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SPECTRAL OBSERVATIONS OF THE HERBIG Be STAR HD 53367

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ABSTRACT. The unusual spectroscopic behavior of star Herbig Be HD53367 is described based on the spectra obtained on the Cassegrain focus of the 2-meter telescope at the Shamakhy Astrophysical Observatory, using the Fiber Echelle Spectrograph (ShAFES), with a spectral resolution of R=28000.The results of comparative behavior analysis of profiles of selected lines (Hα, Hβ, HeI λ5876 Å, NaID, H and K CaII) are presented with analogical data published in the literature.

Keywords: echelle spectrograph, radial velocities, line profiles, star HD53367.

АНОТАЦІЯ. На основі спектрів, отриманих у фокусі Кассегрена 2-м телескопа Шамахінської Астрофізичної Обсерваторії на волоконному ешеле спектрографі (ShAFES), з використанням CCD матриці STA4 150A з 4 x 4 елементів, проаналізовано поведінку незвичайної спектральної особливості зір типу Be Хербіга HD 53367. Розмір елемента матриці 15 мкм, спектральна роздільна здатність R=28000, охолодження – рідкий азот. Обробка ешеле-спектрів проводилася за стандартною методикою з використанням нової версії програми DECH30, розробленої Галазутдіновим.

З метою дослідження навколозоряного середовища, нами для аналізу були обрані наступні лінії у спектрі зорі HD53367: Hα, Hβ, HeIλ5876Å, NaID, H та K CaII, а також, для дослідження зір на предмет подвійності, включені для аналізу лінії фотосферного походження – HeIλ6878Å, HeIλ4471Å. Судячи з встановленої для цієї зорі ознаки (кореляція емісійного спектру з блиском), можна припускати, що спектральні спостереження проводилися близько до максимуму блиску зорі.

У період наших спектральних спостережень (січень 2019 – січень 2020 рр.) з Бальмерівських ліній водню тільки Hα повністю та Hβ частково спостерігаються в емісії, а лінії Hγ – Hε показують абсорбційний спектр. Лінії резонансних дублетів, нейтрального натрію (D1,2 NaI) та одноразово іонізованого кальцію (H & K CaII) представлені у наших спектрах міжзоряною складовою. Геліоцентричні променеві швидкості цих ліній (у середньому): 27,5 км/с (D2NaI); 28,4 км/с (D1NaI); 26,2 км/с (HCaII); 25,7 км/с (KCaII). Профіль лінії нейтрального гелію HeIλ5876Å являє собою центральну абсорбційну та емісійну компоненти на синьому крилі (25 січня 2019 р. та 17 січня 2020 р.) або на обох крилах (14.12 та 21.12.2019).

На основі літературних даних була побудована крива променевих швидкостей для фотосферних ліній: HeI 6878Å, HeI 5875Å, HeI 4471Å для зорі HD 53367, з періодом P = 183.34 дня, запропонованим М. Погодіним (2006). Виміряні нами променеві швидкості лінії HeIλ6878Å задовільно лягають на цю криву.

Ключові слова: ешелле-спектрограф, радіальні швидкості, профілі ліній, зоря HD53367.

1. Introduction

HD53367 (MWC166, V750 Mon, B0e – B1e III – V, V = $7^m.0$) is located in the vast star-forming region CMa R1 which contains more than a hundred young stellar objects of various masses and an association of reflection nebulae. This object is probably the most massive (15 – 25 $M_\odot$) (Tijn, Dije et al., 2001). HD53367 – a visual binary system (RST 3489) with Δm$\sim 1^m.3$ and component distance $\rho = 0''.6$ ($\sim$600 a.u. – assuming a distance of about one kpc proposed by Claria (1974)). Shows emission lines in the optical spectrum, and besides, Hα is the brightest, and its circumstellar environment shows evidence of cold, dusty matter as an excess in the far IR, at $\lambda \geq 10$ μm (Tijn , Dije et al., 2001). HD53367 is on Herbig's original list of young Ae/Be Herbig stars (Herbig, 1960). HD53367 has a long-term photometric variation with a period of 9 years. The brightness decrease of HD53367 is accompanied by the damping of emission in the lines. However, there is a significant difference in the time

scales of these processes. For example, the transition of HD53367 from a bright photometric state to a low one took more than one year (from August 1996 to October 1997), while emission in the Balmer lines was observed for another five years (until the end of 2002). HD53367 is also a spectroscopic binary star (Finkenzeller & Mundt, 1984). The main component shows ray velocity variations that may correspond to a period of 166 days and an amplitude of about 20 km/s at an average velocity of +48.2 km/s.

