

## ABSTARCT

of dissertation for the Doctor of Philosophy (PhD) degree by specialty  
“6D061100 – Physics and Astronomy”

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### **Photometric and spectral regularities of FS CMa type hot stars**

#### **General Performance Characteristics**

Present work is devoted to development of photometric criteria of searching for FS CMa type hot stars and spectrophotometric studies of two objects of this type HD 45677 and AS 78.

#### **Theme actuality**

B [e] phenomenon is the combination of permitted and prohibited emission lines in the spectra of stars of spectral class B and excess infrared (IR) radiation explained by the emission of circumstellar dust.

Among the stars with the B[e] phenomenon, a large group has recently been identified (~100 objects to date) showing strong emission lines of permitted and forbidden transitions and IR excess associated with the emission of dust close to a hot star. The stars of this group were named FS CMa objects by the designation of the prototype star.

The strength of emission lines in the spectra of these objects cannot be explained by the evolutionary loss of matter by single stars having luminosities from ~ 300 to ~ 30,000 luminosities of the Sun observed in objects of the FS CMa type. Energy distribution in IR excess suggests the emergence of circumstellar dust during the evolution of objects, and not residual dust from the protostar cloud. These properties of FS CMa type objects enable us to hypothesize that these are binary systems in which the transfer of matter between stellar components occurs or occurred. Part of the transferred substance forms a circumstellar envelope. Long-term spectroscopic and photometric observations are required to examine this hypothesis.

Along with the above, the evolutionary status of the star HD 45677 (FS CMa) is not exactly clarified. The authors of several studies assign it the status of an object that is at the stage before the Main Sequence, however, observational data indicate an advanced stage of evolution, so this issue is still open.

Based on the above, the main direction of this dissertation study on the topic “**Photometric and spectral regularities of FS CMa type hot stars**” was highlighted, which is devoted to determining the physical parameters and evolutionary status of hot stars with B[e] phenomenon.

**The aim of the work** is to develop photometric criteria and search of new objects in FS CMa group; to determine the nature and evolutionary status of two objects showing phenomenon B[e]: HD 45677 (FS CMa) and AS 78; investigation of series of spectral and photometric observations of these objects.

#### **The objectives of research**

1. Development of photometric search criteria for objects of FS CMa type;

2. Determination of physical parameters of HD 45677 (FS CMa) and AS 78 objects;
3. Determination of the evolutionary status of HD 45677 (FS CMa) and AS 78;
4. Examining the binarity hypothesis of HD 45677 (FS CMa) and AS 78.

**Objects of the study:** FS CMa type hot stars with B[e] phenomenon.

**The subject of the study:** the nature of B[e] phenomenon occurrence in FS CMa type objects.

**Methods of research:** Studies have been carried out by photometry and spectroscopy in the optical spectrum over the past 20-30 years.

Photometric observations were performed at: 1-m telescope FAI TSAO (Kazakhstan) – 8 (FS CMa), 6 – (AS 78); 0.81-m Dark Sky Observatory Telescope (DSO, Appalachian State University, NC, USA) – 1; observations from ASAS-SN (2014-2021), ASAS-3 (2003-2010) surveys.

Spectral observations were obtained on the following observatories: 0.81-m – Three College Observatory (NC, USA) – 68; 2-m – San Pedro Martir observatory (SPM, Universidad Nacional Autónoma de México) – 50; 3.6-m – Canada-France-Hawaii Telescope (Mauna Kea Observatory, Hawaii) – 16; 2.7-m – McDonald observatory (USA) – 11; 2-m – Himalayan Chandra Telescope (India) – 2; 1.5-m – Apache Point Observatory, New Mexico, USA – 1.

Processing and analysis were performed using standard IRAF, Maxim DL, SAO Image DS9, Xmgrace, Excel packages.

#### **Basic Provisions for Defense**

1. Photometric criteria based on (B-V), (V-K), (J-K), K – [12] color indexes make it possible to identify new candidates for FS CMa type objects, in the spectrum of which both permitted and forbidden emission lines and excess infrared radiation are present.

2. The luminosities of HD 45677 and AS 78 are  $9 \cdot 10^{29}$  W and  $3,1 \cdot 10^{30}$  W, respectively, indicating that the objects are on evolution stage after the Main Sequence in the Hertzsprung-Russell diagram and are not young stars.

