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Kinematics of the BLR and NLR in AGN Mrk 817

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Abstract. Mrk 817 is a Seyfert 1.5 galaxy that show very stratified emission structure. Its emission lines, both Narrow (NELs) and Broad Emission Lines (BELs), are very complex and consist of at least two components, indicating different kinematical properties of emission regions. Here we present a study of this galaxy made using three sets of observations, among which are high-resolution spectra obtained with the Isaac Newton Telescope. The main results are: (i) the BLR is kinematically stratified and consists of two components - Very Broad Line Region (VBLR) and Intermediate Line Region (ILR); (ii) the Narrow Line Region (NLR) also has complex structure and the spectral line shapes of the [OIII] lines indicates at least two different regions. In order to model the BLR, we apply the two-component model where one component is the disk or disk-like region and another one is a spherical emission region with isotropic velocity distribution. We found that model can well fit the line profiles.

1. Introduction

Active galactic nuclei (AGNs) are probably powered by the accretion of matter from the host galaxy onto super-massive black hole. The detection and modeling of double-peaked emission lines (Eracleous & Halpern 1994) gave proof to the presence of accretion disks, even though the number of AGNs with double-peaked or broad emission lines is still statistically insignificant (about 5 - 10 %). Beside the disk, emission lines also imply presence of more kinematically different emission regions that contribute to formation of lines: complex broad and narrow line regions (Popović et al. 2003). Recent investigation of Popović et al. (2004) showed that the BLR of some AGNs could be composed of two components: (i) an accretion disk and (ii) a region with geometry different from a disk.

The galaxy Mrk 817 is a Seyfert 1.5 galaxy, with the redshift of 0.03145 (Véron-Cetty & Véron 2000), that shows both broad and narrow emission lines. The reverberation mapping studies of this galaxy showed that the size of its Broad Line Region (BLR) is $\sim$ 15 light days and its central mass is $\sim 10^7 M_\odot$ (Peterson et al. 1998; Wandel et al. 1999; Kaspi et al. 2000). The galaxy was observed spectroscopically several times, as well. The shapes of the spectral lines indicate that the emission line region of Mrk 817 is very complex (Peterson et al. 1998; Popović et al. 2004).

The aim of this work is to explore the properties of the emitting line regions of the

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galaxy Mrk 817. Using the high-resolution spectra (such as one obtained with the Isaac Newton Telescope) and analyzing the Balmer and [OIII] spectral line shapes and applying the two-component model of the BLR, we have find the kinematic parameters of the BLR and NLR of Mrk 817. First we will present the Gaussian analysis of the Hβ, Hα and [OIII] lines and after that we will apply the two-component model for fitting the broad emission lines.

2. Observations

We have used here three different sets of spectral observations of the galaxy Mrk 817:

i) Observations with the 2.5 m Isaac Newton Telescope at La Palma island in Spain. The observations were performed in the period of 21*th* to 25*th* of January 2002. We used the Intermediate Dispersion Spectrograph (IDS) and the 235 camera in combination with the R1200Y grating. Two exposures of 550 and 500 s, included three Hβ and three Hα spectrum. The seeing was $1''.1$ and the slit width $1''$. The spectral resolution was around 1.0 Å. Standard reduction procedures including flat-fielding, wavelength calibration, spectral response, and sky subtraction were performed with the IRAF software package.

ii) Observations with the 4.2 m William Herschel Telescope, at La Palma islands. The observations were performed on 12/13 March 2001. The long-slit spectrograph (ISIS) was used, in combination with CCD cameras TEK4 (grating R158R). The spectral resolution was 2.9 Å. Also, the standard reduction procedures including flat-fielding, wavelength calibration, spectral response, and sky subtraction were performed with the IRAF software package.

iii) Third set was observed at the Crimean Astrophysical Observatory by K. K. Chuvaev on 2.6 m Shain telescope during the period of 1977-1991, and only the Hβ line was observed. The spectral resolution was $\sim$ 8 Å. The spectrograph slit and seeing were in the $1.8''-2.0''$, and $2'' - 3''$ ranges, respectively. The spectra of the Hβ, were scanned with a two-coordinate CrAO microphotometer. The reduction procedure includes corrections for the film sensitivity, sky background, and instrumental spectral sensitivity. The wavelength and flux calibration were made using the SPE data reduction package, developed by S. G. Sergeev. The wavelength calibration was based on the night sky lines and narrow emission lines of the galaxy.

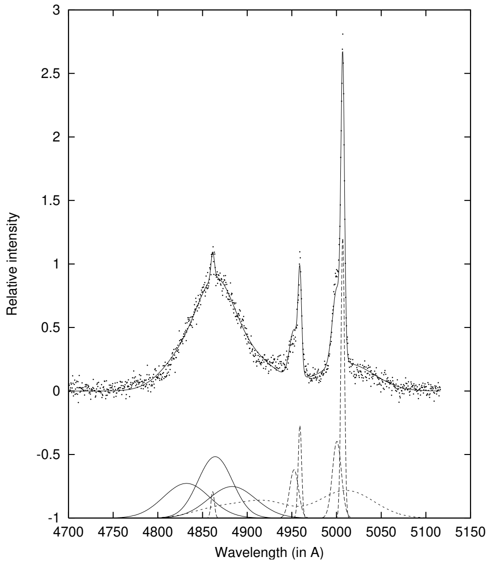

Fig. 1. Decomposition of Hβ line of Mrk 817. The dots represent the observation and solid line is the best fit. The Gaussian components are shown at the bottom. The dashed lines at bottom represent the Fe II template, [OIII] and Hβ narrow lines.

