QSO (AGN) study with PFS

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NAOJ/Subaru Telescope

With help from

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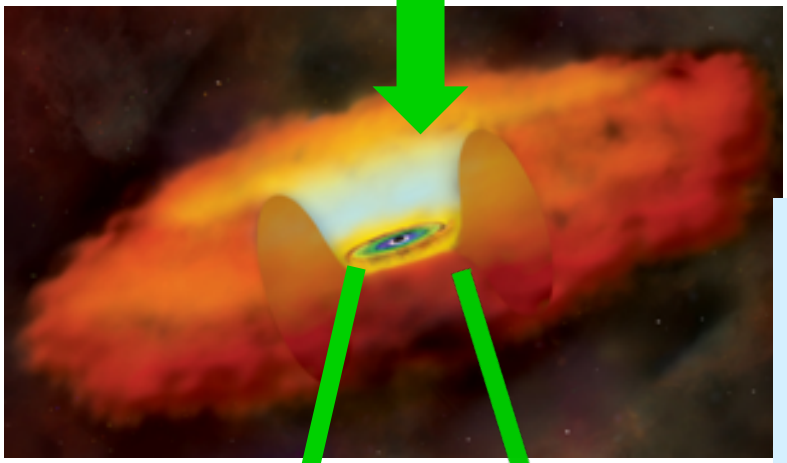
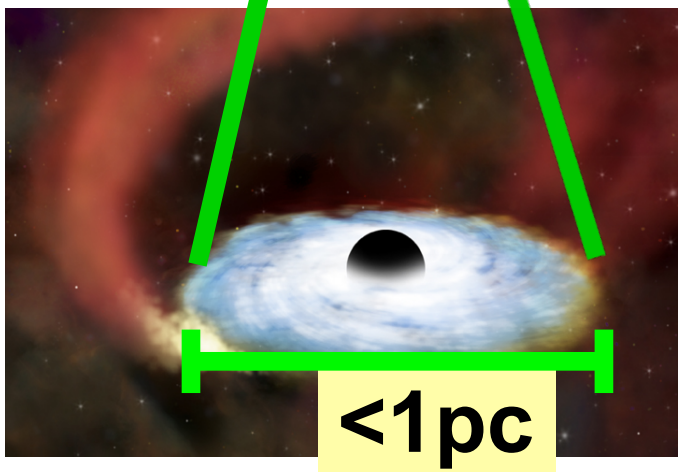
Toshihiro Kawaguchi (Tsukuba)
Tohru Nagao (Ehime)
science discussion inside HSC QSO team

QSO (AGN)

Type-1





Type-1 QSO = bright

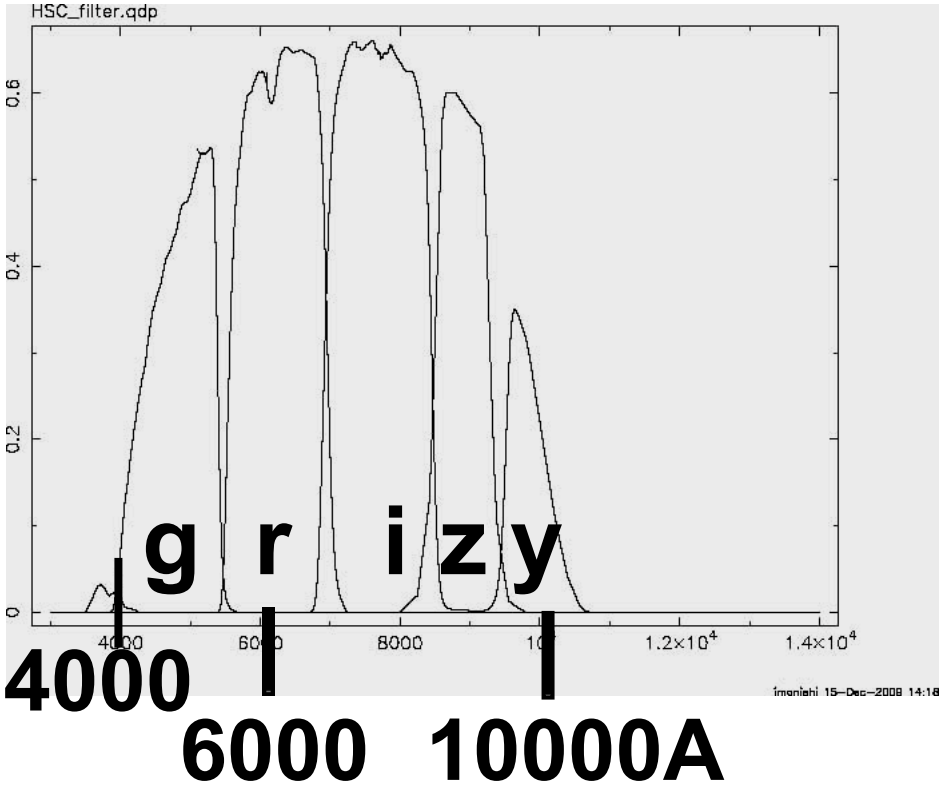
High S/N spectra
even at high-z

AGN-starburst connections
Feedback to host galaxies
Origin of galaxy downsizing?

Energetically dominated
by mass-accreting
Supermassive blackhole
(SMBH) (>10^7 Msun)

QSO science with PFS = follow-up spectroscopy of HSC-detected QSO candidates

HSC wide survey : >1000 deg^2 (g,r,i,z,y)

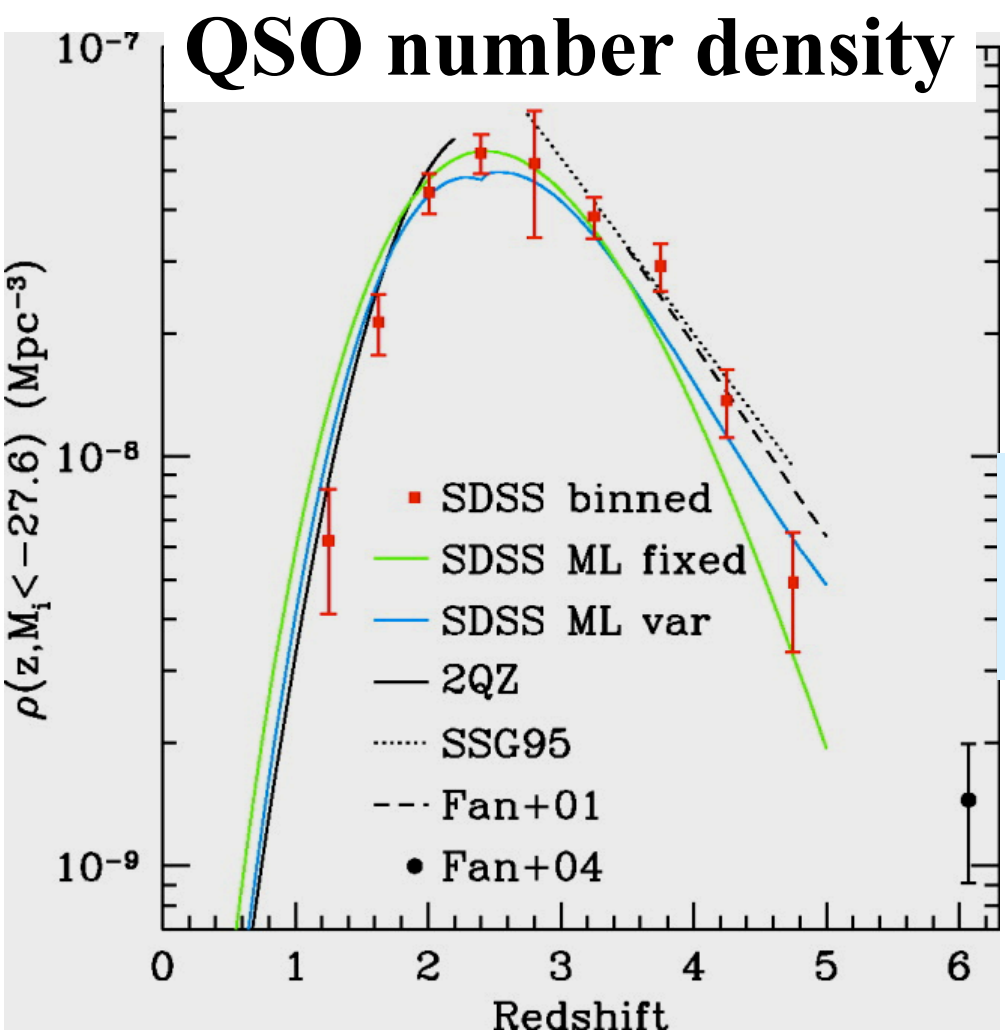


g=26.3, r=26.0, i=26.0, z=24.9, y=23.8 (AB)

1. **numerous faint QSOs at z>3**

2. **z>6.7 QSOs**

z>3 QSOs



Richards+06

QSO number density has a peak at z=2-3

z>3 = SMBH growing phase

Important epoch to understand the cosmic evolution of QSO phenomenon

SDSS found many QSOs only at z>3
(i<20.1 for spectroscopy)

What is unknown about z>3 QSOs ?

