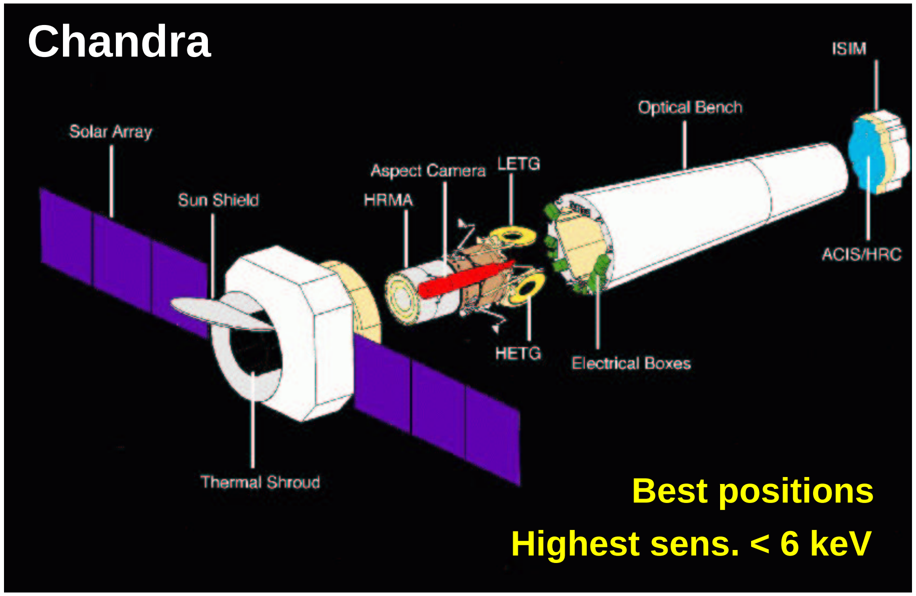
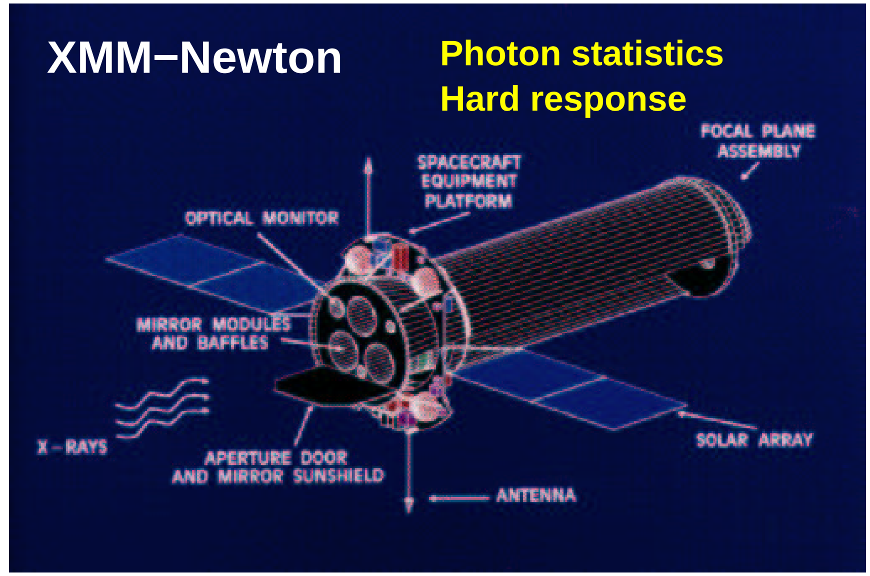
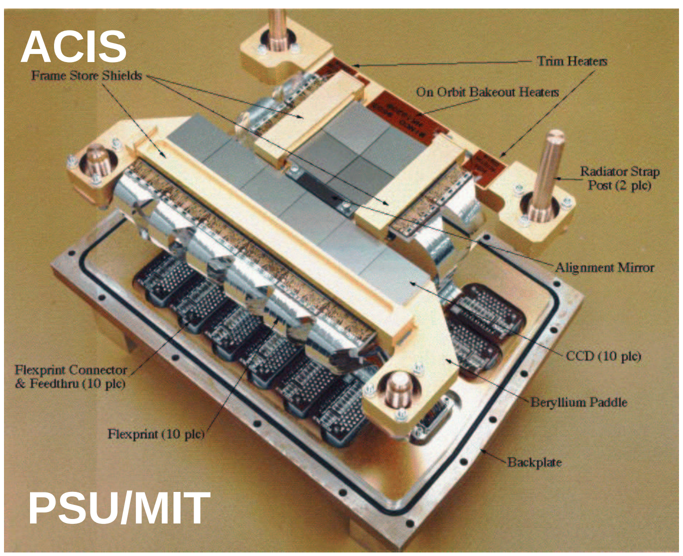
X−ray Survey Results on AGN Physics and Evolution

