ANNOTATION

to the dissertation submitted for the degree of Doctor of Philosophy (PhD) in the educational program «8D05307 – Physics and Astronomy»

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Physical parameters and Nature of the Star MWC 342 with the B[e] Phenomenon

General Characteristics of the Work. The present dissertation is devoted to the study of the emission-line star MWC 342, which exhibits the B[e] phenomenon. The B[e] phenomenon represents a set of spectral and photometric characteristics observed in B-type stars, which display strong forbidden emission lines (denoted by "[e]") and an excess of infrared radiation. These features are associated with the presence of dense, inhomogeneous circumstellar gas and dust, often arranged in the form of a disk or ring. The main characteristics of the B[e] phenomenon include the presence of forbidden lines such as [O I], [Fe II], and others; strong hydrogen emission lines (the Balmer series); a pronounced infrared (IR) excess originating from hot dust; and a complex circumstellar structure consisting of a disk, envelope, and outflows.

The star MWC 342, with an apparent magnitude of approximately 10.0, is located in the Cygnus constellation and was first identified due to its intense hydrogen emission line. In addition, a strong infrared excess has been detected in MWC 342.

Within the framework of this research, photometric and spectroscopic data obtained at various observatories were collected and analyzed. In addition, data from open databases, including APASS DR10, ASAS-SN, INTEGRAL, and KWS, were processed. As a result, observational data for the star MWC 342 covering the period from 1985 to 2025 were compiled.

The second chapter of this dissertation presents a description of the collected observational data and indicates the sources from which they were obtained. Furthermore, the methods used for the analysis of the acquired data are described in detail.

During the course of this study, the principal characteristics of the star MWC 342 were determined. Based on the analysis performed, it can be concluded that the object demonstrates signs of a complex circumstellar envelope structure. The variability of the star's light curve does not follow strictly periodic laws but instead exhibits long-term quasi-periodicity. In addition, an anticorrelation was found between the brightness variability and the variability of the equivalent widths of the Hα line. The spectral energy distribution (SED) was constructed up to 160 μm, revealing a sharp decline in flux at longer wavelengths.

For the first time, the luminosity of MWC 342 has been refined using updated Gaia DR3 data together with a new model of interstellar extinction, which made it possible to exclude its classification as a young stellar object and to revise the evolutionary status of the object.

The comprehensive analysis of the observational data has shown that MWC 342 remains one of the representative objects of FS CMa-type stars with the B[e]

phenomenon and constitutes a valuable target for studying the processes of interaction between a star and its circumstellar environment. The combination of the observed characteristics makes MWC 342 an important astrophysical laboratory for investigating the late evolutionary stages of intermediate-mass stars and the formation of complex circumstellar matter structures.

Relevance of the Research Topic

The study of the physical nature and evolutionary stages of stars is one of the key areas of modern astrophysics, as stars determine the energy balance and chemical evolution of galaxies. Objects exhibiting the B[e] phenomenon are of particular interest, as they are characterized by complex circumstellar environments, emission lines, and an infrared excess, indicating the presence of gas and dust.

One of the least studied representatives of this group is the star MWC 342, which is classified as a member of the FS CMa subclass. Its physical nature and evolutionary status remain a subject of debate: in different years the object has been classified as a Herbig Ae/Be star, a binary system, or an irregular variable. Modern spectroscopic and photometric data indicate that MWC 342 most likely belongs to the FS CMa group; however, the mechanisms responsible for its variability, mass loss, and the formation of its circumstellar disk have not yet been fully established.

The relevance of this research is determined by the need to refine the physical parameters of the star, to analyze its long-term variability, and to study the dynamics of its emission lines. Comprehensive long-term observations make it possible to reveal quasi-periodic variations in brightness and spectral characteristics, indicating the presence of unstable processes in the circumstellar environment.

Thus, the study of MWC 342 is important not only for determining its individual nature but also for understanding the mechanisms of mass loss, disk formation, and the evolution of stars exhibiting the B[e] phenomenon in general.

Research Objective

The objective of this work is a comprehensive study of the emission-line star MWC 342 exhibiting the B[e] phenomenon, as well as the refinement of its physical parameters and evolutionary status based on modern spectroscopic and photometric measurements.

Research Tasks

1. To analyze photometric observations of MWC 342 in order to identify long-term quasi-periodic variability of its optical brightness and to establish a relationship between brightness variations and the equivalent width of the Hα line.
2. To construct and investigate the spectral energy distribution (SED) of the star over a wide wavelength range (from the optical to the far-infrared) in order to determine the nature of the dust component and to test for the presence of cold dust in the system.
3. To apply the information-entropy method to the analysis of the Hα line profile in order to explain the nature of its formation.

Objects of Research: An emission-line star in the spectrum, MWC 342, exhibiting the B[e] phenomenon.

Subject of Research: The observational spectral and photometric properties of the emission-line star MWC 342 with the B[e] phenomenon, their temporal

variability, and the information-entropy parameters reflecting the physical conditions and dynamics of the circumstellar envelope.

Research Methods

1. The method of photometric and spectroscopic analysis for investigating the observational characteristics of the star MWC 342.
2. The method for analyzing photometric variability and spectral line parameters using IRAF and Python to study brightness variations and spectral properties.
3. The method of spectral energy distribution (SED) modeling to determine the physical parameters of the circumstellar environment of MWC 342.
4. The analysis of the relationship between variations in optical brightness and the equivalent width of the Hα line to compute correlation dependencies between photometric and spectral variations.
5. The method for determining luminosity using data from Gaia DR3 and interstellar extinction maps to refine the star's position on the evolutionary diagram.
6. The method of conditional information-entropy analysis for diagnosing the physical conditions and dynamics of the circumstellar envelope.

