ON THE VARIATION OF ABSORPTION LINES IN THE SPECTRUM OF THE LATE SG STAR HD 199478

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The results of long-term (2011-2014) spectral observations of the supergiant star HD 199478, performed on the 2 m ShAO telescope, are presented. In this work, we are analyzed the data of photospheric absorption lines HeI λ 4921, 5876 Å, Si II λ 6347, 6371 C, C II λ 6578, 6583 Å. A significant change in radial velocities (RV) and equivalent widths (EW) were found according to the data of 2011 and 2014. According to the 2011 data, smooth contraction of the star with a characteristic time of different lines from 43 to 59 days was revealed, while the radius of the star is reduced about 15-18%. As we have shown earlier, simultaneously with the contraction of the star, the HVA effect is observed when a high-velocity shift on the blue wing of the Hα and Hβ lines is detected. The 2014 data indicate a synchronous change in the photosphere and the outer gas shell of the star. In general, photospheric lines show the complex nature of variability in different lines.

Keywords: mStars: atmospheres — stars: mass-loss — stars: supergiants — stars: winds, outflows — stars: circumstellar matter — stars: variability.

1. INTRODUCTION

Late B- and early A-type supergiants (BA SGs) are hot stars with an effective temperature near 10,000 K and a high emergent flux resulting in a partially-ionized atmosphere and a line-driven wind [1]. While these stars have long been known to show considerable variability in optical spectroscopic and photometric observations [2], the physical mechanisms underlying this variability are often not well understood. Late B and early A bright supergiants is separated group of stars which has the following properties: these stars exhibited variability of the

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stellar wind on a time scale from several days to several weeks; various observing campaigns carried out in recent years have shown that such stellar wind variability is often associated with active changes at the photosphere level; variability in the BA SGs spectral line parameters and profiles is characterized by the absence of clear periodicities [4, 5, 7–9]

One of the main interesting features of these objects is a sudden appearance and disappearance of strong, blue-shifted high-velocity absorptions, indicating that these stars may experience different wind regimes [4, 5]. There are only a few stars with unusually broad absorption in the blue wing of the Hα line, with a maximum shift of up to -1200 km/s (high velocity absorption – HVA).

Researches of Corliss et al. (2015) showed that HVA events in the supergiant HR 1040 were preceded by photosphere activity. Kaufer et al. (1996a) noted that investigations of these supergiants were relatively rare in comparison to those of O and early B-type stars and set forth four issues needing further study:

(1) the availability of observational data on photospheric and wind variability over a wide range of time and resolution;

(2) the nature, timescale, and cause of variability in Hα line profiles;

(3) the connection between radial and nonradial pulsations and photospheric variability;

(4) the relationship between photospheric variability and wind variability and mass loss. The literature on these stars continues to be sparse, with the many unanswered aspects of these questions offering opportunities for new research.

In our previous work, we analyzed the time variation in the Hα and Hβ hydrogen lines. Our observations have shown that the profiles of the spectral lines under consideration can remain unchanged during the period of 18-24 days. The most probable characteristic time of variability revealed in the hydrogen line parameters is 22 $\pm$ 2 days, which may be due to the axial rotation period of the star.

During the observing season of 2011, we discovered high velocity absorption (HVA) event with a maximal shift of -510 km/s that continued at least 13 days. High velocity absorption was also detected in the Hβ line for the first time, which was observed simultaneously with that of the Hα line.

The broad emission in the Hα line with a maximal shift of $\pm$300 km s-1 was observed in both blue and red wings, irrespective of the central Hα emission.

The quasi-cyclic smooth variability of the Hα and Hβ spectral parameters was discovered, with a maximum full cycle of 90-100 days.

The equivalent widths of the Hα emission core and Hβ absorption vary in counter-phase, which indicates that the emission contributes to the Hβ absorption line. The observed variability in the star's atmosphere is probably related to the axial rotation and the inhomogeneous structure of the atmosphere, its activity probably maintained by a magnetic field [11].

Our data set (2011-2015) is suitable for an application of time-series statistical to study the physical processes in this star and how they change over time intervals ranging from a few days up to several years. In this report, we present the results of studies of the photosphere absorption lines and their relationship with changes in the emission lines of hydrogen. This would allow studying the mechanism of activity in atmosphere of the star.

2. OBSERVATIONS AND RESULTS

The spectral observations were carried out in 2011 and 2013-2015 in the Cassegrain focus of the 2-m telescope of Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences. An echelle spectrometer constructed on the base of the UAGS spectrograph [12] was used together with the 530x580 CCD. Observations of the program star HD 199478 were performed in the spectral range λ 4700-6700 Å. The description of the observing facilities, observational conditions and data proceeding may be found in more detail in Mikailov et al. (2005) and Ismailov et al. (2013).

