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The demography and the evolution of heavily obscured AGN

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COSMOS, CDFS and NuSTAR Teams

Overview

Obscured AGN as a phase in the SMBH/host co-evolution or still consistent with a geometrical interpretation after 30 years from the discovery of polarized lines in NGC1068 or both?

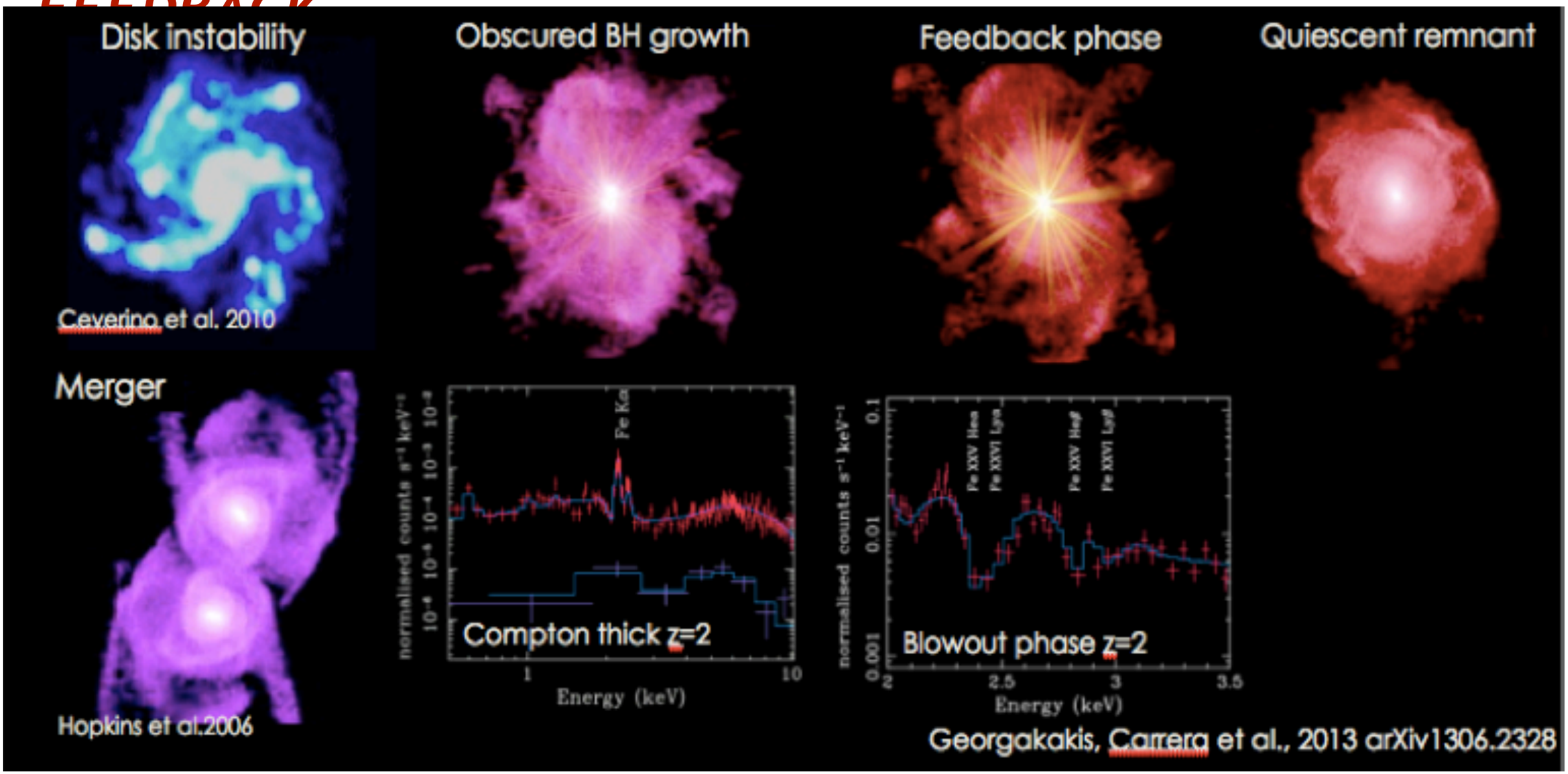
Incomplete review of most recent results biased toward hard X-rays

Census in terms of accreted mass (Soltan argument)

Perspectives

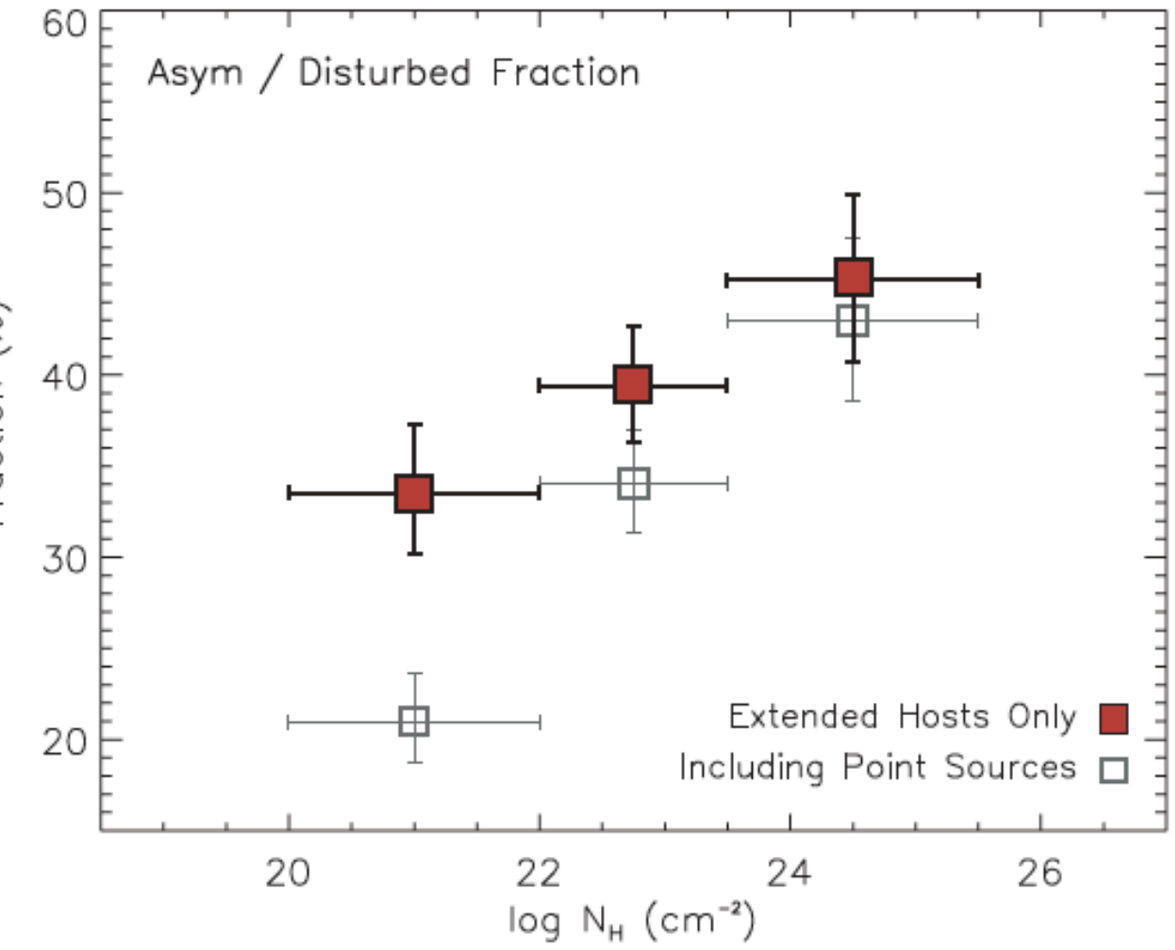
Theoretical framework

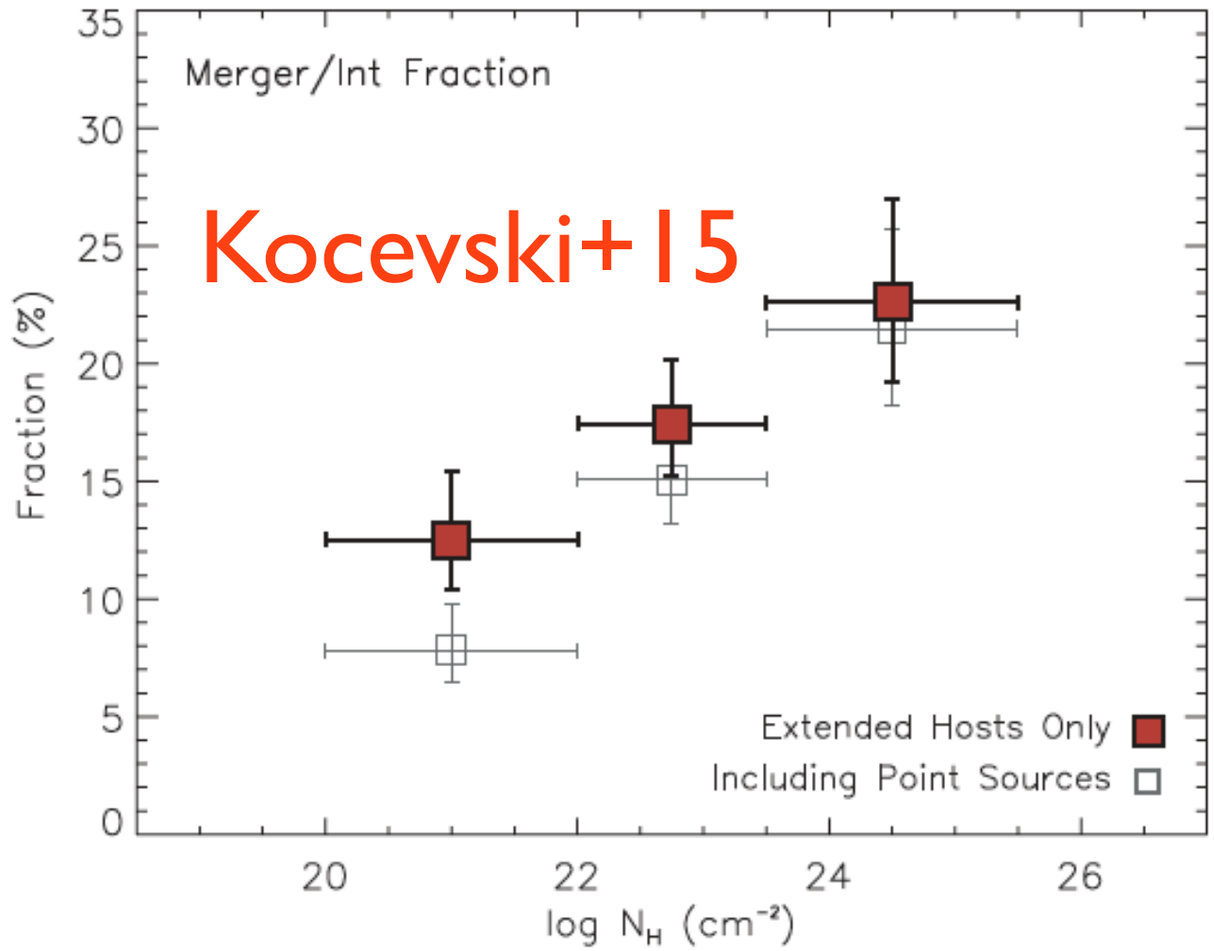
Galaxy/SuperMassiveBlackHoles formation theories "predict"
an obscured phase (likely Compton thick) in the early stages of evolution, expected to play a relevant role in shaping the joint SMBH and host galaxy growth via *FEEDBACK*



