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THE BLR STRUCTURE OF NGC4151 - POSSIBLE OUTFLOW MODEL

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Abstract. Using the 2D CCF of the Hα line of NGC 4151, we analyzed the BLR structure in this active galaxy. We found that the line wings have different response to the continuum variation that line core. This type of variation indicates an outflow model for the BLR of NGC 4151.

1. INTRODUCTION

In the central regions of active galactic nuclei (AGN) the broad emission lines (with widths more than 1000 km/s) are originated. The region where these lines are formed is so called the Broad Line Region (BLR). The BLR is assumed to be photoionized by the continuum from the accretion disk.

From the response of the BLR emission (observed in the broad lines) to the continuum variation can be used to obtain required geometrical characteristics of the BLR by constructing the velocity-delay diagrams of emission lines.

The quality of obtained results depend on homogeneousness of data set, the level of signal to noise ratio,variability of flux of an active galaxy,the length of time spans covered by observations and its sampling rate.

Velocity-delay maps were obtained by many authors (Kolatschny & Dietrich 1996, 1997; Done & Krolik 1996, Kolatshny & Bischoff 2002). However, the most of results are preliminary due to low quality of observations (low signal to noise ratio, short time spans covered by observations, sampling rate is higher than 1 day, nonhomogeneous distribution of observations, etc.).

Here we present and discuss the velocity delay map of the $H\alpha$ line in NGC4151. The aim of this paper is discuss the BLR structure of NGC 4151.

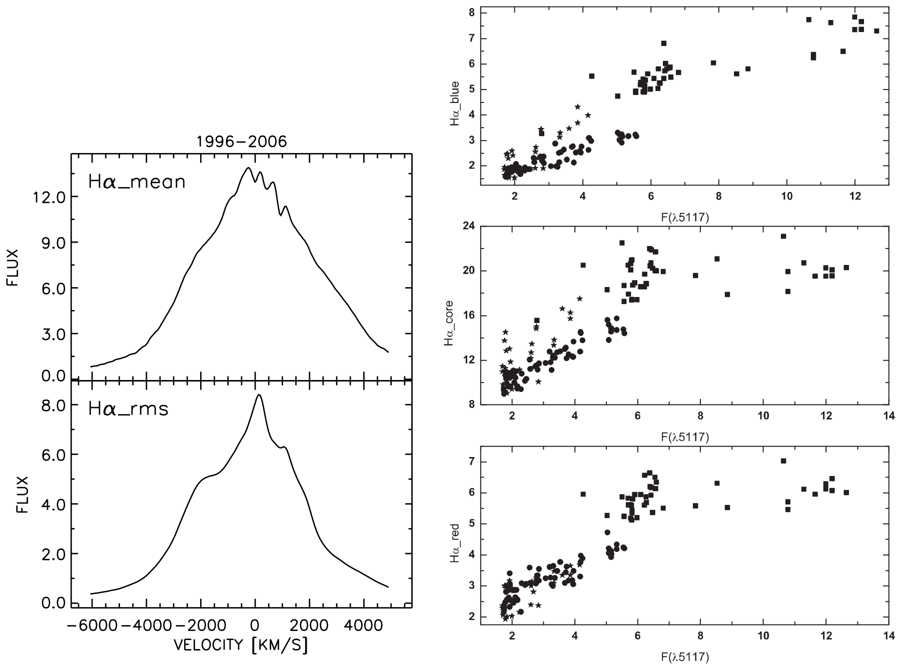

Figure 1: *Left:* The averaged and rms profiles of the broad $H\alpha$ for whole monitoring period 1996–2006; *Right*: he wings and core fluxes as a function of the continuum flux (at $\lambda = 5117$ Å) for $H\alpha$. Shapovalova et al. (2008).

2. OBSERVATIONS AND DATA ANALYSIS

We chose NGC 4151 as our target because it was subject of many monitoring campaigns as well as many authors obtain different response delays in emission lines with respect to changes in continuum (see Shapovalova et al, 2008, hereafter Paper I).

The observations and procedure of data reduction in more details is described in the Paper I and here will not be repeated. The data-set of the Hα line has 141 spectra observed between 1996 and 2006. The spectra cover wavelength range from 4000 Å to 7500 Å with resolution R=4.5-15 Å. In the most cases it was yielded S/N >50 in the continuum. The averaged $H\alpha$ profile and rms is present in Fig. 1 (left).

