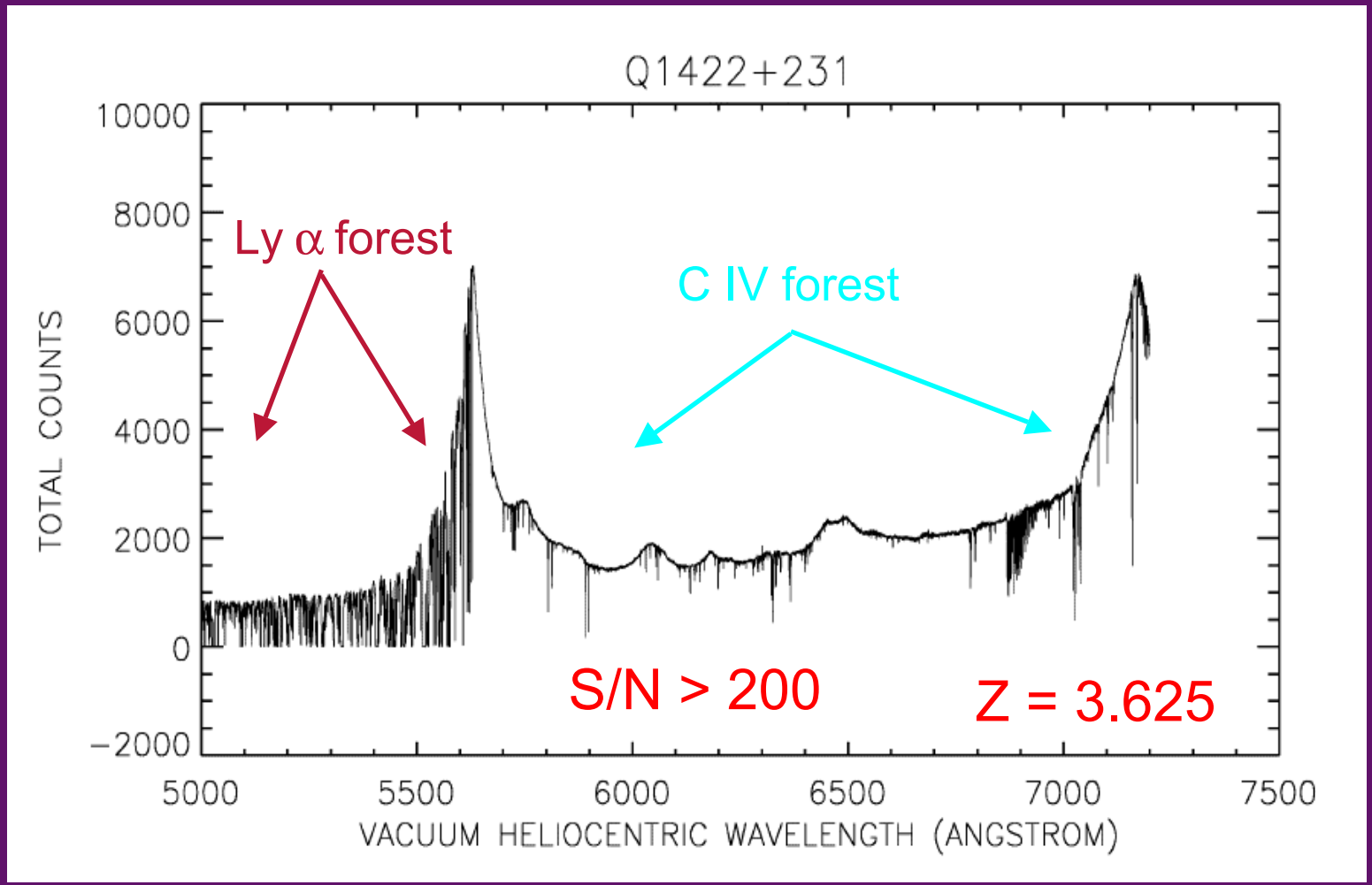
High Redshift Galaxies and the Ionization of the IGM

- Did the intergalactic hydrogen reionize at z just beyond 6 ?
- Can we find the galaxies or faint AGN that ionize the gas at these redshifts ?

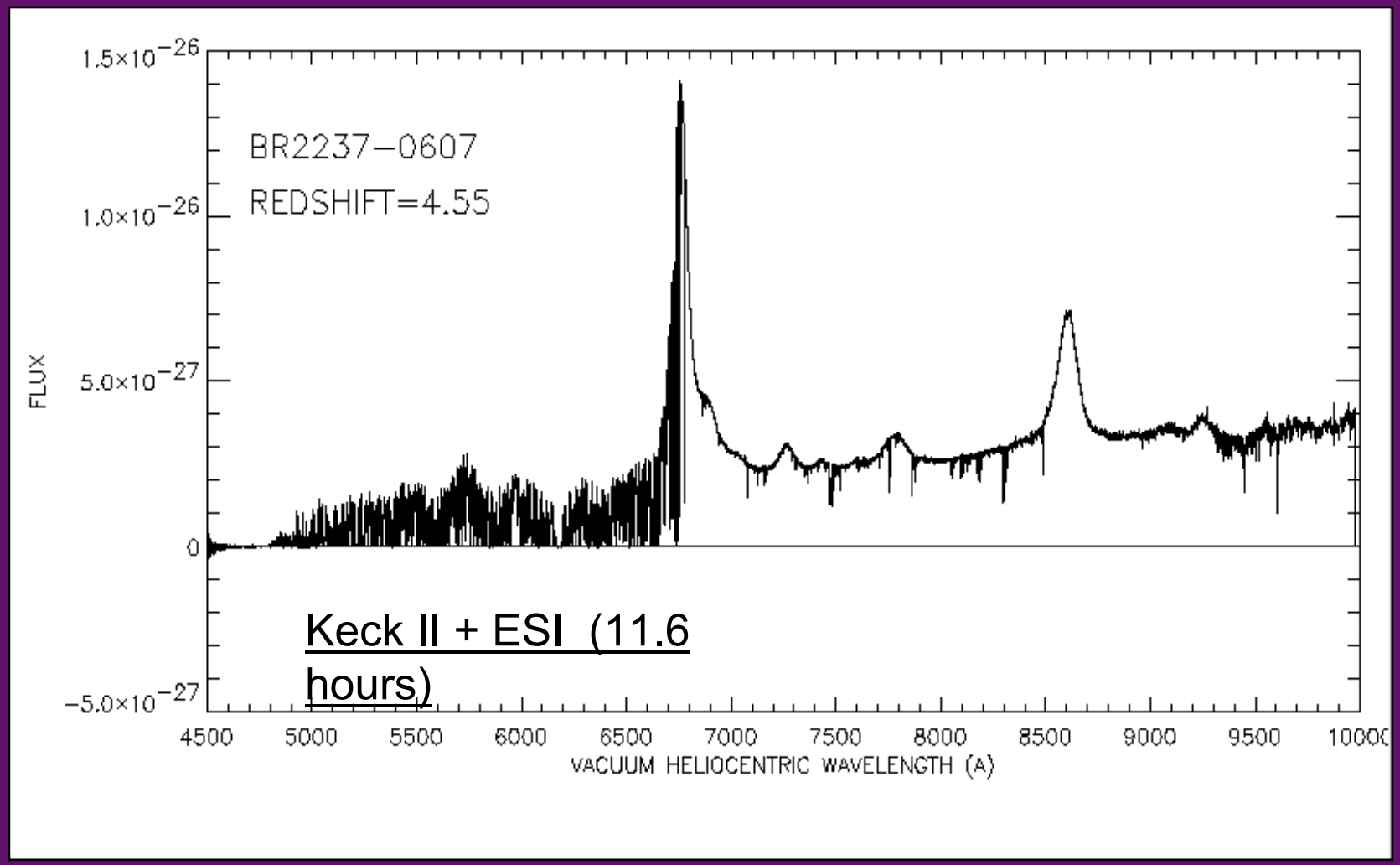


KeckI + HIRES (20 hours)

