44th-COSPER-2022

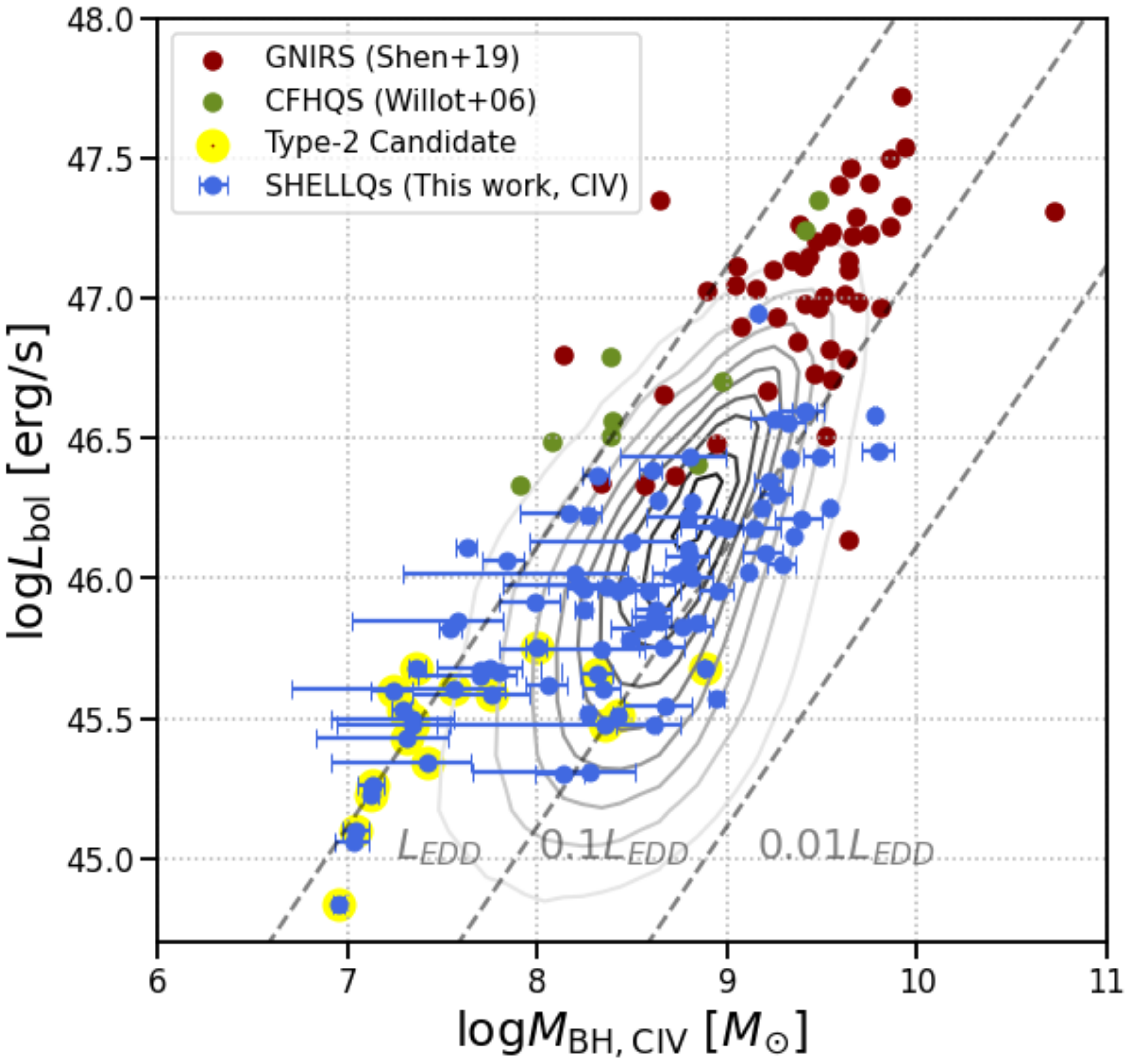
E1.11 # 03-22

BLACK-HOLE MASS DISTRIBUTION OF HIGH-Z LOW-LUMINOSITY QUASARS ESTIMATED VIA SPECTRAL COMPARISON WITH LOW-Z QUASARS

Ayumi Takahashi, Yoshiki Matsuoka (Ehime Univ.),

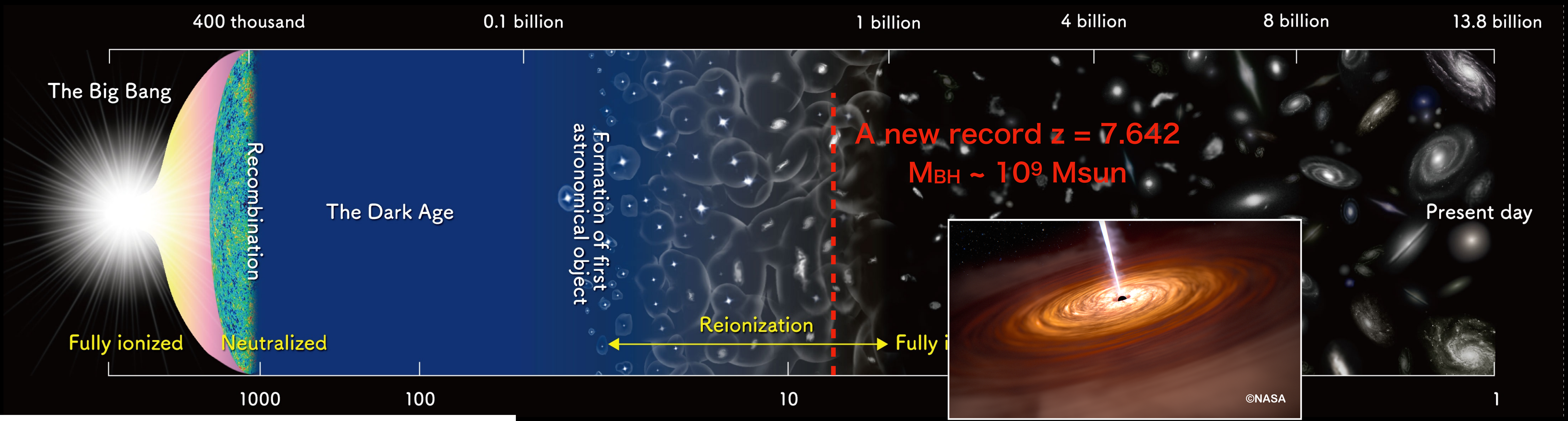
and the SHELLQs collaboration

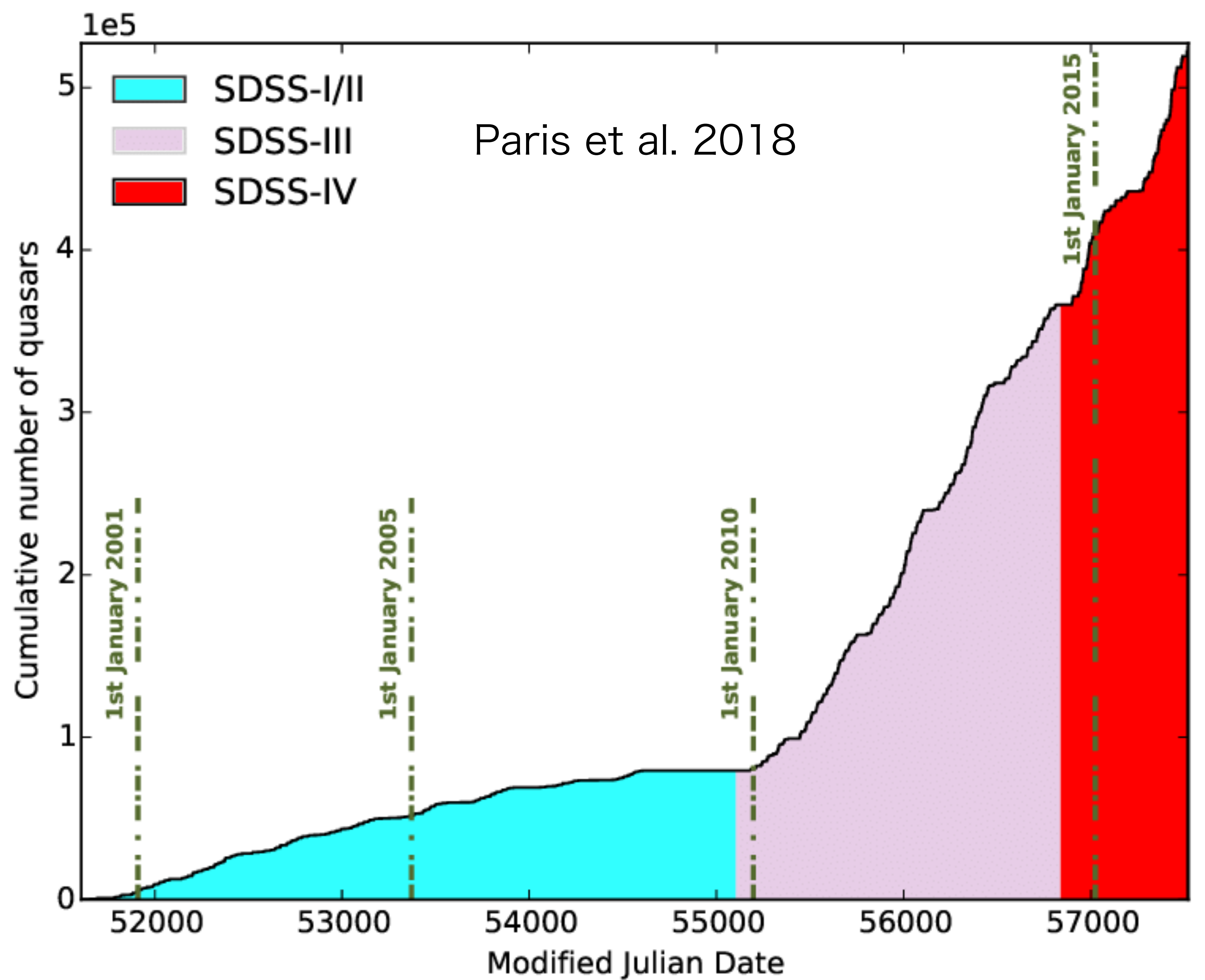
The distribution of BH masses of typical quasars at high-z



We revealed the low-mass end of the M_{BH} distribution at high redshift!

Super Massive Black Holes (SMBHs) in the early universe





SOME SERIOUS QUESTIONS about SMBH

✦When and how their seed populations are born?

✦What is the typical mass of the seed?

