

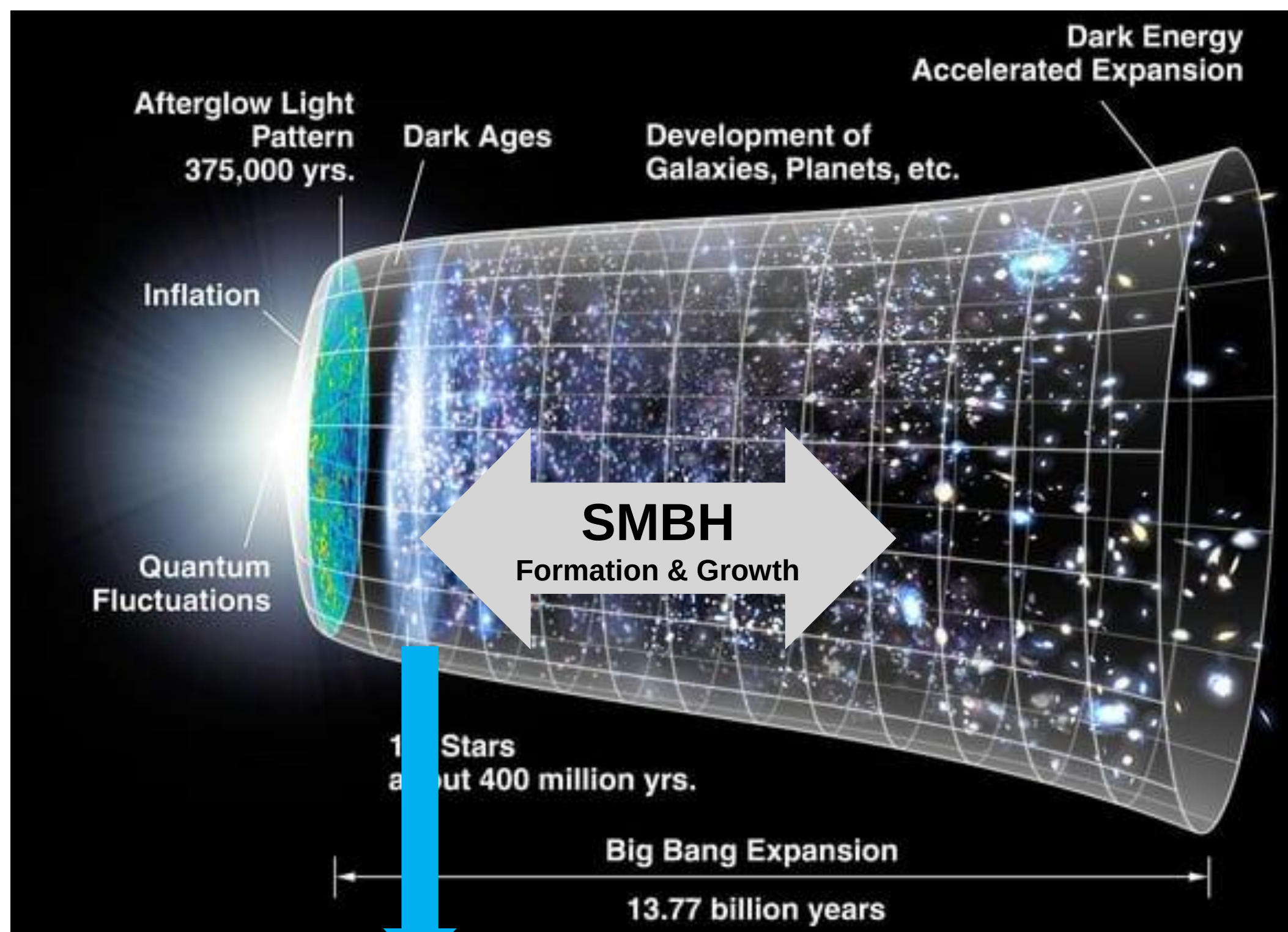
SPHEREx Near-Infrared Spectrophotometric View of Luminous Quasars at $z > 5$ Rest-Frame Optical Properties and Physical Implications

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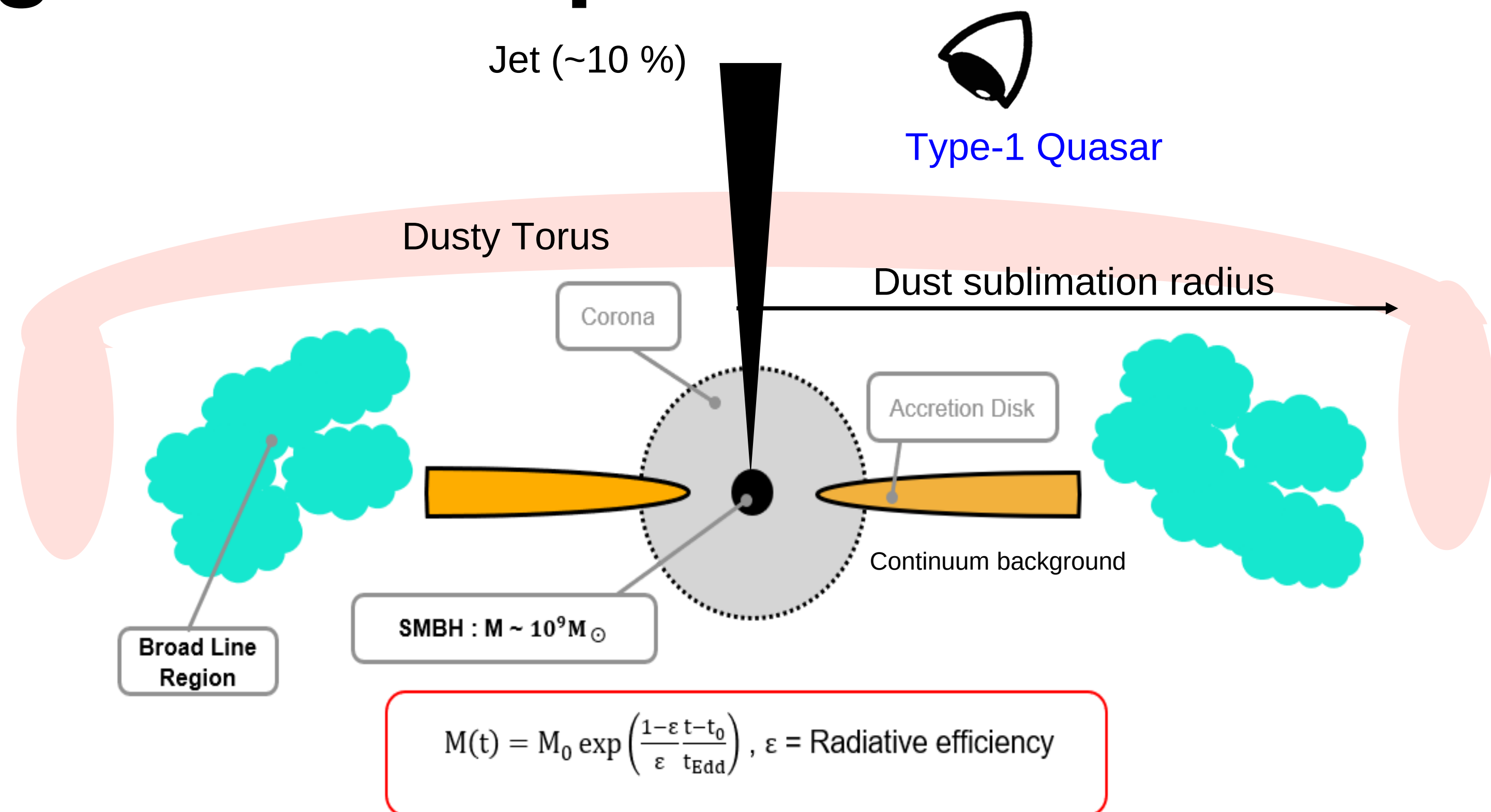
Why we study very high redshift quasars?



