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ON THE ISSUE OF FAMILIES OF PERIODIC COMETS OF GIANT PLANETS (MOID - ANALYSIS)

A. S. Guliyev^{a*}, R. A. Guliyev^a, A. A. Gasimov^a

*^a N.Tusi Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences,
Shamakhy, Azerbaijan*

MOID-values relative to 4 giant planets were calculated for 670 periodic comets with aphelion distances up to 30 astronomical units (a.u.). It is established that 379 comets have values that do not exceed the radii of the planets' spheres of influence. When categorized by families based on MOID-values, the number of comets associated with each giant planet is as follows: Jupiter (309), Saturn (69), Uranus (6), and Neptune (0). It is assumed that the influence of the selection effect on this distribution is very significant.

Key words: periodic comets – MOID-values – Giant planets

1. INTRODUCTION

The issue of the existence of families of periodic comets associated with giant planets has a long history. Opinions on this issue among specialists are divided. While most acknowledge only the existence of the Jupiter family of comets, the remainder are considered to be either periodic or "Halley-type" comets. In a recently published work [1], this issue was considered concerning non-periodic comets, considering MOID distances and convincing digital data were obtained in favor of a positive answer. It was found that the number of such comets is 1.4-1.7 times greater than the background values. Proponents of the existence of such families (Epik, Vsekhsvyatsky, Drobyshevsky, Konoplev, Guliyev, etc.) mainly base their arguments on the distribution of comets' aphelion distances and observed peaks at the average distances of the giant planets. This fact has also been utilized in theoretical searches for unknown trans-Neptunian planets. Even after

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* E-mail: quliyevayyub@gmail.com

the discovery of new periodic comets, the concentration of aphelia in these regions remains significant. However, some of the new objects have aphelions in the intermediate Jupiter-Saturn, Saturn-Uranus, and Uranus-Neptune intervals. It should be noted that specialists who deny the existence of the families of Saturn, Uranus, and Neptune often proceed from the MOID distribution of comet distances. It should be noted that in work [1] MOID-values of distances of long-period comets relative to the orbits of giant planets were calculated and analyzed. In the present work, we decided to act in the same way concerning periodic comets.

USED DATA AND RESEARCH METHOD

In our study, the limiting distances for MOID value analysis for each planet, the values of the radius of the sphere of influence were used, determined by the formula [2]:

$$h = a \sqrt[5]{\left(\frac{m_{pl}}{M_S}\right)^2}$$

where, a – the semi-major axis of the planet's orbit, m_{pl} – its mass, M_S – Solar mass.

It should be noted that the values of the parameter h for Jupiter, Saturn, Uranus, and Neptune are 0.322, 0.364, 0.347 a.u. and 0.58 a.u., respectively. Our study included 785 periodic comets with aphelion distances up to 30 a.u. Compiled List begins with Comet 2P (Encke's Comet) and ends with Comet P/2020 S5 (PANSTARRS). Their data is taken from a NASA source (ssd-jpl-nasa-gov). During the primary analysis of this list, it became apparent the presence of a certain number of separable cometary nuclei. For the purpose of this study, we used data from only one fragment (designated as A) from each such complex (a striking example is the comet D/1993 F2 - Shoemaker-Levy 9). Otherwise, in statistics, we can get false maxima. In addition, it was decided to exclude from the analysis all short-perihelion comets (of the SOHO class, etc.). However, there were no such comets in the compiled list. After this filtering, 670 comets remained for analysis.

2. RESULTS OF CALCULATIONS

For calculating MOID distances, we used a program compiled by Dunby [3]. MOID values relative to the 4 giant planets were calculated for all the comets on our list. The selection of comets for each planet for analysis was carried out based on h . The results of the calculations are given in Table 1.

Table 1. The number of comet families identified by MOID-values.

Planet	Jupiter	Saturn	Uranus	Neptune
h, a.u.	0.322	0.364	0.347	0.58
N	304	69	6	0

The table reveals that Jupiter has the most numerous cometary family, whereas Neptune has none. However, the obtained digital characteristics do not reflect the true picture. The selection effect must be taken into account, as it influences the discovery of new comets. It is clear that the greater the perihelion distance, the lower the chance of discovering a periodic comet. If the theoretical distribution for periodic comets were known, then some corrections could be made to the quantity of the obtained distribution of MOID distances. For example, according to estimates by M. Fouchard et al. [4], the true number of comets of the "family" of Saturn, we can consider the approximate dependence $q^{2.13}$. In this case, the N values in Table 1 may be much larger. The influence of the selection effect is also manifested in the distribution of the dates of discovery of the considered comets. For example, 59 out of 69 Saturn "family" comets were discovered after 2000. Approximately the same picture is found in the "family" of Uranus: 5 out of 6 selected comets were discovered after 1999. This means that the numerical contrast between the cometary families of the giant planets will decrease with time.

3. CONCLUSION

Based on the MOID - distances of periodic comets relative to the giant planets, it can be argued that the families in issue, the existence of which is not accepted by all experts, exist. At least this statement covers 379 of the 650 known comets. The selection influence significantly reduces the true number of these families. The "family" of Jupiter is affected least of all by this factor, and the group of Uranus most of all. The same reason can explain the fact of the absence of "Neptunian" comets. The existence of such groups is well explained by the generally accepted dynamic evolution of comets, the source of which is the Kuiper Belt [5]. In the future, there is a need to carry out such calculations as new periodic comets are discovered.

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RESULTS OF LONG TIME PHOTOMETRIC AND SPECTRAL OBSERVATIONS OF HERBIG BE STAR AS 310

N. Z. Ismailov^{a*}, *V. Bakış*^{c**}, *S. A. Alishov*^a, *Sh. K. Ismayilova*^a,
F. S. Huseynova^b

^a *N.Tusi Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences, Shamakhy, Azerbaijan*

^b *Batabat Astrophysical Observatory, Nakhichevan, Azerbaijan*

^c *Department of Space Sciences and Technologies, Faculty of Sciences, Akdeniz University, Antalya, Türkiye.*

The results of spectral and photometric studies of Herbig's Be-type star AS 310 have been presented. Photometric observations in the BVRclc bands performed in 2016–2021 showed that the amplitude of the seasonal brightness variations of the star changes smoothly in different years and reaches a maximum of $\Delta V \sim 0.6$ mag in 2018. The star is more often in a weak state brightness, but from time to time, there is an increase in brightness. With a decrease in brightness in the V-band, the star's radiation in the blue color increases, while it weakens in the red part of the spectrum. Searches for periodic brightness changes have not revealed significant periods of variability. The emission components observed in the hydrogen lines are rather formed in the nebula where the star itself is immersed. The spectrum contains strong lines of neutral helium, without any signs of emission components. The spectral class corresponds to the combined spectrum B3-5V + B1.5-2V. Our studies have shown that AS 310 is an extremely young binary star that has lost its circumstellar protoplanetary disk.

Key words: Pre-Main sequence stars – HBe stars – young stellar clusters – photometry – spectroscopy – variability

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* E-mail: ismailovnshao@gmail.com

** E-mail: volkanbakis@akdeniz.edu.tr

1. INTRODUCTION

To date, the formation and early evolution of massive stars have been studied very poorly. Immediately after birth, such stars are surrounded by dark gas and dust disks, which causes enormous optical absorption. The existence of the strong stellar wind further complicates the picture. It is expected that the time to enter the MS for massive young stars should be relatively short, so the processes of dissipation of the circumstellar disk and the formation of planets should be qualitatively different from those for cold low-mass stars. It is also unknown at what stage massive young stars lose all the characteristic properties of the HAeBe star phenomenon and turn into ordinary OB stars.

Herbig Be type stars (HBe) is a subclass of young intermediate-mass stars, the so-called Herbig AeBe-type stars (HAeBe), (Herbig 1960). For classical HBe stars, the upper mass limit was considered by many authors to be 8-12 $M_{\odot}$ (see, for example, Herbig, 1960, Finkenzeller & Mundt 1984). Using Gaia Observational Data DR 3 (Verhoeff et al., 2020, Guzman - Diez et al. 2021) showed that for HBe stars the maximum expected mass could be more than 20 $M_{\odot}$. There are only several studies on the individual characteristics of massive HBe stars (see, for example, Pogodin et al. 2017, Ismailov et al. 2020a). Studying the characteristics of massive HBe stars is an important task for understanding the evolution of such stars. This paper presents the results of studies of the HBe star AS 310.

The catalogue (Herbig&Bell, 1988) lists the star HBC 284 = AS 310 as a hot, high-luminosity HAeBe star, which is notable for significant signatures of strong interstellar absorption bands in the spectrum. The spectrograms show an intense $H\alpha$ emission line and narrow helium absorption lines. According to Georgelin&Georgelin (1970), the star is in the HII (S 61) region. Finkenzeller & Mundt (1984) note that the star does not show a broad emission in the $H\alpha$ line, so the object cannot be considered a Herbig star. The star at position 135° at an angular distance of $3''$ has a companion with a brightness difference $\Delta m \approx 1\text{mag}$. Based on observations in the region of 1.3 mm Henning et al. (1994) showed that the mass of the source is estimated at about $30M_{\odot}$.

According to Bastian & Mundt (1979), the star AS 310 has a close companion at an angular distance of $4''$, and both stars contribute to the radiation. Brooke et al. (1993) based on observations in the range of $3\mu\text{m}$ give the spectral type of the star as B2 + B5. According to their data, the energy distribution in the spectrum (SED) satisfactorily agrees with the model of a star with a temperature of 20000 K. According to these authors, it is possible that the stars numbered 1 and 2 given in Lahulla (1987) in the H61 region belong to these components. However, Hunter & Massey (1990) report a spectral type of B1I, and a high degree of interstellar extinction. We have collected data from different authors in

Table 1.

As can be seen from Table 1, some parameters of the star differ significantly for different authors. The main reason for this difference seems to be the complex circumstellar environment and the inaccuracy in determining the interstellar reddening coefficient.

AS 310 is at a distance of 2500 pc (Ageorges et al., 1997; Testi et al., 1998) and shows a lot of gas and dust in the region (Hernandez et al., 2004). It has been shown that stellar components are located at an angular distance of a few arcseconds from the central source, and bipolar jets are also observed (Goodrich, 1993).

Thus, to understand the mechanism of star formation in massive young stars associated with H AeBe stars, more observational studies of systems like AS310 are paramount.

2. PHOTOMETRIC OBSERVATIONS.

Our photometric observations of the star were carried out on the Zeiss -600 telescope by using a BVRcIs photometer, which is mounted in the Cassegrain focus of the telescope ($F = 7500$ mm) with a relative aperture $A = 1 : 12.5$. As a light detector has used CCD FLI 4Kx4 K camera with the size of the element $9\mu\text{m}$. The useful field of the image frames was $17' \times 17'$. When applying binning 2×2 or 4×4 , the resolution per pixel has obtained $0.49''/\text{px}$ or $0.99''/\text{px}$. The photometric data were obtained and processed using the standard procedures of the MaximDL, software package. A detailed description of the photometric system is given in (Abdullayex et al. 2012). Transformation of our photometric system to the international one was carried out in the work (Valiyex et al. 2022).

Under the astroclimate of ShAQ, the turbulent circle of the star is mainly $1.5\text{--}2''$. Under such conditions, the components located at an angular distance of $3\text{--}4''$, which were noted in the works (Finkenzeller & Mundt, 1984, Bastian & Mundt, 1979) with a 4×4 binning combination will not be resolved. In the obtained fits-format frames, the star image did not differ in shape from a circle, and when the brightness was measured, the image of the object was completely covered by the chosen aperture size of the measuring circle. In this case, the aperture size of the measuring circle was about $6''$. The average root-mean-square measurement error according to our data in individual bands was ± 0.02 B, ± 0.008 V, ± 0.005 Rc, ± 0.009 Ic.

Our photometric observations cover the period 2016-2022. A total of 82 measurements were obtained in the V band, slightly less in the other bands. A table with the results of our photometric observations was published by Valiev et al. (2022).

Table 1. Some parameters of the star, which were collected from the literature.

References	Teff, K	Log g [$\text{cm} + \text{s}^{-2}$]	D, pc	Av	Log L/L $_{\odot}$	R, R $_{\odot}$	M, M $_{\odot}$	age, Myr	Sp	EW H α
Wichittanakom et al. 2020	26000	4.4	2110	3.86	4.13	5.7	11.6	0.07 $\pm$ 0.08	B1e	
Verhoeff et al. 2012	25100		2500	3.7	4.23	6.8	12		B1e	
Xirque et al. 2020	24500		2110	4.13	4.17		11.9	0.06		-8.89
Testi et al. 1998	30900		2500		4.55				B0	
Brooke et al. 1993			2500	3.9					B2+B5	
Manoj et al. 2006	25100		2500	6.06	5.21		> 6.00	< 0.01	B1	-7.7 -5.0
Hernandez et al. 2004	25100		2500	4.1, 6.6	4.43 5.43		14.5, 43.5	0.02 0.01	B1, B0, BA	-7.7
Guzman_Diaz et al. 2021	28000		2380	4.0	4.34	6.32	14.4	0.05	B0	
Henning et al. 1994	30900		2500		3.0		30		B0	

Figure 1 shows the star's light curve obtained on our B and V bands data. The vertical line segments indicate the dates on which our spectral observations were made. As can be seen, the star is mostly in a weak state of brightness, but at times it shows an increase in brightness with different amplitudes during the observation season. Over 6 years of observations of the star, the amplitude of brightness changes in the V band gradually increases and reaches a maximum of about 0.6 mag in 2018. Further, until 2022, a gradual decrease in the amplitude of brightness changes is observed. The brightness variability in the B band has the same character as in the V band. Unfortunately, on the night of observations of the maximum amplitude in the V band, observations in the B band were not made, so the change in the amplitude on the same night in the B band could not be observed.

In Figure 2 is shown the color-index diagrams, where variations of B-V, V-Rc, and V-Ic colors of the star as a function of V-band brightness are presented. As can be seen, as the brightness decreases, the B-V color index increases, in other words, the star's radiation is enhanced in the blue, and the color indices V-Rc and

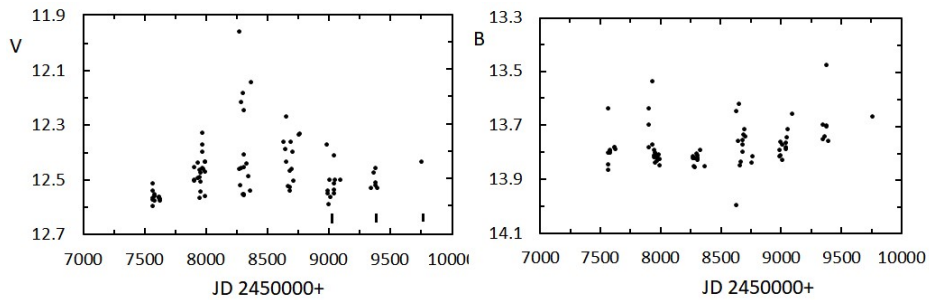


Fig. 1. Variation in the brightness of the star in the V (left panel) and B -bands (right panel), obtained from our data for 2016-2022. On the left panel, the dates of our spectral observations are indicated by vertical line segments.

V- Ic have shown decreasing, i.e., the radiation in the red part of the spectrum is weakened. Such a change indicates that the brightness variability can be caused by the enhancement of radiation in the violet part of the spectrum.

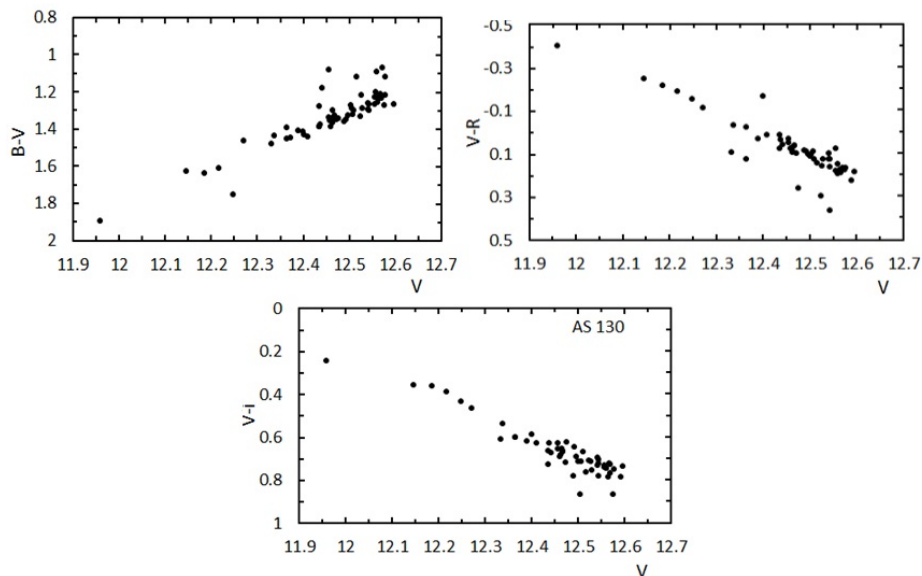


Fig. 2. Variations of the color indexes B-V, V-R and V-Ic versus V-band brightness.

3. SEARCHING FOR A PERIODICAL VARIATION IN THE BRIGHTNESS

To search for periodic components in the brightness variations of the star, we used the Fourier analysis, which used the method of Lomb (1976) and Cargle (1982). The search was performed by the Period 04 program (Lenz & Breger, 2005). The program is designed for statistical analysis of large astronomical time series containing gaps in time. The program offers tools for extracting individual frequencies from multi-period time series content and provides a flexible interface for performing multiple frequency fitting.

The source material for performing the Fourier analysis was the observational data obtained from the archive (Herbst and Shevchenko, 1999). Photometric UBVR measurements of the star have been carried out for 6 years since 1983 at the Maidanak Observatory of the Institute of Astronomy of Uzbekistan. Data from this archive are given in Herbst and Shevchenko (1999) and Grankin et al. (2007). Only 344 measurements were taken from this archive in the V band, some less in the UBR bands. This material was supplemented by 82 measurements in the V band obtained by us. There are no systematic differences between our data and catalogue data. The collected photometric material was divided into separate

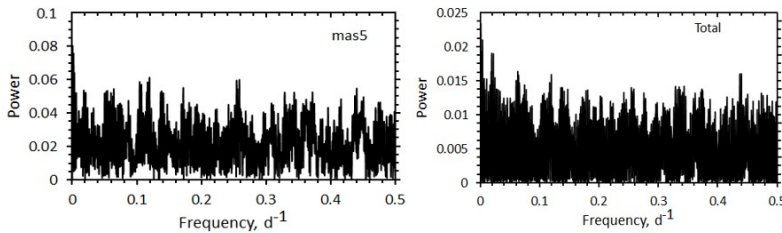


Fig. 3. Examples of the power spectrum for the array with 77 points obtained in 1990 (left) and for all observations simultaneously (right).

files according to the years of observations and was also cleared of trends indicating long-term changes in the average brightness. In total, 6 different arrays were considered, each of which has more than 60 points. For each of the arrays of points, the period was searched separately. In none of the considered arrays, an explicitly allocated value of the period was found. Figure 3 shows, as an example, the power spectrum for an array covering the interval of observations for JD 244 8049-244 8163 (1990) for 77 points of the array. The right panel of Fig. 3 shows the power spectrum for all observational data. As can be seen, a certain period in the change in the star's brightness is not clearly distinguished in the power spectra.

4. SPECTRAL OBSERVATIONS

Spectral observations of the star AS 310 have been made at the ShAO 2-m telescope Cassegrain focus by using the UAGS spectrograph (Universal Astro Grid Spectrograph). As a light detector Andor CCD camera (ikonL-936-BEX2-DD), which is working with a matrix of 2048×2048 elements has been used, pixel size $1\text{px} = 13.5\mu\text{m}$. To adapt the CCD to the spectrograph, in the camera of the spectrograph, a fast lens Canon EF ($f = 200\text{ mm}, f/2$) was used. The focal length of the collimator $f_{\text{coll}} = 1100\text{ mm}$, cameras $f_{\text{cam}} = 200\text{ mm}$, angle of incidence α and diffraction angle β are 27.5° and 20.5° , respectively. The resolution in the camera focal plane is determined by the width of two pixels, so for binning 1×1 the monochromatic image of the slit is $S' = 2\text{px} = 0.027\text{ mm}$. Then for the spectrograph's entrance slit width, we obtain $S = 0.145\text{ mm}$. The focal length of the Cassegrain focus of a 2 m telescope is $F = 29500\text{ mm}$, and the focal plane scale is $\mu = 6.99''/\text{mm}$. Then for the width of the entrance slit, we have to get $0.99''$. Similarly, for binning 2×2 , we have got a size of $1.99''$. In this complex the spectra of standard stars, various types of variable stars and galaxies were obtained. Moreover, for the Gaia program, the spectra of various transient objects were obtained (see, for example, Ismailov et al. 2020b, Gezer et al. 2020).

