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LONG-TIME SPECTRAL VARIABILITY OF THE STAR IL CEP A

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The results of long-time spectral monitoring of the Be Herbig star IL Cep A are presented. It is shown that hydrogen emission lines are formed in the disk, which is formed only around one of the components of the binary system. Orbital elements were calculated in the model of a spectroscopic - binary system with a period of 3550 $\pm$ 28 days. It was estimated fundamental parameters of individual components of the system. It is assumed that the secondary component of the system is a young star, which is at the initial stage of evolution.

Keywords: young stars–spectral variability–spectral binaries–Ae/Be Herbig stars–IL Cep A..

1. INTRODUCTION

The star IL Cep (HD 216629) is visually binary with the components IL Cep A ($\alpha2000 = 22^h53^m15.603^s$, $\delta2000 = +\ 62°08'45.02", V \sim 9.36$mag) and IL Cep B ($\alpha2000 = 22^h53^m15.342^s$, $\delta2000 = +\ 62°08'51.629"$, V $\sim$ 13.82 mag) and with angular distance 6."96 [1]. The system is known as a member of the young association Cep OB3. Wheelwright et al. [2] is showed that the star IL Cep A also has a closer visual component at an angular distance of 0."44, which is weaker than IL Cep A at ΔB = 3.5 mag. Obviously, with such a close companion brightness, the contribution of its radiation to the spectrum of the star IL Cep A will be insignificant. Considering this circumstance in the future in our work we will discuss only on the component IL Cep A.

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According to Assousa et al. [3] IL Cep is an emission object closely related to the reflection nebula, and therefore is an Ae/Be Herbig type star. According to [4] and [5], the star belongs to the Cep OB3 association. However, as shown in [6], using the distance to the star at 720 ps (see, for example, [7]), the star will take a position below the ZAMS (Zero Age Main Sequence) line on the evolutionary HR diagram. Since the star is a visual binary system, in [6] the authors did not estimate its fundamental parameters using evolutionary tracks.

In this paper, we presents the results of research of the spectrum IL Cep A, using also the new spectral material obtained in 2015-2017.

2. OBSERVATIONS AND RESULTS

Spectral observations were performed in 2006–2017 in the Cassegrain focus of the 2 m telescope of the Shamakhy Astrophysical Observatory of the Azerbaijan National Academy of Sciences (ShAO of ANAS). Two spectrometers were used: the first spectrometer (MUAGS – Modified Universal Astronomical Grid Spectrograph) was used in 2006-2015, which was made on the basis of the UAGS spectrograph [8, 9].

The spectral resolution of this spectrograph was R = 14000; the signal-to-noise ratio in the region of the Hα line is S/N = 80-100, and in the region of the Hβ line is S/N = 10-20. All image processing, their processing into a standard format, and further measurements of spectrograms were performed using the DECH20T program developed at the SAO RAS [10].

The second spectrometer was ShaFES Fiber Echelle spectrograph (Shamakhy Fiber Echelle Spectrograph). The pixel size in CCD 4kx4k is 15 μm, the maximum quantum yield at a wavelength of 4000 Åis 90%. A detailed description of the ShaFES spectrograph is given in Mikayilov et al. [9]. For IL Cep spectra were obtained at a resolution of R = 28000, in the range of 3900-7500 Å. For the reduction and processing of the spectrograms, the DECH95 and DECH30 programs developed by Galazutdinov were used (http://www.gazinur.com/Image-Processing-.html) [10].

The control measurements of radial velocities for various standard stars showed a high degree of coincidence of measured RV values with data from the catalog within measurement errors of ± 3 km/s. There was no systematic difference in our RV measurements by standard stars within the measurement errors. The radial velocities from the spectra of the ShaFES spectrograph were measured with an accuracy of about ± 1 km/s.

Our measurements of radial velocities at different intensity levels showed that the best agreement with the obtained Vbis curves was obtained at the continuum level of 1.00Ic to 1.50Ic. At higher intensity levels, the spread of points increases significantly. In Fig. 4 was shown the radial-velocity curve obtained at three different levels of intensity - 1.0Ic, 1.5Ic and 1.75Ic. As can be seen from here, the scatter of points for individual seasons of observations ranges from 10 to 15 km/s. But the average annual value of Vbis smoothly varies from +5 to - 80 km/s.

3. IN MODEL OF THE SPECTROSCOPIC BINARY SYSTEM

The approximation of the observed and theoretical phase curve is carried out by minimizing the sum of squares of the residuals for different values of the orbital elements. When calculating each orbital parameter, the method of successive iterations was used; when first the values of all parameters, except one, are fixed, the value of which is determined at this stage. After that, the next parameter is selected and its value is specified. At each stage of the calculations, the fixed values for the remaining parameters are those that were counted in the previous stages. The process is repeated “in a circle” until convergence occurs, that is, when the sum of the squares of the residuals reaches a minimum. The final set of orbit parameters obtained by this procedure will be the solution. When: a) a small eccentricity and b) a successful choice of initial values of the determined parameters, convergence occurs fairly quickly (3 - 4 iteration cycles).