Reionization : $z \sim 11.5$

- Up to $z \sim 6$: only 0.5 Gyr
- Already massive SMBH at $z \sim 6$: $M \sim 10^9 M_{\odot}$

Study Background



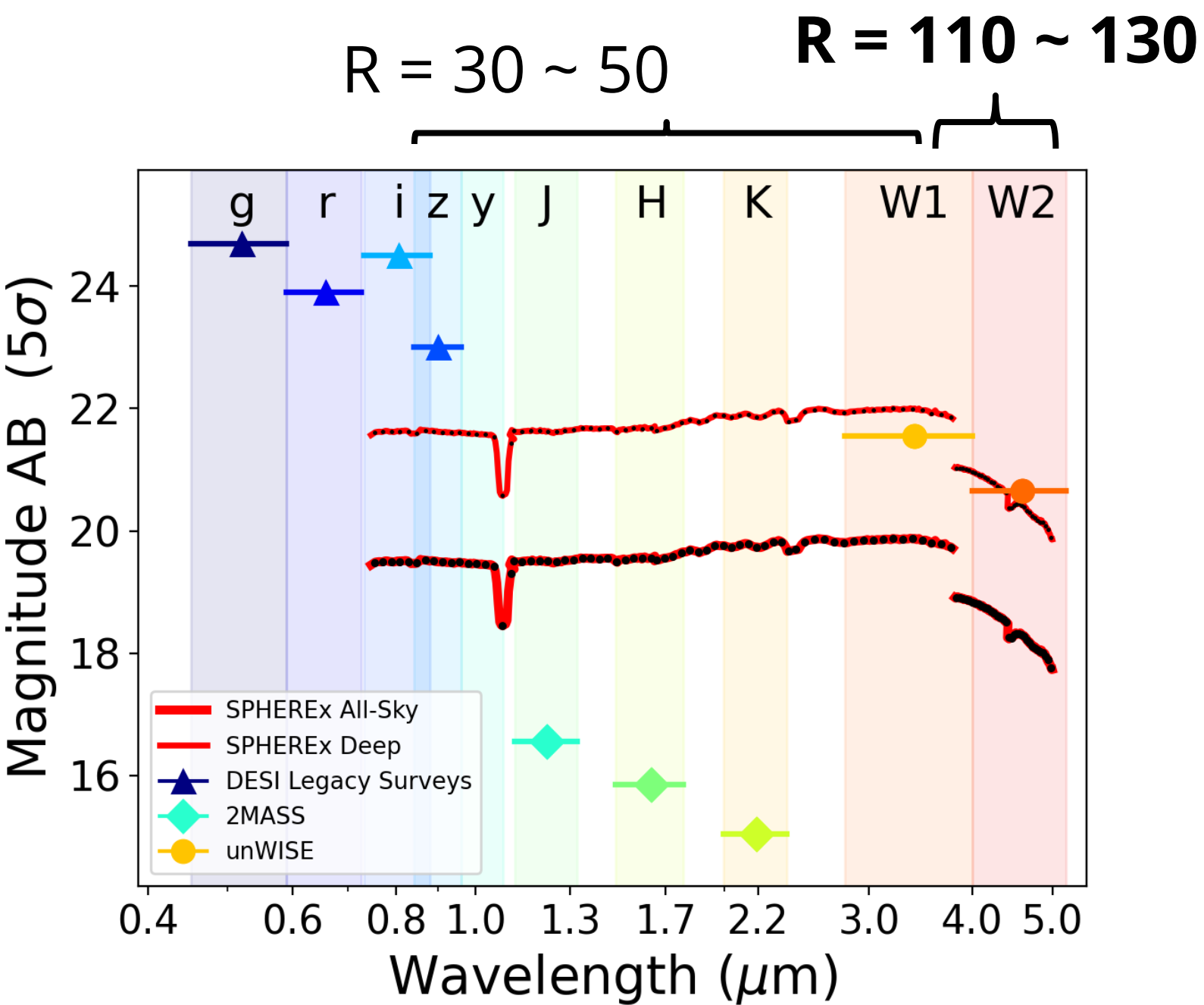
BH can grow by 2×10^4 times over the time span of 0.5 Gyr (Assume $\epsilon = 0.1$) (Hyunseong 2015)

Exact estimation of (high) mass is crucial for the early quasar study!

“How could SMBH grow rapidly at its early evolutionary stage?”

Observing Type-1 AGN through SPHEREx

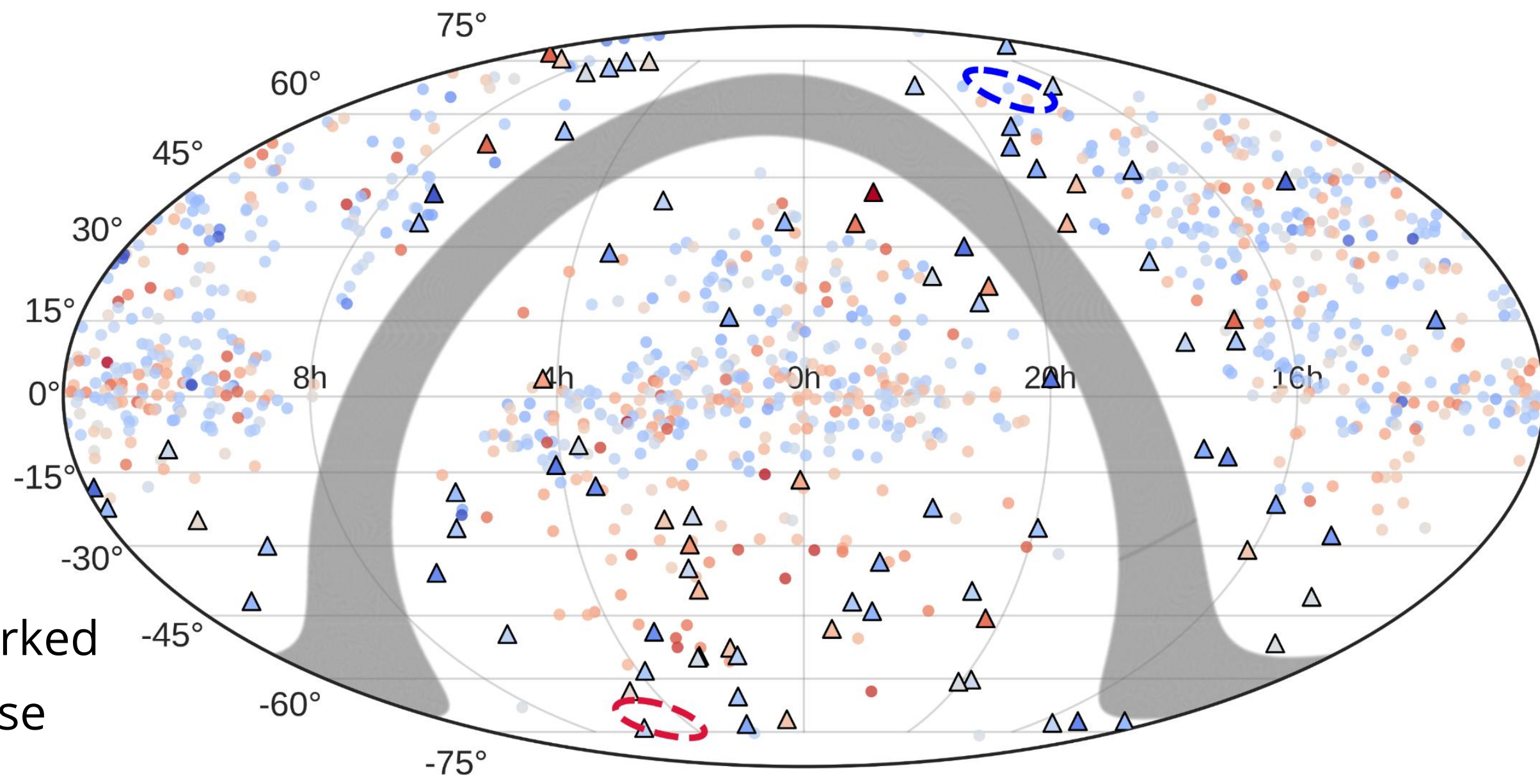
Collect previously discovered quasars (Type-1) from various sources



