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THE Hα AND Hβ LINES IN THE SPECTRUM OF CH CYG IN 2016

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ABSTRACT. We present the results of spectral observations of the symbiotic star CH Cyg, carried out at the Cassegrain focus of the 2-m telescope of the ShAO named after N.Tusi, by using the Shamakhy Fiber Echelle Spectrograph (ShAFES). The spectra of star CH Cyg were obtained with the spectral resolution of R = 28000, between June and November 2016. We also present the results of the comparative analysis of the brightness curve of the star with the main parameters of Hα and Hβ emission lines. During the observation period, both lines exhibited changing profiles characterized by complex structures, predominantly with double peaks. The ratio of the intensities of the blue and red components was typically $I_B/I_R < 1$ for the Hα line and $I_B/I_R \geq 1$ for the Hβ line. A quasi-period of 241 days was found in the variation of the equivalent widths of Hα and Hβ emission lines as well as in the intensities of their components

Keywords: Symbiotic star – CH Cyg; echelle spectra; line profile; radial velocity.

АНОТАЦІЯ. Наводяться результати спектральних спостережень симбіотичної зорі CH Cyg, виконані у фокусі Кассегрена 2-м телескопа ШАО ім. Н. Тусі за допомогою Шамахінського волоконного ешеле-спектрографа (ShAFES). Спектри зорі CH Cyg були отримані зі спектральною роздільною здатністю R = 28000 у період з червня по листопад 2016 р. Також використовуючи фотометричну базу даних змінних зір AAVSO побудовані криві блиску зорі CH Cyg за період наших спектральних спостережень. За профілями емісійних ліній Hα та Hβ були виміряні наступні параметри: променеві швидкості синього та червоного піків випромінювання – RV(I_B та I_R); променеві швидкості центрального поглинання – RV(I_{CA}); еквівалентні ширини емісійних ліній Hα та Hβ – EW; інтенсивності компонентів емісійних ліній Hα і Hβ та їх відношення – I_B/I_R. За період спостережень лінії демонстрували мінливий профіль, що характеризується складною структурою, переважно з подвійним піком. Співвідношення інтенсивностей синьої та червоної компонентів загалом становило $I_B/I_R < 1$ для лінії Hα та $I_B/I_R \geq 1$ для лінії Hβ. Співвідношення інтенсивностей лінії Hβ не так сильно варіюється, як у Hα. Зміна відносин I_B/I_R інтенсивностей синьої (I_B) і червоної (IR) емісійних компонентів лінії Hα корелюється зі змінами променевих швидкостей центрального поглинання (RV(I_{CA})), зі зменшенням відношення I_B/I_R радіальна швидкість центрального поглинання збільшується.

За період спектральних спостережень з червня до листопада 2016 р. яскравість зорі у V-фільтрі зменшилася приблизно на $1^m.5$. Приблизно з 16 по 28 серпня 2016 року яскравість зорі збільшилася приблизно на $0^m.5$ і знову почала зменшуватися. У змінах, еквівалентної ширини та інтенсивності синьої (I_B) та червоної (I_R) емісійних компонент ліній Hα та Hβ, у спектрі симбіотичної зорі CH Cyg, встановлено квазіперіод з характерним часом 241 днів.

Ключові слова: Симбіотичні зорі – CH Cyg; ешеле-спектри; профілі спектральних ліній; променеві швидкості.

1. Introdution

The symbiotic system consists of two completely different types of stars that coexist – interacting, cold red giant – RG (in some cases yellow) and hot compact – WD stars. As a result of strong gravity, the substance flowing from the red giant gathers around this star and forms a disk. This couple is surrounded by nebula as a whole.

By studying symbiotic stars, we simultaneously study 3 different types of space objects: 1. Red giant; 2. White dwarf and accretion disk; 3. Star environment gas and dust nebula. In systems of this type, a powerful flow of matter occurs through the stellar wind from a cold Star, and an accretion disk is formed around a hot compact star. Symbiotic stars can reflect a transitional stage in the evolution of several types of double systems with a powerful flow of matter from a

large-mass star to a small-mass star. (Mikailov, 2010; Mikolajewska et al., 2010).

