The quest for optically selected Type 2 quasars: the SDSS sample

Cristian Vignali
Dipartimento di Astronomia,
Universita` degli Studi di Bologna

In collaboration with
D.M. Alexander and A. Comastri

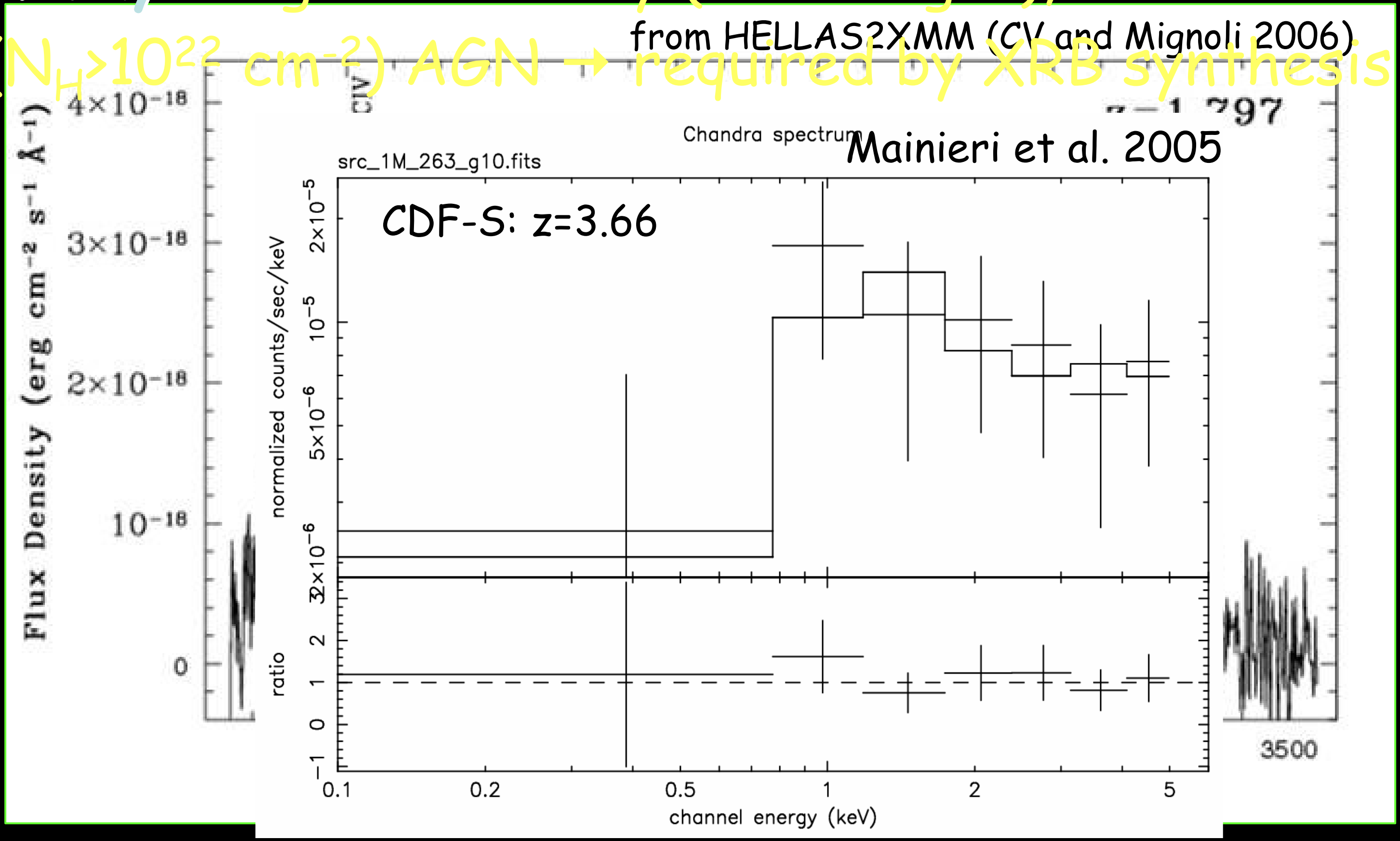
Talk outline

- X-ray vs. optical: how to possibly define a Type 2 quasar
- A roundup of recent discoveries from X-ray surveys
- The Type 2 quasar population from optical surveys: SDSS candidates
- X-ray spectral properties of Type 2 quasars with *Chandra* and XMM-*Newton*
- Compton-thick AGN hiding among the X-ray faintest Type 2 quasars?

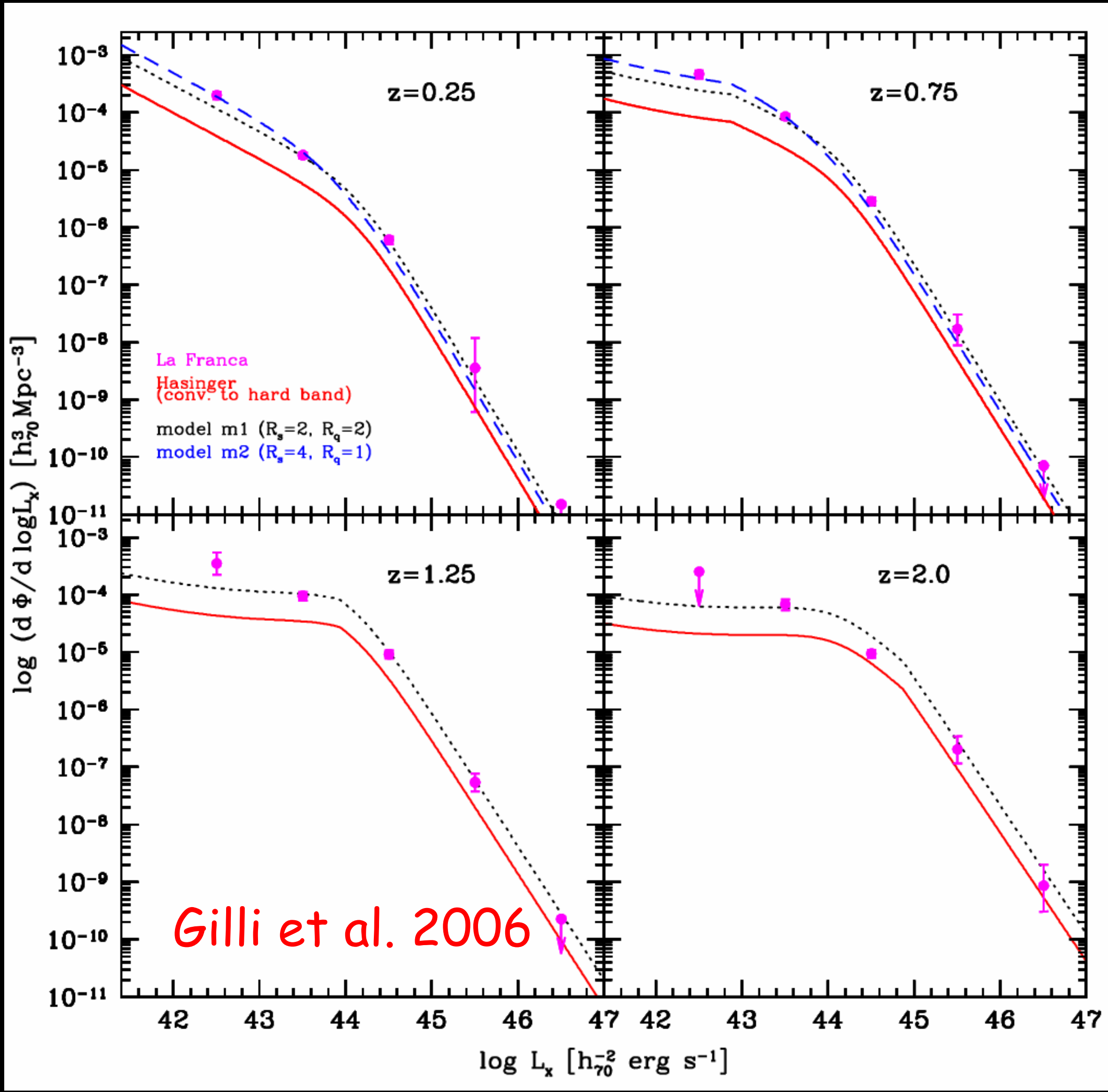
Type 2 quasar: is there a unique definition?

Optical: high-ionization, narrow emission-line (FWHM<1500-2000 km/s) spectrum → "big cousins" of local Seyfert 2 galaxies

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

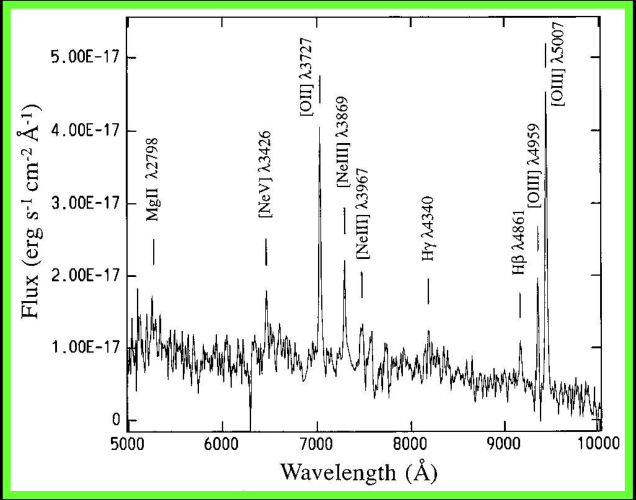


The "ultimate" model for the XLF



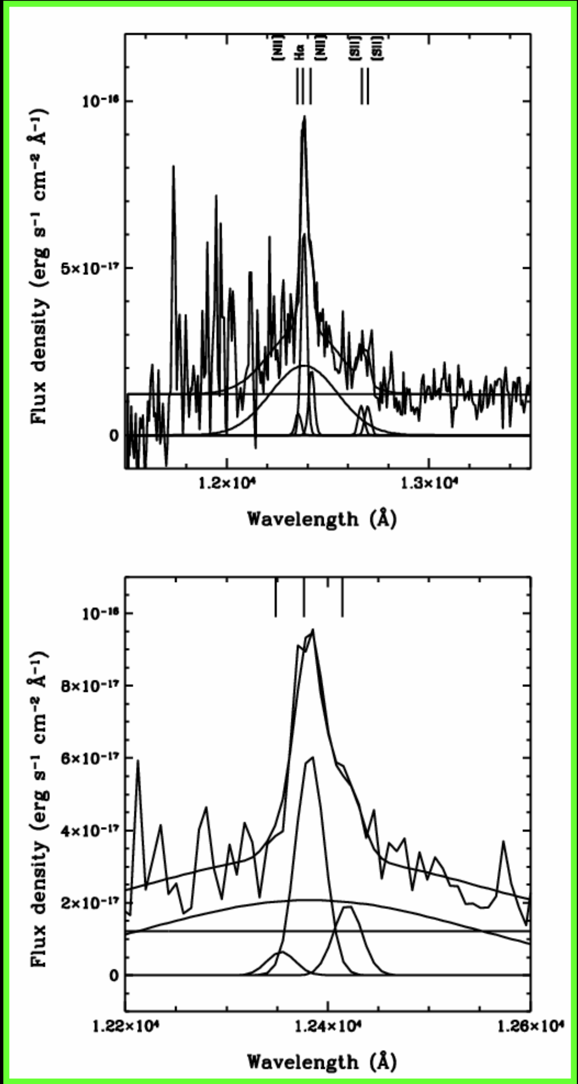
Prior to Chandra and XMM-Newton discoveries

