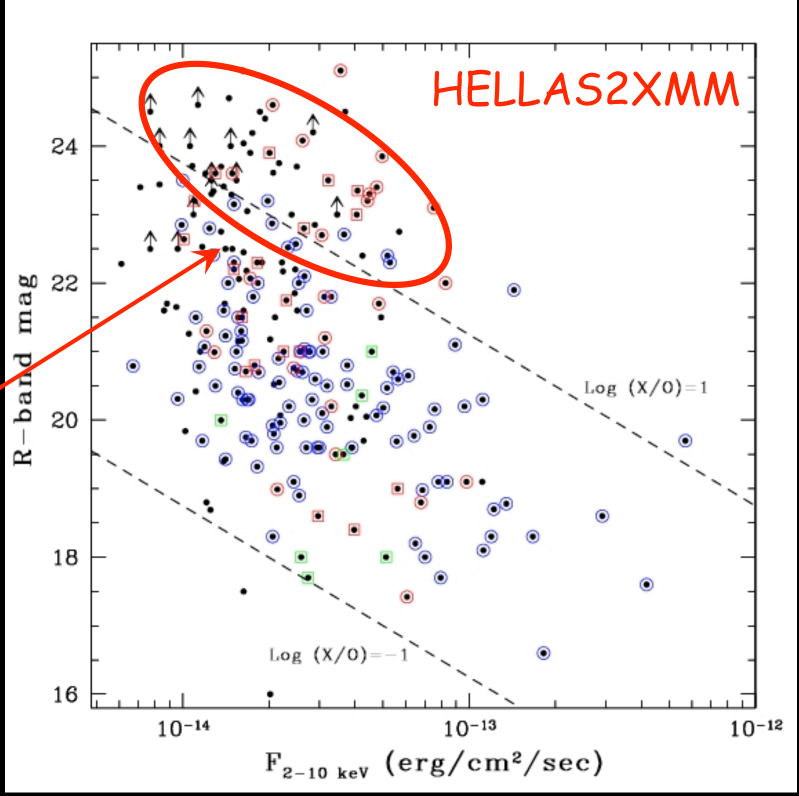
$F_{2\text{-}10\ keV}$ >10^{-14} erg cm^{-2} s^{-1} over 1.4 deg^2

70% spectroscopic completeness

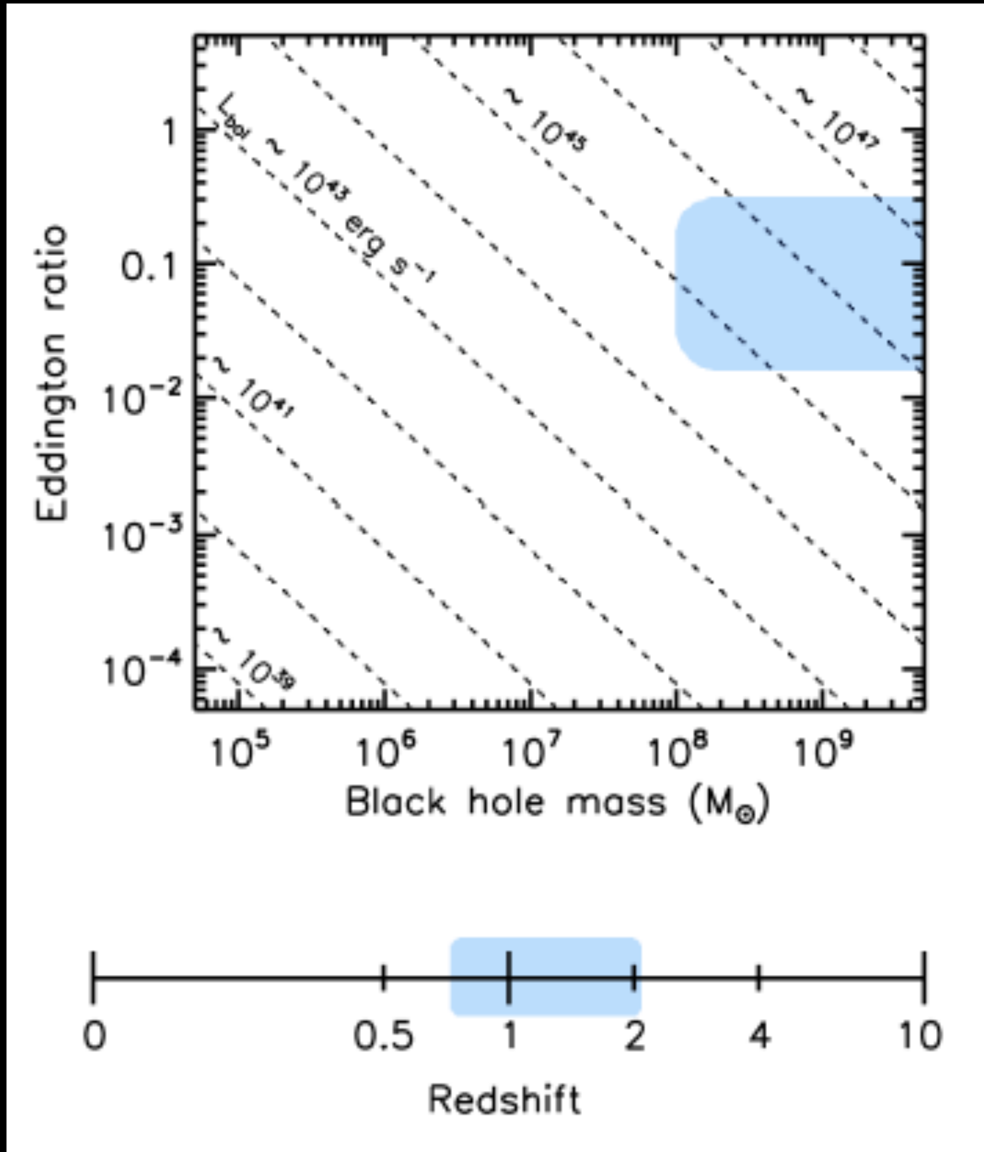
Optically faint (R>24) sources with limited identification + "certified" (with spec-z), mostly high X-ray-to-optical flux ratio (Log(X/O)>1) sources (suggestive of X-ray obscuration)

16 obscured ($\langle N_H \rangle \approx 7\times10^{22}$ cm^{-2}), X-ray luminous ($L_{2\text{-}10\ keV} \approx 10^{44\text{-}45}$ erg/s) quasars at z=0.9-2.1

All bright in the Ks band, the most extreme being EROs (Mignoli et al. 2004)



Spitzer data to characterize their X-ray emission and estimate bolometric luminosities



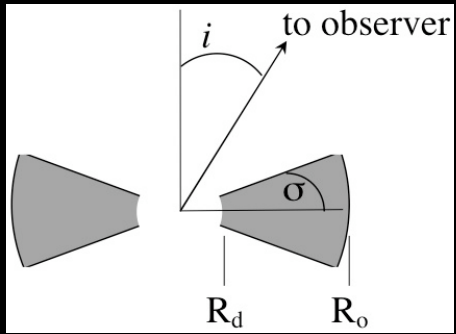
Eddington ratio
1
0.1
10^{-2}
10^{-3}
10^{-4}
$L_{bol} \sim 10^{43}$ erg s^{-1}
$\sim 10^{45}$
$\sim 10^{47}$
$\sim 10^{41}$
$\sim 10^{39}$
10^5
10^6
10^7
10^8
10^9
Black hole mass ($M_\odot$)
0
0.5
1
2
4
10
Redshift

Models for the infrared emission of AGN

Method: using the reprocessed IR emission to estimate the intrinsic optical/UV luminosity ➔ NEED FOR Lbol related to accretion processes

