SPECTRAL INVESTIGATIONS OF THE SUPERGIANT, WOLF-RAYET TYPE STARS AND NOVAE IN THE SHAMAKHY ASTROPHYSICAL OBSERVATORY DURING 60 YEARS

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Introduction

The study of noтstationary stars is one of the main scientific directions of Shamakhy Astrophysical Observatory (ShAO) named after N. Tusi of the Azerbaijan National Academy of Sciences and these studies were started in the sixties of the last century. The first spectral observations were carried out with the telescope AST-452 of ShAO. Since 1966, the spectral observations of stars were started at 2-m telescope by using classical spectrographs. In 1999, the Kude focus, and in 2005, the Cassegrain focus of the 2-m telescope, was equipped with an echelle-spectrometer equipped with modern high-sensitiv light detectors - CCD matrix [1, 2]. This allowed our astronomers to reach a qualitatively new level in the study of nonstationary stars.

This paper is a historical overview concerning investigation of supergiants, Wolf-Rayet (WR) type stars, novae and some important scientific results obtained by the astronomers of ShAO during 60 years. Note that these studies were carried out in close collaboration with the astronomers from Sternberg Astronomical Institute (SAI) at Moscow State University, Crimean Astrophysical Observatory (KrAO), Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS); The Main (Pulkovo) Astronomical Observatory of the Russian Academy of Sciences (MAO RAS), the Tartu Observatory of Estonia, the Ondrejov Observatory of the Czech Republic.

1. The investigation of supergiant stars

No another region contains such a variety of stars as the upper part of the Hertzsprung-Russell diagram, where are located the stars of high luminosity. Among these stars the WR type and hot supergiants are more interesting. Supergiant and WR stars are young (~ 10^6 years old) population I stars of our Galaxy.

According to modern view, supergiants are more evolved stars. In the center of these stars, hydrogen has already burned out; the burning of helium and heavier elements has begun. It is known that at the certain stage of evolution — during the transition from the main sequence (MS) to giants and supergiants, almost complete mixing of matter occurs in stars. As a result of this, the products of nuclear reactions occurring in the center of these stars can also appear on their surface. Studies of the atmospheres of normal stars showed that their chemical composition is not noticeably different from the sun. It can be reasonable to assume that the observed differences in the chemical composition of the atmospheres of supergiants and the Sun are due mainly to the appearance of nuclear reaction products on their surface. Therefore, the study of anomalies in the chemical composition of the atmospheres of supergiants is important for the clarifying their evolutionary features.

By the luminosity supergiants are separated into two group: supergiants of the lowest luminosity (Ib) and supergiants of the highest luminosity (Iab, Ia, and Ia +). Their absolute magnitudes and temperatures range from -3^m to -8^m, and from 32 000 K to 3 650 K correspondingly. These stars are found in spectral subtypes from O8 to K2.

The spectra of supergiants mainly contain lines of the following chemical elements: H, He, C, Na, Mg, Si, Sc, Ti, V, Cr, Mn, Fe, La, Ce, Pr, etc.

In the extended atmospheres of supergiants we observe:

a) change of intensities and profiles of spectral lines;

b) large turbulent and radial velocities of the absorption and emission lines of various elements;

c) chemical composition anomalies.

Many observational features of the spectra of supergiants do not yet find a sufficient and clear physical explanation. In particular, the lack of systematic observational data does not allow us to reveal district pulsation of these stars.

At our observatory the chemical composition of selected supergiants was studied and their physical parameters were determined, the spectral variability of the profiles of various spectral lines was revealed. A study of the radial velocity variations of the Hα line in the spectra of supergiants allow revealing the structure and dynamics of the envelopes of these stars, as well as helps to the development of the theory of stellar radial and nonradial pulsations.

The study of supergiants in the ShAO was begun in 1965 by Dr. S.K. Zeynalov, under the supervision of Academician A.A. Boyarchuk (KrAO). Further investigations of these stars were carried out in the works of A.M. Khalilov, E.B. Zverova, A.Kh. Rzayev, F.A. Musaev, A.R. Hasanov and ets. Observation of supergiant stars were carried out at various telescopes: at 2-m telescope of ShAO, at 6-m telescope of BTA of SAO, at 2.6-m telescope of KrAO.

According to the joint scientific research program between the SAO and ShAO, during 1980-1990 years the systematic observations of O-F supergiants and "runaway" stars were carried out in order to clarify the reason of the uninstability of their atmospheres. For some of these stars, long-period ($P \geq 30^d$) and short-period ($P \sim 1^d$) changes in radial velocities and differential line shifts were detected [3].

For "runaway" stars: α Cam, HD 188209 and 68 Cyg, short-period variations ($P \sim 1^d$ - 5^d) of radial velocities were revealed, which are interpreted with the non-radial pulsations of their atmospheres. For the "runaway" star HD 12323, with an excess of nitrogen and a high z-coordinate, the presence of a low-mass satellite is confirmed. Studies have shown that the star HD 12323 can be a massive close binary system (CBS) located at the stage of before X-ray phase of evolution [4, 5].

The frequency spectrum analysis of long series of spectral observations (from 1976 to 1988) showed that the radial velocity of white supergiants HD 21389 and HD 21291 could be related to the pulsation of these stars [6-9]. It was found that in the atmospheres of these stars there is a stratification of radial velocity. Variation of parameters, i.e. values of the period, amplitude and average value of the radial velocity of the lines differ for different layers. All these parameters increase from the lower to the upper layers. However, they are constant for each layer over a long time interval - from 1976 to 1988. [10].

By using the 240 echelle spectrograms obtained with the echelle spectrograph at Kude focus of 2-m telescope of ShAO during 1998-2000 years, the radial velocity and profile of the Hα line in the spectrum of the α Cyg star were studied. The investigations [11, 12] showed that the pattern of radial velocity variability is due to nonradial pulsations and differs for the blue and red parts of the absorption profile. For both blue and red parts of the absorption profile, the vibration parameters differ for different levels of residual intensity. For the red half of the absorption profile, the amplitude and period increase from the core towards the wing of the line, and for the blue half we observe the opposite, i.e. decrease. On the blue half of the absorption profile, the additional absorption details are observed. The appearance and disappearance of additional absorption details, as well as their minor migrations, are interpreted by the ragged structure of the star's envelope. The similarity in the nature of the radial velocity variability of the absorption and emission components indicates that the variability of the latter is also due to nonradial pulsations. Therefore, the variability of the stellar wind could be partially due to non-radial pulsations of the underlying atmosphere.

By using the spectrograms obtained with the 2-m telescope of ShAO, the variability of the Hα line profile in the spectrum of star 89 Her (F2 Ibe), high-latitude supergiant, were studied. Investigations have shown that the Hα absorption line, depending on the phase of instability of the star's atmosphere, consists of one, two, or three blue-shifted components. One emission component is constantly observed on the red wing of line H_{α} [13]. It was found that the radial velocity of the absorption component, the equivalent width of the absorption and emission components of the H_{α} line profile and the brightness of star 89 Her change synchronously with the period of ~283 days [14, 15]. These studies revealed that the values of the equivalent width of the spectral lines of metals observed in the spectrum of the 89 Her star also change with time. It was received that during the period 1955-2005 years in the spectrum of 89 Her star, the shift of the emission component (V_{em}) and the first component of $|V_1^{ab}|$, absorption of the H_{α} line ($|V_1^{ab}|$), occurs synchronously. The correlation between variations of V_{em} and ($|V_1^{ab}|$) of line H_{α} were observed. It was supposed that these changes takes place with the common mechanism.

