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THE DISK EMISSION IN SINGLE PEAKED LINES FOR 12 AGNs

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SUMMARY: The disk emission in the single peaked Broad Emission Lines (BELs) of Active Galactic Nuclei (AGNs) is difficult to detect. In order to find the disk traces in BELs the line profiles were simulated by the simplified model consisting of two components: accretion disk and surrounding spherical region with isotropic velocities of clouds. The measurements of simulated profiles were compared with the measurements of observed single-peaked Hα and Hβ profiles of 12 AGNs, that had been previously confirmed to show the accretion disk presence in the X domain. The results are in agreement with previous investigations.

Key words. Galaxies: active – Line: formation – Plasmas

1. INTRODUCTION

According to the standard unification model (Urry and Padovani 1995), one could expect an accretion disk around the super-massive black hole in the center of an AGN. The presence of the accretion disk is difficult to detect. The broad Fe K_α emission line is usually broadened by the disk emission. Similar characteristics of the profiles can be found in broad emission lines (BELs). However, double peaked profiles are very rare. Less then 5% of AGNs possess broad double peaked emission lines in optical or UV domain of their spectra (Strateva et al. 2003). Predominant presence of single peaked lines in AGNs spectra does not necessarily mean that the part of the disk flux in emission line should be insignificant in the BELs. For example, for small inclination angles of accretion disks a single-peaked BEL could appear (see e.g. Chen and Halpern 1989, Dumont and Collin-Souffrin 1990, Kolatcshny 2003).

There are several effects which can explain the lack of the disk emission in the BEL profiles, for example the locally viscously dissipated power in the disk (Eracleous and Halpern 1994, 2003). Also, a Keplerian disk with a presence of a disk wind can produce single-peaked broad emission lines (Murray and Chiang 1997). Detailed studies about the BLR geometry are presented in Sulentic et al. (2000).

One possibility is that the disk emission is superimposed on emission of surrounding emitting region. This two component model describes very well these one-peaked lines (see Popović 2003, Popović et al. 2003, 2004, Bon 2005, Bon et al. 2006, Ilić et al. 2006).

The aim of this paper is to apply the method described in Bon et al. (2008), and also in Popović et al. (2008), to 12 AGNs that were previously fitted with the two component model (Bon et al. 2006, Popović et al. 2004), and to compare these results using the constraints derived from the fitting results (Bon et al. 2006, Popović et al. 2004).

2. NUMERICAL SIMULATION

The assumption that the BLR could be composed of two dynamically distinct components, the accretion disk and a surrounding region, with isotropic spherical velocity distribution (Popović et al. 2003, 2004, Bon et al. 2006, Ilić et al. 2006, Popović et al. 2008) has been taken as basic featueres of the model. For the disk emission profile, the Keplerian relativistic accretion disk model of Chen and Halpern (1989) was used.

In this model it was assumed that the kinematics of the additional emission region can be described as the emission of the spherical region with an isotropic velocity distribution, i.e. with a local broadening w_G and shift z_G. Consequently, the emission line profile can be described by a Gaussian function. The whole line profile can be described by:

$$I(\lambda) = I_{AD}(\lambda) + I_G(\lambda),$$

where $I_{AD}(\lambda)$, $I_G(\lambda)$ are the emissions of, respecively, the relativistic accretion disk and the additional region (more details in Popović et al 2004, Bon et al. 2006, Bon et al. 2008).

The flux ratio of the emissions from the spherical region ($F_{\rm s}$) the disk ($F_{\rm disk}$) and is given by the parameter $Q = \frac{F_{\rm s}}{F_{\rm disk}}$. The total flux is $F_{\rm tot} = F_{\rm disk} + F_{\rm s}$. In the simulations the various ratios of these fluxes $\frac{F_{\rm s}}{F_{\rm disk}}$ were considered, with the composite profile normalized to unity.

For each line profile, the full widths at 10%, 20%, 30% of maximal intensity were measured, and compared after being normalized to full width at half maximum,which was introduced by coefficients k_j (j = 10, 20, 30) as $k_{10} = w_{10\%}/w_{50\%}$, $k_{20} = w_{20\%}/w_{50\%}$ and $k_{30} = w_{30\%}/w_{50\%}$. It is obvious that the coefficients k_i are functions of the flux ratios Q and the parameters of disk model.

The measured coefficients k_j of the simulated spectra were compared to determine how they evolve with the model parameters. Then these results were compared with measurements of k_j for the observed profiles, to determine possible domains of model parameters. Therefore, in order to reduce the number of simulated profiles, some constraints and approximations were introduced (more details in Bon et al. 2008).

