Deep X-ray spectroscopy of obscured AGN in the XMM-CDFS

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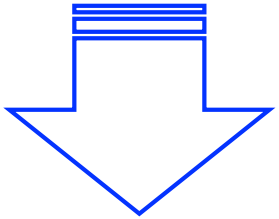
X-ray Universe, Dublin, June 2014

Science drivers

- To search for the most heavily obscured AGN, up to high redshift, and estimate their contribution to the accretion history (XRB) of the Universe
- To study the *obscured AGN growth* − a key phase in shaping the joint SMBH and host galaxy growth − and the role of feedback in the “blow-out” phase
- To understand the link between gas accretion, obscuration and star formation
- To investigate peculiar objects, AGN variability, extended sources, galaxies…

Definitely, needs for a complete AGN census, including the most obscured AGN. How?

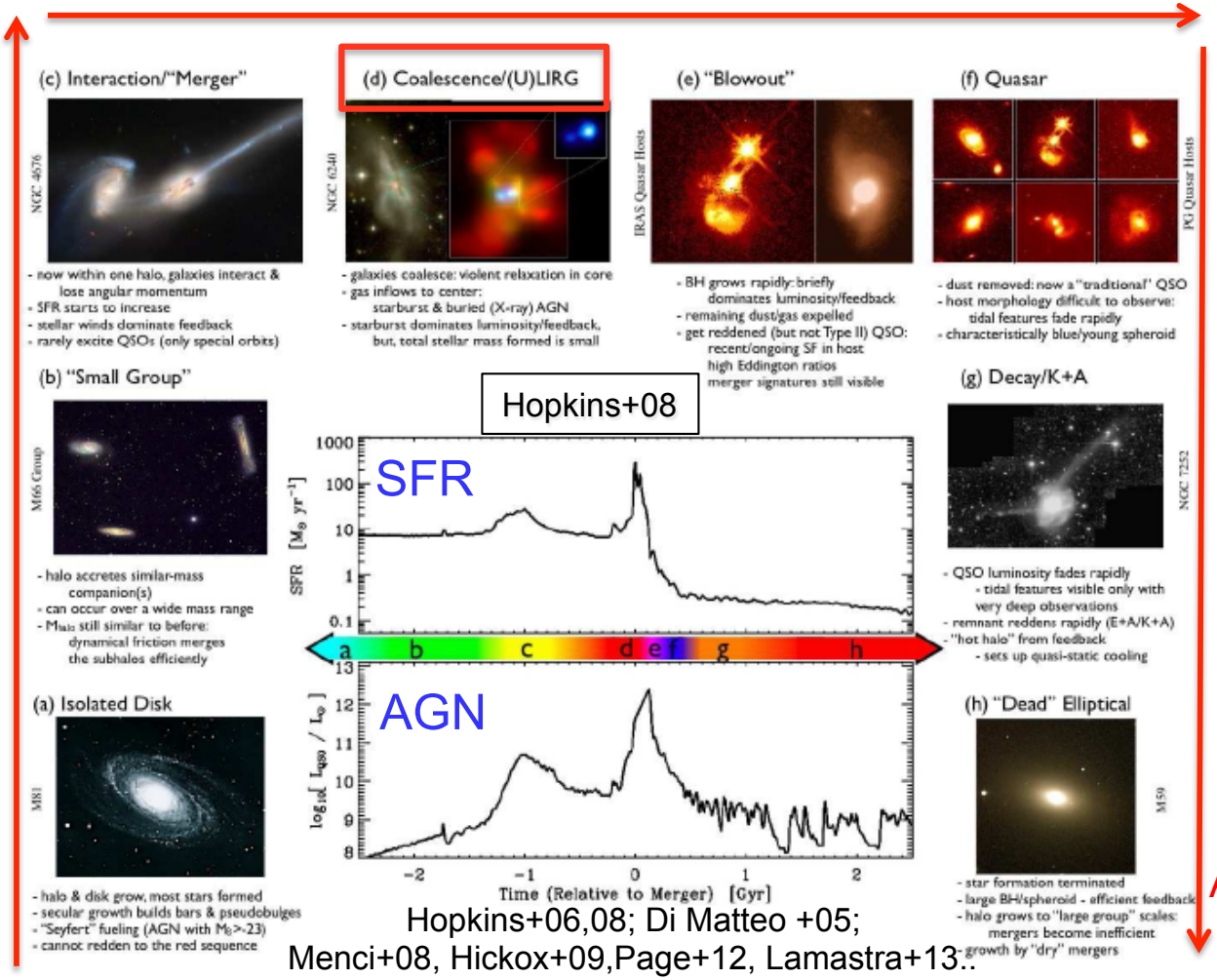


X-ray surveys

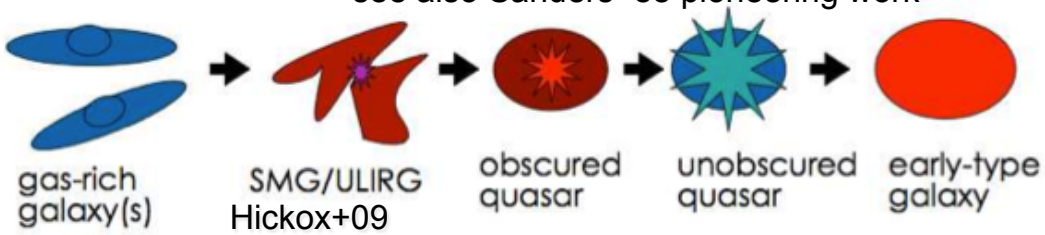
Combined mid-IR/opt/X-ray

Optical spectroscopy

The theoretical framework: the BH/galaxy "evolutionary model"



Hopkins+06,08; Di Matteo +05; Menci+08, Hickox+09,Page+12, Lamastra+13.. see also Sanders+88 pioneering work



Hickox+09

mergers

SF/obscured accretion

"clean" accretion (QSO)

transition (green valley) object

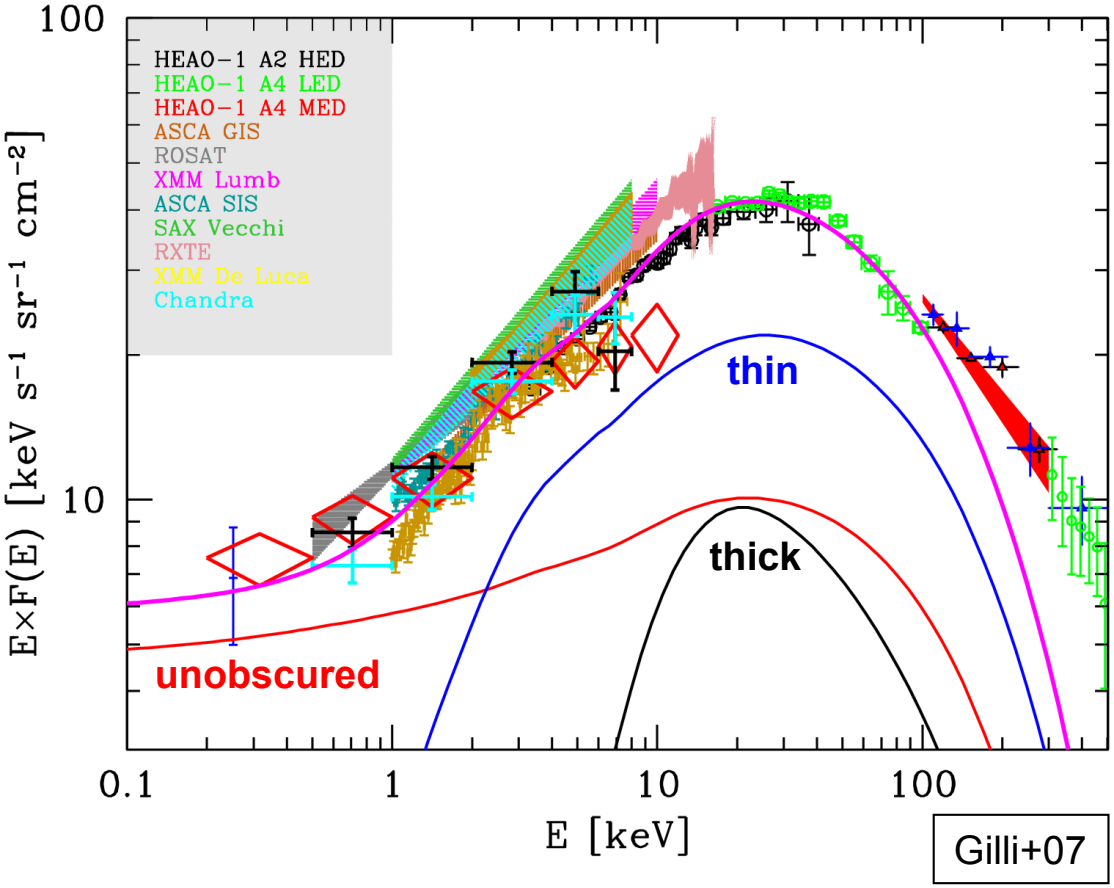
passive red galaxy

	Galaxy	AGN	
SF	Morph.	L/L_{EDD}	Obsc.
Strong	Disturbed	High	High
Moderate	Coalescing	Lower	Lower
Low	Relaxed	Lower	No

AGN feedback is likely the key to control the evolutionary sequence

Hold mainly (only?) for *luminous AGN*, while secular ("smooth") accretion via cold gas flows and minor mergers is more likely for lower luminosity Seyferts