Niel Brandt



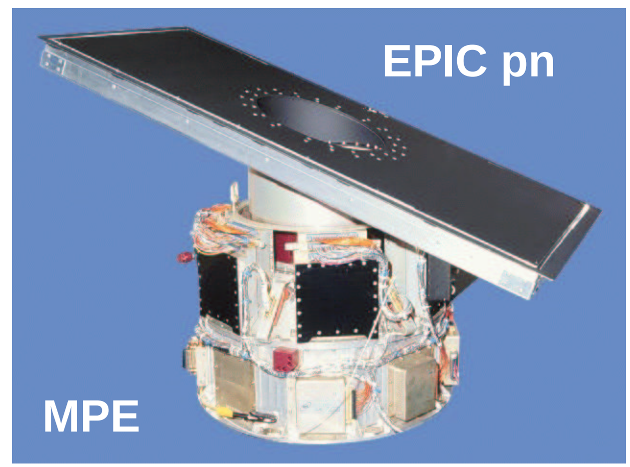




50−250 times sens. of previous missions

Good positions of 0.5−3" for follow−up

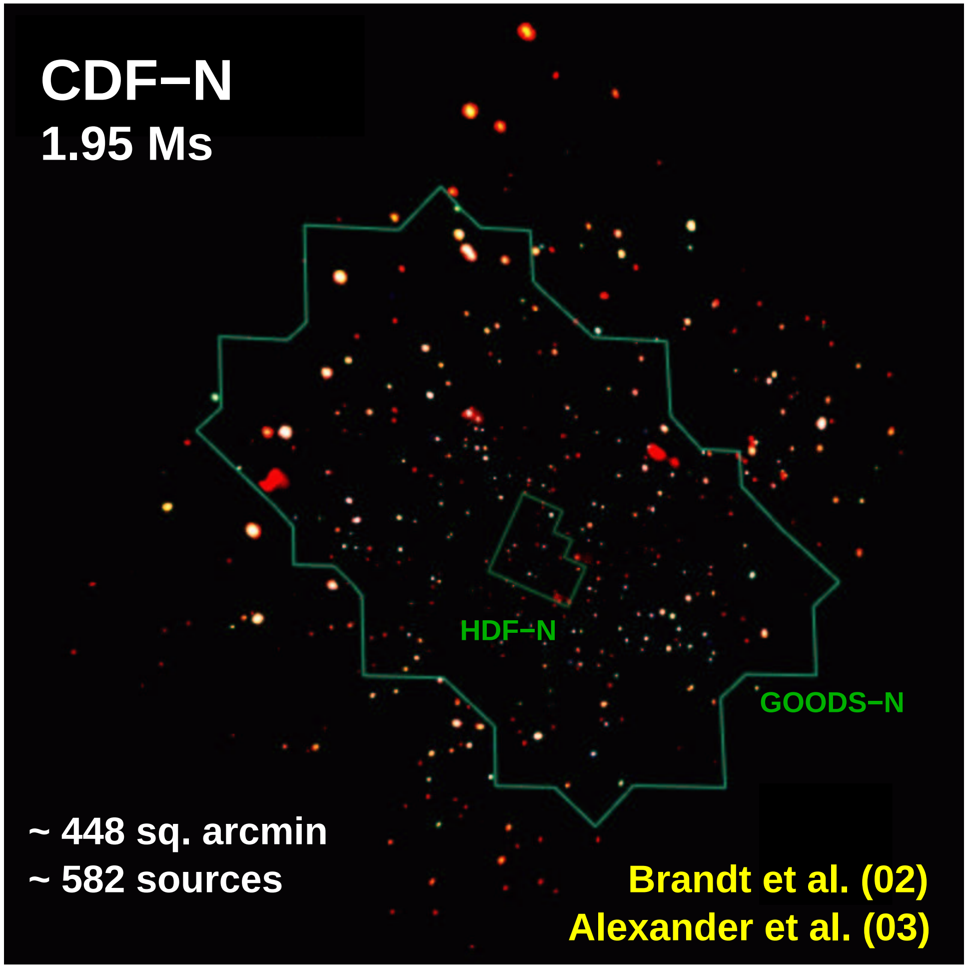
Often few hundred sources per field

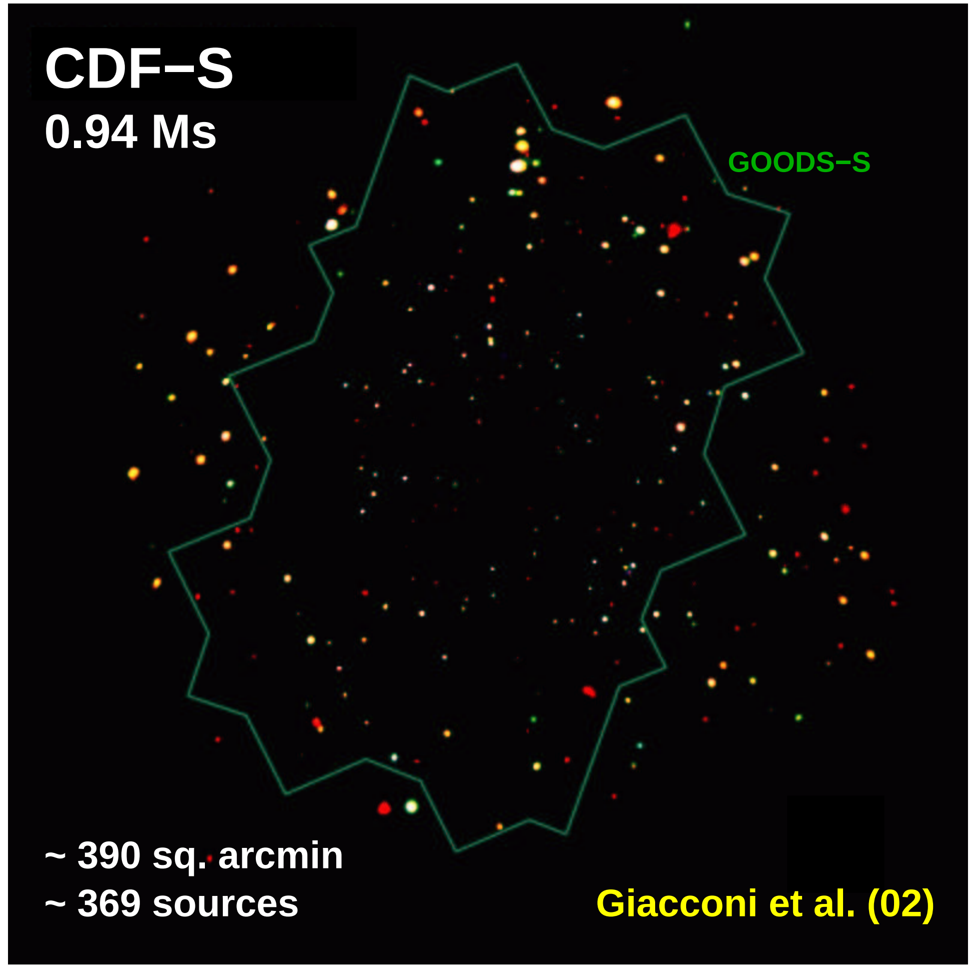


Resolve almost all of 0.5−10 keV X−ray bkg.

Nature of sources with implications for AGN physics
Evolution and role in galaxy evolution

Deep X−ray Surveys with Chandra and XMM−Newton





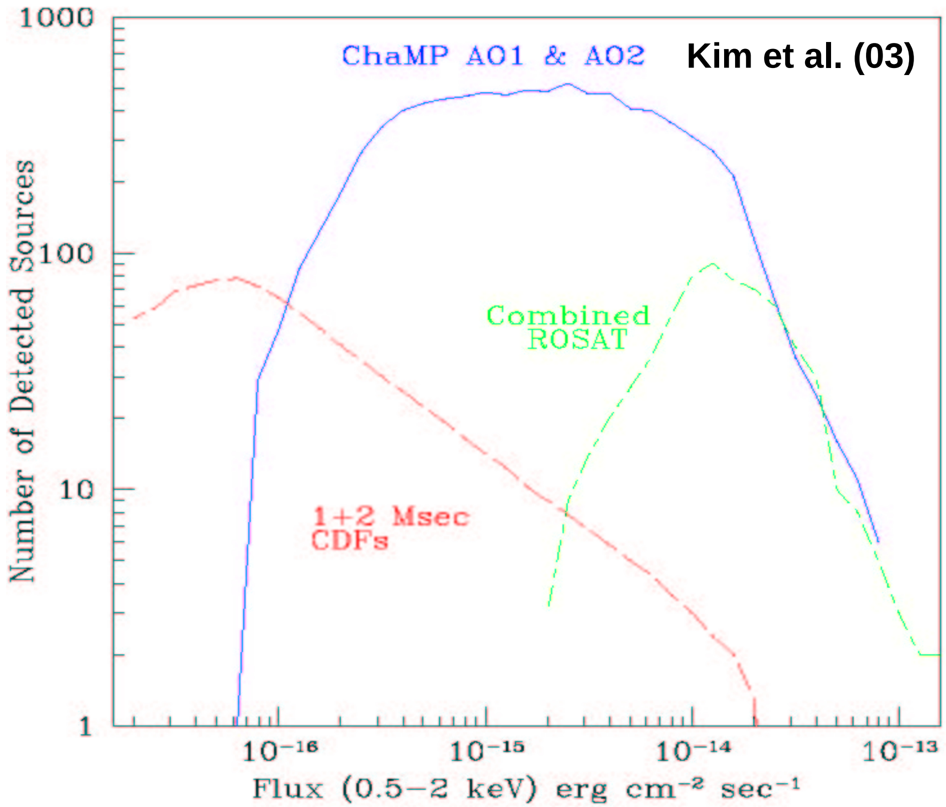
Superb multiwavelength supporting data

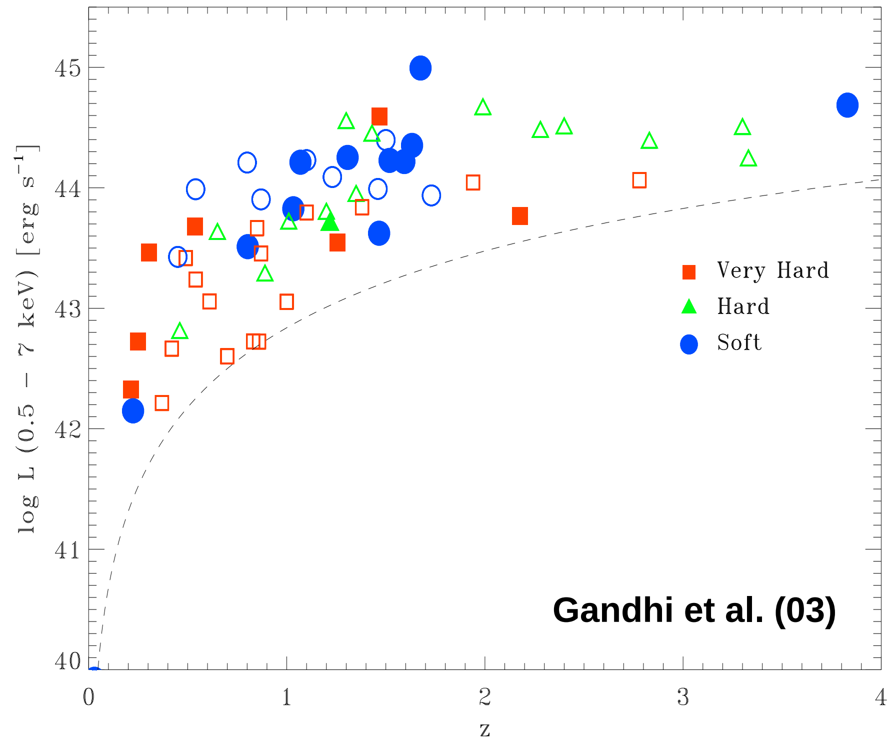
Also

Lockman (e.g., Hasinger et al. 2001)
13 hr (e.g., McHardy et al. 2003)
ELAIS (e.g., Manners et al. 2003)
LALA (e.g., Wang et al. 2003)

Lynx (e.g., Stern et al. 2002)
SSA13 (e.g., Mushotzky et al. 2000)
Subaru Deep
Groth−Westphal

Wider X−ray Surveys with Chandra and XMM−Newton





Bridge "gap" between currently deepest surveys and previous surveys.
Target fluxes where most of X−ray background is created.

Broad census covering large low−redshift volume for rare and bright sources.
High−quality follow−up can be very demanding.

Some examples:

- ChaMP (Kim et al. 03; Green et al. 03)
- CYDER (Castander et al. 03)
- Chandra clusters (Gandhi et al. 03)
- Lockman Hole−NW (Steffen et al. 03; Yuan et al. 03)
- SEXSI (Harrison et al. 03)
- XMM SSC (Watson et al. 02)
- AXIS (Barcons et al. 02)
- HELLAS2XMM (Fiore et al. 03)
- XMM/2dF (Georgakakis et al. 03)
- XMM LSS (Pierre et al. 03)

Nature of the X−ray Sources

Broad diversity of X−ray sources detected.

At faint X−ray fluxes, optical fluxes span range of ~ 100,000.

