

# HSC high- $z$ quasar survey

---

**Nobunari Kashikawa(NAOJ)**

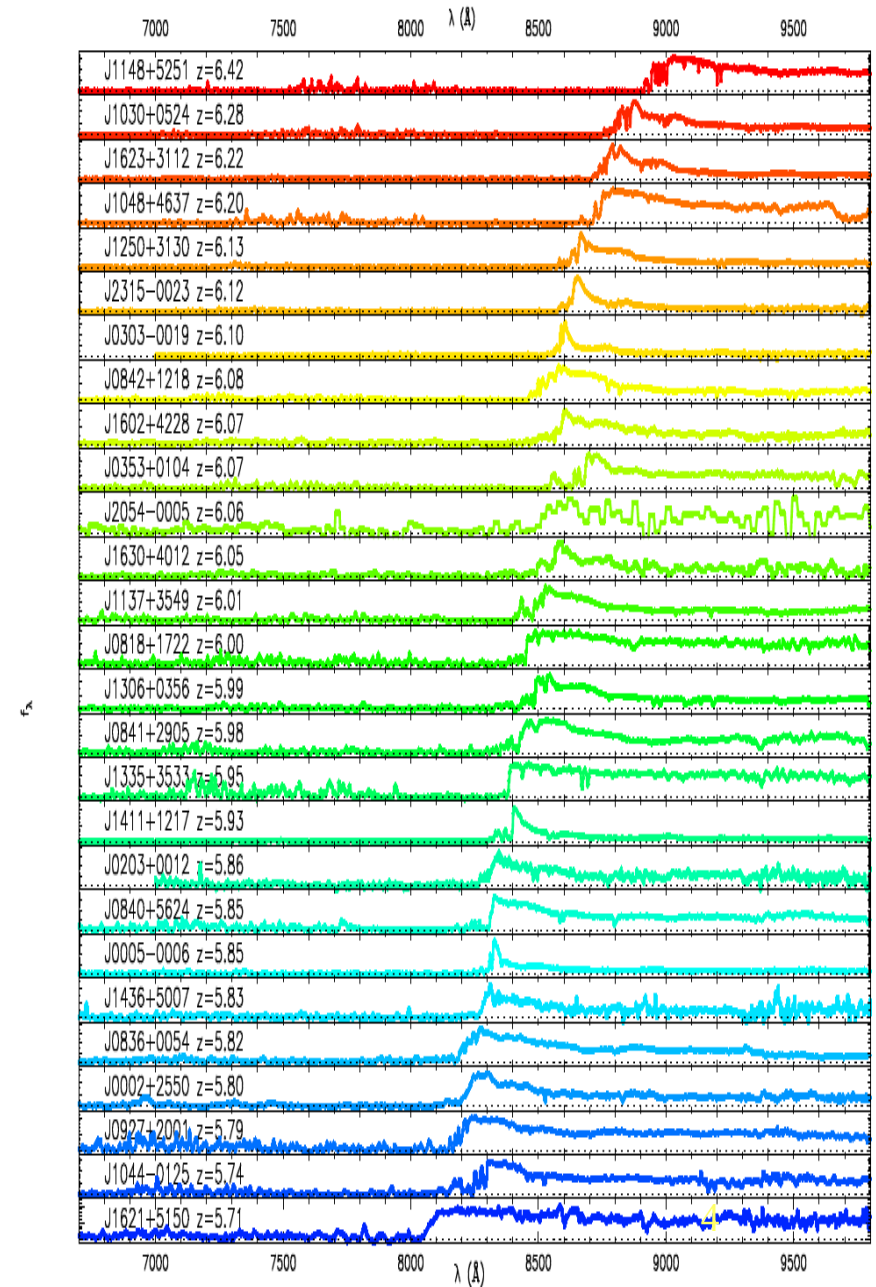
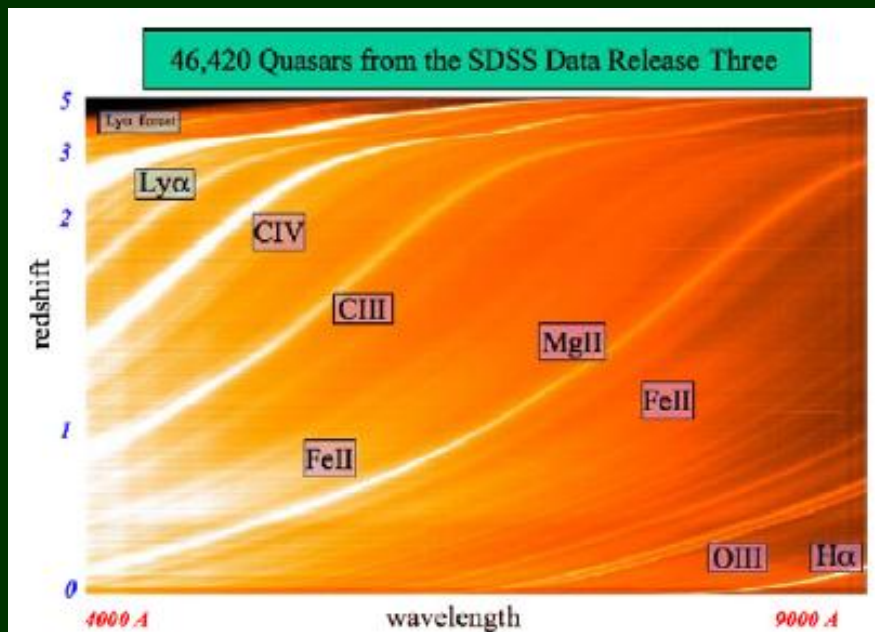
- **Next generation high-z quasar survey**
- **How to select high-z quasars**
- **Science cases**
- **SCam pilot survey**
- **Summary**

The study of high-z ( $z > 6$ ) quasar probes:

- The 1st generation Black Holes
  - SMBH formation
  - Role of BH/AGN activity in galaxy formation
  - Star formation and BH feeding in the host galaxy
- luminous background sources & useful markers
  - Metals in the IGM
  - Initial structure formation
- History of cosmic reionization
  - HI neutral fraction
  - Evolution of the UV ionizing background
  - Complement to LAE / WMAP / GRB / 21cm...

# SDSS $z \sim 6$ quasars

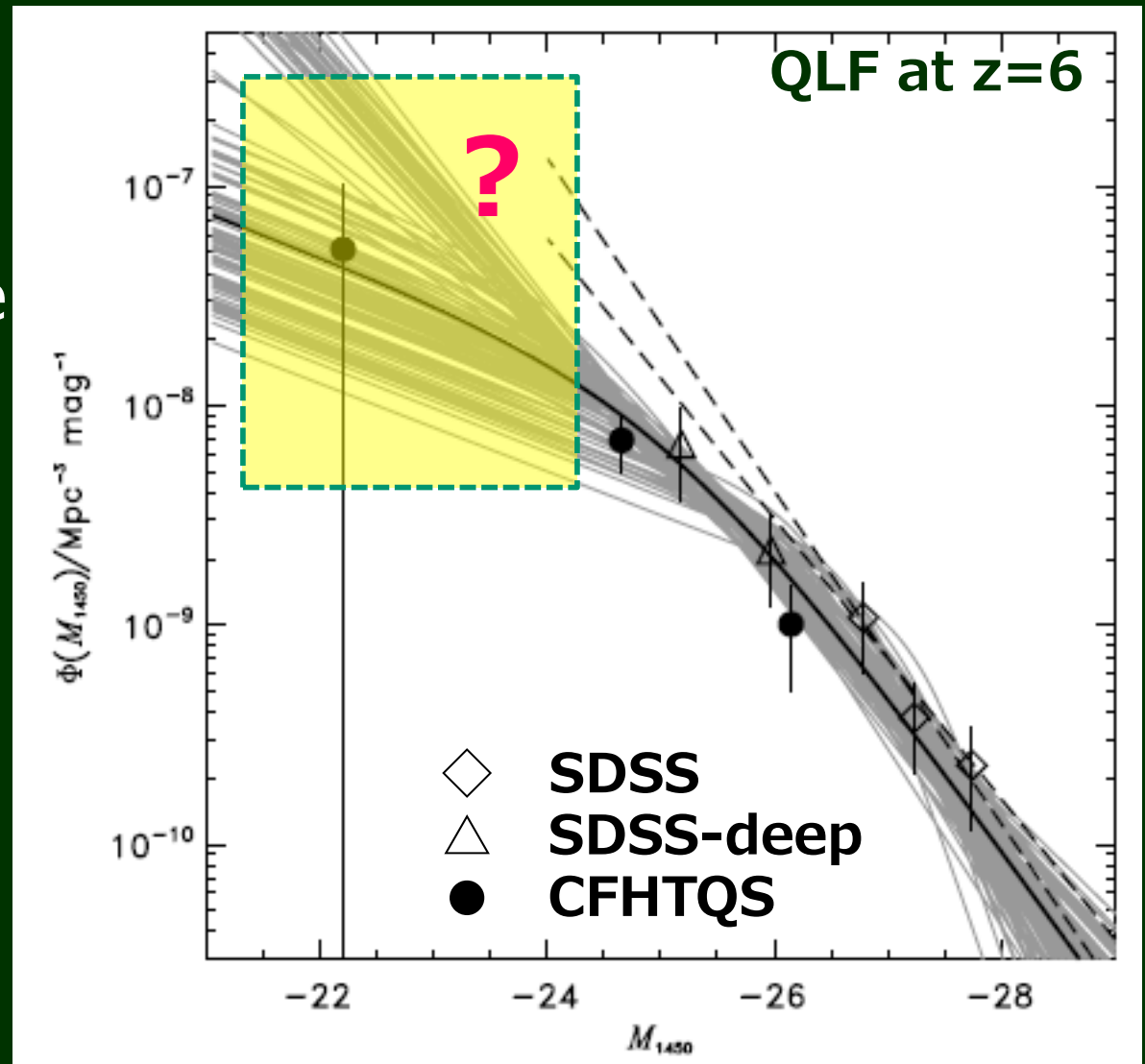
- $z \sim 4$ : >1000 known
- $z \sim 6$ : >50
- SDSS i-dropout Survey:
  - 7700deg<sup>2</sup>,  $z_{AB} < 20$
- SDSS Faint QSO Survey (SFQS):
  - 300deg<sup>2</sup>,  $z_{AB} < 22.5$
- Canada-France high- $z$  QSO Survey (CFHQS):
  - 500deg<sup>2</sup>,  $z_{AB} < 22.5$



# Fainter quasars beyond $L^*$

## ■ Whole shape of the QLF at $z > 6$

- BH evolution models make qualitatively different predictions on the faint end slope of QLF at high- $z$
- Evolution of UVB
- Quasar contribution to the photon budget of the cosmic reionization



