Quasars at z~6 and above: prospects for wide-and-deep X-ray surveys and results from current exploratory programs

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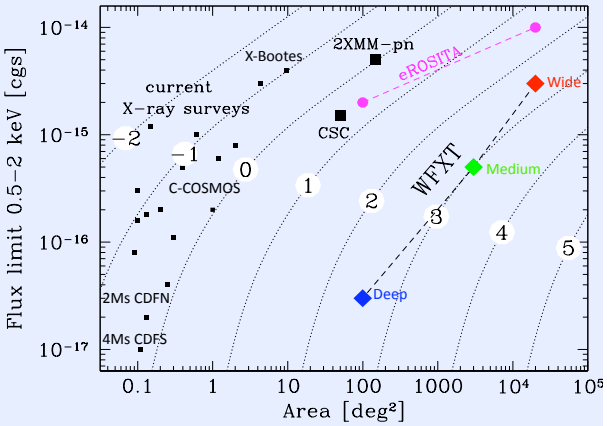
SUMMARY

Quasars at z>6 are rare objects, which are generally found by means of relatively shallow wide-area optical surveys like the SDSS or the CFHQS. Their measured surface densities are of the order of ~ 1 every 500 deg^2 at z_{AB}<20, and 1 every 30-40 deg^2 at z_{AB}<22. By selection, these objects represent only the most luminous and unobscured part of the high-z AGN population, and thus provide limited constraints to theoretical models. X-ray surveys, which could ideally detect weak and obscured objects, are still poorly effective in finding AGN at z~6, either because they sample too small volumes, or because they are too shallow. As shown in **BOX 1**, wide-and-deep X-ray surveys such as those proposed with the Wide Field X-ray Telescope (WFXT) mission are needed to characterize the population of AGN at z>6. The WFXT mission concept is shown in **BOX 2**. In order to test synergies between wide-area optical and X-ray surveys in the search of z~6 QSO, we are carrying on a spectroscopic program with the MMT and the VLT to identify high-z QSOs candidates selected as X-ray sources with red i-z color over the 130-deg^2 area covered by both the SDSS and the Chandra archive. This program is described in **BOX 3.**

BOX 1: Expected number of AGN at z>6 in wide-and-deep X-ray surveys

The abundance of AGN at z>6 is highly uncertain, especially below L*. Assuming a model in which the exponential decline observed in the space density of luminous QSOs (e.g. Fan et al. 2006) is extended to lower luminosity AGN (this model is in good agreement with the current observational constraints) one would expect to detect ~1600 AGN at z>6 and ~70 AGN at z>8 (see decline model in the Table below) with an instrument such as WFXT (see BOX 2).

Quantity	Survey		
	Deep	Medium	Wide
$z > 6$			
$\log L^{min}$(0.5-2 keV)	43.1	44.3	45.1
N. AGN (decline)	300	1000	300
N. AGN (max LF)	15000	2300	300
$z > 8$			
$\log L^{min}$(0.5-2 keV)	43.4	44.6	45.4
N. AGN (decline)	20	45	10
N. AGN (max LF)	4300	210	10

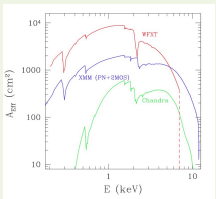


Number of AGN at z>6 expected from the decline model for different combinations of survey area vs 0.5-2 keV limiting flux. Dotted lines are the locii of equal AGN number as labeled (labels are in log units). Only a handful of objects are expected in the Chandra and XMM archives (CSC and 2MM-pn), respectively. See Gilli et al. arXiv:1010.6024 for details

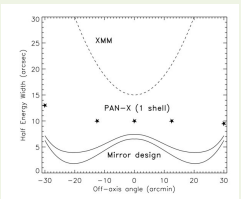
BOX 2: The WFXT mission concept

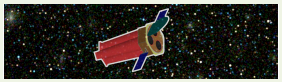
The Wide Field X-Ray Telescope (WFXT) is a medium-class mission designed to be 2 dex more sensitive than any previous or planned X-ray mission for large area surveys and to match in sensitivity the next generation of wide-area optical, IR and radio surveys. Using an innovative wide-field X-ray optics design, WFXT provides a field of view of 1 deg^2 (10x Chandra) with an angular resolution of 5" HEW nearly constant over the entire field, and a large collecting area (1m2) > 10x Chandra over the 0.1-7 keV band.

