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ACTIVE STAGE OF THE SYMBIOTIC STAR CH CYG IN 2015

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ABSTRACT. Symbiotic star CH Cyg is very different from other members of this group by the behavior of its photometric and spectral parameters. CH Cyg also belongs to a small subgroup of symbiotic stars in spectra where the high velocity absorption components have been observed – so called "Jet Absorption Structures" in the Hydrogen lines from the Balmer series. In this paper, the behavior of these jet absorption structures in Hα and Hβ lines in the spectrum of the symbiotic star CH Cyg during 18 nights from July to September of the year 2015 is described. Spectra has been obtained at the Cassegrain focus of the 2-meter telescope at Shamakhy Astrophysical Observatory with the help of echelle spectrograph with spectral resolution of R = 14 000. This paper also provides the profiles of the Hα and Hβ lines with absorption components on the blue wing. Based on the depth and the appearance, the absorption components have changed significantly and the short wavelength boundary reaches velocities of near 2500 km/s. The depth of absorption component on Hα is considerably less than the one at Hβ.

Keywords: symbiotic star – CH Cyg; echelle spectra; line profile; Jet Absorption Structures.

АНОТАЦІЯ. Симбіотична зоря CH Cyg значно відрізняється від інших членів цієї групи поведінкою фотометричних і спектральних параметрів. CH Cyg також належить до невеликої підгрупи симбіотичних зір, в спектрах яких спостерігаються компоненти, так звані Jet структури поглинання в лініях Гідрогену серії Бальмера. З історії фотометричного вивчення цієї зорі відомо, що починаючи з 1967 року було зафіксовано кілька моментів її фотометричної активності. Як правило, у цих активних фазах спостерігається блакитне зміщення високошвидкісних абсорбційних компонент в лініях Гідрогену серії Бальмера, а інколи, і в інших лініях. Починаючи приблизно з 2010 року яскравість зорі в U променях поступово збільшується і вже до кінця 2014 року досягає приблизно 7–8 зоряної величини. Одночасно із синхронним зростанням яскравості в V і U променях у 2014–2015 роках відбуваються помітні фотометричні і спектральні зміни. У цій роботі розглядається поведінка Jet структур поглинання в лініях Hα і Hβ з в спектрі CH Cyg протягом 18 ночей (приблизно 50 діб) з липня по вересень 2015 року. Спектри зорі програми були отримані на телескопі системи Кассегрен з діаметром головного дзеркала 2 м (Шамахинська астрофізична обсерваторія) за допомогою ешелле спектрографа з просторовою роздільною здатністю R = 14000. Фотометрично-активна фаза зорі у 2015 році не дуже сильно відрізняється від попередніх активних фаз, але така різноманітність Jet структур за формою і глибиною спостерігається тільки у 2015 році. Ми також наводимо профілі ліній Hα і Hβ з абсорбційними компонентами у блакитному крилі. Глибина і зовнішній вигляд компоненти поглинання суттєво змінилися і короткохвильова межа досягає швидкості близько 2500 км/с. Глибина складової поглинання в лінії Hα є значно меншою, ніж глибина лінії Hβ. Ми не знайшли залежності глибини короткохвильових границь променевої швидкості Jet структур поглинання від блиску зорі, а також від відношення інтенсивності блакитної і червоної емісійних компонент профілів вищевказаних ліній серії Бальмера.

Ключові слова: симбіотична зоря CH Cyg: ешелле спектри.

1. Introduction

Symbiotic stars – binary star system the spectrally resolved consisting of an interacting red giant and a white dwarf surrounded by a nebula. In this system, a strong flow of matter from the cold star to the hot star occurs through the stellar wind, leading to the formation of an accretion disk around the compact star.

CH Cyg star is a unique observational object, with characteristics of spectral and photometric variability that are very different from other symbiotic stars:

1. In 1984/85, the system showed a strong radio outburst, during which a double-sided jet with multi-

ple components was ejected (Taylor et al., 1986). This event enabled an accurate measurement of the jet expansion with an apparent proper motion of 1.1 arcsec per year. With a distance of 268 pc (HIPPARCOS) (Crocker et al., 2001), this leads to a jet velocity near 1500 km/s. The spectral energy distribution derived from the radio observations suggest a gas temperature of about 7000 K for the propagating jet gas (Taylor et al., 1986).

