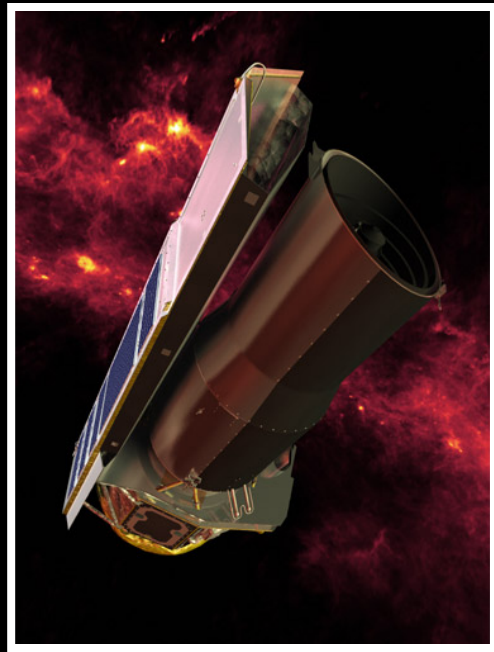
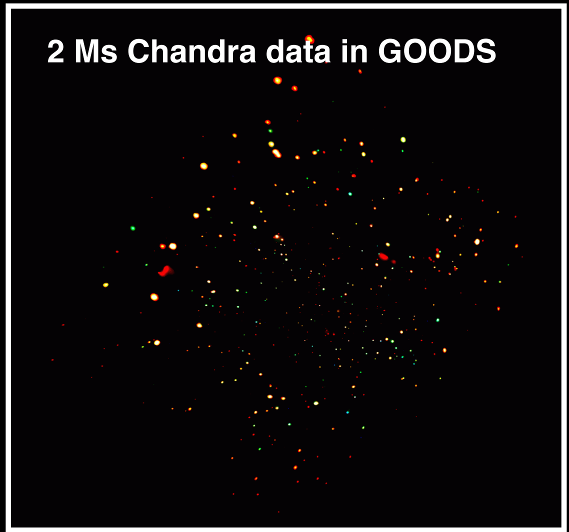
Infrared Identification of Hidden AGNs in the Deepest X-ray Fields



David M Alexander (Durham), Agnese Del Moro (Durham), James Mullaney (Saclay),
Emanuele Daddi (Saclay), David Elbaz (Saclay), and GOODS Herschel team

Main Results



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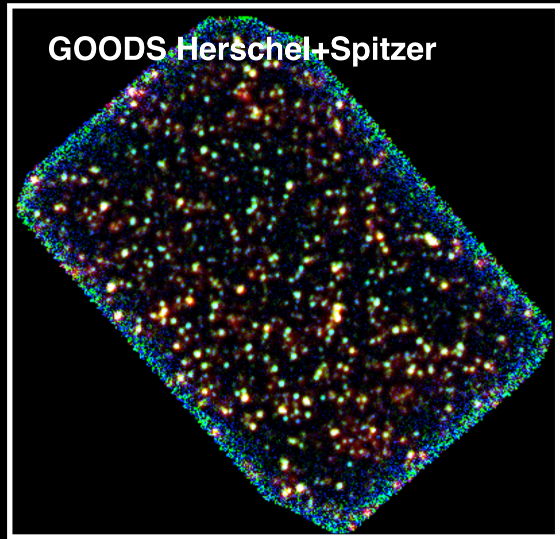


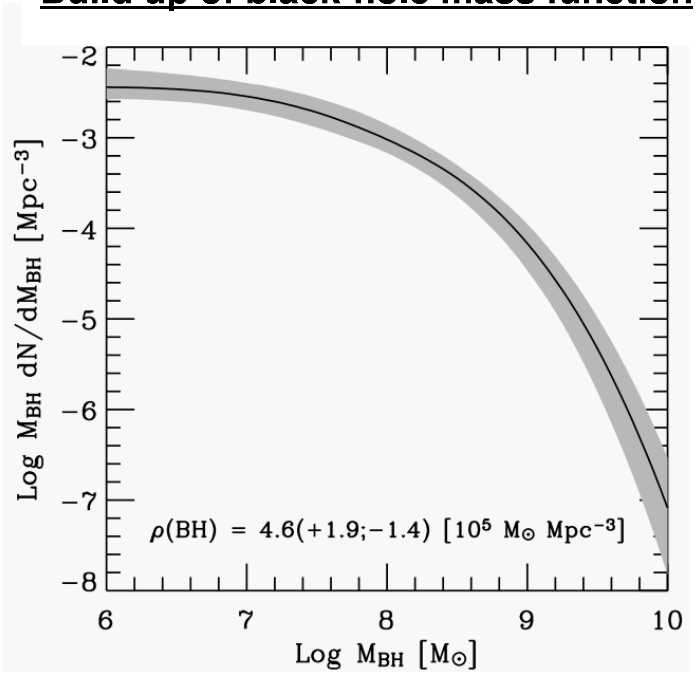
(1) Identified hidden AGN missed in X-ray surveys: z<1 moderate-luminosity IR-identified AGNs: they may dominate the unresolved X-ray background at ~30 keV

(2) Identified a population of z~2 Compton-thick quasars not detected in X-ray surveys: ~3-10x less luminous than WISE z~2 AGNs but ~1,000x more common!

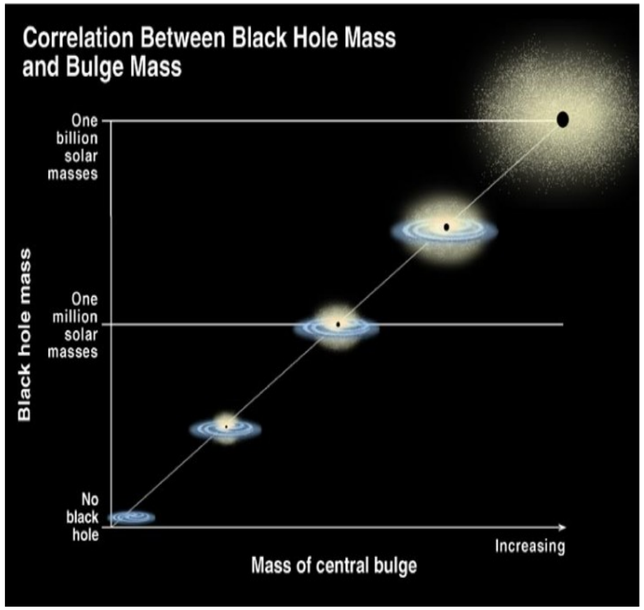
Agnese Del Moro

Why we want to find all of the luminous AGNs in the Universe: What Drives the Growth of Black Holes?

Build up of black-hole mass function

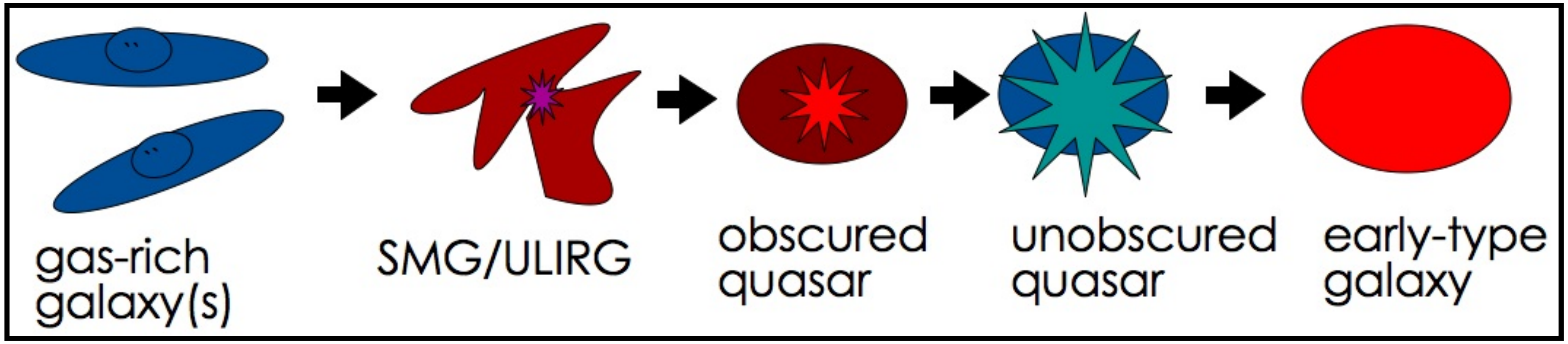


BH-spheroid growth connection

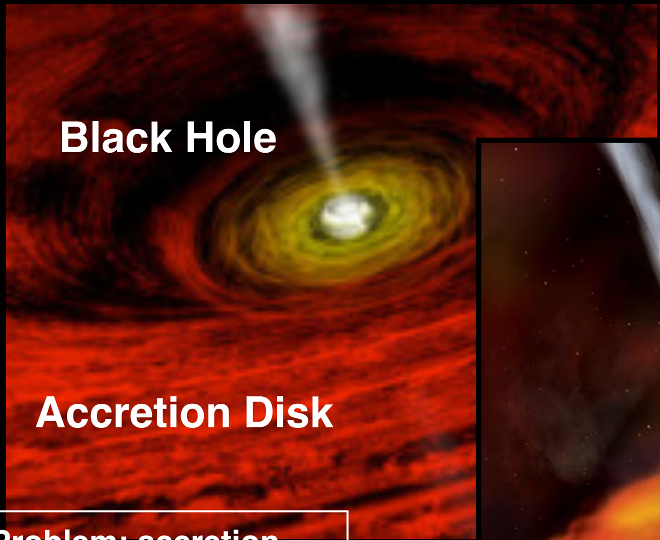


Major-merger driven evolutionary scenarios:

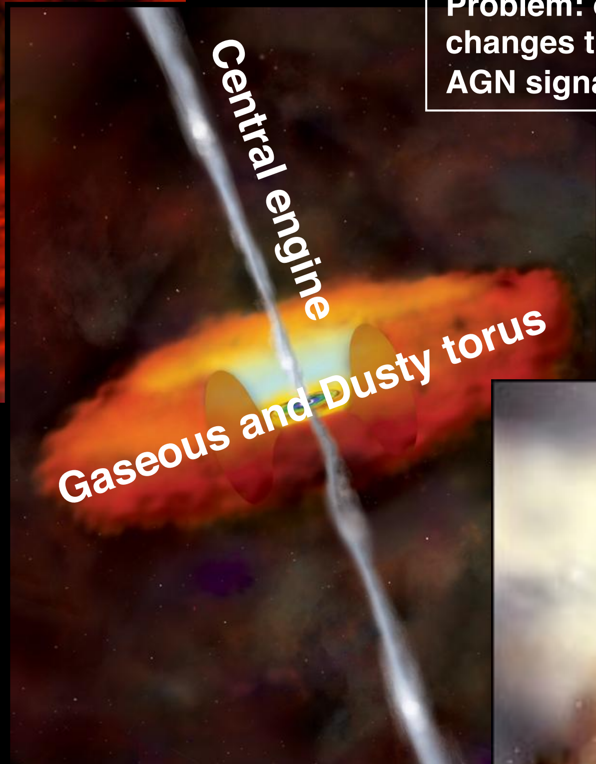
Alexander & Hickox (2012)



Finding the AGN: a multi-scale, multi-component, multi-wavelength challenge



Problem: accretion disk is spatially unresolved

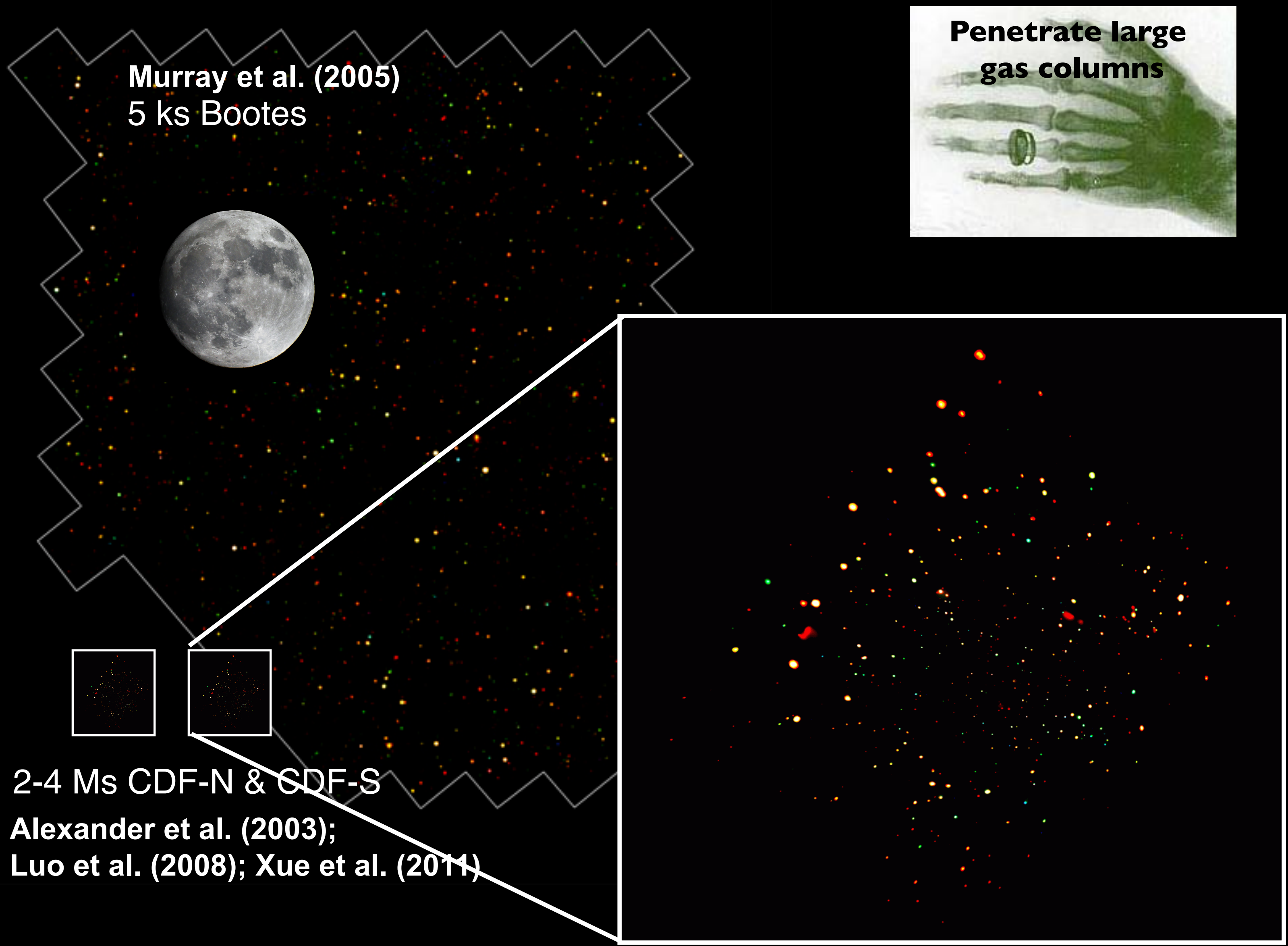


Problem: obscuration changes the observed AGN signatures

Problem: host galaxy can dilute/extinguish AGN signatures

Huge difference in size scale (from galaxy to black hole)

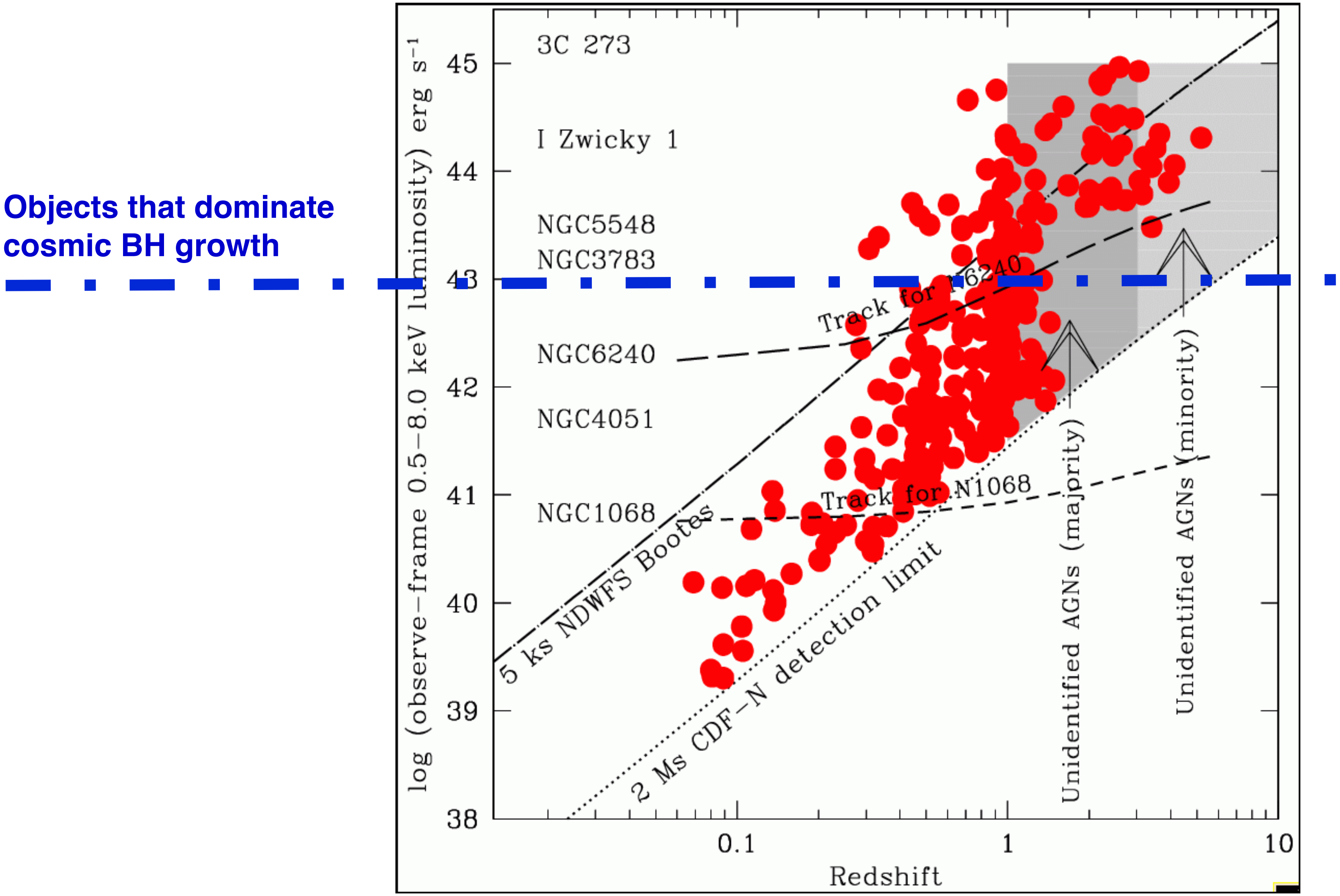
X-ray Surveys: Penetrating Probe of AGN activity



Phenomenal sensitivity of Chandra deep fields to detect distant AGNs

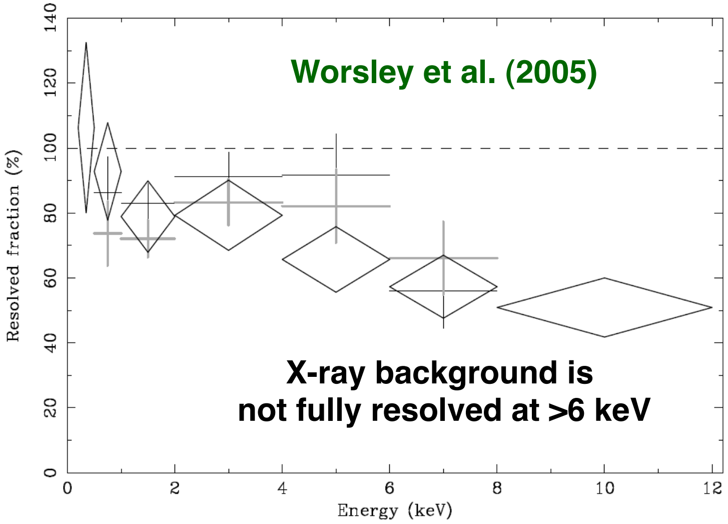
Only sources with spectroscopic redshifts are plotted