By using spectrograms obtained with the 2-m telescope of ShAO, as well as by analyzing the published works of other authors during the period 1955-2005 years the change the Hα line profile into a P Cyg type profile, a change in the number of absorption components from one to three, and also the presence of a gradient in the radial velocity of the absorption component of the Hα line in the spectrum of 89 Her were revealed. The sudden repeated mass loss of this star over the last fifty years have been revealed, which is very consistent with the hypothesis about the binary nature of the star 89 Her [16, 17].

The analysis of the chemical composition of supergiant stars is one of the most important research directions of ShAO. After the seventies of the last century, rapid development took place in the field of modeling stellar atmospheres. In the field of studying the chemical composition of stars underwent the gradual transition from the method known as growth curves to a new, more exact method, the method of atmospheric models. In ShAO, the transition to a method of atmospheric models began in the middle of eighties. Currently the high dispersion spectra of many population I supergiant stars of our galaxy have been studied by using the method of atmospheric model.

Together with astronomers of the CrAO (academician A.A. Boyarchuk, Dr. L.S. Lyubimkov and Dr. I.S. Savanov), a number of research were carried out to study the chemical composition of some supergiants, and UU Her type stars by using atmospheric models. On the basis of homogeneous, high-quality spectrograms obtained with the Kude spectrograph of 2-m telescope of ShAO and the 2.6-m telescope of KrAO, the atmospheric parameters and chemical composition of star α Lyr (A0 V) and γ Gem (A0 IV) were determined [18, 19] . It has been established that anomalies in the chemical composition of these stars caused by the different mechanism.

For the star α Lyr, by using the Kuruc's atmospheres models determined the parameters $T_{eff} = 9650\ ^oK$, lg g = 3.9 and the value of the micro turbulent velocity $\xi_t = (2.0 \pm 0.5)$ km/s. The content of 14 chemical elements was determined. It was revealed that the content of silicon, calcium, scandium, and iron is reduced in relation to solar values and possible lack of nickel and barium. It was not possible to detect the lines of rare-earth elements in the spectrum of α Lyr is assumed to be a moderate λ Voo type star. By using the results of evolutionary calculations, the authors found the values of relative mass $M/M_{\odot} = 2.35 \pm 0.30$, radius $R/R_{\odot} = 2.9$, as well as relative luminosity $L/L_{\odot} = 66$ and age $t = (470 \pm 1.41) \times 10^6$ years for the star α Lyr. These parameters within the error agree very well with the data obtained from the measurements of parallax, angular diameter, and absolute energy distribution [18].

As a result of studying the atmosphere of the star γ Gem by using the atmospheric model method [18], the following atmospheric parameters were found: $T_{eff} = (9300 \pm 100)^o\ K$, lg g =3.40±0.15 and micro turbulent velocity $\xi_t = (2.0 \pm 0.5)$ km/s. The content of 20 chemical elements was determined. It was revealed that the γ Gem star has an anomalous chemical composition similar to metallic Am stars, since for Am stars and γ Gem there is a tendency to increase the chemical composition anomaly with increasing atomic weight. However, the excess of chemical elements increases with the increase in atomic weight more moderate than that of a typical metallic star 68 Tau. Its evolutionary status and moderate metallicity can lead us to the following alternative – the star γ Gem is either massive early Am star with the more moderate metallicity effect, or the star with the shorter time chemical anomalies.

By using the results of evolutionary calculations, we found the mass ratio $M/M_{\odot} = 3.5 \pm 0.30$, radius $R/R_{\odot} = 6.2 \pm 1.4$, luminosity $L/L_{\odot} = 260 \pm 2.10$ and age $t = (200 \pm 1.17) \times 10^6$ of the star γ

Gem. Within the error, these parameters are in good agreement with the data obtained by measuring parallax, angular diameter, and absolute energy distribution.

By using of spectra obtained at the Kude focus of the 2-m telescope of ShAO with the spectral resolution of 0.3 Å and a dispersion of 8-12 Å/mm, the spectra of φ Cas and 45 Dra stars were studied. About 400 absorption lines were identified in the wavelength region λλ3700-6900 ÅÅ, equivalent widths (W_λ) and central depths (R_λ) of these spectral lines were determined [20 - 22].

The parameters of the atmosphere and the chemical composition of the supergiant φ Cas were determined [21]: effective temperature T_{eff} =7200 *ºK* and micro turbulent velocity ξ_t = 4.5 km/s. The content of 22 chemical elements in the atmosphere φ Cas was determined and are compared with the solar content. The content of carbon, silicon, manganese and iron is slightly less than the sun. A significant deficit is obtained for calcium and barium (about six times). The content of heavy elements may be reduced relative to the solar. It was found that the sodium content is higher than that of the Sun. The sulfur content in the atmosphere of the star under study is three times higher than in the sun.

By using echele spectrograms and based on Kuruc's models of atmospheres, the giant star ν Her was studied [23]. About 200 lines were identified in the wavelength range λλ 4760-6600 ÅÅ, and the equivalent widths (W_λ) of the spectral lines were determined. The following values were obtained for the stellar atmosphere parameters: T_{eff} = 5900 ± 200 *ºK*, lg g = 1.9 ± 0.2, and micro turbulent velocity ξ_t = 4.5 km/s for the Fe I lines. The content of 10 chemical elements was determined. It was revealed that the content of Mg, Ca, Sc, Ti, Cr, Mn, Fe, and Ni was decreased on average by Δ lg ε (El) = - 0.6 dex relative to the solar.

In [24], by using the method of atmospheric models, the effective temperature, the acceleration of gravity, the micro turbulent velocity, and the chemical composition of the atmosphere of the high latitude supergiant 89 Her were determined. The following values were obtained: T_{eff} = (6300 ± 150) *ºK*, lg g = 0.5 ± 0.2 and ξ_t = 7.5 km/s.

The content of 23 chemical elements in the atmosphere of the star 89 Her was determined. It was found that the chemical composition of this star is different from the sun. The deficit of carbon, magnesium, calcium, scandium, titanium and a number of heavy elements have been revealed. An excess of sodium was revealed. The contents of Ca, Sc, Mn, Fe, Co, Zr, Ba, La, Ce, Nd, Sm, and Gd are reduced on average by Δ log ε (El) = -1.0 dex relative to solar values. This star has a chemical composition different from the chemical composition of normal massive supergiants of I type of population.

It is known that the existence of bright supergiants at high distances from the galactic plane does not yet have a generally accepted explanation. According to modern view, by their luminosity, these objects must be very young and massive, on the other hand, young and massive stars are located near the galactic plane. From this point of view, a comparative study of the supergiant 89 Her and other F supergiants is of great interest.

The evolutionary status of the high latitude supergiant 89 Her is discussed in [25]. Here, attention is drawn to the fact that among F supergiants located at different distances from the plane of our Galaxy, high-latitude supergiants occupy a special position. Despite the fact that more than 50 years have passed since the discovery, the evolutionary status of high-latitude supergiants remains unclear. According to the location on the GR diagram, it is difficult to belong these stars to I type of population. Several hypotheses have been proposed to explain the evolutionary status of high-latitude supergiants. For example these stars could be 1) young, massive stars that have recently formed and "escaped" a large distance from the galactic plane; 2) old, low-mass stars, which at the end of evolution achieve high luminosity; 3) the result of the evolution of a binary star.

