

$z > 6$ QSO study using HSC wide survey data

Subaru SSP

Wide: $>1000 \text{ deg}^2/200 \text{ nights}$

Masa Imanishi
今西 昌俊

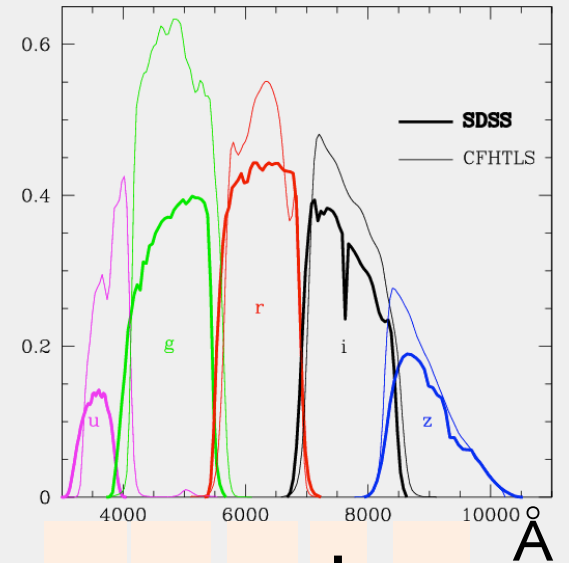
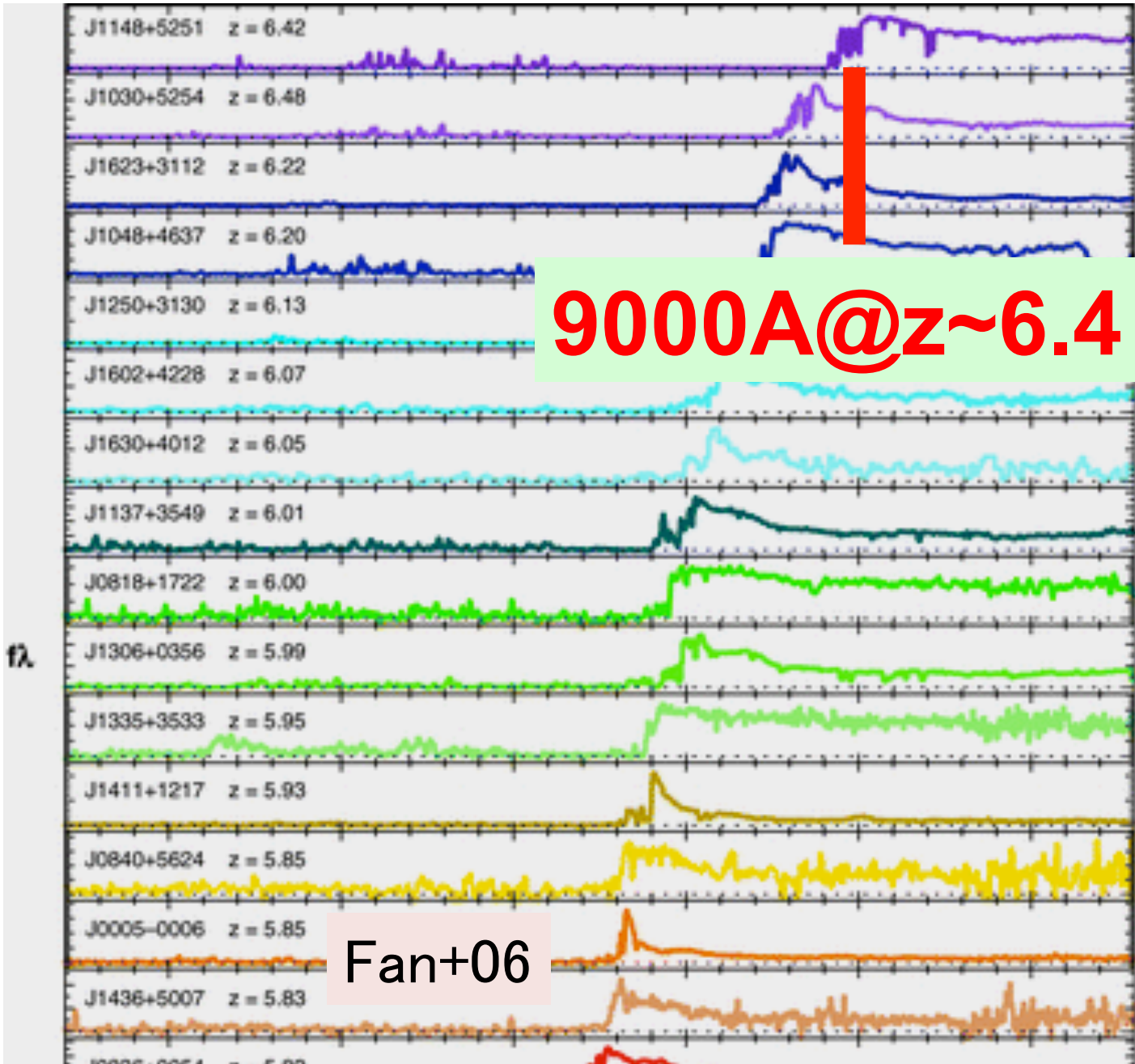


NAOJ/
Subaru Telescope



high-z QSO search

Fan+03
Willott+07,+10



u g r i z

Fan+06

UKIDSS/LAS

Y=20.9, J=20.8, H=20.0, K=21.1 (AB; 5σ)

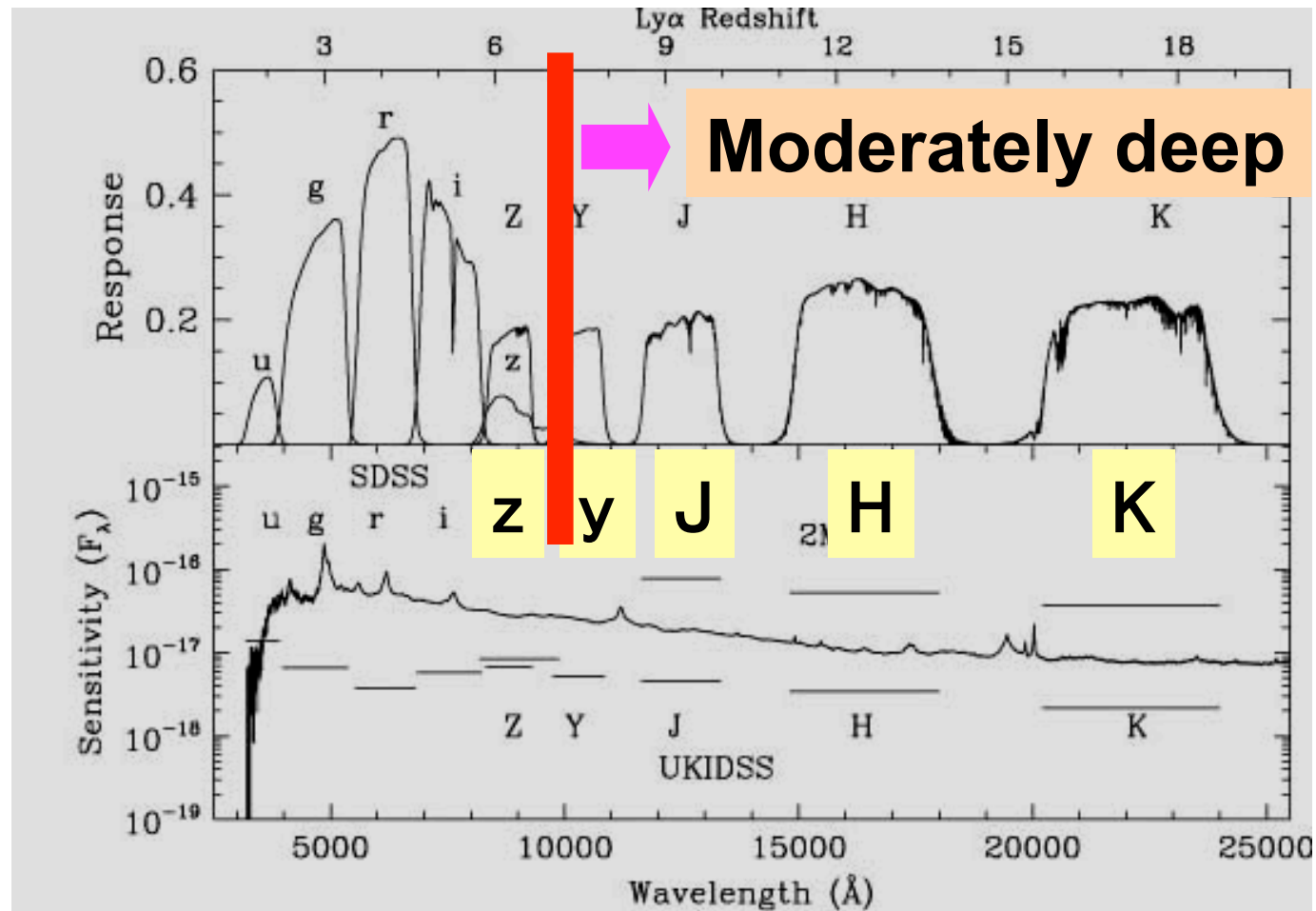


UKIRT

4000 deg²



WFCAM



UKIDSS/LAS

Y=20.9, J=20.8, H=20.0, K=21.1 (AB; 5σ)



