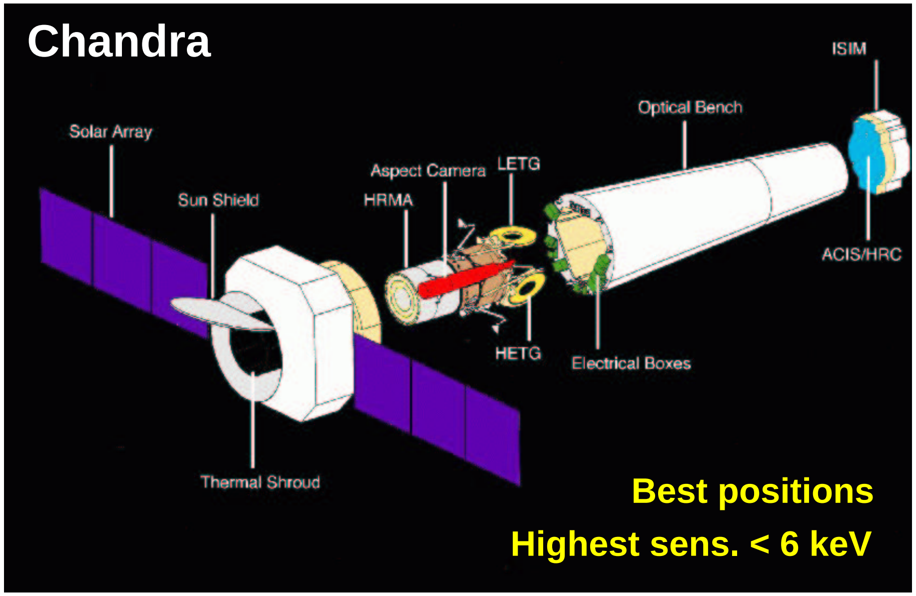
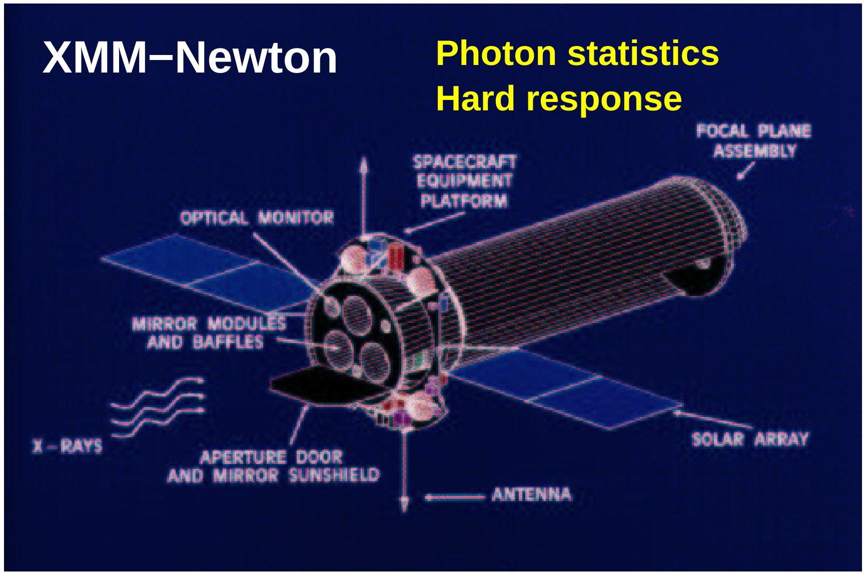
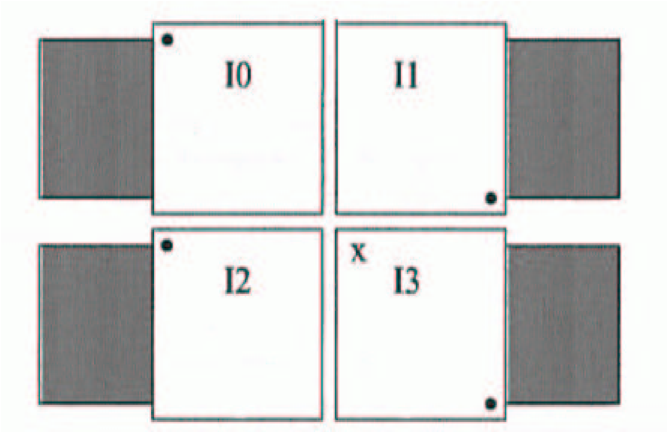
X−ray Surveys and Wide−Field Optical/NIR Imaging

Niel Brandt





ACIS−I − 16.9’ by 16.9’