Two mechanisms were proposed to explain the photometric behavior of HD53367 (Tijn, Dije et al., 2001):

1. Magnetic activity in the star's photosphere stimulates the cyclic development of cold spots on its surface. As a result, it leads to a reduction in effective temperature, causing reddening of the star.

2. The second mechanism suggests the existence of a dense uniform perturbation slowly precessing in the CS disk around the Be star. The periodic eclipse of this region, along with amplified emission from the limb of the star, leads to the observed photometric and spectral variations. Another remarkable property of HD53367 is the significant ray velocity variations observed in several photospheric lines (Corporon & Lagrange, 1999).

As can be seen from the behavior of the profiles of the Balmer hydrogen lines (Hα and Hβ) borrowed from the data published in the literature, the types of profiles endure significant changes depending on the photometric state of the star. The emission and absorption profiles of hydrogen lines in different states of the photometric brightness of the star were recorded from observations, but there are no transition profiles between these states. Along with this, it is essential to carry out tight series of spectral observations of the star in the maximum state of brightness to investigate the behavior of the V/R ratios on periodicity. As mentioned above, significant ray velocity variations in selected photospheric lines are revealed on this star. Investigations of selected lines of cleanly photospheric origin would serve to refine the binary period of the star HD53367. The relevance of these researches is determined by the above experimental statements and, in general, by the role of binarity in the evolution of young Ae/Be Herbig-type stars.

2. Observations and data processing

Spectral observations of the star HD53367 were carried out at the Cassegrain focus of the 2-meter telescope of the Shamakhy Astrophysical Observatory named after N.Tusi, on fiber echelle spectrograph ShaFES (Shamakhy Fiber Echelle Spectrograph), by using CCD matrix STA4150A 4 ×4 K elements, cooled by liquid nitrogen, with an element size of 15 μm (Mikailov et al., 2020).

The quantum efficiency in the wavelength range $\lambda\lambda$ 3000-8000ÅÅexceeds 70 %, with a spectral resolution R = 28000, in the wavelength oblast $\lambda\lambda$ 3900–7500 ÅÅ. For the period January 2019 – January 2020, for 4 nights, we received two spectra of the star HD 53367 each night and a complete set of calibration frames: dark (or bias), flat-field, ThAr, and Sky. 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.htm).

3. Results of observations

The following peculiarities were chosen by us for analysis in the spectrum of the star HD53367:

Balmer series lines: 6562.817 Hα; 4861.332 Hβ; 4340.468 Hγ; 4101.737 Hδ; 3970.074 Hε.

Resonant sodium doublet: D1NaI (λ 5895.940 Å) and D2NaI (λ 5889.973Å).

Resonant calcium doublet: HCaII (λ 3968.492 Å) and KCaII (λ 3933.682Å).

Neutral helium: HeI λ 5876Å.

Lines of ionized iron FeII 42 ($\lambda\lambda$ 4923.921 Å, 5018.434 Å, 5169.03Å).

Photospheric lines: HeI λ 6678 Å, HeI λ 5876 Å, HeI λ 4471Å.

4. The discussion of the results

The picture of the spectral and photometric variability of the star HD53367 is quite complex. Therefore, studies of the circumstellar medium (from the profiles of the Hα and Hβ lines), as well as the gaseous component of this medium (from the profiles of the HeI l5876, NaID, H, and K CaII lines), in various states of the stellar photometric activity, are essential. Furthermore, observational data indicate the spectral binarity of the star HD53367.

Therefore, as indicators of binarity, absorption lines of photospheric origin were chosen by us for analysis Fig. 1 shows in our disposal the observed profiles of the Hα and Hβ, He λ5876Å, and NaID, H and KCaII lines in the spectrum of star HD 53367. As can be seen from Fig. 1 , from the Balmer hydrogen lines, only Hα is entire, Hβ is partially observed in the emission. The (Hγ – Hε) lines show the absorption spectrum. The Hα and Hβ line profile's form and intensities in spectrum of star HD53367, correlate with the star's optical brightness state (Pogodin et.al., 2006).

