

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

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Very high redshift quasars (VHzQs) through SPHEREx

I. Why we study Very High Redshift Quasars (VHzQs) ?

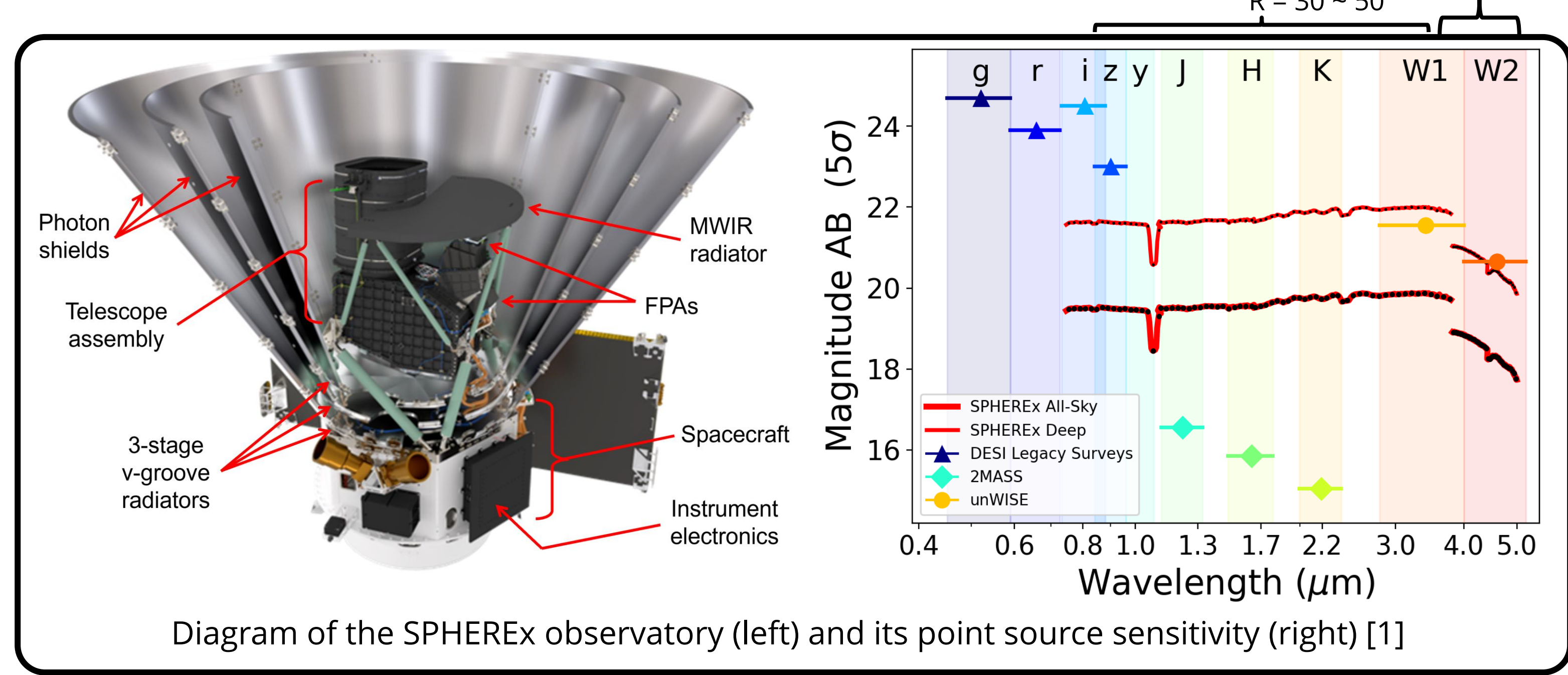
To understand the early growth of Supermassive blackholes. Our main question is:

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

To answer, estimation of its mass (M_{BH}) is essential but most reliable emission lines (H_{α} , H_{β} = 0.6563, 0.4861 μm) are redshifted to infrared regime .

