The census of highly obscured SMBH: X-ray observations of extreme Spitzer AGNs

Fabrizio Fiore

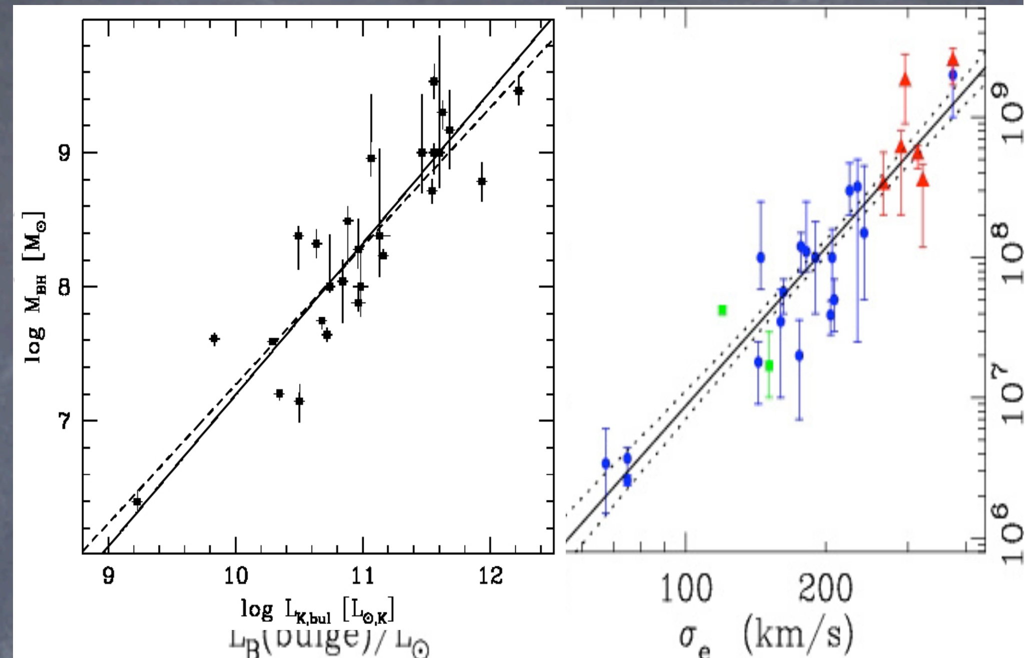
&

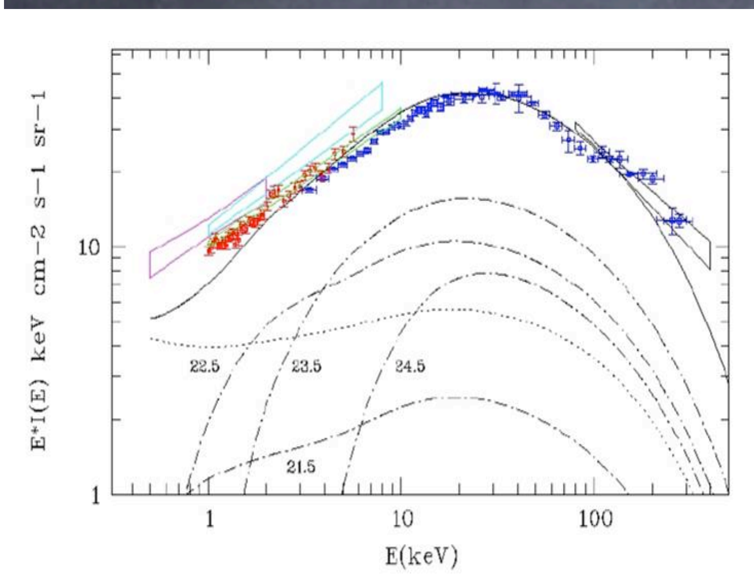
M. Brusa, A. Comastri, C. Feruglio, A. Fontana, A. Grazian,
F. La Franca, P. Santini, E. Piconcelli, S. Puccetti, G. Zamorani
and many others

Co-evolution of galaxies and SMBH

Two seminal results:

1. The discovery of SMBH in the most local bulges; **tight correlation** between M_{BH} and bulge properties.
2. The BH mass density obtained integrating the AGN L.-F. and the CXB ~ that obtained from local bulges





⇒ **most BH mass accreted during luminous AGN phases!**

Most bulges passed a phase of activity:

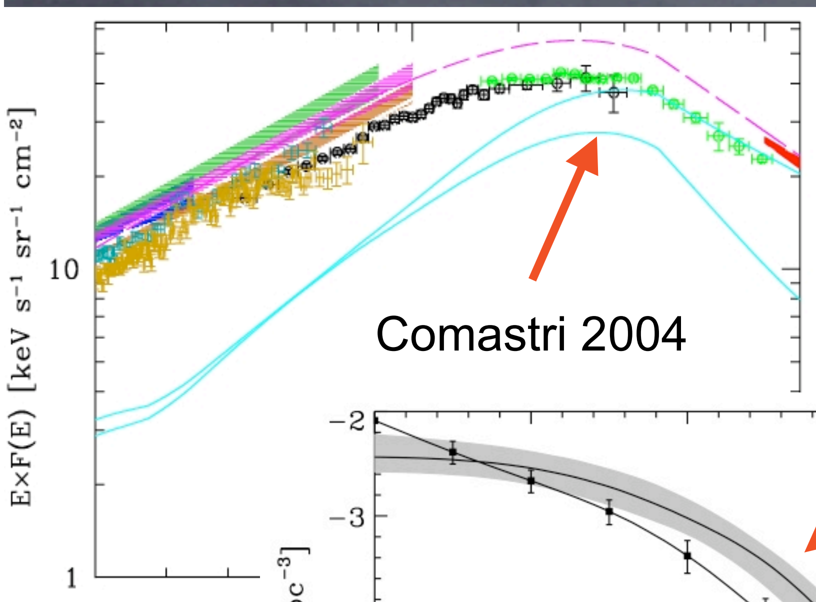
Complete SMBH census, full understanding of AGN evolution and AGN feedback are key ingredients to understand galaxy evolution

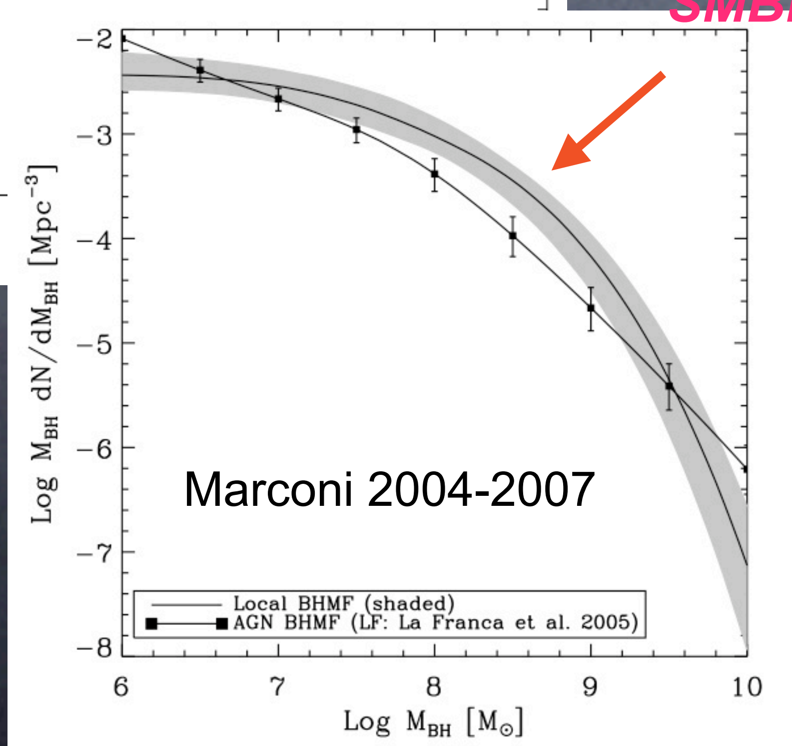
GOAL

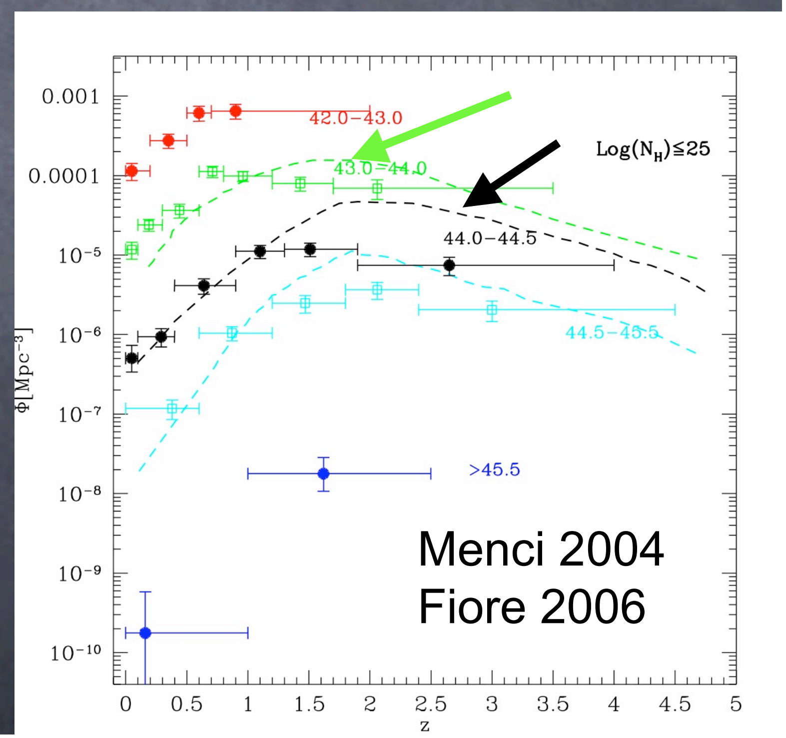
- AGN Bolometric Luminosity function
- Complete SMBH census
- Strong constraints to models for the formation and evolution of structure in the Universe

Evidences for missing SMBH

While the CXB energy density provides a statistical estimate of SMBH growth, the lack, so far, of focusing instrument above 10 keV (where the CXB energy density peaks), frustrates our effort to obtain a ***comprehensive picture of the SMBH evolutionary properties***.

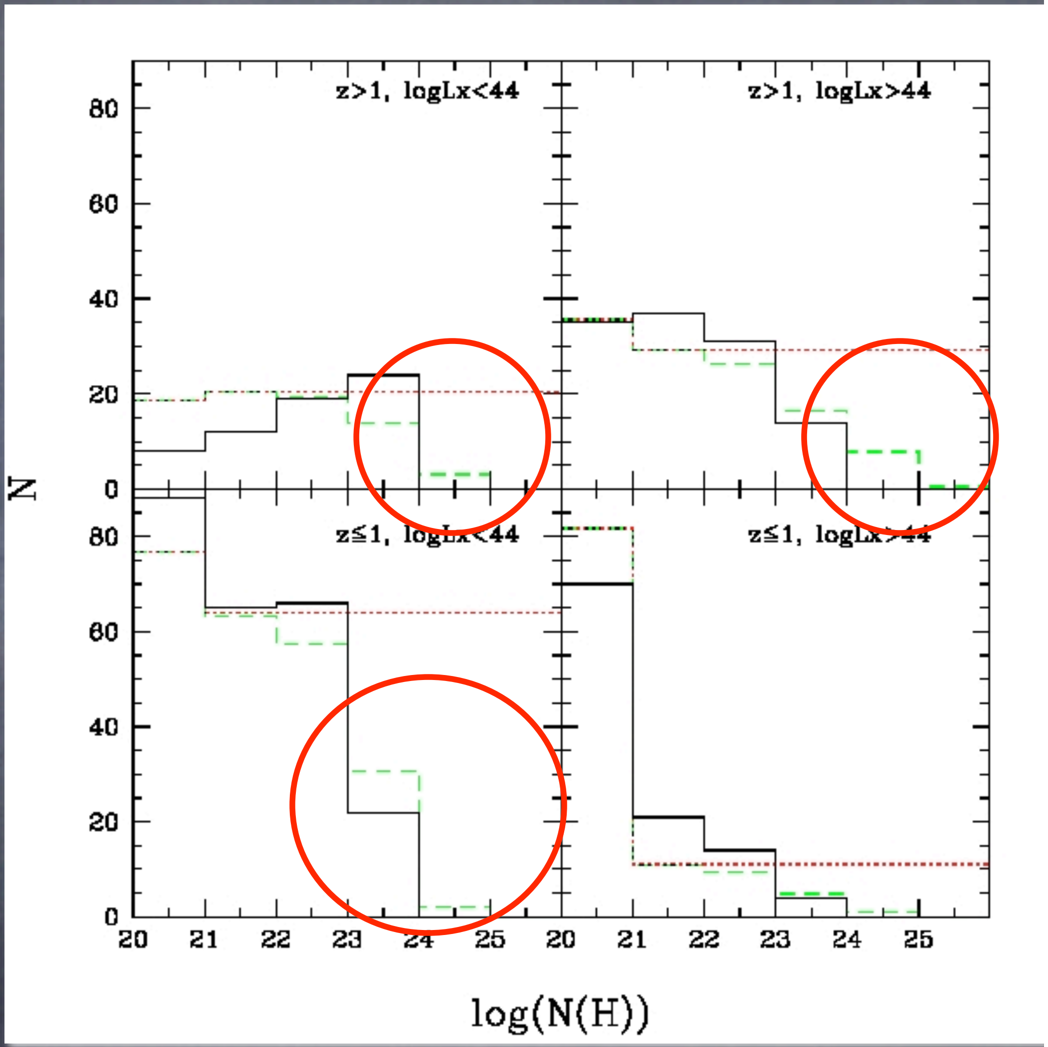






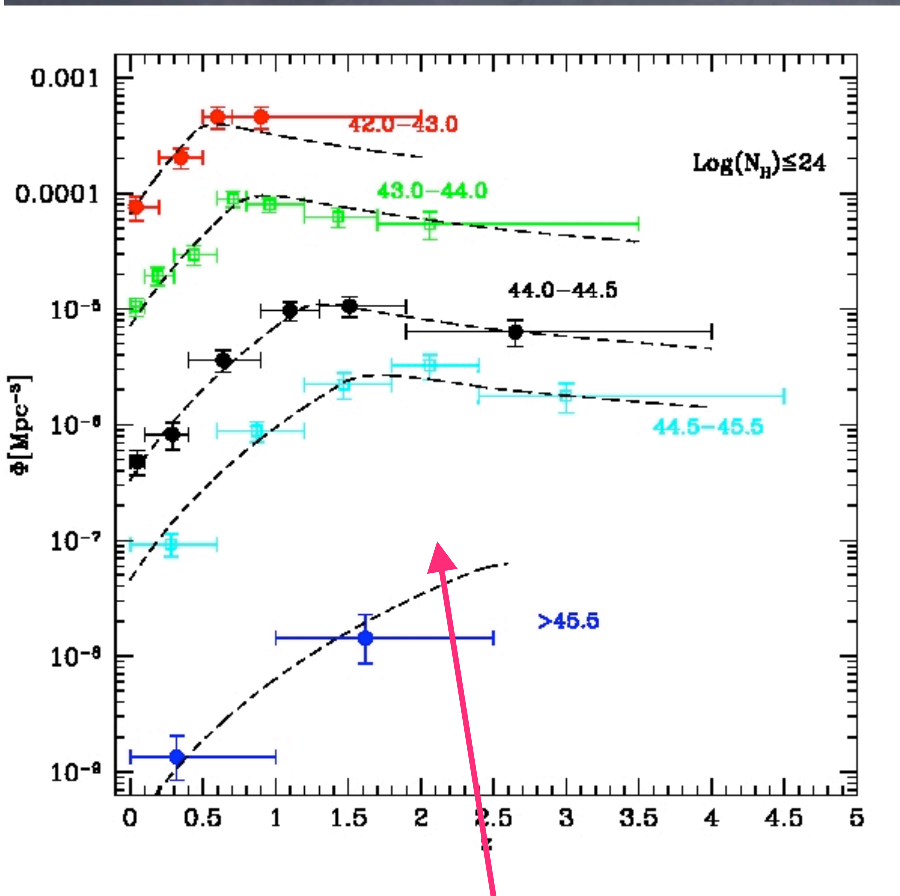
Why multiwavelength surveys

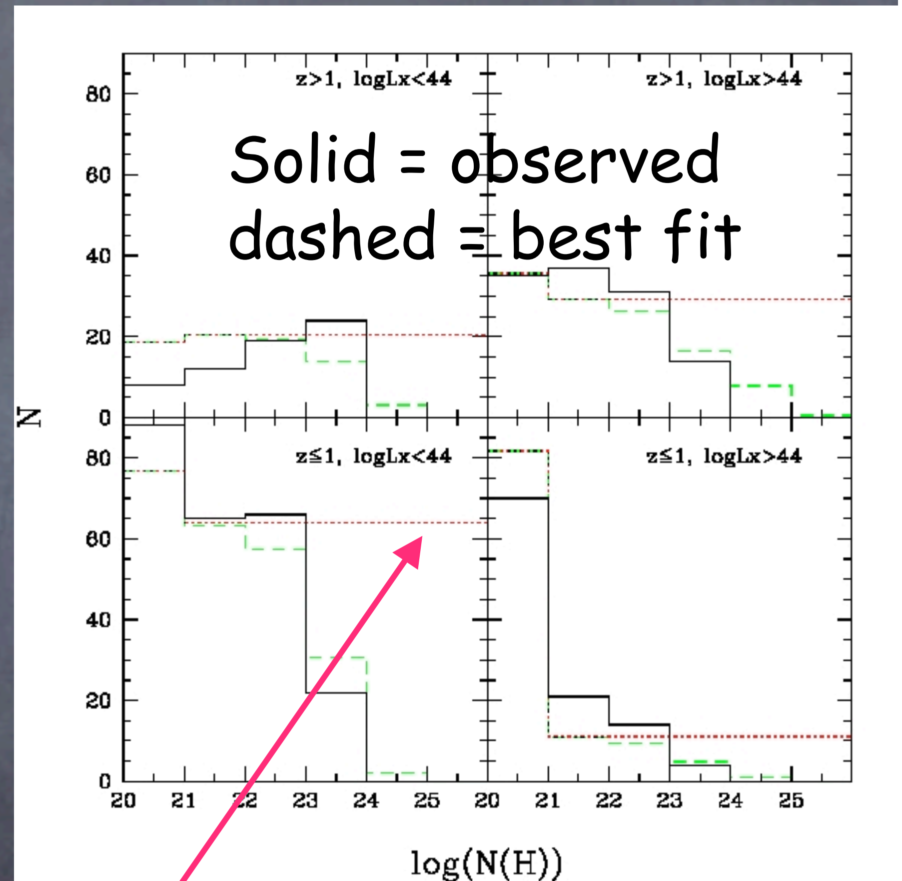
- X-ray surveys:
- very efficient in selecting unobscured and moderately obscured AGN
- Miss most highly obscured AGN