# Higher-z quasars beyond z=6

- Number density of quasars at z=7

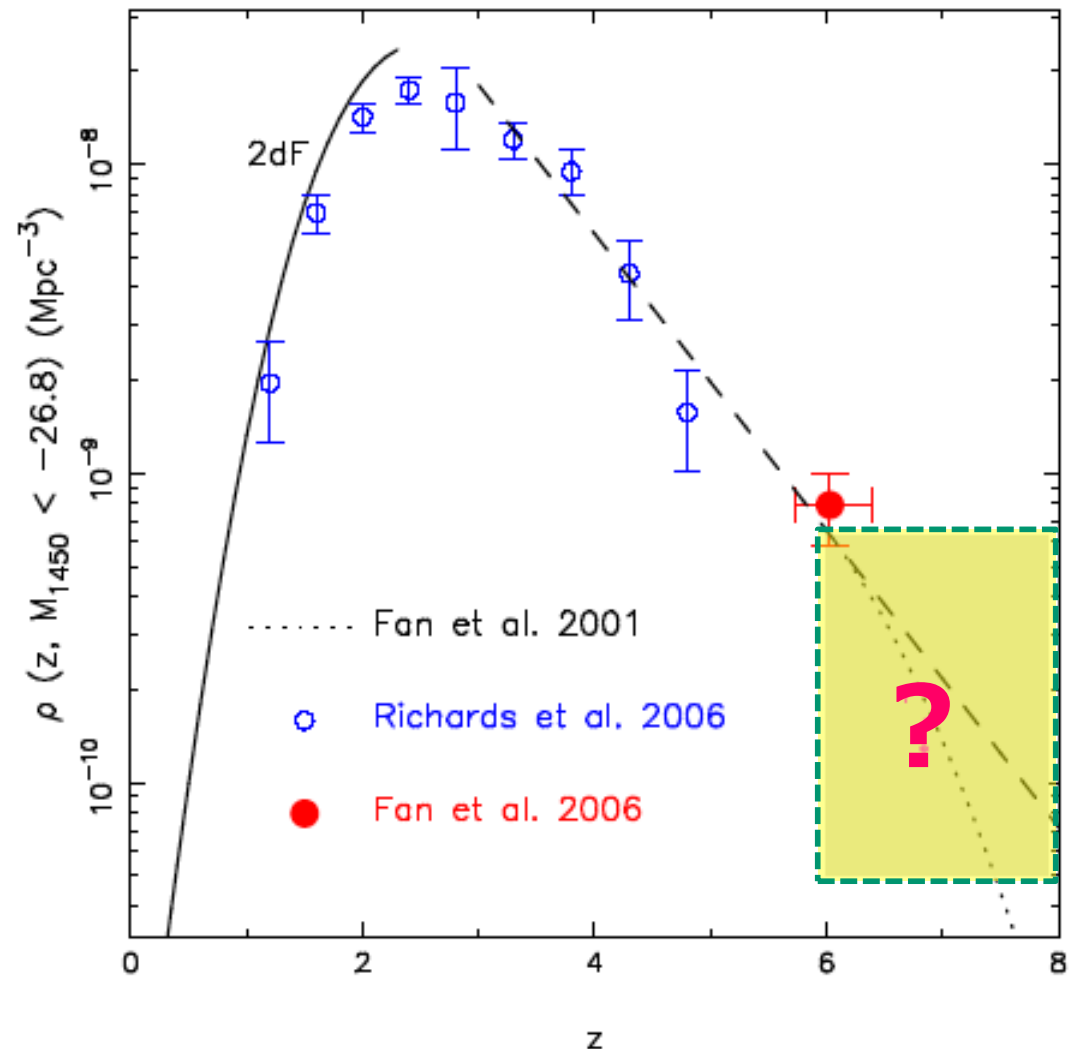
- significant decline w/z:  
factor  $\sim 40$  @ z=2.5  $\rightarrow$  6

- SMBH formation

  - $M_{\text{SMBH}} \sim 10^9 M_{\text{sun}}$

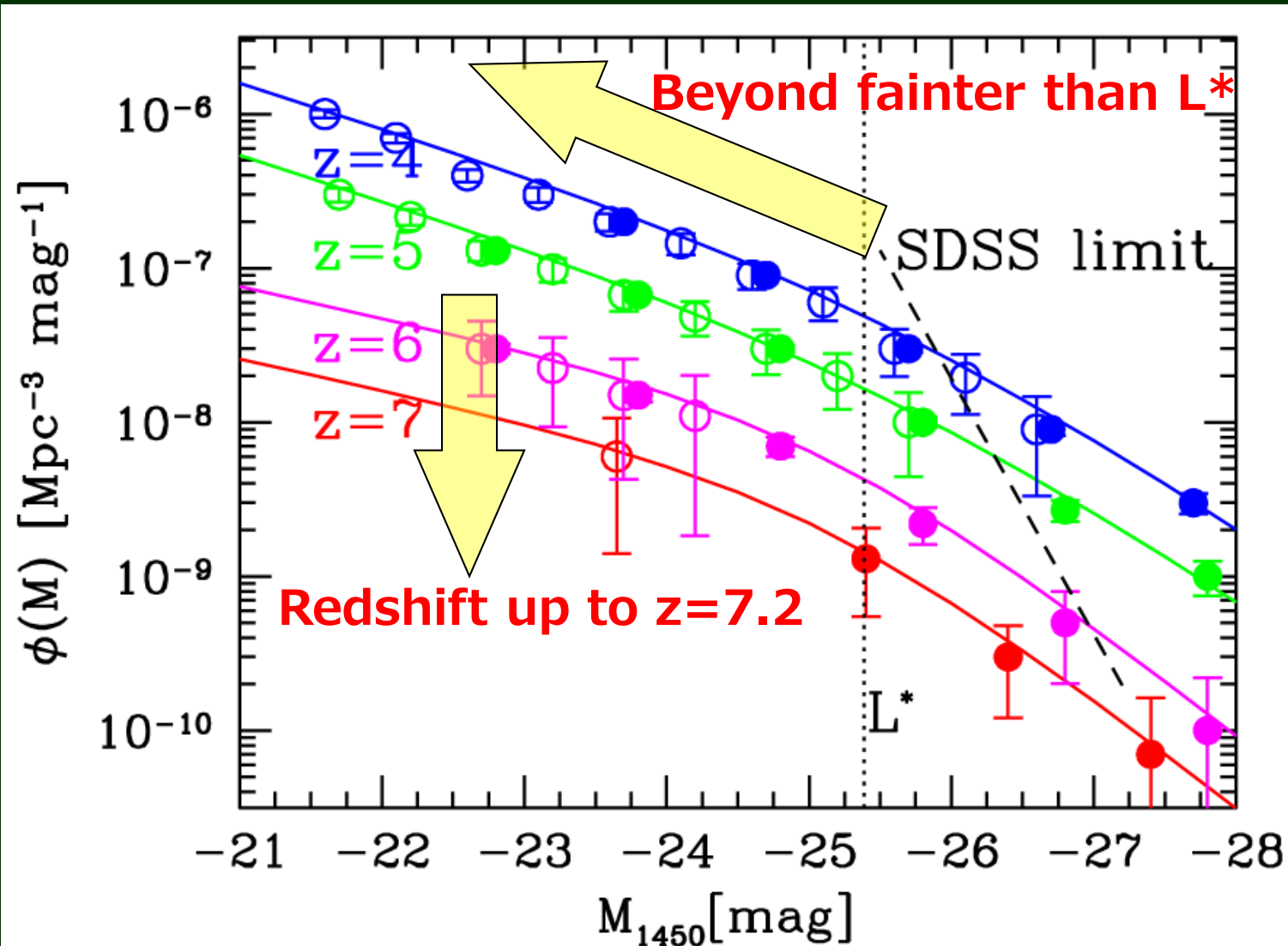
  - z > 7: formed within  
a few Gyr in the  
early epoch

  - constraints on  
models of the SMBH  
formation



# HSC high-z quasar survey

- Beyond the limit of SDSS: Higher-z & fainter quasars
  - Large ground-base telescope
  - High-sensitivity instrument
  - Very wide FOV
  - Effective selection technique

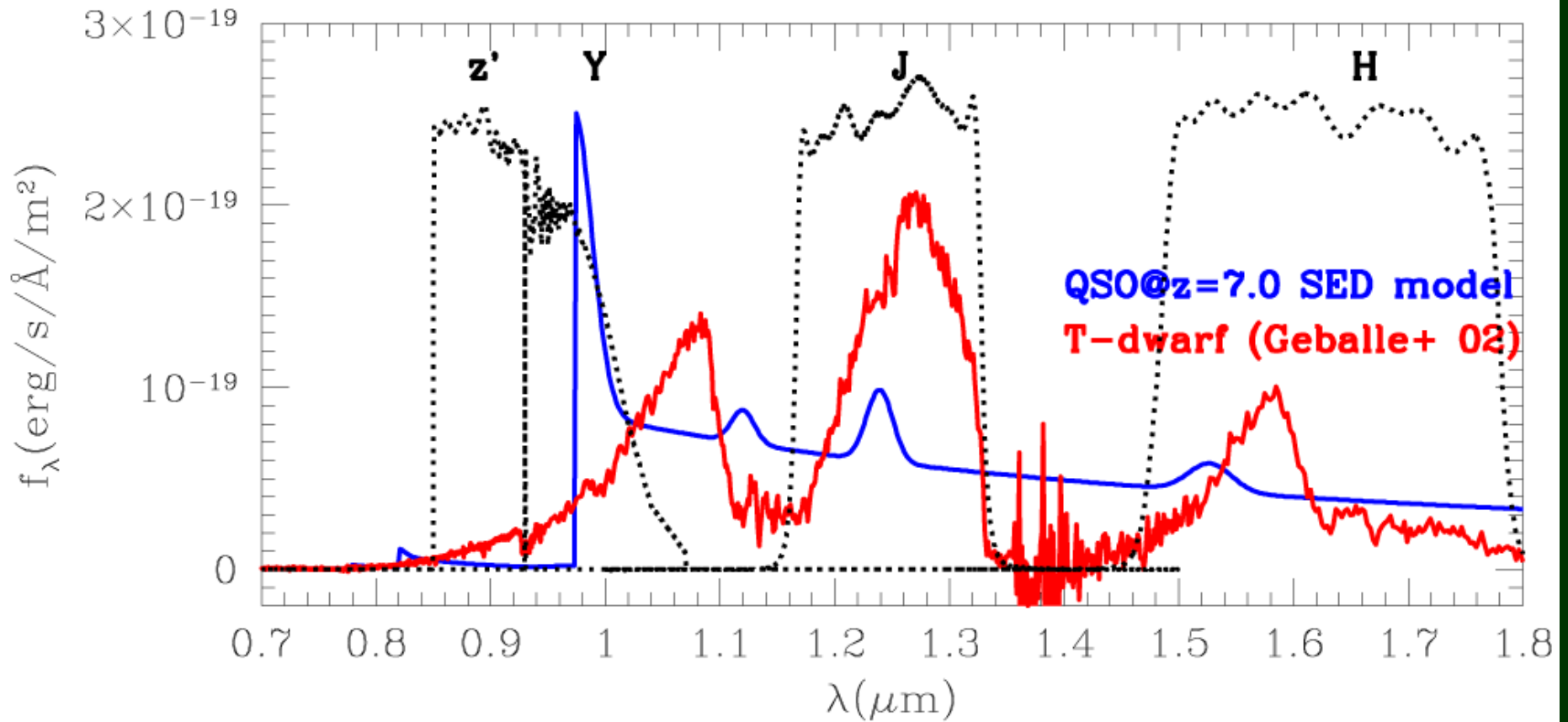


How to select high- $z$  quasars?