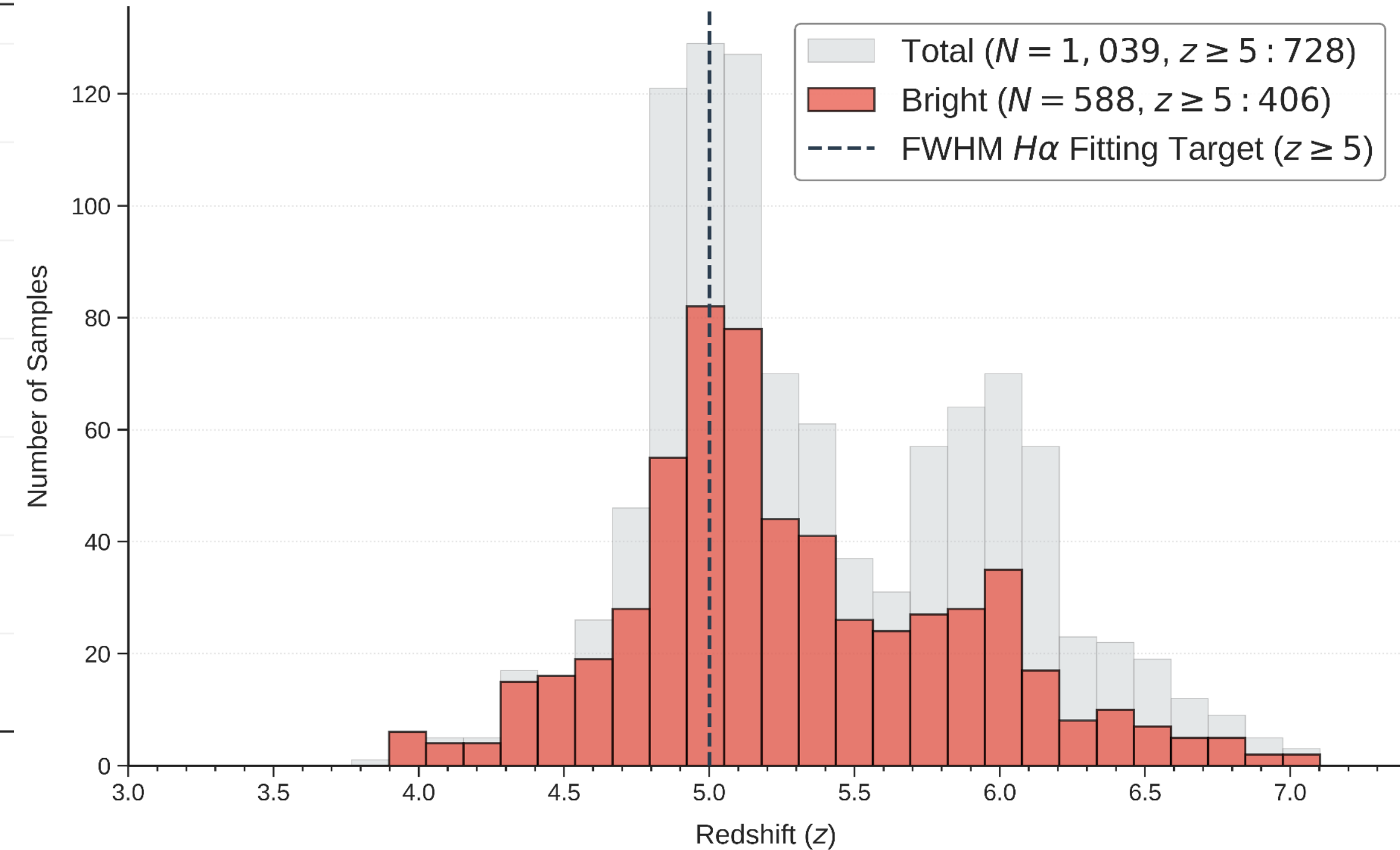
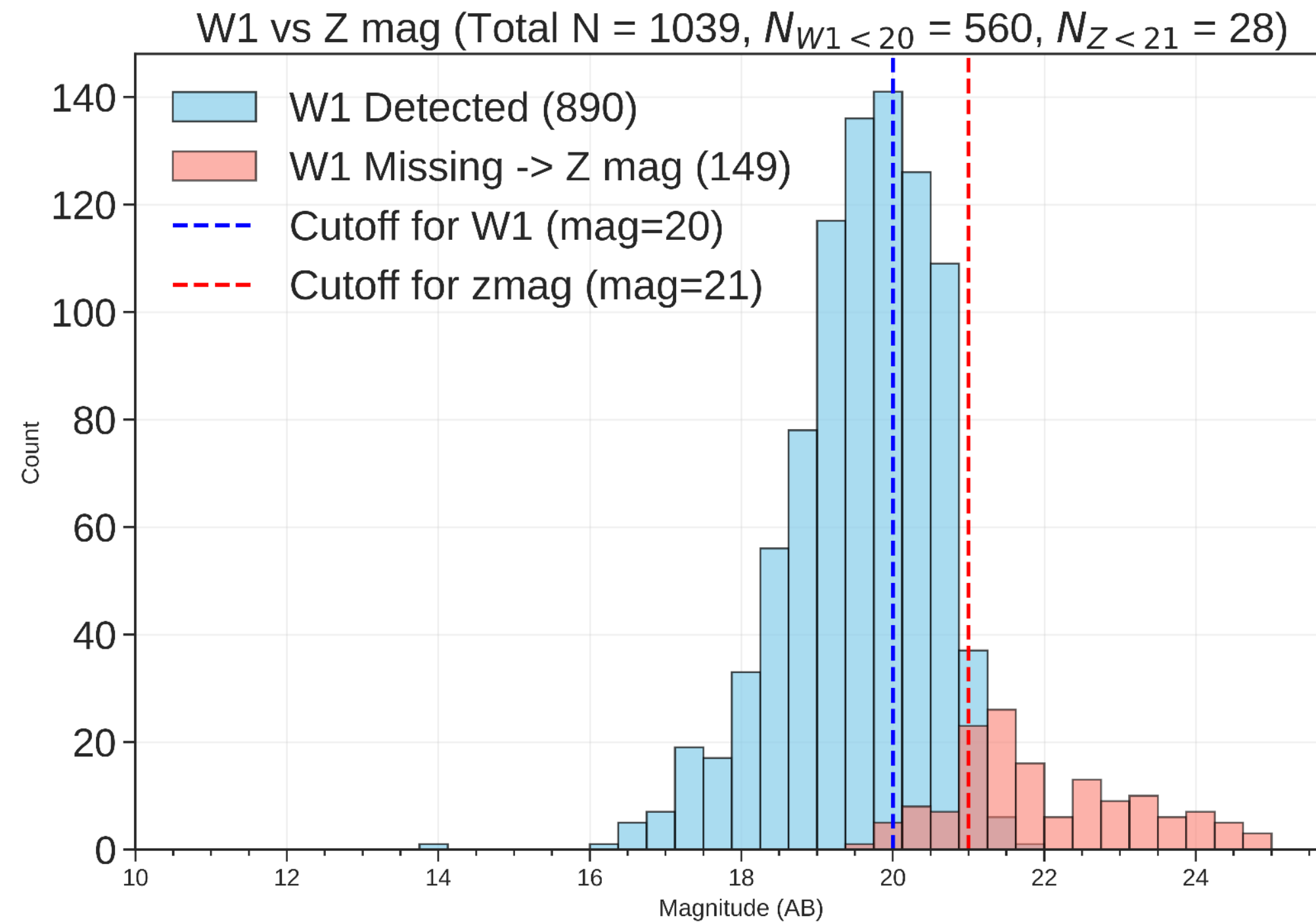
Type-1 AGN Source	Redshift	Number
Ross & Cross (2020)	5.00 – 7.54	488
Fan et al. (2023)	5.30 – 7.64	531
Yang et al. (2024)	3.88 – 6.53	450
Liu et al. (2025)	4.76 – 5.95	27
Davies et al. (2026)	4.03 – 5.73	87

SPHEREx can detect **H α** from broad line region (BLR) in the B5-B6 ($z = 5-6.5$) which has relatively high R.

