Obscured AGN

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Talk Outline

* Rationale: Why obscured AGN are important (especially the Compton-thick AGN)
* Obscured AGN from X-ray surveys (Chandra, XMM, Swift/BAT, Nustar)
* IR+ sub-mm methods (mid-IR colours, Spectral Energy Distributions, IR spectroscopy)
* future surveys

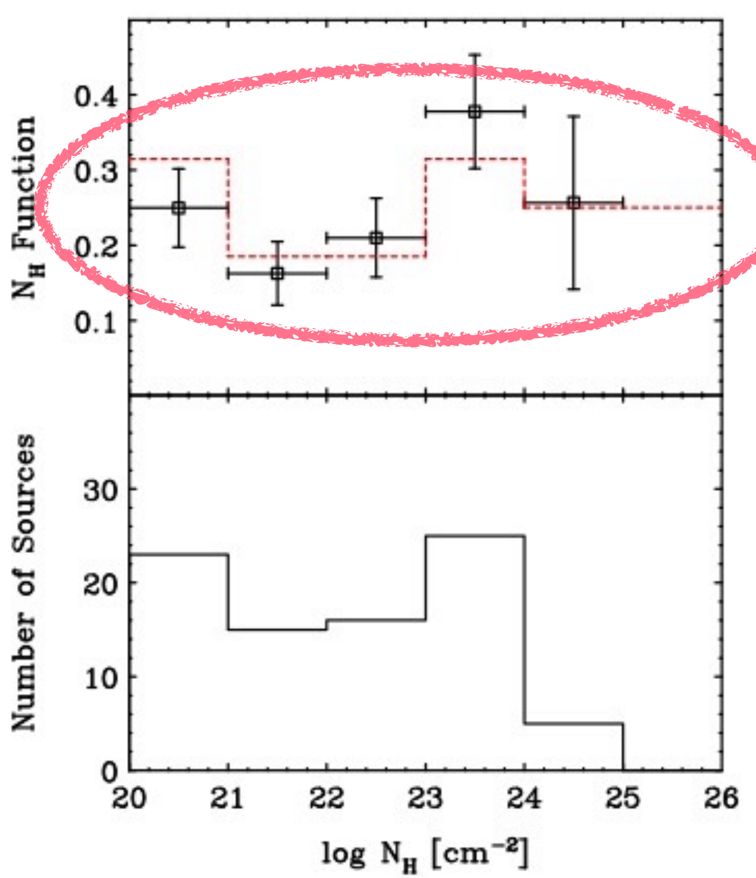
X-ray Surveys

- X-ray surveys provide the most efficient way to detect AGN
- In the CDFS 4Ms the sky density is **20,000 sq. deg. (Xue+11)** cf. with **~300/ sq.** deg   in SDSS (Ross+12)
- This is because X-rays probe faint luminosities and absorbed sources

  -but see variability studies and spectroscopic studies [OIII], [NeV] e.g. Bongiorno+10, Gilli+10 -

cdfs 4Ms

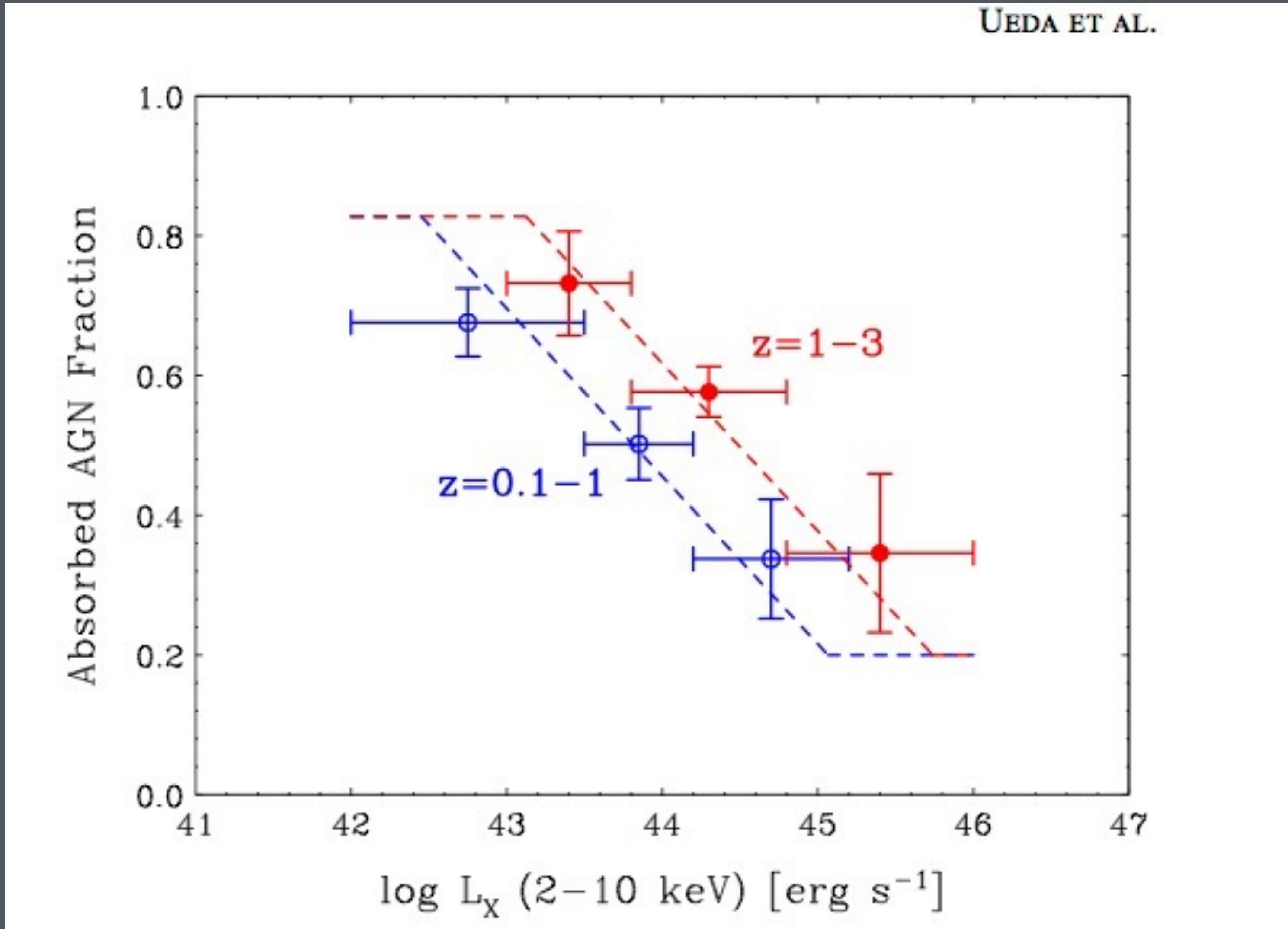
Ueda+15



Snapshot at logL=43.5
z=0

see also Miyaji+15, Ranalli+15, Buchner+15, Fotopoulou+15 for recent derivations of the LF

Obscuration depends on redshift and luminosity

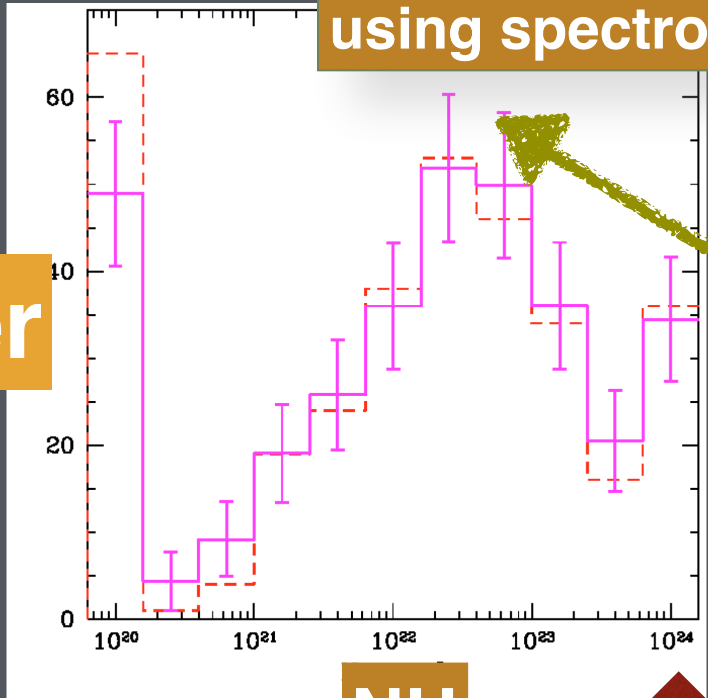


Powerful QSOs prefer not to be obscured !

AGN at high-z are more obscured

DISTRIBUTION OF ABSORPTION

Tozzi+06
Georgantopoulos+07
using spectroscopy 1Ms CDFS



Number

NH

peaks at
Nh~10^{23} cm-2
A_V~30
10^{-16}cgs

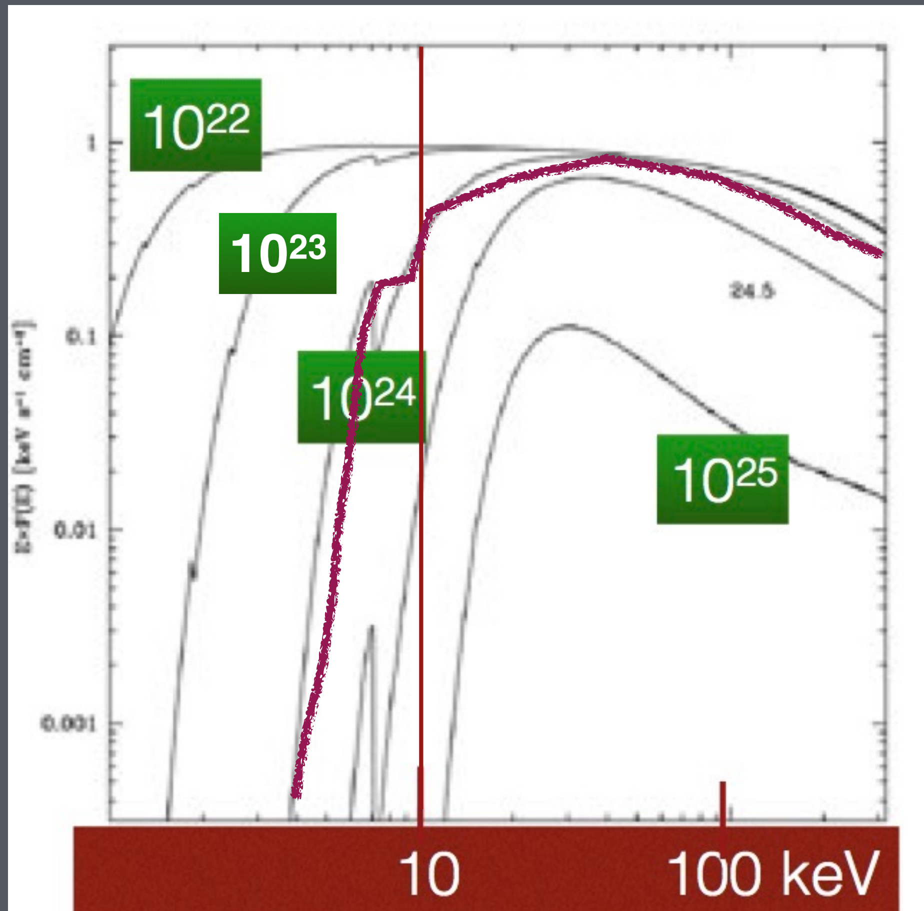
CT– AGN regime

The most obscured AGN: can X-ray surveys detect them easily ?