---



# How to select $z \sim 7$ quasars



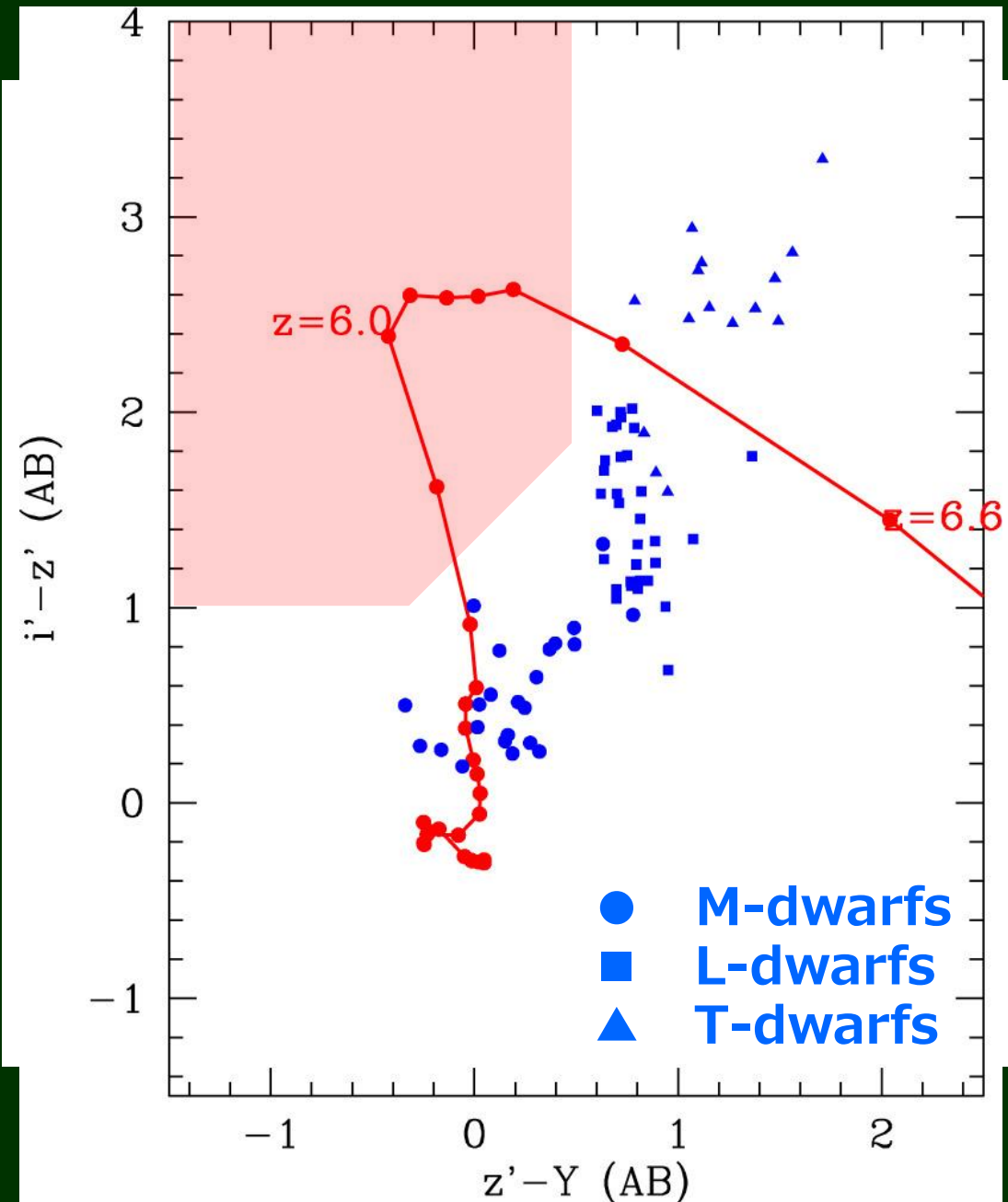
# How to select $z \sim 6$ quasars

## SDSS $z \sim 6$ QSO survey

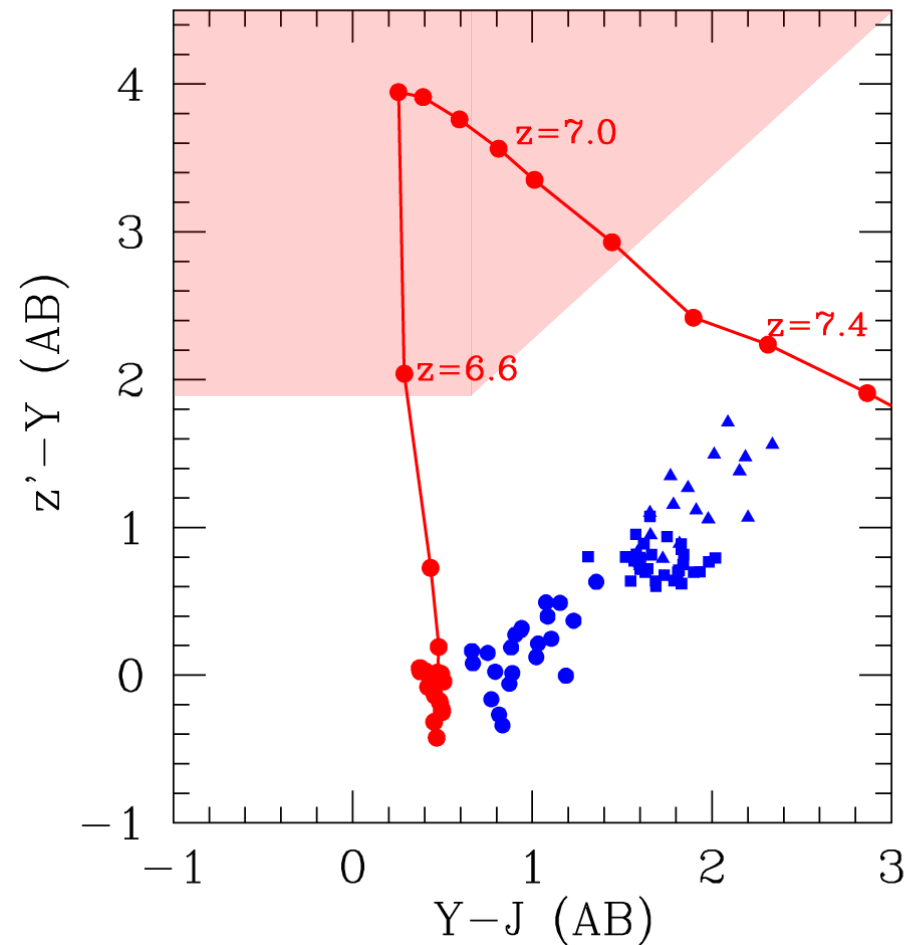
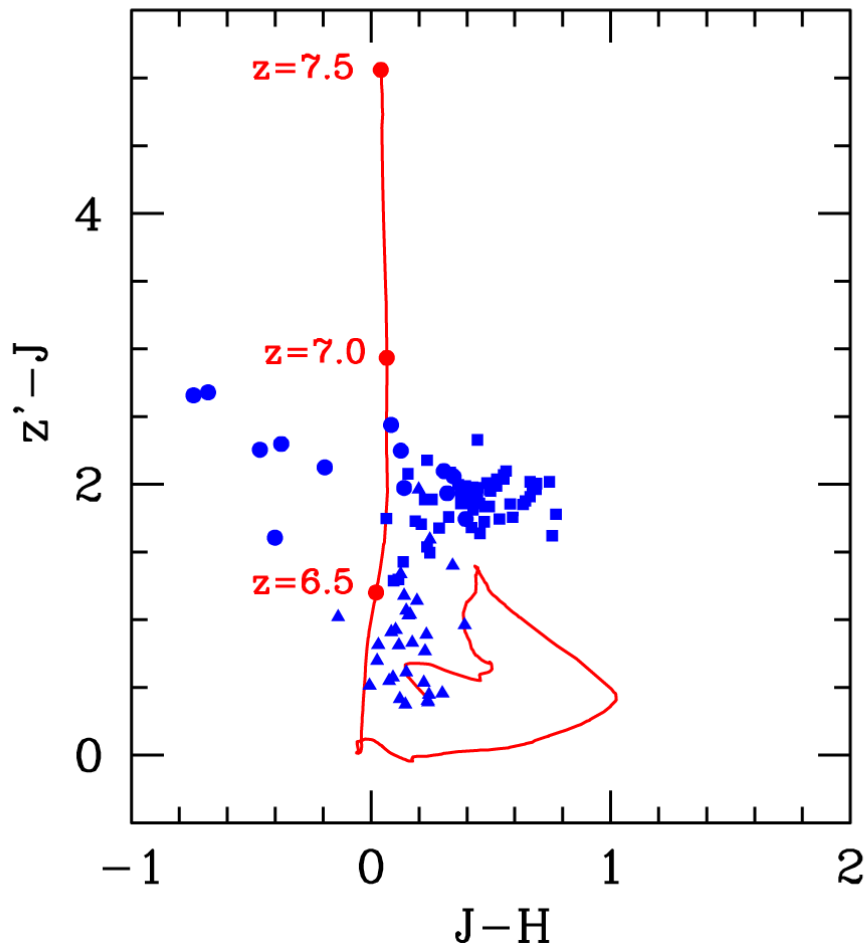
- Contamination from M/L/T dwarf stars
- $(i-z)$  vs.  $(z-J)$
- follow-up NIR imaging is required

## HSC $z \sim 6$ QSO survey

- Y-band fronts for J-band
- go deep with only optical imagings



# How to select $z \sim 7$ quasars



- Y-band is quite effective to isolate  $z \sim 7$  quasars from dwarfs
- Target fields should have J-band photometry
- See mode details in Imanishi-san's talk

# HSC high- $z$ quasar survey: Science goals

---

# Science cases on $z=6/7$ quasars

- Discovery
  - 1<sup>st</sup> discovery, survey strategy
  - statistical sample
- Luminosity function
- Correlation function@ $z\sim 6$
- BH mass, Eddington ratio
  - bright sample
  - faint sample
- Reionization:
  - GP trough for  $z\sim 6$  faint sample
  - Near zone for  $z\sim 7$
  - Damping wing for  $z\sim 7$
  - Correlation w/LAEs
- QSO BLR metallicity
  - Bright sample
  - Faint sample
- High- $z$  IGM metallicity
- Galaxy clustering around QSOs
  - Deep field
  - Wide field w/follow-up deep imaging

1<sup>st</sup> year

2-5<sup>th</sup> year

>10<sup>th</sup> year?

# reionization

- The reionized process of IGM after the "dark ages".
- The HII bubble expands around each object, making overlap each other to occupy the ionized region in the universe.

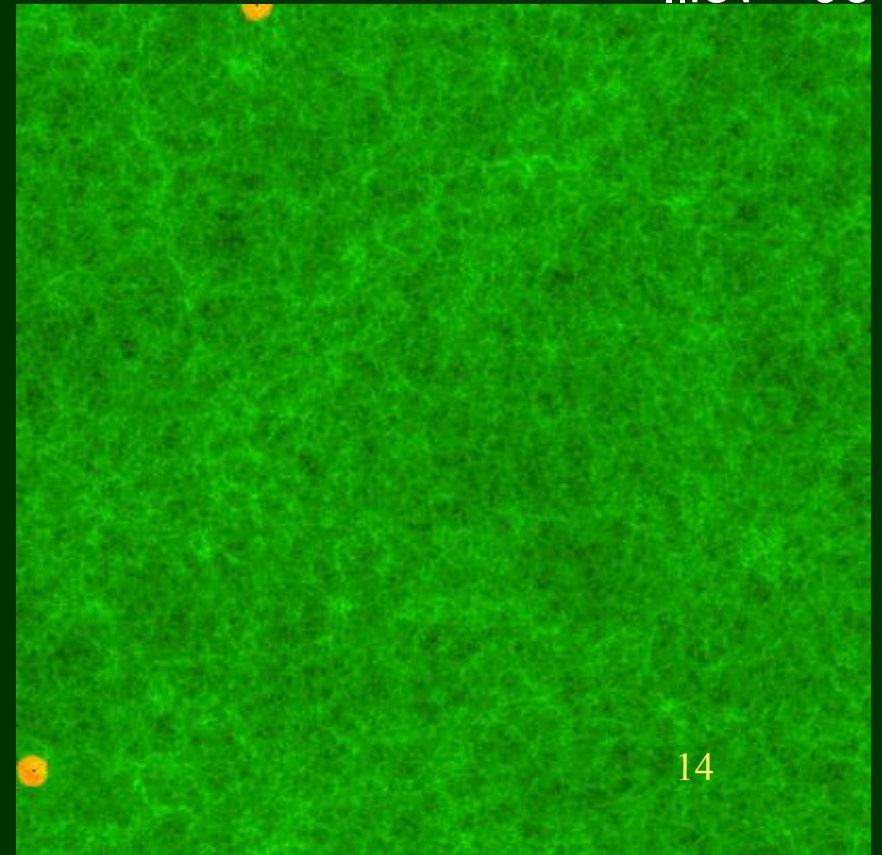
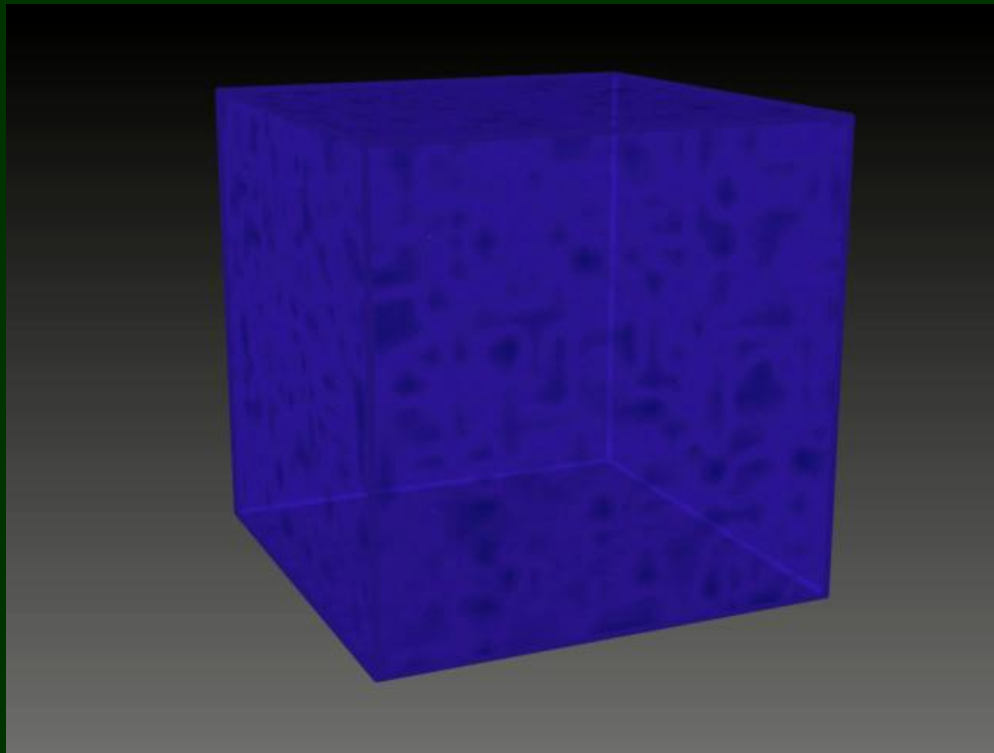
■ **When ?**  $6 < z < 11$  ?

