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THIRD COMPONENT IN ALGOL TYPE ECLIPSING BINARY SYSTEMS

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ABSTRACT. After the application of the echelle spectrograph in combinations with high sensitivity radiation receivers during the observations of short period Algol type binary star systems, in some cases there is a special feature observed in their spectrum which could indicate the presence of the potential third component. Currently the subclass of the star is distinguished among the Algol type stars in spectra of which similar features have been observed. The results of the spectral observations of two Algol type stars that belong to the subclass δ Lib and U Sge are also included. In both stars, there is an absorption detail that appears during the phases of the orbit (0.1 – 0.4) in red and (0.6 – 0.8) in blue wings of the Hα line. These phase intervals correspond to eclipse period of the secondary component. Preliminarily, we are suggesting that this observational fact could indicate the presence of the third component in the system and also provides alternative hypotheses that leads to similar physical conditions.

Keywords: individual: Algol, line profiles, radial velocity curve.

АНОТАЦІЯ. Після застосування ешелле-спектрографа в поєднанні з високочутливими приймачами випромінювання під час спостережень короткоперіодичних подвійних зоряних систем типу Алголя в деяких випадках в їх спектрах спостерігається особливість, яка може вказувати на наявність потенційного третього компонента. В даний час серед зір типу Алголь виділяється підклас зір, в спектрах яких спостерігаються подібні риси. Включені результати спектральних спостережень двох зір типу Алголь δ Lib і U Sge, які належать до цього підкласу.

Спектральні спостереження зорі U Sge проведено у фокусі Кассегрена 2-м телескопа Шамахинської астрофізичної обсерваторії ім. Н. Тусі на ShaFES з використанням ПЗЗ-матриці зі спектральною роздільною здатністю R = 28000, в області довжин хвиль $\lambda\lambda$ 3900–7500ÅÅ, у 2022–2023 роках. Криві радіальних швидкостей обох компонентів системи δ Lib та U Sge були побудовані на основі наших вимірювань радіальних швидкостей і запозичені з публікацій.

В спектрах обох зір є деталь поглинання, яка з'являється на фазах орбіти (0,1 – 0,4) у червоному та (0,6 – 0,8) у синьому крилах лінії Hα. Ці фазові інтервали відповідають періоду затемнення другого компонента. Попередньо ми припускаємо, що цей факт спостереження може вказувати на присутність третього компонента в системі, а також надає альтернативні гіпотези, які призводять до подібних ефектів, зокрема, лінію Hα видно на вторинному компоненті на початку та в кінці затемнення, або, можливо, що ефект Маклафліна–Россітера рідко спостерігається в подвійних системах типу Алголя. Усі три гіпотези є предметом обговорювання в міру отримання додаткових спостережень.

Ключові слова: індивідуальні: Алголь, профілі ліній, крива радіальних швидкостей.

1. Introduction

The Algol-type binaries are semidetached interacting binary systems in which the cool F–K III-IV secondary star has expanded to fill its Roche lobe and is transferring material through a gas stream onto the hot B–A V primary star (see Fig. 1).

As you know the prototype Algol type eclipsing binaries systems star β Per, is a triple system. Until recently, due to the weakness of the visible brightness of the third component, the influence of this component was not taken into account when modeling the light curve and radial velocities of the β Per system. Only in recent years, was it possible to build a satisfactory model of this star as a triple system using observations with many techniques and at many wavelengths.