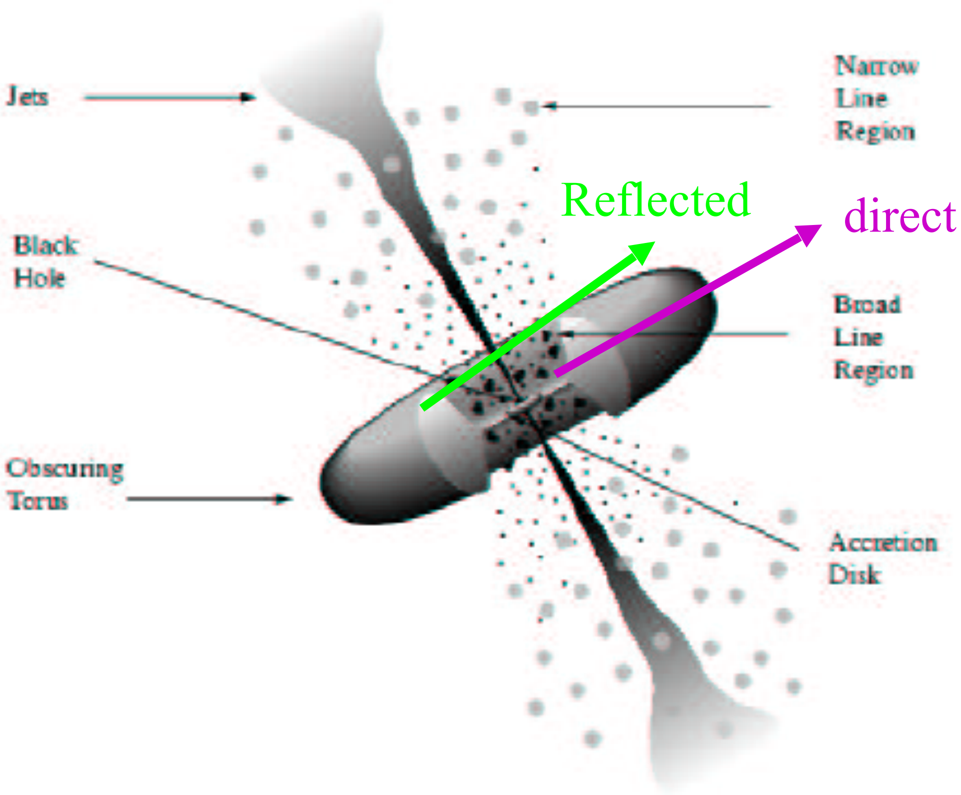
Even the very efficient hard X-rays have difficulties penetrating column densities above $>10^{24}$ cm^{-2} Compton-thick AGN

The attenuation is because of Compton scattering on electrons and not because of photoelectric absorption.

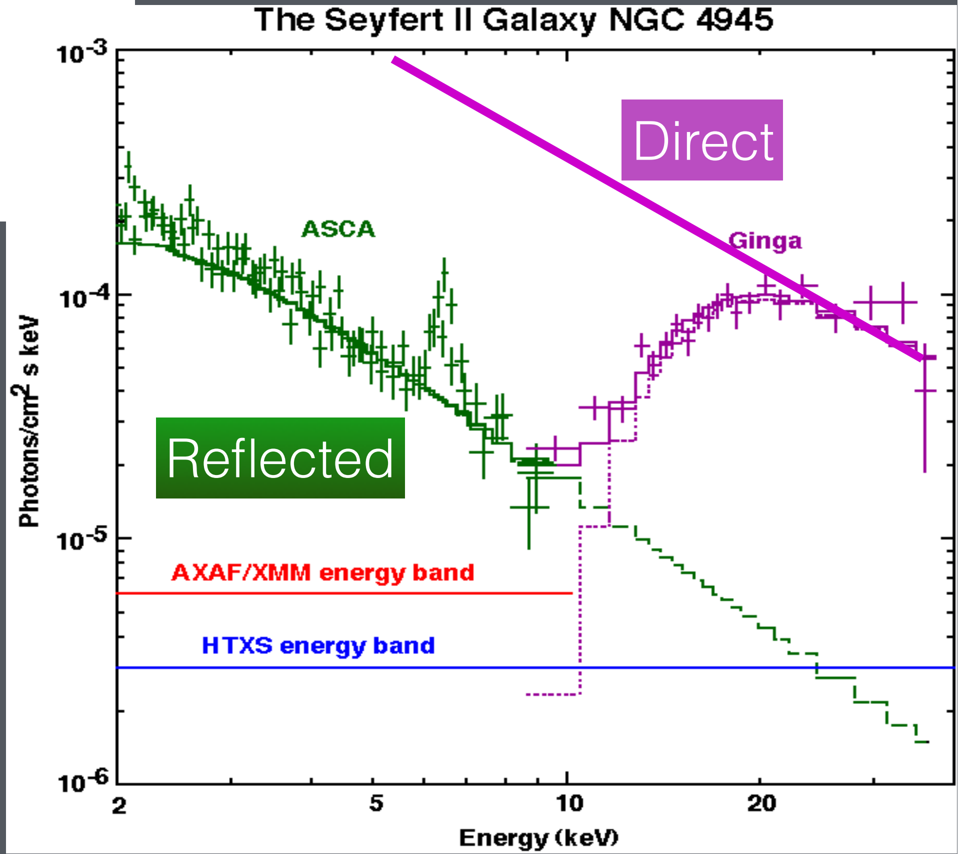
This reduces the X-ray emission in the 2-10 keV band to a few percent of the intrinsic emission



Sy-2



Jets
Narrow Line Region
Reflected
direct
Black Hole
Broad Line Region
Obscuring Torus
Accretion Disk

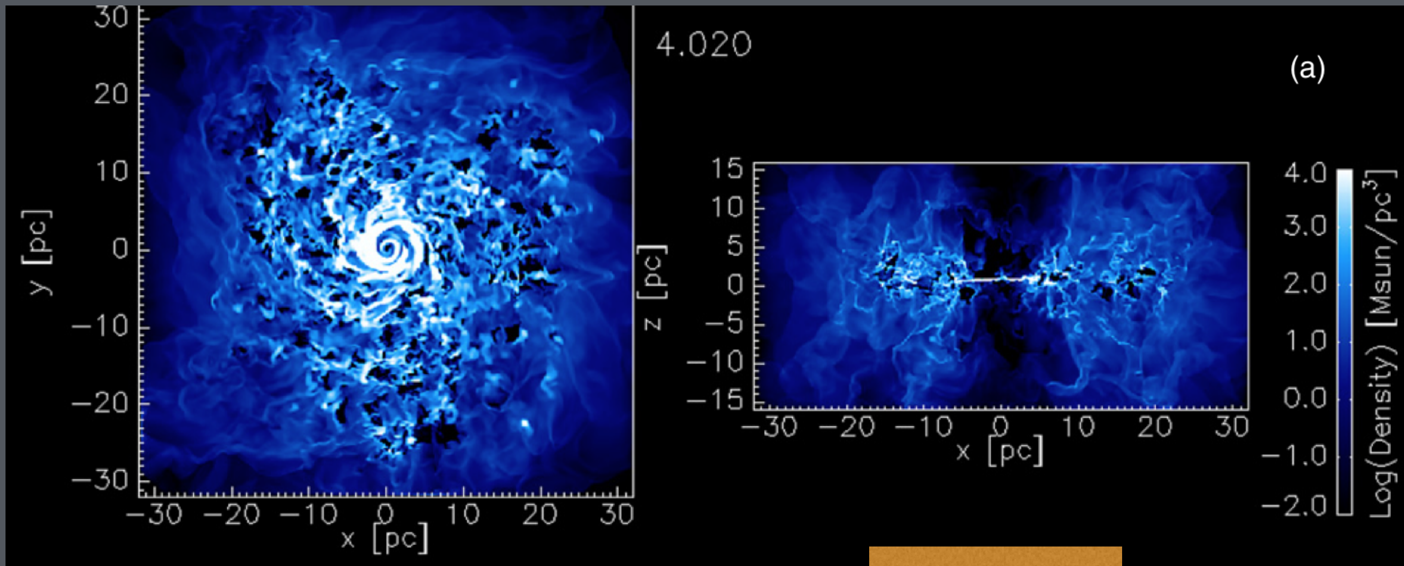


The Seyfert II Galaxy NGC 4945
Direct
ASCA
Ginga
Reflected
AXAF/XMM energy band
HTXS energy band
Photons/cm^2 s keV
10^{-3}
10^{-4}
10^{-5}
10^{-6}
2
5
10
20
Energy (keV)

What does the torus look like?

not really a compact torus.
More of a cloud structure (e.g. Nekova+08)
See also the Hydrodynamical simulations of **Wada+08**

But the most important evidence is the VLT observations which resolve the torus in nearby AGN (Jaffe+04)

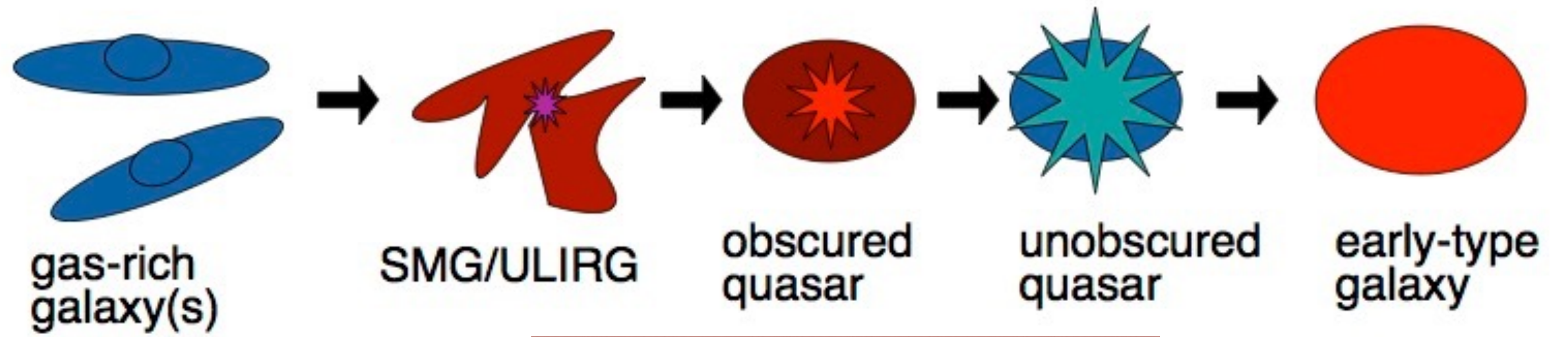


Wada+08

Why are heavily obscured AGN important ?

They may represent a large (evasive) part of the accretion history of the Universe.