Among symbiotic stars, CH Cyg is of particular interest and has remained the focus of most researchers until the present time and attracted them due to its inherent characteristics. These features include:

1. CH Cyg is the brightest and closest symbiotic star. The distance to the star, according to measurements by Hippacrosus, is 268±62 pc. Its average visual magnitude of about $m_v = 6^m.5$ at maximum, $m_v = 10^m.5$ at minimum, and it is brighter in infrared region, and its magnitude at a wavelength of 2mkm is $m_k = -1$. (Munari et al., 1997; Belczynski et al., 2000).

2. In the star CH Cyg, both optical and radio domain, directional jet-shaped bipolar eruptions (jets) are observed at a speed of 1200 km/s, the length of which reaches 750 astronomical units. To understand such phenomena and unravel their origin, CH Cygni is the most optimal laboratory (Karovska et al., 2010; Kellogg et al., 2007).

3. CH Cyg pulsates with the exact period (100 and 750 days) characteristic of the cold red giant o Cet (Mira) of the symbiotic system. As a result, the accretion regime changes, and the system shows changes of an even more complex nature. At the same time, such systems with different short and long orbital periods behave differently than other symbiotic stars. The study of the evolution of such a system is of great importance (Hinkle et al., 2009; Hinkle et al., 1993).

4. In the CH Cyg symbiotic system, evidence has been increasing lately indicating the existence of the 3rd Star. Many researchers perceive it as a system of 3 stars. The 756-day short period may be the period of the 3rd star in an invisible inner orbit of a symbiotic pair of M gigants and hot stars with a 15.5-year long period (Mikailov, 2010).

5. CH Cyg is also completely different from other symbiotic stars due to its long activity dynamics. After many years of passivity, activity began in 1963, and after the great flashing in 1977, this activity continues to the present (Mikailov, 2010).

2. Observations and data reduction

Spectral observations symbiotic star CH Cyg, were carried out at the Cassegrain focus of the 2-meter telescope at the Shamakhy Astrophysical Observatory, named after N. Tusi, using the Shamakhy Fiber Echelle Spectrograph (Mikailov et al., 2020) and the CCD matrix with 4096 x 4096 pixels. The spectral resolution was R = 28000, and the wavelength range was 3800-8000 Å in during June – November 2016 were obtained 9 echelle spectrums of star CH Cyg. Processing of echelle spectra was carried out according to the standard method using the new version of the DECH30 program developed by Galazutdinov (http://www.gazinur.com/DECH software.html). A list of all used spectra is given in Table 1.

For the spectral observations period between June – November of 2016, the brightness curve of the star CH Cyg has been constructed using the AAVSO photometric database. As displayed of the figure, the brightness of the star has reduced by approximately $1^m.5$ in the V filter. Around 16 – 28th of august 2016-time interval, the brightness of the star has increased by about $0^m.5$ and started to reduce once again.

3. Results of observations

The following parameters were measured from the available spectra, from the Hα and Hβ emission lines profiles:

a) the radial velocities of the blue and red emission peaks: RV(I_B and I_R);

b) as well as the radial velocities of the central absorption: RV(I_{CA});

c) the equivalent widths in the Hα and Hβ emission lines (EW);

d) the intensities of the Hα and Hβ emission lines components (I_B and I_R) and their ratios I_B/I_R.

Results of measurements of parameters of Hα and Hβ lines is given in Table 1 and 2.

Figure 1 presents the Hα and Hβ emission lines profiles in the spectrum of CH Cyg for the period of our spectroscopic observations (June – November 2016). During the observation period, both lines exhibited changing profiles characterized by complex structures, predominantly with double peaks. The ratio of the intensities of the blue and red components was typically $I_B/I_R < 1$ for the Hα line and $I_B/I_R \geq 1$ for the Hβ line. The Hα and Hβ emission lines (blue and red emission components as well as the central absorption) as a rule, is blue shifted.