Green: H I

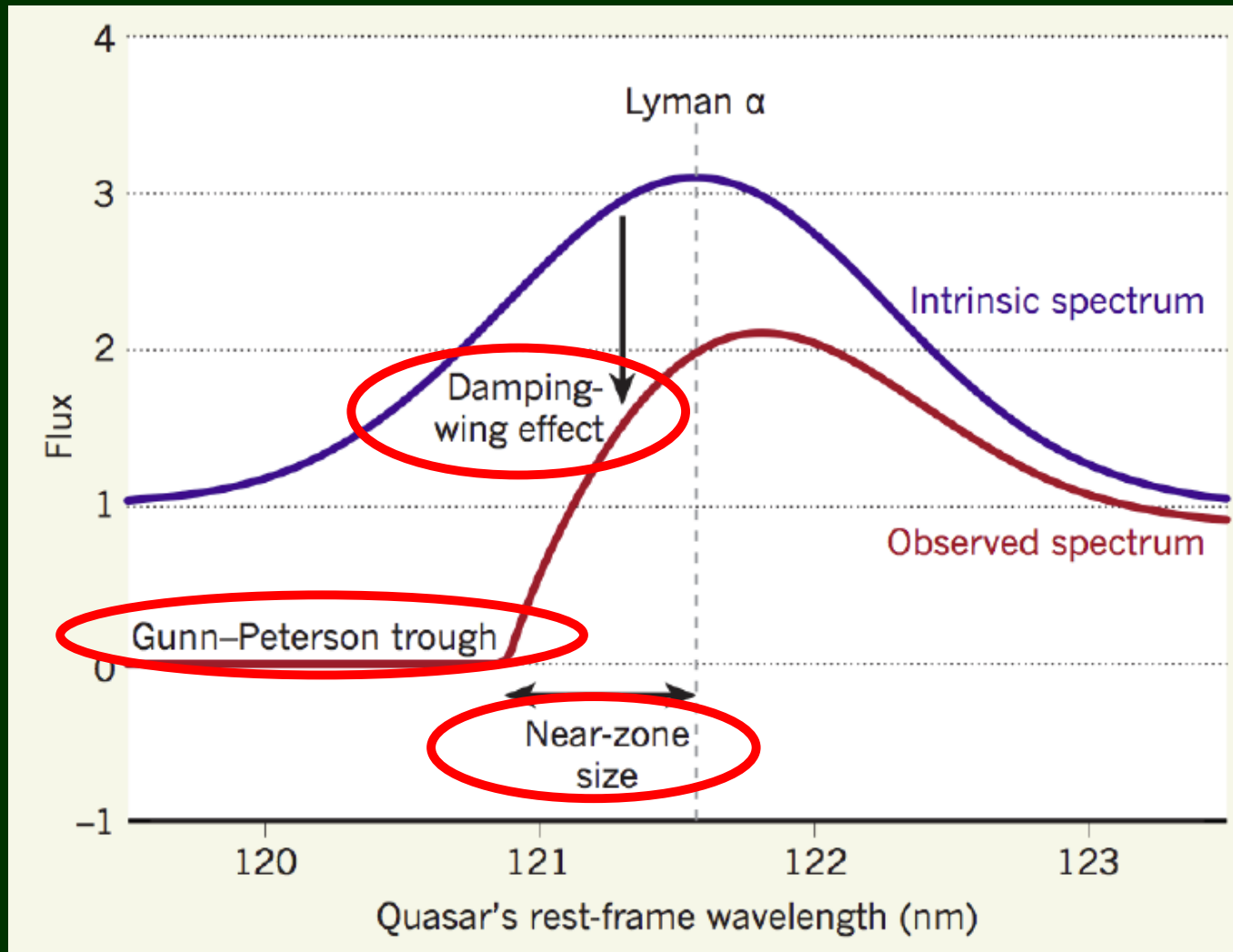
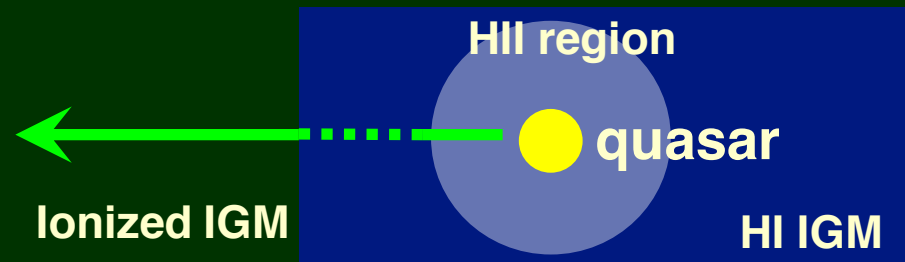
■ **What ?** QSO, LBG/LAE, popIII ?

Orange: H II Iliev+ 06

■ **How ?** inhomogeneous?

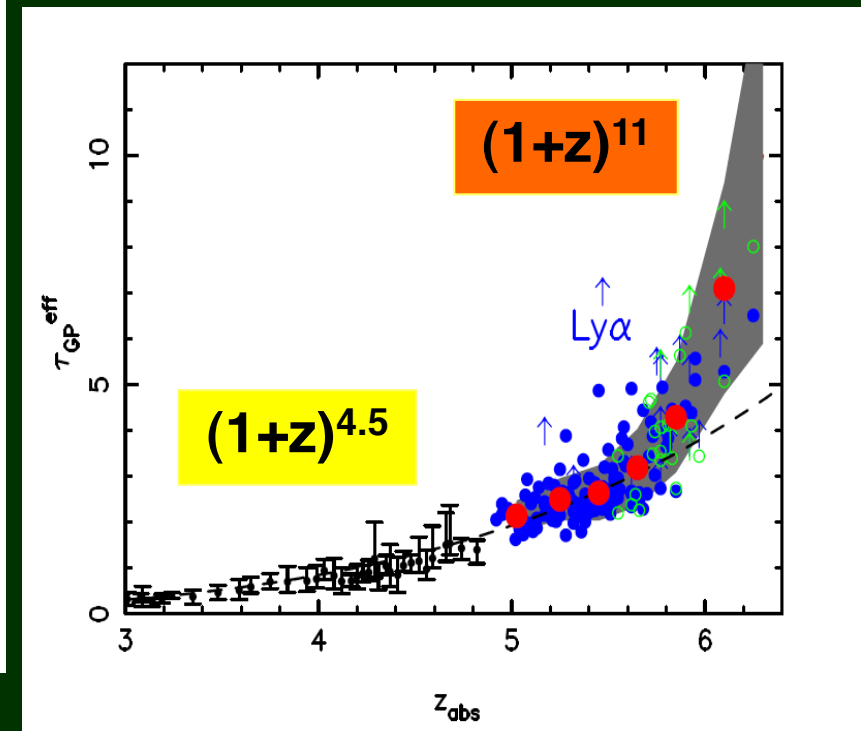
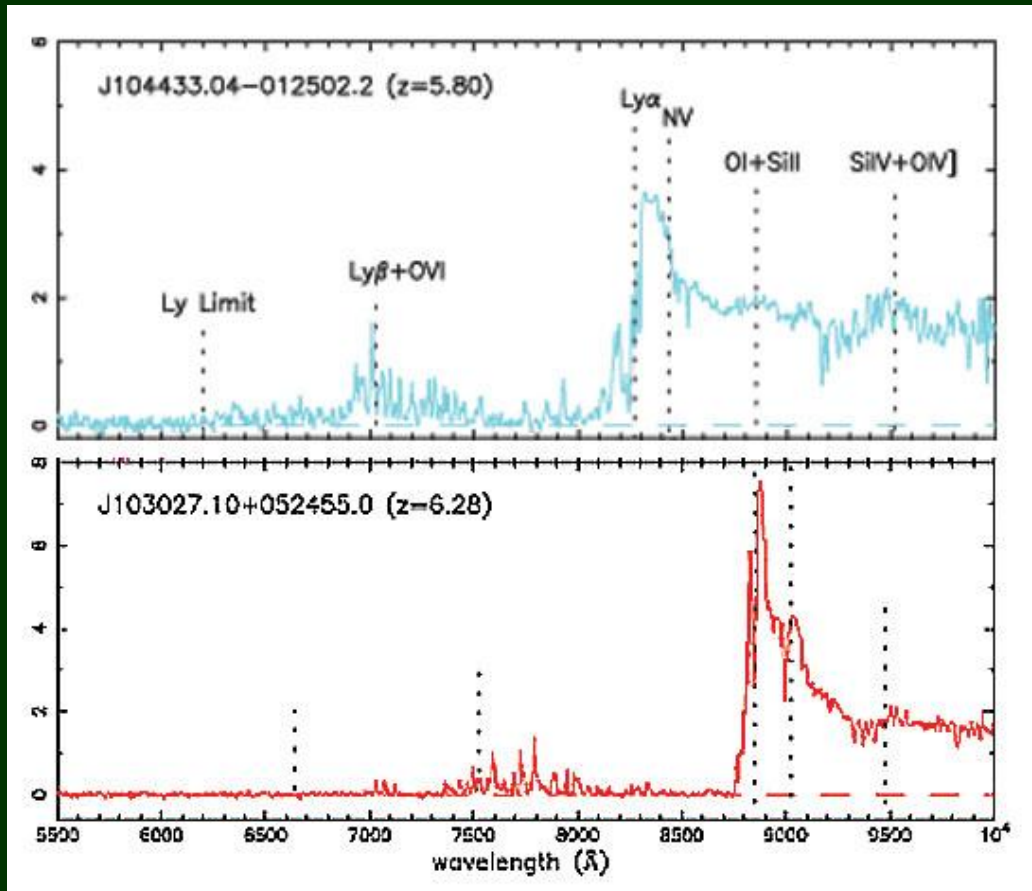
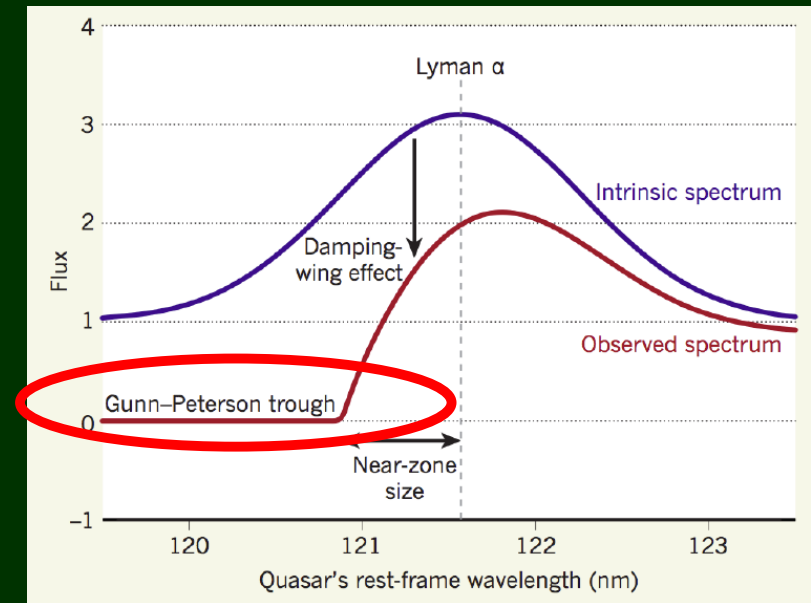