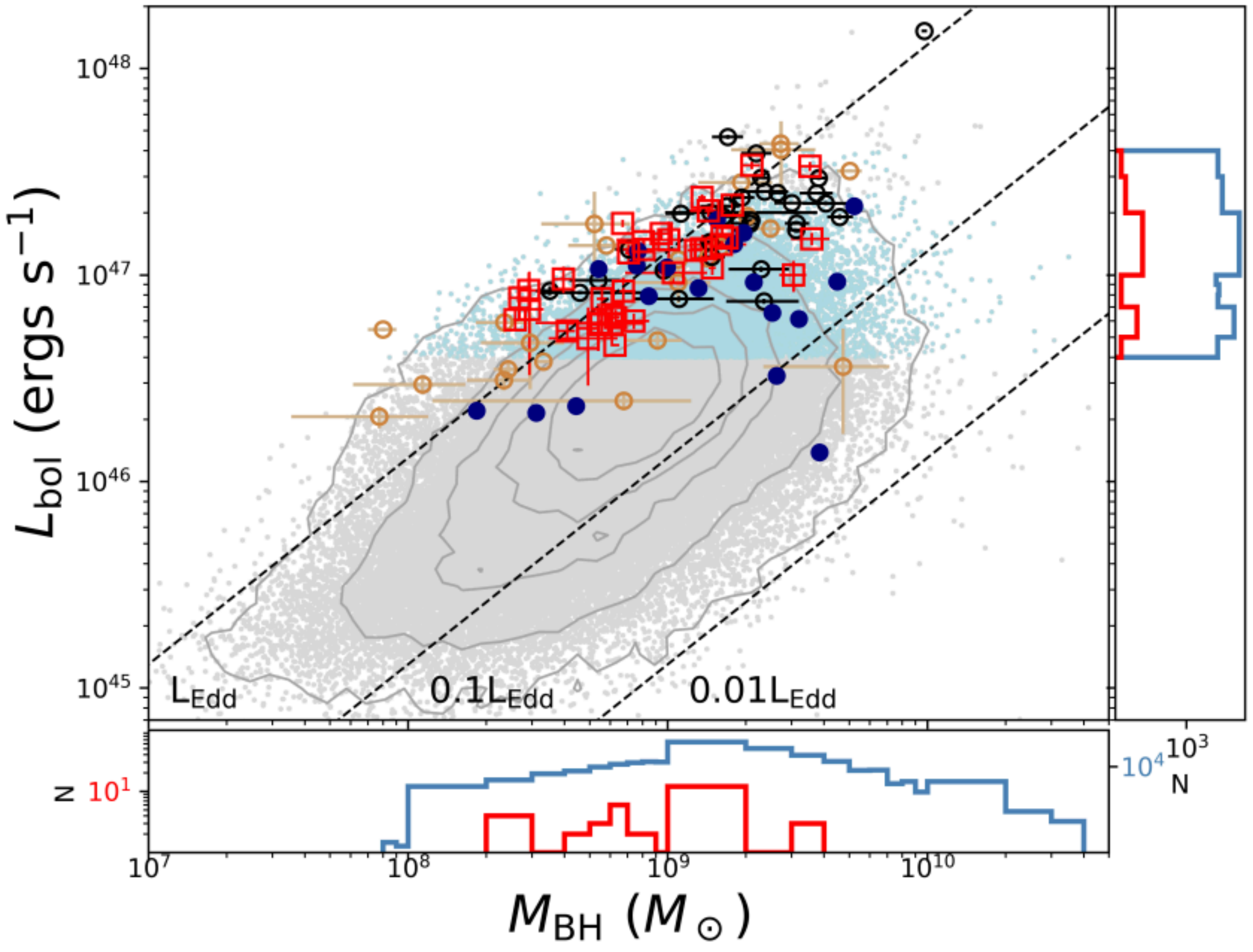
Important parameters to solve these questions are **BH masses** of high-z quasars and **Eddington ratios** which are related to

1. **The time when BH began to grow**
2. **Radiation efficiency**

Super Massive Black Holes (SMBHs) in the early universe

- Distribution of M_{BH} of $z \sim 6 - 7.6$ quasars

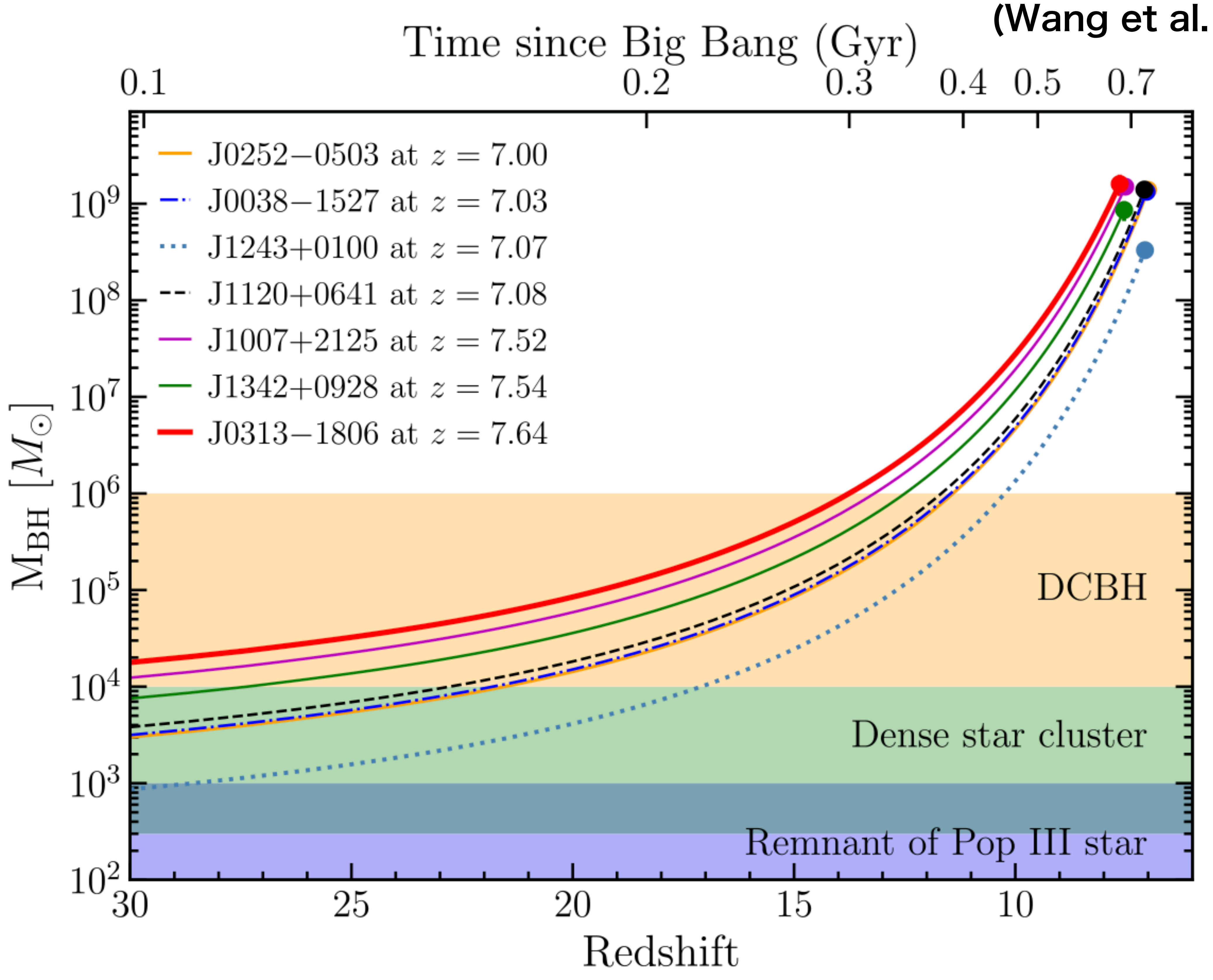
(Yang et al. 2021)



$M_{BH} \sim 10^8$ to 10^{10} [$M_\odot$]

-Black hole grow track of z ≥ 7 quasars with $\lambda_{Edd} = 1$, $\eta = 0.1$

(Wang et al. 2021)