Ohta et al. 1996

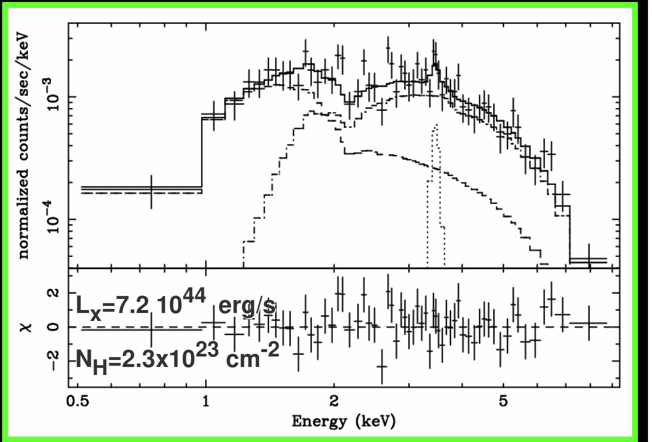


An example: **AX J08493+4454**
z=0.9

Akiyama et al. 2002

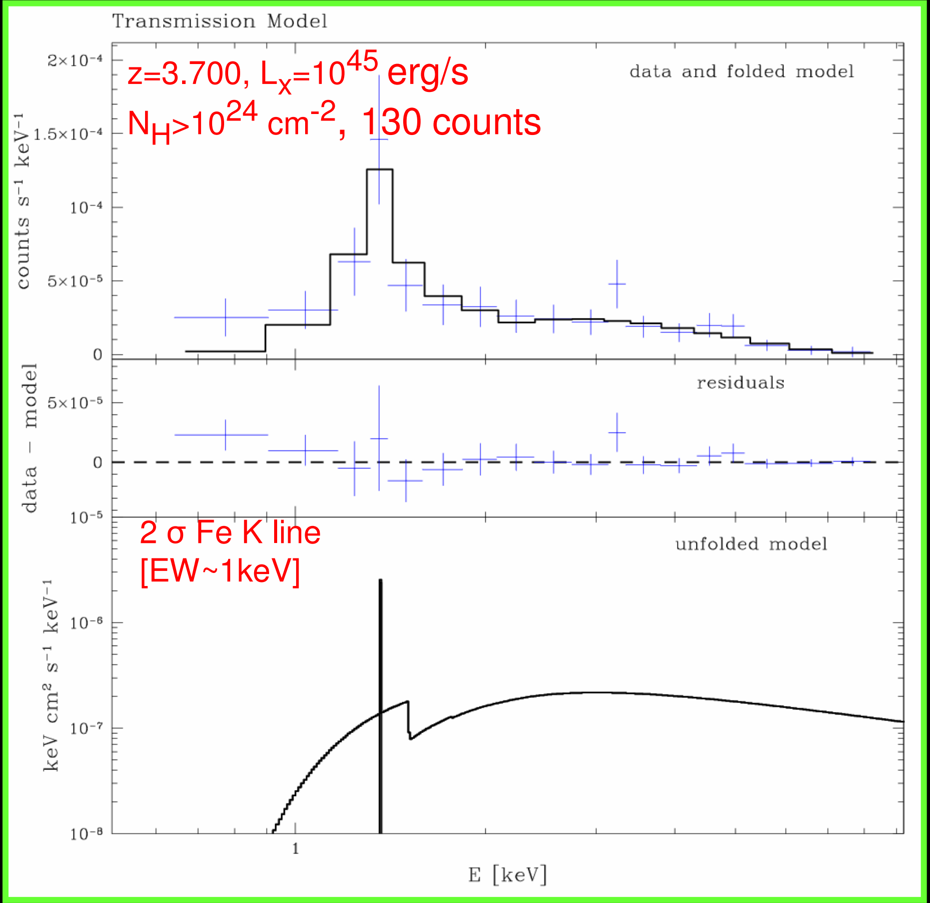


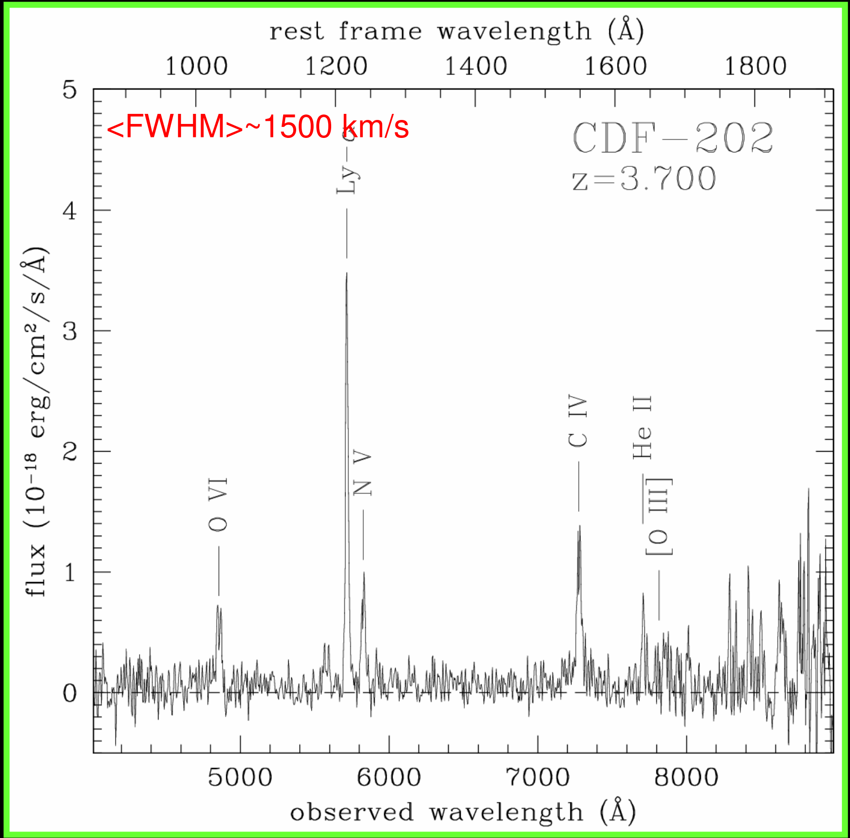
Some mis-identifications of Type 2 quasars due to limited-bandpass optical spectroscopy and poor S/N ratio spectra (e.g., Boyle et al. 1998, Halpern et al. 1999)



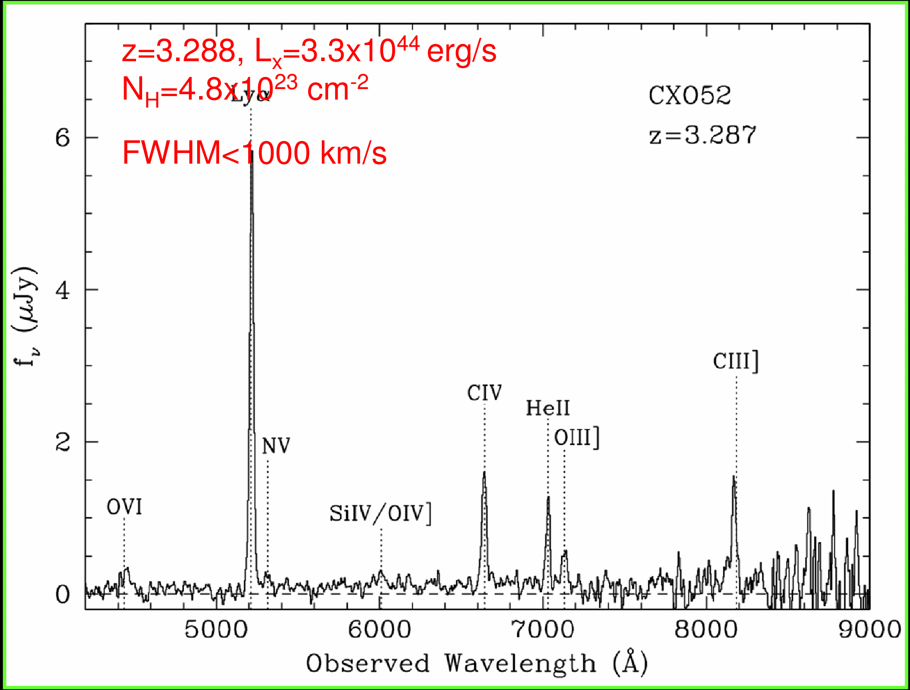
A fast roundup from recent X-ray surveys ...

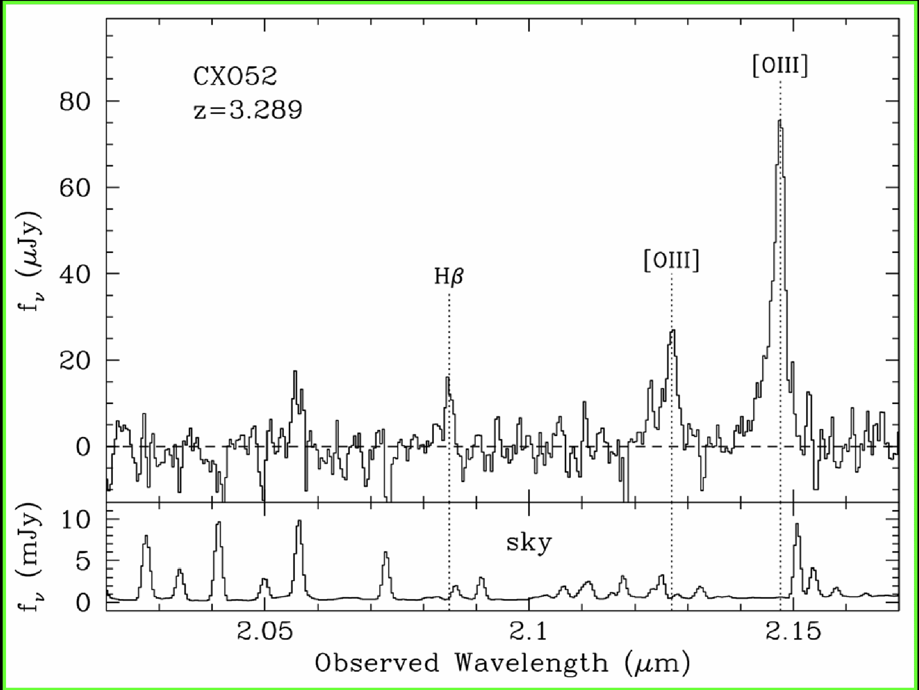
CXOCDFS J033229.9-275106: z=3.70 (Norman et al. 2002)



