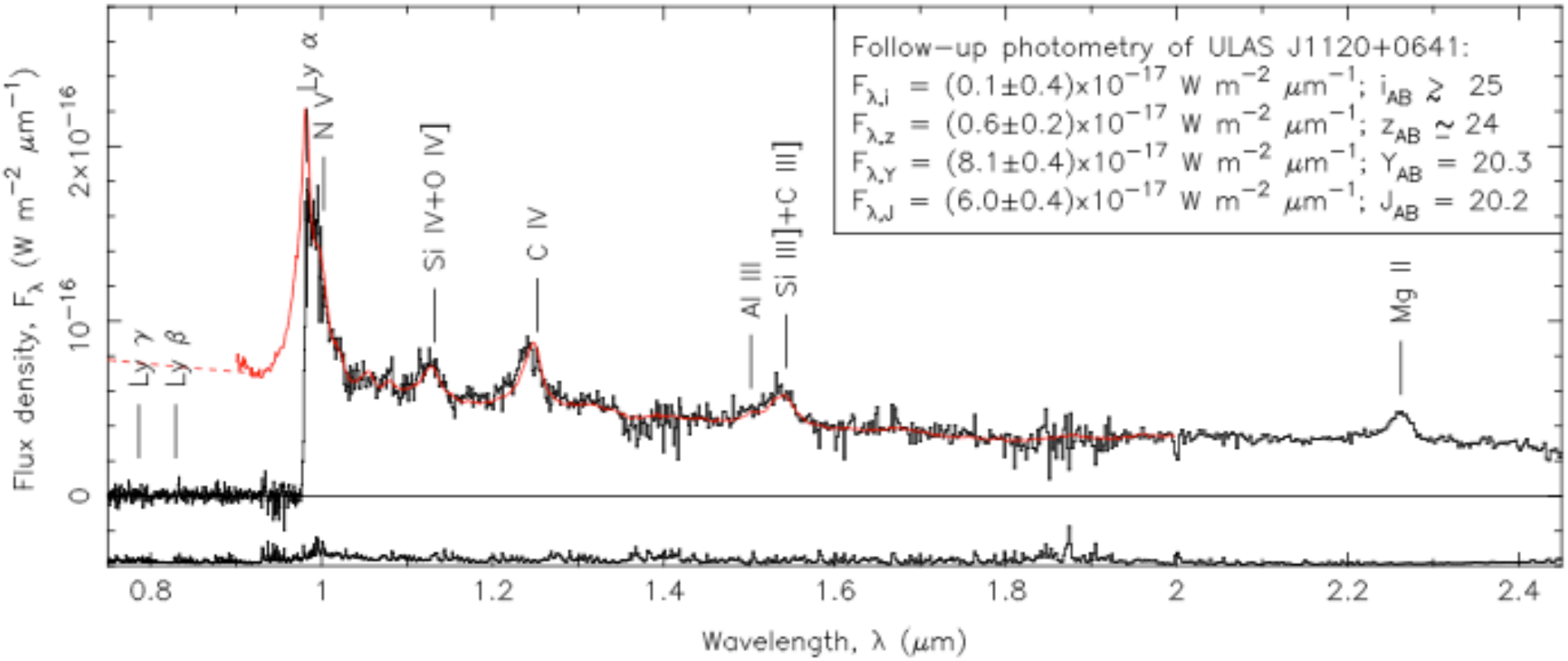
Searching for z~6 QSO in X-ray/optical wide-area surveys

R. Gilli, A. Bongiorno, M. Brusa, N. Cappelluti,
P. Ciliegi, F. Civano, A. Comastri, F. Fiore,
K. Iwasawa, V. Mainieri, **M. Mignoli**, G. Risaliti,
M. Salvati, F. Vito, G. Zamorani

Where do we stand

About 50 QSOs at z>5.8, ~20 at z>6 from wide area optical surveys, i.e. SDSS and CFHQS (i-dropout selection). Some from wide area near-IR surveys, VISTA-VIKING, UKIDSS, including a z=7.08 QSO (Mortlock +12)