Main Provisions Submitted for Defense

Provision 1: The star MWC 342 exhibits photometric brightness variability accompanied by systematic changes in the profiles of hydrogen emission lines (Hα, Hβ), which are caused by the non-stationary nature of the gaseous disk-like circumstellar material.

Provision 2: The absence of ionized helium (He II) lines in the stellar spectrum indicates the lack of high-temperature regions in its immediate environment, which is consistent with the results of the updated spectral energy distribution (SED), determining the star's effective temperature at a lower level of approximately ~20,000 K.

Provision 3: The conditional information-entropy value, defined as the difference between the phase-space entropy H(X,Y) and the conditional entropy H(Y|X, Y = Y(Ẋ)), ($\tilde{I}$ = 0.806), corresponds to a transitional regime between deterministic and stochastic states, indicating the complex nature of the formation of the spectral line profile.

Scientific Novelty of the Work

1. For the first time, a long-term component of quasi-periodic brightness variability (~20 years) has been identified in the star MWC 342, along with its correlation with the variability of the equivalent width of the Hα emission line, indicating changes in the density of the circumstellar material.
2. For the first time for this object, the absence of ionized helium (He II) lines has been considered in conjunction with the updated spectral energy distribution (SED), which allowed the determination of the star's effective temperature at a lower level (~20,000 K), excluding the presence of high-temperature regions in its immediate environment.
3. For the first time, an information-entropy approach has been proposed and tested for analyzing the Hα line profile, enabling a quantitative diagnosis of

transitional dynamic regimes of the radiating medium based on the normalized mutual information of the phase space.

Theoretical Significance of the Work

The work expands our understanding of the nature of B[e] phenomenon stars of the FS CMa type, to which MWC 342 belongs. The newly identified long-term quasi-periodicity in photometric variations and its correlation with changes in the intensity of the Hα line provide deeper insight into the dynamics of dense structures in the circumstellar environment and the mechanisms of interaction between the star and its gas-dust surroundings. The refined parameters of luminosity and the spectral energy distribution (SED) contribute to a more precise classification of the object and clarification of its evolutionary status, thereby advancing the theory of late evolutionary stages of intermediate-mass stars.

Practical Significance of the Work

The results obtained can be applied in the interpretation of observational data of other stars exhibiting the B[e] phenomenon and in the development of models for their dust-gas envelopes. The methods of photometric and spectroscopic data processing and analysis used in this study can be employed in future observational and theoretical investigations of stars showing signs of instability and interaction with circumstellar matter.

Author's Personal Contribution

The author independently carried out the analysis and processing of the observational data. The formulation of the research objectives, the definition of tasks, and the interpretation of the obtained results were conducted with consultative support from the scientific supervisors.

Reliability of the Results

The reliability of the obtained results is ensured by the use of modern and well-established methods for processing and analyzing astronomical data, as well as by the application of independent observational data sources. The accuracy of the photometric and spectroscopic data is confirmed by their consistency with published results from previous studies.

The use of statistical methods and the repeated verification of calculations with specialized software packages, such as IRAF and Python, ensure the reproducibility and objectivity of the conclusions.

The agreement of the derived parameters of luminosity and spectral energy distribution (SED) with independent estimates for similar objects confirms the correctness of the applied approaches and the validity of the research findings.

Approval of the Work

Based on the results of the present dissertation, two scientific articles have been prepared and published in high-impact journals included in the Thomson Reuters database or indexed in the international scientific database Scopus:

- Akniyazova A. Z., Miroshnichenko, A. S., Zharikov, S. V., Van Winckel, H., Manset, N., Raj, A., Chojnowski S.D., Khokhlov S. A., Reva R. I., Kokumbaeva R. I., Omarov Ch. T., Grankin K. N., Agishev A.T. & Vaidman, N. L. A Spectroscopic and Photometric Study of MWC 342 and Its B [e] Phenomenon over the Last 40 Years //Galaxies. – 2025. – V. 13. – No. 3. – p. 63.

https://doi.org/10.3390/galaxies13030063 **(Journal Impact Factor -3.8, WoS - Q2, Scopus -74).**

- Zhanabaev Z., Akniyazova A. Z., Ashimov Ye. K. Information–Entropy Analysis of Stellar Evolutionary Stages with Application to FS CMa Objects //Entropy. – 2025. – V. 27. – No. 11. – p. 1106. https://doi.org/10.3390/e27111106 **(Journal Impact Factor -2.0, WoS - Q2, Scopus -81).**

Connection of the Dissertation Topic with Scientific Research Plans

The dissertation was carried out within the framework of the fundamental research plans of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan under the program "Grant Financing of Scientific Research", specifically under the following projects: BR24992807 – *"Development of the Kazakh Digital Environment for Astronomical Studies of Near- and Deep-Space Objects within the Framework of the International Virtual Observatory Network"* (2024–2026); BR24992759 – *"Development of the Concept for the First Kazakh Orbital Near-Moon Telescope – Stage I"* (2024–2026); AP23484898 – *"Development of a Modern Methodology for Determining the Fundamental Parameters of Galactic Hot Supergiants"* (2024–2026).

Structure and Volume of the Dissertation

The dissertation consists of an introduction, a section on "Definitions, Designations, and Abbreviations of Terms", three chapters, a conclusion, a list of references, and five appendices. The total volume of the work is 103 pages of typed text. The research materials are illustrated with 31 figures, supplemented by 7 tables. The list of references includes 91 sources.