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FIRST RESULTS FROM TIEN-SHAN SURVEY TO SEARCH FOR VARIABLE STARS: LIGHTCURVE ANALYSIS AND VARIABLE STAR CLASSIFICATION

Abstract. We present the first results of the light curve analysis of variable stars identified in Tien-Shan survey conducted on Tien-Shan Observatory (TSO) using Zeiss-1000 telescope. Here we report on 33 high amplitude variable stars among which 31 is previously uncatalogued variables. Using data from the StarHorse catalog, as well as results from the MIST project, Color-Magnitude Diagram and appropriate evolutionary tracks were constructed for each field and individual variable star, corresponding to the star's mass and metallicity. For two objects, we performed spectral observations on the Zeiss-1000 "Zapadny" telescope using a slit spectrograph. The obtained spectra were compared with synthesized spectra. The preliminary identification of variability type of each star is based on parameters of variability (amplitudes and periods) determined from periodograms analysis, evolution stage based on evolutionary track on Color-Magnitude Diagram and, for some targets, on spectral information.

Key words: methods: light curve analysis, photometry; stars: variable stars.

Introduction. Stellar variability plays crucial role in understanding many aspects of stellar structure, galaxy evolution, cosmology, formation and evolution of binary systems and in many other astrophysical problems [1, 2]. Light curve analysis of variable stars is main instrument in discovery of extra-solar planets [3,4,5].

Despite many different campaigns and surveys aimed on variable star discovery and analysis there are many new phenomenon and variability type discoveries still going on. Also, there are several examples of variable stars which is the only object of their kind. For example WD1145+017 is the only known white dwarf with evidence of disintegration phenomenon. To search for variable stars with short period variability the survey was initiated at TSO. One of the goals for TSO survey is search for ultra-compact binary systems (UCB), including interacting ultra-compact binary systems (AM CVn). Searching for UCB and AM CVn conducted by means of single observatory is justified by the fact that the periods of brightness variation in these objects are about several tens of minutes and the amplitudes from 1.0 to 0.01 in magnitudes [6], that is, are within the accuracy of photometry obtained by the telescopes in the TSO.

Additionally, TSO survey can detect variable stars of other types of variability including those intentionally valuable for asteroseismic studies, systems with exoplanets, etc. Project description, strategy for field selection and data reduction process is presented in separate paper in this volume (Paper I). There we reported on discovery of new variables stars from visual inspection of individual light curves. In this part we present detailed analysis of light curve of suspected variable stars using periodorgam analysis, inspecting their evolution stage and spectra.

Stellar parameters, CMD and evolutionary tracks. A visual inspection of the light curves was carried out for each star in each field that successfully passed the photometry process in at least 70%-75% of the total duration of observations, which made it possible to identify stars with unambiguous evidence of change in brightness. The full list of stars with detected variability is presented in table 5 of paper I.

To determine the type of detected variable stars, it is necessary to investigate the amplitude-period characteristics of the light curves, as well as the evolutionary status of the stars and, if possible, spectral characteristics (Sp). To clarify the evolutionary status of the stars, we found their physical characteristics from the GAIA catalog and constructed color-magnitude diagram (CMD) with superimposed theoretical evolutionary tracks obtained from the MIST project [7,8]. The physical parameters of the detected variables, according to the GAIA catalog, are given in table 1, where π is the parallax, Gmag is the magnitude in GAIA G filter.

Table 1 - Parameters of identified variable stars

GAIA ID	π [mas]	Gmag [mag]	T_{eff} [K]	R [R_{Sun}]	L [L_{Sun}]	GAIA ID	π [mas]	Gmag [mag]	T_{eff} [K]	R [R_{Sun}]	L [L_{Sun}]
3420722996343786496	1.8659	13.04	4649.38	1.93	1.575	3404213726175547776	0.7416	15.65	4855.00	1.30	0.847
3420728150304526976	6.7595	16.77	8868.67	---	---	3404200257158109824	0.7620	12.54	5926.25	3.33	12.294
3420726084425443200	0.7500	15.72	3854.00	2.51	1.252	3404217746264940032	0.3361	15.06	4837.26	---	---
473900064311871488	1.1686	14.95	4228.92	1.70	0.832	3404189944938309120	0.7505	12.80	7058.25	2.10	9.884
473906008546567168	---	15.93	4039.89	---	---	241766668329744896	0.3486	16.98	4904.71	---	---
473706893862387328	0.1217	15.33	4687.15	---	---	241771856649828992	---	17.75	---	---	---
473712872456844544	0.5673	14.24	7031.00	1.45	4.597	229267969902029696	1.9891	13.52	4866.05	1.29	0.841
473900304830038144	0.4015	15.49	4855.50	2.59	3.368	277089853758788352	0.2152	16.94	4832.62	---	---
2000667342122793472	0.4200	13.91	7111.67	2.22	11.311	277091262508123264	0.9893	13.03	4374.00	4.39	6.352
2000668544713613952	0.4973	13.65	6519.50	2.51	10.268	277091739248814208	0.4404	16.71	4374.25	---	---
2000677993641422208	0.1093	16.14	6582.00	---	---	277092155861283712	0.9312	16.49	4315.86	0.98	0.303
2000680742420926976	0.3075	13.13	5983.00	---	---	277093014852191616	0.1927	15.71	5008.72	---	---
2000681876292067968	0.2046	15.32	6940.00	---	---	277091911047501568	0.1641	16.34	4740.56	---	---
2000684586402884864	0.2592	14.03	6413.50	4.18	26.626	3342732093967192576	0.5688	15.09	5324.00	1.75	2.204
2000685758942457728	0.2795	13.98	7179.25	3.17	24.013	3433368376498172160	0.7081	16.00	4593.60	1.35	0.733
2000686239978998400	0.3612	14.46	7812.50	1.69	9.560	3433415586778288768	0.2012	15.24	4895.75	---	---
2001434835597456768	1.0201	16.65	4896.07	0.59	0.178						

