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RAPID SPECTRAL VARIABILITY OF THE SYMBIOTIC STAR CH CYG

Mikailov Khidir[1], Mammadov Ruslan[2], Rustamov Bayram [1,3], Rustamova Aysel[3]

[1]*Baku State University, Department of Astrophysics, Baku, Azerbaijan*
[2]*Batabat Astrophysical Observatory of Nakhchivan branch of Azerbaijan National Academy of Sciences, Nakhchivan, Azerbaijan*
[3]*Shamakhy Astrophysical Observatory named after N.Tusi of the Azerbaijan National Academy of Sciences, Baku, Azerbaijan*

Abstract

On 15.07.2015, 14 echelle spectra of the symbiotic star CH Cyg were obtained overnight for 6 hours with exposures of 20 minutes on the 2-m telescope of the Shamakhy Astrophysical Observatory. The change in the intensity of the line Hel ⎣5876 Å occurs synchronously with the changes in the intensity ratios of the blue and red emission components along the profiles of the lines H〈 and H®. The central intensities and equivalent widths of the HeI λ5876 line correlate with similar data of the blue emission component of the H〈 lines. Some correspondences in the radial velocities of the emission line Hα and absorption DNaI have been revealed. We assume that the rapid spectral changes we have detected in the CH Cyg spectrum are related to flickering in the optical brightness of the star, which is characteristic in the active phase of the system.

Keywords: symbiotic star, line profile, line intensity, radial velocity

1. INTRODUCTION

According to the spectral and photometric behavior, in the "quiet" and active phases, as well as according to the revealed sets of periods for the radial velocities and brightness of the system, the star CH Cyg is unique and differs greatly from other classical symbiotic stars. After the manifestation of symbiotic behavior, the photometric history of the star is presented in the form of active phases (a series of flashes: 1969-1970; 1977-1986; 1992-1995 and 1998-1999), separated by "quiet" periods with different durations. Changes in the CH Cyg light curve occur on different time scales: from a few minutes (flickering during the active phase) to hundreds of days (pulsation and rotation of the M giant), and tens of years (orbital motion of components in the system) [1].

Starting from about 2010, the brightness of the star in the rays of U gradually slowly increases and at the end of 2014 reaches a value of about 7^m-8^m. Along with the synchronous increase in the brightness of the star in the U and V rays, the remarkable photometric [2-6] and spectral [2, 7-9] changes occurring in 2014-2015 leave no doubt about the entry of CH Cyg into the next active phase.

The appearance of flickers (a sudden increase in brightness in a time interval from several minutes to several hours, with an amplitude of 0.1^m - 0.5^m) in the optical brightness of CH Cyg, can be considered a characteristic photometric behavior in the active phase of the star.

In the active phases of the symbiotic system, very complex kinematics develops in the near-stellar medium as a result of the interaction between the binary system and the near-stellar matter. The variability of the accretion and emission regime of matter manifests itself in the form of various kinds of changes in the profiles of the Balmer lines of hydrogen. Therefore, despite systematic spectral studies in all active phases of the CH Cyg star [see e.g. 3, 10-12], there is not yet a single model explaining most of the observational data.

For one night - 15.07.2015, spectral observations of CH Cyg were carried out on the 2-m telescope of the Shamakhi Astrophysical Observatory. The results of these observations are partially published in [13, 14]. This article is devoted to the description of rapid spectral changes of the HeI λ5876 lines and the NaI D1 and D2 doublet in the CH Cyg spectrum, and comparative analysis with the results of the H〈 and H® lines [13, 14] based on the same spectra.

2. OBSERVATION

The spectra of CH Cyg in the wavelength range λλ 4700-6800 ÅÅ were obtained for one night (15.07.2015) in the Cassegrain focus of the 2-m telescope of the Shamakhy Observatory. An Echelle spectrometer was used, assembled based on a universal astrospectrograph (UAGS), using a CCD camera of 580×530 pixels with a dispersion of 10.5 Å /mm at H〈 (spectral resolution R = 14,000 [15]. The observations were carried out continuously for 6 hours with an exposure of 20 minutes for each spectrum. A total of 14 Echelle spectra were obtained. Observations and processing of Echelle spectra were performed using the DECH–20 software package developed at the SAO RAS [16].