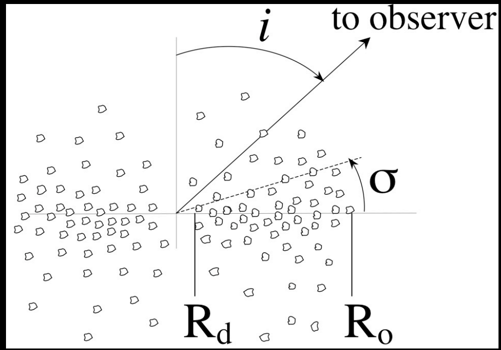
Smooth dust distribution

dust grains around a central source (AGN) in a smooth distribution (e.g., Pier & Krolik 1992, Granato & Danese 1994; Efstathiou & Rowan-Robinson 1995, Fritz et al. 2006)



Clumpy models

dust grains in clouds (not uniform distribution). A Type 2 AGN can be seen also at large inclination angles over the equatorial plane (e.g., Nenkova et al. 2002, 2008a,b; Hoenig et al. 2008, 2010; Schartmann et al. 2008) – *Talks by Gandhi and Schartmann*



Comparison:

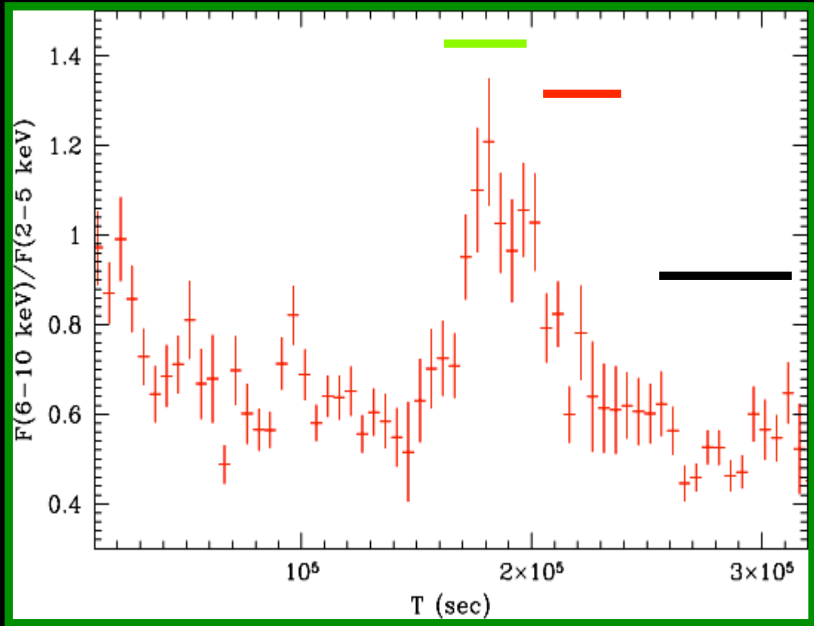
- ✓ Photometric data points generally reproduced by both models (see Dullemond & Van Bemmel 05).
- ✓ 'Smooth model': simpler, well reproduces the emission feature in emission
- ✓ 'Clumpy model' in agreement with X-ray variability (i.e. Risaliti et al. 07,09)

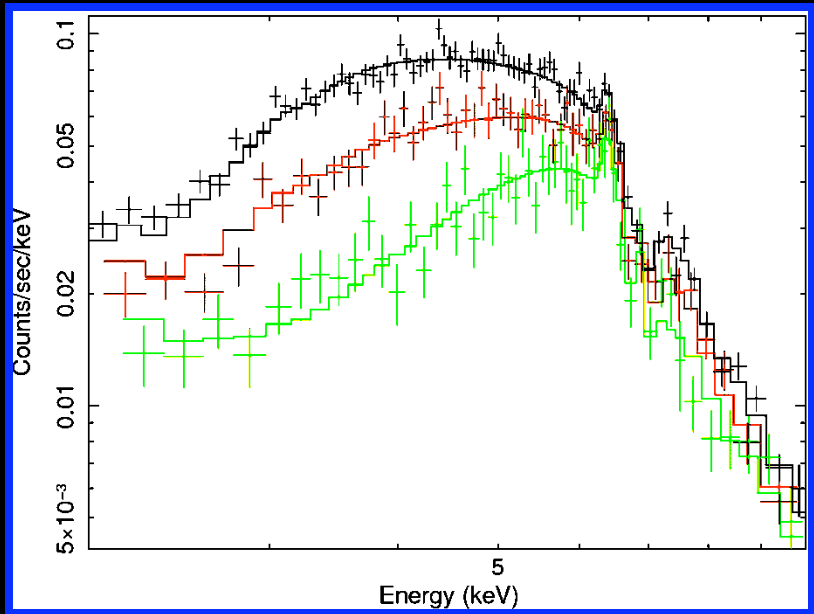
Indications from X-ray observations of Seyferts

Eclipses of the X-ray source are COMMON in nearby AGN:
$\Delta N_H \sim 10^{23}\text{-}10^{24}\ cm^{-2}$

$v > 10^3$ km/s
$D \approx 10^{13}$ cm
$n \sim 10^{10}\text{-}10^{11}\ cm^{-2}$

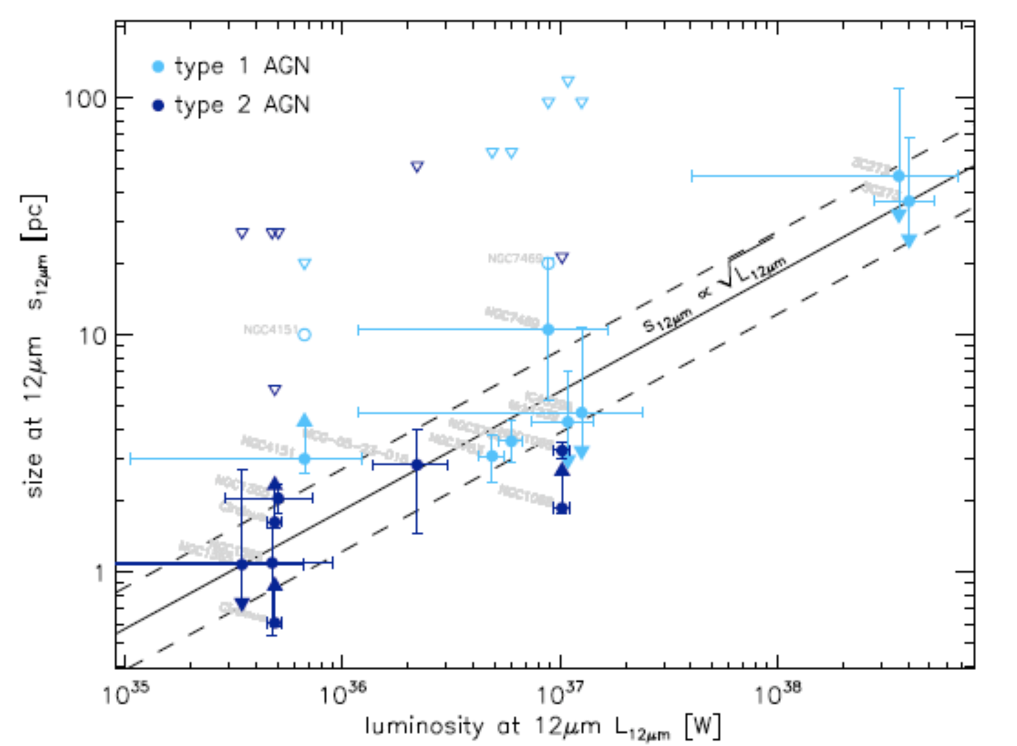
X-ray absorber "made" of BLR clouds





Risaliti et al., 2007, 2009…

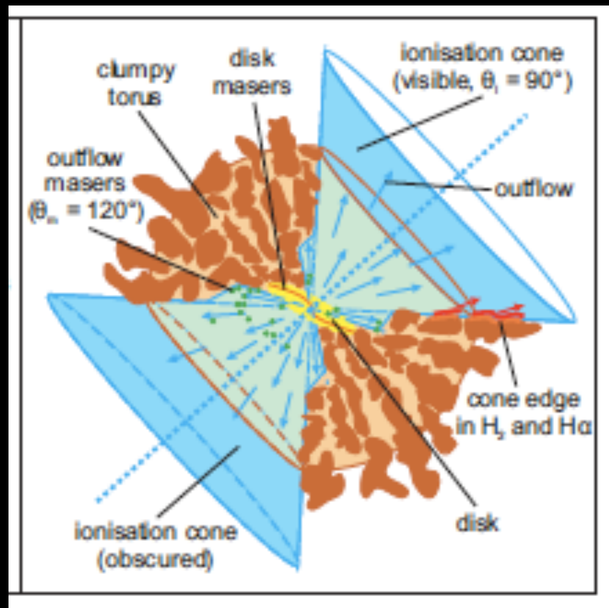
Indications from high-resolution mid-IR observations of Seyferts



