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Variability of Hβ Broad Emission Line in NGC5548

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Abstract. We present preliminary results of five years (1995 - 200) spectral (in the Hβ region) and photometric monitoring on NGC 5548. Observations were carried out at some observatories of the Former Soviet Union and "Guillermo Haro" Observatory in México. The variation of the Hβ emission-line flux is less than 4%. The difference shape of Hβ profiles resembles a double-peaked line, which is characteristic of radiation in an accretion disk. The observed fluxes in the blue and red wings vary quasisimultaneously, which is an evidence of predominantly circular motions in the BLR. These two facts support our hypotesis that the broad Hβ component, in NGC 5548, is probably originated in an accretion disk.

1. Introduction

Broad emission line regions (BLRs) in active galactic nuclei have been the subject of extensive studies for more than two decades. Understanding such regions requires a combination of detailed observations and sophisticated theoretical models. The extensive monitoring campaigns have focused on the broad-line emission variability and on the construction of reverberation mapping in more than a dozen AGNs (see Peterson 1993 and Netzer & Peterson 1997 for reviews) The study of the BLR in AGNs is important for a number of reasons, most obviously because its close proximity implies that the BLR gas must necessarily be intimately connected with the luminous central engine

This report is a part of our program of the BLR investigations in some AGNs. The main goal of the program is to determine basic physical and kinematic properties of BLR in a sample of selected Seyfert galaxies and quasars by means of optical (spectrometry and broad-band photometry), and, possibly, X-ray monitoring. The another aim of this program is to search for changes in the BLR on a dynamical timescales that might be manifest in changes in the Hβ response time or in the emission-line profiles. This program also provides well-sampled continuum observations over an extended period.In the present report, the Hβ emission line and continuum variability in NGC 5548 is investigated.

2. The program object

NGC 5548 has been extensively studied as a prototypical Seyfert galaxy. NGC 5548, to date the best studied of all radio-quite AGNs, is a low-luminosity ($L_{bol} \sim 10^{44}$ ergs s^{-1}), low redshift (z=0.0174) Seyfert 1 galaxy whith a well-documented history of short-timescale, large-amplitude continuum and emission-line variability.

The first systematic attempt to reconstruct the BLR in NGC 5548 is by Krolik *et al.* (1991). The BLR is divided into two distinct zones: one emitting the high-ionization lines and the other emitting the low-ionization lines.

O'Brien, Goad & Gondhalekar (1994) have combined photoionization and reverberation-mapping calculations. Their work focused on the shape of transfer function and the line responsivity in a few generic models. Shields, Ferland & Peterson (1995) used photoionization calculation to examine the C IVλ1549/Lyα line ratio in NGC 5548 and other objects. They concluded that an optically thin non-variable component contributes to the BLR high-ionization lines.

Dumont, Collin-Souffrin & Nazarova (1998) modeled the BLR in NGC 5548 as a three-zone region in which the locations of the various components were determined by the mean line-to-continuum lags. Like most other, they did not campare the observed shape of the emission-line light curves with the prediction of the models.

Goad & Koratzar (1998) reexamined the 1989 NGC 5548 data set. Here again, the main assumption is of a two-zone model, and there is no attempt to use the observed light curves, only the measured time lags.

Evidently, there is a definitive lack of modeling of complete data set, i.e., the information provided by the long time-series observations.

Here we present the preliminary results of a long-time (1995-2000) optical spectral and photometric monitoring of NGC 5548. The analysis will be focused on the Hβ line profiles variations and the responses of the Hβ emission-line to the continuum variations.

3. Observations

3.1. Spectral monitoring

Spectral monitoring of NGC5548 was carried out at 6m and 1m telescopes of SAO RAS (1995-2000) and at 2.1m telescope of INAOE in Cananea, México (1998-2000). Optical spectra were taken with long-slit spectrographs equipped with CCD detectors. Spectral covering range was between 4000 and 8000 Å , the spectral resolution varied from 3 to 15 Å , and the S/N ratio was of the order of 50-100 in the continuum around the Hβ and Hα regions. Optical spectra were scaled to the O IIIλ 5007 Å , under the assumption that this emission line did not vary during the period of observations. The spectra that were taken at 1m telescope of SAO RAS and at 2.1 telescope of INAOE, were corrected to the aperture of 6m telescope of SAO RAS (6 arcsec).