Faint QSO LF at z>3

Clustering properties of QSOs at z>3

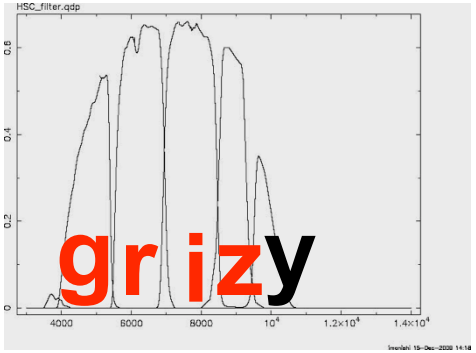
Evolution of general SMBHs (10^8 Msun)

Metallicity in chemically immatured QSOs

z>6.4 QSOs

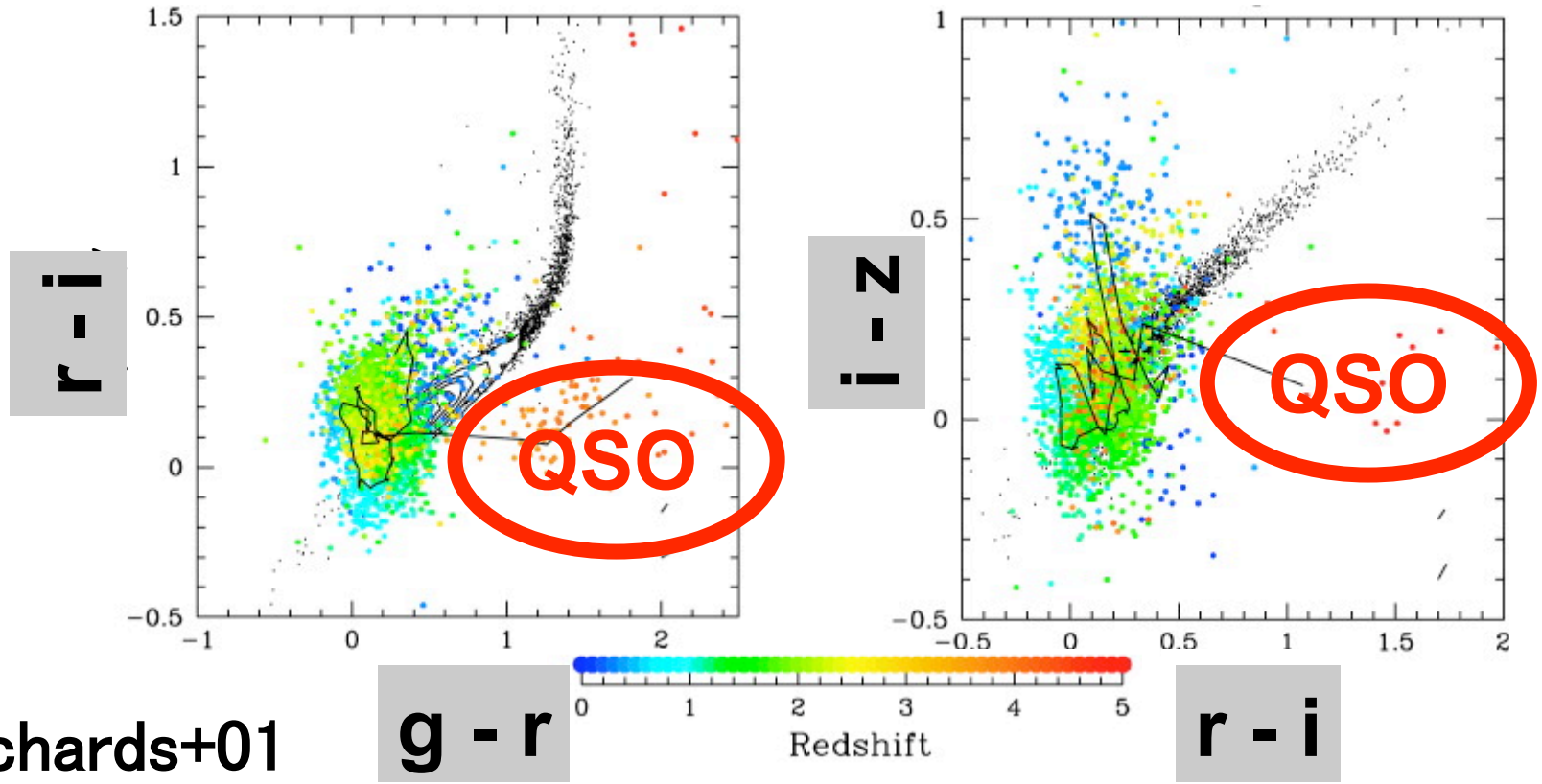
HSC survey will bring a remarkable progress

HSC z~3-5 QSO (g,r,i-selection)



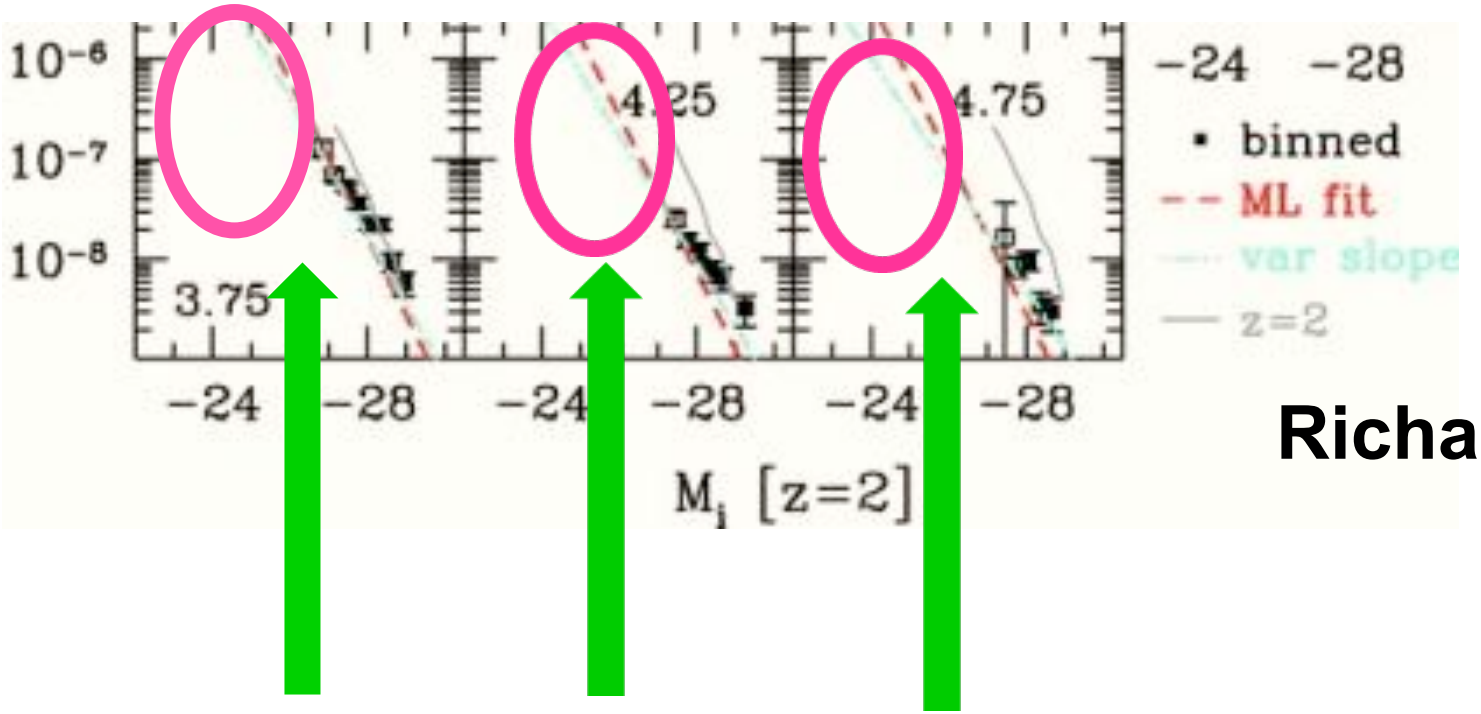
gri : z=3.6-4.4

riz : z=4.6-5.1



Richards+01

QSO LF SDSS : bright QSO LF only at z>3
(i < 20.1 for spectroscopy)