To clarify the evolutionary status of the high latitude supergiant 89 Her, our results are compared [25], with the results obtained for other F supergiants (φ Cas, α Umi, γ Cyg and ρ Cas) [26, 27] located at low distances from the galactic plane. The comparison show that the content of chemical elements in 89 Her decreases on average with an increase in atomic weight compared with the aforementioned F supergiants. However, the carbon content shows an increased average value of 0.15 dex. There is a deficit of rare-earth elements in the atmosphere of star 89 Her compared to the atmospheres of other F supergiants. Anomaly chemical composition of star 89 Her star relative to the Sun and other F supergiants once again proves that this star differs from normal massive supergiants of I type of population.

It is assumed that high-latitude F-supergiants of small mass are at the stage of withdrawal from the asymptotic branch of giants, and they do not belong to the young population of the galactic disk.

The determination of the microturbulent velocity in the atmospheres of supergiants is of interest to verify the accuracy of the calculations of the theory of acoustic waves. For example, Edmunds calculations predict that in the atmospheres of yellow supergiants, the rms amplitude of the vibrational velocity $V\omega$, which is considered as an analog of the usual microturbulent velocity ξ_t, determined from observations, increases rapidly with height, and in the highest layers it can reach supersonic speed. It is important to verify the agreement between the predictions of the theory and the microturbulent velocity determined from the observations.

In works [28-31], together with Dr. L.S. Lyubimkov, the method of atmospheric models was used to determine the effective temperature, acceleration of gravity, microturbulent velocity and chemical composition of the atmospheres of F and A supergiants.

By using modern values of the oscillator strengths, the microturbulence in the atmospheres of F supergiants, γ Cyg (F8 Ib), α UMi (F8 Ib-II), ρ Cas (F8 Iap), and α Car (F0 Ib), was studied for the Fe I lines, and for the lines Fe II, Ti II in the atmosphere of the supergiant star α Cyg (A2 Ia). It was shown that there is a strong dependence of the microturbulent velocity ξ_t on the observed equivalent width, indicating a rapid increase in ξ_t with heigh in the atmosphere. The distributions ξ_t (τ) are plotted. It was found that in the upper atmosphere ρ Cas and α Cyg, there are supersonic ξ_t values, while for other supergiants (γ Cyg, α UMi, α Car), these values do not exceed the velocity of sound.

The obtained distributions ξ_t (τ) are in qualitative agreement with the predictions of the theory of acoustic waves. The conclusions of academician A.A. Boyarchuk and Dr.L.S. Lyubimkov are confirmed that, in the atmospheres of F supergiants, the lines of Fe II, Ti II and Cr II ions produce a higher microturbulence velocity than lines Fe I.

In [28–31], the atmospheric temperature method was used to determine the effective temperature T_{eff} and gravity acceleration g of the stars *l*´Sco, θ Sco, δ CMa and α Cyg. By using relatively weak lines, the chemical composition of these stars was determined. The metal content in the atmospheres of the investigated supergiants was on average close to the solar; some carbon deficiency found. An excess of sodium [Na/Fe]=0.6 was detected in the atmosphere of θ Sco, and an excess of nitrogen [N / Fe] = 1.3 in the atmosphere of α Cyg. By comparing T_{eff} and log g with the results of evolutionary calculations, we estimated the masses, radii, luminosities, and age of stars *l*´Sco, θ Sco, δ CMa and α Cyg.

It seems relevant to study the supergiants in binary systems. When real binary stars do not manifest themselves either as visually binary stars or as spectrally binary stars and, therefore, when analyzing the chemical composition, they are interpreted as single stars. Such an interpretation can lead to errors in the determined content of chemical elements and even to fictitious anomalies of the chemical composition.

In [29, 30], a new method was developed for studying binary systems such as π Sgr and υ Car stars. The spectrum of π Sgr, as a single star, was analyzed: the effective temperature and gravity acceleration were found, microturbulence was studied, and the chemical composition was determined. The metal content showed a general deficit, and especially low Ca and Sc contents were obtained. For a detailed analysis of the total spectrum of the components of the π Sgr binary system, a new method was applied [29, 30] and the fundamental parameters and chemical composition of the components of this system were determined. A and B components themselves have a chemical content close to normal. Estimates of the distance to π Sgr and the lower limit of the orbital period in this binary system are obtained. It was shown that the separation of the lines of components A and B in the total spectrum, if it is detectable in separate phases, should not exceed 0.4 Å. The observed spectroscopic and photometric data in the case of π Sgr related to the total radiation of both components. Unlike π Sgr, υ Car is only a photometrically unresolved binary system. A new method is applied in this case. The fundamental parameters of the components of the υ Car binary system are determined. A higher microturbulence rate was obtained from the ion lines than from the Fe I lines. The content of chemical elements was determined from relatively weak lines and determined value on average is close to the solar [28–31].

One of the directions of investigation is study of close binary stars (CBS) at different stages of evolution. By analyzing of echelle-spectrograms of a WR type star WR 136, obtained at the Cassegrain focus of 2-m telescope ShAO, revealed the asymmetry of the interstellar lines NaI 5890 and NaI 5896 in the spectrum of this star. The revealed asymmetry was explained by the contribution of nebula NGC 6888 surrounding the star WR 136 to the formation of these lines [32].

The spectrally binary star HD206267 (HR 8281, O6.5V + O9V, V = 5.6) was one of the CBS belonging to our research program at various stages of evolution. By using echelle spectrograms of this star obtained at 2-m telescope the following spectral properties have been revealed [33-38]:

1. A stable weak emission was detected in the violet wing of the H_α line;
2. The Discrete Absorption Components (DAC) lines in the core of the H_α line were revealed. Note that the DAC lines are usually observed in the UV spectra of hot stars. Only in a few stars, DAC lines were found in the Hα line. The DAC lines in the core of the Hα line in the spectrum of the star HD 206267 were first revealed by us;
3. According to our studies, no spectral feature was found (for example, strong emission) according to which this star can be identified with the X-ray source CepX-4;
4. The asymmetry of the H_α and H_β lines and the variation these asymmetries over the time (approximately one hour) were revealed. It was revealed that when the H_α line is asymmetric on the violet side, the H_β line is asymmetric on the red side and vice versa;
5. In those cases where there is no discrete absorption component, the H_β line width does not change with time, however, the H_α line widths undergo significant changes, there is no correlation between changes in the H_α and H_β lines widths;
6. In cases where the DAC lines are observed, a significant variability of both lines (H_α and H_β) is detected, the widths of both lines change almost synchronously;
7. In both cases (when DAC lines are observed or not), the largest changes in the width of the Hα and Hβ lines are observed at residual intensity levels of 0.90-0.95, i.e. on the wings of lines;
8. The radial velocity curve of main component was plotted. The radial velocities of the main component varies from approximately +80 km/s to -110 km/s for the lines H_α and H_β, from +60 km/s to -100 km/s for the line HeII 5411 and from +30 km/s to -10 km/s for the line HeI 5875.618. The amplitude of changes in radial velocities of the main component does not differ very much for the H_α and H_β, HeII 5411 lines, however, a significantly smaller amplitude is obtained for the line HeI 5875 line. This observational fact can be interpreted by the formation of various lines in different regions of the envelope surrounding the main star;
9. The radial velocity and the equivalent width of the Hα line change in antiphase, the equivalent width of the H_β and HeI lines 5875.618 does not depend on the phase of the orbital period, the radial velocity and the equivalent width of the HeII line 5411.52 changes synchronously.

The appearance of discrete absorption components and their displacement was explained by the appearance and motion of a dense formation (clump) in the shell of the star HD 206267 [33–38].