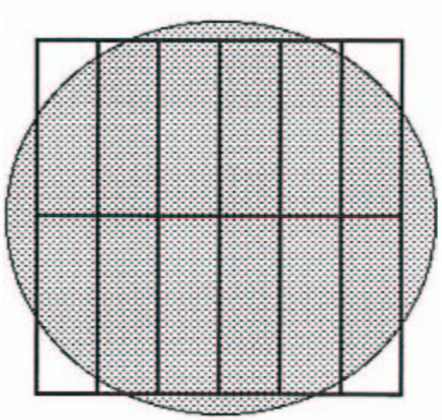


50−250 times sens. of previous missions

Good positions of 0.5−3" for follow−up

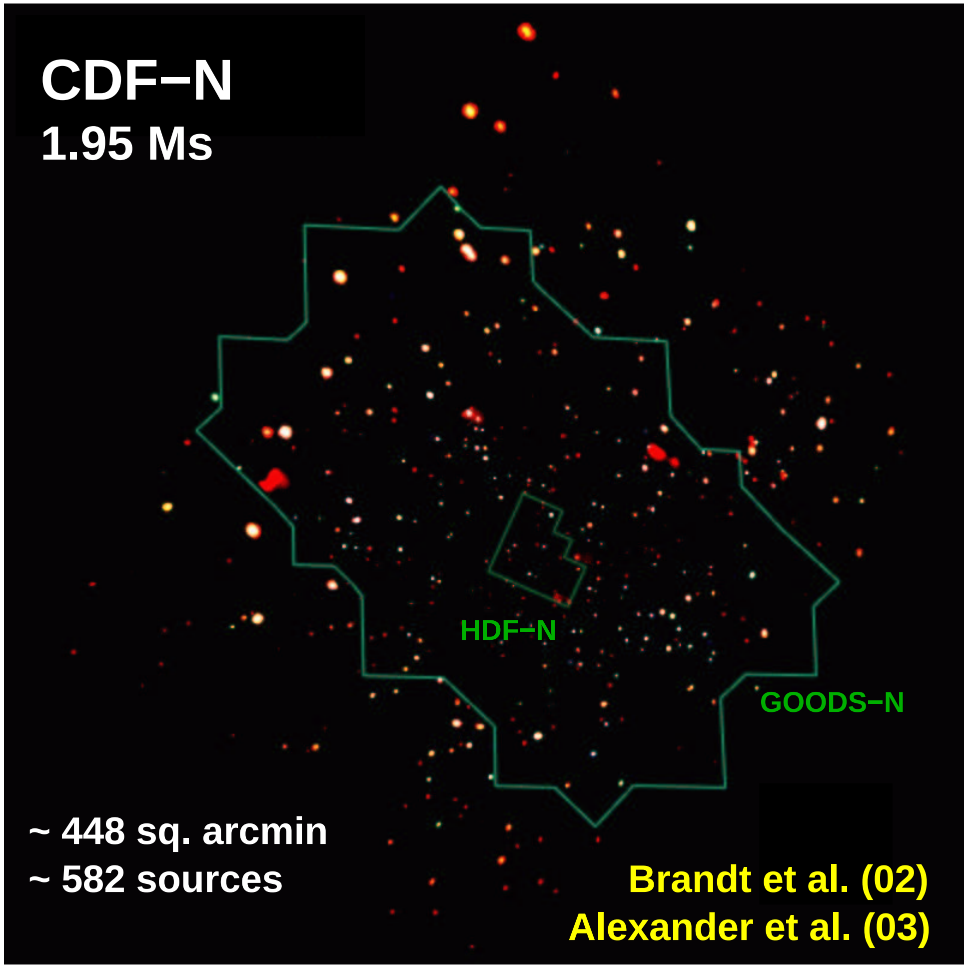
Often few hundred sources per field

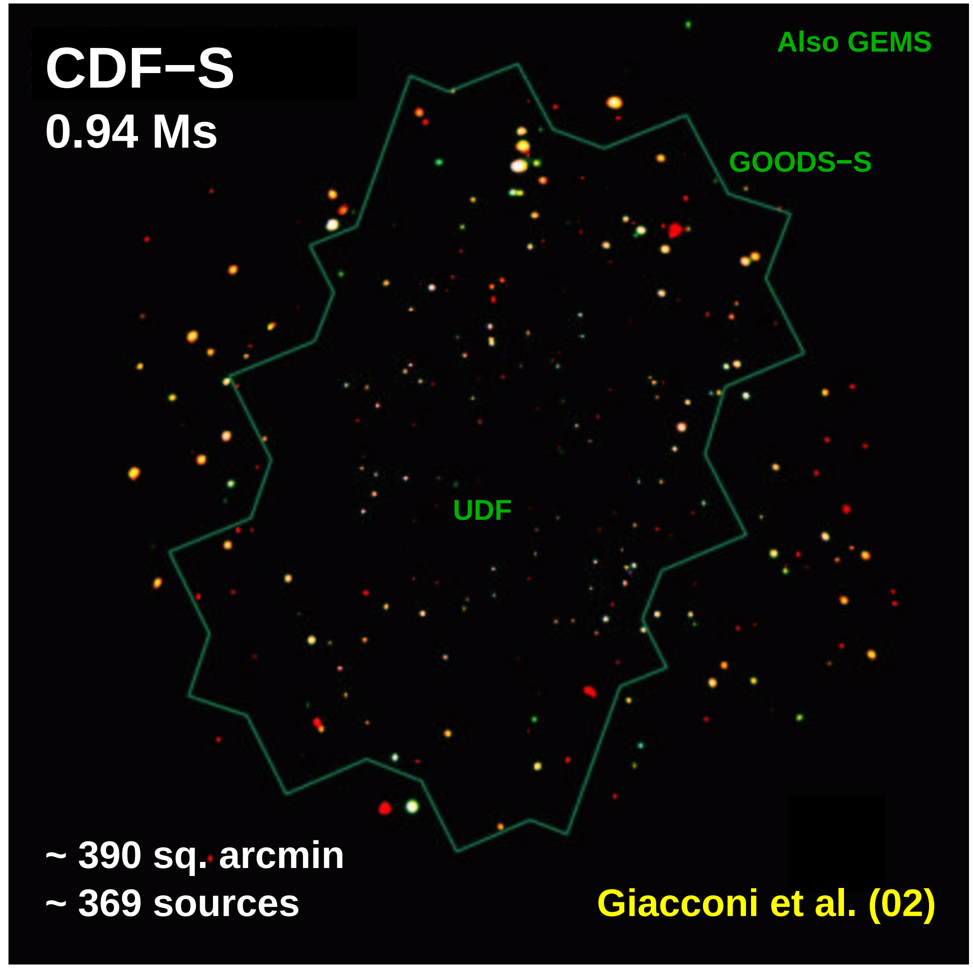
EPIC pn − 27.2’ by 26.4’



EPIC pn
12 CCDs each 13.6 x 4.4 arcmin

Deepest Chandra Surveys and Supporting HST Imaging





19 other deep and 18 "wide" surveys ongoing with Chandra and XMM−Newton.

See astro−ph/0403646 for listing.

Deep surveys cover ~ 3.5 sq. deg in total (not contiguous)

"Wide" surveys cover ~ 0.5−64 sq. deg; most cover < 2.5 sq. deg

Ongoing Chandra and XMM−Newton Surveys

21 Ongoing Deep Surveys

Survey Name	Exposure	Representative Reference or Note
	Chandra	
Chandra Deep Field-North	1950 ks	D.M. Alexander et al., 2003, AJ, 126, 539
Chandra Deep Field-South	940 ks	R. Giacconi et al., 2002, ApJS, 139, 369
HRC Lockman Hole	300 ks	PI: Murray
Extended CDF-S	250 ks	PI: Brandt
Groth-Westphal	200 ks	PI: Nandra
Lynx	185 ks	D. Stern et al., 2002, AJ, 123, 2223
LALA Cetus	177 ks	PI: Malhotra
LALA Boötes	172 ks	J.X. Wang et al., 2004, AJ, 127, 213
SSA13	101 ks	A.J. Barger et al., 2001, AJ, 121, 662
3C295	100 ks	V. D'Elia et al., 2004, astro-ph/0403401
Abell 370	94 ks	A.J. Barger et al., 2001, AJ, 122, 2177
SSA22 "protocluster"	78 ks	L.L. Cowie et al., 2002, ApJ, 566, L5
ELAIS	75 ks	J.C. Manners et al., 2003, MNRAS, 343, 293
WHDF	75 ks	PI: Shanks
	XMM-Newton	
Lockman Hole	766 ks	G. Hasinger et al., 2001, A&A, 365, L45
Chandra Deep Field-South	317 ks	A. Streblyanska et al., 2004, astro-ph/0309089
13 hr Field	200 ks	M.J. Page et al., 2003, AN, 324, 101
Chandra Deep Field-North	180 ks	T. Miyaji et al., 2003, AN, 324, 24
Subaru Deep	100 ks	PI: Watson
ELAIS S1	100 ks	PI: Fiore
Groth-Westphal	80 ks	T. Miyaji et al., 2004, astro-ph/0402617

The Extended *Chandra* Deep Field-South is comprised of four fields (each 250 ks), the *XMM-Newton* ELAIS S1 survey is comprised of four fields (each 100 ks), and the *Chandra* ELAIS survey is comprised of two fields (each 75 ks). The *XMM-Newton* Subaru Deep survey also has seven flanking fields (each ≈ 50 ks). Only the first ≈ 100 ks of the *XMM-Newton* Lockman Hole data have been published at present.