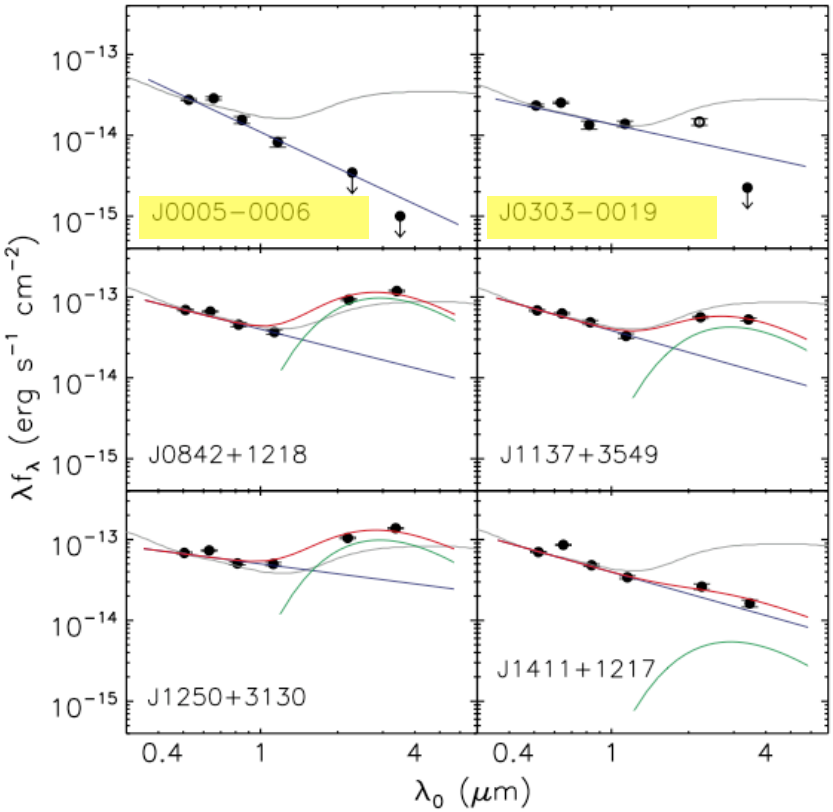


All broad line, unobscured AGN

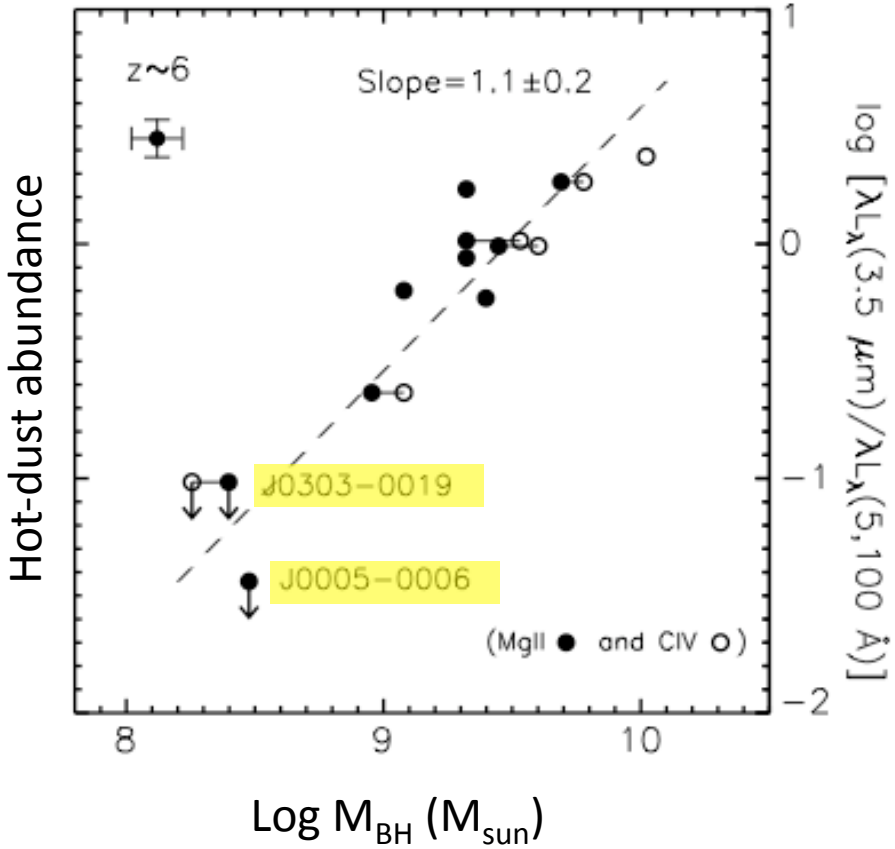
Most are already “mature”: high metallicity and dust content, large BH masses ~$10^{8\text{-}9}$ M_{sun} (Beelen+06, Juarez +09, Kurk +09) Accretion rate is ~ Eddington

Two interesting counter-examples?

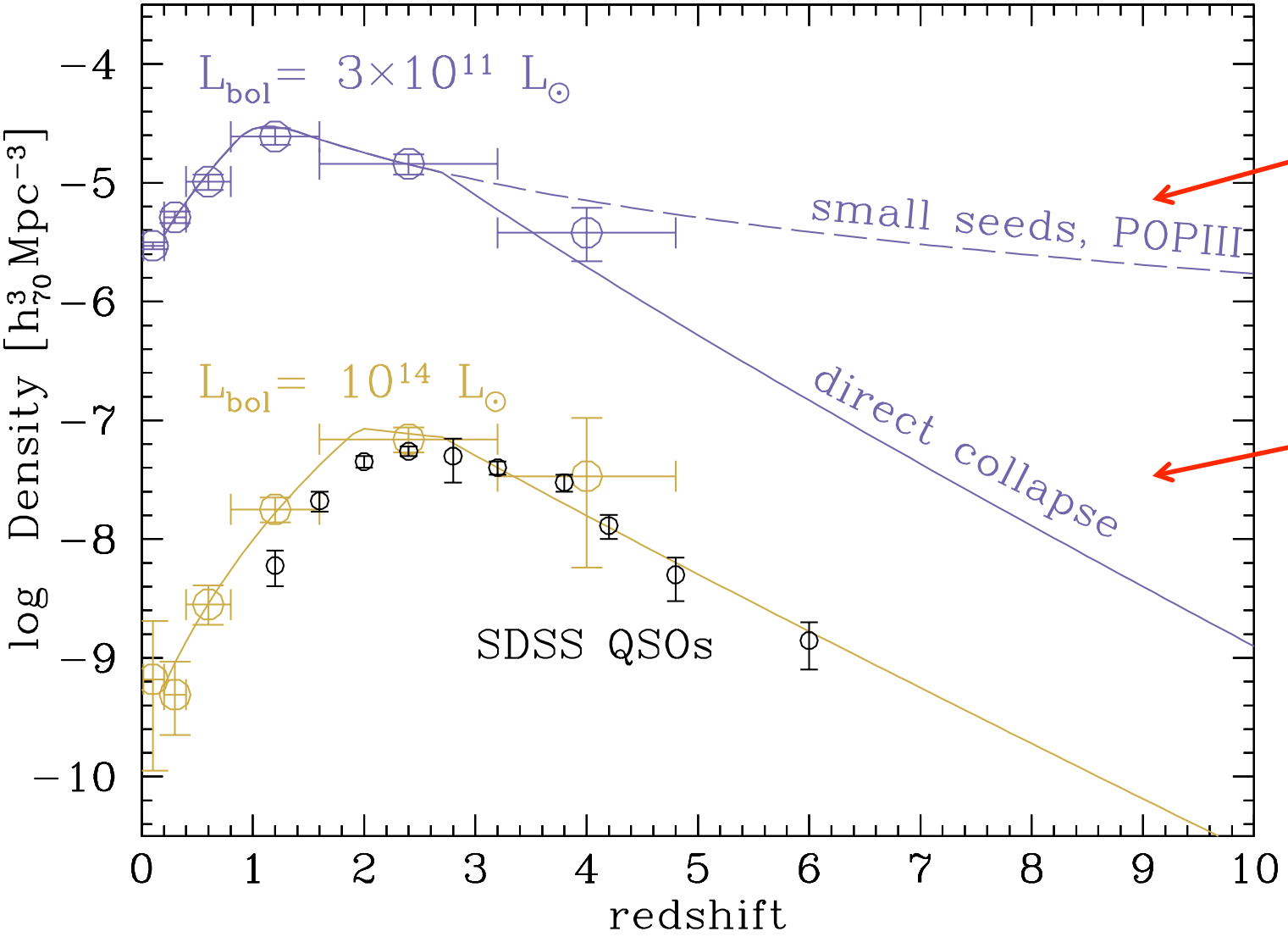
Two z~6 QSOs without NIR bump:
no hot-dust (T~1000 K): no torus? Young, just formed objects?