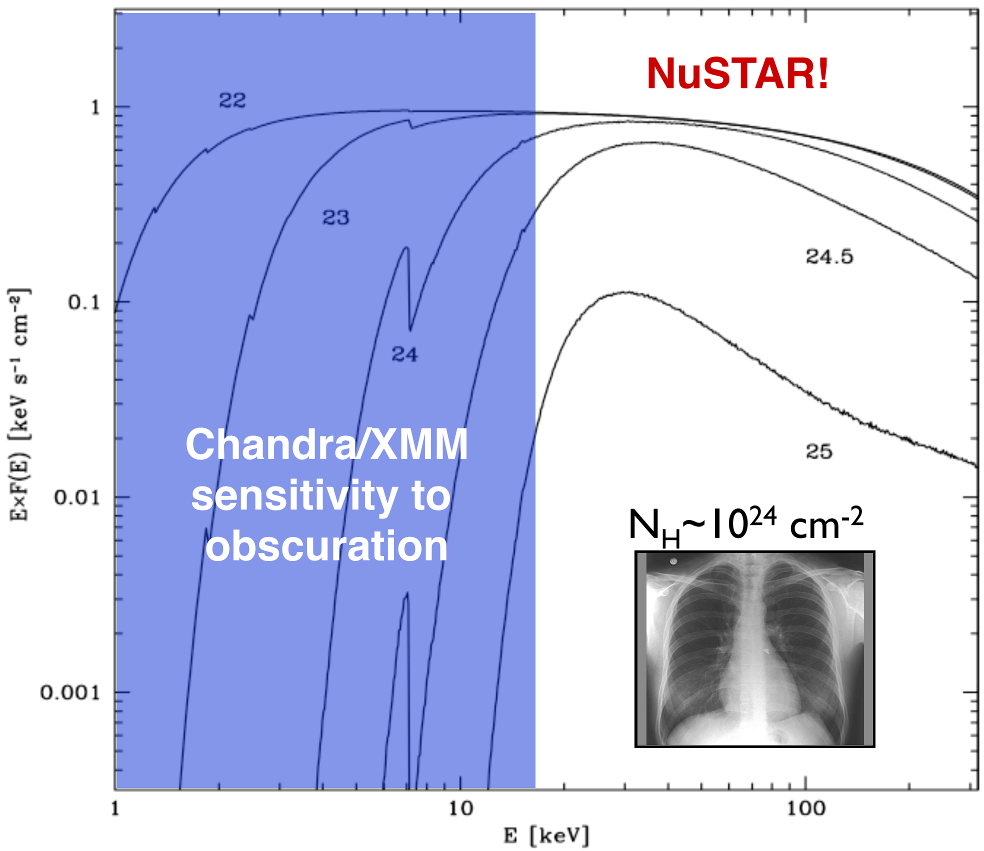
Objects that dominate cosmic BH growth



See Brandt & Hasinger (2005) for a review

But even the deepest X-ray surveys are missing many AGNs



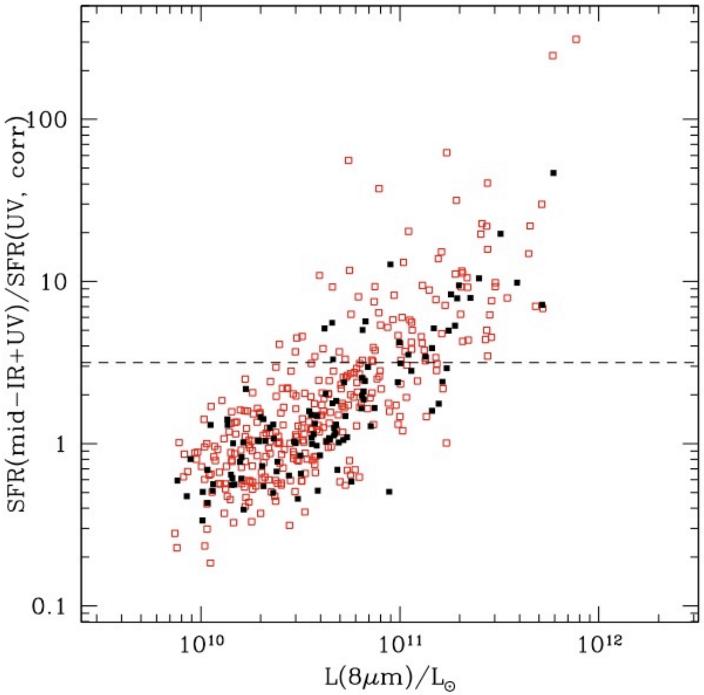


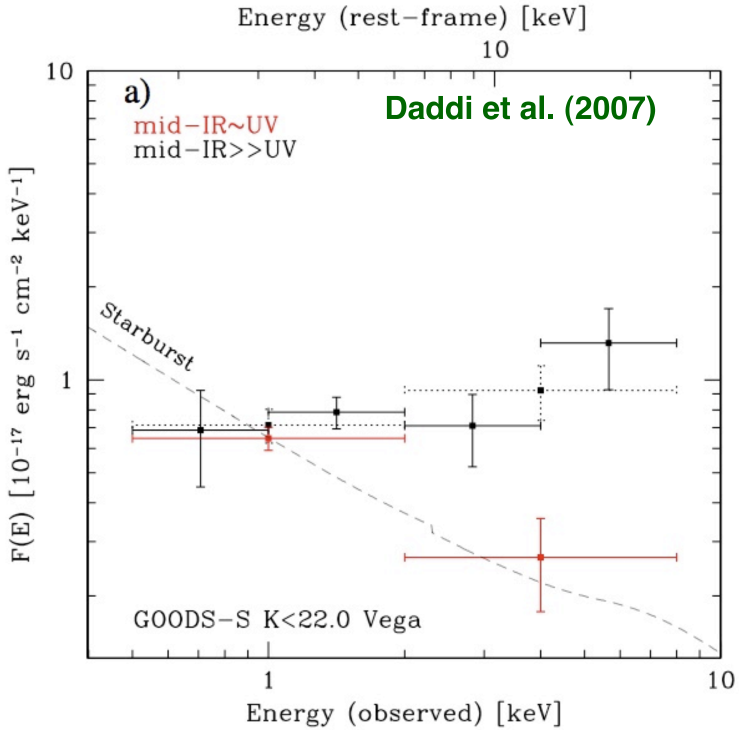
Predictions for the dominant population of the unresolved X-ray background:

Moderately luminous, very heavily obscured AGNs (N_H>3x10^{23} cm^{-2}) at z<1 (e.g., Worsley et al. 2005; Gilli et al. 2007; Treister et al. 2009)

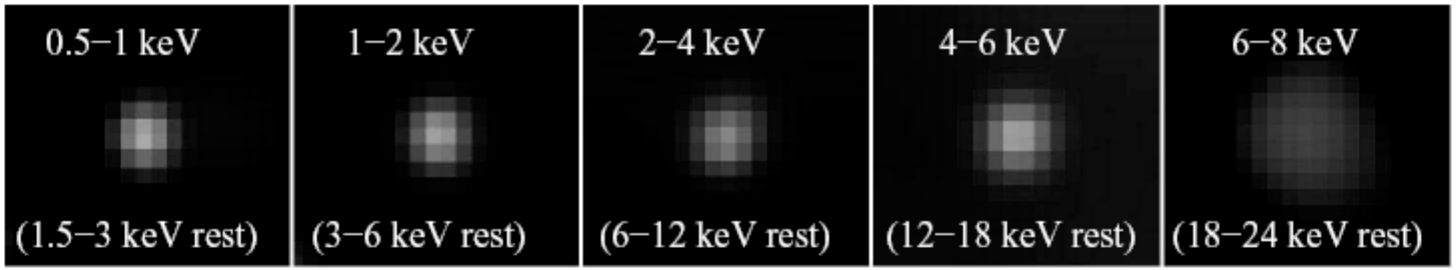
For example, Daddi et al. (2007), Alexander et al. (2008), Fiore et al. (2008), Donley et al. (2010), Juneau et al. (2011), Luo et al. (2011)

Hints of a hidden AGN population at z~2 from Spitzer





Stacked X-ray data (1 Ms) of X-ray undetected IR



Very hard signal => significant fraction of obscured AGNs at z~2

See also, e.g., Donley et al. (2005, 2007), Alonso-Herrero et al. (2006), Fiore et al. (2008, 2009), Georgantopoulos et al. (2008), Luo et al. (2011)