# Reionization probed by high-z quasars



# Reionization probed by high-z quasars

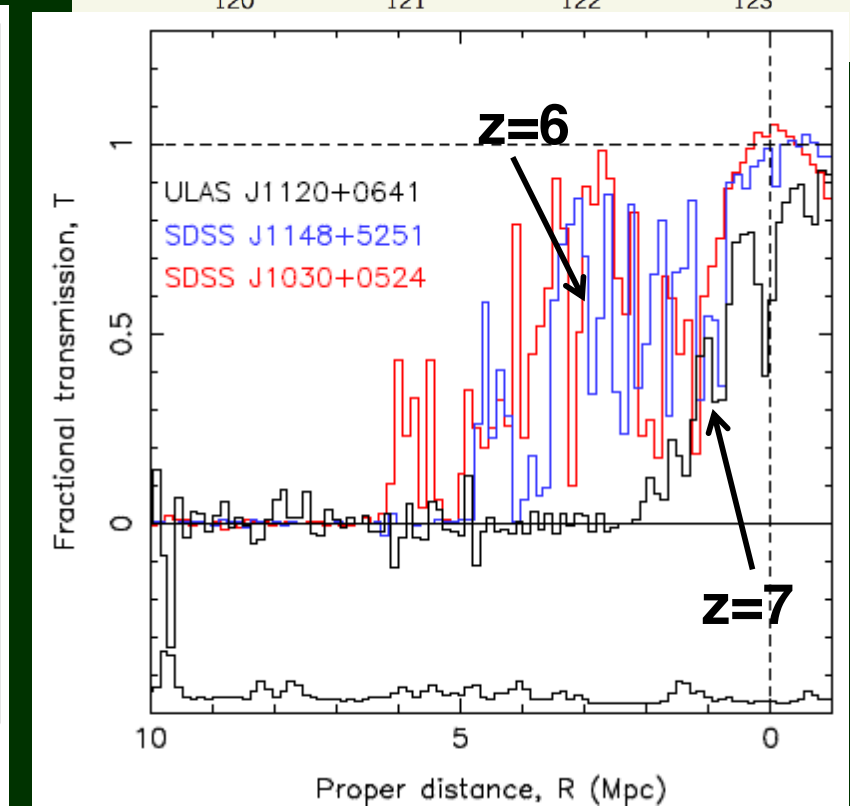
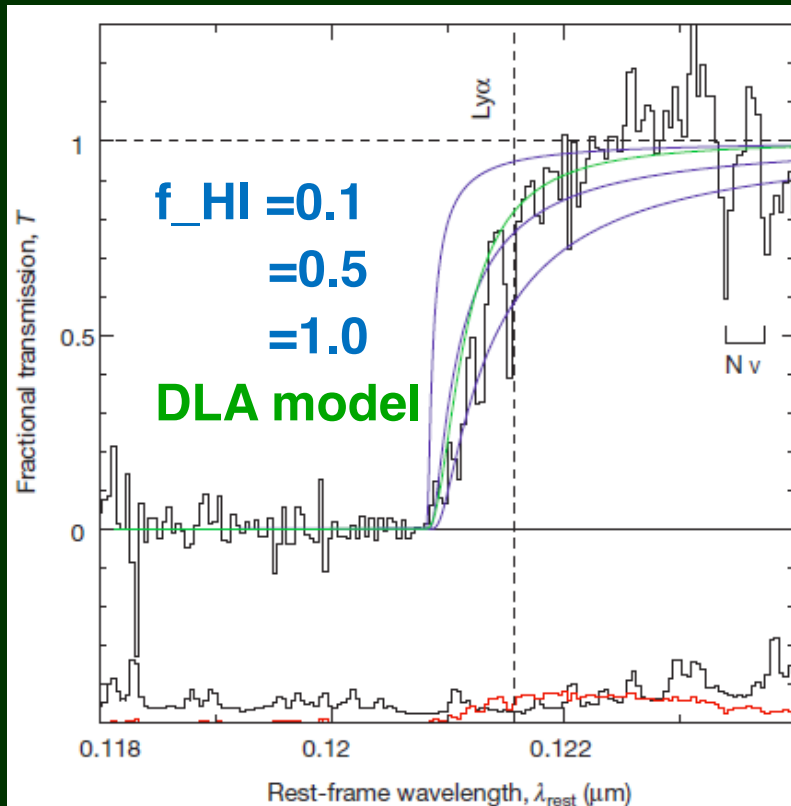
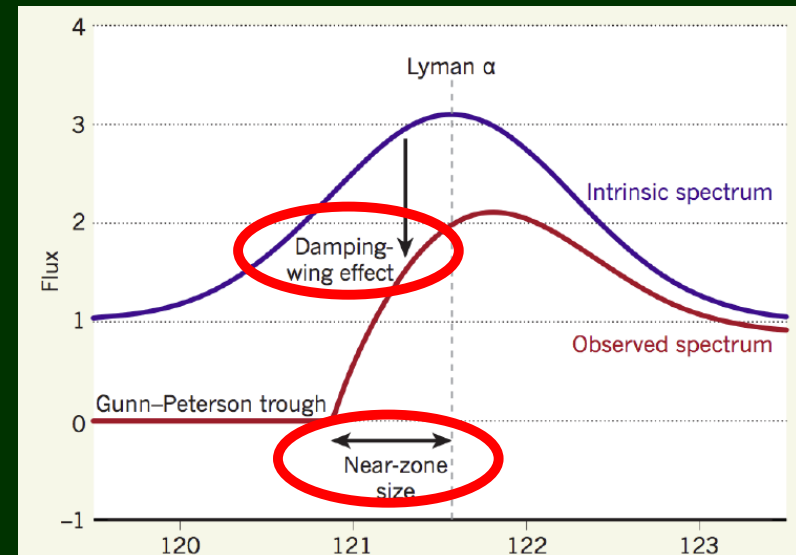
- GP trough
- IGM optical depth rapidly increase at  $z > 5.8$
- significant spatial variation
- $\tau = 2.1 \times 10^4 (1+z)^{3/2} f_{\text{HI}}$





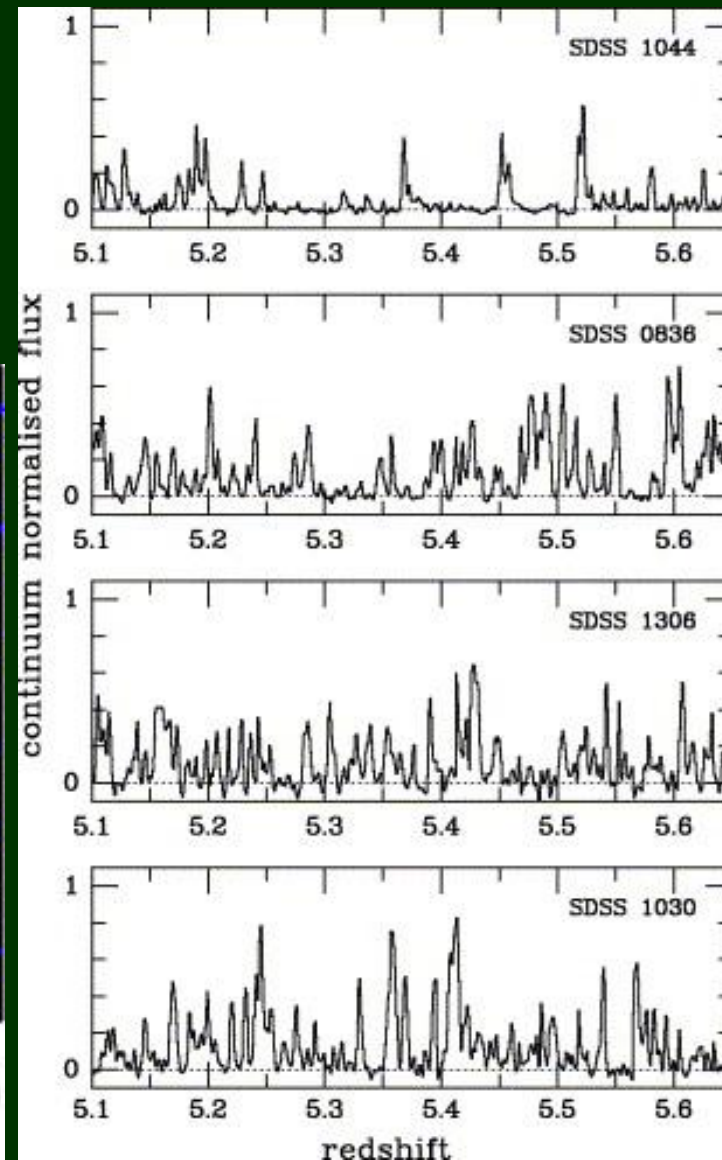
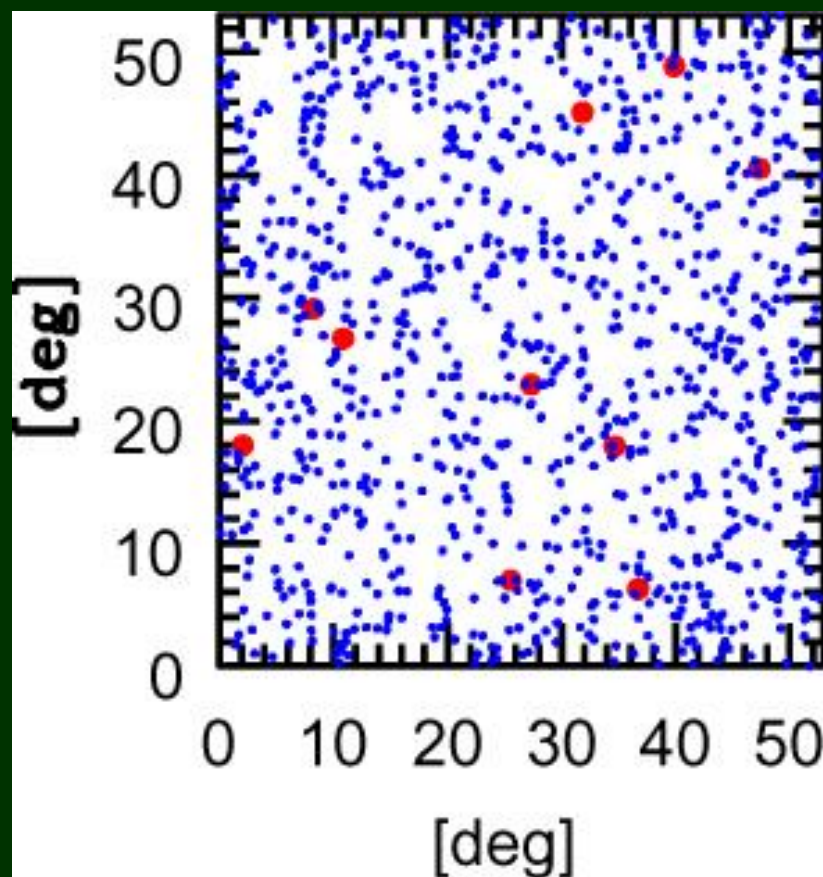
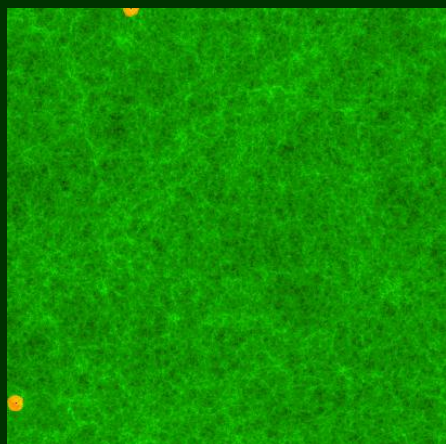
# Reionization probed by high- $z$ quasars

