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VARIABILITY OF REEMISSION SPECTRAL LINES IN THE SPECTRUM HD 179218

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The Herbig Ae/Be type stars (HAeBe) are pre-main sequence (PMS) objects of intermediate mass $2 - 10M_{\odot}$ and are considered to be the progenitors of Vega type stars, which are surrounded with a residual protoplanetary disks. Spectral monitoring of individual objects has shown that in the spectra of these stars are observed variable emission and absorption lines.The same features are also characteristic of classical T Tauri stars (CTTS). HD 179218 (MWC 614, Sp B9-A2) is an isolated HAe/Be type star. Our previous observations were discovered 40 days' timescale quasiperiodic variations of the hydrogen lines Hα and $H\beta$. In this report we have presented results of analysis of spectral variation of the disc reemission spectral lines He I, Si II, D NaI, [OI]. According to our spectra, the D1 and D2 NaI lines are shown an inverse –P Cyg profile. Line parameters also show a synchronous change with a change in the hydrogen lines. It also shows a wave-like variation of parameters with a characteristic time of 10-20 days.The ratio of the values of the equivalent widths of the EW(D2)/EW(D1) lines showed a monotonic de-crease from 1.7 to 0.5, which indicates a smooth variation of the physical condition in the star's disk.The absorption spectral lines SiII λ 6347 and 6371 Å show the absence of synchronous changes with changes in the hydrogen and sodium doublet lines.The existence of stratification in the distribution of radial velocities for different spectral lines was found. Lines with a high ionization potential show positive rates (for example, HeI, SiII), while lines with a low ionization potential have negative velocities (for example, D NaI).This suggests that lines with high ionization potential can form in the accretion zone of the disk. Possible mechanisms of the observed variability of the star are discussed.

Keywords: stars–variables–Herbig Ae/Be– stars– circumstellar matter – stars–individual – HD179218 .

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1. INTRODUCTION

The Herbig Ae/Be type stars (HAe/Be) are pre-main sequence (PMS) objects of intermediate mass 2-10 $M_{\odot}$ and are considered to be the progenitors of Vega type stars, which are surrounded with a residual protoplanetary disks. Spectral monitoring of individual objects has shown that in the spectra of these stars are observed variable emission and absorption lines (see, for example, [16–18]). The same features are also characteristic of classical T Tauri stars (CTTS) (see, for example, [5, 19] and references the rein). It is known that in young stars, emission lines, as well as some absorption lines, are formed in the circumstellar disks or in the envelopes of the stars. Such circumstellar matter can often participate in accretion, polar outflows, winds and other forms of disk interaction with the central star. Tracking the variation in the observed spectral lines makes it possible to perform diagnostics of the physical processes that are occurring in the stellar atmosphere and in the circumstellar environment. In young stars, in particularly, these processes can directly affect the formation of the planets and their evolution. Consequently, one of the important problems in the study of the early stage of evolution of stars is the study of the characteristics of the circumstellar structure and the processes of interaction of the central star with the surrounding matter.

HD 179218 (MWC 614, Sp B9-A2) is an isolated HAe/Be type star. Despite the fact that the star is relatively bright comparatively to other HAe stars, it has been studied less. Only when the star was included in the catalog of The et al. (1994), it became the subject of active research. The circumstellar surroundings of the star were studied by IR photometry and speckle interferometry by [12, 15], which did not reveal closely spaced components. Spectral studies of the star were performed by [6, 7, 13].

According to the classification of [12], the spectral energy distribution (SED) of the star belongs to group I, i.e. starting with the infrared band K and further there is an excess of radiation excited in the dust.On the [10] the profile of the line Hα is consisting of a stable single-peak structure.Perhaps the star has a close companion, about 2.5 arc sec apart [2, 21] showed that the star has two dust rings at distances of 1 AU and 20 AU, and the space between from 1 to 6 AU from the star filled with gas. The magnetic field of the star was measured by [4] where on the data 2008 they have got about 51 $\pm$ 30 G. The purpose of this work is to carry out monitoring of the spectral variability of the star on spectral lines obtained in the visual range of spectrum.

2. OBSERVATIONS AND RESULTS

Spectral observations of the star were performed at the Cassegrain focus of the 2 m Karl Zayss telescope of ShAO of Azerbaijan NAS by using an Echelle spectrometer ShAFES. As a light detector we have used a CCD with 4000x4000 elements. Observations were performed in the range λ 3700-9000 Å. The spectral resolution is R = 28000. Reduction and calibration of the spectrograms is performed in the DECH programs [3]. The observational devices, method of observations were described in more detail in the work [11].

