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ON THE LONG TIME SPECTRAL VARIABILITY OF NGC 5548

Nariman Z. Ismailov & Ulviyye Z. Bashirova
Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences, AZ 5626 settl. Mamedaliyev, Shamakhy, Azerbaijan
E-mail: ismailovn@yahoo.com
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ABSTRACT

We have investigated the long term variability of the intensities of the broad-line region emission lines in the UV spectra of Seyfert I galaxy NGC 5548 from 1973–1996. We have obtained the following results: 1) a high level correlation between the intensities of emission lines as well as between intensities of emission lines and continuum fluxes was discovered. With increasing wavelength the correlation in both cases becomes weaker, 2) the relationship between the intensity of emission lines and the flux radiation in the continuum can be expressed by a power law function with coefficients of $\alpha \approx 0.8 - 1.1$ for different lines. When the difference between the wavelengths of spectral lines and the continuum is increased, the value of the power function decreases, and 3) it was found that the magnitude of the variability of the line intensities are weaker than the range of variability of the continuum fluxes. The magnitude of the variability of the line intensities and the continuum fluxes increase at longer wavelengths.

Key words: NGC 5548: UV spectral variability: continuum radiation: board emission lines

1. INTRODUCTION

It is known that Seyfert type galaxies vary in luminosity on time scales from years to hours, in different wavelength ranges. The central engine in an active galactic nucleus produces a time-variable high-energy continuum that ionizes and heats the surrounding gas, which produces broad emission lines. The emission-line properties are connected to the continuum properties and to the geometry, kinematics, and physical conditions within a region of this gas, referred to as the broad-line region (BLR). Details of the mechanisms of nuclear activity and the surrounding matter are still unclear.

Although a considerable amount of effort has gone into AGN monitoring in the past, the distribution and kinematics of the BLR material remains ill defined. For some examples of AGNs the observed high degree of correlation between emission-line fluxes and the optical continuum fluxes suggests that relationships between the line fluxes, optical continuum fluxes, and ionizing continuum fluxes are not necessarily linear. For example, an inverse correlation between line equivalent width and continuum flux can be appear as a power-law relation, $F_{line} \approx \mathrm{F}_{cont}^{\alpha}$, where $\alpha < 1$. This makes it clear that we collide with the "intrinsic Baldwin effect" (Kinney et al. (1990); Pogge & Peterson (1992); Gilbert & Peterson (2003); Goad et al. (2004)).

NGC 5548 is classified as a Seyfert 1 with broad emission lines, and a redshift $z = 0.017175 \pm 0.000023$ (Springob et al. (2005)). This galaxy was the focus of an intense, 13 yr campaign by the International AGN Watch consortium (Peterson et al. (2002) and references therein) to study variations in the optical continuum and H_β line flux. There have also been concurrent satellite-based observations of NGC5548 in the ultraviolet (Clavel et al. (2005); Peterson et al. (1991);Korista et al. (1995)), the extreme ultraviolet (Marshall et al. (1997)), and X-rays (Markowitz & Edelson (2004)). As a result, the emission line variability properties of NGC 5548 are well characterized.

In the research of Sergeev et al. (2007) for NGC 5548, no significant correlations, except for trivial correlations, were found between various H_β profile parameters and continuum fluxes. The most significant correlation that was found (at 95% confidence for 1989–2001 and 98% confidence for the entire data set) is an inverse correlation between H_β profile widths and the H_β total fluxes, consistent with expectations. In this data set, the mean H_β profiles for 1972–1988 and 1989–2001 are very similar, while the individual profiles shows dramatic changes over several years or even less. All of the above mentioned features in variations of the spectrum and brightness show that although the line emission and the continuum show a high level correlation, broad line hydrogen emission profiles vary in a complicated manner.

In this report we have presented some results of research on the long time variability of intensities of the broad-line region emission lines in the UV spectra of the Seyfert I galaxy NGC 5548.