AGN of several varieties (type 1, type 2, XBONGs)
Starburst galaxies
Normal galaxies
Stars

Most appear to be AGN.

X−ray luminosity
X−ray−to−optical flux ratio
X−ray spectra and variability
Optical spectra

In deepest X−ray surveys, sky density exceeds 6000 deg^{-2}

Highest AGN sky density known by factor ~ 10.

Find obscured AGN and minimal host−galaxy dilution
Probe further down luminosity function

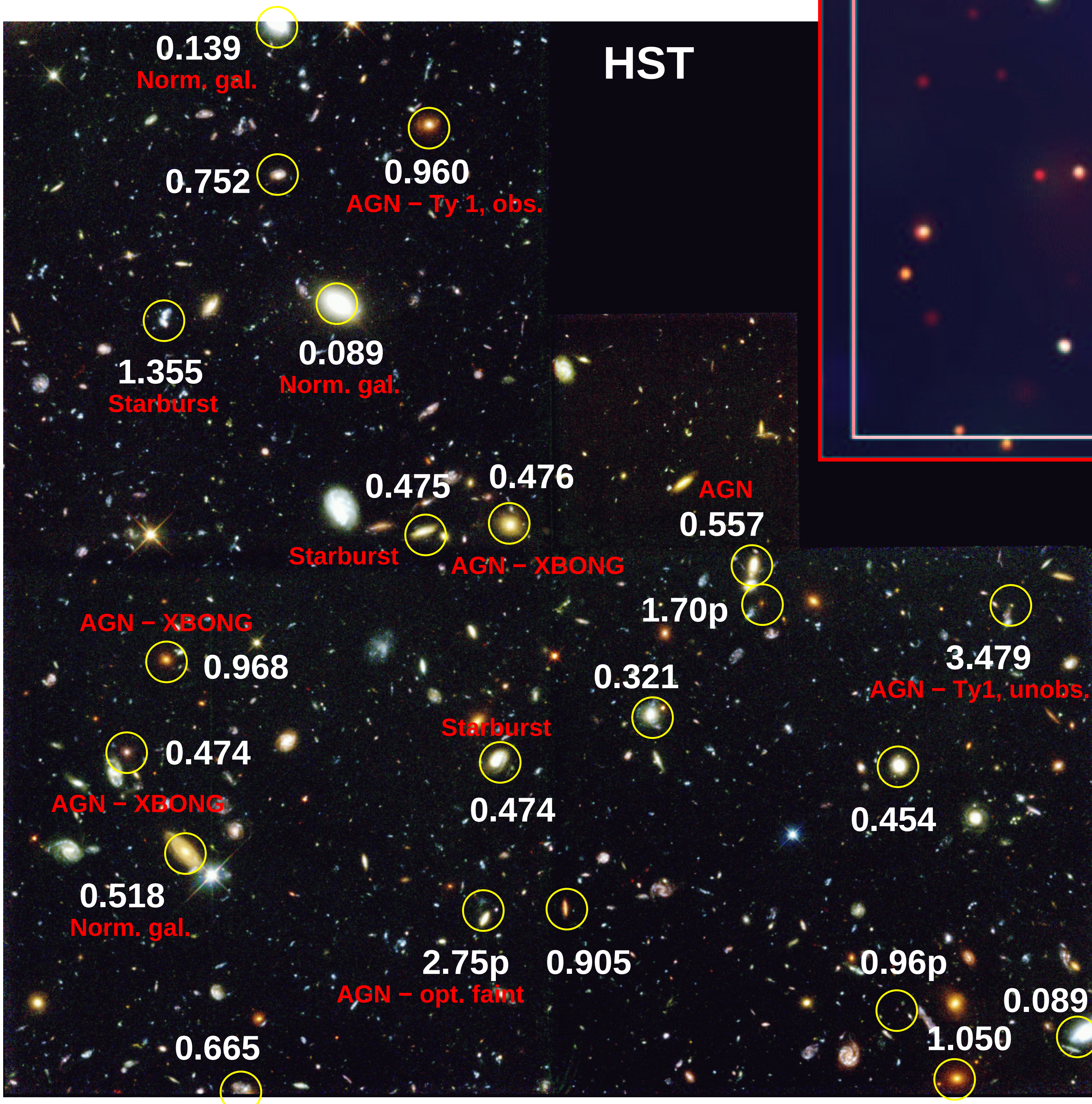
Deepest X−ray surveys appear highly complete

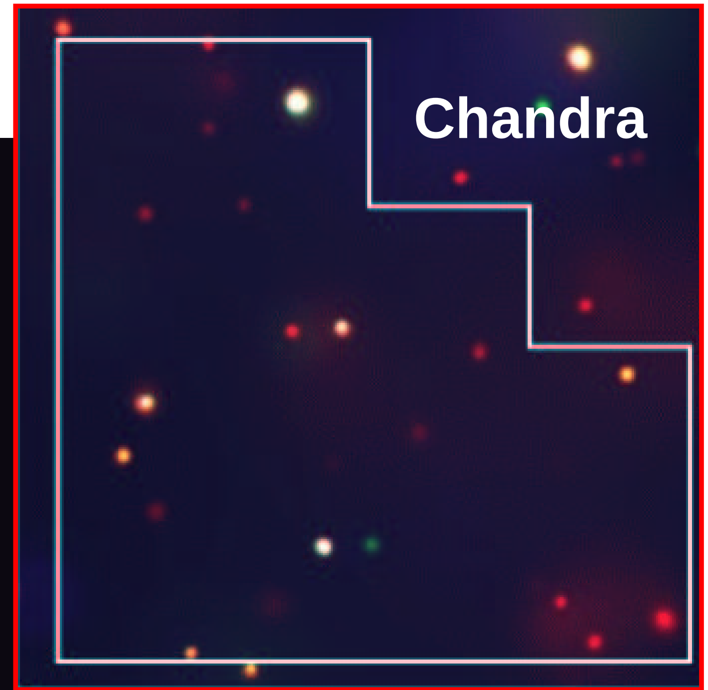
In intensively studied CDF−N field, only 1 known AGN not X−ray detected (z = 2.4 narrow−line AGN from Steidel et al.)

The problem of Compton−thick AGN at z > 2

Obs. sources can plausibly explain 20−40 keV X−ray bkg. and local SMBH density, although significant uncertainty.

Hubble Deep Field−North





Circles show 2 Ms Chandra sources (posn. error circles are much smaller)

