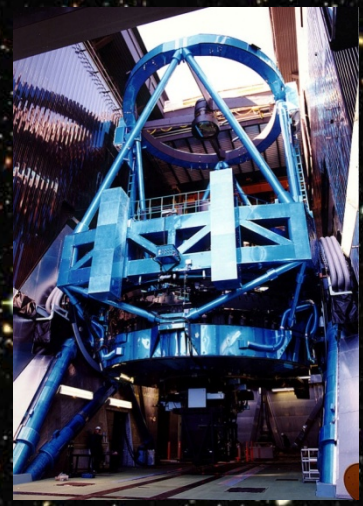
New Deeper Surveys of z=7 Ly α Emitters in the Subaru Deep Fields: Implications for Galaxy Evolution and Reionization



Kazuaki Ota

RIKEN Cosmic Radiation Laboratory

M. Iye, N. Kashikawa (NAOJ), M. Ouchi (Carnegie),
K. Shimasaku (Univ. of Tokyo), T. Totani (Kyoto Univ.),
M.A.R. Kobayashi, T. Morokuma (NAOJ),
M. Nagashima (Nagasaki Univ.),
H. Furusawa, T. Hattori (SubaruTelescope)

THE LYMAN ALPHA UNIVERSE 6-10 July 2009, Paris

Outline

1. New Deep z=7 LAE Survey in SXDS

- Background: Our previous z=7 survey had weaknesses.
- Solution: We conducted a deeper survey with red-sensitive CCD newly installed on Subaru Suprime-Cam.
- Result: Deeper Lyα LF: Implication for gal evol & reionization

2. Stellar Pop. of a z=6.96 LAE IOK-1

- Optical to mid-infrared images of IOK-1
  - SED fitting: constraint on stellar population (M_*, t, Av, SFR)
- Implication for galaxy evolution and reionization

Outline

1. New Deep z=7 LAE Survey in SXDS

- Background: Our previous z=7 survey had weaknesses.
- Solution: We conducted a deeper survey with red-sensitive CCD newly installed on Subaru Suprime-Cam.
- Result: Deeper Lyα LF: Implication for gal evol & reionization

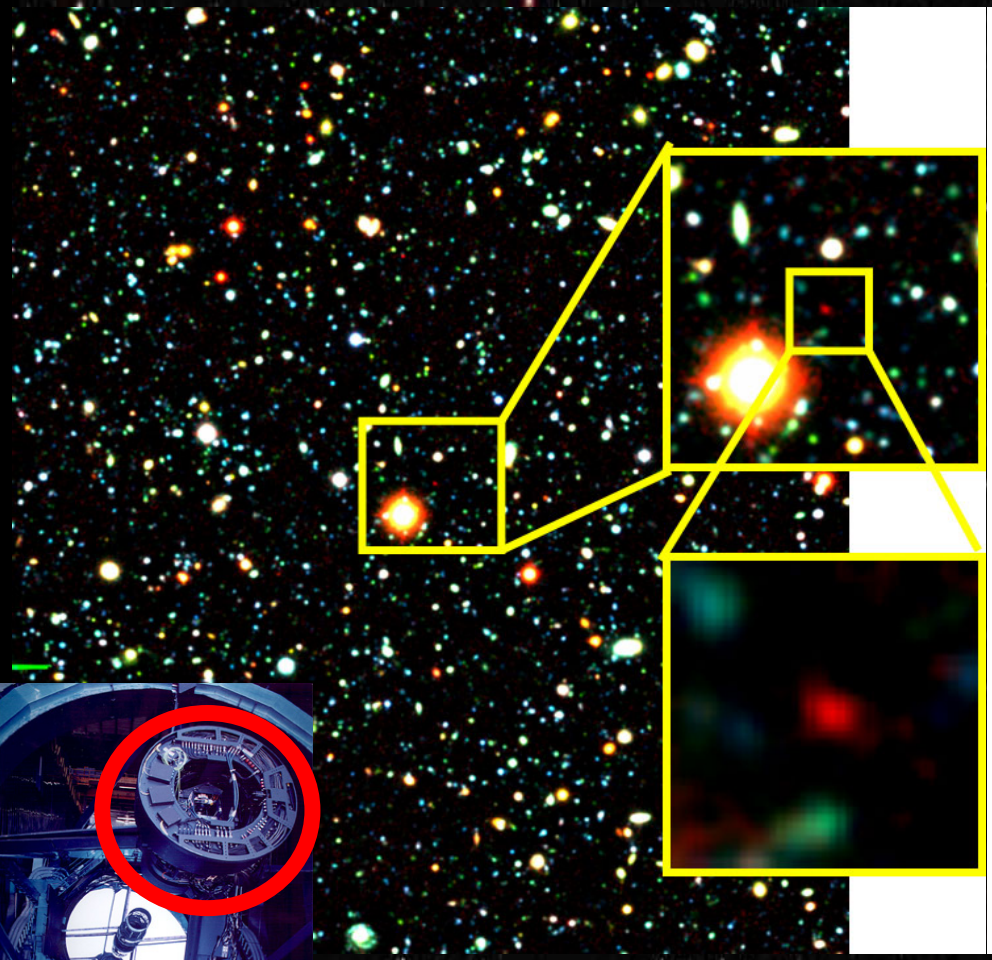
2. Stellar Pop. of a z=6.96 LAE IOK-1

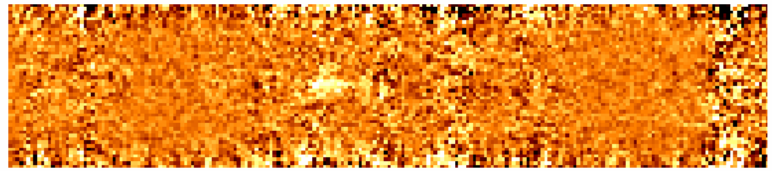
- Optical to mid-infrared images of IOK-1
  - SED fitting: constraint on stellar population (M_*, t, Av, SFR)
- Implication for galaxy evolution and reionization

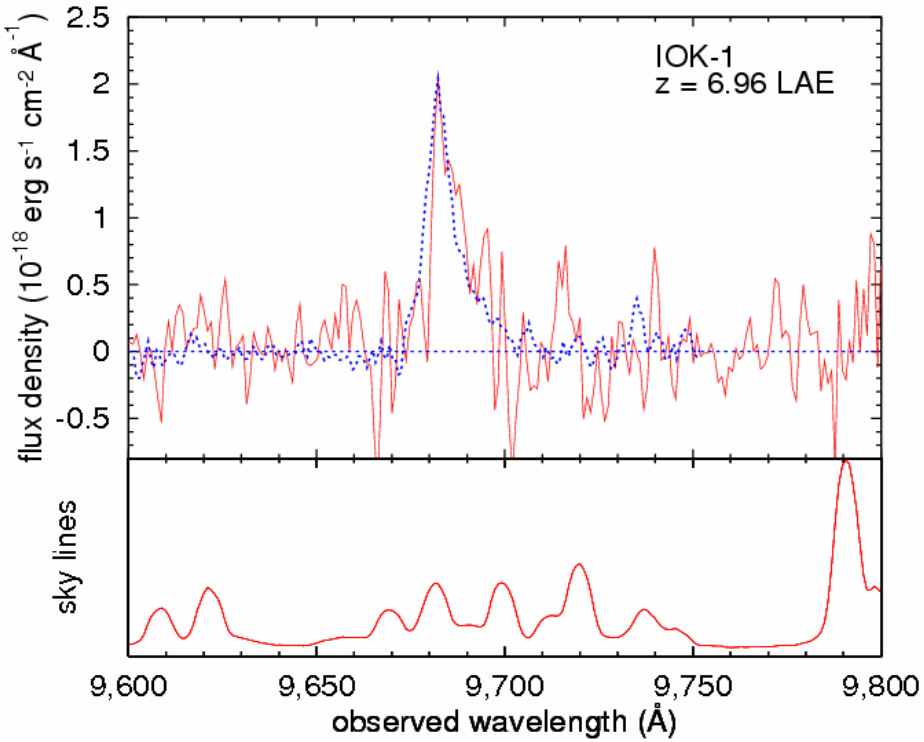
Discovery of a z=6.96 Ly$_\alpha$ emitter IOK-1