Note that the photometric observations of the star HD 206267 have not yet been carried out. Carrying out these observations is necessary to determine the orbital parameters of this binary system.

A spectral study of the star LZ Cep = HD 209481 = 14 Cep (O9 III + ON9.7V, V = 5.54), an eclipsing-binary (half-divided) system with a 3.070507 day period, in the spectrum of which the lines of both components are visible, is carried out. As a result of these studies, the following main results were obtained for the star LZ Cep [39]:

1. The H_α line profile is strongly distorted: the core of this line consists of the red and strongly distorted violet parts;
2. By analyzing the echelle spectrograms obtained during one night near the phase $\phi = 0.00$ we studied the variability of the line parameters. It was shown that the equivalent width of this line does not show rapid variability. Despite the fact that the radial velocity, determined at the half-width level, varies in a chaotic manner, the radial velocity, determined from the red component of line H_α, better reflects the orbital motion;
3. In the radial velocity curve near the phase $\phi = 0.25$ (when the low-mass component is between us and the massive component), a jump (the rapid variation of radial velocity) is detected;
4. In the star spectrum, at certain phases, the profile of the HeI 5875 line doubles, and with a phase near $\phi = 0.00$ the secondary component of this line appears in the violet side of the HeI 5875 line, and with a phase near $\phi = 0.00$ the secondary component of this line appears in the red side. In the remaining phases, the profiles of this line are strongly distorted by the presence of a secondary component;
5. The profile of the line H_β does not double, however, at certain phases, a component is detected at the H_β line, moreover, at a phase near $\phi = 0.00$ the secondary component of this line appears on the violet side of line H_β, and at a phase near $\phi = 0.50$ the secondary component of this line appears in red side. In the remaining phases, the profiles of this line are strongly distorted by the presence of a secondary component.

The spectral study of the mysterious close binary star β Lyr (HD 174638, HR 7106), which is a bright ($V_{max} = 3^m.4$, $B-V = 0^m.0$) semi-divided eclipsing closely binary system with an orbital period of $P = 12^d.943296$ days [40] have been carried out. According to modern view, the close binary star β Lyr consists of a bright giant (B6-8 II), the main component and a secondary (invisible) component surrounded by a thick accretion disk. One of the interesting features of this star is the fact that the main component has less mass (~ 3 $M_\odot$) than the secondary (~ 13$M_\odot$). This fact is explained by the fact that the main component is intensively losing mass. The rate of mass loss for the main component is ~20×10^{-6} $M_\odot$ per year.

As a result of these studies for the star β Lyr, the following main results were obtained [40]:

1. By measuring the radial velocities of the SiII 6347, SiII 6371, and Mg II 4481 lines, the radial velocity curves of the main component were constructed. Using these radial velocity curves, the orbital period of the star β Lyr for the our observation period (2016 year) was determined to be 12.941428 days. It is known that due to the strong loss of mass, the value of the orbital period of this star increases, by ~19 sec, every year. The value of the orbital period of the star β Lyr that we have determined for the our observation is important for the study of this star in the future;
2. Depending on the phase of the orbital period, the ratio of the central intensities of the violet and red components of the H_α and HeI 6678 lines revealed a maximum at phases approximately 0.30 and 0.86. These maxima coincide with the phases of the magnetic poles in the proposed Skulsky model for the star β Lyr [41]. Consequently, our studies confirm the reality of the physical model of this star proposed by Skulsky [41].
3. The radial velocity of the S-component of line H_α from the phase of the orbital period varies approximately synchronously with the variations of radial velocity curve of the main component with a small amplitude. In works [42, 43] reported recently spectral, photometric, polarimetric, etc. observational facts concerning to the Wolf-Rayet stars.

Spectral studies of some supergiants (φ Cas, HD161796, 89 Her, etc.) were performed [44-57]. By analyzing echelle spectrograms of star φ Cas obtained at 2-m telescope of ShAO, determined the physical parameters and chemical composition of this star: T_{eff}=7300±200K, lgg=0.25±0.2 [44, 45]. By using the FeI lines, the value of microturbulent velocity was determined as ξt = 14 km/s. The content of 22 chemical elements have been determined. The resulting chemical composition is compared with the chemical composition of the Sun. It was revealed that the content of chemical elements Mg, S, Sc, Ti, V, Cr, Ni, Y, Zr, Ba, La, Ce, Pr is closer to the solar one, the content of Na is higher, and the content of chemical elements C, Si, Ca, Fe, Mn is less than solar [45, 46].

By the comparison of the profiles of the H_α absorption line in the spectrum of the star HD161796 obtained at the 2-m telescope of ShAO during 2004-2010 years and published before 1980 year scientific results, the following features were found [46]:

1. All measured parameters of lines H_α, H_β, and D2 NaI in the spectrum of star HD161796 show variability with the characteristic time several months or less;
2. It was found that the radial velocity of line H_α, as well as the equivalent widths of line Hα line and the sodium doublet line (NaI 5890) is variable. These variations occur synchronously with the variations of V light curve, with the period of *P= 62* days [48];
3. The variations of radial velocity of line sodium doublet (NaI 5890) are in antiphase with the variations of V light curve and the radial velocity of the Hα line, as well as the equivalent widths of H_α and sodium doublet (NaI λ5890);
4. It was assumed that these variations could be due to the presence of the circumstellar shell, as well as pulsation of the star.

Note that the antiphase variation of the radial velocities of line Hα and the sodium doublet (NaI λ5890) were revealed by the authors of [48] for the supergiant RM_1-667, located in the Large Magellanic Cloud.

By analyzing echelle spectrograms obtained at 2-m telescope of ShAO, the physical parameters of the star HD161796 (F3Ib) have been determined: T_{eff} = 6550±200 K, log g = 0.75±0.2 [49]. By using the lines FeI, FeII, TiII, VII, and CrII, the microturbulent velocities were determined: ξ_t =6.0 km/sec (FeI), ξ_t =6.5 km/s (FeII), ξ_t = 5.5 m/s (TiII), ξ_t =6.0 km/s (VII) and ξ_t =6.0 km/s (CrII). The content of 25 chemical elements in the atmosphere of the star HD161796 was determined. The content of chemical elements is compared with the solar chemical composition. It was revealed that the content of the chemical elements Ca, Sc, Mn, Zn, Y, Zr, Ba, and Sm in the atmosphere of the star HD161796 is significantly underestimated in comparison with the solar one.

By analyzing echelle spectrograms obtained at 2-m telescope of the 89 Her star during 1975-2017 years the variability of the NaI D lines in the spectrum of this star was studied [50]. It was revealed that along with the revealed short-term changes for this star, there are long-term variations. The radial velocities of the lines NaI D vary with an approximately 5,000 day period. The orbital parameters of this star were determined for the first time.

A spectral study of the supergiant HD 208501 was carried out and some interesting scientific results were obtained [51]. It was revealed that, depending on the activity of the atmosphere, the profiles of line H_α could be:

1. Fully absorption profile;
2. Normal P Cyg profile;
3. Inverse P Cyg profile;
4. Weak emission component in both wings and absorption between them;
5. The intensity of the emission components is attenuated to the level of the continuous spectrum.

It was found out that the radial velocities and equivalent widths of lines H_α and NaI D varies with a characteristic time of one week or even less. It was believed that these changes can be due to pulsation and processes occurring in the circumstellar envelope.