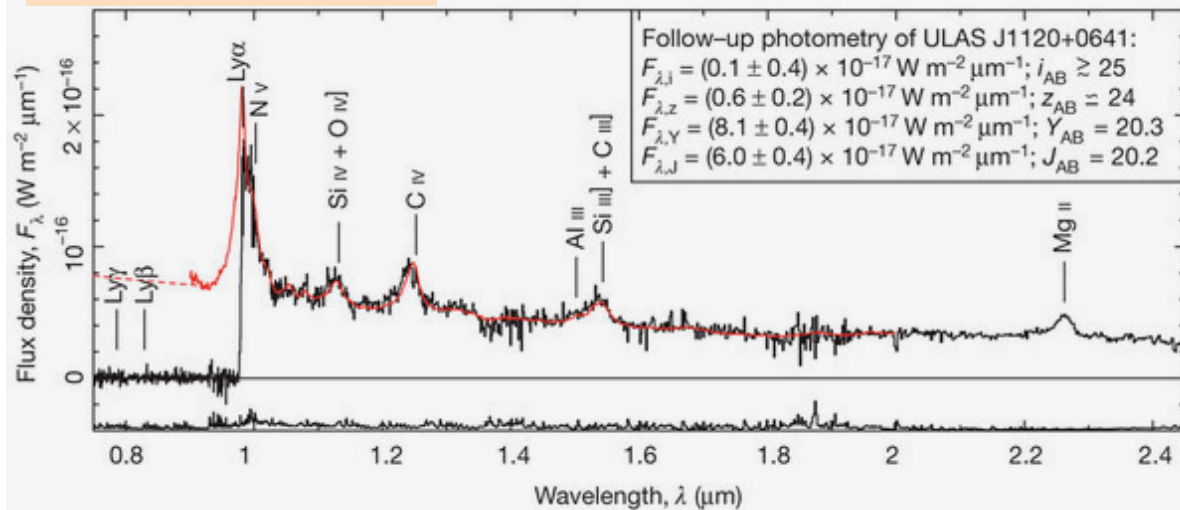
UKIRT



WFCAM

z=7.08 QSO

Mortlock+11 Nature 474 616

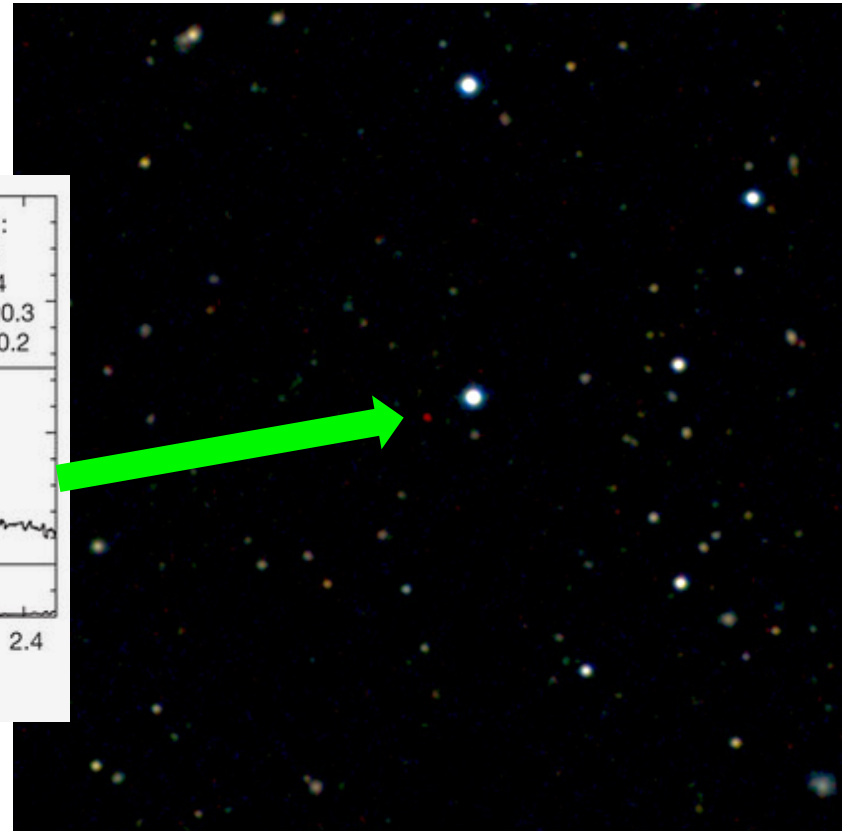


y

J

H

K



VISTA/VIKING

1500 deg²

$z=23.1, Y=22.3, J=22.1$ (AB; 5σ)

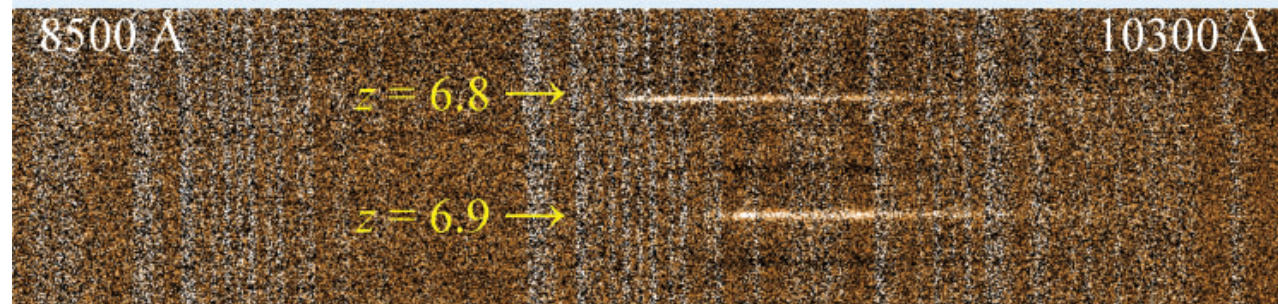
~ 1 mag deeper than UKIDSS/LAS
(3–5 times QSOs/unit area)



VISTA



$z=6.8, 6.9$ QSOs (?)



~ 35 min VLT/FORS2, poor conditions (seeing $\sim 1.4''$)

▪ 2 $z > 6.5$ quasars in 180 square degrees

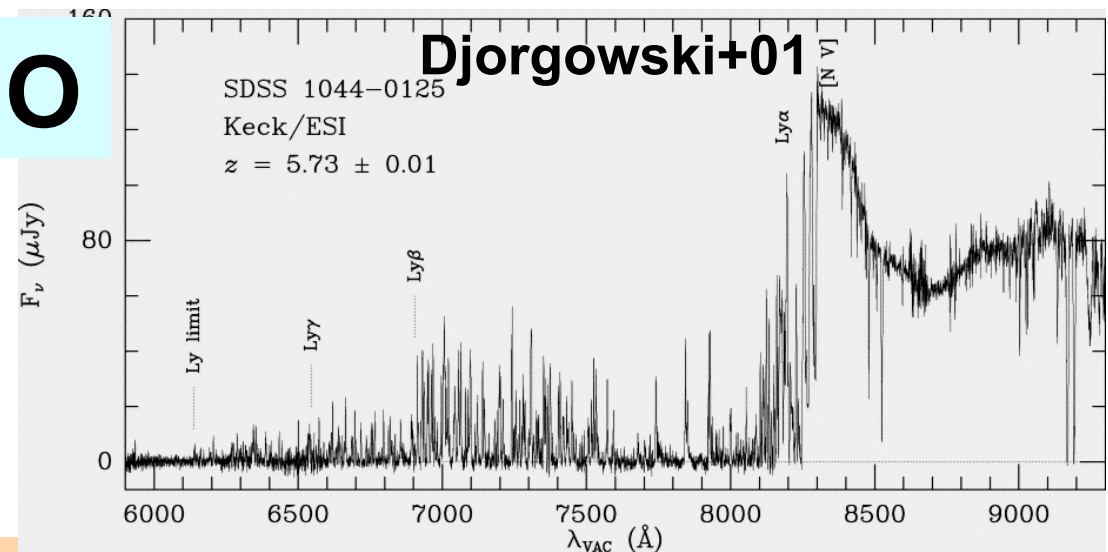
$Y_{AB} \sim 21.2$ and $21.3 \rightarrow M_{1450} = -25.7$

Another 3-4 candidates in a total area of 270 deg²

Venemans 2011 Jul (Conference talk)

