Gas and dust obscuration in Active Galactic Nuclei

Vincenzo Mainieri
ESO

G. Hasinger, M. Brusa, N. Cappelluti, F. Civano, A. Comastri, F. Fiore, R. Gilli, K. Iwasawa, S. Lilly, M. Salvato, J. Silverman, C. Vignali, G. Zamorani

OUTLINE:

what we have learned

introduction to the COSMOS Survey

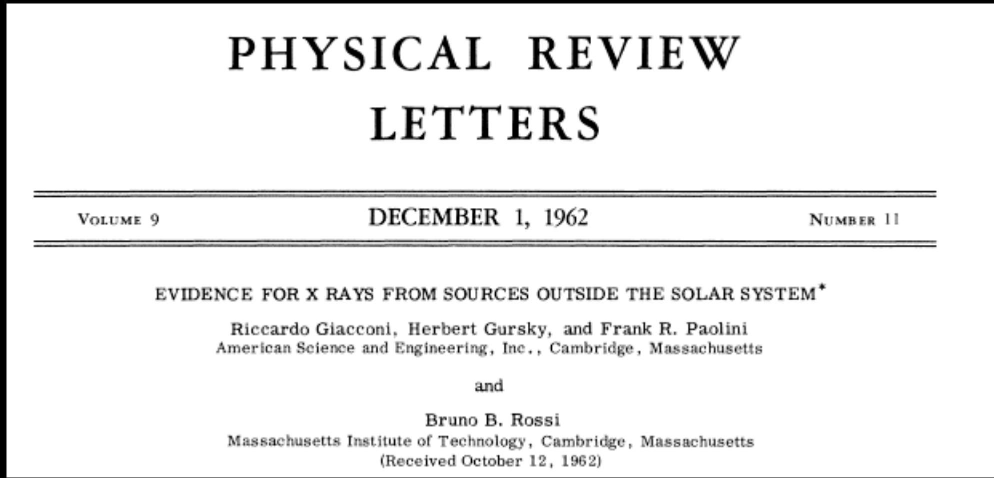
obscuration: an X-ray perspective

obscuration: an optical perspective

moving to longer wavelengths

summary and future

The X-ray background


PHYSICAL REVIEW LETTERS

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EVIDENCE FOR X RAYS FROM SOURCES OUTSIDE THE SOLAR SYSTEM*

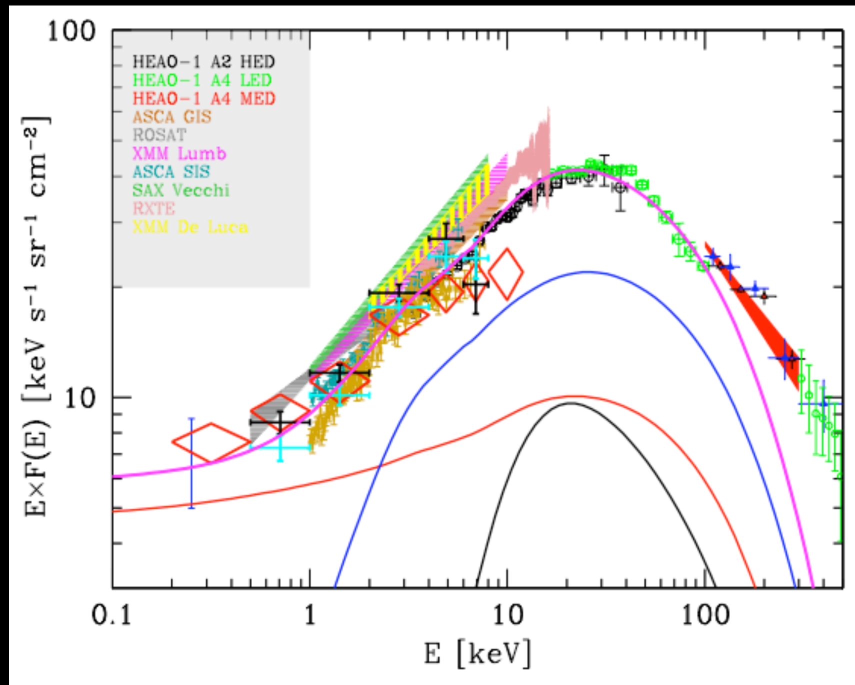
Riccardo Giacconi, Herbert Gursky, and Frank R. Paolini
American Science and Engineering, Inc., Cambridge, Massachusetts

and

Bruno B. Rossi
Massachusetts Institute of Technology, Cambridge, Massachusetts
(Received October 12, 1962)

AGN synthesis models of the XRB

the XRB spectrum is reproduced by summing the contribution of unobscured and obscured AGN (Setti & Woltjer 1989)



What do we know?

- ✦ Unobscured AGN → picture quite clear from optical and soft X-ray surveys (SDSS/ROSAT etc.)
  → Luminosity-Dependent Density Evolution (LDDE)
  see Hasinger, Miyaji, Schmidt 2005

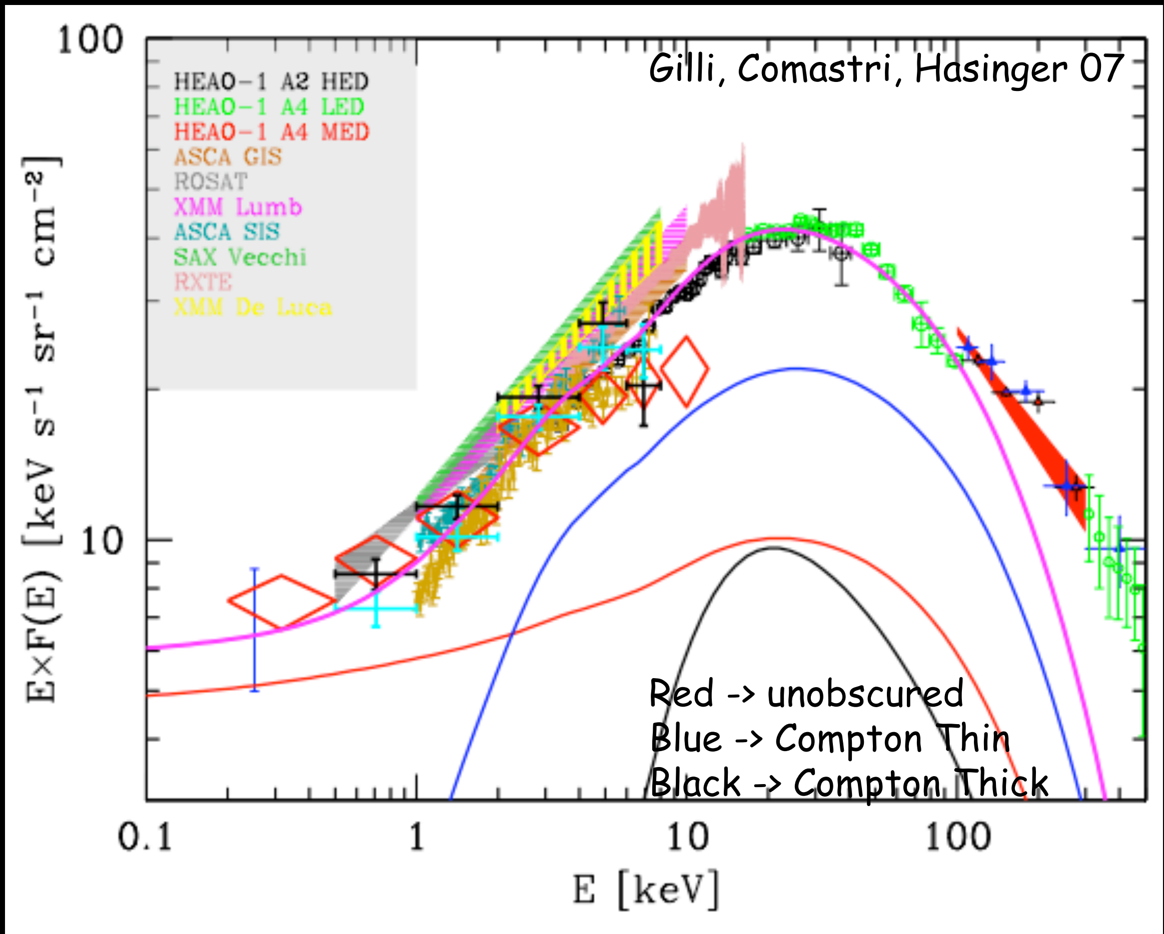
- ✦ Obscured AGN → still large debate on:
  - number density (especially at z~2 – quasar activity peak)
  - ratio obs/unobs
    * well-established only locally (Risaliti et al. 1999)
    * predicted to be 1:1 from unified schemes
    * "needed" 3-4:1 to 10:1 in XRB models (e.g. Gilli et al. 2001/2007)
  - dependence of the ratio obs/unobs on luminosity and/or redshift (see e.g. La Franca et al. 2005/Treister & Urry 2006)

- ✦ Role of the envinronment in triggering nuclear activity --> interplay between galaxy, clusters and dark matter

Still lot of "observational work" to do…

Selection of (compton thin) obscured AGN

Most efficient way: Hard X-ray surveys



Examples:

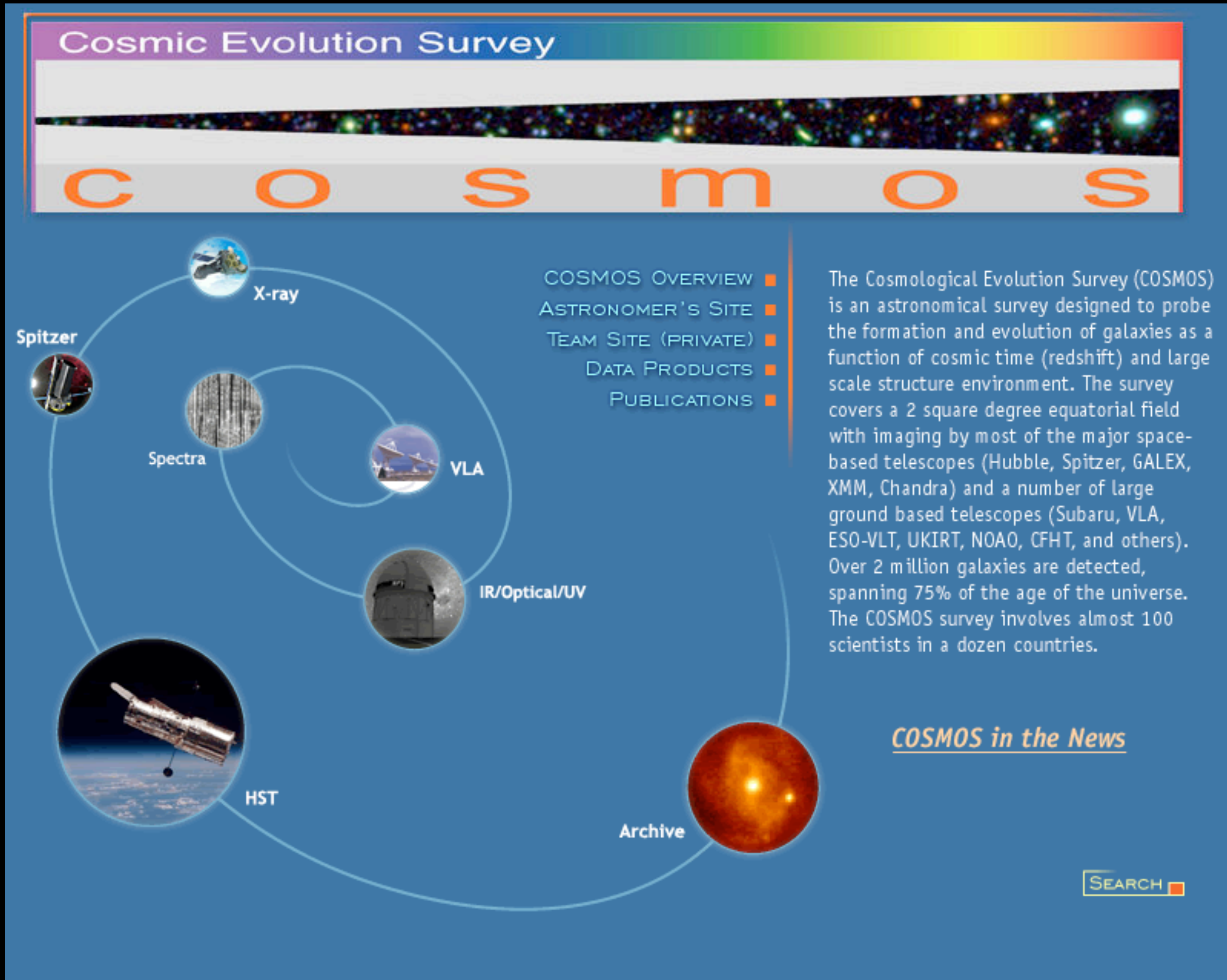
high X/O sources and EXOs (moderate obscured AGN at z~1-2 hosted in massive ellipticals, and very high-z)

Fiore et al. 2003, A&A
Mignoli et al. 2004, A&A
Mainieri et al. 2005, A&A
Maiolino et al. 2006, A&A
Koekemoer et al. 2004 ApJL
etc…

CAVEAT:

hard X-ray surveys still miss the highest obscured sources (don't sample the XRB peak) - see Worsley et al. 2005,2006 http://cosmos.astro.caltech.edu/

PI N. Scoville



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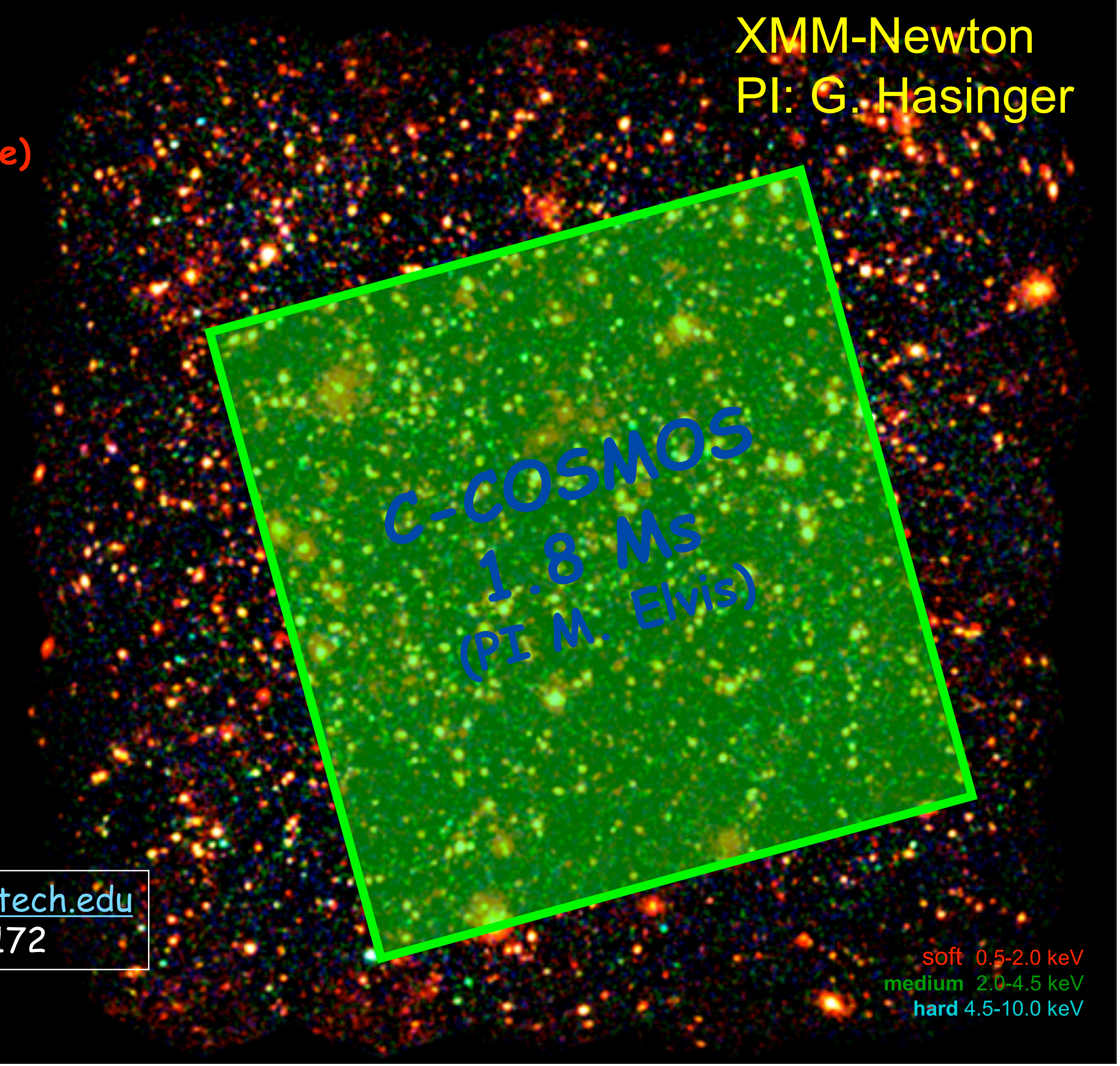
Cosmos Survey

