The quest for obscured quasars through infrared, optical, and X-ray observations

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In collaboration with

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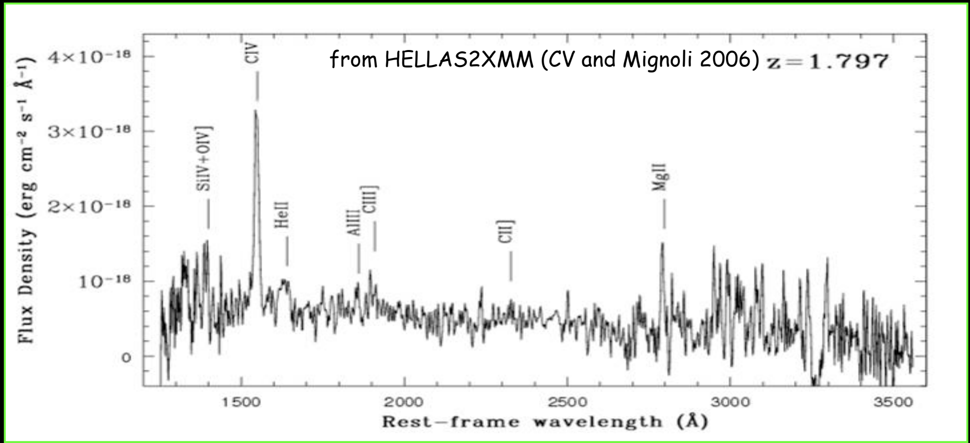
The quest for Type 2 QSOs: outline

- The long quest for Type 2 quasars. But what defines a quasar as a Type 2?
- The *Spitzer* contribution: mid-infrared selection criteria of (obscured) quasars
- Selection of obscured AGN from hard X-rays: the *Spitzer* view of HELLAS2XMM sources
- The Type 2 quasar population from the SDSS: *Chandra* and XMM-*Newton* follow-up observations. Are Compton-thick AGN hiding among the X-ray faintest Type 2 quasars?

Type 2 quasar: optical vs. X-ray definition

Optical: high-ionization, narrow emission-line (FWHM<1500-2000 km/s) spectrum

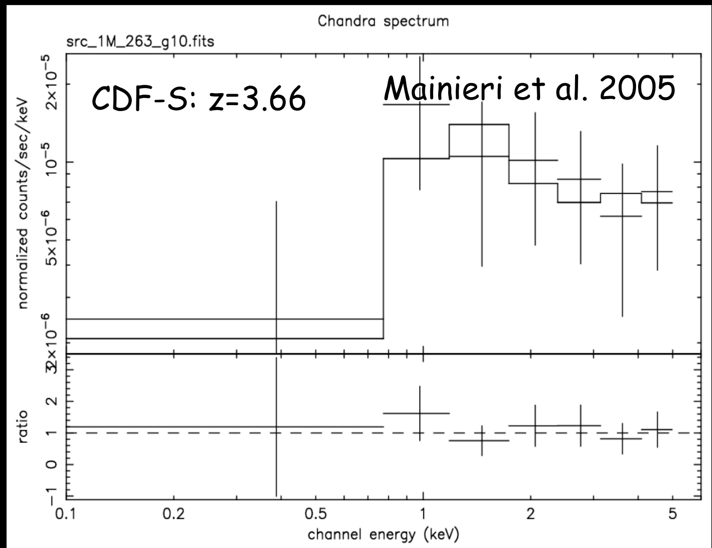
"big cousins" of local Seyfert 2 galaxies



sometimes the two definitions do not match

Selection at other wavelengths (e.g., in the MID-IR?)

+ many more from *Chandra* and XMM-*Newton* surveys (e.g., Stern+02, Norman+02)

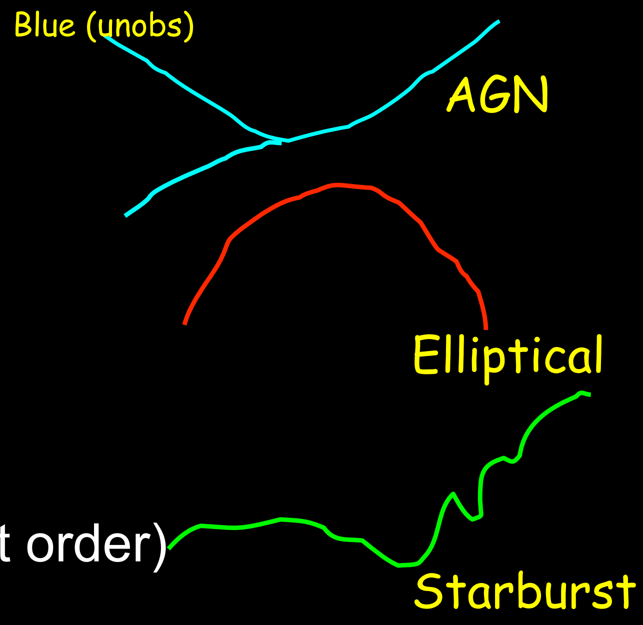


X-rays: high-luminosity ($>10^{44}$ erg/s), obscured ($N_H>10^{22}$ cm^{-2}) AGN required by XRB synthesis models

Mid-IR selection of (obscured) AGN

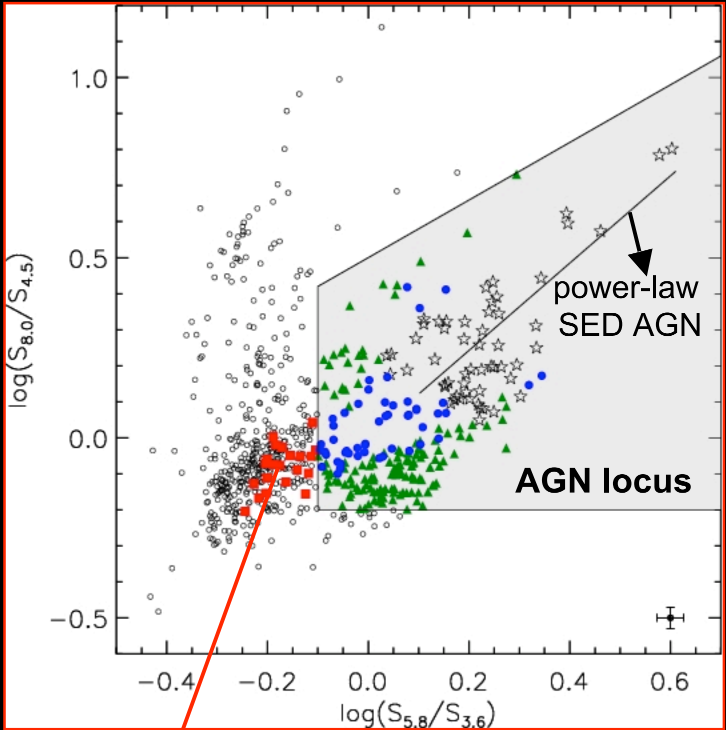
Basic principles:

