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թեկնածուի գիտական աստիճանի հայցման ատենախոսության

ԲՅՈՒՐԱԿԱՆ - 2021

NAS RA BYURAKAN ASTROPHYSICAL OBSERVATORY AFTER V. AMBARTSUMIAN

ANDREASYAN HASMIK

THE INVESTIGATION OF YOUNG ERUPTIVE STARS

SYNOPSIS

A thesis submitted in fulfillment of the requirements for the degree of
Doctor of Philosophy in specialization
01.03.02 - Astrophysics and Radioastronomy

BYURAKAN - 2021

Ատենախոսության թեման հաստատվել է Վ. Համբարձումյանի անվան Բյուրականի աստղադիտարանի (ԲԱ) գիտական խորհրդում:
Գիտական ղեկավար՝ ֆ. մ. գ. դ. Մաղաքյան Տիգրան Յուրիի
Պաշտոնական ընդդիմախոսներ՝
ֆ. մ. գ. դ. Սահարյան Արամ Ազատի
ֆ. մ. գ. թ. Գիգոյան Կամո Սերյոժայի
Առաջատար կազմակերպություն՝ Շտեռնբերգի անվան աստղագիտական ինստիտուտ, Մոսկվայի պետական համալսարան:
Պաշտպանությունը կայանալու է 2021 թ. հուլիսի 27-ին ժամը 13:00-ին, ՀՀ ԳԱԱ Բյուրականի աստղադիտարանում գործող ՀՀ ԲՈԿ-ի «Աստղագիտություն» 048 մասնագիտական խորհրդի նիստում (0213, Բյուրական, Արագածոտնի մարզ):
Ատենախոսությանը կարելի է ծանոթանալ ՀՀ ԳԱԱ Բյուրականի աստղադիտարանի գրադարանում:
Սեղմագիրն առաքված է 2021 թ. հունիսի 14-ին:

Մասնագիտական խորհրդի գիտական քարտուղար՝

ֆ. մ. գ. թ. Ե. Հ. Նիկողոսյան

The subject of the dissertation is approved by the scientific council of the Byurakan Astrophysical Observatory
Scientific advisor: Dr. Tigran Yu. Magakian
Official opponents: Prof. Aram Saharyan
Dr. Kamo Gigoyan
Leading Organization is the Sternberg Astronomical Institute, Moscow State University (GAISh).
The defense will take place on 27th of July 2021 at 13:00, at the meeting of the specialized council of the SCC 048 “Astronomy” of the Byurakan Astrophysical Observatory named after V. Ambartsumian NAS RA (0213, Byurakan, Aragatzotn Prov.).
The dissertation can be found at the Byurakan Astrophysical Observatory library.
The synopsis has been sent out on 14th of June, 2021

Scientific secretary of the special council

Dr. Elena Nikoghosyan

Relevance and motivation

Young stellar objects (YSOs) having ages typically $t=10^5 \sim 10^6$ yrs are named as Pre-Main Sequence (PMS) stars. The members of this group are located above the Main Sequence in Hertzsprung-Russell (HR) diagram. Based on their masses, PMS stars are divided into two main classes – the T Tauri (TTS) ($M<2M_\odot$) and the Herbig Ae/Be (HAeBe) ($2M_\odot<M<8M_\odot$) type stars and both classes show various types of variability. More massive stars ($M>8M_\odot$) skip the PMS phase, because they evolve very quickly.

T Tauri stars can be separated into three subclasses: Classical T Tauri stars (CTTSs), Weak line T Tauri stars (WTTSs) and Early type T Tauri stars (ETTSs). All these subclasses show moderate fluctuations in brightness, differing in their periods and amplitudes. There are members of this group, which, besides of slow variations, demonstrate also powerful outbursts of up to five magnitudes. These objects are classified into two main classes of eruptive variables: FUors and EXors (see a review [1]). Let us discuss an each class separately.

FUors can be found in the regions of star formation and usually are associated with reflection nebulae, Herbig-Haro (HH) objects and dark clouds. The name of the group (FUor) was given by V. Ambartsumian [2]. Up to now, only few objects have been generally classified as members of the class of classical FUors: FU Ori (the prototype of the class), V1057 Cyg, V1515 Cyg and V1735 Cyg. The characteristic feature of all of them is the strong outburst of 5-6 magnitudes on a timescale of a year, following by a very slow fading. Moreover, in the case of FU Ori we see that the star is remaining in high luminosity state for almost 90 years. FUors have non-emission type spectra, dominated by deep CO overtone absorption, with broad blue-shifted Balmer lines, P Cygni profiles in Hα and the Na I lines, which imply a mass-lose rate of about 10^{-5} $M_\odot$ yr^{-1}. In general, the spectral type of FUors is attributed to F-G type giants/supergiants in the visible and M type in the near IR ranges.