Obscured AGN at z ~ 1

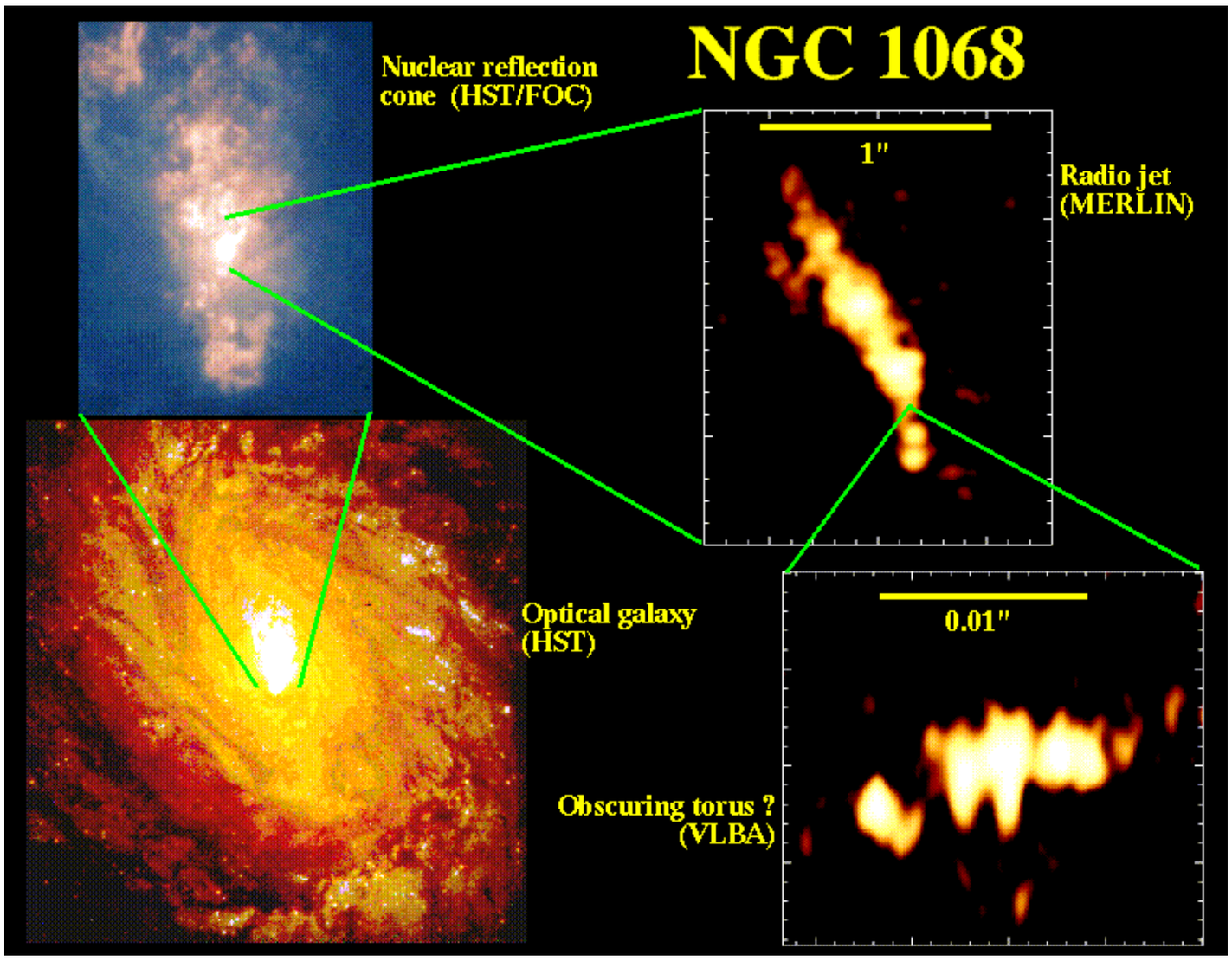
In the evolutionary sequence obscuration is likely to cover a large angle (up to 4π) and correlates with host properties





Increased merger/disturbed fraction (2.5-4σ) for increasing obscuration. Obscured AGN are preferentially hosted by late type galaxies relative to unobscured

Unified AGN model



Direct imaging of disk shaped structures

Spectropolarimetry of NGC1068 and other type 2 Seyferts

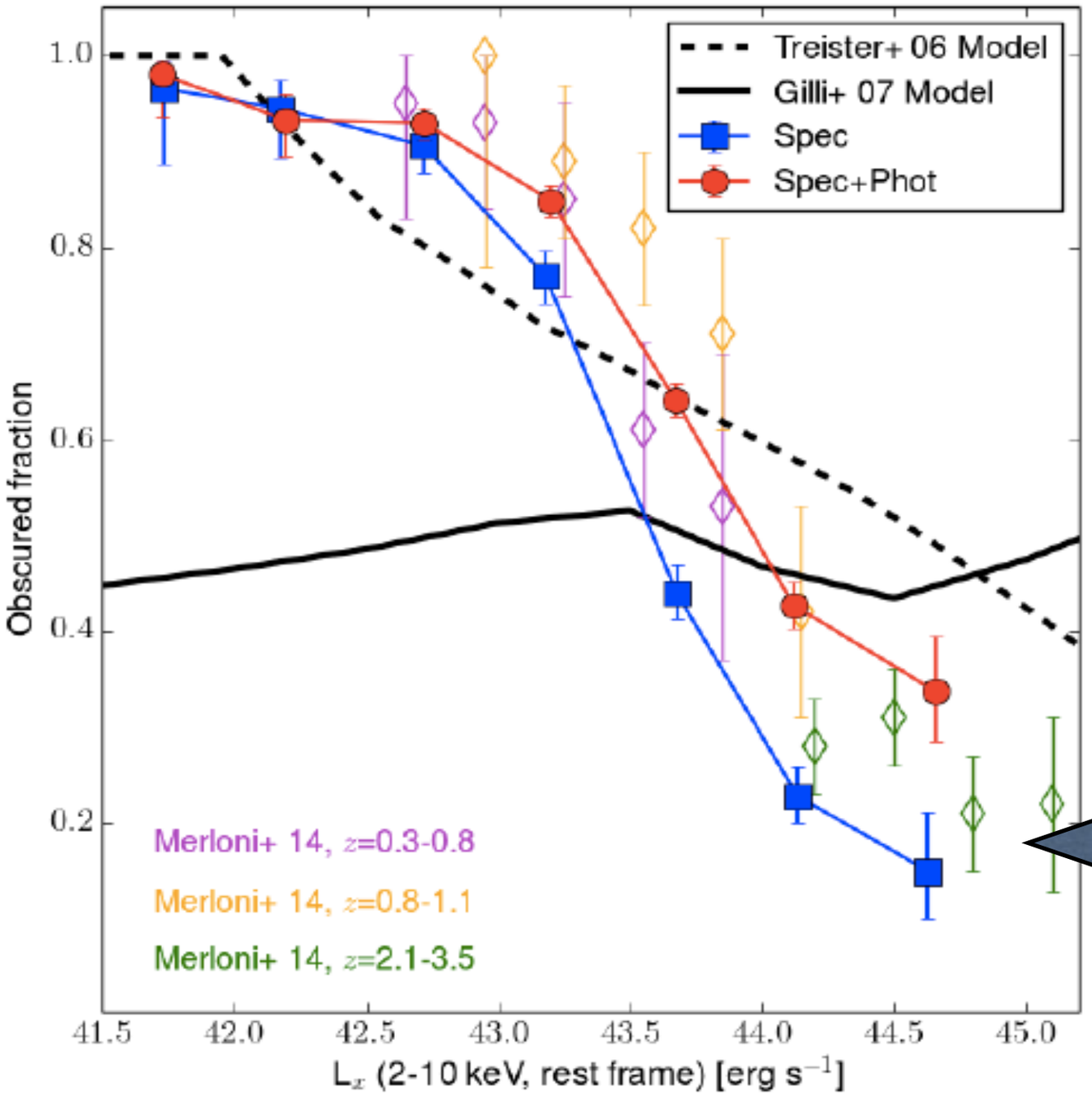
Short term variability of X-ray absorption, Iron Kα line in Type 1 AGN

Many evidences in favor of a "viewing angle" interpretation

Population Synthesis for the XRB

Mateos, Paltani, Annuar, Corral, Buchner, La Franca, Brightman, Masini, ... talks TORUS meeting last week

Modified Unified AGN model



Marchesi+15

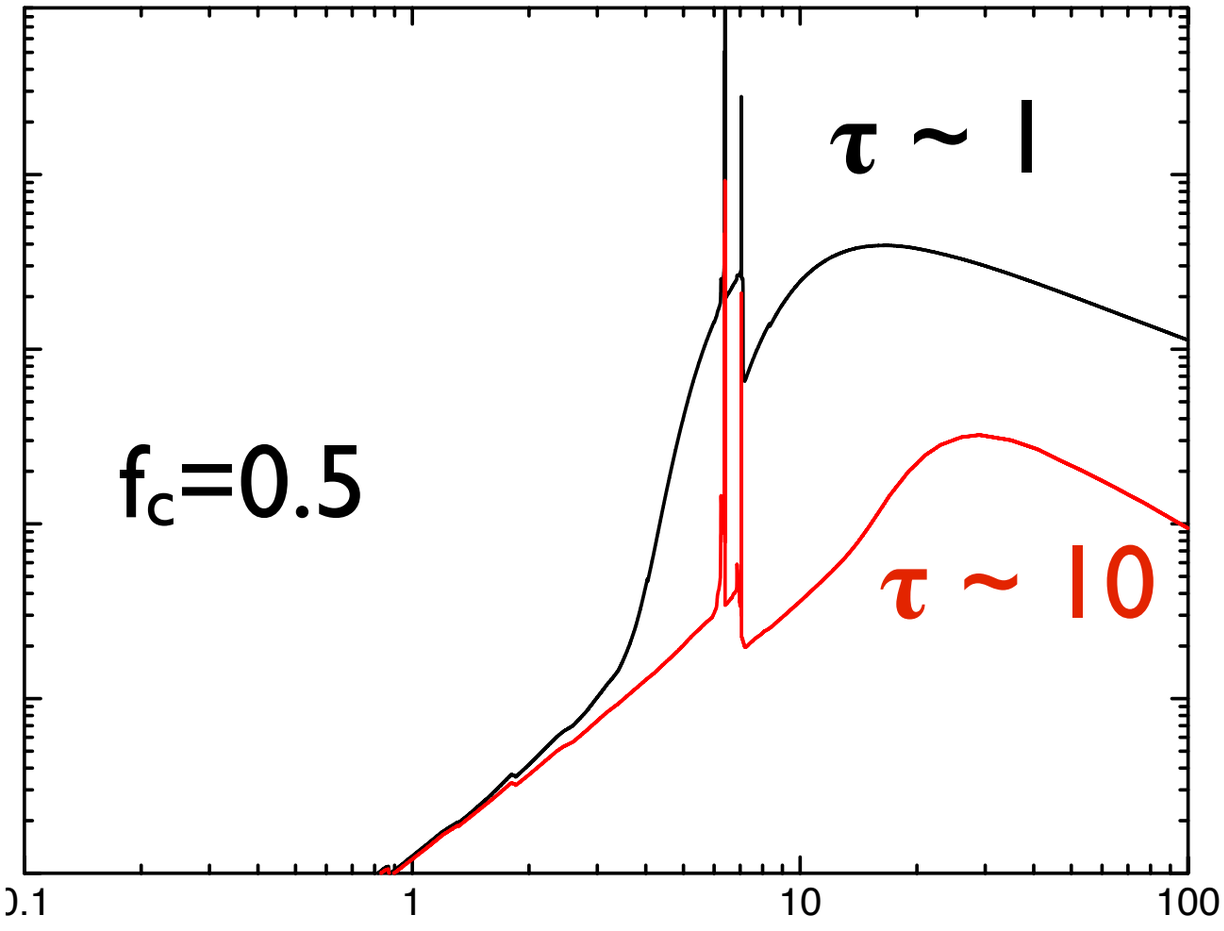
Luminosity (and redshift) dependence of covering factor - possibly due to feedback of central radiation

