Publ. Astron. Obs. Belgrade No. 57 (1997), 95 – 99 *Contributed paper*

THE O III NARROW LINE SHAPES IN SPECTRA OF Mrk 817

L. Č. POPOVIĆ[1] and E. MEDIAVILLA[2]
[1] *Astronomical Observatory, Volgina 7, 11000 Belgrade, Yugoslavia*
E-mail lpopovic@aob.aob.bg.ac.yu

[2] *Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain*
E-mail emg@ll.iac.es

Abstract. The O III (4959, 5007) lines from spectra of Mrk 817 obtained from a 9-year long period were analyzed. A blue asymmetry of the lines is noticeable. We have found that the Narrow Line Region (NLR) of Mrk 817 consists of two subregions (here called NLR1 and NLR2). NLR1 should be closer to the central source with higher velocity of the emitting emission gas than in NLR2. A model which can describe the O III narrow lines as well as broad H_β shapes of Mrk 817 should consist the four regions; Broad Line Region (BLR), Intermediate Line Region (ILR) and two NLRs. Also, an outflow of the emitting gas in BLR, ILR and NLR1 as well as gravitational effects in BLR should be considered.

1. INTRODUCTION

Investigations of spectral line shapes helps us to understand the kinematics and structure of the emitting gas of Seyfert galaxies. In spectra of Sy 1 galaxies two types of lines are present: 1. Broad lines (full width about several thousand km/s) of low ionized atoms and 2. Narrow lines (full width several hundred km/s) of high ionized atoms. Roughly Emission Line Region (ELR) can be divided into two physically distinct regions of line-emitting gas (see e.g. Netzer 1990): high-density ($10^9 - 10^{10}$ cm^{-3} and compact ($r \sim 1$ pc) Broad Line Regin (BLR) and more extended ($r \sim 100 - 1000$ pc) and low density (10^4 cm^{-3}) Narrow Line Region (NLR).

Sometimes broad lines could not be presented with only two components (see e.g. Bonatto & Pastoriza 1990). Then emission of three regions can describe broad-lines: 1. BLR (some of authors for this region use therminology Very Broad Line Region – VBLR, see e.g. Brotherton et al. 1994, Corbin 1995, 1997); 2. Intermediate Line Region (ILR) and 3. NLR. Observations of nearby galaxies also show that the structure of NLR is more complex (see e.g. Veilleux 1991abc, Arribas et al. 1996). Here we present an analysis of the line shapes of narrow O III (4959, 5007) lines of Sy 1 Mrk 817 galaxy observed at Crimean Astrophysical Observatory by K. K. Chuvaev in a 9-year long period.

2. SELECTION OF DATA AND METHOD OF ANALYSIS

As it was described in Popović (1996), the spectra of Mrk 817 were obtained at Crimean Astrophysical Observatory in the period from 1977 to 1991. The spectral regions covered H_β and O III (4959,5007) emission lines. From available spectral data base, only spectra with satisfactory quality were chosen. There is no significant short time variability of the Mrk 817 spectra, so, we averaged the spectra from three periods: I - 1982/83, II - 1984 and III - 1990/91.

First we decomposed the O III (4959,5007) lines from the red wing of H_β, then the lines were fitted with gaussians. The O III (4959, 5007) lines have asymmetric shapes toward blue, so, we tried to fit the lines with several gaussians. The best results were obtained when the lines were fitted (each of them) with two gaussians (see Fig. 1). It suggests that the Narrow Line Region of Mrk 817 is complex, and that two regions exist (here noted as NLR1 and NLR2). The first (NLR1) subregion from which the broader component comes (G_1) and second (NLR2) from which narrower component (G_2) comes.

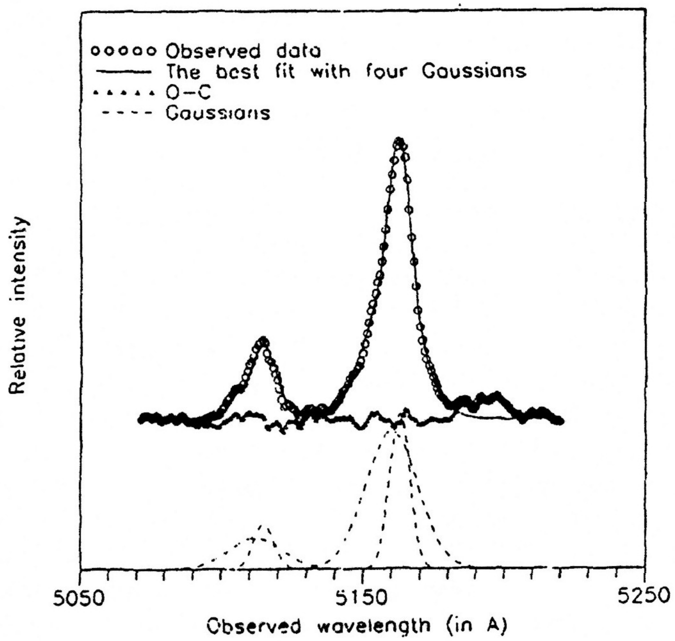

Fig. 1. The observed narrow O III lines and their fits.