A diffraction grating of 651 lines /mm was used, which at a diffraction angle of 20.5° in the first order and at binning 1×1 gives the spectrum with a linear inverse dispersion of $144/\text{mm}$ in the range of $\lambda\ 3600 - 8000$. With the combination of binning 1×1 , the spectrum is obtained with an inverse linear dispersion $D = 1.9/\text{px}$. In other words, in the region of the $H\alpha$ line ($\lambda 6562.816$) in this mode, we have obtained a moderate spectral resolution of about $R = 3400$. A more detailed description of the spectrograph and the observation method is given in Ismailov et al.(2023).

For calibration, auxiliary files flat, bias, dark, as well as the calibration spectrum of the lamp ThAr were obtained. Andor CCD Camera for observations managed by Program Solis 4.31 allows changing various parameters during observations, such as binning, exposure time, operating mode, etc. The obtained spectra were further processed using the DECH 20 program and its modifications (Galazutdinov G., <http://www.gazinur.com/DECH-software.html>). All processing was performed by the standard method. Measurements of radial velocities for standard stars in different lines of the spectrum with binning 1×1 , depending on the signal-to-noise ratio, is $\pm 3 - 10\text{ km/s}$. The equivalent widths of the strongest hydrogen lines in A0-A6 stars can be determined with an error of $\pm 0.5 - 1.0\text{ \AA}$.

5. GENERAL CHARACTERISTICS OF AS 310 SPECTRUM

The spectra of the star AS 310 were obtained in 2020-2022. As can be seen from Fig.1, our spectral observations were obtained in seasons when the brightness amplitude variations in the V band gradually is decreasing. Fig. 4 shows a general view of the spectrum and the two most interesting regions of the star's spectrum for different dates. The $H\alpha$ line is observed in the form of a strong emission, which is barely distinguished from the emission doublet of the forbidden line [NII] $\lambda 6548$ and 6584 on the left and on the right. The full width at half maximums (FWHM) of both the $H\alpha$ line and the forbidden lines are about 8 ± 1.5 and practically do not show large variations. The $H\beta$ line has a relatively weak emission component, the intensity of which varies significantly on different dates until it completely disappears. The FWHM of the emission component in the $H\beta$ line is well measured at JD 2458995, for which we obtained a value of 7.6 ± 1.2 . As can be seen, the strongest emission components in these lines practically have the same FWHM. As shown by Ismailov et al. (2023), the instrumental contour for the UAGS spectrograph with binning 1x1 is about 4.5. Consequently, for the expansion of the emission lines under consideration, we obtain only about ~ 180 km/s. This result suggests that all the above-mentioned emission components of various lines are formed in the HII region dark reflection nebula, where the star AS 310 itself is immersed. The remaining lines of the Balmer series are observed in the form of absorption and contain weak emission in the core. The spectrum of the star also contains emission lines of the [OI] $\lambda 6300$ and 6363 doublet (Fig.4c). In addition, the spectrum of the star shows interstellar absorption lines (DIBs), as well as some Fe II absorption lines (Fig. 5).

The $H\beta$ line has a relatively weak emission component, the intensity of which varies significantly on different dates until it completely disappears. The remaining lines of the Balmer series are observed in the form of absorption. The spectrum of the star also contains emission lines of the [OI] $\lambda 6300$ and 6363 doublet (Fig. 4c). In addition, the spectrum of the star shows lines of interstellar extinction (DIBs), as well as some lines of Fe II (Fig. 5). For comparison, the spectrum of the star in the range $\lambda 4000 - 5000$ for four observation dates is shown in Fig. 5. As can be seen from Fig.5, on the night of JD 2458995 there is a strong emission peak in the $H\beta$ and on a weak form in $H\gamma$, lines. In the spectrum obtained 4 days later, on the night of JD 2458999, the intensity of the emission in these lines decreased significantly.

Figure 6 shows graphs of changes in the equivalent widths and half-widths of these lines in time. It can be seen from the graphs in Fig. 6 that on the first two dates of observations, the EW values for the hydrogen lines are much larger than for the rest of the observation dates.

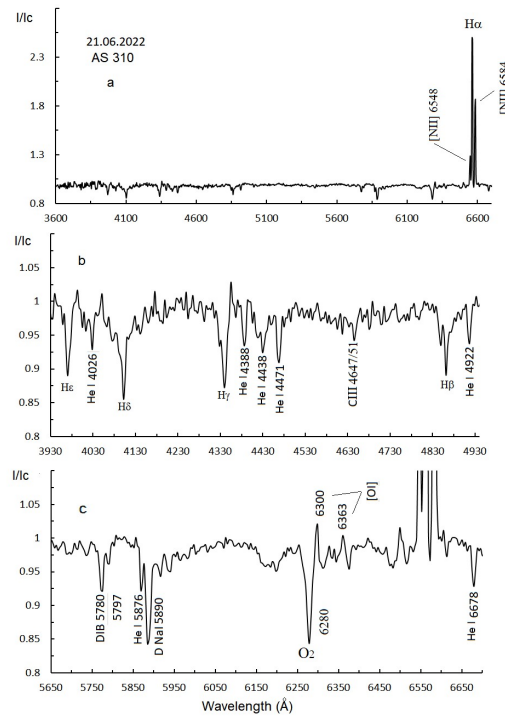


Fig. 4. Full view of the normalized spectrum of AS 310 (a), as well as parts of the spectrum in the interval λ 3900-4900 Å(b) and λ 5600-6700 Å(c).

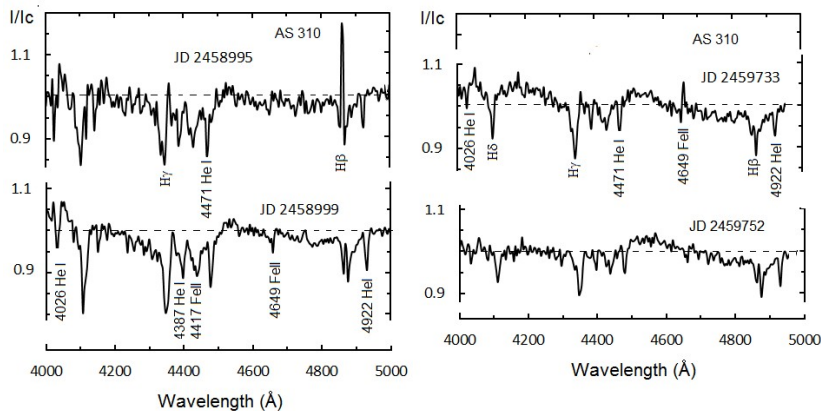


Fig. 5. Spectra of the star AS 310 in the interval λ 4000-5000 Å obtained on different nights.

As can be seen from Fig. 6, the values of the equivalent widths of the $H\alpha$ emission lines according to the spectra obtained in 2020 are greater than in other

Table 2. Equivalent widths of selected helium absorption lines.

EW(Å),HeI							
JD2450000+	4026	4387	4438	4471	4921	5876	6678
8995.291	0.79	1.39	2.41	1.58	0.79	1.44	2.58
8999.421	1.02	2.36	2.84	1.91	1.62	2.79	2.83
9054.321	0.94	1.78	2.17	1.57	1.19	2.81	1.38
9471.301	0.88	0.69	1.96	1.53	0.89	2.62	1.70
9733.419	0.84	0.78	1.55	1.07	0.83	1.74	1.13
9752.353	0.96	0.79	1.02	1.01	0.65	1.03	0.88
mean	0.91	1.30	1.99	1.45	1.00	2.07	1.75
RMS	0.09	0.67	0.64	0.34	0.35	0.77	0.79

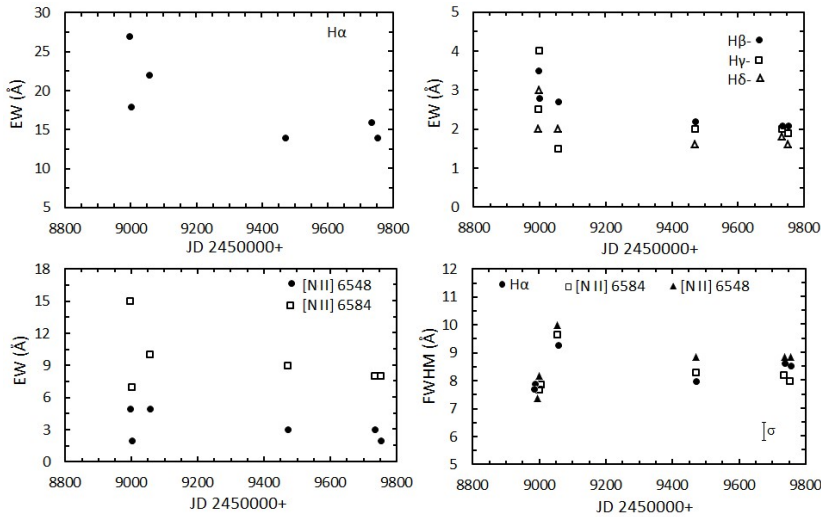


Fig. 6. Time variability of hydrogen lines EW – $H\alpha$ (a), $H\beta$, $H\gamma$, $H\delta$ (b) and $[NII]$ λ 6548, 6584 Å(c) lines. Panel (d) shows the variation of the FWHM of the $H\alpha$ emission and the $[NII]$ doublet λ 6548, 6584 Å. The vertical bar is the average error σ level.

years. In this case, the half-width of the $H\alpha$ line has the smallest value. This indicates that the equivalent widths are enhanced due to the line intensity, i.e., due to the additional radiation that appeared at that moment.

6. NEUTRAL HELIUM LINES

The spectrum of the star contains lines of neutral helium He I λ 4026, 4387, 4417, 4922, 6678 Å, etc. These lines are quite strong, which corresponds to the

spectrum of an early B star, and do not show any obvious traces of emission. Table 3 lists the measured equivalent widths of the strongest lines of He I. Since the expected spectral type of the star AS 310 should be B1- B2 (see Table 1), Table 3 shows that for the first three EW dates, most helium lines show anomalously large values for such a spectral type. This indicates that there may be a contribution from the spectrum of a nearby neighboring star in the helium lines. On the last 3 dates (Table 3), when the star shows a weakening of the emission in the $H\alpha$ and $H\beta$ lines, relatively normal values of EW are observed. Table 3 also shows the average values of the equivalent widths over all observations, as well as the variance from the average over all data. To clarification of spectral type of the star AS 310, we used the equivalent width for 7 lines of He I given in Table 2. To do this, we compared our He I line equivalent widths with theoretical data for the same lines using the model of Auer and Michalas (1973). Figure 7 shows

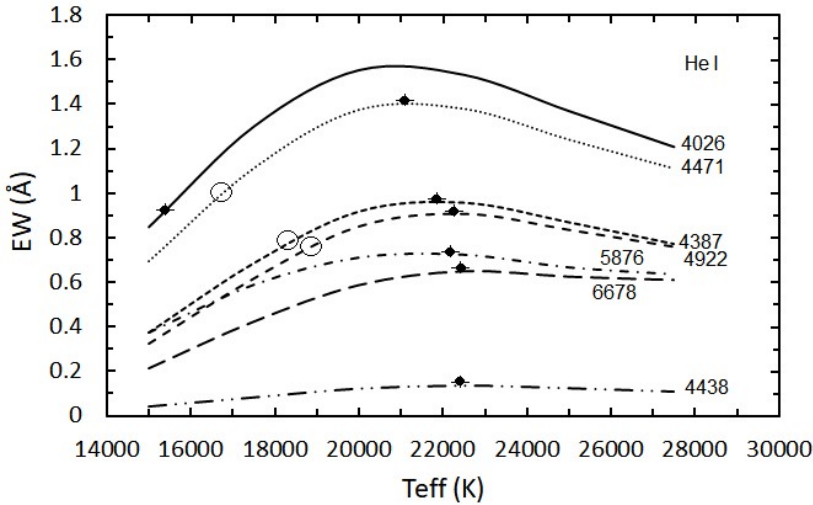


Fig. 7. Plot of the theoretical EW values of the He I lines versus temperature T_{eff} at $\log g = 4.0$ cgs, according to the model of Auer and Michalas (1973) for the normal chemical composition. The black circles show the EW values for our measurements in the active state of the emission spectrum, and the open circles show the values in the low state of the star's emission spectrum. Each line is marked with the corresponding wavelength of the spectral line.

a grid of theoretical equivalent widths for different effective temperatures at $\log g = 4.0$ cgs with solar chemical composition. Each figured line corresponds to one helium spectral line. Black circles correspond to mean EW values. If these values exceeded the theoretical values, then the black dots were placed at the maximum of the theoretical EW curve. Open circles show the EW values corresponding to

the quiescent state of the emission spectrum of the star (the last three dates of observations). This case is singled out only for the He I $\lambda 4471, 4387$, and 4922 lines. For the rest of the lines, the values of EW and the last three dates turned out to be greater than the theoretical values. We constructed a similar diagram for the case $\log g = 3.0 \text{ cgs}$, however, most of our EW values were found to be inconsistent with this plot. This unambiguously indicates that the star has a luminosity type close to V. In addition, the observed values of the equivalent widths on individual dates are about twice larger than the allowable contribution of one star. Comparison of the observational values of EW with the theoretical ones showed that rather, the spectrum of the star in terms of helium lines is combined, consisting of at least the spectrum of two stars. The temperature of one of them is about $22000 \pm 500 \text{ K}$ (according to the location of the black circles), and the temperature of the second star should be about $17000 \pm 1000 \text{ K}$ (according to the light circles) in Fig.7. Stars with such temperatures correspond to spectral types B1.5-2V and B 3-5V (see, for example, Pecaut&Mamajek, 2011). As can be seen from Table1, we get the same result, which is close to Brook's data. et al. (1993).

7. PHYSICAL PARAMETERS AND MODELLING

In addition to the gas-dust nebula in which AS 310 entered, the circumstellar environment of the star also complicated by the radiation of nearby stars in both the visible and the IR range. In addition to the second object, which is located at a distance of 3-4" from AS 310, and which was noted in the works of Bastian & Mundt (1979), Henning et al., (1994), several objects were found in the close environment of the star in the IR range. According to the 2MASS archive data (Skrutskie et al.2006), the star is located in the complex region HII, where up to 7 objects of AS 310 environment have been identified within a radius of 6.7". By using the 2MASS data (2003yCat.2246, 0C), presented in the database SIMBAD (VizieR), we have presented a list of all detected objects of AS 310 environment in Table 3. In columns of Table 3 for each object a distance in arcseconds from AS 310, type of objects, equatorial coordinates according to ICRS (2000), spectral types, and R-band magnitudes have been presented. Table 3. Identified objects in close environment of the AS 310 on the data 2MASS catalog. The strongest radiation from the close environment of the star belongs to the object with identification as NAME SH 2-61 2, which is fainter than AC310 at one magnitude in the R band. In addition, the IR object RMS G026.4488+01.7425A has the same coinciding coordinates as AS 310 itself. Therefore, we can assume that in spectrum AS 310, rather we are dealing with at least the radiation of the two nearest stars of the system.

Table 3. Identified objects in close environment of the AS 310 on the data 2MASS catalog.

No	Identifier	D (arcsec)	type	ICRS(2000) RA	ICRS(2000) DEC	Sp	MagR
1	EM * AS 310	0.00	Ae*	183321.194	-045805.976	B1e	12.62
2	RMS G026.4488+01.7425A	0.10	IR	183321.19	-045805.9		
3	PMN J1833-0458	2.88	Rad	183321.1	-045809		
4	NAME SH 2-61 2	4.35		183321.440	-045808.298	B1I	13.79
5	RMS G026.4488+01.7425B	4.58	HII	183321.21	-045801.4		
6	2MASS J18332120-0458013	4.87		183321.199	-045801.105		
7	NAME SH 2-61 Stellar Group	6.69	OpC	183321	-0458.2		

On the results of spectral observations, we can take the dominant spectral type of the system's brighter star as B2V (see also Table 1). For the B2V spectrum, the color indexes for normal MS stars are ($B - V_Q = -0.21$, $(V - R_c)_0 = -0.094$, $(V - I_c)_0 = -0.23$ (Pecaut & Mamajek, 2013). According to Fig.2, the color indices $B - V$ vary in the range from 1.0 to 1.9, $V - R_c$ - from -0.4 to 0.4, and $V - I_c$ from 0.2 to 0.9. We obtained the maximum value of the amplitude of brightness changes in the V-band $\Delta V \sim 0.6$ mag, and the colors $\Delta(V - R_c) \sim 0.8$ mag, $\Delta(B - V) \sim 0.9$ and $\Delta(V - I_c) \sim 0.6$ mag. The observed increase in the brightness of the system on different dates is apparently associated with an increase in the contribution of the second component of the system. With a more stable, minimum brightness state in the B and V bands (equal to 13.85 and 12.6, respectively (Fig. 1)), for the color-excess of the star B2V we obtain $E(B - V) = 1.21$, and for $A_v = R E(B - V) = 3.75$ (here the standard reddening coefficient was taken as $R = 3.1$). Comparison with Table 1 showed that the obtained A_v is in good agreement with the data Wichittanakom et al. 2012 ($A_v = 3.94$), Brooke et al., 1993 ($A_v = 3.9$). Then, assuming a more stable brightness state $V_0 = 12.6$ mag (Fig. 1), and the distance to the cluster is 2500pc, (Tabl.1) we can calculate the absolute magnitude for this value A_v , as $M_x = -3.14$ mag. Taking into account the bolometric correction, we get $M_{vb} = -5.20$ mag, and for the luminosity and radius of the primary star, $\log L/L_\odot = 4.01$ and $R = 7.0R_\odot$, respectively. With this approach to the analysis of our data of observations, there remains an uncertainty in the parameters of the secondary component of the system. In addition, the accuracy of determining the parameters in this approach is due to the determination of the color indexes and, ultimately, the interstellar reddening coefficient, which, as is known, determined by poor accuracy.

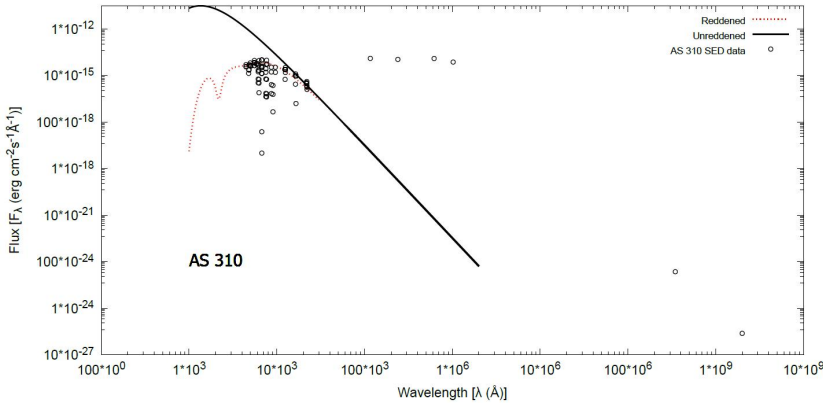


Fig. 8. SED data (empty circles) and model (solid and dotted curves) for AS 310. The observational SED data refers to within 2 arcsecs around the object.

Using the recently developed method proposed in the work by Bakis & Eker (2022), we considered the observational parameters of the binary system model for the AS 310. The main point of this method is that a higher precision (~ 3 times) for the standard luminosities of stars could be obtained by using the multi-band (Johnson B, V, Gaia G, GBp, GRp) bolometric corrections (BC) instead of using the Stefan-Boltzman law. Eker & Bakis (2023) recently improved their method by including the BC for the Transiting Exoplanet Survey Satellite (TESS) passband.