Jiang+10



How and where did they form?



light, widespread seeds

heavy, rare seeds

Optical vs X-ray selection

SDSS/CFHQS QSO at z~6 are
bright but very rare

1 object every ~500 deg^2
down to z_{AB}~20 (SDSS main)

1 every 30-40 deg^2
down to z_{AB}~22 (Stripe82 + CFHQS)

X-ray selection can pick up fainter,
low-lum and obscured AGN
and then sample
the bulk of the AGN population

Spectroscopically confirmed high-z AGN to date

	SDSS	X-ray sel.
$z > 3$	8000	50
$z > 4$	1500	11
$z > 5$	56	3
$z > 6$	10	0

Not even in CDFS/N

Current X-ray surveys are limited by sensitivity over solid angle

Standard optical selection

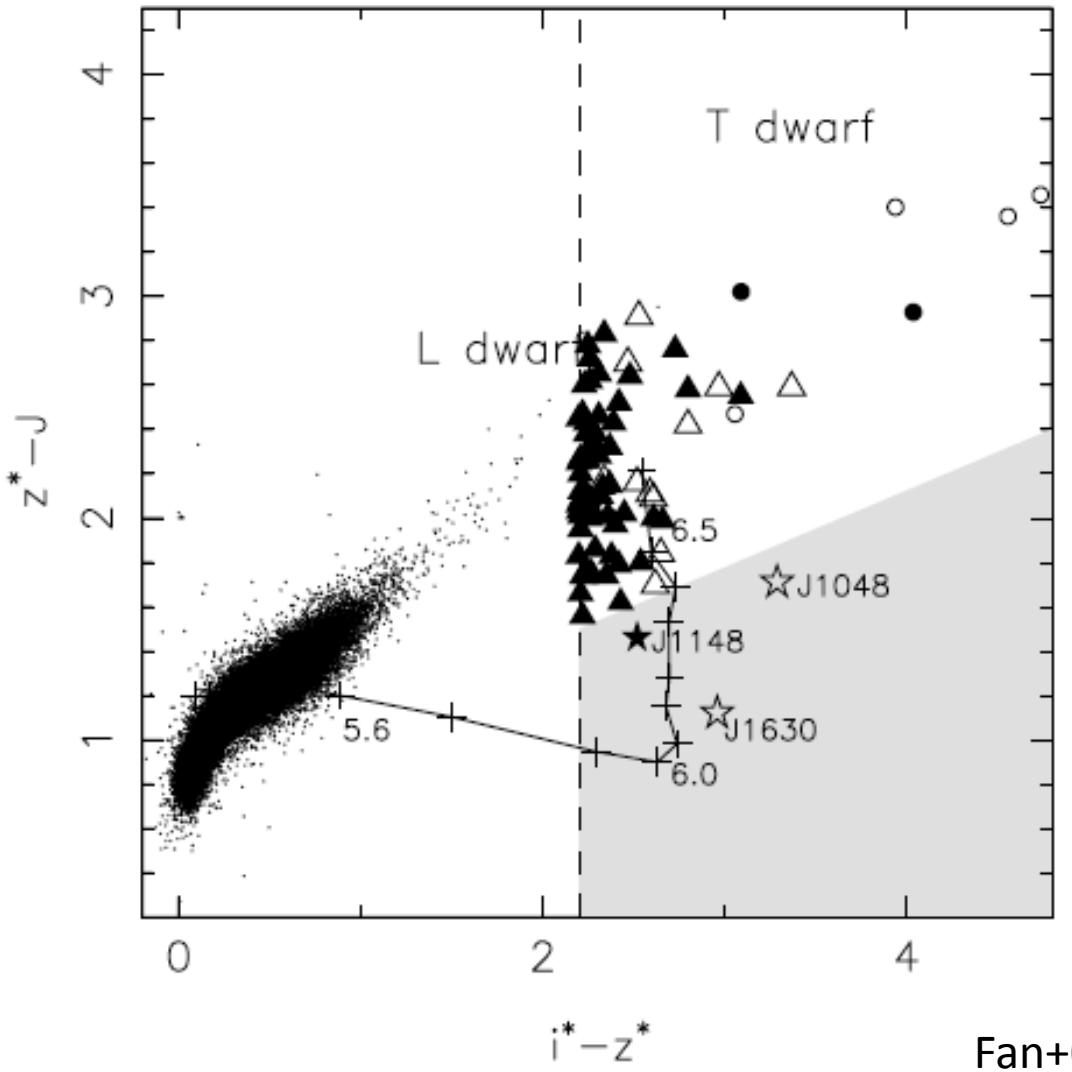
look for i-band dropout : Lya+redward continuum enter in the z band at z>5.7

➔non-detection in u,g,r
and i-z>2.2 for SDSS

➔non-detection in u,g,r
and i-z>2 for CFHQS

main contaminants brown dwarfs: 15 times more abundant than QSO at same mag lim
use J-band to separate.
still spectroscopic success rate <=20%

