# *X-ray selection of quasars at z~6: pilot programs and prospects for wide-and-deep X-ray surveys*

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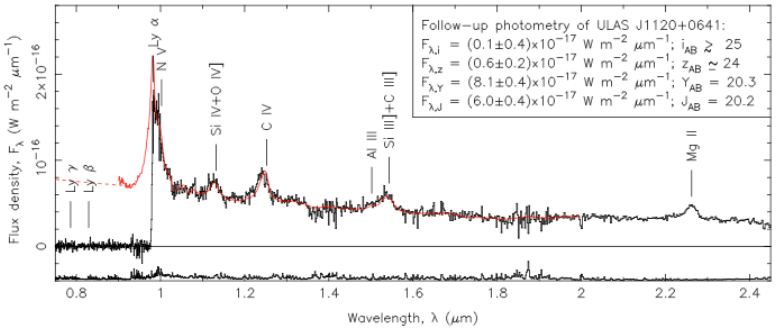
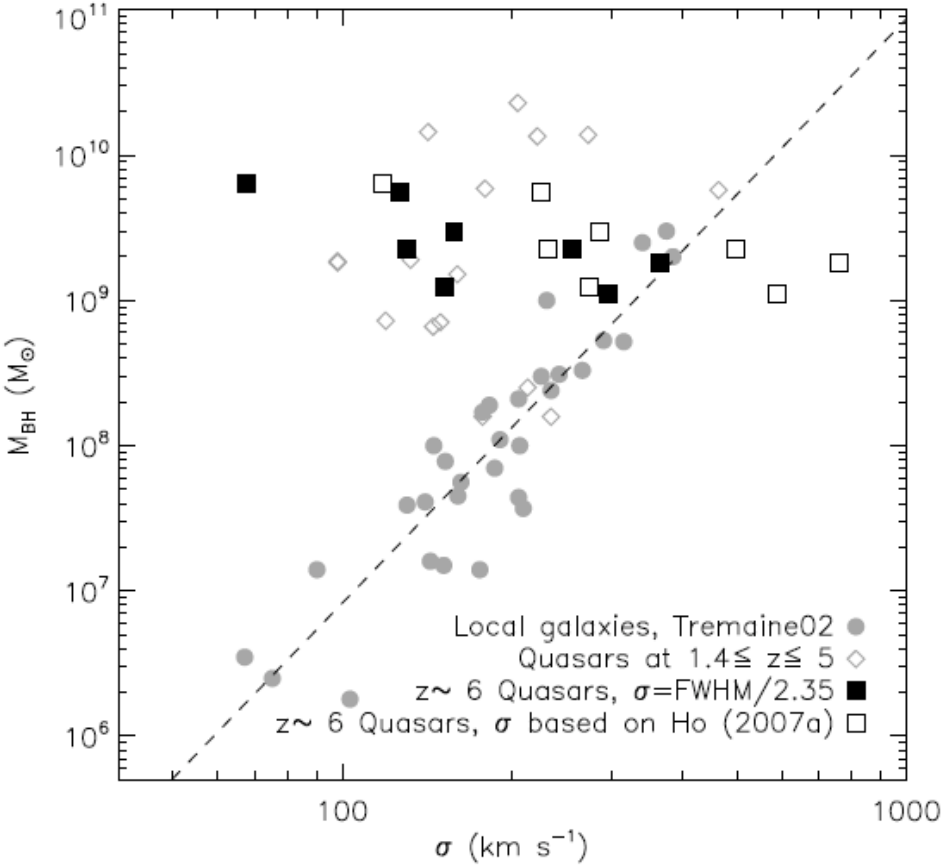
# *Where do we stand?*




About 50 QSOs at z>5.8 known from wide area optical and near-IR surveys. Most distant @ z=7.08 (Mortlock +12)

- rare:
1 QSO / 500 deg$^2$ to $z_{AB}$~20 (Fan+00/06)
1 QSO / 30-40 deg$^2$ to $z_{AB}$~22 (Willott+10)

- All broad line, unobscured AGN

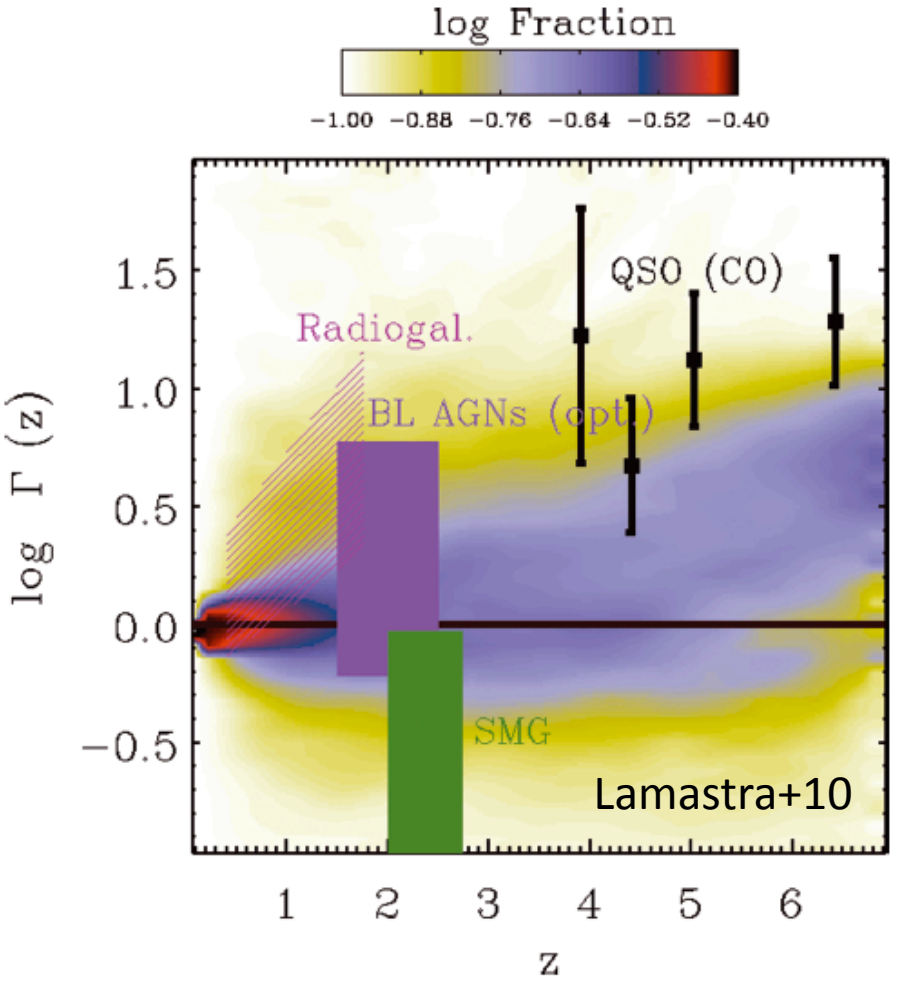
- $M_{BH}$~$10^{8\text{-}9}$ $M_{sun}$ (Kurk+09, De Rosa +10)