Obscured AGN and their role in XRB models



Phase with obscured AGN growth coupled to powerful star formation

AGN likely either Compton thick (N_H>10^{24} cm^{-2}) or heavily obscured in this phase

C-thick AGN at z>0.1 invoked to explain the 30 keV XRB: they are expected to contribute from ~10 to 30%, depending on the models (Gilli+07, Treister+09) – see also recent results from Ueda+14 + Ballantyne, Akylas models

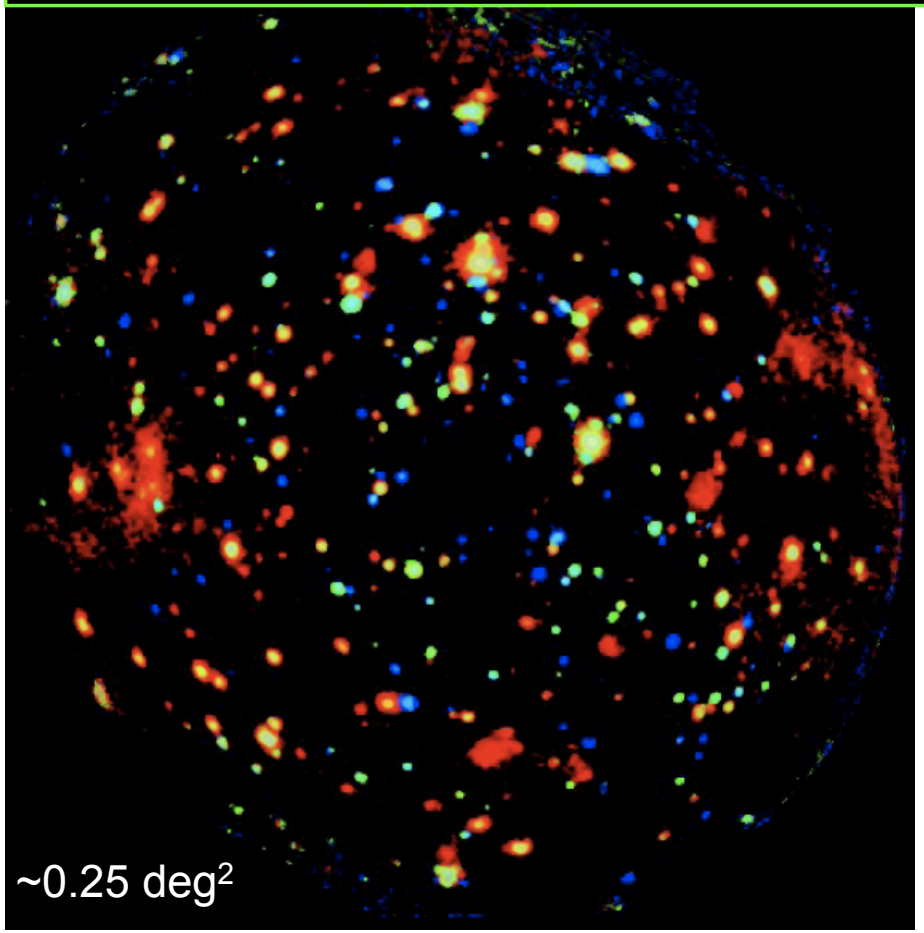
Much of the mass growth of SMBH occurs during the heavily obscured phase? (e.g., Treister+10)

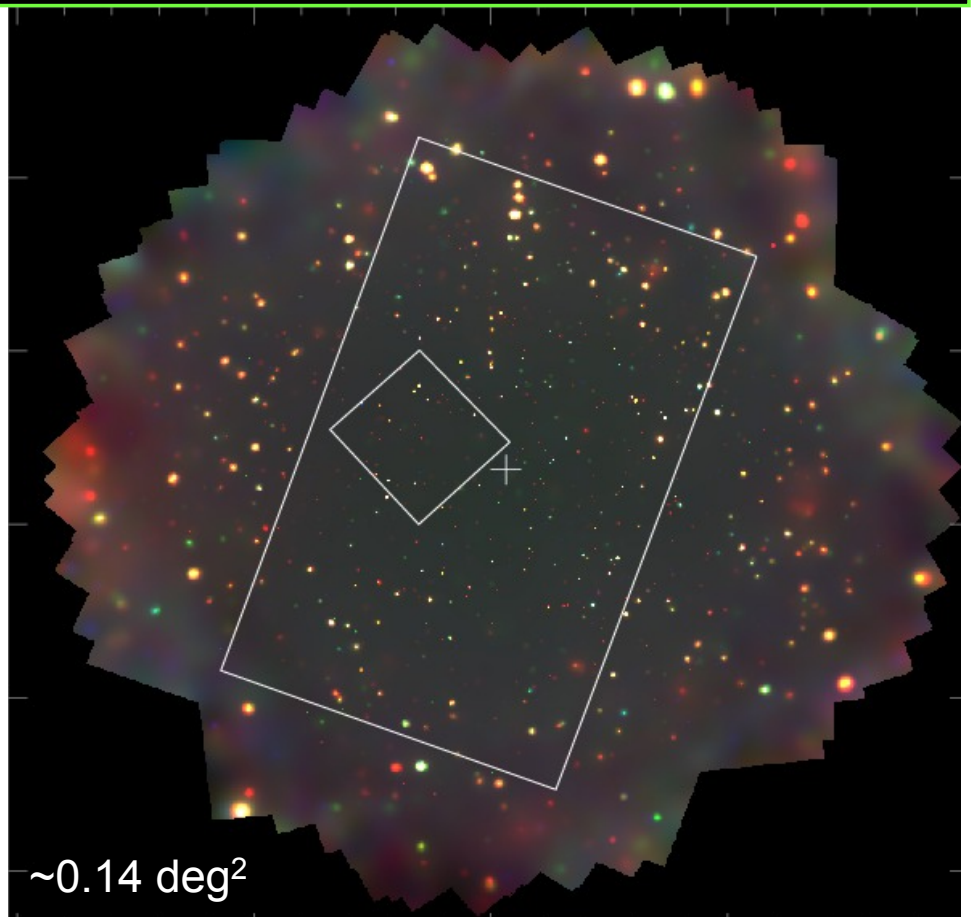
Compton-thick AGN common at low redshift, though not easy to identify as such.

We need to find them beyond the local Universe!

One of the science goals of *Athena* (F. Carrera's talk)

The deepest X-ray field: CDF-S





XMM-CDFS 3 Ms survey
(PI: A. Comastri; Ranalli+13)

F(2-10keV)≈6.6×10^{-16} erg/cm2/s

Chandra-CDFS 4 Ms survey
(PI: R. Giacconi, W.N Brandt; Xue+11)
Further extension to 7Ms (2014)

F(0.5-2keV)≈10^{-17} erg/cm2/s

Capable of probing the high-z Universe with some photon statistics

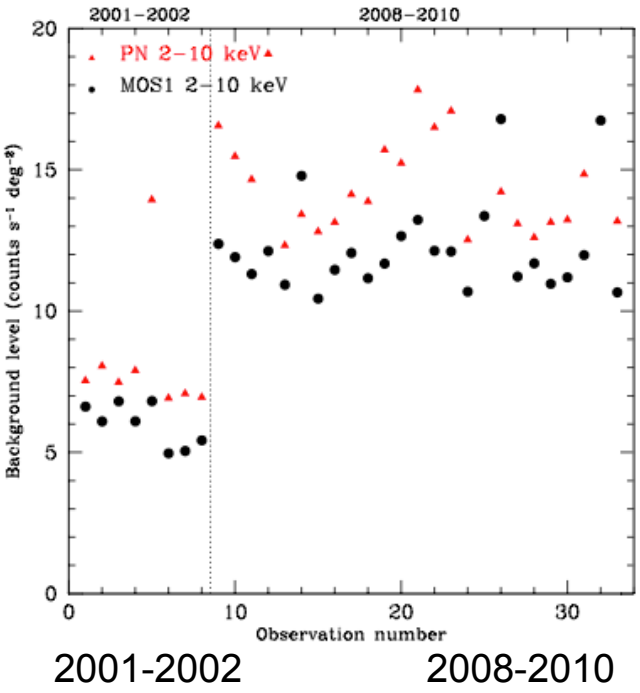
The XMM-CDFS data

- Total exposure: 3.4Ms [clean: 2.4Ms (pn), 2.8Ms (mos)]
- 33 observations (8 in 2001−2002, 25 in 2008−2010)
- N=339 sources (2−10keV), 137 (5−10 keV), 15 “new” wrt. *Chandra*