In the Table 1 shown the log of observations, where in columns are respectively presented the spectrum signatures, the Gregorian and Julian dates, the signal accumulation time

Table 1. The log of observations of the star HD 179218.

Spektr	Date	JD 2450000+	t (sec)	S|N
KF 1296-97	06.07.2017	7940.5256	1800	94
KF 1443-44	21.07.2017	7954.5798	1800	89
KF 1471-72	29.07.2017	7963.3909	1800	103
KF 1483-1484	30.07.2017	7964.4166	2000	90
KF 1495-96	31.07.2017	7964.85	2000	93
KF 1538-39	02.08.2018	7966.5562	2400	89
KF 1554-55	03.08.2017	7967.5715	2400	99
KF 1565-66	05.08.2017	7970.4041	2000	91
KF 1762-63	14.08.2017	7979.3965	2400	97
KF 1859	27.08.2017	7992.402	1800	87
KF 1990-91	02.09.2017	7997.5645	2000	91
KF 2069	10.09.2017	8006.2347	1800	96
KF 2070-2071	13.09.2017	8009.3791	1800	98

and the signal-to-noise ratio in the region of the line $H\alpha$. Observations were conducted for the season May-September 2017. In total, 13 pairs of spectrograms were obtained for 13 nights of observations. For to control of instrument stability and position measurements the spectra of standard stars HR 7300 and HR 7734 for each night were obtained. The equivalent widths EW, the bisector radial velocities Vbis, the radial velocities at the peak of the line Vp, the half-widths FWHM (full width at half maximum), the central depths Rλ (intensities) of lines HeI λ 5876 Å, D1, D2 NaI, SiII λ 6347, 6371 Å, [OI] λ 6300, 6363 Å were measured.

The average error in the intensity measurements as a function of the S/N level was up to 30% for [OI] λ 6300, 6363 Å lines. The average error in measuring the radial velocities for individual spectral lines in the spectra of standard stars does not exceed $\pm$ 1.0-1.5 km/s.

2.1. Line HeI 5876

In the Figure 1 have shown the spectral region containing the lines HeI λ5876Åand the sodium doublet D1, D2 NaI. This section presents the results of the analysis for the helium line.As can be seen, this line has blue and red emission components separated by a central absorption. This is the line in which only a saddle-like two peak emission profile is observed. The average half-width of the absorption is 1.5Å with a scatter of up to 1.0 Å. The total width of the line at the continuum level is more than 20 Å. As can be seen, the profile of the HeI line λ 5876 Å stably keeps the structure from night to night, does not show any noticeable variations. In the Figure 2 have shown the superimposed each to other and mean for 13 nights profile of lines He I, Na D2, NaD1 for the season May-September 2017.

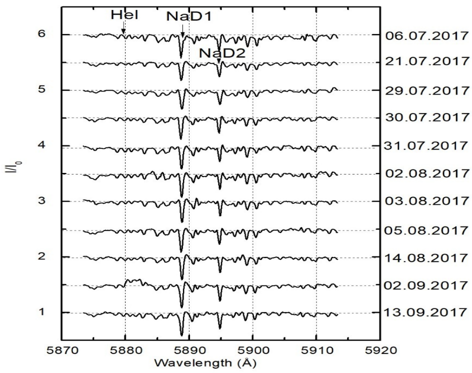
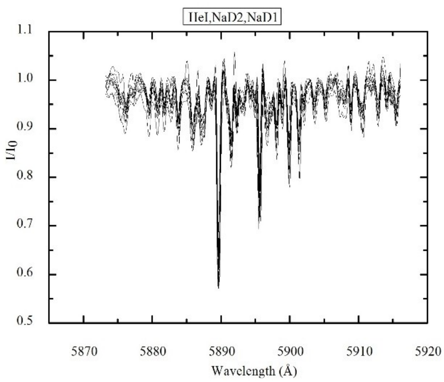


Fig. 1. A spectral range of spectra is containing lines of HeI 5876 Å and doublet D1,D2 NaI.Individual sky (atmospheric) lines are indicated.