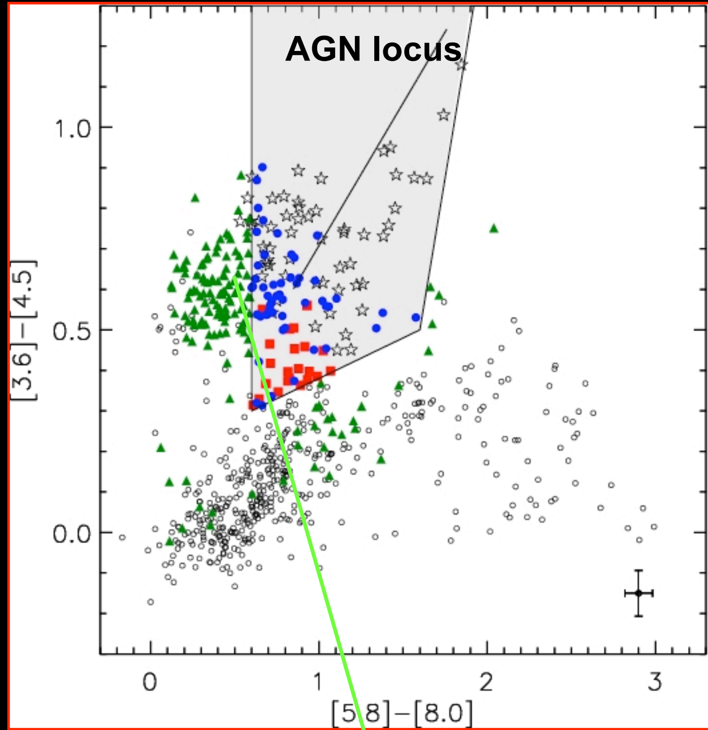
obscured and unobscured AGN are expected to have warm power-law SEDs at $\lambda>1\mu m$ (different from elliptical/starburst)



AGN (both type 1 and 2) can be isolated (at first order) using *Spitzer* colors

Caveat: using only IRAC data may not be conclusive originally in Lacy et al. 2004





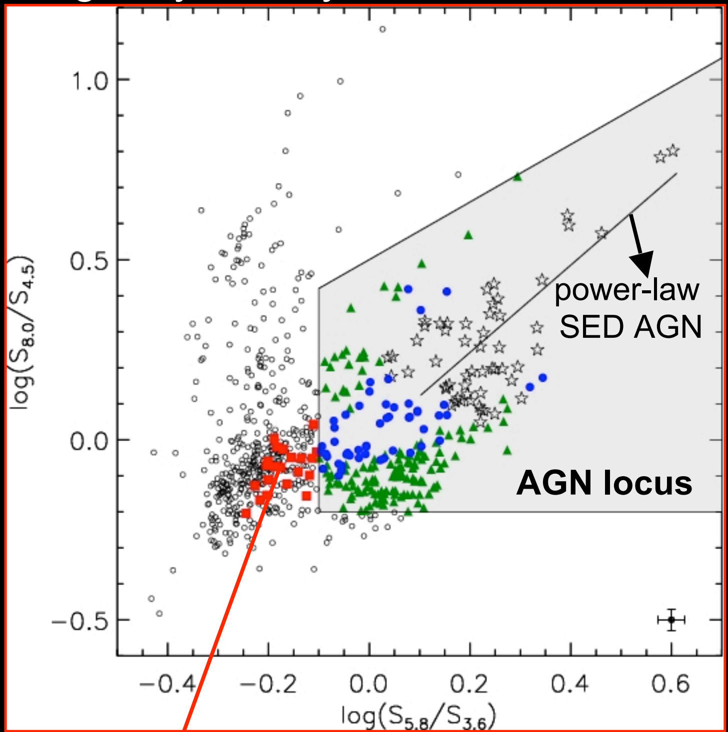
low-z IR-normal galaxies

Donley et al. 2008
Stars=power-law galaxies (PLGs)
Blue circles: both criteria matched
Green triangles: Lacy+04 criteria
Red squares: Stern+05 criteria

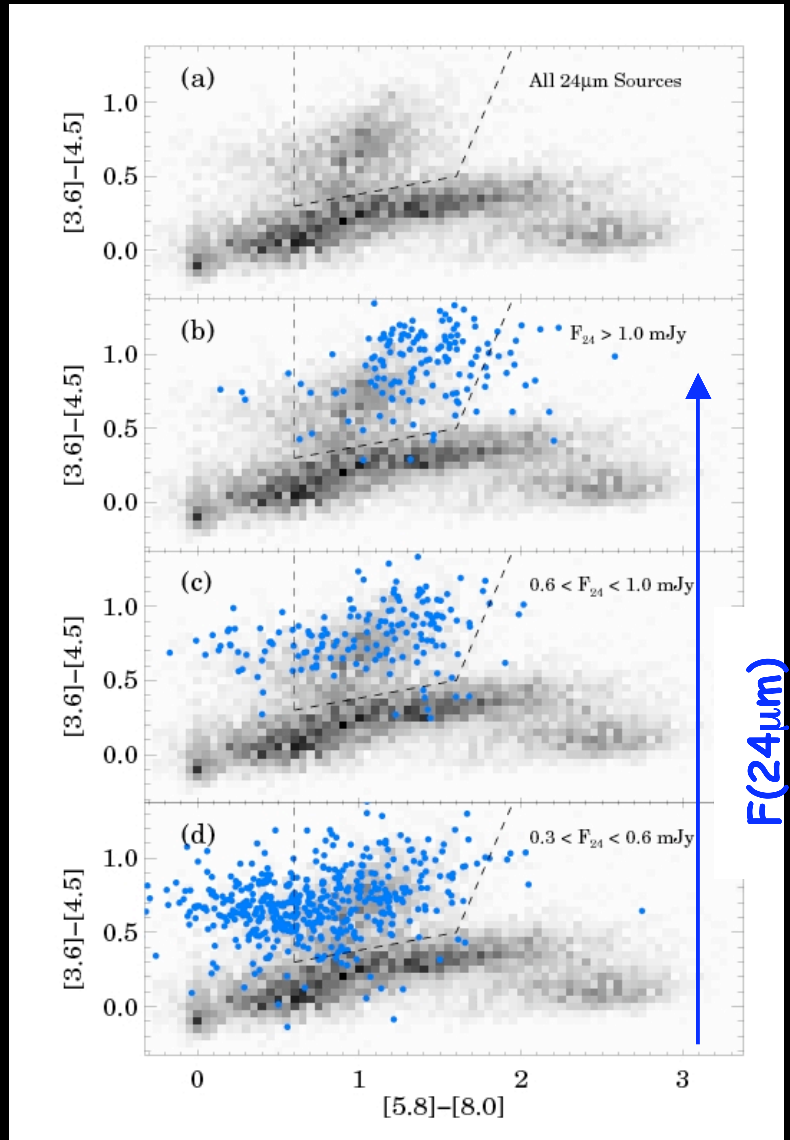
contamination from galaxies
no clear obscured AGN criteria