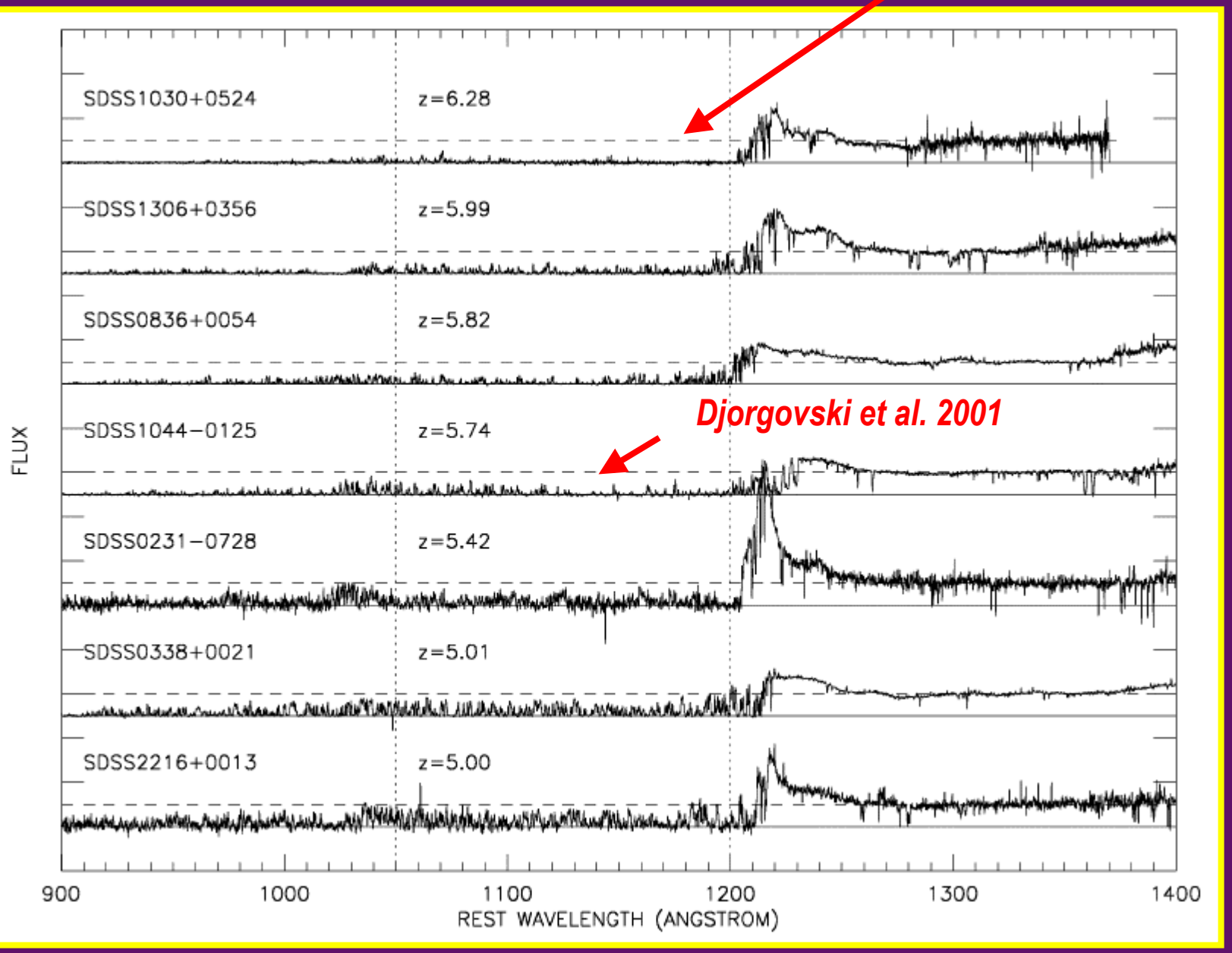
C IV forest to log N(CIV) = 11.7

The forest is still very clear at z=4.5

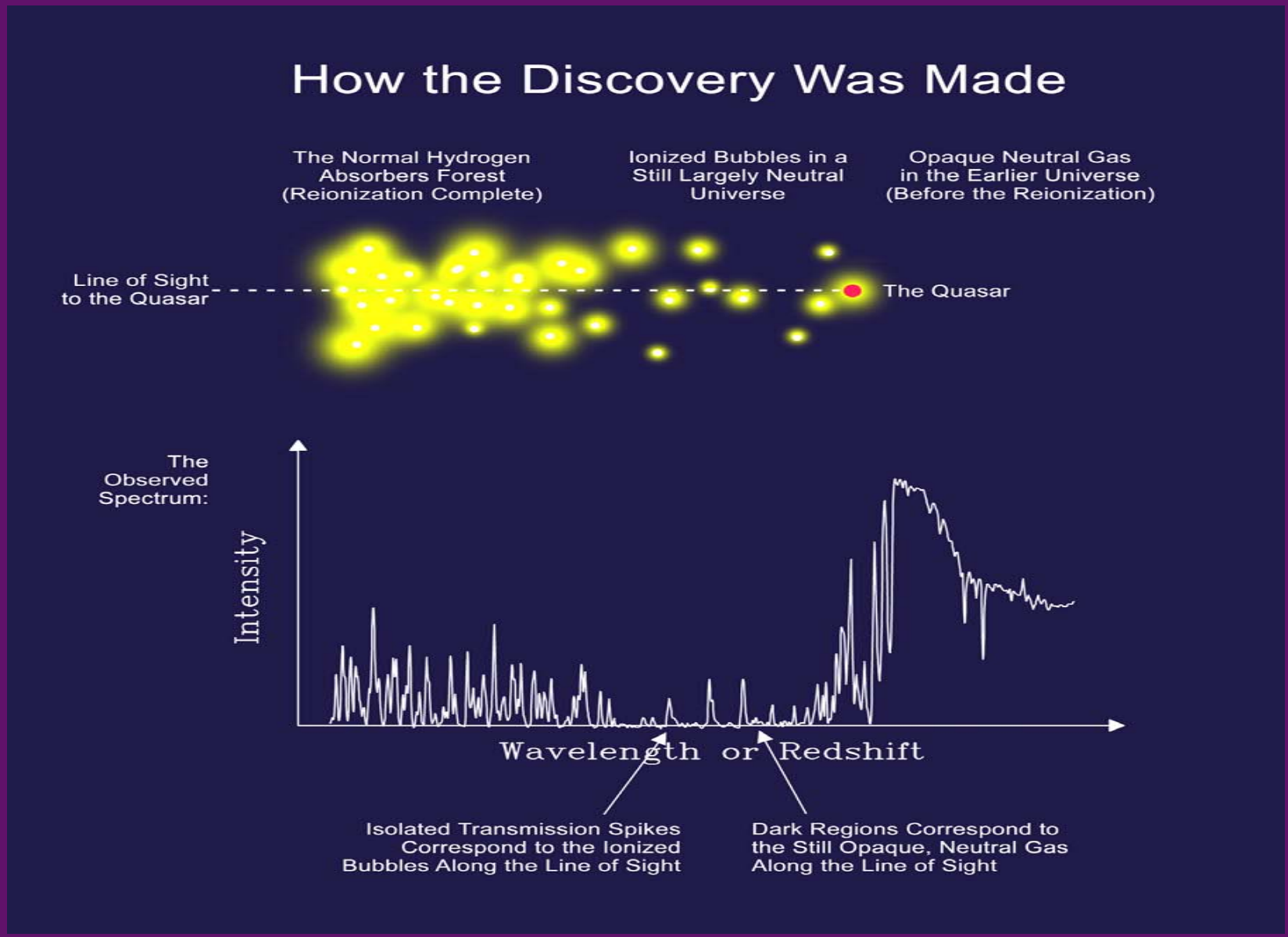
ESI Spectrograph (Songaila 2002)

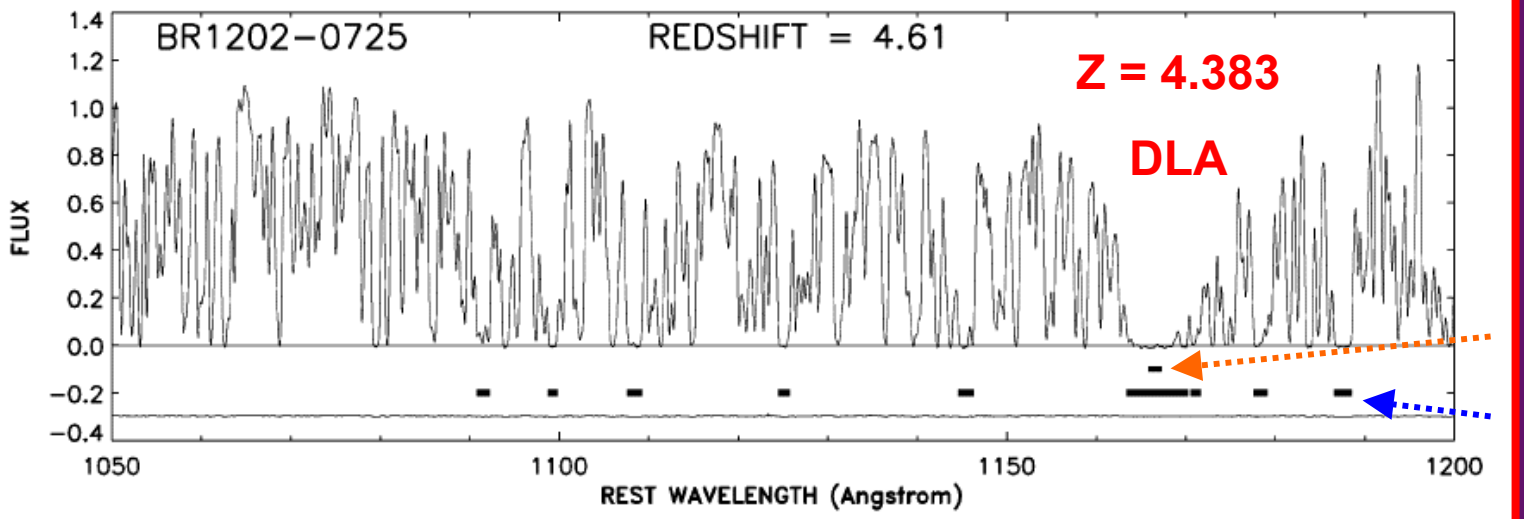


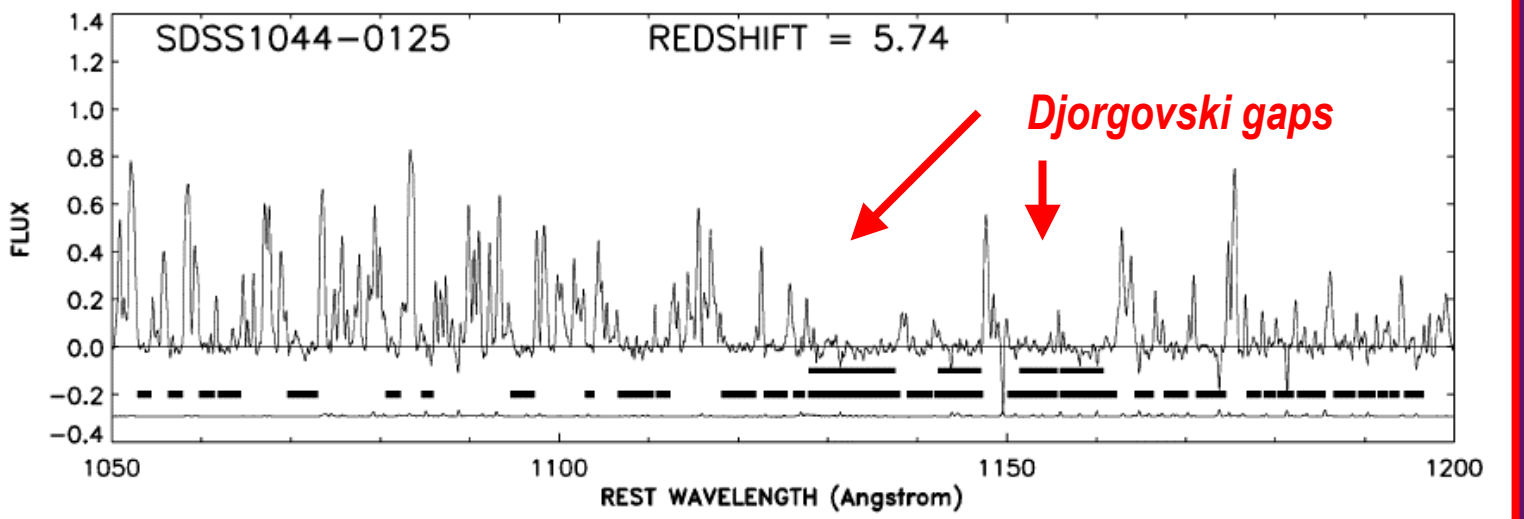
Keck ESI Exposure times = 3 – 7 hours



Djorgovski et al, 2001







Songaila & Cowie 2002,
AJ 123, 2183

τ (Lya) > 2.5

over rest–frame width > 1 A

Big Question

- H REIONIZATION at z~6.2 ???

