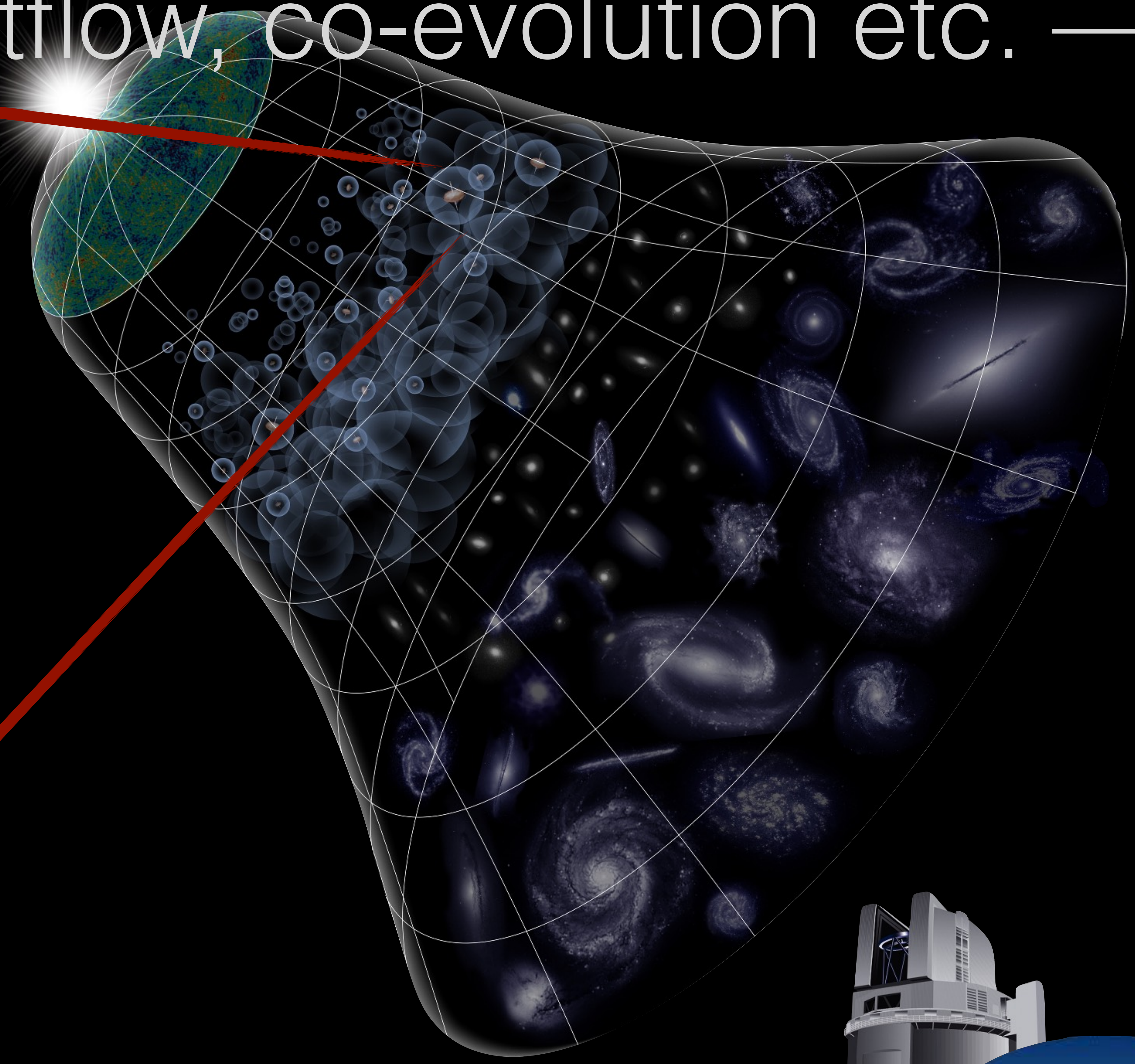
Subaru/SWIMS Views of Low-Luminosity Quasars at z=6-7

— BH mass, BLR metallicity/outflow, co-evolution etc. —



Masafusa Onoue（MPIA Heidelberg）

on behalf of the SHELLQs collaboration

Max-Planck-Institut für Astronomie Heidelberg / Max Planck Institute for Astronomy Heidelberg

