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Spectral investigations of the Algol – type binary star u Sagittae

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Abstract

The results of spectral observations of the Algol-type binary star U Sagittae (U Sge) are presented. The behavior of profiles: hydrogen lines of the Balmer series (Hα-Hδ) and HeI 5876A^0, as well as lines of resonance doublets – DNaI and KCaII, during the orbital period of the eclipsing binary system U Sge, is described. Radial velocities of the hydrogen lines (Hα-Hδ) and HeI 5876A^0, were measured. Based on these measurements radial velocity curve of the main component of the U Sge system were constructed. Value of phases about 0.8 in the blue and about 0.3 the red wing of the absorption line Hα an additional absorption detail appears. Our preliminarily assumption is that this observation may be due to the fact that the H alpha line is also visible on the secondary component at the beginning and end of the eclipse, and it is not excluded that this is related to the so-called of effect Mclaughlin of Rossiter or this absorption line are linked to supposed 3rd component.

Keywords*: Visual binaries, Eclipsing binaries, Mass loss and stellar winds, Accretion and accretion disks*
PACS*: 97.80.Di; 97.80.Hn; 97.10.Me; 97.10.Gz*

1. Introduction

The analysis of the Ha profiles demonstrates that the accretion structures in Algol binaries have four basic morphological types:

1. double-peaked emission systems in which the accretion structure is a transient or classical accretion disk;

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2. single-peaked emission systems in which the accreted gas was found along the trajectory of the gas stream and also between the two stars in an accretion annulus;

3. alternating single- and double-peaked emission systems, which can change between a single-peaked and a double-peaked type within an orbital cycle;

4. weak spectrum systems in which there was little evidence of any accretion structure since the spectra are weak at all phases [1]

The first two types are the dominant morphologies. The first type can be interpreted as a disc-like distribution, while the second is a gas stream-like distribution. U Sge displayed alternating single- and double-peaked emission at different epochs (Type 3).

U Sge belongs to the group of short-period Algol-type binaries which have orbital periods P< 5-6 days. The Ha spectra in 1993 show evidence of weak emission components in the wings of the line profile which are rarely strong enough to extend above the continuum flux level.

The Ha profiles of U Sge (1993) revealed the presence of double-peaked emission features at most orbital phases outside of primary eclipse, and excess absorption throughout primary eclipse. The double-peaked emission features indicate the presence of a transient accretion disk in U Sge (1993) [1].

Orbital and input parameters U Sagittae (U Sge, HD181182): Periods – $P=3.^{d}381$; magnitude: $V=6.^{m}3$-$8.^{m}9$; orbital inclination: 89°, spectral types: B8.5V (Pr.) – G4 III-IV (Sec.); M (pri.)=5.7M_{SUN}; T (pri.)=12500K; R (pri.)=4.20 R_{SUN}; M (sec.)=1.9M_{SUN}; T(sec.)=5500K; R(sec.)=5.50 R_{SUN} [1].

2. Observations and data reduction

Spectral observations of the star U Sge were carried out at the Cassegrain focus of the 2-meter telescope of the Shamakhy Astrophysical Observatory named after N.Tusi, on the fiber echelle spectrograph ShaFES (Shamakhy Fiber Echelle Spectrograph [2], using the detector was an STA4150A CCD camera 4096x4096 pix cooled by liquid nitrogen (pixel size of 15 μm, binning 2 × 2 mode; pixel of 30 μm), with a spectral resolution R = 28000, in the wavelength region λλ 3900–8000 Å, in the years 2022-2023. A list of all used spectra is given in Table 1. Reduction of echelle spectra was carried out according to the standard method using the new version of the DECH30 program developed by Galazutdinov [3]

Orbital phases were calculated based on the ephemeris:

JD [primary minimum] = 2442207.8444 + 3.3806205E [4].

