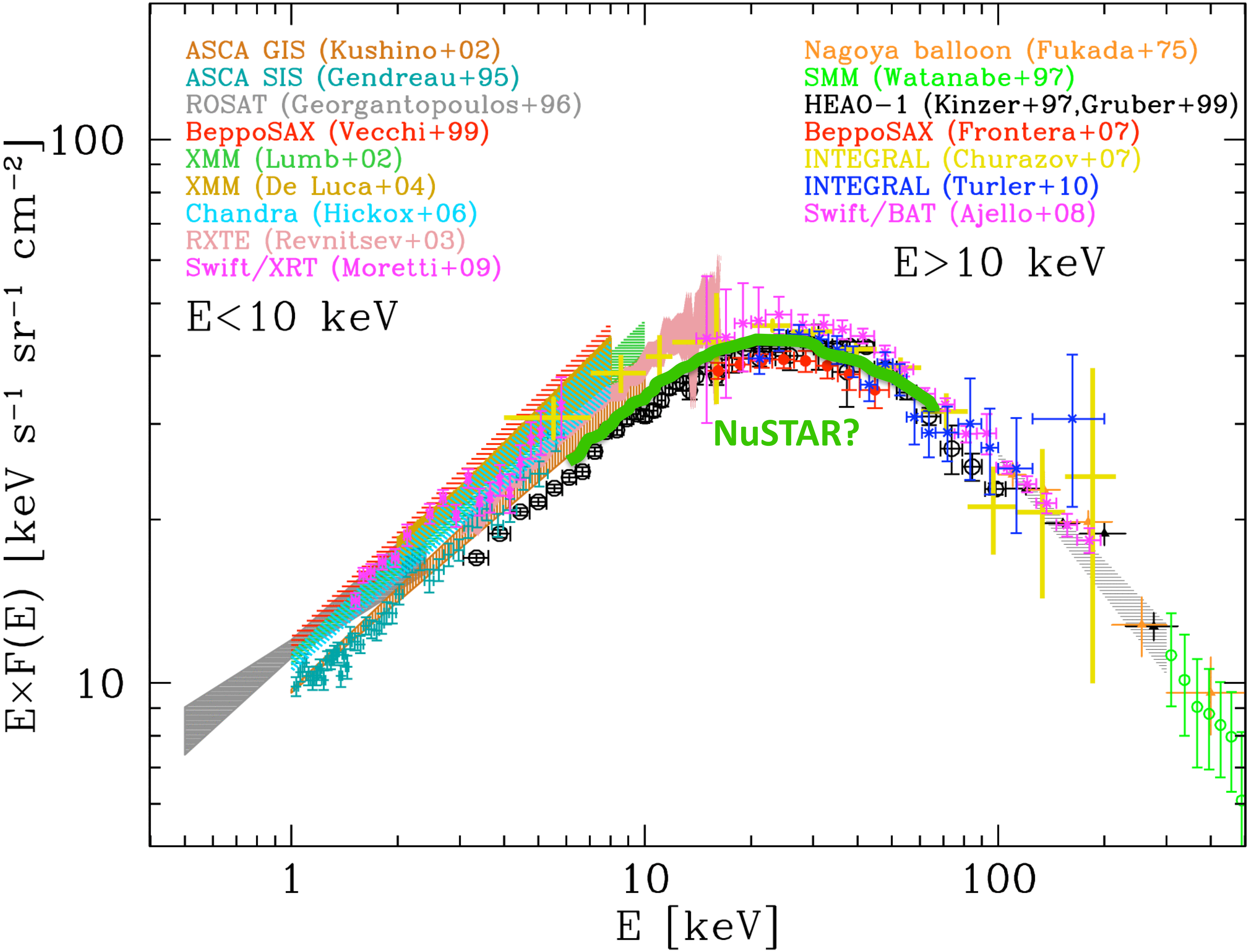
The cosmic X-ray background: abundance and evolution of hidden black holes

R. Gilli (INAF – OaBologna)
with the XMM-CDFS, 4Ms CDFS, COSMOS, WFXT teams

Cosmic X-ray background spectrum =
radiative imprint of cosmic BH accretion =
integral constraint on the abundance of the most obscured (Compton thick) AGN
is it a strong or weak constraint?

Deep X-ray surveys =
resolving the XRB =
history and evolution of hidden black holes ➔
BH/galaxy co-evolution, accretion modes

The cosmic X-ray background spectrum



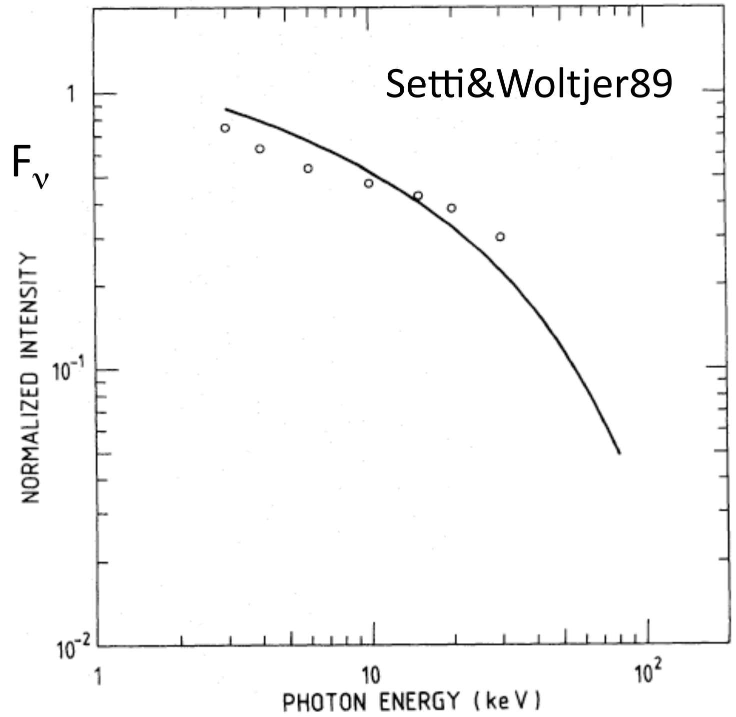
AGN synthesis models

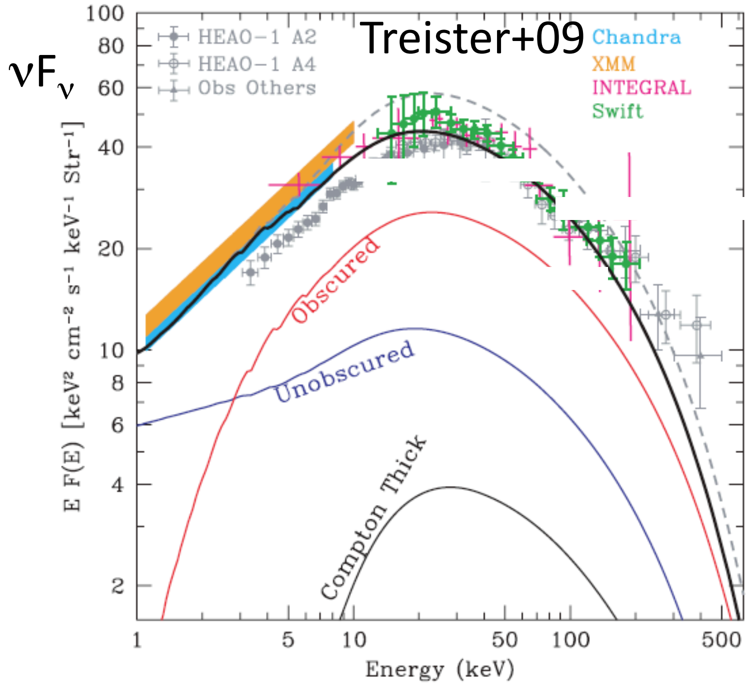
First model by Setti&Woltjer 1989,
several refinements after that:

- full NH distribution (Madau+94, Comastri+95)
- careful treatment of Compton scattering in C-thick AGN (Wilman+99,Pompilio+00)
- inclusion of iron line features (Gilli+99)
- evolution of obscured AGN fraction f_{abs} with L (Ueda+03)
- evolution of f_{abs} with L and z (La Franca+05, Treister&Urry06, Ballantyne+06)
- dispersion in AGN spectral slopes (GCH07)
- exploration of R vs f_thick (Treister+09)
- exploration of full parameter space (Akylas+12)

[as many models not mentioned]

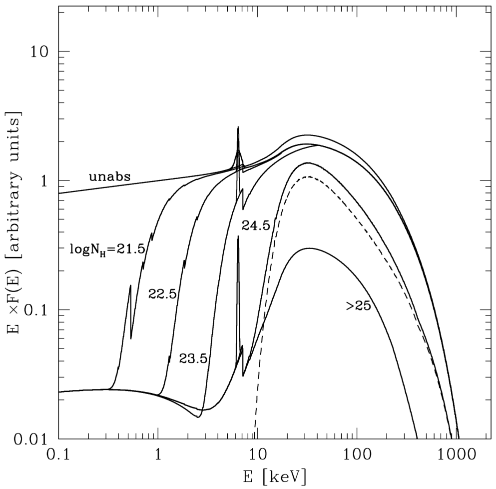
➔valuable resources to make survey predictions
➔provide an estimate of the abundance of C-thick AGN