z≈2 star-forming galaxies

originally in Lacy et al. 2004



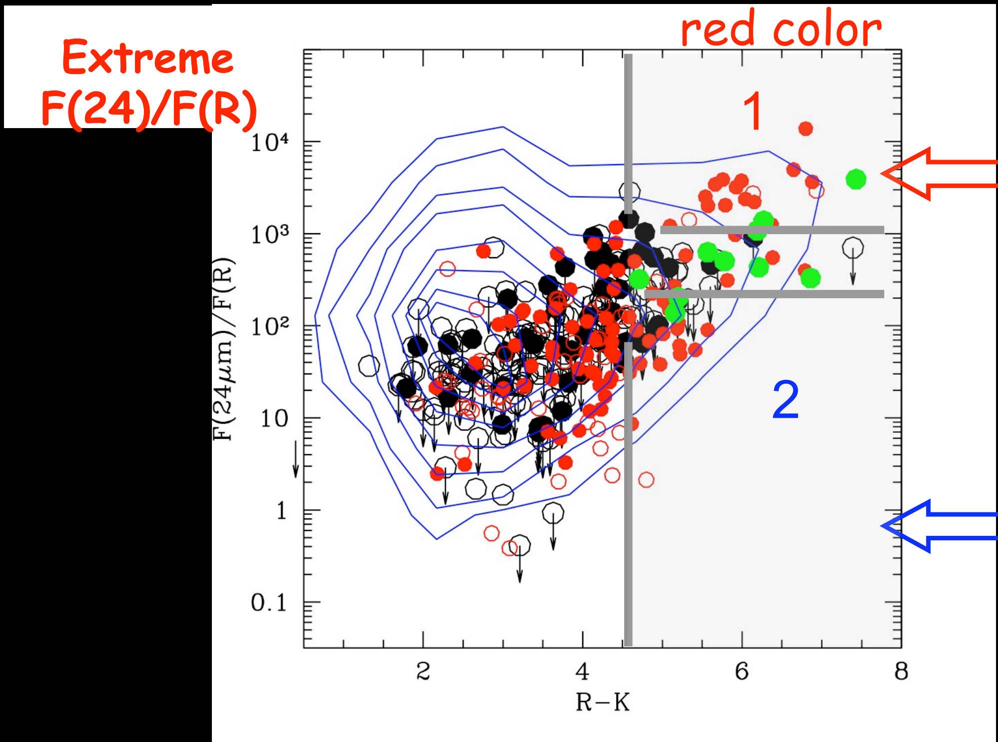
low-z IR-normal galaxies

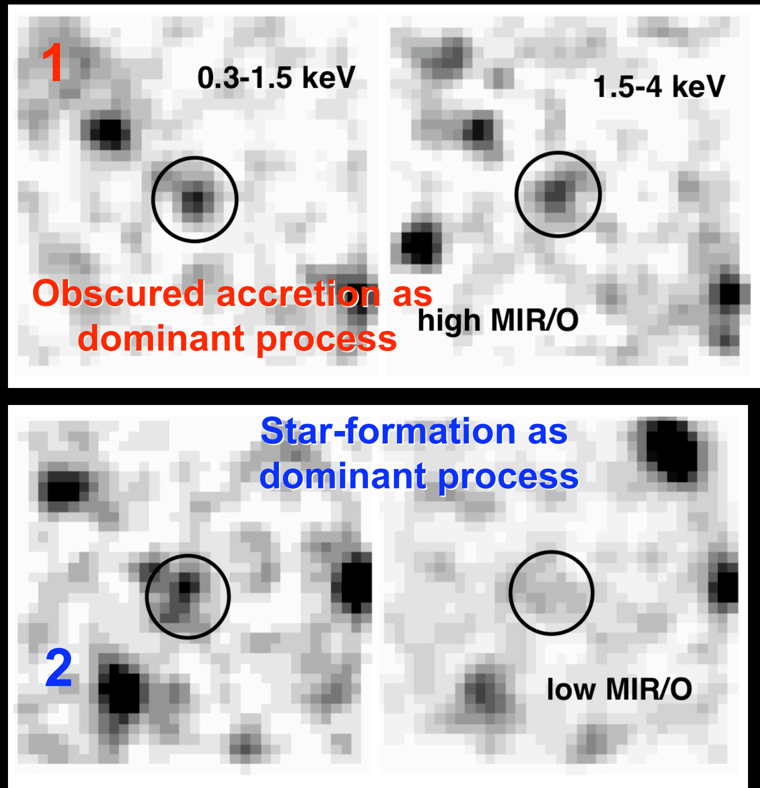


Fraction of AGN candidates increases with F(24 μm)

Distant obscured galaxies
(DOGs; Dey et al. 2008)

Red galaxies with large IR to optical (UV) flux ratios to search for high-z Compton-thick AGN





CDF-S: <log L(5.8 μm)> ≈ 44.6
-> Log(L_X) ≈ 43 (expected) vs. 41.8 (observed from X-ray stacking analysis)
-> Log N_H>24 at z=2 (Compton-thick)

Fiore et al. 2008

see also Daddi et al. 2007

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

Scientific goals

1) To estimate the physical properties of a sample of obscured Type 2 quasars at $z \approx 1-2$ selected in the 2-10 keV band from the HELLAS2XMM survey using

morphological information

+

multi-band photometry (X, opt, NIR, MIR-Spitzer)

Properties: Bolometric luminosities & $K_{x,bol} = L_{bol} / L_{(2-10kev)}$
BH masses
Eddington ratios $\lambda_E = L_{bol}/L_{EDD}$

2) To compare the results with other samples of AGN (mainly Type 1, i.e., broad-line), like the SDSS QSOs