There are significant numbers of stars that kind of mimic the FUors, but in smaller scale. This group of eruptive variable stars is named **EXors** [3], after their prototype **EX Lupi**. The members of this group show occasional flare-ups like FUors, but during their maximum brightness their spectroscopic behavior is different. In contrast to FUors, their spectra are dominated by T Tauri-like emission spectra, with no stellar absorption lines. In addition, they are less luminous and their outbursts are relatively

short-term in comparison with FUors, lasting months to year. Typical values for accretion rate of EXors during the outburst are $m_{acc}= 10^{-8} - 10^{-6}$ $M_{\odot}$ yr^{-1}. During the outburst the number of emission lines increases and undergoes striking variations. Many emission lines exhibit asymmetric profiles. P Cyg profiles at the higher Balmer lines indicate the presence of strong winds with quite high velocities up to hundreds km/s. During both quiescence and outburst phases metallic neutral and ionized lines are detected. Forbidden emission lines ([OI], [SII], [FeII]) usually exhibit blue-shifted profiles, which indicate the presence of shocked gas and jets originating by the star.

But what is the generator of FUor and EXor type outbursts? This question has triggered different hypotheses and it is still open. Based on the accredited theory of Hartmann & Kenyon [4,5], outbursts happen when the circumstellar accretion disk is increasing its surface brightness, as the external envelope falling onto it, i.e., disk accretion rate greatly increases.

A small group of PMS stars of intermediate mass showing eruptive variability are named UXors, after their prototype UX Ori star. Many objects of this group of irregular variables catalogued as HAeBe stars. The members of this group from time to time demonstrate Algol-like minima of two-three magnitudes, which usually last for days or weeks. Their spectra contain many redshifted absorption metallic lines and the Hα line is strong and double-peaked. These spectral features are explained by the infall of gas from the disk material onto the star, just like in the magnetospheric accretion models proposed for TTSs. One could show that the accretion rate for UXors is $M_{acc}\approx 10^{-7}$ $M_{\odot}$ yr^{-1}. Observations in the IR and in the millimeter ranges have shown that UXors are surrounded by optically thick circumstellar disks. It is generally established, that edge-on disks are responsible for the large variability observed in UXors [6]. The variations in the brightness are caused by a dust cloud spinning around the star, in the outer part of stars' circumstellar disk. So, if the disk is oriented nearly edge-on with respect to the observer, then the dust cloud passing in front of the star will obscure the object. As a result we observe that the star becomes reddened and reduced in brightness for several magnitudes. Afterwards, when the obscuring cloud passes away from the line of sight, the star becomes brighter and its color index decreases.

Despite all the great progress made in the field of eruptive variables, there are still many open questions. Even the origin of the outbursts is a matter of debate. While the reason of the UXor type variability is more or

less clear, the mechanism responsible for the FUor and EXor type outbursts is still a controversial issue. It is uncertain whether the same mechanism is responsible for both types' outbursts, or they occur in different ways. Maybe both classes are presenting the same phenomena in different evolutionary stages. The undoubted classification of the objects as FUor, EXor or UXor is another problem. Many recently discovered examples of eruptive stars somehow filled the gap between long-term (FUor) and short-term (EXor) outburst manifestations. These newly discovered objects display a kind of intermediate timescale of outburst decay and other characteristics in comparison of classical FUors and EXors. It is not excluded, that the same object in the same time can represent both, for example FUor and UXor type variability.

Aim of the dissertation

For the further discoveries of probable new types of eruptive YSOs and PMS objects, firstly, we need a comprehensive, long-term, multi wavelength monitoring of eruptive variables, including both photometric and spectroscopic investigations. Nowadays many space-based telescopes are operating, carrying out surveys in different wavelengths. Indeed, large-field monitoring facilities enlarge our arsenal of observational data, but, despite that, we are reliant that the ground-based telescopes still have great potential. The observational material of the individual objects in this case is extremely important, particularly if observations are systematic and include photometry and spectroscopy.

Consequently in 2015 our group started new observational program on the 2.6m. and 1m. telescopes of Byurakan Astrophysical Observatory (BAO). The program was devoted to optical investigation of young eruptive objects. The aim was to re-observe selected young stars, which traditionally show odd and peculiar variations, thus obtaining new observational material on them. Also we were intended to find new possible candidates of different classes of eruptive variables.

The novelty of the work

The proper investigation of the eruptive variables is very important. These stars are among the most intriguing PMS objects, since the

identification of their origin could potentially lead to the consistent picture of the early phases of stellar evolution. They could be used in studies of the evolutionary processes of a circumstellar disks.
Just from the beginning of our observational program several objects showing a peculiar outbursting activity were found. Simultaneous spectral and photometric observations of these objects were conducted. Moreover, for some of the studied objects we managed to track the whole period of the activity, beginning from the quiescent phase -> outburst -> quiescent phase, which is very important in order to understand the complete picture of the phenomenon.