2. The photometric variability, such as flickering, occur of the CH Cyg symbiotic system. The source of these flickering's is believed to be the accretion disk. The disappearance of flickering's after flashes is explained by the disintegration of the disk.

3. The cold red giant in the CH Cyg symbiotic system pulsates with a period of 100 to 750 days, characteristic of o Cet type stars. This pulsation affects the accretion mode, resulting in more complex variations in the system.

4. Recently, many researchers have proposed that the 750-day periodic variation in the CH Cyg system may be due to the presence of a third star rather than pulsation. It is suggested that the 750-day period could correspond to the orbital period of this third star in an inner orbit of the symbiotic pair, which consists of the red giant and the white dwarf, with a longer orbital period of 5650 days.

5. One of the unique features of CH Cyg is its inclusion in the small group of symbiotic stars for which jet structures have been observed. "Jet Absorption Structures" have been detected in only 9 out of 220 stars cataloged as symbiotic stars. CH Cyg, along with MWC 560, serves as a natural laboratory for study the unique mechanism energy releaze due to the variety of shape, spectral parameters of the observed jets.

Most researchers agree that the CH Cyg symbiotic system consists of a pulsating red giant and a white dwarf. Matter is accreted from the red giant to the white dwarf, and the outflowing matter forms a disk around the star. This system is surrounded by a common shell. The observed spectral and photometric properties of this system are determined by the of the interaction of these three components and the physical accretion process.

This model, which has been sufficiently developed by many researchers over many years, and in many cases is in good agreement with observational results, is not accepted by a number of researchers. They suggest that there is a third star in this system. Although the triple star hypothesis is generally accepted by a number of researchers, there is no consensus on the role played by the third star in the physical processes taking place in this system. If a 3rd star is present, its spectrum should be visible (in some phase) as the red giant. Another interesting point is whether the 3rd star produced an eclipse, so far there have been no observations signs of such an eclipse.

Two main periods were found in the variation of photometric and spectral parameters of the CH Cyg star: a long period of 15.6 years (5400, 5600, 5800, 5900 days) and a short period around 750 days.

1. According to the first model, the approximately 15-year period represents the orbital period of the binary system, consisting of the red giant and the white dwarf, around their common center of mass. The short period of 750 days is attributed to the pulsation period of the red giant.

2. According to the second model, CH Cyg consists of three stars: the 15-year period represents the orbital period of the binary system, consisting of the red giant and the white dwarf, around their common center of mass. The short period of 750 days explained by the presence of a third star moving in the inner orbit.

2. Observations and data reduction

The spectral observations of symbiotic star CH Cyg have been performed at the Cassegrain focus of 2-m telescope of Shamakhy Astrophysical Observatory. Echelle-spectrometer with the CCD array (580×530 pixels) was employed. The wavelength range $\lambda\lambda$4700–6800 ÅÅ, spectral resolution R = 14 000, dispersion 10.5 Å/mm at Hα (Mikailov et al., 2005). We used 18 echelle spectra obtained for the period July–September 2015 (Table 1). Processing of echelle spectrograms were performed using software package DECH20T, developed at Special Astrophysical Observatory of RAS (Galazutdinov, 1992).

Data (day, month, year)	UT hrs, min	JD2450000+	Exposure time, s
18.07.2015	19 32	7222.31	1200
24.07.2015	17 06	7228.21	1200
26.07.2015	17 05	7230.21	1200
27.07.2015	17 28	7231.23	1200
29.07.2015	17 05	7233.21	600
30.07.2015	16 51	7234.20	600
30.07.2015	17 09	7235.22	600
01.08.2015	16 43	7236.20	600
04.08.2015	16 51	7239.20	900
07.08.2015	17 24	7242.23	1200
10.08.2015	16 49	7245.20	1100
12.08.2015	17 42	7247.24	1000
13.08.2015	16 54	7248.20	900
16.08.2015	17 43	7251.24	900
18.08.2015	17 55	7253.25	1200
19.08.2015	18 10	7254.26	1200
03.09.2015	17 06	7269.21	1200
04.09.2015	17 40	7270.21	1200

Table 1: Journal of spectroscopic observation.