Numbers show redshifts; note apparent redshift clustering at z ~ 0.475

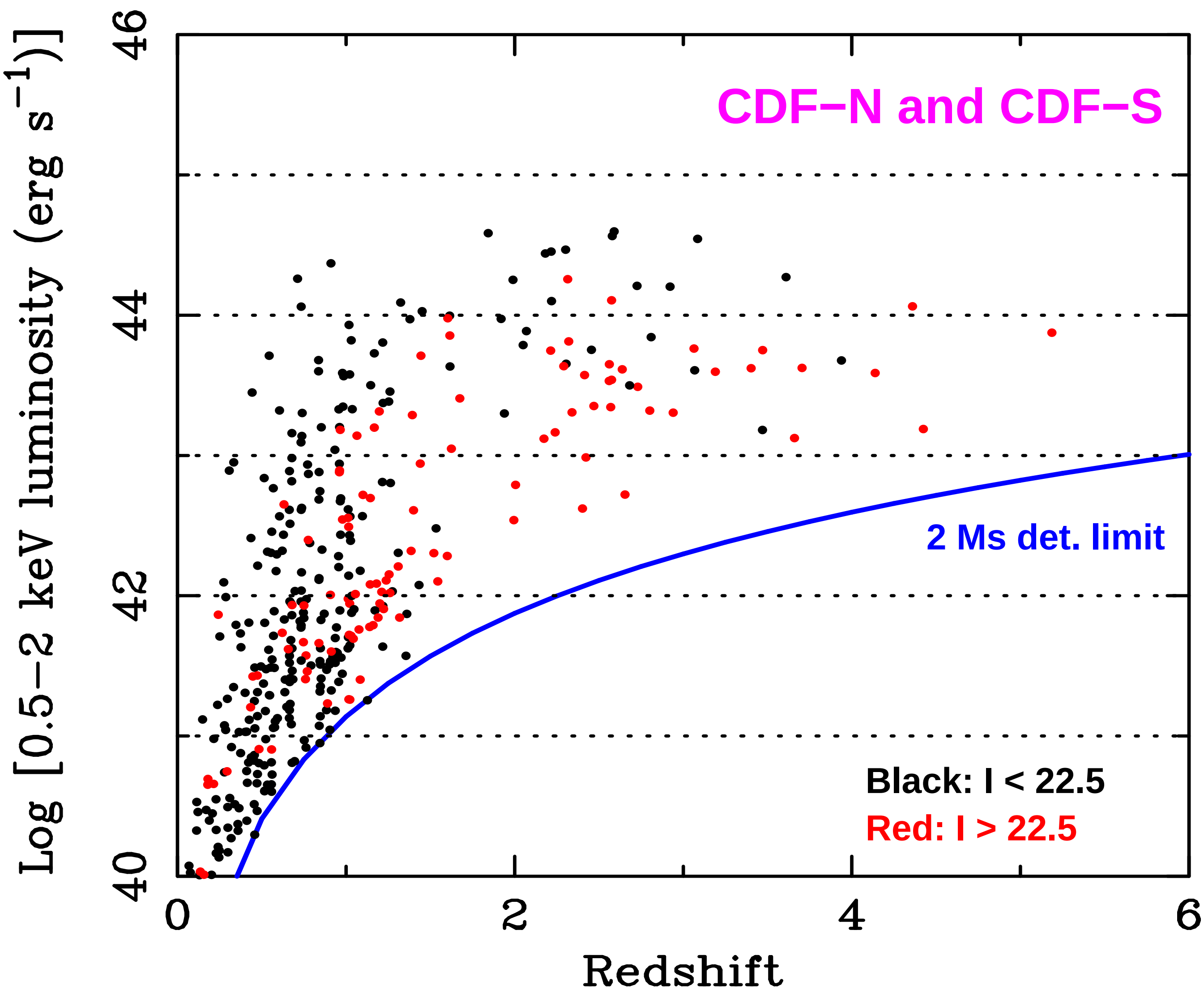
Deep−Field Luminosities and Redshifts

Most deep−field sources have luminosities comparable to local Seyferts − could see these to z ~ 6−10.

Wide−field surveys important for rarer, high−lum. objects.

Most of X−ray bkg. made by moderate−luminosity objects.

Type 2 quasars make only small contribution. Fraction of absorbed AGN drops with luminosity (> 60% to 30%).

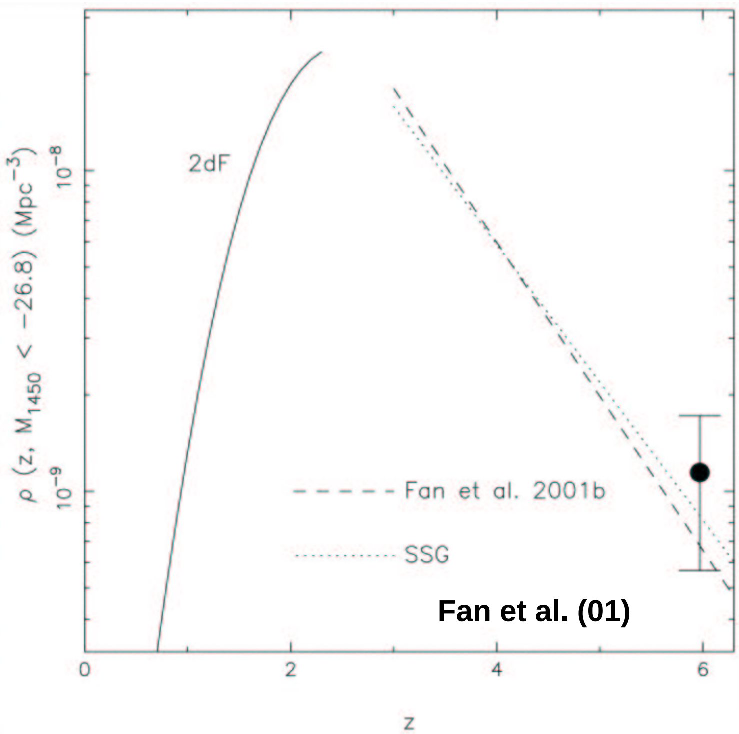


Most identified AGN have z < 2, although significant minority to z ~ 5.2 (some incompleteness bias).

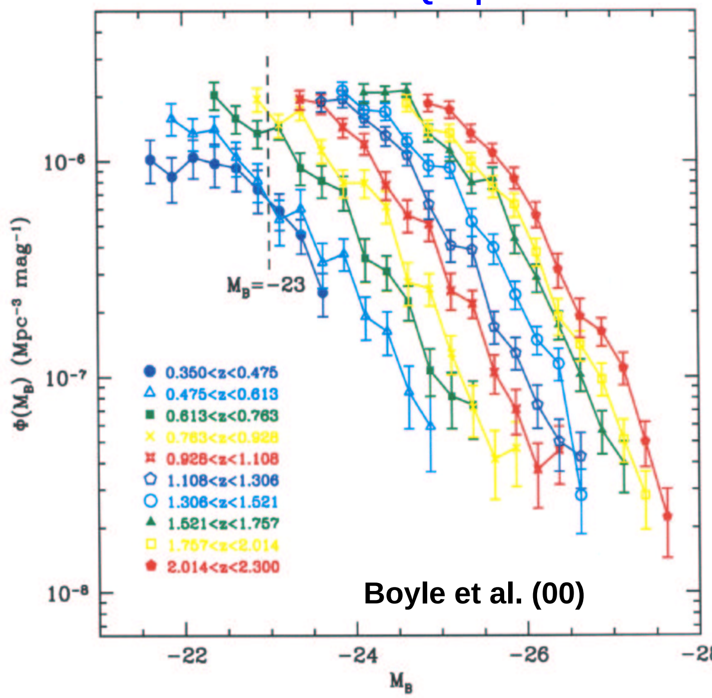
Real enhancement at z < 2, compared to pre−Chandra AGN synthesis models for X−ray bkg.

Evolution of AGN Luminosity Functions

Optical − Mostly luminous quasars

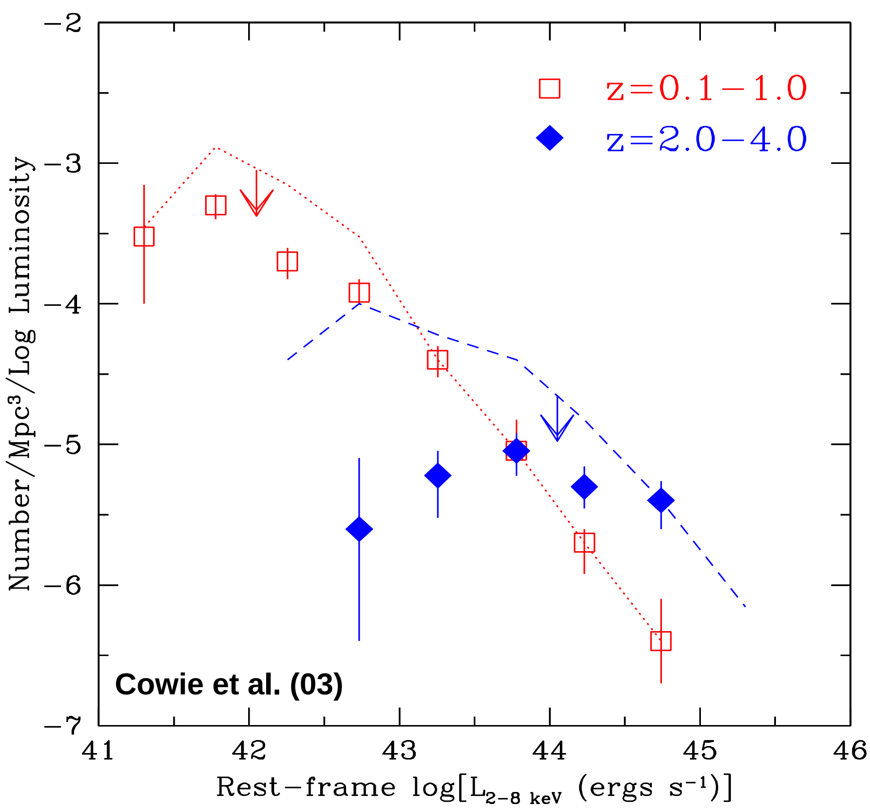


~ 6000 2dF + LBQS quasars



COMBO−17 probes lower luminosity − hints that redshift of max. AGN density is luminosity dependent. Wolf et al. (03)

X−rays − Can sample much lower luminosity



Qualitatively different evoln. for high and moderate X−ray lum. AGN.