There is no data in GAIA catalog for the star 241771856649828992, but we identified this object in the SDSS catalog as J033258.00+452113.5 and find the following parameters: T_{eff} = 5440.0 K, $[Fe/H]_1$ = 0.042 [9]. It should be noted here that GAIA data for extinction in the G band and “reddening” E(BP-RP) should be used with caution since their accuracy is such that the values for individual star are unreliable and therefore it makes sense to work only with an ensemble of values. Much work to refine GAIA data for individual stars were done in the StarHorse project [10]. From the StarHorse catalog, we selected only those stars for which reliable estimates were obtained. An example of a database query on the project website (https://gaia.aip.de/query/) in our case might look as follows:

```
SELECT g.source_id, s.MG0, s.BPRP0, s.TEFF50, s.MET50, s.MASS50
FROM gdr2.gaia_source AS g, gdr2_contrib.starhorse AS s
WHERE g.source_id = s.source_id AND s.SH_OUTFLAG LIKE '00000'
AND s.SH_GAIAFLAG LIKE '000' AND 1=CONTAINS(POINT('GALACTIC',g.l,g.b),
CIRCLE('GALACTIC',196.37,-4.64,1.))
```

Table 2 shows the parameters of some of the variable stars for which data is available in the StarHorse catalog. A comparative analysis of the data from table 1 and table 2 shows a significant discrepancy of values for some stellar parameters. In further analysis, especially for determining the type of variability of a star, in the case where the parameters of the star cannot be determined from the StarHorse catalog we use the parameters from the GAIA catalog, except for the T_{eff} value.

Table 2 - Parameters of the detected variable stars from the StarHorse catalog

GAIA ID	T_{eff} [K]	[Fe/H]	M [M_{Sun}]	GAIA ID	T_{eff} [K]	[Fe/H]	M [M_{Sun}]
420722996343786496	8088	-0.24	1.57	3404217746264940032	6476	-0.12	1.64
473900064311871488	7519	-0.59	1.27	3404189944938309120	7338	-0.33	1.58
473706893862387328	12996	-0.14	3.66	241766668329744896	5903	0.47	1.21
473712872456844544	5263	-0.39	0.90	229267969902029696	5800	0.15	1.03
473900304830038144	7831	-0.19	1.72	277091262508123264	9658	-0.14	2.45
2000667342122793472	7660	-0.21	1.75	277091739248814208	6562	-0.19	1.21
2000680742420926976	6058	-0.29	1.84	277092155861283712	5575	0.46	1.05
2000684586402884864	6669	-0.09	1.80	3342732093967192576	6265	-0.59	1.02

Using data from the StarHorse catalog, as well as results from the MIST project, CMD and appropriate evolutionary tracks were constructed for each field and individual variable star, corresponding to the star's mass and metallicity. These diagrams are shown in figures 1-3. GAIA ID of the stars is given in legends to the figures.

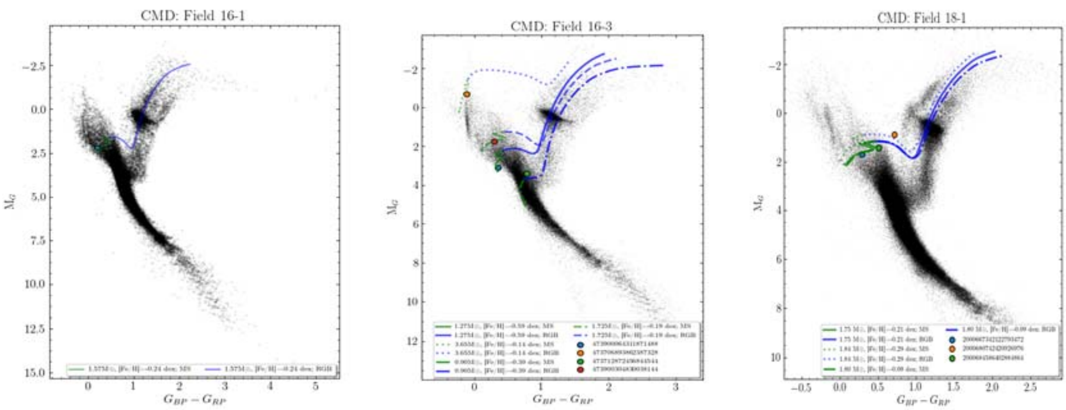

Figure 1 – CMD and evolution tracks for selected variable stars
on the field 16-1 (on the left), 16-3 (in the middle) and 18-1 on the right