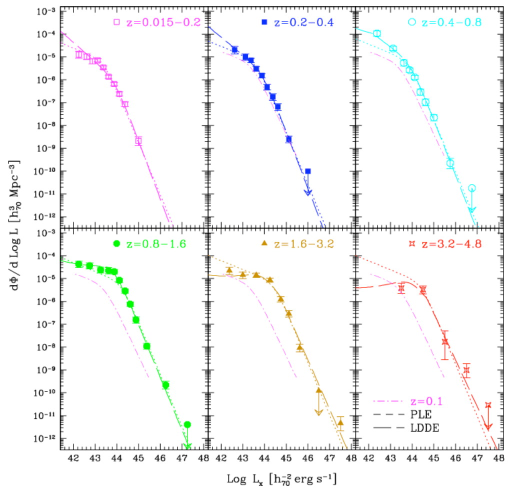


Ingredients for XRB synthesis models

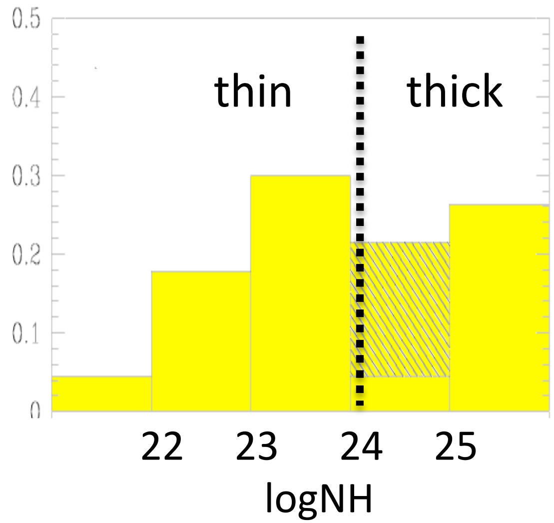
X-ray spectra

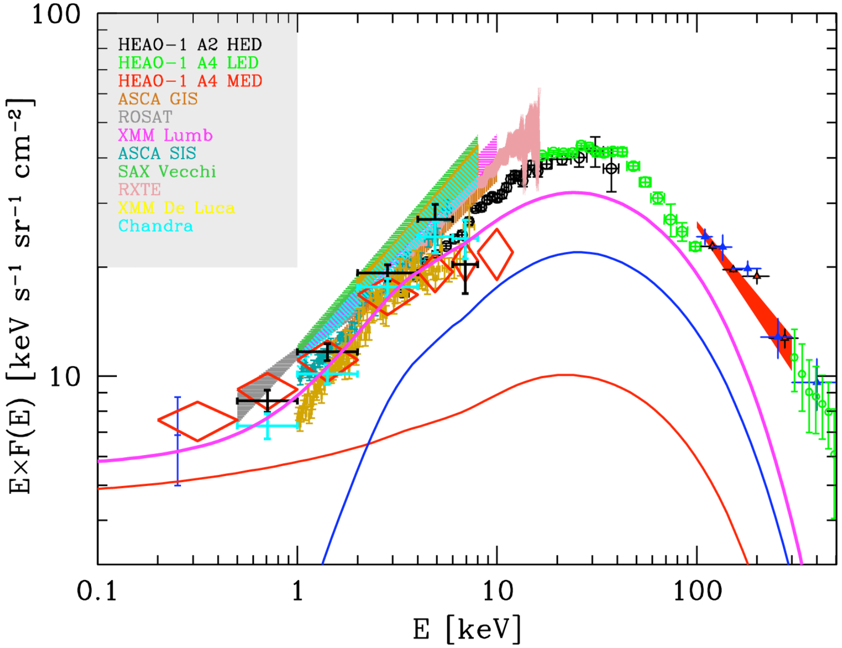


XLF and evolution



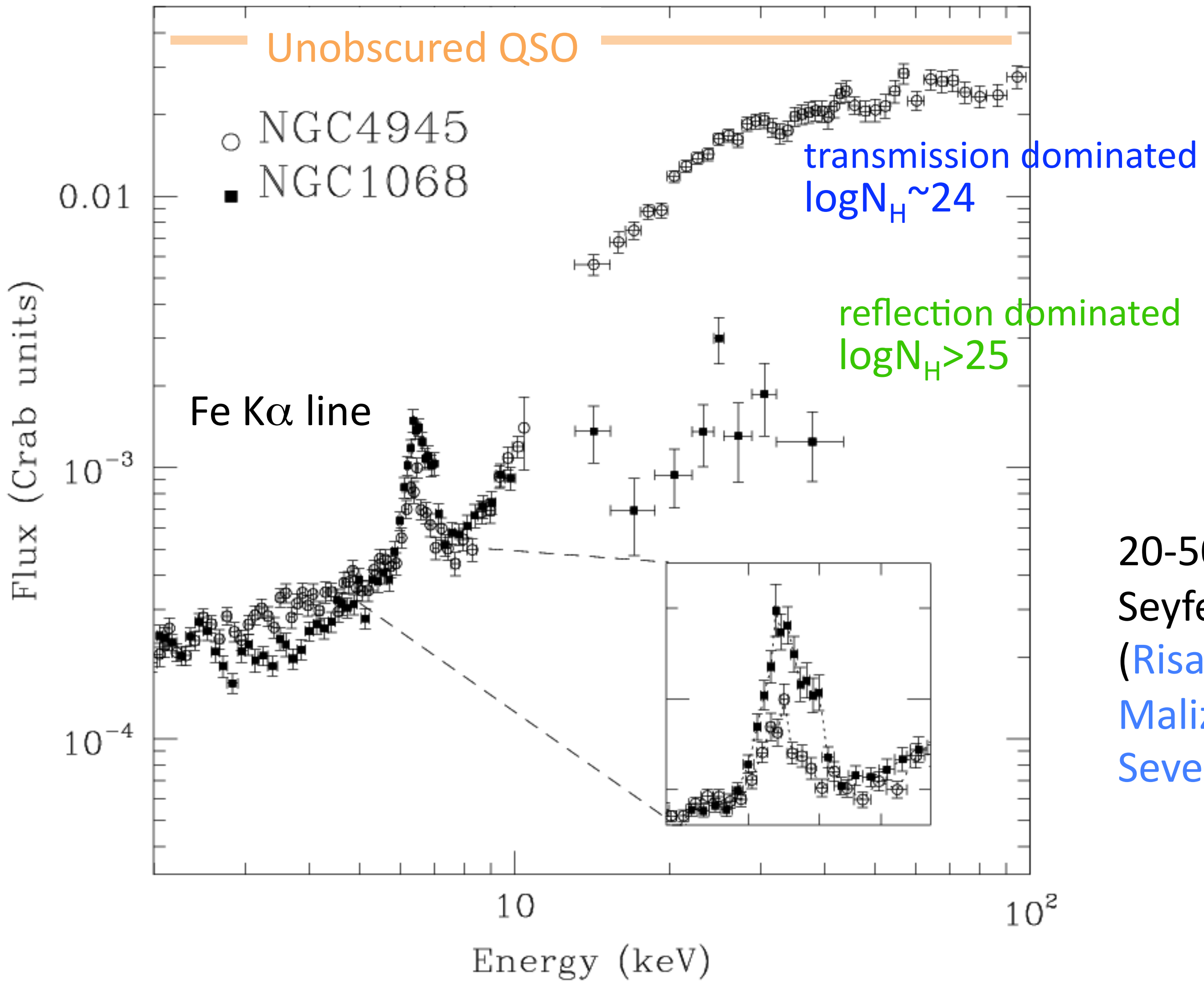
NH distribution





10-30% of XRB @ 30 keV missing,
depending on models

Spectra of Compton-thick AGN



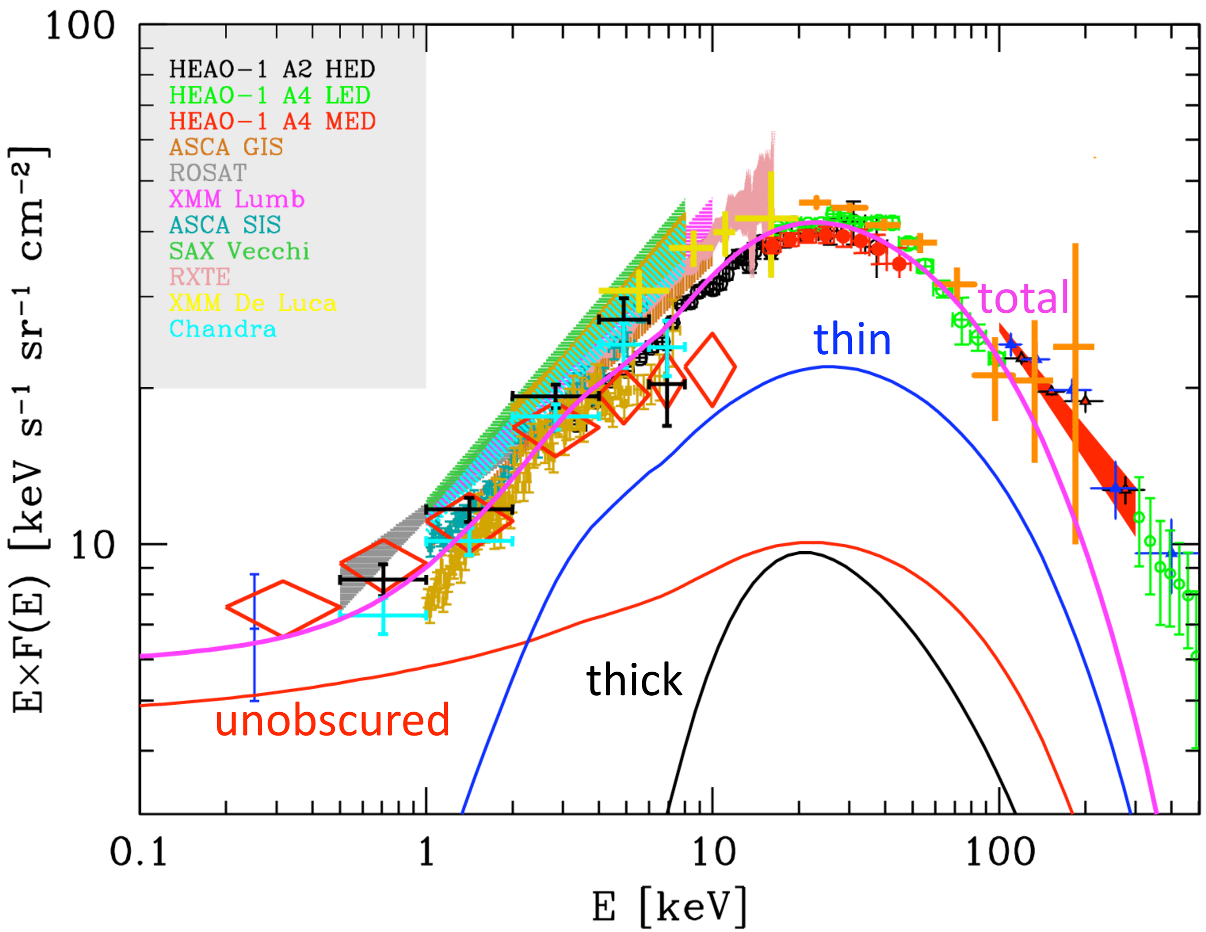
N-thick = N-trans + N-refl

reflected fraction

R a few %

20-50% of nearby (z<0.1) Seyfert 2s are C-thick (Risaliti+99, Akylas+09, Malizia+09, Burlon+11, Severgnini+12)