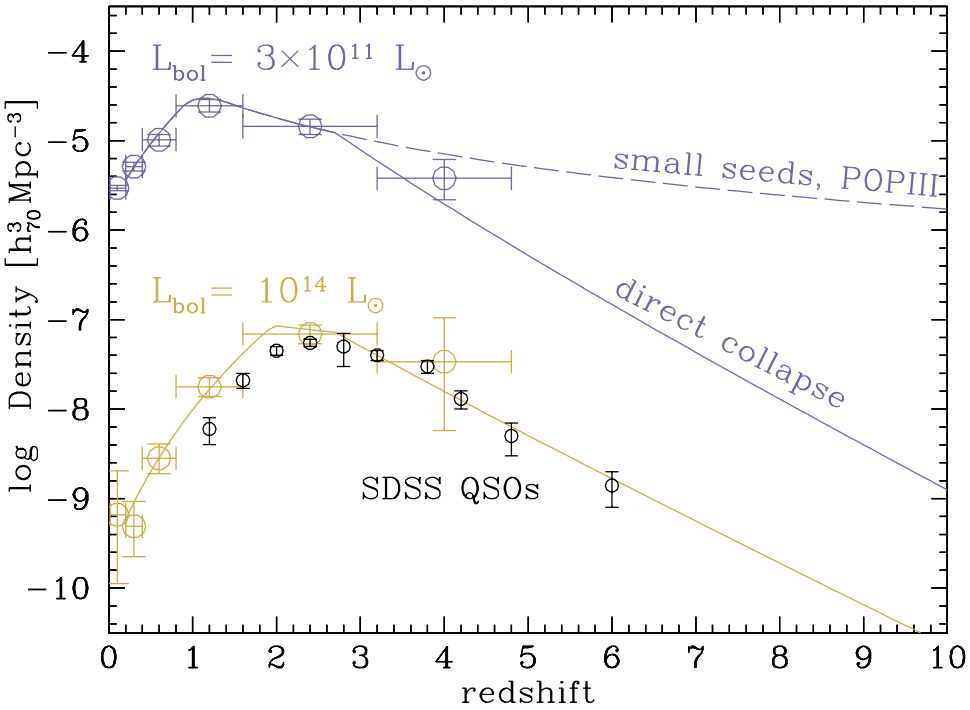
- Accreting at ~ Eddington

-"mature": solar/supersolar Z as in low-z QSOs, $M_{dust}$>$10^8$ $M_{sun}$ (Juarez +09, Wang+11)