Effective Area



Angular Resolution





WFXT: three co-aligned telescopes with wide field optics and CCDs with ΔE/E~20 resolution. A low-earth orbit is chosen (550 km @ 6 deg) to minimize particle background

In five years of operation, WFXT will carry out three extragalactic surveys:
a WIDE survey will cover most of the extragalactic sky (~20,000 deg2) at ~500 times the sensitivity, and 20 times better angular resolution of the RASS;
a MEDIUM survey will map ~3000 deg2 to deep Chandra-COSMOS sensitivity;
a DEEP survey will probe ~100 deg2, or ~1000 times the area of the Chandra Deep Fields, to the deepest Chandra sensitivity.

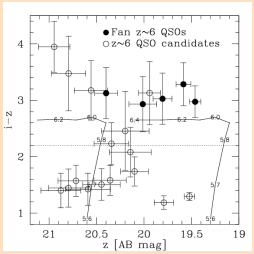
Quantity	Survey		
	Deep	Medium	Wide
Ω (deg^2)	100	3000	20,000
Exposure time	400 ks	13 ks	2 ks
Total time	1.67 yr	1.66 yr	1.67 yr
S_{min} (point-like) (*)	3×10^{-17}	5×10^{-16}	3×10^{-15}
Total AGN detected	5×10^5	4×10^6	1×10^7
S_{min} (extended) (*)	1×10^{-16}	1×10^{-15}	5×10^{-15}
Total clusters/groups	3×10^4	2×10^5	3×10^5
(*) Flux limit in erg cm^{-2} s^{-1} (0.5-2 keV band) at 5σ detection			

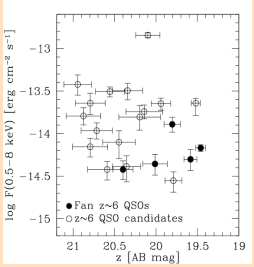
The relevant documentation about WFXT can be found at: http://wfxt.pha.jhu.edu/ and http://www.wfxt.eu/

BOX 3: Searching for high-z QSOs in the Chandra-SDSS matched catalog

We are conducting an optical spectroscopy program at the MMT and at the VLT to observe 16 candidate AGN at z>5.6 selected on the basis of the Chandra–SDSS matched catalog, which covers a total area of ~130 deg2. High-z QSO candidates have been selected as X-ray emitting sources with red i-z color. X-ray detection should exclude the main contaminants of standard optical plus near-IR color selection (e.g. Fan et al. 2006), i.e. brown dwarfs, which are expected to be ~300 times weaker in the X-rays than QSOs of comparable z-band magnitudes. We considered objects which are undetected in the u,g,r bands and with i-z color larger than 1 at more than 1σ level. This is a looser constraint than adopted in standard optical color selection, but we note that, based on average SEDs, QSOs at z>5.6 would show i-z ~1 at z=5.6. The match with an X-ray source will allow us to search an i-z color regime that cannot be accessed by optical/IR surveys because of the overwhelming number of stellar contaminants. Possible contaminants in our selection method are instead obscured QSOs in early type galaxies at z ~ 1.0-2.0.

We are half-way through our program and no high-z QSO has been found yet. Most targets indeed proved to be obscured AGN at z~1, with slightly bluer color than estimated from the SDSS. This highlights the need of having accurate optical photometry to perform such searches. Further selection improvements to be explored rely on the X-ray hardness ratio to exclude hard, obscured QSOs at z~1. We recall that the detection of even 2-3 high-z QSOs would provide a success rate comparable to that of standard optical plus near-IR color selection.





The two tracks with redshift labels refer to QSOs with M1450=-27 and -25.

Confirmed z~6 QSOs in the CSC-SDSS catalog are shown as filled circles. Open circles represent the candidate high-z objects targeted by this program.