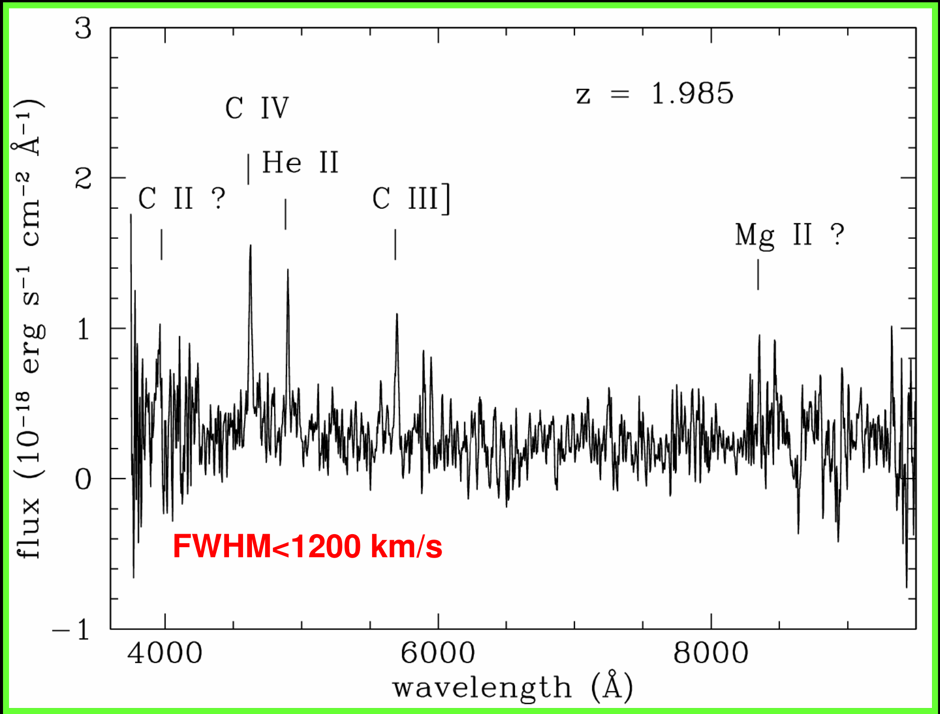


Lynx Field: *CXO J084837.9+445352*: z=3.288 (Stern et al. 2002)



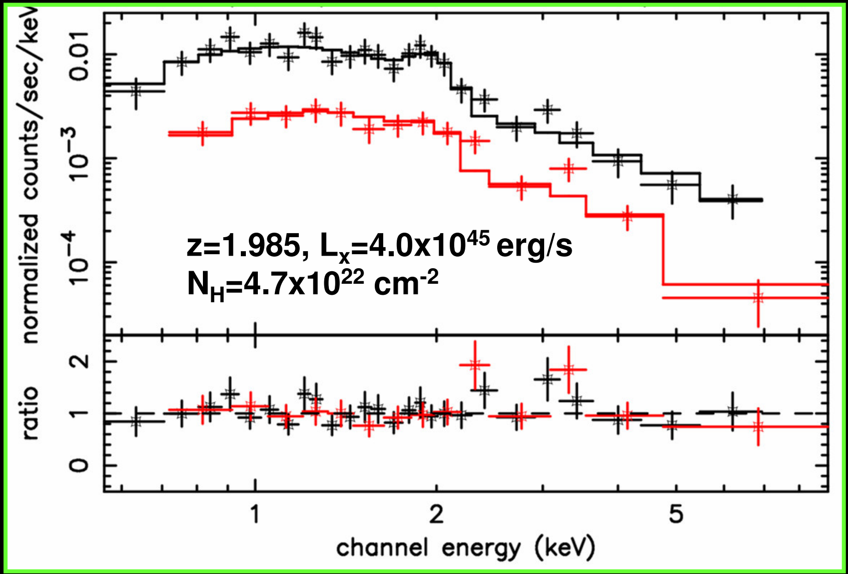


XMM-*Newton* Bright Serendipitous Survey
XMM-BSS J0216-0435 : **z=1.985** (Severgnini et al. 2006)



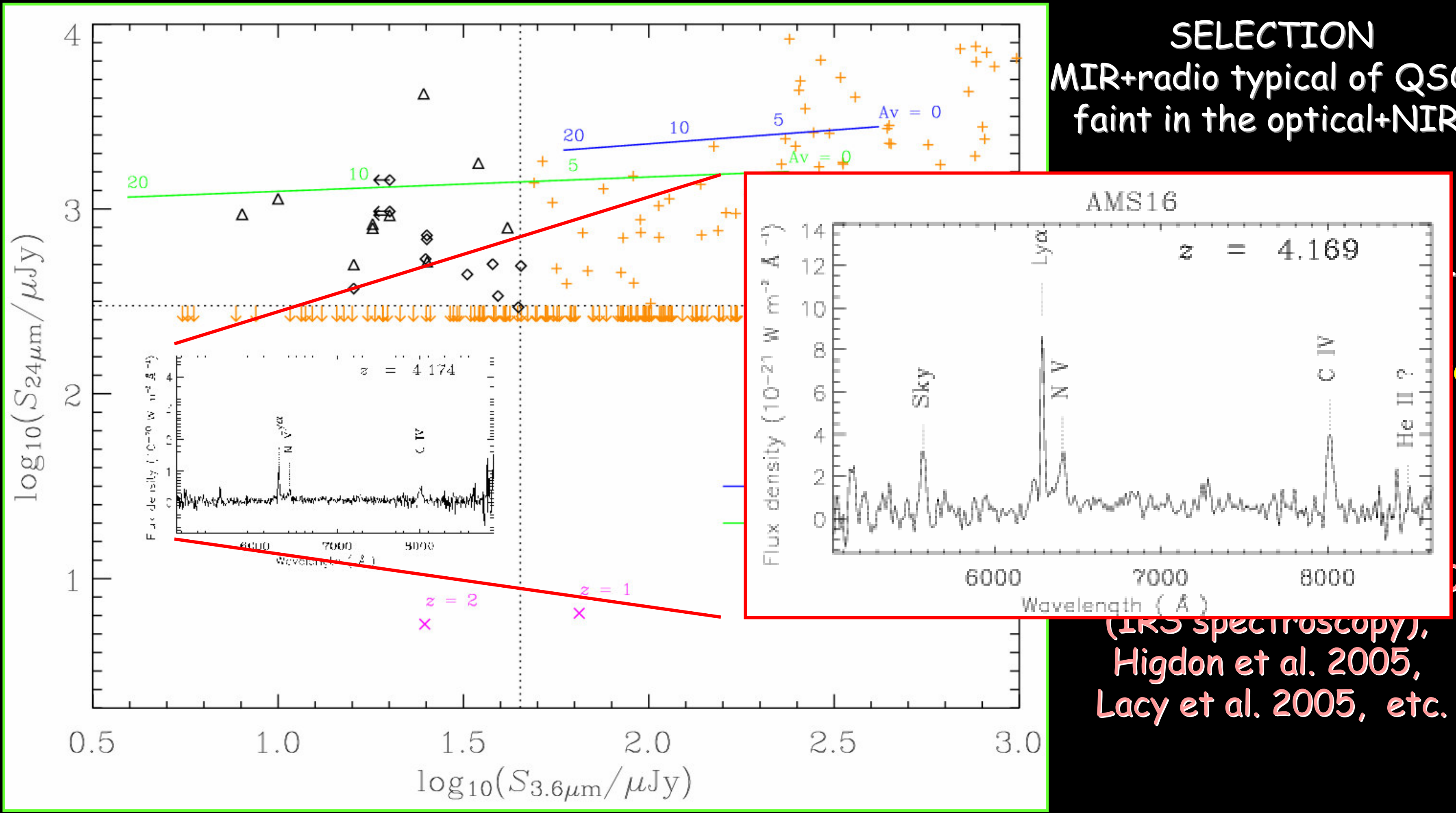
Type 2 quasars in the Extremely Red Object population at high F_X/F_{opt} ratios

(see Civano's and Tajer's talks, and Severgnini's poster; Brusa et al. 2005)



… and also in the mid-infrared with Spitzer

Martinez-Sansigre et al. 2005, 2006



SELECTION
MIR+radio typical of QSOs
faint in the optical+NIR

y

es

05

(IRS spectroscopy),
Higdon et al. 2005,
Lacy et al. 2005, etc.

still not a complete sampling of the Type 2 quasar population…

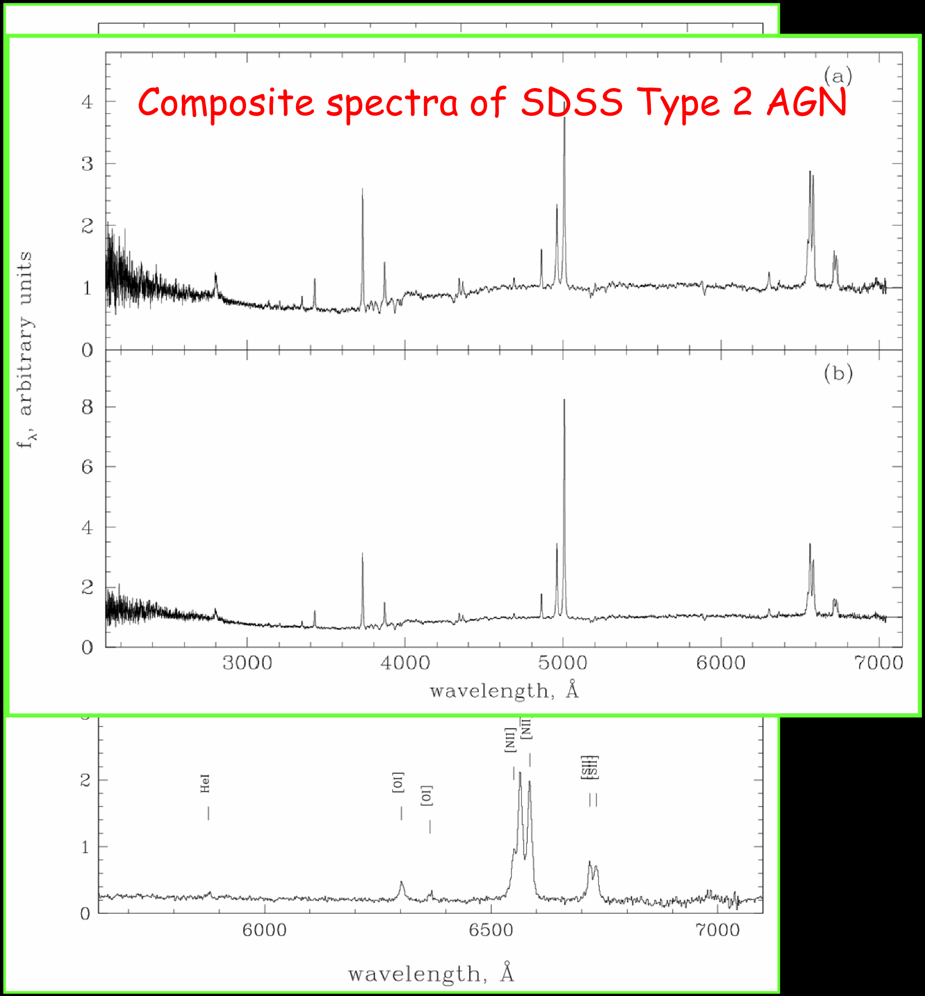
- The majority of the X-ray obscured AGN do not appear as the "big cousins" of the local Seyfert galaxies ➡ less than 20% of the hard X-ray source