Distant bright QSO

Science



1. IGM physics (e.g., re-ionization epoch) from high S/N spectroscopy

2. Contribution to cosmic reionization

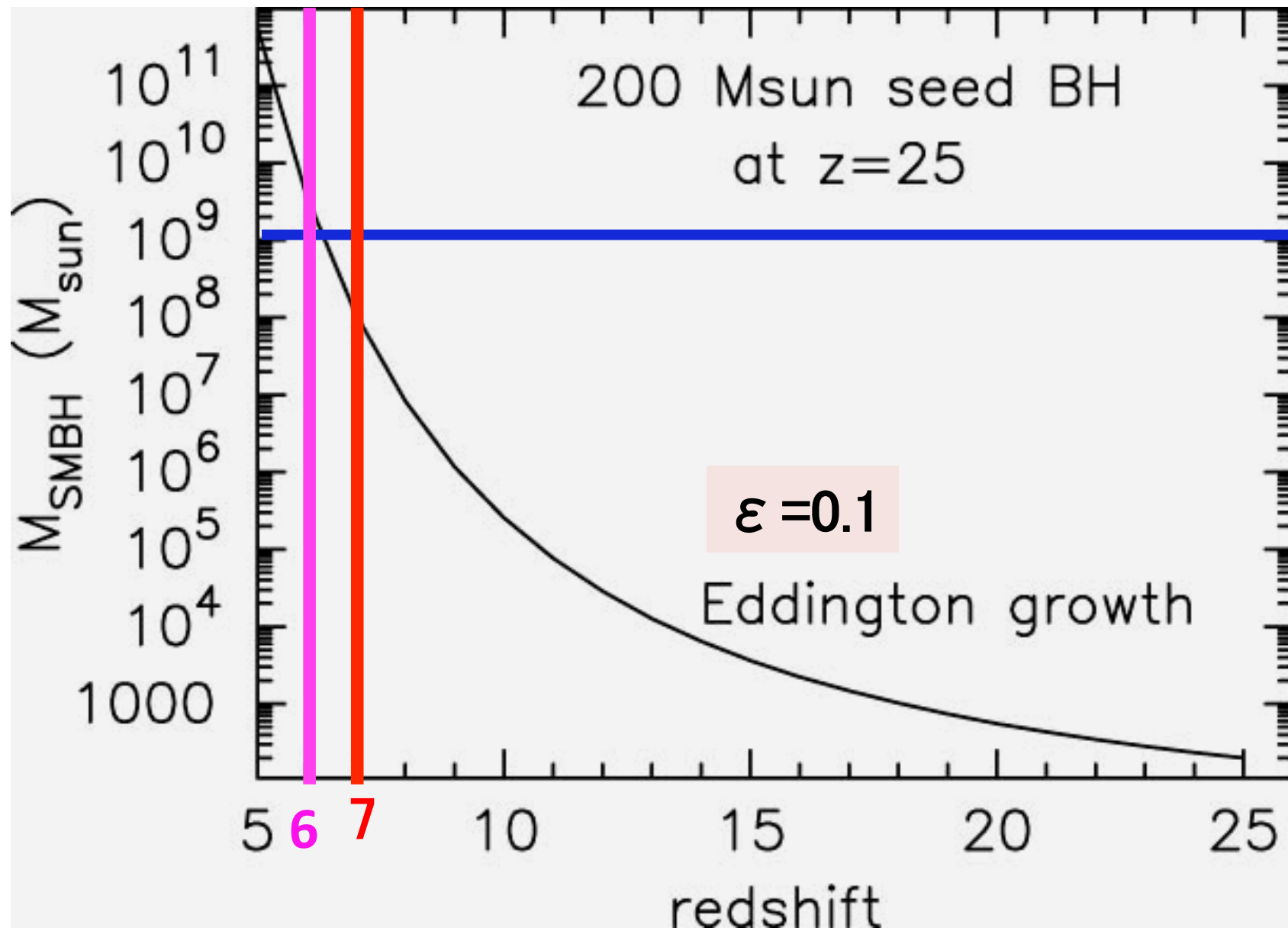
3. High-z proto-cluster search

4. QSO metallicity \rightarrow star-formation history

5. Constrain SMBH formation theory

SMBH growth

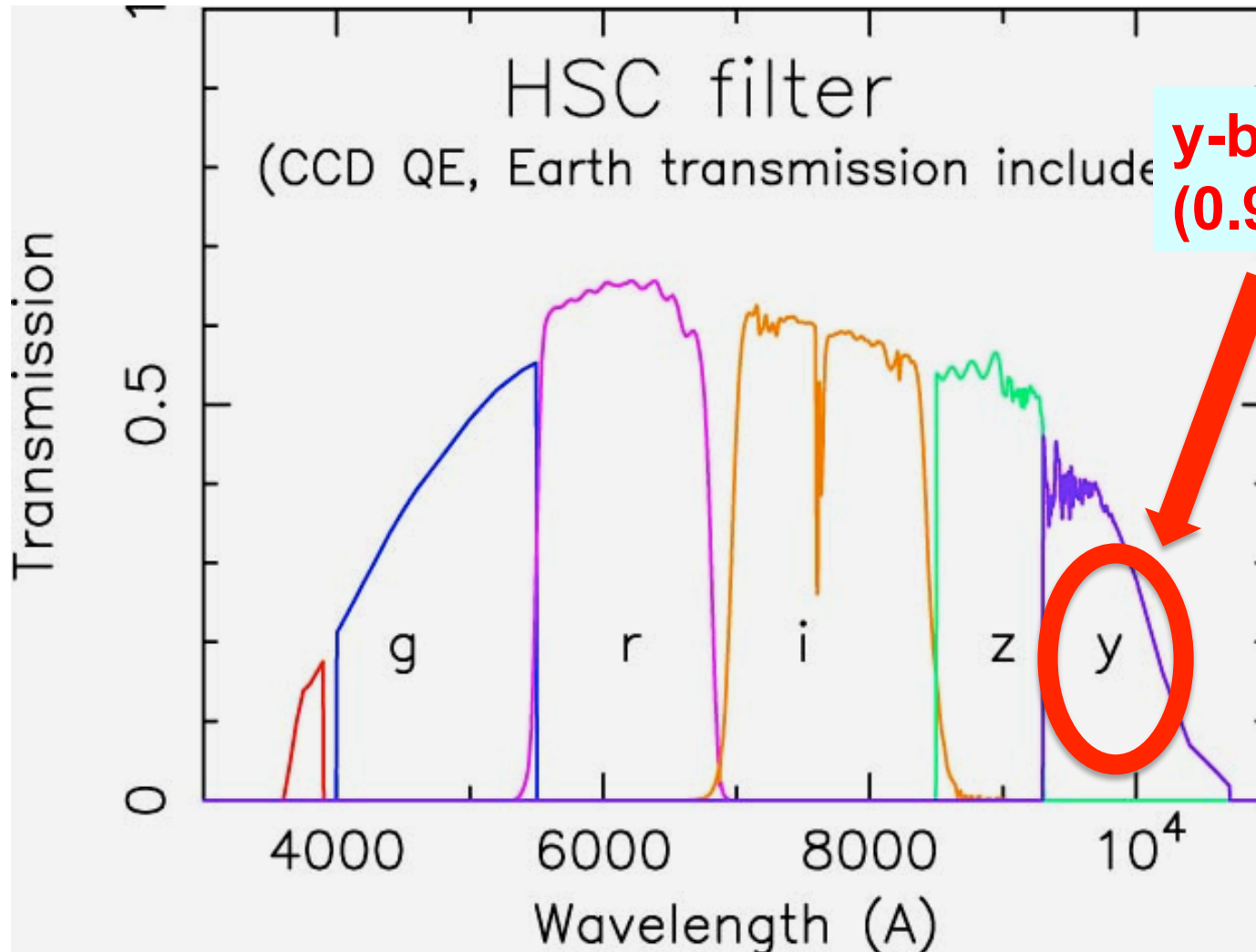
$>10^9 M_{\text{sun}}$ SMBH at $z \sim 6.5$ OK
(but a big issue at $z > 7$)



HSC wide
($>1000 \text{ deg}^2$)

$g=26.5$, $r=26.1$, $i=25.9$,
 $z=25.1$, $y=24.4$

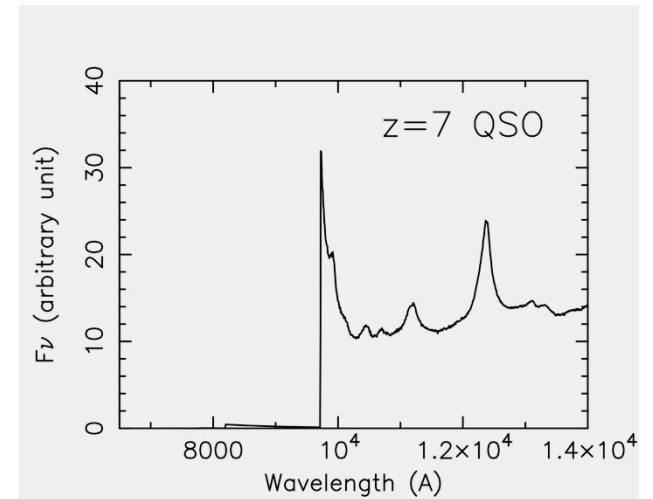
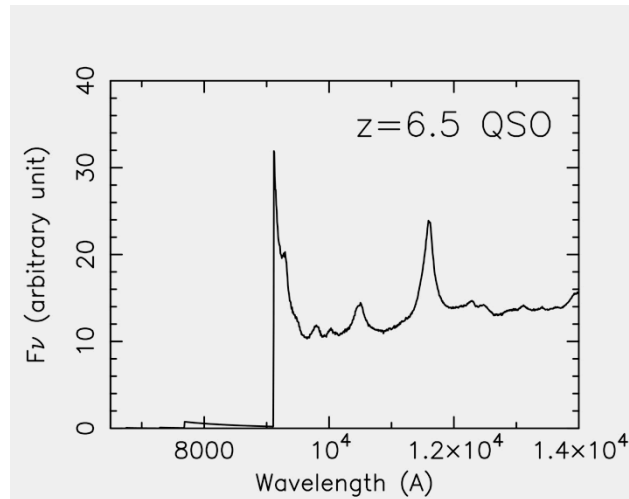
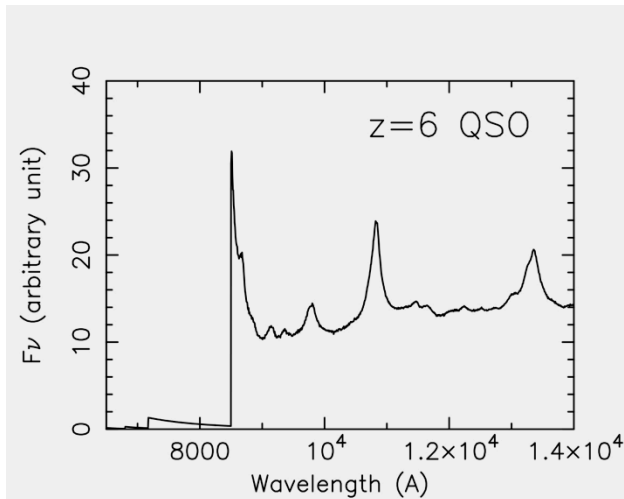
AB, 5σ



y-band
(0.93-1.05um)

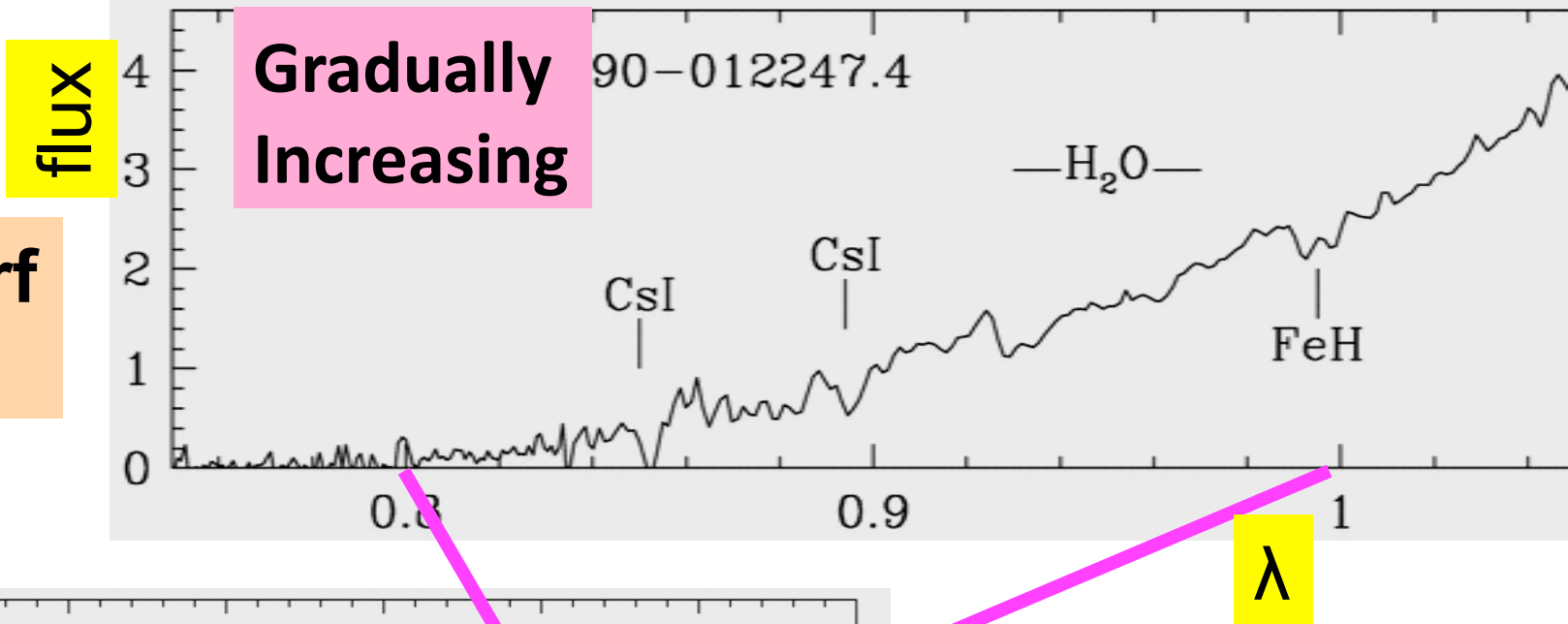
Typical QSO SED (Vanden Berk+01)

