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# LINE PROFILE VARIABILITY DUE TO PERTURBATIONS IN AGN ACCRETION DISK EMISSIVITY

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**Abstract.** In this paper we analyzed the observed variability of the broad double-peaked spectral lines of some Active Galactic Nuclei (AGN). We assumed that such lines originate from outer part of an accretion disk around massive black hole of AGN, and that line variability is caused by perturbations in the disk emissivity. The disk emissivity was studied using numerical simulations based on relativistic ray-tracing method, assuming a modification of power-law emissivity which allows us to introduce the perturbations in form of the bright spots. Our results show that this model of disk emissivity perturbations can satisfactorily reproduce the observed line variability.

## 1. INTRODUCTION

Broad, double-peaked emission lines provide dynamical evidence for presence of an accretion disk feeding a supermassive black hole in the center of AGN. Such line profiles are found in less than 5% of these objects (Gezari et al. 2007; Eracleous & Halpern 1994, 2003). Variability of disk emission is observed in the line profiles (see e.g. Shapovalova et al. 2001) on timescales from months to years (Flohic & Eracleous 2008; Gezari et al. 2007), and this variability does not appear to be correlated to changes in the continuum flux, so it likely traces changes in the accretion disk structure. Shapovalova et al (2001) found that sometimes, the observed H$\beta$ line profiles have prominent asymmetric wings, while at other times, they have profiles with weak, almost symmetrical wings. Also, they found that in some periods "blue" wing of H$\beta$ was brighter than the "red" one. Our goal is to model perturbations in an accretion disk emissivity which can produce the observed variations in the H$\beta$ line profiles.

## 2. MODELING OF DISK EMISSIVITY PERTURBATIONS

Many processes in the accretion disk may lead to perturbations in its emissivity, such as self gravity, disk-star collisions and baroclinic vorticity (Flohic & Eracleous 2008). For emissivity perturbing region we used bright spot model given by Jovanović & Popović (2008). We modeled emission from outer part of accretion disk in optical spectral band. In this case, there is no significant difference between Kerr and Schwarzschild metrics.

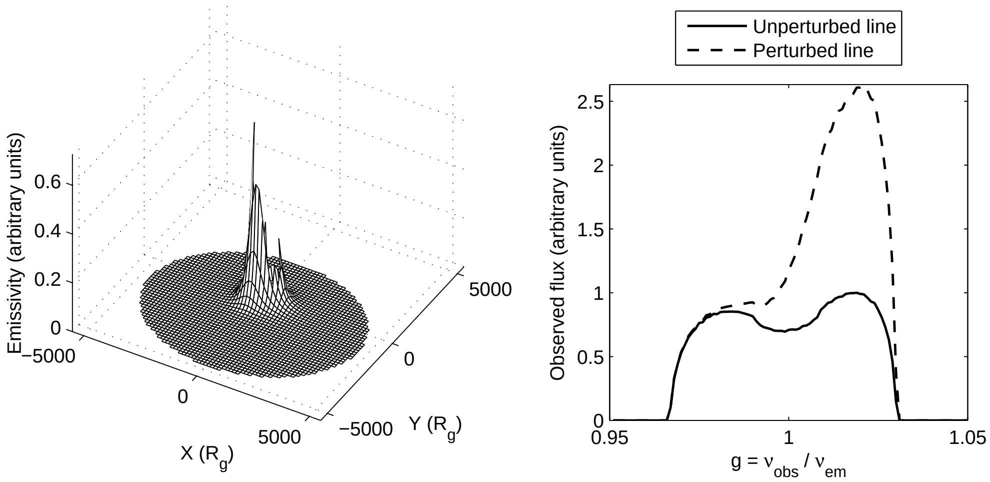


Figure 1: *Left*: Shape of perturbed emissivity of an accretion disk for the following parameters of perturbing region: $x_p = y_p = -550\ R_g$ and $w_x = w_y = 500\ R_g$. The values of the remaining parameters are given in §2. *Right:* The corresponding perturbed (dashed line) and unperturbed (solid line) H$\beta$ line profiles.

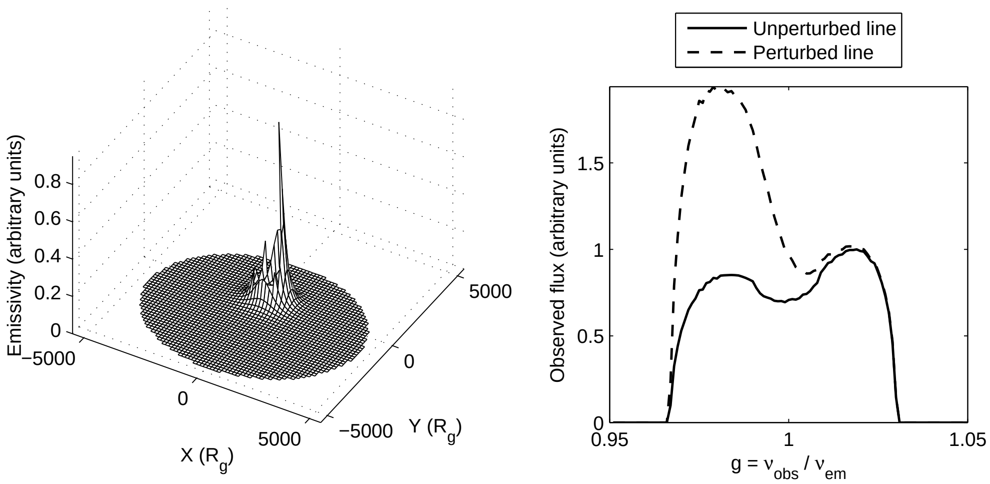


Figure 2: The same as in Fig. 1, but for the following position of perturbing region: $x_p = y_p = 550\ R_g$.