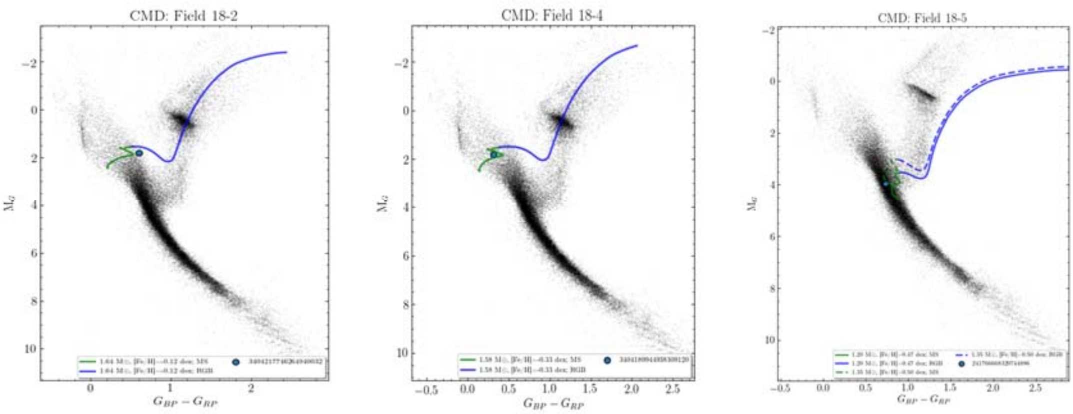

Figure 2 – CMD and evolution tracks for selected variable stars
on the field 18-2 (on the left), 18-4 (in the middle) and 18-5 on the right

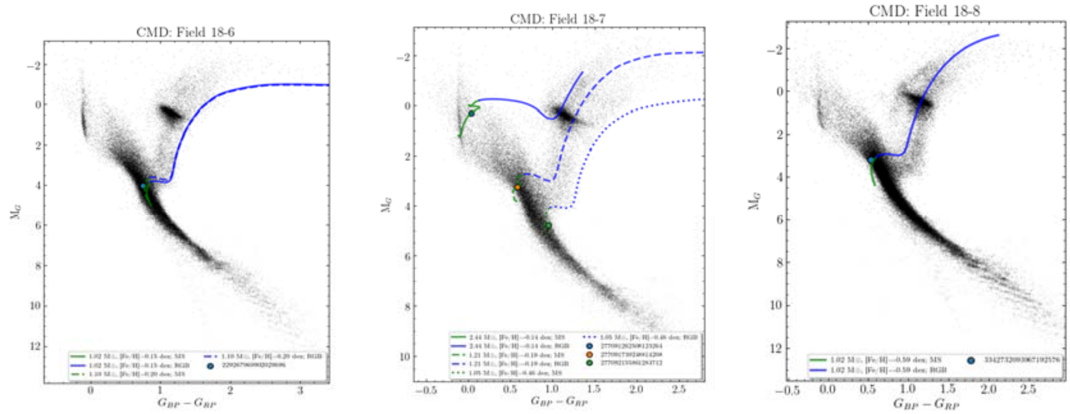

Figure 3 – CMD and evolution tracks for selected variable stars
on the field 18-6 (on the left), 18-7 (in the middle) and 18-8 on the right

Light curve analysis, amplitude-period parameters

The main tool of the light curves analysis utilized in this work is periodogram using two algorithms implemented in the project GATSPY [11] and PyAstronomy (https://github.com/sczesla/PyAstronomy) with successive steps of the ”pre-whitening”, that is, subtracting the detected period of the light curve followed by computing “cleaned” periodogram. The search for oscillation periods was carried out in the range of periods (Π) from 0.003 d to 0.15 d. As an example, and due to pages limit here we show the results for selected stars.

473900304830038144 (field 16-1): the physical parameters (T_{eff} and M_{Sun}), its position on the CMD diagram, and the period of variability (~1.8 - 2.3 hours) indicate that this star belongs to the DSCT type. The light curve is shown in figure 4. Periodograms with an indication of reliable peaks are shown in figure 5. Analysis of the light curve gives the following parameters of pulsation: Π_1 = 0.08410±0.00004 (d), A_1 = 0.0096±0.0009 mag, Π_2 = 0.08934±0.00004, A_2 = 0.0081±0.0008.