IGM transmission = $0.031 \times \left\{ \frac{(1+z)}{7} \right\}^{-8.1}$
(Songaila & Cowie 2001)

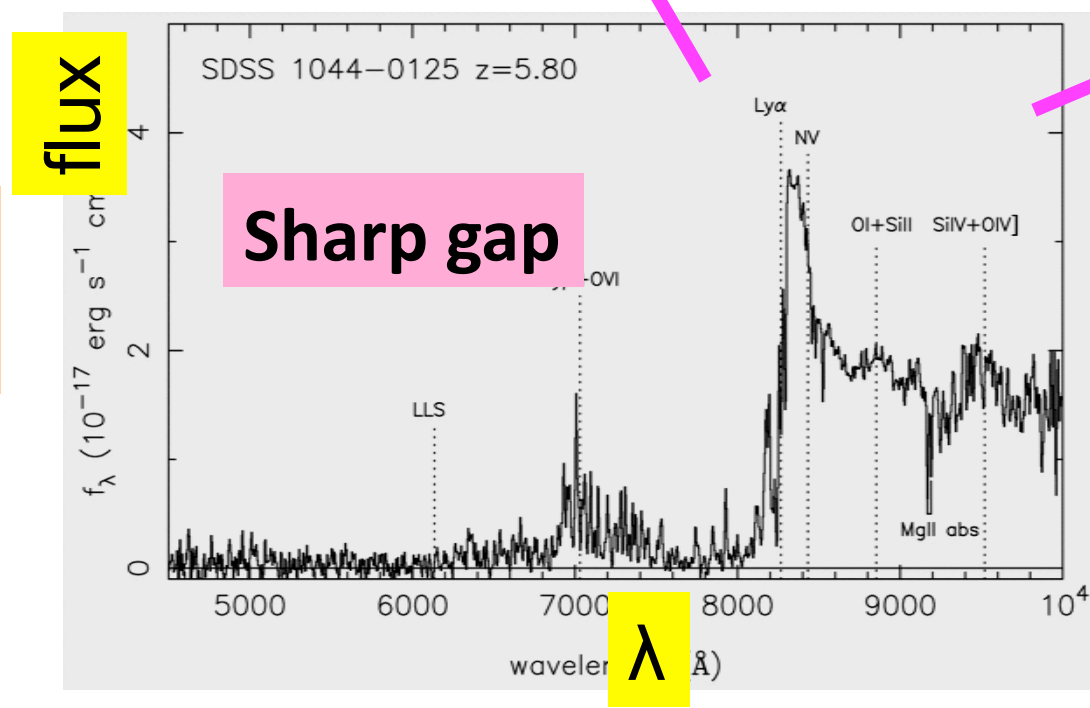


Spectra of high-z QSOs and brown dwarfs

**Brown dwarf
(Galactic)**



**High-z
QSOs**

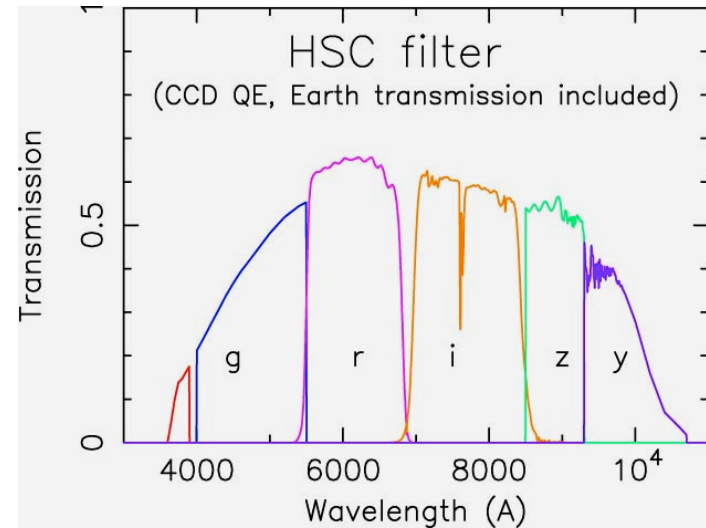


**z~7 QSOs are
even redder
in z-y**

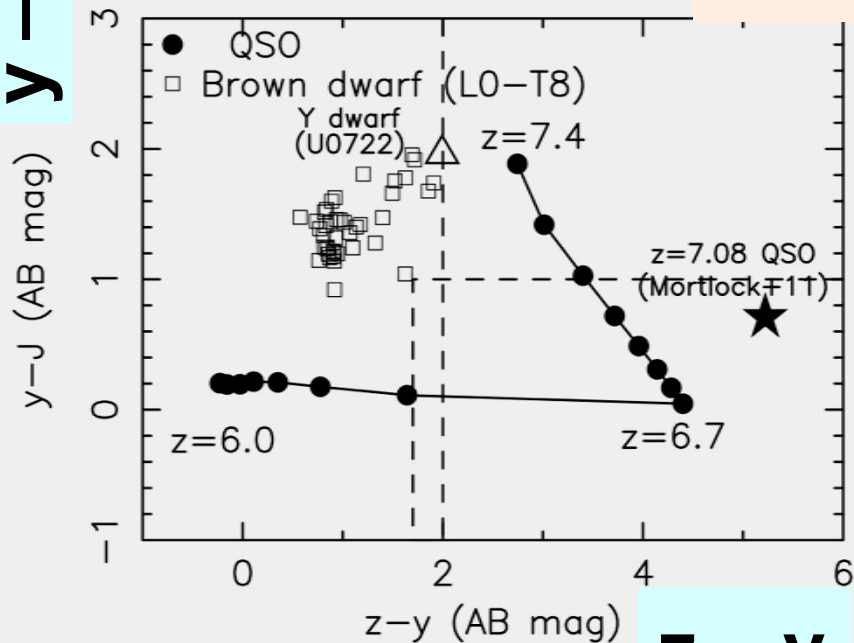
Subaru/HSC

$z > 6$ QSO survey

QSO color selection

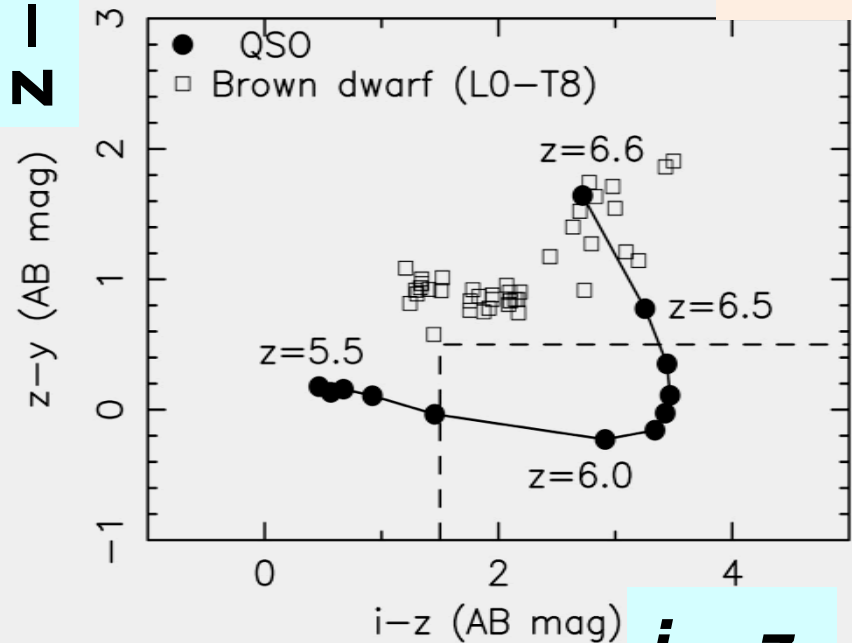


$y - J$



J effective

$z - y$

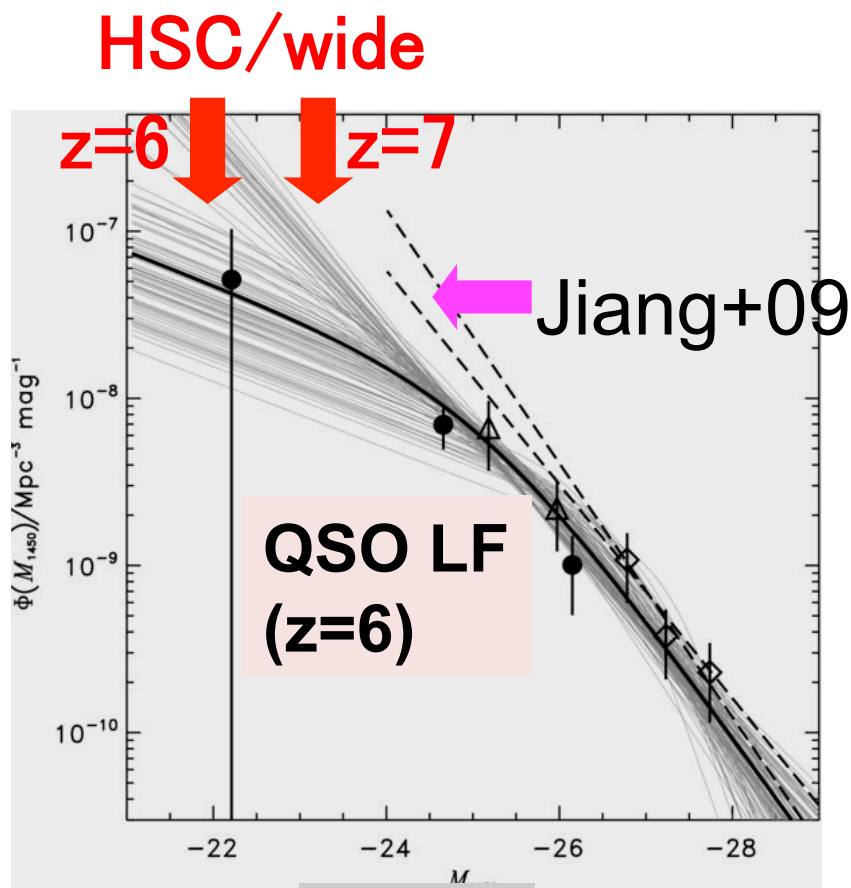


HSC izy only

Subaru/HSC $z > 6$ QSO survey

1. Many QSOs (fainter limiting magnitude)

~70 $z \sim 7$ QSOs
~400 $z \sim 6$ QSOs



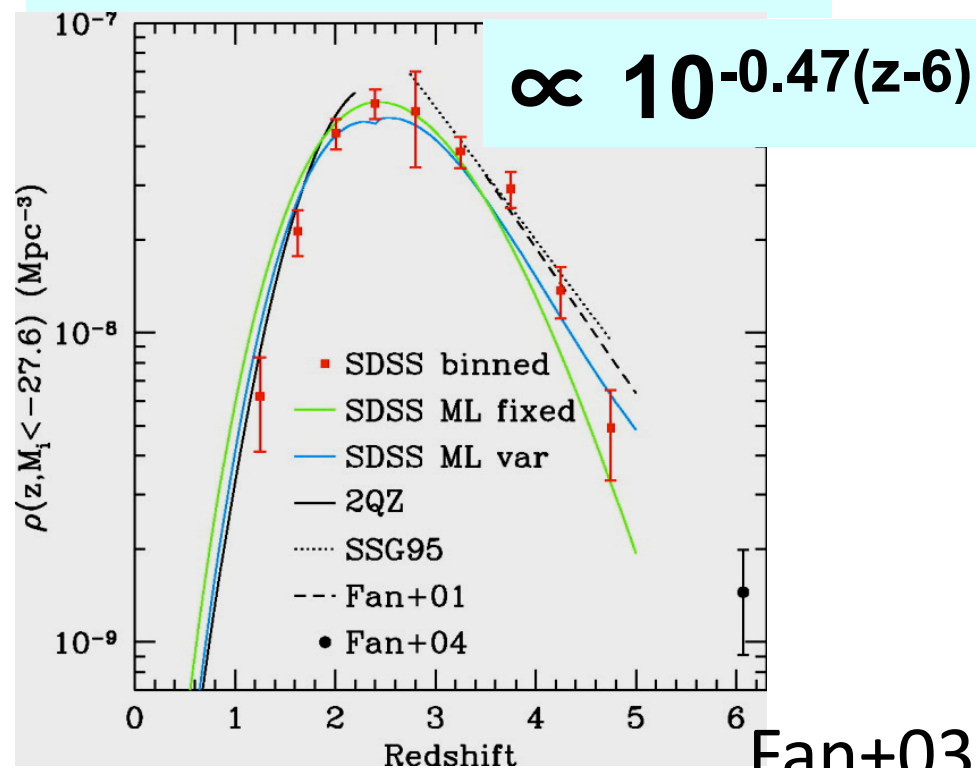
faint

M_{1450A}

bright

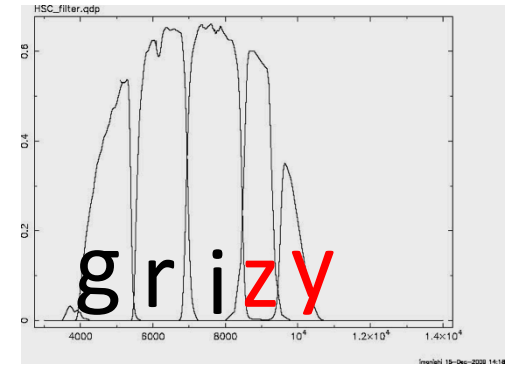
Willott+10