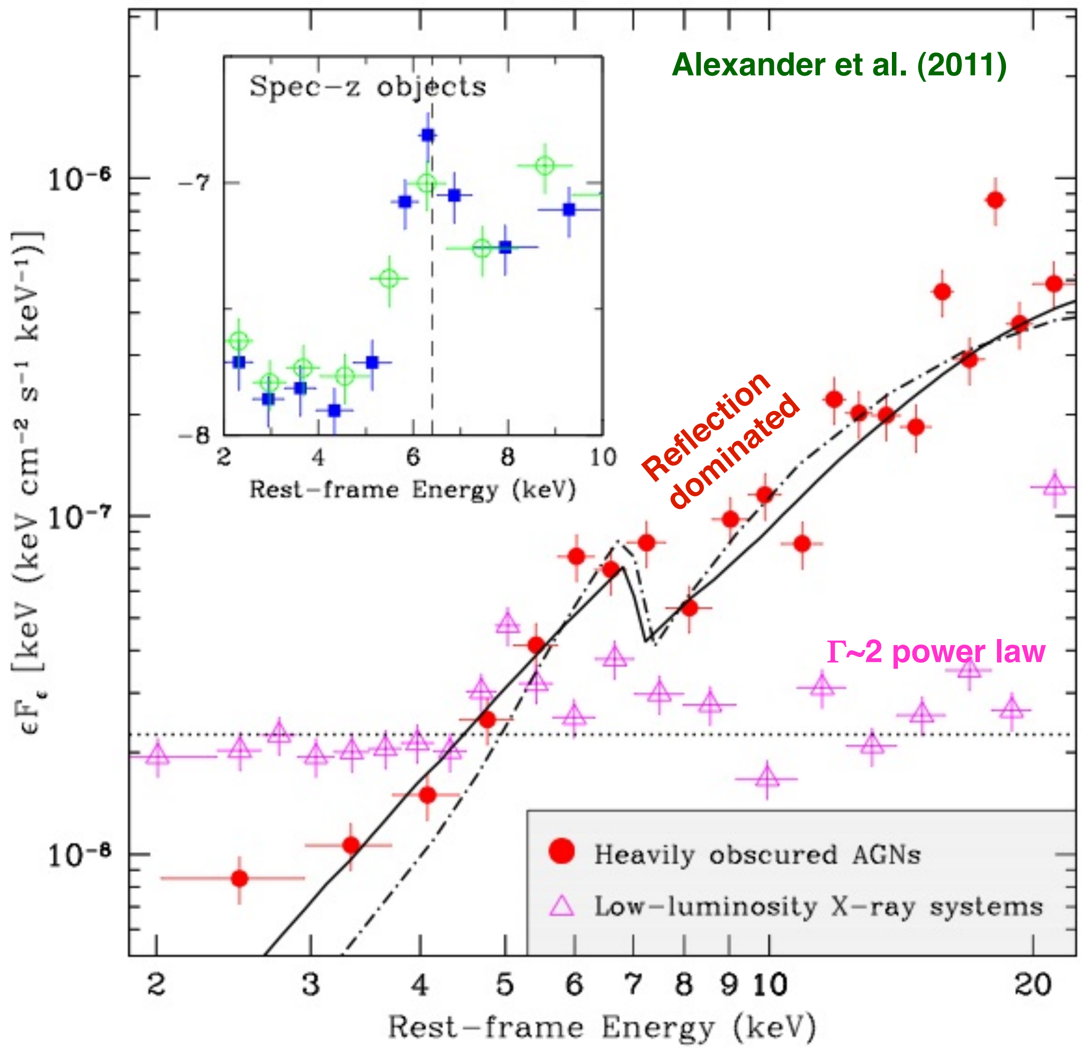
Deeper X-rays (4 Ms Chandra exposure) show these z~2 systems are a mix of AGNs and starbursts

X-ray spectral analyses results

~25% are very heavily obscured AGNs: reflection dominated some (all?) are Compton thick

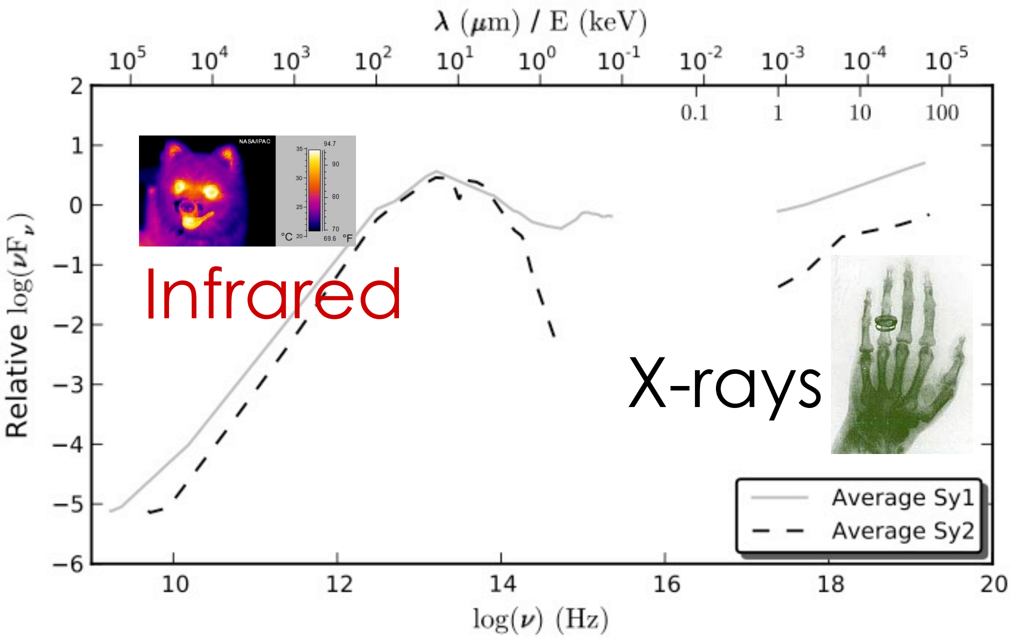
• ~20% are luminous AGNs

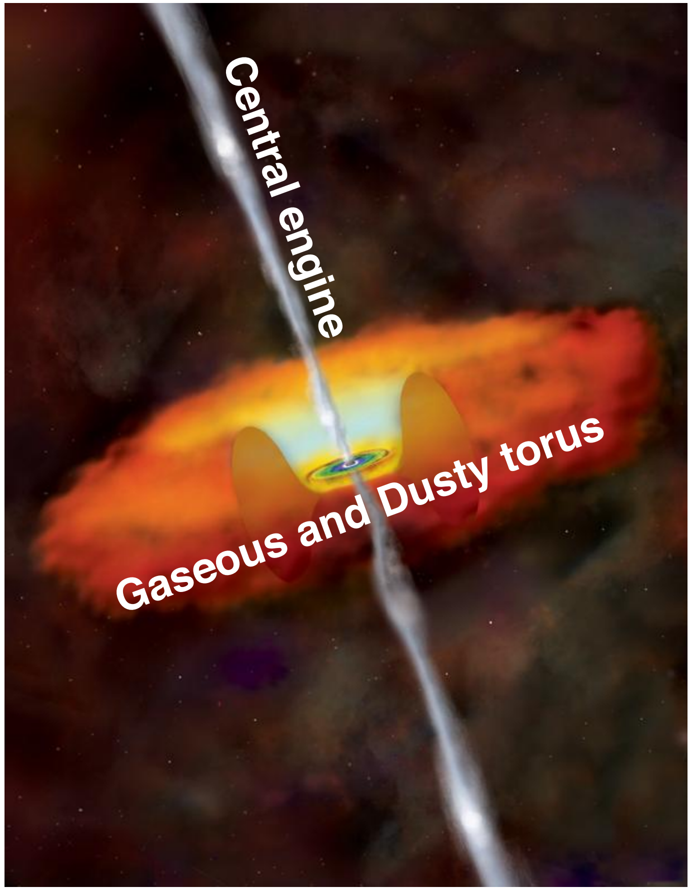
• ~55% are starbursts or low-luminosity AGNs



See Comastri et al. (2011) and Fergulio et al. (2011) for individual distant Compton-thick AGN identifications

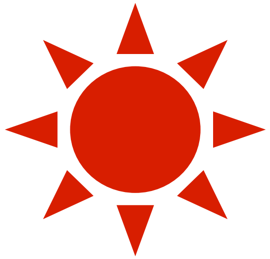
IR AGN selection might complete the AGN census

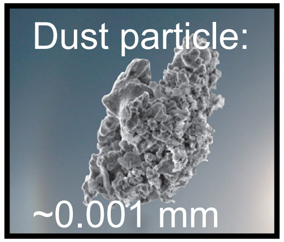




• Similar average SEDs - infrared due to dust emission; near-IR-X-ray differences due to absorption by dust and gas

Primary source (X-ray-optical)