The previously most desitant object ever observed

Evidence of galaxy formation only 750 Myr after Big Bang



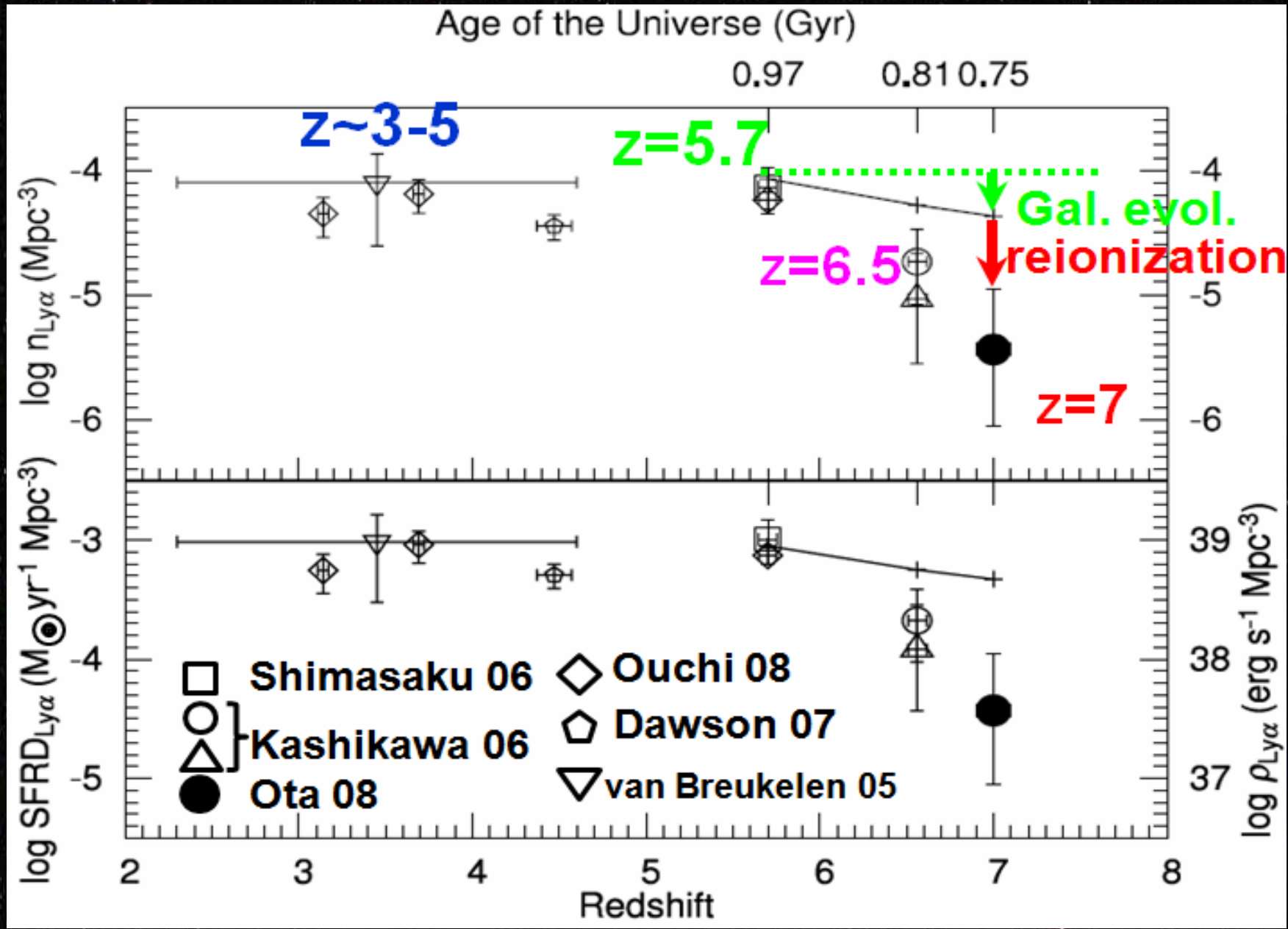




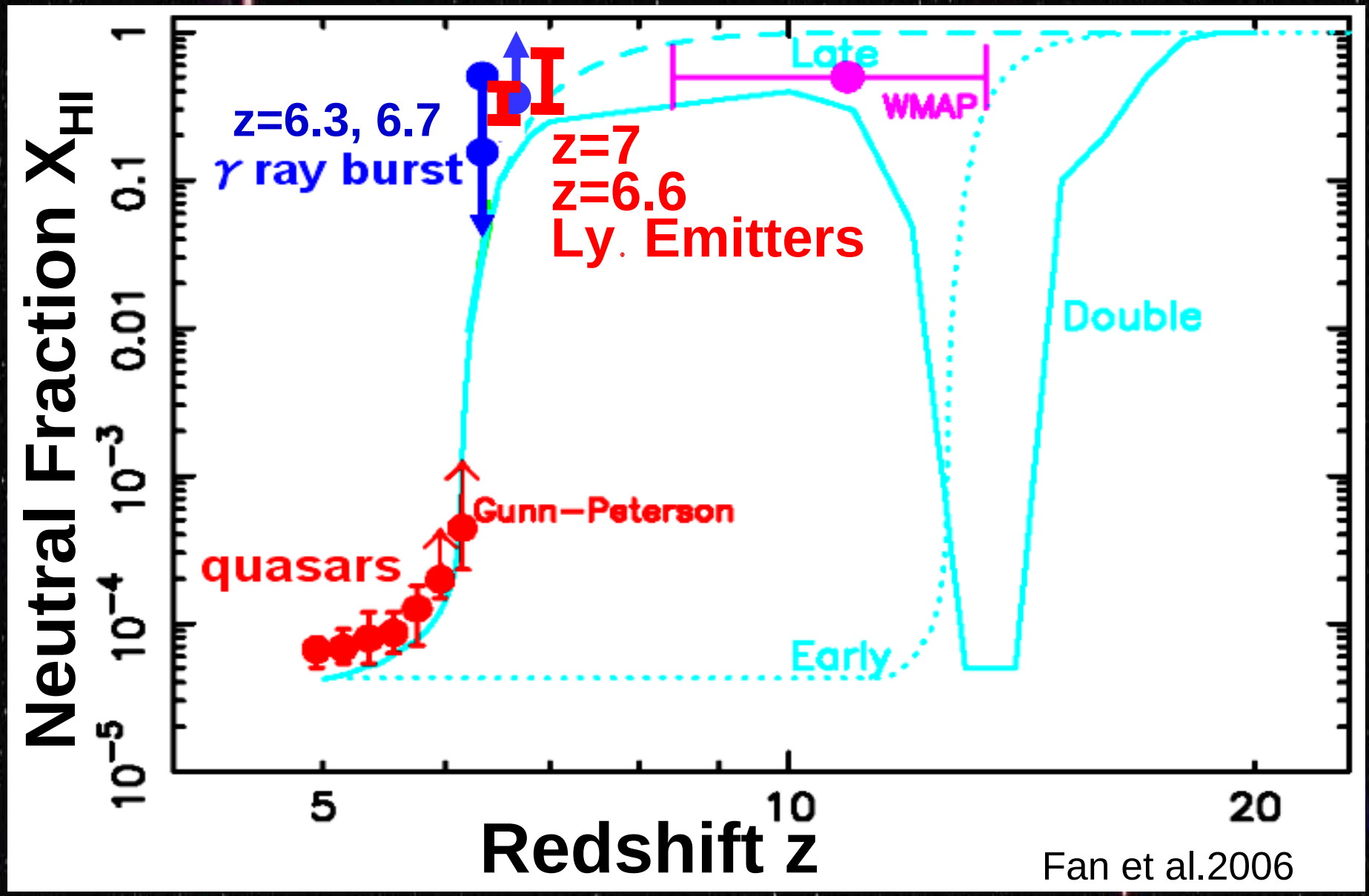
Subaru Deep Field Project

Suprime-Cam: Surveys of z=5.7, 6.6, 7 Ly$_\alpha$ emitters

Galaxy number desnidty decreases at z > 6



Constraint on reionization from LAEs

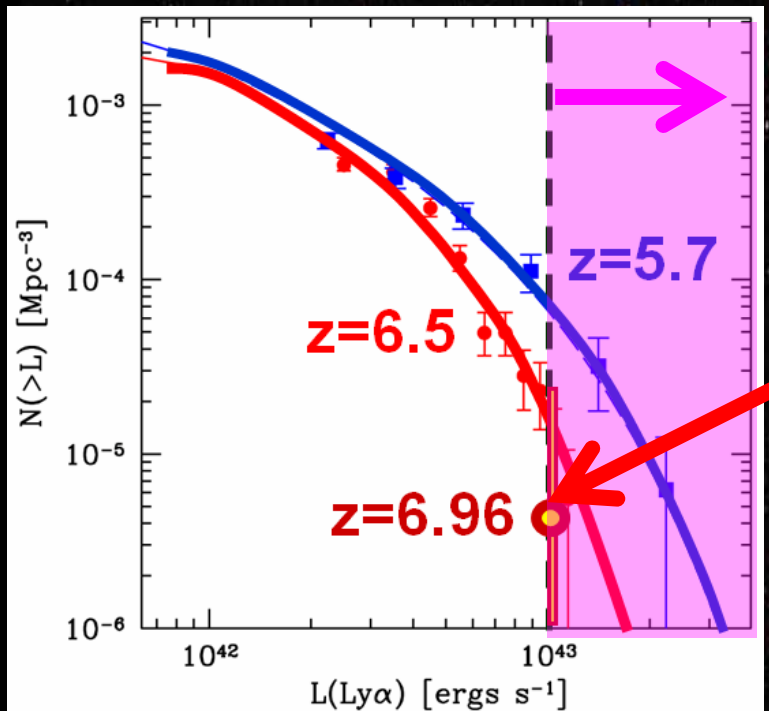


Fan et al.2006

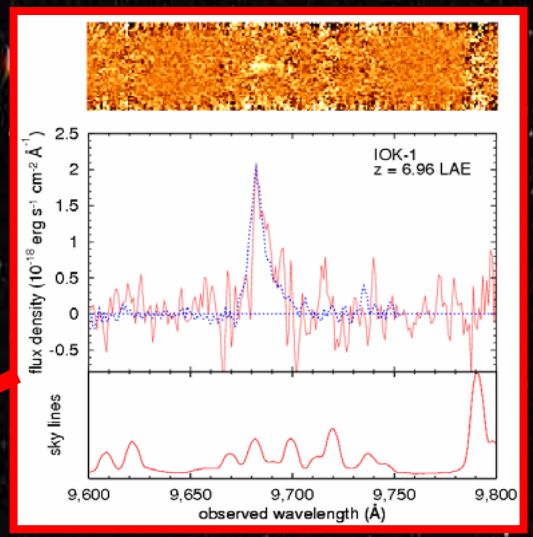
3 weakneses in the previous z=7 survey

(1) Depth was shallow.
(2) Sample was small.
(3) Only one sky field was surveyed.