Mollweide map of sample. Quasars newly discovered by SPHEREx are marked with triangles. At gray band (Galactic plane), quasars are relatively sparse



Sample selection



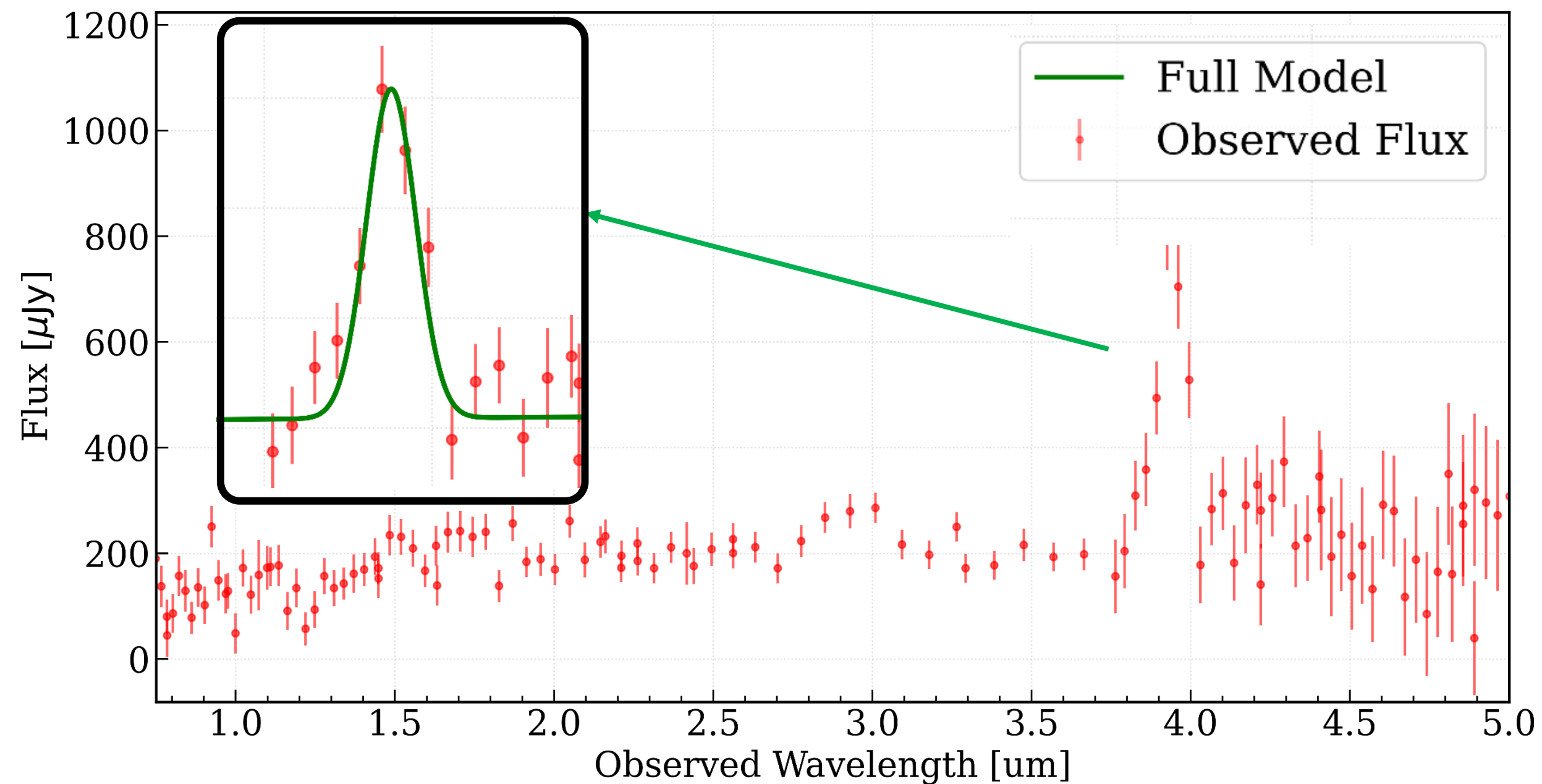
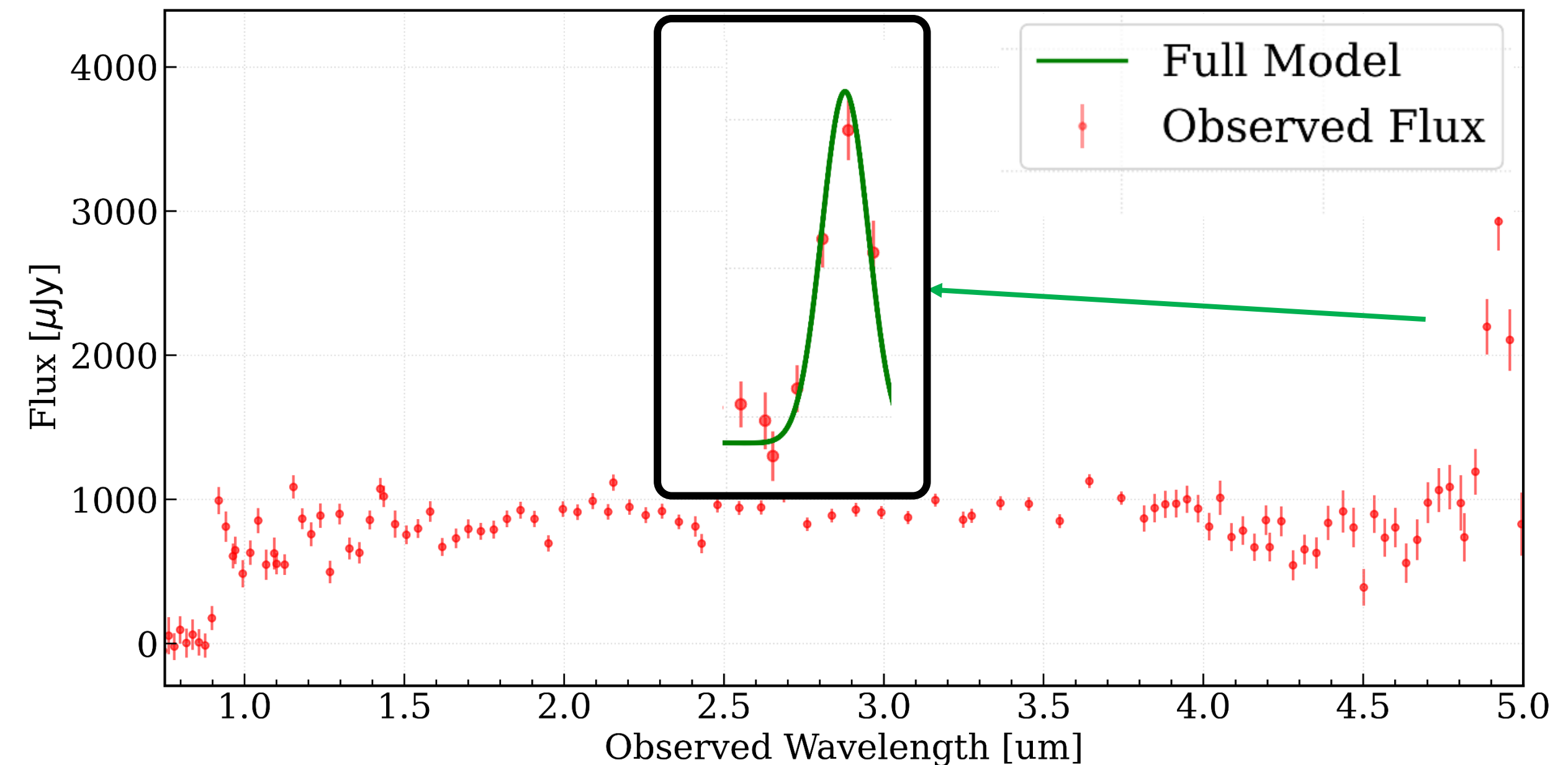
Magnitude distribution (left) and redshift distribution of selected sample (right).

Bright population shows similar redshift distribution with total population.

Fitting method

1. Mask the observed points nearby (H_α , H_β) and fit **the continuum with power law**.
2. Calculate the model flux points of broad H_α line by **using single gaussian model**.
3. Find the **best-fit model** by minimizing χ^2 between observed flux and model flux.