~ 3.5 sq. degrees in total

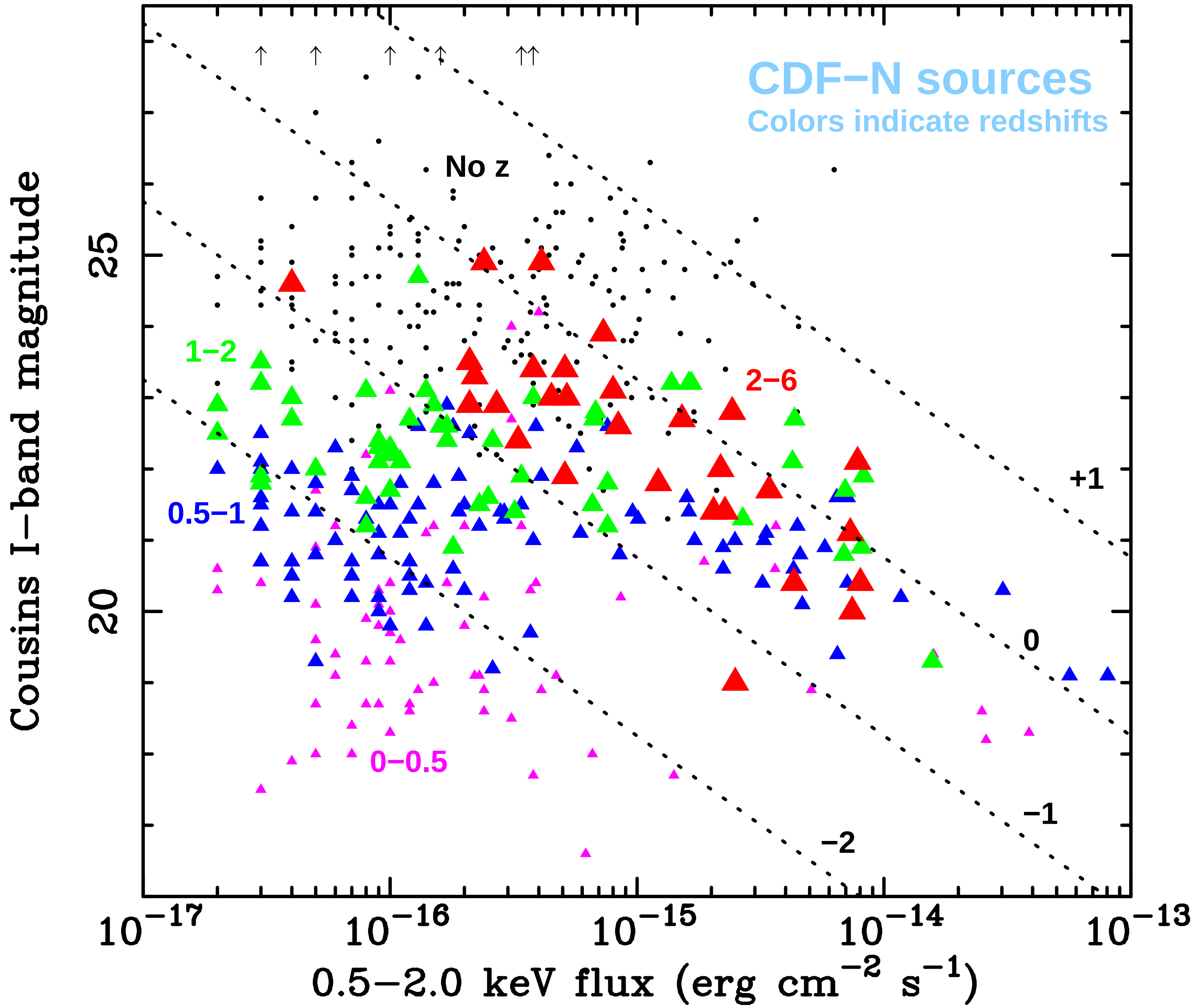
18 Ongoing "Wide" Surveys

Survey Name	Ω (deg^2)	Representative Reference or Note
	Chandra	
ChaMP	14	D.W. Kim et al., 2004, ApJS, 150, 19
Clusters Serendipitous	1.1	P. Gandhi et al., 2004, MNRAS, 348, 529
CYDER	···	F.J. Castander et al., 2003, AN, 324, 40
Lockman Hole NW	0.4	A.T. Steffen et al., 2003, ApJ, 596, L23
MUSYC	1	PI: van Dokkum
NOAO DWFS	9.3	PI: Jones
SEXSI	2.2	F.A. Harrison et al., 2003, ApJ, 596, 944
SWIRE Lockman	0.6	PI: Wilkes
1 hr Field	0.2	PI: McHardy
13 hr Field	0.2	I.M. McHardy et al., 2003, MNRAS, 342, 802
	XMM-Newton	
AXIS	···	X. Barcons et al., 2002, A&A, 382, 522
CFRS	0.6	T.J. Waskett et al., 2003, MNRAS, 341, 1217
HBS28	9.8	A. Caccianiga et al., 2004, A&A, 416, 901
HELLAS2XMM	2.9	A. Baldi et al., 2002, ApJ, 564, 190
LSS	64	M. Pierre et al., 2004, astro-ph/0305191
Survey Science Center	···	M.G. Watson et al., 2001, A&A, 365, L51
VIMOS	2.3	PI: Hasinger
2dF	1.5	A. Georgakakis et al., 2003, MNRAS, 344, 161

The second column above lists estimated survey solid angles; survey sensitivities are not uniform but rather vary significantly across these solid angles. In some cases, survey solid angles are not well defined and thus are not listed. In these cases, the reader should consult the listed reference or note for further details.

Lists above available from astro−ph/0403646

X−ray Source Classification Challenges



Many sources too faint for efficient spectroscopy.

50−70% spectroscopic completeness for deepest Chandra & XMM−Newton fields.

Many have modest apparent optical luminosities, so signif. host−galaxy dilution in a spectroscopic aperture.

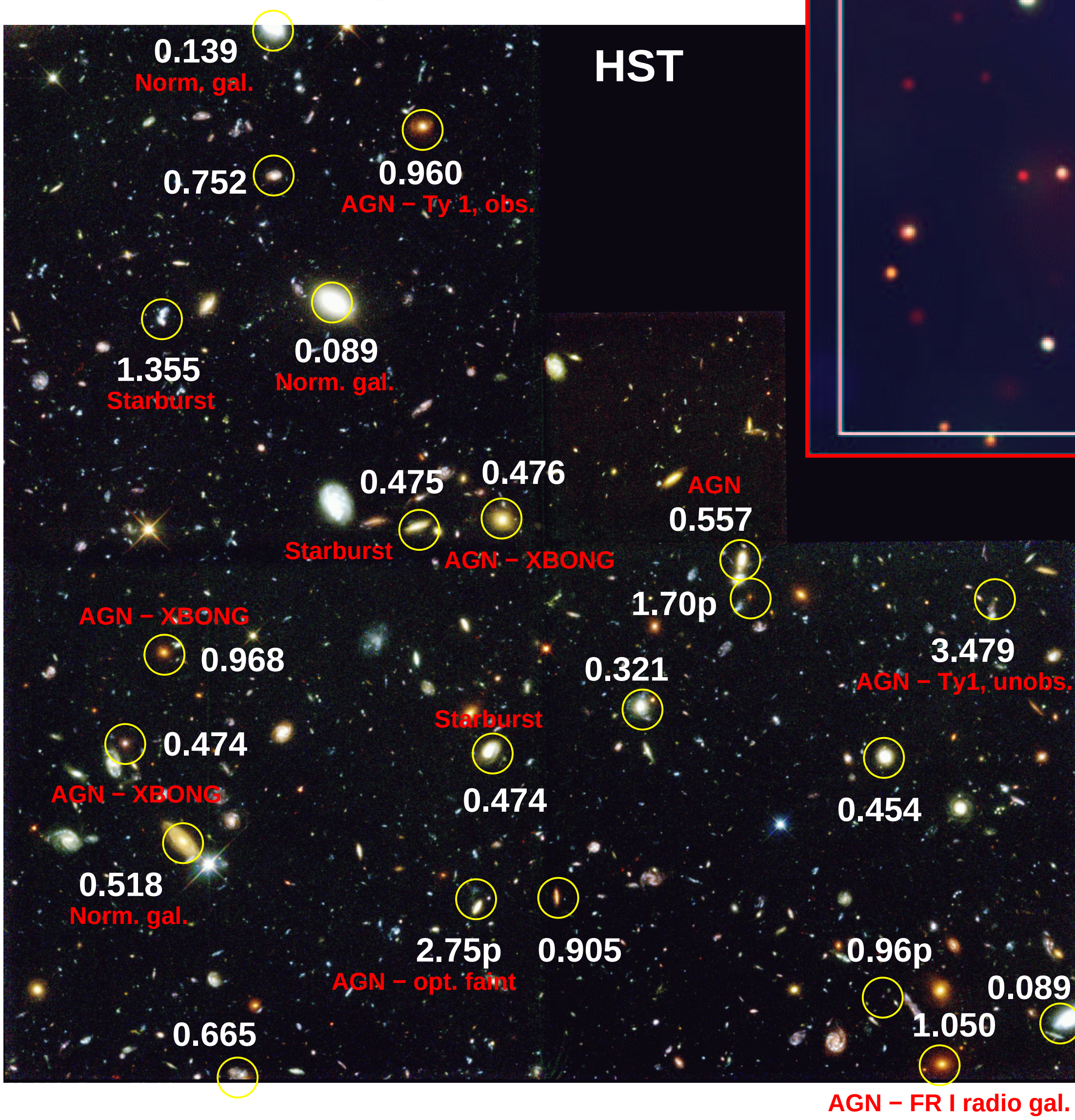
"Schism" between optical and X−ray classification schemes.

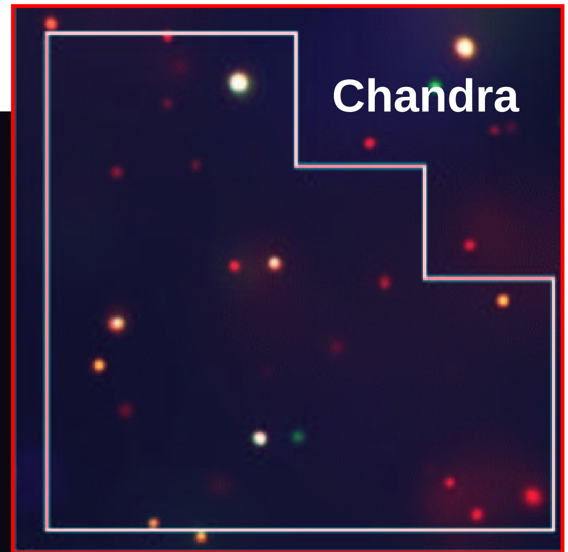
Optical Type 1 / 2 versus X−ray unobscured / obscured.

Broad diversity of source types.