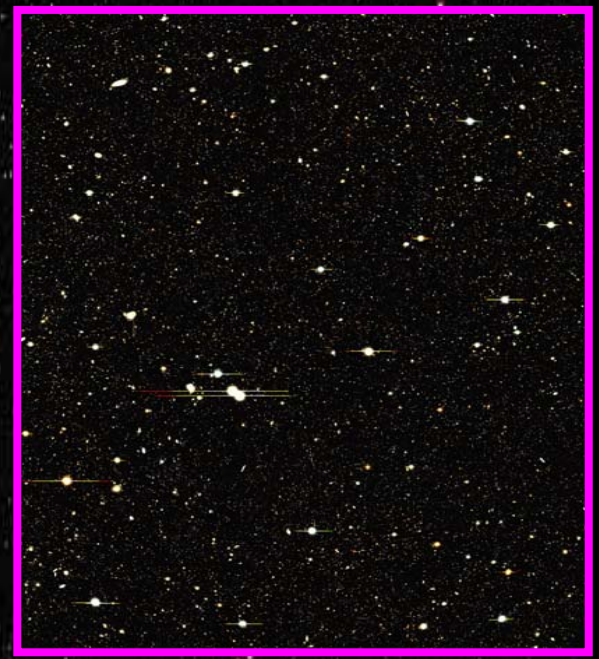
L(Lyα) > 10^{43} erg/s



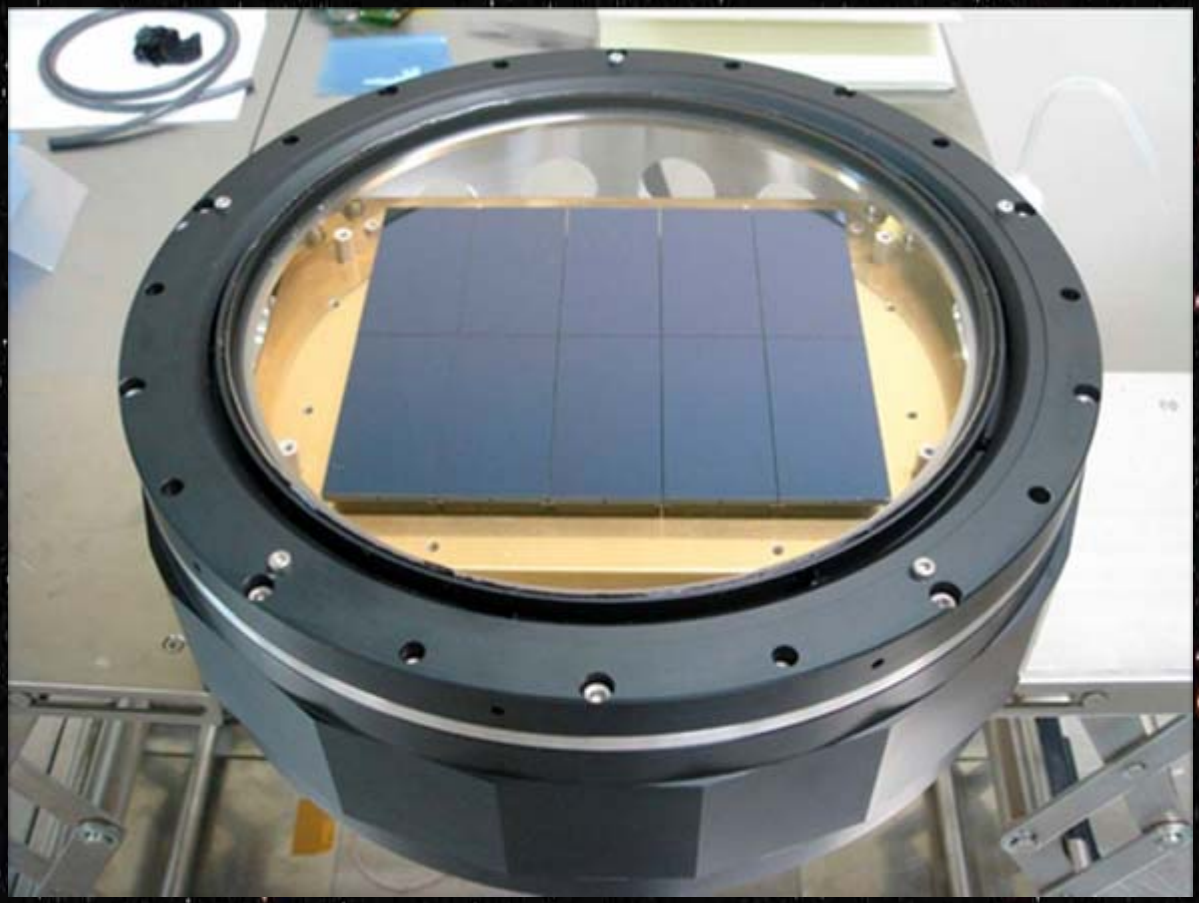
Only 1 Lyα emitter

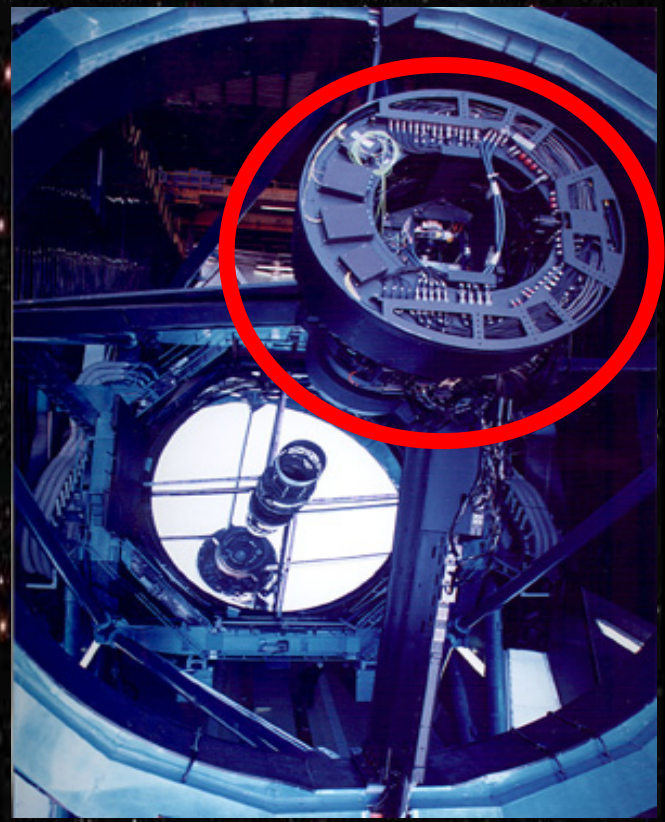


Subaru Deep Field
876 arcmin^2

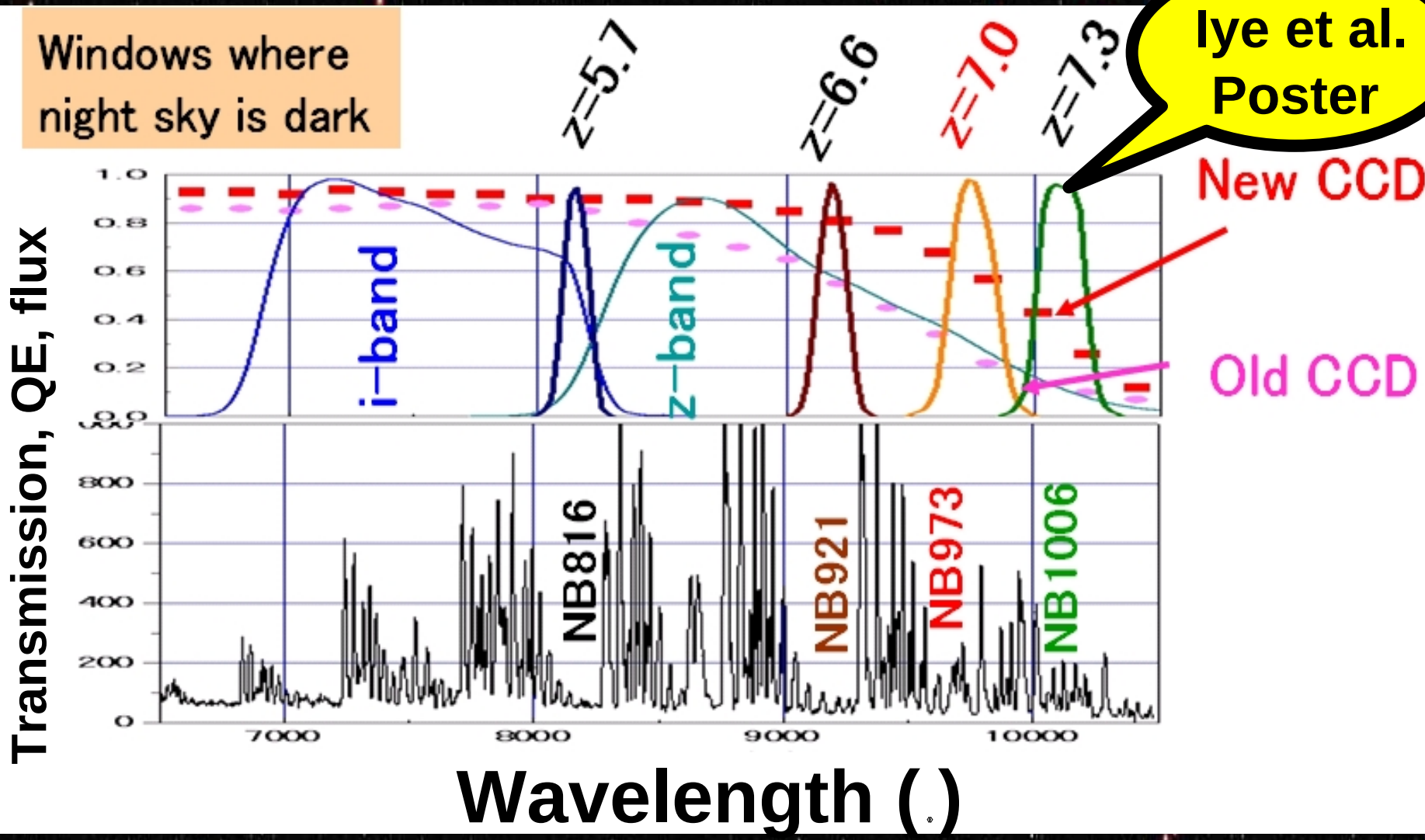


New Red-sensitive CCD installed on Suprime-Cam in July 2008





2 x more sensitive to z=7 Lyα emission