- $M_{BH}/M_*$ ratio higher than local

# *How and where did they form?*

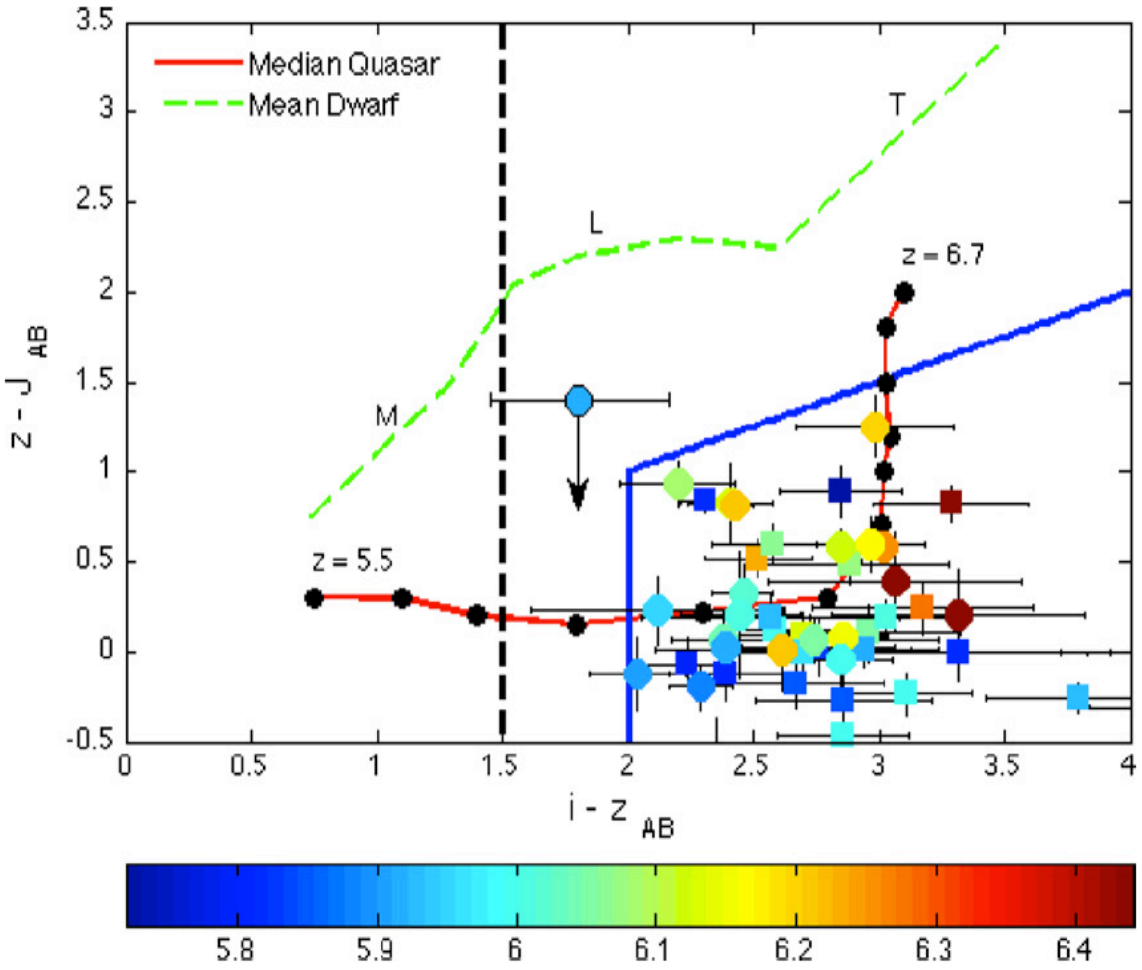



AGN: galaxy interactions
SF: quiescent + galaxy interactions

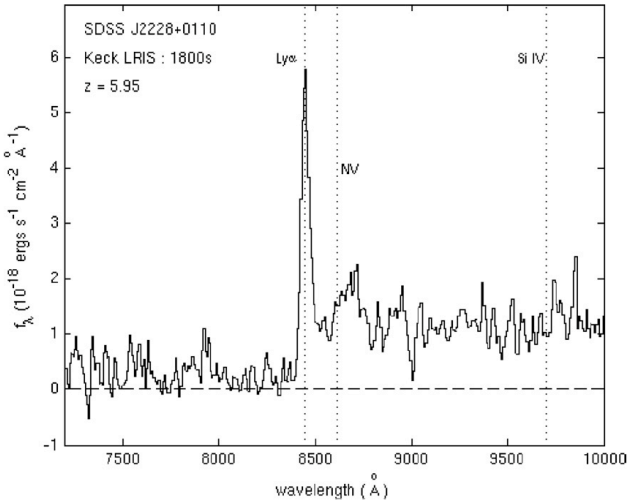
Only bright tail sampled: X-rays
can sample low lum / high obscuration,
i.e. the bulk of the AGN population

# *Color selection of z~6 QSO: i-band dropouts (i-z>2)*




J-band to separate high-z QSOs from brown dwarfs

Zeimann+10




radio + red optical color selection in Stripe82:
50 candidates, one is a z=5.99 QSO with i-z~1.8
➔ missed by standard color selection (i-z>2)

narrow Lyα?
$FWHM_{rest}$=1980 km/s

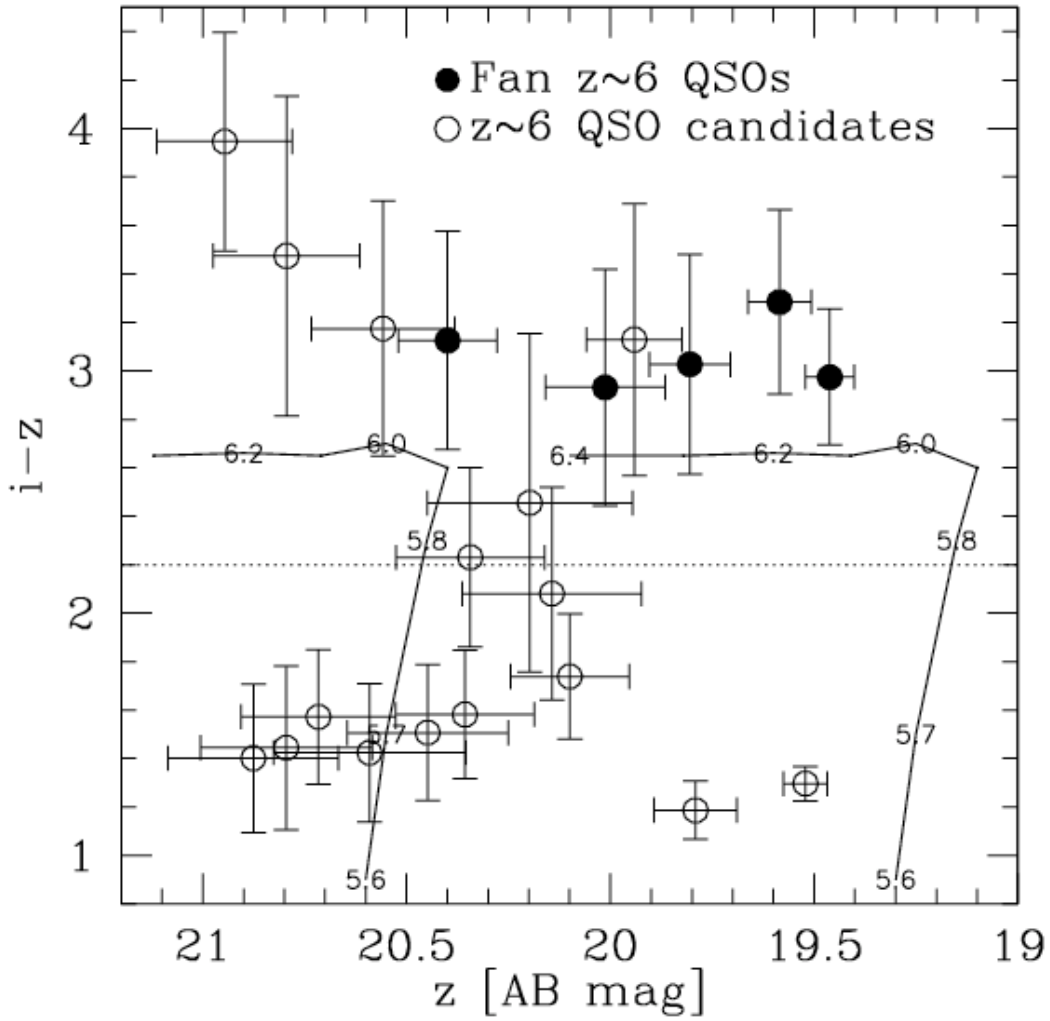
# *Selection of z~6 QSO candidates in the Chandra vs SDSS DR7 matched catalog (CSC-SDSS)*