The presense of the potential third component could be indefinied with special features observed in the spectrum of short period Algol type binary star systems af-

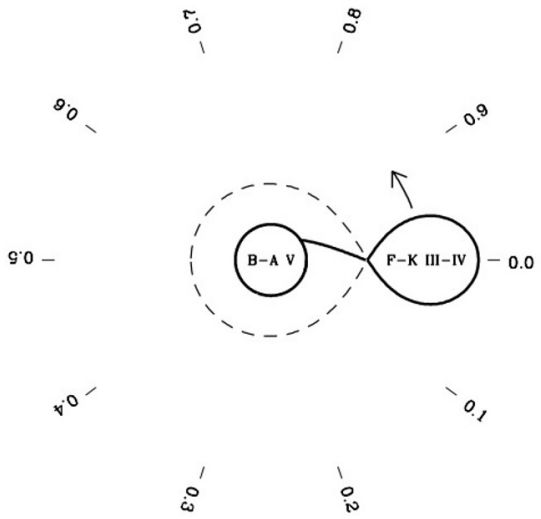

Figure 1: Scale model of an Algol-type binary system showing the predicted path of the gas stream, the range of spectral types, the spectral classes, and the lines of sight for different orbital phases

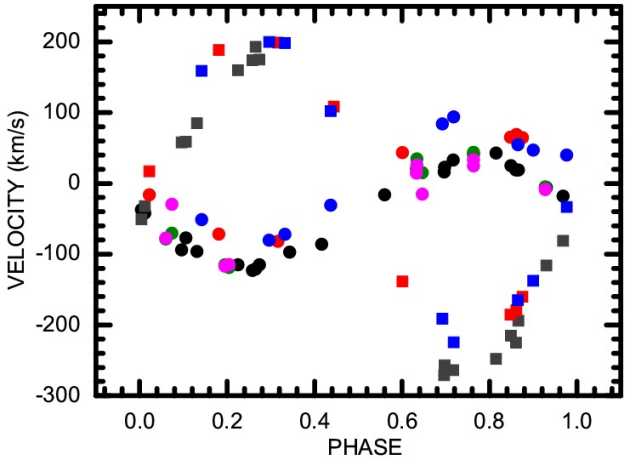

Figure 2: Primary and secondary components radial velocity curves of the δ Lib star Algol type binary system. **Primary component** full circles: black – Tomkin J., 1978 (date 1977); red – Baksh V., 2006 (Ondrejov, date: 1996, 1997 and 2003); blue – Baksh V., 2006 (Rozhen, date: 1996, 1997 and 2003); magenta – ShAO + Czech (Hα, this work); olive – ShAO + Czech (Hβ, this work); **Secondary component** full rectangles: black – Tomkin J., 1978 (date 1977); red – Baksh V., 2006 (Ondrejov, date:1996, 1997 and 2003); blue – Baksh V., 2006 (Rozhen, date: 1996, 1997 and 2003).

ter the application of the echelle spectrograph in combinations with high sensitivity radiation receivers during the observations. Currently the subclass of the star is distinguished among the Algol type stars in spectra of which similar features have been observed. (Tomkin, 1978; Tomkin, 1979 Tomkin, 1981; Tomkin, 1983; Tomkin, 1985; Tomkin, 1992; Francis,Tomkin, 1982).

At the Shamakhy Astrophysical Observatory named after N.Tusi is conducting a spectral study project of Algol-type stars from this subclass. Spectral observations will be carried out at the Cassegrain focus of 2-m telescopes of the Shamakhy Observatory over a period of time of the orbital period on a fiber-optic echelle spectrograph SHAFES, using a CCD matrix with a spectral resolution of R = 28000 and 56000 (Mikailov, 2020).

The following stars have been preliminary selected: δ Librae; U Sagittae; U Cephei; λ Tauri; EK Cephei; R Canis Majoris; V505 Sagittarii.

This paper presents preliminary results of spectral observations of two Algol-type stars belonging to this subclass: δ Lib and U Sge.

2. Observations and data processing

Spectral observations of the stars: δ Librae and 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) (Mikailov, 2020), using a CCD matrix, with a spectral resolution R = 28000, in the wavelength region $\lambda\lambda$ 3900–7500ÅÅ, in the years 2020-2023. 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).