Modeling the XRB spectrum



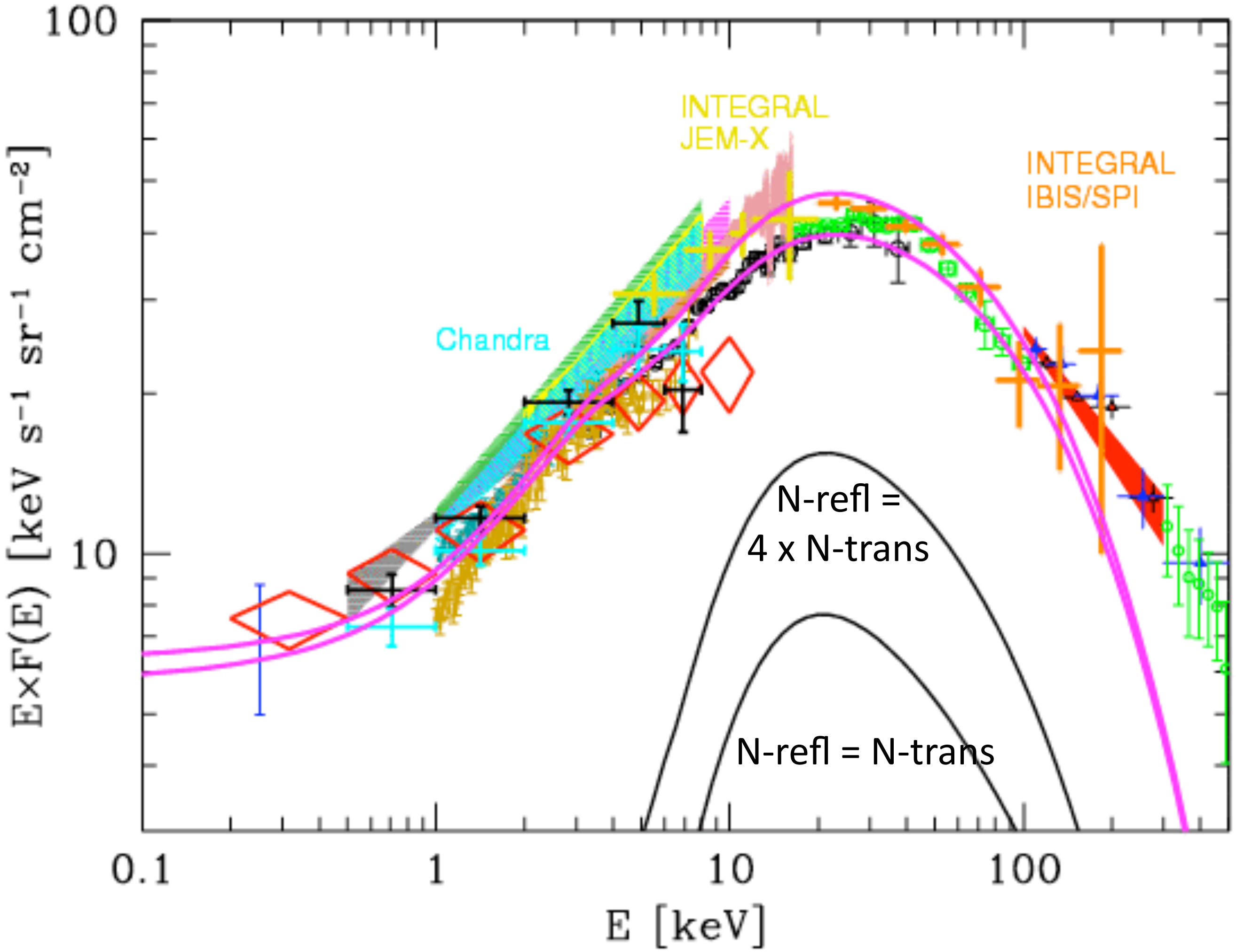
Good fit is obtained with:

1) N-trans=N-refl
2) N-thick = N-thin

80-90% of accreting BHs are hidden, ~ 50% are C-thick ➔ ok with relic SMBH mass function (e.g. Marconi+04)

BUT beware of large uncertainties

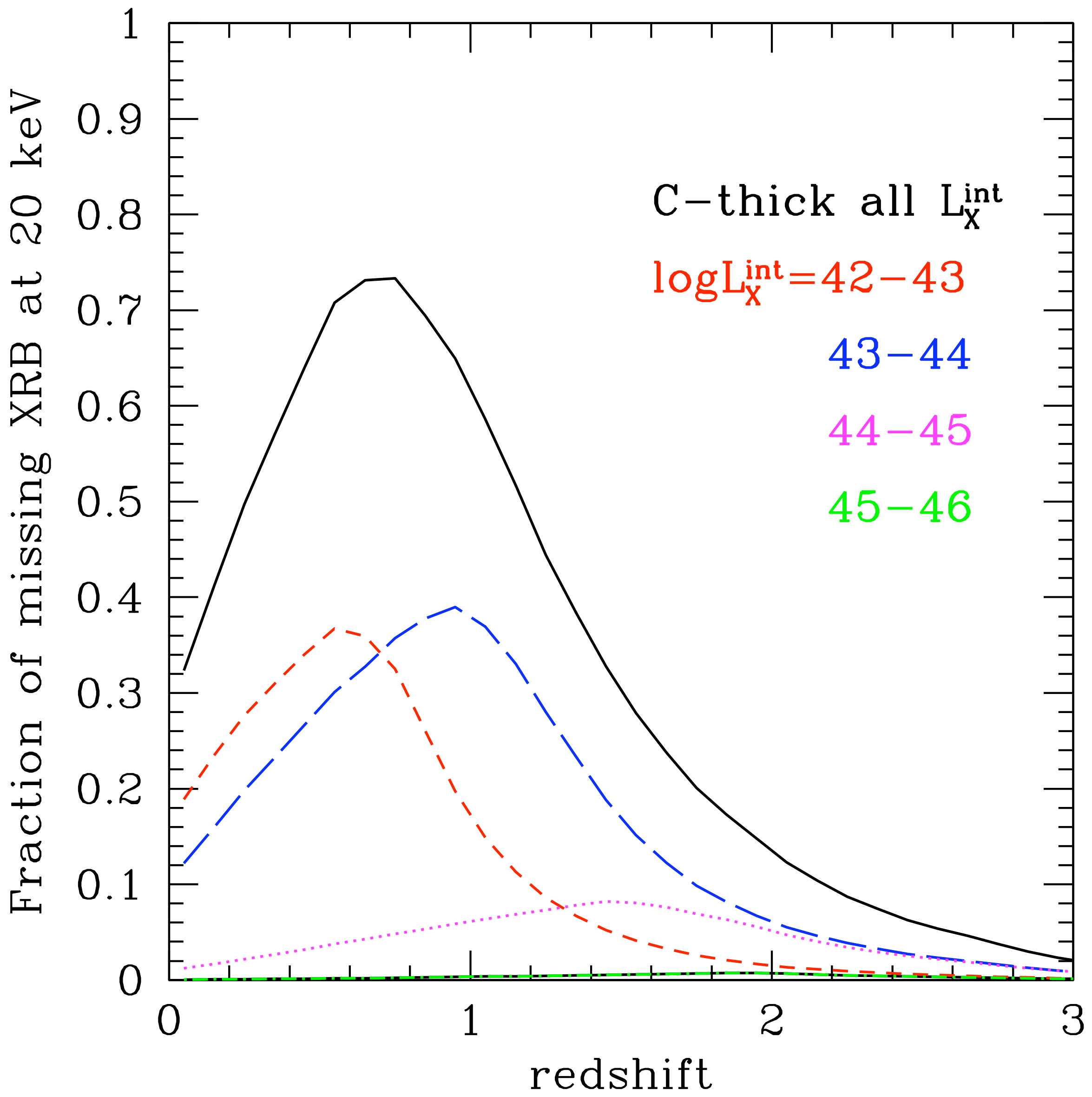
Uncertainties on C-thick abundance



- uncertainties on N-refl
- uncertainties on R
- contribution @ 30 keV from other populations?
  ~10% blazars (Giommi+12)
  + 10% HMXB (Gilfanov+?), etc

➔ need to try to measure C-thick abundance DIRECTLY

E>10 keV: when was the “missing” XRB emitted?



Predicted peak at z~0.8

tiny contribution from high-z objects

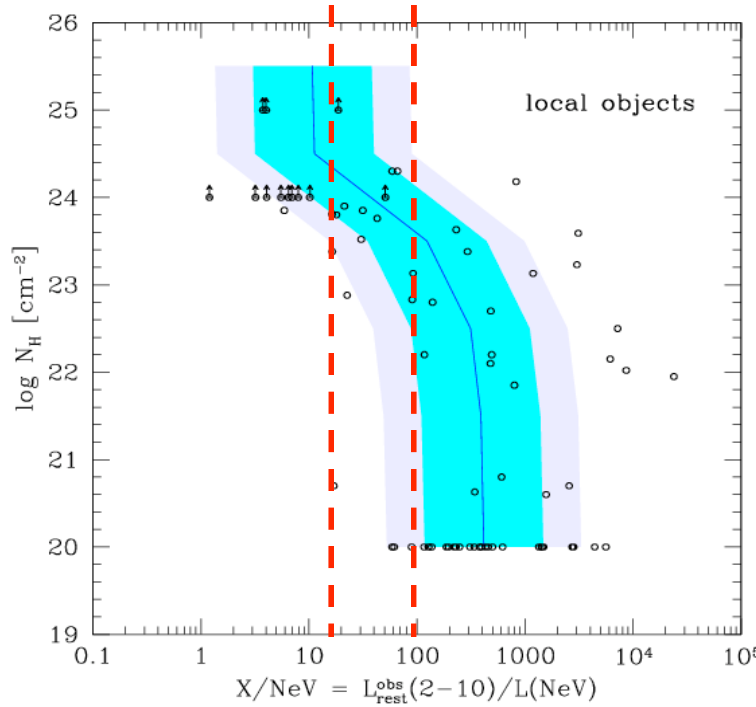
The search for C-thick AGN @ z~1: [NeV]3426 selection

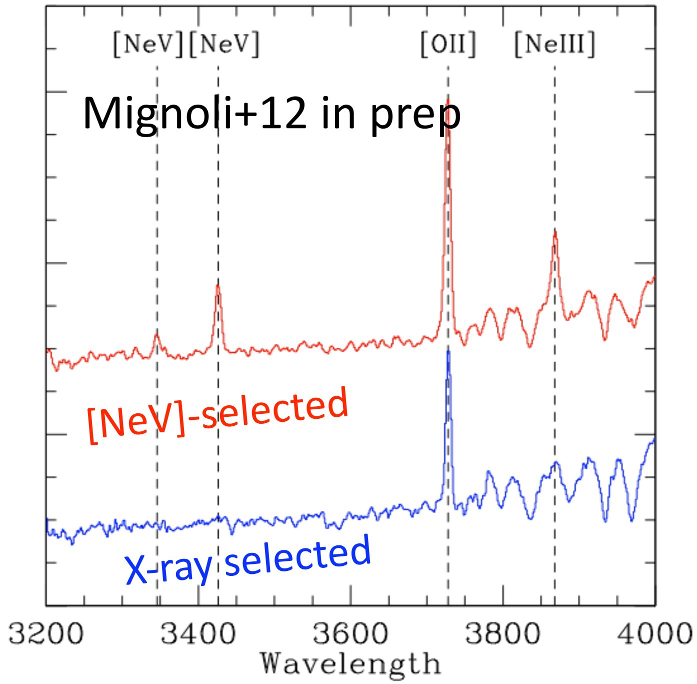
Local Seyferts
X/NeV<15 : almost exclusively C-thick AGN
X/NeV<100 : 80% have logNH>23
(confirmed by SDSS at z>0.4)

Search for [NeV] emission on ~7400 galaxies with 0.65<z<1.20 from zCOSMOS bright (I_{AB}<22.5, Lilly+07)

72 [NeV]-selected type-2 AGN in the 1.8Ms Chandra area (median z ~ 0.9)