Clumpy tori from IR SED of Type 2 AGN (Almeida+11)

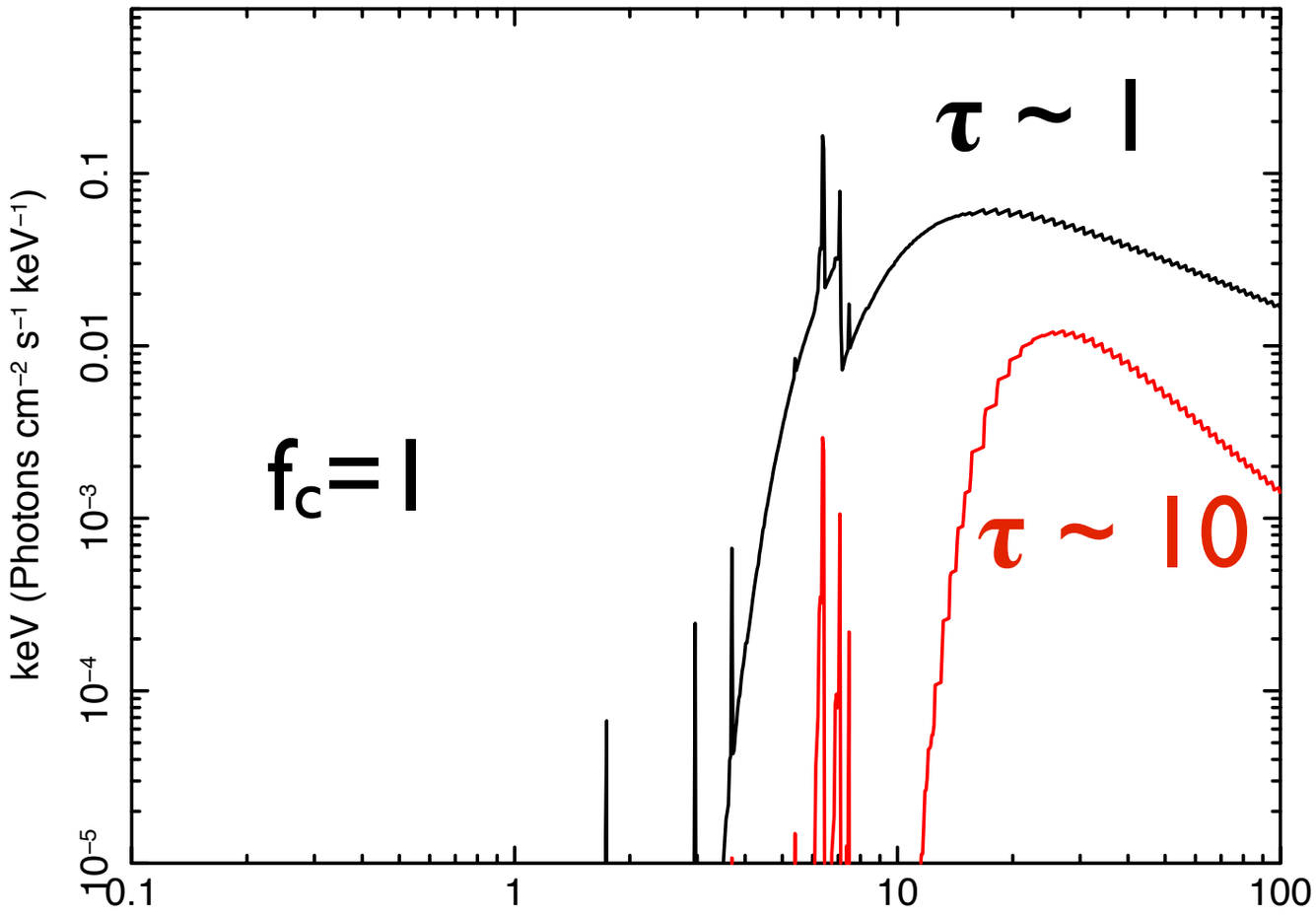
Sazanov+15 -selection effects Combination of a steep LF and some mild anisotropy consistent with no luminosity dependence of covering factor

Tests

Current picture is biased against obscuration especially beyond the local Universe and at both low and high luminosities.



"Torus Model" Murphy&Yaqoob09

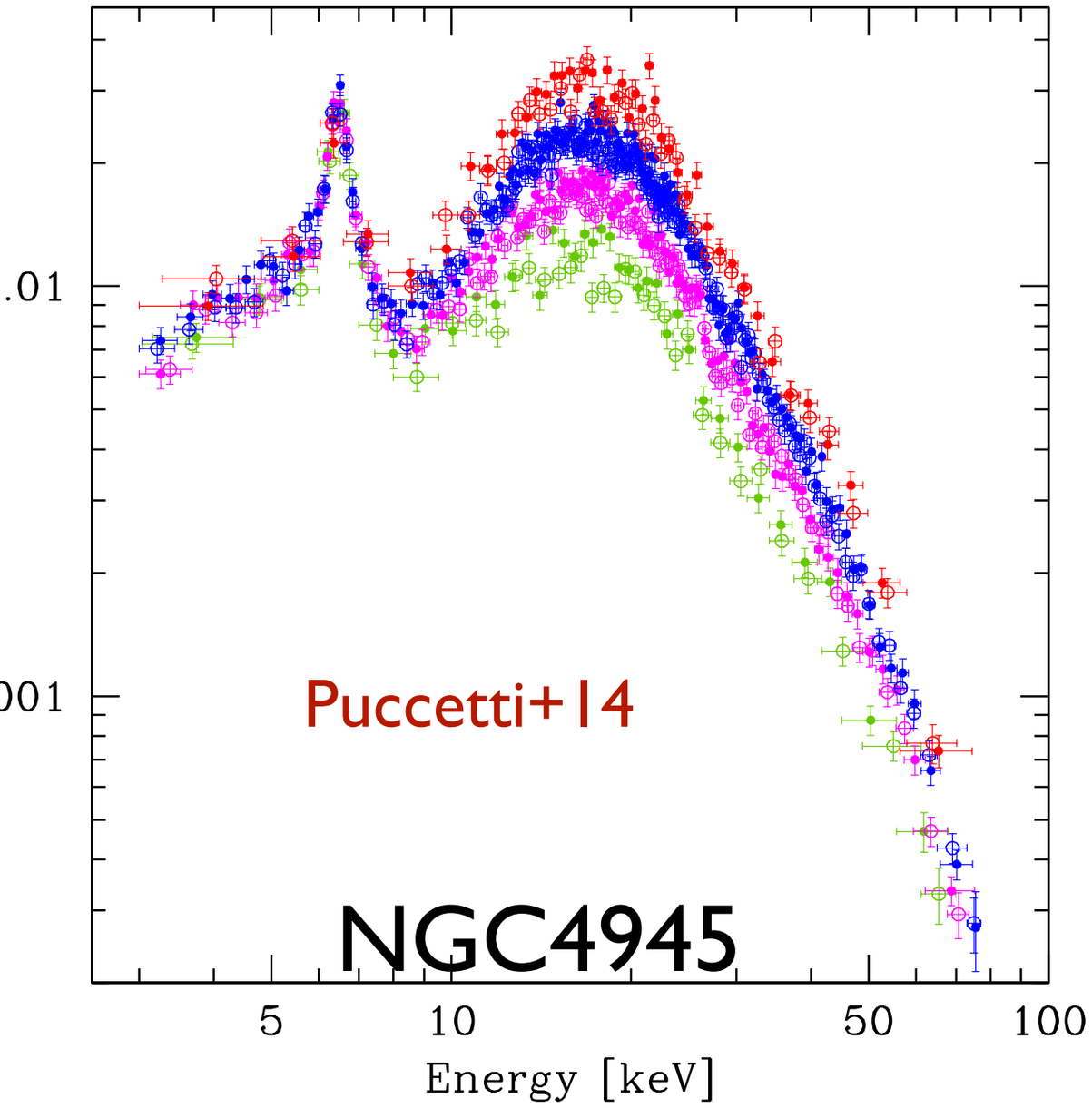


"Sphere" Brightman&Nandra11

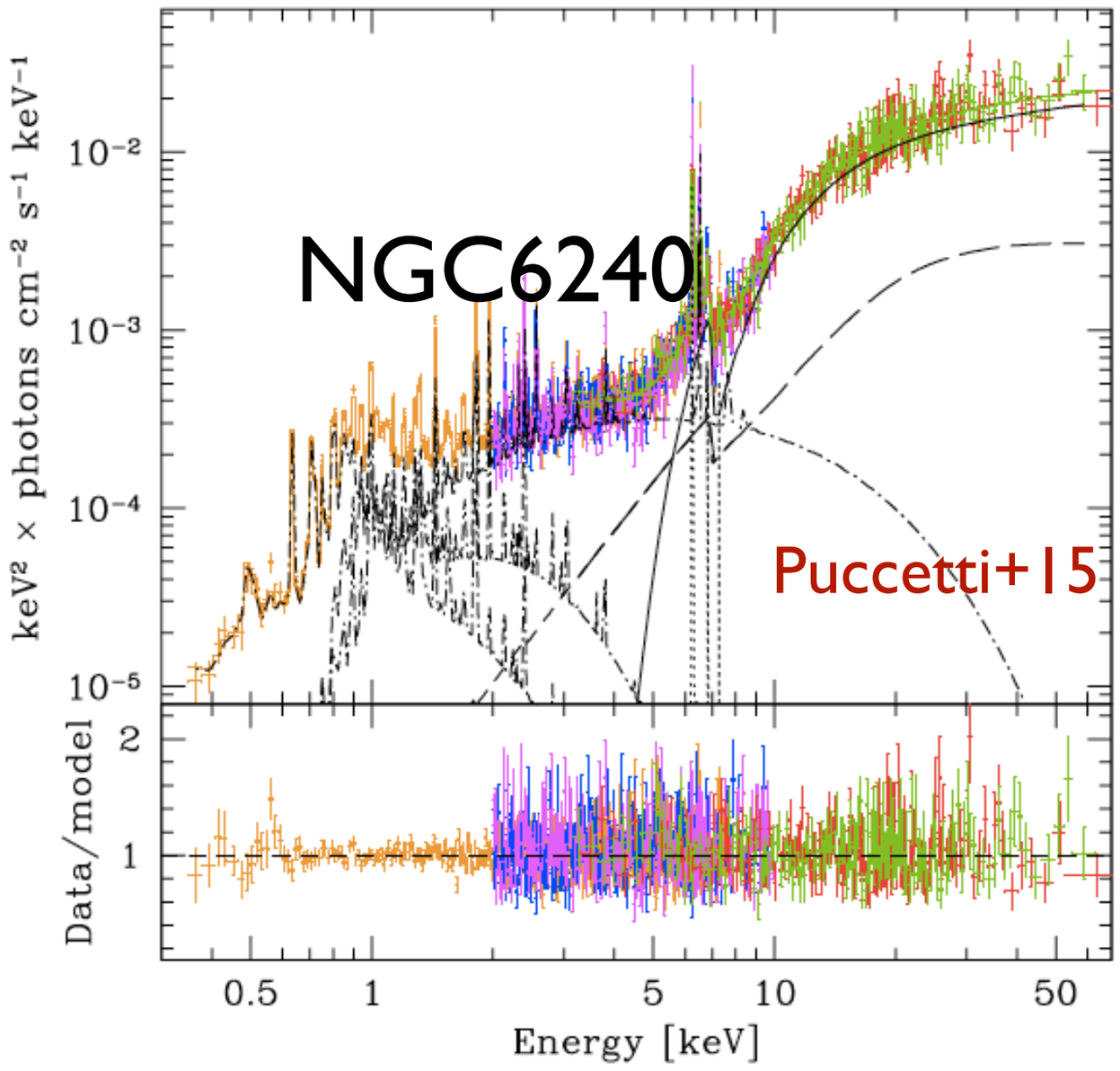
Sample the X-ray spectrum with good sensitivity above 10 keV