To obtain the standard luminosities of binary star components, interstellar extinction in the abovementioned passbands and component light contributions of the binary system in the above-mentioned six passbands are needed which could be obtained by studying their spectral energy distribution (SED) data. The new method provides not only component contributions but also provides the amount of dimming due to interstellar extinction in magnitude scale ($A\xi$) which is needed when computing absolute magnitude (M_ξ) of a component from its apparent magnitude ξ ,

$$M_\xi = \xi + 5 \log \pi + 5 - A\xi$$

where π and $A\xi$ are trigonometric parallax in arcseconds and interstellar extinction in magnitudes for the passband ξ , respectively. Together with the total magnitude of the binary star and its parallax, the equation of Bakis & Eker (2022) yields the absolute magnitudes of the components in the six passbands.

The interstellar extinction (A_ξ) of an object is a function of its unreddened SED (f_λ^0), its reddened SED (f_λ) and wavelength dependent filter sensitivity func-

tion ($S_\lambda(\xi)$) as follows:

$$A_\xi = 2.5 \log \frac{\int_0^\infty s_\lambda(\xi) f_\lambda^0(\text{system}) d\lambda}{\int_0^\infty s_\lambda(\xi) f_\lambda(\text{system}) d\lambda^2}$$

In this study, we retrieved the SED data of AS 310 using the SIMBAD database (Wenger et al. 2000) within an aperture of 2 ". Using the temperature of the components obtained above ($T_1=22000\text{K}$ and $T_2=17000\text{ K}$) and the distance of 2500pc, the SED data is modelled. The radii of the components, which are not used in the calculation of standard luminosities but used for only obtaining interstellar extinction (A_g) in 6 passbands, are adopted from similar systems in the list of Double-Lined Detached Eclipsing Binaries (DDEBs) of Bakish & Eker (2022) as $R_1 = 4.0R_\odot$ and $R_2 = 2.6R_\odot$. After obtaining the standard luminosities, these radii are updated and listed in Table 4. In Fig. 8, the SED data is shown together with reddened and unreddened SED models. As it is seen in Fig. 8, the lower limit for the color excess is $E(B - V) = 1.0$ mag which denotes the multi-band interstellar extinctions as $A_B = 4.094\text{mag}$, $A_V = 3.066\text{mag}$, $A_G = 2.957\text{mag}$, $A_{GBP} = 3.526\text{mag}$, $A_{GRp} = 1.914\text{mag}$ and $A_{TESs} = 1.980\text{mag}$. The SED data under the reddened model SED (dotted red curve in Fig. 8) imply higher extinctions are possible probably due to the state of the system. Therefore, it is expected to have different values of extinction depending on the observing time of the system, the case we have in this study.

The multiband BC s could be easily obtained by using the temperature-BC relations (see Table 2 of Eker & Bak1s, 2023 for all relation parameters) for each passband. Thus, the bolometric magnitude and the standard luminosities could be calculated using Eqs. 3 and 9, respectively. The methodology for determining parameter uncertainties is described for each parameter in Eker & Bakish (2023).

The multi-band absolute magnitudes (M_ξ), BCs, bolometric magnitudes ($M_{bol\xi}$) and luminosity (L) of the components are given with their uncertainties in Table4. Using the T_{eff} and L of the components, the radius for each component is calculated and presented in Table4 . As can be seen in Table 4 , the adopted radii of the components in the SED analysis are very close to the derived values.

Figure 9 shows the HR diagram with evolutionary tracks, taken from Vioque et al. (2022), where positions signed with black circles are well-known Herbig. AeBe stars (Ismailox et al..2022), the square and triangle marks the possible position of the main and secondary star of the system AS 310 . Hence, for the masses and the upper age limit, we obtain $M_1 = 9M_\odot$, $M_2 = 4.6M_\odot$ and $t < 1\text{Myr}$, accordingly.

8. DISCUSSION

The results of our photometric observations performed in 2016-2022 showed that the brightness and colors of AS 310 vary with time. Since the star is in a complex HII region and probably has similar stellar components nearby, this makes it difficult correctly distinguish the contribution of individual components of the system to the change in brightness and magnitude of the interstellar extinction coefficient in the direction of the system. We have shown that the seasonal

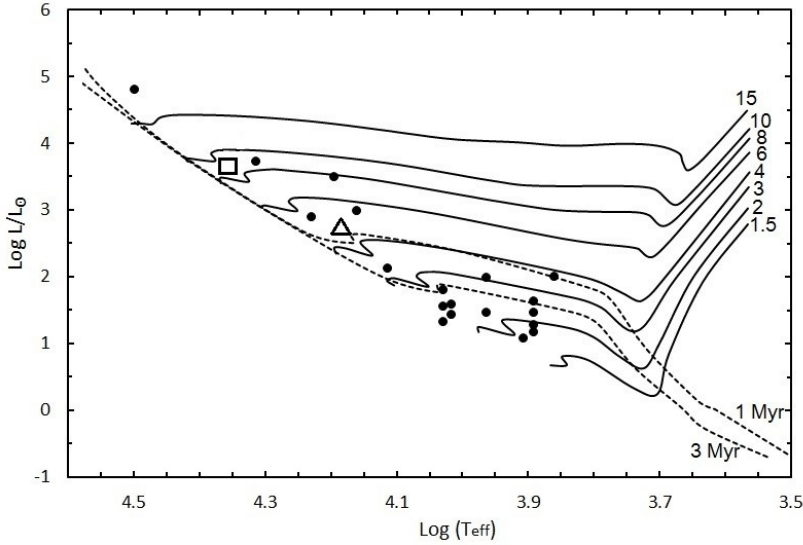


Fig. 9. HR diagram for well-known Herbig AeBe stars (black circles) Ismailov et al., 2022. Evolutionary tracks are plotted from data (Bressan et al. 2012 and Marigo et al. 2017). Bold lines indicate masses, dotted lines, –ages. The square and triangle marks the possible position of the main and secondary star of the system AS 310.

variations in the amplitude of the brightness in the V-band, starting from 2016, gradually increase and reach a maximum of 0.6 magnitudes in 2018. Then the amplitude of the brightness variations gradually decreases and reaches a minimum in 2022. On the branch of decreasing amplitude of the brightness variation in 2020-2022, we have executed spectral observations, which showed that in 2020 the emission spectrum in an enhanced state is observed. In 2021 and 2022, when the stellar brightness variability is minimal, the intensity of the emission has decreased significantly. In the quiescent state of the emission spectrum, the lines of neutral helium are comparable to the theoretical equivalent widths in the atmosphere of a star with spectra B1.5-2V and B3-5V. This result also confirms the assumption of the existence of a close companion of the star, which apparently contributes to the change in the brightness and spectrum of AS 310.

Table 4. Obtained parameters of separate components in binary system AS 310.

Parameter	Primary	Secondary
m_B (mag)	13.82 ± 0.01	15.338 ± 0.01
m_V (mag)	12.774 ± 0.01	14.221 ± 0.01
m_g (mag)	12.6458 ± 0.0028	14.0655 ± 0.0028
m_{GBp} (mag)	13.2827 ± 0.0028	14.7476 ± 0.0028
m_{GRp} (mag)	11.8437 ± 0.0028	13.2186 ± 0.0028
m_{TESS} (mag)	11.920 ± 0.014	13.294 ± 0.0028
BC_B (mag)	-1.789 ± 0.136	-1.190 ± 0.136
BC_V (mag)	-1.868 ± 0.12	-1.271 ± 0.12
BC_G (mag)	-1.926 ± 0.111	-1.323 ± 0.111
BC_{GBR} (mag)	-1.718 ± 0.127	-1.166 ± 0.127
BC_{GRR} (mag)	-2.188 ± 0.109	-1.510 ± 0.109
BC_{TESS} (mag)	-2.266 ± 0.111	-1.595 ± 0.111
M_B (mag)	-2.264 ± 0.093	-0.745 ± 0.093
M_V (mag)	-2.282 ± 0.093	-0.835 ± 0.093
M_G (mag)	-2.300 ± 0.093	-0.881 ± 0.093
M_{GBR} (mag)	-2.233 ± 0.093	-0.768 ± 0.093
M_{GRR} (mag)	-2.060 ± 0.093	-0.686 ± 0.093
M_{TESS} (mag)	-2.050 ± 0.094	-0.676 ± 0.094
$Mbol_B$ (mag)	-4.052 ± 0.164	-1.935 ± 0.164
$Mboly$ (mag)	-4.150 ± 0.151	-2.107 ± 0.151
$Mbol_G$ (mag)	-4.227 ± 0.144	-2.204 ± 0.144
$Mbol_{GBR}$ (mag)	-3.951 ± 0.157	-1.934 ± 0.157
$Mbol_{GRp}$ (mag)	-4.249 ± 0.143	-2.196 ± 0.143
$Mbol_{itess.}$ (mag)	-4.316 ± 0.145	-2.271 ± 0.145
$Mbol$	-4.168 ± 0.055	-2.119 ± 0.059
$L (L_\odot)$	3657 ± 187	555 ± 30
$R (R_\odot)$	4.16 ± 0.14	2.71 ± 0.11

The results of our observations can be qualitatively explained as follows: it is possible that when we observe anomalous EW values of helium lines, the contribution of the secondary component to the spectral lines increases. At the same time, an increase in the emission of hydrogen lines is observed, which may be the result of an increase in the emission of the nearby H II region due to an increase in the heating of the nebula by hot stars. The variability of emission in hydrogen lines, as well as their unusually small width for HAeBe stars, which was noted

also by Finkenzeller & Mundt (1984), confirms our conclusion that emission in hydrogen lines occurs in the H II region in the circumstellar gas under the UV radiation of the hot stars. The absence of emission components in the He I lines suggests that, rather, the stellar components of the system do not have the strong form of a circumstellar accretion disk. Similar hot OB stars have been detected before, for example, in the extremely young trapezium θ^1 Ori in the Orion Nebula M42 (see, for example, Parenago 1954, Antokhina et al. 1989, Balega et al. 2016). The observed brightness and spectrum variability in such massive systems is due to the dynamics of individual components in the system.

Thus, the revealed active and quiescent states of the stellar spectrum and brightness, the synchronous variation in the intensity of emission lines with the activity of changing brightness, and the anomalous values of the equivalent widths of helium lines in the active state can be explained in the model of the binary system. The observed variability may be the result of the visibility of the condition of radiation during the orbital motion of the components. Rather, it is an extremely young binary system, the components of which have reached the MS in about 1 Myr.

9. CONCLUSIONS

1. The star AS 310 is more often in a quiescent state of brightness, but from time to time, an increase in brightness with a variable amplitude is observed. The color and brightness of the star vary in different seasons. During the observation period 2016-2022, a smooth increase in the amplitude of the brightness variability in the V band have detected. Having reached a maximum in 2018 by 0.6 mag in the V band, the amplitude of brightness variations then gradually decreases to a minimum in 2022.

2. The same FWHM of the emission components have observed in the $H\alpha$, $H\beta$, and [NeII] lines, which indicates that these lines are formed in the HII region where the star is located, and the star itself does not have a significant protostellar disk. An increase in the emission in these lines is observed with an increase in the amplitude of variations in the brightness of the star.

3. Comparison of the equivalent widths with the theoretical spectrum for helium lines showed that the observed equivalent widths of neutral helium lines apparently refer to the combined spectrum of B3-5V and B1.5-2V. This showed that AS 310 is an extremely young binary system that quickly lost its circumstellar disk and entered the Main Sequence.

4. Using the method of spectral energy distribution of the star with the help of multicolor photometry, in model of the binary system the more probable phys-

ical parameters of the components and the evolutionary status of the system are determined.

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AMPLIFICATION OF ENERGY OF COSMIC RELIC ANTINEUTRINOS IN STRONGLY MAGNETIZED ASTROPHYSICAL OBJECTS

V. A. Huseynov^{a,b,c,d*}, R. E. Gasimova^{e,f}

^a *Laboratory for Physics of Cosmic Ray Sources, Institute of Physics, Baku, Azerbaijan*

^b *Department of Engineering Physics and Electronics, Azerbaijan Technical University, Baku, Azerbaijan*

^c *Department of Physics, Baku Engineering University, Khirdalan, Azerbaijan*

^d *Department of Physics and its Teaching Methods, Sumgayit State University, Sumgayit, Azerbaijan*

^e *Department of Theoretical Astrophysics and Cosmology, Shamakhy Astrophysical Observatory, Baku, Azerbaijan*

^f *Department of General Physics, Azerbaijan State Pedagogical University, Baku, Azerbaijan.*

We have calculated the energy loss in the scattering of relic antineutrinos by ultra relativistic electrons with the allowance for the transverse polarization of the spins of the electrons participating in the considered processes proceeding in strongly magnetized astrophysical objects. We have determined that when the cosmic electron-positron plasma bypasses a white dwarf, energy is transferred from the plasma electrons to the relic antineutrinos at the expense of the antistokes transitions and the energy of relic antineutrinos are amplified about 10^9 times and reaches $\sim 10^5$ eV. This is a new mechanism of amplification of the energy of antineutrinos, in particular, relic antineutrinos.

Key words: neutrinos – acceleration of particles – white dwarfs – polarization – magnetic fields – cosmic rays

1. INTRODUCTION

The energy of cosmic rays is mainly in the range from $\sim 10^{-4}$ eV to $\sim 10^{19}$ eV and sometimes higher than $\sim 10^{19}$ eV. The energy of $\sim 10^{-4}$ eV corresponds to

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* E-mail: vgusseinov@yahoo.com

relic neutrinos and antineutrinos. The known values of the masses of elementary particles vary in the range from $\sim 10^{-1}\text{eV}$ to $\sim 10^{11}\text{eV}$. According to the results obtained from the KATRIN experiment, the upper limit of the electron neutrino mass is estimated as $\sim 10^{-1}\text{eV}$. The mass of the Higgs boson detected in the ATLAS and CMS experiments performed at the Large Hadron Collider was determined to be approximately 125 GeV. The mass of the t -quark, which is heavier than the Higgs boson and is generally considered the heaviest particle among the elementary particles, is 173 GeV, that is, approximately, $\sim 10^{11}\text{eV}$. Therefore, the maximum kinetic energies of particles obtained from the decay of existing elementary particles known to science are much smaller than their rest energies. It is known that moving in galaxies and intergalactic space cosmic particles gain energy and accelerate due to various acceleration mechanisms (dynamic mechanism, hydrodynamic mechanism, electromagnetic mechanism, Fermi acceleration mechanism, acceleration due to a strong shock wave etc). For instance, PeV-energy ($\sim 10^{15}\text{eV}$) antineutrinos was discovered among cosmic particles as a result of observing Glashow resonance [1] in the Ice Cube experiment performed in Antarctica [2]:

$$\tilde{\nu}_e + e^- \rightarrow W^- . \quad (1)$$

The energy of an electron antineutrino for this resonance reaction to occur in a system where the electron is at rest is to be

$$\omega_R = \frac{M_W^2}{2m_e} = 6.32 \text{ PeV} . \quad (2)$$

It is known that in an electromagnetic field charged particles are accelerated and their energies increase. However, electromagnetic field cannot accelerate neutral particles, in particular, neutrinos and antineutrinos. A natural question arises. What mechanisms are responsible for the amplification of the energies of neutrinos and antineutrinos? Finding an answer to this question is the main motivation of this research.

The object of the study is the antineutrino-electron scattering processes in a constant homogeneous magnetic field

$$\tilde{\nu}_i + e^- \rightarrow \tilde{\nu}'_i + e^{-'} , \quad (3)$$

where $\tilde{\nu}_i = \tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau$ and $\tilde{\nu}'_i = \tilde{\nu}'_e, \tilde{\nu}'_\mu, \tilde{\nu}'_\tau$ are the antineutrinos of three flavours in the initial and final states, respectively.

Various aspects of the antineutrino-electron scattering in a magnetic field were studied in the papers [3–6]. The analyses of the papers [3–6] show that energy loss in the antineutrino-electron scattering in a magnetic field was not calculated

with allowance for the transverse polarization of the spins of the electrons participating in the considered processes in the above-mentioned investigations. In the presented work, we calculate the energy loss in the scattering of relic antineutrinos by ultra relativistic electrons, taking into account the transverse polarization of the spins of the electrons participating in the processes (3).

The purpose of the presented investigation is to clarify the mechanism of energy transfer by calculating the energy losses in the scattering of relic antineutrinos by ultra relativistic electrons in an external constant homogenous magnetic field with allowance for the transverse polarization of the spins of the electrons participating in the processes (3) and to determine how the energy of relic antineutrinos changes.

2. THE PHYSICAL CONDITIONS AND ASSUMPTIONS

We consider the antineutrino-electron scattering in a constant homogenous magnetic field within the physical conditions and assumptions used in [7]. We assume that electrons in the initial and final states are ultra-relativistic

$$\varepsilon^2 \gg m_e^2, \quad \varepsilon'^2 \gg m_e^2 \quad (4)$$

and possess large transverse momenta

$$p_{\perp} = (2eBn)^{1/2} \gg m_e, \quad (5)$$

$$p'_{\perp} = (2eBn')^{1/2} \gg m_e, \quad (6)$$

where n (n') is the number of the Landau energy level belonging to the electron in the initial (final) state, B is the magnitude of the magnetic field vector $\mathbf{B}$ that is directed along the z -axis and assumed to be

$$B \ll B_0 = \frac{m_e^2}{e} \cong 4.414 \times 10^{13} G \quad (7)$$

We use the system of units $c = \hbar = k_B = 1$ and the pseudo-Euclidean metric with signature $(+ - - -)$.

The assumptions (4)-(7) mean that the main contribution to the energy loss in this process comes from the electron states occupying high Landau levels ($n, n' \gg 1$). In this case, the motion of the electrons in the initial and final states is semiclassical [8, 9]. We consider the case when the longitudinal momentum of the electron in the initial state is zero: $p_z = 0$.

Within the above considered physical conditions we can neglect the mass of an antineutrino and we can apply the massless antineutrino model. Let the incident

low-energy antineutrino fly along the z-axis (along the magnetic field direction) and its energy is in the range

$$\omega_{\min} \ll \omega \ll m_e \quad (8)$$

where $\omega_{\min} = eB/p_{\perp}$.

The above-mentioned physical conditions and assumptions indicate that the energy loss in the processes (3) depends on the dynamical parameter

$$\chi = \frac{e}{m_e^2} \left[- (F_{\mu\nu} p^{\nu})^2 \right]^{1/2} = \frac{B}{B_0} \frac{p_{\perp}}{m_e} \quad (9)$$

and the kinematical parameter [9]

$$\kappa = \frac{2\omega\varepsilon}{m_e^2} = \frac{2kp}{m_e^2} \quad (10)$$

where $F_{\mu\nu} = \partial_{\mu}A_{\nu} - \partial_{\nu}A_{\mu}$ is the tensor of an external electromagnetic field of the magnetic type.