X/NeV selection is clean but likely not complete





[NeV]-selected C-Thick AGN in COSMOS

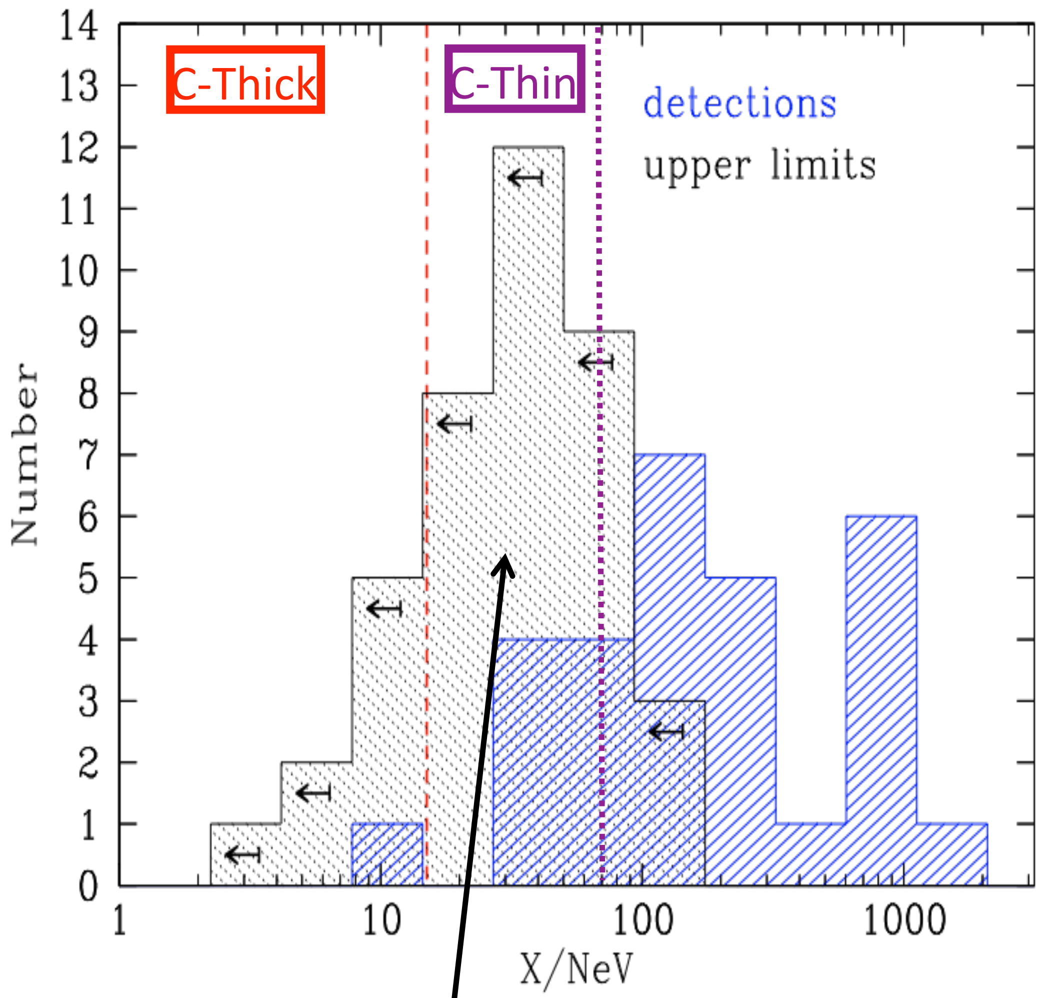
23 detected by Chandra,
49 undetected.

46/72 (64%) have X/NeV < 100 ➔
heavily obscured, i.e. logNH>23
(mostly u.l., could be C-thick)

9/72 (13%) have X/NeV<15 ➔
good C-thick candidates

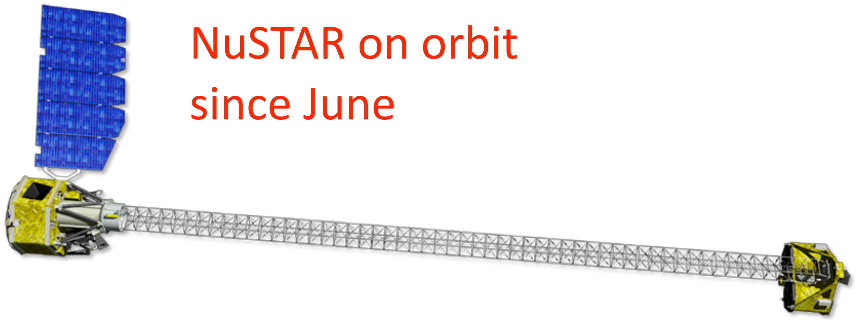
significant C-thick fraction
@ z~1: [13% - 53%]

Mignoli+12

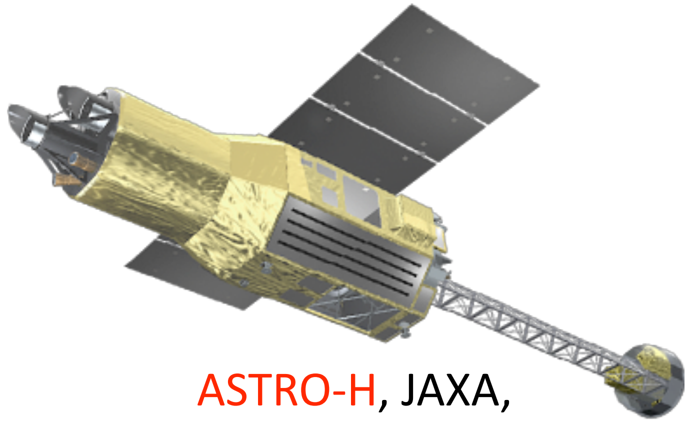


half of u.l. 2x sharper from
2.8Ms Chandra COSMOS XVP (PI F. Civano)

E>10 keV: expectations for NuSTAR (and ASTRO-H)



NuSTAR on orbit
since June

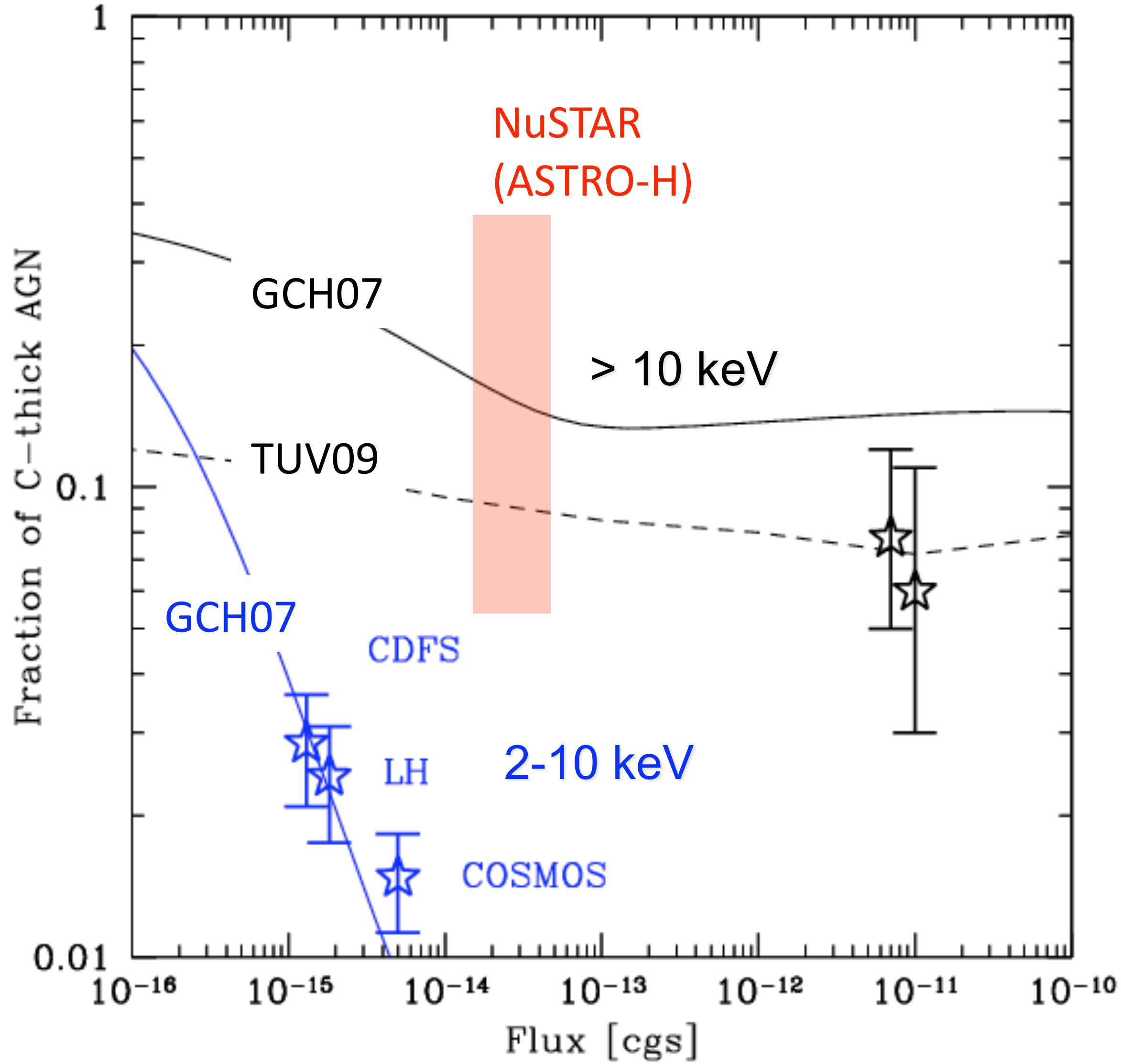


ASTRO-H, JAXA,
launch 2014

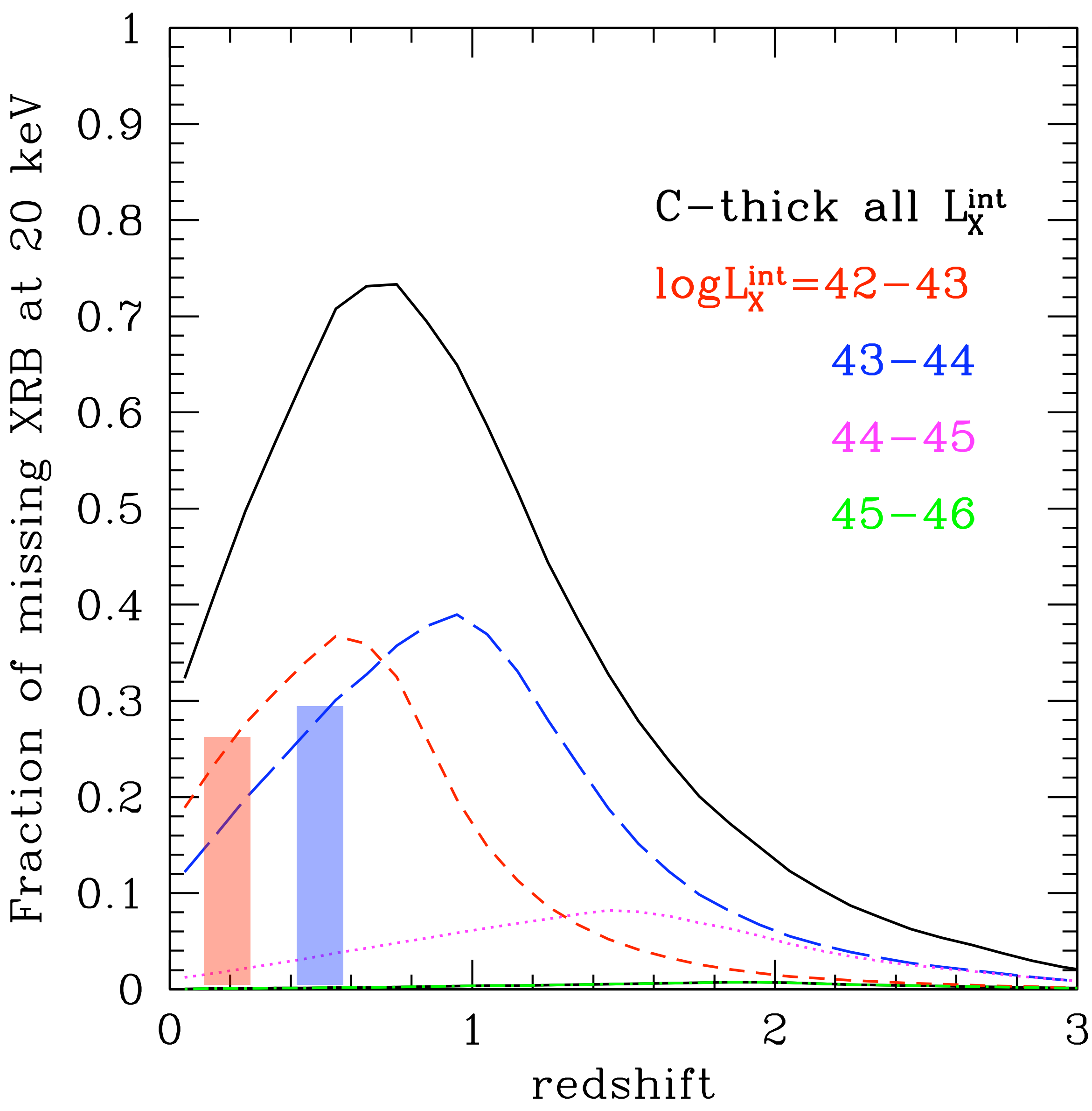
Similar area at 30 keV (~300 cm^2)