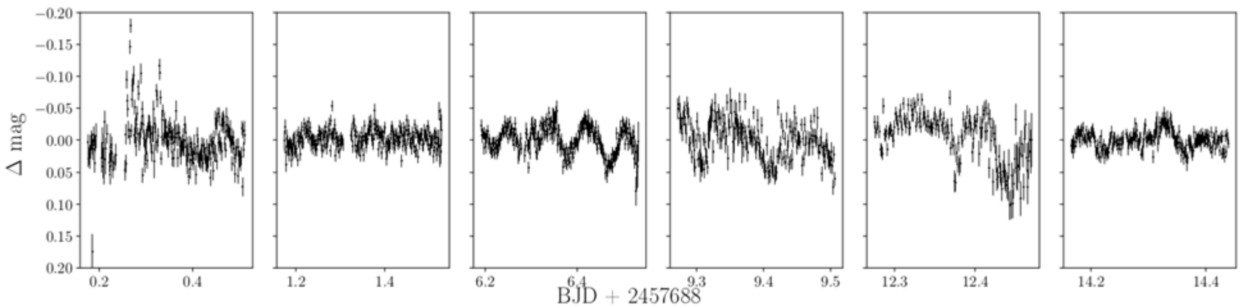

Figure 4 - Light curve of the star 473900304830038144

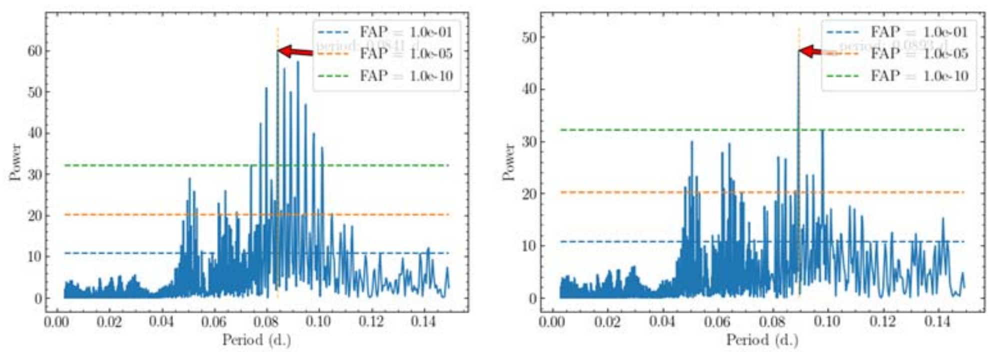

Figure 5 - Periodograms for the star 473900304830038144 with indication of found periods

473906008546567168 (field 16-3): the light curve (figure 6) shows the changes in brightness from minimum to maximum with an amplitude of about 0.3 magnitude and a period of ~0.1 days. The analysis reveals three modes of oscillations: Π_1=0.13885±0.00002 (d), A_1=0.112±0.003 mag, Π_2=0.06488±0.00003 (d), A_2=0.021±0.002 mag, Π_3 = 0.1213±0.0001 (d), A_3 = 0.020±0.002 mag. The corresponding periodograms are shown in figure 7. The nature of the pulsations suggests that this star belongs to the HADS (high amplitude DSCT).

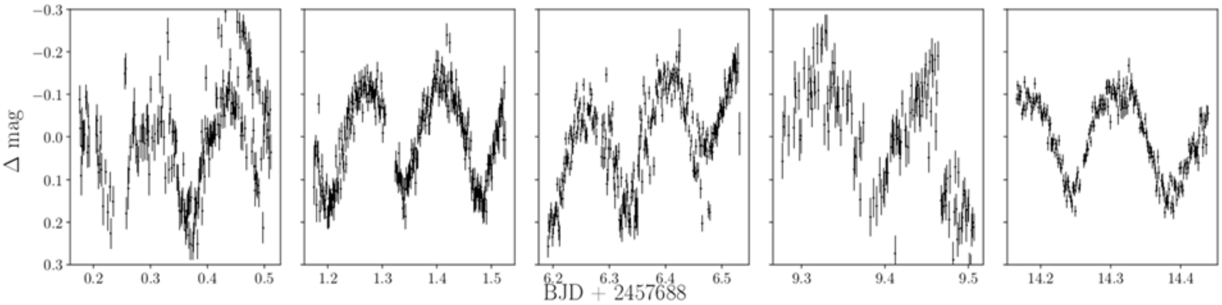

Figure 6 - Light curve of the star 473906008546567168

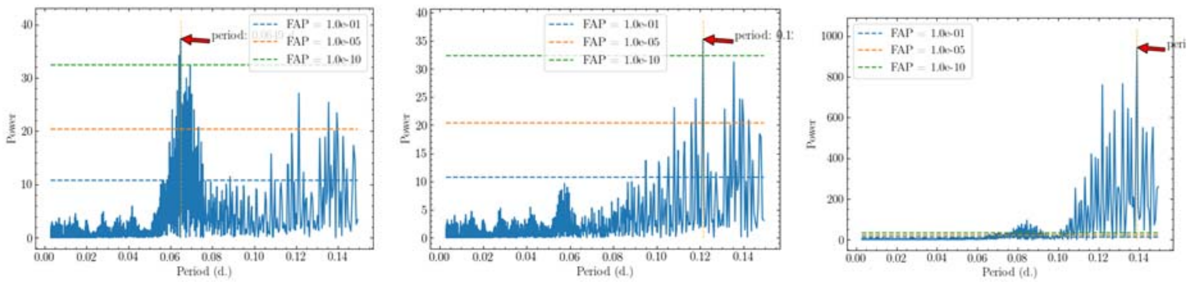

Figure 7 - Periodograms for the star 473906008546567168 with indication of found periods

277091262508123264 (field 18-7): the analysis of the CMD diagram (figure 3) shows that it is the Main Sequence star of spectral type A (T_{eff} was used). The light curve is shown in figure 8. Despite the short duration of the light curve, the star shows the presence of a rich spectrum of pulsations, which may be due to the irregular variability. If we exclude the possible periods 0.2 d and to limit the periods search within the duration of one epoch (~3 hours), we reliably detect three modes: Π_1=0.0811±0.0004 d, A_1=0.0103±0.0007 mag, Π_2=0.0599±0.0003 d, A_2=0.0057±0.0006 mag, Π_3 = 0.0445±0.0002 d, A_3 = 0.0041±0.0005 mag (figure 9). The nature of the oscillations shows that this variable may belong to the DSCT, but it may be of roAp type. The object is of particular interest for subsequent observations and possibly asteroseismic analysis.