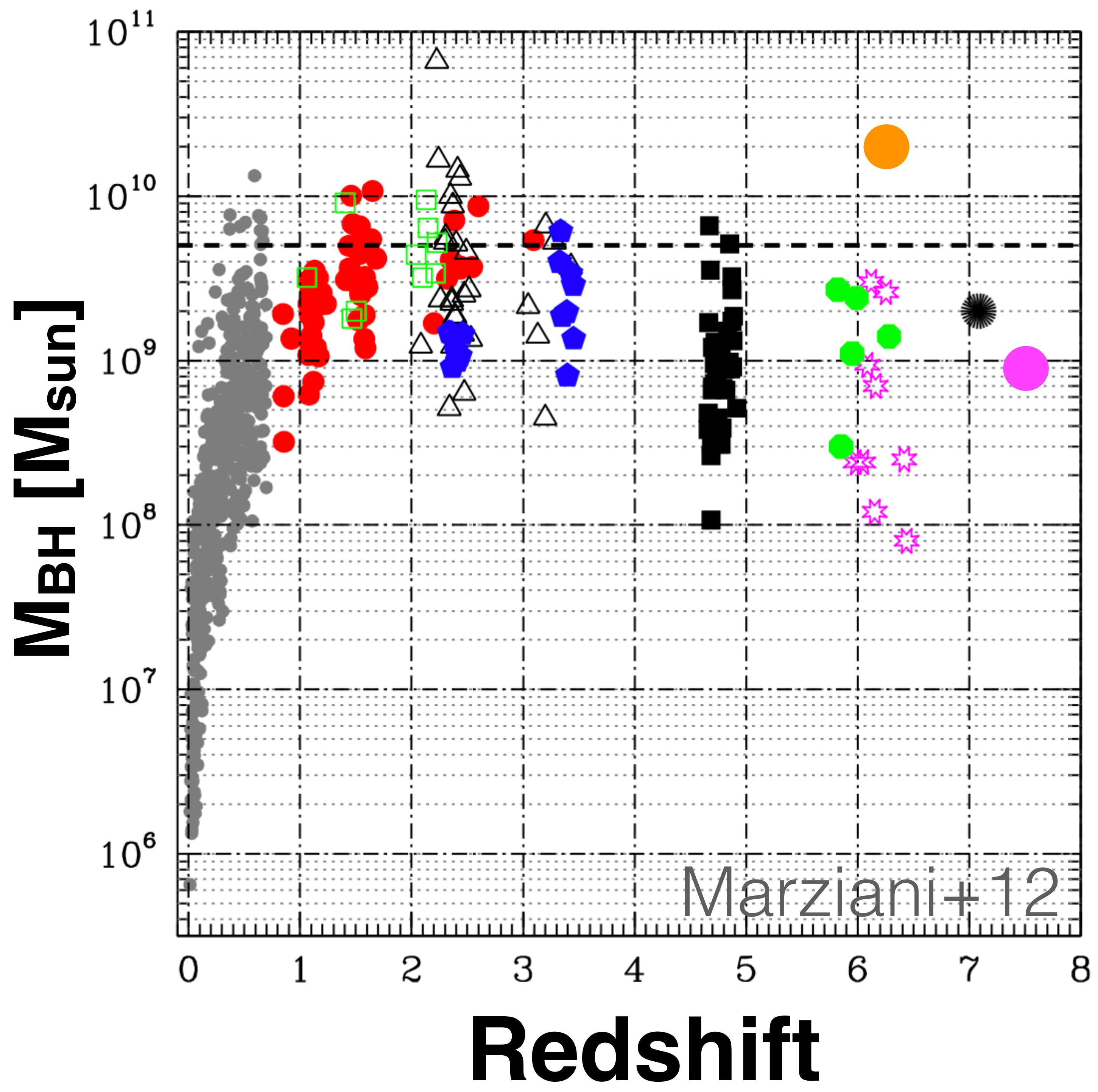
HSC

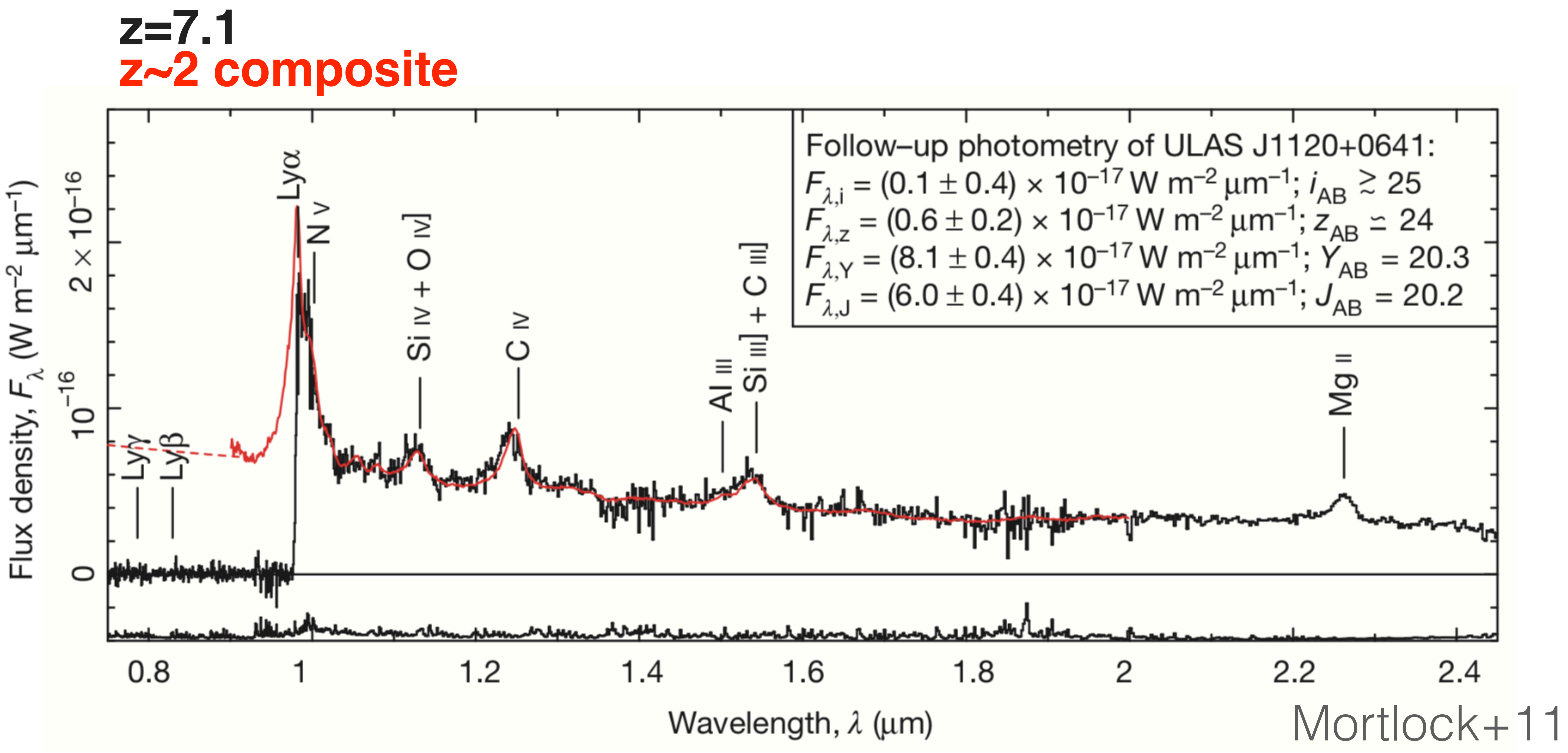
2020/07/27 SWIMS on Subaru Workshop

Credit: Y.Matsuoka

Super Massive Black Holes

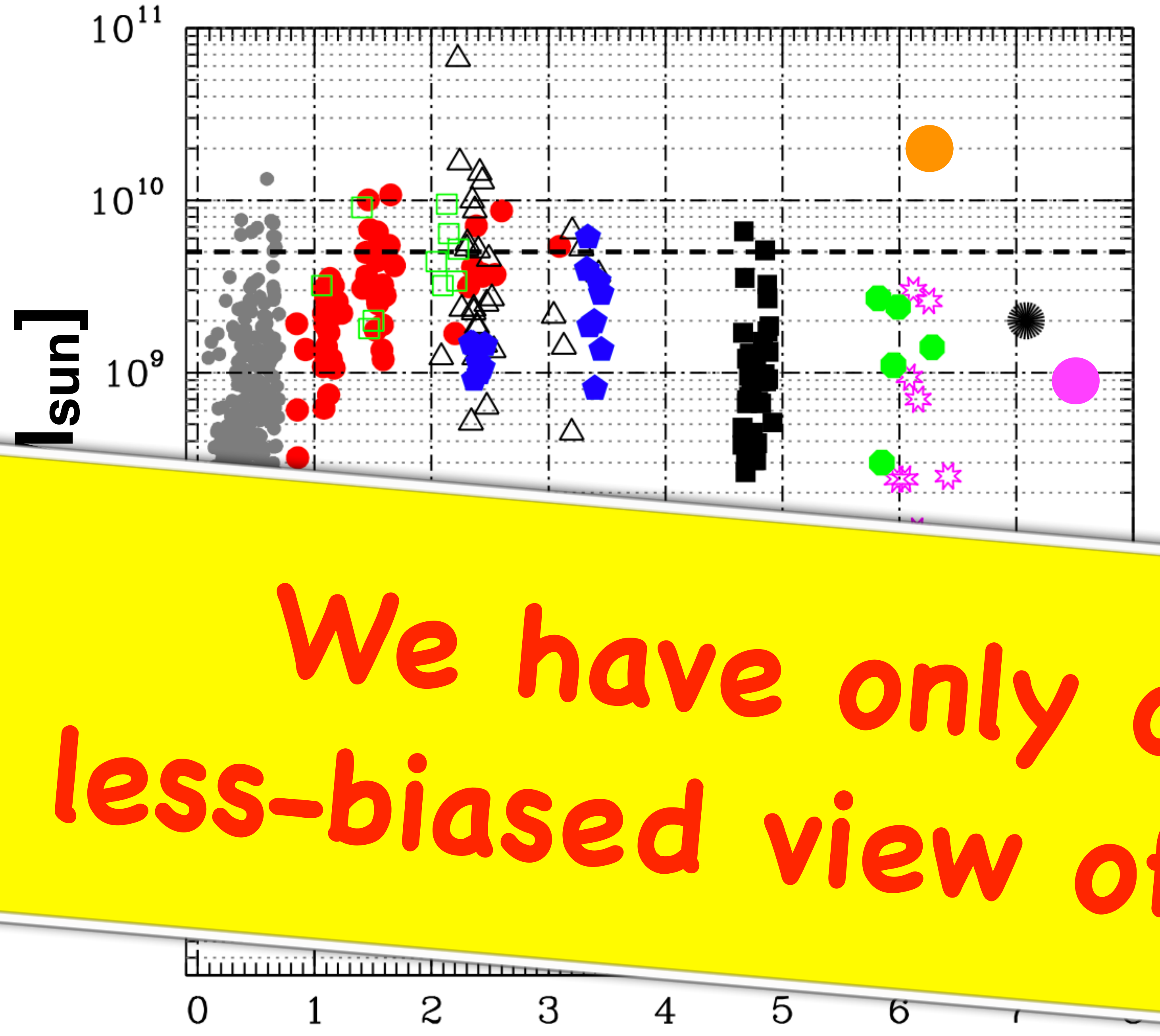
SMBH Early Growth & Chemical Evolution

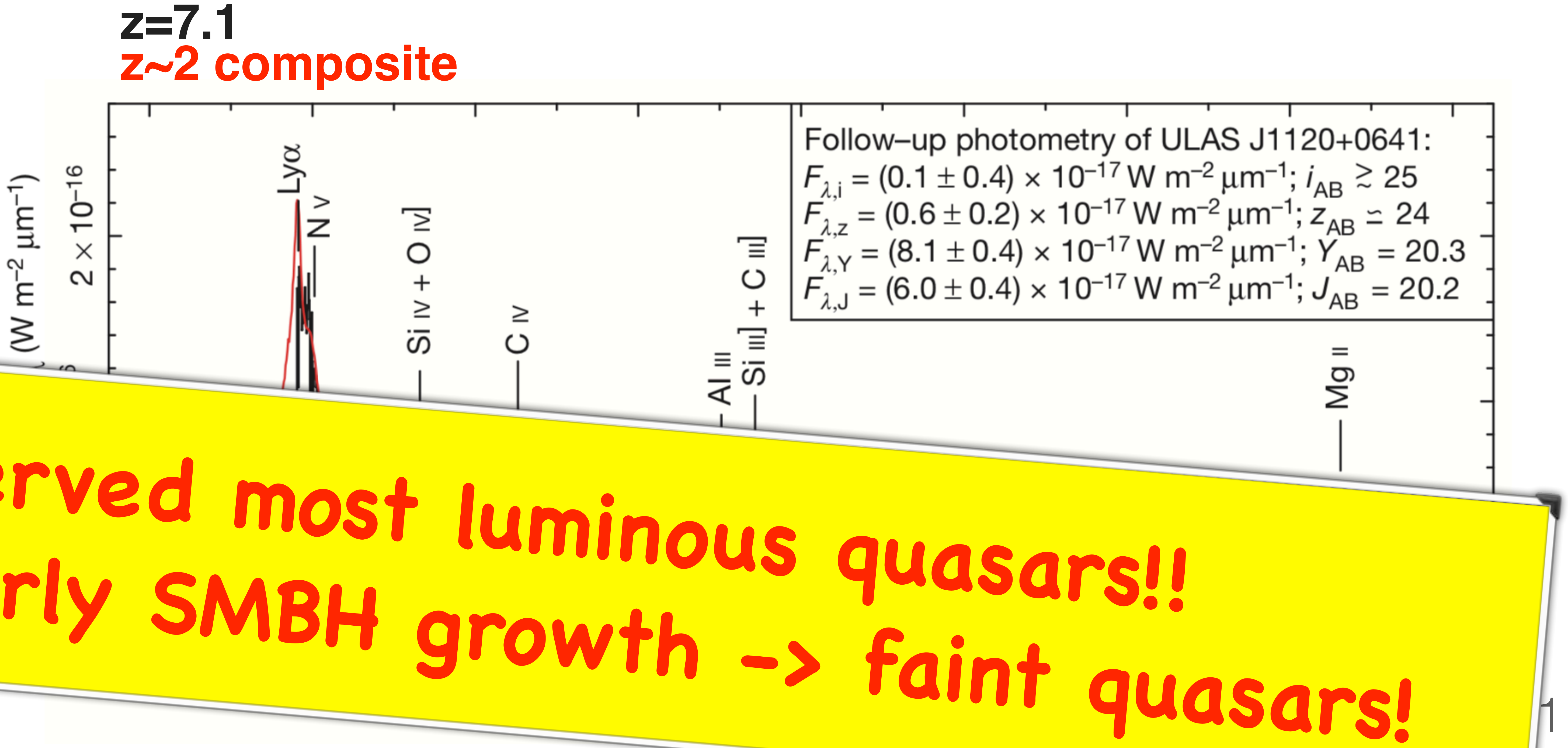




- ✦ $M_{BH}>10^9\ M_{sun}$ SMBHs exist at z>6 (e.g., Wu+15, Banados+18). Mostly Eddington accretion
  - ➡ Stringent constraints on the seed BH formation scenario (cf. Inayoshi+20)
- ✦ Rest-UV spectrum seems unchanged up to z=7.5 (t_{univ}~0.7Gyr; e.g., Onoue+20)
  - ➡ No metallicity evolution in broad-line-region gas (Z_{BLR}~5Z_{sun}; e.g., Nagao+06)
  - ➡ Rapid star formation of the quasar hosts?

SMBH Early Growth & Chemical Evolution





We have only observed most luminous quasars!!
A less-biased view of early SMBH growth -> faint quasars!

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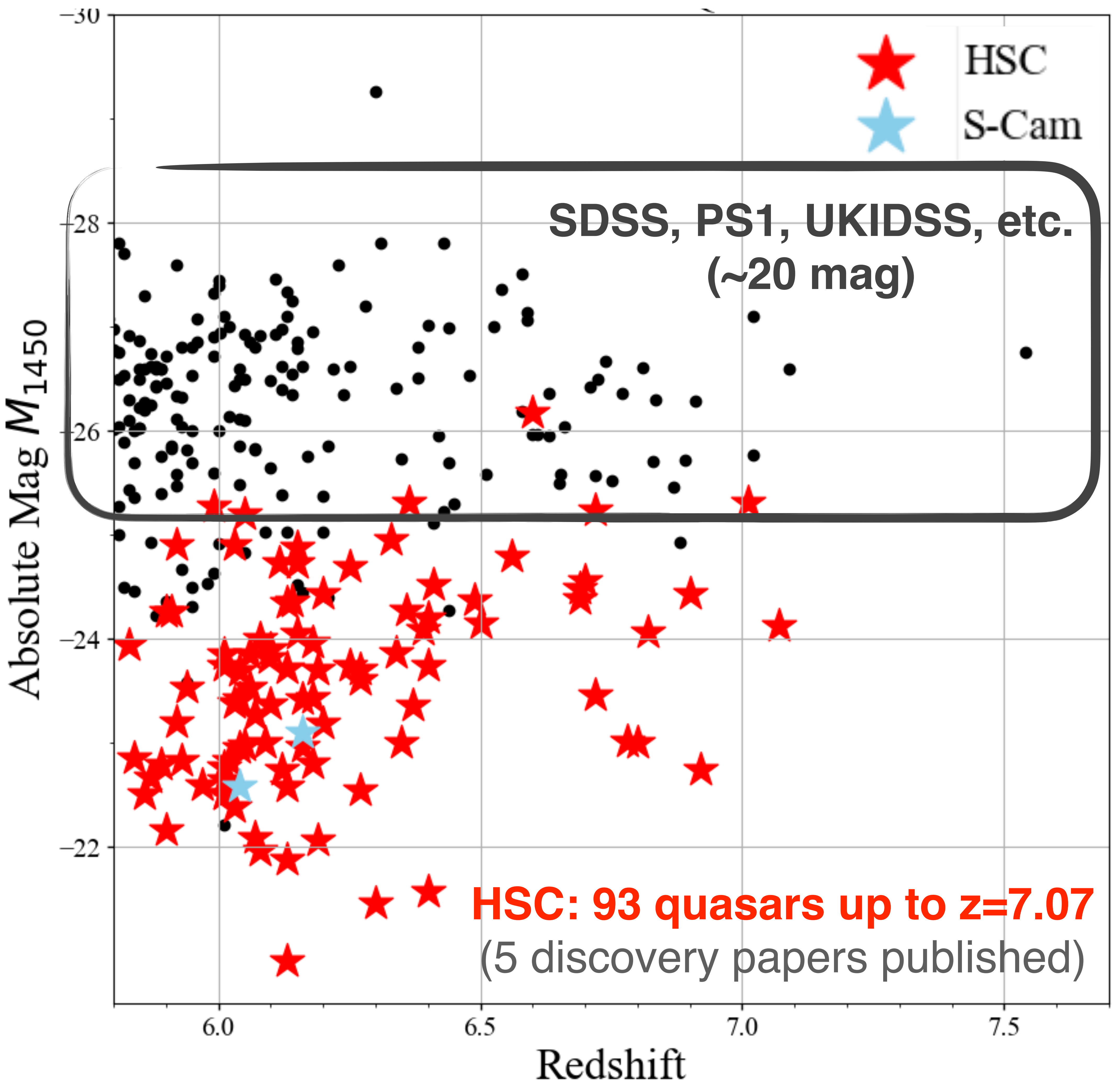
Our Project:
Searching for z=6-7 low-luminosity quasars

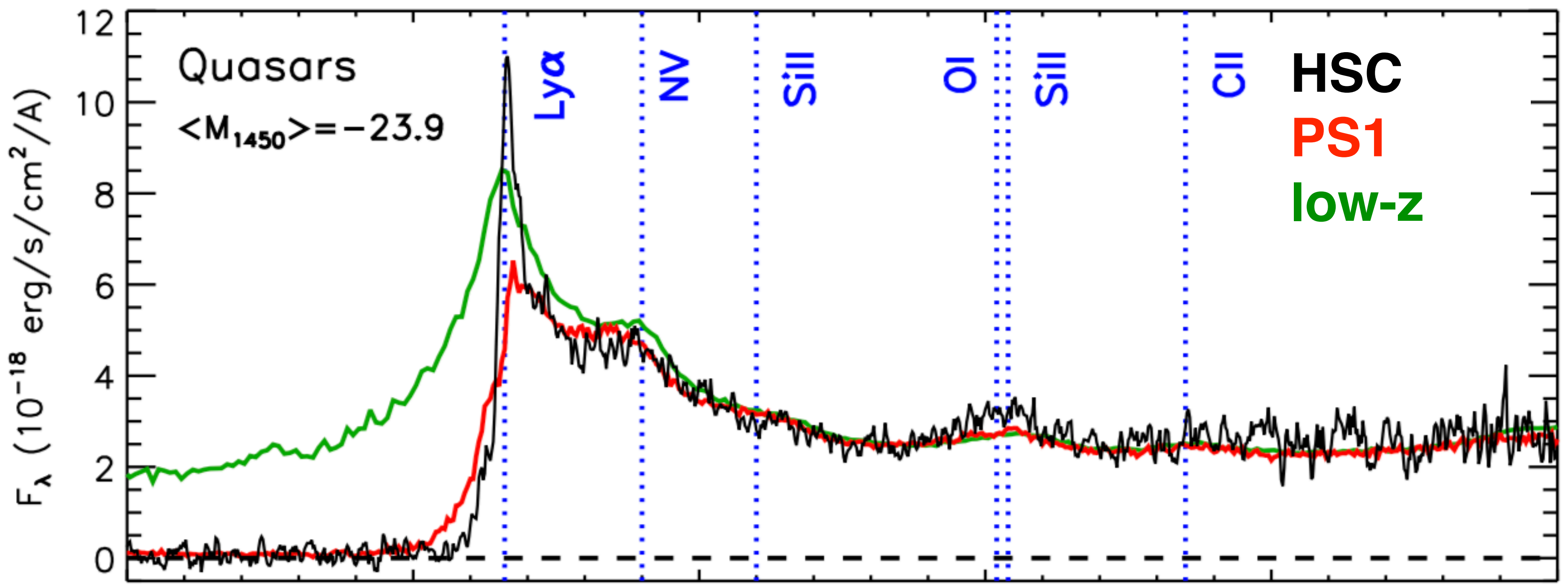
Credit: Y.Matsuoka

z=6-7 Quasar Search with HSC-SSP

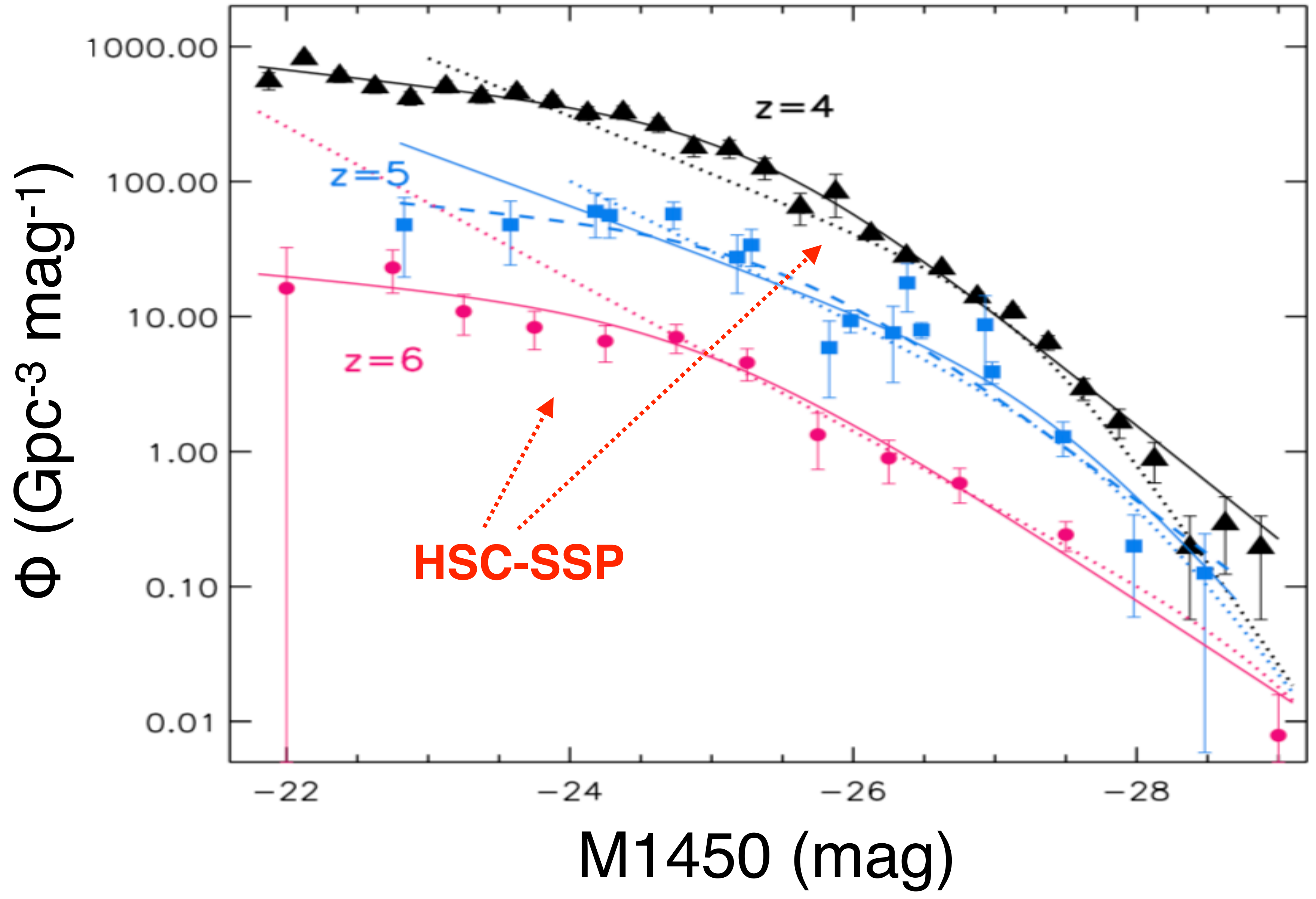
- Known quasars at z>5.8



- Composite spectrum (Matsuoka, MO+19b)