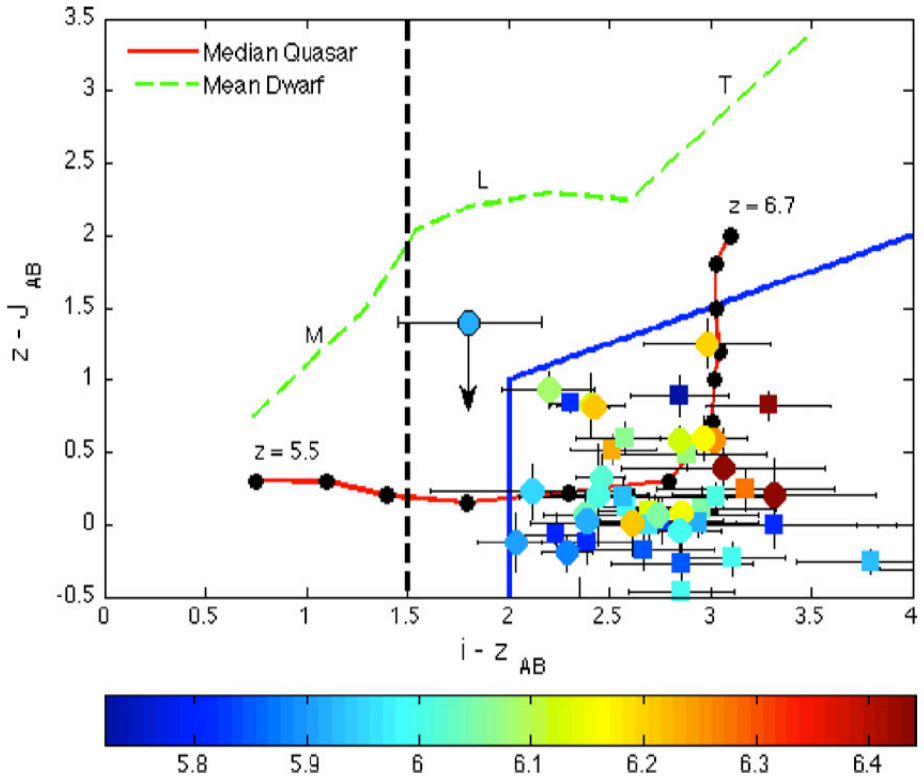
1<i-z<2 colors not searched because of overwhelming BD contaminants (Willott +05), but z>5.5 QSOs expected there

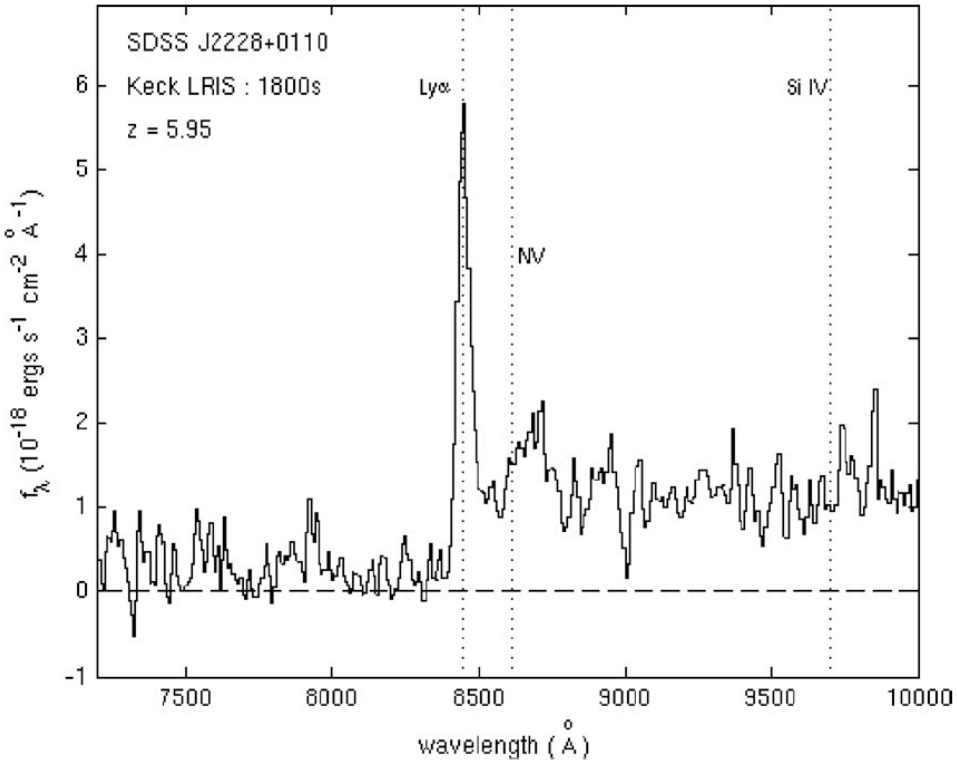


Fan+03

Other possibility: use X-rays to flag out stars, explore a new color space and skip near-IR photometry

Using radio data, instead of X-rays, plus i-z selection on SDSS deep stripe
Zeimann+10 found 1/50 candidates is high-z QSO
it has i-z~1.8 ➔ missed by standard color selection (i-z>2)