The spectral resolution is R = 14000. The mean signal-to-noise level is S/N = 200-300 in the region of the Hα line, and S/N = 100 in the region of the Hβ line. The procession of images, their conversion into the standard format and further measurement of spectrograms were performed using the DECH20T software developed at the Special Astrophysical Observatory of the Russian Academy of Science (SAO RAS) (Galazutdinov 1992).

The spectrograms of the standard stars HR7300 (G8II-III) and HR 7794 (G8III-IV) obtained under the same conditions showed that, of 14 nights of observations, the standard deviations of the EW values varied between 12 per cent and 3.5 per cent for the lines with mean EWs ranging from 0.05 Åto 0.5 Å, respectively. So our measurements have shown that the measurement uncertainty in EW for the central emission in the Hα line does not exceed 5 per cent. Measurements of RVs for standard stars showed a high degree of coincidence of the measured RV values with the catalog data within the measurement errors of $\pm$3 km/s. No systematic differences were revealed in our RV measurements for standard stars within the measurement errors [13].

Results in 2011. In the Figure 1a was shown a time variation in radial velocities of the absorption lines D1, D2 NaI, SiII λ6347, 6371 Å, He I λ4921, 5876 ÅCII λ 6578, 6583 Å. All lines showed a redshift with certain amplitude. For the He I and SiII lines, the RV change occurs with a characteristic time of 43 days with amplitude of 8-10 km/s. And for the D Na I and CII lines, the cycle

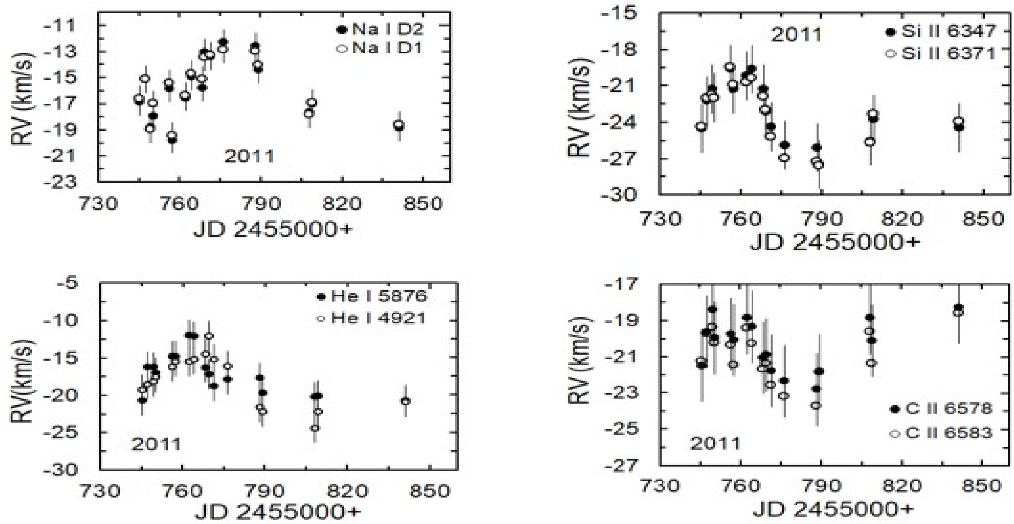

Fig. 1. Variations in time of the radial velocities of lines D NaI, SiII, HeI and CII in 2011.

ends in about 59 days, but with smaller amplitude - 5 km/s. As can be seen from Fig. 1a that for CII lines, the radial velocity changes slightly offset in time. It must be said that, just when the star's contraction cycle in the absorption lines is observed, we detected the appearance of the high-speed absorption effect of the Hα and Hβ hydrogen lines on the blue wing [11]

In the Figure 2 was shown diagrams of time variation in the equivalent widths of the same absorption lines D NaI, SiII, HeI, and CII. In these figures, it can be seen that synchronously with the contraction of the star (with increasing redshift), an increase in the values of equivalent widths is observed. For different lines, the change in EW occurs from 10 to 40% with a characteristic time of 22-23 days.

3. RESULTS IN 2014.

In other seasons of observation, we did not detect an effect. Moreover, in different years, the obtained change in the spectral parameters of the absorption lines differs significantly from the data obtained in 2011.