3.OBSERVATION RESULTS

PROFILES OF HeI λ5876 LINES AND NaI DOUBLET D1 AND D2 AND THE IR VARIABILITY

The profiles of the lines HeI λ5876 and NaI D1 and D2 were constructed from all available spectra, and the equivalent widths and radial velocities of the lines were measured from these profiles. Figures 1 a, b shows the profiles of the lines HeI λ5876 and NaI D1 and D2 in the spectrum of the star CH Cyg obtained for one night.

As can be seen from Fig.1a, the central intensity of the HeI λ5876 line profiles undergoes strong changes over a period of about 20 minutes, quasi-synchronously with the change in the Ib/Ir ratios of the H〈 and H® lines [13, 14]. As it was noted in [13, 14], the change in the Ib/Ir ratio is mainly due to the variability of the intensity of the blue emission component. Therefore, it can be indirectly stated that the change in the intensity of the lines HeI λ5876 and Ib emission lines H〈 and

H® occur quasi-synchronously. At the beginning of the observations, the relative intensity of the HeI λ5876 line was 1.93, and by the end of the observations, it increased approximately twice, reached a value of 3.36. The profile parameters of the blue component of the H〈 and HeI λ5876 lines correlate well with each other. The relative intensities and equivalent widths of these lines correlate with correlation coefficients 0.92 and 0.70, respectively (see Fig.2(a, b)). The change in the central intensity and half-width of the HeI λ5876 line occurs in the antiphase (Fig.3 (a, b)). The relative intensities and equivalent widths of these lines correlate with correlation coefficients 0.92 and 0.70, respectively (see Fig.2(a, b)). The change in the central intensity and half-width of the HeI λ5876 line occurs in the antiphase (Fig.3 (a, b)). The relative intensities and equivalent widths of these lines correlate with correlation coefficients 0.92 and 0.70, respectively (see Fig.2(a, b)). The change in the central intensity and half-width of the HeI λ5876 line occurs in the antiphase (Fig.3 (a,b)).

As shown in Fig. 1(b) of the NaI D1 and D2 lines, especially NaI D1 have a profile of type P Cyg. The radial velocity of the absorption component NaI D1 approximately corresponds to the radial velocity of the blue component (V_{be}) of the emission lines H〈 and H® (approximately -100 km/s), and the radial velocity of the emission component of the line NaI D1 is close to the velocity of the red component (V_{re}) of the emission lines H〈 and H® [14].

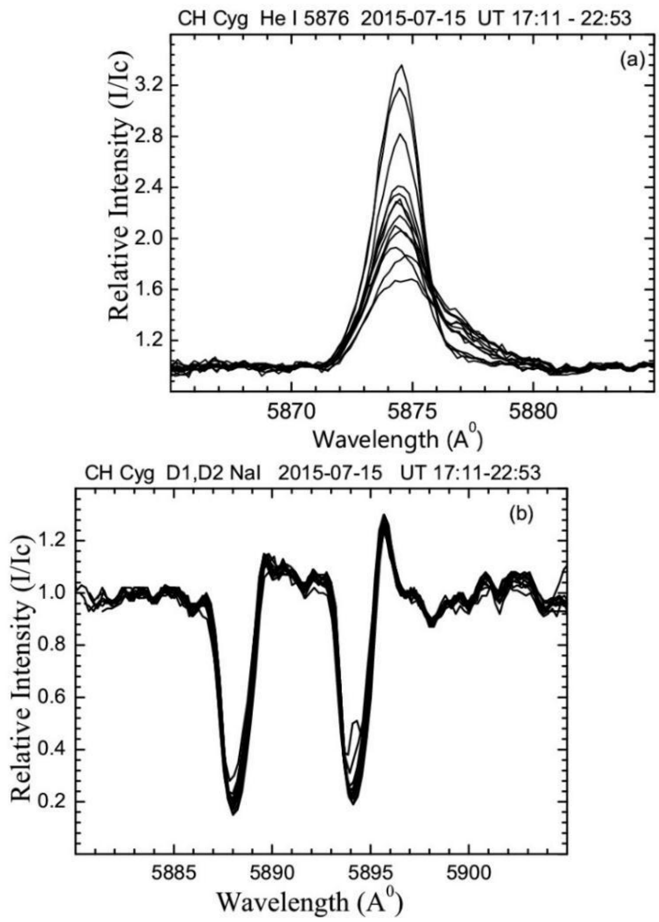

Fig.1 (a, b). Profiles of HeI λ5876 and NaI D1.2 lines in the spectrum of the star CH Cyg observed for one night (2015-07-05 UT 17:11 – 22:53).