La Franca et al. 2005

2-10 keV AGN luminosity function models





LDDE with constant N_H distribution

La Franca et al. 2005

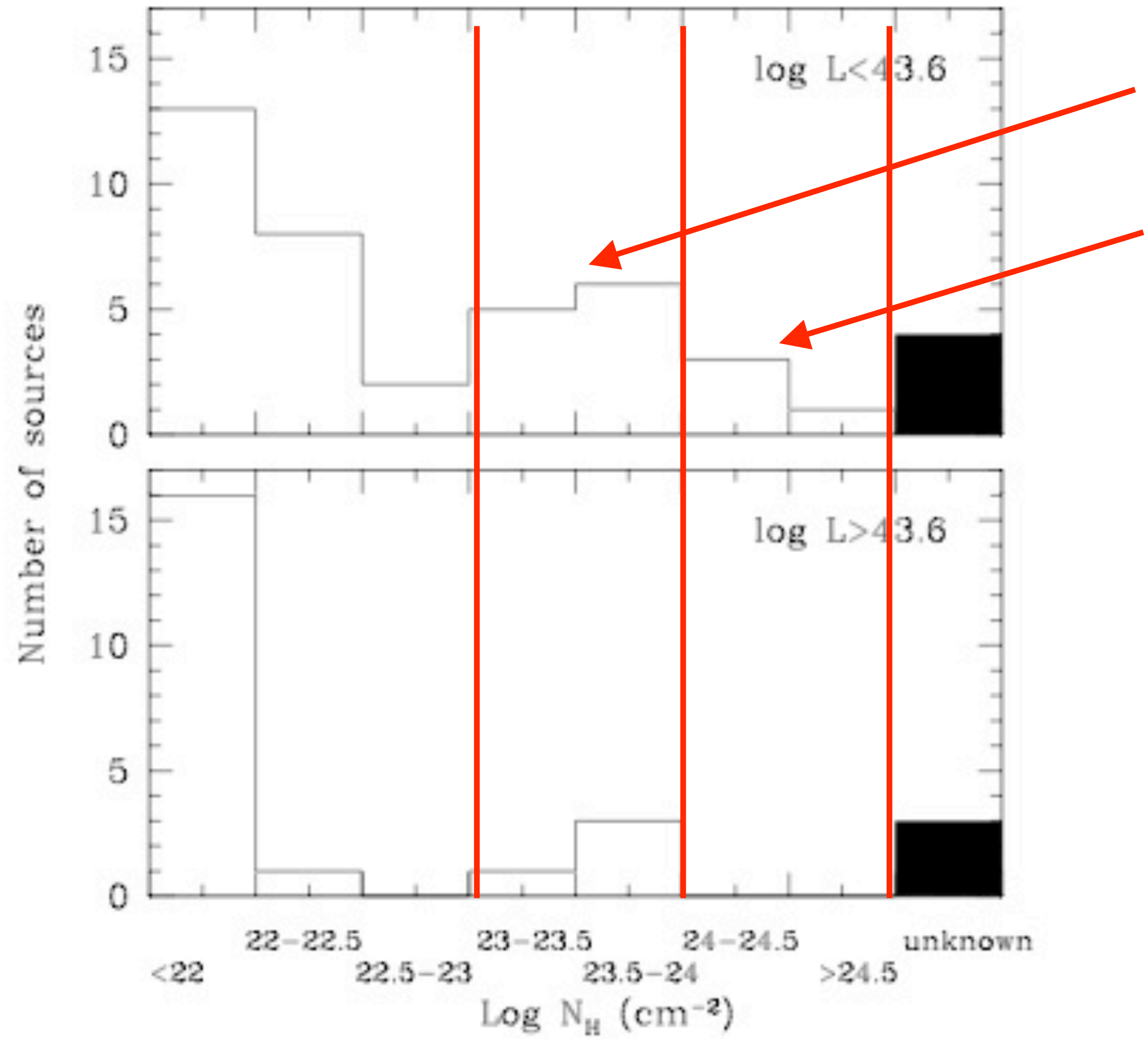
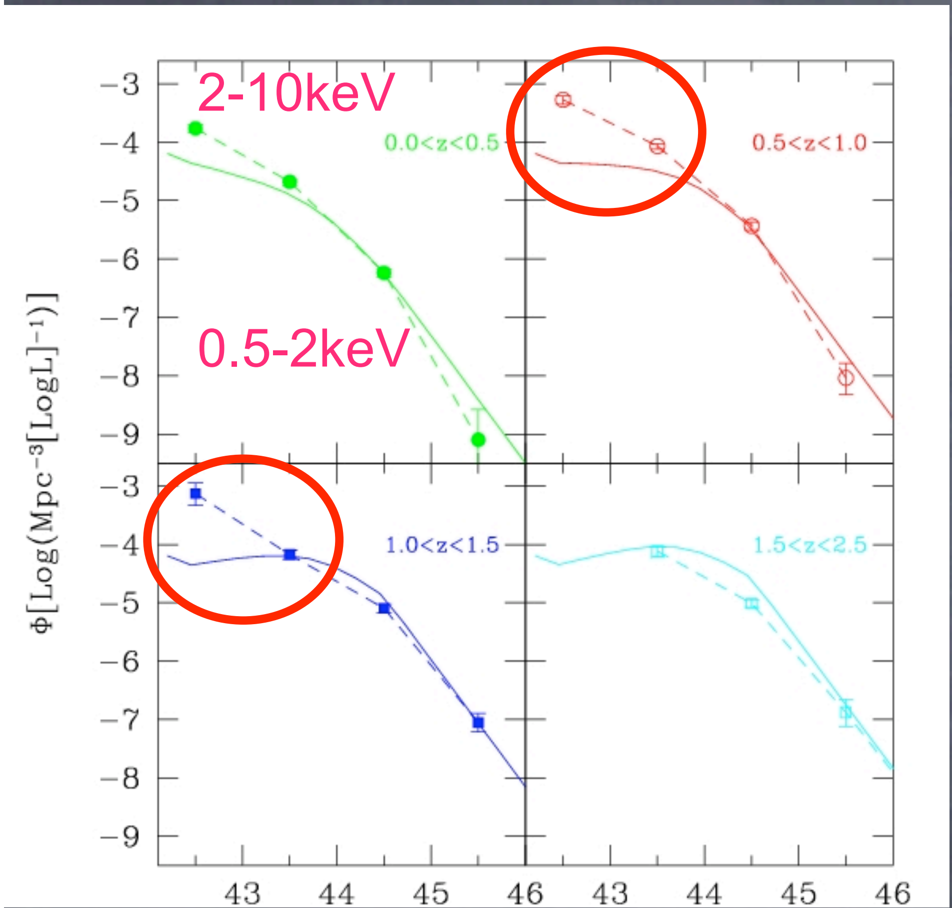


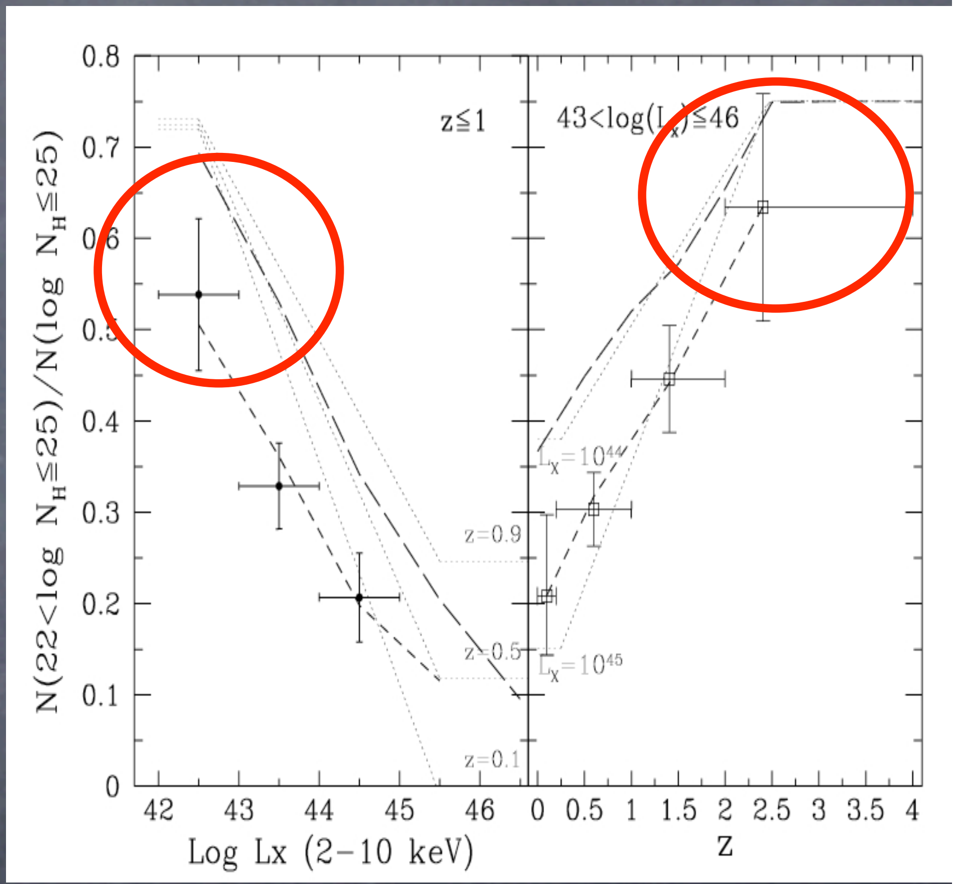
Fig. 2. Observed X-ray absorption distribution of the low-luminosity AGN (top panel), and high-luminosity AGN (bottom panel). The shaded part of each diagram shows the number of AGN with unknown N_H.

INTEGRAL survey
~ 100 AGN

Sazonov et al. 2006

2-10 keV AGN luminosity function models



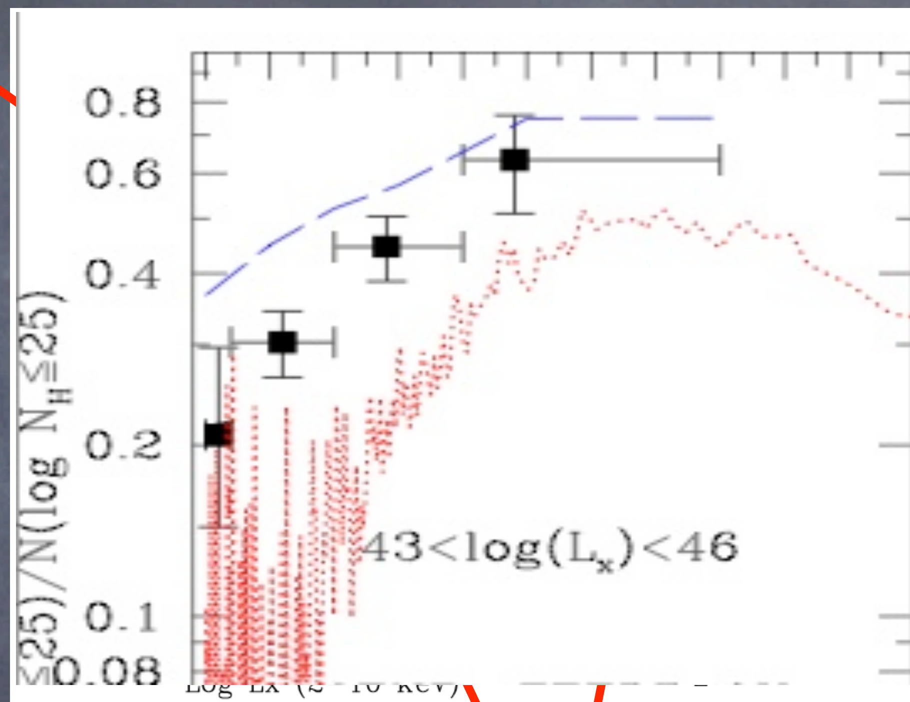


LDDE with variable absorbed AGN fraction

La Franca et al. 2005

A working scenario

small mass progenitors. Feedback is effective in self-regulating accretion and SF, cold gas is left available



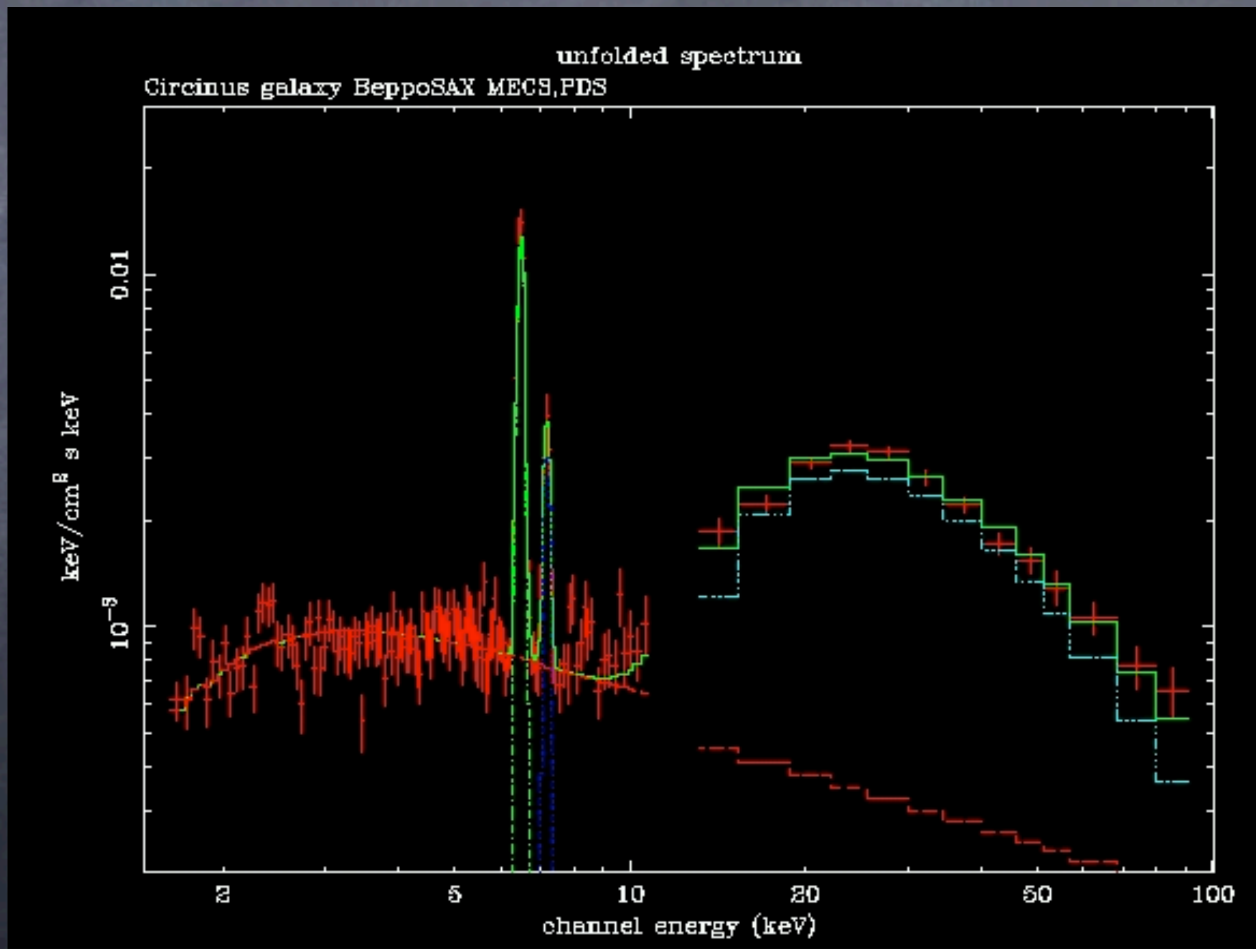
Galactic cold gas available for accretion and obscuration increases at high z

large mass progenitors. Feedback is less effective, most gas is quickly converted in stars at high z.