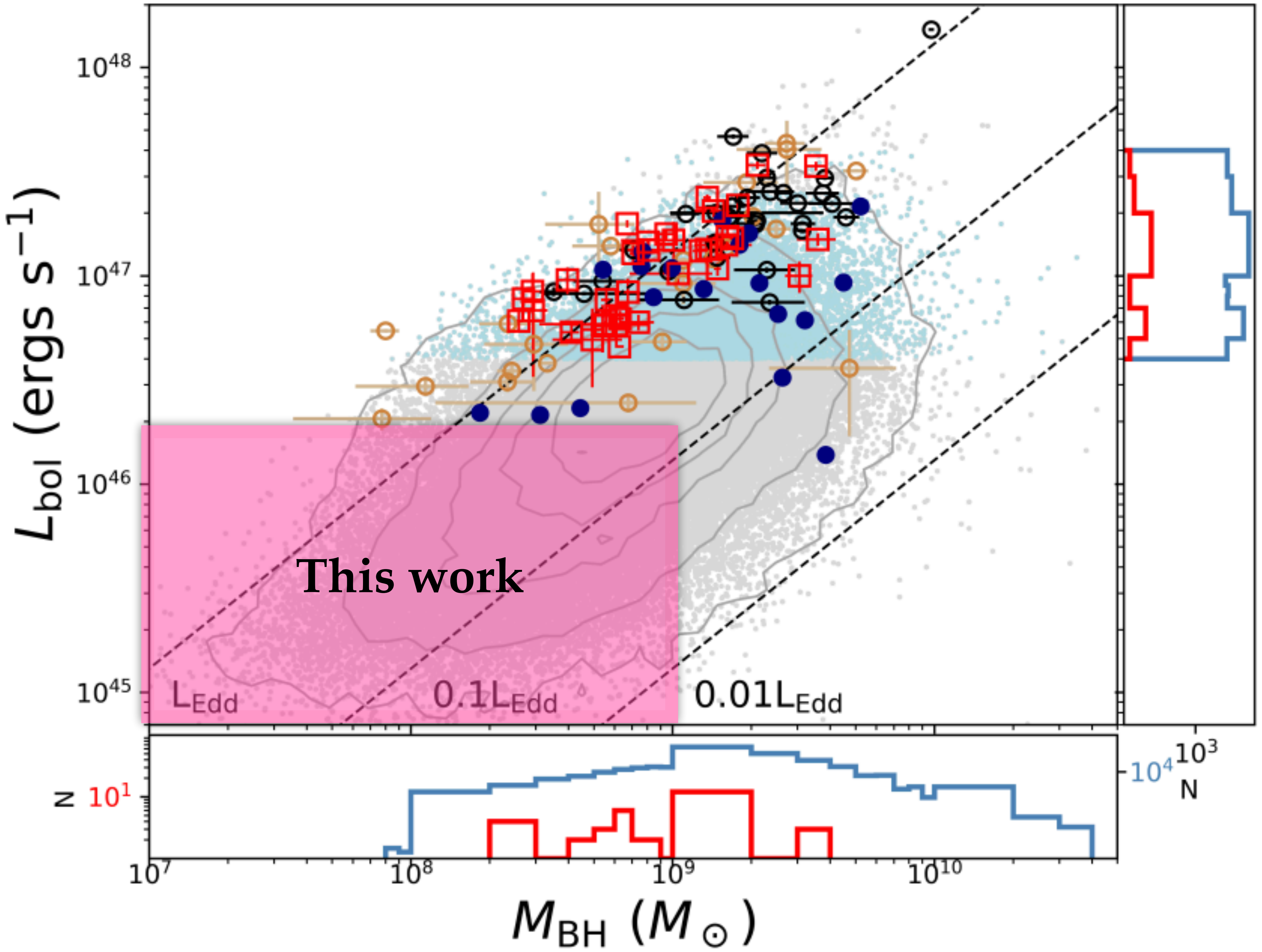


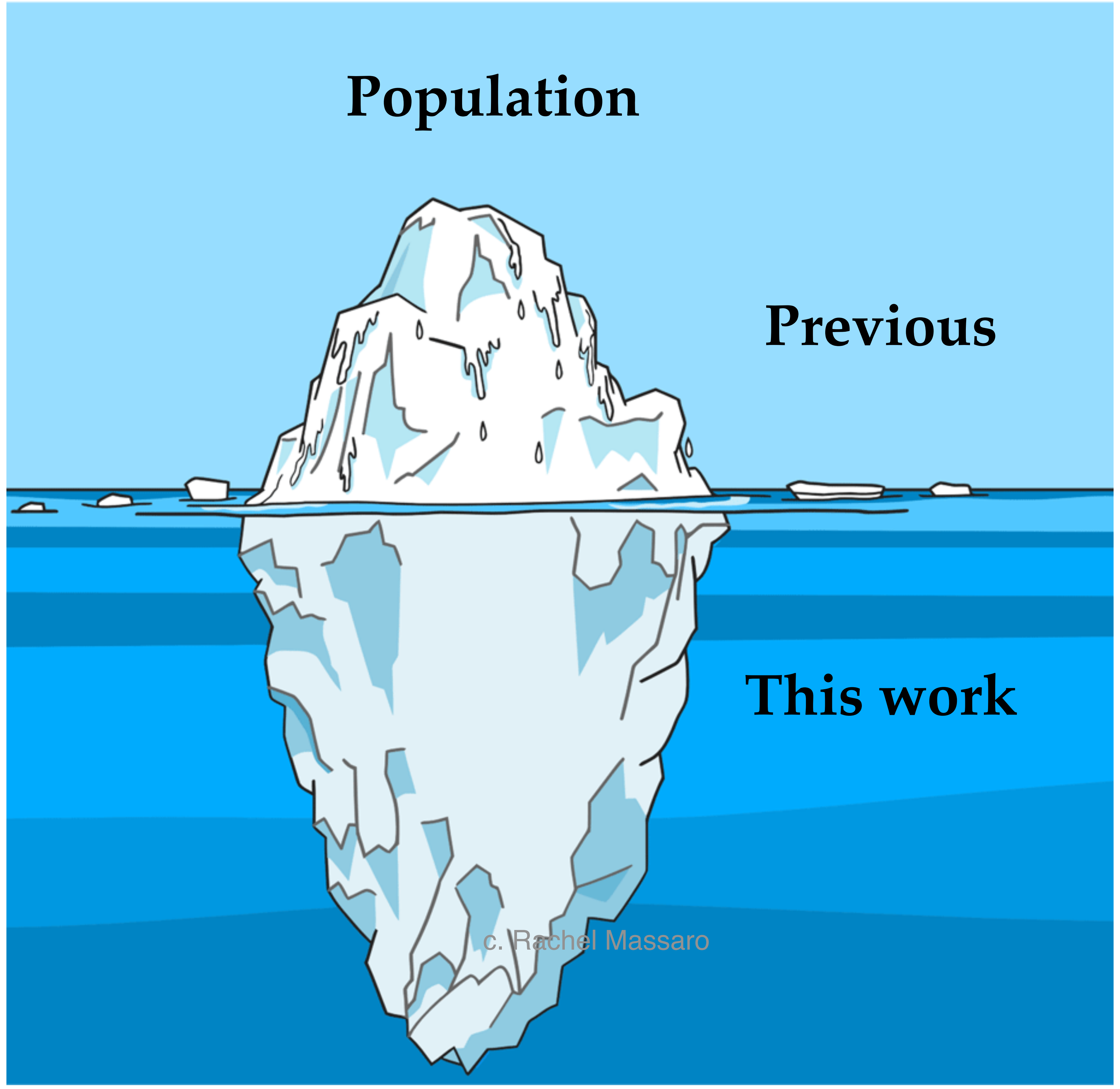
$M_{seed} \sim 10^3$ to 10^4 [$M_\odot$]

- Previous results support the rapid growth of Black Hole

Super Massive Black Holes (SMBHs) in the early universe

The number of quasars $M_{BH} < 10^8$ $[M_\odot]$ was very limited!



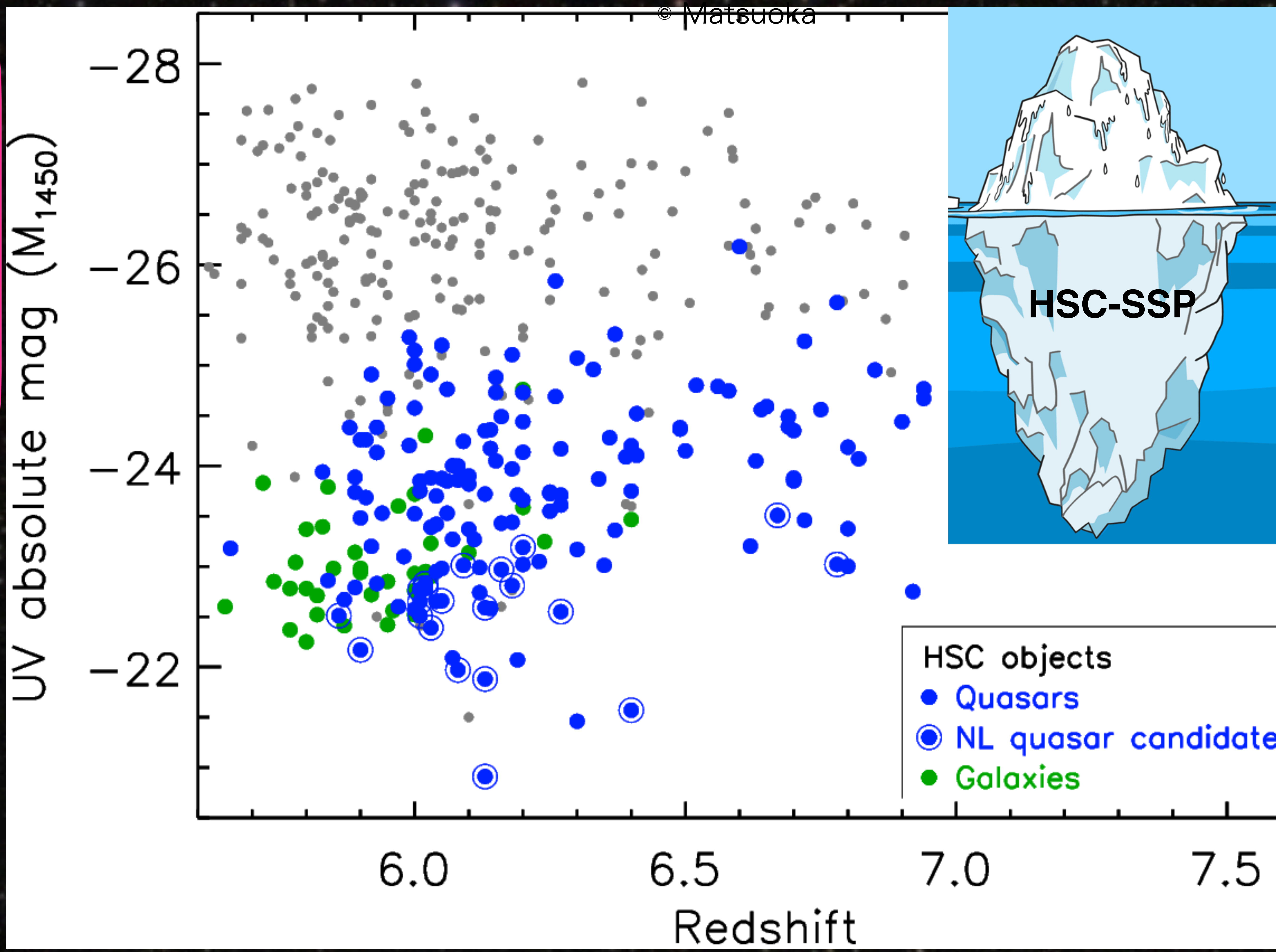


Focus on a deeper sample that is a "typical" species in the quasar population.

SHELLQs project (PI: Y.Matsuoka)

“Subaru High-z Exploration of Low-Luminosity Quasars ”

Spectroscope install on



SHELLQs sample is composed of 180 quasars

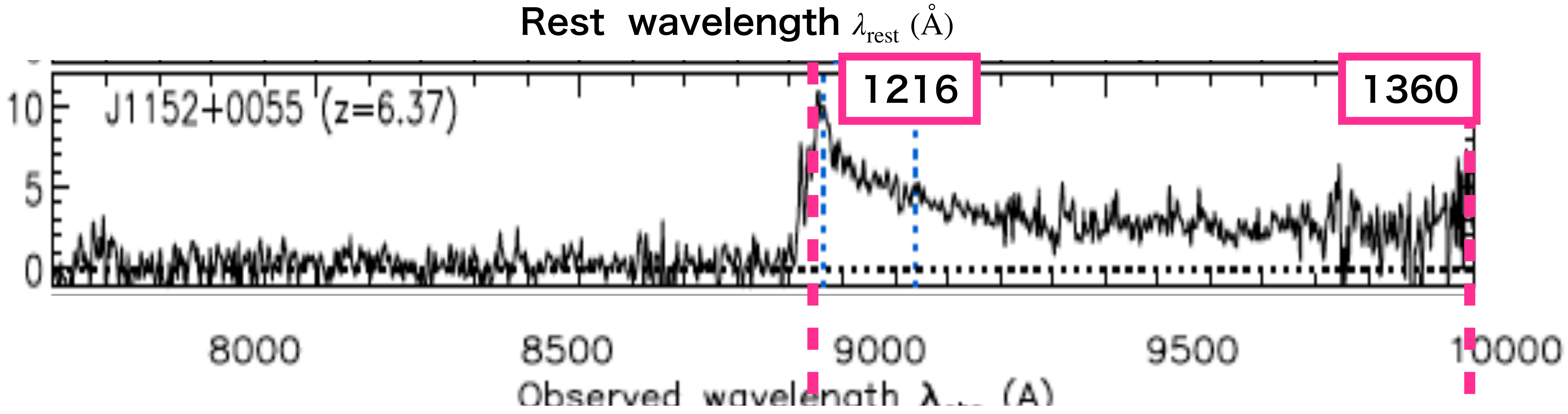
This low-luminosity sample may contain the low-mass quasars…

→ **Yoshiki Matsuoka’s talk!**

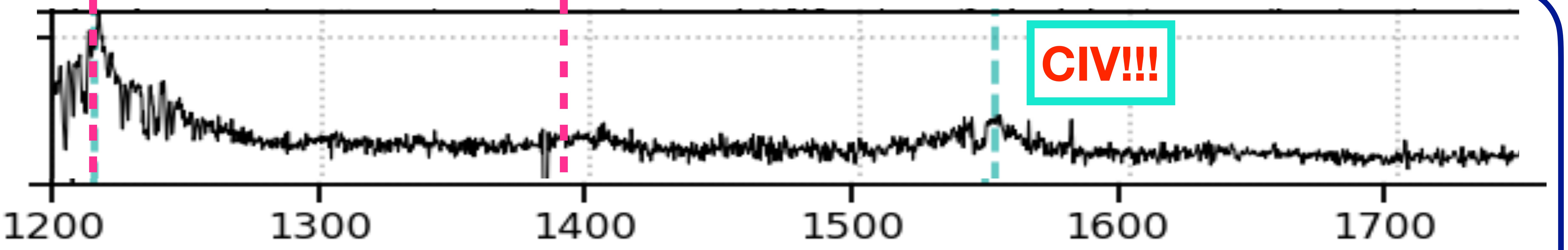
High-z quasars sample in this work:

- 75 type-1 objects (published in Matsuoka+16, 18ab, 19ab)

The problem of / solution to the mass measurements



(1) SHELLQs discovery spectra do not cover SMBH mass indicators (CIV 1549, Mg II 2800, and/or Hβ)



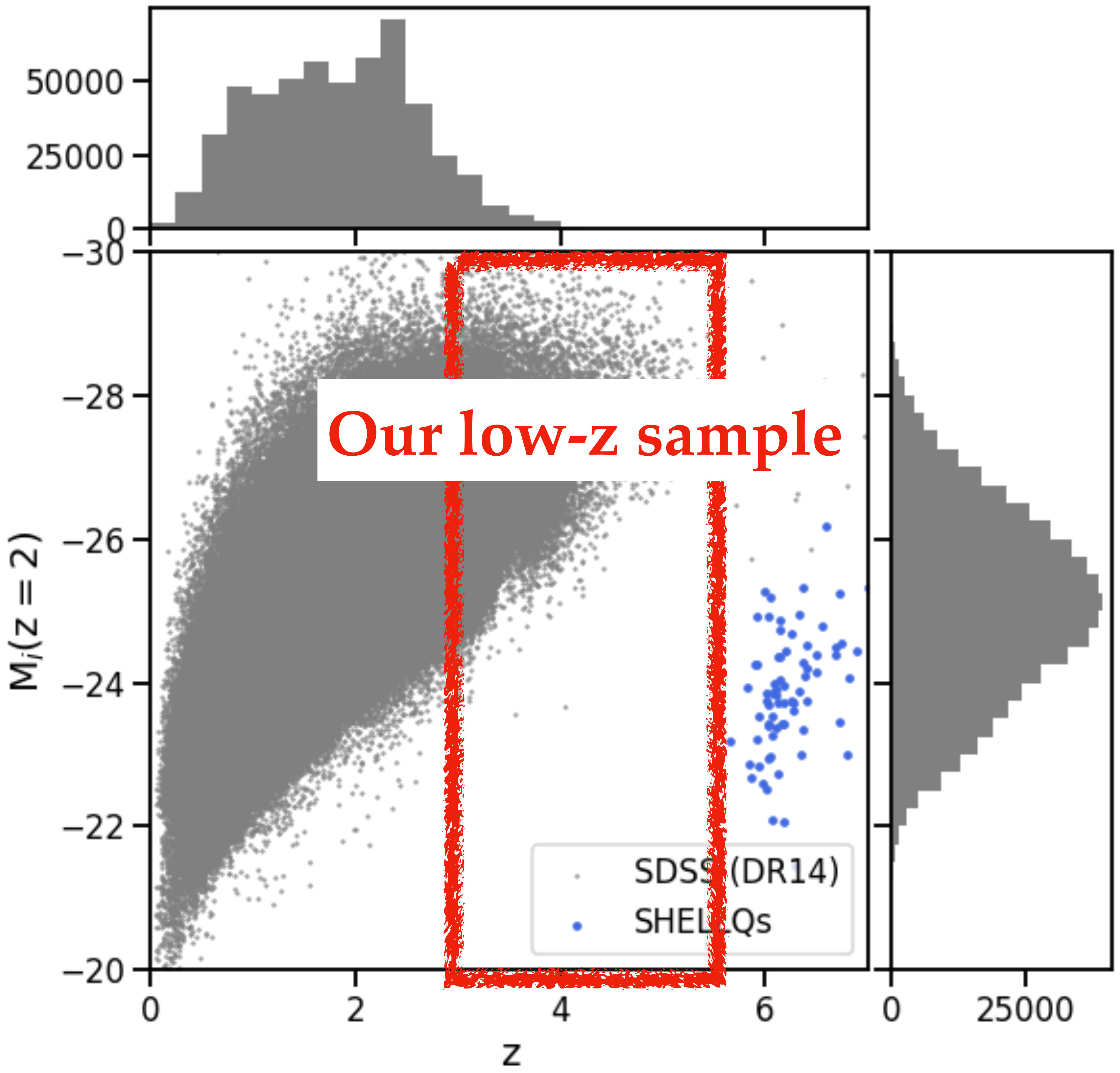
(2) We find a low-z quasar ("counterpart") that has the best-match spectrum to each SHELLQs quasar in the overlapping spectral coverage ($1216 < \lambda_{rest} < 1400$ A), through χ2 fitting.