NuSTAR

Compton thick in the Backyard: NuSTAR (I)

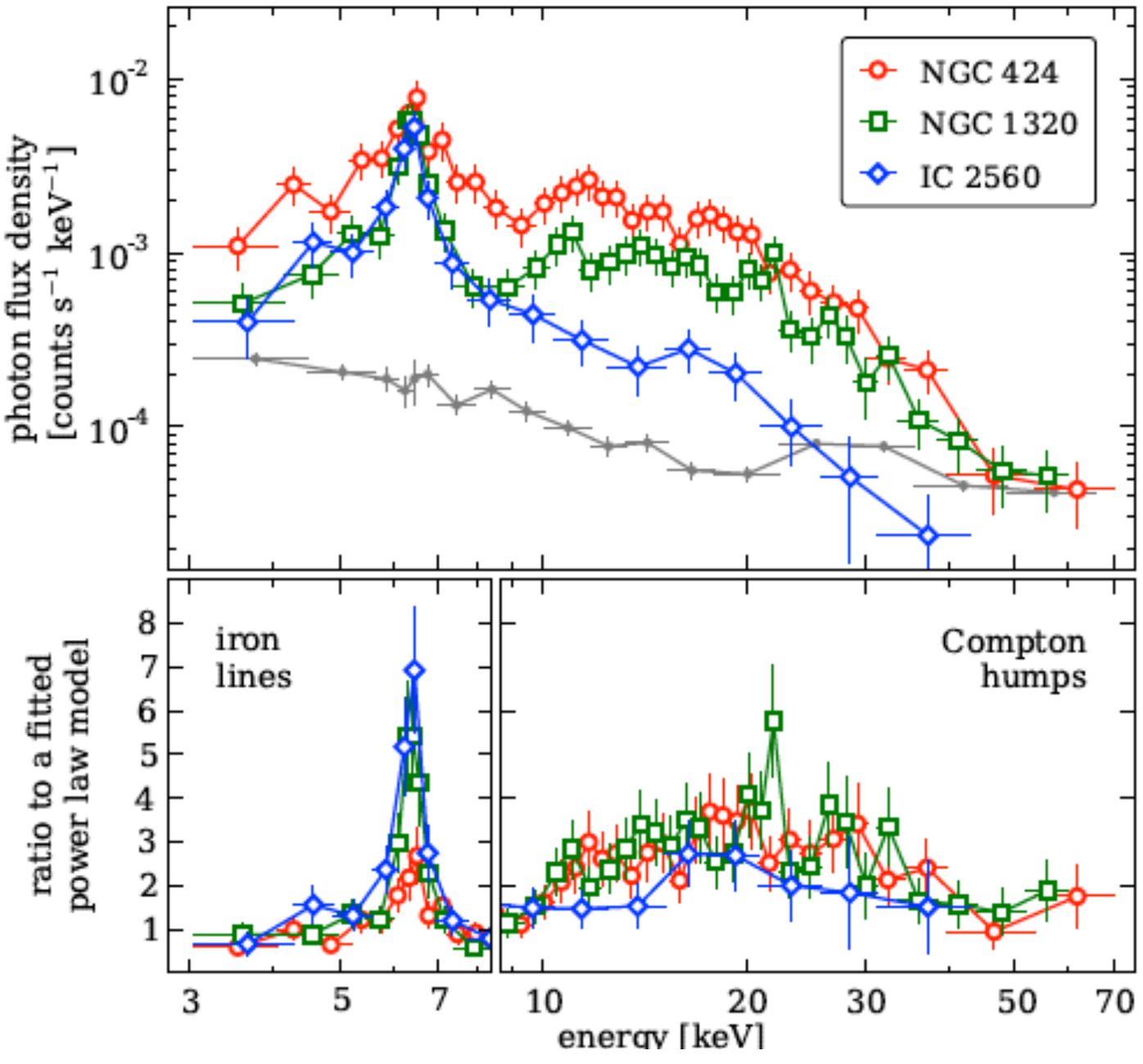


The brightest Sy 2 at 100 keV in the local Universe
$N_H \sim 4 \times 10^{24}$ cm^{-2}



Rosetta Stone of CT AGN contributing to the peak of the XRB $N_H \sim 1.5 \times 10^{24}$ cm^{-2}

Compton thick in the Backyard: NuSTAR (II)



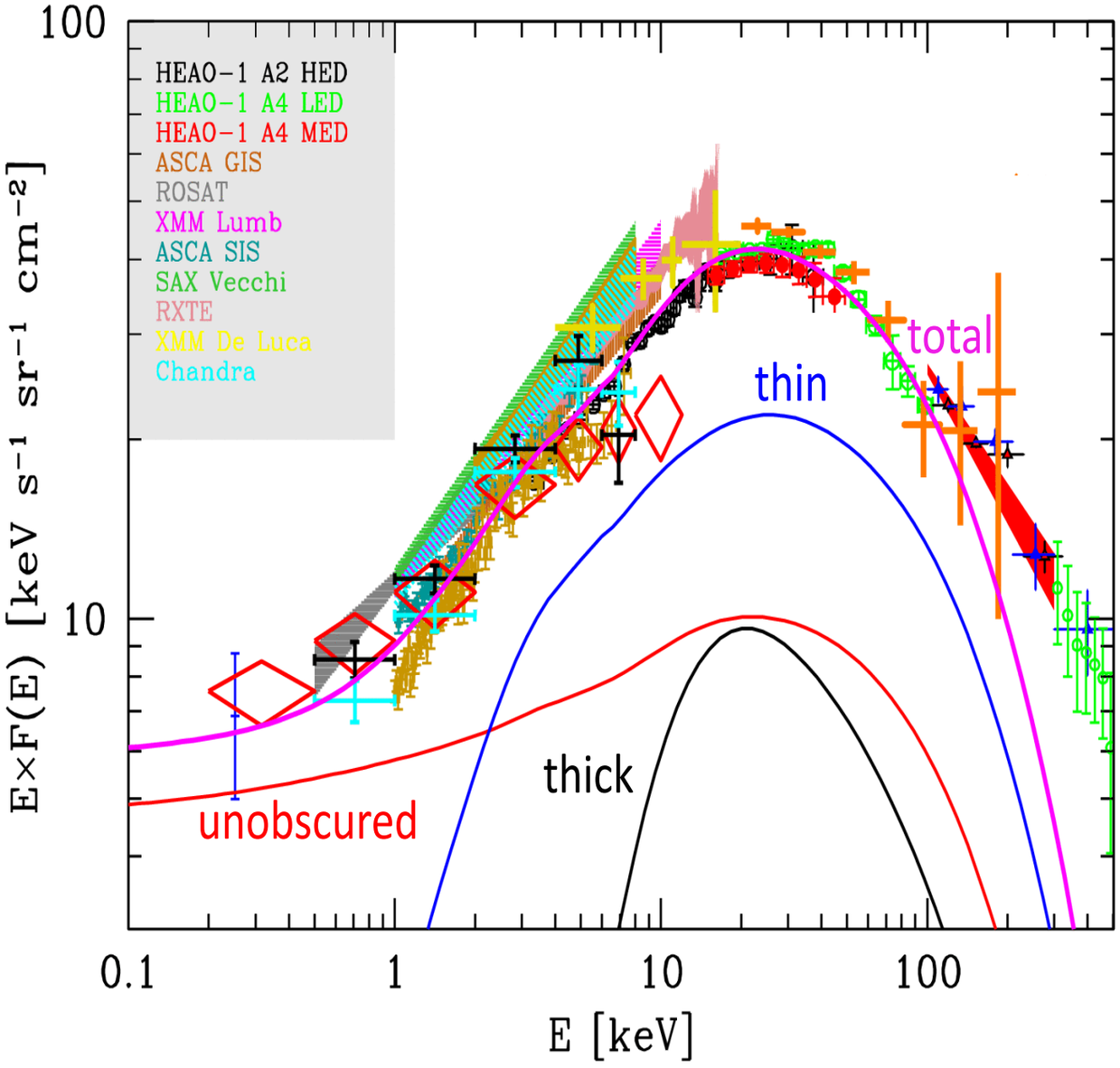
Relatively bright Sy 2 in the local Universe, Swift/BAT selected

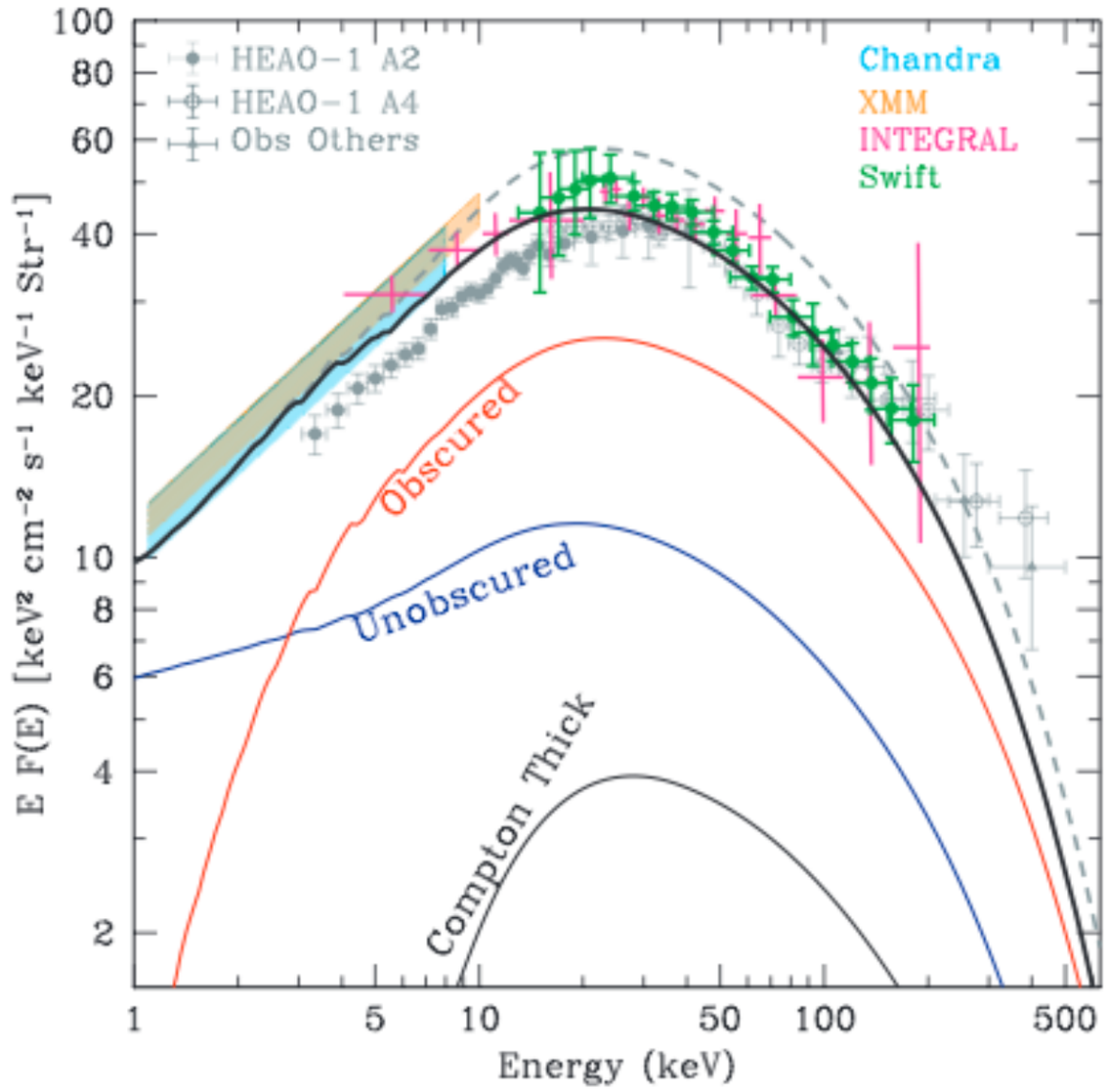
20-40 ksec NuSTAR observations

$N_H >\sim 10^{25}$ cm^{-2}
Reflection Dominated
strong iron lines
(EQW up to 2-3 keV)