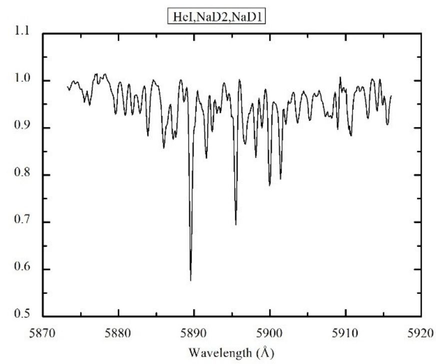


Fig. 2. Superimposed each to other (in left) and mean profile (in right) of 13 nights of lines HeI, Na D2, NaD1

The average value of the shift of the emission peaks in the HeI line of 5876 Å corresponds to approximately -150 and +150 km/s, for the blue and red components, respectively. The radial velocities of individual emission peaks is showing a variability of about an average value 50 km/s. The central absorption is displaced about +20 km/s.

Figure 4 is presentded diagrams of variations in the equivalent widths of the central absorption of EWa, the radial velocities of the absorption vertex Vp, the ratio of the equivalent widths of the blue component to the red EW1/EW2, and the half-width of the FWHM absorption in the line HeI 5876. As can be seen, while parameters of the hydrogen lines are decreased, the parameters of the absorption component of the line HeI 5876 is showing a certain variation: EWa tends to increase, Vp is shifted to the red part of the spectrum by about 20 km/s, the ratio EW1/EW2 is increased by 5-7 times, and the parameter FWHM is also increased. A decrease in the FWHM of the absorption is observed between two waves of parameter reduction.

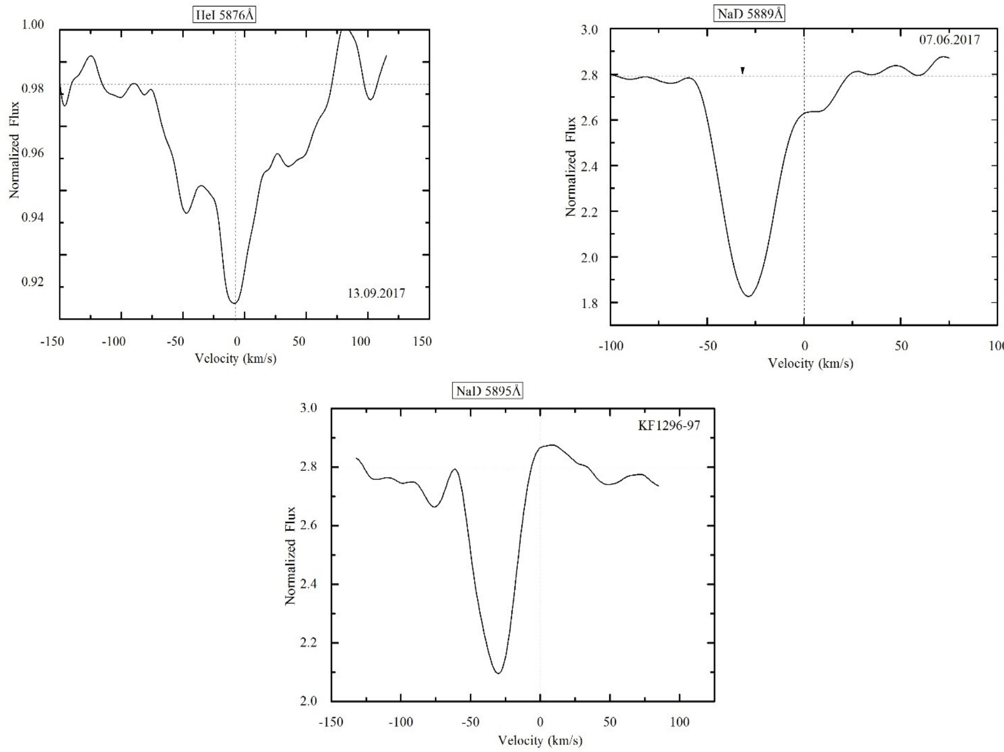


Fig. 3. Profiles HeI, Na I D of individual ranges of the star's spectrum, averaged over 13 nights of observations for the 2017 data

2.2. Lines D NaI

Figure 1 shows that the profiles of the D1, D2 NaI lines represent narrow blue-wing absorption lines in which they will have a weak emission (inverse P Cyg). Such structure is a sign of matter accretion.Interestingly, according to [7], the profiles of these lines have an emission component on the red wings. This indicates that in these lines in different seasons both the matter outflow and its accretion can be observed. Perhaps this depends on the orientation of the direction of motion of the circumstellar gas to the observer.