$z=6 \rightarrow 7$: 1/3 assumed



Fan+03

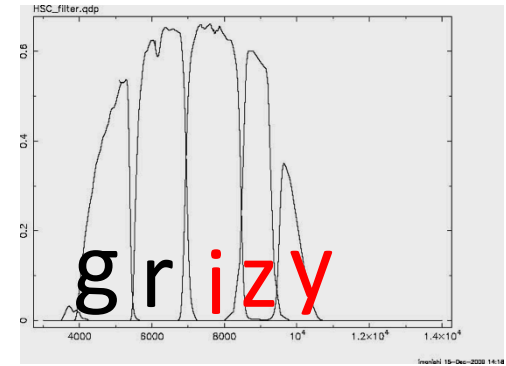
$z \sim 7$ QSO: $y < 24.4, z > 26.1 (< 2\sigma)$



<u>y-mag</u> (AB) (apparent mag)	M1450 (AB) (Absolute mag)	Number /1000 deg ²	
23.4–24.4	–23.65 ~ –22.65	40	
22.4–23.4	–24.65 ~ –23.65	20	
21.4–22.4	–25.65 ~ –24.65	9	~30 QSOs (spectroscopy)
20.4–21.4	–26.65 ~ –25.65	3	
19.4–20.4	–27.65 ~ –26.65	0.5	

Total ~ 70 / 1000 deg²

$z \sim 6$ QSO: $z \sim 25.1$, $i > 27 (< 2\sigma)$

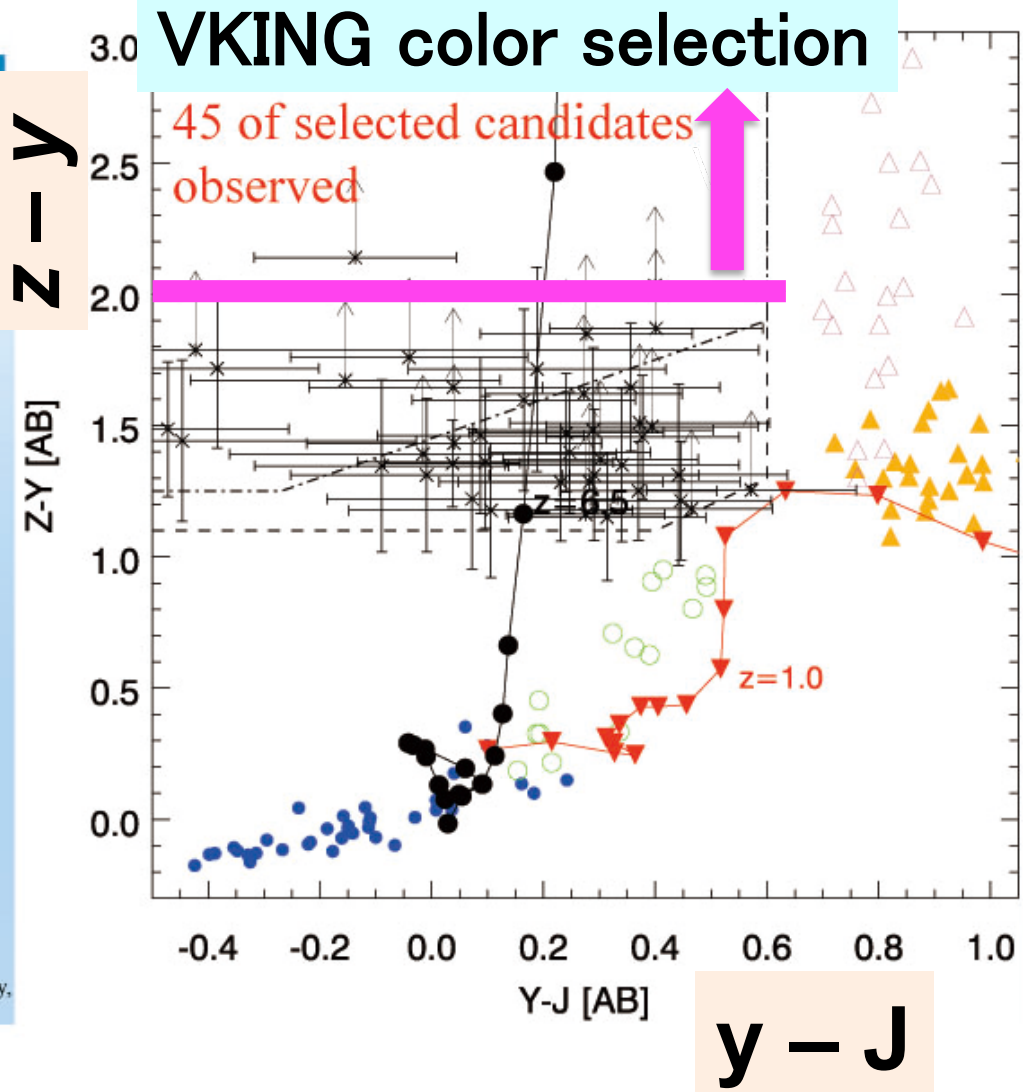


<u>z-mag</u> (AB) (apparent mag)	M1450 (AB) (Absolute mag)	Number /1000 deg²	
24.1–25.1	-22.7 ~ -21.7	190	(LBG contamination)
23.1–24.1	-23.7 ~ -22.7	110	
22.1–23.1	-24.7 ~ -23.7	50	
21.1–22.1	-25.7 ~ -24.7	20	~200 QSOs (spectroscopy)
20.1–21.1	-26.7 ~ -25.7	7	
19.1–20.1	-27.7 ~ -26.7	1	