Menci hierarchical clustering model, Menci, Puccetti Fiore 2006

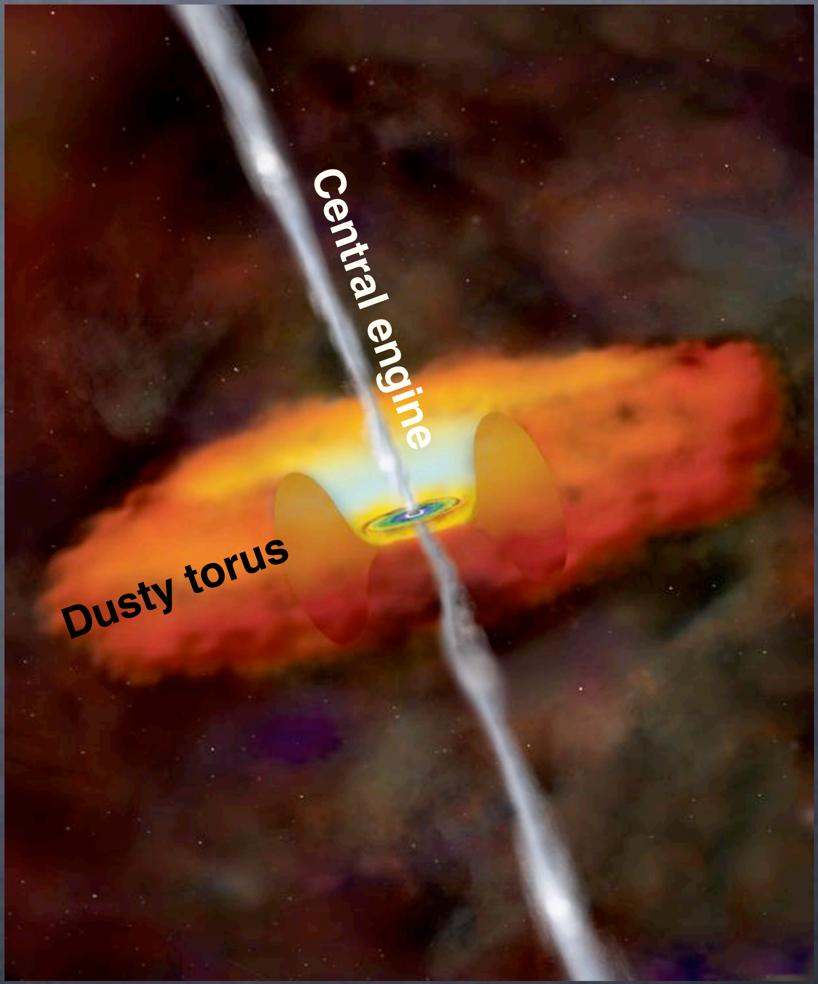
Paucity of Seyfert like sources @ z>1 is real? Or, is it, at least partly, a selection effect?

Are we missing in Chandra and XMM surveys highly obscured ($N_H \times 10^{24}$ cm^{-2}) AGN? Which are common in the local Universe…



Why multiwavelength surveys

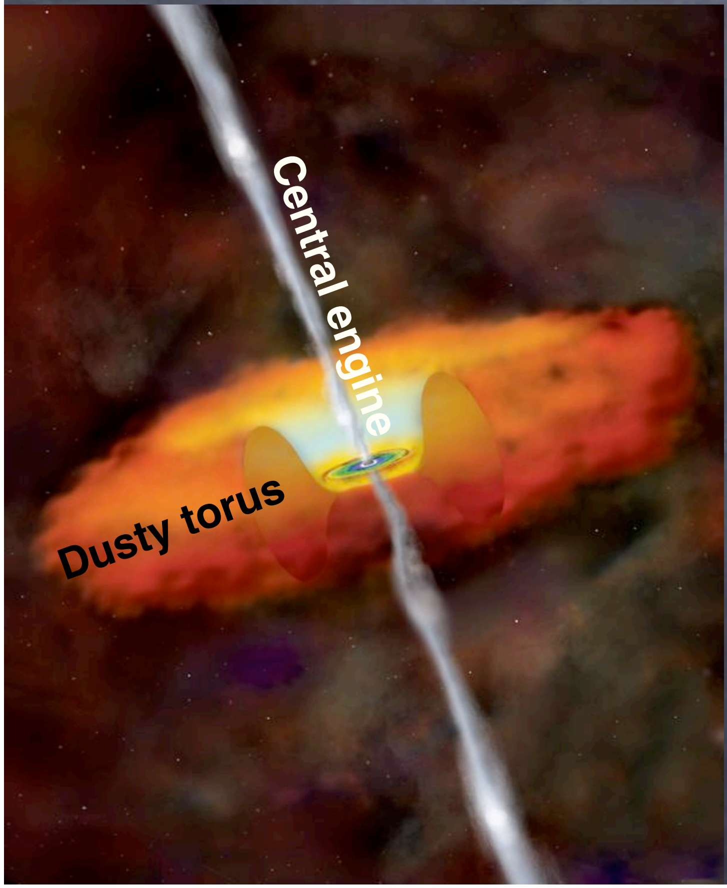
- IR surveys:
- AGNs highly obscured at optical and X-ray wavelengths shine in the MIR thanks to the reprocessing of the nuclear radiation by dust

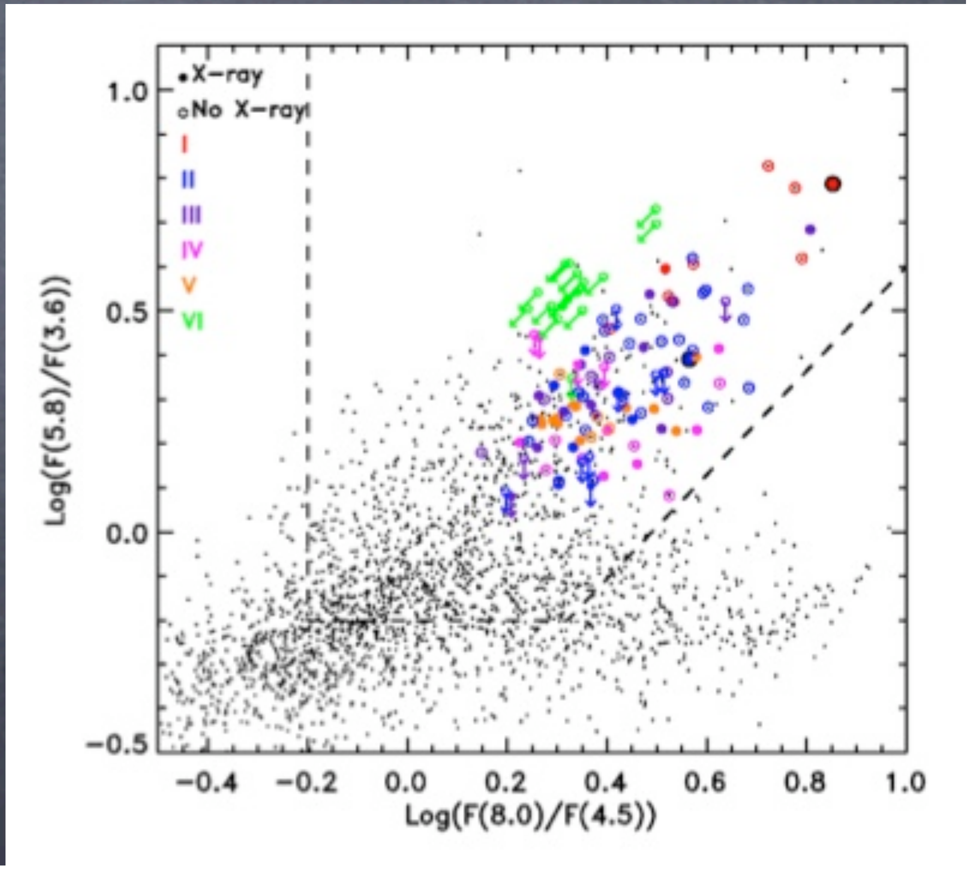


IR surveys

- AGNs highly obscured at optical and X-ray wavelengths shine in the MIR thanks to the reprocessing of the nuclear radiation by dust

- Very difficult to isolate AGN from passive and star-forming galaxies (Lacy 2004, Barnby 2005, Stern 2005, Polletta 2006 and many others)





Why multiwavelength surveys

- Use both X-ray and MIR surveys:

- Select unobscured and moderately obscured AGN in X-rays
- Add highly obscured AGNs selected in the MIR

- Simple approach: Differences are emphasized in a wide-band SED analysis

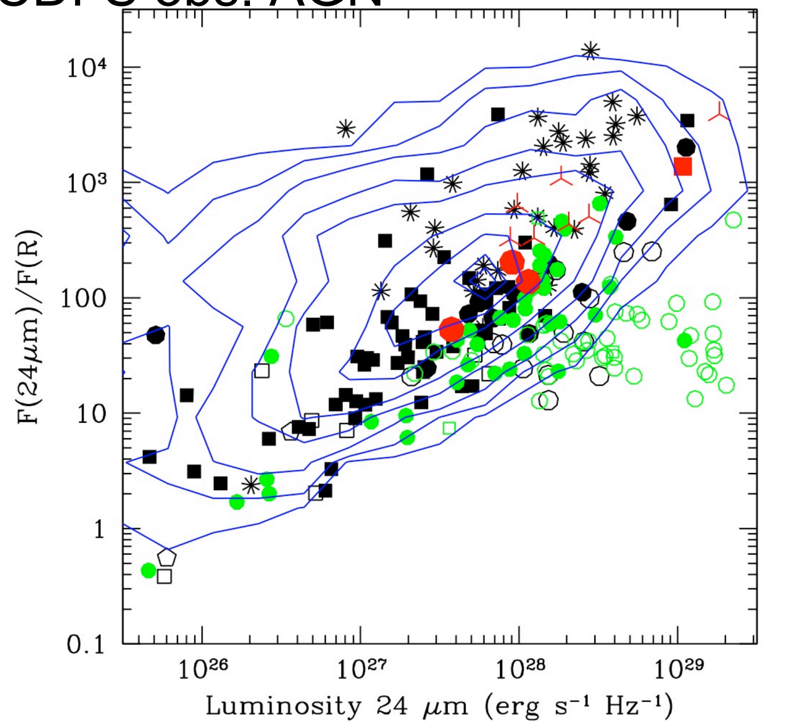
X-ray-MIR surveys

- CDFS-Goods MUSIC catalog (Grazian et al. 2006, Brusa, FF et al. 2007)
- Area 0.04 deg2
- 173 X-ray sources, 104 2-10 keV down to 3×10^{-16} cgs, 109 spectroscopic redshifts
- 1700 MIPS sources down to 40 μJy, 3.6mm detection down to 0.08 μJy
- Ultradeep Optical/NIR photometry, R~27.5, K~24
- ELAIS-S1 SWIRE/XMM/Chandra survey (Puccetti et al. 2006, Feruglio et al. 2006).
- Area 0.5 deg2
- 500 sources, 205 2-10 keV down to 3×10^{-15} cgs, half with spectroscopic redshifts.
- 2600 MIPS sources down to 100 μJy, 3.6mm detection down to 6 μJy
- Relatively deep Optical/NIR photometry, R~25, K~19

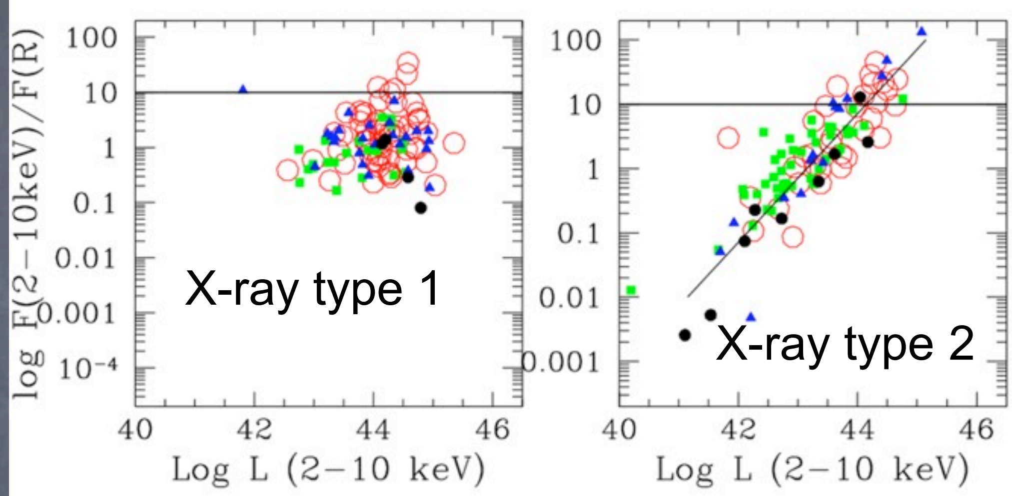
- In future we will add:
- COSMOS XMM/Chandra/Spitzer. Area 2 deg^2
- CDFN-Goods. Area 0.04 deg2

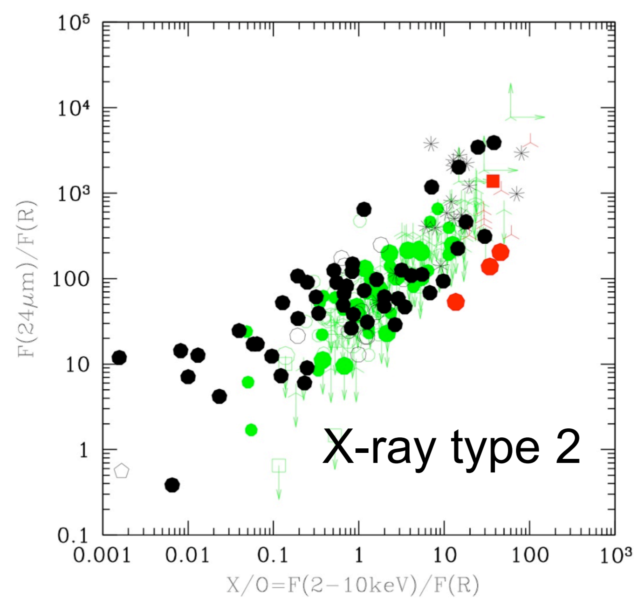
MIR selection

Open symbols = unobscured AGN
Filled symbols = optically obscured AGN
ELAIS-S1 obs. AGN
ELAIS-S1 24mm galaxies
HELLAS2XMM
CDFS obs. AGN