3. Results of observations

The results of spectral observations of the Algol-type binary star U Sagittae (U Sge) are presented. The behavior of profiles: hydrogen lines of the Balmer series (Hα – Hδ) and line HeI 5876Å, as well as lines of resonance doublets – DNaI and

KCaII, during the orbital period of the eclipsing binary system U Sge is described. Radial velocities of these lines were measured. The results of measurements of heliocentric radial velocities of selected lines are given in Table 2. These lines are related to the main component of the U Sge binary system.

Table 1. Circumstance of spectral observations star USge

№	date	JD	phase
1	2022-07-10	2459771.2946	0.33
2	2022-07-15	2459776.2737	0.81
3	2022-07-16	2459777.3945	0.14
4	2022-07-17	2459778.2632	0.4
5	2022-07-18	2459779.3838	0.73
6	2022-07-19	2459780.2113	0.97
7	2022-07-20	2459781.3169	0.3
8	2022-07-21	2459782.2223	0.57
9	2023-07-09	2460135.4296	0.05
10	2023-07-21	2460147.3931	0.59
11	2320-07-22	2460148.4395	0.89
12	2023-08-07	2460164.4643	0.63
13	2023-08-09	2460166.4261	0.22
14	2023-08-10	2460167.3077	0.48

Based on these measurements, radial velocity curves of the main component of the U Sge system were constructed here (Fig. 1).

Fig. 4 shows the radial velocity curve of the main component of the U Sge binary system: Hα and Hβ are our measurements, P12 are borrowed from the paper [4].

As can be seen from Table 2 and Fig. 1, 2 the heliocentric radial velocities of hydrogen lines (Hα – Hε) and neutral helium – HeI5876 are in satisfactory agreement between themselves, as well as with measurements [4]. This feature is blue shifted during the phase interval 0.1-0.5 and redshifted from 0.6-0.9.

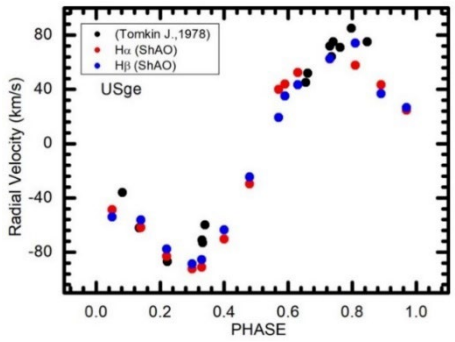

Fig. 1. Velocity curves for the primary components of the U Sge Algol type binary system (our measurements) binary system.

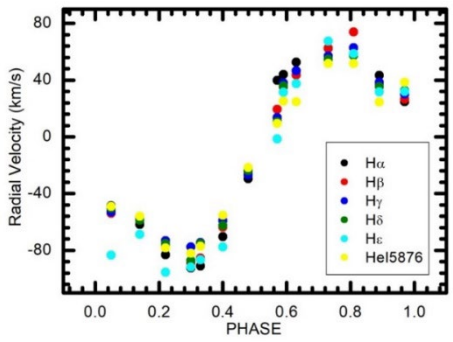

Fig. 2. Velocity curves for the primary components of the U Sge Algol type binary system. Hα and Hβ are our measurements, P_{12} [4]

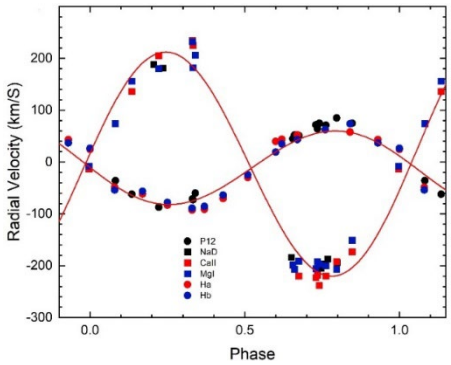

Fig. 3. Velocity curves for the primary and secondary components of the U Sge Algol type binary system. Primary component – *full circles*:
dark – P_{12} [r];
red – Hα (this paper);
blue – Hβ (this paper).
Secondary component – *full rectangles*:
dark – DNaI;
red – CaII;
blue – MgI. [l]

Table 2. Radial velocity data of USge star in 2022-2023 (unities of km/s)