The determined value of log g = 4.0 for the star HR 8718 (F5II) indicates that the luminosity class of this star is IV, and not II as indicated in star catalogs. Therefore, the star HR 8718 (F5II) belongs to the luminosity class IV [52]. The dependence “effective temperature - spectral class” is plotted for all stars belonging to all classes of luminosity. The method of atmospheric models is used to determine the physical parameters of supergiants.

It was revealed that the microturbulent velocity in the atmospheres of stars depends on the acceleration of gravity: in stars with dense atmospheres, the value of microturbulent velocity is less. The determination of the chemical composition showed that for the supergiants located on the galactic plane, metallicity is closer to solar. This fact was interpreted by the fact that these stars and the Sun were formed in an interstellar medium with the same chemical composition. Note that the Sun belongs to the II type of population, i.e. the medium in which the Sun was formed was enriched with heavy chemical elements. These heavy chemical elements were synthesized in stars of the previous generation. Consequently, the stars located in the galactic plane belong to the II type of population, like the Sun.

It was revealed that in the atmospheres of giants and supergiants of spectral class A, F, the carbon content is less and sodium is greater than solar. This result is consistent with the conclusions of the modern theory of star evolution.

It was found that the metallicity of high latitude F stars, i.e. stars located at high distances from the galactic plane are smaller than solar. It is assumed that these stars are in phase after the asymptotic branch of giants (after AGB). The metal content in the atmospheres of these stars was originally normal (closer to the solar). Due to the fact that the atoms of the iron group participated in the formation of dust particles, the amount of these chemical elements decreased. So, F supergiants located at high distances from the galactic plane are young objects that formed in the galactic plane and then moved away from this plane [51]. The physical parameters and chemical composition of some supergiants were determined [54–61].

Spectral study of the star HD21389 (A0Ia) was carried out and the following results were obtained:

1. The profile of line H_α in the spectrum of the star HD 21389 is quite complex. In the active phase of the star’s atmosphere, this line is observed as an inverse P Cyg profile. The appearance and disappearance of emission lines in the red and violet wings of line H_α were revealed. All parameters of line H_α varies with the time. It is assumed that these changes can be associated with the variability of the star’s atmosphere, with the outflow of matter and pulsation instability;
2. The appearance and disappearance of asymmetry of profile NaID line, and also simultaneously appearance the inverse P Cyg profile of line H_α, can be caused by macroscopic radial motions in the atmosphere of this star and irregular pulsation;
3. Studies have shown that the radial velocity of line FeII varies with the time. However, this change does not occur with the 7.7 day period found by other authors earlier.

Spectral studies of the bright supergiant HD 199478 were carried out and the following results were obtained [61]:

1. The parameters of the absorption lines show quasiperiodic variations similar of H_α and H_β line variations. These variations occur within approximately 90-100 days. In various observational seasons, the radial velocities of the absorption lines vary within 1.5-5 km/sec;
2. The greatest variations are found for the HeI and Na D lines. The Si II and Ca II lines show almost no variability and the radial velocity of these lines is equal to the velocity of the star’s centers of mass (-12 km / sec);
3. In different observational seasons, equivalent widths and radial velocities vary synchronously, but the nature of these changes is not the same in different observational seasons.
4. In 2011 year, when the so-called high velocity absorption (HVA) effect was detected, the dynamic characteristics of the absorption lines showed compression and an increase in

equivalent widths was detected at that time. Only CaII lines showed expansion. This fact is interpreted as the fact that the effect of pulsations in the lines formed in different regions of the shell is not the same;

5. In 2014 year, the maximum radial velocity of the line turned out to be equal to 85 km/s, for the absorption lines the average radial velocity was equal to (-12) - (-15) km/s. These variations occurred within 26 days.

2. Investıgatıon of the Wolf- Rayet type stars

In 1867, astronomers of the Paris Observatory Wolf C.L.E. and Rayet C. for the first time, in the constellation Cygnus, observed three stars with strong and wide emission lines: HD191765 = WR 134, HD192103 = WR 135, HD 192641 = WR 137 [62]. After that, stars with such features were named Wolf-Rayet (WR) stars in honor of their discoverers.

The study of these stars is associated with the following global problems of modern astrophysics:

1. the evolution of massive single stars and close binary stars (CBS);
2. the formation of neutron stars and black holes, because WR stars are potential progenitors of neutron stars and black holes, the study of which is the central problem of modern science about the Universe;
3. generation of the cosmic gamma-ray bursts;
4. evolution of galaxies, because intensively losing their mass, WR stars enrich galaxies with heavy elements, which plays an important role in the formation of the next generation of stars.

The stars actively losing their mass (even temporarily) show WR-like spectra: novae after some time of outburst, P Cyg stars, symbiotic stars, Of stars, etc. WR stars are radically different from ordinary stars of the Sun type in that their radiation in emission lines of helium, nitrogen, carbon and oxygen is comparable to the radiation emitted in the continuous spectrum. In addition, WR stars also differ from stars of the Sun type in chemical composition: they mainly consist of helium and contain very little hydrogen, the proportion of which in ordinary stars reaches ~75% by mass.

According to the VII catalog of the Galactic WR stars [63] of I type of population, 226 stars of this type have been discovered in our Galaxy. The theoretically expected number of WR stars in our Galaxy is ~10^3. WR stars are also discovered in other galaxies. There are 134 known WR stars in the Large Magellanic Cloud (LMC) [64], 11 in the Small Magellanic Cloud (SMC) [65], in M33, M31 [66-68] and about 10 in the Andromeda galaxy [69]. The presence of WR stars in other galaxies was revealed. In addition, a special type of galaxies was identified as WR galaxies, which mainly consist of WR type stars [70]. Problems and topical issues of the study of WR stars were widely discussed in reviews [71–73]. Several International Symposiums were dedicated to the investigation of these stars [74-78].

Here we consider only massive WR stars of I type of population of our Galaxy, which are concentrated to the Galactic plane. It should be noted that low-mass hot stars of the II type of population of our Galaxy, the nuclei of planetary nebulae, also possess the characteristics of WR stars [78, 79]. To distinguish WR stars of I type of population from the nuclei of planetary nebulae, the latter are denoted as [WR]. Note that I type of population WR stars are more massive and bright than [WR] stars. In addition, the I population WR type stars are younger (average age about 10^6 years) compared to [WR] stars.

Currently, the following main observational properties of I type population WR stars have been revealed:

1. The spectra of these stars consists of bright and wide emission lines of nitrogen, carbon, oxygen and helium at different stages of ionization (N II - NV, C II - CIV, OIV-OVI, HeI, HeII).