Extragalactic X−ray Source Types

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

Unobscured and obscured AGN
Optically faint X−ray sources
X−ray Bright, Optically Normal galaxies (XBONGs)
Starburst and "normal" galaxies
Groups and clusters

AGN dominate the number counts; get ~ 7000 deg^{-2}

- Higher than optical spectroscopic selection by factor ~ 10
- Reduced obscuration bias
- Minimal host−galaxy dilution in X−rays

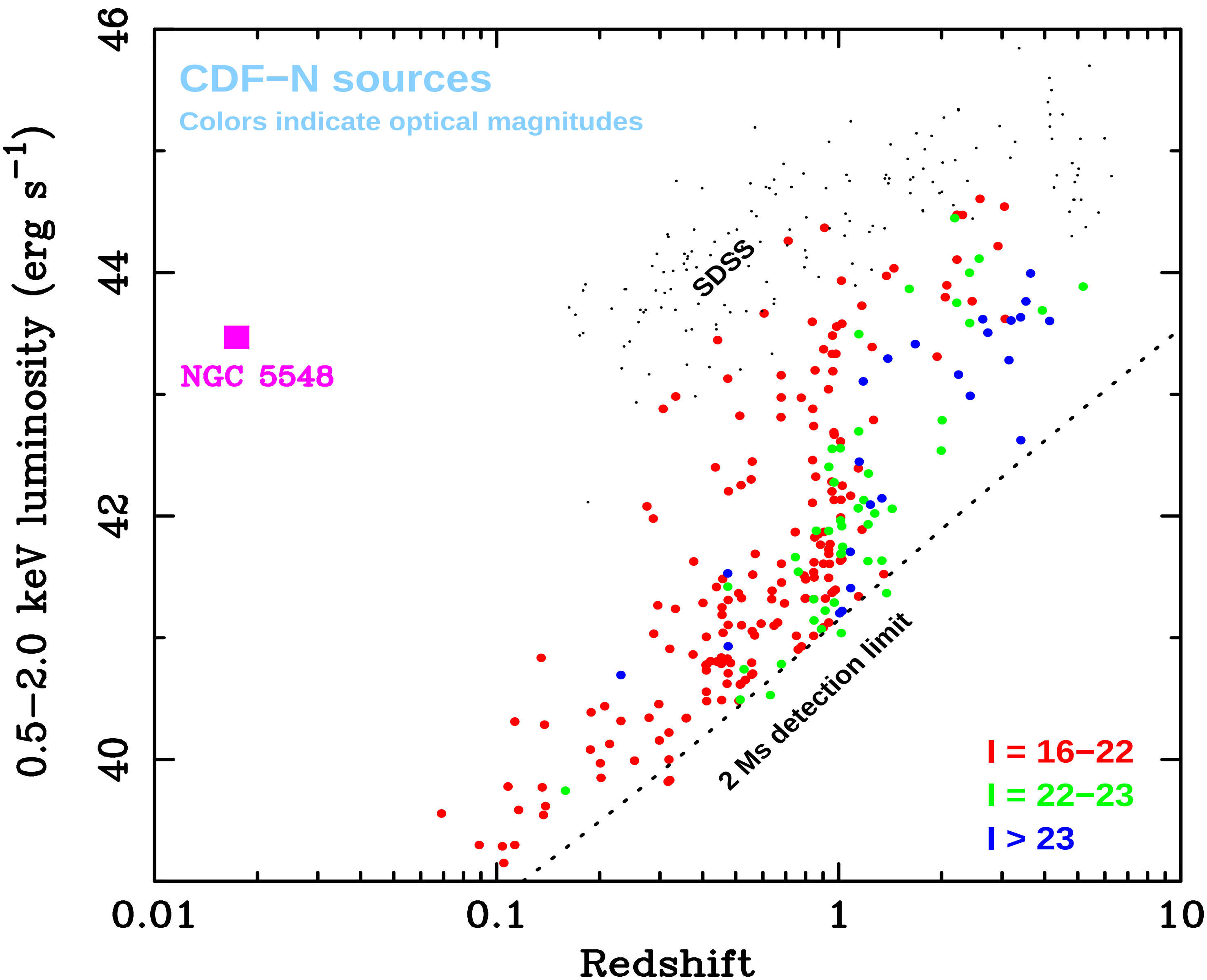
Deep−Field Luminosities and Redshifts

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

Most of XRB made by moderate−lum. objects at z < 2

Type 2 quasars etc. make only small contribution.

Some incompleteness bias, but real low−z enhancement compared to expectations.



Completeness of X−ray AGN selection good relative to methods at other wavelengths − only 1−2 AGN missed in CDF−N.

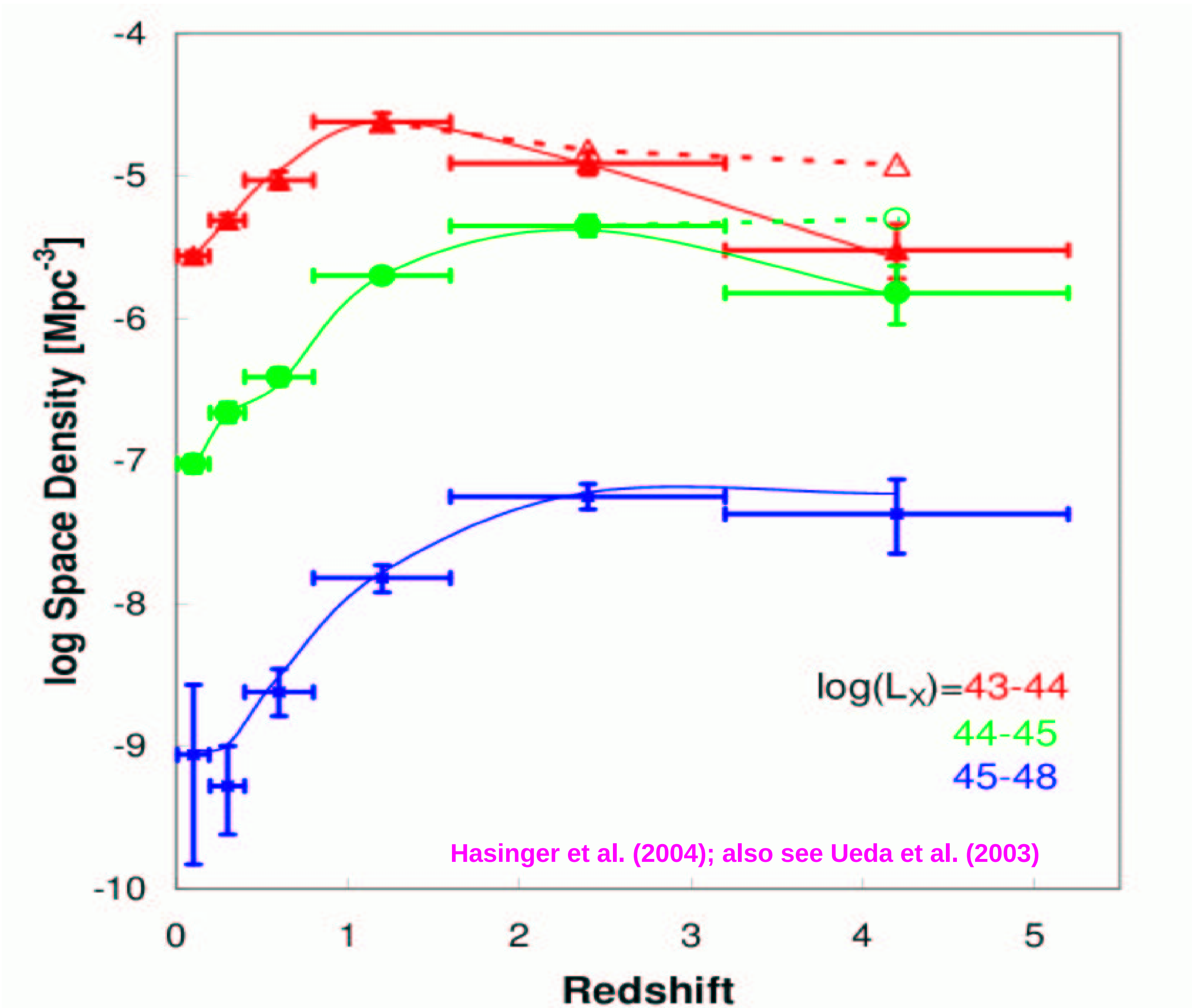
Problem of Compton−thick AGN at z > 0.5−2.

AGN like NGC 1068, NGC 6240, Mrk 231 will still be missed.

Number Density Evolution with Redshift

X−ray surveys allow the evolution of lower−luminosity AGN to be studied (relative to optical quasar surveys).

Lower−luminosity AGN do not evolve as strongly with redshift as quasars, and they "peak" at lower redshift.



Incompleteness of

Optical follow−up

AGN X−ray selection

at high redshift remain significant error sources.

Nuclear Fluxes and Host Morphologies

Many of the mod.−lum. and obsc. AGN in the Chandra Deep Fields have subst. AGN/host−galaxy optical light blending.

Superb imaging needed for AGN opt. light and host−galaxy measurements.