Issues

Background level

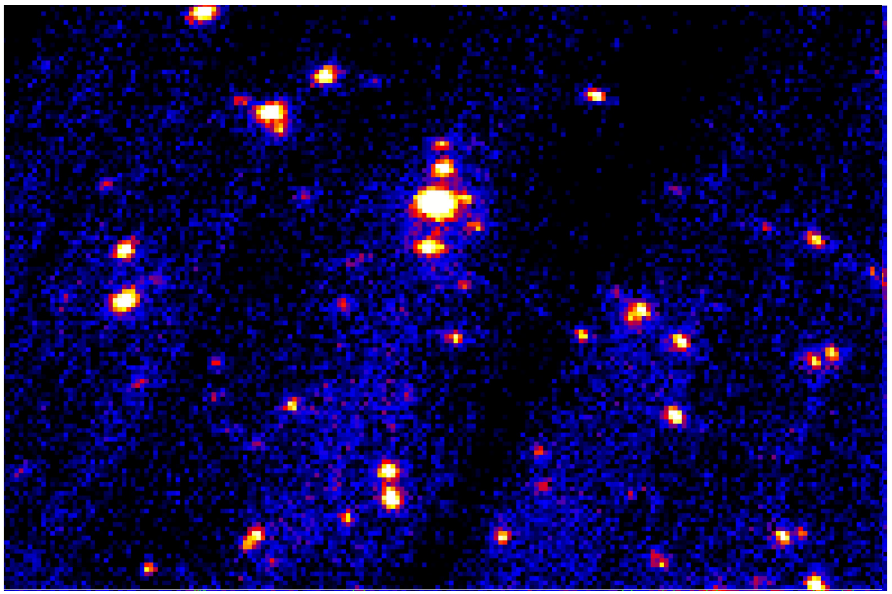
Much higher in 2008−2010 obs. Limits the detection of faint AGN and the SNR of spectra



2001-2002 2008-2010

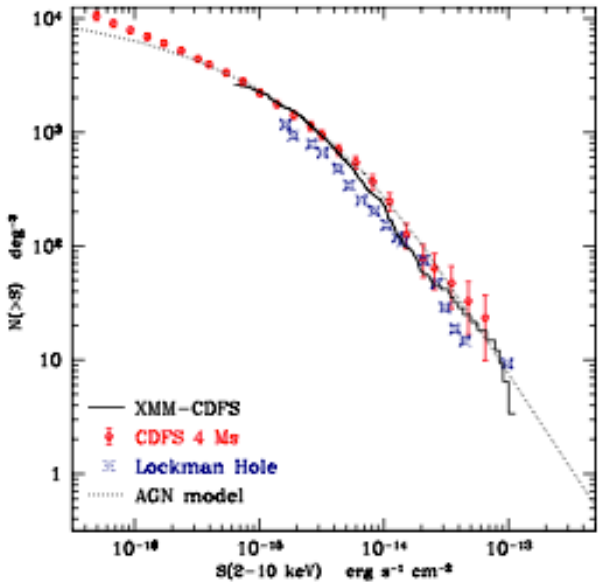
Source blending/confusion

Much worse than in *Chandra*, but less evident in the 2-10 keV band, where the src. catalog has been produced

