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## SPECTRAL OBSERVATIONS OF THE ALGOL - TYPE BINARY STAR $\delta$ LIBRAE

B.N. Rustamov<sup>1,2</sup>, Kh.M. Mikailov<sup>1</sup>, K.I. Alisheva<sup>1</sup>, S.O. Mammadova<sup>2</sup>,  
Sh.A. Agayeva<sup>2</sup>, O.V. Maryeva<sup>3</sup>

<sup>1</sup> Baku State University, Baku, Azerbaijan

<sup>2</sup> Shamakhy Astrophysical Observatory named after N. Tusi, Azerbaijan

<sup>3</sup> Astronomical Institute of the Czech Academy of Science, Czech Republic  
*bayram\_rustam@yahoo.com*

**ABSTRACT.** The results of spectral observations of the Algol-type binary star  $\delta$  Lib are presented. The behavior of  $H\alpha$  and  $H\beta$  lines in the star's spectrum during the orbital period phase is described. Based on our measurements of the radial velocities of the  $H\alpha$  and  $H\beta$  lines and using published data, the radial velocity curves of both components of the  $\delta$  Lib system were constructed. In some phases of the orbital period, an absorption component was detected in the blue, or red, part of the  $H\alpha$  and  $H\beta$  line profiles. The observed  $H\alpha$  and  $H\beta$  absorption lines are attributed to the main component of the binary system  $\delta$  Lib. It is assumed that the appearance of absorption components at these lines is associated either with suspicion of a third component in the system, or at these phases of the  $H\alpha$  and  $H\beta$  lines, the primary and secondary components of the  $\delta$  Lib system are observed simultaneously.

**Keywords:** eclipsing – binaries, individual:  $\delta$  Lib – stars, line spectroscopic – stars, profiles – stars.

**АННОТАЦІЯ.** Наведено результати спектральних спостережень подвійної зорі типу Алгола  $\delta$  Lib. Було використано два набори спектрів. Перший був здобутий у фокусі Кассегрена 2-м телескопа Шамахінської Астрофізичної Обсерваторії ім. Н. Тусі на оптичному ешелі-спектрографі ShAFES за допомогою ПЗЗ-матриці у червні 2020 р. Спектри отримані зі спектральною роздільною здатністю  $R = 56000$ , у діапазоні довжин хвиль  $\lambda = 3900-7500$  Å. Другий набір спектрів отримано на 2-м телескопі ім. Л. Перека Астрономічного Інституту Чеської Академії Наук за допомогою ешелі-спектрографа Ондрейова (OES) у фокусі куди у червні та липні 2022 р. Діапазон довжин хвиль  $\lambda = 3750-9200$  Å та  $R = 50000$ . Обробка спектрів проводилася за стандартною методикою, за допомогою нової версії програми DECH 30. Для порівняльного аналізу кривих променевих швидкостей також використані опубліковані дані променевих швидкостей спектральних

ліній  $\delta$  Lib.

Описано поведінку ліній  $H\alpha$  і  $H\beta$  в спектрі зорі протягом фази орбітального періоду. За нашими даними променевих швидкостей ліній  $H\alpha$  і  $H\beta$  і з залученням опублікованих даних, побудовані криві променевих швидкостей обох компонент системи  $\delta$  Lib. У деяких фазах орбітального періоду виявлено абсорбційний компонент у синій (фази 0.62 та 0.75) або червоній (фази 0.18 та 0.19) частини профілів ліній  $H\alpha$  та  $H\beta$ . Абсорбційні лінії  $H\alpha$  і  $H\beta$ , що спостерігаються нами, відносяться до основної компоненти подвійної системи  $\delta$  Lib.

Передбачається, що поява абсорбційних компонентів у цих ліній пов'язана з тим, що в цих фазах у  $H\alpha$  і  $H\beta$  спостерігаються первинний і вторинний компоненти системи  $\delta$  Lib одночасно, або з підозрою про третій компонент системи, і не виключено, що цей ефект пов'язаний з так званим ефектом Маклафліна – Россітера, який у поодиноких випадках спостерігається у подвійних системах типу Алгола. Попередньо ми надаємо перевагу першій гіпотезі, але надалі всі три гіпотези будуть ретельно досліджені, в міру накопичення спостережного матеріалу.