As seen in Figure 1 and Table 1, 2: a) The intensity of red (I_R) and blue (I_B) components of H alpha lines show abrupt variations. In two nights, the intensity ratio was $I_B/I_R > 1$, but for the rest of the nights was $I_B/I_R < 1$ displaying strong variability. This variability agrees with the radial velocity of central absorption of Hα lines RV(I_{CA}). As the I_B/I_R ratio reduces, the radial velocity of central absorption increases. b) The intensity ratio of blue and red components of Hβ was $I_B/I_R > 1$ for 6 nights and for the rest 3, it was $I_B/I_R \approx 1$. The intensity ratio doesn't display as much variability as it did in Hα.

A quasi-period of 241 days was found in the variation of the equivalent widths of Hα and Hβ emission lines, as well as in the intensities of their components (Fig. 2).

Table 1: Results of measurements of parameters of profiles of Hα line.

Data	JD	EW (Å)	Rv (km/s)			Int		I_B/I_R
	+2457000		I_R	I_{CA}	I_B	I_R	I_B	
15.05.2016	524.455	15.01	-17.15	-77.00	-113.34	3.88	5.00	1.29
13.06.2016	553.444	5.07	-28.42	-72.53	-113.58	2.20	2.57	1.17
16.07.2016	586.304	8.05	-34.82	-80.01	-109.33	4.54	3.08	0.68
16.08.2016	617.233	18.21	-38.79	-90.67	-115.02	9.67	3.79	0.39
19.08.2016	620.254	13.96	-37.41	-85.58	-117.42	5.82	3.58	0.62
28.08.2016	629.21	13.76	-39.04	-84.20	-120.55	4.77	3.77	0.79
21.09.2016	653.198	10.27	-41.36	-87.6	-119.20	3.47	2.60	0.75
			-15.96		-184.90			
26.11.2016	719.186	34.27	-30.41	-91.23	-118.67	11.16	6.91	0.62
30.11.2016	723.161	41.10	-36.74	-95.65	-120.36	15.75	7.25	0.46

Table 2: Results of measurements of parameters of profiles of Hβ line.

Data	JD	EW (Å)	Rv (km/s)			Int		I_B/I_R
	+2457000		I_R	I_{CA}	I_B	I_R	I_B	
15.05.2016	524.455	10.66	-8.22	-52.60	-102.46	4.81	6.41	1.33
13.06.2016	553.444	5.53	-17.10	-53.41	-107.57	2.49	3.23	1.30
16.07.2016	586.304	6.42	-22.59	-66.40	-97.90	2.98	3.68	1.23
			-44.87		-170.40			
					-216.60			
16.08.2016	617.233	11.82	-14.76	-28.99	-102.56	3.89	5.20	1.34
19.08.2016	620.254	11.33	-13.44	-36.06	-106.75	3.86	5.57	1.44
28.08.2016	629.21	12.08	-10.47	-39.56	-109.46	4.32	5.50	1.27
				-55.36				
21.09.2016	653.198	10.91	-7.85	-35.24	–103.33	4.16	4.08	0.98
				-54.00	-165.41			
26.11.2016	719.186	24.37	-22.94	-54.61	-110.69	9.55	9.28	0.97
				-74.11				
30.11.2016	723.161	25.13	-23.50	-57.75	-110.41	9.74	8.96	0.92
				-79.35				