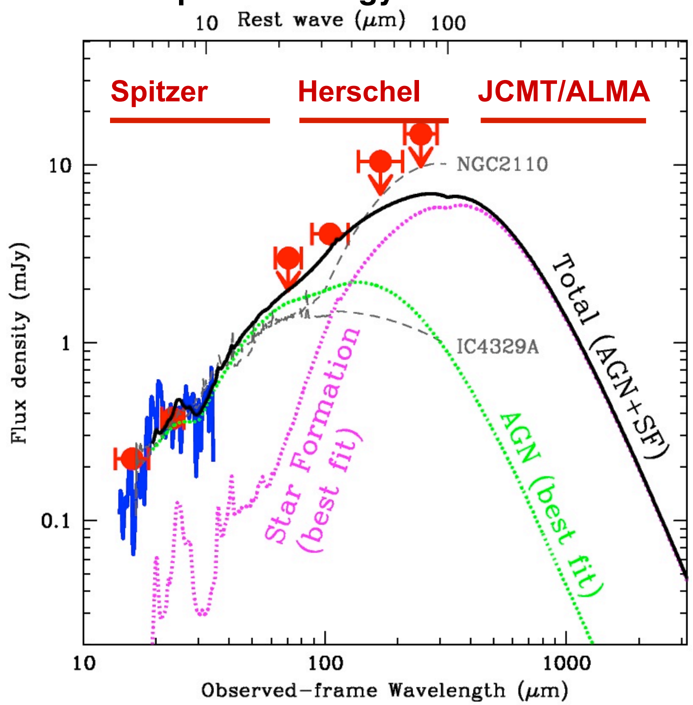


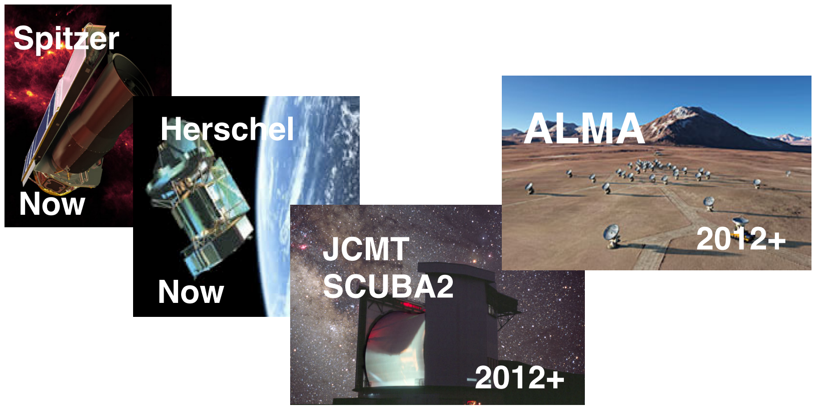


≈ **Reprocessed emission (infrared/ submm)**

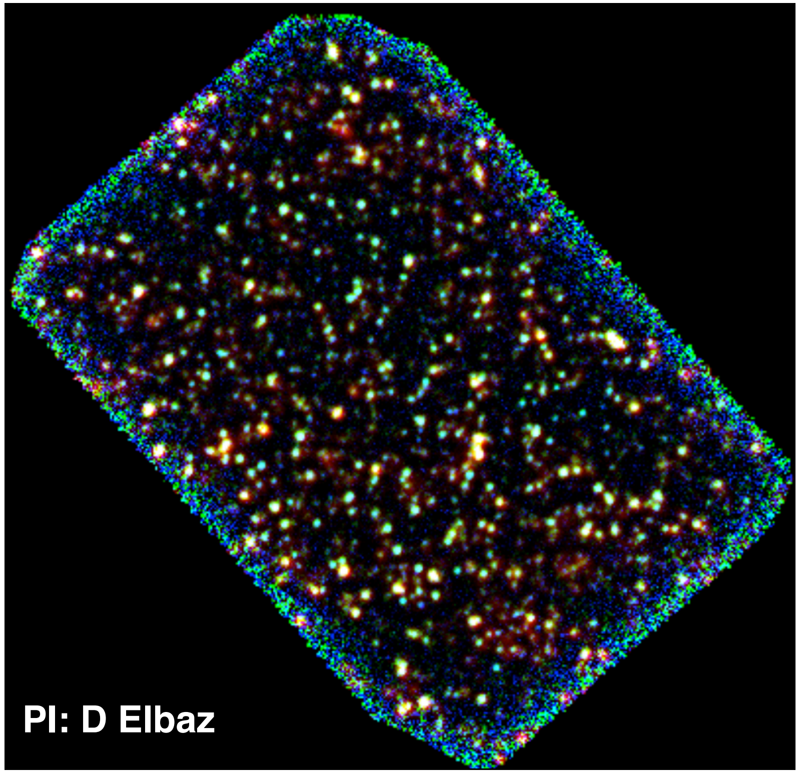
New opportunities: revealing the AGN-heated dust

z=2 spectral energy distribution





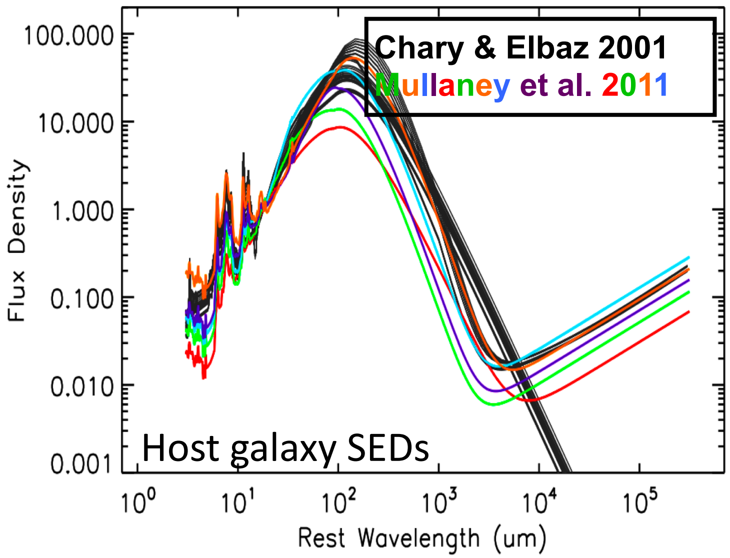
Herschel key project in GOODS fields: 100+160um (250+350+500um)

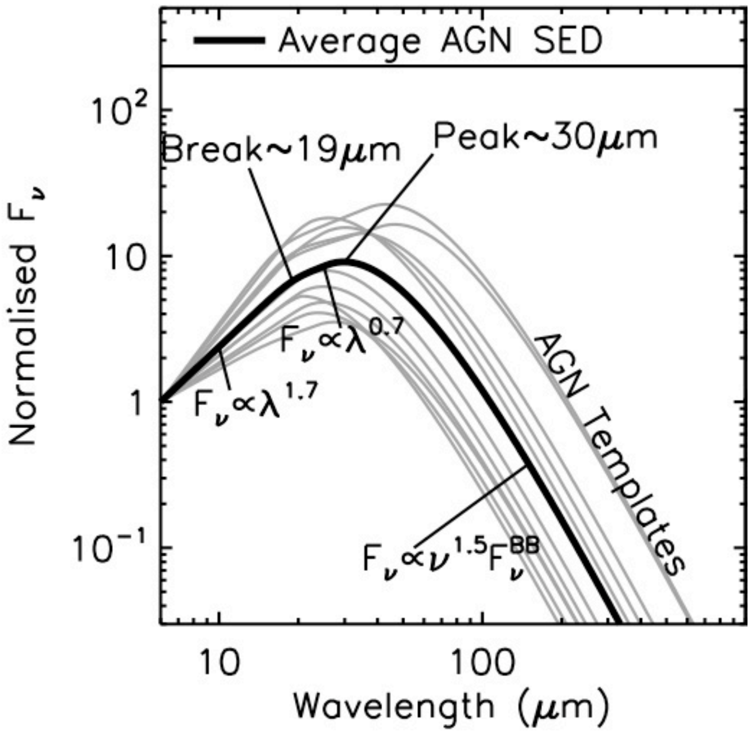


Herschel+Spitzer: IR SEDs (3-500um) to identify AGN and star formation (Elbaz+ 11)

Deepest X-ray data (Alexander+ 03; Xue+ 11)
Deepest radio (Morrison+ 10)

AGN-Starburst SED fitting tool





5 host galaxy templates (Mullaney et al. 2011)

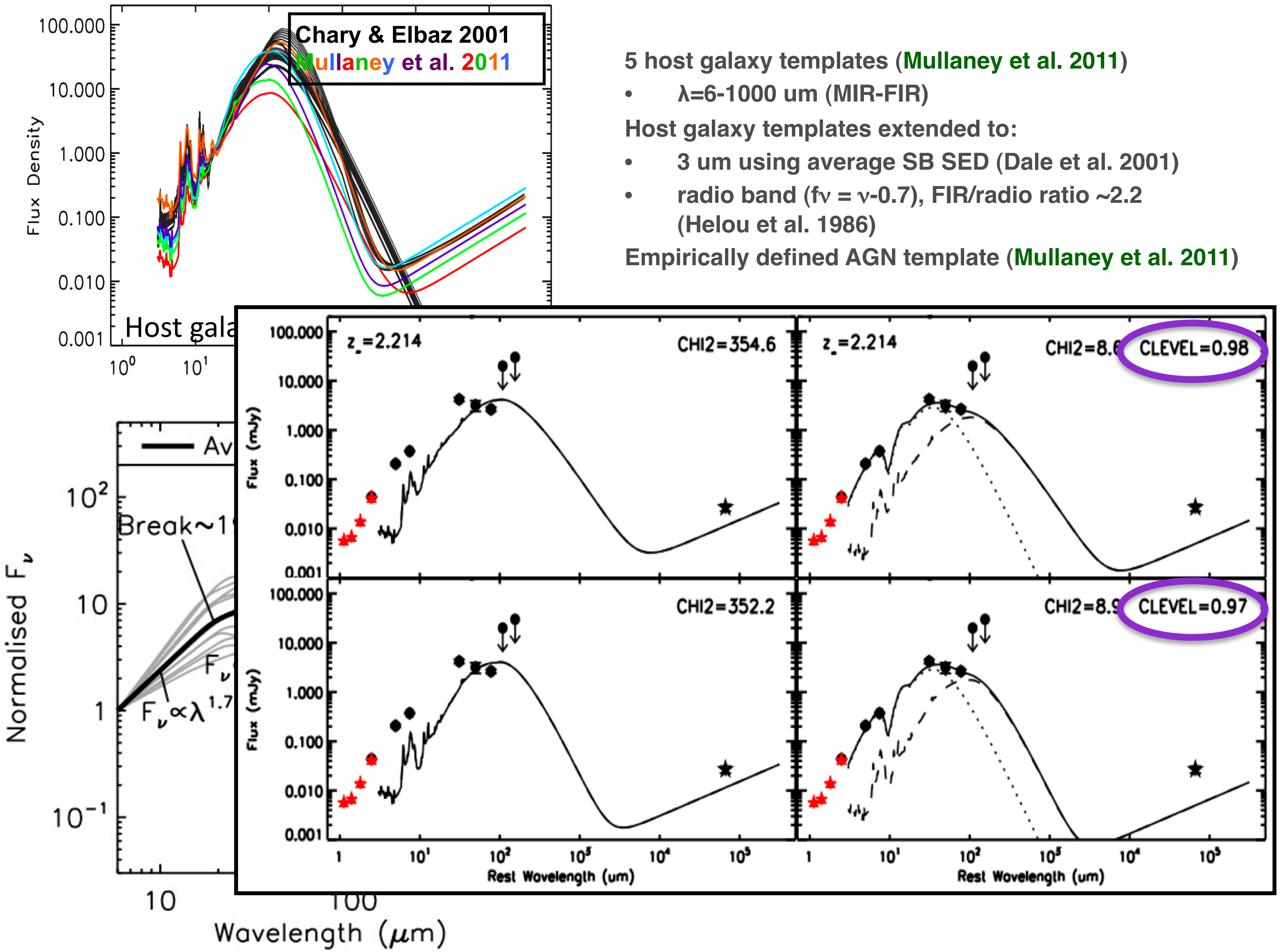
- λ=6-1000 um (MIR-FIR)

Host galaxy templates extended to:

- 3 um using average SB SED (Dale et al. 2001)
- radio band (fν = ν-0.7), FIR/radio ratio ~2.2 (Helou et al. 1986)

Empirically defined AGN template (Mullaney et al. 2011)