Balokovic+14

Population synthesis for XRB





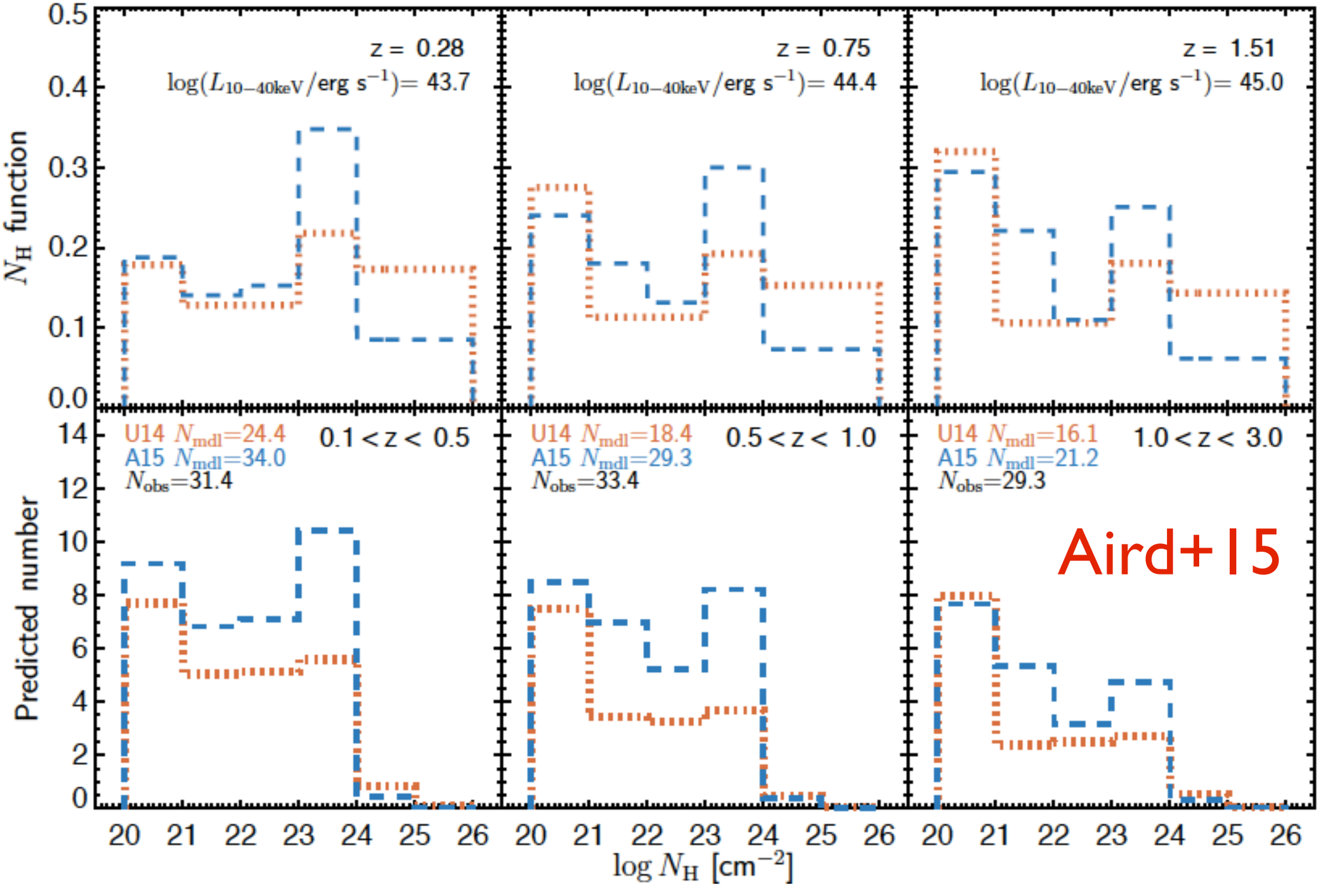
Gilli, Comastri,Hasinger 2007 GCH07

Treister, Urry,Virani 2009 TUV09

Some 80% of accretion power is "mildly" obscured. About 1/4 (GCH07) or ~10% (TUV09) are Compton thick.

The bulk of energy output is emitted at z ~ 1.

Expected absorption distribution in NuSTAR

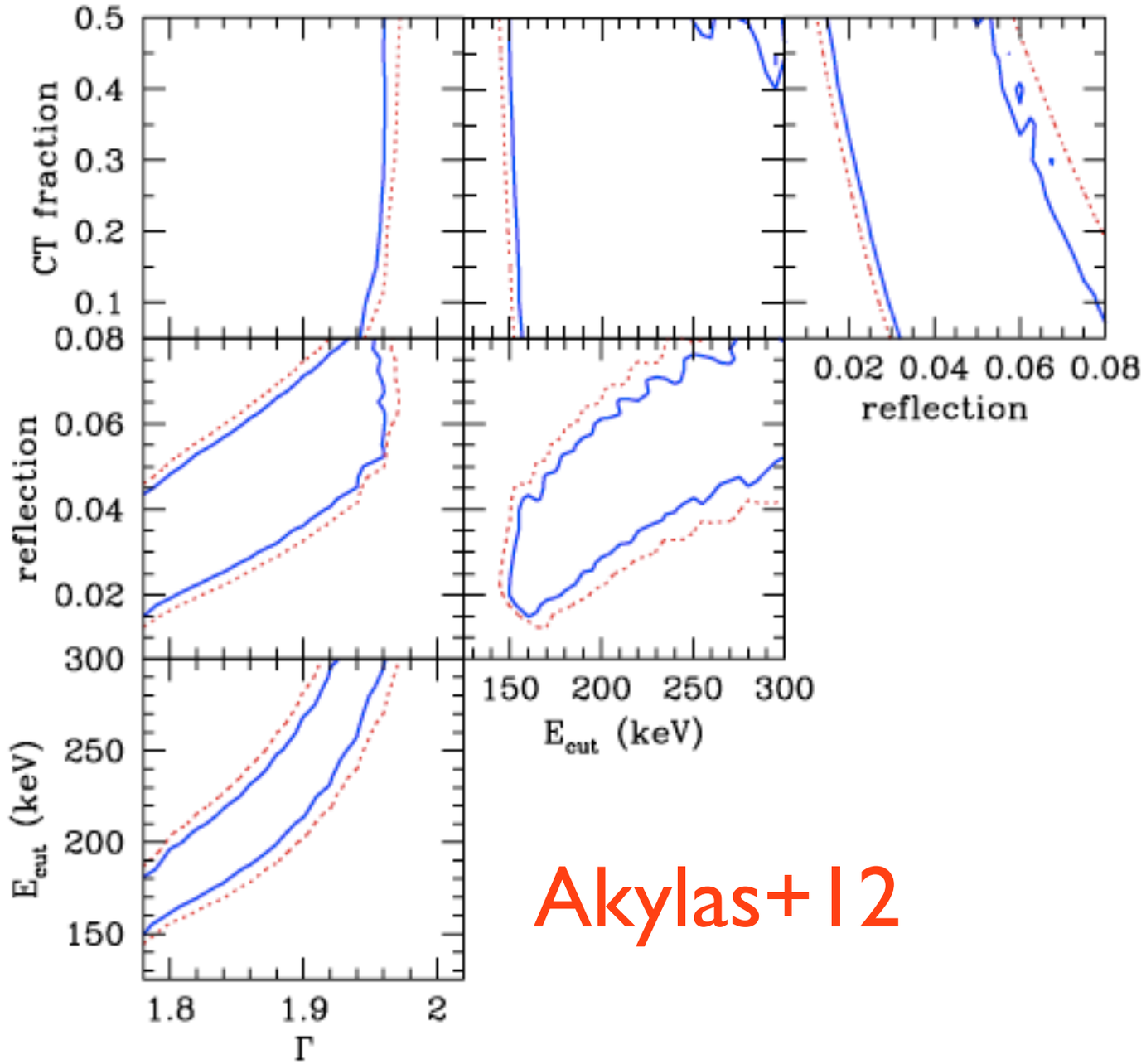


NuSTAR surveys Civano+15, Mullaney+15 have resolved ~30% of the 8-24 keV XRB

Degeneracies

Ueda+14 higher CT fraction (and different N_H distribution ~ $10^{23\text{-}24}$) wrt Aird+15

Gilli+07 vs Treister+09

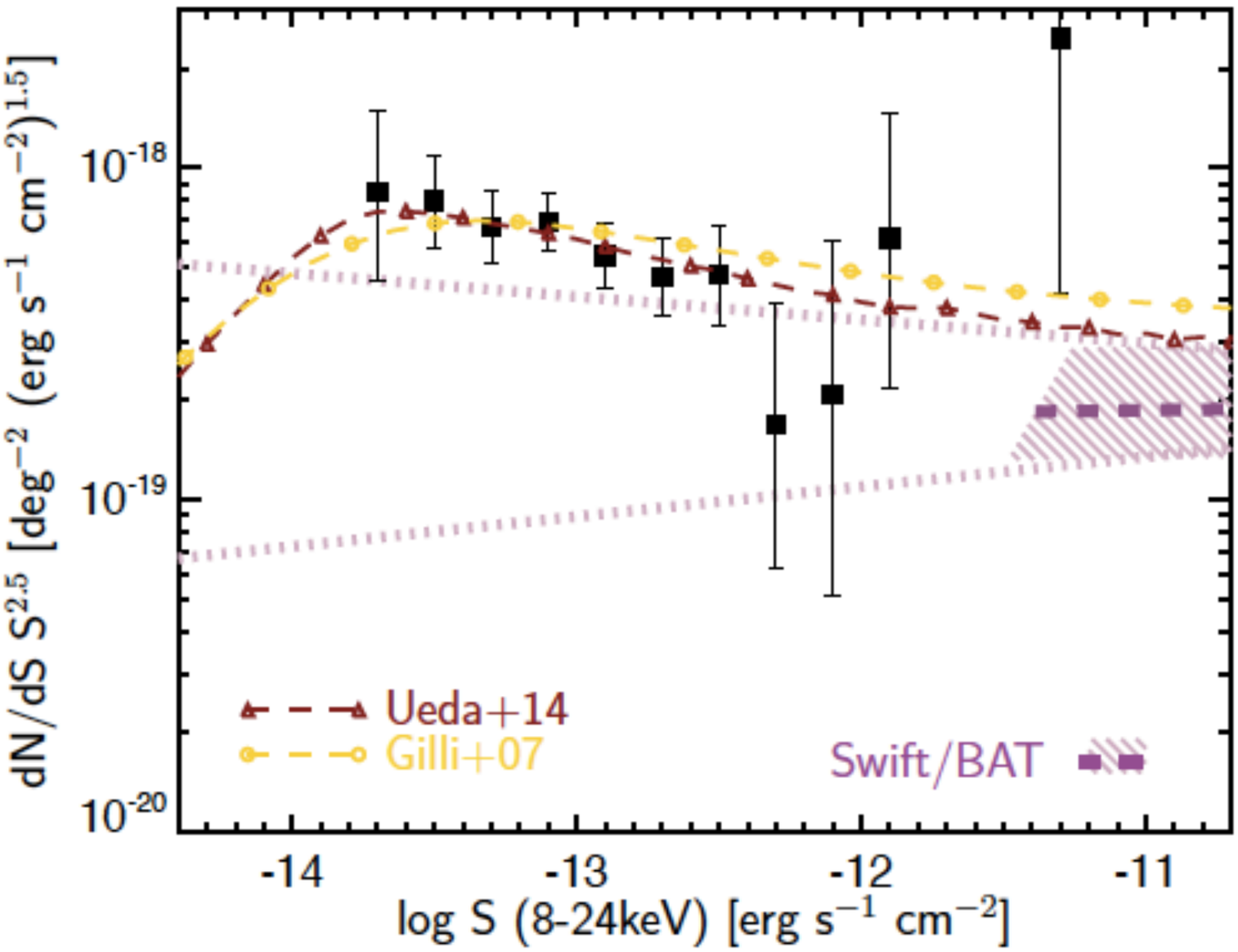


Akylas+12

- uncertainties on N-refl
- uncertainties on R
- contribution @ 30 keV from other populations? i.e. blazars (Giommi+12)

Reduce the uncertainties anchoring to the Swift BAT CT fraction which is likley to be biased as well

Source Counts



Harrison+15

The 8-24 keV counts over predict the extrapolation of the Swift/BAT logN-logS (Ajello+12)

To reconcile the two measurements one need a fast evolution of the spectral properties from z~0 to z~0.5-1.
Cfr. Ballantyne+14

Compton thick AGN

Current surveys are still not able to measure the geometry of obscuring material and its evolution beyond the local Universe. A modified version of the UM seems to work well modulo the bias toward "lower" obscuration (reflection/scattering)

Looking forward for further NuSTAR surveys and combined XMM-Chandra-Suzaku-NuSTAR spectral analysis to infer the geometry of the CT obscuring gas and break the degeneracies

A sizable population of highly obscured and CT AGN over a range of redshifts (say 0.5-2), is inferred from INDIRECT methods (optical/MIR line and continuum vs X-ray).