3. Results of observations

δ **Librae** (HR 5586, HD 132742, HIP 73473) is one of the nearest (≈90 pc) Algol systems a close, interacting binary made of A0V + K0IV stars with V ≈ 4.9 mag orbital period close to P = 2.327 days. The hotter and more massive star is A0 and it is on the main sequence; we will refer to it as star A. Its companion, which we call star B, is a cooler and less massive K0 subgiant filling its Roche lobe. Mass is being transferred from star B (the mass-donor) to star A (the mass-gainer).

Fig. 2 shows the radial velocity curve of the main and secondary components of the binary system δ Lib: Hα and Hβ are our measurements, others are borrowed from publications data. Phases computed with Koch's (Koch, 1962) ephemeris:

$$JD[Pr.Min.] = 2422852.3598 + 2.32735297E$$

U Sagittae (U Sge, HD181182): periods P=

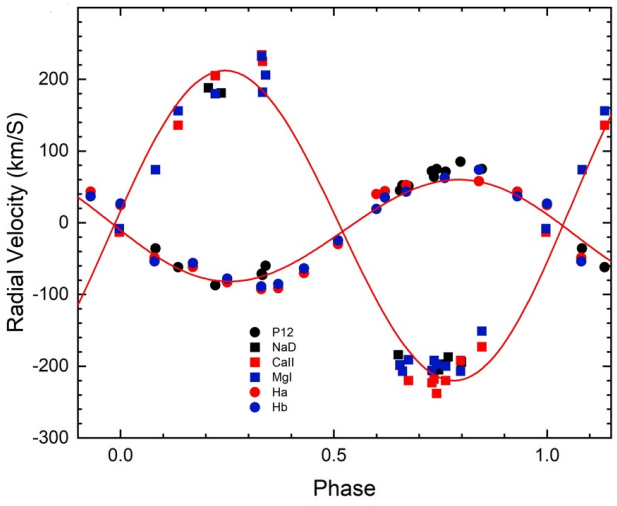

Figure 3: Velocity curves for the primary and secondary components of the U Sge Algol type binary system. **Primary component** full circles: black – P_{12} (Tomkin, 1978); red – Hα (ShAO); blue – Hβ (ShAO). **Secondary component** full rectangles: dark – DNaI; red – CaII; blue – MgI. (Tomkin, 1978)

3.381days, magnitude V=6.3 – 8.9, spectral types B7.5 (Pr.) – G4 III–IV (Sec.) or B8V (Pr.) – G2 III–IV (Sec.), orbital inclination 89^0, V_0 = –10 km/s, HJD min = 2440774.4856 (Olson, 1987).

Papameters: Primary component: M = 5.7 $M_\odot$, T = 12500 K, R= 4.20 $R_\odot$;

Secondary component: M = 1.9 $M_\odot$, T = 5500K, R= 5.50 $R_\odot$.

Fig. 3 shows the radial velocity curve of the primary and secondary component of the U Sge binary system: Hα and Hβ are our measurements, others are borrowed from publications data.

Orbital phases were calculated based on the ephemeris:

$$JD[Pr.Min.] = 2442207.8444 + 3.3806205E$$

borrowed from (Tomkin, 1979).

During the period of our spectral observations, both components of the KCaII resonance line are observed in the USge spectrum – interstellar (IS) and circumstellar (CS). Radial velocities (IS) of the KCaII component average (–23.6 km/s) in the phase range 0.1 – 0.5 and (–15.6 km/s) from 0.6-0.9. Fig. 4 shows the profiles of the KCaII line at close values of orbital phases on U Sge Algol type binary system. The radial velocities of the circumstellar (CS) and/or stellar components of the KCaII line correlate with the Hα line. Fig. 5 shows example the profiles Hα and KCaII lines in USge of Algol type binary star spectrum.

The fragments of Hα line region for 0.18, 0.19 and 0.62, 0.75 values of δ Lib binary system's orbital phases have been displayed on Fig. 6. As you see, the absorption element (depression) is being observed in the direction towards red of the Hα line at values 0.18 and 0.19 and towards violet at values 0.62 and 0.75.