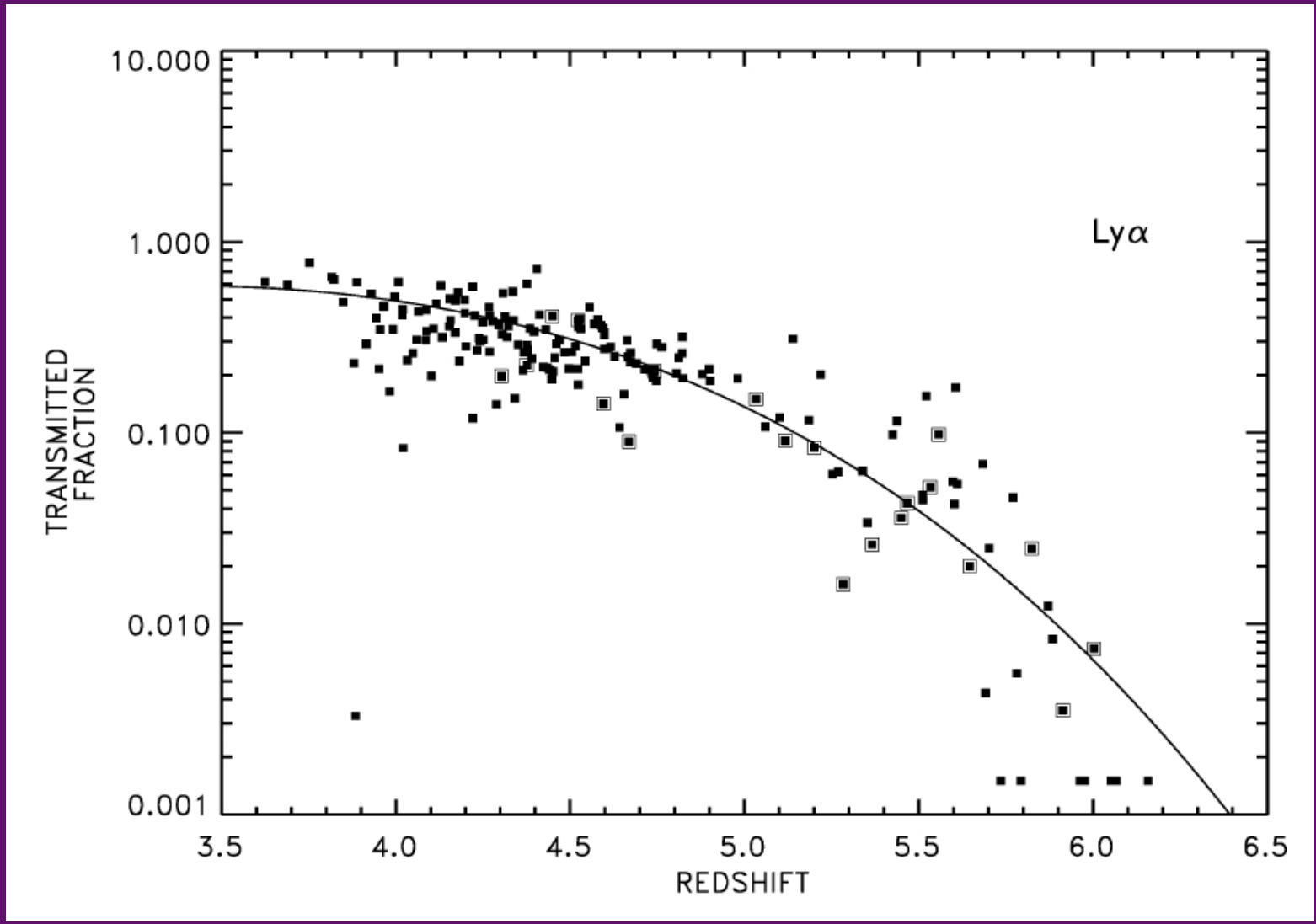
•Or is it just the natural thickening of
the forest as we move to high redshift?

VERY HARD to tell the difference between an optical
Depth of 10 and one of 10000!

ONE TEST: is there an abrupt transition at some redshift
or is the evolution a smooth extrapolation from lower redshifts……

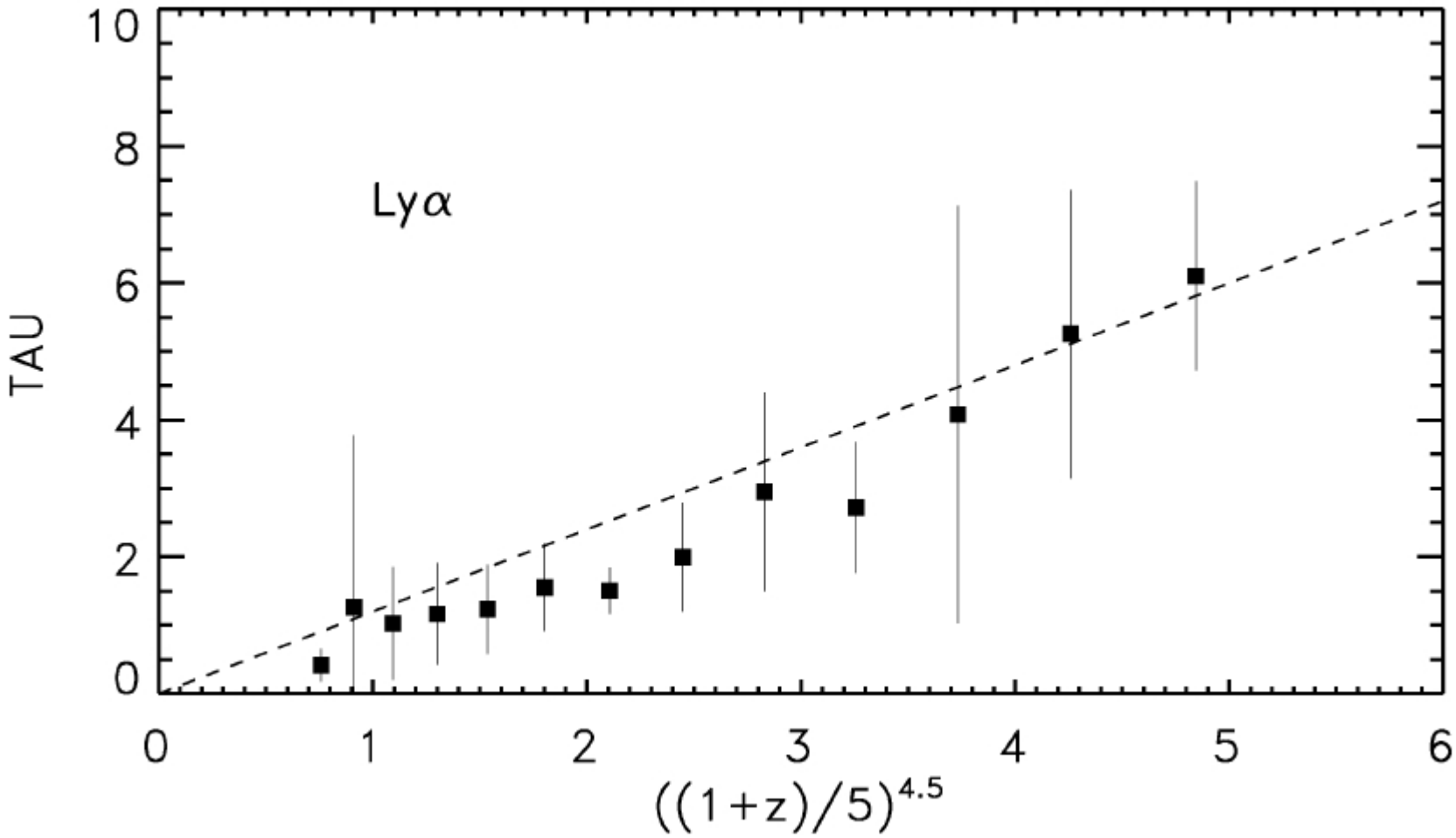
Mean transmission in Ly α forest (ESI sample)

25 Angstrom bins (rest-frame) blueward of Lyα emission (1075-1175 A)



Songaila 2003

Mean observed points with dispersion

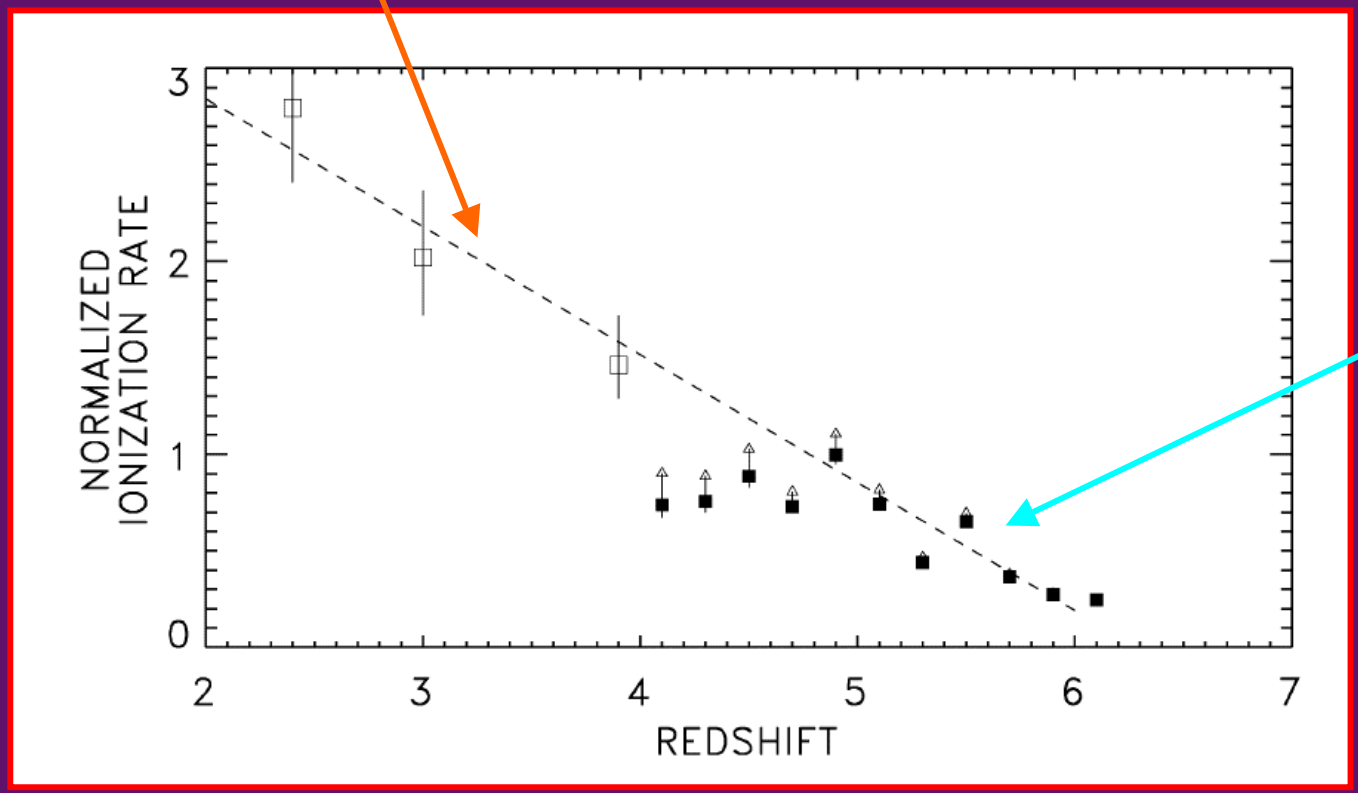


Ionization rate as a function of redshift

$$g \equiv \Gamma_{-12}\, T_4^{0.75} \left(\frac{\Omega_m}{0.35}\right)^{0.5} \left(\frac{\Omega_b h^2}{0.0325}\right)^{-2} \left(\frac{H_0}{65\ \mathrm{km\ s^{-1}\ Mpc^{-1}}}\right)$$