narrow Lyalpha?
fwhm_rest=1980 km/s

Using the CSC-SDSS DR7 matched catalog: the MMT/VLT campaign

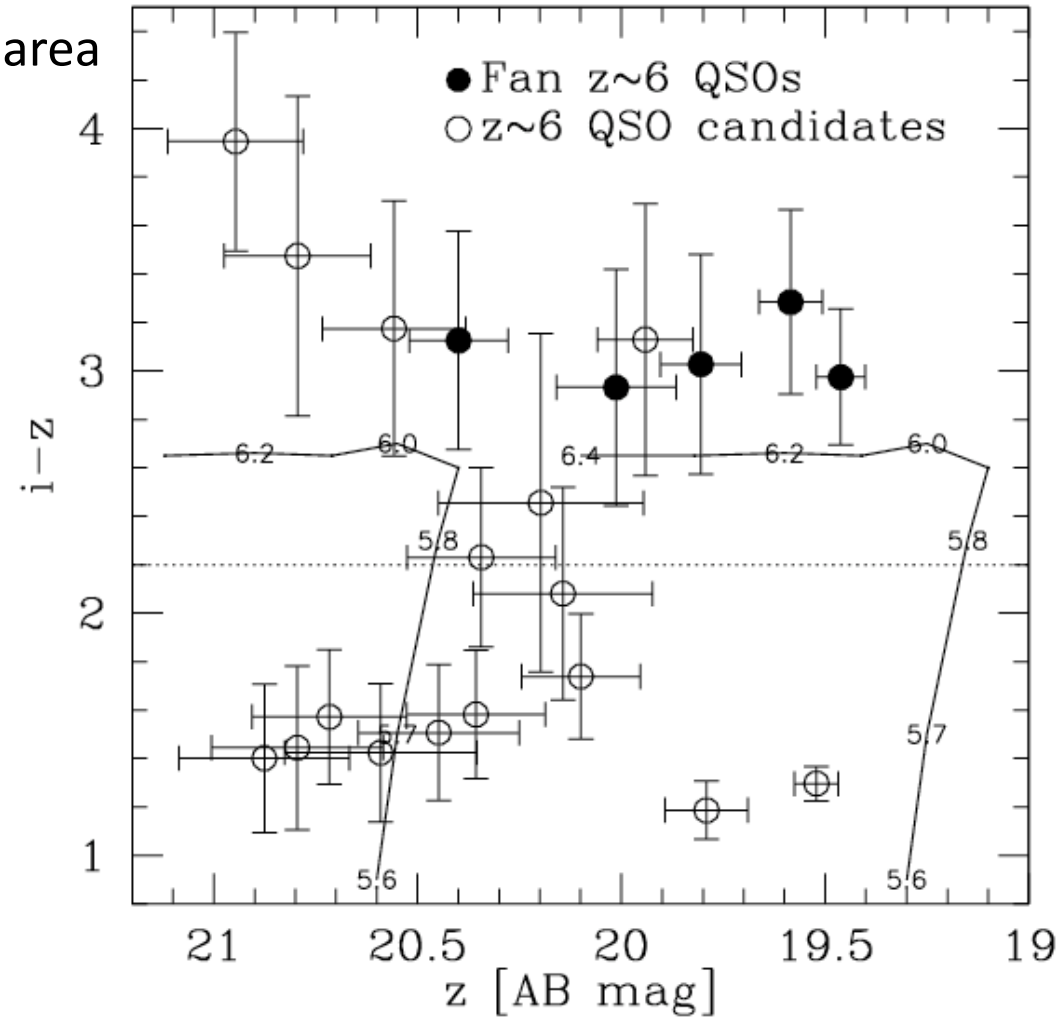
Chandra-SDSS: ~130 deg2 common area

Selection criteria:

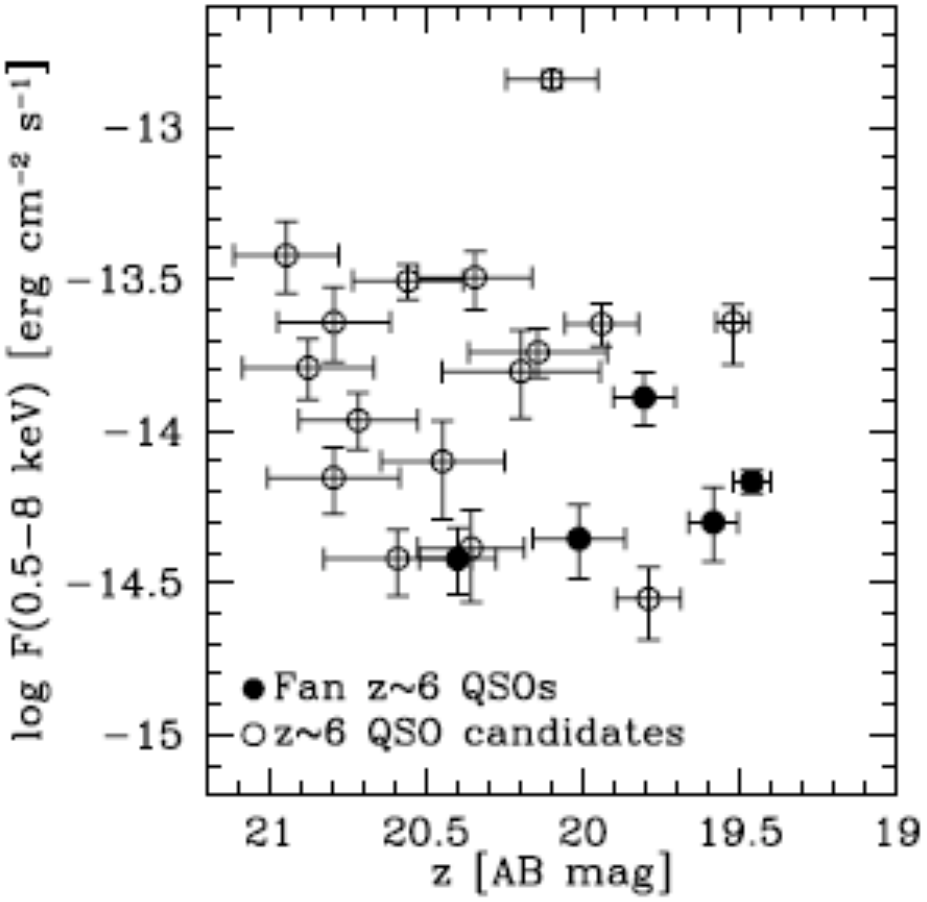
* ugr>23,
* 1sigma lower limit on i-z >1,
* zAB<20.9
* visual inspection of X-ray and SDSS images ok

➔16 candidates

also 5 QSO from Fan recovered by this selection



Using the CSC-SDSS DR7 matched catalog: the MMT/VLT campaign



13 out of 16 candidates observed

at the MMT (2 nights in March 2011)

or FORS2@VLT (20h, service, May-Sep 2011)

