The search for heavily obscured AGN in the Chandra Deep Fields, and prospects for SPICA

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The quest for obscured AGN at different cosmic times

Obscured SMBH growth as a key phase in AGN/galaxy life

Needs for a complete AGN census

⇓

see review talk by Comastri

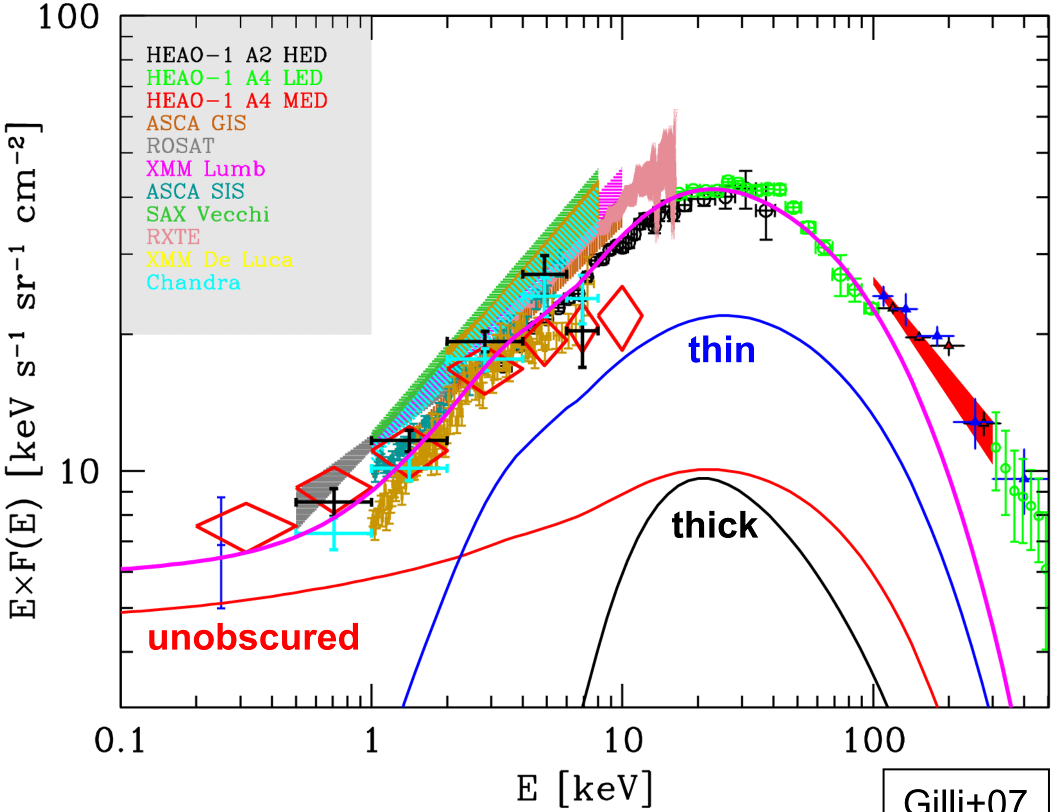
X-ray surveys

Combined mid-IR/opt/X-ray

Optical spectroscopy

The strength of deep X-ray spectroscopy and SED fitting (including the mid-IR/far-IR) − SPICA

Obscured AGN and their role in XRB models



Gilli+07

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 and Ballantyne…

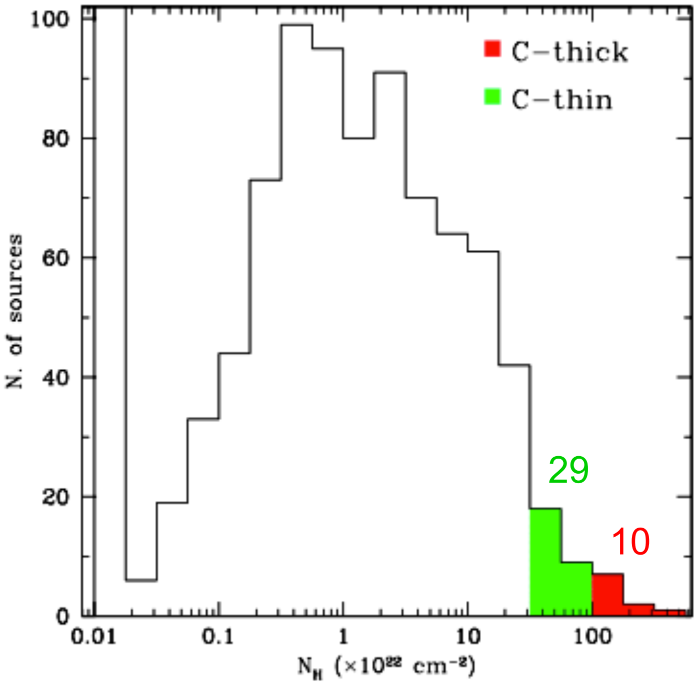
Much of the mass growth of SMBH occurs during the heavily obscured phase? (e.g., Treister+10)

Strong winds/outflows (=feedback) expected in the "blowout" phase

Recently, on the very obscured AGN issue

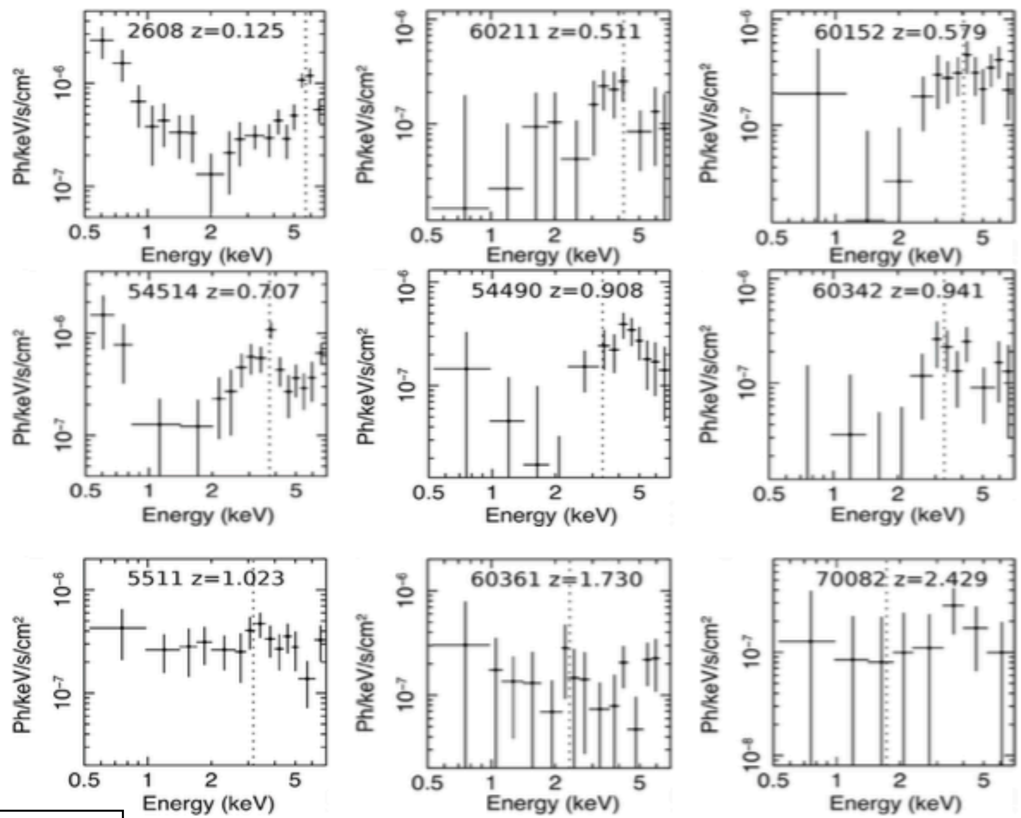
Compton-thick AGN in the COSMOS survey

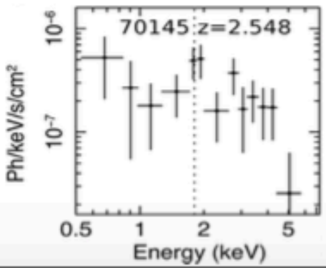
Searching for the most obscured AGN
Almost complete X-ray spectra coverage



see also Del Moro et al. 2015
in the Chandra Deep Fields,
and Buchner et al. 2015