Total ~ 400 / 1000 deg²

Subaru/HSC $z \sim 7$ QSO survey

2. Efficient QSO selection (deep optical z)



HSC:
 $y < 23.4$ ($y = 24.4$ (5σ))
 $z = 25.1$ (5σ), $z = 26.1$ (2σ)

select $z - y > 2$

Contamination reduced

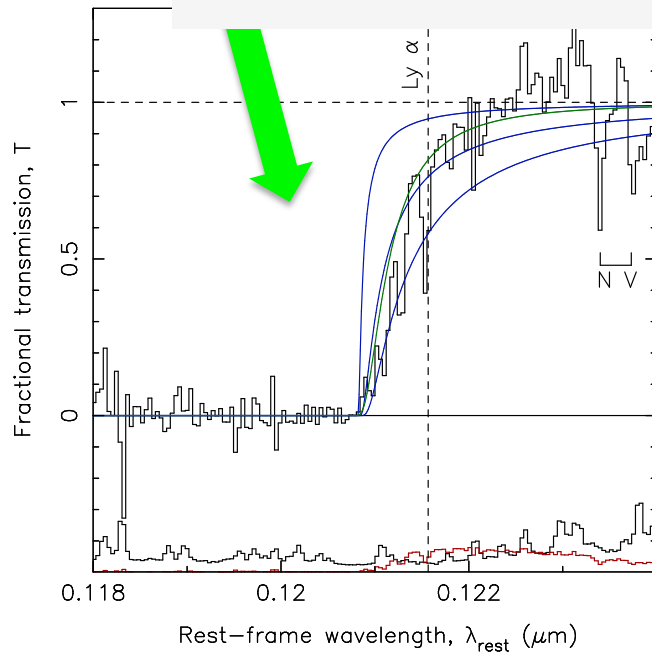
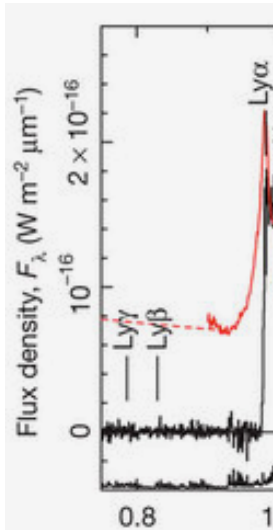
My personal research Plan

1. Propose follow-up spectroscopy ($<1\mu\text{m}$) of HSC wide detected $z\sim 7$ QSO candidates (Subaru/FOCAS, Gemini/GMOS, KeckI/LRIS)



Identification of bona-fide $z\sim 7$ QSOs

Subaru/FOCAS, Gemini/GMOS, Keck/LRIS



QSO ID and IGM study possible

M(SMBH) from L(Edd) assumption ?

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Identification of bona-fide $z\sim 7$ QSOs

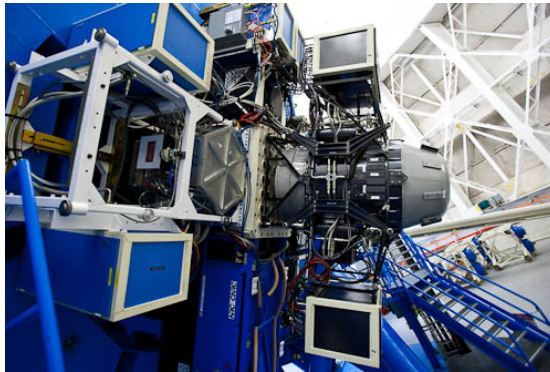
2. Propose follow-up NIR (1-2.5 μm) spectroscopy



SMBH mass estimate

Gemini/GNIRS

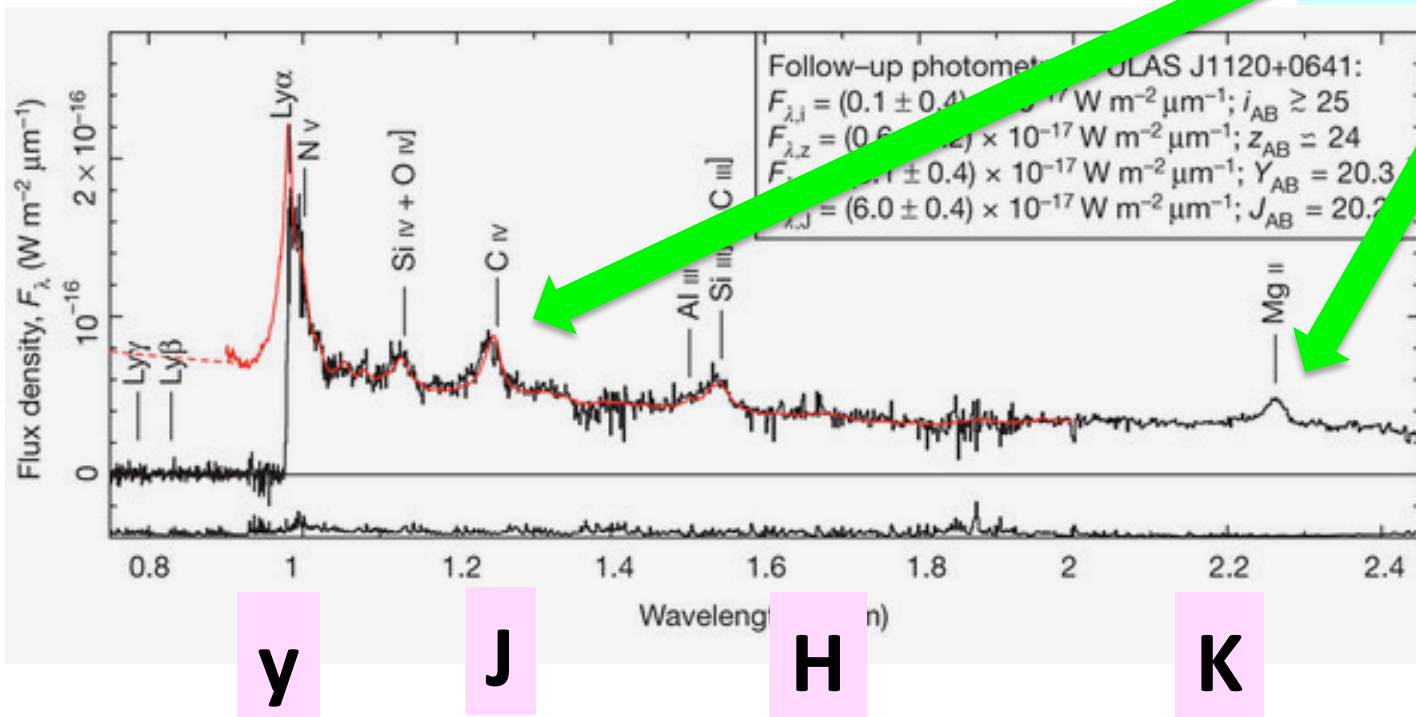
0.9-2.5 μ m simultaneous spectroscopy



z=7.08 QSO

Mortlock+11

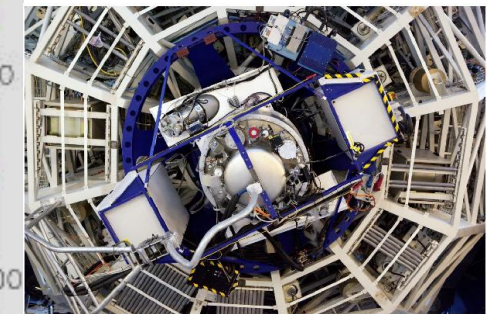
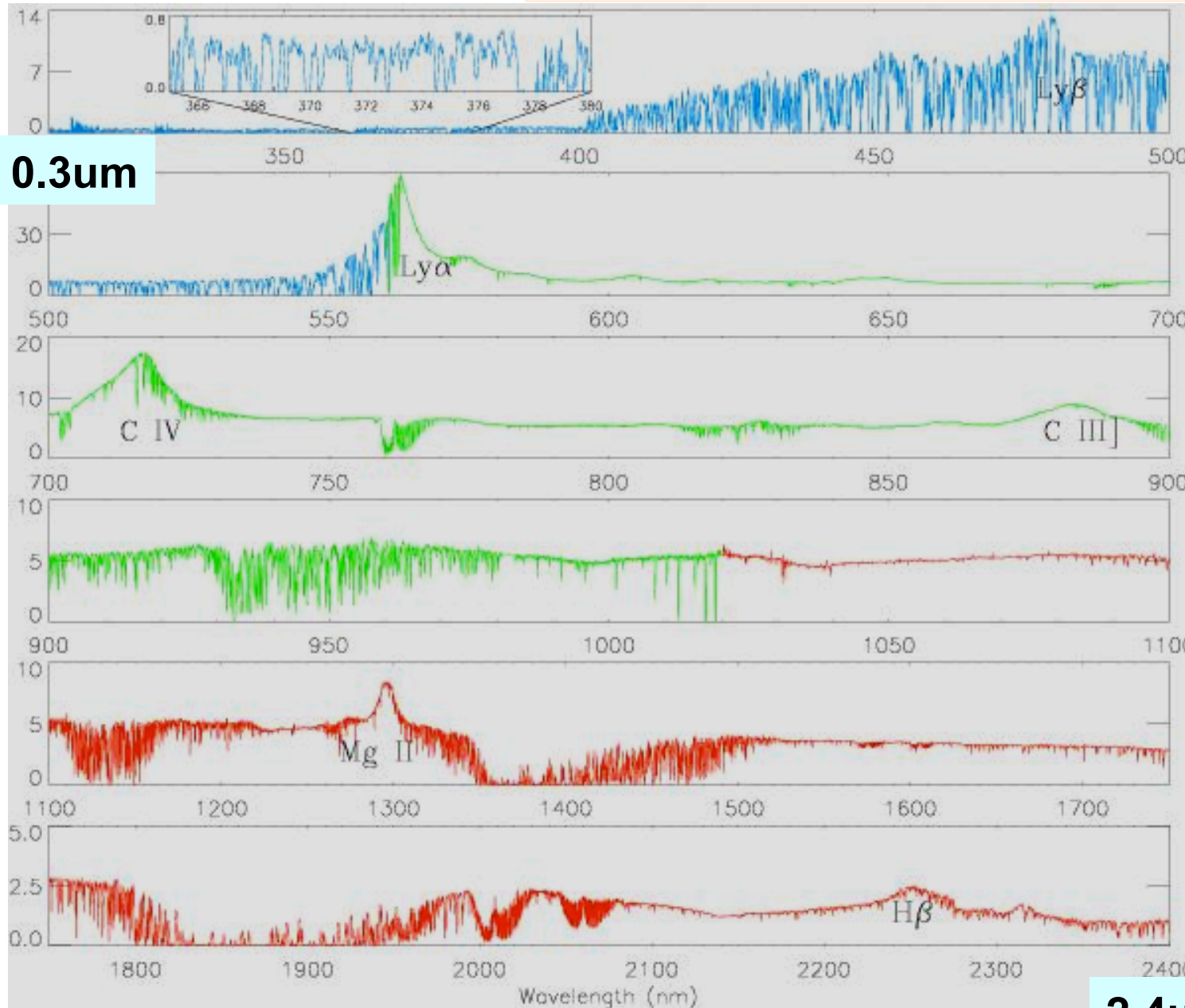
M(SMBH) from CIV, MgII