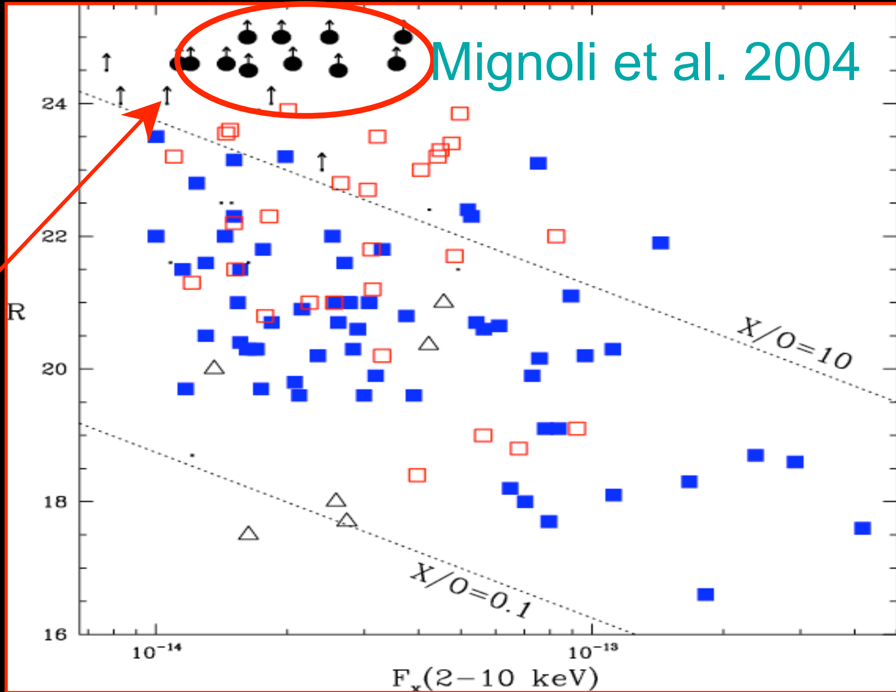
Sample selection: extreme X/O sources

•SAMPLE: **HELLAS2XMM**

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

•Optically faint (**R>24**) sources with no optical identification

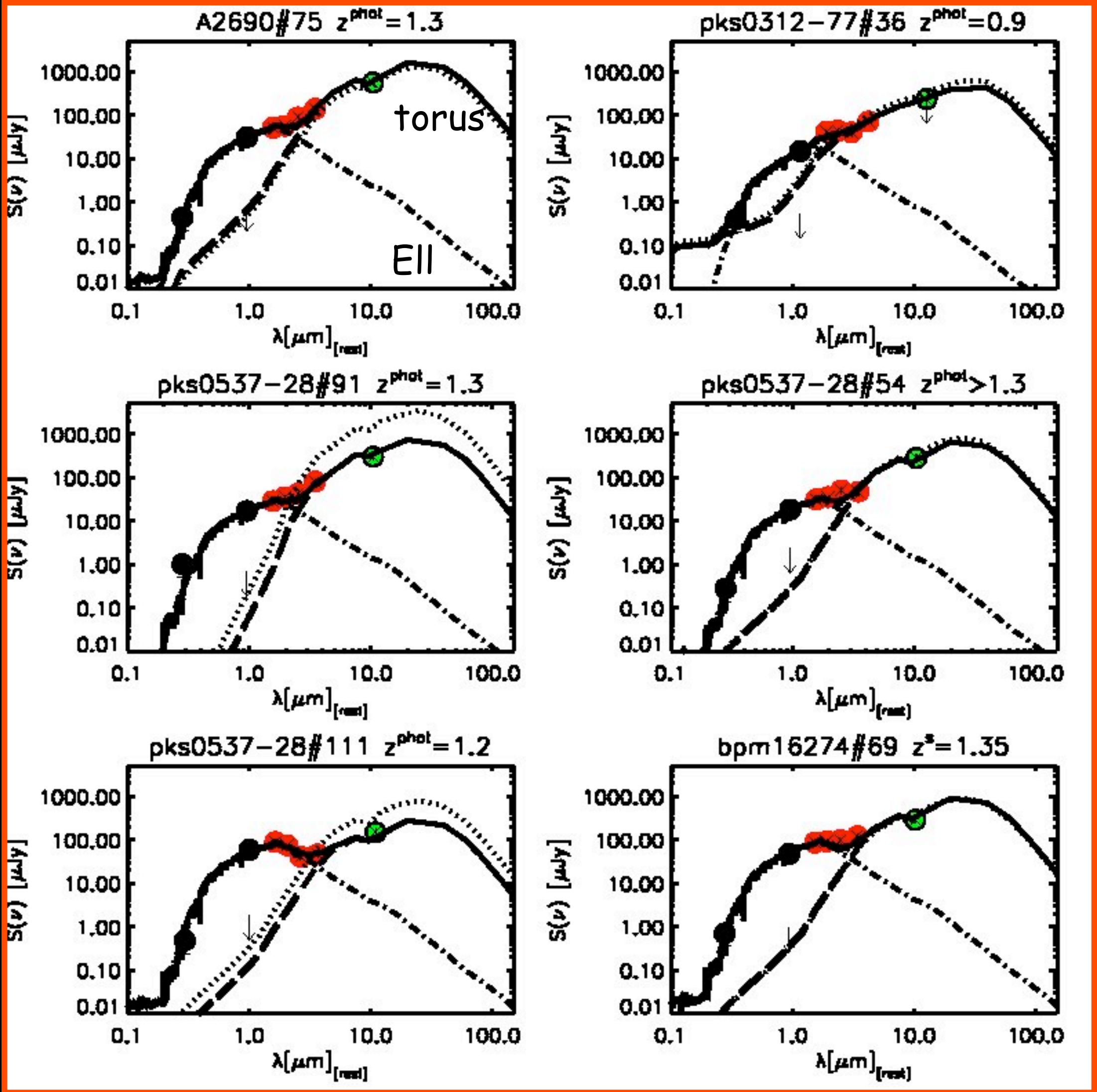
➔high X-ray-to-optical flux ratio (X/O>10) sources with indications of X-ray obscuration



ISAAC K_S-band follow-up

- **ALL bright in the K_S band**
- All have **R-K_S>5** ➔ Extremely Red Objects (**EROs**), some are extreme
- Most have **elliptical** profiles, two are point-like (Mignoli et al. 2004)

SED analysis: bulge-dominated sources: Nuclear + host-galaxy emission



Pozzi et al. 2007

- ✓ Nuclear comp. consistent with K_S upper limits
- ✓ Nucleus starts dominating at ≈6 μm
- ✓ Torus consistent with Silva et al. (2004) predictions -normalized to the X-rays- within factor of 2-3
- ✓ z-phot consistent with the spectroscopic ones (when available)

Bolometric luminosity and correction

Bolometric luminosity = L_{BOL} = $K_{bol,x} \times L_{2\text{-}10\ keV}$

bolometric correction (≈35 in Type 1 QSOs from Elvis+ 94)
BUT large dispersion in the broad-line QSO SEDs

L_{BOL}

1. Sum the radiation directly linked to the accretion

→ $L_{BOL} = L_{X,INT} + L_{OPT,UV}$

REQUIRED: ►to remove IR bump (re-processed radiation)
►to correct for gas/dust absorption in X & optical/UV