Fitting method

 $z_{\text{fit}} = 5.0030 \mid \text{FWHM} = 6588 \text{ km/s}$

 $z_{\text{fit}} = 6.4940 \mid \text{FWHM} = 4716 \text{ km/s}$


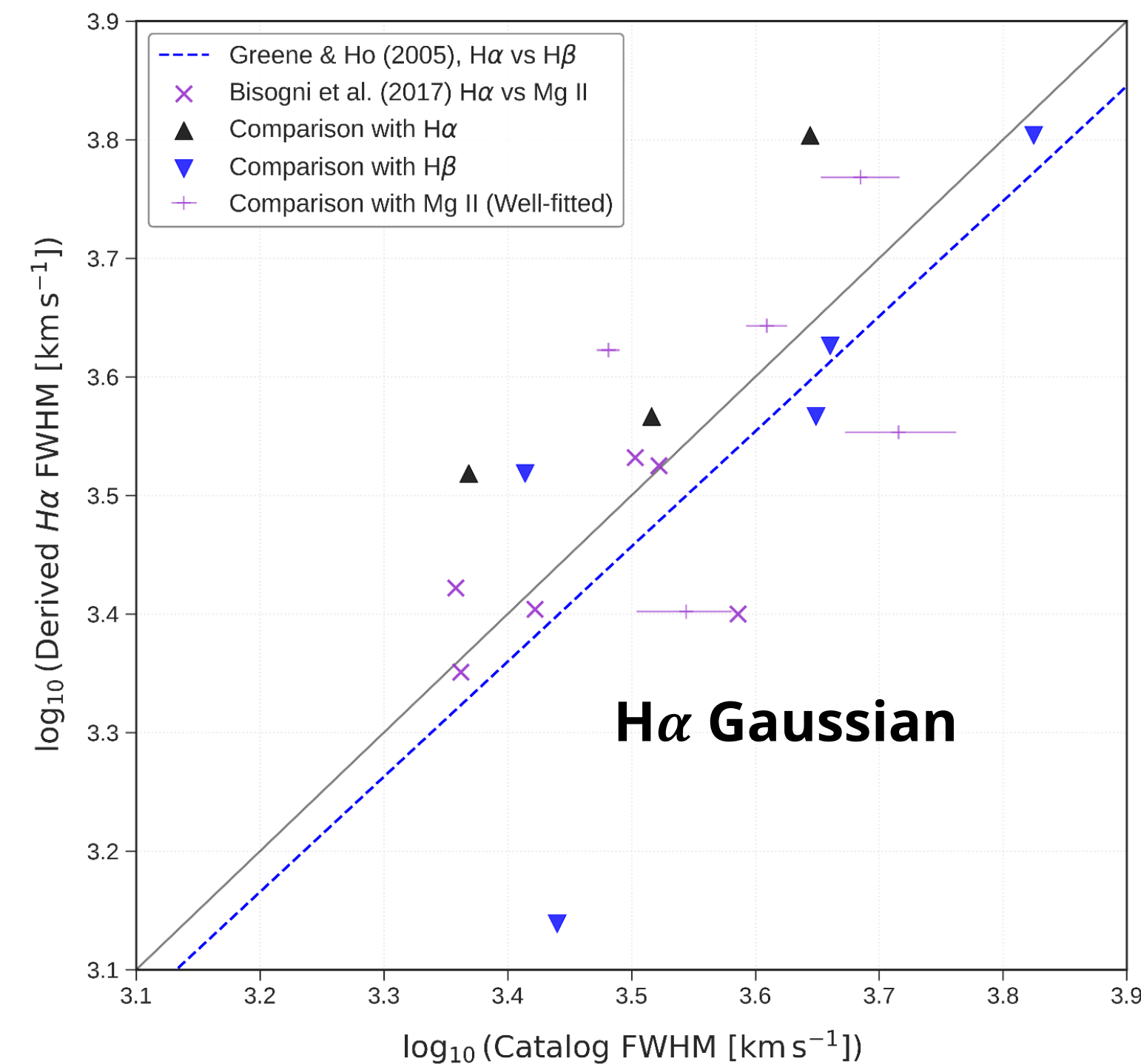
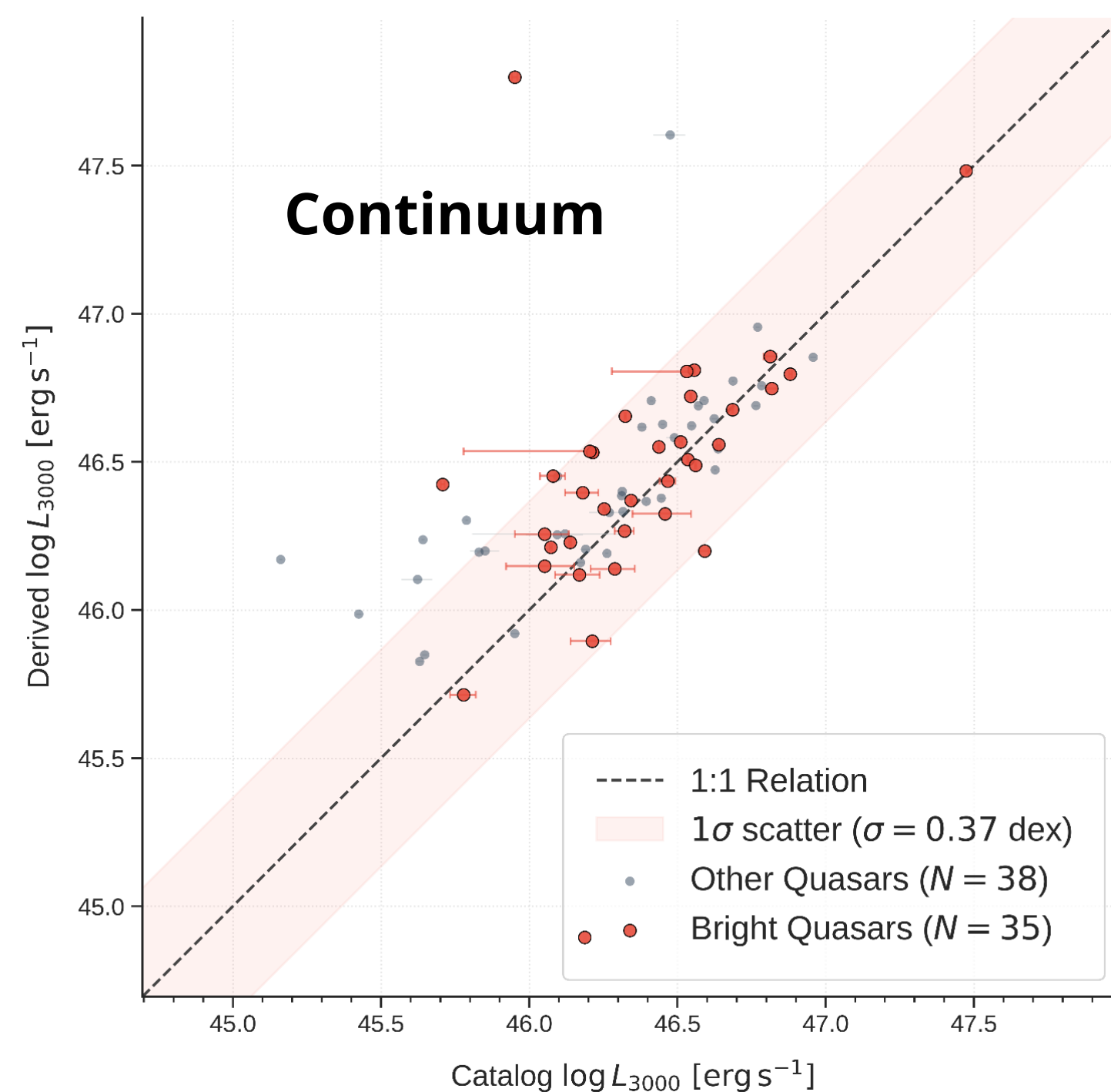
Spectral Fitting Result of well-fitted sample. For $z < 5$, $\text{FWHM}_{\text{H}\alpha}$ is hard to estimate due to low R. For $z > 6.5$, H α emission is out of SPHEREx observation band.

Fitting Evaluation for continuum & $H\alpha$ component

We derive L_{3000} to assess the continuum fitting quality and also $\text{FWHM}_{H\alpha}$.