Theoretical models postulate that heavily obscured AGN represent the birth of an AGN (e.g. **Hopkins+08**)



Hickox & Alexander 2012

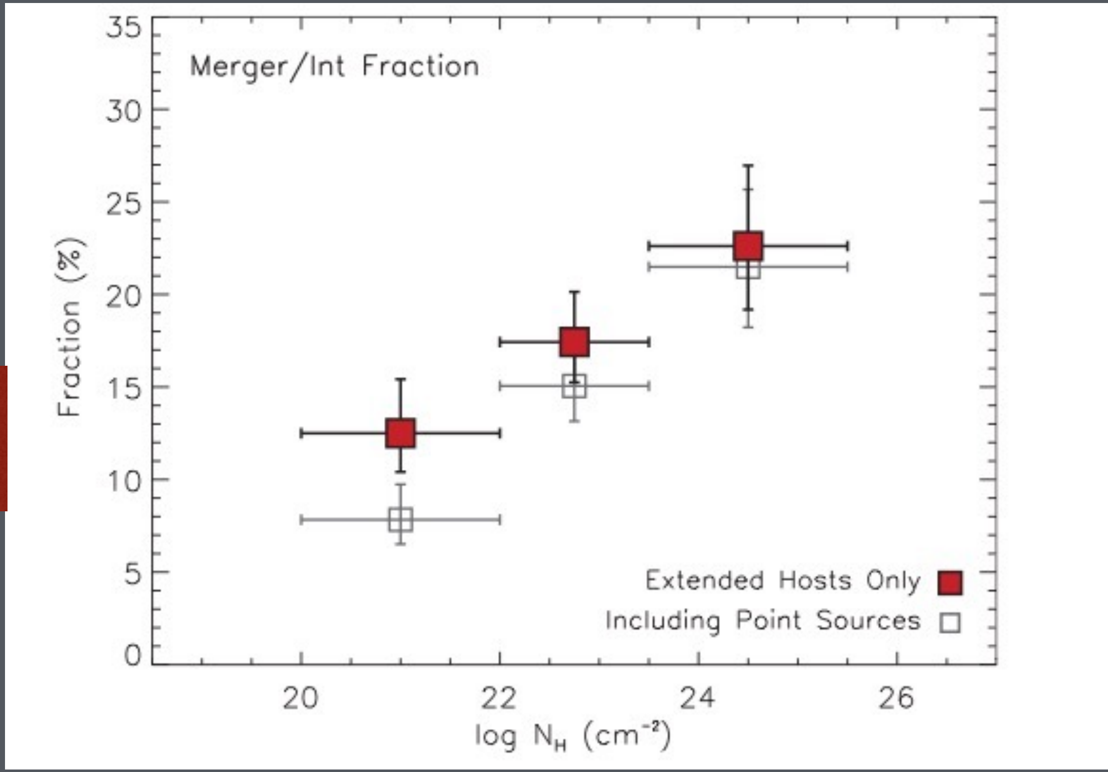
Observational evidence of this scenario ?

Kocevski+15

Morphology of heavily obscured sources with HST

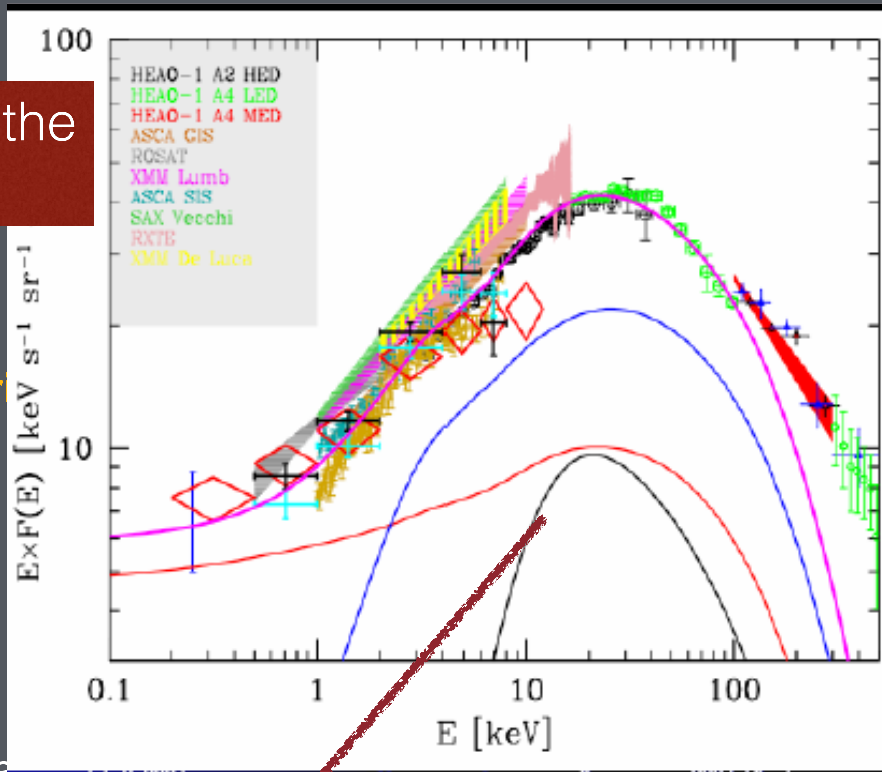
(CDFS, Aegis, COSMOS)

Fraction of mergers vs. column density Nh



Why do we need the most heavily obscured AGN?

An argument often mentioned is that among the nearby AGN most are Compton-thick



Compton -thick

✱Spectrum X-ray background

X-ray background population synthesis models: **Comastri +95,** Gilli+07, Treister+09,Ballantyne+11, Akylas+12, Ueda+14

✱Soltan argument: The Luminosity becomes BH mass

$\rho_{BH} = (k_{bol}/\varepsilon)\,(1+<z>)\, I_o$ (**Soltan82**)

On the basis of this **Iwasawa&Fabian(1999)** claimed that most accretion in the Universe is heavily obscured (assuming a value for accretion efficiency ε)

Density of BH locally factor of 1.5 higher than LFluminosity function (e.g. **Merloni & Heinz)**

Most Heavily obscured AGN in X-ray surveys ($N_H \sim 10^{24}$ cm^{-2})

Ultra-hard X-ray surveys:

SWIFT/BAT

NuSTAR

Hard (2-10keV) X-ray surveys: Chandra and XMM

How do we find extreme obscuration?

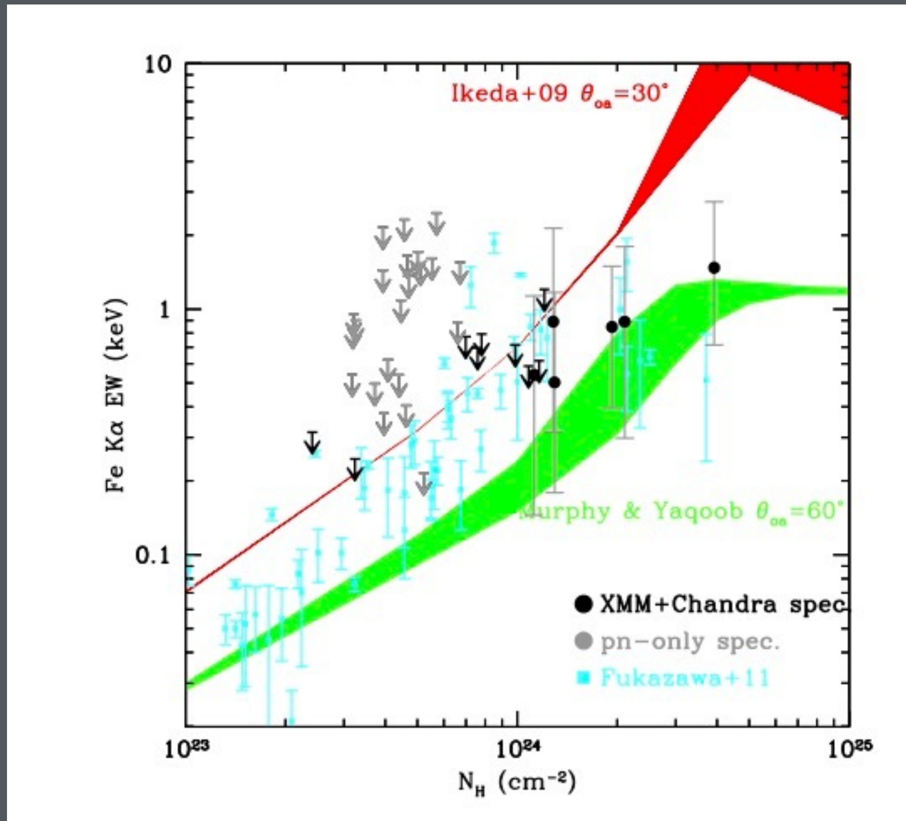
X-ray spectroscopy

Looking for 3 features:

1. The absorption turnover

2. A flat spectrum with Γ~1 indicative of reflection in the back side of the torus

3. An FeKα line with a high EW



Lanzuisi+15

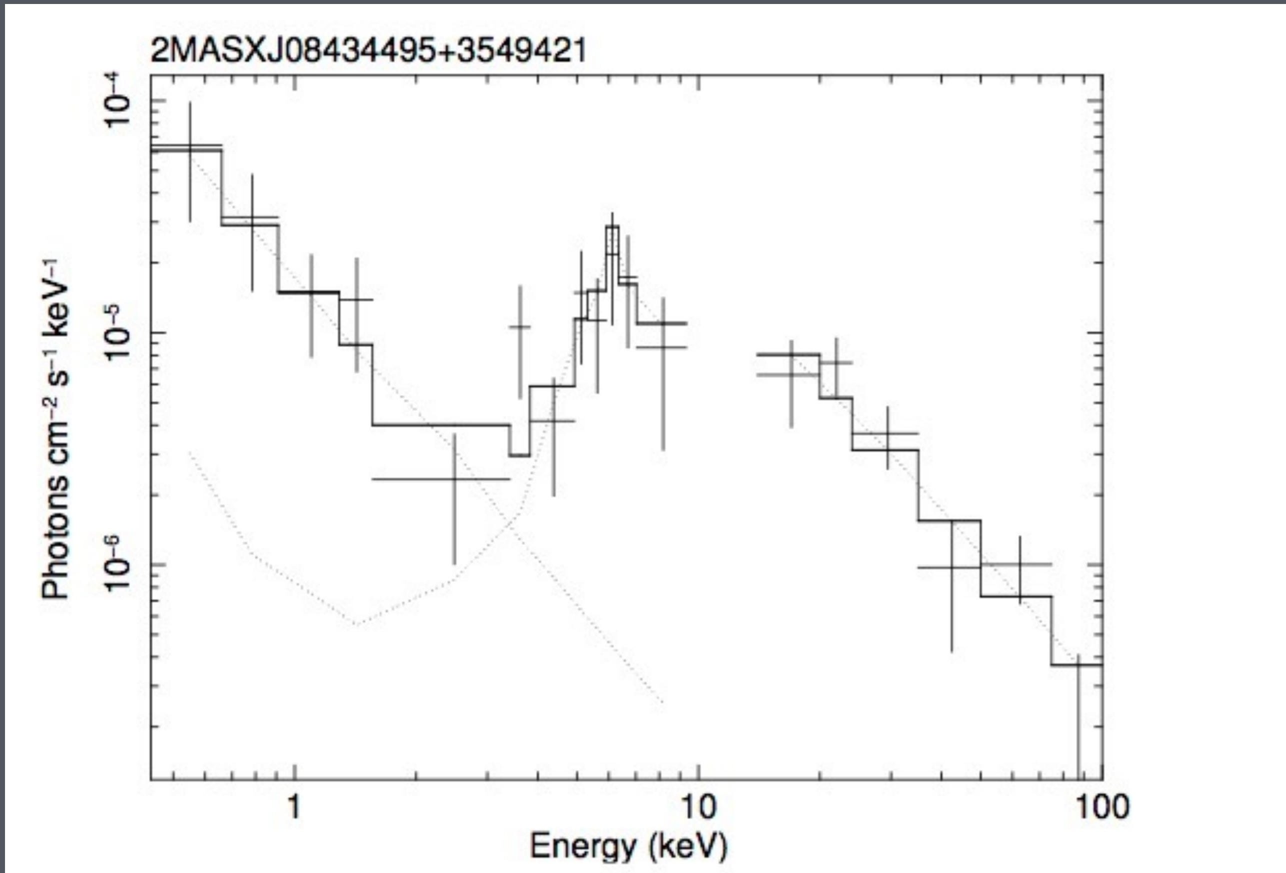
SWIFT/BAT

SWIFT/BAT : All sky survey with coded mask imaging
down to ~10^{-11} erg cm-2 s-1 (14-195 keV) and getting deeper as new scans are added.
Burlon+11, Ajello+13, Baumgartner+13