The parameters of the disk model were chosen to correspond to the fixed values of the parameter of the disk emission, p=3, since as explained in Bon et al. (2008), for the normalized spectra there were no significant changes in the shape of the profiles. Also, the broadening parameter of the Chen-Halpern disk model was fixed to the value of $\sigma = 1000$ km/s, together with the Gaussian broadening of the spherical region. The inner radius of the disk chosen to be $R_{\rm inn} = 400 R_{\rm G}$, since this was averaged values of this parameter in the previous fittings (Popović et al. 2004, Bon et al. 2006). For the outer radius, the chosen value was $R_{\rm out} = 3000\ R_{\rm G}$, although the averaged outer radius for the sample was about 30000 (Bon et al. 2006). This choice is justified since variation of this parameter, above several thousand gravitational radii, have not been found to have significant influence on the shape of the line (in particular, if the line is noisy, such an influence would be hard to determine). In addition the smaller outer radious reduces the calculation time for the simulation of profiles. These values correspond to the values of averaged disk parameters of Eracleous and Halpern (2003) fitting results for the set of double peaked radio loud AGNs. Since these AGNs had two broad peaks (dominant disk accretion), profiles of these lines would corespond to the flux parameter $Q < 0.1$ in this two component model (as for the case without Gaussian, or negligible emission of the Gaussian component).

After defining the domains and aproximations for parameters, it was possible to monitor the changes of inclination i and the flux ratio Q by measuring the coefficients k for both simulated and observed profiles.

3. OBSERVATIONS AND DATA REDUCTION

The observations were performed with the 2.5 m Isaac Newton Telescope (INT) at La Palma in January 2002 (12 AGNs sample) and in 1998 (III Zw2). We also used HST observations obtained with the Space Telescope Imaging Spectrograph (STIS) in January 2000 (NGC 3516). The spectral resolution was ~ 1 Å. We observed the Hα and Hβ line regions for all galaxies, except Mrk 141 where only the Hα region was observed. For III Zw2, only the Hβ line was used. Also, after calibration of the spectra, the Hβ line of Mrk 493 was too weak and the red wing of the 3C 273 Hα was too noisy, and for these two spectra we used the low resolution spectra observed with the HST (on Sep 4, 1996 and Jan 31, 1999) with G400 and G750L gratings, respectively. The narrow and satellite lines were removed as described in the Hα and the Hβ (Popović et al. 2001, 2002, 2003, 2004).

It is very important to notice that the two peaks produced by the disk may appear as two bumps in blue and red parts of the Hα and Hβ line profiles. To find the line substructure containing the disk emission, one should obtain the spectral lines with a relatively high spectral resolution and S/N ratio. We observed 12 AGNs (see Table 1) with the INT, which have been previously observed in the X-ray band (Fe Kα line; see e.g. Nandra et al 1997, Sulentic 1998). According to these results, one can expect that the disklike feteure is present at least in the X-ray emitting region, i.e. that a disk exists, whose signature might be observed in optical lines (emission from the outer part of the disk). The observed AGNs have no double-peaked Hα and Hβ lines.

After narrow line subtraction, the software package DIPSO[1] was used for reducing the level of the local continuum (by using the DIPSO routine 'cdraw'), while the 'sm' routine was used for Gaussian smoothing (as a noise subtraction). Thus the measurement of the coefficients could be performed in the same way as for the simulated spectra.

[1] http://www.starlink.rl.ac.uk/

The redshifts of the considered AGNs were taken from Veron et al. (2000).

3.1. Results and discussion

The measurements of widths at 10%, 20%, 30% and 50%, were used to calculate the coefficients k_i, disk size parameters were $R_{\rm inn} = 400\ R_{\rm G}$ and $R_{\rm out} = 3000\ R_{\rm G}$. Also, that the emissivity was kept constant (p=3).

In Fig. 1 we present k_{10} vs. k_{20} and k_{10} vs. k_{30} measurements of the broad components of the Hα and Hβ lines for each AGN from the sample. With lines we plotted measurements of the simulated profiles for different disk inclinations i and flux ratios Q. As one can see, the majority of the measured points are between $0.5 < Q < 1.5$, and $10^\circ < i < 25^\circ$ (see histograms presented in Fig. 2). There was no significant change for the varying values of the outer radii of the disk ring as well as the size of the disk emitting region.

After plotting the measurements, we concluded that this method could not be applied some of the data. These were measurements of highly noisy profiles or profiles with some problems in removal of the blending lines (Mrk 817, Hβ profiles for Mrk 1040, Mrk 141, Mrk 841, and Hα of 3c273). These measurements were not presented in the analysis.