3.2. Photometric monitoring

UBVR broad-band monitoring was carried out at the following telescopes: 1m and 60cm telescopes of SAO RAS with a CCD detector, 60cm telescope of the South Station of the Sternberg State Institute, equipped with an electrophotometer (UBV) and a CCD detector (BVRI), and 60cm and 1.5m telescopes on mountain Majdanak (Uzbekistan) with an electrophotometer (UBVR)

4. Results

4.1. NGC5548 in 1996-2000 period

(1) The Hβ line profiles are asymmetric, but this asymmetry shows different behaviors: red wing asymmetry in 1996-1997 period, and blue wing asymmetry in 1998-2000 period. The blue wing has a steeper brightness gradient than the red one.
(2) In the high state (June 1998), the observed fluxes in the continuum and in Hβ line, were 2.4 and 1.5 times higher than those in the low state (April 1997). During the high state, the continuum slope in the blue region was steeper.
(3) In periods of one month, when NGC5548 was observed several times, the Hβ emission-line fluxes and the shape of the profiles varied insignificantly (by $\sim$ 1-3 %).
(4) The average shape of the Hβ profiles varied in subsequent months. From February 1996 to July 1996 the red wing was brighter than the blue one (red asymmetry). In April 1997 Hβ wings were weakest and almost of similar brightness. In January 1998 the blue wing became brighter than the red one (blue asymmetry), this behavior had keep up to February 2000.
(5) The difference shape of the Hβ profiles (the difference between each spectra and the low state spectra) resembled a double-peaked line, which is characteristic of radiation in an accretion disk. There are rather stable peaks, varying in intensity: in the blue wing at velocoties of -3500, -2000, and -1400 kms^{-1}, and in the red wing at velocities of $+1600$, $+2200$, and $+3500$ kms^{-1}. The maximum contribution of the blue and red wings (velocity interval from -4000 to -1000kms^{-1} and from $+1000$ to $+4000$ kms^{-1} respectively) and core (velocity interval from -1000 to $+1000$ kms^{-1}) to the integral flux of Hβ in June 1998 is $\sim$ 12% for each component (Figure 1).
(6) The fluxes of Hβ and the continuum were observed to increase during the following periods of time: July 1996, May-June 1998, and June-July 1999. The fluxes were at minimum values in April 1997, September 1999 and January-March 2000.
(7) There is a time delay from $\sim$ 10 days to about a month between the flux increases in the continuum (flares in April 26 and May 18 1998) and flux increases in Hβ line emission (May 4-8 and June 17-26 1998).
(8) The observed fluxes in the red wing of Hβ varied with a larger maximum amplitude (2.3 times) than in the blue wing (2.1 times).
(9) Variations of the observed fluxes in the red and blue wings ocurred quasisimultaneously, which is an evidence of predominantly circular motions in the region where the broad Hβ emission is formed (Figure 2).

5. Conclusions

The study of the profiles of broad Hβ emission-line component of NGC5548 has shown some features, which suggest that this emission component has probably originated in an accretion disk. They are listed in the following.

(1) One can readily see double peaks with clearly defined peaks on different wings of Hβ, which is characteristic of radiation from an accretion disk.
(2) The observed fluxes in the red and blue wings vary quasisimultaneously, which is an evidence of predominantly circular motions in the BLR.
(3) The difference profiles of the broad Hβ component depart strongly from the gaussian or logarithmic profiles as normally seen in AGN. The blue wing edgeward brightness gradient drops faster than the red wing brightness gradient.
(4) The contribution of radiation from a possible accretion disk in NGC5548 accounts only for a fraction of the total radiation in the broad Hβ component ($\sim$ 36%). The main fraction of radiation must come from other regions.