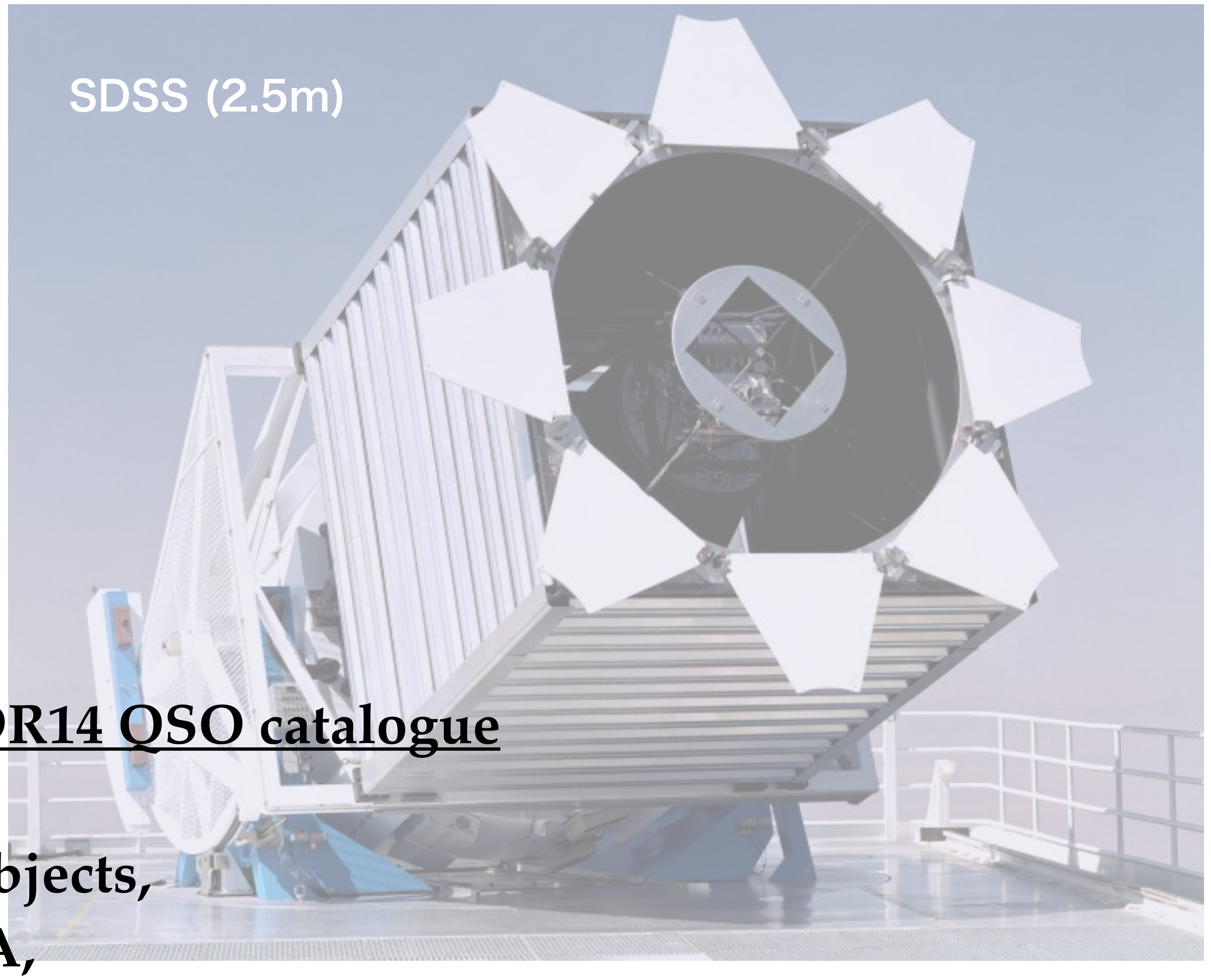
(3) Black hole mass is derived using the CIV profile of the counterpart spectrum.

SHELLQs: λL_λ; CP (SDSS): FWHM

$$\log\left(\frac{M_{BH}}{M_\odot}\right) = A + B\log\left(\frac{\lambda L_\lambda}{10^{44}\,\mathrm{ergs}^{-1}}\right) + 2\log\left(\frac{\mathrm{FWHM}}{\mathrm{kms}^{-1}}\right)$$

Sloan Digital Sky Survey Quasar Catalog (release14)





Basically information of DR14 QSO catalogue

- **Mi[z = 2] < -20.5**
- **Constructed by 526356 objects,**
- **coverage： 3610 - 10140 A,**
- **resolutions： 1300 < R < 2500**
- **Survey field : A quarter of the sky**

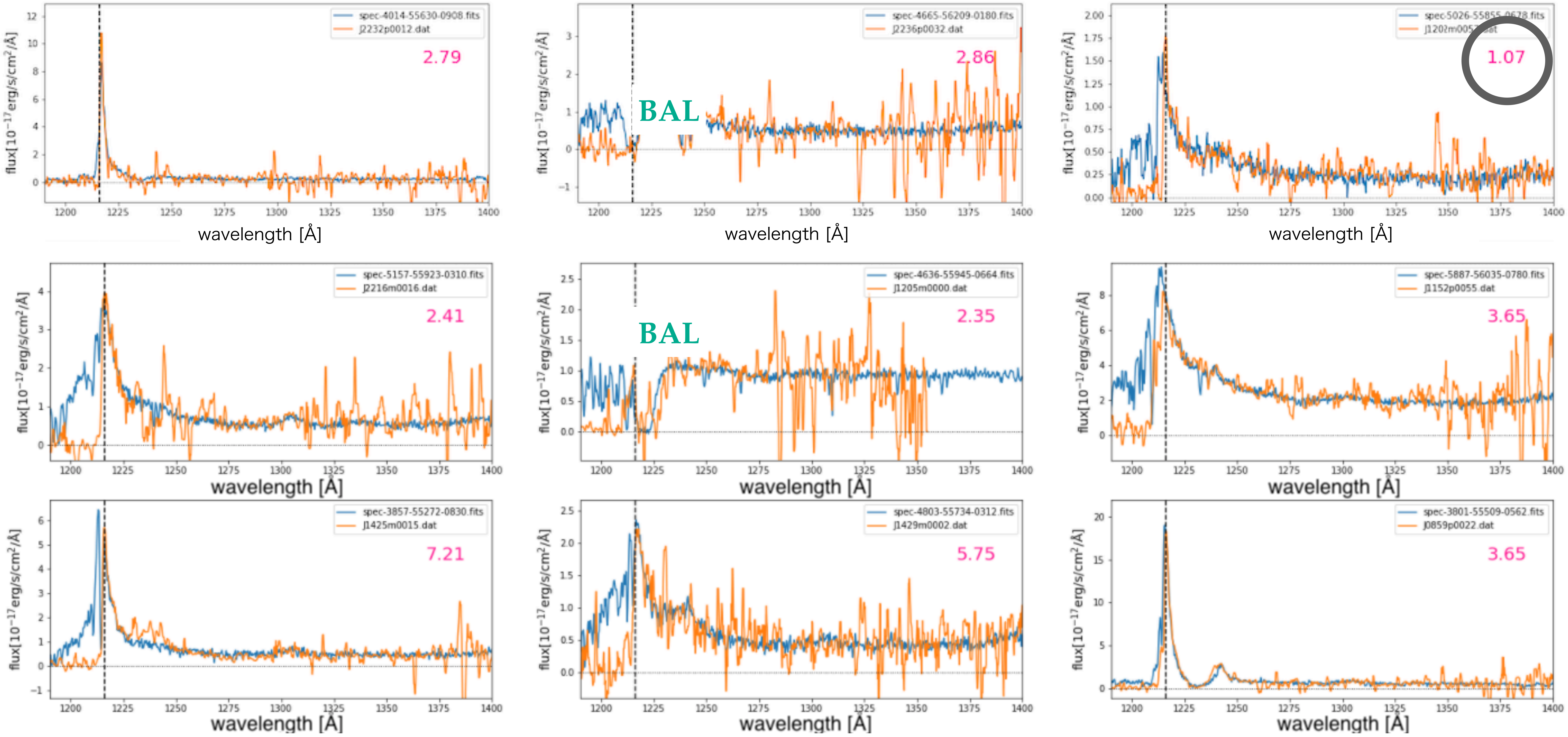
In this work, we selected SDSS quasars at 2.5 ≤ z ≤ 5.0; 101489 objects whose spectra cover the rest-UV portions around Lya emission lines.