AGN-Starburst SED fitting tool



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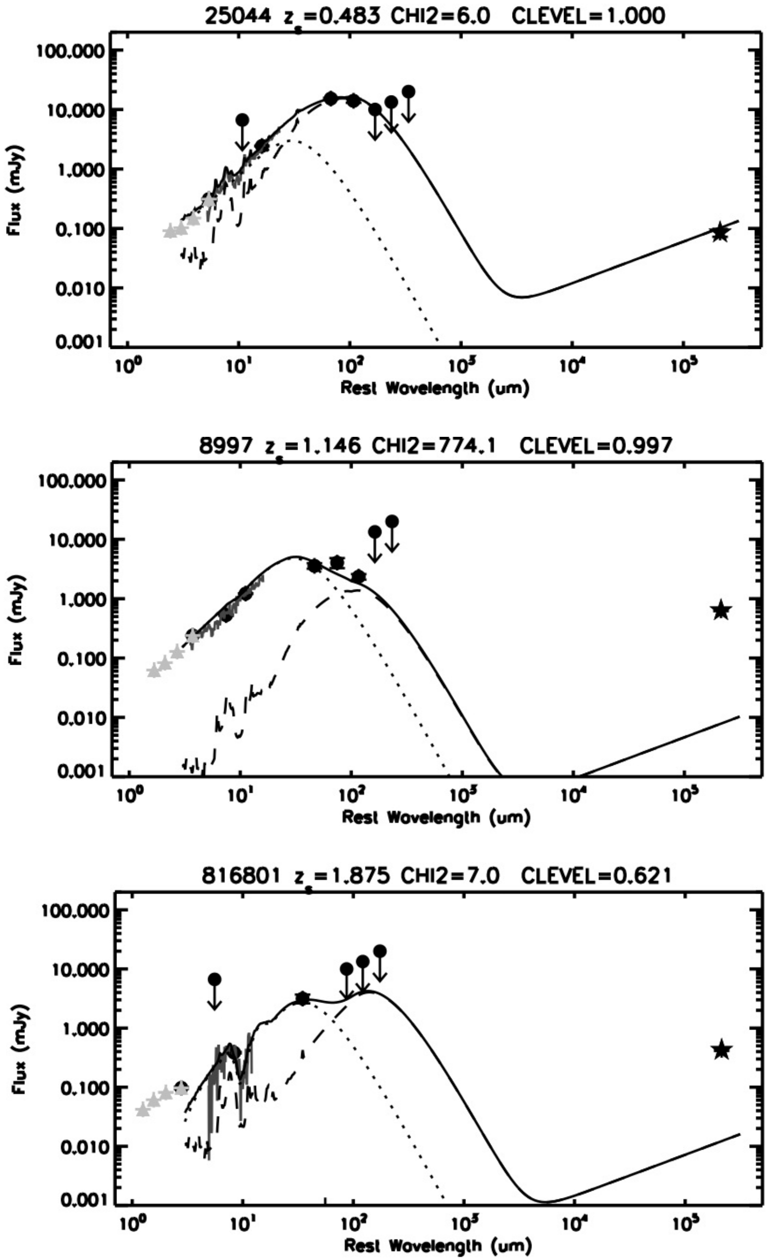
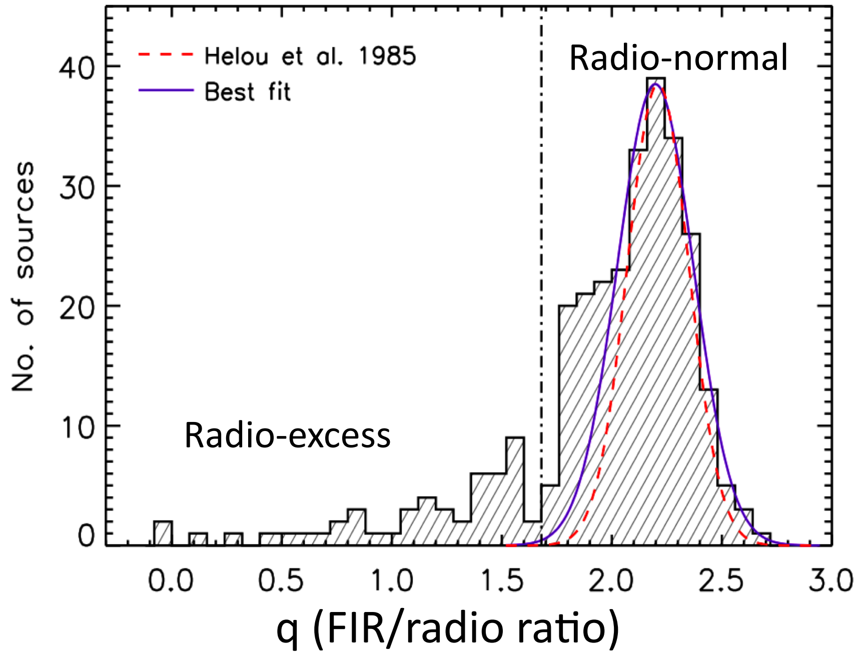
Some example fits to demonstrate validity of our approach



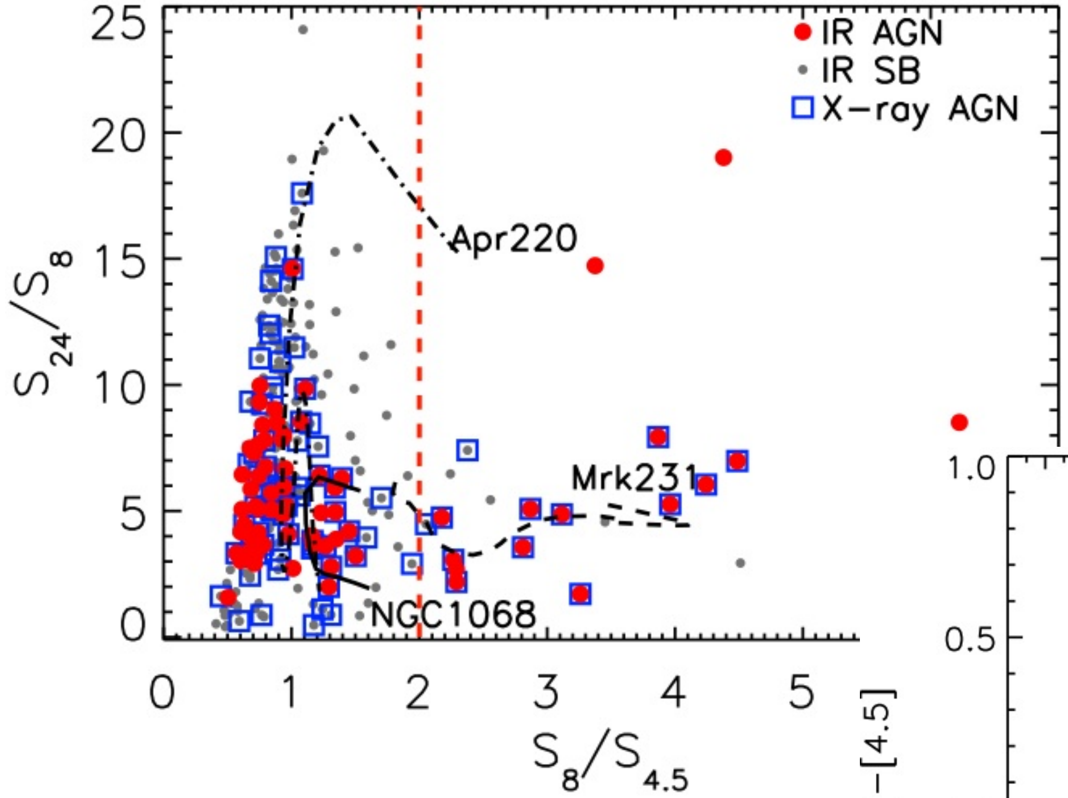


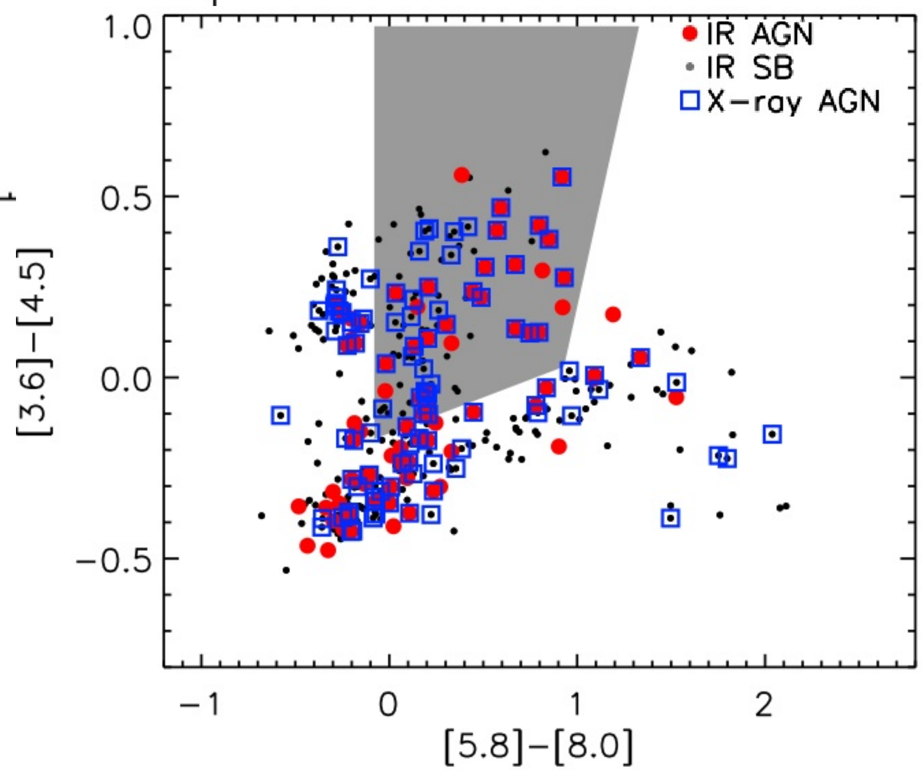
IRS spectroscopy is not fit: but SEDs agree with IRS data (for ~20 systems with such data)

Radio data is not fit: but average far-IR/radio relationship (of all systems - AGN+starbursts) in good agreement with canonical relationship (with a tail of radio-excess AGNs)

Del Moro et al. (in prep)