3. ENERGY LOSS BY THE ELECTRONS IN THE ANTINEUTRINO-ELECTRON SCATTERING

We obtain the following general formula for the energy lost by the electrons in the antineutrino electron scattering in an external constant homogenous magnetic field with allowance for the transverse polarization of the spins of the electrons participating in the considered processes

$$\frac{dE}{dt} = -\frac{G_F^2 m_e^2}{\pi^{3/2} V} \varepsilon \int_0^{\infty} \left[\tilde{A} \Phi_1(z) - \tilde{B} \left(\frac{\chi}{u} \right)^{2/3} \Phi'(z) - \tilde{C} \left(\frac{\chi}{u} \right)^{1/3} \Phi(z) \right] F \frac{u^2 du}{(1+u)^5} \quad (11)$$

where

$$\tilde{A} = \frac{\kappa}{2u} \left[g_R^2 (1+u)^2 + g_L^2 + 2g_L g_R \zeta \zeta' (1+u) \right] - g_L g_R (1 + \zeta \zeta') (1+u), \quad (12)$$

$$\tilde{B} = g_R^2 (1+u)^2 + g_L^2 + 2g_L g_R \zeta \zeta' (1+u), \quad (13)$$

$$\tilde{C} = g_R^2 \zeta' (1+u)^2 - g_L^2 \zeta + g_L g_R (\zeta - \zeta') (1+u), \quad (14)$$

$$F = f (1 - f') = \frac{1}{e^{\frac{\varepsilon - \mu}{T}} + 1} \left(1 - \frac{1}{e^{\frac{\varepsilon' - \mu}{T}} + 1} \right) \quad (15)$$

is the statistical factor, $f(f')$ is the Fermi-Dirac distribution function for the electrons in the initial (final) state, $\mu(\mu')$ and $T(T')$ are the chemical potential and the temperature of the electron gas before (after) the antineutrino-electron scattering, respectively. In (11-14) $\zeta(\zeta')$ is the projection of the spin of the electron in the initial (final) state onto the z -axis, $g_L = 0.5 + \sin^2 \theta_W$ and $g_R = \sin^2 \theta_W$ for the $\bar{\nu}_e e^- \rightarrow \bar{\nu}_e' e'^-$ process, $g_L = -0.5 + \sin^2 \theta_W$, $g_R = \sin^2 \theta_W \cong 0.23$ for the $\bar{\nu}_\mu e^- (\bar{\nu}_\tau e^-)$ scattering, θ_W is the Weinberg angle, G_F is the Fermi constant, V is the volume of the spatial domain where the process is formed,

$$u = \frac{\chi}{\chi'} - 1 = \frac{p_\perp}{p'_\perp} - 1 \simeq \frac{\omega'}{\varepsilon - \omega'}, \quad (16)$$

is the spectral variable, ω' is the energy of the scattered antineutrino, χ' is defined according to the formula (9) and belongs to the electron in the final state,

$$\Phi(z) = \frac{1}{2\sqrt{\pi}} \int_{-\infty}^{+\infty} dt \exp \left[i \left(zt + \frac{t^3}{3} \right) \right] \quad (17)$$

is the Airy function depending on the argument

$$z = \left(\frac{u}{\chi} \right)^{2/3} \left(1 - \frac{\kappa}{u} \right), \quad (18)$$

$$\Phi'(z) = d\Phi(z)/dz \quad \text{and} \quad \Phi_1(z) = \int_z^\infty \Phi(y) dy.$$

The analyses of the argument z of the Airy function shows that the influence of the external magnetic field on the antineutrino-electron scattering is determined by the parameter

$$\eta = \frac{\chi}{\kappa} = \frac{1}{2} \frac{B}{B_0} \frac{m_e}{\omega} \gtrsim 1. \quad (19)$$

The influence of the external magnetic field on the antineutrino-electron scattering is essential when $\eta \gtrsim 1$. The condition $\eta \gg 1$ corresponds to the strong field case and the condition $\eta \ll 1$ corresponds to the weak field case. When $\eta \sim 1$, the proceeding of the process depends on the ratio u/κ . As can be seen from expression (19), the influence of the external field on the considered process is significant when the magnetic field is strong enough (but $B \ll B_0$), and antineutrinos possess extremely low energy. Very low energy antineutrinos are relict antineutrinos.

When $\chi \gg \kappa$ (i.e., $\eta \gg 1$) we obtain the following asymptotic formula for the energy loss per unit time

$$\begin{aligned} \frac{dE}{dt} = & -\frac{\Gamma(2/3)G_F^2 m_e^2}{27\pi} \frac{\varepsilon}{V} \left\{ \left(2g_R^2 + \frac{5}{27}g_L^2 + \frac{8}{9}g_L g_R \zeta \zeta' \right) (3\chi)^{2/3} - \right. \\ & \left. - \frac{5\Gamma(1/3)}{\Gamma(2/3)} \left[g_R^2 \zeta' - \frac{1}{27}g_L^2 \zeta + \frac{1}{9}g_L g_R (\zeta - \zeta') \right] (3\chi)^{1/3} \right\} F. \end{aligned} \quad (20)$$

4. NUMERICAL ESTIMATIONS

Using the relations (8) and (19), taking into account the energy of relic antineutrinos ($\omega \cong 1.677 \times 10^{-4} \text{eV}$) and the energy of the electrons in the cosmic plasma that is $\sim 10^2 \text{GeV}$ (e.g., $\varepsilon \cong 281.27 \text{GeV}$) we obtain the following numerical value for the magnetic field strength $B \cong 8 \times 10^8 \text{Gs}$. This is the characteristic magnetic field strength of ordinary white dwarfs. It means that when the electrons of the energy $\sim 10^2 \text{GeV}$ of cosmic electron-positron plasma bypasses a white dwarf, the influence of a magnetic field of the white dwarf on a relic antineutrino-electron scattering becomes essential: $\eta = 2.757 \times 10^4 \gg 1$. On the basis of the above-mentioned values of the physical quantities we obtain that $\varepsilon \cong T \gg \mu, \varepsilon' \cong T' \gg \mu, \varepsilon' \lesssim \varepsilon, F \cong 1.966 \times 10^{-1}$ and $\chi = 10 \gg 1$. The characteristic size of the domain of formation of the process under consideration is

$$l \sim \frac{m_e}{eB} = \lambda_c \frac{B_0}{B} = 2.13 \times 10^{-6} \text{sm} \quad (21)$$

where λ_c is the Compton wavelength of an electron. The corresponding volume is $V = (4\pi/3)l^3 \cong 4.05 \times 10^{-17} \text{sm}^3$.

If we consider the process $\tilde{\nu}_e + e^- \rightarrow \tilde{\nu}'_e + e^{-'}$ and assume that the spin of the electron in the initial (final) state is oriented along (opposite to) the direction of the magnetic field vector $\mathbf{B}$, i.e. $\zeta = +1$ and $\zeta' = -1$, we obtain the following numerical estimation for the energy loss by the electrons

$$\frac{dE}{dt} = -1.458 \times 10^{-8} \frac{\text{eV}}{\text{s}}. \quad (22)$$

This is the energy taken or absorbed by the relic electron antineutrinos from the medium per unit time. The negative sign indicates that energy is transferred from the medium (cosmic plasma electrons) to the relic electron antineutrinos, not from the relic electron antineutrinos to the medium. This happens at the expense of the antistokes transitions. In this case the electrons in the final state make transition to relatively low Landau levels and the energy of relic electron antineutrinos increases significantly. The antistokes transitions take place when the condition $B \gg B_0 (\omega m_e / \varepsilon^2)$ is satisfied. The magnetic field strength existing in a white dwarf satisfies this condition. Really, in case of relic antineutrinos and $\varepsilon \cong 281.27 \text{GeV}$, we obtain the following estimation $B \gg 4.77 \times 10^8 \text{Gs}$. So, when the energy of the electrons of the cosmic plasma bypassing a white dwarf is $\sim 10^2 \text{GeV}$, relic antineutrinos and a white dwarf satisfy the antistokes condition.

Energy transferred to relic electron antineutrinos from a unit volume of medium per unit time is

$$\frac{1}{V} \frac{dE}{dt} = -3.6 \times 10^8 \frac{\text{eV}}{\text{sm}^3 \times \text{s}}. \quad (23)$$

If we take the relic antineutrino concentration $n_{\bar{\nu}} \cong 57\text{sm}^{-3}$ into account, we can calculate the energy carried by each relic antineutrino from the medium per unit time

$$\frac{\left(\frac{1dE}{Vdt}\right)}{n_{\bar{\nu}}} \cong 6.32 \frac{\text{MeV}}{\text{s}}. \quad (24)$$

If we take into account that the size of an ordinary white dwarf is about $0.8 - 2\%$ of the radius of the Sun ($R_{\odot} \cong 6.957 \times 10^8 \text{ m}$) and relic antineutrinos pass this distance during $(1.85 - 4.63) \times 10^{-2} \text{ s}$, the energy gained by the scattered relic electron antineutrino reaches $\omega'_{\bar{\nu}_e} \sim 10^5 \text{ eV}$ that is 10^9 times more than the initial energy of a relic antineutrino ($\omega \cong 1.677 \times 10^{-4} \text{ eV}$).

5. CONCLUSION

We calculated the energy loss in the scattering of relic antineutrinos by ultra relativistic electrons, taking into account the transverse polarization of the spins of the electrons participating in the processes (3). We have determined that when the condition $B \gg B_0 (\omega m_e / \varepsilon^2)$ is satisfied for the scattering of relic antineutrinos by ultra relativistic electrons in a magnetic field, energy is transferred from the electrons to the relic antineutrinos at the expense of the antistokes transitions. We have also determined that when the cosmic electron-positron plasma bypasses a white dwarf, the energy of relic antineutrinos are amplified about 10^9 times and reaches $\sim 10^5 \text{ eV}$. Search for the antineutrinos of the energy $\sim 10^5 \text{ eV}$ coming from white dwarfs in the future experiments in neutrino observatories opens prosperity for understanding the mechanism of amplification of the energy of relic antineutrinos.

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THE IMPACT OF GIANT PLANETS' INTERNAL ENERGY ON THE EVOLUTION OF THEIR ATMOSPHERES.

A. A. Atai^{a*}, B. E. Asgarova^b

^a *N.Tusi Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences, Shamakhy, Azerbaijan*

^b *Baku State University*

The internal energy of the giant planets of the solar system has not yet been determined. Determination of internal energy by various space missions and observations from Earth gives different results. The article discusses the internal energy of giant planets and the sources of this energy. The effect of internal energy on the atmospheres of giant planets is also emphasized.

Key words: planets:solar system planets – giant planets- – planet atmospheres – internal energy sources

1. INTERNAL ENERGY SOURCES OF GIANT PLANETS

The specific radiation emanating from the surfaces of planets is thermal in nature, belonging to the infrared and radio spectra, and its spectral density is determined by the Planck law:

$$B_v(T) = (2\pi h v^3 / c^2) \left(e^{[h/kT]} - 1 \right)^{-1} \quad (1)$$

where h is the Planck constant, k is the Boltzmann constant, v - the frequency, T - the surface temperature, and c - the speed of light. By integrating formula (1) with respect to frequency, we obtain the Rayleigh-Jeans formula for radiation, which describes thermal radiation in the radio spectrum for planets when the condition $h\nu \ll kT$ is satisfied.

All planets in the Solar System processes internal energy: the energy of a planet's matter and any internal processes or motion represents its internal en-

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* E-mail: atai1951@yahoo.com

ergy. Various factors, including mass, temperature, and composition, influence a planet's internal energy. For instance, Earth possesses significant internal energy due to the heat generated by the decay of radioactive elements and the friction of moving tectonic plates. The Earth's internal energy also includes the energy accumulated from the movement of molten rock and magma within the mantle and the motion of oceans and the atmosphere. Other planets in the Solar System also have internal energy, although the sources and amounts of energy may vary. The internal energy of the giant planets, which are larger in size and mass than Earth, depends on:

- Heat generated from gravitational compression,
- Energy released during phase transitions,
- Conversion of hydrogen molecules in the planet's atmosphere,
- Tidal heating from their moons,
- Heat flow from the planet's core,
- Natural convection,
- Radioactive decay in the planet's core,
- Seismic energy dissipation during exothermic phase transitions,
- Energy released during gravitational differentiation processes as heavy metals "sink" from the mantle to the core.

The energy of matter is generated when it collapses under its own gravity. The internal energy of a planet plays a critical role in its structure and behavior, generally in its geology, climate, and other environmental aspects. [1,3,4,8]

2. THE ENERGY BUDGET OF GIANT PLANETS

For the planets of the Solar System, the primary source of energy is the Sun, which provides heat and light in the form of electromagnetic radiation. For the giant planets in our Solar System (Jupiter, Saturn, Uranus, Neptune), the energy budget is the balance of energy entering and leaving the planet.

The energy budget of the giant planets is influenced by internal processes such as the generation of heat through the reduction of size under their own gravity, changes in the planet's matter distribution known as gravitational contraction, and the conversion of rotational energy. Additionally, the internal energy of giant planets includes spontaneous internal processes and motions like the circulation of their atmospheres and the movement of their moons. The energy budget of the giant planets is further affected by the composition of their atmospheres, thickness, the presence of dynamic weather patterns (variations in the disk), and the characteristics of other derivatives. Giant planets have larger and more massive atmospheres than the terrestrial planets and are subject to complex weather patterns and other phenomena that contribute to their energy budgets.

In summary, the energy budget of giant planets depends on a combination of solar energy, internal processes, and the characteristics of the planet's atmosphere. This balance plays a specific role in the planet's behavior and structure and affects the formation and evolution of its atmosphere and moons. [2]

3. GRAVITATIONAL ENERGY AS A SOURCE OF ENERGY ON JUPITER

Gravitational energy is a form of potential energy related to the position of objects within a gravitational field. On Jupiter, gravitational energy results from the process of gravitational contraction (compression). It is the energy associated with the collapse of planetary matter within its own gravitational field in space. During compression, the planet undergoes a process of combining gas and dust, which results in exposure to higher temperatures and pressures. This causes a reduction in the geometric size of the matter under its own gravity and leads to the release of energy. This energy ultimately represents Jupiter's internal energy and heat. In addition to gravitational compression, Jupiter's gravitational energy enhances the influence of its gravitational field on the motion of its moons and other objects. The gravitational energy of these objects, affected by their velocities and positions within the field, can be converted and released as they move and interact with other objects. Overall, gravitational energy is an important source of energy for Jupiter and plays a role in the structure and behavior of the planet. The study of interactions between objects in the gravitational field and gravitational forces is a fundamental concept. [8]

4. VARIATIONS IN THE ABSOLUTE REFLECTIVITY OF JUPITER AND SATURN IN THE SPECTRAL RANGE λ 0.38-1.7 μ M OVER TIME AND SPACE

A planet's absolute reflectivity is the measure of the portion of electromagnetic radiation (such as light) that is reflected by its surface or atmosphere. The absolute reflectivity of a planet varies over time and space due to various factors, including the characteristics of the planet's surface and atmosphere, the angle of incidence of solar rays, the presence of clouds, and other atmospheric phenomena. In the spectral range λ 0.38 – 1.7 μ m, the absolute reflectivity of Jupiter and Saturn is influenced by the properties of the gases in their atmospheres, as well as the presence of clouds and other atmospheric phenomena. In this spectral range, Jupiter's absolute reflectivity generally tends to be lower compared to the λ 0.1-0.4 μ m range, with varying values. Jupiter's absolute reflectivity is affected by the presence of clouds composed of water, ammonia, and other substances. These

clouds can block radiation, leading to a decrease in reflectivity. Saturn's absolute reflectivity in the λ 0.38-1.7 μm spectral range is generally slightly higher than Jupiter's, with values fluctuating around λ 0.2 – 0.5 μm . The presence of clouds made of ammonia and other gases affects Saturn's absolute reflectivity. Similar to Jupiter, these clouds can block radiation, which lowers the reflectivity. Overall, the absolute reflectivity of Jupiter and Saturn in the λ 0.38 – 1.7 μm spectral range is influenced by atmospheric characteristics, the presence of clouds, as well as by surface properties and the angle of radiation, among other factors.

5. THE ATMOSPHERE OF THE PLANET URANUS

The atmosphere of Uranus is primarily composed of hydrogen and helium, with small amounts of methane, ammonia, and water vapor. The temperature of Uranus's atmosphere is much colder than Earth's, with temperatures around -217 degrees Celsius. Uranus has an active atmosphere with strong winds and other atmospheric phenomena. Winds in the atmosphere of Uranus can reach speeds of up to 900 km/h in the equatorial region, making them among the fastest in the solar system. These winds are driven by the planet's rapid rotation and result in a more active and turbulent atmosphere. The atmosphere of Uranus also features the presence of clouds and hazes made up of substances such as methane, ammonia, and water vapor. These hazes and clouds play a role in the formation of weather phenomena and in the planet's energy balance. Overall, the atmosphere of Uranus is a complex and dynamic system. It is influenced by factors such as the planet's size, composition, and distance from the Sun, which are important in the planet's behavior and structure and play a role in its climate and other environmental aspects.

6. THE ATMOSPHERE OF THE PLANET NEPTUNE

The atmosphere of Neptune is also primarily composed of hydrogen and helium, with small amounts of methane, ammonia, and water vapor. The temperature of Neptune's atmosphere is even colder than that of Uranus, with temperatures around -226 degrees Celsius. Like Uranus, Neptune has an active atmosphere with strong winds and other atmospheric phenomena. Winds in Neptune's atmosphere can reach speeds of up to 960 km/h in the equatorial region, which also ranks them among the fastest in the solar system. These winds are driven by the planet's rapid rotation and contribute to a more active and turbulent atmosphere. Neptune's atmosphere is characterized by the presence of clouds and hazes made up of substances such as methane, ammonia, and water vapor. These hazes and

clouds are important in the formation of weather phenomena and in maintaining the planet's energy balance. In general, the atmosphere of Neptune is a complex and dynamic system, affected by the planet's size, composition, and its distance from the Sun. These factors are crucial in shaping the planet's behavior and structure and play a role in its climate and other environmental aspects.

7. EVOLUTION OF PLANETARY ATMOSPHERES.

The study of the evolution of planetary atmospheres involves investigating the characteristics and properties of the gases, particles, and other materials that make up the atmosphere, as well as the events and processes that occur within it. Researchers employ various methods, including the laboratory analysis of atmospheric samples, in-situ measurements using space probes and other instruments, and remote sensing techniques from Earth and space.

In studying planetary atmospheres, scientists rely on several fundamental concepts:

- **Composition:** Understanding the chemical composition of planetary atmospheres is crucial. It provides insights into a planet's history, evolution, and potential to support life. Researchers examine the quantity and distribution of particles and various gases in a planet's atmosphere to discern its origins and behavior.
- **Temperature and Pressure:** The atmospheric temperature and pressure on a planet influence its climate, weather phenomena, and other environmental conditions. Scientists investigate how these factors affect atmospheric motion and the planet's overall energy balance.
- **Dynamics:** The movement of gases and particles within a planet's atmosphere can drive processes such as winds, storms, and other atmospheric events. These processes are studied to understand their effects on the planet's climate and environment.
- **Energy Balance:** A critical factor in determining a planet's climate and environment is its energy balance. Scientists explore the transfer of heat and energy within the atmosphere, the role of greenhouse gases, and the impact of the planet's distance from the Sun.

Addressing these issues sheds light on the sources of internal energy of planets. The evolution of planetary atmospheres is a complex and multifaceted process that involves studying a broad array of factors and phenomena. This comprehensive approach allows scientists to learn about the characteristics and dynamics of planetary atmospheres, which are essential for understanding their climates and environments. The process of radiating additional internal energy in a planet

within the solar system is intrinsically connected to the planet's formation location; hence, studying these aspects in isolation is not sufficient. Previous research indicates that the internal energy change of a planet varies across different wavelengths over time and exhibits different values in various regions of the planet. This uneven distribution and generation of internal energy are manifested in phenomena occurring at different latitudes within the planet's atmosphere. For instance, the Great Storm on Saturn in 2010 provides a compelling example. Data from the Cassini spacecraft revealed that from 2010 to 2011, the great storm altered Saturn's thermal structure in the latitude bands between 20°N and 55°N , markedly increasing the planet's radiated energy. Although the storm lasted only one Saturnian year (until the end of 2011), the resultant increase in Saturn's internal energy was detectable until 2014 [5–7]. This suggests that the additional energy radiated by the planet originates not in the atmosphere but from deeper layers, with the atmosphere then responding to this excess energy. Identifying the sources of internal energy in planets is key to understanding the physical conditions of their origins.

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SPECTRAL PROPERTIES OF THE STAR HD 141569A IN THE OPTICAL RANGE

*H. N. Adigozalzade^{a*}, U. Z. Bashirova^a, N. Z. Ismailov^a,
S. A. Alishov^a, A. Z. Aghayeva^a, A. A. Aghayeva^b*

^a *N. Tusi Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences,
Shamakhy, Azerbaijan*

^b *Baku State University*

In this work, the results of homogeneous spectral observations of HD 141569 of the Herbig Ae type star conducted at the Shamakhy Astrophysical Observatory in 2017-2018 are presented. It was shown for the first time that the spectrophotometric parameters of emission lines show both short-term (days) and long-term (years) variations. The reason for the variability in the emission spectrum in the optical range can be explained by the stellar wind and disk accretion. Based on the obtained spectral characteristics, it is shown that the star belongs to the class of β Pic-type fragmented protoplanetary debris disk stars.