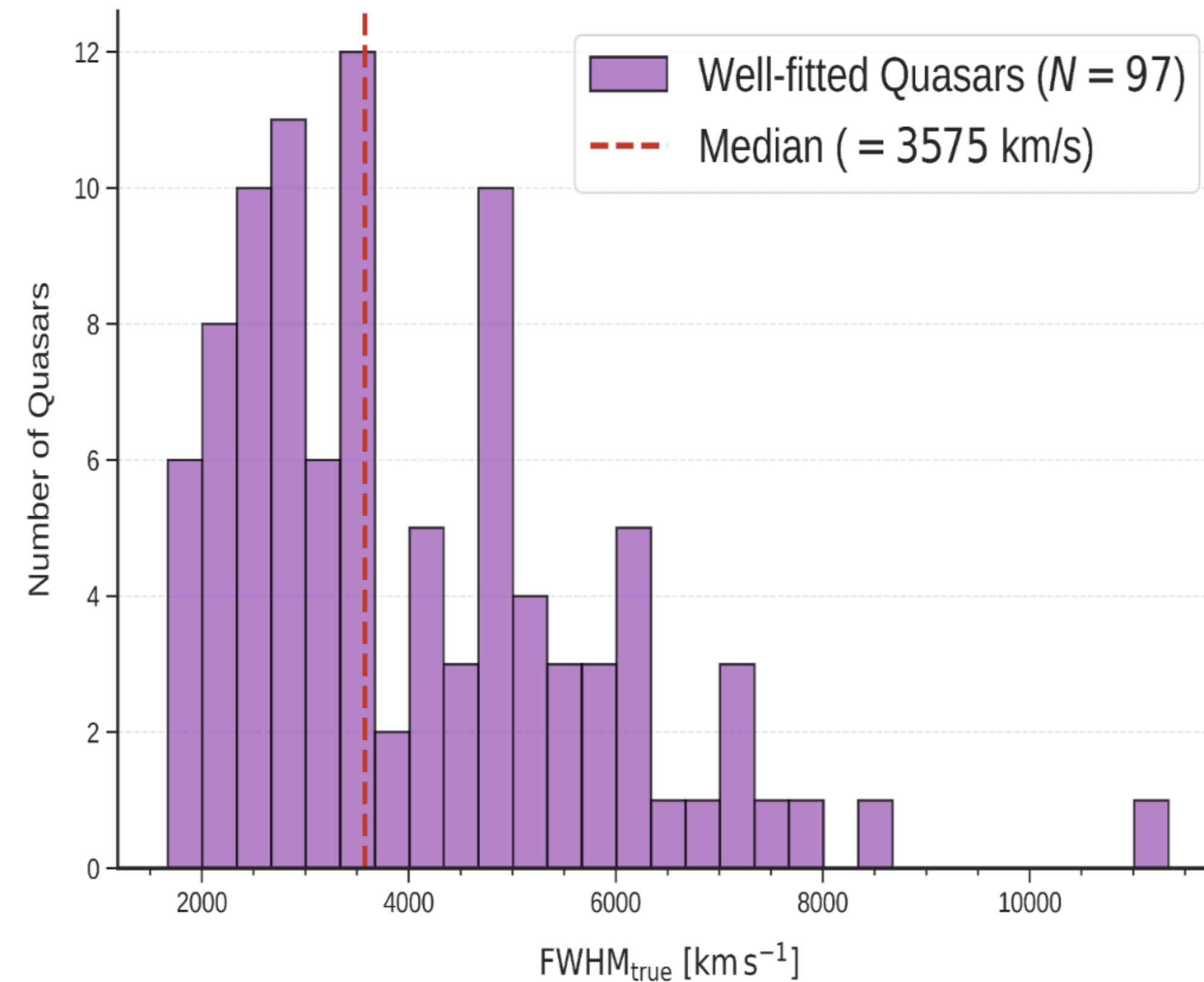
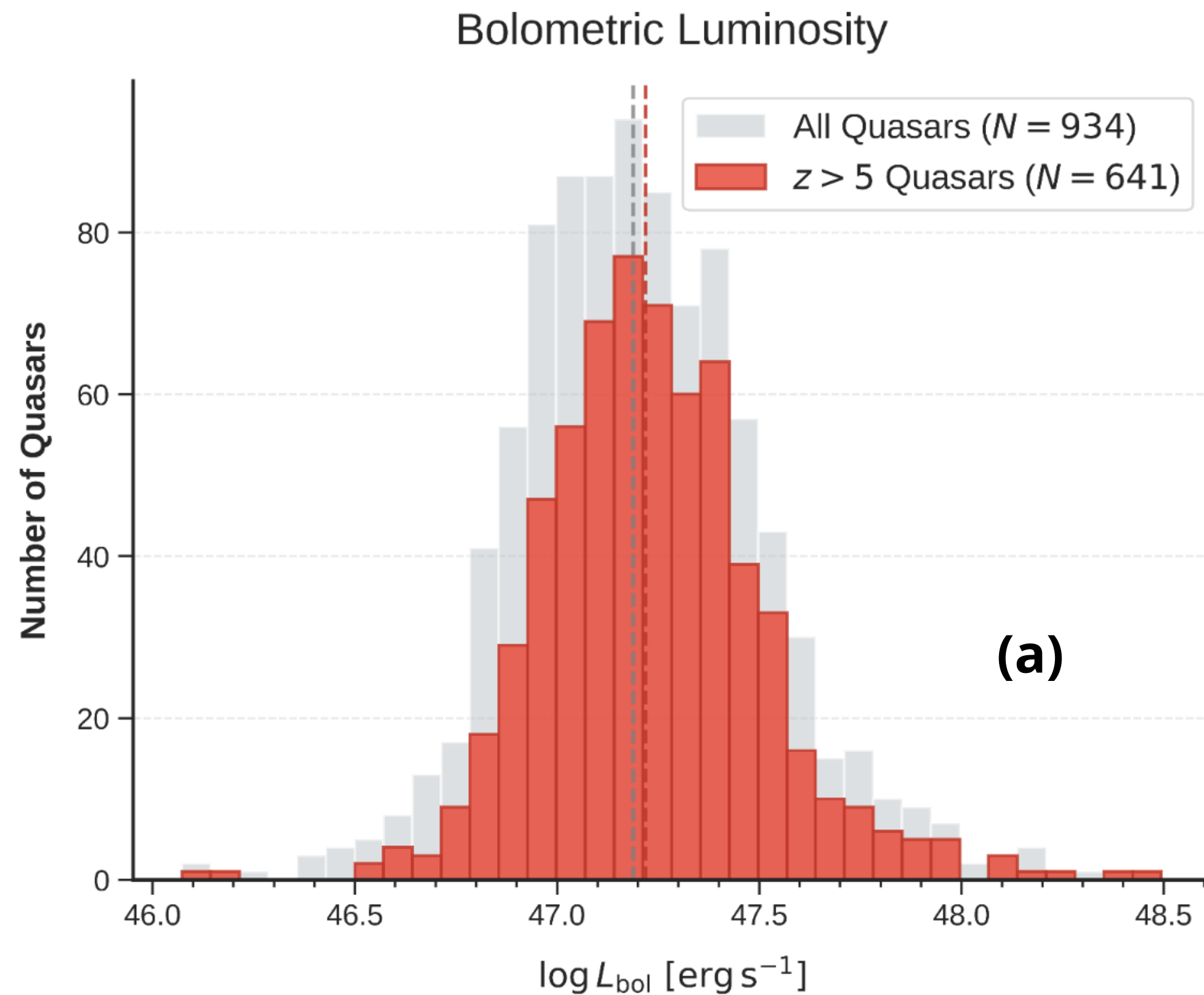
For both case, VHZQs are broadly consistent with previous studies, scattering closely along 1:1 relation.

Fitting Evaluation for continuum & H α component



Comparison of L_{3000} continuum luminosities for all continuum-fit success samples (left) and $\text{FWHM}_{\text{H}\beta}$ (right) to the values for well-fitted samples in catalog. (matched confirmed only)

