**ANNOTATION**

to the dissertation for the Philosophy Doctor (PhD) degree
in specialty "6D061100 - Physics and Astronomy"

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# The physical characteristics of the Galactic stars and the influence of interstellar medium on their evolution

**General description of work.** This study is devoted to the investigation of stellar atmospheres and determination of physical parameters, clarification of the evolutionary status for stars of various types. The analysis of high-resolution and high signal-to-noise ratio spectroscopic observations of stellar atmospheres allowed finding the atmospheric parameters and the chemical composition of barium star ζ Capricorni (HD204075), δ Scuti type star - V1719 Cygni, and planetary-host halo giant star HD47536.

For HD204075, no correlation between chemical element's abundances and their second ionization potentials was found, which indicates that the anomalous content of chemical elements should be explained by the accretion from evolved companion of double system.

For V1719 Cyg the abundances of 28 chemical elements were found using synthetic spectrum method. The accretion of interstellar hydrogen and helium on the star's atmosphere was not found.

For HD47536 the abundances of 38 chemical elements were found. Correlations of the abundances of these elements against their second ionization potentials, and condensation temperatures were detected. The chemical composition of the star can be explained by interaction of interstellar hydrogen and helium accretion on the atmosphere, separation of dust and gas in the circumstellar envelope and also by protostellar cloud enrichment in heavy elements.

The dissertation also conducted a study of previously published abundance patterns for 1149 F-K giants, located within 200 parsecs from the Sun. The analysis of previously published data was carried out, representing a homogeneous study of their chemical composition. It is shown that the correlation coefficients of relative abundances chemical elements against the second ionization potentials of these elements differ for stars with radiative and convective energy transfer in atmospheres. This means that the chemical composition anomalies in the atmospheres of these stars are due to the influence of accretion of interstellar and circumstellar gas.

**The relevance of topic.** The investigation of stellar chemical compositions is one of the most important branches of astrophysics. These researches allow understanding the stellar evolution and the evolution of different stellar systems, for example stellar clusters and galaxies. The stars which are influenced by interstellar or circumstellar matter are of particular interest. These are the barium stars, the stars with planetary systems and the stars with dust envelopes. The abundances of

chemical elements in the atmospheres of such stars differ from the abundance patters of single stars.

The atmospheres of most of Galactic disk stars show the solar or close to solar chemical composition of their atmospheres. Only a few percent of stars show significant deviations from the solar or scaled solar chemical composition. On the main sequence, these are metallic (Am) stars, magnetic peculiar (Ap) stars, mercury-manganese (HgMn) stars, and others. Many stars with anomalous chemical compositions were also found on the red giant branch. It becomes possible due to very informative spectra of these objects crowded by narrow spectral lines.

The investigations of abundance patterns in the atmospheres of giant stars is of particular interest. The direct observations of products of thermonuclear and nuclear synthesis. One of the most interesting groups of peculiar red giants are barium stars (BaII)- peculiar giants of G-K classes. These stars show the overabundances of carbon and s-process elements, the binarity is proven at least for majority of these stras. These features are found also in other groups of cool peculiar stars, maybe these groups are evolutionary connected.

It should be noted that these stars have relatively high temperatures and less complicated spectra. It makes possible the use of usually accepted methods (with minimum modifications) to find the chemical composition and model atmosphere parameters using high dispersion spectra. That is why the investigations of chemical abundance anomalies in barium stars are very important for the theory of stellar evolution and for theory of stellar nucleosynthesis.

In this dissertation research three individual stars and one group of stars were investigated. The first of the stellar objects is the barium star HD204075, which is a peculiar red giant with an increased abundance of barium, an excess of carbon and s-process elements. Most of the barium stars are the companions of binary stellar systems, which is also characteristic of many other types of cold peculiar stars and, possibly, can be explained by the features of the evolution of binary stars.

The second object is V1719 Cyg. A special place in stellar astrophysics is rightfully occupied by variable stars with anomalies in the abundance of chemical elements in their atmospheres, in particular, pulsating stars of the δ Scuti type. Their luminosities, radii and temperatures change due to radial and non-radial pulsations. Periods are relatively stable on a multi-year time scale, but amplitude variations can be observed.