Richards+06

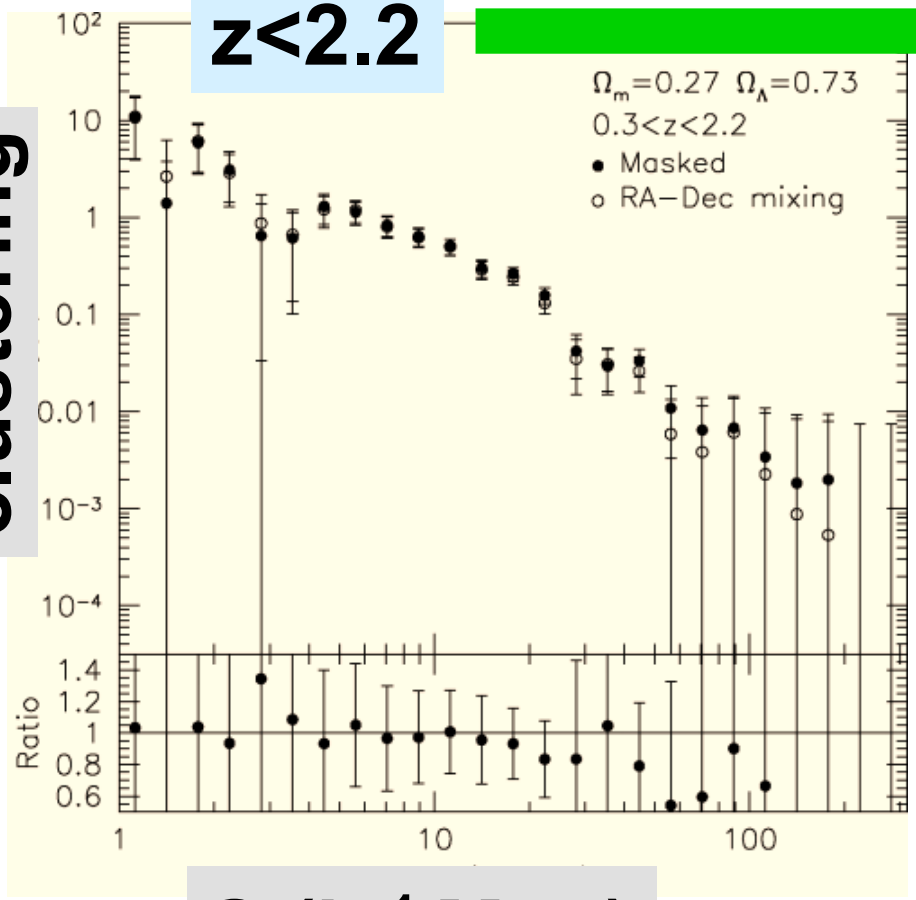
Understanding the faint end of QSO LF
= origin of cosmic UV background radiation

Effect to subsequent galaxy formation

QSO-QSO clustering

z<2.2 → z>3

clustering



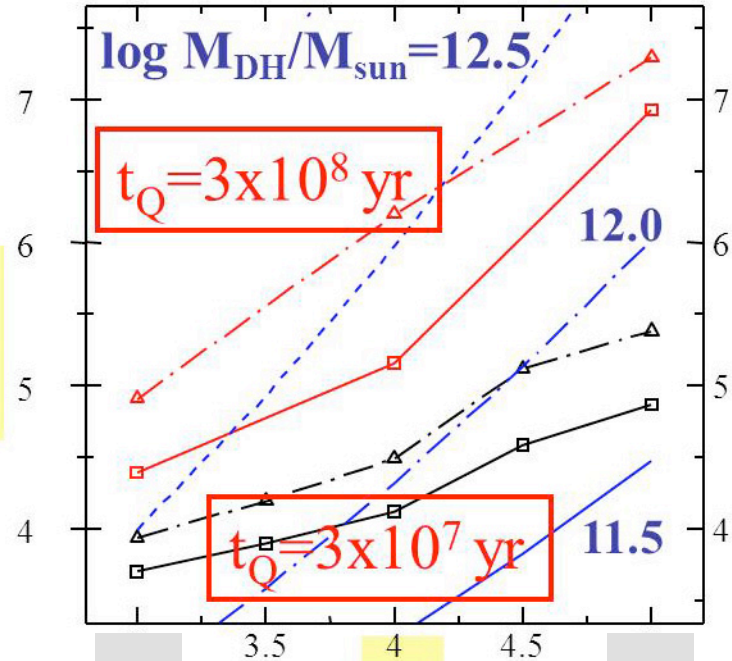
S (h^{-1} Mpc)

Croom+05 (>20,000 QSOs)

Halo mass

QSO lifetime

beff



3 z 5

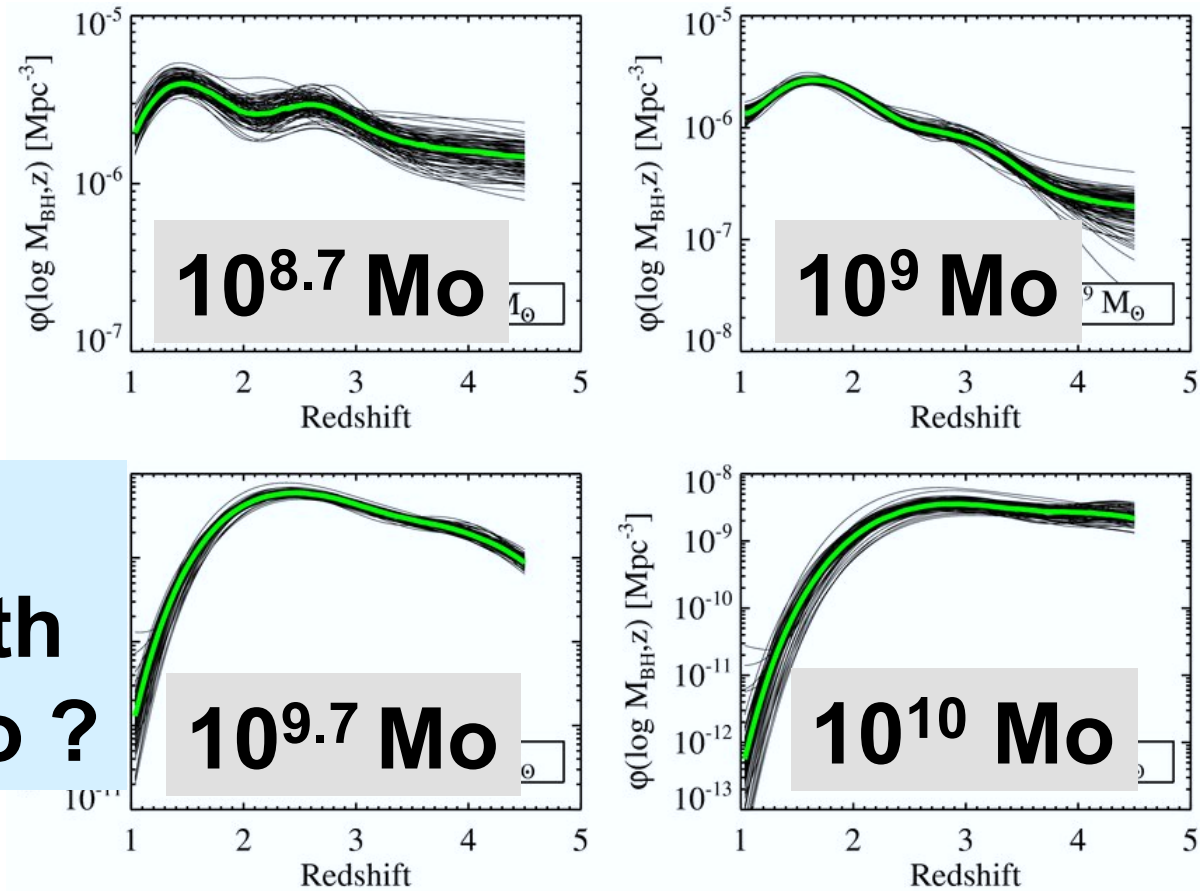
Enoki+03

SMBH evolution

LF → SMBH evolution (qualitative)

Constant L/L(Edd) assumed

M(SMBH) and L/L(Edd) in individual QSOs

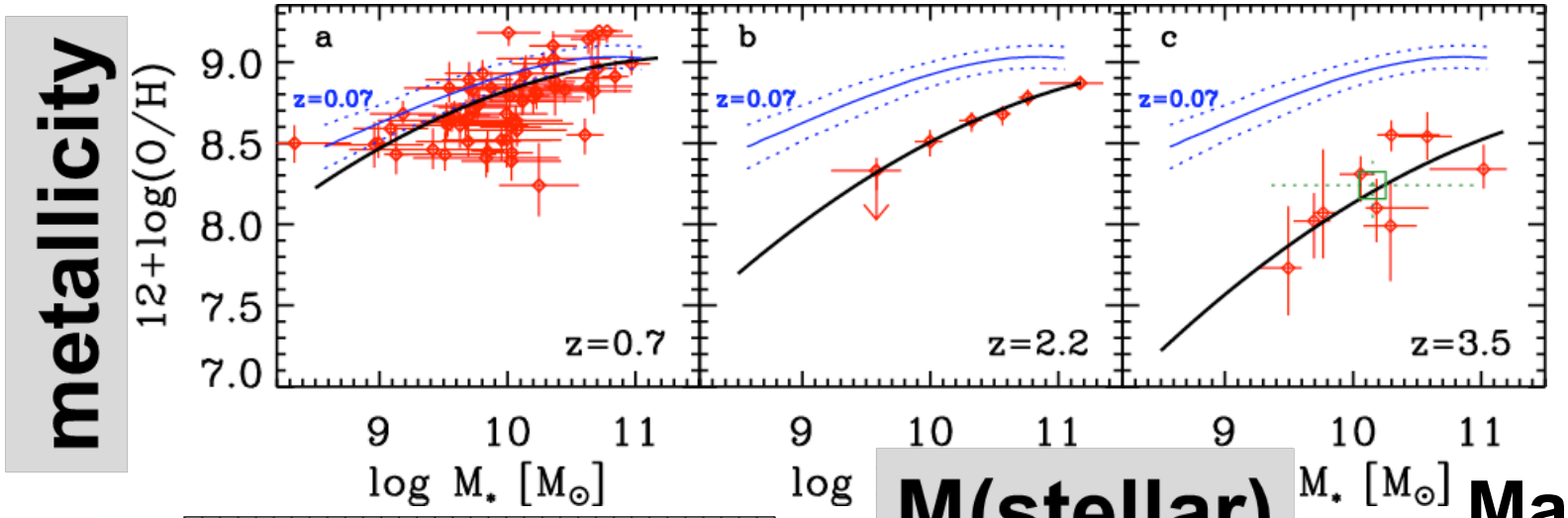


How about more general QSOs with M(SMBH) <10^8 Mo ?