2. Sum of the X-ray intrinsic radiation + IR radiation

→ $L_{BOL} = L_{X,INT} + corr{*}L_{IR,OBS}$

our approach

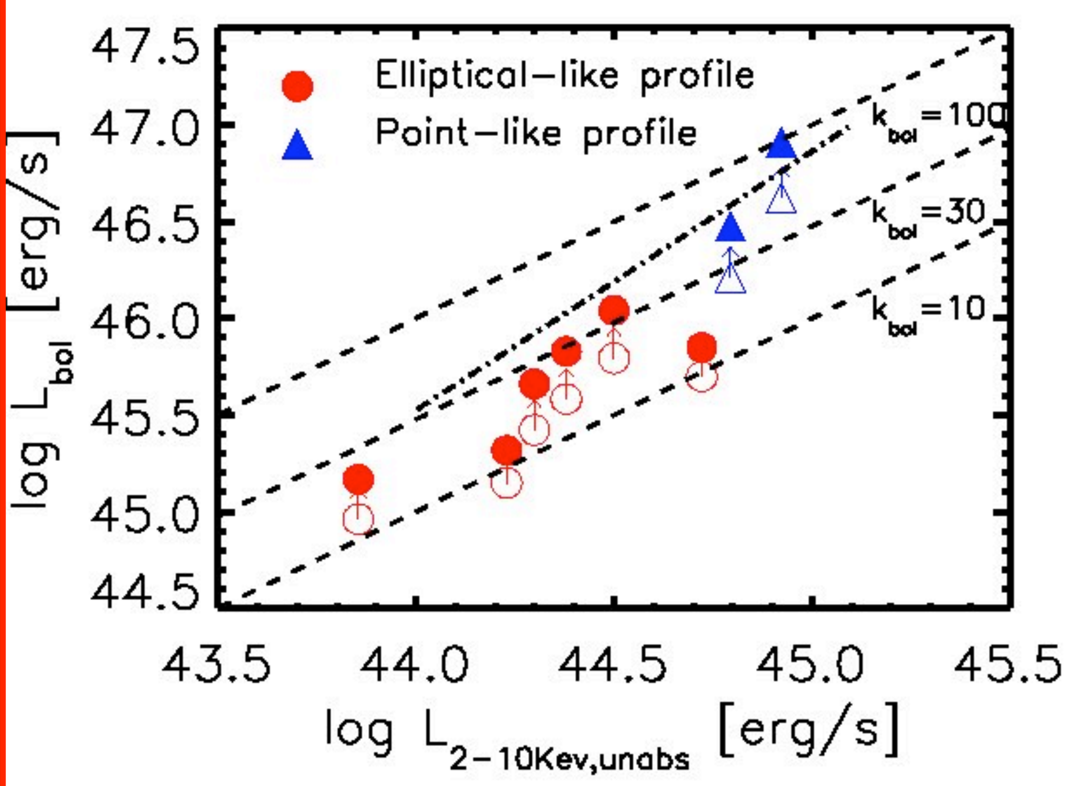
REQUIRED: ► to correct for gas absorption in X-ray
► to correct IR emission for geometry & orientation

Results: Bolometric correction

$L_{BOL} \approx 10^{45}$- 10^{47} erg s^{-1}

$k_{X,bol} = L_{BOL}/L_{2\text{-}10\ keV} \approx 25$ (median)

$= 35 \pm 9$ (average); **22 (only Ell.)**



$k_{X,bol}$

- large spread ⇒ important to use for each source its own value (see also Vasudevan & Fabian 2007)
- mean value consistent with Elvis et al.1994

Results: bulge and black hole masses

Bulge-dominated sources

Bulge masses: Ks -band flux density mostly from the host galaxy.

$M_{bulge}/L_k \approx 0.3$-1 (for old population - Bruzual & Charlot '03)

$M_{bulge}=8\times10^{10}-6.2\times10^{11}\ M_\odot$

Massive host galaxies

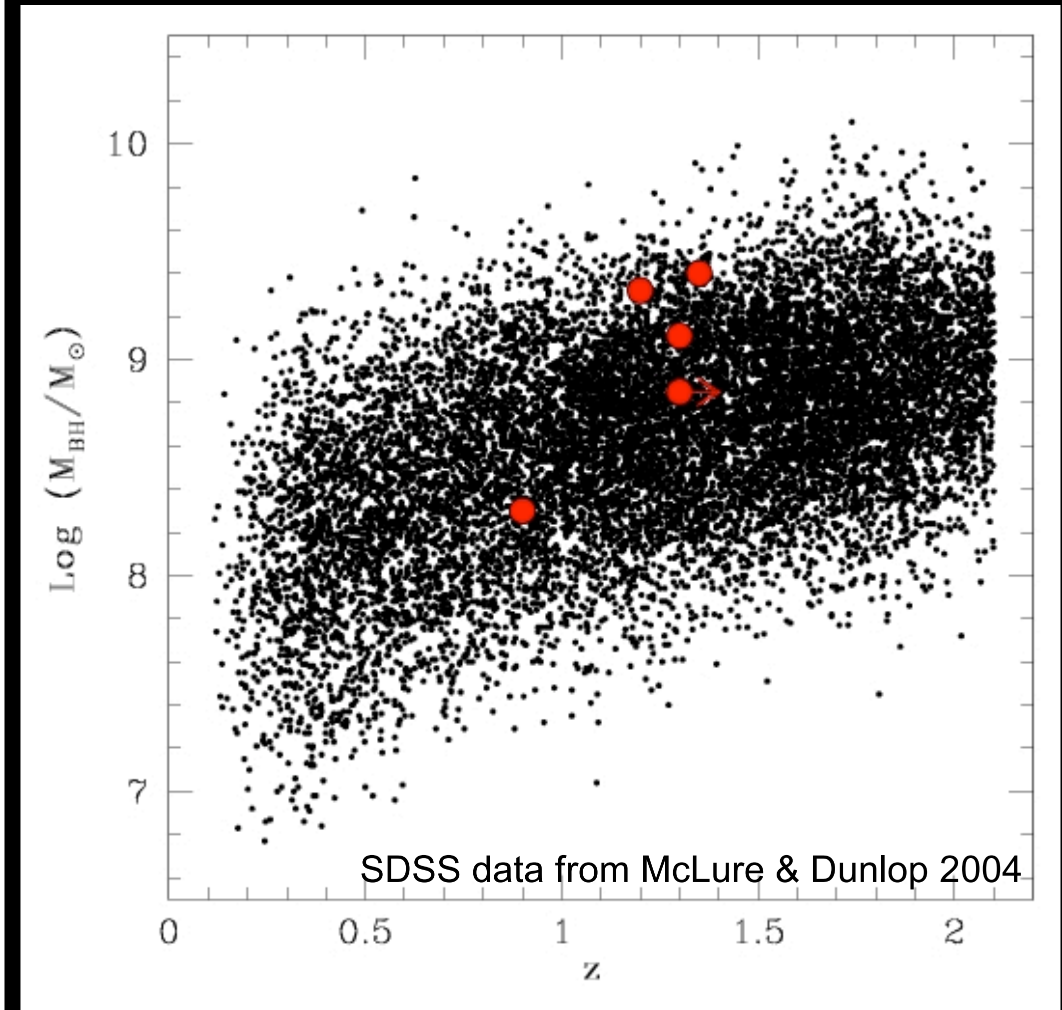
BH masses: using the Marconi & Hunt (2003) local relation + assuming $(M_{BH}/M_*)_{z=1} = 2\times(M_{BH}/M_*)_{z=0}$ (Peng et al. 06)

$M_{BH}\approx 2\times10^{8}-2.5\times10^{9}\ M_\odot$

Massive black holes consistent with SDSS quasars (see work by McLure & Dunlop 2004)