**Ключові слова:** затемнювано-подвійні зорі, спектрально-подвійні зорі, індивідуально:  $\delta$  Lib.

### 1. Introduction

$\delta$  Librae (= HR 5586 = HD 132742 = HIP 73473) is one of the nearest ( $\sim 90$  pc) Algol systems. This system is a close, interacting binary made of A0V + K0IV stars, with  $V \sim 4.9$  mag and an 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

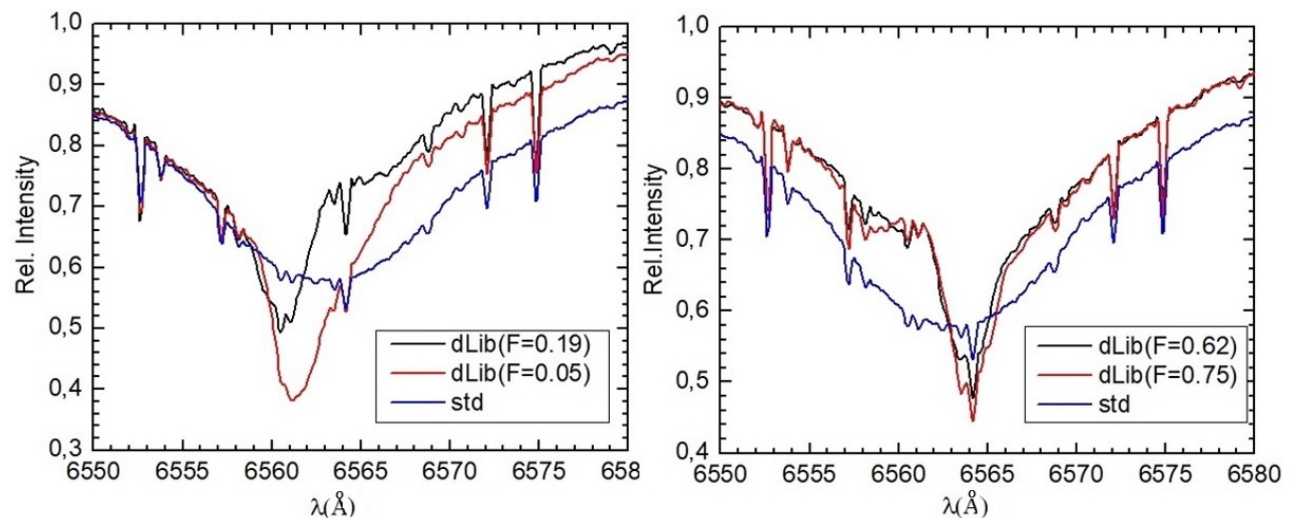


Figure 1: Example the profiles of the standard star and H $\alpha$  line at close values of orbital phases on  $\delta$  Lib binary star spectrum

Roche lobe. Matter is being transferred from star B (the donor) to star A (the recipient). (Tomkin, 1978; Budding et al., 2005).

## 2. Observations and data processing

Two sets of spectroscopic observations were used in the present study. The first one was spectral observations of the Algol-type binary star  $\delta$  Lib 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 (Mikhailov et al., 2020), by using CCD matrix STA4150A 4 $\times$ 4 K elements, with an element size of 15  $\mu$ m. The spectra are obtained at the resolution  $R = 56000$ , in the wavelength region  $\lambda = 3900 - 7500 \text{ \AA}$ . In June 2020, during four nights, every night two spectra of the studied star, and a complete set of calibration images were obtained, and two spectra of the standard star 109 Vir (sp. AO) were also obtained.

The second set spectrum were carried out at the Perek's 2-m telescope of the Ondrejov observatory from 2022 June and July 2022, with the echelle spectrograph (OES). The OES provides a wavelength range of  $\lambda = 3750 - 9200 \text{ \AA}$  and a spectral resolving power of 50000 (Koubský et al., 2004; Kabáth et al., 2020).

Processing of 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](http://www.gazinur.com/DECH_software.htm)). A list of all used spectra is given in Table 1.

Table 1: Circumstances of spectral observations star  $\delta$  Lib

No	Date	JD +2450000	Phase	Radial velocity H $\alpha$	H $\beta$
1	07.06.2020	9008.263	0.204	-118.7	-114.7
2	08.06.2020	9009.263	0.634	34.6	25.6
3	09.06.2020	9010.255	0.060	-78.5	-77.3
4	13.06.2020	9014.219	0.763	40.8	24.7
5	10.06.2022	9741.357	0.195	-115.0	-117.0
6	16.06.2022	9747.335	0.763	43.9	33.4
7	02.07.2022	9763.324	0.633	20.6	14.6
8	12.07.2022	9773.317	0.927	-5.0	-8.7
9	16.07.2022	9777.317	0.646	15.1	-15
10	17.07.2022	9778.315	0.074	-70.3	-29.6

## 3. Results of observations

Orbital phases of  $\delta$  Lib binary system has been provided according to the date of acquisition of the spectrum shown in Table 1.