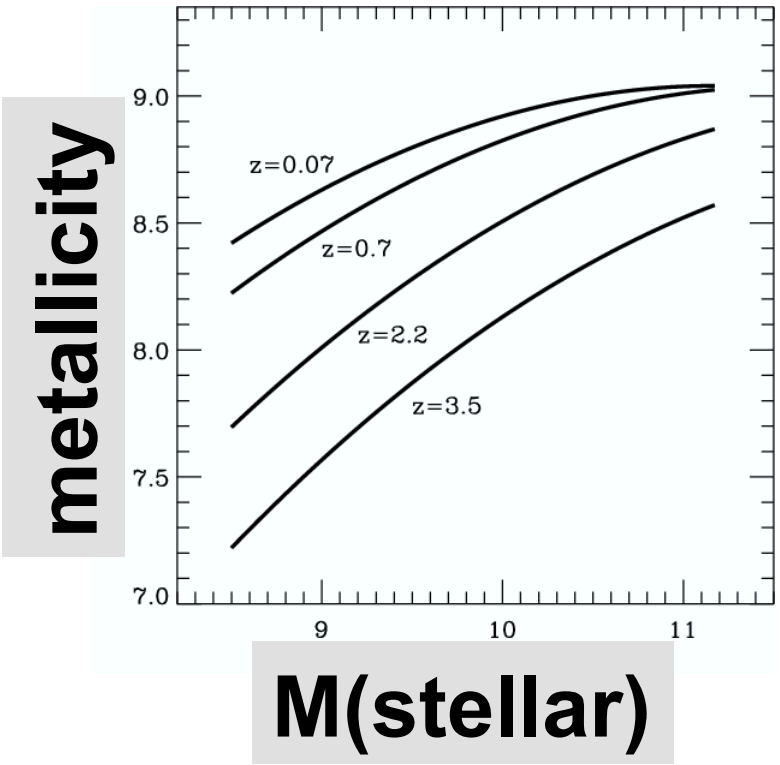
HSC

Kelly+10 (SDSS)

Cosmic chemical evolution



M(stellar) **Maiolino+08**



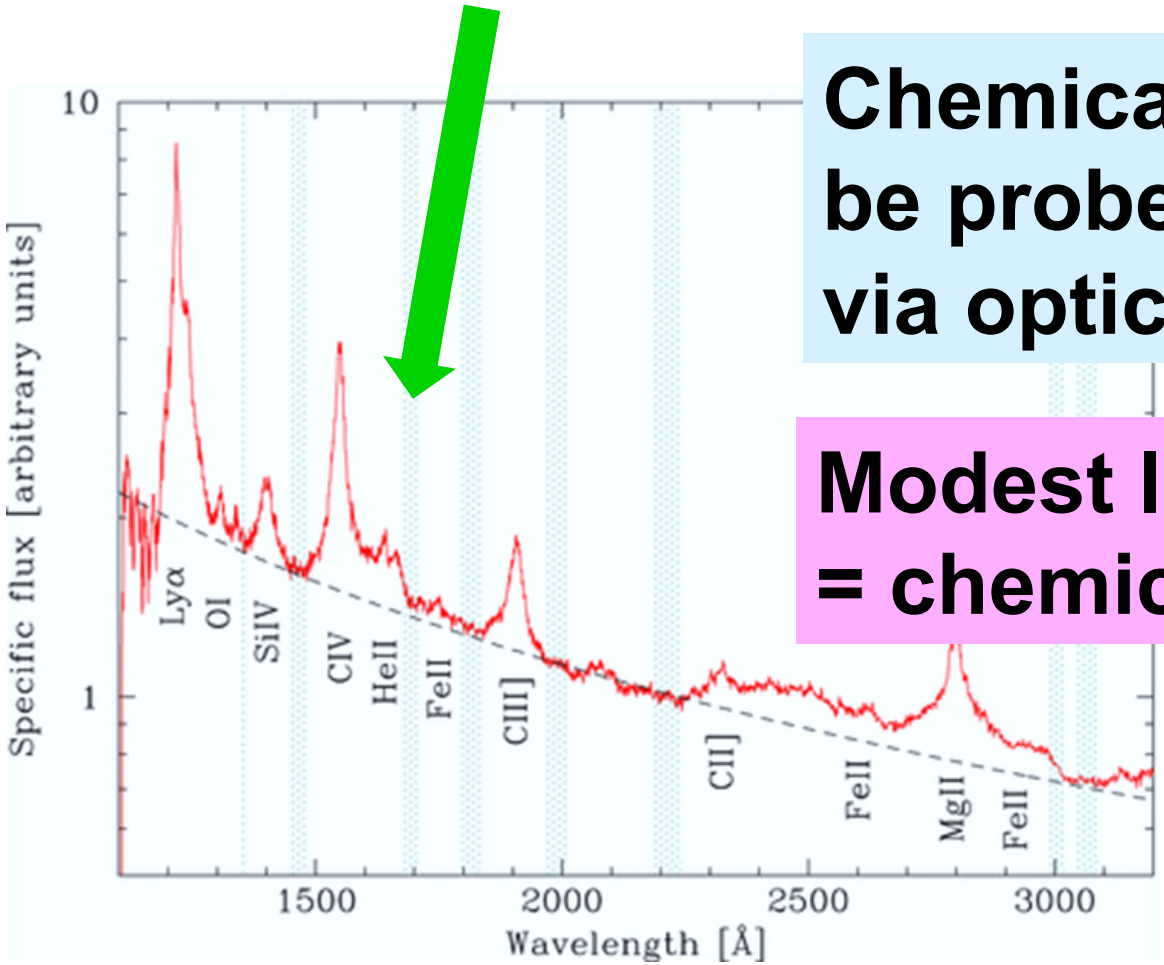
Star-forming galaxies: not applicable to z>3.5

QSOs

Cosmic chemical evolution (2)

QSOs are bright

QSOs have metal emission lines in UV



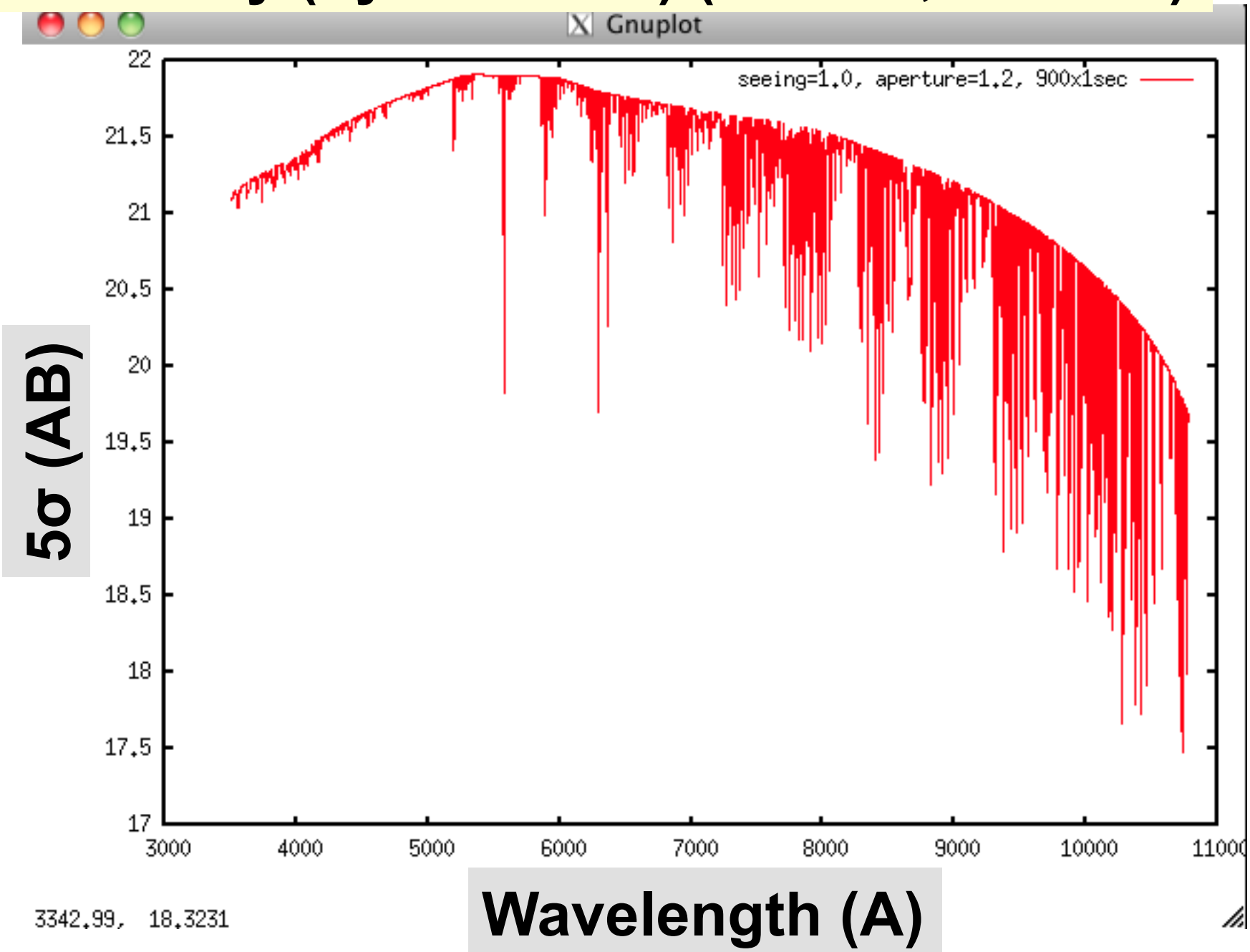
Chemical evolution can be probed at z>3.5 via optical spectroscopy