Results: bulge and black hole masses

Bulge-dominated sources



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Massive host galaxies

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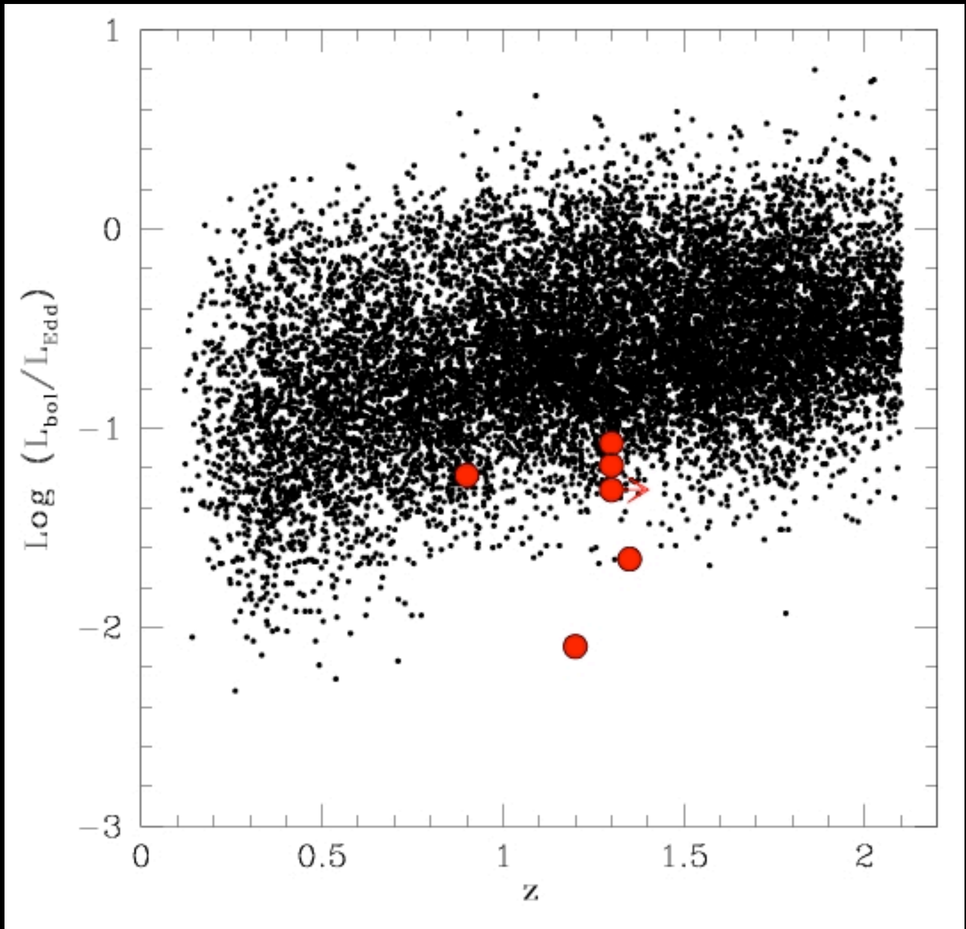
Results: Eddington ratios

$\lambda = L_{BOL} / L_{EDD} \approx 0.06$



Indications that:

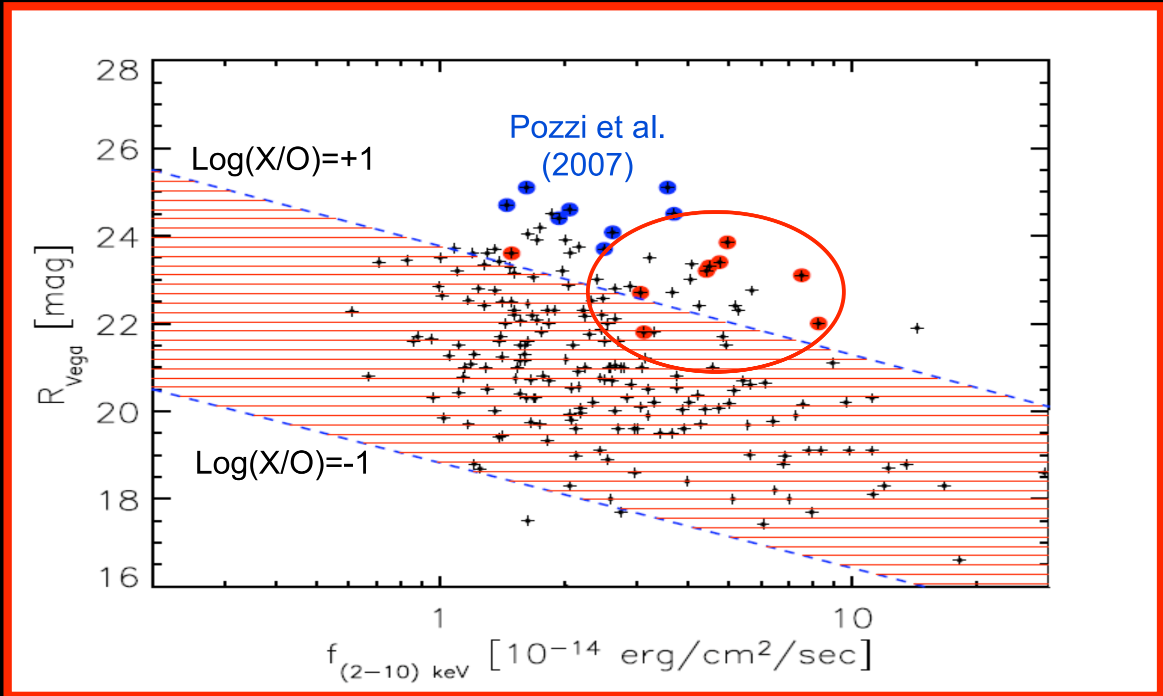
- these very massive, X-ray luminous black holes at $z \approx 1$-2 have already passed their rapidly accreting phase

- they have reached their final masses with currently low accretion rates

SDSS data from McLure & Dunlop 2004

Work in progress …

- Extending the analysis to HELLAS2XMM hard X-ray selected Type 2 QSOs with spectroscopic identification (z=0.7-2, 21.8<R<24)
- Proper modeling of the *Spitzer* data using the torus model by Fritz et al. (2006) to estimated the physical properties of the obscuring medium (torus)



Bellochi et al., in prep.

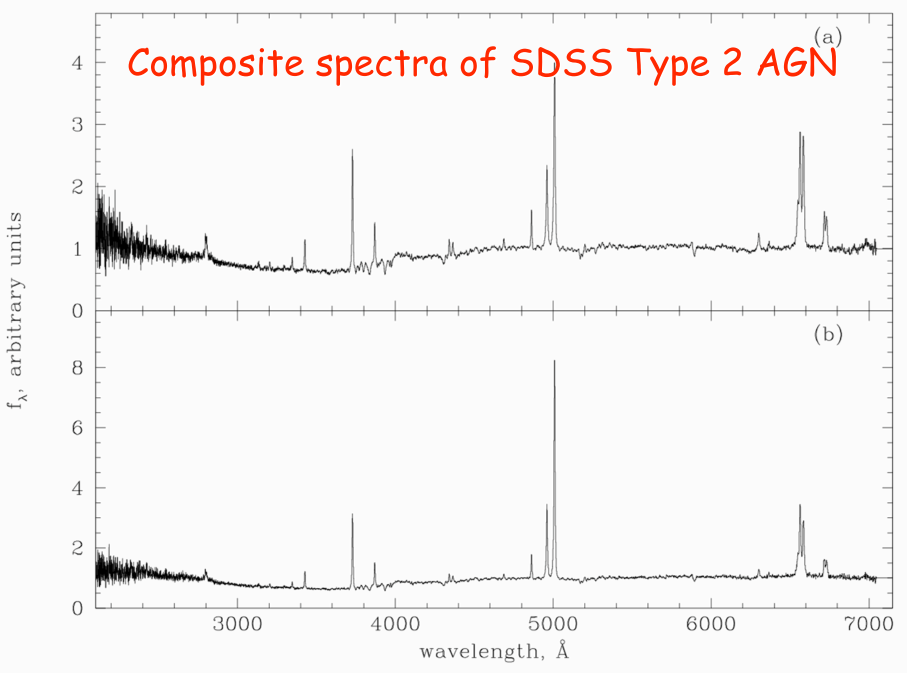
Sloan Digital Sky Survey Type 2 QSOs: the X-ray perspective