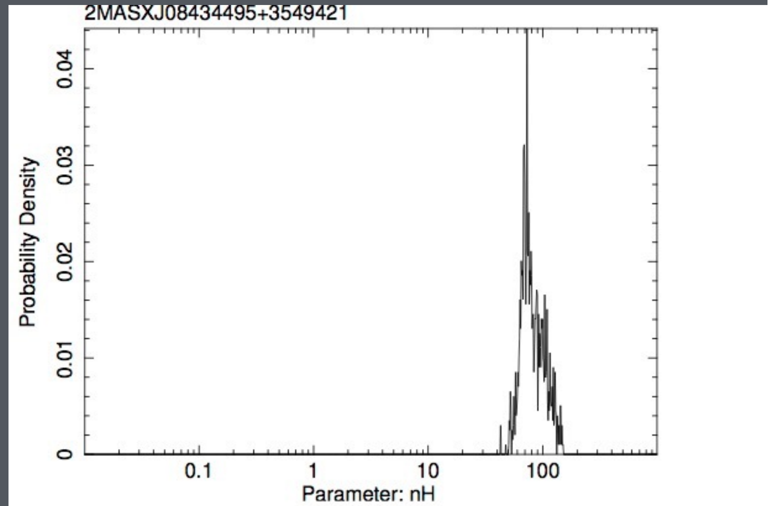
1210 sources with about **700** AGN.

Heavily obscured AGN can be found only by using BAT+XRT
BAT only is not very effective because of the lack of soft energy coverage (two groups, Ricci et al, Akylas et al.)

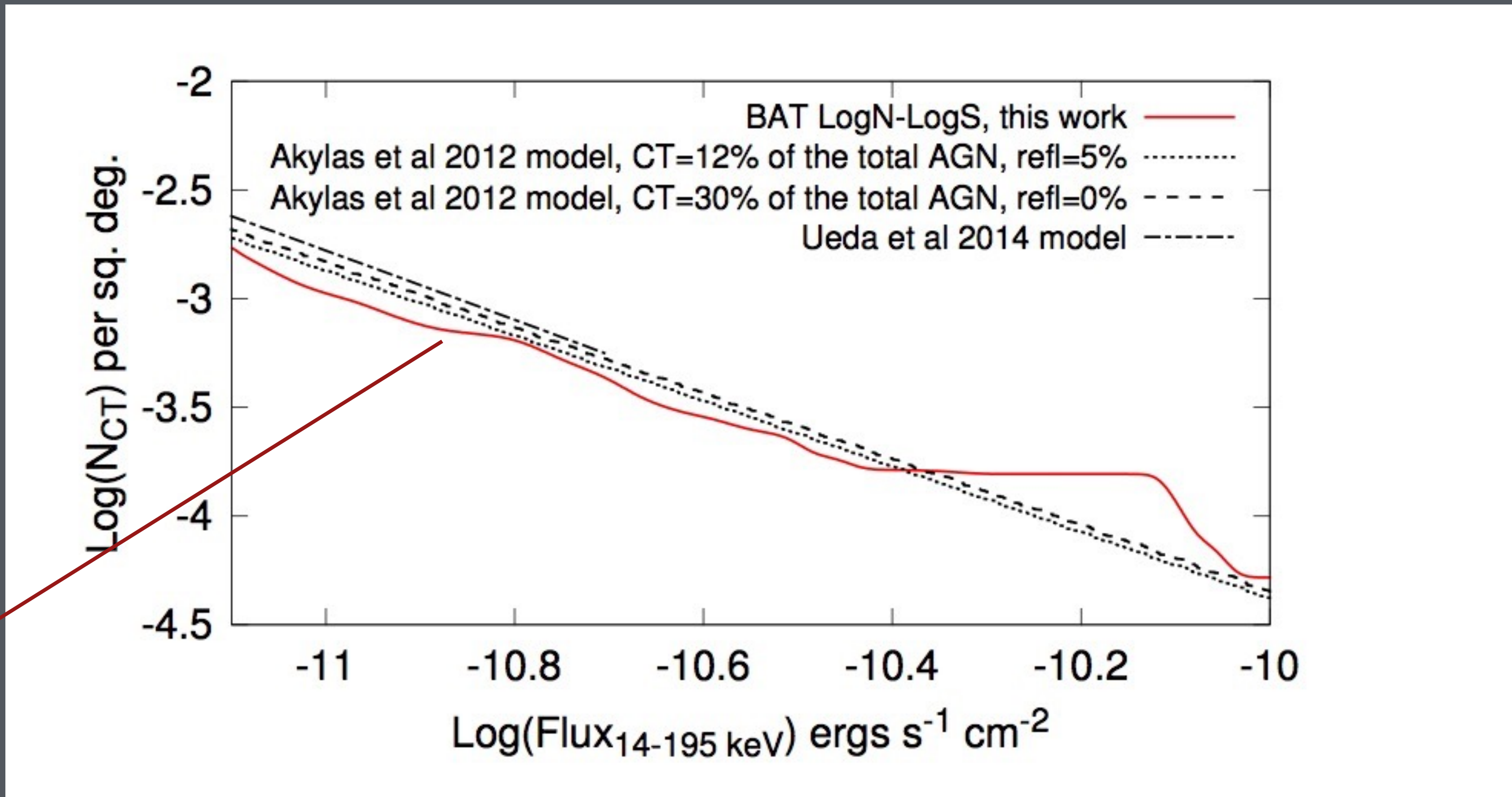
2MASXJ08434495 +3549421



XRT+BAT



Number counts + comparison with models



This work

Note the degeneracy between the reflection component and the fraction of CT AGN in the models

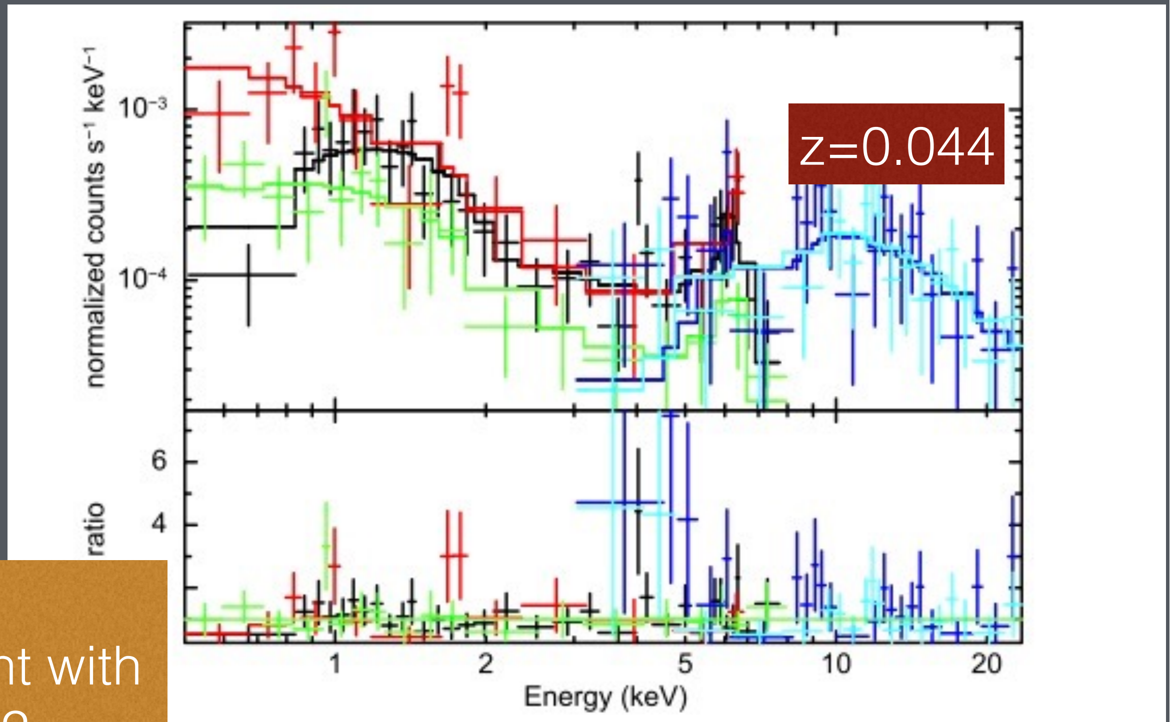
NuSTAR

Alexander+13 serendipitous fields

Civano+15 1.7deg2 COSMOS: 1bona fide CT

Mullaney+15 eCDFS

CT COSMOS



he apparent lack of CT AGN is consistent with
Because of small number statistics
both Gilli+07, Treister+09, Akylas+12

We must go a factor of 3 deeper hitting the confusion limit OR wait for the serendipitous CT sources

Recent Searches for CT AGN at softer energies <10keV

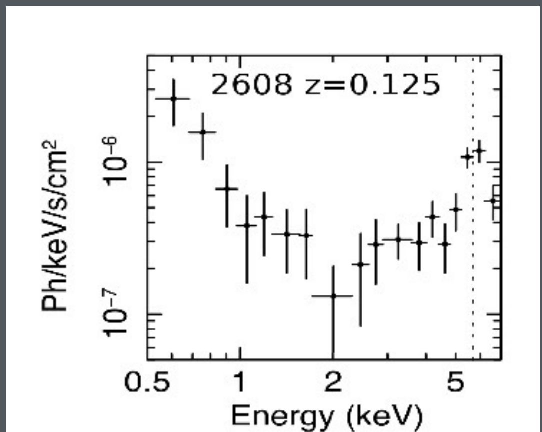
0.5-8 Brightman+14 BUCHNER+15 CDF, AEGIS, COSMOS

2-10 Corral et al. CDFS 7 Ms (in prep.)