Modest luminosity QSOs = chemically-immatured ?

Assumption about PFS

- 1.5 deg^2 FOV
- 3900-10800 A (extended to 13000A ?)
- 2400 fibers
- R=3000

Sensitivity (by Dr. Iwata) (900sec, R=2500)



5σ (AB)

Wavelength (A)

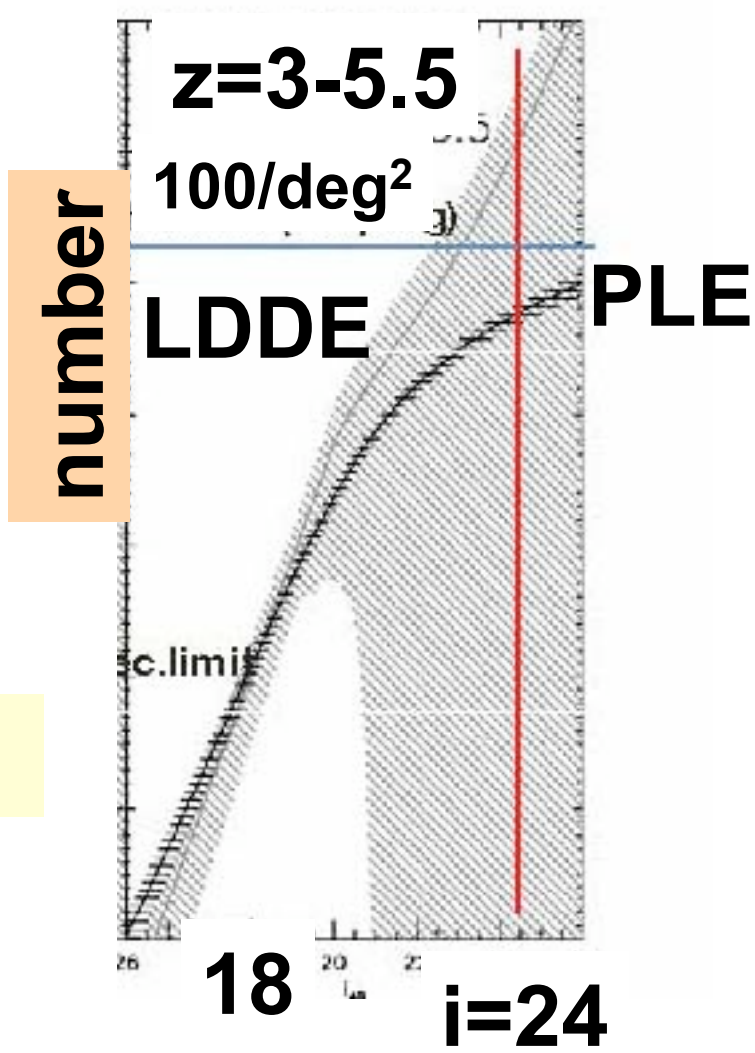
Number density of z=3-5.5 QSOs

Casey+08

30-650 QSOs / deg^2

i<24

Candidates = 50-2000 / deg^2



Survey strategy (z=3-5.5 QSOs)

LF, clustering

ID as z>3 QSOs (i<24, S/N>3-5,R~300-500)

1 hr, 75 deg^2, <10 nights (LF)

1 hr, >400 deg^2, >40 nights (clustering)