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

the GOAL

to possibly extend the knowledge of the Type 2 QSO population using ground-based optical surveys such as the **Sloan Digital Sky Survey** (SDSS) and the Digital Palomar Sky Survey at relatively bright magnitude limits and to probe any difference in the X-ray properties of optically vs. X-ray selected Type 2 QSOs

The SDSS Type 2 quasar sample



Zakamska et al. 2003

SELECTION: high-intensity, 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

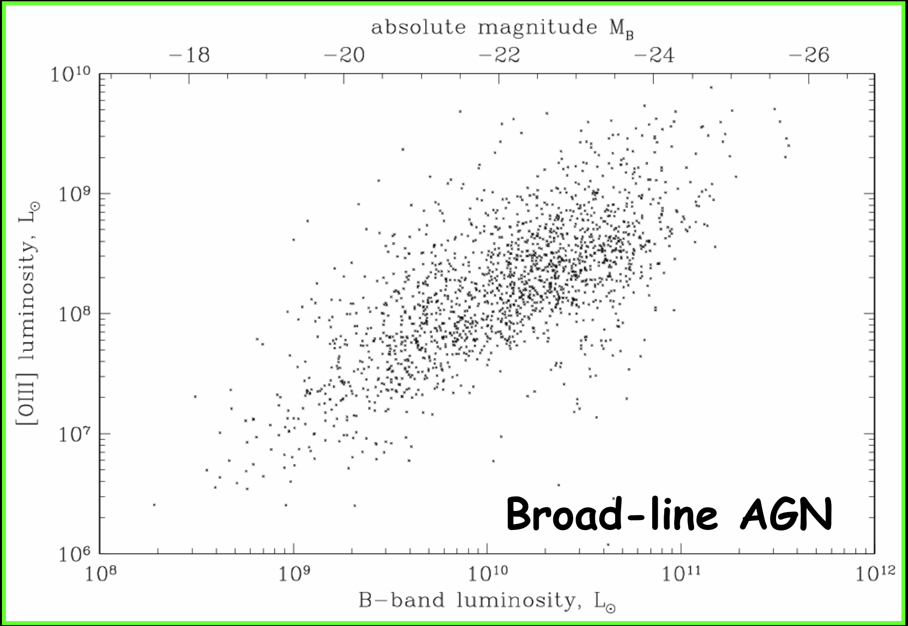
careful subtraction of the host galaxy contribution

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

→291 Type 2 AGN
z≈0.3-0.8

Selection of Type 2 quasar candidates

[OIII] emission line as a proxy of the AGN activity - emitted from the extended (and likely less obscured) narrow-line region [see also Simpson 1998, Croom et al. 2002, Kauffmann et al. 2003].

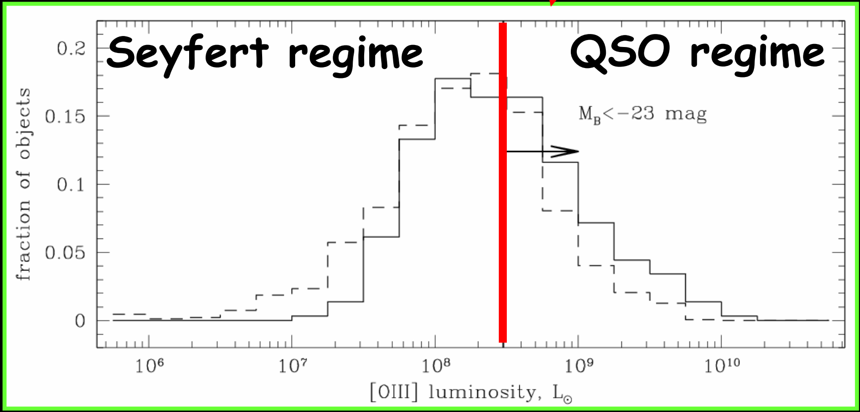


QSO regime (classic): $M_B < -23$

$<L_B/L_{[OIII]}>$ ~ 100 for BL AGN

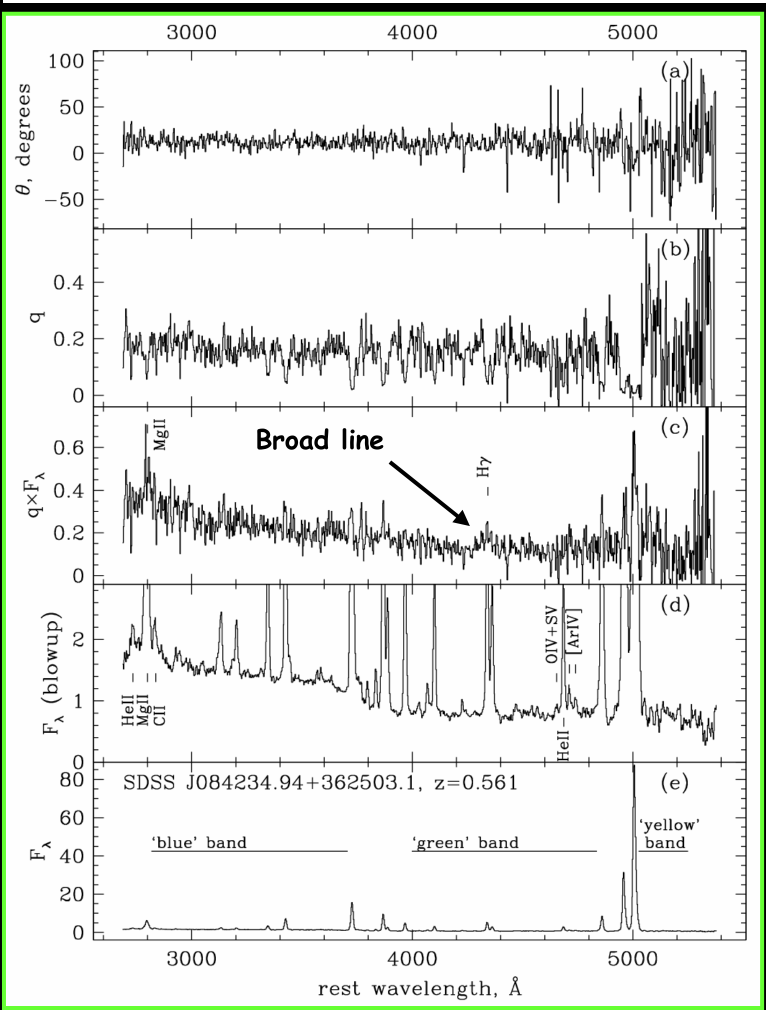
$M_B < -23$ → $L_B > 2.9\times10^{10}$ L◆

→ **$L_{[OIII]} > 3\times10^{8}$ L◆**



Spectropolarimetry of SDSS Type 2 quasars

Highest [OIII] luminosity object in the sample (log $L_{[OIII]}$>10.1 L◆)



Zakamska et al. 2005

~15 sources with polarimetry studies

➡65% with <polarization> >3% [up to 17%]

vs. NONE in the PG QSO sample
(mean =0.5%, Berriman et al. 1990)

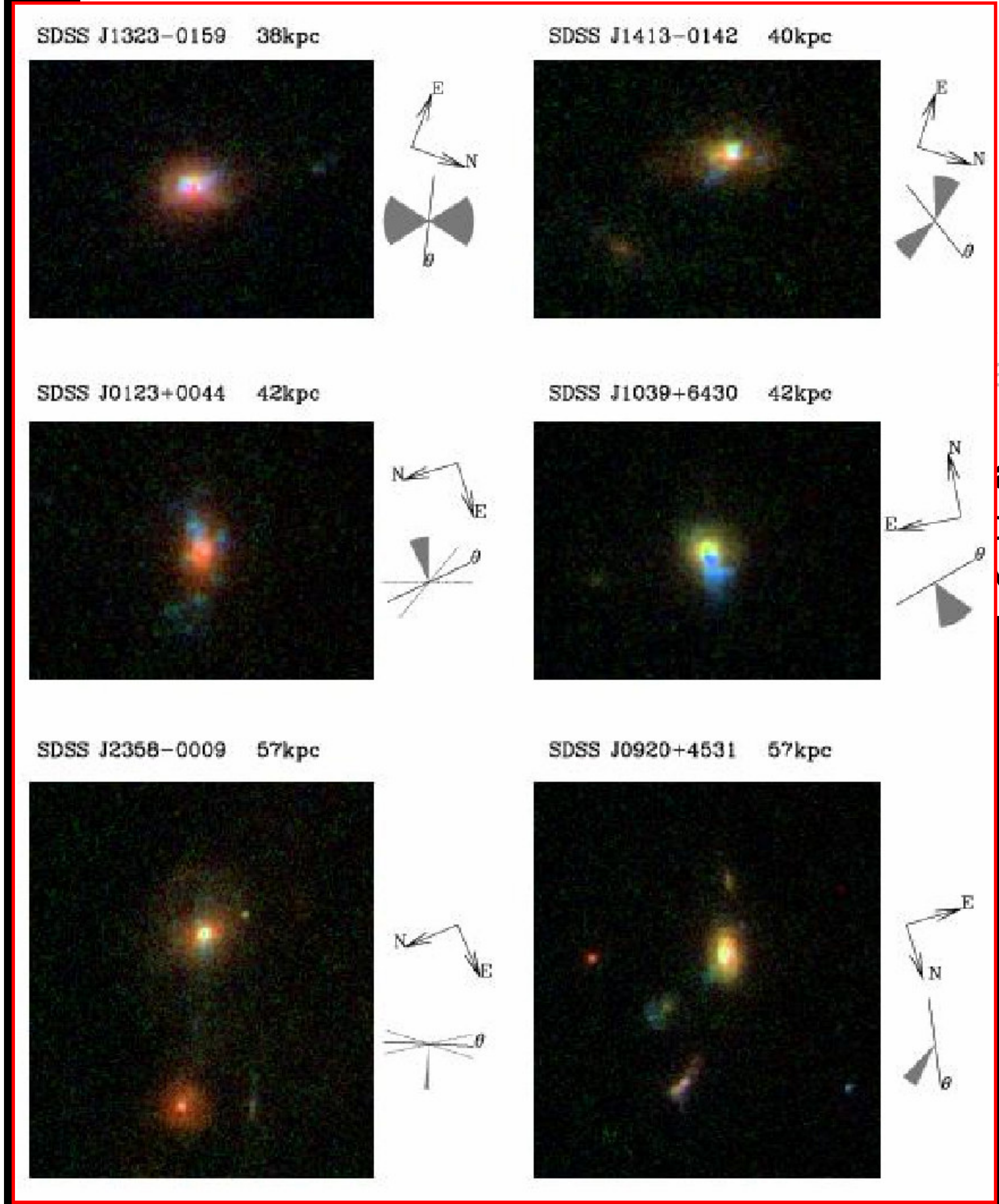
vs. 10% in the 2MASS AGN sample (Smith et al. 2002)