A part of the counterpart's spectra (9/93)

SHELLQs counterparts

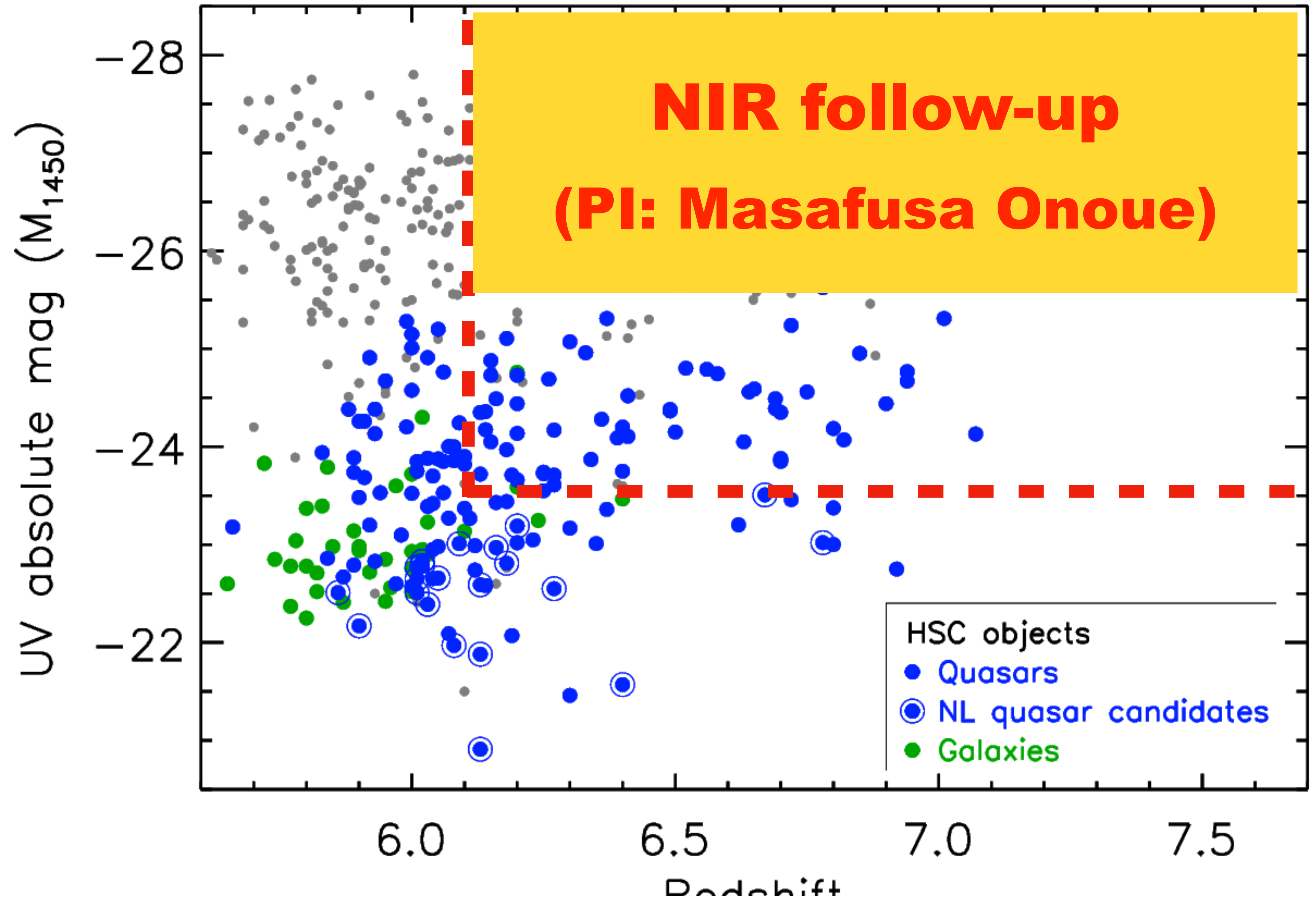
- Successfully got spectrally matched counterparts!
- Their spectral shapes much resembled each other, even in the absorbed cases.

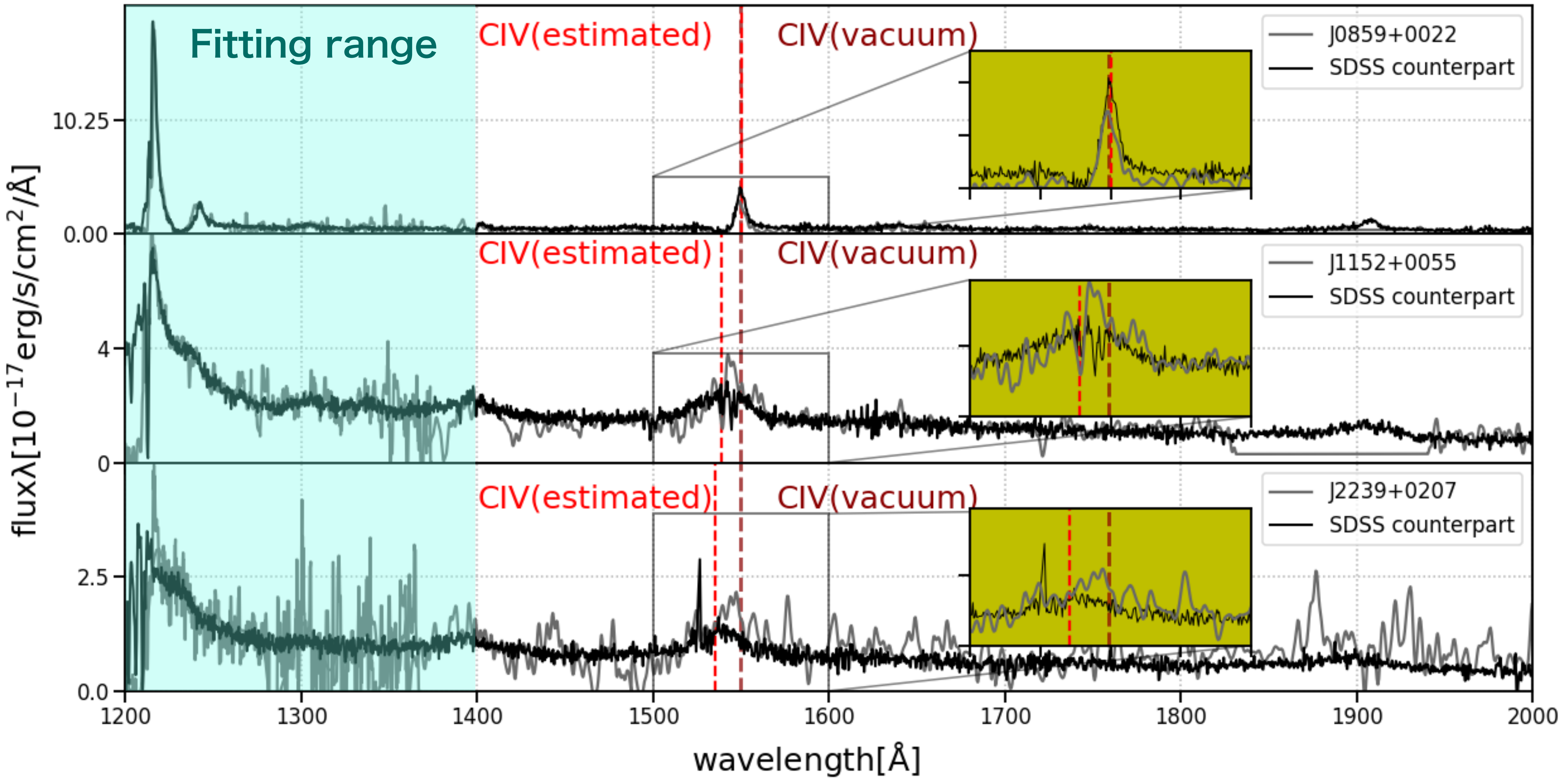
reduced - $\chi 2$



Random selected

Our measurements vs. Literatures

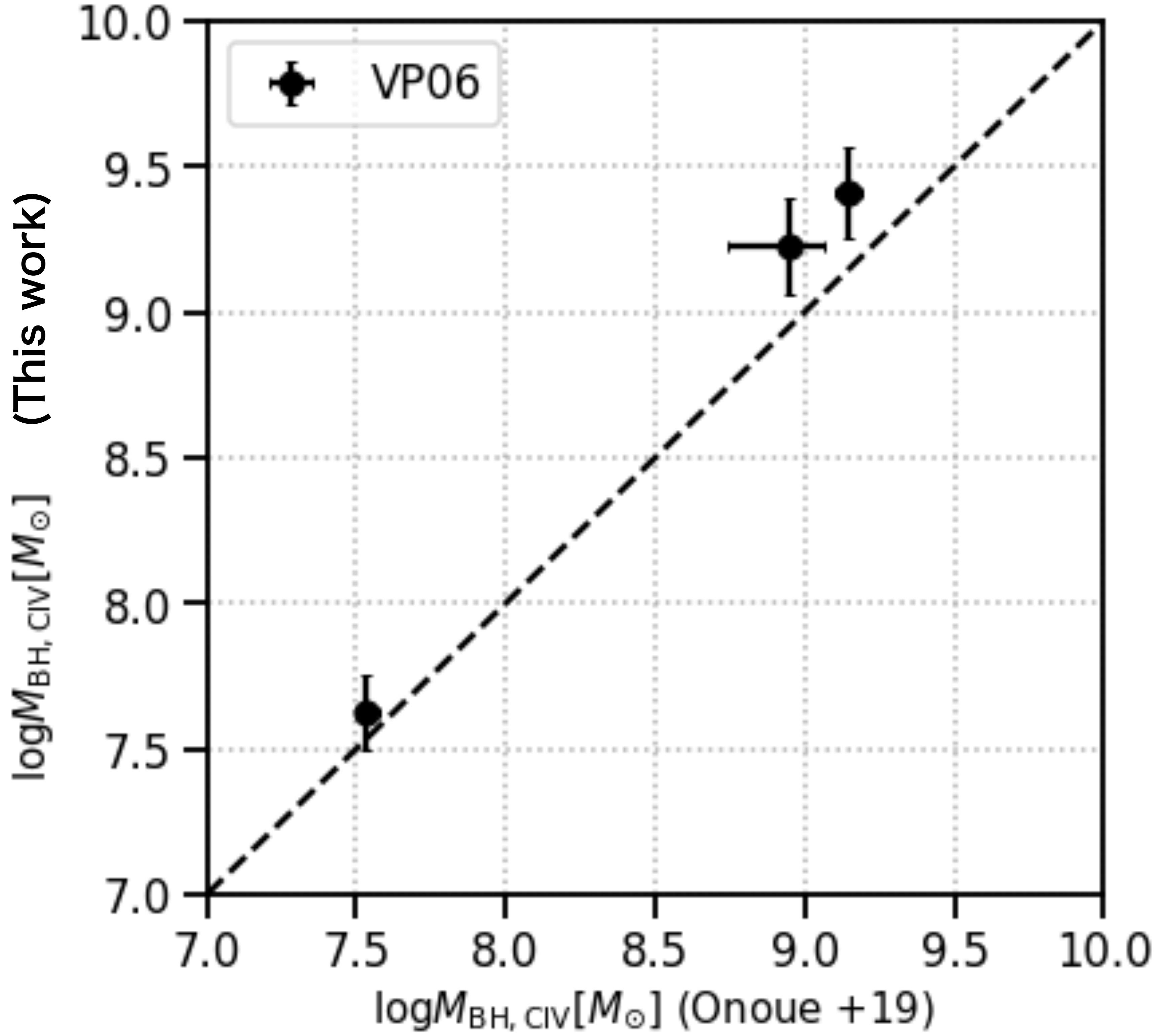




Our predicted BH masses :

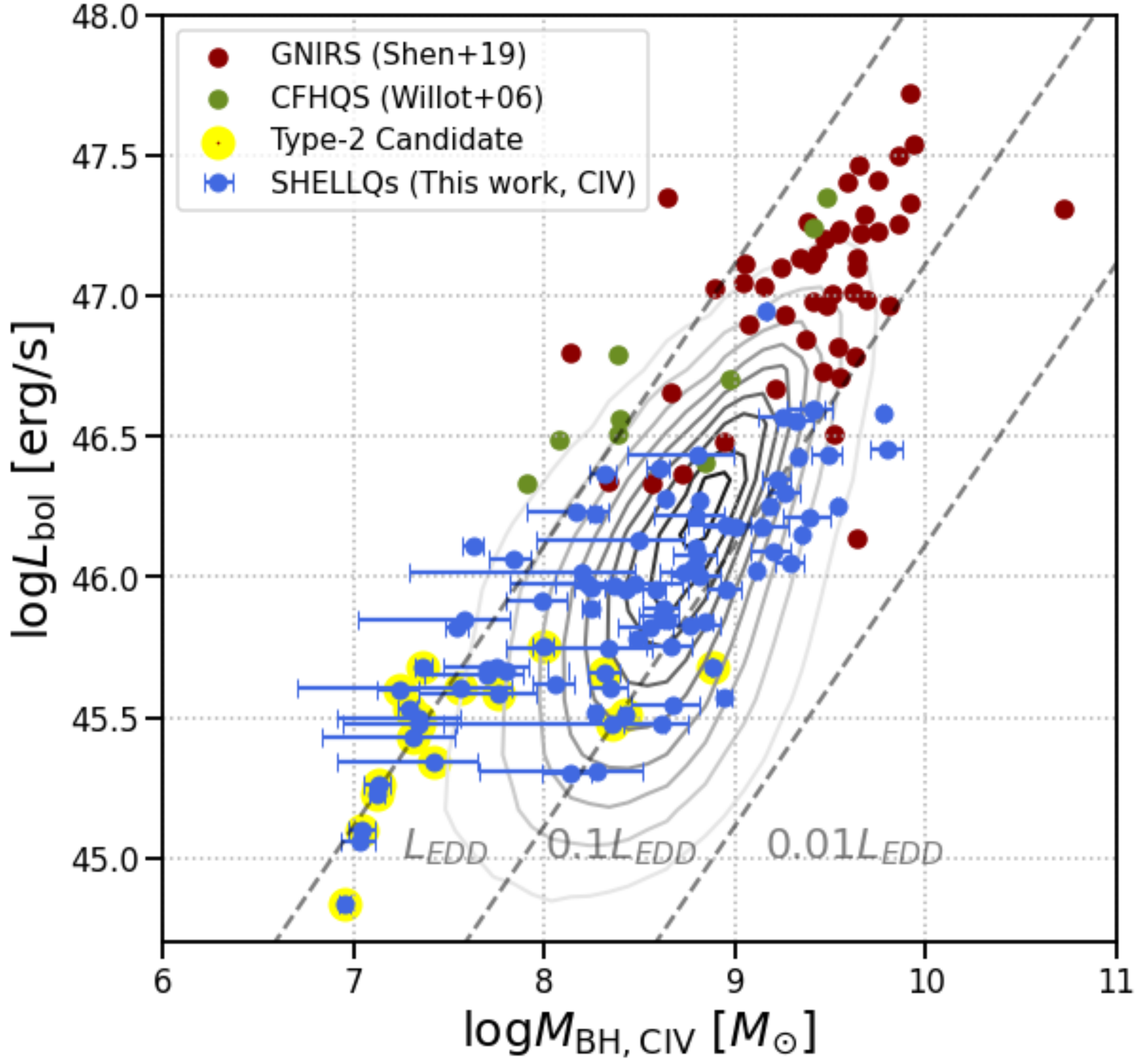
SHELLQs CP (SDSS)