2-10 keV lanzuisi+15 COSMOS

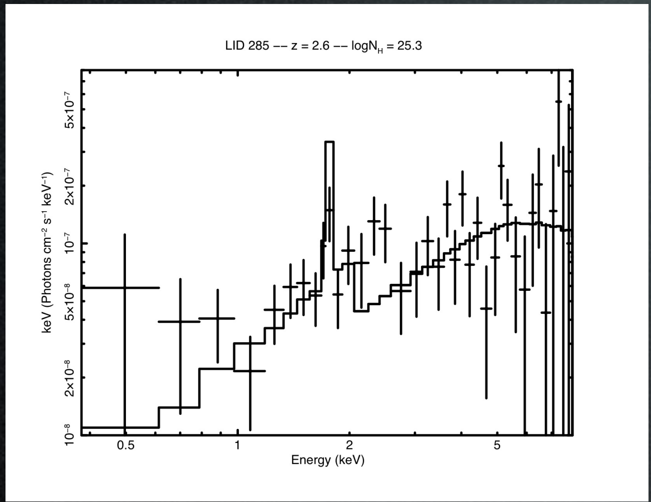
XMM INITIAL selection BUT XMM+Chandra fits are performed

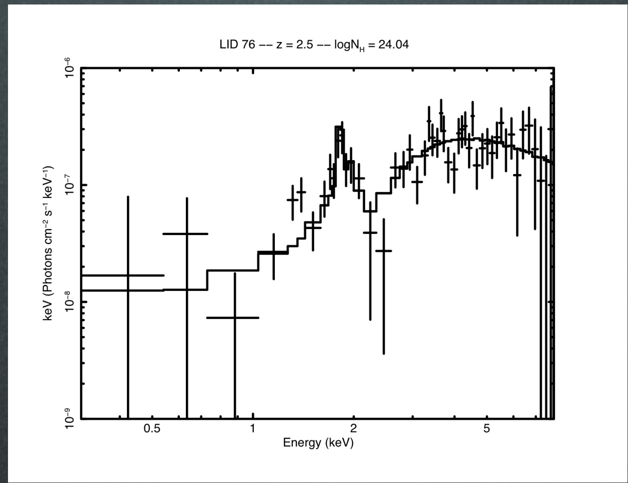
10 CT AGN of which 6 have EW(FeKa) ~ 1 keV

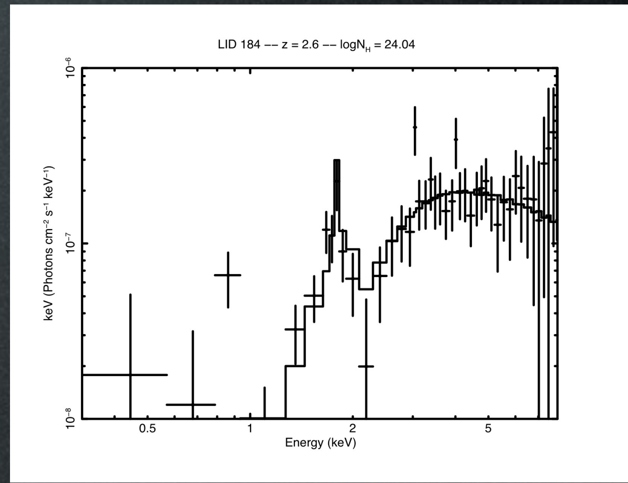


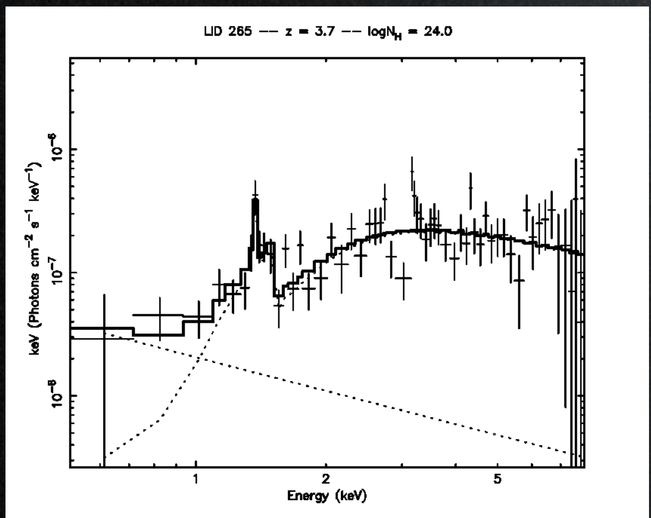
1 common CT in cosmos between the Brightman and Lanzuisi samples at z=0.125

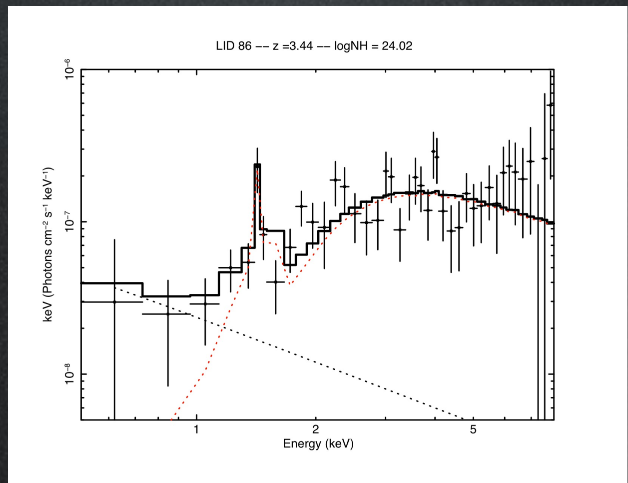
7Ms search Compton-thick (Luo 2Ms catalogue)

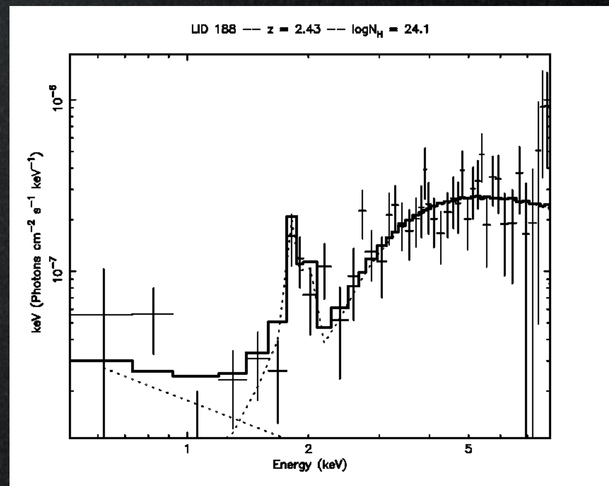




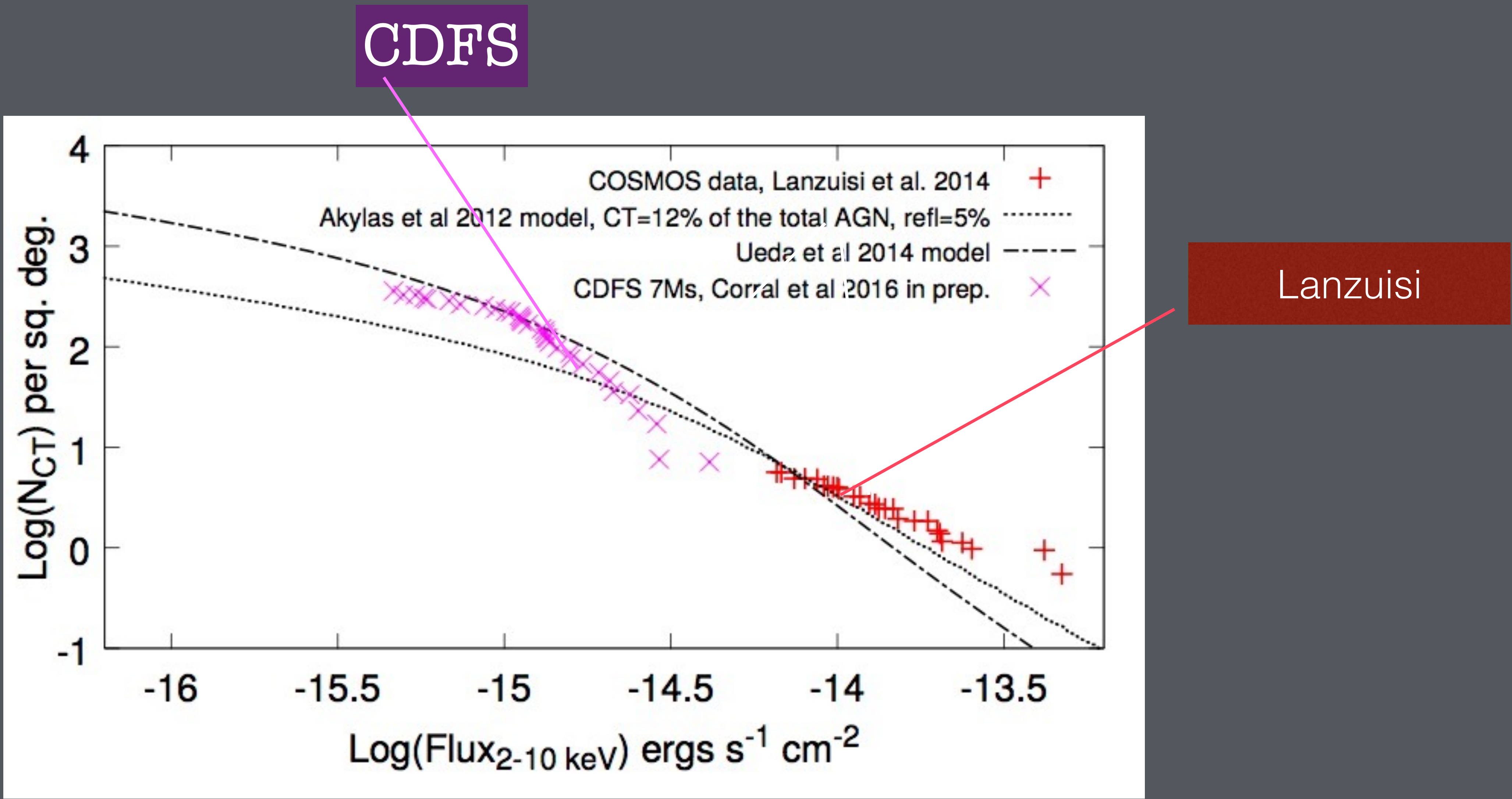








7Ms CDFS + COSMOS vs. models



there may be a a hint for additional evolution of CT AGN with z

IR techniques

- IR can provide insight on obscured objects as the absorbed radiation is re-emitted at IR wavelengths.