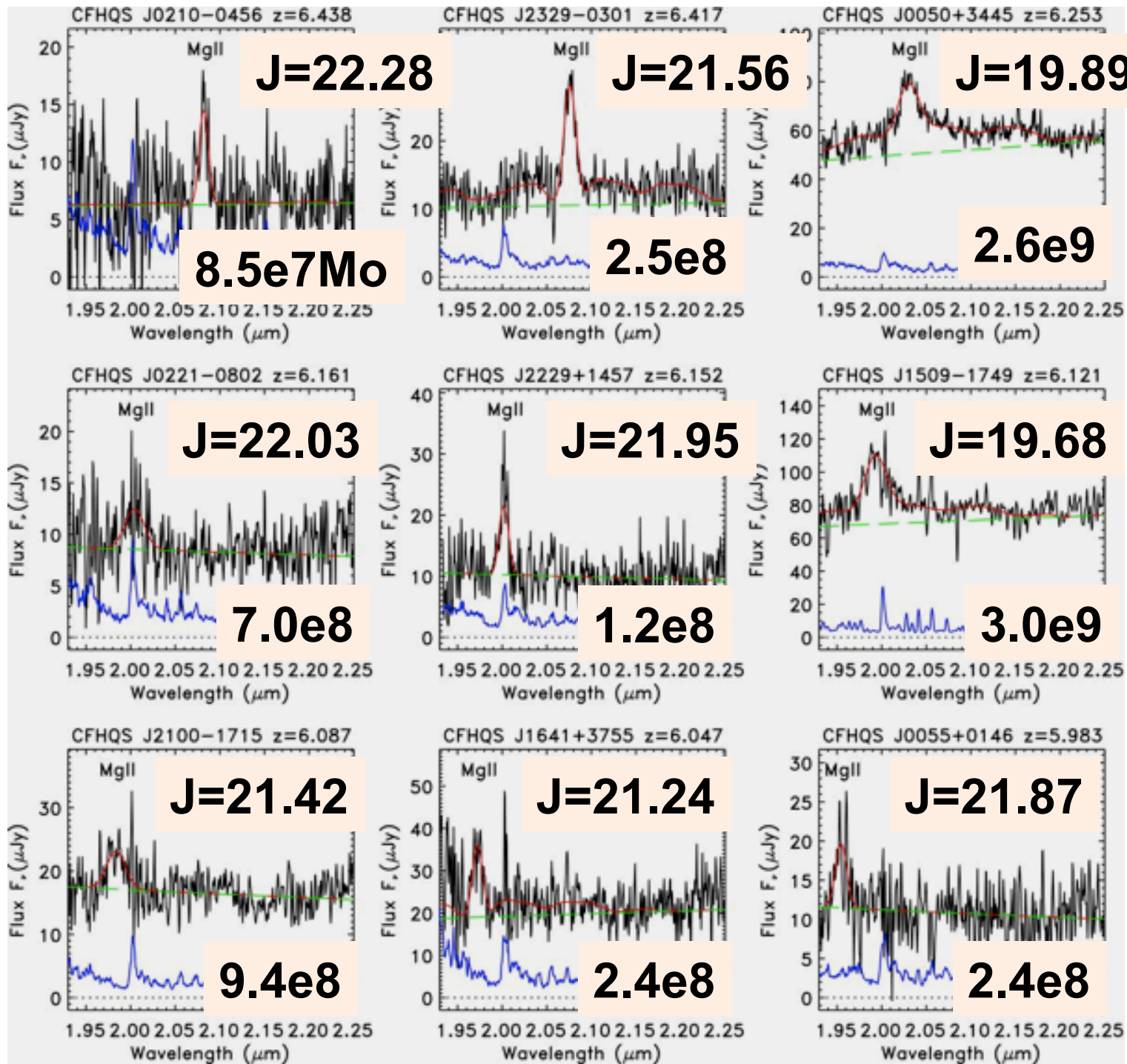
$M_{\text{SMBH}} \sim 2 \times 10^9 M_{\odot}$

VLT/X-shooter

0.3-2.4 μm simultaneous spectroscopy
(with high sensitivity)



Vernet+11



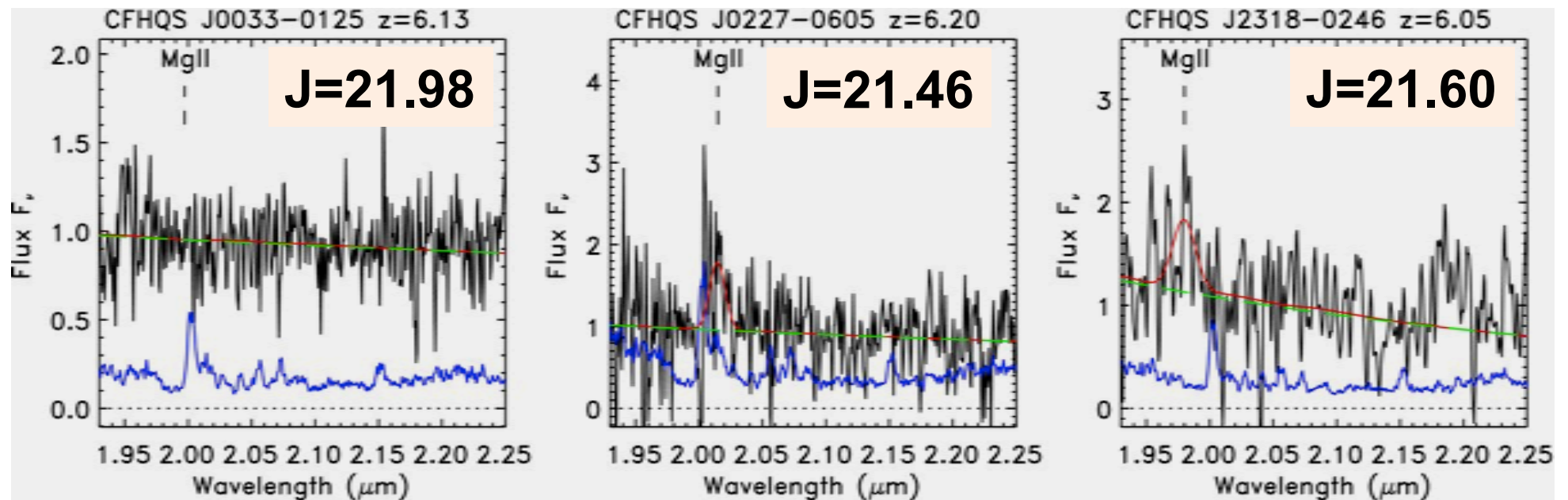
Gemini/NIRI
1.3-4 hr

HSC wide
z~7 QSO:
y<23.4
J<22.5-23 ?