2. The widths of the emission lines reach to 50-100 Å, and the intensities in the center of the lines are sometimes 10-20 times higher than the intensities of neighboring continuous spectrum.
3. The peculiarity of the spectra of WR stars is explained by the presence a hot "core" and an extending envelope at speeds of ~1000-3000 m/s, in which emission lines of various ions are formed.
4. The most interesting fact is the simultaneous presence in their spectra a relatively low-temperature continuum and lines of atoms and ions with high (up to 160 eV) ionization potentials.
5. The main observational feature of WR stars is the simultaneous existence in the spectrum of lines with very different excitation potentials and ions with very different ionization potentials (10-160 eV). This observational fact could be explained by the presence strong temperature stratification in the envelopes of these stars.
6. According to the ratios of intensities of the selected lines of nitrogen, carbon and oxygen ions at different stages of ionization WR stars are divided into three types: nitrogen (WN), carbon (WC) and oxygen (WO). The spectra of WN stars mainly contain nitrogen lines, the spectra of WC stars contain mainly carbon lines, and the spectra of WO stars contain oxygen and carbon lines. The spectra of all types of WR stars contain helium and hydrogen lines, but the hydrogen lines are weak, the hydrogen atoms in the shells of these stars are several times smaller than the helium atoms, and in some subtypes of stars WR hydrogen is absent. For comparison, we indicate that there is about 10 times more hydrogen on the Sun than helium.
7. According to [80] the average mass of WR stars is about 20 $M_\odot$, although most WR stars in WR + OB systems have masses close to 10 $M_\odot$ and the mass ratio of the components ($q = M_{WR}/M_{OB}$) lies in the range 0.3-1. According to [81], the mass of the star WR 22 is about 55 $M_\odot$. The star WR 20a has a record mass of 83 $M_\odot$ [82]. The masses of WC stars are on average no less than the masses of WN star, although statistics are still insufficient for reliable conclusions. The masses of WR stars determined from binary stars are in the range from 10 $M_\odot$ to 83 $M_\odot$.
8. Spectroscopic data indicate that a powerful outflow of matter occurs from WR stars. The widths of the emission lines correspond to the flow velocities of 1000-3000 m/s, which exceeds the parabolic speed, i.e., the star loses matter. Some emission lines have violet absorption components, which is in favor of a model of the radial outflow of matter. The average mass loss rate of WR stars, found from the analysis of spectroscopic data, is $M \sim 0.3 \cdot 10^{-5}$.
9. The most reliable information about the masses, radii, temperatures, and bolometric luminosities of WR stars is obtained from an analysis of the emission of eclipsing binary systems for which the radiation of an extended atmosphere can be separated from the radiation of the actual star ("core") WR and for which the results obtained are independent of the interstellar absorption. Currently, five eclipsing WR + O systems have been discovered: V444 Cyg, CX Cep, CV Ser, CQ Cep, WR 22.
10. In the Hertzsprung-Russell diagram, WR stars lie in the region between the main sequence and the sequence of homogeneous helium stars. This indicates that the WR stars are at a late stage of stellar evolution and have already passed the stage in which hydrogen "burned out".
11. The average height z for stars WR above the galactic plane is ~ 85 pc. Being absolutely young objects (average age about 10^6 years), they are at the final stage of their evolution, at the stage of exhaustion of nuclear energy reserves, after which the star should collapse to form a relativistic object (neutron star or black holes depending on the initial mass).
12. The population I WR stars are hot stars of very high luminosity: $L \sim 10^5$ - 10^6 $L_\odot$. The absolute magnitudes of WR stars are in the range from ~ -4^m to - 7^m.
13. According to modern view, the I type of population WR stars of our Galaxy are naked hot helium nuclei of initially massive O stars that have lost their powerful hydrogen

shells either due to the flow of matter in CBS system or as a result of intense mass loss as stellar wind. At the end of their evolution, WR type stars explode as type I b/c supernovae (in their spectra there are no hydrogen lines, but only helium -Ib and carbon - Ic lines) and form neutron stars or black holes.

1.1. The first stage of the study of WR stars in the ShAO

The study of WR stars in ShAO can be divided into two stages. The first stage of research was performed during 1962-2005 years. At this stage of investigation, a photographic plate or photo electronic amplifiers was used as a light вуеусещк. After 2005, at the second stage, spectral and photometric observations were carried out by using modern high sensitive light detectors – CCD matrices.

The first studies of WR type stars in ShAO carried out by using classical light detectors by Dr.A.Huseynzade [83-85] in the seventies of the last century under the supervision of Dr.Nikonov. He studied the possible variability of the parameters (equivalent width, half-width etc.) of the HeII4686 and HeII5411 emission lines in the spectra of WR type stars, V 444 Cyg, and CQ Cep. The variability of the parameters of the above mentioned emission lines were revealed, both during the night and from night to night. The equivalent width of emission line HeII4686 in the spectra of V 444 Cyg and CQ Cep stars changed 2.1 and 1.9 times, respectively. From these investigations made a conclusion concerning on the variability of the shells and gas outflow in binary systems V 444 Cyg and CQ Cep. To explain the variations revealed during the night, the presence of ejection of matter from these stars was assumed. It was concluded that the outflow of matter from these stars is unsteady. This result for the stars V 444 Cyg and CQ Cep were obtained for the first time and was very important for the construction of physical models of these stars. Dr.A.Huseynzade also performed photometric observations of V 444 Cyg and CQ Cep stars in the international photometric system UBV. Unusual variations of brightness of the star V 444 Cyg were revealed both during the night and from night to night. The significant variations were found in the width of the minima of the light curve. Similar brightness variations were also revealed for the star CQ Cep.

According to that time generally accepted model, it was believed that WR stars consist of a hot core with an outflowing shell. However, based on the newly obtained observational facts, Dr.A.Huseynzade proposed the following model for the WR type stars: a hot active core, from which takes place frequent ejections of matter, but not all ejections occur at a critical rate. This model was confirmed by numerous subsequent observations by other astronomers.

The study of WR stars by classical methods was continued by Dr. V.B.Babaev [86-89] in the seventies of the last century. In the works of Dr.M.B.Babaev the rapid spectral variability of some emission lines (NIII 4640, HeII 4686, CIII 5696, etc.) in spectra of WR type stars, HD 16523, HD 186943, HD 192103, HD 192163, HD 191765 was revealed. It was concluded that short-term spectral variability is characteristic for the WR type stars.

The study of WR stars by classical methods was continued by Dr.J.N.Rustamov in the eighties of the last century [90-100]. The WR stars in the spectra of which the emission doublet OVI 3811, 3834 is present have been investigated. These stars are named as WR-OVI stars and a catalog of these stars has been compiled. The spectral and photometric studies of two WR-OVI stars from this catalog, HD 16523 and HD 17638, have begun. In addition to these, one unique WN+WC star, WR145=AS 422, was also studied. This star is unique because it belongs to the mixed type: WN+WC. There are only several such type stars in our Galaxy. It was assumed that these objects are in an intermediate evolutionary phase between WN and WC stars. The following results were obtained for WR-OVI stars:

1. Catalog of WR stars in the spectra of which the emission doublet OVI 3811, 3834 was revealed (i.e. catalog of WR-OVI stars) was compiled;
2. The periodic variability ($P = 2^d4096$) of brightness and radial velocities was revealed for the WR-OVI star HD 16523, which is interpreted as a manifestation of binarity;

3. The rapid spectral variability of the emission doublet lines OVI 3811, 3834 in the spectrum of WR-OVI stars HD 16523 and HD 17638 and the variability of the emission band λλ3680-3780 Å in the spectrum of WR-OVI star HD 16523 have been revealed;
4. The new subtype WO5 was proposed for the first time, for the spectral classification of some WR stars, which according to spectral characteristics occupy an intermediate position between early WC (WC4-6) and late WO (WO3-4) types. The classification criteria are given for determining the WO5 subtype;
5. The similarity was found between the distributions over the galactic high z of the WR-OVI stars and WR stars with the stars with probable relativistic (neutron star or black hole) components;
6. It was found that the most intense emission doublet OVI 3811, 3834 is observed in subtypes WC4, WC5 and with the transition to late WC (WC7-8) subtypes; the intensity of this emission doublet gradually decreases.

