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

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**Chandra**

- Best positions
- Highest sens. < 6 keV

**XMM–Newton**

- Photon statistics
- Hard response

**ACIS–I** – 16.9’ by 16.9’

- 50–250 times sens. of previous missions

**EPIC pn** – 27.2’ by 26.4’

- Good positions of 0.5–3” for follow–up

- Often few hundred sources per field
Deepest Chandra Surveys and Supporting HST Imaging

CDF−N
1.95 Ms
~ 448 sq. arcmin
~ 582 sources

CDF−S
0.94 Ms
~ 390 sq. arcmin
~ 369 sources

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

18 Ongoing "Wide" Surveys

Lists above available from astro–ph/0403646

~ 3.5 sq. degrees in total
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

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 $z \sim 6−10$.

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
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.

16 variable galactic nuclei in HDF–N

Sarajedini et al. (2003)

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?

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
Constrain rates; Rapid X–ray follow–up
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

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?

Adapted from Aldering (2001)