The third object is the red giant HD47536 belonging to the halo or intermediate population of the Galaxy. It is a single star with one or two detected planets in the constellation Canis Major at a distance of approximately 400 light-years (about 123 parsecs) from the Sun.

The group of 1149 F, G and K stars of luminosity class III in the Local Region was investigated using previously published abundance patterns. The study of these stars and the comparison with earlier results helps to understand the mechanism of energy transfer in the atmospheres of stars of spectral types B-K.

Therefore, in this dissertation research, a barium star, a star of the δ Scuti type, a planetary-host K-type giant belonging to the halo or intermediate population of the

Galaxy, and the group of F-K stars of luminosity class III in the Local region were investigated.

**The aim of this work** is to study the anomalies in the abundance of chemical elements in the atmospheres, determine the physical parameters and clarify the evolutionary status of various types stars in the Galaxy.

**Research objectives**

1. The review of studies of stars with anomalies in the chemical composition, analysis of modern methods and algorithms for investigations of stellar atmospheres and interstellar medium.

2. Initial processing and calibration of high resolution and high signal-to-noise ratio stellar spectra. We used of IRAF standard software and also developed the new codes.

3. Determination of the physical parameters of the studied stars ($T_{eff}$, log g, $v_{micro}$), identification of spectral lines and determination the abundance of chemical elements in their atmospheres using model atmospheres and synthetic spectrum methods.

4. Search for signs of matter accretion from the interstellar medium on the atmospheres of the studied stars and on the atmospheres of previously studied main sequence and red giant branch stars.

**Objects of study**: ζ Capricorni (HD204075), V1719 Cygni (HD 200925), and HD47536.

**Subject of study**: atmospheric parameters and chemical composition of stars of different spectral classes.

**Research methods:** high resolution spectra with a high signal-to-noise ratio were used. Effective temperatures $T_{eff}$, surface gravity log g, and microturbulent velocities $v_{micro}$ were calculated using the method proposed by Yushchenko et al., based on the analysis of iron abundances calculated from lines of neutral and ionized iron on a grid of model atmospheres. The synthetic spectrum method was used to calculate the chemical composition of stellar atmospheres.

**The main results of this dissertation:**

1 The anomalies in abundance pattern of young barium star HD204075 with parameters $T_{eff}$ = 5300±50 K, log g = 1.82±0.15, $v_{micro}$ = 2.52±0.10 km/s, logN(Fe) = 7.32±0.06 are due to the accretion of matter from evolved double companion.

2 The atmosphere of a variable star V1719 Cyg with a chemical composition of 28 elements were not subjected to accretion of hydrogen and helium from the interstellar medium.

3. The atmosphere of the star HD47536 contains 38 chemical elements, the abundance of which is due to charge exchange reactions occurring due to the accretion of matter from the interstellar medium.

**Scientific novelty**

1. Barium star HD204075 (ζ Cap). The atmospheric parameters were refined by modeling stellar atmosphere: $T_{eff}$ =5300±50 K, log g=1.82±0.15, $v_{micro}$=2.52±0.10 km/s, logN(Fe)=7.32±0.06. The absence of correlations between the relative abundances of chemical elements and their second ionization potentials

has been shown for the first time. It means that anomalies in the abundances of chemical elements in stellar atmosphere arose due to the accretion of matter from evolved binary companion.

2. Pulsating δ Scuti type star: V1719 Cyg. For the first time, the abundances of 28 chemical elements in its atmosphere were found using the synthetic spectrum method. It has been shown that the relative abundances of elements with atomic numbers Z>30 are increased. For the first time, the absence of accretion of interstellar gas, mainly hydrogen and helium, on the star's atmosphere has been proven.