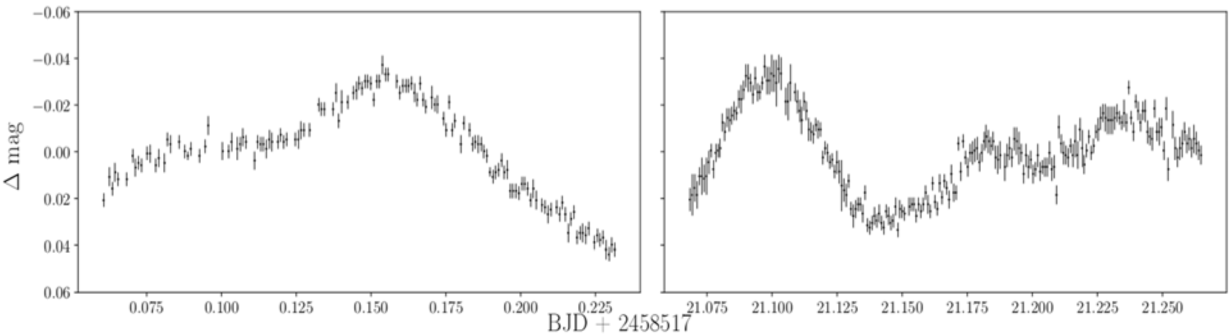

Figure 8 - Light curve of the star 277091262508123264

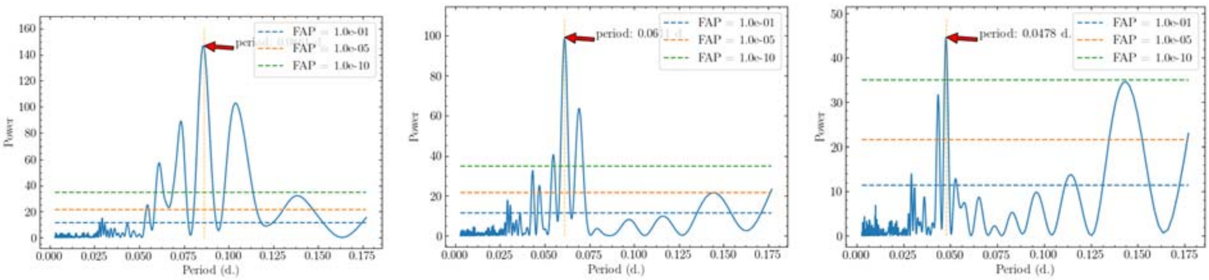

Figure 9 - Periodograms for the star 277091262508123264 with indication of found periods

Catalog of variable stars and types of variability

The classification of the type of variability was made based on the obtained oscillation parameters (period and amplitude), the position of the star on the CMD evolutionary track, as well as using an available spectral data. For two objects, we performed spectral observations on the Zeiss-1000 "Zapadny" telescope using a slit spectrograph. The obtained spectra were compared with synthesized spectra computed utilizing the SPECTRUM package [12] and based on grids of atmospheric models from [13].

For the star designated in the GAIA catalog as 3404189944938309120 we found the following parameters according to the StarHorse project: T_{eff} = 7338K, [Fe/H] = -0.33, M_* = 1.58 M_{Sun}. Based on these parameters, synthesized spectra were constructed with the spectral resolution corresponding to our observations for two values of T_{eff} – 7250K and 8000K, with the parameter *log*g = 4.0 and [Fe/H] = -0.5. A comparison of the synthesized spectra with the spectrum obtained at TSO is shown in Figure 10. From comparison with model spectra, it can be concluded that the data of the StarHorse project correspond to reality and this variable star can be attributed to the DSCT type with a high probability.

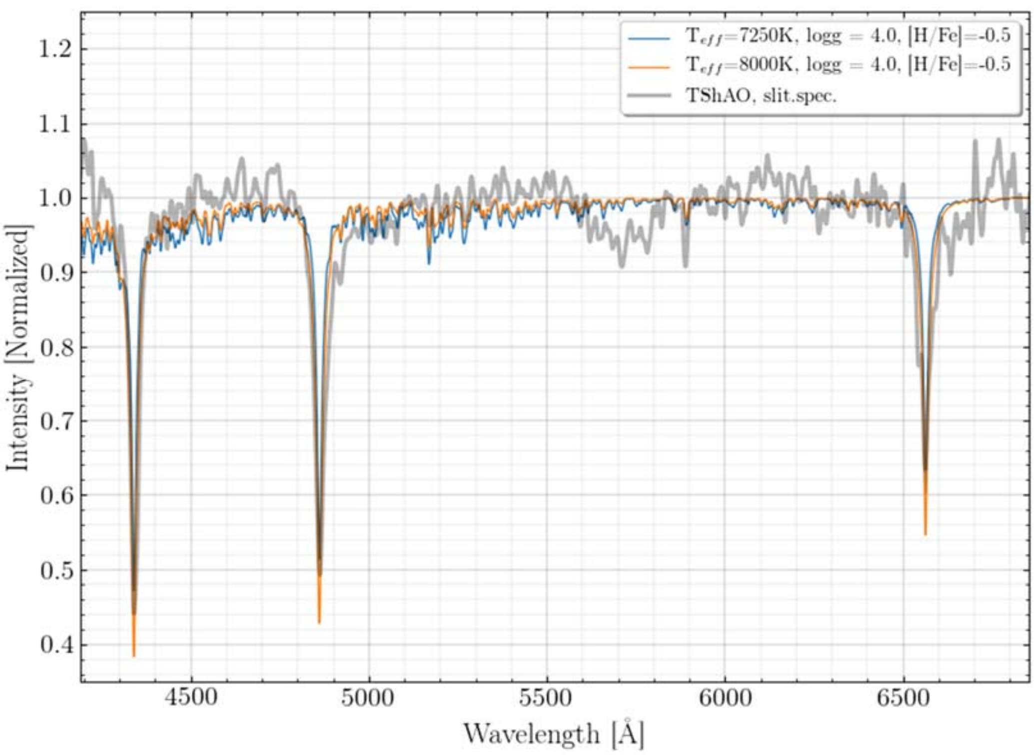

Figure 10-Comparison of spectra obtained at the TSO using a slit spectrograph mounted on the Zeiss-1000 "Zapadny" telescope with synthesized spectra for two T_{eff} values