$$\log\left(\frac{M_{BH}}{M_\odot}\right) = A + B\log\left(\frac{\lambda L_\lambda}{10^{44}\mathrm{ergs}^{-1}}\right) + 2\log\left(\frac{\mathrm{FWHM}}{\mathrm{kms}^{-1}}\right)$$



It is possible to predict BH masses of high-z quasars with high accuracy without their actual spectra by just doing spectral matching with low-z quasars.

The distribution of BH masses of typical quasars at high-z



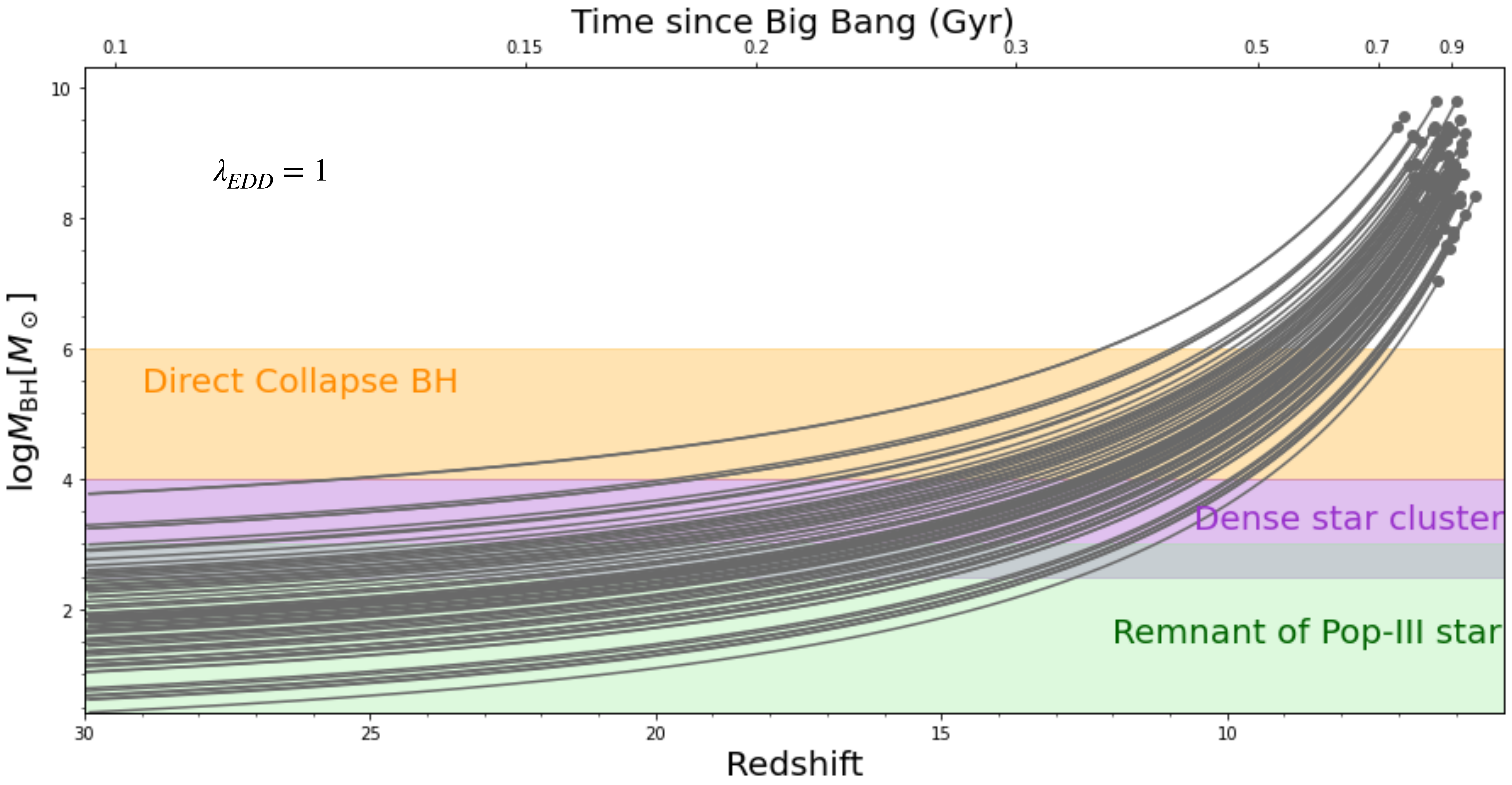
We revealed the low-mass end of the M_{BH} distribution at high redshift!

- ✦ M_{BH} range of our sample of M_{BH} ~ $10^{7.0} - 10^{9.8}$ [$M_\odot$] (without Type-2 candidates)
- ✦ The majority of our sample accrete at sub-Eddington rates
- ✦ Our BH masses are lower by 1-1.5 orders of magnitude than the previous sample.

Estimated growth history of SHELLQs quasars

$L_{EDD}/L_{BOL} = 1$

· $\eta = 0.1$ (i.e., Shakura & Sunyaev 1976)

