

FeII strength in NLS1s – dependence on the viewing angle and FWHM(H β)

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Abstract. We address the effect of orientation of the accretion disk plane and the geometry of the broad line region (BLR) in the context of understanding the distribution of quasars along their Main Sequence. We utilize the photoionization code CLOUDY to model the BLR, incorporating the ‘un-constant’ virial factor. We show the preliminary results of the analysis to highlight the co-dependence of the Eigenvector 1 parameter, R_{FeII} on the broad H β FWHM (i.e. the line dispersion) and the inclination angle (θ), assuming fixed values for the Eddington ratio ($L_{\text{bol}}/L_{\text{Edd}}$), black hole mass (M_{BH}), spectral energy distribution (SED) shape, cloud density (n_{H}) and composition.†

Keywords. accretion; accretion disks; radiation mechanisms: thermal; radiative transfer; galaxies: active; (galaxies:) quasars: emission lines; galaxies: Seyfert

1. Introduction

Narrow-Line Seyfert 1 (NLS1) galaxies constitute a typical class of Type-1 active galaxies which have “narrow” broad profiles (e.g. $\text{FWHM}(\text{H}\beta) < 2000 \text{ km s}^{-1}$) and contain supermassive black holes (BH) that have masses lower than the typical broad-line Seyfert galaxies (Marziani *et al.* 2014; Shen & Ho 2014). Having a lower-than typical mass is a result of how the black hole mass (M_{BH}) is estimated. One of the methods to estimate the M_{BH} is the dynamical method that involves the use of the virial relation (Chen *et al.* 2019). According to this, the M_{BH} is a function of (i) the size of the emitting region, here, the broad-line region (BLR); and (ii) the $\text{FWHM}(\text{H}\beta)$ of the virialized gas. The size of the BLR (i.e. R_{BLR}) is measured by estimating the light-travel time from the central ionizing source to the emitting medium. This method is known as reverberation mapping (Peterson 1993). The other quantity, the line FWHM, can be measured reliably from high quality spectroscopy.

Since, the emitting line regions of quasars are extended, the energy that an observer receives from these luminous objects is also dependent on the geometry of the source with respect to the observer. By geometry, we mean the structure and how this structure is oriented to the observer’s line of sight. We address this aspect of the geometry of the quasars using photoionisation modelling with CLOUDY v17.01 (Ferland *et al.* 2017) in

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the context of understanding better the main sequence of quasars (see Panda *et al.* 2019, 2020 for more information).

The eigenvector 1 of the original principal component analysis (PCA) paved way for the quasar main sequence picture as we know it today (Sulentic *et al.* 2000; Shen & Ho 2014). The main sequence connects the velocity profile of ‘broad’ H β with the strength of the FeII emission (R_{FeII}), i.e., the intensity of the FeII blend within 4434–4684 Å normalized with the ‘broad’ H β intensity.

2. Method

We assume a single cloud model where the density (n_{H}) of the ionized gas cloud is varied from 10^9 cm^{-3} to 10^{13} cm^{-3} with a step-size of 0.25 (in log-scale). We utilize the *GASS10* model (Grevesse *et al.* 2010) to recover the solar-like abundances and vary the metallicity within the gas cloud, going from a sub-solar type ($0.1 Z_{\odot}$) to super-solar ($100 Z_{\odot}$) with a step-size of 0.25 (in log-scale). The total luminosity of the ionizing continuum is derived assuming a value of the Eddington ratio ($L_{\text{bol}}/L_{\text{Edd}} = 0.25$) and the respective value for the black hole mass ($M_{\text{BH}} = 10^8 M_{\odot}$). The Eddington ratio is appropriate for sources of Population A (Sulentic *et al.* 2000; Marziani *et al.* 2014). The M_{BH} is representative of optically-selected low- z quasar samples. The shape of the ionizing continuum used here is taken from Korista *et al.* (1997). The size of the BLR is estimated from the virial relation, assuming a black hole mass, a distribution in the viewing angle [0–90 degrees] and FWHM of H β which is given as:

$$R_{\text{BLR}} = \frac{GM_{\text{BH}}}{f * \text{FWHM}(\text{H}\beta)^2}, \quad (2.1)$$

where G is the gravitational constant. The f factor, which contains the information about the geometry of the source, can be expressed as:

$$f = \frac{1}{4[\kappa^2 + \sin^2\theta]}, \quad (2.2)$$

where, θ is the angle of inclination with respect to the observer and κ is the ratio between v_{iso} and v_{K} , which decides how isotropic the gas distribution is around the central potential. If the value is close to zero, it represents a flat disk with thickness almost zero. On the other hand, if the value of κ is close to unity, it represents an almost spherical distribution of the gas. Here, we assume $\kappa = 0.1$ that is consistent with a flat, Keplerian-like gas distribution.

Substituting the values for the M_{BH} and κ , we have

$$R_{\text{BLR}} \approx 5.31 \times 10^{24} \left[\frac{0.01 + \sin^2\theta}{\text{FWHM}(\text{H}\beta)^2} \right] \quad (\text{in cm}) \quad (2.3)$$

3. Results and Conclusions

Figure 1 shows dependence of the R_{FeII} both on $\text{FWHM}(\text{H}\beta)$ and θ . R_{FeII} values are anti-correlated with the $\text{FWHM}(\text{H}\beta)$. This is directly coming from the Eq. 2.3, where the R_{BLR} is anti-correlated with the square of the $\text{FWHM}(\text{H}\beta)$, but also correlates with θ which shows that if R_{BLR} is too low, the ionizing radiation is too high for the FeII species to exist and the emitting zones of the FeII only begins to materialize deeper in the cloud (see Panda *et al.* 2018). This effect reduces the R_{FeII} for lower R_{BLR} values. θ is $< 60^\circ$ for Type-1 quasars. Within this limit, we find an increasing trend in R_{FeII} with respect to θ . This trend is more substantial for lower values of the $\text{FWHM}(\text{H}\beta)$ that are consistent with NLS1 population, i.e. $\lesssim 3000 \text{ km s}^{-1}$. These results are described and analyzed in Panda *et al.* (2019b).

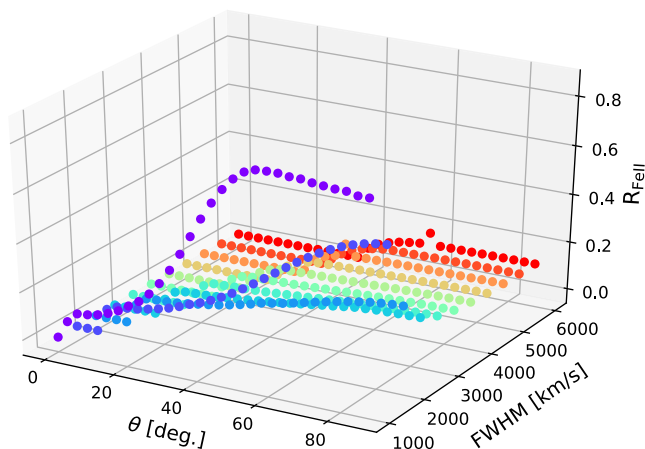


Figure 1. 3D scatter plot showing the dependence of the parameter R_{FeII} on the $\text{H}\beta$ FWHM and the inclination angle (θ). The $\text{H}\beta$ FWHM ranges from 1000 km s^{-1} to 6000 km s^{-1} with a step size of 500 km s^{-1} . Similarly, the θ values range from 0° - 90° with a step size of 3° . The black hole mass is assumed to be $10^8 M_\odot$ and the Eddington ratio, $L_{\text{bol}}/L_{\text{Edd}} = 0.25$. The value of the $\kappa = 0.1$ consistent with a flat, Keplerian-like gas distribution around the central supermassive black hole.

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