II. SPHEREx : All-sky mission is on survey.

1. Spectrophotometry of 6 band within 0.75 – 5.0 μm through linear variable filter.
2. Satellite R is dependent on its band with *low spectral resolution* (R).



SPHEREx can detect H_{α} from broad line region (BLR) in the B5-B6 which has relatively high R.

“ We want to estimate physical parameters such as reliable blackhole mass (M_{BH}) even with statistical analysis with large N. ”

Sample Selection

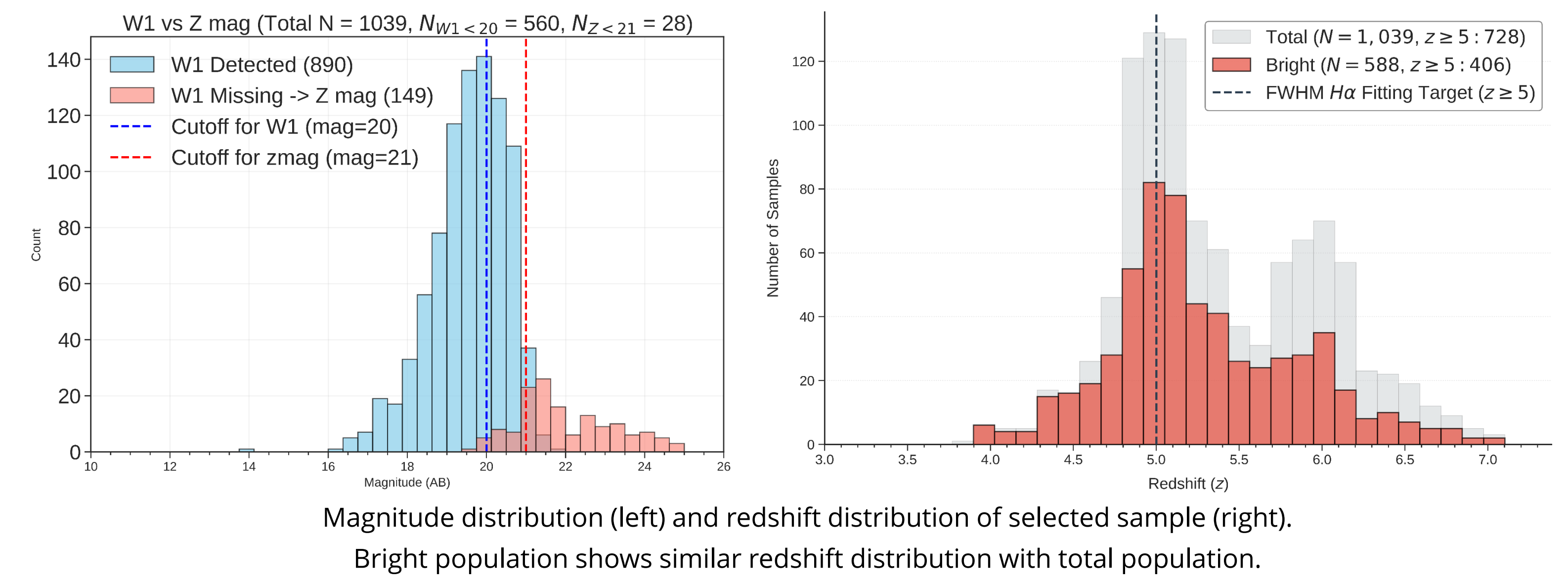
I. How to select samples

[Right] Mollweide map of quasars used in this study. Quasars newly discovered by SPHEREx are marked with triangles. At gray band (Galactic plane), quasars are relatively sparse