SED fitting: efficient and effective method of identifying heavily obscured AGNs



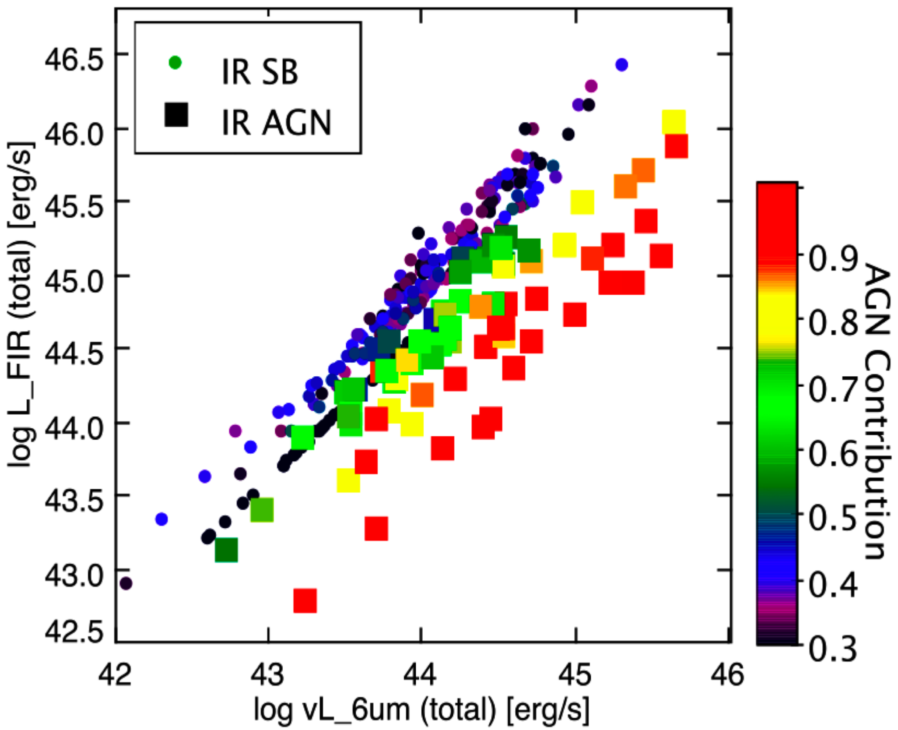


More effective than simple colour selection: ~40% of IR AGN are X-ray undetected in deepest X-ray surveys

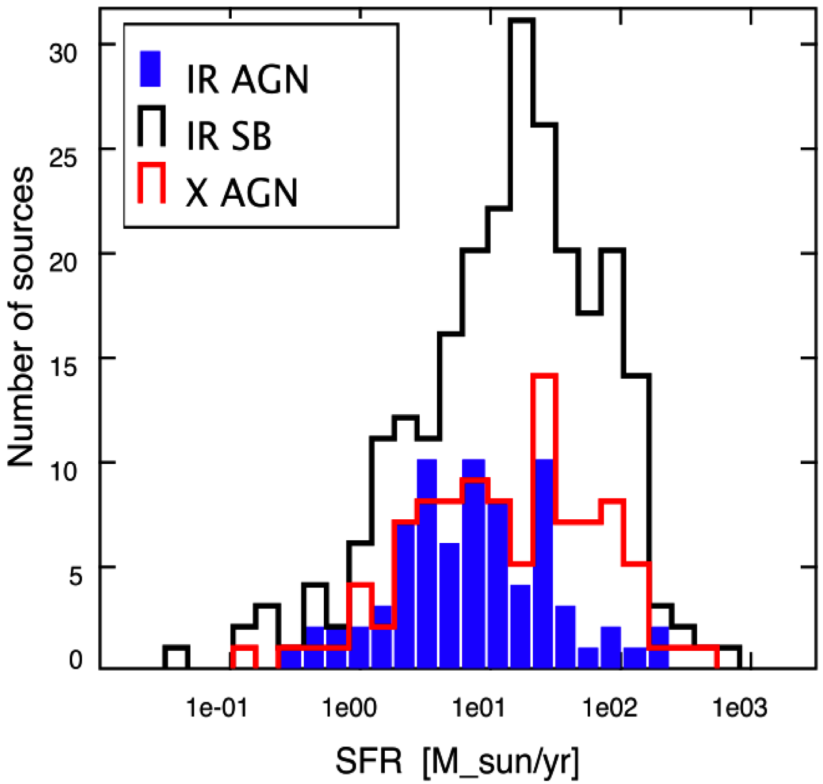
Distribution of colour ratios for IR AGNs similar to the X-ray AGNs

Del Moro et al. (in prep)

AGN vs star formation contributions



We can robustly identify an AGN so long as it dominates at 6um (>50% contribution)

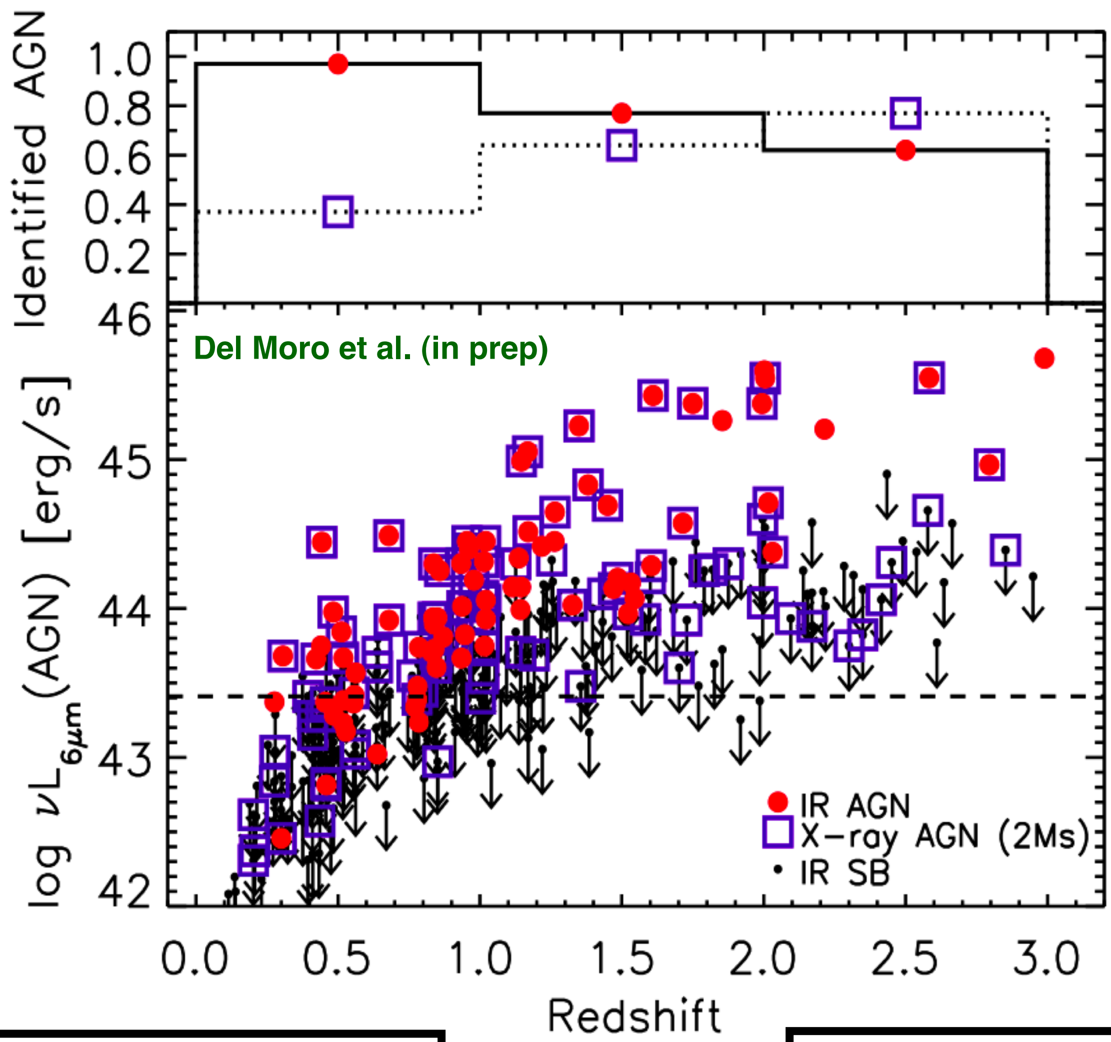


IR AGNs that we identify rarely found in the strongest star-forming systems - almost certainly an effect of star formation dominating over the AGN signature rather than being real

Del Moro et al. (in prep)

IR detected AGNs vs X-ray detected AGNs

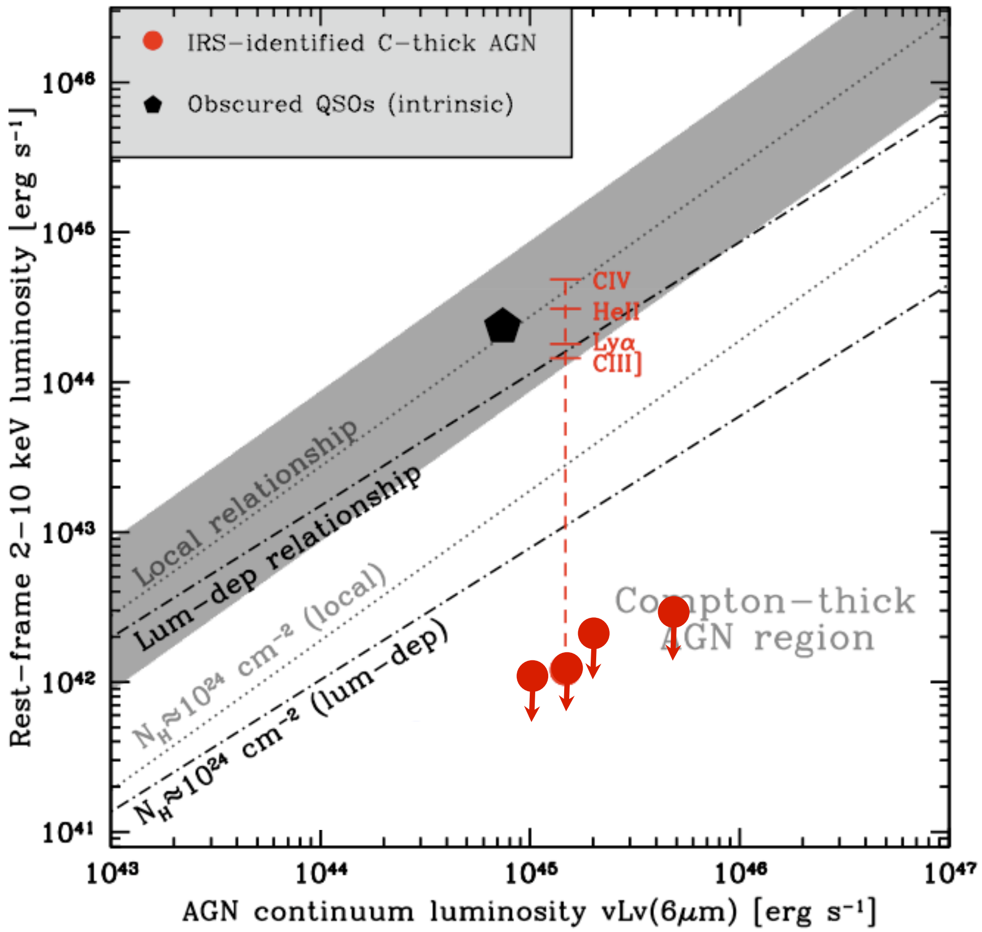
80 IR AGN, 50 X-ray detected, 30 X-ray undetected (~40%)