Key words: Pre-main sequence stars – circumstellar disks – star formation – HD141569.

1. INTRODUCTION

The formation and evolution of young stellar protoplanetary disks is closely related to the processes of planet formation. The physical properties of the outer parts of such discs have been studied in recent years in scattered light images taken with large telescopes [1] and at the ALMA complex of sub-millimetre radio telescope [2]. These studies have shown that the sizes of rings, gaps, and asymmetric structures in disks reach several hundred au [3,4]. In the inner layers, signs of gas accretion, stellar wind, matter flow and dust sublimation are visible. All these processes lead to the formation of planets at a distance of a few au and their migration over millions of years. All these processes can be indirectly studied by

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* E-mail: hadigozalzade@gmail.com

spectral observations. Although a statistically large number of young stellar discs have been studied so far, it is very important to continue research in this direction. For example, unusual systems such as HD141569 due to their evolutionary sequence warrant further study. The mechanism of formation of hydrogen lines in the star-disk system in this star remains unclear.

The spectral class of Herbig AeBe type star HD141569 is classified as B9-A0 [5], temperature 9750 ± 250 K, age 7.2 ± 0.02 Myr, luminosity $16.6 \pm 1.07 L_{\odot}$ [6] and $27.0 \pm 3.6 L_{\odot}$ [7], with a mass of $2.14 \pm 0.01 M_{\odot}$ and a Gaia distance of 110 ± 1 pc [8]. The star has a nonigniting disk system, shows a weak emission excess in the near-IR region, and is classified as type II according to the spectral energy distribution (SED) curve [9]. According to the results obtained in recent years, the protoplanetary disc formed around the star has a very complex structure and consists of separate arms distributed at different distances [10, 11]. At the same time, there is very little information about the internal structure of the disk. The study of the SED curve shows that the energy distribution in the near-IR region can be attributed to a normal photosphere, while the outer parts of the disk are already fragmented and the process of planet formation is proceeding rapidly [12]. An evolution scheme based on the amount of IR excess is proposed and this star is shown to be close to β Pic and α Lyr type [13].

Peristellar gas is observed in both atomic and molecular form, indicating that the disc has not yet reached the gas-rich fragmented disc stage. [14] and [15] showed that hydrogen lines do not show short-term variability.

Gahm et al. [16] showed that the $H\alpha$ and $H\beta$ lines in the spectrum of HD141569 show an emission profile, only the $H\delta$ line is relatively clean. According to the initial classification criteria of Herbig [17], HAeBe stars are closely associated with gas-dust nebulae, with hydrogen lines showing a strong emission profile. Later, The et al. [18] added to these criteria the presence of emission excess in the near and far IR region. HD141569 shows an emission excess in the $12 - 100 \mu\text{m}$ range, but it is not associated with any bright nebula. In 1938 Rossiger [19] proposed the star HD141569 as a potential triple system. The second component B is 7.5 arcsec from the center A, and the third component C is 1.5 arcsec. Gahm et al. [16] assigned the spectral class of the component as G0V, and Lindroos [20] assumed it to be a background star based on photometric color and brightness. However, Gahm et al. [16] attributed it to young stars due to the presence of H , $KCaII$ and $H\beta$ emission lines in this component, which are attributed to young stars. Also, an interesting point is that the projection of the disk of the component A onto the line AB is about halfway along the line. The study of the spectrum of this three-fold system in the visual field can allow us to make an opinion about the dynamics of the system.

Based on photometric and spectral observations, Weinberger et al. [21] showed that HD141569 forms a triple system. The spectral classes of D and C components are assigned as M2 and M4, respectively. A characteristic H α emission line and TiO bands were observed in the spectra of both components.

In this work, the results of spectral observations of the HD141569 star at the Shamakhi Astrophysical Observatory in 2017-2018 are given.

2. OBSERVATION MATERIAL

Observations in 2017-2018 carried out using the ShAO Fiber-Echelle Spectrograph (ShAFES), developed jointly by specialists from ShAO and SAO. A detailed description of the technical characteristics of this spectrograph is given in [22]. A CCD STA4150A (USA) with a size of 4096×4096 px, with a pixel size of $15 \mu\text{m}$, was used. The CCD cooled to a temperature of -120°C using liquid nitrogen. Spectral range $\lambda 3700 - 8000$. Observations were performed with a combination of 2×2 pixels (binning), which allows to obtain a spectral resolution of $R = 28000$.

As mentioned above, HD141569 is a dense triple system, with the B component 7.5 arcsec and the C component 1.5 arcsec from the central star. It was not possible to observe the components individually for two reasons: a) the brightness of the central component A is 6.88 mag in the J band, the brightness of the component B is 9.2mag, and the brightness of the component C is 10.16mag [21], b) the size of the image during the observation is $2 - 4$ arcsec, as a result of which the components cannot be distinguished in the image taken in the slit plane of the spectrograph. Therefore, although the received spectra have a share of emission from other components included in the triplet, the main emission is from the brighter component A.

A total of 8 pairs of spectra were obtained during the indicated period. The resulting pair of spectra were averaged for each night and subjected to the necessary processing at all initial stages. The acquired spectra were transferred to *.200 vector format and measurements were made. All processing and measurement procedures were performed in the DECH package (Galazutdinov G., <http://www.gazinur.com/DECH-software.html>). Table 1 provides basic information about the observation. In Table 1, columns from left to right show date of observation, Julian date, identification number of night-averaged spectrum, signal-to-noise ratio, universal time UT, and exposition time in seconds.

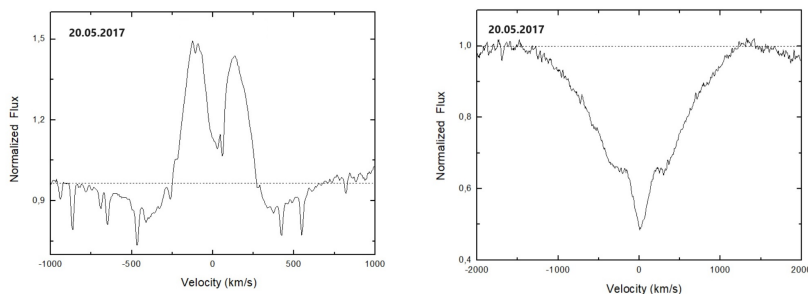
In each observation, the spectra of the object and standard stars were obtained. The errors obtained in the measurements are 4-5% in equivalent widths and 0.5% in intensities. In radial velocities it is ± 1.0 km/s. In this work, 2 pairs of spectra of the star obtained in 2017 and 6 pairs obtained in 2018 were studied.

Table 1. Journal of spectral observations of the star HD141569.

Observation dates	JD 2450000+	Mr	S /N	UT	Exp. time
20.05 .2017	7894.371	KF1011-12	100	20 : 54	3000
06.06 .2017	7911.2305	KF1046-47	100	17 : 32	2400
02.05 .2018	8240.5472	KF2245	100	01 : 08	2400
22.05 .2018	8260.5833	KF2395-96	100	02 : 00	2400
25.05 .2018	8264.2451	KF2447-48	100	17 : 53	2400
06.06 .2018	8276.2417	KF2457-58	100	17 : 48	2400
07.06 .2018	8277.2256	KF2880-81	100	17 : 25	2400
27.06 .2018	8297.2312	KF2644-45	100	17 : 33	2400

3. HYDROGEN LINES- $H\alpha$.

The measured spectrophotometric parameters of the $H\alpha$ line are also given in Table 2 consists of two parts. In the first part, from left to right, JD dates, the equivalent width of the blue absorption component EWa1, the equivalent width of the emission component EWe, the equivalent width in the red wing absorption EWa2, and the intensities of the blue absorption, blue emission, red emission, and red wing absorption components, respectively, Ia1, Ie1, Ie2, Ia2 are given. In the second part of table 2, the half-width FWHM of the emission component, the radiative velocities of the blue emission peak (RV1p), the red emission peak (RV2p), the bisector velocity (RVbis) and the central absorption of emission component radial velocities (RV_Ca) are given for the same JD dates. Figure 1 shows one of

**Fig. 1.** Profiles of the lines $H\alpha$ (left) and $H\beta$ (right).

the typical profiles of the $H\alpha$ line. As can be seen, the broad wings belonging to the A0V photosphere line and the emission component with a two-peak emission profile in the center of the line are clearly distinguished. In the profiles taken

Table 2. Obtained spectral parameters of selected components in the line $H\alpha$.

Date	E W a1 ($\text{\AA}$)	E W e ($\text{\AA}$)	EWa2 ($\text{\AA}$)	Ia1	Ie1	Ie2	Ia2
20.05 .2017	2.01	2.64	1.3	0.18	-0.47	-0.16	0.39
06.06 .2017	2.6	1.85	1.93	0.25	-0.36	-0.25	0.34
02.05 .2018	2.04	3.35	1.38	0.26	-0.58	-0.22	0.55
22.05 .2018	2.58	2.45	1.59	0.24	-0.44	-0.35	0.21
25.05 .2018	1.91	2.7	1.08	0.3	-0.5	-0.39	0.26
06.06 .2018	2.13	2.88	0.98	0.23	-0.5	-0.45	0.2
07.06 .2018	1.78	3.04	1.01	0.26	-0.49	-0.44	0.23
27.06 .2018	3.23	2.65	1.39	0.28	-0.44	-0.41	0.24
Date	FWHM ($\text{\AA}$)	RV1p (km/h)	RV2p (km/h)	RVbis (km/h)	RV Ca (km/h)		
20.05 .2017	8.21	-130	118	-4.11	1.61		
06.06 .2017	8.15	-134	122	6.91	-2.11		
02.05 .2018	8.27	-124	103	-0.76	-11.98		
22.05 .2018	8.08	-129	119	0.54	-7.38		
25.05 .2018	8.13	-137	107	-4.03	-15.7		
06.06 .2018	8.3	-130	112	-1.58	-1.58		
07.06 .2018	8.61	-125	133	3	8.61		
27.06 .2018	8.34	-122	135	0.32	3.37		

on different nights, the radial velocity and intensities of the components show obvious variations. At the same time, the materials obtained in 2017 and 2018 show that changes have occurred in the spectrum for a long time.

4. $H\beta$ LINE

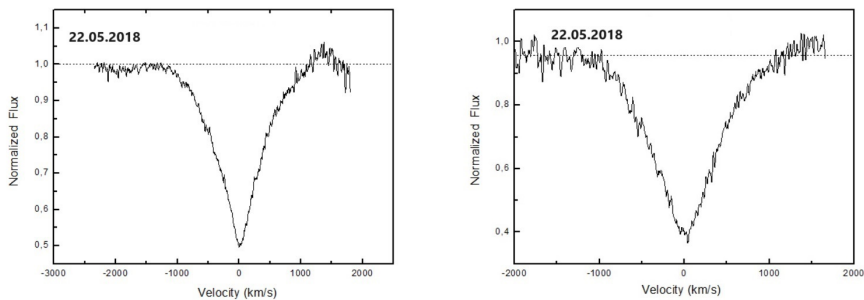
In the $H\beta$ line profile, unlike $H\alpha$, the emission components are sharply weaker (Fig. 1, right panel). Therefore, it was not possible to measure the parameters of the emission components. Table 3 lists the parameters of the absorption profile of the $H\beta$ line. Both the line profile and the smaller equivalent width compared to normal A0V stars indicate that the inner part of the line is distorted by the emission component. Table 3 shows that the bisector velocity of the $H\beta$ line changed significantly in 2017 and 2018.

Table 3. Selected parameters of the line $H\beta$.

Date	EWa (Å)	Ie	FWHM(Å)	RVp (km/h)	Rxbis (km/h)
20.05 .2017	8.76	0.51	16.15	1.05	-6.21
06.06 .2017	8.29	0.51	15.63	0.46	-9.41
02.05 .2018	10.42	0.58	16.4	-13.33	-11.09
22.05 .2018	9.4	0.52	17.21	-7.57	-17.66
25.05 .2018	8.87	0.53	18.17	7.67	4.71
06.06 .2018	8.73	0.51	16.71	-8.43	-16.23
07.06 .2018	8.4	0.51	15.53	4.95	4.95
27.06 .2018	8.19	0.5	15.49	2.36	13.67

5. $H\gamma$ - $H\epsilon$ LINES.

The emission component is completely absent in the profiles of the $H\gamma$ and subsequent $H\delta$ and $H\epsilon$ lines of the star. Figure 2 shows the $H\gamma$ and $H\epsilon$ line profiles as examples. No significant changes in profiles were detected during the observation period. Some selected parameters of the indicated lines were measured and

**Fig. 2.** Profiles of the lines $H\gamma$ (left) and $H\epsilon$ (right).

listed in Tables 4 and 5.

6. HeI AND D NAI LINES.

Table 6. the results of selected parameters of the lines HeI 5876. Designers of parameters the same as in other tables.

In the table designed of parametrs is the same as in other tables. In the table we see that relation of the the equivalent widts of lines D2/D1 is equal nearly 3:1. It is mean that this lines is formed in steallar atmosphere which normal termodinamic condition.

Table 4. Selected parameters of the line $H\gamma$.

Date	EWa (Å)	Ie	FWHM (Å)	RVp (km/h)	R V bis (km/h)
20.05 .2017	5.93	0.5	10.76	-6.87	-27.49
06.06 .2017	6.4	0.5	11.43	-2.44	-15.34
02.05 .2018	7.9	0.59	11.77	-25.9	-12.53
22.05 .2018	7.03	0.52	11.64	-14.33	-25.68
25.05 .2018	6.47	0.51	12.45	-15.22	-24.6
06.06 .2018	7.1	0.53	11.59	-22.17	-34.88
07.06 .2018	6.27	0.5	10.83	-1.38	-4.88
27.06 .2018	7.88	0.53	13.09	-10.59	-14.18

Table 5. Selected parameters of the line $H\epsilon$.

Date	EWa (Å)	Ie	FWHM (Å)	RVp (km/h)	RVbis (km/h)
20.05 .2017	6.7	0.56	10.42	4.53	-21.34
06.06 .2017	7.26	0.6	10.81	2.79	-21.42
02.05 .2018	7.04	0.57	11.03	4.8	2.24
22.05 .2018	7.11	0.6	10.67	-2.51	-2.51
25.05 .2018	7.49	0.62	11.04	-2.93	-32.76
06.06 .2018	7.81	0.61	11.44	-1.24	11.79
07.06 .2018	8.01	0.62	11.38	3.54	-15.75
27.06 .2018	8.26	0.6	12	4.92	1.29

Table 6. Parameters of the line HeI 5876.

Date	EW	Ie	FWHM	Rvp	Rxbis
20.05 .2017	0.04	0.04	0.94	28.76	27.16
06.06 .2017	0.13	0.07	1.45	20.67	13.26
02.05 .2018	0.29	0.07	4.85	10.52	10.52
22.05 .2018	0.2	0.04	2.47	-12.77	33.29
25.05 .2018	0.19	0.06	4.21	-7.28	8.99
06.06 .2018	0.05	0.03	1.13	-9.5	6.24
07.06 .2018	0.29	0.08	4.54	-21.66	-1.88
27.06 .2018	0.05	0.02	1.16	-21.57	-25.21

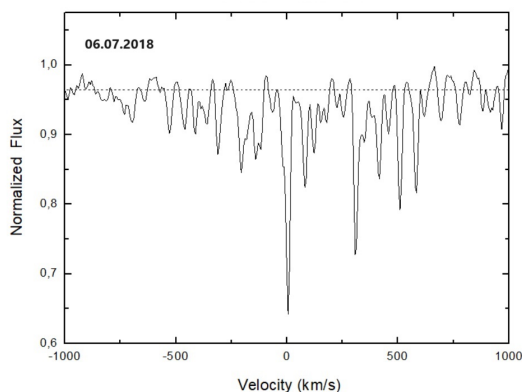


Fig. 3. Profiles of the lines D1, D2 NaI

Table 7. Selected parameters D1, D2 NaI lines

Date (D2)	EWa	I	FWHM	RVp	RVbis
20.05 .2017	0.18	0.35	0.43	-14.84	-14.84
06.06 .2017	0.32	0.39	0.56	-14.39	-14.39
02.05 .2018	0.72	0.45	1.44	-13.05	-13.05
22.05 .2018	0.28	0.37	0.44	-16.47	-16.47
25.05 .2018	0.43	0.4	0.53	-14.49	-14.49
06.06 .2018	0.49	0.33	0.47	-15.59	-15.59
07.06 .2018	1.54	0.34	0.48	-13.34	-14.46
27.06 .2018	0.5	0.33	0.48	-13.13	-13.13
Date(D1)	EWa	I	FWHM	RVp	RVbis
20.05 .2017	0.11	0.26	0.36	-14.14	-14.14
06.06 .2017	0.13	0.28	0.45	-13.03	-13.03

7. GENERAL SPECTRAL CHANGES

The emission components observed in the $H\alpha$ line are symmetrically redshifted from the center of the line by about 120 ± 10 km/s, respectively. The central intensities of both components show little variation (Table 2). Figure 4 shows the graphs of the total equivalent width of the $H\alpha$ emission line and the bisector radial velocity over time during the year 2018. As can be seen from the graphs, the equivalent width of the emission line varies around the average value of 2.6 with a deviation of approximately ± 1 . The bisector radial velocity varies around the mean value of 0 with a deviation of ± 3 km/s. Steinmetz et al. [23] $+3.5$ km/s,

Gontcharov [24] -6.4 km/s for the velocity of the star's mass center. As can be seen, the bisector radial velocity of the emission line is in good agreement with the velocity of the center of mass. The radial velocities of the other lines also show small variations around values corresponding to the velocity of the center of mass.

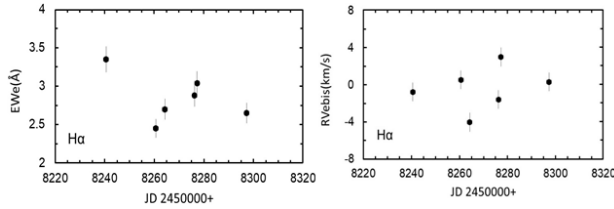


Fig. 4. Time variation of $H\alpha$ emission line equivalent width and bisector radial velocity during 2028.

Figure 5 shows the changes in time of the equivalent widths of the $H\delta$ photosphere line, free of the emission component, according to the observations made in 2027-2028, and the time changes of the radial velocity obtained in 2018. It can be seen from the figure that in 2017-2018 the equivalent widths show a change of up to 3. From the right panel of Figure 5, it can be seen that the maximum change in the bisector radial velocity due to the vary in intensity in the wings of the $H\delta$ line in 2018 alone is 25 km/s. It should be noted that similar variations in the spectrum of the star are also manifested in other spectral lines.

Figure 5. Variation of the equivalent width of the $H\delta$ line over time in 2017-2018 (left panel). The right panel shows the change in the bisector radial velocity only in 2018.

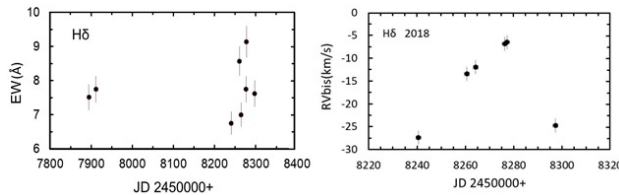


Fig. 5. Variation of the equivalent width of the $H\delta$ line over time in 2017-2018 (left panel). The right panel shows the change in the bisector radial velocity only in 2018.

8. DISCUSSION AND CONCLUSIONS

This, the spectrum of the HD141569 star obtained in 2017 and 2018 were compared and it was shown that certain variations in the spectrophotometric parameters of the lines were detected during this period. It should be noted that despite the star's luminosity being $V = 7mag$, its optical spectrum has not been extensively studied. Most of the articles written in a large number are devoted to the structure of the circumstellar disk and the issues of planet formation in the disk. Herman and Duval [25] first showed that the H line has a two-peaked emission and central absorption profile, and the equivalent width of this line varies in the range of 2 – 5. These authors determined the distance between the peaks to be 2.5 (114 km/s). Hubert Delplas and Hubert [26], summarizing the material obtained over 12 years, showed that the emission lines in the spectrum of this Be-type star do not varied.