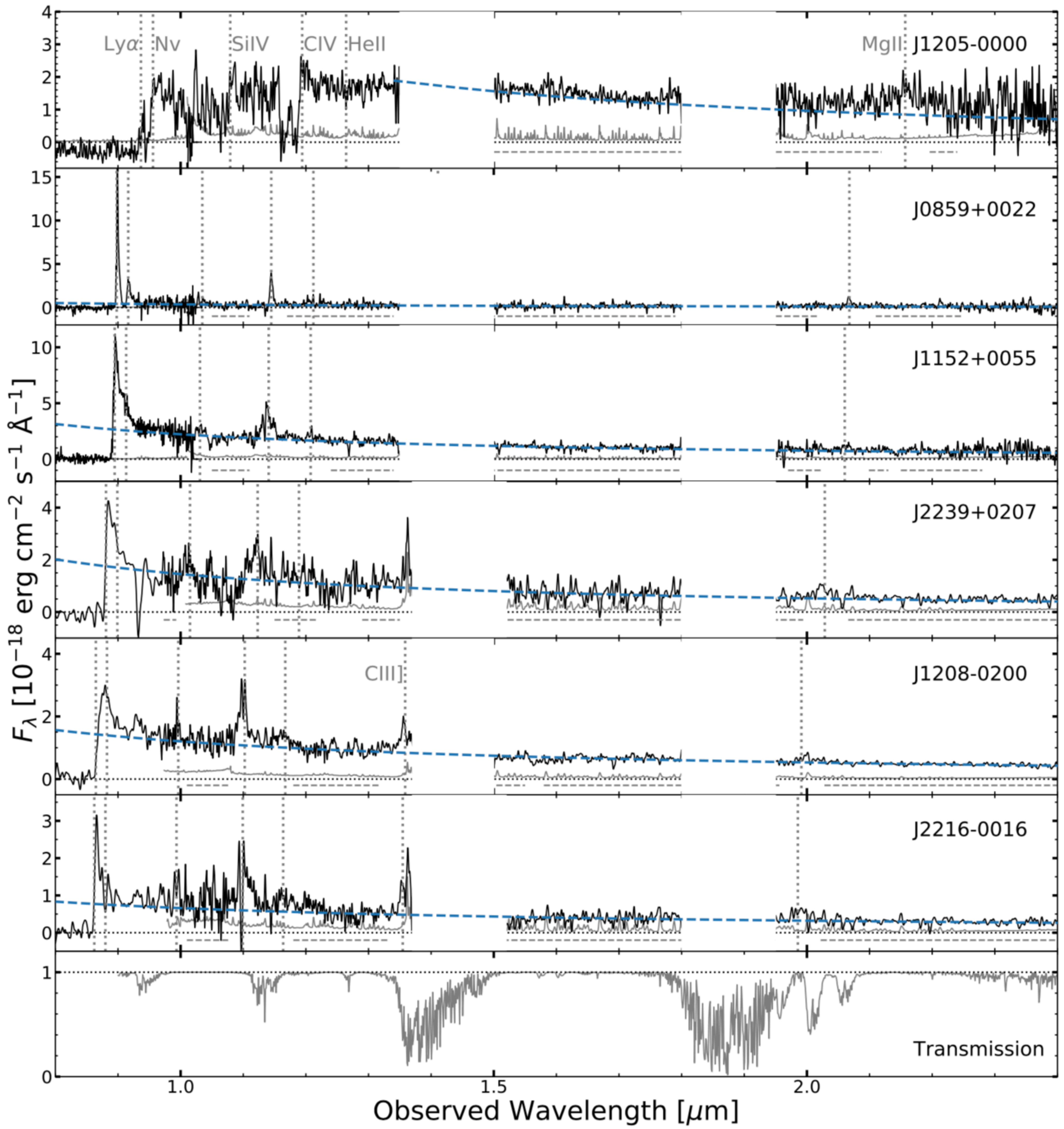
- Quasar luminosity function (Matsuoka+18c; Akiyama+18)



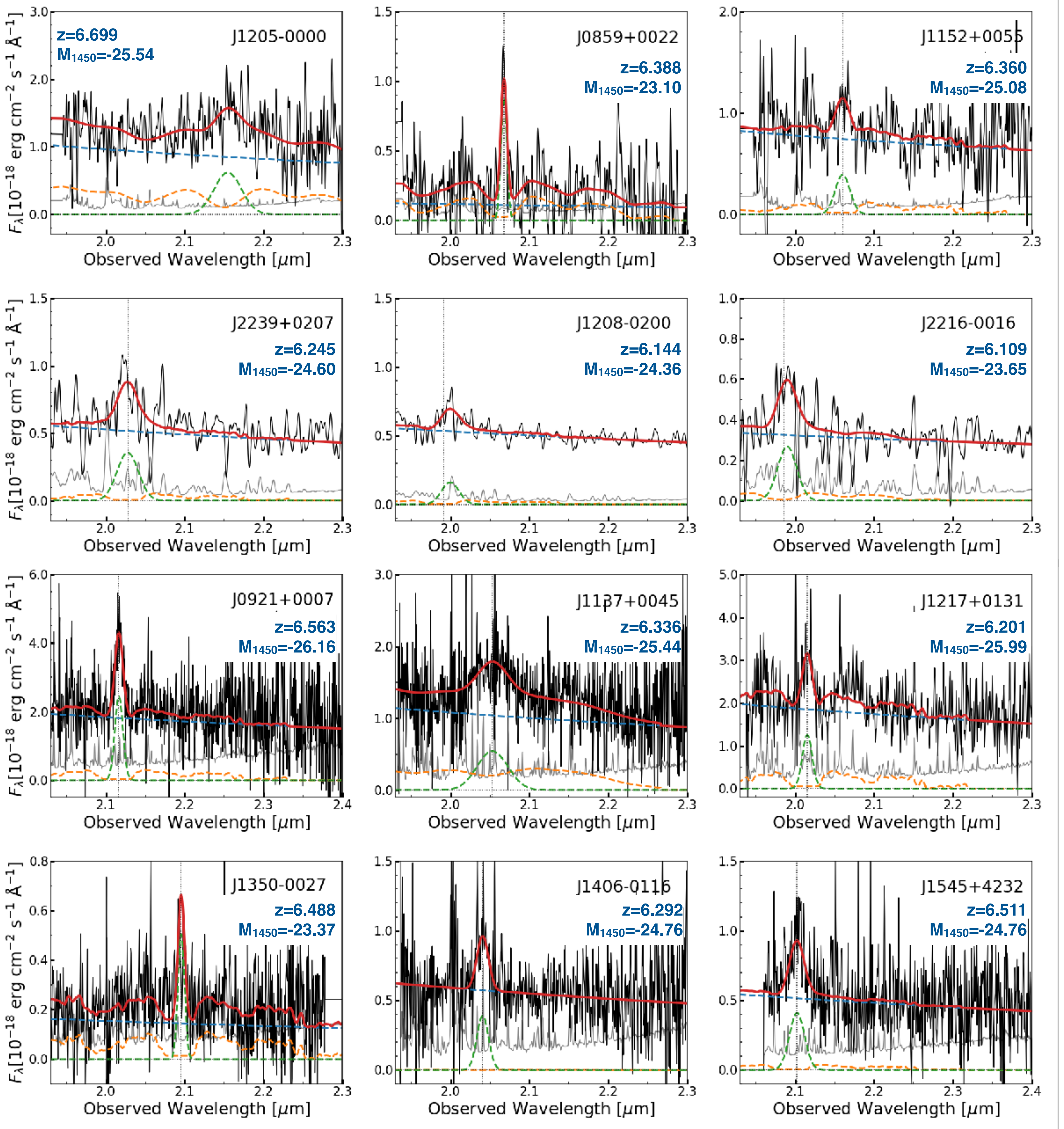
Subaru is leading faint quasar searches at highest-z!!

NIR follow-up

- VLT/XShooter & Gemini/GNIRS spectra (MO+19)



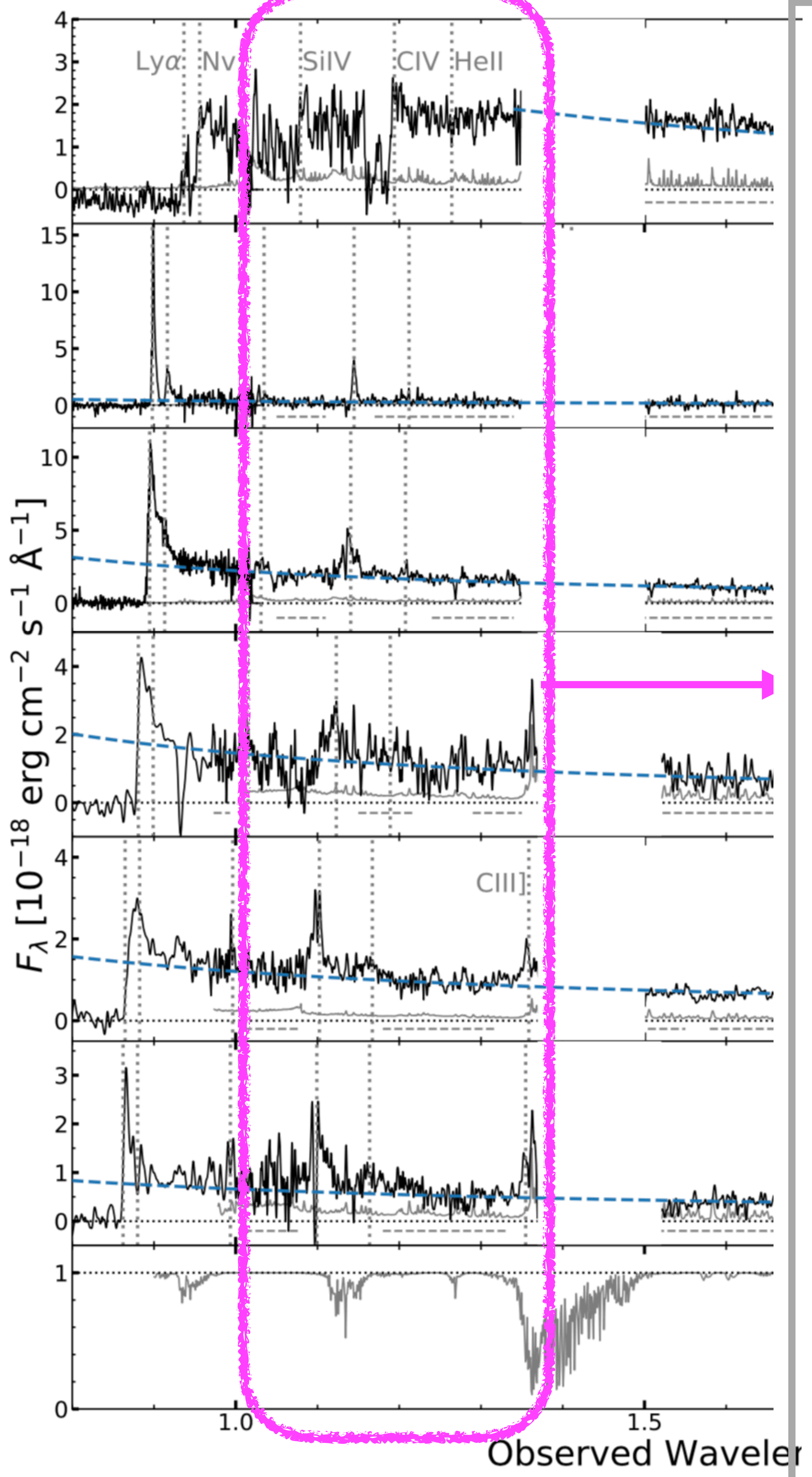
- MgII spectra at K-band (XShooter, GNIRS, MOIRCS)



NIR spectra are essential to evaluate MBH and BLR properties

NIR follow-up

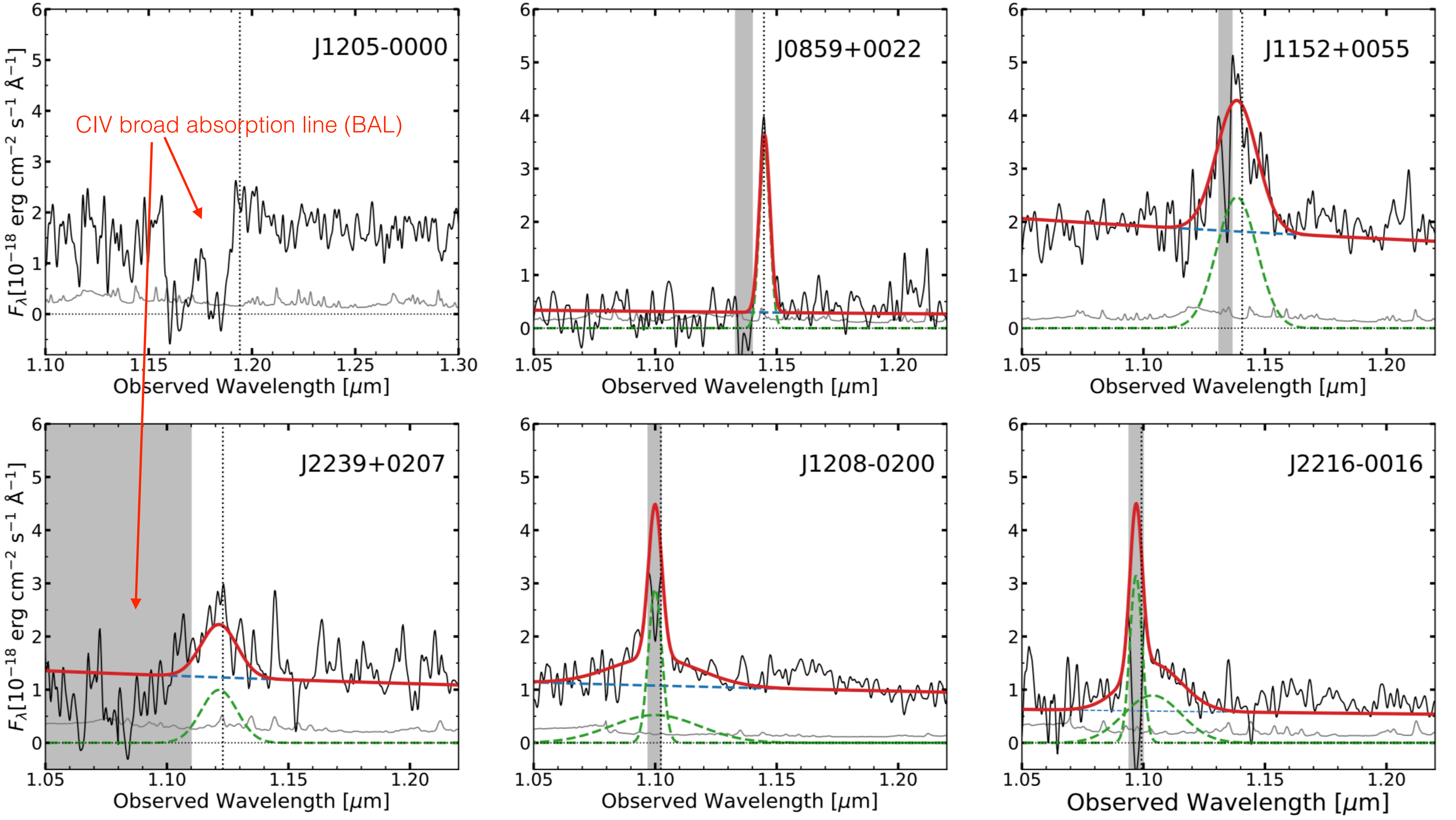
- VLT/XShooter & Gemini/GNIRS spectra (MO+19)



