High-Redshift AGNs and the Next Decade of XMM-Newton

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Demographics and Surveys

X-ray Spectroscopy

Brandt & Alexander (2015)

Shemmer et al. (2005)

Gilli et al. (2011)
Current Observational Status

Over the past ~ 16 yr, the capabilities of Chandra and XMM-Newton have allowed a large expansion in the number of X-ray detected AGNs at $z = 4-7$.

X-ray follow-up of high-redshift AGNs first found in other multiwavelength surveys; e.g., SDSS, PSS, FIRST.

X-ray selected high-redshift AGNs in X-ray surveys.

Now have 153 X-ray detections at $z = 4-7$ (according to Brandt & Vignali 2016 public list), allowing reliable basic X-ray population studies out to the reionization era.
Demographics and Surveys
Space Density Declines for High-Luminosity X-ray AGNs

In contrast to early suggestions from ROSAT, clearly see ~ exponential decline for luminous X-ray selected AGNs at $z > 3$.

$\Phi \propto (1 + z)^p$ with $p = -6.0 \pm 0.8$

Space-density comparisons with optically selected quasars indicate agreement to within factors $\sim 2-3$. 

Vito et al. (2014)
Space Density at $z \sim 3-5$ for Moderate-Luminosity X-ray AGNs

Remaining debate here – small samples, follow-up and completeness tough, results can depend on analysis details.

Similar Decline at Moderate Luminosities as at High Luminosities?

Drop by a Factor of $\sim 5$ from $z = 3-4$ to $z = 4-5$, but with Perhaps a Milder Drop at High Luminosities?

Vito et al. (2014)

Georgakakis et al. (2015)
7 Ms Chandra Deep Field-South

465 arcmin$^2$

1009+ point sources

Luo et al. (2016)
Chandra Deep Field-South Stacking

X-ray stacking of individually undetected galaxies (100-1300) can provide average X-ray detections to $z \sim 4.5+$, and useful upper limits at higher redshifts.

Much, and perhaps all, of the observed flux can be plausibly attributed to X-ray binaries.

Most high-redshift SMBH accretion occurs in short AGN phase – continuous low-rate accretion contribution appears small.

Collectively, surveys indicate that AGNs unlikely to drive reionization at $z \sim 6$.

0.5-6 Gs Observations of Average High-Redshift Galaxies
Some Future Large Survey Projects

Next Decade of XMM-Newton

Note relation to LSST, HSC, DES, Euclid, WFIRST.
LSST Becoming Real!

M1M3 after polishing - in storage in Tucson, and soon will be joined to mirror cell.

LSST support building - 3rd floor under construction
20 billion galaxies and 20 billion stars with exquisite photometry, image quality, and astrometry.

LSST alone can select AGNs to $z \sim 7.5$.

This LSST image simulation covers $\sim 0.03$ deg$^2$. 

18,000 square degrees of this...
Sensitivities of LSST, WFIRST, and Euclid

- LSST (10 yr, S Hemisphere, AM 1.2)
- WFIRST (1.6k deg$^2$/yr, ref zodi)
- Euclid (15-20k deg$^2$, $\beta=45^\circ$)

Labels indicate PSF half light radius in units of 0.01 arcsec

- LSST: 2000 deg$^2$
- WFIRST: 15000 deg$^2$
- Euclid: 15000 deg$^2$
X-SERVS: Need Good X-ray Coverage of LSST Deep-Drilling Fields (40,000 Visits)

Study SMBH growth across the full range of cosmic environments – voids to massive clusters.

Expect 11,000 AGNs and 760 X-ray groups/clusters.

Incredible legacy value as LSST/DES Deep-Drilling Fields and best multiwavelength fields.
X-ray Spectroscopy
Simulation of the Formation of a $z \sim 6$ Quasar from Hierarchical Galaxy Mergers

Gas density and temperature for high-redshift quasar host

Albeit at somewhat lower redshifts, we observe similar phenomena at $z \sim 4-5$:

1. X-ray obscured protoquasars of moderate luminosity.

2. Powerful winds from luminous quasars, likely capable of host feedback.
X-ray Obscured Protoquasars of Moderate Luminosity at $z \sim 4-5$

- Compton-thick AGN at $z = 4.76$ in strongly star-forming host
  - Gilli et al. (2011)

- $N_H \sim 2 \times 10^{23}$ cm$^{-2}$
  - Vignali et al. (2003)

- 60% of CDF-S AGNs at $z = 3-5$ heavily obscured
  - Vito et al. (2013)
Powerful Winds from Luminous High-Redshift Quasars

Implied X-ray velocity is \( v \sim 0.2-0.4c \).

Implied mass-outflow rate is \( \sim 10-30 \, M_\odot \, yr^{-1} \)
and kinetic luminosity is \( \sim 10^{46-47} \, \text{erg s}^{-1} \).

Could be present but undetected in many other high-redshift quasars (had boost from gravitational lensing).

X-ray Broad Absorption Lines from Iron K Indicating a Powerful Wind – High-Redshift Feedback in Action?
X-ray Continuum and $L / L_{\text{Edd}}$

Theoretically challenging to grow the $\sim 10^9 M_\odot$ SMBHs found at $z = 4-7$.

Would like to determine if they are growing via rapid or super-Eddington accretion.

For radio-quiet objects, can use the $\Gamma - \lambda_{\text{Edd}}$ relation.
Basic Chandra and XMM-Newton Results on X-ray Continuum Shape

Current studies do not indicate widespread extraordinary $L / L_{\text{Edd}}$ for radio-quiet quasars out to $z \sim 4-5.5$.

Hints of steep X-ray spectra for two $z \sim 6-7$ quasars – one debated (Farrah et al. 2004; Page et al. 2014; Moretti et al. 2014).

All current studies suffer from limited photon and source statistics.

XMM-Newton could improve the situation and push to higher redshifts.

It would be very helpful if background flaring accommodations could be made for faint sources.
XMM-Newton Targets at $z \sim 6-10$ from LSST, Euclid, and WFIRST

Adapted from Barret et al. (2013)

Euclid

WFIRST+LSST

WFIRST expected to give $1490 / 29$ above $z = 7 / 10$. 

WFIRST+LSST at $z > 8$
Weak-Line Quasars at High Redshift

SDSS has now found ~ 400 WLQs at $z \sim 1-6$.

WLQ fraction may rise toward high redshift.

X-ray studies of 51 WLQs support a thick inner disk model due to high $L / L_{\text{Edd}}$.

Further X-ray spectroscopy of exceptional WLQs can usefully test the model.

Luo et al. (2015)
Highly Radio-Loud Quasars Show Evidence for Enhanced Jet-Linked X-ray Emission at $z \sim 3-5$

HRLQs at $z = 3-5$ appear 2-3 times X-ray brighter than matched HRLQs at lower redshifts.

Could be IC/CMB growing as $(1+z)^4$, in which case only makes significant contribution at $z > 2$.

Further XMM-Newton spectroscopy needed.
The End