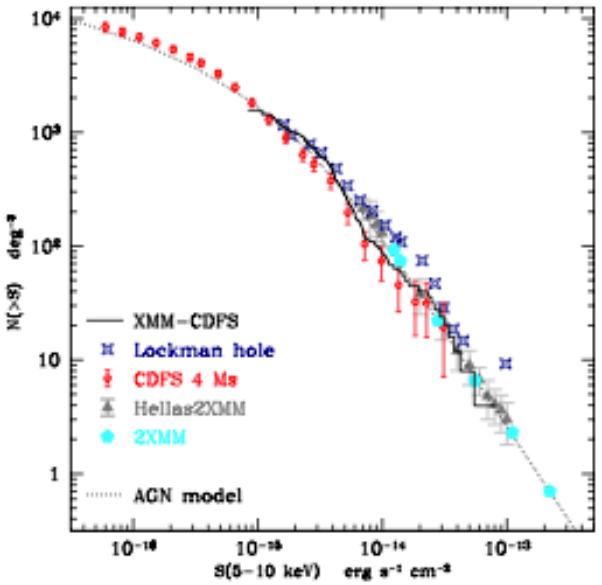


Ranalli+13

The XMM-CDFS survey: LogN-LogS



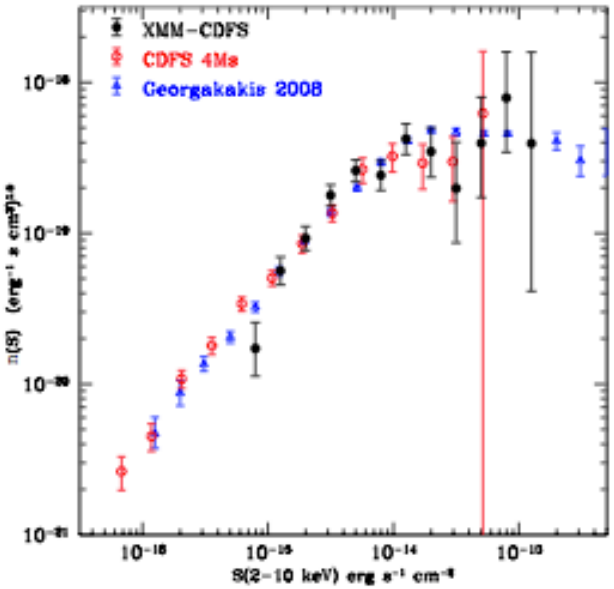
2−10 keV

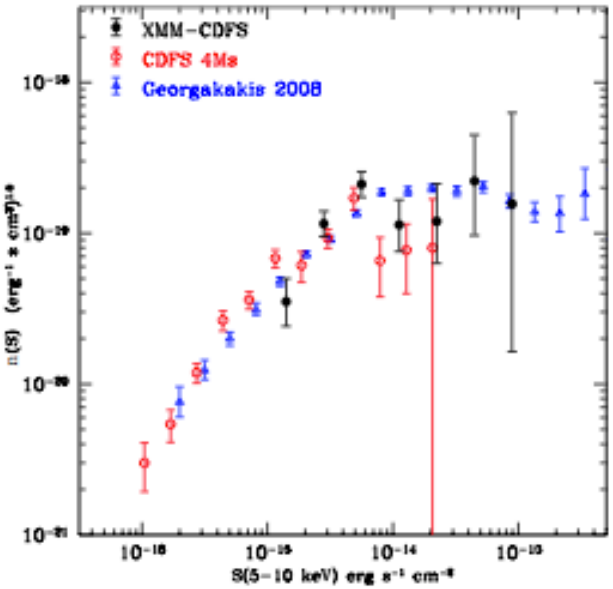


5−10 keV

Cumulative LogN-LogS

~80% of the 2−10 keV background resolved



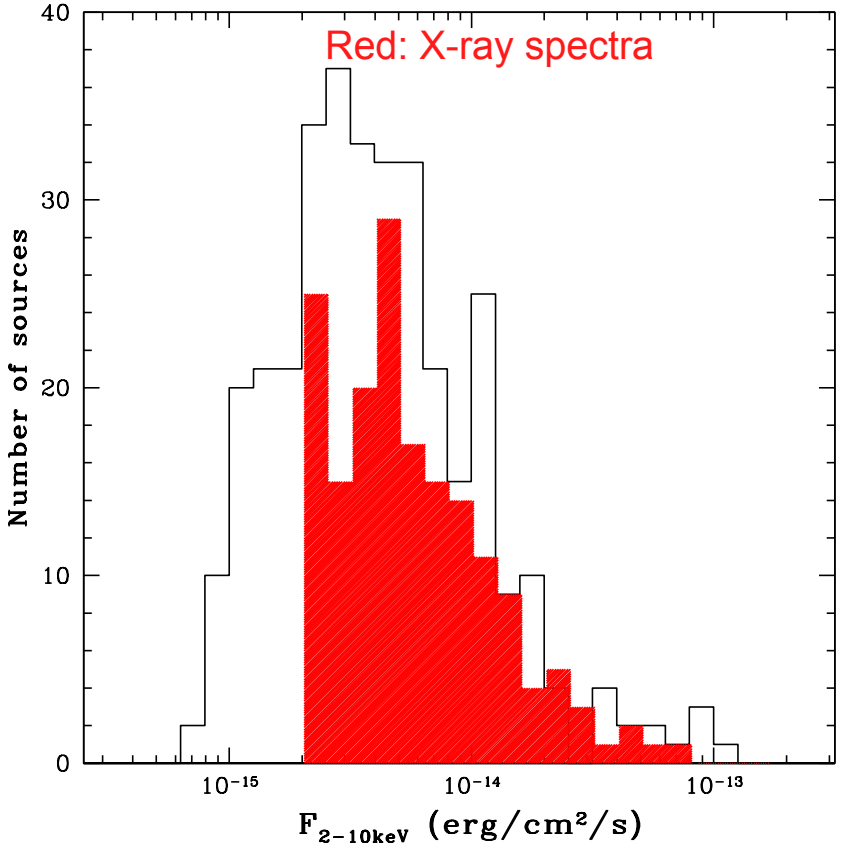


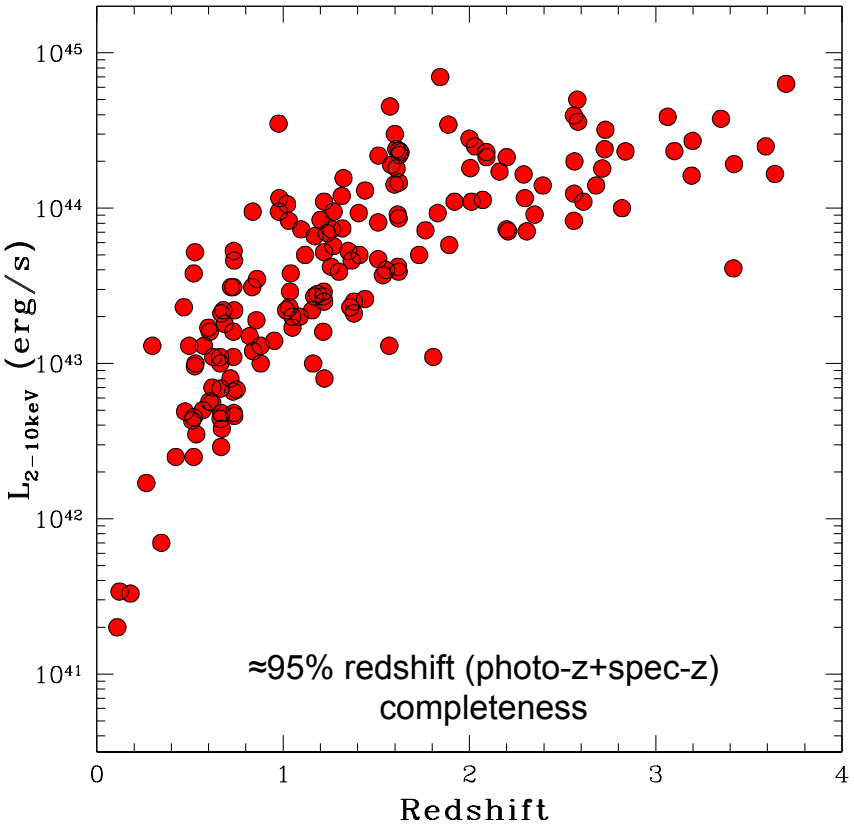
Differential LogN-LogS

Ranalli+13

The XMM-CDFS survey: source properties (I)

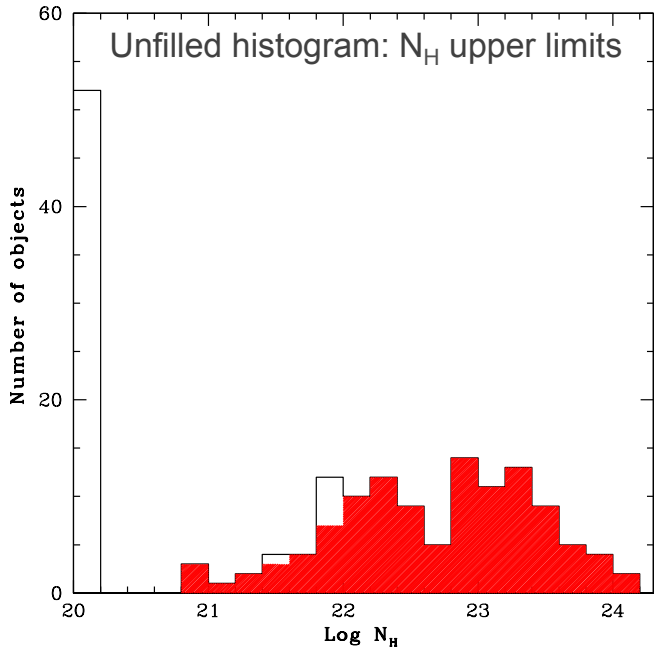
X-ray spectral analysis starting from the ≈180 at >8σ c.l, $F_{2-10keV}$>1.8×10^{-15} erg/cm^2/s

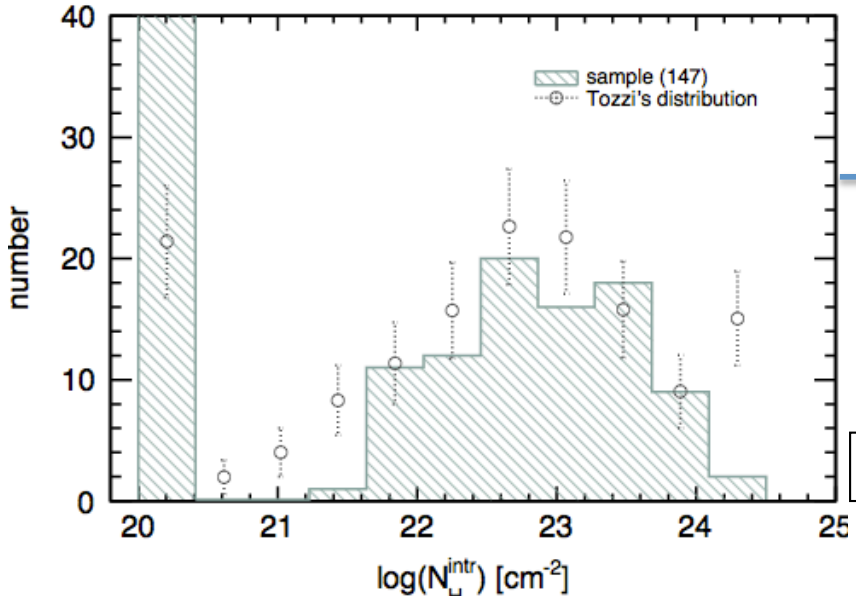




Comastri et al., in prep.

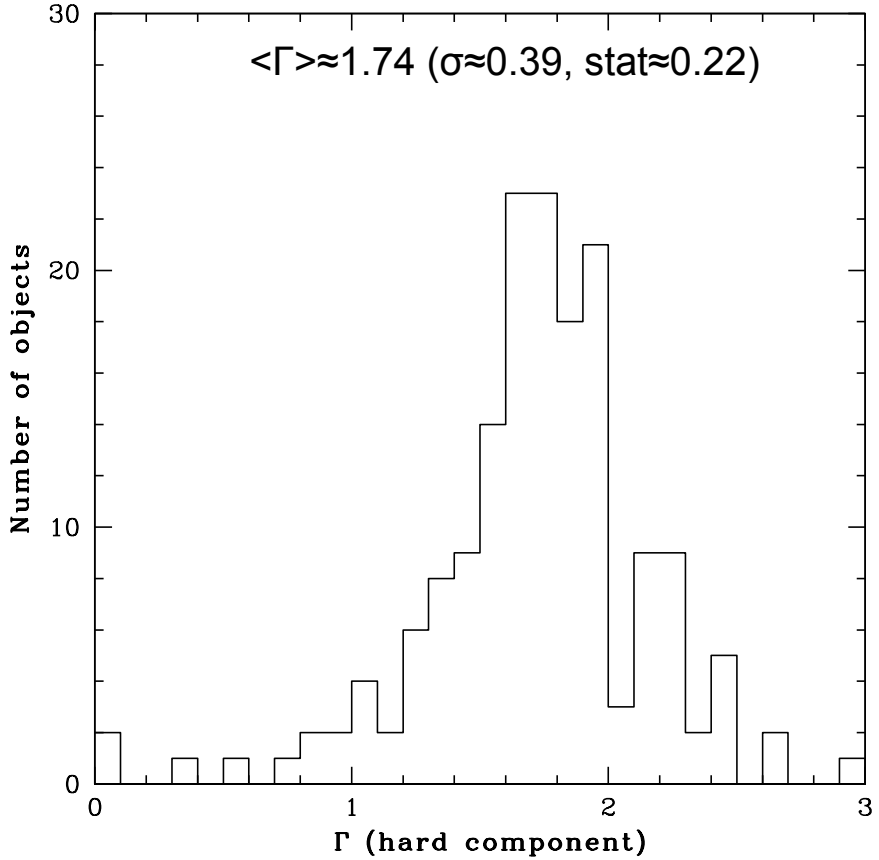
The XMM-CDFS survey: source properties (II)





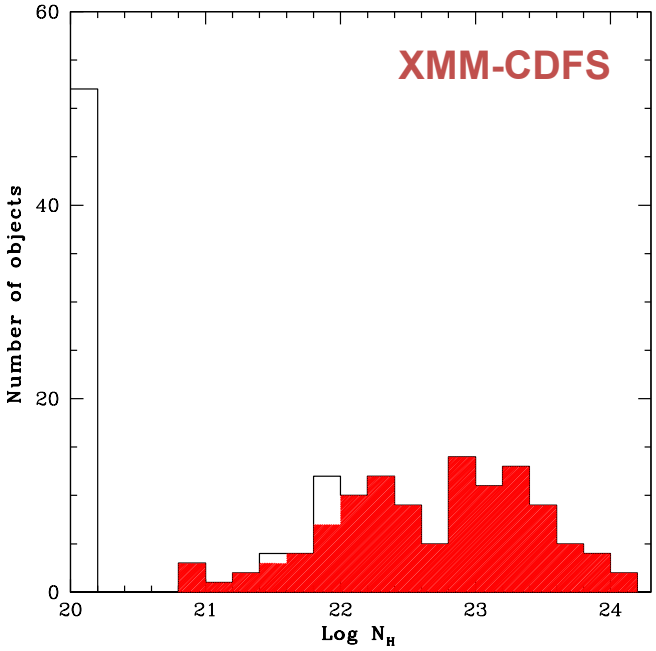
XMM-CDFS, two independent analyses

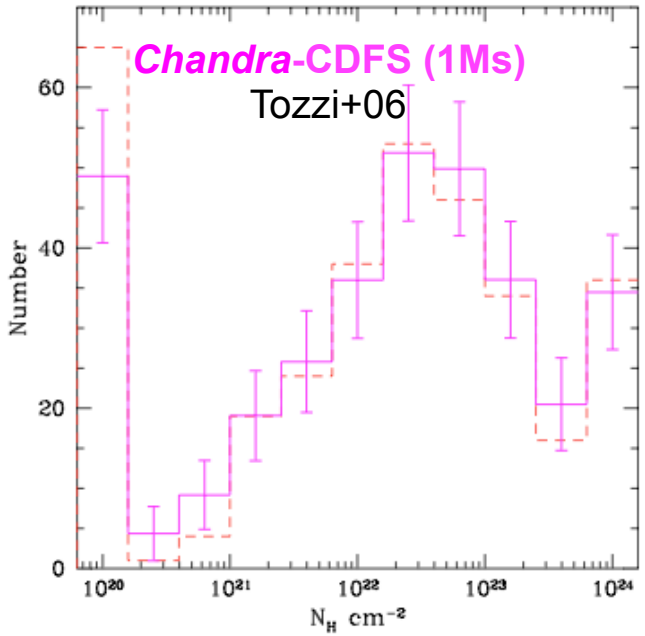
Castello-Mor et al. 2013



Comastri et al., in prep.