3. The peak ratio of hydrogen line profiles in the spectrum of the HD 45677 star varies with a period of 184 days, and the position of Si II photospheric line and the optical brightness of AS 78 object change with a period of 120 days, indicating that they are binary star systems.

#### **Novelty of the work**

The novelty and originality of the dissertation work lies in the fact that for the **first time** in it:

1) Photometric criteria of search criteria for candidates for the group of FS CMa type objects have been developed, based on them 25 new objects showing B[e] phenomenon have been discovered;

2) Analysis of photometric and spectroscopic observations of FS CMa stars: HD 45677 and AS 78 at 20-30 years' time scale was carried out, which made it possible to establish the evolutionary status of the objects under study;

3) A change in the peak ratio of hydrogen line profiles in the spectrum of HD 45677 star, additionally, a change in the position of the photosphere line Si II 5056 Å and the optical brightness of AS 78 object were determined.

### **Theoretical and practical significance of the work**

The results obtained in the work can be used by specialists of astronomical research laboratories, for the activities of teachers, doctoral students, undergraduates and students of higher educational institutions, physics teachers and students of general education schools. The developed new methods of sampling objects with signs of substance transfer were tested during the educational process, introduced into special courses of bachelor's, master's and doctoral studies of the specialty "Physics and Astronomy" at the Physics and Technology Faculty of Al-Farabi KazNU.

The practical benefit of the results obtained in the dissertation is that the new results of observations make a significant contribution to the international database of experimental data, on a national and international scale is determined by the orientation of research data to solve urgent problems of observational astrophysics, observations and their interpretation are important for understanding the mechanisms of formation of stars with a gas-dust envelopes, the formation of dust near hot stars, which ultimately leads to an understanding of the formation of the Universe.

### **Reliability and validity of obtained results**

The results and conclusions obtained during the study reflect the content of all sections and are confirmed by publications of the main scientific results in peer-reviewed international and domestic scientific publications. The validity of the scientific conclusions of the work is confirmed by consistency with the results of independent studies and the conclusions obtained by other authors.

### **Author's personal contribution**

Spectral observations of 2018 were obtained by the author during a research internship at the 0.81-meter telescope of the Three College Observatory, controlled by the University of North Carolina Greensboro (UNCG, USA). Part of photometric observations (2017, 2019) were obtained by the author at the 1-m telescope of the Tien-Shan Astronomical Observatory (TSAO) of Fesenkov V.G. Astrophysical Institute (FAI, Kazakhstan).

Processing and analysis of spectral and photometric observations were performed by the author. Objective setting and discussion of the results were carried out jointly with scientific consultants.

### **Publications**

Main results contained in the dissertation were published in 11 scientific papers, of which:

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

1. Khokhlov S.A., Miroshnichenko A.S., Kusakin A.V., Zharikov S.V., Kuratov K.S., **Kuratova A.K.** et al. Toward Understanding the B[e] Phenomenon. VII. AS 386, a Single-lined Binary with a Candidate Black Hole Component // *Astrophysical Journal*. – 2018. – Vol.856. – № 2. – P.158 (**IF=5.58**)

2. Miroshnichenko A.S., Danford S., Zharikov S.V., Zakhochay O.V., **Kuratova A.K.** et al. Properties of Galactic B[e] Supergiants: V. 3 PUP – Constraining the Orbital Parameters and Modeling the Circumstellar Environments // *Astrophysical Journal*. – 2020. – Vol.897. – №1. – P.48. (**IF=5.75**)

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

1. Manapbaeva A.B., **Kuratova A.K.**, Kuratov K.S., Alimgazinova N.S., Komesheva T., Demesinova A.M., Naurzbaeva A.Z., Kyzgarina M.T. Zhas zhuldyzdar spektrlerindegi energiya taraluyn baqylau zhane modeldeu // Bulletin of KazNU. Ser. physical – 2019. - № 2(69). - pp.17-26.

*Publications in collections of abstracts of reports:*

1. Manapbaeva AB, Demesinova AM, **Kuratova A.K.** MWC 342 zhas zhuldyzyn zertteu // Mat. Intern. scientific conf. stud. and young scientists “Farabi Alemi” - Almaty. - 2019. - P. 270.

2. Tileukulova A.K., **Kuratova A.K.**, Perdebaeva M.N. Photometric studies of a star with B [e] phenomenon IRAS 20090 + 3809 // Mat. Intern. scientific conf. stud. and young scientists “Farabi Alemi” - Almaty. – 2019. - P. 287.