CSC-SDSS: ~130 deg$^2$ common area,
~$10^5$ objects

Selection criteria:

* ugr>23
* 1$\sigma$ lower limit on i-z >1
* $z_{AB}$<20.9
* visual inspection of X-ray and SDSS images ok

5 Fan z~6 QSOs recovered
+ 16 new candidates




X-ray emission should remove
brown dwarfs without J-band imaging

# *z~6 QSO candidates: observations with MMT and VLT*

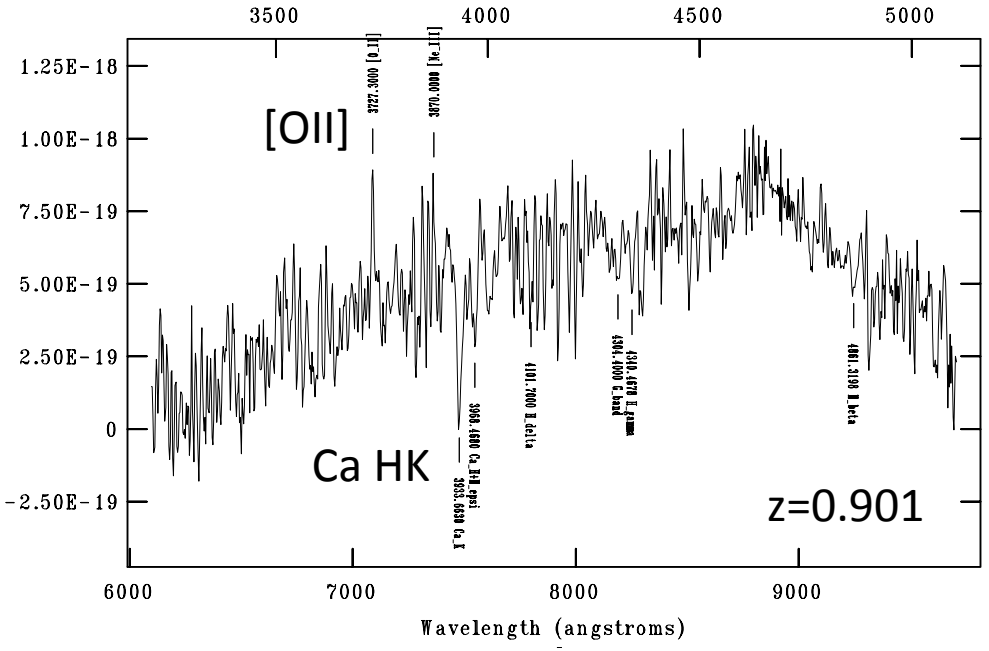
13 out of 16 candidates observed at MMT (2 nights in March 2011) or VLT (FORS2, 20h, service, May-Sep 2011)

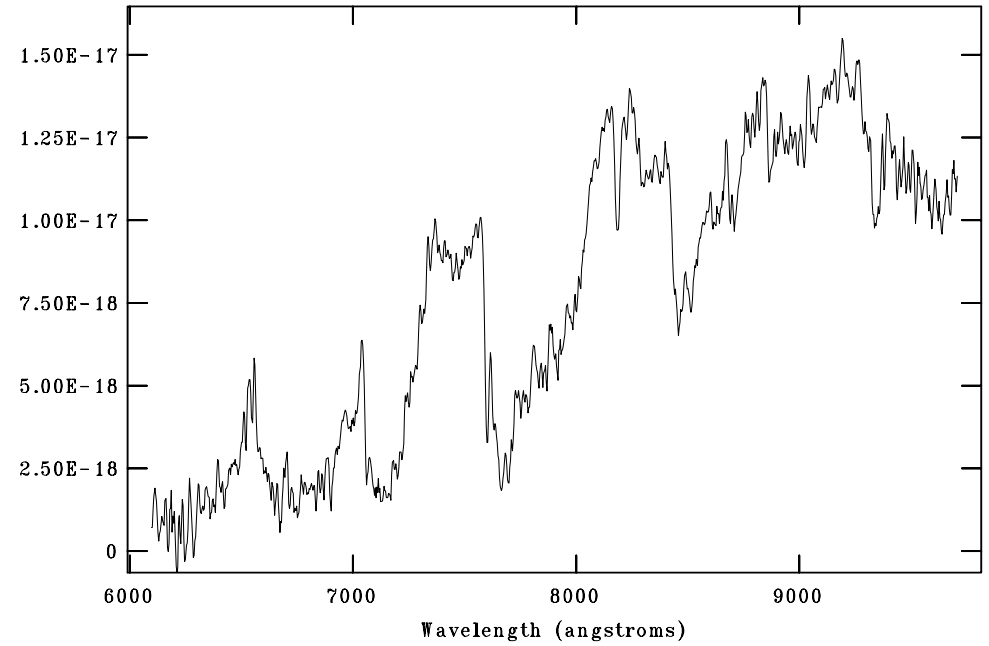
NO QSO found

10/13 obscured AGN at z~1

2/13 are brown dwarfs (X-ray flaring)