Γ_{-12} = ionization rate/baryon in units of 10^{-12}/s

(McDonald, 2000)

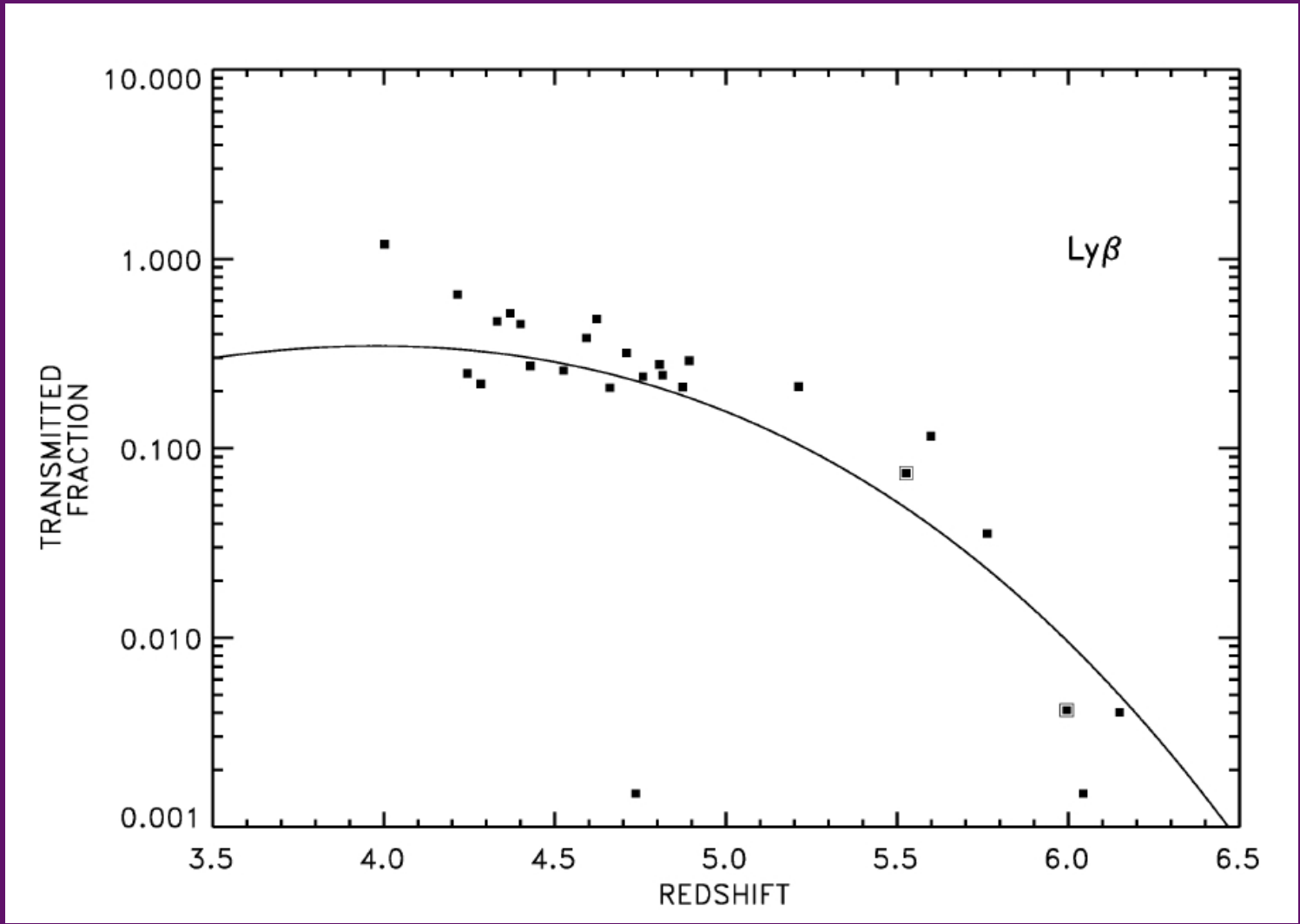


(ESI sample)

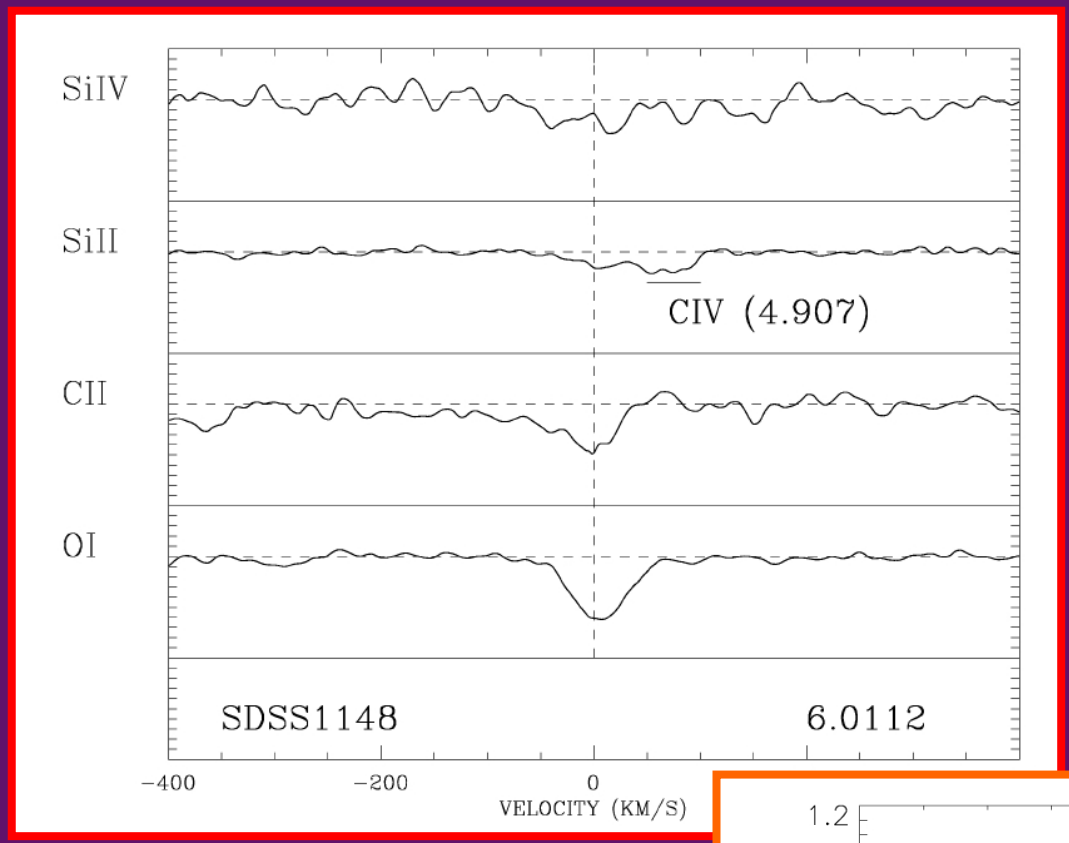
See also Songaila & Cowie 2002, AJ 123, 2183

Mean transmission in Ly β forest (ESI sample)