	NuSTAR	ASTRO-H
Band (keV)	3-80	5-80
HEW(“)	58	100
FOV ($arcmin^2$) FWHI@40 keV	8 x 8	3 x 3
Confus. lim. (10-40 keV)	~10^{-14}	>10^{-14}

The fraction of C-thick AGN

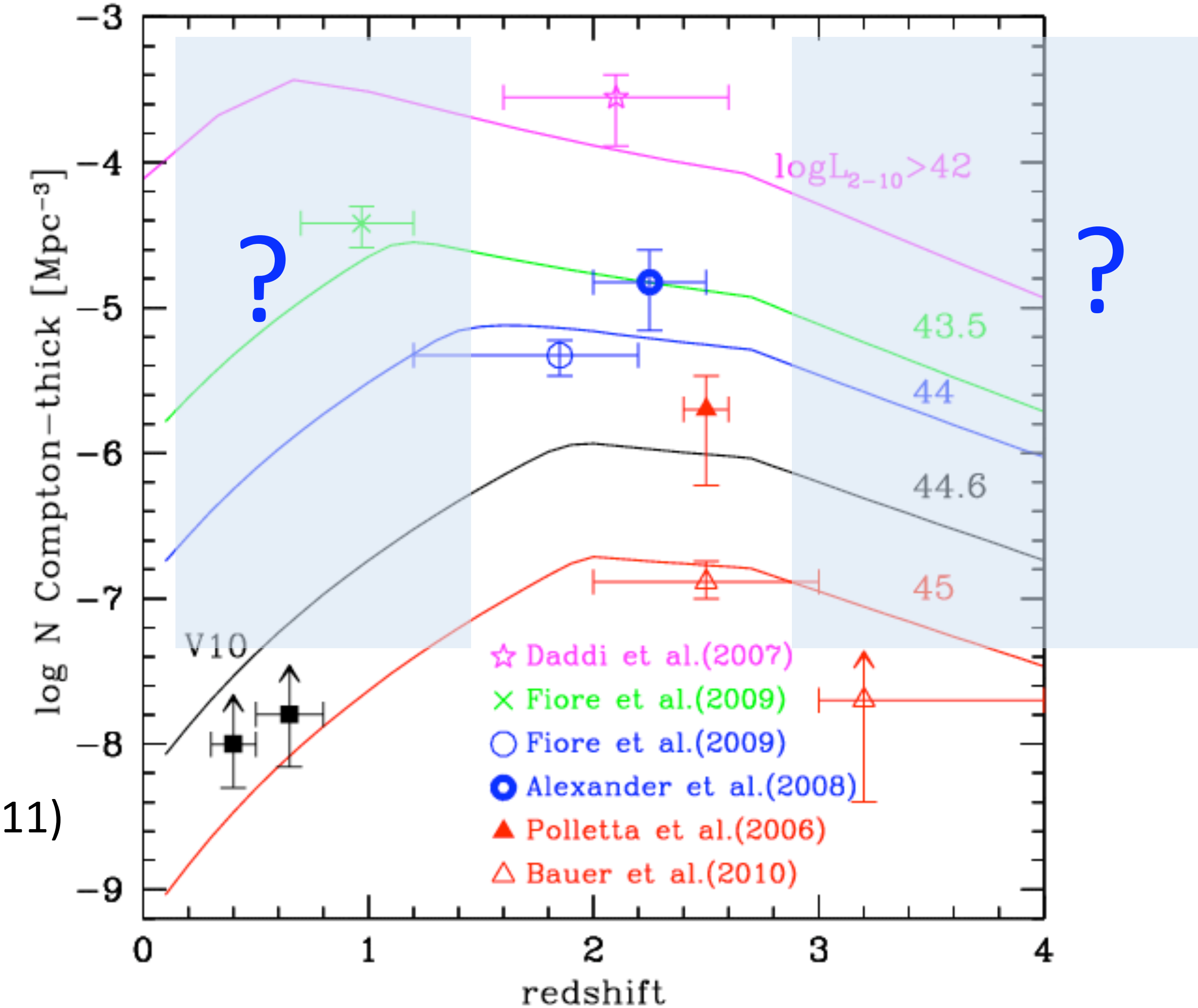


Redshift distribution



NuSTAR limited
to moderate redshifts

Space density of distant C-thick AGN: indirect measurements

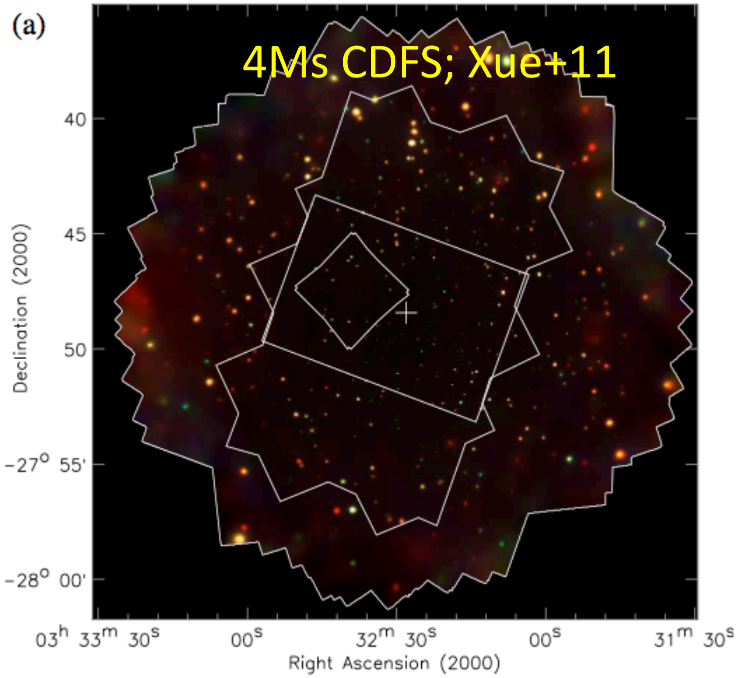


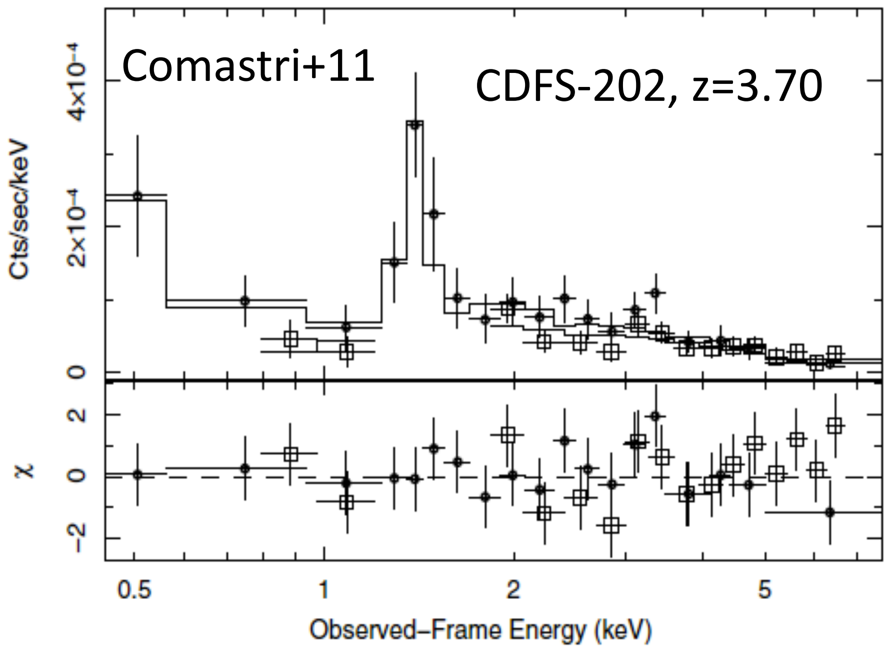
all datapoints suffer from severe systematics (e.g.Alexander+11)

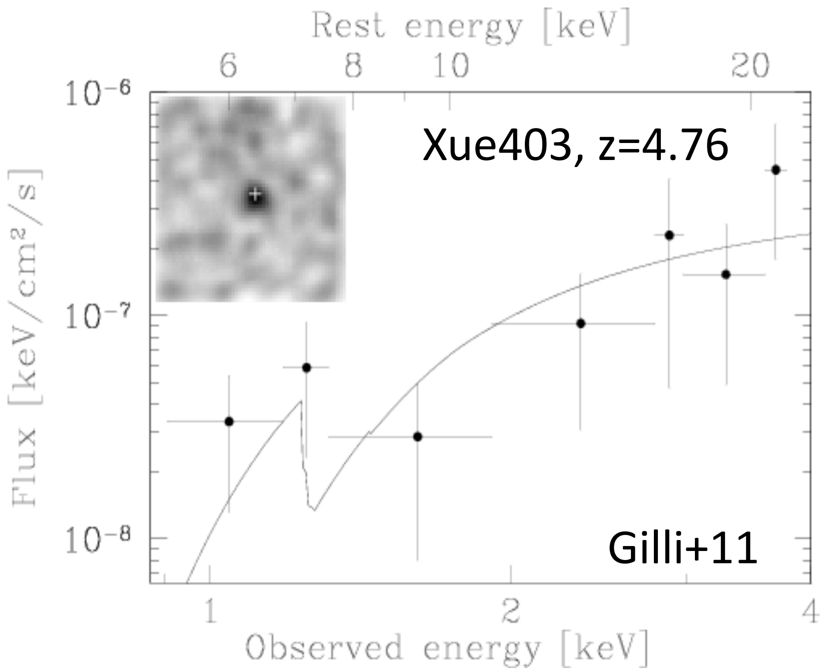
Adapted from Vignali+10

The deepest X-ray surveys:
1) X-ray spectra of C-thick AGN
2) resolution of the XRB at E<10 keV
3) history of obscuration