Tristram+09;
(see also Jaffe+04, Meisenheimer+07; Tristram+07)

Talk by Schartmann on Monday

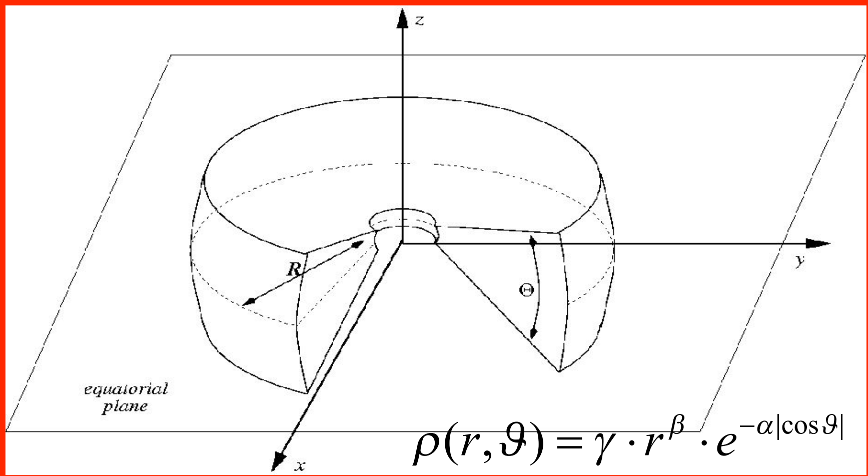
- Compact (a few pc) tori with a clumpy/filamentary dust distribution (warm disk + geom. thick torus)
- No significant Sey1/Sey2 difference



Tristram+07 - Circinus

Torus model: flared disk (Fritz+ 06)

- IR emission computed by solving the radiative transfer equations (absorption, scattering and re-emission from graphite and silicate dust grains)
- Model: original parameters:
- α, β → density distribution
- Θ → covering factor
- $\tau(9.7\mu m)$ → optical depth along the l.o.s.
- $R = R_{max}/R_{min}$ of the torus
- ψ → line of sight (w.r.t. the eq. plane)



$$\rho(r,\vartheta) = \gamma \cdot r^{\beta} \cdot e^{-\alpha|\cos\vartheta|}$$

SED modeling: stars, AGN, and starburst (if data>24 μm)

- SSP for stellar population, Schmidt-like law of star formation, Chabrier IMF, MW extinction law
- AGN emission re-processed by the torus in the mid-IR (grid of 388 models)
- starburst templates to account for the FAR-IR/sub-mm data points

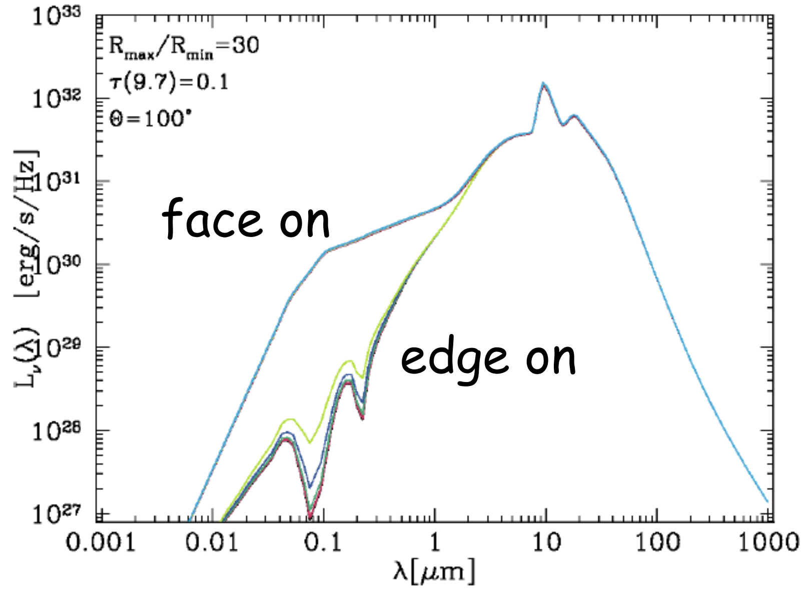
Fit over the observed optical, IR (and sub-mm in one case) photometric points

Fitting model and parameter space

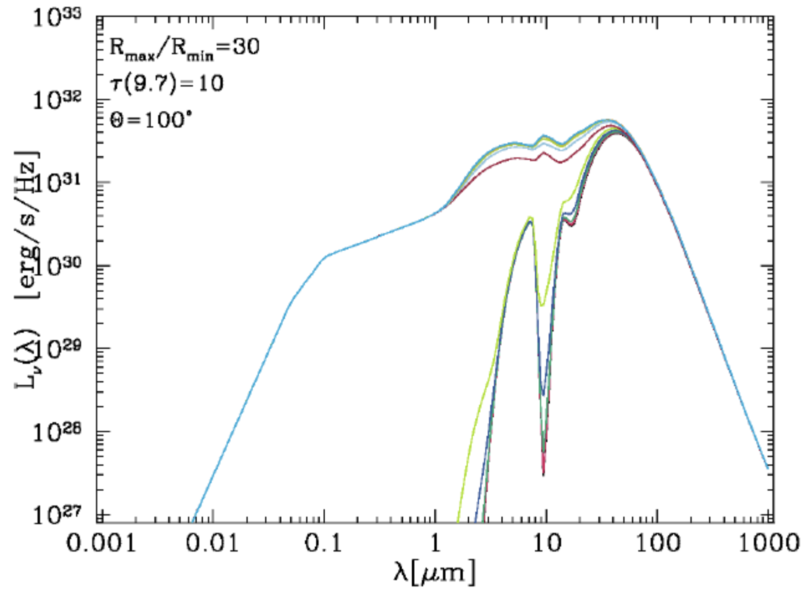
Limited number of photometric data points and degeneracy in the parameters

- β, Θ and $\tau(9.7\mu m)$ as free parameters
- best-fitting SED + 1σ solutions (χ^2)