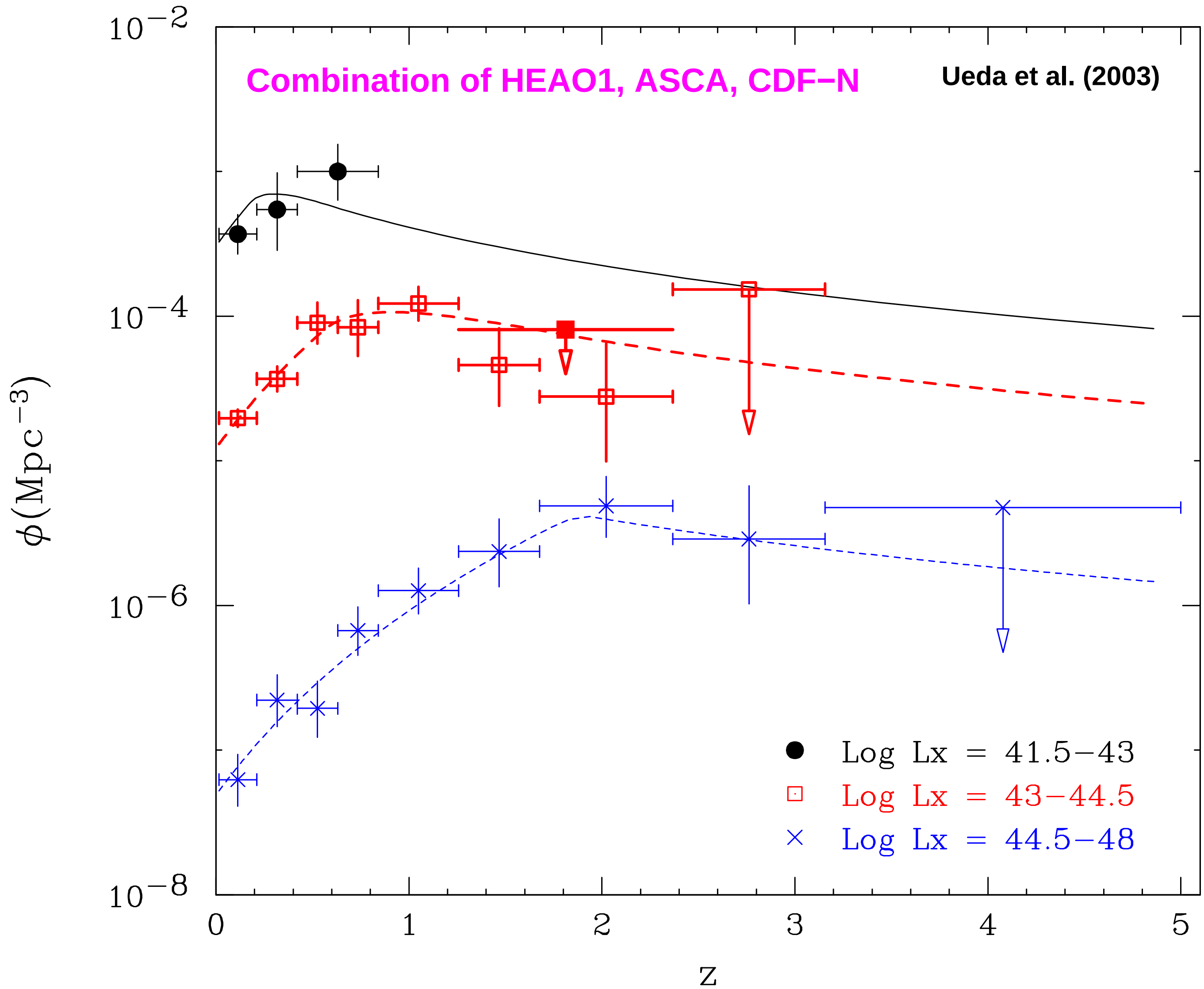
Strong positive evolution in num. dens. only for highly X−ray luminous AGN.

Rare, highly lum. AGN grow efficiently at high redshift.

BUT

Most AGN had to wait longer to grow.

Number Density Evolution with Redshift



LDDE with cutoff redshift increasing with luminosity?

Peak / Present spatial density larger for more luminous AGN.

Incompleteness of optical follow−up at high−redshift remains significant error source.

Heavily absorbed AGN at high redshift could still be missed.

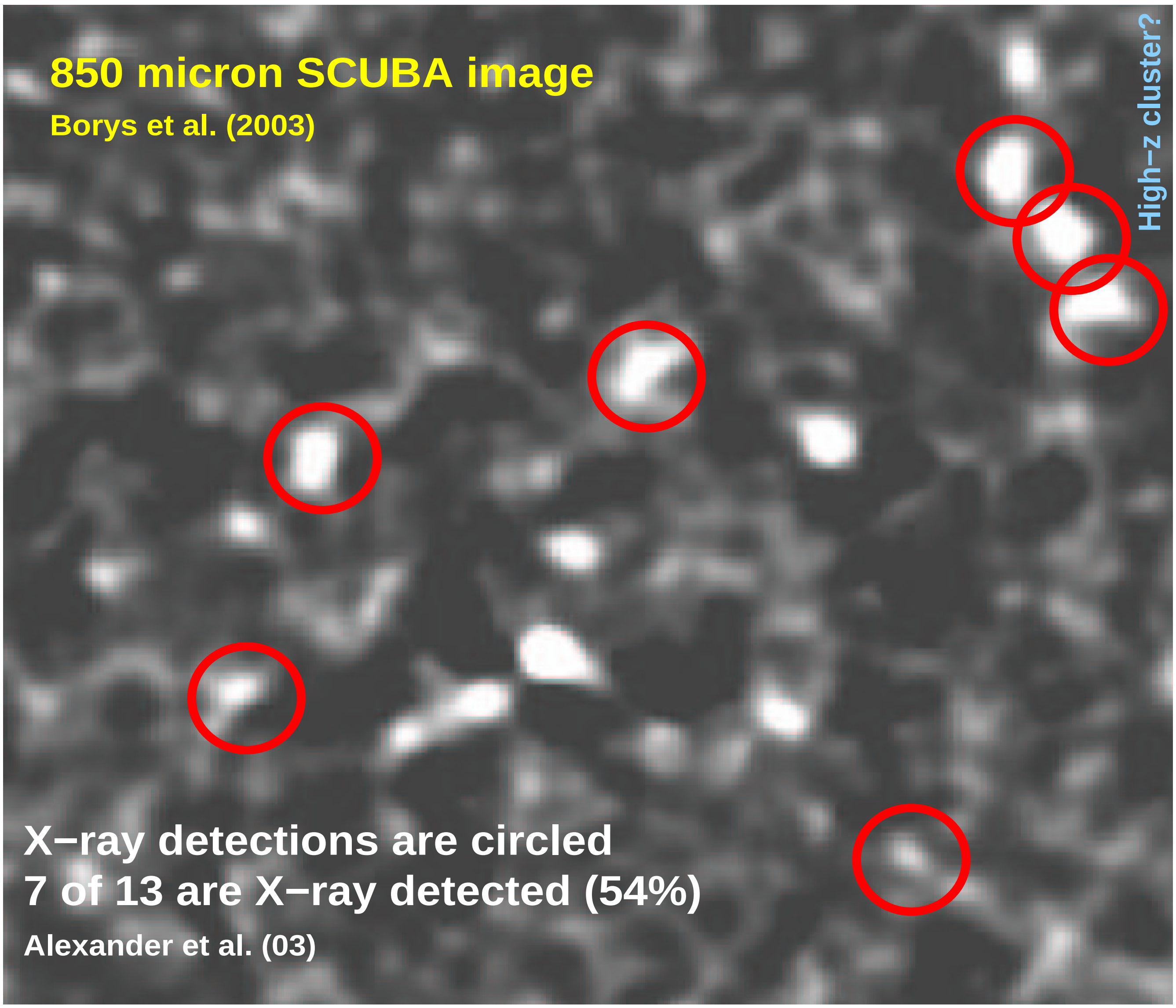
Need more moderate−luminosity AGN at z > 2

Role of X−ray AGN in SCUBA Galaxies

Opt. studies of high−redshift galaxies often miss those in which greatest number of stars forming − dust shrouded starbursts (100+ solar masses / yr)

SCUBA srcs. at z ~ 1.5−3. About 1000 times more common at z ~ 2 as today.

Over lifetime of Universe, galaxies have radiated about as much energy at IR−submm as at optical wavelengths.



What fraction of these young, forming galaxies contain actively accreting SMBH? Are SMBH significant in overall energetics?

