ABSTRACT

of the research work for the Doctor of Philosophy (PhD) degree by educational program “8D05307 – Physics and Astronomy”

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Physical parameters of selected stars with the B[e] phenomenon

General characteristic of the work

This work presents studies of two selected stars with B[e] phenomena of different nature, MWC 645 and HD 327083, which are at different stages of evolution. The main criterion for selecting these stars in one research work is their observed distributions in the spectrum, from which it follows that these objects are surrounded by envelopes containing warm circumstellar dust.

MWC 645 is a V~13.0 mag star located in the northern hemisphere. Another object of study is the star HD 327083, located in the southern hemisphere, whose magnitude is V~9.6-10.1 mag. In this work based on the material of multicolor photometry of both the stars themselves and stars from their surroundings, as well as high-resolution spectra were determined the main physical parameters of the researching systems. As a result of the analysis of the data, were concluded about the nature and evolutionary status of the objects of study.

The main result of the study of the star MWC 645 is the identification in the optical spectrum of a number of weak absorption lines of neutral metals, which indicate the presence of a cold component in this system. Another important result is the explanation of the observed properties of MWC 645, proposed by the evolutionary model of a close binary system, in which is currently taking place a non-conservative transfer of matter between stars of intermediate mass.

The main result of the study of the star HD 327083 is the discovery of an orbital period of 107.68 days, which was calculated both from the variability of the position of the spectral lines and from the visual light curve, as well as the determination of a new set of fundamental parameters of the system.

Relevance of the topic

Stars and stellar systems of all masses go through periods when objects are surrounded by large amounts of circumstellar matter in the form of gas and dust. These stages of evolution have different durations, which mainly depend on the mass of objects and the distance between the components in the case of binary systems. The reasons for the presence of circumstellar matter are associated with the formation of stars in molecular clouds, stellar winds, and mass transfer between components in close systems**.**

Stars with the B[e] phenomenon are a known member of the above mentioned stage of evolution in which dust is present. These objects are of great interest from the point of view of many unsolved problems of modern stellar astrophysics, including:

● problem of classification - selection of the observed characteristics of a certain class of objects;

● determination of the physical parameters of stars and their circumstellar envelopes;

● the problem of determining the evolutionary status of a star.

The last one is connected with conflicting opinions about the nature of some objects with the B[e] phenomenon. This is primarily due to the fact that stars with the B[e] phenomenon can be divided into two large subclasses according to the time of dust formation: current and formation at previous stages of evolution. This division was proposed by professor Miroshnichenko Anatoly in 2007. As a result of this, a group consisting of galactic stars was identified and named objects of the FS CMa type and supergiants with the B[e] phenomenon. The main criterion for selecting these stars in the general group is their observed distributions in the spectrum, from which it follows that these objects are surrounded by dust particles located at small distances from the central stars in these systems. At the same time, the most probable scenario for the formation of these objects, supported by the obtained data is the evolution of a close binary system, which undergoes a strong transfer of matter due to the filling of its Roche lobe with a more massive and rapidly evolving component, which ultimately leads to the removal of matter into the circumstellar medium, which, ultimately contributes to the formation of dust in the Galaxy, as well as to the formation of a dust envelope, usually disk-shaped, around a binary system.

At the moment, this group is new and includes about 100 stars for which there are a number of questions, primarily related to understanding their nature and evolutionary status. Therefore, a detailed study of each object is necessary. The main direction in these studies is the determination of the physical parameters of systems that give a basic representation of the stars.

The aim of the work is a comprehensive study of selected stars with the B[e] phenomenon MWC 645 and HD 327083.

The tasks of research

1. Processing and analysis of spectral and photometric data of the objects of study.

2. Based on the analysis of spectral and photometric data, determine the main fundamental parameters of the stars MWC 645 and HD327083.

3. Draw conclusions about the nature and evolutionary status of the objects of study based on their observational manifestations.

Objects of study: stars with the B[e] phenomenon: MWC 645 and HD327083.

Research methods:

1. Obtaining and collecting photometric and spectral (high resolution) data of the objects of study.

2. Reduction and analysis of the observational material using the IRAF software.

3. Use of evolutionary models of non-conservative mass transfer between components in close binary systems.

Basic provisions for defense

1. The object MWC 645 with the B[e] phenomenon is a binary system consisting of a star of spectral class B and a cold component, with absorption lines of neutral metals (LiI, CaI, FeI, TiI, etc.) in the optical spectrum.

2. Strong emission lines (I/Ic ~ 194 and ~384 for Hα) in the spectrum of MWC 645 evidence to the ongoing transfer of matter ($\sim 2 \times 10^{-4} M_{\odot}$ yr^{-1}) between the components of the system, for which an evolutionary model of close a binary system with non-conservative mass transfer, initial component masses of 7.0 $M_{\odot}$ and 2.8 $M_{\odot}$, and an initial orbital period of 15 days.

3. Based on the results of a study of the variability of the positions of spectral lines and the visual light curve, it was determined for the first time that the orbital period of the binary system HD 327083 is 107.68±0.02 days.

The novelty of the work

The novelty of the research work is that:

1) In the spectrum of the star MWC 645, for the first time were identified a number of weak absorption lines of neutral metals (for example, LiI 6708 Å, CaI 6717 Å and a number of FeI and TiI lines) indicating the presence of a cold component in the system.

2) Based on the evolutionary models of binary systems, it was concluded that there is a strong transfer of matter between the components of the MWC 645 system.

3) For the first time was determined the orbital period of 107.68±0.02 days based on the analysis of photometric and spectroscopic data obtained for the star HD 327083.

4) Based on the material of multicolor photometry, both of the stars themselves and of stars from their vicinity, as well as high-resolution spectra and the Gaia EDR3 distance were determined the main fundamental parameters of the study systems.