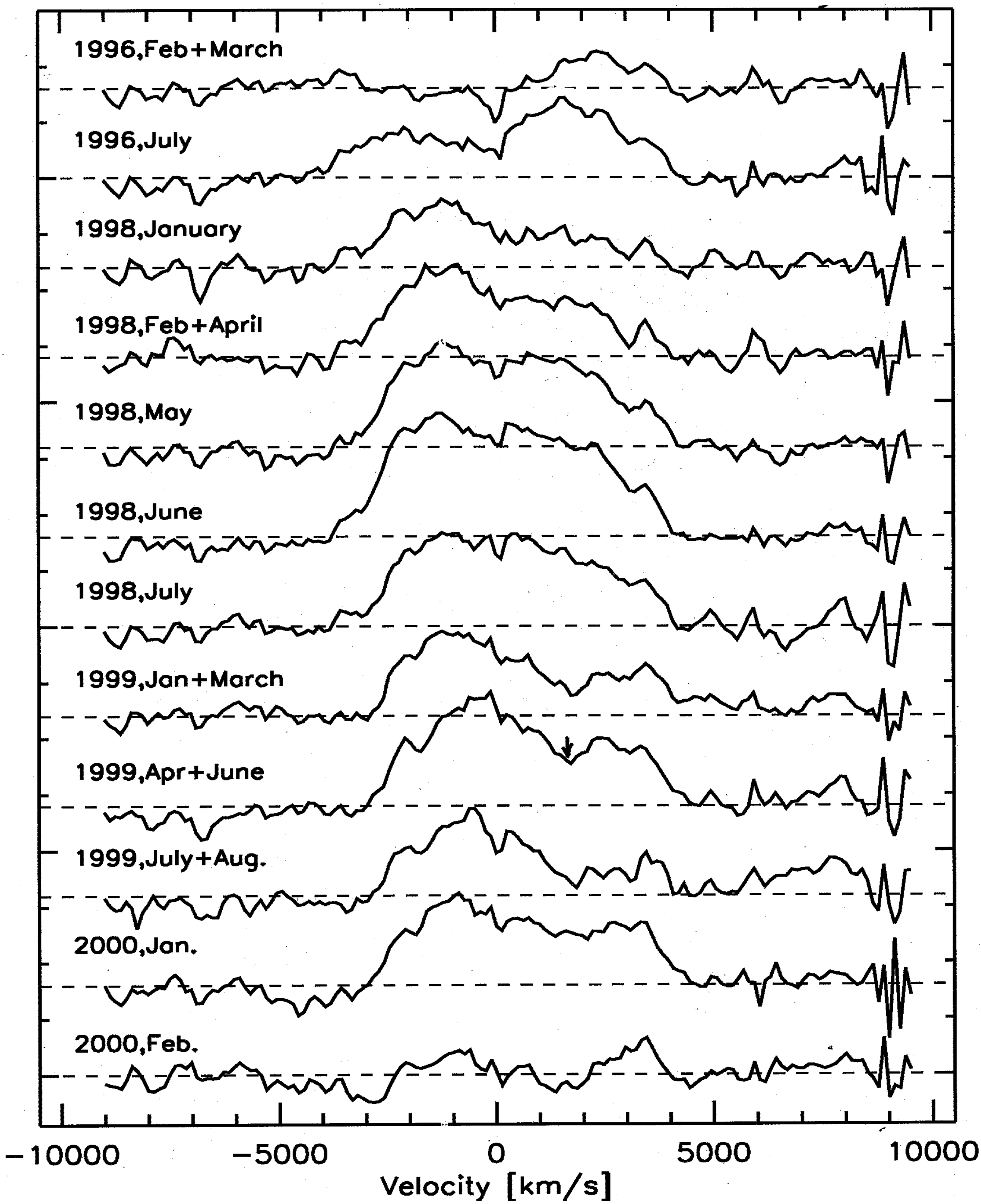

Fig. 1. The double-peaked shape of the broad Hβ component line profile during the 1996-2000 period.