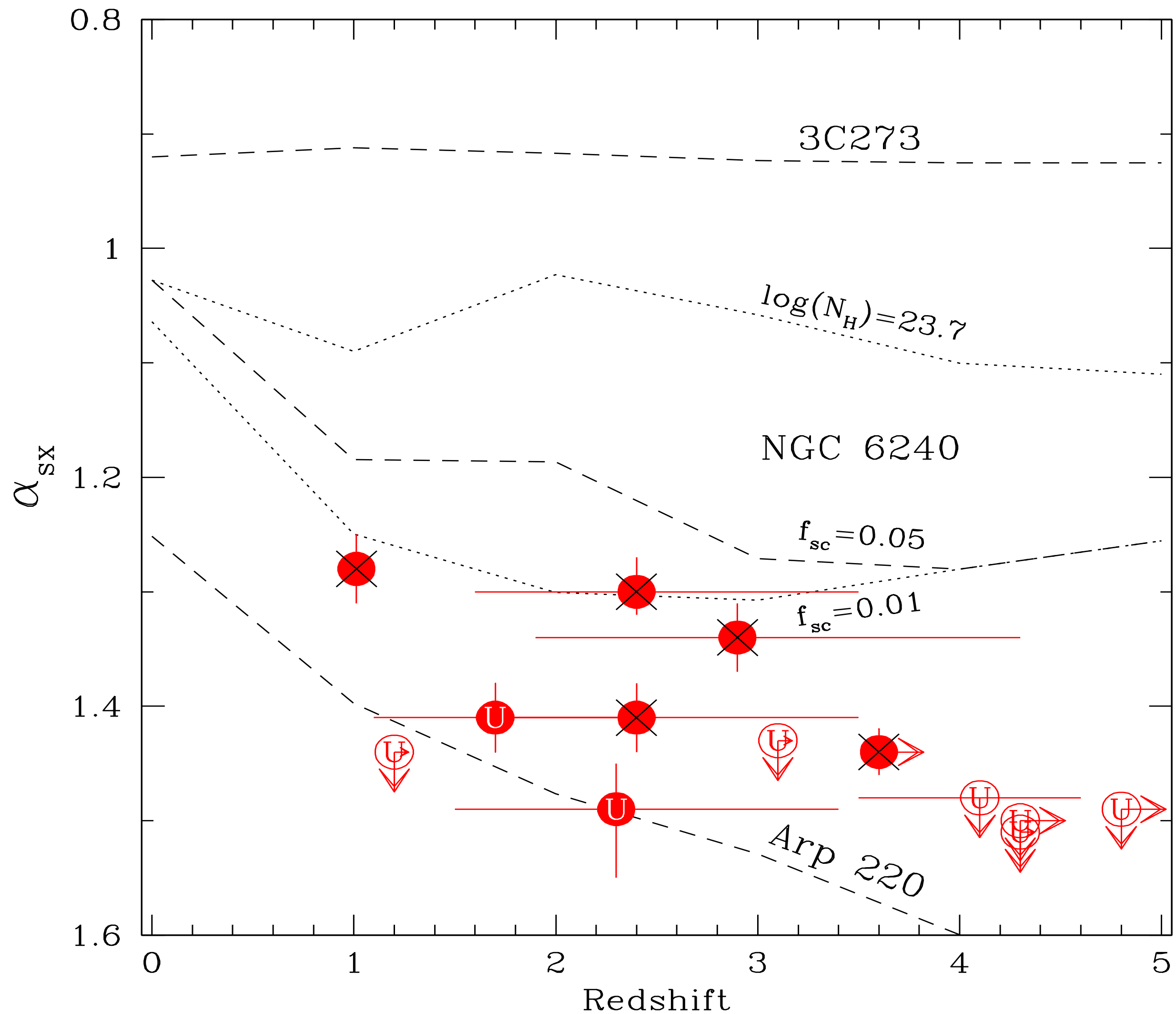
X−rays serve as useful AGN diagnostic for opt. faint SCUBA srcs. − majority population that is otherwise difficult to investigate.

X−ray/SCUBA Connection at 2 Ms Level

Comparisons between SCUBA and ~ 20−150 ks Chandra surveys yield little source overlap.

e.g., Fabian et al. (00); Hornschemeier et al. (00); Barger et al. (01); Almaini et al. (03)

But at 2 Ms level for CDF−N, 7 of 13 (54%) bright SCUBA sources are X−ray detected (filled circles). Alexander et al. (03)



Enough counts in some cases for spectral constraints − needed to assess amnt. of absorption and underlying X−ray luminosity.

5 of 7 host Seyfert−luminosity AGN (crosses)

3 Compton thin, 1 possibly Compton thick, 1 poorly constrained

AGN do not appear to make a large contribution to powering submm emission − mostly starburst?

2 of 7 may be X−ray detected starbursts

Perhaps most X−ray luminous starbursts detected to date

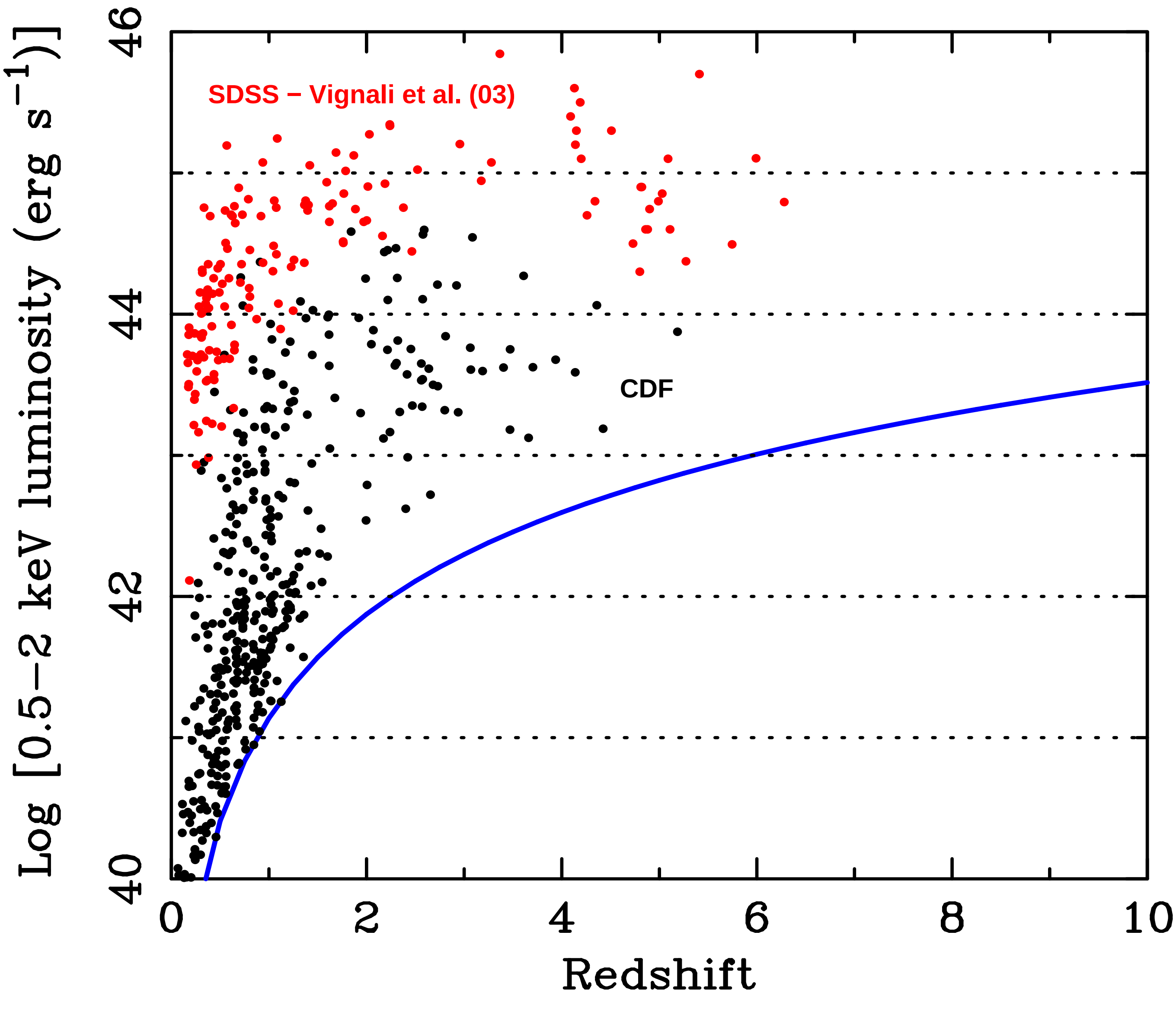
May contain weak or Compton−thick AGN

High−Redshift AGN Demography

Deep X−ray surveys probe z > 4 AGN that are 10−30 times less luminous than SDSS quasars.

More numerous and representative than rare SDSS quasars.

Minimal absn. bias − sample 2−40 keV rest−frame X−rays.



Constrain sky density with follow−up and Lyman break.

No more than ~ 8 detectable AGN at z > 4 per field.