2 deg^2 (PI: N. Scoville)

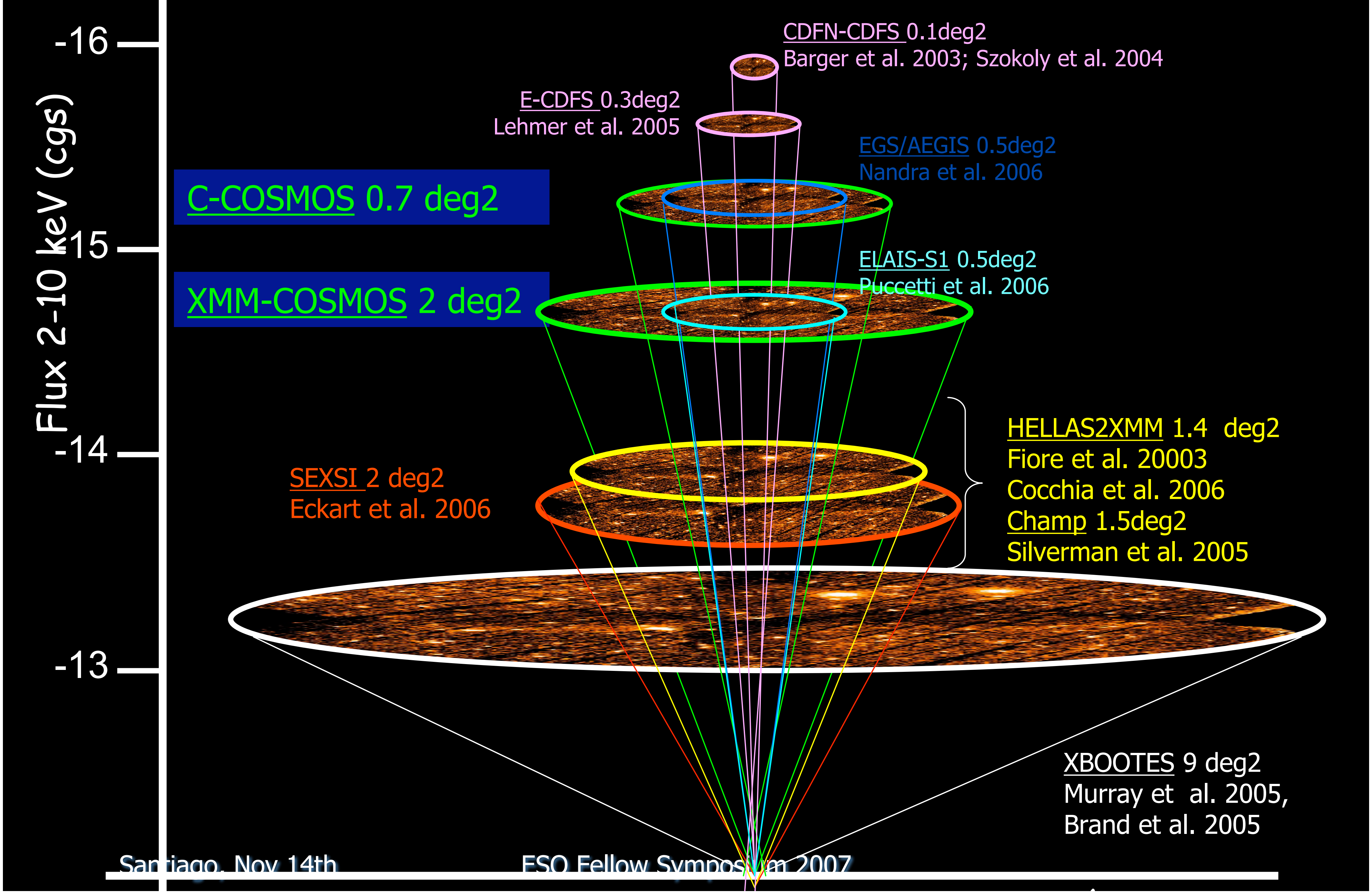


http://cosmos.astro.caltech.edu

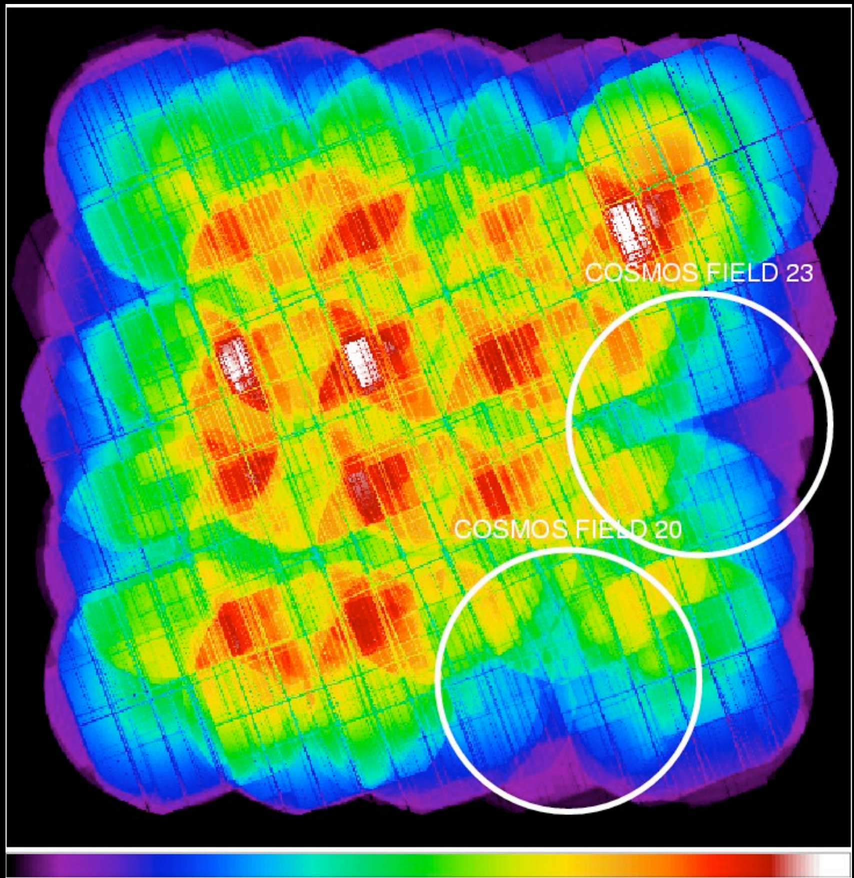
ApJS special issue vol. 172

Santiago, Nov 14th

Relative sizes of X-ray surveys



XMM observations: tiling strategy



Why 1.4 Ms?

Average 50 ks exposure →
transition between source
and background limited detection
+ not confusion limited

Homogeneous exposure map →
homogeneous limiting flux

→Mosaic of 25 pointings, closely
spaced, repeated twice

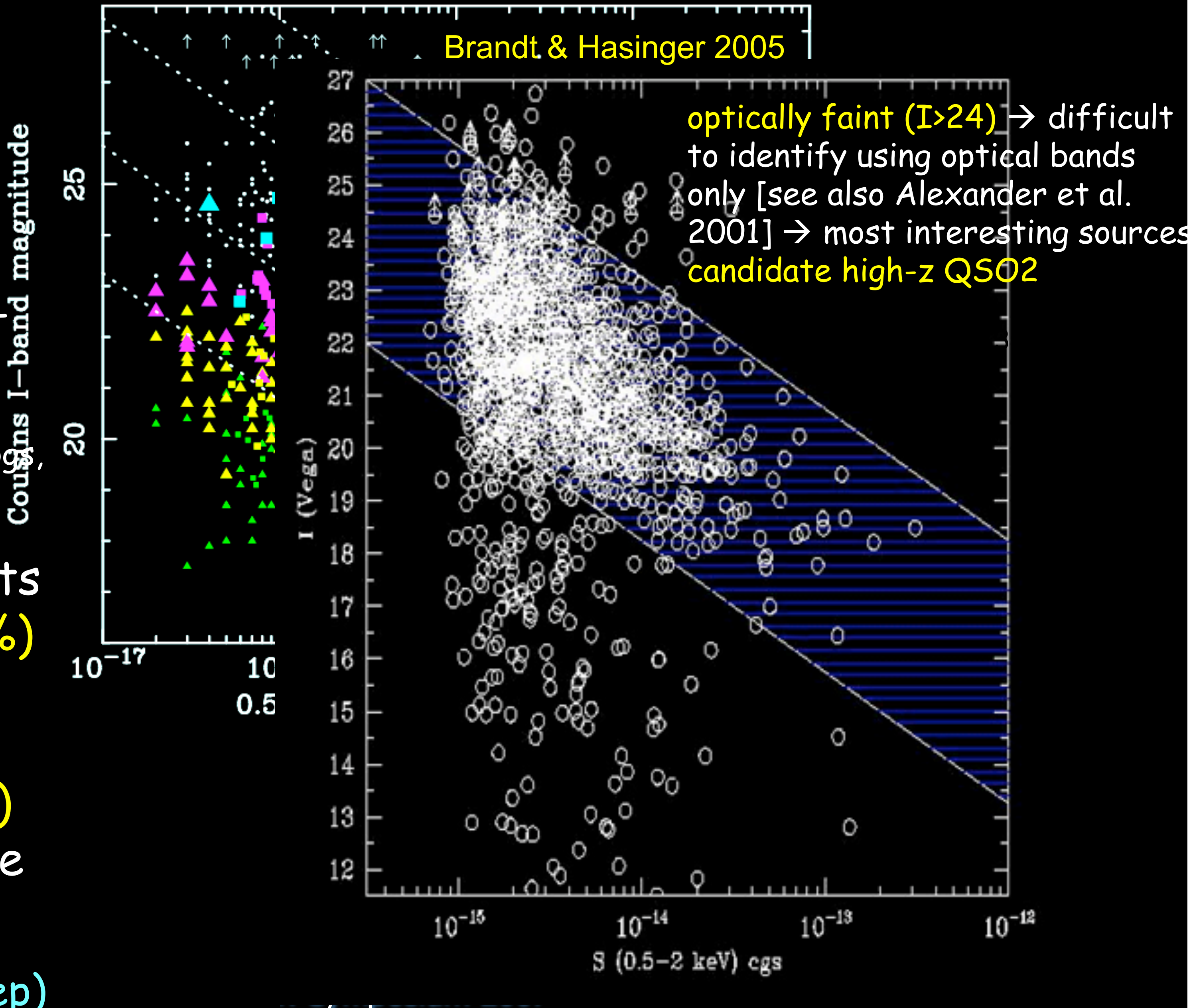
X-ray to optical diagram

1865 independent
X-ray sources (5 sigma)

1608 soft (0.5-2 keV)
1103 hard (2-10 keV)
250 very hard (5-10 keV)

Identification status
(based on likelihood ratio technique, K-band/IRAC catalogs, Chandra validation & visual inspection)

-"secure" counterparts
1441 sources (82.4%)
- "ambiguous" counterparts:
298 sources (16.4%)
-"unidentified" sample
21 sources (1.2%)



(Brusa et al., in prep)

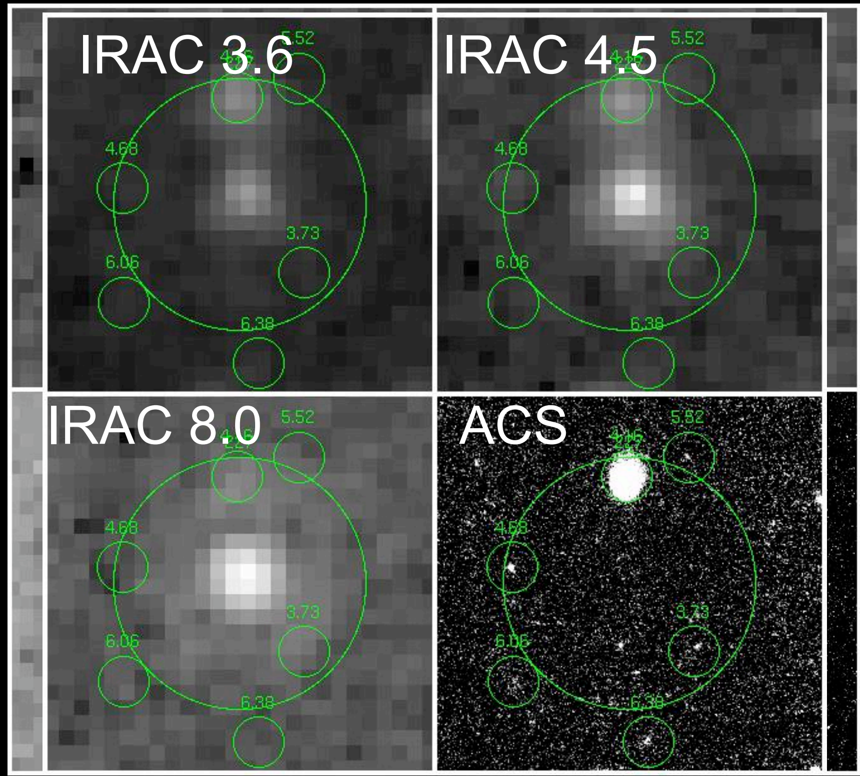
Examples of XMM/IRAC coincidences
IRAC identified sources

Courtesy: Salvato, Ilbert + S-COSMOS

- ~150 objects in XMM-COSMOS identified through K/IRAC (most of them EROs/red objects/optically faint)

- Very hard to get redshift from optical → alternative approaches: ISAAC/MOIRCS/IRS spectroscopy and/or SED fitting

  [Koekemoer et al. 2004, Mainieri et al. 2005, Maiolino et al. 2006]