The XMM-CDFS survey: N_H distribution

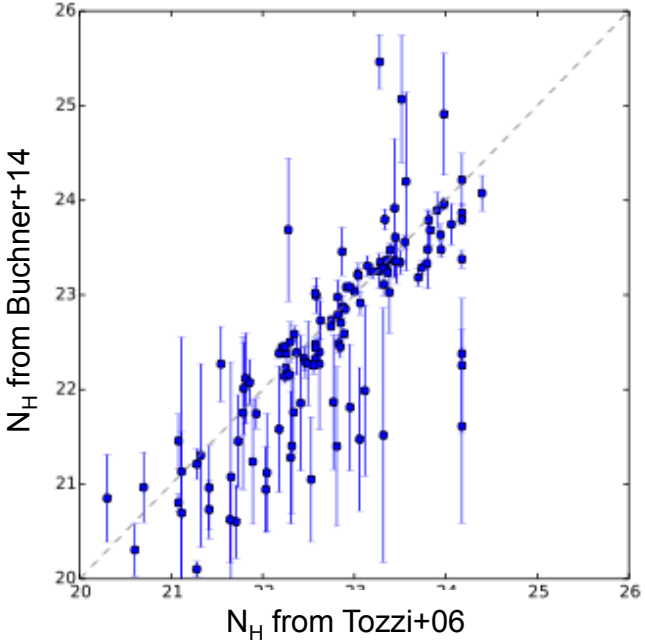




The number of heavily obscured (Compton-thick) AGN in the highly X-ray exposed CDF-S area is still limited (e.g., ≈40 in Brightman & Ueda 2012 using *Chandra* data)

Limited photon statistics strongly limits the accuracy of the derived spectral parameters

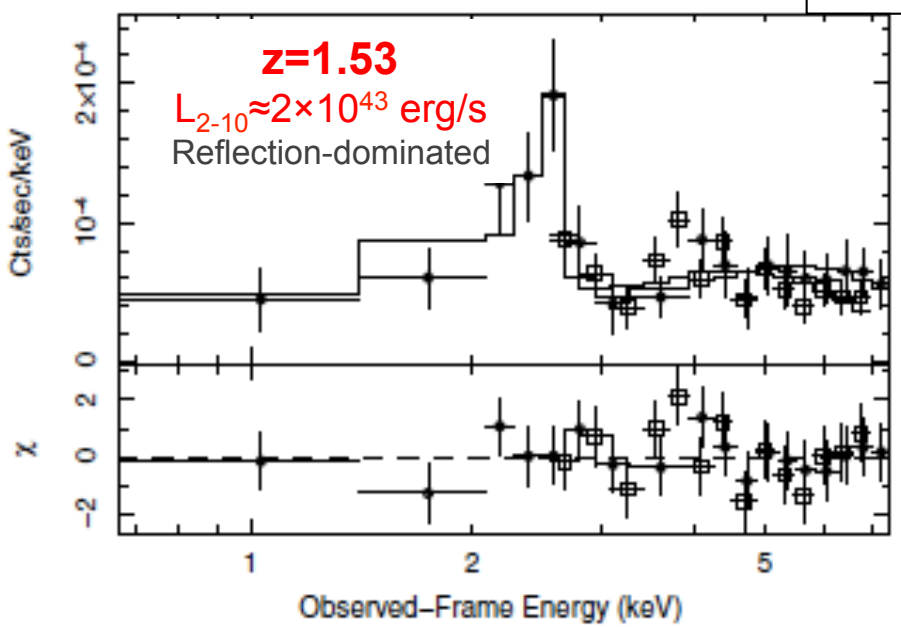
This may be responsible also for different X-ray spectral results obtained sometimes for the same sources (see Table 4 of Castello-Mor+13), besides the different analyses of the data (see Buchner+14 for the Bayesian approach)