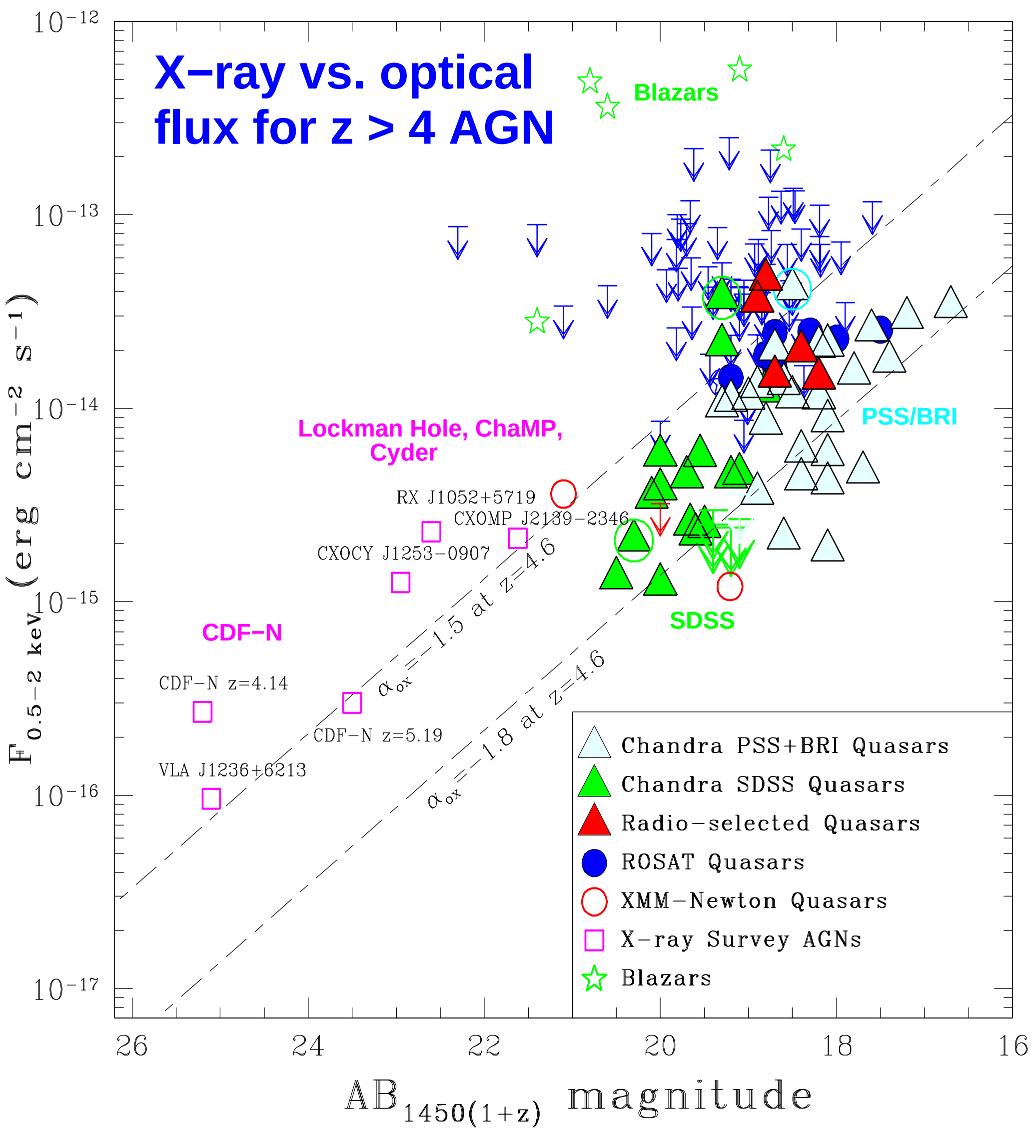
Alexander et al. (01), Barger et al. (03), Cristiani et al. (03), Koekemoer et al. (03)

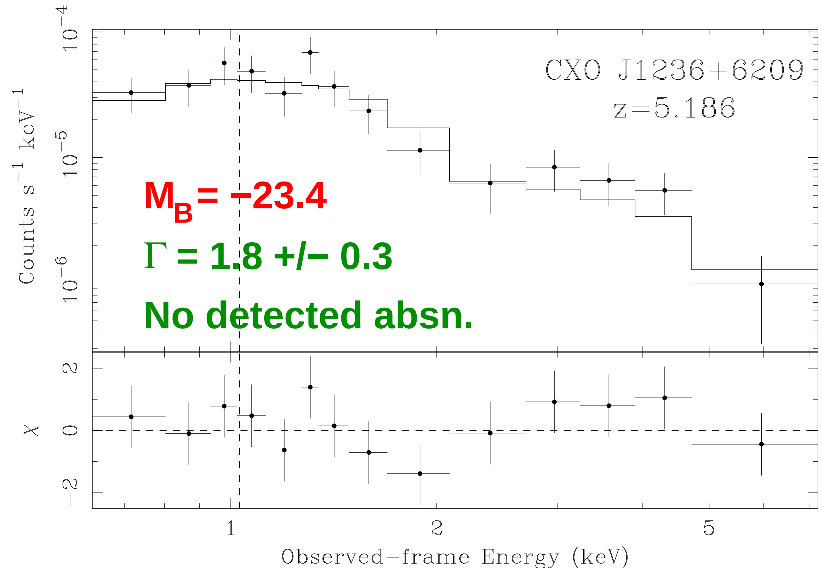
Contribution to z ~ 6 reionization small.

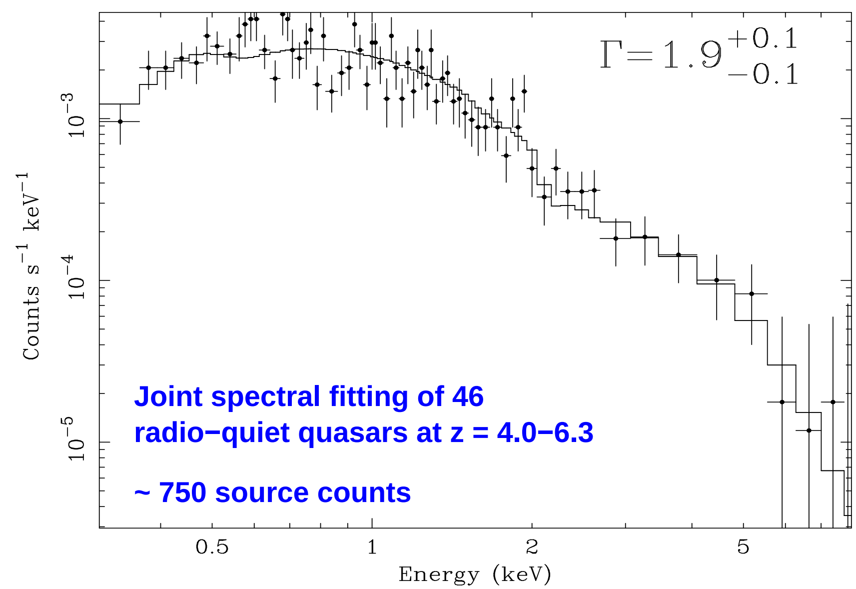
Better source statistics needed. 6 mod−lum. at z > 4
1 mod−lum. at z > 5