1.2. The second stage of research on WR stars in ShAO

The second stage of spectral and photometric observations of WR stars begins from 2005 year by using of modern high sensitive light detectors - CCD matrices by Dr. J.N.Rustamov [95-100]. The spectral observations of WR type stars were carried out at the Cassegrain focus of 2-m telescope of ShAO by using an echelle spectrometer [2], and photometric observations on the Zeiss-600 telescope with an Apogee Alta U-47 CCD matrix (1024x1024 pixels), in the filter V of the international photometric system UBV [101].

The spectral observations of WR type stars (WR134 = HD 191765, WR136 = HD 192163, WR 138 = HD 193077HD) were carried out at the Cassegrain focus of the 2-m telescope during 2005-2011 years. The profiles of five strongest emission lines were studied: HeII 4859, HeII 5411, CIV 5808, HeI 5875, (HeII+H_α) 6560. The studied stars of the WR type (HD 191765, HD 192163, HD 193077 HD) were previously considered WR stars with the probable relativistic components (WR + C) [102]. However, further studies did not confirm the nature of these objects as WR + C binary systems. In [103], it was hypothesized that the WR type stars, which were previously considered as WR + C stars, could be CBS containing low-mass “normal” stars as components. The main argument for this hypothesis was that currently a large number of low-mass X-ray binary systems are observed. These X-ray binary systems consists of a low-mass optical A-M star and an accreting neutron star or black hole. According to modern theory of evolution of CBS, the progenitors of such low-mass X-ray binary systems should be WR stars with low-mass AM components that formed after the stage of primary mass exchange in the regime with a common shell. The next explosion as a supernova WR formed after the initial mass exchange leads to the formation of a low-mass X-ray binary system. Thus, should be existence of WR stars with the “normal” low-mass stars components. The author of [103] proposed that WR stars, which were previously considered as WR + C stars (for example, HD 191765, HD 192163, HD 193077 stars), can be CBS containing low-mass “normal” stars as component. In order to search for signs of the presence of a compact component or a low-mass A-M star, the spectral observations of the aforementioned WR stars at 2-m telescope of ShAO and photometric observations of HD 191765 star at 60-sm telescope of ShAO were carried out.

The following interesting results were obtained:

1. Comparison of the shape of the profiles of the emission band (HeII+H_α)6560 in the spectrum of star HD 192163, obtained for different dates, showed that the violet wing (region from λ ~ 6496 Å to λ ~ 6532 Å) of this profile is variable. Narrow emission details sometimes appear in this region (mainly at a wavelength of λ ~ 6496 Å). It is possible that the appearance of narrow emission components in the violet emission wing of (HeII+H_α)6560 in the spectrum of star HD 192163 is due to the interaction of a low-mass satellite with the stellar wind of the WR star during its orbital revolution around the WN6 component;

2. The statistical analysis of the radial velocity dates of the emission band (HeII+H_α)6560 in the spectrum of the star HD 192163 revealed that the series under consideration contains

a peak at ~1% level at a frequency of ν = 0.195 day^{-1}, which corresponds to P = 5.128^d. The period we found is very close to the value of the period P = 4.57^d, found in [104] for the star HD 192163;

3. By using the modern classification scheme, for the spectral classification of WR stars of nitrogen sequence, the spectral subtypes of stars HD 191765 and HD 192163 were determined. Both stars belong to the subtype WN6. Revealed that despite the fact that the spectral subtypes of these stars are the same, the ionization structure of the shells of these stars is significantly different. This observational fact may be related to the difference in the initial masses of these stars;
4. From 17 profiles of the emission band (HeII+H_α)6560 that we studied in the spectrum of the star HD 191765 obtained on different dates, a symmetric profile was detected in only one case, and in the remaining cases a change in the shape of the profiles of various degrees was observed. It was revealed that the variability in these profiles is observed mainly in the of the red wing of the indicated emission band;
5. From photometric observations of the star HD 191765 it was revealed that during some nights the brightness of the star HD 191765 undergoes significant changes (by ~0^m.05 and even, in one case, by ~ 0^m.1 during a short time);
6. By applying statistical methods for studying periodicity to an values obtained by us from photometric observations of star HD 191765 at 60-sm telescope, a peak was detected at a frequency of ν = 0.530 d^{-1}, which turned out to be significant at a ~1% level. This frequency corresponds to the period P = 1^d.887. Therefore, we found the photometric variability of the star HD 191765 with a period of P=1^d.887, which is very close to the period found in [105] for this star.
7. The found variability of stars HD 192163 and HD 191765 with the periods P = 5^d.128 and P = 1^d.887, correspondingly, supports the assumption that these stars can be the precursors of a low-mass X-ray binary system consisting of a relativistic object and K-M stars.

All of the above mentioned results are presented in [97-100]. Studies carried out by Dr. J.N.Rustamov of the WR type stars were carried out under the supervision of the academician of the Russian Academy of Sciences, professor, Dr. A.M.Cherepashuk, and these studies currently continues.

2. **Investigation of Novae**

One of the directions of research of ShAO was the study of the Novae performed by Dr.M.B.Babayev during 1967-2001 years [106-112]. The spectrum of five Novae (HR Del, LV Vul, FH Ser, V 1229 Aql, V 1500 Cyg) obtained at 2-m telescope have been investigated.

In 1572, a “super bright” star suddenly appeared in the constellation Cassiopeia, and this star was called the New Star. The accumulated collections of photographs showed that in fact the so-called “new” star actually existed before, but suddenly flared up, as a result of which its brightness increased tens of thousands of times in a short time. Later the stars such type was called novae. At maximum brightness, their absolute magnitude varies from -6^m to -9^m. Bright novae, whose maximum brightness reached the first magnitude, were rarely observed, such case known for 1901, 1918, and 1925 years. An outbreak of novae usually occurs in a few days - catastrophically, and a return to its former brightness lasts for years and is accompanied by fluctuations in brightness. At the moment of maximum brightness, the diameter of the novae is larger than the diameter of the Earth’s orbit, the outer layer breaks off the star, and this layer expands at a velocity of about 1000 km/s. According to modern view, the explosion of novae is connected with their binary nature. It was assumed that the system consists of a very hot star (white dwarf) and a cold component, which at some stage of evolution fills its critical Roche lobe. After filling the critical Roche lobe, through the inner point of Lagrange, underwent a powerful outflow of matter towards the white dwarf. After a certain time, a white dwarf shell forms. This shell is strongly heated from below by a white dwarf and, at some point in time, an ejection of matter occurs, which is observed as an explosion. In this outburst, a matter with a mass of ~0.0001 $M_\odot$ ejects from novae and an oval-shaped shell forms around the binary system. The reason for the formation of an oval shell in novae, according to Dr.M.B.Babayev may be due to the large difference in the masses of the components of the binary system ($m_1/m_2 \gg 1$).

Novae are a subclass of cataclysmic variable stars. For the classical (typical) Novae the outbreak takes place only once and for the repeated Novae the outbreak could be observed at least twice. Repeated Novae have powerful flares with intervals of several tens of years. Many works of Dr.M.B. Babayev are devoted to the Novae HR Del. This star was discovered as a Novae on June 15, 1967. Dr.M.B. Babayev observed this star from October 24, 1967 to September 1, 2001.

The HR Del star belongs to a small group of ultra-slow Novae. Six months before the outbreak, Stephenson observed this star. At that time the photographic magnitude of HR Del was $11^m.8 \pm 0^m.3$, and the spectral class was defined as O or B. The star was discovered as Novae on June 15, 1967. Observations revealed that all phases of the flare proceeded very slowly. Only after four weeks (in July) it reached a magnitude of 5^m, then during five months its brightness remained almost constant, and only on December 6-13 of 1967 it unexpectedly increased its brightness to $3^m.5$. Due to the fact that the outbreak of the HR Del star was very slow, many were able to observe the development of the outbreak.