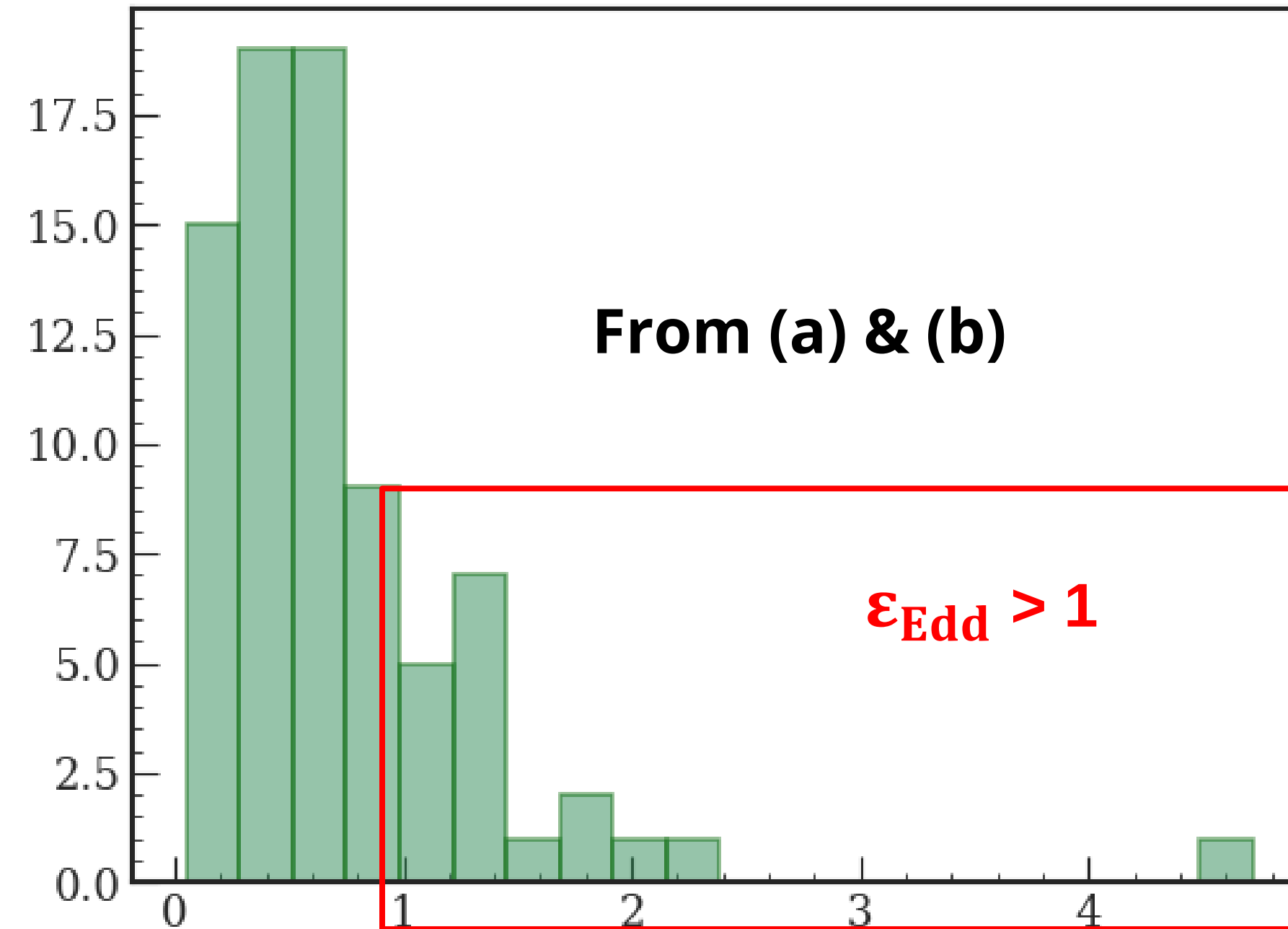
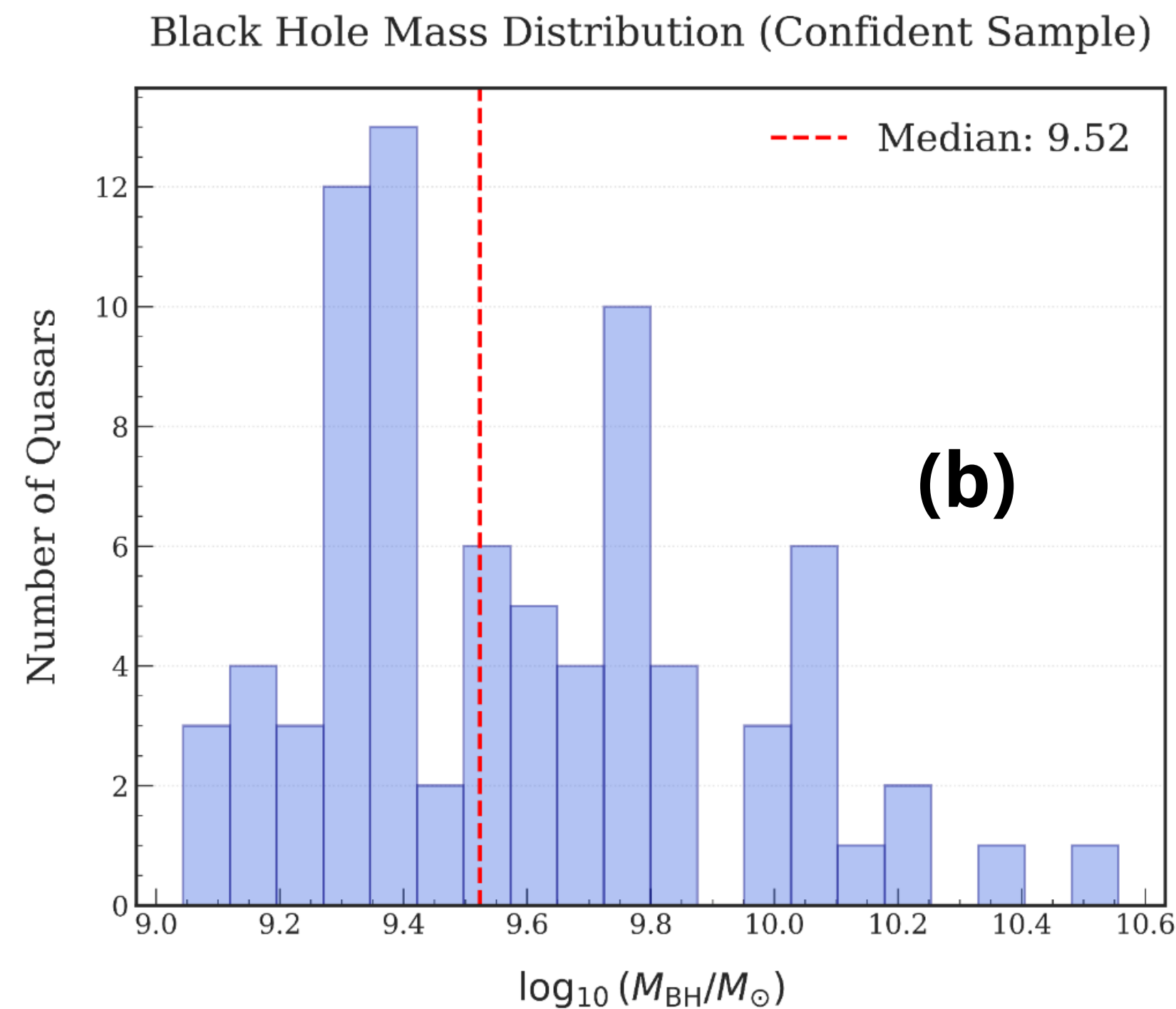
Physical Implication from single-epoch approach



Sample distribution of L_{bol} (left) and $\text{FWHM}_{\text{H}\alpha}$ (right)

$$L_{\text{bol}} = 9.26 \times L_{5100}$$

Physical Implication from single-epoch approach



Estimated Black hole mass (left) and Eddington ratio ϵ_{Edd} (right).

$$\log(M_{\text{BH}}/10^6 M_{\odot}) = \log \left[(2.0^{+0.4}_{-0.3}) \left(\frac{\text{FWHM}_{\text{H}\alpha}}{1000 \text{ km/s}} \right)^{2.06 \pm 0.06} \left(\frac{L_{\text{H}\alpha}}{10^{42} \text{ erg/s}} \right)^{0.55 \pm 0.02} \right]$$

Fitting Evaluation for continuum & $H\alpha$ component

Spectrophotometric Identification of VHzQs.

- a. $H\alpha$ emission line was successfully detected in the bright subsamples.
 - b. While Ly- α breaks and $H\beta$ emissions are also identified for some samples. Robust fitting of $H\beta$ is challenging due to low spectral resolution of SPHEREx. ($R \sim 30$ at B4)
 - c. Reliable $H\alpha$ is approximately 10% of the continuum-fitted VHzQs population.
- uncertainties in L_{bol} and M_{BH} estimation.

Fitting Evaluation for continuum & $H\alpha$ component

Estimation of Physical Properties

- a. Based on confident $H\alpha$ fitting, we estimated M_{BH} and Eddington ratio (ϵ_{Edd}).
- b. M_{BH} primarily range between $10^9 M_{\odot} \sim 10^{10} M_{\odot}$ confirming the presence of SMBH in the early universe.