As seen from the radial velocity curves provided at the Fig. 2 the lines of the secondary component of the system are not visible at the phase values 0.4 – 0.6 (Ondrejov and Roshen) or 0.35 – 0.7 (Tomkin). As observed, this phase interval corresponds to the period of the secondary component's eclipse (see Fig. 2).

Based on our measurements of the radial velocities of the lines Hα and Hβ and using published data, the radial velocity curves of both components of the U Sge system were constructed (Fig. 3).

In some phases of the orbital motion of the U Sge binary system, an absorption detail (depression) is observed on the red and blue wings of the line Hα.

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. As observed, phase interval [0.3 – 0.7] corresponds to the period of the secondary component's eclipse (see Fig. 6).

Fig. 6 shows for example fragments of Hα line region with additional absorption detail. Phase 0.05 corresponds to the eclipse of the primary component.

4. Conclusions

The radial velocity curves of both components of the δ Lib and U Sge systems were constructed based on our measurements of the radial velocities and are borrowed from publications data.

An absorption detail (depression) is observed on the red and blue wings of the Hα line in certain phases of the orbital motion of the binary systems δ Lib and U Sge. An additional absorption detail appears for δ Lib, at the orbital phases 0.18 and 0.19 in the red and at 0.62 and 0.75 in the blue wing of the absorption line, while for U Sge in value of phases about 0.3 in the red and about 0.8 the blue wing of the absorption line Hα. As inferred from Figs. 2 and 3, these phase intervals correspond to the eclipse period of the secondary component.

Thus, we are suggesting that this observational fact could indicate the presence of the third component in the system.

At the same time, we do not exclude alternative hypotheses that leads to similar physical conditions:

1. The Hα line are visible on the secondary component at the beginning and the end of eclipse.

2. The McLaughlin–Rossiter effect is rarely observed in Algol-type binaries systems.

All three hypothesis are the discussion topics of the Algol type binary system research. As more observation material is acquired, all three hypotheses will be widely researched and evaluated.

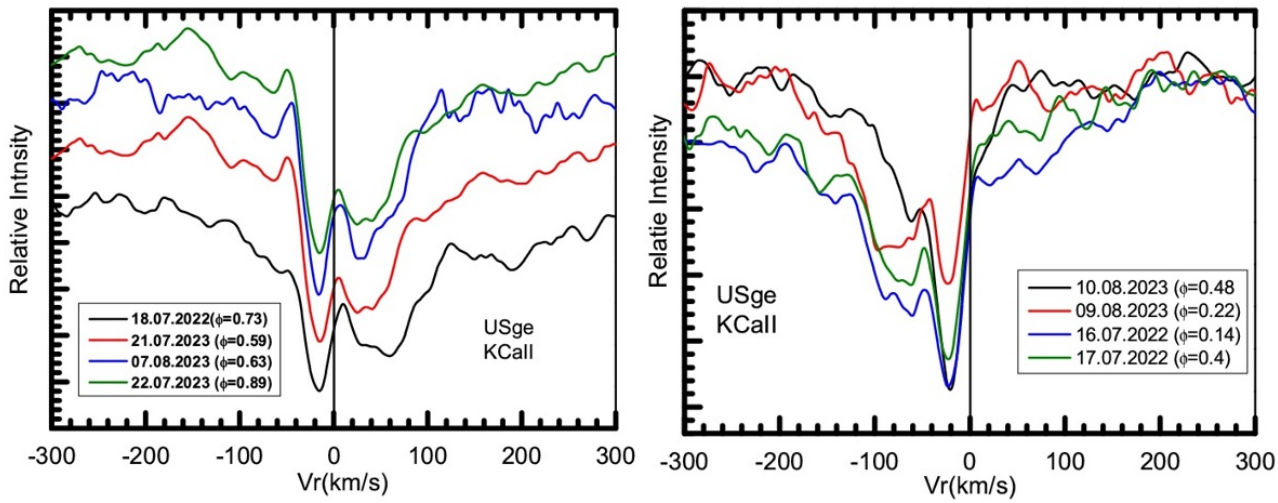

Figure 4: The profiles of the KCaII line at close values of orbital phases on U Sge of Algol type binary system

