

## Black holes and accretion disk parameters

1. This part of the assignment is designed as a guide for estimating black hole mass using *scaling relations derived from reverberation mapping studies*.

You are given a sample of 500 quasars with a selection of measured spectral parameters from Shen et al. (2011), including SDSS spectral identification numbers (mjd, plate, fiber) and full width at half maximum of H $\beta$  line<sup>1</sup>. Other parameters, like H $\beta$  line luminosity, bolometric luminosity, black hole masses, and Eddington ratio are provided as a reference for comparison to the values you calculate yourself. See Shen et al. (2011) catalog for detailed description of these and other parameters. For the purpose of this exercise, you are allowed to use only FWHM H $\beta$  for your calculations.

a) To begin, cross-match provided catalog with SDSS to obtain H $\beta$  flux and redshift. Do some exploratory data analysis of the sample: plot redshift and FWHM distribution of the sample, plot i-band magnitude vs. redshift, and describe sample limitations in terms of these plots and parameters (hint: pandas is useful for this).

b) Next, using the provided FWHM and SDSS data, find:

- The luminosity of the H $\beta$  emission line. For this, you will need to calculate the luminosity distance for each object using formulas given by Hogg (2000). For cosmological constants, use ones from Planck ( $H_0=67.8$  km/s Mpc,  $\Omega_m=0.31$ ,  $\Omega_\lambda=0.69$ ). Using luminosity distance, H $\beta$  flux and redshift, find the luminosity of the H $\beta$  emission line.
- Using the empirical relation from Section 3 in Wu (2009), calculate black hole mass using the luminosity of the H $\beta$  line and FWHM H $\beta$ . You should elaborate on the assumption you have to make to use this relation.
- Estimate the Eddington luminosity and Eddington ratio after having derived the bolometric luminosity (e.g., use empirical relations from Wu 2009).

c) How would you describe these AGNs based on the properties you found? Provide histograms of obtained black hole masses and Eddington ratios. Present your results as in Figure 2 from Wu (2009), and Figure 7 from McLure & Dunlop (2002), or on any plots that you find appropriate to illustrate your conclusions. Optionally, you can compare your values to values from Shen et al. (2011).

---

<sup>1</sup> Optionally, you are invited to test for a selected object from the given sample, what would you get for the H $\beta$  FWHM with your own spectral analysis with FANTASY.

2. In this part of the assignment you will learn how to *estimate black hole mass from galactic host bulge luminosity*. It is useful in cases when you don't have spectroscopic data for broad emission lines.

Calculate black hole mass for at least 10 objects from Wu (2009) using the relation between black hole mass and host galaxy absolute magnitude in the R band given in Wu (2009) and proposed by McLure & Dunlop (2002). Elaborate on the assumptions you have to make in order to use this relation. You will need to obtain magnitudes in Johnson-Cousins photometric system (e.g., you can try searching the [NED database](#)). Additionally, find the Eddington ratio and plot it against obtained black hole masses. Optionally, you can plot your black hole mass and Eddington ratio estimates against ones from Wu et al. (2009) and discuss what you find.

**It is preferred to create a report in the form of a Jupyter notebook (with text describing the steps you take, code and plots), but other formats are also accepted.**

**Please submit your report by April 7<sup>th</sup> 2023, 23:59h.**

References:

Hogg 2000; <https://arxiv.org/abs/astro-ph/9905116>

McLure & Dunlop 2002; <http://adsabs.harvard.edu/abs/2002MNRAS.331..795M>

Shen et al. 2011 paper; <https://ui.adsabs.harvard.edu/abs/2011ApJS..194...45S/abstract>

Shen et al. 2011 catalog; <https://vizier.cds.unistra.fr/viz-bin/VizieR-3>

Wu 2009; <http://adsabs.harvard.edu/abs/2009MNRAS.398.1905W>

NED database: <https://ned.ipac.caltech.edu/>

SDSS DR18: <https://skyserver.sdss.org/dr18/>