3. Demesinova A.M., Manapbaeva A.B., **Kuratova A.K.**, Bazarova G.A. Study of the evolution of binary systems of intermediate masses // Mat. Intern. scientific conf. stud. and young scientists “Farabi Alemi” - Almaty. - 2019. - P. 252.

*In international conferences:*

1. **A. K. Kuratova**, A. S. Miroshnichenko, K. S. Kuratov, A. Zh. Naurzabayeva, N. Sh. Alimgazinova, and A. B. Manapbayeva. A Search for New Objects with the B[e] Phenomenon // The B[e] Phenomenon: Forty Years of Studies ASP Conference Series, Astronomical Society of the Pacific, Vol. 508, Prague, Czech Republic, 2017. – pp. 229-232.

2. **Kuratova Aizhan K.**, Miroshnichenko Anatoly S., Kusakin Anatoly V., Zharikov Sergei V. et al. Spectroscopic monitoring of the B[e] objects FS CMa and MO Cam // Odessa Astronomical Publication, Vol.32, Ukraine, 2019. – pp.63-65.

3. Khokhlov, S.A., Miroshnichenko, A.S., Kusakin, A.V., **Kuratova, A.K.**, Zharikov, S.V., Zakhochay, O.V., et al. The Emission-Line Dusty Object IRAS 07080+0605, a Less Evolved Example of the Red Rectangle // Odessa Astronomical Publication, Vol.33, Ukraine, 2020. – pp.141-146.

4. D. Korčáková, A. S. Miroshnichenko, F. Sestito, S. V. Zharikov, N. Manset, V. Votruba, M. Šlechta, S. Danford, P. Kroupa, A. Raj, N. Dvoráková, S. A. Khokhlov, A. V. Kusakin, I. V. Reva, R. I. Kokumbaeva, Ch. T. Omarov, S. D. Chojnowski, N. Sh. Alimgazinova, A. Zh. Naurzabayeva, **A. K. Kuratova**. The First Detection of a Strong Magnetic Field in a FS CMa Star // International conference OBA Stars: Variability and Magnetic Fields (STARS-2021), Saint Petersburg State University, Saint Petersburg, Russia, April 26–30, 2021. – p.43.

5. A. S. Miroshnichenko, N. Sh. Alimgazinova, A. Zh. Naurzabayeva, **A. K. Kuratova**, S. V. Zharikov, N. Manset, A. Raj. A New Search for Galactic Objects with the B[e] Phenomenon // International conference OBA Stars: Variability and Magnetic Fields (STARS-2021), Saint Petersburg State University, Saint Petersburg, Russia, April 26–30, 2021. – p.48.

*Aprobation of work*

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

– at the International Scientific Conference “The B[e] Phenomenon: Forty Years of Studies” (2017, Prague, Czech Republic);

- at the International Scientific Conference of Students and Young Scientists “Farabi Alemi” (2019 Almaty, Kazakhstan);
- at the 6th and 20th Gamow International Conference “New Trends in Cosmology, Astrophysics and HEP after Gamow” and “Astronomy and beyond: Astrophysics, Cosmology and Gravitation, High Energy Physics, Astroparticle Physics, Radioastronomy and Astrobiology” (2019, 2020, Odessa, Ukraine);
- at the International Scientific Conference “OBA Stars: Variation and Magnetic Fields (STARS-2021)” (2021, St. Petersburg, Russia).

#### **The connection of dissertation topic with the plans of scientific works**

The dissertation work was carried out within the framework of targeted programs for fundamental research of the Ministry of Education and Science of the Republic of Kazakhstan, funded from the state budget:

1. “F.0679 – Astrophysical Studies of Stellar and Planetary Systems” the project “Studies of Mass Loss and Dust Formation near Hot Stars” (2015-2017);
2. “F.0795 – Studies of physical processes in extragalactic and galactic objects and their subsystems” the project “Study of evolution of intermediate masses binary systems” (2018-2020);
3. “G.2013 – Study of fundamental problems of modern physics as the basis of industrial and innovative development of the Republic of Kazakhstan” project “Photometric and spectral studies of hot stars” (2016).

#### **Scope and structure of the dissertation**

The dissertation work consists of an introduction, 3 sections, a conclusion and a list of used sources of 91 titles, contains 111 pages of basic computer text, including 59 figures, 8 formulas and 10 tables.