The spectroscopic correlations and model of dusty hyperboloid with a thin disk

M. Lakićević & J. Kovačević Dojčinović, M. Stalevski & L. Č. Popović
Astronomical Observatory Belgrade, Volgina 7, 11060 Belgrade, Serbia

Introduction

Narrow line Seyfert galaxies (NLS1s) and the broad line active galactic nuclei (BLAGNs) have various differences. NLS1s have more polycyclic aromatic hydrocarbons (PAHs), more dust spirals and higher accretion rates, while BLAGNs have heavier black hole masses (M_{BH}), and higher optical, X-ray and UV luminosities. NLS1s have lower optical variability, higher X-ray variability and possibly a lower inclination, than the BLAGNs. It is believed that NLS1s are AGNs in the early stage of evolution (Mathur 2000, MNRAS, 314, 17) and that their black holes are growing. The correlations among FWHM(Hβ) and luminosities show different characteristics for NLS1s than for BLAGNs (see Lakićević et al. 2018, MNRAS, 478, 4068, L18). The cause of correlations can be 1) NLS1s and BLAGNs may be different type of objects, 2) the geometry of the system, where NLS1s may be seen under lower inclinations; for example model of thin dusty disc with dusty cones (see Stalevski et al. 2019, MNRAS, 484, 3334; S19) or 3) selection effect by mass such that NLS1s are objects with lighter M_{BH}, less confined, therefore harder to spot at higher inclinations. Here we explore if the inclination (*i*) of the AGN and the geometry of the model S19 have connection with FWHM(Hβ)-luminosity correlations, as well as with NLS1/BLAGN differences.

Recent discoveries show existence of the mid-infrared (MIR) bipolar structures erupting from the black holes (BHs). S19 model of AGN Circinus galaxy consists of the hyperboloid (conical) shells, with a cone angle of 30º, and the thin dusty disc (Fig. 1). Here, we assume that the cones are perpendicular to the broad line region.

The sample and method of analysis

The sample consists of Type 1 AGNs, that have available reverberation measurements, observed with InfraRed Spectrograph – IRS on Spitzer Space Telescope, and have available optical parameters FWHM(Hβ), L5100 (luminosity at 5100 A) and M_{BH} in the literature. MIR parameters (fractional contribution of PAH component to the integrated 5-15μm luminosity, RPAH and monochromatic luminosity of the source at 6 μm, L6) were calculated using deblendIRS code (Hernán-Caballero et al. 2015, ApJ, 803, 109). The inclination was found using formula $\mathrm{Sin}(i)= \sigma(R_{BLR} / M_{BH} \times G)^{1/2}$ (see Afanasiev et al. 2019, MNRAS, 482, 4985).

The assumption is that model from S19 is observed under the different *i* and the observed surface of the AGN is changing with *i*, therefore it is likely that the luminosity depends on *i* and that FWHM(Hβ)--luminosity correlations are the consequence of that. It is shown that FWHM(Hβ) depends on *i*.

Results

In Fig. 2 we present the correlation between FWHM(Hβ) and inclination for our sample (similar as in Zhang, & Wu 2002, Chin. J. A&A, 2, 487). We use the model of dusty thin disc with a dusty hyperboloid shell (S19, Fig. 1). In Fig. 3 there are projections of a model from S19, seen under different *i*. We notice that the observed surface is changing with *i,* as one can see in Fig. 4a. Here it is assumed that the luminosity is proportional to the observed surface of the model, while the optical depth is neglected. In Fig. 4b the same approximation of luminosity is given, but here the optical depth is included as the intensity ~ $e^{-\tau}$.

In Figs. 5a and 5b there are relations between FWHM(Hβ) and luminosities L6 and L5100, respectively (data from L18), where the boundary is around 4000 km s^{-1}: FWHM(Hβ)<4000 km s^{-1} have correlations, while higher FWHM(Hβ) do not have them. These plots are similar to the ones from Fig 4.

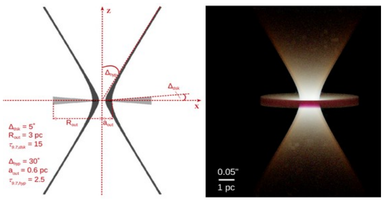

Figure 1. AGN MIR model as hyperboloid shell with a thin dusty disc, from the paper S19.