For example, according to 2013 and 2015. a noticeable change in the parameters of RV and EW for absorption lines were not detected. The longest observations in 2014 showed that the absorption lines this season show significant changes. In the Figure 2a was shown the results of time variability of RV for absorption lines on the data 2014. As can be seen, a certain cycle of changes that we observed for the Hα emission line and for the absorption of Hβ [11] is clearly

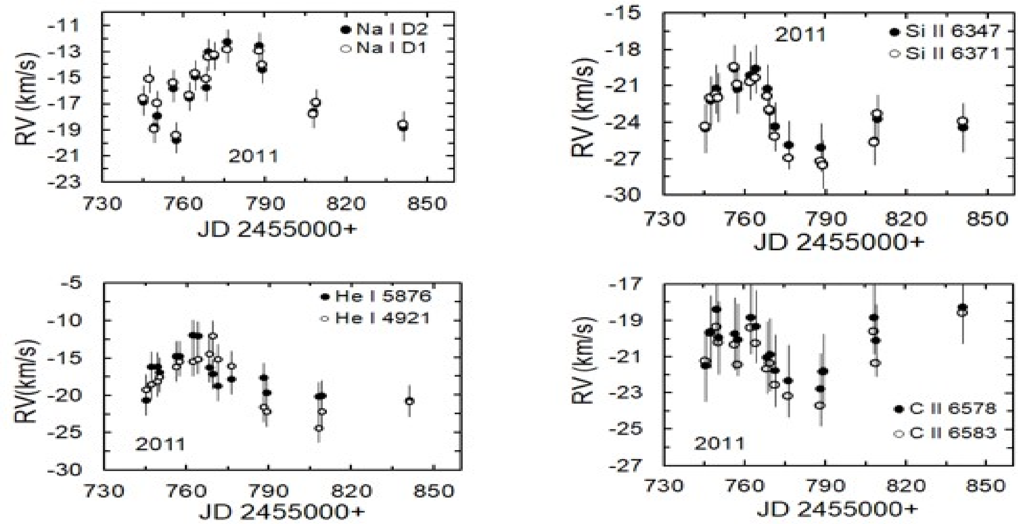

Fig. 2. Variation in time of the EW for the lines D NaI, SiII, HeI and CII in 2011

distinguished here. For absorption lines in the interval JD 2456860-2456900, all absorption lines have a smooth shift to the red part of the line and its gradual return. This cycle lasts about 40 days, and the maximum amplitude of changes in radial velocities for different absorption lines is 10-12 km/s. Recall that according to our data, the change in RV emission in the Hα line had an amplitude of about 70-75 km/s. Our data show that the variation in the RV of absorption lines occurs simultaneously with the variation in the emission component of Hα.

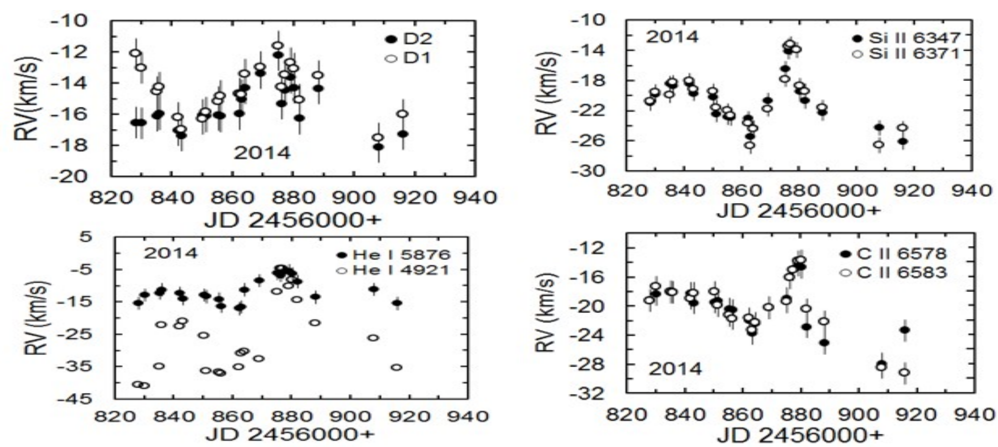

Fig. 3. The same as in fig.1a for the data 2014.