The intensity of the emission component in the $H\alpha$ line is much stronger than in other lines of the Balmer series. The emission appears only in a weak form in the $H\beta$ line. This means that the Balmer decrement can be maximally overestimated in the radiation from the disk. Such emission can be excited in gases only by electrons photons and that are not transparent to the Layman series. The mechanism of the generation of such high-energy particles in the circumstellar disk requires additional investigation.

The results obtained in this study showed that there are small changes in the emission spectrum of the star. This may be due to various variations occurring in the invariant disk, including accretion and stellar wind. The features in its spectrum indicate that HD141569 is a young star with a fragmented protoplanetary debris disk and may belong to the class of β Pictoris stars.

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SHAO SPECTROGRAPH FOR LOW-RESOLUTION SPECTRA

N. Z. Ismailov^{a*}, *S. A. Alishov*^a, *Sh. K. Ismailova*^a,
F. S. Huseinova^b

^a *N. Tusi Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences,
Shamakhy, Azerbaijan*

^b *Batabat Astrophysical Observatory, Nakhichevan, Azerbaijan*

The paper describes an improved spectrograph of the Cassegrain focus of the 2 m SHAO reflector using a CCD camera. The classic Universal Astro Grid Spectrograph (UAGS) has been adapted to use the Andor CCD camera to obtain spectra of low-brightness objects in the range 3600-8000 Å. A spectrograph with a diffraction grating of 651 pcs/mm makes it possible to obtain spectra of stars on the 2 m SHAO telescope up to magnitude 18 with a resolution of $R = 1200$, with a signal to noise ratio of about 50 per half hour of exposure. The maximum allowed resolution is $R=3400$. The complex can be used to observe various types of transient objects, stars, and extragalactic objects.

Key words: astronomical instruments – spectrographs – CCD spectroscopy

1. DESCRIPTION OF THE SPECTROGRAPH

As is known, with the beginning of the use of CCD arrays in spectral observations, taking into account the compact dimensions of the light detector, in many observatories classical spectrographs were replaced by echelle spectrographs. When designing the echelle spectrograph at ShAO [1], the main goal was to obtain a high-resolution spectrum. With a 2 m telescope, such a spectrograph allows one to obtain spectra only of relatively bright objects. To carry out scientific work, it is often necessary to obtain spectra of radiation sources that are weak in brightness. Performing spectroscopy of faint stars and galaxies on telescopes of moderate and

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* E-mail: ismailovnshao@gmail.com

medium size, with an aperture of 1–2 meters, is always an important observational task (see, for example, [2, 3]). To solve the above observational problem in the ShAO, we used the classical spectrograph UAGS (Karl Zeiss), which was previously used for photographic spectrophotometry (see, for example, [4, 5]). The spectrograph has been updated so that it can be used with modern CCD light detectors. To adapt the CCD to the spectrograph, a high-aperture Canon EF lens ($f=200$ mm, $f/2$) was used in the spectrograph camera. The remaining standard parts of the spectrograph were retained and adapted to this camera. The general view and optical scheme of the spectrograph are shown in Fig.1.

An Andor CCD camera (ikonL-936-BEX2-DD) (matrix 2048x2048, pixel size $13.5\mu\text{m}$) was used as a light receiver. The spectrograph is equipped with various classical diffraction gratings, which make it possible to obtain spectra in different ranges with different resolutions. The focal length of the collimator is $f_{\text{coll}} = 1100$ mm, the camera $f_{\text{cam}} = 200$ mm, the angles of incidence α and diffraction β are 27.5° and 20.5° , respectively. Then the width of the monochromatic image of the slit on the focal plane S' is determined by the relation

$$S' = S \frac{f_{\text{cam}} \cos \alpha}{f_{\text{coll}} \cos \beta}$$

Here S is the width of the entrance slit. Knowing the above parameters as a working formula for the input slot width S , we can obtain the following expression:

$$S = 5.275 S'$$

The receiver resolution element in the focal plane is equal to the size of two pixels, so for 1×1 binning the maximum width of the monochromatic image is $S' = 2\text{px} = 0.027$ mm, and accordingly, for the width of the entrance slit we obtain $S = 0.14$ mm. The equivalent focal length of the Cassegrain focus of a 2 m telescope is $F = 29500$ mm, and the scale is at the focal plane is $\mu = 6.99''/\text{mm}$. Then for the angular width of the entrance slit we get a value of $0.99''$, and when using the 2×2 pixel combining mode - $1.99''$. In order to simultaneously obtain the spectrum of the nearby background and the object, the slit height was set to about $10''$.

A diffraction grating with 651 pieces /mm was used, which at a blaze angle of 20.5° in the first order gives a spectrum with a linear inverse dispersion of about $144/\text{mm}$ in the range $\lambda 3600 - 8000 \text{ \AA}$. This is the most optimal combination of parameters for performing spectral observations of objects with low brightness. Table 1 lists the following parameters: entrance slit size $S(\text{mm})$; the size of the monochromatic image of the slit $S'(\text{mm})$ for a given binning; inverse linear dispersion in pixels $d(\text{/px})$; inverse linear dispersion $D(\text{/mm})$; the corresponding

Table 1. Some spectrograph parameters

binning	S (mm)	S' (mm)	d (/px)	D (/mm)	$R(H\alpha)$
1x1	0.142	0.027	1.94	144	3400
2×2	0.285	0.054	3.89	288	1700
3×3	0.427	0.081	5.60	415	1170
4×4	0.570	0.108	7.56	560	870

spectral resolution $R = \lambda/\Delta\lambda$ in the region of the $H\alpha$ line for a given combination of parameters. From Table1 it can be seen that the best resolution can be obtained with a combination of binning 1×1 , with inverse linear dispersion $d = 1.9/\text{px}$. In other words, in the region of the $H\alpha$ line ($\lambda 6562.816$) in this mode we obtain a moderate spectral resolution, about $R = 3400$. With this resolution, the spectrum of a $V = 12$ mag star can be obtained in 15 minutes with a signal-to-noise ratio of about 50 .

2. OBSERVATION AND PROCESSING

2.1. Primary processing of observational material

We obtained many spectrograms of standard stars, as well as spectra of T Tauri and AeBe Herbig stars, etc. In addition, the spectra of various transient objects were obtained using this complex according the Gaia program (see, for example, [6,7]). During observations, you it is necessary to obtain 3 spectra of the star under study and standard stars, and then average them. Supporting frames flat, bias, dark were taken, as well as a comparison spectrum of the ThAr lamp for wavelength calibration. The Andor Solis 4.31 CCD camera control program allows you to change various parameters during observations, such as pixel binning mode, exposure time, operating mode, etc. The resulting spectra were further processed using the DECH20 program and its modifications (Galazutdinov G., <http://www.gazinur.com/DECH-software.html>).

The procedure for primary processing of spectral material is as follows: median frame averaging dark, bias, flat. Averaging of the resulting three images of the spectra of the program object and the spectra of standard stars. During the averaging process, the program simultaneously eliminates traces of cosmic radiation particles, which introduce a lot of distortion to the spectrum at long exposures. Subtraction of dark and bias frames from frames with spectra of observed objects. Construction of a mask that determines the position of the spectrum, its extraction using this mask, i.e. receiving a file in vector format *.200. The same procedure was performed for the flat field spectrum flat and the ThAr calibration

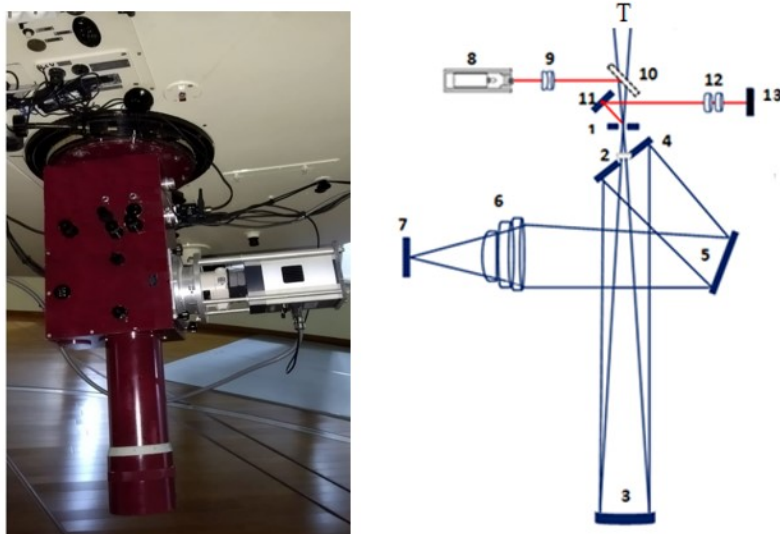


Fig. 1. General view and optical scheme of the spectrograph. The numbers indicate: 1-entrance slit, flat mirror 4 with hole 2, 3-collimator, 5-diffraction grating, 6-Canon camera, 7-CCD matrix window, 8-slit illumination lamp, 9-set of guide lenses, 10, 11 - folding mirrors, 12 - guide lenses for viewing the gap, 13 - monitor for tracking the slit.

lamp, which is needed for wavelength calibration. If, for some reason, during observations, not 3, but 2 spectra of a program star were obtained, then the extraction procedure is carried out without averaging, and only after the file extraction is completed and converted to the *.200 format, the resulting spectra are averaged. With this averaging, the program also cleans up non-repeating features in the spectrum, which mainly arise from cosmic particles.

2.2. Cleaning spectra from background illumination and light scattering of the spectrograph

Since in recent years there has been significant light pollution of the atmospheric background in the area where the ShAO is located, in spectrograms obtained with sufficiently long exposures details of this pollution are observed in the form of emission lines from mercury and other lamps and a weak continuum. This distortion is also supplemented by light scattering inside the spectrograph, which is distributed in a complex manner over the observed wavelength range and is superimposed on the spectrum of the observed object. The influence of the sky spectrum was taken into account in areas not illuminated by the light of the

observed star, thanks to the sufficient height of the slit (up to 10 arcseconds). As a result of this, in one image we get the spectrum of the object and the spectrum of the background below and above the spectrum of the object.

Figure 2 shows an example of inverted (negative) fits images for the resulting spectrum of classical T Tauri stars DI Cep (binning 1x1) and AS 205 (binning 2x2), where the spectrum of the star in the center and a wide spectrum of the background along the edges are highlighted. A bright line from mercury lamps $\lambda 5461$ is clearly visible in the spectra of the objects.

When extracting such a fits image, in addition to the main spectrum of the object, a mask is also built for the upper and lower background on each side. Using the resulting individual background and spectrum masks, you can obtain separate spectra of the background and object in *.200 vector format.

The average background spectrum is subtracted from the resulting spectrum, which makes it possible to clear background contamination and light scattering in the spectrograph. Figure 3 shows an example of the resulting *.200 file star+background, background and cleaned spectrum for Herbig Be type stars AS 310. This procedure allows you to almost completely get rid of the background radiation and the radiation of scattered light from the spectrograph. Figure 4

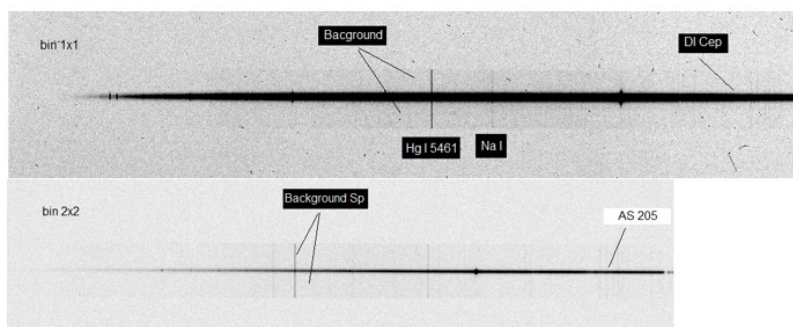


Fig. 2. Positive fits images of the spectra of classical T Tauri stars DI Cep (binning 1x1) and AS 205 (binning 2x2). The position of the Hg I and Na I lines from the background spectrum is noted

shows examples of the obtained spectrograms of two T Tauri stars DI Cep and AS205, and two Herbig AeBe stars AS310 and AS 442. The most intense lines are marked in the spectrum. And Fig. 5 shows parts of the spectra of these stars in the region $\lambda 4000 - 5000$. As can be seen from the spectrum, it is possible to measure the parameters of individual parts using the spectra.

2.3. Wavelength calibration

For wavelength calibration, spectra of the ThAr lamp, as well as spectra of standard stars with known radial velocities were used. When calibrating against the spectrum of a standard star, the reference points were set taking into account its radial velocities and barycentric speed of the Earth.

To evaluate the instrumental profile of the UAGS spectrograph, we measured the half-widths of the purest spectral lines from the spectrum of the ThAr calibration lamp. From about 10 lines selected, 2.20 ± 0.18 px were obtained for the half-width. With binning 1x1, such an instrumental contour is $\delta\lambda = 4.27 \pm 0.34$ Å. Figure 6 shows, for comparison, part of the spectra ($\lambda 4000 - 6700$) of dif-

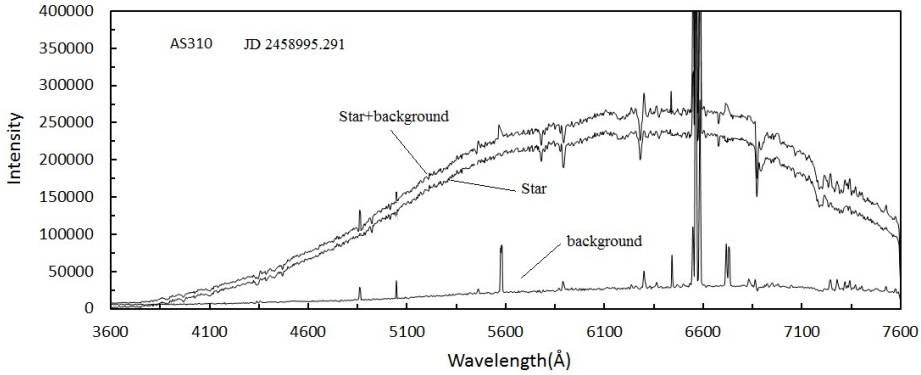


Fig. 3. Spectra from observation of the star AS 310: (Star+background) stars with background, (background) background, The star spectrum after clearing the parasitic background.

ferent stars obtained with our spectrograph, as well as the spectra of the same stars obtained with the 1.93 – m telescope of the Haute Provence observatory (ELODIE archive <http://atlas.obs-hp.fr/elodie/> [8]). The spectra of this archive can be convolved with an instrumental profile that is equal to the instrumental profile of our spectrograph. Our instrumental contour value is very close to the instrumental contour ~ 4.5 , which is given in [8]. The comparison showed that our spectra demonstrate good agreement with the compared spectra.

Figure [7] shows an example of a dispersion curve constructed in the DECH20 program from the spectrum of a ThAr lamp when approximated by a 3rd degree polynomial. The standard deviation of the positions of points near the reference lines from the polynomial curve is ± 0.008 mm (± 1.115). The errors in determining radial velocities for individual lines are $\pm 3 - 10$ km/s.

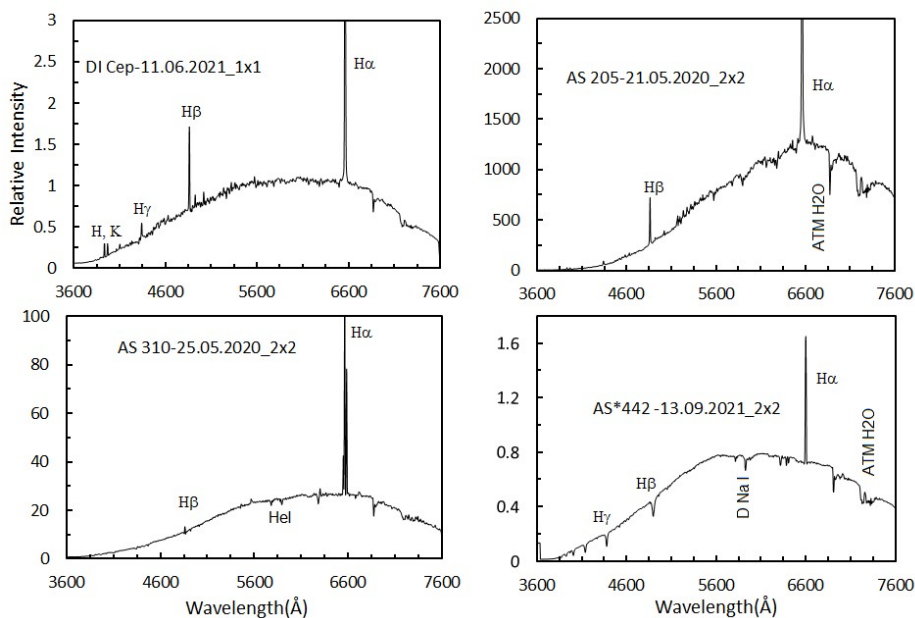


Fig. 4. Spectrograms of T Tauri stars DI Cep, AS 205, and Herbig AeBe stars AS 310 and AS 442. Text fields contain object names, spectrum acquisition dates, and binning.

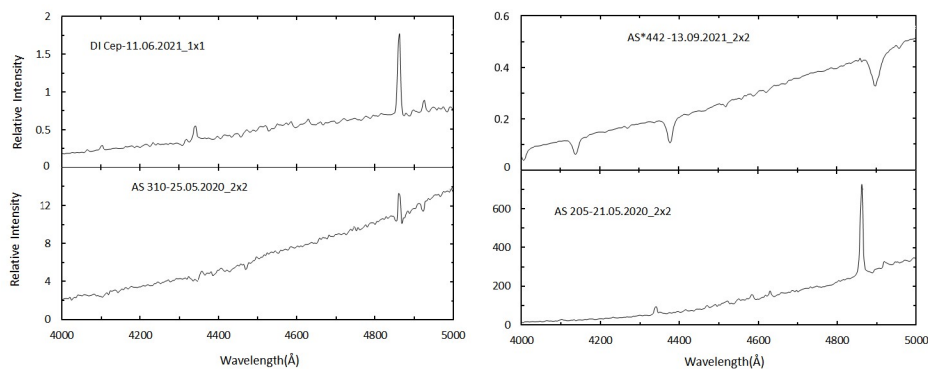


Fig. 5. Section (λ 4000-5000 Å) of the spectra of stars from Fig.4.

2.4. Measurement of some spectrophotometric parameters

The DECH program allows you to draw a continuum and perform spectrum normalization. After this procedure, the wavelength of the area is set and the required measurement of the spectrophotometric parameters of individual spectral lines is performed. The program also allows you to display spectrum data in digital form (ASCII), as wavelength-intensity, and it is also possible to save

individual sections of the spectrum as a file in BMP format.

The equivalent widths of the strongest hydrogen lines in stars of spectral class A0-A6 can be determined with an average error of $\pm 0.5 - 1.0$. Figure 8 shows an example of the results of measurements of equivalent widths EW of hydrogen lines $H\alpha - H8$ of the Balmer series based on the results of 6 nights of observations in August 2022 at the standard star 56 Cyg with an A6V spectrum. The standard deviation from the average EW does not exceed 10%. For comparison, in Fig. 8 on the right, large symbols show the results taken from [9] and [10] for a standard star with an A6 V spectrum. As can be seen, based on individual six nights of observations of the spectrum of 56 Cyg, our measurement results for the $H\gamma$, $H\delta$, and H8 lines are in satisfactory agreement with the data of [9, 10].