In the IR you get both SFR and accretion and the task Is to separate one from the other

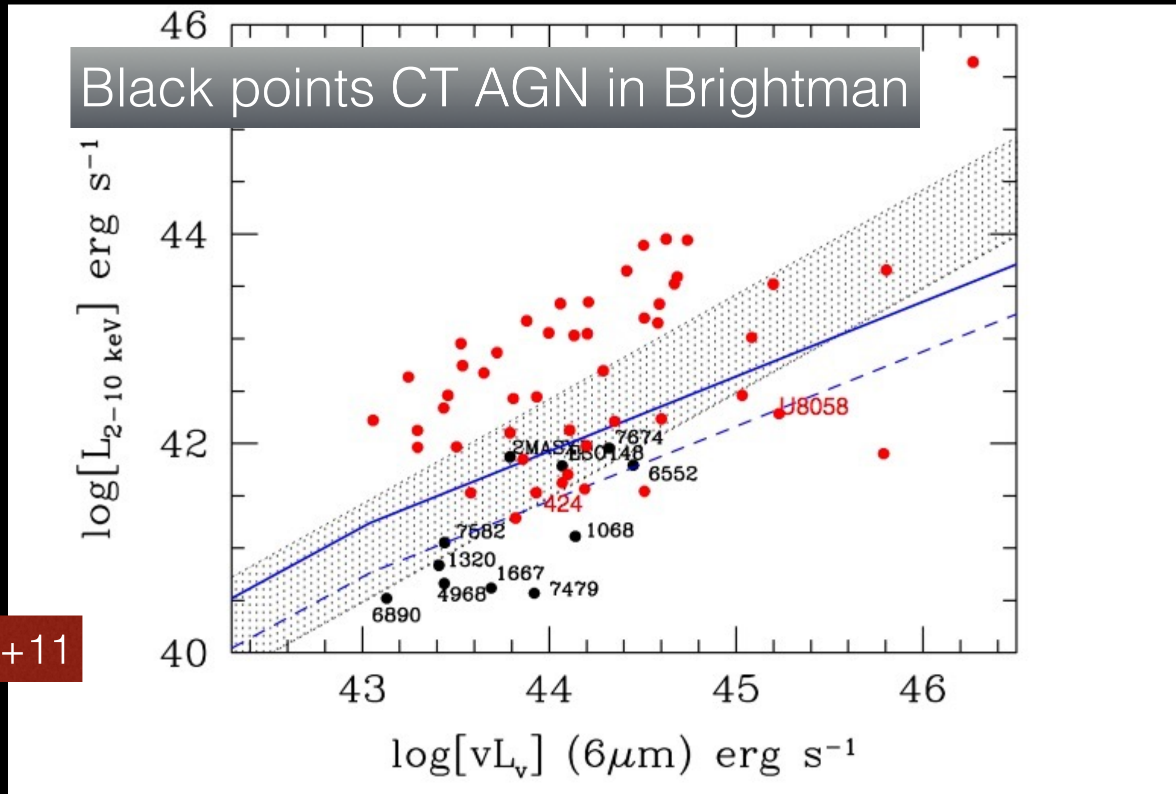
Spitzer/MIPS 24µm CDFS

- AGN SEDs
- $L_x/L_{6\mu m}$ ratio
- Dust Obscured Galaxies (R/24μm)
- IR spectroscopy (Si Absorption)

X-ray to 6μm (or 12μm) luminosity ratio

introduced by Alexander+08

X-ray obscuration relative to the torus emission is an excellent diagnostic as for heavily obscured AGN, **X-rays DECREASE while the torus emission remains constant.**



Rovilos+14 applied this technique in the WISE survey using 3XMM data

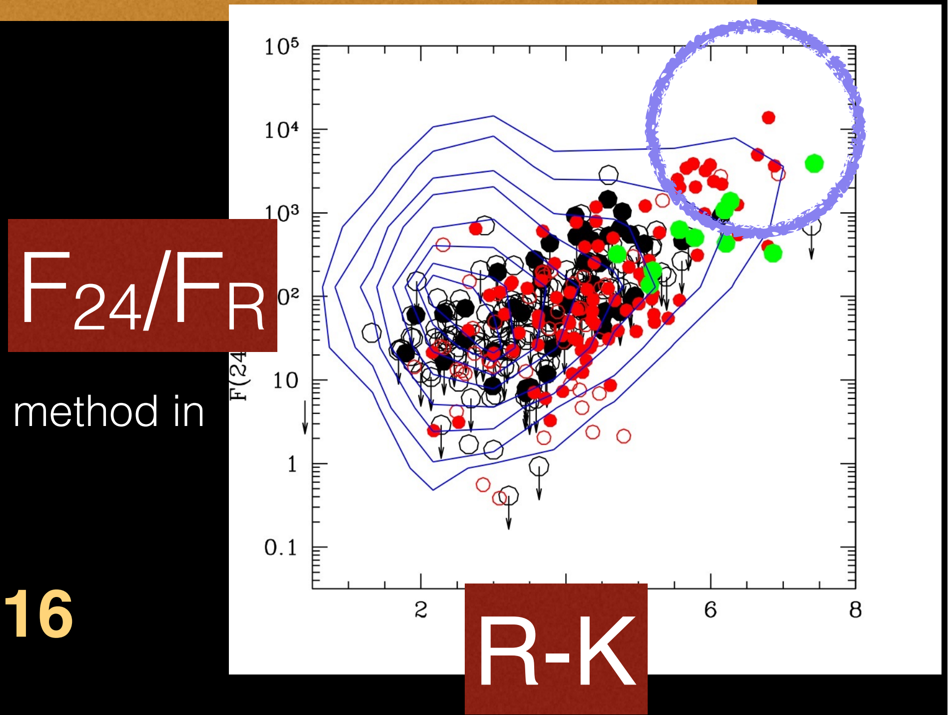
Dust obscured galaxies (DOGs)

High $f_{24\mu m}/f_R < 1000$ ratio

see e.g. Pope+08

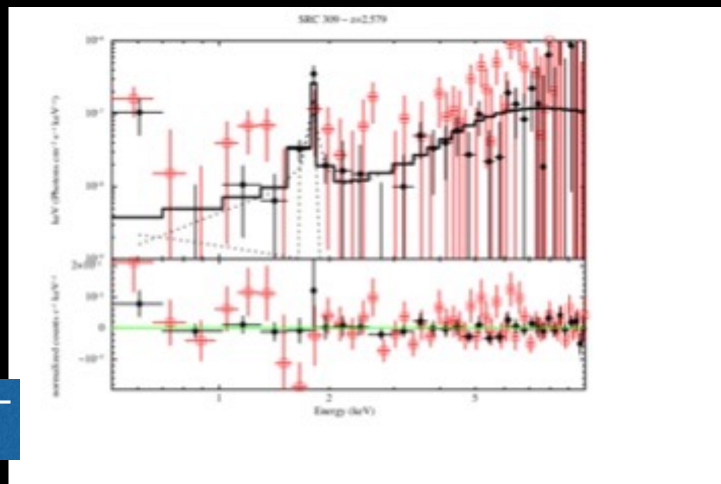
Fiore+08, Georgantopoulos+08, Fiore+09 applied this method in the CDF.S

Some sources are detected in the X-rays: **Corral+16**



6Ms Chandra+3Ms XMM

14 sources: 9 heavily absorbed (at least 1 CT)

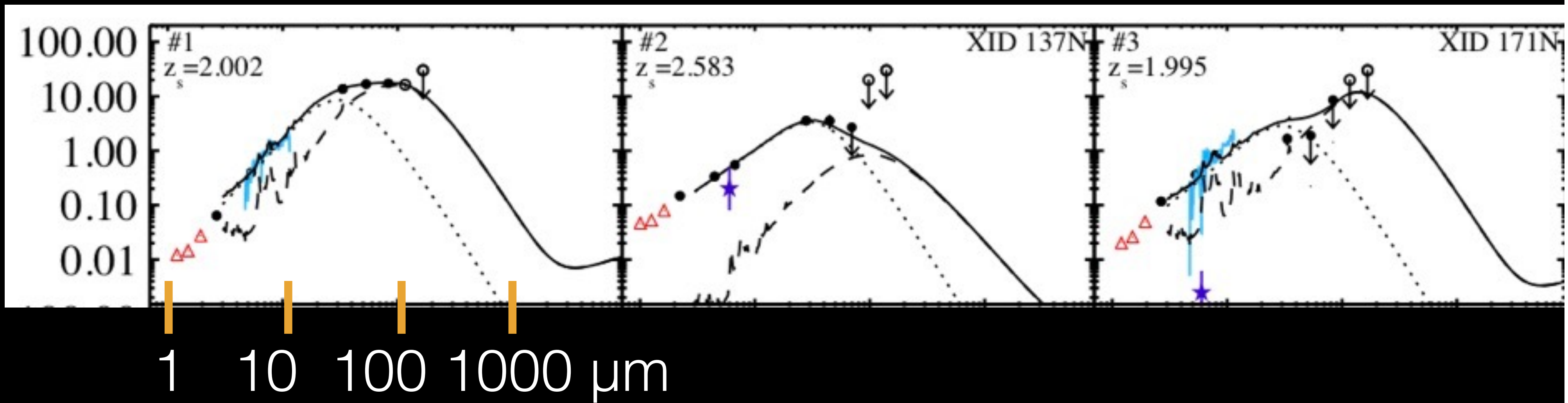


Spectral Energy Distributions

SEDs may provide a more refined way to find the AGN

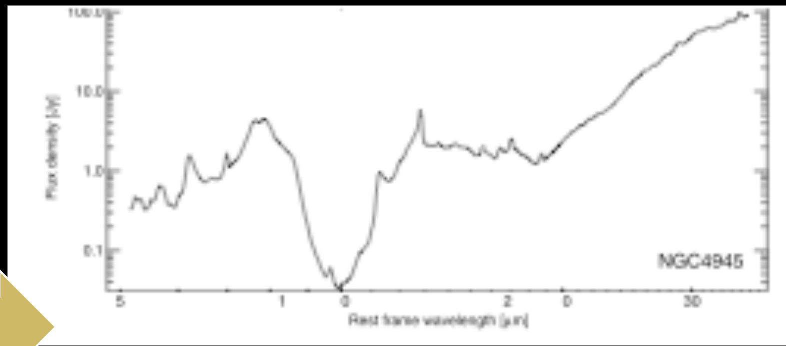
del Moro+2015 derive SEDs (Herschel & Spitzer) in the CDFS for the most luminous mid-IR sources ($L_{6\mu m}$>$10^{44.8}$), redshift z=1-3.

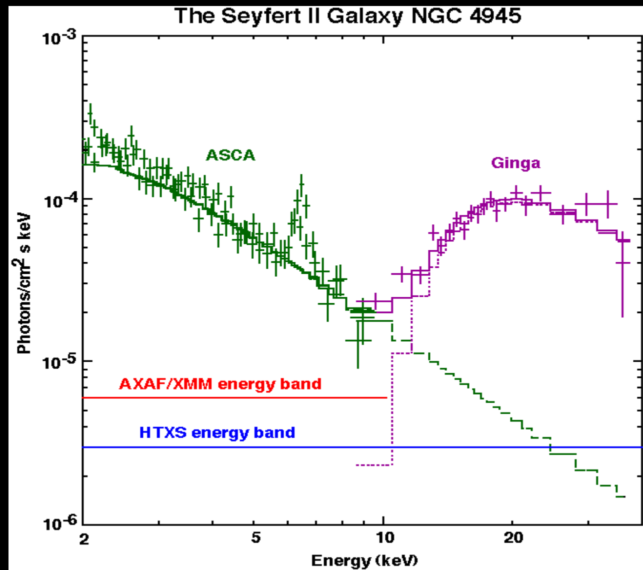
From the SEDs of the luminous AGN, 70% are obscured with N_H> 10^{22} cm-2 , some unobscured while for the non-detected ones it is assumed that they are CT.