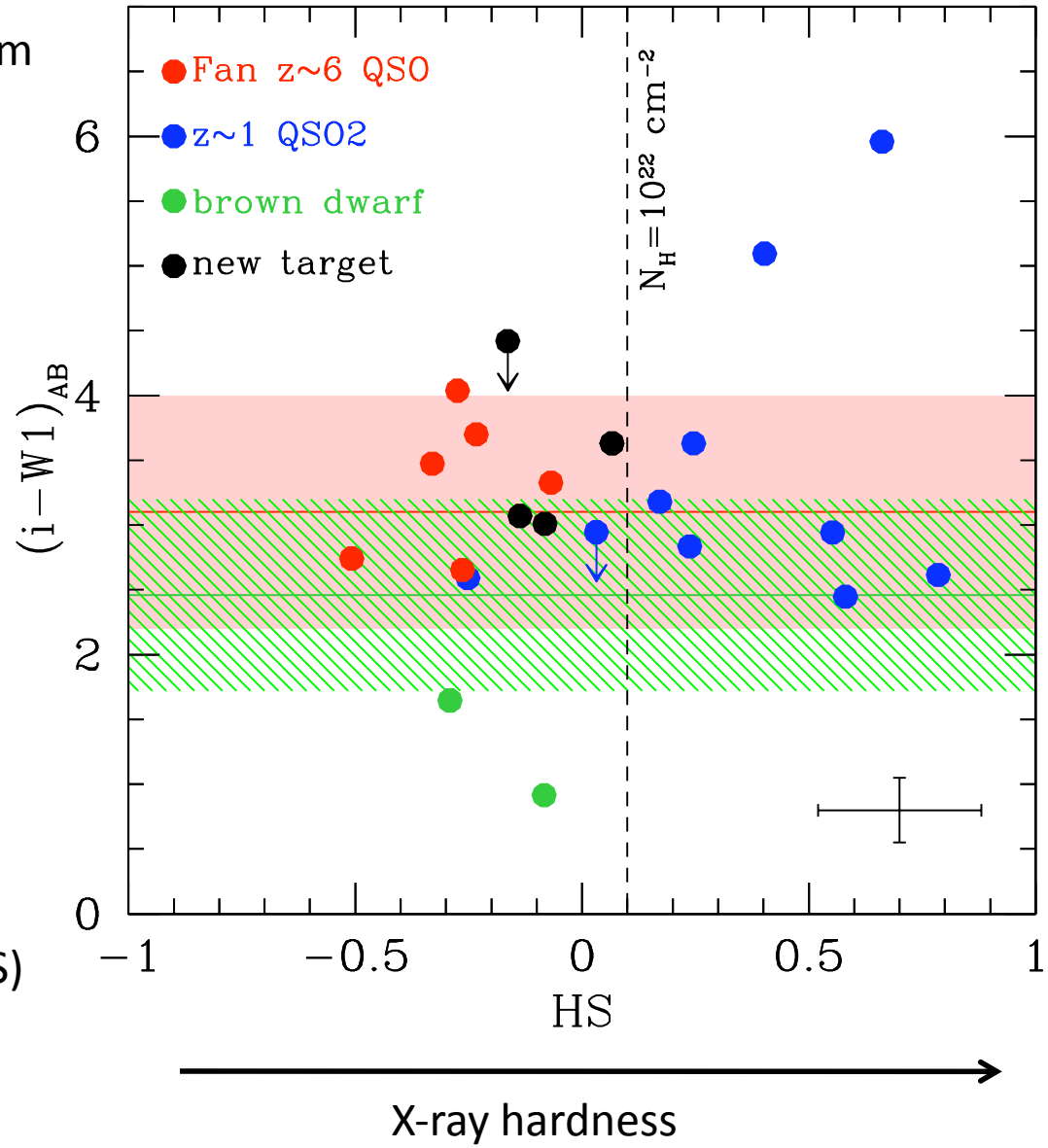
1/13 is a likely fake match



# *What have we learned: can we improve selection?*

W1=WISE 3.6um




X-ray hardness can separate z~6 QSOs from z~1 QSO2s

i-W1 color may separate brown dwarfs

HS = (H-S)/(H+S)
S=0.5-1.2 keV
H=2-7 keV

# *New candidate selection*

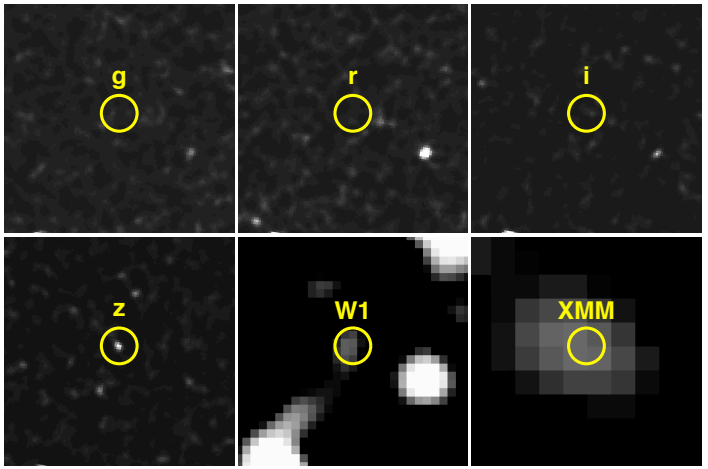
match SDSSIII-DR8 (= SDSS-DR7+ 3000deg$^2$)
with CSC + 2XMMi-DR3 (500 deg$^2$, 2.6x10$^5$ objects: flim@50% sky cov ~ 4x10$^{-15}$ erg/cm$^2$/s soft band)