Fig. 1 shows the historical light curve of the star CH Cyg in U and V magnitude for the period between the years 1967 and 2015, taken from (Skopal, 2015a). As

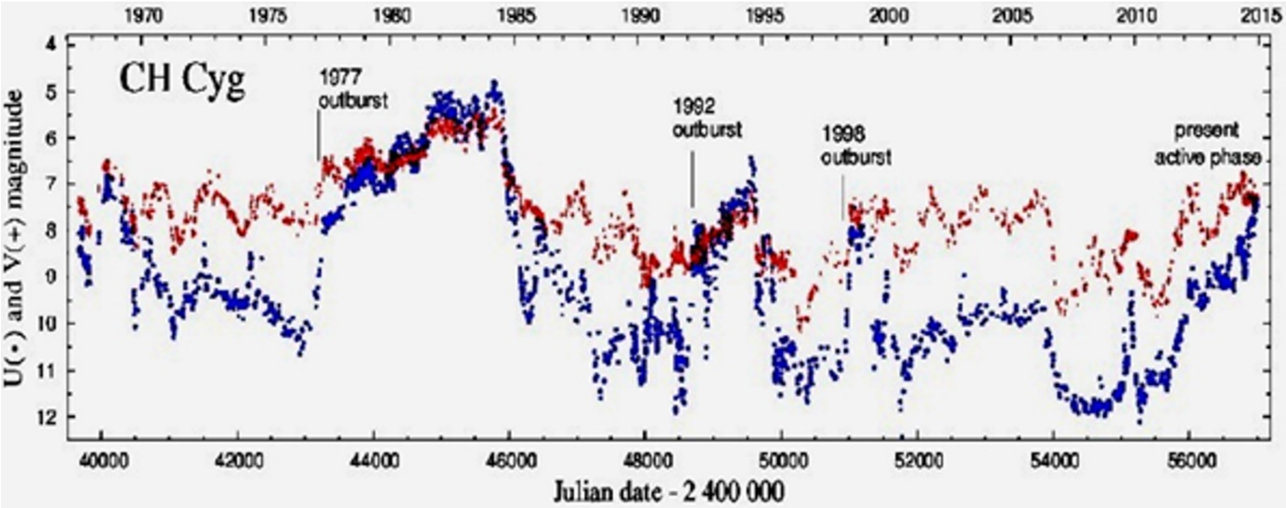

Figure 1: Historical light curve of the symbiotic star CH Cyg in U (dots, blue) and V (pluses, red), taken from (Skopal, 2015).

can be seen from the figure, several episodes of photometric activity of the star were recorded during this period (1984–1985; 1992–1995; 1998–2000; 2011–2015). As a rule, blue-shifted high-velocity absorption components are detected in these active phases in the lines of the Balmer series of hydrogen and sometimes in some other lines. Starting around 2010, the brightness of the star in U light gradually increases slowly and reaches a value of about 7^m–8^m (Skopal, 2015a) at the end of 2014. Along with the synchronous increase in U and V rays, remarkable photometric (Rspaev et al., 2014; Shugarov et al., 2015; 2008) and spectral (Rspaev et al., 2014; Skopal, 2015b,c,d) changes occurring in 2014–2015 leave no doubt that CH Cyg is entering into its next active phase.

Figure 2 shows the light curve in the visual region of the star CH Cyg for the period of our spectral observations – in July–September 2015 (AAVSO data for CH Cyg).

Vertical red lines indicate the time of spectral observations. As can be seen from the figure, in July–August the star's brightness increases slightly and at the beginning of September decreases again.

3. Results of observations

In 2015, during the spectral observations of the symbiotic star CH Cyg that has been conducted at the Shamakhy Astrophysical Observatory, unique "Jet Absorption Structures" have been discovered for the first time in the history of observations of this star. During the characteristic time of about 50 days, almost all types of Jet Absorption Structures established in symbiotic stars to date were observed.

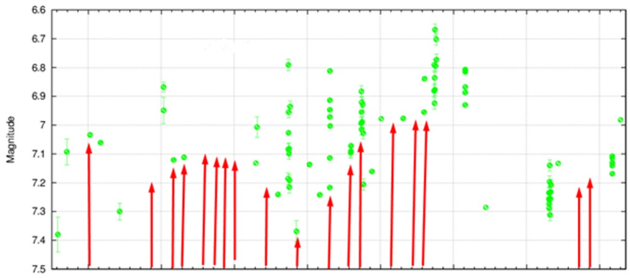

Figure 2: V light curve of the CH Cyg star in July–September 2015. Vertical red lines indicate the time of spectral observations

As can be seen from Fig. 1, the photometric active phase of the star CH Cyg in 2015 does not differ too much in appearance from previous active phases, but such a diversity in the shape and depth of jet structures absorptions was observed only in 2015.