GOODS Chandra−source morphologies

Grogin et al. (04)

Rest−frame B−band concentration index
asymmetry index
near−neighbor counts

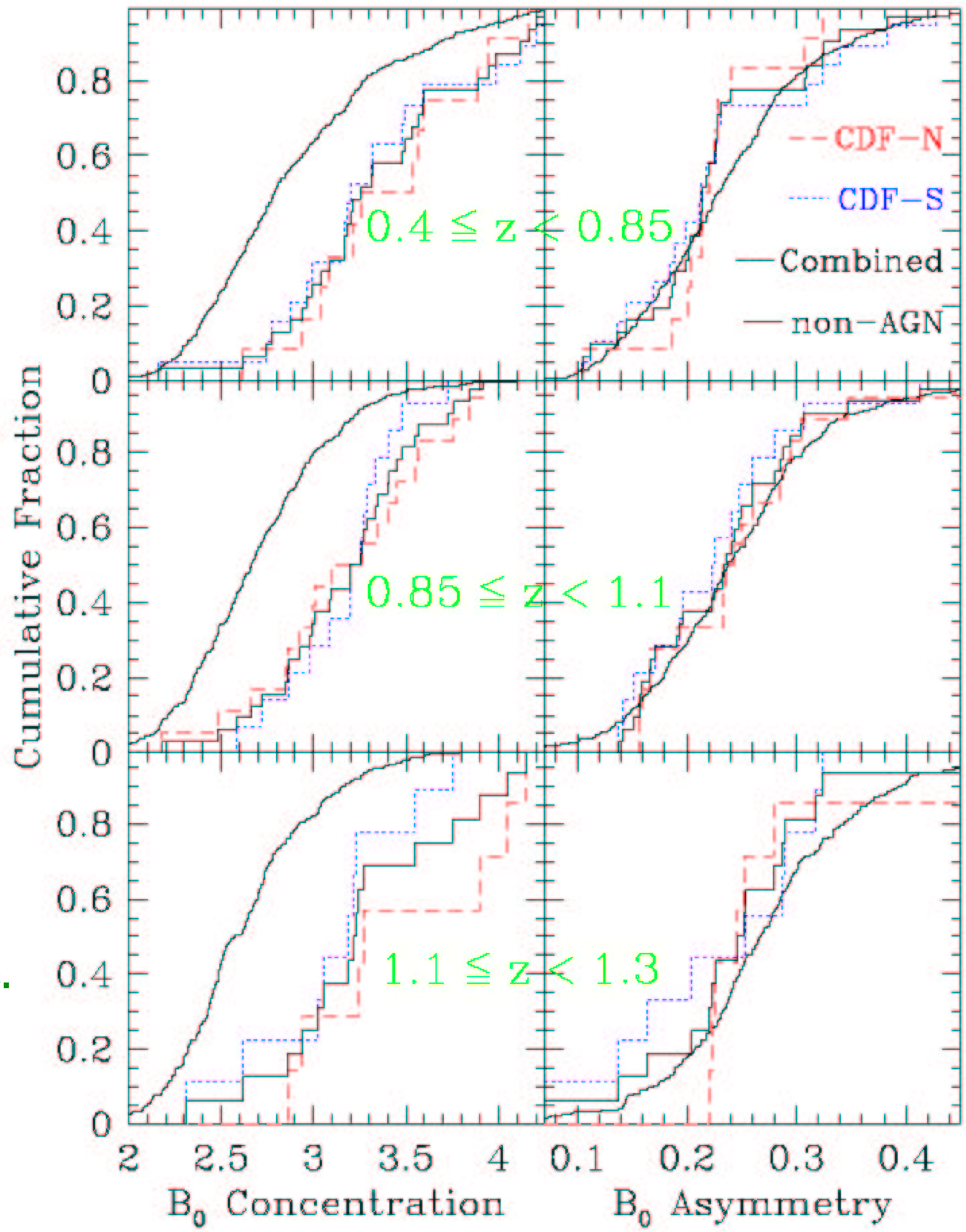
Compared 100−200 AGN vs. field galaxies

No sig. difference for asym., near−neighbors

Recent merging, interaction seem no more prevalent among AGN to z ~ 1

AGN preferentially in galaxies with highly conc. light profiles, generally corresponding to more bulge−dominated morphologies.

Argue that locally observed correln. between SMBH mass and conc. already in place at z ~ 1

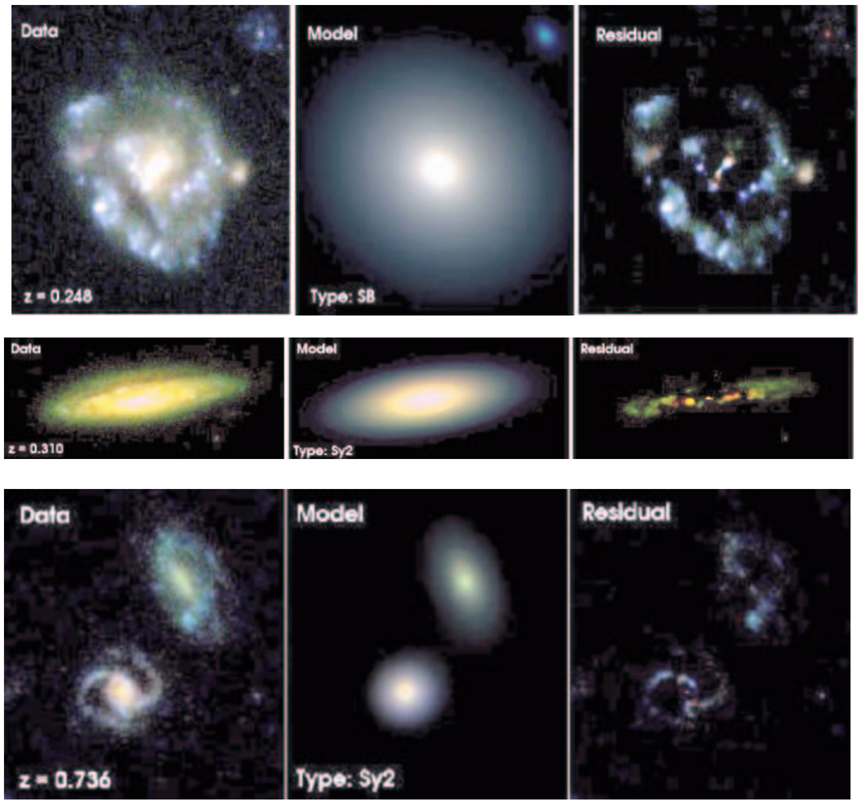


Also see Sanchez et al. (04), Simmons et al., in preparation

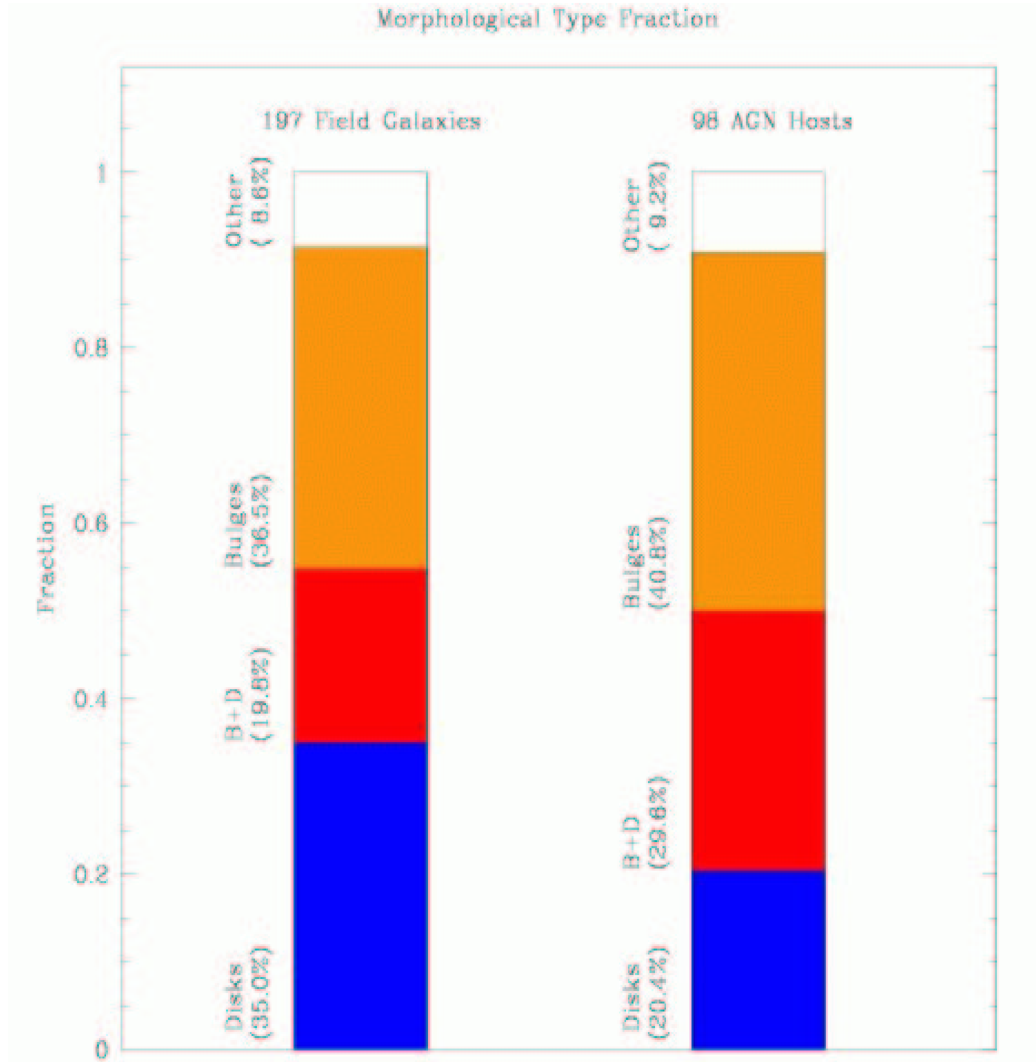
Host Morphologies of Chandra Sources in the GOODS Fields

Simmons et al., in preparation

Fitting of host images of X−ray AGN using Sersic models. Explicitly include nuclear point source.