№	Hα	Hβ	Hγ	Hδ	Hε	HeI5875	D1NaI	D2NaI	IS(KCaII)	CS(KCaII)
1	-91.1	-85.5	-74.6	-75.3	-86.6	-77.1	-14.5	-15.2	-23.4	-89.5
2	57.8	74	62.8	57.3	58.6	51.6	-14.7	-14.7	-25.3	37.9
3	-61.8	-56.3	-57.7	-58.7	-68.8	-56.1	-15.4	-15.3	-23.1	-71.5
4	-70.3	-63.6	-59.1	-62.6	-77.5	-55.4	-15.3	-15.3	-23.4	-72.4
5	62.4	62.6	57	54.7	67.5	51.6	-14.9	-14.0	-16.3	49.4
6	24.6	26.5	30.0	32.5	32	38.5	-15.3	-14.1	-14.5	37.1
7	-92.4	-88.7	-77.7	-87.1	-91.8	-82.1	-15.0	-14.5	-20.2	-89.5
8	39.9	19.3	13.5	10.5	-1.6	9.4	-15.4	-14.7	-16.6	36.6
9	-48.6	-54.0	-53	-50.2	-83.5	-49.0	-14.9	-14.2	-28.5	-55.6
10	43.9	35.1	37.9	35.9	31.4	25.1	-14.1	-13.9	-15.6	32.3
11	43.3	36.9	38.5	35.3	31.7	24.5	-14.2	-14.2	-15.5	34
12	52.5	43.4	46.6	37.5	37.5	24.6	-15.0	-14.7	-15.3	29.5
13	-83.1	-77.8	-73.1	-75.4	-95.4	-78.4	-15.1	-15.3	-22.6	-79.5
14	-29.6	-24.5	-26.8	-23.8	93.1	-21.8	-15.1	-16.1	-21.9	-61.8

Resonance doublets – DNaI in our spectra is represented only by the interstellar component (IS), as the circumstellar (CS) and/or stellar component is not detected. The radial velocities of the components (IS) D1NaI and D2NaI are consistent with each other within the margin of error, Resonance line KCaII both components are observed - interstellar (IS) and circumstellar (CS) (tabl. 2, fig. 4).

The radial velocities (IS) of the KCaII component are on average (–23.6 km/s) during the phase interval 0.1-0.5 and (-15.6 km/s), from 0.6-0.9 (Tabl. 2).

The radial velocities of the circumstellar (CS) and/or stellar components of the KCaII line correlate with the Ha line (Tabl. 2, Fig. 5).

In some phases of the orbit of the U Sge binary system, an absorption detail (depression) is observed on the red and blue wings of the line Hα. In the phase values of about 0.8 in the blue and about 0.3 the red wing of the absorption line Hα, an additional absorption detail appears.