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

Sources that we used

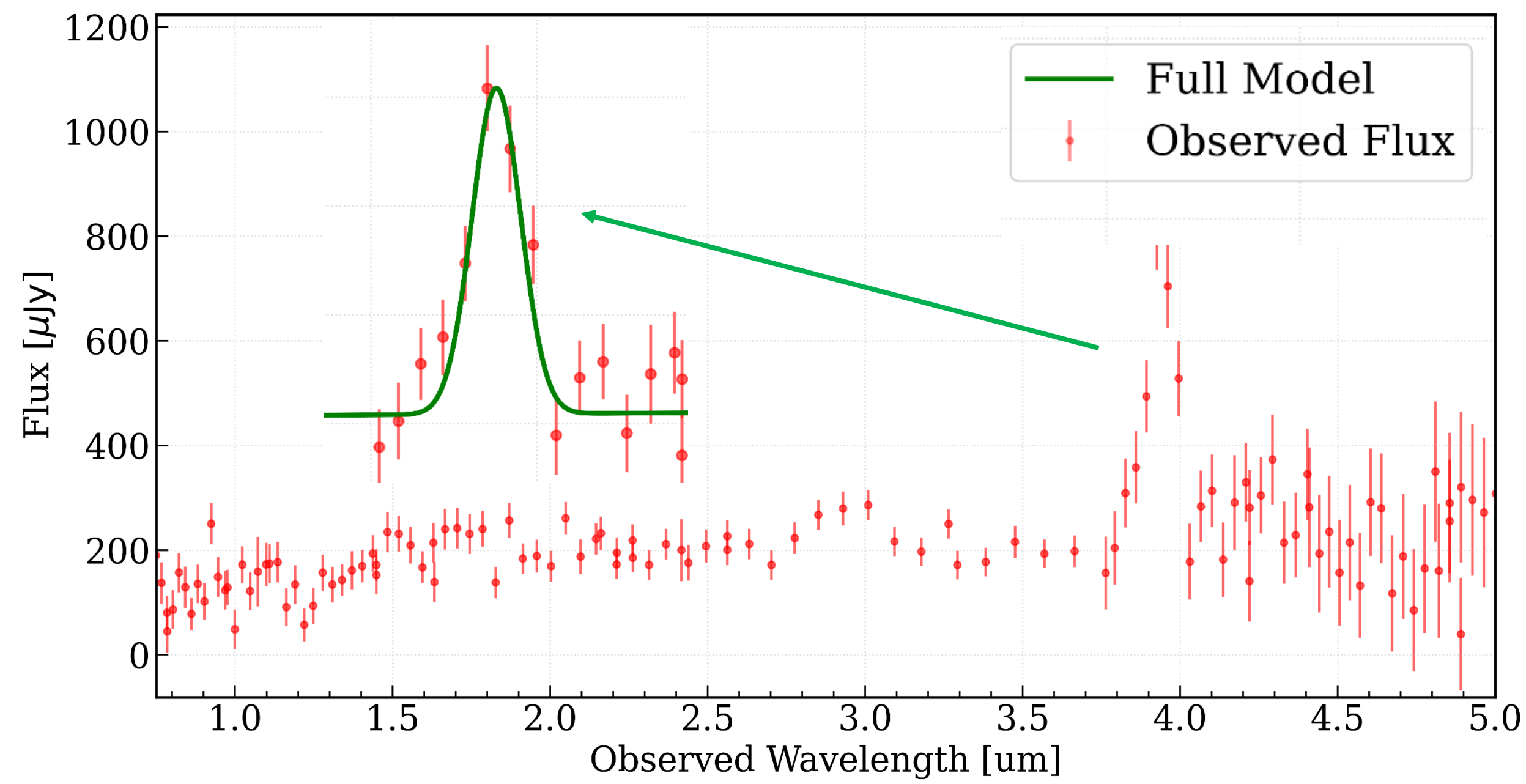
1. Collect previously discovered VHzQs from various sources
2. Match them with the SPHEREx reference catalog based on RA & DEC, selecting only successfully photometered objects. Remove duplicates using reference ID. $N_{\text{total}} = 1041$
3. Apply the magnitude cut ($W1 < 20$ & $LS_z < 21$) to select bright objects. $N_{\text{bright}} = 588$