Lanzuisi+15a



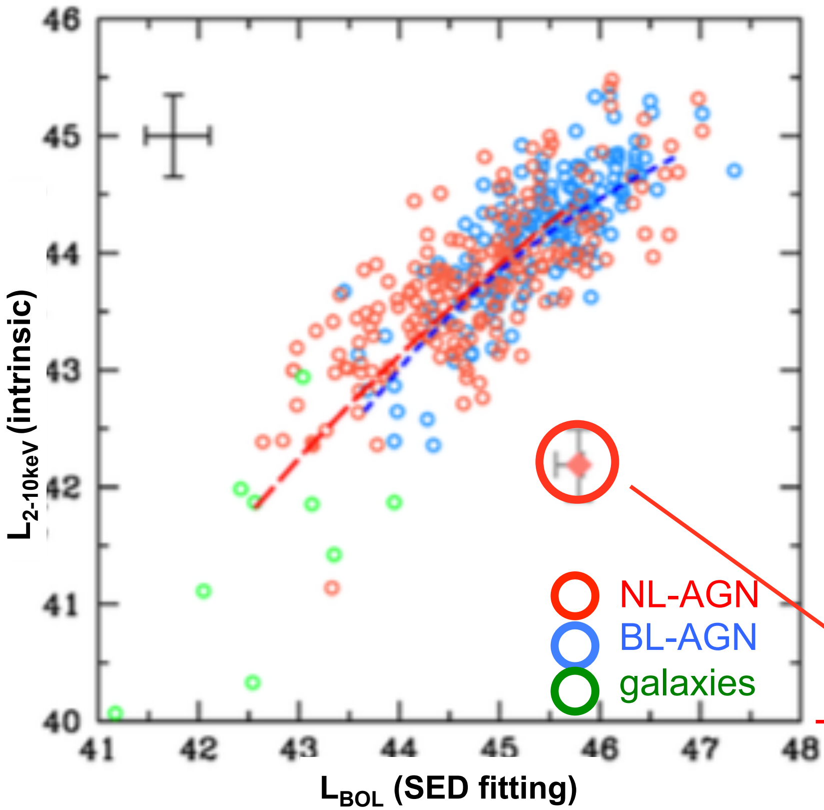


z=0.1−2.5
$\log L_{2\text{-}10keV}$≈43.5−45

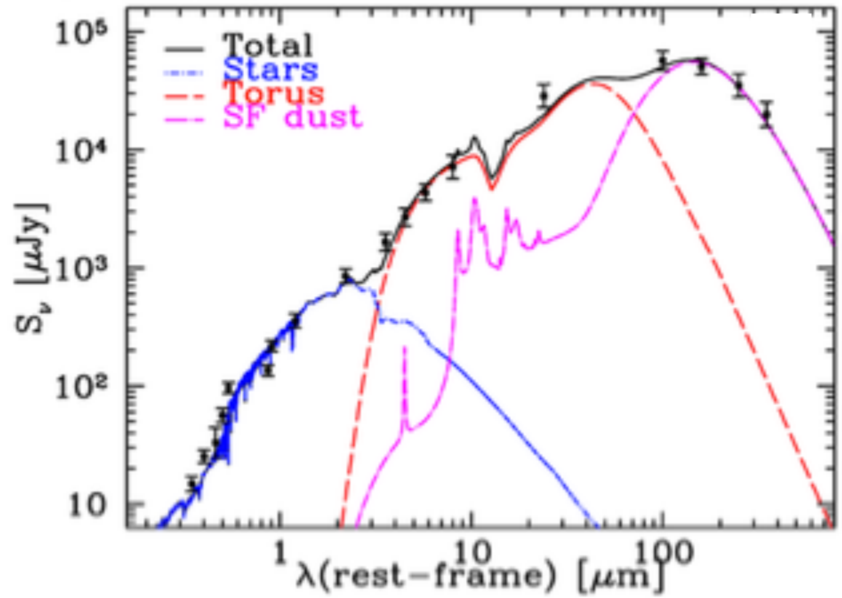
Typically, low-SNR X-ray spectra,
careful modeling needed
HR selection may be not appropriate
if a soft component is present at low z

The most obscured AGN in the COSMOS (field) – I.

The power of combining X-ray vs. mid-IR information (from SED fitting)



z=0.35 ULIRG in COSMOS
Similar to DOGs (MIR/O>1000) but at much lower z

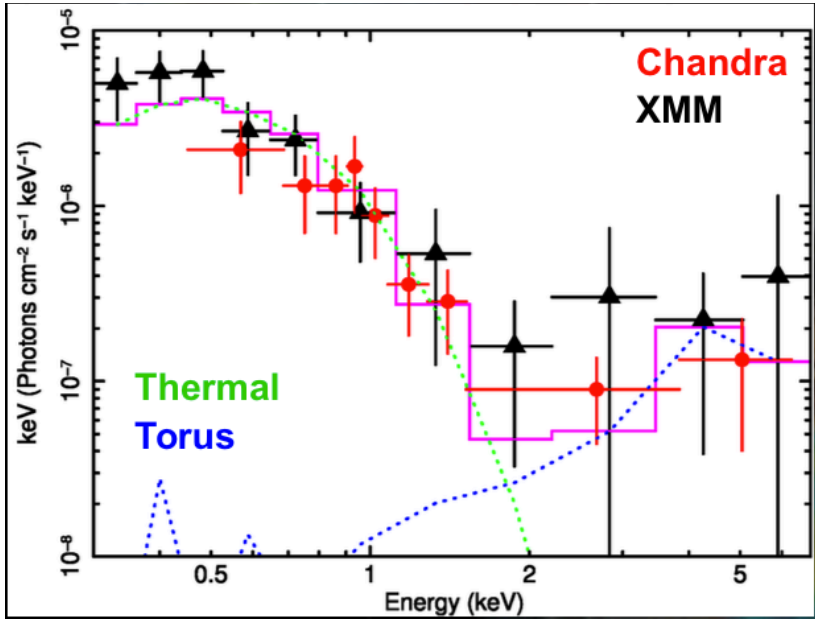


Lanzuisi+15b

The measured L_X is too low compared to L_{BOL} assuming a "standard"
$k_{BOL}=L_{BOL}/L_{2\text{-}10keV}$

Typically, low-SNR X-ray spectra, careful modeling needed

The most obscured AGN in the COSMOS (field) – II.



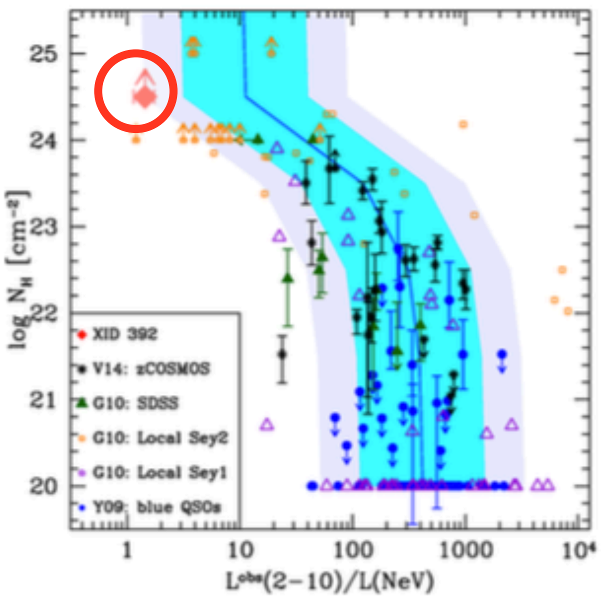
Checks with different models to account for obscuration (MYTorus, etc.)