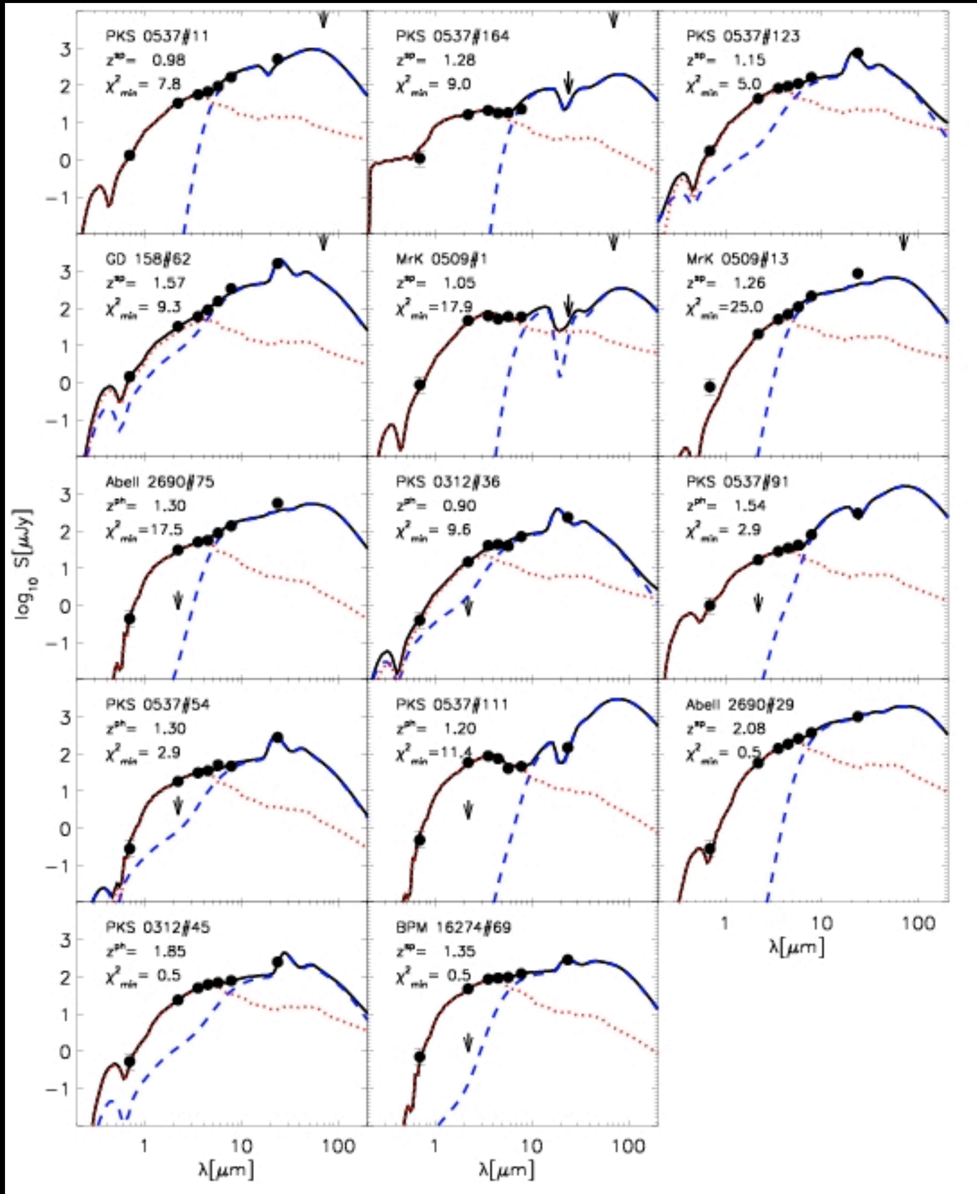
Low $\tau_{eq}(9.7\mu m) \Rightarrow$ Silicate feature in emission



High $\tau_{eq}(9.7\mu m) \Rightarrow$ Silicate feature in absorption



Results – I. SED deconvolution analysis



Pozzi et al., A&A (2010)

Torus (AGN)
Host Galaxy

✓ Typically, good fits to the R, K_S and *Spitzer* data

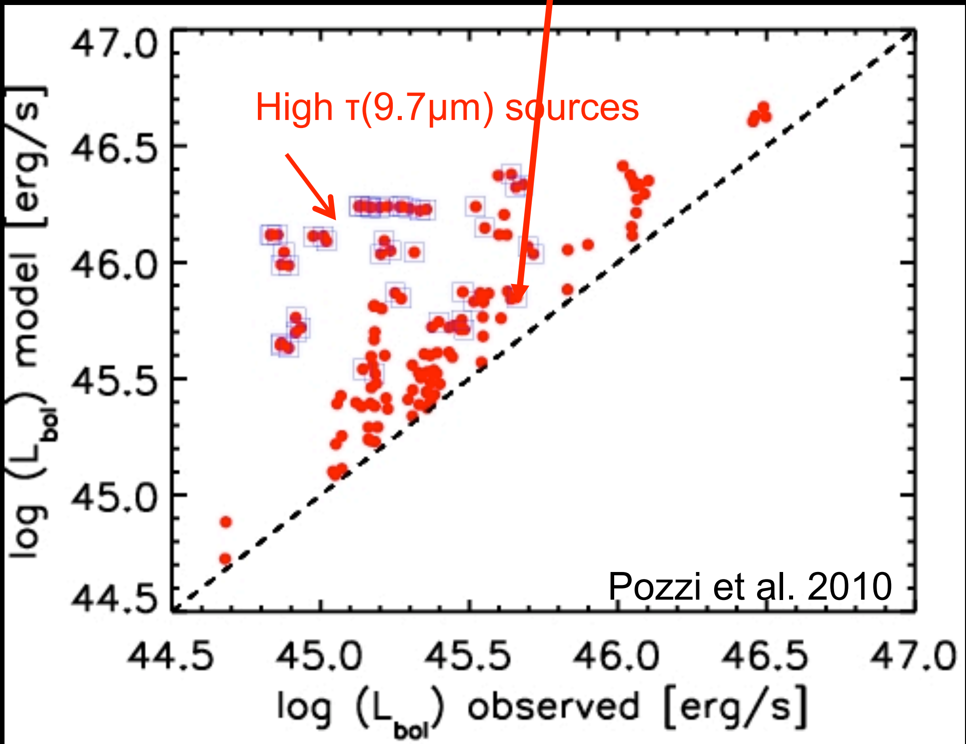
✓ Host galaxy required, prominent for extreme X/O sources

✓ Nucleus starts dominating at the longest-λ IRAC bands

✓ 80% of sources have τ(9.7μm)<3

Results – II. "Corrections" to the observed L_{bol}

Mainly geometric correction factor

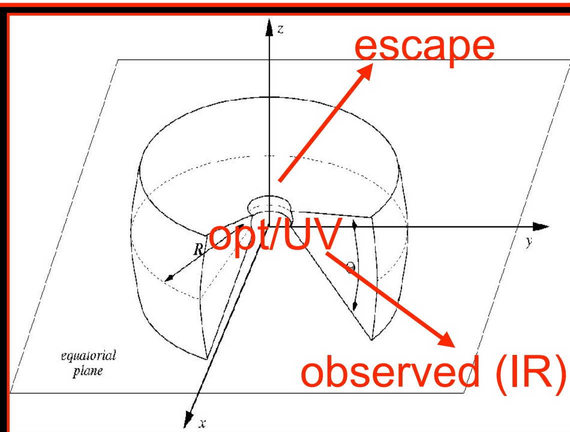


Only a fraction of the intrinsic accretion disc radiation is intercepted by the torus (function of the covering factor

$$CF= (4\pi- 2\pi\ (1+\cos\Theta))/\ 4\pi$$

+

Dust self-absorption effects for large τ(9.7μm)



L_{bol} (model) = L (accr, from SED fitting) + L_X

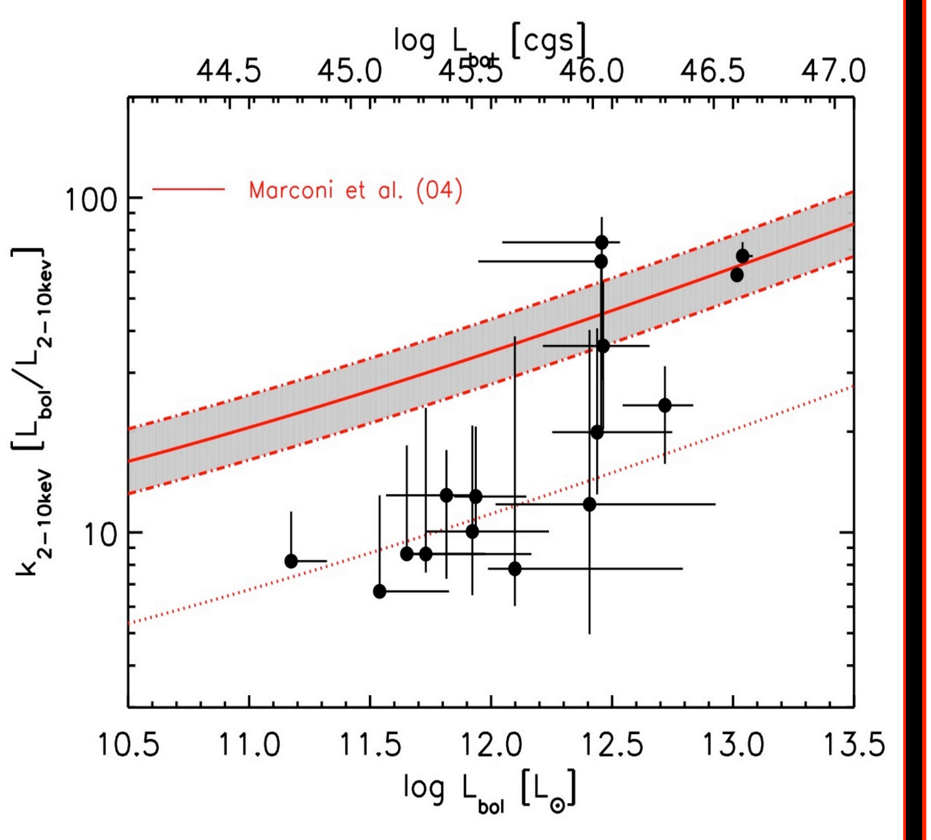
L_{bol} (observed) = L_{IR} + L_X

➔ L_{bol} (model) ≈ 2 × L_{bol} (observed)

