History of cosmic accretion: obscured AGN

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The high-z Universe: open issues

Future facilities (JWST, ALMA, ELT, EVLA, Lofar,) will investigate high-z galaxies and AGN in many bands. Questions for a future X-ray observatory:

How do early BHs form and grow?
What triggers nuclear activity? External (i.e. mergers, fly by) or internal?
How do accretion modes evolve? [radiative efficiency, $L/L_{\text{Edd}}$, SED($\alpha_{\text{ox}}$)]
What’s the distribution of obscuring gas at “high” redshifts

What formed first, BH or galaxy?
Some evidence for larger BH per fixed stellar mass at $z \sim 0.3-0.6$ (Treu+06, Woo+08). Also, suggestions for $M_{\text{BH}}/M_* \sim 0.1-0.3$ in bright QSOs at $z > 4$ (Walter+04, Maiolino+07, Riechers+08)
What is the high-z BH mass function?

Representative samples of high-z ($>4$) and very high-z ($>6$) obscured SMBH
Building a $\sim 10^9 M_{\text{sun}}$ BH at $z=6.4$

There is (just) time … Without invoking Super-Eddington

Multiple mergers with Eddington limited accretion can explain both BH and host galaxy properties of SDSS QSOs at $z>6$ ($\epsilon = 0.1$)

Early phase (Heavy) Obscuration
Redshift dependence of obscured fraction in X-ray surveys

expected/predicted in feedback models (i.e. Menci+08)

Seen in (some) data [e.g. La Franca+05, Treister+06, Hasinger08], not seen in others (Ueda+03, Dwelly&Page 2006), not needed in XRB models (Gilli+07)

COMPTON THICK ?

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XRB

\[ \text{Alexander+08} \]
Compton Thick “obsession”

CT never see the source
Super-Eddington

Back of the envelope argument (i.e. Daddi+07)

Compton Heating by hard X-rays

$$M \sim 10^{11} \, M_{\text{sun}}$$
$$E \sim M \sigma^2 \sim 10^{59} f_{\text{gas}} \text{ erg}$$
$$L_X \sim 10^{44} \, \text{erg s}^{-1}$$
$$f_{\text{gas}} \sim 0.1$$
$$t \sim 3 \times 10^6 \, \text{yr}$$

Effects of rad. pressure on dusty gas  Fabian+08
Accretion Parameters

\[ <\varepsilon> = 0.06 - 0.10 \]
\[ <\lambda> = 0.2 - 1.0 \]

Marconi+04 (see also Yu&Tremaine02, Shankar+04, Merloni+08, ...)

The average radiative efficiency depends on the obscured AGN fraction, especially C-thick AGN, unknown at high-z.

Is there any dependence on redshift?
Is spin (i.e. \( \varepsilon \)) dependent on z or BH mass? (see eg. Volonteri+05)
Chandra 2 Ms aim at 5 Ms

XMM ~ 0.7 Ms will reach ~ 3 Ms
Fe K line sources
known from the Chandra observations

✧ Type2 QSO $z = 3.7$
  (Norman+02)
The high-z Universe is a key science driver of JWST & ALMA E-ELT - TMT... mainly SF accretion & co-evolution -> IXO

REDSHIFT !!!
Where do we stand?

The number of high-z AGN detected so far:

| $z > 3$ | 8000 | 50 |
| $z > 4$ | 1500 | 11 |
| $z > 5$ | 150  | 3  |
| $z > 6$ | 10   | 0  |

*from DR6 “SpecObjAll” table

$ see eg. compilations by Silverman+08, Hasinger08
What's the density of low $L_X$, high-z AGN?

Evolution of the bulk of the AGN population still to be determined at moderate to high-z.

Flatter evolution or decline as for high luminosity?