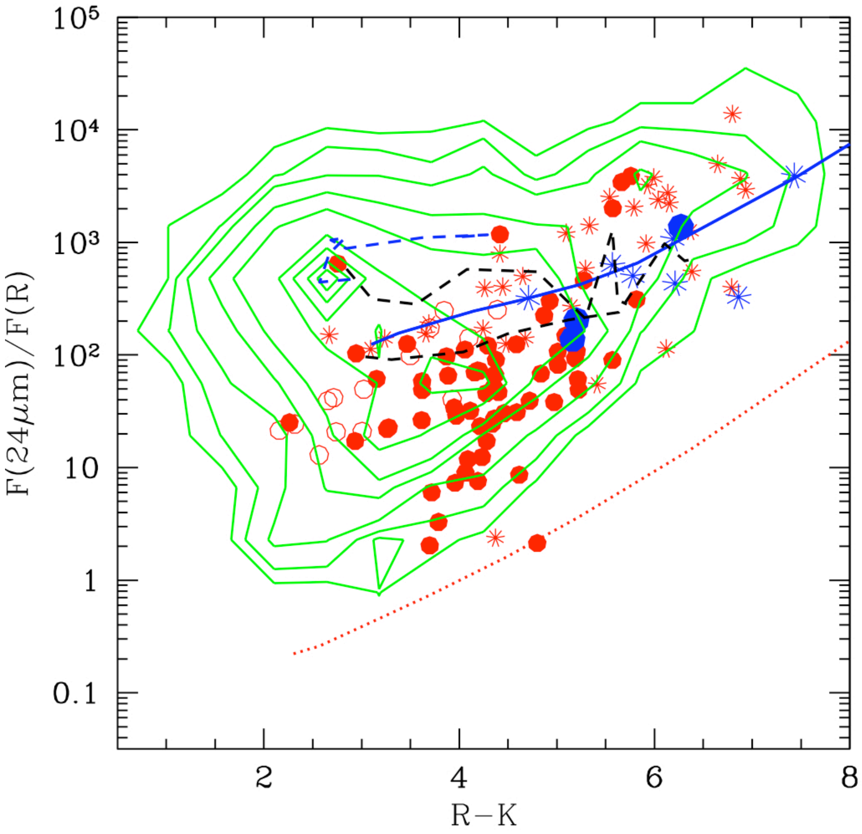


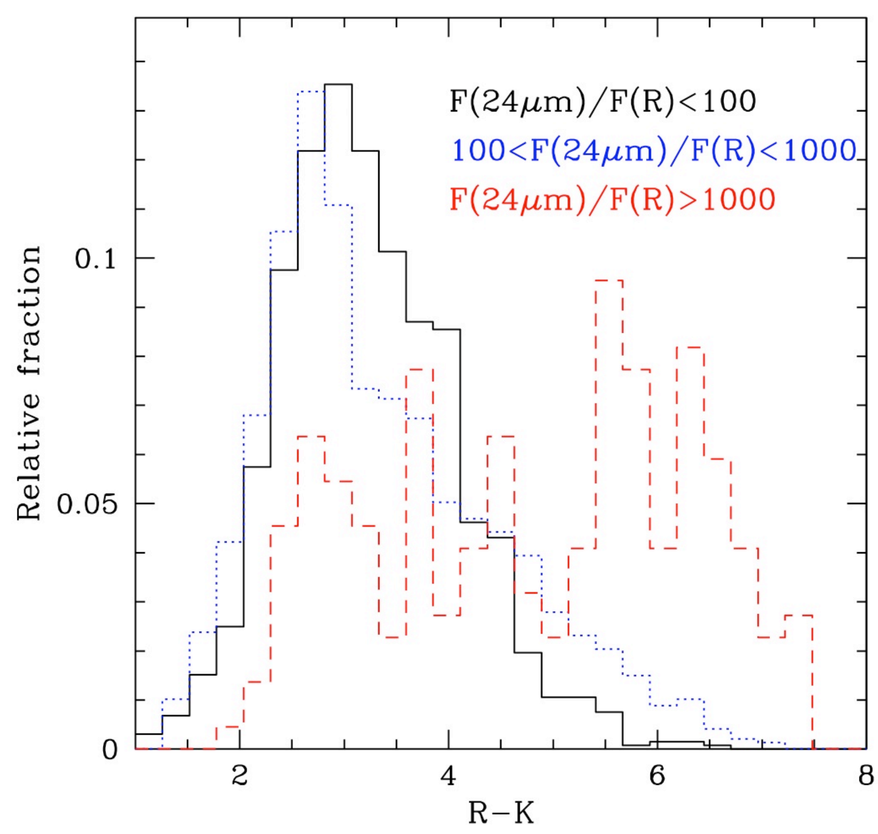
Fiore et al. 2003





MIR selection





CDFS

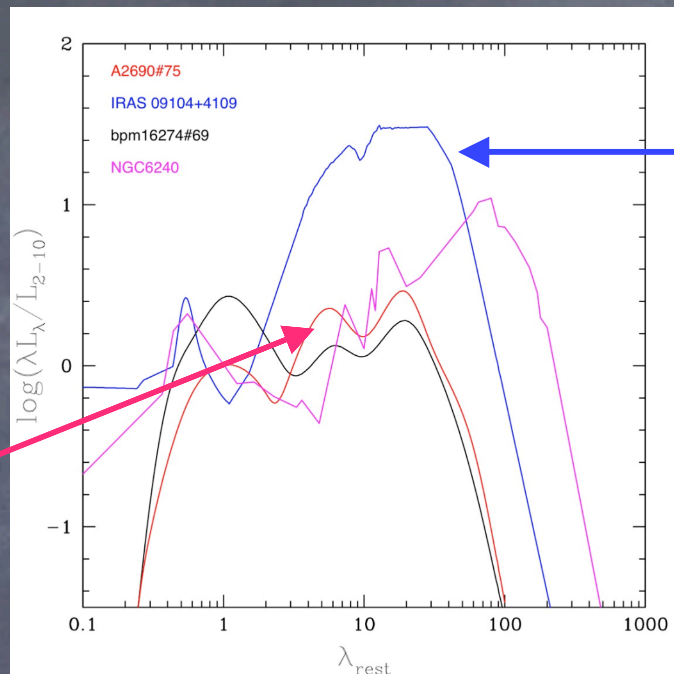
HELLAS2XMM

GOODS 24mm galaxies

Template highly obscured QSOs

Abel2690#75

(Pozzi et al 2007)



- IRAS09104+4109
- High L(IR)/Lx ratio
- No PAH emission features in IRS spectrum
- IR SED dominated by the AGN

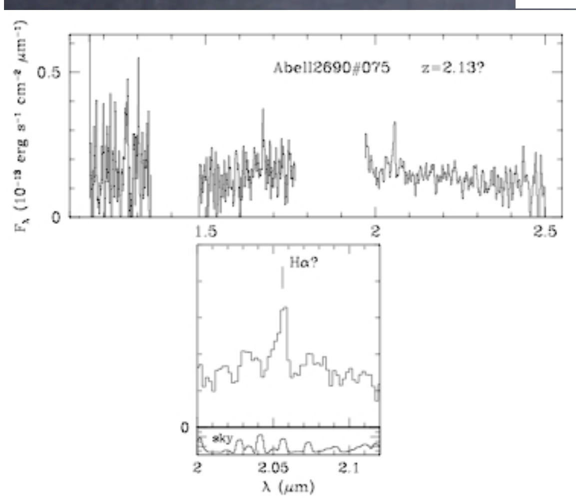
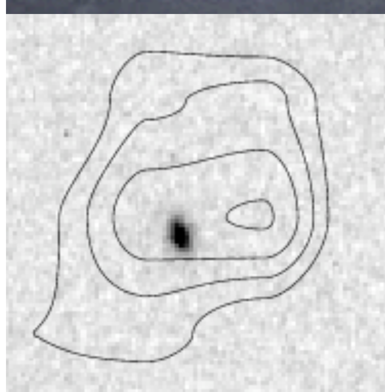
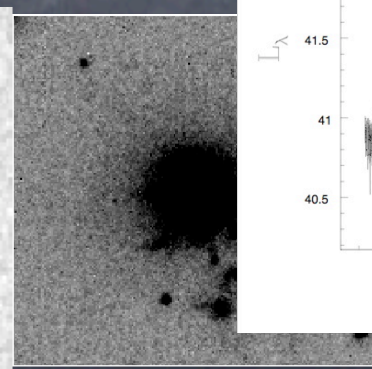
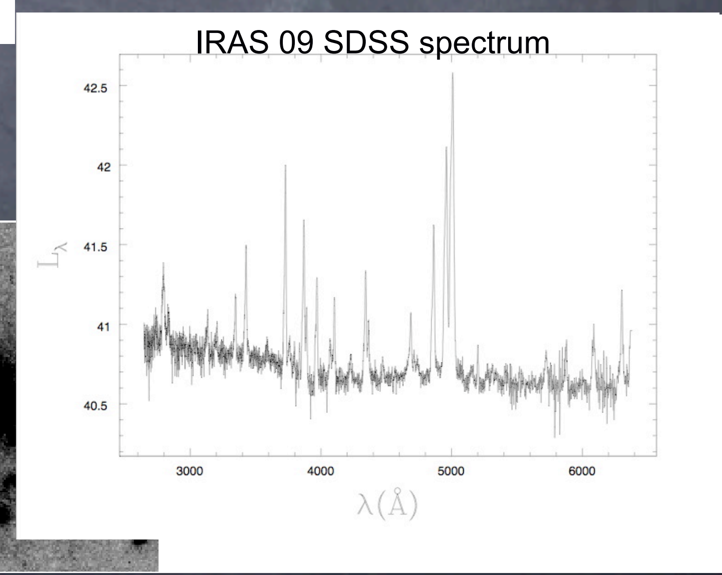


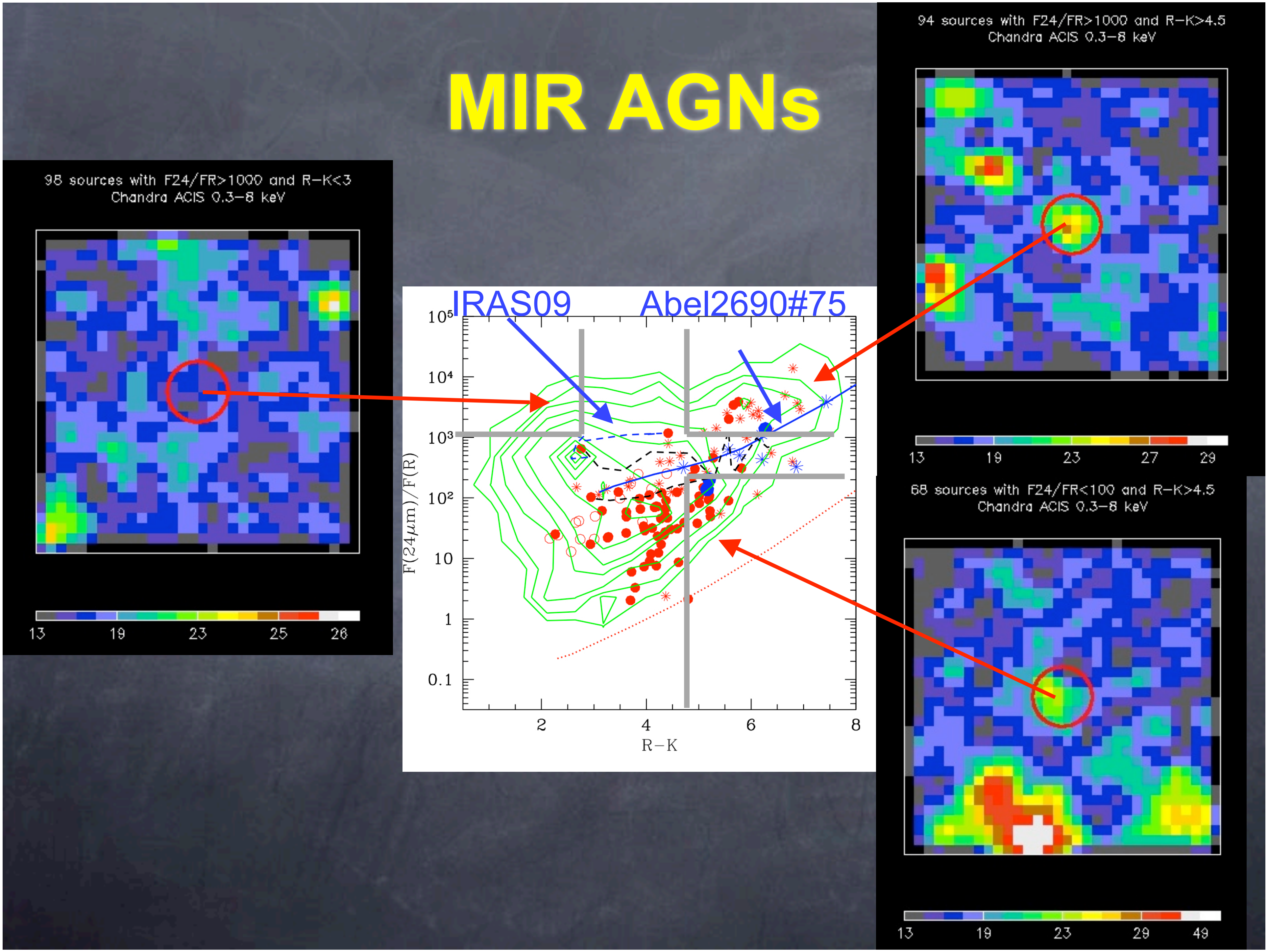
Fig. 4. As Fig.2 for Abell2690#075. The bottom panel shows the zoom around a line tentatively identified as Hα at z=2.13.





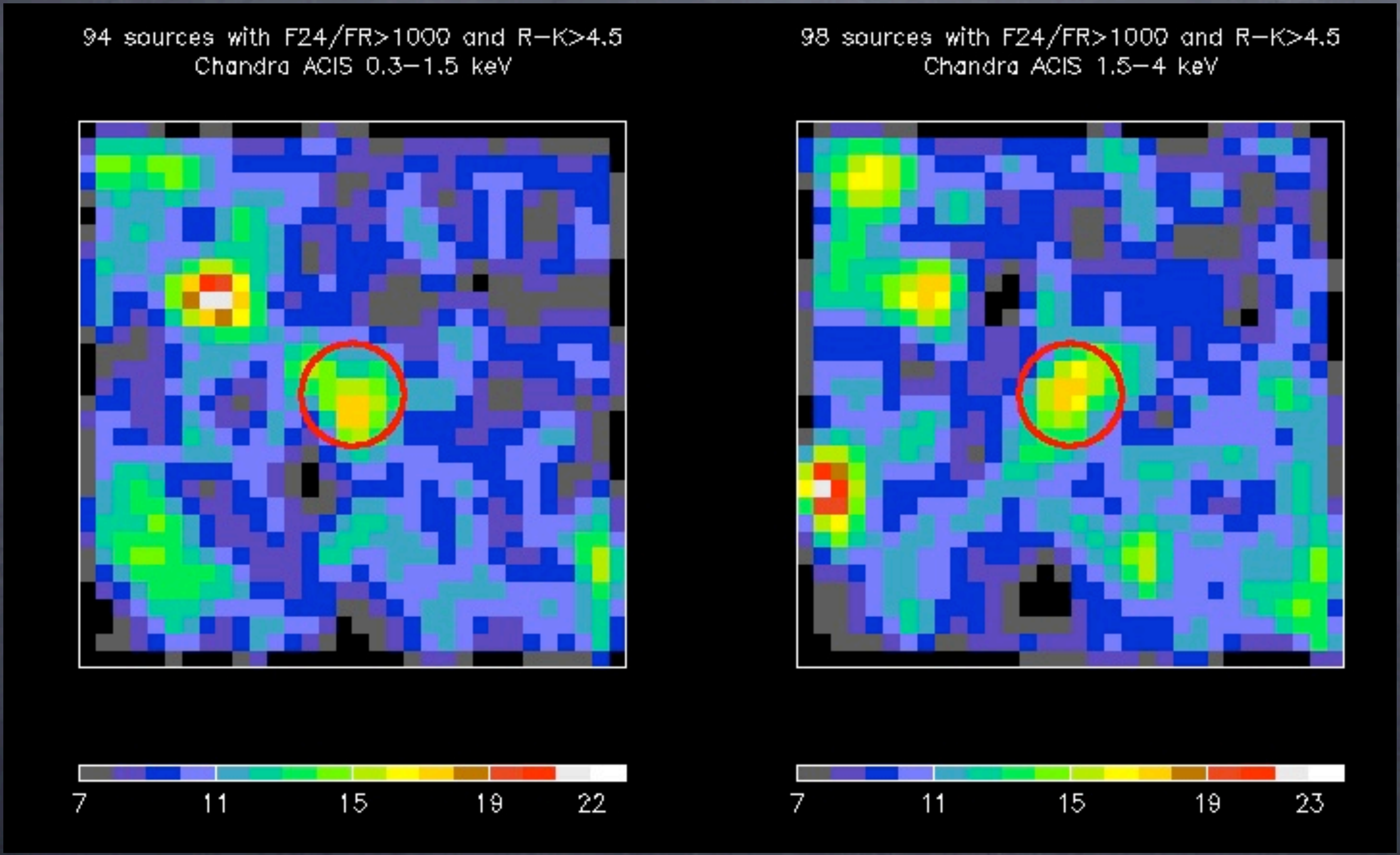


MIR AGNs



98 sources with F24/FR>1000 and R−K<3
Chandra ACIS 0.3−8 keV
13 19 23 25 26
94 sources with F24/FR>1000 and R−K>4.5
Chandra ACIS 0.3−8 keV
13 19 23 27 29
68 sources with F24/FR<100 and R−K>4.5
Chandra ACIS 0.3−8 keV
13 19 23 29 49
IRAS09
Abel2690#75
F(24μm)/F(R)
R−K