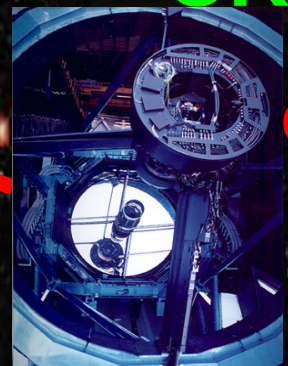


Target Sky Region

Subaru/XMM-Newton Deep Survey Field **SXDS**

Spitzer

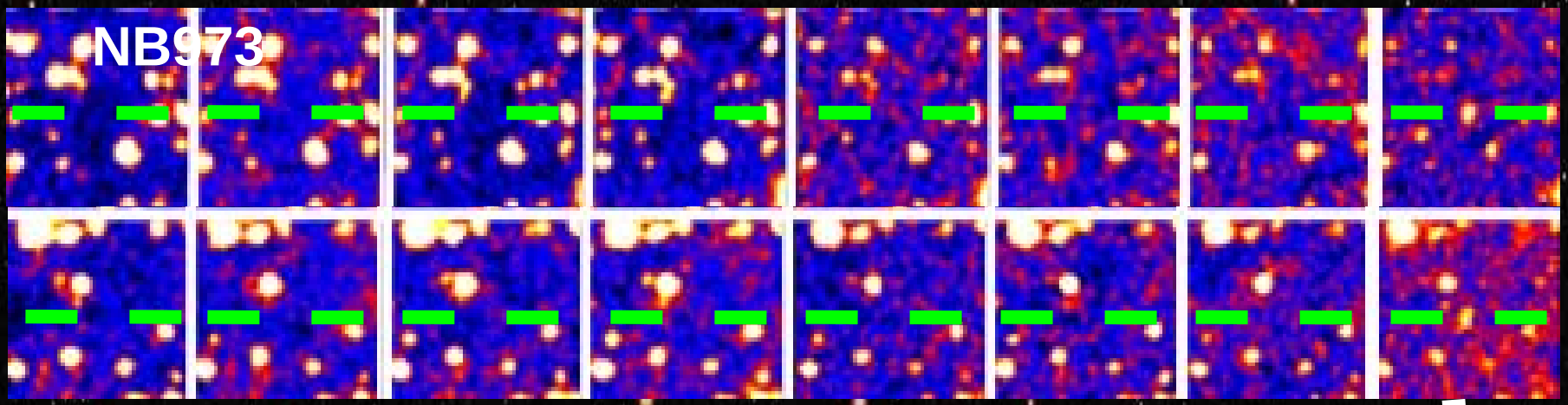
UKIDSS-UDS



13 hours imaging
NB973 = 25.4 (5)
(previously, 24.9)

Oct, Nov 2008
Subaru
This Work

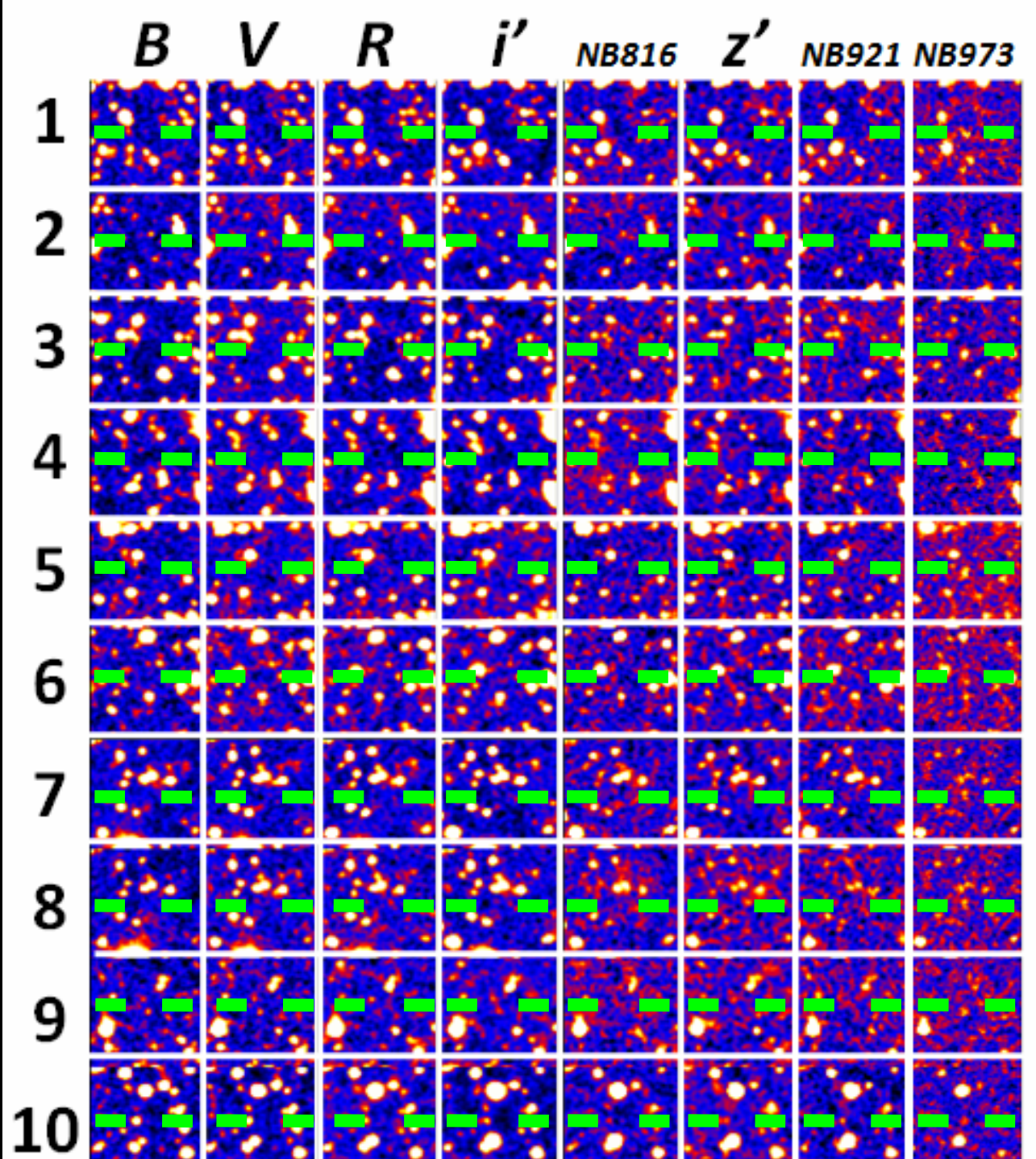
New z=7 Lyα emitter candidates



No detection (< 3σ)

NB973 25.4 (5σ)