- Damping wing profile may constrain the neutral fraction
- Extremely small near zone at  $z=7.1$ 
  - Can be applied for  $f_{\text{HI}} > 0.1$
  - Based on some assumptions



# IGM ionization mapping

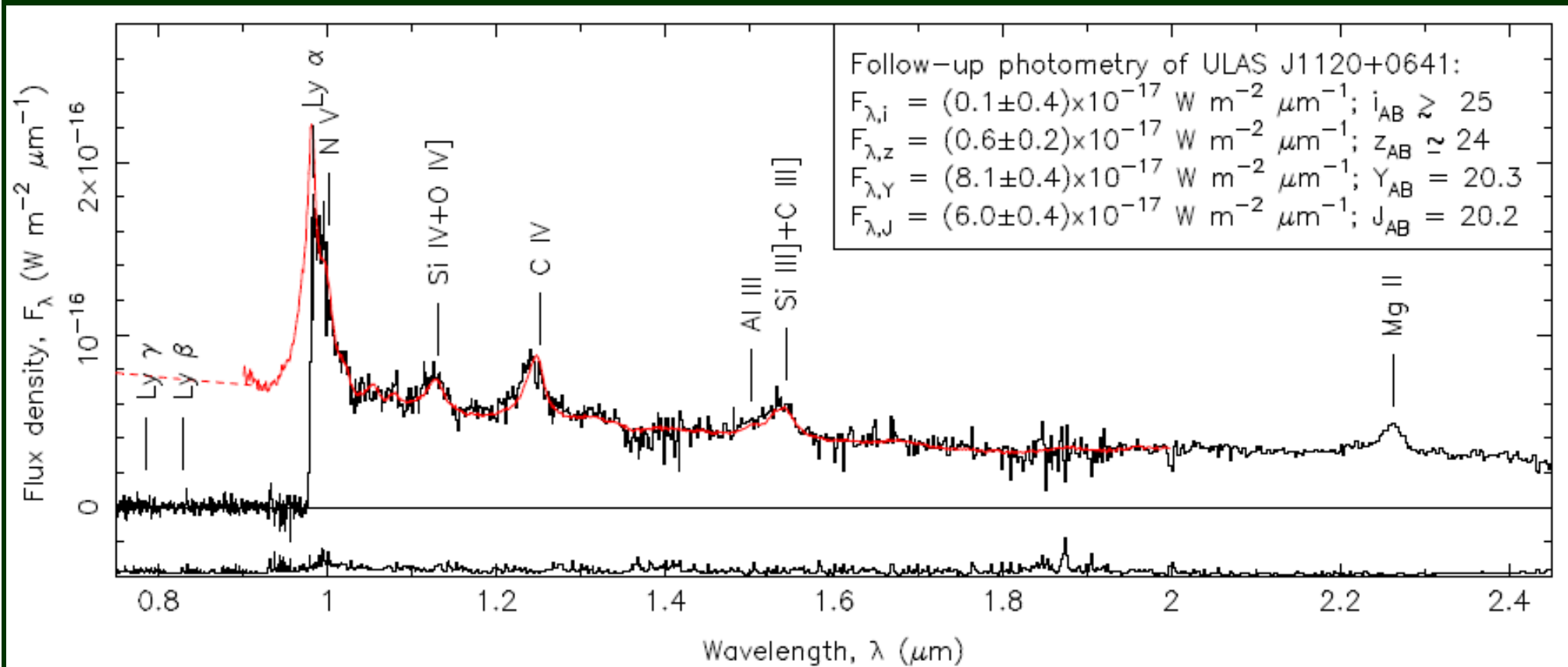
- Large variance of GP trough among many different QSO-LOS at  $z \sim 6$
- Evidence for a patchy reionization ?
- **mapping the IGM ionization**
- Requires ELTs



Djorgovski+ 06

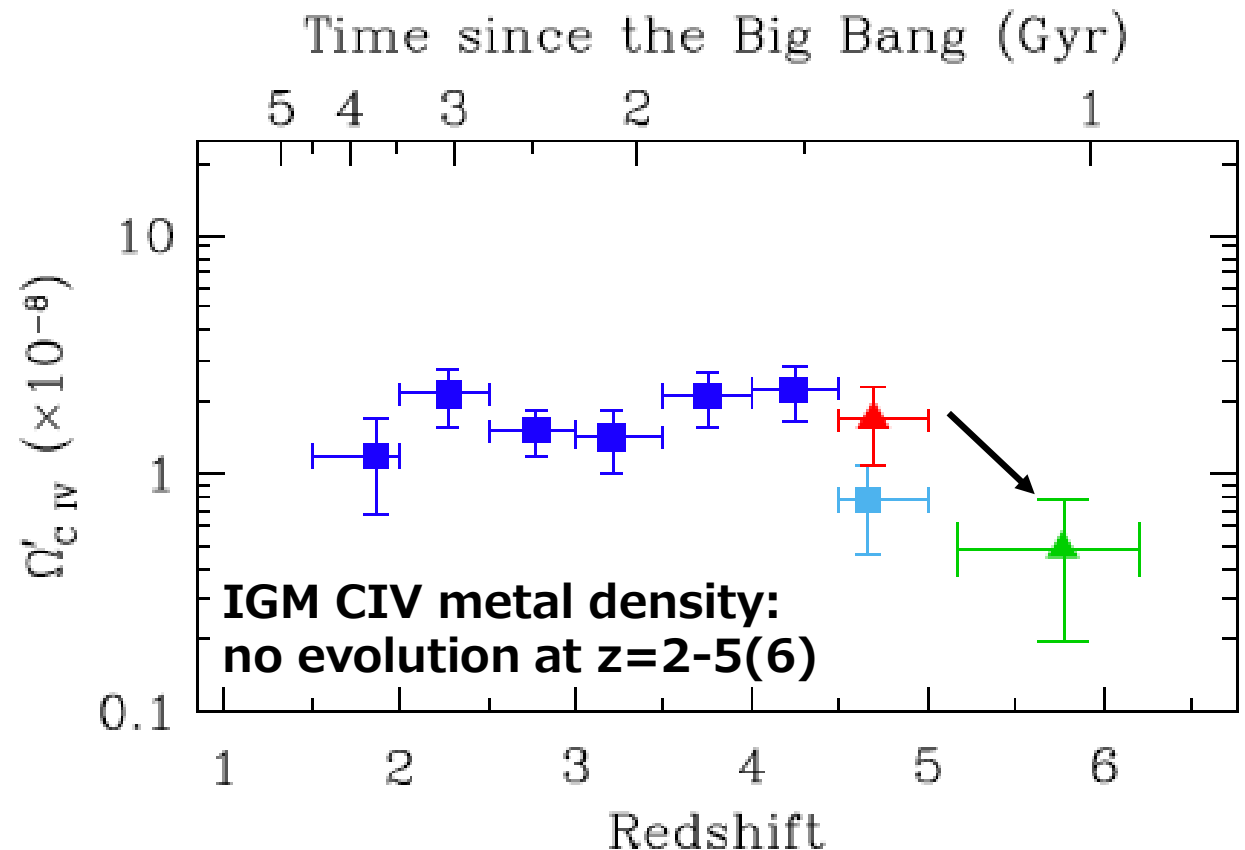
# Metallicity of High-z QSOs

- The  $z \sim 7$  spectrum strikingly good fit to the spectral shape of lower- $z$ . Not yet the 1<sup>st</sup> QSO.
- $NV/CIV \sim 0.7 \rightarrow$  Supersolar metallicity at  $z=6.28$  ( $t \sim 0.8$  Gyr)?
- Constraints on the initial star formation history and SMBH evolution



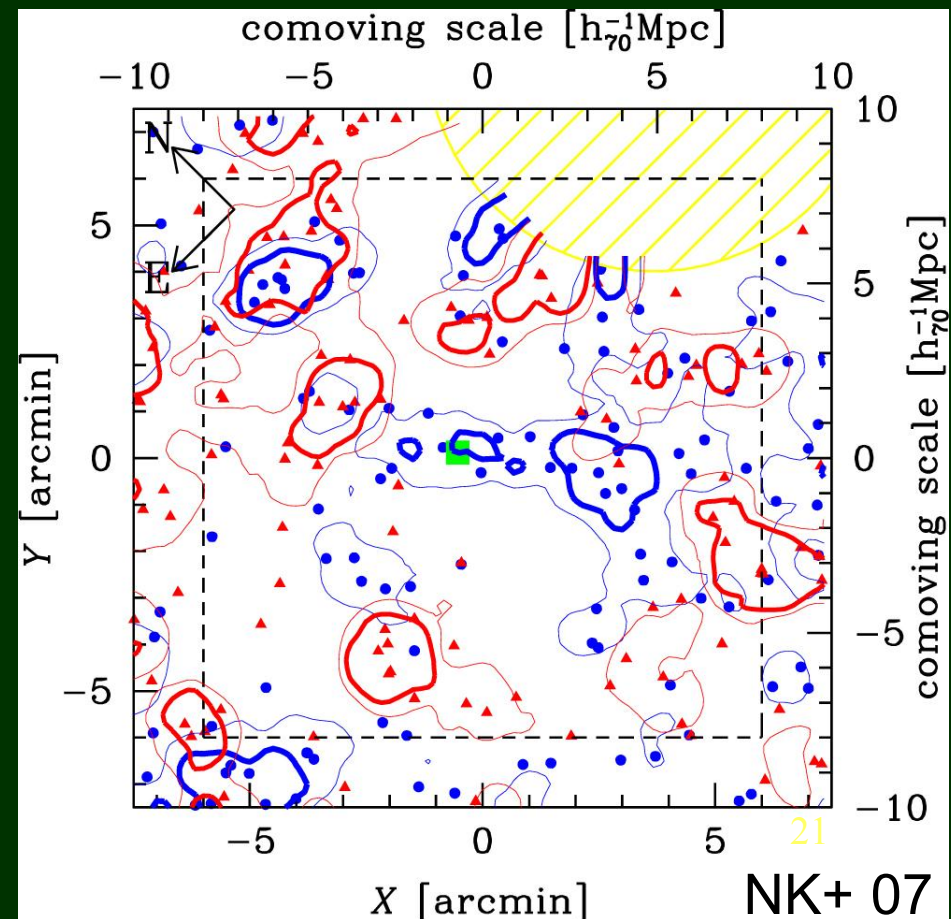
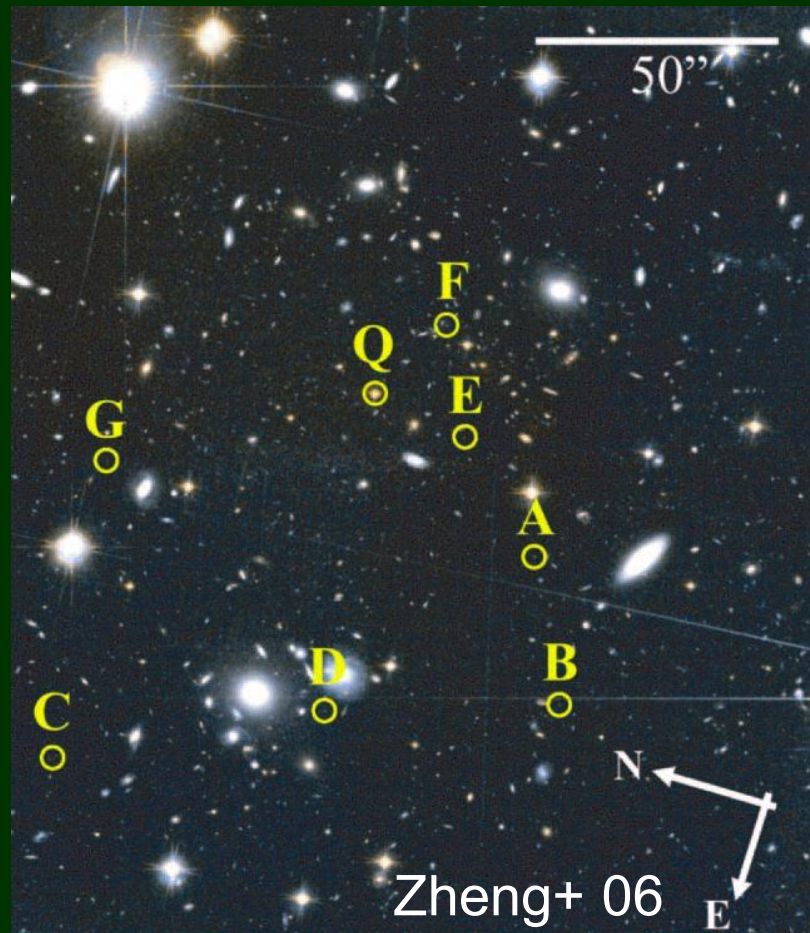
# Evolution of IGM Metallicity