Eddington Ratio larger than 1 ($\epsilon_{Edd} > 1$)

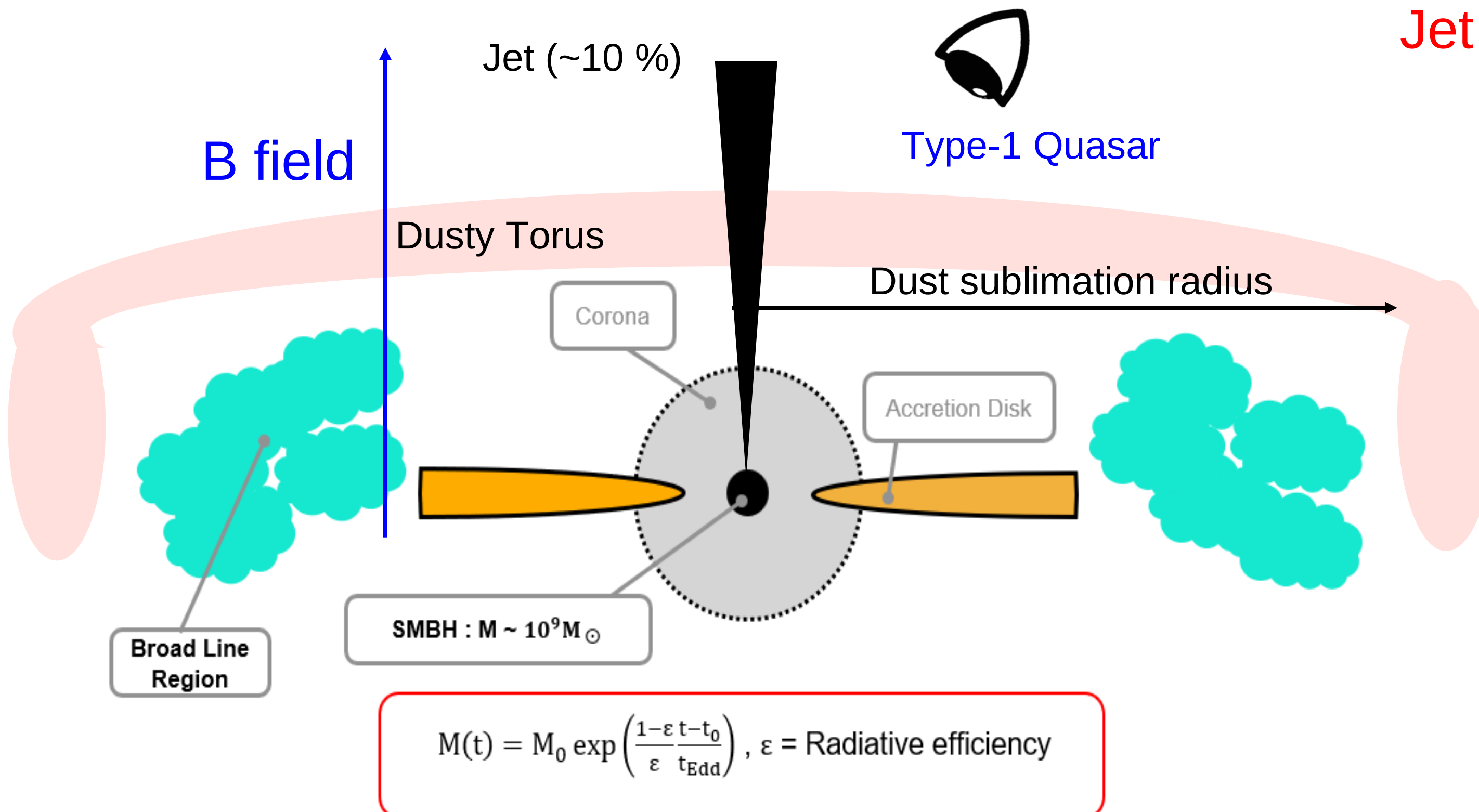
- a. They may originate from uncertainties in L_{bol} and M_{BH} estimation.
- b. Selection bias from high luminous Quasars.

Future Plan

1. Integration of updated survey results to increase the effective survey depth. (Improved SNR)
2. Identification of anomalous VHzQs for high-resolution follow-up observations such as JWST.
3. Quasar Luminosity Function : is it credible? Is it worthy?

FYI : Lack Radio Lobe in high z AGN

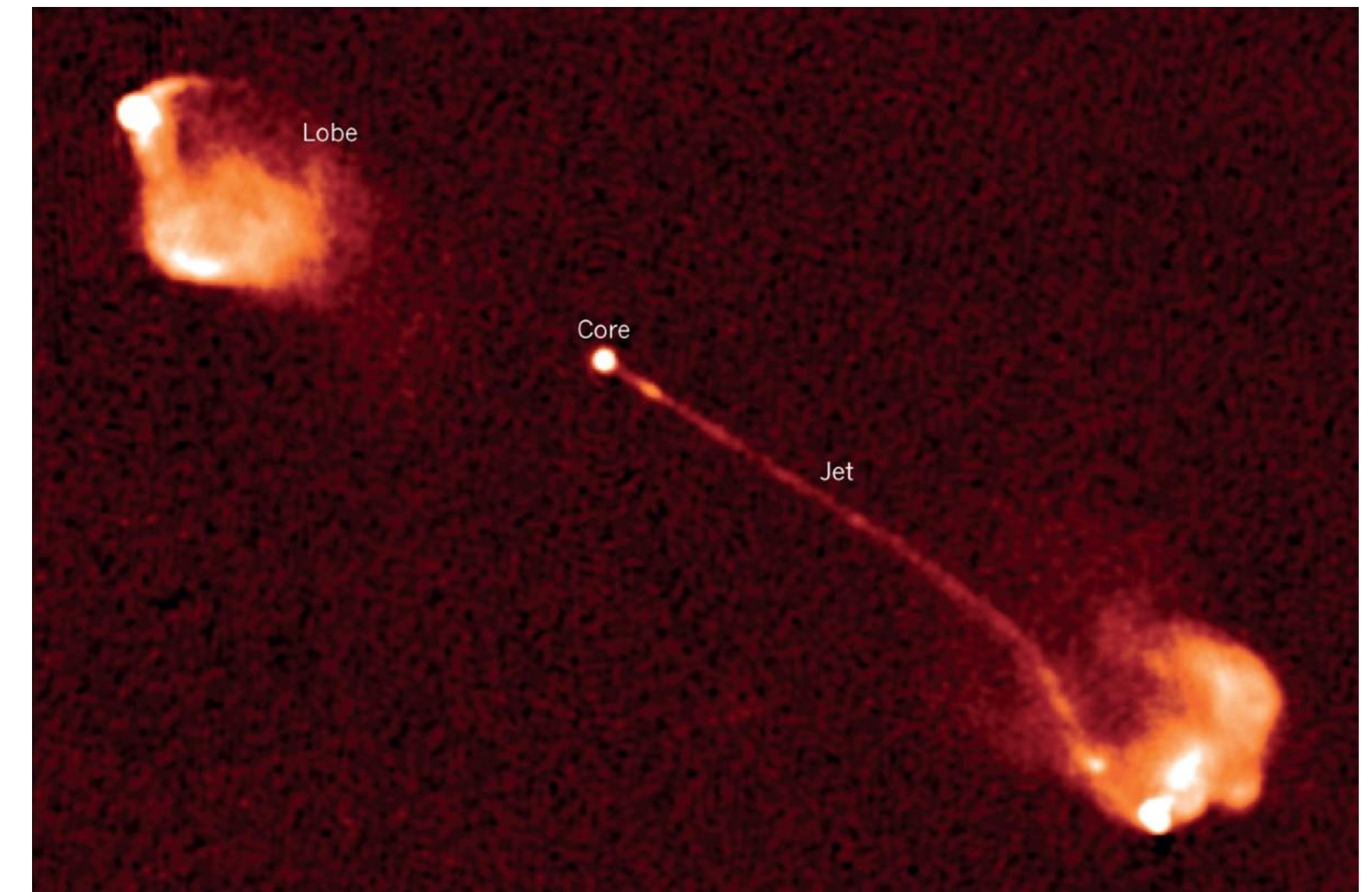
Collimation, relativistic Jet



Jet remains 10 % for overall redshift. Two scenario

- Two distinct quasar group
- Duty cycle of Jet

Jet + IGM : Shock, Radio Lobe



But Radio Lobe becomes rare at high z AGN

- High CMB density, Inverse Compton scattering
- Radio is weakened, X-ray is strengthened.