Equivalently, z' – NB973 $\gtrsim$ 1



Color Selection

+

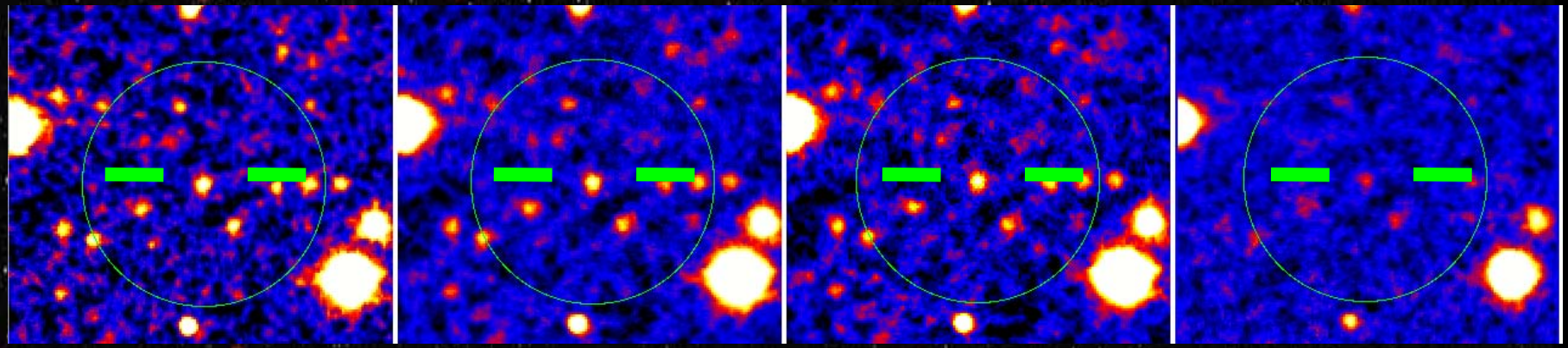
Visual Inspection

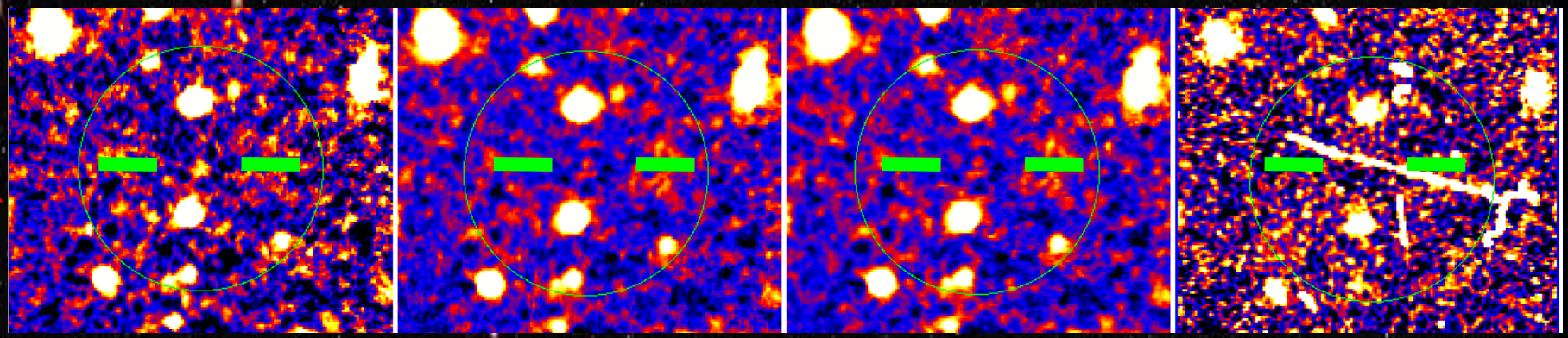
↓

10 z=7 LAE candidates

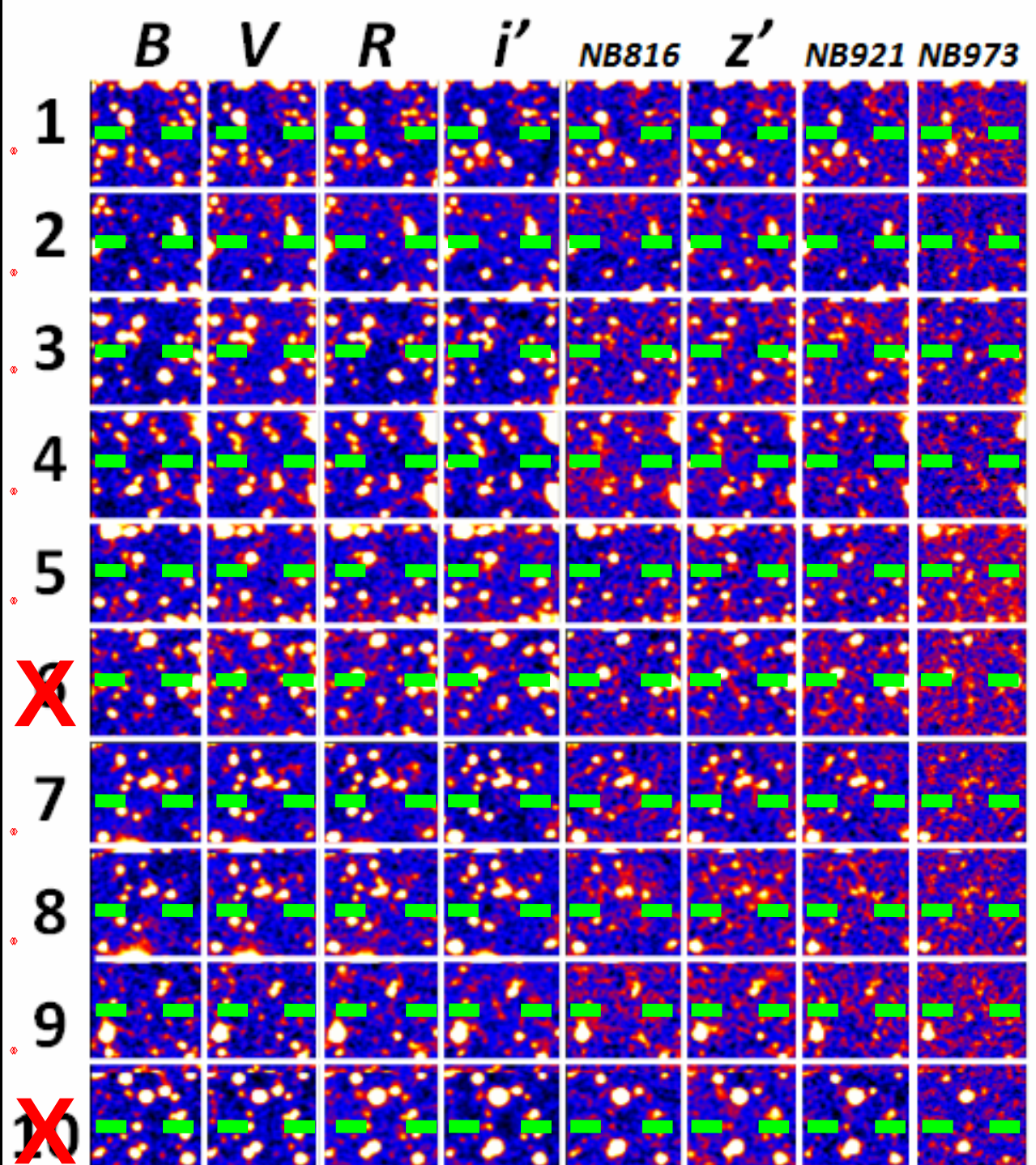
Checking NB images taken in different periods
Remove spurious and transient objects

13hr 1”	16.7hr 1.”2	11hr 1.”2	5.7hr 1.”2
Oct + Nov	Oct + Nov	Oct	Nov





X



#Candidates . 7

. Promissing 3
. Probable 2
. Possible 2

same object
Count as 1

Lyα LF for 7 candidates
F(Lyα) = F(NB filter)

Observed Densities

$n_{Ly\alpha}$: 2.5×10^{-5} Mpc^{-3}

$\rho_{Ly\alpha}$: 3.6×10^{38} erg/s/Mpc^{-3}

Predicted Densities when x_{HI}=0

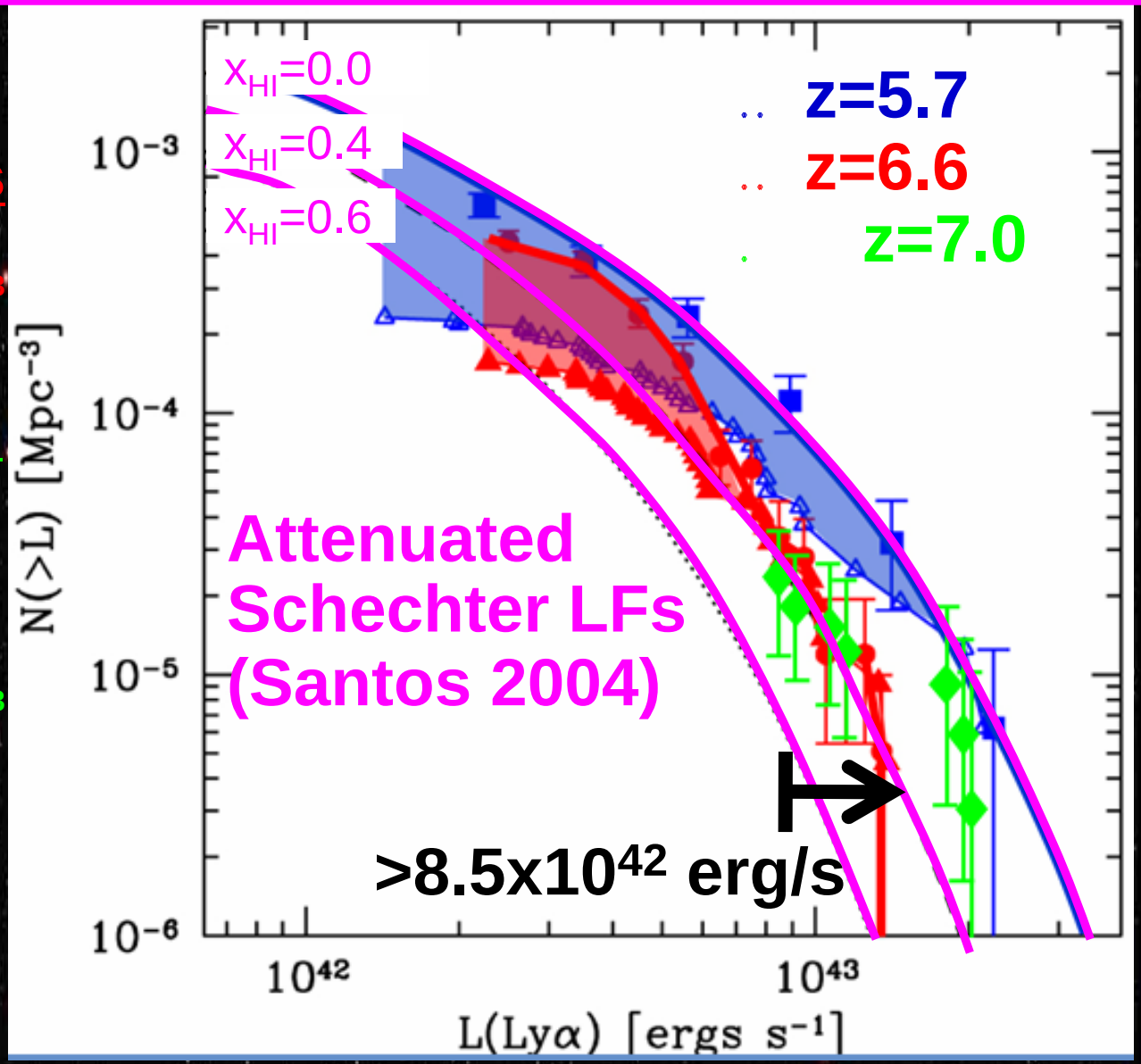
(Kobayashi et al. 2007 LAE evolution Model)

$n_{Ly\alpha}$: 5.8×10^{-5} Mpc^{-3}

$\rho_{Ly\alpha}$: 6.4×10^{38} erg/s/Mpc^{-3}

Neutral Fraction

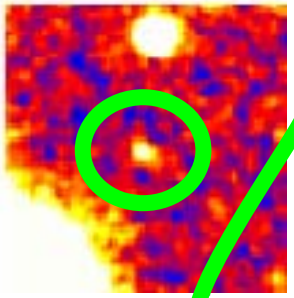
z=7.0 ~43%



Fraction of Lyα flux in NB filter flux

F(Lyα) ~ 0.7 x F(NB973)