Results – III. AGN bolometric corrections

Keep in mind: hard X-ray selected sample

$$K_{bol,X} = \frac{L_{bol,mod}}{L_{2\text{-}10\,keV}}$$



$L_{BOL} \approx 6\times10^{44}-4\times10^{46}$ erg/s

$K_{2\text{-}10\,keV} \approx 20$ (median), with large spread

Similar to large (≈540) Type 1 QSOs in XMM-COSMOS (Lusso et al. 2010)

For comparison:

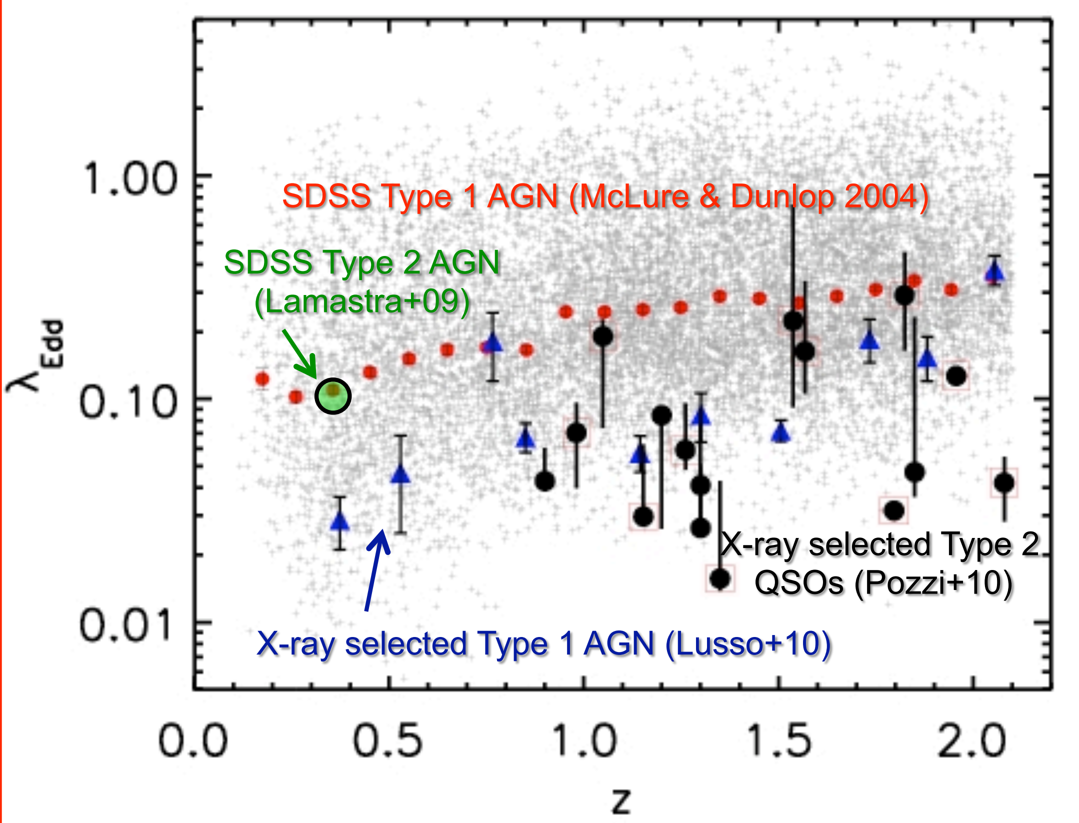
- ✓ ≈30 in Type 1 QSOs from Elvis+94 but large dispersion in the broad-line QSO SEDs
- ✓ X-ray luminous ($L_X \approx 10^{43\text{-}46}$ erg/s) AGN by Kuraszkiewicz+03: k≈18
- ✓ low-luminosity ($L_X \approx 10^{42\text{-}43.6}$ erg/s) AGN by Ballo +07; k≈12

Systematically lower than predicted by Marconi et al. (2004)

Results – IV. Eddington ratios

Keep in mind: hard X-ray selected sample

$$\lambda = \frac{L_{bol}}{L_{Edd}}$$



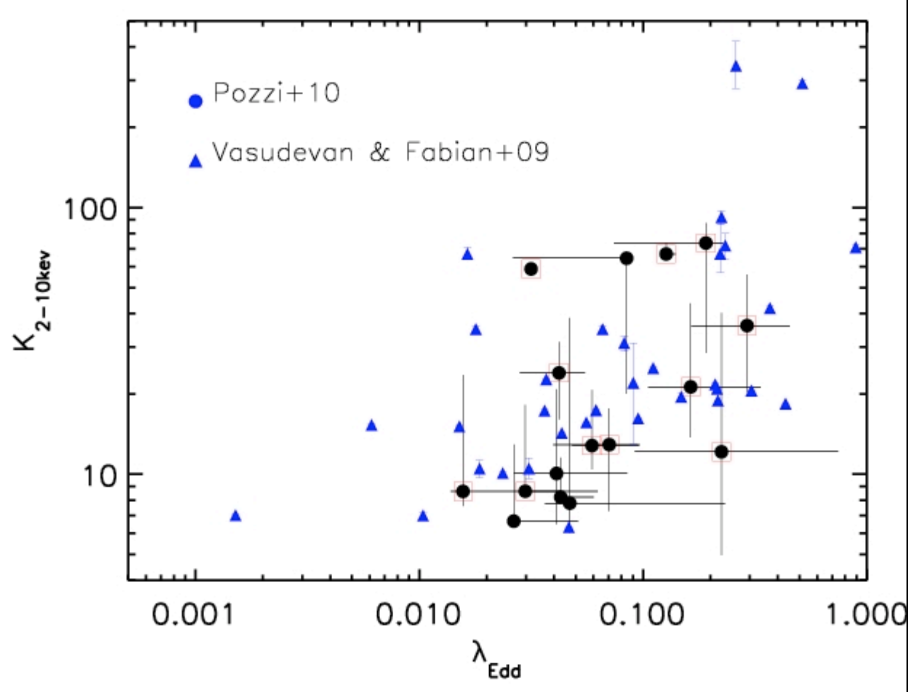
median λ≈0.08

Lower than SDSS in the same redshift interval

Consistent with XMM-COSMOS Type 1 AGN (Lusso et al. 2010)

Effect of X-ray selection?