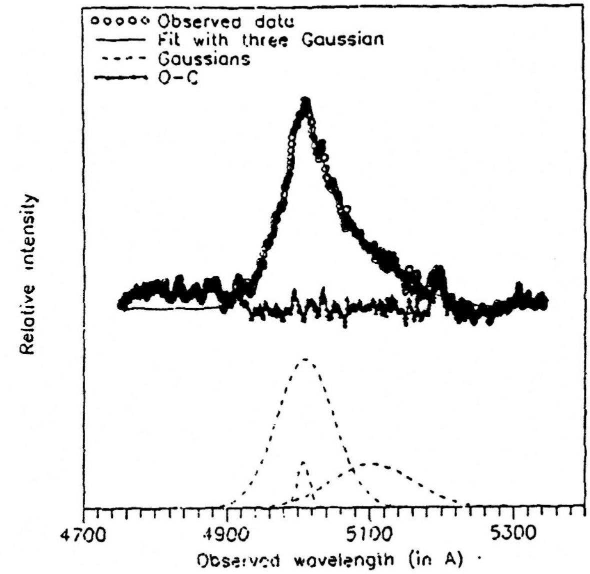

Fig. 2. The H_β fitted with three gaussians, the broadest component has the largest redshift. It is the rule for all three considered periods.

Since both lines (4959 and 5007) originate from the same multiplet (1F) of double ionized oxygen we have restricted wavelength difference between two components, width and intensity of the components. The components of lines that come from the same region have to have same wavelength difference, and their widths are $\Delta W_{4959}/4959 = \Delta W_{5007}/5007$, where W is the line width.

Also, we take that $I_\lambda \sim S_\lambda$, where I_λ is the intensity and S_λ is the line strength, then the ratio of intensities is $I_{5007}/I_{4959} \approx 3.03$

These restrictions were included in order to reduce the errors in the obtained Gaussian fit parameters.

3. DISCUSSION

In Table 1 we present the obtained velocity of the emitting gas in NLR1 and NLR2 as well as the wavelength differences between two Gaussian components from the three periods. The velocities given in Table 2 were calculated by using the following relation

$$V_{1,2}[\mathrm{km/s}] = \frac{2 \cdot \Delta W_{1,2}}{2.31 \cdot \lambda} \cdot c$$

where $\Delta W_{1,2}$ are the half-widths of Gaussian functions, λ is the rest wavelength and c is the speed of light. The displacements of two gaussians in velocity scale are calculated as

$$V_{em} = \frac{\lambda_2 - \lambda_1}{\lambda} \cdot c$$

where λ_1, λ_2 are observed wavelengths of the fitted gaussian profiles, and λ is the rest wavelength.

As one can see from Table 1 the NLR2 is stable region with the emitting gas velocity $\overline{V}_{NLR2} = 350 \pm 10$ km/s, whereas in NLR1 a small progressive variability is noticeable. Also, emitting gas velocity in this region is higher than in NLR2 (see Table 1). This region should be closer to the central source. The blue asymmetry of 4959 and 5007 lines may be caused by an outflow of the emitting gas in this region.

Table 1. The emitting gas velocities in two the narrow line regions obtained from the best fit of the O III (4959,5007) lines.

	I (82-83)	II (84)	III (90-91)
V_{NLR1} (km/s)	930	900	740
V_{NLR2} (km/s)	360	340	350
V_{em} (km/s)	170	60	200

The blue asymmetry in narrow (forbidden) O III lines of Sy 1 galaxies Mrk 817 is present in all three periods. A blue asymmetry is present in most Sy 2 galaxies investigated by Veilleux (1991a). Veilleux (1991b) found that 10 galaxies from a sample of 16 Sy 2 galaxies had blue asymmetry. According to Veilleux (1991b) it is caused by the dust within the line emitting clouds or by the effects of an occulting component near the nucleus. In our opinion this explanation cannot be used here. It is well known (see e.g. Osterbrock 1989) that H_β is partly formed in NLR. In order to find an appropriate model which can describe the asymmetry of the narrow lines we analyzed the H_β line profile. We have fitted the H_β with a model of four regions, where we have taken into account that the components from NLR1 and NLR2 should be present in H_β, but we found that the component of H_β which comes from NLR2 is negligible. Then the H_β line profiles from three periods were fitted with three gaussians (see Fig. 2) which were supposed to come from BLR, ILR and NLR1. As we expected, the variability was clearly seen in the BLR and ILR. Also, we noticed a conection betwen redshift and velocities of the emitting gas in these four regions (see Fig. 3).

