# Measurments of black holes masses using photometry in high redshift quasars

Yanina López [1] Patricia Arévalo [1] Fuyan Bian [2] Samuel Lai [3]

[1]Instituto de Física y Astronomía, Universidad de Valparaíso, Chile
[2]European Southern Observatory
[3]Research School of Astronomy and Astrophysics, Australian National University

## Abstract

Quasars are extremely energetic and luminous active galactic nuclei, allowing their radiation emitted from the earliest times of the Universe to be detected. This work studied the measurements of black hole masses from **30 quasars in a redshift range of 5.8 < z < 6.6** belonging to the XQR-30 sample (The ultimate XSHOOTER quasar sample at the reionization epoch) part of the ESO Large Programs. For obtaining the masses, we used the **accretion disk model fitting with Slim and Thin models**, as well as **MCMC Bayesian interference** to limit the inherent degeneracies of the problem. This code uses **only photometric data**, so in principle, it can be a powerful tool for obtaining masses of large numbers of quasars without needing expensive spectra. The spectroscopic sample is used as a comparison between the Single-Epoch method for the mg II line with the results obtained in this study. **The lack of correlation** can be explained that, at least for **quasars at z>6.1**, the **absorption produced by neutral hydrogen** in the IGM severely affects the photometry, so the masses deviate from those expected, resulting in higher values.

## Research goal

- Determine the validity of the mass obtaining method through the adjustment of the spectral energy distribution (SED) with the use of photometric data, comparing the results obtained with those presented in the sample calculated with observational spectroscopy.

## Methodology: BADFit Code

To obtain the masses of the quasars we used the code BADFit (Black Hole Accretion Disk Fitting; Lai S. 2023), a code that uses two **XSPEC models** from the SHERPA module, **KERRBB** and **SLIMBH**, to generate the accretion disk fit from the photometric data. The code requires a file .CSV that must contains the flow density, error in the flow density, the wavelength in the rest-frame and the redshift of the object. After producing the possible models, the code uses **MCMC** to obtain the best set of values of the posterior distribution generated by the space parameter produced by the **mass, the rate of accretion or luminosity, the inclination and the spin**. The output include the model fit and histograms of probability distribution of the four parameters.

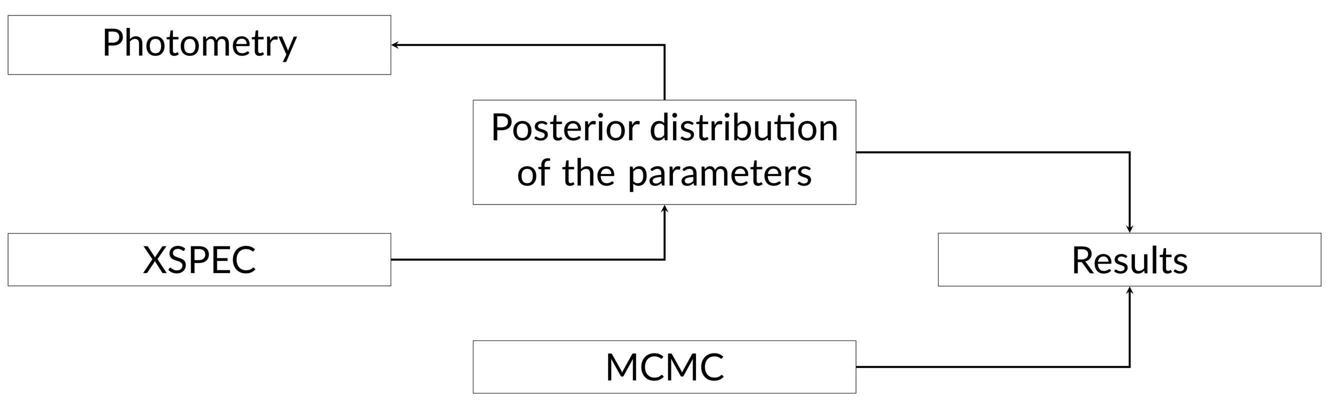


Figure 1. Summary of how the code works.