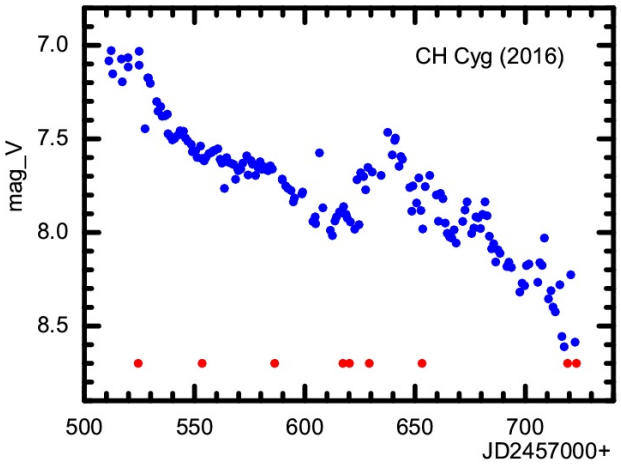

Figure 1: Visual light curve of the CH Cyg star in June – November of 2016. The filled red circles indicate the time of observations.

4. Conclusions

1. Over the period of our spectral observations (June-November 2016) of the symbiotic star CH Cyg, the profiles of the Hα and Hβ lines represent the emission profiles with predominantly double peaks, highly variable intensities of the red (I_R) and blue (I_B) components. The I_B/I_R ratio is < 1 for the Ha line and $I_B/I_R \geq 1$ for the Hβ line.

2. Changes in the I_B/I_R ratios of the intensities of the blue (I_B) and red (I_R) emission component of the Hα line is correlated with changes in the radial velocities of the central absorption (RV(I_{CA}); as the I_B/I_R ratio decreases, the radial velocity of the central absorption increases.

3. During the spectral observation period from June to November 2016, the luminosity of the star in the V-filter decreased by about $1^m.5$. From about August 16 to August 28, 2016, the luminosity of the star increased by about $0^m.5$ and began to decrease again.