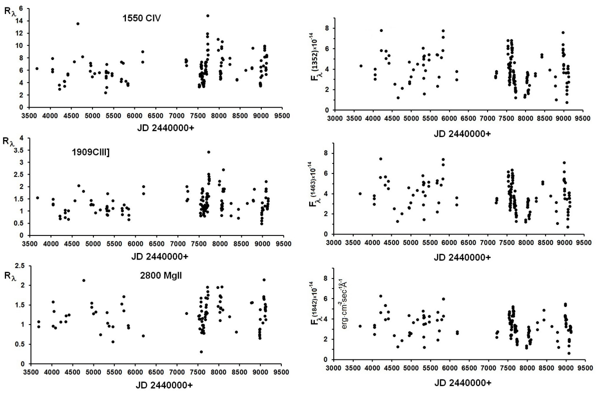

Figure 1. In left panels: from top to bottom, time variations of residual intensities R_λ of emission lines CIV 1550, CIII 1909 and MgII 2800, respectively. In right panels the same for the continuum flux F_λ for wavelengths λ 1352, 1463 and 1842 Å, respectively.

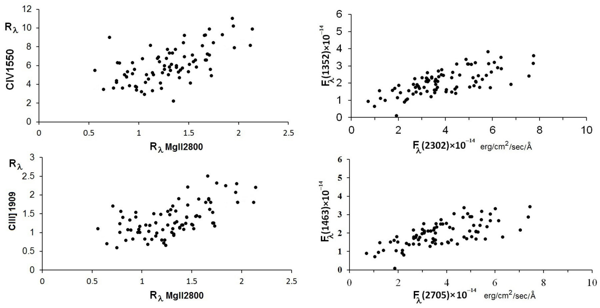

Figure 2. In the left side panels: a relation between residual intensities of lines CIV1550 and CIII1909 versus intensity R_λ of MgII 2800 line. In the right panels: diagrams of relations between the absolute flux for F_λ (1352 Å) versus F_λ (2302 Å) and for F_λ (1463 Å) versus F_λ (2705 Å).

2. OBSERVATIONAL MATERIAL AND RESULTS

150 SWP ($\lambda\lambda 1100-2000$ÅÅ), and 101 LWR and LWP ($\lambda\lambda 2000-3000$ ÅÅ) spectra of the star have been used from the IUE archive, which were obtained for 1973 – 1996. The mean spectral resolution is 6 Å. After the first transformation of spectrograms by the IUE team (Nichols&Linsky (1996)) we have taken the data and have constructed diagrams of absolute flux radiation versus wavelength in Å. Data for the UV spectra of NGC 5548 are readily available through the SIMBAD database. It is clear from a casual inspection that there are numerous overlapping lines creating blends and complicating analysis. Because of the heterogeneity of the spectra, and to account for interstellar reddening, we have applied a classical method of processing of spectrograms (Ismailov et al. (2010)). For each spectrogram, a residual intensity R_λ in units of the local continuum intensity and full with at half maximum (FWHM) have been measured for each line. The mean precision in residual intensities of the line intensity R_λ is equal ±5%, in FWHM at 10%.

In this report, we have presented the result of measurements of intensities for the strongest emission lines; CIV λ 1550, CIII λ 1909, MgII λ 2800 and HeII λ 1640. Furthermore, we have measured absolute continuum fluxes at 6 different wavelengths. Figure 1 presents a plot of the time variation of the intensities of CIV 1550, CIII 1909 and MgII 2800 emission lines and for continuum fluxes at wavelengths of 1352, 1463 and 1842 Å. As can be seen from Figure 1, there is a chaotic variability of the intensities of different lines which show synchronous variation.