blowup of the optical spectrum

total flux density

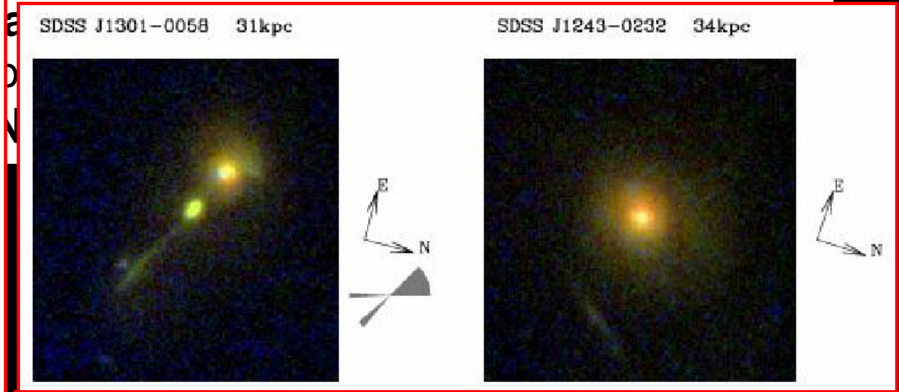
➡Continuum polarization of ~16%

Polarization mechanisms



emission:
the polarized spectra
2 AGN in case of moderate extinction
he continuum is heavily extincted

tinction:
at reflects the direction of grain alignment

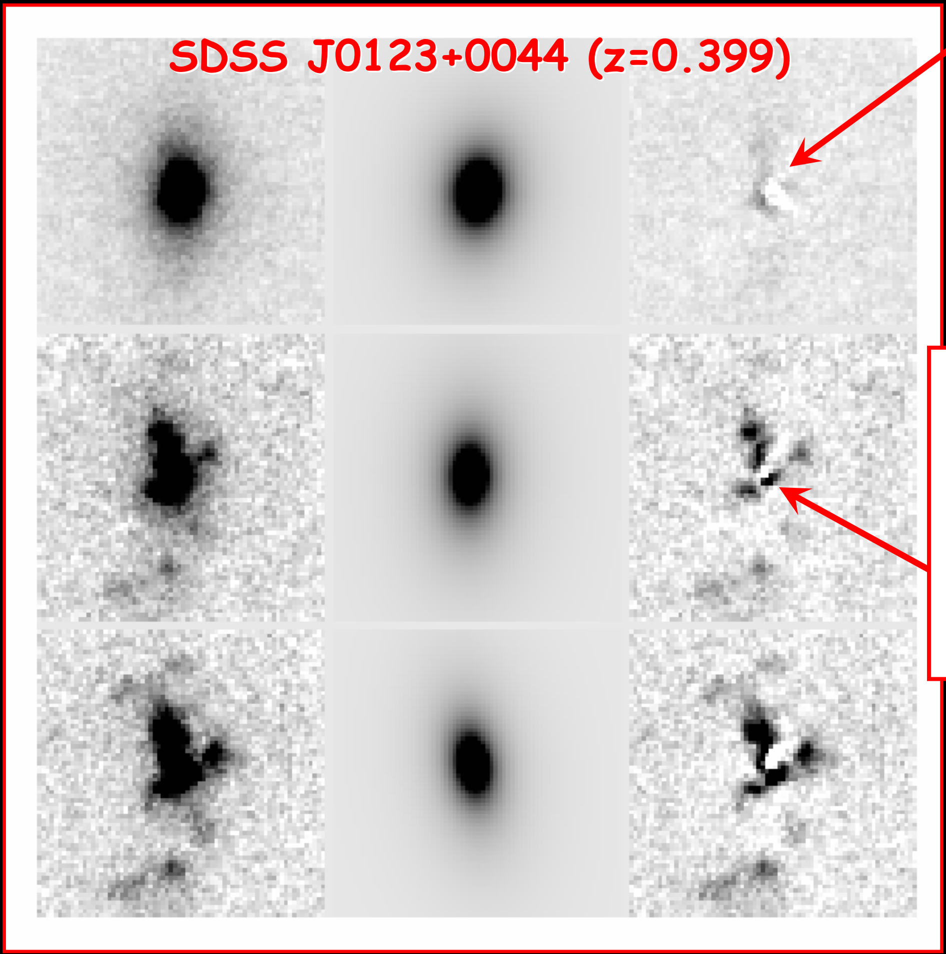


Zakamska et al., submitted

Dust scattering – wavelength dependent polarization fraction and scattering efficiency
Generally produces a scattering efficiency rising to the blue and a polarization fraction of the scattered light rising to the red ➝OK for SDSS J1715+2807
The dilution-corrected polarization values of 10-20% and the size of the scattering regions agree better with dust scattering

The host galaxies of SDSS Type 2 quasars

image   best-fit model   residuals



18.4 kpc

Zakamska et al., submitted

negative (white) residuals:
dust obscuration?

yellow band: 5700-5800 Å rest frame

6/9 Type 2 quasars observed with HST at 0.2<z<0.4

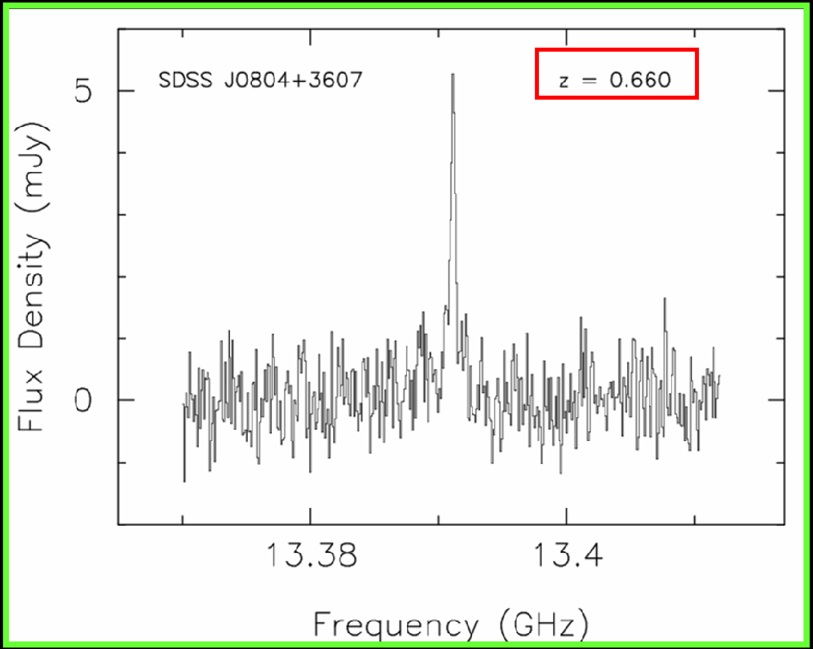
➡6/9 have elliptical profiles, 1 disky, 2 mixed

➡ stellar populations of the hosts are 0.3-0.7 mag brighter and 0.4 mag bluer than M_* galaxies at their z

UV band: 3000-3200 Å rest frame

➜ $-26 < M_B < -24$

The highest redshift H_2O megamaser



Barvainis & Antonucci 2005

Previous highest redshift H_2O megamaser at z=0.059 (Tarchi et al. 2003)

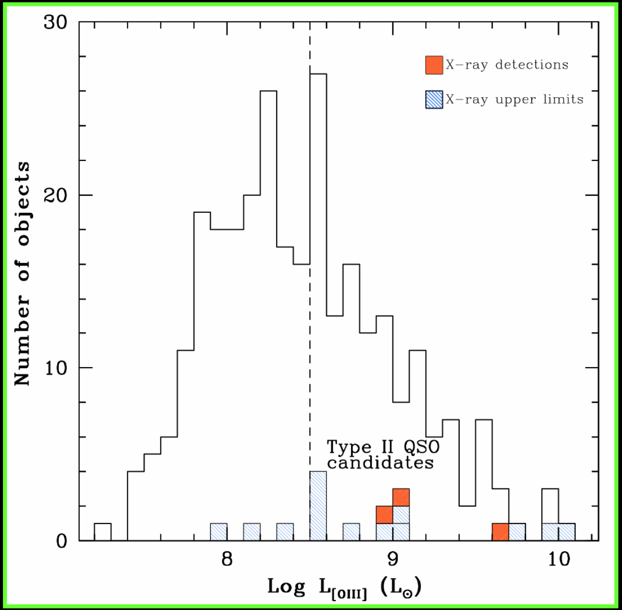
L=23,000 $L_\odot$

H_2O megamasers mostly associated with Seyfert 2 galaxies

Half of them appear to be Compton-thick

The X-ray view of SDSS Type 2 quasars

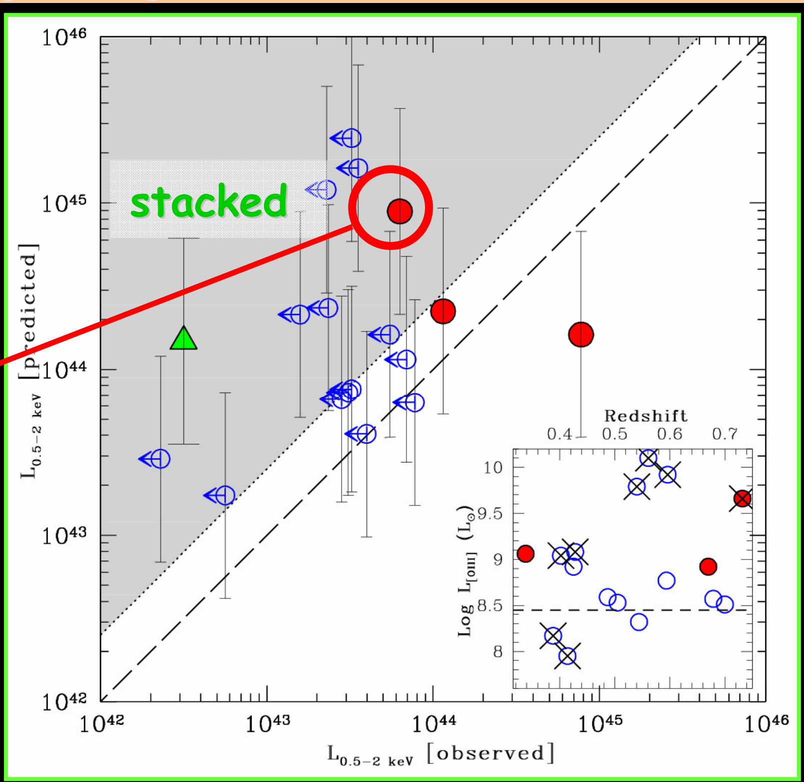
Using mostly ROSAT data (CV, Alexander & Comastri 2004a,b)