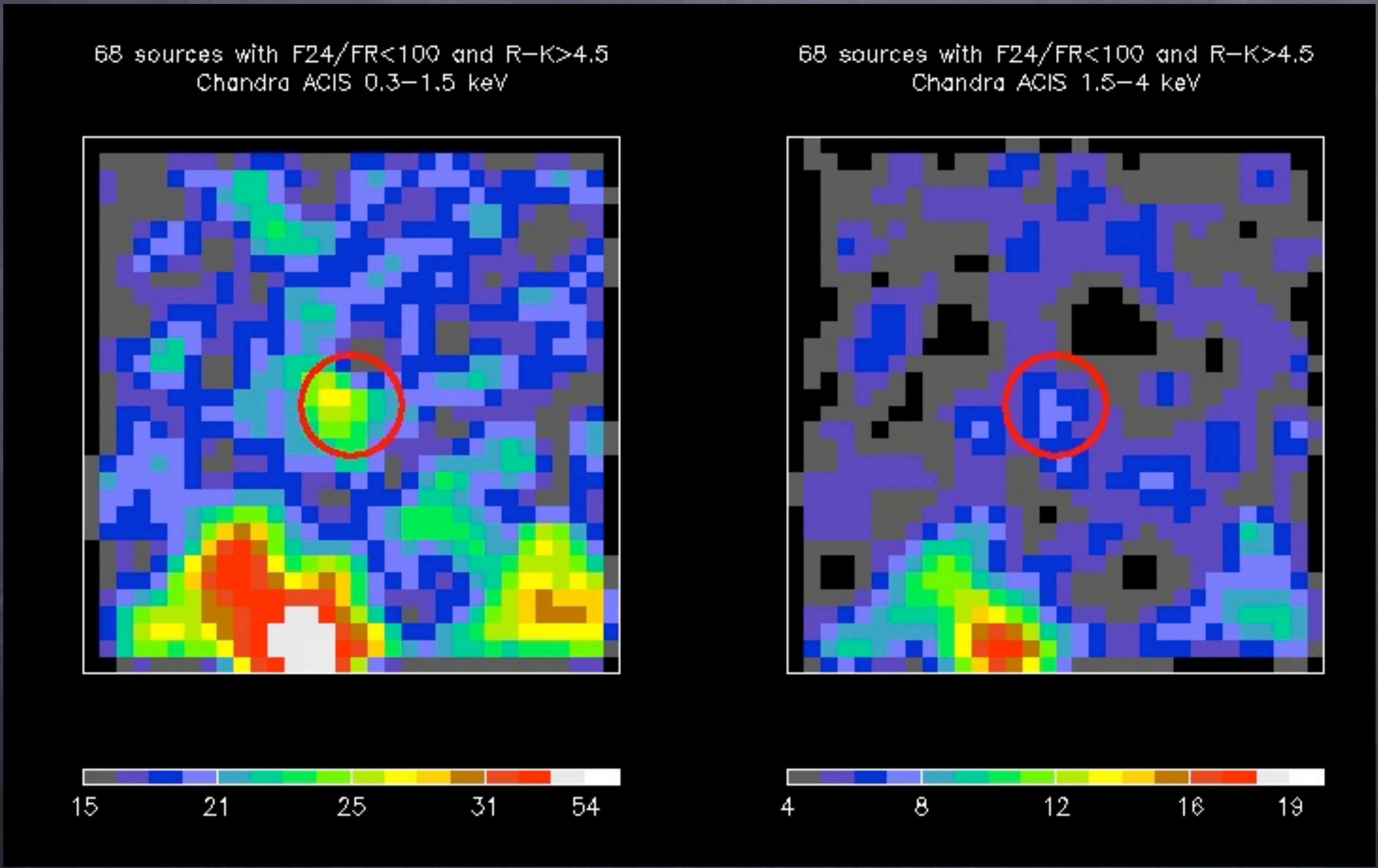
F24μm/FR >1000 R-K>4.5



F(0.3-1.5keV)~10^{-17} cgs

F(1.5-4keV)~10^{-17} cgs

F24μm/FR <100 R-K>4.5

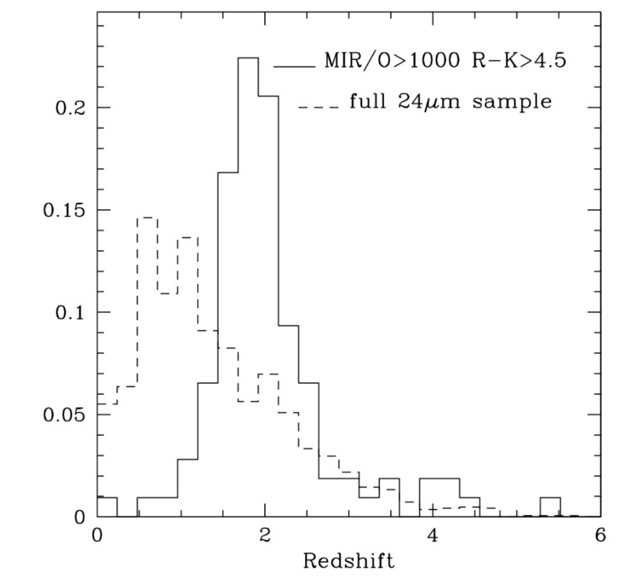


F(0.3-1.5 keV)~2×10^{-17} cgs

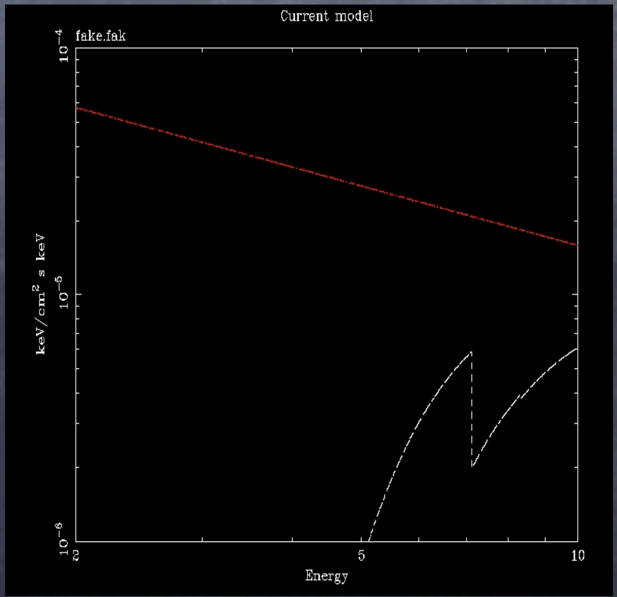
F(1.5-4 keV) < 5×10-^{18} cgs

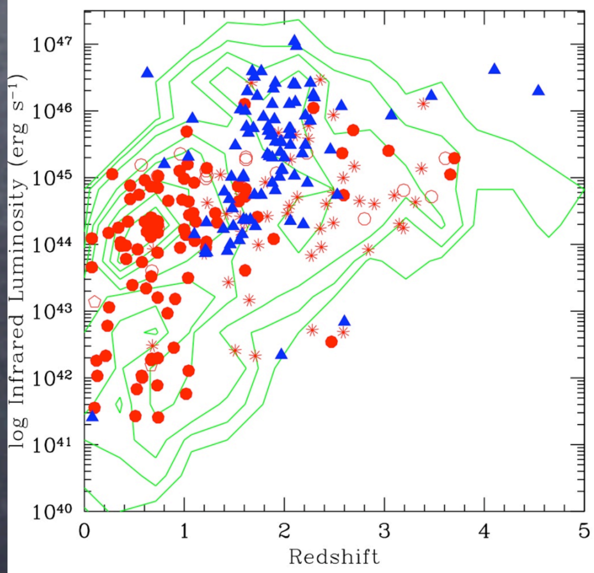
F24μm/FR >1000 R-K>4.5

- 135 sources (8% of the MIPS sample)
- 18 detected by Chandra (9 2-10 keV band) 4 more visible in the image <LX>=43.45+/-0.24, <N_H>=22.9+/-0.8, <z>~2.1
- logF(1.5-4keV) stacked sources=-17
- @z~2 logL_{obs}(2-8keV) stacked sources ~41.8
- log<LIR>~44.8 ==> logL(2-8keV) unabs.~43
- Difference implies logN_H~24



- <SFR-IR>~200!!
- Msun/yr
- <SFR-UV>~7!!
- Msun/yr
- <SFR-X>~65
- Msun/yr

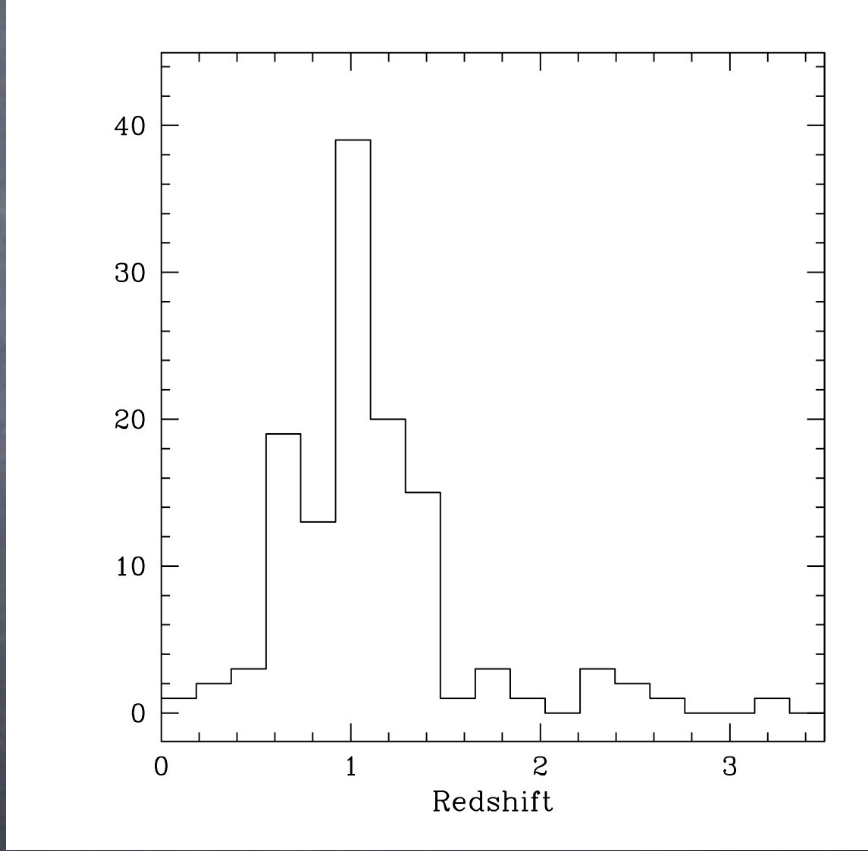




F24mm/FR <200 R-K>4.5

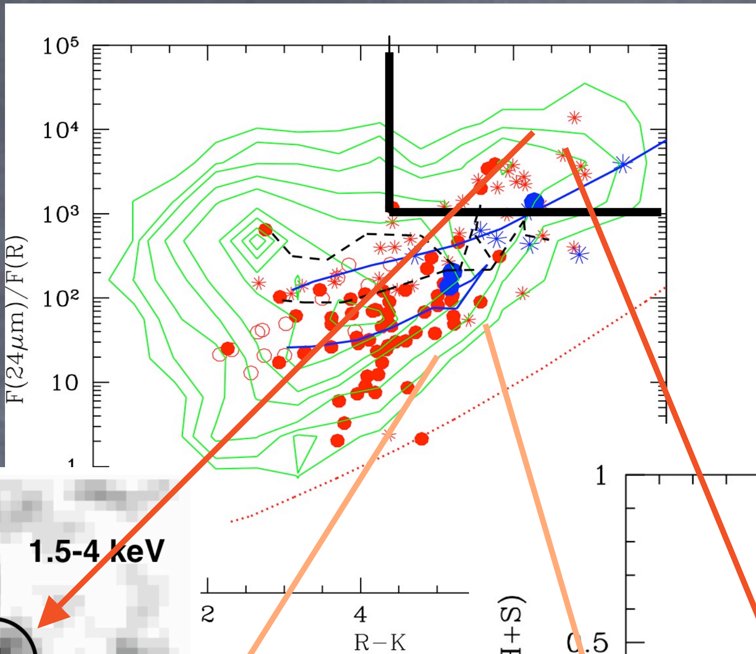
- 110 sources (7% of the MIPS sample)
- 29 detected by Chandra, 19 2-10 keV, <LX>=43.4+/-0.4 <NH>=23.2+/-0.6, <z>~1.4

- <SFR-IR> ~ 18 Msun/yr
- <SFR-UV> ~13 Msun/yr
- <SFR-X>~20 Msun/yr



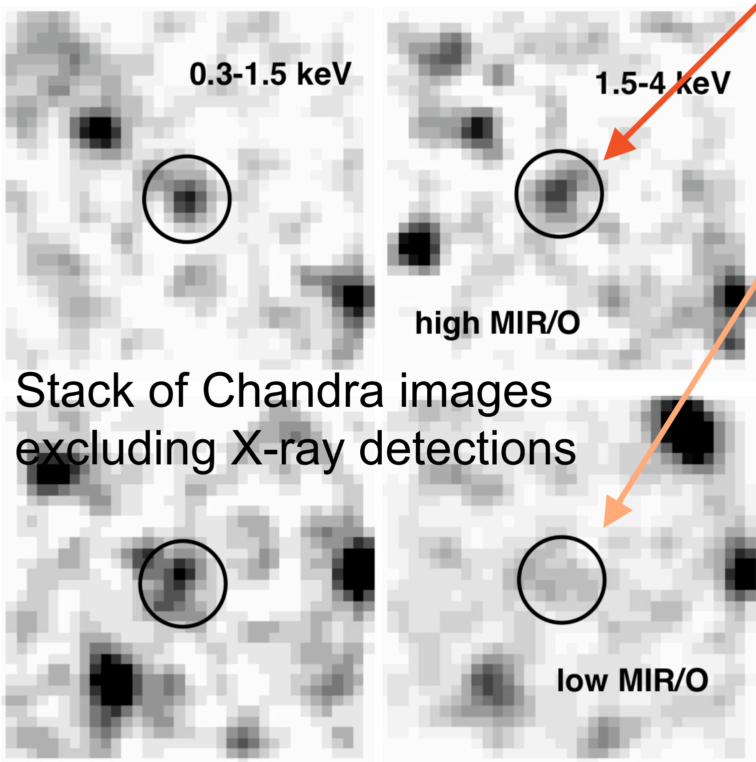
A new population of CT AGN

Using the observed counts rate and hardness ratios we evaluated the fraction of highly obscured AGN ($logN_H>24$) in the samples

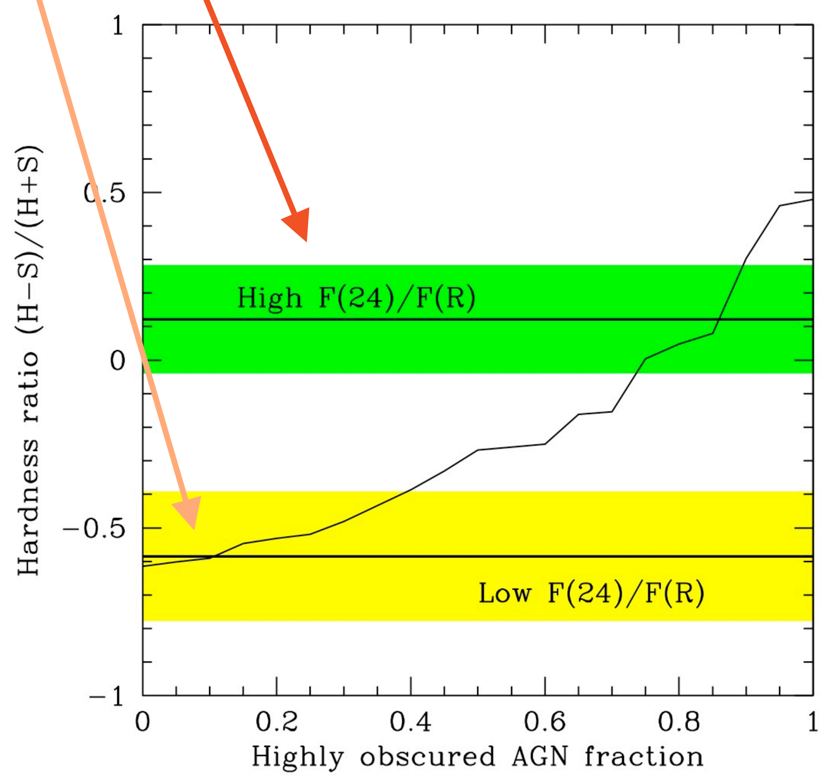


Assuming a reasonable LIR/LX ratio, a flat N_H distribution from $logN_H$=24-26 and a reflection component =1% of the direct one