The Fig.4 shows diagrams of time variations for the parameters of D1, D2 NaI lines. As can be seen, in general, the radial velocities of the peak of lines Vp show a radial velocity of -15 km/s with a mean scatter $\pm$ 10 km/s. The shift of the radial velocity of the peak Vp to the blue part of the spectrum is observed with a decrease in the intensity of the hydrogen lines.

The intensities Rλ of the D1, D2 NaI lines show a wavy-like variation with a small amplitude.A similar character of the variations is shown also by the FWHM of lines (Fig.4).The characteristic time of variations in individual waves is about 10-20 days.The last line of the panels below shows the variation in the intensity ratios and the equivalent widths of the lines D2 to D1. As can be seen from this, in general, the intensities and equivalent widths of these lines are varied from night to night. This is especially right for equivalent widths of the line, which are continuously decreasing with time.

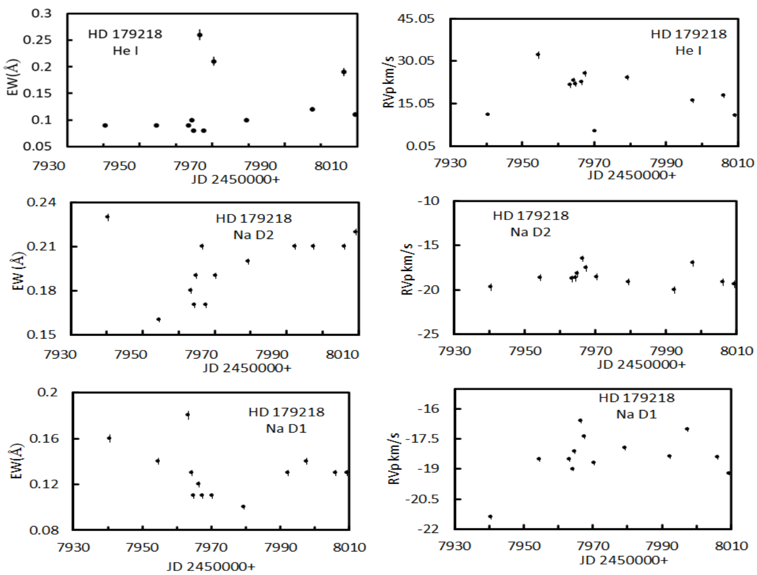


Fig. 4. The time variation of the spectral parameters of the HeI, D1, D2 NaI line for the whole observation season in 2017.The top panels are from left to EW-equivalent width of the absorption component, Vp is the radial velocity of the absorption peak.

2.3. Si II lines

The lines Si II λ6347, 6371 Å are observed in the absorption without signs of the presence of the emission components.The mean value of FWHM of the lines Si II λ6347, 6371 Å was obtained 2.37 ± 0.05 Å with the mean-square deviation from the mean value ± 0.37 Å and ± 0.50 Å, respectively. In the Fig 5. have shown the overlap and mean profile of 13 nights of lines SiII and [OI] for the season May-September 2017.

In the Fig.6 was shown fragments of the star's spectrum section containing Si II lines of λ6347, 6371 Å, as well as the [OI] λ6363 Å line. As can be seen, the general structure of Si II line profiles varies considerably from night to night. This is also seen from the variation in the parameters of the spectral lines.In the Fig.1 is given, for example, diagrams of the dependence of the radial velocities and equivalent widths of the Si II λ6347 Å line, as well as the ratio of the half-widths of the mentioned silicon lines.As can be seen, the average value of the radial velocity of these lines has positive values of +12 and +18 km/s with a scatter of 7-8 km/s at the mean. The values of the equivalent widths show a significant variation after the first wave of variations observed in the parameters of the hydrogen lines. The ratio of the half-widths of the lines also shows a smooth variation, reaching a maximum between the first and second minima of the variations.In addition, the forbidden lines [OI] $\lambda 6300$, 6363 Å are observed in the spectrum of the star in a weak form.