SMBH evolution

10^8 Mo at z=4

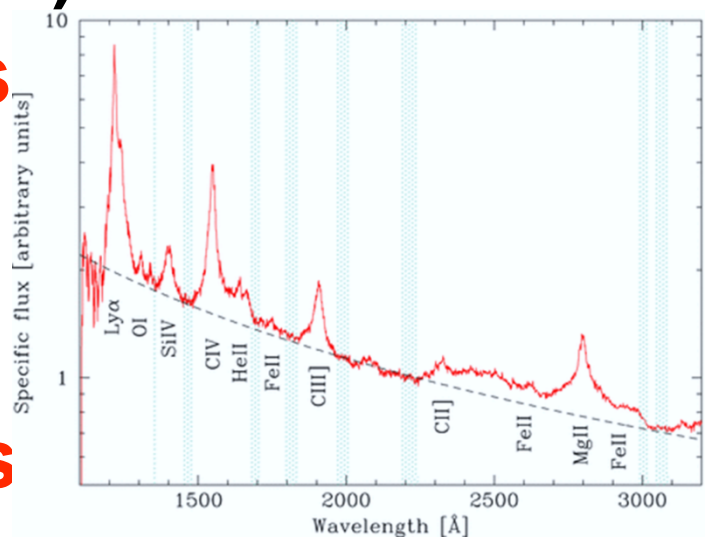
S/N>10 to estimate M(SMBH) i<22.5

1 hr, 400 deg^2, ~35 nights

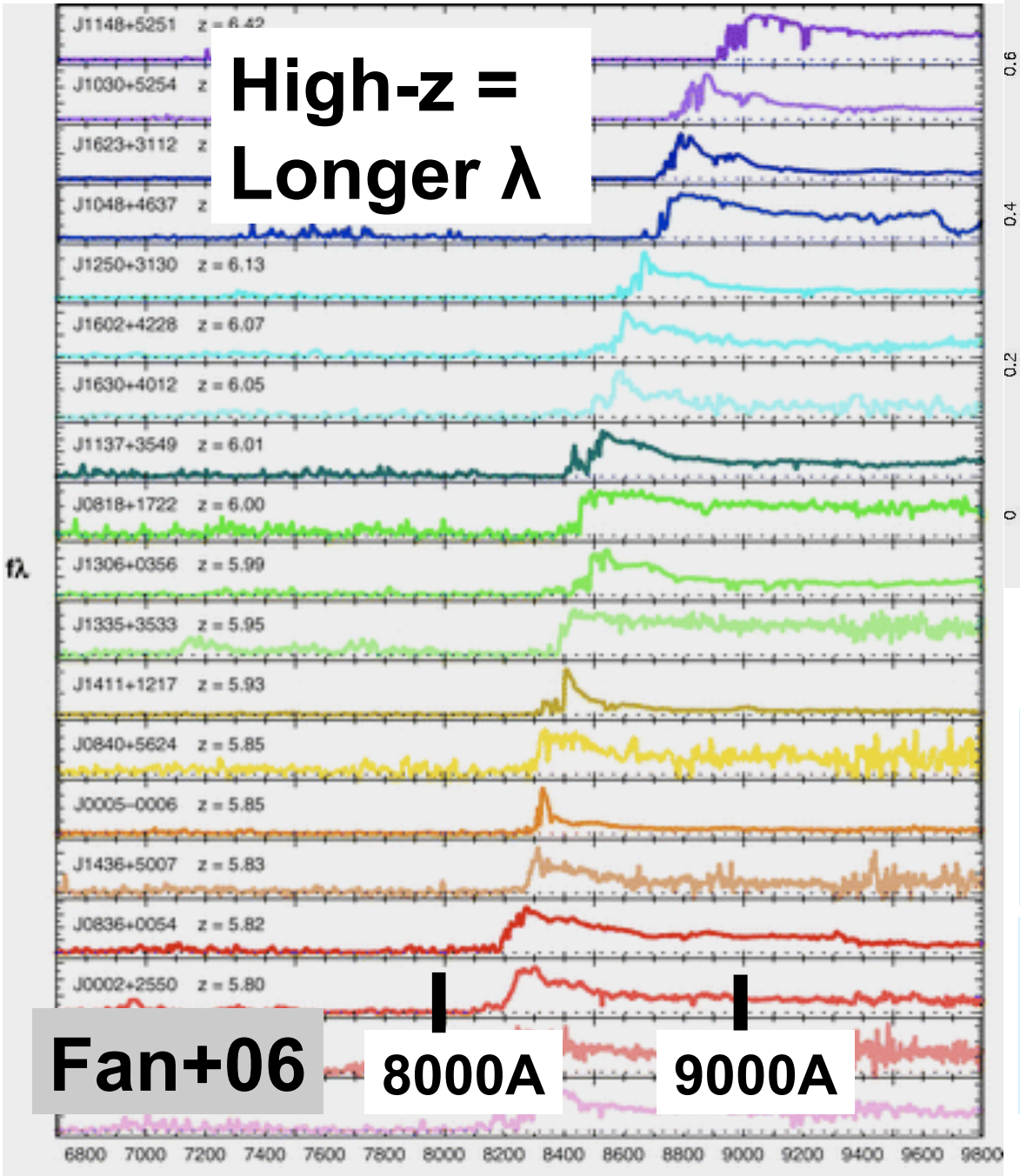
Chemical evolution

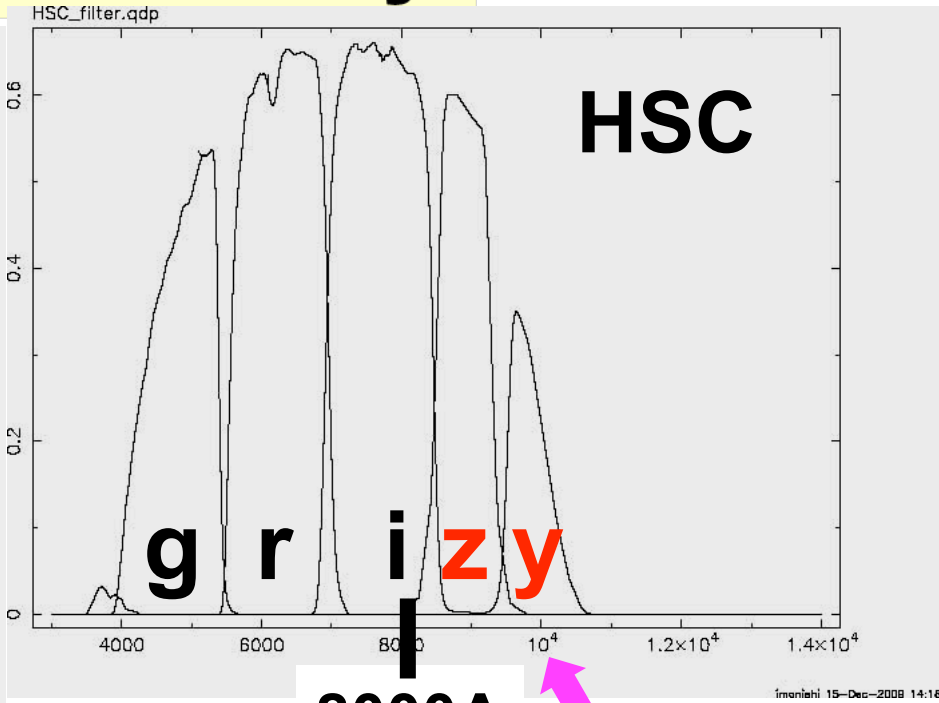
Weak metal lines i<23

2.5 hr, 150 deg^2, ~35 nights



z>6 QSOs in HSC wide survey





350 z~6 QSOs (z<24.2)

35 z~7 QSOs (y<23.8)

z~7 QSO science

Currently, most distant QSO : z~6.4

Most distant, bright QSOs

Constraints on SMBH formation theory

z=25 : 100Mo BH Eddington growth

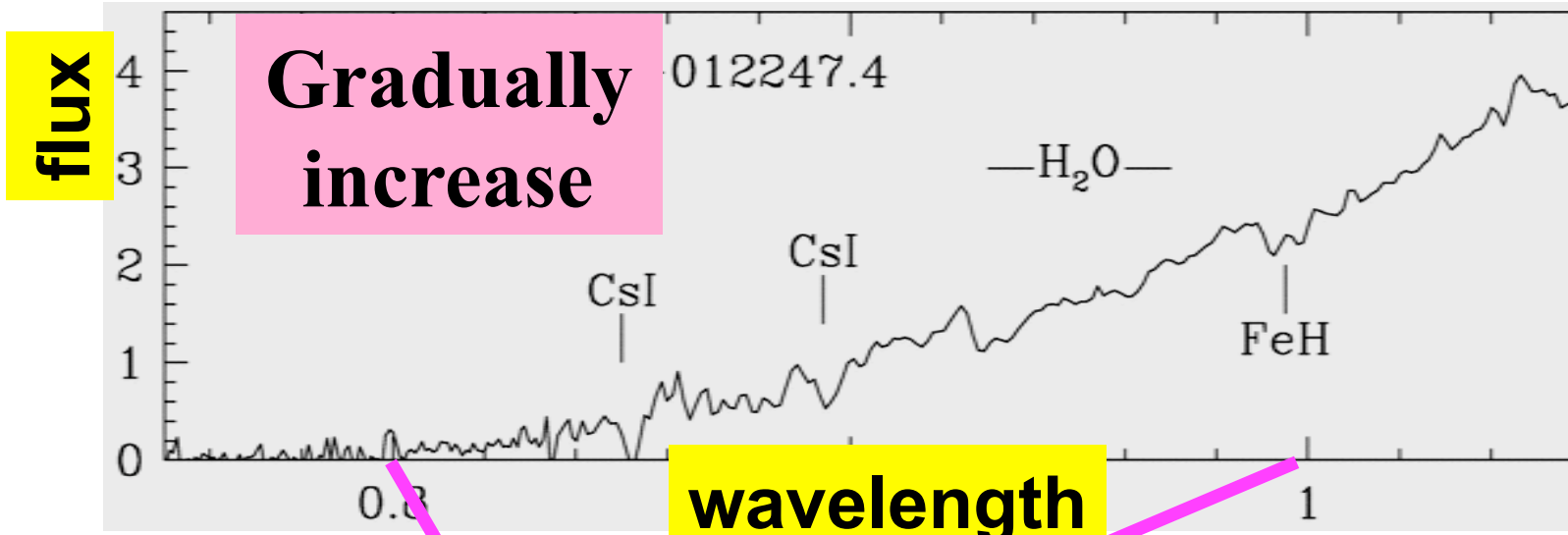
↓

z=6.5 :10^9 Mo z=7.5 : 10^8 Mo

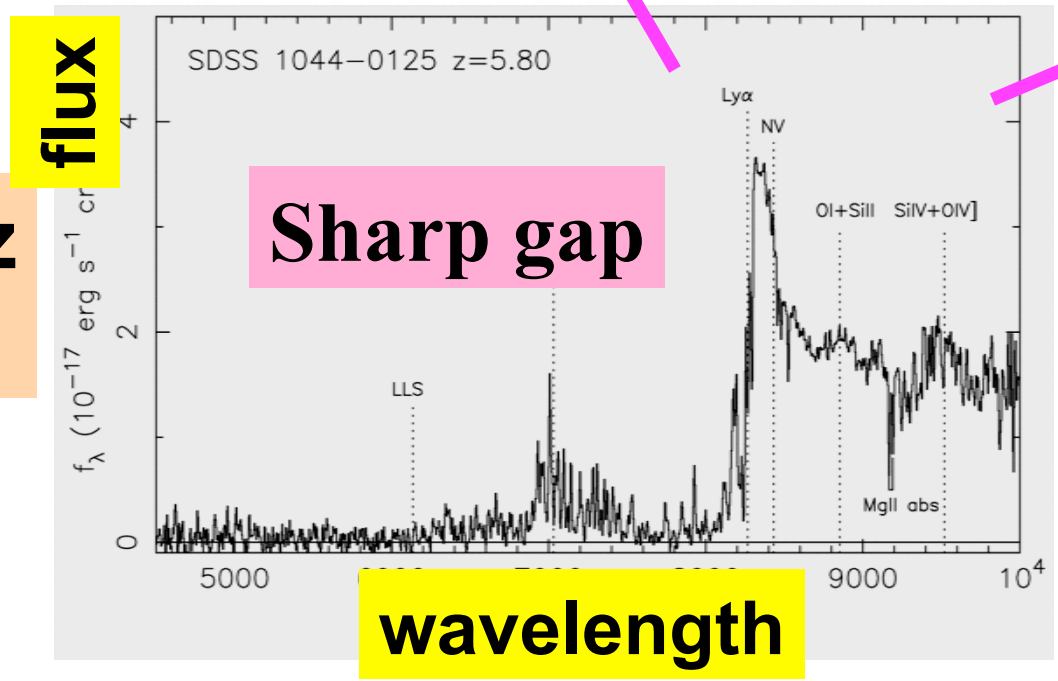
Study the physics (including neutral fraction) of more distant IGM with high S/N

High-z QSO and brown dwarf (BD)