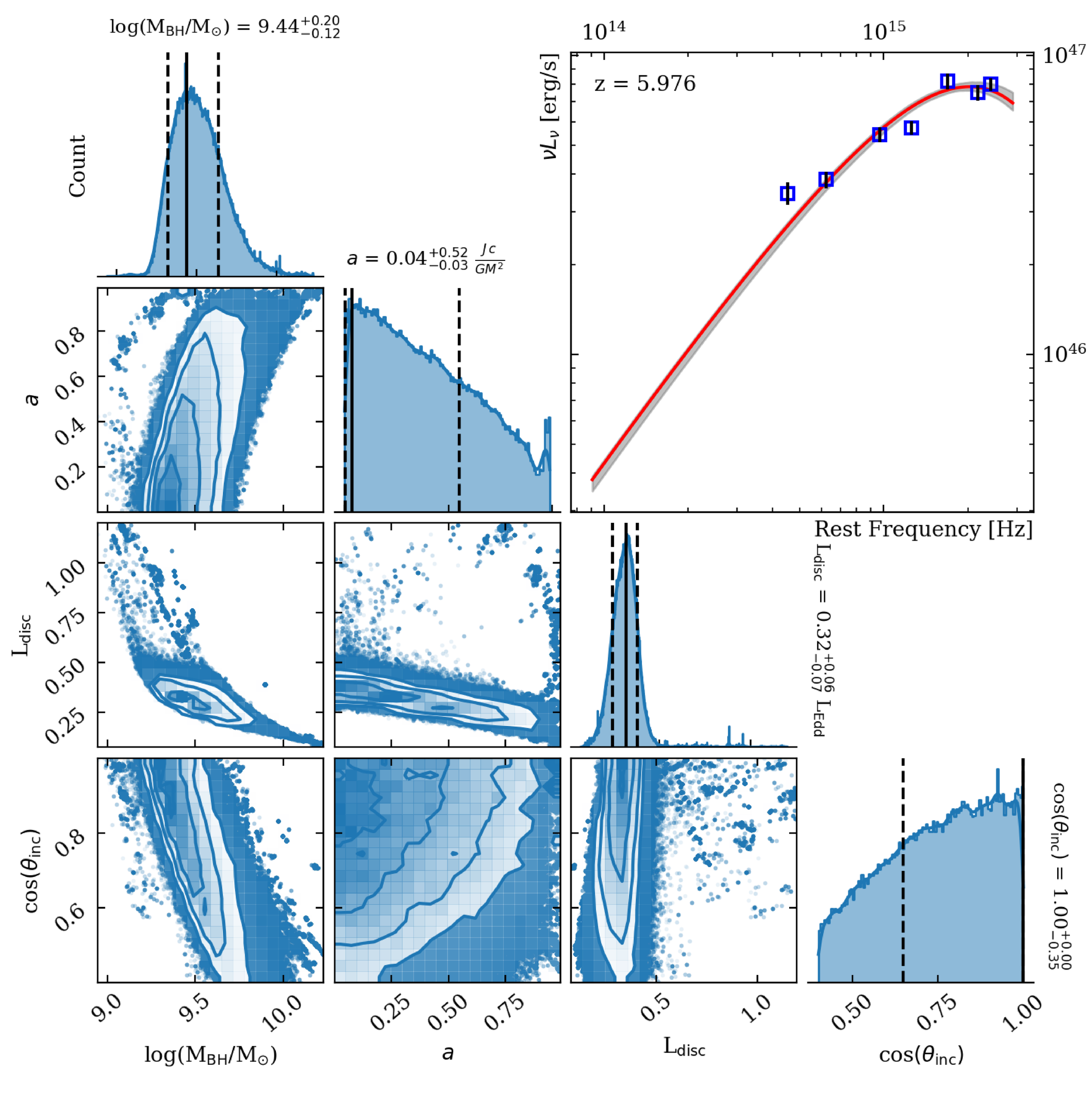


Figure 2. Example of the code output for the quasar PSO J029-29.

## Sample and data collection

The sample uses photometric data in the **J, H, K** bands to calibrate the spectra. To complement the photometry we search on catalogues available on VizieR web, also the data were managed with TOPCAT. The focus was on the infrared bands **z, y** and the **W1, W2** bands of WISE. Photometry was found for all objects in the desired bands, whose average magnitude is approximately 20 [mag].

## Results and discussion

The masses and luminosity/accretion rate were obtained for the 30 quasars of the sample. Both models gives similar results, with an average error of log $(M/M_\odot)$ = 0.2.