Could they be related to high covering factors and in turn to the evolutionary sequence?

SMBH Mass Density

$$\rho_\bullet c^2 = \frac{1-\epsilon}{\epsilon} \times U_T = \frac{1-\epsilon}{\epsilon} \times \langle k_{bol} \rangle U_X$$

εaccretion efficiency
K_{bol} X-ray Bolometric correction

$$U_T = \int dz \frac{dt}{dz} \int L\phi(L,z) dL$$

U_T Comoving Bolometric energy density

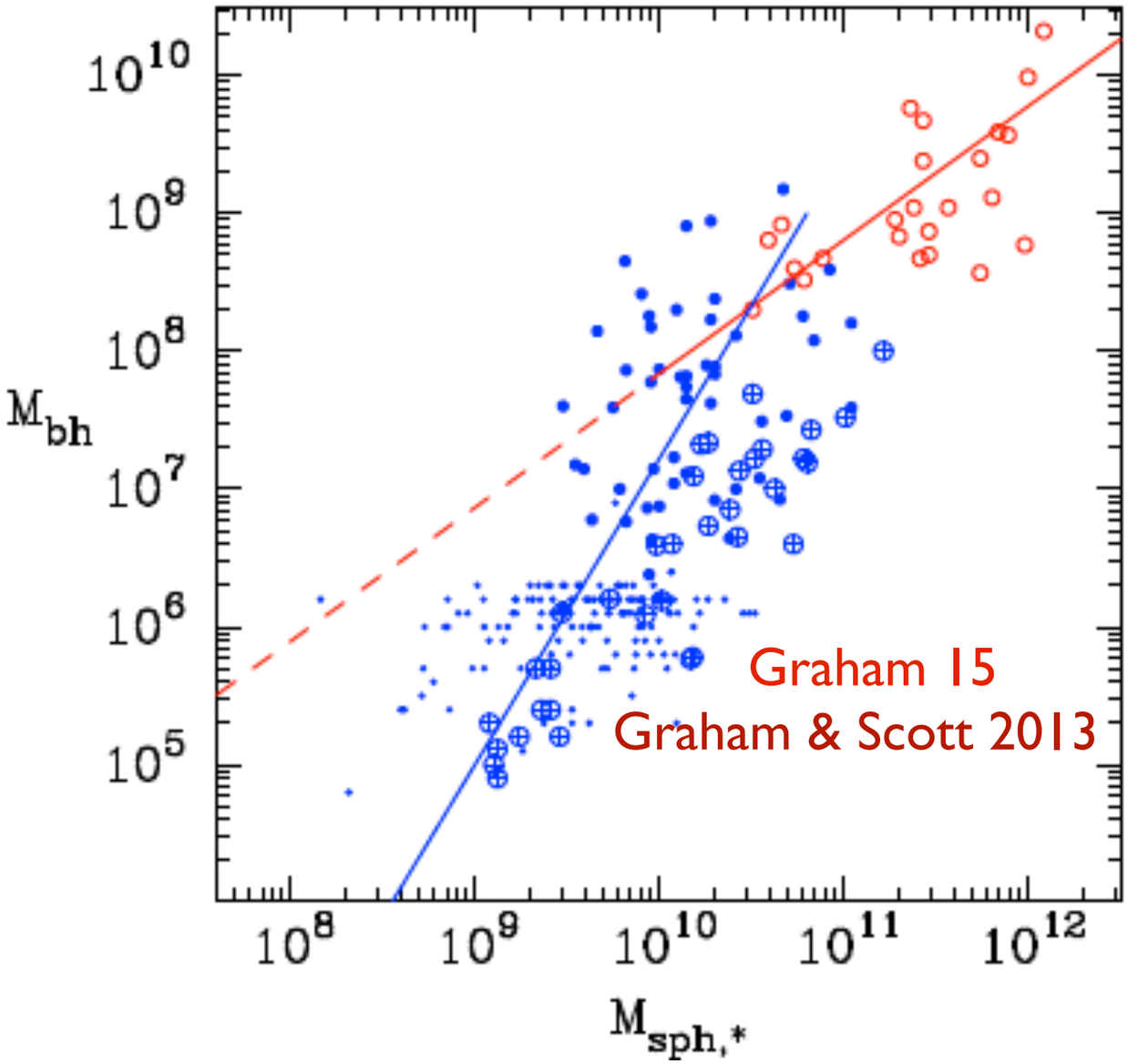
$$U_T = \langle k_{bol} \rangle \frac{4\pi I_0}{c}(1+\langle z \rangle)$$

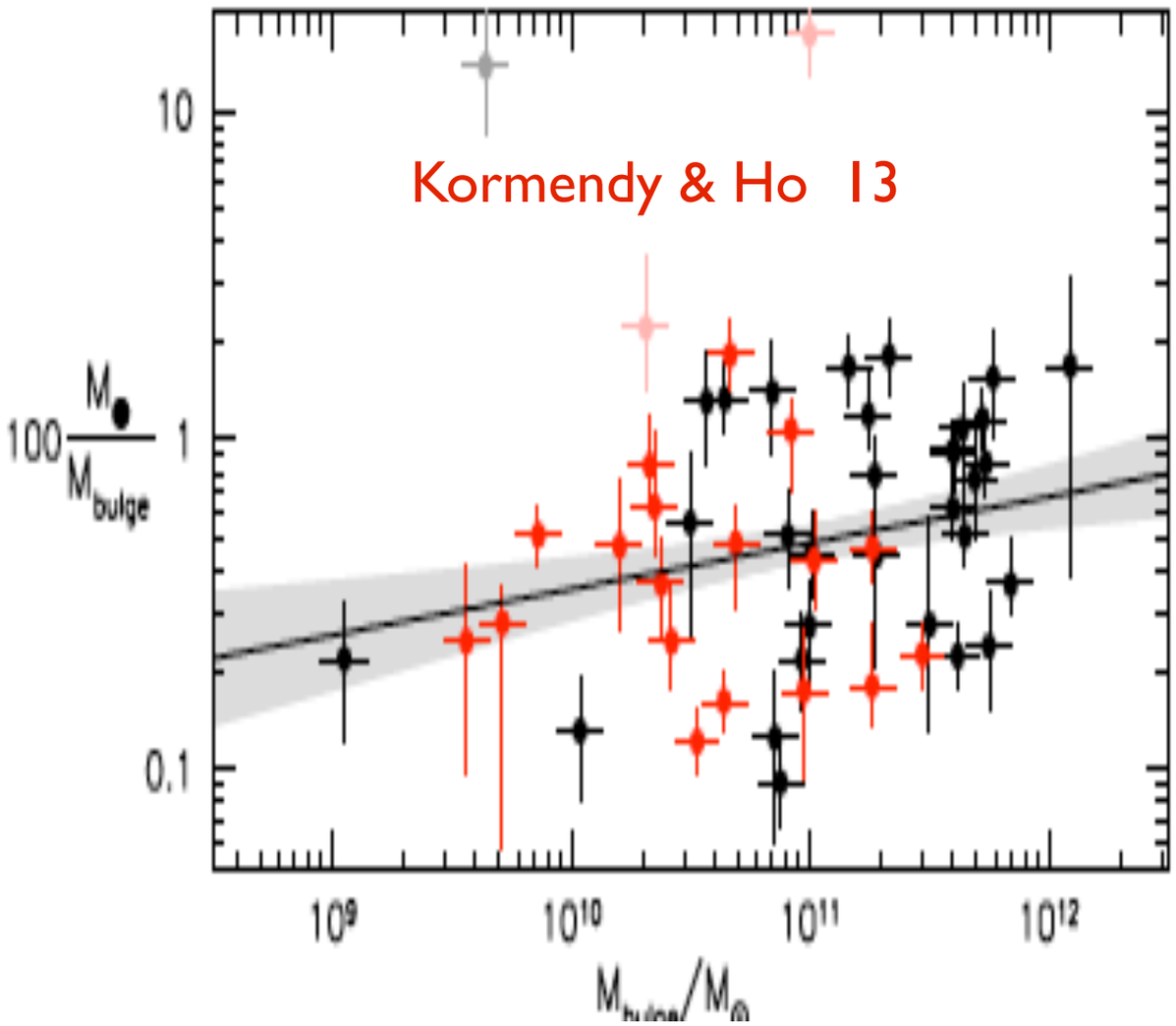
I_0 XRB energy density

Assume XLF evolution, obscured fraction, bolometric correction account for Compton thick AGN or the XRB intensity at its peak.

Require consistency with the local value from scaling relations ($M_\bullet$-M_{Bulge}-σ) get average efficiency or constrain parameters entering in the above equations.