Mid-IR spectroscopy: 9.7 Si absorption feature

NGC4945: Spitzer IRS spectra from nearby galaxies Brandl+06

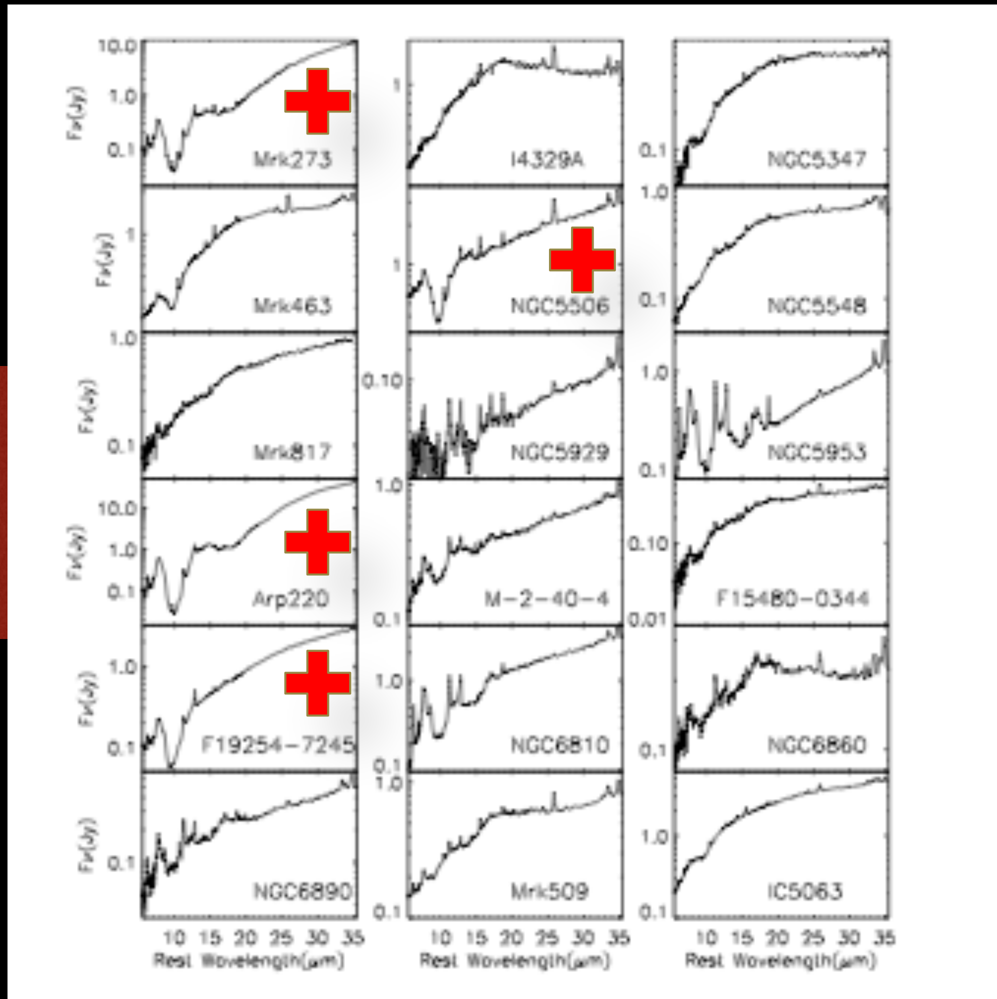




Spitzer IRS observations of the 12μm sample : Wu+09

but see Goulding+12

Note that column density from τ is always lower than $10^{24}cm^{-2}$



Concluding Remarks

The LF of obscured AGN has been extremely well defined (fraction of obscured AGN evolution with redshift, Luminosity) (e.g. Ueda+14, Buchner+14)

Statistically complete samples of CT AGN are found at both high redshift and low redshift in the last couple of years (Akylas+16, Ricci+15, Brightman+14, Buchner +14)

The number of CT AGN is rather low (~15-20% in the local Universe with the exact value depending on reflection but may evolve with redshift)

Comastri+15 point out that the local BH density is higher than previously thought. This can be explained by either non efficient accretion OR a population of very low luminosity Compton-thick AGN. These are very hard to detect even in deep surveys and they play no role to the X-ray background (remember the high density of nearby CT AGN)

Future (X-ray + IR)

eROSITA (3,000,000 AGN). A large number of heavily obscured AGN is expected even in the soft band (a few thousand). The tasks is to identify them. Combination of **ART-XC** and **eROSITA** are or eROSITA and WISE are two routes.

Till then the **3XMM** catalogue provides an invaluable resource. There are many added value products: **XMMFITCAT** provides spectra for 120,000 sources. A prerequisite is the derivation of phot-z.**ARCHES** is the obvious step to exploit this resourceJWST near IR spectroscopy to find the Si absorption feature.

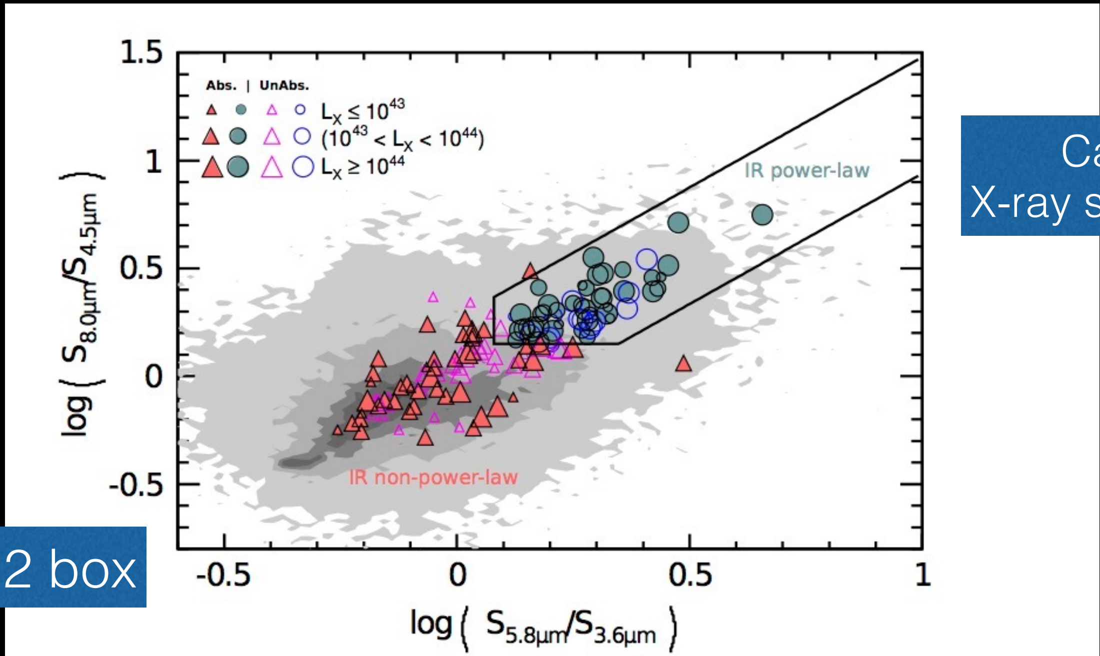
JWST is a mid-IR telescope and e.g. Si 9.7μm

ATHENA will be able to find a very large number of heavily obscured AGN (see white paper by the WG)

THE END

[redacted]

IR colours



Castello-Mor+13
X-ray sources XMM/CDFS

Donley+12 box

Colours are used as a thermometer of the dust: hot dust is heated by the AGN

Spitzer boxes: Donley, Stern, Lacy

comparison with X-ray Barmby+06, Georgantopoulos+08, Castelo-Mor+12

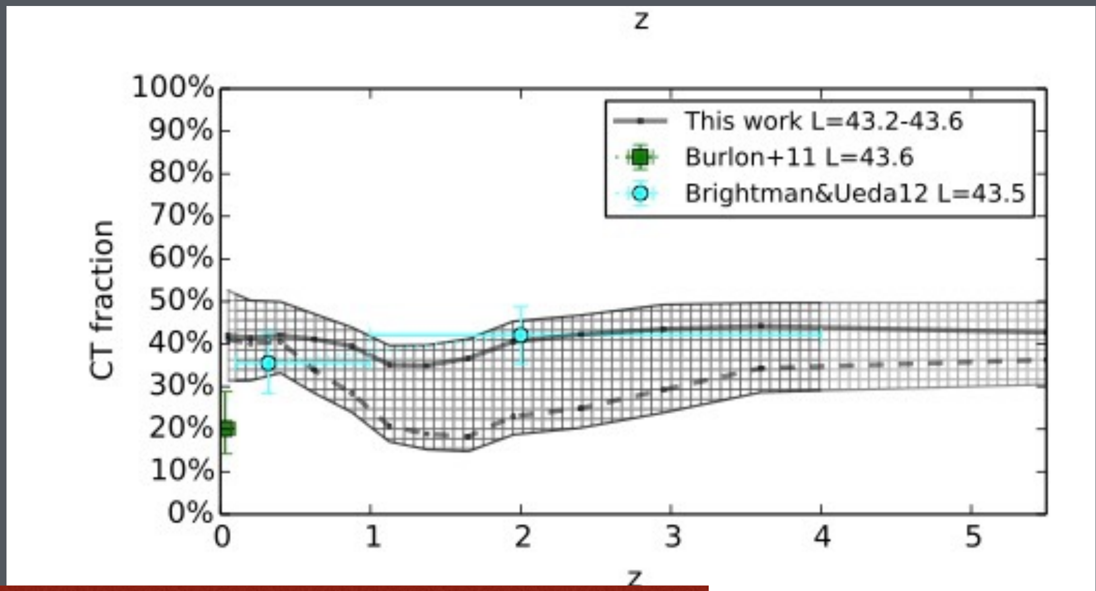
Similar boxes in WISE: Stern+12, Mateos+12 (Secrest+15)

Yan+13 propose r-[4.5] colour to select the obscured ones

The X-ray surveys have provided a good knowledge of the AGN luminosity function (LF) and its evolution (a few thousand cf. tens of thousand in the optical)

e.g. **Aird+11, Aird+15, Ueda+14, Miyaji+15, Buchner+15, Ranalli+15**
see also Vito+14, 15, Georgakakis+15 present the high-z (z>3) LF

Of particular interest for this talk : **Buchner+15** present the LF and its evolution as a function of the column densiry



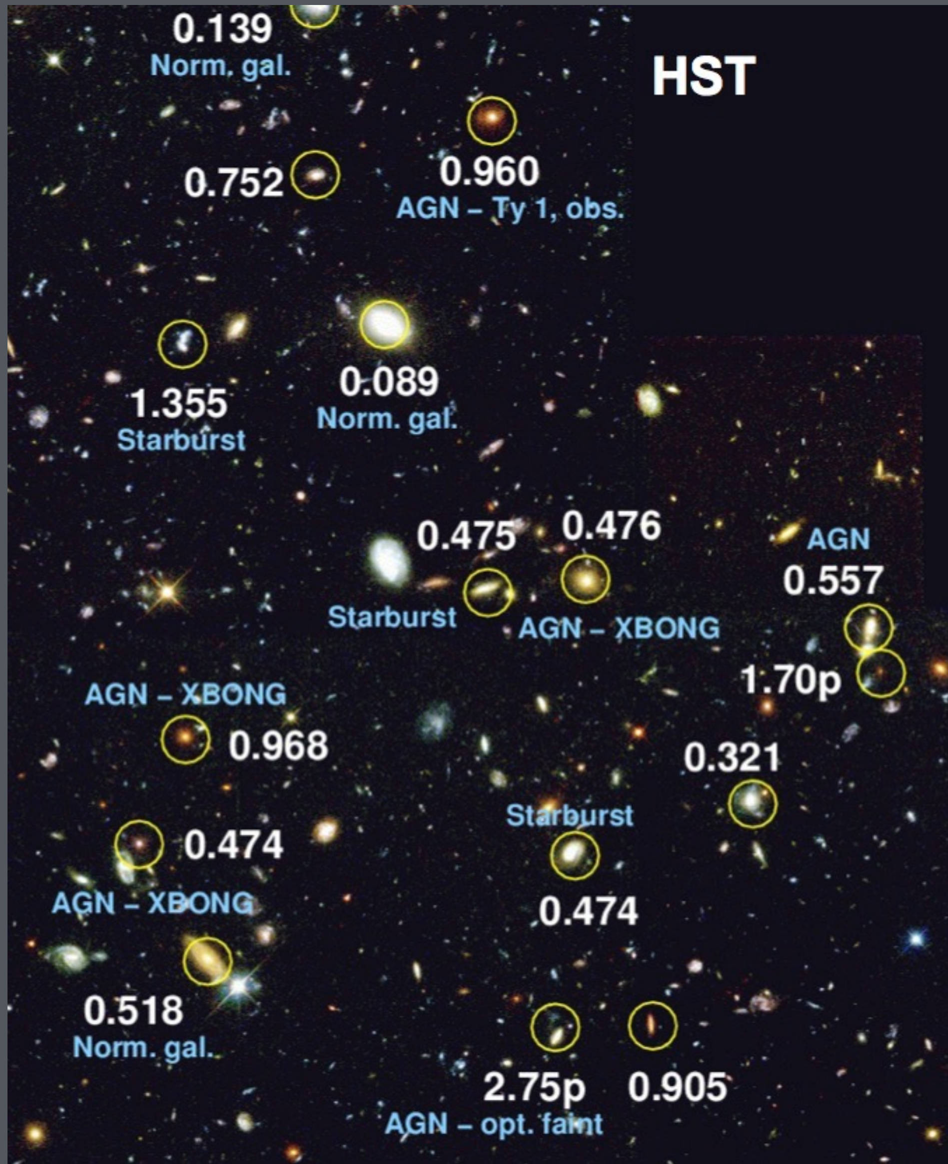
Buchner+15, AEGIS/XXL/COSMOS/CDFS

HST vs Chandra 2 Ms

* Just to be fair: optical surveys can sample low luminosities using optical spectroscopy (**Bongiorno+10, Heckman+09 vs Georgantopoulos+10, Gilli+10**