Fiore et al. 2007

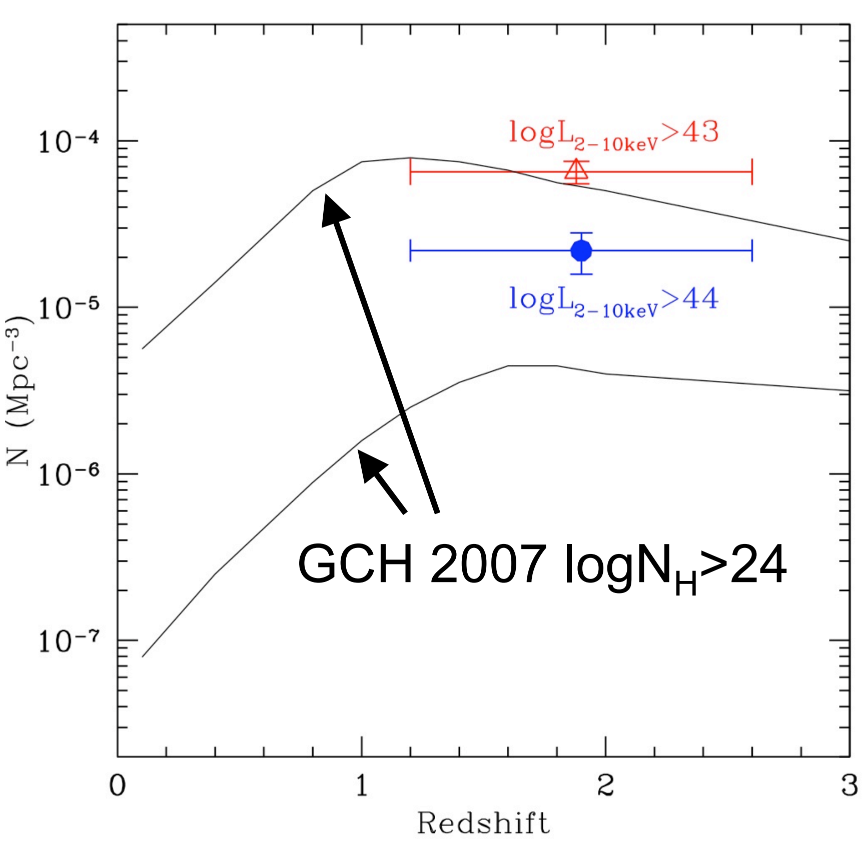


Stack of Chandra images excluding X-ray detections

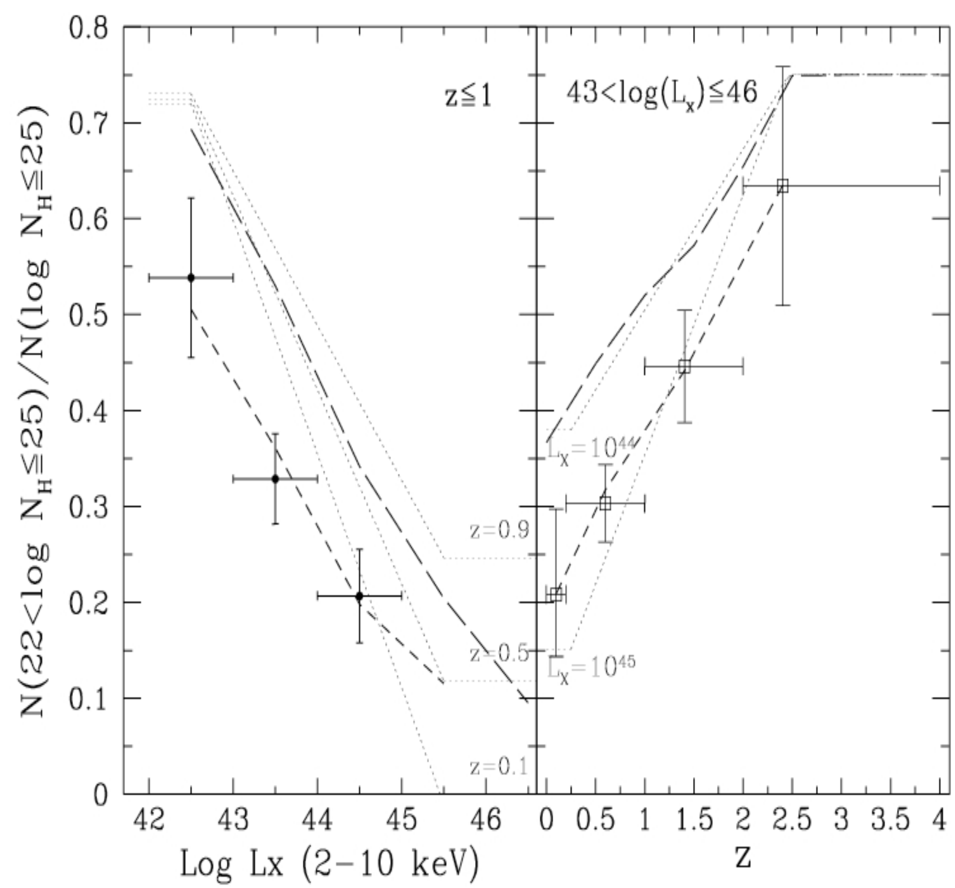


Density of Obscured AGNs

IR selected



2-10 keV selected

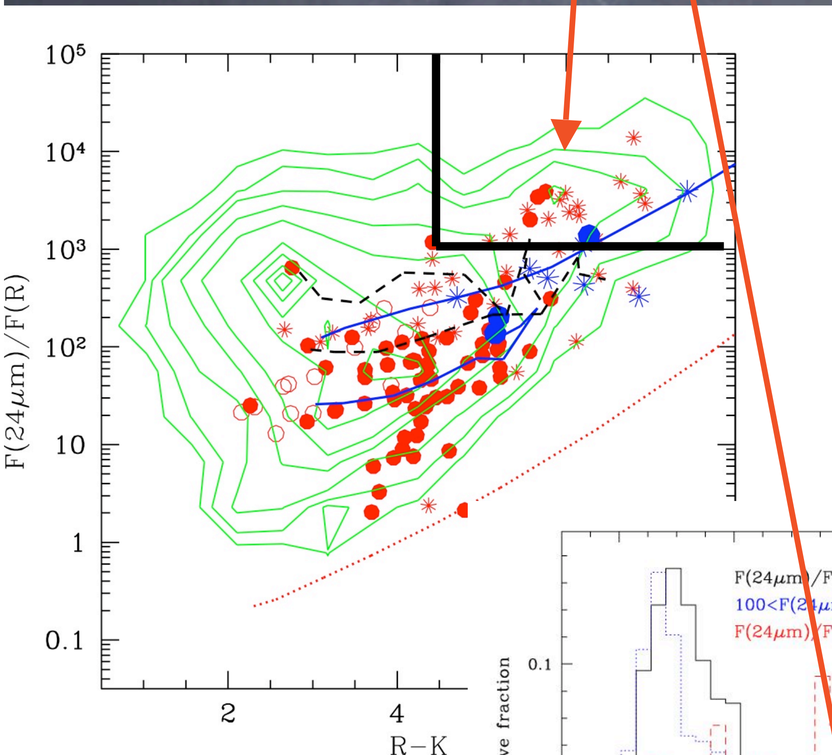


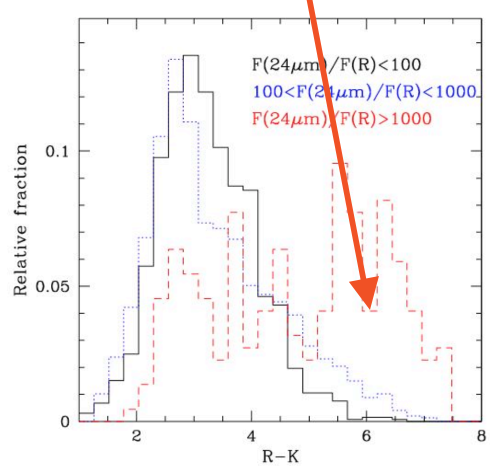
Is this the end of the story?

High F(24μm)/F(O), high R-K sources

A new population of CT AGN

But only on statistical ground!

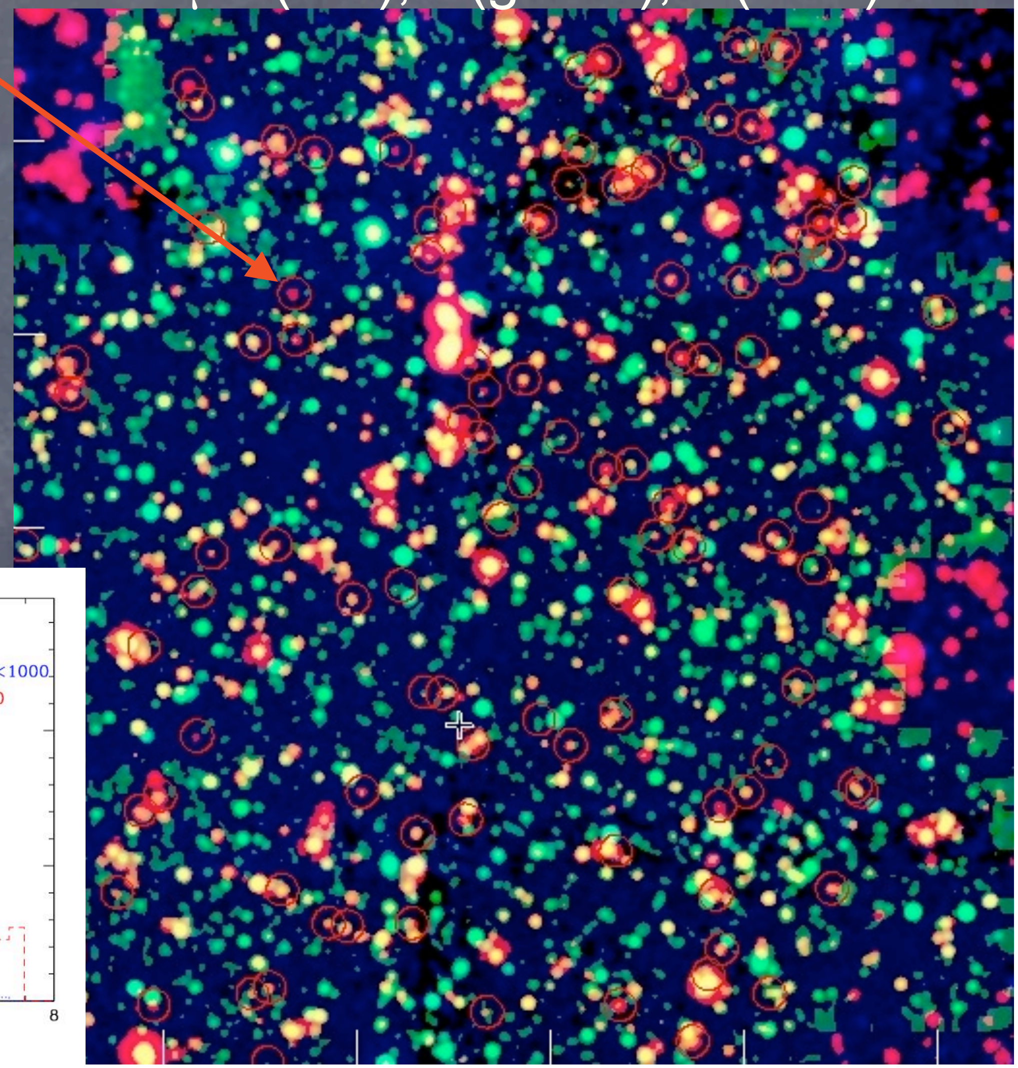




Fiore et al. 2007

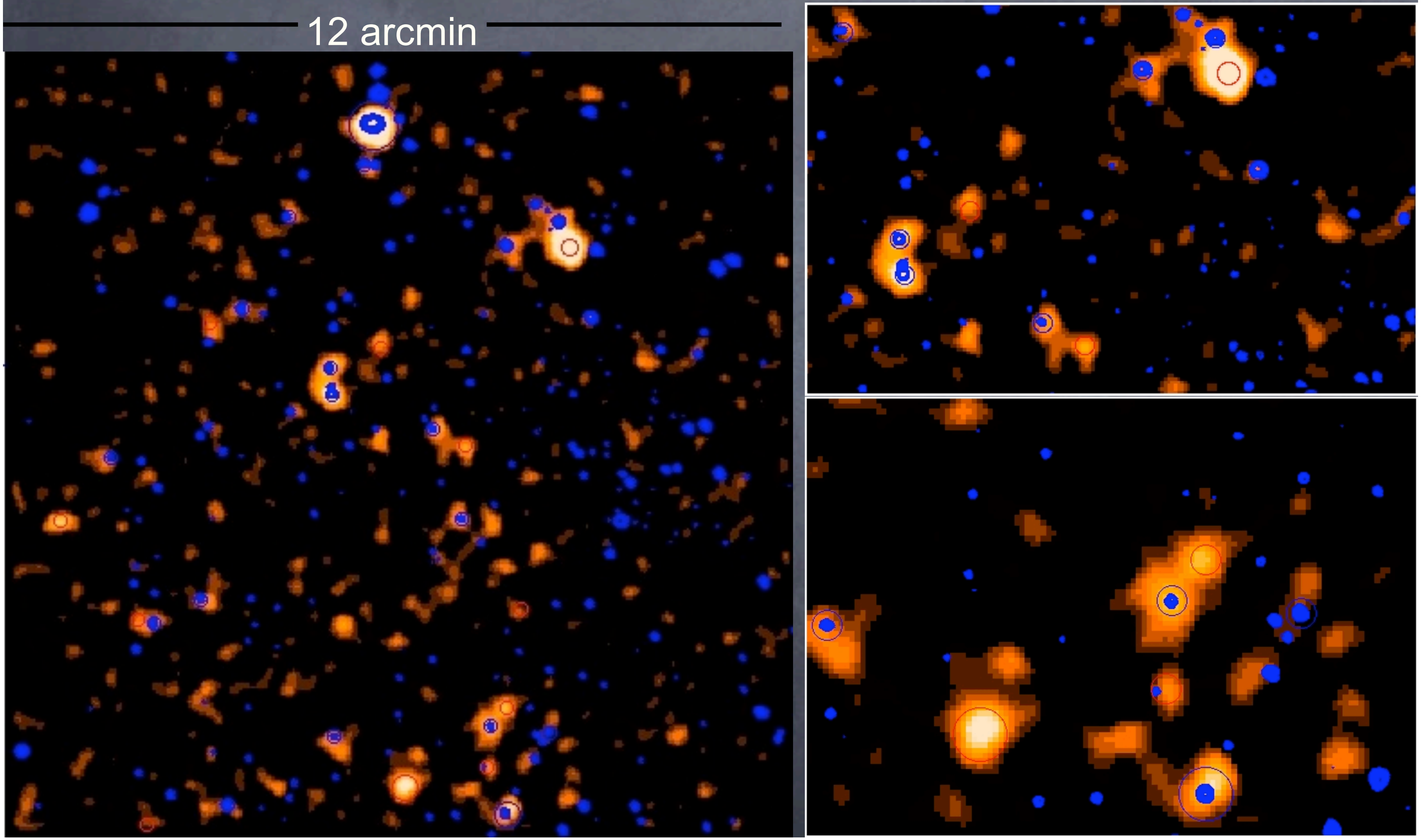
CDFS truecolor

24μm(red), K(green), R(blue)



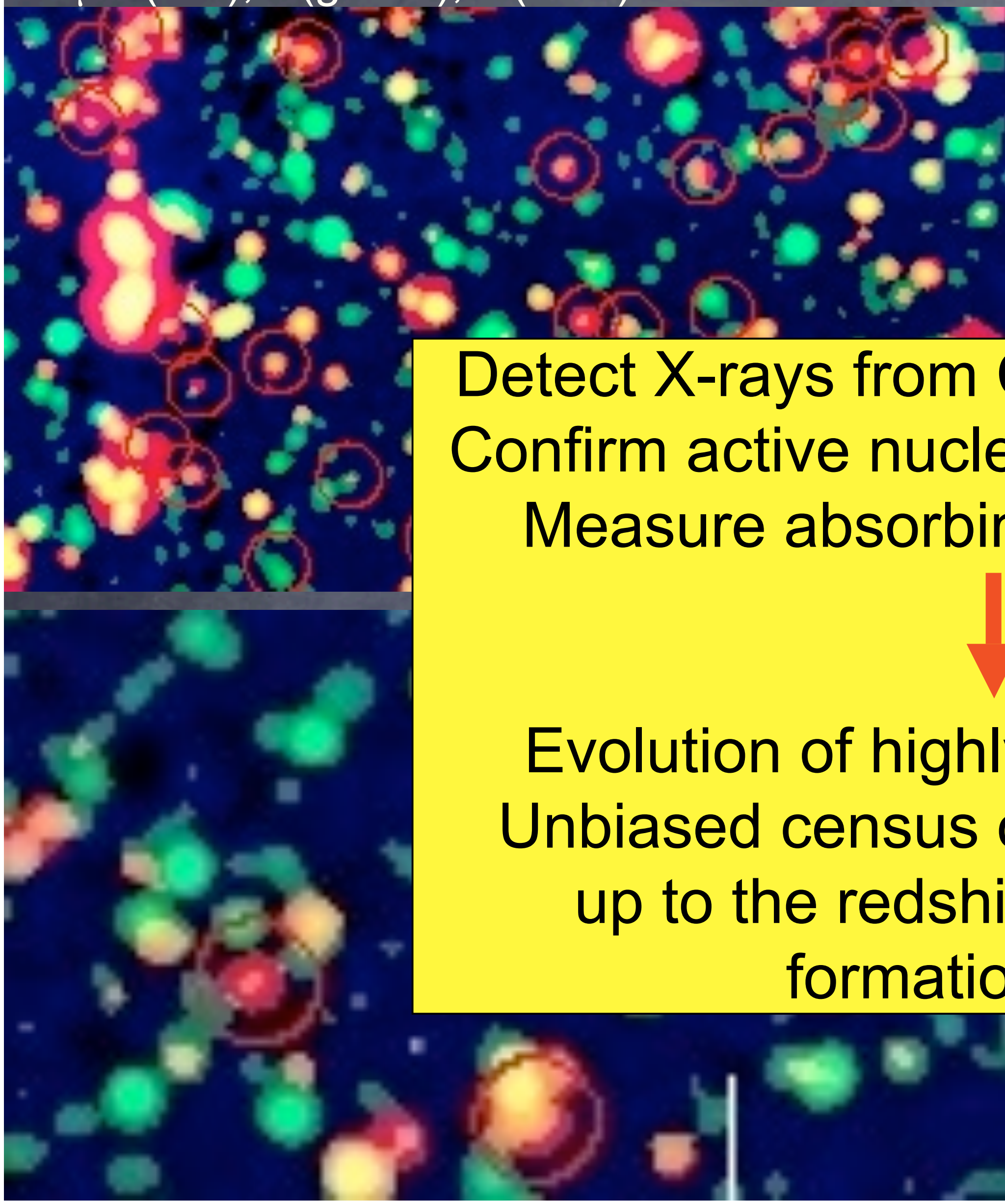
Simbol-X 10-40 keV CDFS simulation

1Msec CZT+ 0.5Msec SDD. Chandra sources + MIPS selected CT AGNs
Blue contours = Chandra 0.3-8 keV