At the next step, the sum of the residuals is minimized for different values of the orbital period P, which allows it to be significantly clarified. As a result, we obtained a period of P = 3550 ± 28 days and a half-amplitude of the orbital velocity K = 28.8 ± 1.1 km/s. A theoretical orbital radial velocity curve for Vbis levels at 1.0Ic and 1.5Ic is shown in Fig.1 with a sinusoid curve. The observational data are best approximated by the theoretical radial velocity curve presented. For two values of the intensity level 1.0Ic and 1.5Ic, we obtained the system orbit elements, which are listed in Table 1.

By using the above mentioned results, we have carried out the RV curves of system for the Hα emission line at different intensity levels. The most stable curves were obtained at the intensity level 1.0 Ic - 1.5 Ic of the spectral continuum. By using this method, we have determined the orbital elements of the system. An analysis of the obtained mass function of the system showed that if the mass of the primary component for a typical B2V star is 10 M$\odot$, then the second component, which contains a disk emitting in emission lines, will have a mass of about 0.7 M$\odot$.

The change for B-V occurs across all observations from 0.72 to 0.77 [11]. A similar value of the color index B-V for the IL Cep star is given in [13] and [12]. According to [14] and [13] for the complex Cep OB3, the extinction coefficient is RV = 3.1 mag. If we assume that the brightest state of the B-V color corresponds to the brighter B2V component, then on the color index value for the main sequence stars (B-V)o = -0.22 [15] for the color excess we can get E(B-V) = +94. Then for the coefficient of reddening we get Av = 2.9 mag. For absolute and bolometric luminosities, one can obtain Mv = -2.9, Mbol = - 5.25 and log L/L$\odot$ = 4.1. For the star B2V Te = 22000 K [15], then for the radius we get logR/R$\odot$ = 0.83. As we noted above, for the bright component, the mass should be about 10 M$\odot$, and for the secondary component - 0.7 M$\odot$. The secondary component of the system is rather a low-mass K4V star and has a long semi-transparent gas envelope. It must be said that, apparently, there are this type spectral-binary systems among the young stars. One of them is the well-known in Orion young θ1Ori trapezium member system BM Ori [16].

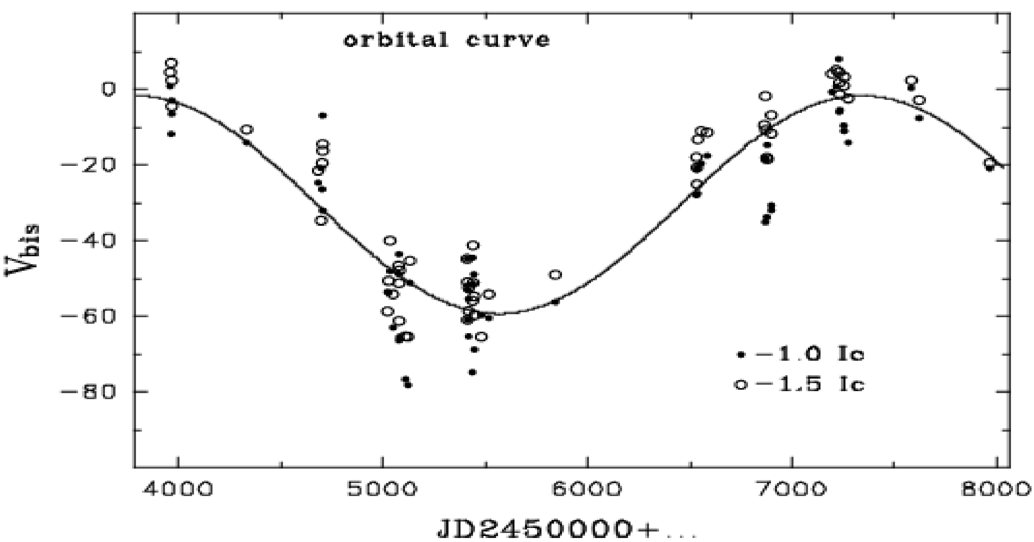

Fig. 1. Approximation of observational data using a theoretical radial-velocity curve for data from two different intensity levels, points - 1.0 I c and - 1.5 I c.

Here, P -is the period, K -is the semi-amplitude, γ -is the radial velocity of the center of gravity of the system, e - is the eccentricity, a2sini is the major semi-orbital of the orbit, and To is the moment the curve passes through the gamma velocity.

Based on the results of this work, the following conclusions can be presented:

1. For the first time, the long-time periodic variability of the radial velocities of the hydrogen emission lines Hα and Hβ was established. The period of variability is P = 3550 $\pm$ 28 days and the spectroscopic elements of the orbit of the system are determined.

2. Equivalent widths and half widths of hydrogen lines show a certain variability, which does not occur synchronously with variations in the radial velocities of the emission component.

Table 1. Approximation of observational data using a theoretical radial-velocity curve for data from two different intensity levels, points - 1.0 I c and - 1.5 I c.

Orbital elements	1.0 Ic	1.5 Ic	Mean
Porb (days)	3570	3530	3550 ± 28
γ (km/s)	28.0	29.6	28.8±1.1
K (km/s)	-33.3	-27.5	-30.3 ± 4.1
e	0	0	0
a2sini (au)			9.5
To=JD 2450000+	2921	2885	2903 ± 25

3. For the first time we have shown that the circumstellar disk, in which the emission spectrum is formed, belongs to only one of the components - the low-mass component of the system.

4. Part of the D Na I lines can be formed in the stellar wind, the main part of these lines belongs to the interstellar medium.

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