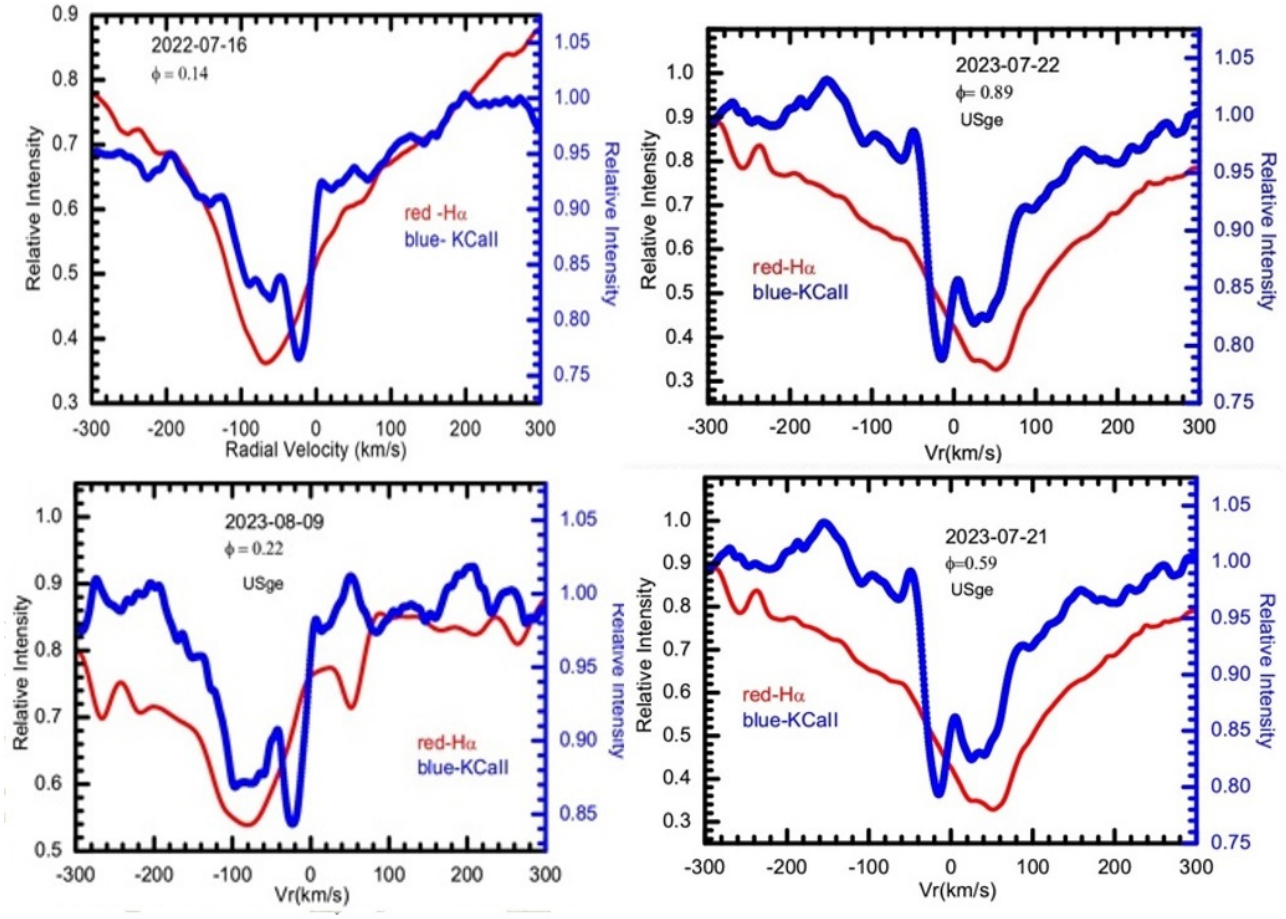

Figure 5: Example the profiles of the Hα and KCaII lines at close values of orbital phases on spectrum USge system