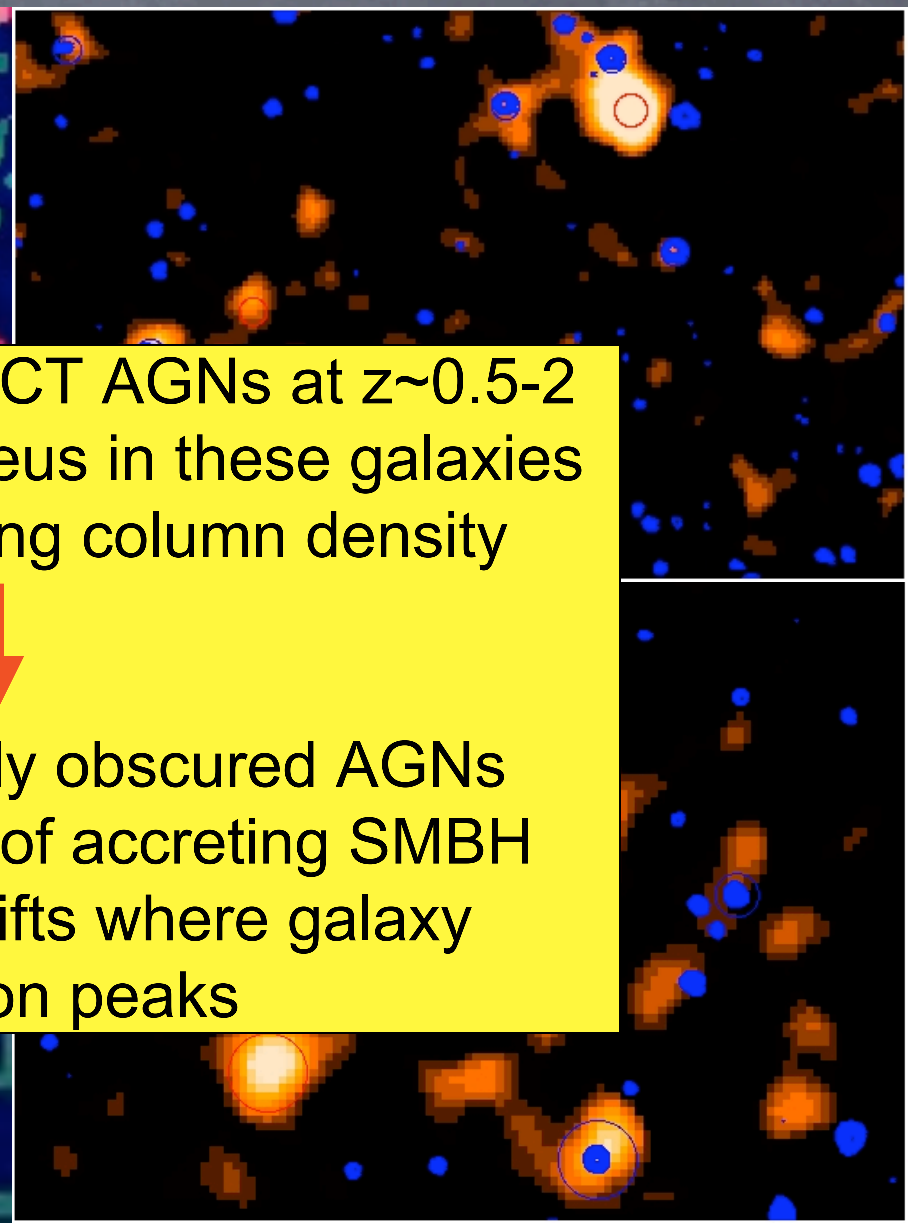


Unveiling obscured accretion in the CDFS

24μm(red), K(green), R(blue)



Simbol-X simulations



Detect X-rays from CT AGNs at z~0.5-2
Confirm active nucleus in these galaxies
Measure absorbing column density

↓

Evolution of highly obscured AGNs
Unbiased census of accreting SMBH
up to the redshifts where galaxy
formation peaks

High MIR/O SWIRE Sources

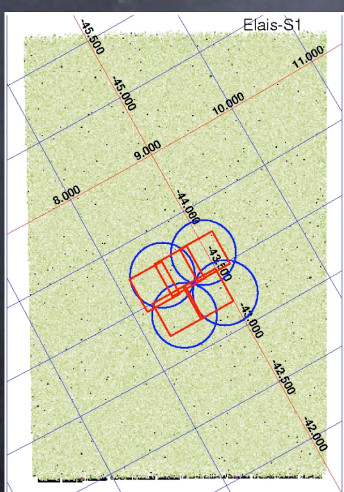
- Large area (~50 deg^2) with sensitive IR (Spitzer), NIR and optical data

well suited for searching for type2 QSO

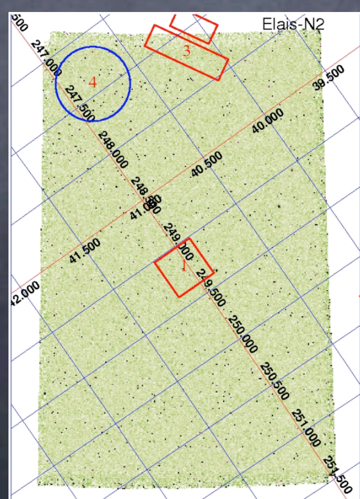
- Small fraction covered with shallow X-ray observations below 10 keV

- ~ 30% of the high MIR/O sources with XMM/Chandra coverage are detected below 10 keV

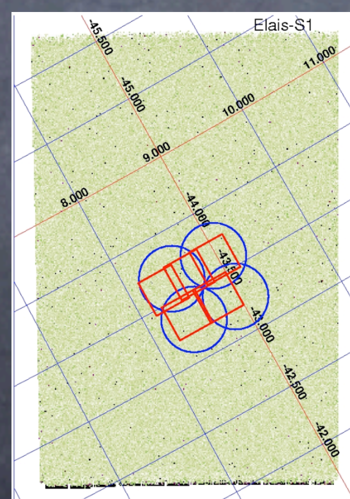
Elais N1



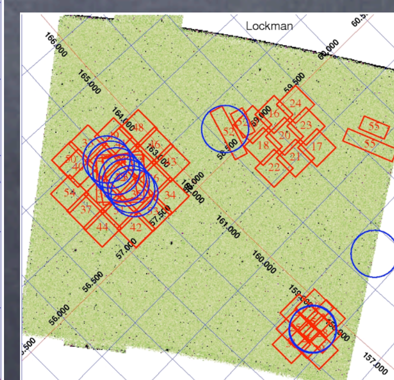
Elais N2



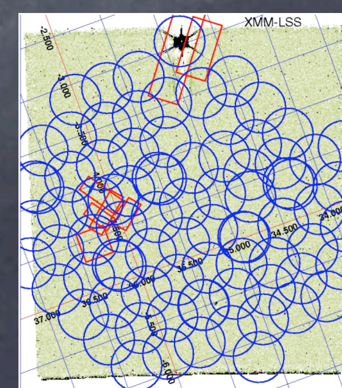
Elais S1



Lockman Hole

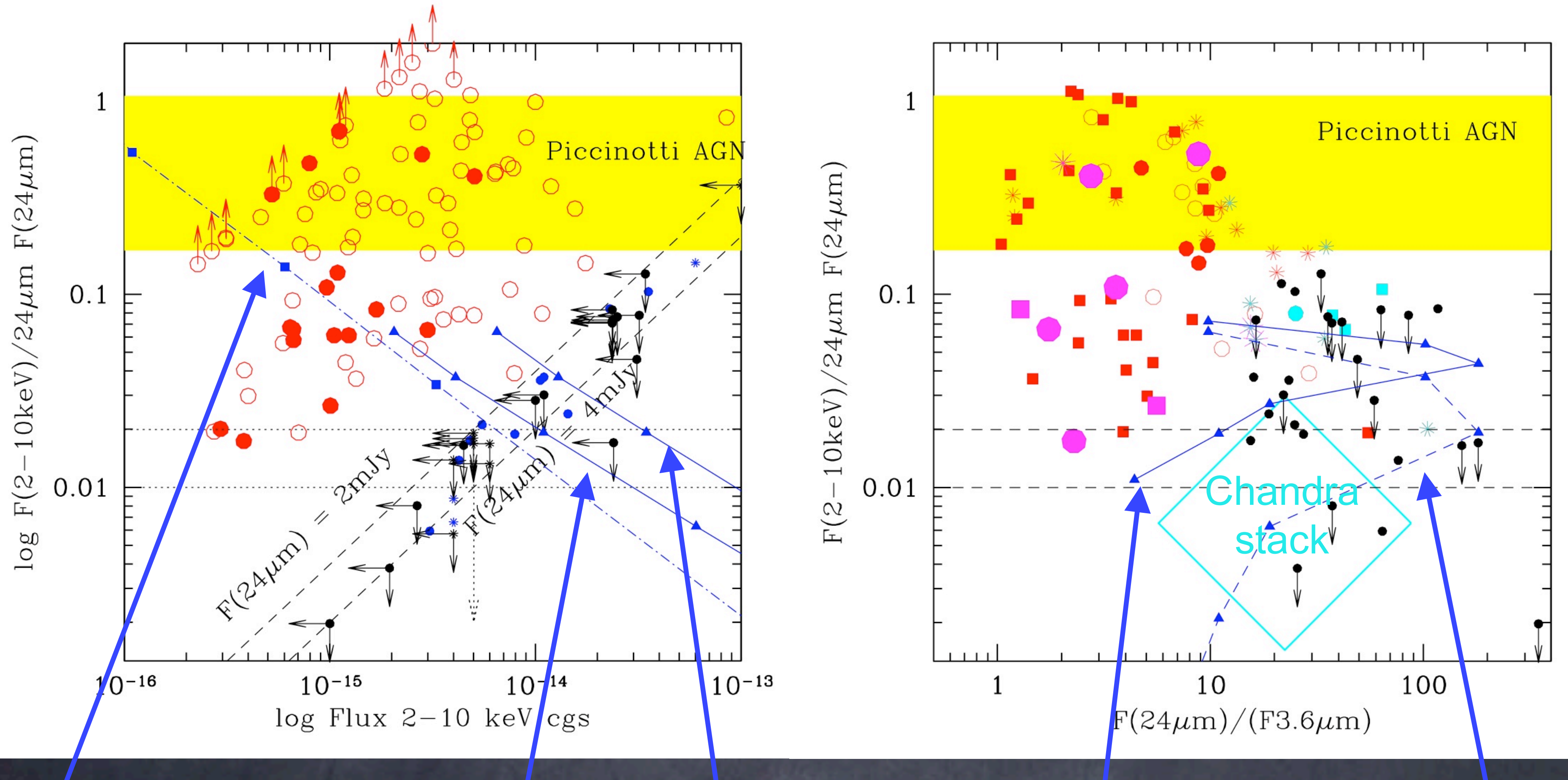


XMM-LSS



Blue circles = XMM pointings; Red polygons = Chandra ACIS-I and ACIS-S pointings

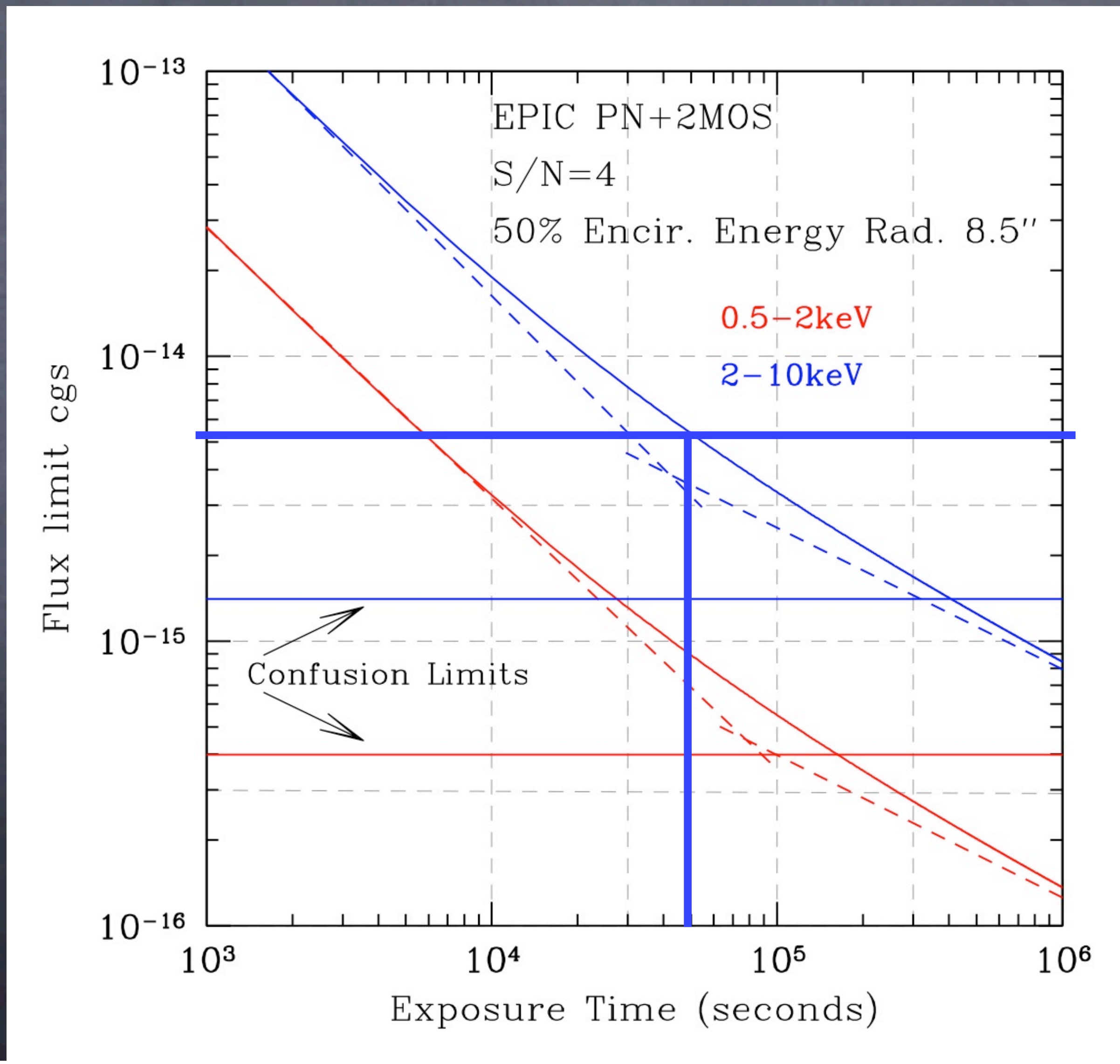
How deep should we go?