3. Halo giant with planets HD47536. For the first time, the abundances of 38 chemical elements were found using the synthetic spectrum method. For the first time, correlations were found between the abundances of these elements and the second ionization potentials and condensation temperatures of these elements. For the first time, the abundance pattern of a star was explained by the interaction between the accretion of interstellar gas on the atmosphere, the dust-gas separation in the circumstellar envelope, and the enrichment of protostellar cloud by heavy elements.

4. For 1149 giant branch stars of spectral types F-K in the vicinity of the Sun the correlations of previously published relative abundances of chemical elements in their atmospheres on the second ionization potentials of these elements have been studied for the first time. A difference was found between these correlation coefficients for stars with convective and radiative energy transfer in the atmospheres.

**Theoretical and practical significance of the work**

The results of this work can be used to study the physical parameters and evolutionary status of the stars of the Galaxy and the Local Group of galaxies, to study the accretion of interstellar and circumstellar gas on stellar atmospheres, which will allow a deeper understanding of the evolution of stars and the creation of chemical elements in the Universe.

**Personal contribution of the author**

Processing and analysis of spectral observations, generalization of data, basic calculations of fundamental parameters ($T_{eff}$, log g, $v_{micro}$, and [Fe/H]) for barium star ζ Capricorni (HD204075), the δ Scuti type star V1719 Cyg, halo giant star with planets HD47536, and analysis of literature data. data on the abundances of chemical elements in the atmospheres of 1149 F-K giants in the vicinity of the Sun were performed by the applicant together with co-authors. Problem setting and discussion of the obtained results were carried out jointly with scientific consultants.

**Reliability of results**

The reliability of the results of the work is confirmed by the results of similar studies obtained by other authors and published in international scientific journals.

**Approbation of work**

Based on the materials of this dissertation, five papers were published. Three of them - in high-ranking journals included in the Thomson Reuters database, as well as in the international Scopus database.

1. Yeuncheol Jeong, Alexander Yushchenko, Vira Gopka, Volodymyr Yushchenko, Pakakaew Rittipruk, Kyung Sook Jeong, **Aizat Demessinova**. The Barium Star HD204075: Iron Abundance and the Absence of Evidence for Accretion // ***Journal of Astronomy and Space Sciences***. – 36 (3), P. 105-114, 2019. Quartile: Q3. DOI: https://doi.org/10.5140/JASS.2019.36.3.105

2. Alexander Yushchenko, Chulhee Kim, Yeuncheol Jeong, Dmytry N. Doikov, Volodymyr Yushchenko, Sergii V. Khrapatyi, **Aizat Demessinova**. The Chemical Composition of V1719 Cyg: δ Scuti Type Star without the Accretion of Interstellar Matter // ***Journal of Astronomy and Space Sciences***. – 37 (3), P. 157-163, 2020. Quartile: Q3. DOI: https://doi.org/10.5140/JASS.2020.37.3.157

3. Alexander Yushchenko, Seunghyun Kim, Yeuncheol Jeong, **Aizat Demessinova**, Volodymyr Yushchenko, Dmytry N. Doikov, Vira Gopka, Kyung Sook Jeong, Pakakaew Rittipruk. The Possible Signs of Hydrogen and Helium Accretion from Interstellar Medium on the Atmospheres of F-K Giants in the Local Region of the Galaxy // ***Journal of Astronomy and Space Sciences***. – 38 (3), P. 175–183, 2021. Quartile: Q3. DOI: https://doi.org/10.5140/JASS.2021.38.3.175

**Connection of the dissertation topic with the plans of scientific investigations**

The dissertation was carried out in accordance with the science research plan within the framework of the Fundamental Research Programs of the Ministry of Science and Higher Education of the Republic of Kazakhstan of grant funding for young scientist's research under the «Zhas Galym» project, IRN AR14972694 "Influence of the interstellar medium and circumstellar shells on the evolution of stars."

**The structure and scope of the dissertation**

The dissertation consists of an introduction, five sections, a conclusion, a bibliography and an appendix. The work is presented on 110 pages of 90 typewritten text pages, illustrated with 31 figures, 14 formulas, and 7 tables. The list of references contains 151 items, the appendix - 15 pages.