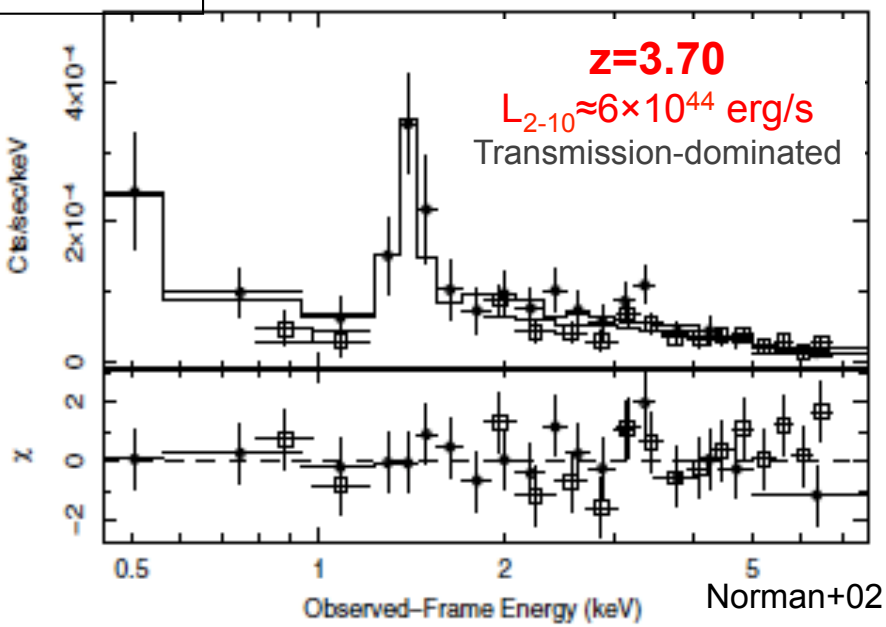


***Chandra*-CDFS (4Ms)**
Buchner+14
(Bayesian approach)

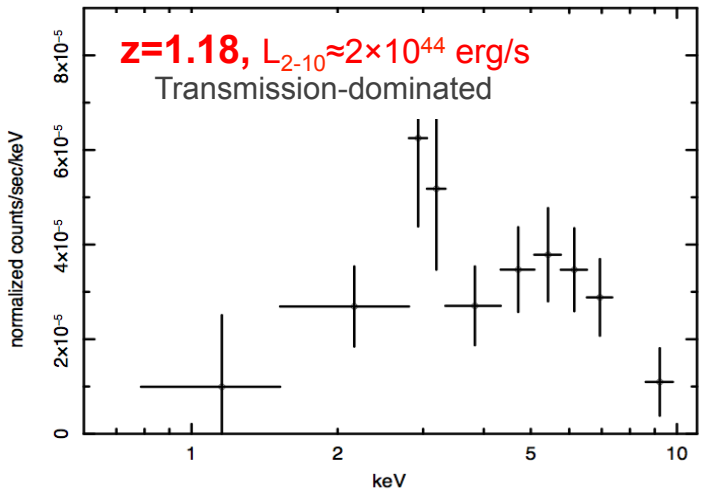
Distant Compton-thick AGN in the CDF-S

Comastri+11

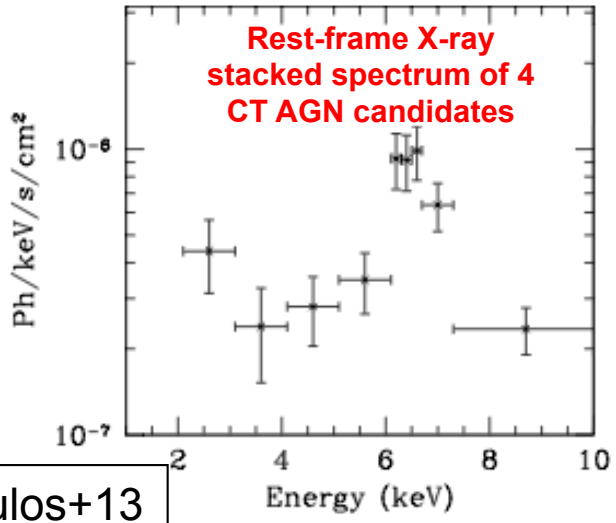




Norman+02 src

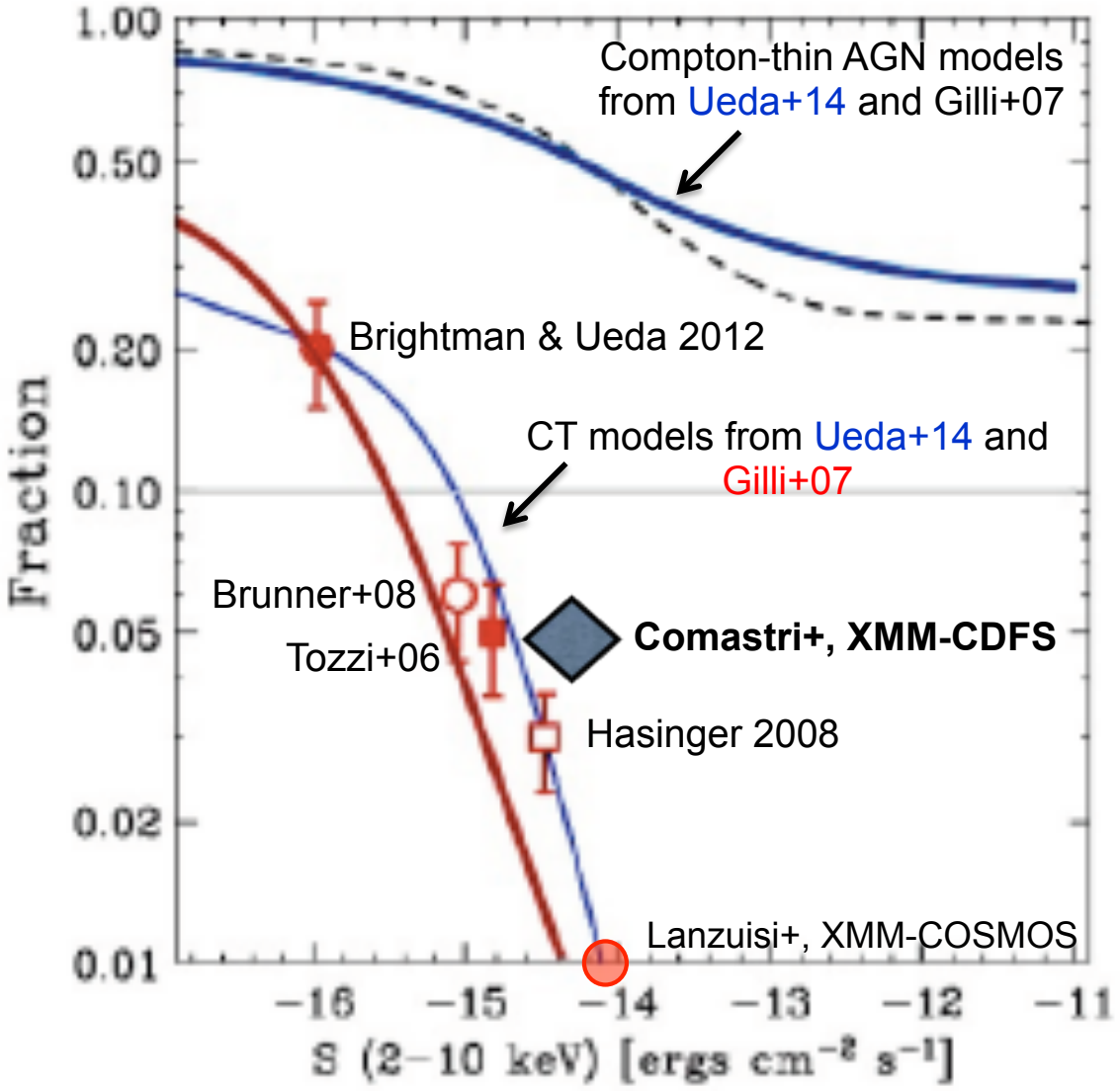


66+144+147+324



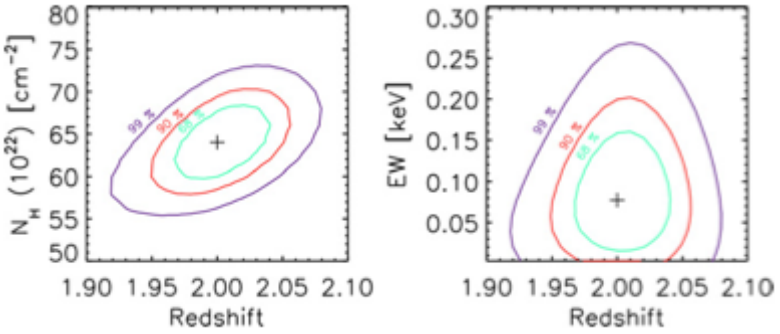
Georgantopoulos+13

Compton-thick AGN fraction



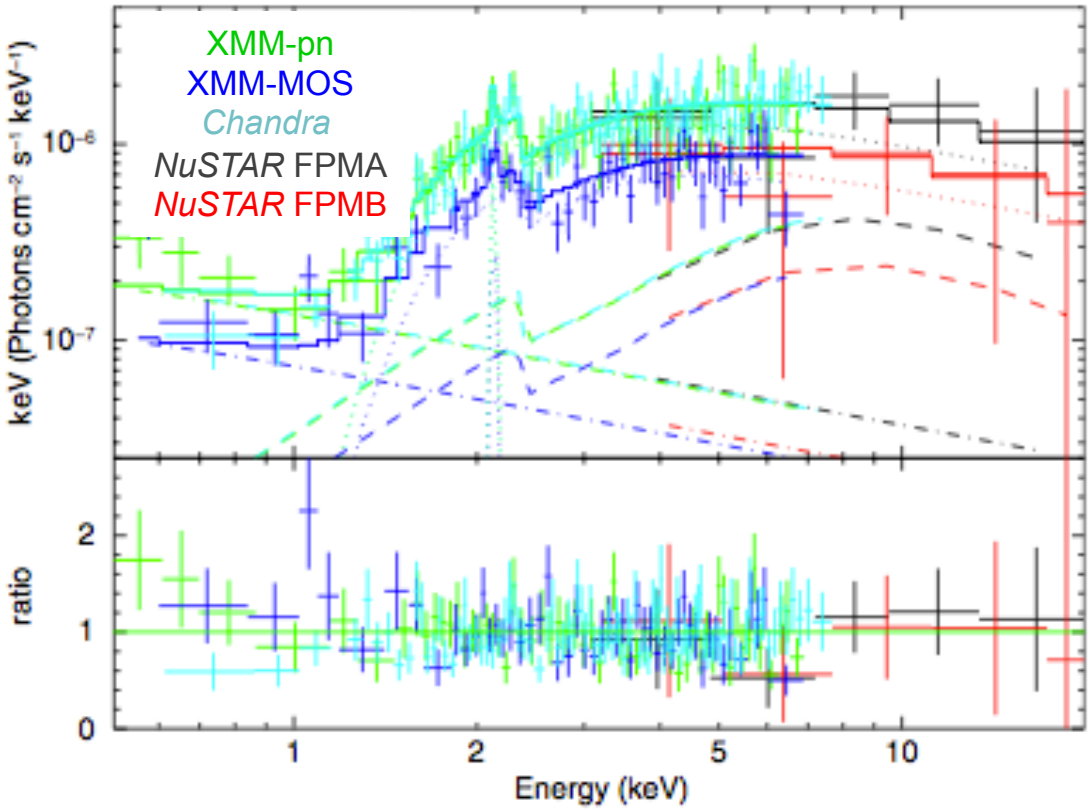
5% fraction of CT AGN in XMM-CDFS thus far (the faintest sources are not fitted yet)

Distant obscured AGN in the CDF-S (I)



z=2.00±0.04 from iron line and Fe K abs. edge

$N_H \approx 6\times10^{23}$ cm^{-2},
better constrained than using E<10 keV data alone



Detected by NuSTAR at E=8−24 keV
The highest-redshift non-blazar AGN imaged at E>10 keV

Strong reflection in a high-luminosity radio-loud ($P_{1.4GHz}\approx10^{27}$ W/Hz) obscured AGN ($L_{2\text{-}10keV}=4.0\times10^{44}$, $L_{10\text{-}40keV}=6.4\times10^{44}$ erg/s)

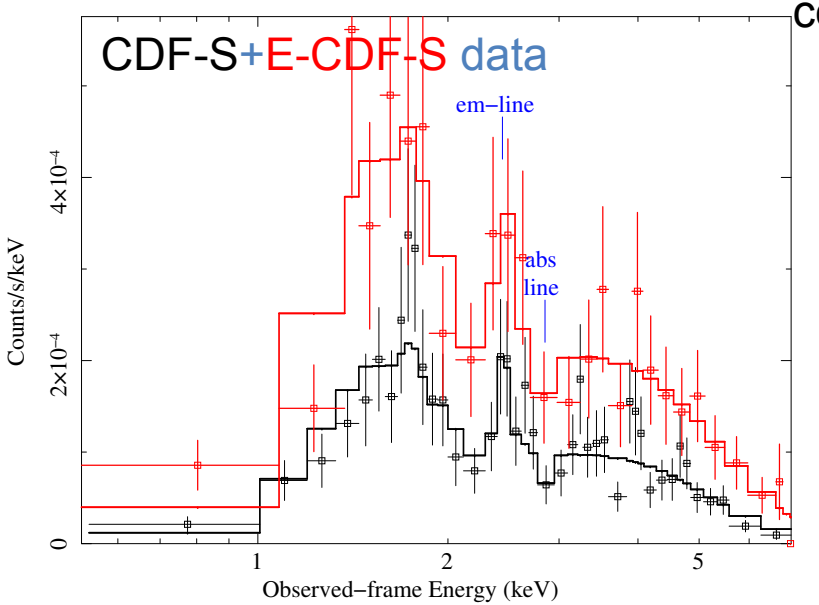
Possible implications for XRB models if large number of high-L_X AGN with strong reflection