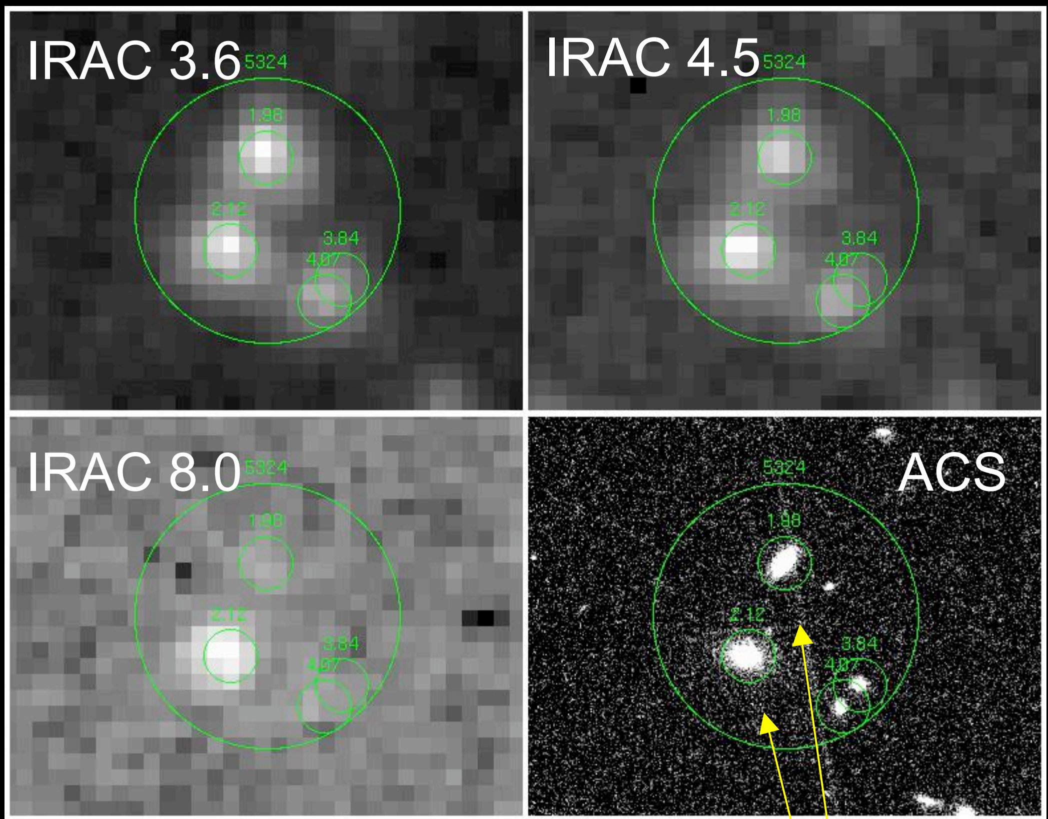


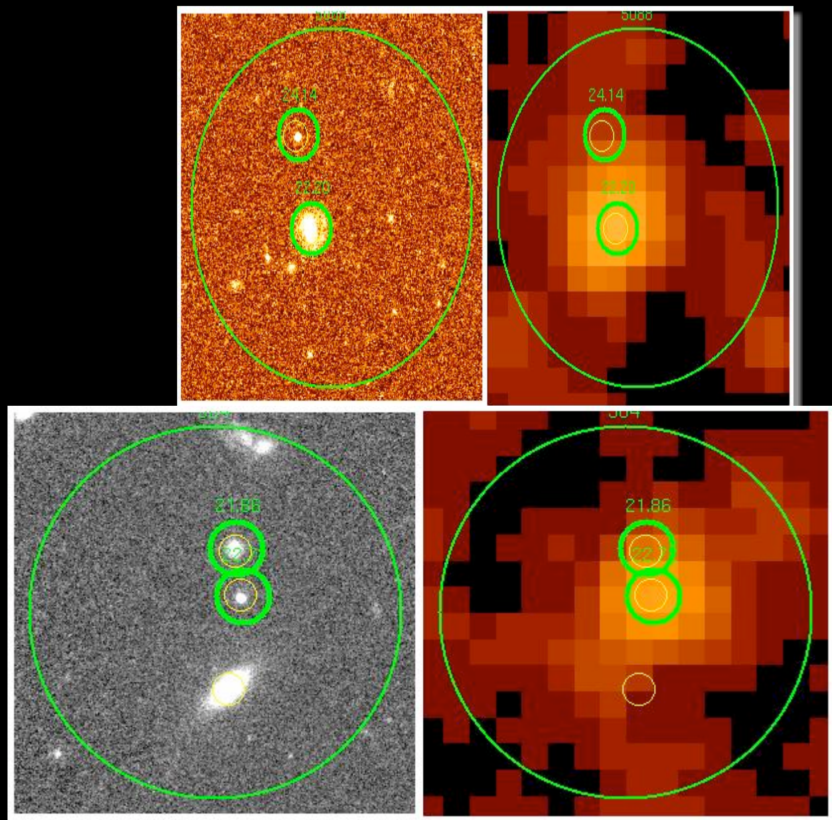
Brusa et al. 2007

Anton's program on SUBARU/MOIRCS!

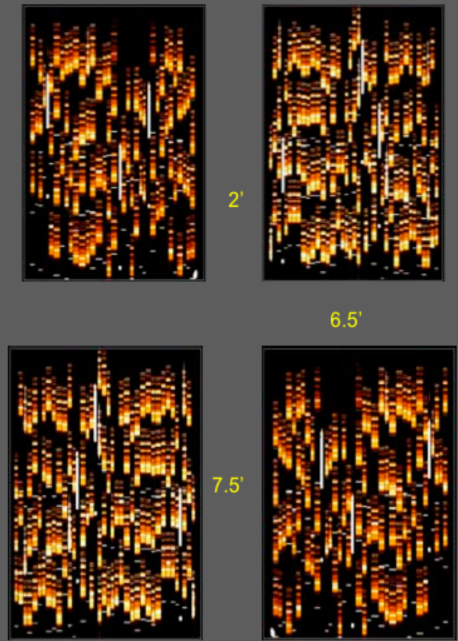
Examples of XMM/IRAC coincidences on bright/ambiguous sources

- ~300 objects in XMM-COSMOS with multiple/none IRAC cps
  → more accurate X-ray positions needed to pick up the right cp
  → **C-COSMOS → reduced them to ~150 (half area)**





Both can be counterparts
→Try to put BOTH in slits



zCOSMOS DPT institutes

ETH Zurich

LAM Marseille

LAOMP Toulouse

INAF Milano

INAF Bologna

ESO - MPE Garching

Very hard to reliably automate redshift measurements from faint spectra → ~ 30 FTE effort

zCOSMOS (600 hrs on VLT, started April 2005): PI S. Lilly

- about 20,000 spectra $0.1 < z < 1.4$ in "-bright": $I_{AB} < 22.5$ over 1.7 deg^2
- about 10,000 spectra $1.4 < z < 3.5$ in "-deep": colour-selection, $B < 25$, over 0.9 deg^2
- designed for high success rate (~ 90% in bright, ~ 80% in deep)
- and high sampling rate (~ 70%) with multiple passes (8 in bright, 4 in deep)
- with velocity accuracy of 100 kms^{-1} in bright, 300 kms^{-1} in deep
- duplication in spectral data reduction, redshift identification and other measurements

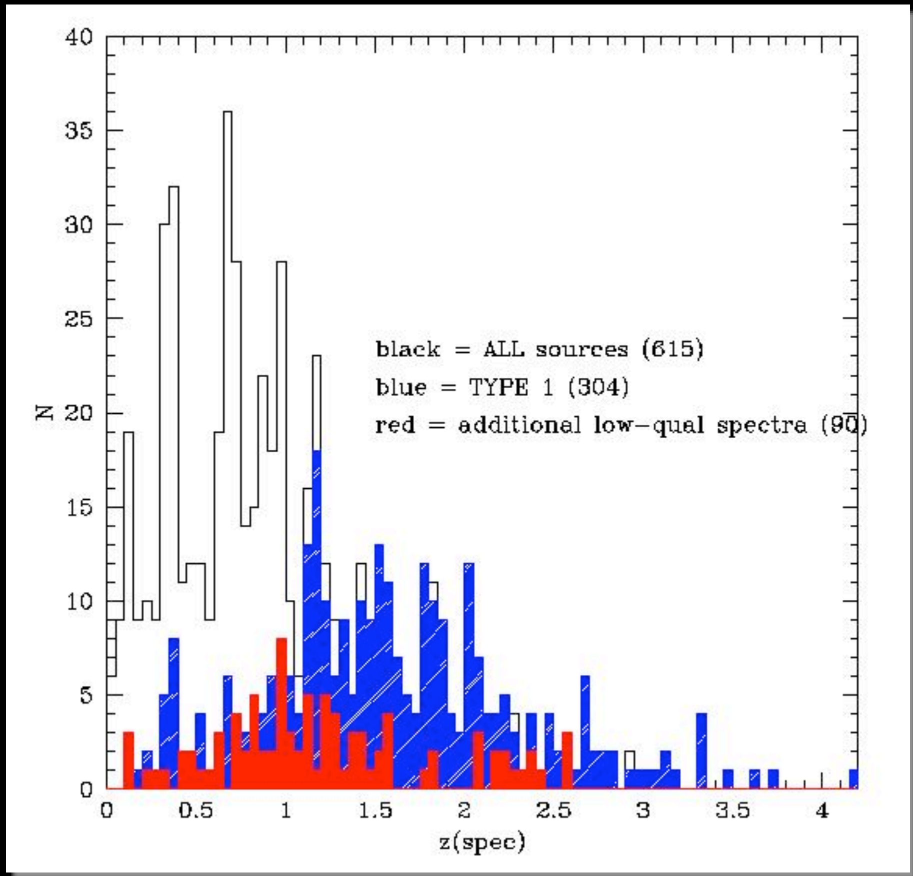
3) From optical cp to rest-frame properties → Redshifts distributions

compilation from ongoing spectroscopic projects [IMACS/zCOSMOS + SDSS + literature data]

- ~650 "secure" spectroscopic identifications [35% of the full sample, almost 50% completeness in the I<22 sample]

- BL AGNs dominate at z>1 → High redshift type 2 objects missing (partly selection effect)

  [see also results from HELLAS2XMM, Cocchia et al. 2007 and from the SEXSI survey, Eckart et al. 2006]



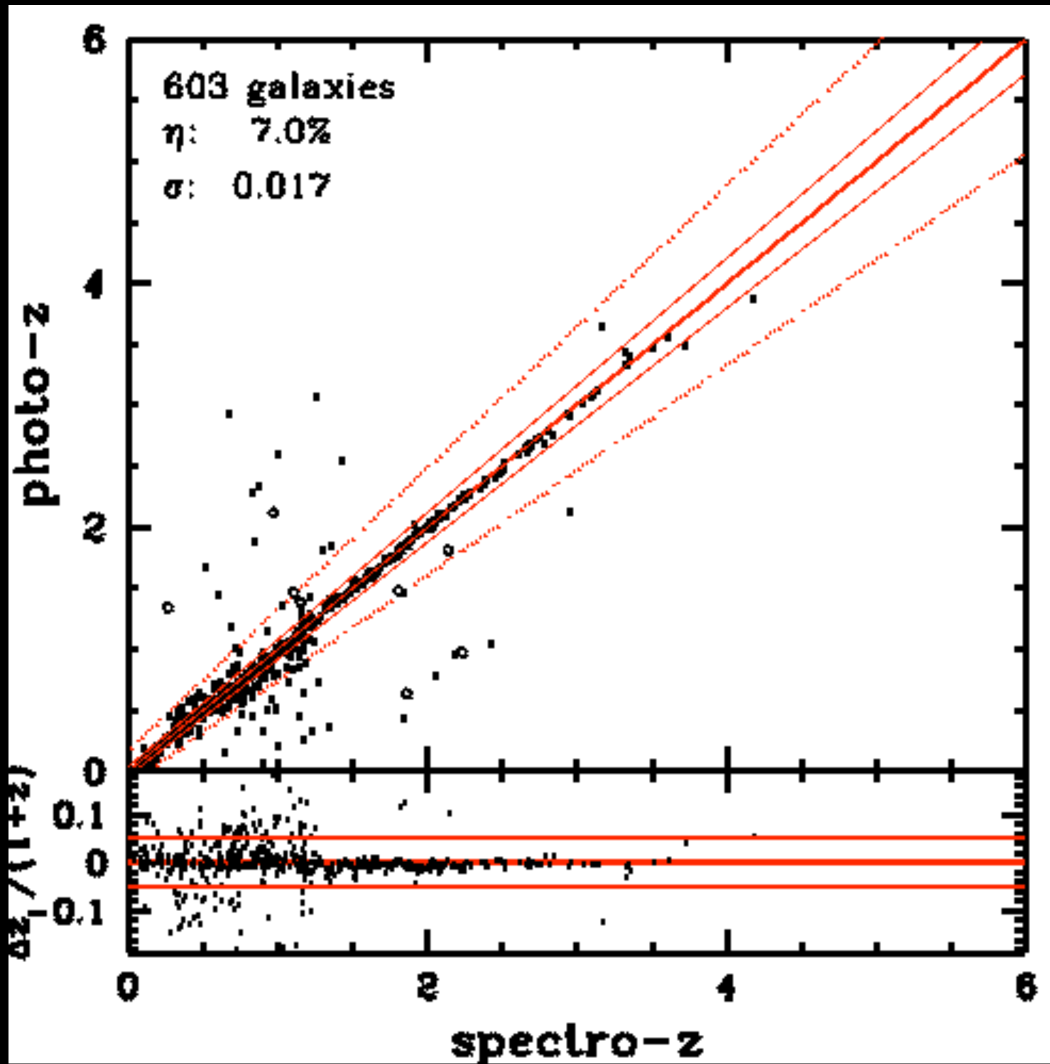
(adapted from Brusa et al. 2007 ApJS)

Photometric redshifts for AGN

σ = 0.017

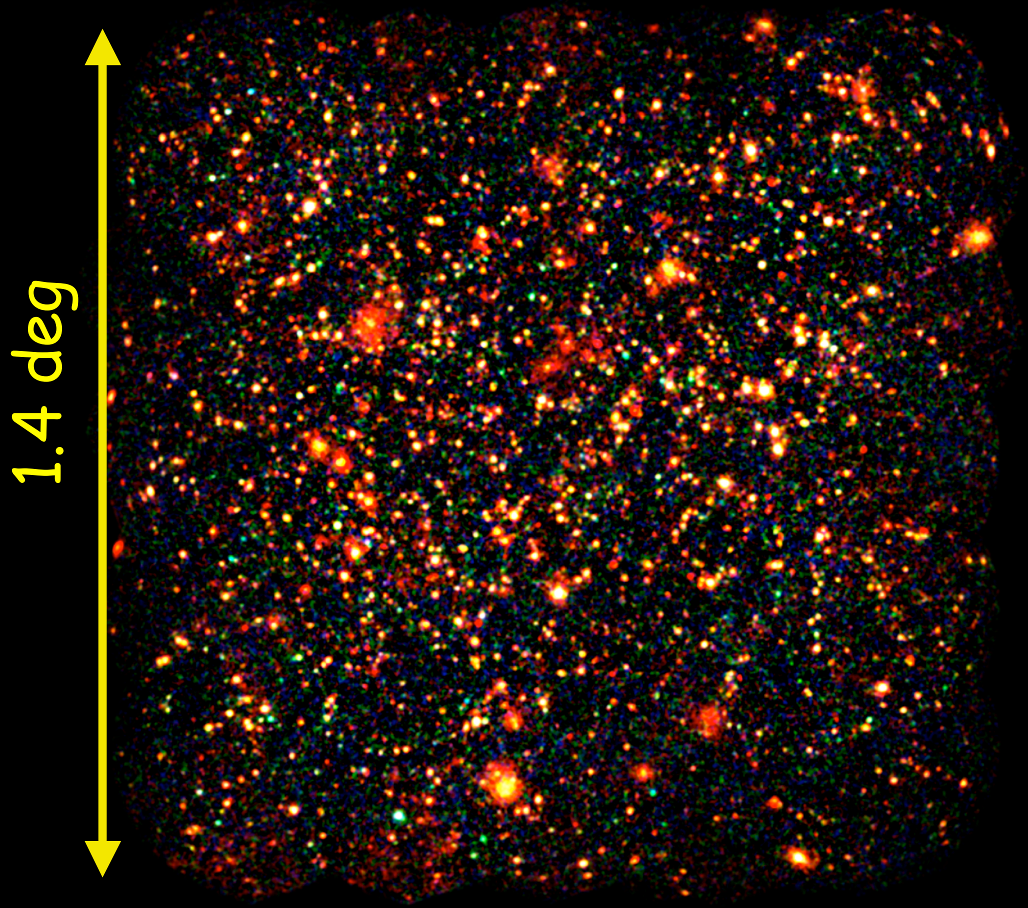
Less than 10% of catastrophic errors

- improved templates, including hybrids of galaxy+AGN
- Photometry from >30 bands (SDSS, Subaru including IB, CFHT, J, K, IRAC)



Salvato et al., in prep
using LePhare

The XMM-COSMOS survey (PI G. Hasinger)



Area = 2 deg^2

Flux limits:

[0.5-2] keV -> 7.0×10^{-16} cgs

[2-10] keV -> 3.3×10^{-15} cgs

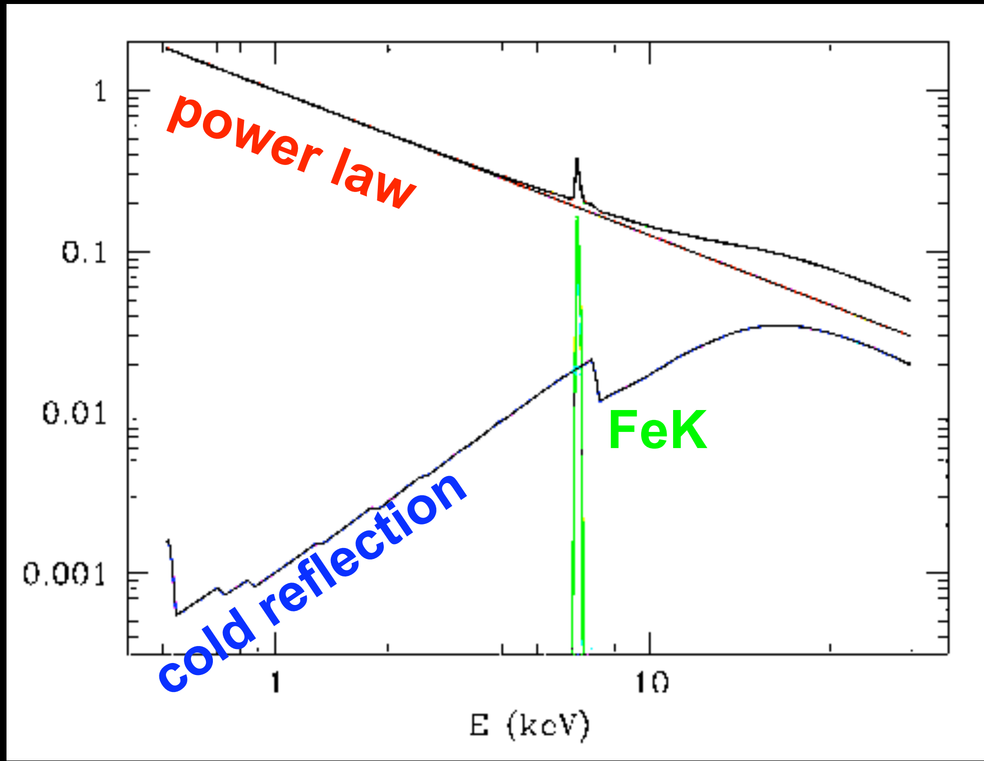
[5-10] keV -> 1.0x10-^{14} cgs

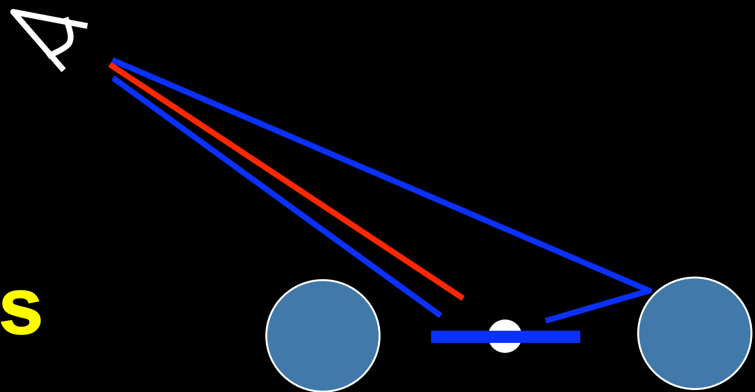
~1800 point-like X-ray sources

X-ray spectral analysis:

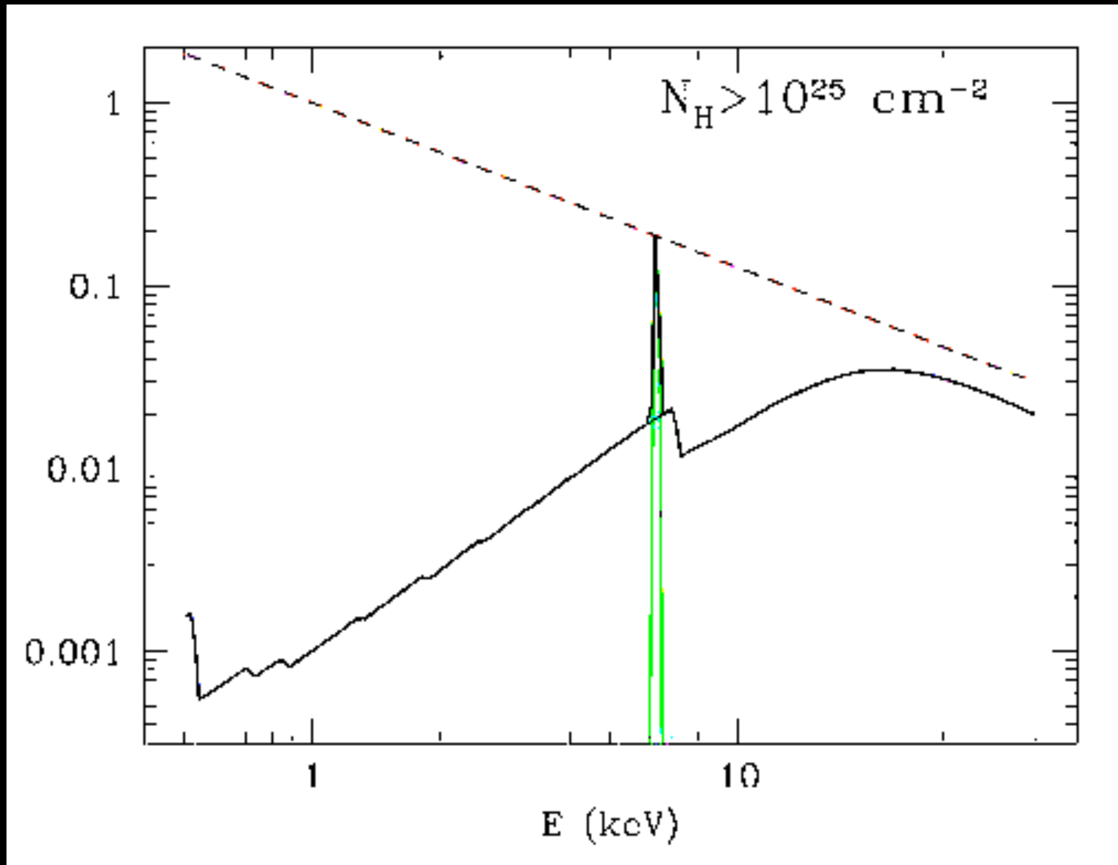
483 with zspec

900 with zspec or zphot

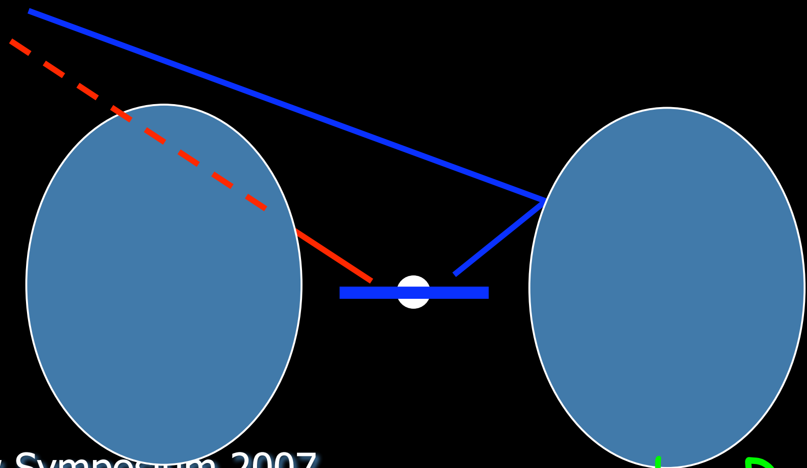




Emission components

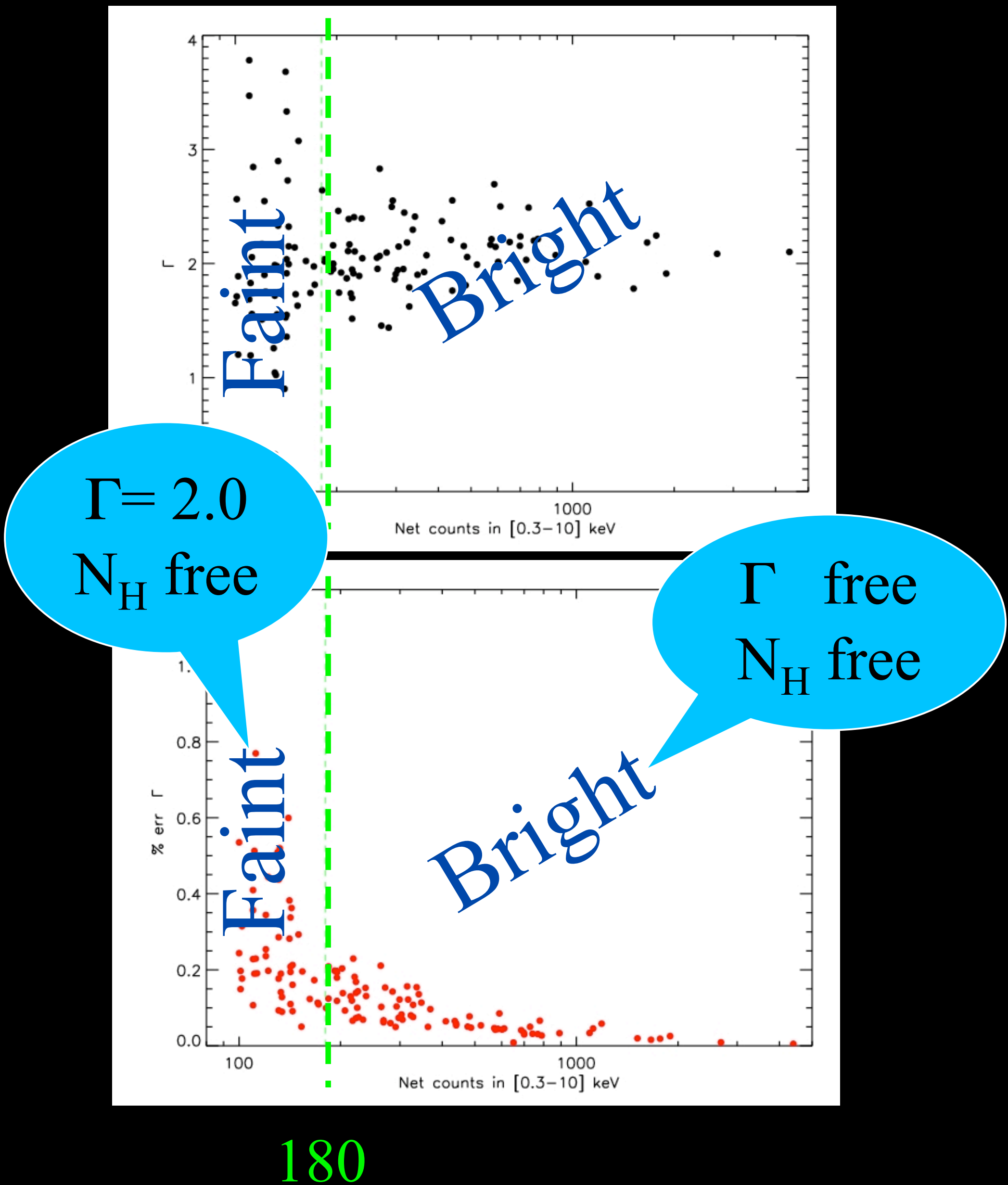


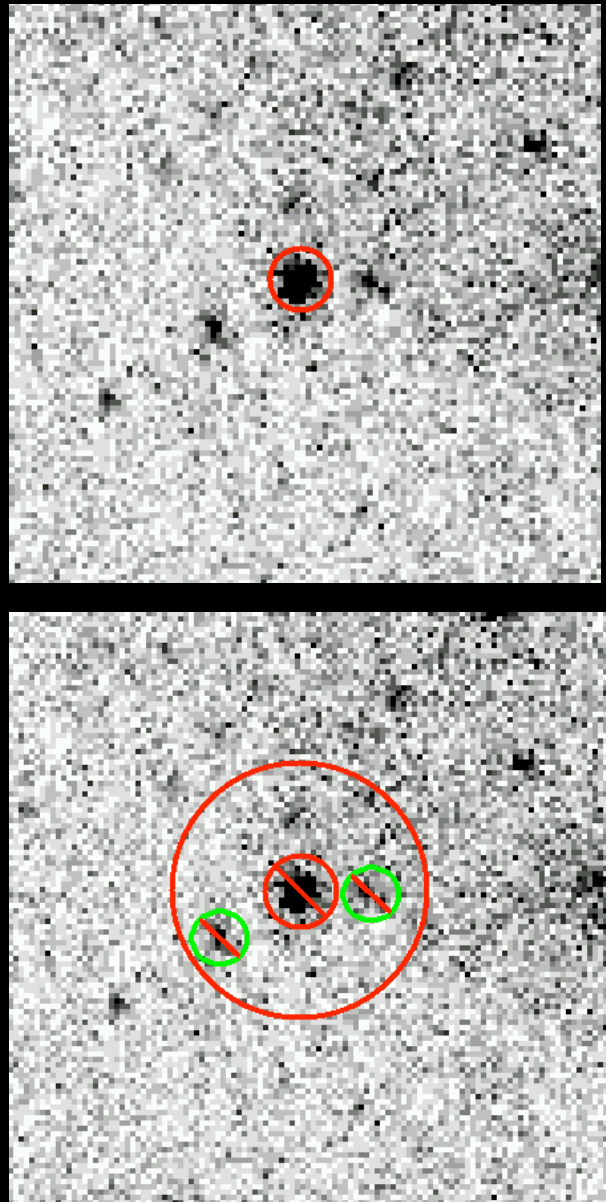
Cold absorber



by R. Maiolino

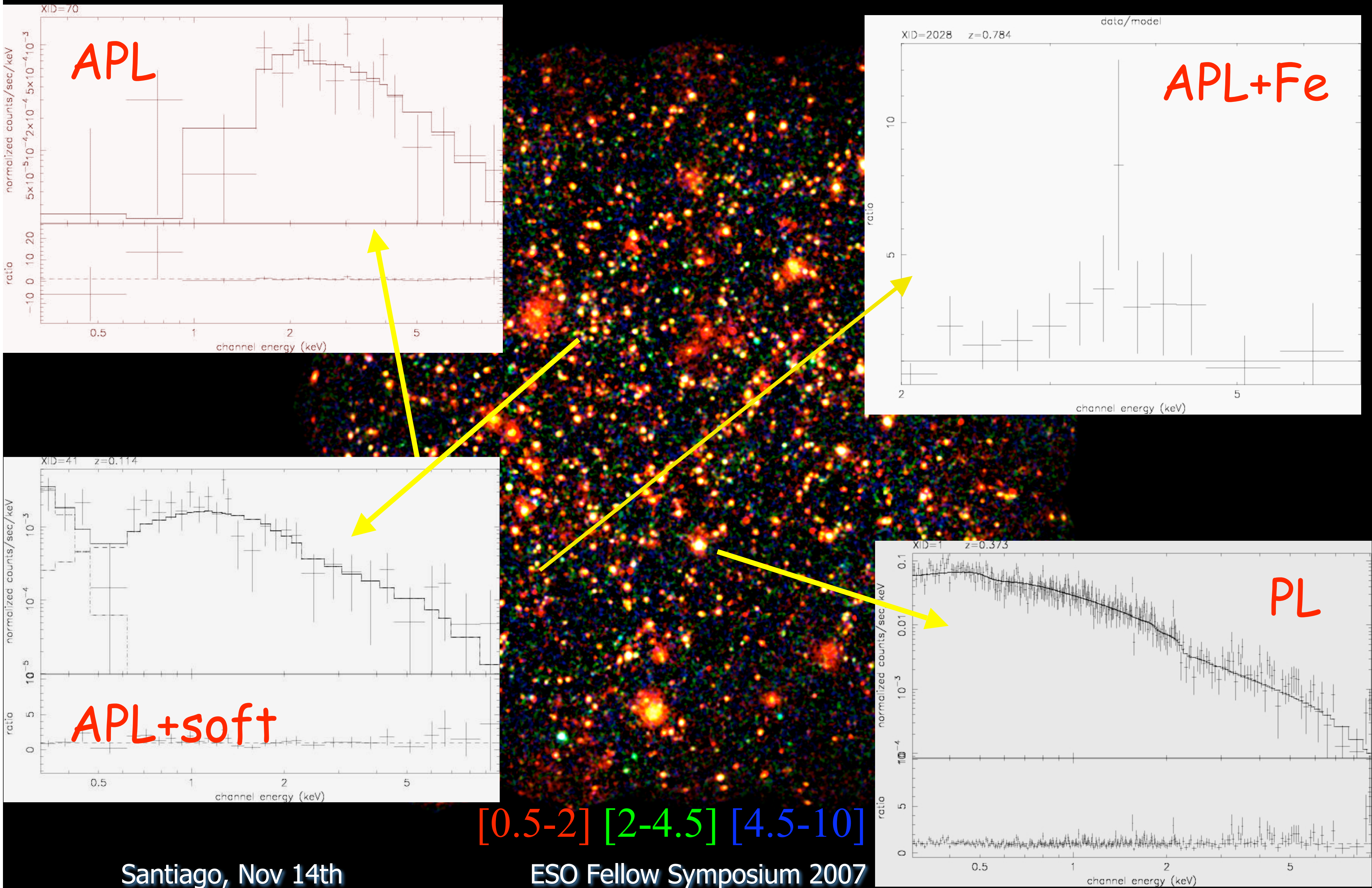
Spectra extraction



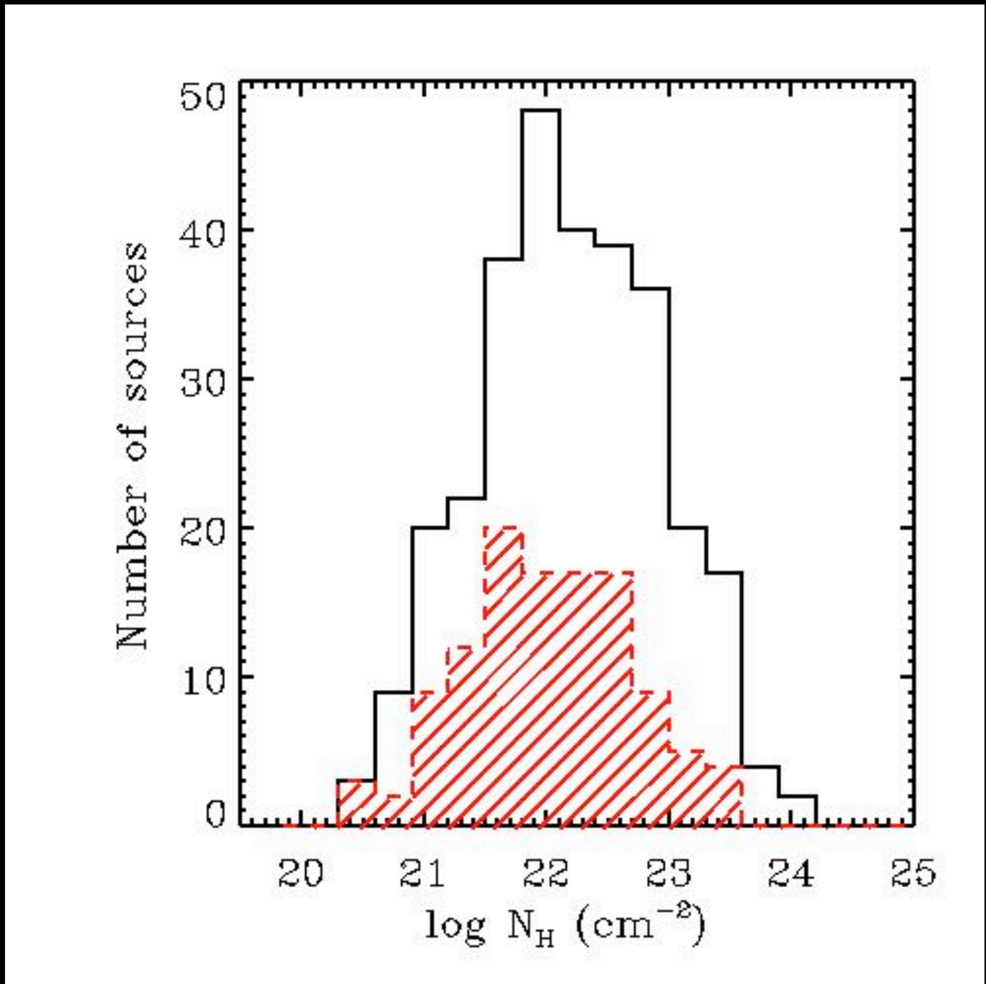


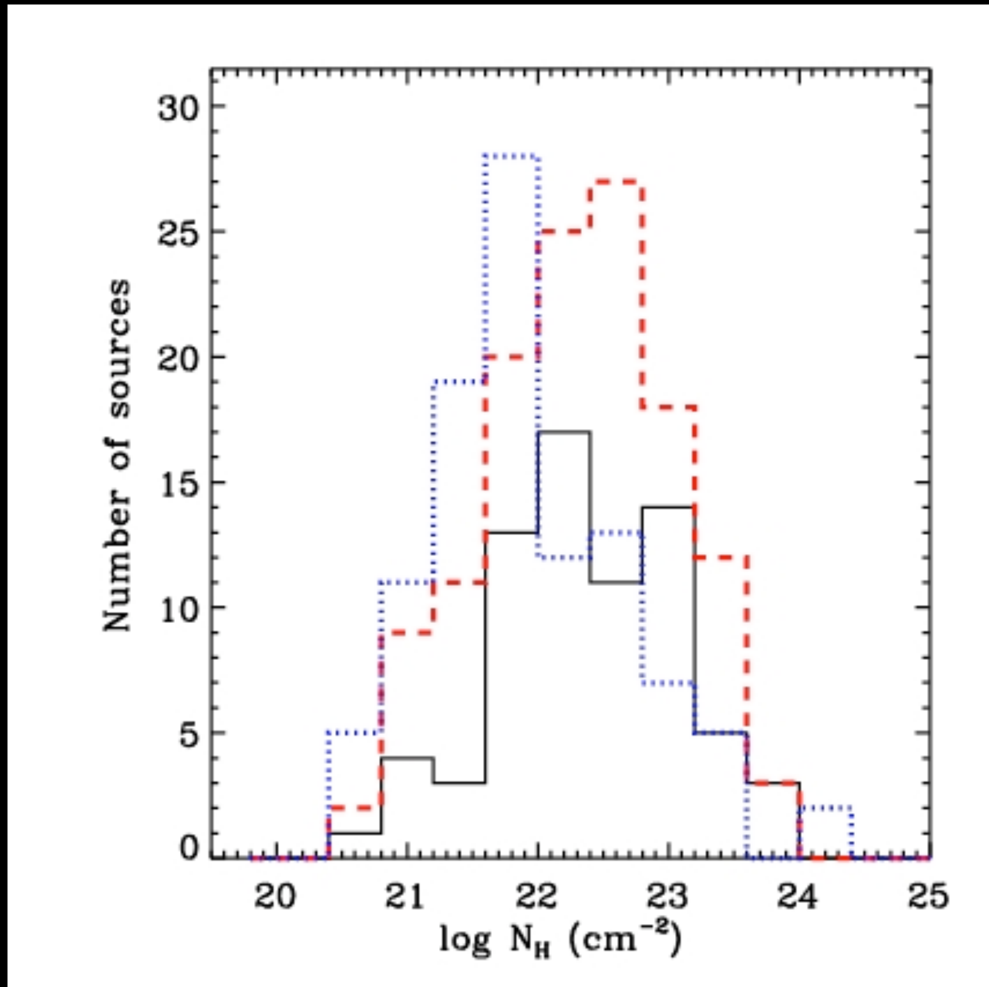
See also Tozzi et al. 2006

X-ray zoo


APL
XID=70
normalized counts/sec/keV
ratio
channel energy (keV)
APL+Fe
XID=2028 z=0.784
data/model
ratio
channel energy (keV)
APL+soft
XID=41 z=0.114
normalized counts/sec/keV
ratio
channel energy (keV)
PL
XID=1 z=0.373
normalized counts/sec/keV
ratio
channel energy (keV)
[0.5-2] [2-4.5] [4.5-10]

N_H distribution



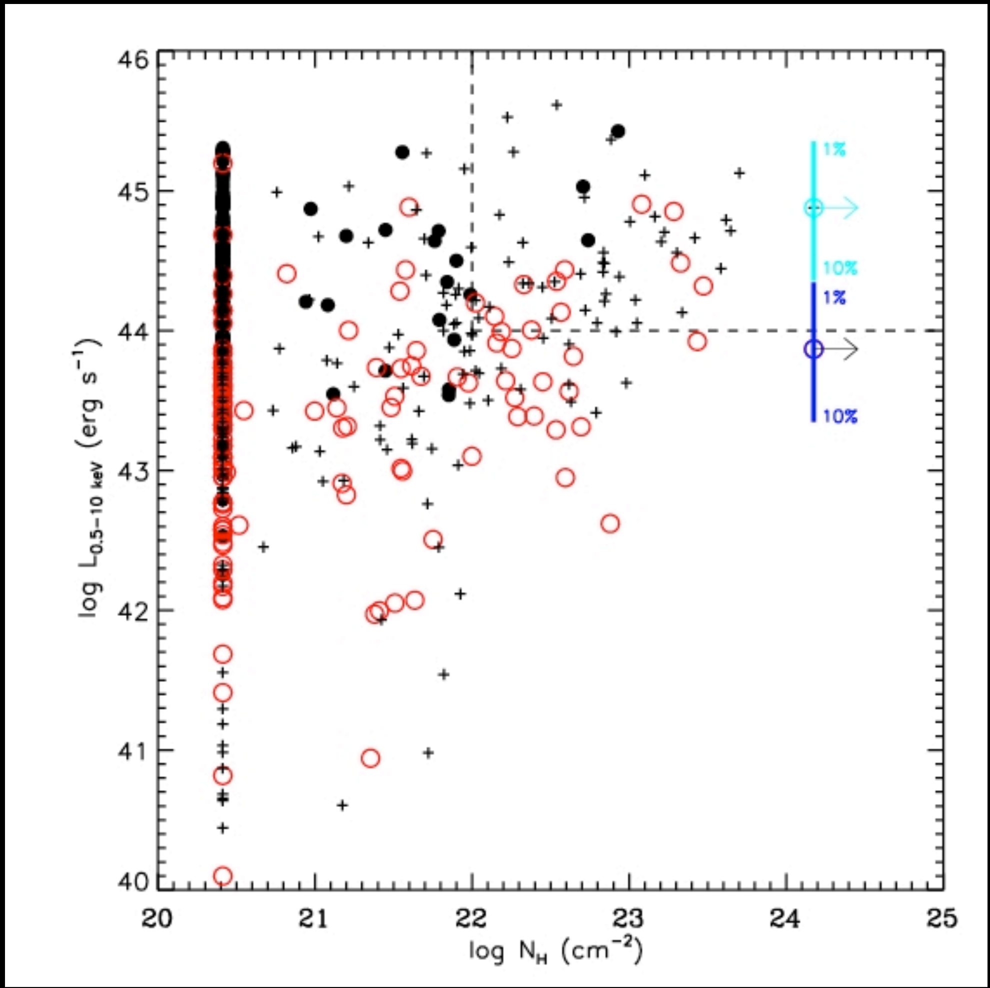


z<0.8 (102 objects)

0.8<z<1.5 (127 objects)

z>1.5 (71 objects)

QSO-2 candidates



X-ray surveys are finding the radio quiet population of QSO-2

They are spanning a large redshift range: [0.6-2.8]

R-K ~ 4-5 (Vega)

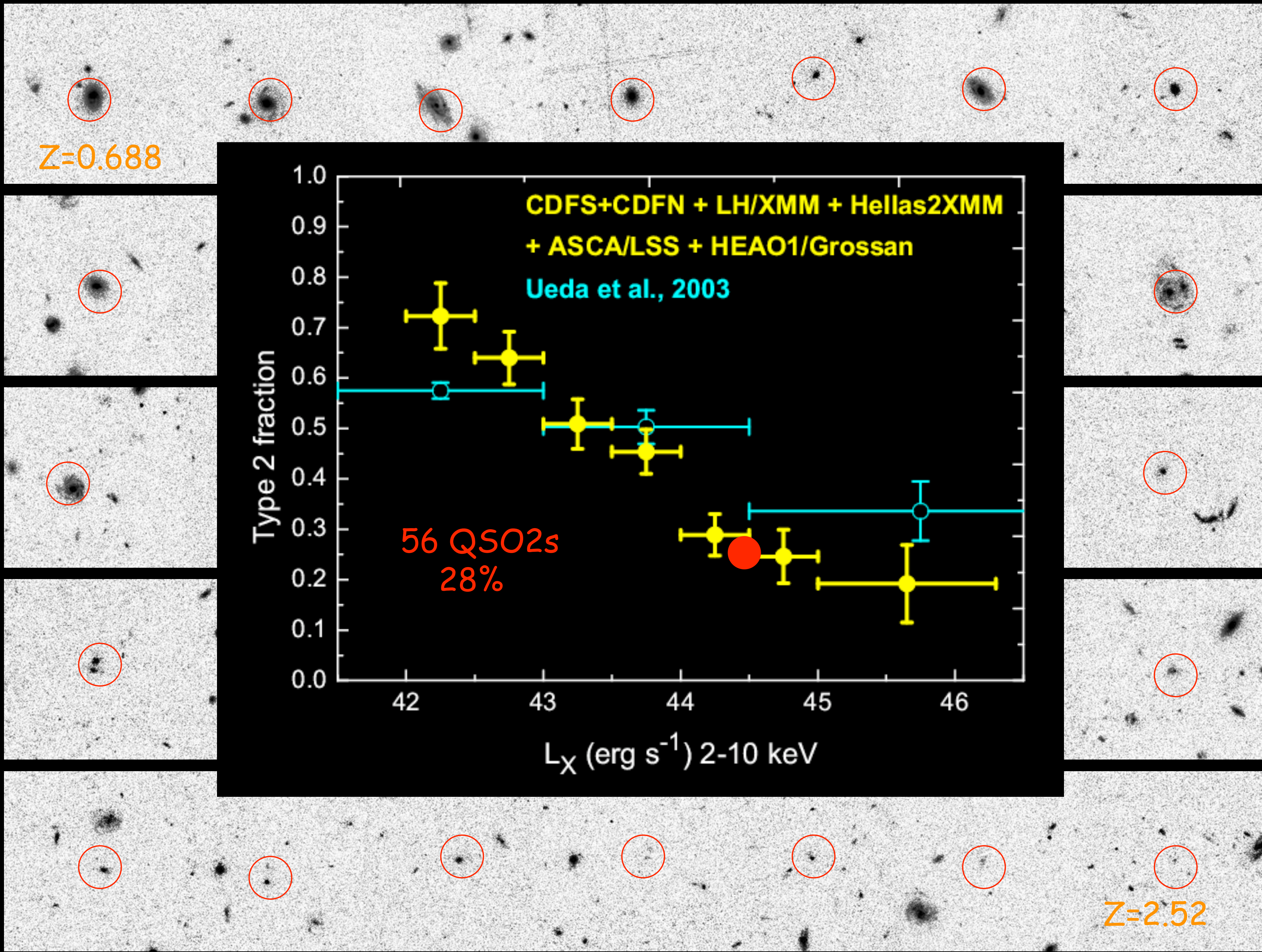
Two are detected at 20cm:

540±24 μJy -> 9.8×10^{23} W/Hz

52±11 μJy -> 1.5×10^{23} W/Hz

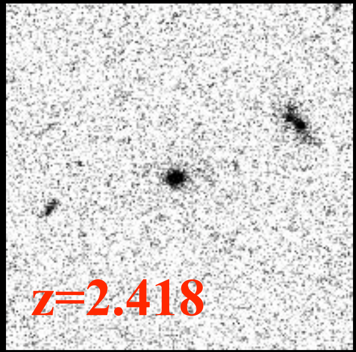
For the other two:

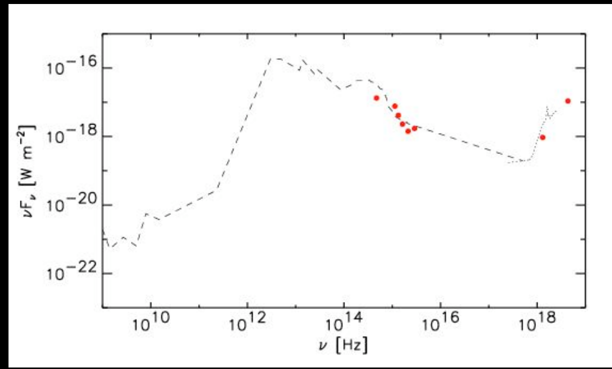
$F_{20cm}(4.5\sigma) \sim 50$ μJy


Z=0.688
Z=2.52
CDFS+CDFN + LH/XMM + Hellas2XMM
+ ASCA/LSS + HEAO1/Grossan
Ueda et al., 2003
56 QSO2s
28%
Type 2 fraction
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
42
43
44
45
46
L_X (erg s^-1) 2-10 keV