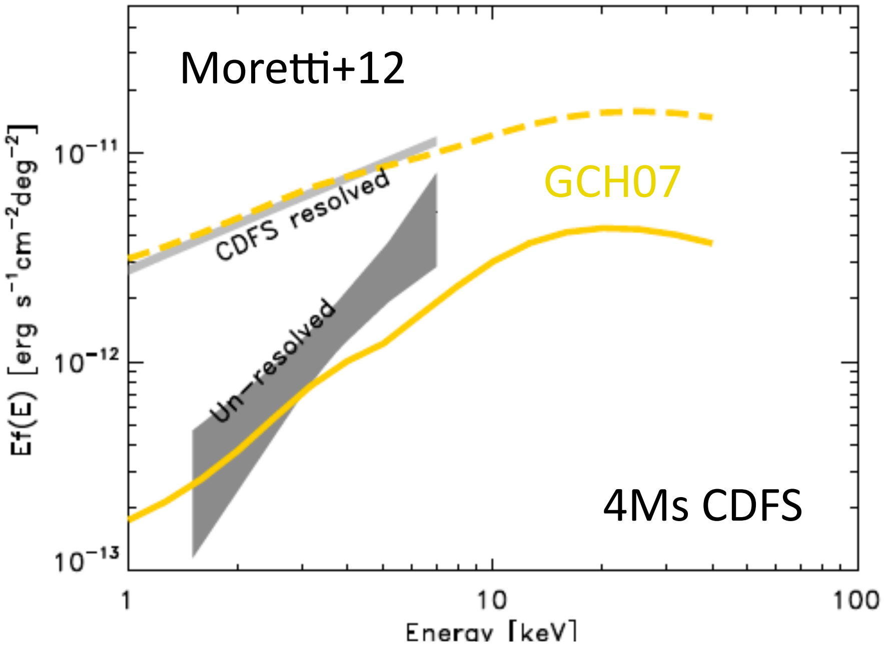
Some objects known at z>1.5-2 (Norman+02,Feruglio+09,Georgantopoulos+12) but sizeable samples of distant bona-fide C-thick AGN still missing





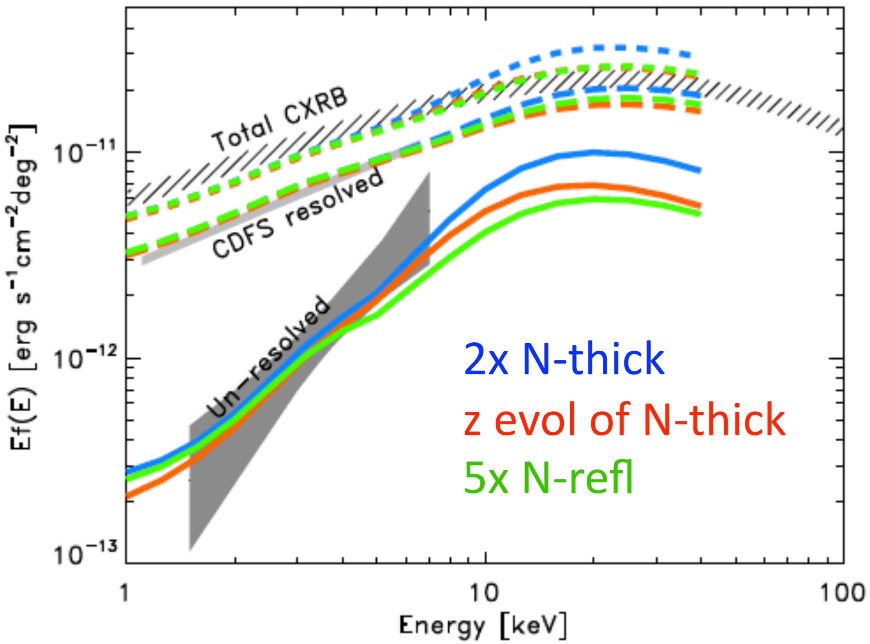


E<10 keV: is the XRB now resolved?

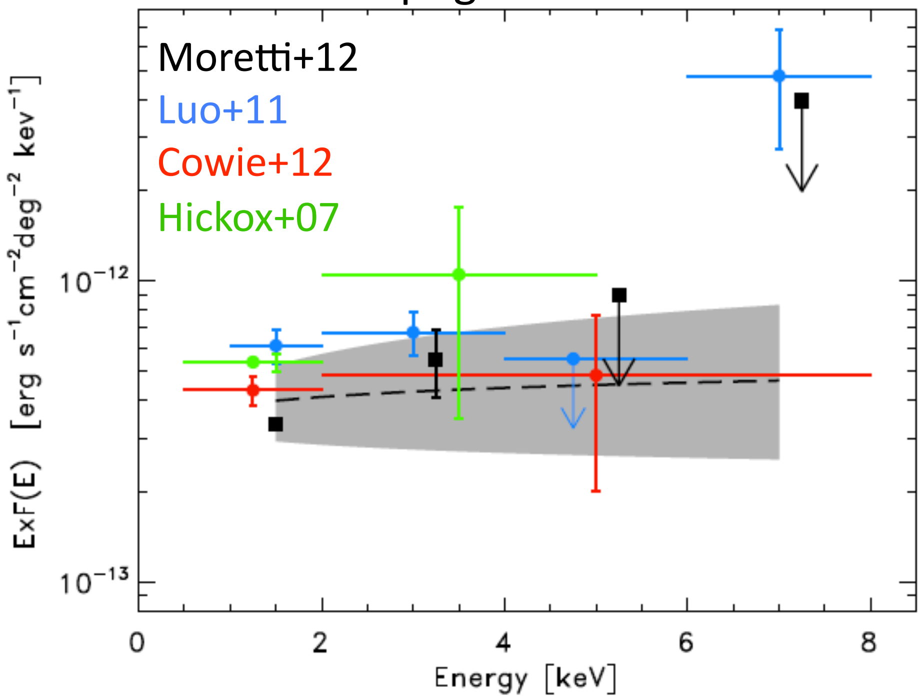


Probably not yet..

1) what is the absolute level of the XRB?
2) stacking contradictory (Luo/Xue vs Moretti)



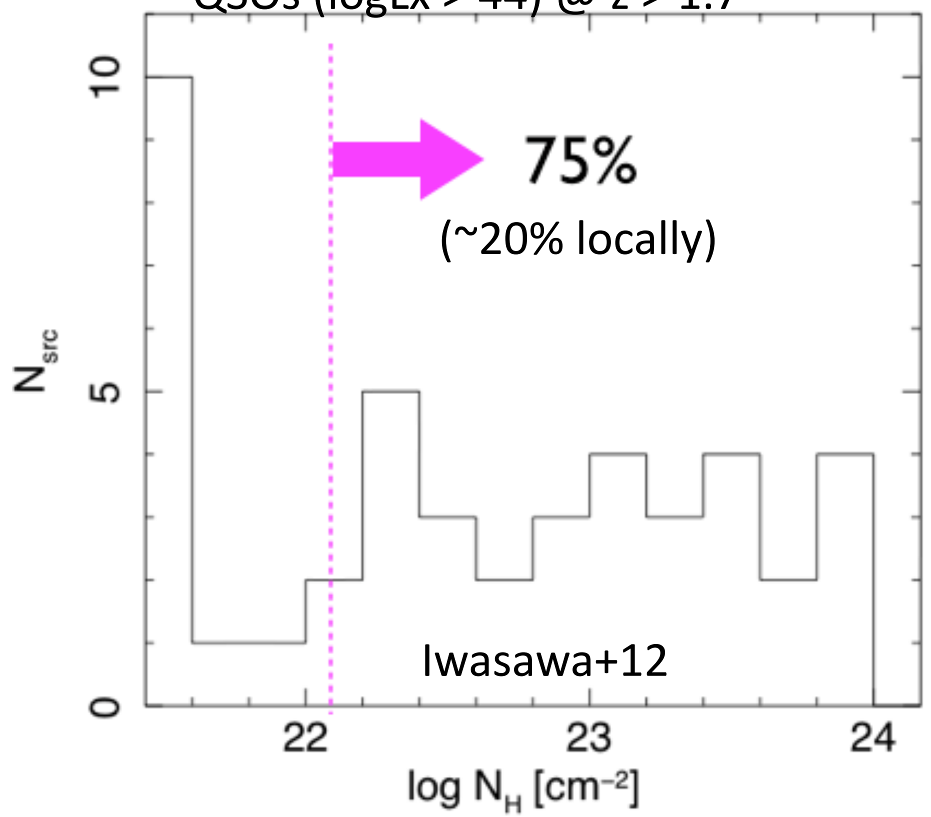
stack of opt galaxies in GOODS



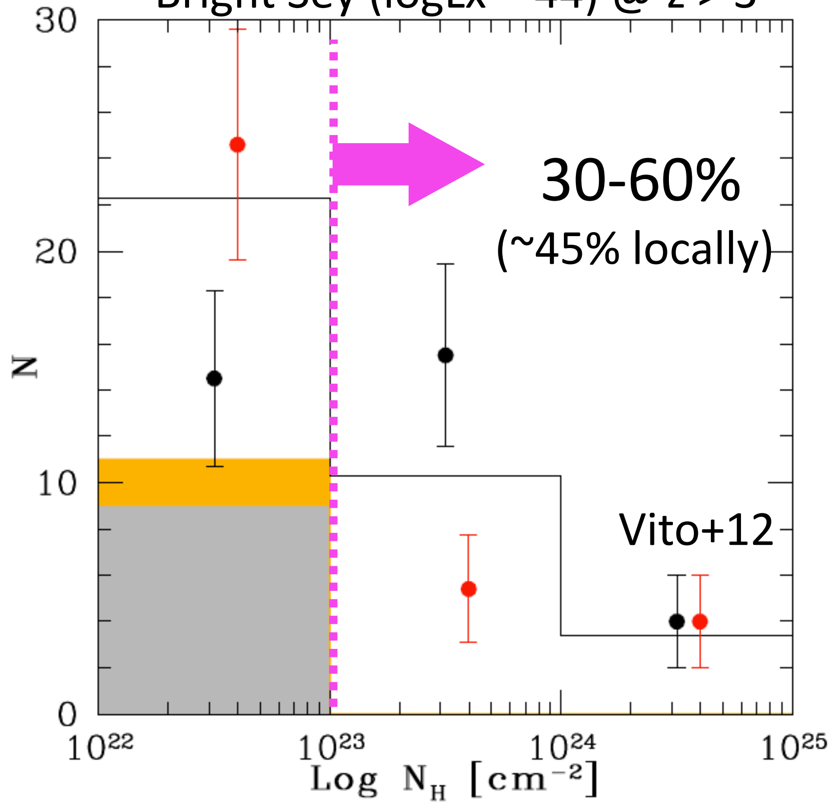
Cosmological evolution of obscuration

key input for BH/gal coevolution SAM

QSOs (logLx > 44) @ z > 1.7



Bright Sey (logLx ~ 44) @ z > 3



see also Hiroi+12

absorbed QSO fraction f_{abs} increases with z (La Franca+05, Ballantyne+06, Treister+06, Brightman+12). Increase less significant or absent for logLx<44 ➔ behaviour explained by two modes of accretion/obscuration: main ingredients mergers AND higher f_{gas} at high-z