The behavior of jet absorption structures in Hα and Hβ lines in the spectrum of the symbiotic star CH Cyg during 18 nights from July to September of the year 2015 is described. In Provides the profiles of the Hα and Hβ lines with absorption components on the blue wing. Based on the depth and the appearance, the absorption components have changed significantly and the short wavelength boundary reaches velocities of near –2500 km/s. The depth of absorption component on Hα is considerably less than the one at Hβ. Figure 3 shows the profiles of the Hα and Hβ lines in demonstrates temporal variations for the jet absorption structure of Hα and Hβ lines in the spectrum of the symbiotic star CH Cyg. Fig. 2 and Fig. 3 shows the type and wavelength boundaries of the "Jet Absorption

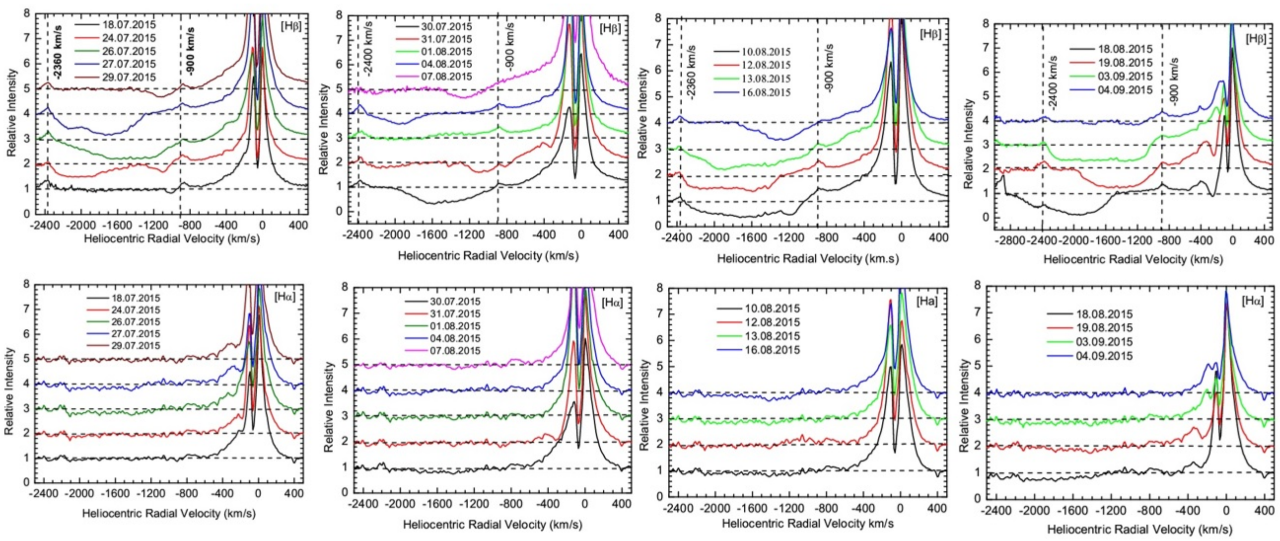

Figure 3: Temporal variations for the jet absorption structure of Hα and Hβ lines in the spectrum of the symbiotic star CH Cyg

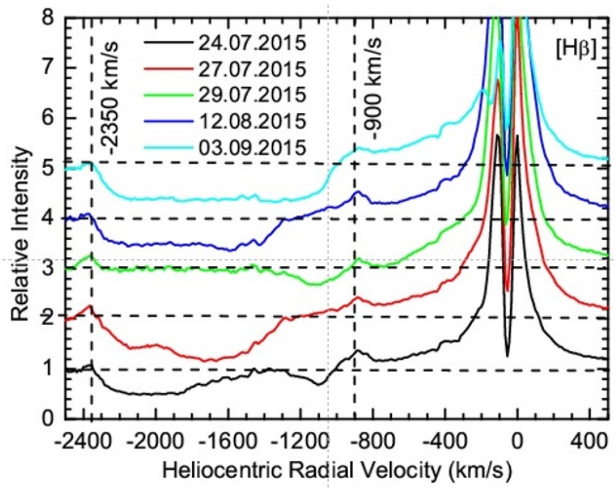

Figure 4: The selected profiles line Hβ, with the jet absorption in the spectrum of the symbiotic star CH Cyg