4. A quasi-period with a characteristic time of

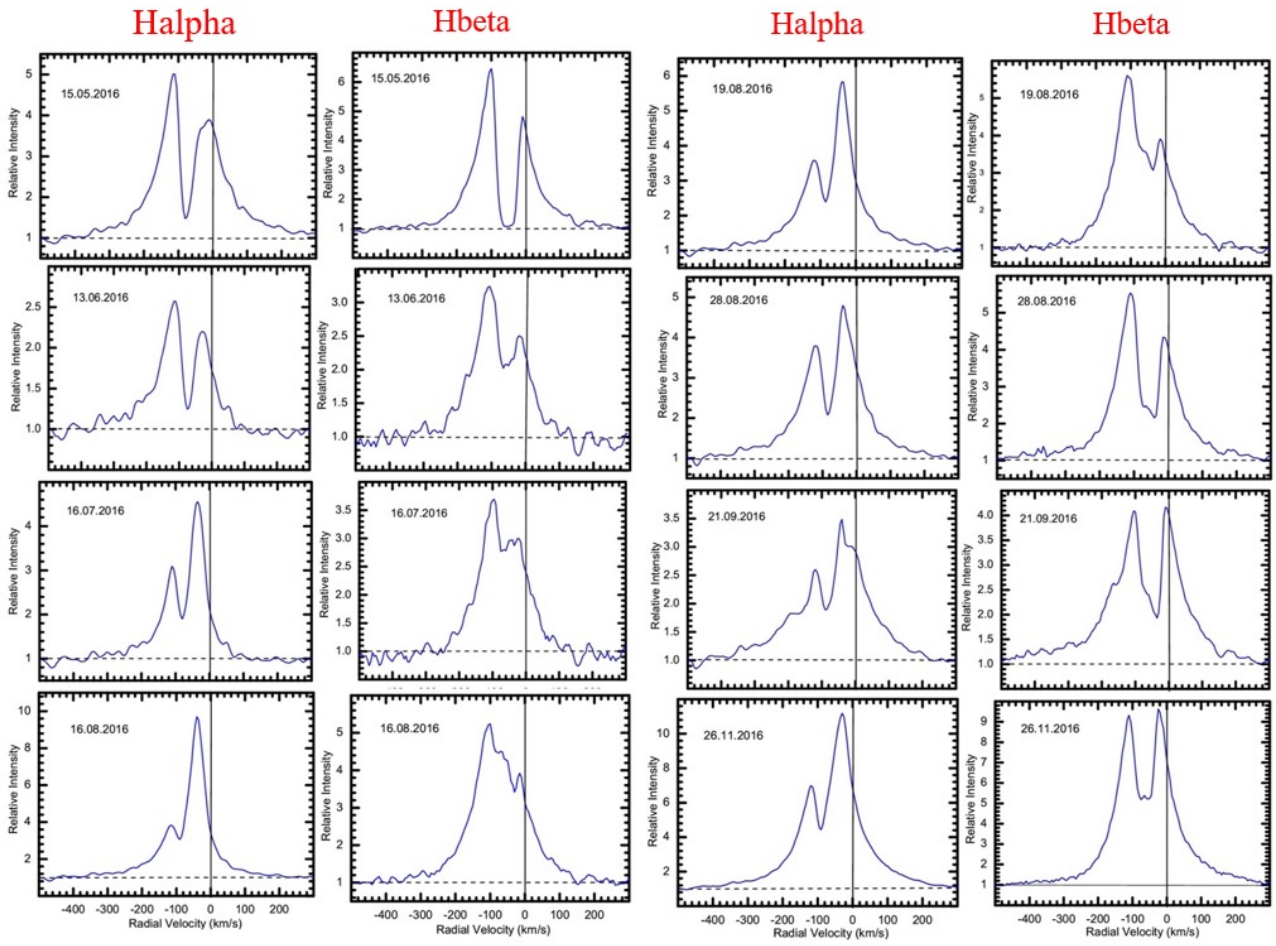

Figure 2: Profiles of Hα and Hβ lines in spectrum CH Cyg.

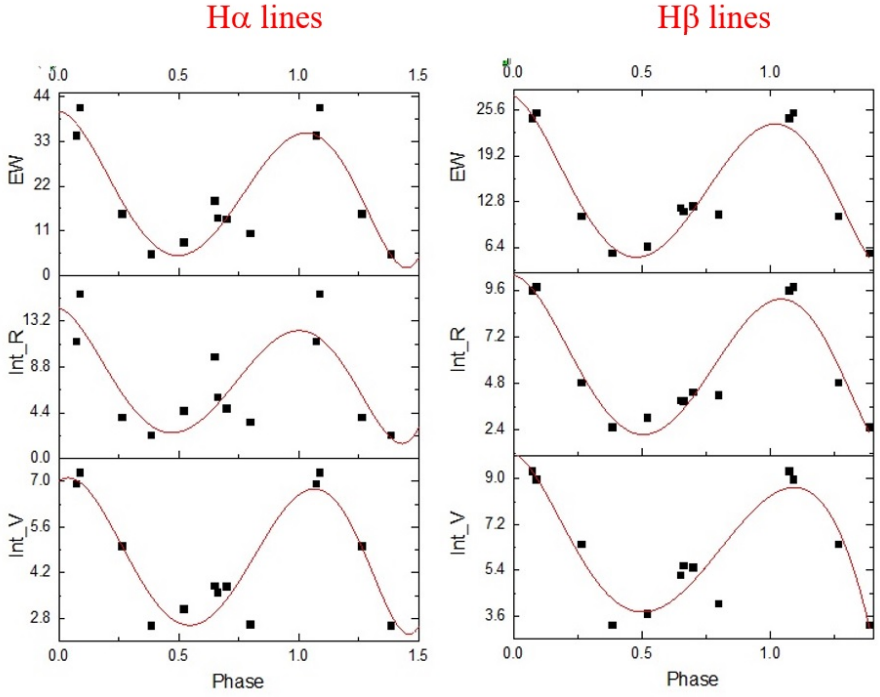

Figure 3: Periodicity in the variabilities of the equivalent widths of Hα and Hβ emission lines, as well as in the intensities of their components.

241 days has been established in the changes in the equivalent width and intensities of the blue (I_B) and red (I_R) emission component of the lines Hα and Hβ in the spectrum of the symbiotic star Cyg.

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