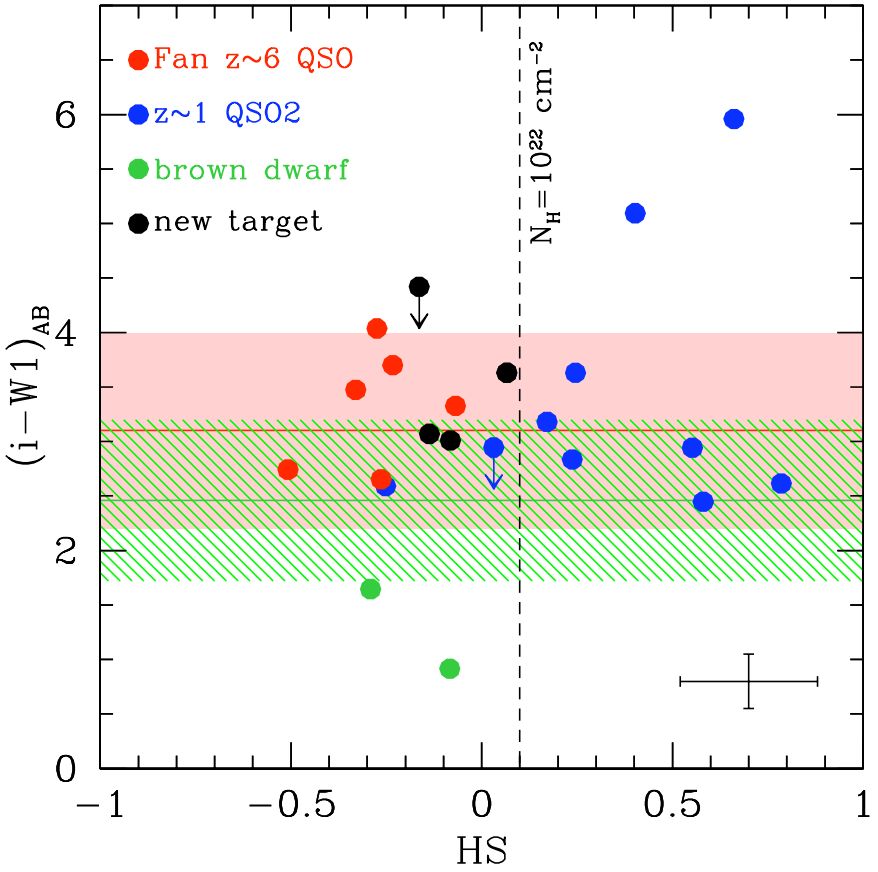
X-ray/optical matched area ~ 420deg$^2$:
"a few" z~6 QSO expected

same selection as before
plus HS< 0.1 and refined visual inspection
(VO tool searching all available databases (CFHT, HST, ESO, WISE,…) ➔
significant fraction of contaminants removed

4 candidates left

new targets accepted in low priority @LBT
(MODS1, 1hr each)



# Possible extensions for optical-IR/X-ray matched selection

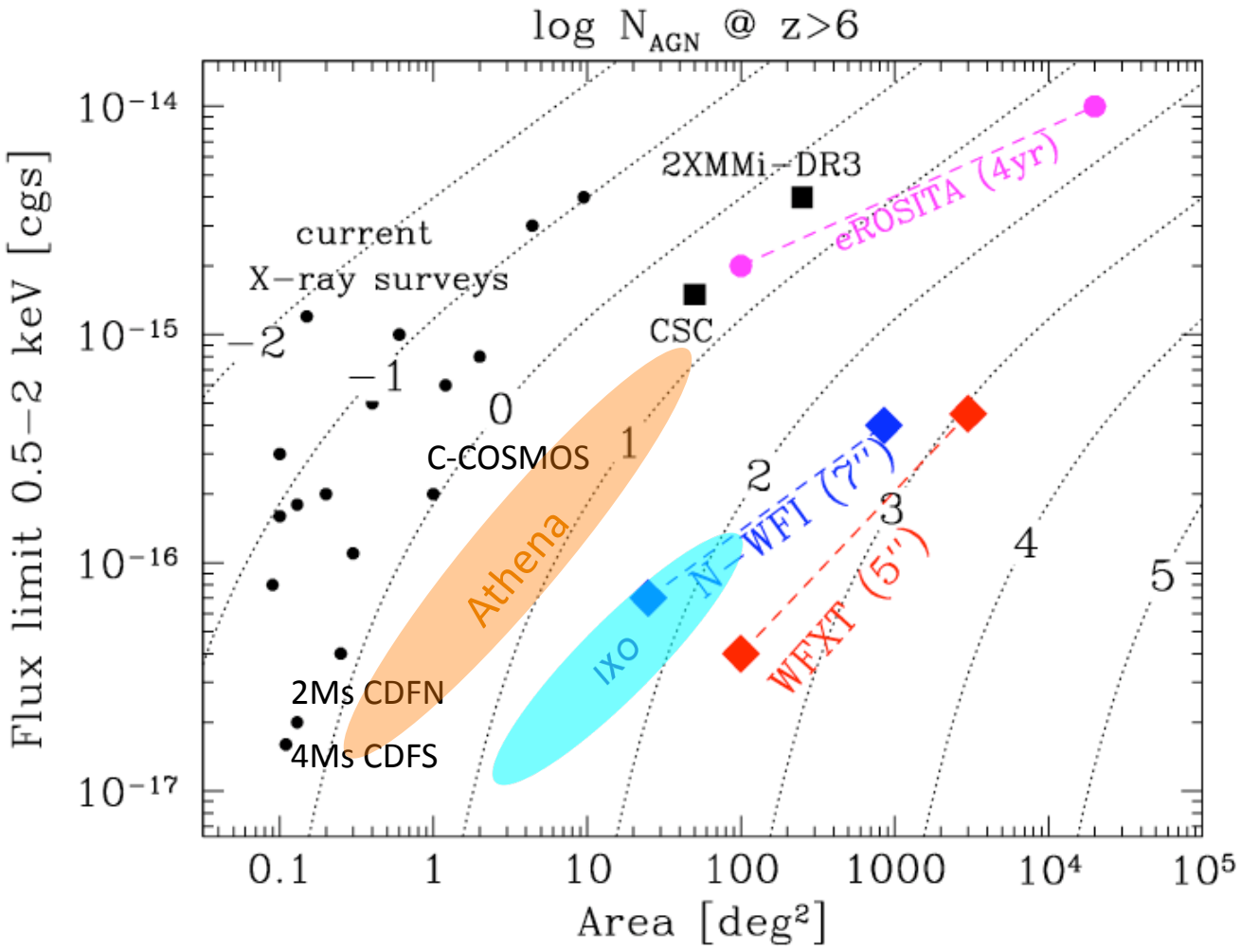
Chandra + XMM < 820 deg$^2$ total (some overlaps). It increases by ~90 deg$^2$/yr
Sky fraction: Chandra + XMM <2%