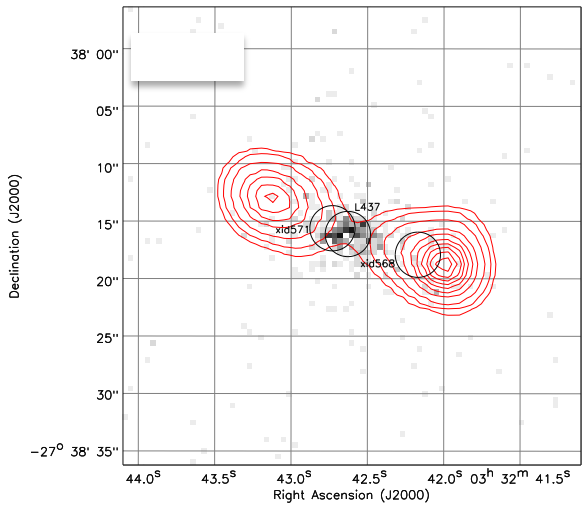
Del Moro+14

Distant obscured AGN in the CDF-S (II)

Absorption line with outflowing velocity ~(0.09−0.17)c, depending on the ionization state of the gas

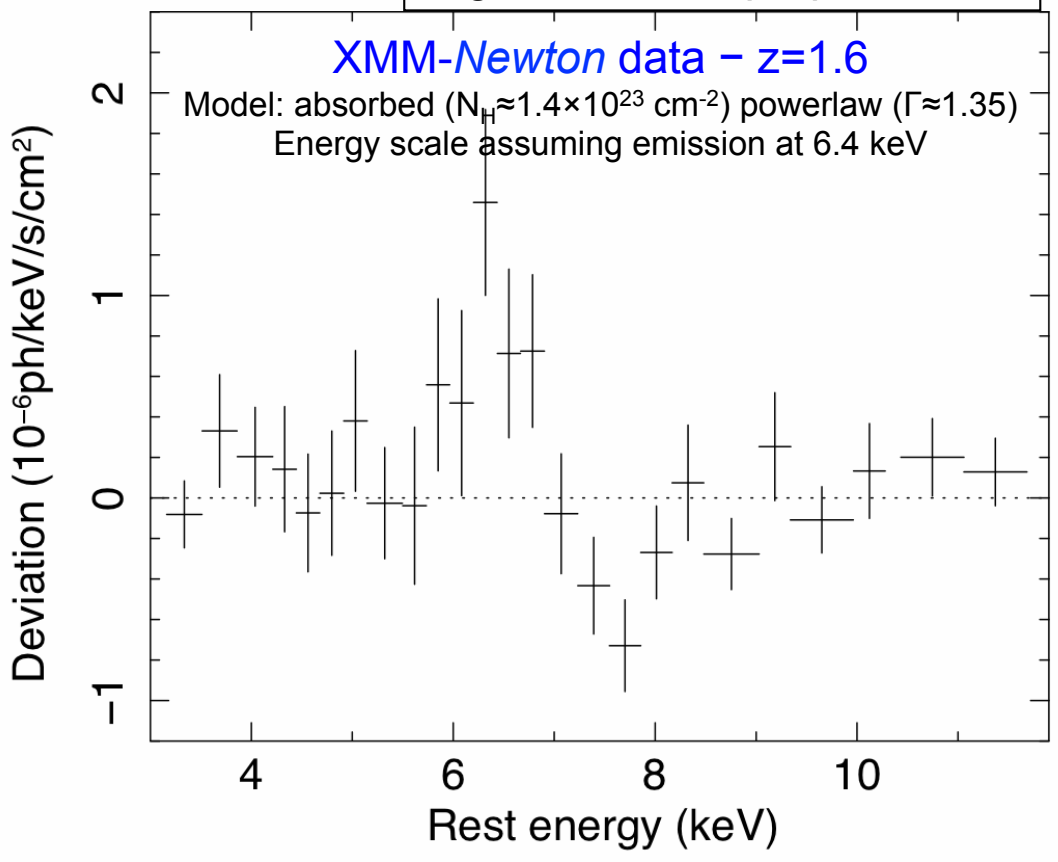
Detection both in *Chandra* and in XMM-*Newton* data − Obscured luminous ($L_{2\text{-}10keV}$≈3×10^{44} erg/s) core of a radio galaxy





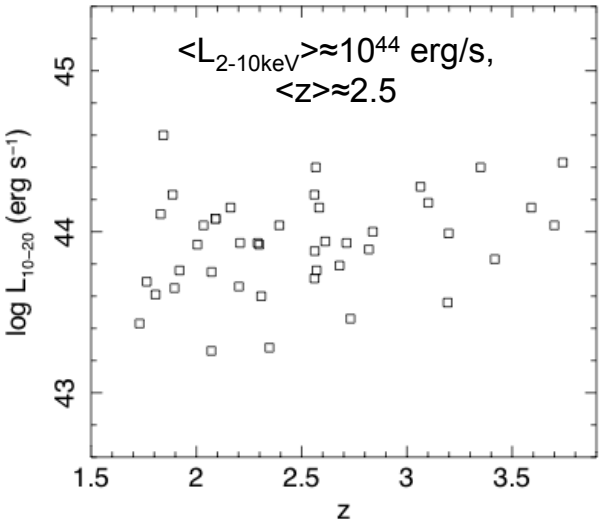
$$\dot{M}_{out} \approx \dot{M}_{acc} \approx \text{a few } M_{sun}/yr$$

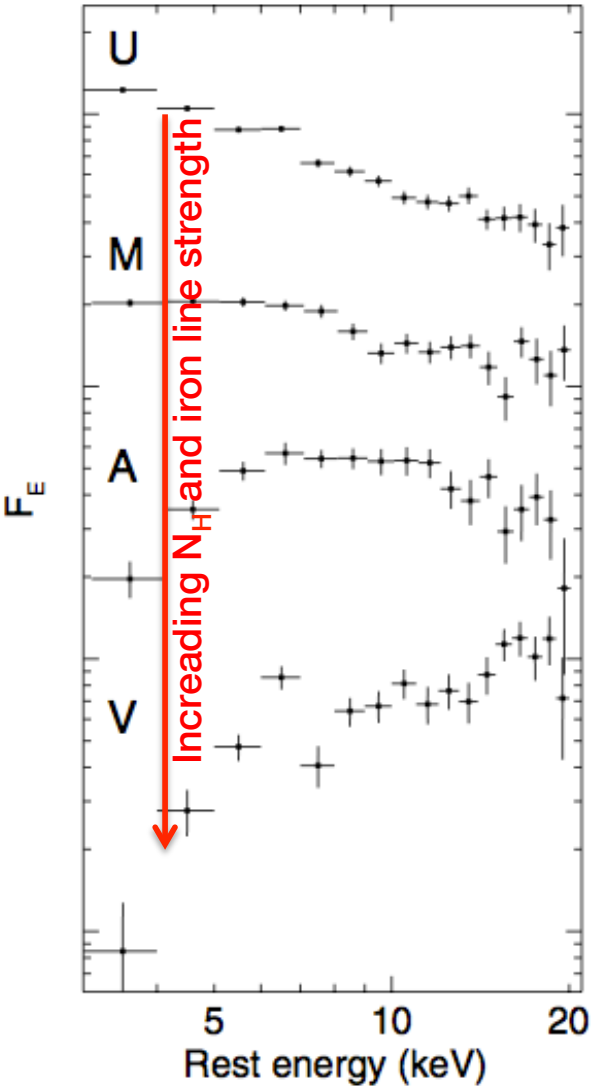
Vignali et al., in prep., + poster

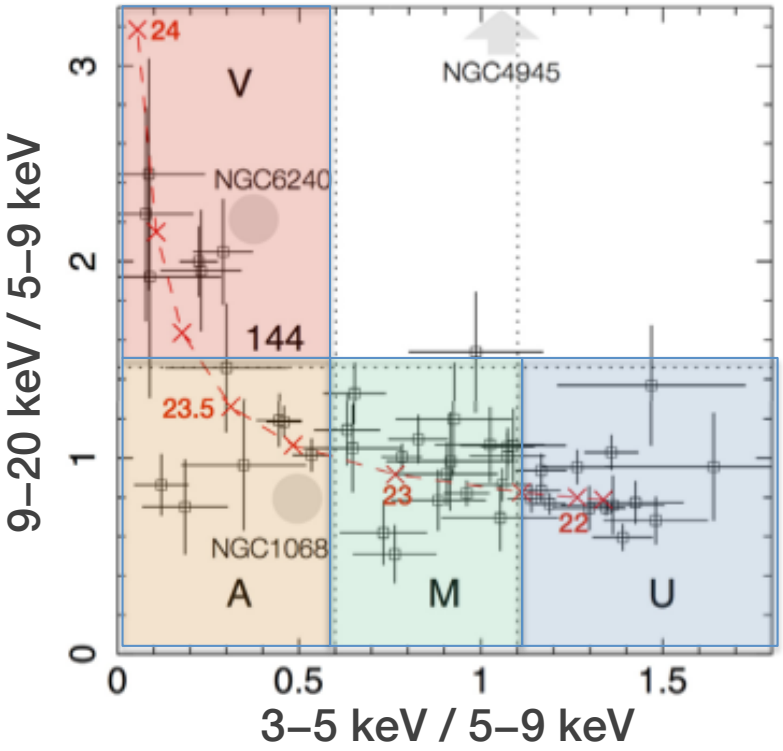


X-ray stacking to probe high-redshift sources

At **z>1.7**, the rest-frame 10−20 keV band enters the XMM-*Newton* bandpass ➔ search for obscured AGN using the hard (>10 keV) excess − 44 AGN in the 2−10 keV source catalog