X−ray Spectral Energy Distributions and Spectra

Accretion processes and environments

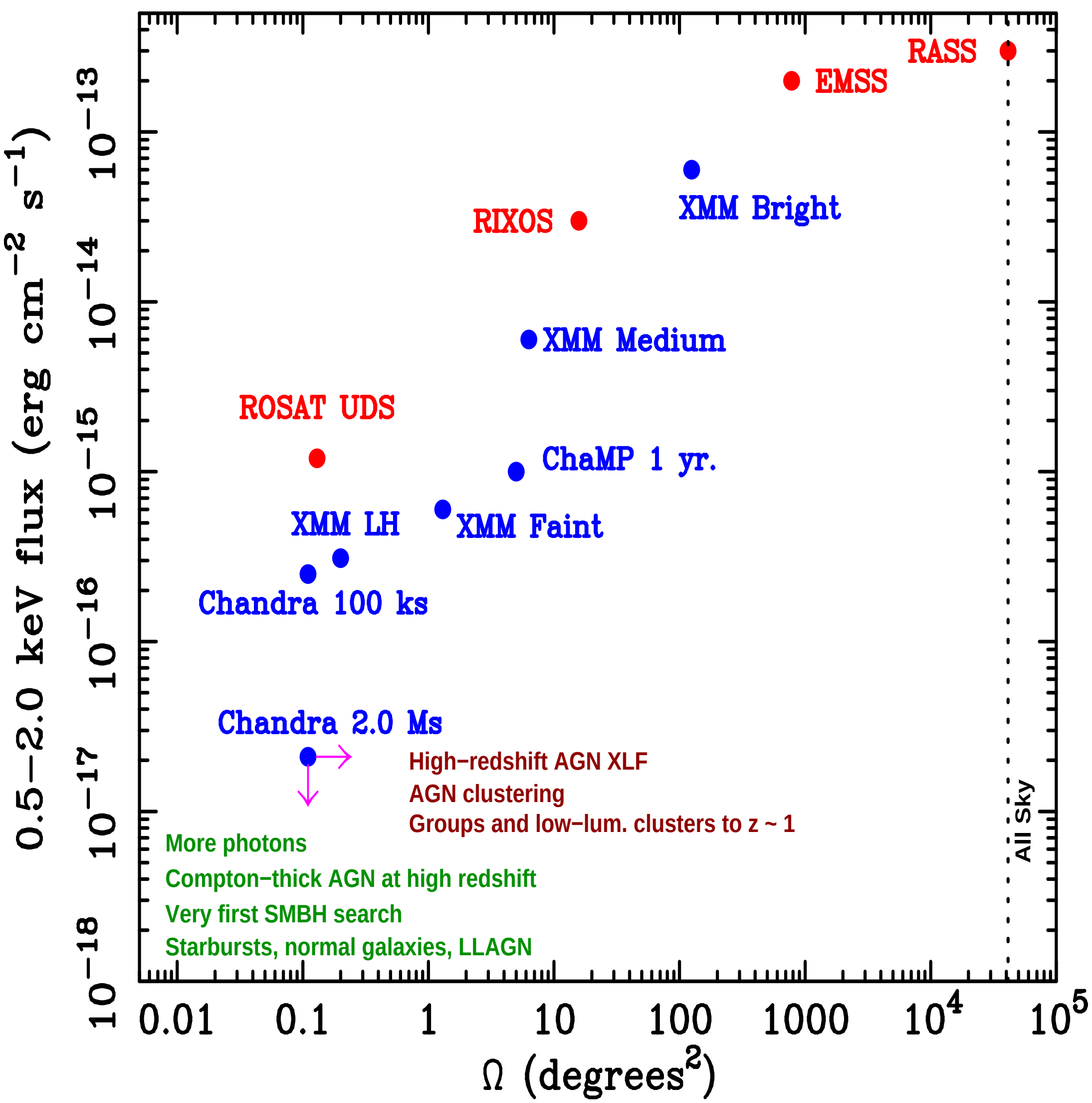






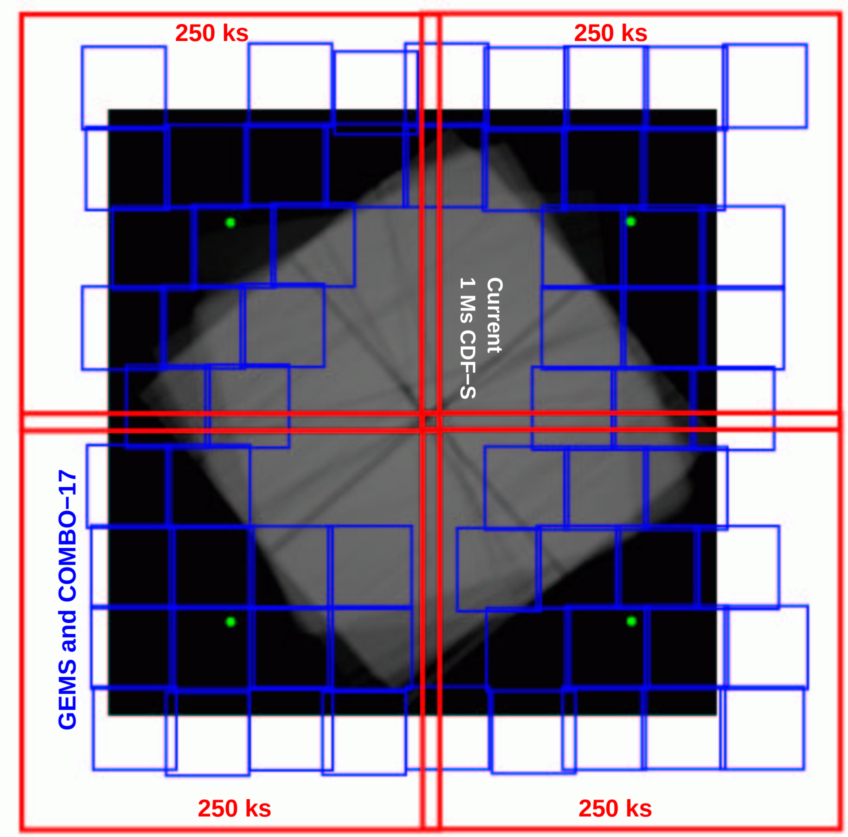
Vignali et al. (2002, 2003)

Future Prospects for X−ray Surveys − 1



Extended Chandra Deep Field−South

Allocated 1 Ms for Chandra Cycle 5



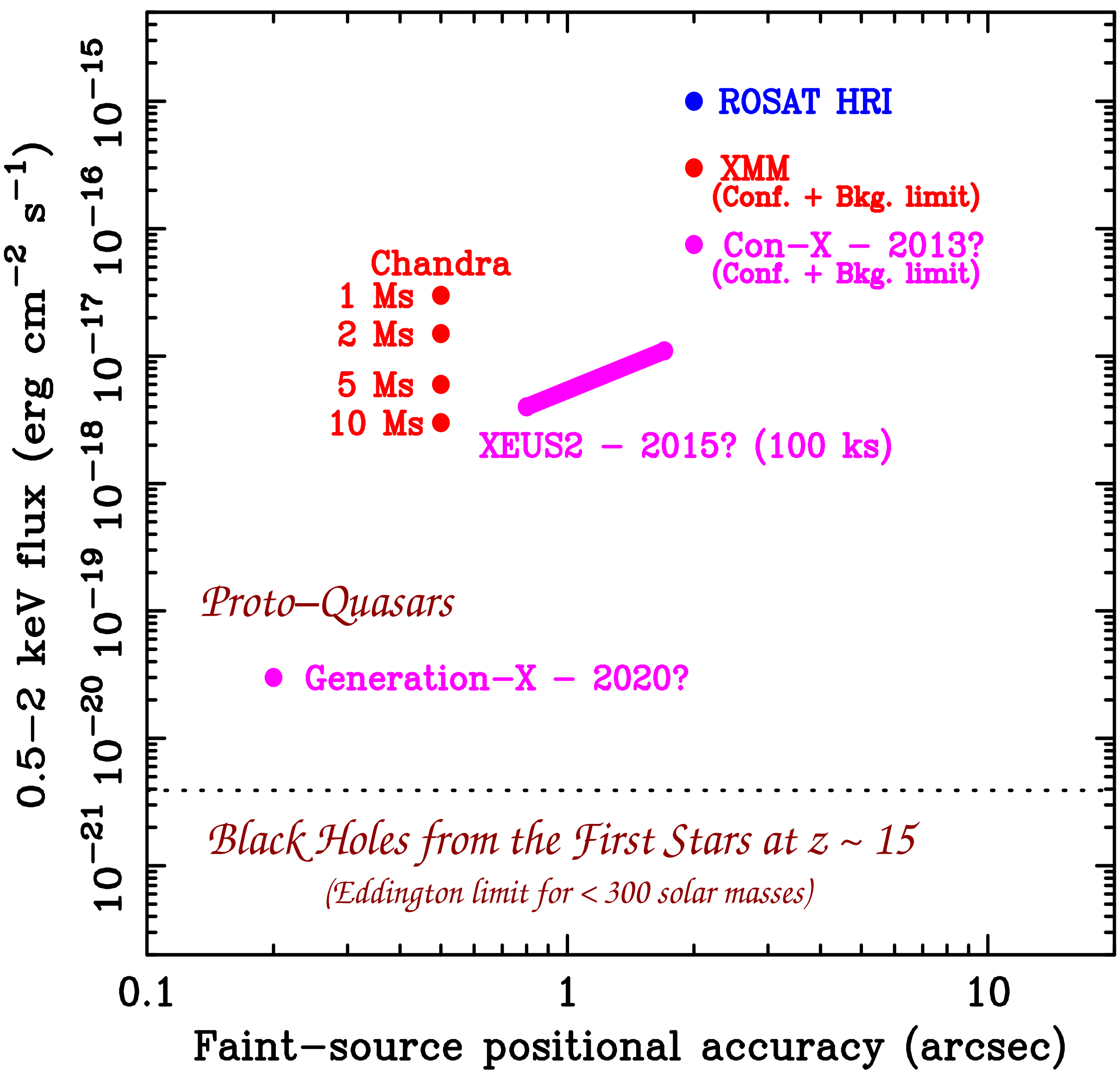
GEMS, GOODS, ACS UDF
734+ HST orbits

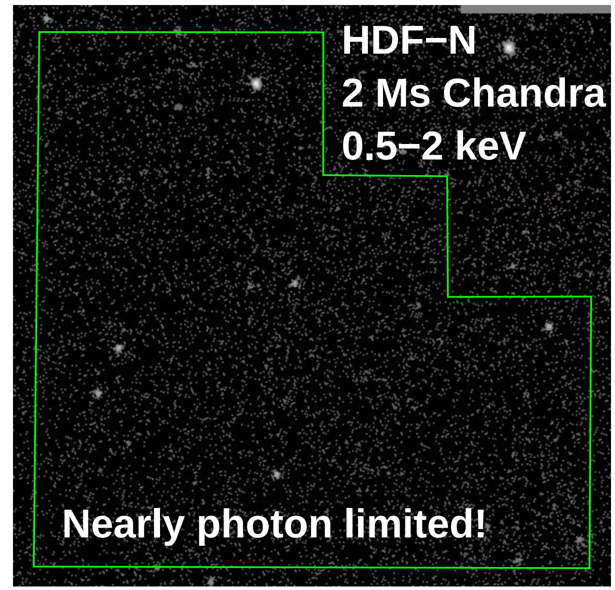
PI: W.N. Brandt

VLT/Keck spectroscopy
6000+ VLT redshifts

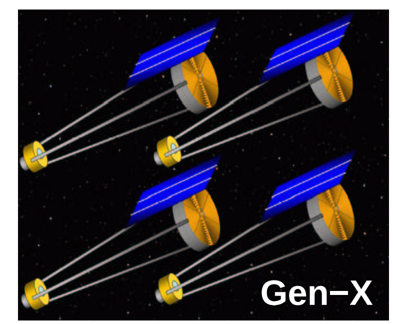
SIRTF coverage coming

Future Prospects for X–ray Surveys – 2





Future Deep Survey Missions



Future Wide–Area, Hard X–ray Missions