Black Holes and Bulges





BH-to Bulge ~ 0.5% cfr 0.1-0.2% of previous relations i.e. Sani+11, Marconi & Hunt 03

1) omit pseudobulges
2) omit mergers in progress
3) omit galaxies with BH mass based on ionized gas dynamics

The low normalization of the scaling relation is consistent with current knowledge of AGN evolution, including CT fraction from XRB models, and "returns" 0.1 efficiency (Marconi+04)

$$\rho_\bullet c^2 = \langle k_{bol} \rangle \frac{1-\epsilon}{\epsilon} U_{xo} (1 + \sum_i R_{ob})$$

To fit more mass you may decrease the average accretion efficiency (ADAF like, i.e. Novak 2013)

$$\rho_\bullet = \rho_{\rm S} - \rho_{\rm GW} + \int (\dot{\rho}_{UO} + \dot{\rho}_{\rm OB} + \dot{\rho}_{\rm CT} + \dot{\rho}_{\rm RI})\, dt$$

Could heavily obscured, Compton Thick AGN make the job? Accretion efficiency is not a free parameter but is assumed to be 0.1. The bolometric correction is also assumed to be consistent with the recent observational framework (i.e. Lusso+12)

$$\Sigma R_{obs} = R_{Thin} + R_{MThick} + R_{HThick} * (0.02/f_s)$$

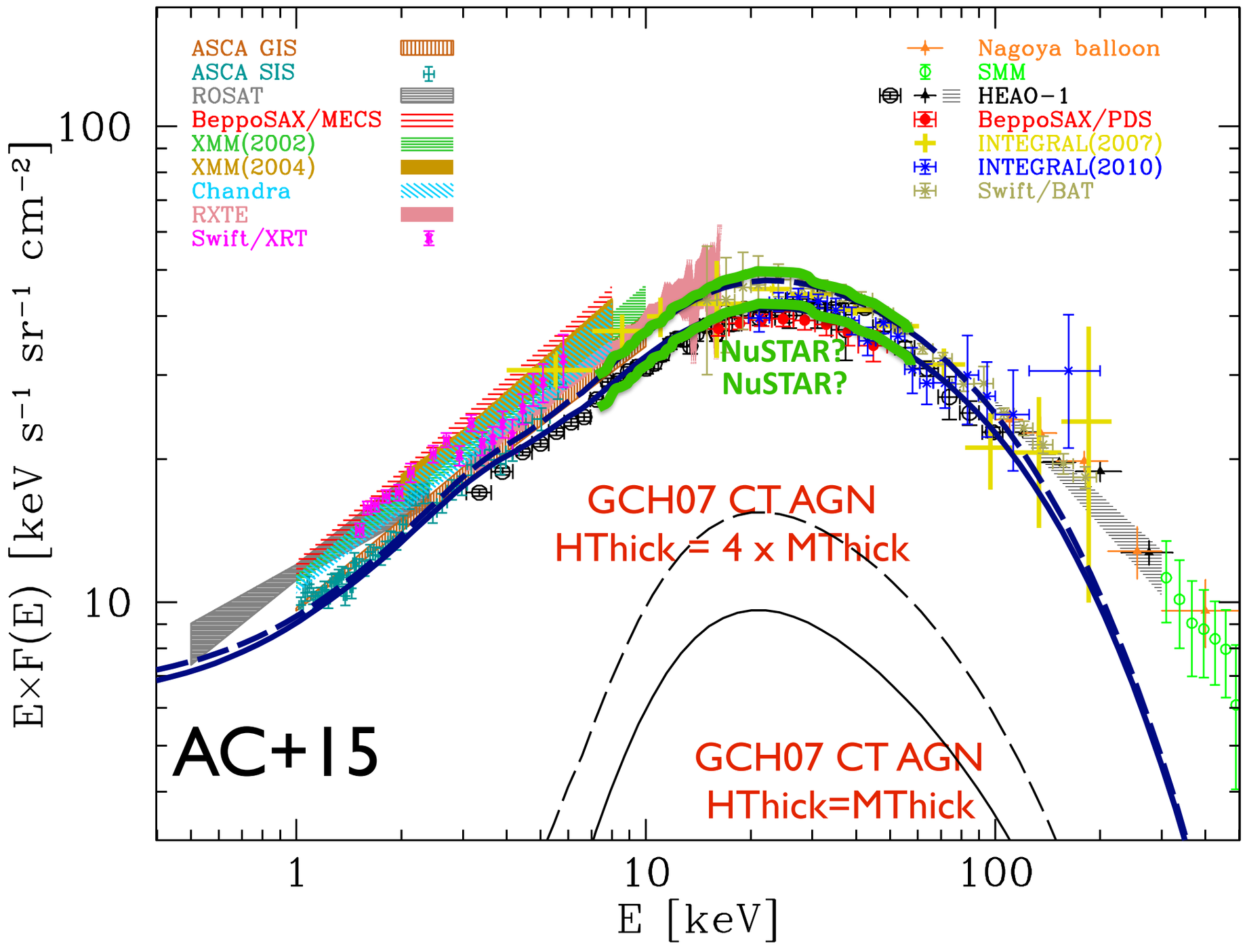
The reflection/scattering yield f_s normalizes the contribution of Compton thick AGN in GCH07.
The lower the average reflection/scattering intensity, the higher is the number of heavily Compton thick SMBH which can be accommodated.
The "mass increase" is a factor 2 (on the lower side of the revised value) and consistent with that adopted in Marconi+04,06

$$2\rho_\bullet c^2 = \langle k_{bol} \rangle U_o \frac{1-\epsilon}{\epsilon} (1 + \Sigma_i R_{obs} + R_{new})$$

In GCH07 the luminosity averaged ratio between Thick, Thin, unobscured is 3:3:1 (Thick equally splitted between Hthick and Mthick)

$$R_{new} = (1 + \Sigma R_{obs}) = 7$$

For each SMBH contributing to the XRB (unobscured, thin & thick) there is an X-ray silent object contributing to the mass density only

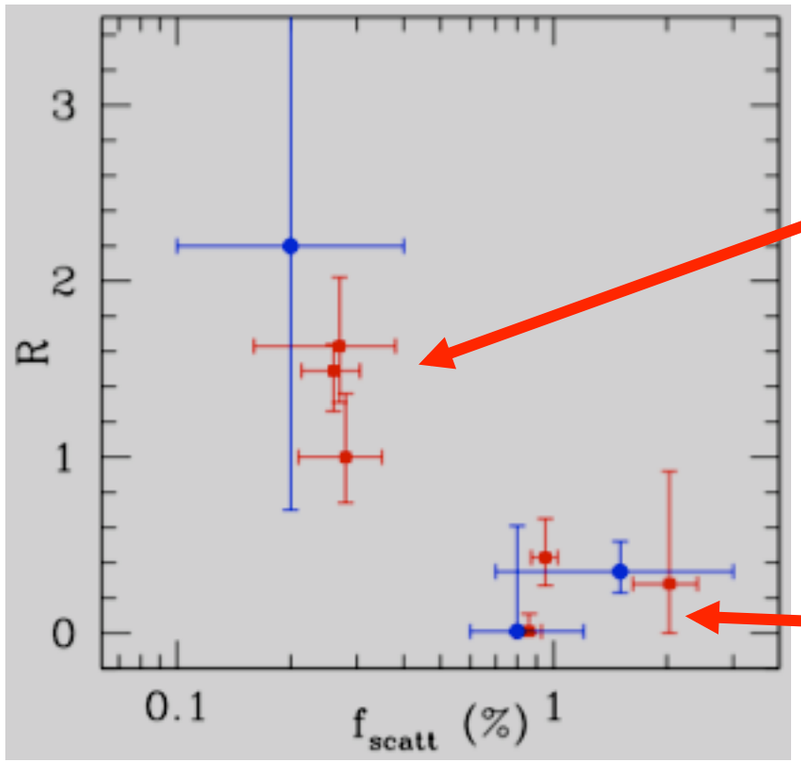


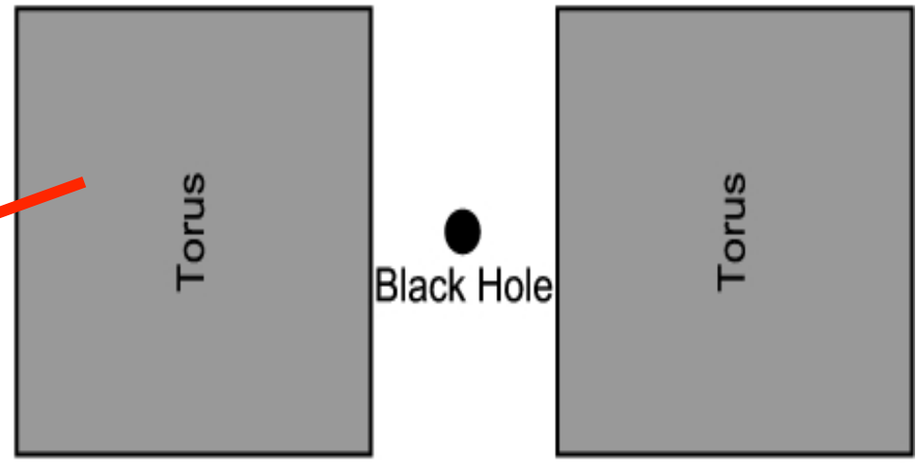
You may "play" with current uncertainties on the intensity of XRB peak

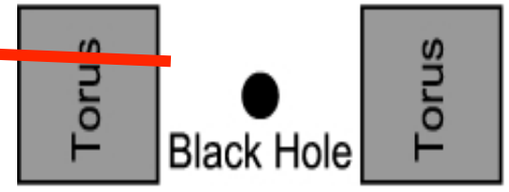
Still a sizable fraction (~20%) of "all" SMBH could be X-ray silent

Alternatively the new population would not exceed the XRB limits provided their scattering efficiency is 0.004-0.01 i.e. a factor 2-5 lower than assumed in GCH07 (f_s = 0.02)

A new class of obscured AGN?





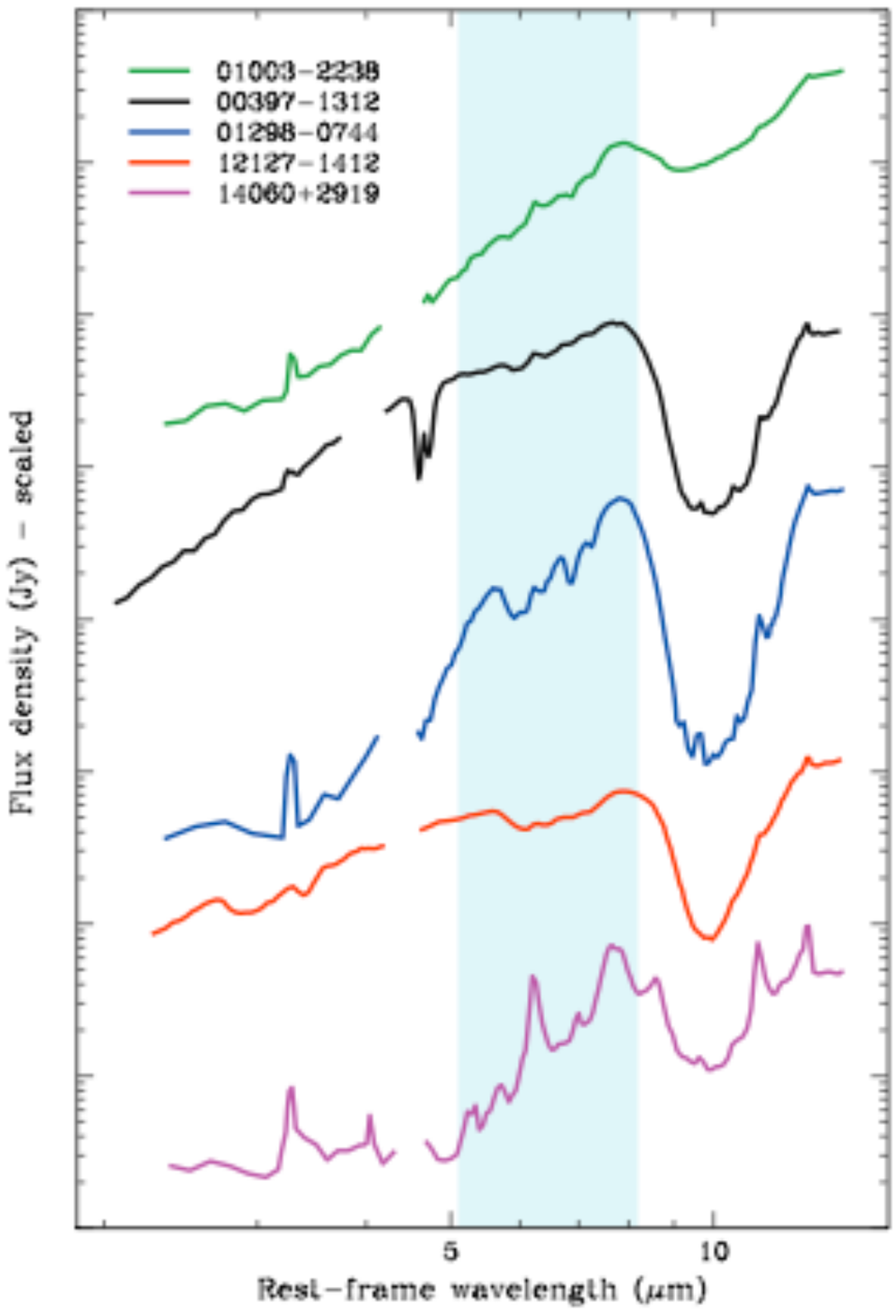


New Type AGN are seen almost face-on through a geometrically thick torus w/ small opening angle

Large population of heavily Compton Thick ($N_H \sim 10^{25}$) missed by present hard (> 10 keV) surveys !