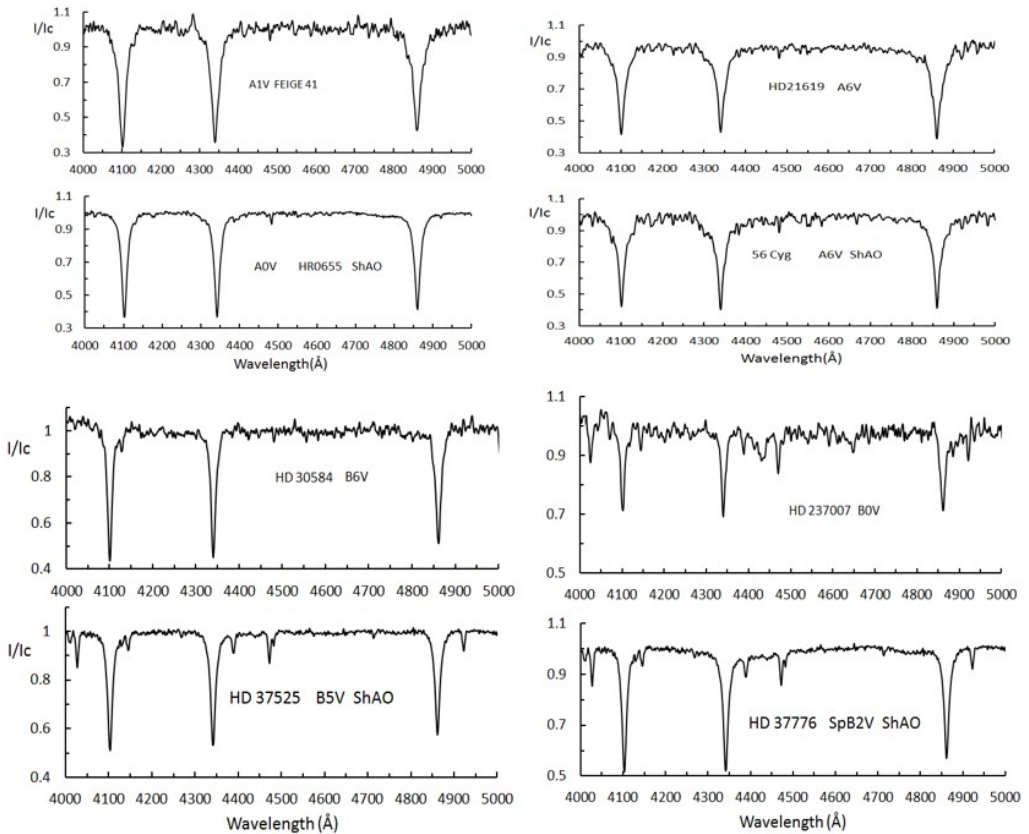


Fig. 6. Examples of normalized range $\lambda 4000-5000 \text{ \AA}$ for the spectra of different stars, given from the Vizer catalog [8] and obtained with our spectrograph. One of each pair of spectra of stars with similar spectral types was obtained at ShAO with the UAGS spectrograph with binning 1x1.

2.5. Expressing the spectrum in absolute fluxes

Since the entire spectrum of an object is obtained at the same order in classical linear form, transforming such a spectrum into absolute fluxes is not difficult. To express the spectrum in absolute fluxes, the hardware response curve (DQE) must be taken into account. To obtain an instrumental distortion for a given spectrum, it is necessary to obtain the spectrum of a standard star with a known distribution of the spectrum in absolute fluxes. In Fig. 9, as an example, we present the obtained instrumental spectrum of the standard star HR 0655 with spectral class A0V, and the equipment response curve of the DQE in this range.

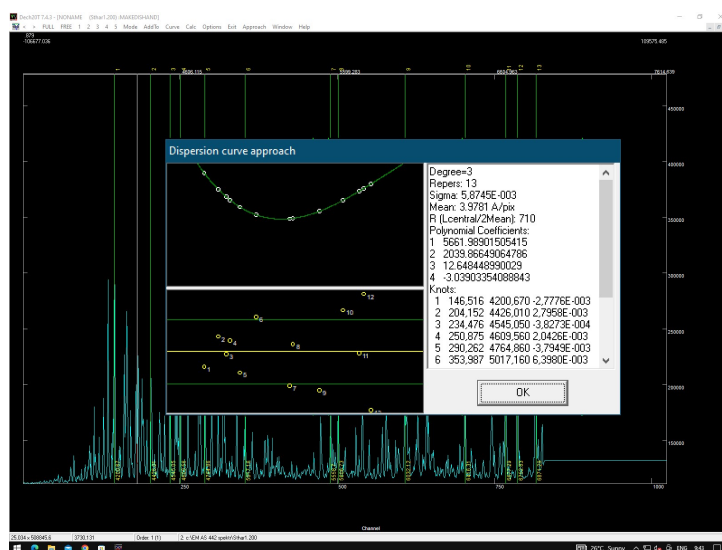


Fig. 7. An example of a plotted dispersion curve for the spectrum of a ThAr lamp in the DECH20 program window.

When the instrumental response curve is known, to transform the spectrum into absolute fluxes, the instrumental spectrum must be divided by the response curve and the spectral absorption due to the air mass must be taken into account. If, when obtaining the spectrum of the object under study, we simultaneously obtain the spectrum of a star with a known spectral distribution in absolute fluxes, which is located sufficiently close to the star, then the task of transformation into an absolute flux is significantly simplified. Figure 10 shows examples of spectra of various transient objects expressed in absolute fluxes. We published preliminary results of our studies of these stars in communications [6, 7].

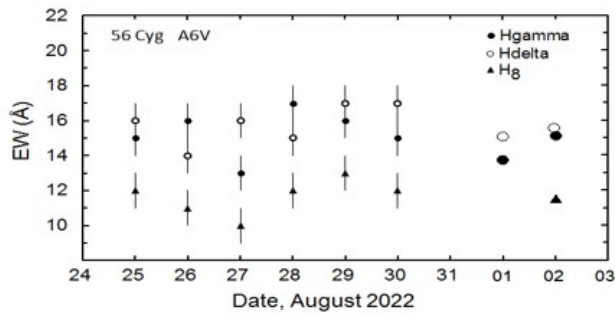


Fig. 8. The result of measurements of the equivalent widths of the Balmer lines $H\gamma$, $H\delta$ and $H8$ over 6 nights of observations in the spectrum of the standard star 56 Cyg. Vertical bars show the level of average measurement error. On the right, large individual symbols show the results taken from [9] and [10] for stars with A6V spectra.

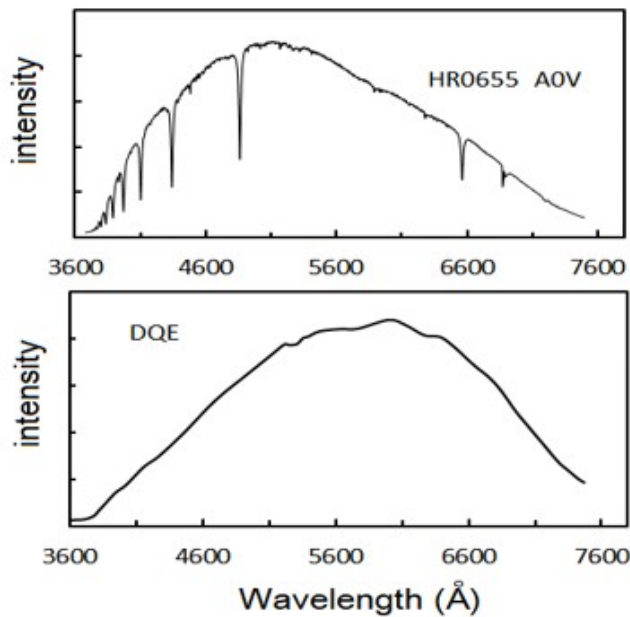


Fig. 9. An example of the instrumental spectrum of the standard star HR 0655 with an A0V spectrum (top panel) and an instrumental DQE curve for this spectral region.

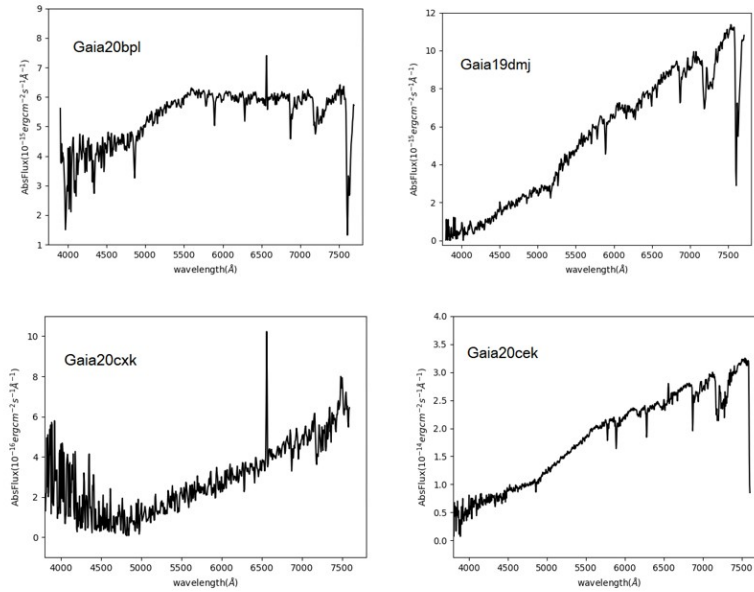


Fig. 10. Spectra of different transient Gaia objects, expressed in absolute fluxes.

3. CONCLUSION

Thus, the paper describes a modified classical UAGS spectrograph in combination with an Andor CCD camera. The device allows you to obtain spectra of objects with magnitude up to 18th magnitude with a resolution of $R = 1200$ in the spectral range $\lambda 3600 - 8000$ in 60 minutes of exposure with signal to noise ratio is 20 . The best resolution in this system is $R = 3400$; with the binning parameters 1x1 and $R = 3400$ and with a signal-to-noise ratio of about 100 , the penetrating ability of the spectrograph on the 2 m SHAO reflector is about 15 magnitudes with an exposure of 30 minutes. A technique for purifying spurious radiation on the spectrum of a software object is described. The instrumental contour of the spectrograph was assessed and the profiles of different stars given in the literature and obtained at the ShAO were compared.

A technique for obtaining a spectrum in absolute fluxes is presented, which is important when studying the spectra of galaxies, quasars, supernovae and other transient objects. Examples of the spectra of some emission stars, expressed in absolute fluxes, are given. The spectra of standard stars show the magnitude of errors in measurements of equivalent widths and radial velocities. The spectrograph can be successfully used both for carrying out current planned scientific work and for carrying out various international cooperation.

4. ACKNOWLEDGMENTS

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PRELIMINARY RESULTS OF STUDY OF COMET C/2020 F3 (NEOWISE)

A. S. Guliyev^{a*}, Kh. M. Mikailov^b, N Farzi^b, R. A. Guliyev^a

*^a N.Tusi Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences,
Shamakhy, Azerbaijan*

^b Baku State University, Azerbaijan

This paper presents the results of low-resolution spectral observations of the comet C/2020 F3 (NEOWISE). The emission lines in the spectrum of the comet, observed in the wavelength region $\lambda\lambda 3800-7500$, on July 20 and 27, 2020, were identified using the 2-meter telescope at Shamakhy Astrophysical Observatory. The wavelengths of 90 emission lines, including 31 emission lines from the carbon molecule C_2 , 40 from the NH_2 molecule, 7 from CN , 4 from C_3 , 1 from CH , 2 from the water ions H_2O^+ , and 3 unidentified lines were determined. Using approximately 110 visual magnitudes, the comet's absolute magnitude was calculated. The light curve of the comet was analyzed, and specific dynamic characteristics of the comet's orbit were noted.

Key words: emission spectrum – comet – C/2020 F3 – evolution – orbit

1. INTRODUCTION

Introduction Comet C/2020 F3 (NEOWISE), or Comet NEOWISE, is a long-period comet with a near-parabolic orbit. It was discovered on March 27, 2020, by astronomers during the NEOWISE mission of the Wide-field Infrared Survey Explorer (WISE) space telescope. At the time of discovery, it was an 18th-magnitude object, located 2AU from the Sun and 1.7 AU from Earth and was observable with the naked eye. The orbital parameters of the comet are as follows: Epoch 2458953.5 (April 14, 2020); $q = 0.295$; $e = 0.99921$; $i = 128.93^\circ$; $\Omega = 61.01^\circ$; $\omega = 37.28^\circ$. This paper provides a concise overview of the research conducted at the Shamakhy Astrophysical Observatory on this comet.

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* E-mail: quliyevayyub@gmail.com

2. SPECTRA OF THE COMET (OBSERVATIONS AND DATA REDUCTION)

The comet's spectra were obtained using the 2-meter telescope at the Shamakhy Astrophysical Observatory on July 20 and 27, 2020. During the observations, the comet was at heliocentric distances of 0.503AU and 0.361AU, respectively. The spectra were captured using the 2-meter telescope equipped with a UAGS + Canon EF objective ($f = 200 \text{ mm}, f/2$) and a CCD Andor (ikonL936-BEX2-DD, 2048x2048 pix, 1 pix=13.5 μm) spectrograph at the Shamakhy Astrophysical Observatory in Azerbaijan [1]. The spectral range covered was $\lambda\lambda 3800 - 7500$. The slit width was 1.1 arcsec, and the height was 50 arcsec, with a spectral resolution of $R = 1700$. Spectra processing was carried out by using the latest version of the DECH 30 software package [2]. The spectral extraction process included dark current subtraction, flat field corrections, cosmic ray removal, 2D linearization of wavelengths, and subtraction of the standard star spectrum, all performed using an IRAF mask.

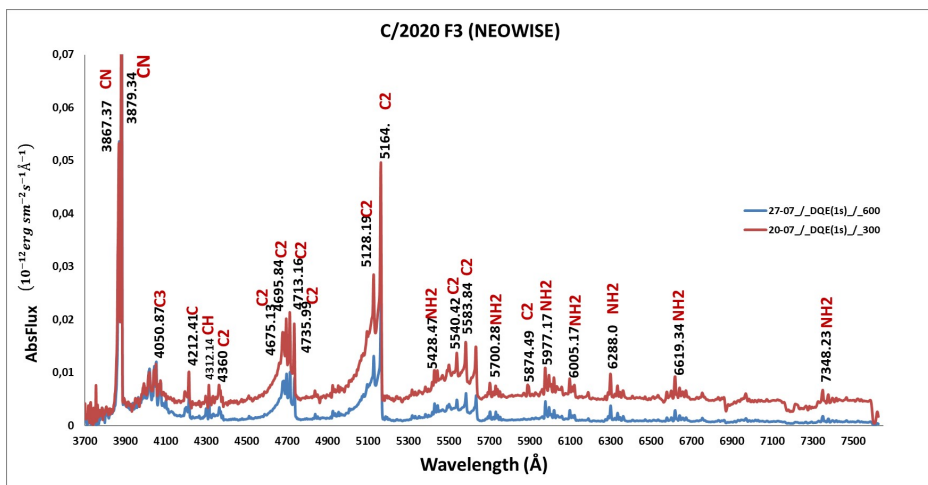


Fig. 1. Spectrum of comet C/2020 F3

3. RESULTS OF OBSERVATIONS

Figure 1 presents the spectra obtained on both nights. The spectra of the comet are displayed in absolute energy units, and corrections for the instrument's response (rectification) were applied based on the spectrum of a standard star. In the comet's spectra, numerous prominent emission features were observed in the range of 3865 Å to 7376 Å. The spectral lines within the comet's spectra have

Table 1. Catalog of emission lines in the spectrum of the comet C/2020 F3

cat	Molecule	cat	Molecule	cat	Molecule	cat	Molecule
3865.38	CN	5163	C2	5963.68	C2	6360	NH2
3867.38	CN	5164.99	C2	5977.17	NH2	6468	NH2
3871.37	CN	5331	C2	5995.02	NH2	6506	NH2
3873.36	CN	5334.13	C2	6005.17	NH2	6534.03	NH2
3879.34	CN	5383.56	NH2	6019.95	NH2	6577	H2O+
4038.43	C3	5398.65	NH2	6020.36	NH2	6599	UNID.
4040.89	C3	5417.02	NH2	6031	C2	6600.16	NH2
4046.4	C3	5428.47	NH2	6034	C2	6617	NH2
4050.87	C3	5443.78	NH2	6055	C2	6619.34	NH2
4195.92	CN	5464	NH2	6059.74	C2	6640.71	NH2
4212.42	CN	5498	C2	6098.23	NH2	6655	NH2
4312.14	CH	5502.92	C2	6108.19	NH2	6659.18	NH2
4360.01	C2	5540.42	C2	6121.13	NH2	6671.76	NH2
4675.13	C2	5583.84	C2	6122.15	C2	6750.58	NH2
4679	C2	5585.49	C2	6186	C2	6754.61	NH2
4695.84	C2	5632	C2	6190.77	C2	6970.88	NH2
4713.16	C2	5700.28	NH2	6274.27	NH2	6982	CN
4734	C2	5703.05	NH2	6288.05	NH2	7070	H2O+
4735.99	C2	5707.04	NH2	6298	UNID.	7348.23	NH2
4924	C2	5752.75	NH2	6320.76	NH2	7376.49	NH2
5093	C2	5867	C2	6332	NH2		
5095.96	C2	5874.49	C2	6334.53	NH2		
5128.19	C2	5925	UNID.	6345.27	NH2		

been identified, and their associations with specific elements and molecules have been determined. Emission lines of CN, CH, C_3 , C_2 , and NH_2 were observed in the comet's spectrum. The intensities of the strong lines observed at wavelengths 3867.37, 3879.3, 4212.41, 4695.84, 5128.19, 5164.99, and 5583.84 Å are reported, respectively. Table 1 presents the specific results of the spectral processing, including the identified molecules and their corresponding wavelengths. The identification procedure based the catalog referenced as [3].

Visual Photometry of the Comet Based on approximately 110 visual magnitudes published on the International Comet Quarterly website (<http://www.icq.eps.harvard.edu>), we determined the absolute magnitude of the

comet. Using Orlov's formula [4],

$$H_y = m + 5 \lg \Delta + 2.5n \lg,$$

(where n -photometric parameter, Δ and r -geo- and heliocentric distances, accordingly) we obtained the values:

$$H_y = 7^m.35; n = 6.22.$$

Similarly, according to Vsekhsvyatsky's formula

$$H_{10} = m + 5 \lg \Delta + 10 \lg,$$

we calculated the value of $H_{10} = 7^m.71$. We calculated the absolute magnitude of the comet for pre- and post-perihelion periods using both formulas. The comparison of these values suggests that the comet has a slight perihelion asymmetry in its magnitude.

4. DYNAMICAL PROPERTIES OF THE COMET

We have also determined some specific dynamic characteristics of the comet's orbit. The comet's orbit, due to its configuration relative to the orbits of the giant planets, is very stable. Its aphelion distance is approximately 480AU, indicating its origin from the scattered disc.

We calculated the Tisserand's constant of the comet relative to the four giant planets:

$$T_J = -0.41; T_S = -0.26; T_U = -0.14; T_N = -0.05.$$

These values are significantly different from the optimal value of 3, suggesting that interactions between the comet and these planets are unlikely. This assumption is further supported by the positions of the comet's orbital nodes relative to the ecliptic, with $R_{\text{near}} = 0.33$ and $R_{\text{dist}} = 2.86$, both far from the orbits of the giant planets.

Additionally, we calculated the comet's Minimum Orbit Intersection Distances (MOID) values relative to the orbits of the nine planets. These values (Mercury-0.014; Venus-0.365; Earth-0.362; Mars-0.315; Jupiter-0.812; Saturn-2.647; Uranus-5.719; and Neptune-11.260 AU) exceed the sizes of the planets' spheres of influences. Consequently, we can assume that the comet avoids close approaches to the known planets.

We also projected the evolution of the comet's orbit for 30,000 years into the past and future. The numerical calculations were conducted in a heliocentric frame of reference, extending 3×10^4 years into the past, using the Bulirsch-Stoer

algorithm within the MERCURY package [5]. Our numerical explorations considered a model of the solar system including the gravitational forces of the Sun and the eight main planets, with initial data sourced from the JPL HORIZONS Ephemeris System DE441.

In the context of the origin of comets, we are particularly interested in the orbit's past evolution. Figure 1 allows for tracking the evolution of the semi-major axis in the past. During this period, the semi-major axis did not change significantly, casting doubt on the comet's origin from the Oort cloud. Instead, the source of the comet may be the scattered disc. However, there are noticeable periodicities in its changes, the reasons for which are currently unknown. These periodicities may be associated with planetary configurations.