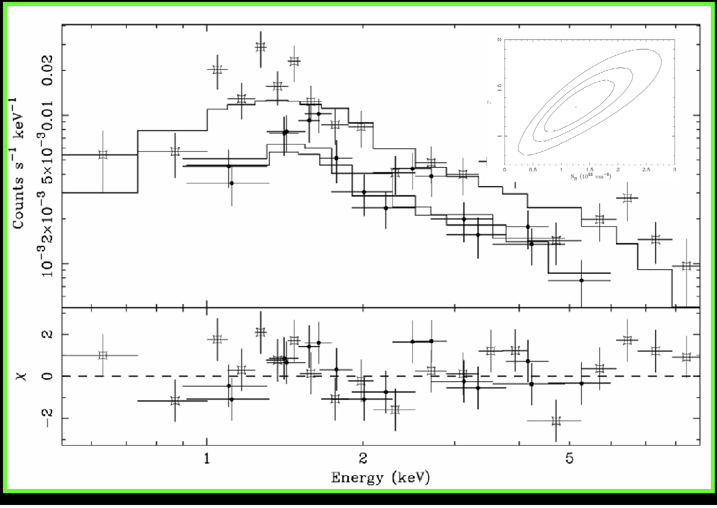


3/17 SDSS Type 2 quasar candidates detected

"Toy model": $L_{[OIII]}$ → $L_{[2\text{-}10\ keV]}$ using Mulchaey et al. '94

→ extrapolated $L_{[0.5\text{-}2\ keV]}$ to be compared with that observed





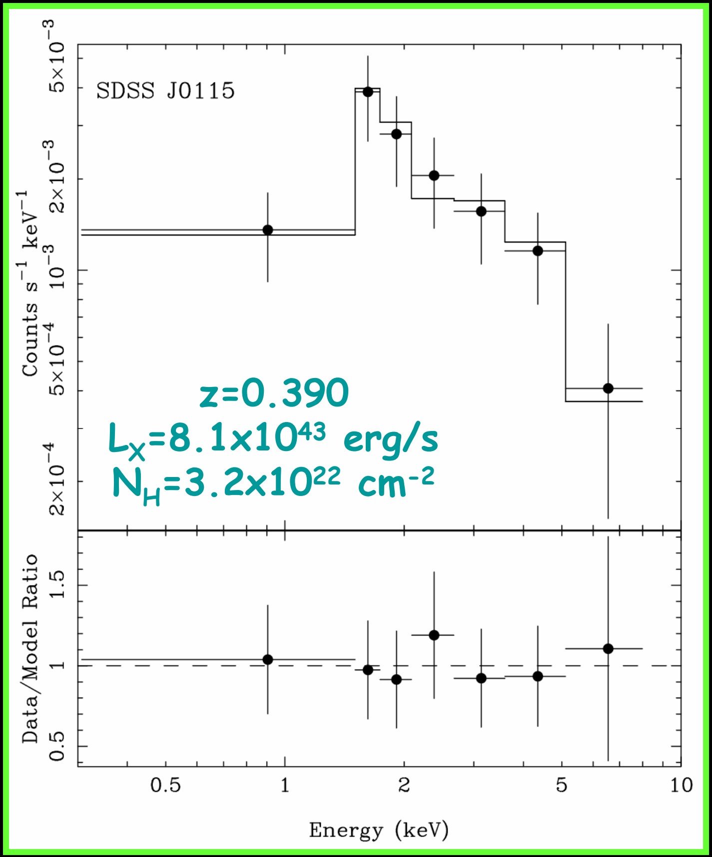
XMM-Newton → "genuine" Type 2 quasar
(L_X=4.5x10^{44} erg/s, N_H=1-3x10^{22} cm^{-2})

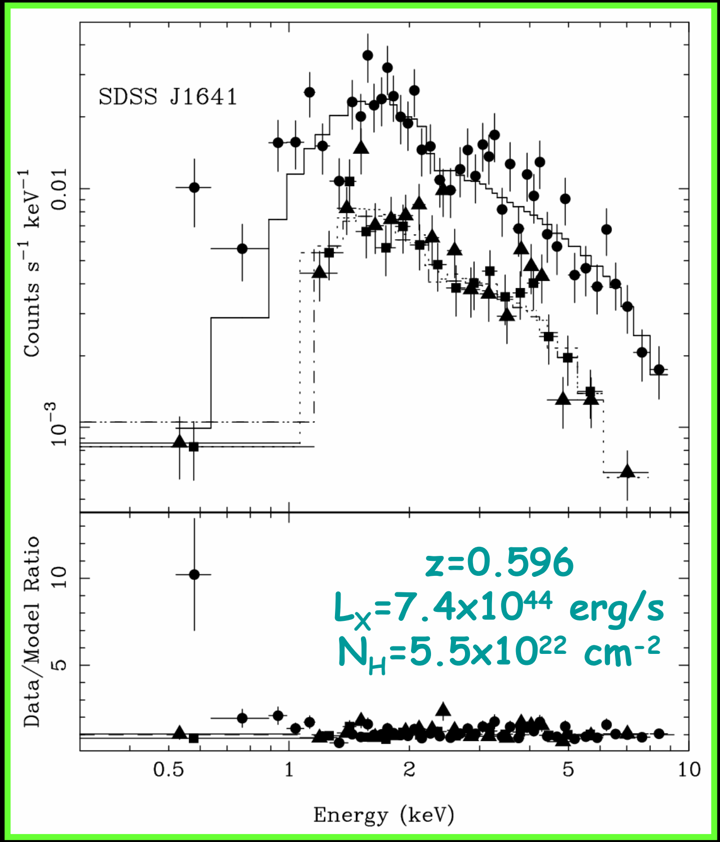
some caveats …

- Mulchaey et al. (1994) correlation valid for higher luminosity (redshift) objects
- Large uncertainties due to the scatter in the correlation ⇨ range in the derived column densities
- Reddening to NLR itself not accounted for [via Balmer decrement; e.g, Maiolino et al. 98, Bassani et al. 99] ⇨ leads to a conservative determination whether or not a source is absorbed in the X-ray band
- **(**Predicted – Observed**)** 0.5-2 keV flux ascribed only to **absorption**
- Γ=1.6 instead of Γ=2.0 implies NH ~20% lower; additional soft component in the opposite direction

since 2004 ...

Chandra and XMM-*Newton* follow-up observations of the optically brightest

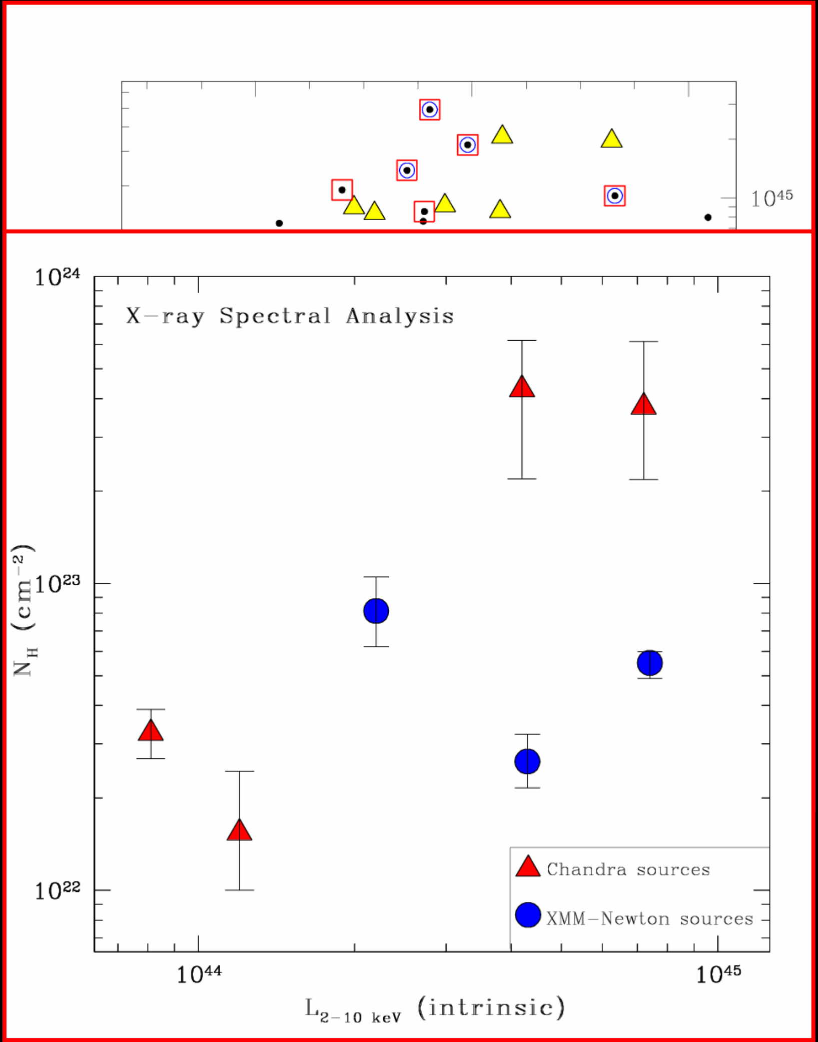




Ptak et al. 2006

up to the most recent results...

Chandra exploratory observations + archival fields
(CV, Alexander & Comastri '06)

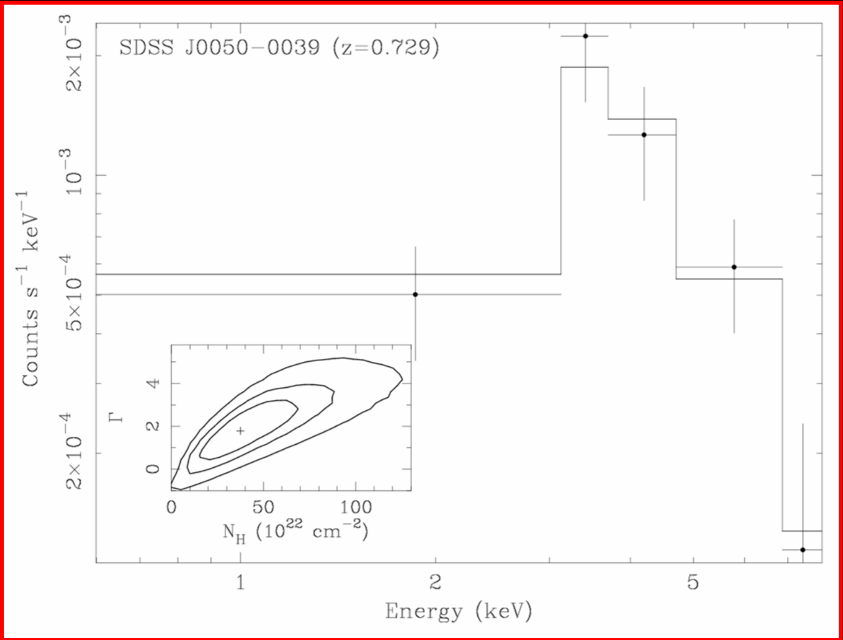


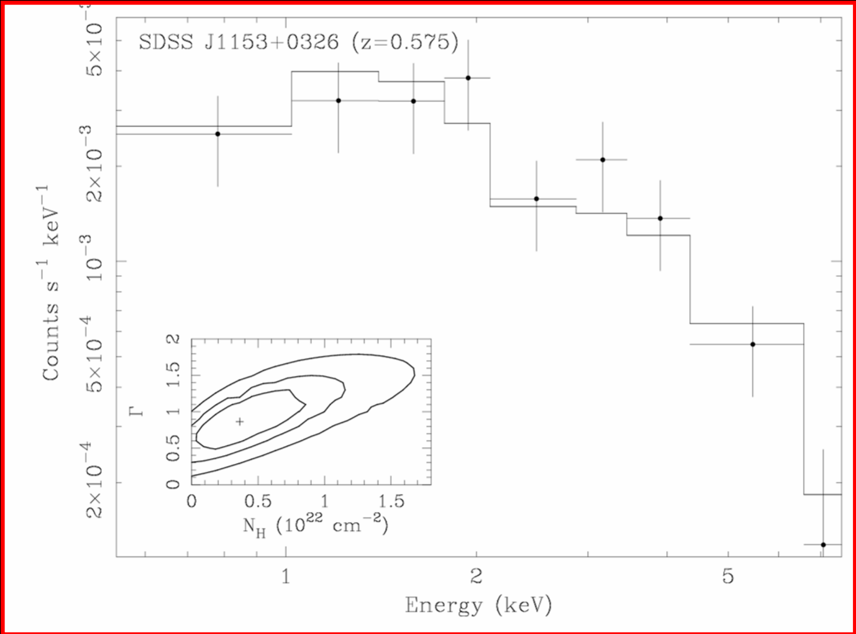
4/6 targets detected
(3-80 counts, 7-11 ks, $F_X \approx 10^{-15}$-10^{-13} erg/cm^2 s)
+
6/10 archival/serend detected