Table 3 - Detected variable stars from TSO survey

GAIA ID	Π	σ_{Π}	A	σ_A	Type
3420722996343786496	0.0485 0.0925 0.0708	0.00001 0.0001 0.0001	0.0033 0.0026 0.0023	0.0003 0.0003 0.0023	DSCT
3420726084425443200	---	---	0.7	0.0001	EB
3420728150304526976	a rich spectrum of pulsations				ZZB
473706893862387328	0.0867 0.0347 0.0344	≈0.0001	0.05-0.1	≈0.0003	SX Phoenix, βCep(?)
473712872456844544	a rich spectrum of pulsations				PNCS
473900064311871488	0.3765	≈0.0001	≈0.6	≈0.0003	EV
473900304830038144	0.08410 0.08934	0.00004 0.00004	0.0096 0.0081	0.0009 0.0008	DSCT
473906008546567168	0.13885 0.06488 0.12130	0.00002 0.00003 0.00010	0.112 0.021 0.020	0.003 0.002 0.002	DSCT
2000667342122793472	≈0.05	≈0.01	≈0.025	≈0.001	DSCT
2000668544713613952	>0.15	---	≈0.020	---	DSCT
2000677993641422208	≈0.1	---	≈0.10	---	DSCT
2000680742420926976	>0.15	---	≈0.20	---	DSCT
2000681876292067968	0.060 0.042	0.001 0.001	0.037 0.015	0.002 0.001	DSCT
2000684586402884864	>0.15	---	≈0.03	---	DSCT(?)
2000685758942457728	≈0.12	---	0.03	---	DSCT(?)
2000686239978998400	0.0363	0.0005	0.0151	0.0008	DSCT
2001434835597456768	>0.2	---	>0.6	---	EV(?)
3404200257158109824	Nonregular, with amplitude ≈ 0.01				IV(?)
3404213726175547776	>0.2	---	0.4	0.001	EV
3404217746264940032	Nonregular, with amplitude ≈ 0.01				IV(?)
3404189944938309120	Nonregular, with amplitude ≈ 0.01				DSCT(?)
241766668329744896	>0.12	---	>0.5	---	EV(?)
241771856649828992	>0.15	---	≈0.1	---	DSCT(?)
229267969902029696	---	---	≈0.5	<0.001	EB
277089853758788352	0.0820	0.0003	0.025	0.003	DSCT(?)
277090815831501568	Nonregular, with amplitude ≈0.2				(?)
277091262508123264	0.0811 0.0599 0.0445	0.0004 0.0003 0.0002	0.0103 0.0057 0.0041	0.0007 0.0006 0.0005	DSCT, roAP(?)
277091739248814208	≈0.125	≈0.001	≈0.1	≈0.001	DSCT(?)
277092155861283712	≈0.30	≈0.01	≈0.6	≈0.001	EV
277093014852191616	Nonregular, with amplitude ≈ 0.01				(?)
3342732093967192576	>0.12	≈0.01	≈0.3	≈0.01	EV(?)
3433368376498172160	>0.12	≈0.01	≈0.3	≈0.01	EV(?)
3433415586778288768	≈0.1	---	≈0.03	---	DSCT(?)

For a star with the number 277091262508123264 according to the GAIA catalog classification, we found the following parameters of this star according to the StarHorse project: T_{eff} = 9658K, [Fe/H] = -0.14, $M_* = 2.45\ M_{Sun}$. It should be noted that for this object, there is a large discrepancy in the T_{eff} values between the GAIA and StarHorse data. Therefore, we also consider the parameters of this star obtained from the LAMOST project: T_{eff} = 7088 K, [Fe/H] = 0.043. Based on these parameters, synthesized spectra were constructed with a spectral resolution corresponding to our observations and those of the LAMOST project for two values of T_{eff} - 7000K and 9500K, with the *log*g = 4.0 and [Fe/H] = 0.0. A comparison of synthesized spectra with the spectra obtained at TSO and in the LAMOST project is shown in figure 11. From figure 11, we can conclude that the data from the StarHorse project does not seem to be correct and LAMOST gives more accurate value. From the obtained comparison, we can conclude that this star also likely belongs to the DSCT variable type.