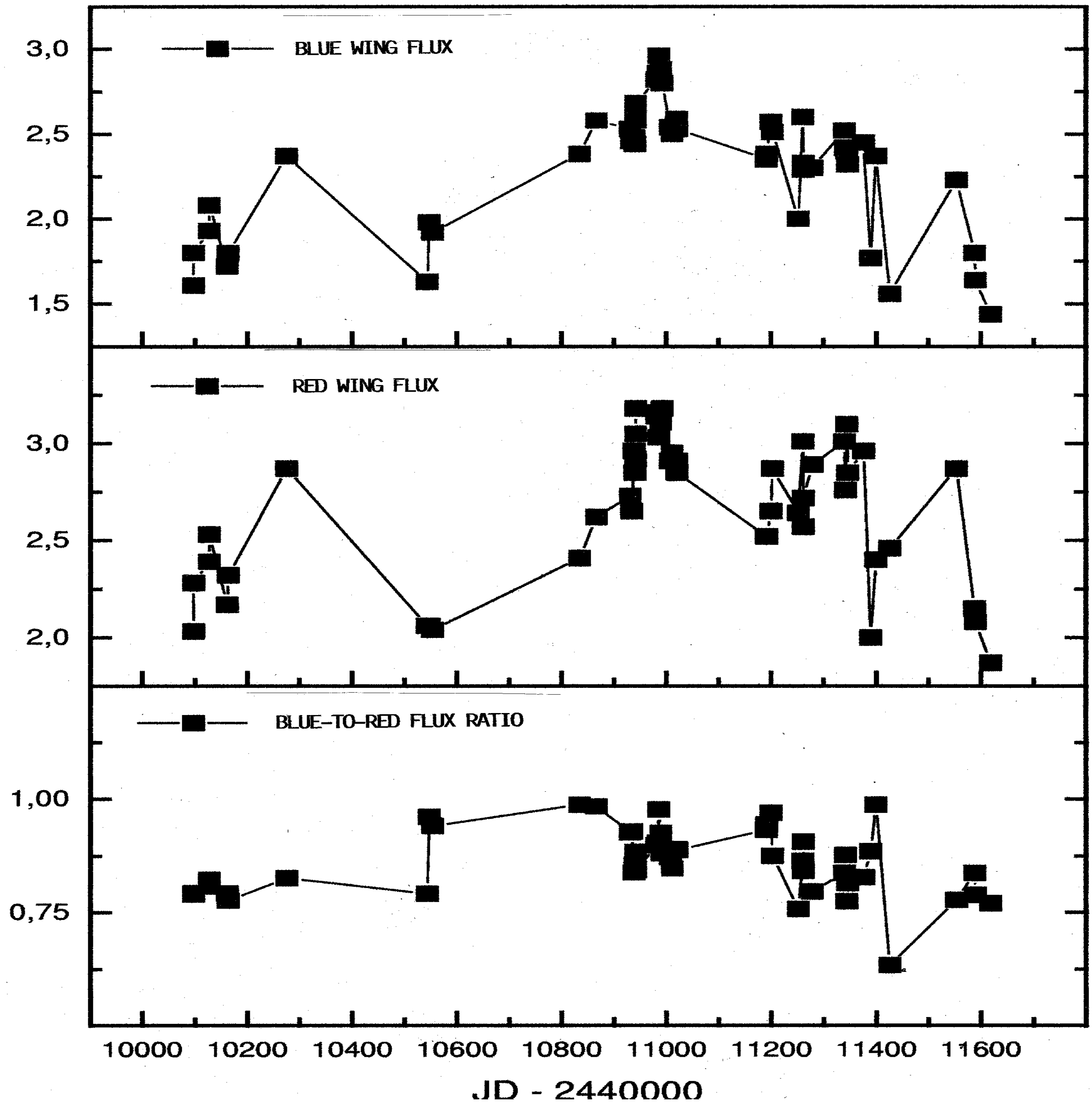

Fig. 2. Variations of the Hβ blue and red wings fluxes during the 1996-2000 period. The botton panel is the blue-to-red flux ratio. The fluxes are in units of 10^{-13} erg s^{-1} cm^{-2}

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