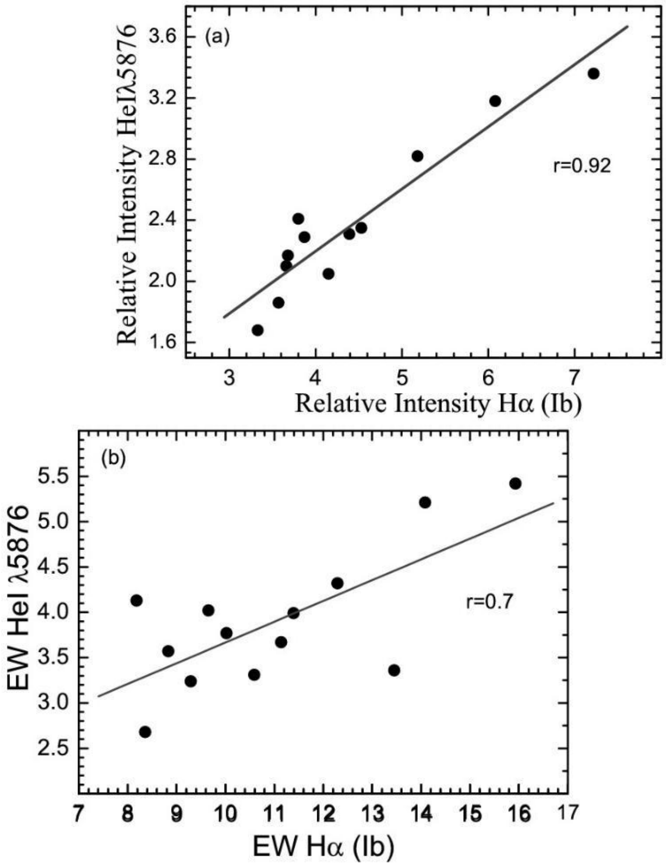

Fig.2 (a, b). Dependences of the profile parameters of the blue component of the H〈 lines on HeI 5876.

The residual intensity of the NaI D1 and D2 lines does not show sharp changes, although some variability is noticeable in the absorption core, especially in the NaI D1 line. The emission component NaI D1 for the observation period does not show variability. On one spectrum (UT 22:37), a second absorption component appears at the NaI D1 line at a speed of 68 km/s, which is close to the central absorption rate of the H〈 line [14]. The intensity of the HeI λ5876 line on this spectrum has a maximum value.

4. DISCUSSION

Using the spectra of one night for a time interval of about 6 hours, we found the dependences of the intensity of the HeI 5876 emission line, the equivalent width of the blue emission component, and the residual intensity of the high-speed absorption components on the Ib/Ir ratios of the double profiles of the emission H〈 and H® lines.

As can be seen from fig.4, there is some correspondence in the radial velocities of the emission line H〈 and the absorption DNaI. This, apparently, indicates that sodium lines are formed in a relatively hot and dense gas, in the region of the formation of the H〈 line. Such conditions are achieved in relatively small areas of the disk or wind, whereas the region of the emission line formation is longer [see for ex.] [17].

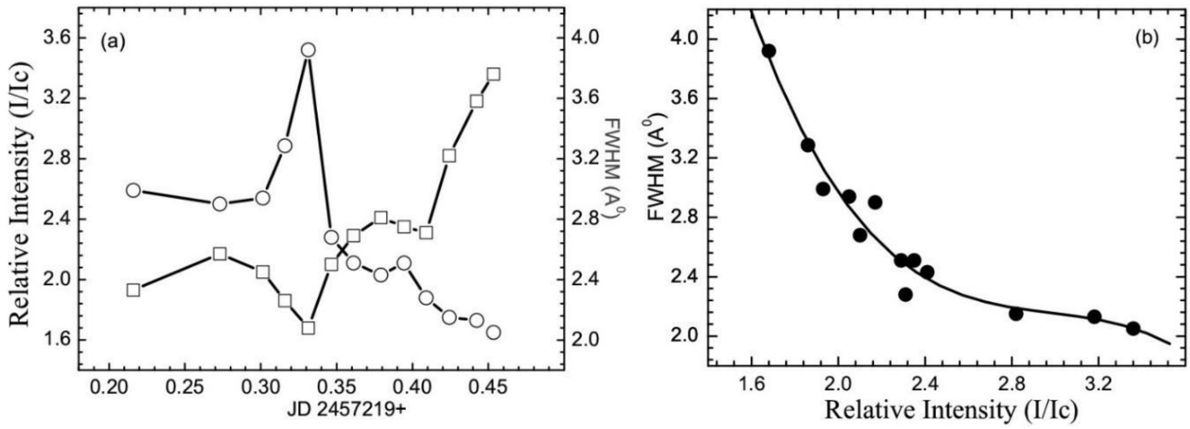

Fig.3 (a, b). The change in the central intensity (y–axis scale on the left scale) and the half–width (y-axis scale on the right scale) - (a) and the dependence between the central intensity of the half-width - (b) - line HeI λ5876 on a time scale of about 6 hours during the night in the spectrum of the star CH Cyg.