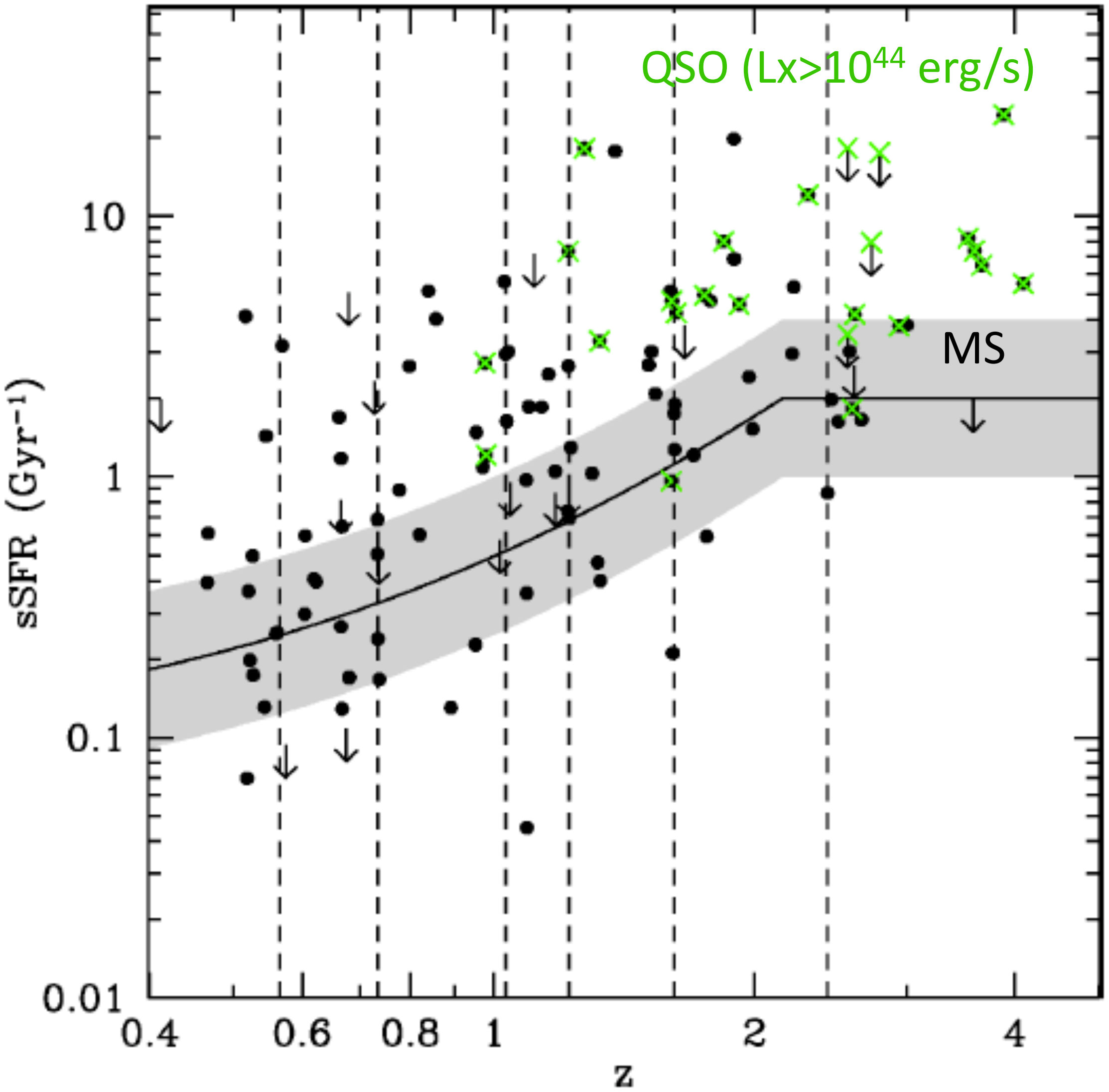
Two modes of star formation (and accretion?)

Elbaz+11 (GOODS-Herschel): two modes of star formation: main sequence (MS) and starburst mode (SB)
90% of star formation in MS (Rodighiero+12)

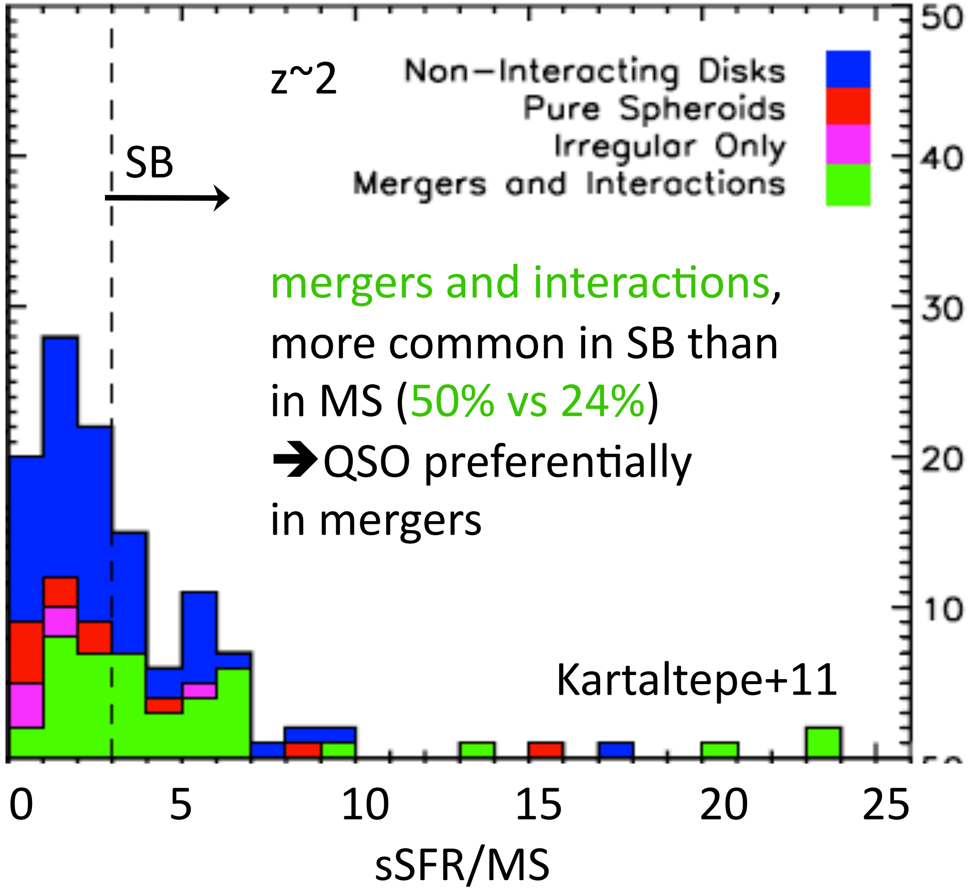
QSOs preferentially hosted by SB (but see contrary claims, Mainieri+10,Page+12)

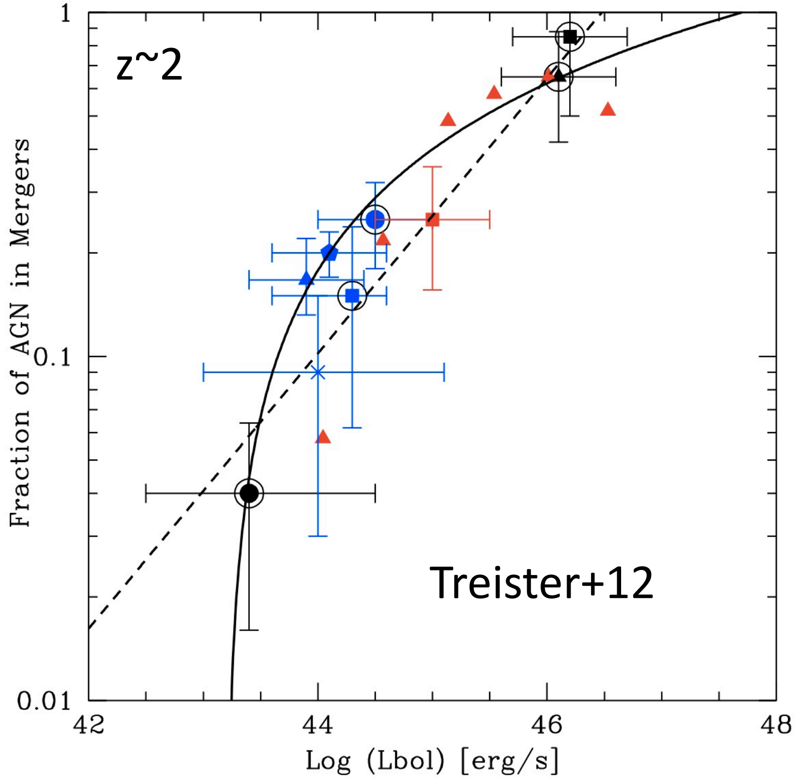
broader distribution for lower lum. AGN (but mainly in MS)

Rovilos+12



BH triggering: mergers for QSOs, secular accretion for lower lum AGN



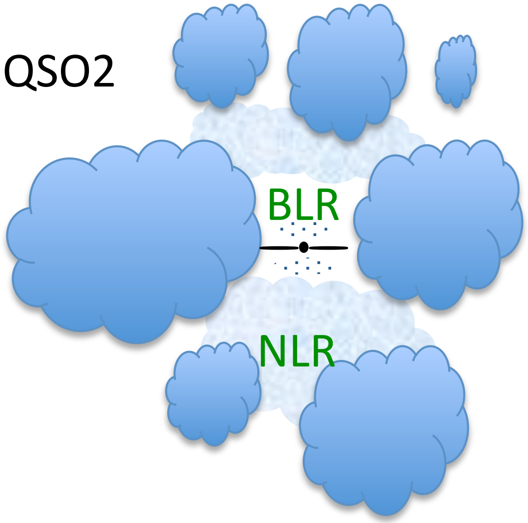


fraction of AGN in mergers increases with Lbol

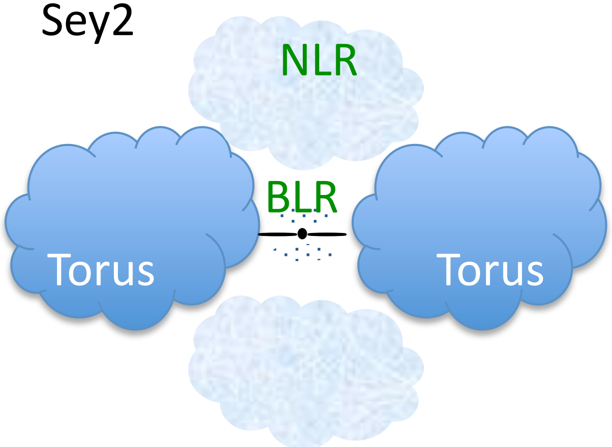
clustering analysis lends support to this scenario (Hopkins+08, Fanidakis+12)

How does this relate to the obscuration history?

QSO2



Sey2



It is tempting to make this divide:

ULIRGs/QSO2s: Merger-induced accretion/SF bursts with compact and chaotic geometry, transition to QSO1s; evol seq. on ~10^{7-8} yrs.

at high z:

higher merger rate ➔ higher QSO(1+2) abund

higher f_{gas} ➔ higher f_{abs} (abs phase longer)

Seyferts: secular accretion (and SF), ~static geometry, unified model.