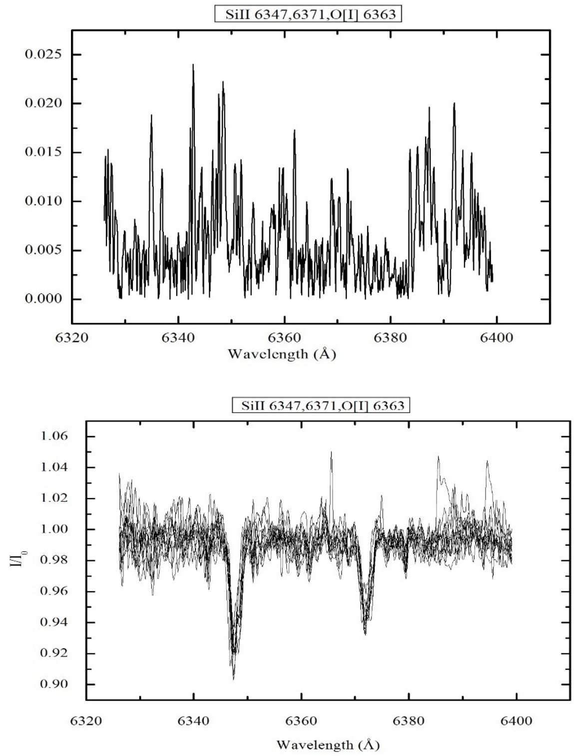


Fig. 5. Superimposed each to other (top) and mean profile (bottom) of 13 nights of lines SiII and [OI].

3. DISCUSION AND CONCLUSIONS

The rotation velocity of HD 179218 by the data Bernacca Perinotto (1970) is 60 km/s, and Guimaraes et al. (2006) gives the value $\nu sin\ i = 72\pm$ 5 km/s. According to Dent et al. (2005), the angle of inclination to the axis of rotation of the star is about 40°. Then, if we consider the observable minimum characteristic time equal to 10 days, for the projection of rotation velocity of the star we obtain $\nu = 112 \pm 8$ km/s and for the star radius - about 22 $R_\odot$, which is not reasonable and differs significantly from the data of [2] (4.8 $R_\odot$). An even greater discrepancy is obtained for the radius if we take the angle $i = 20°$, as suggested by [8]. This means that the observed cycle of about 10 days can not be a period of axial rotation of the star. Recall that the characteristic time of 10 days is obtained from the variation in the radial velocities of the peak of the dominant

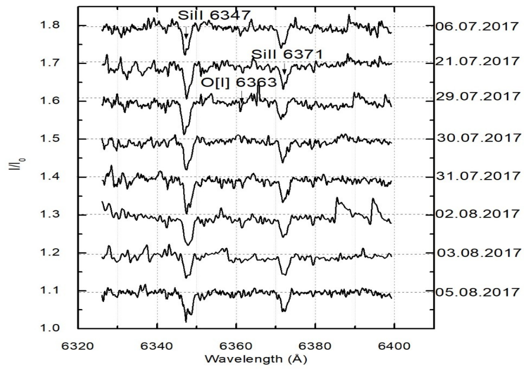


Fig. 6. The segment of the spectrum of star HD 179218 containing lines Si II $\lambda6347$, 6371 Å, and [OI] $\lambda6363$ Å. Dotted lines indicate the continuum level.

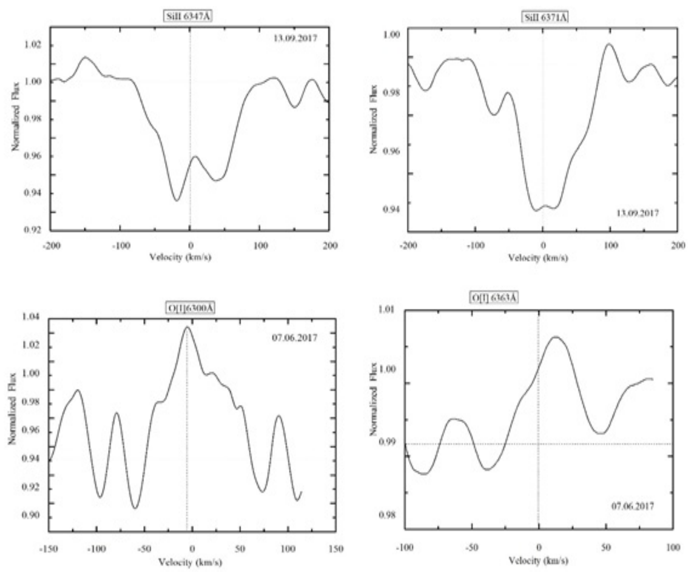


Fig. 7. Profiles SiII, O[I] of individual ranges of the star's spectrum, averaged over 13 nights of observations using the 2017 data

emission component and the intensity of the line. Therefore, it should be assumed that it arises in the outer parts of the disk. However, if the observed 10-day activity is related to the axial rotation of the disk, it can be assumed that such a variation could occur at the boundary between the accretion and outflow streams. Then one of the assumptions of the cause of the observed variations in the emission lines of the star may be the existence