Galactic BD



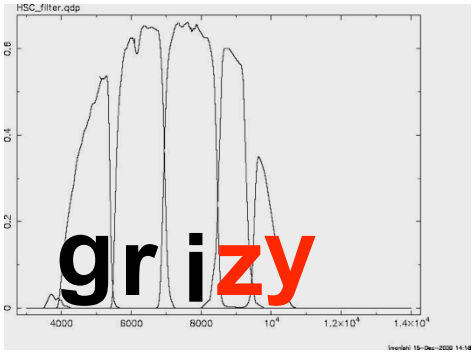
High-z QSO



z~7 QSO (z-dropout,y-detected)

z-y>2.3 selection（remove BD）

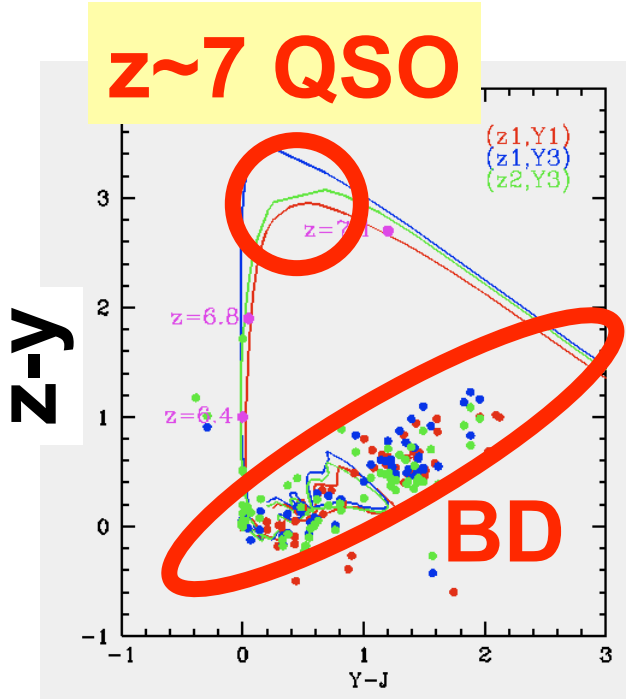
z=24.9,y=22.6



In VIKING field (J=22.2)AB,
z-y>1.7, y-J<1

z=24.9,y=23.2

(HSC: z=24.9,y=23.8)



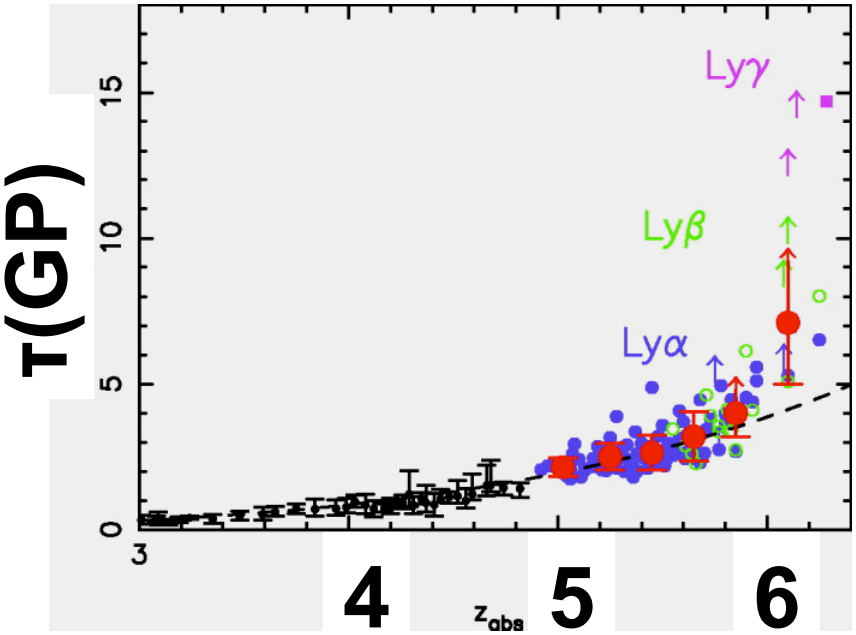
y-J

Kashikawa10

z~6 QSO science

Many faint z~6 QSO

z~6 IGM study in many sightlines (neutral fraction increases?)

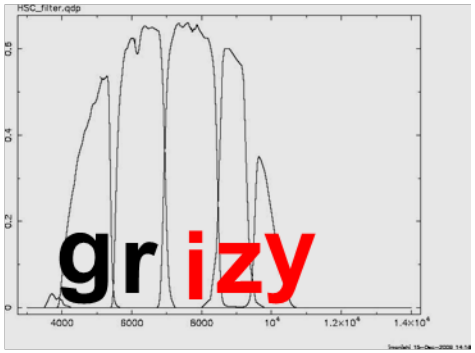


Fan+06

z~6 QSO (i-dropout, z-detected)

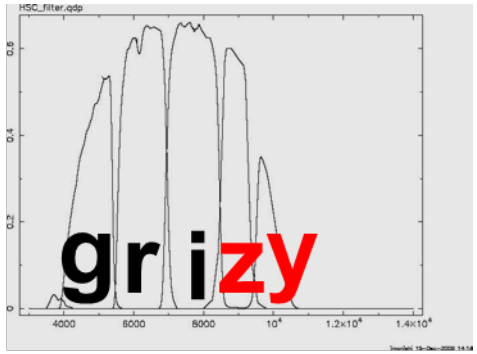
i-z red（>1.8）：by IGM absorption

z-y blue（<0.5）：BD removal



i=26.0,z=24.2,y=23.8

z~7 QSOs (z-dropout,y-detected)



35 z~7 QSOs should be included in HSC wide 1000 deg^2 (y<23.8)

We can select only 10 z~7 QSOs (from BDs) (y<23.2) via Subaru FOCAS spectroscopy

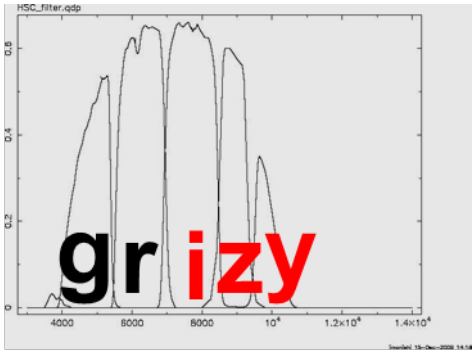
How about remaining 25 z~7 QSOs ?

PFS spectroscopy of z-dropout sources (z>24.9, y=23.2-23.8)

2.5hr, >500 deg^2, >100 nights

<10 candidates / PFS FOV

z~6 QSOs (i-dropout, z-detected)



Impossible to spectroscopically identify 350 z~6 QSOs (z<24.2) with Subaru FOCAS

PFS spectroscopy of i-dropout sources (i>26.0, z<24.9)

2.5hr, >500deg^2, >100 nights

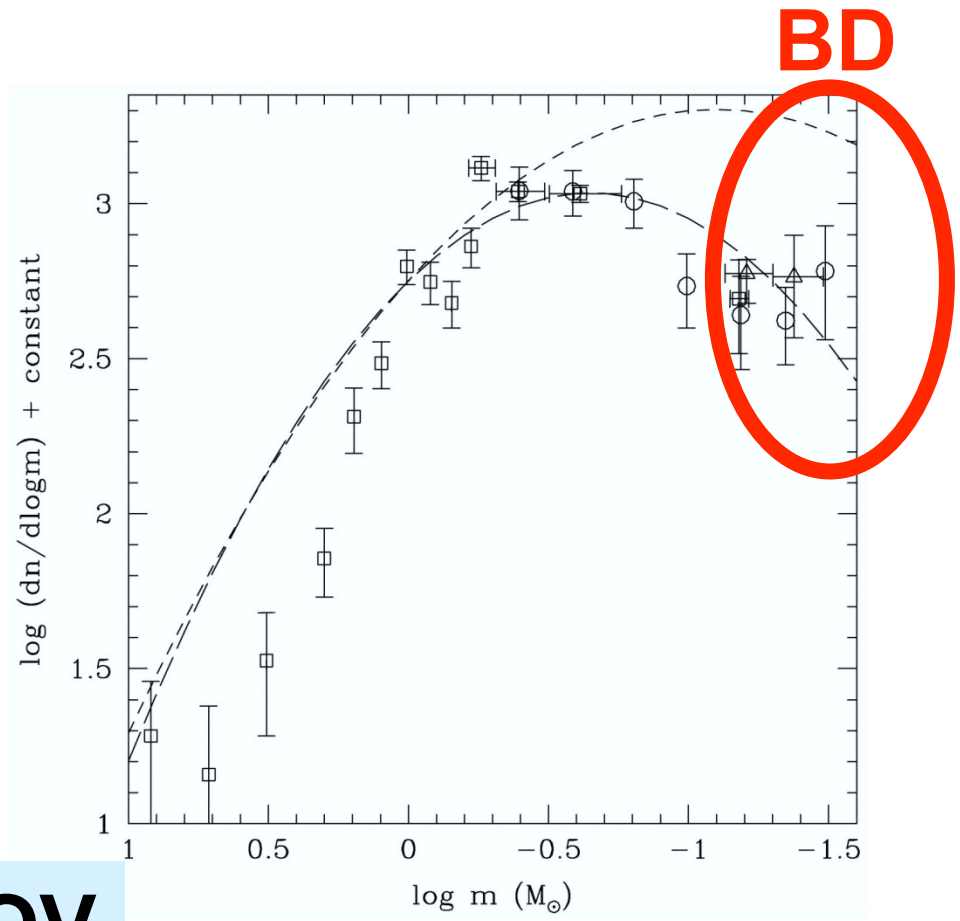
<10 candidates / PFS FOV

Brown dwarf (BD) science

PFS spectroscopy (z<22.6) of HSC-wide area will find 500 BDs

Stellar IMF in BD regime

2.5hr, >500 deg^2, >100 nights



Chabrier+03

<10 candidates / PFS FOV

Summary

1hr, 400 deg^2, 40 nights

LF, clustering, SMBH evolution of QSOs at z=3-5.5

50-1000 / PFS FOV

2.5hr, >500 deg^2 (?), >100 nights

Chemical evolution, z>6 QSOs, BD

<500 / PFS FOV

Combined with 4hr, 300 deg^2 galaxy survey ?