| Survey | Area (deg2) | Depth | X-ray matched area (deg2) (*) |
|---|---|---|---|
| Stripe82 | 300 | $z_{AB}$=22 | 6 |
| CFHTLS Wide | 170 | $z_{AB}$=24.6 | 3.4 |
| UKIDSS LAS DR9 | 4000 | $Y_{vega}$<20.2, $J_{vega}$<19.6 | 80 |
| VISTA VHS 1° release | 1500 | $Y_{vega}$<20.6, $J_{vega}$=20.2-20.6 | 30 |

UKIDSS and VHS have little overlap ➔ 80+30 = 110 deg$^2$ X-ray matched area

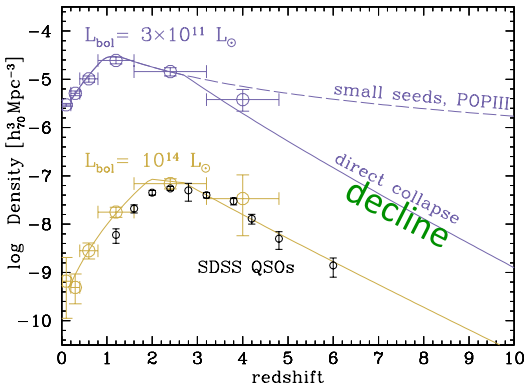
(*) maybe ~2x larger: CSC-SDSS gives ~130 deg$^2$ vs ~64 deg$^2$ expected