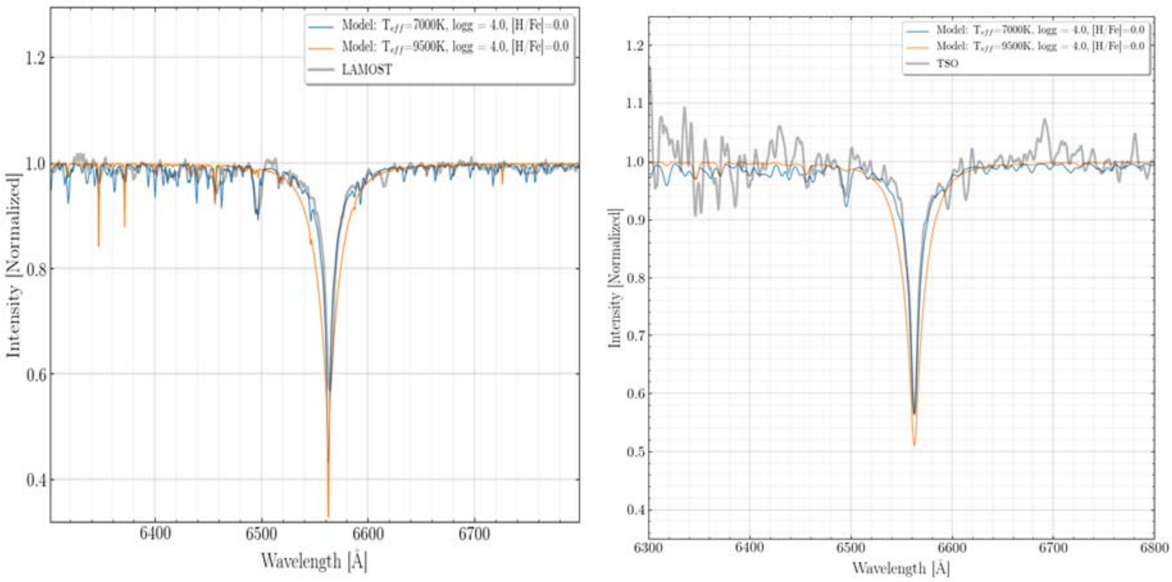

Figure 11-Comparison of the spectra obtained in the LAMOST project (left) and at the TSO (right) on a slit spectrograph mounted on the Zeiss-1000 "Zapadny" telescope with synthesized spectra for two T_{eff} values

More accurate spectral characteristics can be obtained from iterative approximation (or MCMC method) of model spectra to the observed ones, using a grid of models with a certain step in the values of [Fe/H], *log*g and T_{eff}.

Conclusion

Survey observations of 15 selected fields were carried out. Photometric pipeline data analysis conducted for 23 fields, including observations for 2016 and 2018. As a result, light curves for 9836 stars with the duration of observations at least 3 hours were obtained. Analysis of the light curves of these stars leads to the identification of 33 variable stars. Among them, 31 stars are previously unknown variables. The amplitude-period analysis of the light curves of the identified variables was carried out, which allowed us to give a preliminary classification of their type of variability. Where possible, we analyzed the color-magnitude diagrams and constructed the corresponding evolutionary tracks. Table 8 presents the main information obtained on the detected variable stars.

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ЕЖШС «В.Г. Фесенков атындағы Астрофизика институты»

ТЯНЬ-ШАНЬДА ӨЗГЕРМЕЛІ ЖҰЛДЫЗДАРДЫ ІЗДЕУДЕГІ ФОТОМЕТРИЯЛЫҚ ЗЕРТТЕУДІҢ АЛҒАШҚЫ НӘТИЖЕЛЕРІ: ЖАРЫҚ ҚИСЫҚТАРЫН ТАЛДАУ ЖӘНЕ ӨЗГЕРМЕЛІ ЖҰЛДЫЗДАРДЫҢ ЖІКТЕЛУІ

Аннотация. Айнымалы жұлдыздарды іздеуге арналған көптеген науқандарға қарамастан, барлық жаңа айнымалылардың, соның ішінде бұрын белгісіз болған кластардың ашылуы жалғасуда. Сонымен қатар, ерекше нысандар бар. Мысалы, WD1145 + 017 – қазіргі кездегі экзопланеталық жүйелердің бұзу феноменінің бар болуының дәлелдеуі бар белгілі жалғыз ақ ергежейлі. Қысқа мерзімді айнымалы жұлдыздарды іздеу үшін ТШОА-да фотометриялық науқан басталған болатын. Оның мақсаттарының бірі – өзара әрекеттесетін ультра-ықшам екілік жүйелерді (AM CVn) қоса алғанда, екілік ықшам жүйелерді (UCB) іздеу. Мұндай жүйелерді бір обсерваторияның күшімен іздеу олардың жарықтық вариациясының бірнеше ондаған минутқа созылатындығымен, ал жарық вариациясының амплитудасы жұлдыздық шамамен 0,01-ден 1,0-ге дейінгі аралықта өзгеретіндігімен ақталған. Сонымен қатар, мұндай зерттеу басқа ауыспалы жұлдыздардың түрлерін, соның ішінде астросейсмологиягға қызығушылық тудыратын объектілерді, экзопланеталары бар жүйелерді және т.б. іздеу үшін пайдаланылуы мүмкін.

Тянь-Шань обсерваториясында (ТАО) Zeiss-1000 телескопының көмегімен жүргізілген фотометриялық зерттеу барысында анықталған өзгермелі жұлдыздардың жарық қисықтарын талдаудың алғашқы нәтижелері ұсынылды. Мұнда біз 33 жоғары амплитудалы ауыспалы жұлдыздар туралы баяндаймыз, олардың ішінде 31 бұрын айнымалы жұлдыздар каталогына енбеген.