Practical value

The systematic study of the described groups of eruptive variables began relatively lately. Thus there are many open questions in the theory, as well as a lack of observational data for individual stars.
This thesis encompasses the systematic monitoring (both-spectroscopy and photometry) of five stars during 2015 Sept. to 2020 Dec. The results of this thesis can be helpful for theoreticians for development of disk models of PMS stars. It can lead to further discoveries in the field of young eruptive variables. One can take our data into account, when planning a new observational program.

Summary

Here I outline the main results of the thesis.

- We discovered the powerful outburst for more than 5 magnitudes of V1318 Cyg binary PMS star. Regular observations of this object for almost two years, and subsequent studies show that it remains at this brightness level until nowadays. This star is probably evolving into FUor type star.
- The whole period of the outburst for almost 3 magnitudes of the V1686 Cyg is traced, due to the spectral and photometric combined observations. The analysis of the historical light curve of V1686 Cyg shows that the outburst detected by us is atypical for this star.

- The little studied variable V565 Mon is observed. Besides of other spectral characteristics, we detected two λ6141.71 and λ6496.89 Ba II absorption lines. Their presence in the spectrum of PMS star is surprising and nowhere before was stressed the peculiarity of barium overabundance in such a young star.
- The whole period of the new outburst of PV Cep, which generally lasted from 2011 to 2019, is examined. The possible reason of the multicomponent structure of the forbidden lines is given. PV Cep can be classified as an intermediate object between FUors and EXors.
- New observational data, obtained by us, show that V350 Cep constantly keeps its high brightness level and does not undergone significant changes for more than 40 years. We conclude that V350 Cep is gradually develops towards typical FUors.

Content

The dissertation consists of six chapters and references. Chapter 1 is an introduction to the problems addressed in the thesis. In Chapter 2 the observational process and the main methods of a data reduction are described. In Chapter 3 and Chapter 4 the new outbursts of V1318 Cyg and V1686 stars are discussed. In Chapter 5 the new observations of V565 Mon are presented. Chapter 6 concerns to the new spectral observations of V350 Cep and the new outburst of PV Cep.

Chapter 1

This chapter is an introduction of the thesis. Here I present the theory of young eruptive stars and their classification. The origin of the main open questions in this field is presented.

Chapter 2

The chapter is mainly introducing our new observational program, dedicated to the investigation of young eruptive variables. The observations from 2015 to 2017 were conducted on 2.6m., while from 2017 to 2020 – on 1m Schmidt type telescopes in (BAO). In addition some spectra of the PV Cep star were obtained with the 6m. telescope of the Special Astrophysical Observatory (SAO) in 2020. Besides, the data from the various virtual observatories and large surveys (e.g. Gaia, Pan-STARRS, WISE, 2MASS) are used. The data reduction has been done using IRAF and MIDAS software packages.

Chapter 3

The variable star V1318 Cyg belongs to a small young cluster around the bright BD+40°4124 Herbig Be star. The V1318 Cyg fluctuated near the certain main brightness level (V≈17.0), sometimes demonstrating deep minima. After the deep decline in the brightness (in 1990s), it became obvious that this object actually consists of two stars- V1318 Cyg N and V1318 Cyg S and a nebulous knot between them.

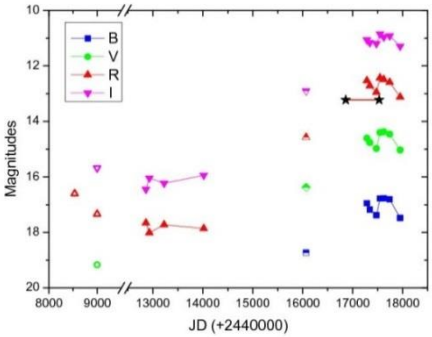

Fig. 3.1 BVRI light curve of V1318 Cyg S for the period of 1991-2017. Filled symbols show our measurements for IPHAS and Byurakan images; open symbols show data from the older observations; half-open symbols show mean estimates for the four-year period of time from PanSTARRS survey (see text); and the line bounded by asterisks shows the level in G magnitude and time period of observations from Gaia DR2.

In the period of 2015-2017 we obtained fourteen spectra and 7 direct images of V1318 Cyg. From the first observations we immediately found that the star underwent a powerful outburst for more than 5 magnitudes. We conclude that V1318 Cyg S is the outbursting star.