B + V + (i+z) images

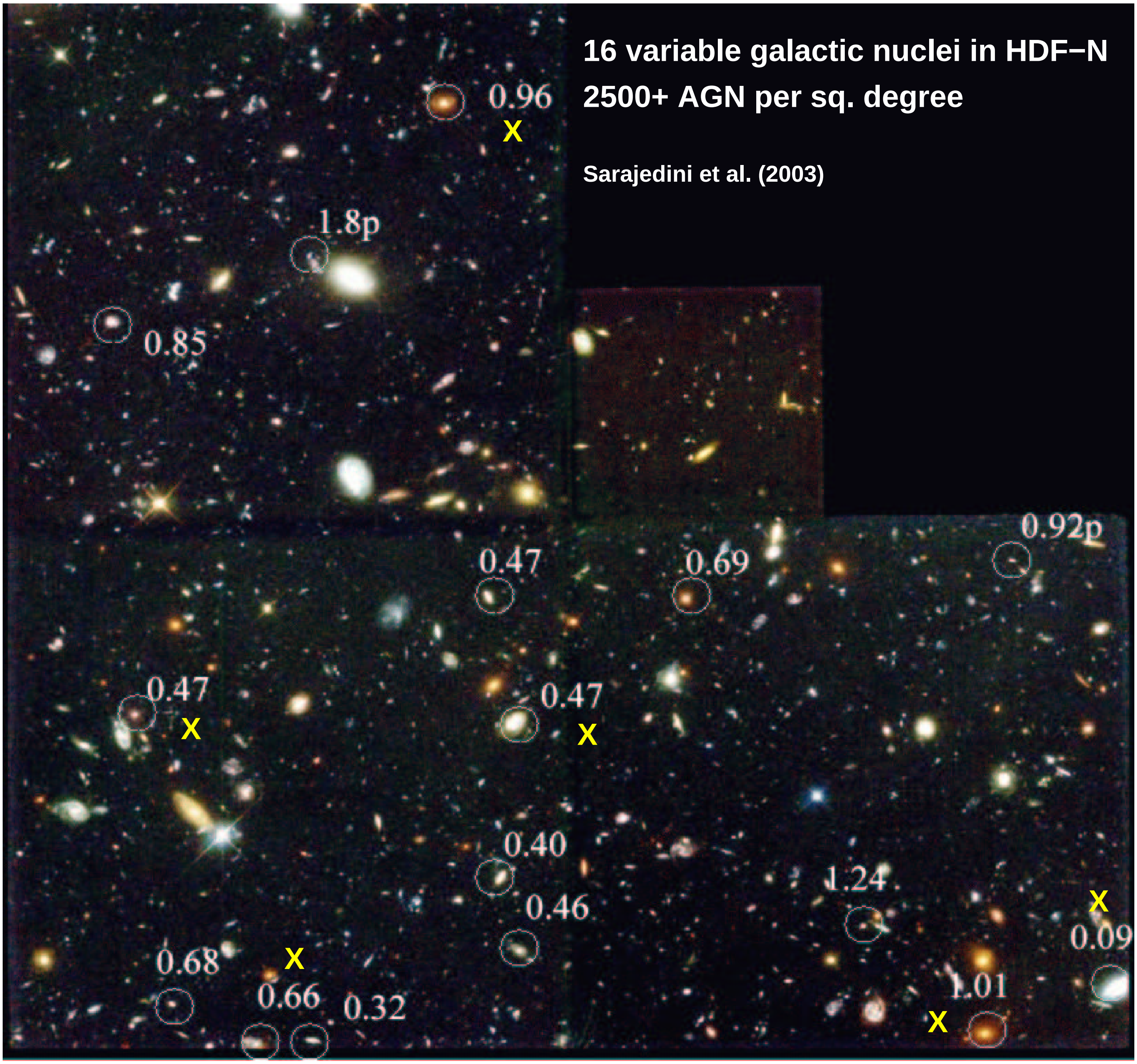


Disks are rarer in AGN than in field galaxies (rest−frame B−band).
Usually need large bulges to have a luminous AGN.

X−ray vs. Variability Selected AGN

Only method competitive with X−ray selection is ultradeep var. selection.

~ 40% of variables have X−ray matches − what is other ~ 60%? Stacking.



Expect ~ 40,000+ variability selected AGN in SNAP deep fields.

Opt. var. can help to confirm AGN nature of X−ray sources.

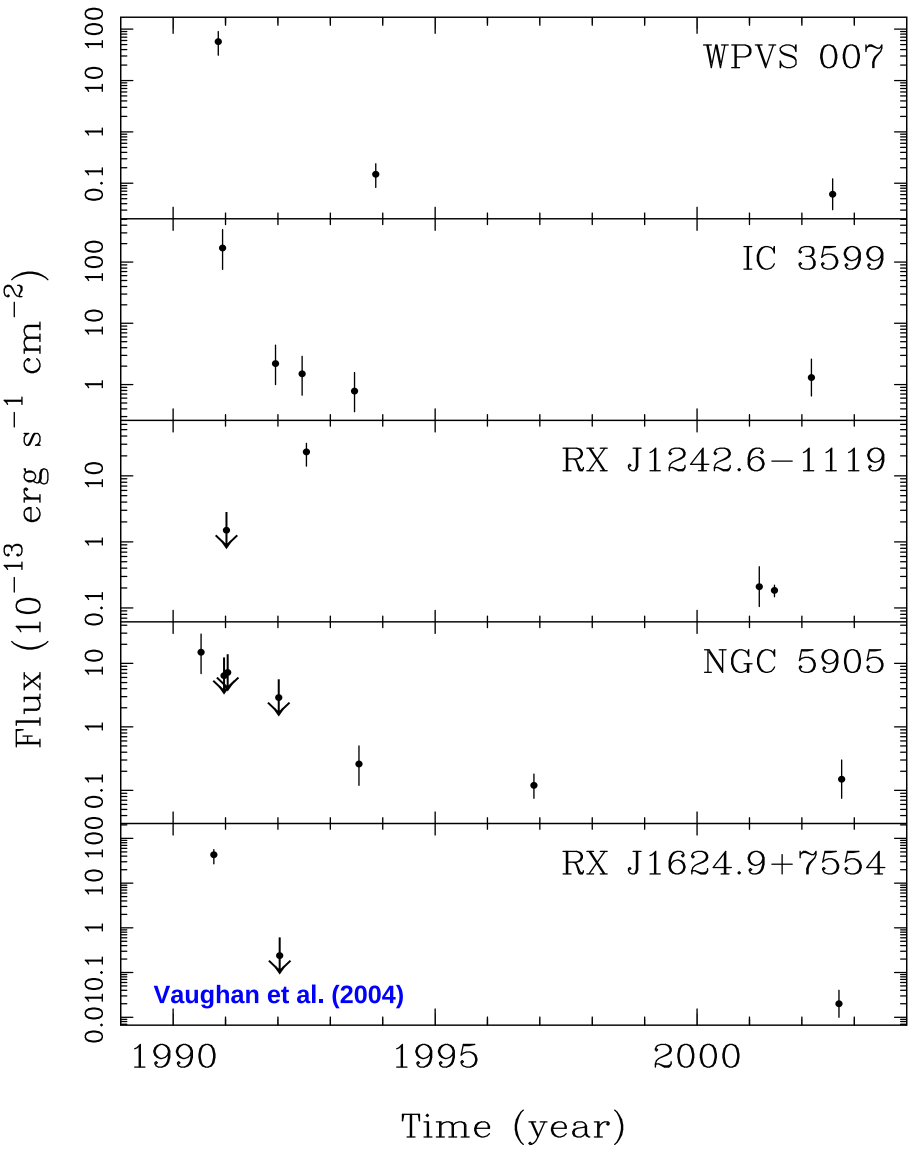
Complement X−ray selection by revealing potential missed AGN.