Note that the star HR Del has some features that are not found in other Novae. After the maximum brightness at HR Del, two more secondary flashes were observed, which were comparable in intensity to the main flash. Interestingly, the second and third outbreaks occurred after fluctuations in the HR Del brightness relative to a certain average level. The reason for the repeated outbreaks of this kind in the Novae is still unexplained.

By using the images of HR Del obtained with the aid of ACT-452 telescope of ShAO during 1978-1981 years the variability of the photographic stellar magnitude of this star with a period of 0.177125 days was revealed.

By using obtained spectrograms at 2-m telescope of ShAO, the hydrogen line profiles were studied. A pre-maximal spectrum was obtained. After the pre-maximum, lines with a complex structure appear in the spectrum. At the beginning of the maximum, each line consists of three components. One of them is emission, and the other two are absorption, which belong to the main (V_r=-400 km/s) and diffuse-spark spectrum (V_r = -1050 km/sec). After the third flare, two more components are formed with radial velocities V_r = -323 km/s and V_r = -800 km/s, respectively. A component with the radial velocity V_r = -400 km/s appears after the main flare and forms in the main shell. The component with the radial velocity V_r= -1050 km/s appears after the maximum brightness, it belongs to the diffuse-spark spectrum. The component with radial velocity V_r= -323 km/s is connected with the shell, which was formed after the third outbreak. Interestingly, exactly the same structure was observed in the spectrum of the fast Novae - LV Vol, in the post-maximum phase of the flare. Subsequently, the absorption components disappear, leaving an emission line having a four-component structure. These components form in separate parts of the shell that formed after the outbreak of Novae. For a long time, a change in the structure of emission lines was observed. In the HR Del spectrum at a very late nebular stage (since 1984), absorption components were found for hydrogen lines belonging to the photosphere of the star itself, and not of its shell.

The study of the profiles and parameters of the emission lines of hydrogen, helium, nitrogen, forbidden oxygen lines, etc., showed that after the disappearance of the absorption components of these lines, all emission lines had a four-component structure. At first, at the maximum, all emission lines had one component, after the maximum they bifurcated, then, during the spark-diffuse stage, they were already three component, and after the disappearance of the absorption components, at the nebular stage, they became four component . This structure persists after the nebular stage. These observational facts were interpreted by the possible four-component shell structure of the HR Del star. Another interesting feature of the HR Del star is that, with further evolution, this star has features concerning to the Polars. Polars are binary systems consisting of white and red dwarfs. They differ from the Novae mainly by the presence of strong magnetic fields. For Novae, the magnetic field is $\sim 10^6$ G, and in Polars - $\sim 10^7$ G. In the works of Dr. M.B. Babayev, it is assumed that there is an evolutionary connection between the Novae and the Polars, i.e. Novae evolves into Polars. It is known that the Polars have a sudden drop in brightness. A similar sudden drop in brightness was also observed in HR Del in the minimum phase of brightness. It has been revealed that at the post-new stage, the brightness attenuation occurs spasmodically.

From the analysis of long-term observations, Dr.M.B. Babayev concluded that the star HR Del may be a triple system, and not a binary system, as was previously thought. For this star, periods of 0.14 and 0.19 days were found. According to Dr.M.B. Babaev, in this triple system two stars flashed - one after the other.

3. Theoretical investigations

For 60 years in the ShAO the theoretical studies of stars in various directions have been carried out by Dr.O.Kh. Huseynov, Dr.Z.A. Seidov, Dr.T.A. Eminzade, Dr.J.S.Aliyev and others. Here we present only the results of theoretical studies performed by Dr. J.S.Aliyev. Since 1977, he has performed theoretical research in the following areas [113-124]:

1. Radiation transfer in spectral lines, taking into account incoherence and anisotropy in optically semi-infinite and finite media;
2. The problem of stability of self-gravitating gas. Possible solutions and the existence of short-wave instability;
3. The problem of solar activity and its impact on social disasters;
4. Creation of software packages for describing the motion of bodies in the solar system.

By the beginning of the seventies of the last century, classical methods, mainly integrated ones, had exhausted their capabilities of analytical study of such complex problems as radiation transfer in spectral lines with partial frequency redistribution. At the same time, in parallel, purely mathematical studies of the integro-differential transport equation were carried out by using spectral methods. The need to obtain the results of analytical studies on the one hand and the development of methods for solving the transfer equation on the basis of a new mathematical ideology, on the other hand, merged, and a new solution method emerged that considers the integro-differential transfer equation as a differential equation with an operator coefficient. However, the methods were developed and applied exclusively to equations arising in the theory of neutron transfer and gas kinetics. Moreover, the energy dependence in the studied transport equations was not taken into account. The problems of astrophysics have remained outside these studies. At the same time, in the late seventies and early eighties, a new operator method was applied to the radiation transfer equation that takes into account the partial frequency redistribution, which allowed solving this complex problem analytically. The problem of radiation transfer in the spectral line during anisotropic and incoherent scattering in optically semi-infinite and finite media was considered. The boundary-value problem for this problem was solved and explicit forms of exact analytical solutions were constructed. These were the first explicit solutions in the theory of radiation transfer taking into account the partial redistribution in frequency.

Investigation of the sustainability problem of self-gravitating gas has a long history and goes back to the works by Jeans. This old problem was again considered in order to reveal a new quality in the simplest setting. It turned out that historically the solutions of the equation of motion of a self-gravitating gas were missed. Further studies of the stability of the gas state showed that the instability spectrum is discrete. Moreover, it was proved that there is a short-wave instability, the presence of which until that time was not mentioned in the literature. The results of these studies were partially published in the works.

The solar activity cycle is a cyclic process of the emergence and development of active regions on the Sun. By activity is meant a complex of different phenomena occurring in different layers of the solar atmosphere, such as sunspots, torches, prominences, flares, etc. The effect of solar activity on the Earth occurs mainly by two types of radiation: electromagnetic and corpuscular. Impacts on the upper atmosphere, i.e., the ionosphere, lead to the appearance of geomagnetic storms, northern lights, and radio communication breaks. Global climate changes occur in the troposphere, cyclones and anticyclones intensify variations in meteorological parameters such as pressure, temperature, humidity, etc. In the hydrosphere, activity affects the freezing of the Arctic seas, fluctuations in the surfaces of the oceans, ripples of the Gulf Stream, changes in the levels of the Scandinavian mountain lakes, as well as the level of the Caspian. Dates of volcanic eruptions and the appearance of catastrophic earthquakes also fall on years of solar activity, which indicates the influence of the solar cycle on active geophysical processes in the earth's crust. In the biosphere, epidemics of cholera, plague, encephalitis, and flu are spreading. The number of sudden deaths, cases of exacerbation of diseases of the cardiovascular system, neurosis is growing.

Earth collision warning with celestial bodies is part of space security. This program consists of two parts: detection by observation of an approaching object and determination of its coordinates; building programs for fast calculation of the orbit of an object and its possible collision with the Earth. A program package ***CBM (Celestial Body Motion)*** was created, with the help of which it calculates the “time and distance of the closest approximation”, builds a graph of the distance between two objects at a given time interval, and finally creates an animation of the motion of celestial bodies. Program has many different versions. The latest version also includes the movement of satellites (including artificial) of celestial bodies. Another advantage of the program is that the name and coordinates of the object can be set at any time during its discovery, while the program itself is not subject to any changes.

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