### Comparison with spectroscopic masses

The linear correlation coefficients Spearman and KS gives similar values of **ρ = 0.3 (p = 0.10)** and **KS = 0.33 (p = 0.07)**, indicating that the correlation between the masses is moderately low and not very significant. The **dispersion** of the points with respect to the black line is **2.06**, so the measurements are not consistent and the points are further apart than expected by the error bars.

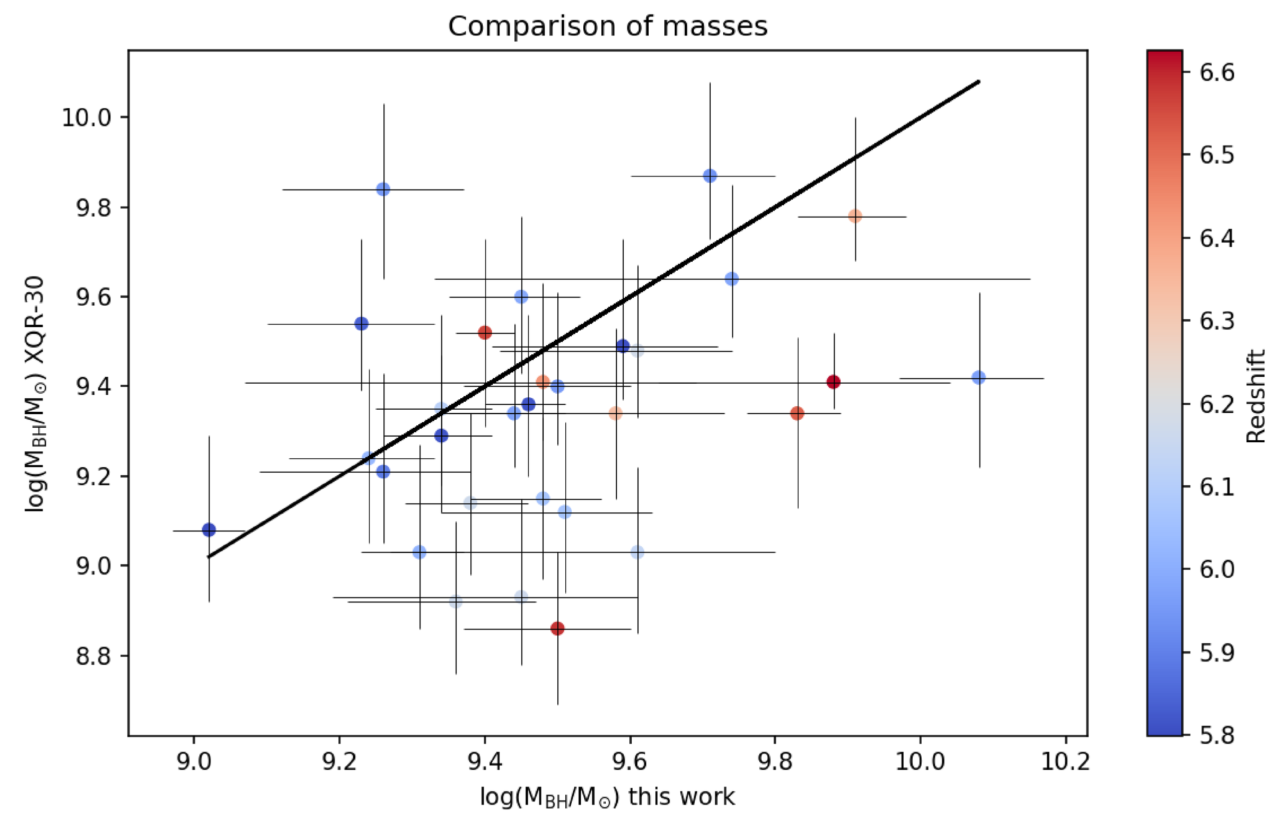


Figure 3. Comparison of the masses.The black line indicates the 1:1 ratio for the masses calculated with BADFit. The redshift is shown through the color bar..

The analysis is repeated considering objects at **z<6.1**, where values of **ρ = 0.37(p = 0.14)** and **KS = 0.24(p = 0.75)** are obtained, indicating a small improvement in the correlation but a decrease in significance. The **dispersion** of the points for the sub sample has a value of **1.59**, which can be interpreted as an increase in the consistency of the data.