NB973 Filter Total Flux

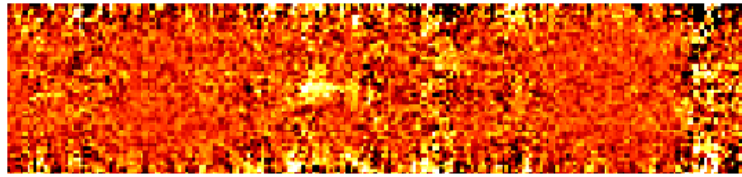


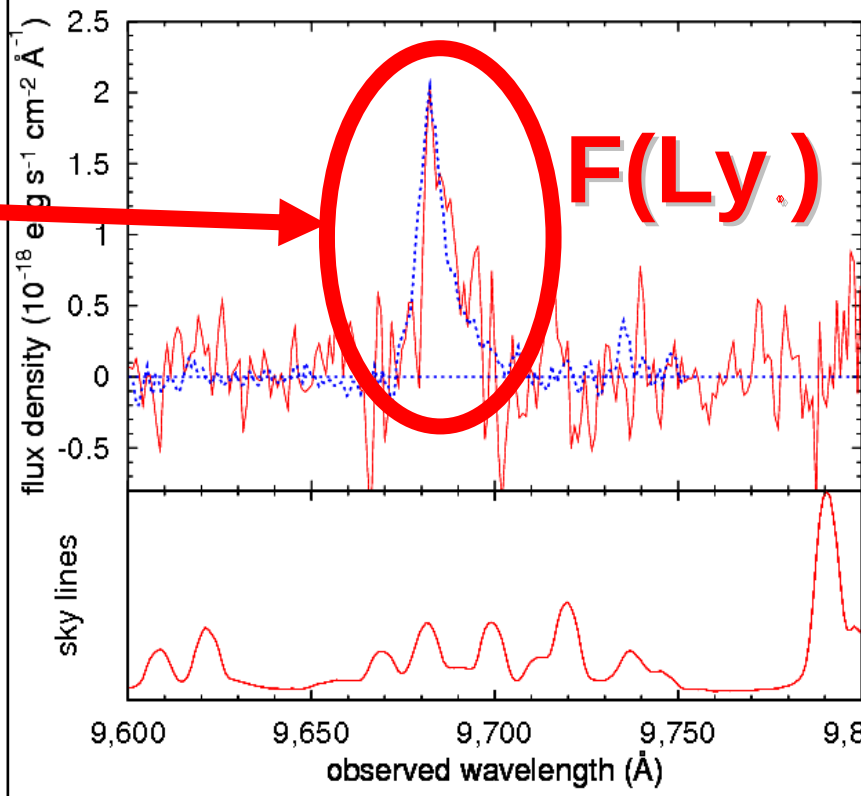
F(Lyα)
~70%

30%
F(UV)

F(NB973)
= F(Lya) + F(UV)

Spectrum





Ly$_\alpha$ LF for 7 candidates
F(Ly$_\alpha$) = 0.7×F(NB filter)

Observed Densities

$n_{Ly\alpha}$: 2.5×10^{-5} Mpc^{-3}

$\rho_{Ly\alpha}$: 3.6×10^{38} erg/s/Mpc^{-3}

Predicted Densities when x_{HI}=0

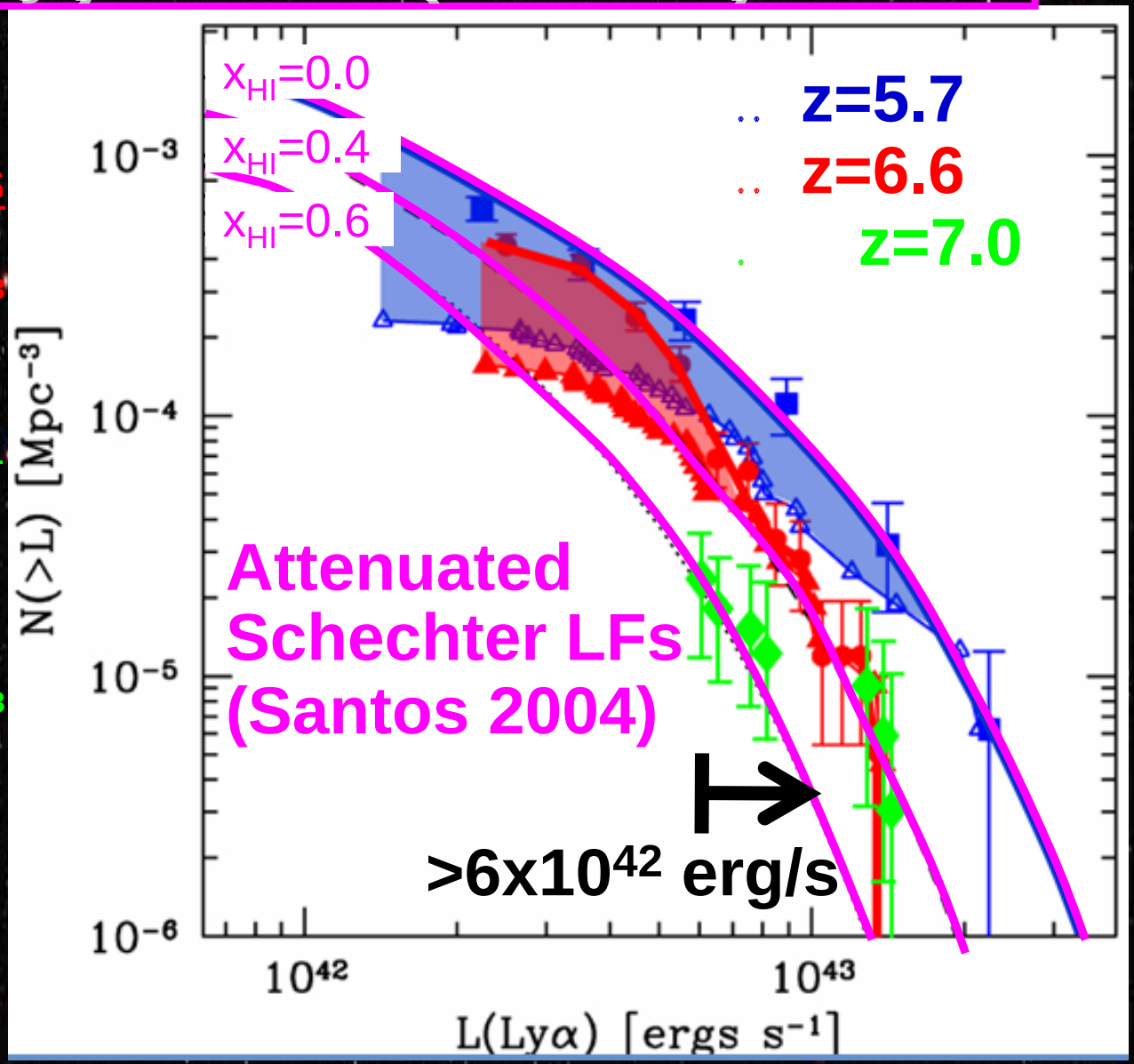
(Kobayashi et al. 2007 LAE evolution Model)

$n_{Ly\alpha}$: 1.1×10^{-4} Mpc^{-3}

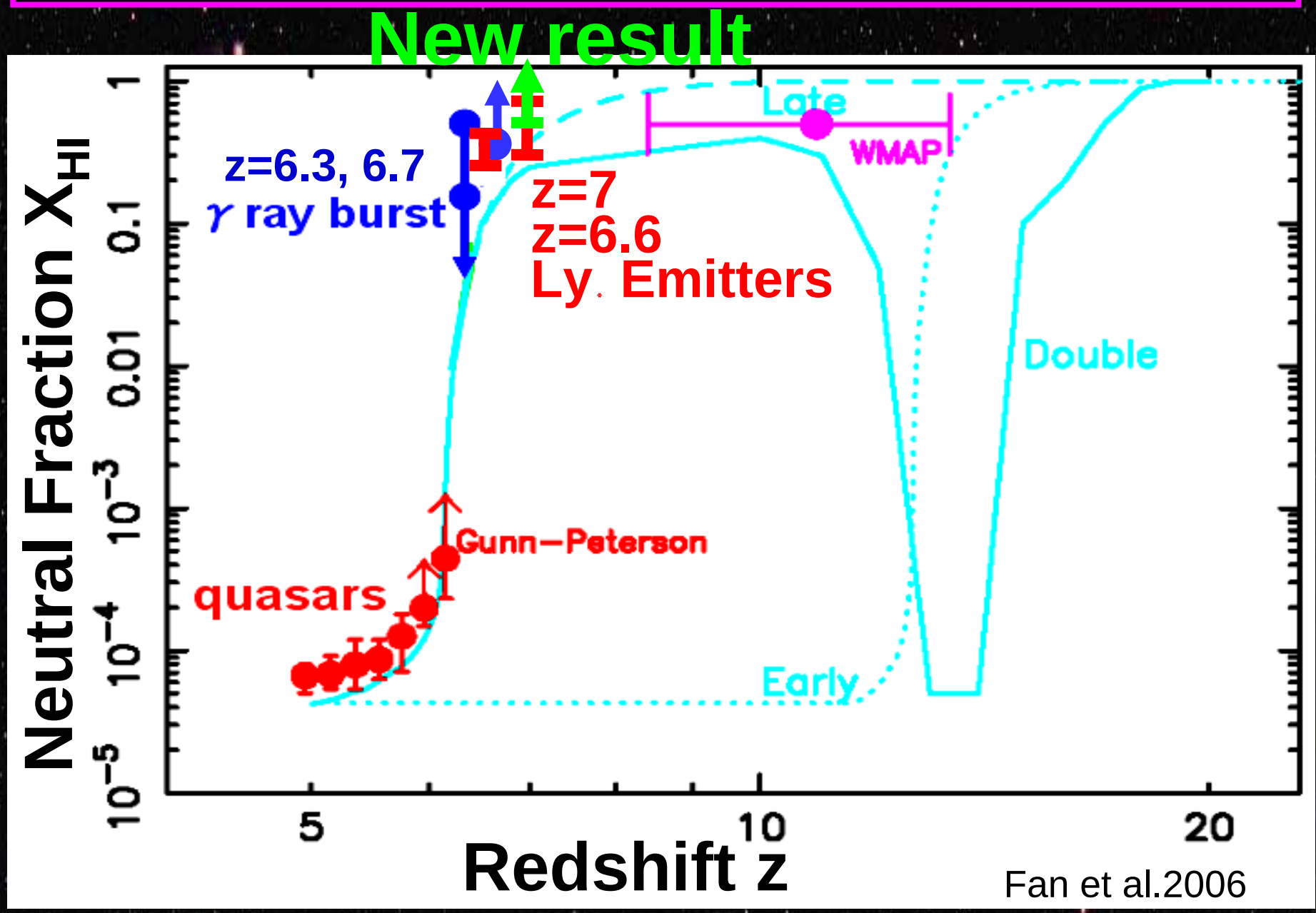
$\rho_{Ly\alpha}$: 9.5×10^{38} erg/s/Mpc^{-3}