At the maximum brightness, the Hα line in the emission, while the brightness decreases, the emission intensity decreases, and after some threshold value of the brightness, the emission disappears, and the line becomes completely absorbing. Judging by this sign, from the shape of the profiles of the Hα and Hβ lines,

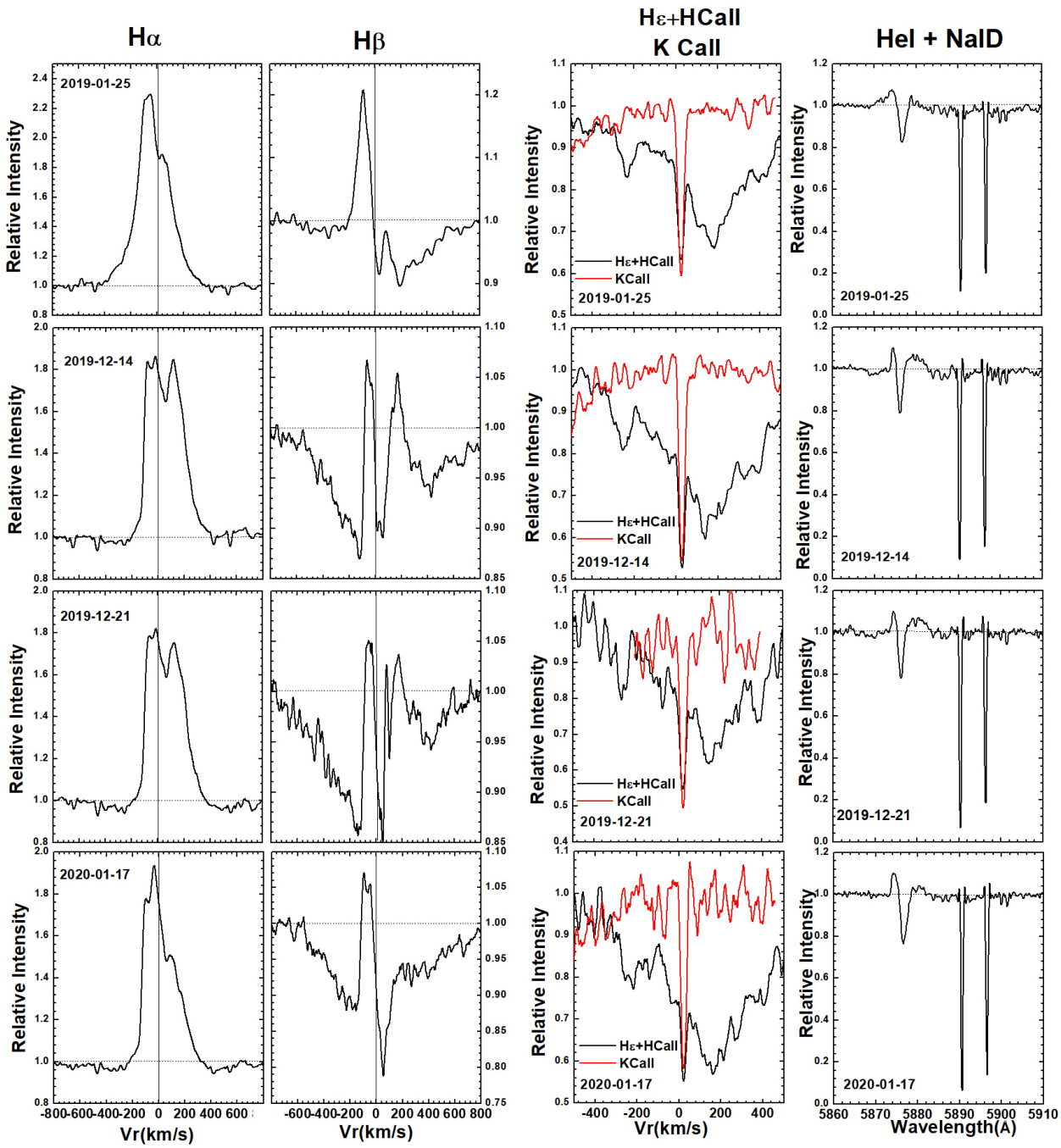

Figure 1: The observed profiles of the Hα and Hβ, H and KCaII, NaID and He λ5876Ålines in the spectrum of star HD 53367 (from left to right)