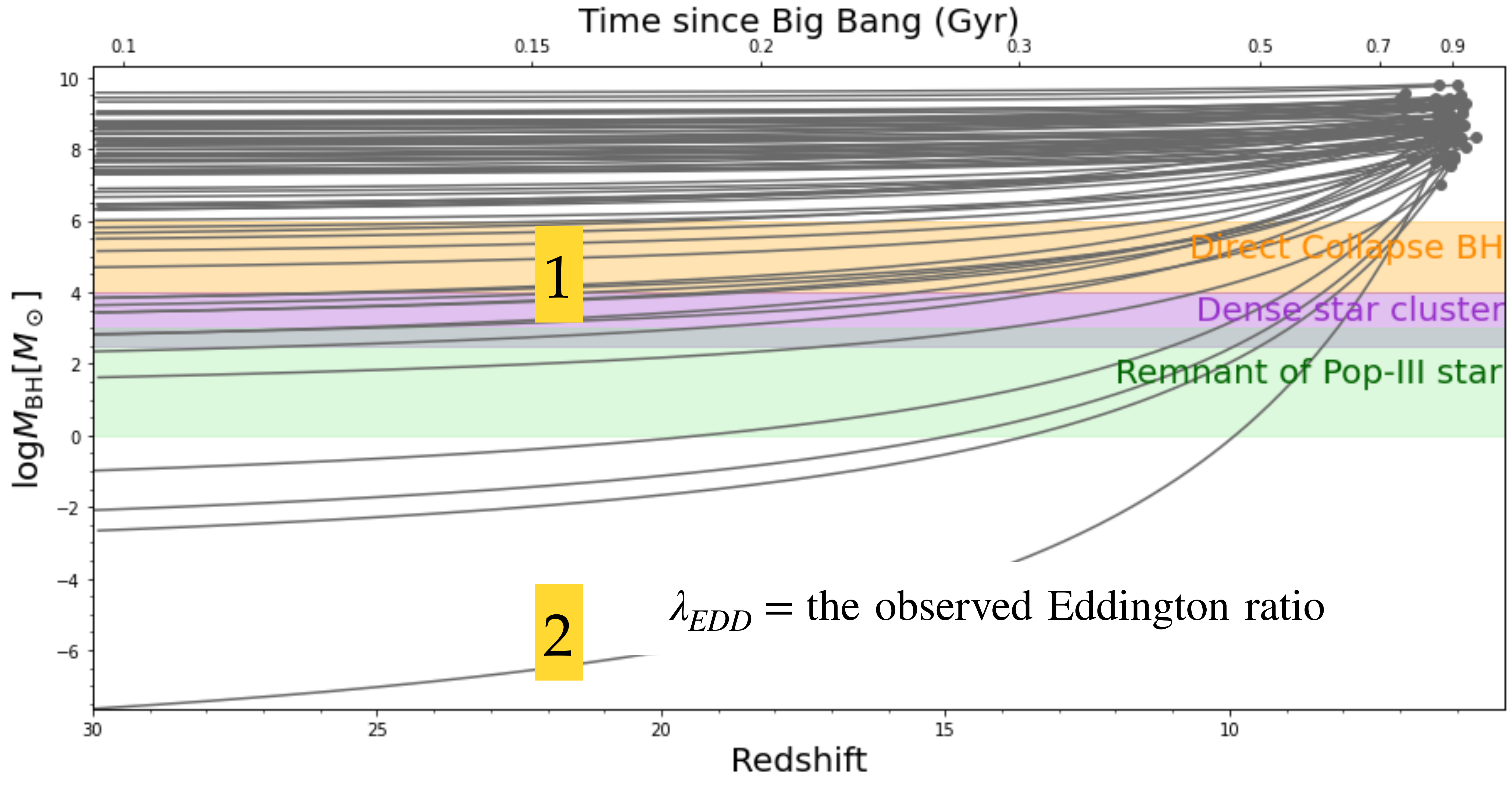


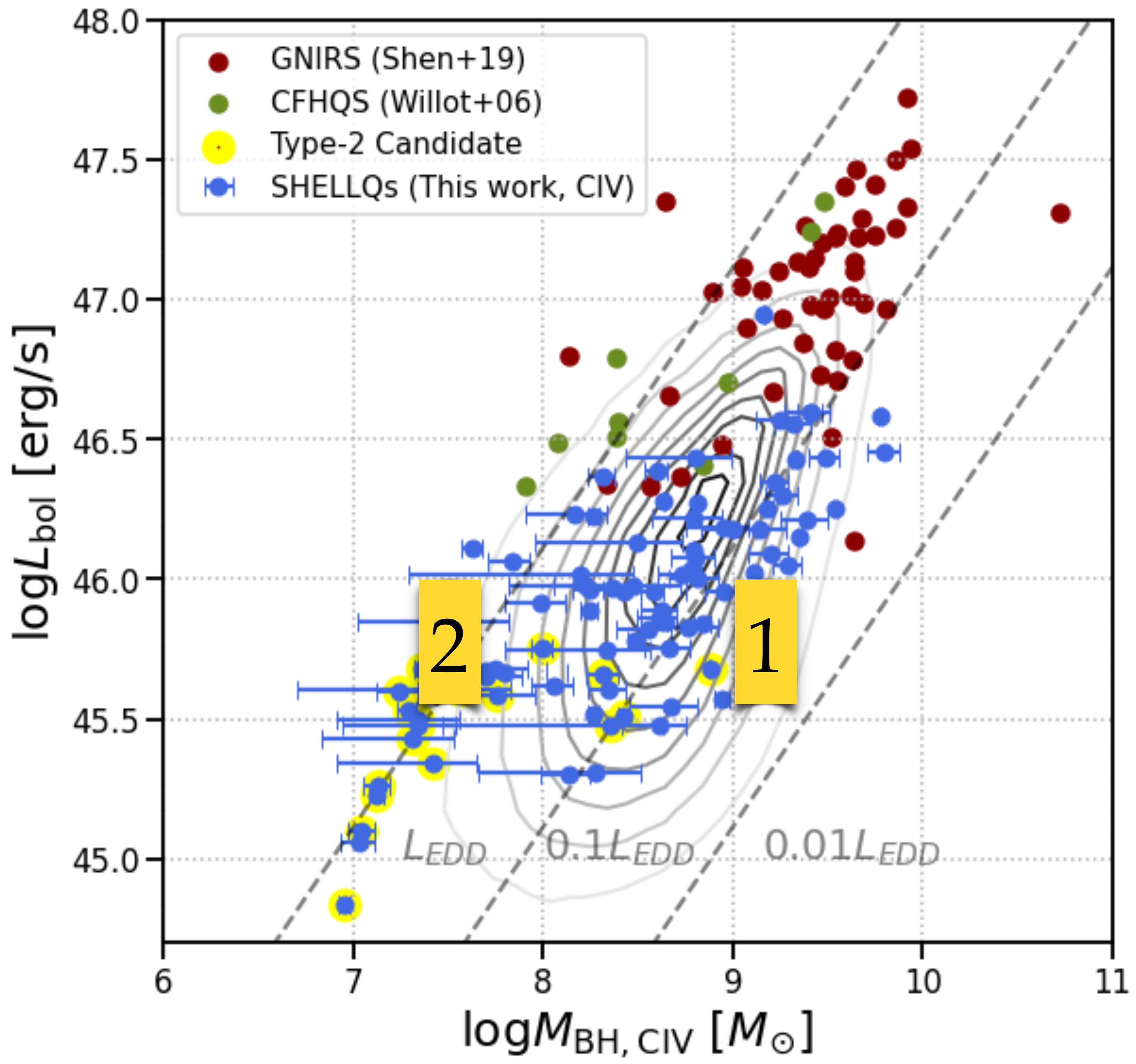
Most of SHELLQs quasars BH seed into the Pop-III remnants

Estimated growth history of SHELLQs quasars

L_{EDD}/L_{BOL} = each observed values

$\cdot\,\eta = 0.1$ (i.e., Shakura & Sunyaev 1976)





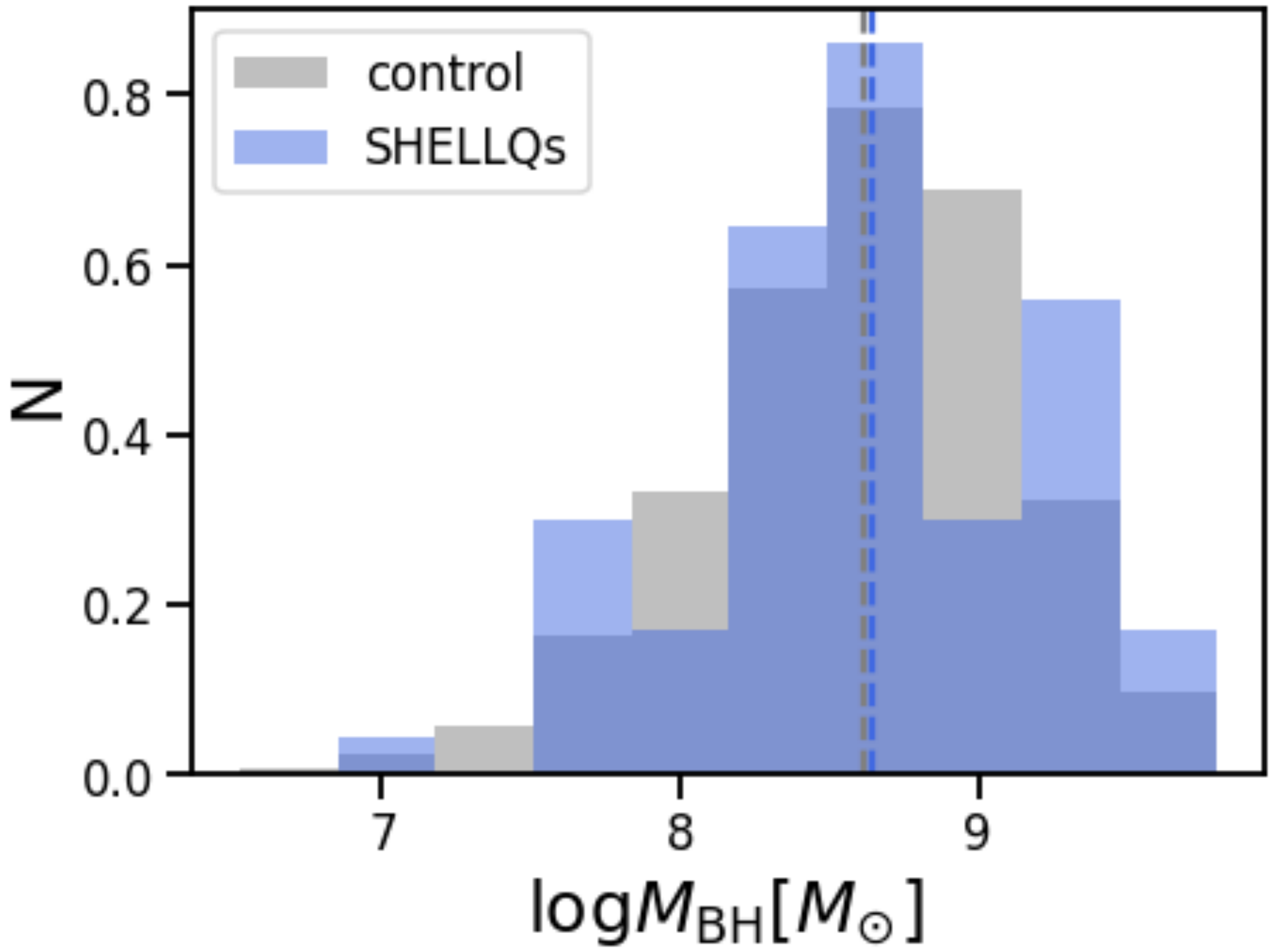
High-z & typical quasars are divided into different activity phases

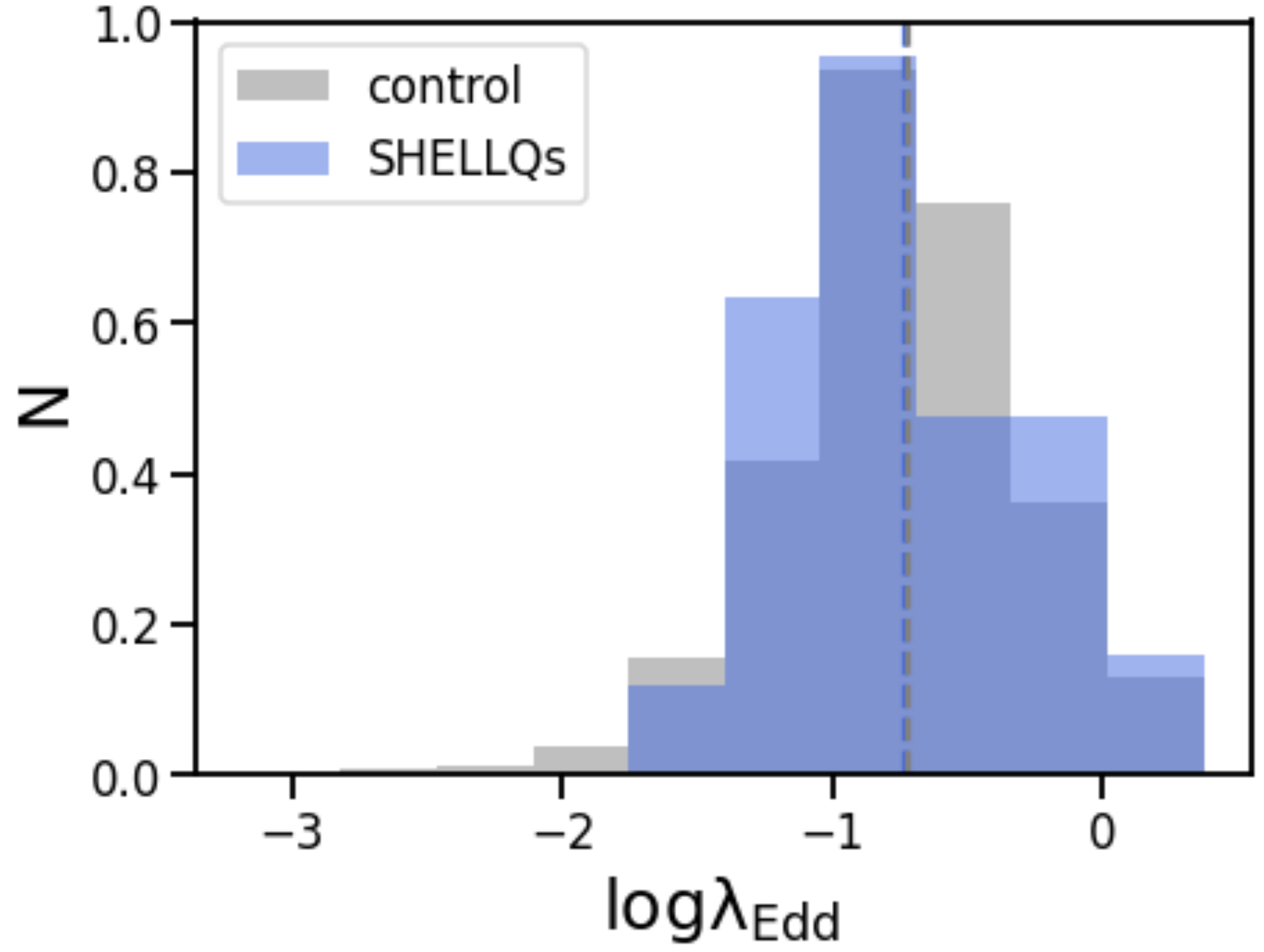
1. In the less active phase. These should have a growth path with higher Eddington ratios in the past from z= 30 to z~6.
2. In the young, active phase. Some of these should have a growth path with lower Eddington ratios from z= 30 to z ~6