25 Angstrom bins (rest-frame) blueward of Lyα emission (1075-1175 A)



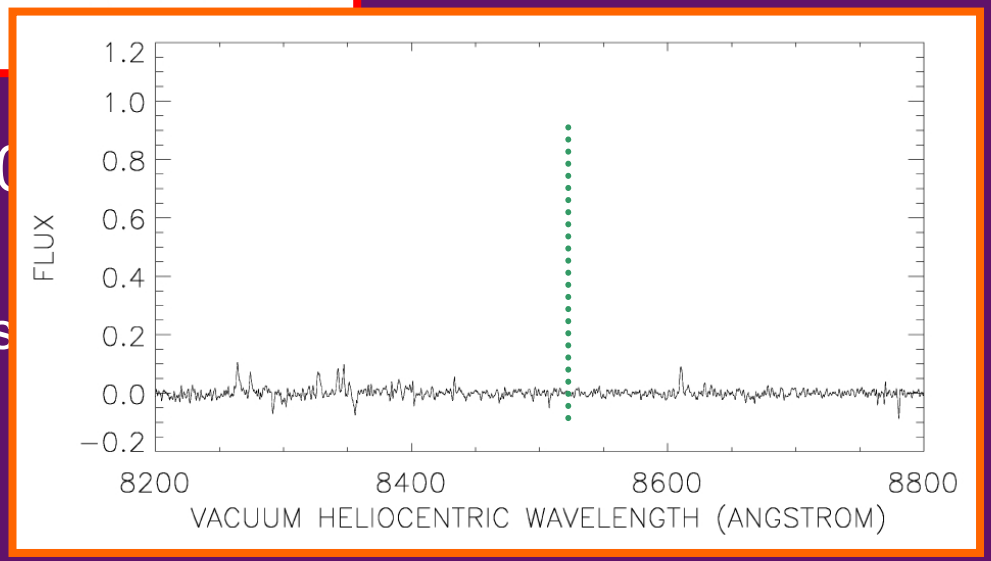
Songaila 2003



DLA at z = 6.0

At z ~ 6, can detect DLAs
ionization lines

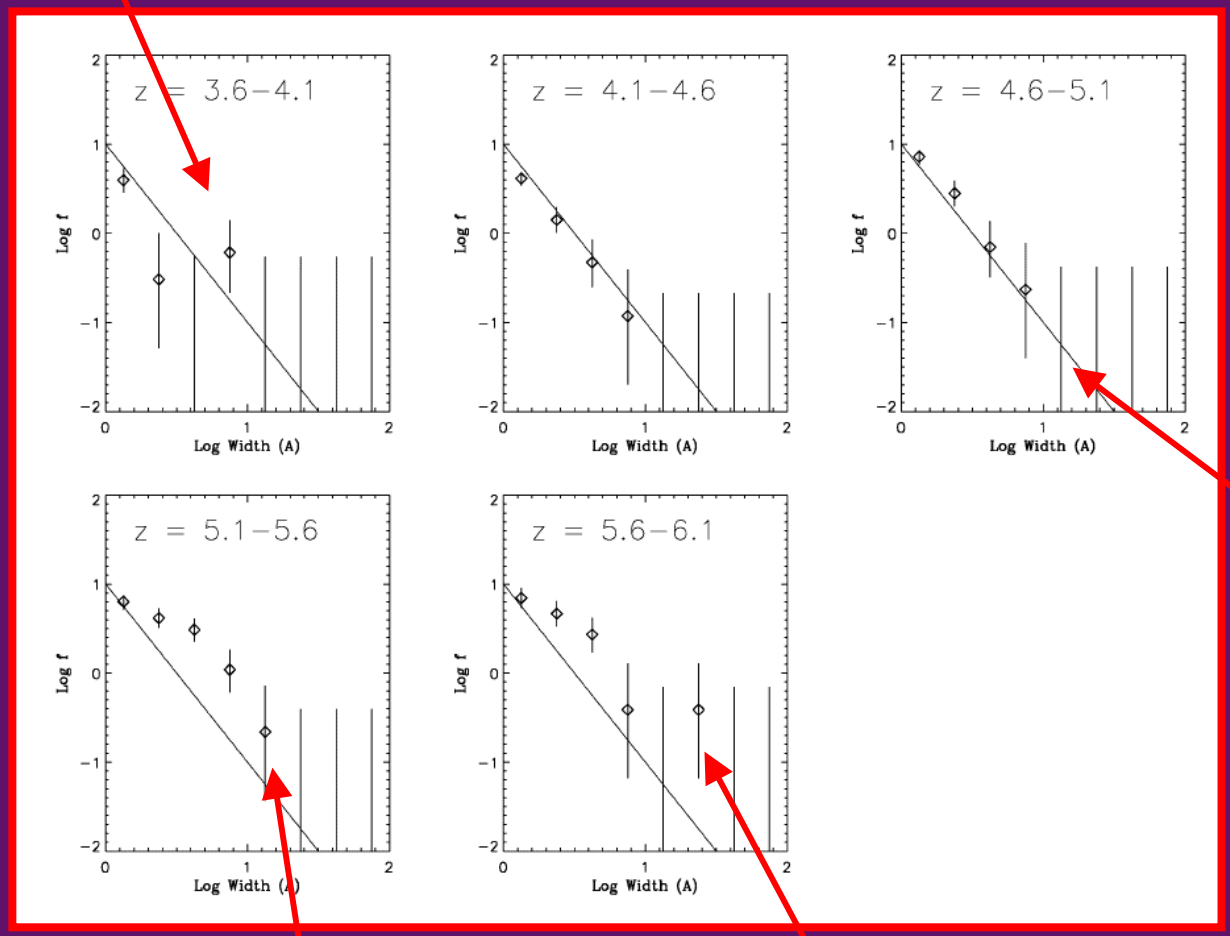
No confirming Ly α line



Distributions of Dark Gaps

DLA

Contiguous regions with $\tau > 2.5$

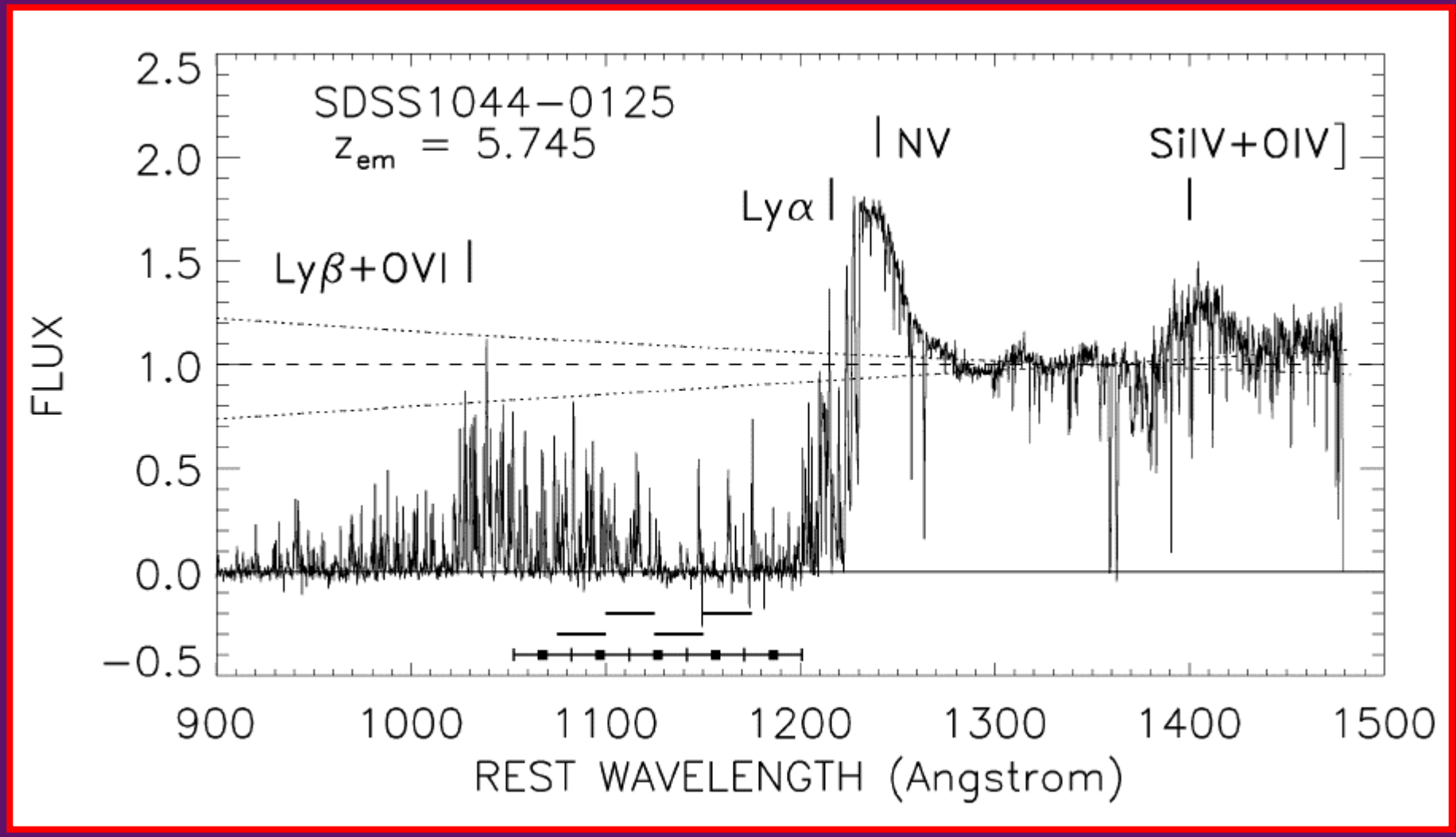


Fiducial line:

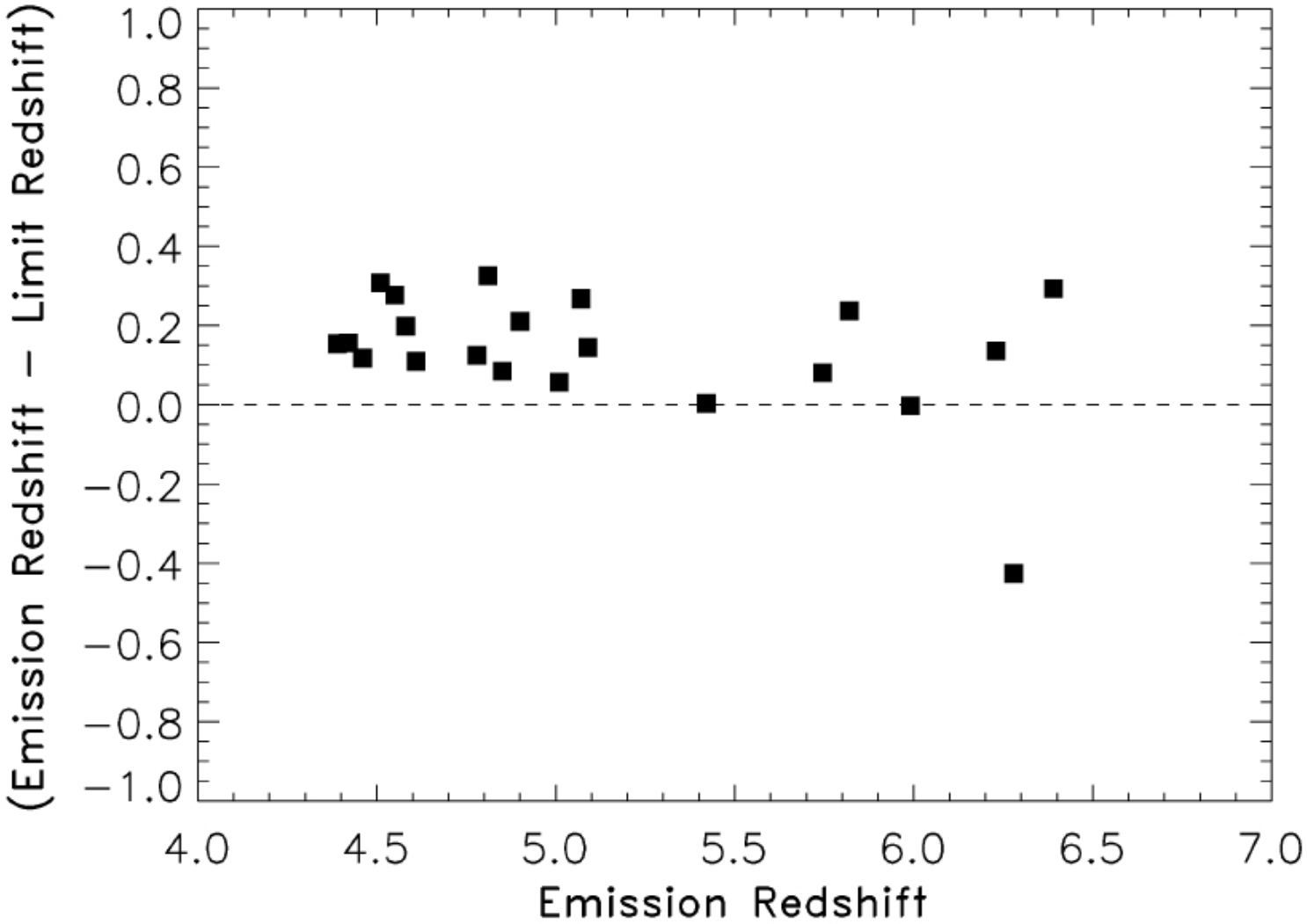
–2 power law slope normalized at z=4.75

Djorgovski et al. gap

Becker et al. gap


SDSS1044−0125
z_{em} = 5.745
NV
SiIV+OIV]
Lyα
Lyβ+OVI
FLUX
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
900
1000
1100
1200
1300
1400
1500
REST WAVELENGTH (Angstrom)

Photon Mean Free Path at these redshifts?



Songaila 2003

CONCLUSIONS

- Forest thickness evolves quite smoothly to z=6.2
- Metals in the IGM to the highest redshifts
- CIV distributions nearly constant from z=1.6 to z=5.4
- Minimum metallicity nearly constant over redshift range

•Need roughly constant production rate of ionizing photons

CAN WE FIND THE AGN OR GALAXIES PRODUCING THE IONIZATION AT THESE REDSHIFTS?