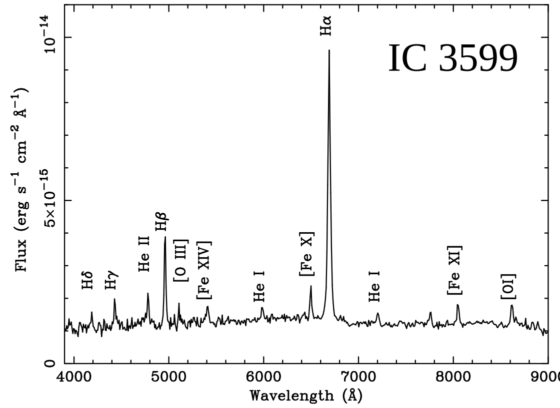
Large X−ray and Optical Outbursts in Galaxies

7 large−amplitude X−ray outbursts; 3−4 in AGN, rest in normal gals.

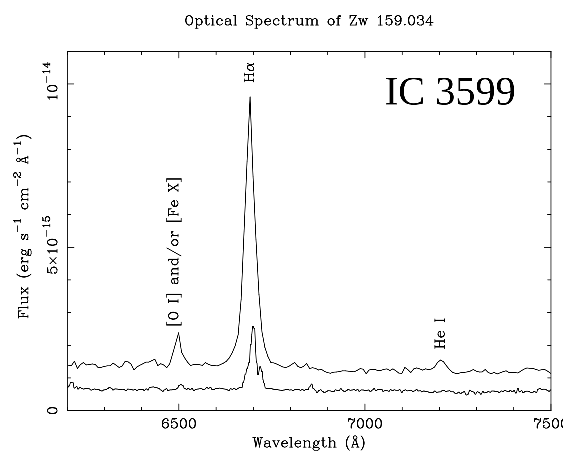
- X−ray variability factors of ~ 50−400
- Peak X−ray luminosities comparable to local Seyfert galaxies
- Soft X−ray spectra
- Decay timescales of months−years
- Some evidence that optical responds to X−ray outburst

Stellar tidal disruption flares? Large−scale acc. disk instabilities?





Brandt et al. (1995)



Also optical outbursts

NGC 4552 UV flare in 1991−1996
Cappellari et al. (1999)

NGC 1068 opt. flare in 1890?
de Vaucouleurs (1991)

Normal galaxy X−ray outburst rate ~ 1 per 100,000 yr

Rate broadly agrees with predictions for tidal disruption flares

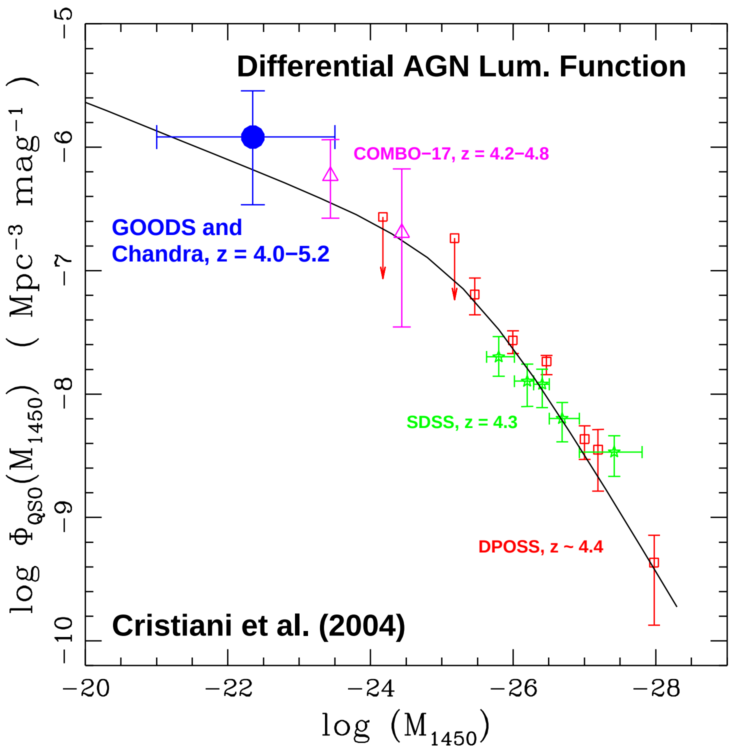
Expect ~ 2−10 from SNAP over its lifetime

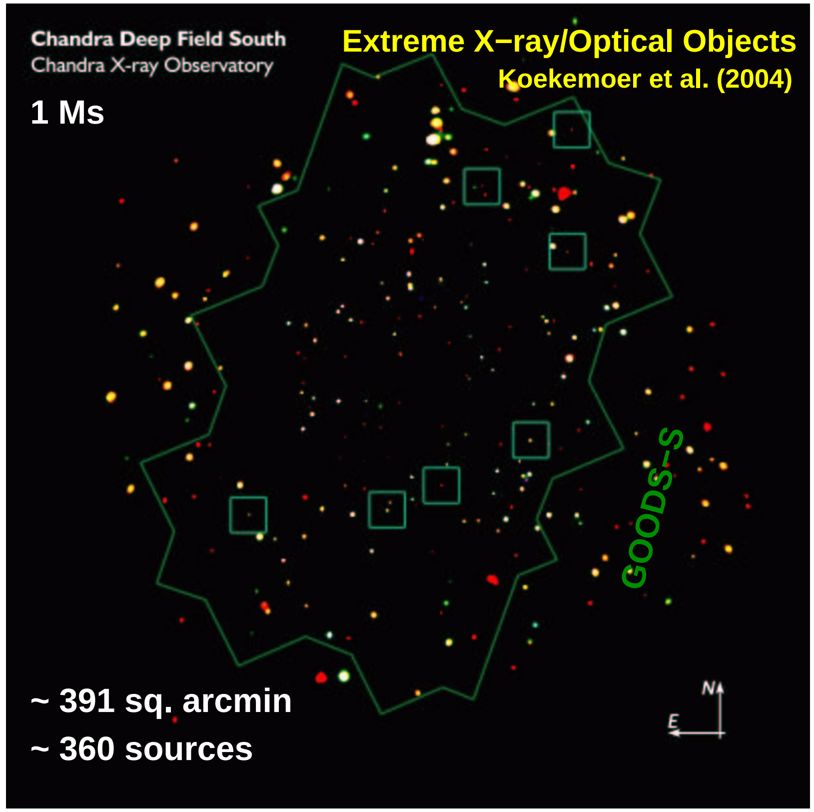
e.g., Donley et al. (2002)
Wang & Merritt (2004)

Constrain rates; Rapid X−ray follow−up

Deep X−ray Survey Constraints on High−Redshift AGN

Probe AGN ~ 30 times fainter than SDSS – Minimize absorption bias (rest−frame 2−40 keV)





Constrain sky density exploiting Lyman break.

Alexander et al. (2001), Barger et al. (2003), Cristiani et al. (2003), Koekemoer et al. (2003)

3 AGN known at $z > 4$ in Chandra Deep Fields.

In SNAP deep−survey fields, expect ~ 190 such AGN.

Hard to isolate without X−rays. Considering obscuration, optical variability might get ~ 2/3.

Candidates for higher redshift ($z > 7$) AGN identified as extreme X−ray/optical objects.

Stacking analyses can also constrain average AGN content of high−redshift populations.