Жұлдыздардың айнымалылық түрін анықтау үшін олардың жарық қисықтарын талдап, амплитудасы мен периодтарын анықтау керек, сонымен қатар жұлдыздың эволюциялық күйін және егер мүмкіндік болса, оның спектрлік сипаттамаларын да анықтау керек (Sp). Бұл жұмыста жарық қисықтарын талдаудың негізгі құралы – тербеліс спектрін «ағарту» тізбекті қадамдары бар PyAstronomy пакеті (https://github.com/sczesla/PyAstronomy) және GATSPY пакет алгоритмі көмегімен орындалған периодограммаларды құру. Біз тербелістердің периодтарын 0.003-тен 0.15 күнге дейінгі аралықта іздедік. Мақалада мысал ретінде бірнеше жұлдыздарға арналған жарық қисықтары келтірілген.

StarHorse каталогындағы деректерді, сондай-ақ MIST жобасының нәтижелерін қолдана отырып, сәйкес металлылыққа және анықталған өзгермелі жұлдыздардың массасына эволюциялық жолдар түсті-жарықтығы диаграммаларында алынды.

Цейсс-1000 «Батыс» ТШАО телескопында екі нысанда спектрлік бақылау жүргізілді. Алынған спектрлер модельді спектрлермен салыстырылды. Әрбір жұлдыздың өзгергіштік түрін алдын-ала анықтау периодограммалармен анықталатын тербеліс режимдерінің параметрлеріне (амплитудасы мен периодтары), түсті жарықтылық диаграммаларына (CMD) негізделген эволюция сатысына және кейбір жұлдыздарға спектрлік ақпарат негізінде жасалады.

Нәтижесінде айнымалылық кластары және өзгергіштік параметрлері бар 33 жұлдыздың тізімі пайда болды: 17 DSCT жұлдызы, 2 EB (тұтылған екілік), 7 EV (эллипстік айнымалы), 2 IV (дұрыс емес айнымалы), 1 PNCS (планетарлық тұмандылықтың орталық жұлдызы), 1 ZZB (ақ ергежейлі) және 2 белгісіз айнымалылық типі бар жұлдыз.

Түйін сөздер: әдістер, жарық қисықтарын талдау, фотометрия, жұлдыздар, ауыспалы жұлдыздар.

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ПЕРВЫЕ РЕЗУЛЬТАТЫ ТЯНЬ-ШАНСКОГО ФОТОМЕТРИЧЕСКОГО ОБЗОРА ПО ПОИСКУ ПЕРЕМЕННЫХ ЗВЕЗД: АНАЛИЗ КРИВЫХ БЛЕСКА И КЛАССИФИКАЦИЯ ПЕРЕМЕННЫХ ЗВЕЗД

Аннотация. Несмотря на большое количество разных кампаний по поиску переменных звезд, открытие все новых переменных, включая неизвестных ранее классов, продолжается. Кроме того, встречаются уникальные объекты. Например, WD1145+017 – единственный известный в настоящий момент белый карлик с доказательством существования феномена разрушения экзопланетных систем. Для поиска переменных звезд с короткими периодами была предпринята фотометрическая кампания на ТШОА. Одной из ее целью является поиск двойных компактных систем (UCB), включая взаимодействующие ультра-компактные двойные системы (AM CVn). Поиск таких систем силами одной обсерватории оправдан тем, что вариации блеска у них имеют периоды несколько десятков минут, а амплитуды вариации блеска – от 0.01 до 1.0 звездной величины. Кроме того, такой обзор может быть использован для поиска других типов переменных звезд, включая объекты, имеющие интерес для астросейсмологии, системы с экзопланетами и др.

В этой статье представлены первые результаты анализа кривых блеска переменных звезд, выявленных в ходе фотометрического обзора, проведенного на Тянь-Шаньской обсерватории (ТШАО) с помощью телескопа Цейсс-1000. Здесь мы сообщаем о 33 высокоамплитудных переменных звездах, среди которых 31 – ранее не вошедшие в каталоги переменных звезд.

Для определения типа переменности у звезд необходимо проанализировать их кривые блеска и определить амплитуды и периоды, а также определить эволюционный статус звезды и, если есть такая возможность, ее спектральные характеристики (Sp). Основным инструментом анализа кривых блеска в данной работе является построение периодограмм, реализованное с применением алгоритма пакета GATSPY и пакета PyAstronomy (https://github.com/sczesla/PyAstronomy) с последовательными шагами “отбеливания” спектра колебаний. Поиск периодов колебаний проводился нами в диапазоне периодов от 0.003 до 0.15 суток. В статье в качестве примера приведены кривые блеска лишь для нескольких звезд.

Используя данные каталога StarHorse, а также результаты проекта MIST, были получены и нанесены на диаграммы Цвет-Светимость эволюционные треки для соответствующей степени металличности и массы обнаруженных переменных звезд.

Для двух объектов были проведены спектральные наблюдения на телескопе Цейсс-1000 “Западный” ТШАО с использованием щелевого спектрографа. Полученные спектры сравнивались с модельными спектрами. Предварительная идентификация типа изменчивости каждой звезды осуществляется на основе параметров мод колебаний (амплитуд и периодов), определяемых по периодограммам, стадии эволюции – на основе диаграмм цвет-светимость (CMD) и для некоторых звезд – на основе спектральной информации.

В результате был получен список из 33 звезд с параметрами осцилляций и классом переменности: 17 звезд DSCT, 2 EB (затменные двойные), 7 EV (элиптические переменные), 2 IV (неправильные переменные), 1 PNCS (центральная звезда планетарной туманности), 1 ZZB (белый карлик) и 2 звезды с неизвестным типом переменности.

Ключевые слова: методы, анализ кривых блеска, фотометрия, звезды, переменные звезды.

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