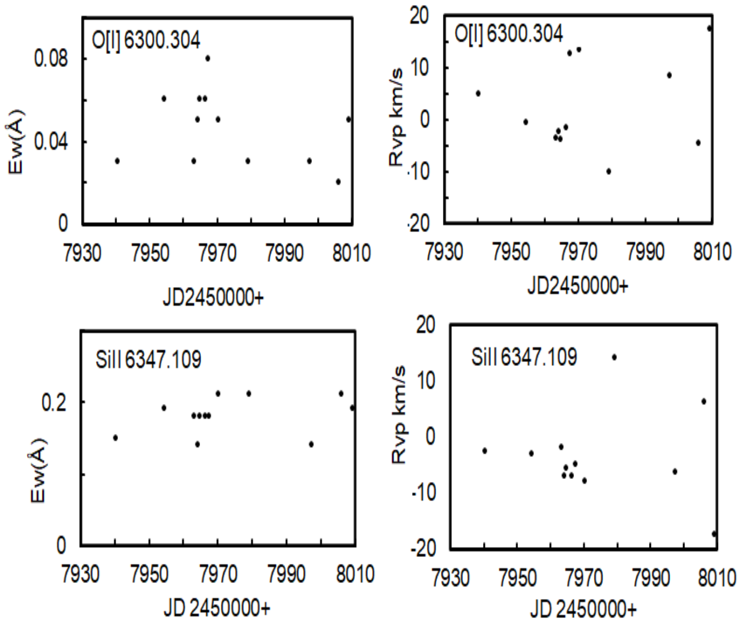


Fig. 8. Time variation in the parameters of the Si II lines λ6347, 6371 Å. The top panels from left to right are the ratio of half-widths FWHM (6347/6371), RV-radial velocities, and below EW-equivalent line widths of Si II λ 6347 Å

of a stellar magnetosphere. In favor of the possibility of the existence of magnetospheric accretion, the star is also proposed in the work of [9]. The dispersion of velocities found in our work along different lines indicates that lines with a higher ionization potential can form in the accretion zone. The main indicator of the existence of the magnetosphere of a star is the magnitude of the magnetic field.In classical T Tauri stars, for which the presence of the magnetosphere is assumed, the magnitude of the magnetic field is several kilogauss (see, for example, [1]).However, the results of measuring the magnetic field of star HD 179218 shows the existence of a weak magnetic field [4].

It is also possible that a star can be a spectral-double or multiple system. In fact, it is difficult to explain the observed wave-like variation of the radial velocities and other parameters of the $H\alpha$ line. Kozlova & Alekseev (2017) showed that the dependence of the brightness V on the color index V-I has two separate distributions. This fact is accepted by the authors in favor of the duality of a star. The time of our observations from May to September 2015 corresponds to the minimum of the 4000-day cycle of variability found in [6]. Therefore, the observed features of the variation in the spectrum of a star in the H line can be related to the moment of the star's stay at the minimum of the 4000-day cycle. Then the results obtained by us, perhaps, are a kind of unique event and can be observed only in the minima of the 4000-day cycle. Our observations have shown that in order to elucidate these questions it is necessary to perform a more dense series of photometric and spectral observations of the star.

Our results showed that perhaps, accretion and outflow processes are occurred in the magnetosphere of this star. So we conclude that Ae/Be Herbig type star MWC 614, just as its low mass counterparts - T Tauri type stars may be possessed the stellar magnetosphere.

Based on the results obtained in this paper, we can draw the following conclusions:

1.Our results for spectral monitoring of the reemitted lines are confirmed our previous results, obtained for the star, where we had discovered two wave-like variations lasting about 40 days each, in the parameters of the emission component of the $H\alpha$ line in the spectrum of the star HD 179218. For considered lines D NaI, [OI] in this work we have obtained variability in time scale at 40 days.

2.Obtained spectral parameters and profiles of lines SiII, HeI etc. are demonstrated variability in time. Profiles of these lines often were demonstrated complex structure with 2-3 components. It is indicated that some additional components of emission lines can be formed in the region at the star and disc boundary layers.

3.Observed properties of the spectral lines HeI 5876 and D NaI showed that we have some indicators of the matter accretion and outflow in the star atmosphere. These are:

- Observed invers-P Cyg and P Cyg profiles in lines D NaI;
- Observed emission component in the red wing of the line HeI 5876;
- Possible cyclic wave like variability of spectral line parameters with characteristic time $\sim$40 days.

4. ACKNOWLEDGMENTS

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