Motivation

A large fraction of the X-ray obscured AGN do not appear as the “big cousins” of the local Seyfert 2 galaxies

incomplete view of the Type 2 quasar population from current X-ray surveys?

The SDSS Type 2 quasar sample



Zakamska et al. 2003

SELECTION: high-EW, narrow emission-line spectra [3800-9200 Å, 1800<R<2100]

S/N>7.5
EW[OIII] > 4 Å (rest frame)
FWHM(H_β) < 2000 km/s

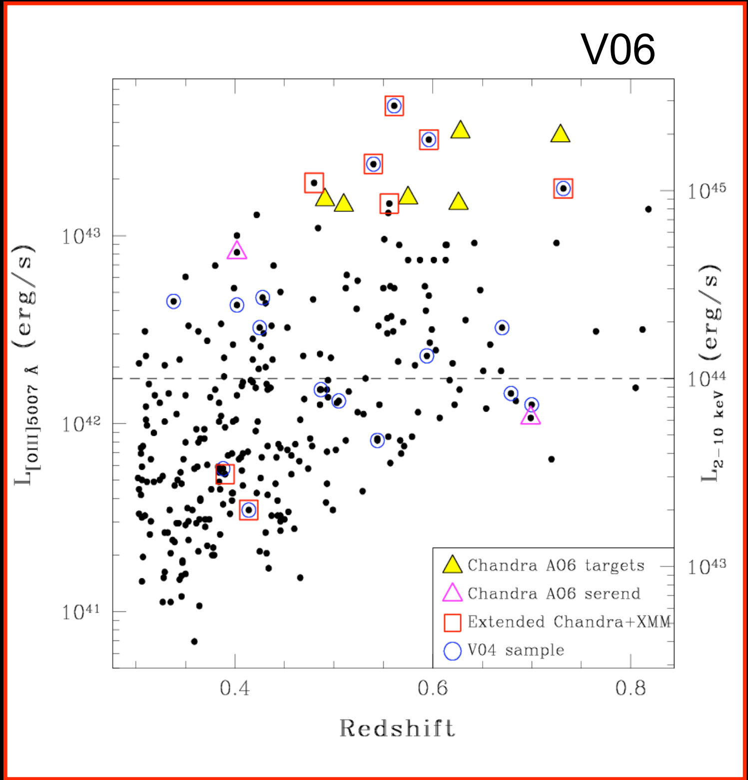
careful subtraction of the host galaxy contribution

not-homogeneous selection: 28% targets, 42% serend, 19% DSES, 11% special plates

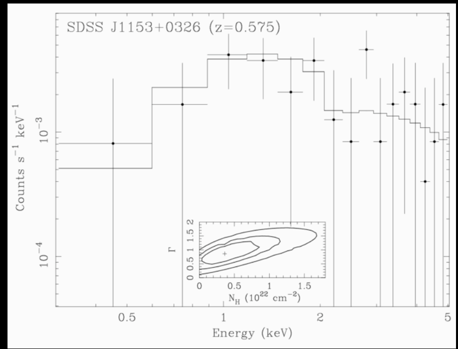
➡291 Type 2 AGN
z≈0.3-0.8

QSO regime (classic): $M_B < -23$
$\langle L_B/L_{[OIII]} \rangle \sim 100$ for BL AGN
$M_B < -23$ ➔ $L_B > 2.9\times10^{10}\ L_\odot$
➔ **$L_{[OIII]} > 3\times10^8\ L_\odot$**