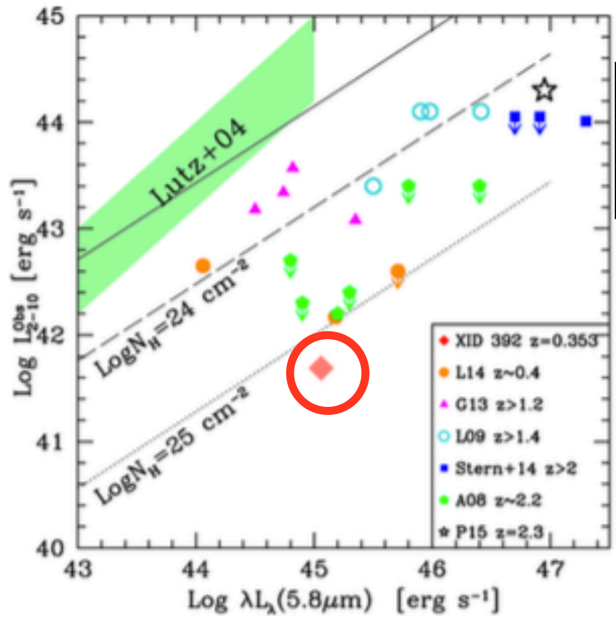
Strong soft X-ray emission may 'hide' the Compton-thick nature of the sources in case of simple hardness ratio analysis

Lanzuisi+15b

"diagnostic" diagrams

Log N_H vs. $L^{obs}_{(2\text{-}10keV)}/L([NeV])$





Log $L^{obs}_{(2\text{-}10keV)}$ vs. Log $\lambda L_\lambda(5.8\mu m)$

Using *Chandra* Deep Field data

Selection of obscured AGN candidates

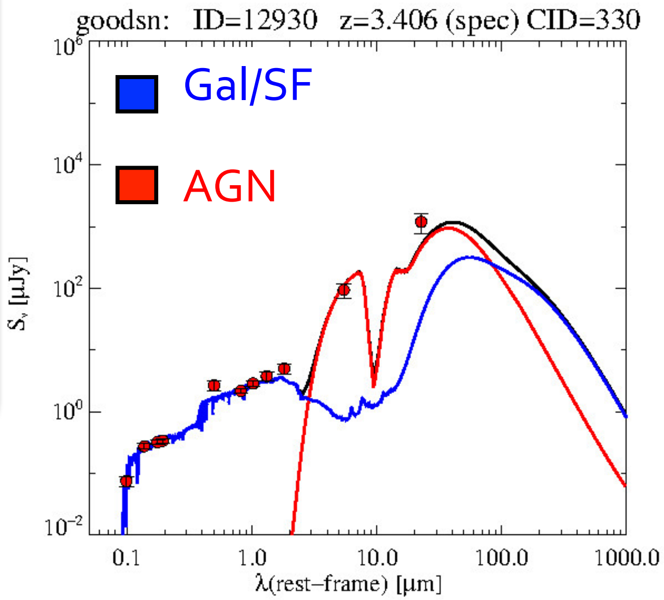
Delvecchio et al. (2015): *Herschel*-selected galaxies in GOODS and COSMOS
(goal: to study BHAR vs. SF as a function of cosmic time via SED fitting)

X-ray detection in 4Ms CDF-S and 2Ms CDF-N catalogs (Xue+11; Alexander+03)

Likely presence of an AGN from SED decomposition (using modified MAGPHYS)

X-ray spectral analysis to constrain N_H and derive intrinsic L_X

Intrinsic L_X predicted from L_{BOL} (SED fitting) + k_{BOL} $>10\times L_{X,observed}$



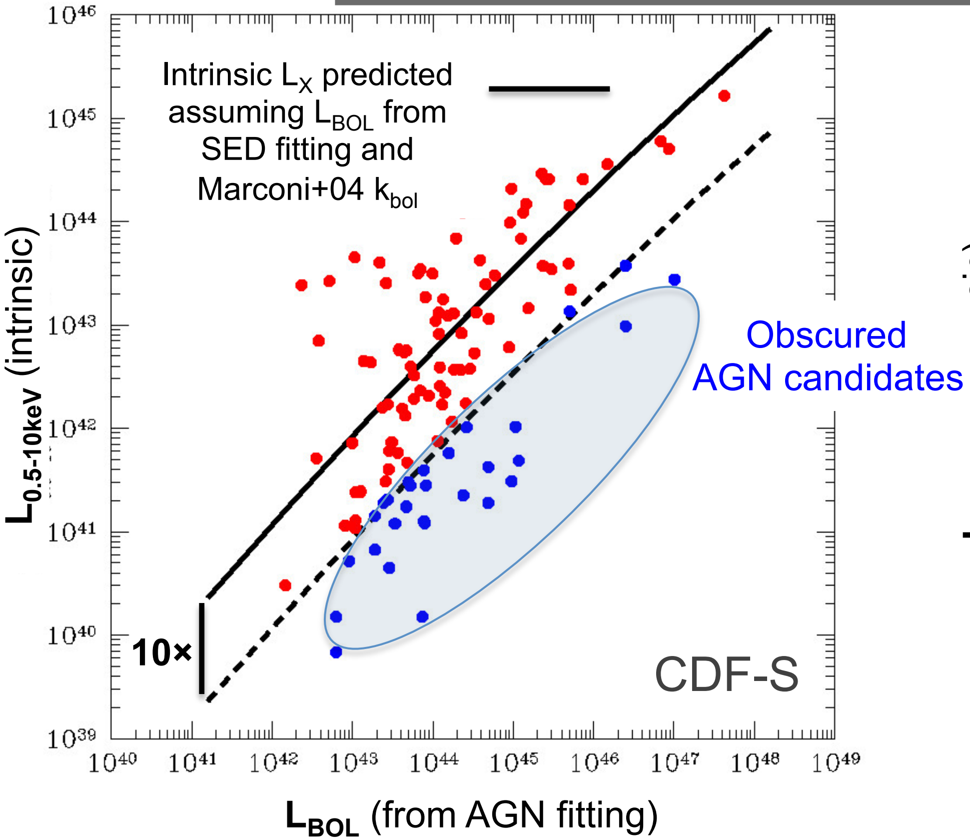
Not a complete selection

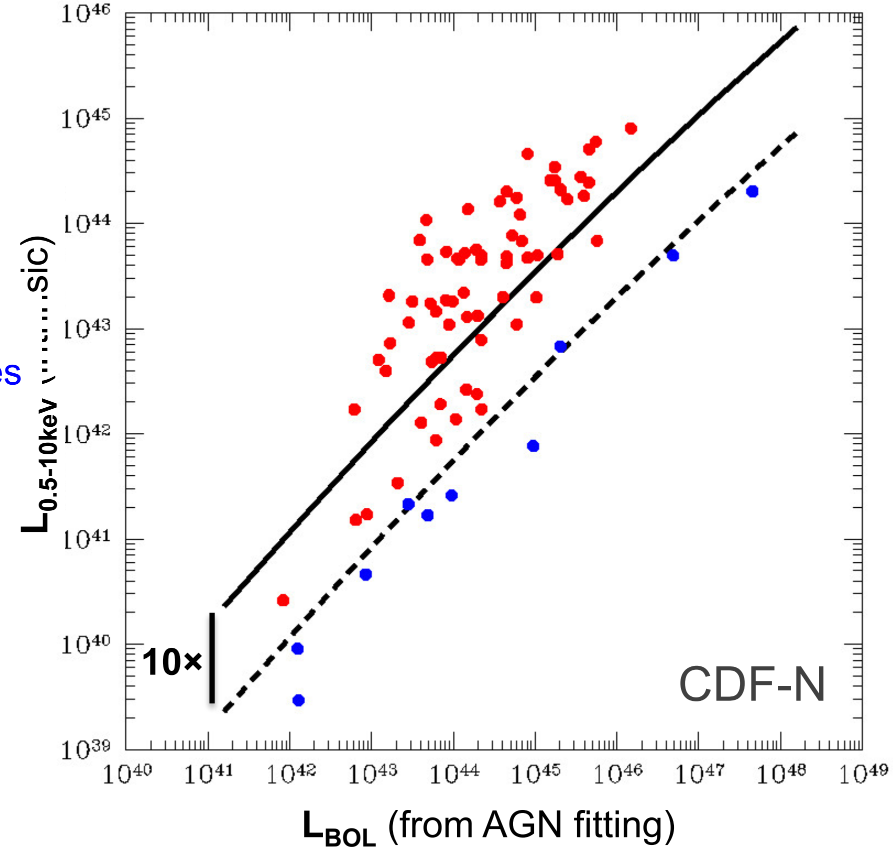
CDF-S
29 obscured AGN candidates

z=0.07−3.51
<z>≈0.8

CDF-N
10 obscured AGN candidates

Red + **blue** datapoints: 115 (CDF-S) and 79 (CDF-N) sources with X-ray detections and AGN apparently required in the mid-IR (SED fitting)