direct X-ray spectral information for 7 sources
$N_H \approx 10^{22}$ – 5×10^{23} cm^{-2}

more deeply into the spectral results

$N_H \approx 3.8 \times 10^{23}$ cm^{-2}



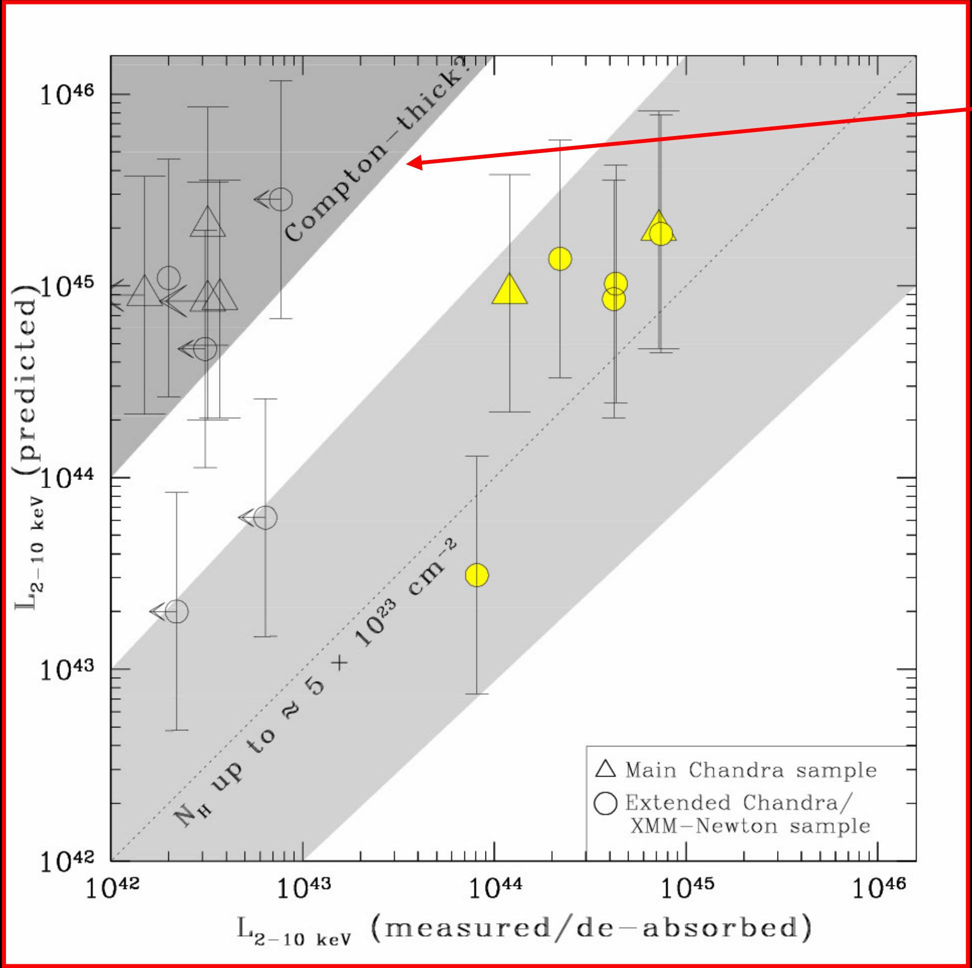


$N_H \approx 1.5 \times 10^{22}$ cm^{-2}

CV, Alexander & Comastri '06

Chandra's ability to provide X-ray constraints with <100 counts …

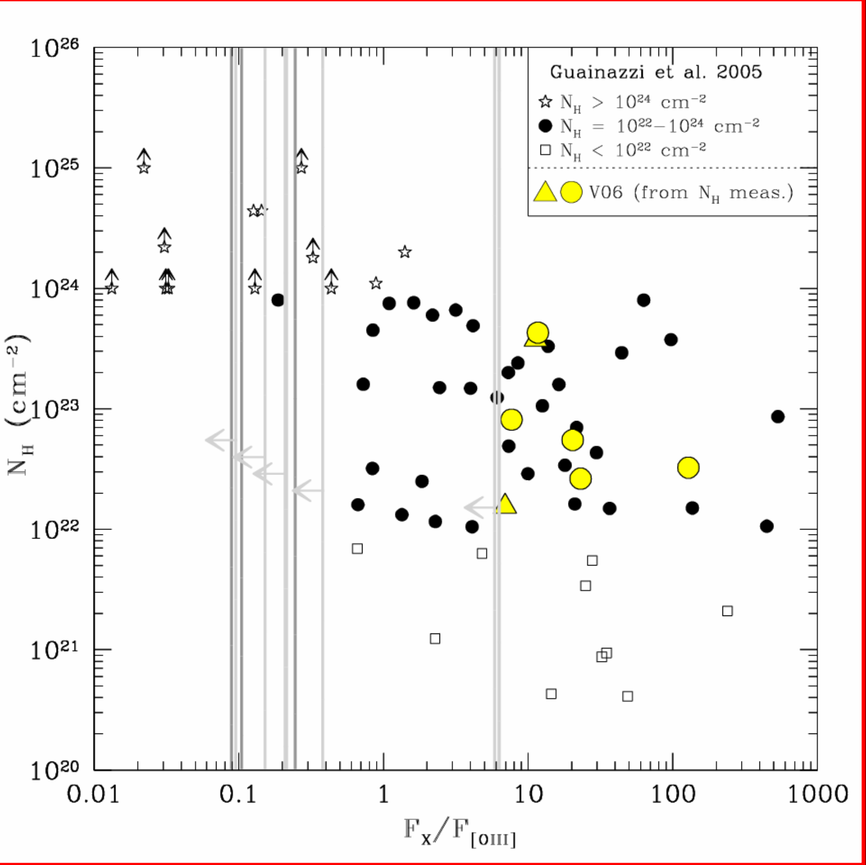
Compton-thick quasars?



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

➜ needs further checks and larger samples with sensitive X-ray observations to probe the X-ray weak Type 2 quasar population

another way of looking at the results



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

Highly variable population? Weak in the X-ray (X-ray quiet state) but still luminous in [OIII]?

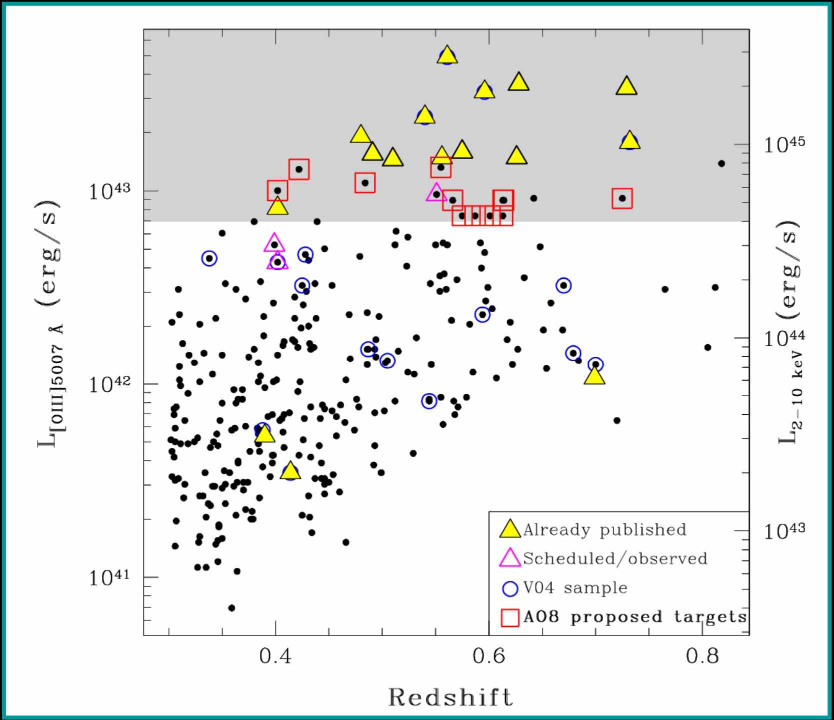
Next steps: further observations

- To probe the X-ray properties of SDSS Type 2 QSOs further with *Chandra* and XMM-*Newton:*

  average properties from stacking analysis for the X-ray weak sources *(limited at present by the paucity of counts)*

  stacked X-ray spectra in different N_H bins to search for faint spectral features *(e.g., Alexander et al. 2005)*

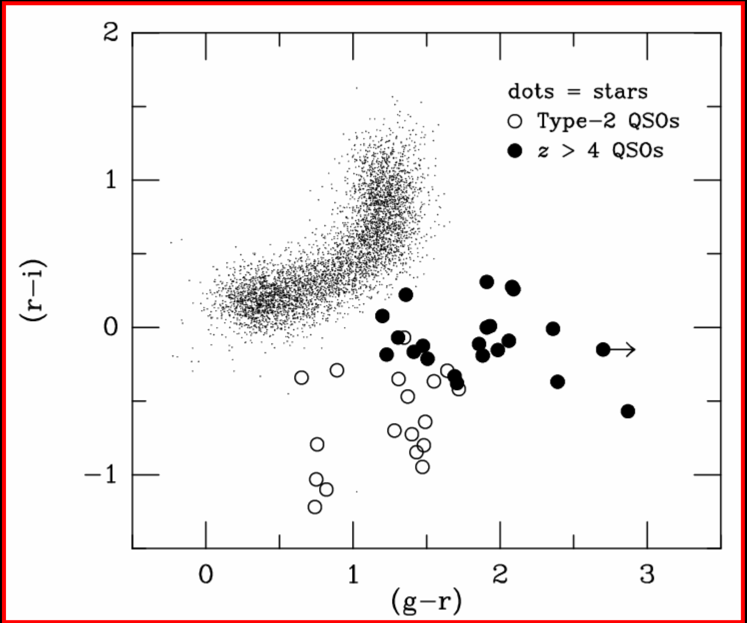
- To define the number of optically selected Type 2 QSOs → contribution to the XRB?