Chandra and XMM-*Newton* follow-up programs

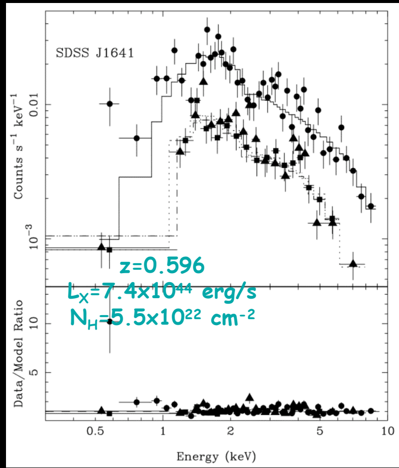


Chandra

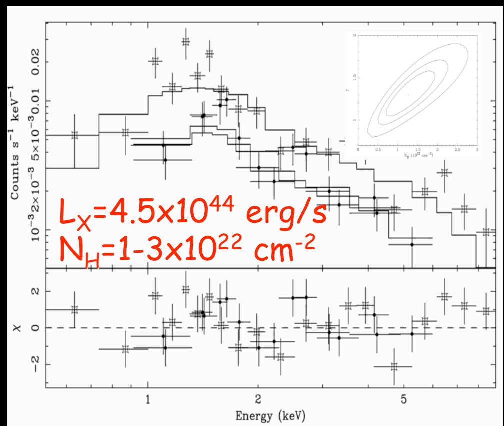


AC, Alexander & Comastri 06

XMM-*Newton*



Ptak et al. 2006



AC, Alexander & Comastri 04

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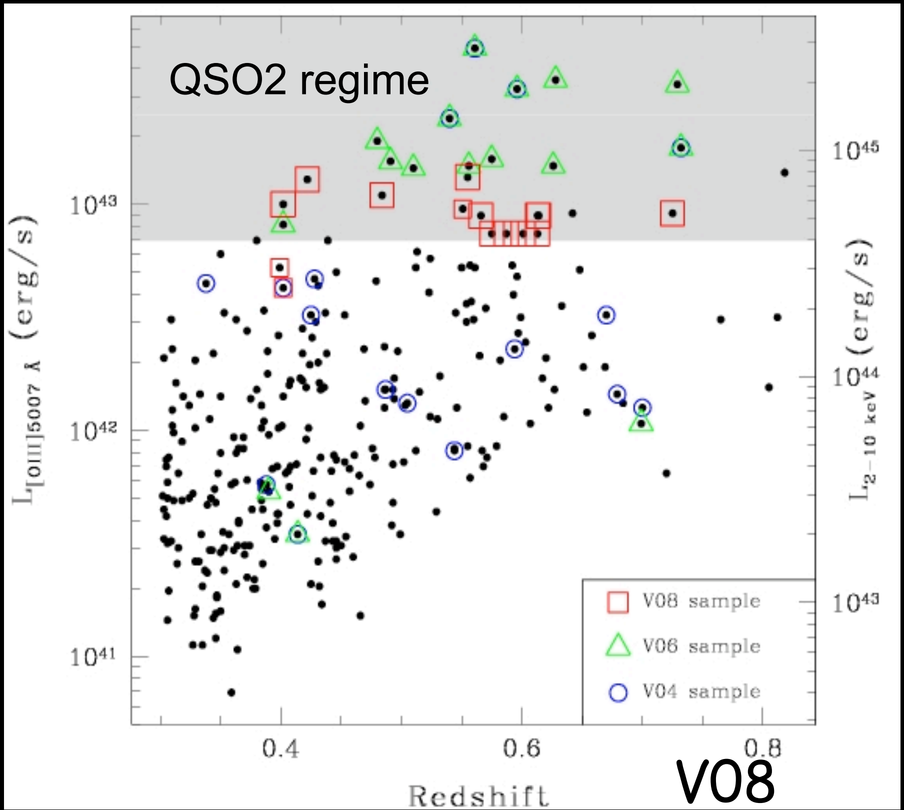

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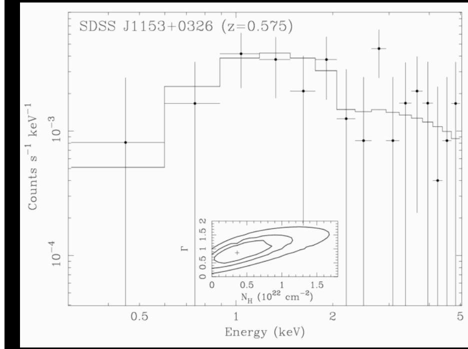

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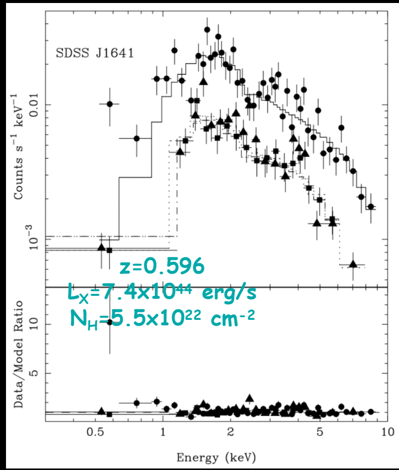

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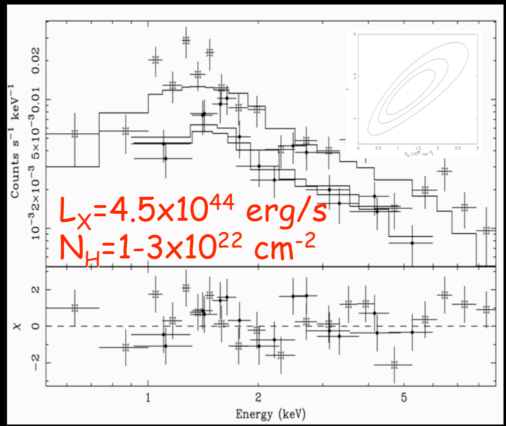
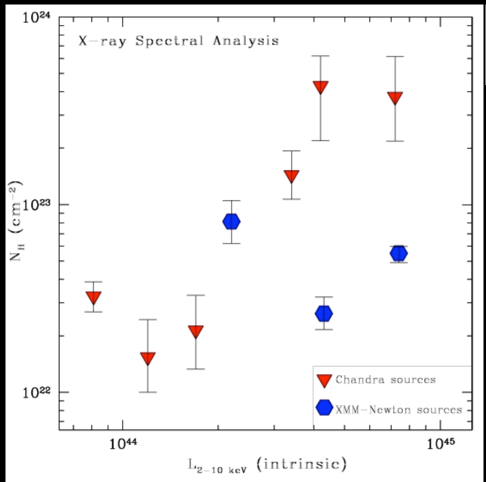


AC, Alexander & Comastri 04

Compton-thick quasars?

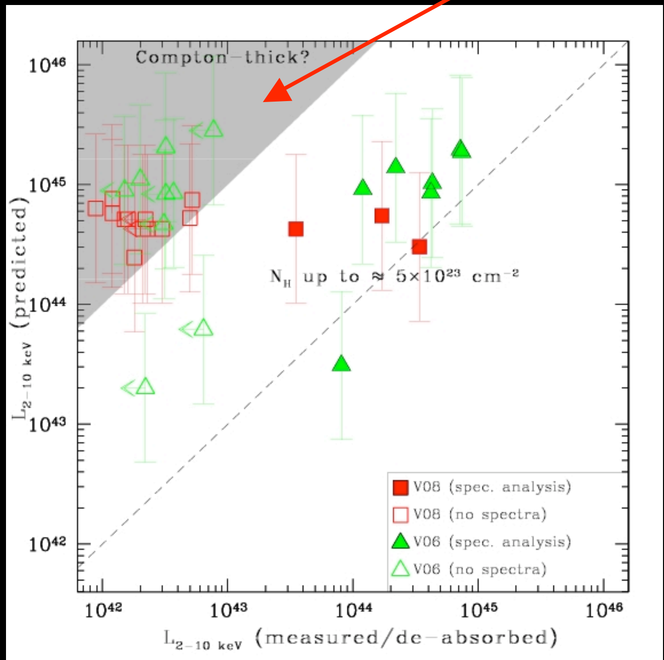


X-ray spectral analysis

underlying assumption: [OIII] as a proxy of the nuclear (2-10 keV) emission

possibility that the X-ray faintest Type 2 QSOs and those undetected hide Compton-thick quasars

(see also Ptak et al. 2006)

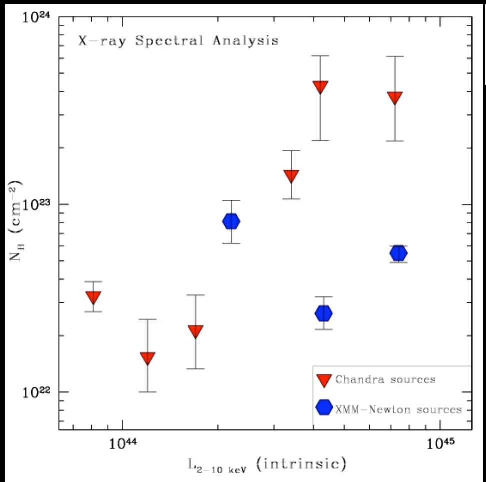


X-ray brightest Type2 QSOs: peak of the iceberg of the SDSS Type 2 QSO population, where many are either Compton-thick or intrinsically X-ray faint

or

highly variable population: weak in the X-rays (X-ray “quiet” state) but still luminous in [OIII]?

Compton-thick quasars?



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