- MgII spectra at K-band (XShooter, GNIRS, MOIRCS)

- CIV spectra

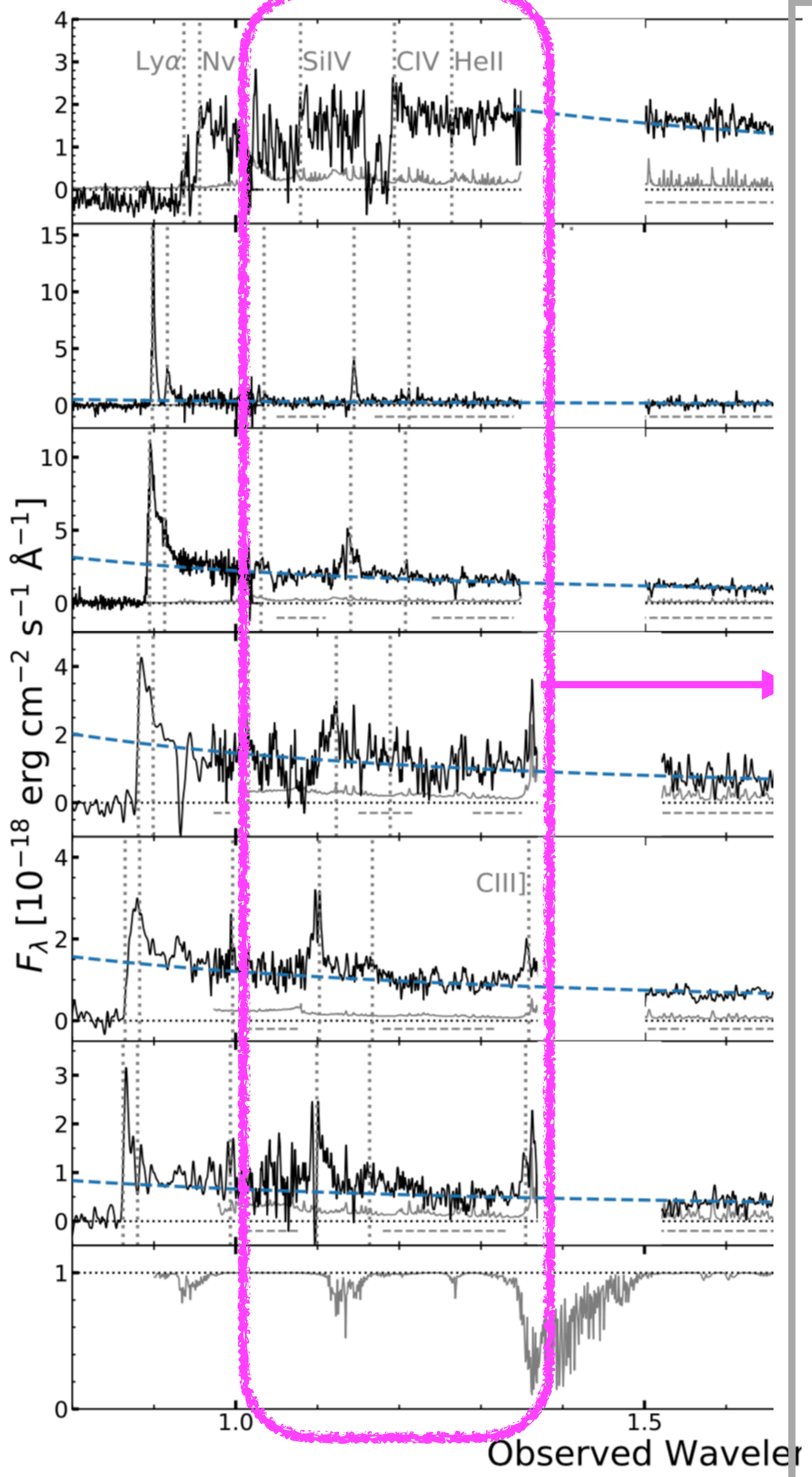
Vertical dotted line: expected CIV peak from systemic redshifts



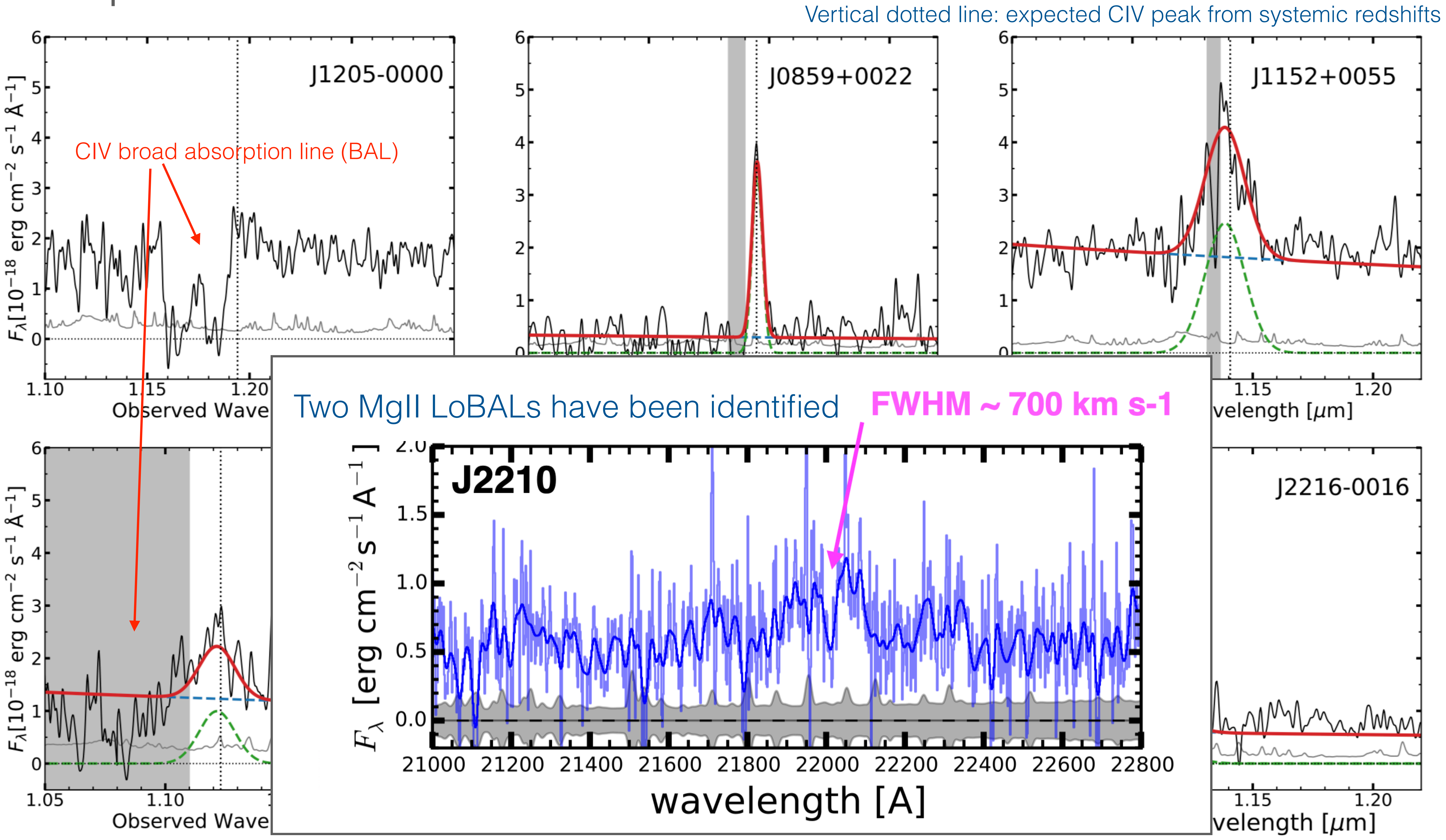
Broad / Narrow absorption is common at high-z?

NIR follow-up

- VLT/XShooter & Gemini/GNIRS spectra (MO+19)



- MgII spectra at K-band (XShooter, GNIRS, MOIRCS)
- CIV spectra



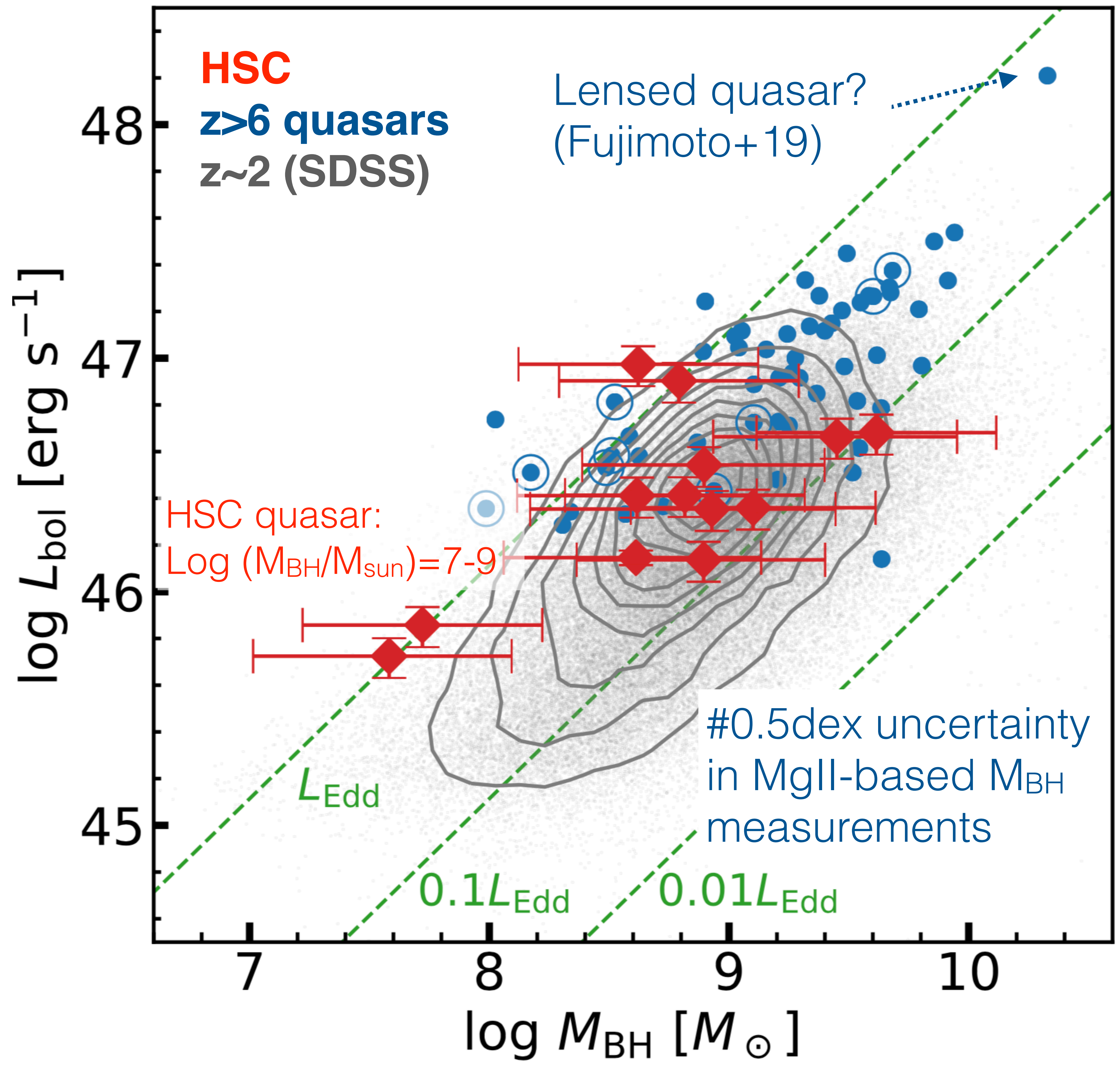
Broad / Narrow absorption is common at high-z?

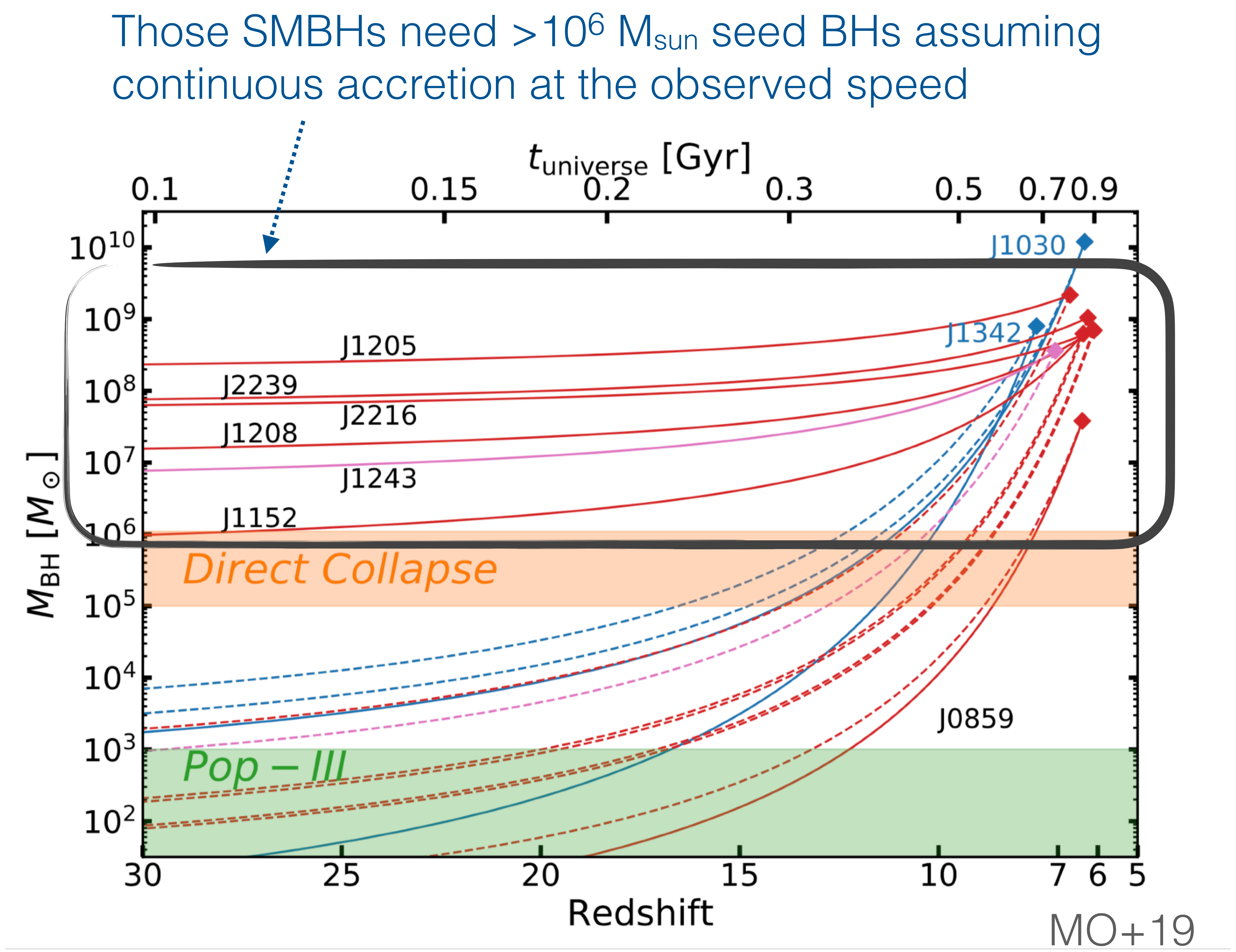
Quasar nuclear-scale outflows

in prep.