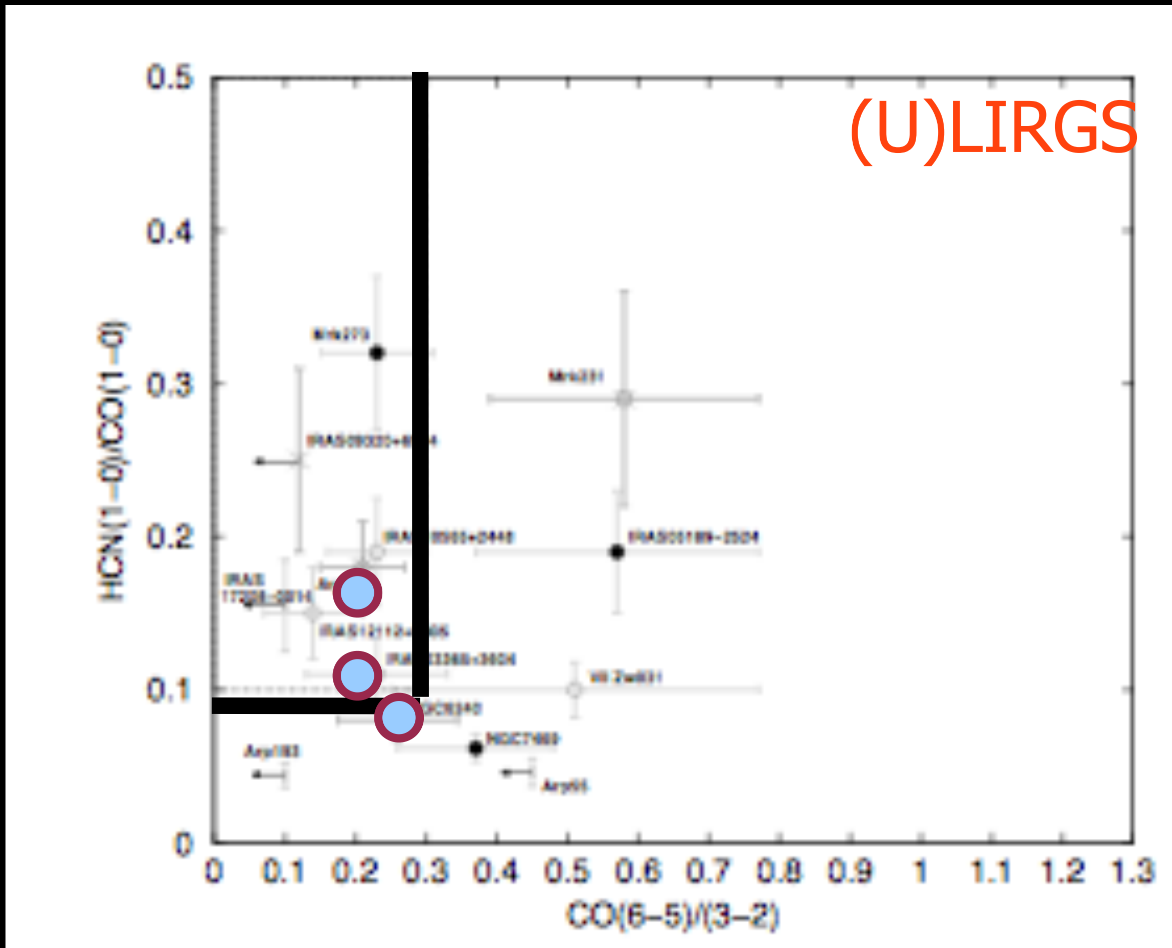
  Also variability studies [**e.g. Vilforth+11, Palanque+10]**

  An underlying sea of galaxies most of which contain BH remain undetected



N. Brandt
PennState

Molecular lines as a probe of highly obscured AGN

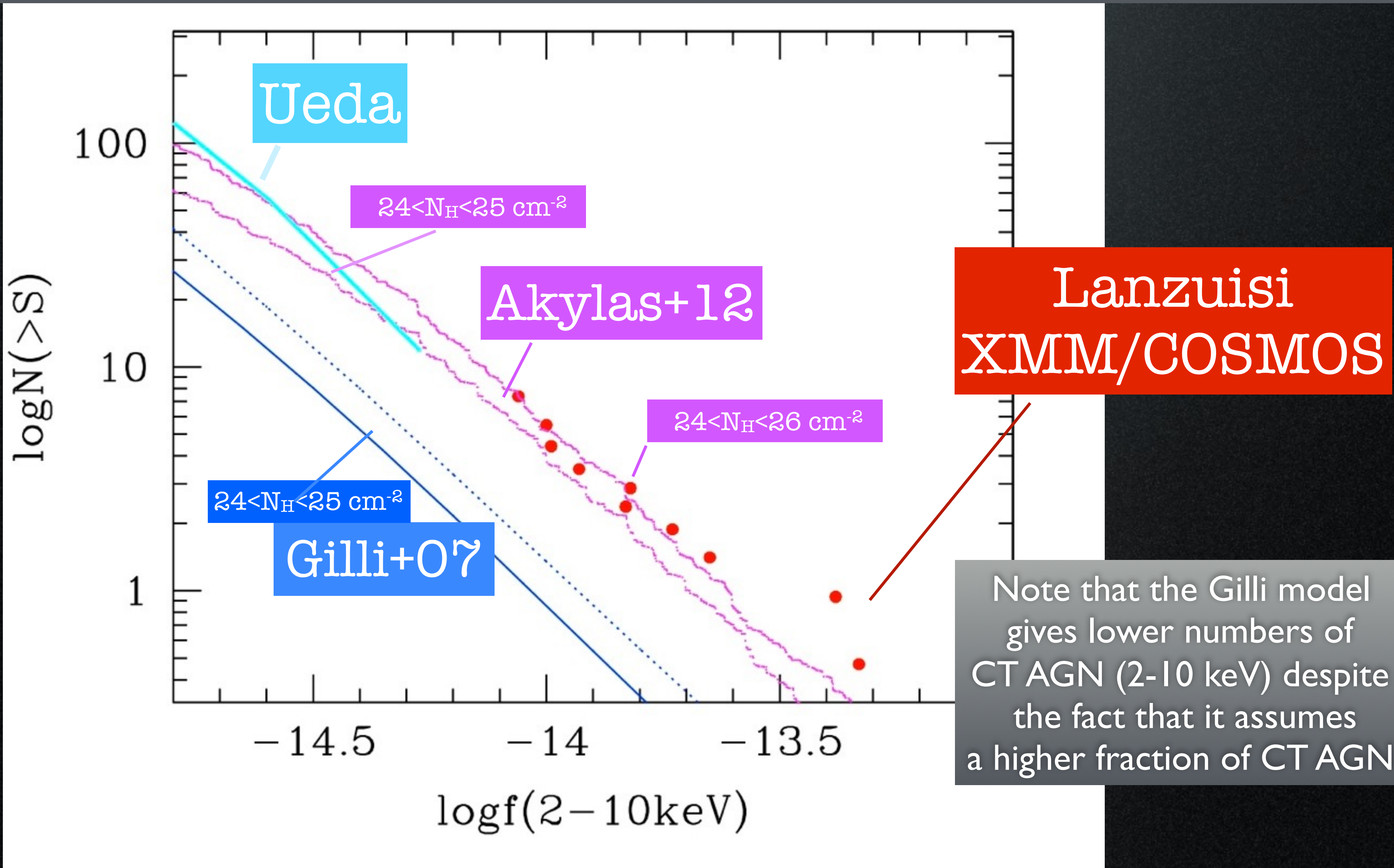


Papadopoulos+10 (observing ULIRGS from HERCULES Legacy Spitzer survey)
Proposed that high Dust obscuration can be probed with CO flux ratios

but see Aalto+15

Obscuration is that high (AV~4000, NH~10^{25}) that can absorb sub-mm wavelengths !!

COMPARISON WITH MODELS: 2-10 KEV

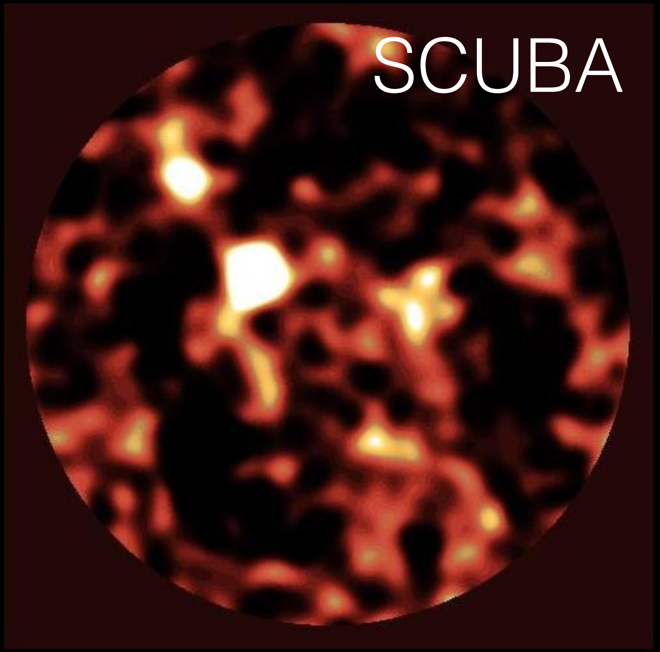


Note that the Gilli model gives lower numbers of CT AGN (2-10 keV) despite the fact that it assumes a higher fraction of CT AGN

sub-mm galaxies

These massive star-forming systems at z>2 have been proposed as sites where SFR and BH galaxy growth simultaneously take place with the majority being candidate CT sources
Alexander+05 matched using radio positions

Laird+11 in the CDFN challenged these claiming a low number of AGN.
Similar results were claimed in the CDF-S (based on LABOCA sub-mm sources
Georgantopoulos+11 matched via 24 Spitzer) The AGN fraction was found less than 20%



Wang+13 using ALMA observations made a step forward finding an AGN fraction of 17%