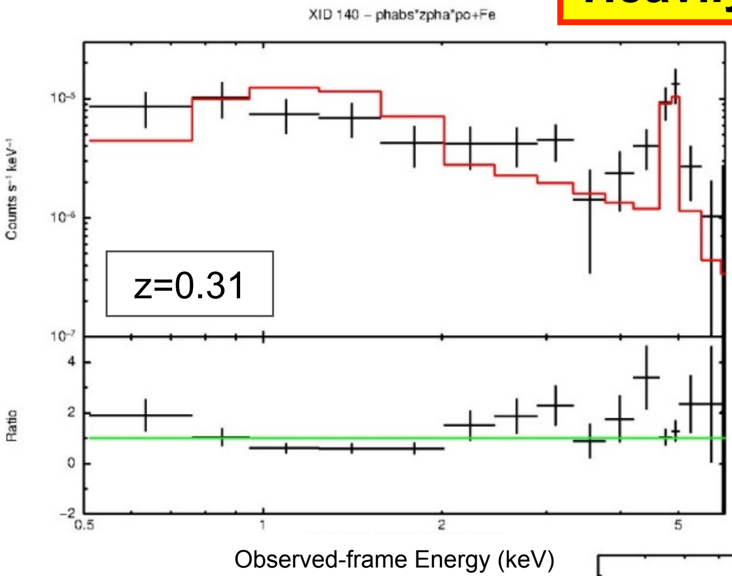
L_{BOL} ➔ intrinsic L_X vs. measured L_X
Difference likely ascribed to obscuration

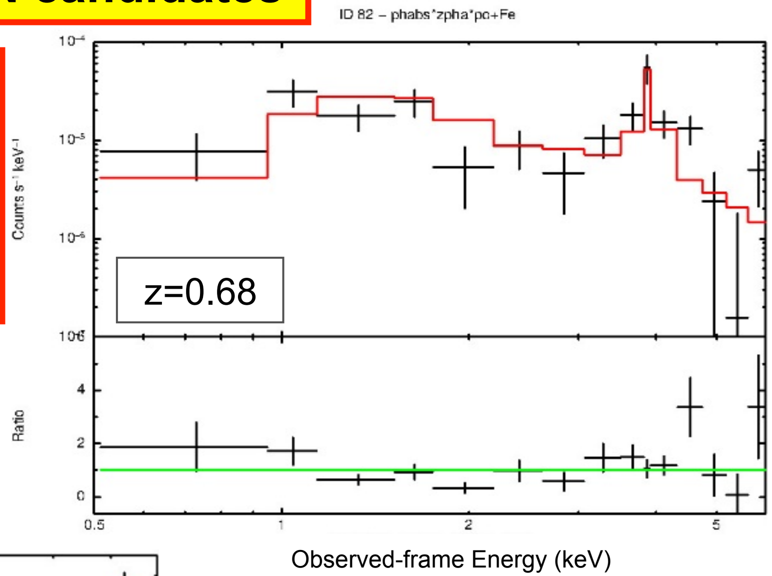
Modeling the X-ray spectra. I

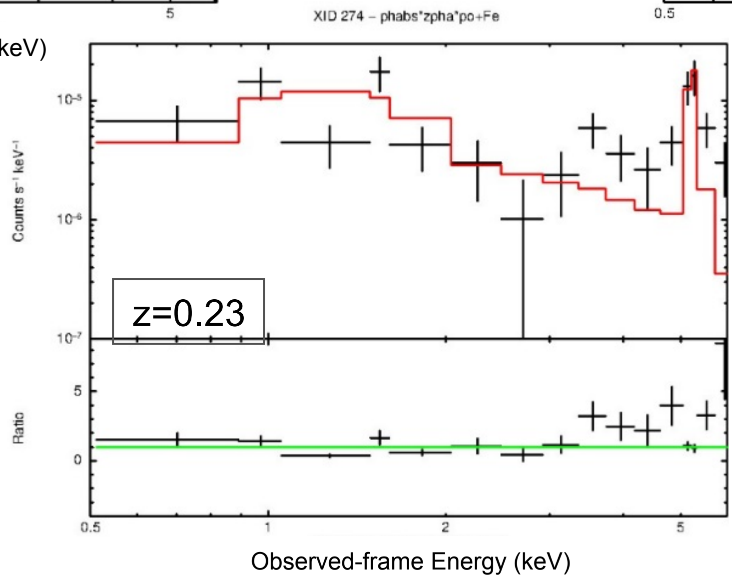
Net counts=[20−560, av.=100] **CDF-S** − [220−150, av.=50] **CDF-N**

Heavily obscured AGN candidates

Recently available
7Ms data CDF-S
+
2Ms data CDF-N





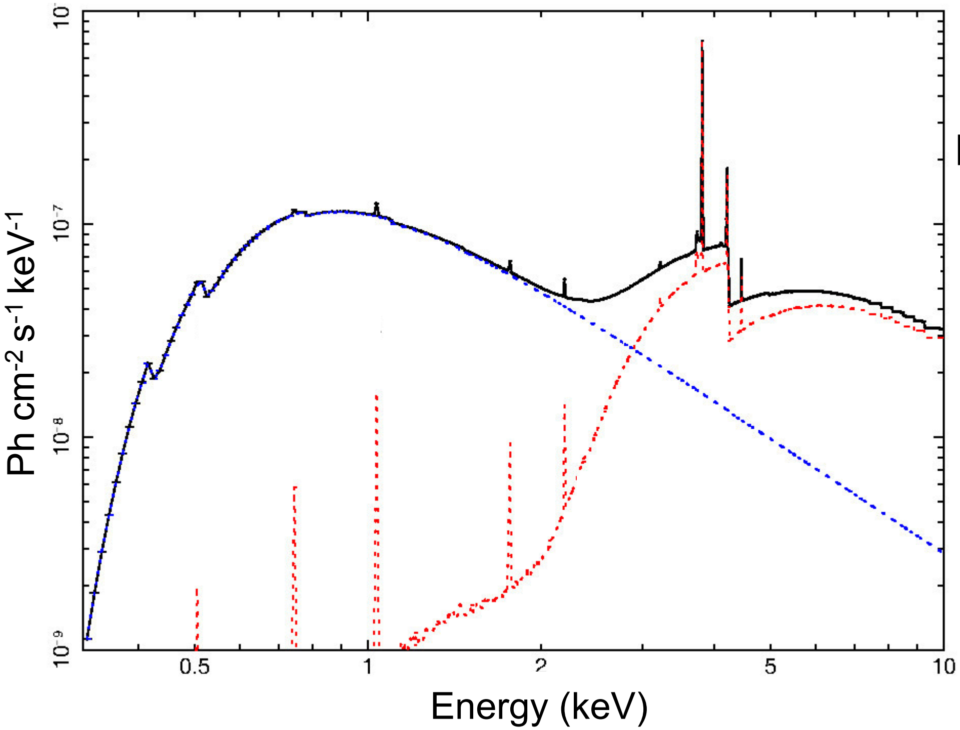


Fit with a simple transmission model + iron line leaves strong residuals

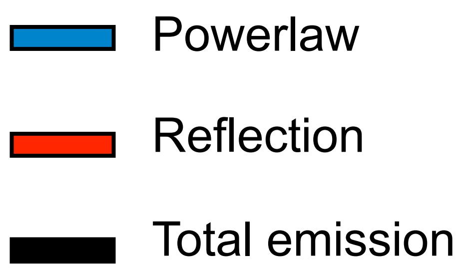
More physical modeling needed

Using appropriate "torus" modeling

Example of an AGN at z=0.68 with $N_H \approx 10^{24}$ cm^{-2}

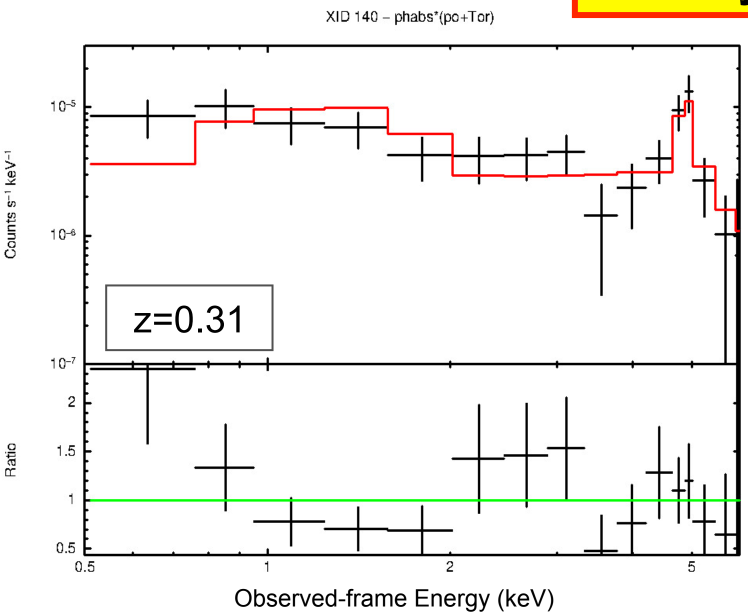


BNtorus modeling (Brightman & Nandra 2012)
Checks with MYTorus (Murphy & Yaqoob 2009) ongoing