3. RESULTS AND DISCUSSION

In Paper I it was found that an excess line emission with the respect to a pure photoionization model during whole monitoring period. Light curves of the $H\alpha$ line core as well as $H\alpha$ line wing segments in function of the optical continuum ($\lambda = 5117$ Å) are shown in Fig. 2 (right). As it is shown, the flux in the wings and core of the line express a very similar flow during the whole period. Based on the similarity of line profiles, we found three characteristic profiles during the period 1996-2006. In the first period (1996-1999, JD=(2450094.466-2451515.583), where the $H\alpha$ line was very intense, a red asymmetry and a shoulder in the blue wing were present. In the

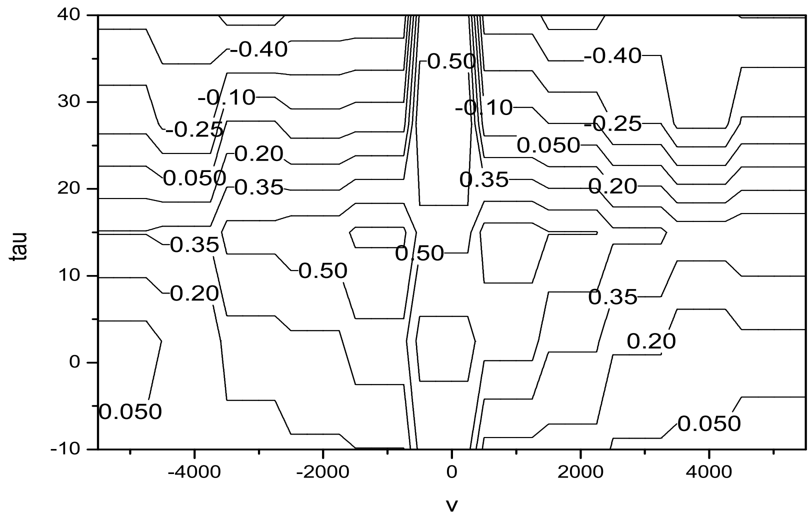

Figure 2: The 2-D CCF(τ, v) shows the correlation of the $H\alpha$ line profile with core variations as a function of velocity and time delay.

second period (2000-2001, JD=2451552.607-2452238.000), the $H\alpha$ was weaker and the shoulder in the blue wing is smaller and a shoulder in the red part is present. From 2002 to 2006 (third period, JD=2452299.374-2453846.403), the line showed a blue asymmetry, and a shoulder in the red part was dominant in the line profiles.

As a description of the $H\alpha$ line vs. continuum variation, the CCF analysis was carried out for the full data set which covers the whole monitoring period from 1996 to 2006 and the three periods mentioned above. The time lags for $H\alpha$ in the whole period are 5 days, but they were different in the three subperiods. In the first and in the third period, the time lags were much smaller (from 0.6 to 1.1 days) than in the second period (11 and 21 days).

In Paper I we found that the BLR is very complex so we generated the light curves from various $H\alpha$ velocity segments ($\Delta v = 1000$ km s^{-1}).

Also, we computed cross-correlation functions (CCF) of all $H\alpha$ line segment light curves with the (6573-6595) Å core light curve (for CCF calculation details see Paper I). The light curve of the outer wings segments (for whole monitoring period) show the same time delay 5 days.

Having in mind this, we derived from the cross-correlation functions a delay map of the $H\alpha$ line segments ($\Delta v = 1000$ kms^{-1}) for the first subperiod which is shown in Fig. 2. This 2-D CCF shows some clear trends. The outer red and blue $H\alpha$ line wings respond almost symmetrically to core variations with a delay of about 5 days only. Towards the line center the delay is getting systematically shorter until up to about 0 days at the line center.

The 2-D CCF(τ, v) has similar mathematical characteristics as a 2-D response function (Welsh 2001). Our observed velocity-delay map for core vs line follows some patterns predicted by model calculations for continuum vs line (Perez et al. 1992;

Welsh & Horne 1991; O'Brien et al. 1994). For example, both $H\alpha$ line wings show the largest delay (around 15 days) with respect to the core (~ 0 days) and react nearly simultaneously (it is specific for radial inflow or outflow motions models).

As it can be seen, short delays are observed at the center which is in contrary to the spherical BLR models with chaotic virial velocity field or randomly oriented Keplerian orbits. On the other hand, a Keplerian disk BLR model cannot describe exactly the observed velocity-delay pattern, since in this model we expect the faster response of both line wings compared to the center.

A slightly faster and stronger response of the red line wing vs the blue wing, as seen in Fig. 2, follows the disk-wind model of the BLR of Chiang & Murray (1996).

The correlation of the red [+500; +2000] kms^{-1} wing with the core is about 9% stronger than that of the blue wing [−2000; −500] kms^{-1} (Fig. 2). The blue wing ($v = [-4000;\ -3000]$ kms^{-1}) lags the red wing ($v = [+3000;\ +4000]$ kms^{-1}) by 2 days.

4. CONCLUSION

We performed 2D-CCF analysis of the $H\alpha$ vs. continuum variation, in order to investigate the BLR strucutre in NGC4151. We found that different lags for line wings and core corresponds to the outflow model for the BLR of NGC 4151.

Acknowledgements

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