Phases computed with Koch's (Koch, 1962) ephemeris:

$$Pr.Min. = 2422852.3598 + 2.32735297E.$$

For a comparative analysis of radial velocity curves, published radial velocity data for spectral lines belonging to both components of the  $\delta$  Lib binary system were also used (Tomkin, 1978 (date 1977); Bakış, 2006 (Ondrejov, Rozhen, date: 1996, 1997 and 2003)).

The phases of the components of this star according to radial velocities taken from the published date have been calculated using the same formula.

The profile of H $\alpha$  and H $\beta$  absorption lines from

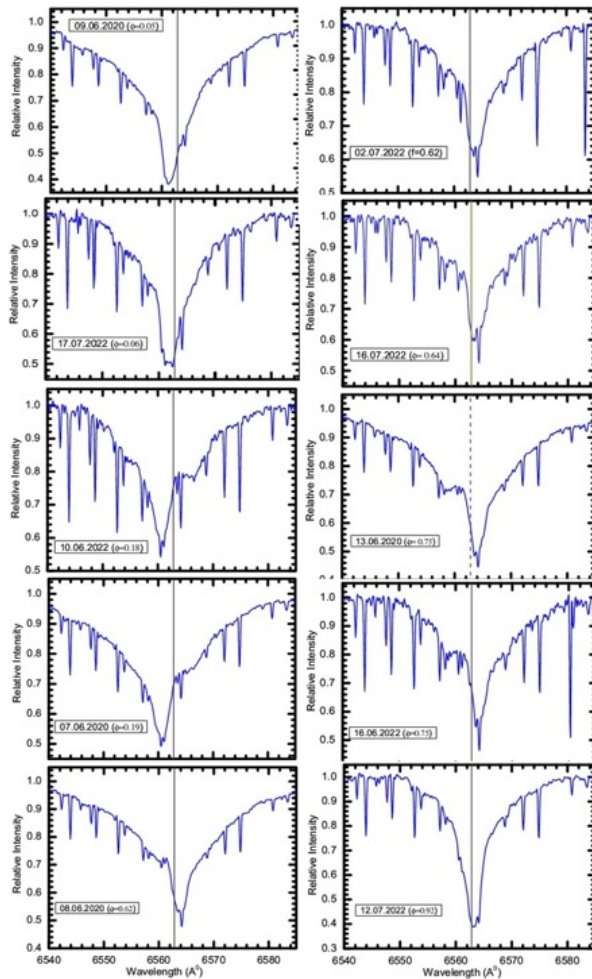


Figure 2: The profiles of  $H\alpha$  lines depending on the phase of the orbital period on  $\delta$  Lib binary star spectrum

Balmer's series has been constructed and heliocentric radial velocities have been calculated using Galazutdinov's DECH 30 software. The results of measurements of the radial velocities of the  $H\alpha$  and  $H\beta$  lines are given in Table 1. Fig.1 presents examples of profiles of the standard star and  $H\alpha$  line at close values of the orbital phases on  $\delta$  Lib binary star spectrum. Fig. 2 shows with the variations in the profiles of  $H\alpha$  lines depending on the orbital phase of the binary system.

$H\alpha$  and  $H\beta$  lines belong to  $\delta$  Lib binary system's primary component; the radial velocity curves have been constructed. Figure 3 shows the radial velocity curve of the main component of the delta Lib binary system based on our measurements from the  $H\alpha$  and  $H\beta$  lines and from data from the P14 line borrowed from (Tomkin, 1978). As can be seen from Fig.3, our measurements are in satisfactory agreement with the measurements from (Tomkin, 1978).

Figure 4 shows the radial velocity curve of the pri-

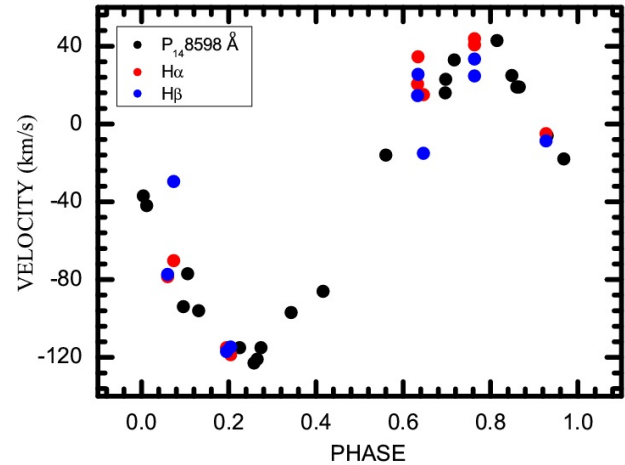


Figure 3: The radial velocity curve of the primary component of the  $\delta$  Lib Algol type binary system based of our measurements of  $H\alpha$  and  $H\beta$  lines (2020-2022) and spectrum P14 8598  $\text{\AA}$  (Tomkin, 1978 (date 1977)).

mary and secondary component of the  $\delta$  Lib double system based on our measurements and published data from (Tomkin, 1978 (date 1977); Bakish V., 2006 (Ondrejov, Rozhen, date: 1996, 1997 and 2003)).