As it is shown in the lightcurve (see fig. 3.1) in the period between 2006 and 2010 the brightness of V1318 Cyg S started to rise. It reached its maximum by the second half of 2015 (V=14.3), when we first observed this star. Moreover V1318 Cyg S remains at this brightness level until now (2021). Therefore all our spectrograms of V1318 Cyg are presenting the star at the maximal brightness, without prominent changes (see fig. 3.2). We estimated the equivalent widths and radial velocities of all main lines, thus assigning its spectral type as early A. We evaluate the extinction value as A_V=7.2, and using the newly estimated distance of the star we derive M_V=-2.36 and L=7500$L_\odot$ for V1318 Cyg S at the maximum in the optical range.

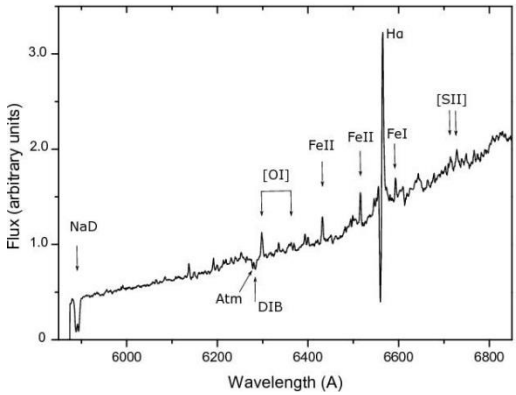

Fig. 3.2 Red part of V1318 Cyg spectrum. The spectrum was obtained with the 2.6m telescope. P Cyg profile of Hα line and strong NaI D absorptions are prominent.

The possible classification of the V1318 Cyg S to known types of eruptive variables is discussed in detail.

Combining our observations with the recent data [namely very large brightness amplitude in the optical range (more than 5 mags.), very long duration of minimum (10 years or more) and the long duration of the recent outburst, which is still in progress, with corresponding spectral

changes], we conclude that V1318 Cyg S is developing towards FUor type star.

Chapter 4

In the vicinity of bright BD+40°4124 star LkHα 224 is situated. Its photometric variability was detected in 1980 and as the variable this star received V1686 Cyg designation. According to photometric data, the star fluctuates near the mean brightness level, sometimes (usually one time per year) demonstrating irregular Algol-like minima, which lasts one-two months. V1686 Cyg was the subject of many spectral studies, but prominent variations of absorption features make its spectral classification very problematic. Estimates of its spectral type vary from B2 to F9.
Since 2015 Sept. to 2017 Jul. we obtained fourteen spectra and seven directed images.

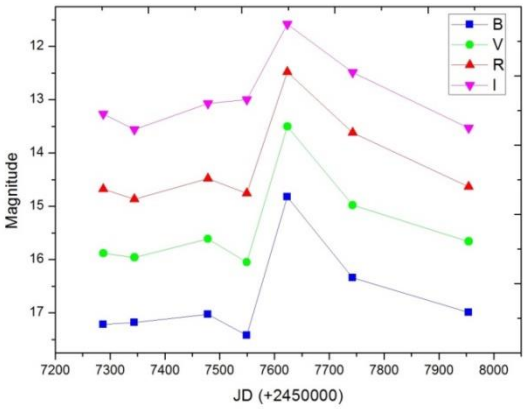

Fig. 4.1 BVRI light curve of V1686 Cyg for the period 2015-2017

During our systematic observations of this field the unusual and unsuspected brightening of V1686 Cyg up to almost 3 mags. was found and traced (Fig. 4.1). Photometric estimations demonstrate that the brightening lasted probably several months and then the brightness of the star returned to its previous level.

The spectral variations, observed by us during the 2016 brightening event, are important. Moreover first significant changes we have noticed in the spectra, when photometric variations were not detected yet. We noticed that the central absorption in Hα became much stronger, nearly dividing the emission line into two almost equal components. The existence of the blue-shifted absorption component in the Hα line profile shows the presence of an expanding envelope. Estimated equivalent widths of the most typical emission and absorption lines show that the strength of emission lines relative to continuum significantly lowered during the maximal brightness period. All measurable absorption lines demonstrate negative radial velocity.
Our combined data confirm that V1686 Cyg is one of the most photometrically and spectrally variable HAeBe star. Moreover, at least in this present case, the spectral and photometric variations of V1686 Cyg are directly related. The observed short-time brightening is not typical for V1686 Cyg. It can be considered as an outburst, because its accompanying spectral changes could be interpreted as the formation of dense expanding envelope around the star, with its subsequent dissipation during several months.