Comparison with Vasudevan & Fabian results

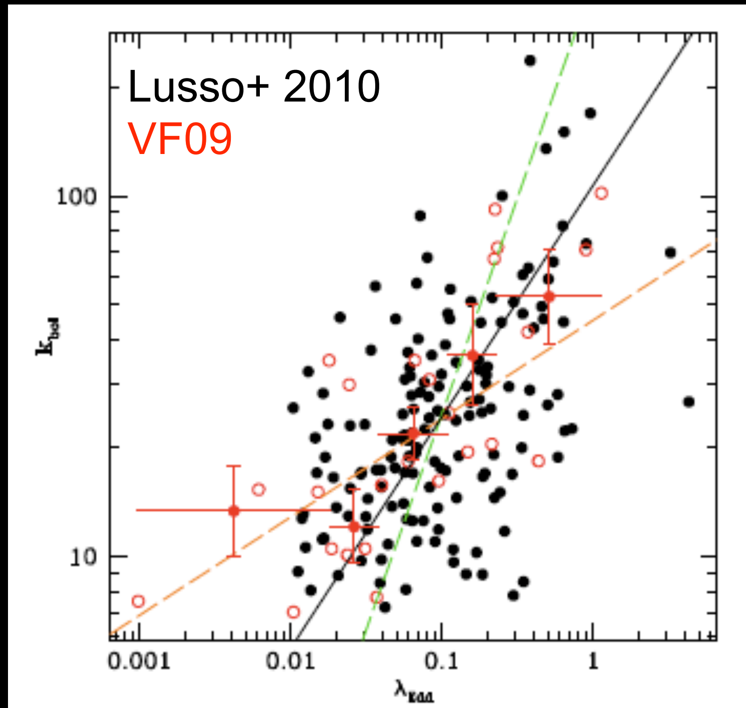


Recent indications for a trend of increasing K_{bol} at increasing Eddington ratios using a sample of AGN with simultaneous UV/X-ray observations

SED=function(λ_{Edd}), different fraction of ionizing UV photons

Agreement with XMM-COSMOS results for Type 1 AGN (Lusso et al. 2010)

k_{bol}≈22 for λ≤0.1, k_{bol}≈27 for 0.1<λ≤0.2, and *k_{bol}≈53 for λ>0.2*



A case of coeval AGN and starforming activity at z≈2

Similar cases reported in Page et al. (2001, 2004), Stevens et al. (2004), Mainieri et al. (2005), Polletta et al. (2008), Aravena et al. (2008), Brusa et al. (2010)

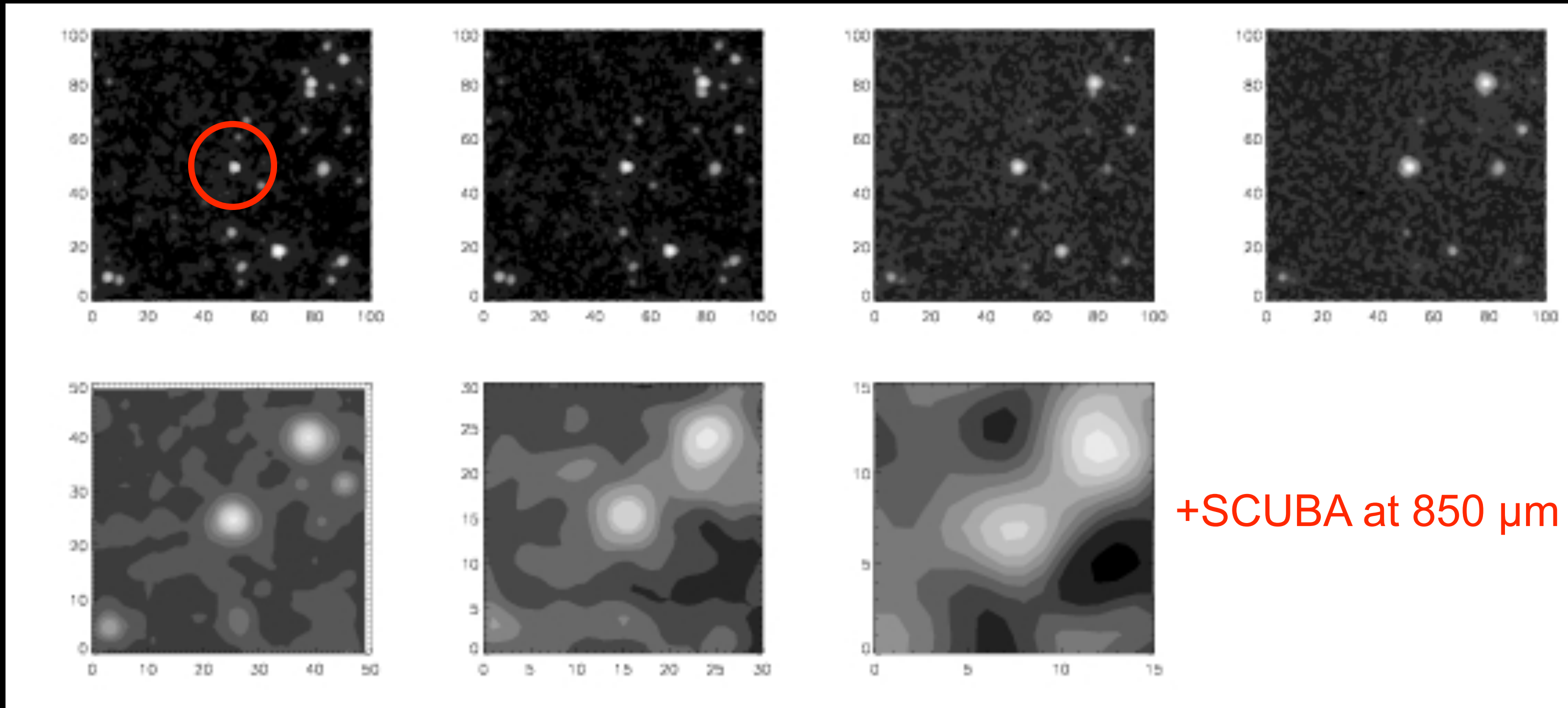
+

M. Page's talk +

+ *see posters by M. Brusa and F. Carrera*

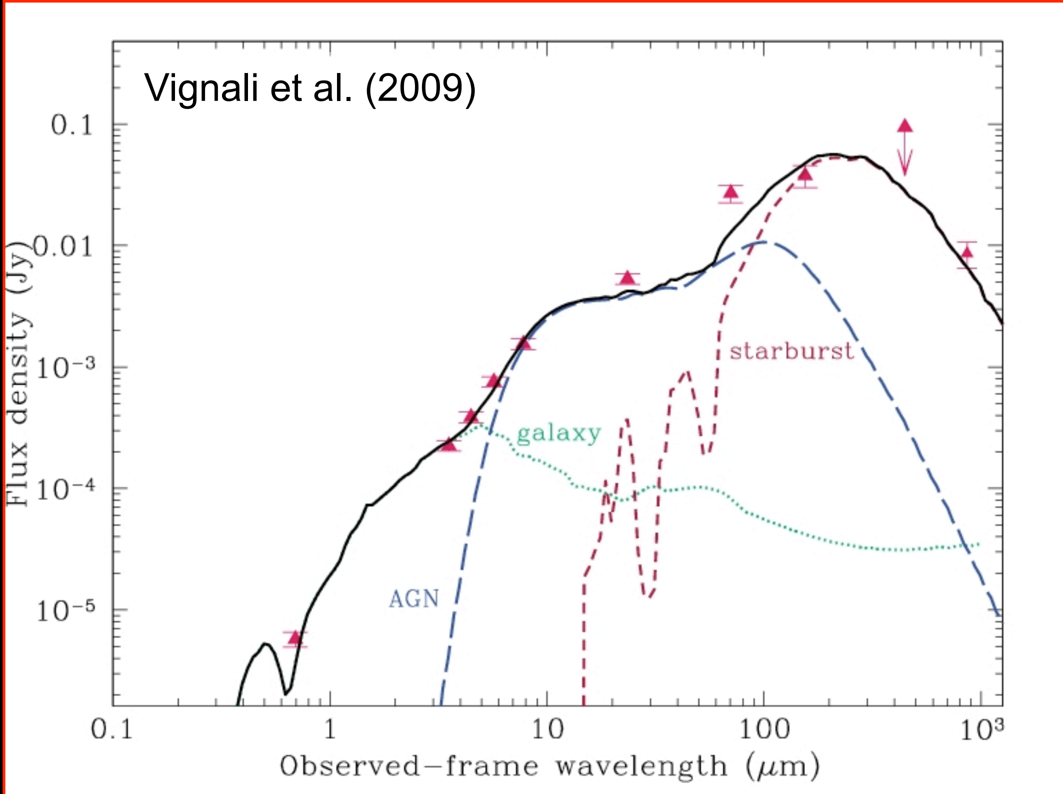
The *Spitzer* view of H2XMMJ003357.2−120038 at z=1.957

3.6 4.5 5.8 8.0 micron



24 70 160 micron

SED fitting results



- τ (9.7) ≈1.0
- covering angle≈140 deg
- SFR≈1500 $M_\odot$/yr (Arp 220 best FIR SED)
- ≈54% is the AGN contribution to the 1-1000 μm

Using MH03: $M_{BH} \approx 1.9 \times 10^9\ M_\odot$

$L_{bol} = 4.3 \times 10^{46}$ erg/s

$\Rightarrow \lambda$=Edd. ratio≈0.19

Some open issues…

- Besides being found through many different observational approaches, an overall picture explaining the multi-wavelength properties of Type 2 quasars is probably still missing.