A thorough examination has revealed an interesting detail in the spectra of the  $\delta$  Lib star. In some phases of the orbit of the  $\delta$  Lib binary system, an absorption detail (depression) is observed on the red and blue wings of the line  $H\alpha$ , namely in the phases 0.18 and 0.19, red, and in the close phases 0.62 and 0.75 in the blue wing of the absorption line  $H\alpha$  an additional absorption detail appears. Fig. 5 for example, shows the fragments of  $H\alpha$  line region with additional absorption detail.

As seen from the radial velocity curves provided at the Fig.4 the lines of the secondary component of the system are not visible at the phase values 0.4 – 0.6 (Bakish et al., 2006, Ondrejov and Roshen) or 0.35 – 0.7 (Tomkin, 1978). As observed, this phase interval corresponds to the period of the secondary component's eclipse.

In the region of the Ca II 8542  $\text{\AA}$  and P15 lines in the spectrum  $\delta$  Lib, in (Tomkin, 1978) a similar picture was found at phase 0.815 on the blue wing and at phase 0.265 on the red wing of the Paschen line, additional absorption is observed. The authors explain this with the appearance of Ca II 8542  $\text{\AA}$  lines also on the secondary component of the binary system  $\delta$  Lib.

#### 4. Conclusions

The hypothesis below may be linked to the absorption element observed at the values 0.18 and 0.19 in

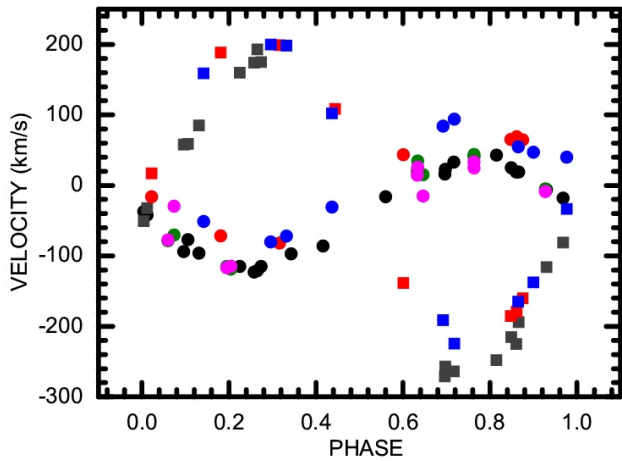


Figure 4: Primary and secondary components radial velocity curves of the  $\delta$  Lib star Algol type binary system.

**Primary component - full circles:** dark - Tomkin J., 1978 (date 1977); red - Bakish V., 2006 (Ondrejov, date: 1996, 1997 and 2003); blue - Bakish V., 2006 (Rozhen, date:1996, 1997 and 2003); magenta - ShAO + Czech ( $H\alpha$ , this work); olive - ShAO + Czech ( $H\beta$ , this work); **Secondary component - full rectangles:** dark - Tomkin J., 1978 (date 1977); red - Bakish V., 2006 (Ondrejov, date:1996, 1997 and 2003); blue - Bakish V., 2006 (Rozhen, date:1996, 1997 and 2003).

the direction towards red of  $H\alpha$  lines and at 0.62 and 0.75 towards violet of the orbital phases of  $\delta$  Lib binary system:

1. The  $H\alpha$  and  $H\beta$  lines are visible on the secondary component at the beginning and the end of eclipse.
2. These absorption lines are linked to supposed 3rd component.
3. In close binary star systems, namely Algol type binary systems are related to rarely observed McLaughlin – Rossiter effect.

All three hypothesis are the discussion topics of the Algol type binary system research. Initially the first hypothesis is preferred, however as the observation material accumulates, all three will be widely researched.

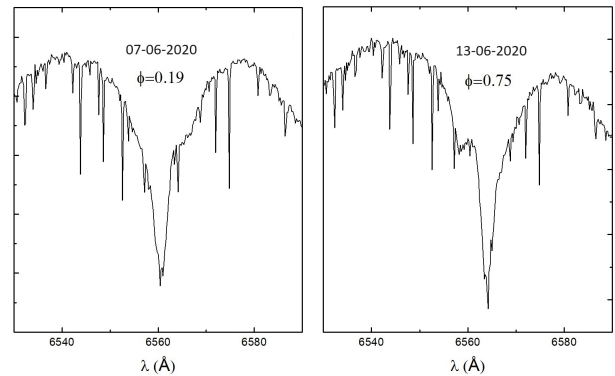


Figure 5: Example the fragments of  $H\alpha$  line region with additional absorption detail.

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