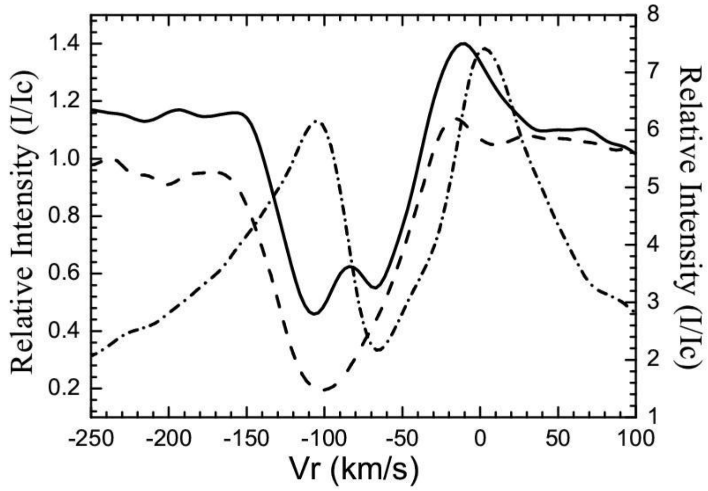

Fig.4. Profiles of the lines NaI D1 (solid line), NaI D2 (dashed line) - scale on the y axis on the left scale and the emission line H〈 (dashed line) - scale on the y axis on the right scale, according to the spectrum obtained in 2015-07-05 (UT 22:37).

Apparently, the shape of the profiles and the intensity ratios of the emission lines strongly depend on the activity levels of the white dwarf and on its position in orbit. For the orbital period of 5689.2 days according to the ephemeris given in [18].

$$JD\ (periastre) = 2445681\ (\pm 192) + 5689.2\ (\pm 47.0) \times E$$

calculated the phase corresponding to our spectral observations: ⎞= 0.028. During our spectral observations, the hot component was almost periastric. Due to the large value of the orbital period, it can be assumed that the 2014-2015 hot star was located near the periaster. The maximum convergence of the system components leads to the activation of the mass exchange process and is accompanied by significant spectral variability.

In 2014-15, rapid photometric variability with amplitudes of $0.^{m}1$-$0.^{m}3$ and ~$0.^{m}5$ was detected in the active phase of the CH Cyg system for a characteristic time of 7-15 minutes and 4 hours, respectively [6, 7]. Summing up the above observational facts, it can be concluded that in 2014-15 and the previous active phases of the CH Cyg system, rapid photometric variability (flickering) is observed with characteristic times comparable to the time of spectral variability.

Apparently, the rapid spectral changes we have detected in the CH Cyg spectrum are associated with flickering in the optical brightness of the star.

5. CONCLUSION

1. It was found that with changes in the Ib/Ir ratios of the blue emission component of the emission lines H〈 and H® synchronously occur:
    a. changes in the intensity of the line HeI λ5876. The central intensities and equivalent widths of the HeI λ5876 line correlate with similar data of the blue emission component of the H〈 lines.
    b. changes in the equivalent widths of the blue emission component of the H〈 and H® lines
    c. the intensity of high-speed wide absorption components on the blue wing of the H® line. During the observations, at first for a time of 2.5 hours, with a decrease in the Ib/Ir ratio, the intensity of the absorption components increases, and the next 3 hours, with an increase in the Ib/Ir ratio, the intensity of the absorption components decreases.
2. The radial velocity of the absorption component NaI D1 approximately corresponds to the radial velocity of the blue component (-100 km/s), and the radial velocity of the emission component of the NaI D1 line is close to the velocities of the R components of the emission lines H〈 and H®.
3. The rapid spectral changes detected by us in the CH Cyg spectrum are apparently related to flickering in the optical brightness of the star, which is characteristic in the active phase of the system.

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