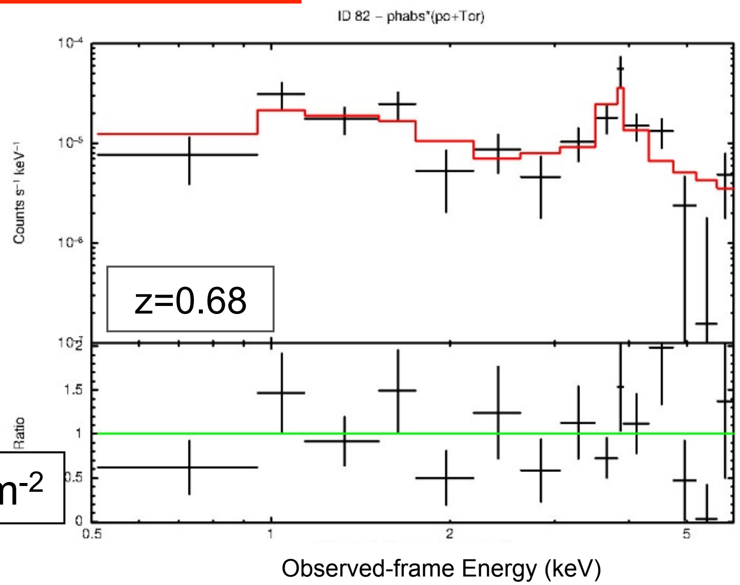


Modeling the X-ray spectra. II

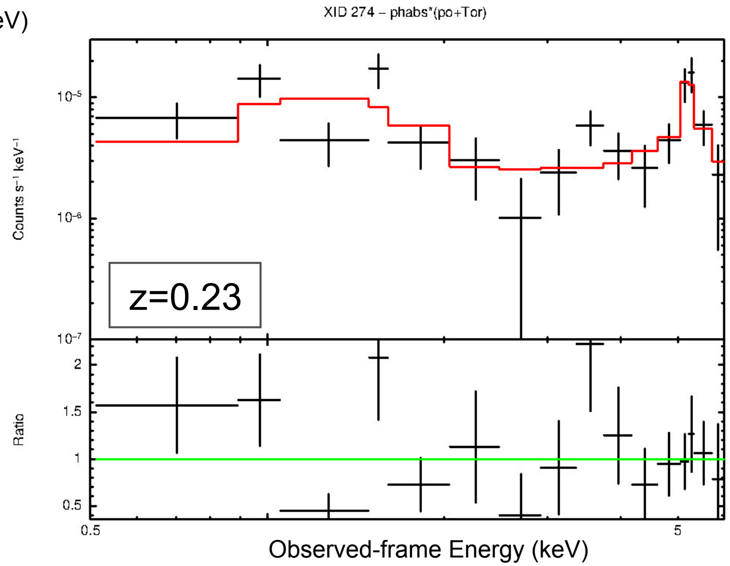
Heavily obscured AGN candidates



$N_H > 3\times10^{24}$ cm^{-2}

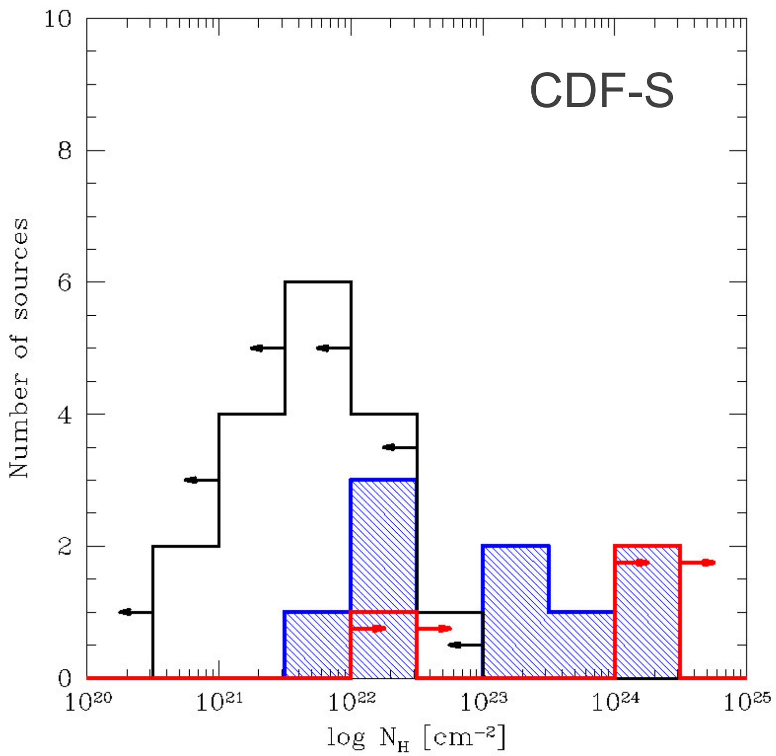


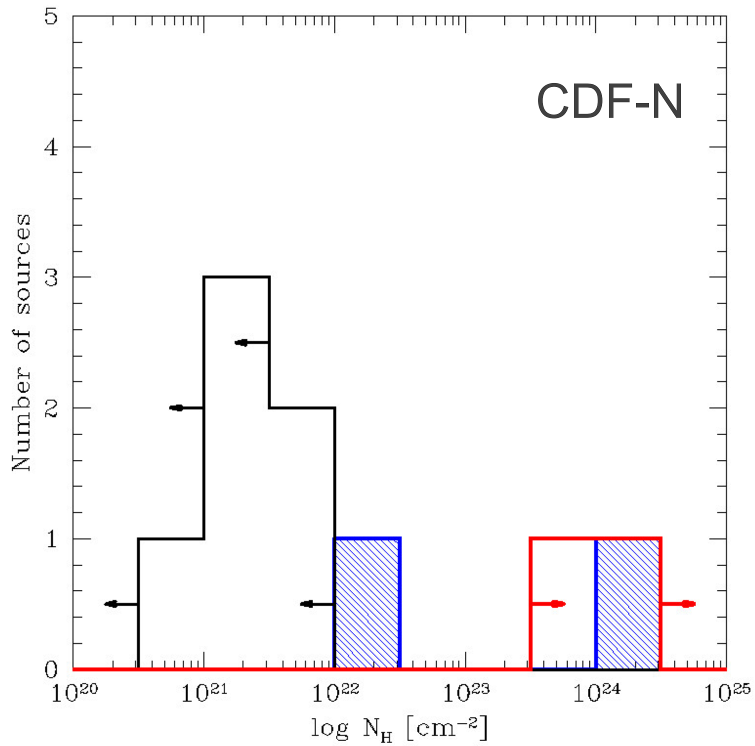
$N_H > 1.8\times10^{24}$ cm^{-2}



$N_H \approx 1.3\times10^{24}$ cm^{-2}

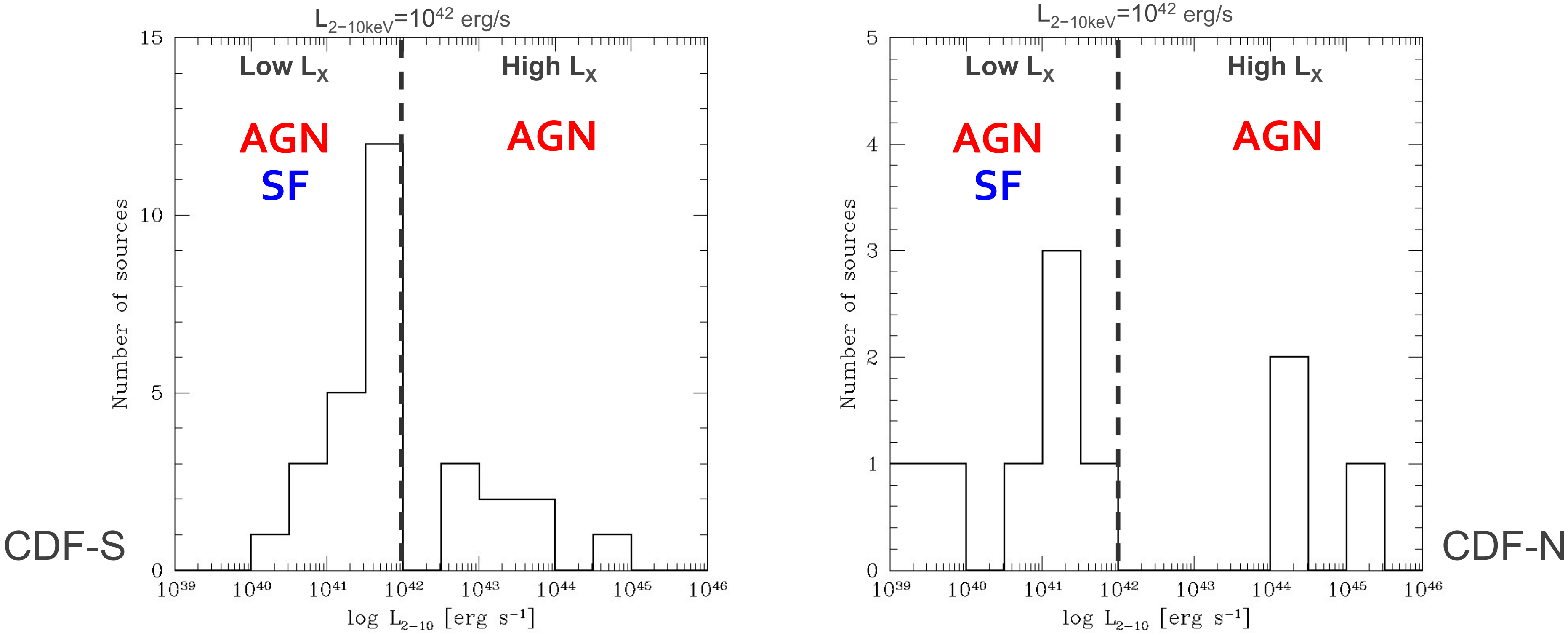