Table 1
RANGES OF VARIATIONS IN INTENSITIES OF EMISSION LINES AND IN THE CONTINUUM FLUX.

parameter	min	max	max/min
CIV λ 1550	2.32	14.8	6.40
HeII λ 1640	0.35	2.9	8.3
CIII λ 1909	0.47	3.41	7.20
MgII λ 2800	0.3	2.14	7.10
F_λ(1352Å)	0.72	7.74	10.75
F_λ(1463 Å)	0.7	7.44	10.63
F_λ(1842 Å)	0.6	6.24	10.40
F_λ(2302 Å)	0.29	3.82	13.17
F_λ(2705 Å)	0.26	4.08	15.69
F_λ(3124 Å)	0.23	4	17.39

Fluxes in the continuum are varied and very complex. We found the same variability for the half-widths (FWHM) of emission lines and for the flux F_λ from the continuum. Our measurements showed that the ranges of amplitudes of variations in the spectral line intensities and continuum flux are different (Table 1): while the ratio of the amplitudes of line intensities from maximal to minimal values are 6-7, the ratio of the amplitudes of the continuum flux from maximal to minimal values are 10-17.

For the analysis we have considered a correlation between residual intensities of these lines and between line intensities and continuum flux. For example, in Figure 2 in the left side panels we have presented a relation between the residual intensities of the CIV 1550 and CIII 1909 lines versus of the intensity of the MgII 2800 line. The coefficients of correlation for these lines are $r = 0.612 \pm 0.079$ and $r = 0.616 \pm 0.080$ respectively.

In the right side panels of Figure 2, we have presented analogous diagrams between the absolute continuum flux for F_λ (1352 Å) versus F_λ (2302 Å) and for F_λ (1463 Å) versus F_λ (2705 Å). The coefficients of correlation for these flux relations are $r = 0.574 \pm 0.083$ and $r = 0.561 \pm 0.084$, respectively. Coefficients of correlations for the continuum flux between close wavelengths are higher than for those between distant wavelengths. For comparison, for fluxes F_λ (1352 Å) and F_λ (1840 Å) we obtained very high values for the coefficient of $r = 0.97 \pm 0.02$ with a confidence no less than 80%.

In Figure 3, we show relations for CIII 1909 and CIV 1550 line intensities and continuum flux for different wavelengths. These relations appear as a power-law relationship between line intensities and continuum fluxes, where the coefficient is different for different lines. For our measurements, lines which show higher amplitude of variability, such as CIV 1550, have higher values of the

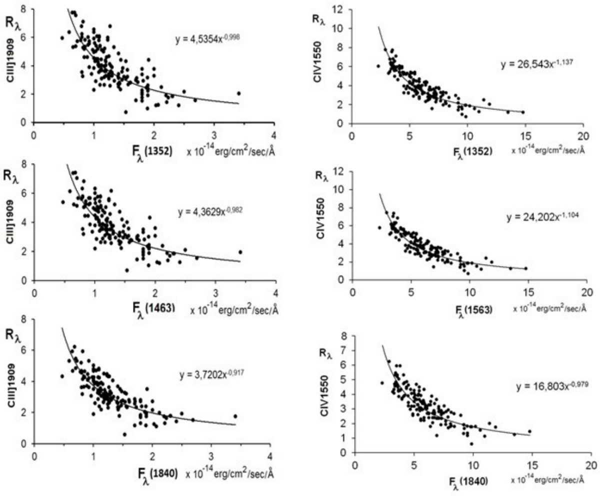

Figure 3. Relations for CIII1909 (left) and CIV1550 (right) for line intensity fluxes and the continuum for different wavelengths. The wavelength of the radiation is presented in brackets in Å.

coefficient ($\alpha > 1$), while for CIII 1909 and HeII 1640 lines $\alpha < 1$. For the doublet Mg II 2800 line intensity and continuum flux there is a very complex dependence. This means that we have complex structure in the gas radiation field in the doublet of MgII 2800.

3. CONCLUSIONS

In this study of UV spectra of NGC 5548 we have obtained the following results: 1) there is a high level of correlation between the intensities of emission lines as well as between the intensities of emission lines and continuum fluxes. With increasing wavelength the correlation in both cases become weaker. 2) The relationship between intensities of emission lines and the continuum flux can be expressed by a power law function with a coefficient $\alpha \sim 0.8 - 1.1$ for different lines. When the difference between wavelengths of spectral lines and the continuum increases, the power-law functions degree decreases. 3) It was found that the range of variability of the line intensities is weaker than the continuum flux range of variability. The range of variability in the intensities of lines and in the continuum flux increases at longer wavelengths.

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