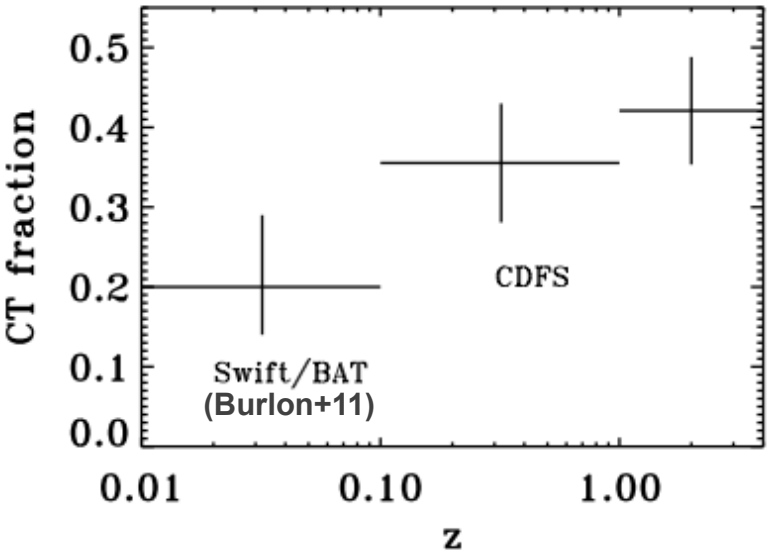




Iwasawa+12

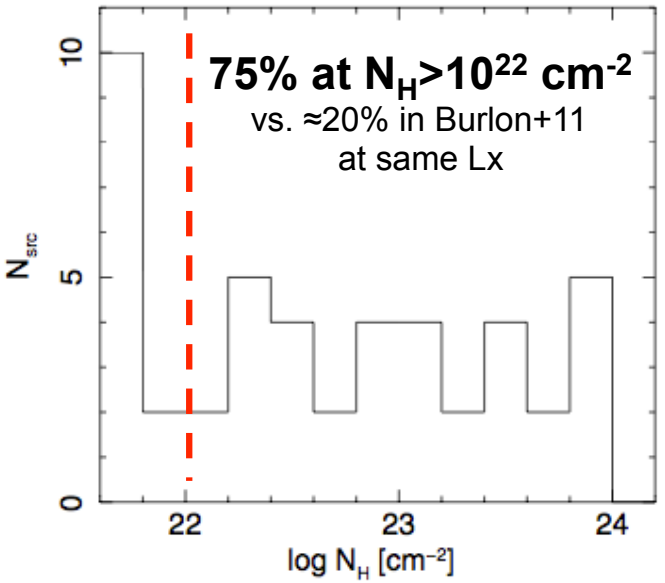
High obscured AGN fraction at high redshift

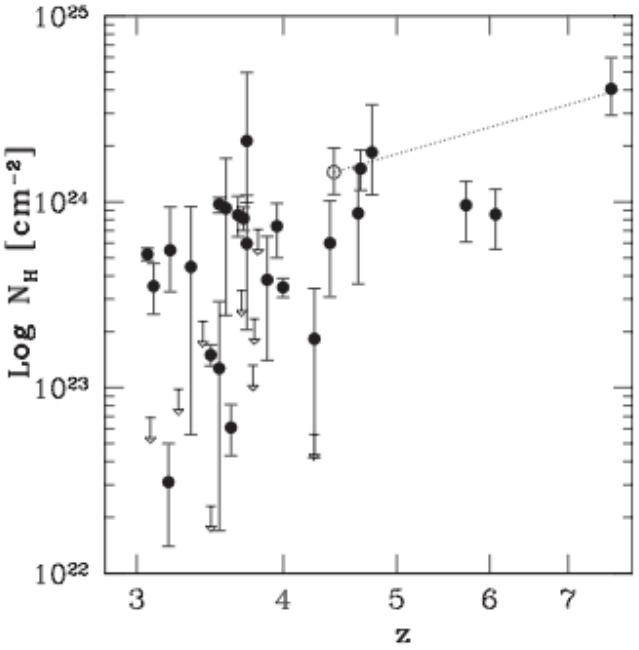
The evolution of the obscured AGN fraction over cosmic time has been a debated issue since almost a decade (Ueda, La Franca, Gilli, Hasinger, Treister, …) − see also Merloni+14



Compton-thick (N_H>10^{24} cm^{-2}) AGN,
CDF-S, 4Ms (normalized to LogL_X=43.5)
Brightman & Ueda 2012

XMM-CDFS, 3Ms, **z=1.7−3.7**
Iwasawa+12





CDF-S, 4Ms, **z>3** AGN
65% with N_H>10^{23} cm^{-2}
Vito+13

Higher merger rate and more gas available
for the accreting SMBHs at high redshift

X-ray spectral analysis and stacking are fundamental tools,
but we need photons and low background

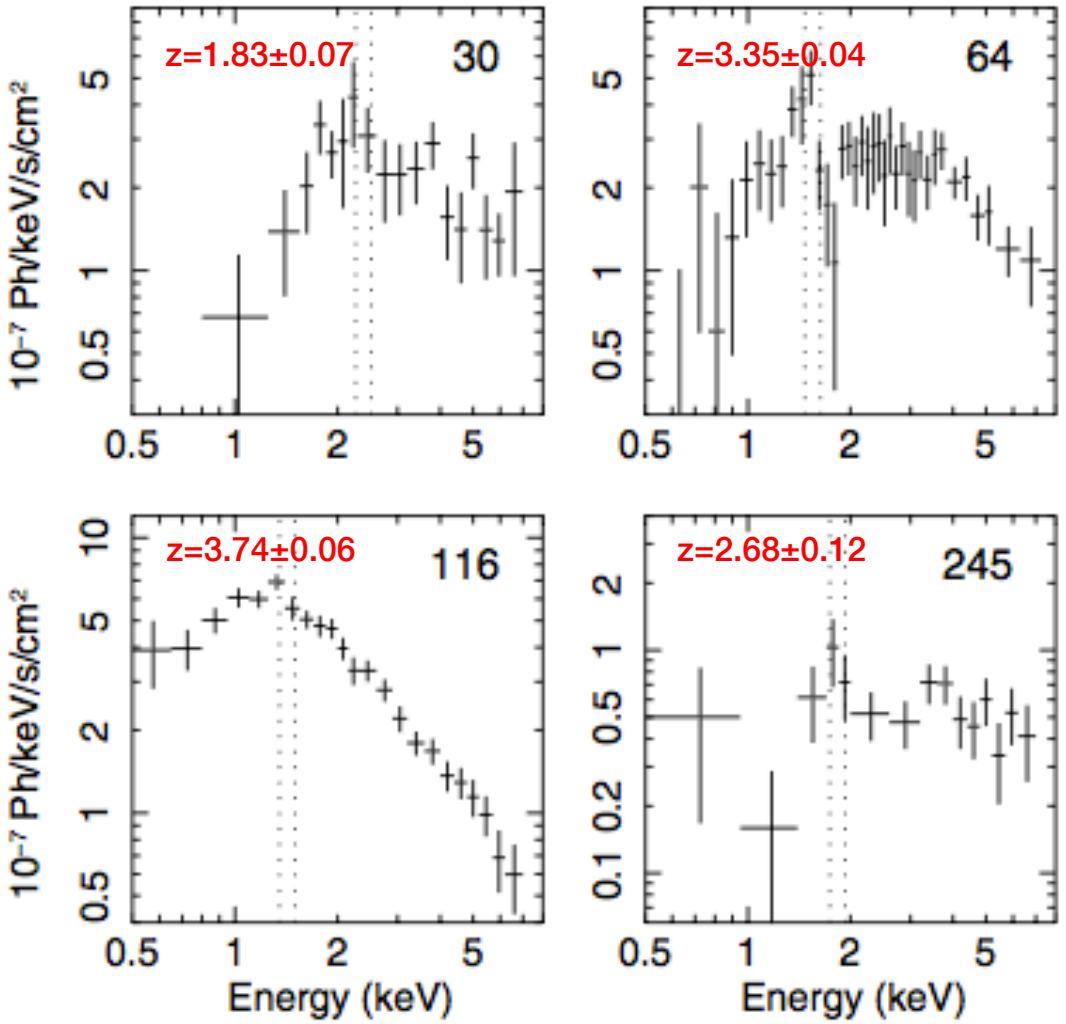
X-ray determined redshifts

Method: to use the Fe Kα emission line and absorption edge in strongly absorbed (V/A) AGN

XMM-*Newton* + CDF-S + E-CDF-S data

X-ray redshift estimates typically more accurate than photo-z solutions

Sometimes the only way to get a redshift for optically faint (obscured) AGN



Iwasawa+12

Summary

XMM-CDFS survey

X-ray spectroscopy allows for a proper spectral characterization of >100 AGN in the XMM-CDFS, up to high redshifts

The number of Compton-thick AGN is in fairly good agreement with XRB model expectations
Still need to analyze the faint AGN population (but poorer photon statistics and much lower snr)

X-rays are a good tracer of obscured accretion. Deep X-ray survey strategy is the way to go, but combined mid-IR/optical selection may help picking up the obscured AGN population