Column density distributions





9 sources (6+3) with $N_H > 10^{23}$ cm^{-2}

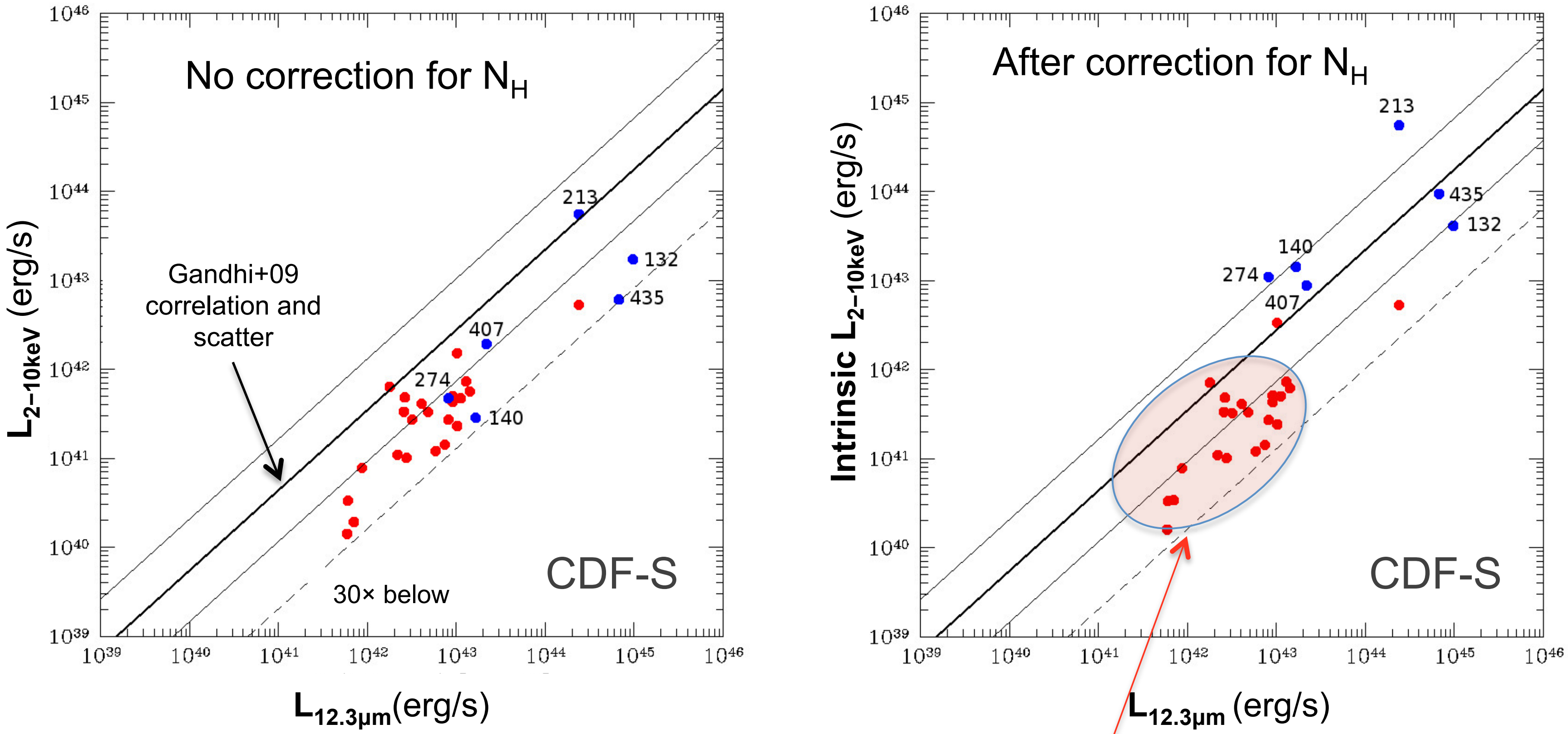
X-ray luminosity distributions



Combining the mid-IR information with the strength of X-rays

$L_{2-10keV}$ vs. $L_{12\mu m}$: CDF-S

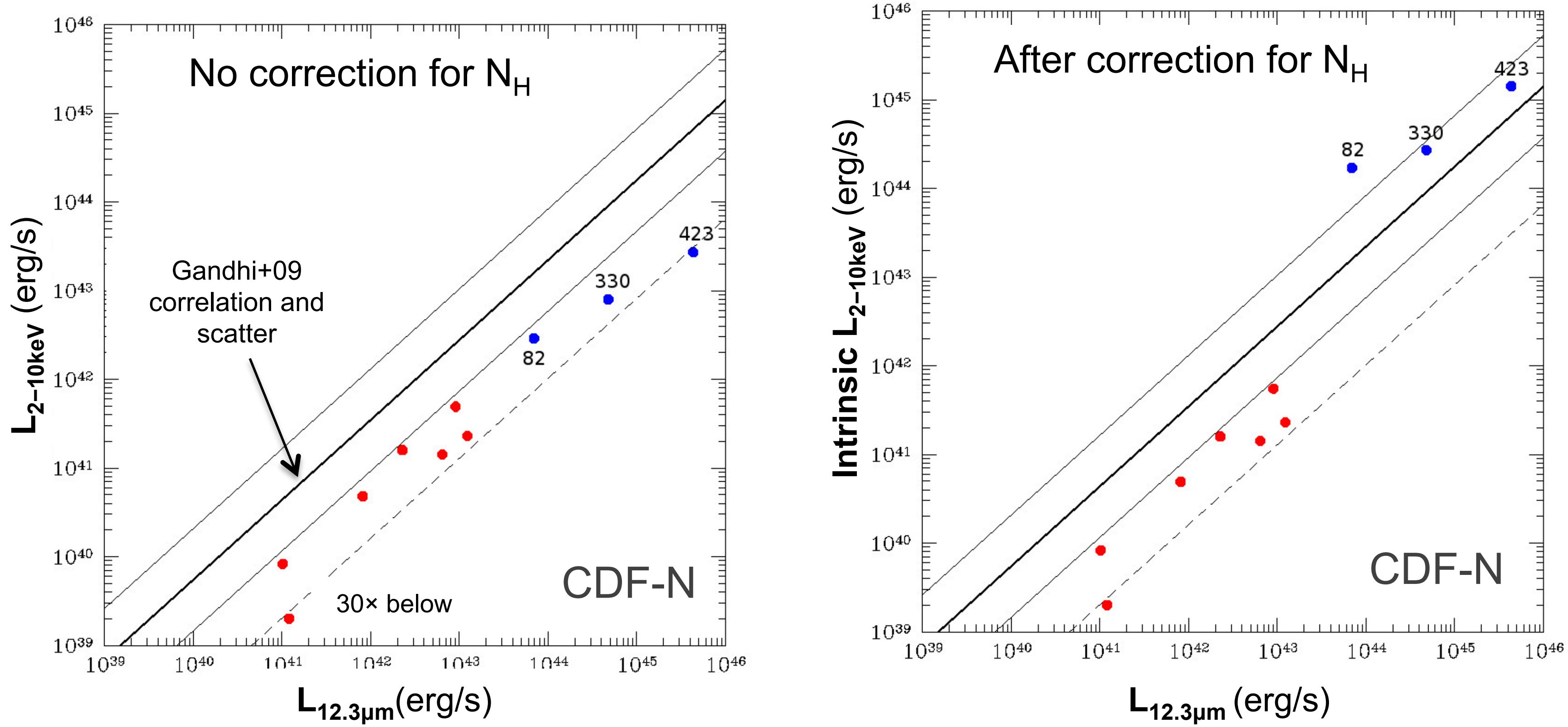
Comparison of the X-ray luminosity with the AGN 12.3μm luminosity (from SED fitting)