Some Future Prospects and Issues

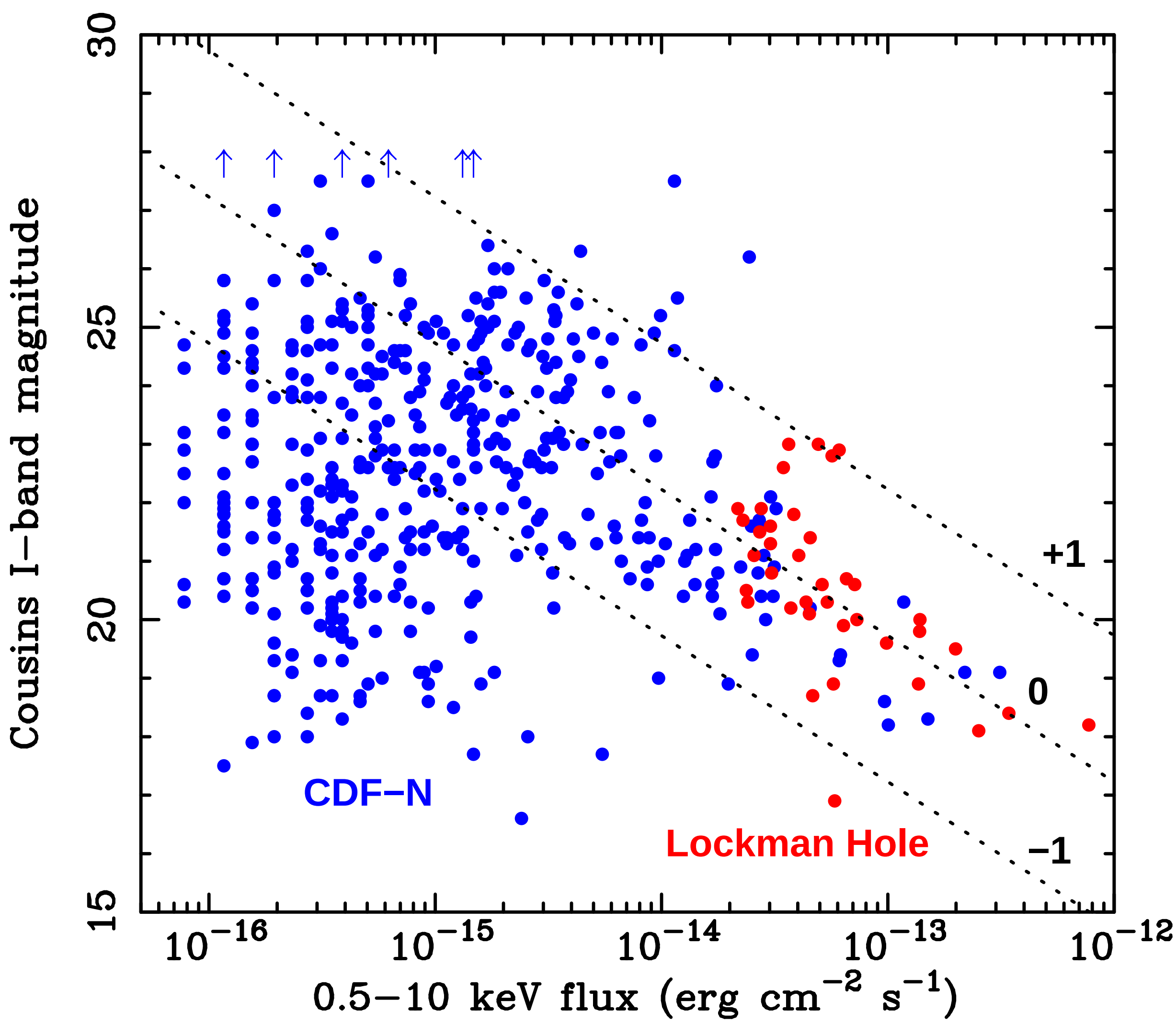
Some superb wide−field X−ray survey missions planned. e.g.,

DUO
- 0.3−10 keV
- ~ 6000 sq. deg. in North Galactic Cap, South Galactic Pole
- ~ 10,000 X−ray clusters for dN/dz, P(k), SZ effect
- ~ 160,000 AGN

EXIST
- ~ 10−600 keV
- All−sky

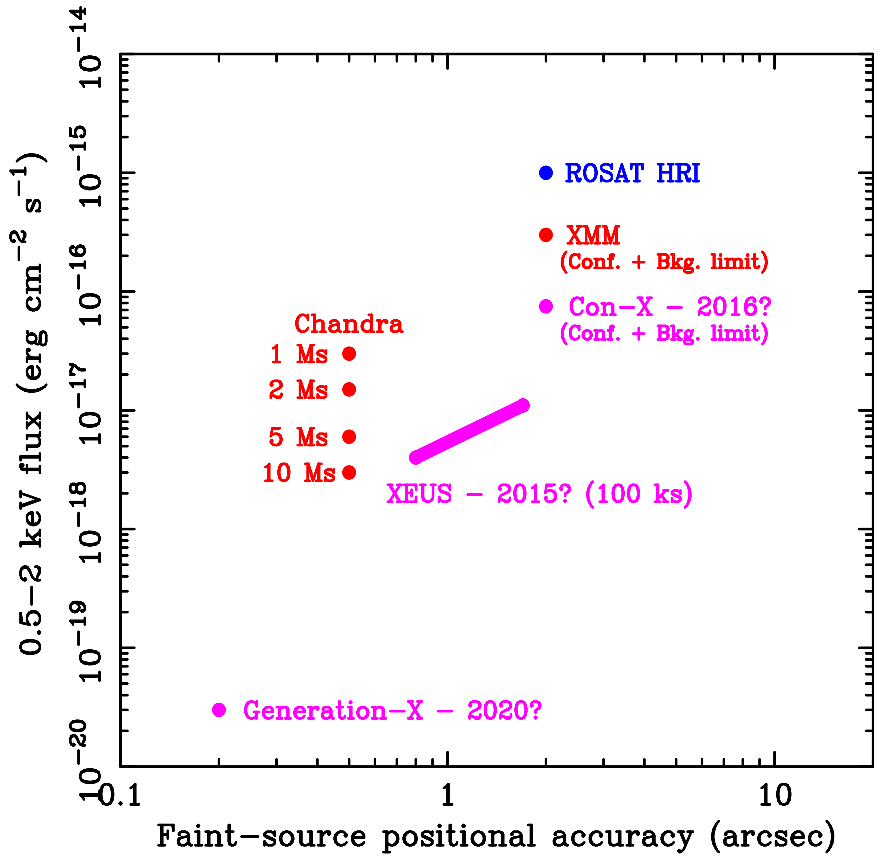
Also Swift, NuSTAR, MAXI, LOBSTER

But need higher X−ray sensitivities and 1−2 arcsec positions to complement optical imaging to I ~ 28−30.



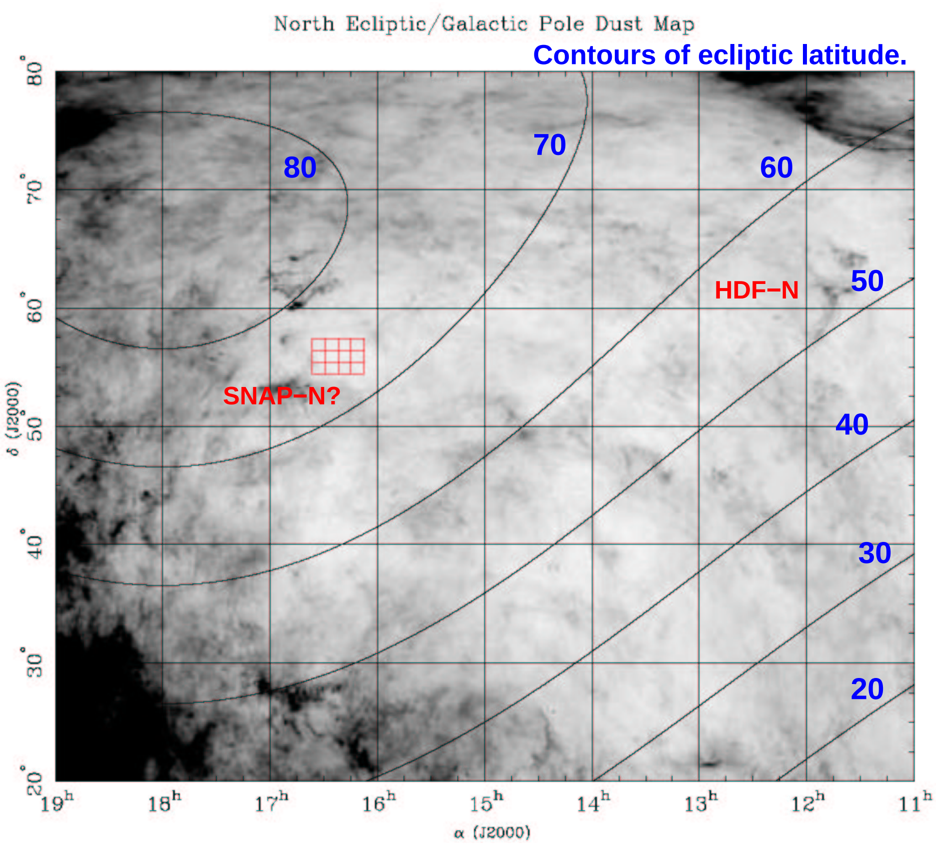
Some Future Prospects and Issues

Chandra and XMM−Newton have such sens. now, but long wait for such sens. future X−ray missions.



Lots of Chandra time needed to cover one SNAP deep field.

95 Chandra pointings x 100 ks = 9.5 Ms



Adapted from Aldering (2001)

Formally define supernova deep−field "footprints" ASAP so can try to get X−ray coverage.

Hopefully can choose fields already having great X−ray and multiwavelength coverage.

Flexibility on solar panels?