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THE BROAD EMISSION LINES IN AGN: HIDDEN DISK EMISSION

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RESUMEN

Se discute la posible presencia de emisión del disco en la región de líneas anchas de los núcleos activos de galaxias, aún cuando sólo posean líneas anchas con un solo pico. Se propone un modelo con dos componentes suponiendo que existen dos regiones que contribuyen a las líneas de emisión anchas: la emisión de un disco y la emisión de una región con un campo de velocidades isotrópico. Simulamos los perfiles de línea y los comparamos con los observados. Resulta que aunque la emisión del disco si puede contribuir a las líneas anchas de emisión con un solo pico, la contribución del disco es menor que un 70% del flujo total de la línea y la inclinación del disco debe ser menor que 20°.

ABSTRACT

Here we discuss possibility that a disk emission is present in the Broad Emission Lines (BELs) of Active Galactic Nuclei (AGN), even if they have only broad single-peaked lines. We introduce a two-component model assuming that two regions contribute to the BELs: a disk emission and an emission region with isotropic velocity field. Then we simulate the line profiles and compare them with observed ones. We found that the disk emission may be present in the broad single peaked lines, but the disk contribution tends to be smaller than 70% of the total line flux and the disk inclination seems to be smaller than 20°.

Key Words: accretion, accretion disks — galaxies: active — galaxies: nuclei — quasars: emission lines

1. INTRODUCTION

In the last years, arguments supporting the presence of disk winds show the ability to explain a number of observed phenomena such as X-ray and UV absorption, line emission, reverberation results, and some differences among Seyfert galaxies, quasars, broad-line radio galaxies, and the presence or absence of double-peaked emission-line profiles (see e.g. Murray & Chiang 1995, 1997, 1998; Proga & Kallman 2004). Therefore, one can expect that a BLR is composed from two dynamically distinct components, a disk and a wind. But, a small fraction of AGN (3–5%) clearly show a double peaked broad emission lines in their spectra (Strateva et al. 2003). The majority of AGN with BELs, have only one-peaked profiles, but this does not necessarily indicate that the contribution of the disk emission can be neglected in their profiles. It is well known that a disk with a small inclination angle also produces a single-peaked broad lines (see e.g. Dumot & Collin-Soufrin 1990). To explain very complex BELs, different geometrical models are discussed (see more details in Sulentic et al. 2000). In some cases the BEL profiles can be explained properly only if two or more kinematically different emission regions are considered to contribute to the line profiles (see e.g. Popović et al. 2004; Bon et al. 2006; Ilić 2006). Moreover, the existence of the Very Broad Line Region (VBLR) with random velocities at 5000–6000 $\mathrm{m\,s^{-1}}$ within an Intermediate Line Region (ILR) has been considered to explain BELs (Corbin & Boroson 1996).

Here, we present the investigation about possible hidden disk emission in BELs which show single peaked profiles.

2. THE MODEL

In order to simulate the line profiles, we use the Keplerian relativistic accretion disk model given by Chen et al. (1989). The emissivity of the disk as a function of radius, r, is given by $\epsilon = \epsilon_0 r^{-p}$. Since the assumed illumination is due to a point source radiating isotropically, located at the center of the disk, the flux in the outer disk at different radii should vary as r^{-3} (Eracleous & Halpern 2003). We note here that this is indeed the way the incident flux varies, but not necessarily the way in which the lines respond to it. However, the power index $p \approx 3$ can be adopted as a reasonable prescription at least for Hα (Eraclous & Halpern 2003).

We express the disk dimension in gravitational radii, $R_g = GM/c^2$, (with G the gravitational constant, M the mass of the central black hole, and c the velocity of light). The local broadening parameter (σ) and shift (z_l) within the disk have been taken into account as in Chen & Halpern (1989), i.e. the δ