Request for PFS specification and survey design

High sensitivity at >8000A

Wide wavelength coverage (3900-10800A)

A wider FOV (>1.5 deg^2) may help

2400 fibers and R=3000 are sufficient

Target field must be HSC wide

HSC+PFS is most powerful until LSST (and subsequent follow-up spectroscopy) start operation

TMT

Spectroscopy of z>6 QSOs to study IGM

ALMA

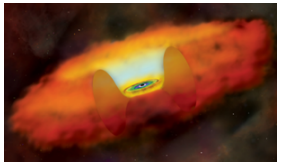
gas of QSO host galaxies

WFIRST/WISH

Numerous fainter z>7 QSOs

Other potential QSO science with PFS

- Obscured AGNs (via galaxy survey)



Type-2

- z<3 QSOs (u-band available ?)
- Ly alpha forest toward z<3 QSOs
- variability-selected low-L AGN (deep)

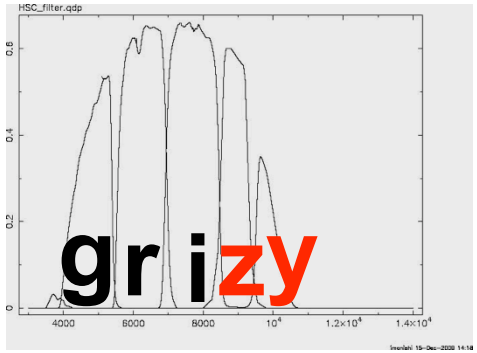
Other people's talk

If z>3 QSO number per PFS FOV is << 2400, z<3 PFS QSO science should be combined

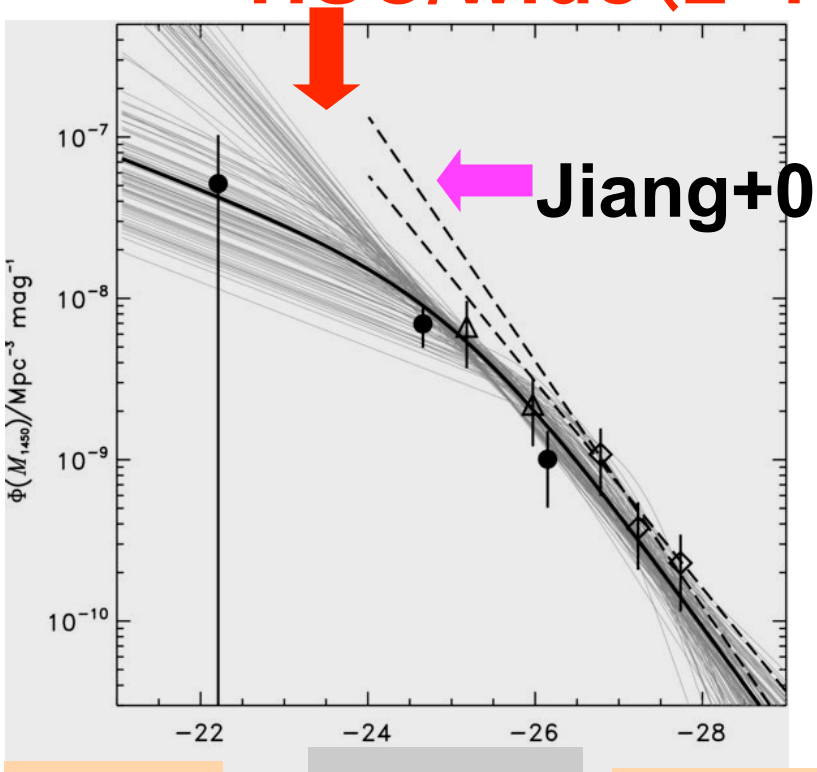
End

z~7 QSO

Number of faint QSOs :
Smaller than previously expected



HSC/wide（z~7）



faint **M_{1450A}** **bright**

Selectable z~7 QSO:
7/1000 deg^2
12（VIKING）
（conservative）

Lim-mag:
(z,y) = (24.9, 23.8) AB

z~7 QSOs included
in y-band : ~35/1000deg^2

Selection z-y>1.5

PFS（z~7 QSO）

Follow-up spectroscopy of HSC z~7 QSO candidates

Several 10s candidates/1000 deg^2

Use extra several fibers in other galaxy surveys

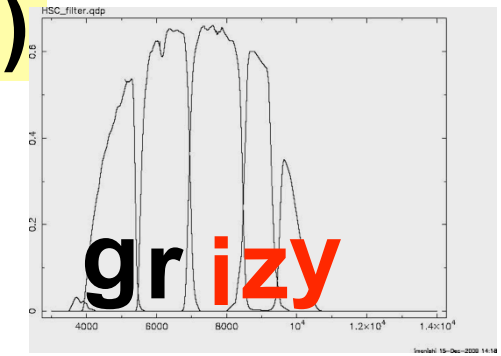
At least cover Lyα : 9000 - 10500A

High sensitivity required

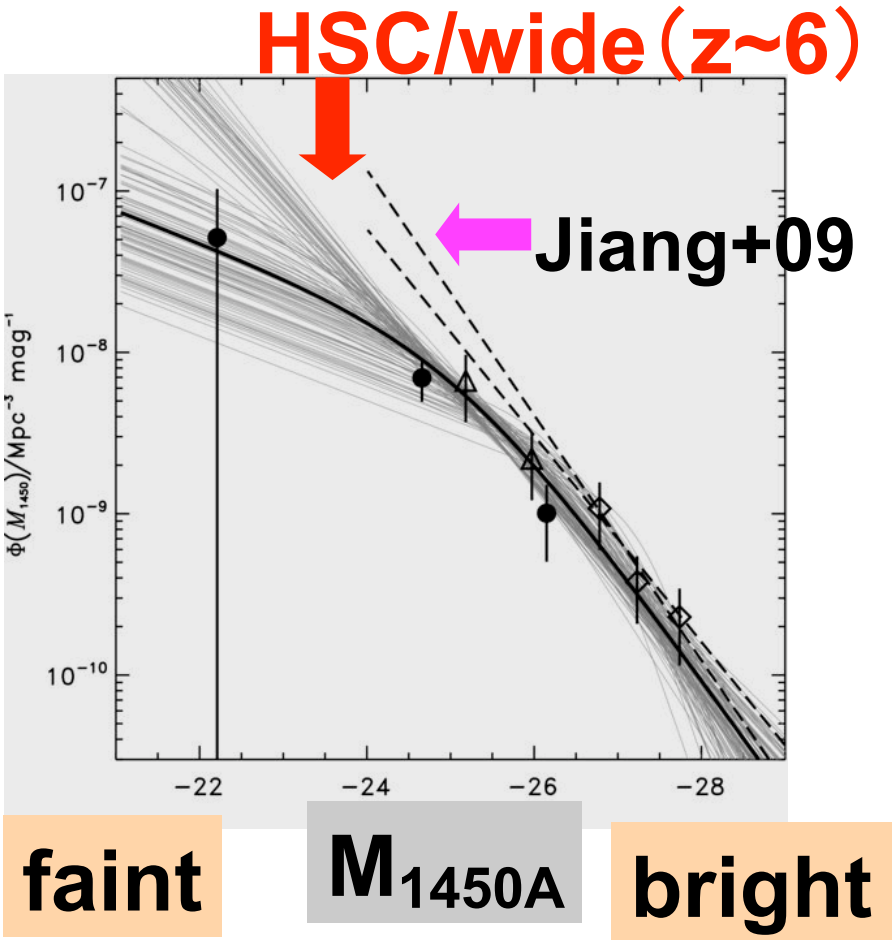
SMBH mass → MOIRCS

IGM physics → TMT

2. z~6 QSO (i-dropout, z-detected)



i-z red（>1.8）：by IGM absorption
z-y blue（<0.5）：BD removal



350/1000 deg^2
（conservative）

Selection :
i=26.0,z=24.2, y=23.8
(AB)

PFS（z~6 QSO）

Follow-up spectroscopy of HSC z~6 QSO candidates

1000 candidates/1000 deg^2（1/deg^2）

Use extra several fibers in other galaxy survey

At least cover Lyα : 8000 – 9000A

High sensitivity required

z~6 IGM multiple sightlines → TMT