For numerical simulations in case of this disk perturbing model, the following parameters were used: disk inclination $i = 45°$, inner and outer radii of the disk $R_{in} = 500\ R_g$ and $R_{out} = 5000\ R_g$, emissivity constant $\varepsilon_0 = 1$, emissivity index $q = -3.5$ and the emissivity of perturbing region $\varepsilon_p = 5$. The widths of perturbing region are $w_x = w_y = 500\ R_g$. We performed simulations for different positions of perturbing region along $y = x$ direction, where $x_p$ and $y_p$ take values between 500 and 2500 $R_g$ and between -500 and -2500 $R_g$. Radial distances are measured in units of gravitational radius, $R_g = GM/c^2$, where $G$ is Newton gravitational constant, $M$ is the mass of central black hole and $c$ is the speed of light. Obtained results show that for adopted parameters the emissivity perturbations become insignificant outside 2500 $R_g$. Observed wavelength is given by $\lambda = \lambda_0/g$, where $\lambda_0 = 4861.32$ Å is transition wavelength of the H$\beta$ line and $g$ is energy shift due to relativistic effects which in our case, takes values between 0.95 and 1.05.

## 3. RESULTS AND DISCUSSION

The obtained results for two different positions of perturbing region are presented on left panels of Figs. 1. and 2, and the corresponding perturbed and unperturbed profiles of the H$\beta$ line are given in the right panels of the same Figs. As one can see from these Figs, the perturbing model has greater influence on one of the H$\beta$ line wings, the "blue" one in Fig. 1, or the "red" one in Fig. 2. The first case corresponds to the approaching side of the disk, while the second one corresponds to the receding side of the disk.

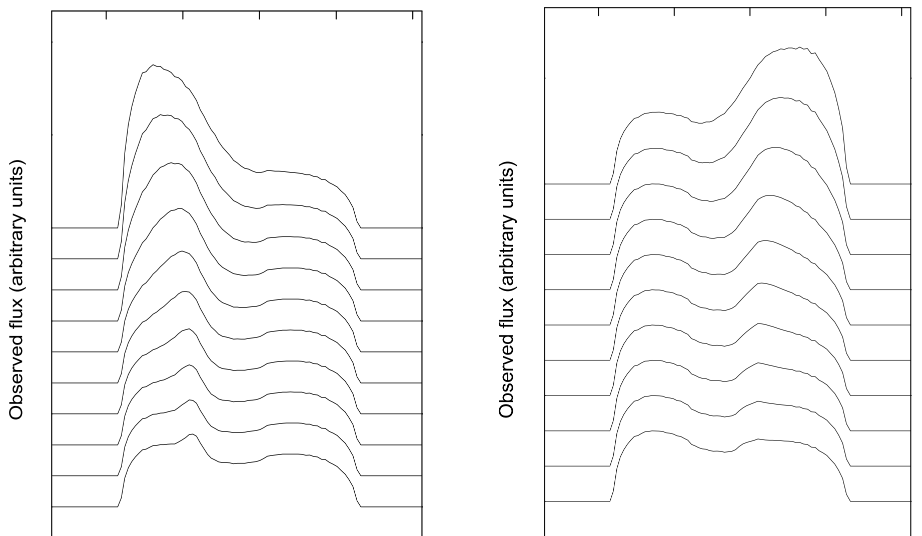


Figure 3: Variations of perturbed H$\beta$ line profile for different positions of the perturbing region (bright spot) along the $y = x$ direction. Left panel corresponds to the positions of perturbing region on approaching side of the disk, while the right panel corresponds to the receding side of the disk. In both cases, the positions of perturbing region are varied from the inner radius towards its outer radius.

Fig. 3. shows variations of the perturbed H$\beta$ line profiles for different positions of the perturbing region along the $y = x$ direction. For certain positions of perturbing region we obtained almost symmetrical wings (see middle profiles on the right panel of Fig. 3). In other cases either the "blue" wing is brighter than the "red" one (see top profiles in the left panel of Fig. 3) or the "red" peak is stronger than the "blue" one (see the top profiles in the right panel of Fig. 3). This is in a good agreement with the observed profiles of H$\beta$ line in the case of 3C 390.3 (see e.g. Fig. 8. in Shapovalova et al. 2001) where the similar variations were detected.

## 4. CONCLUSIONS

In this paper we performed numerical simulations in order to study the variability of the H$\beta$ spectral line due to emissivity perturbations. From these simulations we can conclude the following:

1. Observed variations of the H$\beta$ line could be caused by perturbations in the disk emissivity.
2. Depending on the position of the perturbing region, it has greater influence on one of the H$\beta$ line wings than on the other one.
3. Using the bright spot model for perturbation region we were able to reproduce the observed variations of the H$\beta$ line profile in the case of some AGN such as 3C 390.3.

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