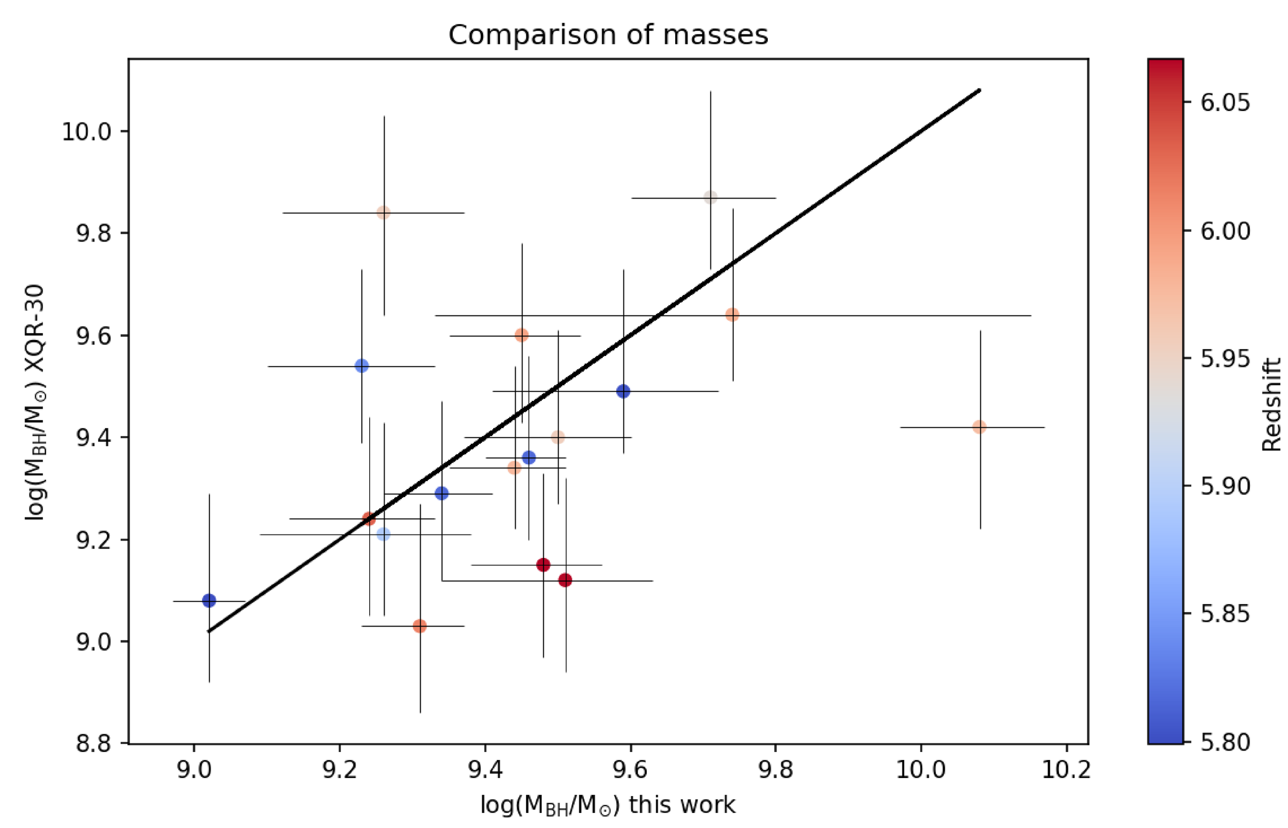


Figure 4. Comparison of the masses oonsidering the subsample of quasars at redshift less than 6.1.

## Conclusions

- We have proved that both luminosity and mass can be obtained well **without needing** for a well-defined spin and inclination.
- The method used provided **consistent results** in **mass** and **luminosity** for the two disc models, where all values are within the error.
- The **comparison** between our measurements and spectroscopic measurements does **not show strong correlation** or consistency when applying the Spearman and KS coefficients and the dispersion test.
- Considering masses below **z ∼ 6.1** shows low correlation and lower significance, but the dispersion test indicates **higher consistency**.
- In quasars at **z>6** the **Gunn-Peterson effect** affects the measurements, resulting in larger masses.