Chapter 5

The variable star V565 Mon belongs to a little studied star formation region. It is the illuminating star of the Parsamian 17 reflection cometary nebula, in which it is deeply embedded. The observational data about the star are scarce. The spectrum of the star was roughly estimated as G, with Hα emission line and very strong Ba II lines in the red part. V565 Mon is an extremely bright in the mid-IR range. Near the symmetry axis of P17 a group of HH 947 A/B objects were discovered. Logically, V565 Mon can be considered as a source of this flow.
Observations of V565 Mon were carried out on 2018 February 15.
The reduced spectrum of V565 Mon is presented in Fig. 5.1. Taking into account all the characteristics of this star, the spectral range of V565 Mon can be from late F to early G. We estimated the EWs and heliocentric radial velocities of the most prominent absorption and emission lines. One can see that negative radial velocities are observed only for forbidden lines, which indicates that these lines are related to HH outflow. The general strength of emission lines is not high. Even for Hα emission, the

total EW is ≈-7Å. The mean radial velocity of V565 Mon, computed by the six strongest absorption lines, is +34±14 kms^{-1}.

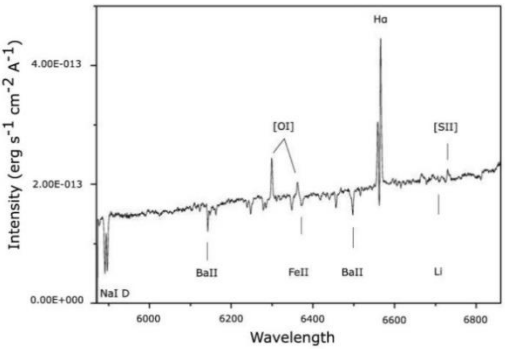

Fig. 5.1 Spectrum of V565 Mon in absolute intensities

We estimated the distance of V565 Mon as 1150pc (±91pc), based directly on the newly obtained Gaia parallaxes. We built the Spectral Energy Distribution (SED) of the star, which shows that V565 Mon emits in the mid and far IR ranges at least the same amount of energy, as in the optical range. By integrating the SED curve of V565 Mon we obtained L_{V565}≈130 $L_{\odot}$ for its bolometric luminosity. Using general equations

$$M_{bol,*} - M_{bol,\odot} = -2.5 log_{10}(L_*/L_{\odot}) \quad (5.1)$$

and

$$m - M = 5 log d - 5 + A_v \quad (5.2)$$

for the main parameters of V565 Mon we obtained M_V=–0.55, A_v=2.86. It is not easy to classify the V565 Mon star, because its significant luminosity suggests that it has intermediate mass and consequently, belongs to the HAeBe class. On the other hand, its spectrum corresponds to T Tau stars.

The most unusual feature of V565 Mon is the presence of two strong λ6141.71 and λ6496.89 Ba II absorption lines in its spectrum. Nowhere is stressed the peculiarity of barium overabundance in such a young star (the age of V565 Mon do not exceed several million years). We considered

the possibility that V565 Mon can be a FUor–like object. There are circumstances that speak for, as well as against this. Anyway V565 Mon can represent non typical case of FUor-like stars, or its spectral characteristics can be due to its orientation with respect to the line of sight. The subsequent study of this somewhat neglected object could be an important step in understanding the nucleosynthesis problems in young stars.

Chapter 6

In this chapter, we present the new spectra of PV Cep and V350 Cep obtained over the past five years and compares these results with available data.

The variability of PV Cep and the nebula GM1-29 (RNO 125), connected with the star, was discovered in 1977. It is the source of the extended Herbig-Haro flow and of the bipolar molecular outflow. Despite the considerable number of subsequent studies the classification of PV Cep is still uncertain.

The variable star V350 Cep, located in a cluster within the NGC 7129 nebula, was first noticed in 1977 when it reached 16.5 magnitudes (in the V band). The increase in the brightness of V350 Cep had began approximately in 1972 and since 1978 this star mainly remains at the same level of brightness (e.g. almost 50 years).

Although the historical light curve of V350 Cep resembles FUor type star, however the first spectral observations have shown very developed emission spectrum. On the other hand V350 Cep can hardly be attributed to EXors, since it does not show outbursts characteristic for the latter ones, but it is almost constantly at the maximal brightness level. The spectral type of V350 Cep was assessed as M2.

Since 2015 Sept. to 2018 June seven spectra with different resolutions, were obtained for PV Cep, with 2.6m telescope in BAO. In additional, one spectrum of PV Cep was obtained with 6m telescope in SAO. For V350 Cep one spectrum was obtained on 2015 September with 2.6m telescope in BAO.

Analysis of the light curve of PV Cep show that from the beginning of 2011, the star began gradually and almost continuously rise in brightness,

reaching almost its maximum (R≈13.6) by the end of 2016. After that, a rapid decline in brightness had begun. Our observations correspond to almost all brightness levels of the star, from the rise to the subsequent decline in brightness.