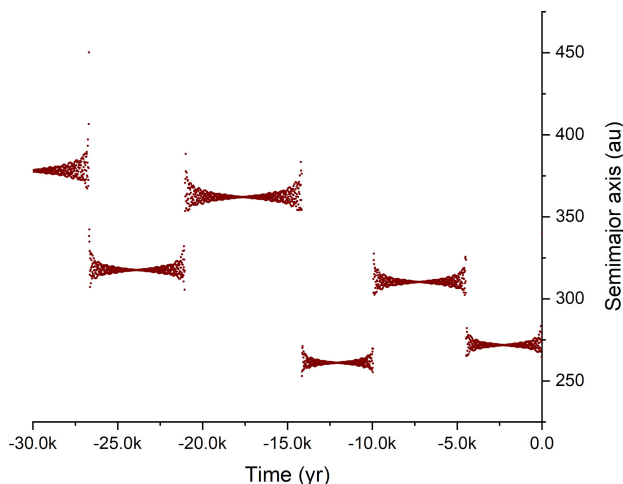


Fig. 2. Evolution of the semimajor axis in the past for the 30 000 years.

5. CONCLUSIONS

- The molecules identified in the comet's atmosphere include CN, CH, C_3 , C_2 , and NH_2 .
- In terms of absolute brightness, the comet holds a middle position among the long-period comets.
- The comet's orbit is highly stable; its favorable trajectory allows it to avoid close encounters with known planets.
- Based on calculations extending back 30,000 years, it is evident that the comet did not originate from the Oort cloud. Throughout this period, the comet's trajectory remained within the boundaries of the scattered disk.

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COMPLEX STUDIES OF MAGNETIC CP STARS. III. ANALYSIS OF VARIABILITY AND EVOLUTIONARY STATUS MAGNETIC CP - STARS θ AUR

S. H. Aliyev^{a*}, *V. M. Khalilov*^a, *Z. M. Alishova*^a

^a *N. Tusi Shamakhy Astrophysical Observatory of Azerbaijan National Academy of Sciences,
Shamakhy, Azerbaijan*

Based on complex observations, the characters of the photometric, magnetic and spectral variability, with a period of $P = 3^d.6188$, of the magnetic CP of the star θ Aur = HD 40312 were studied. The phase curves of the magnetic field (B_e), brightness (V) and equivalent widths ($W\lambda$) of the lines of peculiar elements (Si, Cr, Sr, etc.) are constructed, by means of which the phases corresponding to the maximal peculiar (P) and normal region (N) on the surface of the star are determined. It is revealed that all phase dependences are synchronous; that is, the extrema of the values of B_e , V , and $W\lambda$ coincide within the error ($\varphi = \pm 0.05$). Hydrogen line profiles ($H\gamma$, $H\delta$) were used to determine the fundamental parameters (T_e and $\log g$) for the normal ($T_e = 8800$ K, $\log g = 3.65$) and peculiar ($T_e = 9800$ K, $\log g = 3.90$) regions on the stellar surface. The effective temperature was also determined from the photometric indices ($T_e = 10100$ K and 9500 K).

The location of the star θ Aur on the Hertzsprung-Russell diagram has been established, and thus its evolutionary status has been determined. It was found that the star HD 40312 is located closer to the upper boundary (TAMS) of the MS band.

Key words: Variability magnetic chemically peculiar stars – evolutionary status.

1. INTRODUCTION

To study the nature of peculiar effects and the origin of the family of magnetic chemically peculiar stars (MCP stars), it is very important to carry out compre-

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* E-mail: sabirshao5@gmail.com

hensive studies for a sufficiently large number of typical representatives of these stars.

The common properties of MCP stars are that their spectra contain anomalously strong lines of a large set of chemical elements (Si, Cr, Sr, Mn, Eu, etc.), the presence of a powerful magnetic field, and relatively low axial rotation velocities ($V \sin i \leq 60$ km/s) compared to $V \sin i \approx 170$ km/s for normal stars of the same Main Sequence (MS) spectral types.

So far, there is no clear picture of the evolution of MCP stars during their stay on the Main Sequence. The question of the evolution of the intensity of magnetic fields in MCP stars has not yet been confirmed by sufficiently reliable observational data. Of particular interest are also questions about changes in chemical anomalies and velocities of axial rotation of MSR stars during their stay on the MS.

Of particular interest is the question of possible changes in the course of evolution of peculiar characteristics - powerful magnetic fields and chemical anomalies in magnetic stars, in clusters of different ages. Clearly, cluster membership provides the age parameter. Therefore, the problem of studying the atmospheric parameters and the evolution of MCP stars belonging to clusters of different ages seems natural.

This paper presents mainly the results obtained for θ Aur (HD40312). The star θ Aur = HD40312 = HR2095 is one of the brightest magnetic stars ($M_v = 2.7$) of spectral class B9-A0p with the type of peculiarity SiCr.

The purpose of the work is to determine the nature of spectral and other variability as well as the evolutionary status of the MCP of the star θ Aur (HD40312). To compare the data obtained with the results obtained for magnetic stars of this type of peculiarity of different ages.

2. OBSERVATIONS AND PROCESSING

To date, a large number of spectra have been obtained in two versions: a) classical photographic spectra with a dispersion of 4Å/mm; b) CCD spectra that are obtained using echelle spectrometers installed in the focus of Coude, and Cassegrain, Photographic spectrograms were obtained in Coude focus is the 2nd Shao Telescope. A large number of high-quality spectrograms with a dispersion of 4/mm were obtained . [1]

Over the course of three nights, about 50 CCD spectrograms of the star θ Aur were obtained using an echelle spectrometer installed in the focus of the Coude 2-m telescope SHAO NAS of Azerbaijan with the use of CCD matrix with 530x580 elements [2].

In 2021, another 12 CCD spectrograms with a resolution of $R = 55000$ and two spectra with a resolution of $R = 27500$ were obtained using ShaEES. Detailed information on the equipment and processing techniques is presented in [3].

On the basis of spectral, magnetic and photometric observations, an analysis of the variability and evolutionary status of the magnetic CP-stars of θ Aur was carried out.

Complex observations have shown that it is a photometric, spectral and magnetically variable star with a period of $P = 3^d.619$ [4].

3. SPECTRAL VARIABILITY

With the help of the obtained spectrograms, line equivalent widths (W_λ) for Si II, Fe I, Fe II, Cr I, Cr II, Ti II, Sr II, Ca II, etc. were measured. Phase curves equivalent widths W_λ for the above elements are constructed [4]. As an example, fig. 1 shows the phase curves of the quantities W_λ for H δ , Si II and Cr II. As you can see, a double wave is observed on all phase curves of the W_λ .

Equivalent widths of W_λ line for all examined specified elements change synchronously. On all phase curves there are two maxima, which are associated with the presence of two peculiar regions on the surface of the star.

4. PHOTOMETRIC VARIABILITY

Photometric studies of the star's brightness variability were carried out by Adelman [?] in the Strömgren (uvby) system. Over the course of several years, 47 photometric observations were carried out for this star. It has been shown that changes in the brightness of the star occur synchronously with the period $P = 3^d.6188$ [?]). The amplitude of changes in the filter is $u = 0.07$, in the filter $v = 0.035$, in the filter $b = 0.04$ and in the filter $y = 0.035$, respectively.

Although the equivalent widths of different peculiar elements (Cr, Si) change in phase, there is phase mixing ($\Delta\varphi \leq 0.07$). (see Fig. 1). This may indicate that the centers of maximum concentration of the regions of these peculiar elements are located at different distances from the pole of the magnetic field.

5. MAGNETIC FIELD VARIABILITY

In the spectrum of stars, θ Aur lines are $\approx 1\text{\AA}$ wide, which does not allow, measuring the magnetic field by photographic method along metal lines. Therefore, magnetic field measurements were performed by photoelectric method along lines with hydrogen [5]. The authors of this work observed a variable magnetic

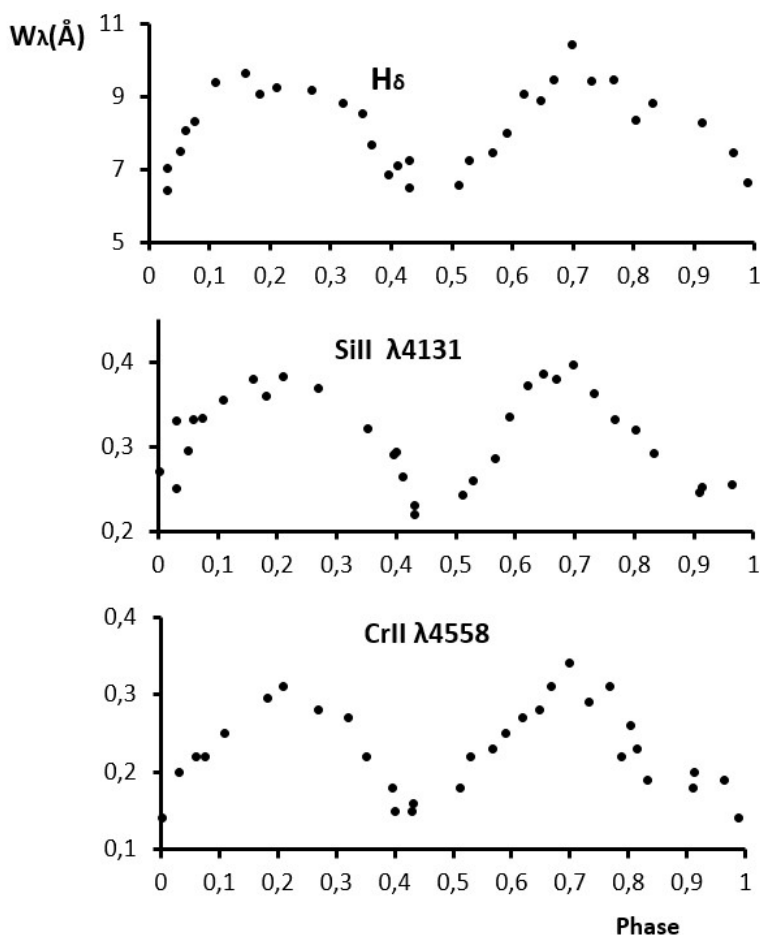


Fig. 1. Phase curves of W_λ values for $H\delta$, Si II $\lambda 4131\text{\AA}$ and Cr II $\lambda 4558\text{\AA}$

field (+400/−275Gs), which varies with the period $3^d.618$. According to [7], we have constructed phase curves of the magnetic field (see Figure 2). It can be seen from Fig. 1 that there are two maxima on the phase dependencies of B_e values ($\phi_1 = 0.15 - 0.20$ and $\phi_2 = 0.75 - 0.80$).

Hubrig [6] observed the magnetic field using Babcock methods and obtained 9 Zeeman spectrograms in the spectral range $\lambda 3800 \text{\AA}$ – $\lambda 4650 \text{\AA}$ with $4\text{\AA}/\text{mm}$ dispersion. Measurements of the effective magnetic field ($B_e = +1375/-1270 \pm 75\text{Gs}$) were carried out along the metal lines Si II, Fe I, II, Cr I, II, Ti II. On the basis of these observations, we built phase curves of the magnetic field (see Fig. 2). Comparison of the results of works [5] and [6] shows that the measured value of the effective magnetic field intensity along the lines of peculiar elements is about

three times more than obtained along the lines of hydrogen. This observed fact is explained by the fact that, unlike hydrogen, peculiar elements are concentrated in peculiar (in spotted) regions where the poles of the magnetic field are located.

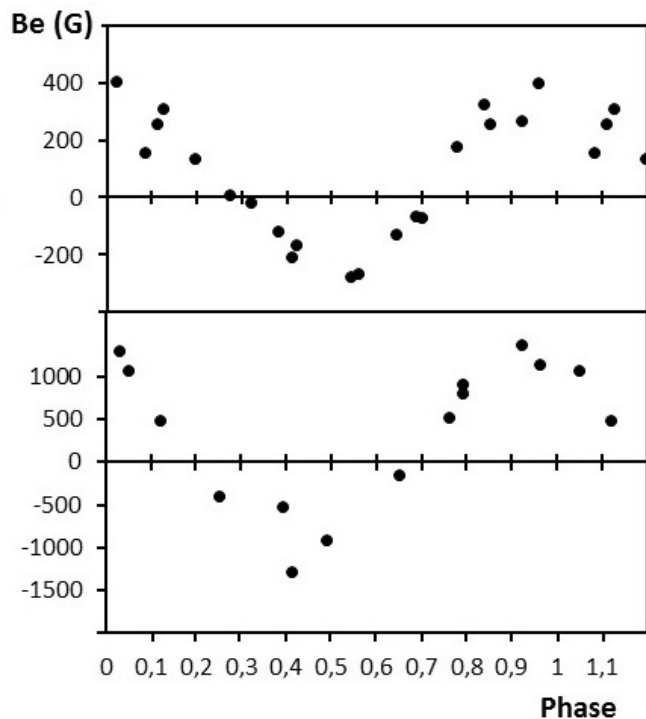


Fig. 2. Phase dependencies of magnetic field strength for a star θ Aur

6. PECULIARITY-P(E) SPECTRAL INDICES.

Quantitative spectral indices of peculiarity characterize the measure of amplification of the lines of the chemical element in the magnetic spectrum of CP stars; then eats the ratio equivalent to the line width (W_λ) of the element in question for a magnetic star to its (W_λ) from the spectrum of a normal star with the same T_e and Sp . Thus, the $P(E) = W_\lambda(P)/W_\lambda(N)$ index characterizes to a certain extent the degree of anomaly of the chemical composition [8]. The values found for $P(E)$ are shown in the last row of Table 1 .

7. EVOLUTIONARY STATUS

Landstreet et al. [8] noted that average magnetic field in magnetic stars decreases with increasing age of these stars. Therefore, it can be assumed that the different values of the magnetic field of the group of evolved stars (TAMS) and young stars comparison (ZAMS) may be the result of evolution. To confirm this explanation, more research is needed on new members of this group of stars. Therefore, determining the evolutionary statuses of magnetic chemically peculiar stars is an urgent issue and determining their exact positions on the Hertzsprung - Russell diagram is of particular interest to the physicist and evolution of these stars.

To determine the evolutionary status of a HD40312 star, its luminosity was calculated using standard ratios.

$$\log (L^*/L_{\odot}) = 0.4 (M_{\odot} - M_{*}) \quad (1)$$

- where the $M_{\odot}$ absolute magnitude of the Sun is $4^m, 8$ and $\Delta M_{bal} = -0^m.1$ Using the found values of luminosity and effective temperature, the location of the star under study was determined on the Hertzsprung-Russell diagram (Fig. 3) and thereby its evolutionary status was determined.

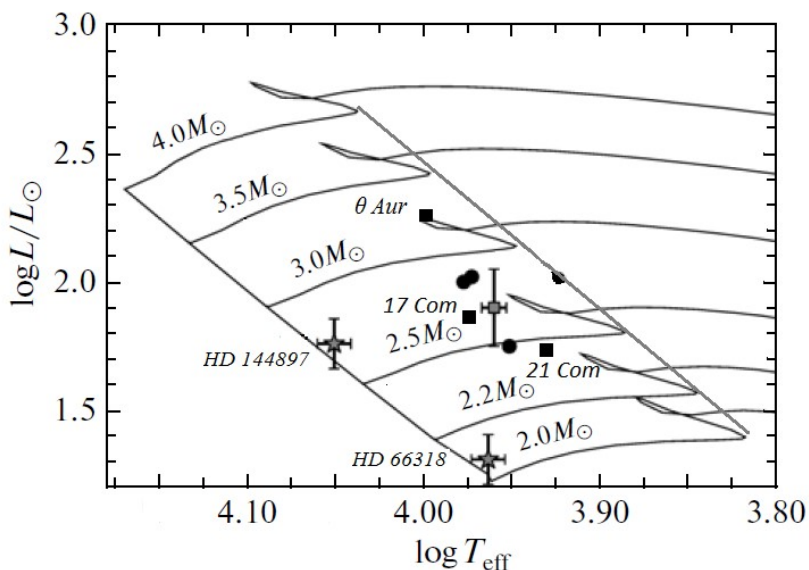


Fig. 3. Hertzsprung-Russell diagram with marked positions of the star θ Aur ■ and comparison stars HD 66318, HD 144897

Table 1. Main parameters for peculiar (P) and normal (N) region atmosphere of magnetic CP-star θ Auriga.

Nº	Parameters	P	N	Data of the Literature
1	The phases correspond to the peculiar (P) and normal (N) regions of the atmosphere.	0.15 – 0.20	0.48 – 0.52	-
2	T_{eff} (K) and $\log g$ found by $H\gamma$ profiles and $H\beta$	9800 ± 200 K 3.65	8800 ± 200 K 3.91	10100 [11] 9900 [9]
3	T_{eff} (K) found by photometric indices.	10100 ± 150 K	9500 ± 150 K	10100 [7]
4	Radius $R/R_{\odot}$ found by T_{eff} (P) and T_{eff} (N)	3.90 $R [R_{\odot}]$	3.55	3.6 [9]
5	Effective magnetic field (B_e) measured by Zeeman analyzer (Gauss)	$+1375/-1270$ ± 75 Gs	< 50 G	[6]
6	Value of value B_e measured by means of hydrogen magnetometer. (Gs)	$+270/-370$ ± 55 Gs	≈ 10 G	[5]
7	Luminosity $\log L^*/L_{\odot}$	2.44	2.31	2.42 [10]
8	Pecularity spectral indices P (E) for SiII, MnII, CrII, SrII.	2.60; 1.60; 1.50; 1.05		2.55; 1.5 1.60 [7]

In this diagram, (■) with an arrow marks the position of the θ Aur star. It is located next to previously studied advanced MCP stars marked with black circles. From Fig. 3 it can be seen that the θ Aur star is a devolving star, which is approaching the end of life on the GP. The same group includes a number of old stars, such as HD 8441, HD 5797, HD 40711, HD 103498, HD 204411 etc. This group of stars is characterized by strong and numerous lines of elements of the iron peak in the spectra. However, the lines of the peculiar elements Si, Cr and Ca are somewhat weakened compared to young stars (comparison). In the diagram, stars with strong magnetic fields (HD66318 and HD144817) are indicated by asterisks. These young stars have strong magnetic fields ($B_e \geq 3000$ Gauss), in the spectra of which high contents are observed, both elements of the

iron peak and peculiar elements Si, Cr and Ca. These young stars were chosen for comparison with the evolving MCP stars.

8. CONCLUSION.

It was revealed that all phase dependences of the magnetic field (B_e), brightness (V) and equivalent widths (W_λ) of the lines of peculiar elements (Si, Cr, Sr et al.) are synchronous; that is, the extremes of the quantities B_e , V and W_λ within the error range ($\varphi = \pm 0.05$) coincide. According to the oblique rotator model, it is possible to tell that on a surface of the star θ Aur most peculiar areas which are located in phases $\varphi \approx 0.15 - 0.20$ and $\varphi \approx 0.48 - 0.52$ on a star surface.

According to the oblique rotator model, the phase of the main maximum ($\varphi \approx 0.15 - 0.20$) of the phase curves of the values B_e , V , and W_λ corresponds to the largest peculiar (P) region, and the phase of the minimum ($\varphi \approx 0.48 - 0.52$) (relatively) to the normal (N) region on the surface of the star (see Table 1). The results of complex studies allowed us to establish the location of the θ Aur star on the Hertzsprung-Russell diagram and thereby determine its evolutionary status. It is located next to the evolved MCP stars that are approaching the end of life on the MS. In the spectra of this group of magnetic stars, the lines of peculiar elements, compared to young MCP stars, are somewhat weakened. Stars of this group have weak magnetic fields that are not characteristic of magnetic CP stars [8]. It was obtained that during the evolution of MCP stars θ Aur the magnetic field and peculiarity indices $P(E)$ of peculiar elements are reduced in comparison with young magnetic CP stars corresponding to the spectral class. The results of our study, basically, do not contradict the assumption of Landstreet et al. [8] that the average magnetic field value in magnetic stars decreases with increasing age of these stars.

Based on the observational facts presented above, the following conclusions can be drawn.

1. By means of comparison of phase dependences of intensity of magnetic field, peculiar elements and gloss were revealed that on a surface of a star of θ Aur there are two most peculiar areas which are located in phases $\varphi \approx 0.2$ and $\varphi \approx 0.7$ on a star surface.

2. Obtained, measured value of effective magnetic field intensity along lines of peculiar elements is approximately three times more than obtained along lines of hydrogen.

3. It has been established that the θ Aur star is located closer to the upper border (TAMS), which is approaching the end of life on the MS.

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