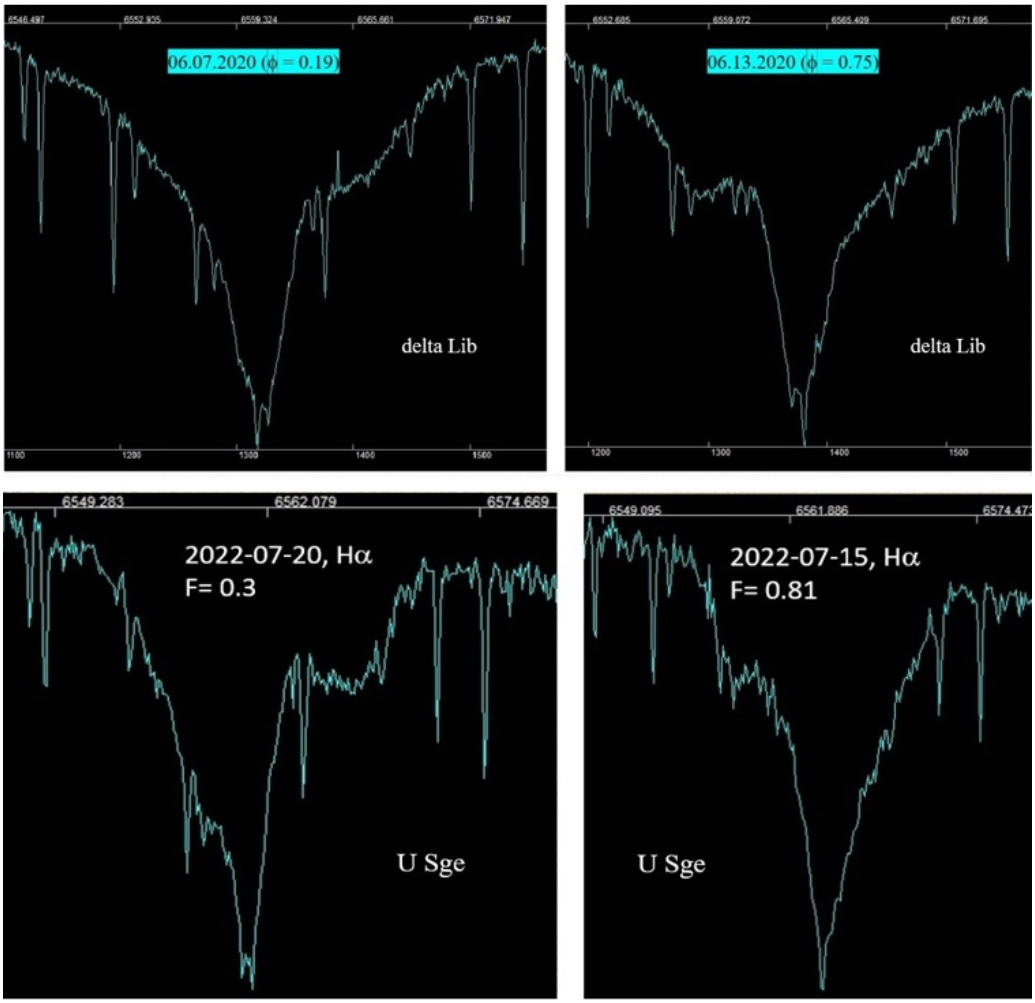

Figure 6: Examples from the fragments of Hα line region at the spectrum δ Lib and U Sge systems

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