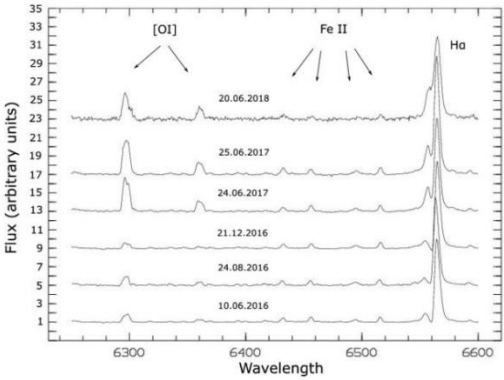

Fig. 6.1 Sections of the PV Cep spectrum normalized to the continuum corresponding to different observational dates. Strong changes in the profiles and intensities of the Hα and of the [O I] lines are seen, while the Fe II emissions remain unchanged.

From the very first observations, it became apparent that the PV Cep was surrounded by an expanding envelope. In addition, it gradually became clear that this star is the source of bipolar outflow. We measured the radial velocities of all main lines. We obtained the average velocity of five Fe II and Fe I lines to be -15±11 km s^{-1} (see fig. 6.1).

From Fig. 6.2 it is easy to see, that EWs of the forbidden lines unambiguously increase with decreasing brightness, while the EW of one of the strongest permitted emissions (λ6516 Å Fe II) practically does not change.

Strong and wide forbidden lines [OI] and [SII] were found in the spectrum of PV Cep immediately after its discovery. They have multicomponent structure. These phenomena are especially pronounced for the [S II] lines. Often, with the sufficient resolution, four components can be distinguished in each of the lines of the doublet.

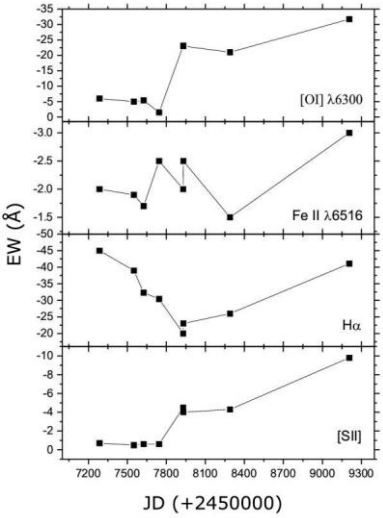

Fig. 6.2 The equivalent widths of some lines in the PV Cep spectrum as a function of time. For the Hα line, the total emission EW was measured; for the [SII] lines, the total EW of both lines of the doublet is given.

The radial velocities of the [S II] components in the spectra (see fig. 6.3), considered in this work, can be estimated by the following values: -230, -170, -50, and +70 km s^{-1} (moreover, the component with a positive velocity changes especially noticeably and often is completely absent). Such phenomenon is explained by the fact that emitted components with a high absolute velocity belong to a collimated outflow from PV Cep, while the components with low absolute velocity are concentrated around the star. Besides, such a multicomponent profiles of forbidden lines can be connected to a miniature jet, originating from the PV Cep. If so, in the coming years it will become possible to observe this jet directly. Similar observations of the formation of new jets after bursts are extremely rare. As an object experiencing fairly frequent and powerful outbursts, PV Cep offers a good opportunity to test and explore the mechanism of occurrence of jets.

In contrast with PV Cep, V350 Cep keeps its maximal brightness for more than 40 years, without any significant variations.

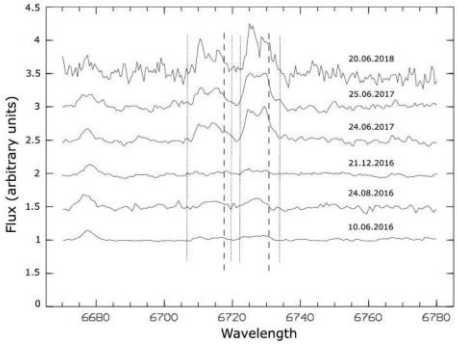

Fig. 6.3 Appearance of [S II] lines and its changes in the spectrum of PV Cep from 2016-2018. The wavelength values corresponding to the zero radial velocity are shown by the dotted line. The limits for the FWZI lines are also indicated.

Some fragments of its spectrum, obtained by us, are shown in Fig. 6.4. A comparison of the available literature data on the Hα line profile leads us to an interesting and previously unmentioned conclusion. Namely, from the moment of the first observations in 1978 to July 1985 inclusively, the P Cyg profile in the Hα line was not observed, while since October 1986 it has been constantly present. These facts indicate that V350 Cep is surrounded by an accreting disk.