brown dwarfs expected to be here

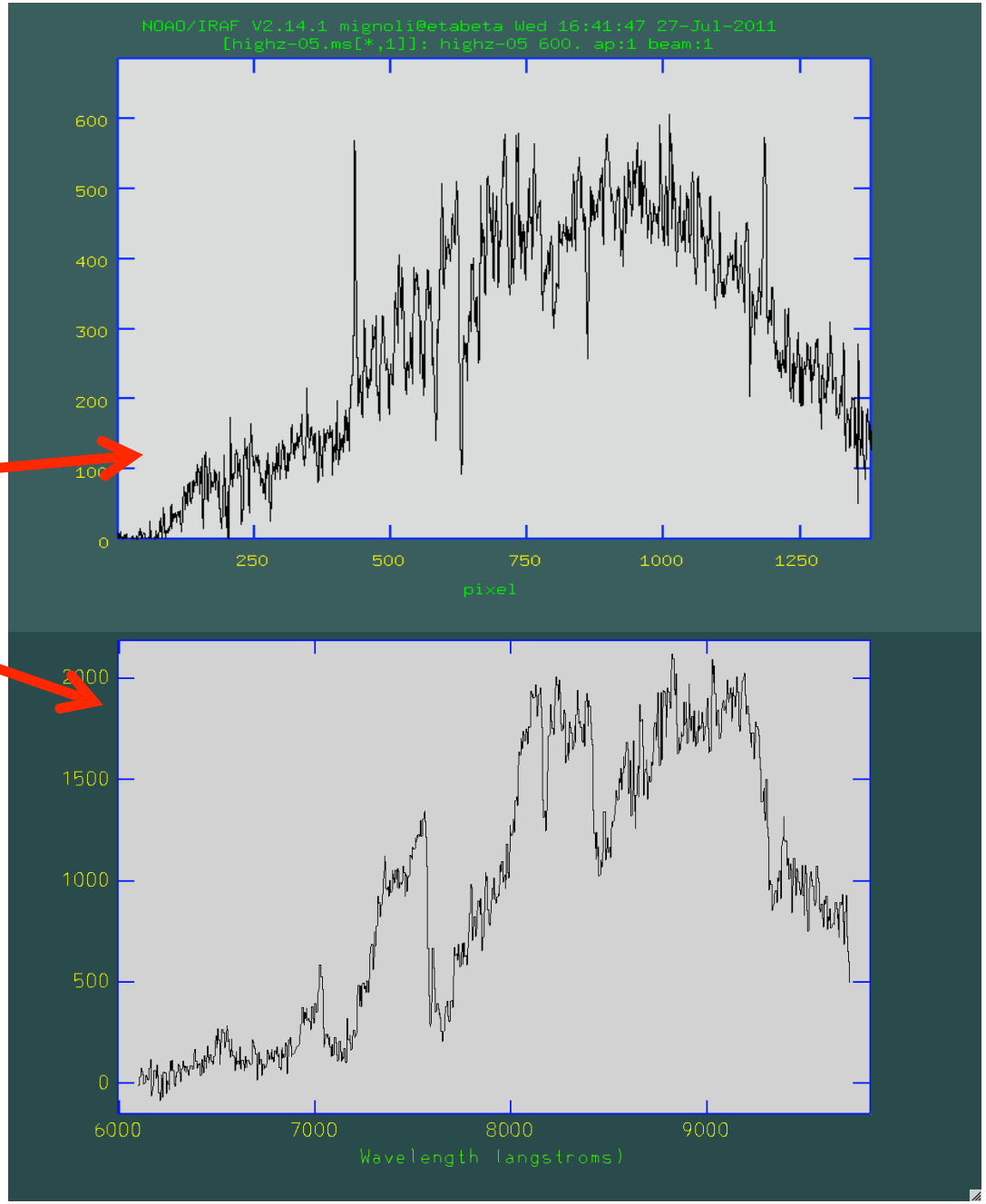
The MMT/VLT campaign: results

NO QSO found:

10/13 obscured AGN at z~1

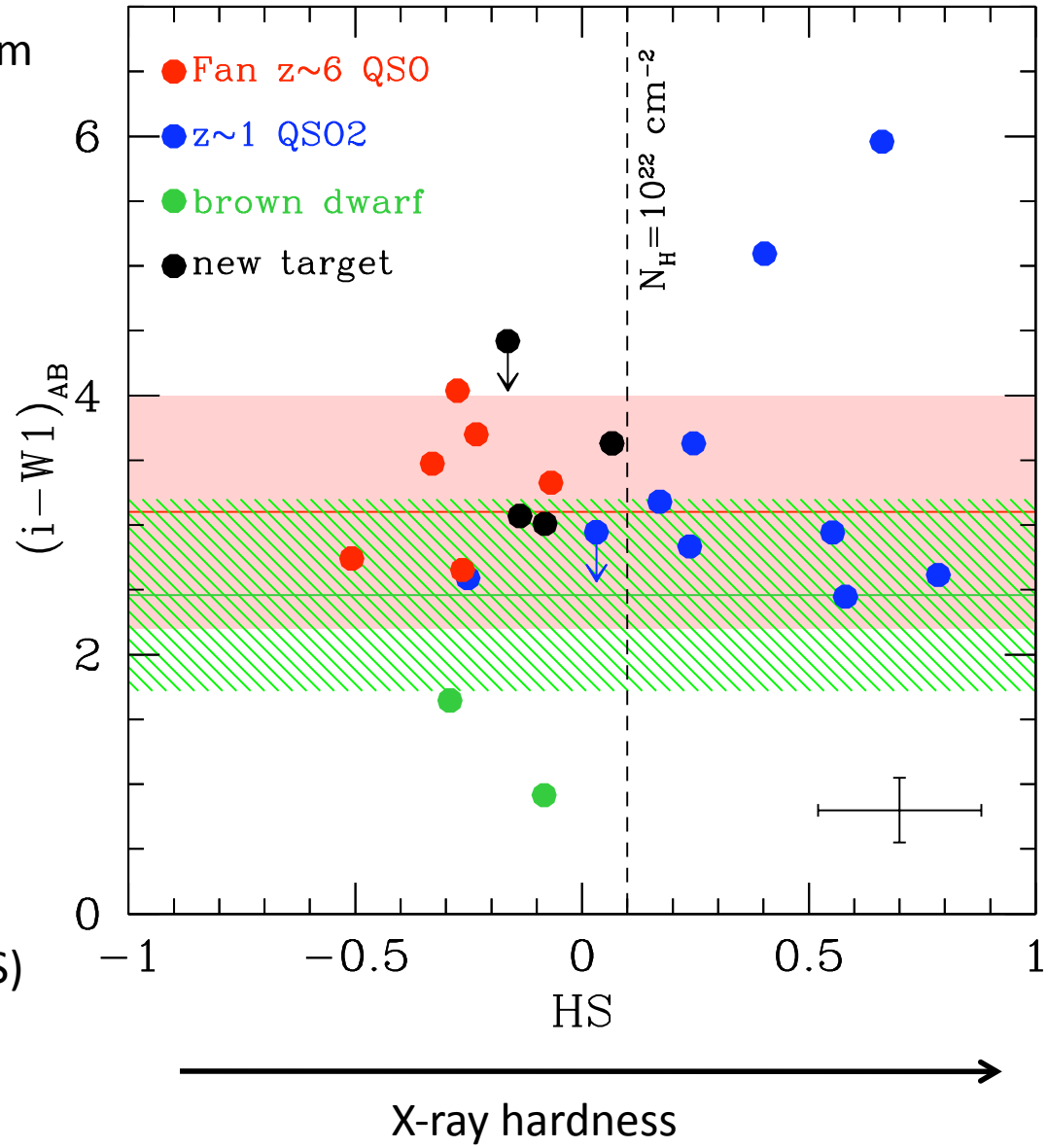
2/13 are brown dwarfs
(X-ray flaring)