BLR blueshifts get sharply larger at z>6 (even for low-ionization lines)
How are they linked to the SMBH growth and host galaxy evolution?

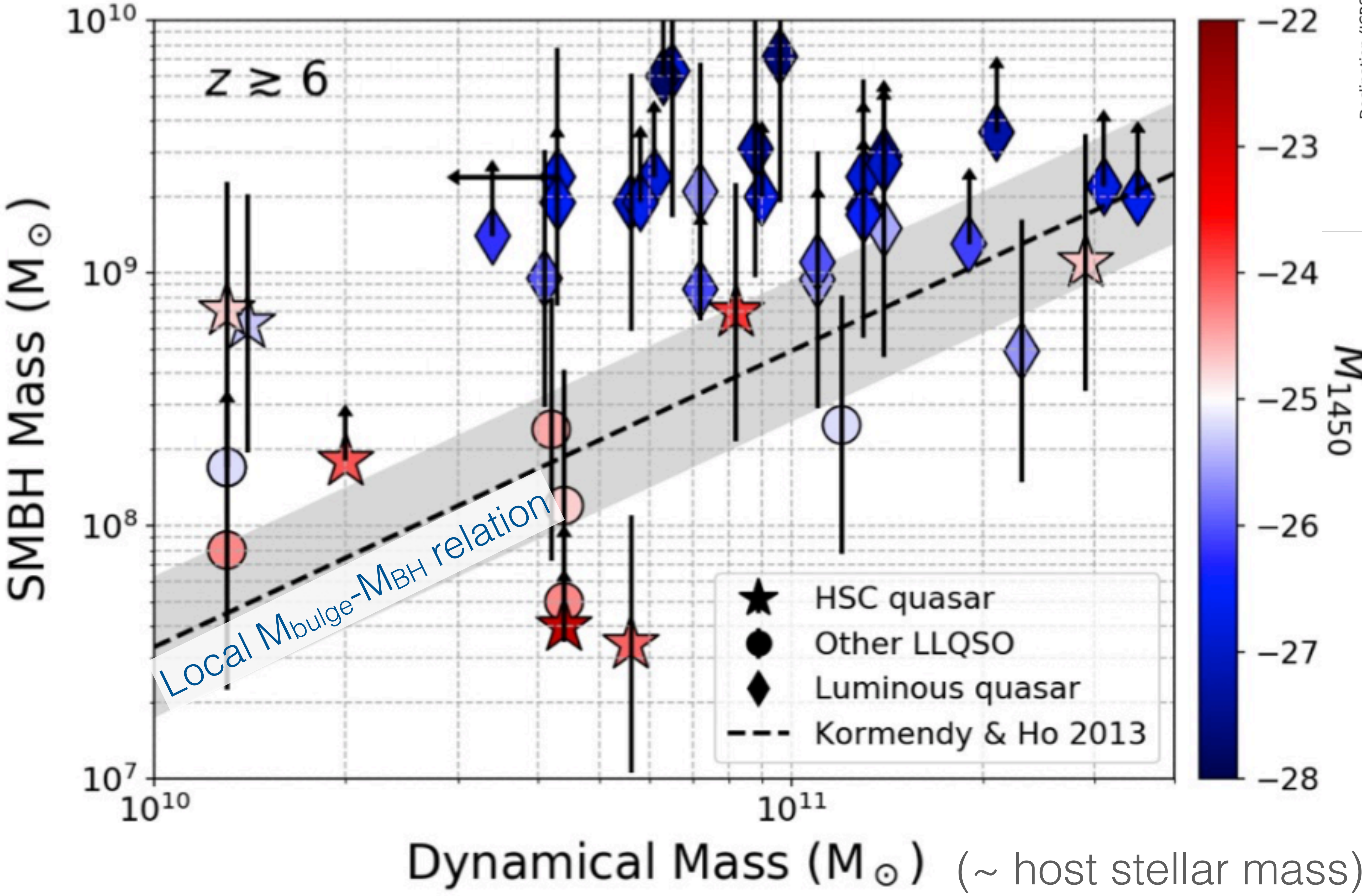
M_{BH}-L_{bol} distribution at z>6





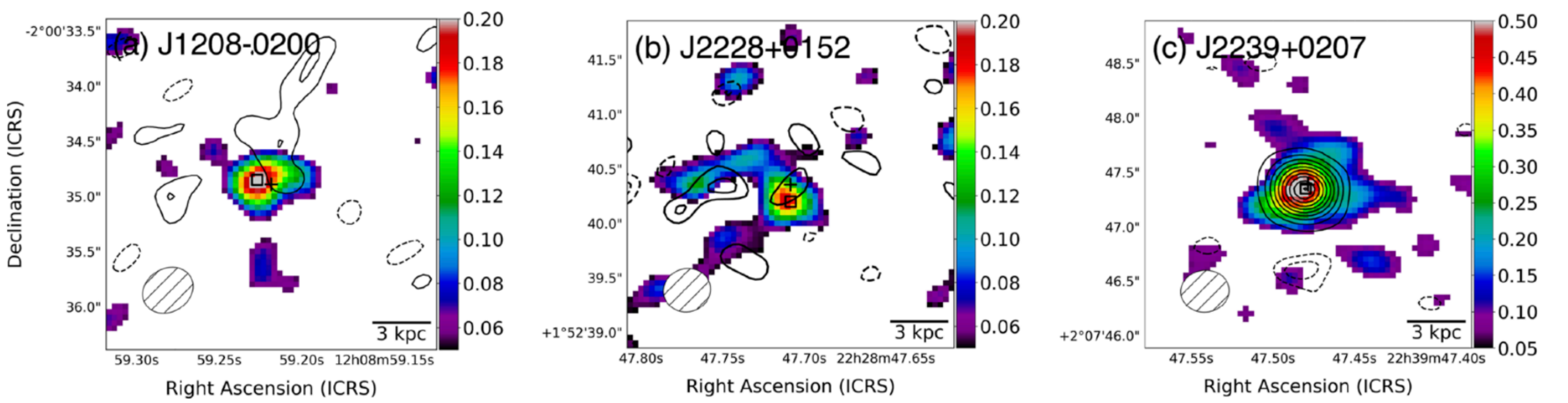
Diverse MBH & Edd ratio distribution found in HSC low-luminosity quasars
z>6 sub-Edd SMBHs are likely in quiescent phase even at z>6

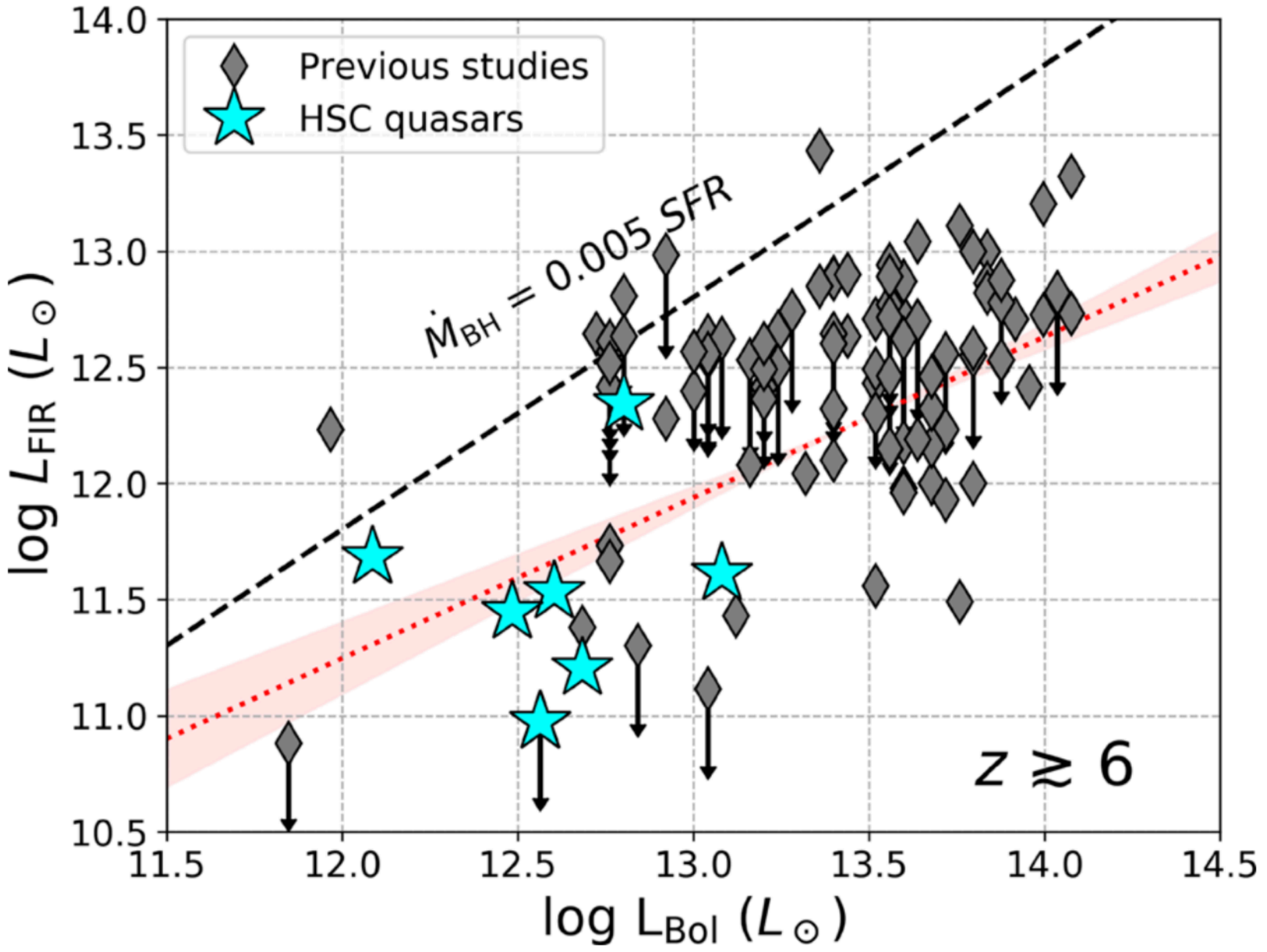
Early SMBH-galaxy Co-evolution



(~ host stellar mass)