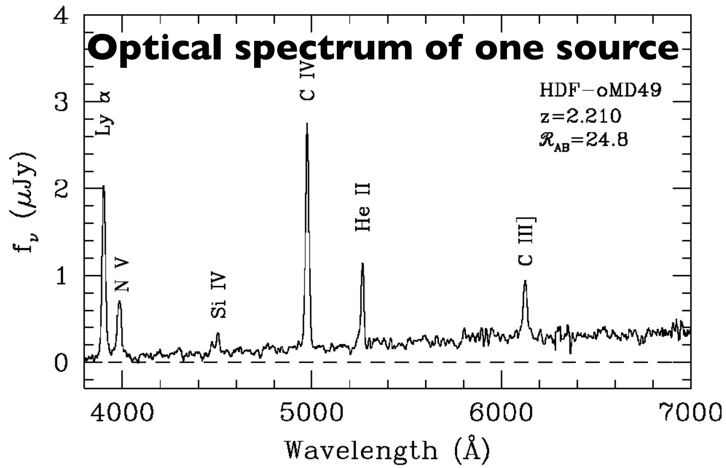
(1) 4 very luminous IR AGN at z~2-3 that are undetected in 2Ms Chandra data!

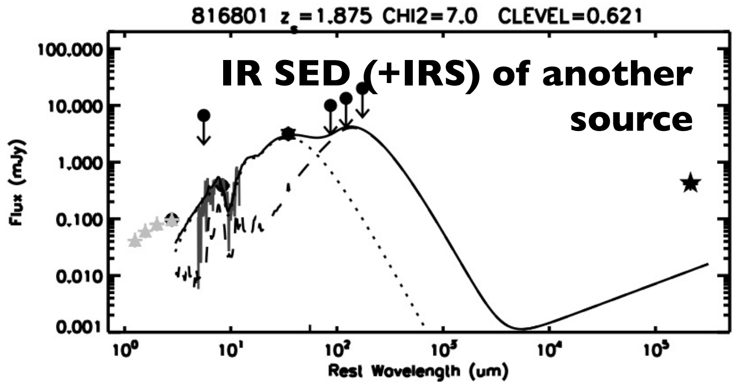
(2) IR AGN selection more effective at finding z<1 AGNs than X-ray data

(I) z~2 Compton-thick quasars



Based on Alexander et al. (2008)



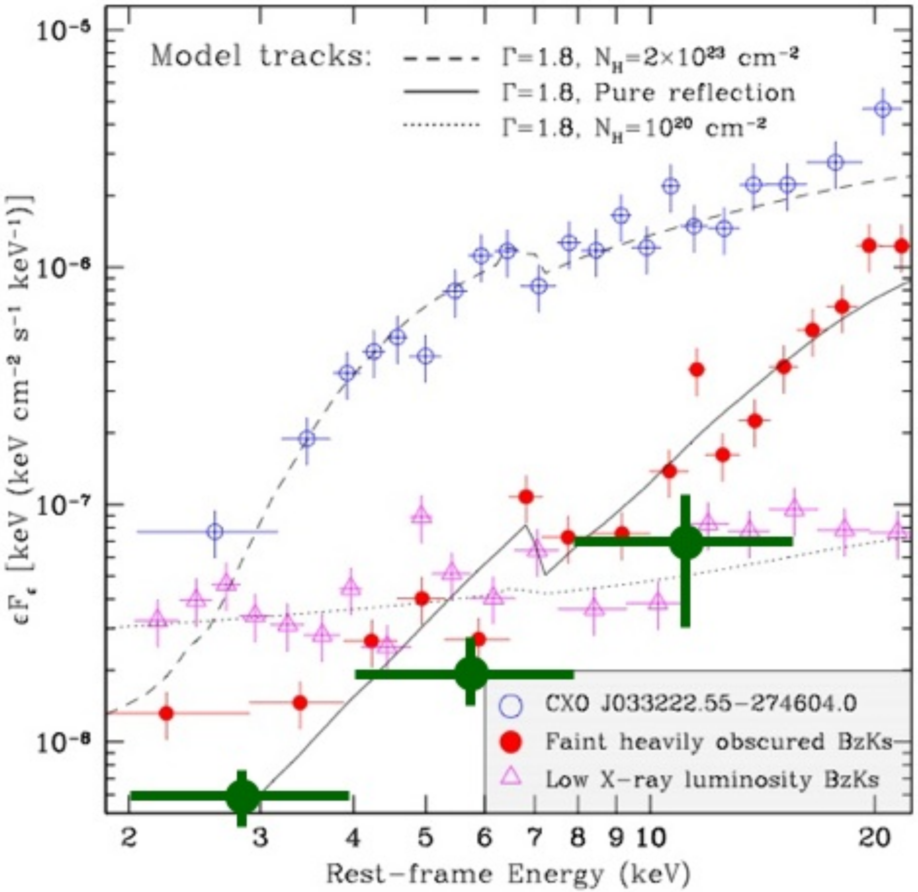


3 of the 4 systems have IRS spectroscopy

~10x less luminous than z~2 WISE AGNs but ~1,000x more common!

At least as many Compton-thick quasars as unobscured quasars at z~2 (e.g., Alexander et al. 2008)

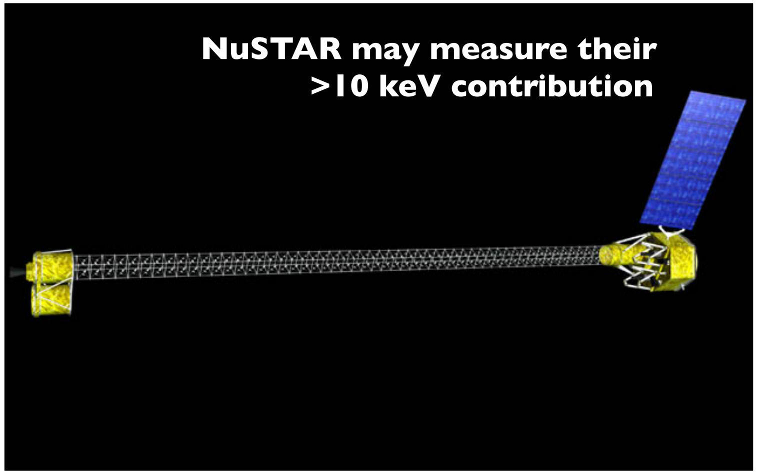
(2) z~1 IR AGNs: the unresolved X-ray background?



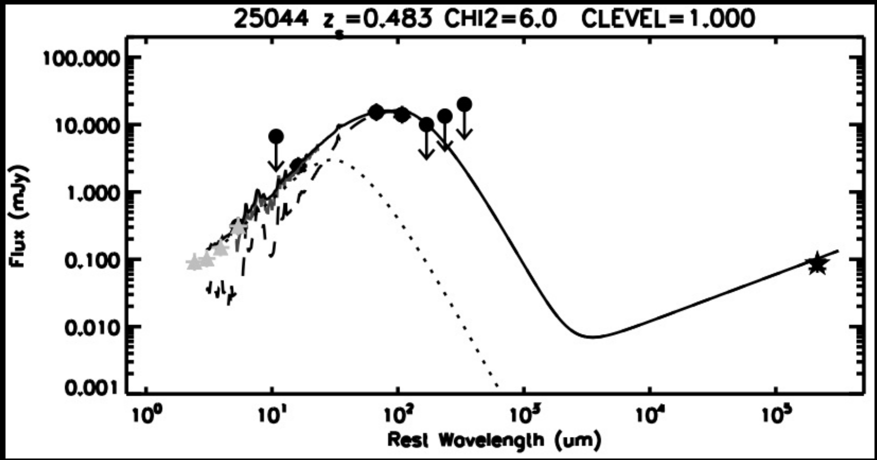
Stacked X-ray data of the X-ray undetected IR AGNs: consistent with reflection dominated: heavily obscured/ Compton thick

Properties consistent with producing the unresolved X-ray background at 30 keV:

z~1, intrinsic L_X~10^{43} erg/s
And heavily obscured



Summary



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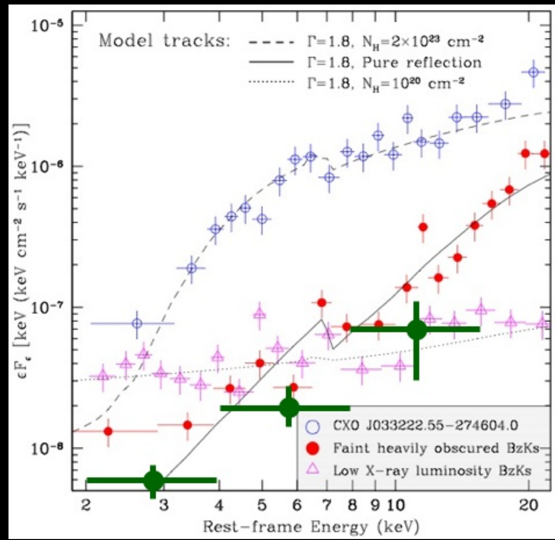

(1) Identified hidden AGN missed in X-ray surveys: z<1 moderate-luminosity IR-identified AGNs; they may produce the unresolved X-ray background at 30 keV

NuSTAR may measure their contribution at >10 keV

(2) Identified a population of z~2 Compton-thick quasars not detected in X-ray surveys: ~3-10x less luminous than WISE z~2 AGNs but ~1,000x more common!

How do they fit into the picture of BH and galaxy growth picture?