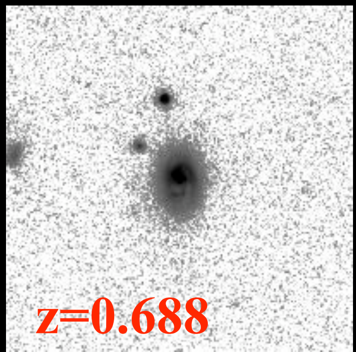
Composite Sy2

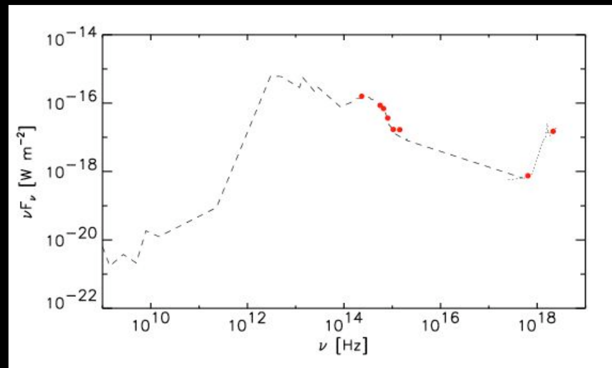
xid=122



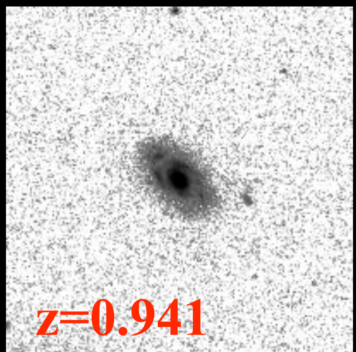


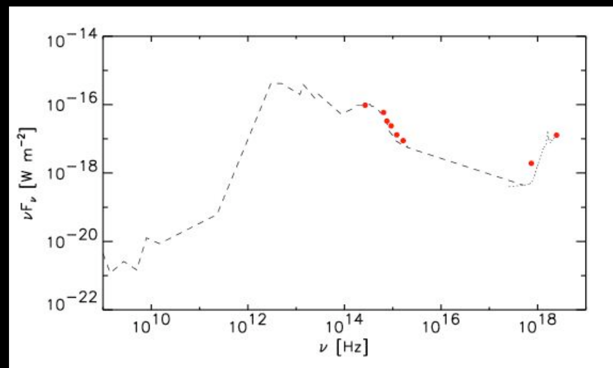
xid=70



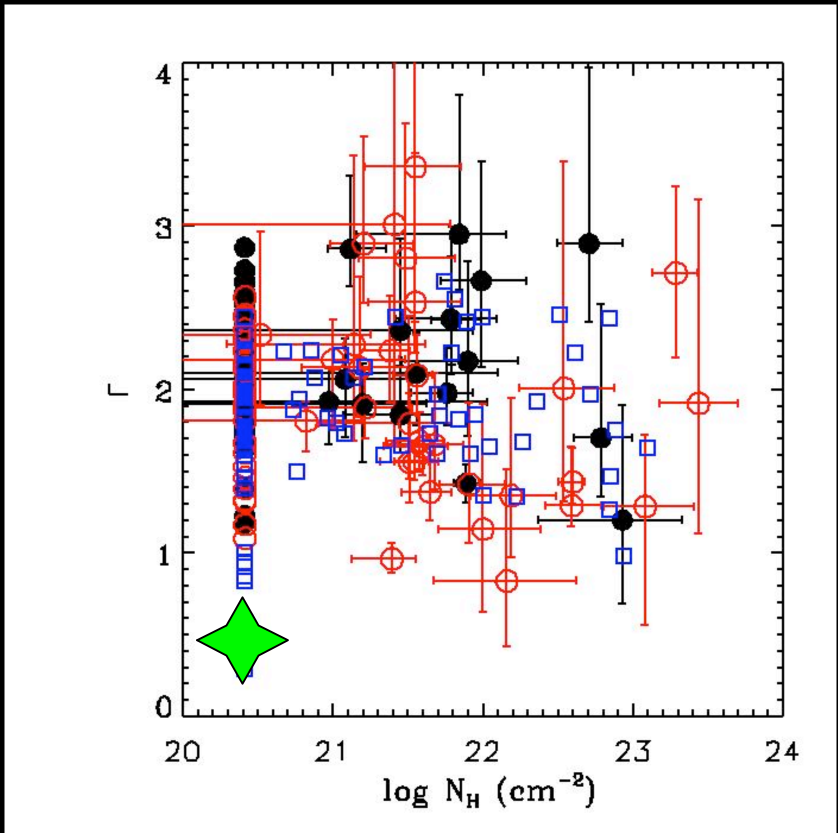


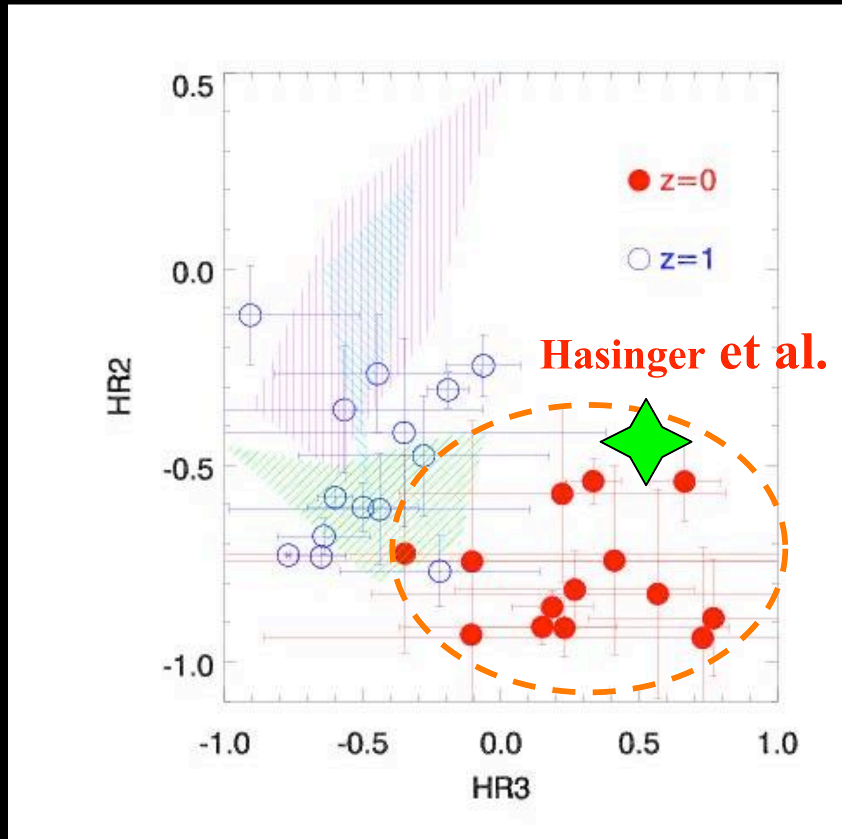
xid=2237





Compton-thick





Hasinger et al. 2006

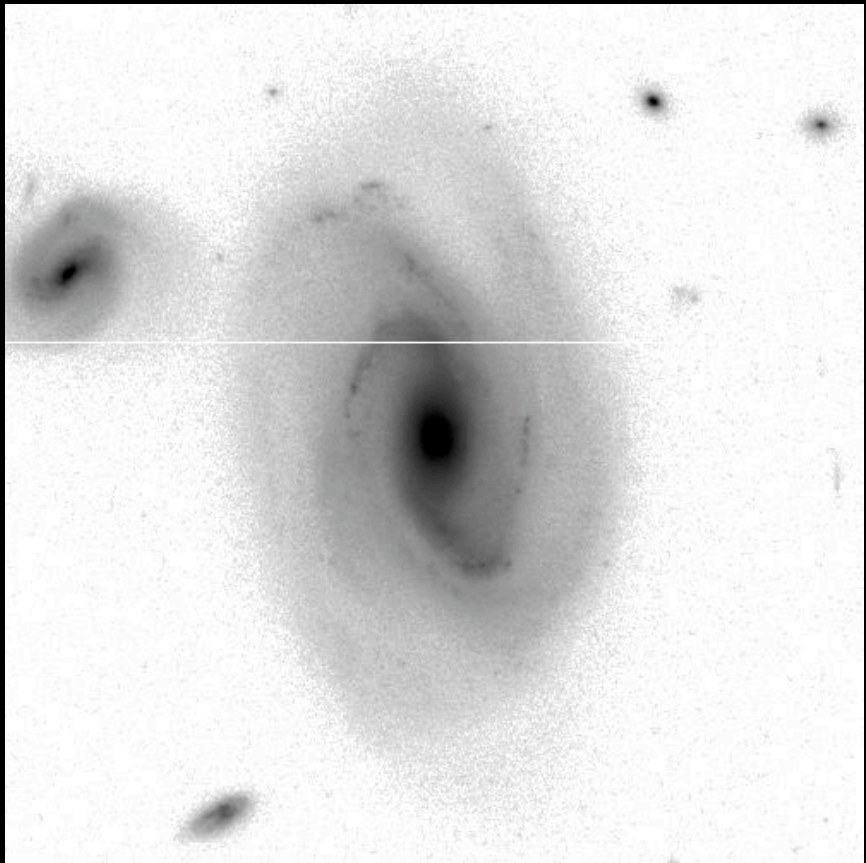
Guainazzi, Matt & Perola 2005

Local (z=0) sample of Compton thick sources

Compton-thick

25 arcsec

ACS/HST



z=0.1248 (SDSS spectrum)

pexrav+gauss

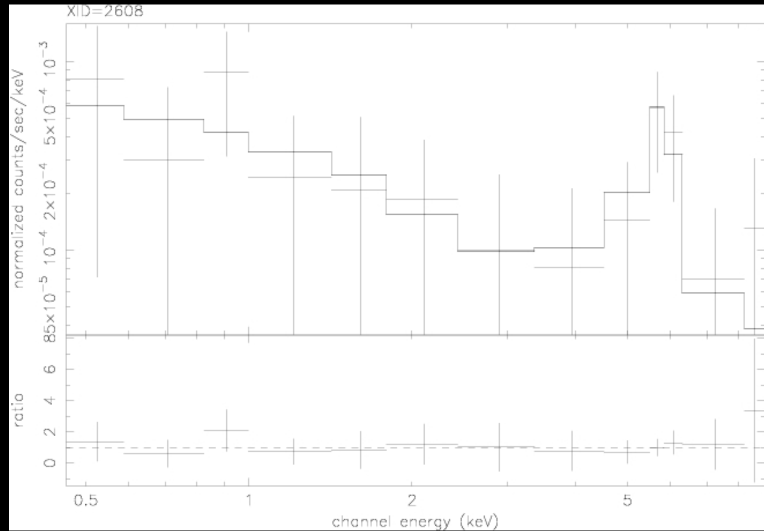


Table 3. Parameters of the best fit model for source xid 2608

Model[a]	Γ	N_H[b]	EW[c]	χ^2	d.o.f.
APL	2.0	$0.16^{+0.75}_{-0.16}$		9.3	11
pexrav	2.0			4.1	9
pexrav+gauss	2.0		792^{+1151}_{-493}	1.7	7

[a]Best fit model: *APL* = absorbed power-law; *pexrav* = pure reflection model; *pexrav+gauss* = pure reflection model plus a Gaussian line.

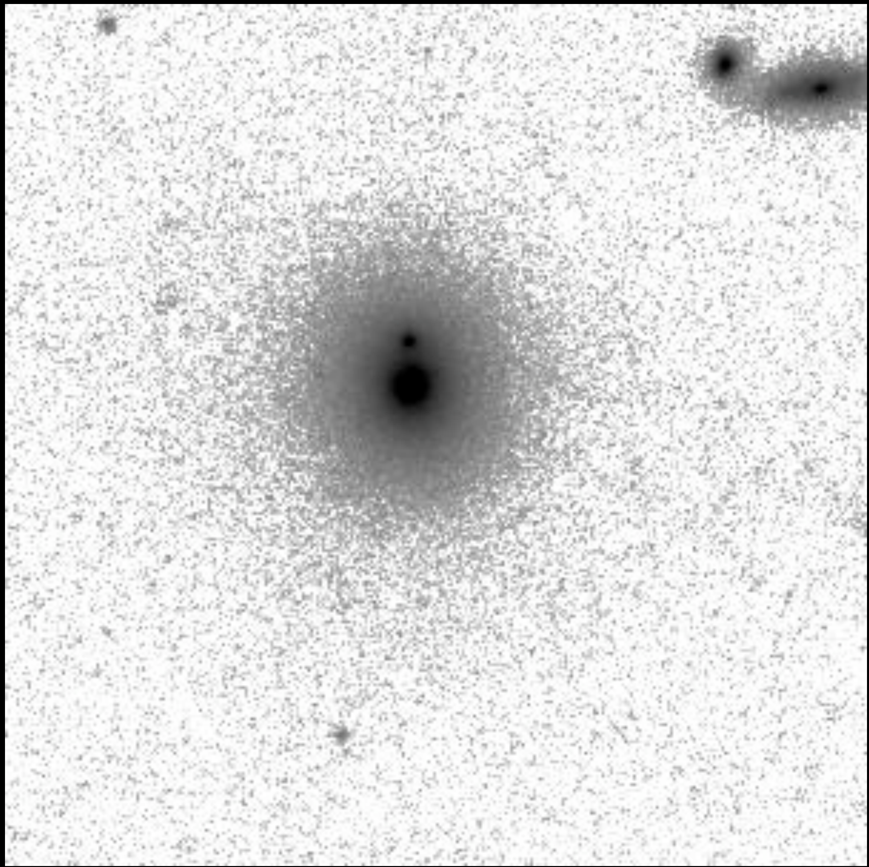
[b]Hydrogen column density in unit of 10^{22} cm^{-2}.

[c]Equivalent width of the Fe Kα line expressed in eV.