For the cases where both lines (Hα and Hβ) could be measured, it was found that the estimates of the inclinations were nearly the same, but the flux ratios of the disk and of the other component differed (see Table 1). This indicates that both lines originate from the disk, since they have nearly the same values of parameters, but with slight flux differences.

Table 1. The observed profiles with labels of AGNs, spectral lines, inclination i, and flux ratio Q of disk and surrounding clouds.

Object	line	i	Q
3C 120	Hα	21.5 ± 0.5	1.1 ± 0.3
3C 120	Hβ	21.2 ± 0.2	1.15 ± 0.05
3C 273	Hα	18.9 ± 0.3	1.4 ± 0.5
3C 273	Hβ	19.8 ± 0.3	1.0 ± 0.1
Mrk 1040	Hα	17.7 ± 0.2	0.75 ± 0.05
Mrk 110	Hα	16.5 ± 0.1	1.45 ± 0.05
Mrk 110	Hβ	17.3 ± 0.2	1.5 ± 0.2
Mrk 141	Hα	17.2 ± 0.6	0.65 ± 0.05
Mrk 493	Hα	22.0 ± 0.1	1.1 ± 0.1
Mrk 841	Hα	14.5 ± 0.5	0.55 ± 0.05
Ngc 3227	Hα	12.2 ± 0.1	1.7 ± 0.2
Ngc 3227	Hβ	15.6 ± 0.1	1.45 ± 0.05
Ngc 4253	Hα	17.9 ± 0.1	1.1 ± 0.1
Ngc 4253	Hβ	20.5 ± 0.2	1.8 ± 0.2
Pg 1116	Hβ	18.3 ± 0.3	1.6 ± 0.3
Pg 1211	Hα	24.5 ± 0.1	1.1 ± 0.3
Pg 1211	Hβ	24.2 ± 0.2	1.05 ± 0.3
III Zw2	Hβ	19.0 ± 0.3	1.0 ± 0.3

For each AGN from the sample, the disk inclination and the fraction of the disk emission (Q) were roughly estimated, for above mentioned simulations, taking the matrix (i, Q) for three values of k_i and finding six values of the disk inclination i and Q. The obtained values of i and Q and their standard deviations for each AGN are given in Table 1.

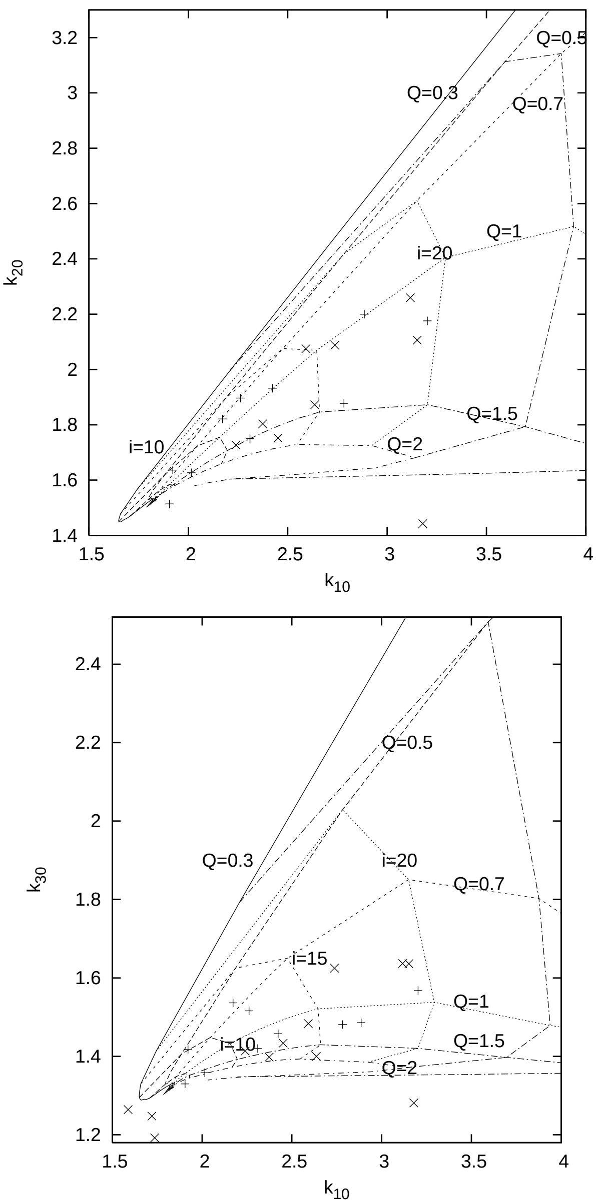

Fig. 1. *The coefficients k_{10} vs. k_{20} (top) and k_{10} vs. k_{30} (bottom) and for the sample of observed spectra ("+" corresponds to Hα, while Hβ is represented with "x"), and for the simulated profiles (represented by lines). Different inclinations were considered, while each line corresponds to the different flux ratios ($F_{\rm disk}/F_{\rm sph}$) of 0.3, 0.5, 0.7, 1, 1.5 from top to bottom, respectively.*