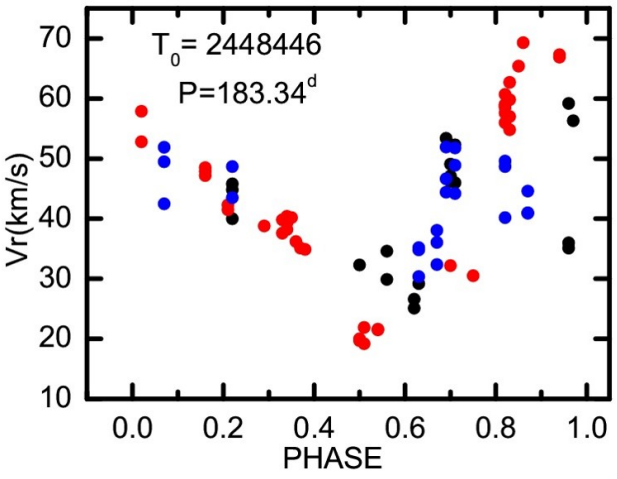

Figure 2: Radial velocities of the star HD53367 folded with the period of P = 183.34 days suggested by M. A. Pogodin et al. The following symbols are used measured for different authors: black circles – Corporon P., Lagrange A.M., 1999, A&AS, 136, 429; red circles – Pogodin M. A. et al., 2006, A&A, 452, 551; and blue circles measured at ShAO.

we can assume that our spectral observations were carried out near the maximum brightness of the star. The shape of the Hα line profiles in our spectra indicates the presence of an accretion disk around the star. During the formation of Hα lines, the dominant role on the dates [(12-14 and 12-21) 2019] belongs to the rotation (V/R≈1), and on the dates 01-25-2019 and 01-17-2020 – an accretion of matter to the surface of the star. During the transition from the emission mode to absorption, signs of accretion are observed in the profiles of the Hα and Hβ lines. In the spectra obtained in a time difference of 7 days [(12-14 and 12-21) 2019], the Hα; Hβ; HeI λ5876Åline profiles; are practically the same both in terms of the profile and ray velocities.

The lines of resonant doublets, neutral sodium (D1,2 NaI), and once ionized calcium (H, KCaII) are represented in our spectra by the interstellar component (IS); the circumstellar component (CS) is not visible. Heliocentric radial velocities of these lines (on average): 27.5 kms (D2NaI); 28.4 (D1NaI); 26.2 (HaII); 25.7 kms (KaII). The neutral helium line profile (HeI 5876Å) represents the central absorption and emission component on the blue wing (2019-01-25 and 2020-01-17) or both wings [(12-14 and 12-21) 2019].

Fig. 2 shows the radial velocity curve based on the measured radial velocities of the photospheric lines: HeI λ 6878Å, HeI λ5875Å, HeI λ4471Å. Radial velocities of the star HD53367 folded with the period of P = 183.34 days suggested by M. A. Pogodin et al. (see Fig.2). As can be seen from Fig. 2, our measurements fit satisfactorily on this curve.

5. Conclusions

1. The shape of the Hα line profiles in our spectra indicates the presence of an accretion disk around the star. During the formation of Hα lines, the dominant role on the dates [(12-14 and 12-21) 2019] belongs to the rotation (V/R≈1), and on the dates 01-25-2019 and 01-17-2020 – an accretion of matter to the surface of the star.
2. During the transition from the emission mode to absorption, signs of accretion are observed in the profiles of the Hα and Hβ lines.
3. The lines of resonant doublets, neutral sodium (D1,2 NaI), and once ionized calcium (H, KCaII) are represented in our spectra by the interstellar component (IS); the circumstellar component (CS) is not visible. Heliocentric ray velocities of these lines (on average): 27.5 km/s (D2NaI); 28.4 (D1NaI); 26.2 (HaII); 25.7 kms (KaII).
4. The neutral helium line profile (HeI 5876Å) represents the central absorption and emission component on the blue wing (2019-01-25 and 2020-01-17) or both wings [(12-14 and 12-21) 2019].
5. In the spectra obtained in a time difference of 7 days [(12-14 and 12-21) 2019], the Hα; Hβ; HeI 5876Åline profiles; are practically the same both in terms of the profile and ray velocities.

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References

Claria J.J.: 1974, *AJ* , **79**, 1022.
Corporon P., Lagrange A.M.: 1999, *A&AS*, **136**, 429.
Finkenzeller, Mundt: 1984, *Astron. & Astrophys. Suppl. Ser.*, **55**, 109.
Galazutdinov G.: http://www.gazinur.com/DECH software.html.
Herbig, G.H.: 1960, *ApJS*, **4**, 337.
Mikailov Kh.M. et al.: 2020, *Kinem. and Physics of Celes. Bodies* , **36**, 22.
Pogodin M.A. et.al.: 2006, *A&A* **452**, 551.
Tjin A Djie et al.: 2001, *MNRAS*, **325**, 1441.