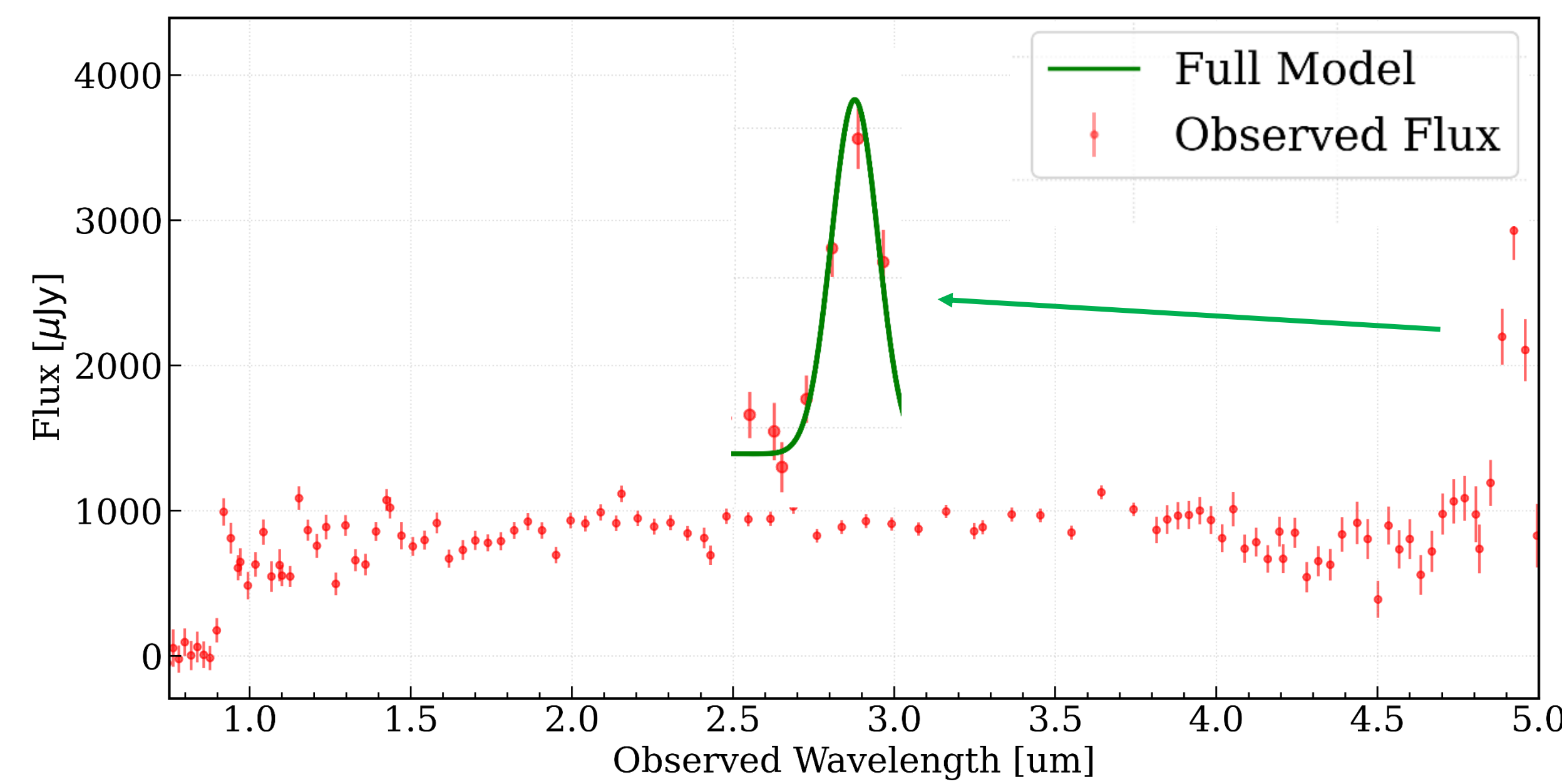
How to fit?

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.