  In particular:
  - ✓ How much confident are we about their accretion rates? → need for large, well defined samples with broad coverage
  - ✓ Structure/geometry of the absorber (torus, clouds, winds) around SMBHs?
  - ✓ How common is coeval accretion and star-formation activity at high redshift?
  - ✓ What are the perspectives for deep *Chandra*/XMM-*Newton* surveys to select the most heavily obscured quasars? How do different selection criteria (band) relate each other?
  - ✓ Prospects for next-generation of X-ray satellites?

Towards a census of the most obscured (Compton-thick) AGN

Heavily obscured, Compton-thick AGN are mostly unconstrained beyond the local Universe (for a listing, Comastri 2004; Della Ceca et al. 2008). Overall, required by XRB models (e.g., Gilli et al. 2007)

Infrared selection

• Mid-IR/optical extreme colors + X-ray stacks, IRS spectra, etc. (e.g., Houck+05, Weedman+06, Polletta+06, Daddi+07, Fiore+08,09, Alexander+08, Lanzuisi+09, Bauer+10)

➔up to z≈2, in most cases via X-ray stacking analysis

Spectroscopic surveys

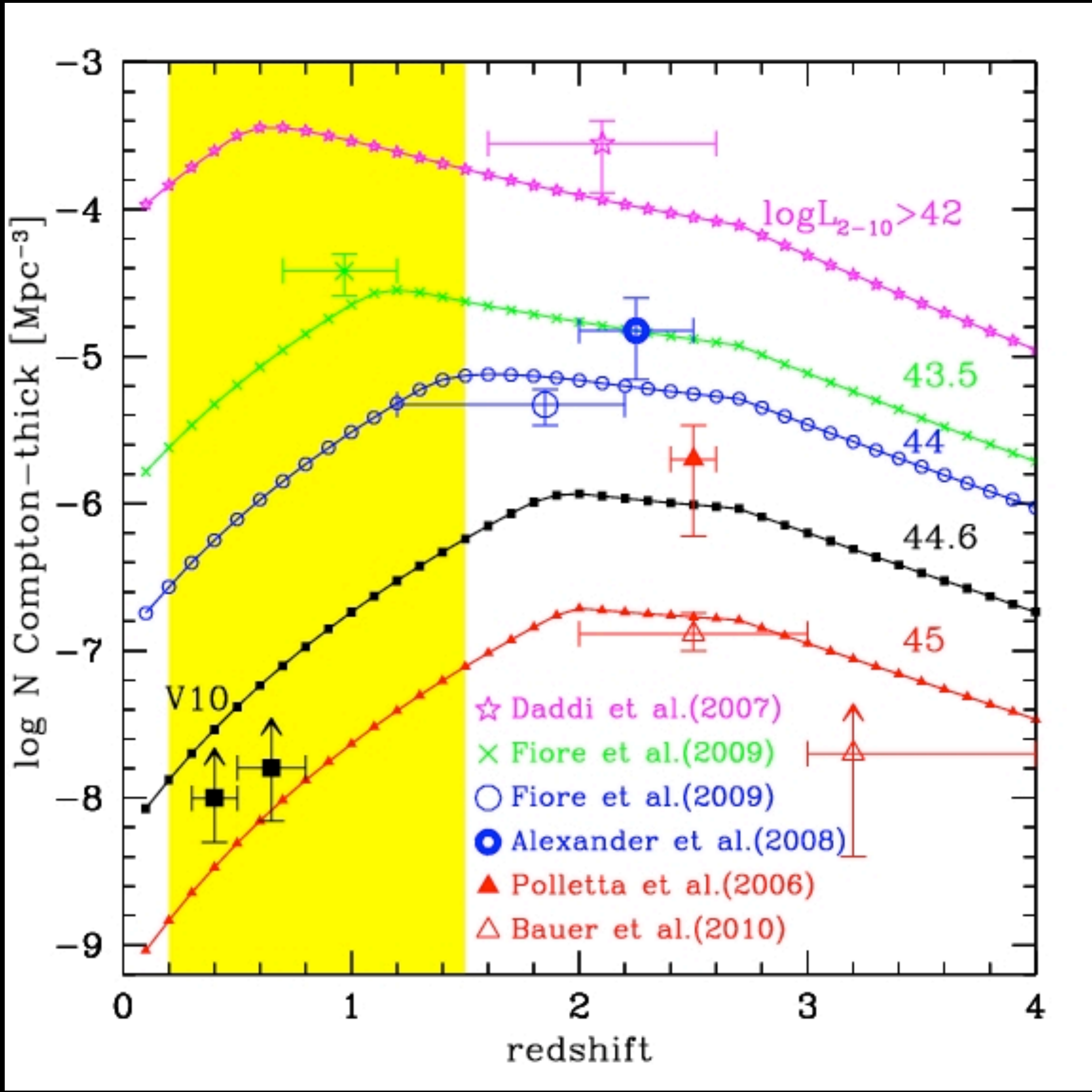
Based on high-ionization narrow emission lines as proxy of nuclear emission

• [OIII]5007Å (e.g., Zakamska+03, Vignali+06,10 + many others) – z=0.3−0.8

• [NeV]3426Å (Gilli+10) – z up to 1.4

• [OIV]26μm (*Spitzer* IRS spectra; Diamond-Stanic+09, Rigby+09) – local z

The space density of Compton-thick AGN



see Vignali et al. 2010
Gilli et al. 2010

see poster by Feruglio et al.
(BzK in C-COSMOS)