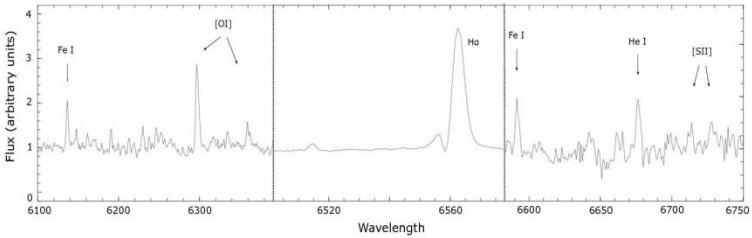

Fig. 6.4 Fragments of the V350 Cep spectrum normalized to the continuum: the P Cyg profile of Hα line, forbidden lines [OI] and [S II], and Fe I fluorescent lines are presented.

Estimates of the main parameters (e.g. distance, luminosity, extinction value) of PV Cep and V350 Cep led us to some conclusions about the classification of these stars.

V350 Cep shows the impressive stability of its brightness and the spectral characteristics. If subsequent observations confirm the further development of the P Cyg component in the Hα line, it can be assumed that V350 Cep gradually develops towards a typical FUor state.

In contrary to V350 Cep, PV Cep shows repeated outbursts. But it cannot be attributed to EXors or FUors in classical terms, for a number of reasons. Thus, PV Cep resembles V1647 Ori star, which is an intermediate object between FUors and EXors. The number of such "intermediate" objects has been growing in recent years.

Conclusion

This thesis is dedicated to the proper investigation of diverse manifestations of phenomena of the eruptive variability of YSO's, such as FUors, EXors, intermediate objects and UXors. Here I will bring the general remarks, as conclusions for separately taken objects are presented in Summary and Chapters 3-6.

On the example of aforementioned five stars: V1318 Cyg, V1686 Cyg, V565 Mon, PV Cep and V350 Cep we demonstrated a difficulty of the definite classification of YSO's. In course of time, some previously identified EXor turns out to be a FUor, and vice versa, FUor-like object turns to be an EXor. Or, it happens, that a certain classification is clarified by observations performed over several, maybe even decades after. Consequently, a regular update of the lists of various classes of eruptive young variables is indeed necessary. For that reason the whole scientific community, including our group, constantly emphasize the importance of monitoring programs on individual objects, showing eruptive variations. The studies of intermediate type objects can bring more light on the nature and the origin of this, still not well understood phenomenon.

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Ամփոփում

Ատենախոսությունում ուսումնասիրվել են երիտասարդ էրուպտիվ աստղերի փոփոխականության տարբեր դրսևորումները: Նպատակն էր օգտագործելով Բյուրականի աստղադիտարանի (ԲԱ) դիտակները հետևել պատմականորեն տարօրինակ փոփոխական վարք ունեցող աստղերին և հայտնաբերել նորերը: Մյուս կարևոր հանգամանքն է փորձել կատարել ուսումնասիրված օբյեկտների ճշգրիտ դասակարգում: Դիտումները կատարվել են 2015-2020 թթ-ի ընթացքում, օգտագործելով 2.6մ. և 1մ. դիտակները (ԲԱ): Ի հավելումն, ուսումնասիրված օբյեկտներից մեկը նաև դիտվել է Ռուսաստանի հատուկ աստղադիտարանի 6մ. դիտակով: Ատենախոսության հիմք են հանդիսանում՝ V1318 Cyg, V1686 Cyg, V565 Mon, PV Cep և V350 Cep աստղերը:

Ստացվել են հետևյալ հիմնական արդյունքները՝

1. Մենք առաջինը դիտեցինք V1318 Cyg կրկնակի աստղի ավելի քան հինգ մեծությամբ բռնկումը: Ավելի քան երկու տարվա համակցված սպեկտրալ ու լուսաչափական դիտումների ընթացքում այս աստղը փոփոխություններ չկրեց: Վերջին տարիների դիտումները հաստատեցին, որ V1318 Cyg աստղը պահպանում է իր պայծառության բարձր մակարդակն առնվազն վեցը տարի: Աստղը դասակարգվել է որպես FUor-ի տիպի փոփոխականի ճանապարհին գտնվող օբյեկտ: Դասակարգելիս հաշվի են առնվել պայծառության կայուն մակարդակը և սպեկտրալ առանձնահատկությունները:
2. Սպեկտրալ և լուսաչափական համակցված դիտումների ընթացքում հայտնաբերվել է V1686 Cyg աստղի գրեթե երեք մեծությամբ բռնկումը: Հաջողվել է հետևել աստղի բռնկման ամբողջ ընթացքը: Ուսումնասիրելով պատմական լուսատվության կորը, պարզ է դառնում որ մեր կողմից դիտված բռնկումը ոչ տիպիկ է այս աստղը համար:
3. Դիտվել է շատ քիչ ուսումնասիրված V565 Mon աստղը: Ի թիվս մյուս առանձնահատկությունների, այս աստղի սպեկտրում հայտնաբերվել են հզոր λ6141.71 և λ6496.89 Ba II կլանման գծերը: Այս գծերի առկայությունը նման երիտասարդ (PMS) աստղի սպեկտրում շատ անսպասելի և