color: [CII] 158um, contour: dust





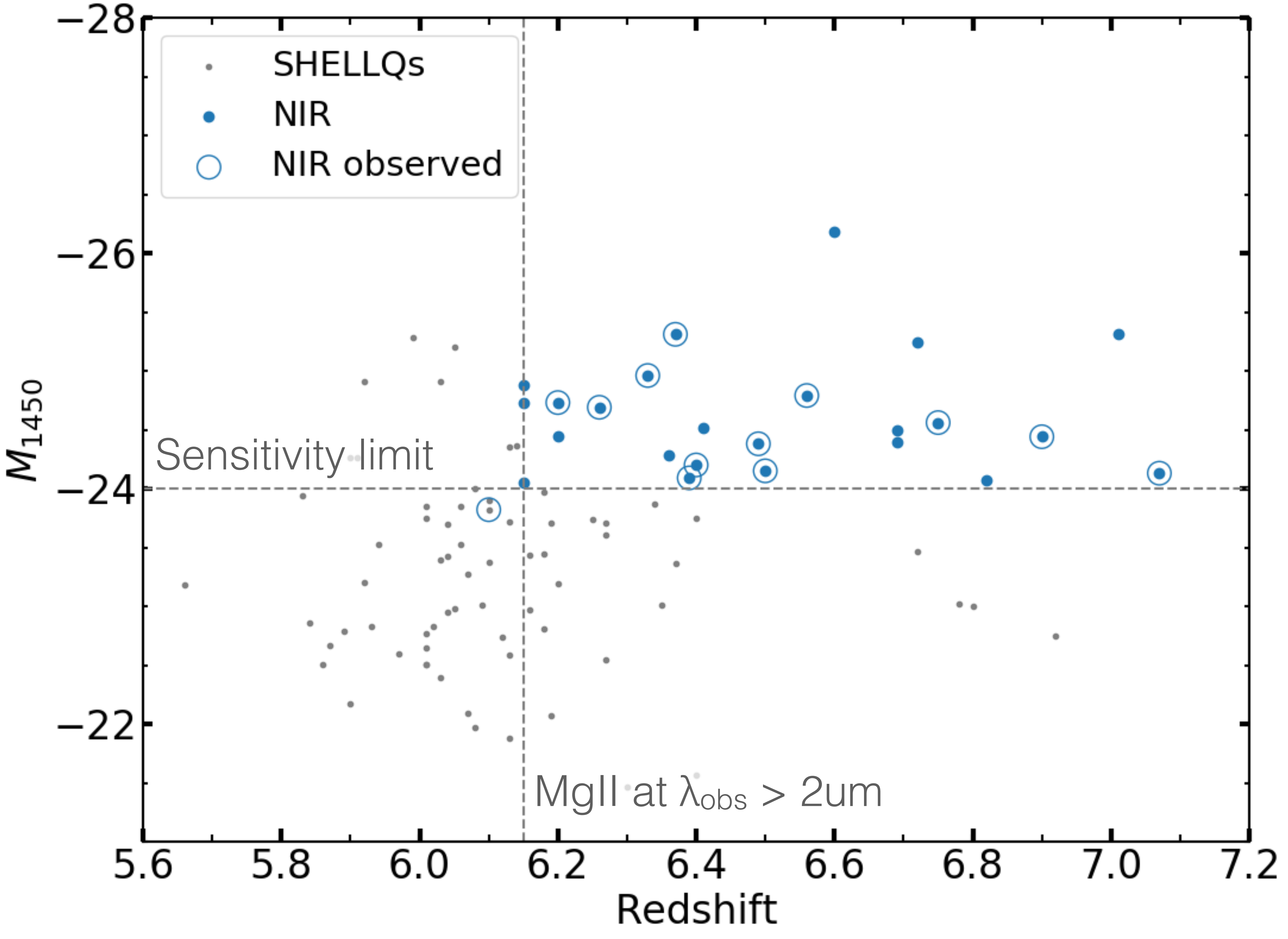
Izumi+19

ALMA revealed that co-evolution has already been in place at z=6

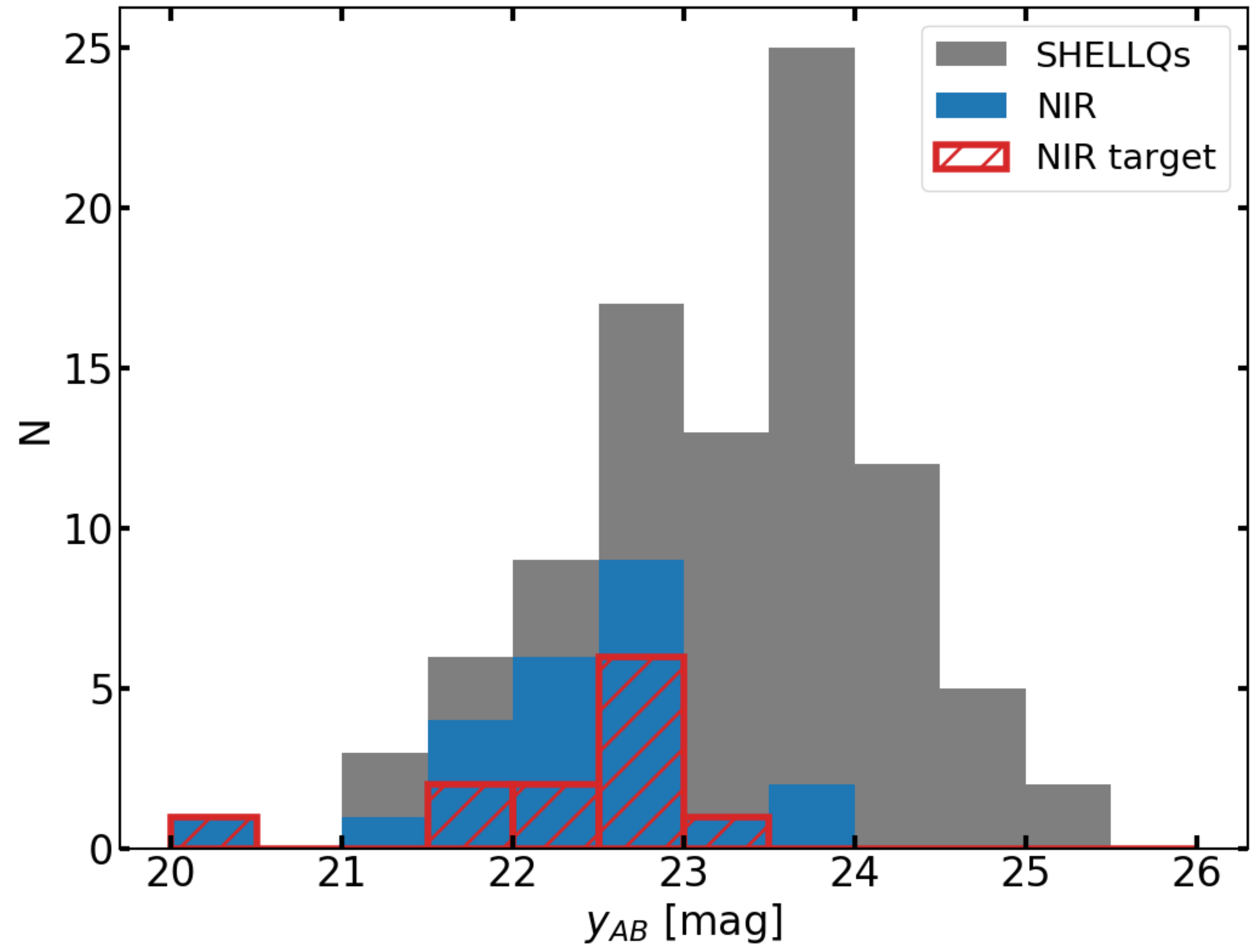
(with a variety of the FIR properties)

Subaru/SWIMS follow-up

Subaru/SWIMS follow-up



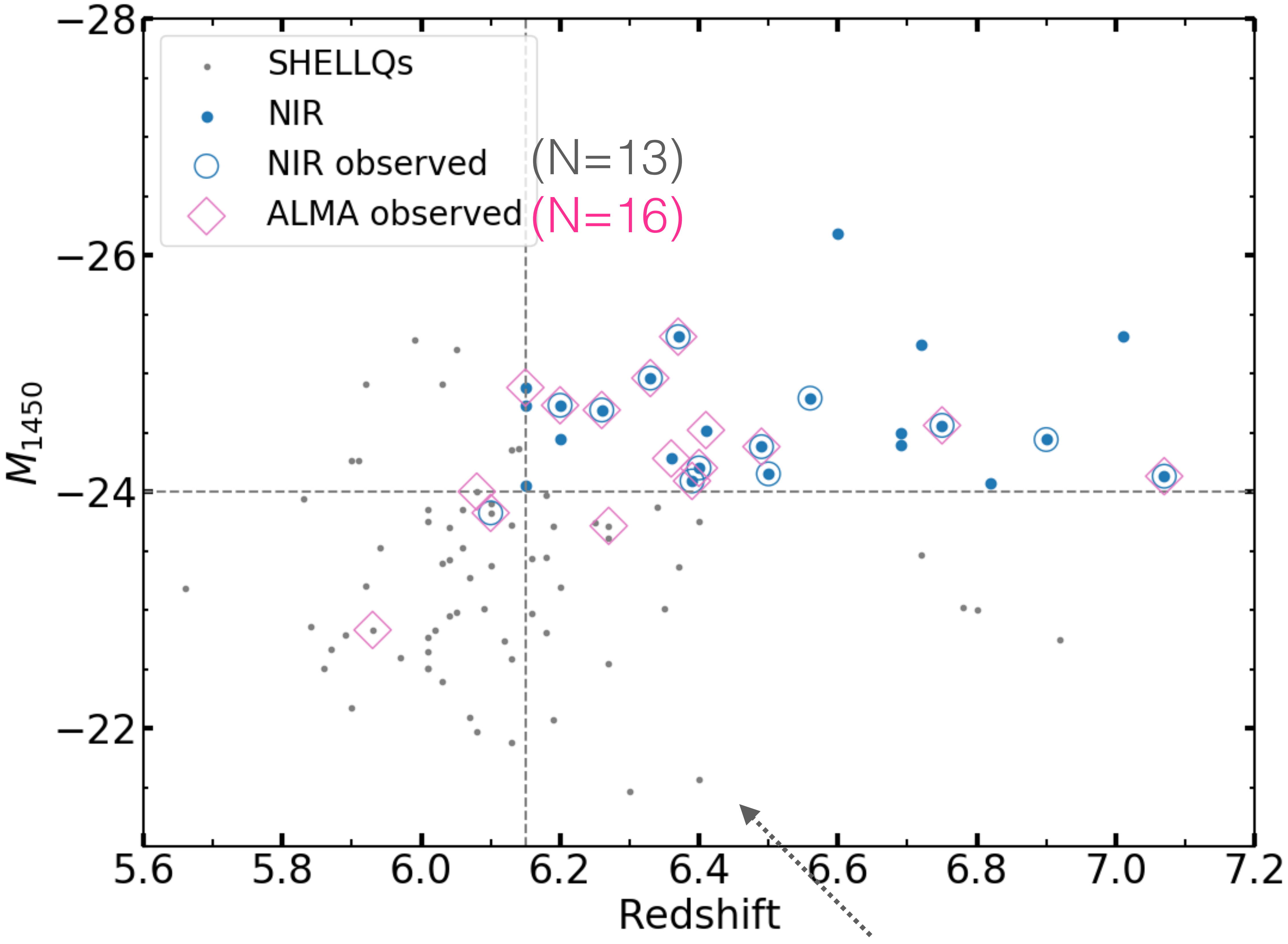
Selection: $z>6.15$ & $M_{1450}<-24$
-> 12/24 remaining quasars so far
-> ~20 targets expected when HSC-SSP completes



Increasing our NIR sample is a key for statistical studies (e.g., mass function, BAL fraction)!!
Requiring telescope times: 10 nights (~4hr/target)

Why is Subaru/SWIMS needed?

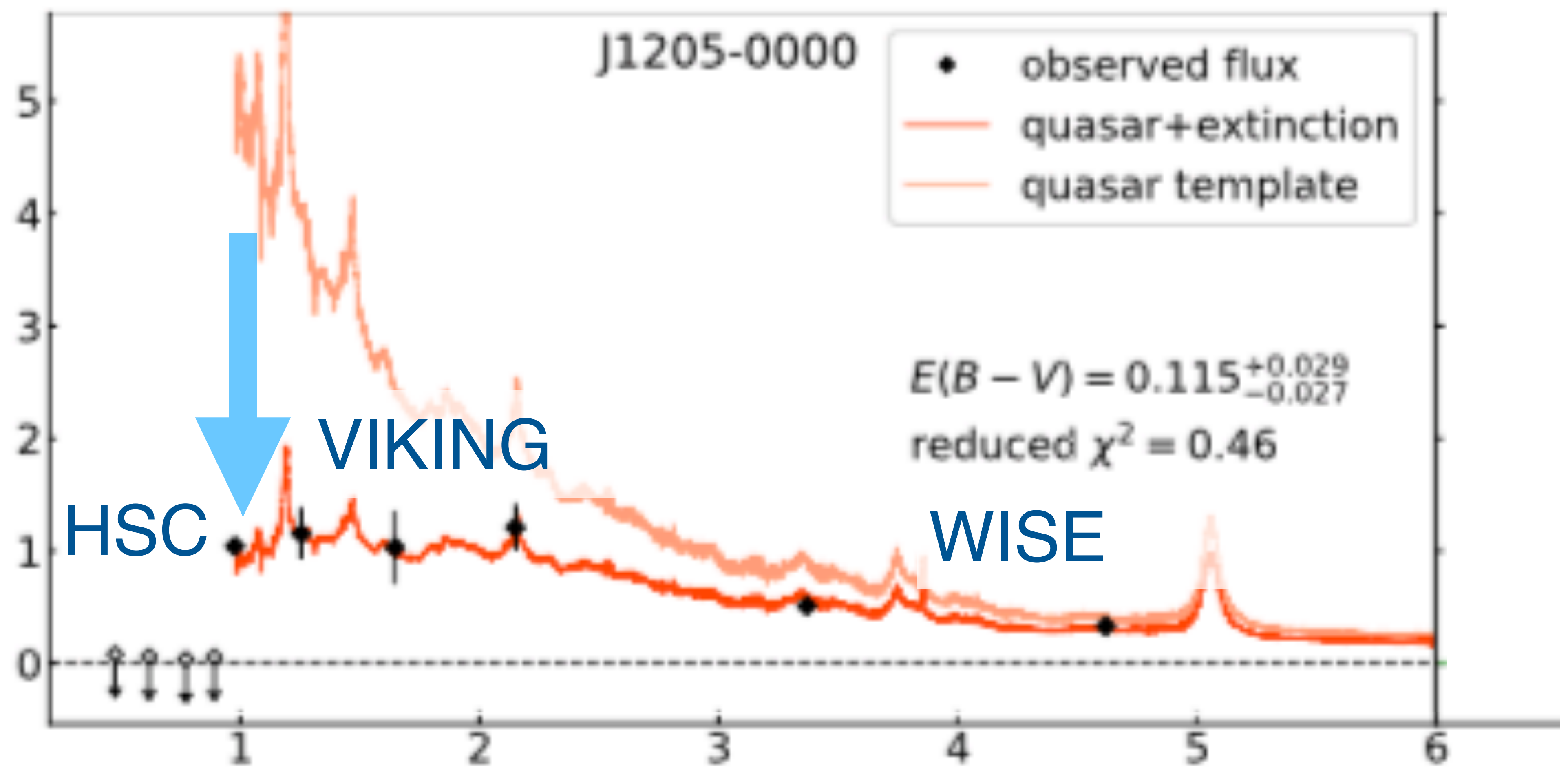
- ✦ The capability of simultaneous NIR spectroscopy is ideal (i.e., more emission lines, better continuum estimate). Spectral resolution of R~1000 is sufficient to detect broad emission lines (FWHM>1000 km s-1)
- ✦ NIR follow-up has been our bottleneck (<9hr per target). Since we will propose an ALMA large (PI: T.Izumi), we need a block of observing times in NIR as well to have a sample size of N~30
- ✦ Quick NIR follow-ups enable us to provide unique targets to JWST (e.g., super-Eddington SMBHs). #GO cycle-2 due mid 2022
- ✦ We want to explore high-z low-luminosity quasars before Rubin, Euclid, and Roman are in operation.
- ✦ Ancillary science cases (next slide)

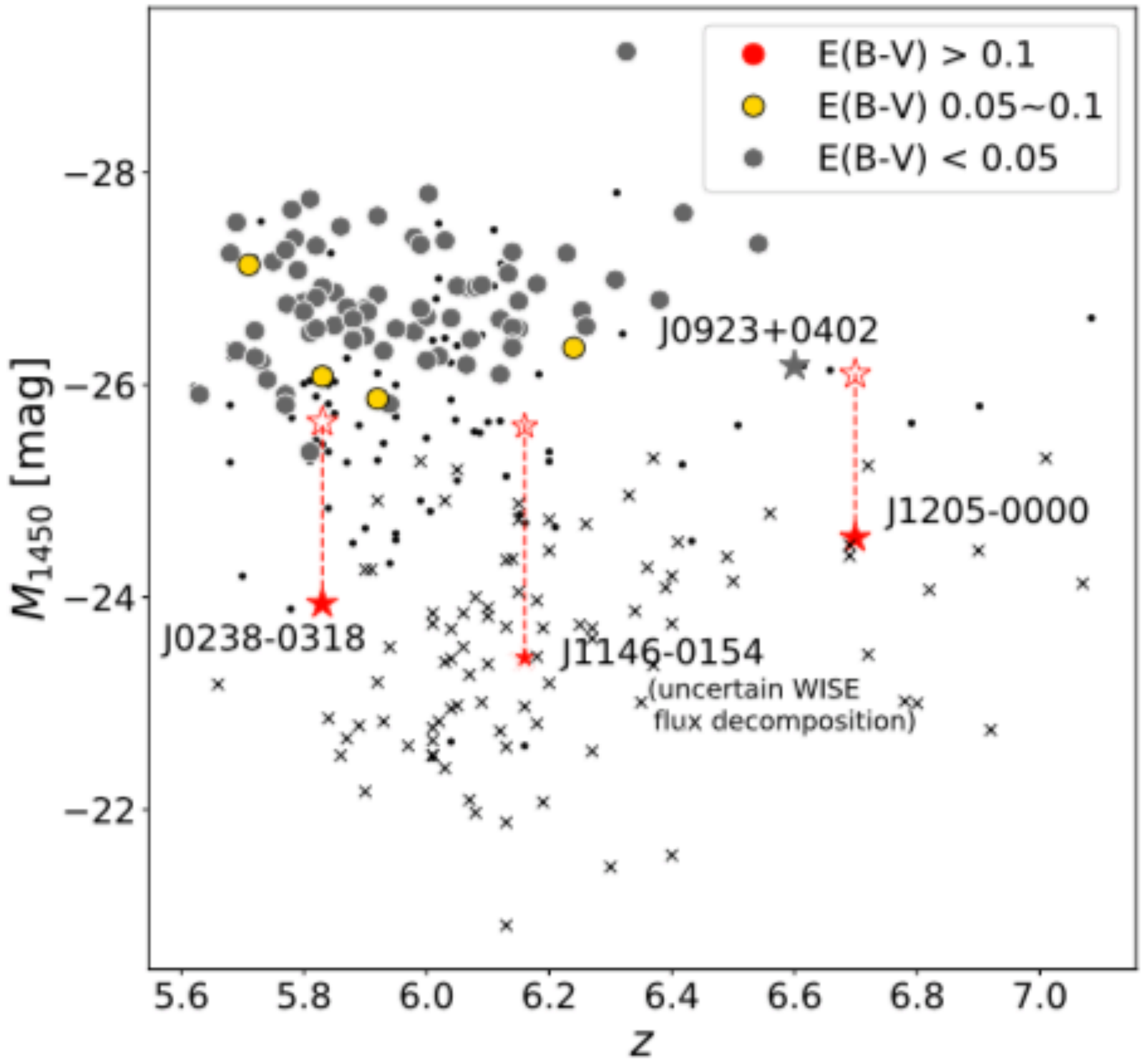


Faintest HSC quasars will be observed with JWST

Ancillary Science Cases

- Dust-reddened quasar (bright in NIR)