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



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



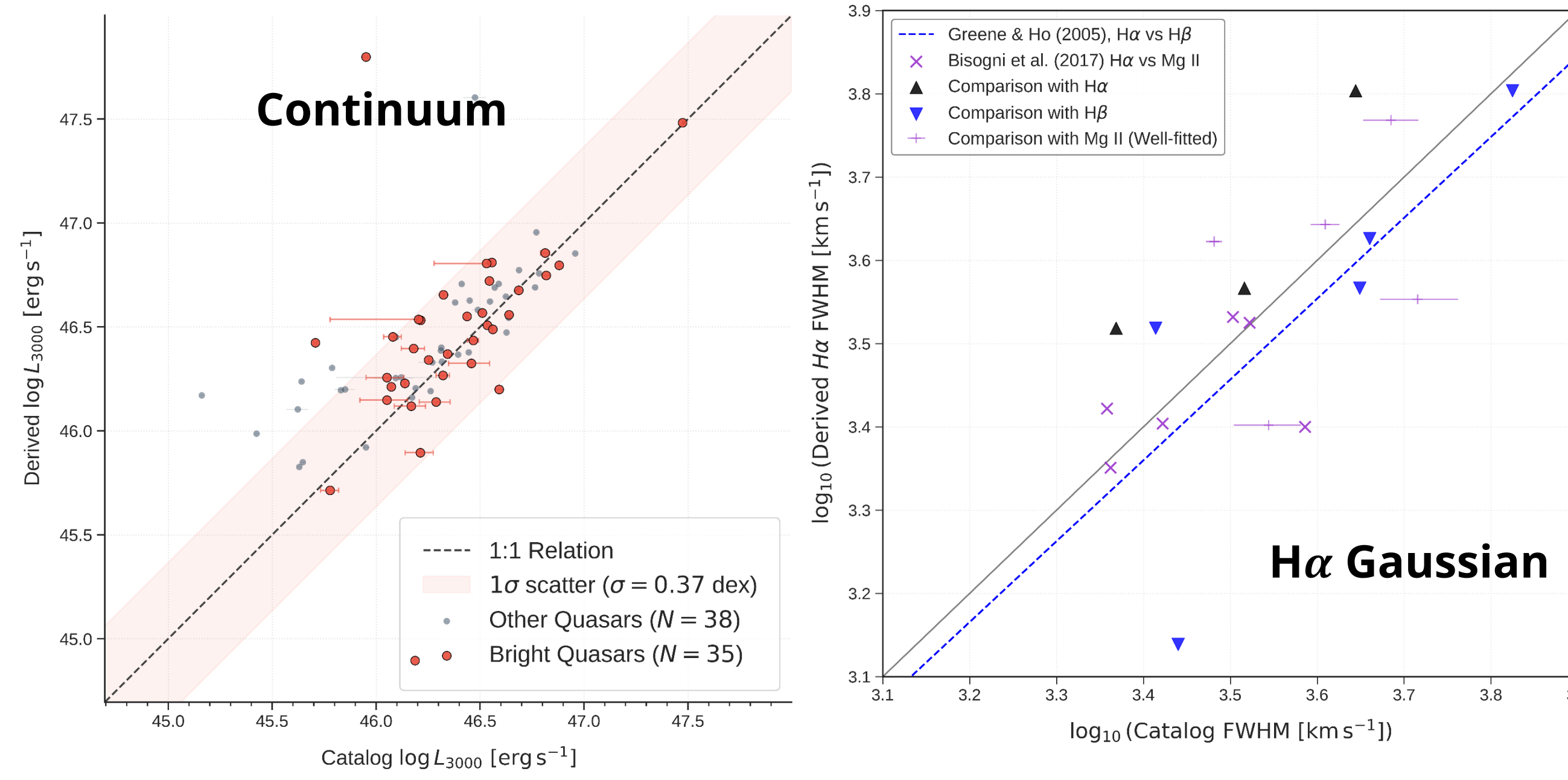
Spectral Fitting Result of well-fitted sample. For $z < 5$, $\text{FWHM}_{H_{\alpha}}$ is hard to estimate due or low R. For $z > 6.5$, H_{α} emission is out of SPHEREx observation band.