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Hard X-ray surveys

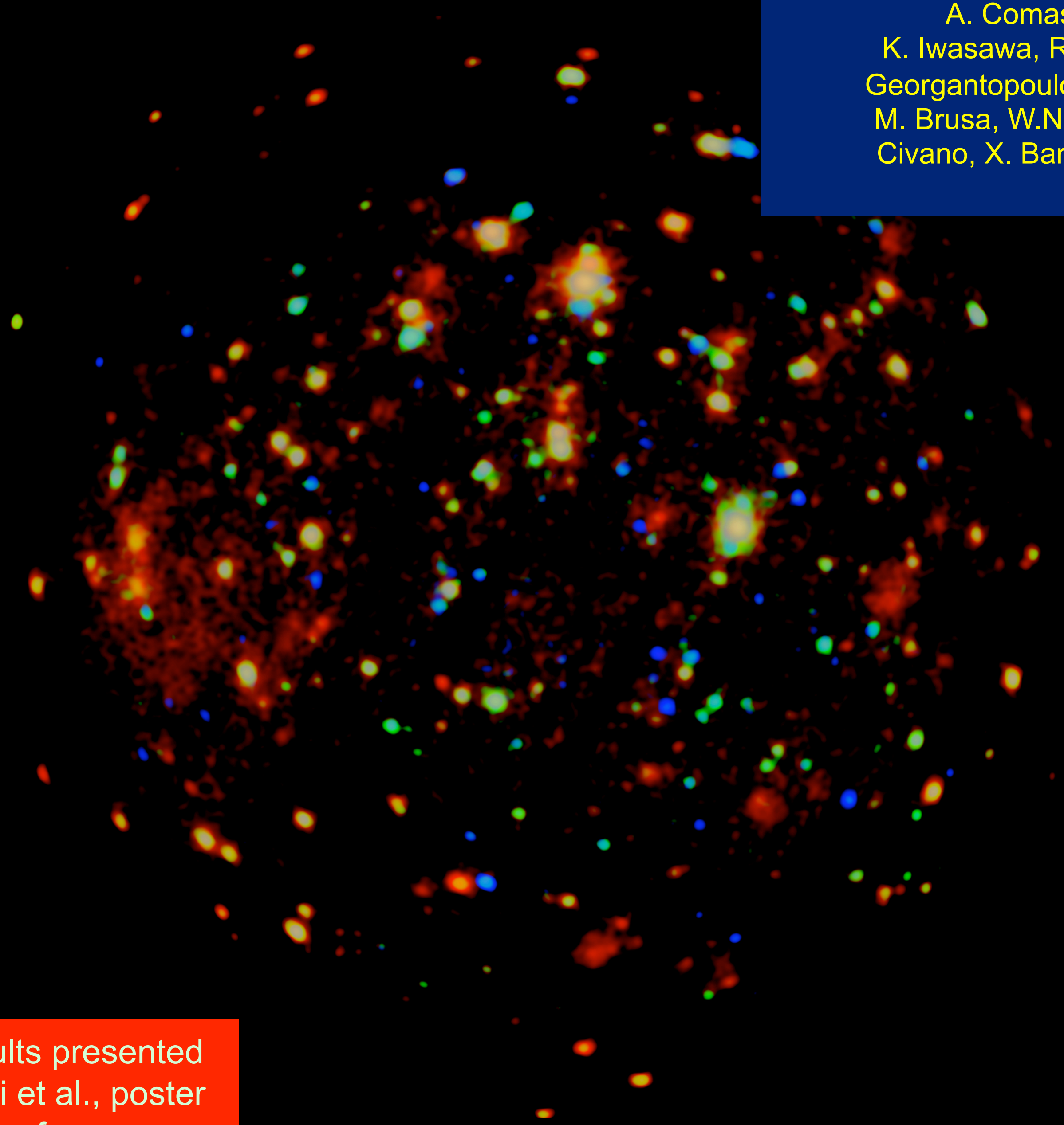
• INTEGRAL and Swift/BAT surveys (>10 keV; e.g., Beckmann+08; Tueller+09)
➔limited sensitivity, mostly local Universe

• Deep X-ray surveys, by means of X-ray reflection signatures (e.g., Tozzi+06, Georgantopoulos+07,09)
➔ potentially up to high redshift, limited by photon statistics

Goal of XMM-CDF-S + incoming 2Ms *Chandra* CDF-S data

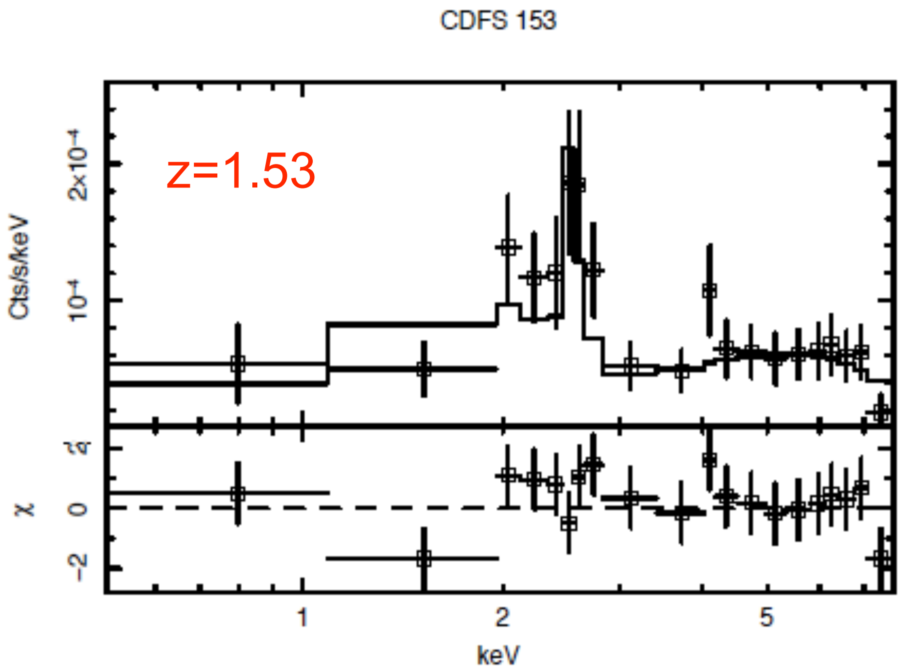
≈3 Ms XMM-*Newton* granted exposure in the CDF-S

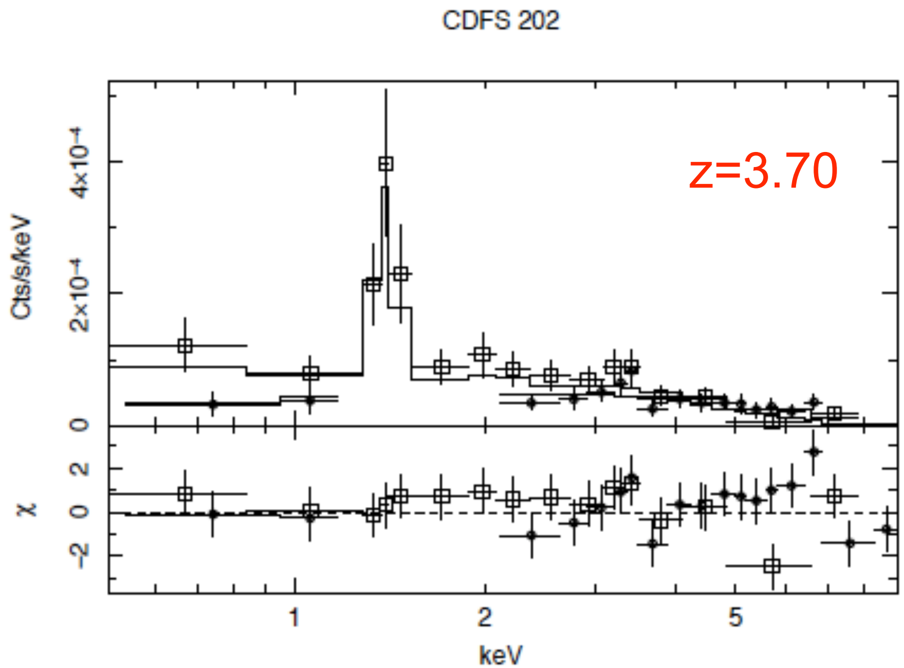
A. Comastri, P. Ranalli, K. Iwasawa, R. Gilli, C. Vignali, I. Georgantopoulos, G. Zamorani, F. Fiore, M. Brusa, W.N. Brandt, J. Silverman, F. Civano, X. Barcons, F. Carrera + many more



Preliminary results presented by Comastri et al., poster at this conference

The 3 Ms XMM-*Newton* Survey in the CDF-S





Comastri et al., in prep.

Summary

Method:

Application of the Fritz et al. 06 model for the AGN IR emission to estimate the nuclear physical parameters of a sample of X-ray selected Type 2 Quasars

Results:

- ✓ Observed SEDs (optical-24μm) well reproduced by the model
- ✓ Median $K_{bol,X}$≈20 with large dispersion
- ✓ λ_{EDD} ratios (≈0.08) systematically lower in comparison to optically selected (SDSS) AGN (0.4±0.4)

Coming next:

- Test the results using clumpy models
- Enlarge the sample
- FIR (*Herschel*) data to reduce/break the degeneracy
- Search for further cases of co-eval AGN+SB at high-redshift

The End