Original selection seems to pick up also “hybrid” sources, where the AGN is not dominant

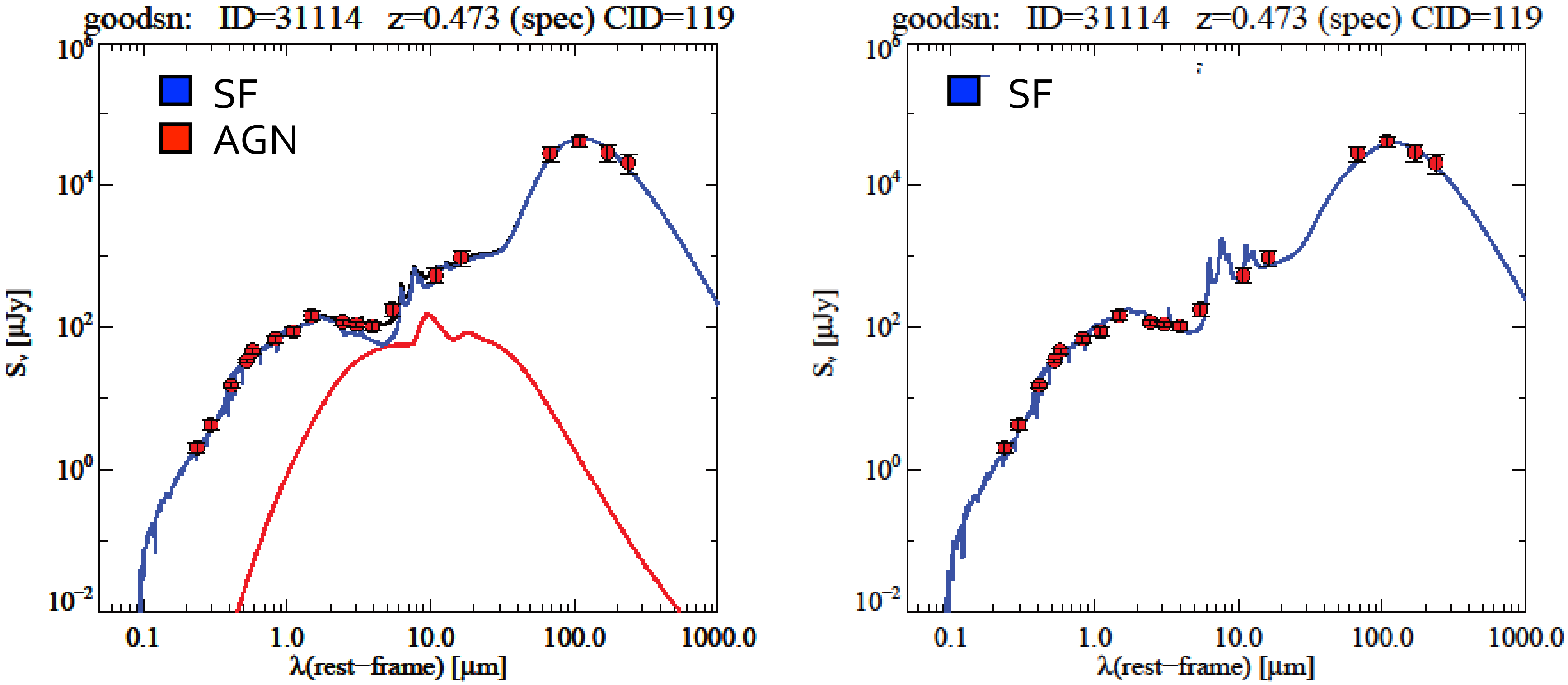
$L_{2-10keV}$ vs. $L_{12\mu m}$: CDF-N

Comparison of the X-ray luminosity with the AGN 12.3μm luminosity (from SED fitting)



Original selection seems to select also "hybrid" sources, where the AGN is not dominant

Example of a source originally selected as having an AGN in mid-IR but with low X-ray luminosity ($LogL_X \approx 41.4$)



X-ray emission from the heavily obscured AGN candidates: clear accretion dominance

XID	$L^{X}_{0.5-8keV}$	$L^{IR}_{8-1000\mu m}$	SFR_X converted from L_X (Mineo+14 (see also Ranalli+03))	SFR_{IR} converted from $L_{(8-1000\mu m)}$ (Kennicutt98)
132	4.2×10^{43}	6.0×10^{44}	10500	27
140	2.1×10^{43}	3.5×10^{44}	5250	16
213	6.8×10^{44}	4.9×10^{45}	170000	221
274	1.6×10^{43}	1.1×10^{44}	4000	5
407	1.3×10^{43}	9.3×10^{44}	3250	42
435	1.1×10^{44}	9.5×10^{45}	27500	428

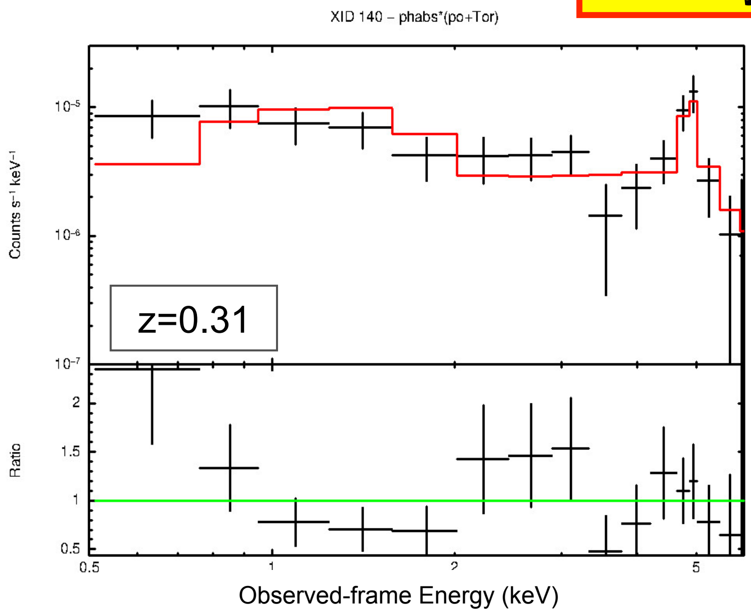
Accretion is the only explanation

ID	$L^{X}_{0.5-8keV}$	$L^{IR}_{8-1000\mu m}$	SFR_X converted from L_X	SFR_{IR} converted from $L_{(8-1000\mu m)}$
82	2.5×10^{44}	1.1×10^{45}	62500	50
330	2.9×10^{44}	5.5×10^{44}	72500	25
423	1.5×10^{45}	2.8×10^{46}	375000	1260

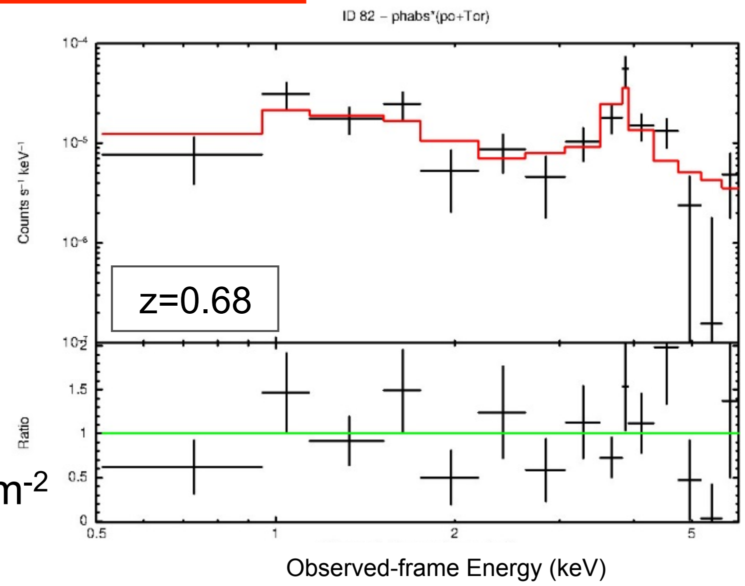
For the heavily obscured AGN candidates, X-ray emission is due to accretion [SFR(X-ray) too high]. **AGN + SF for the other sources**