Chandra data (AGN)

L alpha searches (Galaxies)

CAN WE USE THE HIGH REDSHIFT GALAXIES TO TEST THE OPACITY OF THE IGM AT z>>6 ?

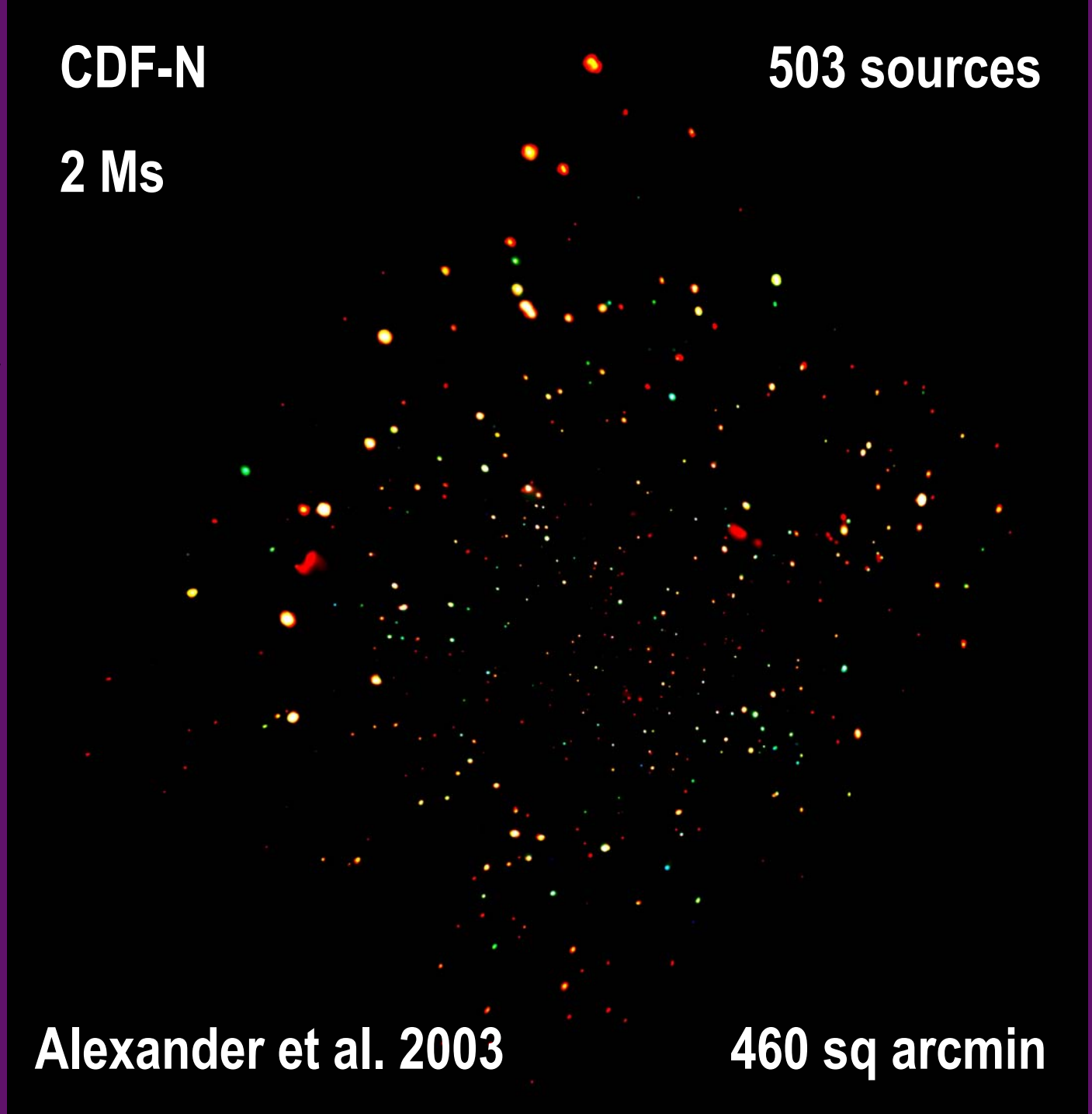
Fundamental goal of Chandra: resolve hard XRB into discrete sources

At these energies, photons can penetrate all but highest column densities (10^{24} cm^{-2})

Two deepest X-ray surveys:

1 Ms (Brandt et al. 2001)**, now 2 Ms, of Chandra Deep Field North (CDF-N)**

1 Ms (Giacconi et al. 2002) **of Chandra Deep Field South (CDF-S)**


CDF-N
503 sources
2 Ms
RED:
0.5-2 keV
GREEN:
2-4 keV
BLUE:
4-8 keV
Alexander et al. 2003
460 sq arcmin