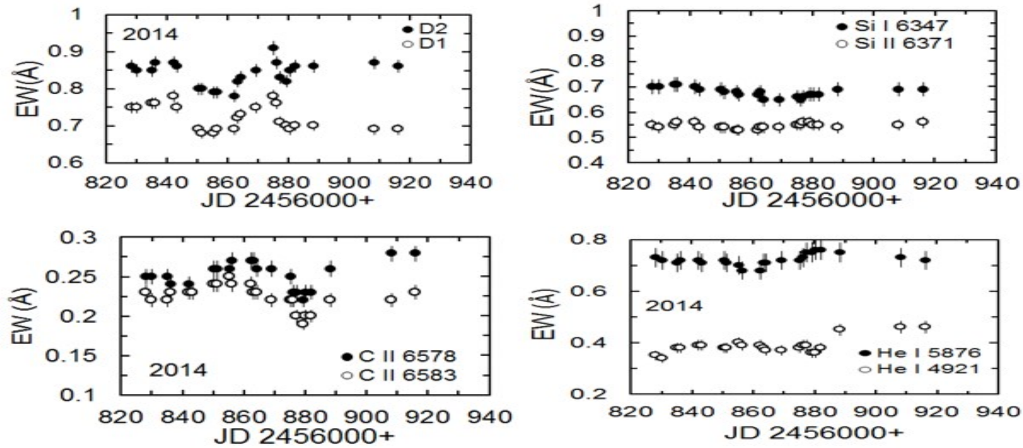

Fig. 4. The same as in fig.1a for the data 2014.

4. CONCLUSION

Our results of studies of absorption lines showed that, in separate lines, like the hydrogen lines Hα and Hβ, a wave-like change in the star's photosphere is observed, with characteristic times of 90-100 days. However, in different seasons, the standard deviation of radial velocities from the average is 1.5 -5 km/s. Most often, the variability is observed in the lines He I, D Na I. The lines Si II and C II are more stable and the average radial velocities are in good agreement with the velocity of the center of mass of the system -12 km/s.

In individual seasons, it is possible to observe a synchronous variation in the equivalent widths and radial velocities of the absorption lines. But such variations are not observed in all seasons.

The photospheric lines showed a significant change in spectral parameters during the HVA effect, which we discovered according to 2011 data. We have shown that a maximum displacement of up to 5 km/s, as well as an increase in FWHM and equivalent width, is observed for the D NaI, SiII, HeI lines. At the same time, with CII lines, when the equivalent widths increase, from peak to peak, up to 5 km/s range a blue shift is observed. Other photospheric lines showed that during the HVA event the star is contracted. The lines C II is showed different character in variation, relatively other absorption lines.

According to 2014 data, the Hα line shows a maximum displacement of -85 km/s, and the average radial velocity of the absorption lines is -12-15 km/s. If you subtract the speed of the center of mass of the system, then the maximum speed in the Hα line will be -68 km/s. This change in RV from peak to peak occurs in approximately 26 days of observation. Then the acceleration with the ejected mass falls on the surface of the star is only -3.4 cm /s2. In this case, the distance crossed by the matter at about 0.45 AU can be calculated. From this estimate it is clear that the movement of matter by stellar wind can rise to this distance from the surface of the star and then return to the surface of the star. The process can occur locally, and depending on the orientation of the axis of rotation to the observer, different profiles of hydrogen emission lines can be obtained.

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REFERENCES

1. Aufdenberg, J. P., Hauschildt, P. H., Baron, E., et al. 2002, ApJ, 570, 344 Abt, H. A. 1957, ApJ, 126, 138

2. Rosendhal, J. D., & Wegner, G. 1970, ApJ, 162, 547

3. Kaufer, A., Stahl, O., Wolf, B., et al. 1996a, A&A, 305, 887

4. Kaufer, A., Stahl, O., Wolf, B., et al. 1996b, A&A, 314, 599

5. Kaufer A. et al. 1997, A&A, 320, 273

6. Markova, N., Prinja, R. K., Markov, H., et al. 2008, A&A, 487, 211

7. Richardson, N. D., Morrison, N. D., Kryukova, E. E., & Adelman, S. J. 2011, AJ, 141, 17

8. Moravveji, E., Guinan, E. F., Shultz, M., Williamson, M. H., & Moya, A. 2012, ApJ, 747, 108

9. Corliss D. J., Morrison N. D., Adelman S. J. 2015ç AJ, 150, 190 (26pp)

10. İsmailov N.Z., İsmayilova Sh.K. 2019, MNRAS 485, 3558–3568

11. Mikailov K. M., Khalilov V. M., Alekberov I. A., 2005, Tsirkulyar Shamakhinskoi Astrophysicheskoi Observatorii, 109, 21

12. Ismailov N. Z., Bahaddinova G. R., Kalilov O. V., Mikailov K., 2013, Astrophysical Bulletin, 68, 196

13. Galazutdinov G. A., 1992, Preprint SAO RAS, No. 92