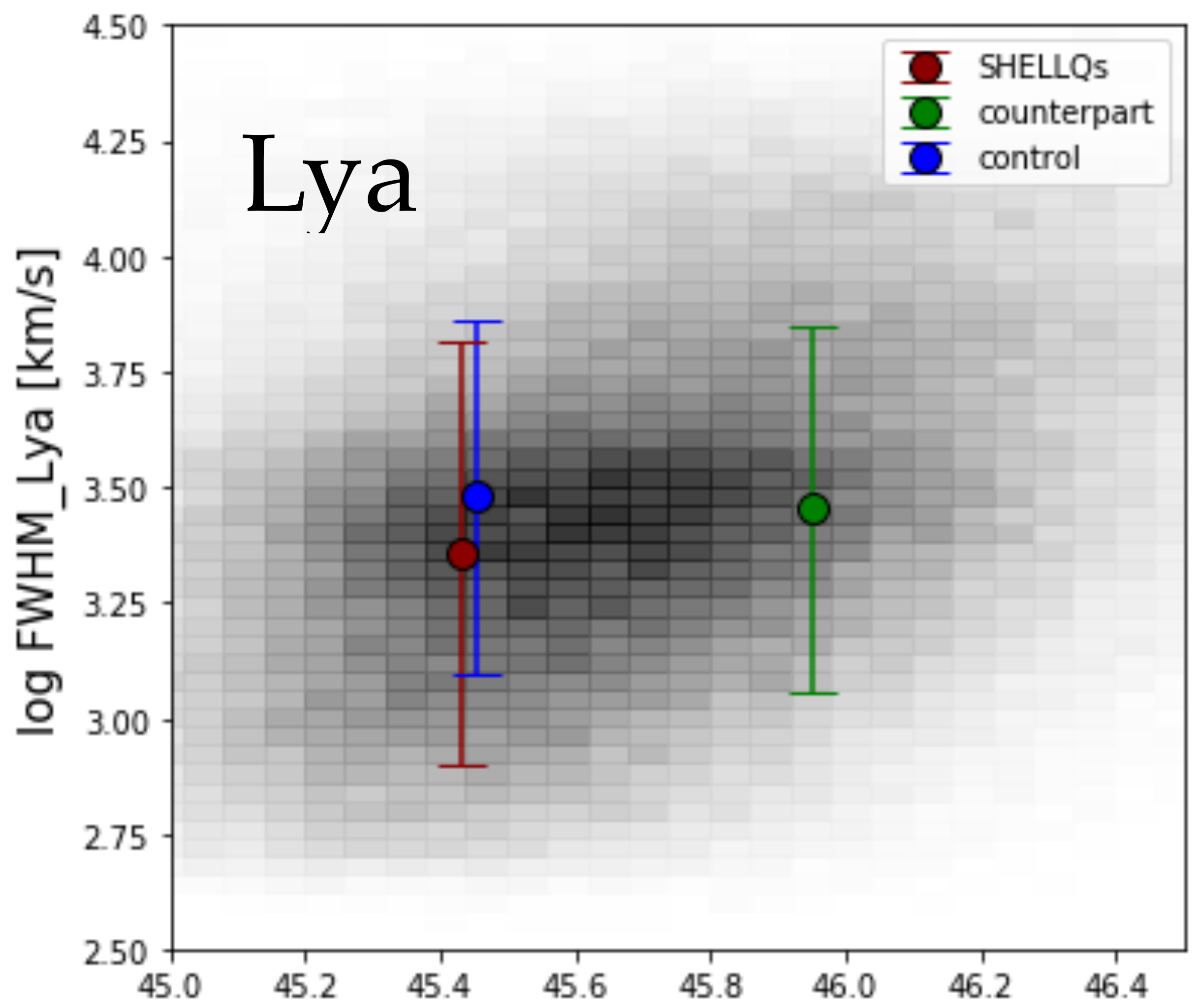
What is the spectral properties of typical quasars at high-z ?

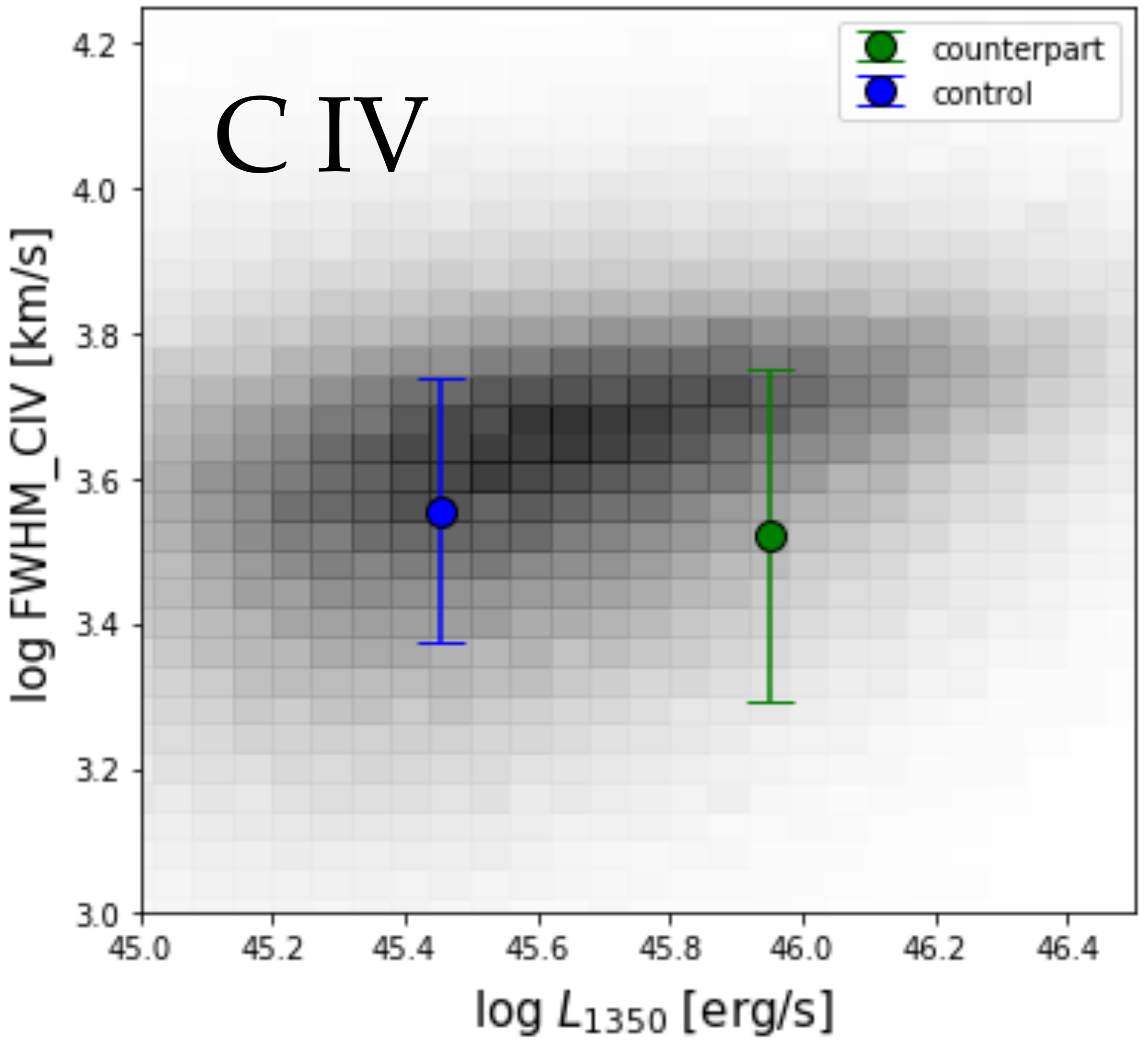
Comparison of high-z QSOs and low-z QSOs/Emission profiles

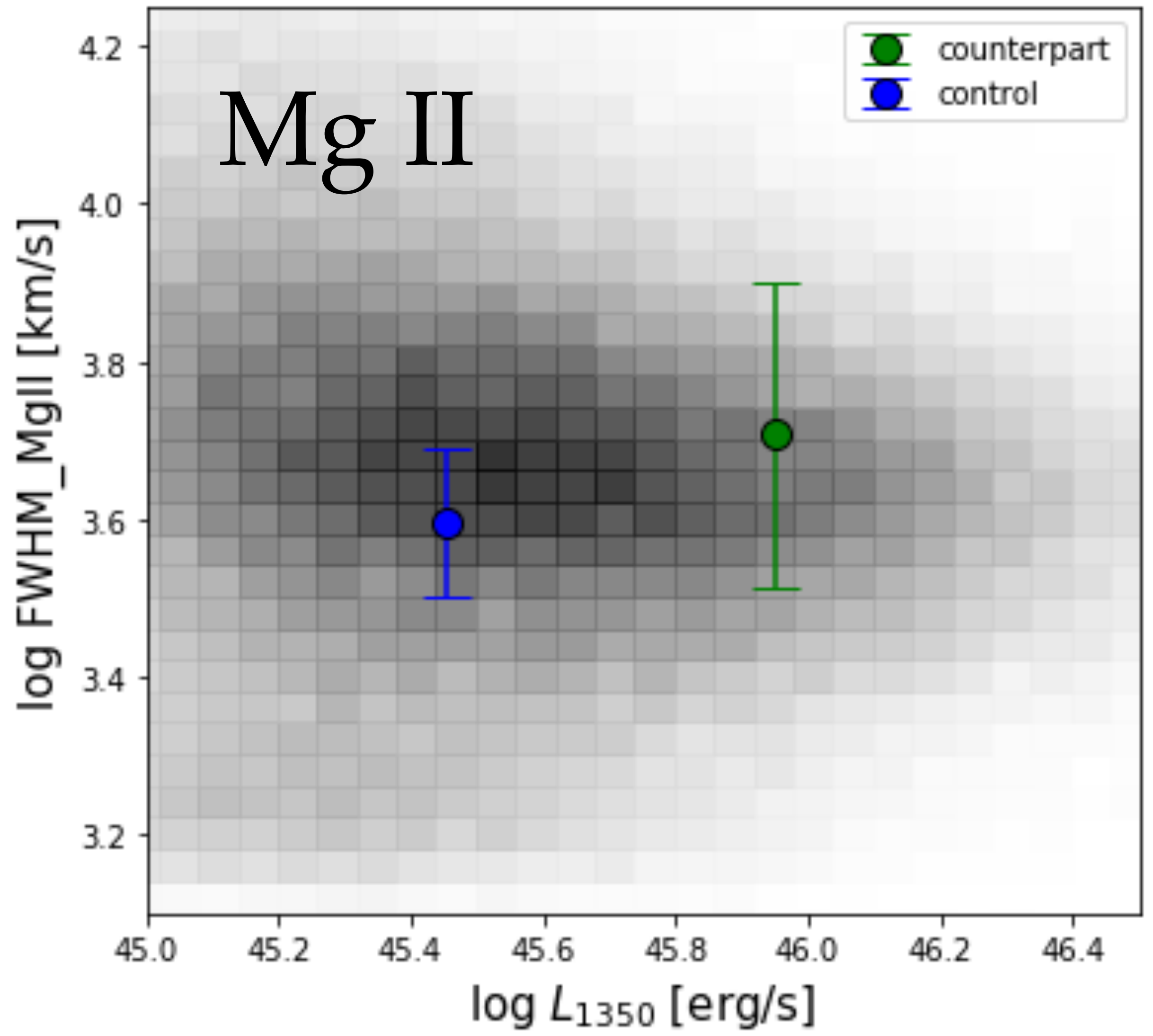
- Create luminosity-matched low-z QSOs (control) sample with SHELLQs sample
- Create composite spectra of three samples (SHELLQs, counterparts, control)









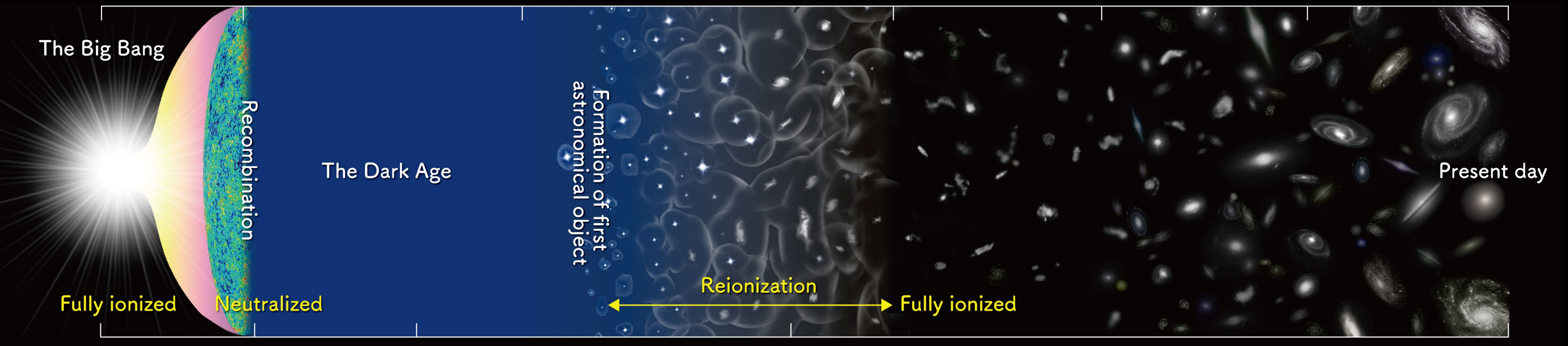


No difference!

They are consistent within 1σ uncertainty with each other.

This means there is no significant difference between high-z and low-z quasars, which is consistent with the previous studies.

FUTURE PROSPECTS



- Confirm the predicted properties of our sample with the actual NIR-spec (especially the lowest candidate!)
- Investigate host properties of quasars at the low-mass side of the MBH distribution (e.g., the distribution of gas, outflow, and halo masses)

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