# *Prospects for X-ray detection of high-z AGN*

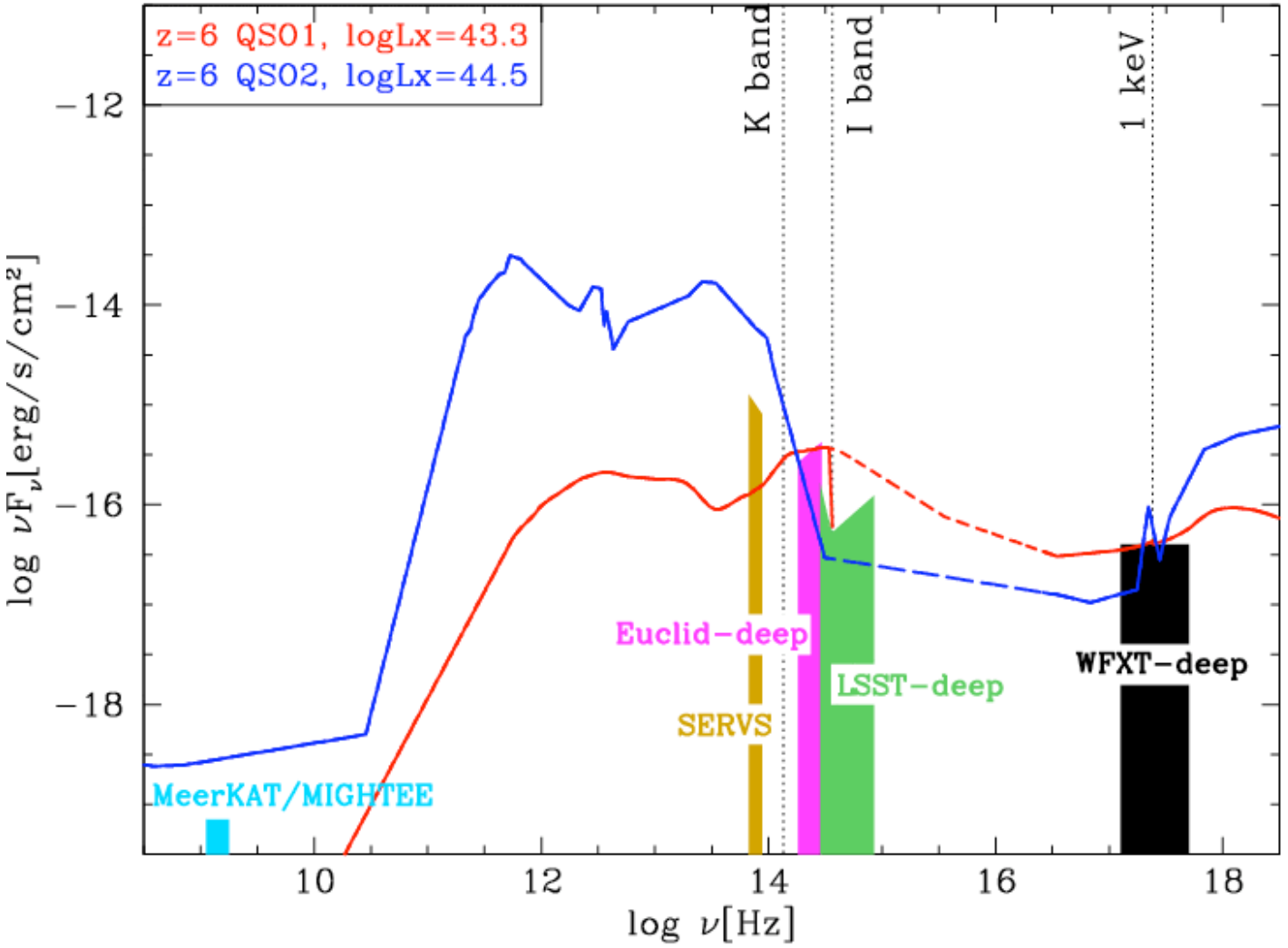



~40 z>6 QSOs
in 4-yr eROSITA,
mostly SDSS-like

dotted lines:
Number of AGN at z>6
(labels are log N)
expected with decline



# *WFXT synergies with future wide-area surveys*



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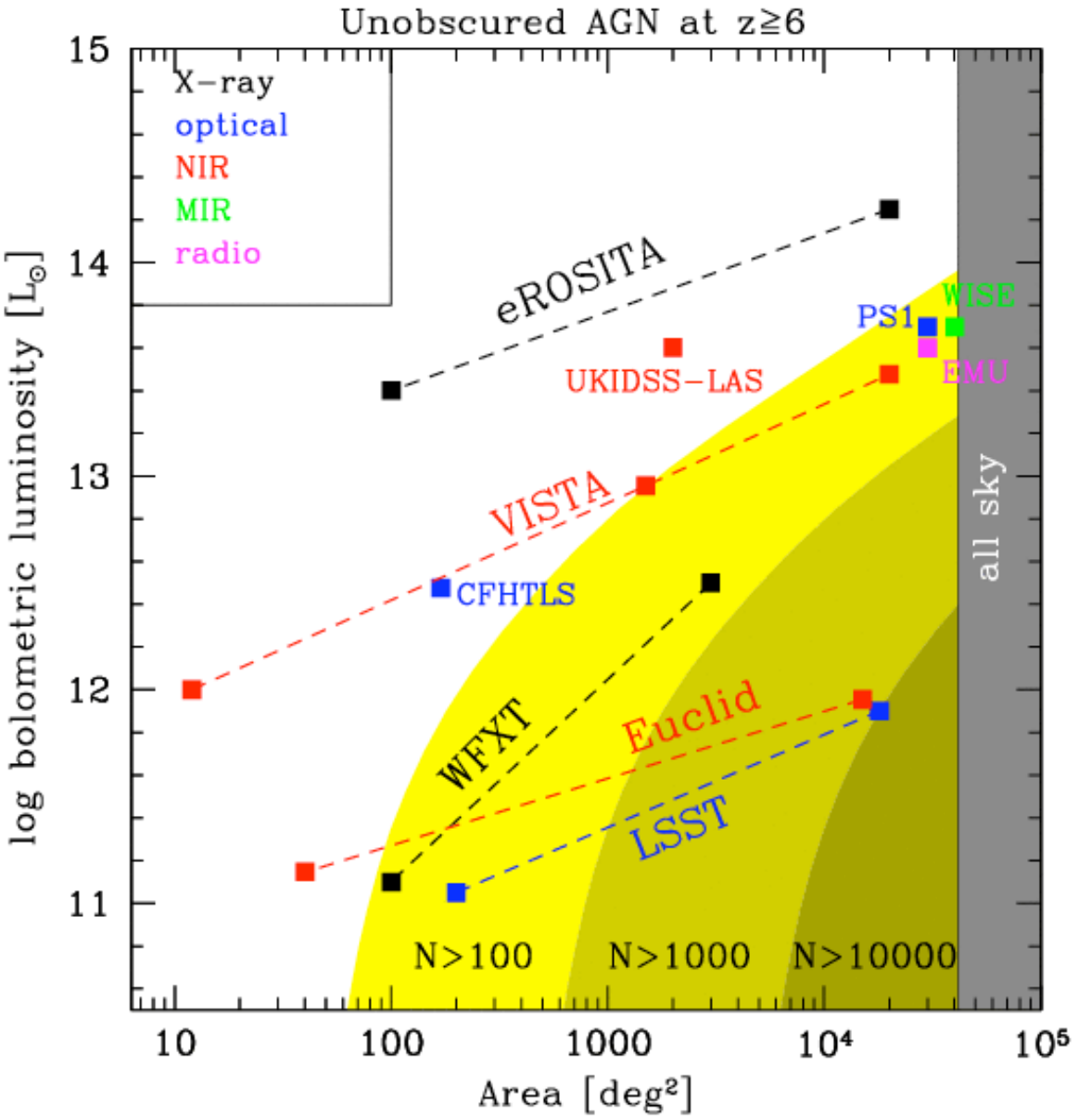

# Conclusions

X-ray selection of high-z QSOs would sample the bulk of the early BH population
➔ map the beginning of the BH/galaxy co-evolution

Current instrumentation (Chandra+XMM surveys) is limited by the area covered at sufficient depth: only a few X-ray selected QSOs at z>6 expected (with a conservative model).

Pilot programs matching the Chandra/XMM catalogs with SDSS unsuccessful so far: possible extensions using other wide-area optical/near-IR surveys (UKIDSS, VISTA.. or go to somewhat lower redshifts, z~5)

Mission concept like WFXT can provide hundreds to thousands of z>6 QSOs perfectly matching in area AND sensitivity the leading future wide area surveys (e.g. Euclid). How do we build it (ESA/NASA/JAXA)?