Neutral Fraction

z=7.0 ~65%

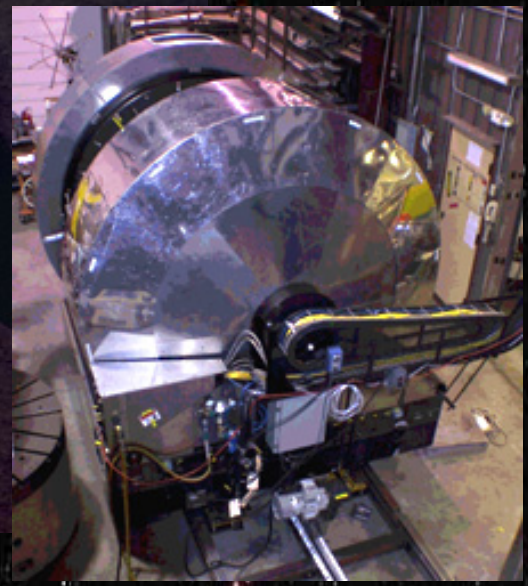


New reuslt agrees with previous results



Fan et al.2006

Keck DEIMOS Spectroscopy of z=7 LAE Candidates 13 and 14 Nov. 2009



Outline

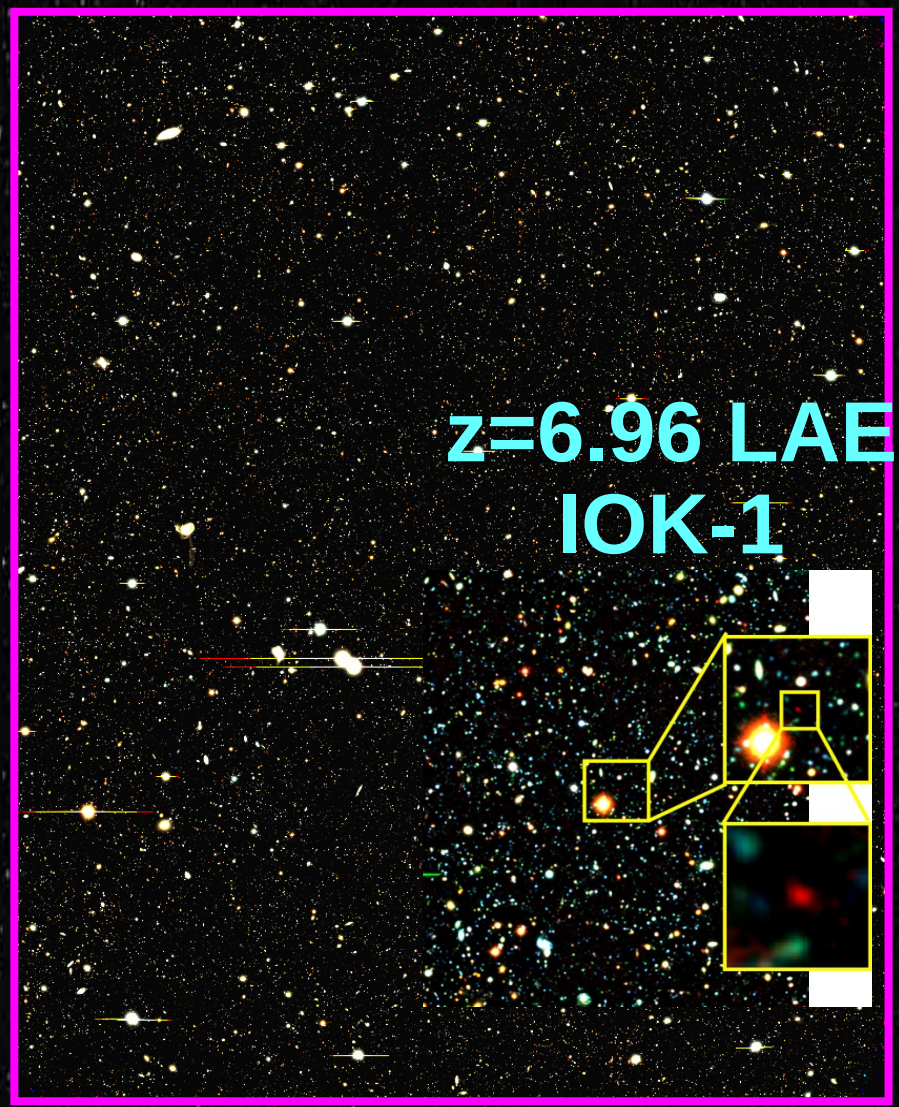
1. New Deep z=7 LAE Survey in SXDS

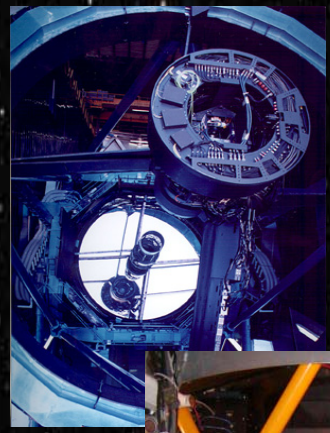
- Background: Our previous z=7 survey had weaknesses.
- Solution: We conducted a deeper survey with red-sensitive CCD newly installed on Subaru Suprime-Cam.
- Result: Deeper Lyα LF: Implication for gal evol & reionization

2. Stellar Pop. of a z=6.96 LAE IOK-1

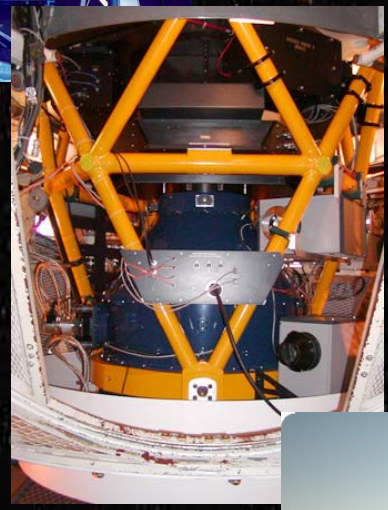
- Optical to mid-infrared images of IOK-1
  - SED fitting: constraint on stellar population (M_*, t, Av, SFR)
- Implication for galaxy evolution and reionization