HDF

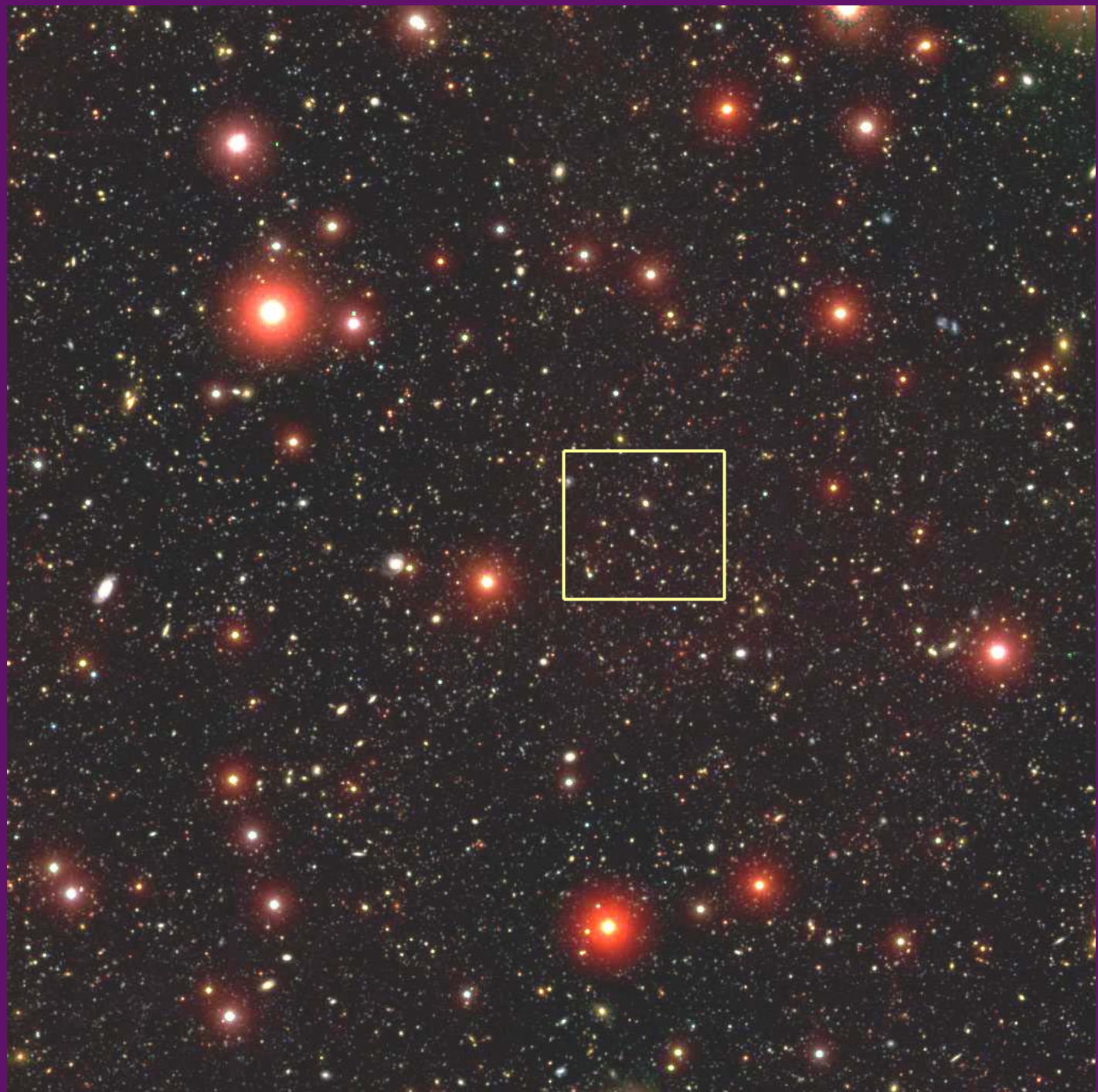
B,R,Z

SUPRIME

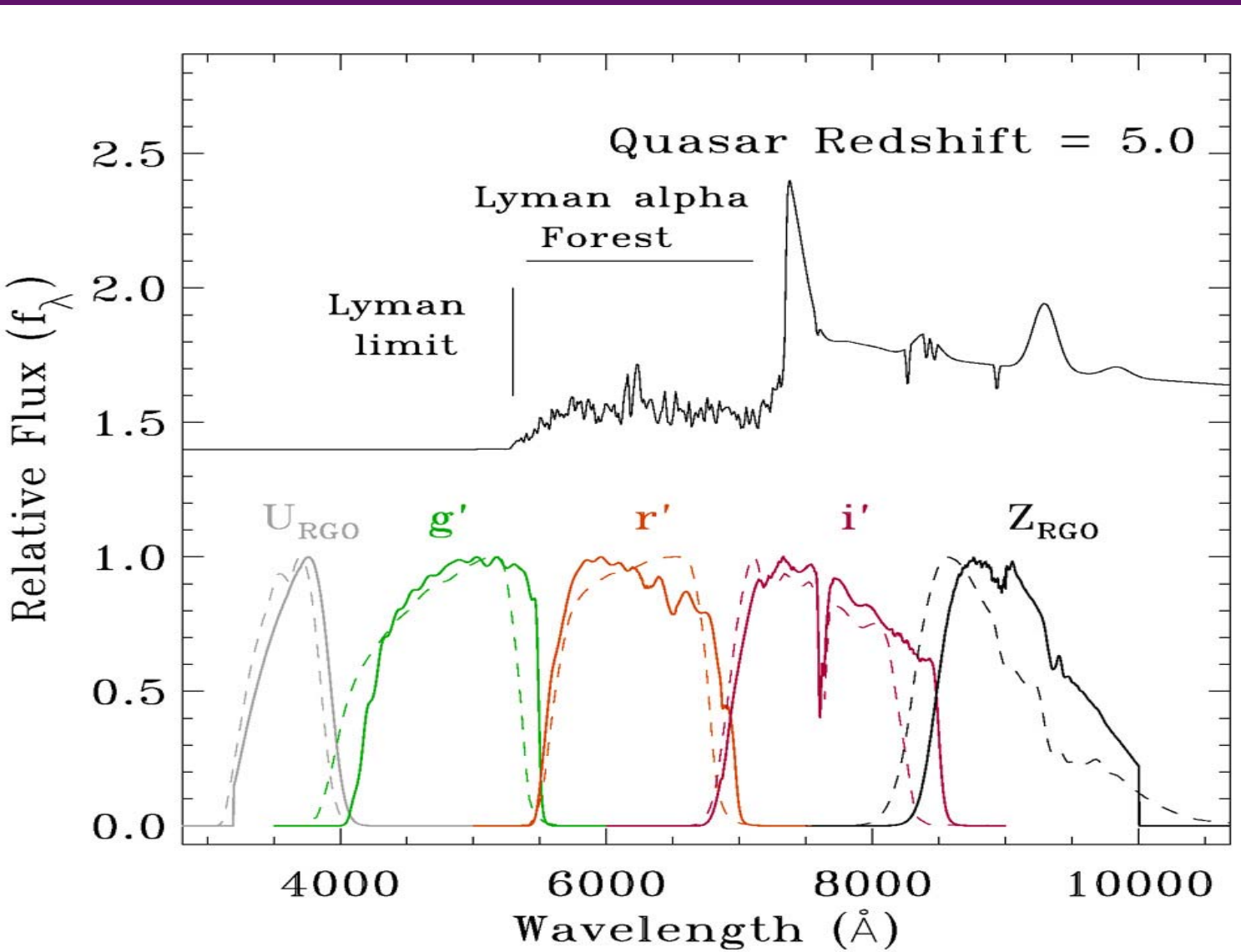
15′ X 15′

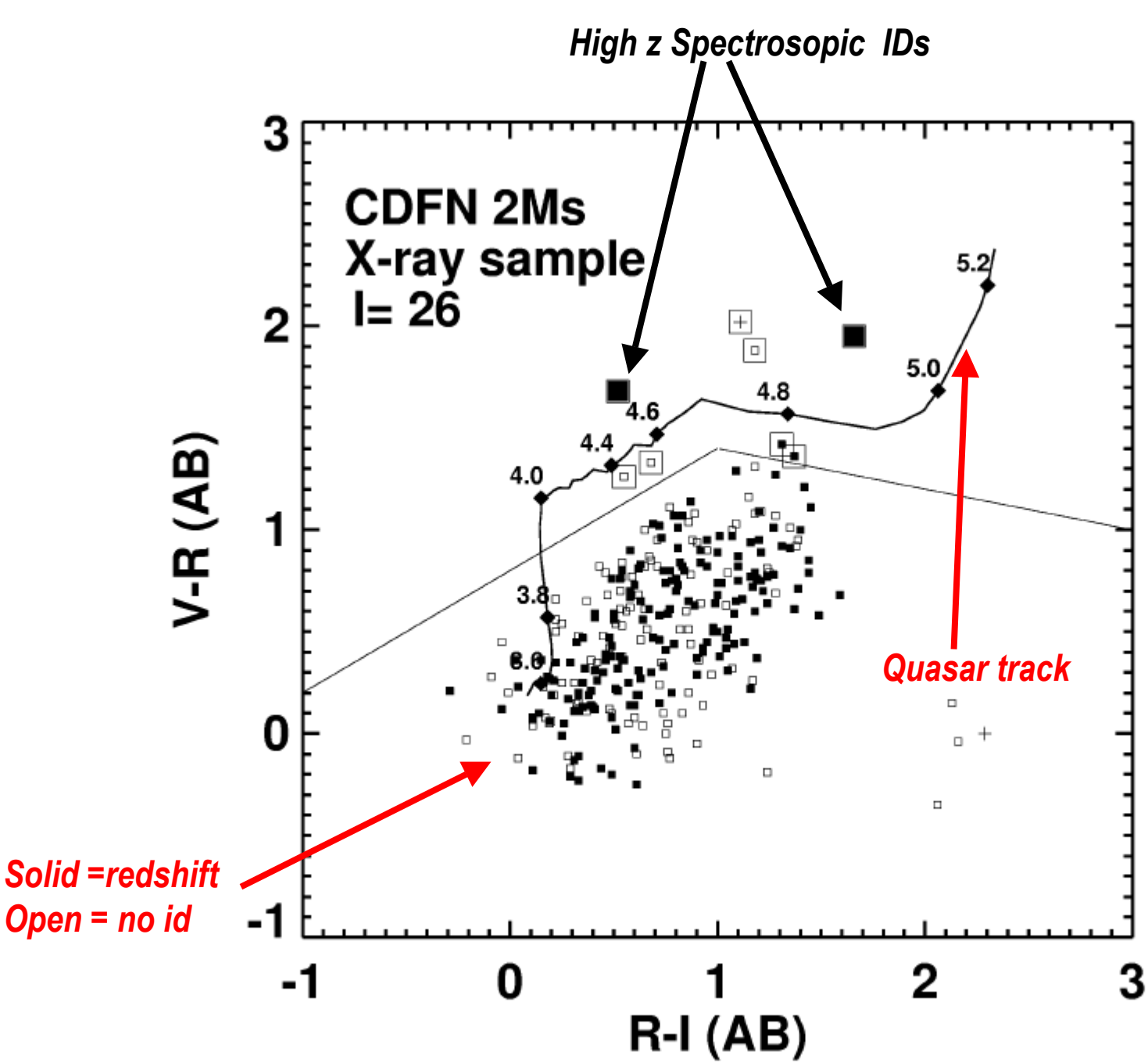
Capak

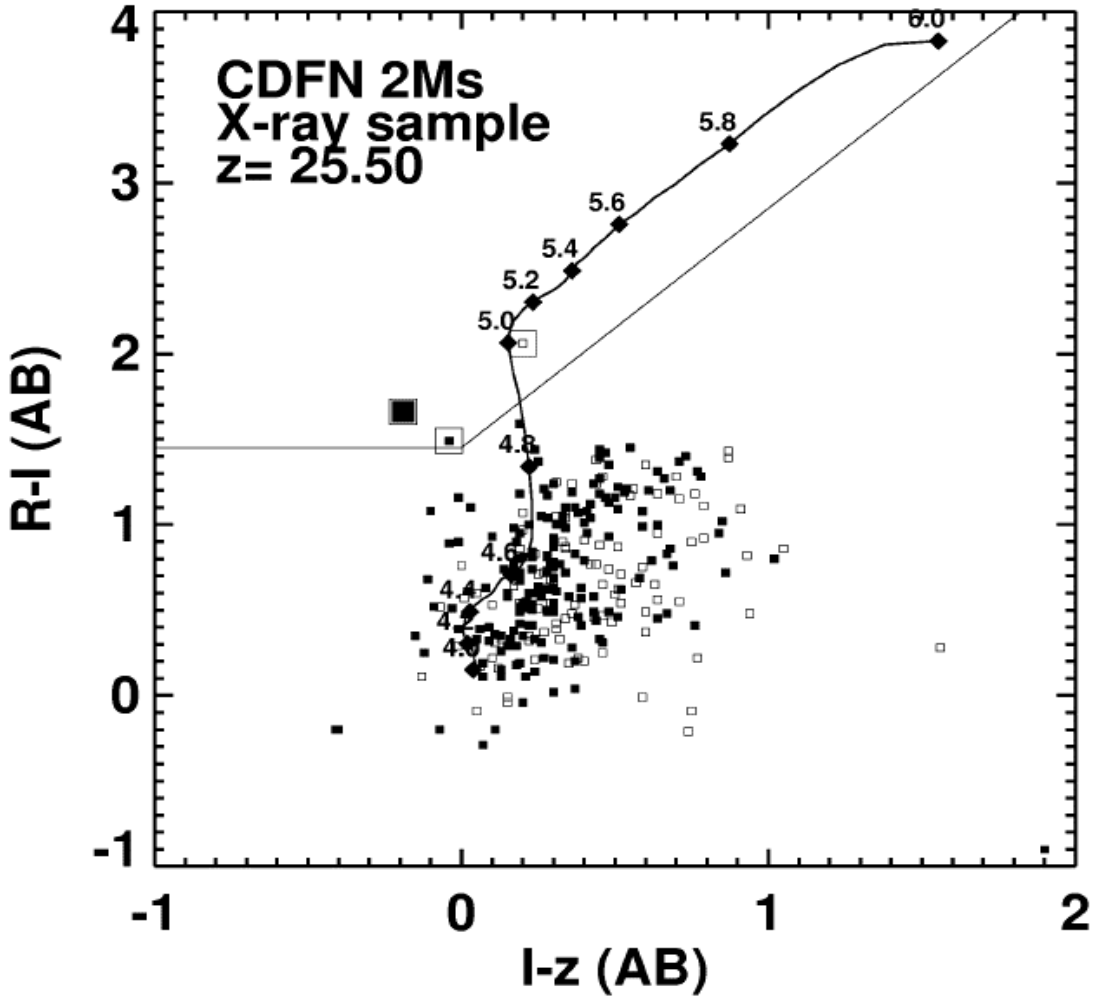
et al. 2002



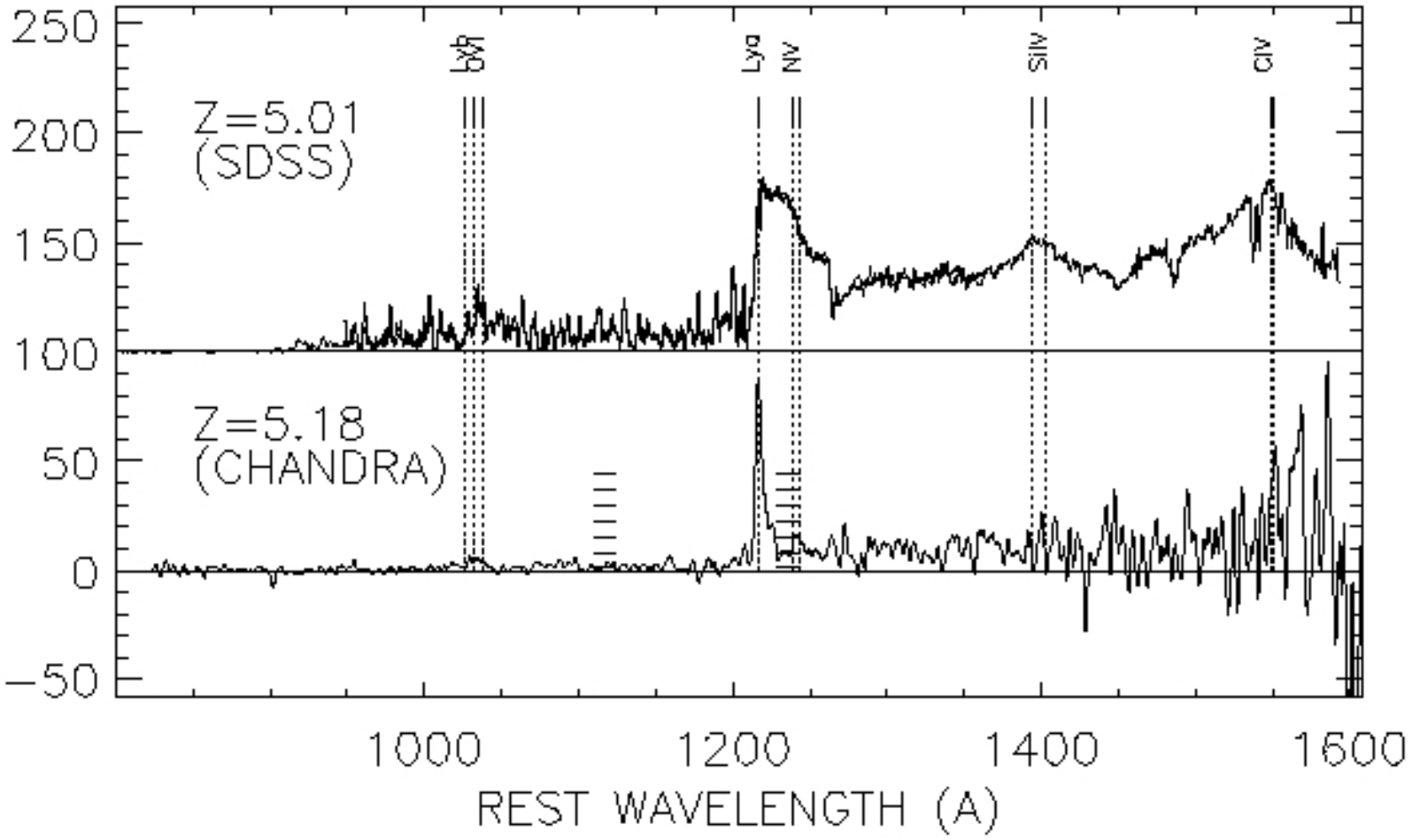
McMahon

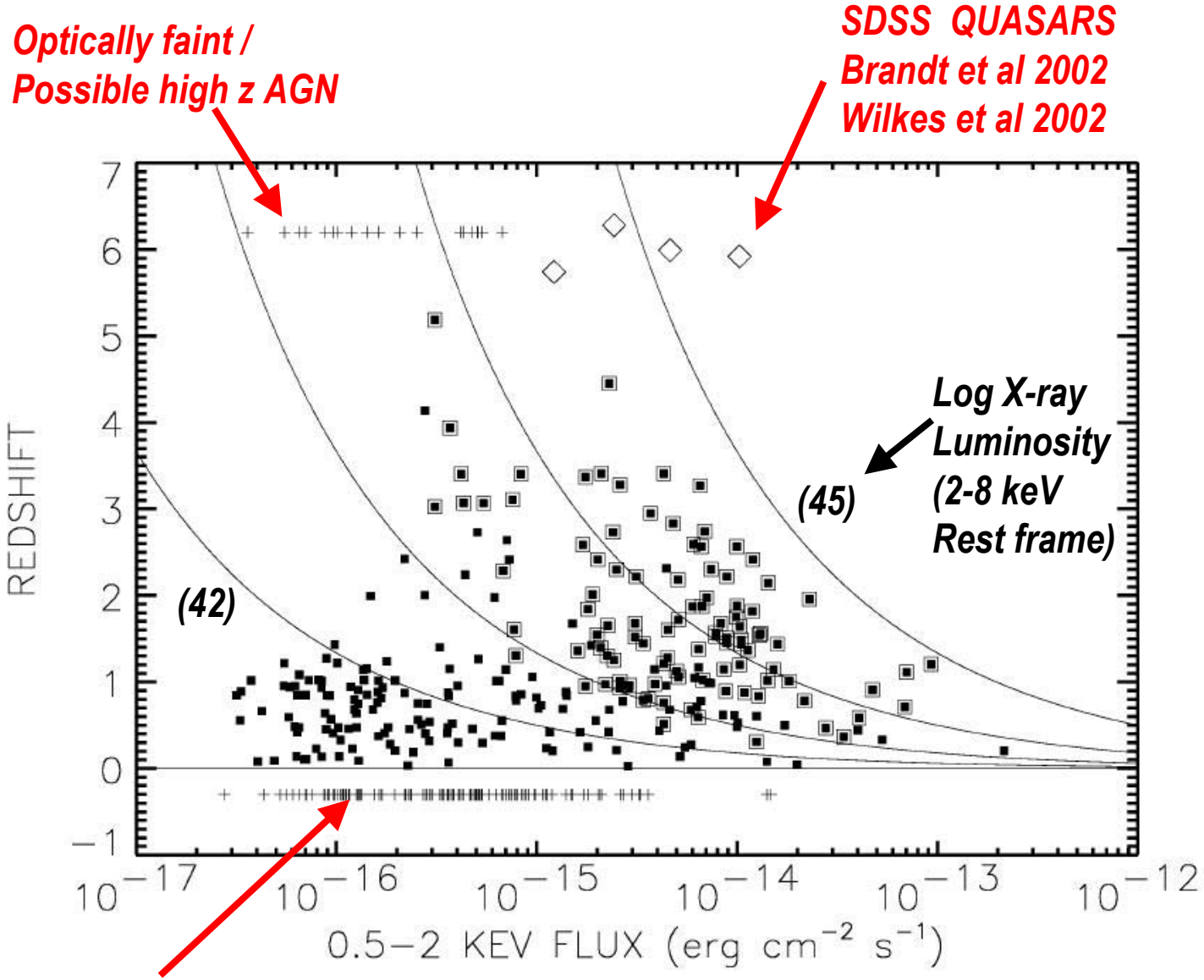

Quasar Redshift = 5.0
Lyman alpha
Forest
Lyman
limit
U_{RGO}
g'
r'
i'
Z_{RGO}
Relative Flux (f_λ)
2.5
2.0
1.5
1.0
0.5
0.0
4000
6000
8000
10000
Wavelength (Å)


High z Spectrosopic IDs
CDFN 2Ms
X-ray sample
I= 26
V-R (AB)
R-I (AB)
3
2
1
0
-1
-1
0
1
2
3
4.0
4.4
4.6
4.8
5.0
5.2
3.8
6.0
Quasar track
Solid =redshift
Open = no id

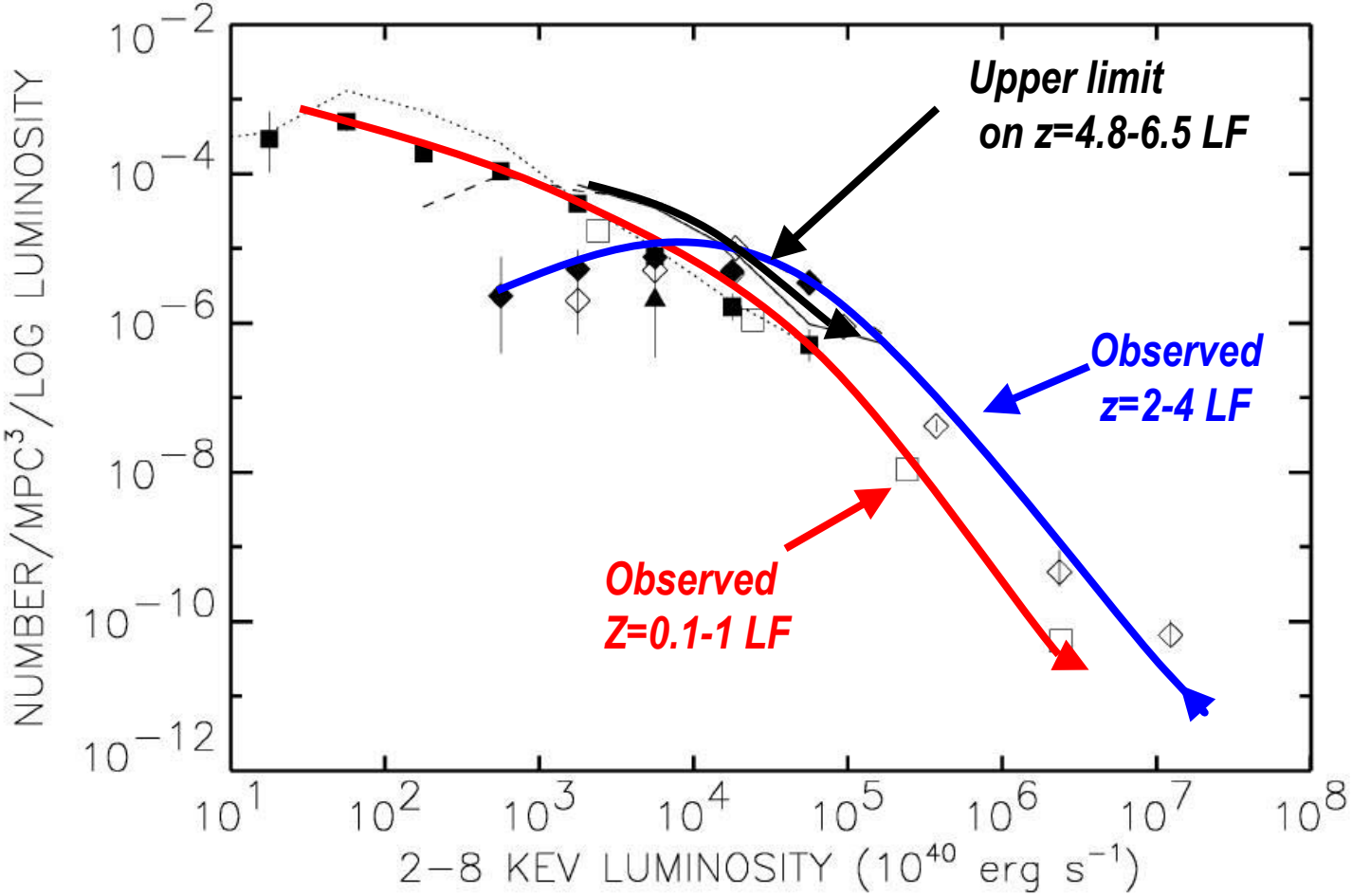

CDFN 2Ms
X-ray sample
z= 25.50
R-I (AB)
I-z (AB)
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
4
3
2
1
0
-1
-1
0
1
2

COMPARISON OF SLOAN SELECTED QUASAR WITH Z = 5.18 *CHANDRA* SOURCE IN HDF-N




Optically faint /
Possible high z AGN
SDSS QUASARS
Brandt et al 2002
Wilkes et al 2002
Log X-ray
Luminosity
(2-8 keV
Rest frame)
(45)
(42)
REDSHIFT
0.5–2 KEV FLUX (erg cm^{-2} s^{-1})
Unidentified sources detected in R band
Cowie et al. 2002

Cowie et al. 2002



SUMMARY:

Faint AGN luminosity function is declining at high redshift (even including every possible!!!)

Potential sources are optically faint

Two orders of magniitude too little rest frame UV light for ionization

AGN do not appear to be the ionization source