Compton-thick

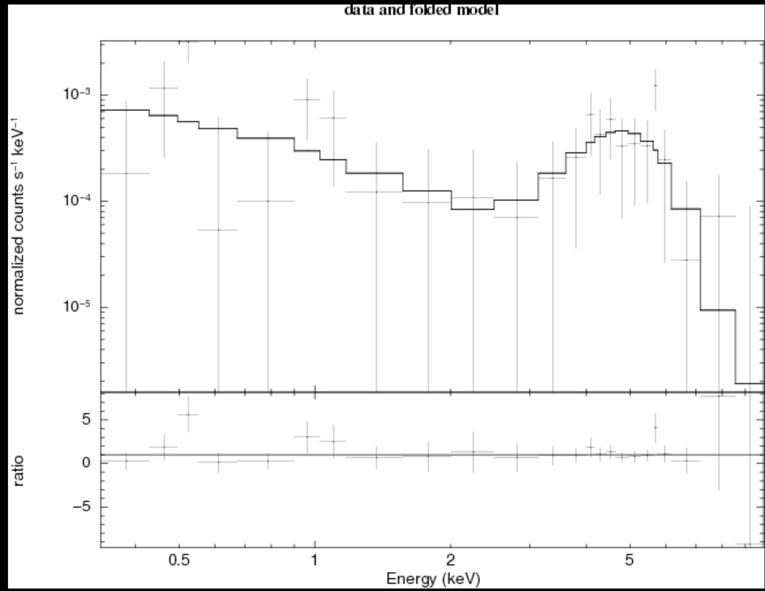
25 arcsec

ACS/HST



zphot=0.43

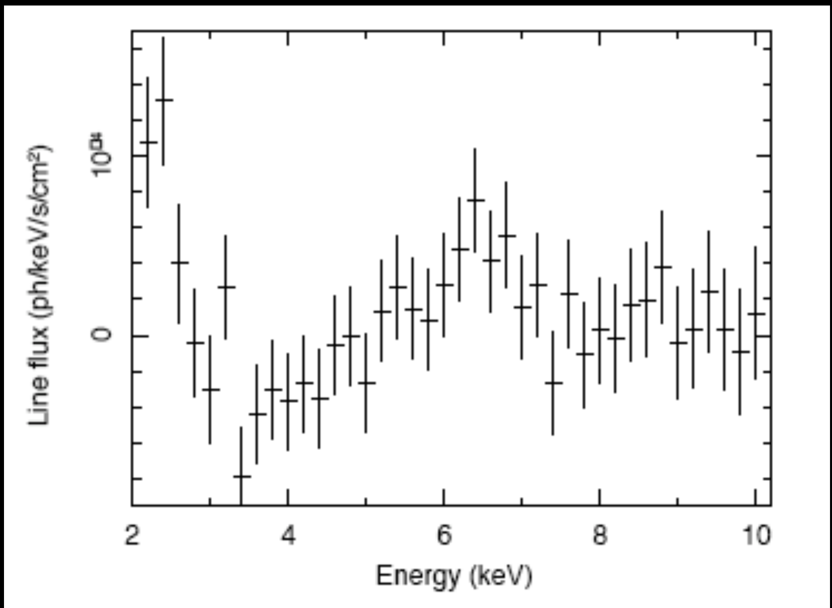
pexrav+gauss

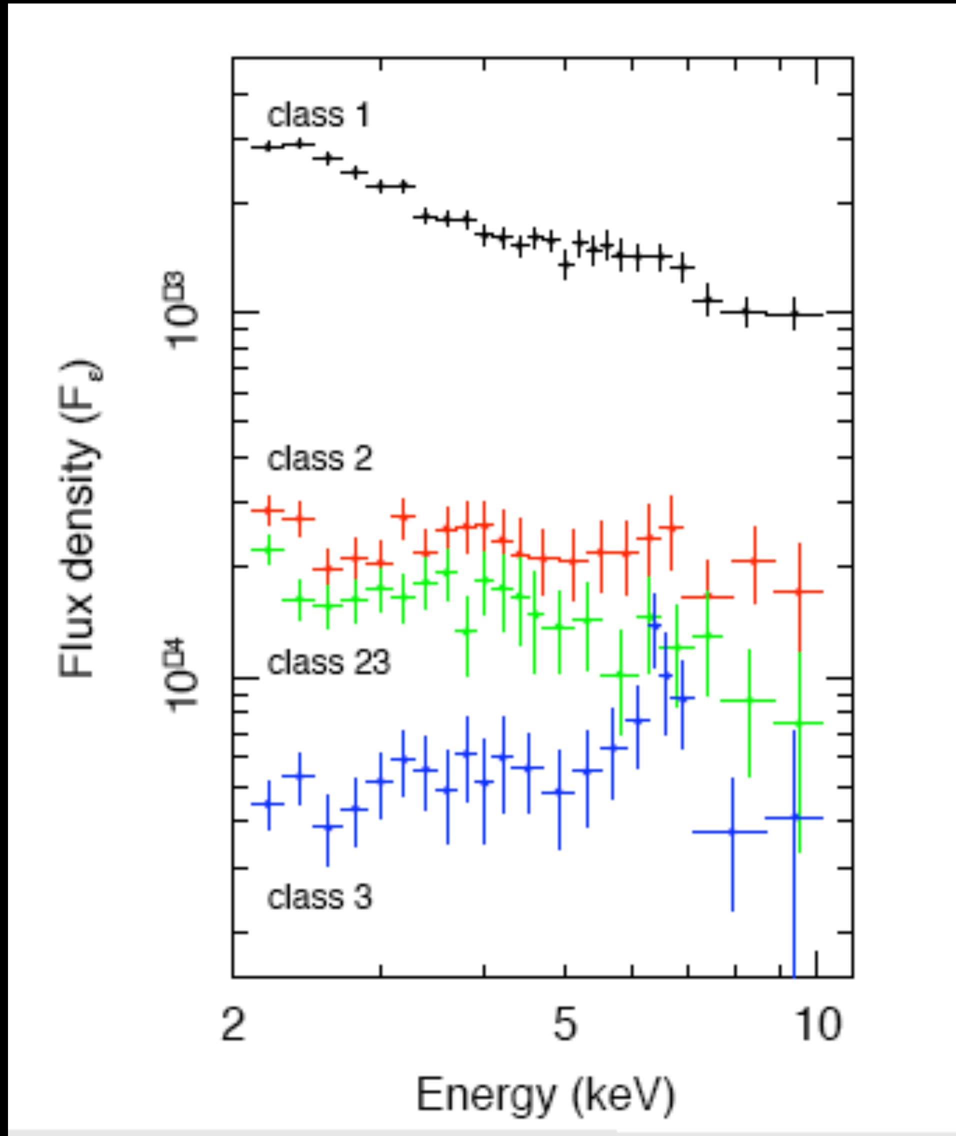


$EW_{FeK\alpha} = 1023^{1400}_{600}$ eV

Fe K line stacking

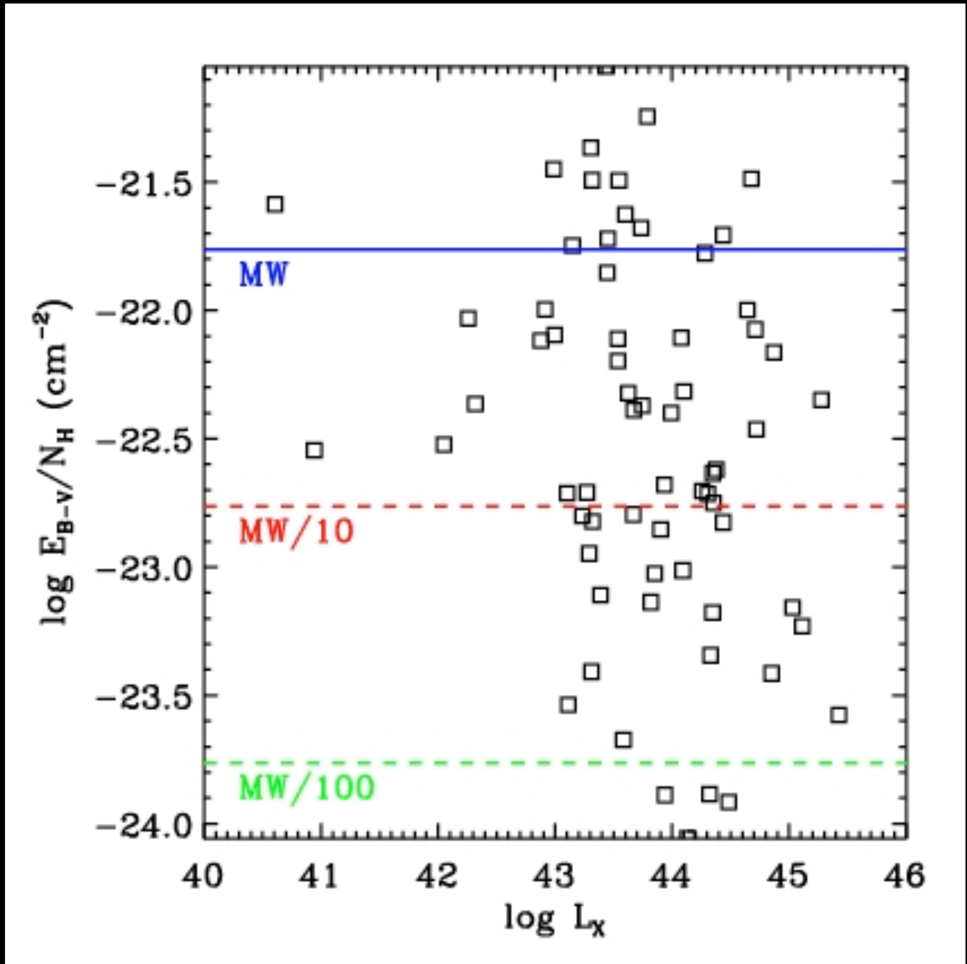
Method: the continuum is estimated for individual sources and subtracted, the residuals after correcting for the instrumental response curve are added together to form a stacked line profile. Spectral binning was designed to match a fixed rest-frame 200eV intervals.





Iwasawa & VM, in prep

Dust in AGN

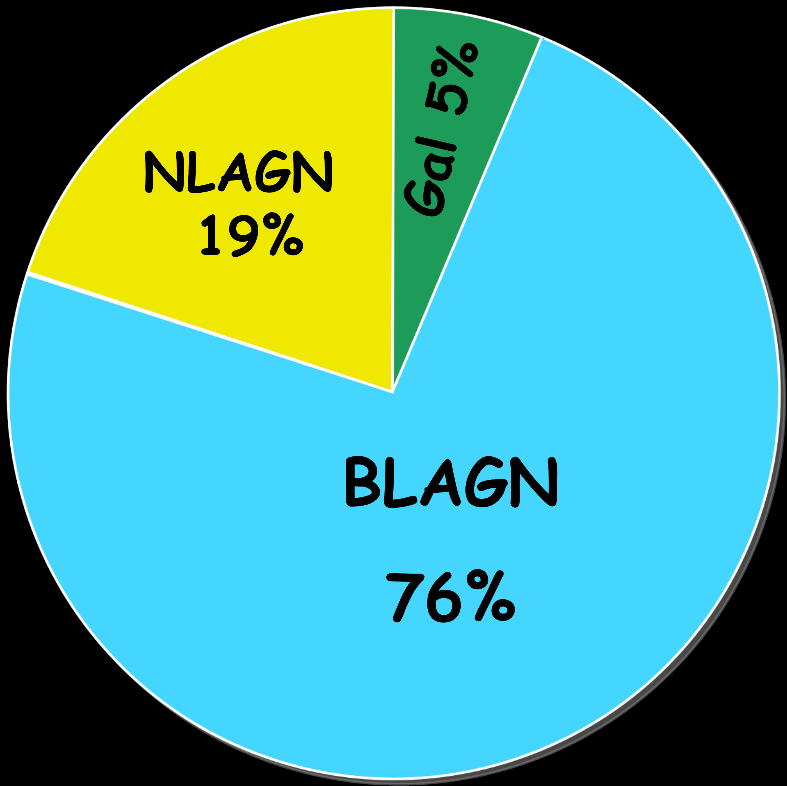


For a sub-sample of 70 sources optical dust reddening E(B-V) has been calculated from a detailed SED fitting. We confirm previous findings (e.g. Maccacaro et al. 1982; Reichert et al. 1985; Maiolino et al. 2001; Willott et al. 2004) that the dust reddening is generally lower than the values expected from the gaseous column density measured in the X-rays, if a standard Galactic dust-to-gas ratio and extinction curve are assumed.

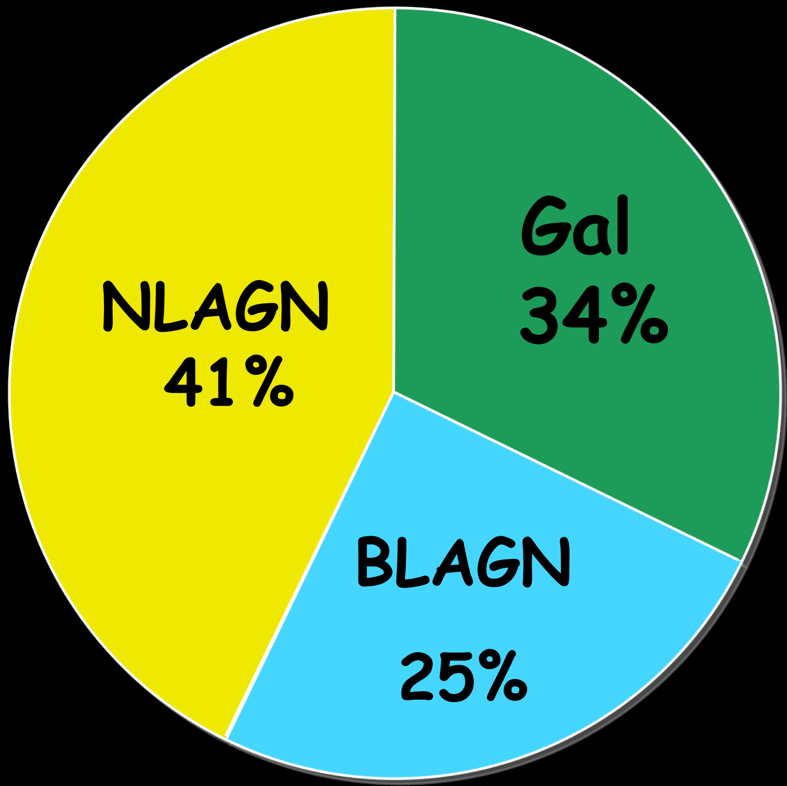
- the BLR is dust free, because inside the dust sublimation radius
- large dust grains, therefore less effective in absorbing optical and UV radiation
- sampling different physical scales

Comparison between X-ray and optical classification

X-ray unabsorbed



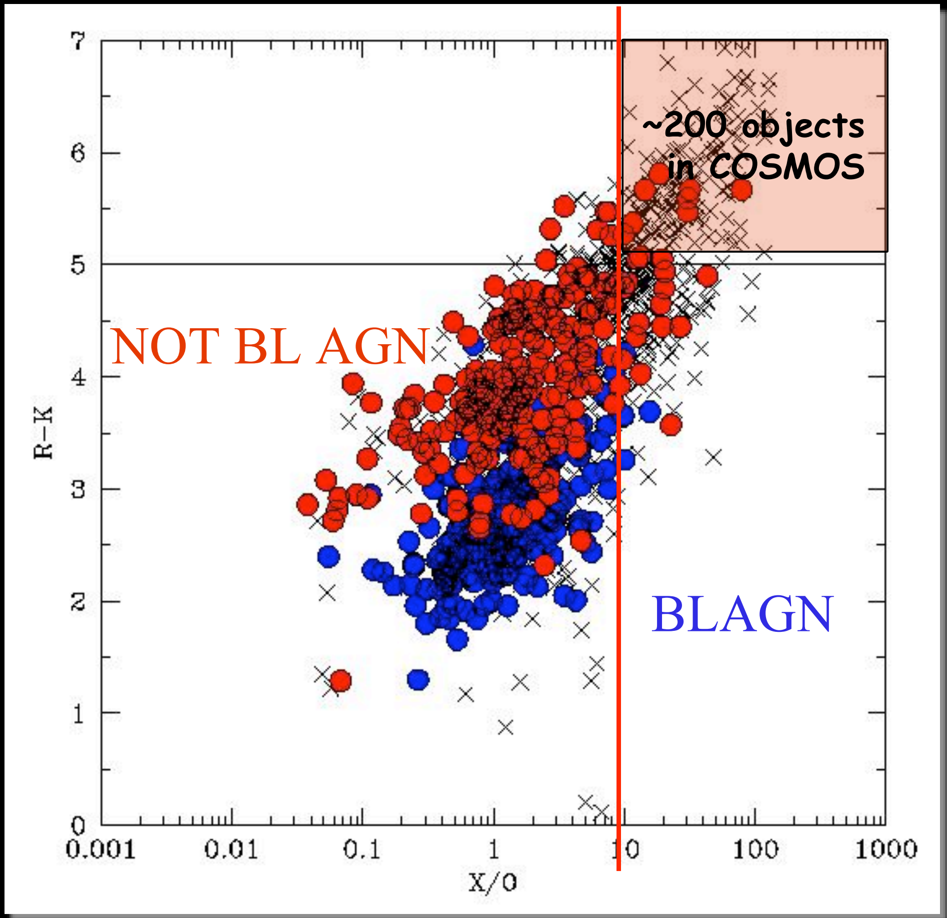
X-ray absorbed



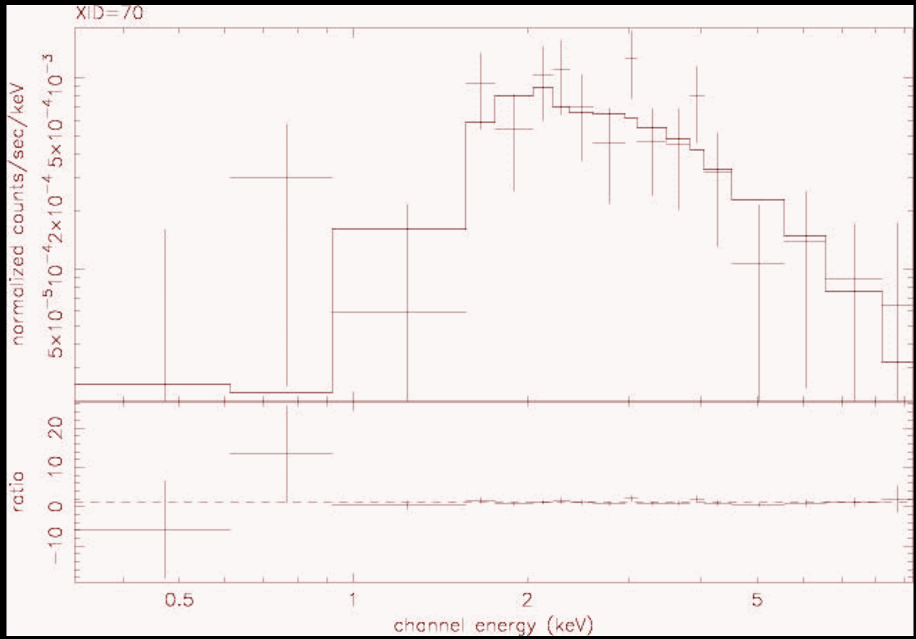
2/3of NLAGN do not show X-ray absorption:
80% z>0.4 --> Hα outside
50% have MgII inside but not enough S/N

combining R-K and X/O

X/O correlates with R-K
→combine these 2 criteria to isolate most obscured (QSO2) sources