Willott+10
AJ 140 546

Gemini/NIRI 1.3-4hr

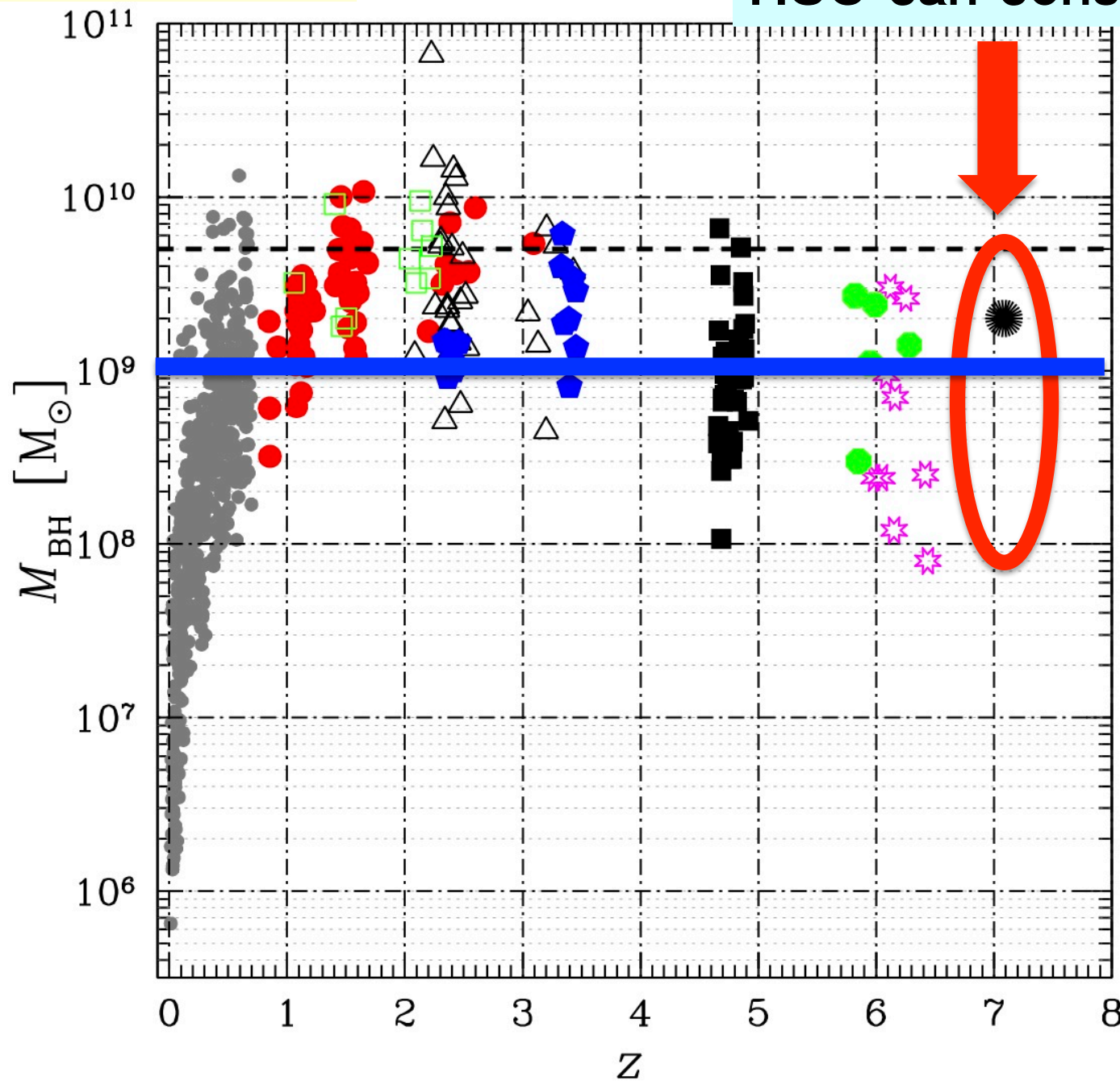
MgII \rightarrow M(SMBH) not successful



Willott+10 AJ 140 546

QSO SMBH

HSC can constrain

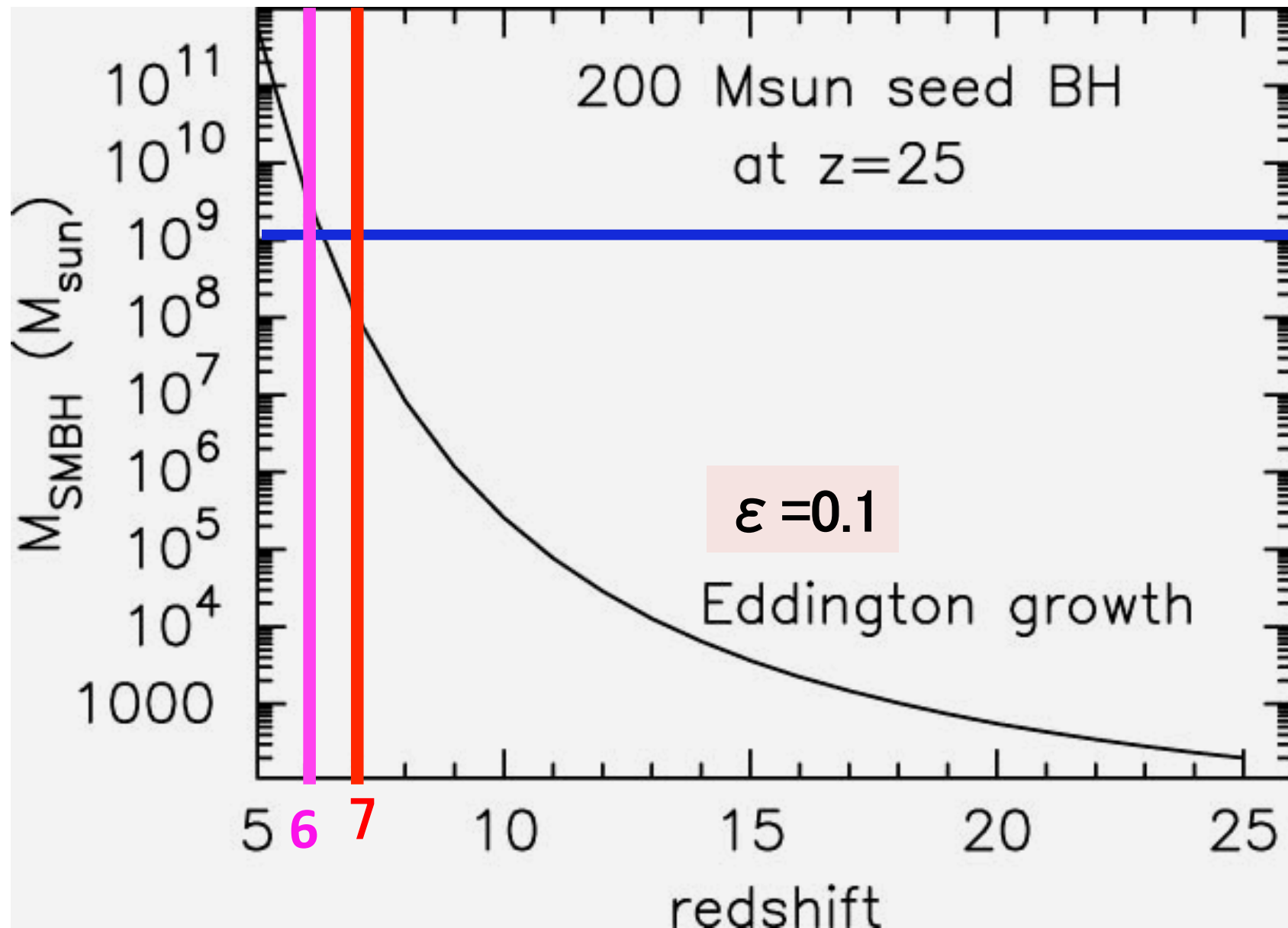


$10^9 M_{\odot}$

Marziani+12
NewA 56 491

SMBH growth

$>10^9 M_{\odot}$ SMBH at $z \sim 6.5$ OK
(but a big issue at $z > 7$)



>10⁴Mo seed BH ?

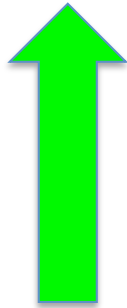
Broom+03 ApJ 596 34

Begelman+06 MNRAS 370 289

Umeda+09 JCAP 8 24

Sethi+10 ApJ 721 615

Mayer+10 Nature 466 1082



**Important observational constraints
on SMBH formation theories**

Omukai+08 ApJ 686 801 ruled out (<10³Mo)

**Inayoshi & Omukai+12 MNRAS 422 2539
(>10⁵Mo if shock photo-dissociates H₂)**

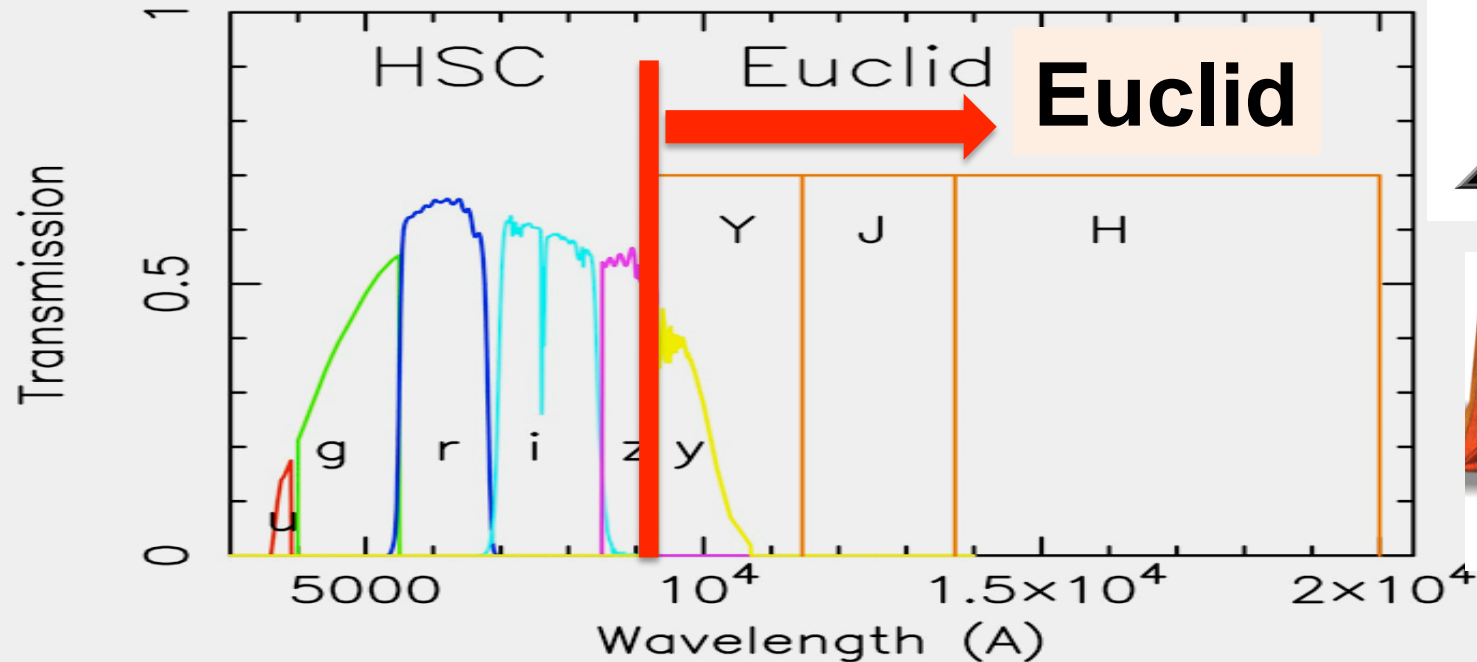
Publication

I want to write papers of $M(\text{SMBH})$ of HSC-wide detected $z \sim 7$ QSOs within 2-3 years from the start of the HSC survey

It is unlikely that I can contribute to the HSC 1st year paper series

To Euclid era

Y,J,H=24mag (5 σ ; AB)

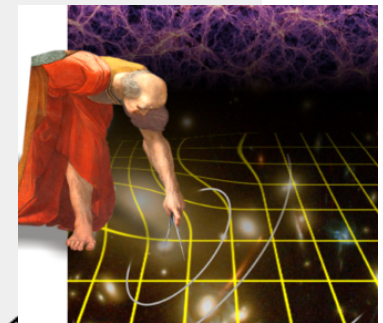
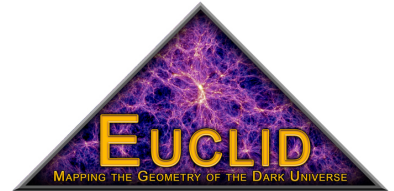
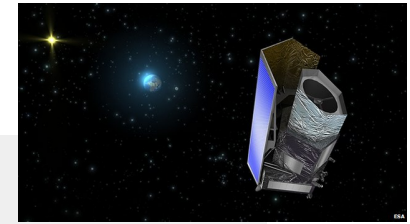


15000 deg²

North: 7500 deg² ?

Several 10s z~8 QSOs (Y-dropout; J<23, Y>25(2 σ))

>10 z=9-10 QSOs (J-dropout; H<23, J>25(2 σ))



End