Ueda+07
Eguchi+09
AC+10
Brightman+14

ULIRG ?



Nardini & Risaliti 2011

Near IR spectroscopy of ULRIG AGN. Lack of PAH features, no SB, but buried nuclei.
X-ray observations: weak or undetected with XMM

"The upper limits on the reflected flux are an order of magnitude lower than the usual reflection efficiency observed in type 2 active galaxies, suggesting an almost complete covering."

ALMA observations of Arp220
$N_H \sim 0.6\text{-}1.8 \times 10^{25}$ cm^{-2} (Wilson+14)

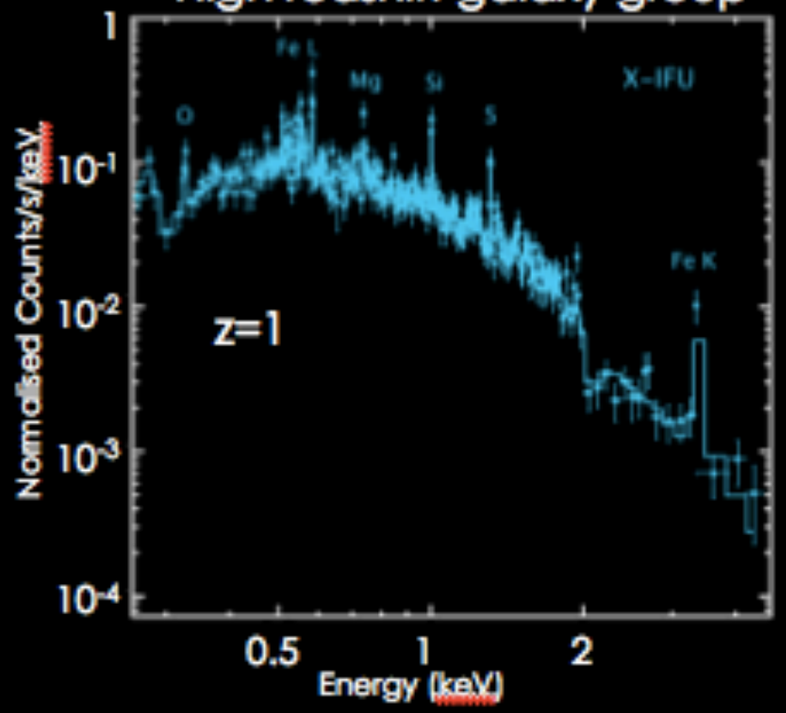
Deep silicate absorption at 9.7μ (Fu+10)
$\tau_{9.7} > 1$ and $\tau_T > 1$ only partly overlap (i.e. Georgantopoulos+11)

Future Perspectives

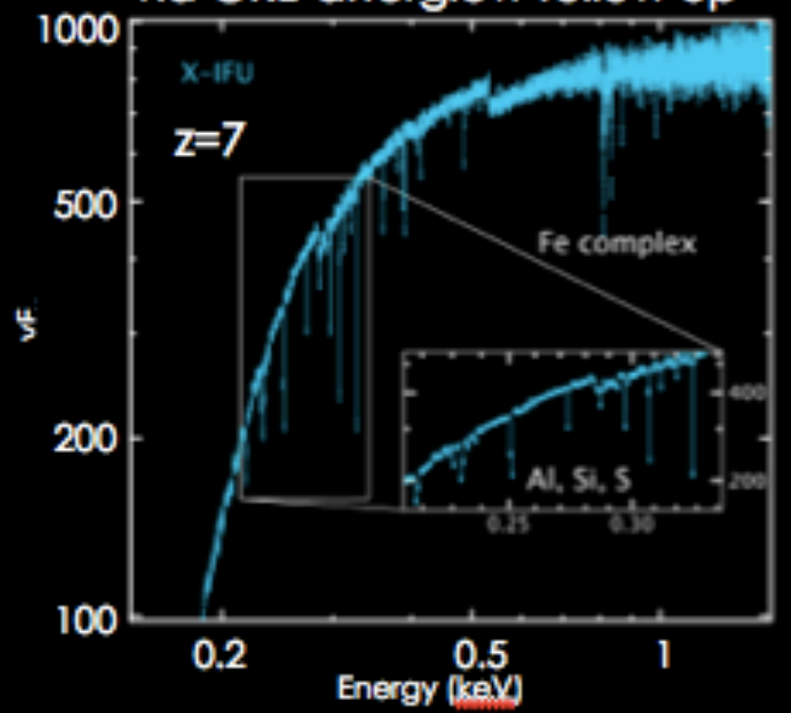
- CDFS 7 Ms - Cosmos Legacy - UDS
- Additional XMM surveys?
- Scheduled and planned NuSTAR surveys (*and ASTRO-H)*
- ATHENA

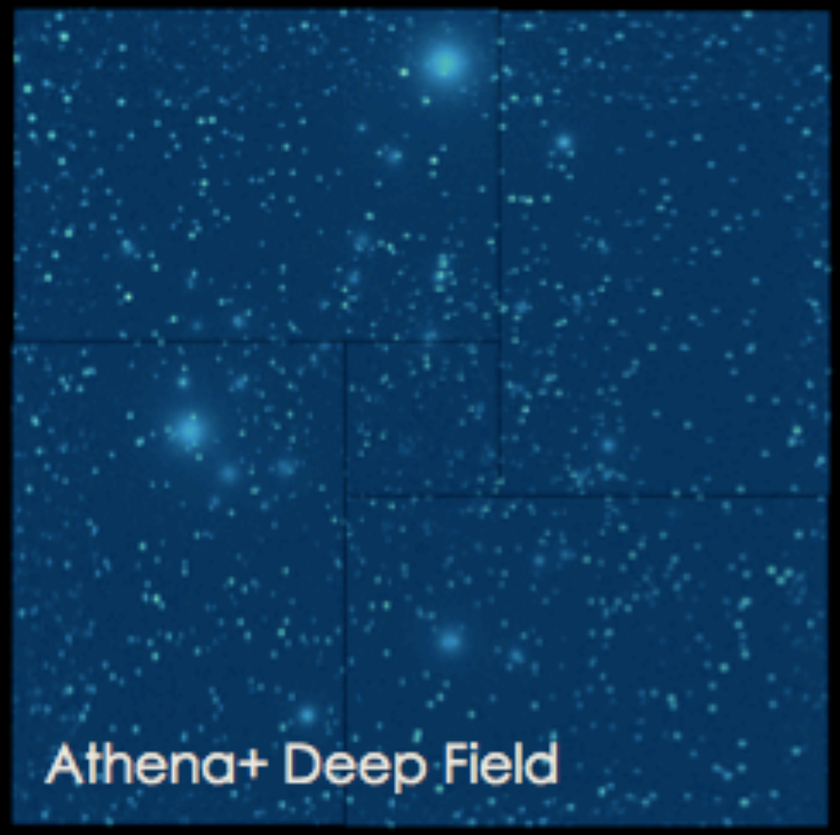
Athena+
The first Deep Universe X-ray Observatory

High redshift galaxy group

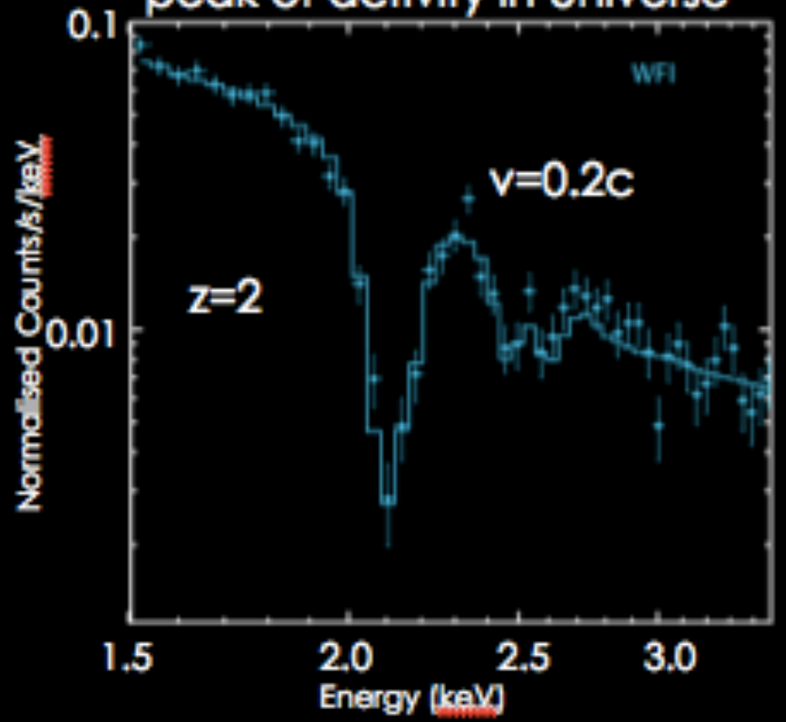


Primordial stellar populations via GRB afterglow follow up



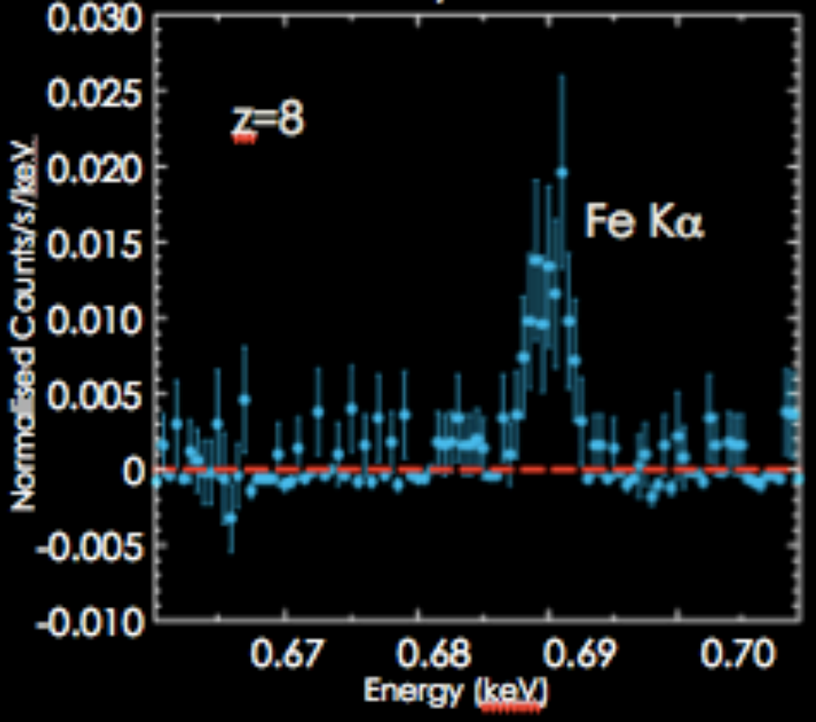


Black hole feedback at peak of activity in Universe



Nandra, Barret, Barcons, Fabian, den Herder, Piro, Watson et al. 2013 arXiv 1306.2307

Obscured black hole in the early Universe



Conclusions

Compton thick hunting season re-opened

Heavily Compton thick AGN could be responsible of the "mass excess", satisfy the constraints imposed by the XRB and FIRB and accrete "efficiently". Need to be either X-ray silent and/or highly covered. They could be associated with the rapid obscured growth of SMBH envisaged by theoretical models

ULIRG (Arp220-like) could be promising candidates.

Deep Chandra/XMM and NuSTAR coupled with multi-wavelength observations may provide interesting constraints while waiting for ATHENA wide and deep surveys