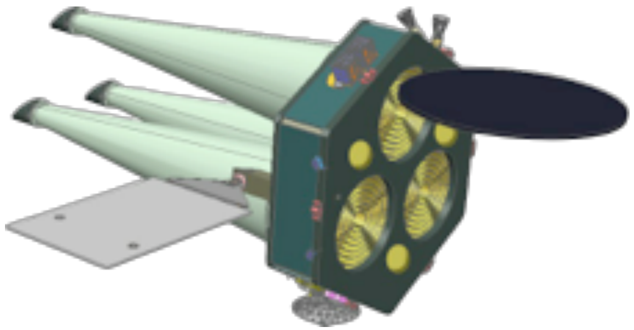
at high z:

higher f_{gas} , but lack of mergers keeps gas away from BH (just turns into stars) ➔ geometry constant with z, and hence f_{abs}

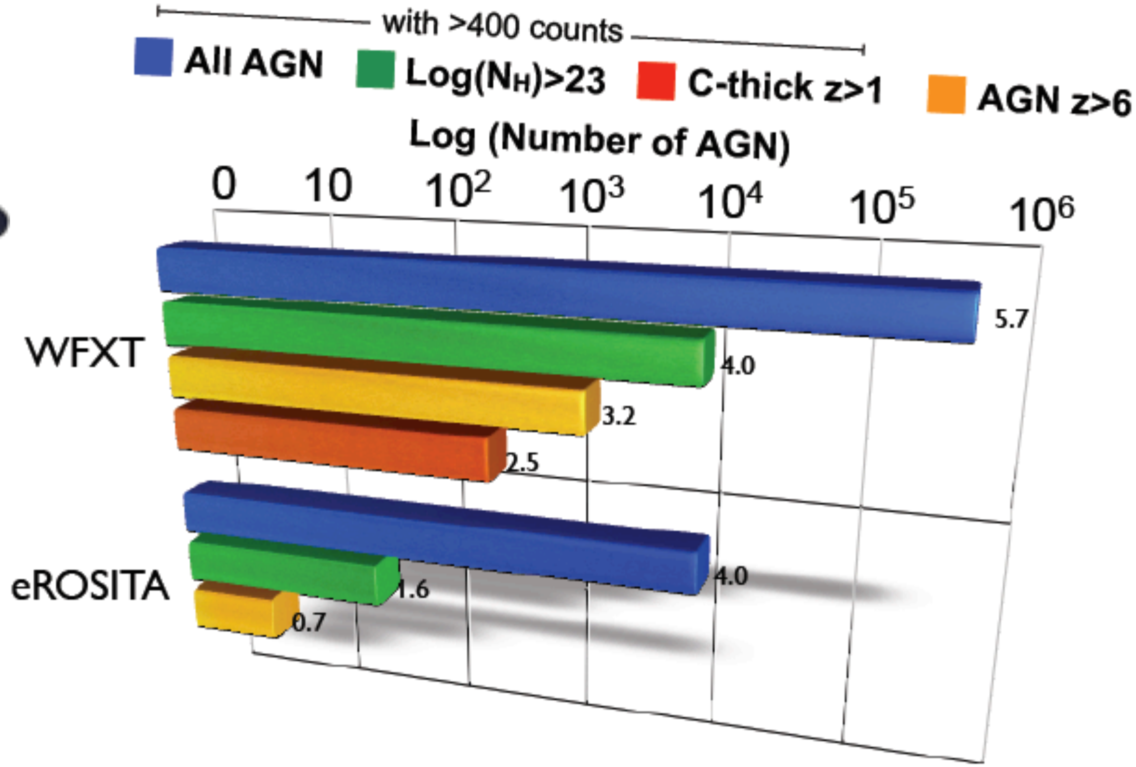
(Iwasawa+12)

Cosmological evolution of obscuration: routes to the future

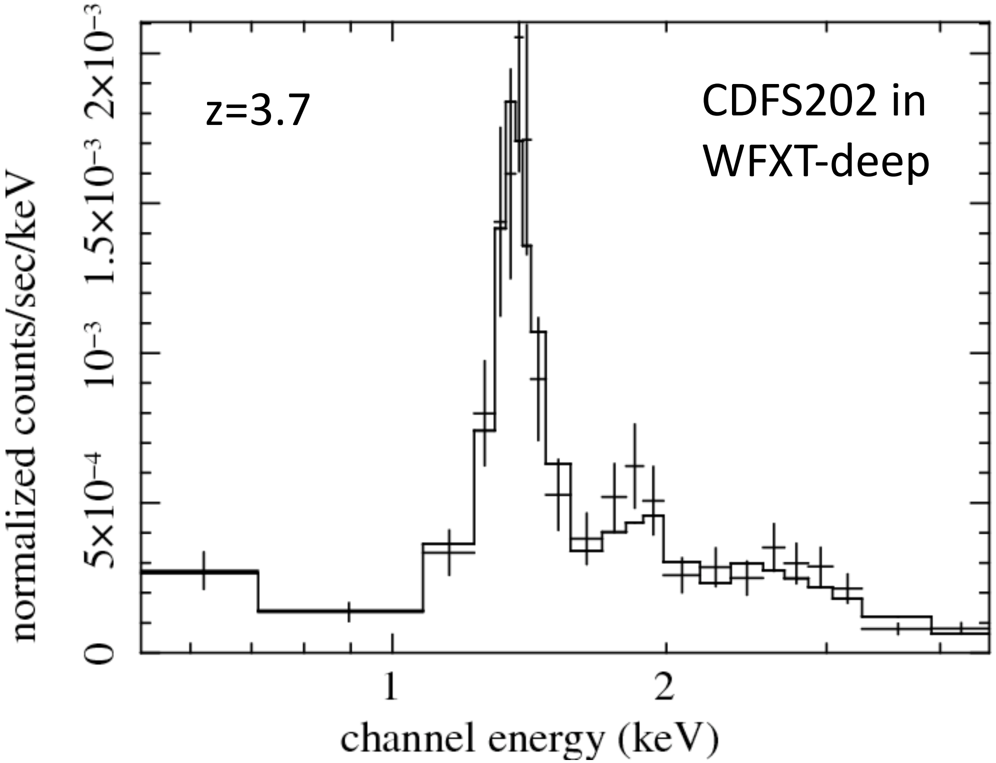
WFXT = 1000 x 1Ms CDFS + 2000 x 4.6Ms C-COSMOS



WFXT concept
Murray+11



Samples of distant C-thick AGN with WFXT

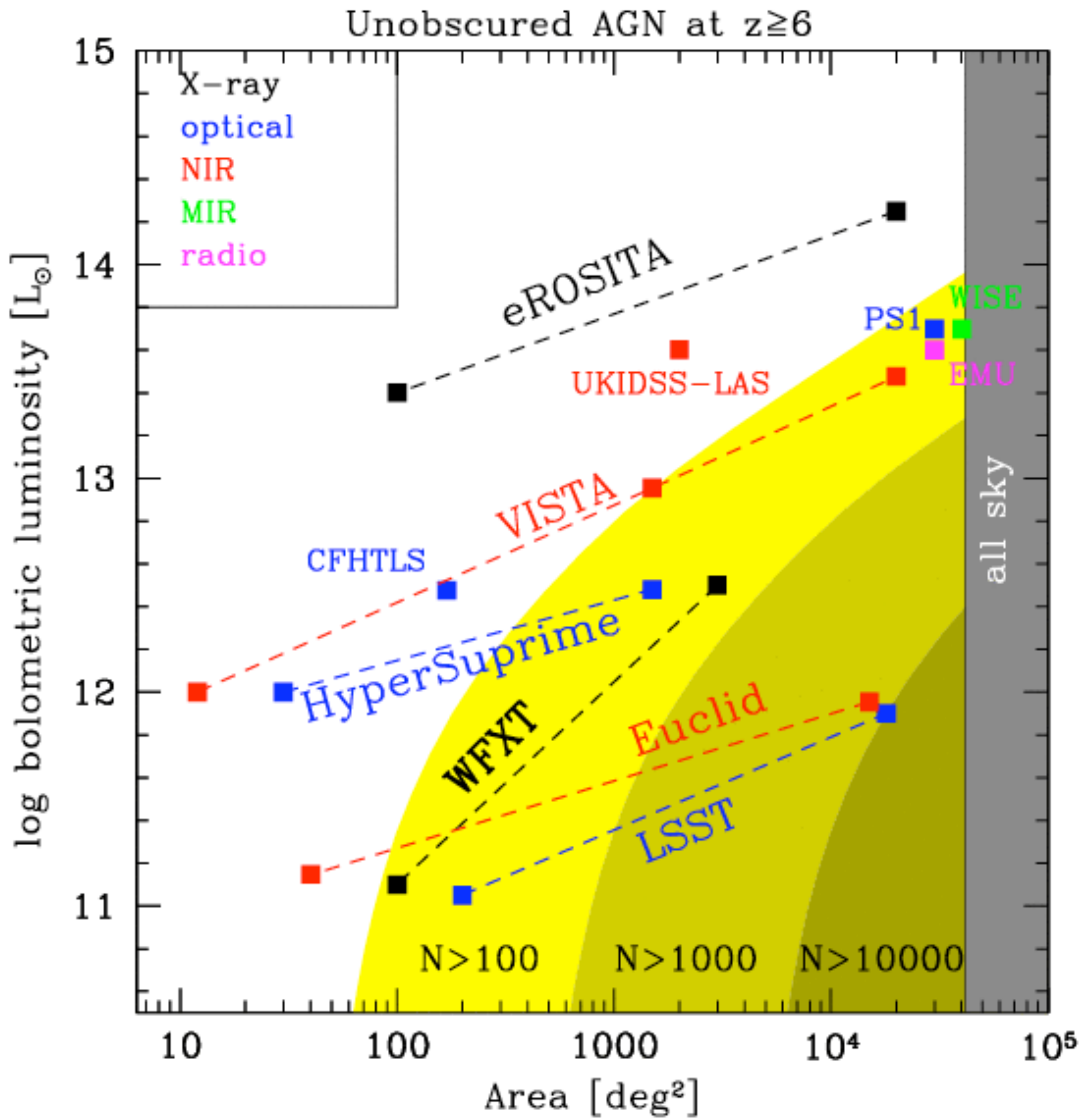


z >	N thick
1	500
2	270
3	60
4	12

NH and z directly from Fe line
(see also Iwasawa+12)

F(2-10) = 3 10^{-15} cgs, ~500 cts > 0.5 keV
Line EW ~ 1 keV , err ~ 30%
Err. on line centroid ~ 2%

The early coevolution of galaxies and BHs: AGN at z>6 with WFXT



eROSITA will sample moderately obscured (logNH<23) AGN at z~2
NuSTAR heavy obscuration at z<=1, but not early BHs

need WFXT (5”) to match with future multi-λ surveys and sample heavily obscured AGN at z>1
and early QSOs at z>6

Conclusions

Surveys at E>10 keV promising to estimate C-thick abundance at z<=1 (and firm up XRB measurements)

E<10 keV technology is in better shape to study the evolution of (Compton-thin) obscuration to higher redshift.

Two modes of accretion in the current preferred scenario:
secular for low lum AGN vs merger/burst for QSOs.
Mapping the evolution of obscuration is key to understand BH/galaxy coevolution.

A survey mission like WFXT can study Compton thin and thick obscuration at z> 1 and map BH/galaxy coevolution up to the early Universe