Fig. 6 shows, for example, fragments of H alpha line region with additional ab-

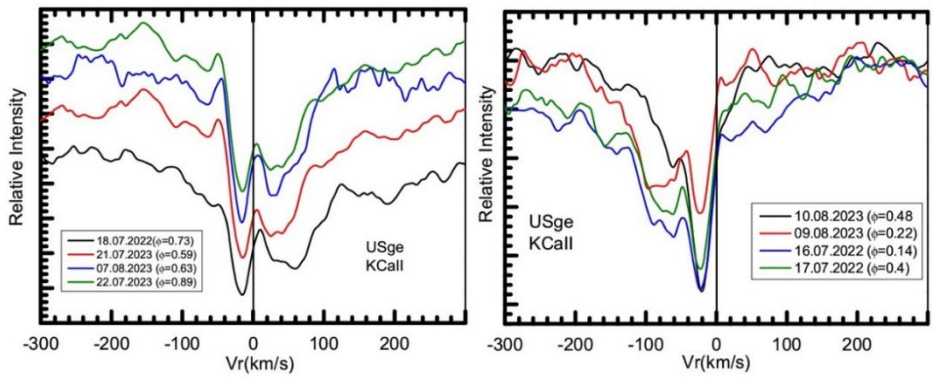

Fig. 4. Profiles line KCaII

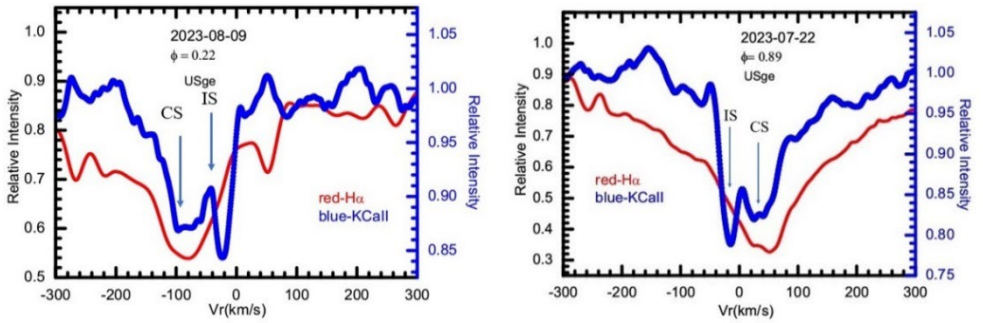

Fig. 5. Profiles lines Hα+KCaII

sorption detail. A similar picture was previously identified by us for the Algol-type binary star δ Lib.

To explain this observational feature, we are confirming the hypotheses proposed by us in article [5]:

1. The H alpha line is visible also on the secondary component at the beginning and the end of eclipse.
2. These absorption lines are linked to supposed 3rd component.
3. That this is related to the so-called of effect Mclaughlin of Rossiter.

4. Conclusions

Using of homogeneous sets of spectra, the spectral features of the Algol-type eclipsing binary star U Sagittae were studied. The spectra were obtained at the Cassegrain focus of the 2 telescopes of the Shamakhy Observatory over a period of time similar to the binary system's orbital period.

The behavior of hydrogen lines corresponding to the Balmer series (Hα - Hδ) and line HeI 5876Å as well as lines of resonance doublets - DNaI and KCaII, during the

orbital period of the eclipsing binary system U Sge is described.

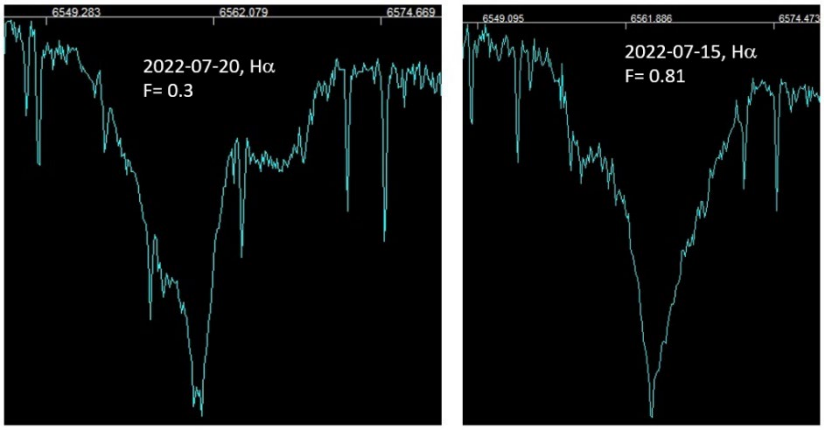

Fig. 7. Examples from the fragments of H alpha line region at the U Sagittae spectrum

Based on our measurements of the radial velocities calculated using overmentioned lines and also by using published data, the radial velocity curves of both components of the U Sagittae system were constructed. In some orbital phases of the U Sge binary system, for the orbital phase values of about 0.8 in the blue and about 0.3 the red wing of the absorption line Hα an additional absorption detail appears. A similar picture was previously identified by us for the Algol-type binary star δ Lib. We proposed three hypotheses for a possible explanation of this observational feature. Our preliminary hypothesis of preference: The H alpha line is visible on the secondary component at the beginning and the end of eclipse.

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