Sensitivity needed for high-z AGN census

What do we expect?
Semi analytic models of BH growth

Many semi-analytic models based on LCDM:
Volonteri+06, Salvaterra+06, Rhook&Haehnelt08, Menci+08, Marulli+08. These follow the evolution and merging of Dark Matter Halos with cosmic time and use analytic recipes to treat the baryon physics. Some use the Press-Schechter formalism to get halo merger trees, others are based on the Millennium simulation.

Common assumption: nuclear trigger at merging

Free parameters:
- BH seeds (from ~20 to $10^4 M_{\odot}$) as remnants of PopIII ($M>260 M_{\odot}$) stars (Madau&Rees01): $M_{\text{BH}} \sim M_{\text{popIIIstar}}$, zero metallicity, no mass loss. Massive seeds ($10^4 M_{\odot}$) also possible (Koushiappas+04, Volonteri+08).
- recipes for accretion (radio mode and QSO mode) $\Rightarrow$ Eddington ratio, AGN lightcurves
- relation between initial BH mass and halo mass (eg bias)
- SED (eg obscuration)
- room for accretion due to internal processes (i.e. not related to mergers)
The Merger Tree

\[ M_*=3.4 \times 10^{11} \, M_\odot/h \]

- BH
- Galaxy
- AGN

Marulli+09

Extension of Croton+06 & De Lucia+07
SAM models based on Millennium
AGN lightcurves and luminosity functions

Example of lightcurves for $10^7 M_{\odot}$

Bolometric LF

Marulli+08

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What will we see? Prospects for IXO

Two possible ways to make predictions on the high-z Universe:

1) “Fair” (?) extrapolations towards high-z and low luminosities of present XLF (obscured fraction/distribution …)

2) SAM models for early BH growth from seed BHs
Predictions for high-z Universe very, very uncertain …

max. XLF:

XLF that predicts the maximum number of high-z AGN while being in agreement with current “low-z” XLF.
Confusion at \( N(>S) \sim 2 \times 10^4 \, \text{deg}^{-2} \),
i.e. \( S \sim 10^{-17} \, \text{erg/cm}^2/\text{s} \)
in \( \sim 1 \, \text{Msec} \) (depending on the bkg level)

XLF \( @ \, z > 6 \)
would constrain the physics of early BH formation

BH seeds mass function, accretion mechanisms
high-z AGN yields: \[ N_{\text{tot}} \approx S^{1-\alpha} \]

if \( \alpha > 1 \)

depth in a single field

if \( \alpha < 1 \)

wider areas

\begin{array}{|c|c|c|}
\hline
z > 4 & \text{Decline} & \text{maXLF} & \text{SAM} \\
\hline
355 & 1350 & 1375 \\
\hline
z > 6 & 15 & 300 & 4 \\
\hline
\end{array}

FOV \sim 18'x18'

Vignetting as in Willingale document
IXO X-ray Spectra

Compton Thick ($N_H \sim 10^{24}$ cm$^{-2}$) AGN at $z = 5$ ($L_X \sim 10^{43}$ cgs - $F_X \sim 10^{-16}$ cgs, line EW $\sim 1$ keV (rest-frame))

XMS simulation of a Compton Thick AGN at $z = 7$, $L_X \sim 5 \times 10^{42}$ cgs - $F_X \sim 5 \times 10^{-17}$ cgs , line EW $\sim 1.2$ keV (rest-frame).
Final remarks

✧ 5” HEW or better + ~350 arcmin$^2$ or larger

enough z>6 objects to build up an XLF and constrain early BH formation and growth (assuming a “clever” strategy is adopted and “enough” time is invested in surveys)

✧ IXO is well matched to the sensitivity of other future facilities like JWST and ALMA to recognize high-z SMBH

✧ IXO would provide excellent spectra for moderately bright high-z QSOs. Unique capability to identify through X-ray spectroscopy faint obscured AGN at high redshift. Dedicated follow up observations of high-z QSO identified by eROSITA and/or Pan-STARRS, LSST.