The spectra have been normalized to the [OIII]λ 5007 emission line. The software package DIPSO was used for reducing the level of local continuum, by subtracting the N order polynomial, fitted through the points in the local continuum in spectral range 4700 – 5100 Å for the Hβ emission region. The same was done for the Hα local continuum in 6350 – 6750 Å.

3. Line Profile Analysis

We fitted each line with a sum of Gaussian components using a χ^2 minimization routine to obtain the best fit parameters. The fitting procedure has been described several times (Popović et al. 2002, 2003), but in this case we have assumed that the narrow emission lines can be composed by more than one Gaussian componet. In the fitting procedure, we look for the minimal number of Gaussian components needed to fit the lines. Taking into account the intensity ratio of [OIII] lines (the atomic value 1:3.03) and the fit of Fe II template (Korista 1992) for the Hβ. In the case of Hα line, for the narrow [NII] lines we assume their intensity ratio is 1:2.96 (Popović et al. 2003). It was found that three broad Gaussian and one narrow components could fit well the profiles of the Hα and Hβ lines. One result of our analysis is presented in Fig. 1, where we can recognize clear evidence of substructure in these emission lines, not only in the broad component of the line, but also in the narrow emission lines.

4. The Narrow Line Emission Region

The Narrow Emission Region of the considered active galaxy show a complex structure, and we can clearly see at least two NLR regions:

(i) the NLR1, which has an internal random velocity ~ 500 km/s, and relative approaching velocities around 300 km/s with respect to the systemic red-shift of the observed galaxy; and

(ii) the NLR2 which has an internal random velocity around 150 km/s, and a red-shift equal to the systemic one of Mrk 817.

The different shifts and widths of the [OIII]$\lambda\lambda$4959,5007 lines between these two NLRs indicate different kinematic and physical properties. The blue shift of the NLR1 support the idea of a jet geometry in this AGN (Dopita et al. 2003).

5. The Broad Line Emission Region and the two-component model

Considering only the broad line Gaussian components we can conclude that:

(i) the Hβ and Hα line shapes of the considered AGN is very complex, and usually cannot be described by one Gaussian, i.e. the Gaussian decomposition indicates a very complex kinematic structure of the BLR;

(ii) the Gaussian decomposition indicates the existence of a central broad component with low random velocities (~ 1500 km/s) and

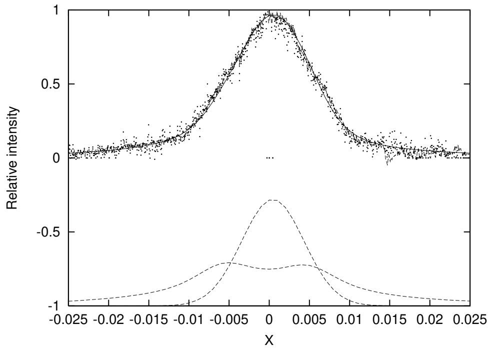

Fig. 2. The averaged profile of Hα and Hβ emission lines fitted with the two-component model.

a red-shift consistent with the systemic velocity.

(iii) the Gaussian decomposition shows the existence of the red- and blue-shifted broad components with higher velocities and higher (positive or negative) redshift. This implies that the emission in the wings could originate in an accretion disk.

In order to model the BLR, we applied the two-component model where one component is the disk or disk-like region and another one is a spherical emission region. First component was used for fitting the line wings and the other for fitting the line core. For the disk we used the Keplerian relativistic model (Chen & Halpern 1989). The kinematics of the additional emission region can be described as emission of a spherical emission region with isotropic velocity distribution. Consequently, the emission line profile for this region 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 emissions of the relativistic accretion disk and the spherical emission region, respectively.

For fitting the broad lines with the two-component model, first we cleaned the lines from the narrow component and the satellite lines and found the average profile for both Balmer lines. Using the results from the Gaussian analysis for some input parameters (e.g. the maximal outer radius), we found that this model can well fit the line profiles (see Fig. 2) and taking into account the large number of

Table 1. The parameters of the disk for the galaxy Mrk 817: z_l is the internal shift and $W_l = \sqrt{2}\sigma$ is the random broadening term from the disk, R_{inn} is the inner radius, R_{out} is the outer radius. z_G and W_G represent the parameters of the Gaussian component, i is the inclination of the disk and p^{min} is the minimal index of emissivity, where emissivity is taken to be $\varepsilon = \varepsilon_0 r^{-p}$.

i	$z_l^{\mathrm{min,max}}$	$W_l^{\mathrm{min,max}}$ (km/s)	R_{inn}^{min} (R_g)	$R_{\mathrm{out}}^{\mathrm{max}}$ (R_g)	$z_G^{\mathrm{min,max}}$	W_G (km/s)	p^{min}
12-35	-450,+300	850,1200	140	14000	0,+130	1550±100	1.8

parameters we were able to estimate only the disk parameters.

6. Results

The Gaussian analysis applied to the Hα and Hβ lines showed that both BLR and NLR are complex regions.

The Broad Emission Lines can be decomposed into three broad Gaussians one red- and blue-shifted and one at the systemic redshift. This imply that we can fit these lines with the two-component model, that consists of an accretion disk which contributes to the line wings and a spherical region, in which the core of the lines is formed. We applied this model to the observed line profiles and found that the model fit well the complex line shapes. The results of this fit are presented in Tab. 1. We would like to stress that the velocities in these two regions are similar. This suggests that they are linked through a common process, like a disk wind (Popović et al. 2004).

The Narrow Emission Lines can be fitted only with two Gaussians, one blue-shifted and one at the systemic redshift. From this we conclude that there exist two NLRs with different physical properties, where one is relatively approaching the observer and can be formed within the jet.

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