Subaru Deep Field
876 arcmin^2

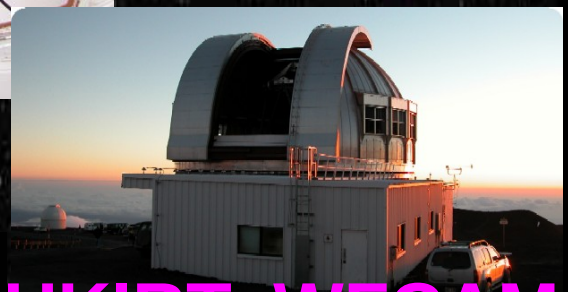




Subaru
Suprime-Cam
BVRiz, NB973



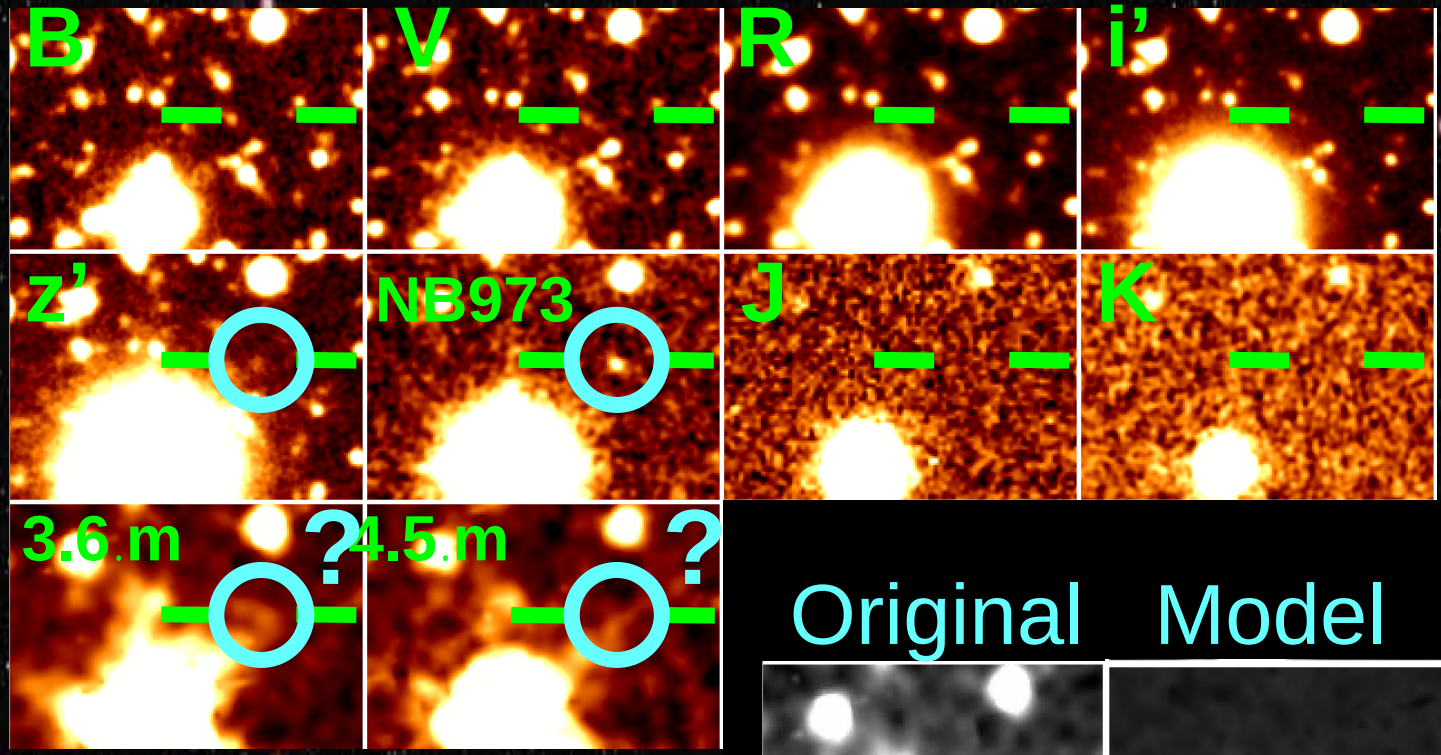
Kitt Peak 4m
NEWFIRM
J-band



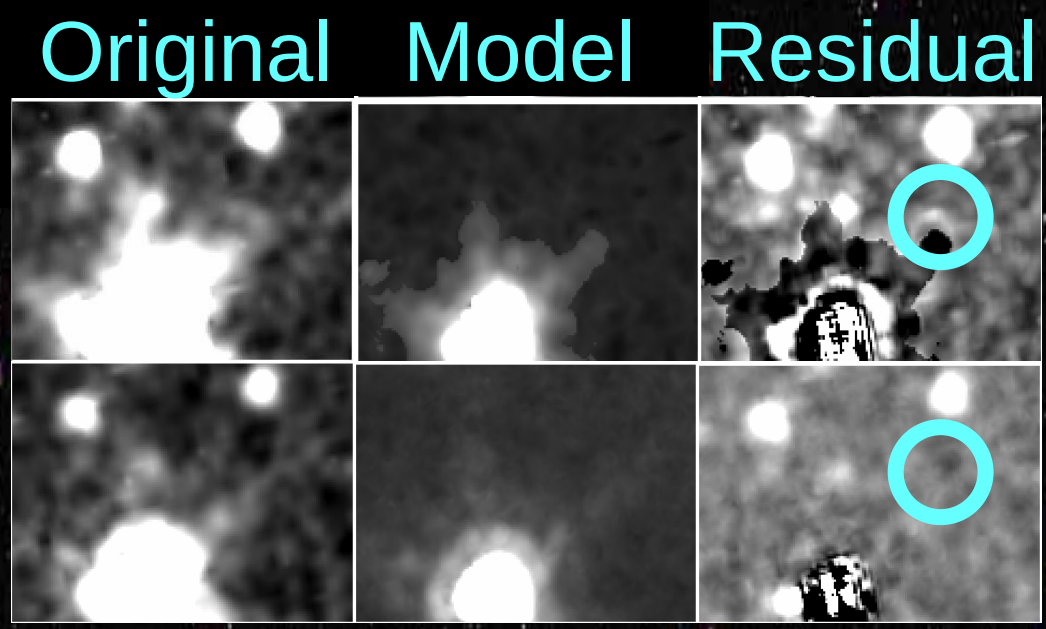
UKIRT WFCAM
K-band

Spitzer IRAC
3.6,4.5,5.8,8 m

Rest frame UV to Optical images



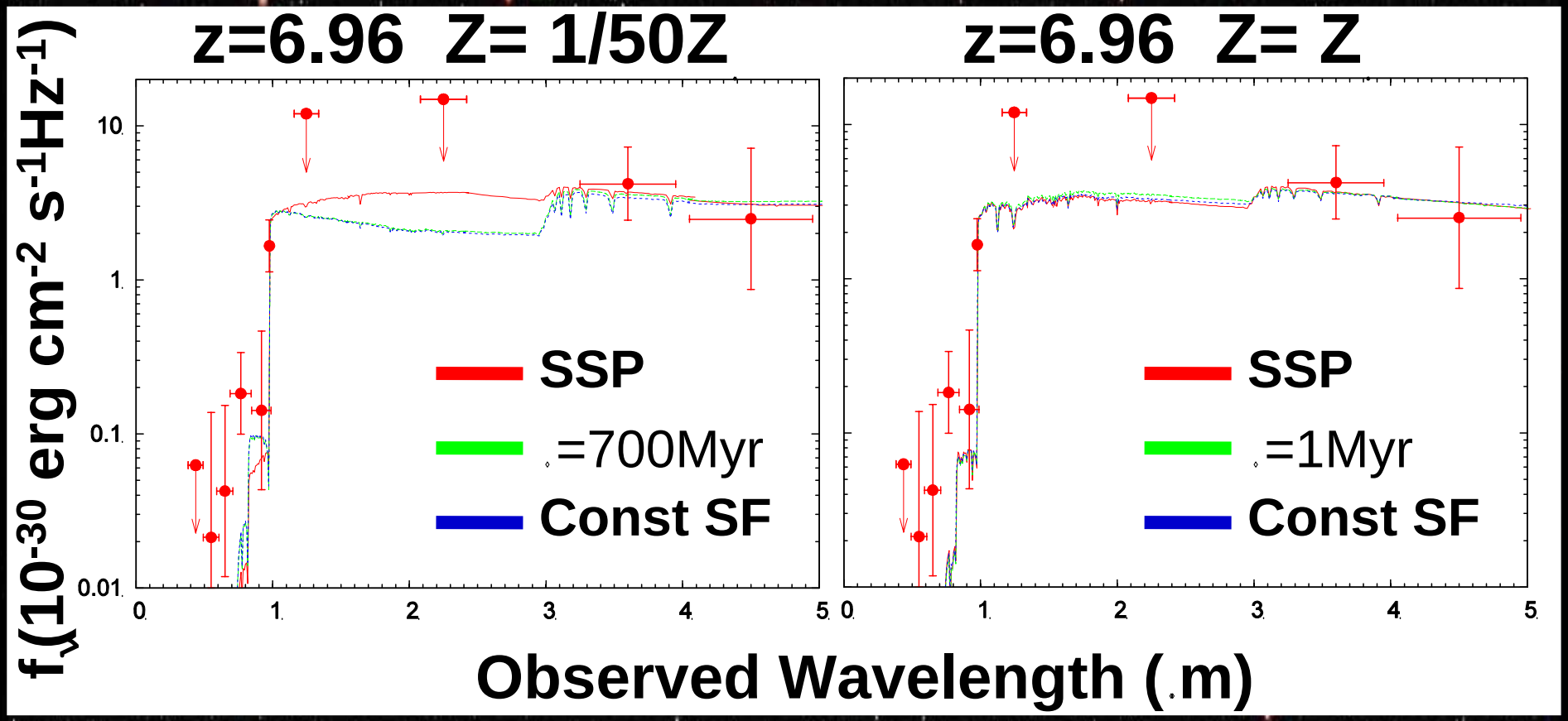
Subtracting the neighbor with GALFIT



SED fitting: Bruzual & Charlot 03 + HyperZ

.JH did not reproduce observed SFR . Did not include them.
.Used measured fluxes (instead of upper limits)
.B flux not measurable . 1. upper limit

Age = 1 – 750 Myr, Av = 0 – 3, . = 1 – 750 Myr, Salpeter IMF



Best-fit Stellar Population Model Parameters

Model	M_{star} 10^9 M	age Myr	Av mag	SFR M yr^{-1}	SSFR Gyr^{-1}	χ^2
Z= Z						
SSP	$1.1^{+6.6}_{-1.9}$	4.0	0.55			3.409
=1Myr	$1.8^{+3.7}_{-0.0}$	4.0	0.80	35.4	19.7	3.437
CSF	$2.1^{+4.9}_{-1.5}$	6.3	0.77	330	157	3.451
Z= 1/50Z						
SSP	$6.1^{+5.5}_{-3.1}$	6.3	1.07			3.479
=700Myr	$9.6^{+8.2}_{-6.9}$	510	0.00	16.2	1.7	3.451
CSF	$9.7^{+0.0}_{-6.8}$	720	0.00	17.2	1.8	3.465

Summary: Implications for Gal Evo & Reion

M_{star}: z~7LAE: 0.9–18 x 10^9 $M_\odot$ (68%CL)

z~7LBG: 0.3–16 x 10^9 $M_\odot$ (Labbe et al 06; 68%CL)

z~6LBG: 0.4–30 x 10^9 $M_\odot$ (Eyles et al 07, 05)

$\dot{M}_{star}$: z~7LAE: 0.12–2.3 x 10^6 $M_\odot$ Mpc^{-3}

z~7LBG: 0.8–3.2 x 10^6 $M_\odot$ Mpc^{-3} (Labbe et al 06)

z~7CDM: 0.9 x 10^6 $M_\odot$ Mpc^{-3} (Nagamine et al 05)

z~6LBG: 2.5–8.0 x 10^6 $M_\odot$ Mpc^{-3} (Eyles et al 07)

→ **LAE could be lower mass extension of LBG z~7 LAEs possibly evolve to z~6 massive LBGs**

(Age, Av) = (6.3Myr, 1.1) – (720Myr, 0)

→ **No meaningful**

SFR=16–330 $M_\odot$ yr^{-1} (best-fit, dust corrected)

SFR_{Ly}=15.8 $M_\odot$ yr^{-1}, SFR_{UV}=16.5 $M_\odot$ yr^{-1} (Observed SFRs)

→ **Dust corr. + Santos(2004) model => X(HI)~0–0.3**