Civano et al. in preparation

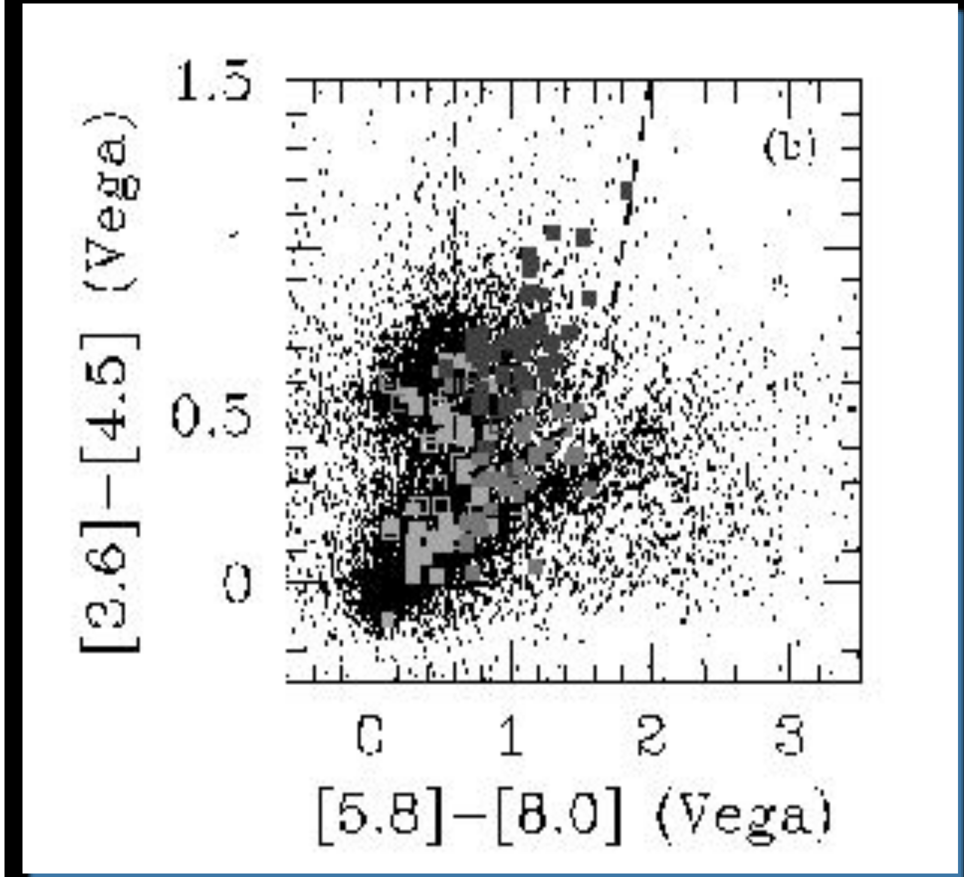


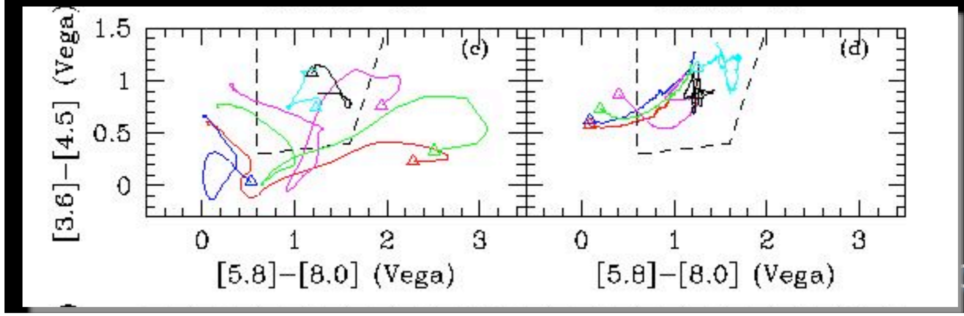
Mainieri et al. 2007

QSO2:

$N_H \sim 10^{23}$ cm^{-2}
$L_{2\text{-}10\ keV} = 5\times10^{44}$ erg/s
z(phot)=1.2

Where are X-ray sources in MIR diagrams?





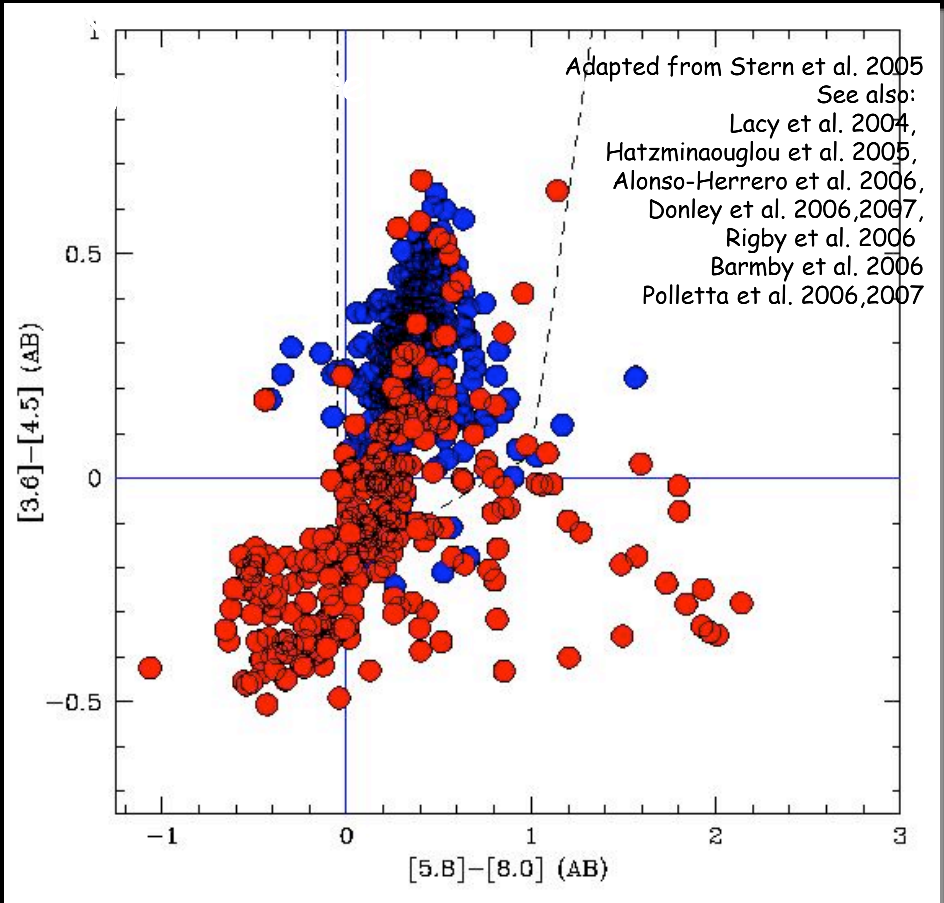
-51% of all the X-ray sample
-9% of all IRAC sample

Tracks of elliptical, Scd, Arp220, M82, NGC1068 (black), NGC5506 at z=0-2 and z=2-7

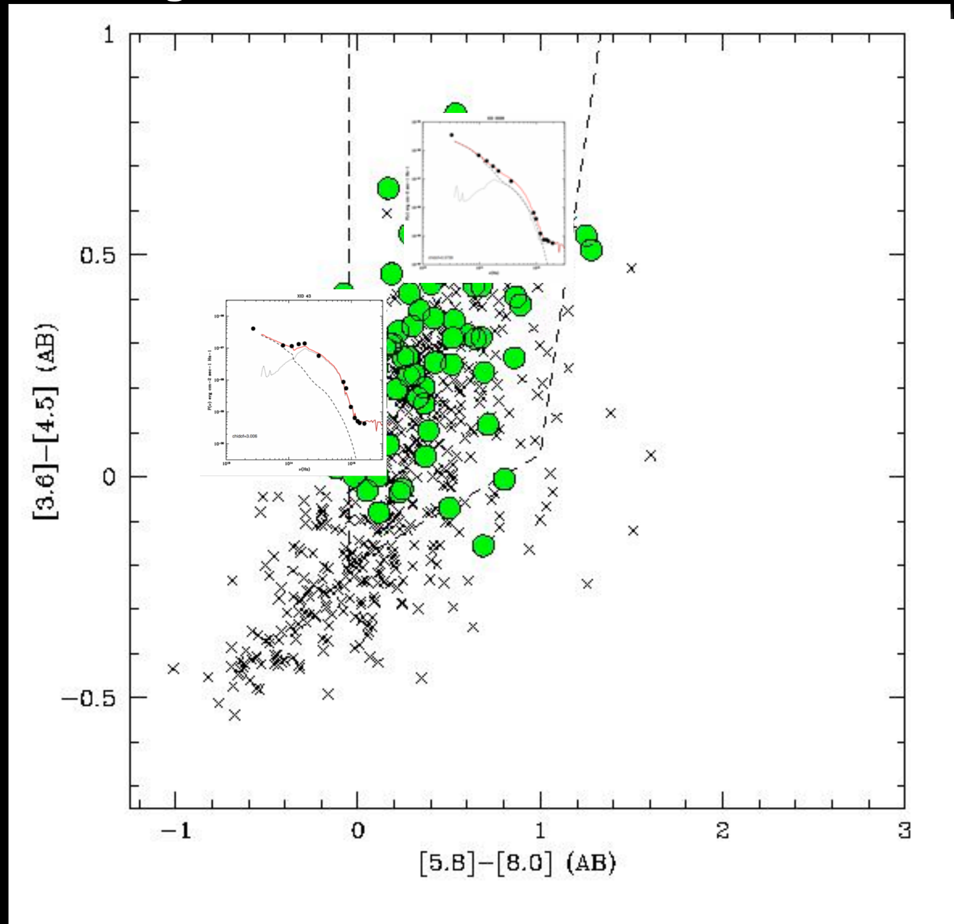
AGN → @any z
Starbursts → in & out
Elliptical → in at z>2

IRAC colors of X-ray sources

IRAC colors of identified (mostly low-z)
NOT BL AGN show significant contribution
from host galaxy light → 50% outside



Fraction of AGN outside the wedge increases with decreasing X-ray flux
Population of obscured AGN at z~2 emerges at the faintest fluxes

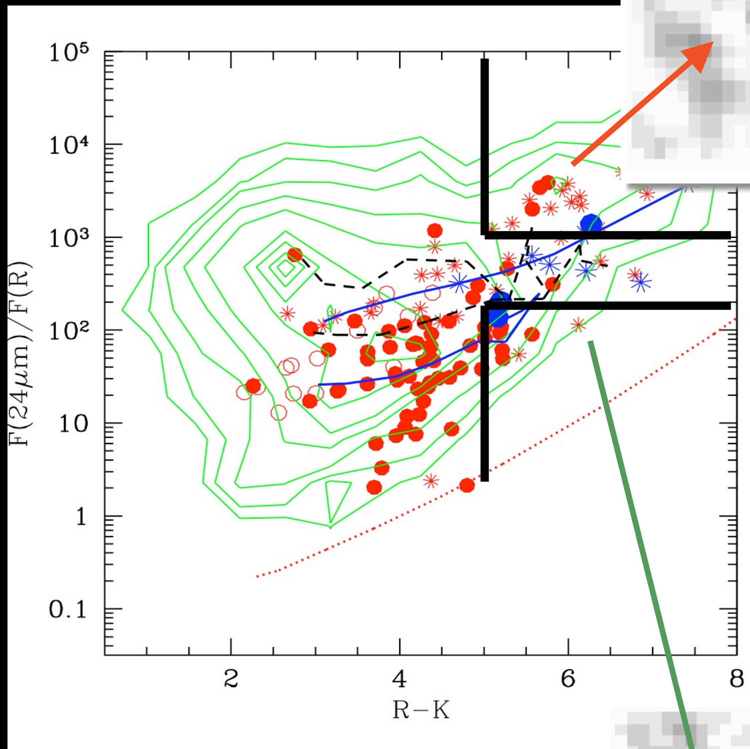


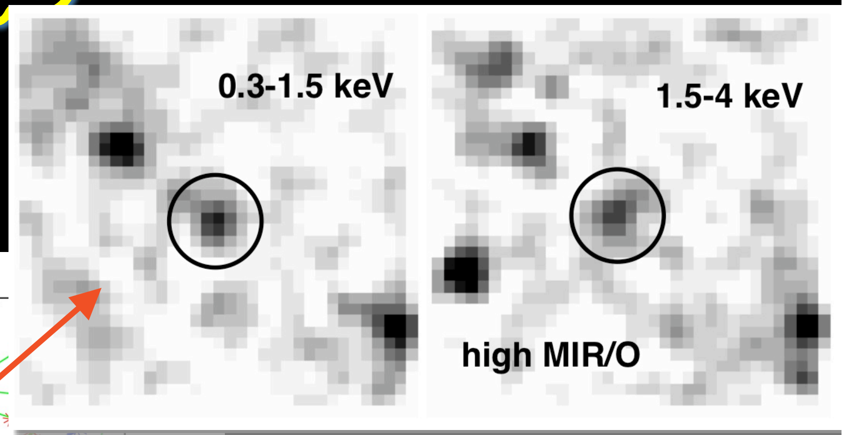
See also Hickox et al. 2007 from Bootes survey

Combining MIR/O and R-K criteria: selection of CT AGN at z~2

GOODS CDFS field

Stack of Chandra images excluding X-ray detections in two different MIR/O and R-K bins

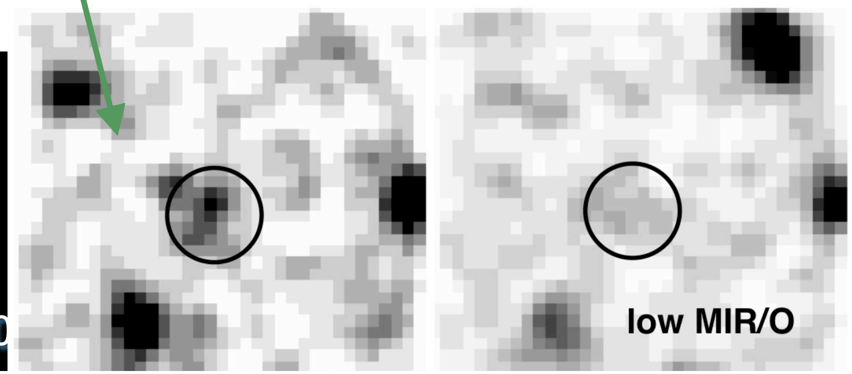




Stacked signal implies (unobs) Lx>43, NH>23 → Compton Thick

Fiore et al. 2007

See also Daddi et al. 2007



Summary

- C-thin AGN: hard X-ray surveys are quite effective, COSMOS has an excellent X-ray coverage (XMM+Chandra) and spectroscopic follow-up
- A large population of QSO-2, the observed number density is in agreement with the decrease of the type-2/type-1 with X-ray luminosity
- Dust-to-gas ratio lower than the Galactic value for a large fraction of the AGN
- C-thick: hard X-ray surveys miss a large fraction of them
    - move to longer wavelength: X-ray + mid-IR
        - SED of obscured sources are not always PL in IRAC (caution on using IRAC only colors diagram to select obscured AGN)
    - extremely deep XMM exposure (not confusion limited in the 5-10 keV band)
    - future missions (Simbol-X, [0.5-80] keV) and XEUS