"Structures" do not depend on the brightness state of the star. Figure 4 shows selected characteristic profiles of line Hβ, with the jet absorption in the spectrum of the symbiotic star CH Cyg. Fig. 5 demonstrates that the Hβ line profiles with high-speed absorption components (Jet Absorption Structures) are not normalized to the continuum. According to this figure, the red emission component of the Hβ line practically does not react to the notable change occurring on the blue wing of the line. Fig. 6 displays the time dependence of the intensity ratios of the blue (V) and red (R) emission components of the Hα and Hβ lines. As inferred from

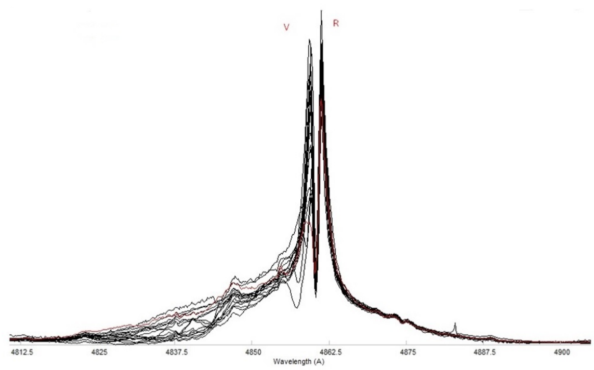

Figure 5: The profiles Hβ lines with jet absorption structure the superimposed one easer other, no normalized at the continuum.

this figure and Fig. 3, the shape of the "Jet Absorption Structures" does not depend on the V/R ratios either.

Our spectral observations only cover the Hα and Hβ lines from the hydrogen lines. Therefore, there is no information about other hydrogen lines.The given profiles of jet structures are a characteristic or averaged profile obtained on a given night of observations.

4. Conclusions

In symbiotic stars, the matter for accretion onto the compact object is supplied from the primary component which is the red giant. However, not every symbiotic star is a source of jets. It is still unclear what parameters this depends on. The velocity in the jets

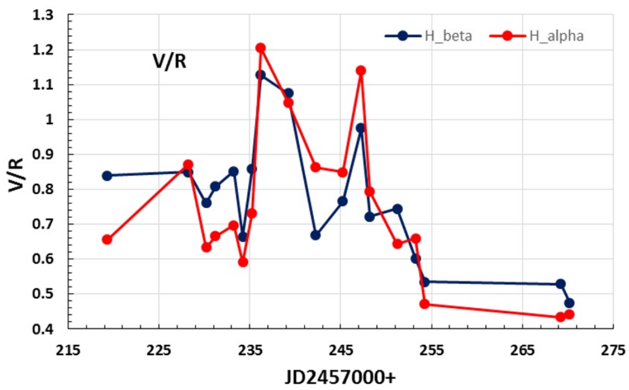

Figure 6: Variations of ratio V/R, for the intensities of blue and red emission components of Hα and Hβ lines in the spectrum of CH Cyg in July–September 2015.

of symbiotic stars reaches several thousand km/s. Apparently, these jets operate in a pulsed mode, and in the case of CH Cyg. The impulsive nature of the jet producing stars of symbiotic systems suggests that the critical mass for the formation of jets is required to get accumulated in the accretion disk around the white dwarf before the jets begin to form. In a binary system, this may occur due to a change in the flow in the stellar wind from the second component, and/or a change in the distance between the components during orbital motion at a significant eccentricity. Since the white dwarf may have a strong magnetic field, its role in the formation of collimated jets is not disregarded.

In spectroscopic observations of the symbiotic star CH Cyg conducted at the Shamakhi Astrophysical Observatory in July–September 2015, high-speed absorption components (Jet Absorption Structures) were discovered on the blue wing of the Hα and Hβ lines. The short-wavelength boundary of these absorptions reaches approximately –2500 km/s. Virtually all types of Jet Absorption Structures found in symbiotic stars to date were detected over the course of 18 nights (about 50 days).

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