Results: the most obscured AGN

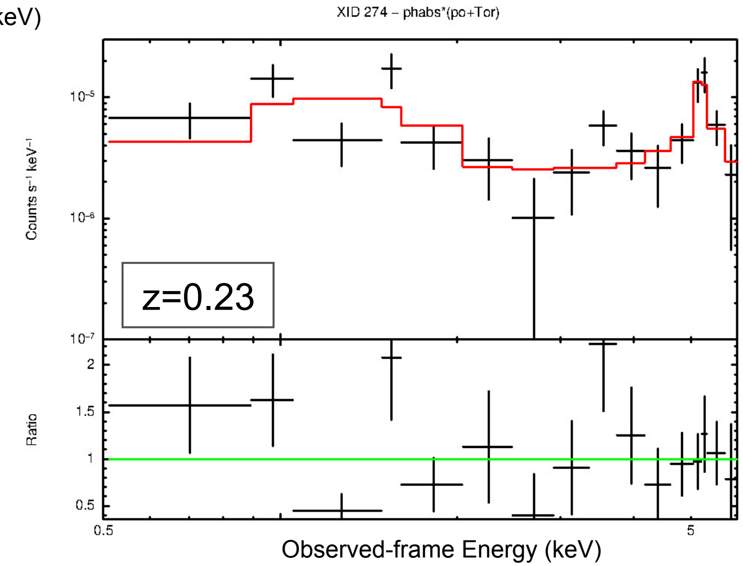
Heavily obscured AGN candidates



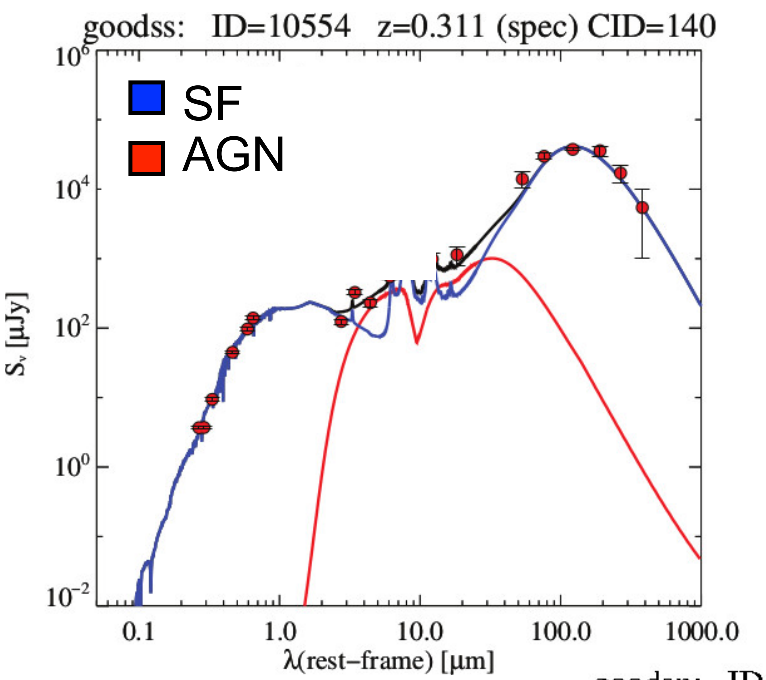
$N_H > 3\times10^{24}$ cm^{-2}

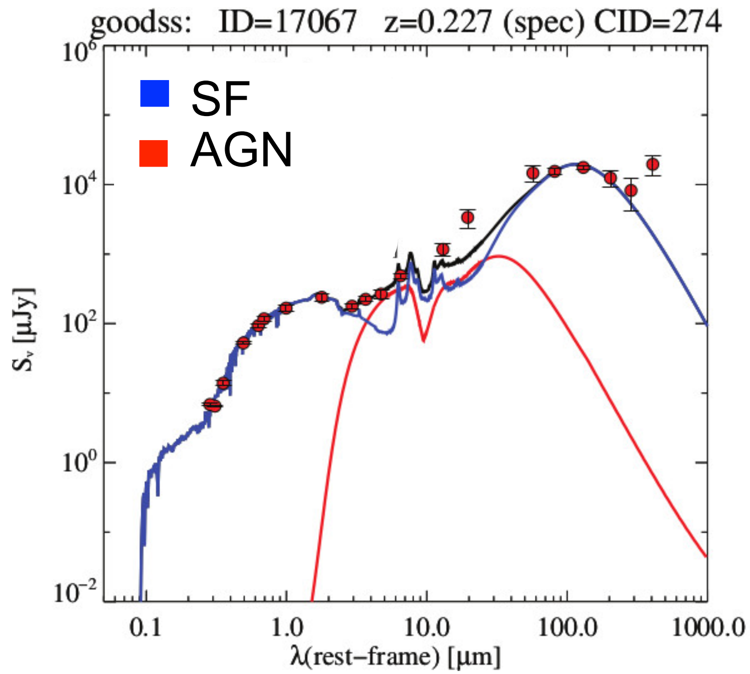


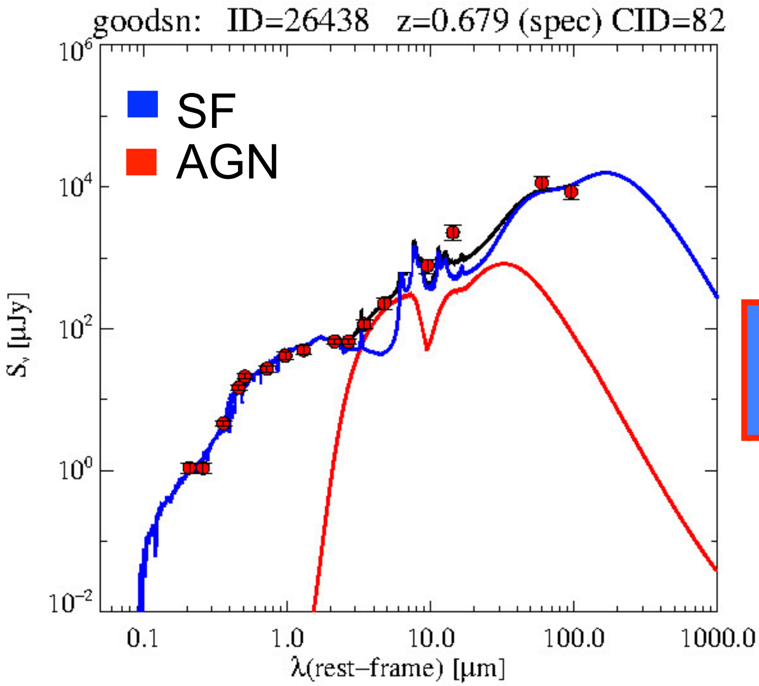
$N_H > 1.8\times10^{24}$ cm^{-2}



$N_H \approx 1.3\times10^{24}$ cm^{-2}







Need for mid-IR +
far-IR facilities!

Obscured AGN: Prospects for SPICA

SMI-LRS (low-resolution spectrometer, R=50, 17−36 μm)

will allow detection of obscured AGN via mid-IR continuum (torus) emission and mid-IR/optical selection (e.g., DOGs, HotDOGs)

SMI-MRS (medium-resolution spectrometer, R≈1000−2000, 18−36 μm)

more "detailed" physics and selection for AGN/SF & modeling via [NeV]$_{14.3\mu m}$, [NeV]$_{24.3\mu m}$, [OIV]$_{25.9\mu m}$ mid-IR emission lines (see Spinoglio & Malkan 1992, Gruppioni+16) as with *Spitzer*/IRS

Safari (grating spectrometer, R=300, 34−210 μm)

will allow extension of AGN studies to high redshifts

Overall, potentially strong synergies with X-ray surveys (e.g., *Athena*)