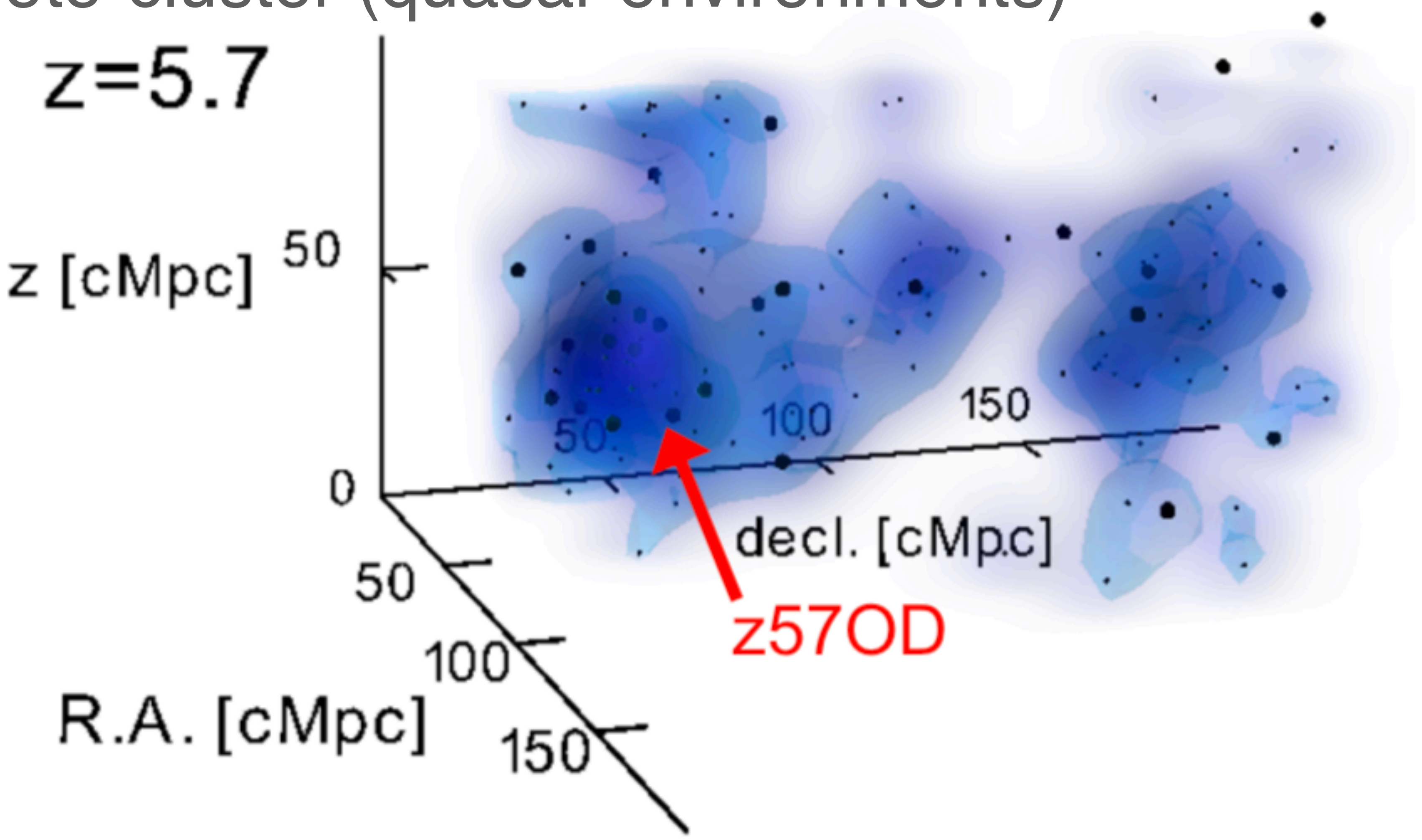


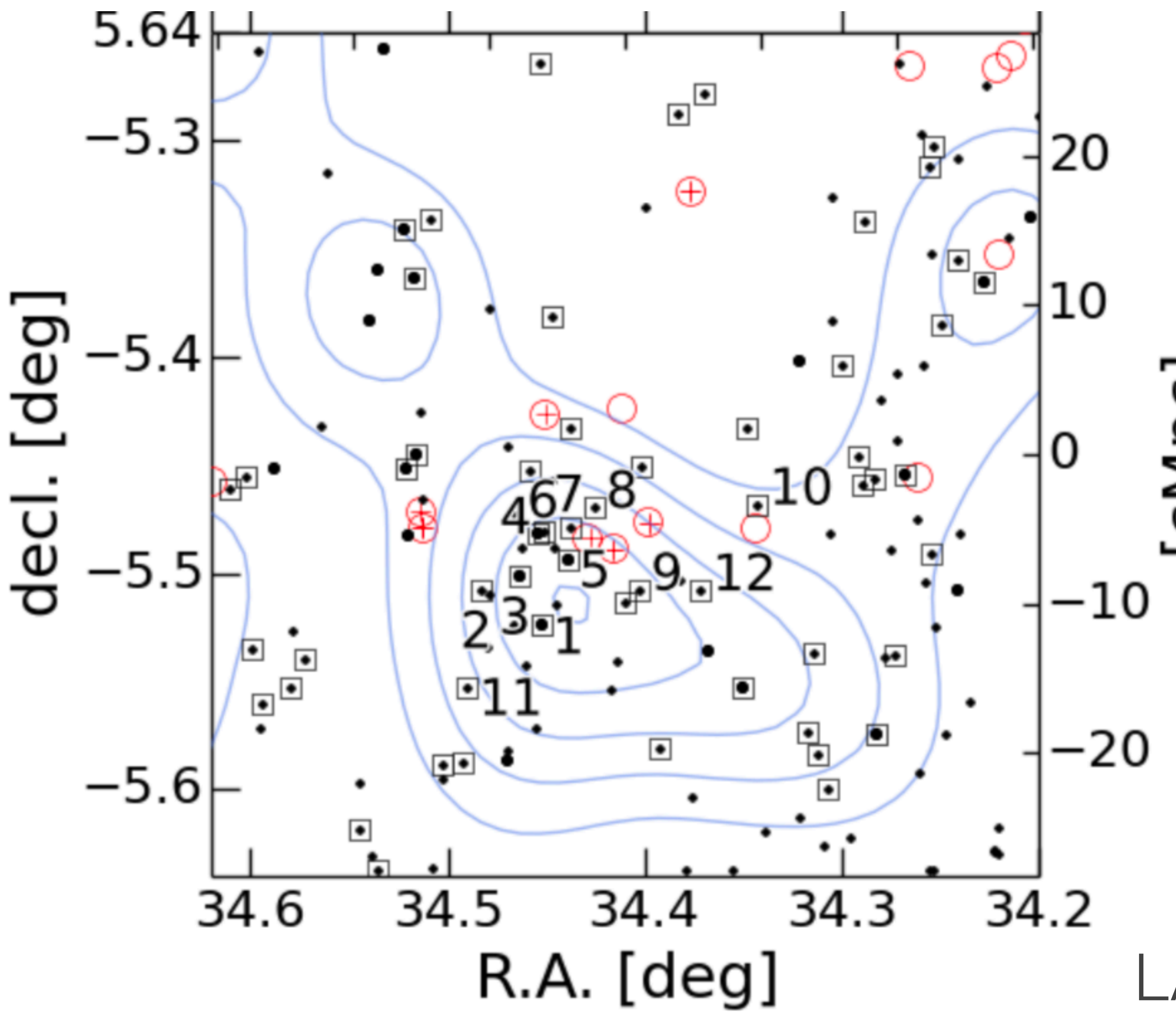
Red quasars are obscured counterparts of the SDSS-class quasars in ``blowout” phase

We will have more red quasars from Gemini & GTC NIR imaging follow-up observations

Kato+20

- Proto-cluster (quasar environments)





Surrounding LBGs are good use of the MOS capability of SWIMS (not possible with XShooter and GNIRS)

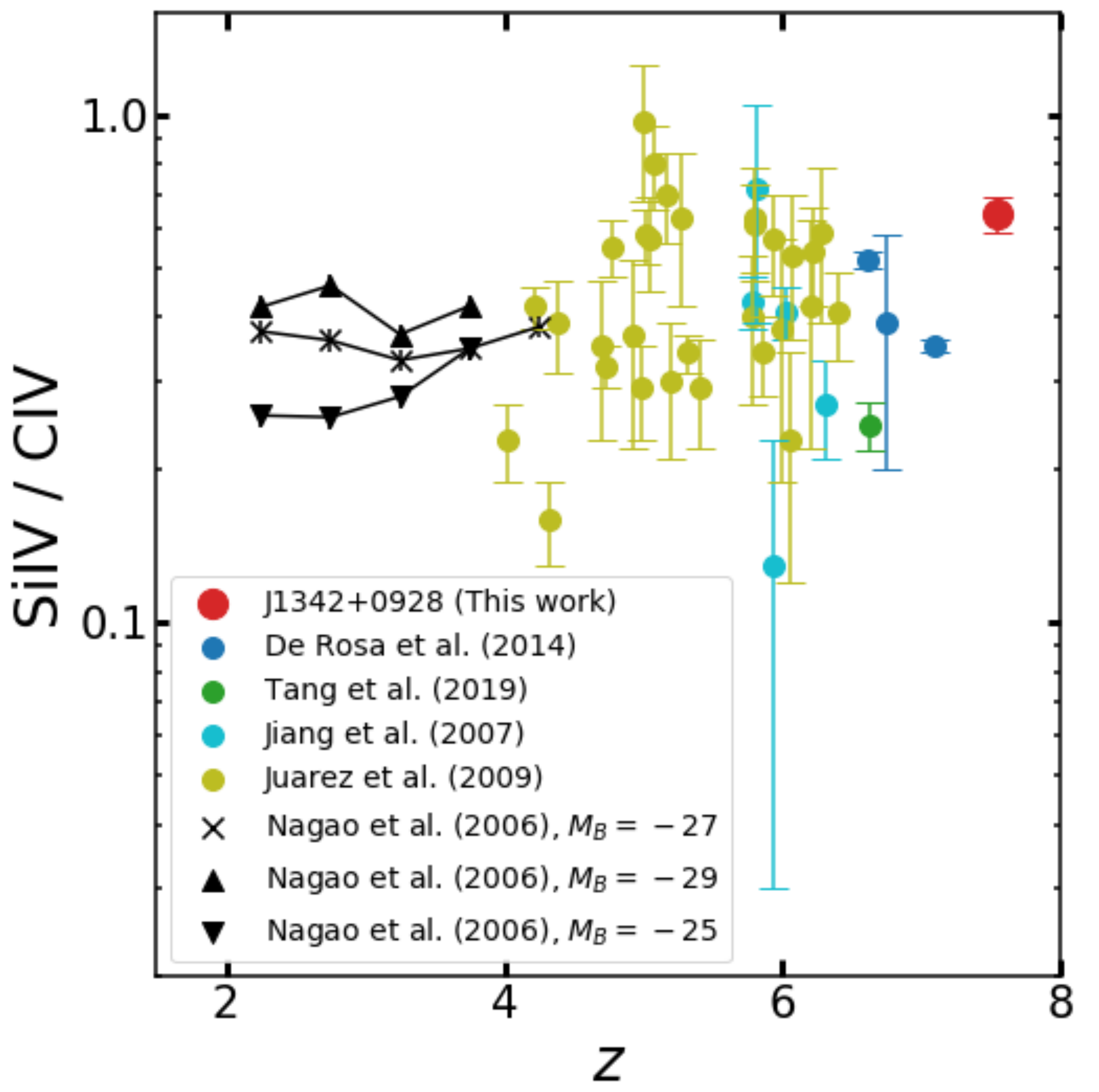
LAE overdensity from Harikane+19

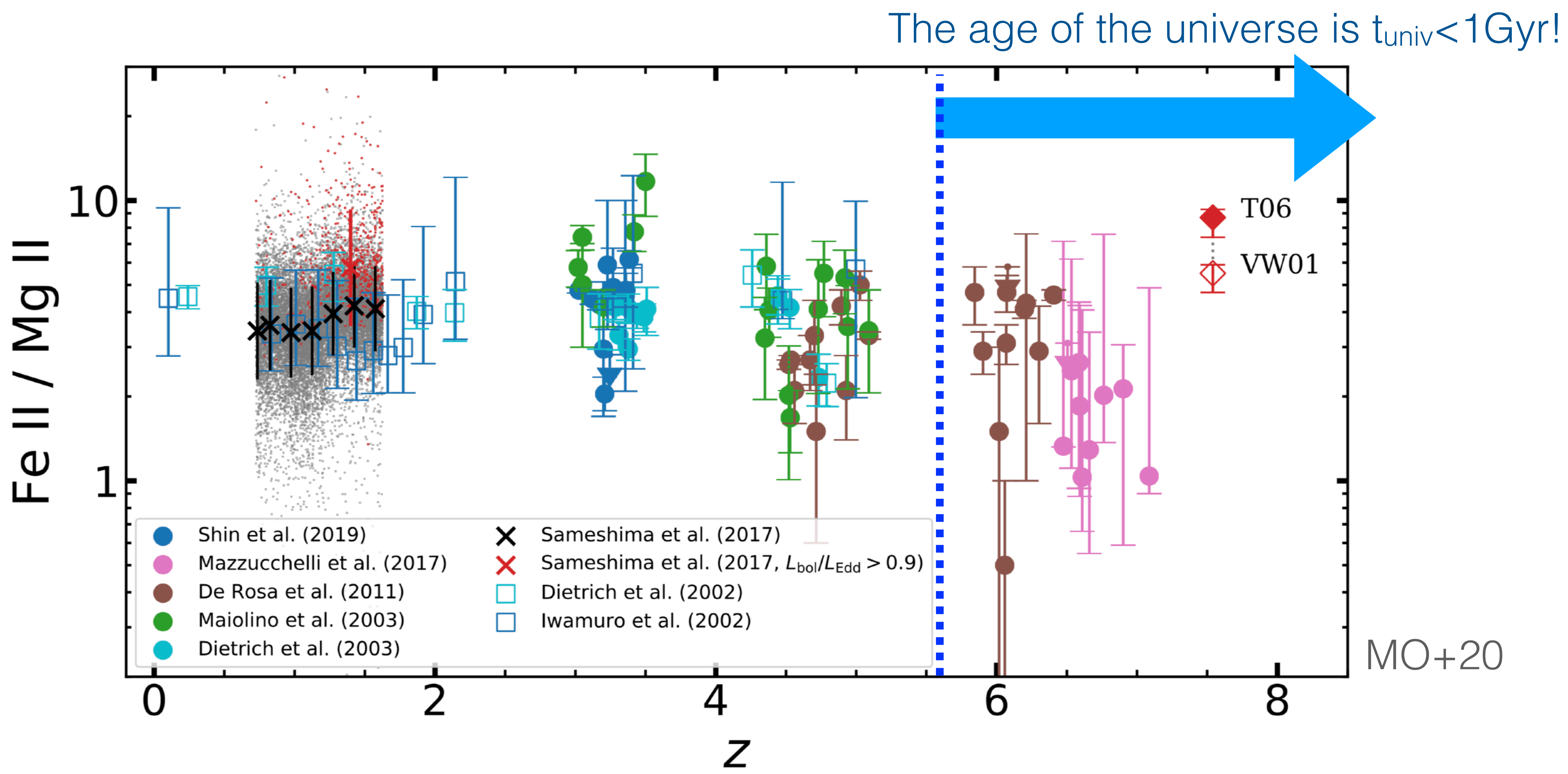
Summary

- **Mode:** Subaru/SWIMS spectroscopy (0.9-1.4 & 1.4-2.5um, MOS?)
- **Targets:** z=6-7 low-luminosity quasars (y_{AB}=21-23) from HSC-SSP
- **# of targets:** ~20, ~10 nights
- **Key science cases:**
  - MgII / CIV-based MBH measurements -> MBH distribution, super-Edd SMBHs
  - Galaxy-SMBH co-evolution (ALMA large in prep.)
  - Quasar BLR metallicity and outflow: SiIV, CIV, CIII], MgII
  - Characteristic quasars (e.g., dust-reddened quasars)
  - Quasar environments

Backup slides

Rapid Chemical Enrichment in BLR





- ✦ **BLR metallicity indicators: NV, SiIV, CIV, HeII** (e.g., Maiolino & Mannucci 2019)
- ✦ **FeII/MgII:** “cosmic clock” (cf. Sameshima-san’s talk)
  no FeII/MgII break up to t_{univ}=0.7Gyr —> prompt iron production by SNe Ia or PISNe?