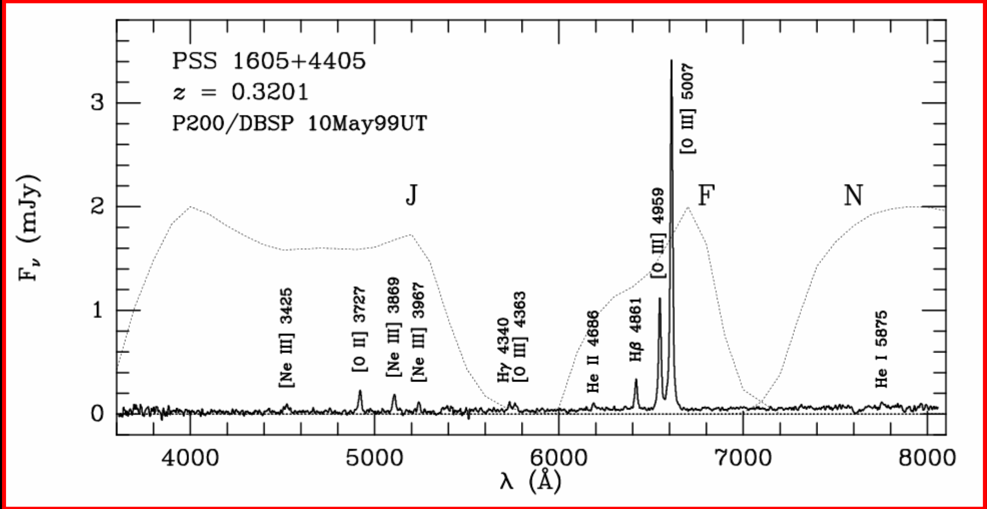


requested 12 more Type 2 QSOs for observations with Chandra

…or…

The DPOSS Type 2 quasar sample





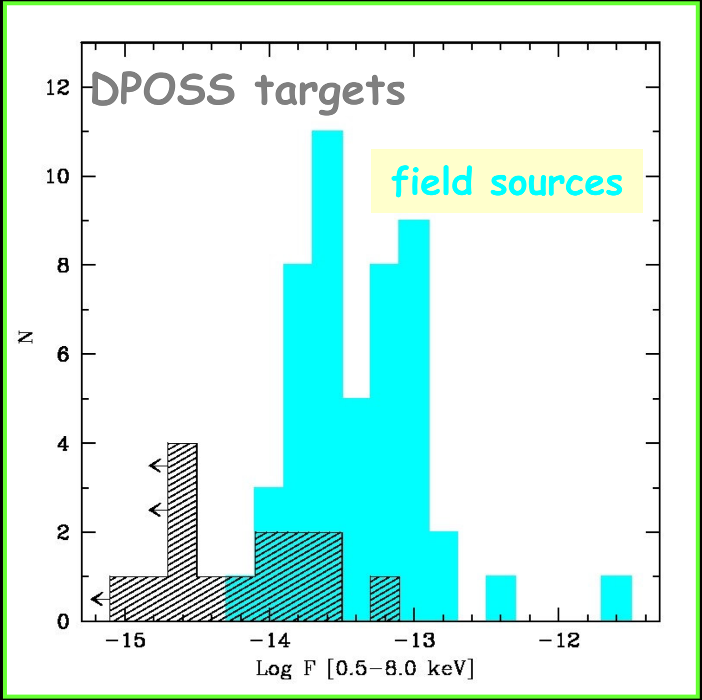
[OIII] line in the r band → z=0.31-0.38
ρ<0.01/deg² (Djorgovski et al. 2001)

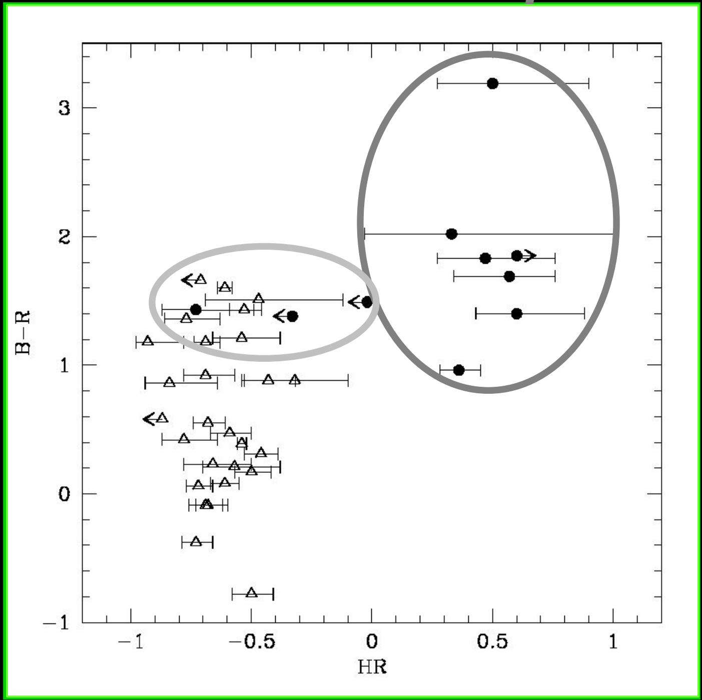
poor published information but ...

15 Chandra observations (5-15 ks) in the archive...
Laurea thesis by Agnese Del Moro

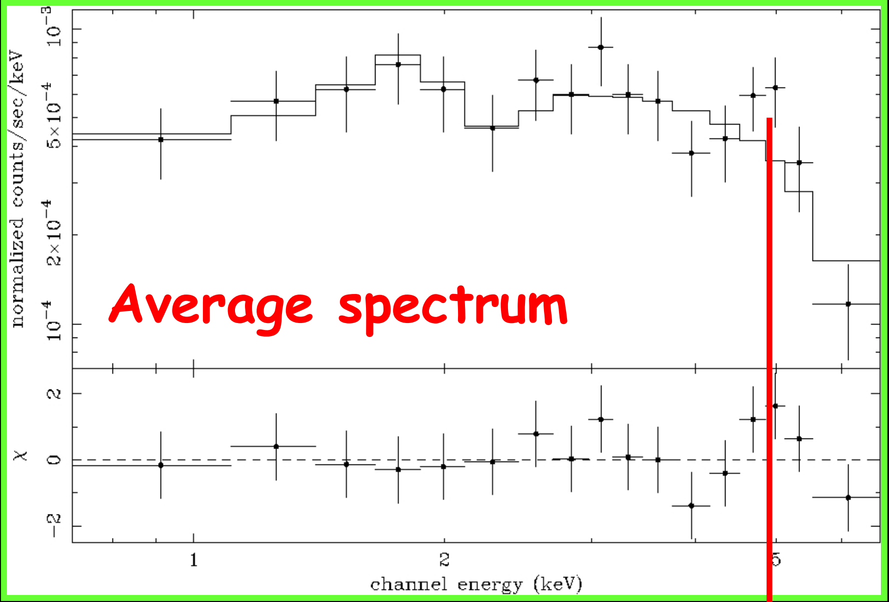
12/15 sources detected
(11 with <40 counts)
$F_{(0.5\text{-}8\ keV)} = 1\times10^{-15}\text{-}7\times10^{-14}$ erg/cm^{2}s

11 measured HR
8 sources have HR>0
suggesting $N_H > 10^{22}$ cm^{-2}





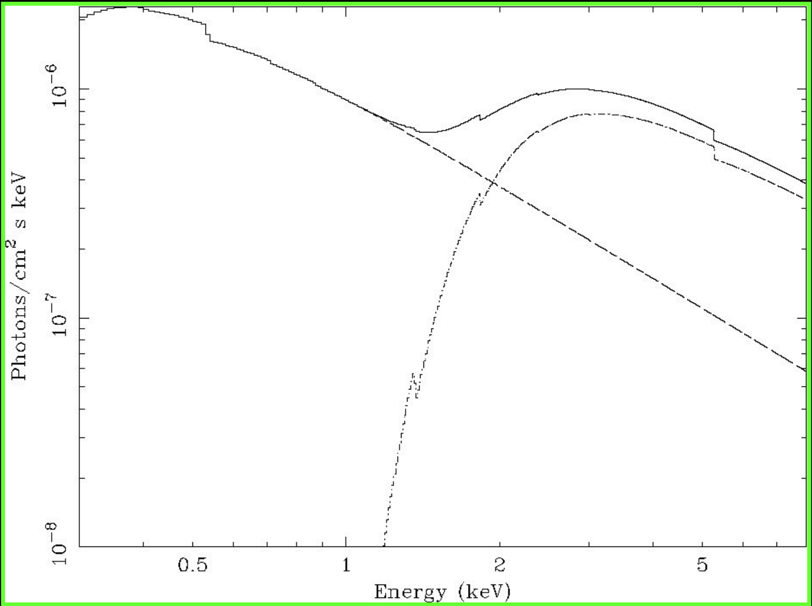
Spectral results for the DPOSS Type 2 QSOs



iron line? z=0.32±0.05 keV

low significance, EW≈700±500 eV

scattering model
→N_{Hz}≈8x10^{22} cm^{-2}
scattering fraction≈17%



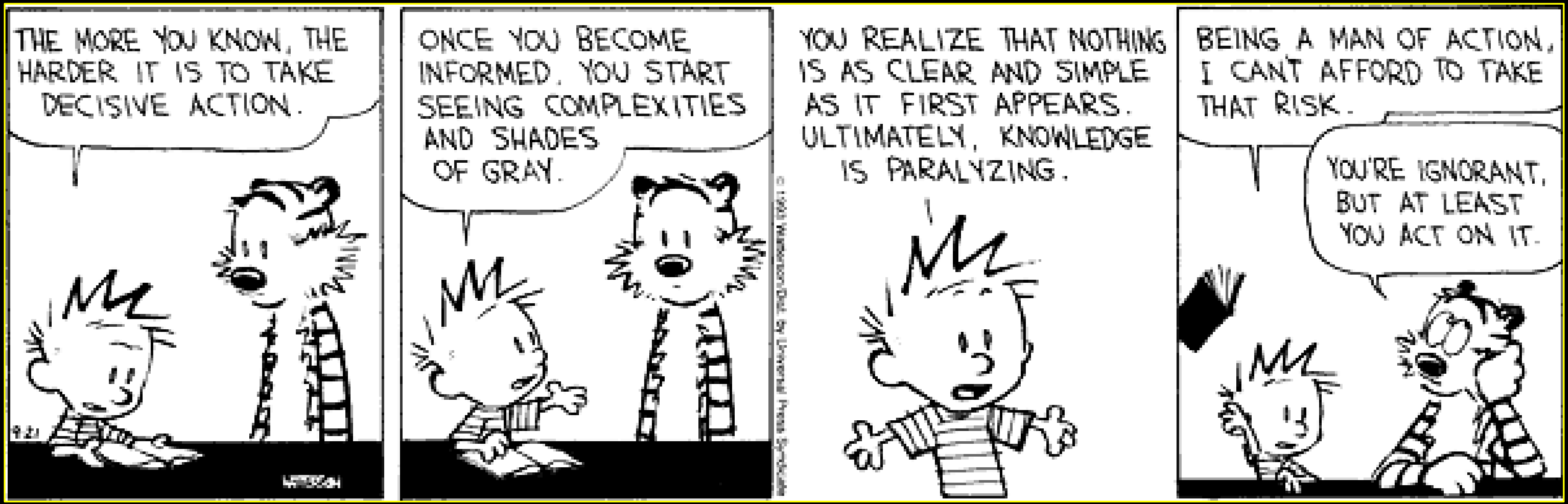
individual X-ray spectrum for one source only (half of the total counts) →N_{Hz}≈4x10^{22} cm^{-2}

similar spectral results using only the 8 sources with HR>0

If the same scattering model is applied for the 3 sources with HR<0 (33 counts) →N_{Hz}≥10^{24} cm^{-2} (**Compton-thick**)

a different approach to the problem

… the Calvin's attitude …



The end