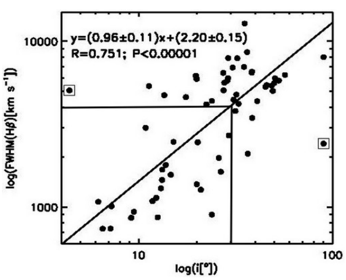

Figure 2. FWHM(Hβ) compared to the inclination calculated from the spectroscopy.

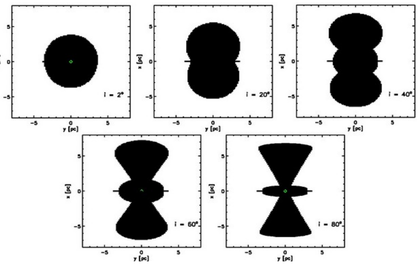

Figure 3. The model S19 seen under the different inclination angles.

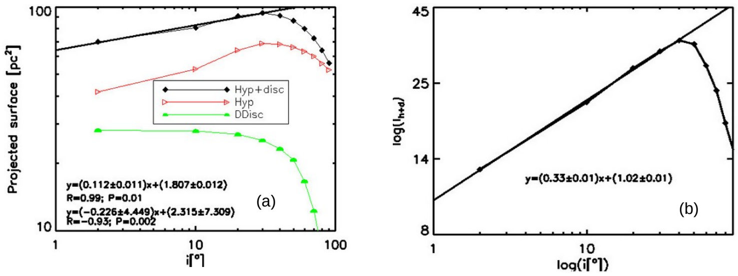

Figure 4: Projected surface changing with the inclination (a) and projected surface changing with inclination when the optical depth is included (b).

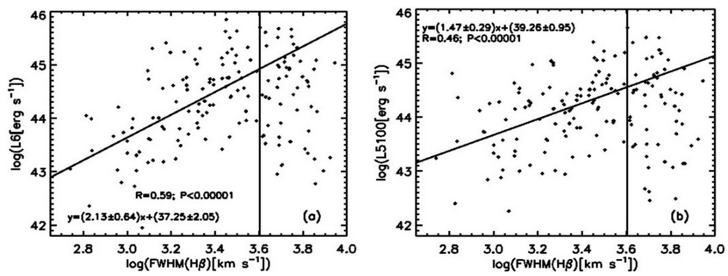

Figure 5. Relations FWHM(Hβ)–luminosity for (a) L6 and (b) L5100 for the dataset from L18. The boundary of ~4000 km s^{-1} corresponds to ~30º in Fig. 2.

Discussion

The similarity of the plots from the Fig. 4 with the ones in the Fig 5. is noticeable. This suggests that the geometry of the system (S19 model) together with the inclination angle may cause these FWHM(Hβ)–luminosity correlations. However, the slopes are significantly higher for the real data (Fig. 5) than in Fig. 4. There are several possible reasons for that. The first is that the diversity of the AGNs gives a larger scatter to the real data. The second reason is the possibility of the selection effect by mass such, that could also make the slope steeper, such that objects with lower BH masses (small inclinations) are not seen in larger inclinations as they are less confined systems. Similarly, it could be that massive AGNs are less visible in small *i* because of large optical depths.

The FWHM(Hβ)–luminosity correlations (Fig. 5) have the boundary at 4000 km s^{-1}, which matches to the cone angle from S19 model, which is 30º, according to the FWHM(Hβ)-*i* connection (Fig. 2), although the correlation fracture in Fig. 4 is around 40º. At *i*> 30 or 40º the observed surface becomes smaller and the luminosity should decrease, but possibly also the galactic contribution becomes more significant in the MIR.

Selection effect by mass or the geometry+inclination, together or one of them may be the cause for the FWHM(Hβ)–luminosity correlations. NLS1s can be the same objects as BLAGNs, but seen in smaller inclination angles.

Conclusion

The explanation for the FWHM(Hβ)–luminosity correlations may be in the geometry of the system (conical shell with a thin dusty disk; model from S19), or the selection effect by mass, where the AGNs with low M_{BH} are not seen in the higher inclination angles. The differences between NLS1s and BLAGNs may be only the consequence of a viewing angle.