What we can get?

I. Fitting Evaluation for continuum & H_{α} component

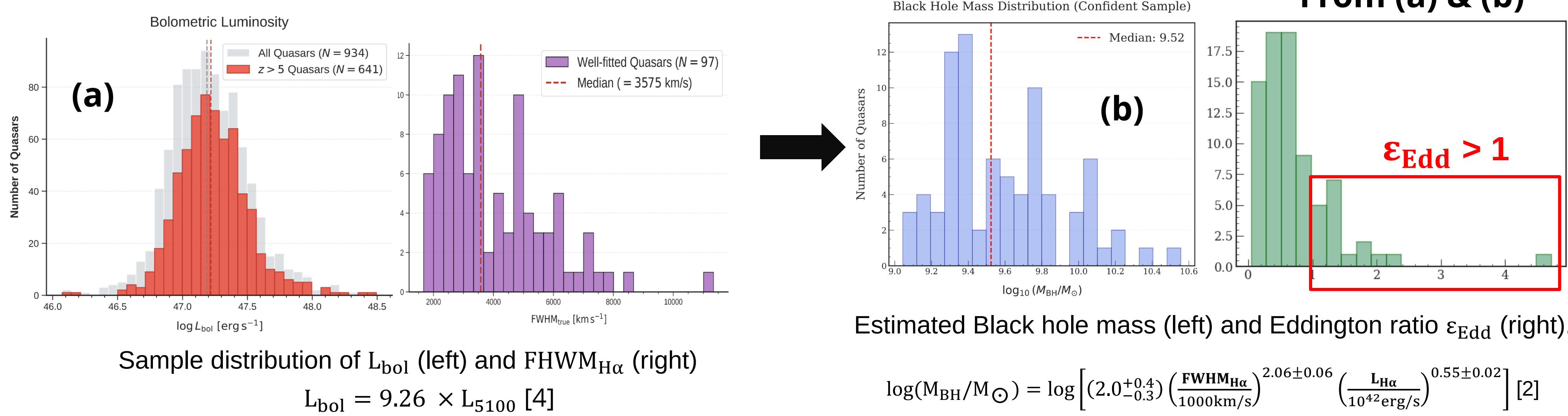
We derive L_{3000} to assess the continuum fitting quality and also $\text{FWHM}_{H_{\alpha}}$.

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



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

II. Distribution of $\text{FWHM}_{H_{\alpha}}$, Physical Implication of L_{bol} and M_{BH}



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

$$\log(M_{\text{BH}}/M_{\odot}) = \log \left[(2.0^{+0.4}_{-0.3}) \left(\frac{\text{FWHM}_{H_{\alpha}}}{1000 \text{ km/s}} \right)^{2.06 \pm 0.06} \left(\frac{L_{H_{\alpha}}}{10^{42} \text{ erg/s}} \right)^{0.55 \pm 0.02} \right] [2]$$

Conclusion

Spectrophotometric Identification of VHzQs.

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

Estimation of Physical Properties

- a. Based on confident H_{α} 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 ($\epsilon_{\text{Edd}} > 1$)

- a. They may originate from uncertainties in L_{bol} and M_{BH} estimation.



Future Plan

1. Integration of updated survey results to increase the effective survey depth. (Improved SNR)
2. Refinement of spectral modeling for underfitted sample by using double-Gaussian fitting.
3. Identification of anomalous VHzQs for high-resolution follow-up observations such as JWST.

References

[1] Bock et al. (2025) The SPHEREx Satellite Mission. [2] Liu et al. (2025) [3] Ross et al. (2020) [4] Fan et al. (2023) [5] Yang et al. (2024) [6] Davies et al. (2026) [7] Bitgsoni et al. (2017) [8] Richard et al. (2006)