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

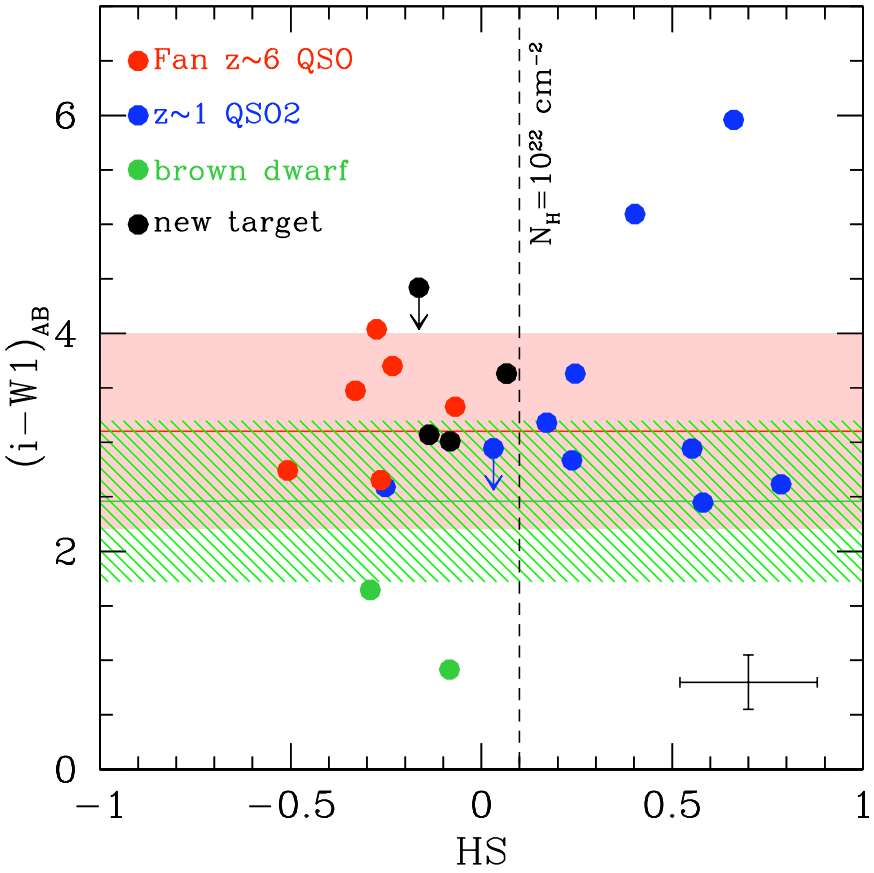
Match SDSSIII-DR8 with
CSC: 320 deg2, ~1e5 obj.
2XMMi-DR3: 500 deg2, 2.6e5 obj:
flim,soft@50% sky coverage ~ 4e-15 erg/cm2/s

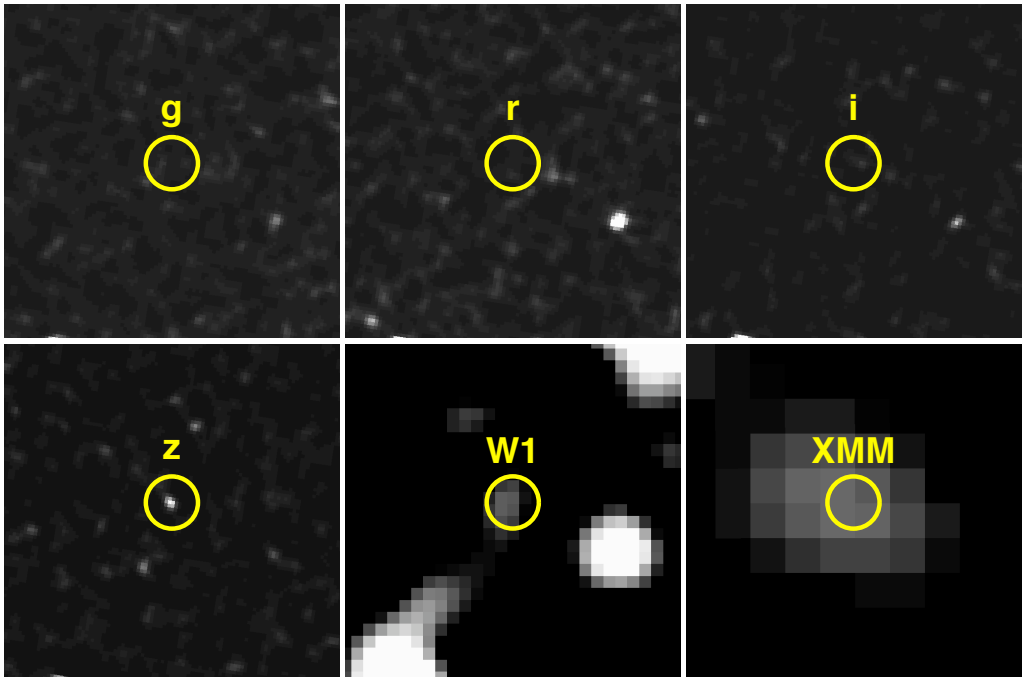
SDSSIII-DR8 = SDSS-DR7 +3000 deg2 (~27% gain)

rough x-ray/optical matched area ~ 420deg2 (~300deg2 allowing for xmm/cxo overlaps?)
"a few" z~6 QSO expected in that area at those limiting X-ray/optical fluxes
again use ugr>3, 1sigma lower lim on i-z> 1, zAB<20.9
and IN ADDITION: HS< 0.1
plus refined visual inspection using VO tool:
http://heasarc.gsfc.nasa.gov/cgi-bin/vo/datascope/init.pl

which searches among all available source catalogs and imaging databases (CFHT, HST, ESO, WISE, and so on) at a user specified position ➔ this removes a significant fraction of contaminants: 4 candidates left