- IGM CIV metal density : no evolution at  $z=2-5(6)$
- IGM was metal polluted in the early universe ( $z \gg 5$ ) by the first (2nd) stars?
- NIR spec for the early IGM metals at  $z > 6 \Rightarrow$  IGM metal abundance and ionization  $\Rightarrow$  constraint on the models of the first QSO/the first star



# Quasar-galaxy clustering

- Galaxy overdensity region around high- $z$  quasars
  - Primordial cluster formation
  - Initial galaxy formation in high-density region
- Possible suppression of galaxy formation in strong radiation fields

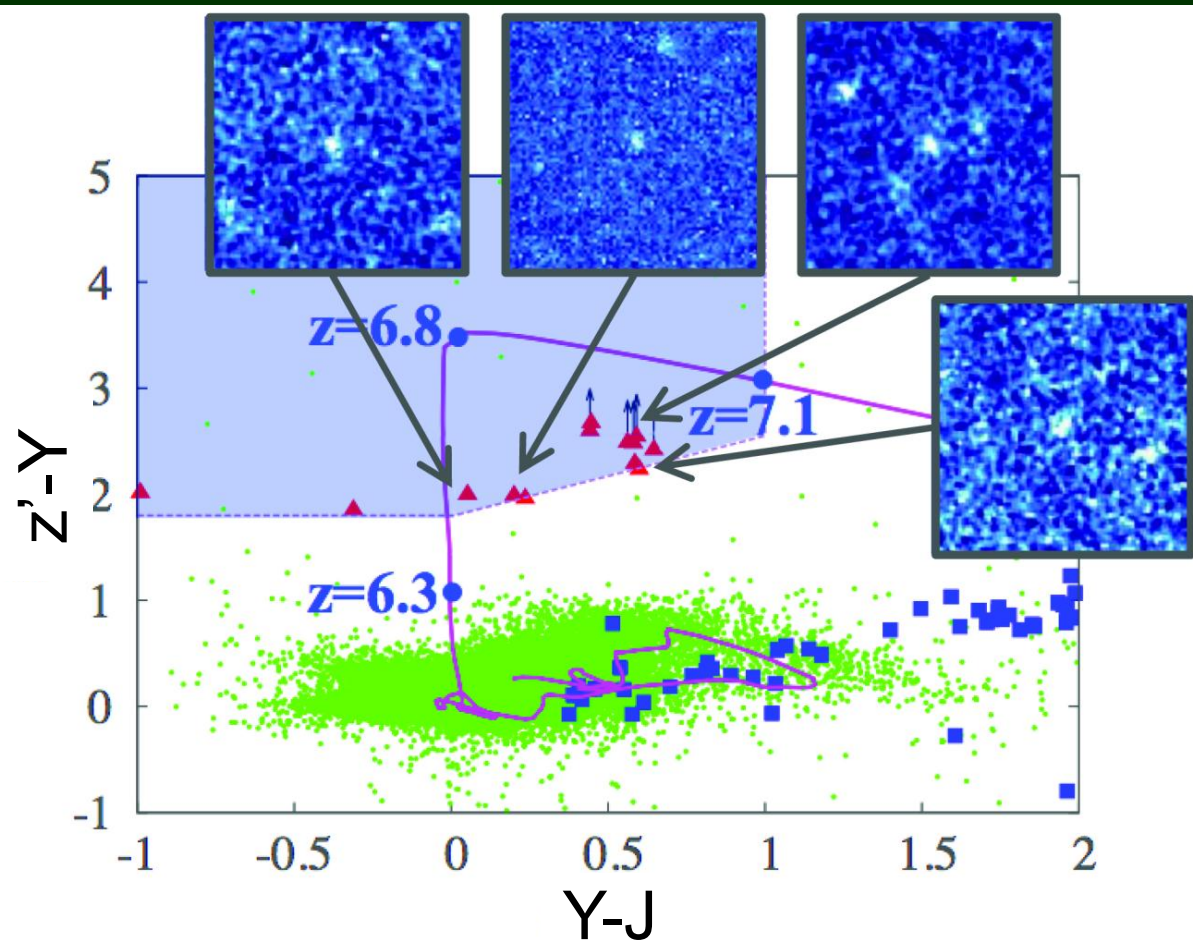


# Scam pilot survey

---

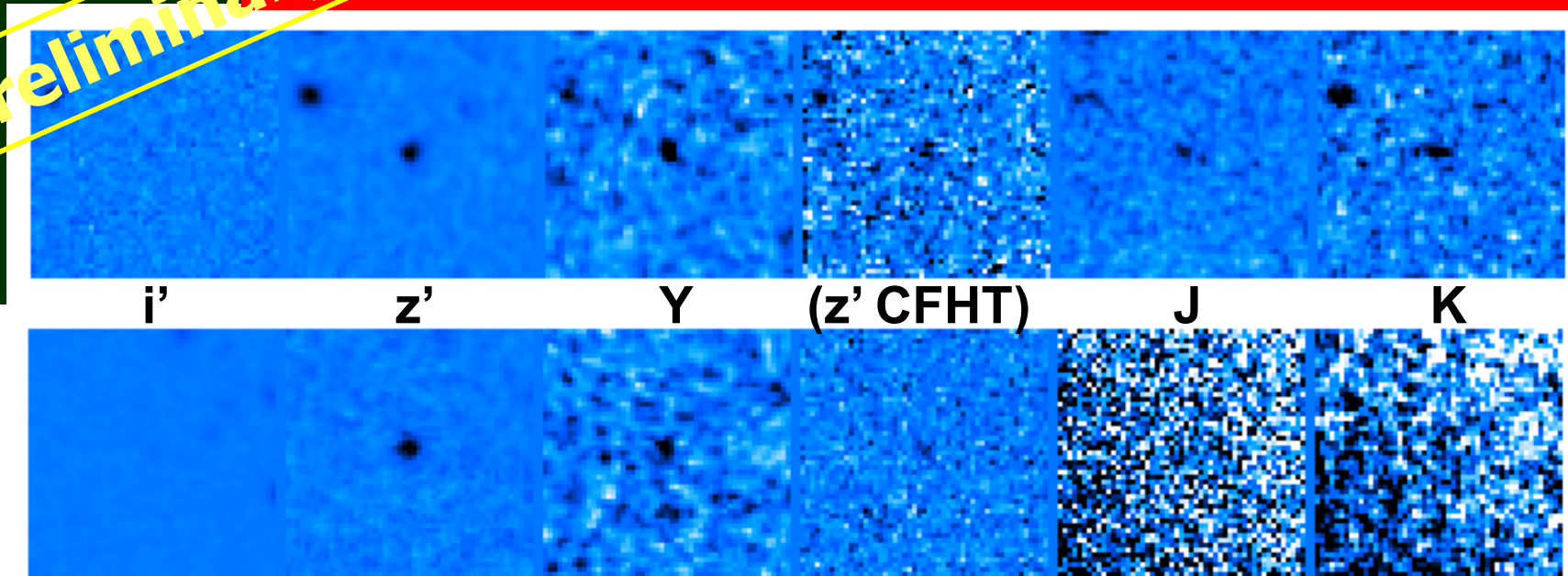
# Pilot survey w/SCam

- Pilot high- $z$  quasar survey w/Scam
  - lead by Y. Ishizaki
  - targeting quasars at  $z \sim 6/7$
  - Scam Y/ $z'$ -imaging
  - 7sqdeg (28 Scam FOVs),  $i < 28$ ,  $J, K < 23.5$  are available