In our analyses of O III and H_β lines for explanation of the shapes of these lines we prefer the model with gas outflows in the BLR, ILR and partly in NLR (in NLR1). Then how can we explain the red asymmetry of broad H_β line? As it was noticed in Mediavilla & Insertis (1989), Atanacković-Vukmanović et al. (1994), Corbin (1995, 1997) and Popović et al. (1994,1995) a red asymmetry can be caused by the gravitational redshift i.e. the broadest line of the emitting gas comes from the region of strong gravitation field that can cause a part of the observed redshift. It produces a strong red asymmetry of the H_β line profile. Also, an outflow of the emitting gas is present. The velocity of outflow decreases with distance from the nucleus.

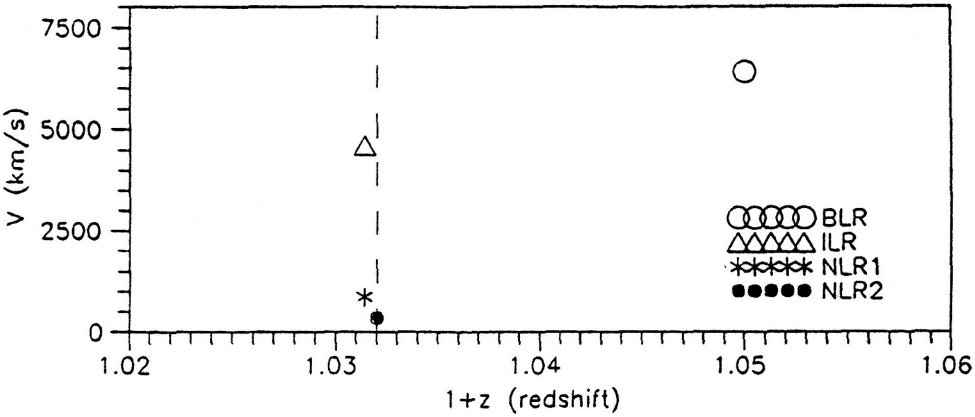

Fig. 3. The averaged emitting gas velocities from the four regions as a function of redshift. The broken line is the cosmological redsift ($z = 0.032$) taken from Hewitt & Burbridge (1991).

Such a model may be more appropriate for explanation of the broad H_β line shape as well as of the narrow O III (4959,5007) lines.

References

Arribas S., Mediavilla E. and García-Lorenzo B., 1996, *Astrophys. J.* **463**, 509.

Atanacković–Vukmanović O., Popović L. Č., Vince I. & Kubičela A., 1994, *Bull. Astron. Belgrade* **150**, 1.

Bonatto C. J. and Pastoriza M. G., 1990, *Astrophys. J.* **353**, 445.

Brotherton M. S., Wills B. J., Francis P. J. & Steidel C. C., 1994, *Astrophys. J.* **430**, 495.

Corbin M. R., 1995, *Astrophys. J.* **447**, 496.

Corbin M. R., 1997, *Astrophys. J.*, in press.

Hewitt A. & Burbrdge G., 1989, *Astrophys. J. Suppl. Series* **75**, 297.

Mediavilla E. & Insertis F. M., 1989, *Astron. Astrophys.* **214**, 79.

Netzer H., 1990, *in Active Galactic Nuclei, eds. R. D. Blandford, H. Netzer & L. Woltjer*, Saas-Fee Advanced Course 20, Berlin: Springer - Verlag.

Osterbrock D. E., 1989, *Astrophysics of Gaseous Nebulae and Active Galactic Nuclei*, Mill Valley, California.

Popović L. Č., 1996, *Publ. Astron. Obs. Belgrade* 54, 49.

Popović L. Č., Vince I., Kubičela A., Atanacković-Vukmanović O. & Samurović S., 1994, *Bull. Astron. Belgrade* 149, 9.

Popović L. Č., Vince I., Atanacković-Vukmanović O. & Kubičela A., 1995, *Astron. Astrophys.* **293**, 309.

Veilleux S., 1991a, *Astrophys. J. Suppl. Series*, **75**, 357.

Veilleux S., 1991b, *Astrophys. J. Suppl. Series* **75**, 383.

Veilleux S., 1991c, *Astrophys. J.* **369**, 331.