New candidate selection





new targets just proposed for MODS1@LBT (1hr each)

Possible extensions

SDSS deep stripe, ~300 deg2, zAB<22
CFHTLS Wide, ~170 deg2, zAB<24.6
UKIDSS LAS DR9, ~4000 deg2, Yvega<20.2, Jvega<19.6
VISTA VHS 1° release, ~1500 deg2, Yvega<20.6, Jvega=20.2-20.6

chandra source catalog: ~320 deg2 , fsoft~4e-15 (~100,000 objects)
xmm source catalog: ~500 deg2, fsoft~4e-15
total (non overlapping) X-ray coverage ~700 deg2?

sky fractions:
chandra ~8e-3
xmm ~1.2e-2
totalX ~1.7e-2 ?

likely to increase by fact of ~2
(csc-sdss gives ~130 deg2 vs ~64 deg2 expected)

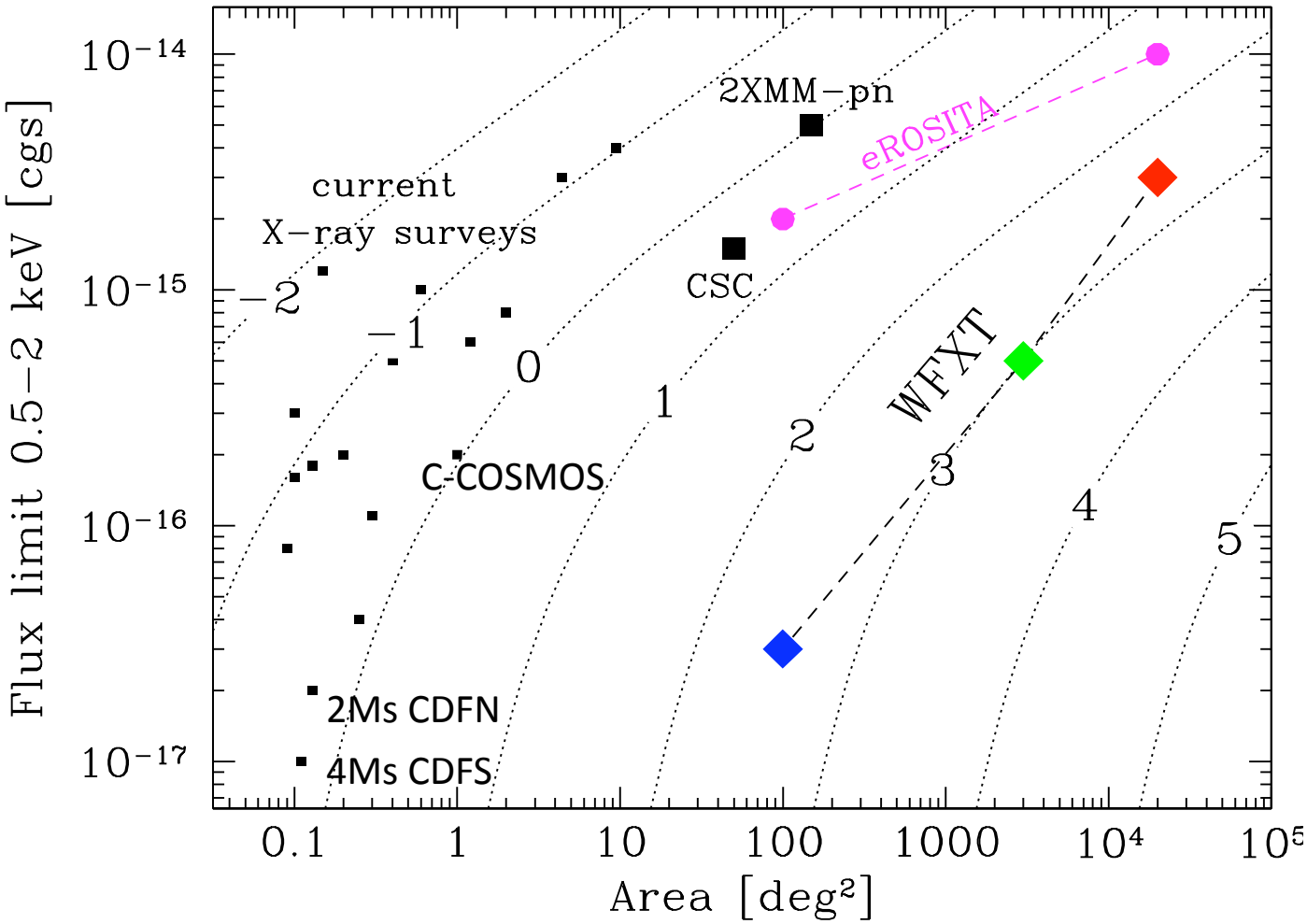
expected matches with X-ray source catalogs
CFHTLS Wide:
~2.6 deg2 chandra
~6 deg2 totalX
➔cosmos et al. likely in a better shape?

UKIDSS
~60 deg2 chandra
~130 deg2 totalX

VHS
~24 deg2 chandra
~52 deg2 totalX

UKIDSS and VHS have little overlap (dec >=0 and <=0, respectively)
➔ total area 5500 deg2, chandra ~84 deg2, totalX~180 deg2

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

NEED 100-1000 deg^2 TO DEEP SENSITIVITY ➔
WFXT mission (see Murray +10, Rosati +11)

so either wait for WFXT (for how long? L2, M4, US?) or meanwhile..

go to slightly lower z, e.g. z>5

- gain of fact 4 in space density wrt z>6 QSO
- no systematic search, i.e. specific color selection, in SDSS? (although 56 QSOs at z>5 already found in DR7)
- ~90 QSOs at z>5 expected in CSC