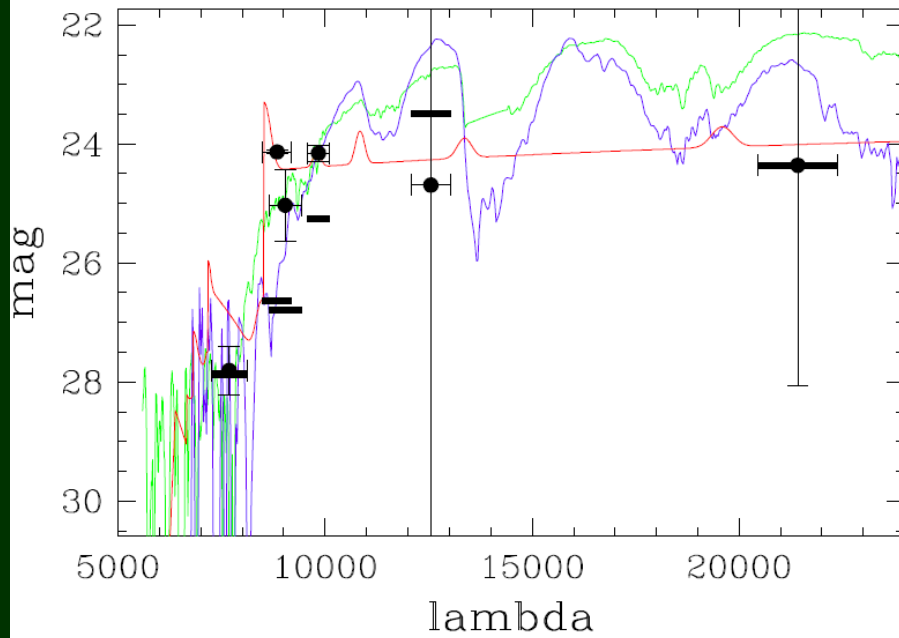


# Pilot survey w/SCam

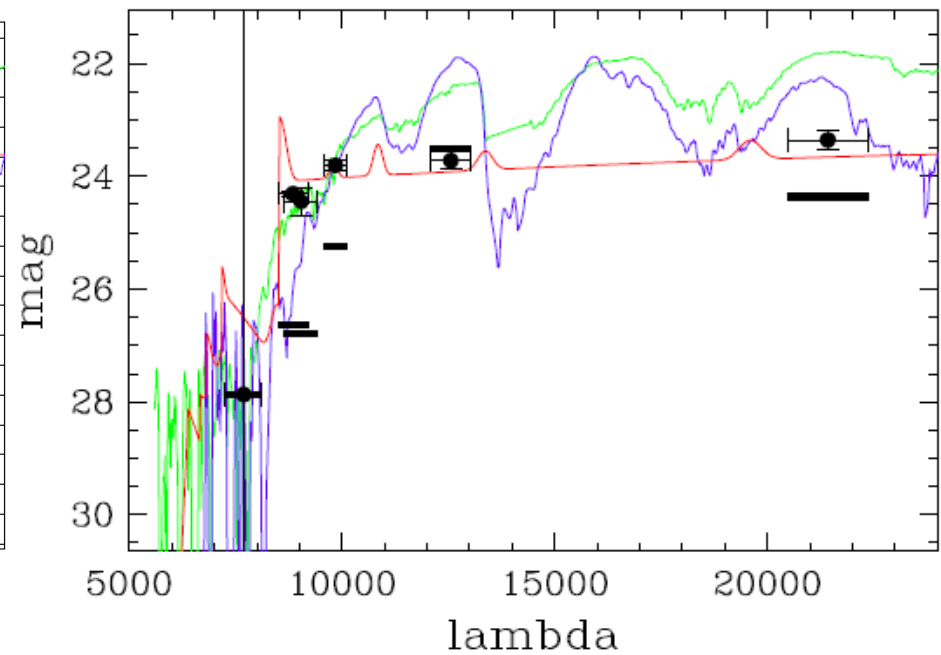
preliminary



1091000446



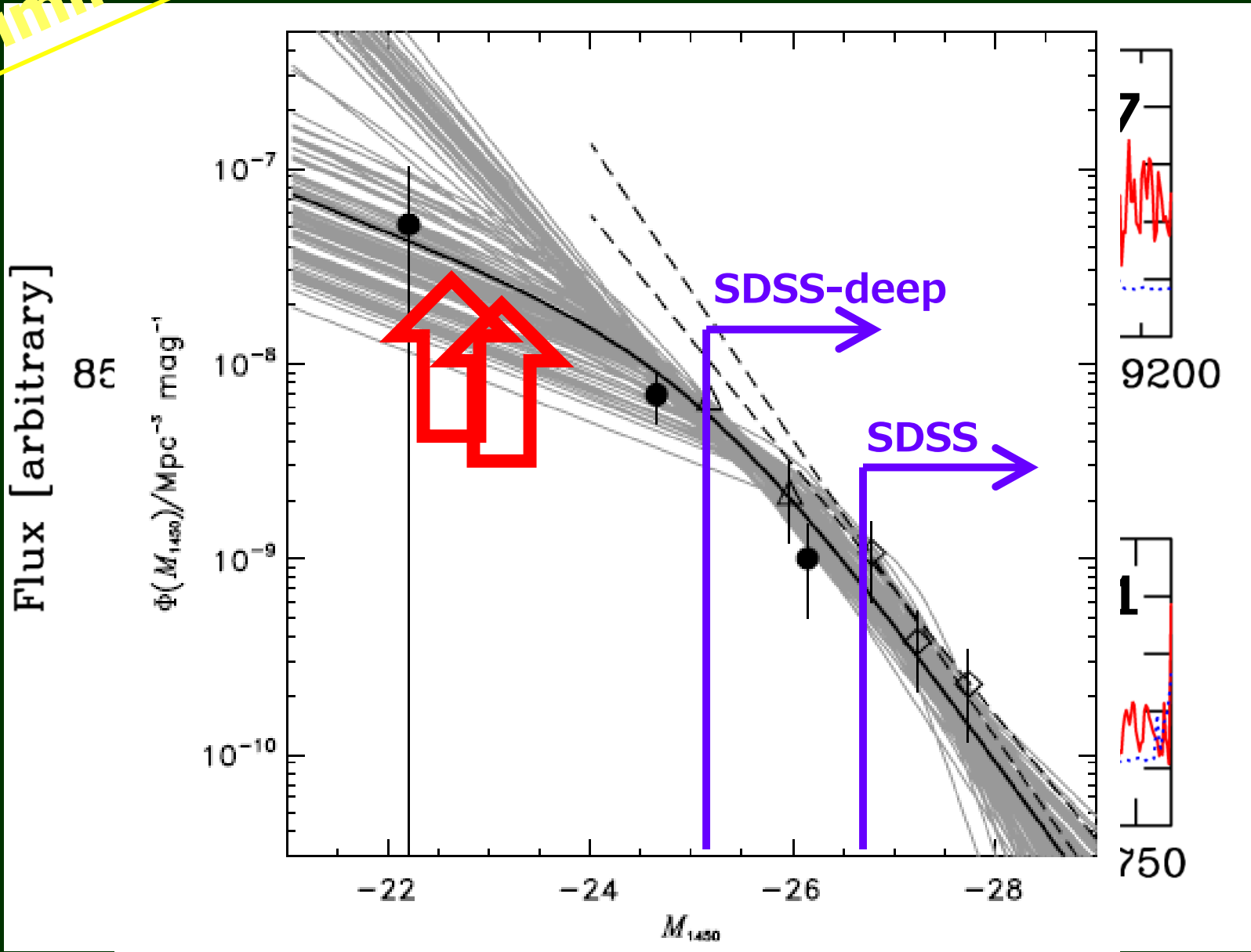
2752003989





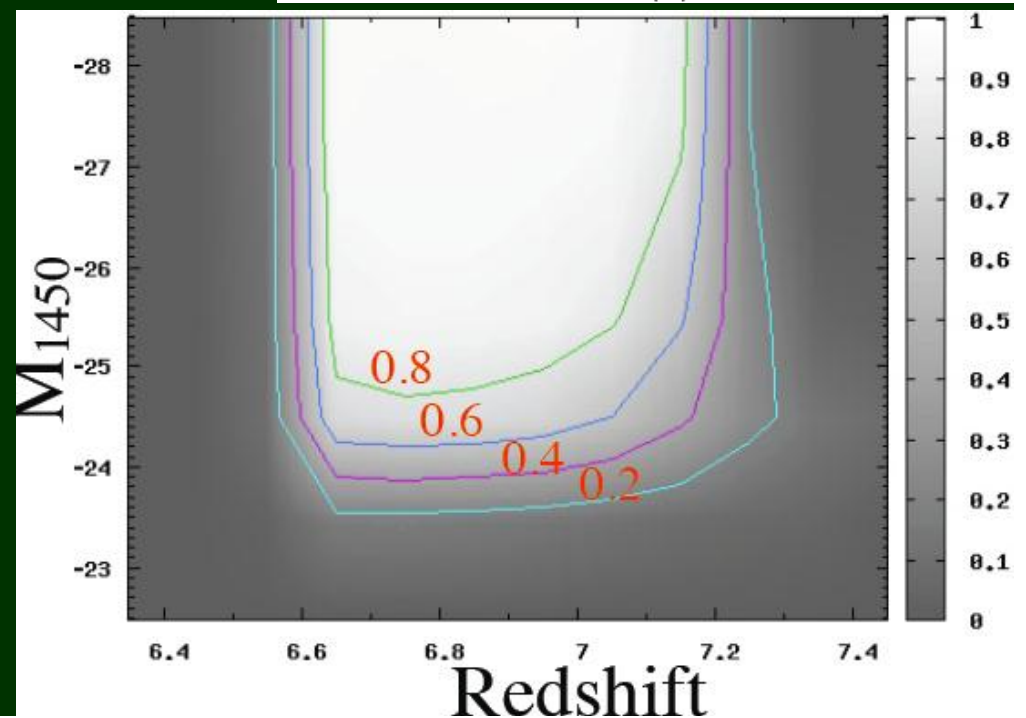
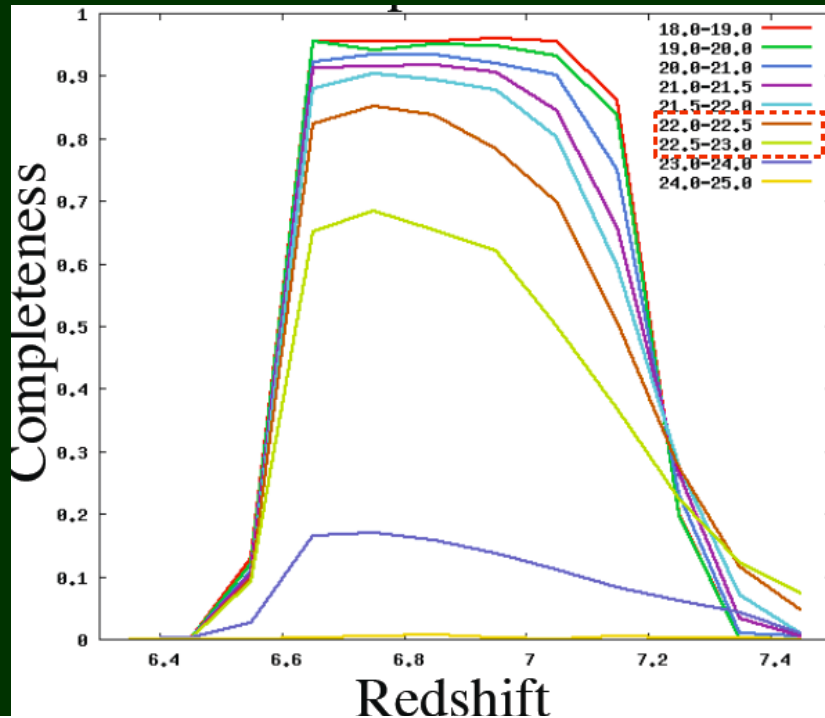
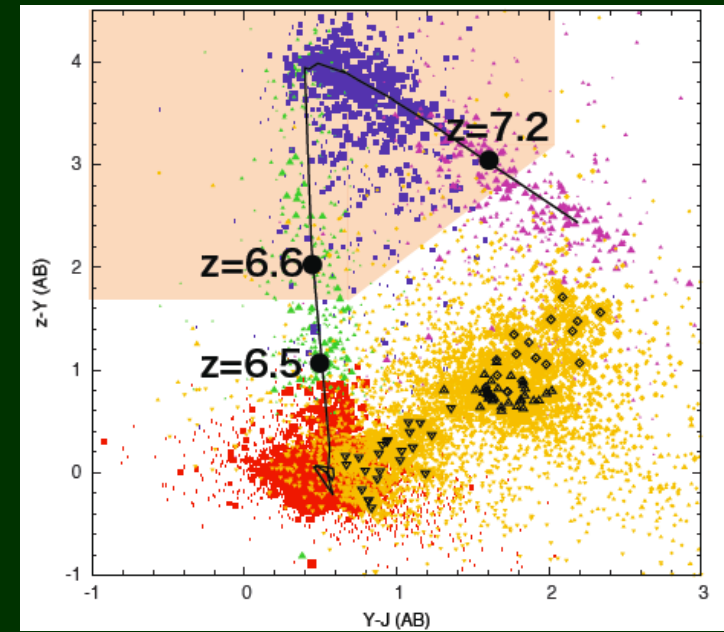
# Pilot survey w/SCam

preliminary



# Completeness estimate

- Counting artificial objects distributed on pseudo HSC images
- Wide layer:  $z \sim 7$  80% at  $J=23.4$   
 $z \sim 6$  70% at  $Y=24$
- Work in progress. Need more realistic images.
- See more details in Matsuoka-san's talk



## HSC high-z quasar survey:

### ■ Target fields:

- Wide: 1400sqdeg, VIKING( $J_{AB} < 22.1$ )+UKIDSS(<21.0)
- Deep: 27sqdeg (UKIDSS-DXS 16sqdeg)

### ■ Selection:

- $z \sim 6$ : (i-z) vs.(z-y)
- $z \sim 7$ : (z-y) vs.(y-J)

### ■ Expected numbers:

- $z \sim 6$ :  $W = 280(m_{1450(1+z)} < 24)$ ,  $D = 50(m_{1450(1+z)} < 25)$
- $z \sim 7$ :  $W = 50(m_{1450(1+z)} < 23.4)$ ,  $D = 3(m_{1450(1+z)} < 25.3)$

### ■ Science cases:

- QLF (SMBH, photon budget)  $\rightarrow z=6, z=7, \text{ faint QSOs}$
- Constraint on reionization  $\rightarrow z=6, z=7$
- IGM opacity mapping  $\rightarrow z=6, \text{ space density}$
- metallicity evolution ( $5 < z < 7$ )  $\rightarrow z=7(6)$
- Protocluster around QSOs  $\rightarrow z=6(7)$