անհասկանալի է: Քննարկվել են բարիումի առաջացման մեխանիզմները: Այս աստղը կարող է յուրահատուկ օրինակ հանդիսանալ, երիտասարդ աստղերում նուկլեոսինթեզի պրոցեսների ուսումնասիրության համար:

4. Մանրամասն սպեկտրալ ուսումնասիրության է ենթարկվել PV Cep աստղի նոր բռնկման ամբողջ ընթացքը: Նշվել են արգելված [OI] և [SII] գծերի բազմակոմպոնենտ պրոֆիլները, և քննարկվել դրանց առաջացման մեխանիզմները երիտասարդ աստղերում: PV Cep աստղը կարելի է դասել FUor-ների և EXor-ների միջև գտնվող միջանկյալ օբյեկտների շարքին: Վերջին տարիներին շատ նոր օբյեկտներ են ընդգրկվում այս դաս (միջանկյալ օբյեկտներ):
5. V350 Cep աստղի մեր կողմից կատարված նոր դիտումները ցույց են տալիս, որ այս աստղը 1977-79 թթ. -ին պայծառանալուց հետո, ոչ մի էական փոփոխություններ չի կրում: Մանրամասն ուսումնասիրվել է աստղի սպեկտրը: Հաշվի առնելով սպեկտրալ առանձնահատկությունները և այն հանգամանքը, որ վերջին քառասուն տարում աստղը պահպանում է իր պայծառության մակարդակը, թույլ է տալիս ենթադրել որ V350 Cep-ը աստիճանաբար զարգանում է դեպի FUor-ի տիպի աստղ:

Резюме

В диссертации исследованы различные проявления переменности молодых эруптивных звезд. Главная идея состояла в том, чтобы с использованием телескопов Бюраканской астрофизической обсерватории (БАО) пронаблюдать звезды, которые исторически показывали необычную переменность, а так же обнаружить схожие новые объекты. Следующей целью была точная классификация изучаемых эруптивных объектов, которая во многих случаях является очень трудной задачей. Наблюдения проводились в течение 2015-2020 гг. на 2.6 м. и 1 м. телескопах (БАО). Кроме того, один из исследуемых объектов в том числе наблюдался с помощью 6м. телескопа Специальной астрофизической обсерватории (САО) Российской Федерации. В основе диссертации лежит подробное исследование пяти звезд: V1318 Cyg, V1686 Cyg, V565 Mon, PV Cep и V350 Cep.

1. Мы первыми зарегистрировали мощную вспышку южного компонента двойной звезды V1318 Cyg величиной более 5 звездных величин. Регулярные наблюдения этого объекта в течение почти двух лет, и последующие исследования показывают, что он остается на этом уровне яркости до сих пор (2021г.). V1318 Cyg S может оказаться звездой развивающейся к переменным типа FUori.
2. С помощью комбинированных спектрофотометрических наблюдений в течение двух лет был прослежен весь период вспышки V1686 Cyg почти на три звездные величины. Анализ исторической кривой блеска V1686 Cyg показывает, что обнаруженная нами вспышка нетипична для этой звезды.
3. Наблюдалась малоизученная звезда V565 Mon. Среди других особенностей в спектре этой звезды обнаружены мощные λ6141.71 и λ6496.89 линии поглощения Ba II. Наличие этих линий в спектре такой молодой (PMS) звезды очень неожиданно и непонятно. Обсуждены механизмы образования бария в молодых звездах. V565 Mon может быть уникальным объектом для изучения процессов нуклеосинтеза в молодых звездах.
4. Детально изучен весь процесс новой вспышки звезды PV Cep. Отмечены многокомпонентные профили запрещенных

линий [OI] и [SII], обсуждены механизмы их возникновения. Звезду PV Cep можно классифицировать как промежуточный объект между FUor-ами и EXOR-ами. В последние годы этот класс "промежуточных объектов" становится все многочисленее.

5. Проведенные нами новые наблюдения звезды V350 Cep показывают, что эта звезда не претерпевает каких-либо существенных изменений с момента ее обнаружения в 1977-79 гг. Спектр звезды изучен подробно. Учитывая спектральные особенности и тот факт, что звезда сохраняет свою яркость на том же уровне в течение последних сорока лет позволяет нам предположить, что V350 Cep постепенно эволюционирует в сторону звезды типа FUori.

Հասմիկ Անդրեասյան/Hasmik Andreasyan/Асмик Андреасян