Theoretical and practical significance of the work

The results obtained in the research work can be applied to study the causes of dust formation, the nature and evolution of stars, as well as the Galaxy as a whole.

Reliability and validity of obtained results

The results and conclusions of the study reflect the content of all sections and are confirmed by publications in peer-reviewed international and native scientific journals. The reliability of the scientific conclusions of this work is confirmed by consistency with theoretical models, conclusions about the nature of similar objects, with the results of independent studies and conclusions obtained by other authors.

Author's personal contribution

Computer analysis and processing of spectral and photometric observations were performed by the author. Problem setting and discussion of the obtained results were carried out jointly with scientific consultants.

Publications

The main results contained in the research work were published in 11 scientific papers, of which:

Articles with a high impact factor in the Thomson Reuters database or in publications included in the international scientific database Scopus:

1. **Nodyarov, A. S.,** Miroshnichenko, A. S., Khokhlov, S. A., Zharikov, S. V., Manset, N., Klochkova, V. G., Grankin, K. N., Arkharov, A. A., Efimova, N., Klimanov, S., Larionov, V. M., Rudy, R. J., Puetter, R. C., Perry, R. B., Reva, I. V., Omarov, C. T., Kokumbaeva, R. I. Toward Understanding the B[e] Phenomenon. IX. Nature and Binarity of MWC 645 //The Astrophysical Journal. – 2022. – Т. 936. – №. 2. – С. 129.(**Q1**)

2. Miroshnichenko, A. S., Zharikov, S. V., Manset, N., Khokhlov, S. A., **Nodyarov, A.S.,** Klochkova, V. G., Danford, S., Kuratova, A. K., Mennickent, R., Chojnowski, S. D., Raj, A., Bisht, D. Recent Progress in Finding Binary Systems with the B[e] Phenomenon //Galaxies. – 2023. – Т. 11. – №. 1. – С. 36. (**Q2, review**)

3. **Nodyarov, A. S.,** Miroshnichenko, A. S., Khokhlov, S. A., Zharikov, S. V., Agishev, A. T., Gabitova, I. A., Vaidman, N. L., Manset, N. Properties of Galactic B[e] Supergiants. X. Refined Orbit and Fundamental Parameters of the HD 327083 Binary System //The Astrophysical Journal. – 2024. – Т. 968. – №. 2. – С. 52. .(**Q1**)

Articles in publications recommended by the CQASES of the Ministry of Education and Science of the Republic of Kazakhstan:

1. A.S. Nodyarov, S.A. Khokhlov. IRAS 22023+5249 zhane IRAS 22150+6109 zhuldyzdarynyn evolutsiyalyk dengeyin anyktau.// Journal of PEOS. - Almaty. -p. 16. V1/ 2020

Publications in collections of abstracts of reports:

1. Nodyarov A.S. B[e] PHENOMENY BAR MWC 645 ZhULDYZY.// International scientific conference of students and young scientists, "FARABI ALEMI". - Almaty. - 2020. - p. 300.

2. Nodyarov A.S. NATURE AND SPECTRAL ANALYSIS OF THE B-TYPE STAR MWC 645.//International scientific conference of students and young scientists, "FARABI ALEMI". - Almaty. - 2021. - p. 210.

3. Nodyarov A.S. HIGH RESOLUTION SPECTROSCOPY OF B[e] STAR MWC 645.// International scientific conference of students and young scientists, "FARABI ALEMI". - Almaty. - 2022. - p. 207.

4. Nodyarov A.S. STUDY OF THE GALACTIC SUPERGIANT HD 327083.// International scientific conference of students and young scientists, "FARABI ALEMI". - Almaty. - 2023. - p. 180.

In foreign international conferences:

1. **Nodyarov A. S.,** Khokhlov, S. A., Miroshnichenko, A. S., Manset, N., Zharikov, S. V., Klochkova, V. G., Chentsov E. L., Arkharov A. A., Larionov, V. M. Nature and spectral variations of the B-type emission-line object MWC 645 // International conference OBA Stars: Variability and Magnetic Fields.Saint

Petersburg State University, Saint Petersburg, Russia, April 26–30, – 2021. – C. 18.

2. **Nodyarov A. S.,** Miroshnichenko, A. S., Khokhlov, S. A., Zharikov, S. V., Manset, N., Klochkova, V. G., & Usenko, I. A. High-Resolution Spectroscopy of the B[e] Star MWC 645 //Odessa Astronomical Publications. – 2021. – T. 34. – C. 59-64.

3. **Nodyarov A. S.,** Miroshnichenko, A. S., Khokhlov, S. A., Zharikov, S. V., Manse, N., & Usenko, I. A. Refined Physical Properties of the HD327083 Binary System //Odessa Astronomical Publications. – 2022. – T. 35. – C. 62.

Approbation of work

The results obtained in the research work were reported and discussed:

– at the International scientific conference of students and young scientists "Farabi alemi" (2020, 2021, 2022, 2023 Almaty, Kazakhstan);

– at the 21st and 22nd Gamow International Conference on Astronomy "Astronomy and beyond: Astrophysics, Cosmologyand Gravitation, Astroparticle Physics, Radioastronomy and Astrobiology" (2021, 2022, Odessa, Ukraine);

– at the International Scientific Conference "OBA Stars: Variability and Magnetic Fields (STARS-2021)" (2021, St. Petersburg, Russia).

The connection of the research work topic with the plans of scientific work

The research work was completed in accordance with the plans of fundamental research works of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan "Grant financing of scientific research" on the topic: "AP08856419 - Observational manifestations of accretion flows in close binary star systems and their analysis by computer modeling methods" and "AP19578879 - Study of observational manifestations of FS CMa type stars by computer modeling methods"