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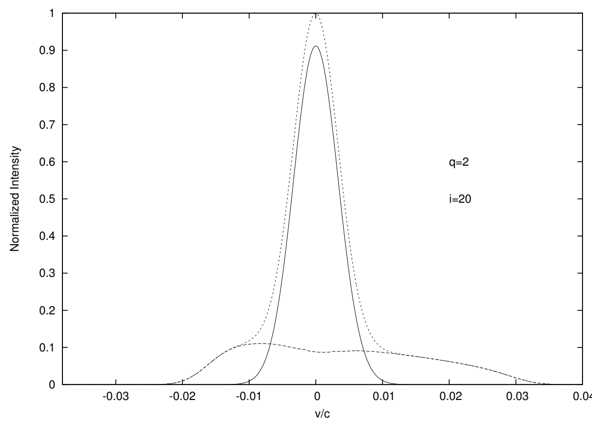

Fig. 1. Simulated line profiles (dashed line) emitted from the two-component model (disk emission is given the lower profile and spherical region emission is represented with the solid line). The flux of the disk emission is taken to be two times smaller than spherical one ($q = F_s/F_d = 2$). The inclination of the disk is taken as $i = 20°$. The inner radius $R_{inn} = 200\ Rg$ and outer $R_{out} = 5000\ Rg$. The intensity is scaled to 1, and at x-axis $v/c = (\lambda - \lambda_0)/\lambda_0$ is presented.

function has been replaced by a Gaussian function: $\delta \rightarrow \exp\frac{(\lambda-\lambda_0-z_l)^2}{2\sigma^2}$ where z_l and σ are the local shift and the broadening parameter of the disk emission.

On the other hand, we assume that the kinematics of the additional emission region can be described as the emission of a 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 the relation: $I(\lambda) = I_{AD}(\lambda) + I_G(\lambda)$, where $I_{AD}(\lambda)$, $I_G(\lambda)$ are the emissions of the relativistic accretion disk and of an additional region, respectively.

According to Popović et al. (2004), one can expect that the random velocity dispersion in the disk is similar to that in surrounding region, consequently in our simulations we assumed that these velocities are the same for both regions.

3. RESULTS

Using the two-component model we did several simulations of the line profiles, taking different disk parameters and the flux ratios of the line emission from the disk (F_{disk}) and a spherical region (F_s) as $q = F_s/F_{disk}$ and considered the total flux (F_{tot}) as

$$F_{tot} = q \cdot F_{disk} + F_s\,. \tag{1}$$

The line profile was constructed as:

$$I_{tot}(\lambda) = \frac{I_{disk}(\lambda)}{F_{disk}} + \frac{I_s(\lambda)}{F_s}\,, \tag{2}$$

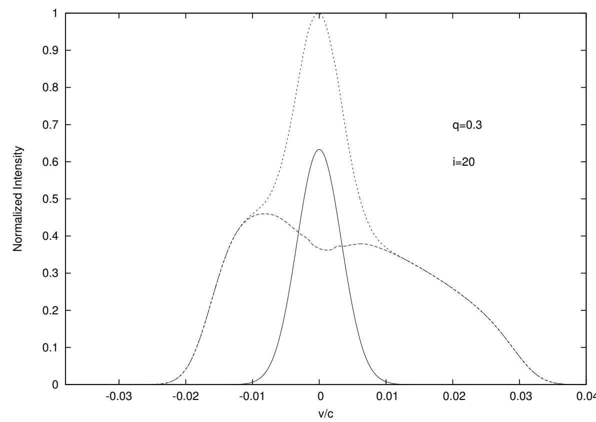

Fig. 2. The same as in Figure 1, but for higher fraction of the disk emission ($q = 0.3$).

where $I(\lambda)$ the intensity as function of wavelengths is given. The composite profile is normalized, taking

$$\Im(\lambda) = \frac{I_{tot}(\lambda)}{I_{tot}^{max}}\,, \tag{3}$$

where I_{tot}^{max} is the maximal intensity of the composite line.

To find some measurable values in the line profile where we have the disk plus an emission region we used parameters that can be measured from simulated and observed BEL profiles, such as:

(i) Full widths at 10%, 20%, 30% and 50% of maximal intensity of a composite profile, i.e. $w_{10\%}$, $w_{20\%}$, $w_{30\%}$ and $w_{50\%}$. Then we define coefficients k_i (i=10, 20, 30) normalized to the full width at half maximum (FWHM), 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 q value and the parameters of disk.