Sy2 SED IRAS09 SED logLX=44 logLX=45 logNH=24.5

logNH=23.5 logNH=24.5

How deep should we go? 50-60ks

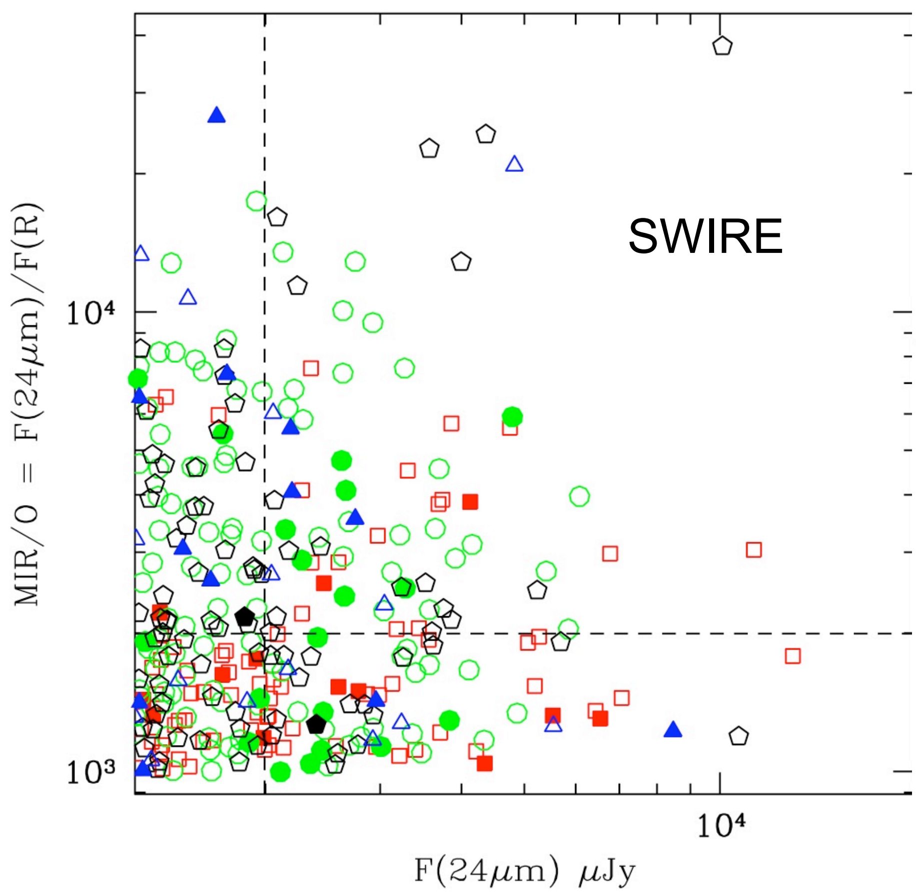


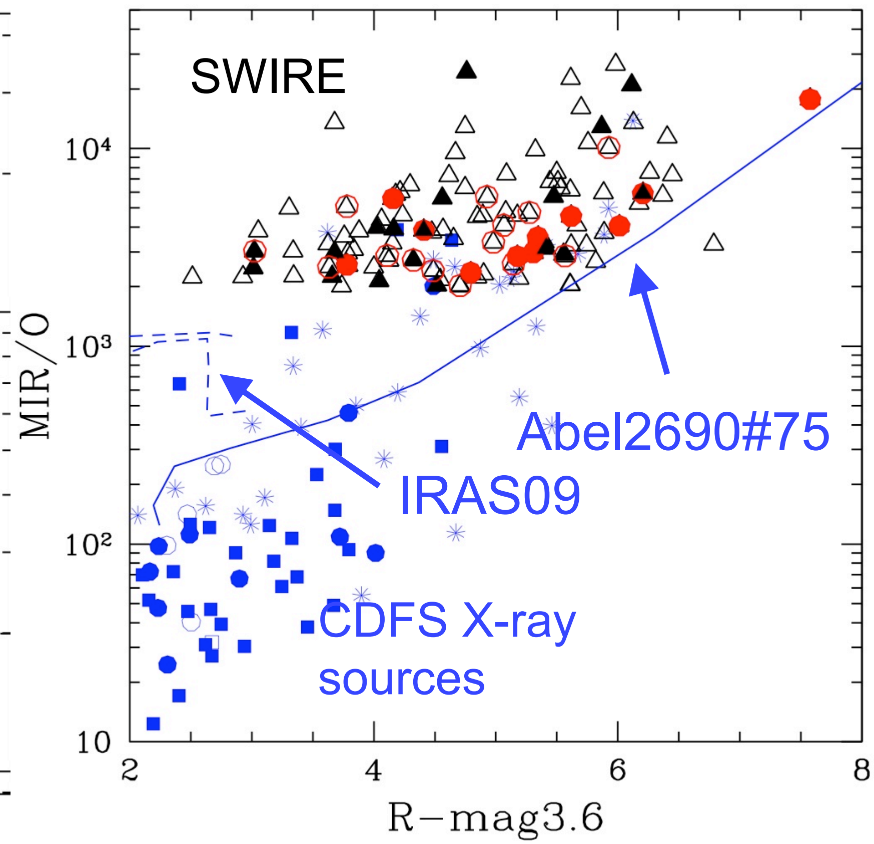
SWIRE highly obscured QSOs

~100 SWIRE sources with F(24um)/F(R)>2000 & F(24um) > 2 mJy

~half with R-mag(3.6um)>4.5

small minority with sensitive X-ray data

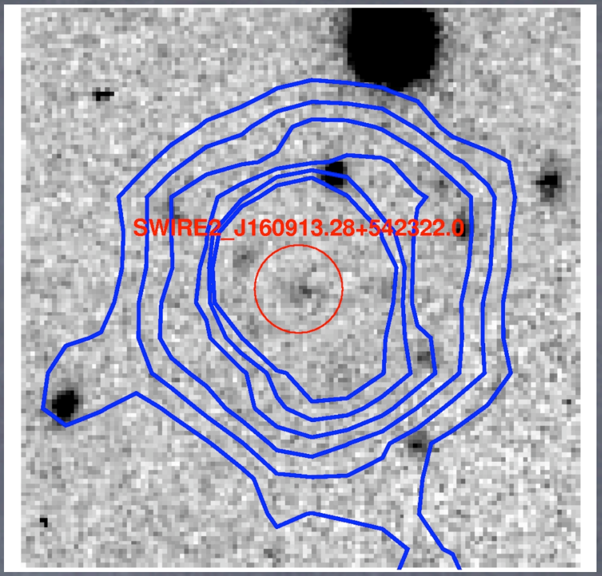


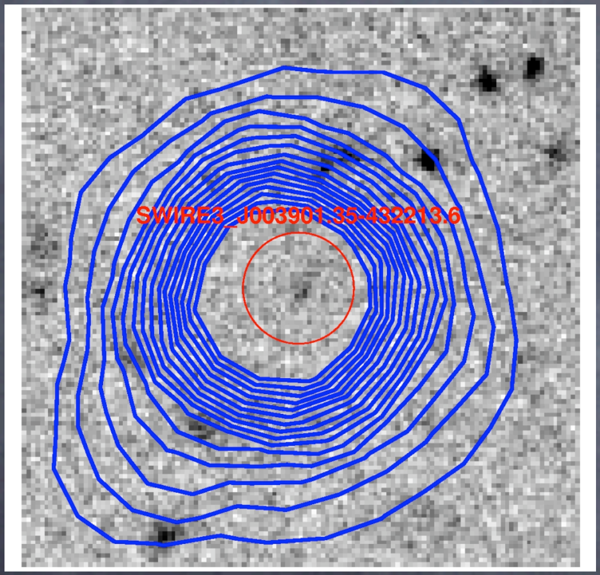


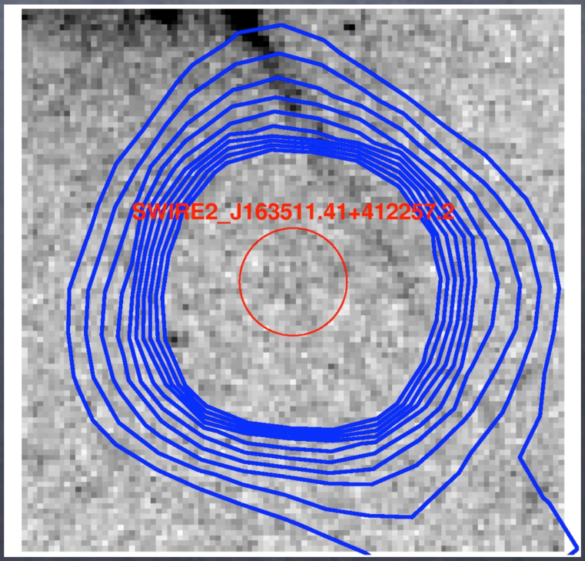
Bright MIPS sources

F(24um) > 4 mJy

with faint optical counterparts (R>24)

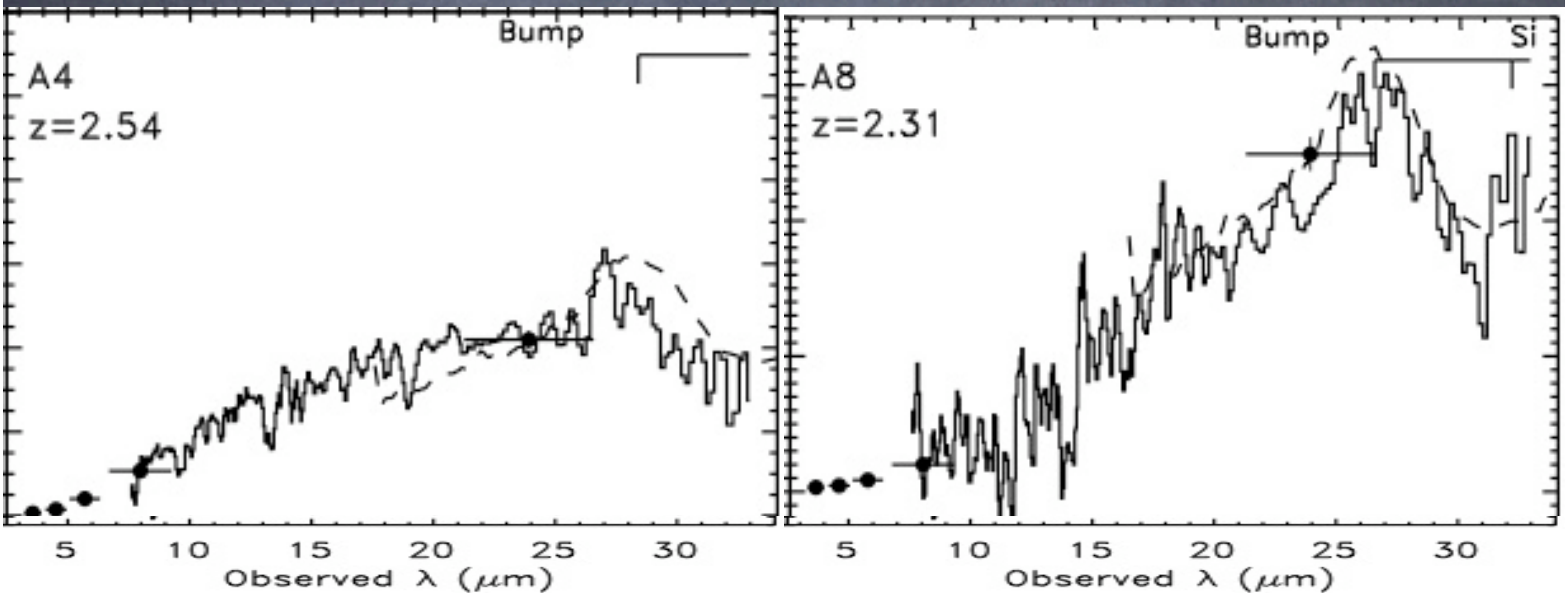






Spitzer fields with X-ray data

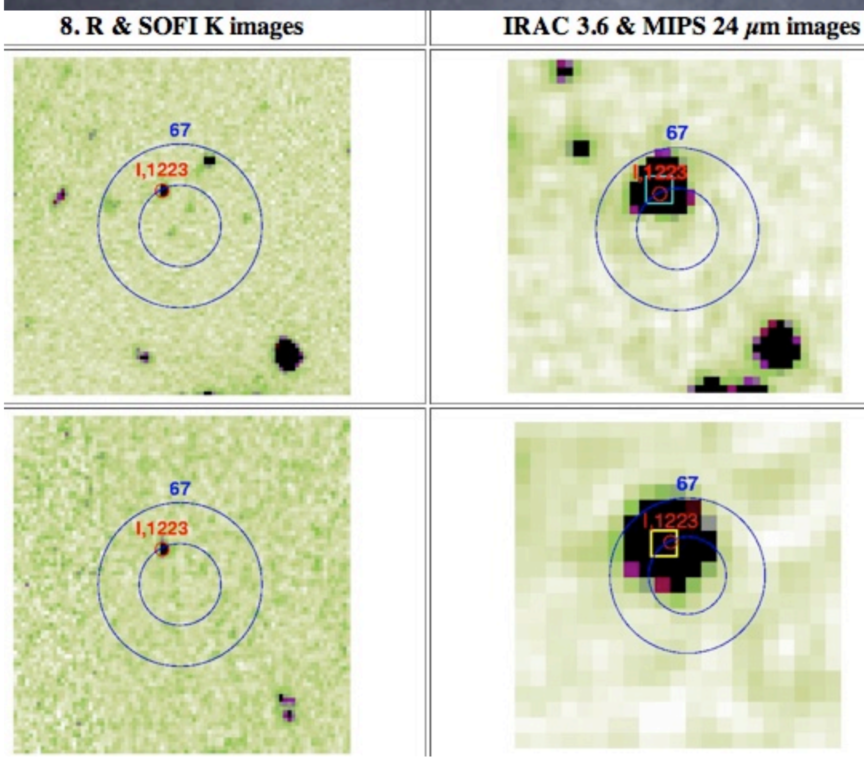
- LH+SXDS+ES1+EN1+EN2+CDFS+COSMOS (~30deg^2)
- F(24um)>2mJy & F(24um)/F(R)>2000 37 sources
- ~20 sources with 2-10 keV data down to $5{\times}10^{-15}$ cgs
- 14 detections, 3 spectro. redshifts
- LH A4, A8, z=2.54, 2.31 logN_H~24 logLX~45.6 Weedman et al.2006

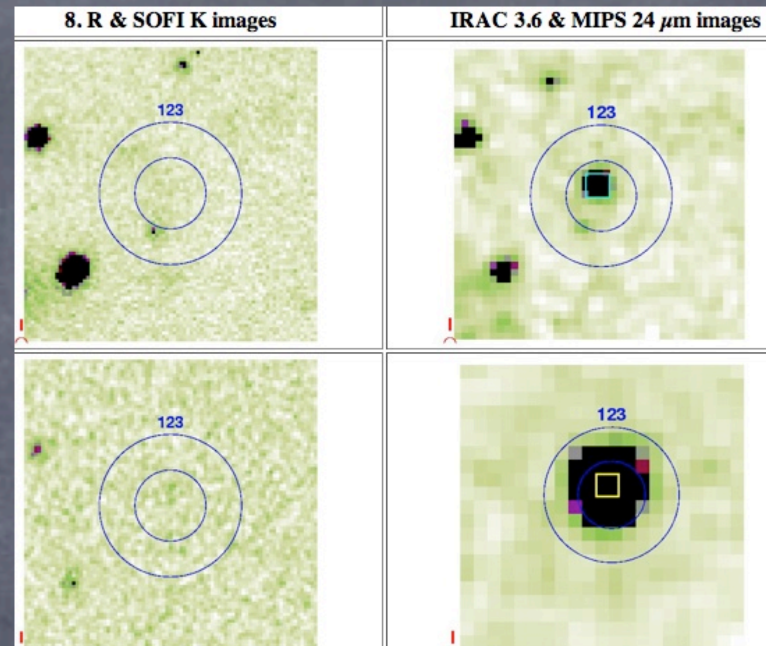


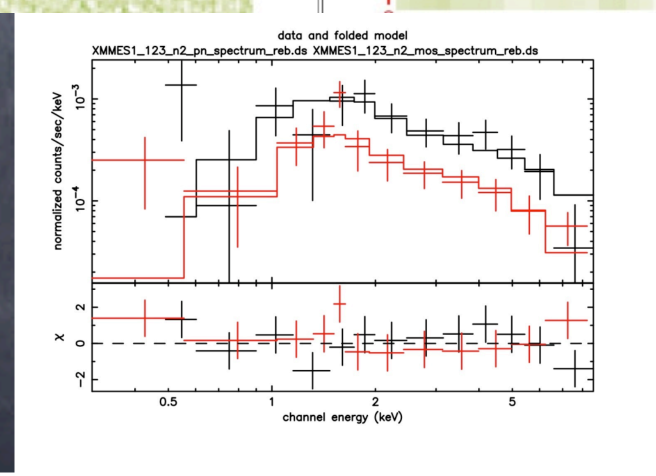
Spitzer fields with X-ray data

•ES1_67, ES1_123 z=0.689, 0.57
$\log N_H \sim 23$
logLX~43-43.5

Feruglio et al. 2007







Summary

- XMM & Chandra surveys can probe unobscured and moderately obscured accretion up to z=2-4
- INTEGRAL/Swift find CT AGN up to z~0.1
- Spitzer finds luminous CT AGN at z~0.5-2, *ideal targets for:*
- **XMM & Chandra dedicated observations. They will unveil high luminosity, highly obscured (type 2) QSOs**
- Herschel will further increase the band, so helping in separating AGN from normal galaxies and pushing toward higher z.
- All this will allow a precise determination of the evolution of the accretion in the Universe and a precise census of accreting SMBH.