The results show good agreement with the previous fitting results (see Bon et al. 2006, Popović et al. 2004), having smaller errors and values closer to the lower boundaries of inclinations in the results. This was expected, since these lower values were estimated in fitting with the emissivity value as the p=3. Also, as seen in the Table 1, in most cases the inclinations of both lines are similar, which is expected in the model, since they are originating from the same disk. Furthermore, there are no large differences in the flux ratios (Q), although the Hβ show slightly smaller Q then Hα, and this could mean that it is originating in less heated parts of AGNs (more from the spherical region). This is in agreement with the physics of the model.

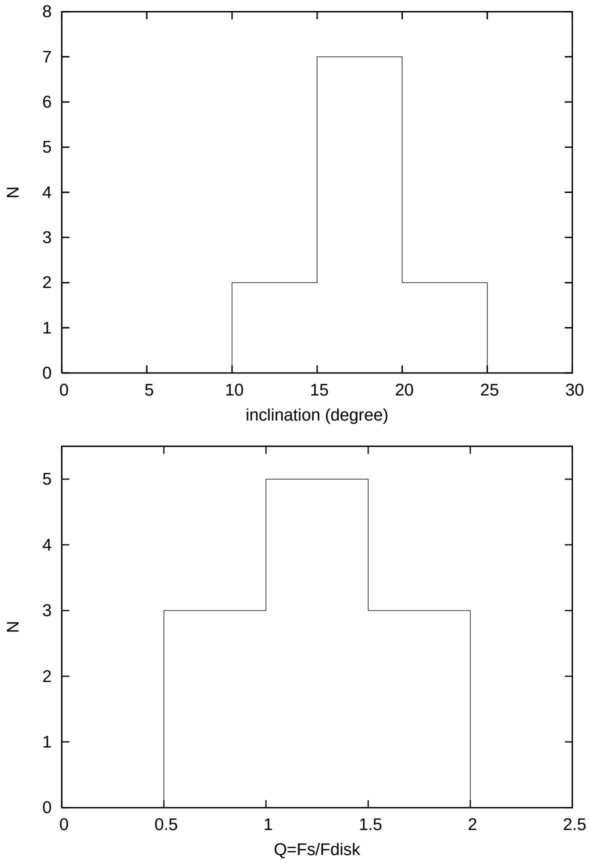

Fig. 2. *Histograms of the inclination i and* $Q = F_{\rm s}/F_{\rm disk}$.

4. CONCLUSIONS

In this paper, the method explained in more detail in Bon et al. (2008), has been applied on a sample of Balmer single peaked lines of 12 AGNs, in order to find the disk emission and to compare the results with the previous investigations by Popović et al. (2004) and Bon et al. (2006).

It was concluded that:

1) the inclinations of considered 12 AGNs should be in the interval of $12° < i < 25°$, what implies the nearly face-on disks;

2) the flux ratios of the disk and the spherical region emissions, were in the interval of $0.5 < F_{\rm disk}/F_{\rm sph} < 1.5$,

3) the estimates of the inclinations (for Hα and Hβ) were nearly equal (see Table 1), which confirms that both lines originated in the disk.

With this approach, after measuring coefficients k_{10}, k_{20} and k_{30} for different flux contributions of the disk and spherical region in simulated spectra, it could be concluded that the parameters k_j may be very useful for detection of the disk emission in the single peaked lines.

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ЕМИСИЈА ДИСКА У ЛИНИЈАМА СА ЈЕДНИМ ПИКОМ КОД 12 АКТИВНИХ ГАЛАКТИЧКИХ ЈЕЗГАРА

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Емисију диска код широких емисионих линија са једним пиком код активних галактичких језгара је релативно тешко уочити. У циљу откривања трагова диска у широким емисионим линијама симулирани су профили оваквих линија користећи поједностављен модел који се састоји од две компоненте: акрециони диск и сферна област са изотропном расподелом брзина која окружује акрециони диск. Мерења симулираних профила су упоређена са мерењима посматраних спектара са емисионим профилима са једним пиком, Hα и Hβ профилима, за 12 активних галактичких језгара, код којих је раније потврђено присуство акреционог диска у X-области спектра. Добијени резултати су у сагласности са претходним истраживањима.