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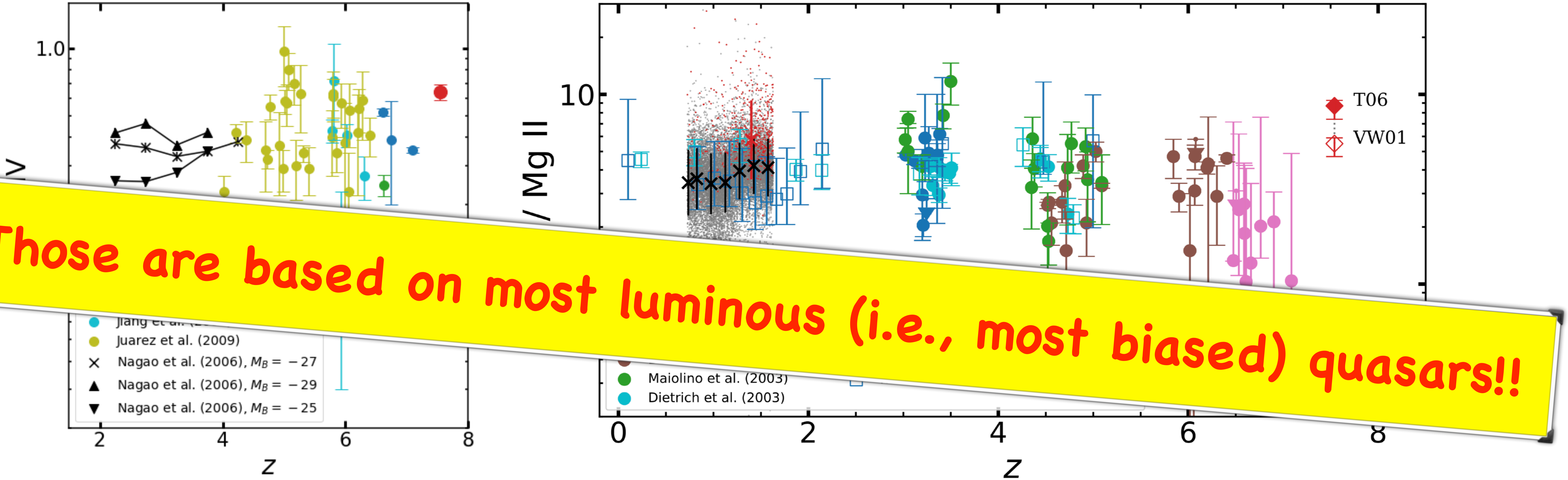

Those are based on most luminous (i.e., most biased) quasars!!

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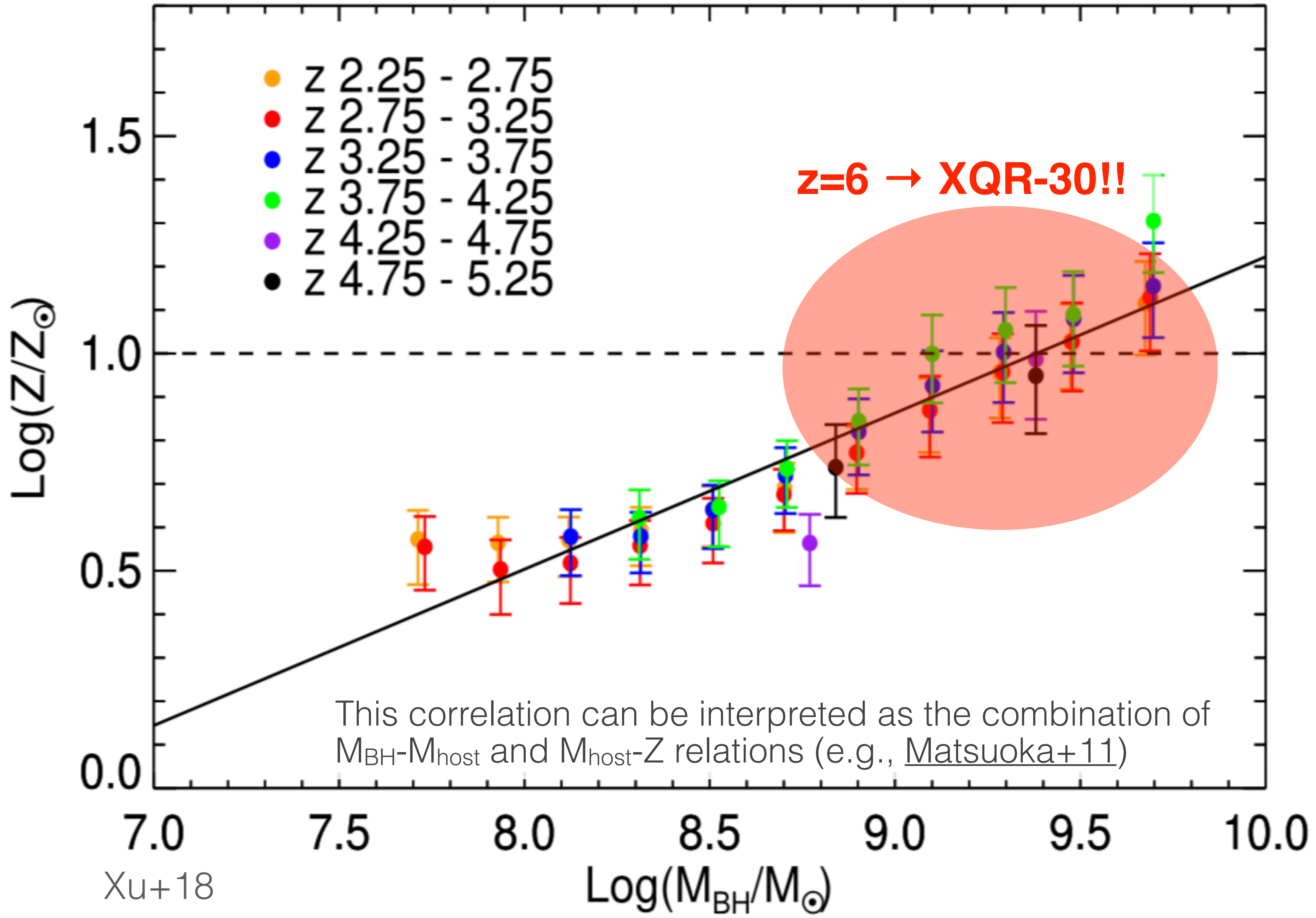
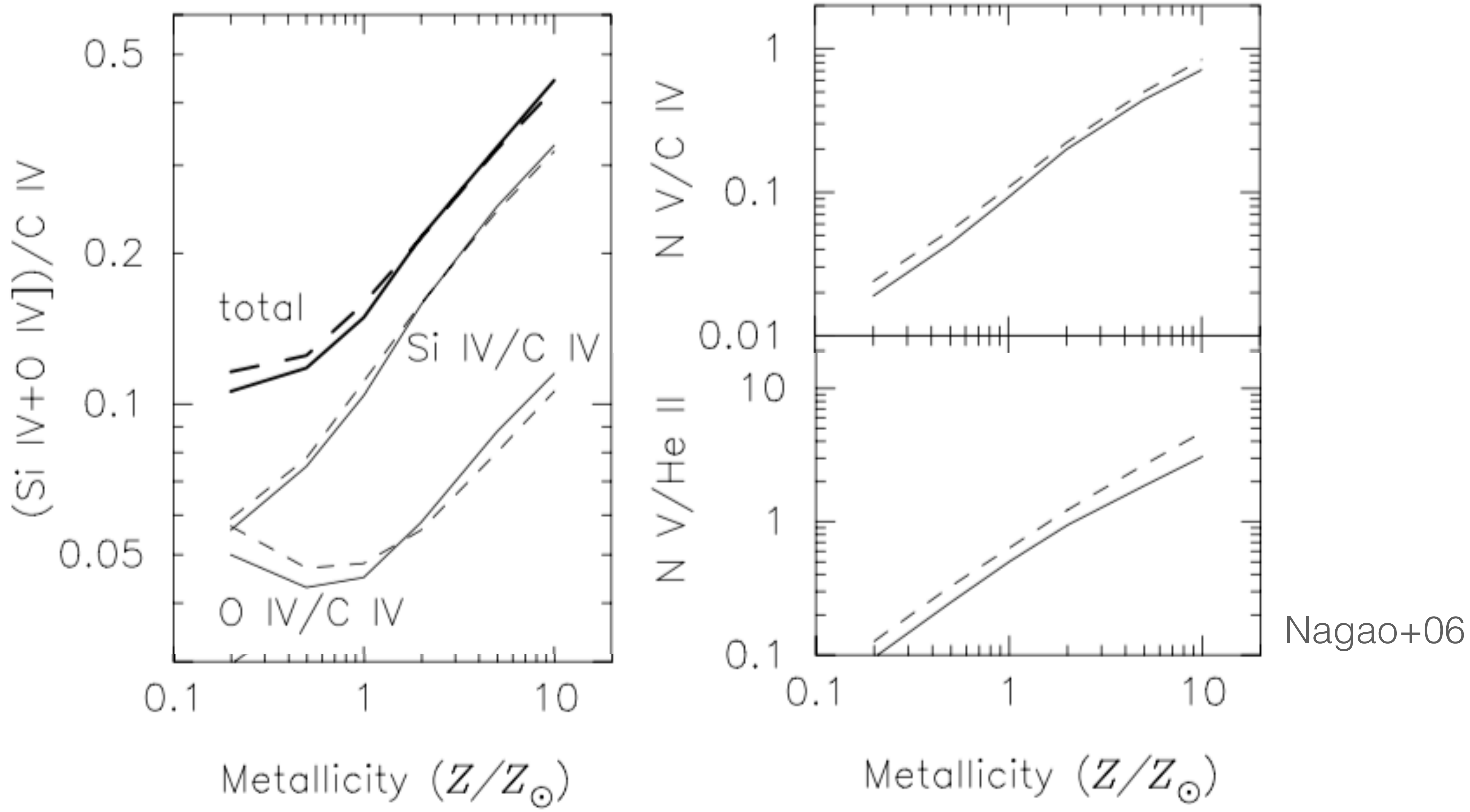
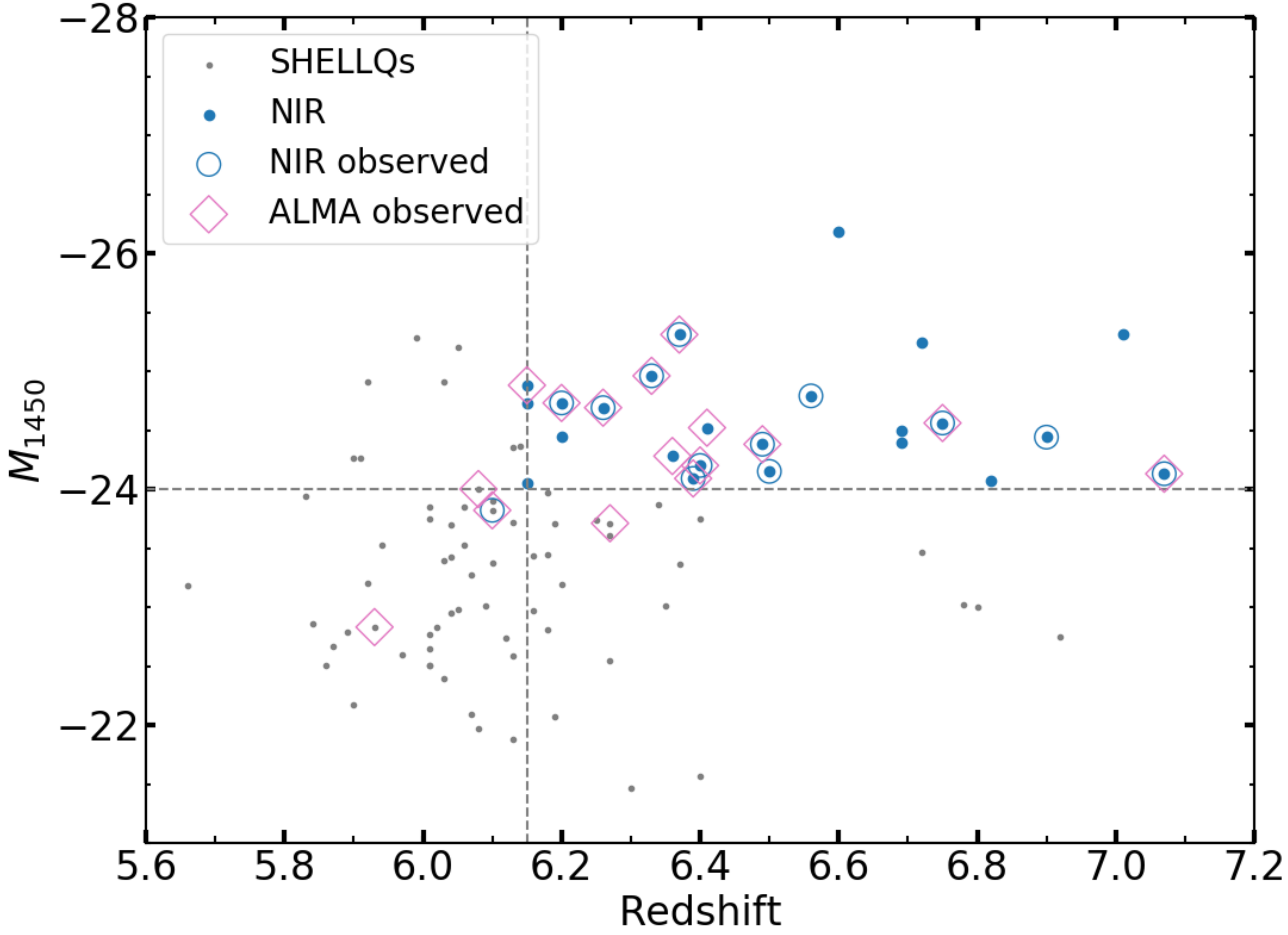
Why is the XQR-30 useful for BLR studies?





- ✦ **The XQR-30 sample gives an important benchmark of the mean z=6 BLR metallicity** (plus FeII/MgII, blueshifts, etc.)
  - Large sample size, high data quality (weak BLR lines can be identified such as NV1240 and HeII1640)
- ✦ **Rich data sources are/will be available** (ALMA: host ISM, MUSE: CGM)


SHELLQs
NIR
NIR observed
ALMA observed
−28
−26
−24
−22
M_{1450}
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
Redshift