(ii) We measure asymmetry (A_i) at i =10%, 20%, 30% of maximal intensity of the modeled (and observed) lines as

$$A_i = \frac{W_i^R - W_i^B}{FWHM}\,, \tag{4}$$

where W_i^R and W_i^B are red and blue half widths at i = 10%, 20% and 30% of maximal intensity, respectively.

In Figures 1 and 2 we present examples of the composite line profiles as a result of the emission from the disk ($i = 20°$, $R_{inn} = 200$ Rg, and $R_{out} = 5000$ Rg) and the surrounding region, but with different q value.

From our simulation we can conclude:

(i) The disk contribution to the core or to the wings of a broad line depends first on the disk inclination. The contribution of the disk to center or to wings of a composite line is not so much sensitive to the outer radius, but significantly depends on the disk inclination. The face-on disk emission will contribute to the line core, while a higher inclined disk ($i > 10°$) contributes to the line wings. Also, we should note here that above $i > 40°$ the emission will affect strongly the wings of the composite profile.

(ii) We found that if the contribution of the disk is smaller than 30% in the total line emission, the contribution of the disk to the total line profile is hard to detect. In the case of a low inclined disk, this emission will contribute to the core of the line, and changes in the line profile of spherical region will be negligible, while in the case of a highly inclined disk, the emission will be in far wings and will act on the level of the continuum (see Figure 1). On the contrary, if the emission of the spherical region is smaller than 30% ($q < 0.3$), then the disk emission is dominant (see Figure 2), i.e. for lower inclination, the line will be shifted to the red, and for higher inclination, the two peaks, or at least shoulders should appear in the total line profile.

3.1. *Modeled vs. observed profiles*

In order to find hidden disk emission in broad single-peaked line profiles of AGN, we use a sample of 90 Sy1 AGN spectra taken from SDSS database (sample of La Mura et al. 2007), using the selection criteria as in the mentioned paper. We measured parameters k_i and A_i for the Hα line and compare them with ones obtained from simulated line profiles.

As an example, in Figure 3 we presented measured (crosses) and simulated (dashed lines) k_{20} and k_{10} values (k_{20} vs. k_{10}). Different values for disk inclinations (solid lines) and q are considered, where a disk with $R_{inn} = 200$ Rg and $R_{out} = 5000$ Rg has been assumed. As is shown in Figure 3, the majority of measured points are between $0.7 < q < 1.5$, and $0° < i < 20°$. This thend is found similar if we change inner and outer radii of the disk.

Comparing the observed and simulated profiles we found that the observed line profiles indicate that the disk emission can be present in the observed, broad, single-peaked line profiles, but inclination tends to be small $< 20°$ and the disk contribution to the total profile is smaller than 70%. An extensive study about the hidden disk emission will be presented elsewere (Bon, Popović, & Gavrilović, in preparation).

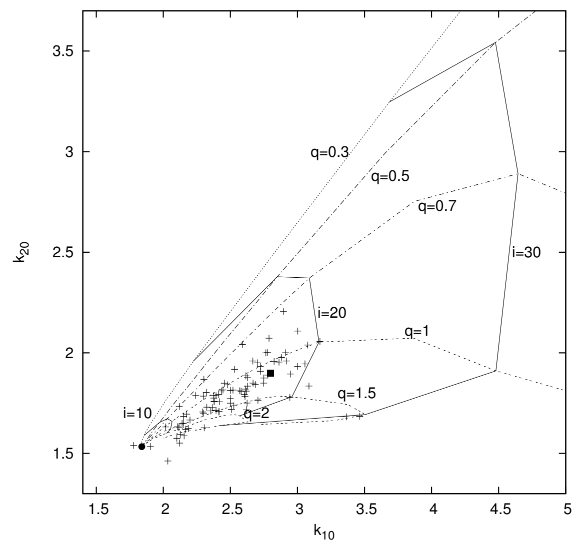

Fig. 3. The measured (crosses) width ratio for the Hα and simulated values (dashed lines) from the two-component model for different contribution of the disk emission to the total line flux (q=0.3, 0.5, 0.7, 1, 1.5 and 2). The inner disk radius is taken to be 200 Rg, outer 5000 Rg, and different inclinations are considered (solid line isophotes presented calculation for i= 10, 20 and 30 degrees).

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