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Stratification in the broad line region of AGN: The two-component model

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Abstract

Here we present our investigation of the kinematic structure of the broad emission line region (BLR) in a sample of 14 single-peaked Active Galactic Nuclei (AGN), which have been previously observed in the X-ray (Fe Kα line) and where, according to the X-ray emission, a disk geometry is expected. To explain the BLR complex structure we apply a two component model assuming that line wings originate in a very broad line region (VLRB) and the line core in an intermediate line region (ILR). The VLRB is assumed to be an accretion disk. The model can well describe the complex line shapes of the considered sample of AGN.

Keywords: AGN; BLR

Contents

1. Introduction

The concept of a disk geometry in the BLR is very attractive because of the most widely accepted model for AGN which includes a super-massive black hole fed by an accretion disk. Recently, Popović (2003) investigated the physical processes in BLR using a Boltzmann-plot method, and found that probably physical conditions in regions which contribute to the line core and line wings are different. This supports the idea that the broad optical lines originate in more than one emission region. The aim of this paper is to test the validity of the two-component model of the BLR which contains an accretion disk and one additional emission region, i.e. to try to find evidence that suggests that the disk emission can contribute to the line emission even if they have single-peaked line profiles. The AGN from the sample have been previously observed

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in the X-ray (Fe Kα line) and where, according to the X-ray emission, the disk geometry have been expected (Nandra et al., 1997). The observed AGN have no double-peaked Hα and Hβ lines.

2. Observations and data reduction

For 13 objects from the sample, the observations were performed with the 2.5 m INT at La Palma in 2002 (12 AGN sample) and 1998 (IIIZw2). Also, HST observations were used, obtained with the Space Telescope Imaging Spectrograph (STIS) on January 2000 (NGC 3516). The spectral resolution was 1 Å. The Hα and Hβ were observed for all galaxies, except Mrk 141 where only the Hα line was obtained. 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 use the low resolution spectra observed with the HST (on Sep 4, 1996 and Jan 31, 1999) with G400 and G750L gratings, respectively (Popović et al., 2004).

Standard reduction procedures including flat-fielding, wavelength calibration, spectral response, and sky subtraction were performed with the help of the IRAF software package.

The software package DIPSO was used for reducing the level of the local continuum (by using the DIPSO routine 'cdraw 1') fitted through the dots taken to be on the local continuum.

3. Line profile analysis

To analyze the shape of the Hβ and Hα lines, first each line was fitted with the sum of Gaussian components. The χ^2 minimalization routine was used to obtain the best fit parameters. Also it was assumed that the narrow emission lines can be represented by one or more Gaussian components. In the fitting procedure, a minimal number of Gaussian components were needed to fit the lines. To limit the number of free parameters in the fit some *a priori* constraints have been accepted as it was given in Popović et al. (2001, 2002, 2003).

4. Two-component model for the BLR

A two-component model can probably be represented by different geometries. Here we assumed the model where a disk contributes to the wings of the lines, and a spherical region contributes to the core of the lines. A Keplerian relativistic disk (Chen et al., 1989; Chen and Halpern, 1989) is assumed. The emissivity of the disk as a function of radius, R, is given by $\epsilon = \epsilon_0 R^{-p}$.

Generally, when trying to fit the double-peaked line profiles by disk emission one should leave the index p as a free parameter. But the two facts should be taken into account: (1) we have single-peaked lines here, i.e. the profile coming from the disk is not *a priori* well defined; (2) we are going to use a two-component model which includes more parameters than the disk model alone. We should therefore include some constraints. Since the 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 and Halpern, 1994). However, the power index $p \approx 3$ can be adopted as a reasonable prescription at least for Hα (Eracleous and Halpern, 2003). This assumption was used in the case of NGC 3516 and IIIZw2 (see Table 1, also Popović et al. (2002, 2003)). For the rest of the AGN from the sample, p was a free parameter. In Table 1, we give estimation for the minimal value of p.

The disk dimension have been expressed in gravitational radii ($R_g = GM/c^2$, G being the gravitational constant, M the mass of the central black hole, and c the velocity of

Table 1
The parameters of the disk obtained from the best fit of the *Hα* and *Hβ*

Object	i	$z_l^{\min,\max}$	$W_l^{\min,\max}$	$R_{\rm inn}^{\min}$	$R_{\rm out}^{\max}$	$z_G^{\min,\max}$	W_G	$p^{\min}$
3C 120	8–30	−300, +300	1050, 1500	350	20000	+30, +300	900 ± 150	2.0
3C 273	12–30<	−30, +300	690, 1760	400	15400	+30, +60	1380 ± 150	2.3
MRK 1040	5–27<	−250, +300	800, 1400	100	18000	0 ± 30	500 ± 200	1.3
MRK 110	7–50	−320, +300	450, 1250	400	49000	+150 ± 30	960 ± 50	1.7
MRK 141	12–33	−630, −450	700, 1500	300	10000	+200, +300	1620 ± 100	2.1
MRK 493	5–30<	−480, +60	360, 560	600	124000	+60 ± 30	360 ± 50	1.8
MRK 817	12–35	−450, +300	850, 1200	140	14000	0, +130	1550 ± 100	1.8
MRK 841	15–50	−750, −150	1070, 1800	450	27400	−300 ± 30	1500 ± 100	2.1
NGC 3227	12–34	−780, −300	900, 1550	350	12000	−300, 300	1500 ± 100	2.1
NGC 4253	5–25<	−630, −90	280, 850	500	69500	−90, −30	550 ± 50	2.0
PG 1116	8–30<	−450, 0	1100, 1800	500	15800	0, +90	1400 ± 250	2.2
PG 1211	8–30	−660, 0	540, 1100	600	67400	90 ± 30	600 ± 300	1.9
IIIZw2[a]	7–17	−600, 0	1400, 1550	400	13400	120 ± 10	1200 ± 100	3.0
NGC 3516[b]	8–18	−880, −640	600, 840	400	1550	1500 ± 200	1500 ± 200	3.0
⟨...⟩	9–31	−515, −5	770, 1330	390	32700	110	1110	2.1

z_l is the shift and $W_l = \sqrt{2}\sigma$ is the Gaussian broadening term from disk indicating the random velocity in disk, $R_{\rm inn}$ are the inner radii, $R_{\rm out}$ are the outer radii, presented in gravitational radii.

[a] Popović et al. (2003).

[b] Popović (2005).